Ionization at the Origin of an Electron Pair of Very High Energy.

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Recently two papers appeared concerning ionization caused by electron pairs of very high energy near their origins. A. E. ČUDAKOV (1) estimated theoretically the reduction of ionization caused by an electron pair (as compared with ionization produced by two particles separately) on the length on which the separation between negaton and positon is smaller than the maximum value of the interaction radius for ionization. Assuming for this value $5\cdot10^{-7}$ cm and neglecting the influence of the relative scattering of the two particles A. E. ČUDAKOV obtained a formula from which follows that for energies of pairs of some 10^{11} eV we can expect measurable effects of reduction of ