History of Physics

Leonardo Gariboldi
Luisa Bonolis
Antonella Testa

The Milan Institute of Physics

A Research Institute from Fascism to the Reconstruction

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A Research Institute from Fascism to the Reconstruction

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How many and how many episodes, which took place at the Institute, I could tell of that troubled and tragic period of Italian life. But, without getting lost in little stories, I shall only say, briefly, that, despite everything, the Institute, even if materially dismembered in people and things, always knew how to maintain its own unbreakable spiritual compactness.

Giovanni Polvani

Foreword

This book is the first one presenting a historical reconstruction of the life and of the development of the Institute of Physics of Milan. The reconstruction is made in a very appealing way and concentrates in the years 1924–1960 so that starting from the very beginning, it covers the period in which major developments in physics research took place at and around the Università degli Studi di Milano, founded in 1924.

It is very interesting to realize, by the facts described in the various chapters, how important was the contribution of the physicists of Milan to the general scenario of physics during those years.

This was the period in which the foundations of many aspects of modern physics were established and important achievements were obtained in spite of the political situation creating difficult conditions also for the scientific and academic world.

In Milan during those years, new research activities in physics started and grew rather rapidly, in particular after the Second World War. By reading this book, one can learn on the progress in research made there, how the new areas of research were born and how the physics research in Milan was well recognized and connected in the national and international context.

There were several actors strongly engaged in the construction and in the rapid expansion of the Institute of Physics of Milan. The coherent and collaborative approach was the key of success but certainly some figures as Aldo Pontremoli, Giovanni Polvani, Giovanni Gentile jr., Piero Caldirola, Guido Tagliaferri and Giuseppe Occhialini played a very prominent role. Their very high scientific standing is unquestionable together with their capability to construct research groups and attract resources.

The Departments of Physics of the Università degli Studi di Milano and of the Università di Milano Bicocca are named after Aldo Pontremoli, the former, and Giuseppe Occhialini, the latter.

As President of the Italian Physical Society (SIF), I would like to point out that Giovanni Polvani was the president of this Society from 1947 to 1961 and he was the founder in 1953 of the International School of Physics "Enrico Fermi" in Varenna, lake Como. For the "Enrico Fermi" International School of Physics, more than 200 courses were held up to now and 61 Nobel prize winners, including Giorgio Parisi, have given lectures there. Among the Nobel prize winners lecturing in Varenna there is Riccardo Giacconi, who was student in Milan and carried out research on cosmic-rays for his thesis using the cloud chamber which is today located at the entrance of the Physics Department of the Università degli Studi di Milano.

I would like to conclude this short foreword by mentioning that the Italian Physical Society was strongly interested to have this book, unique also for the book catalogue of Springer Nature, and thus stimulated in this endeavor the author Leonardo Gariboldi, whom I thank for his great effort. The strong interest in this book is because historical reconstructions, as this one, show the importance of the legacy from the past for the present and for the future.

Milan, Italy

Angela Bracco
Italian Physical Society, President

Società Italiana
di Fisica

Preface

The Physics Department "Aldo Pontremoli" of Milan University is currently located in a north-eastern district of Milan called "Città Studi" (City of the Studies). It is planned to move in 2025 together with other scientific departments to a new seat, the MIND Campus, in a location which hosted the World Exposition Rho 2015, Italy.

It will be the third time the physics-based institute of Milan University changes its location. It happened a first time in 1927, when the first institution, the Institute of Complementary Physics joined other scientific institutes in the Palace of Sciences, then a second time in 1961, when the second institution, the Institute of Physics (or of Physical Sciences), which needed much more space for its research teams and its students, moved to a newly built seat, the current one.

The choice of an initial and a final date in a historical reconstruction of the life of an institution is always subjective and contestable. The starting date, the foundation date (in this case 1924) is rather obvious, but an institution never comes from nothing. That is why an introductory chapter, written by Antonella Testa, tells some relevant topics of the history of physics in Milan before the foundation of the Institute of Complementary Physics of Milan University. In both the periods during the Fascist regime and the Reconstruction time, the professors and some assistants played a fundamental role in the development of the didactic and research activities. A special chapter is devoted to Giovanni Gentile, the second professor of Theoretical Physics, written by Luisa Bonolis, the expert on Gentile's studies.

The choice of a final date is in this case more difficult and subtle. The Institute of Physics formally ended in 1980 with the transformation into the current Department of Physics. The year 1980 is but well too much after the Reconstruction time. The post-Reconstruction life of the Institute of Physics will deserve a future study of its own. I have therefore chosen 1960 for several reasons: it covers the history of the Institute of Physics at one of its premises in the Palace of Sciences for three decades before it moved to the current seat; it corresponds to the scientific direction of the Institute by Aldo Pontremoli and Giovanni Polvani, before the new direction in the 1960s by Piero Caldirola; it sees the beginning of a deeply reformed degree course in Physics which started its classes in the new seat; it includes the period of symbiosis with the CISE (a research institute of nuclear physics and technology) and the National Institute of Nuclear Physics during the post-war Reconstruction period and the phase of rapid development of the Italian economy. I did not want to strictly handle with this time limit, so I will deal with a couple of topics that extend beyond it, but were prepared before 1960, as an open window to the future life of the Institute of Physics: the transition from cosmic-ray physics to space physics, and the planning and building of the relativistic cyclotron, an accelerator which was a dream becoming reality two decades after the first attempts to build one in Milan.

I would like to thank my colleagues and all those people with whom I took inspiration for my work. First of all, I thank all the people and institutions without whose work mine would be impossible: Claudia Piergigli, Gaia Riitano and Raffaella Gobbo of Centro APICE (Milan University); Tiziana Morocutti, Laura Stefanizzi and Monica Folini of the BICF Library (Milan University); Primo Ferrari of the archive of Fondazione ISEC (Institute for the History of Contemporary Age); Simona Casonato, Marco Iezzi, Luca Reduzzi and Laura Ronzon of the National Museum of Science and Technology "Leonardo da Vinci", Milan; Aurelio Ascoli, Flavio Parozzi and Tommaso Rossini of CISE2007; Maurizio Guerri and Andrea Torre of National Institute "Ferruccio Parri"; Lucio Andreani for having put at my disposal his family archive on Jacopo Dentici; Aurora Bonfoco of the Classicum Lyceum "Severino Grattoni" in Voghera; the archivists of the Historical Archive of Intesa San Paolo; the archivists of Bristol University Special Collections, Powell Papers; the librarians of the Université Libre de Bruxelles; the archivists of the Mauthausen Memorial KZ-Gedenkstätte; the archivists of the International Committee of the Red Cross; Gianni Battimelli, Fabio Bevilacqua, Alberto Bonetti, Luisa Bonolis, Angela Bracco, Lucio Fregonese, Olival Freire jr, Francesco Gnecchi Rusconi, Luca Guzzardi, Roberto Lalli, Adele La Rana, Massimo Lazzaroni, Maria Grazia Marcazzan, Luca Arthur Molinari, Etra Occhialini, Cristina Olivotto, Giovanni Onida, Matteo Pontremoli, Alberto Pullia, Nadia Robotti, Paolo Rossi, Giorgio Sironi, Antonella Testa, Pasquale Tucci, Simone Turchetti, Paolo Vavassori, Guido Vegni. Then my former students who worked on their thesis dissertations and stimulated many questions: Silvia Belmuso, Valeria Beretta, Claudia Biscotti, Federica Burla, Chiara De Falco, Charlotte Michi, Roberto Mondini, Federico Scagliotti, Mariachiara Valtorta, Edoardo Vassura, Mattia Verzeroli, Simone Zanin, Guido Zorzi. I apologize for any missing name; it is just a fact of bad memory and not the willingness to ignore them. The notes on the local, national and international collaborations of the Institute of Physics benefitted from the SEED 2019 project of Milan University on "Reassessing Scientific Collaboration" with Luca Guzzardi, Massimo Lazzaroni, and Andrea Guardo.

Milan, Italy
January 2022

Leonardo Gariboldi

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Acronyms

CAMEN	Centro per le Applicazioni Miliari dell'Energia Nucleare: Centre for the Military Applications of Nuclear Energy
CISE	Centro Informazioni Studi Esperienze: Centre Information Studies Experiences
CNR	Consiglio Nazionale delle Ricerche: National Research Council
CNRN	Comitato Nazionale per le Ricerche Nucleari: National Committee for Nuclear Researches
COPERS	Comité Preparatoire Européen pour la Recherche Spatiale: European Preparatory Committee for Space Research
ENI	Ente Nazionale Idrocarburi: National Hydrocarbons Board
EPS	European Physics Society
ESRO	European Space Research Organisation
FIAT	Fabbrica Italiana Automobili Torino: Italian Car Factory in Turin
FIEN	Forum Italiano Energia Nucleare: Italian Forum of Nuclear Energy
FORATOM	European Atomic Forum
GAIFUM	Gruppo degli Amici dell'Istituto di Fisica dell'Università di Milano: Group of the Friends of the Institute of Physics of Milan University
GIFCO	Gruppo Italiano di Fisica dei Raggi Cosmici: Italian Group of Cosmic Rays Physics
IFCTR	Istituto per la ricerca in Fisica cosmica e Tecnologie Relative: Institute for the Research in Cosmic Physics and Relative Technologies
IFSI	Istituto di Fisica Spaziale Interplanetaria: Institute of Interplanetary Space Physics
INFN	Istituto Nazionale fi Fisica Nucleare: National Institute for Nuclear Physics
ITESRE	Istituto per le Tecnologie e gli Studi della Radiazione Extraterrestre: Institute for the Technologies and Studies of Extraterrestrial Radiation
SADE	Società Adriatica di Elettricità: Adria Electricity Society
SIF	Società Italiana di Fisica: Italian Physics Society

Chapter 1
Highlights on the History of Physics in Milan Before 1924

Antonella Testa

Abstract In the history of physics in Milan before 1924 two cases are especially noteworthy as the scientific activity was intertwined with the birth and the development of two of the most important research and high education institutions in the city: the Osservatorio Astronomico di Brera (Brera Astronomical Observatory) and the Politecnico di Milano (Polytechnic University of Milano). This is why the chapter will focus on these two cases, selecting some highlights about remarkable characters and particularly interesting episodes of their history. Some of them are also interesting because they refer to disciplinary areas that afterwords developed in autonomous research fields, as meteorology or geomagnetism.

1.1 The Oldest Scientific Institution in Milan

The Osservatorio Astronomico di Brera (Brera Astronomical Observatory) is the oldest scientific institution in Milan. Its Milanese headquarters is still located in the south-east area of the historical Palazzo di Brera (Brera Palace), in the centre of Milan. The first two-storey observatory was built in a few months in 1764, according to the project designed by the Jesuit priest Giuseppe Ruggiero Boscovich (1711–1787); the original wooden model of the building is preserved at the National Museum of Science and Technology in Milan. Palazzo Brera was the seat of the Jesuit College, where amateur astronomical observations were carried out for some years, using rudimentary instruments but achieving promising results.[1] Alongside its main educational activities carried out in its schools in humanities, the Society of Jesus during the 18th century supported attention and dedication to scientific disciplines, which had already led some of its members to obtain authoritative roles, including Boscovich himself, professor of mathematics at the University of Pavia.

At that time Milan did not have a university, nor a scientific academy, thus the scientific knowledge and development was mainly concentrated in educational con-

[1] In February 1760 a decisive event was the observation of a comet not previously documented by other observers, by the Jesuits Giuseppe Bovio and Domenico Gerra, both being men of letters at the College. On the history of the Brera Astronomical Observatory see: [3, 16, 19].

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texts.[2] With the aim of establishing a stable astronomical activity in Brera, the director of the Jesuit College Federico Pallavicini, had commissioned Boscovich to design a new observatory building. At that time Boscovich had already published his main work, *Theoria Philosophiae Naturalis redacta ad unicam legem virium in natura existentium* (1758), exposing his natural philosophy. However, he was an eclectic scientist ranging from theoretical speculations on basics of natural philosophy to practical problems like the static of buildings, and he was also recognized for his skills in astronomy, engineering, meteorology, and geodesy. This is why he was in charge of the project for the new observatory, that also found the trust of Carlo Firmian, the plenipotentiary minister and governor of Lombardy, and thus had the approval of the Austrian governmental authorities.

At different levels, fortunate conditions had arisen for the birth of a real scientific institution. Shortly before, in 1762, priest Luigi La Grange (1711–1783) had been appointed to Brera as the director. While acknowledging the zeal of the Jesuits of the Brera College, a referring scientific guide was needed, and La Grange was an expert astronomer. As an assistant to priest Esprit Pezenas, director of the Marseille Observatory, La Grange had achieved good knowledge about apparatuses as well observational practice in interesting research topics of his time, like the observation of comets, the motion of the Sun, the Moon and of other celestial objects [2]. Importantly, the Observatory had begun to obtain instruments adequate to professional activities, similar to the equipment in use at that time in other observatories, like pendulum clocks, quadrants, sextants, telescopes.

These are all elements enabling the Observatory's development, and soon it became one of the most authoritative institutions in Italy, under the leading roles of La Grange and Boscovich. These two skilled scientists had a fruitful collaboration, but their very different characters led to strong disagreements that eventually ended in the moving of Boscovich to Paris in 1772.

1.2 First Steps in Celestial Mechanics

It deserves mentioning the dedication that astronomers gave to basic activities, such as the correct determination of the geographical position of the Observatory and the rigorous control of the accuracy of the new instruments, and the exact determination of time. This is far from obvious, but these elements were absolutely essential to ensure reliable astronomical observations, and to make effective comparison with star catalogues, and other astronomers' results. In fact, the reliability of the results was

[2] At this time Pavia university was the nearest reference for Milan. The first university in Milan, devoted to a wide variety of scientific fields (as well as humanities, and laws) is the Università degli Studi di Milano, founded in 1924. Moreover, in Milan there were no scientific academies that could have played a main role for the development of knowledge in many of the fields of physics, like for example the Accademia del Cimento in the 17th century in Florence. In 1810 in Palazzo Brera was established the Istituto Reale di Scienze, Lettere e Arti, later called Istituto Lombardo Accademia di Scienze e Lettere, whose first president was Alessandro Volta.

dependent on the precision of the data: a possible source of error could be structural, depending of the instrument itself like planar defects of surfaces or low precision in the graduation of the limb for sextants or quadrants. Thermal expansion of the different metals used could also cause other kinds of error, as well as the positioning of the instrument lying in a specific plan and pointing the correct direction.[3]

The main research interests in Brera were focussed on positional astronomy and celestial mechanics: locating star position, studying the parameters and tracking the motion of the planets, finding comets, and other celestial objects, describing their trajectories. The Reports published in the annual Effemeridi Astronomiche di Milano, evidence Brera's astronomers unremitting efforts. These are extremely stimulating subjects of investigation in the second half of the 18th century, involving the most important astronomers in Europe, like Joseph J. L. de Lalande or Charles Messier. Furthermore, Brera astronomers contributed, also thanks to regular exchange of correspondence with their colleagues in Europe, to which Boscovich also participated from Paris. An example are the orbital calculations for a comet, first observed by Johann E. Bode and Johann G. Köhler, and then by Messier in the first months of 1779, and the related observations that in Brera were carried out by astronomers Francesco Reggio (1743–1804), Angelo De Cesaris (1749–1832), and Barnaba Oriani (1752–1832)[4] [11, 12].

In those decades, the description of the sky was rapidly enriching. The first edition of the Messier Catalogue (*Catalogue des Nébuleuses et des Amas d'Étoiles*, 1774) included 45 "fixed" objects (nebulae, star clusters, and galaxies); the identified objects became more than one hundred in the 80's of the 18th century, including the object called as M61 discovered by Barnaba Oriani during the comet observation in 1779. Subsequently, the number of objects further increased to over 2500, described in the three catalogues of Wilhelm Herschel, published in the *Philosophical Transactions of the Royal Society of London* between 1786 and 1802. These catalogues were further developed by his son John, and subsequently by Charler Dryer in the following century. For comet hunters, Messier catalogue was a useful tool to distinguish any new ones from those already identified "fixed" objects but having a similar appearance to instrumental observation; and vice versa, searching for comets could lead to unexpected discovery of new clusters or nebulae, as happened to Oriani in 1799.

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[3] These are just some examples of the accurate evaluation the astronomers were used to make; it also has to be taken into account that the instrumental equipment was provided according to its quality, although under limited resources available, and with reference to what was in use in other institutions in Europe. The first equipment included a sextant and mural instrument by Canivet (Paris, France) made in the '60s of 18th century, as well as two Dollond refractor telescopes of the 70s. In this context, it was relevant the role of the technical assistant, who was very often a skilled instrument maker, like it was Joseph Megele (1740–1816), and later Carlo Grindel (1780–1854). Many of the instruments were in fact improved by them, according to original technical solutions, or entirely made. The compensated pendulum clock made by Megele (1798) is a significant example.

[4] The astronomical ephemeris (Effemeridi Astronomiche) is an annual book that the Observatory published continuously from 1774 to 1874; it included the tables of the calculated positions for the Sun, the Moon and the planets for the following year, useful for observations; the second part was a summary of the reports of the activities carried out during the year. Among them, many were about celestial mechanics, on planets and other celestial objects.

1.3 Discovering a Celestial Object as a New Planet

A prominent contribution came from the Brera observatory during the debate about the nature of the celestial object that Wilhelm Herschel, in 1781, had hypothesized to be a comet [15], and which had led to the awareness of having discovered a new planet in the Solar System; Johann Bode would later give this planet the name of Uranus. It is a significant episode in which, once again, precise astronomical observations were crucial, but calculation skills and theoretical speculation were also relevant to achieve a good agreement between data and the calculation of the orbital parameters; these were the contribution that Oriani, and Boscovich, together with astronomers De Cesaris, and Reggio gave to the discovery of the celestial object as a planet [14, 25].

After all, the analysis of the orbits of the planets, and in particular of their perturbations, became more and more an object of interest, stimulated by numerous increasingly accurate observations, but also by a growing and reliable framework of understanding. The French physicist Pierre Simon de Laplace, with his *Traité de mécanique céleste* published between 1798 and 1827, mostly contributed to this framework, using gravitation to explain the deviations from theoretical orbits for all bodies in the solar system. Francesco Carlini (1783–1862) astronomer in Brera along most of the 19th century, and who also was director since 1832, worked in this field, and especially in the 10 and 20s he dedicated himself to the analytical description of the motion of the Moon, one of the most difficult problems in celestial mechanics due to the many perturbations of our satellite's orbit. This gave rise to the scientific collaboration with Giovanni Plana (1781–1864), and they both were awarded, together with Damoiseau, the prize established by the Académie des Sciences in Paris under suggestion of Laplace himself, for their methodology to achieve lunar tables only based on the law of universal gravitation [26].

1.4 Contributions in Geodesy and Cartography

Among Francesco Carlini's activities there are contributions in geodesy, a field that was an object of interest by many of the Brera astronomers on several moments of the institution history, and that is linked to one of the most interesting scientific problems in the history, already from ancient times: understanding and describing the shape of the Earth. This challenge involved some of the most influential physicists, mathematicians and astronomers of their times, as Jean Picard, Isaac Newton, Pierre L. M. de Maupertuis, and was still a matter of debate in 17th and 18th century. The shape of the Earth was still an open question: under the framework given by Newton, it was thought to be an oblate spheroid, modelled by the effects of the gravitational forces. Others described it as an elongated sphere, as it seemed to be from observations, made for instance by Picard, and later by Gian Domenico Cassini. Moreover, the description of the shape of the Earth and the characteristics of its surface meant a lot of efforts. Solving such a problem could not be a matter of a single institution, and it requested the contribution from many scientists. It was also a matter that intertwined to local initiatives of cartographical descriptions, stimulated by practical and political needs to achieve reliable maps about a certain territory.

The triangulation was a methodology already known from the 16th century and useful for cartographic representation, and used to calculate fractions of the local meridian. It was based on connecting selected points on the ground to form a set of triangles having two by two sides in common, and so obtaining a network that describes the interested area. Indeed, surveys on the field were necessary to obtain data, as well as precise calculations to adapt to the irregularities of the surface of the considered area. Contributions from local determinations were very important, as well as measuring the length of the meridian degree possibly from the closest possible position to the North Pole up to the Equator.

The Académie Royale des Sciences expeditions made by Charles De La Condamine and Pierre Bouguer in Perù (1735–1744), and by Pierre L. M. de Maupertuis in Lapland (1736–1737) provided essential measurement to sustain Newton's description, but other contributions came to the subject. Boscovich himself, before arriving at the Brera Observatory, was involved together with Christopher Maire, in the determination of the length of the meridian grade between Roma and Rimini, in 1751–1753, and the evaluation of gravitational anomalies. A few years after, in Piedmont, Priest Giovanni Battista Beccaria carried out the first determination of the length of the meridian grade between Mondovì and Andrate.

In the 1820s i.e. less than a century later, Francesco Carlini would be commissioned to repeat, in the context of the activities the Observatory was involved in, for the determination of longitudes and latitudes. In this framework, a relevant activity of the Brera astronomers has to be mentioned as it started not only for the purpose of scientific activity but mainly for practical reason. It gave rise to the *Carta topografica del Milanese e del Mantovano* (1788–1796), the first scientific description of the large area of the Austrian Lombardy, that contributed to overcoming the main problems related to the inaccuracy of the previous maps, in which geographical and political borders were often imprecise, shapes of natural elements unreal, and inaccurate distances between sites.

There were also previous occasions happened in which the Brera astronomers were engaged in cartographical and geodetic measurements, like for instance the latitude and longitude determination linked to the design of the 45° parallel, which was carried out under César F. Cassini suggestion, being one of their scientific interests; several other occasions also followed, as the ones carried out by Carlini and mentioned just above. But as the Carta topografica del Milanese e del Mantovano was mainly stimulated by political needs of the Austrian government to achieve a good knowledge of its territory, a formal assignment arrived at the Observatory to allow Angelo De Cesaris, Barnaba Oriani and Francesco Reggio carrying out all the steps to realize the map.[5] Furthermore, it also supported a journey made by a

[5] The project for a scientific designed map had a long gestation in the previous years, also marked by disagreements among astronomers and the mathematician Paolo Frisi, involved in the process. The

young astronomer (Barnaba Oriani) to meet European scientists to collect necessary information to prepare the cartographical map.

The used methodology was the already described triangulation, for the first time applied in Italy. Once again it deserves focusing on the accuracy of the measurements. Between June and July 1788, a month was needed to obtain excellent results in measuring the geodesic base, the distance of about ten km between two points (Nossate and Somma Lombardo) located north-west of Milan, and the verification done with a repetition of the measurement resulted as a difference of only few centimeters. It was carried out by placing one after the other three iron rods with a T-section, made with meticulous attention by the observatory technician Giuseppe Megele, and resting on trestles. Any possible source of error was considered, like horizontality and alignment of the rods, correction of height gradients and deviations, any temperature variations that could produce thermal expansion. During all the triangulation activities that followed the geodesic base determination, careful measurements were done, together with necessary correction calculations, even considering the many difficulties encountered because of the natural characteristics of the geographical area to measure, such as slopes, mountains, waterways, lakes, buildings. Using an equipment that included also theodolites and a portable quadrant, all measurements in the field were carried out, and integrated with necessary determination of the position of selected referring points on the map, using astronomical observations. In 1796 the phases of the realization of the map were about to be completed with the engraving of seven out of the final nine plates when the French invasion caused a sudden interruption of the work.[6]

The short period of French domination in Milan started.

However, contribution to geodesy by Brera astronomers continued also in following times, under the direction of Giovanni Virginio Schiaparelli (1835–1910), who succeeded Francesco Carlini. It is particularly significant as Schiaparelli was already an authoritative person when, in 1865, he was appointed to the commission for measuring the degree of meridian (which later became the Italian Geodetic Commission). The previous year he had represented Italy at the General Geodesic Conference on measuring the degree of the meridian circle in Central Europe, in Berlin, with thirteen countries taking part. Thus he was a leading scientist, also recognized in institutional roles who led him to be successful in guiding a great era for the Observatory.

Of that time, an open-air historical heritage evokes the events. It's a little astronomical dome that Schiaparelli decided to build in the 1870 in the Brera Botanical Garden, the other scientific institution in the Brera Palace that was, and is still nowadays, located close to the south facade of the building, underneath the main dome of the Observatory.

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commitment from the Austrian government could finally promote the start of the works, developed around the following stages: the determination of the main and fundamental points, the location of the intermediate places, the design of the map, and the engraving of it.

[6] The plates are preserved in the historical archive of the Brera Astronomical Observatory. An anastatic printing of the map was realized in 1992.

Schiaparelli worked there using transit instruments, together with Giovanni Celoria (1842–1920), who would later become director, being involved in the campaign of measurements to determine differences in longitude between the Milan Observatory, the Simplon Trigonometrical Station and the Neuchâtel Observatory. To this aim, observations of the meridian transit of selected stars were to be carried out, and a measurement station at a ground level, in the Garden, could avoid the vibrations suffered by the instruments in the main building, and thereby ensured higher accuracy. The station was completed with a telegraph pole near the dome, to communicate time signals to other stations, when contemporaneous observations were carried out. The difference in longitude, in fact, can be calculated by the difference in time of the meridian culmination of the same star in several stations.

1.5 Meteorological Activity

The collection of meteorological parameters data at the Brera Observatory began in 1763 thanks to Luigi La Grange, who thus started the collection one of the most important series of meteorological datasets in Italy, almost uninterrupted until recent times. Obviously, a number of discontinuities have occurred, due to various reasons, among them: the use of different thermometers in the temperature surveys, or the method used in collecting precipitation; the displacement of the position of the instruments; the frequency of data collection, and the measured parameters. From the very beginning of the history of the institution, temperature, pressure, the state of the sky and, since 1764, rainfall were measured, once a day. But the frequency of temperature measurements and the methodolody of determining the daily average value, for example, have changed several times. Since 1763, there was only the daily average value of the temperature; from 1778, the measurement was carried out twice a day, at dawn and in the evening, while from 1835 the maximum and minimum temperature began to be measured [4–6].

Many of the astronomers participated in the collection of meteorological data over time: in addition to La Grange himself, also Reggio, De Cesaris, Carlini, Schiaparelli, Celoria carried out measurements. Francesco Carlini, in particular, promoted the development of the meteorological activity, increasing the number of daily observations, from two to seven per day, introducing the survey of the minimum and maximum temperature, and improving the conditions of the measuring sites.

Although the collection of meteorological parameters was a routine and subsidiary activity to the observational one, also because it was for them important to know the state of the sky for the correct analysis of the astronomical data, interestingly, the reports of the astronomers have sometimes gone so far as to analyze the data for their intrinsic value. An example is given by the synthesis work carried out by De Cesaris on the first 50 years of meteorological observations in Brera, from which he derived considerations on the Milanese climate and on the height above sea level obtained from barometric measurements [10].

Another significant example comes from Giovanni V. Schiaparelli, despite he had repeatedly shown skepticism towards meteorological activity especially due to the considerable obligation it requested to astronomers. Schiaparelli recognized the value of the data series throughout the history, and supported the continuation of the activity, and published papers, including considerations on the climate of Milan, starting from the data of the series, and the comparison with other cities in Italy [20].

Today the meteorological data series represent a valuable heritage to contribute to the understanding of the evolution of the local climate.

1.6 Geomagnetic Measurements

During the ‘30s of the 19th century Brera astronomers dedicated experimental activity in a field that was fruitfully developing at that time: the geomagnetic activity. Geomagnetism was considered having an inner origin in the Earth, however it was a matter of interest to understand more about the possible internal and external contributions and their relevance, the description of its characteristics (through inclination, declination, and intensity), and variations in time. One of the leading scientists in this field was the German physicist and mathematician Karl Friedrich Gauss (1777–1855), who would come up with his model of Earth’s magnetic field, also thanks to the collection of data from several stations. In 1836, Gauss established the *Magnetischer Verein*: it was a project at an international level, that aimed to measure the Earth’s magnetic forces simultaneously in many locations distributed in several regions of the world. Campaigns of measurement had to be carried out in specific periods, according to a common methodology and with specialist instruments, in order to achieve the highest accuracy of the global description of the geomagnetic field, and of its spatial and temporal variation.

Also the Brera Observatory participated in this project, as the geomagnetic experimental activity was of interest at the Observatory. In fact, already in 1830 Francesco Carlini already carried out measurements of the geomagnetic inclination, in comparison to the ones executed by the director of the Bruxelles Observatory Lambert Quetelet, and using an inclinometer made by Étienne Lenoir, one of the most recognized instrument maker in this field.[7]

In 1836 a declinometer made by the instrument maker Moritz Meyerstein, was acquired by the Brera Observatory: it was realized under the idea of Gauss, in order to achieve high precision measurements of the magnetic field declination. Starting in 1836, it was used in the framework of the measurements of the *Magnetischer Verein*, but regular measurements continued involving many of the astronomers of the Observatory. Karl Kreil (1798–1862) first, but later also Schiaparelli himself and others up to about the 1920s, as the astronomers were interested in understanding

[7] See [1, 8], pp. 95–96.

possible influences on sunspots or on the position of the Moon, due to variation of the magnetic field.[8]

The Meyerstein declinometer still exists, although the magnetic bar lost his magnetism, and constitutes one of the most important instruments being part of the nowadays collection that witnesses the history of the Observatory and gave rise to the Brera Astronomical Museum, under a more than 40 years old fruitful collaboration between INAF-Osservatorio Astronomico di Brera, and Università degli Studi di Milano-Istituto di Fisica Generale Applicata/Dipartimento di Fisica.

1.7 A Sundial for Milan

On May 12, 1786, the Royal Imperial Supreme Council of Government in Milan appointed the astronomers of the Brera Observatory to equip the Milan Cathedral with a sundial, that was realized in a few months by Giovanni Angelo De Cesaris and Francesco Reggio. In October 1786 the sundial could start functioning as the official time instrument for the city, according to the definition of the time based on the culmination of the Sun at noon, that was just adopted to regulate civil time.

In many occasions Brera astronomers were involved in practical activities, useful for the government or the citizens: the sundial is for sure an interesting example, and still today the sundial exists. The sundial line is realized in brass, decorated with the zodiac sign symbols, and is located embedded in the floor of the Cathedral, near the entrance, in order to be easily visible to anyone and not to disturb religious services. Moreover, it lies parallel to the main facade, crossing the entire width of the Cathedral from south to north, and ascending for a few meters along the wall. Sunlight entered the Cathedral through the sundial hole on the ceiling of the nave, more than twenty meters high, close to the south facade [9, 13].

Time measurement has been part of the work of astronomers. Starting from the Cathedral sundial, the Brera astronomers accomplished this task for a long time, up to the first half of the 20th century.

1.8 Giovanni Virginio Schiaparelli, a Leading Scientist

In 1962, after the death of Francesco Carlini, Giovanni Virginio Schiaparelli was appointed first astronomer and director of the Brera Observatory. He arrived in Brera as second astronomer in 1859, and his career intertwined with the events that marked the birth of the future Polytechnic of Milan and the formation of the Consortium of higher education institutions, under the leadership of Francesco Brioschi (1824–1897). Brioschi, who had been a student of the free school of astronomy which the Observatory had established in 1827, was in fact one of the influential figures

[8] See [1, 8], pp. 140–142.

who positively regarded Schiaparelli as a possible director; Schiaparelli had a solid training as engineer carried out in Turin, and the experience he obtained in Berlin and Pulkovo to improve his observational and scientific skills, were relevant reasons to consider him a good candidate.[9]

Under Schiaparelli's guidance the observatory encountered a number of significant changes, and had a remarkable scientific development, as he was determined to bring the Observatory at the highest possible level. This meant a renewal of the instrumental equipment, a reorganization of the scientific activities, an increase in highly qualified scientists in his staff, the development of the relations with other scientific institutions.

One century had passed since the first activities in the Brera Observatory but still the identification of celestial objects was a prominent research interest: Schiaparelli linked his name to some of the major contributions, like understanding the nature of the shooting stars, and cataloguing of a huge amount of double stars along more then 20 years of observations.[10] Some of them were executed with the Merz refractor telescope that also allowed him to start a long series of Mars surface observations achieving the first scientific descriptions of the Mars planet. He perfectioned his most celebrated Mars maps along many following observations during Mars oppositions (in 1877, 1879–1880, 1881–1882, 1883–1884, 1886, 1888, and 1890) and published by the Reale Accademia dei Lincei from 1878 to 1910. Schiaparelli wasn't interested in spectroscopy and astronomical photography, that were rapidly developing in the second half of the 19th and became fundamental in the 20th century astrophysical research. Therefore, the observatory didn't use them for a long time.

In 1900 Giovanni Celoria, that had been working together with Schiaparelli since 1863, succeeded him in the direction. In the last years of the century a great change would happen in Milan, as the electrical lighting started to be developed. This contributed to stimulate the idea to find another observational seat of the Observatory, that was located about 30 kms from Milano in 1922, in Merate.

1.9 The Foundation of a Polytechnic University in Milan

The Milan Polytechnic university was established in 1863,[11] with the name of Regio Istituto Tecnico Superiore (Royal Higher Technical Institute), being one of the actions in the application of the education reformation promoted by the Casati law (1859).

[9] See [7], pp. 95–98.

[10] See Schiaparelli, G. V.: Osservazioni sulle stelle doppie. Serie prima comprendente le misure di 465 sistemi eseguite col refrattore di otto pollici di Merz negli anni 1875–1885. Pubblicazioni del Reale Osservatorio di Brera in Milano, 1909, XLVI in [21], pp. 9–262; Schiaparelli, G. V.: Osservazioni sulle stelle doppie. Serie seconda comprendente le misure di 636 sistemi eseguite col refrattore equatoriale di Merz-Repsold negli anni 1886–1900. Pubblicazioni del Reale Osservatorio di Brera in Milano, 1888, XXXIII in [21], pp. 263–525.

[11] A first history of the Polytechnic of Milano is due to Ferdinando Lori: former rector of the University of Padua he became professor of electrical engineering at the Milan Polytechnic [18].

The founder and first rector was Francesco Brioschi, already mentioned in the previous paragraph.

The law, that provided important renovations in all levels of education, also paid attention to university education. Article 310 explicitly referred to the establishment of a technical high education college in Milan, for civil engineers.[12] The cultural environment in Milan, which did not yet have a university and would not have one until 1924, was rather fragmentary. However, the Brera Astronomical Observatory remained a unique reference for the scientific culture, and in particular for physical-mathematical and astronomical knowledge.

In other fields of scientific knowledge there was the Natural History Museum, founded in 1838 and the Brera Botanical Garden, established in 1774. Moreover, with the aim of supporting the technical knowledge requested as a consequence of the industrial development in Milan and in Lombardy, in 1838 the Società di Incoraggiamento Arti e Mestieri (Society for the Encouragement of Arts and Crafts) was born, that dedicated its practical schools, its courses, its laboratories to grow and improve skilled workers and managers in technical-productive fields [17].

The Istituto Lombardo Accademia di Scienze e Lettere (Lombard Institute and Academy of Sciences and Humanities) was also an important institution, especially through its competitions that promoted the development of the applied technical-scientific knowledge. Through these activities the Institute created a cabinet rich in models, drawings and equipment relating to solutions and inventions in many fields, from agriculture to health care, and engineering, making it available to any scholar. The need for a reformation in the public education system, including scientific and technical fields, had long been evident; and significant episode was the proposed structure made by Carlo Cattaneo and the Istituto Lombardo in 1848 [34].[13]

1.10 Professors and Courses

When the regulations of the newborn Polytechnic were to be defined, the prevailing idea was to set up a high education system strongly oriented towards respecting the needs of applied professional education, aimed at issuing the graduation in civil engineering and mechanical engineering. However, it had to be not only based on specialized teaching but also basic courses should be included in mathematics, physics,

[12] The Law was enacted on 13th November 1859. It takes its name from Gabrio Casati, the Minister of Education of the Kingdom of Sardinia. In fact, as a result of the events in the Second War of the Independence, in 1859 there was the annexation of Lombardy by Sardinia-Piedmont Kingdom. The Law came into application in 1861, in the newly established Kingdom of Italy.

[13] Carlo Cattaneo was convinced about the role of the scientific and technical knowledge in the improvement of the society; in 1839 he also founded the magazine *Il Politecnico* to foster the spread of the scientific and technical knowledge; in it, in 1862 he pointed out that the training of engineers should also have been based on mathematical skills and physics (See [7], p. 50).

chemistry, and natural sciences, even if the institute aimed at supporting specialist training; this set up was established on the model of other polytechnic institutes in Europe.[14]

The idea was based on the expectation that the Polytechnic could become independent of the University. Until 1875, in fact, the Polytechnic could be attended by students aiming at their engineering degree, if they had already successfully attended a three-year education course in a university. During the first three years they were trained in mathematics, chemistry and physics, including often experimental physics, inorganic chemistry, analytical geometry, differential calculus, and others. Some of the courses in the Polytechnic programs were entrusted to Brera astronomers; geodesy was first taught by Giovanni Schiaparelli and then by his successor Giovanni Celoria, together with the rational mechanics courses. Emilio Bianchi (1875–1941), director of the Observatory since 1922, was also in charge of the mathematics course.

And some others were obviously modelled towards specialization. As part of the civil engineering profile, as an example, the static course was provided, held by the mathematician Luigi Cremona (1830–1903), to learn geometric and calculation methods to determine forces and equilibrium conditions useful to design any structures. From 1867, the course in technological chemistry, entrusted to Angelo Pavesi (1830–1896) and then Luigi Angelo Gabba (1841–1916) was added to the metallurgy course for the future industrial engineers. Within the laboratories, specific activities were carried on. As an example, a laboratory on the resistance of metals to traction and compression of stones was managed by Celeste Clericetti (1835–1887), a mathematician who taught construction sciences, together with Leonardo Loria (1844–1917), a railway engineer who was the first president of the College of Italian Railway Engineers, founded in 1899.

1.11 A Polytechnic Linked to Its Productive and Economic Environment

The organization of the courses of the engineering degrees in Milan included formal university courses as well as laboratory activities and training. But the attention to the connections with the referring environment was anything but neglected.

Polytechnic students had the great occasions to participate in journeys and educational trips to explore workplaces, ongoing projects, the production systems of local factories, and for instance the sites where the construction of railway bridges was in progress. These were considered as part of the training strategy, and constituted also opportunities to establish contacts and create relationships between the training institution and stakeholders involved: large and small companies, ministries, local authorities [22].

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[14] See [23], pp. 51–70.

This is also why destination journeys were sometimes very representative. For instance, the construction sites of the Frejus tunnel, that started in 1857 under Sardinia Kingdom and was completed in 1870, provides a good example of a relevant technical, political and economic enterprise. The tunnel construction also represented an example of the application of innovative mechanical solutions, particularly important when considering the hostile conditions of the working site.

According to Brioschi, his successor Giuseppe Colombo (1836–1921) and many of the professors of the institution, the best engineers who graduated at the Polytechnic in Milan should achieve a high level of technical and specific preparation. But they should also have the ability to relate with stakeholders, to understand needs developing in the society, at a productive level, and at a political level.

It is therefore no coincidence that also many of them did not limit their work within the educational institution or their profession, but they also had political roles, or were members in technical commissions of the Public Administration, or advisors for private entrepreneurs. The role of the engineer had to overcome the strict technical specialism.

1.12 Giuseppe Colombo and the Birth of the Electrical Industry in Milan

Towards the end of the 19th century, electrical engineering had a rapid development with wide effect in the field of industrial applications. Some chapters of this development were all Italian, such as the conception of Pacinotti's ring, in 1860, the magnetoelectric machine which was then commercially exploited by Zenobe Gramme. Galileo Ferraris' contribution was also fundamental, in Turin in 1885 he built the first alternating current transmission system for electrical power.

Moreover, in Milan in 1876, head of Tecnomasio Bartolomeo Cabella (1847–1907), had experimented with the first public electric lighting in Piazza Duomo, using five lights and a dynamo of his own realization. The rising interest was therefore not surprising in this field, and had also its influence on the Polytechnic activities, especially under the initiative of Giuseppe Colombo and Rinaldo Ferrini (1831–1908), who was professor of technological physics. Giuseppe Colombo, who obtained its training at the University of Pavia by Francesco Brioschi, was since 1865 appointed for the course of mechanics at the Polytechnic, in addition to his teaching at the Società di Incoraggiamento Arti e Mestieri. He also became Rector of the Polytechnic in 1897, succeeding Brioschi after his death. Colombo understood the crucial role and possible promising developments linked to the evolution of electrical applications and took action to create a Milanese electrical industry. In 1881, in fact, he got to know the lighting system conceived by Thomas Alva Edison on the occasion of the Paris International Electricity Exhibition. He then decided to negotiate with Edison its acquisition in Milan in order to give rise to an electrical production development.

In Milan, Colombo stood at the base of the realization of the first European thermoelectric plant, located in the very center of Milan in an old disused theater in Via Santa Radegonda. The power plant, inaugurated in 1883, initially operated with four dynamos and a total power of 350 kW. It started the supply of the electric lighting service first only in a very small area, and subsequently in the main streets of the city, favoring the most representative buildings such as the Teatro alla Scala, the Gallery, and the Dal Verme Theater. At the National Museum of Science and Technology in Milan, a jumbo dinamo of the equipment of the Centrale Santa Radegonda still remembers these times.

However, it was a largely entrepreneurial operation rather than a scientific development, as the equipment and technical-scientific skills involved came almost entirely from the American company Edison. In other words, at the birth and development of such an important power-plant for the city and production activities, there was no corresponding development in research and education in the electrical and electrotechnical fields.

Undoubtedly, however, the construction of the plant had fostered attention to a sector well recognized as being in great turmoil on the international scene and on which it was clear that there was a need for specialized training. In this context, in 1887, the pharmaceutical industrialist Carlo Erba, a friend of Giuseppe Colombo, decided to support the development of a School for the high education of electrical engineers which allowed the foundation of the Carlo Erba Italian Electrotechnical Institution, being part of the Polytechnic of Milan.[15]

The School included courses in electrical engineering, electrical technologies, electrical measurements, as well as electrotechnical laboratories. The institute started its activity under the direction of Luigi Zunini (1856–1938), who came from the Montefiore Institute, the electrotechnical section within the École des Mines of the University of Liège, that represented at the time a referring institution in the field. In 1883, engineer Georges Montefiore created it after attending the 1881 Paris International Electricity Exhibition, under the same enthusiasm as Colombo had.

An important impulse also came from the figure of Riccardo Arnò (1866–1928) who was called to Milan for the chair of general electrical engineering. He also had to develop the activities of another Institute within the Polytechnic that Colombo decided to establish to enhance teaching and research about alternating current motors.

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[15] See [7], pp. 78–91.

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Chapter 2
The Institute of Complementary Physics

Leonardo Gariboldi

Abstract The Institute of Complementary Physics (1924–28) was the first institution of physics research of Milan University. The institute was a subdivision of the highly fragmented Faculty of Sciences, established in 1924 with the foundation of Milan University thanks to Luigi Mangiagalli's willingness to have in Milan a public university complete with the four faculties of literatures and philosophy, medicine and surgery, law, and sciences. The director of the Institute of Complementary Physics was Aldo Pontremoli, a young scientist from the Rome school of physics who also trained at the Cavendish Laboratory in Cambridge. He was the winner, with Enrico Fermi and Enrico Persico, of the first public competition for a chair of Theoretical Physics in Italy. Pontremoli quickly established a modern institute with a laboratory of radiology for applicative researches in medicine and industry. No graduation course in Physics was however established. Pontremoli's direction abruptly ended in 1928 when he disappeared onboard the "Italia" airship after an accident on the ice-shelf, while he was participating to the scientific polar expedition led by Umberto Nobile.

2.1 The Foundation of the Institute of Complementary Physics

The history of Milan University (as "Royal University of Milan") started [1] with the reform plan of the higher education system promoted by the minister of public education, Giovanni Gentile, and the Royal Decree 2102, on September 30, 1923. According to article 143, Milan was granted the establishment of a public university formed by the Royal Scientific-Literary Academy (transformed into the Faculty of Humanities and Philosophy) and the Clinical Specializing Training Institutes for the specialization of students after their graduation in Medicine and Surgery. In the same decree, Milan University was listed in the "Table B" which listed the universities supported by an agreement between the State and other institutions.[1] The agreement

[1] "Table A" listed the public universities, entirely supported by the State: the Universities of Bologna, Cagliari, Genoa, Naples, Padua, Palermo, Pavia, Pisa, Rome, Turin; the Engineering Schools of

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would have determined the financial support on charge of the State and that of the other institutions, and the list of the faculties and schools constituting the university. The main agent who worked to establish the four traditional faculties (Medicine and Surgery, Literatures and Philosophy, Law, and Sciences) was Luigi Mangiagalli[2] helped by the lawyer Giuseppe Biraghi who was the first secretary general of Milan University. Mangiagalli organized the provisional committee which had the aim to prepare the agreement. He collected representatives from Milan Municipality, the Province of Milan, the Chamber of Commerce, the Cassa di Risparmio delle Provincie Lombarde, the Council of the hospital institutes.

Pavia University feared losing too many students and opposed the establishment of the faculties of law and sciences. Mangiagalli, however, insisted that it was necessary to found a comprehensive university with all four classical faculties to be culturally qualified. In June 1924, the Superior Council of Public Education agreed to established a university with the four faculties. The convention for the constitution of the University of Milan was signed on August 28, 1924. It included the institution of the Medical-Surgical Perfecting Schools and the Schools of Modern Foreign Languages and Literatures. The minister of public education, Alessandro Casati, inaugurated the new university during the official ceremony on December 8, 1924.

In order to better understand the history of the Institute of Physics it might be useful to remind how complex was the structure of any faculty. A first component to be taken into consideration was the “chair” (in Italian: cattedra). A chair was a tenured position in a given discipline, e.g. the chair of Experimental Physics. The minister of public education decided, according to the public funds at disposal, how many chairs were to be given to a faculty. It was then up to the faculty to decide which kind of chairs should they be, depending on the disciplines officially listed by the faculty themselves; e.g. a faculty could decide that one of the chairs should be the chair of Theoretical Physics only if Theoretical Physics was among the disciplines listed by the faculty. Year after year, the minister of public education could decide, if requested by the universities or if required by a reform of the undergraduate courses,

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Bologna, Naples, Padua, Palermo, Pisa, Rome; the Architecture School of Rome; the Superior Institutes for Agriculture of Bologna, Florence, Milan, Perugia, Pisa, Portici; the Superior Institutes of Veterinary Medicine of Bologna, Messina, Milan, Naples, Parma, Pisa, Sassari, Turin. In the list in “Table B” there were: the universities of Bari, Bologna, Catania, Florence, Macerata, Messina, Milan, Modena, Parma, Perugia, Sassari, Siena; the Engineering Schools of Milan, Turin; the School of Industrial Chemistry of Bologna; the School of Naval Engineering of Genoa; the Superior Institute of Veterinary Medicine of Perugia; the Superior Institutes of Business and Economics of Bari, Catania, Florence, Genoa, Naples, Rome, Turin, Trieste, Venice. In the “Table C” were listed the free, or private, universities: the Universities of Camerino, Ferrara, Milan “Catholic University of the Sacred Heart”, Urbino; the Institute of Social and Political Sciences “Cesare Alfieri” of Florence; the Free Superior Institutes of Business and Economics: Bologna, Milan “Bocconi”, Palermo. The distinction between the two groups of public or royal universities (in tables A and B) was abolished with the Royal Decree no. 1071, June 20, 1935.

[2] Luigi Mangiagalli (1850–1928) was a professor of Obstetrics and Gynecology in the universities of Sassari, Catania, Pavia and Milan. He was also a politician of liberal ideas: a representative of the Chamber of Deputies (1902–1905), a member of the Kingdom Senate (1905–1928), Mayor of Milan (1922–1926). He was the first rector of Milan University (1926–1928). He retired in 1925.

to add more chairs to a given faculty, of course if the corresponding new funds were at disposal of the minister.

If a faculty had a chair in a given discipline, then that discipline had to be taught in an undergraduate course. Other “extra” courses could be taught if the correspondent chair had not been assigned to the faculty. If the number of chairs was small, the extra courses could easily be the great majority.

A chair was meant to be assigned to a tenured professor or full professor. To became a full professor, a person had to win a public competition for that chair. When necessary, a faculty requested the minister of public education to organize the public competition. If the minister agreed with the request, a commission of professors of the same or similar disciplines was convened to Rome to discuss the documents submitted by the candidates. Eventually the commission prepared a ranking of three winners. The first winner, if called by the requesting faculty, could not decide to accept the call from another university. The second winner could be called by other universities (or by the requesting one if the first winner was not called by them and had gone to another university), only after the first winner had accepted a call. Similarly the third winner could accept a call only after the first and second winners had been called. The second and third universities could not have the chair of that discipline yet. For instance, when Aldo Pontremoli won the public competition in Theoretical Physics as third in the rank, the Faculty of Sciences of Milan University had not a chair of Theoretical Physics. He was commissioned to taught Theoretical Physics (see below) but not as full professor.

If a winner would have assigned a chair then he/she would have taught the corresponding discipline. A full professor who had won a public competition was called extraordinary professor. After usually three years a commission had to confirm his/her tenured position. If they confirmed it, the extraordinary professor became an ordinary professor. As for the full professors of the Institute of Physics of Milan University, it never happened that an extraordinary professor was not confirmed as ordinary professor.

If a chair was not assigned or if a chair did not exist in a faculty, the corresponding discipline could be commissioned. In this way, a full professor was a professor of his/her discipline but could be commissioned to teach one or more other disciplines. For example, Giovanni Polvani was professor of Experimental Physics and for some years was commissioned to teach Theoretical Physics. Given the small number of chairs at the Faculty of Sciences of Milan University, full professors were not able to be commissioned to teach all other disciplines. A second kind of professor is thus to be taken into consideration: the lecturer or commissioned professor (in Italian: professore incaricato) who was not necessarily a member of the university. A lecturer was nominated for only one academic year[3] by the minister of public education, after request from the Faculty Council. A lecturer was payed by the State with a limit on the number of courses. The Faculty Council could commission a teaching for free, but only for complementary courses.

[3] If a person was a lecturer in the same discipline for more than one year, it means that every year he/she was appointed lecturer by the minister of public education.

Usually a lecturer had obtained the “libera docenza” in one or more disciplines. The “libera docenza” was obtained after a public evaluation given by a commission convened in Rome and authorized the person who obtained it to teach in a university.

As we have seen a lecturer could be a person not formally related to the university; in many cases he/she was a person with an academic position of various kinds known as assistant (in Italian: assistente) and help (in Italian: aiuto). An assistant was always associated to a chair. An assistant could range from a newly graduated student to a person with many years of high-quality research and teaching activities, and could work part time or full time.

An ordinary assistant was appointed for one academic year by the minister of public education after a public examination. The commission was proposed by the faculty and named by the university, the president of the commission was the full professor of the corresponding chair. The commission nominated three winners in alphabetical order. The full professor chose the winner to be called as assistant; the other two winners had the right to be appointed as assistants in the next two years. Ordinary assistants were payed by the State.

A commissioned assistant was appointed by the minister of public education in temporary substitution of an ordinary assistant. A commissioned assistant was proposed by the full professor corresponding to the ordinary assistant. They were payed by the State.

An extraordinary assistant was appointed by the Board of the University. They were proposed by the full professor of the corresponding chair. They were payed by the University or by the Institute.

A volunteer assistant was appointed by the Rector of the University. They were proposed by the full professor of the corresponding chair. There were rather wide limits to the number of volunteer assistants and to the number of their renewals. They were not usually payed; they could be payed with a wage per hour for the exercitations.[4]

A full professor or a lecturer could organize an Institute corresponding to a chair. An Institute had a full professor or a lecturer as director, some assistants of any kind, a number of non-academic people (technicians, secretaries, janitors, etc.), who had at their disposal some rooms for offices, classrooms, research laboratories, didactic laboratories, a library, etc. In some cases, as it happened with the Institute of Physics, two or more full professors agreed to join in one Institute in order to collaborate more strictly in the research and teaching activities, and to make a better use of the people and the facilities, laboratories and libraries at disposal. In other cases, a full professor did not organize an Institute and there was only the chair.

The Faculty of Sciences was established in a highly fragmented way. At the beginning the minister assigned to the Faculty of Sciences only five full professors (see: Table 2.1): Luigi Berzolari, Livio Cambi, Gian Antonio Maggi, Rina Monti,

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[4] With exercitations (in Italian: esercitazioni), they meant extra-classes on topics not covered by a course, and/or tutorial classes on how to solve exercises and problems, and/or laboratory activities.

Table 2.1 Faculty of sciences (1924–25): full professors

Name	Role
Luigi Berzolari	Full professor of Higher Geometry; lecturer in Complements of Geometry; lecturer in Projective and Descriptive Analytical Geometry
Livio Cambi	Full professor of Industrial Chemistry; lecturer in Physical Chemistry
Gian Antonio Maggi	Full professor of Mathematical Analysis; lecturer in Celestial Mechanics
Rina Monti	Full professor of Comparative Anatomy; lecturer in Hydrobiology
Giulio Vivanti	Full professor of Higher Analysis; lecturer in Differential Geometry

and Giulio Vivanti.[5] It was therefore one of the smallest Faculty of Sciences in Italy. None of them was a full professor (nor lecturer) of Physics. Five other chairs had been assigned by the minister of public education but they were left vacant.

The three full professors of mathematical disciplines did not organize their corresponding institutes. Livio Cambi directed the Institute of Industrial Chemistry, and Rina Monti the Institute of Anatomy and Compared Physiology. Five other institutes were organized by lecturers (see: Table 2.2).[6] Among these, there was the Institute of Complementary Physics.

A striking fact, which highlights the fragmentation of the Faculty, is the number of institutes hosted by other institutions, five out of seven: the Institute of Anatomy and Compared Physiology and the Institute of Zoology were actually part of the Civic Aquarium; the Institute of Industrial Chemistry was part of the Arts and Crafts Encouragement Society (Società di Incoraggiamento Arti e Mestieri); and the Institute of Paleontology and the Institute of General Biology were part of the Civic Museum of Natural History. With being part of another institution, we mean that people, rooms, libraries, laboratories, etc. belonged to their institution, and that with an agreement with Milan University they were considered also belonging to the university. It also meant that the students had to go to these institutions to attend the classes offered to them. The other two institutes, the Institute of Anthropology and the Institute of Contemporary Physics were instead in a school building offered by Milan Municipality.

[5] Centro APICE, Historical Archive Milan University: Milan University 1924–25 yearbook, pp. 126–130.

[6] Centro APICE, Historical Archive Milan University: Milan University 1924–25 yearbook, pp. 126–130.

Table 2.2 Faculty of sciences (1924–25): the institutes

Institute	Name	Role
Institute of Anatomy and Compared Physiology[a]	Rina Monti	Director; lecturer in Hydrobiology
	Maria Segrè	Assistant
Institute of Industrial Chemistry[b]	Livio Cambi	Director; lecturer in Physical Chemistry
	Gino Bozza	Help; lecturer in Elements of Machines; lecturer in Drawing of Chemical Machinery
	Virginio Toia	Assistant
	Vittorio Verga	Assistant
Institute of Complementary Physics	Aldo Pontremoli	Director; lecturer in Complementary Physics
	Glauco De Mottoni	Assistant
	Giovanni Adorni	Technician
Institute of Anthropology	Gioacchino Sera	Commissioned director; lecturer in Anthropology
Institute of Paleontology[c]	Carlo Airaghi	Commissioned director; lecturer in Paleontology
Institute of Zoology[a]	Felice Supino	Commissioned director; lecturer in Zoology
	Paola Manfredi	Assistant
Institute of General Biology[c]	Luisa Gianferrari	Commissioned director; lecturer in General Biology

[a] At the Civic Aquarium,
[b] At the Arts and Crafts Encouragement Society
[c] At the Civic Museum of Natural History

Sixteen other disciplines were instead organized in fourteen cabinets (see: Table 2.3), without a particular difference with an institute.[7] Also in this case other institutions contributed to the Faculty of Sciences: the Cabinet of Mineralogy and the Cabinet of Geology were parts of the Civic Museum of Natural History; the Cabinet of Astronomy and Geodesy was a part of the Astronomical Observatory of Brera and Merate; the Cabinet of Technical Physics, the Cabinet of General and Applied Electrochemistry, the Cabinet of Electrotechnics, the Cabinet of Metallurgy, the Cabinet of General Hydraulics, the Cabinet of Mechanics Applied to Constructions, and the Cabinet of Drawing were actually institutes of the Royal Superior School of Engineering (today's Milan Poltytechnic); the Cabinet of Agricultural Chemistry, the Cabinet of Chemical-Agricultural Technologies, and the Cabinet of Botany were part of the Agricultural Superior Institute (which will become the Faculty of Agriculture in later years). Only the Cabinet of Physical Geography and Terrestrial Physics

[7] Centro APICE, Historical Archive Milan University: Milan University 1924–25 yearbook, pp. 126–130.

Table 2.3 Faculty of sciences (1924–25): the cabinets

Institute	Name	Role
Cabinet of Mineralogy[a]	Ettore Artini	Commissioned director; lecturer in Mineralogy
	Maria De Angelis	Assistant
Cabinet of Astronomy and Geodesy[b]	Emilio Bianchi	Commissioned director; lecturer in Astronomy; lecturer in Geodesy
	Giovanni Andrissi	Assistant
Cabinet of Physical Geography and Terrestrial Physics	Luigi De Marchi	Commissioned director; lecturer in Physical Geography and Terrestrial Physics
Cabinet of Geology[a]	Ernesto Mariani	Commissioned director; lecturer in Geology
Cabinet of Technical Physics[c]	Angelo Izar	Commissioned director; lecturer in Technical Physics
Cabinet of Agricultural Chemistry[d]	Angelo Menozzi	Commissioned director; lecturer in Agricultural Chemistry
Cabinet of Chemical-Agricultural Technologies[d]	Ugo Pratolongo	Commissioned director; lecturer in Chemical-Agricultural Technologies
Cabinet of General and Applied Electrochemistry[c]	Giacomo Carrara	Commissioned director; lecturer in Electrochemistry
Cabinet of Electrotechnics[c]	Riccardo Arnò	Commissioned director; commissione professor of Electrotechnics
Cabinet of Botany[d]	Ugo Brizi	Commissioned director; lecturer in Botany
	Luigi Fenaroli	Assistant
	Luigi Pagliani	Assistant
Cabinet of Metallurgy[c]	Antonio Ferrari	Commissioned director; lecturer in Metallurgy
Cabinet of General Hydraulics[c]	Gaudenzio Fantoli	Commissioned director; lecturer in General Hydraulics
Cabinet of Mechanics Applied to Constructions[c]	Antonio Danusso	Commissioned director; lecturer in Mechanics Applied to Constructions
Cabinet of Drawing[c]	Carlo Bianchi	Commissioned director; lecturer in Drawing

[a] At the Civic Museum of Natural History
[b] At the Astronomical Observatory of Brera and Merate
[c] At the Royal Superior School of Engineering
[d] At the Agricultural Superior Institute

Table 2.4 Faculty of sciences (1924–25): the laboratories

Institute	Name	Role
Laboratory of General and Inorganic Chemistry[a]	Giuseppe Bruni	Commissioned director; lecturer in General and Inorganic Chemisty
	Adolfo Ferrari	Assistant
Laboratory of Organic Chemistry[a]	Giorgio Renato Levi	Commissioned director; lecturer in Qualitative Chemical Analysis (for naturalists and chemists); lecturer in Organic Chemistry (for naturalists); lecturer in Analytic Chemistry (for chemists); lecturer in Quantitative Chemical Analysis (for chemists); lecturer in Complements of Chemistry (for chemists); lecturer in Chemical Preparations (for chemists)
Laboratory of Analytic Chemistry[a]	Giorgio Renato Levi	Commissioned director
	Mario Rossini	Assistant
Laboratory of Technological Chemistry[a]	Ettore Molinari	Commissioned director; lecturer in Technological Chemistry
Laboratory of Experimental Physics[a]	Oreste Murani	Commissioned director; lecturer in Experimental Physics

[a] At the Royal Superior School of Engineering

was in a building assigned to Milan University by Milan Municipality, the same building were there was the Institute of Complementary Physics.

Other disciplines were taught with both lectures and experiments at the Royal Superior School of Engineers were organized as "laboratories" (see: Tables 2.4).[8]

Finally, three assistants were assigned to the chairs of mathematics which were not organized as institutes (see: Table 2.5) and two lecturers did not belong neither to institutes, nor to cabinets or laboratories (see: Table 2.6).[9]

The Faculty of Sciences of Milan University started its courses in January 1925 with ten chairs assigned by the minister of public education; only five of them had a correspondent full professor. The Faculty did not organize a graduation course in Physics from the beginning, in agreement with Pavia University. Actually, the first

[8] Centro APICE, Historical Archive Milan University: Milan University 1924–25 yearbook, pp. 126–130.

[9] Centro APICE, Historical Archive Milan University: Milan University 1924–25 yearbook, pp. 126–130.

Table 2.5 Faculty of sciences (1924–25): assistants to the chairs of mathematics

Name	Role
Bruno Finzi	Assistant to the chair of Infinitesimal Analysis; assistant to the chair of Rational Mechanics
Francesco Jannuzzi	Assistant to the chair of Geometry
Beatrice Rossi	Assistant to the chair of Higher and Mathematical Analysis

Table 2.6 Faculty of sciences (1924–25): lecturers not belonging to institutes or cabinets or laboratories

Name	Role
Umberto Cisotti[a]	Lecturer in Mathematical Analysis; lecturer in Complements of Analysis; lecturer in Hydroaeromechanics
Giovanni Battista Traverso	Lecturer in General Pathology

[a] Professor of Rational Mechanics at the Royal Superior School of Engineering

degree course in Physics will be established by Giovanni Polvani, starting only from the 1930–1931 academic year, as the degree course in Applied Physics.

At the beginning, the Faculty of Sciences offered only the teaching of two courses in physics—Experimental Physics (i.e. classical physics) and Complementary Physics (advanced classical physics and modern physics, considered from an experimental point of view)—to the students of the degree course in Applied Mathematics.

Furthermore, when still in the preparatory phase, the University did not look for a lecturer of Experimental Physics and set an agreement with the Royal Superior Technical Institute (today's Polytechnic School) to use the class and laboratory of Experimental Physics as "Laboratory of Experimental Physics". The students of Milan University would have thus attended the course of Experimental Physics taught at the Technical Institute by Oreste Murani. This situation continued until the 1926–1927 academic year, when Aldo Pontremoli was commissioned as lecturer to teach Experimental Physics. It was instead decided that any effort had to be done to have at least the course of Complementary Physics taught by a professor of the future university from the beginning.

The organizers of Milan University consulted Orso Mario Corbino, the director of the Institute of Physics in Rome, for help in finding a suitable candidate to teach Complementary Physics. Corbino advanced the proposal to call one of his assistants, Aldo Pontremoli.

The rector named Aldo Pontremoli as lecturer in Complementary Physics on September 22, 1924.[10] With this act, the Institute of Complementary Physics was formally founded.

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[10] Centro APICE, Historical Archive Milan University: serie 7, titolo 9, personal file 2497 (Pontremoli): rector's decree n. 57, September 22, 1924.

2.2 The People Working at the Institute of Complementary Physics

The Institute of Complementary Physics started its activity in 1924 with Aldo Pontremoli as commissioned director and lecturer in Complementary Physics, Glauco De Mottoni y Palacios as assistant and Giovanni Adorni as technician (see: Table 2.7). De Mottoni was assistant for just two years. Adorni was a technician of the workshop of the Institute of Complementary Physics and then of the Institute of Physics for the whole period covered in this book.

2.2.1 Aldo Pontremoli

The founder of the Institute of Complementary Physics, Aldo Pontremoli,[11] was born in Milan on January 19, 1896. He was the son of Alfredo Pontremoli (1865–1911) and Lucia Luzzatti (1867–1957), both descendent from important Jewish-Italian families. Alfredo Pontremoli was an engineer who, at the time of Aldo's birth, directed a paper mill in Besozzo, a location close to the Maggiore Lake. From his father, Aldo got the curiosity and interest in science and art (Fig. 2.1).

His grandfather on his mother's side was Luigi Luzzatti[12] who played a relevant role in his life as a very inspiring figure. Luzzatti was professor of Political Economics in Milan in 1863–1867, professor of Constitutional Law at Padua University in 1867–1896. He founded and was the first president of the Banca Popolare di Milano in 1865. He was one of the constituent founders of Venice University. He acted as a member of the Italian Government more than one time from 1869 on, and was President

Table 2.7 Institute of complementary physics (1924–25 academic year)

Name	Role
Aldo Pontremoli	Commissioned director; lecturer in Complementary Physics
Glauco De Mottoni	Assistant
Giovanni Adorni	Technician

[11] On Aldo Pontremoli, see the biographies [2–8]. The biography written by Giordana [6] is a romance-like book for the laypeople. It is however interesting because it handles with Pontremoli's intimate life. His main sources were the conversations he held with Pontremoli's mother and the correspondence with her and with Pontremoli's friend Massimiliano Majnoni. In their opinion, Giordana's biography was to be considered a faithful one (Archivio Storico Intesa San Paolo, Archivi personali della Banca Commerciale Italiana, fondo 10 P-MAJ, carte personali di Massimiliano Max Majnoni d'Intigano, 25–78 lettere di amici, colleghi e conoscenti, fasc. 54–3.).

[12] On Luigi Luzzatti, see: [9].

Fig. 2.1 Aldo Pontremoli (Copyright: Public image)

of the Council of Ministers in 1910–1911. Luigi Luzzatti was another person who supported Pontremoli's developing interests in science and taught him how to behave and get the best chances in high class society.

As a child, Pontremoli was very interested in radio-wave transmission and, thanks to his grandfather, he could get in touch with Guglielmo Marconi. Pontremoli merged his scientific curiosity with his organisational abilities and established with two of his friends a radiotelegraphy society to study radio wave devices, which lasted until he began his studies in physics.

Pontremoli attended the Gymnasium and Classical Lyceum "Beccaria" in Milan. His physics professor was Temistocle Calzecchi Onesti[13] (1879–1922), who was a scientist known for the invention of the coherer[14] later improved by Guglielmo Marconi for the radio waves detection in his apparatus. Calzecchi Onesti inspired in Pontremoli a much stronger passion in the study of physics. Since there was no graduation course in Physics in Milan, Pontremoli enrolled the Engineering course at the Royal Superior Technical Institute in Milan. His physics professor was Oreste

[13] On Temistocle Calzzecchi Onesti, see: [10].

[14] Calzecchi Onesti's coherer was a glass tube filled with nickel and silver powders. Their conductivity increased when they were struck by electromagnetic waves.

Murani[15] (1853–1937) for whom Pontremoli will feel a profound esteem also when they will be colleagues at Milan University. In Murani's laboratory, Pontremoli was introduced to research topics such as the transmission of electromagnetic waves, the properties of X-rays, the ionization of gases.

When Italy entered the First World War on May 24, 1915, Pontremoli left Milan. He was a convinced interventionist and decided to volunteer in the Army. He was sent to a balloon division close to Padua, then to Udine as the director of the observational tower which was located on top of the Udine castle. He was taught to fly military tethered balloons and to draw surveys of the enemy army stations from above. He was promoted second lieutenant of the Balloon Military Engineering Corps of the Third Army in the Fifth Balloon Section. In 1916 he was promoted to the Fourth Balloon Section and in 1917 to the Third Balloon Section which was moved to Ferrara after Italy's defeat in Caporetto. In 1918 he was sent to France where he fought in the Ardennes French-German front and in the Bois de Bligny. In late 1918 he was sent to Belgium before he came back to Italy. At the end of the war he was awarded with a silver medal, a military cross, a French war cross, and two Italian war crosses for his war merits.

In 1919 Pontremoli resumed his studies but decided to move to a degree course in Physics. He enrolled at the fourth year of Physics at Rome University. He became a student of Orso Mario Corbino[16] (1876–1937) who was his thesis tutor in a research on the birefraction fringes in a liquid in a permanent plane motion [13]. Pontremoli graduated in Physics with full marks on July 3, 1921 and soon became one of Corbino's assistant at the Institute of Physics of Rome University. He continued his studied on birefraction fringes in liquids [14], in particular in solutions of Bravais colloidal iron, a substance used by Corbino in his researches on magnetic fields.

The Associazione Nazionale Combattenti financed with a 8,000 lire scholarship a post-graduate period of research and education in nuclear and atomic physics at the Cavendish Laboratory in Cambridge. Pontremoli could in this way get an excellent formation in some relevant topics of contemporary physics. He attended lectures given by Charles Galton Darwin, Arthur Eddington, Joseph Larmor, Ernest Rutherford and Joseph John Thomson. At the same time he was trained in radioactivity measurements and helped in counting the atoms recoiling from a homogeneous α-ray beam in an experiment [15]. Ernest Rutherford appreciated Pontremoli's contribution and for his "great fertility in speculation and suggestions for further experiment." ([7] p. 42).

Once back to the Institute of Physics at Rome University, Pontremoli worked with two other young scientists who had joined Orso Mario Corbino, Enrico Fermi and Enrico Persico, who also spent some time abroad to be better trained in contemporary physics.

Besides his work as a physicist assistant, he was engaged in the organization of several activities. Pontremoli supported the Italian University Federation, which sent him to Prague as the Italian delegate to the international congress of the Confédéra-

[15] On Oreste Murani, see: [11].

[16] On Orso Mario Corbino, see [12].

tion internationale des étudiants (from March 23 to April 6, 1921). Thanks to his diplomatic ability, Italy was admitted unanimously admitted as a titular member of the Confédération. In 1924 he was named secretary of the Italian Committee for the Transportation and the Settlement of the Armenian Refugees who had escaped the genocide in Turkey.

As for his researches in Rome, Pontremoli studied a possible modification of Maxwell equations of a linearly polarized wave inside a dielectric material placed in two longitudinal electric and magnetic fields [16]. He suggested the existence of optical phenomena in isotropic materials placed in two electric and magnetic longitudinal fields, such as circularly polarized waves propagating parallel to the lines of force of the fields [17].

Pontremoli analyzed the proton-electron compound neutral structure inside the atomic nucleus [18] whose existence was advanced and called "neutron" by Ernest Rutherford in his 1920 Bakerian Lecture [19]. Pontremoli studied two different models for Rutherford's neutron compatible with Bohr's atomic theory [20]. With Enrico Fermi, Pontremoli wrote a short contribution to relativistic physics with a study of the electromagnetic mass and the inertia of charged particles [21].

In spectroscopic research, Pontremoli studied the electric discharges in rarefied gas and the effect of a magnetic field on these discharges [22], the effect of the magnetic field on the discharge of rarefied gases [23] with a high level of dissociation in the gas produced with a Corbino-Trabacchi apparatus. He analyzed the thermionic emission from a quantum point of view [24] and criticized Richardson's proposal to consider the photoelectric effect a thermionic emission [25] highlighting its incompatibility with the experimental results. Another theoretical quantum research concerned the study of the electric conductivity of flames containing alkaline salts [26]; his formulas were compatible with the experimental results.

Following Corbino's suggestion, Pontremoli was called as lecturer in Complementary Physics and director of the corresponding institute by Milan University. On September, 22 1924, the Rector named him even before he had obtained the "libera docenza" for Higher Physics.[17] The young professor in Milan, thanks to his descent from Luigi Luzzatti, was a person well introduced to the high class society and the more relevant milieus in the Milan of the time. This was of the utmost help in the foundation of the Institute of Complementary Physics, since Pontremoli was very able in obtaining private financial support to be added to the scarce university funds. In his quality of Luzzatti's grandson, he easily obtained from the Banca Popolare di Milano a huge funding of 100,000 lire on occasion of the seventieth anniversary of the bank foundation.[18] For comparison, the annual endowment that the State assigned to the entire Milan University since its establishment amounted to 300,000 lire. The Institute of Complementary Physics was thus quickly equipped with instruments for

[17] He obtained the 'libera docenza" to teach Higher Physics on December 9, 1924 (Archivio Centrale dello Stato, MPI, DGIS Div. 1, Liberi docenti 2a serie (1910–1930): 263 "Aldo Pontremoli"; ministerial decree December 9, 1924.). Higher Physics was a course of advanced physics.

[18] Centro APICE, Historical Archive Milan University, serie 7, titolo 8, busta 170 "Fisica 1924–1938": letter from the Banca Popolare di Milano to the rector Luigi Mangiagalli, March 5, 1926.

a laboratory of radiology for applicative researches on the use of radioactivity, X-rays and UV-rays in medicine and industry.

In May 1926 the first Italian public competition for a chair of Theoretical Physics was published.[19] Quantum theoretical physics was not taught at that time in Italian universities in a course explicitly concerning it.[20] Corbino wanted Enrico Fermi as professor of Theoretical Physics in Rome and succeeded to convince the minister of public education to create this new chair and organize a public competition. The commission formed by Michele Cantone, Orso Mario Corbino, Antonio Garbasso, Gian Antonio Maggi and Quirino Majorana decided the winners rank as: 1st Enrico Fermi unanimously, 2nd Enrico Persico by majority, and 3rd Aldo Pontremoli unanimously.[21] The establishment of the Institute of Complementary Physics with its laboratory of radiology were highly appreciated by the evaluating commission.[22] Because of bureaucratic problems (there was no chair of Theoretical Physics at the Faculty of Sciences), Pontremoli was lecturer in Theoretical Physics only from April 1927. This fact irritated somehow Pontremoli. At the same time, the Institute of Complementary Physics had to join all other institutes of the Faculty of Sciences in the Palace of Sciences; this meant to transfer everything to another building and start again to set the laboratories. To recover from Luigi Luzzatti's death, Pontremoli worked in the organization of the International Congress of Physics held in Como.

In Milan, Pontremoli continued his studies on advanced classical optics, birefraction, spectroscopy, and the electric and thermal conductivity of metals (see Sect. 2.5). Pontremoli also wrote divulgative papers on atoms and stars [30], the experimental foundations of quantum theory [31], the scientific schools and the progress of science [32], and the disintegration of matter [33]. For the Mathematical and Physical Seminary of Milan he gave two lectures on some preliminary experiences on plane parallel currents meeting a circular cylinder with the axis perpendicular to the directing plane of the current [34] and on the new ways of mechanics, i.e. quantum mechanics [35].

In 1927 Umberto Nobile invited Pontremoli to join him in his next polar expedition to the Arctic on board of the Italia airship. He was engaged in the preparatory plans of the expedition, designed and tested some of the instruments to be carried on board (see Sect. 2.6). Pontremoli disappeared due to the accident which occurred during the third flight, on May 25, 1928.

[19] On the first competition for a chair of Theoretical Physics, see: [27, 28].

[20] On the diffusion of quantum theory in Italy see: [29].

[21] Archivio Centrale dello Stato, MPI, DGIS Div. 1, Conc. catt. univ. 1924–1954. Minutes of the Theoretical Physics competition in the Royal University of Rome, 2nd meeting, pp. 6–7.

[22] Archivio Centrale dello Stato, MPI, DGIS Div. 1, Conc. catt. univ. 1924–1954, 15, 176.

Table 2.8 Institute of complementary physics (1925–26)

Name	Role
Aldo Pontremoli	Commissioned director; lecturer in Complementary Physics
Glauco De Mottoni	Assistant
Enzo Pugno Vanoni	Assistant
Giovanni Adorni	Technician

2.2.2 Glauco de Mottoni

Glauco De Mottoni y Palacios was born in Trieste on July 30, 1901. He graduated in Electrotechnical Engineering at the Royal Superior Technical Institute in Milan in 1924 and in Applied Mathematics at Milan University in 1926. In 1924–26 he was assistant to Aldo Pontremoli at the Institute of Complementary Physics in Milan, while he started to work as an engineer. In Pontremoli's laboratory he carried on researches in optics. Due to a pneumonia, he could not join Aldo Pontremoli in the 1928 polar expedition.

At the same time he had a deep interest in astronomy. Already as a student he had started to collaborate with the Astronomical Observatory of Brera and Merate where he will lead the planetary division; in 1922–25 he studied Venus. Later he was one of the leading researchers on Mars at an international level. From 1948 he studied the oppositions of Mars at the aphelius. In 1956 he proved that some white spots observed on Mars were clouds and determined their characteristics. He made a very detailed map of Mars from photographic maps; Mottoni's map was adopted by the International Astronomical Union in 1957 and was used by the Mariner 4 space probe of the NASA in 1964.

He worked on the projects of the objective lens with the Ruths company in Genoa for the reflector telescope which was put on work in the Merate division of the observatory in 1968, and was a consultant in the production of the objective of the telescope for the Astronomical Observatory of Turin.

Glauco De Mottoni y Palacios died on May 9, 1988.

2.2.3 Enzo Pugno Vanoni

In 1925 Enzo Pugno Vanoni, an engineer, joined Pontremoli and De Mottoni at the Institute of Complementary Physics (see: Table 2.8). He was assistant for two years, then help until the 1930–31 academic year.

Enzo Pugno Vanoni[23] was born in Milan on March 4, 1899, the son of the engineer Francesco Pugno. He graduated in Industrial Engineering (Electricians division)

[23] On Enzo Pugno Vanoni, see: [36].

at the Royal Superior Technical Institute in Milan on November 28, 1922. He was appointed volunteer assistant of Riccardo's electrotechnical laboratory and teacher at the Industrial Institute Feltrinelli and other schools in Milan. He left the Technical Institute to become assistant at the Institute of Complementary Physics of Milan University from 1925 to 1931. He obtained the "libera docenza" in General Electrotechnics in 1927. He was lecturer in Experimental Physics for the Faculty of Medicine and Surgery from 1927, and of Electrotechnics and Physics of Röntgen Radiations for the School of Medical Radiology of the same faculty. His main research field was the physical study of X-rays and their applications to medicine [37–39], and the generation of rectified high voltages [40–42, 44–48].

When Aldo Pontremoli left Milan to join the 1928 polar expedition, Pugno Vanoni was appointed pro tempore director the Institute of Complementary Physics and was lecturer in Experimental Physics until the arrival of Giovanni Polvani in the late 1929.

In late 1931 he won a public competition of Electrotechnics and became extraordinary professor at the Faculty of Engineering of Padua University. In Padua he was the director of the Laboratory of Electrotechnics. He planned and built a powerful plant for Röntgen-therapy at the Institute of Radiology of Rome University and a 1000 kV plant for researches in nuclear physics at the Institute of Physics in Padua. He was the Italian representative in the international commissions for the units of measurement and protections in radiology in Chicago in 1937. He was an authoritative member of the Italian Electrotechnical Association, the Italian Electrotechnical Committee, the National Technical Committee of Cinematography and the Italian Society of Medical Radiology.

Enzo Pugno Vanoni, after two months illness, prematurely died on April 4, 1939 at the age of forty.

2.2.4 Giusto Rossi, Sergio Beer and Maria de Marco

Three other assistants were appointed for the Institute of Complementary Physics: Giusto Rossi in 1926–27 (see: Table 2.9), Sergio Arturo Beer in 1927–29 (see: Table 2.10), and Maria De Marco as volunteer assistant in 1928–29 (see: Table 2.11) and assistant in 1929–1931. Another technician, Giovanni Adorni, was employed for the Institute of Complementary Physics and worked with Mario Pessina for the Institute of Physics for the period covered in this book.

Giusto Rossi was born in Fabriano on April 17, 1883. He graduated in Chemistry at Rome University in 1914. He was assistant as a chemist at the Institute of Complementary Physics of Milan University in 1926–27. He then left the university to accept a work proposal in a national industry.

Sergio Arturo Beer[24] was born in Ancona on December 17, 1903. He graduated in Natural Sciences at Milan University in 1927. He was assistant to the Institute of

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[24] On Sergio Arturo Beer see [49].

Table 2.9 Institute of complementary physics (1926–27)

Name	Role
Aldo Pontremoli	Commissioned director; lecturer in Complementary Physics
Enzo Pugno Vanoni	Assistant
Giusto Rossi	Assistant
Giovanni Adorni	Technician
Mario Pessina	Technician

Table 2.10 Institute of complementary physics (1927–28)

Name	Role
Aldo Pontremoli	Commissioned director; lecturer in Complementary Physics; lecturer in Theoretical Physics
Enzo Pugno Vanoni	Help
Sergio Arturo Beer	Assistant
Giovanni Adorni	Technician
Mario Pessina	Technician

Table 2.11 Institute of complementary physics (1928–29)

Name	Role
Aldo Pontremoli	Commissioned director; lecturer in Complementary Physics; lecturer in Theoretical Physics
Enzo Pugno Vanoni	Help
Sergio Arturo Beer	Assistant
Maria De Marco	Volunteer assistant
Giovanni Adorni	Technician
Mario Pessina	Technician

Complementary Physics in 1927–29. He obtained the "libera docenza" in Sericulture and Silk Technology in 1932. In 1929–33 he was commissioned assistant for the Laboratory of Agricultural Zoology and Sericulture or the Royal Superior Institute of Agriculture in Milan. In 1933–35 he worked as experimenter at the Royal Chemical-Agricultural Institute in Rome, before coming back to the Milan Institute.

While collaborating with Milan University, Beer became high school teacher. In 1939 he had to leave Milan University because of the racial laws; at that time he was dean and teacher for the Jewish community in Ancona. He managed to organized elementary and middle school classes for the students expelled from the public schools between 1938 and 1942. After the end of the war he became lecturer in Zooculture at Rome University.

Sergio Arturo Beer died in Ospedaletti on November 8, 1997.

Maria Anna Saveria Francesca d'Assisi De Marco was born in Naples on May 1, 1896. She graduated in Electrotechnical Engineering in 1921 (the first woman in Italy) at the Royal School of Application for Engineers in Rome. She was the first woman assistant at the School for Engineers. She was voluntary assistant at the Institute of Complementary Physics at Milan University in 1928–29 and assistant in 1929–31.

She was also assistant at the Royal School of Application for Engineers in Rome from 1930. In 1936 she became extraordinary assistant at the Institute of Electrotechnical Engineering. She was assistant for the courses of Electrical Measurements and of Electrotechnics, and was the director of one of the laboratories until her death.

Maria De Marco died on February 8, 1941.

2.3 The Mathematical and Physical Seminary of Milan

The Mathematical and Physical Seminary of Milan[25] was established on November 27, 1926 and was inaugurated on February 9, 1927. The dean of the Faculty of Sciences, Gian Antonio Maggi, was appointed its first director. The role of the Seminary was the diffusion of mathematical and physical culture and to promote researches and studies. The seat of the Seminary was alternatively Milan University and the Milan Polytechnic School.

The members of the first Board were: Gian Antonio Maggi (director), Umberto Cisotti (secretary), Riccardo Arnò, Emilio Bianchi, Cesare Capelli, Ugo Cassina, Oscar Chisini, Arturo Danusso, Gaudenzio Fantoli, Bruno Finzi, Luigi Gabba, Giorgio Mortara, Oreste Murani, Aldo Pontremoli, Luigi Santarella, Giulio Vivanti.

The members of the Seminary were the professors, helps and assistants of the Faculty of Sciences of Milan University, of the Engineering School of Milan Polytechnic, and of the Astronomical Observatory of Brera and Merate, the post-graduate students of the former institutions, the undergraduate students of mathematics, physics and engineering, and everybody interested in mathematics and physics. The Seminary published the "Rendiconti del Seminario Matematico e Fisico di Milano", with an interruption in 1943–45. The most relevant activity of the Seminary was the organization of conferences on topics in contemporary mathematics and physics. People invited from other Italian universities or from abroad increased in time. Every new full professor of both Milan University and Milan Polytechnic School was invited to give his/her first public lecture at the Seminary.

Pontremoli contributed to the life of the Seminary, which hosted a conference by him on quantum mechanics. On March 30, 1928, the Seminary Board visited the airship Italia where Pontremoli was preparing the polar expedition. Also during the

[25] On the history of the Mathematical and Physical Seminary of Milan, see: [50].

subsequent Institute of Physics, Giovanni Polvani gave important contributions to the Seminary. Several important physicists gave lectures at the Seminary, but the prevalent number of conferences concerned mathematics. These conferences were an important occasion for the researchers and the students to be aware first hand of the main contemporary topics in experimental or theoretical physics.

In 1949–52, the Seminary had some divisions also called Seminary. The Physics Seminary was directed by Giovanni Polvani, Giuseppe Bolla, Bruno Ferretti and Piero Caldirola. From 1965, the Seminary had two directors, a physicist and a mathematician.

2.4 The Institute of Complementary Physics

The Institute of Complementary Physics[26] was established in 1924 by Aldo Pontremoli.[27] The Institute was hosted in some rooms of a former technical school of Milan Municipality, in via Antonio Sacchini 34.[28] The university had planned to finance the Institute of Complementary Physics with 150,000 lire in 1924–25, 200,000 lire in 1925–26, and 150,000 lire in the following years, to buy furniture, instruments for the laboratories and the workshop, books and journals for the library, and to build the electric plants. Pontremoli was able to obtain other funds from private patrons and industries. The most relevant extra funds were the donation of 100,000 lire from the Banca Popolare di Milan for the instruments of the radiation laboratory and the donation of 50,000 lire from the Società Edison di Elettricità to be shared with the Institute of Industrial Chemistry (27,476 lire were assigned to the Institute of Complementary Physics). Pontremoli followed himself all the works to adapt the existing rooms to laboratories, workshops and classrooms. The Institute of Complementary Physics, located on three floors, was ready within a few months.

On the first floor, there were on the northern wing: the direction, the scientific library, the director's laboratory, the help's laboratory, the laboratory for thesis researches, the darkroom for photography, the darkroom for spectroscopy, a protected cabinet for X-rays researches, a workshop, a room with the scales. On the southern wing there were: a small laboratory for thesis researches, three rooms for the students exercitations (one of them was a darkroom for optics experiments), the electrical cabinet, the goods lift, a small preparatory room for experiments in the classroom, the classroom for eighty students. All movable instruments were stored in the corridor wardrobes.

On the ground floor, only three rooms were assigned to the Institute of Complementary Physics: two rooms for the Radiology Laboratory, and the workshop.

[26] On the Institute of Complementary Physics see [51].

[27] On the establishment of the Institute of Complementary Physics see [52].

[28] The building currently hosts the Istituto Comprensivo “Quintino Di Vona—Tito Speri” formed by the elementary school “Tito Speri” and the secondary school “Quintino Di Vona”.

On the underground floor, there were: two laboratories protected from the building vibrations, the electric plants, the goods lift, the batteries storage room. The electric plants were composed of a Marelli 10.7 kW, 165/230 V dynamo group, a Giampiero Clerici & Co. 5 kVA three-phase 160/10,000 transformer, and four 95 Ah Hensemberger batteries.

The library was equipped with the most important journals. They bought the whole collection of Zeitschrift für Physik and of Physikalische Zeitschrift. All other journals were bought only from 1924 on: Annalen der Physik, Annales de Physique, Astrophysical Journal, Atti della Reale Accademia Nazionale dei Lincei, Comptes Rendus de l'Academie des Sciences, Comptes Rendus de la Société Polonaise de Physique, Elettrotecnica, General Electric Review, Giornale di Chimica Industriale ed Applicata, Il Nuovo Cimento, Journal de Physique et le Radium, Journal of the American Institute of Electrical Engineering, La Radiologia Medica, Mount Wilson Contributions, Nature, Periodico di Matematiche, Philosophical Magazine, Physical Review, Physikalische Berichte, Rivista Italiana di Actinologia, Science Abstracts, Scientia, Zeitschrift für technische Physik.

Pontremoli organized the Radiation Laboratory for scientific and technical measurements on X-rays. The Radiation Laboratory was entrusted by the Technical Commission of the Italian Society of Medical Radiology of all radiological studies and tests on their account. The Radiation Laboratory would have been a fundamental part of a planned institute for the cure of cancer in Milan. The Radiation Laboratory could release certificates of tests and researches carried on tests of radiology devices, X-ray tubes, ionic and thermoelectric valves; calibration of devices; X-ray spectrographic measurements; ionization measurements.

Four sections built up the Radiation Laboratory. The research section mostly carried on radio-metalloscopy experiments to detect any defects in metal structures, the study of the energy distribution emitted by tubes supplied by different tension shapes, the study of radiation-absorbing screens minimizing the diffused radiation. The three other sections concerned electrotechnics, the testing of tubes and thermoelectric vales, and the calibration of radiometric devices.

The most relevant instruments of the Institute of Contemporary Physics were: an intensive Corbino-Trabacchi apparatus with a 280,000 V rectified tension to produce an electrical current as power supplier for X-ray tubes; one quartz and two glass big Littrow spectrographs for measurements with prisms (with 30°, 60°, and 90° angles; the face opposing the 60° angle was coated with a reflective film) in the visible and the ultraviolet; a spectrograph with constant deviation, with a Lummer-Gehrcke plate for high-resolution multiple-beam interferometry, a Michelson grating, a Fabry-Pérot etalon, and a set of oculars; a monochromator for infrared, visible and ultraviolet radiations; a big Möll microphotometer; a Yvon spectrophotometer to study the absorption, diffusion, polarimetry, photometry, homochromatic and heterochromatic spectrophotometry, and position microphotometry; a big circle of Jamin and Sénarmont to study refractions and reflections; a Jamin optical bench to study diffraction and interference; a Weiss electromagnet with cylindrical iron-cobalt poles wrapped by copper tubes as coils, producing a magnetic field up to 38,000 gauss;

a Compton quadrant electrometer for radioactivity measurements; a Hartmann and Braun millivoltmeter and milliamperometer.

In 1927 Milan University decided to gather all the institutions of the Faculty of Sciences in one building: the Palace of Sciences, in Via Saldini 50. The palace had been planned and built to host the central administration of the University. Its architectonical structure was not suitable to host scientific institutes. The rectorate, the central administration and the Faculty of Arts and Philosophy were moved to another building in a more central location in the city, in Corso Roma (today's Corso di Porta Romana), and the original palace was transformed into the Palace of Sciences. Another location for the rectorate was considered at that time, its current location in the historical Major Hospital in Via Festa del Perdono. This second choice required to move the hospital to Niguarda, a northern district of Milan. This transfer was already planned but happened only in 1939.

In April 1927, the rectorate with the faculties of Law and of Arts and Philosophy were transferred to a building in Corso Roma 10, in the town centre. In the next three months, the building in Via Saldini was adapted by architect Magistretti to host the scientific institutes. In November 1927, the scientific institutes had all moved to this new location. The Palace of Sciences was inaugurated by the rector, Baldo Rossi, on December 3, 1927.

The Institute of Complementary Physics was located on the ground floor of the Northern wing and in the cellars below it. The total number of rooms at disposal for the offices and the laboratories was about ten (the number varied in time by changing some separating walls). Other spaces at disposal were a lecture room, a small workshop, and a small library.

On the first floor there was the Institute of Chemistry. Also in this case, the architectural features of the building caused problems to the Institute of Complementary Physics. There were occasional leaks of water contaminated by the drains of the Institute of Chemistry and flooding the rooms below. Over the years this caused damage to the equipment as well as to the health of those who attended the Institute of Physics.

2.5 Research Activities

Several research topics were carried on at the Institute of Complementary Physics under Pontemoli's scientific leadership. They ranged from advanced classical optics and electrotechnical technology to topics studied with quantum theories, such X-ray spectroscopy and the properties of materials. Applicative research comprised electrotechnical plants and the use of radiations in biological studies. It is evident the role played by Pontremoli's education in part as an engineer (even his first assistant, Glauco De Mottoni, and his main assistant, Enzo Pugno-Vanoni, were both engineers themselves) and his being a member of Rutherford's and Fermi's research groups, open to contemporary topics and research in quantum physics, but also his interest in applying physics to technological and biological problems.

2.5.1 Optical Research

In Milan, Pontremoli continued the optical researches he had carried on in Rome starting from his degree dissertation. His main interest concerned birefraction in different materials, but in general he afforded the problem of light-matter interaction. His first research, preliminary to future applications to optics, was on the orientation of the ellipsoidal molecules of a gas with an anisotropic behavior in an electric or magnetic field [54]. Thermal agitation acted against the orientation imposed by an external field. Pontremoli found the number of molecules dN per unit volume, whose polar axis was at angle between θ and $\theta + d\theta$ with respect to the external field H:

$$dN = N \frac{e^{\frac{(P-E)\cos^2\theta}{2k_B T}} H^2 \sin\theta d\theta}{\int_0^\pi e^{\frac{(P-E)\cos^2\theta}{2k_B T}} H^2 \sin\theta d\theta}$$

where $P\cos\theta$ and $E\sin\theta$ are the molecular moments ($P > E$ due to the asymmetry). Without an external field the orientation distribution was isotropic:

$$dN_0 = \frac{N}{2}\sin\theta d\theta.$$

Pontremoli wondered if there was an orientation angle for which the two numbers where the same ($dN = dN_0$) and found, in a classical non-quantistic way, $\theta = 54°44'7''$.

In order to study the propagation of light in this gas, Pontremoli considered that each molecule had only one polarization electron with two proper frequencies, ν_P for the motion along the polar axis P and ν_E for the motion in the plane perpendicular to that axis [54]. A molecule in an external field obtained the correspondent moments m_P and m_E. For frequencies far from ν_P and ν_E, to avoid damping factors, the moments were:

$$m_P = \frac{e^2}{4\pi^2 m(\nu_P^2 - \nu^2)} F' \cos\rho$$

$$m_E = \frac{e^2}{4\pi^2 m(\nu_E^2 - \nu^2)} F' \sin\rho$$

where e is the electron charge, m is the electron mass, F' is the sum of the external field F and the induced polarization, ρ is the angle between the molecule axis and the external field F of the incident radiation. The total moment of the gas in the external field direction was thus:

$$M_F = F' \int_0^N \left[\frac{e^2}{4\pi^2 m(\nu_E^2 - \nu^2)} + \left(\frac{e^2}{4\pi^2 m(\nu_P^2 - \nu^2)} - \frac{e^2}{4\pi^2 m(\nu_E^2 - \nu^2)} \right) \cos^2\rho \right] dN$$

From this relation, he considered the superposition of an external magnetic or electric orientating field to the electric field of the electromagnetic wave. For the angle he had obtained, $54°44'7''$, the electric polarization of the gas was invariant with respect to the orientating field. The gas was therefore birefracting with an outgoing electromagnetic waves with elliptical polarization. Pontremoli tested this induced magnetic or electric birefraction with the Jamin interferometer.

The analysis of birefraction was applied to colloidal materials in motion [55]. Some experiments on Bravais colloidal iron in motion inside a tube had already been carried on by Dario Graffi. Pontremoli repeated Graffi's experiment but did not obtain the same results. Pontremoli's theory was valid for a liquid in motion at constant dilation speed and flux in all the points on any axis parallel to the observation axis. Pontremoli's theory furthermore showed that the birefracted radiation produced two fringe families, the first one dependent on the position of the polarizer principal section and on the deformation speed of the liquid, the second one function of the physical properties of the liquid. Graffi could observe only the first fringe family. A possible explanation of the experimental disagreement could be the fact that Pontremoli's theory unified the effects of two distinct kinds of birefraction, one due to the molecules orientation, and the other to the liquid internal deformation.

The study of the behavior of ellipsoidal molecules in material in an external electric or magnetic field benefitted from the help of Glauco De Mottoni [56]. They took into consideration the diffusion and depolarization of light in a gas with a rotational ellipsoidal symmetry with respect to the polarization induced by the electric field of an incident radiation. The polarization electrons were shifted and their motion was the cause of the radiation diffusion. They found for the intensity of the radiation diffused in the x-direction the relation (and similar relations for the y- and z-directions):

$$I_x = \frac{2\pi^3 ce^2}{r^2\lambda^4}\overline{x_0^2}$$

where c is a constant, x_0 is the amplitude of the x-component of the electron motion, λ is the wavelength of the incident radiation.

Pontremoli and De Mottoni then wanted to see if and when the second-degree moments of the polarization electrons were dependent on the external field and find the intensity of the diffused light through the Ponyting vector in the hypothesis of a negligible actions among the molecules. They took again into consideration the case of dielectric, diamagnetic, polarisable, ellipsoidal molecules [57]. They obtained relations equal to those of the null field hypothesis. In this way they showed that the light diffused from a gas in an external orientating field had an intensity independent from the external field in a given observational direction.

De Mottoni, because of his deep interest in astronomy, further studied diffraction gratings [58]. He considered the gratings used by Ronchi for stellar interferometry and wanted to show that they could give good results also in microscopic observations. De Mottoni showed that if the gratings were used with an immersion microscope, the resolving power could be made six times larger. De Mottoni tested with an experiment the observation of microscopic spherical objects with a grating applied to the microscope objective. With different grating orientations, it was possible to measure the object dimensions in those directions and obtain its shape. With a different choice of the microscope objective, the grating and the observational geometry, De Mottoni could observe other fringe families [59]. The fringe order had no effect on the displacement of interference fringes for small variations of the incident wave direction, independent on the position of the grating with respect to the microscope objective.

2.5.2 *Spectroscopical Research*

In Milan Pontremoli continued also his researches in spectroscopy. He considered Bohr's theory on the monochromatic radiation emitted by an electron in the transition between two stationary orbits and wanted to find how long it took for the electron to go from one orbit to another one [60]. The intensity of some absorption lines showed that the transition was long enough with respect to the mean life of a stationary state. He considered a hydrogen-like atom with $Ze = E$; its one electron moved from a first stationary orbit with radius r_1 to a second stationary orbit with radius r_2. The equation of the electron motion was:

$$m\dot{\mathbf{v}} = -\frac{eE}{r^2}\mathbf{u} + \frac{2}{3}\frac{e^2}{c^3}\dot{v}\,\mathbf{t}$$

From the energy lost due to radiation emission he obtained, under the assumption $v << c$:

$$\dot{r} = -\frac{4}{3}\frac{e^3}{E}m^2c^3\frac{e^2E}{mcv^3r^2}$$

By integration of this formula, Pontremoli found the formula for the emission duration which was:

$$t_{r_1\to r_2} = \frac{m_e^2c^3}{4e^3E}(r_2^3 - r_1^3)$$

The larger the distance between the two orbits, the longer the time taken by the electron to go from one to the other. For elliptical orbits, the formula was meant to give a mean value of the transition time. Pontremoli calculated the transition durations for the first lines of the hydrogen emission spectrum in the Balmer, Lyman, and Paschen series: $t = 1.05 \times 10^{-8}$ s for the Balmer series, $t = 9.94 \times 10^{-10}$ for the Lyman series, and $t = 5.31 \times 10^{-8}$ for the Paschen series. If the radius was written as a function of the quantum number n, Pontremoli's formula could be written as:

$$t_{r_1\to r_2} = \frac{m_ec^3}{64\pi^2e^2}\frac{1}{r^2Z^4}(n_2^6 - n_1^6)$$

where $R = 2\pi^2me^4/h^3$ was Rydberg constant. By considering the orbital periods T_1 and T_2 of the two orbits, Pontremoli's formula was eventually:

$$t_{r_1 \to r_2} = \frac{3m_e c^3}{16\pi^2 e^2}(T_2^2 - T_1^2)$$

For transitions between two stationary orbits with large quantum numbers, Pontremoli developed an approximate formula:

$$t = \frac{3m_e c^3}{8\pi^2 e^2}\left(\frac{1}{2RZ^2}\right)^{1/3}\frac{1}{\nu^{5/3}}$$

where ν is the frequency of the radiation emitted by the electron. The action lost by the atoms in the transition between two contiguous stationary orbits $(h/2\pi)$ was equal to the action of the emitted radiation:

$$I = \frac{2}{3}\frac{e^2}{c^3}\int_0^t v\,\dot{v}\,dt.$$

Eventually, Pontremoli proved that, for great quantum numbers and circular orbits, the mean life of an atom in an excited state was equal to the emission duration of the radiation emitted from that state. For circular obits, the mean life of the atom was smaller than the emission duration.

A second spectroscopic research concerned the K_α emission line in the X-ray spectrum, with the orbit radiuses given by Moseley law [61]. The K_α line was emitted with the transition from the $n = 2$ orbit to the $n = 1$ orbit, with respective radiuses:

$$r_K = \frac{h^2}{4\pi^2 me^2(Z-1)} \qquad r_L = \frac{h^2}{\pi^2 me^2(Z-1)}$$

The application of Pontremoli formula of the emission duration gave:

$$t = \frac{9.94 \times 10^{-10}}{(Z-1)^4}\text{s}$$

The duration of the emission of the K_α line for each element was thus inversely proportional to the fourth power of the effective atomic number $(Z-1)$. With Moseley law, Pontremoli formula could be written as a function of the radiation frequency ν:

$$t = \frac{5.99 \times 10^{21}}{\nu^2}\text{s}$$

or

$$t \times \nu^2 = 5.99 \times 10^{21}\text{s} = \text{constant}$$

that is a constant for any chemical element. By simple numerical calculation, Pontremoli obtained the emission duration, once known the K_α line frequency, from sodium (9.94×10^{-14} s) to uranium (1.45×10^{-17} s).

2.5.3 Electrical and Electrotechnical Research

When in Rome, Pontremoli had studied the electrical conductivity of flames containing alkali salts [26]. In Milan, he extended his study to metals and to thermal conductivity. At that time, they were able to calculate some coefficients when the metals were part of a saline structure, but not when the structure was a non-ionic one. X-rays analysis showed that the most frequent metallic structures were cubic and hexagonal. Pontremoli considered the free electrons in a metal as a ultra-rarified gas, and considered a metal with a cubic structure exposed to an electric field perpendicular to one of its faces. He obtained in this case the free electrons distribution which let him write an expression for the total current of the free electrons through a perpendicular cylinder of diameter d and for the conductivity σ_E per unit volume at constant concentration and temperature:

$$\sigma_E = \frac{4}{3} d \sqrt{\frac{1}{2\pi m k_B T}} e^2 N$$

with N total number of free electrons per unit volume. For symmetrical crystals, σ_E had the same values along similar structural directions. With the same model, Pontremoli found the thermal conductivity σ_T as:

$$\sigma_T = \frac{4}{3} d \sqrt{\frac{2k_B T}{\pi m}} k_B T$$

The ratio of the two conductivities was in agreement with Lorentz theory:

$$\frac{\sigma_T}{\sigma_E} = 2\frac{k_B^2}{e^2} T.$$

As for electrical instruments, Pontremoli studied the Coolidge tube (a kind of X-rays tube) with an applied constant or rectified sinusoidal tension [63]. Under the assumption that a constant current was generated in the tube by the sinusoidal tension, Pontremoli obtained the X-ray wavelength corresponding to the maximum intensity of radiation and observed how this wavelength varied as a function of the shape of the tension applied to the tube. The theoretical analysis was confirmed only qualitatively with microphotograms impressed by the X-rays produced by the Coolidge tube with different applied tension shapes.

Besides his studies, which were purely of electrotechnical engineering on the rectifiers of currents at extremely high tensions for radiological uses, on the multiple uses of thermionic valves, on self-protected transformers against over-tensions, Enzo Pugno Vanoni was engaged also in researches on electrical devices which had an immediate application in physical research. He made an important study on dielectric materials concerning the detection of gaseous inclusions. The electrical discharges inside the gaseous inclusions affected the electrical and mechanical properties of the dielectric. Pugno Vanoni studied a possibile use of a Braun tube to detect these gaseous inclusions [64]. A ionization tension threshold was observed when the gas started to be ionized depending from the temperature, pressure and electrification. Pugno Vanoni tested the behavior of paper cover by paraffine and of paper impregnated with a mixture of rosin, in both cases with and without gaseous inclusions. His experiments confirmed the different behavior of the dielectric.

2.5.4 Instruments for the Polar Expedition

Aldo Pontremoli built some devices to be used in the 1928 polar expedition (see Sect. 2.7). After the expedition, Glauco De Mottoni and Enzo Pugno Vanoni described three of them in a chapter in [74] (pp. 89–98): the gravimeter, the device to study sea currents and measure salinity and temperature, and the magnetometer.

Pontremoli's gravimeter [71, 72] was a device which had to be used in unstable locations, such as onboard the airship or on the icepack. He adapted a gas barometer to microscopic measurements of the mercury meniscuses positions to obtain the gravity acceleration when it was in equilibrium with the pressure of the gas trapped inside the closed branch of the barometer:

$$g = \frac{p_0 V_0}{V} \frac{1 + \alpha T}{\mu} \frac{1}{x - y}$$

where p_0 and V_0 are the pressure and volume of the gas at the testing temperature T_0, V is the gas volume at the temperature T of measurement, α is the gas dilation coefficient, μ is the density of mercury at the testing temperature T_0, and x and y are the positions of the meniscuses on the two branches of the barometer. To this formula, Pontremoli added the dilation coefficients of the barometer glass γ and of the scaling rules γ_1 on which he read the meniscuses positions:

$$g = \text{constant} \frac{1 - (\alpha - 2\gamma - 2\gamma_1 + \beta)T}{x(x - y)}.$$

By measuring the positions x' and y' at a testing temperature T' in a location with gravity acceleration g', the measured acceleration at the same temperature in a different location was therefore:

$$g = g' \frac{x'(x' - y')}{x(x - y)}$$

with an absolute error of 0.025 cm/s^2. The gravimeter had to be calibrated in this way at the base camp in King's Bay. Due to possibile difficulties in observing directly the meniscuses positions, he attached a camera to the gravimeter for the automatic registration on a film.

Pontremoli's magnetometer was only planned and not built. It should have been a set of three perpendicular coils. The geomagnetic fields would have induced an electromotive force which would have been measured by galvanometers. The measurements would have been made on photographs of the light rays reflected by the galvanometers mirrors taken by a camera. This magnetometer was further simplified because of its excessive weight. The coils were only two. One coil could be quickly oriented in the geomagnetic field then fixed when it was parallel to the geomagnetic lines of force. The electromotive force induced in the other coil was directly proportional to the geomagnetic field intensity.

Pontremoli's oceanographic probe was meant to measure salinity and temperature of sea water at various sea depths. Salinity was obtained by a measure of electrolytic conductivity with a Wheatstone bridge. Temperature was measured through a resistance thermometer containing a set of batteries and a galvanometer, with the batteries resistance as a function of temperature.

2.5.5 Silk Cocoon Fluorescence Induced by UV-rays

Sergio Beer worked as assistant for the Institute of Complementary Physics in order to use the radiation laboratory facilites for his studies on silkworms [65–68]. Beer used a Wood lamp with a 365 nm UV radiation to induce fluorescence in the silkworm cocoons by exposure to the UV-radiation spectrum emitted by a lamp with mercury vapors and to the 365 nm UV-radiation emitted by a Wood lamp. Spectrophotometric analysis of the fluorescence radiation was made with a spectrophotometer comparing the it with the light emitted by a 0.5 W lamp.

Beer observed a difference between the cocoon layers. The external layers were less fluorescent than the middle and central ones. The most intense fluorescence radiation was emitted from the middle layers which contain most of the silk. Beer therefore argued that the intensity of fluorescence radiation was a parameter to be used to quantify the cocoons quality. The most pregiate cocoons were those with the maximum emission of fluorescence radiation.

2.6 Teaching Activities

During the life of the Institute of Complementary Physics, the Faculty of Sciences offered degree courses in Applied Mathematics, Industrial Chemistry, and Natural Sciences. They did not offer a degree course in Physics. At the beginning, there were only two courses strictly connected to Physics: the two-years long course of Experimental Physics, commissioned to Oreste Murani of the Laboratory of Experimental Physics of Milan Polytechnic, and Complementary Physics, commissioned to Aldo Pontremoli. Mathematical Physics was instead a course of mathematical kind, which was always commissioned to a mathematics professor, at the beginning Gian Antonio

Maggi. Technical Physics was a course commissioned to a professor of the Institute of Chemistry. Complementary Physics, commissioned to Aldo Pontremoli, was a non-mandatory course which could be chosen by the students of the degree course in Applied Mathematics. Furthermore, the professors of physics courses of the Faculty of Sciences were also commissioned of the Physics course (Experimental Physics from the 1926–27 academic year) for the Faculty of Medicine and Surgery.

The degree course in Applied Mathematics was organized in the following way:

- 1st year: Analytic and Projective Geometry; Complements of Analysis; Experimental Physics (I); General and Inorganic Chemistry; Mathematical Analysis (I).
- 2nd year: Complements of Analysis; Complements of Geometry; Descriptive Geometry; Experimental Physics (II); Mathematical Analysis (II); Rational Mechanics.
- 3rd and 4th years: Astronomy and Geodesy; Mathematical Analysis; Higher Analysis;
- three courses chosen by the students of the 3rd and 4th years out of the following nine: Celestial Mechanics; Complementary Physics; Differential Geometry; General Electrotechnics; General Hydraulics; Hydro-Aero-Mechanics; Mechanics Applied to Buildings; Physical Geography; Higher Geometry.

Complementary Physics was a course which taught, from an experimental point of view, advanced topics in electromagnetism and thermodynamics, and the theoretical and experimental aspects of the "old quantum theory". The lessons varied year after year following the historical evolution of the discoveries. For instance, in the 1926–27 academic year, Pontremoli added the following topics:

> Hydrogen atom with a fixed nucleus and circular orbits, photoelectric effect. Determination of the dissociation energy through cycles, homopolar and heteropolar molecules. Heisenberg quantum mechanics, matrix calculus and physical results of Heisenberg theory, Schrödinger wave mechanics, applications to Planck oscillator, to the rotor, to Bohr atoms, radial quantum and total quantum.[29]

It is evident that quantum mechanics was taught by Pontremoli just one year after the formulation of Heisenberg matrix mechanics and Schrödinger wave mechanics. It is also evident that Pontremoli did not limit its course to experimental aspects only.

As an example of the course structure, the lessons of the first course (1924–25 academic year) can be reconstructed by the detailed register held by Pontremoli[30]:

- General introduction to the topics of the course. Theoretical consequences of: researches on specific heat, Michelson experiment, radiation emission, Planck theory, Bohr theory, and relativity.
- Methods used in Physics: Dimensions theory and its heuristic value; examples (pendulum, flux of viscous fluids), calculation of the proper frequency of the molecules in a solid. Parameters needed to identify a physical quantity, their behavior under coordinate

[29] Centro APICE, Historical Archive Milan University: Faculty of Sciences lectures registers, AUS, S 3, SS 3.8, R. boxes 10-16: Complementary Physics, 1926-27 academic year.

[30] Centro APICE, Historical Archive Milan University: Faculty of Sciences lectures registers, ASU, S 3, SS 3.8, R. boxes 10–16: Complementary Physics, 1924–25 academic year.

transformations, symmetries theory and its heuristic value. Curie principle, cylindrical and spherical frames of reference, force, velocity, electric field, natural rotatory power, magnetic field, angular velocity, magnetic rotatory power, scalars and pseudo-scalars, polar and axial vectors, spectral symmetries. Elements of vector calculus, divergence, rotor, scalar and vectorial potential, Laplace equation, Poisson equation, Green theorem, flux theorem, Stokes theorem.

- Coulomb law, theory to explain the electric phenomena, field energy in a dielectric, energy due to a magnetic field, Ampère theorem, electromagnetic induction forces, Laplace second law, force created by an electric of magnetic field on a moving charge. Maxwell equations in an isotropic dielectric or in the vacuum, general solution of $a\mathbf{E} = \nabla^2\mathbf{E}$ and its physical meaning.
- Transversality: magnetic and electric fields perpendicular to each other, refraction index of isotropic dielectrics. Polarization plane: the case with a conduction or a convection current and following modification of Maxwell equations. In an ω-space the diminution of electromagnetic energy per time unit is equal to the work of the electromagnetic forces added to the flux of electromagnetic energy through the surface limiting ω. Poynting vector. Hertz solution of Maxwell equations, calculations of the magnetic and electric fields, spherical waves. Examples: dipole, irradiated energy, damping, results of interference experiments and mean life. Radiation reaction on an electron, transverse and longitudinale Zeeman effect. Plane electromagnetic waves in semiconductors, refractor index, reflexion coefficient and phase between the magnetic and electric fields, comparison with the experimental data.
- Electricity: electromagnetic vibration in perfect conductors, extinction: numerical data. Complex Poynting vector: real component and Joule heat, physical meaning of the imaginary part coefficient and applications in conductors and semiconductors. Dispersion of electromagnetic waves, Drude formula, Lorentz formula, Lorentz-Lorenz theorem, discussion on the refraction index formula, normal and abnormal dispersion, electromagnetic theory of absorption, complex refraction index, extinction of absorption bands, absorption and selective reflection, remaining rays. Zeeman effect, magnetic rotatory effect index: phenomenology and physical explanation. Law of the magnetic rotational power: analytical study. Natural rotational polarization, rotational dispersion, Drude theory and phenomenology.
- Entropy and probability: introduction, entropy of an isolated system, Boltzmann formula, mathematical probability and thermodynamical probability, entropy formulas, verification of the final state, distribution law, integration constants and their calculation. Number of molecules with any velocity in a given volume and with a determined velocity, calculation of pressure, calculation of Boltzmann K-constant, identification of absolute temperature. Systems with one freedom degree.
- Fundamental hypothesis of quantization, linear oscillator, its energy, mean energy, number of vibrations in a continuum, Planck formula, Stefan law, Wien displacement law, Einstein derivation of Planck formula, how to obtain Wien formula, respective considerations. Debye theory of specific heats of solids and discussion. Bohr theory for Balmer series, number relations, notions of the nucleus, spectroscopic consequences, He^+ series, LI^{++} series, m_e/m_H ratio deduced from spectral series.
- Generalities in Hamilton equations, Planck constant and phases space. Elliptic orbits and their quantization, energy, symmetry. Quantization in space, Langevin theory of paramagnetism, Weiss magneton, Bohr magneton. Stern and Gerlach experiment, Curie law from a thermodynamical point of view. Magnetic susceptivity and space quantization, Weiss and Bohr. Modifications of the orbital motions of an electron for a magnetic field, quantum theory of Zeeman effect, circular and linear polarization, mean electric center of an orbit, Stark effect, correspondence principle. Spectral series, peripheral electronic structure and valence characteristics.

Starting from the 1926–27 academic year, the course of Complementary Physics could be chosen also by the students of the degree course in Industrial Chemistry. In the same year, the first year of the course of Experimental Physics was added to the study plan of the degree course in Natural Sciences. To have an idea of the number of students who attended these classes, we can mention the data for the 1927–28 academic year[31]: the first year of Experimental Physics had 11 students of Applied Mathematics, 14 students of Natural Sciences, and 44 students of Industrial Chemistry; the second year of Experimental Physics had 8 students of Applied Mathematics and 34 students of Industrial Chemistry; the course of Theoretical Physics could be chosen by the students of the third and fourth year of Applied Mathematics (11 and 13 people) and of Industrial Chemistry (41 and 36 people).

In the 1927–28, Milan University commissioned the course of Experimental Physics to Aldo Pontremoli instead of Oreste Murani. In the same year, the course of Complementary Physics was substituted with the course of Theoretical Physics. Since in 1928 Pontremoli was engaged with the preparation and the following participation to the polar expedition, he gave only the first thirty-five lectures until 28 February 1928. The second semester lectures were given by Enzo Pugno Vanoni. The lectures registered by Pontremoli show however how different the course was with respect to that of Complementary Physics[32]:

- General aspects of atom physics, dimensions theory, proper frequencies of the molecules in a solid, Bohr theory through dimensional considerations, photoelectric effect, neutralization continuous spectrum, actions of an electric and magnetic field on charges in motion.
- Bohr circular orbits, quantization fundaments, Hamilton equations, rotator and linear oscillator. Spectroscopy experiments, array, Michelson array, Lummer plate, ultraviolet rays. Relation between kinetic and potential energy for a Coulombian field, nucleus motion and spectroscopic consequences, elliptic orbits and degenerate systems, orbit orientation in space, Stern and Gerlach experiment. Bohr magneton and Weiss magneton.
- Relativistic corrections for circular and elliptic orbits, spectroscopic consequences and selection. Correspondence principle, Boltzmann theorem, action of a magnetic field on an electron orbit, Zeeman effect, Stark-Lo Surdo effect and experimental characteristics. Continuous spectrum, Einstein derivation of Planck formula.
- Kinetic theory of gases, Stefan law, maximum intensity and temperature, mathematical probability and thermodynamics, entropy, mean energy of a linear oscillator, blackbody spectrum and equilibrium radiation. Specific heat of solids, Debye theory, specific heat of dipoles.

Lectures on Heisenberg mechanics, Schrödinger wave mechanics, and quantum statistical mechanics would have been given in the second semester. No extant documents let us know if there were textbooks and/or if copies of scientific papers were given to the students.

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[31] The number of students for the precedent academic years is currently known only for the Faculty of Sciences as a whole.

[32] Centro APICE, Historical Archive Milan University: Faculty of Sciences lectures registers, ASU, S 3, SS 3.8, R. boxes 10–16: Theoretical Physics, 1927–28 academic year.

2.7 The Polar Expedition

In 1927 Pontremoli was invited by Umberto Nobile to join him in his next polar expedition.[33,34] Pontremoli had already shown a deep interest in a former expedition, the one on board the Norge airship. Now he should have taken care of the experiments on board the Italia airship. The polar expedition was planned to be the first one with the aim to study a wide range of biological and physical topics in the Arctic environment north to Scandinavia: terrestrial magnetism, terrestrial gravity, atmospheric electricity, radioactivity, penetrating radiation, radio wave transmission, oceanography [70]. At the same time, we cannot ignore the political implications of an expedition of this kind, such as the prestige that the Fascist regime would have derived from it by showing that Italy was a leading country in airship and aircraft technology the world over.

Pontremoli was joined by other two scientists: the Czech physicist František Běhounek, who was an expert in radioactivity and penetrating radiation (i.e. cosmic rays), trained by Marie Curie, and the Swedish meteorologist Finn Malmgren. The latter had already been a member of previous polar expeditions: in 1922–1925 on board the Maud ship led by Roald Amundsen and Harald Sverdrup, and in 1926 on board the Norge airship led by Umberto Nobile. The director of the Central Institute for Meteorology and Geodynamics in Rome, Luigi Palazzo, also collaborated to organize the expedition. Běhounek provided some instruments: an electrometer to measure atmospheric conductivity, metal plates to measure atmospheric radioactivity, a Wiechert electrometer to measure the electric gradient in the atmosphere, and a Kolhörster electrometer to study the penetrating radiation. Malmgren provided the meteorological instruments.

Pontremoli was engaged in the preparatory plans of the polar expedition concerning the scientific laboratory and the researches to be carried on in atmospheric electricity, geomagnetism, gravimetry, meteorology, oceanography, optics, penetrating radiation, and radio-waves transmission in the Arctic atmosphere. In particular he designed and tested some of the instruments to be carried on board. Very strict demands on size, weight and operativity at low temperatures had to be satisfied. Pontremoli built the instruments for the measurement of gravity, oceanography and of geomagnetism (with Palazzo) (see Sect. 2.5.4). The devices were tested in refrigerators to check if they worked properly at low temperatures. Philips and Allocchio and Bacchini provided the devices to study short wave transmissions. Researches in oceanography were to be carried on with a sounder with an inner resistance thermometer for electrolytic conductivity and seawater temperature, and with a Chauchard apparatus to measure seawater salinity; the oceanography devices were built by Allocchio and Baccini.

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[33] Centro APICE, Historical Archive Milan University, serie 7, titolo 9, personal file n. 2497 (Pontremoli): letter from Umberto Nobile to the rector Baldo Rossi, January 17, 1928; letter from the rector Baldo Rossi to Aldo Pontremoli, February 28, 1928.

[34] On the polar expedition see [69].

Some instruments – mostly spectroscopes, spectrographs, and batteries – belonged to the Institute of Complementary Physics.[35] Some of them – a telescope with two nicols, a pair of nicols for spectroscopy, a UV-spectrograph with its chassis, a chassis a visible radiation spectrograph, a Weston battery – were not given back to the Institute after the rescue operations.[36]

The Italia airship left from a field in Baggio, a western division of Milan, in the night between April 14 and 15, 1928. It landed in the King's Bay, Svalbard Islands on May 6. In King's Bay they organized the base camp. The first explorative flight from the Svalbard Islands left on May 11. During the third flight, on May 25, the airship quickly lost altitude and hit the ice pack. Ten people were thrown on the icepack with part of the load useful for their survival; eight of them were rescued between June and July. The airship, suddenly lightened, resumed altitude and disappeared with six people on board, including Aldo Pontremoli. Their destiny is still completely unknown. The airship was never found, and nobody knows if it landed somewhere on the icepack or if it sank in the Arctic ocean, nor if the people could get down from it or not.

The tragic end of the accident on the pack and the international operations of rescue completely diverted the attention from the scientific aspects of the polar expedition. A new epic was born, that of the "red tent" (tenda rossa). Disputes on the causes of the accident started in Italy and abroad. In particular, in Norway the reactions to the accident were negative [73]. Norwegian hostility was supported by the fact that Roald Amundsen disliked Umberto Nobile.

Only one work [74][37] was devoted to the preparation and the analysis of the scientific results of the polar expedition. Besides that, all the books written at the time on the expedition and all the survivors' memorials[38] hardly mention the scientific goals of the expedition.

Since Pontremoli was not saved and could not be connected to the red tent epic might explain why he was put in the background and his memory was not permanent in the Italian popular memory.

The hope of recovering the members of the expedition who had disappeared aboard the airship was alive for a few months after the accident. The attempts lasted until September. Gianni Albertini led another Italian expedition to try to identify any of the survivors in the middle of 1929. The last rescue attempt ended on September 22, 1929 when the Soviet icebreaker Krassin was called back.

Milan University followed with the utmost interest any news about the rescue operations. One month after the accident, in the meeting of the Faculty of Sciences,

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[35] Centro APICE, Historical Archive Milan University, serie 7, titolo 8, R. bb. 164–175 (BE), u.a. 101, "Elenco del material dell'Istituto di Fisica Complementare inviato per la spedizione Nobile", January 24, 1929.

[36] Centro APICE, Historical Archive Milan University, serie 7, titolo 8, R. bb. 164–175 (8E), u.a. 101, Giovanni Polvani's report on the Institute of Physics to the rector, Baldo Rossi, April 5, 1930.

[37] The original German version was translated into Italian with the addition of two more chapters: [75].

[38] The most relevant reminiscences are in: [75–79, 81–87].

the dean Gian Antonio Maggi read the telegram sent by Pontremoli the day before his disappearance. They all wished to receive positive news as soon as possible.[39]

At the inauguration of the 1928–1929 academic year, the rector commemorated Pontremoli:

> I must now remember another brave teacher. over whose fate we have been anxious and would still like to hope! Prof. Aldo Pontremoli, a glorious pioneer of Latin audacity.
>
> Very young, surrounded by a large esteem, he had the coveted honor of being chosen by General Nobile as Physicist of the heroic Italian polar expedition. He left smiling, full of faith and pride "to serve" as he said in one of his letters, "*even at the cost of every sacrifice*", the scientific fortunes of the Fatherland and keep the fame of our young university high.
>
> May the cordial participation and profound emotion of the whole Academic Body be a comfort to His good Mother, who weeps and is still waiting.[40]

In the meanwhile, all of Pontremoli's teaching assignments had already been attributed to other Faculty members in anticipation of his absence from April. The course of Experimental Physics was commissioned to Enzo Pugno Vanoni, the course of Theoretical Physics was temporarily commissioned to the mathematician Bruno Finzi, and the course of Application of Physics of the Art of War was not activated.[41]

After the official declaration of Pontemoli's death, he was commemorated. At the inauguration of the 1929–30 academic year, the rector remembered him with these words:

> Aldo Pontremoli, fighter and decorated for his valor, protomartyr of science in our University, who sacrificed his bold youth in a glorious attempt to shed new light on the mysteries of the Arctic.
>
> Go to the disconsolate Mother, who still mourns for him, our moving participation in so much pain. In memory of him, the Academic Body will erect a worthy and everlasting memory in this Hall.[42]

A committee was formed to honor his memory. His members were the rector Baldo Rossi, the director of the new Institute of Physics Giovanni Polvani, Livio Cambi, Emilio Bianchi of the Astronomical Observatory of Brera and Merate, Enzo Pugno Vanoni as committee secretary, and Federico Jarach.[43] The committee planned the dedication of a plaque in the library of the Institute of Physics, a bust in the *aula magna* of the University, and to name after him the laboratory of radiology. The plaque was inaugurated by the rector Baldo Rossi[44] on June 7, 1930, while the dean

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[39] Centro APICE, Historical Archive Milan University: serie 1.4.4, u..a. 2: Minutes of the Faculty of Sciences meetings, June 21, 1928: 40.

[40] Centro APICE, Historical Archive Milan University: Milan University 1928-29 yearbook, p. 9.

[41] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 2: Minutes of the Faculty of Sciences meetings, February 2, 1928: 21.

[42] Centro APICE, Historical Archive Milan University: Milan University 1929-30 yearbook, pp. 11-12.

[43] Centro APICE, Historical Archive Milan University: serie 7, titolo 14, u.a. 40, Onoranze al prof. Aldo Pontremoli.

[44] Centro APICE, Historical Archive Milan University. Milan University 1929–30 yearbook, p. 155.

of the Faculty of Sciences, Gian Antonio Maggi, gave a commemorative speech.[45] The bust was inaugurated in the *aula magna* during the inaugural address of the 1930–1931 academic year.[46] In the Sixties, the plaque and the bust were moved to the atrium of the new building of the Institute of Physics were they are currently on exhibition. No documents prove that the laboratory of radiology was named after Pontremoli, but in 1932 the Faculty of Sciences voted in favor of naming the Institute for Physics after him.[47]

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[45] Centro APICE, Historical Archive Milan University. Milan University 1929–30 yearbook: "Discorso del prof. Gian Antonio Maggi", pp. 156–163.

[46] Centro APICE, Historical Archive Milan University. Milan University 1930–31 yearbook, Inauguration speech of the academic year: p. 9.

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Chapter 3
Giovanni Polvani and the Institute of Physics Before the Second World War

Leonardo Gariboldi

Abstract After the death declaration of Aldo Pontremoli, Giovanni Polvani was called to Milan University as professor of Experimental Physics in 1929. Polvani actually founded a new institution, the Institute of Physics, which took the place of the Institute of Complementary Physics. In the early 1930s Polvani was willing to face some important problems: to start a degree course in Physics, to re-organize the laboratories on fundamental research topics also in function of their educational use, to create a new research group by calling to Milan new assistants from Pisa, such as Giuseppe Bolla and Amedeo Giacomini. In the late 1930s, when both Bolla and Giacomini left Milan University, Polvani had to create a new research team, this time with the former students they had educated in Milan, devoted to the study of cosmic radiation with cloud chambers and counters. At the same time, the development of the research activities and the arrival to Milan of Giovanni Gentile jr. as professor of Theoretical Physics made urgent to find a new seat for the Institute of Physics with more space for the people working in it.

3.1 Introduction

After Aldo Pontremoli's death, the dean of the Faculty of Sciences, Gian Antonio Maggi, asked Giovanni Polvani, at the time professor at the Engineering School of Pisa University, if he agreed to come to Milan University. Polvani's situation in Pisa was not the happiest; he was not well regarded by the local Fascist authorities and had already been cautioned a few times since he was not a member of the Fascist National Party. Milan could offer him a new university with a possible future expansion of the research activities in physics, a fact which stimulated his interest and willingness in engaging himself in the foundation of a new Institute of Physics. He could also take with him his father, who had to retire as dean of the lyceum of Lucca after some fascist attacks. He thus promptly accepted the offer advanced by Maggi and agreed to move to Milan. Since he was called to the chair of Experimental Physics, the Institute of Complementary Physics changed its name into Institute of Physics. The Institute was hosted in the new see in the Palace of Sciences, which was not suited for the

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activities of a scientific institute. The expansion of the research activities happened mostly during and after the Reconstruction period, but is was the result of the work done by Polvani in the 1930s.

Polvani was the director of the Institute of Physics until 1960 when he was appointed president of the CNR (National Research) and he left Milan to Rome. Since the very beginning, his main task was the institution of the degree course in Physics. In Polvani's own mind only with a degree course the Institute could have an aim and flourish. Only as a second step, it was important to support the development of research activities as a consequence of the clear definition of the Institution finality. The first task was soon reached with the establishment in 1932 of the degree course in Applied Physics and, in 1935, of the degree course in Physics, with the hybrid courses in Mathematics and Physics.[1] The second one, before the Second World War, saw in a first time the researches in spectroscopy, in particular Raman spectroscopy, by Giuseppe Bolla and in ultra-short Hertzian waves and in the generation and application of ultrasounds by Amedeo Giacomini, two assistants who joined him from Pisa. They both left Milan University in 1938: Bolla had won the public competition for the chair of Higher Physics at Palermo University, and Giacomini went to Rome to the CNR Institute of Electroacoustic. This meant a sudden lack of two good physicists, but also of two lecturers who had to be replaced in a short time.

After 1938, a new research team was created with new physicists, most of them freshly graduated in Milan. Their research subject was cosmic radiation, which could be studied in Milan at sea level and on the Alps with not too expensive instruments made in the Institute workshop. At the same time, researches in Theoretical Physics benefitted from the arrival to Milan of Giovanni Gentile jr who came to cover the second chair of physics at Milan University, another success signed by Polvani.[2]

Everybody, who worked with Polvani, acknowledged his ability and willingness to join physics with his philosophical and humanistic interests, a fact which is testified not only by his speeches full of references to classical culture, or by his philosophical conversations with Giovanni Gentile jr, but also by his noteworthy activities in the history of physics. Polvani was a scientific policy maker. As director of a scientific institute he was mostly concerned with institutional problems, and developed a particular ability in finding financial support for the researchers carried out by his assistants and collaborators. He had anyway time to follow the research activities, to guide or just to offer suggestions how to solve specific problems.

[1] The degree courses in Mathematics and Physics had the aim to train students who wanted to work as high school teachers of mathematics and physics.

[2] Giovanni Gentile jr. is treated only briefly in this chapter. See Chap. 4 for a thorough analysis of his life and work.

3.2 The People

When he arrived at Milan University, Polvani found Enzo Pugno Vanoni (see Sect. 2.2.3) as help, Maria De Marco (see Sect. 2.2.4) as assistant, and two technicians, Giovanni Adorni and Mario Pessina, who will work for him for the whole period covered by this book (see Table 3.1).

3.2.1 Giovanni Polvani

Giovanni Polvani[3] (Fig. 3.1) was the founder and first director of the Institute of Physics of Milan University. He was born in Spoleto on December 17, 1892, the son of Carlo Polvani, a physicists who was a high school professor of mathematics and physics, and of Debora Repanai (her family's name is not sure). His family followed his father to Perugia and to Ascoli Piceno where Polvani obtained his high school diploma at the classical lyceum in 1911. He was admitted to the Superior Normal School of Pisa and enrolled to the course in Mathematics, and in 1913 he published his first scientific work, on Lambert's fractions. He then decided to enroll to the third year of the course in Physics. In 1915 he had to stop his regular studies when Italy entered the First World War. He attended the course for military officers at the Military Academy in Turin. As second lieutenant of military engineers he spent almost three years, from 1916 to 1918, on the military front at Mount Pasubio. During a short license, he could come back to Pisa and graduate in Physics on June 27, 1917 with a "war graduation" with the highest score. His thesis dissertation was "On the properties of the Audions". He could come definitely come back from the military front in 1919. On October 16, 1919 he started his academic career as assistant to Luigi Puccianti at the Institute of Physics of Pisa University.

In 1920 he obtained his "libera docenza" for Experimental Physics. From 1922 he was lecturer of Higher Physics. Among his students in Pisa there were Giovanni Gentile jr, whom he succeeded to call to Milan University as professor of Theoretical Physics, and Enrico Fermi. In 1926 he won, first in the rank, the public competition for the chair of Experimental Physics for Bari University. In 1927 he won, again first in the rank, the public competition for the chair of Technical Physics for Bologna University, but he was called by Pisa University to the chair of Technical Physics for the School of Engineering.

Most, but not all, of his scientific research activity was carried out in the 1920s at Pisa University. He worked on several experimental topics which were relevant in the acceptation of many aspects of quantum physics. His researches show not only his experimental ability but also his consideration of any physical problem to be faced as a whole, with no particular distinction between experimental and theoretical aspects:

[3] On Polvani, see: [1–7].

Table 3.1 Institute of Physics (1929–30)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Theoretical Physics
Enzo Pugno Vanoni	Help
Maria De Marco	Assistant
Giovanni Adorni	Technician
Mario Pessina	Technician

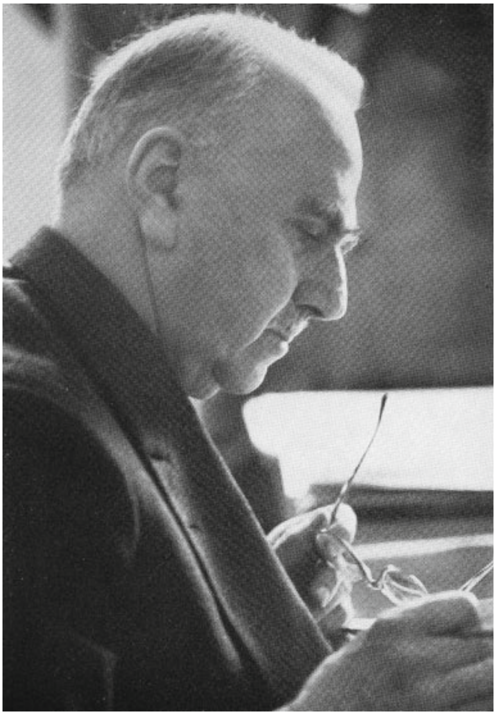

Fig. 3.1 Giovanni Polvani (Copyright: Milan University, BICF Library)

- classical and quantum theories of gases: Polvani generalized Maxwell-Boltzmann kinetic theory and considered the effects on it of possible external forces depending on molecular velocities [8]; he analyzed the thermodynamical consequences of quantization of the monoatomic ideal gases [9], he found the general form of the characteristic equation of the monoatomic ideal gas [10] and studied its connection with Avogadro's law [11, 12].
- spectroscopy: Polvani studied the temporal variations of spark spectra [13], the patterns of the hydrogen spectrum with the Stark effect [14], the stroboscopic techniques applied at high frequencies sparks spectra, with time precision below 10^{-6} s [15], the way to study casualty law by means of electric sparks [16], and how the spectral lines are widened by Doppler effect [17].

- the photoelectric effect: Polvani proved that Einstein's theory of the photoelectric effect did not depend from specific conditions such as the effects of a magnetic field on ferromagnetic metals [18], and that the emission of photoelectrons is simultaneous to the arrival of photons of the metal plate as a further confirmation of the validity of Einstein's theory [19].
- the blackbody radiation: Polvani studied the blackbody radiation from a theoretical point of view and proved that it could be considered as a saturate vapor of photons [20, 21].
- the Hall effect, which was not fully understood at the time: Polvani performed a new experiment to study the Hall effect on different configurations of an external magnetic field [22], he search possible delays of the Hall effect with respects to the action of the magnetic field [23], and studied it with other electrodynamic effects on metals [24].
- galvanomagnetism: Polvani carried out galvano-magnetic experiments on iron [25].
- magnetrons: Polvani studied Albert Hull's magnetron and found the equations describing its behavior [26].
- acoustics: Polvani studied the behavior of the density of sound energy diffused in a resonant room with periodically intermittent sound sources [27].

His interest in the history of physics started in Pisa. He collected instruments, documents and book with the plan to build a museum devoted to Antonio Pacinotti. The museum was approved by the professors council of the Engineering School in 1928 and by the Government in 1930.

In 1929 Polvani accepted to be called as extraordinary professor (ordinary professor from 1930) of Experimental Physics by Milan University. He founded a new Institute of Physics, with a laboratory more suitable to the experimental activities for the students, and succeeded in having a degree course in Physics. The Institute had to be reshaped from an institution devoted to applicative research to one working on fundamental problems. As a director, he was now well aware that the future development of the Institute of Physics would have rested on his shoulders. He was no more an assistant to Puccianti, free to carry out researches and build his own scientific career; now he had raise his own pupils and let them work on their research projects trying as far as possible to find financial supports for them.

In Milan he was joined by Giuseppe Bolla and Amedeo Giacomini as assistants, and Giovanni Gentile jr as professor of Theoretical Physics. All of them were the product of Pisa University. The Institute of Physics was a kind of New Pisa, but in a context very different from that in Pisa: it was easier for Polvani than for Puccianti to know industrial and bank managers and ask them for help, but at the same time the Fascist regime was strengthening its dictatorial and oppressive aspects. The Institute of Physics was going along the way of development in order to try to reach the same level of scientific importance of the two leading physics schools in 1930s Italy: the school of Arcetri, working on cosmic ray physics, and the school of Rome, working on nuclear physics. This result will be fully attained only after the Second World War.

In the 1930s, Polvani's institutional career saw him as dean of the Faculty of Sciences in 1932–34; at the same time he fulfilled his teaching duties as professor of Experimental Physics and lecturer of Higher Physics and Theoretical Physics (until the arrival of Giovanni Gentile jr). Polvani's role as director and organizer of a new Institute put a strong limit to his research activity, and he chose not to sign papers which had not a fundamental contribution from him, but were at the same time in debt with his suggestions. His name can be read in almost every acknowledgements at the end of scientific papers published by his assistants or at the end of thesis dissertations which had not him as a tutor. Besides a few original works on free electrons in metals [28] and on the electric conductivity of metallic films and its dependance on the films electric charge [29], Polvani contributed to the activities of the Mathematical and Physical Seminar with very detailed conferences on the experimental, theoretical and philosophical meaning of quantum wave mechanics [30], the statistical distribution of prime numbers [12], the velocity of light [31], thermodynamics with his lecture on the devil and thermodynamics, in which he considered the relationships between entropy, equilibrium, information and choice in a thermodynamical system [32], and (after the war) on the trace of a transformation and the second principle of thermodynamics [33], and the theory of the magnetron [34]. According to Carlo Salvetti, Polvani suggested Giovanni Gentile jr to study the intermediate statistics [35].

Polvani's activity in the history of physics flourished in the 1930s s and 1940s with his researches on Antonio Pacinotti [36–38], Ottaviano Fabrizio Mossotti [39, 40], and Alessandro Volta [41], the history of the researches on the nature of light [42] and the Italian contribution to the development of physics in the last century [43].

In 1938 Bolla and Giacomini left Milan University. From mid 1938, Polvani was for months at hospital after a very bad accident. Besides Gentile, the scientific research had to be restarted from the ground. Polvani supported the birth of a new research group, now made by young physicists raised in Milan, which decided to study cosmic radiations in Milan at sea level and on the Alps with cloud chambers and counters. The development of the research group, and the presence of Gentile, prompted the search for a new seat, more suitable to the activities of a scientific institute.

During the Second World War, while the research activities had mostly to stop, Polvani did his best to continue the institute teaching activities in accordance to the increasing difficulties: some assistants were called by the army for most of the time, and Gentile died from septicemia. The allied bombings on Milan caused many damages, and Polvani decided to move his family to Cantù (Como province) where he hid some of the instruments and part of the library to prevent their requisition by the German troops which had invaded Italy after September 1943. Polvani contributed to hide also draft dodging students, Giorgio Salvini who did not want to join back the army of the Italian Social Republic, and helped a Greek student, Andrea Loverdo, to escape to Switzerland.

After the war, Polvani could start again to direct an Institute with expanding activities. Researches on cosmic radiation resumed with cloud chambers and counters, while other research fields became of immediate interest in theoretical physics with the arrival of Piero Caldirola in 1949 and in experimental physics with the study of cosmic radiation with nuclear emulsions with the arrival of Giuseppe Occhialini in 1952; all of them put the Institute of Physics on an international level of scientific research. Polvani agreed with the foundation in 1946 of the CISE, a private research institute on nuclear physics and technology which worked in a first time in a kind of symbiosis with the Institute of Physics, with the direct engagement of Giuseppe Bolla, who had come back to Milan as professor of Higher Physics, and Carlo Salvetti, a former student then professor of Radioactivity (Nuclear Physics).

Polvani's activity was an example of the huge work of reconstruction that Italy was facing not only in physics research. Actually, Polvani was elected president of the SIF in 1947 and directed it until 1961. He was therefore one of the main leading physicists, with Edoardo Amaldi in Rome, of the post-war reconstruction of Italian physics and managed to have in Milan a local division of the newborn INFN. Under his presidency, the official review of the SIF, Il Nuovo Cimento, became a journal of international relevance and started to publish papers in English. Furthermore, in 1953 he founded the International Physics School of Varenna which hosted the most important Italian and foreign physicists for summer schools and other events. In 1950 Polvani founded the GAIFUM to support research activities and to collect funds for a new seat. The lecture rooms wing could host the reformed degree course in Physics in 1961 already, whereas the main building was inaugurated in 1964.

In March 1960 Polvani was appointed president of the National Committee for Physics of the CNR, but already in September 1960 he was appointed president of the CNR for four year. He therefore left the presidency of the National Committee for Physics, the direction of the Institute of Physics to Piero Caldirola, and the presidency of the SIF. After having collected information on all research institutions and activities in Italy, he started the reform plan of the universities and of the financial support of research projects. He inspired the reform law n. 283 of March 2, 1963; the law multiplied by ten the number of researchers, merged within the CNR humanistic, juridical, economic and social research activities, and created the Ministry for Scientific Research. With Edoardo Amaldi, he made it possible to the National Laboratories in Frascati to build ADONE, the storage ring for e^{-} e^{+}. He advanced, with Luigi Broglio, president of the Italian Center of aerospace researches, the San Marco project which started the Italian space race with the launch of San Marco I satellite on December 15 1964. Italy was thus the third country, after the USA and the USSR, to put an artificial satellite in orbit around the Earth. Polvani ended his activity as CNR president with the first report on scientific research in Italy.

While still president of the CNR, Polvani came back from Rome to Milan, for the official inauguration (on February 10, 1964) of the new seat of the Institute of Physics in via Celoria, a seat able to host many research activities in a proper way, a dream which Polvani tried and succeeded to make true with stubbornness from his arrival in Milan 1929. In 1966 Polvani was elected rector of Milan University. During his rectorate, the “1968” student protests began. His rector's office was devastated during one violent revolt which saddened him deeply. At the end of his rectorate

(October 31, 1969), Polvani worked as president of the National Commission for the Leaning Tower in Pisa and was able to complete the final report before his health conditions worsened.

Giovanni Polvani died in Milan on August 11, 1970.

3.2.2 Giuseppe Bolla

In 1930, the Institute of Physics was joined by Giuseppe Bolla from Pisa University as a new assistant (see Table 3.2). In the same year, Camillo Modignani was appointed as janitor of the Institute. Modignani was janitor until 1937; in 1938 he became a subordinate technician. Modignani died during the Second World War.

Giuseppe Bolla[4] (Fig. 3.2) was born in Cagliari on December 4, 1901, the son of Achille Bolla and Maddalena Larco. He graduated in Physics at Pisa University in 1926. Following Puccianti's suggestion to work with Polvani, he joined as assistant the Institute of Physics of Milan University in 1930. He was lecturer in Physics for the Faculty of Medicine. In this first period of his scientific activity, Bolla's main field of research was Raman spectroscopy. He studied the Raman bands in water [47–51] and aethylic alcohol [52, 53]: he discovered five Raman low-intensity bands of water (at $510\,\mathrm{cm}^{-1}$, $780\,\mathrm{cm}^{-1}$, $1645\,\mathrm{cm\ cm}^{-1}$, $2150\,\mathrm{cm\ cm}^{-1}$, and $3990\,\mathrm{cm\ cm}^{-1}$) and studied the dependance of the Raman spectrum from temperature [54]. His results had a certain notoriety at an international level. Bolla also studied the properties of microphotographers [55, 56], photographic plates for polarized light [57] and glass [58, 59] and quartz spectrographs [60, 61]. These researches caught the attention of Giovanni Gentile jr.

Bolla won the public competition for the chair of Experimental Physics for Palermo University after Emilio Segrè had to leave the same chair because of the racial laws. In 1942 he came back to Milan University as full professor of Higher Physics. He stopped to work on atomic physics and started to study nuclear physics and supported the researches of the group working on cosmic radiation.

After the end of the Second World War, Bolla was one of the promotors, with Carlo Salvetti, Giorgio Salvini and Mario Silvestri, for the establishment of the CISE, a private research institute for studies in nuclear physics and technology which had the aim to plan the first Italian nuclear power plant. Bolla was appointed first director of the CISE, and acted in this role until 1956. As director of the CISE he was also the director of the CISE review, "Energia nucleare", where he signed editorials and papers on nuclear research policy. Under his direction, the researches in nuclear physics and technology succeeded in obtaining technical results, in particular the fission cross section for uranium, which were not at public disposal because of the military secret active in the countries with working nuclear technology.

In 1950 Bolla left Milan University to Milan Polytechnic. At the same time he moved to the chair of Experimental Physics and became director of the Institute of

[4] On Bolla, see: [44–46].

Table 3.2 Institute of physics (1930–31)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Theoretical Physics
Enzo Pugno Vanoni	Help
Giuseppe Bolla	Assistant
Maria De Marco	Volunteer assistant
Giovanni Adorni	Technician
Mario Pessina	Technician
Camillo Modignani	Janitor

Fig. 3.2 Giuseppe Bolla (Copyright: CISE2007)

Experimental Physics until 1962 when he obtained the chair of Atomic and Nuclear Physics. At Milan Polytechnic, Bolla was engaged in a great project of creating didactical and research facilities for nuclear technology. He immediately organized the course of Applied Nuclear Physics, the first course of Nuclear Engineering in Italy. When the CNRN (National Committee for Nuclear Researches) was founded in 1952, Bolla was not invited to be a member of the committee. If he was no more engaged in the national organization of nuclear research, at the same time this left him the time to continue the development of researches in nuclear technologies in Milan. In 1955 he organized the School of Radioisotopic Technics at Milan Polytechnic.

In 1956 Bolla left the direction of the CISE and founded the Institute of Nuclear Engineering at Milan Polytechnic and was its director from 1962 to 1973. In 1957 he supported the foundation of the CESNEF (Center of Nuclear Studies "Enrico

Fermi”), based in the Polytechnic, and was its first director from 1957 to 1973. At the CESNEF, Bolla’s policy succeeded with the building of the first Italian nuclear reactor for educational purposes. It was a homogenous reactor with a maximum power of 50 kW. It reached its critical point first in November 1959. Bolla retired from the Polytechnic School in 1973.

Giuseppe Bolla died in Milan on January 28, 1980.

3.2.3 The Assistants, 1931–37

Other assistants joined the Institute of Physics before the arrival of a new professor, Giovanni Gentile jr., for the chair of Theoretical Physics. In 1931 two more assistants were appointed for the Institute of Physics, Amedeo Giacomini and Gastone Del Puglia who was volunteer assistant for only one academic year (see Table 3.3).

Amedeo Giacomini[5] was born in Cuneo on March 5, 1905, the son of Amedeo Cesare Giacomini and Anna Riccardi. He graduated in Physics at the Superior Normal School of Pisa in 1929. He was volunteer assistant at the Institute of Physics of Pisa University in 1929–30. In 1930 he obtained from Milan Polytechnic the license to work as engineer. In 1931 he spent some time at the Heinrich Hertz Institute in Berlin. Following Puccianti’s suggestion to work with Polvani, he was assistant at the Institute of Physics of Milan University in 1931–38. He was lecturer in X-rays Physics for the Faculty of Medicine in 1932–38 and of Electrical Measurements for the Faculty of Sciences in 1936–38.

Giacomini’s main field of research in Milan was the study of the generation of microwaves [63–65]. Giacomini studied in particular the magnetron as generator and detector [66, 67], which he presented in a lecture to the Mathematical and Physical Seminary of Milan [68]. Giacomini also carried on researches in acoustics. He started with the study of an acoustical method to measure the microwaves wavelength and the visualization of ultrasounds (ultrasound waves can act as a diffraction grating for light) [69, 70].

In 1938 Giacomini left Milan University to Rome. He became a member of the National Institute of Electroacoustics of the CNR. He was appointed vicedirector in 1940, and director 1944 (until 1973). Under his direction, Giacomini studied the applications of ultrasounds and their application to optics, to the study of the properties of different kinds of materials (isomeres, liquids, metals, etc.). He obtained his “libera docenza” in Electrology in 1939. In 1955 he won the public competition for the chair of Experimental Physics for Perugia University. In 1962–68 he was dean of the Faculty of Sciences and director of the Institute of Physics until 1979.

Amedeo Giacomini died in Rome on April 6, 1979.

In 1932, Olga Bertoli, the first female student graduated in Physics at Milan University, became assistant (see Table 3.4).

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[5] On Giacomini, see: [62].

Table 3.3 Institute of Physics (1931–32)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Theoretical Physics
Giuseppe Bolla	Help
Amedeo Giacomini	Assistant
Gastone Del Puglia	Volunteer assistant
Giovanni Adorni	Technician
Mario Pessina	Technician
Camillo Modignani	Janitor

Table 3.4 Institute of Physics (1932–33)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Theoretical Physics
Giuseppe Bolla	Help
Amedeo Giacomini	Assistant
Olga Bertoli	Assistant
Giovanni Adorni	Technician
Mario Pessina	Technician
Camillo Modignani	Janitor

Olga Bertoli was born in Milan on November 22, 1908. She graduated in Applied Physics at Milan University in 1932. She was assistant for the Institute of Physics in 1932–34, commissioned assistant in 1935–36, assistant in 1937, adventitious in 1940, and adventitious technician in 1941–43. She wrote two review works on the conductivity of solid and liquid dielectrics irradiated by α, β, γ, and X-rays [71] and on the superconductivity phenomena [72].

Although her career appears to be worsening, from assistant to technician and from ordinary to adventitious positions, Polvani had a profound esteem for her, "always full of enthusiasm and very good collaborator in all the minute housekeeping" [6]. The extant documents do not permit to understand if Bertoli's career was a very small piece of the general plan of the Fascist government to gradually limit the presence of women in the public offices. As a matter of fact, only some male assistants had a career to a professor position in the decades to come until Constance Dilworth became the first woman professor of the Institute of Physics of Milan University.

Olga Bertoli died in La Spezia on January 6, 1958.

In 1933, Saverio Cavuoti, who graduated in Physics with a dissertation on the study of cosmic radiation, was appointed commissioned preparer for the laboratories (see Table 3.5). Cavuoti's dissertation shows that a certain interest in the study of cosmic radiation in Milan can be traced back at least to 1933, but his work was mostly a

Table 3.5 Institute of Physics (1933–34 and 1934–35)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Theoretical Physics
Giuseppe Bolla	Help
Amedeo Giacomini	Assistant
Olga Bertoli	Assistant
Saverio Cavuoti	Commissioned preparer
Giovanni Adorni	Technician
Mario Pessina	Technician
Camillo Modignani	Janitor

Table 3.6 Institute of Physics (1935–36)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Theoretical Physics
Giuseppe Bolla	Help; lecturer in Higher Physics
Amedeo Giacomini	Assistant
Olga Bertoli	Commissioned assistant
Saverio Cavuoti	Commissioned preparer
Giovanni Adorni	Technician
Mario Pessina	Technician
Camillo Modignani	Janitor
Arturo Balladori	Janitor

review one with a very limited experimental activity which consisted essentially in building a counter. Cavuoti was renewed in his position until 1937. No new people joined the Institute of Physics in 1934.

In 1935 a second janitor, Arturo Balladori, was assigned to the Institute of Physics (see Table 3.6). Balladori worked at the Institute for only three years. In the same year, the Milan University started to offer degree course in Physics. The course of Higher Physics was commissioned to Giuseppe Bolla as lecturer.

3.2.4 Giovanni Gentile Junior

In 1936 Giovanni Gentile junior joined the Institute of Physics as lecturer in Theoretical Physics. He was appointed to the chair of Theoretical Physics which made him formally independent from the Institute of Physics (see Table 3.7). The actual situation, in this case and in the future, was instead that of an Institute with two pro-

Table 3.7 Institute of Physics (1936–37)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics
Giuseppe Bolla	Help; lecturer in Higher Physics
Amedeo Giacomini	Assistant
Olga Bertoli	Commissioned assistant
Saverio Cavuoti	Commissioned preparer
Giovanni Adorni	Technician
Mario Pessina	Technician
Camillo Modignani	Janitor
Arturo Balladori	Janitor
Chair of Theoretical Physics	
Giovanni Gentile	Extraordinary professor of Theoretical Physics, lecturer in Probability Calculus

fessors who made used together of the same facilities without establishing parallel structures (libraries, laboratories, offices, classrooms, etc.).

Giovanni Gentile[6] was born in Naples on August 6, 1906, the son of the philosopher and politician Giovanni Gentile and Erminia Nudi. He was a student of Mathematics and later Physics at the Superior Normal School of Pisa. He graduated in Physics with a dissertation on a solution of Schroödinger equation in 1927 with Luigi Puccianti. He was appointed assistant to Orso Mario Corbino at the Institute of Physics in Rome where he worked with Enrico Fermi and Ettore Majorana. After the fulfillment of his military duties, in 1929 he went to the Institute of Theoretical Physics in Berlin, where he studied the quantum theory of valence with Fritz London. In 1930 he moved to Leipzig to work with Heisenberg on the magnetic phenomena in crystal arrays.

Gentile obtained his "libera docenza" in Theoretical Physics in 1931 and was called to Pisa University in 1932 as lecturer in Theoretical Physics. In 1936 he accepted the call from Milan University as lecturer in Theoretical Physics and Probability Calculus. He won the second public competition for a chair of Theoretical Physics in 1937 (the other two winners were Giulio Racah and Giancarlo Wick).[7] He was also appointed lecturer of Probability Calculus. Gentile's main research result in Milan was the theory of intermediate or Gentilian statistics.

Giovanni Gentile jr. died in Milan from septicemia on March 30, 1942.

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[6] On Giovanni Gentile jr, see: Chap. 1, [73, 74].

[7] That competition had a fourth winner, Ettore Majorana who became professor for scientific merits and was exceptionally not listed in the final ranking.

3.2.5 *The Assistants, 1937–40*

In 1937 Saverio Cavuoti left the Institute of Physics. He was replaced by Mario Colombo as commissioned preparer for the laboratories for one year (see Table 3.8). From 1938, the position of commissioned preparer was not assigned anymore.

In 1938 the Institute of Physics underwent profound changes (see Table 3.9). Giuseppe Bolla and Amedeo Giacomini left the Institute. Bolla had won the public competition for Palermo University, but he would have come back to Milan University a few years later, while Giacomini left to CNR Institute in Rome. Polvani was commissioned as lecturer in the course of Higher Physics, left vacant by Bolla. Giuseppe Cocconi, a freshly graduated student of Physics, joined the Institute as assistant acting as help. With a pause for his military duties, Cocconi stayed at the Institute of Physics until the end of 1944. Anselmo Andreoli was appointed subordinate for three years until 1941.

Giuseppe Cocconi[8] was born in Como on October 3, 1914. He was interested in astronomy since a teenager. He graduated in Physics at Milan University in 1937 with a dissertation on the Hall effect self-induced by rotating magnetic field. In February 1938 he accepted Edoardo Amaldi's invitation to spend six months at the Institute of Physics in Rome where he studied cosmic ray physics with Enrico Fermi and Gilberto Bernardini and worked on the project to build a cloud chamber with Fermi. Back to Milan, he was appointed assistant to the Institute of Physics, where he studied some topics on cosmic rays with cloud chambers and counters at sea level and on the Alps with Andrea Loverdo and Vanna Tongiorgi: the secondary radiation [77], the coherence of cosmic radiation [78], the secondaries in the mesonic component [79], the cosmic ray neutrons [80], the equilibrium of the component of cosmic radiation at sea level [81], the spectrum at 2200 m above sea level [82], the penetration of showers at sea level and at 2200 m above sea level [83], the extended showers in air [84], and the density spectrum of extensive showers [85]. In 1942 he joined the army and made research for the Italian Air Force in Rome. Then he became professor at Catania University, but could not reach it until the end of 1944 because of the war. In 1945 he married his colleague Vanna Tongiorgi.

In 1947–63 Cocconi was professor at Cornell University, invited there by Hans Bethe. He continued his studies on cosmic rays, in particular on the nuclear spallation of neutrons and on the existence of extensive cosmic ray showers. In 1959 he wrote, with Philip Morrison, the paper on the search for interstellar communications based on the 21 cm hydrogen line, which led to the foundation of the SETI project.

In 1959–61 Cocconi spent a sabbatical leave at the CERN in Geneva for the experimental project of the proton synchrotron and researches on elementary particles scattering and cross sections. He continued these studies at the Brookhaven National Laboratory. From 1963 Cocconi worked at the CERN as director of the protosynchrotron project in collaboration with the physicists of Rome University. His research fields concerned the studies on elementary particles scattering, the search of the hypothetical pomeron, and in several collaboration at LHC and LEP accelerators.

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[8] On Cocconi, see: [75, 76].

Table 3.8 Institute of Physics (1937–38)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics
Giuseppe Bolla	Help; lecturer in Higher Physics
Amedeo Giacomini	Assistant; lecturer in Electric Measurements
Olga Bertoli	Assistant
Mario Colombo	Commissioned preparer
Giovanni Adorni	Technician
Mario Pessina	Technician
Camillo Modignani	Janitor
Arturo Balladori	Janitor
Chair of Theoretical Physics	
Giovanni Gentile	Extraordinary professor of Theoretical Physics; lecturer in Probability Calculus

Table 3.9 Institute of Physics (1938–39)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Higher Physics
Giuseppe Cocconi	Assistant acting as help
Giovanni Adorni	Technician
Mario Pessina	Technician
Camillo Modignani	Subordinate
Anselmo Andreoli	Subordinate
Chair of Theoretical Physics	
Giovanni Gentile	Extraordinary professor of Theoretical Physics; lecturer in Probability Calculus

Giuseppe Cocconi died in Geneva on November 9, 2008.

In 1939 two more assistants joined the Institute of Physics (see Table 3.10). Antonino Mura, who was appointed help for 1941–46, commissioned help in 1946–47, again help in 1947–50, ordinary assistant acting as help in 1950–57 until his premature death. Vanna Tongiorgi, a freshly graduated student in Physics, who was assistant in 1939–40 and volunteer assistant in 1940–41.

Antonino Mura[9] was born in Florence on March 19, 1916. He graduated in Physics in 1938 with a dissertation on electrons diffraction. In 1938–40 he was assistant at Turin Polytechnic, then he moved to Milan University where he was appointed help for Giovanni Polvani. During the Second World War he fought as artillery official in the Balkans.

[9] On Antonino Mura, see: [86, 87].

Table 3.10 Institute of Physics (1939–40)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Higher Physics
Giuseppe Cocconi	Assistant acting as help; lecturer in Exercitations of Experimental Physics
Antonino Mura	Assistant
Vanna Tongiorgi	Assistant
Giovanni Adorni	Technician
Mario Pessina	Technician
Camillo Modignani	Subordinate
Anselmo Andreoli	Subordinate
Chair of Theoretical Physics	
Giovanni Gentile	Extraordinary professor of Theoretical Physics; lecturer in Probability Calculus

Mura's main field of research was the development of cloud chambers for the study of cosmic rays. With his cloud chambers he studied the extended showers in air, the interactions of the μ-mesons and the composition of cosmic rays at high altitude.

Antonino Mura died in Casatenuovo (Como province) on July 24, 1957.

Vanna Tongiorgi[10] was born in Milan on January 19, 1917, the daughter of Alcandro Tongiorgi and Ada Corti. She graduated in Physics at Milan University in 1939 with a dissertation on the researches on the presence of neutrons in cosmic rays, with Giuseppe Cocconi as tutor. She was then assistant and help for Giovanni Polvani at the Institute of Physics.

Tongiorgi's field of research was the study of cosmic rays with Cocconi and Andrea Loverdo [77–85, 89–92]. In 1940 she won a public competition and became teacher of mathematics and physics at the lyceum of Varese and in 1941 at the lyceum-gymnasium "Daniele Crespi" of Busto Arsizio.

Tongiorgi married Cocconi in 1945. In 1947 they moved to the United States where Cocconi was full professor at Cornell University. She continued her researches on cosmic radiation. Her main result was the observation of neutronic spallation, i.e. the neutron multiple production from cosmic rays hitting heavy atoms. She also studied elementary particle interactions at the Brookhaven cosmotron and at the Cornell synchrotron.

In 1959–61 Tongiorgi spent a sabbatical leave at the CERN to work with the European accelerators. She moved with Cocconi to the CERN where she worked in the bubble chamber project.

Vanna Tongiorgi died in Geneva on October 15, 1997.

[10] On Vanna Tongiorgi, see: [88, 106].

3.3 The Graduation Course in Physics

With the arrival of Giovanni Polvani at the Institute of Physics,[11] only three courses were taught by the personnel of the Institute: Complementary Physics for the degree courses in Mathematics and in Chemistry; Theoretical Physics for the degree course in Mathematics; Physics for the degree courses in Medicine and in Natural Sciences. There was also a short course of Radiation Physics for the students of medicine who were specialized in radiology. Polvani was appointed to the courses of Experimental Physics (biannual) and Theoretical Physics, while Pugno Vanoni was appointed for the courses of Physics for the students of medicine and of natural sciences.

With the last modifications of the Statute of Milan University with the Royal Decree n. 1845 on October 30, 1930, Milan University started the degree courses in Applied Physics (four year) and Mathematics and Applied Physics (four year).[12] The latter course prepared the students to become high school teachers of mathematics and physics.

To achieve the degree in Applied Physics, the student had to enroll and pass the exams in the four-year period in at least twelve subjects from the nineteen listed below. The student had also to attend the physics laboratory for two years and two laboratories for the subjects referred to in the previous paragraph for one year.

The nineteen subjects were: Algebraical Analysis; Infinitesimal Analysis; Analytic and Projective Geometry; Descriptive Geometry; Rational Mechanics; Higher Mechanics; Higher Analysis; Higher Geometry; Complementary Mathematics; Mathematical Physics; Experimental Physics; Theoretical Physics; Technical Physics; General Electrotechnics; Astronomy; Geodesy; Hand Drawing; General and Inorganic Chemistry; Organic Chemistry; Physical Chemistry; Electrochemistry; Qualitative Chemical Analysis; Mineralogy; Physical and Terrestrial Geography. It is evident that the degree course of Applied Physics was actually much more a course of Mathematics. The number of physics subjects had not substantially increased, and the same can be said for the personnel at disposal. The whole Faculty of Sciences had at the time only eight full professors, one of the lowest numbers in Italy. It was but a significant fact that the public lecture for the inauguration of the 1931–32 academic year was asked to be delivered by Giovanni Polvani.[13]

The degree course of Mathematics and Applied Physics was the same with just Geology instead of General Electrotechnic.

Given the complete lack of instruments and devices necessary for educational purposes and fundamental research, Polvani obtained from the University an extra financial support of 50.000 lire (to be added to the yearly dote of 25.000 lire) to buy instruments for thermology, acoustics and electrology.[14]

[11] On the Institute of Physics, see: [93].

[12] On the degree courses in Applied Physics and in Physics at Milan University during the Fascism see [94].

[13] Centro APICE, Historical Archives Milan University: 1931–32 yearbook, Polvani: Causalitàe casualitànella filosofia naturale, November 8, 1931, pp. 33–57.

[14] Centro APICE, Historical Archives Milan University: 1931–32 yearbook, p. 534.

In the 1932–33 academic year, Polvani started a yearly course of specialization in Technical Radiology for graduates in Physics, Applied Physics, Chemistry, Industrial Chemistry, or Industrial Engineering. This course was a further didactical burden to small institute, but at the same times shows how open was the Institute of Physics to some practical applications of modern physics to medicine which characterizes the Milan school of physics even today. The courses were: Physics of Radiations; Roentgen Rays Technique; Theoretical and Practical Cristallographic Applications of Roentgen Rays; Application of Ultraviolet Radiations; Technical Problems about the Medical Application of X and Ultraviolet Rays.

In the 1932–33 academic year the first three students took their graduation exams: Federico Arborio Mella with a dissertation on magnetism, Olga Bertoli with a dissertation on the conductivity of solid and liquid dielectrics irradiated with X, α, β, and γ rays, and Cataldo Schiralli with a dissertation on the anomalous dispersion. The topics studied in the thesis dissertations show a connection with the researches carried out by Bolla, Giacomini and Polvani (and later by Gentile), that is the students' work was fully integrated in the research activities of the Institute.

Polvani's success in his didactical plans was finally reached with the establishment of the graduation course in Physics, which replaced the course in Applied Physics, in the 1935–36 academic year. Students who had successfully taken their final exams from a classical or scientific lyceum could enroll the new four year long course in Physics. The students had to attend the classes of twelve fundamental courses (some of them were two or three years long) and of at least two complementary courses. The fundamental courses were: Mathematical Analysis (two years: algebraic and infinitesimal), Analytic Geometry with Elements of Projective Geometry, Higher Analysis, Rational Mechanics with Elements of Graphic Statistics, Experimental Physics (two years), Exercitations of Experimental Physics (three years), Mathematical Physics, Theoretical Physics, Higher Physics, Physical Chemistry, General and Inorganic Chemistry with Elements of Organic Chemistry, Chemical Preparations. The complementary courses were: Organic Chemistry, Technical Physics, Electrotechnics, Astronomy, Mineralogy, Probability Calculus. It is evident the increase in the number of physics courses with Higher Physics and the Exercitations of Experimental Physics mostly at the expenses of mathematics courses such as Descriptive Geometry, Higher Mechanics, Higher Geometry, Complementary Mathematics. The new graduation course in Physics was therefore much more centered on Physics.

The study plan suggested by the Statute of Milan University was[15]:

- 1st year: Mathematical Analysis (algebraic), Analytic Geometry with Elements of Projective Geometry, Experimental Physics (I), General and Inorganic Chemistry with Elements of Organic Chemistry, Chemical Preparations.
- 2nd year: Mathematical Analysis (infinitesimal), Experimental Physics (II), Exercitations of Experimental Physics (I), Rational Mechanics with Elements of Graphic Statics, Physical Chemistry.
- 3rd year: Higher Analysis, Theoretical Physics, Mathematical Physics, Exercitations of Experimental Physics (II).

[15] Centro APICE, Historical Archive Milan University: 1935–36 yearbook, p. 323.

Table 3.11 Number of freshmen in 1935–1945

Academic year	Male	Female	Total
1935–1936	4	1	5
1936–1937	1	0	1
1937–1938	2	1	3
1938–1939	3	1	4
1939–1940	6	2	8
1940–1941	3	0	3
1941–1942	7	7	14
1942–1943	10	4	14
1943–1944	6	3	9
1944–1945	5	8	13

- 4th year: Higher Physics. Exercitations of Experimental Physics (III), two complementary courses.

The graduation exam consisted in the discussion in front of a commission of eleven professors or lecturers of a written dissertation on researches on a topic of the disciplines of the course in Physics. The researches had to be carried out in one of the chairs of the Faculty of Sciences. Before the graduation exam, the students had to take a practical exam on topics from the experimental fundamental physics courses.

The number of freshmen was very small in the first few years (Table 3.11). A few units per year were comparable with the numbers of freshmen at Pavia University which had feared to lose students with the institution of a degree course of Physics in Milan. The number of freshmen started to increase and became greater than ten after the beginning of the Second World War. This trend continued after the war, when the number of freshmen continuously grew to much larger numbers.

The total number of students (Table 3.12) shows a similar increase. The numbers starts to be large enough to make a comparison between the number of male and female students. In the 1930s the male students were definitely many more than the female students who preferred to enroll to the degree course of Mathematics and Physics, in which they were usually twice as many than the male students. In the early 1940s the number of female students steadily increased and became quite similar to that of the male students. It is evident that the male students, during the war, were more easily not able to complete the degree course in due time, most probably to the fulfillment of some of them of their military duties.

The total numbers of students are reflected by the numbers of graduates (Table 3.13), with the effect of the war on the male students, and with the graduated female students as about one fourth of the total. The maybe unexpected high number of male students graduated in the 1944–45 academic year takes into account the students coming back after the end of the war and graduating in large numbers in the following months with the so-called “war graduations”.

Table 3.12 Total number of students[rma] in 1935–1945

Academic year	Male	Female	Total
1935–1936	10 (12)	6 (7)	16 (19)
1936–1937	7 (9)	5 (6)	12 (15)
1937–1938	8 (10)	8 (9)	16 (19)
1938–1939	13 (15)	5 (7)	18 (22)
1939–1940	23 (26)	5 (6)	28 (32)
1940–1941	24 (26)	3 (4)	27 (30)
1941–1942	28 (35)	11 (12)	39 (47)
1942–1943	36 (39)	17 (18)	53 (57)
1943–1944	29 (42)	20 (22)	49 (64)
1944–1945	22 (39)	24 (26)	46 (65)

[rma]The numbers between parenthesis are inclusive of the undergraduate who have not completed course in due time

Table 3.13 Number of graduates after in 1935–1945

Academic year	Male	Female	Total
1935–1936	1	1	2
1936–1937	2	3	5
1937–1938	3	0	3
1938–1939	0	2	2
1939–1940	1	3	4
1940–1941	6	0	6
1941–1942	2	1	3
1942–1943	3	0	3
1943–1944	1	0	1
1944–1945	7	1	8

3.4 The Research Activities

3.4.1 Polvani's Lectures and His Studies in History of Physics

As we have seen in Polvani's biography, his role as director and organizer of the Institute of Physics put a strong limit to his research activity. We can however identify three fields of research pursued by Polvani: in the early 1930s a couple of theoretical works on metals, in the whole 1930s theoretical reflections on some different topics treated in public lectures for the Mathematical Physical Seminar of Milan, and his studies on the history of physics.

In 1931 Polvani prepared a review work [28] on free electrons in metals for the Italian Society for the Advancement of Science. He took into consideration the possible existence of free electrons in metals, their relations among them and with the metal ionic array, and their reactions to actions of elastic or electromagnetic forces at different temperatures and pressures. In classical physics context, Polvani recalled the already known results (thermoelectric effect, Volta effect, electric and thermic conductivity, the Wiedemann-Franz-Lorenz law, and Einstein's interpretation of the photoelectric effect). The impact of quantum ideas was analyzed by Polvani in detail. He highlighted what could explained by models such Fermi's model of electron gas, but also their limits. Considerably different was a description based on quantum mechanics with the movement of the free electrons seen as the propagation of a Schrödinger wave function following Fermi-Dirac statistics. The comparison of the different solutions to any problem led Polvani to their classification in four classes of phenomena: (1) phenomena which were well described by the models at disposal (specific heath, thermoelectric effect, Volta effect); (2) phenomena whose right solution was envisaged but not yet fully developed (electric and thermic conduction, Hall effect, photoelectricity, paramagnetism, ferromagnetism, cohesion); (3) unexpected phenomena (diamagnetism of free electrons); (4) unsolved problems (superconductivity). The behavior at very low temperatures of the electric conductivity of a metal film in dependance from its electric charge was foreseen by Polvani in a note [29] in 1932 with a critical analysis of Mariano Pierucci's studies on the subject.

The lectures given by Polvani to the meetings of the Mathematical and Physical Seminar of Milan concerned the following topics: in 1930 the experimental, theoretical and philosophical meaning of quantum wave mechanics [30] with a wide description of the fundaments of wave mechanics and its experimental confirmation, the probabilistic interpretation of wave mechanics by Max Born, and an interesting exposition of Heisenberg's indetermination principle and its connection with the philosophical problem of causality; in 1933 a review [12] on the statistical analyses of the empirical distribution of prime numbers; in 1933 with Bruno Finzi and Emilio Bianchi the relation between the velocity of light and the expansion of the universe [31], in which Polvani exposed the velocity of light in the contexts of a corpuscular and of a wave theory, the experimental methods to measure it, and the problem of its constancy or of its possible variation in time; in 1936 a sumptuous lecture [32], full of references to classical and humanistic culture, devoted to the second principle of thermodynamics and Maxwell's devil.

Polvani's researches in the history of physics were carried out in the 1930s and 1940s. Polvani found Antonio Pacinotti's papers in Pisa and catalogued them for the Institute of Technical Physics of Pisa University. A first catalogue of Pacinotti's papers was published by Polvani in 1930, and a more detailed one in 1934. Pacinotti's heirs left the extant machines and devices to Pisa University; all the instruments were put by Polvani in the same collection of Pacinotti's papers. Polvani's studies on Pacinotti [36, 37] are to be considered as part of historical researches on Pacinotti which flourished in the 1930s and concerned his studies on induction machines, the invention of the electric dynamo, the electric motor (Pacinotti's ring), and his astronomical activities. Given the attention drawn by Italian culture of the time to the primacy of Italian discoveries, it is not surprising the fact that these historical studies insisted on Pacinotti's priority in the invention of the dynamo.

Another nineteenth-century physicist of Pisa University who draw Polvani's attention was Ottaviano Fabrizio Mossotti [40]. Polvani, with Luigi Gabba, collected Mossotti's papers which they published in 1951 [39]. In 1942 Polvani published an impressive biographical work on Alessandro Volta [41] which is still today an important reference. On these three physicists, Polvani wrote the entries for the Italian Encyclopaedia (Mossotti in the 1934 edition, Pacinotti in the 1935 one, and Volta in the 1937 one).

The history of the researches on the nature of light [42] and the Italian contribution to the development of physics in the last century [43]. This work, written with the help of Bolla, Cocconi and Gentile, analyzes the Italian contributions to physics from the First Meeting of Italian Scientists, held in Pisa in 1839, up to 1939. The main topics considered by Polvani were: Molecular Physics, Thermology, Thermodynamics (the molecular-atomistic concept of nature; the mechanical theory of heat; thermodynamics and the classical kinetic theories; the quantum kinetic theories; heat transfer through matter; phenomena of molecular physics; thermology); Acoustics (the propagation of sound; particular cases of vibrating bodies; some demonstrative experiments; phonometry; architectonic acoustics; physiological acoustics; other topics); Electricity and Magnetism (electrostatics; structure of dielectrics; experimental researches on dielectrics; constitutions of magnetic materials; constitution of diamagnetic materials; experimental researches on ferromagnetism; Matteucci, Wiedemann and Joule effects; experimental researches on para- and diamagnetism; Volta effect; metallic conductivity; electrolytic conductivity; gaseous conductivity; photoelectricity; electromagnetic induction; Pacinotti's work; Ferraris's works; Hertzian waves; researches promoted by the technical use of Hertzian waves; electromagnetism and its organization; systems of electric and magnetic units; instruments and devices for electric and magnetic measurements; Seebeck, Peltier and Thomson effects; Hall, Ettingshausen, Nernst and Righi effects); Optics (general conceptions on the nature of light; photometry; geometric-instrumental optics; refraction and dispersion; interference and diffraction; polarization and birefraction; magneto-optics and electro-optics; global irradiation; spectroscopy up to 1900; anomalous dispersion in spectroscopy; spectroscopic multiplicity in arcs and sparks; researches on emission spectroscopy; researches on absorption spectroscopy, fluorescence; width of spectroscopic lines; Zeeman effect; Stark-Lo Surdo effect; molecular diffusion; instrumental spectroscopy; qualitative spectroscopy; X-rays); Radioactivity and Cosmic Rays (researches on radioactivity; researches on cosmic rays); Atomic theory (first atomic models; atomic quantum models; atomic statistical models; other topics on modern atomism; Raman effect; hyperfine structure; nuclear theory); Relativity (relativity of mechanical phenomena; relativity in optical phenomena; different aspects of relativity; quantum relativity.

Eventually, Polvani's interest for the history of science played a fundamental role with the establishment of the courses of History of Physics in the physics degree study plans after the 1961 reform.

3.4.2 Raman Spectroscopy

Raman spectroscopy and its theoretical interpretation attracted the attention of several physicists in Italy (Fermi, Segrè, Brunetti, Ollano, Specchia) and abroad. Bolla started his researches on Raman spectroscopy by photographing the Raman band of water excited by the mercury line at 2537 Å at a temperature of 17 °C [47, 48] from a Heräus cold lamp. The choice of this line was recommended by Bolla for the intensity of both the line itself and the excited Raman light. Furthermore, the same line could be absorbed in the spectrograph. The 2537 Å line could be absorbed in excitation with a quartz tube filled with mercury vapors to act as a filter, a fact which favored the precise measurements in particular in the case of the Raman band of water.

The Raman band was known to be 600 cm^{-1} wide with a mean $\Delta\nu$ of about 3400 cm cm^{-1}. Bolla used for his first researches a Hilger spectrograph with exposures of 125 h. He observed some weak and diffuse bands, which were not to be found when excited by different mercury lines. These first bands could not be reproduced. With two spectrographs, an self-collimator spectrograph with a 2 Å/mm dispersion and a Hilger E_2 spectrograph with a 11 Å/mm dispersion, he found the three components, a faint one at 3630 cm cm^{-1}, an intense one at 3435 cm cm^{-1} (intense), and one of medium intensity at 3200 cm cm^{-1} [49]. A further study [50] led Bolla to photograph the 3200 cm cm^{-1} and 3435 cm cm^{-1} bands in 15 s, the 3630 cm cm^{-1} and 172 cm^{-1} in 5 min, that is in much shorter times than in his first experiments. He discovered five new bands with $\Delta\nu$ = 510 cm^{-1}, 780 cm^{-1}, 1645 cm cm^{-1}, 2150 cm cm^{-1}, and 3990 cm cm^{-1} $\pm$5 cm^{-1}. In a further experimental study Bolla found that the Raman band in the interval 510–780 cm^{-1} could be observed in a temperature range between 28 °C and 92 °C [54] in disagreements with an observation which would have shown their disappearance around 40 °C.

A similar study was made on ethyl alcohol with the 2537 Å mercury line [52, 53]. Bolla found fifty-six frequencies. Fourteen fundamental frequencies were isolated, while the other forty-two were to be found as combinations of the fourteen fundamental ones. The newly found frequencies at 3632,0 cm^{-1}, 3359,3 cm^{-1}, 3240,3 cm^{-1}, 1617,8 cm^{-1}, 814,2 cm^{-1} and 256,6 cm^{-1} were associated to the OH-group of the alcohol molecule.

Bolla's studies on the photographic technique used to take Raman spectra led him to study in more detail the instruments used for spectrographic research. He obtained relevant results on the polarisation effects with photographic plates and quartz spectrographs, and perfectionized the technique of photographic spectrophotometry.

Although Bolla's results were published also on international journals, this was not enough to consider the Milan Institute of Physics as an important scientific institution for contemporary research and did not create a school of Raman spectroscopy. When Bolla left Milan to Palermo, the researches on Raman spectroscopy stopped.

3.4.3 Magnetron

Giacomini, with the help from Polvani who had already studied Hull's magnetron from a theoretical point of view in the 1920s, studied the magnetron as a generator and detector of microwaves [66–68].

The magnetron is a diode, made of a cylindric anodic plate and a hot metal wire place along the axis of the plate. A uniform magnetic field, parallel to the wire, acts on the diode. The electrons emitted by the hot wire undergo the electric force due to the potential difference between the plate and the wire and the electrodynamic force due to the magnetic field. The projection of the electrons trajectories on a plane perpendicular to the wire bend towards the wire. If the magnetic field is strong enough, the electrons cannot reach the plate, go back to the wire and the current between the wire and plate is annulled. From Polvani's fundamental equation of the magnetron:

$$\pm \frac{d}{dr}\left(r\frac{dV}{dr}\right) = \frac{a}{\sqrt{2\left(\frac{e}{m}\right)V - \frac{1}{4}\left(\frac{e}{m}\right)^2 H^2 r^2 \left\{1-\left(\frac{r_0}{r}\right)^2\right\}^2}} \tag{3.1}$$

(where: r is the distance of the electron from the magnetron axis, V is the electric potential in the point where the electron is, a is a parameter whose sign is opposite to that of the electric current; e is the electron charge; m is the electron mass; H is the magnetic field intensity; r_0 is the cathodic ray) Polvani obtained the following equation and the way to solve it in 1934:

$$x\psi'' + \psi' = \frac{p}{\sqrt{\psi - x^2\left(1 - \frac{1}{x^2}\right)^2}} \tag{3.2}$$

All the quantities in this equation have no physical dimension. The integration of the fundamental equation permitted to find the relevant quantities concerning the motion of the electron, such as the shape of the trajectory or the time it takes to move along it.

Given the time of motion of the electrons, Giacomini showed that this time is related to the generation of Hertzian waves in the magnetron and to the anomalous dispersion phenomena when the magnetron is irradiated by an electromagnetic radiation whose period is comparable to the time of motion of a closed electronic trajectory.

When the magnetron was used as a microwave detector, the system was put in forced oscillatory motion by the microwaves. Giacomini found that the damping strongly depends on the electric constants of the tube power supply. In the conditions of maximum damping, Giacomini obtained that there is a resonance with the revolution periods close to the microwave periods. As a confirmation of the resonance, Giacomini observed an anomalous dispersion: at maximum damping the magnetron behaved like a capacitor (whose armature is made by the plate and the wire) with a dielectric constant equal or larger than one.

Also in the case of the magnetron and microwaves, Giacomini's researches did not put the Institute of Physics at the front of contemporary scientific research and did not gave birth to a school.

3.4.4 Cosmic Radiation

After Bolla and Giacomini left Milan, a new research group was formed with some graduates of the Institute of Physics. Their research subject was the cosmic radiation. Researches on cosmic radiation were not a novelty in Italy. In particular the Arcetri school in Florence, led by Bruno Rossi, had obtained internationally relevant results in the early 1930s with the development of the coincidence circuits applied to counter telescopes used for the study of topics such as the latitude effect or the east-west effect. The attractiveness of cosmic ray physics for a research group in Italy was mostly based on two aspects: cosmic radiation is free (to be compared to the high costs to buy radioactive sources) and the instruments to study are quite simple – they can be built in an institute workshop. The study of cosmic radiation at different altitudes could furthermore benefit from the closeness of Milan to the Alps.

Two research fields in cosmic radiation physics were studied when Giuseppe Cocconi started his first measurements: the study of the meson and the study of the extensive showers. The meson was a particle whose mass was intermediate between that of the electron and that of the proton. It had been predicted by Hideki Yukawa to be the exchange particle corresponding to the strong nuclear interaction and it should had been created by the interaction of primary cosmic radiation with nuclei at high altitude. In 1936 Carl Anderson and Seth Neddermeyer at Caltech announced they had discovered in a cosmic ray shower a particle with a mass corresponding to that calculated by Yukawa. All the studies made in Milan before and during the Second World War considered the meson as the particle predicted by Yukawa; it was later shown that the meson was actually another particle (today's muon) and Yukawa's particle was discovered in 1947 by the Bristol group led by Cecil Frank Powell with Giuseppe Occhialini (who will be later professor at the Milan Institute of Physics).

The first research on cosmic rays at the Milan Institute of Physics was actually Vanna Tongiorgi's graduation work. Polvani had asked Cocconi to be co-tutor for Tongiorgi's dissertation on the search of neutrons in cosmic radiation. In early 1938 Cocconi was in Rome, invited by Amaldi, and learnt from Franco Rasetti a radio-chemical method to detect neutrons by filtering with paper a solution of potassium permanganate irradiated by neutrons: Mn^{55} absorbed the slow neutrons transforming into Mn^{56} which decayed β in 2.6 h. They could measure the β-rays with an energy up to 2.8 MeV with a Geiger counter. Tongiorgi and Cocconi built the electronic circuit with a counter for the detection of these β-rays. The counter was calibrated in Rome with a neutron source lent by the Institute of Health. In early 1939 they performed the measurements of cosmic neutrons in a 15 m deep hole in the Public

Gardens in Milan. The difference between the results in open air and underground were not convincing. Polvani obtained from the Edison Company the financing to send the two young physicists to Cervinia (2000 m altitude) to expose on a daily base for two weeks the instruments at the Plateau Rosà (3500 m altitude). No difference was recorded between the two altitudes [80]. Cocconi and Tongiorgi came back to the detection of cosmic neutrons only when in the United States after the Second World War.

Cocconi and Tongiorgi decided to study the mesons or, as they called them, the jukons (after Yukawa). At the time (1939) they thought that primary cosmic rays were high-energy electrons. From the energy spectra known in literature, Cocconi tried to find the production probability of mesons from the latitude effect [95]. He noticed that the observational results were in strong disagreement with the values obtained by Heitler-Bhabha theory. His analysis led him to an esteem of the primary electronic spectrum and of the meson spectrum at sea level, but the production probability obtained by their ratio could not be compared with any theoretical model.

The meson decay had been predicted by Yukawa and was used to explain the different absorption of the mesons in various materials. Cocconi followed Caly and Van Germer's hypothesis (a dependence of the absorption from the electronic density) in his measurements of the absorption at different zenith angles. He used a counter telescope [96, 97, 107] with lead absorbers at sea level in the Institute of Physics. Cocconi, Tongiorgi and Carlo Salvetti compared the Milan results with Caly's ones and found they were compatible. They assumed that the mesons were produced in high atmosphere and calculated the path travelled by them in dependence of the angle of arrival to the counters (they inclined the telescope at $0°$, $60°$ and $75.5°$ angles). With Caly and Van Germer's hypothesis they could find the curves of absorption and the meson spectrum as a function of the path travelled in atmosphere, the initial energy and the zenith angle. Eventually they were able to confirm the value of 2×10^{-6} s for the mean life of the meson.

After the Rome group had found primary electrons at sea level, in Milan they decided to repeat the measurements [98, 99] at 120 and 2200 m above the sea level, and calculate the meson mean life with three methods: Pomerantz's integral method, Pomerantz's differential method, and by a comparison with different strata of lead absorbers. From the new results with the first method (the most reliable one) they thought that the mean life of the meson could be greater than the previously obtained one [100] (between 3 and 4 μs) in agreement with the value found at Rome.

The Milan group made again measurements on the meson mean life after new hypothesis were advanced, such as the possible existence of more than one kind of mesons with different mean lives, or the dependence of the meson mean life from the path length in atmosphere. The results showed that the life time did not increase with the path in atmosphere, and that the values were constant within a 10% incertitude [101, 102].

The second main topic was the study of cosmic ray showers. Showers were considered as composed by three components: hard (highly penetrating particles), soft (electrons and positrons produced in atmosphere), and ultra-soft (produced by the soft component). A shower was detected when several not aligned counters were activated in coincidence. The results could but show a coherence effect, that is a dependence from the counters disposition. Coherence was defined as the simultaneous appearance in a counter of more than one secondary particles created by one primary particle. Due to lack of space, they built a wooden hut (nicknamed "Villa Vanna") in the main court of the Palace of Sciences, where to carry out their measurements with a set of three counters [77, 78] and a lead absorber. They found that the coherence effect could be observed only in the soft component of the showers with a minimum angular width of 30°–40°. The lack of coherence in the ultra-soft component implied that the showers were at least 100° wide. Cocconi then published also a theoretical analysis of the counting probability of two counters in coincidence for the detection of showers [103].

Cocconi and Tongiorgi then analyzed the dependence of the number of secondary rays from the atomic number of the absorber material which produced the showers [79]. By using lead, iron and sand absorbers they found that the number of secondary rays decreased with increasing atomic number, in disagreement with Bhabha's model which had advanced a direct proportionality. With a set of four counters they repeated the measurements with lead and iron absorbers of different thickness [104]. As a result they confirmed that the number of soft secondaries increased with a decreasing atomic number. Tongiorgi repeated the measurements a third time with a similar experiment [105] and confirmed that the number of secondaries in lead were higher than in aluminum.

The extant archive documents cannot help us in understanding in full detail the research activities of other collaborators. For instance, we know that Olga Bertoli published at least two review papers, one on solid and liquid dielectrics irradiated with α, β, γ and X rays [71] and one on the phenomena of superconductivity [72], but they do not describe any research work made by her or by other researchers in Milan.

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Chapter 4
Giovanni Gentile Junior. Physics as an Intellectual and Spiritual Adventure

Luisa Bonolis

Abstract In 1936, the arrival of the young theoretical physicist Giovanni Gentile Jr. at the Institute of Physics of Milan University directed by Giovanni Polvani, opened novel horizons both in terms of the choice of research topics in the field of modern physics and of modernization of teaching. Gentile's solid education at the Pisan school of physics and mathematics in the 1920s and his relationships with Fermi's school in Rome and later with the great German school of theoretical physics through Schrödinger, London, Heisenberg and Sommerfeld, as well as his special friendship with Ettore Majorana, became the premises on which to build a stimulating research environment with the consequent formation of a new generation of theorists in contact with the international scientific community. The unique partnership between Polvani and Gentile, rooted in a deep human, cultural and scientific affinity, immediately resulted in an effective revitalizing impulse both for the Milan Institute of Physics and for Gentile Jr.'s personal research path. Despite his brief passage in Milan—barely five years before his premature death in 1942—Gentile planted a few seeds of renewal that flourished after the war, contributing to the rebirth and revival of Italian physics almost destroyed by Mussolini's racial laws and the dramatic consequences of the war.

4.1 Introduction

Upon his arrival in 1929 at the Milan University, Giovanni Polvani was extremely determined not only to give new life to the Institute of Physics he had been called to direct, but also to make it a center for modern physics that could compete with other traditionally prominent Italian institutes such as those at the Pisa University o and the Regio Istituto Fisico of the ancient University La Sapienza in Rome, whose experimental tradition could by that time boast the presence of Enrico Fermi, who had won in 1926 the first competition ever announced in Italy for theoretical physics along with Enrico Persico and Aldo Pontremoli. The latter, who had been appointed to the newly created chair of this discipline assigned to the Milan University, had disappeared in May 1928 during the polar expedition on the airship Italia organized by Umberto Nobile. After such a dramatic event, only two professors of theoretical

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physics were left in Italy. The chair in Florence was occupied by Persico, Fermi's brotherly friend, who was an outstanding teacher and gave at the time a great contribution to the spread of modern physics holding one of the first courses in Italy on quantum mechanics. He mentored among others Bruno Rossi, Gilberto Bernardini, Giuseppe Occhialini, Giulio Racah and Daria Bocciarelli, before moving to Turin in 1931. In parallel, after the masterful work on the quantum statistics that bears his name, Fermi in Rome gathered a few brilliant new recruits, who would in different ways give great contributions to the advancement of physics in Europe and the United States. After having formulated in 1933 his masterpiece, the theory of nuclear beta decay [1], the following year Fermi conducted the well-known experiments on artificial radioactivity induced by neutrons [2] first alone and later with his formidable team, including Franco Rasetti (his old friend and collaborator since when they were both students in Pisa), Emilio Segrè (who would be awarded the Nobel Prize in Physics for the discovery of the antiproton), Edoardo Amaldi (who with Gilberto Bernardini would promote the reconstruction and renewal of Italian and European physics after the war) and Bruno Pontecorvo (who became a brilliant physicist, later named "Mr Neutrino" for his successful work on neutrino theory). Ettore Majorana was also part of this group, although in a more detached and irregular way.

By 1935–1936, while Fermi's group was already beginning to disperse after the brief, albeit successful research season, Polvani was continuing to exert his efforts to promote the growth of his Institute in Milan. In his determination to strengthen its academic staff with a theoretical physicist, Polvani aspired to have at his side the young theorist Giovanni Gentile Junior, who had graduated in the fall of 1927 from the Pisa University, where Polvani had a teaching position at the Institute of Physics directed by Luigi Puccianti before he moved to Milan. Gentile was born in Naples on 6 August 1906, the day after the birth, in Catania, of Ettore Majorana, of whom he would later become a great friend. He was the son of the homonymous idealist philosopher, Giovanni Gentile, an extremely influential figure in the fascist period, deeply involved both intellectually and politically in Mussolini's regime, and thus, to distinguish the son from the famous father, his name was usually followed by Junior, but family and friends affectionately called him Giovannino, an appropriate appellation for a notoriously kind-hearted person.

Polvani's desire dated back to a few years earlier, when the young theoretician had obtained his teaching qualification, the "Libera docenza", once back from his post-graduation stay in Berlin—where he had contacts with Erwin Schrödinger and Fritz London and other illustrious physicists, notably Einstein—and in Leipzig, where he had worked under the guidance of Werner Heisenberg. But Polvani's initial aspiration to have Gentile with him in Milan had not been realized, because Gentile had responded positively to his old professor Puccianti's offer of a teaching assignment in Pisa. Giovannino had agreed to such request, probably for more than one reason. On the one hand it would have been difficult to refuse Puccianti's invitation, moreover, for a young man at the beginning of his career the University of Pisa was much more prestigious than that of Milan. On the other hand, one can easily imagine that Gentile also felt a subtle satisfaction in returning as a professor to the places where he had been a student. For his part, Polvani did not want to insist, "out of a regard for our common master" [3, 156]. Moreover, at that time Gentile's father was director of the Scuola Normale Superiore, and so his influential presence seemed to suggest the appropriateness of this choice, also because the powerful senator would certainly make every effort to support Puccianti's initiatives aimed at improving the situation of physics in Pisa.

But Puccianti, by now elderly, turned out to be rather lazy and not even remotely as dynamic as Polvani, thus making the situation definitively uninteresting and so Gentile in agreement with his father, made himself available to accept a new invitation from Polvani in 1936. In his obituary of the young colleague who died too prematurely when he was just under 36 years of age, Polvani recalled [3, 156],

> […] In this way, an aspiration that was, after all, in both of us was fulfilled: to come together in didactic and scientific collaboration.

These few words, even in their simplicity, express the profound sense of the human and intellectual partnership between Polvani and Giovanni Gentile Junior, that had already begun when the latter was a student at the University of Pisa and Polvani a young professor at the Institute of Physics directed by Luigi Puccianti.

Polvani had the far-sighted vision of placing side by side with the experimental tradition to which he himself belonged, the novelty deriving from the nascent Italian theoretical school, which at that time was represented by a very small group of young people who, although having as a reference the luminous example of Fermi and Persico, were finding their own style of research pursuing the novel frontiers of physics, a discipline which was still growing explosively after the revolutionary developments that had characterized the first twenty years of the twentieth century. This new generation of physicists, such as Gian Carlo Wick, Giulio Racah, Gleb Wataghin, later became highly regarded at international level, even if, unfortunately, they ended up lending their work as scholars and teachers very often, if not entirely, abroad. Post-war Italy became in fact singularly lacking in theoretical physicists first because of the diaspora due to the racial laws and then, after World War II, because of the attraction exerted by international centers that offered better prospects or, in the case of Gentile and Majorana, to their early disappearance from the Italian scene, which dramatically interrupted the path they had started.

Gentile faced with enthusiasm the role of responsibility that Polvani was offering him and in perfect harmony with his ancient professor deeply committed to both educational and scientific levels, projecting himself into the future on the front of the formation of new recruits and alongside Polvani in the requalification and development of the Institute. In seeking his own way, either independently or under the impetus of a new and dynamic Italian scientific community that for the first time was strongly in tune with the great innovations coming from the international panorama, Gentile shared his experience with a series of original personalities who, in different ways, contributed to the consolidation of such turning point for Italian physics. At the same time, as a beloved and generous teacher, Gentile was instrumental in the continuation of such outstanding tradition.

His intellectual and scientific experience was closely intertwined with philosophical, historical and epistemological interests. The breadth of his cultural horizons is also evidenced, among other things, by his affective and intellectual association with leading figures, respectively, of physics and philosophy of those years, such as the already mentioned Ettore Majorana and Gentile's brotherly friend Delio Cantimori, of which there is a substantial and precious trace in the correspondence. In Majorana's case, this correspondence is of special relevance, considering that, apart from the real family letters—and the interesting scientific exchange with his uncle Quirino—this series is the only known direct evidence of the private life of the brilliant physicist. Gentile and Majorana were full of cultural curiosities and strongly attracted by the increasing level of abstraction that characterized some aspects of the new physics and by their formal elegance. Both considered physics as an intellectual adventure and a fascinating challenge, also by virtue of its unique conceptual difficulties deeply embedded in the revolutionary new developments that had characterized the first two decades of the twentieth century. They themselves, during the 1930s, would make their contribution to such a profound renewal of the physical sciences.

This breadth of horizons and the rich interweaving of interests drove Gentile, in parallel with his commitment more closely aimed at research and teaching, to spend a large part of his time in writing essays focused on the breakthroughs of twentieth century physics and in the preparation of volumes addressed to the general public and high-school teachers. In this constant desire to integrate physics into the cultural panorama of the country, Gentile was certainly ahead of his time and can be compared to an illustrious exponent of Italian scientific and cultural life such as the mathematician Federigo Enriques, who, since the beginning of the century, had moved in the context of a vast and articulated plan in which reflection on the nature of scientific knowledge and on its cultural role was a central element [4]. The history of intense "meditation", the evolution of Gentile's thought as a philosopher and a scientist which makes manifest the cross-fertilization of knowledge in different areas, can only be retraced through the entirety of his writings, as well as from his correspondence, from which his search for a cultural unity of knowledge is emerging.

In 1940 he published, among others, his first paper on intermediate statistics, followed by applications to the peculiar properties of liquid helium and to the phenomenon of Bose–Einstein gas condensation. These works constitute his major theoretical contribution of his Milanese period and still today an important scientific legacy that testify his farsightedness in the choice of research topics. In his honor, the particles subject to intermediate statistics are called "Gentilions", to distinguish their properties from those of the "bosons" and "fermions". At this time of his life Gentile was not yet 36 years old, full of initiatives and plans for the future. Then, quite unexpectedly, a septicemia ended his young life on 30 March 1942.

Despite his brief passage at the Institute of Physics in Milan—barely five years—Gentile planted a few seeds of renewal that sprouted and flourished after the war, contributing to the rebirth and revival of Italian physics almost destroyed by the racial laws and the dramatic consequences of the war.

It is my deepest wish to dedicate this chapter to Enrico Gentile, the son of Gentile Jr., who with extraordinary commitment and high sense of filial love has dedicated himself for many years to the study and understanding of the cultural, spiritual and scientific world of his father's figure constantly also promoting related historical studies and making every effort to ensure that all the papers and the documentation concerning his research work and personal life, as well as copies of the correspondence, were gathered together and properly preserved in an archive and made available to scholars. In this passionate form, he was able to deeply reacquaint himself with the figure of a father he had not been so fortunate to know due to the latter's dramatic death when he was only a few months old. To him goes my fond memory of many years of constant and intense discussion and close collaboration during my work of analysis and organization of his father's papers he donated to the 'Edoardo Amaldi Archives' of the Physics Department at Sapienza University of Rome.

Last but not least, I am very grateful to Alessandra Gentile for her most helpful comments on this contribution.

4.2 A New Generation of Theoretical Physicists in Italy

With his dissertation in theoretical physics, the first theoretical thesis in Italy, on which he worked in complete autonomy from the late spring of 1927, Giovanni Gentile Jr., became part of the advanced research of the time, which presented not only radically new problems from the physical point of view, but also the formidable challenge of new mathematical formalisms. Gentile studied the consequences of the Schrödinger's equation, the partial differential equation expressing the wave-like nature of atomic particles, which proved its power providing the solution for the energy levels of the hydrogen atom, that were found to be in accord with experimental data. Tackling a topical research theme, "a new form of quantum theory" published by Schrödinger in December 1926 [5], Gentile shows his ability to master the necessary mathematical tools integrating them perfectly with the physical analysis. On the other hand, as he himself pointed out, after attending for two years the university courses in Pisa as a student of mathematics, it was experimental physics that fascinated him and induced him to switch to the physics course. The next step had been the discovery of modern physics, which he arrived at through the initial topic of his thesis, the Stark-Lo Surdo effect, which was assigned to him by Polvani himself. This effect, discussed at length by Schrödinger in his third article of 1926, certainly attracted Gentile's attention towards quantum theory and in particular towards its wave-mechanical formulation provided by Schrödinger and applied to the simplest atom, hydrogen, having a single electron orbiting the nucleus. The temporary departure from Pisa of Polvani, who had won a competition for a chair of Experimental Physics in Bari, induced Gentile to take the decision to fully devote himself to the theoretical aspects of the problem, that he also tried to discuss from the point of view of the involved epistemological implications. His constant attention toward the foundations of the new quantum mechanics and the philosophical aspects of science in general was an attitude that characterized his research activity since then. It is in any case remarkable that in this decision he was not opposed by Puccianti, director of the Institute, made tolerant probably thanks to the influential figure of Gentile's father, who on the other hand had an enormous respect for his son's aspirations toward theoretical physics, and for his enthusiasm that made this discipline—still entirely new to the Italian academic world—appear far closer to philosophy than the experimental aspects of physics.[1] In those years a thesis in theoretical physics in a certain sense was not even conceivable in Italy, since this discipline was not included in the university curriculum. And indeed, on 26 November 1927, when Giovanni Gentile and his friend and colleague Gilberto Bernardini graduated in physics at Pisa University with 110 cum laude, Fermi, Persico and Pontremoli had just won the first national competition for theoretical physics, and were settling on their respective chairs in Rome, Florence, and Milan.

Since December of that year, after rejecting the possibility of working with Vasco Ronchi, who was about to found the the Institute of Optics in Florence, Gentile made a brief stay in Rome, as an assistant to Orso Mario Corbino, starting his scientific career under the best auspices. At that time Fermi, Rasetti and the small group of young people who were beginning to gather around them, were tackling atomic physics with very advanced techniques. With his first published work Gentile successfully went as far as touching on topics concerning the atomic nucleus, a domain still virtually unknown, and thus a completely novel research subject even in Rome (and in general in Italy and other research centers in the rest of the world). He discussed a model just formulated by Ernest Rutherford for the nuclear structure, whose theoretical basis Gentile showed to be without foundation [8]. Such work testified the growing interest of Fermi and Rasetti for the nuclear realm, which they considered the new frontier, while they continued to investigate the atomic electronic structure using the successful Thomas–Fermi statistical model. The structure of the nucleus would have been clarified only in 1932, with the demonstration of the existence of the neutron, a constituent of the nucleus hypothesized by Rutherford and long sought by his collaborators, in particular by James Chadwick [9].

During those six months in Rome Gentile became a good friend of Ettore Majorana, for whom he felt a deep affection and extreme admiration. Gentile was bringing in the Roman Institute a taste for the philosophical reflection on the new physical theories that was completely foreign to that environment and that most probably was at the root of his intellectual fellowship with Ettore Majorana, which naturally involved many other aspects, such as the passion for theater, or cultured readings. In this sense Gentile represented a rather lonely voice, able to deal with the awareness of a scientist and the animus of the philosopher very complex issues with which physicists such as Niels Bohr and Werner Heisenberg, whom he admired unconditionally, were confronted. We don't have much evidence to reconstruct what was the nature of their "elective affinities" [10]. What we know is that the series of letters written by Majorana to his friend Gentile represent the only known extra-familiar correspondence. With Ettore, at the time still a student, Gentile wrote the second [11] of his three papers on problems of atomic and nuclear physics presented at the Reale Accademia dei Lincei [12]. As some of these letters testify, the close collab-

[1] For an in depth discussion of the very special relationship between Giovanni Gentile Junior and his father see the beautiful contribution written by Gabriele Turi [6]. See also Roberto Maiocchi's biographical entry in the *Dizionario Biografico degli Italiani* [7].

oration between Gentile and Majorana continued during the following years, even if they did not publish any joint paper, most probably because of academic reasons, suggesting to write single-authored articles. Their shared interests can also be found in some of their articles. Majorana's pioneering paper *Relativistic Theory of Particles with Arbitrary Intrinsic Momentum* [13] was the first attempt to develop a relativistically invariant linear theory for particles with arbitrary spin, both integer and semi-integer, in which all mass eigenvalues are positive. Such constraint was introduced by Majorana in order to eliminate the negative-energy solutions characterizing the Dirac equation, which were considered an embarrassing result before the discovery of the positive electron in 1932. This requirement led Majorana to a remarkable pioneering achievement: the first ever development and application of the unitary infinite-dimensional representations of the Lorentz group. In 1939 and 1940 Gentile returned on these issues writing two very elegant works about the representations of the inhomogeneous Lorentz group [14], and a relativistic theory for particles with arbitrary spin, à la Majorana but in the light of new results obtained by Dirac [15]. And actually, since the beginning of their friendship, they had both a deep interest in group theory—that Gentile had learned in Pisa from one of the greatest Italian experts, the mathematician Luigi Bianchi—and its application to quantum physics.[2]

After six months in Rome, Gentile left for 18 months of military service. In the meantime, his friend Majorana had been working on his dissertation. He graduated in July 1929 with a thesis entitled *La teoria quantistica dei nuclei radioattivi* (The quantum theory of radioactive nuclei). It was the very first theoretical work on nuclear physics in Rome and the first in this field in Italy. In their dissertation topics the two young men were indeed both pioneers in every respect.[3]

In the fall of 1929 Gentile won a fellowship for further study abroad and went first to Berlin at the Institute of Theoretical Physics directed by Erwin Schrödinger. There he came in contact with the great German physicists of the time—such as Planck and Einstein—still in an era before the advent of the Nazi regime. Gentile

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[2] Both Majorana and Gentile had in their personal libraries the first editions of the books by Hermann Weyl (*Gruppentheorie und Quantenmechanik*, 1928) and Eugene Wigner (*Gruppentheorie und ihre Anwendung auf die Quantenmechanik der Atomspektren*, 1931) as well as Luigi Bianchi's *Lessons on the theory of finite continuous groups of transformations*, Andreas Speiser's *Theorie der Gruppen von Endlicher Ordnung* and Bartel van der Waerden's *Die Gruppentheoretische Metode in der Quantenmechanik*. Majorana's investigations on group theory are largely present in his personal papers, preserved in his personal papers at Domus Galilaeana in Pisa. On Majorana and Gentile's interest in group theory see [16]. See also [17] for the onset of group theory in the new quantum mechanics.

[3] As mentioned in Majorana's letter to Gentile of 22 December 1929 (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1) a copy of his dissertation was requested by Johann Kudar, then in Berlin: "As soon as I will have confirmation of your new address, I will send you some of the well-known works of Fermi, as well as, for necessary deference to the desire expressed by the illustrious Kudar, the only copy in my possession of my dissertation." And actually, starting from January 1929, Kudar published a series of articles discussing the connection between quantum mechanics and radioactive decay, topics that were very close to Majorana's dissertation. A copy of Majorana's dissertation can be found in Gentile's papers, Box 7.

was stimulated by Fritz London to work on the valence bond theory [18], at a time when the latter had recently published with Walter Heitler his classic paper on the homopolar bond [19]. In April 1930 Gentile moved to Leipzig and worked under the direction of Werner Heisenberg until early August. Heisenberg's institute was a world-class research center, especially attractive for brilliant young physicists who came from all over the world. During his stay in Leipzig 1930, Gentile wrote in collaboration with Felix Bloch a work on magnetic phenomena of crystalline lattices that became fundamental for the theory of metals [20]. Heisenberg, like Fermi, was only five years older than Gentile and Majorana, who would visit Leipzig himself in 1933. Although Heisenberg was already very famous as one of the founders of the new quantum mechanics, he was quite informal and had a passion for chatting about physics with his collaborators, making them feel part of such a unique era of which he had been one of the protagonists. He was also an excellent pianist and a person endowed with great classical culture and deep interest in philosophy. Such characteristics, along with his boyish appearance, made him extremely fascinating in the eyes of the young Italians (Fig. 4.1). Moreover, as Bloch himself recalled [21, p. 26], one of Heisenberg's great qualities as a teacher was "his immensely positive attitude towards any progress and the encouragement he thereby conferred."

These months in Germany were a formative experience that left a deep and lasting mark on the young Gentile. He was back in Leipzig in January–March 1931, and on 12 November he took the free teaching (the "Libera Docenza") in theoretical physics.

Fig. 4.1 Heisenberg's Institute in Leipzig, 1931. Front row (L-R): George Placzek (sitting on desk), Rudolf Peierls and Werner Heisenberg; back row (L-R): Giovanni Gentile Jr., Gian Carlo Wick, Felix Bloch, Viktor Weisskopf and Fritz Sauter. Copyright: Alessandra Gentile

4.3 At Pisa University with Luigi Puccianti

In 1932, called by Luigi Puccianti, Gentile obtained a position in theoretical physics in Pisa. However, the environment at Puccianti's Institute for Physics turned out to be not very stimulating, after the impact with Fermi's lively group in Rome and in particular after the beginning of his friendship with Ettore Majorana and the later interaction with the great German theoretical school. Gentile lost his way as a physicist and had a period of poor scientific production, accompanied by an existential crisis.[4] The analogy with the case of Ettore Majorana is striking: after his return in August 1933 from his stay with Heisenberg in Leipzig—whom he deeply admired and spoke about enthusiastically in his letters to the family—Majorana no longer attended the Institute in Via Panisperna and did not publish anything until his masterly work: *The symmetrical theory of the electron and the positron* [23].[5]

Nevertheless, in these years of scientific stagnation Gentile devoted himself with passion to his cultural interests and to his epistemological reflections on physics, with which he had already been confronted at the time he was writing his thesis. In discussing the philosophical thought of Bohr, Heisenberg and Pascual Jordan, who he considered to all intents and purposes modern thinkers, he systematically dedicated himself to the diffusion of their ideas on modern physics with his activity of high popularization of science. In those years, he wrote also several entries on physics topics for the *Enciclopedia Italiana*, which he accepted with enthusiasm "because they dealt with classic questions of physics that are always of lively interest".[6] This group of essays was later published in a booklet entitled *Questioni Classiche di Fisica* [26]. The first one dealt with the "Experimental Method", to which Gentile attached great importance, as it related to the concept of the complex relationship between theory and experiment, which as a theoretical physicist concerned him very closely.[7] These texts were a manifestation of Gentile's cultural commitment to reflections on scientific culture—and its dissemination—with particular attention to modern physics, that in Italy was emerging in those years thanks to the pioneering work and institutional commitment of figures such as Enrico Fermi in Rome, Enrico Persico in Florence and Turin, Bruno Rossi in Florence and later in Padua, and their students and collaborators. Polvani's contribution to this panorama—especially because of the

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[4] The last published work during his stay in Pisa is *Sopra la teoria della Rimanenza e della curva di Magnetizzazione*, submitted in December 1933, but of course it was related to research work arising from Heisenberg's deep interest in ferromagnetism [22].

[5] Nevertheless, Majorana continued to pursue his research interests and every year proposed free courses at the University of Rome submitting extremely advanced programs, but without any outcome [25]. Moreover, he was never offered any academic position during this period [24].

[6] Curriculum Vitae, G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[7] In this regard, see also [27]. Gentile's deep interest and involvement in reflecting on the epistemological and scientific implications raised by the theories that had profoundly revolutionized physics from the beginning of the twentieth century, were discussed by Maiocchi in the biographical entry dedicated to Gentile [7].

continuity he provided between the pre-war and post-war period—was to prove essential also in the reconstruction and revival of Italian Physics after the tragedy of World War II.

In Pisa Gentile already showed clear signs of his dedication to teaching. The lecture notes of his course in Theoretical Physics he edited at the end of the academic year 1933–1934, extremely advanced for the time, were published under the title *Lezioni di Meccanica Quantistica* [Lectures of Quantum Mechanics] [28]. They would deserve a more thorough analysis, in any case they are of extraordinary modernity with respect to the programs of physics courses of the time. Interestingly, they included sections dedicated to group theory, similarly to Majorana's proposed topics in his free courses.[8]

That was the time when Fermi's group in Rome was carrying out the fundamental experiments on neutron-induced radioactivity, which paved the way to the study of the structure of the atomic nucleus and eventually to the discovery in the late 1930s of the phenomenon of nuclear fission by Otto Hahn and Fritz Strassmann, an event that marked the transition to a completely new era in human history. Between 1934–1935, following the announcement of a competition by a publishing house for a monograph on modern nuclear physics, Gentile once again seized the opportunity to write a book that, if it could not entirely satisfy the interest of a physicist, could at least be useful to the chemist or engineer and in general to the cultured person who wished to know the fundamental ideas and concepts about nuclear physics and which are, so to speak, the basic tools in this research field [29]. Gentile immediately sent a copy of the book *Fisica Nucleare* to his friend Ettore Majorana, who on 20 June 1937 wrote words of appreciation: "[…] nothing similar has been seen in Italy long since, nor will it be seen so soon. It should really get into everyone's hands."[9]

Gentile's stay in Pisa lasted until 1936, when, according to Polvani's account [3, p. 149], "[…] following a new invitation from me to come to Milan, he accepted."

4.4 Finally Professor in Milan

In 1935–1936 Polvani finally succeeded in having the two degree courses in Physics and Mathematical Physics instituted and with the arrival of Gentile, by the academic year 1936–1937, it seemed that he had "touched the sky with a finger"[10]:

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[8] In the hapter on magnetic moments and vector model of the atom, Gentile introduces the fundamental concepts of reducible and irreducible representations of a group, concepts which are then used for the determination of the group representations of rotations and infinitesimal rotations and the selection rules for spectral emission. At that time no theoretical physics course included this kind of teaching.

[9] G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[10] From the text of the speech given by Polvani for the inauguration of the new seat of the Institute of Physics on 10 February 1964 [30, p. 38].

> […] the fundamental teachings, in addition to my own of experimental physics, were now in place. Gentile and Bolla were respectively in charge of Theoretical Physics and Higher Physics and Giacomini was in charge of Electrical Measurements […]. In short, it seemed that after six years of hard work, things were finally on a path of calm and profitable activity. In a word, the school of Physics was beginning to flourish…"

In October 1936, Gentile was put in charge of the Calculus of Probability and Theoretical Physics courses. He took his mission as a teacher extraordinarily seriously, as was in his nature. But he was also critical of himself, as he later wrote to his fiancée, Maria Vincenza Bartalini, a young scholar of art history, known as Nani[11]:

> I'm a bit too logical when I'm teaching, this gives a somewhat harsh tone to my reasoning. But my pupils love me and are passionate about me. This is already something, don't you think?
>
> I now have, for example, to think about a student who is doing his thesis with me. He can't get past certain difficult points. If I don't solve these difficulties, who can help him? Thus, we have to get down to work…

In that period Gentile edited new lecture notes, of which apparently only one copy exists, preserved in the library of Milan University.[12] The passion for teaching and the awareness of working alongside Polvani on the construction and consolidation of what was becoming an important center of Italian physics, soon led Gentile to find new motivations for his theoretical research. In Milan, Gentile brought atomic and nuclear physics, subjects with which he had come into contact during his six-month stay in Rome, immediately after graduation, and which he continued to study in Germany, also exploring novel paths following Heisenberg's research interests, such as ferromagnetism or the conductivity of metals, which prepared his mind for later even more challenging research topics.

One of his students was Carlo Salvetti, who had enrolled in physics in parallel with the arrival of Gentile in Milan[13]:

> My first interest was mainly in theoretical studies. As a student I had done very well, first with Polvani and then with Giovanni Gentile […] The textbooks were almost all German. He taught the Probability calculus course, but then he also taught metal theory. Really beautiful! I took the exam on electrons in metals …

Later Edoardo Amaldi would recognize in Gentile one of the most effective and enthusiastic teachers of their young scientific community [31]:

> Animated by a lively enthusiasm for research, he knew how to push and guide his students in their work, inspiring in them a very high respect for science and a deep love for culture.

Salvetti also recalled the feeling of having contacts with the international world of modern physics[14]:

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[11] Gentile to Vincenza Bartalini, 2 and 22 February 1938. All excerpts from the letters to Nani, still kept by the family, are reproduced with kind permission of Alessandra Gentile.

[12] He was helped by his student Piera Pinto, who would later marry her fellow student Carlo Salvetti.

[13] C. Salvetti, interview by L. Bonolis, Rome, 18 July 2002.

[14] C. Salvetti, interview by L. Bonolis, Rome, 18 July 2002.

> There was a good atmosphere there, starting from the third year in particular, because there was Giovannino Gentile, who was instrumental in renewing the environment. He animated the group with seminars, inviting some physicists [...] including Piero Caldirola. And then also some mathematicians, especially those with a physical orientation, such as rational mechanics, and also mathematical physicists. These were seminars on theoretical physics…I learned a lot from these seminars. Gentile had probably learned this practice in Rome from Fermi and then certainly in Germany, where there was a great tradition in this sense [...] At that time there was a predominantly German culture, but I don't think only in Milan. In fact, the seminar participants came mainly from Germany and Holland. It seems to me that Thursday was the day when Gentile asked us students do seminars. Either he invited people from outside or he had us undergraduates do it. In my third year I had to give a very difficult seminar on the atom and the nucleus: on the Heisenberg-Majorana theory of the nucleus—with all the forces of exchange of nucleons—and, thus, for example, from the classical works to the Heisenberg-Majorana model…There were a lot of discussions! Yes, it was all really nice, indeed!

Gentile's interest in the foundations of physics led him in the second half of the 1930s to implement an ambitious publishing project dedicated to fundamental themes of the discipline, inspired by a similar work edited by the great mathematician Federigo Enriques, *Questioni riguardanti le matematiche elementari* [32].[15]

In Milan, Gentile's epistemological-philosophical interests well complemented with Polvani's growing commitment to the historical dimension of the physical sciences, that Gentile himself shared thoroughly.[16] The synergy resulting from the combined influence of Gentile's philosophical views on science and Polvani's commitment to the history of science cannot be undervalued, as there is no doubt that it exerted a deep impact on Gentile Jr.'s father, the philosopher Giovanni Gentile, who in 1939, during the centennial symposium of the Society for the Advancement of Science, launched the idea to create an institution destined to collect the relics of Galileo Galilei, the father of the experimental method. The project would lead to the foundation of the *Domus Galilaeana* in Pisa, the first institution devoted to the History of Science—whose first activities were also based on Polvani's extraordinary historical work on the physicists Antonio Pacinotti, Ottaviano Fabrizio Mossotti, Alessandro Volta—and of which the latter was also president for many years.

It is crucial at this point to emphasize how Gentile's reflections on the philosophical problems connected with atomic and nuclear physics, as well as with the methods of classical physics, were stimulated at that time also by his parallel involvement in the experimental research activities that were being carried out at the Physics Insti-

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[15] Due to his early death in March 1942, when the first volume of *Questioni di Fisica* was nearly ready, Gentile was unfortunately unable to complete his project himself and the first volume was published by Sansoni after the war, edited by Bernardini and Polvani [33]. For this collection of essays Gentile had secured the collaboration of leading Italian physicists. Related papers and correspondence are in G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[16] Gentile helped Polvani to write an historical essay on the Italian contribution to physics during the years 1839–1939 [34]. See also, for example an unpublished manuscript on the evolution of the energy concept in its different aspects written with Vanna Tongiorgi, who later married Cocconi and was his collaborator in cosmic-ray studies (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 4).

tute and which he personally dealt with from a theoretical point of view. As Polvani recalled [3, p. 157],

> In that year in my institute Professor [Giuseppe] Bolla [...] was studying experimentally the dependence of the polarizing effects of slits on their depth: and he found that the behaviour of very deep slits is totally and unexpectedly different from that, already discovered by Fizeau and interpreted by Rayleigh, relating to slits of very small depth, such as can be obtained by scratching very thin metallic films deposited on glass. The theoretical interpretation of the phenomenon, although clearly part of classical optics, was obscure and fraught with difficulties. Gentile immediately took an interest in the question, to which he soon made a new and substantial contribution [...] in an extensive and beautiful work.

Gentile's article "Per la teoria degli effetti polarizzanti delle fenditure. Diffrazione della luce da due cilindri paralleli e indefiniti" [For the theory of polarizing effects of slits. Diffraction of light from two parallel indefinite cylinders] [35], attracted the attention of Arnold Sommerfeld, one of the deans of German physics, the beloved teacher and mentor of an entire generation of German theoretical physicists, notably Werner Heisenberg and Wolfgang Pauli. On June 23, 1937, Sommerfeld wrote Gentile a very long letter[17]:

> Dear colleague, since for 40 years I am struggling, and uselessly, with the problems of 'slits' I was very interested in your solution of the problem [...]

Contacts between Sommerfeld and Gentile dated back at least to 1935, when Gentile arranged for Sommerfeld to be invited to give a seminar at the Scuola Normale Superiore on the theory of electrons in metals, one of the very first successful applications of quantum statistics developed by Fermi in 1926 and independently by P. A. M. Dirac.[18]

Gentile published his work on the theory of polarizing effects of slits privately, as a small volume for the Sansoni publishing house [35], which at the time belonged to his family.[19] The reason was that he was in a hurry, as it was his intention to use it for the national competition in theoretical physics, the announcement of which had appeared in the Official Gazette on 15 March 1937.

4.5 The 1937 National Theoretical Physics Competition: A Challenge for Gentile and Polvani

The national competition for a full professorship in theoretical physics was announced by the University of Palermo, where Emilio Segrè, Fermi's first student in Rome, had occupied the chair of Experimental Physics. It was the second in Italy in this discipline after the one won in 1926 by Fermi, Persico and Pontremoli.

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[17] G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[18] Gentile had been also asked at the time to write Sommerfeld's biographical entry for the *Enciclopedia Italiana* (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1).

[19] Giovanni Polvani, who had this article reprinted in *Il Nuovo Cimento* after the author's death [36], paid great attention to it in his account of Gentile's scientific career.

The deadline for submitting applications for the competition had been set by the Official Gazette at 15 June. Soon after, in an undated message, Gentile's father, who must have already received the news through unofficial channels, wrote to him a telegraphic message[20]:

> Competitors for Theoretical Physics. Gentile, Majorana, Racah, Wick, Pincherle, Wataghin. News received at this moment. Best wishes!

Three positions for 5 competitors, of which at least three of them (Majorana, Racah, and Wick) made the situation very delicate and not without risk for Gentile, who did not have many scientific publications to his credit.

Towards the end of August, Gentile received a letter from Majorana mentioning the competition[21]:

> Dear Gentile,
>
> I thank you for your letter and for your study on polarizing slits which I received some time ago. Although the subject is not familiar to me, I could see that your preparation is solid and complex even in this field of classical physics.
>
> As you must have guessed, I am still in Monteporzio, and I too look up to the sky (at the sea from afar) and I can see every day how the weather forecasts fail. I also cultivate astronomy.
>
> I think your deliberate distrust of Fermi, who spoke of you with the most sincere sympathy, is unjustified. As for the other members of the commission, either I have never seen them, or I have not seen them since ancient times. But it seems to me that at least one of them should have the authority and the will and the duty to testify for Giovanni Gentile[…]

In this last sentence Majorana implied that Giovanni Polvani was among the members of the commission, chaired by Enrico Fermi and including also Antonio Carrelli, Orazio Lazzarino and Enrico Persico.

Anxiety in Gentile's family was sky-high. Senator Gentile was even firmer than his son in his determination that Giovannino should be among the winners of the competition, and in fact another ten years would elapse before a new theoretical physics competition would be announced. On the other hand, since the beginning of his son's career, Gentile senior had intervened behind the scenes guiding his son's choices, but also using his influence as an academic, senator of the kingdom, director of the *Enciclopedia Italiana*, one of the most influential personalities in the cultural world of fascism. The family style was very patriarchal, but left room for deep union and affection within the family, as is amply testified by the family correspondence.[22] At the same time, he did so with a deep conviction of the value of his son, whose challenge of becoming a physics scholar he deeply admired and whom he felt was culturally and intellectually very close to him.

Giovannino was eventually included in the winning trio, from which he had risked being excluded mainly because of the presence of his own friend Ettore Majorana—whose scientific production was of an unquestionably high level— and because both

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[20] Brief undated note (Giovanni Gentile Foundation for Philosophical Studies, Archive, Sapienza University, Rome).

[21] Majorana to Gentile, 25 August 1937 (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1).

[22] Giovanni Gentile Foundation for Philosophical Studies, Archive, Sapienza University, Rome.

Wick (first classified) and Giulio Racah, were ahead of him in terms of scientific work. The solution was to have Majorana appointed full professor "independently of the competition rules" because of "high and well-deserved reputation", excluding his nomination from the final triplet of winners.[23]

Everyone could certainly be satisfied with this epilogue, which in the final analysis made it possible to secure four chairs for theoretical physics in Italy, after ten years during which only Fermi and Persico had remained the only full professors in a discipline that at the end of the 1930s had yet to acquire a stable status in Italy.

4.6 The Beginning of Cosmic-Ray Research in Milan

On 27 January 1938, Gentile wrote to his fiancée Nani[24]:

> […] tomorrow I shall speak and give my, at least for you, famous lecture. I am as if absorbed in certain thoughts — which I like after all. An intellectual love this mine …".

The lecture he gave at the Mathematical and Physical Seminar in Milan, entitled "On the Limits of Electrodynamics and the New Experimental Results on Cosmic Radiation" was related to the recent discovery of the so-called mesotron of cosmic rays, a new elementary particle which was of great interest to theoretical physicists, as it could be the key to explain the apparent failure, at the high energies of cosmic-ray phenomena, of quantum electrodynamics, the quantum field theory of the interactions of charged particles with the electromagnetic field.

The subject, on which Gentile wrote a couple of articles [38, 39],[25] was also discussed in a letter written to Gentile by Gilberto Bernardini, who had been interested in cosmic-ray studies since his arrival in Florence, where he collaborated with Bruno Rossi, the pioneer of cosmic ray studies in Italy. When Rossi left Italy, Bernardini continued to cultivate research on cosmic rays, contributing to maintain in Italy the excellence of the research tradition started by Rossi. In this undated letter, which was certainly written in 1937, Bernardini was mentioning the recently formulated theory explaining the underlying processes and mechanisms of electromagnetic showers initiated by high-energy cosmic rays interacting with nuclei in the high atmosphere and producing cascades of photons, electrons and positrons. But in particular it clarified that such a theory could be reconciled with the observed phenomenology related to the penetrating component of cosmic rays hypothesizing the existence of a charged particle of both signs and mass intermediate between those of the electron and proton. One such a particle had been detected in 1936 by Carl D. Anderson and Seth Neddermeyer in cosmic-ray showers and named "mesotron". Because of

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[23] For details on the competition see [37].

[24] Such personal correspondence is kept by the family.

[25] Both contain a post-script related to Heisenberg's work on similar topics that Gentile had discussed in June 1938. See also his article in *Scientia* [40] as well as his Preface and Appendix to the Italian translation of Jordan's book on twentieth century physics published by Sansoni [41].

its mass, it was thought to be the particle postulated by Hideki Yukawa in 1935 as the mediator of the strong force binding protons and neutrons in atomic nuclei.[26] Bernardini would have liked Gentile to make some calculations on the interactions of cosmic rays with the atmospheric layer at about 200 km height, which might be of "some interest."[27] Bernardini's high-altitude experiments would later give impulse to the researches carried out in Rome during the war by Marcello Conversi, Ettore Pancini and Oreste Piccioni, that eventually showed how the mesotron of cosmic rays could not be the particle hypothesized by Yukawa, because it interacted too weakly with nuclear matter, a remarkable experiment inaugurating "modern particle physics" [43, p. 241]. The identification of this particle, clarifying the mechanisms of the electromagnetic cascades in cosmic-ray processes brought such studies into the limelight as a fundamental instrument in the investigations of interactions at the nuclear level. Such topics aroused great interest in theoretical physicists such as Heisenberg, Hans Bethe, Homi Bahbha, and Fermi himself, who not by chance decided to work more actively on cosmic rays between 1937 and 1938.

Invited by Edoardo Amaldi, the recently graduated Giuseppe Cocconi, spent six months at the Physics Institute of Sapienza University in Rome where he worked with Fermi and Bernardini at the construction of a Wilson chamber to study the mesotron's decay modes. He was still in Rome when Majorana mysteriously disappeared. Cocconi completed the Wilson chamber in Milan where, since August 1938, laid the foundations for research in cosmic rays which were instrumental in training a new generation of physicists many of whom—including himself—would become particle physicists during the transition from cosmic-ray studies to high-energy physics with accelerators in the 1950s.

4.7 Ambitions to Launch "big science" at the Institute

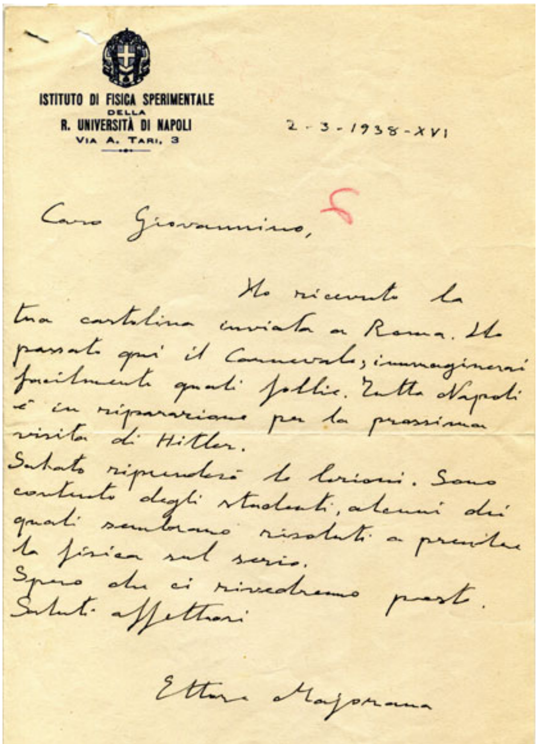
Between February and March Gentile's letters to his fiancée provide a glimpse into the lights and shadows of his life as a researcher and educator, but also into his inner solitude[28]:

> You asked me what is the meaning of that "boat waiting for the wind". You see, the shallows are those moments when we do nothing and we are dissatisfied with ourselves and everyone else. We look around us and see nothing but disappointment and regrets for lost opportunities. Then at a certain moment the work resumes — behind a cue, behind an inspiration that in general we can't quite figure out how strong it is in us. Doesn't this happen to you?
>
> [...] I'm certainly more relaxed now. Maybe because I'm starting to like Milan and maybe because I'm starting to see the fruits of my labors. Efforts, sometimes without a light to illuminate them; because in every activity there's always something that's just a job. Today, for example, I exhausted myself for half a day to verify a formula, given by a guy. There was a mistake in the sign, and it took a lot to get it out!

[26] For a wide discussion on such issues see Galison's article [42].

[27] G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

[28] Gentile to Nani, 22 February and 3rd March 1938 (family papers).


ISTITUTO DI FISICA SPERIMENTALE
DELLA
R. UNIVERSITÀ DI NAPOLI
VIA A. TARI, 3

2-3-1938-XVI

Caro Giovannino,

Ho ricevuto la tua cartolina inviata a Roma. Ho passato qui il Carnevale; immaginerai facilmente quali follie. Tutta Napoli è in riparazione per la prossima visita di Hitler.
Sabato riprenderò le lezioni. Sono contento degli studenti, alcuni dei quali sembrano risoluti a prendere la fisica sul serio.
Spero che ci rivedremo presto.
Saluti affettuosi

Ettore Majorana

Fig. 4.2 Majorana's last letter to Gentile Jr sent from Naples on 3rd March 1938 (Copyright: Archive Physics Department, Sapienza University, Rome)

In that same March 1938, Majorana wrote from Naples—where he had his chair of theoretical physics—what turned out to be the last letter to his friend before his mysterious disappearance (Fig. 4.2).[29]

> Dear Giovannino,
>
> I received your postcard sent to Rome. I spent the Carnival here, you can easily imagine what follies. All of Naples is being repaired for Hitler's next visit.
>
> I will be resuming classes on Saturday. I'm pleased with the students, some of whom seem determined to take physics seriously.
>
> I hope we will see each other again soon. Warm greetings
>
> Ettore Majorana.

The following May Hitler visited Italy for a week. By that time, Austria had been incorporated into the German Reich, and Hitler's demand for annexation of the Sudetenland was setting the stage for the invasion of Czechoslovakia and later of Poland, which in turn would trigger the start of World War II.

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[29] Majorana to Gentile, 2 March 1938 (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1).

In an undated letter—most probably written around May 1938, when the rumor circulated that Majorana had locked himself up in a convent—Gilberto Bernardini wrote to Gentile:

> Dear Giovanni,
>
> as you can imagine the news about Majorana were a real joy to me. It is not very nice maybe, but on the other hand it is not as tragic as we thought and we can be happy about it.
>
> I am also pleased with the news that you are going to Germany and I very much approve of your initiative. When you will be back we will agree for a real collaboration.
>
> Once in Heidelberg, you should do me the favor of asking Bothe in which period the Institute is closed during the summer. And, possibly, when you know, write to me. As I told you, I have received money from the Academy and I would like to go to Bothe, who is currently the smartest person in Europe.
>
> By the way, Bothe has put on a magnificent Van der Graaff. Now in Italy, and in Milan, a Van der Graaff would be just right and would have the advantage of costing relatively little (about 200.000 liras) […]
>
> See you soon Giovannino. Many affectionate greetings from your
>
> Gilberto

In the meantime, in April 1938, the Ministry of National Education, had in fact approved Gentile's request for a grant to be used for a study trip in Germany and Switzerland, that would include visiting laboratories where the first high-energy accelerators had been built in order to explore nuclear complex reactions in elements of intermediate and heavy atomic weight. This meant particles with energies well beyond those obtained by decay products of radioactive elements, such as those used by Fermi and his group in Rome or by the couple Irène Curie and Frédéric Joliot in Paris, for example. Apart from studies of nuclear processes performed by means of very high energy particles provided by cosmic rays, these investigations could be carried out by means of the first accelerators that were being developed at the time. However, there were very few of them around the world. By the mid 1930s, Walther Bothe's Institute for Physics at the Kaiser Wilhelm Institute for Medical Research in Heidelberg was the first in Germany to build a Van de Graaff band generator, and later, during the war, a cyclotron. This explains Gilberto Bernardini's enthusiasm for Gentile's opportunity of visiting Bothe's laboratory. Bernardini, now a professor in Bologna, often went to Rome to continue his experimental work there and together with Amaldi he later presented the ambitious project to build a cyclotron which could be used also as a research tool. They were not funded and at the moment cosmic rays continued to ensure the daily research life at the Roman Institute for Physics.

4.8 Back to Germany for a Strategic Trip

After several years Gentile remembered Germany with nostalgia. He missed the scholarly contact with the prominent figures he had known early in his career, the international context, as he wrote to his fiancée in May 1938:

> I'm going back to Germany as if following an impulse that had been in my soul for many years. I like those cities. I like those wide, rich rivers […]
>
> I am restless, I like my job, too, and I would like to do it well […]
>
> My chess game? I am playing it with all of myself, otherwise it would be a trivial matter. But it's not only science, it's the whole life […] I'm going to Germany to get a little bit out of my scientific loneliness in Milan. I want to see what others are doing and talk with them.

In October, after a very satisfactory tour, during which he also had the opportunity to strengthen the intellectual ties that already bound him to the great German physicists, Gentile sent his report to the Ministry, in which he illustrated with passion, conviction and energy his very clear and ambitious ideas on what the Institute's objectives for the near future should be in terms of accelerator facilities for the study of the nucleus and related processes.[30]

> I was in Munich with Prof. Sommerfeld, with whom I had the opportunity to discuss one of my works on diffraction of light and further work on different topics.
>
> Then I went to Heidelberg, where I visited the Kaiser Wilhelm Institute, of which the director is Prof. Bothe. I was prompted to make that visit by the desire to question this professor about the possibility of building a van de Graaff machine of easy operation with which to start in our Institute of Physics in Milan researches of nuclear physics. Because I am convinced that also in our University of Milan the students themselves, as well as the professors, must be able to have the possibility to participate with a serious scientific work to the researches in this field. Our Institute of Physics in Milan, of recent formation, does not lend itself to modest research in classical physics, which have a relative usefulness and an interest almost of school exercises […]
>
> From Heidelberg I moved on to Leipzig, where I stayed about four weeks: until the end of the German academic year. Leipzig was my main destination because I wanted to discuss the problems I am particularly interested in with Prof. Werner Heisenberg, with whom I had already worked in my previous trip to Germany in the years 1930–31 […]
>
> From Leipzig I went to Berlin to visit the Kaiser Wilhelm Institute for Physics, whose director is Prof. Debye. In this Institute, besides a large high voltage plant, I was able to visit a very low temperature plant. The field of low temperatures would be the other field of physics in which would be useful to start the research for a serious scientific work. But I found that for such research the financial effort that a scientific institute would have to tackle would be much more relevant.
>
> At the end of this report I can not help but note that if it is convenient in a nation to concentrate in a few institutes of high-level research the necessary means, even a University such as that of Milan cannot be satisfied with an Institute of Physics such as the existing one in which students often have to hear from a teacher about research done elsewhere and that they will not be able, I do not say to continue, but not even to repeat. In such conditions it becomes very difficult to initiate students in experimental work. On the other hand in nuclear physics, after the period of the first non-systematic researches, relatively inexpensive means have been devised for further research. My trip to Germany has confirmed me in this idea and I hope to present to His Excellency, in agreement with my colleagues, a well-defined program of research to submit to your high approval and obtain the necessary means.

[30] G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1.

By November 1938, Gentile was in full swing, and ready to begin a new academic year, as we learn from letters to his fiancée Nani, where he communicated his daily life and his reflections[31]:

> […] Today I had my first class this year—the audience increases and the work increases—I don't mind. I do care that in our University our institute counts for something, and on the other hand the students encourage us to start again every year the usual work, finding it new and fresher. Otherwise, imagine the boredom of repeating, or at most, to work scientifically always in the same situation.
>
> […] I have been very pleased with these five first lessons (if you've done well, afterwards you feel at least peaceful, if everything didn't go well, a sort of uneasiness remains, difficult to overcome […]
>
> I could read your last letter only in the afternoon, as I was invited at twelve o'clock to a banquet that the Marelli Factory gave in honor of Fermi […]

Those were Fermi's last days in Italy, before leaving for Stockholm to be awarded the Nobel Prize in Physics 1938 "for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons." In 1938, after the promulgation of the infamous racial laws by the Mussolini government, that threatened his own family, Fermi decided to emigrate to the United States immediately after the Nobel Prize ceremony in December. The second fundamental reason for Fermi's emigration was that he was refused funding for his project to establish a large national institute for radioactivity and nuclear research. This was due first of all to the loss of protection by Orso Mario Corbino (who had supported Fermi in particular having the chair for theoretical physics established in Italy and continued to do so during the years as director of the Physics Institute of via Panisperna) and by Guglielmo Marconi (Fermi's supporter as head of the National Research Council), who died both in 1937. Such circumstances were greatly exacerbated because of the growing economic commitment that was looming for Mussolini's Italy, which by that time was even more closely hooked to Hitler's chariot of conquest. The racial laws greatly affected the physics community, many were obliged to emigrate, others, such as Rasetti, decided to leave the country for political reasons.

In late 1938, while physicists in Rome were living with the sad realization that Fermi would never return from Stockholm, Polvani had taken Salvetti with him to visit the Guglielmo Marconi Institute of Physics in the new premises of La Sapienza University[32]:

> I was then in my third year and I was one of the most promising students […] Polvani dreamed of making a new institute because we were in the old building of the Rectorate, absolutely unsuitable for a scientific institute, so he wanted to go and see for himself and he took me with him. I don't know why, maybe because I was working at his lecture notes at that moment. At that time we were very few and he invited me to see two institutes that had been inaugurated quite recently.

[31] Gentile to Nani, 18–19 November and 1st December (family papers).

[32] C. Salvetti, interview by L. Bonolis, Rome, 18 July 2002.

> We went to Rome to see the Guglielmo Marconi Institute of Physics, brand new, just completed. He was interested in seeing how they had organized the structure, the services, the distribution, the teaching part, the research area…
>
> We paid another visit to Bruno Rossi's institute in Padua! A wonderful institute! He had made trips to Germany to visit other research institutes and had designed it down to the smallest detail; it was really a model institute. Then with the racial laws, shortly after completing it, he was thrown out! We arrived soon after, the institute was entirely new, brand new!

These events first, and the war soon after would deeply mark the fate of Italian physics for the next ten years.

4.9 Creating the Premises for Post-war Renewal

The 1939 year began with a happy event—on January 3 Giovannino married Maria Vincenza Bartalini—and ended with his appointment as extraordinary professor of theoretical physics in December (Fig. 4.3). In the meantime, he was following the thesis work of several students, who were working on research topics that interested him closely and on which he himself published articles.[33]

Gentile's influence on the philosophical and epistemological front is clearly visible in his former student Vittorio Somenzi, who later became professor of philosophy of science at the University Sapienza in Rome and was one of the first in Italy to study cybernetics and the emerging artificial intelligence, addressing from a philosophical point of view issues such as the relationship between mind-brain and mind-machine, which he introduced in the context of Italian studies.[34]

In fact, Salvetti himself, would have preferred to do a theoretical thesis with Gentile, but he had become very close to Polvani and thus did an experimental dissertation on the electronic amplification circuits to be used for the detection of phenomena related to the newly discovered phenomenon of nuclear fission, as suggested by Giuseppe Cocconi.[35]

> Cocconi and I had read the article sent in December 1938 by Hahn and Strassmann on fission, published in January 1939, and we were so excited—he especially, I did not understand it well at the time—that he insisted with Polvani that I should do an experimental thesis on uranium fission, but studying it from a physical point of view. It was about what a lot of physicists

---

[33] See for example Elisa Bonauguri's dissertation on the vector model of the atom, discussing the properties of the group of rotations as an expression of the spherical symmetry of the electron cloud, part of which was published in 1939 [44]. See also Gentile's article on the same topic [45]. After Gentile's death, in order to honor the memory of her teacher and his inspiring guide, Teresa Magri Materossi published part of her dissertation discussed in 1941 with the title *The problems of Lecher wires or propagation of electromagnetic waves along parallel wires*, in a special issue of *Il Nuovo Cimento* dedicated to Gentile [46].

[34] Somenzi's work, inspired by Gentile, was related to a theory on superconductivity formulated by Sommerfeld's collaborator Heinrich Welker [47, 48]. Somenzi's personal papers are preserved at the Physics Department of Sapienza University of Rome.

[35] The title was *Il metodo dell'amplificatore proporzionale a lampada per lo studio delle particelle elementari*. I am grateful to Leonardo Gariboldi for providing the exact title of Salvetti's thesis.

Fig. 4.3 Giovanni Gentile Jr. in Tuscany, at Forte dei Marmi, August 1939. Copyright: Alessandra Gentile

> had done since January in America, and before them in Copenhagen, that is to confirm the existence of fission with physical and not chemical methods. So they made me build—I did not know anything about electrons—a proportional amplifier. In Rome they gave me the design of their amplifier, the one they used at the Istituto Superiore di Sanità for the work with the accelerator of the Institute. So I built a linear accelerator—I had to get an electronic valve from Holland—and I also built an ionization chamber to detect fission products. I enjoyed it very much! It was a differential chamber, as it was called then, and I had to measure the range…so that went on for a long time. I couldn't see the fission products because I had some uranium salts—so that wasn't the problem—and I also had some beryllium, but it was a long time before the polonium discs for alpha radiation came from Rome. It was before the war, so the problem was that they had a big demand…With the polonium disks I would have done neutrons in reactions (α, n). For understandable reasons in that very turbulent period, I arrived at the degree without having been able to make measurements on fission products, but I obtained extremely beautiful curves of ionization of α particles! So beautiful that I graduated with an experimental thesis in June 1940 with 110 cum laude. And I had made an ionization chamber that was a dream! […] But I was not a 'war graduate'! I graduated at 3 o'clock in the afternoon of June 10. Then, at 5 o'clock we left to hear Mussolini's speech…one of his oceanic rallies…It was the announcement of the declaration of war…[36]

Difficult times began for the institute, but luckily as Salvetti recalled, they at least managed until 8 September 1943 to receive the *Physical Review*, which arrived through Switzerland even during the war. Between 1940–1941, the journal contained some articles by Donald Kerst in which he described the betatron, a new accelerating machine, in which electrons could reach relativistic speeds thus producing high-energy X rays once the beam was directed at a metal plate and which could thus be used also for medical therapy [50–52]. Especially after his trip to Germany, Gentile had become strongly interested in accelerators, and thus suggested the subject to Giorgio Salvini, who had taken the examination of theoretical physics with him in 1941 and wanted to write a theoretical thesis. However, while his work was

[36] After the discovery of nuclear fission announced at the beginning of 1939, a main topic of the utmost interest among physicists became the neutron cross section, which was directly involved in the mechanism of the nuclear chain reaction. In this regard, Gentile's student Carlo Borghi wrote a dissertation completed in 1940 on the neutron cross section and Compton effect, which resulted in a work published in the issue of *Nuovo Cimento* including articles honoring Gentile's memory [49]. Borghi would be in charge of the Calculus of Probability course after Gentile's death.

in progress (*Electron acceleration with magnetic induction pulses*), he received a telegram announcing that Gentile had tragically passed away. Salvini completed his dissertation in 1942, while he was still a soldier. Gentile however was no more there to enjoy another successful accomplishment of one of his students[37]:

> But today, sixty years after his death, I know how much scientific wisdom there was in him, how much originality of thought, how much desire to know, and above all how much ability to inspire his students to science. I am among those who benefited from him, who felt his drive and his generous trust.

Salvini was one of the first in Italy to have a unique knowledge about accelerators, a circumstance that determined his future role in the process of renewal of Italian physics after the war.[38] In 1946, with Carlo Salvetti, Giuseppe Bolla, and the engineer Mario Silvestri, Salvini promoted the foundation of CISE (Centro Italiano Studi Esperienze), the first Italian research facility dedicated to the peaceful development of nuclear energy, where a Cockcroft-Walton accelerator was operating since 1951. After conducting research on cosmic rays in Milan and for some time in US, Salvini became a professor in Pisa and then in Rome. When he was only 33 years old, thanks to his skills in particle and nuclear physics and his dynamic personality, as suggested by Amaldi and Bernardini he was appointed by the newly founded National Institute for Nuclear Physics (INFN) to lead the construction of an electron synchrotron. This new generation accelerator, the first powerful Italian accelerator went into operation in 1959 at the National Laboratories especially built in Frascati to host such machine. As director of the Frascati Laboratories, Salvini fully supported the proposal made in February 1960 by the Austrian-born physicist Bruno Touschek to explore the particle-antiparticle annihilation processes as a fundamental tool for studying the subnuclear universe. Touschek himself had begun his career working on the theory of a betatron built in Germany during the war, and had graduated in 1946 with a dissertation on this topic. The matter-antimatter collider AdA built in Frascati under Touschek's leadership, ushered a new era in high-energy physics [55].

In a sense, the small seed planted by Gentile fully developed following unexpected paths and flourished through cross-fertilization with other brilliant minds. At that time, Gentile and Polvani's pre-war dream of a high-energy facility was realized in Milan at the Institute for Physics with a cyclotron, which was built starting from 1960 and took its first data in 1965.

Carlo Salvetti, for his part, became Polvani's assistant and then professor at the Institute of Physics. He was one of the fathers of nuclear energy in Italy: in the 1950s he directed the realization of the Nuclear Center of Ispra and then became Director of Research of the International Atomic Energy Agency (IAEA); later he was Vice-President of the National Committee for Nuclear Energy (CNEN), continuing to be a leading figure in the promotion of Italian and European pacific use of nuclear energy.

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[37] G. Salvini, interview by L. Bonolis, Rome, 25 November 2004, 6 February 2005.

[38] See G. Salvini, interview by L. Bonolis, February–May 1998, Rome, in [54] and personal recollections in [53]. Salvini's personal papers are preserved at the Archives of the Physics Department of Sapienza University, Rome.

4.10 The Intermediate Statistics and Its Relevant Applications

Since the 1920s, Polvani had written about the kinetic theory of gases and later had been actively interested in quantum physics and quantum statistics of a monoatomic gas (the physical system discussed by Fermi to formulate his quantum statistics), issues on which he wrote articles between 1928–1933.[39] He also extended his research on the theory of gases to a gas of photons [62], in an article where he explicitly mentioned the three statistics (the classic Maxwell–Boltzmann, the Bose–Einstein and the Fermi–Dirac) and in particular Léon Brillouin's recent article discussing the three of them and the possibility of their unification, also implying the case of an intermediate statistics [63].[40] At the beginning of 1940, during one of their usual fruitful exchanges of ideas, probably touching such issues, Polvani asked Gentile the following question [56, p. 101]:

> But, purely on theoretical grounds, wouldn't one think that a statistics could be formulated in which the maximum number of occupation of a quantum state is any integer and positive number d? In particular if $d = 1$ we would have the Fermi statistics, if $d = \infty$ the Einstein statistics; for any d we would have the intermediate statistics between Einstein and Fermi.

In order to answer such a challenging question, Gentile formulated the law of statistical distribution of a quantized gas consisting of a finite number of indistinguishable particles for which it was assumed that in each quantum state there can be at most *a finite and determined number of particles*. The so-called intermediate statistics, was a natural alternative to the two well-known quantum statistics models: the Bose–Einstein statistics and the Fermi–Dirac statistics [57]. Fermions, such as electrons—having half-integer spin—have the property that at most one can occupy each quantum state while Bose–Einstein statistics allows any number of particles having integer values of spins, named bosons, to occupy the same quantum state. Both are in turn fundamentally different from the Maxwell–Boltzmann statistics that is applied in classical mechanics to systems of distinguishable particles. In this latter case, not only individual particles can be tracked, but there is no restriction in the number of particles that can occupy any state accessible to the system.

The impetus given by Polvani to address the problem of intermediate statistics was briefly recalled by Carlo Salvetti himself, who began to work on Gentile's statistics soon after he graduated in 1940.[41] The episode was also mentioned by Piero Caldirola in a memorial lecture on Polvani.[42] At the time, Caldirola, who was professor in Pavia, took an interest in the intermediate statistics and started a scientific correspondence

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[39] See for example [58–60] and his famous "Il Diavolo e la Termodinamica" [61].

[40] Brillouin's article was later cited by Gentile [64, p. 493], who criticized Brillouin's method as not proper to treat the case of an intermediate statistics.

[41] C. Salvetti, interview by L. Bonolis, Rome, 18 July 2002. See also [65, p. 123]. Polvani, too, later recalled how he had challenged Gentile to investigate such a problem [3, p. 157].

[42] Manuscript given to the author by the late Carlo Salvetti in 2002.

with Gentile during the Summer of 1941,[43] related to an article he was writing on a more general formulation of the problem within quantum field theory [66].

By the end of December 1940, Gentile had ready his first article on the new quantum statistics, which began with the following observation:

> Whoever considers the two quantum statistics of Bose-Einstein and of Fermi–Dirac is naturally led to wonder which properties remain and which are modified, when we do not make any more the particular hypothesis (of Fermi-Dirac) that in an elementary cell there can be at most one particle, or the other, no less special, (of Bose-Einstein) that there can be any number, even infinite.

Gentile concluded his first article thanking his friend "Prof. G. Polvani for interesting discussions on this topic" [64].[44] After showing that from his general expression for the energy distribution of the particles one could derive the individual known distributions for bosons, fermions and for particles following Maxwell–Boltzmann classical statistics, Gentile showed that "intermediate" particles—as he named them—could exist that do not follow the two well established quantum statistics. With his new statistics, according to which the maximum occupation number of a level of energy was given by a finite number that could assume any integer value d between the two limiting cases, $d = 1$ (Fermi–Dirac statistics) and $d = \infty$ (Bose–Einstein), Gentile was launching an entirely new research field at the Institute that would be further developed between 1941 and 1942 with its remarkable applications to the exotic properties of liquid helium. And indeed, soon after, Gentile investigated the possibility of applying his statistics to the "the study of behaviour of matter at very low temperatures. A study that in recent years has led to the discovery of new, wonderful phenomena presented by liquid helium, phenomena that, for their uniqueness can only be compared to those, for many respects still so mysterious, of superconductivity in metals" [56, p. 96].

Only a couple of years before, between 1937 and 1938, the existence of superfluidity of liquid helium, and some related totally anomalous properties, had emerged as the result of research carried out by different scientists [70]. It was discovered that helium-4, a stable isotope of helium—the most abundant on Earth—has almost no viscosity at temperatures near absolute zero and can thus flow through the finest capillaries with no apparent resistance and give origin to the so called fountain effect, due to its capacity of flowing without friction even up the sides of its container. The phenomenon of superfluidity, is related to the phenomenon of condensation in which atoms behave like a gas of bosons thus leading to the so-called Bose–Einstein condensate, a new state of matter first predicted by Einstein in the mid 1920s. At temperatures very close to absolute zero a large fraction of bosons occupy the lowest quantum state giving rise to a strange and quite anomalous behaviour.

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[43] "Most illustrious Professor, I would like to report some results that I have reached after some considerations on the intermediate quantum statistics with the prayer for your judgment." Caldirola to Gentile, 18 July 1941 (G. G. Jr. Papers, Physics Department, Sapienza University, Rome, Box 1).

[44] Gentile's statistics have been discussed in [67, 68]. For an outline of Gentile's work on the new statistics and its impact see also [69].

The fascinating and unique properties of liquid helium, as a manifestation at a macroscopic scale of the microscopic properties of such unusual quantum-mechanical system, were certainly striking. They clearly required a radically new interpretation and the nature of superfluid helium as a collection of bosons suggested Gentile the use of his intermediate statistics as a natural tool to find a theoretical explanation for the observed surprising phenomena [71]. Sommerfeld himself was especially intrigued by the possibility of using Gentile's statistics for liquid helium to get better results if compared with Bose–Einstein statistics. He gave a seminar in München that he closed with the words: "Gentile and I believe that the mystery of Helium II can be solved by the new statistics, which combines the statistics of Bose–Einstein and Fermi under a unified point of view" [72, p. 154].

The already mentioned correspondence with Caldirola in summer 1941 was also focused on such further relevant applications, on which the latter wrote later a new article [73].[45] Caldirola, who became professor of theoretical physics first in Pavia and then, in 1949, in Milan on the chair left vacant after Gentile passed away, had a leading role in the creation of the Italian theoretical school of solid state physics. Caldirola's early works on the intermediate statistics are never mentioned in his biographical sketches, but his discussions with Gentile and debates within the Institute about the physical foundations of the intermediate statistics and its wider implications in the context of the quantum theory of many-particle systems certainly had a role in orienting his interest in new research fields, different from the Italian dominating culture of nuclear and particle physics, which owed its prominence to the great tradition of studies established by Fermi and Rossi, and their collaborators.[46]

Those early research activities involved also Carlo Salvetti [77], who sent a draft of his second article to Sommerfeld [78], who in turn cited it in his own paper on liquid helium [79]. But as a follow up of this first burst of interest, others would explore the subject during the war and early post-war years, also stimulated by Sommerfeld [80–84].[47] Gentile's statistics proposed in a thermodynamical context was extended and developed during the years in very different realms, and in his honor such particles were named Gentilions, to distinguish them from the usual bosons and fermions.[48]

In January 1941, Gentile had become full professor of Theoretical physics at the Milan University (Fig. 4.4), but he did not live enough to enjoy the satisfaction for this achievement and continue his relevant investigations as he passed away after only one year, on 30 March 1942.

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[45] See also [74] and the review article on classical and quantum statistics [75].

[46] Caldirola revisited the subject of intermediate statistics in 1975, in a review article on the exclusion principle in which he recalled the debate that flourished at the time in the Milanese school and discussed its subsequent evolution and possible applications to modern physics [76].

[47] Antonio Borsellino, at the time working at Politecnico in Milan, demonstrated the incompatibility of Gentile's statistics with quantum field theory [85].

[48] See [86] and references therein.

Fig. 4.4 Giovanni Gentile Jr. with his wife Maria Vincenza Bartalini and their first daughter Erminia. Milan 1941. Copyright: Alessandra Gentile

Gentile's last article on the intermediate statistics and liquid helium appeared one month after his death [87]. Just a few days earlier he had felt delighted and proud of having invited Sommerfeld to lecture at the Seminario Matematico e Fisico in Milan.[49] In remembering the late "young friend" and his scientific legacy, Sommerfeld began his obituary with the following words [72, p. 151]:

> He was an outstanding scholar. Especially his last works secured him a prominent position in theoretical physics.

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Chapter 5
The Institute of Physics During the Fascist Regime and the Second World War

Leonardo Gariboldi

Abstract Since Milan University was founded in 1924, two years after the beginning of the Mussolini government, the Institute of Physics had to deal with Fascism since its beginning. Almost all university professors did not act against the regime in a public way. The director of the Institute of Physics, Giovanni Polvani, and the other physicists working with him had all to be members of the Fascist National Party and sweared loyalty to the Fascist Regime. The main example of the opportunity to please the regime was the honorary degree in Physics and Mathematics awarded to marshal Pietro Badoglio. The application of the racial laws did not concern any person in the Institute of Physics; they however led to the suspension of a scholarship named after Aldo Pontremoli. The war caused problems to both educational and research activities, with the sudden suspension of the lectures during the bombings on Milan and the call to army of some researchers and students. After the armistice signed by Italy in September 1943, the occupation of northern and central Italy by the German troops and the establishment of the Italian Social Republic, the Institute of Physics had to face further problems. Polvani hid the most important instruments in several locations outside Milan to avoid them to be taken to Germany. The instruments from Pisa University were take to Milan by the Germans and given back after the end of the war. Furthermore, a partisan student, Jacopo Dentici, was arrested by a fascist autonomous legion, handed over to the Germans and sent to the Gusen II subfield of Mauthausen were he died.

5.1 The Impact of Fascism

Besides the Italian racial laws, whose impact on the Milan Institute of Physics we shall analyze in the next section, the relationship between Milan University and Fascism shows all the general aspects valid for all Italian universities and a few specific ones. Fascist rhetorics and actions had, in the case of the universities, the aim to act on the students minds in order to build a new kind of citizen, indoctrinating them

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starting from the primary schools. Many policies of the regime were meant to create a new Italian people, active and aggressive, at the price of physically eliminating the political opponents and all those who were unfit to realize this vision; these policies eventually failed. Italian universities did not rebel against them; they instead accepted, one after one, all the impositions from the government and adapted their cultural activity to the situation.

We cannot ignore the fact that Milan University was established in 1924, that is two years after the beginning of the Mussolini Government. Within a few years, the government led by the National Fascist Party evolved with a series of legislative actions into a regime. Depending on which action is to be considered, the evolution towards a regime was completed between 1925 and 1926. The almost coincidence in the foundation of the two institutions (Milan University and the Fascist regime) was a purely contingent fact, but it was used to their advantage by both of them. Even for facts of minor importance, it was evident the advantage for Milan University to point out this particular aspect of a being a university born in the fascist era and viceversa. For instance, in 1927 the scientific institutes of the Faculty of Sciences, which at the foundation of the university were hosted in various zones of Milan, were united in a single building, the Sciences Palace (originally planned to host the rectorate and the central offices). The building was erected thanks to governmental funds. In the 1927–28 report,[1] the rector Baldo Rossi, who could have limited himself to thank the government in a proper way for the financial support, decided to highlight that the Sciences Palace was honored of being mentioned in the "Foglio d'Ordini"[2] of the Fascist National Party as one of the great national works of the year V of the Fascist era.[3]

Many speeches, reports, and documents at every institutional level contained public statements in support of the Fascist government. On every important occasion in the history of Fascism, Milan University was quick in publicly showing its enthusiasm. For instance, when Italy declared war on Ethiopia in 1935, the Faculty of Sciences (with no opposition from the Institute of Physics) sent to the Minister of National Education and to the high commander of the Italian troops in Eastern Africa telegrams, supported the war and wished victory over the enemy.[4] The same Faculty did not protest against the massive use of chemical weapons against the Ethiopian army and civil people that could not defend from such an attack in any way. Again in 1935, the Faculty of Sciences fully agreed with the accession by the Milan University

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[1] Centro APICE, Historical Archive Milan University: serie 7.3.76, u.a. 119: 1927–28 yearly report: p. 2.

[2] The "Foglio d'Ordini" was a document that contained the orders from the party hierarchs, the orders and the communications from the general secretary, and some explanatory notes.

[3] Years in the Fascist era were counted starting from 1922. Note that the rector explicitly used the Fascist year.

[4] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 2: Minutes of the meetings of the Council of the Faculty of Sciences, October 22, 1935: p. 346.

on the initiative to donate gold to the fatherland[5] unable to oppose to an act which showed the failure of the governmental economic policies.

An evident example of the willingness to please the Fascist regime happened in 1937. In November, the three Marshals of Italy—Emilio De Bono, Rodolfo Graziani, and Pietro Badoglio—visited Milan. Milan University quickly took the opportunity to award them an honorary degree. Three faculties were commissioned to write the reasons supporting the award: Humanities for De Bono, Law for Graziani, and Sciences for Badoglio. The honorary degrees were awarded on December 7, 1937 to Badoglio and De Bono, and on April 16, 1937 to Graziani. Badoglio and Graziani were actually responsible for war crimes, respectively in Ethiopia and Libya, and well represented the regime under this aspect.[6] The Faculty of Sciences unanimously agreed and supported the proposal to honor Badoglio with the degree in Physical and Mathematical Sciences. The official statement is rather interesting:

> His Excellency the Marshal of Italy, Cav. Pietro Badoglio, Marquis of Sabotino, Duke of Addis Ababa, [is awarded] the *honoris causa* degree in Physical and Mathematical Sciences with the following motivation: He was an heroic soldier of the Libyan enterprise [i.e. the conquest of Libya from the Ottoman Empire] and of the liberation war [i.e. the First World War], architect of the rescue and victory, a strenuous leader of the conquering army of the Ethiopian Empire, a master in the organization of the weapons and the devices that modern science and technology places at the service of the armies. He promoted and excited the studies and the researches in every field of the physical and mathematical sciences for the greater military power of the Nation, with a work that rejoins the glorious polytechnic traditions of the great captains of the Italic people.[7]

Notwithstanding the pompous rhetorical motivation, they were actually clutching at straws with a very vague speech. There was no contribution at all by Badoglio to physics or mathematics to be taken into consideration. This award was nothing more than a pure political move by Milan University to show again their public support to the Fascist regime. At the same time, the Fascist regime benefitted from these honorary awards. Nine days before, Badoglio had been appointed president of the Italian National Council for Researches by Mussolini [3]. His appointment was not grounded on scientific reasons, but was a purely political action. The appointment of a Marshal of Italy to that scientific position showed the willingness of the Fascist regime to make use of the Italian scientists and technologists to support the military development of the country. Milan University continued to honor Badoglio: during his presidency of the CNR (from the 1938–39 to the 1941–42 academic year), he was listed in the yearly report as a member of the Faculty of Sciences as honorary doctor in Physics and Mathematics.

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[5] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 2: Minutes of the meetings of the Council of the Faculty of Sciences, December 5, 1935: p. 352.

[6] Both Badoglio and Graziani were in the UN lists of the Italian war criminals. After the Second World War, Ethiopia and Libya respectively requested their extradition to be sentenced for their war crimes. Italy always refused to agree to these requests of trials abroad. Eventually, Italy did not experience anything similar to the Nuremberg and Tokyo trials as it instead happened in Germany and Japan.

[7] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 3: Minutes of the meetings of the Council of the Faculty of Sciences, November 29, 1937, p. 63.

A deeper impact of Fascism on the universities was exerted by the oath of fidelity to the king and to the Fascist regime and the introduction of courses on racism in the medical and biological courses:

> I swear to be loyal to the King, to his Royal successors, to the Fascist Regime, to loyally observe the Statute and the other laws of the State, to exercise the office of teacher and to fulfill all academic duties with the aim of forming industrious, honest citizens devoted to the Fatherland and the Fascist Regime.
>
> I swear that I do not belong or will not belong to associations or parties, whose activity does not reconcile with the duties of my office.[8]

The Royal Decree no. 1227, August 28, 1931, imposed this oath of fidelity on all university professors. In all of Italy only twelve professors refused to swear [1, 2]. The professors not only swore to observe the State laws but also to educate the students and to make them good subjects of the Fascist regime. Only one professor of Milan University, the philosopher Piero Martinetti, refused to accept this imposition. Giovanni Polvani and the later professors of the Institute of Physics—Giovanni Gentile jr and Giuseppe Bolla—accepted and swore. In 1933 a further step was taken by the regime. All university professors and all the candidates for a university chair were obliged to be members of the Fascist National Party thus becoming an organic component of the regime's structure. Again, Giovanni Polvani and all the subsequent professors of the Institute of Physics or of other universities—Giuseppe Bolla, Giovanni Gentile jr, Giuseppe Cocconi, Piero Caldirola, Giuseppe Occhialini—became members of the Fascist National Party if they had not yet been.

Polvani, when he was the dean of the Faculty of Sciences, was directly involved in a trial which concerned a professor of mathematical analysis, Guido Ascoli. Ascoli had been called from Pisa University to replace the former professor, Giovanni Vailati, who had retired. Some members of the Faculty had the suspect that Ascoli was not a member of the Fascist National Party. They asked Polvani to call the Faculty Council with the outmost urgency. They accused each other while everybody swore they knew nothing about it. Eventually they wrote in the minutes that:

> Only today the Faculty has come to know in a precise way that Prof. Ascoli is not a member of the Fascist National Party. The scientific judgment on Prof. Guido Ascoli's work remains completely unaltered. The unanimous Faculty declares that, if at the time of the call, they had known this circumstance, none of its members would have voted or even proposed his transfer to Milan University. We ask the Rector to immediately make known to the superior Ministry this statement.[9]

The university militia[10] of Milan University—the 2nd University Legion—was named after the Duce's younger brother, Arnaldo Mussolini, and it was a matter

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[8] Centro APICE, Historical Archive Milan University: 1932–33 yearbook, Statute of Milan University, art. 18: p. 525.

[9] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 2: Minutes of the meetings of the Council of the Faculty of Sciences, October 30, 1934: p. 312.

[10] The university militia was a component of the Voluntary Militia for National Security. Their members were all recruited from university students.

of honor for Milan University to have so many students aware of their duties.[11] In the 1934–35 yearly report on the university militia, the rector, Ferdinando Livini, mentioned 1802 students in black shirt and 125 officials in five cohorts: official cadets, cyclists, motorcyclists, Alpine troops, militia musicians. The milita was in charge of pre-military education of about 4,000 middle-school and university students. 245 university students were enrolled in the courses for cadets.

Milan University was particularly proud of the students who competed in the national Fascist games. For instance, the 1937–38 yearly report, Milan University states that:

> For the sixth time, they have adorned the insignia of our University Team in the results of the lictorial games with the Duce's coveted sign and the award of the Golden Rostrum. Thus the university students, who have moved after the times and the historical needs of an outdated goliardic conception, become, with growing awareness of their own duties, active elements of the national life.[12]

Even if a student was not a member of the university militia, they were not completely alien to military life. In 1925, the Ministry of Public Education disposed the organization of courses of military culture.[13] The Faculty of Science of Milan University organized four courses, two chemistry courses—Toxic and aggressive substances and chemical warfare services; Explosive substances—and two mathematics courses—Aiming and shooting; External ballistics.[14] A fifth, physics course—Application of Physics to the art of war—was entrusted to Aldo Pontremoli. It was never activated because of the his participation to the 1928 polar expedition. The topics covered by this physics course were planned to be: (1) communications with radio, infrared, visible, and ultraviolet waves; (2) ground telegraphy; (3) telephone wiretapping; (4) protection of explosive deposits from lightning; (5) electrified crosslinks technique; (6) telemetry for infantry, artillery and air forces; (7) applications of meteorology to ballistics and to gas technique; (8) identification of aircrafts, submarines and batteries in action by acoustic methods.[15]

To the two chemistry courses were admitted the officers of artillery and military engineering and the students who had passed the exams in general inorganic and organic chemistry and chemistry for medicine. Officers of the Royal Army and similar military institutions were admitted to the aiming and shooting course, as well as students from universities and high schools who did not have a classical or scientific high school diploma. Artillery officers and military engineers were admitted to the external ballistics course, as well as the students who had passed the first two years of the Faculty of Sciences.

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[11] Centro. APICE, Historical Archive Milan University: serie 7.3.76, u.a. 136: minute of the 1937–38 yearly report, November 10, 1938: p. 3.

[12] Centro APICE, Historical Archive Milan University: serie 7.3.76, u.a. 136: minute of the 1937–38 yearly report, November 10, 1938: p. 4.

[13] Royal Decree no. 1615, August 7, 1925.

[14] Centro APICE, Historical Archive Milan University: serie 7.3.76, u.a. 119: 1927–28 yearly report.

[15] Centro APICE, Historical Archive Milan University: serie 7, titolo 11, u.a. 124: Corsi di cultura militare: p. 7.

At the end of the courses in military culture, the enrolled students obtained a certificate. The students belonging to the land and sea forces, who had attended at least two courses in military culture and had passed the exams, could enjoy four benefits: (a) the right of choice in the fulfillment of the obligations relating to the military service, the service and the specialty, in relation to the requisites required by law; (b) the right of precedence, with equal qualifications, for admission to recruiting schools for effective permanent service officers if university qualifications were required for such admissions; (c) the right of precedence, other qualifications being equal, in the competitions for the admission to special categories of officers in effective permanent service; (d) the right of precedence, other qualifications being equal, for the admission to courses for reserve officer cadets, or in competitions for the appointment as reserve officer.

Institutional rhetoric at Milan University culminated with the inauguration ceremony of the 1940–41 academic year. The speech delivered by the rector Uberto Pestalozza was so regrettable that it was alleged as one of the indictment documents in the purge trial against him in 1945. The students of the university militia attending the ceremony were completely described from a Fascist point of view:

> The Fascist student – "one of a thousand" when wearing bourgeois clothes – acquires a very special appearance when is in uniform: the black Saharan uniform makes him a soldier, clothes him with discipline, makes him proud of his bearing: but above it, the goliardic cap stands out - bold and neglected, aggressive in the vivacity of its colors and in the daring of the long tip – perpetuated symbol of our doctrinal glories forged in the ancient athenaeums. Uniform and cap do not contrast, no, on the contrary, they harmonize, they perfectly dress Mussolini's students, serene, happy and healthy, intelligent and understanding, prepared "to keep the musket close to the book".[16]

The black Saharan uniform and the cap were a component of that code clothing which was another aspect of public adherence to the dictates of the regime. Code clothing acted as a way to frame the Italian society and create a new Italian people. The use of a uniform became mandatory for the students in the early Forties[17] and it was strongly suggested also to the professors to wear a black shirt or the uniform of the Fascist National Party a least during the examinations.[18]

If a part of the students were more or less convinced by the work of persuasion exerted on their minds since the early childhood, another relevant made enough critical sense to resist even if the social and political circumstances prevented the free expression of dissenting thought.

If, before the Second World War, the regime enjoyed widespread support from the Italian public opinion, the continuous military failures that highlighted the empty militarist rhetoric of the "fascist war" undermined popular confidence in the regime and contributed to its downfall.

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[16] Centro APICE, Historical Archive Milan University: serie 7.3.76, u.a. 127: "La cerimonia inaugurale dell'anno XVIII".

[17] Centro APICE, Historical Archive Milan University: serie 1.3.1, u.a. 12: rector's decree n. 2219, August 2, 1940.

[18] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 3: Minutes of the meetings of the Council of the Faculty of Sciences, October 9, 1940: p. 192.

An unknown but not little number of students took part in clandestine resistance activities; many others just refused to serve in the army of the Italian Social Republic and had to hide. Given the number of several tens of fallen students, we can estimate that the students active in clandestine resistance were at least some hundreds, a number that corresponds to the number of students who graduated each year. Soon after the end of the war[19] Milan University decided to recognize the students fallen as soldiers of the army[20] (not of the Fascist militias, in particular those of the Italian Social Republic) and as resistant partisans. Milan University asked their relatives by radio and in the press to send documentation testifying the role played by the fallen students. Fifty-five fallen students were awarded an honorary degree during the inauguration ceremony of the 1946–1947 academic year. The number refers to the students for whom they collected sufficient documentation for the award.[21] Eight out of them were students of the Faculty of Sciences. Jacopo Dentici, whom we shall consider in detail in a separate section of this chapter, was a second-year student of the degree course in Physics, and died in the Gusen II sub-field of Mauthausen in 1945.

5.2 The Racial Laws

The Italian racial laws were a set of several legal laws and decrees promulgated by the Italian Government (and, later, by the Italian Social Republic) from 1938 on [4]. They had a profound impact on the Italian society. Italian universities were not an exception and contributed to these laws with the signature of the shameful "Manifesto of the racist scientists" on July 14, 1938.[22] The Italian racial laws were in part the expression of the anti-Judaism traditionally diffused in the Western countries, and in part the direct product of the racist component of Fascist thought, independently from any connection with the contemporary German situation. The very definition of a Jew according to the Italian racial laws, for instance, did not reflect the biological definition which could be found in the corresponding German laws, but were instead a replica of the precedent racist definitions of the non-European white people living in the Italian colonies according to the Italian colonial laws.

Historiography on the impact of the racial laws on the Italian university, besides a general analysis [5, 6], has already considered some relevant cases: Florence [7], Padua [8], and Pisa [9]. The impact on Italian physics has been analyzed for the cases

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[19] April 25 is the date of the Feast of Liberation in Italy. It is the date when Milan and other cities in Northern Italy where liberated from the last remnants of the government of the Italian Social Republic and from the occupying German troops.

[20] A physics graduate, Giovanni Fioretti, fell as soldier of the Italian army.

[21] Centro APICE, Historical Archive Milan University: 1946–47 yearbook, pp. 4–6.

[22] The Manifesto was mostly written by Mussolini himself, but it was signed by university professors.

of the team of the Institute of Physics in Rome and of Bruno Rossi in Padua.[23] Milan University, as well as the other Italian universities, were very quick in identifying their Jewish members and expelling them. The census made at Milan University concerned eventually 839 people.[24] Nine Jewish professors—Alberto Ascoli (General Pathology and Pathologic Anatomy), Guido Ascoli (Mathematical Analysis), Paolo D'Ancona (History of Medieval and Modern Art), Mario Donati (General Surgery), Mario Falco (Ecclesiastic Law), Carlo Foà[25] (Human Physiology), Mario Attilio Levi (Roman History), Giorgio Mortara (Statistics), Aron Benvenuto Terracini (Glottology)—and five assistants—Giorgio Ara, Massimo Calabresi, Giuliano Fiorentino, Paolo Levi, Gina Luzzatto—were identified. Also technicians and people of the administrative staff were expelled.

Jewish students were not expelled from the university. In 1939 they were but separated from the "aryan" students. They could not take the exams together, and the "aryan" students had the precedence in the oral examinations.[26]

If the census of the Jewish university people is well documented, the same cannot be said for the public narrative of the expulsion. A not hidden event which was happening under everybody's eyes, fostered by a State's laws, was an event of which little was talked about in the university public speeches. During the inauguration speech of the 1938–39 academic year, the rector Alberto Pepere just mentioned the expulsion of the Jewish professors and did not name them:

> Significant variations occur in the academic staff this year: not all of them can be taken into account in this report, since for contingent reasons it has not yet been possible to provide for several vacant chairs with definitive provisions. Some recent higher provisions of racist kind have exempted from their teaching nine tenured professors and one permanent lecturer in our University: we leave them with respect for the work they have done in the service of science.[27]

The Faculty of Sciences replaced the Jewish professors as for their teaching assignments already approved. The replacement also happened with very few words. They decided to replace the professor of Drawing, Bruno Finzi Contini,with Ismaele Secchi and Bonaventura Taraci, to suspend Guido Ascoli from teaching Mathematical Analysis, to suspend Carlo Foà (of the Faculty of Medicine and Surgery) from

[23] On the Jewish Physicists in 1930s Italy see [10].

[24] Centro APICE, Historical Archive Milan University: serie 7, titolo 9, u.a. 307, "Razza, Censimento personale di razza ebraica".

[25] The case of Carlo Foà is noteworthy since he was very active in Fascist institutions and held a plenary lecture on the Fascist Regime on January 18, 1931, for the inauguration of the academic year. Centro APICE, Historical Archive Milan University: 1930–31 yearbook: Il Regime Fascista, pp. 205–232.

[26] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 3: Minutes of the meetings of the Council of the Faculty of Sciences, June 16, 1939: pp. 136–137.

[27] Centro APICE, Historical Archive Milan University: 1938–39 yearbook, inauguration speech of the academic year: p. 9.

teaching General Physiology, and to accept the resignation of the professor of Chemistry, Luigi Szegoe, to be replaced by Lamberto Malatesta.[28]

At the time of the racial laws, the Institute of Physics in Milan did not host any Jewish scientists or, as for we know, students. An *a posteriori* impact can be nonetheless found in a kind of *damnatio memoriae* on Aldo Pontremoli, the abolishment of a scholarship named after him [11, 12]. Pontremoli's mother, Lucia Luzzatti, decided to support a scholarship and signed in Rome a deed of donation of public securities to Milan University.[29] The securities amounted to 50,000 lire with coupons with annual interest of 5% that would have financed the scholarship. The scholarship would have been awarded by competition to a student of Milan University regularly enrolled in the third or fourth years for the degree in Applied Physics. The Faculty of Sciences delegated Polvani and the dean to handle with the donation agreement.[30] After some bureaucratic steps, Milan University got the authorization to accept the donation when the King Victor Emanuel III signed the Royal Decree on August 14, 1931.[31]

The Faculty of Sciences approved the statute of the Aldo Pontremoli scholarship and appointed the first evaluation commission (Livio Cambi, Giovanni Polvani, Giulio Vivanti).[32] The first winner was Olga Bertoli,[33] a student of the fourth year of Applied Physics. The second commission (Gino Bozza, Bruno Finzi, Giovanni Polvani) was appointed in 1933.[34] It is not currently known if the second scholarship was ever actually awarded due to the lack of any indication in the extant documents. The same commission was appointed again in November 1933[35]: the scholarship was awarded in 1934 to student whose name is not reported.[36] No extant

[28] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 3: Minutes of the meetings of the Council of the Faculty of Sciences, October 31, 1938: p. 89.

[29] Archivio Centrale dello Stato, MPI, DGIS Div. IV, 122. "Milano R. Università. Borsa di studio Pontremoli Aldo": Atto di donazione.

[30] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 2: Minutes of the meetings of the Council of the Faculty of Sciences, January 17, 1931: p. 144.

[31] Archivio Centrale dello Stato, MPI DGIS Div. IV, 122, "Milano R. Università. Borsa di studio Pontremoli Aldo": letter from the rector Ferdinando Livini to the Minister of National Education, May 23, 1931; letter from the Minister of National Education to the rector Ferdinando Livini, May 30, 1931; Consiglio di Stato, seduta della 1a Sezione, July 14, 1931. Centro APICE, Historical Archive Milan University: serie 1.2.1, u.a. 2: Minutes of the meetings of the Administrative Board, July 12, 1932: p. 265. The Royal Decree n. 1201 was published on the Gazzetta Ufficiale n. 287 on October 1, 1931.

[32] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 2, Minutes of the meetings of the Council of the Faculty of Sciences, October 20, 1931: p. 161; and December 21, 1931: p. 177.

[33] Centro APICE, Historical Archive Milan University: 1932–33 yearbook, speech for the inauguration of the academic year: p. 17.

[34] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a. 2: Minutes of the meetings of the Council of the Faculty of Sciences, January 14, 1933: p. 239.

[35] Centro APICE, Historical Archive Milan University: serie 1.4.4, u.a.2: Minutes of the meetings of the Council of the Faculty of Sciences, November 22, 1933: p. 282.

[36] Centro APICE, Historical Archive Milan University: 1935–36 yearbook, speech for the inauguration of the academic year: p. 16.

documents concern a possible commission appointed in 1935. In 1936 the scholarship was temporarily suspended in accordance with not specified provisions in force.[37] A new commission, whose composition is unknown, was appointed; they assigned the scholarship for the last time, in 1937, to Vanna Tongiorgi.[38]

Since the racial laws contained a disorganized system of exceptions, their effective application raised several problems. In the case of the universities, the solution was asked to the Minister of National Education case by case. The "Aldo Pontremoli" scholarship concerned the authorization granted by the King to accept a donation from Jews or to support a scholarship named after a Jew. The racial laws affected the living Jews, but in the case under consideration they had to do with illustrious Jews long dead. The Minister of National Education, Bottai, sent a reserved document to the rectors of all Italian universities providing an answer about the retroactive effects on the already formalized donations:

> Since I have made the appropriate agreements with the Hon. Presidency of the Council of Ministers [Mussolini], I arrange that such donations and legacies should not be accepted. [...] As regards, then, the institutions entitled to the name of people of Jewish race, which have already been legally recognized before the recent known provisions, I reserve the right to adopt the appropriate measures, case by case, in relation to the particular situation of each Institution and the statutory rules that regulate its functioning. To this aim, please inform me as soon as possible the complete list of the aforementioned institutions, specifying for each of them the initiatives they have arisen from, and also sending copies of their respective statutes, regulations, etc.[39]

All documents on the scholarship were sent to Rome and never sent back to Milan University. There was a complete lack of reactions, at least formal ones, from the Institute of Physics and the Faculty of Sciences. Since the consequences of the racial laws were not of immediate awareness, they probably thought that the scholarship was only temporarily suspended.

Pontremoli's mother, Lucia Luzzatti, asked many times that the scholarship could be authorized again. As a matter of fact, since she was the daughter of a former President of the Council of Ministers, she was somehow exempted from the application of the racial laws and the same happened for her other son, Giorgio.[40] She concluded that a similar exemption would have been granted to Aldo too. Contrary to what was written in the confidential circular letter, Bottai did not take any decision. He passed the case to Mussolini who never made any decision regarding the whole matter. No known document affirms any will of the Fascist government to cancel Aldo Pontremoli's name from Italian history. It might be the case that, however much of little importance in the dramatic context of the racial laws, an action in favor of a Jewish physicist could have been a source of embarrassment for the Fascist regime which

[37] Centro APICE, Historical Archive Milan University: serie 1.4.4., u.a.3: Minutes of the meetings of the Council of the Faculty of Sciences, February 3, 1936: p. 2.

[38] Centro APICE, Historical Archive Milan University: 1938–39 yearbook, speech for the inauguration of the academic year: p. 21.

[39] Centro APICE, Historical Archive Milan University: serie 7, titolo 9, u.a. 439, "Difesa della razza": Ministry of National Education, confidential circular, November 12, 1938.

[40] Decree of the Minister of the Internal Affairs no. 1195/1693, August 10, 1939.

was moving towards a tighter alliance with Germany. After the establishment of the Italian Social Republic the Pontremolis left to Switzerland on September 11, 1943 ([13] pp. 55–56) and it was absurd continuing to ask to authorized the scholarship. After the end of the war, the scholarship was very little worthy due to the rapid depreciation of the lira.

As a happy ending, in 2018 Milan University decided to start a yearly award named after Aldo Pontremoli for graduated physics students. In this way, the wound inflicted to the memory of Pontremoli by the Fascist regime, with the collaboration of the university, was healed.

The Italian physics community did not experience what happened in Germany with a split caused by the supporters of a German or Aryan Physics to be opposed to a Jewish Physics. It is true that a part of the old physicists were not at easy with the new physics theories (i.e. relativity and quantum physics), but any discussion was focussed only on scientific aspects, as it happened for instance in the many attacks against Einstein's relativity. Einstein, at the same time, was never attacked as a Jew, but only as a pacifist.

Attempts to create a similar opposition of an Italian Physics opposed to a Jewish Physics were conducted by Fascist propagandists who were not scientists. As Jewish Physics they mostly meant nuclear physics and cosmic-ray physics. Only one attack concerned the Milan Institute of Physics, in particular Polvani, for the cloud chamber built with a financial support from the CNR.[41]

5.3 The Institute During the Second World War

During the Second World War and the military occupation by the German troops of Northern and Central Italy after the Kingdom of Italy signed the armistice with the allied power on September 8, 1943[42] with the establishment of the puppet State known as the Italian Social Republic,[43] it was maybe even much more dangerous to show in public a behavior different from that expected by the Fascist regime. Polvani and the other physicists of the Institute of Physics in Milan continued not to go beyond a public adhesion to Fascism. During the purge processes held soon after the end of the War, no charges were brought against Polvani nor against any other physicists of the Institute in Milan, not even for facts of minor importance. There is not any proof that they ever helped the regime or the Fascist and German troops in their crimes. The charges were brought against 47 full professors, 214 lecturers, 4 managers and 133 assistants. A member of the purge commission was Guido Ascoli,

[41] The attack was in the article "Science and Jews" written by Giuseppe Pensabene and published on "Il Tevere" on July 1–2, 1941. It is reprinted in [14] on pp. 96–99.

[42] The armistice was signed in Cassibile, Sicily, on September 3, 1943 but it was effective from September 8, 1943.

[43] The Italian Social Republic or Salò Republic was established on September 23, 1943. It got no international recognition besides Germany, Japan and their allies.

who had been expelled from Milan University on racial grounds and who knewn well the members of the Faculty of Science and could have easily attacked Polvani, Bolla, or any other physicists if there would have been any reason to do it. Only three professors of the Faculty of Sciences—Livio Cambi, Ardito Desio, and Umberto Sborgi—were tried and eventually acquitted of all charges.

In 1949, Polvani decided not to write the usual yearly report of the activities of the Institute of Physics. He instead wrote a rather long report with history of the Institute of Physics from his arrival in Milan in 1929. It was a political move to show that the future scientific development of the Institute of Physics would have required many more funds to support adequate activities of research. While writing of the war years, he shortly listed what he did in the worst times:

> Speaking of the war, we like to remember how, in spite of the complete lack of assistant personnel and with an extremely reduced subordinate one, prof. Polvani succeeded, assisted with a truly fraternal understanding and concern by the rector De Francesco, in saving, in spite of the Germans and the Italians enslaved to the Germans, all the material of the Institute and to recover a large part of that of the Institute of Physics of Pisa, stolen by the German SS. In the Social Republic period, the Greek dr. Loverdo, wanted by the SS and then made to flee to Switzerland, was welcomed in the Institute;[44] the assistants were all reluctant to the calls of the Republic of Salò; many students belonged to the partisan groups.[45]

A similar reminiscence by Polvani can be found in the inaugural speech of the new Institute of Physics that he gave on February 10, 1964 [15]. No more details are known about Loverdo's flee to Switzerland; it is highly probable that no document is extant and testifying any activity in organizing his escape. In these reminiscences, Polvani mentioned Plinius Campi—"a man who, not a Fascist, enjoyed certain Fascist impunity", very interested in physics, popularizer of physics even if he never graduated—was always ready to help Polvani and the Institute of Physics. In the same speech Polvani talked about the anxiety and distress during the first bombing of Milan on October 24, 1942.

As we have seen in the previous section, the scholarship named after Aldo Pontremoli was suspended because of his Jewish origin. At the same time, the Institute of Physics continued to be named after him. Nobody, as for we know, asked to deleted his name. The commemorative plaque and bust were not damaged and there was no need to hide them to avoid vandalic actions on them. His name on the letterhead was not deleted (there are no known examples of this case), whereas a line of pen was drawn instead on the Savoy coat of arms and on the R for Royal during the Italian Social Republic.

Another problem faced by the Institute of Physics during the war was to avoid the theft of scientific instruments and books by the German troops. Polvani succeeded in hiding them in some locations in the city and outside Milan. The clearing operations took several weeks and were carried out by Giovanni Adorni, Lazzaro Fumagalli.

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[44] After the war, Loverdo was assistant in Zurich, then he worked in France at the Pic-du-Midi laboratories and at the École Normale Supérieure in Paris.

[45] Centro APICE, Historical Archive Milan University: serie 7, busta 77, Scienze: "Relazione sull'attività dell'Istituto di Fisica dell'Università di Milano dalla sua fondazione ad oggi e sulla sua situazione attuale", February 2, 1949: pp. 10–11.

Camillo Modigliani, Teresa Panizza, Mario Pessina, and Bassano Prada. The instruments too large to be taken away were walled in a hidden room in the cellar of the institute. Some old, useless didactical instruments were instead left in the institute and shown to the German officers as of great value and very delicate when they came to the institute for an inspection to look for noteworthy instruments to send to Germany.

Soon after the end of the war, the pro-rector Mario Rotondi considered it necessary to provide for the return of all scientific material displace outside Milan. To organize their transport organically, he asked the directors of the institutes for information about the quantity and volume of the objects and their location.[46]

Polvani wrote to the pro-rector in response to his request, and compiled a very simple list[47] of materials hidden outside Milan (Polvani himself had left Milan to Cantù with his family):

> I have the honor to inform you that the educational and scientific material of this Institute, displaced outside Milan, is located in the locations indicated below and consists of the following objects:
> (a) Venegono (Varese): about thirty cases of books (25 quintals). 4 non-separable shelves (about 4 quintals and 4 m^3 volume).
> (b) Cantù (Como): 15 crates of appliances (12 quintals). 1 large shelf (about 2 quintals and 2 m^3 volume) and 1 table (2×1 m^2)
> (c) Como: 2 crates (1.5 quintals and 0.25 m^3)
> (d) Busto Arsizio: 1 box (1 1/2 quintals)
> (e) Caldana di Trevisago (Varese): (outside and far from the railway lines):
> (f) 3 cases (4 quintals, 0.5 m^3)
> (g) Barlassina: 1 box, 1 quintal, 0.25 m^3).
> Other material has been displaced in the city or in nearby locations, from which the Institute can arrange for the withdrawal by itself.[48]

After having collected information from all the institutes, the pro-rector wrote to Mario Apollonio, the regional commissioner of the National Liberation Committee for the Public Education, to inform him that he was not able to provide to have the scientific material returned to Milan University. The negative result was due to the absolute lack of means of transport owned by Milan University and to the exaggerated demands of the private companies consulted. The pro-rector therefore asked the Commissariat to ask the Allied Command to obtain some vehicles with an average capacity of 20–25 quintals to carry out the transport.[49] In agreement with the Commissariat, the pro-rector was authorized to ask the Transport Office of Milan

[46] Centro APICE. Milan University Historical Archive. Istituti 8A/0 Pratiche generali. Materiale sfollato. Letter from the Pro-rector of Milan University to the directors of the institutes, June 4, 1945.

[47] A detailed list of materials has not been found yet.

[48] Centro APICE. Milan University Historical Archive. Istituti 8A/0 Pratiche generali. Materiale sfollato. Letter from Giovanni Polvani to the Pro-rector of Milan University, July 13, 1945.

[49] Centro APICE. Milan University Historical Archive. Istituti 8A/0 Pratiche generali. Materiale sfollato. Letter from the Pro-rector of Milan University to the Regional Commissioner of the National Liberation Committee for the Public Education, July 5, 1945.

to obtain the necessary means of transport for a work which would have occupied about ten days.[50]

Only in the second half of August, the Transportation Division of the Headquarter Allied Military Government for Lombardy issued instructions to the director of the Transport Office of Milan to provide the university with the transport needed to collect the material. The transport had to be paid for at the official tariff rates.[51] This intervention followed a last request from the Pro-rector, complaining that the Transport Office of Milan, which at first guaranteed to carry out the transport but, subsequently, due to lack of vehicles, sent the file to transport cooperative which would have applied higher rates due to lack of fuel. In order to avoid the speculation of private firms, the Pro-rector requested the prompt intervention of Major Vesselo.[52] Eventually, all material of fourteen institutes was brought back to Milan University. The Institute of Physics almost did the lion's share with more than 58 quintals from six locations out of a total of 350 quintals.

Probably due to a mistake, boxes of Italian instruments taken to Germany through Milan were erroneously attributed to the Milan Institute of Physics. Major Vesselo, of the Regional Bureau for Education of the General Headquarter of the Allied Military Government of Lombardy, wrote to Milan University as for the request to recover these physics instruments:

> 1. 150 cases of equipment from physics laboratories were found in a school in Lenz[53] (Austria) from Milan.
> 2. It is suspected that, despite the Lenz school declaring that it legally ordered its shipment from Milan, this material was instead removed from Italian secondary schools or universities.
> 3. If any institute has well-founded reasons to believe that any apparatus from physics laboratories it owns have been removed by the Germans and taken out of Italy, that institute should send this Office a detailed description of each apparatus, with all the details of how and when it was removed and what suggests it may be part of Lenz's material. The descriptions should be so precise that it is very easy to identify the exact devices sought.[54]

The instruments in the aforementioned letter on August 2, 1945 from Major Vesselo were probably part of the material stolen by the Germans from the Institute of Physics of Pisa University. The Rector of Pisa University wrote to the Minister of Foreign Affairs for information:

> In the dutiful interest of Pisa University, I allow myself to address my heartfelt prayers to ascertain whether 300 crates containing material and books are found in Linz (Austria), which

[50] Centro APICE. Milan University Historical Archive. Istituti 8A/0 Pratiche generali. Materiale sfollato. Letter from the Pro-rector of Milan University to the directors of the Transport Office of Milan, July 10, 1945.

[51] Centro APICE. Milan University Historical Archive. Istituti 8A/0 Pratiche generali. Materiale sfollato. Letter from the Headquarter Allied Military Government, Lombardy, Transportation Division to the Pro-rector, August 18, 1945. Letter from the Headquarter Allied Military Government, Lombardy, Transportation Division to the Transport Office of Milan, August 18, 1945.

[52] Centro APICE. Milan University Historical Archive. Istituti 8A/0 Pratiche generali. Materiale sfollato. Letter from the Pro-rector of Milan University to Major A.A. Vesselo, August 18, 1945.

[53] Most probably it is Linz.

[54] Centro APICE. Milan University Historical Archive. Istituti 8A/0 Pratiche generali. Materiale sfollato. Letter from A.A. Vesselo to Milan University, August 2, 1945.

> are presumed to belong to the Institutes of Pisa University, plundered by the Germans. In this hope we are confirmed by the fact that these boxes come from Milan, where a considerable part of the material of our Institute of Physics has already been found. The response that can be provided will eventually constitute the basis for sending staff to this University for a prompt recovery. In the meantime, this Honorable Ministry is requested to recommend the conservation of the indicated boxes.[55]

Actually the Milan Institute of Physics was concerned in the theft of physics instruments from Pisa University by the German troops. With the establishment of the Italian Social Republic and its military occupation by the Germans, there were several attempts to take to Germany relevant collections of scientific instruments and libraries.

The local German Command in Pisa requested the University to get into possession of some scientific instruments, in particular microscopes.[56] The acts for an agreement on such requests between the Ministry of National Education and the competent German authorities had actually already started.[57] In the meanwhile, the Minister asked the Fascist Chief of Pisa Province to set an agreement with the local German authorities so that such material was as little as possible stolen and that any such request was always made through the Ministry.[58]

A visit to the Engineering School was carried out on March 3, 1944 by Lieutenant Colonel Beck and a representative for high-frequency research. The rector was requested to submit a complete list of the entire inventory available in the school, as well as the number of staff. The inventory had also to contain the devices relocated outside Pisa for security reasons. A detailed list of the equipment and facilities that belonged to the former Naval Academy in Livorno, which had been moved to the Engineering School for safekeeping around August 9, 1943, had similarly to be submitted. All devices, especially those of the former Navy, were considered to be seized.[59] The request of the material from the former Naval Academy was particularly sensitive. According to a decree of the Italian Ministry of National Education of January 1943, universities were prohibited from taking in war material or the property of parts of the armed forces. In order to ensure that the material of the Naval Academy were put to an appropriate use for the common warfare, all inventory of

[55] Archivio generale dell'Università di Pisa. Institute of Physics, 1948, X/6: Letter from the Rector of Pisa University to the Minister of Foreign Affairs, August 6, 1945.

[56] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Rector to the Minister of National Education, November 4, 1943.

[57] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Minister of National Education to the Rector of Pisa University, November 8, 1943.

[58] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from Minister of National Education to the Chief of Pisa Province, November 10, 1943.

[59] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Generalbeauftrÿgte für Italien des Reichsministers für Rüstung und Kriegsproduktion to the Rector of the Engineering School in Pisa, March 3, 1944. Letter from the Rector of Pisa University to the Minister of National Education, March 6, 1944.

Pisa University had been blocked.[60] One month later, the German commissioner for high-frequency research and the Fascist Republican Navy set an agreement about the use of the material from the Italian Navy in the new research institute in Campo San Martino.[61]

Since the military front was approaching Pisa, measures for the protection of scientific and didactical materials had to be taken, such as a transfer to places in Northern Italy. General Leyers of the German troops made it known that he could provide the means of transport for the transfer.[62] On June 24, 1944, the representative for high-frequency research, Dessauer, wrote to the Rector about the possible transfer of the physics instruments to Northern Italy:

> Considering the extremely endangered situation of the city of Pisa and the likelihood of further bombings, this safeguarding must be carried out with all urgency as long as the transport space can be made available. The seized devices and books will be stored in the astronomical observatory of Milan University in Merate near Como at the disposal of the Italian Ministry of Education.[63]

Actually a first requisition of scientific instruments had already happened the day before. On Friday June 23, some ammeters, voltmeters and galvanometers, a calculator used by the students for laboratory exercitations, and a Mercedes electric calculating machine of the Institute of Mathematics were removed.[64] The Rector complained with the German Command in Pisa:

> I hasten to report that German officers and soldiers entered the Institute of Physics by forcing the entrance doors, which were closed, and precisely the entrance from the rear. In this way, on Friday at 5 pm in the absence of the Institute staff, they chose the scientific material, removing a part of it. On the 24th at 05.05 pm, two German soldiers equipped with tricycle trucks in the presence of Prof. Ciccone[65] loaded almost everything, books and tools that will be indicated in a special list, as follows. The two aforementioned soldiers were equipped with a letter addressed to the Rector and another addressed to the Minister of Education, which they did not want to deliver to the aforementioned Mrs. Prof. Ciccone. I thought it necessary and urgent to communicate the above, with the prayer to give clarifications

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60 Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Generalbeaufträgte für Italien des Reichsministers für Rüstung und Kriegsproduktion to the Rector of Pisa University, March 4, 1944.

61 Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Generalbeaufträgte für Italien des Reichsministers für Rüstung und Kriegsproduktion to the Rector of Pisa University, April 6, 1944.

62 Archivio generale dell'Università di Pisa. Varie. 1944, 1: Letter from the Minister of National Education to the Rectors of Florence, Pisa, Siena, Camerino, Urbino Universities, June 21, 1944.

63 Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Minister of National Education to the Rectors of Florence, Pisa, Siena, Camerino, Urbino Universities, June 21, 1944.

64 Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Rector to the German Command, without date, after June 24, 1944.

65 On Mariannina Ciccone, see: [16].

and urgent provisions regarding the recovery of material removed and how to prevent the repetition of damage and removal of the scientific material of this University.[66]

The list of stolen instruments was sent to the German Command the day after.[67] A similar letter was sent to the Chief of the Pisa Province with request to notify the Minister of National Education of the fact that had occurred.[68] The Rector sent the complete list of instruments and books from the scientific institutes to the Minister of National Education on July 15, which contained also a group of objects taken from the Institute of Experimental Physics on July 7.[69]

A vividly summary narrative of the removals committed by the Germans to the detriment of the Institute of Physics was written by the director, Luigi Puccianti, in October 1944. The courage of Prof. Ciccone in affronting the German soldiers is a page not to be forgotten of the history of Pisa University.[70]

After the libration of Northern Italy, Puccianti tried to find if the instruments and books removed by the Germans were or not in the Astronomical Observatory in Merate. He asked the Rector to take an interest in the return of the objects to the Institute of Physics.[71] Eventually the Rector wrote to the director of the Astronomical Observatory and to the Minister of Public Education, asking for a prompt restitution of the stolen material.[72] Puccianti suggested that his assistant, Cosimo De Donatis, would go to Milan for a recognition of the material from Pisa.[73] The Rector agreed with Puccianti's proposal and introduced De Donatis to the Rector of Milan University.[74] In the meanwhile, the Minister of Public Education had ordered to transfer the material from the Astronomical Observatory to the Institute of Physics.[75] From a letter written by the Rector of Milan University that all material delivered by the

[66] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Rector to the German Command, June 26, 1944.

[67] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Rector to the German Command, June 27, 1944.

[68] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Rector to the Chief of Pisa Province, June 26, 1944.

[69] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from the Rector to the Minister of National Education, July 15 1944.

[70] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Report by Luigi Puccianti, October 16, 1944.

[71] Archivio generale dell'Università di Pisa. Request of scientific instruments by the German Command. 1943–44, 27: Letter from Luigi Puccianti to the Rector, May 18, 1945.

[72] Archivio generale dell'Università di Pisa. Institute of Physics, 1948, X/6: Letter from the Rector to the Minister of Public Education, May 23, 1945.

[73] Archivio generale dell'Università di Pisa. Institute of Physics, 1948, X/6: Letter from Luigi Puccianti to the Rector, June 14, 1945.

[74] Archivio generale dell'Università di Pisa. Institute of Physics, 1948, X/6: Letter from the Rector of Pisa University to the Rector of Milan University, June 19, 1945.

[75] Archivio generale dell'Università di Pisa. Institute of Physics, 1948, X/6: Letter from the Rector of Pisa University to the Minister of Public Education, June 27, 1945.

Germans was deposited at the Milan Institute of Physics and that no scientific material belonging to any university was at the Astronomical Observatory of Brera and Merate.[76]

Good news were reported by De Donatis after his recognition in Milan and Como:

> Following the assignment you gave me, on June 27, 28, 29, 30 and July 1, 2, I went to Milan and Como, where I personally took care of the recovery of the scientific material already removed by the Germans from the Institute of Physics of this University.
>
> Thanks to the interest and cooperation of prof. Bolla of the R. Milan University, and of prof. Ranzi of the R. University of Florence, as well as prof. Allegretti of this University, the aforementioned material was largely found and secured at the Physics Institute of the R. Milan University.
>
> The state of conservation of the instruments is relatively good; only some of them will need a thorough review by some competent company.
>
> [...]
>
> It seems that the binocular microscope was delivered by Eng. Dessauer to a German hospital, and that the Mercedes calculating machine was sent by the same to the Ferdinand Braun Institute in Landsberg am Lech.[77]

Eventually the instruments and books were sent back to Pisa University. The name of Polvani cannot be found in these documents, so that we can just wonder how active he was in helping his first university and his mentor Puccianti in recovering their instruments. In his reminiscences speech on February 10, 1964, Polvani thanked the rector De Francesco in the name of his friends in Pisa [15].

5.4 The People

5.4.1 Carlo Salvetti

In the 1940–41 academic year, Carlo Salvetti (Fig. 5.1) joined the Institute of Physics as assistant (Table 5.1).

Carlo Salvetti was born in Milan on December 30, 1918. He graduated in Physics at the Milan University in 1940 with a dissertation on the proportional amplifier method for the study of elementary particles, with Giovanni Polvani as tutor. He fulfilled his military duties during the Second World War in 1941–43, then he started his research activity in nuclear physics at Milan University and at the Collège de France in Paris. He obtained his "libera docenza" in 1950.

In 1946 Salvetti was, with Giuseppe Bolla, Giorgio Salvini and Mario Silvestri, one of the scientific proposers of the CISE where he worked as researcher and consultant in 1946–57. In the 1950s, as an expert in nuclear power plants, he was a member

[76] Archivio generale dell'Università di Pisa. Institute of Physics, 1948, X/6: Letter from the Rector of Milan University to the Rector of Pisa University, July 11, 1945.

[77] Archivio generale dell'Università di Pisa. Institute of Physics, 1948, X/6: Letter from Cosimo De Donatis to the Rector of Pisa University July 6, 1945.

Table 5.1 Institute of Physics (1940–41)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Experimental Physics II and III
Giuseppe Cocconi	Assistant acting as help; lecturer in Higher Physics
Carlo Salvetti	Assistant
Vanna Tongiorgi	Volunteer assistant
Corrado Mazzon	Volunteer assistant
Giovanni Adorni	Technician
Mario Pessina	Technician
Olga Bertoli	Adventitious
Camillo Modignani	Subordinate
Anselmo Andreoli	Subordinate
Chair of Theoretical Physics	
Giovanni Gentile	Professor of Theoretical Physics; lecturer in Probability Calculus

Fig. 5.1 Carlo Salvetti (Copyright: CISE2007)

of official Italian delegations in the Organization for the European Economic Cooperation experimental reactors and power reactors groups and one of their members in 1956–58. He also was a member of the working group of the European Atomic Energy Society.

Salvetti won the public competition for the chair of Theoretical Physics in 1953. He was professor of Theoretical Physics at Bari University in 1954–55; at the same time he was lecturer of Radioactivity at Milan Polytechnic. In 1955 he was the director of the 3rd summer school of the International School of Physics of the SIF on low energy nuclear physics. In 1955 he left Bari University and became full professor of Nuclear Physics at Milan University. In the same year he created the centre of nuclear studies in Ispra and was its director in 1957–59. His career in the organization of nuclear research continued in several Italian and international institutions: director of research and of the laboratories of the International Atomic Energy Agency in 1959–62, member of the Council of Governors of the International Atomic Energy Agency in 1962–64 and 1968–70, vice-president of the direction of the CNRN in 1963–81, president of the EURATOM scientific technical committee in 1969–70, chairperson of the management committee of the nuclear agency of the OECD in 1969–73, president of the Italian Nuclear Society in 1975–80, president of the European Nuclear Society in 1979–81, member of councils and committees of the International Scientific Forum on Energy. In 1981 he moved to Rome University where he worked until his retirement.

Carlo Salvetti died in Rome on February 11, 2005.

5.4.2 Corrado Mazzon

Corrado Mazzon was born in Venice in 1918. He graduated in Physics at Milan University in 1940 with a dissertation on the Wilson chamber. He built the first cloud chamber in Italy and used it on the Plateau Rosa to study cosmic radiation. He pursued his academic career at the Institute of Geodesy of Milan Polytechnic. He was an expert in the topographic instruments and their history (he was the author of a relevant work on Ignazio Porro, an eighteenth-century instrument maker). In the 1970s he left Milan Polytechnic and became professor of Geodesy and Astronomy at the Hydrographic Institute of the Italian Navy in Genoa.

Corrado Mazzon died in 2004.

5.4.3 Carlo Borghi, Piera Pinto, Ermanno Santambrogio

In the 1941–42 academic year, Giuseppe Bolla came back to Milan University as professor of Higher Physics. Carlo Borghi became assistant for the Institute of Physics (Table 5.2) and replaced Giovanni Gentile after his death as lecturer of Theoretical

Table 5.2 Institute of Physics (1941–42)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Experimental Physics II and III
Antonino Mura	Help
Carlo Borghi	Assistant
Piera Pinto	Assistant
Ermanno Santambrogio	Volunteer assistant
Giovanni Adorni	Technician
Mario Pessina	Technician
Olga Bertoli	Adventitious technician
Lazzaro Fumagalli	Subordinate
Teresa Panizza	Subordinate
Giovanni Pesciani	Subordinate
Pierino Scaricabarozzi	Subordinate
Bassano Prada	Subordinate
Chair of Higher Physics	
Giuseppe Bolla	Professor of Higher Physics; lecturer in Spectroscopy; lecturer in Terrestrial Physics
Chair of Theoretical Physics	
Giovanni Gentile	Professor of Theoretical Physics; lecturer in Probability Calculus

Physics and Probability Calculus. Piera Pinto also became assistant and Ermanno Santambrogio volunteer assistant for the Institute of Physics.

Carlo Borghi was born in Barlassina (Monza-Brianza province) on July 3, 1910. He studied at the Classical Lyceum-Gymnasium "Parini" in Milan. He then studied theology at the Gregorian University in Rome, and was ordained a Roman catholic priest in 1933. He was sent to teach algebra at the seminar of Saint Peter in Seveso. His superiors realized his predisposition to mathematics and physics and wanted him to enroll in the degree course in Physics at the Milan University. He graduated in 1940 with a dissertation on the Compton effect of the free neutron, with Giovanni Gentile jr as tutor.

During the war, Borghi was sent to the front as military chaplain to the Italian-French border in 1940–41 with the alpine troops, and to North Africa in 1942 with the Sardinian grenadiers. Due to health reasons, he was sent back to Italy in 1942. Gentile had died a short time before and Borghi was commissioned to replace him in the course of Theoretical Physics. He also taught History of Science at the Catholic Milan University. Borghi worked at the Institute of Physics until the end of the war. His research interests concerned subatomic physics, in particular neutron physics. He studied the interaction of a neutron with an electromagnetic field, the possible production of neutrons from protons and electrons and, viceversa, the decay of a neutron into a proton and an electron when stimulated by a γ-ray in a Compton effect.

He left scientific research to work for some years as a priest in Calco (Lecco). Borghi's subsequent scientific activity started again in a laboratory in Rome (1952–59) and at the University of Recife, Brazil (1960–73). In Rome he studied the production of neutron fluxes from fusion reactions. In Recife he founded and was the director of the Centro de Estudios Nucleares de Universidade de Recife, with researches on the applications of radioactivity to medicine, agriculture and biology. With his collaborators he studied the possibility of the existence of a non-coulombian interaction between a proton and an electron. He continued his studies on neutrons fluxes and observed some interactions which were considered a proof of cold fusion. Due to health reasons he left Brazil in 1973.

Carlo Borghi died on March 30, 1984 in Parma.

Piera Pinto was assistant for the Institute of Physics in the 1940s. She became professor of mathematics and physics at the Scientific Lyceum "Vittorio Veneto" in Milan. She married Carlo Salvetti.

Piera Pinto died in 2021.

Ermanno Santambrogio was born in Seregno on July 12, 1919. He studied at the Classical Lyceum "Zucchi" in Monza and graduated in Mathematics and Physics at the Milan University in 1943. He left the university career after Gentile's death. He was a partisan in the National Liberation Committee. After the war he was professor and dean in several high schools in Northern Italy.

Ermanno Santambrogio died on January 14, 2013.

No new assistants joined the Institute of Physics in the 1942–43 academic year (Table 5.3).

5.4.4 Giorgio Salvini

Also in the 1943–44 and 1944–45 academic years no new assistants joined the Institute of Physics (Tables 5.4 and 5.5). Actually a young Giorgio Salvini was hidden from the fascist authorities in the Institute and could obviously have no official position in it.

Giorgio Salvini was born in Milan on April 24, 1920.[78]

He was a member of the alpine corps; during the war he fought in the Julia division in Jugoslavia. He graduated in Physics in 1942 with a dissertation on the betatron, with Giovanni Gentile jr as tutor.[79] After the 1943 armistice he decided to resist the call of the Italian Social Republic. He was therefore kept hidden in the Institute of

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[78] On Giorgio Salvini, see: [17, 18].

[79] Salvini's dissertation has not yet been found. It might have been an oral "war" dissertation. When interviewed on his dissertation, Salvini always explained that his work was based on Donald Kerst's and Robert Serber's studies. Kerst had built the first betatron in 1940, and Salvini studied how to increase the induction flux.

Table 5.3 Institute of Physics (1942–43)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Experimental Physics II and III
Giuseppe Cocconi	Help
Carlo Salvetti	Assistant
Giovanni Adorni	Technician
Mario Pessina	Technician
Olga Bertoli	Adventitious technician
Camillo Modignani	Subordinate
Vittorio Montipò	Subordinate
Giovanni Pesciani	Subordinate
Chair of Higher Physics	
Giuseppe Bolla	Professor of Higher Physics; lecturer in Spectroscopy; lecturer in Terrestrial Physics
Chair of Theoretical Physics	
Carlo Borghi	Lecturer in Theoretical Physics; lecturer in Probability Calculus

Table 5.4 Institute of Physics (1943–44)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Experimental Physics II and III
Antonino Mura	Help; lecturer in Exercitations of Experimental Physics
Carlo Borghi	Assistant; lecturer in Theoretical Physics; lecturer in Probability Calculus
Piera Pinto	Assistant
Carlo Salvetti	Assistant
Giovanni Adorni	Technician
Mario Pessina	Technician
Teresa Panizza	Technician
Lazzaro Fumagalli	Subordinate
Ignazio Ortelli	Subordinate
Pierino Scaricabarozzi	Subordinate
Bassano Prada	Subordinate
Chair of Higher Physics	
Giuseppe Bolla	Professor of Higher Physics; lecturer in Spectroscopy; lecturer in Terrestrial Physics
Mario Granata	Subordinate

Table 5.5 Institute of Physics (1944–45)

Name	Role
Giovanni Polvani	Director; professor of Experimental Physics; lecturer in Experimental Physics II and III
Carlo Borghi	Assistant; lecturer in Theoretical Physics; lecturer in Probability Calculus
Carlo Salvetti	Assistant
Giovanni Adorni	Technician
Mario Pessina	Technician
Teresa Panizza	Technician
Lazzaro Fumagalli	Subordinate
Pierino Scaricabarozzi	Subordinate
Bassano Prada	Subordinate
Chair of Higher Physics	
Giuseppe Bolla	Professor of Higher Physics; lecturer in Spectroscopy; lecturer in Terrestrial Physics
Giorgio Salvini	Assistant
Mario Granata	Subordinate

Physics by Giovanni Polvani and Giuseppe Bolla. He was assistant at the Institute of Physics in 1944–49. His main research fields were the study of meson interactions in nuclei and of cosmic radiation in extended showers with Bruno Ferretti, Gilberto Bernardini and Gian Carlo Wick. He worked with the CISE in 1946–48.

In 1949 he left Milan and accepted an invitation to the University of Princeton where he studied the scintillation properties of fluorescent solutions and the production ratios of charged and neutral mesons in cosmic radiation. Back to Italy, he became professor of Experimental Physics at Cagliari University in 1951, at Pisa University in 1952–55 and then at Rome University as professor of General Physics.

He was the first director of the National Laboratories in Frascati until 1960. In Frascati, from 1953, he planned and directed the building of the 1100 MeV electrosynchrotron which started to work in late 1958. The electrosynchrotron permitted to study the radioactive decay of the η-meson. He approved the building of another accelerator in Frascati, AdA, the first accumulator ring in the world advanced by Bruno Touschek. AdA started to work in February 1961 and was the prototype of the colliders. After the successful results obtained with AdA, Salvini worked in one of the four experimental groups of another new accelerator, Adone, to study the electron-positron high energy collisions. With the latter machine, in 1974 Salvini and the Frascati team confirmed the discovery of the J/Ψ made at the SLAC in Stanford and in Brookhaven and missed for just one week its discovery. He was president of the INFN in 1966–70. Under his presidentship the Institute obtained its full legal autonomy from political appointments. In 1977–78 he worked at the CERN in Geneva where he studied the proton-antiproton collisions and the mixing between the B and $\overline{B}$ mesons with the UA1 group which detected the W and $Z^{\pm}$ intermediate bosons. In the 1990s he was president of the Lincei Academy and promotor of the Amaldi Conferences for Peace. He was nominated Minister of University and Scientific and Technological Research in 1995-96 in the Dini Government. In this role he reorganized the Italian Space Agency and its collaboration with the European Space Agency.

Giorgio Salvini died in Rome on April 8, 2015.

5.5 Jacopo Dentici, a Physics Student Who Died in Gusen II

When the relation with the Fascist regime and the occupying German troops is to be considered as a matter of life or death, a person related to the Institute of Physics must be considered, Jacopo Dentici (Fig. 5.2) who was a second-year student of Physics when he was arrested and sent to Mauthausen and its sub-field in Gusen II where he died.

Jacopo Dentici was born in Rio Grande, Brazil, on September 11, 1926, the son of two physicians, Salvatore Dentici and Olga Marcella Ferrero. His family moved soon back to Italy, and from 1933 he lived in Voghera (Pavia province). He attended the "Edmondo De Amicis" elementary school and the "Severino Grattoni" gymnasium and classical lyceum. He was a brilliant student, as it is documented by his school report cards. Just like any other person of that time between the ages of six and twenty-one, he was pressured by his school to be a member of a youth movement of the Fascist National Party, the Italian Youth of the Lictor, a paramilitary organization which aimed to train young people for military purposes and to indoctrinate them. He obtained the classical high school diploma in the first exam session of the 1942–43 school year.

In that period he wrote a short manuscript, the "Value and Character of Physical Knowledge",[80] which shows us his deep curiosity in physics, with all the naivety of a 16-year-old young man who read popularizing books written by physicists like Arthur Eddington. It is worth to report it in full, since it is a very rare fact to have such a document written by a teenager student a few months before he started his studies in Physics at university:

> First of all, it is necessary to agree on the meaning of this expression: "physical knowledge". A.S. Eddington, in his book "Philosophy of Physical Science" defines it as the knowledge achieved with the methods of physical science …limited to the knowledge that follows and results from observation". Now, considering the observation as an "unappealable" Court of Appeal to knowledge means attributing a purely subjective value to the results of physics, since different methods of observation, used by different experimenters, can very easily lead to different results: Eddington himself recognizes, as a fact too clearly established to be discussed, that "the Universe revealed by observation …cannot be completely objective" (Op. cit.). Admitting this fact is ultimately equivalent to saying: "We physicists know that

[80] Centro APICE, Scheiwiller Archive: u.a. 5611.

Fig. 5.2 Jacopo Dentici (Copyright: Public image).“The moral law must be brought into the world and into society, it must be implemented as a sacrifice to serve as an example”. “The new civilization must be born of sacrifice, made up of service to society, of self-denial, of accomplished actions and of (self) holocaust”

if we rely only on experience, we will never be able to arrive at an objective vision: but we prefer to renounce the latter a priori rather than our beloved goddess Experience”.

The usual lawyers of lost causes will certainly lash out at me in defense of the modern theories, saying that General Relativity has demolished the inveterate prejudice of the objectivity of the physical world. Just a moment: Einstein’s theory, in its most recent formulation, in no way excludes the real existence of a world independent of our sensations; we only come to affirm the impossibility of understanding this world in its essence if we trust too much in the results obtained from our senses, or from our intellect when working on the sensory data. But to say: “If we continue on this path, we will never be able to get to something good” is, in the end, like postulating the existence of that “something good” to be achieved—that is, out of metaphor, something of absolute, “an absolute goal”, at the end of the path of knowledge: I believe that even the most convinced and irreducible relativist would not dare to argue, for example, that the corrections introduced by Einstein in many physical calculations are destined rather to deny the impossibility to perform these calculations exactly that to increase their precision, and, consequently, their “usefulness” for the purposes of progress: because it is beyond doubt that all physical and scientific researches in general have as their purpose the progress of humanity—be it material and practical as well as spiritual and purely theoretical. It could be objected, with a good dose of pride, that, if progress is to be of the human race, it is useless, and perhaps even impossible, for men to try to cross their limits to reach the abstract and distant world of objectivity: also because this world, for the simple fact of its objectivity, that is, of its complete independence from us, could in no way be useful to us. This reasoning is clearly wrong, for the following two reasons: the first is that a world may not need another to exist, although it is useful, at the same time, and perhaps necessary: we could imagine ourselves, for example, with a very easy analogy but not without efficacy, to the Sun, which can exist even without the Earth, while the latter draws its entire life from solar energy. The second reason is that, even if the Goal had no practical importance for what concerns the "HOMO OECONOMICUS", it would always have an essential one for the "HOMO SPIRITUALIS".

With this reasoning we do not intend to split the human person into "matter and spirit": we arei n fact convinced that this non-existent dualism has been overcome since the great Niels Bohr introduced, in physics and at the same time in philosophy, the concept of "complementarity", the virtue of which, for example, an electron must be looked at now according to the corpuscular model, now according to the wave model, without any contradiction; the idealization of pure wave, like that of pure material corpuscle, is like the two sides of the same coin that complete each other, and can never come into conflict, because when we look at one, the other is out of sight: which we can express with regard to the example given, that is, the electron, with the well-known uncertainty principle. This concept of complementarity, whose importance and fruitfulness is still far from having fully grasped, can also help us to determine (to return to the initial problem) which of the two methods, the empirical or the theoretical, should bring the palm back into research of the Absolute. Certainly not the experimental one, which, as we said before, gives too subjective results; but not even the theoretical one, which is based exclusively on mathematical methods: in fact, as H. Maros dell'Oro[81] says, "behind the calculations there can be everything, or even nothing …; the qualitative element can be reduced to a minimum, but not completely left aside." For example, certainly Heisenberg has introduced a very previous element into modern physics by replacing the material atomic model with the mathematical "matrix" model (in his matrix mechanics the atom is represented by a matrix, that is, by a numerical table in which the values of the spectral lines of the atom): but Lord Rutherford would certainly have been very embarrassed to have to bomb a matrix, without being able to refer to that macroscopic world, whose physical characteristics Heisenberg wished to eliminate in his works, noting, rightly, that many concepts, for example, those of space and time, of our common experiences, no longer hold up when applied to microphysics. Therefore we must conclude that physical knowledge is based on both methods: the theoretical calculation, precisely, will have the task of organizing, coordinating and explaining the results obtained with empirical observation, and also that of predicting the explanation of new phenomena not yet observed experimentally. But, at this point, our physical knowledge would not be complete: it would be a set of purely quantitative, inconsistent and apparently contradictory notions, some not proven by experiments, other not justified by calculation. The resulting Welstanschauung would be a chaotic confusion, and the venerable scientists would roll wildly in the academic arenas defending some one opinion, some another: and all would be right and wrong together.

A similar theory of complementarity in epistemology, which really deserves the widest development, leads us to affirm as necessary the intervention, in physics, of a "conciliatory judge" who finally brings together theorists and empiricists: but, since physical knowledge is no longer the exclusive property of scientists, but it is one of the foundations of the tower that human thought raises to the Truth, it is natural that the conciliatory judge is nothing physical, but rather something philosophical, since there is no doubt that only philosophy can coordinate the various branches of human knowledge. The final picture that would result from the results acquired by means of "complementary" methods would certainly be a more complete and orderly vision of the world. Certainly not—our presumption does not arrive at this—an objective vision: but at least, certainly, more in conformity with the order and unity that we cannot deny to the infinite variety of Nature. Today, it is impossible to predict what this unifying philosophical principle will be: it could be the pure spatiality of relativists,

[81] H. Maros dall'Oro is most probably Angiolo Maros dall'Oro, a professor of history and philosophy. He was the author of many popular books. On physics he wrote: "New Ways to Eddington's Science" (1936), "Relativity Theory" (1937), "The Theory of Quanta" (1937), "Wave Mechanics" (1937).

> or following Schuppe,[82] and immanent solipsism, or a less limited type of structuralism than Eddington's purely mathematical one: what matters today is not to lose ourselves in the apparent contradiction of the phenomena and to keep our faith intact in the intellectual faculties of the human spirit.

After Italy signed the armistice, he became a partisan of the Patriotic Action Groups, in the Piazza Headquarters of Voghera. Dentici was active in the distribution of the underground press, in the collection and distribution of weapons to the partisans, and in the recovery and rescue of the allied soldiers who escaped capture by Nazi-Fascist troops nearby Voghera. Some tens of prisoners where collected by Dentici and other partisans in an abandoned hotel on Mount Bogleglio before an indictment provoked a German roundup [19]. The rescue operations had to stop for ever in that zone.

Dentici enrolled at Pavia University as a student of Physics. The Political Investigative Bureau of the Republican National Guard took into consideration putting him under close observation because he was suspected of being part of a communist cell ([20] p. 79.). He then preferred to leave Pavia to escape from a dangerous situation [21]. He came to Milan in June 1944 and enrolled at Milan Polytechnic as a student of Architecture. In Milan he became a member of the General Command of the Volunteer Corps of Liberty and worked in the Secretary of a partisan leader, Ferruccio Parri. Dentici's name was written at the fifth place in a list of people membership to the Action Party had been ascertained by the Fascist secret service.[83]

He left Milan Polytechnic and enrolled as a second-year student of Physics at Milan University for the 1944–45 academic year.[84] From his university exam records we know that he had only taken two exams—General and Applied Chemistry, and Italian Literature—in May 1944 (i.e. in Pavia), both with full marks.[85] Out of prudence he avoided attending theaters and concerts[86]

On November 7, 1944, he was arrested by the "Ettore Muti" Mobile Autonomous Legion, a paramilitary organization of the Italian Social Republic.[87] Having learned that the secret office was controlled by the fascist militias, they had managed to get most of the documents and money out of time. Dentici was arrested during a last attempt to recover the last documents. He was imprisoned in the Salinas Barracks until the beginning of December. Dentici's signature under the interrogation report cannot be identified: it might be a counterfeiting[88] or a bad writing due to torture

[82] Wilhelm Schuppe (1836–1913) was a philosopher interested in epistemology.

[83] Istituto "Ferruccio Parri", Fondo Ostéria, 9, 01119.

[84] Centro APICE, Historical Archive Milan University: File "Jacopo Dentici" matr 3842, no 20751: letter from Jacopo Dentici to the university rector, September 26, 1944; and Minutes of the Meetings of the Council of the Faculty of Sciences, October 24, 1944.

[85] Centro APICE, Historical Archive Milan University: File "Jacopo Dentici" matr 3842, no 20751: Jacopo Dentici university exams booklet.

[86] Andreani-Dentici Private Archive: letter from Jacopo Dentici to Olga Marcella Ferrero, October 11, 1944.

[87] On the "Ettore Muti" Mobile Autonomous Legion, see: [22, 23].

[88] The report is part of a set of documents given by the adventurous secret agent Luca Ostéria after the war; Ostéria might have forged some of them.

exerted on his hands, one of the torture techniques commonly used by the Muti Legion. Dentici confessed what he could not deny, nothing the legionaries did not already know, otherwise he lied or kept silent details that had to remain secret.[89]

Probably on December 2, 1944, or a few days before, he was handed over to the German troops and imprisoned in the San Vittore Prison, in the cell number 65 of the German radius.[90] He was interrogated and tortured by the Germans, but no interrogation report is known to be extant. He managed to secretly get some short notes for his relatives out of the prison. He had still hope to be saved in some way. In one of these notes[91] he asked to his mother some clothes, food and cigarettes, but also his books and exercise-books; he listed, in particular, Danssen's "Das System der Vedānta", and Dargupita's "A History of Indian Philosophy". In a note to his sister, he wrote that he was quite sure to be deported to the Bolzano lager[92] but he had still the hope "to go away without saying goodbye",[93] i.e. to escape from prison. A few days later, he wrote again to his sister that it was useless to hope for amnesty and that he would have be deported to Bolzano soon after Christmas.[94]

Dentici was imprisoned in the Bolzano lager from January 16 to February 1, 1945 ([25], p. 163). In his last note to his sister, he wrote:

> We will probably leave for Germany very soon. So I'm afraid there's not much more to do. It was not possible for me to escape. The only hope is a very fast request—exchange acceptance. Do what you can but I do not hope any more.[95]

He was deported to Mauthausen where he arrived on February 4[96] and where he stayed until February 17, listed under the prisoner number 126163.[97] The Mauthausen lager was the only third level lager: its prisoners were accused with heavy charges or they were considered irrecoverable. The prisoners had to be exterminated through physical exhaustion with work at the service of the Nazi regime [28]. The

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[89] Istituto "Ferruccio Parri", Fondo Ostéria, 9, 01119.

[90] The San Vittore Prison was built as a panopticon with a central tower and six radiuses. Jewish prisoners were locked up in the fifth radius, and political prisoners in the sixth radius.

[91] Andreani-Dentici Private Archive: note from Jacopo Dentici to Olga Marcella Ferrero, undated. The note might refer to his imprisonment both in the Salinas Barracks and in the San Vittore Prison.

[92] On the Bolzano lager, see: [24, 25, 27].

[93] Andreani-Dentici Private Archive: note from Jacopo Dentici to Ornella Dentici, December 19, 1944.

[94] Andreani-Dentici Private Archive: note from Jacopo Dentici to Ornella Dentici, after December 20 and before 25, 1944.

[95] Andreani-Dentici Private Archive: note from Jacopo Dentici to Ornella Dentici, undated. The last note, written by Dentici at the end of January, just before leaving to Mauthausen, is published in: [26] p. 231.

[96] He was handled over to the Mauthausen lager by the Security Policy (Sipo) of Verona. National Archives and Records Administration: WWII Captured German Records, Mauthausen, Camp Records, Inmate Cards, Records on Prisoners Boh-Gas, 2089: Jacopo Dentici Häftlings-Personal-Karte.

[97] Mauthausen Memorial Archive, AMM/Y/36b. International Tracing Service, Bad Arolsen: 1.1.26.1; ID 1310532.

prisoners extermination was organized to be economically advantageous. An estimate calculation made by the SS Economy Division considered an average daily income of 6,00 Reichsmark to rent the prisoner to an industry, from which to deduct 0,60 RM for food and 0,10 RM for the clothes depreciation. Assuming an average life of 9 months or 270 days, the total income to the Lager administration was 1.431,00 RM. The rational exploitation of the dead body (e.g. the extraction of gold teeth) would have granted other 200,00 RM, for a total income 1.631,00 RM. This obscene calculation continued with the deduction of 2.00 RM for the cremation costs and the extra income from the possible use of bones and ashes as fertilizers ([29] p. 24).

On February 17, 1945, Dentici was shifted to the Gusen II sub-lager.[98] There the prisoners had dug huge tunnels in the Bergkristall-Bau to host the production plants of Steyr-Daimler-Puch, and Messerschmitt AG, and the research laboratories on the V1 and V2 rockets. Dentici died in Gusen II on March 1, 1945. His official death cause, reported at 6.10 a.m., was weakness of the heart muscle and pneumonia.[99] According to a declaration act issued by two witnesses, Anillo Venari and Osvaldo Bolluoni, to the Milan district court, Dentici fell ill in Gusen II.[100] According to Franco Trivini Bellini, Dentici worked as a digger in the tunnel and died about the middle of March of mistreatment and dysentery ([32] p. 118.). According to colonel Antonio Pais he died at the end of March. Both these reminiscences disagree with the official death date as reported in the Gusen II Dead Book and should be considered just a bad memory of a chronological detail.

After the end of the war, a memorial plaque with an urn containing some ashes of the Gusen crematorium was erected in the Voghera cemetery. In Voghera Dentici is remembered every year with a ceremony together with other Voghera people fallen for freedom. Marshall Alexander, of the supreme allied command of the central Mediterranean forces, signed the patriot certificate which attested that Dentici had the right to be acclaimed as a patriot who had fought for honor and freedom.[101] The Volunteers for Freedom Corps similarly authorized Dentici to wear the commemorative medals of the partisan formations of the Oltrepò Pavese.[102] Reminiscences on Jacopo Dentici by Ferruccio Parri and other partisans kept alive his memory[103] besides being listed in all historiographical works on the partisans in the Pavia province and on the deported people who died the Nazi lagers.[104] In 1946 he was awarded the honorary degree by Milan University.[105] In 1952, the Physics Room of the "Severino Grattoni" Lyceum

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[98] On Gusen, see: [30, 31].

[99] Mauthausen Memorial Archive: AMM1.1.6. International Tracing Service, Bad Arolsen: 1.1.26.1.; ID 1291586: Gusen Totenbuch.

[100] Andreani-Dentici Private Archive: draft of the declaration act to the Milan district court, undated.

[101] Andreani-Dentici Private Archive: "Certificato al Patriota alla memoria Dentici Jacopo", no 231279.

[102] Andreani-Dentici Private Archive: Corpo Volontari della Libertà, April 25, 1947.

[103] See [33–35].

[104] See [20, 25, 32, 36–41].

[105] Andreani-Dentici Private Archive: Jacopo Dentici's honorary degree diploma, November 1, 1946.

was named after Jacopo Dentici.[106] Dentici's translation of Euripides's Cyclops was published in 1955 [42]. Some poetry written by Dentici were collected by his sister and published with the title "Le ali del nord" (The North wings)[107] in 1958 [43] and in a second edition in 2000 [44]. A street in Voghera was named after him, as well as a prize awarded by his Lyceum. Dentici is mentioned in the documentary "Jacopo—oder: Was bleibt? (Unsterbliche Überreste) by Angela Huemer (OmdtU, 2016), shown at the "Der neue Heimatfilm" film festival. A memorial Stolperstein (stumbling stone) as a victim of Nazi extermination was posed at the entrance of the his lyceum on January 23, 2019.

The students' study room of the Physics Department of Milan University was named after Jacopo Dentici on the anniversary of his death on March 1, 2019.

5.6 Research Activities During the Second World War

Besides Gentile's studies in theoretical physics (see Chap. 1) and a collaboration with two assistants of the Faculty of Medicine, Federico Fanucchi and Livio Bussi, on the action of ultrasounds on tumor tissues [45], the researches during the Second World War concerned cosmic ray physics. The researches were carried out in difficult conditions since, differently from the Rome case, the war lasted in Milan until its very end in April 1945. Not only the male researchers were often away from Milan for military reasons, but also economic and movement restrictions did not favor scientific activity. The experimental studies on cosmic rays, however, could continue and reached relevant results.

In January 1939, Polvani asked Ugo Bordoni, president of the Physics Committee of the CNR, to finance the project of building a cloud chamber. He also asked Giacinto Motta, president of the Edison Company, for the same reason. The first cloud chamber was so successfully financed. The project was planned by Corrado Mazzon as his graduation work with Cocconi as tutor. The cloud chamber was built with the help of Giovanni Adorni and Mario Pessina and was ready in July 1939. Some components for the automatic recorder were completed by Cocconi in 1941 after Mazzon left Milan for his military duties [46]. The first cloud chamber was a 25 cm diameter, 5 cm depth cylinder, filled with air saturated with a 1:3 water-alcohol mixing (in a second time it was filled with argon to avoid vapor condensation on the glass walls). The chamber was controlled by a coincidence system of Geiger–Müller counters. It was the first cloud chamber built in Italy, and for some years it was the only one working at high altitude. This cloud chamber was donated to the National Museum

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[106] Andreani-Dentici Private Archive: Speech by Don Preti in the Grattoni Lyceum in Voghera, January 31, 1952.

[107] From a verse "Ma le ali del Nord/versano veleno/su gli appassiti volti di chi spera" (But the North wings/pour poison/on the withered faces of those who hope) in the poetry "Versano veleno" (They drop poison), [43] p. 22.

of Science and Technology “Leonardo da Vinci” where it is currently on permanent exhibition (Extreme exhibition on particle physics).

The cloud chamber was used in 1941 with a set of four counters in coincidence [47] to check its good operation in the detection of cosmic showers at sea level [48]. Cocconi then used it to study the showers generated by the mesonic component in different materials. The absorber was put above the cloud chamber; its role was also to absorb the secondary electrons. Furthermore the measurements were made inside the Institute of Physics, i.e. with another set of absorbers given by the ceilings of the rooms above the chamber. 543 photographs contained useful tracks for the analysis of the radiation tracks. The photographs helped Cocconi in understanding the nature of the secondary showers from mesons and of the extensive showers in air [49, 50].

In 1940 Gentile suggested to make cosmic ray measurements again at high altitude. Polvani asked and obtained a financing from the Committee for Geophysics and Meteorology of the CNR for a campaign of measurements at Passo Selva (Bolzano province) at 2200 m above sea level during the summer 1940 [51, 69]. In Milan they tested a set of counter telescopes for the determination of the ratio between the electronic and the mesonic components. They did not observe an equilibrium between the two components at sea level but only under 12 m water [52]. The first set of measurements in Milan showed that the ratio depended on the inclination of the counter telescopes. The cloud chamber was then taken to Passo Sella where it was placed in a hut of the Italian Alpine Club. The measurements were taken for different inclinations from 0° to 71° and with lead and iron absorbers. The dependence of the e/m ratio from the angle was explained with a diffusion effect. The ratios found were in good agreement with the results found by the Rome group. The cloud chamber was taken back to Passo Sella next summer for a confirmation of the 1940 results [53], in particular that the diffusion effects were sensitive only for inclinations above 60°. A puzzling fact that they observed in 1940 was relation of the electronic component (and of the electronic/mesonic ratio) and atmospheric pressure [54].

In 1941 more and more evidence showed that the primary cosmic radiation was not made of electrons but of positive particles. Cocconi supported the latter idea [55] based on the known azimuth and zenith anisotropies and proposed that the primary radiation was made of protons. By interaction with the nuclei in high atmosphere they could generate the hard secondary component (mesons), which could generate the electronic component and the showers. A minor component of the primary radiation was instead made of primary electrons to explain the barometric effect. To test this model, Cocconi and Tongiorgi performed new measurements at Passo Sella [56, 57] but their results were not conclusive. The zenith curves were taken with a set of counters [58] and showed a regular behavior according to a proportionality to $\cos 2\theta$ [59, 60].

At Passo Sella in 1940, Cocconi and Tongiorgi carried out some measurements on extensive air showers and found results in good agreement with those found by Auger, Maze and Fréon. Then in the summer 1942 they decided to look for mesonic showers in an extensive air shower with the help of a student, Andrea Loverdo [61]. They found an experimental confirmation of the generation of mesonic showers in extensive showers with $10^{11} - 10^{14}$ eV. A 100 day long campaign of measurements was made in the summer 1943 [62, 63] and observed that in an extensive air shower there were always mesonic showers besides the electronic showers. In the 1942 and 1943 summers, they also studied the relation between the distribution of extensive air showers and their particle density [64–66]. The spectrum of extensive air showers was measured also in Milan in the difficult months between February and November 1944 [67, 68], and compared with the spectrum obtained by the date collected at Passo Sella. They confirmed that the radiation generating the extensive showers started with electrons, but they did not get any indication on the nature of the primary radiation.

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Chapter 6
The Institute of Physics in the Post-War Period. Part 1: The Reconstruction

Leonardo Gariboldi

Abstract After the end of the war, Giovanni Polvani was engaged in a double activity of reconstruction: of the Institute of Physics in Milan and of the physicists community in Italy. He was elected president of the SIF: he started to organize a national congress every year, started the International School of Physics in Varenna, and succeeded in making the society's journal, *Il Nuovo Cimento*, a physics journal on an international level. The Institute of Physics saw the arrival of two professors, Piero Caldirola for Theoretical Physics, and Giuseppe Occhialini for Higher Physics, who decided to work with Polvani as one institution, which was renamed Institute of Physical Sciences. Three other professors joined them in the 1950s—Carlo Salvetti for Radioactivity (later Nuclear Physics), Ugo Facchini for Experimental Physics II, and Guido Tagliaferri for Radioactivity—not to mention a large number of assistants who, in many cases, pursued a brilliant academic career at Milan University or in other Italian or foreign universities. The Institute of Physics stimulated the industrial milieu in Northern Italy to support researches in nuclear physics and technology for the possible construction of a nuclear power plant. A research institution, the CISE, was established in 1946 and for a decade worked in a strict symbiosis with the Institute of Physics. In 1952 Polvani managed to host in Milan the fourth division of the newly established INFN which helped his researchers to work in national and international collaborations, in particular in cosmic rays physics with Occhialini and at the CERN. An important step in Polvani's activity in finding financial supporters for the research activities of the Institute of Physics was the establishment of the GAIFUM.

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6.1 The Reconstruction in Milan

The post-war period was a time of reconstruction,[1] in particular in Northern Italy where the war lasted until 1945. Milan was heavily bombarded by the allied air forces. Many infrastructures had to be rebuilt: industries, transport services, communication routes. In 1947 the Bank of Italy estimated that the industrial production capacity was damaged of only about 8% with respect to the pre-war level.[2] Italian economy was still mostly based on agriculture[3] so that economic policy could not only rebuild, but above all build the development of the industrial system. In parallel with the dismantling of fascist corporatism and of the protectionist system, the lack of energy sources and raw materials pushed Italian economic policy to accept and support the liberalization of international trade among the countries of the European Organization for the Economica Cooperation. This was the first step to the subsequent policy to support the establishment of other European organizations, in particular the European Coal and Steel Community established by the Treaty of Paris in 1951, the European Economic Community established by the Treaty of Rome and the European Atomic Energy Community established by the EURATOM Treaty in Rome both in 1957.

The harsh political divisions among the Italian people had to be healed with an analogous reconstruction of the Italian society. Similarly, the scientific institutions had to be reconstructed in both the material and social aspects. Instruments and people of the Institute of Physics which were hidden or dispersed during the last years of the war could eventually return to that their right place in Milan. Polvani was a fundamental actor under this point of view. His action cannot be understood in the due way if we ignore his contribution to the reconstruction of Italian physics as a whole and limit ourselves only to the Institute of Physics in Milan.

Polvani was among those physicists who reconstructed the SIF. The society had actually stopped to work for a few years during the war. In a meeting of Italian physicists in Bologna in the spring 1946, they decided to restart the society and elected Polvani as president of the SIF.[4] He acted in this role until 1961. The conditions of the SIF, in Polvani's own words, were these:

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[1] The reconstruction period in physics was considered by Edoardo Amaldi in a conference he held in 1978 [1]. He started it with the allied troops entering Rome and ended it just before the end of 1954. The notion of "reconstruction" is debatable since in most cases Italian physics was constructed and not reconstructed. We might question if the Rome school was reconstructed even if Fermi did not come back from the US to restart studies in nuclear physics. In the Milan case, I use the word "reconstruction" since Polvani restarted to work on his main aims: having a research group working on fundamental topics (in this case, cosmic ray physics), trying to build an accelerator in Milan, increasing the number of professors, having a new larger seat to properly host all the scientific activities. These aims were reached between the 1950s and the early 1960s. For this reason I consider the Reconstruction period concluded with the moving to the new seat in Via Celoria and the building of the relativistic cyclotron.

[2] The industrial capacity during the war also increased due to the investments made during the war especially in the military sector.

[3] Only 30% of the workforce was engaged in industry.

[4] On the history of the SIF, see: [2].

> the journal [Il Nuovo Cimento] had not been printed for a year, the members and subscribers were reduced to forty-four in all. Since the end of 1947 the journal has regularly resumed its publications, the members and subscribers have risen overall to more than five hundred. With gratitude we recall that the University contributed, with an extraordinary assignment of 25,000 lire, to the rebirth of the Society. Today it distributes prizes and scholarships for more than a million, organized in the years 1947, 1948 two very successful national physics congresses (in Como and in Lecco); it is organizing two international congresses in the current year (one in Florence[5] and one in Como[6]), which are already guaranteed the participation of the highest personalities of the international scientific world.[7]

Under his presidency, the official journal of the society, Il Nuovo Cimento, became quickly a journal of international importance, in particular for the publication of articles in English of the international collaborations, which involved also the team of the Milan Institute of Physics, working in cosmic rays physics. Again during Polvani's presidency, in 1953 the SIF founded the International School of Physics in Varenna [5], a summer school which every year convenes some of the most important physicist the world over to talk about a given topic. The consequences of Polvani's activity for the SIF were extremely positive also for the Institute of Physics:

> Although these activities are outside the scope of the University, they bring great prestige and advantage to the Institute: this in fact comes to be in close contact with all Italian physicists, and practically follows their activity, which is demonstrated from the fact that all the original works of Physics published in these last two years in Italy have been included (except three or four of lesser importance) in the Nuovo Cimento.[8]

Polvani's role on Italian culture went beyond physics when he was elected president of the CNR in 1960. He worked on a reform law which introduced the humanities researches in the CNR.

A relevant aspect of the new post-war research teams in Milan was, in some cases, the transition to big science.[9] If this aspect is obvious as for the participation of Milan physicists to the CERN,[10] it was nonetheless important also for those research fields which experienced a transition to big science in the Fifties. This is particularly evident in the Milan team working on cosmic radiation with nuclear emulsions.

The international character of the scientific activity in the researches on cosmic rays physics became more evident showing, particularly after the Second World War, a transition to more and more complex internal structures that can be described as an evolution to a big science practice. The gradual changes in some aspects of cosmic rays physics can be analyzed as in their parallel counterparts: particle physics

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[5] International Conference on Statistical Mechanics, held in Florence, May 17–20, 1949. [3]

[6] International Conference on Cosmic Ray Physics, held in Como, September 11–16, 1949. [4]

[7] Centro APICE, Historical Archive Milan University: serie 7, busta 77, Scienze: "Relazione sull'attività dell'Istituto di Fisica dell'Università di Milano dalla sua fondazione ad oggi e sulla sua situazione attuale", February 2, 1949: pp. 11–12.

[8] Centro APICE, Historical Archive Milan University: serie 7, busta 77, Scienze: "Relazione sull'attività dell'Istituto di Fisica dell'Università di Milano dalla sua fondazione ad oggi e sulla sua situazione attuale", February 2, 1949: p. 12.

[9] On the transition from Little Science to Big Science in 1945–60, see: [6].

[10] On the Italian participation to the foundation of CERN, see: [7, 8].

experiments carried on with accelerating machines [9, 10] and space physics [11]. Starting from a typical laboratory organization of little science, where experiments on cosmic rays were carried out by one or few people who built most of their own apparatuses themselves,[11] we can identify a transition period with the researches with nuclear emulsions in the Forties, leading to the great European collaborations in the Fifites.

Cosmic rays physics in the mid 1950s showed the emergence of some characteristics typical of big science. The necessity to create a network of laboratories, joint in an international collaboration, implied an increasing role of the collaboration directors as the leading decisional actors, instead of scientists not devoted to the solution of organizing and bureaucratic problems. The intrinsic qualities of scientific research required more and more an industrial approach to the production of the devices bought from industries (nuclear emulsions, for instance, were bought from Kodak or Ilford), versus a in-house craft-work. The team composition in such networks of scientists implied also the increasing engagement of engineers and non-scientific actors.

The period of time concerning this suggested transition of cosmic rays physics from little science to big science overlaps with the beginning, after the Second World War, of what Cohen [13] proposed as a possible fourth Scientific Revolution. The two main features of Cohen's analysis are the expenditure of large sums of money by governments to support scientific research, and the conduction of scientific research in groups. Cohen traced back these two features to the researches on the invention of the atomic bomb and on the development of antibiotics, both carried on during the Second World War. After the Second World War, the lack of a governmental financial support might prevent the mere possibility of carrying on research in high-energy physics and in space science.

Although the governmental financial support was well important in space research, it was not the case in cosmic rays physics in the 1950s. However, as we shall see in the chapter on post-war cosmic rays researches, the organization of flights of balloon carrying stacks on nuclear emulsions required the collaboration with public or governmental institutions, such as the Italian Navy and Air Forces. Another feature, which is not the very same of Cohen's second suggestion, was the greater number of people involved; let us just think to the microscopists necessary to scan a stack of nuclear emulsions. the increasing number of researchers working on a same subject in different cooperating teams is clearly shown by the equally growing number of signatories of the published scientific papers. Furthermore, non- and para-scientific institutions were more and more involved in side aspects of the current researches, as it is shown in a very simple way by the longer and longer acknowledgements at the end of the papers.

The Milan team of cosmic physicists working with nuclear emulsions and led by Beppo Occhialini can in this way considered as a working actor of the transition of cosmic rays physics from little science to big science on the basis of six noteworthy features:

[11] See, for instance, for the researches in the Cavendish Laboratory [12], in particular on page xxxiii.

(a) the growing number of researchers and assistant: from a few people to tens of scanners and researchers;
(b) the internationalization of the research team: whereas the pre-war team (which worked with cloud chambers) was a small isolated team with a strong national connotation (it hosted only a student of Greek origin), the nuclear emulsion team was a member of a research network of different countries since the very beginning;
(c) increasing technological development: from the home-made cloud chambers of the pre-war team to nuclear emulsions produced by industries and the consequent loss of control of every aspect of their production by the scientists;
(d) the transition from a university-only laboratory to groups of laboratories and extra-university institutions;
(e) the birth of a functional network of communication among the different teams (an example is the bulletin started by Cosyns and Occhialini in Brussels);
(f) the transition from a view of the world made by a few elementary particles which interact only by means of electromagnetic forces to a more complex view as represented by the Standard Model.

Nuclear physics was another field which was supported by Polvani for the development of the Institute of Physics. In a later section we shall see the strict collaboration of the Institute of Physics with the CISE, a research institute founded after the war to study the pacific exploitation of nuclear energy, and with the INFN, whose local division was founded thanks to Polvani's insistence. Polvani and Edoardo Amaldi in Rome were the two scientific policy makers who reconstructed Italian Physics. They met in Como, at the first post-war SIF national congress on the second centennial of Volta's birth on November 10–12, 1945 [14, 15]. Back from Como, Amaldi was in Milan where he met Luigi Morandi, a chemical industrial and commissary of Montecatini. After this colloquium, Amaldi wrote a report on "Nuclear Physics and Its Applications".[12] The report was sent to Morandi and Vittorio Valletta, the chief executive officer of FIAT. Amaldi's report was functional to the establishment of the CISE and to a gentlemen's agreement between the physicists of Milan and Rome. They decided to collaborate in the development of Italian physics and to avoid any rivalries. The Milan physicists would have been engaged with applied research, in particular low energy or nuclear physics, whereas the Rome physicists would have studied fundamental research in high energy or particle physics. This agreement was based on the different local economical-industrial reality and on a different tradition of scientific interests. The Lombard industrial milieu would have interacted with the

[12] University of Rome "Sapienza", Physics Archives, Amaldi Papers, i9: Amaldi gennaio 1946: "Rapporto di E. Amaldi a Morandi e Valletta. Gennaio 1946". The report describes the use of nuclear energy and other applications of nuclear physics, the development of nuclear physics in various countries, the relations between scientific and practical problems, and some fundamental points for the organization of the researches of nuclear physics and its applications. As an appendix, Amaldi listed twenty-nine Italian physicists who had published at least one scientific work in nuclear physics and did not change their field of research. The physicists who had or would have worked at the Institute of Physics in Milan were: Piero Caldirola, Giuseppe Cocconi, Bruno Ferretti, Carlo Salvetti, Giorgio Salvini, and Vanna Tongiorgi.

Milan Institute of Physics (and the CISE) for the pacific use of nuclear energy with researches on nuclear physics and technology, while the Rome Institute of Physics, traditionally financed mostly by the State, would have continued Fermi's tradition of researches in fundamental physics and studied particle physics.

The strict collaboration with the CISE and the INFN, and later the participation of Milan physicists at the research projects at the CERN, was also the evident sign that it was impossible in many cases to develop relevant research projects in physics by making use of only the people, instruments and laboratories at disposal of any university institute of physics. The limited financial support to some projects coming from the CNR, as it happened before the Second World War, could not be anymore the way to make Italian physics flourish and compete on an international level. Polvani's scientific policy both in Milan and on a national level, when president of the SIF and of the CNR, was a fundamental contribution to the evolution of Italian physics.

Furthermore the development of the Institute of Physics in the 1950s brought the number of professors, lecturers, assistants, technicians and administrative personnel so high that, with the INFN personnel, made more and more urgent the search of a new seat. In 1947–48, the rector Felice Perussia made build some more rooms for the Institute of Physics, but that was a very temporary relief. The need of space became a problem in a short time. In his Reminiscences [16], Polvani recalled that an office for one person hosted usually from three to five people. They used any space at disposal—basements, cellars, corridors, and landings, even toilets illegally adapted to the new use—for research activites.

6.2 The Degree Course in Physics

The degree course in Physics saw in the Reconstruction time[13] the introduction of some teachings, such as Radioactivity or Solid State Physics, which reflected the new research field of the Institute of Physics. The new teachings but were just added to same global structure of the degree course which was changed only with the reform on July 26, 1960.

No extant documents let us know at the moment which textbooks were used with the exception of the handbooks written by the professors themselves. Polvani's books of Experimental Physics were actually the transcription of his lectures made by Carlo Salvetti. They concerned mechanics, the kinetic theory of gas, vibrations, and thermodynamics. With respect to the textbooks of Experimental Physics commonly used in Italian universities before the Second World War, Polvani's ones are characterized by a greater use of mathematics of a university level, following a use introduced by Egidio Perucca.

The number of freshmen (Table 6.1), with two minor exceptions, steadily increased from a total number of 14 students in the 1946–47 academic year to 177 in 1961–62.

[13] On the teaching of physics in 1945–65 see: [17].

Table 6.1 Number of freshmen in 1946–1962

Academic year	Male	Female	Total
1946–1947	9	5	14
1947–1948	6	4	10
1948–1949	13	14	27
1949–1950	19	13	32
1950–1951	19	7	26
1951–1952	22	19	41
1952–1953	22	14	36
1953–1954	29	19	48
1954–1955	27	19	46
1955–1956	60	23	83
1956–1957	57	19	76
1957–1958	94	37	131
1958–1959	126	45	171
1959–1960	114	45	159
1960–1961	113	38	151
1961–1962	143	34	177

This increasing number shows how attractive was considered this degree course to young people who were then mostly interested in continuing their career as scientists in a research institute. Also the total number of students (Table 6.2) enrolled to the degree course in Physics increased from 97 (inclusive of the undergraduates who had not completed the degree course in four years) to 756 in the same period of time. If Polvani considered the students as the life of an institute, at the same time these large numbers were a nightmare for an institute with very limited space for classroom and didactical laboratories. The search for a new, much larger seat became more and more impelling during the 1950s. In his 1949 special report, Polvani described the very bad situation, even if an enlargement had been occurred a couple of years before:

> The whole life of the Institute took place, in the nineteen years of the direction of prof. Polvani, in the most painful distress of the premises. Suffice it to say that three tenured professors, five assistants, three coadjutors, three technicians, to which the students must be added, had to work scientifically and didactically, in only three rooms equipped as a laboratory, in two classrooms (one with one hundred and forty seats and one with twenty-five places), in a cellar for the exercises, in a very small workshop, and in five rooms used as management, library and office.
>
> It should be added that the Institute, being placed below that of General Chemistry, had until last year, that is for at least 18 consecutive years, to enjoy annually those five, six, seven, eight floods a year produced by water. coming from the overlying Institute of Chemistry, more or less filthy and more or less smelly such as are suitable for a Chemistry Institute and latrines. This filth has been removed, we hope forever, only a year ago: praise be to the administrators of the University.

Table 6.2 Total number of students[a] in 1946–1962

Academic year	Male	Female	Total
1946–1947	40 (62)	29 (35)	69 (97)
1947–1948	32 (52)	22 (29)	54 (81)
1948–1949	33 (53)	29 (38)	62 (91)
1949–1950	42 (55)	32 (39)	74 (94)
1950–1951	63 (72)	24 (30)	87 (102)
1951–1952	80 (91)	41 (45)	121 (136)
1952–1953	78 (102)	44 (55)	122 (157)
1953–1954	90 (106)	48 (57)	138 (163)
1954–1955	108 (123)	55 (66)	163 (189)
1955–1956	155 (169)	64 (74)	219 (243)
1956–1957	187 (215)	63 (80)	250 (295)
1957–1958	249 (286)	82 (103)	331 (389)
1958–1959	319 (366)	103 (130)	422 (496)
1959–1960	370 (402)	121 (146)	491 (548)
1960–1961	404 (486)	131 (150)	535 (636)
1961–1962	501 (595)	134 (161)	635 (756)

[a] The numbers between parenthesis are inclusive of the undergraduate who have not completed course in due time

> For the Institute of Physics, some improvements and building expansions are currently underway: precisely the large classroom has already been enlarged, bringing it from 140 to 400 seats, and a new building is nearing completion which, together with the old one of the Institute, will allow a less narrow breath to those who have to live in it.
>
> But these improvements and extensions, useful, indeed precious, of course, to temporarily alleviate an extremely painful situation, unfortunately reduce the probability and the hope of being able to build a new Physics Institute in short years that fully corresponds to the scientific and didactic needs of the University and Milan.[14]

Polvani's dream of a new building became a reality in the early 1960s.

The degree course was but a very hard one. The number of graduates (Table 6.3) for the same period of time shows an increase from 8 to 35, but each number has to be compared with the number of freshmen of four academic years before. Even if it is not possible to associate the undergraduate who had not completed the course in four years to a given year more than four years before, it is evident that less than half the freshmen concluded their studies with a graduation exam. The students who succeeded to graduate in physics had a very good training which can be seen in the academic career in Italy and abroad of many of them. They sat on the shoulders of teachers—such as Polvani, Caldirola, Salvetti or Occhialini—who were true masters of their respective disciplines.

[14] Centro APICE, Historical Archive Milan University: serie 7, busta 77, Scienze: "Relazione sull'attività dell'Istituto di Fisica dell'Università di Milano dalla sua fondazione ad oggi e sulla sua situazione attuale", February 2, 1949: pp. 13–14.

Table 6.3 Number of graduates after in 1946–1962

Academic year	Male	Female	Total
1946–1947	5	4	8
1947–1948	1	0	1
1948–1949	5	3	8
1949–1950	6	4	10
1950–1951	5	5	10
1951–1952	2	3	5
1952–1953	7	0	7
1953–1954	5	4	9
1954–1955	11	6	17
1955–1956	9	6	15
1956–1957	11	8	19
1957–1958	7	5	12
1958–1959	17	4	21
1959–1960	21	10	31
1960–1961	16	14	30
1961–1962	23	12	35

6.3 The People

The constant growth of the number of people working at the Institute of Physics during the Reconstruction time, even if corresponding to a similar trend in the physics groups in some of the other Italian universities, was the result of Polvani's ability in organizing a scientific institution as an attractive workplace for young graduates and professors. Polvani succeeded in covering in a short time all the chairs at disposal with new professors when they were left vacant (e.g. Occhialini replacing Bolla on the chair of Higher Physics, or Caldirola replacing Ferretti on the chair of Theoretical Physics) and in obtaining new chairs (e.g. the chairs of Radioactivity and Nuclear Physics). The largest increase can be observed in the number of assistants.

The very fact that the three chairs (Experimental Physics, Higher Physics, and Theoretical Physics) had already worked as one institute of physics was formalized on February 1, 1952, when Caldirola, Occhialini, Polvani and the rector De Francesco signed a pact[15] stating their willingness to be considered as one institute. The Institute of Physics (which was, strictly speaking, the institute corresponding to the chair of Experimental Physics) changed therefore its name into Institute of Physical Sciences.

As a matter of public recognition from the scientific community it is worthy to mention the international prizes awarded to people who worked and/or were educated in the Institute of Physics during the Reconstruction time. The most known prize, not only in popular culture, is the Nobel Prize. One student of the Institute of Physical

[15] It was called the "Paris pact" since the last signature was written in Paris.

Sciences, who worked in the cloud chamber group before moving to the United States, Riccardo Giacconi was awarded the 2002 Nobel Prize for Physics "for the pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources".

The Wolf Prize in Physics was awarded twice to physicists connected to the Institute of Physical Sciences. Riccardo Giacconi was awarded the 1987 Wolf Prize in Physics with Bruno Benedetto Rossi "for the discovery of extra-solar X-ray sources and the elucidation of their physical processes". Giuseppe Occhialini, who was Giacconi's tutor in Milan, was awarded the 1979 Wolf Prize in Physics "for his contributions to the discoveries of electron pair production and of the charged pion", two research activities which he had pursued in Great Britain respectively in Cambridge in the 1930s and in Bristol in the 1940s.

Two prizes awarded for researches performed while working at Milan Universities are the Enrico Fermi Prize, awarded by the SIF, and the Bruno Pontecorvo Prize, established by the Joint Institute for Nuclear Research in Dubna, Russia.

The 2017 Enrico Fermi Prize for Physics was awarded to Gianpaolo Bellini "for the measurement of the solar neutrino spectrum, providing the evidence for nuclear hydrogen fusion in the Sun and for adiabatic neutrino flavour conversion in matter." The 2011 Enrico Fermi Prize for Physics was jointly awarded to Antonino Pullia and Dieter Haidt "for their fundamental contribution to the discovery of the weak neutral currents with the Gargamelle bubble chamber at CERN." The 2007 Enrico Fermi Prize for Physics was awarded to Ettore Fiorini "for his contribution to the discovery of weak neutral currents and to the study of solar neutrinos."

The 2016 Bruno Pontecorvo Prize was awarded to Gianpaolo Bellini "for his outstanding contribution to the development of detection methods for low-energy neutrinos, their realization in the Borexino detector, and the important results on solar and geoneutrinos provided by the experiment. The 2013 Bruno Pontecorvo Prize was warded to Ettore Fiorini "for his outstanding contribution to the search for neutrino-free double beta decay."

These prizes show how Milan University contributed to the development of particle physics in a wide range of research topics and necessarily in an international context of large collaborations with research institutions such as the CERN and the INFN.

6.3.1 1945–46: Guido Tagliaferri, Alberto Masani, Bartolomeo Todeschini, Luisa Basilico

The Institute of Physics was joined during the 1945–46 academic year by Guido Tagliaferri as assistant, Alberto Masani, Bartolomeo Todeschini and Luisa Basilico as volunteer assistants. Only Tagliaferri had his career as professor at Milan University where he played an important role in cosmic ray physics, nuclear physics and history

Table 6.4 Institute of Physics (1945–46)

Name	Role
Director	Giovanni Polvani
Professors	Giuseppe Bolla[a] (Higher Physics); Giovanni Polvani (Experimental Physics)
Lecturers	Giuseppe Bolla (Spectroscopy); Antonino Mura (Exercitations of Experimental Physics II); Giovanni Polvani (Experimental Physics II); Carlo Salvetti (Theoretical Physics); Giorgio Salvini (Exercitations of Experimental Physics I)
Help	Antonino Mura
Assistants	Carlo Salvetti; Giorgio Salvini[a]; Guido Tagliaferri
Volunteer assistants	Luisa Basilico; Alberto Masani; Bartolomeo Todeschini
Technicians	Giovanni Adorni; Mario Pessina; Teresa Panizza
Subordinates	Lazzaro Fumagalli; Mario Granata[a]; Bassano Prada; Pierino Scaricabarozzi

[a] Chair of Higher Physics; in this and in the following tables, the people whose name has no alphabetic suffix (as specified in the note) were working for the Chair of Experimental Physics

of physics; he became professor of Radioactivity (an old name for Nuclear Physics) starting from the 1960–61 academic year (Table 6.4).

Guido Tagliaferri[16] was born in Rome on January 27, 1920. He studied at the Normal School of Pisa. He graduated in Physics in 1942 with a dissertation on spectroscopic researches in the far infrared, with Luigi Puccianti as relator. Pucciani suggested him to become assistant to Giovanni Polvani at the Institute of Physics of Milan University. In Milan he was a member of the research group on cosmic radiation. He studied the extensive showers, in particular he conducted the experimental studies and checked the electronic components of the detectors used at sea-level and on high mountains. His expertise in the use of the cloud chamber led him to work with it in an international context. He built an overcompression chamber at Birmingham University in 1956 and worked with the multiplate cloud chamber at Princeton in the late 1950s. From Princeton he went on license to the Brookhaven National Laboratory as a member of the scientific staff of the Cosmotron Department.

Back to Italy, Tagliaferri won the public competition for the chair of General Physics of Parma University in 1959 and of Experimental Physics of Bari University in 1960, but he accepted the call to the chair of Radioactivity at the Institute of Physical Sciences of Milan University. In collaboration with the local division of the INFN he worked at the construction of an azimuthally variable magnetic field cyclotron which worked from 1965 until the early 1980s.

[16] On Guido Tagliaferri, see: [18].

In 1979 Tagliaferri moved to the first chair of History of Physics of Milan University. His first main work concerned the history of quantum mechanics from the internal historiography point of view. He played a fundamental role in preventing the dispersion of the historical heritage of the Astronomical Observatory of Brera, entrusting the safeguard project to Pasquale Tucci. The documents of the current Historical Archives were reorganized and inventored, and the historical instruments were catalogued and put on display in the current Brera Astronomical Museum. He also promoted coordination between research activities in the history of physics groups in Italy. He was the first chairperson of the National Coordination Group for the History of Physics in 1982–86.

Guido Tagliaferri died in Milan on September 1, 2000.

Alberto Masani was born in Fucecchio (Florence province) in 1956. He graduated in Physics in 1942. He was assistant to Giovanni Polvani at the Institute of Physics of Milan University in 1945. In 1946 he won a public competition to work at the Astronomical Observatory of Brera. There he introduced new instrumental techniques, such as the photoelectric photometer. His main fields of research were the theoretical study of stellar structure and evolution.

Masani was lecturer in Astrophysics at the universities of Milan, Genua and Turin. He was the director of the Astronomical Observatory of Turin in 1984–86. There he studied the neutrino production in the final stages of stellar evolution and supported the experimental researches in the laboratory under the Mont Blanc tunnel. He left the Astronomical Observatory when he became full professor of Astrophysics at Turin University.

Alberto Masani died in Marina di Carrara in 2005.

Bartolomeo Todeschini was among the students of Bruno Finzi, professor of Rational Mechanics at Milan University. He was assistant to Giovanni Polvani at the Institute of Physics in 1945. Next year he followed Bruno Finzi to the Institute of Mathematics of Milan Polytechnic where he worked on mathematical physics with him. He studied the mathematical aspects of the unified field theories.

Luisa Basilico worked at the Institute of Physics as volunteer assistant to Giovanni Polvani in 1945–46, commissioned assistant to Carlo Salvetti in 1946–47, coadjutor to Bruno Ferretti in 1947–48, and coadjutor to Giovanni Polvani in 1948–50.

6.3.2 1946–47: Ugo Facchini, Antonio Lovati, Luigi Terra

In the 1946–47 academic year, three more coadjutors joined the Institute of Physics: Ugo Facchini, Antonio Lovati, and Luigi Terra. Ugo Facchini had a career at CISE, where he made experimental measurements which made the history of nuclear physics with his measurements of the cross sections of uranium. At the same time he worked for the Institute of Physics mostly as lecturer in 1948–52 and in 1957–58; from 1960–61 on, he was full professor of General Physics and director of the Institute of Physical Sciences and then of the Institute of Applied General Physics. Antonio Lovati was an assistant and lecturer; he was a fundamental member of the

Table 6.5 Institute of Physics (1946–47)

Name	Role
Director	Giovanni Polvani
Professors	Giuseppe Bolla[a] (Higher Physics); Giovanni Polvani (Experimental Physics)
Lecturers	Giuseppe Bolla (Exercitations of Experimental Physics III; Spectroscopy); Antonino Mura (Exercitations of Experimental Physics II); Giovanni Polvani (Experimental Physics II); Carlo Salvetti (Theoretical Physics); Giorgio Salvini (Exercitations of Experimental Physics I); Guido Tagliaferri (Exercitations of Experimental Physics)
Commissioned help	Antonino Mura
Assistant	Carlo Salvetti
Commissioned assistants	Luisa Basilico[b]; Giorgio Salvini[a]; Guido Tagliaferri
Coadjutors	Ugo Facchini; Antonio Lovati; Corrado Mazzon; Luigi Terra[a]
Technicians	Giovanni Adorni; Mario Pessina
Adventitious technician	Teresa Panizza
Subordinates	Emilio Bonelli; Lazzaro Fumagalli; Bassano Prada
Adventitious subordinate	MarioGranata

[a] Chair of Higher Physics; [b] Chair of Theoretical Physics

cosmic ray physics group working with cloud chambers. Luigi Terra was coadjutor and lecturer for a few years. In 1946–47, another subordinate, Emilio Bonelli, was assigned to the Institute of Physics (Table 6.5).

Ugo Facchini (Fig. 6.1) was born in Milan on November 4, 1924. He graduated *cum laude* in Physics in 1946 at Milan University with a dissertation on “Researches on Geiger-Müller counters”, with Giuseppe Bolla as tutor.

In 1948–50 Facchini was lecturer in Exercitations of Experimental Physics at Milan University. In 1950–57 he was lecturer in Nuclear Physics, then of General Physics at Milan Polytechnic. In 1954 he obtained his “libera docenza” in Nuclear Physics. In 1957–60 he became extraordinary professor of Experimental Physics for the degree course in Chemistry at Turin University. From 1960 he was full professor of Experimental Physics II, then General Physics at Milan University. In 1968–1980 he was the director of the Institute of Physical Sciences after the direction by Piero Caldirola. In 1981, he founded the Institute of Applied General Physics with Laura Colli and Guido Tagliaferri. He was its first director until 1999.

Facchini’s scientific career started in the field of neutrons and nuclear physics at the CISE. Among his most important results was the measurement of the U^{235} fission cross section for neutron capture. It was the first measurement of this kind in Italy, and the result was at the time covered by military secret in the United States. Facchini’s

Fig. 6.1 Ugo Facchini (Copyright: CISE2007)

career at the CISE further developed; he became the director of the Nuclear Physics Division until 1972.

In the 1950s Facchini studied new kinds of particle detectors and their physical processes. With Laura Colli, Facchini made spectroscopical studies of the emission spectra of α particles and of protons from (n, p) reactions. Facchini was the author of important research works on the models of low energy nuclear reactions, such as: the measurements of cross sections from reactions involving neutrons and α particles; the fluctuations of the excitation nuclear cross section; the study of the density of nuclear levels in the nuclear statistical model. In his experimental studies Facchini used the accelerators built at the CISE for the production of neutrons.

At the same time, Facchini was interested in the experimental study of a physical-biological phenomenon: the weak photon emission from biological systems, or bio-photons.

In the 1970s Facchini was engaged in the studies on alternative energy sources, in collaboration with the CNR His main interests concerned solar and geothermic energy: small-scale thermomechanical conversion of solar and geothermal energy; solar greenhouses and heat storage; the drying of fodder with solar energy; the use of geothermal energy in agriculture; solar air collectors; air conditioning of buildings.[17] In the 1980s his studies concerned Environmental Physics. He built a station for measuring air quality on a Tower of the Astronomical Observatory of Brera in Milan downtown. He put his deep knowledge of nuclear physics at the service of environmental physics with the organization of campaigns of measurement of the concentration of argon in a living environment. On the occasion of the accident at

[17] Ugo Facchini Papers. Museum of Industry and Work, Brescia.

the Chernobyl nuclear power plant in 1986, he made a systematic study of the data of radioactive contamination in the environment in Northern Italy.

Ugo Facchini died in 2008.

Antonio Lovati graduated in Physics in 1942. He was assistant to Giovanni Polvani and lecturer of Exercitations of Experimental Physics II at the Institute of Physics. His main research field was the study of cosmic radiation in the cloud chamber group; he made measurements both at sea-level and on high mountains. He then moved to nuclear physics and was a preeminent actor in the industrial applications of physics.

Luigi Terra was born in Feltre on 20 January 1920. He graduated in Electrotechnical Industrial Engineering at Bologna University and in Physics at Milan University. He was assistant to Giovanni Polvani at the Institute of Physics in 1946–47 and 1949–50. He worked at the research division of the Scientific Society Radio Brevetti Ducati where he was engaged in the design of measurement instruments.

6.3.3 1947–48: Bruno Ferretti, Bruno Finzi Contini, Costanza Catenacci

In 1947, Bruno Ferretti became professor of Theoretical Physics at Milan University. He stayed in Milan only for one academic year; in any case, he was able to inspire new research activities in nuclear and cosmic-ray physics. In the same year, two other new assistants joined the Institute of Physics: Bruno Finzi Contini and Costanza Catenacci (Table 6.6).

Bruno Ferretti[18] was born in Bologna on July 1, 1913. He graduated in Physics at Bologna University where he became assistant to Quirino Majorana.

In 1937 Ferretti became a member of the research group of cosmic ray physics at Rome University where he had to study their theoretical aspects. When Enrico Fermi left Italy in 1938, Ferretti became the director of the research group.

In 1947 Ferretti won the public competition for the chair of Theoretical Physics for Milan University. Next year he moved back to Rome University. His research interests concerned statistical mechanics, nuclear physics, and the theoretical study of accelerators. In 1952 he became a member of the CNRN council.

In 1956 Ferretti moved to Bologna University where he studied the quantum theory of fields and quantum electrodynamics. He also continued his activity in applied nuclear physics. He managed to have constructed a reactor in Bologna, the RB1, which started to be critical in August 1961, and founded the School and Labs for Nuclear Engineering.

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[18] On Bruno Ferretti, see: [19].

Table 6.6 Institute of physics (1947–48)

Name	Role
Institute of Physics	
Directors	Bruno Ferretti[b]; Giovanni Polvani
Professors	Giuseppe Bolla[a] (Higher Physics); Bruno Ferretti[b] (Theoretical Physics); Giovanni Polvani (Experimental Physics)
Lecturers	Giuseppe Bolla (Exercitations of Experimental Physics III until 31.10.1948; Spectroscopy); Antonino Mura (Exercitations of Experimental Physics II); Giovanni Polvani (Experimental Physics II); Carlo Salvetti (Spectroscopy until 31.10.1948; Theoretical Physics); Giorgio Salvini[a] (Exercitations of Experimental Physics); Guido Tagliaferri (Exercitations of Experimental Physics)
Help	Antonino Mura
Assistants	Carlo Salvetti; Giorgio Salvini[a]; Guido Tagliaferri
Commissioned assistant	Bruno Finzi Contini
Coadjutors	Luisa Basilico[b]; Costanza Catenacci[a]; Antonio Lovati
Technicians	Giovanni Adorni; Mario Pessina
Adventitious technician	Teresa Panizza
Subordinates	Emilio Bonelli; Bassano Prada
Adventitious subordinates	Lazzaro Fumagalli; Mario Granata[a]

[a] Chair of Higher Physics; [b] Chair of Theoretical Physics

In 1957 Ferretti became the first director of the Theoretical Studies Division at the CERN which had already started in Copenhagen in 1953–54 before moving to Geneva.

Bruno Ferretti died in Bologna on August 11, 2010.

Bruno Finzi Contini obtained his “libera docenza” in Technical Physics (which was related to Chemistry) in 1939. He was forced to leave Milan University due to the racial laws. After the war he was assistant to Giovanni Polvani at the Institute of Physics for a short time in 1947. He was a professor of Technical Physics in Milan and Trieste where he became the director of the Institute of Technical Physics at the Faculty of Engineering.

Costanza Catenacci graduated in Physics and was assistant to Giovanni Polvani at the Institute of Physics in 1947–49. In 1951, she married Giorgio Salvini whom she helped to hide when he did not go back to fight with the army after a leave during the Second World War.

6.3.4 1948–49: Sergio Gallone, Ruggero Renzoni

Two researchers from the CISE, Sergio Gallone and Ruggero Renzoni became lecturers for the Institute of Physics from the 1948-49 academic year; Renzoni was also assistant. Their work as lecturers was part of the very close collaboration between the CISE and the Institute of Physics in the first decade of activity of the nuclear research institute (Table 6.7).

Sergio Gallone was, with Carlo Salvetti and Luciano Orsoni, involved in the theoretical studies on nuclear reactors at the CISE. They started to study nuclear reactors from the Smyth Report; since the latter contained very few details, the problem had actually to be studied from scratch in both its theoretical and experimental aspects. He studied the structure of nuclei and models for nuclear fission. He was lecturer of Radioactivity (an old name for Nuclear Physics) and Nuclear Physics at Milan University.

Ruggero Renzoni was a researcher at the CISE where he was supervisor of the workshops. He was engaged in the making of particle detectors, such as Geiger-Müller counters, and was a specialist in geophysical detection equipments, such as

Table 6.7 Institute of Physics (1948–49)

Role	Name
Directors	Giovanni Polvani; Carlo Salvetti[b]
Professors	Giuseppe Bolla[a] (Higher Physics); Giovanni Polvani (Experimental Physics); Carlo Salvetti[b] (Theoretical Physics)
Lecturers	Giuseppe Bolla[a] (Spectroscopy); Sergio Gallone[c] (Radioactivity); Antonino Mura (Exercitations of Experimental Physics II); Giovanni Polvani (Experimental Physics II); Ruggero Renzoni[c] (Exercitations of Experimental Physics I); Giorgio Salvini[a] (Exercitations of Experimental Physics II); Guido Tagliaferri (Exercitations of Experimental Physics I)
Help	Antonino Mura
Assistants	Antonio Lovati; Carlo Salvetti; Giorgio Salvini[a]; Guido Tagliaferri
Coadjutors	Costanza Catenacci[a]; Luisa Basilico[b]; Piera Pinto
Technicians	Giovanni Adorni; Mario Pessina
Adventitious technician	Teresa Panizza
Subordinates	Emilio Bonelli; Bassano Prada
Adventitious subordinates	Lazzaro Fumagalli; Mario Granata[a]

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]not formally a member of the Institute of Physics

gammascopes and quartz Wood lamps for fluorescent luminescence. He cooperated with the Institute of Physics and was an assistant in 1948–52.

6.3.5 1949–50: Piero Caldirola, Carlo Succi, Laura Colli, Ettore Bellomo

In the 1949–50 academic year, Piero Caldirola joined the Institute of Physics as extraordinary professor of Theoretical Physics. The chair left vacant by Giovanni Gentile's death and occupied for too a short time by Bruno Ferretti was now assigned for many years to a professor who guaranteed a collaborative growth of the Institute in connection with the theoretical physics group at Pavia University as in the case of Ettore Bellomo who was assistant to Caldirola in that year (Table 6.8).

Table 6.8 Institute of Physics (1949–50)

Role	Name
Directors	Piero Caldirola[b]; Giovanni Polvani
Professors	Giuseppe Bolla[a] (Higher Physics); Piero Caldirola[b] (Theoretical Physics); Giovanni Polvani (Experimental Physics)
Lecturers	Giuseppe Bolla[a] (Exercitations of Experimental Physics III); Piero Caldirola[b] (Probability Calculus; Terrestrial Physics); Ugo Facchini[c] (Exercitations of Experimental Physics III); Sergio Gallone[c] (Radioactivity); Antonino Mura (Exercitations of Experimental Physics II); Giovanni Polvani (Experimental Physics II); Ruggero Renzoni[c] (Exercitations of Experimental Physics I); Carlo Salvetti (Statistical Mechanics); Guido Tagliaferri (Exercitations of Experimental Physics I)
Help	Antonino Mura
Assistants	Antonio Lovati; Carlo Salvetti; Giorgio Salvini[a]; Guido Tagliaferri
Coadjutors	Luisa Basilico; Ettore Bellomo[b]; Laura Colli[a]; Piera Pinto; Carlo Succi; Luigi Terra
Technicians	Giovanni Adorni; Mario Pessina
Adventitious technician	TeresaPanizza
Subordinates	Emilio Bonelli; Bassano Prada
Adventitious subordinates	Mario Decarli[a]; Lazzaro Fumagalli

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]not formally a member of the Institute of Physics

Two other young physicists, Carlo Succi and Laura Colli, became coadjutors to Giovanni Polvani. Succi contributed to the development of the cosmic-ray physics group working with cloud chambers, while Colli made the ties with the CISE stronger.

From the 1949–50 academic year, Mario Decarli was assigned to the Institute of Physics as subordinate, later janitor.

Piero Caldirola (Fig. 6.2)[19] was born in Como on December 5, 1914, the son of Giuseppe Caldirola and Ida Cavadini. He attended the scientific lyceum "Paolo Giovio" in Como, then he was accepted as a member of the Ghisleri College at Pavia University. He graduated in Physics in 1937 with an experimental dissertation on the diffusion of hydrogen through heated palladium. In 1938 he went to Rome thanks to the Prince of Piedmont scholarship to study nuclear physics with Fermi's group after being introduced to Fermi by Rita Brunetti, a professor of Physics at Pavia University. In Rome, he was particularly attracted by Ugo Fano, whom he met after his return from Germany where he had worked with Werner Heisenberg. Caldirola made use irregularly of another ministerial scholarship,[20] after Fermi left Italy for the Nobel Prize ceremony, to go to Padua to study with Gian Carlo Wick. In Padua he learnt Rabi's method to measure magnetic moments and analyzed the non-adiabatic processes in an oscillating magnetic field.

In 1939 Caldirola became assistant to the chair of Experimental Physics in Pavia and started to work on both experimental and theoretical problems. In particular, Caldirola collaborated with another assistant, Luigi Giulotto, in studies on Raman spectroscopy in calcite and carbon bisolphid [24–26]. Their joint researches were interrupted during the Second World War when Giulotto left Italy to Switzerland to avoid being arrested by the Italian Social Republic. A relevant theoretical study concerned the non-conservative forces in quantum mechanics, which was published in 1941 [27]. This study was connected to Kanai's research on the quantization of dissipative systems and led to the Caldirola-Kanai model of quantum dissipative systems.

His work during the Second World War was randomly interrupted by his military duties in the region around Pavia. He had planned and obtained a scholarship to go to Leipzig to study with Heisenberg, but eventually he preferred to stay in Italy. Soon after the end of the war, he published a theoretical work on the state equation of gases for pressures up to 500,000 atmospheres, based on his experimental data about solid explosive materials when he had to engage with the physics of explosives [28].

In 1941 Caldirola obtained his "libera docenza" in Theoretical Physics and became lecturer for the same discipline at Pavia University. In 1947 he participated to the third public competition for a chair of Theoretical Physics and was the third winner after Nicolò Dallaporta (who was professor in Padua 1947–79 and at the International School for Advanced Studies in Trieste 1979–85) and Bruno Ferretti (who was professor in Milan 1948–49, Rome 1949–56, and Bologna 1958–88). Caldirola was extraordinary professor at Pavia University in 1947–49 and then in Milan (full

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[19] On Caldirola see: [20–23].

[20] The scholarship was awarded for the prosecution of his studies in Rome. He did not communicate to the ministry the change of destination. After four months the scholarship was suspended.

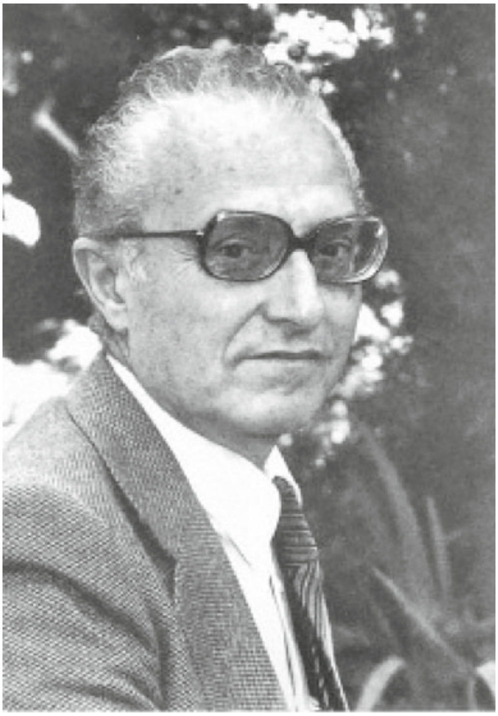

Fig. 6.2 Piero Caldirola (Copyright: Milan University, BICF Library)

professor from 1950–51). He was then full professor of General Physics in 1966–76 and of Institutions of Theoretical Physics in 1974 until 1984. Caldirola was the director of the Institute of Physical Sciences in 1960–67 after Polvani's resignation, of the graduate school in Atomic and Nuclear Physics (1961–84) and of the graduate school in Sanitary and Hospital Physics (1961–84).

Since Caldirola continued to be a lecturer of Theoretical Physics at Pavia University, a strict collaboration between groups of physicists working in Milan and Pavia was centered on him. Two students, Roberto Fieschi and Paolo Gulmanelli, graduated with him in Pavia and followed him in Milan where they could work as assistants and gave birth to the studies in theoretical solid state physics in Italy who struggled for the recognition of these kind of studies as theoretical physics of the same level as that engaged in the study of fundamental problems. The solid state group was then joined by Fausto Fumi from Urbana University. The collaboration with universities abroad—Bristol, Leiden, Urbana, Utrecht—permitted a good level of scientific development on an international level.

Caldirola's theoretical studies on particles concerned several topics. The study of magnetic moments started in 1946 with a relevant research facing the problem of the relativistic correction of the magnetic moment of a deuton [29, 30]. A physical interest for supplementary magnetic moments arose in the analysis of a wave equation for 1/2 spin particles advanced by Corben. By comparing it with Dirac wave equation, Caldirola noticed differences in the eigenfunctions; with a supplementary magnetic moments, the magnetic properties were shown to by dependent from the nature of the mass of the particle [31].

In 1949 Caldirola developed a theory of the meson component in cosmic radiation under the assumption that the primary component entering the upper atmosphere were protons and that the pions were generated by interactions between pairs of nucleons [32]. With Loinger of Pavia University, he developed the distributions of pions to describe the positive excess and the production multiplicity [33], while with Zin of the National Electrotechnic Institute "Galileo Ferraris" of Turin, he examined the latitude effect on the protonic and neutronic components of cosmic radiation due to the action of the terrestrial magnetic field [34]. Fieschi and Gulmanelli contributed, already as thesis students, to the calculations of the latter work and developed them in the comparison of the experimental data on geomagnetic effects with a theoretical scheme [35, 36]. To sum up all the previous results, a phenomenological theory of all the processes concerning cosmic radiation in the atmosphere was developed to compute the distribution of the fast protonic and neutronic, of the mesonic and of the electronic components, the mesonic energy spectrum, the positive excess as a function of altitude, and the latitude effects [37].

Caldirola's studies on the electrons concerned the relativistic equation of motion of an electron in the framework of classical electrodynamics [38]. Caldirola was not able to integrate the general relativistic equation but was able in any case to solve it for six particular cases: free particle, particle subjected a constant force, particle subjected to a time-dependent force, particle in a constant magnetic field, particle subjected to an elastic return force, electron launched along a line against a fixed proton. A second, finite-difference equation, of a classical electron interacting with an electromagnetic field, was advanced with Duimio through the introduction of a fundamental length, considered as a universal constant [39]. The results obtained by Caldirola corresponded to an electron of spherical shape with its charge spread out on its surface and its mass of electromagnetic nature. Classical electrodynamics was applied by Caldirola also to the study of the equation of motion of the positive electron [40]. A further study concerned the irradiation by a classical electron [41]

The classical theory of electrons, in Caldirola's formulation, assumed that the macroscopic motion of an electron could be defined only in a discreet succession of time instants. The time interval between these instants—the "chronon"—was meaningful also in a quantum frame of reference through Heisenberg indetermination principle [42]. Caldirola developed the concept of chronon in subsequent studies in the 1970s [43–47].

Among Caldirola's many other theoretical topics we can mention his studies on the ergodic methods in statistical mechanics [48, 49], the quantum theory of dissipative systems (which Caldirola started in 1941 with the model later known as the Caldirola-Kanai model) with the Caldirola-Montaldi equation [50].

In the 1950s, Caldirola worked with some researchers of the CISE in the study of the theoretical isotope separation by gaseous diffusion through porous barriers [51–54]. He patented his method of isotope separation of uranium hexaphluorid, which was used not only by CISE but also by the French Commissariat à l'Energie Atomique at the Nuclear Site of Tricastin in the Pierrelatte nuclear plant.

Caldirola's involvement in nuclear physics research on applicative topics of such a technological relevance permitted him to become a member of national and international nuclear and energy institutions. In 1951 he was appointed as first president of the Milan division of the newly founded INFN (1951–60). In 1956 he became a member of the CECA commission for uranium enrichment (Syndicat d'étude pour l'enrichissement de l'uranium). In 1958, he was among the founders of the Italian Forum of Nuclear Energy (FIEN).[21] In 1958–63 he was a member of the administrative board of AGIP Nucleare. In 1960–63 he was a member of the administrative board of ENI Laboratori Riuniti. In 1961 he participated to the working group of the NATO Council for the feasibility studies of an international scientific institute, similar to the CERN, for researches in applied physics and science-intensive technology. The working groups was led by James Rhyne Killian jr and had as members Caldirola, Hendrik Brugt Gerhard Casimir and John Douglas Cockcroft. Caldirola collaborated with NATO in several occasions between 1965 and 1975 as councillor for the scientific laboratories in Southern Europe. In connection with the army, he was the scientific director of the nuclear reactor of the Centre for the Military Applications of Nuclear Energy (CAMEN) in San Pietro a Grado (1961–76). in 1966 he entered the CISE scientific council. In 1968 he was appointed by the CNEN as president of the Italian Group for Uranium Enrichment (1968–78), which acted in the plans to build the Tricastin nuclear plant. In the same year he became member of the EURATOM scientific and technical committee (1968–73). In 1981–82 he was president of the European Atomic Forum (FORATOM).[22]

Strictly connected to nuclear studies was his interested in their applications to sanitary topics such as the use of radioisotopes in cancer therapies and the use of resonances in plasma for medical diagnosis. He put his organizational abilities at disposal of the groups of sanitary physics. Was appointed president of the Italian Association of Sanitary Physics in 1961–73, founder of the Italian Association for the Protection against Radiations, and vice-president of the International Radiation Protection Association (IRPA) in 1964–67.

Caldirola's activity in plasma physics and its technological applications started with the study of the propagation of electromagnetic waves in weakly ionized gases. Again his scientific activity had an immediate organizational impact. In 1966 he was appointed president of the management committee of CNEN for the studies on nuclear fusion at the Laboratories for Ionized Gases in Frascati (1966–77) in collaboration with EURATOM, and director of the Laboratory of Plasma Physics and

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[21] The FIEN was established in Rome on November 12, 1958, and merged together with the National Association of Nuclear Engineering (ANDIN) and the Italian Nuclear Society (SNI) in the Italian Nuclear Association (AIN) on December 31, 1998, in accordance with the new law on no-profit associations.

[22] The FORATOM was founded on July 12, 1960 as a trade association for the European nuclear energy industry. It currently has fifteen national nuclear associations representing 3,000 firms from 13 countries. It interacts with the EU institutions and other stakeholders providing information and expertise on nuclear energy plants.

Fig. 6.3 From the left: Occhialini, Riccardo Levi-Setti, Livio Scarsi, Bice Locatelli, Alberto Bonetti in front of the Palace of Sciences (Copyright: Milan University, BICF Library)

Quantum Electronics of the CNR. In 1969 he became a member of the EURATOM group for plasma physics and controlled fusion (1969–73). He founded the Varenna International School of Plasma Physics, named after him, of the SIFy.

Besides his courses at Milan and Pavia Universities, Caldirola was also lecturer of Physics of Nuclear Reactors at Milan Polytechnic. For his teaching activity he wrote textbooks used by generations of students of Milan University [55–57] and [58]. He also wrote physics textbooks for high school students [59, 60] and a divulgative texts on twentieth century physics [61–63].

Piero Caldirola died in Milan on July 31, 1984.

Carlo Succi[23] was born in Ravenna on 19 December 1919 Fig. 6.3. He graduated in Mathematics and Physics in 1949 and in Physics in 1951 at Milan University with a dissertation on “the continuously sensitive cloud chamber”. He was commissioned then ordinary assistant to Giovanni Polvani in the 1950s. In 1957 he obtained his “libera docenza” in Experimental Physics.

Succi’s research activity started in the field of cosmic rays for which he built a continuously sensitive cloud chamber. He later planned and built the huge multiplate cloud chamber with Ettore Fiorini and Riccardo Giacconi. Succi worked also at the National Laboratory of the CNEN in Ispra in order to plan the construction of a source of polarized protons. In Milan he coordinated the planning and building of the

[23] On Carlo Succi, see: [64].

azimuthal variable frequency relativistic cyclotron in collaboration with the Milan division of the INFN.

Succi became extraordinary professor of General Physics in 1967 and full professor in 1970 at Milan University. From the 1970 he was more and more concerned with the educational problems of physics both in high schools and universities.

Carlo Succi died in 2000.

Laura Colli was born in Cernobbio on February 23, 1925. She graduated in Physics in 1949 at Milan University with a dissertation of the methods to prepare monocrystals. From 1950 she worked at the CISE with Ugo Facchini and Emilio Gatti. They studied collision and discharge phenomena in gases for their application in radiation detectors. Colli's studies on discharge in gases, in particular in argon, culminated in 1954 with the analysis of the corona breakdown mechanism. With photomultipliers Colli and Facchini started their studies on biophotons emitted by vegetal cells of germinating plants. From 1956 she started to study the mechanisms of nuclear reactions by means of 14 MeV neutrons produced with the CISE Cockcroft-Walton accelerator. Another machine used by Colli in her studies was the CISE van der Graaf. With new kinds of solid state detectors, made in the CISE laboratories, she could work on the experimental detection of Erikson's statistical fluctuations. In 1977 Colli organized the first Varenna conference on nuclear reaction mechanisms for the SIF.

Colli was coadjutor at the Institute of Physics of Milan University in 1949–50, and then lecturer of Nuclear Physics from 1958.

Laura Colli died in January 1985.

Ettore Bellomo was born in Florence on July 17, 1927.

He graduated in Physics at Pisa University in the 1949–50 academic year and was assistant to Piero Caldirola in Milan for the same year. He was then assistant at Pavia University where he was lecturer of Exercitations of Experimental Physics in 1950–54. In the 1950s he got scholarships from the Dublin Institute for Advanced Studies in Dublin to study relativity theory in Dublin. He worked at the universities of Pavia, Milan and Padua. Among his research topics was Physics of Fluids.

Ettore Bellomo died in Padua on October 7, 2019. The library block 3 and 3bis of the INFN National Laboratories in Legnaro was named after him in September 2020.

6.3.6 1950–51: Sergio Albertoni, Angela Bernasconi, Roberto Fieschi, Fausto Fumi, Paolo Gulmanelli, Riccardo Levi-Setti, Martina Panetti, Sergio Terrani

The 1950–51 academic year saw the arrival of five new assistants—Sergio Albertoni, Angela Bernasconi, Roberto Fieschi, Paolo Gulmanelli, and Sergio Terrani—and three lecturers—Fausto Fumi, Riccardo Levi-Setti, and Martina Panetti. Albertoni, Fieschi, Fumi, Gulmanelli and Terrani pursued their academic careers becoming professors in Italy, and Levi-Setti in the US. With the arrival of Fieschi and Fumi to

Table 6.9 Institute of Physics (1950–51)

Role	Name
Directors	Piero Caldirola[b]; Giovanni Polvani
Professors	Piero Caldirola[b] (Theoretical Physics); Giovanni Polvani (Experimental Physics)
Lecturers	Piero Caldirola[b] (Probability Calculus; Terrestrial Physics); Ugo Facchini[c] (Exercitations of Experimental Physics II); Fausto Fumi[c] (Statistical Mechanics); Sergio Gallone[c] (Radioactivity); Riccardo Levi-Setti[c] (Exercitations of Experimental Physics I); Antonino Mura (Exercitations of Experimental Physics II); Marina Panetti[c] (Experimental Physics—for Geology); Giovanni Polvani (Experimental Physics II; Higher Physics); Ruggero Renzoni[c] (Exercitations of Experimental Physics I); Carlo Salvetti (Electromagnetic Waves); Carlo Succi[c] (Exercitations of Experimental Physics II); Luigi Terra[c] (Exercitations fo Experimental Physics—for Geology)
Ordinary assistants	Antonio Lovati; Antonino Mura (acting as Help); Carlo Salvetti; Giorgio Salvini[b]; Guido Tagliaferri
Extraordinary assistant	Angela Bernasconi[a] (from 01.11.1950 to 30.06.1951)
Commissioned assistant	Sergio Albertoni[b] (from 16.10.1951)
Commissioned alternate assistant	Sergio Terrani[a] (from 01.03.1951 to 30.11.1951)
Volunteer assistants	Roberto Fieschi[b]; Paolo Gulmanelli[b]
Technicians	Giovanni Adorni; Mario Pessina
Adventitious technician	Teresa Panizza
Subordinates	Emilio Bonelli; Mario Decarli[a]; Lazzaro Fumagalli; Bassano Prada

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]not formally a member of the Institute of Physics

Milan, the Institute of Physics became one birthplace of Solid State Physics in Italy (Table 6.9).

Sergio Albertoni was born in Novara on September 22, 1926. He graduated in Mathematics and Physics at Milan University in 1950. He was alternate assistant in 1950–51 and commissioned assistant in 1951–53. His main field of research concerned models and the application of numerical simulations. He studied with Marco Cugiani important contributions of Schwartz distributions theory to industrial applications. He founded the ARS (Applicazioni della Ricerca Scientifica) in 1963 for the solution of applicative projects with private and public clients on a wide range of topics such as operational research, nuclear reactors, software, numerical fluido-dynamics.

Albertoni was lecturer of Nuclear Physics at Milan University from 1950, full professor of Numerical Analysis at L'Aquila University in 1967–70, of Mathematical Methods for Engineering at Pavia University in 1970–85, and of Numerical Calculus at Milan University from 1985.

Sergio Albertoni died on May 18, 2008.

Angela Bernasconi graduated in Physics in 1950–51 academic year with a dissertation on the approximate integration of Dirac equation. She was extraordinary assistant to Giovanni Polvani in 1950–51 and coadjutor in 1951–53.

Roberto Fieschi[24] was born in 1928. He graduated in Physics at Pavia University in 1950 with Piero Caldirola, with a dissertation on cosmic radiation. He received his doctorate at the University of Leiden in 1955. He was assistant at the universities of Milan, Pavia, Pisa, and Genoa. In Milan he was among the founders of the group of theoretical solid state physics. He was lecturer of Solid State Physics in Milan from 1955–56 and full professor of Structure of Matter at Parma University in 1965–2005. He was the director of the Laboratory of Special Materials for Electronics and Magnetism of the CNR in Parma in 1970–76.

Fieschi's main fields of research were cosmic ray physics, solid state physics, molecular physics, and the thermodynamic of irreversible processes.

Fausto Fumi[25] was born in Milan on August 22, 1924. He graduated in Chemistry at Genoa University in 1946, and in Physics in 1950. In 1948 he went to the University of Pittsburgh, then of Urbana to work with Frederick Seitz. He came back to Italy and worked at the Institute of Physics of Milan University in 1951–55 and was lecturer of Statistical Mechanics. Caldirola stimulated him to work with the group of solid state physics and in collaboration with the Pavia Institute of Physics. He spent some time in Pittsburgh with Parr and in Bristol and Cambridge with Nevill Mott to study the application of group theory to the properties of crystals and the study of defects in metals.

Fumi won the 1956 public competition for a chair of Theoretical Physics. He was professor at Palermo University in 1955–57, then at Pavia University. In Pavia he studied and developed the theory of ionic crystals with Paolo Tosi. In 1966 he returned to Palermo University as director of the Institute of Physics and professor of Theoretical Physics.

Paolo Gulmanelli was born in Forlì on February 5, 1928. He graduated in Physics in Pavia in 1950 with Pietro Caldirola with a dissertation on cosmic radiation. He followed Caldirola to the Institute of Physics of Milan University where he was assistant through the 1950s. He won the 1964 public competition in Theoretical Physics and became professor of Theoretical Physics for Pavia University. He then became professor of Medical Physics.

Paolo Gulmanelli died in Pavia in 2017.

[24] On Roberto Fieschi, see his autobiography: [65].

[25] On Fausto Fumi, see: [66, 67].

Riccardo Paolo Levi was born in Milan on July 11, 1927. In honor of Elisa Setti, his godmother who helped his family in hiding from the German SS during the war, he changed his family name into Levi-Setti. He graduated in Physics at Pavia University in 1952.

Levi-Setti was assistant at the Institute of Physics of Milan where he worked with Giuseppe Occhialini in 1950–55. Then he accepted an invitation from Enrico Fermi to join the University of Chicago in 1956. There he was assistant professor of particle physics and was a member of the team which discovered the neutral K-meson decay. In Chicago Levi Setti was engaged in the study of hyperons and mesons and developed new visualizing techniques such as the bubble chamber. In 1963 he was at the CERN to work on the search for heavy hyperon resonances. In the 1970s he left particle physics for ion microscopy and developed a scanning ion microscope with Hughes Research Laboratories for the precise observation of objects with a resolution 100 times better than an electron microscope. In 1992–2000 he was the director of the Enrico Fermi Institute of the University of Chicago Medical center where he studied biology (he was an expert on trilobites) and biomedicine.

Levi-Setti died in Chicago on November 8, 2018.

Martina Panetti[26] was born in Turin on June 11, 1918. She graduated at Turin University in Mathematics and Physics in 1940 with a dissertation on some problems of hydrodynamics.

Panetti was assistant at Turin University in 1949–52. She studied the motion of electrons in electrostatic fields, in magnetrons and cavities, and on aerials in the laboratories of the National Electrotechnical Institute. She studied cosmic radiation at high altitude with Gleb Wataghin.

In 1952, Panetti moved to Milan University where she was assistant from 1950 and lecturer of Physics. She married Antonio Lovati.

Sergio Terrani graduated in Physics at Milan University in 1950–51 with a dissertation of Geiger counters. He was alternate assistant to Giovanni Polvani in 1950–51 and extraordinary assistant in 1951–52.

Terrani continued his career as nuclear engineer at CISE. He became professor at Milan Polytechnic where he was the director of the Institute, later Department, of Nuclear Engineering and worked with the Milan Polytechnic L-54 reactor.

6.3.7 1951–52: Giuseppe Occhialini

The chair of Higher Physics, left vacant for one year after Bolla left Milan University for Milan Polytechnic, was assigned in the 1951–52 academic year to Giuseppe ("Beppo") Occhialini. Occhialini was convinced by Polvani to leave Genoa University also because a local division of the INFN was planned to start its activities in Milan. Occhialini took with him his expertise in the study of cosmic radiation with nuclear emulsions; he started a new research group which took all the free space at

[26] On Martina Panetti, see [68].

Table 6.10 Institute of Physics (1951–52)

Role	Name
Directors	Piero Caldirola[b]; Giovanni Polvani
Professors	Piero Caldirola[b] (Theoretical Physics); Giuseppe Occhialini[a] (Higher Physics); Giovanni Polvani (Experimental Physics)
Lecturers	Piero Caldirola[b] (Spectroscopy); Ugo Facchini[c] (Exercitations of Experimental Physics II); Fausto Fumi[c] (Statistical Mechanics); Sergio Gallone[c] (Radioactivity); Riccardo Levi-Setti[c] (Exercitations of Experimental Physics I); Antonino Mura (Exercitations of Experimental Physics II); Martina Panetti[c] (Experimental Physics—for Geology); Giovanni Polvani (Experimental Physics II); Ruggero Renzoni[c] (Exercitations of Experimental Physics I); Carlo Salvetti (Electromagnetic Waves); Carlo Succi[a] (Exercitations of Experimental Physics II); Guido Tagliaferri (Terrestrial Physics); Luigi Terra[c] (Exercitations of Experimental Physics—for Geology)
Ordinary assistants	Antonio Lovati; Antonino Mura (as Help); Carlo Salvetti (on leave from 05.11.1951 to 25.02.1952); Giorgio Salvini[a] (on leave from 30.01.1952 to 01.02.1952); Guido Tagliaferri
Extraordinary assistant	Sergio Terrani (from 01.11.1951 to 30.06.1952)
Commissioned assistants	Sergio Albertoni[b]; Carlo Succi[a] (from 01.03.1952)
Volunteer assistant	Paolo Gulmanelli[b]
Coadjutor	Angela Bernasconi[a] (from 01.11.1951 to 30.06.1952); Roberto Fieschi[b] (from 01.11.1951 to 30.06.1952)
Technicians	Giovanni Adorni; Mario Pessina
Adventitious technician	Teresa Panizza
Subordinates	Emilio Bonelli; Mario Decarli[a]; Lazzaro Fumagalli; Walter Mantovani (on trial from 01.09.1952); Bassano Prada
Adventitious subordinate	Walter Mantovani (from 01.04.1951 to 31.08.1952)

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]not formally a member of the Institute of Physics

disposal in the Institute necessary for researches of this kind and further contributed to make the Institute of Physics a research institution at international level.

A new subordinate, Walter Mantovani, was assigned to the Institute of Physics. He was one the janitors for the next decades (Table 6.10).

Fig. 6.4 Constance Charlotte Dilworth (Copyright: Milan University, BICF Library)

Giuseppe Paolo Stanislao Occhialini[27] (1907–1993), more known with the nickname "Beppo", was born in Fossombrone (Pesaro Province) on December 5, 1907 (Fig. 6.4). He was the son of Raffaele Augusto Occhialini [83, 84], a physicist who collaborated with Angelo Battelli until 1918, was assistant to Antonio Garbasso in Florence (1938–1921), professor of physics at the University of Sassari (1921–1924), Siena (1924–1928), and Genoa (1929–1951). His scientific production comprised works of experimental physics on electromagnetism, optics, gas physics, and atomic physics, and published two treatises on Electrical Engineering and Radioactivity.

Occhialini attended the Scientific High School in Florence and in 1927 he decided to study physics at Florence University [85]. The director of the Institute of Physics was at the time Antonio Garbasso. Among the professors was Enrico Persico as professor of Mechanics who introduced him to Theoretical Physics. Occhialini graduated in Physics in 1929 and in 1930 became a volunteer assistant of the Institute of Physics.

In the Institute of Physics in Florence, under Garbasso's direction, they carried out researches on optical and X spectroscopy. In this laboratory [86], Lo Surdo had discovered the separation in an electric field of the hydrogen lines (Stark-Lo Surdo effect). Of valuable importance for the cultural and technical training was the col-

[27] On Occhialini, see: [69–82].

lective reading of the main scientific journals and the Physical and Astrophysical Seminar that promoted the contact with Italian and foreign scientists. The Seminar had been founded by Giorgio Abetti, the director of the nearby Astrophysical Observatory in Arcetri.

A considerable development of the researches carried on at the Institute of Physics started with the arrival of Bruno Rossi in 1927 and of Gilberto Bernardini in 1928. They left the researches on spectroscopy to cosmic rays giving birth to the Arcetri school. According to Russo [80], the first problem the Arcetri school had to face was the definition of a research program with three features: the freshness of the research subject; a subject able to stimulate young physicists; the cost of the devices. The solution was Bothe and Kolhörster's paper on the nature of cosmic rays [87] with the application of Bothe and Geiger's coincidences method to the study of cosmic rays. At this time, Rossi invented the Rossi circuit [88] that permitted to detect the simultaneous discharge of several counters (multiple coincidences), realizing a decisive advance compared to Bothe's coincidence circuit.

In the summer 1930, Rossi went to Bothe's laboratory in Berlin. There he met Patrick Blackett and discussed with him the possibility to admit one of his collaborators at the Cavendish laboratory to learn how to build and use a cloud chamber. The eventual choice fell on Occhialini who would have brought to the Cavendish his working knowledge of the coincidence circuits. Occhialini's stay in Cambridge was bound to the conclusive demonstration of the discovery of the positron in 1933, after its existence had been made known by Carl Anderson in 1932. Occhialini and Blackett developed the controlled cloud chamber technique which permitted a valuable progress in obtaining useful photographs of tracks inside the chamber [89, 90]. Thanks to the coincidence circuite, the particles themselves started the controlled cloud chamber when they entered it and ionized. With the controlled cloud chamber they confirmed the existence of Anderson's positron [91, 92], but they also showed that it was produced by cosmic rays as an electron-positron pair thus confirming Dirac's theory: the photographs actually showed the positron track together with the electron track, both starting from a same point [93, 94].

Occhialini came back to Italy in 1934. The situation in Arcetri had worsened: Garbasso died prematurely, Persico had moved to Turin University and Rossi to Padua University. To continue his university career, Occhialini had to take an oath and to enroll as a member of the National Fascist Party. There was no sufficient financial funds to start researches similar to those he had carried on in Cambridge [95, 96]. He got no answer to his request to the CNR to finance the construction of a cloud chamber. He was invited by Gleb Wataghin to join him in organizing a new school of physics in São Paulo, Brazil [97–99]. Due to the lack of local resources, Brazil called from Europe many professors to build a new large university, the University of São Paulo, established in 1934. The presence of Italian scientists at the University of São Paulo was supported by the Italian government, because it was considered an activity of cultural and political mission in a Latin American country with a consistent Italian immigration. Thanks to the geomagnetic latitude of Brazil, the results of the researches on cosmic rays in São Paulo were of particular interest: the latitude effect [100, 101], the ultra-soft component [102–104], the effects of solar eclipses on cosmic radiation [105], and the technical developments of the instruments used by them [106–111].

In March 1942, Brazil joined the nations fighting against Italy and Occhialini called back to Italy and, at the same time, became an enemy alien in Brazil. He was removed from the University of São Paulo but he could not leave the country since the British government refused to permit him the free passage, maybe because he was associated with atomic research [112]. He escaped to the Agulhas Negras mountains where he stayed until Italy signed the armistice (September 1943). Eventually he could go to England only in January 1945. In September 1945 he joined the Wills Laboratory in Bristol where he worked in the nuclear emulsion team directed by Cecil Powell. With the collaboration of Waller of Ilford photography industry, Occhialini and Powell and their collaborators developed new kinds of nuclear emulsions which were used to particles in cosmic radiation and their interactions inside the emulsion sheets [113–116].

In 1947, during one of his speleological expeditions to the Pyrenees, Occhialini exposed on the Pic-du-Midi a stack of the new C2 Ilford emulsions. Marietta Kurz, a scanner, found the track of a meson till its stopping point, and a second track, beginning from the end of the first one, of a second meson, stopping in the same emulsion too. It was the first track of a π-meson decaying into a μ-meson [117, 118]. Other similar tracks were soon found in emulsions exposed on the Andes in Bolivia. The studies continued on cosmic neutrons [119], mesons [120–122, 165], and on the development of the nuclear emulsion technology [123–125].

The researches carried out by Blackett in Cambridge and Powell in Bristol, in collaboration with Occhialini, were rewarded with Nobel Prize for Physics awarded respectively in 1948 and 1950 [126].

In 1948 Occhialini decided to leave Bristol for another country. He accepted an invitation to join the Free University of Brussels where he stayed until the end of the Fifties, and won the public competition for the chair of Higher Physics in Italy where he became professor in Genoa and then in Milan. In Brussels, Occhialini hosted researchers from Genoa and Milan. They continued to develop the nuclear emulsion technique—the clarifying technique [122], the temperature shutter [127, 128], the electron sensitive plates [129], the temperature development [130, 131], the wire method of loading nuclear emulsions [132], the cylindrical emulsions [133]—and its application to the study of cosmic rays during the 1950s: the μ-mesons [134], the double stars [135], the heavy mesons [136–138].

Occhialini was among the organizers of international studies as the G-Stack [139, 166, 167] and the K^--Collaboration [140, 141]. Eventually this kind of researches ended in favor of the exposition of nuclear emulsion to particle beams from accelerating machines.

Occhialini spent the 1959–1960 academic year as a sabbatical year at the Massachusetts Institute of Technology with Bruno Rossi. Once back in Milan, he started a group that in 1968 was configured as a Laboratory of Cosmic Physics and Related Technologies. The Milan group was engaged in the programs of the European Space Research Organization with the launch of instruments on balloon and satellite for the study of the cosmic rays components. The SAX satellite, the Italian-Dutch satellite for X-rays astronomy launched in 1996, was named Beppo-SAX in his honor. In the last chapter we shall consider the transition of Occhialini's team to space physics. After his retirement, Occhialini spent long periods of time in Marcialla di Certaldo, a hamlet in Tuscany.

Giuseppe Occhialini died in Paris on December 30, 1993.

6.3.8 1952–53: Alberto Bonetti, Maria Bossi, Fiorenzo Duimio, Angelo Rossi

In the 1952–53 academic year, Renato Ballerini was assigned as technician to the Institute of Physics where worked for many subsequent years.

Alberto Bonetti, Maria Bossi, Fiorenzo Duimio and Angelo Rossi were the new assistants and coadjutors. Bonetti and Duimio pursued their academic careers as professors in Italy (Table 6.11).

Alberto Bonetti was born in 1920. He graduated in Physics with Augusto Occhialini at Genoa University. In 1945 he became assistant for Augusto Occhialini and in 1948 for Giuseppe Occhialini and started to work in cosmic ray physics with nuclear emulsions. He followed Occhialini to Milan and Brussels. He was ordinary assistant for the Institute of Physics from the academic year 1952–53, and ordinary assistant acting as help from the 1959–60 academic year.

In 1961 he spent a year working at the MIT on interplanetary plasma with Bruno Rossi, Herbert Bridge, and Alberto Egidi. They made the first direct observation of solar wind and a measurement of its velocity; the first observation of the geomagnetic cavity behind the Earth and the measurement of its dimensions.

In 1962 he won the public competition for the chair of General Physics for Bari University. He was the director of the Bari Division of the GIFCO (Italian Groups of Cosmic Physics). In 1967 he went to Florence University as professor of Space Physics. In 1992 he joined the new Department of Astronomy and Space Science.

Maria Bossi graduated in Physics at Milan University in the 1950–51 academic year with a dissertation on the determination in a Wilson chamber of quantities concerning elementary particles. She was coadjutor for the Institute of Physics for three years (1952–55) and lecturer of Exercitations of Experimental Physics for the students of Industrial Chemistry in 1957–58.

Bossi married Carlo Succi. She was the author of a physics textbooks for high school [142].

Fiorenzo Duimio was born in Milan on March 16, 1930. He was a student of Ghisleri College of Pavia University where he graduated in Physics in 1952 with a dissertation on the artificial production of mesons. He became commissioned assistant for the Institute of Physics for three years (1952–55). Thanks to a scholarship of the Comité Européen des Recherches Nucléaires he could study Theoretical Physics in Copenhagen. He was lecturer of Electromagnetic Waves and Probability Calculus.

Table 6.11 Institute of Physics (1952–53)

Role	Name
Directors	Piero Caldirola[b]; Giovanni Polvani
Professors	Piero Caldirola[b] (Theoretical Physics); Giuseppe Occhialini[a] (Higher Physics); Giovanni Polvani (Experimental Physics)
Lecturers	Sergio Albertoni[b] (Probability Calculus); Piero Caldirola[b] (Spectroscopy); Fausto Fumi[c] (Statistical Mechanics); Sergio Gallone[c] (Radioactivity); Riccardo Levi-Setti[c] (Exercitations of Experimental Physics I); Antonio Lovati (Exercitations of Experimental Physics II); Antonino Mura (Exercitations of Experimental Physics III); Martina Panetti Lovati[c] (Experimental Physics—for Geology); Giovanni Polvani (Experimental Physics II); Carlo Salvetti (Electromagnetic Waves); Carlo Succi[c] (Experimental Physics—for Geology); Guido Tagliaferri (Astrophysics)
Ordinary assistants	Alberto Bonetti[a]; Antonio Lovati; Antonino Mura (as Help); Carlo Salvetti (as Help); Guido Tagliaferri
Extraordinary assistant	Angelo Rossi
Commissioned assistants	Sergio Albertoni[b] (until 28.02.1953); Fiorenzo Duimio[b] (from 01.03.1953)
Volunteer assistants	Roberto Fieschi[b]; Paolo Gulmanelli[b]
Coadjutors	Angela Bernasconi[a]; Maria Bossi (until 30.06.1953)
Technicians	Giovanni Adorni; Renato Ballerini (on trial from 16.02.1953); Mario Pessina
Adventitious technician	Teresa Panizza
Subordinates	Emilio Bonelli; Walter Mantovani
Adventitious subordinates	Mario Decarli[a]; Lazzaro Fumagalli

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]not formally a member of the Institute of Physics

Duimio won the public competition for a chair of Theoretical Physics in 1967. He was professor of Theoretical Physics at Parma University.

Angelo Rossi was extraordinary assistant for the academic year 1952–53 and lecturer of Physics for the students of Biology, and of Exercitations of Physics in 1953–55.

6.3.9 1953–54: Rosario Attardi, Giuseppe Bassani, Maria di Corato, Antonio Scotti

In the 1953–54 academic year the Institute of Physical Sciences was joined by Antonio Scotti as assistant, Giuseppe Franco Bassani and Maria Di Corato as coadjutors. Rosario Attardi was appointed as lecturer. Bassani was in Milan for one year only and became later a prominent character in Italian physics. Di Corato and Scotti continued with their academic career at the Institute of Physical Sciences (Table 6.12).

Rosario Attardi was appointed lecturer of Exercitations of Experimental Physics for the 1953–54 academic year and extraordinary assistant for the subsequent year.

Giuseppe Franco Bassani[28] was born in Milan on October 29, 1929. He studied Physics at Pisa University where he graduated in 1952 with a dissertation on the color centers. He worked with Caldirola in Pavia and for one year (1953–54) in Milan in the solid state physics group. In 1954–56 he carried out his researches in the United States, at the University of Illinois with Frederick Seitz thanks to a Fullbright scholarship. He was then lecturer at Palermo University (1956–57) and Pavia University (1957-59). In 1959–64 he was as associate physicist at the Argonne National Laboratory.

Bassani won the public competition for a chair in Theoretical Physics in 1963. He was full professor of Theoretical Physics at the universities of Messina (1964–66) and Pisa (1966–69), of Solid State Physics at Rome University (1969–80) and at the Superior Normal School in Pisa (1980–2004), invited professor at the Ecole Polytechnique Fédéral in Lausanne (1972–73), and the University of Illinois (1979–80). He was the director of the Superior Normal School of Pisa (1996–99), president of the Division of Condensed Matter Physics of the EPS (1984–92), and president of the SIF (1999–2007).

Bassani's main fields of research were the theoretical studies on the properties of condensed states, in particular ionic crystals, semiconductors and dielectrics: the electronic band structure, the optical response of crystals, linear and nonlinear optical effects, the theory of excitons and polaritons.

Giuseppe Franco Bassani died in Pisa on September 25, 2008.

Maria Di Corato graduated in Physics at Milan University in the 1952–53 academic year with a dissertation on the distribution of stars in nuclear emulsions. She joined Occhialini's group as coadjutor from the 1953–54 academic year and continued to work with him in the nuclear emulsion projects to study cosmic radiation. She was lecturer of Exercitations of Physics from the 1956–57 academic year. She won the public competition for the chair of Atomic Physics for Milan University. Di Corato continued her researches in elementary particle physics also at CERN and Fermilab.

Antonio Scotti was born in Milan on February 15, 1930. He graduated in Physics at Milan University in the 1953–54 academic year with a dissertation on the application of group theories to nuclear spectroscopy. He joined the Institute of Physical Sciences

[28] On Giuseppe Franco Bassani, see: [143–145].

Table 6.12 Institute of Physical Sciences (1953–54)

Role	Name
Directors	Piero Caldirola[b]; Giovanni Polvani
Professors	Piero Caldirola[b] (Theoretical Physics); Giuseppe Occhialini[a] (Higher Physics); Giovanni Polvani (Experimental Physics)
Lecturers	Rosario Attardi[c] (Exercitations of Experimental Physics—for Geology); Alberto Bonetti[a] (Exercitations of Experimental Physics III); Piero Caldirola[b] (Spectroscopy); Fiorenzo Duimio[b] (from 01.02.1954); Fausto Fumi[c] (Mechanics); Sergio Gallone[c] (Radioactivity); Riccardo Levi-Setti[c] (Exercitations of Experimental Physics I); Antonio Lovati (Exercitations of Experimental Physics II); Martina Panetti Lovati[c] (Experimental Physics—for Geology); Giovanni Polvani (Experimental Physics II); Angelo Rossi[c] (Physics—for Biology); Carlo Salvetti (Electromagnetic Waves until 31.01.1953); Carlo Succi (Exercitations of Experimental Physics II); Guido Tagliaferri (Electrology)
Ordinary assistants	Alberto Bonetti[a]; Paolo Gulmanelli[b] (from 01.10.1954); Antonio Lovati; Antonino Mura (as Help); Carlo Salvetti (as Help until 31.01.1954); Carlo Succi; Guido Tagliaferri (as Help)
Commissioned assistant	Fiorenzo Duimio[b] (until 31.01.1954); Antonio Scotti[b] (from 17.02.1954 to 30.09.1954)
Volunteer assistants	Roberto Fieschi[b]; Paolo Gulmanelli[b] (until 30.09.1954)
Coadjutor	Giuseppe Franco Bassani[b] (until 30.06.1954); Maria Bossi (until 30.06.1954); Maria Di Corato[a] (until 30.06.1954)
Technicians	Giovanni Adorni; Renato Ballerini (on trial); Mario Pessina
Adventitious technician	Teresa Panizza
Subordinates	Emilio Bonelli; Walter Mantovani; Bassano Prada
Adventitious subordinates	Mario Decarli[a]; Lazzaro Fumagalli

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]not formally a member of the Institute of Physical Sciences

as commissioned assistant in the same year. He was lecturer of Statistical Mechanics and Probability Calculus from 1956. He won the public competition for a chair of Theoretical Physics in 1969. He was professor of Theoretical Physics at Parma University.

6.3.10 1954–55: Pietro Bocchieri, Riccardo Giacconi, Camillo Giori, Giovanni Maria Prosperi

In the 1954–55 academic year, Carlo Salvetti became professor of Radioactivity. This chair was financed by Mediobanca. Pietro Bocchieri and Giovanni Maria Prosperi joined the Institute of Physical Sciences as assistants, Camillo Giori as coadjutor, and Riccardo Giacconi as lecturer. Riccardo Giacconi continued his scientific career, which culminated with the award of the Nobel Prize for Physics, in the United States. Pietro Bocchieri and Giovanni Maria Prosperi were both professors of Theoretical Physics. Camillo Giori continued his scientific career at Milan and Parma universities while being also a Roman catholic priest (Table 6.13).

Pietro Bocchieri was born in Milan on February 22, 1930. He graduated in Physics at Pavia University. He followed Piero Caldirola to the Institute of Physical Sciences of Milan University where he was volunteer assistant from 1954. He won the public competition for the chair of Theoretical Physics in 1967. He was professor of Theoretical Physics at Pavia University (1967–97). He was the author in 1978, with Paolo Gulmanelli, of a physics textbook for the high schools.

Riccardo Giacconi was born in Genoa on October 6, 1961. He graduated in Physics at Milan University in 1954 with a dissertation on the preparation of an experience on V-particles with a Wilson chamber. He was lecturer of Exercitations of Physics II in 1954–56. On Occhialini's suggestion, he left Italy to the United States with a Fulbright scholarship as research associate at Indiana University in R.W. Thompson's group (1956-58), then at Princeton. He became US citizen in 1960. In 1962 he discovered the first known extraterrestrial X-ray source, Scorpius X-1. He worked on the Uhuru satellite project, launched in 1970, for the deep-sky study of X-ray sources. He was appointed professor of Astronomy and director of the Harvard-Smithsonian Center for Astrophysics in 1973, and worked on the HEAO-2 project of an orbital X-ray telescope. He was the first permanent director of the Space Telescope Science Institute in Baltimore (1981–93), and general director of the European Southern Observatory in Garching (1993–99). He was professor of physics and astronomy (1982–97) and research professor (from 1998) at Johns Hopkins University. He was the principal investigator for the Chandra Deep Field-South project. His main research topic was X-ray astronomy.

He was awarded the 2002 Nobel Prize for Physics "for the pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources".

Riccardo Giacconi died in San Diego on December 9, 2018.

Table 6.13 Institute of Physical Sciences (1954–55)

Role	Name
Directors	Piero Caldirola[b]; Giovanni Polvani
Professors	Piero Caldirola[b] (Theoretical Physics); Giuseppe Occhialini[a] (Higher Physics); Giovanni Polvani (Experimental Physics); Carlo Salvetti[c] (Radioactivity)
Lecturers	Alberto Bonetti[a] (Exercitations fo Experimental Physics III); Piero Caldirola[b] (Statistical Mechanics); Fiorenzo Duimio[e] (Electromagnetic Waves); Sergio Gallone[f] (Spectroscopy); Riccardo Giacconi[f] (Exercitations fo Experimental Physics II); Riccardo Levi-Setti[d] (Electrology); Marina Panetti Lovati[f] (Experimental Physics—for Geology); Giovanni Polvani (Experimental Physics II); Angelo Rossi[f] (Exercitations of Experimental Physics I); Carlo Succi (Exercitations of Experimental Physics II)
Ordinary assistants	Alberto Bonetti[a]; Paolo Gulmanelli[b]; Antonio Lovati; Antonino Mura (as Help); Carlo Succi; Guido Tagliaferri (as Help)
Extraordinary assistant	Rosario Attardo
Commissioned assistant	Antonio Scotti[b] (until 30.06.1955)
Volunteer assistants	Pietro Bocchieri[b] (from 01.05.1955); Roberto Fieschi[b] (until 26.04.1955); Giovanni Maria Prosperi[b] (from 01.05.1955)
Coadjutors	Maria Bossi (until 30.06.1955); Maria Di Corato[a] (from 01.03.1955 until 30.06.1955); Camillo Giori (from 20.11.1954 to 30.06.1955)
Technicians	Giovanni Adorni; Renato Ballerini (on trial); Mario Pessina
Adventitious technician	Teresa Panizza
Subordinates	Emilio Bonelli; Walter Mantovani; Bassano Prada
Adventitious subordinates	Mario Decarli[a]; Lazzaro Fumagalli

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]Chair of Radioactivity; [d]Chair of Electrology; [e]Chair of Electromagnetic Waves; [f]not formally a member of the Institute of Physical Sciences

Camillo Giori was born in Milan on February 23, 1922. During the resistance after the armistice he collaborated with the partisan brigade "C. Berra". In 1945 he was ordained Roman catholic priest for the Milan Archdiocese and sent to teach mathematics in the Milan seminary. At the same time he studied Physics at Milan University where he graduated in the 1954 with a dissertation on the electrons scattering in a diffusion chamber. In 1954 Giovanni Polvani asked the archbishop to let Giori work for the university. He was coadjutor (1954–55), extraordinary assistant (1955–56), and lecturer of Exercitations of Physics for the Institute of Physical Sciences until 1961. In 1961 he was asked to move to Parma university to start a biophysics laboratory, which he led for three years. He was professor of General Physics for Parma University.

Camillo Giori died in Parma on August 16, 2011.

Giovanni Maria Prosperi was born in Cagliari on March 15, 1931. He graduated in Physics at Milan University in 1954 with a dissertation on the field theory with non-localized interaction. He was volunteer assistant (1954–56 and 1958–61), coadjutor (1956–58) for the Institute of Physical Sciences at Milan University. He was lecturer of Theoretical Physics from 1961. He spent one year in 1961–62 at the Lawrence Laboratory in Berkeley. In 1966 he won the public competition for a chair of Theoretical Physics. He was professor of Institutions of Theoretical Physics at Bari University in 1966–68, then at Milan University. He was a member of the INFN Council and of the Commission for Thermodynamics and Statistical Mechanics of the IUPAP. His main research topics were the fundaments of quantum mechanics and statistical mechanics, the standard model, problems of invariance and symmetry.

6.3.11 1955–56: Ugo Businaro, Ettore Fiorini, Giancarlo Ghilardotti, Adele Sichirollo

In the 1955-56 academic year, four new assistants joined the Institute of Physical Sciences: Ugo Lucio Businaro, Ettore Fiorini, Giancarlo Ghilardotti and Adele Sichirollo. Businaro was for three years a researcher at the CISE. Businaro and Ghilardotti then left the university to work for industries. Fiorini and Sichirollo pursued instead their academic career at Milan University (Table 6.14).

Ugo Lucio Businaro was born in Vimercate in 1929. He graduated in Physics at Milan University in 1955 with a dissertation on nuclear stability. He was volunteer assistant at the Institute of Physical Sciences in 1955–56 and researcher at the CISE where he worked on the project of a nuclear reactor with Sergio Gallone and Carlo Salvetti for three years. He then worked for industrial groups such as FIAT and consultant in Italy and Belgium.

Ettore Fiorini was born in Verona on April 19, 1933. He graduated in Physics at Milan University in 1955 with a dissertation on the study and realization of a stereoscopic reconstruction device for a plate Wilson chamber. Assistant for the Institute of Physical Sciences since 1955. He won the public competition for the chair of Higher Physics in 1970. He was professor of Higher Physics at Milan University and of Nuclear and Subnuclear Physics at Milan-Bicocca University. He gave fundamental contributions to the discovery of neutral weak currents with the Gargamelle detector at CERN in collaboration with Carlo Rubbia and Riccardo Giacconi. He carried out the first double-beta decay experiments and directed the NUSEX experiment on significant limits on nucleon decay. In the INFN Gran Sasso Laboratories he contributed

Table 6.14 Institute of Physical Sciences (1955–56)

Role	Name
Directors	Piero Caldirola[b]; Giovanni Polvani
Professors	Piero Caldirola[b] (Theoretical Physics); Giuseppe Occhialini[a] (Higher Physics); Giovanni Polvani (Experimental Physics); Carlo Salvetti[c] (Radioactivity)
Lecturers	Alberto Bonetti[a] (Exercitations of Experimental Physics III); Piero Caldirola[b] (Electromangetic Waves); Fiorenzo Duimio[d] (Probability Calculus); Roberto Fieschi[d] (Solid State Physics); Fausto Fumi[d] (Statistical Mechanics until 31.01.1956); Sergio Gallone[d] (Spectroscopy); Riccardo Giacconi[d] (Exercitations of Experimental Physics II); Camillo Giorgi (Exercitations of Experimental Physics I); Piero Gulmanelli[b] (Physics—for Biology); Riccardo Levi-Setti[d] (Exercitations of Experimental Physics I); Antonio Lovati (Electrology); Martina Panetti Lovati[d] (Experimental Physics—for Geology); Giovanni Polvani (Experimental Physics II); Carlo Salvetti[c] (Nuclear Physics); Antonio Scotti[b] (Statistical Mechanics from 01.02.1956); Carlo Succi (Exercitations of Experimental Physics II)
Ordinary assistants	Alberto Bonetti[a]; Paolo Gulmanelli[b]; Antonio Lovati; Antonino Mura (as Help); Carlo Succi; Guido Tagliaferri (as Help; on leave from 01.11.1955 until 31.10.1956)
Extraordinary assistants	Giancarlo Ghilardotti; Camillo Giori
Commissioned alternate assistant	Ettore Fiorini (until 30.06.1956); Adele Sichirollo (from 01.07.1956)
Volunteer assistants	Pietro Bocchieri[b]; Ugo Lucio Businaro[c] (from 16.11.1955); Giovanni Maria Prosperi[b] (until 01.02.1956)
Coadjutors	Maria Di Corato[a] (from 01.03.1956 to 30.06.1956); Giovanni Maria Prosperi[b] (from 01.02.1956 to 30.06.1956); Antonio Scotti[b] (until 01.02.1956)
Technicians	Giovanni Adorni; Renato Ballerini (on trial); Mario Pessina
Adventitious technician	Teresa Panizza
Janitors	Emilio Bonelli; Walter Mantovani; Bassano Prada
Commissioned janitors	Mario Decarli[a]; Lazzaro Fumagalli

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]Chair of Radioactivity; [d]not formally a member of the Institute of Physical Sciences

to the studies on solar neutrinos from p-p reactions with the Gallex experiment and to the study of neutrinoless double-beta decays with the CUORE experiment.

Giancarlo Ghilardotti graduated in Physics at Milan University in 1955 with a dissertation on focalization, detection and analysis of the proton beam extracted from a synchrocyclotron. He was assistant for the Institute of Physical Sciences in 1955-58. He then worked for energy companies. He wrote a textbook on the physics of nuclear reactors with Sergio Gallone. His main research topics were nuclear reactors and, in recent years, renewable energies.

Adele Emilia Sichirollo graduated in Physics at Milan University in 1954 with a dissertation on an experience in Wilson chamber, under rocks, on the electromagnetic interactions of mesons. She was assistant for the Institute of Physical Sciences in 1955–56. She worked in the study of elementary particles in cosmic rays with Occhialini's group and then with accelerators. In later years she changed her research topic to medical physics. She was the director of the Department of Medical Physics of the National Institute for the Study and Treatment of Tumors.

Adele Sichirollo died in April 2016.

6.3.12 1956–57: Gianluigi Bacchella, Renzo Cirelli, Stefanello de Petris, Sergio Micheletti, Marcello Pignanelli, Franco Potenza

In the 1956–57 academic year four new assistants and coadjutors joined the Institute of Physical Sciences: Stefanello De Petris, Sergio Micheletti, Marcello Pignanelli, and Franco Potenza. Gianluigi Bacchella, a researcher working at CISE, was a coadjutor for the Institute of Physical Sciences in 1956–57. Renzo Cirelli began to collaborate with the Institute of Physical Sciences as lecturer. Cirelli, Micheletti and Pignanelli pursued their academic careers and became later professors at Milan University (Table 6.15).

Gianluigi Bacchella was a researcher at CISE. He was coadjutor for the Institute of Physical Sciences in the 1956–57 academic year.

Stefanello De Petris graduated in Physics at Milan University in 1954 with a dissertation on problems concerning the realization of a high-energy cosmic rays spectrometer. He was extraordinary assistant for the Institute of Physical Sciences in 1956–57. He became en expert in electronic microscopy. He worked as microscopist at the Clinic for Occupational Diseases of Milan University, at the National Institute for Medical Research in London, and at University College London.

Sergio Micheletti became assistant for the Institute of Physical Sciences in 1956–57. He pursued his academic career at Milan University and INFN. He was full professor of Experimental Physics. His research activity covered a wide range of topics of experimental and theoretical nuclear physics with experimental facilities in Italy and abroad.

Marcello Pignanelli was born in 1933. He graduated in Physics in 1956. He was assistant for the Institute of Physical Sciences from 1956–57. He was appointed

Table 6.15 Institute of Physical Sciences (1956–57)

Role	Name
Director	Piero Caldirola[b]; Giovanni Polvani
Professors	Piero Caldirola[b] (Theoretical Physics); Giuseppe Occhialini[a] (Higher Physics); Giovanni Polvani (Experimental Physics); Carlo Salvetti[c] (Radioactivity)
Lecturers	Alberto Bonetti[a] (Exercitations of Experimental Physics III; from 01.12.1956); Piero Caldirola[b] (Electromagnetic Waves); Renzo Cirelli[d] (Statistical Mechanics); Maria Di Corato[d] (Exercitations of Experimental Physics I); Roberto Fieschi[d] (Solid State Physics); Ettore Fiorini (Exercitations of Experimental Physics I); Sergio Gallone[d] (Spectroscopy); Camillo Giori[d] (Exercitations of Experimental Physics II); Paolo Gulmanelli[b] (Physics—for Biology); Antonio Lovati (Electrology); Maria Panetti Lovati[d] (Experimental Physics—for Geology); Giovanni Polvani (Experimental Physics II); Carlo Salvetti[c] (Nuclear Physics, from 01.12.1956); Antonio Scotti[d] (Probability Calculus); Carlo Succi (Exercitations of Experimental Physics II)
Ordinary assistants	Alberto Bonetti[a]; Paolo Gulmanelli[b]; Antonio Lovati; Antonino Mura (as Help; died on 24.07.1957); Carlo Succi; Guido Tagliaferri (as Help)
Extraordinary assistants	Stefanello De Petris; Giancarlo Ghilardotti (until 01.01.1957); Sergio Micheletti (from 01.01.1957)
Commissioned assistant	Marcello Pignanelli[c] (from 16.06.1957)
Commissioned alternate assistant	Ettore Fiorini (from 01.07.1957)
Volunteer assistant	Pietro Bocchieri[b]; Franco Potenza[a] (from 16.11.1956)
Coadjutors	Gianluigi Bacchella[a] (until 30.06.1957); Giovanni Maria Prosperi[b] (until 30.06.1957)
Technicians	Giovanni Adorni; Renato Ballerini (on trial); Mario Pessina
Adventitious technician	TeresaPanizza
Janitors	Emilio Bonelli; Walter Mantovani; Bassano Prada
Commissioned janitors	Mario Decarli[a]; Lazzaro Fumagalli

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]Chair of Radioactivity; [d]not formally a member of the Institute of Physical Sciences

lecturer from 1963. He became full professor in 1976. He was professor of several courses; among them Nuclear Physics and Nuclear and Subnuclear Physics. He was director of the Institute of Physical Sciences in 1978–80 and of the Department of Physics in 1980–88 and in 2000–04. He was the dean of the Faculty of Sciences in 2004–07. He was the director of the local division of the INFN in 1994–2000. In his research activity he was engaged in several topics concerning theoretical and experimental nuclear physics beginning with the relativistic cyclotron of the Institute of Physical Sciences; among the others: nuclear reactions induced by neutrons and light ions; nuclear models; magnetic spectroscopy; gamma spectroscopy.

Franco Potenza graduated in Physics at Milan University in 1955 with a dissertation on the application of scintillation counters to gamma-radiation spectroscopy. He was volunteer assistant for the Institute of Physical Sciences since 1956–57. He worked for the Milan Planetarium and published several popularization books of astronomy. He collaborated to the project of the Italian national telescope.

Renzo Cirelli was born in Villafranca Lunigiana (Massa-Carrara province) on August 10, 1925. He graduated in Physics at Milan University. He became lecturer of Statistical Mechanics from the 1956–57 academic year and worked with the group of Theoretical Physics of Piero Caldirola. His main research topics concerned the mathematical aspects of theoretical physics, group theory and mathematical physics. He won the public competition for a chair of Theoretical Physics in 1976 for Milan University. He was professor of Mathematical Methods of Physics. He was the author, with Caldirola and Prosperi, of the textbook of Institutions of Theoretical Physics used at Milan University. He translated some important physics texts such as Max Born's Atomic Physics and Landau-Lifsic's Quantum Mechanics: Non-relativistic Theory.

Renzo Cirelli died in 2017.

6.3.13 1957–58: Fernanda Emilia Pugno Santagata, Sergio Peppino Ratti

In the 1957–58 academic year Fernanda Emilia Pugno Santagata and Sergio Peppino Ratti joined the Institute of Physical Sciences as assistants. Ratti pursued his academic career as professor at Milan and Pavia universities (Table 6.16).

Sergio Peppino Ratti was born in Garlate (Lecco province) on September 5, 1934. He graduated in Physics at Milan University in 1957 with a dissertation on an experience project for the search of 500 m_e particles. He was assistant for the Institute of Physical Sciences from 1957-58. He was associate professor of Experimental Physics at Milan University (1960–72) and full professor of Experimental Physics at Pavia University (1972–2006). He was permanent visiting scientist at CERN and Fermilab, and worked at the Northwestern University in Evanston. He was among the founder of the doctoral studies in Italy in 1981. His main research topics concerned experiments in elementary particle physics culminating in the development

Table 6.16 Institute of Physical Sciences (1957–58)

Role	Name
Directors	Piero Caldirola[b]; Giovanni Polvani
Professors	Piero Caldirola[b] (Theoretical Physics); Giuseppe Occhialini[a] (Higher Physics); Giovanni Polvani (Experimental Physics); Carlo Salvetti[c] (Radioactivity)
Lecturers	Alberto Bonetti[a] (Exercitations of Experimental Physics III); Maria Bossi Succi[d] (Exercitations of Experimental Physics—for Industrial Chemistry); Renzo Cirelli[d] (Statistical Mechanics); Maria Di Corato[d] (Exercitations of Experimental Physics I); Fiorenzo Duimio[d] (Electromagnetic Waves); Ugo Facchini[d] (Nuclear Physics II); Roberto Fieschi[d] (Solid State Physics); Ettore Fiorini (Exercitations of Experimental Physics II); Sergio Gallone[d] (Spectroscopy); Paolo Gulmanelli[b] (Physics—for Biology); Maria Panetti Lovati[d] (Experimental Physics—for Geology); Giovanni Polvani (Experimental Physics II); Carlo Salvetti[c] (Nuclear Physics); Antonio Scotti[d] (Probability Calculus); Carlo Succi (Experimental Physics I—for Industrial Chemistry); Guido Taglaiferri (Electrology)
Ordinary assistants	Alberto Bonetti[a]; Paolo Gulmanelli[b]; Antonio Lovati; Ettore Fiorini (from 17.02.1958); Carlo Succi; Guido Tagliaferri (as Help)
Extraordinary assistants	Sergio Micheletti; Fernanda Emilia Pugno Santagata
Commissioned assistants	Marcello Pignanelli[c]; Sergio Peppino Ratti (from 16.02.1958)
Commissioned alternate assistant	Ettore Fiorini (until 16.02.1958)
Coadjutors	Franco Potenza[a] (until 30.06.1958); Giovanni Maria Prosperi[b] (until 30.06.1958)
Volunteer assistants	Pietro Bocchieri[b]; Giancarlo Ghilardotti[c] (until 01.03.1958)
Technicians	Giovanni Adorni; Renato Ballerini (on trial); Mario Pessina
Adventitious technician	Teresa Panizza
Janitors	Emilio Bonelli; Walter Mantovani; Bassano Prada
Commissioned janitors	Mario Decarli[a]; Lazzaro Fumagalli

[a] Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]Chair of Radioactivity; [d]not formally a member of the Institute of Physical Sciences

of the compact muon solenoid detector for the large hadron collider at CERN; the development of counters for the positron emitting tomography; the application of multi-fractals to the dynamics of dioxin environmental pollution.

Sergio Peppino Ratti died in Pavia on September 10, 2020.

Fernanda Emilia Pugno Santagata was extraordinary assistant in 1957-58.

6.3.14 1958–59: Giancarlo Baldini, Ernesto Giuseppe Canobbio, Gianmaria de Munari, Maria Franceschetti, Carla Morlacchi, Massimo Pauri

In the 1958-59 academic year, four new assistants joined the Institute of Physical Sciences: Giancarlo Baldini, Ernesto Giuseppe Canobbio, Maria Franceschetti, and Massimo Pauri. Baldini and Pauri pursued their academic careers as professors, respectively at Milan and Parma University. Canobbio became a preeminent member of EURATOM. In the same academic year, Gianmaria De Munari became lecturer; he then worked at Parma University.

Carla Morlacchi was hired as non-permanent government employee (Table 6.17).

Giancarlo Baldini was born in Guastalla (Reggio Emilia province) on January 24, 1934. He graduated in Physics at Milan University in 1958 with a dissertation on the optical properties of potassium iodide containing metallic ions. He was a member of the solid state group of research at the Institute of Physical Sciences then moved to the University of Rochester, New York, where he worked at the Institute of Optics in 1962–65. He pursued his academic career at Milan University with researches in solid state physics. From the 1980s his studies concerned biophysics. He was full professor at Milan University and Milan-Bicocca University from 1998.

Ernesto Giuseppe Canobbio was extraordinary assistant for the Institute of Physical Sciences for the 1958–59 academic year. From the 1960s he worked for the Commissariat à l'Energie Atomique in France and at a EURATOM association at the Centre of Nuclear Studies in Saclay and at the Department of Plasma and Controlled Fusion Physics in Grenoble. He joined the Brussels EURATOM headquarters of the European Fusion Programme. He was an advisor of the Nuclear Physics and measurements commission of the European Communities and chair of the International Fusion Research Council.

Gian Maria De Munari worked in the cloud chamber group of the Institute of Physical Sciences in 1955. He was lecturer of Exercitations of Experimental Physics for chemistry students from the 1958–59 academic year. In 1965 he worked for the CNEN in Rome on rare gases. He worked at the Institute of Physical Sciences of Parma University in the research group of solid state physics, at the Milan division of INFN and at the CNR group of Structure of matter.

Maria Franceschetti graduated in Physics at Milan University in 1958 with a dissertation on the study of a radiofrequency ion source in a magnetic field. She

Table 6.17 Institute of Physical Sciences (1958–59)

Role	Names
Directors	Piero Caldirola[b]; Giovanni Polvani
Professors	Piero Caldirola[b] (Theoretical Physics); Giuseppe Occhialini[a] (Higher Physics); Giovanni Polvani (Experimental Physics); Carlo Salvetti[c] (Radioactivity)
Lecturers	Alberto Bonetti[a] (Exercitations of Experimental Physics III); Renzo Cirelli[d] (Statistical Mechanics); Laura Colli[d] (Nuclear Physics); Gianmaria De Munari[d] (Exercitations of Experimental Physics I—for Chemistry); Maria Di Corato[d] (Exercitations of Experimental Physics I); Fiorenzo Duimio[d] (Electromagnetic Waves); Roberto Fieschi[d] (Solid State Physics); Ettore Fiorini (Exercitations of Experimental Physics II); Sergio Gallone[d] (Nuclear Physics); Paolo Gulmanelli[b] (Physics—for Biology); Antonio Lovati[d] (Experimental Physics I—for Industrial Chemistry); Marina Panetti Lovati[d] (Experimental Physics—for Geology); Giovanni Polvani (Experimental Physics II); Antonio Scotti[d] (Probability Calculus); Carlo Succi (Experimental Physics II—for Industrial Chemistry); Guido Tagliaferri (Electrology)
Ordinary assistants	Alberto Bonetti[a] (as Help); Ettore Fiorini; Paolo Gulmanelli[b]; Sergio Peppino Ratti (from 01.03.1959); Carlo Succi (on leave from 01.11.1958 until 31.10.1959); Guido Tagliaferri (as Help; on leave from 01.02.1959)
Commissioned assistant	Marcello Pignanelli[c]; Franco Potenza[a] (from 01.02.1959)
Extraordinary assistant	Ernesto Giuseppe Cannobbio; Maria Franceschetti (from 01.02.1959); Sergio Micheletti (until 01.02.1959)
Alternate assistant	Giancarlo Baldini; Sergio Micheletti (from 01.02.1959)
Commissioned alternate assistant	Sergio Peppino Ratti (until 01.03.1959)
Volunteer assistants	Pietro Boccheri[b]; Giovanni Maria Prosperi[b]; Massimo Pauri[a] (from 01.02.1959); Franco Potenza[a] (until 31.01.1959)
Non-permanent government employee (group C)	Carla Morlacchi
Technicians	Giovanni Adorni; Renato Ballerini (on trial); Mario Pessina
Adventitious technician (3rd category)	Teresa Panizza
Janitors	Emilio Bonelli; Walter Mantovani; Bassano Prada
Commissioned janitors	Mario Decarli[a]; Lazzaro Fumagalli

[a]Chair of Higher Physics; [b]Chair of Theoretical Physics; [c]Chair of Radioactivity; [d]not formally a member of the Institute of Physical Sciences

was extraordinary assistant for the Institute of Physical Sciences from the 1958–59 academic year. She shortly cooperated with the CISE in the early 1960s.

Massimo Pauri was born in Milan on April 12, 1933. He graduated in Physics in Milan in 1958 with a dissertation on some considerations on a model of extended particle. He was assistant for the Institute of Physical Sciences from 1958-59. He worked then at the Department of Physics and Earth Sciences, Parma University from 1960 and at the Institute of Physical Sciences of Milan University (1966–1975). He won the public competition for a chair of Theoretical Physics in 1975 and became professor of Theoretical Physics for Parma University (1975–2000). He was also interested in philosophy of science. He was vice-president of the Academie international de philosophie des Sciences and senior fellow of the Center for the Philosophy of Science of Pittsburgh.

6.3.15 1959–60: Giampaolo Bellini, Giuseppe Mambriani, Bruno Montagnini, Antonino Pullia, Nice Terzi, Guido Vegni

In the 1959–60 academic year, five new assistants joined the Institute of Physical Sciences: Giampaolo Bellini, Bruno Montagnini, Antonino Pullia, Nice Terzi, and Guido Vegni. Giuseppe Mambriani joined as lecturer. Bellini, Pullia, Terzi and Vegni pursued their academic careers becoming professors at Milan University, Mambriani at Parma University, and Montagnini at Pisa University.

Alfredo Matuonto was hired as technician and Alessandro Di Nicola as janitor (Table 6.18).

Gianpaolo Bellini was born in Milan on June 12, 1935. He graduated in Physics at Milan University in 1959 with a dissertation on the interaction of high-energy protons on light nuclei. He became extraordinary assistant for the Institute of Physical Sciences from 1959. He was NATO fellow at the École Normale Supérieure d'Orsay in 1966–67, CERN fellow in 1984–85, guest scientist at CERN, IHEP, the Fermi National Laboratory, and INFN Gran Sasso Laboratory. He obtained the "libera docenza" in 1967 and became full professor at Milan University in 1976.

In the 1960s, Bellini worked in high energy physics with researches on particle resonances studied with cloud and bubble chambers. His studies continued on high energy particle collisions on complex nuclei in the 1970s with the little Omega magnet at CERN and at IHEP. In the 1980s he worked on experiments on heavy flavors at CERN and at Fermilab. For these experiments, the research group led by Bellini developed silicon detectors and chambers. After three decades in high energy physics, Bellini moved to the study of neutrinos in underground laboratories. From 1990 he planned and directed the Borexino experiment at the INFN Gran Sasso Laboratories, for which he developed the methods to achieve high levels of radiopurity. This fundamental experiment, which made the history of physics, measured the solar neutrino fluxes from the p-p cycle and the CNO cycle, and the geoneutrinos from

Table 6.18 Institute of Physical Sciences (1959–60)

Role	Name
Directors	Piero Caldirola[c]; Giovanni Polvani
Professors	Piero Caldirola[c] (Theoretical Physics); Giuseppe Occhialini[b] (Higher Physics); Giovanni Polvani (Experimental Physics); Carlo Salvetti[d] (Radioactivity)
Lecturers	Alberto Bonetti[b] (Exercitations of Experimental Physics III); Renzo Cirelli[e] (Statistical Mechanics); Larua Colli[e] (Nuclear Physics); Gianmaria De Munari[e] (Exercitations of Experimental Physics—for Chemistry); Maria Di Corato[e] (Exercitations of Experimental Physics I); Fiorenzo Duimio[e] (Electromagnetic Waves); Roberto Fieschi[a] (Solid States Physics); Sergio Gallone[e] (Spectroscopy); Paolo Gulmanelli[c] (Physics—for Biology); Antonio Lovati[e] (Experimental Physics I—for chemistry); Giuseppe Mambriani (Experimental Physics II—for Industrial Chemistry); Sergio Micheletti (Electrology); Martina Panetti Lovati[e] (Experimental Physics—for Geology); Marcello Pignanelli[d] (Exercitations of Experimental Physics—for Mathematics and Physics); Giovanni Polvani (Experimental Physics II); Sergio Peppino Ratti (Exercitations of Experimental Physics III); Antonio Scotti[e] (Probability Calculus); Carlo Succi (Experimental Physics I—for Industrial Chemistry)
Ordinary assistants	Alberto Bonetii[b] (as Help); Ettore Fiorini (on leave from 01.11.1959 to 31.10.1960); Paolo Gulmanelli[c]; Sergio Micheletti (from 01.03.1960); Marcello Pignanelli[d] (from 17.12.1959); Sergio Peppino Ratti; Carlo Succi (as Help; on leave from 01.11.1959 to 31.10.1960); Guido Tagliaferri (as Help; until 01.02.1960)
Extraordinary assistant	Giampaolo Bellini (from 16.11.1959); Maria Franceschetti Oberto
Commissioned assistants	Marcello Pignanelli[d] (until 16.12.1959); Sergio Micheletti (until 01.03.1960); Guido Vegni[b] (from 16.12.1959)
Commissioned alternate assistant	Giancarlo Baldini (from 15.12.1959); Antonio Pullia
Volunteer assistants	Pietro Bocchieri[c]; Bruno Montagnini[d] (from 16.11.1959); Massimo Pauri[b]; Giovanni Maria Prosperi[c]; Nice Terzi[a] (from 09.02.1960)
Non-permanent government employee (group C)	Carla Morlacchi
Technicians	Giovanni Adorni; Renato Ballerini (on trial; 3rd category); Mario Pessina (principal; retired 01.10.1960)
Adventitious technician (3rd category)	Teresa Panizza
Commissioned adventitious technician	Alfredo Matuonto (from 04.07.1960)
Janitors	Emilio Bonelli; Alessandro Di Nicola; Walter Mantovani; Bassano Prada
Commissioned janitor	Mario Decarli[b]
Non-permanent government auxiliary employee	Lazzaro Fumagalli

[a]Chair of Solid State Physics; [b]Chair of Higher Physics; [c]Chair of Theoretical Physics; [d]Chair of Radioactivity; [e]not formally a member of the Institute of Physical Sciences

deep layers of our planet. Bellini was member of the INFN Council in 1973–83 and of the EPS council in 1980–83, INFN vice-president in 1983–89.

Giuseppe Mambriani graduated in Physics at Milan University in 1959 with a dissertation on the contributions to a dishomogeneous method to study heterogeneous nuclear reactors. He became volunteer assistant for the Institute of Physical Sciences from 1960.

Giuseppe Mambriani was professor of General Physics at Parma University where he worked on elementary particle physics.

Bruno Montagnini was born in Verona in 1935. He graduated in Physics at Pavia University in 1957. He worked at AGIP Nucleare in 1958–69. At the same time he was assistant and lecturer for Milan University, Milan Polytechnic, and Pavia University. He obtained his "libera docenza" in 1972. He was full professor of nuclear reactor physics at Pisa University since 1976. His main field of research concerned reactor physics.

Antonino Carlo Luigi Pullia was born in Castiglione d'Adda (Lodi province) on May 1, 1935. He graduated in Physics at Milan University in 1959 with a dissertation on the determination of the molecular and crystalline structure of bis(N,N-diethyldithiocarbammate)-Cu(II). He became assistant for the Institute of Physical Sciences in 1959. He started his research career with the studied on the bubble chamber in collaboration with Lagarrigue's group of École Normale Supérieure in Paris to study strong interactions. He then worked with the Gargamelle giant bubble chamber at CERN. He contributed to the interpretation of neutrino interactions as the neutral weak current. His further collaboration with CERN concerned the researches with LEP. With Ettore Fiorini he carried out the first experiments on double-beta decays. He was full professor at Milan University and Milan-Bicocca University. He was director of the Physics Department of Milan-Bicocca University and director of the local division of INFN of Milan and Milan-Bicocca universities.

Antonino Pullia died on April 14, 2020.

Nice Terzi graduated in Physics in 1959 with a dissertation on the first order isotopic effects in simple liquids. She married Gianpaolo Bellini. She started her academic career as a volunteer assistant for the chair of Solid State Physics. She was professor of Solid State Physics at Milan University from 1979 and at Milan-Bicocca University. She was the director of the Conference of the International School of Physics Enrico Fermi in 1987. She was the Director of the Physics Department of Milan University in 1988-91. She was the national coordinator of the degree courses in Material Sciences. She was engaged with the post-graduate courses for high school physics teachers and the coordinator of the master in Sciences Teaching at Milan-Bicocca University.

Guido Vegni was born in Barlassina (Monza-Brianza province) on March 14, 1931. He graduated in Physics at Milan University in 1957 with a dissertation on the study of the tau meson decay in nuclear emulsions. He became assistant at the Institute of Physical Sciences in 1960 and was a CERN fellow. He was full professor of Elementary Particle Physics at Milan University.

In 1963–66 he worked with the bubble chamber in Saclay in an international experiment which discovered the g-meson or $\rho 3$ (1690). With the Milan group, Vegni built a target of pioneering silicon detectors to study the diffractive dissociation of mesonic states on nuclei. In the 1970s Vegni worked on the use of the first personal computers. He was a member of an Italian-Soviet collaboration in Dubna. He worked with the Serpukhov accelerator to study the products of interactions of nuclear targets with π^- at 40 GeV/c. They observed two states which were considered radial excitations of π^-. The experimental technique used in Dubna was further developed at CERN, with a telescope of sensors for the WA71 experiment. His expertise in the use of silicon detectors made his contribute to the development of the silicon microvertex detector for the DELPHI experiment. As for the LHC collider he supported the ATLAS experiment and directed the Milan group which built the silicon pixel detector. Vegni was also engaged in physics education and directed the local division of the post-graduate specialization school for high-school teaching. He retired in 2006.

Guido Vegni died on June 2, 2016.

6.3.16 1960–61: Vincenzo Ardente, Giancarlo Bassani, Constance Dilworth, Michelangelo Fazio, Emilio Gatti, Alfredo Luccio, Santina Menardi, Nello Morresi, Fausto Pellegrini, Emanuele Quercigh, Francesco Giuseppe Resmini, Lucia Tallone

The 1960–61 academic year saw again a large number of new assistants and lecturers. Some of them had a brilliant academic career at Milan University or in other institutions.

Vincenzo Amorosini, a non-permanent State auxiliary employee was also assigned to the Institute of Physical Sciences (Table 6.19).

Vincenzo Ardente graduated in Physics at Milan University in the 1960 with a dissertation on the strong interactions. He was then voluntary assistant for the Institute of Physical Sciences for the 1960–61 academic year.

Giancarlo Bassani graduated in Physics at Milan University in the 1960 with a dissertation on the study of a source of polarized protons: project and partial experimental realization of a preliminary experience. He then became assistant for the Institute of Physical Sciences. He was a post-doctoral fellow and research associate at the School of Physics Research, University of Minnesota in the early 1960s. He worked with Norton Hintz and his 30 inch radius, 180 °C spectrometer. Bassani detected the (p, t) reactions which were theoretically studied by Hintz and Bayman. He died in a car accident soon after his return to Italy.

Constance Charlotte Dilworth[29] was born in Streatham (London) on February 5, 1924 (Fig. 6.5). She studied at King's College, London University, in 1941–44. She obtained her B.Sc. in 1944 and her M.Sc. in 1945. She was a research student at the

[29] On Constance Charlotte Dilworth, see: [146, 147].

Table 6.19 Institute of Physical Sciences (1960–61)

Roler	Name
Director	Giovanni Polvani
Professors	Piero Caldirola[o] (Theoretical Physics); Ugo Facchini[h] (Experimental Physics II); Giuseppe Occhialini[n] (Higher Physics); Giovanni Polvani (Experimental Physics); Carlo Salvetti[f] (Nuclear Physics); Guido Tagliaferri[r] (Radioactivity)
Lecturers	Sergio Albertoni[g] (Nuclear Physics); Renzo Cirelli[p] (Statistical Mechanics); Laura Colli[a] (Electrology); Gianmaria De Munari[u] (Exercitations of Experimental Physics—for Chemistry); Constance Dilworth Occhialini[t] (Thermology); Roberto Fieschi[e] (Solid State Physics); Ettore Fiorini[i] (Experimental Physics I); Sergio Gallone[s] (Spectroscopy); Emilio Gatti[b] (Electronics); Paolo Gulmanelli[q] (Electromagnetic Waves); Giuseppe Mambriani[n] (Experimental Physics I—for Industrial Chemistry); Nello Morresi[c] (Physics—for Agriculture); Martina Panetti Lovati[k] (Experimental Physics); Fausto Pellegrini[u] (Exercitations of Experimental Physics II; Marcello Pignanelli[m] (Experimental Physics with Exercitations II); Giovanni Maria Prosperi[o] (Probability Calculus); Sergio Peppino Ratti (Exercitations of Experimental Physics III); Carlo Succi[j] (Experimental Physics II); Guido Tagliaferri[d] (Physics—for Biology); Lucia Tallone[l] (Experimental Physics with Exercitations I)
Ordinary assistants	Alberto Bonetti[n] (as Help; on leave); Ettore Fiorini; Paolo Gulmanelli[o]; Sergio Micheletti (on leave); Marcello Pignanelli[f], *r* (on leave from 16.06.1961); Sergio Peppino Ratti; Carlo Succi (as Help); Guido Giuseppe Vegni[n] (from 17.12.1960)
Extraordinary assistant	Giampaolo Bellini; Maria Franceschetti Oberto; Alfredo Luccio[r]
Commissioned assistant	Santina Menardi[h]
Alternate assistant	Francesco Giuseppe Resmini[r] (from 16.03.1961)
Commissioned alternate assistant	Michelangelo Fazio; Emanuele Quercigh[n]
Volunteer assistants	Vincenzo Ardente[o] (from 16.11.1960); Giancarlo Bassani[h] (from 01.12.1960); Pietro Bocchieri[o]; Giuseppe Mambriani[n]; Bruno Montagnini[f]; Massimo Pauri[n]; Giovanni Maria Prosperi[o]; Nice Terzi[e]; Guido Giuseppe Vegni[n] (until 16.12.1960)
Non-permanent government employee (3rd category)	Carla Morlacchi
Technician (principal)	Giovanni Adorni
Technicians (3rd class)	Renato Ballerini; Teresa Panizza
Janitors	Emilio Bonelli; Mario Decarli[h], *n*; Walter Mantovani; Bassano Prada
Non-permanent auxiliary government employees	Vincenzo Amorosini; Lorenzo Fumagalli

Chairs other than Experimental Physics: [a]Electrology; [b]Electronics; [c]Physics for Agriculture; [d]Physics for Biology; [e]Solid State Physics; [f]Nuclear Physics; [g]Nuclear Physics—for Physics; [h] Experimental Physics II; [i]Experimental Physics I for Industrial Chemistry; [j]Experimental Physics II for Industrial Chemistry; [k]Experimental Physics for Geology; [l]Experimental Physics with Exercitations I—for Mathematics and Physics; [m]Experimental Physics with Exercitations II—for Mathematics and Physics; [n]Higher Physics; [o]Theoretical Physics; [p]Statistical Mechanics; [q]Electromagnetic Waves; [r]Radioactivity; [s]Spectroscopy; [t]Thermology; [u]not formally a member of the Institute of Physical Sciences

Admiralty Research Laboratory in 1943–45. After she graduated, she joined the H.H. Wills Laboratory in Bristol to carry on studies on the effects of insulating surface films on the behavior of contacts between semi-conducing crystals. She soon joined the team led by Cecil Frank Powell working on nuclear emulsions for the detection of elementary particles from cosmic radiation or from radioactive sources. Dilworth worked in particular to the uniform processing of nuclear emulsions in collaboration with Giuseppe Occhialini and Ron Payne. In 1948, Dilworth and Occhialini were called to Brussels by Max Cosyns to work at the Centre du Physique Nucléaire of the Université Libre de Bruxelles. Her researches, with Occhialini and Eric Samuel, continued to develop new kinds of better nuclear emulsions, in particular the Kodak NT2 and Nt4 and the Ilford G5. Dilworth worked in Brussels until the end of the 1950s. Her main scientific results were the study of the Auger effect in the μ-mesons capture in nuclear emulsions (with the Brazilian theoretician physicists Mario Schönberg), the multiple production of mesons, the magnetic deflection of fast charged particles from nuclear emulsions, the production of cosmic ray stars in nuclear emulsions, the sagitta method to study the tracks of particles in nuclear emulsions.

In 1950 Dilworth married Occhialini and followed him to Italy in 1954, after he became extraordinary professor of Higher Physics at Genoa University in 1949 and at Milan University in 1952. They divided their working time between Italy and Belgium. Dilworth came to Italy in 1954 as a INFN researcher and collaborated with other Italian physicists who shared their research activity with the Brussels laboratory. With the INFN Milan division, she collaborated to the Italian and European flights of emulsion packs on balloon to detect cosmic rays at high altitude, in particular the strange particles. In the 1950s Dilworth studied the K-mesons, first the natural ones in the secondary cosmic rays and later the artificially produced one at the Bevatron in Berkeley or at the CERN. Among their researches on K-mesons: the study of the $\tau - \theta$ puzzle, the Kμ problem, hyperfragments, the decay schemes of the Σ-hyperon. In particular, she observed three different kinds of K-meson decays. In 1959-60 Dilworth and Occhialini spent a sabbatical year at the Massachusetts Institute of Technology with Bruno Rossi. Dilworth worked in the Laboratory for Nuclear Science on meteorological and geophysical researches on cosmic rays and interplanetary plasma to be studied on satellites.

Back to Milan, Dilworth became a member of the Institute of Physical Sciences. In Milan, Dilworth and Occhialini founded a new research group on cosmic physics and supported the birth of Italian and European scientific research studies. Dilworth collaborated with the European Space Research Organisation (ESRO) from 1946. The Milan group cooperated with the Centre d'Érudes Atomiques in Saclay, Paris, to send a spark chamber on balloon to study primary cosmic electrons. After this successful flight, they organized other flights, on balloon or satellite, of instruments to study cosmic electrons and atmospheric and albedo neutrons. Within the ESRO, Dilworth was engaged in the organization of the launches of some satellites: the HEOS-A to study interplanetary magnetic fields and solar wind (1968), the TD-1 to study UV, X, and γ-rays, heavy cosmic nuclei and solar wind (1972), COS-B with the Gamma Ray Telescope on board to draw the first γ-map of the Galaxy (1975), and the EXOSAT to study active galactic nuclei, star coronae, cataclysmatic variable stars, white dwarfs, X binaries, cluster of galaxies, and supernovae remnants (1983). Dilworth was also a coordinator of the project for the Gornergrat national observatory for infrared astronomy, near Zermatt in Switzerland.

Constance Dilworth died in Florence on May 17, 2004.

Michelangelo Fazio was born in Parma on September 6, 1936. He graduated in Physics at Milan University in 1960 with a dissertation on the project and building of a new gaseous discharge detector for particles. He then became assistant. He was professor of General Physics from 1961 until his retirement in 2006, at Milan University. His main field of research concerned nuclear physics and worked on nuclear magnetic resonance at Niguarda Hospital in Milan. He was engaged with publishing and translating tens of books on general physics for high school and university students.

Michelangelo Fazio died in 2015.

Emillio Gatti was born in Turin on March 18, 1922. He graduated in Industrial Engineering at Padua University in 1946, with Giovanni De Fassi and Giovanni Someda as tutors. He obtained a post-graduation degree in Electric Communications at the National Electrotechnical Institute "Galileo Ferraris" in Turin, with.a dissertation on a variabile selectivity amplifier for low frequencies.

Gatti was a researcher at the CISE since 1948. He was engaged in the development and local production of new electronic instruments for nuclear physics and technology. In 1950 he was appointed head of the electronics division at the CISE, which soon became an electronics laboratory of international level. From 1957 he was professor in charge of Electronics at Milan Polytechnic. He obtained his libera docenza in Applied Electronics in 1953. He left the direction of the electronics division in 1957 when he became extraordinary professor of Electronics at Milan Polytechnic. He was later professor of Nuclear Electronics, of Physics, and again of Applied Electronics. His main inventions are: the added step method for single channel discriminators (1953); the charge pre-amplifier to process the signals of ionization chambers (1955); the Vernier method for the time localization of events (1956); the streamer chamber (1961); the sliding scale method (1963) or Gatti correction for high differential linearity in multichannel amplitude analyzers; the Silicon Drift Detector (SDD), with Pavel Rehak of the Brookahven National Laboratory (1983). Gatti was awarded the honorary degree in Physics from Milan University in 1995.

Emilio Gatti died in Milan on July 9, 2016.

Alfredo Luccio was born in 1936. He graduated in Physics at Milan University in the 1957–58 academic year with a dissertation on an experience project for the search in a Wilson chamber of a double beta-decay. He was assistant at the Institute of Physical Sciences from 1960 and was engaged in the building of the relativistic cyclotron. He obtained his "libera docenza" in 1967. He was lecturer of Physics II from 1970 at the Pisa University and became assistant in 1971. He worked at the Frascati Laboratories in 1978-80, then he worked at Brookhaven National Laboratory. His main research fields were accelerator physics and the free electron laser. He retired from Pisa University in 1988.

Santina Menardi was commissioned assistant for the Institute of Physical Sciences in 1960–61 for the chair of Experimental Physics II.

Nello Morresi was lecturer of Physics for the Institute of Agriculture of Milan University in 1960. He became professor of Applied Acoustics at Milan Polytechnic, and conducted his researches in acoustics at the Institute of Technical Physics. He was among the founders of the Italian Association of Acoustics. He patented sound-absorbing panels for air-conditioning ducts

Fausto Pellegrini graduated in Physics at Milan University in the 1958 with a dissertation on the realization of a spectrometer for protons. He was lecturer of Applied Electronics. He worked at the INFN Laboratories in Legnaro and was professor at Padua University.

Fausto Pellegrini died in 2015.

Emanuele Quercigh was born in Naples in 1934. He studied at Milan University where he graduated in Physics in the 1958-59 academic year with a dissertation on a contribution to the problem of discrimination of slow particles in nuclear plates. He became assistant in 1960. In 1964 he started to work as fellow at CERN, then as staff physicist. He worked on experiments with the 2m bubble chamber, which had just been commissioned, used in connection with the Proton Synchrotron. Quercigh and David Lord led the ERASME (Electron RAy Scanning and Measuring Equipment) project which began in 1970. With five working units, the ERASME measuring table analyzed the films from both the 2 m bubble chamber and the Big European Bubble Chamber (a 3.7 m bubble chamber). From 1968, Quercigh supported a proposal for a large magnet and spark chamber system, the OMEGA project, a spectrometer which permitted new experiments, and in the early 1990s a proposal for ALICE (A Large Ion Collider Experiment) in connection with LHC. In 1974, Quercigh became the spokesperson of the T209 bubble chamber experiment which led to the observation of the ϕ-meson and to the study of the lifetime and spin of the Ω^--baryon produced in $K^- p$ interactions at 8.25 GeV/c. He then played a role in the WA85, WA94 and WA97 experiments on strange quark plasma. Quercigh retired from CERN in 1999.

Francesco Giuseppe Resmini was born in 1938. He graduated in Physics at Milan University in the 1960-61 academic year with a dissertation on the study of a magnetic field for an AVF cyclotron. His main research field was the theory of accelerator physics, in particular of cyclotrons and their components, and the applications to environmental and medical diagnostics. In 1976 he had the idea of a superconducting cyclotron to be built by the INFN. After a period of research at Ganil and at Michigan State University, his project of a K800 superconducting cyclotron was financed by the INFN. Resmini coordinated the group who built the machine. It was the first European cyclotron of this kind. Resmini prematurely died in 1984. In 1994 Resmini's cyclotron was moved to the INFN National Laboratories of the South in Catania for fundamental research and applications to medicine.

Lucia Felicita Tallone[30] was born in Villafalletto (Cuneo Province on March 19, 1928. She graduated in Physics at Turin Univeristy on December 9, 1952 with a dissertation on reflection and refraction of a wave by a corrugated surface. In 1953 Tallone joined the research group on cosmic radiation led by Carola Maria Garelli at Turin University. They worked on the properties of heavy mesons and hyperons by

[30] On Lucia Tallone, see: [148].

the analysis of the tracks in emulsions flown on balloons in 1953–55. In particular, Tallone was among the scanners who observed a track that permitted to estimate the mass of the Σ^- particle. In 1958-59 she worked at the Research Center for High Energies in Berkley in Emilio Segrè's team, and in 1959–61 at CERN to train in the use of bubble chambers. She became assistant at Milan University in 1960. In 1980 she became associate professor. In 1983 she started the laboratory of radiobiology at the Physics Department for studies in the biological effects of α-rays, radiotherapy, and radioprotection. In 1988 she became professor of Medical Physics at Milan University.

6.4 The Collaboration with CISE, INFN and GAIFUM

Three institutions played a fundamental role in the development of the research activities of the Institute of Physics during the Reconstruction period: the CISE, a research centre on nuclear physics and technology; the INFN, in particular the Milan division; and the GAIFUM, an association of industrial and bank companies which financed many researches of the Institute. Polvani's role was a primary one in linking the Institute of Physics to them: he was actually the founder of the GAIFUM, he insisted in having in Milan a local division of the INFN, and was a member of the board of the CISE.

The CISE (Centro Informazioni Studi Esperienze)[31] was established in 1946 as a limited liability company[32] for studies, researches and scientific experiences in any field. This generic name hid the fact that they wanted to do research on the use of nuclear energy for civil purposes. Italy had surrendered to the allies in 1943 when they signed the armistice, but in 1946 there was still no peace treaty. The intension to do nuclear research could not yet be made explicit.

The post-war reconstruction had to face a relevant problem for the Italian economic structure: the scarcity of energy sources. The energetic question posed as an objective the development of national sources. The war damages were quickly repaired: the electricity transmission networks and the hydroelectric plants were rebuilt in a short time. The continuously growing request of electrical energy pushed the development of hydroelectric plants up to the almost total exploitation of the natural resources in the late Sixties. At the same time the industrial development cause a parallel development of the thermoelectric sector which, due to the shortage of national sources, had to resort to a considerable increase in imports of hydrocarbons. The establishment of ENI in 1953 favored the exploitation of the national methane deposits in Northern Italy. At the same time, immediately after the end of the war, interest arose in the possible industrial exploitation of electricity from nuclear sources. It is in this energy and industrial context that some private companies decide to found the CISE.

[31] On the origin of the CISE see: [149–154].

[32] The CISE became a joint stock company in 1976.

The CISE was born on the initiative of university institutes and private companies. The Milan Institute of Physics contributed with three members, Giuseppe Bolla, Carlo Salvetti and Giorgio Salvini, so that in the first decade, the collaboration between the Institute and the CISE can be considered, under a certain point of view, a symbiosis. Bolla, Salvetti and Salvini had clear in mind that the Institute of Physics also had to contribute to the modernization of the national industry, in particular to special studies on energy production. In particular, Bolla was not willing to consider the traditional division between pure and applied research; in his opinion the technological applications of theoretical results were a moral duty for a physicist.

In an initial period (1946–1960) the CISE was located in Piazza Cimitero Monumentale in Milan. Due to the tight spaces, the company expanded into adjacent buildings. The headquarters was established in a central area of Milan. Eventually they planned a new site, with a unitary structure, and which was in any case close to the university institutes. In 1960 they moved to a new location in Redecesio, in the municipality of Segrate, close to the North-Western borders of the municipality of Milan. In the Milan site, the CISE was structured in seven research divisions: Chemistry; Electronics; Nuclear Engineering; Nuclear Physics; Theoretical Physics; Medical-Biological Service and Sanitary Physics. In the new Redecesio site, the CISE laboratories[33] were six—Chemistry and Radiochemistry, Electronics, Nuclear Physics, Solid Physics, Nuclear Engineering, Technologies—with the aid of three services-Documentation, Workshop, Health Service.

In May 1946, Bolla, Salvetti and Salvini founded the "board of promoting physicists" and suggested to the Società Edison[34] to start an initiative in the nuclear field. With the help of an engineer, Mario Silvestri, the Società Edison financially supported a "Division of special studies in physics" where the Institute physicists would have shared their knowledge with the industry. Other two societies, Cogne[35] and FIAT,[36] joined the project and the CISE was founded as an autonomous society under Giuseppe Bolla's scientific leadership and Vittorio De Biasi, the Edison managing director, as their president, on November 19, 1946. The Institute of Physics would make the professors and researchers available while the companies took care of the administrative management and provided other qualified personnel. The three founding companies paid in as a symbolic share capital 40.000 lire each.[37] They were

[33] On the laboratories in the Redecesio site, see: [155].

[34] The Società Generale Italiana di Elettricità Sistema Edison was and still is (as Edison S.p.A.) one of the largest Italian electrical companies. It was founded in Milan in 1884 to produce and distribute electric energy. It became soon the most important electrical company on a regional level and, after the Second World War, on a European level.

[35] The Cogne was founded in 1909 in Aosta as "Società Anonima Miniere di Cogne" (Cogne Mines Limited Company) as a mine, steel and hydroelectric power industry.

[36] The FIAT was founded in Turin in 1899. It is the main Italian automotive industry.

[37] As a comparison, a newly graduate hired by Edison had a monthly wage of 18.000 lire. Both the capitals and the number of people working for CISE were too small as compared with the US, UK and France cases. At the same time, in the first year of its life, the wages were directly paid by the universities and industries, so that almost all the funds were used for research only.

soon joined by other ones: SADE[38] and Montecatini[39] in 1947, Falck[40] and Pirelli[41] in 1949, Terni[42] in 1950, the Municipality of Milan through its municipal electricity company in 1952.

The first CISE scientific committee was formed by Bolla (president), Salvetti, Salvini and Silvestri (promotors), Polvani (director of the Institute of Physics), Antonio Cavinato (FIAT representative, and CISE managing director), Arturo De Benedetti (Cogne representative). They were joined from February 1947 by Edoardo Amaldi and Gilberto Bernardini of Rome University, Ugo Facchini (Institute of Physics), Gerlando Marullo (Montecatini representative), and Francesco Scandone (SADE representative). Amaldi and Bernardini worked for CISE for some years by teaching theoretical aspects of nuclear physics: Amaldi taught neutron physics, Bernardini taught particle detection techniques.[43] They were joined in 1949 by Bruno Ferretti who faced theoretical and computational problems of applied nuclear physics.

The CISE had not a see of its own in the first six months and was hosted by the Institute of Physics. In May 1947, the Edison put at their disposal three rooms at a bolts factory near the Milan Monumental Cemetery. One year later, in June 1948, the usable rooms were ten with thirteen people working in them. If it is true that the private companies were investing very little funds in the CISE, it was also evident that only the State could support (as it was happening in the nuclear leading countries of the time) such a project in a proper way.

The main aim of CISE was to build a nuclear power plant. The CISE was thus engaged in many fields of research such as nuclear physics and technology, electron-

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[38] The SADE was a private electricity society founded in Venice in 1905 and operated in some Italian regions.

[39] The Montecatini was a chemistry company founded in Tuscany in 1888 as "Società anonima delle miniere di Montecatini" (Limited Company of the Montecatini Mines) for the exploitation of ferrous pyrites and sulfur. It became one of the most important Italian industrial groups in many other chemistry sectors.

[40] The Falck is a steel company. It was founded in Milan in 1906 as "Società anonima Acciaierie e Ferriere Lombarde" (Steel and ironworks Ltd. company in Lombardy). It changed its name in "Acciaierie e Ferriere Lombarde Falck" (Falck Steel and Ironworks) in 1932.

[41] The Pirelli company was founded in Milan in 1872. It is a global operator in the tire sector and in the production of rubber objects.

[42] The Terni company was founded in 1884 as "Società degli altiforni, fonderie e acciaierie di Terni" (Company of the blast furnaces, foundries and still mills of Terni) is a steel industry. In the period under consideration, its name was "Terni società per l'industria e l'elettricità S.p.A.' (Terni society for industry and electricity).

[43] Amaldi advanced some conditions to their adhesion to the CISE activities: (1) the existence of the organization in question had not to be secret; (2) the character of the organization had to be on a national basis and, if the opportunity arose, on an international basis; (3) the organization had to be as serious as possible; (4) the secrets relating to the results obtained had to relate exclusively to technical and not to scientific discoveries; (5) the development of this organization for essentially practical and applicative purposes had not to clip the already existing Centre for Nuclear Physics center of the CNR, whose purpose was purely scientific and didactic, in the sense of training young researchers. University of Rome "Sapienza", Physics Archives, Amaldi Papers, 211.3.1: Letter from Edoardo Amaldi to Giuseppe Bolla, February 3, 1947.

ics, radiochemistry and nuclear chemistry, nuclear engineering, theory of nuclear reactors. At the end of the first decade of life, the CISE could boast at least three successful results: the 400 keV Cockcroft-Walton accelerator,[44] the electrolytic system for the concentration of heavy water, and the chemical plant for the purification of uranium salts and the production of metallic uranium. From 1951, the CISE started the publication of a monthly review, "Energia nucleare", with papers and reviews in Italian and English.

Only in 1952 did the State also become interested in nuclear research. The CNRN was founded to support researches in nuclear physics and the industrial applications of nuclear energy. The CISE acted as the operational base of the CNRN. The public participation in CISE funding favored the development of research projects for the design of national nuclear reactors. Two international events contributed to the governmental interest in the exploitation of nuclear energy: the 1955 international conference "Atoms for Peace"[45] which started the unveiling of the military secret on technical knowledge to build a nuclear plant, and the 1956 Suez crisis. The second half of the Fifties saw in rapid succession a series of steps that led to the production of electricity from nuclear sources in Italy: the signing of the EURATOM Treaty in 1957, the establishment of two centers of research and experimentation in Ispra[46] and Frascati,[47] the plans to build nuclear power plants in Latina, Garigliano, Trino Vercellese, and Caorso.

In 1957 the CNRN. decided to set up own operation groups. Forty-eight researchers decided to leave the CISE to work for the CNRN. Even if the CISE managed to return to the same staff numbers of about 230 people only in 1960, they started to work on a project of an entirely national reactor, the CIRENE (CISE REattore a NEbbia),[48] which was completed in 1987. The reactor was but never activated due to the result of the 1987 nuclear referendum, heavily influenced by the Černobyl accident the year before. They managed instead to complete a 3 MeV Van de Graaff accelerator for protons (it was later transformed into a 7 MeV Tandem) and a plant for the isotopic separation of O_{18}.

A first step in the establishment of the INFN[49] was the creation of a "Center for the study of nuclear physics" of the CNR in 1947. One year later, the Center changed its name into "Center for the study of nuclear physics and elementary particles physics". The high costs to sustain researches in cosmic ray physics were not adequately financed by the CNR anymore in the first very difficult years after the war. Polvani

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44 On the Cockcroft-Walton at the CISE, see: [156].

45 On the "Atoms for Peace" conference, see: [157]. On the participation of the CISE to the "Atoms for Peace" conference, see: [158].

46 The Ispra Laboratories started in 1956 and were the first research institute of the CNRN. The researches began with a 1.000 kW nuclear reactor bought from the United States, the first working reactor in Italy.

47 The Frascati Laboratories of the CNRN. started in 1957. The Frascati Laboratories of the INFN were already active since 1954. Relevant machines in the history of Italian physics were built in Frascati: the Electrosynchrotron (1957), AdA (1961), ADONE (1969), and DAΦNE (2000).

48 On the history of the CIRENE, see: [159].

49 On the history of the INFN up to the mid 1970s, see: [160–162].

denounced this situation as very dangerous for the mere survival of group of the Milan Institute of Physics:

> Before the war, the Institute of Physics of Milan had annually sufficient CNR grants to carry out the researches organized each time in the high mountains. After the war it also obtained other subsidies, but inadequately in relation to the increase in the prices of things and the cost of living: for the past year it had a million lire (now almost completely consumed); for the current year, on the other hand, according to the news brought by prof. Amaldi, secretary of the Committee for Physics of the CNR, there is the eventuality that for the Institute of Physics of Milan lacks any subsidy of the CNR. And this is happening right now that the cost of accommodation in Cervinia has also increased!
>
> With regard to the situation that has thus arisen for our Institute, the profound and unjust disparity in which it finds itself in confrontation with the Institute of Rome, precisely because of the National Research Council, cannot be ignored; and the comparison between the two institutes is imposed by this precise circumstance: that they are the only ones in Italy who work in the field of cosmic ray physics.
>
> It is undeniable that they both work with great activity, intensity, competence and success; but while the Institute of Rome, in addition to university funds (i.e. university endowments and laboratory fees), can—because the establishment of a Nuclear Physics Center within it, subsidized by the CNR with an annual endowment of five million—also have this last sum available; the Institute of Milan, not having a fixed assignment of the CNR, is continually threatened, and this year it seems inevitably, of not having access to other funds than university funds.
>
> The request, insistently and repeatedly made to the CNR to establish in our Institute a research center for cosmic rays, has never had (like so many requests), any response; and thus the unjust situation mentioned above has arisen.
>
> And if this situation is not removed, the Institute of Milan will inevitably end up having to abandon research in the high mountains on cosmic rays, that is, more properly it will have to abandon any scientific activity: what is of very serious damage not only to the Institute itself for the loss of resonance that it would suffer, but even more so for the assistants, who, by ceasing all scientific activity, would be excluded from the gymnasium where those who aspire to make their name not unknown in the field of science compete. [50]

Eventually the solution for proper fundings to cosmic ray and nuclear physics was the establishment of a national research institute of its own. The INFN was established by a decree of the president of the CNR on August 8, 1951 [163]. The INFN planned and built the first electron accelerator in Italy, the electrosynchrotron in Frascati, the seat of the first national laboratory of the INFN. Further national laboratories were established in Legnaro (1960), Catania (1976) and under the Gran Sasso (1985).

In this respect two events could have changed the history of Italian and European physics but, above all, of the Institute of Physical Sciences. In December 1951-January 1952 the discussions on the future location of the CERN took into consideration the possibility of Como, an Italian city close to the Italian-Swiss border and about 50 kilometers far from Milan.[51] The CNR National Committee of Physics

[50] Centro APICE, Historical Archive Milan University: serie 7, busta 77, Scienze: "Relazione sull'attività dell'Istituto di Fisica dell'Università di Milano dalla sua fondazione ad oggi e sulla sua situazione attuale", February 2, 1949: pp. 21–23.

[51] For a detailed reconstruction of this proposal, see Chap. 9 of [164].

agreed to support the nomination of Como in case the project to host the CERN in Geneva would have fallen (other European cities, such as Copenhagen and Oslo, had been nominated). Few days before Christmas holidays, Polvani urgently got in touch with the mayor of Como, Giuseppe Terragni, to submit him the question. In a meeting on December 14, 1951, with the Mayor of Como, Polvani and Caldirola illustrated the benefits Como would have enjoyed in case they hosted the CERN. The Italian delegation in Paris, where they were discussing the establishment of the CERN, advanced informally the Como proposal. News of a meeting in Alassio on December 30, 1951 with Polvani, Terragni, and some members of the Italian government leaked to the press; according to Terragni the informer was Caldirola who denied. The local population started to think that the research center could have been connected to nuclear weapons or that Como would have become a military target for a possibile nuclear bombing. On January 2, 1952 the Como municipal executive board voted in favor of offering about 1 square kilometer (not in the territory of Como municipality) to the future research center, but the negative reaction of the people prevented them to write the vote in a legally valid document. Due to the population negative reaction, the municipal council voted against the Como proposal on January 11.

The second event was, for a very short time, the possibility to have the electrosynchrotron (and the first national laboratory of the INFN) built in Milan and not in Frascati (another possibile location was Pisa).[52] The construction of a big Italian machine for electrons was advanced by the first INFN president, Gilberto Bernardini. In a meeting of the INFN board held in Pisa in April 1953, the physicists from Milan and Turin supported the building of this machine in Northern Italy. Discussions between Amaldi (in favor of Rome) and Caldirola soon followed. Caldirola got in touch with the mayor of Milan who reacted positively. A similar reaction came from the local industrial milieu and was supported by the local press. Notwithstanding the fact that the INFN board voted in favor of Milan, with the only opposition of Amaldi, eventually Frascati was chosen as seat of the synchrotron.

A local division of the INFN in Milan was not listed in the 1951 decree. This exclusion made Polvani upset. He urgently wrote to the president of the CNR and strongly advocated to include the Milan Institute of Physics in the new institution:

> The Institute of Physics of the University of Milan should be called to take part of the constituting new Institute.
>
> This Institute namely carries on, from 1938 on, researches in the branch of nuclear physics relative to cosmic rays, many off them on high mountains: at Plan Maison (1939), at Passo Sella (1940, '41, '42, '43), at Lago d'Inferno (1946, '47), at Plateau Rosaz (from 1948 on).
>
> The studies in this field, made by assistants and collaborators of the Institute, permitted the publication of more than 50 works, all in the Physical Review and in the Nuovo Cimento; and they made the Milan "cosmicists" known and esteemed by Italian and foreign scholars. A sure testimony of the seriousness, industry, and willingness of the Milanese "cosmicists" and of the importance of the results attained by them, is the fact that, among the worthiest young people who graduated in this last decade from the Institutes of Physics of the Universities in Italy and obtained chairs of Physics, there are Prof. G. Cocconi, now at Ithaca, and Prof.

[52] See Chap. 10 of [164].

> G. Salvini, now at Princeton, both educated at the Institute in Milan, and here they had been skillful and industrious researchers of the phenomena concerning cosmic radiation.
>
> The leaving away of these young physicists from Milan did not stop nor slow down the activity of the Institute: the latter is in fact engaged nowadays not only in continuing several researches on high mountain on cosmic rays, by means of a large Wilson chamber built in the meanwhile in the Institute itself, but also, from about a year, in beginning several experimental studies with nuclear emulsions that, with the recent move to Milan of Prof. G. Occhialini, will further increase, together with those made by means of the Wilson chamber and of other detectors.
>
> This intensive and time-long activity, that the Institute of Milan makes in the researches of cosmic rays physics, doubtless lends it the specific qualities to include in the constituting National Institute for Nuclear Physics.
>
> In any case, just with the aim to support and unify the researches on cosmic rays, as you will remember, there was a meeting on September 19, 1949, in Turin, called by you, that had the aim to constitute an inter-university Centre with Rome, Milan, Padua, Turin, for such researches. You invited me to that meeting, as one of the participants to the future Centre. Thus I will not hide from you that, given the seniority, so to say, that the Institute of Milan has in the researches on cosmic rays, given the importance of the attained results, given lastly my own participation to the mentioned meeting in Turin, it made no little astonishment, disappointment and sorrow to see that the Institute of Milan was excluded from the mentioned Institute you constituted with three Centre of Rome, Padua, Turin (with presidential decree of August 8, 1951): a patent injustice that you spontaneously recognised with me on January 4, in Alassio.[53]

Polvani's action fully succeeded in hosting in the Institute of Physics the Milan division of INFN since the beginning. As Polvani's letter clearly highlighted, that the establishment of the local division of INFN could only favor the development of the researches in cosmic ray physics. This did not only concern researches with cloud chambers and counter but also facilitated the calling of Occhialini from Genoa University to introduce the researches with the new nuclear emulsions technique in Milan.

If the presence of INFN in the Institute of Physics implied new fundings for research in many fields, it also increased the number of technicians, a kind of worker highly necessary in experimental physics research but too underrepresented in the university. These technicians were, strictly speaking, not members of the Institute of Physics but employees of the INFN only; the collaboration between the Institute of Physics and the Milan division of the INFN was but so close that there presence had a positive effect on the development of the Institute of Physics too. At the same time, the presence of the INFN made the search of new space for the institute more impelling. In particular, Occhialini's group benefitted from the activities with the INFN, and many scanners of nuclear emulsions, requested by an efficient analysis of the exposed emulsions, could be employed by the INFN. Occhialini's group but needed a lot of space and eventually was the first to leave the Palace of Sciences and build a new laboratory (nicknamed "Occhialini's shed") in the location of the future new seat of the Institute of Physics.

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[53] Milan University, BICF Library, Occhialini-Dilworth Papers, 6, 1, 6: Letter from Giovanni Polvani to the president of the CNR, February 14, 1952.

The INFN worked in strict connection with the Institute of Physics by financing research activities and by collaborating to large research projects. An example was the building of the relativistic cyclotron (see Chap. 7), which saw some INFN technicians contributing to the assembling of the accelerating machine.

A last word on Polvani's activities in the development of the Institute of Physics must be said about the GAIFUM, an association of friends of the institute, i.e. of members of the main industrial and financial institutions of the Milan area who were solicited by Polvani to finance scientific research. The GAIFUM was established on February 14, 1950 during a meeting of the Rotary Club in Milan after a preparation activity which lasted for more than one year.[54] The statute was eventually written in February 1952.[55] Besides some individual members, such as Eugenio Somaini, Vittorio Boghi, F. Casighini, and Stefano Jacini, the GAIFUM members were private and public institutions: AGIP Nucleare (nuclear power), Ansaldo San Giorgio (electrotechnic and mechanic industry), Associazione Cotonieri Italiana (Italian cotton industry association), Associazione Industriale Bresciana (industrial association of Como), Associazione Industriale di Como (industrial association of Como), Associazione Industriale di Lecco (industrial association of Lecco), Associazione Industriale Lombarda (industrial association of Lombardy), Associazione Nazionale Industrie Elettriche (national association of electrical industries), Cassa di Risparmio delle Provincie Lombarde (bank), Comitato Onoranze di Alessandro Volta (committee of honors of Alessandro Volta), Como Prefecture, Credito Italiano (bank), Dinamo, Edison (electricity power), Elettrica Bresciana (electrical industry in Brescia), Ferrovie Nord Milano (railways), Innocenti (automotive industry), Italcementi (cement factories), Manifattura del Seveso (textile industry), Metallurgica Bresciana (metallurgy industry in Brescia), Montecatini (chemical industry), Orobia (electricity power), OSRAM (electrical lighting industry), Pirelli (rubber and tire industry), SNAM—Società Nazionale Metanodotti (methane pipeline industry), SNIA (Società Navigazione Industriale Applicazione) Viscosa (chemical industry). The GAIFUM financed scholarships and supported many researches such as the building of the giant cloud chamber.[56]

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Chapter 7
The Institute of Physics in the Post-war Period. Part 2: Some Highlights on Research in the Post-war Period

Leonardo Gariboldi

Abstract Soon after the end of WWII, the cosmic ray physics group started again their researches with cloud chambers and counters on some locations on the Alps. Their researches culminated with the construction of the huge multi-plate cloud chamber, built by Fiorini, Giacconi and Succi, and used on the Alps. Among the results obtained by them was the observational proof of the non-existence of the varytrons erroneously discovered by Alikhanian. Another group working on cosmic ray physics started with Occhialini's arrival to Milan. He created an international group, working in strict collaboration with other other groups in Italy and abroad, with nuclear emulsions exposed to cosmic radiation on balloons. The Milan group was an important member of the G-stack collaboration, with the exposition of a giant stack of emulsions to cosmic rays for the study of mesons, strange particles and hyperons, and of the K^--collaboration with the exposition of a stack to artificially produced particles at the Bevatron for the study of strange particles. Nuclear physics research was carried on in particular in collaboration with the CISE and the INFN. An important field of research was the theoretical study of nuclear reactors. Carlo Salvetti and Sergio Gallone developed solutions of the equations for the transient regime and the working conditions of nuclear reactors. The experimental study was based on electrostatic machines built at the CISE and INFN. Theoretical physics researches covered a wide range of topics, from the phenomenology of cosmic rays to the ergodic conditions in quantum theory. An interesting research group was that of solid state physics, one of the first in Italy, founded by Fumi.

7.1 Introduction

With the great increase of the number of professors, from two in 1946 (Giovanni Polvani and Giuseppe Bolla) to six in 1960 (Piero Caldirola, Ugo Facchini, Giuseppe Occhialini, Giovanni Polvani, Carlo Salvetti, Guido Tagliaferri), and of the number of assistants, the research activities covered in the Reconstruction period many different topics. The strict collaboration and overlapping activities with the CISE and the INFN further amplified the number of research topics, making it difficult, in many cases impossible, to draw a hypothetical line which could separate what was done as Institute of Physics and what was done as CISE or INFN. In order to avoid an

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excessive fragmentation and dripping of information, a selection of topics has been made. The analysis of cosmic ray researches imposes itself automatically given the role they played in the last years before and during the Second World War. We shall therefore consider the continuation of the studied made with counters and cloud chambers. A second reason to face cosmic ray researches was the new group of nuclear emulsions led by Giuseppe Occhialini since the most people, instruments and facilities were devoted to these studies. A second field comprises research topics of theoretical physics: theoretical nuclear physics by Salvetti's group, and a wide range of topics by Caldirola's groups. The description of two electrostatic accelerating machines, built at the CISE and at the INFN, introduces to the topic of nuclear physics research which was mostly conducted in the frame of those institutions. A last research field concerns the beginning of solid state physics studies in Milan with the group established by Fumi.

7.2 Cosmic Radiation with Counters and Cloud Chambers

The Reconstruction of cosmic ray physics research was based on a new group with Antonio Mura, Giorgio Salvini and Guido Tagliaferri.[1] They continued the studies on extensive showers in air: the analysis of their lateral development and of their composition. Polvani found a new location on the Alps for them: Lago Inferno at 2100 m above sea level, in Sondrio province. They made two expeditions to Lago Inferno: in summer 1946 with the first cloud chamber, and in summer 1947 with counters only since Mura, the cloud chamber operator, was ill.

The researches on the lateral development of extensive showers concerned several topics which had been studied by Auger's group [7] and continued the previous researches by Cocconi's group. Mura, Salvini and Tagliaferri used the first cloud chamber [8] with a set of counters and analyzed more than 1200 photographs of tracks of showers. The experimental distribution of the tracks photographs was compatible with the results obtained with counters only. The lateral distribution was a Poisson distribution. The results were a confirmation of the work made, with counters only, by Cocconi, Loverdo and Tongiorgi during the war on the lateral development of the showers, in agreement with Molière's theory according to Williams's calculations.

The incertitudes on the identification of a mesonic component in cosmic ray showers moved Mura, Salvini and Tagliaferri [9] to use simultaneously in a same experimental disposition some criteria: the penetrating power; the probability of multiplication through the absorbers; the absorption in elements of different atomic numbers. After the analysis of about 200 photographs, they decided that the cloud chamber was not able to give a consistent indication of the presence of mesons. Mura, Salvini and Tagliaferri concluded the first expedition to Lago Inferno with the following results: (a) the extensive showers in air are not fully compatible with the

[1] Reminiscences on these researches can be found in: [1–3]. On the researches with cloud chambers by physicists of the Milan Institute of Physics see [4–6].

theory of the cascade process; besides electrons and photons, also more penetrating ionizing particles could be found in a shower; (b) they were not able to identify these other particles which were supposedly mesons; (c) mesons could be originated with the primary radiation (they still thought it was made of electrons) or during the cascade development of the shower.

In 1947, Salvini and Tagliaferri took with them a set of counters to Lago Inferno [10]. Mura was at that time ill and could not repair the cloud chamber. They build particular systems, in the shape of castles, made of counters and iron or lead absorbers. They found [11, 12] that the penetrating particles were mostly generated inside the absorbers and, at least partially, in groups. They were instead not able to estimate the percentage of particles already existing in the air; the local production could be found in greater percentage in the less dense showers.

From these measurements it emerged for the first time that a penetrating component participated in the constitution of the extensive showers in air, formed by several types of particles, some of which were able to interact with the absorbers and give rise to showers that contained other penetrating particles. This fact showed that these particles were able to interact strongly. It was hypothesized that this penetrating component was constituted by nucleons or by π-mesons. They compared these results with the work of other cosmic ray physicists who had used a cloud chamber, for example W. Fretter. They was concluded that the showers in air also included penetrating and mixed showers, i.e. formed by both a penetrating component and by an electromagnetic one. The processes by which these swarms were generated were similar to those observed locally in cloud chambers, that is, produced by the interaction of cosmic radiation with matter.

Salvini made a further theoretical study to identify the better criteria to distinguish the electronic from the penetrating component in the extensive showers in air [13, 14]: the different probability of multiplication when they go through the absorber (electrons lose energy mostly in cascade multiplication processes, while mesons with ionization processes), and the different absorption in materials with different atomic number.

Salvini was also interested in the proposal advanced by Auger and other physicists about the existence of another particle in the extensive showers in air [15]. The new particles should have had a mass of the order of some electronic masses, and their number should have been about one fourth of the number of electrons. Salvini compared the results of the Milan group with the consequences of this hypothesis and concluded that there were not enough results to support the existence of another kind of particles in the extensive showers in air. Salvini advanced a general frame which summed up the current knowledge on the extensive showers in air [16] as for their components, their development in the atmosphere, and the spectra of the soft and penetrating components.

In the researches with the first cloud chamber, they collected some photographs with traces of highly ionizing particles and a two-branched star. The star was generated in the gas. The analysis of the phenomenon seemed to require the presence in the process of one or more neutrons. This experience was somewhat the anticipation of the researches undertaken by Tagliaferri, with the third cloud chamber, on nuclear interactions.

The experiments carried out in the second phase of research by Tagliaferri's group, starting from 1948, with the use of the second cloud chamber at the Testa Grigia laboratory[2] at 3505 m, had as their purpose the analysis of the nuclear interactions produced by cosmic radiation with the matter that constituted the plates inserted in the chamber. In particular, attention was focused on the phenomenon of nuclear explosions.

The Testa Grigia laboratory was built in 1947 on the initiative of the CNR [18]. The project was supported by the group of the Rome Institute of Physics, at the time directed by Edoardo Amaldi. This group was made up of Gilberto Bernardini, Claudio Longo and Ettore Pancini. The structure of the Testa Grigia laboratory was intended for the study of elementary particles in the domain of high energies as in the cosmic rays. It was inaugurated in 1948. Gilberto Bernardini's far-sightedness highlighted the limits of such a research program, due to the imminent use of accelerators which, in his opinion, would soon supplant cosmic rays as a means of research in elementary particle physics. At the same time this laboratory, given the limited resources and funding available for research in general, constituted a fundamental research center, at least for Italy. Actually, very important results were obtained at the Testa Grigia laboratory. This laboratory took on an echo over the years to an international level and is still in operation today. The laboratory was operational until the mid 1950s then was abandoned due to lack of funds. It began to be reused in 1965, with the management of the Institute of Cosmogeophysics of the CNR. Most of the equipment for the experiments was provided by a State organization which managed the war material left by the allied troops operating in Italy. In the difficult period of the first post-war period, the lack of resources was a major limitation for scientific research and the availability of this organization was an important help for the Testa Grigia groups.

The first to carry out experiments on the Testa Grigia were Cocconi and Tongiorgi in 1939, before the laboratory was built, with a study on the neutron component of cosmic radiation. Then followed the experiments in the cloud chamber by Salvini and Tagliaferri, who continued the research undertaken in the previous years at Lago Inferno. In 1949 Salvini left the Testa Grigia laboratory to Princeton. Carlo Succi joined the Milan group soon after. In 1952–1954, Riccardo Giacconi, who had practiced with another cloud chamber built by Lovati, Mura, Succi and Tagliaferri for research on mesons at sea level, carried out experiments at the Testa Grigia laboratory for his degree dissertation. This experience constituted a fundamental stage in the career of Giacconi who, impressed by the scarcity of statistics that could be accumulated with the highly energetic particles of cosmic radiation, was stimulated in his subsequent studies in the field of high energy to the conception

[2] On the history of the Testa Grigia laboratory, see [17]. The Testa Grigia laboratory was planned by Gilberto Bernardini, with the help of Ettore Pancini and Marcello Conversi, on the Italian-Swiss border close to the Teudolo Pass. It was used by physicists from Bologna, Milan, Rome and Turin universities.

of a kind of concentrator, which will materialize in 1960 in the grazing incidence telescope for X-rays.

The research on the extensive showers in air carried out at Lago Inferno during the first expedition in 1946 had shown that it was necessary, for a more accurate knowledge of the phenomenon, the use of a larger cloud chamber. They decided to build a second cloud chamber thanks to the works led mainly by Mura and the technicians Adorni and Pessina [19]. The second cloud chamber was finished by the summer of 1948, thanks also to the help of Antonio Lovati for the assembly and development. The second cloud chamber was brought to the Testa Grigia laboratory. The second cloud chamber is on exhibition at the National Museum of Science and Technology "Leonardo da Vinci" in Milan.

It is worth mentioning the fact that the research activities on cosmic ray studies were not very expensive but were not for free either. The economic conditions soon after the war were but of extreme poverty. The materials to build counters and cloud chambers, the circuits, the absorbers, the transportation of material and the accommodation costs for researches on the Alps, all summed up required and new way to get funds. Polvani's ability in finding financial support was exceptional, almost legendary. Tagliaferri, in his reminiscences [1], mentions that it was Polvani's claim that "procuring the means to work was his business". Polvani knocked at every possible door: he got the use of the mountain locations from electric companies, the iron and lead absorbers from metallurgy companies, etc. He was a master of the spoken and written word, and was able to convince with rhetorical appeals such the one to the rector in 1949:

> Now the Institute of Physics of Milan has been carrying out research on cosmic rays for ten years, a subject of great and important topicality; and the works released in this regard by the Institute itself have always been warmly welcomed in the international field. A tradition has thus been formed, a commitment to which the Institute is essentially linked, and to which it cannot fail without its serious scientific and moral damage.
>
> Scientific and moral damage not only towards ourselves as a university institution; but also with regard to the individual assistants: in fact, all the assistants of the Institute are now involved in the work on cosmic rays, who through these jobs can form the scientific qualifications to get to the libera docenza and possibly even higher.
>
> Don't make them work anymore? But it is necessary that they attend to scientific work as well as to didactic work; otherwise they inevitably become men without features, ignorant and whiners. Woe to the staff of a scientific institute if the flame of pure research fails!
>
> Make only a few work? But research on cosmic rays, the only ones in the rest of modern physics that can be carried out in Italy with the scarce means available, necessarily obliges us to employ many, very many people simultaneously. Now in all laboratories in the world, physicists are waiting for this field of research with "teams" of researchers. This depends on the complexity and delicacy of the experiments. These are in fact photographic recordings of events which, under particular conditions, take place in a Wilson chamber controlled by Geiger and Müller counters, and which require complex and delicate electronic circuits, complex and delicate photographic takes, minute and continuous control of the Wilson [chamber]: three parts of the same body which must work automatically day and night and therefore requires the collaboration and supervision of two or three specialized people.
>
> Furthermore, the recordings in question must be made at high altitudes: the experiments carried out by the staff of the Institute took place at Plan Maison (2600 meters above sea level), at Passo Sella (2200 meters), at Lago Inferno (2100 meters) and for a year at Plateau

Rosaz (3500 meters) above Cervinia. Undoubtedly, the latter location is the one that, given its greater height, lends itself best to the research in question.

The expenses necessary for these are enormous: not only for the construction of the Wilson machines and the Geiger and Müller counters, also used in the number of forty, fifty simultaneously; not only for the preparation of electronic command and control circuits, which involve dozens and dozens of electronic valves and which must be almost always modified, and almost always profoundly, when passing from one search to another; not only for the preparation of photographic processes (two Leica machines operating simultaneously with electro-controlled flash lighting); not only for having the huge masses of lead and iron, tons and tons, which are required in absorbers; not only for the exercise of the whole experimental arrangement (only of photographic films the Institute consumes 4 or 5 rolls of panchromatic or green sensitive ones per day); not only for the transport of materials and people from Milan to Cervinia and vice versa; but also for the cost of food and accommodation for the researchers themselves.

At Plan Maison and Passa Sella the Milanese researchers were retired in hotels; in Lago Inferno they found free accommodation in a house of the Orobia Society and for food they disengaged themselves by buying food in the nearby town and providing them with cooking; in Plateau Rosaz they have free accommodation in the Testa Grigia Laboratory, and eat their meals (for a fee) at the nearby restaurant.

The “accommodation” in the Testa Grigia Laboratory consists of the room where all the recording equipment of the events under study is mounted, and one or two sailor’s kennels for sleeping; services are reduced to the bare minimum; absolutely missing any essential comforts. And since at 3500 meters one cannot stay, much less work continuously than for a few days, researchers need another place lower down where they can rest, change, wash, recover from the effort made by living every four or five days. at 3500 meters; and also to develop the films (since there is no convenience in the Plateau Rosaz Laboratory), to collect, examine, catalog, discuss the experimental data gradually obtained, etc.

For this purpose, the premises given free of charge by Mayor Greppi in the building that in Cervinia was built in the past for the Dopolavoro[3] of the Municipality of Milan, optimally provided for this purpose. In these premises (a dozen rooms in all) the researchers had single rooms, a bathroom, a dining room and study room, in an inactive faction in Plateau Rosaz: both those of the Physics Institute of Milan University and those of the Physics Institute of Rome University; the only ones, moreover, the Milanese and the Romans, who work at Plateau Rosaz. And both, during their stops in Cervinia eat their meals at the Fior di Roccia restaurant, spending modestly and receiving a good treatment.

But then this happened. The Municipality of Milan has rented the Dopolavoro building to the Italian Alpine Club; and the CAI has posed this harsh alternative: either the physicists, if they want to stay in the Dopolavoro building, pay the pension of 1800 lire per day and per person, or else they leave. Despite the intervention of prof. Colonnetti, who tried to have the CAI withdraw their decision, this has not changed their requests; and the physicists, unable to pay the sums requested, abandoned the rooms of the Dopolavoro last December, already assigned to them for free!

The situation is now very serious for everyone, Romans and Milanese. The former have temporarily adapted to a small hotel in Cervinia, where they pay relatively a lot and have no comfort: not even running water, not even a bathroom. The Milanese, on the other hand, both because the research already carried out from last July onwards could constitute a closed cycle in itself, with results already completed, and because in order to continue the research, some profound changes were required both in the electronic circuits of the counters and in the plates inside Wilson chamber and in its lighting; were by prof. Polvani called back to Milan to prepare the new experimental arrangements as the events mature. Now these, soon,

[3] Dopolavoro, lit. “after work”, were the recreational activities a company organized and paid for its employees.

> at the end of February, will be ready, and then the problem of accommodation in Cervinia will arise.
> Or more properly and in reality the problem of financing the research in progress will then be exacerbated in a very rude way, with the not rosy forecast, if it is not resolved, that the more than ten-year activity pursued by the Institute in research on cosmic rays in the high mountains must stop.[4]

With the second cloud chamber, the Milan group, first of all, studied those events that were classified as penetrating or mixed showers and they verified their analogy with the showers detected with counters. From this first analysis they concluded that the nuclear explosions produced in the chamber's plates had the same structure as those generated in the atmosphere within the development of a shower [20–22]. Furthermore, the observations also agreed with what was found by Powell's group in Bristol with the technique of nuclear emulsions. In the second place, they were able to obtain an estimate of the nuclear interaction cross section of the penetrating particles that caused the explosions in lead. Its value was of the same order of magnitude as the geometric cross section. This result was a further and considerable confirmation that the penetrating particles that interacted strongly with the lead nuclei were π-mesons or protons, and could not be muons.

By comparing the events observed in different materials, the Milan group reported data in favor of the theory that predicted a multiple interaction between the incident particle and the nucleus, at least in heavy nuclei [23]. These results were achieved by measuring the ratio between the number of nuclear explosions observed with more than four relativistic particles in carbon and lead respectively [24, 25]. This value, although very uncertain due to the difficulty in estimating the cross section, was however different from that expected for a single nucleon-nucleon interaction within the nucleus. Further data were then shown in favor of the theory proposed by Fermi, also similar to that of Heitler and Jánossy [26], which predicted a multiplicity, i.e. the number of particles produced in each interaction, proportional to the energy of the strongly interacting particle. This theory also explained the fact that the particles produced in a first explosion could give rise to other secondary explosions, in a sort of nuclear cascade.

A measure that they repeated several times, over two years, was the average free path for the production of nuclear explosions in lead. The values they obtained with the cloud chamber, were in disagreement with those obtained with nuclear emulsions: they were systematically higher. The difficulties of this measurement consisted mainly in determining the total number of explosions that actually occurred in the cloud chamber. There was a certain probability that some explosions that occurred between the lead plates or between the screens placed above the counters would not appear as such inside the cloud chamber and for this reason the average free path was larger than the real one. To be sure to observe all the nuclear explosions

[4] Centro APICE, Historical Archive Milan University: serie 7, busta 77, Scienze: "Relazione sull'attività dell'Istituto di Fisica dell'Università di Milano dalla sua fondazione ad oggi e sulla sua situazione attuale", February 2, 1949: pp. 15–21.

that occurred, it would have been necessary to work with random expansions and with thinner plates, but this was not achievable with the second cloud chamber, as it decreased the statistics of the observed events too much. They made an attempt to estimate theoretically the number of nuclear explosions that were lost in the count. The mean free path of interaction of the particles with heavy nuclei was very close to the geometric mean free path. Assuming, for this reason, that the explosions were generated either by π mesons or by protons, the Milan group estimated the percentage of protons emitted in the explosions. The protons turned out to be about 1/3 of the penetrating particles, a value not far from today's data.

Furthermore, the presence of an electromagnetic component originating from nuclear explosions was clearly proven with the second cloud chamber [27, 28]. The diffusion of electrons, at angles even greater than 40°, suggested that the electrons and photons had different origins, independent of each other, and did not come from the cascade development attributable to the initial interaction of a single electron or a single photon. For this reason they supported the hypothesis that at the origin of the electromagnetic component there was the decay of a neutral meson. Their results concerned the relationship between the number of neutral and charged mesons. This series of measurements on the electromagnetic component and on the π^0-mesons continued with the use of the third cloud chamber.

A third cloud chamber was built at the Institute of Physics in Milan thanks to Mura, who was assisted by the whole group of cosmic ray physicists and had the collaboration, in the various phases of construction and point, of P. Casale, of M. Stella, together with his collaborators of the Technical Institute Feltrinelli in Milan, of the technicians Adorni, Pessina and Massignan. The realization was possible thanks to financial aid that Polvani obtained from Milan University, the CNR, the GAI-FUM, ANIDEL (the national association of companies producing and distributing electricity), L. Sessa.

The third cloud chamber [29] was designed to be used above all in research on cosmic rays at high altitudes in mountain laboratories, in particular for the study of the nuclear interactions caused by cosmic radiation in different materials and their association with the extended showers in air. For these reasons it was much larger than the two previous chambers and was able to contain a fairly large series of metal plates, thus reaching a total weight of a few quintals. The whole set that made up the complex of this third cloud chamber, at the end of the set-up, had an overall size in the horizontal area of 2×3 m^2 and was about 2 m high. The third cloud chamber was always used at the Testa Grigia laboratory from October 1950 until January 1951. Carlo Succi took the place of Giorgio Salvini, who moved to America, in Tagliaferri's group. However, the group kept in contact with Salvini, who contributed to the studies carried out at the Testa Grigia laboratory both with theoretical work and with experimental research.

With the third cloud chamber it was possible to carry out random expansions without diminishing too much the statistics of the nuclear explosions that occurred in the chamber plates, as the size of the chamber allowed to insert a greater number of plates and greater thickness. In this way the probability of detecting all the explosions that occurred inside the chamber was greater. Studies still concerned the phenomenology of nuclear interactions produced by cosmic rays and were focused in particular on the production of π^0 mesons. To study their behavior, the electromagnetic component associated with nuclear explosions was analyzed: the penetrating particles present in the showers with the electromagnetic showers that were observed [30]. This analysis proved rather difficult for both experimental and theoretical reasons. It was not possible, for example, to modify the experimental arrangement in order to detect photons with an energy lower than 150 MeV and, at the same time, not to decrease the probability of π^0 production. Furthermore, to trace the spectrum of π^0-mesons starting from the energy distribution of the electron showers, it was necessary to recognize and associate the two showers originating from the disintegration of the π^0 meson, measuring the angle formed by their axes and their energies. To derive the number of π^0 it was also necessary to proceed theoretically starting from the photon spectrum measured at various altitudes and the data obtained up to then from the measurements on the photons were not yet completely conclusive.

A more reliable result was that regarding the ratio between the number of neutral and charged mesons, a measurement they had already made [31]. From the energy distribution of protons and π-mesons, they could deduce that the charged mesons were about 60% of the penetrating particles observed in the showers. They able to estimate their number and that of the electron showers associated with them, obtaining a value for the ratio between neutral and charged mesons. This result, close to the current value, was in agreement both with their previous measurements, carried out with the second chamber and in less favorable working conditions for this type of analysis and with the results reported by Salvini.

With regard to the π^0-mesons, they could also determine the production cross section. By dividing the number of disintegrations with an electromagnetic component by the number of disintegrations associated with them, it was possible to trace, as a first approximation, the ratio between the cross section of $\pi 0$ production and that corresponding to the production of nuclear disintegrations in nucleon-nucleus collisions in lead. Their results were in agreement with those obtained in America by Salvini. Subsequently, they studied the dependence on the zenith angle of the hard, muonic component. A similar study was also conducted on the soft component [32].

In 1956, in a second series of measurements, when Giacconi had joined the group, they directed the study to the nuclear cascades, the multiplicity of interactions and the mean free path for strong interaction of the penetrating particles [33, 34]. The cloud chamber was used this time with controlled expansions. The aim was the study of the interactions produced by protons of a few tens of GeV and, in particular the jets already observed in nuclear emulsions. It turned out that the cascade developed mainly forward and slightly laterally, unlike the electromagnetic ones. They also found 15 decays of V^0 particles and 3 decays of $V^{\pm}$ ($\Sigma^{\pm}$) particles. Among the V^0 particles they identified 4 with the particle Λ^0 and 3 with the θ^0 (K^0_S).

The third cloud chamber was also taken to a locality on Lake Maggiore, Verbania, in a railway tunnel [35]. The chamber was dominated by a quantity of granite rock equivalent to 55 m of water. The studies were conducted with the aim of verifying the extent of the interaction of the cosmic muons with matter and to compare it with the recent data obtained by Wolfendale and Trent. The Milan group analyzed a lead path equal to 352 m and they did not observe any example of secondary penetrating particle production, denying Wolfendale and Trent's result and supporting instead that of Amaldi [36] who had obtained a similar mean free path value to that of the Milan group.

The electronic component produced by muons by knock-on was also analyzed [37]. Emerging electrons with an energy greater than 1 MeV were taken into consideration, which did not undergo strong deviations in the gas of the cloud chamber chamber. 13 electron showers with an energy greater than 1 GeV were observed and analyzed. With these experiments they confirmed that the main interaction of a muon with a nucleus was a Coulomb interaction. Finally, they analyzed the nuclear interactions produced by penetrating particles and observed the analogy with those revealed at 3500 m [38]. In particular, the presence of neutral π mesons and also of a neutron component was confirmed.

A major disadvantage inherent in the functioning of the cloud chamber consisted in the dead time, in which the cloud chamber was not sensitive to ionizing radiation. To try to overcome this problem, Langsdorf in 1939 had already attempted to build a continuously sensitive chamber: a diffusion chamber. It was thought that this instrument could more advantageously replace the cloud chamber in the study of cosmic rays but its most immediate use was in the field of radioactivity and nuclear physics, because the geometry of the sensitive area did not allow an effective detection of cosmic radiation. The second diffusion chamber in Milan, which was built by Succi and Lovati [39, 40], was designed, for example, to be used in experiments with accelerators. However, only a few experiments were carried out with it and it was never used with an accelerator [41]. An attempt made by Fiorini, Giacconi, Succi and Sichirollo was made to build an instrument with a dead time smaller than that of a normal cloud chamber with an overcompression mechanism [42]. They wanted to applied the overcompression also to large chambers, but they modified the first, small cloud chamber. Their results were however positive.

A last, fourth cloud chamber (Fig. 7.1) was built by Succi, and Fiorini and Giacconi as graduate students, in 1956 [43]. The technicians Nicolai, who later went to work at CERN, and Gennaro also contributed to the realization. Also Camillo Giori and Adele Sichirollo collaborated. Succi had asked Tagliaferri, who was in the US at the time, for advice in making a large cloud chamber:

> I would also like to know something about the essential characteristics of a large Wilson camera […] as regards the preparation of a cosmic ray camera.
> As far as the so-called national enterprise of the Wilson chamber is concerned, it seems that everything has come to naught: the Paduans have withdrawn; the Turinese have not given any sign of life anymore. Nobody knows what the Romans do.
> Lovati has decided to definitively devote himself to nuclear physics with Salvetti. Rossi will go to America in September. Occhialini made a strong connection with the groups of Padua and Bristol. We are working hard enough: perhaps we have come out of that period of uncertainty and crisis in which we suddenly found ourselves due to the absence of the elderly. […] Mura is unfortunately always away and this is my greatest concern.[5]

[5] Milan University, BICF Library, Polvani Papers, 10, 1, 2.6: Letter from Carlo Succi to Guido Tagliaferri, June 1, 1955.

Fig. 7.1 The giant cloud chamber built by Ettore Fiorini, Riccardo Giacconi and Carlo Succi (Copyright: Leonardo Gariboldi)

The construction project was supported by financial contributions which Polvani obtained from the GAIFUM, the Milan division of INFN, the Cassa di Risparmio delle Provincie Lombarde, and ANIDEL, the national association of electricity distributors. The chamber was built with a relatively low price: 10 million lire. For a comparison, at the CERN, the construction of two smaller chambers had required a loan of 120 million lire. This room, when it was built, was the largest cloud chamber in the world [44]. It had a $156 \times 156 \times 98\ cm^3$ volume with twenty-one 1.5 cm thick plates, for a maximum weight of 5000 kg. The workshops of Società Innocenti, Pirelli and the Materials Laboratory of Milan Polytechnic cooperated to the operations of building components and testing them with radiographic analysis.

The chamber required a room with a $50\ m^2$ area for convenient assembly. The Testa Grigia laboratory was occupied by groups of other universities at the time of the decision to undertake a new series of research with the fourth chamber. Furthermore, the fourth cloud chamber was too bulky to be transported and stored in the Testa

Grigia laboratory. Polvani consulted Candiani of the Edison company, who suggested a construction site for the Sabbione dam in the upper Val Formazza [45, 46]. The construction of the laboratory was possible thanks to the contributions asked by Polvani to the GAIFUM, the Edison and Edison-Volta Company, ANIDEL, Pirelli, Linoleum and Agipgas.

They conducted their studies at the Sabbione dam, in collaboration with a group of physicists from Pisa University. Their researches concerned the search for a particle of 550 m_e mass hypothesized by a group of Soviet physicists, after a series of experiments started in 1951 [47–49]. From the study of the Milan group, concluded in 1959, it turned out that such a particle did not exist [50–55]. The fourth cloud chamber is on exhibition in the hall of the Physics Department of Milan University.

The 550 m_e particle had been hypothesized by the Soviet group led by A.I. Alikhanian [56]. In their researches, using a system of two coupled cloud chambers, they had based the determination of the mass of the detected particles, on the analysis of their traces, with measurements of range, ionization, loss of energy in crossing the septa of a multilayer chamber, and also of multiple scattering.

Succi wrote again to Tagliaferri asking for information on the future possible use of the chamber with accelerators:

> We have finished the chamber which is currently located in the mountain at 2600 m a.s.l. Our immediate plan is to use it for a run-in and tuning experience on the 500 mass particles reported by the Russians.
> This experience will be carried out in collaboration with Conversi and should last a few months and in any case end no later than August 1957.
> Our intentions would then be to turn to proton accelerator machines: as you know, by 57 in Europe the protosynchrotron of about 2 GeV at Saclay and a 10 GeV machine in Moscow should come into operation.
> You would do us a great courtesy if you could quickly orient us about the technical difficulties of working on an accelerating machine with a Wilson Chamber and above all give us a synthetic picture of the main research in progress and in the project with Wilson's Chamber on the great American machines.[6]

The Milan group the Soviet experiment in a similar way with two cloud chambers, as Succi described to Tagliaferri:

> Here we have finished the assembly of our large Wilson chamber: the traces are quite good […] We should start collecting the first photos next week. […]
> The experience we would like to carry out would concern the search for the 500 mass particles reported by the Russians at the Moscow congress last May: we asked Segrè about this, who had visited the plants and was particularly interested in the matter. He says this time the experience feels good to him and that it's worth the expense of checking the results.
> The experiment would be performed as follows: with the Cervinia chamber, measurement of the ionization; with the large camera, new range and scattering measurement.

[6] Milan University, BICF Library, Polvani Papers, 10, 1: 2.6: Letter from Carlo Succi to Guido Tagliaferri. October 17, 1956.

> The command should select isolated end-of-range particles with ionization greater than twice the minimum. The range chamber would contain about 20 carbon plates to stop the particles and be able to distinguish them from mu mesons.
> To make this experience we got together with the Pisans: Conversi and other young people.[7]

They actually made a very careful selection of the traces that could generate even the slightest doubt about their identity. The experience was set up so that the traces of protons or π.mesons, those that could be confused with the 550 m_e particle, were well identified. Two series of measurements were repeated, making changes also in the instrumental apparatus in which a cloud chamber was replaced with a liquid scintillator, and in 1959 they concluded that such a particle did not exist. A similar conclusion was drawn by other groups in other countries.

7.3 The Arrival of Occhialini to Milan and the Flights of Emulsion Stacks in the 1950s

Occhialini left Powell's team in Bristol in 1948 (on Occhialini: see Chap. 6) to work in Brussels at the Centre of Nuclear Physics of the Free University of Brussels. He worked continuously in Brussels from 1948 to 1950. Thereafter, he was appointed professor of Higher Physics for Genoa University from 1950 to 1952, and for Milan University from 1952 up to his retirement. While teaching and carrying out research in Italy, Occhialini continued to collaborate with the Centre of Nuclear Physics in Brussels where he spent a lot of time every year until 1959. The Brussels and Genoa/Milan groups in the 1950s had a common core of researchers, together with people from INFN, so that it can be considered under its main aspects a single one research team under Occhialini's scientific leadership. Occhialini had been called to Brussels, together with his wife Constance Dilworth by Max Cosyns to start a new laboratory where they could study nuclear emulsions and publish a new journal, the "Bulletin du Centre de Physique Nucléaire de l'Université Libre de Bruxelles".

In the Brussels laboratory, they continued their researches on the new NT2 and NT4 Kodak plates by Berriman and the new Ilford electron-sensitive film, the G5, by Waller. While in Brussels and in Genoa/Milan, Occhialini played a fundamental role in the development of some research teams working with the new nuclear emulsions in Italy.[8] Italian young cosmic ray physicists – such as Alberto Bonetti, Marcello Ceccarelli, Giulio Cortini, Carlo Franzinetti, Riccardo Levi-Setti, Michelangelo Merlin, Giovanna Tomasini, Livio Scarsi – went to Bristol or Brussels to learn how to carry out research with nuclear emulsions. Alberto Bonetti was Occhialini's assistant and helped him in creating the research groups in Genoa and Milan. Then with the help of Riccardo Levi-Setti and Giovanna Tomasini, they started the Genoa-Milan collaboration [58]. A sad fact shattered the Brussels laboratory in 1952: the so-called

[7] Milan University, BICF Library, Polvani Papers, 10, 1, 2:6: Letter from Carlo Succi to Guido Tagliaferri, August 12, 1956.

[8] On the role played by Occhialini in the development of the nuclear emulsion technique, see: [57].

"affaire du treuil" (the winch affair) [59]. On August 14, 1952, during a speleological exploration of the Pierre-Saint-Martin cave, Marcel Loubens died due to the breaking of a cable winch. Both the use of research funds for a sporting expedition and Cosyns's insistence in having the winch at expenses of safety caused a scandal which destroyed the research team from the inside. This caused a deep state of crises in the Brussels group which lasted through 1953 when eventually Cosyns left Brussels to Paris. Eventually the Brussels group was able to get over the worst, and Occhialini succeeded in making it again a part of the European network of laboratories that were sending stacks of emulsions on balloons at high altitude.

Occhialini's most important contribution to the development of the studies on cosmic rays in Milan was the engagement of the Milan team to international cooperations[9] which organized flights of balloons carrying stacks o nuclear emulsion plates at high altitude.[10] The prelude to the European collaborations was, in 1947-48, the launch of balloons to expose nuclear plates at an altitude of 30 km. This launch was organized by Powell's team in Bristol with the collaboration of the University of Padua [63]. In 1952 they decided to launch balloons from the Mediterranean because of the strict British rules on air-traffic control and of the necessity of better weather conditions [64]. Some Italian universities, the Italian Air Force and Navy supported Powell's plan to fly balloons from Italy. The further development of the activities of Powell's team saw therefore the engagement of the INFN divisions of Milan, Padua and Rome. The first great expedition involved thirteen European research teams in 1952. The balloons were launched from the Italian bases of Naples and Cagliari. The stacks of glass-supported plates were recovered after the landing on sea of the balloons. Besides the importance of the tracks recorded in the plates themselves, the study of the balloons flight permitted to get useful information on the speed and direction of wind at high altitude.

Between June and July 1953, eighteen European research teams launched twenty-five balloons from Elmas airport in Sardinia, and exposed to cosmic radiation more than one thousand stripped emulsions,[11] for a total volume of 9.3 dm^3, seven hours long at an altitude between 25 and 30 km. All emulsions were processed in the Bristol, Padua, and Rome laboratories. In October 1953, they held a meeting in Bern in order to distribute the processed plates among the teams. The first results were then discussed in an international conference held in Padua in April 1954. Further results were the subject of the second course of the International School of Varenna of the SIF, in the summer 1954.

The third significant flight was the launch of the G-Stack (G stands for "giant") from Novi Ligure, in October 1954. The G-Stack was a single stack of emulsions with a volume of about 15 dm^3. The choice to launch a single giant stack came

[9] On the collaborations among nuclear emulsion groups in Europe during the 1950s see: [60].

[10] On balloon flights for cosmic ray research in the Mediterranean see: [61, 62].

[11] Stripped emulsions were already known, but they had not been used for scientific research because it had been impossible to identify with a sufficient precision their relative position after their processing. The solution they found to face this problem was to mount the stripped emulsions on glass before their processing. The precision requested by scientific research for this new technique was eventually reached by Waller of Ilford so that they could be used for the 1952 flights [58].

from the aim to study in the most advantageous way part of the recorded tracks in their whole length in order to obtain precise values of their energy and decay modes. The most important result of the G-Stack was the determination of the equality of the mass values of the then supposed different K-mesons, and the statement that the different decay modes were alternative decay processes of a same particle. The solution to the related $\theta - \tau$ puzzle was, in such a way, a first step to the discovery of the non-conservation of parity in weak interactions.

After the launch of the G-Stack, the results on elementary particles obtained by means of accelerating machines soon outnumbered the ones found in cosmic ray physics. In the second half of the Fifties, the Milan team continued their studies on elementary particles by exposing the nuclear emulsion plates to beams of artificially produced particle beams at the CERN or elsewhere, but with a different role played by Occhialini as before.

One of the most important actors in planning the international collaborations of flights was without any doubt Cecil Powell. He played an important decisional role in the organization of these flights, and was the reference point for the initiatives to be undertaken by the representatives of all other teams. What Powell wrote to Occhialini in 1951 can be ideally extended to the Milan team too (even if not mentioned explicitly) as for its contribution to the collaboration, in particular if we consider the geographical relevance of Milan position:

> We have been considering the possibility of making high altitude balloon flights in Northern Italy in the spring. The object of flights at this geo-magnetic latitude are set out in our recent paper on τ–mesons in the Phil. Mag. What we should like to do would be to fly plates for other labs. These plates would then be the property of the individual labs themselves. I hesitate, however, to make any very concrete offers about flying plates at the present juncture as we have had a number of recent failures with 130 ft. balloons designed to reach about 100,000 ft. and we are not clear what went wrong. We hope to overcome the difficulties during the next few months so that we can make flights in the spring or early summer. However successful we are in overcoming our present difficulties, a joint discussion round about Xmas time might be very useful. I have in mind for such a discussion, 2 or 3 representatives from Bristol, Brussels, Imperial College, Manchester, Padua, Paris, and perhaps one or two others.[12]

An epoch-making event for these collaborations and the Milan team was the International Cosmic Rays conference held in Bagnères-de-Bigorre in 1953.[13] The conference started with the presentation of the known different hyperon decay modes: $\Lambda^0 \rightarrow p + \pi^-$; $\Sigma^+ \rightarrow p + \pi^0$; $\Sigma^+ \rightarrow n + \pi^+$; and $\Xi^- \rightarrow \Lambda^0 + \pi^-$. The discussion on the plethora of K-meson decay modes, thanks to Bruno Rossi's argument (two particles are equal until they are proven different), led to the conclusion that many different events actually corresponded to different decay modes of one kind of particle.

The plates impressed during the 1953 launches from Sardinia were shared among the participants during a meeting held in Bern. Their results were discussed in April

[12] Powell Papers. Bristol University Special Collections DM 1947/E.303: Letter from Cecil Powell to Giuseppe Occhialini, October 8, 1951.

[13] The Milan physicists contributed with five talks, four of the nuclear emulsion group and one of the cloud chamber group: [65–69].

1954 at the International Congress on Heavy Unstable Particles and High Energy Events in Cosmic Rays held in Padua. The main subject of the Padua Congress was a problem that arose from the analysis of the tracks left by the τ-particle, or $K\pi_3$, that is a K-meson decaying into three coplanar charged π-mesons. The problem was known as the $\tau - \theta$ puzzle, the search for a possible relation between the θ^0 ($K^0 \rightarrow \pi^+ + \pi^-$) and the $\tau+$ ($K^+ \rightarrow p^+ + \pi^+ + \pi^-$). Since they had quite the same mass and decayed into π-mesons only, according to Rossi's argument, they could have been two different decay modes of a same particle. The theoretical device used was the so-called Dalitz plot, concerning a spin-parity relation of the particles. If J was the orbital angular momentum, then the θ^0-decay corresponded to a state with parity $(-1)^J = 0^+, 1^-.2^+$, etc. The analysis of the τ-decays recorded in the stripped emulsions led but to a spin-parity value of 0^-, instead of the 0^+ value of the θ^0-decay. Another problem discussed at the Padua congress was the new $K\mu_2$-decay mode (the "Camus"), suggested by the French team of the École Polytechnique of Paris [70]. In order to solve both the $\tau - \theta$ puzzle and the $K\mu_2$ problem, the Bristol, Milan and Padua teams decided to undertake the G-Stack flight.

The results of the G-Stack flight were the main subject of the International Conference on Elementary Particles held in Pisa in 1955. Seven different decay modes ($\tau, \tau', K\pi_2, K\pi_3, K\mu_2, K\mu_3, Ke_3$) were definitely assigned to only one particle, the K^+-meson. The θ^0-decay mode corresponded to the K^0-meson. Lastly, the $K\mu_2$-decay mode was confirmed in its existence, and was furthermore seen to be ten times more frequent than the τ-decay mode. The $\tau - \theta$ puzzle continued to be unsolved since the spin-parity of the τ-decay was confirmed to be 0^-. Strange particles [71] led to the definition by Murray Gell-Mann [72] of the strangeness (S), a new quantum number, related to the electric charge (Q), the third component of the isotopic spin (T_3), and the baryonic number (B) through the Gall-Mann-Nishijima relation ($Q = T_3 + B/2 + S/2$). $S = 0$ for the proton and the neutron, $S = 1$ for K^+ and K^0 mesons, $S = -1$ for K^- and $\overline{K}^0$ mesons, with $T_3 = 1/2$.

The $\tau - \theta$ puzzle was eventually solved in 1957, when cosmic rays were no more the main source of K mesons, but accelerating machines, the Berkeley Bevatron in a first time, were used instead. The solution consisted in abandoning the unproved hypothesis of parity conservation in natural laws, at least in the weak interactions [73] (with $|\Delta S| = 1$ and $|\Delta T_3| = 1/2$) while they found that strangeness was conserved in strong and electromagnetic interactions.

Researches by means of nuclear emulsions improved in Milan thanks to the development of microscope technique (Fig. 7.2) [74]. Physicists could not intervene in the industrial production of the nuclear emulsions, therefore a collaboration between physicists and industrial chemists had been limited. Generally speaking, nuclear emulsions were but quite satisfactorily in most of their properties, but much less in other ones such as the discriminating power. Uniformity and flexibility of the development had their effect on the results which they could obtain from the recorded tracks once processed. To insure uniform development, Occhialini had invented the Temperature Development [75–77]. He tested the Temperature Development on both Kodak and Ilford emulsions [78, 79]. The use of the new reflecting microscopic

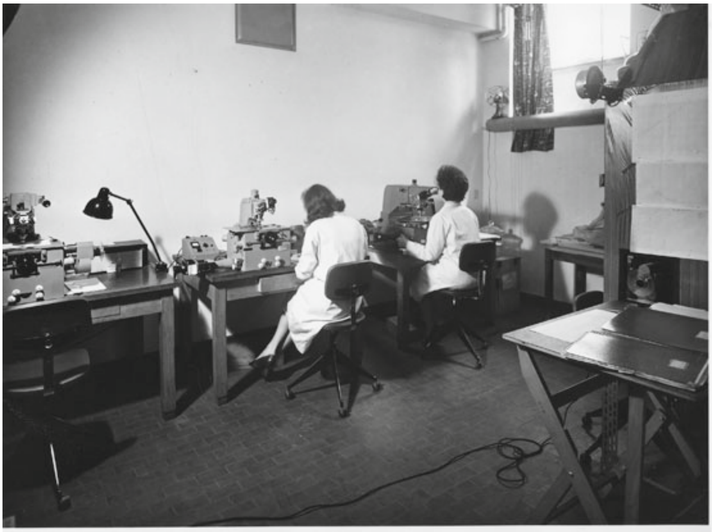

Fig. 7.2 Scanners in the nuclear emulsions laboratory (Copyright: Milan University, BICF Library)

technique by Occhialini and Bates [80] permitted to analyze very thick processed emulsions with amidol. One goal of the Milan group was the possibility to gain useful information from the profile of short tracks such as those left by slow interacting particles, by their low energy products of interaction, and by hyperfragments. Following Occhialini's pleasure in language games, hyperfragments were classified as a function of the increasing difficulty of interpretation as: normal, goks (God only knows), doks (Devil only knows), and boks (Beppo only knows) [81]. Their main aim was to find any parameter sensitive to the variation of ionization in a few microns [82]. The contribution of the Milan group to the development of the nuclear emulsion technique was a relevant one. Its application in the Brussels laboratory and by the other teams was therefore of primary importance in the analysis of the plates exposed to cosmic radiation in the mid 1950s.

After the discovery of natural K^- mesons in cosmic radiation, physicists at the Bevatron and the Cosmotron started to produce them artificially in order to study them, with cloud chambers and nuclear emulsions stacks, in an easier and systematic matter not subject to the uncertainties due to the random arrival of cosmic particles. The most striking result was what seemed to be a contradiction between the fast production of K mesons and their slow decay. This fact led to the concept of strangeness and of strange particles, and to the postulate of associated production, in order to explain the relatively small number of K^- mesons produced both by the cosmic radiation [83] and by the accelerators. The disintegration stars due to the capture at rest of K mesons showed the frequent emission of hyperons or hyperfragments, but the quantitative results on the various decay branches were affected by an unfavorable K/π ratio.

At the end of 1955, the research group of the Milan Institute of Physical Sciences and of the Milan division of INFN together with similar research groups of the H.H. Wills Physical Laboratory in Bristol, the Institute for Theoretical Physics in Copenhagen, the Institute for Advanced Studies in Dublin, the University College of Dublin, the Institute of Physics of Genoa University, the Laboratory of Nuclear Physics of the Free University of Brussels, the Institute of Physics of Padua University with the Padua division of INFN, agreed to form the G-Stack Collaboration. Besides the scientific teams, many other Italian military and civil institutions were involved in the organization of the flight [84]. Other research groups were not involved since, thanks to their previous experience, they could take into account the negative consequences of the excessive technical division of their work among the groups; the individual tracks had frequently to be followed from plates in one laboratory to those in another, and sometimes on to a third and even a fourth. If the stack was too widely dispersed, the advantages could be lost through the complications involved in following tracks [84].

The G-Stack was a large stack of Ilford G5 emulsions made up of 250 sheets each of dimensions 37 cm $\times$ 27 cm $\times$ 600 μm, packed together with thin paper spacers, so that to form a block 15 cm thick, volume 15 dm^3 and weight 63 kg. The dimensions of the stack were chosen to be sure that about 15% of the μ-meson of the maximum possible range given by the decay of a K-meson of mass about that of the τ, would stop within it [84]. The stack was exposed to cosmic radiation at a mean altitude of 27,000 m for six hours. During the descent, a failure of the parachute caused a damage to about 10% of the emulsion during the impact with the ground. The rest of the emulsion was processed and available to the scanners by the end of 1954.

Heavy mesons had been observed decaying according to at least six modes of decay:

(A) the τ-meson: $\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{+} + \pi^{-}$; [85]

(B) the τ'-meson: $\tau'^{\pm} \rightarrow \pi^{\pm} + \pi^{0} + \pi^{0}$; [86–88]

(C) the K_{μ}-mode of decay: $K_{\mu} \rightarrow \mu + \nu$. It was first suggested by the cloud chamber team of the École Polytechnique in Paris [89, 90] and then confirmed by the Massachusetts Institute of Technology [91];

(D) the χ-meson: $\chi \rightarrow \pi + ?$ with a secondary unknown neutral particle of mass about 300 m_e and $E_{\pi} = 116 \pm 5$ MeV. Further studies showed that the secondary was a neutral π-meson: $\chi \rightarrow \pi + \pi^{0}$ [91–93].

(E) the κ-meson: $\kappa \rightarrow \mu + ? + ?$ with unknown secondary particles both in their nature and energy spectra [94–96].

(F) the K_{β}-meson: $K_{\beta} \rightarrow \beta + ? + ?$ observed by the Bristol [97, 98] and Dublin [99] groups.

The different modes of decay would correspond to only one kind of primary heavy meson only in the case that the primary mass were constant. Experiments carried on by the Paris group showed, for instance, that the K_{μ}-mode of decay should correspond to heavy meson with a lesser mass than the other modes. Studies on the masses of the K-mesons were made also in Berkeley with the 6 GeV proton accelerator.

The evaluation of the different relative frequencies of the modes of decay had the disadvantage that in the G-Stack there was a large background of tracks due to protons and other particles. The selections of the K-meson tracks showed that there was a sufficient number of them useful to understand their different modes of decay. Eventually they could conclude that a percentage between 50% and 70% of K-mesons decayed in the K_μ-mode. The proportion of K-mesons decaying in the χ-mode was between 15% and 30%. The K_μ and χ modes of decay constituted together at least 80% of the total. The K_β, κ, and τ'-modes of decay constituted respectively about 9%, 3% and 1% of the decaying K-mesons. The G-Stack Collaboration was therefore a scientific success in the study of strange particles found in cosmic radiation as they recognized in their paper.

The two main conclusions of the analysis of the G-stack were: (1) the confirmation of the existence of two monoenergetic groups of secondaries which were the greatest components of the K-particle secondaries: the μ-mesons from the K_μ-decay and the π-mesons from the χ-decay; (2) the estimated mass of the parent particles were close that the mass of the τ-meson. The results of the G-Stack Collaboration were discussed at the Pisa conference, which can be considered the final triumphal event of the studies made by cosmic-rays physicists with nuclear emulsions or cloud chambers. The so-called "strange particles jungle" had been classified with the Λ^0, Σ^+, Ξ^-, K^0 particles, and the five decay modes of the K^+, while the Σ^- had been discovered first with an accelerating machine, and the Σ^0 and Ξ^0 were still only theoretically predicted. During the Pisa conference, the results obtained with a stack of nuclear emulsions exposed to a monochromatic beam at the Bevatron in Berkeley were announced too. They definitely showed that the K^--meson was one and only one meson that could decay in different modes.

A striking aspect of these studies is the fact that the discovery of strange particles was made without a theoretical predicting model underlying the general lines of research. Strange particles were thus a family of, in a first time, unnecessary and unwanted particles found in the preceding and following decades too, such as the μ-meson and the neutrino. All these unwanted particles had but a fundamental role in the theoretical development of elementary particle physics, in particular in the formulation of the Standard Model.

7.4 The K^- Collaboration

The Milan group led by Occhialini was a member of a second relevant European collaboration which followed in the years after the G- Stack Collaboration to continue their researches on the strange particles produced in cosmic radiation. The K^- Collaboration, besides the Institute of Physical Sciences of Milan University, involved researchers of the H.H. Wills Physical Laboratory in Bristol, the Laboratory of Nuclear Physics of the Free University of Brussels, the School of Cosmic Physics of the Institute for Advanced Studies of Dublin, the University College of Dublin, the Physics Department of the University College of London, the Institute of Physics of Padua University, the INFN divisions of Milan and Padua [100–102].

They prepared a stack of 100 emulsions of 6 in. × 8 in. × 600 μm. It was exposed at the Bevatron to a K^--beam by W. Barkas's team. The aim of the K^- Collaboration was a thorough study of the interactions and decay of K^--mesons. The dimension of the stack could not always ensure the analysis of the disintegration stars of K^--mesons because only an insufficient proportion of the fast mesons emitted could happen inside the emulsions. The use of artificially produced K^--mesons had instead the advantage to obtain a constant momentum variation through the depth of the stack with an average momentum of about 300 MeV/c. After the exposure to the K^--mesons beam, the stack was processed at Bristol and then distributed among the scanners teams. Unfortunately the stack was not always kept at low temperature between its delivery from Ilford and its return to Bristol after the exposure at the Bevatron. This caused a diminution of its sensitivity and a fading of the latent image during the plates processing.

Previous results had showed that a charged π-meson was emitted in about 30% of the disintegration stars while a charged Σ-hyperon was emitted only in 15% of the stars. Studies on the scattering of incoming K-mesons had shown that inelastic scattering was a seldom event, with a strong interaction, while elastic scattering from free protons was more frequent with a cross-section much greater for K^--mesons than for K^+-mesons [103]. The exposure to the Bevatron beam was meant to help them in finding new details of the K^--mesons interactions with nuclei, and new information on properties and interactions of hyperons. The scientific results had to be compared with those on the interactions of K^--mesons with neutrons which could be found with a bubble chamber [104].

The interaction of a K^--meson with a nucleus could happen actually with a single nucleon or with two or more nucleons. Several problems affected the correct analysis of the interaction products in the emulsions, for instance because of the very short path of most hyperfragments. In this case, it was particularly difficult, not only to estimate their charge or mass, but even to evaluate their total number. Very short tracks were furthermore very difficult to be detected when inside the general blackening in the emulsion due to an interaction star. The comparison of the relative number of stars produced by the K^--mesons interacting at rest and in flight showed only a small change in the percentage of unstable particles, while there was a greater difference in the mean number of stable prongs and their association with π-mesons and Σ hyperons. For instance, the fraction of (π, Σ) events without stable prongs in flight was only about 50% of those at rest. Σ–hyperons, from interactions in flight, showed no increasing kinetic energy due to the residual energy of the K^--mesons.

The results of the different interaction processes of K^--particles with nucleons obtained by the K^--Collaboration could be compare with those from the experiments on K^--capture in hydrogen and deuterium bubble chambers. The disagreement between the results obtained by the K^--Collaboration and those with the bubble chambers were interpreted by taking into account that K^--mesons were in flight when detected with the nuclear emulsions, while they were at rest when they were detected in a bubble chamber. The discrepancies could show a velocity dependence of K^--interactions. Furthermore, the results were theoretically interpreted in terms of the K^--capture mechanism, according to which a substantial percentage of the incoming K^--mesons could interact mainly with the nucleons on the nuclear surface. For instance, the absorption probability $p(\pi^-) = 10\%$ suggested that the K^--mesons brought at rest would have been captured by bound protons near the nuclear surface.

The conclusions of the K^--Collaboration on the K^--interactions were:

(1) the multi-nucleon absorption of K^--mesons was between the 15% and the 40% of all interactions of K^--mesons at rest with the nuclei inside the emulsion. This relevant probability suggested a high degree of correlation of clusters of nucleons on the nuclei surface.

(2) the probabilities of the various processes obtained with the nuclear emulsions are different from the same probabilities of the same processes obtained in a bubble chamber if the K^--mesons are captured at rest in hydrogen, while they are closer if the bubble chamber was filled with deuterium.

(3) most of the one-nucleon interactions which produced a Σ-hyperon took place with protons.

(4) The absorption probability of π^--mesons produced in association with Σ^+-hyperons, when the π^--mesons emerged from the nucleus in which they were produced, was very small (about 0.10%). This value was compatible with the absorption of the K^--mesons on the nuclear surface.

(5) The absorption probability off the charged Σ-hyperons produced in association with charged π-mesons was also very small (about 0.50%). This value was compatible with the interaction mean free path for Σ-hyperons in nuclear matter (about 1.5 fm).

The third and last step in the studies carried on by the K^--Collaboration concerned the properties of the K^--mesons (cross-section for reactions in the range 10-80 MeV, lifetime, mass) and of the Σ-hyperons (mass, lifetime, interactions, scattering, non conservation of parity in decay).

The study carried on the strange particles found in the emulsions from the stack of the K^--Collaboration were repeated on a new stack of Ilford §K.5 emulsions exposed to a filtered K^--beam for the same European collaboration. The scan of these emulsions was carried out by teams in Milan, Brussels, Bari, and London. They exposed a 18 cm × 20 cm × 18 cm stack of Ilford K-5 emulsions to a K^--meson beam of 300 MeV/c momentum at the Bevatron in order to study the fast Σ-hyperons emitted from the interactions of K^--mesons. Fast Σ^--hyperons were found to be associated with protons of energy greater than 30 MeV, while this case was more seldom to happen with Σ^+-hyperons. They thus concluded that the decay of $\Sigma^\pm$ to π in flight associated with protons with energy greater than 30 MeV were mostly negative, while the Σ-hyperons emitted alone were mostly positive.

The observed interactions of the K^--mesons with two nucleons producing a Σ^--hyperon ($K^- + n + n \rightarrow \Sigma^- + n$ and $K^- + n + p \rightarrow \Sigma^- + p$) showed that the transition amplitude leading to the first modality of interaction was much smaller than the second one. This fact showed that K^--mesons interacted with clusters of nucleons if at least one of them was a proton. In particular, K^--mesons commonly interacted with clusters such as α-particles, as it was seen in bubble chambers filled with helium, but less with deuterons.

They selected a sample of 7600 K^--meson interactions at rest for the study of the emission of fast stable particles such as protons, deuterons, and tritons, unaccompanied by charged π-mesons of slow Σ-hyperons of kinetic energy smaller than 60 MeV. A total of 180 protons, 23 deuterons, and 5 tritons, all with energies greater than 84 MeV, were identified. Deuterons and tritons with these energy values could be emitted if a $(\Sigma^- n)$ hypernucleus was formed. These hypernuclei were looked for by examining Σ-tracks of anomalous mass but no mass measurement showed any anomalous result. Uncertain results had also been obtained at the Enrico Fermi Institute for Nuclear Studies in Chicago and at the Lawrence Radiation Laboratory in Berkeley. The production of $(\Sigma^- n)$ hypernuclei was therefore very infrequent if not inexistent at all.

7.5 Theoretical Physics

Researches in Theoretical Physics [105] in Milan covered several topics. The group working with Carlo Salvetti at the CISE faced the theory of nuclear reactors, nuclear structure and nuclear reactions, while the group working with Caldirola was engaged in the phenomenology of cosmic radiation in the atmosphere, the theory of the isotopic separation of uranium with gaseous diffusion, the relativistic theory of the classical electron, the quantum field theory, and the ergodic theorem in quantum mechanics.

Theoretical studies in nuclear physics were carried out also in collaboration with both the CISE and the INFN. The main interest of the physicists, mainly Carlo Salvetti and Sergio Gallone, working at the CISE was the development of a theory of nuclear reactors from 1949. The nuclear reactors active around 1950 were about a hundred the world over, for the production of energy or for scientific research in physics and chemistry. New kinds of reactors were built or planned when they started their studies in collaboration with the CISE. Examples are the researches on breeder (self-fertilizer) reactors[14] in the U.S.A., the French Zoé reactor[15] for the production of neutrons for scientific researches, and the Canadian NRX reactor.[16] Technical details, in particular of essential physical quantities, were but hidden by military secret. Since the CISE group needed to know how a reactor worked, they had to develop the theory of reactors by themselves.

Carlo Salvetti studied the transient regime of nuclear reactors ([106–108]). The transient regime happens when a change in the reactor activity occurs, such as when

[14] The aim of these researches was the production of ^{239}Pu from ^{238}U.

[15] Zoé - Zéro de puissance Oxyde d'uranium Eau lourde (Zero power, Uranium oxidum, Heavy water) was planned by Frédéric Joliot-Curie and built in Paris in 1947. It was the first French nuclear reactor.

[16] NRX - National Research Experimental. It was built in 1947.

it is switched on or off, or when the control bars are inserted or taken out from the reactor. Salvetti followed Fermi and Amaldi's theory on the absorption and the diffusion of slow neutrons [109].

As a first case, Salvetti considered a reactor without retarded neutrons. He studied the slowing and diffusion of fast neutrons, based on Fermi's age theory [109], and found an expression for the epithermal neutrons for energies up to the highest resonance level of uranium. This density, multiplied by the transparency factor to resonance was the source terme of thermal neutrons. By considering the source term of thermal neutrons, he obtained the number of neutrons which becomes thermal per unit volume and unit time in stationary conditions, with a multiplying factor for a reactor of infinite dimensions corresponding to the number of thermal neutrons produced for each absorbed thermal neutron. Salvetti's macroscopic equation of the thermal neutrons in the pile in the static approximation was in a non-stationary state:

$$D\nabla^2 n(\mathbf{r}, t) + q(\mathbf{r}, t) - \frac{n(\mathbf{r}, t}{\tau} = \frac{\partial n(\mathbf{r}, t)}{\partial t}$$

where D is the diffusion coefficient of thermal neutrons in the pile, $n(\mathbf{r}, t)$ is the density of thermal neutrons in the reactor, $q(\mathbf{r}, t)$ is the number of neutrons which become thermal per unit volume and unit time. The study of this equation showed that the multiplication caused the period of the reactor to be much larger than the neutrons mean life, and that the finite dimension of a reactor caused a larger period than in a infinite reactor. The general solution of Salvetti equation was

$$n(\mathbf{r}, t) = n(\mathbf{r}, 0)e^{t/T}$$

The introduction of the effective multiplying factor k (the number of thermal neutrons produced in the reactor for each disappearing thermal neutron) into Salvetti equation showed that the reactor was stationary ($T = \infty$) for $k = 1$ (critical conditions); for $k > 1$ the reactor was divergent, for $k < 1$ convergent. The study of a non-static solution required a modification of Salvetti equation by adding a temporal term. The study of its solution showed that a neutron inside a reactor spent most of its life as a thermal neutron. This conclusion justified a static treatment for a reactor with thermal neutrons except in those cases when there was a sudden variation of its reactivity (e.g. when heavy water starts to boil, or when the control bars are taken out too fast). Salvetti then considered the solution of his equation in reactors of cubic and spherical shape and found that, at the same power, a spherical reactor required 16% material less than a cubic one, due to a lesser surface effect and to a better use of materials.

Salvetti then considered a rector with delayed neutrons, i.e. created by a nuclear fission or by a deuton photodisintegration. Before being emitted, the delayed neutrons were considered as latent neutrons. The presence of delayed neutrons caused the existence of more than one period in the reactor, but Salvetti showed that only one period was of a practical relevance. With the data reported by Hughes [110], Salvetti found that the k-value for a dangerous divergent reactor was $k = 1.0076$.

Sergio Gallone and Carlo Salvetti started in 1950 a thorough analysis of the neutron behavior inside a reactor. They analyzed the symbolic calculation methods for neutron multiplication [111] They considered monokinetic neutrons from both the source and fusion, and a homogeneous multiplying material which did not capture fast neutrons, and used Salvetti's previous results on the slowing equation in the diffusion of thermal neutrons. Harmonic analysis was conducted for some geometrical configurations, with a more detailed analysis for ta cylindrical multiplying medium injected by a fast neutron point source. They extended these results to the case corresponding to the energy of the neutrons from the course higher than the energy of the fission multiplication neutrons [112] and studied the effect of the mean free path of the fast neutrons on the distribution of the thermal neutrons in the multiplying media [113]. In the case of modulated and moving neutron sources, they studied the subcritical multiplying media with non periodical time-depending sources [114] for the study of subcritical pile elements. Relevant examples were the instantaneous injection of neutrons from a point source, the switching of a neutron source of constant intensity, and a moving neutron source. Only for the case of prompt neutrons, they studied the influence of the reflectors on the transient behavior inside a nuclear reactor [115]. For the case of a flat reactor they evaluated the critical size and the time constants. As a result they found that the critical pile with a diffusor was less inert that a nude critical pile with the same multiplying medium. Eventually, Gallone deduced the criticality condition for a pile in a case of very simple geometry [116] of an infinite heterogeneous pile in two dimensions, and limited in the third one.

Salvetti and Gallone also studied theoretical models of the nucleus of a certain relevance for the CISE researches. They took a few models into consideration. In the first model, they studied the energy level perturbations of a nucleon in a nucleus seen as a spheroidal potential well [117] and found the energy shift relative to the unperturbed eigenvalues in agreement with Feenberg and Hammack results [118]; the case of an impenetrable spheroidal box was obtained with the limit of well depth diverging to the infinity. In the case of the orbital nuclear model, they studied the magnetic moments of specular nuclei [119] with a model of a core and an odd nucleon. They observed a correspondence between the magnetic moments of the specular nuclei falling close to the lines with the same quantum numbers. The third model under consideration was Rainwater's asymmetric nuclear model[17] [120], which they studied in the case of a strong spin-orbit pairing and more general deformations [121, 122] and considered it able to predict the right order of magnitude of the nuclear quadrupole moments. They showed that the asymmetry was not strictly related to Rainwater's model in the case of an independent particle nuclear model [123] with the nucleons in motion in a deformable potential in which the volume enclosed by an equipotential surface did not vary with the deformation.

In the 1950s, Caldirola worked with some researchers of the CISE in the study of the theoretical isotope separation by gaseous diffusion through porous barriers [124–128]. He patented his method of isotope separation of uranium hexafluoride. Caldirola's method of isotope separation was used at the CISE and at the Nuclear Site

[17] Rainwater's model was a mixed model, intermediate between the drop model and the shell model.

of Tricastin in the Pierrelatte nuclear plant by the French Commissariat à l'Energie Atomique. Caldirola furthermore analyzed the isotopic effects in the absorption of gases on solids [129], the phenomena of adsorption and surface migration of the gas [130], and the influence of the boundary limit on the isotopic separation in the diffusion of a gas through a porous wall [131]. He evaluated the effects of these processes and how they depended on temperature: they diminished the isotopic enrichment, with a stronger decreasing at low temperatures.

Theoretical studies on mesons started with Bruno Ferretti in the only year he was professor at the Institute of Physics of Milan University. He considered the absorption of artificially produced mesons [132] and the atomic capture of slow mesons [133]. In nuclear emulsions, the μ-meson tracks were observed to end with a star (with one or two branches) in the 50% of cases, whereas the π-meson tracks ended with a star in the 80% of cases (with between two and seven branches). In Ferretti's opinion, the high percentage of π-mesons absorption with stars suggested that the mesons were absorbed also by the nuclei of the gelatin and not only by the nuclei of silver bromide. The stopping power of the gelatin should cause that at least 20% of mesons stopping in it. It was therefore highly probable that a part of the starts corresponded to disintegrations of light nuclei in the gelatin. This fact was considered by Ferretti a proof that the Conversi-Pancini-Piccioni effect was a nuclear and not an atomic phenomenon. The remaining 20% of π-meson tracks, without ending stars, were attributed by Ferretti to the emission of neutrons with or without a second charged particle with percentages depending on the isotopes.

In order to solve the problem concerning the interpretation of the Conversi-Pancini-Piccioni effect, Ferretti calculated the transition probabilities for a meson bound to an atom colliding against atomic electrons. Before interacting the nuclei in Be, C, and O atoms, π-mesons were captured in a K-orbit, then they were absorbed by the nuclei with the transformation of a proton into a neutron. Ferretti calculations on the collision of an electron against a meson, made with both a non quantum approximation and Born approximation, confirmed the results obtained by Fermi and Teller.

In the early 1950s Caldirola was interested in the theoretical study of the phenomenology of cosmic radiation, which he pursued with his students from Pavia University. In 1949 he had developed a theory of the mesonic component under the assumption that the primary component entering the upper atmosphere was made of protons and that the π-mesons were generated by interactions between pairs of nucleons [134]. Together with Angelo Loinger, he analyzed the distributions of π-mesons in the atmosphere to describe the positive excess and the production multiplicity [135]. With Giovanni Zin of the National Electrotechnic Institute "Galileo Ferraris" of Turin, Caldirola studied the latitude effect of cosmic protons and neutrons due to the action of the Earth's magnetic field [136]. With other two students from Pavia University, Roberto Fieschi and Paolo Gulmanelli, he developed the calculations of the Gulmanelli's thesis work and developed them in the comparison of the experimental data on geomagnetic effects with a theoretical scheme concerning the distribution in atmosphere of mesons and electrons [137], in particular the latitude effect on the distribution of mesons [138]. Eventually they developed a wide phenomenological theory of all the processes concerning cosmic radiation in the atmosphere to compute the distribution of fast protons and neutrons, mesons and electrons, the mesons energy spectrum, the positive excess as a function of altitude, and the latitude effects [139, 140].

Theoretical studies on the particles in cosmic radiation were carried out also by Fiorenzo Duimio who studied the binding energy of the unstable fragments found among the new particles (hyperons, heavy mesons, etc.) [141], in particular the light fragments [142], and the decays of π- and K-mesons in light fermions [143].

Besides the phenomenology of the different components in cosmic rays, Caldirola's interest was attracted also by other aspects concerning particles. When still at Pavia University he had studied the problem of the relativistic correction to the magnetic moment of a deuton [144, 145]. In 1951 he faced, with Paolo Gulmanelli, the wave equation for 1/2 spin particles advanced by H.C. Corben [146]:

$$\left[\gamma_i\left(\partial_i - \frac{ie}{\hbar c}A_i\right) + \frac{ie}{\hbar bc}\gamma_5 + \chi\right]\psi = 0$$

where γ_i are Neumann operators, $b = e/m_e c^2$, $\chi = m_e c/\hbar$. They compared Corben equation with Dirac wave equation (they differ for the γ_5 term), and noticed the differences in the eigenfunctions for two particular problems: the motion of a particle in a central Coulombian field, and the magnetic moment of a 1/2 spin particle and its relativistic corrections [147]. The eigenvalues for a particle (hydrogen-like atom) in a central field were the same of Dirac equation if $m = \sqrt{m_e^2 + e^2/b^2c^4}$ was considered to be the effective mass of the particle. For a free particle in a constant magnetic field, they obtained that the magnetic moment was the sum of three components due to the precession motion of the particle around the field direction, to the intrinsic magnetic moment connect to the spin, and to the charge of Dirac particle and Pauli supplementary factor. This third factor caused a difference between of the eigenvalues of the two equations, and the magnetic properties of the particle were dependent from the nature of its mass. The anomalous magnetic moment of the electron was interpreted by Caldirola with a classical explanation [148].

Caldirola's studies on the electrons concerned the relativistic equation of motion of an electron in the framework of classical electrodynamics [149]. Caldirola was not able to integrate Dirac general relativistic equation

$$m_e c\frac{du_\alpha}{ds} = F_\alpha + R_\alpha$$

where F_α is the tetravector of the external force and R_α is the tetravector of the reaction. He was but able in any case to solve it for six particular cases: free particle, particle subjected a constant force, particle subjected to a time-dependent force, particle in a constant magnetic field, particle subjected to an elastic return force, electron launched along a line against a fixed proton. A second, finite-difference equation,

$$\frac{m_0}{\tau_0}\left[\mathbf{v}(t) - \mathbf{v}(t - \tau_0)\right] = \mathbf{F}(\mathbf{r}, \mathbf{v}, t)$$

of a classical electron interacting with an electromagnetic field, was advanced with Fiorenzo Duimio through the introduction of a fundamental length $\lambda \approx r_0 = e^2/m_e c^2 = 2.81 \times 10^{-13}$ cm, considered as a universal constant [150]. The Caldirola-Duimio equation was integrated for some particular cases. They showed that their equation corresponded to Bohm and Weinstein's model of an electron of spherical shape with its charge spread out on its surface and its mass of electromagnetic nature [151], and obtained from it the solution for the irradiation of the electron in the frame of classical electrodynamics [152]. Classical electrodynamics was also applied by Caldirola also to the study of the equation of motion of the positive electron [153], an equation which was equivalent to that describing the motion of an electron under the action of the anticipated proper field and describing a chronotopic time line directed towards the past.

The classical theory of electrons, in Caldirola's formulation, was based on the assumption that the macroscopic motion of an electron could be defined only in a discreet succession of time instants separated by a fundamental interval [154]

$$\tau_0 = \frac{4}{3}\frac{e^2}{m_0 c^2}$$

The time interval between these instants – later named "chronon" – had a noteworthy meaning also in a quantum frame through Heisenberg indetermination principle ($\Delta\tau \times \Delta E \geq \hbar$). A measurement on a particle caused an uncontrollable fluctuation motion with an energy the greater the faster the measurement. If a particle had excited states with different mass values, stating that the particle had a given mass was meaningful only if ΔE was lesser than the mass difference, which caused an incertitude $\Delta\tau$. The value of mass could not be given at an exact instant but only within a time interval $\Delta\tau$. Caldirola developed the concept of chronon in subsequent studies in the 1970s [155–159].

Caldirola showed that it was possible to make use of Fokker variational principle to interpret in a classical frame the creation and the annihilation of electron-positron pairs when an electron went through a sufficiently high potential barrier. At the same time he obtained a classical explanation of Klein's paradox with a new model of classical electron [160].

Further studies on the electrons were made by Caldirola's assistants. We mention the study by Giovanni Maria Prosperi and Paolo Tosi on the mathematical relations between the classical theories of the electron by Feynman and Rzewuski [161] and the study by Renzo Cirelli on the motion of an electron under the action of an instantaneous electromagnetic pulse [162].

Mathematical studies on Schwartz distribution theory were carried out by Sergio Albertoni. He took into consideration the problem of a transformation of variable quantities and gave a proof of some formulas concerning Dirac's singular functions used in quantum theories such as quantum electrodynamics [163, 164]. Another mathematical research concerned the structure of Hilbert spaces in quantum field theories, giving a possible physical interpretation of some subspaces [165], and the properties in various subspaces of the hamiltonian operator of the beta-theories [166].

Quantum electrodynamics and quantum field theories were the subject of many studies in the 1950s. Sergio Albertoni carried out a thorough analysis of Tomonaga-Schwinger fundamental equation of quantum electrodynamics [167, 168, 212] and wrote the motion equations in a covariant form for two interacting dynamical systems, such as electrons in a radiation field. In the case of a finite number of particles of a same kind, Pietro Bocchieri and Angelo Loinger of Pavia University showed that Tomonaga-Schwinger theory was equivalent to Dirac-Fock-Podolsky theory [169]. With Giovanni Maria Prosperi, Bocchieri and Loinger showed that Feynman quantization method was limited to a bosonic field and could not be used with a fermionic field [170]. The application of Feynman's functional method to the case of a scalar neutral bosonic field interacting with infinitely heavy nucleon was studied by Renzo Cirelli [171] in order to check that it was equivalent to the usual methods of field theory. Gulmanelli proved the possibility to define the asymptotic conditions in the ordinary field theory in the case of no occurring zero-mass particles [172].

Paolo Gulmanelli applied Peierls's formalism to a theory of non-locally interacting fields [173]. He showed that Poisson brackets for the ingoing and emergent fields are the same to those of free fields. Non locality was a feature of the theory of β-interaction which was found by Gulmanelli following the formalism applied to electrodynamics by Nishijima [174].

A last group of theoretical studies which must be mentioned concerned the ergodic theory. The ergodic theorem in quantum mechanics had already been a very interesting topic studied by Caldirola's collaborators of Pavia University, Bocchieri and Loinger [175, 213]. Caldirola analyzed the misunderstanding occurring in the ergodic approach to statistical mechanics which led to objections against the ergodic method (a physical system is never isolated as it is instead requested by the ergodic method; the quantities averaged over an infinite time interval have no operational meaning whereas macroscopic quantities are measured in short time intervals) which Caldirola confuted [176]. Bocchieri and Loinger formulation of the quantum ergodic theorem, instead of the unsatisfactory classic formulation by von Neumann, was considered by Prosperi and Scotti to evaluate the probability of exceptional initial conditions; they deduced a stronger relation by the evaluation of the probability of finding an initial condition with $[u_\nu(t) - s_\nu/S]^2 / (s_\nu^2/S^2)$ (the square deviation of the quantum mechanical probability of occupation of the ν-th cell from the microcanonical value s_ν/S) larger than a fixed value for a time interval greater than the assigned one [177–179]; the quantum ergodic conditions were then rewritten by averaging over all the microscopic states corresponding to a given macroscopic state [180]. The studies on the ergodic theorem continued in the next decade; a relevant result was obtained in 1962 with the study of the ergodic conditions in connection with the quantum theory of measurement [181].[18]

[18] On the reception of this paper see: [182, 183].

7.6 Electrostatic Machines for Experimental Nuclear Physics

Giovanni Polvani and Giovanni Gentile jr started to talk about the possibility of building an accelerator at the Institute of Physics. Their dream became reality only in the 1960s with the construction of the relativistic cyclotron. Other accelerating machines, however, were built by other research institutions in Milan and were used in collaboration by the Milan physicists. We shall talk here about the first machine built at the CISE, a Cockcroft-Walton accelerator, and the first machine built at the Milan division of INFN (and hosted in the Institute of Physics), an electrostatic accelerator for deutons.

The Cockcroft-Walton accelerator built at the CISE in 1951 was the third electrostatic machine of this kind built in Italy after the double rectifier built in Rome in 1938 in the Superior Institute of Health which could reach a 1100 kV tension, and the Cockcroft-Walton built in Pavia in 1941, dismantled and buried in 1943 to avoid that it was taken away by the German troops and restarted at 560 kV in 1956.[19] The CISE Cockcroft-Walton was planned in 1948 in order to measure the total cross section of uranium with the production of neutrons from the d + Li and d + d reactions. It accelerated deutons at 400 keV with a mean current of 0.8 mA [184] (Fig. 7.3).

The generator was a quadruplicator of tension in two steps, producing a 400 kV tension and 3 kVA power. The ion source was a Penning Ionization Gauge or Philips Ionization Gauge. The accelerator tube was made of two coaxial cylinders placed in a vertical configuration. The first tube was connected to the high tension generator, while the second tube was at –500 V. At the bottom of the accelerator tube was placed the target. With a $d(Li^7, n)He^3$ reaction they could produce 3×10^{12} n/s for 1 μA of ions on the target, i.e. about one neutron every 3×10^7 deutons. The neutrons energy was above 1 MeV, so that they had to be slowed down with heavy water or paraffin.

The CISE Cockcroft-Walton was used to study the spectra of the γ-rays emitted by the p+n reaction [185], in order to measure the binding energy of the deuton. The most relevant research was carried out in 1954 when they measured the total cross sections for cadmium, nickel and uranium. Whereas these data for cadmium and nickel were already known, the total cross section for uranium[20] was covered by military secret in the US. The CISE was the first group to publish these data on a scientific journal [188]. These researches, as well as those carried out in other countries, forced to unveil the technical details for the construction of nuclear reactors.

The CISE Cockcroft-Walton is currently on permanent exhibition at the National Museum of Science and Technology “Leonardo da Vinci” in Milan.

In the Segrate seat of the CISE, another accelerator was built, a 3.5 MeV van de Graaff electrostatic accelerator, by Ileana Iori, P. Principi and Tommaso Rossini[189].

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[19] The Pavia Cockcroft-Walton is currently on exhibition at the Museum of Electrical Technique in Pavia.

[20] A first determination of the cross section of uranium for slow neutrons had been obtained at the CISE in 1950 [186, 187], but it did not cover the whole range of energy.

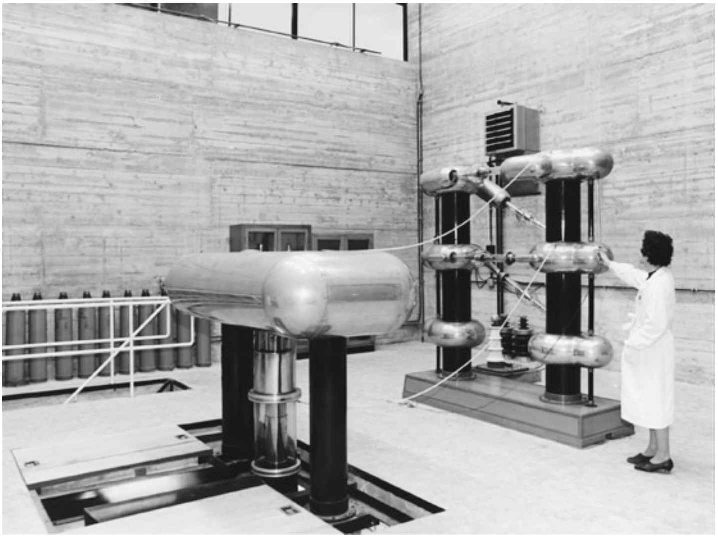

Fig. 7.3 The CISE cockcroft-walton accelerator (Copyright: CISE2007)

The CISE researchers also made some solid state detectors (Si detectors) to be used with the two accelerators. In this way they could experimentally confirm Ericksson's fluctuations of the fast neutrons cross sections in 1960–62. These fluctuations highlighted some relevant properties of compound nuclei.

In March 1958, an accelerator for deutons started to work at the Milan division of the INFN [190]. It had been planned in order to have a source of intense beams of 14 MeV neutrons. The neutrons were produced with the reaction

$$H^2 + H^3 \rightarrow He^4 + n + 17.587\,\text{MeV}$$

with a maximum cross section when the deuton energy was 120 keV. With commercial zirconium-tritium targets it was possible to obtain a beam of 10^{10} n/s. The small potential difference requested to accelerate the deutons favored the building of a simple and cheap machine.

The about 2 m long accelerator tube was made of steel and placed in a vertical position with the deutons source at the bottom. The tube contained three electrostatic lenses. The tension of the first lens was given by a generator of a maximum tension of 50 kV and maximum current of 10 mA. The tension of the second and third lenses was given by an induction generator with a maximum tension of 160 kV and a maximum current of 2.5 mA, built by the SAMES company. The ion source was of radiofrequency kind and deuterium was injected in it through a hot palladium purifier at a pressure of 1.5×10^{-3} mm Hg. The discharge was excited by a radiofrequency oscillator at 14 MHz coupled to the source, with a maximum power of 200 W. The ionic beam was extracted with a potential difference of 3000-4000 V between the extractor electrode and the bottom of the source.

The potential difference was created between the ion source of the deuton beam kept at 0 V and the zirconium-tritium target at –160 keV. This choice permitted act on the source even when the accelerator was working, and to keep at 0 V all the instruments necessary for the source activity. The target tension at 106 keV prevented instead to get too close to the target; the external wall around the target was therefore a metal pipe at 0V so that it was possible to put the detectors at 10 cm from the neutron source.

In the late 1950s, the INFN electrostatic accelerator was used to study the energy spectra of the protons from the (n, p) reaction of the 14 MeV neutrons on different kinds of nuclei. They gave information on the energy dependence of the nuclear level densities as a function of the internal energy of the nuclei and temperature [191].

The CISE and INFN machines were used by researchers who were already members of the Institute of Physical Sciences (starting with Marcello Pignanelli) or that would have become after they were built (Ugo Facchini, Laura Colli, Ileana Iori). Their first researches in the 1950s, with the 14 MeV neutrons, paved the way to the school of applicative, experimental and theoretical nuclear physics which has been flourishing in Milan from the 1960s onwards.

7.7 Solid State Physics

Researches on Solid State Physics [192] were promoted at the beginning of the 1950s by Piero Caldirola who called Fausto Fumi to join the Institute of Physics from the US where he had worked with Frederick Seitz at the Carnegie Institute of Technology in Pittsburg and at the University of Illinois at Urbana. Solid state physics was a completely new subject in Milan and lacked of a tradition in all Italian universities[21] According to Chiarotti [195], there was no industrial demand for solid state physics research in Italy in the 1950s; the reasons for an interest in solid state physics were instead: the instruments at disposal for research no more used by other groups due to the evolution of nuclear physics studies, the application to solid state physics of techniques developed in other fields, the studies on nuclear reactors which required to know the effects and damages of radiations on the metal components, the request of cooled hydrogen or deuterium targets for accelerators, and the modern electronic instrumentation put on sale by the stores of the US Army.

Fumi brought to Milan the knowledge he had acquired in the US, in particular the studies on color centers. While in Pavia University they started to perform experiments with Giulotto, in Milan Fumi created a group of theoretical research [196, 197] with a few young physicists graduated in Pavia: Franco Bassani (who stayed in Milan only one year), Roberto Fieschi and Mario Tosi. The first researches in Milan

[21] On the Italian researches on matter in the solid state before the Second World War, see: [193]; after the Second World War, see: [194].

were of theoretical kind concerning the elastic coefficients of crystals [198, 199] obtained by the direct inspection method and by group theory; the photoelasticity in crystals [200]; the schemes of high-order matter tensors relevant in crystals capable of spontaneous electric or magnetic polarization by the method of direct inspection for triclinic, monoclinic, rhombic, tetragonal and cubic groups, and by elementary group theory for trigonal and hexagonal groups [201]; the calculation of the binding energies of divalent impurity ions and positive-ion vacancies in NaCl and KCl crystals [202]; the general study of reticular defects in ionic solids [203, 204]; the electronic states of diatomic molecules [205].

Fumi left Milan in 1955 when he won the public competition for a chair of Theoretical Physics and went to Palermo University. In the meanwhile Fieschi had spent two years in the Netherlands to specialize in statistical mechanics and thermodynamics of irreversible phenomena. Fieschi continued the researches on the electronic states of diatomic molecules [206] by the method of atoms in molecules; the thermal conduction of dielectric under electric fields [207] with a thermodynamical treatment; the thermodynamical properties of the isotopes of noble gases in the solid state [208] to test the validity of Einstein's anharmonic model.

At the end of the 1950s Fieschi was able to organize a solid state physics group with other young physicists (Elisabetta Abate, Giancarlo Baldini and Nice Terzi). They started the first experimental activities, thanks to the financings from the CNR and the INFN. The collaboration with the CISE became relevant when in 1955 they established a solid state physics laboratory where researchers of the Institute of Physical Sciences could work under the direction of Elio Germagnoli and with the CISE researchers, Aurelio Ascoli and Maria Asdente [209].

At the CISE, two main results were obtained: the production of metal (Pb, Sn, Zn, Ag, Cu) crystals were produced to study the self-diffusion in well characterized systems, and the determination of formation and migration energies of vacancies via the resistivity measurements on quenched-in lattice vacancies in Copper [210] and Platinum [211].

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Chapter 8
Towards the New Seat

Leonardo Gariboldi

Abstract In 1961 the Institute of Physical Sciences started the classes of the reformed degree course in Physics in the new seat of their own, while the buildings and facilities for research, offices and administration had not been completed yet, with the exception of Occhialini's shed for researches in space physics. An important building in the back yard of the Institute of Physical Sciences was planned to host the synchrocyclotron (the project was modified in order to build a relativistic cyclotron), an accelerating machine which stimulated collaborations and applications of the research groups of the Institute of Physical Sciences. This was the last project which saw Polvani as a fundamental scientific policy maker. As a trait d'union from the old and the new seat, in this chapter we shall show the planning and construction of the cyclotron and the activities of Occhialini's group in space physics.

8.1 Moving to the New Seat in Via Celoria

Whereas the number of students of technical and scientific course decreased during the twenty years of the Fascist government, a decrease due to the centrality given to the humanities by the Gentile Reform of the educational system, the Sixties were a decade characterized by a marked increase in the number of students of all disciplines which culminated with the Law no 910, December 11, 1969, which granted the access to all university degree courses for those students who had obtained a high school diploma of any kind. At the same time Milan University planned new buildings. The Law no 158, March 5, 1961, and the Law no 1073, July 24, 1962, with the Three-years Plan of School Development, made it possible to complete the new building of the Institute of Physical Sciences in Via Celoria.

The rector De Francesco and the administrative director Carlo Baccarino had managed to obtain the assignment of the land from Milan Municipality. The plan for the new institute was prepared by the architect Orlando Villa. It was based on a central, large building with classrooms and offices and some peripheral, smaller buildings for particular research activities and workshops. Suggestions from the members of the institute were collected by Camillo Giori. The first building was erected in the north-eastern corner of the assigned land and hosted the nuclear emulsion research

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group, so that it was called the "baraccone di Occhialini" (Occhialini's shed). The central building was inaugurated by Polvani on February 10, 1964.

At the same time, the reformed degree course in Physics caused a deep restructuring of the Institute of Physical Sciences, with many more chairs then ever before.[1] With the appointment of Giovanni Polvani as president of the CNR and his move to Rome, They named Piero Caldirola as new director of the Institute; he acted as such until the end of the decade when he was substituted by Ugo Facchini during the "1968" students protests. The list of chairs of full professors, with their assistants and technicians, was as follows[2]:

Chair of Experimental Physics I

- Full professor: Giovanni Polvani;
- Ordinary assistants: Carlo Succi (acting as help), Ettore Fiorini, Sergio Micheletti (on leave from 01.06.1962 to 30.09.1962), Sergio Peppino Ratti (on leave from 01.12.1961);
- Alternate assistants: Pietro Negri (commissioned; from 01.12.1961);
- Extraordinary assistants: Ettore Gadioli (until 01.10.1962), Elio Sindoni (from 01.10.1962);
- Volunteer assistants: Franco Tonolini (from 16.12.1961 to 01.10.1962 then extraordinary assistant), Lidia Severgnini Tonolini (until 01.10.1962), Nicolino Angelo (from 01.01.1962), Gianenrico Frigerio (from 01.12.1961), Giampiero Maria Tosi (from 01.12.1961);
- Adjoined applied: Carla Morlacchi (2nd class);
- Graduated technicians: Mario Fois (from July 16, 1962);
- Executive technicians: Giovanni Adorni (principal), Renato Ballerini (2nd class), Teresa Panizza (2nd class), Mario Scalvini (commissioned, until 01.03.1962);
- Janitors: Mario Decarli (2nd class, until 01.03.1962 then executive technician on trial), Emilio Bonelli, Mantovani Walter, Bassano Prada;
- Non-permanent auxiliary government employees: Vincenzo Amorosini, Lazzaro Fumagalli, Gino Pacchioni (from 01.07.1962).

Chair of Experimental Physics II:

- Full professor: Ugo Facchini;
- Assistants: Enrica Erba (commissioned assistant until 01.07.1962, then ordinary assistant);
- Volunteer assistants: Giancarlo Bassani (until 09.12.1961), Elisa Menichella Saetta (from 01.12.1961), Elio Sindoni (from 01.12.1961 to 01.10.1962);
- Daily workers: Adriana Ingrassia (3rd class), Elvira Baioni Frigeri (4th class), Giovanni Antonio Posadinu (4th class), Gianmario Rimoldi (4th class).

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[1] In 1960, the Institute of Physical Sciences had the unprecedented number of six professors: Piero Caldirola (Theoretical Physics), Ugo Facchini (Experimental Physics II), Giuseppe Occhialini (Higher Physics), Giovanni Polvani (Experimental Physics I), Carlo Salvetti (Nuclear Physics), Guido Tagliaferri (Radioactivity).

[2] Centro APICE: Milan University Historical Archive: Milan University 1961–62 yearbook.

Chair of Nuclear Physics

- Full professor: Carlo Salvetti;
- Lecturer: Renzo Cirelli (until 18.03.1962);
- Ordinary assistant: Marcello Pignanelli (from 16.12.1961; on leave from 16.12.1961 to 16.04.1962);
- Volunteer assistants: Giancarlo Ghilardotti, Bruno Montagnini (until 01.02.1962).

Chair of Radioactivity

- Extraordinary professor: Guido Tagliaferri;
- Ordinary assistants: Marcello Pignanelli (on leave until 15.12.1961, then for the chair of Nuclear Physics);
- Alternate assistants: Francesco Giuseppe Resmini (until 16.12.1961, then commissioned assistant).

Chair of Superior Physics

- Full professor: Giuseppe Occhialini;
- Ordinary assistants: Alberto Bonetti (acting as help, on leave until 31.08.1962), Guido Giuseppe Vegni;
- Alternate assistants: Emanuele Quercigh (commissioned until 31.08.1962);
- Volunteer assistants: Giuliano Boella, Giovanni Degli Antoni, Giovanni Gregori, Virgilio Pelosi;
- Daily workers: Girolamo Bellani (3rd class), Rosa De Bernardi (4th class).

Chair of Theoretical Physics

- Full professor: Piero Caldirola;
- Ordinary assistants: Paolo Gulmanelli;
- Commissioned assistants: Lodovico Giovanni Lanz;
- Volunteer assistants: Vincenzo Ardente (until 21.05.1962), Pietro Bocchieri (until 18.05.1962), Oreste Rodolfo De Barbieri (from 16.11.1961), Giovanni Maria Prosperi, Germana Valentini.

To this list of chairs, we have to add that of the chairs without a professor and covered by lecturers (who could be professors of a different discipline) of the Institute of Physical Sciences or from other institutions such as the CISE, the INFN and the Astronomical Observatory of Brera and Merate. Their number shows us the different structure of the Institute of Physical Sciences as compared to that in the previous decade. At the same time, it is evident that, since all assistants and technicians were formally assigned to the few chairs with a full professor, the Institute of Physical Sciences was really acting as one institution as they had decided with the Paris agreement. The list of chairs with a lecturer and few other assistants was:

- Applied Electronics: Umberto Pellegrini;
- Astrophysics: Margherita Hack De Rosa;
- Atomic Physics: Maria Di Corato;
- Calculating Machines: Vincenzo Gervasio;

- Complements of General Physics I: Carlo Succi;
- Cosmic Physics: Constance Dilworth Occhialini;
- Electronic Optics: Pier Giorgio Sona;
- Electronics: Emilio Gatti;
- Elementary Particles Physics: Livio Scarsi;
- Exercitations of Experimental Physics I (for chemists): Giorgio Spinolo;
- Exercitations of Experimental Physics II (for chemists); Giampaolo Bellini;
- Experimental Physics (for geologists): Martina Panetti Lovati;
- Experimental Physics I (for chemists): Ettore Fiorini;
- Experimental Physics II (for chemists): Sergio Micheletti;
- Institutions of Nuclear Physics: Laura Colli;
- Institutions of Theoretical Physics: Piero Caldirola;
- Mathematical Methods for Physics: Sergio Albertoni Bruno Montagnini (volunteer assistant from 01.02.1962);
- Neutron Physics: Ileana Jori;
- Nuclear Reactor Physics: Piero Caldirola, Silvio Edoardo Corno (volunteer assistant);
- Physics (for biologists): Vittorio Amar;
- Physics Experimentations I: Lucia Tallone Lombardi;
- Physics Experimentations II: Mario Milazzo;
- Physics Laboratories: Fernando Cristofori (General field), Maria Franceschetti Oberto (General field), Paolo Principi (Applied field: Electronics), Ugo Facchini (Applied field: Electronics), Michelangelo Fazio (Applied field: Nuclear Physics), Grazia Marcazzan (Applied field: Nuclear Physics);
- Preparation of Didactic Experiences: Alfredo Luccio;
- Quantum Mechanics: Paolo Gulmanelli;
- Semiconductors: Elisabetta Abate, Rosanna Capelletti (volunteer assistant, from 01.05.1962), Roberto Marco Oggioni (volunteer assistant, from 01.05.1962);
- Solid State Physics: Roberto Fieschi, Nice Terzi Bellini (volunteer assistant), Cesare Amelio Bucci (volunteer assistant from 16.02.1962);
- Statistical Mechanics: Renzo Cirelli;
- Structure of Matter: Guido Tagliaferri;
- Thermodynamics: Emilio Montaldi.

Lastly, Lorenzo Lunelli was the lecturer in Theory and Applications of Calculating Machines, but he was not formally a member of the Institute of Physical Sciences.

8.2 The Relativistic Cyclotron

The first Italian cyclotron was built at the Institute of Physical Sciences of Milan University between 1960 and 1965 (Fig. 8.1). It was a relativistic cyclotron. The idea of the project of a synchrocyclotron was put forward by Guido Tagliaferri and Carlo

Succi in the late 1950s.[3] The idea was accepted by Giovanni Polvani, who started to look for financing the project and considered it his farewell gift to the Institute, and by the new director of the Institute, Piero Caldirola, who started to get in touch with the CNR for a contribution to the building costs:

> The Institute of Physical Sciences of Milan University is currently in an expansion phase determined mainly by the assignment of two new chairs of Physics (in addition to the four already existing) and by the construction, at an advanced stage, of the new headquarters.
> This situation requires the formulation of an organic research program for the next few years to come. As illustrated in the attached proposal, the factors mentioned above, together with others, converge in indicating nuclear physics as the main direction of the scientific activity of the Institute.
> Based on these considerations, the Institute of Physical Sciences of Milan University proposed to build a synchrocyclotron to accelerate protons up to an energy of 50 MeV. This is a machine of which type in Italy there are no examples and which is of particular interest due to the fact that it can be used not only for research in nuclear physics in the strict sense, but also for research in chemistry, biology, radiology and for isotope production.
> The construction of the 50 MeV synchrocyclotron project involves a total cost of approximately 4300 million Italian lire, of which approximately 160 million for the construction of the machine and the remainder for the building, auxiliary services and personnel expenses. This overall expenditure may be spread over three financial years.
> This Institute is working to find the necessary funding. Given the very wide interest that the realization of the project presents for scientific research in general, the undersigned, also on behalf of all the other colleagues of this Institute of Physical Sciences, submits to the consideration of this honorable Presidency the opportunity to grant an adequate financing mainly for the construction costs of the machine.[4]

A similar proposal was sent to the INFN which found it of the utmost interest.[5]

A developed proposal to equip the Institute of Physical Sciences with a cyclotron was advanced to the President of CNR, Giovanni Polvani, in June 1960 and was accepted with favor. It contained the scientific and socio-geographical frame in which to consider the machine, the advantages expected from the researches carried on with it, and a first mention of its cost:

> 1. The forthcoming completion of the 1st lot of the construction works of the new Institute of Physical Sciences of Milan University suggests the need to promptly define the guidelines according to which the didactic and scientific activity will have to develop over the years to come.
> The latter can be considered as advanced teaching, intended to train highly qualified scientific personnel from which teachers of higher culture institutions and experts from research centers, both pure and applied, will have to draw in the future. The preparation of qualified personnel is a task that universities must carry out not only to meet the needs of the community, which is increasingly dependent on scientific progress, but also to ensure its own

[3] Milan University. BICF Library. Polvani Papers, 2.5 Relazioni sciolte sull'Istituto di Scienze Fisiche: Relazione sull'attività svolta dai gruppi sperimentali dell'Istituto di Fisica dell'Università di Milano durante gli anni 1955–57. In this 1958 document they advanced the idea to take into consideration the opportunity of planning a 25–30 MeV cyclotron for deutons.

[4] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Piero Caldirola to the President of CNR, May 18, 1960.

[5] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from the President of INFN (Edoardo Amaldi) to Piero Caldirola, May 21, 1960.

survival.
2. The choice of the fields of research activity of a university institution is obviously determined by the specialization of the scientific interests of the teachers, by tradition (ie by the availability of particular knowledge and experience), and by environmental conditions (city or regional or even national). For the Institute of Physical Sciences of Milan University all these factors converge in designating nuclear physics, experimental and theoretical, as a pre-eminent subject of higher education and original research. The Milan Institute has a long-standing tradition of successes and initiatives in this field.
The numerous publications, the recognized competence of teachers and researchers, the assignment of chairs to teachers of Radioactivity and Nuclear Physics, the establishment of post-graduate specialization schools are proof of this. It should be added that the Institute is the seat of a Section of the National Institute for Nuclear Physics.
The environmental conditions then make Milan particularly suitable for the development of activities in the field of nuclear physics. Various bodies (CISE, Centro E. Fermi of the Polytechnic, Ispra, AGIP Nucleare, etc.) operate in the nuclear sciences and their applications in and around Milan, which maintain scientific links with the University Institute, from which moreover, various members of the managerial and research staff have drawn on. On the one hand, this circumstance makes the Milan environment particularly suitable and prepared for initiatives in the nuclear field; and on the other, it requires the University Institute to keep up with the situation.
3. Carrying out research in nuclear physics requires the use of significant capital, both for the construction of equipment and for its operation. The most powerful and demanding of these devices (high energy and intensity accelerating machines, high flux nuclear reactors) require the availability of financial and organizational means such that their realization can only be conceived in large national or even international research centers. But, even if excluded from the most ambitious projects, university institutes dedicated to nuclear research cannot renounce to equip themselves with equipment of a certain commitment, such as, for example, low and medium energy accelerating machines. Without them, the gap between academic teaching and experimental practice risks becoming unacceptable.
4. Some Physics Institutes of Universities in the North of Italy have already supplied themselves, or are supplying themselves, with nuclear equipment of considerable importance. For example, the 100 MeV electron synchrotron of Turin University can be mentioned; the nuclear reactor of Milan Polytechnic; the 5 MeV Van de Graaff machine of Padua University. The availability of such machines allows institutes that are equipped with them to set up training or research programs of multi-year extension; that is, it allows you to do "school", to give a more specialized physiognomy to scientific activity, to establish the conditions for the continuity of an effective and updated cultural action.
It should be noted that the aforementioned achievements are the result of initiatives by the institutions concerned, supported by the help of public and private local bodies. Only later, and precisely on the basis of pre-existing local funding, was it possible to obtain, where necessary, the interest and help of the central authorities. A procedure of this type appears, on the basis of the experience acquired so far, the most suitable for achieving the aim of equipping a university with an important nuclear equipment.
5. Taking into account the considerations set out in numbers 1–4, the Institute of Physical Sciences of Milan University has prepared this proposal. The contemplated apparatus is a synchrocyclotron for accelerating protons up to an energy of about 50 MeV. The choice resulted from the consideration of the following factors:
a) containment of expenditure within admissible limits;
b) scientific interest of the possible research program;
c) availability of personnel trained for the design, construction and operation of the accelerator;
d) possibility of realization in Italy with national means;
5) insertion of the accelerator, with its laboratories and services, in the framework of the

> buildings of the Milan Institute.
> The remainder of this proposal will be devoted to an exposition of the technical characteristics of the desired synchrocyclotron. Anticipating the conclusions, we can say that this machine:
> a) it would cost about 300 million lire;
> b) it would allow the execution of interesting researches, especially if equipped with a polarized particle injector;
> c) would find competent manufacturers and users in Milan;
> d) it would be feasible, in all its components, by the national industry;
> e) it would find a place in the building complex of the Milan Institute, and all the more economically now that the construction of the buildings of the Institute is underway.
> It should be added that neither cyclotrons nor synchrocyclotrons currently exist in Italy; and that an accelerator of the proposed type could also be used for research in chemistry, biology, radiology and for the production of isotopes. In short, there is reason to believe that the proposed machine would interest a vast public of users, on a national scale.[6]

In early 1960 Guido Tagliaferri asked for the approval and financial help of the INFN. The synchrocylotron program was approved, on the basis of a report written by Giorgio Salvini report, by the INFN Board of Directors in the session held in Rome on May 18, 1960 when they discussed the project presented by the Milan division. Technical discussions with the experts of the Frascati laboratories immediately began. The INFN president obtained the transfer to the Milan division of the equipment for the polarization of protons under construction in the Center of Ispra.

In June 1960 Polvani, after consulting numerous entities and private individuals (the Ministry of Public Education, the Municipality and Province of Milan, Cassa di Risparmio delle Provincie Lombarde, Assolombarda) was convinced that the sum of 300 million necessary in the first approximation to the construction of the cyclotron would have been found as follows: 100 million from the Ministry of Public Education; 100 million from Assolombarda; 100 million from the Municipality of Milan, the Province of Milan and the Cassa di Risparmio delle Provincie Lombarde.[7]

On June 8, Tagliaferri had an interview with the general secretary of CNEN, Felice Ippolito, to whom he illustrated the initiative, concluding with a request for financial assistance directly from the CNEN. Ippolito argued that an assignment directly from the CNEN would have been unlikely, but that an extraordinary assignment from the CNEN to the INFN would have been possible with the understanding that the INFN would use this sum for the Milan cyclotron.[8]

In the session of the INFN Board of Directors held on June 21, 1960 in Bologna, they discussed the request from the Institute of Physical Sciences, submitted by Guido Tagliaferri, that the INFN pay for the staff and part of the management. The request was of about 20 million lire a year for a period of three years. The request

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[6] Proposta di dotare l'Istituto di Scienze Fisiche dell'Università di Milano di una macchina acceleratrice di particelle sub-atomiche. Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Proposal to equip the Institute of Physical Sciences of the University of Milan with a sub-atomic particle accelerator machine.

[7] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Giuseppe Occhialini, June 28, 1962.

[8] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from an unsigned sender to the hon. Colleoni, June 26, 1962.

that the staff belonged to the INFN seemed suitable to Tagliaferri for ensuring in a natural and continuous way the desired connection between the synchrocyclotron activity and the scientific competence of the INFN. However, the INFN board did not intend to make any specific assignment for the synchrocyclotron to the Milan division of the INFN. They authorized the Milan division to use the allocation of funds that would be made for the synchrocyclotron as well. At the end of 1960, 2.5 million lire had been obtained from the INFN for management costs, plus the hiring of a young graduate and two technicians. Tagliaferri advanced to the INFN a further request of a sum of the order of 6 million lire, of which approximately 4.5 million for personnel and the remainder for management.[9]

Tagliaferri also started to collect information from other laboratories abroad in order to better specify the technical aspects of the synchrocyclotron, an activity which he pursued even after the machine started to work.[10] At the same time the Milan project attracted attention and physics from abroad came to Milan to talk with Tagliaferri and his group about the machine project and, of course, to see it while it was built and when it was working.[11]

The project of a synchrocyclotron was soon modified into a project of a relativistic cyclotron, better suited for the kind of researches planned by the Milan group. The machine was designed as a fixed frequency, fixed energy, three-sector AVF (azimuthal variable frequency) cyclotron, 166 cm diameter, with a strong Thomas focalization. The cyclotron was planned to be mainly used with negative hydrogen ions at different energies and for the acceleration of protons in nuclear physics experiments.

The choice of planning an AVF cyclotron was due to the limit that characterized a classical cyclotron: at relativistic speeds the mass of the particles is no longer constant, and this imposes a higher non-relativistic value on the energy. In the case of protons this limit is about 30 MeV. It could be overcome if the magnetic field was made to increase radially in intensity from the center towards the edges of the Dee's. This magnetic field however could destabilize the beam: in a relativistic cyclotron In fact, any changes in the orbit in both the radial and the horizontal and vertical azimuthal directions had to be reduced to a minimum, to prevent the particles from colliding with the ends of the Dee's and destroying the beam. The problem was solved by L. H. Thomas in 1939. He designed the shape of magnetic poles capable of producing a magnetic field that increases with the radius and at the same time varies

[9] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Giuseppe Occhialini, January 11, 1961.

[10] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 Gruppo ciclotrone. Letter from Guido Tagliaferri to L. Jackson Laslett, June 19, 1961. Letter from L. Jackson Laslett to Guido Tagliaferri, June 22, 1961. Letter from Fred T. Howard to Guido Tagliaferri, November 6, 1961. Letter from Guido Tagliaferri to J. D. Lawson, September 7, 1964. Letter from J. D. Lawson to Guido Tagliaferri, September 14, 1964. Letter from Guido Tagliaferri to H. G. Blosser, February 26, 1965.

[11] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 Gruppo ciclotrone. Letter from L. Jackson Laslett to Guido Tagliaferri, April 27, 1961. Letter from L. Jackson Laslett to Guido Tagliaferri, June 28, 1961. Letter from R. E. Worsham to Guido Tagliaferri, May 30, 1963. Letter from J. Fermé to Guido Tagliaferri, June 7, 1963. Letter from Guido Tagliaferri to J. Roux, March 21, 1964. Letter from Dieter von Ehrenstein to Guido Tagliaferri, October 7, 1964. Letter from Robert Barjon to Guido Tagliaferri, December 8, 1965.

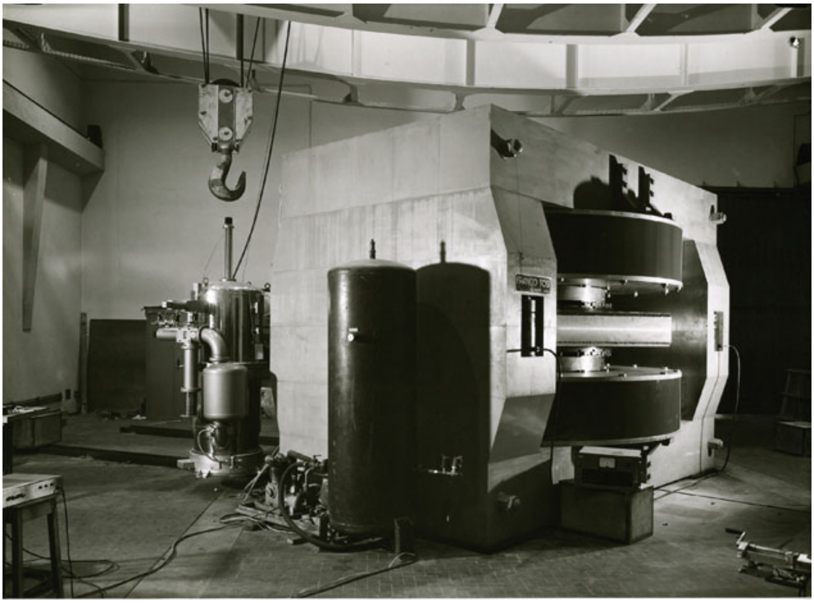

Fig. 8.1 The Milan relativistic cyclotron (Copyright: Milan University, BICF Library)

in azimuth. An AVF (Azimuthal Varying Field) cyclotron was thus a cyclotron with a magnet of the Thomas kind. If the magnets were made of a sequence of different sectors (the ridges and the valleys), made by joining various independent magnets, the cyclotron was part of the SSC (Separated Sectors Cyclotrons): the magnetic field in the ridges and valleys had a different average value, and the overall effect was a good beam focalization.

The project started in September 1960 with a very limited budget. In a first time, the budget was meant to cover the costs for making the preparatory plans. In January 1961 only two contributions had been obtained from two local industries: 5 million lire from Falck and 10 million lire from Montecatini.[12] In early 1961, the actual prosecution of the plans was still in doubt and the possibility to have the machine built by an industry, the German AEG, was taken into consideration. Steimel, head of the research laboratories of the AEG-Forschungs-Institut in Frankfurt, got the news that they were working on a cyclotron project in Milan. He informed Gilberto Bernardini that the AEG was working to build an isochronous relativistic cyclotron for the acceleration of deutons in Karlsruhe and offered to be a consultant for the Milan machine.[13] At the same time, Steimel's name was suggested to the Milan group by

[12] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Piero Caldirola to Furio Cicogna, President of Assolombarda, January 18, 1961.

[13] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Steimel to Gilberto Bernardini, January 25, 1961.

Helmut Neu of EURATOM.[14] Tagliaferri asked for information to Steimel about a possible AVF cyclotron to accelerate protons up to 50 MeV.[15] Steimel replied that the AEG would be in a position to build a 50 MeV proton cyclotron and deliver it to the Milan Institute. He gave a rough estimate of cost of 3.5–4 million German marks, with a delivery time of about three years.[16] After the INFN gave an extraordinary financing of 3 million lire,[17] Tagliaferri wrote to Edoardo Amaldi, at the time president of the INFN, to thank for the financing of the personnel, and let him know of his correspondence with AEG and the decision taken to continue with the original project:

> The information obtained [...] encourages me to continue along the path taken; that is to build the machine in Italy. In fact: (1) the AEG machine for deuterons is not yet functional, indeed the magnetic field measurements have not yet begun; (2) however, and it was obvious, the experience acquired with a deuteron machine is not entirely transferable to a proton machine, for which the fulfillment of the isochronism condition is more complicated; and (3) the cost of the AEG machine would approximately 40% exceed the cost of our project.[18]

In spring 1961, thanks to Polvani's interest, consistent funds were promised by four institutions: the CNR 10 million lire for the 1960/61 financial year, the Minister of Public Instruction 100 million lire, the Lombard Industrial Association (Assolombarda) 100 million, and the INFN offered to cover part of the personnel costs. However these were just promises. In any case, Tagliaferri could prepare the following scientific and financial note.

> For the development of a program in the field of low energies it is considered convenient to create a small synchrocyclotron for the acceleration of protons, deutons and alpha particles at energies ranging between 10 and 40 MeV, in the case of p and d, and of about 10 and 80 MeV in the case of α. A machine of this kind, built with extremely versatile characteristics, would lend itself to development in many fields of research and teaching activities. Since the time necessary for its realization can reasonably be considered to be 2 1/2 – 3 years, it is not easy today to foresee in detail the specific research problems that may develop at the date of its entry into operation.
> However, observing the scarcity of data relating to research carried out in the energy range between 20 and 40 MeV, it can be expected that researches relating to the following problems will still be interesting:
> a) Activity with non-polarized particles:
> 1) Study of scattering reactions;
> 2) Measurements of cross sections for different reactions;
> 3) Study of nuclear structures;
> 4) Measurements of the degree of polarization of the particles emitted in nuclear reactions;

[14] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Helmut Neu to Carlo Succi, February 6, 1961.

[15] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Steimel, February 10, 1961.

[16] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Steimel to Guido Tagliaferri, February 23, 1961.

[17] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from the President of INFN (Edoardo Amaldi) to Giuseppe Occhialini, February 17, 1961.

[18] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Edoardo Amaldi, February 27, 1961.

5) Scattering on resonant levels and measurement of polarization degrees.
b) Activity with polarized particles:
1) Measurements of cross sections in scattering reactions (p-p) at various energies and various angles, and comparison with the corresponding sections for scattering reactions (p-p);
2) Measurements of cross sections in reactions (p-A) and comparison with the corresponding sections (p-A);
3) Measurements of the degree of polarization of the particles emitted in reactions induced with polarized protons and comparison with those of the particles emitted in reactions induced by non-polarized protons at the same energies;
4) Study of nuclear levels and structures and in particular analysis with the shell model and the optical model;
5) Measurement of the polarizing and depolarizing power of nuclei and determination of the Wolfenstein parameters;
6) Experiences on time reversal and on the preservation of parity in strong interactions (if still topical).
c) Didactic activities:
1) Exercises in the use of an accelerating machine;
2) Activation of tags and development of calibration methods for radioactive samples;
3) High level exercises of neutron measurements;
4) collaborations with other institutes (radiology, occupational medicine, geology, etc.).

Approximate characteristics of the required synchrocyclotron (on which the cost estimates are based).
- Maximum energy for protons: 40 MeV
- Maximum flux of protons: 10 microamps; extractable beam
- Air gap 18 cm
- Induction: possibly 71.5 Weber / m^2
- Total weight 120 tons.
- Very low impedance windings (20 turns);
- Air cooling
- Power supply: 12 volt homopolar dynamo, 30,000 amps.
- Absorbed power 80 KW
- Vacuum in the acceleration chamber: better than 10^{-6} torr.
- Pumping group: suction speed 13,000 l / s
- Modulated radio frequency: 10 KW, peak voltage 20,000 volts (possibly increasing).

Personnel to be employed: May 1, 1960 – September 1961
Project study:
N. 1 elderly physicist (at least l.d.)
N. 1 physicist 4-5 years of seniority
N. 2 physicists 1-2 years of degree
N. 1 electrical engineer 3-4 years of seniority
N. 2 electromechanical experts and designers
October 1961 – December 31, 1962
Project realization:
The same staff as before increased by 4 technical workers (two mechanics and two electricians).

Construction time forecast:
May 1 - September 30, 1960 - Magnet and power supply assembly design. Study of the arrangement of the equipment and design of the building.
October 1 - December 31, 1960 - acceleration chamber and vacuum system project.

January 1 - May 31, 1961 - radio frequency project; study of trajectories and problems related to beam extraction
June 1 - September 30, 1961 - study of accessory parts: control unit, detector source, plates, development of methods for measuring magnetic fields
October 1 - January 31, 1962 - assembly of the magnet and acceleration chamber
February 1 - April 30, 1962 - magnet setup
May 1s- July 31 - assembly of the vacuum system and radio frequency installations
August 1 - 31 December 31, 1962 - injection tests and beam search.

Expense forecasts:
1960: Personnel expenses (6 months) l. 8 million
Travel expenses and consultancy and documentation l. 3 million
Advances for various commissions and contracts l. 20 million
Total l. 31 million

1961: Personal expenses (12 months) l. 15 million
Travel and consulting l. 2 millions
Magnet advance payment l. 20 million
Homopolar dynamo and plant l. 20 million
General commands l. 10 million
Radio frequency advance payment l. 10 million
Vacuum system advance payment l. 5 million
Measuring and miscellaneous equipment l. 5 million
total l. 87 million

1962: personal expenses l. 20 million
Travel and consulting l. 1 million
Radio frequency budget l. 20 million
Vacuum system budget 10 million lire
Magnet budget l. 40 million
Various equipment l. 10 million
Various operations l. 5 million
Total l. 106 million

1963: personal expenses: l. 15 million
Research equipment l. 15 million
Exercise l. 12 million
Total l. 42 million

Summary of total expenses:
Personnel expenses and consultancy l. 64 million
Expenses for the Machine l. 155,000,000
Various equipment and operation l. 47,000,000
Total l. 266,000,000

To the previous total expenditure must be added the expenditure of l. 50,000,000 for the building, lifting equipment and screens. Funds for this expenditure could be found locally.[19]

[19] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Explanatory note on the precedents and on the situation of the cyclotron of the University of Milan. April 28, 1961.

Neither the time table nor the cost plans could be respected as advanced by Tagliaferri. In particular, recurrent difficulties in getting the promised funds caused a delay in the machine making. Soon after Tagliaferri's plan, they definitely decided to work on a cyclotron and not on a synchrocyltron after having valued its convenience and feasibility. The direction of the works was entrusted to Guido Tagliaferri, assisted by Carlo Succi. Other people working at the project were Emilio Acerbi, Francesco Resmini, G. Pavanati and Alfredo Luccio. Giovanni Polvani was in a first time contact person for the industrial and political actors.

The constructive design of the cyclotron magnet and its power supply was defined in all its details. This definition was also reached on the basis of tests on a model of the magnet, specially built, on a scale of 1:6. The construction of the cyclotron magnet (diameter of the poles: 165 cm) was commissioned to the industry, and the delivery of the parts was foreseen for the first months of 1962.[20] The experimental study of the characteristics of the Dee's and of the radio-frequency line began, by means of a 1:1 scale model. The construction of the building that would have housed the cyclotron was underway, with the expected completion of the wall by 1961. To carry out the research program with the cyclotron, it was also necessary to be able to accelerate polarized protons. The problem of polarizing atomic hydrogen had already been posed by some of the members of the cyclotron group who had worked at the Ispra Center. The equipment prepared there was subsequently given by CNEN to the Milan division of the INFN, at the latter's request, to be used in the study of a source of polarized particles to be used for the cyclotron. The parts received from Ispra were completed and assembled in Milan before June 1961, and production and detection tests of the atomic hydrogen beam were underway.

A total of 49.5 million lire had been collected in the meanwhile: 35 million lire from Assolombarda, 10 million lire from the CNR, 2.5 million lire from the INFN, and 2 million lire from a private donator. The 10 million lire from the CNR had to be spent as such: 7 million lire to buy instruments; 3 million lire for people and other material, for measurements of cross sections and study of nuclear reactions with different targets.[21] The request to the INFN of further 5 million lire was rejected by the Board session of May 25. This fact saddened Tagliaferri who was then puzzled about the role played by INFN:

> From the INFN I notice a disconcerting alternation of approvals and exclusions with regard to the cyclotron activity. It is comforting, if nothing else, that the approvals were on a scientific level (with the exception of Bernardini's reprimand in Rome on 31.1.961); the exclusions on the financial level: or rather, of a very modest finance. On the other hand, the machine is now under construction, and the staff who work there are almost all of the INFN. The logic of the principle according to which this group should be excluded from any distribution of money escapes me: a logic that resembles that with which certain Faculty councils accept conventioned chairs but stipulate not to give them neither assistants nor endowments. May I mention that we already had the case of Wilson's chambers in the division? In short, I insist

[20] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Report of the cyclotron group, June 5, 1961.

[21] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Giovanni Polvani to Guido Tagliaferri, November 23, 1961.

> in my request for funding, at least for an amount no less than that given in 60/61: 2.5 million lire.[22]

A new situation had to be faced. The 100 million lire that Assolombarda had offered to find from Milan industries and institutions were not requested by them. Assolombarda informed the Institute of Physical Sciences that they preferred not to deal with the matter. It was therefore necessary and urgent to fill the gap of 100 million lire.[23]

By the end of 1961, they proposed to use to the contribution of 100 million lire, promised by the Ministry of Public Education[24] in this way: 91 million lire for the purchase of a short wave generator of 100 kW, produced by Marconi Italiana, type AD 312 (complete with a frequency counter type TF 1345, with amplifier type TM 5950 and converter type TM 5951), and 9 million lire for the installation and commissioning of the aforementioned generator, including safety automatisms, electrical screens and remote controls.[25] On January 15, 1962, the Ministry ordered the payment of 50 million lire as the first share of the contribution granted for the construction and installation of the cyclotron.[26] The financial support as for 1962 was therefore as follows: from the CNR 10 million lire (1960/61) and 10 million lire (1961/62); from Assolombarda 35 million lire (1960/61) and 50 million lire (1961/62); from the INFN 2.5 million lire (1960/61) and 3.278 million lire (1961/62); from the Ministry of Public Education 50 million lire (1961/62); from the CNEN 13 million lire (1960/61); for a total of 148.278 million lire.[27]

The aforementioned scale model of the cyclotron is currently preserved at the National Museum of Science and Technology "Leonardo da Vinci" in Milan. They made the model to study the optimal and most economical shape of the electromagnets. In particular, they used the model to develop a polar profile correction method, to establish focalization properties of the field, and to find the actual size of the expansions of the real electromagnet. The general structure of the model was designed to be as similar as possible to the final machine in order to study also the difficulties they might expect to meet when assembling the cyclotron components.

The polar diameter of the model electromagnet (Fig. 8.2) was 31 cm long, and its excitation consisted of two coils, fixed to the crosspieces, each wound with 840 turns of enameled copper strip with a $2 \times 6\,\text{mm}^2$ section. Each coil was made up of 14 wafers of 60 turns each; between the wafers, coupled two by two, there were interposed annular-shaped copper plates, cooled with water circulation along the

[22] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Giuseppe Occhialini, June 14, 1961.

[23] Milan University, BICF Library, Polvani Papers 10, 1: 2.6 Gruppo Ciclotrone. Letter from Piero Caldirola to the Rector: Reminder on the funding situation for the Cyclotron. August 28, 1961.

[24] General Direction for Higher Education, note n. 5033 Div. III pos. 27, July 19, 1960.

[25] Milan University, BICF Library, Polvani Papers 10, 1: 2.6 Gruppo Ciclotrone. Reminder, December 2, 1961.

[26] Milan University, BICF Library, Polvani Papers 10, 1: 2.6 Gruppo Ciclotrone. Letter from the Rector Mario Cattabeni to Piero Caldirola, January 24, 1962.

[27] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to A. Carrelli, May 30, 1962.

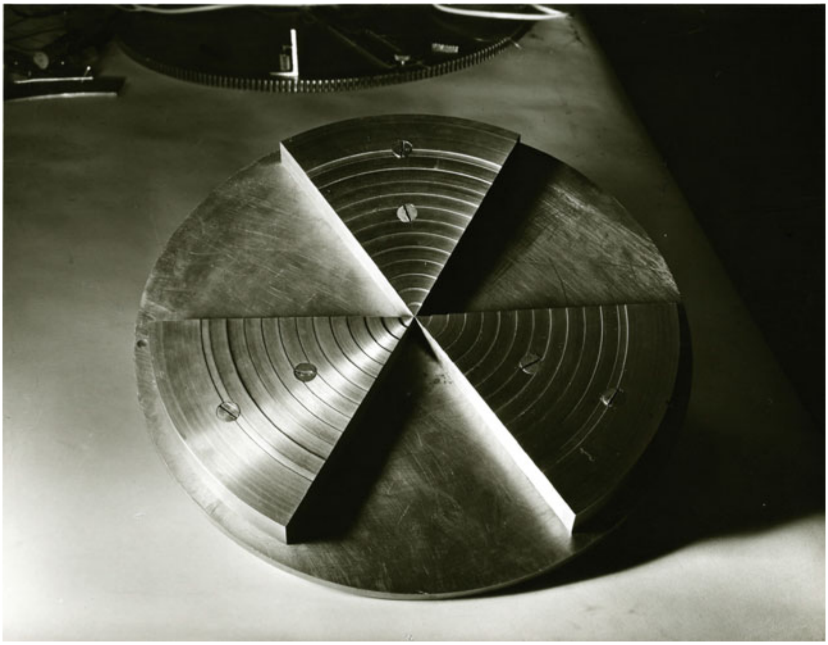

Fig. 8.2 Model of the Azimuthal variable magnet for the relativistic cyclotron (Copyright: Milan University, BICF Library)

internal and external contours. The whole was tightened by two flat rings of duralumin held by stainless steel tie rods.

The electromagnet model was powered by a rotating unit with a 10 kW maximum power and a 220 V voltage. This model proved to be fundamental for studying the behavior of the cyclotron and determining the economic choices suitable for making the actual cyclotron. In particular it was useful to determine the azimuth magnetic field and the winding system with good precision. To meet the need to accelerate not only protons, but other particles (in particular α-rays), the designers devised how to intervene on the electromagnet so that only the parts of the poles facing the air gap could be changed.

The shape of the magnetic field of an Azimuthal Varying Field cyclotron must satisfy the isochronism condition and ensure the vertical and horizontal stability of the particles orbit. The shape of the magnetic field is expectedly more complicated than the simple magnetic field applied to a normal cyclotron.

In the spring of 1962, Carlo Salvetti proposed to the Secretary General of the CNEN, Felice Ippolito, the worrying situation of the cyclotron in Milan, whose construction—at the time advanced and fully satisfactory on a scientific and technical level—risked having to be suspended. Once again Ippolito opted that the CNEN could not intervene directly. The President and the Board of Directors of INFN were informed on June 23, 1962 of the extremely precarious situation in which the Milan cyclotron was. The opinion expressed several times by the INFN was however that of not being able, with the limited budget at its disposal, to substantially help the cyclotron in Milan.[28]

The missing funds caused to slow down the building of the machine in mid 1962. On June 7, Tagliaferri had to make the decision to suspend any further supply orders. The cyclotron account was already without coverage for orders issued in the previous months.

> The practical consequence of this decision is that from today the delay with respect to the estimate of the realization times begins. The work of building the cyclotron is continuing regularly for now, aided by the fact that the staff employed are not affected by financial difficulties, being paid, in full if technical and partially if researcher, by the Milan Section of the INFN. But, barring immediate interventions, a progressive decrease in activity is to be expected, up to a complete stop within 4 or 5 months.[29]

A reason for the delay was the fact that the Municipal and Provincial Administrations of Milan had lapsed, and their reconstitution after the elections took a long time. There was also the change in the presidency of Assolombarda, and the refusal of the new president (E. Dubini) to head the funding consortium proposed by the old (F. Cicogna) to collect both public and private Milan grants. In August 1961, Tagliaferri had already exposed the situation to the Rector, who was also the head of the Christian Democrat council group in the Municipality; but the Rector preferred not to intervene. In October 1961, Tagliaferri visited the deputy mayor and councilor of public education, the hon. Meda. He had a good reception, but nothing followed. Subsequent letters to both the Mayor of Milan and the Presidents of the Province and the Cassa di Risparmio did not receive an answer. Tagliaferri noted that in the records of Polvani's negotiations he could not find any written commitments or promises from any of the Milanese private or public entities.[30] Eventually, Tagliaferri wrote to Polvani asking for financial help from the CNR:

> Through vicissitudes that are known to you, the financing plan of this project has been interrupted; and attempts to reconnect them, even if they are successful, will not have tangible results until several months from now. Instead, the construction of the cyclotron has so far taken place in full compliance with the budget of the times, and we are about to begin the assembly of the large electromagnet. But, unless we receive timely financial help, we will not be able to put the electromagnet into operation, much less carry out the long series of measures and adjustments necessary for its development. I do not think it is necessary to explain to you what deplorable consequences an interruption of the works would have at this point. Allow me to hope that this extreme will not be reached when, let it be said without modesty, many foreign laboratories envy us the speed and economy of our entirely Italian realization. I therefore ask you to consider, Mr. President, the possibility of granting an

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[28] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from an unsigned sender to the hon. Colleoni, June 26, 1962.

[29] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Giovanni Polvani, Piero Caldirola, Giuseppe Occhialini and Carlo Salvetti, June 7, 1962.

[30] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Giuseppe Occhialini, June 28, 1962.

> urgent and extraordinary grant to the Milan cyclotron, not attributable to the budget of the Physics Committee, which is already overwhelmed with requests.[31]

Polvani wrote to the Ministry of Public Education about this financial problem. He highlighted the fact that in the course of the construction of the cyclotron, certain circumstances occurred which entailed an increase in the necessary expenditure. The continuous increase in industrial costs, an increase which on average was not less than 10% per year, and the fact that they changed the classification of the device from synchrocyclotron to cyclotron in order to stay on par with world scientific progress. The main consequence of the technical improvements was the increase, by a factor of about 100, of the intensity of the protons accelerated by the machine. It was therefore necessary to increase the radio-frequency power used in the machine, which entailed an increase of about 30 million lire in the cost of the radio-frequency generator. Polvani concluded that an additional funding of no less than 60 million lire was needed, half of which to meet the cost increase, and the other to increase the power of the radio-frequency generator.

> It would be really a pity that this beautiful machine – one of the most modern and rare in the world, which is a bit of my farewell gift to the Institute that had me director for 33 years, absorbing practically my whole life of scholar – became less efficient than it could if that sum were available to it, and – worse than ever – were to remain incomplete.[32]

In 1962, the electromagnet was built at Officine Franco Tosi in Legnano.[33] They made a composite structure to simplify the problems concerning the preparation of the materials, and the transport and installation of the magnet in Milan. At the same time, a composite structure required a more in-depth study of any technical problem. It weighed 200 t. It was designed according to the classic double-C structure with two cylindrical poles. In Legnano they tested the assembly of the magnet and measured the errors. The electromagnet was assembled in the cyclotron shed between January and April 1963. The horizontal base was constructed with a quite good error of less than 20 μm/m. The maximum error on parallelism measured along the outer edge of the polar expansions was 50 μm and the deviation from the polar axis was 40 μm.

The electromagnet excitation windings consisted of two coils of 594 turns each, formed by copper pipes with a $16 \times 24\,\text{mm}^2$ rectangular section, insulated by four layers of 0.6 mm thick paper and four other layers of Montivel[34] 0.3 mm thick. The coils were made at Pirelli in Cusano Milanino. 5300 h work were required to make them.

The winding of each coil was carried out by overlapping eighteen wafers, each with 33 turns, about 250 m long. They built in total 46 wafers were built, and used

[31] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Giovanni Polvani, July 11, 1962.

[32] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Giovanni Polvani to the Ministry of Public Education, July 31, 1962.

[33] Technical details on the cyclotron during its building are in: [1–5].

[34] Montivel is a plastic film made of a saturated polyester resin prepared with terephthalic acid and ethylene glycol.

36 of them. The electrical resistance of each coil was 0.325 Ω, and the weight was about 15 t. The copper components weighed 11.8 t, the remaining 3.2 t were of steel, aluminum and insulating material, about 450 kg of paper, 300 kg of Montivel, 500 kg of heavy paper and 100 kg of bakelite cloth. In order to transport the wafers, they used a low-floor wagon, pulled by animal locomotion to save costs. The final construction of the coils took place entirely at the Institute of Physical Sciences and lasted about six months.

The excitation of the electromagnet was obtained by means of a 200 kW rotating converter unit which delivered a maximum current of 500 A. The excitation current of the main magnet was given by an auxiliary rotating unit stabilized through transistor electronic circuits.

Demineralized water was used to cool the coils. It was put into circulation by a stainless steel pump with a 3.5 atm pressure and about 1 kW power. The water was cooled by means of a heat exchanger with stainless steel blades and 0.1 m^3 volume. The secondary water was taken from a well, with a 15 m^3/h flow. The input temperature was between 15 and 17 °C. The output temperature was kept below 45 °C to have a 100 kW dissipation. The primary water passed from the pump to the container, from which eighteen nylon-reinforced PVC pipes departed, which carried the water to the coils. The outgoing water flowed through another eighteen PVC pipes to a second container, from which it then returned to the pump. The circulation of water was monitored by a flow sensor. The input and output temperature of each pair of wafers was controlled through thermal switches. Any overheating was signaled acoustically, causing the electromagnet to be automatically de-energized. Eight pairs of corrective coils were also made, in order to obtain the field isochronism at each beam.

The protons source [6–8] was a small chamber into which they introduced hydrogen. An incandescent filament emitted electrons which were attracted by a positive voltage plate and ionized the hydrogen gas to make it almost a plasma, thus creating protons and negative hydrogen ions (i.e. with two electrons and one proton). The ratio of protons to negative hydrogen ions was about 1/100.

A slot in the small chamber faced the Dee, which was subject to an alternate positive and negative tension. In this way both the protons and negative hydrogen ions were extracted and accelerated in opposite directions. A puller was used to stop one of the two beams. In a first time, they accelerated only protons with the cyclotron, but soon they preferred to accelerate the negative hydrogen ions. The latter had a much smaller production ratio than the protons one (about 1/100) but, at the same time, could form a beam of particles with variable energy.

The Dee was the terminal element of a cantilevered structure, part of a quarter-wave resonant cavity. It was made by covering a duralumin frame with a copper sheet. The radio-frequency generator, which supplied the accelerating voltage to the accelerating electrode, was built by Società Marconi Italiana. It absorbed a power of 250 kW, delivered a maximum radio frequency power of 120 kW and could be tuned to any frequency between 6 and 30 MHz. The accelerating voltage that was planned to be used between the Dee and the fake or dummy Dee was 70 kV. The working voltage actually used was around 40 kV.

The Dee's mouth was 162 cm wide and 36 mm high, except in the central part where for about 20 cm it reached 60 cm. At a distance of 40 cm from the Dee's mouth was the dummy Dee, placed on the ground. This solution was adopted also in other cyclotrons. It was advantageous during the extraction, to the detriment of a loss of power and of final kinetic energy of the particles.

The transfer of energy from the generator to the cavity was obtained by means of a "bal-un" type impedance transformer, which adapted the generator impedance to that of the cavity. The realization of the radio-frequency generator was preceded by feasibility studies on two resonant cavity models in 1:1 scale.

The last installment of the assignment of 100 million lire, which Polvani obtained from the Ministry of Public Education arrived in March 1963.[35] 93 million lire were still lacking from the obtained funds: 33 million from the Province of Milan, 34 million from Cassa di Risparmio, 26 million from Assolombarda.[36] Tagliaferri wrote to senator Cesare Merzagora begging to plead their cause with his authority to anyone, organization or person, who could help them. Actually the construction of the cyclotron had advanced to the point that the machine could be put into operation in the first half of 1964. Having to stop it would have constituted a very considerable damage, not only on the material level, but even more so in terms of the repercussions in the scientific community of a failure due solely to financial reasons.[37] Polvani succeeded in getting further 19 million lire from the Ministry of Public Education[38] and the Province of Milan eventually decided to grant them a contribution of 18 million lire, 15 million less than requested.[39]

In 1964, Tagliaferri submitted to Polvani's consideration the possibility that the cyclotron could become an asset acquisition of the CNR, since, in the years from 1960/61 to 1964, they had subsidized for a total of about 57 million.[40] This money was mostly used for the cyclotron itself, so that certain inventoried components (e.g. the 200 kW generator for the magnet; the pumps) were actually owned by the CNR. With an adequate and timely administration of further funds, the CNR could become the owner of the cyclotron. Tagliaferri believed that it would have been a significant asset acquisition, and of a real intrinsic value much higher than the expenditure possibly incurred. The operation was made possible by the fact that the purchase of the raw materials used in the construction of the magnet, the vacuum chamber, etc., did not involve inventarial inscriptions; and consequently the finished machine would

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[35] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 Gruppo ciclotrone. Letter from Guido Tagliaferri to Giovanni Polvani. March 4, 1963.

[36] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to the Province of Milan, May 8, 1963.

[37] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Cesare Merzagora, November 3, 1963.

[38] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 Gruppo ciclotrone. Letter from Giovanni Polvani to Guido Tagliaferri. November 25, 1963.

[39] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 Gruppo ciclotrone. Letter from Guido Tagliaferri to Giovanni Polvani. November 27, 1963.

[40] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone. Letter from Guido Tagliaferri to Giovanni Polvani, June 10, 1964.

have gone to the inventories of that entity that has paid the invoices for materials and work.

However new funds were granted for the next financial year: 18 million lire from the Ministry of Public Education for the payment of an installment for the 120 kW radio-frequency generator, 26 million lire from the EURATOM on the low energy contract for the transport of the external beam, further possible 80 million from EURATOM for the transport of the external beam and for researches. A new financial supporto of 60 million lire was approved for 1965 by the INFN.[41]

The experiments with the cyclotron began on 19 January 1965 [9, 10].[42] A proton beam was visibly identified on a quartz sample at a short distance from the ion source. The beam could be viewed externally up to a distance of about 70 cm, corresponding to an excess energy of 40 MeV. The start up was quite fast. The azimuth modulation of the magnetic field was produced by three pairs of straight Thomas sectors at 60° without harmonic coils. The poles were shaped so as to give a field within 0.03% of the one required for the isochronous acceleration of 45 MeV protons, without the need for corrections on the coils. The little number of variables to be controlled let them achieve more easily the essential conditions for operations. The low power required for the operations put a limit to the operating costs.

In the next days, they verified these results by the use of three copper samples to collect beam currents at different azimuth positions around the cyclotron. The evidence was therefore consistent with the purpose of the tests, i.e. to accelerate protons up to an energy of 45 ± 1 MeV. The energy value was deduced from the characteristics of the orbit and of the magnetic field. The operative working conditions of the cyclotron were: central magnetic field 13,470 gauss; magnet power 60 kW; resonance frequency 20510 kHz; radio-frequency voltage peak of the Dee: 50 kV; radio-frequency power output supply: 40 kW; residual pressure of the empty tank: 2×10^{-6} Torr. The cyclotron operated at low intensity to avoid any danger from contamination and radiation: they usually kept the beam current at 0.1 μA. The beam current was seldom raised above 1 μA.

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[41] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 CNR: Relativamente al ciclotrone: Letter from the INFN to Guido Tagliaferri, January 25, 1965.

[42] Telegrams and letters of congratulations testify the utmost consideration with which the Milan cyclotron was considered in Italy and abroad. Milan University, BICF Library, Polvani Papers 10, 1: 2.6 Gruppo ciclotrone. Telegram from Edoardo Amaldi, Marcello Conversi and Giorgio Salvini, January 25, 1965. Telegram from Giovanni Polvani, January 26, 1965. Letter from the rector Mario Cattabeni, January 27, 1965. Letter from Giuseppe Schiavinato, January 27, 1965. Two telegrams from Michelangelo Merlin, January 28 and 29, 1965. Letter from the senator Carlo Arnaudi (Ministry for the Coordination of Scientific and Technological Research), February 1, 1965. Letter from the Institute of Physical Sciences of Genoa University, February 4, 1965. Letter from the Institute of Physical Sciences of Padua University, February 4, 1965. Telegram from Giulio Cortini, Ruggero Querzoli, Eduardo Caianiello, Ettore Pancini and Bruno Vitale, February 5, 1965. Letter from John David Lawson (Rutherford High Energy Laboratory), February 8, 1965. Letter from Italo Federico Quercia, February 8, 1965. Letter from Hendrik Brinkman (Groningen University), February 10, 1965. Letter from Emilio Segré, February 11, 1965. Letter from André Cabrespine (Institut du Radium), February 11, 1965. Letter from Elmer L. Kelly (University of California), February 15, 1965. Letter from William C. Parkinson (University of Michigan), February 18, 1965.

The space at disposal for experimental activities was quite limited in the first period of activity. Two main paths were prepared: one for the beam to be analyzed, and the other for the normal beam. The beam was channeled through quadrupole magnets towards the experimental chambers. Protection from radiation problems was guaranteed by the fact that the cyclotron and the experimental chambers were in rooms with concrete walls. In this first period, the equipment for transporting the beam and the experimental area were located in a very small space, 9 m from the cyclotron. Around 1972, new experimental areas came into operation and the functionality of the cyclotron was improved.

In a first time, they extracted the protons by means of an electrostatic extractor at the end of their orbit, with a fixed value of energy dependent on the number of accelerating steps. This method was soon abandoned because it was impossible to extract particles with different values of energy. Furthermore the electrostatic extractor posed some serious operating problems.

They decided then to try the stripping extraction. They accelerated the negative hydrogen ions, which then hit an aluminum target that could be moved along the plane of the orbit of the particles. There the hydrogen ions were stripped of the two electrons, producing free protons that were able go through the plate. Because of their positive electric charge, the protons reversed the direction of rotation, could escape from one of the dummy Dee's being channeled towards the experimental apparatus outside the cyclotron. The energy of the extracted protons depended on the radius of the orbit to which the stripping was carried out. The energy of the extracted protons could be varied by moving the aluminium target.

A synthetic description of the researches made in the first year of activity of the cyclotron can be found in a funding request that Piero Caldirola wrote to the president of the National Agency for Electric Energy in 1967:

> In the hope that ENEL intends, as in the past, to continue its meritorious work in aid of the scientific research carried out at this Institute of Physical Sciences, I would like to ask this same institution for a new contribution to be used in these two research sectors:
> a) contribution for the purchase of the electronic spin resonance instrumentation: L 8,000,000.
> b) completion of the instrumentation for radio-frequency plasmas: 2,000,000 Lire. instrumentation for diffusion plasmas L. 3,000,000.
>
> Attachment A
> Research with the Milan cyclotron
> A) The 45 MeV cyclotron of Milan University currently provides an external proton beam of 1 μA of intensity, obtained by electron stripping from H^{--} ions accelerated to the final energy.
> The beam is currently used for three types of searches:
> a) nuclear research: the cross sections of type reactions (p, p), (p, d), (p, α) are measured on nuclei of low and medium atomic weight (of type c, Ca, Al, Mg, Fe, etc);
> b) atomic research: we measure cross sections of electron capture in flight by high energy protons in gas (H_2, He, N_2, O_2, A etc.) and in solid materials;
> c) condensed states: the effects of the lattice structure of crystals on highly collimated proton beams are studied; these effects essentially consist of: 1) variations in the loss of energy undergone by the protons that cross the lattice, impacting parallel to the crystalline axes; 2) angular distributions of the scattered beam which can differ considerably from those obtainable on amorphous materials and foreseen by the normal theories of "scattering"; 3)

emission of particles from the crystal surfaces according to privileged directions correlated to the symmetry axes of the crystal.
B) Within the next month of May the cyclotron will be completed with the assembly of the electrostatic deflector of the beam: in this way it will be possible to obtain an external beam of 45 MeV protons of some tens of microamps of intensity. Interesting experiments in the field of radiation chemistry and the treatment of materials with radiation will therefore be feasible. We will then proceed with the development of the He source to obtain an internal He^3 beam of some μA and an energy between 30 and 40 MeV.
C) Once the external beam of high intensity protons has been obtained, part of the machine time will be devolved to applicative research. In particular, we want to acquire the possibility for the laboratory to carry out research on the treatment of materials with radiation.
Topics of study will be:
a) variations in the electrical resistivity coefficient of different materials during bombardment with protons of variable energy.
b) Changes in the F.N.M. of thermoelectric pairs treated with fast neutrons and protons.
c) variations of the Hall coefficient in semiconductor single crystals during the production of defects induced with protons of different energy.
d) influence on the Young's modulus of elastic materials of interstitial defects and vacancies produced with protons of variable energy.
e) analysis of the evolution of the damage produced by radiation in transparent single crystals by means of the Brillouin scattering technique.
f) Influence of damage induced by protons and neutrons on piezoelectricity.
D) We believe it is not inappropriate to underline the importance of the researches mentioned in point C) made possible by the presence in Milan of a machine such as the cyclotron. However, it should be remembered that the theoretical and practical importance of the results that can be achieved will not be separated from the consistency of the means of investigation that will be made available to researchers who are about to operate in this sector.
Although not as demanding as those necessary in certain fields of fundamental physics, these means are difficult to find through the normal ways of financing pure research: economic aid from other sources, more closely interested in thermological research, are indispensable for development. initial of this activity and are highly desired.
In the specific case of the researches cited in C), the basic instrumentation, which would allow to enormously extend the field of these researches, consists mainly of:
1) helium liquefactor for reaching temperatures close to absolute zero. The cost of this equipment is around 40 million lire.
2) instrumentation for the analysis with electronic spin resonance: the cost is around 8 million lire.
3) Mass spectrometer for the analysis of quasi-reaction products, the amount of which is around 20 million.
With this basic instrumentation, the cyclotron laboratory would reach a level comparable to that of similar laboratories in other technologically more advanced nations.[43]

The cyclotron was used for applied research in different fields between 1970 and 1975. The main researches concerned: (1) Nuclear chemistry: the study of the effects of radiation on chemical reactions; (2) Biology: the study of the biological effects of radiation on living tissues; (3) Medicine: the production of radioisotopes, in particular Pb and I isotopes, for diagnostic; (4) Industry: non-destructive analysis by means of nuclear activation with measurements of X-rays spectra excited by protons and α-rays; analysis of air or water samples to track traces of pollutants, e.g. metals

[43] Milan University. BICF Library. Polvani Papers 10, 1: 2.6 Gruppo ciclotrone. Letter from Piero Caldirola to the President of ENEL (Ente Nazionale per l'Energia Elettrica). April 3, 1967.

such as Pb. This method was efficient thanks to the availability of the new solid-state detectors, with a X-ray resolution of 150–250 eV. It was thus possible measure X-rays emission spectra with high precision and detect heavy materials, which could not be detected with the other methods at disposal.

In the early 1980s the cyclotron was dismantled when the construction of the superconducting cyclotron began at the LASA laboratories in Segrate. The original hangar was later converted to other laboratories.

8.3 Space Physics

The G-Stack Collaboration was the last impressive scientific enterprise in which the Milan group used nuclear emulsions to detect cosmic rays before the beginning of the accelerators era [11]. The exposition of emulsion stacks to an accelerator beam, as it happened with the K^--Collaboration, had at least two major advantages: (1) the temporization, i.e. the possibility to study the time dependence of some physical quantities; (2) the possibility to produce any kind of elementary particles, with the requested energy and momentum, within the technological limits of the accelerating machines.

The second half of the Fifties can be considered a transition period in Occhialini's group. The K^--collaboration—the exposition of a stack to artificially produced colliding beams of K^--mesons—was not only a renounce to cosmic rays as the primary source of elementary particles, but also the last great experiment by them with stacks of nuclear emulsions. Occhialini himself had a clear view of the future developments of this kind of research characterized by a exclusively electronic detection or by the use of new visualizing techniques, such as the bubble chamber, in international centers and facilities, such as the CERN [12].

In a letter to Bruno Rossi, written in 1960 about a summer school to be held by Bernard Peters in Varenna, Constance Dilworth expressed Occhialini's and her own preoccupation about the future of cosmic ray physics in Europe:

> I have seen Peters again in Geneva and he asked me to write to you about the Varenna school story. He is very anxious that the initiative he took in asking for a summer school on space in '61, and which he took before knowing you are organising one in '62, should not in any way conflict with your plains. In fact if you find that the school in '61 would spoil yours of '62, I think that he would give up the idea completely.
>
> The point of holding it in '61 was to help convince European Cosmic Ray physicists that there is a future for them in space there in Europe before they take off for the States. It was meant as an introduction to the subject, the lectures being mainly reviews of the present state of information, mainly given by European.[44]

The "future for them" had been offered by the launch of the Sputnik in September 1957. Bruno Rossi at the Massachusetts Institute of Technology began at once a series

[44] Milan University, BICF Library, Occhialini-Dilworth Papers, 7, 1, 7: Letter from C. Dilworth to Bruno Rossi, November 28, 1960.

of research activities in space physics[45] on the interplanetary plasma and cosmic γ-rays. Occhialini decided to spend a sabbatical year at the MIT as visiting professor to rise, once back to Milan, a group of space physics. The Milan group of nuclear emulsions was thus converted to the new space adventure by means of detectors on balloon and satellite,[46] in a close international collaboration with the French group in Saclay, while the bubble chamber group continued to work at the CERN.

The Milan group played a primary role in Italian space physics, together the groups in Bologna and Rome. Occhialini, together with Amaldi, Castagnoli and Puppi, was the actor of the passage of the Italian groups of cosmic ray physics from the INFN to the CNR with the constitution of the Italian Group of Cosmic Physics (GIFCO), which became a group of CNR laboratories in 1969. The GIFCO members were the Institute for the Technologies and Studies of Extraterrestrial Radiation (ITESRE) in Bologna, the Institute of Interplanetary Space Physics (IFSI) in Frascati, the Institute for the Research in Cosmic Physics and Relative Technologies (IFCTR) of the CNR in Milan, the CosmoGeofisica in Turin, and the sections in Florence and Palermo.

Occhialini was one of the founding fathers of the European institutions working in space physics.[47] The first steps were organized by the COPERS (COmité Preparatoire Européen pour la Recherche Spatiale—European Preparatory Committee for Space Research), a preparatory commission, based in Paris, established in 1961 by the countries involved in the planning of the ESRO (European Space Research Organisation), whose convention was in force since 20 March 1964 [15]. The ESRO was formed by ten European countries: Sweden, Denmark, the Federal Republic of Germany, the Netherlands, Belgium, the United Kingdom, France, Switzerland, Italy, and Spain. Austria and Norway did not join the ESRO but had an observer status.

Occhialini was one of the members of the ESRO Council and of its Scientific and Technical Committee, while Constance Dilworth was the chairperson of the Space Committee. The selection of the experiments to be flown followed an elaborate procedure: the Directorate of Programmes and Planning submitted to the Council, through its Scientific and Technical Committee, mission specifications and payload composition, and gathered the necessary scientific advice through the Launching Programmes Advisory Committee. Occhialini was the chairperson of the COS-Group (the Advice Committee for Cosmic Ray Physics) and a member of the restricted Launching Program Advisory Committee devoted to choose and define the European space missions that were organized following the "street-car principle" (each mission was a cluster of experiments advanced by the various scientific communities).

A first period of activity of the Milan group can be identified in 1960–65 [16] when they carried on some experiments on balloon and planned experiments on rocket which for the subsequent years. The Milan group was composed of people from both the Institute of Physical Sciences and the INFN. Occhialini was the leader, as full pro-

[45] Space science is not a single field of research; it can be considered as an "umbrella" covering different fields characterized by the use of space platforms [13].

[46] Milan University, BICF Library, Occhialini-Dilworth Papers, 7, 41, 2, 52, Report on the Cosmic Ray Group.

[47] On the history of European space physics in the period under consideration, see: [14].

fessor of Superior Physics, with collaborators such as John Bland (lecturer in Cosmic Physics), Giuliano Boella (lecturer in Nuclear Electronics), Giovanni Degli Antoni (lecturer in Information Theory), Constance Dilworth (professor of Radioactivity), Martina Panetti (lecturer in Physics for Geologists), Emanuele Quercigh (research fellow at CERN), Livio Scarsi (lecturer in Elementary Particle Physics) and Giorgio Sironi, and some graduated students who joined the group at different times, and the technicians Giuseppe Aloardi, Renato Ballerini, E. Bardeggia, Nino Dell'Era, E. Franchini, Aldo Igiuni, Piero Inzani, and E. Ronchi.

The research activities were funded both with wages and special funds given by the CNR, whose astrophysics committee financed researches on balloons and the development of instruments in the laboratory, the US Air Force, which financed part of the researches on albedo neutrons, and the National Space Committee, which financed the making of instruments on rocket and satellite.

The experiments on balloon, carried on in 1960–65, had the aim to study albedo neutrons, 1 GeV primary electrons, and to search for gamma-rays sources. At the same time, they planned experiments for rockets and satellites to measure the neutrons flux at intermediate latitudes, 50–600 MeV electrons, 100 MeV solar gamma rays, and to measure conjointly gamma rays and electrons. The first collaboration of the Milan group was with the French group of the Centre d'É tudes Atomiques of Saclay (Paris), directed by Jacques Labeyrie. The launched spark chambers (Occhialini thought they were the optimal instrument) on balloon.

The study of albedo neutrons[48] was carried on since 1960 in collaboration with the space physics group of the MIT (in particular with Shapiro) and with the US Air Force. The relevance of these studies consisted in the analysis of the contribution from the albedo neutrons to the Van Allen radiation belts and in the sensitive monitoring of small solar flares. The main results were the development of a neutron counters sensitive up to 20 MeV, the measurement of the neutrons flux and spectrum, and the study of the latitude effect.

The first neutron counter (Mk I), with enriched and natural boron, was made in 1960–61 already, while a second counter (Mk II), with enriched and depleted boron, was built in 1961–62. Both counters were flown on balloons launched from Linate (east of Milan, at 40 °N geomagnetic latitude) and measured the flux of cosmic neutrons. The second counter was also launched from New Mexico at a geomagnetic latitude similar to that of Linate, in 1962–63, to evaluate the extent to which albedo neutrons contribute to the formation of the Van Allen Belts. The instruments was calibrated in the group laboratory and was exposed to the thermal channel of the Reactor L-54 of CESNEF at Milan Polytechnic and to the thermal channel of a 1-Cu Ra-Be source of the Laboratory Agip Nucleare in San Donato. The efficiency of the instrument was determined with the standard Ra-α-Be source of the CISE. The results at the sea-level and those of the Italian and American flights [17] were presented at the International Conference on Cosmic Rays in Jaipur (India) in 1964

[48] Albedo neutrons are neutrons produced in the interaction of cosmic rays with the nuclei in high atmosphere and diffused upwards. They move towards the Van Allen belts. They decay beta and become a source of particles, which are accumulated in the Van Allen belts.

[18]. The sea-level (Milan) flux was measured on open ground during dry periods with and without a paraffin moderator, and with and without a 1 mm thick Cd sheet screen. They obtained a mean value for the flux of neutrons with $E < 0.4$ eV = $(3.2 \pm 0.6) \times 10^{-3}$ n/cm^2 s, and with $E > 0.4$ eV = $(4.2 \pm 1) \times 10^{-3}$ n/cm^2 s. The flights from Milan, with the permission and assistance of the officers and men of the Meteorological Service of the Italian Air Force, were made onboard of rubber balloons up to burst altitude on July 29 and September 16, 1962. The maximum counting rate was attained at (90 ± 15) g/cm^2 residual atmosphere, with a counting rate of (76 ± 4) count/min, corresponding to a flux of (3.0 ± 0.5) n/cm^2 s.

A third neutron counter (Mk III) was made in 1963–64 and launched from Kiruna (Sweden, at 65 °N geomagnetic latitude) in October 1964 in order to study neutron fluxes also at high latitudes and test the existence of a latitude effect. The Mk III counter was launched in 1964–65 also from Linate and from Aire-sur-l'Adour (France). In the same period, they also planned the Mk IV counter to launch on rocket for the measurement of high energy neutrons [19–22]. The work on the latitude effect on neutron albedo flux was sponsored by the Air Force Cambridge Research Laboratories through the European Office of Aerospace Research-United States Air Force and by the Italian Commission of the International Quiet Sun Year. They observed a steady increase of the latitude effect on the neutron flux with altitude. In general, the neutrons contributing to the increased flux intensity come from sources at higher altitude at higher latitude; in this way they suffer less moderation and their flux is more intense. In the particular case of albedo neutrons the increase was evident but less intense as predicted by Lingenfelter in 1963.

The study of primary cosmic electrons was in collaboration with the French group in Saclay (MiSa collaboration). This collaboration played a noteworthy role in the making and developing of spark chambers. The coupling of spark chambers with counters was studied for flight conditions on balloon and was used to measure the flux, spectrum and east-west effect of cosmic electron with energy larger than 4.5 GeV.

In a first time the Milan group focussed on the study of high energy primary electrons. In 1960–61 they started the preliminary tests on a counter-controlled spark chamber for flights on balloon (Mk I chamber). The chamber was made after the tests in 1961–62, and was calibrated both in Saclay and at CERN, and was completed in 1962–63. The spark chamber was a 17 cm high, 26 cm diameter, duraluminium cylinder with nine (10×10) cm plates of different thickness, separated by 1 cm gaps. The chamber was filled with a Ne-Ar gas mixture at 800 mm Hg pressure. The chamber had a memory time of 1 μs and was triggered by a 30 ns fast coincidence circuite between two plastic scintillators. In Saclay, the chamber was tested by exposing it to a beam of mostly π-mesons, and a small amount of μ-mesons and electrons produced by the protosynchrotron (Saturne) between 570 MeV/c and 1450 MeV/c. At the CERN protosynchrotron, they used a testing beam between 12 and 19 GeV/c. The average efficiency of spark formation permitted a good discrimination between electron showers and nuclear interactions for momenta above 1 GeV/c. The energy of a shower could be measured with a 15–30% error in the 0.5–8 GeV/c range. The functioning of this spark chamber was presented at the Colloque international sur l'éléctronique nucléaire in Paris in 1963. The flights of the MkI spark chamber were launched from Aire-sur-l'Adour (in Southern France, with a cutoff rigidity of 4.5 GV) on 5 November 1963 and permitted to measure the flux of high energy primary cosmic electrons [23]. The chamber flew at an altitude between 36 and 37 km for 37 min. On the assumption of a $kE^{-2.5}$ energy spectrum and a 3×10^{-6} gauss magnetic field, the measured electron intensity corresponded to a synchrotron emission of $(1.7 \pm 0.5) \times 10^{-40}$ erg cm^{-3} Hz^{-1} s^{-1} power at a frequency of 10^9 Hz, with a critical frequency corresponding to 4.5 GeV/c. The results of the measurements of these flights [24, 27] were also presented at the International Conference on Cosmic Rays in Jaipur [25] and at the 5th International Space Science Symposium in Florence in 1964 [26].

The flights to measure the east-west effect concerned more advanced models of the Mk I spark chamber: the Mk II spark chamber, which was the Mk I chamber with an added magnetometer, built in 1963–64, and the Mk III spark chamber, which was the Mk II chamber with a radio cut-off, built in 1964–65. The results of these flights [28–30] were presented during the IUPAP Conference on Cosmic Radiation held in London in 1965.

In 1963–64 they prepared the S79 project to study low energy primary electrons. They coupled a Čerenkov detector with a CsI scintillator. The device was calibrated at the CERN with an electron beam and in Saclay with electrons and protons beams.

The MiSa collaboration also planned the study of discreet gamma-ray sources. This work concerned a large spark chamber with thin plates coupled to a system of anticoincidence-coincidence counters for the measurement on balloon of gamma-ray sources with intensity greater than 5×10^{-6} g/cm^{2}s. This collaboration was extended to the Munich group (Mi-Mo-Sa) collaboration and later to the "Caravane" project (see below). The fundamental final result of the search for cosmic gamma-ray sources was the launch of the COS-B satellite in the 70's.

The Milan Institute of Physical Sciences with Occhialini's group was then involved in the organization of several space missions, among which we can shortly recall the HEOS A1, the TD1, the HEOS A2, and the COS-B.

The HEOS A1 was a mini-satellite built by Junkers-Werke in Munich. It was a cylindrically shaped satellite (1.30 m diameter, 0.75 m height, 104.5 kg weigh). It was launched from the Eastern Test Range, Florida, on a Thos Delta DSV3-E launcher, on December 5 1968, into a highly elliptical $424 \times 223, 428$ km orbit, with an inclination of 28°.28 and an orbital period of 4d 16h 19min. It penetrated interplanetary space to about 33 earth radii. It was operative for 16 months, then lost functionality and re-entered the atmosphere on 28 October 1975. Seven experiments were performed on-board. It was launched for the study of the interplanetary magnetic fields and of solar wind. The Milan and Saclay groups worked on the detection of primary cosmic ray electrons. They observed high energy electrons emitted during solar flare events, and the echo reflected from a distant border some days later.

The TD1 was a mini-satellite built by Estec (Fig. 8.3). It was a 2.11×4.5 m, 471 kg satellite. It was launched from the Thor-Delta launching pad of the Western Test Range, California, on a Delta-N launcher, on March 12, 1972, into an elliptical 545×533 km orbit, with an inclination of 98°.55, and orbital period of 97 min. It

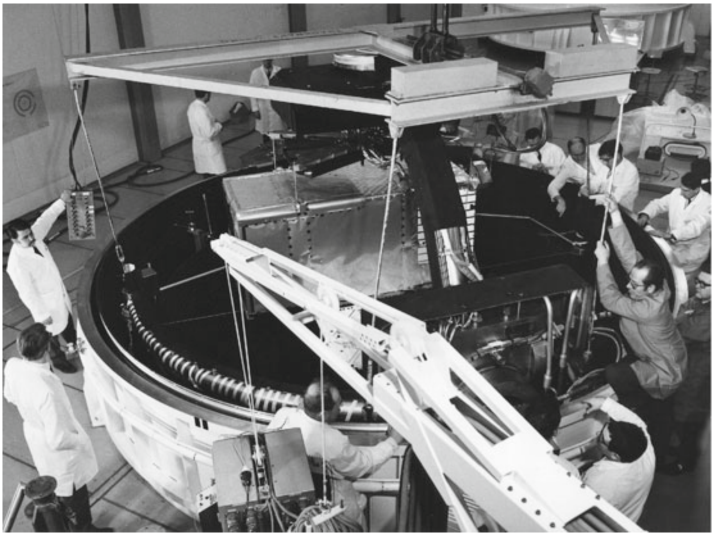

Fig. 8.3 The TD1 satellite thermal model (Copyright: Milan University, BICF Library)

was active since May 4, 1974, two years after the launch, and decayed on January 9, 1980. The satellite carried on board instrumentation to study UV, X and γ-rays, heavy nuclei in cosmic rays, and solar radiation. The Milan, Munich and Saclay groups measured celestial γ-rays with energy in the range 70–300 MeV [31, 32].

The HEOS A2 was a mini-satellite built by Estec. It was a cylindrically shaped (1.30 m diameter, 0.75 m height, 117 kg) satellite. It was launched from the Western Test Range, California, on a Thor Delta launcher, on January 31, 1972, into a highly elliptical $359 \times 238, 199$ km orbit, with an inclination of 89°.91, and an orbital period of 4d 18h. It re-entered the atmosphere on August 2, 1974. It was the first vehicle to penetrate into the area of the neutral point at the border of the Earth's magnetic field and that of interplanetary space. The Milan and Saclay groups carried on measurements on high-energy electrons.

After these first generation satellites, the ambitious COS-B ESRO project was planned by the Caravane collaboration formed by the Laboratory for Space Research (Leiden), the CNR Institute of Cosmic Physics and Informatics (Palermo), the Laboratory of Cosmic Physics and Related Technologies (Milan), the Max-Planck Institute for Extraterrestrial Physics (Munich-Garching), the CEN Service of Physical Electronics (Saclay), the ESRO Scientific Laboratory (Nordwijk).

The COS-B satellite was a 276.9 kg satellite. It was launched on a Delta 2913 launcher, on August 8, 1975, into a highly elliptical $442 \times 99,002$ km orbit, with an inclination of 90°.2. It failed on April 26, 1981. The COS-B satellite had on board the Gamma Ray Telescope which permitted to draw the first detailed γ-map of our Galaxy and to have a first catalogue of discrete γ-sources in the range of a few 100 MeV. In the same year of the COS-B launch, the ESRO and the ELDO (an industrial organization which planned European launchers) merged and gave birth to the European Space Agency [33]. The Milan Institute of Physical Sciences, with Occhialini and Dilworth, and their collaborator researchers, once considered all the work they did in the organization of the satellites launches and the analysis of the scientific data, can be therefore be considered in the due right one of the parents of the European Space Agency.

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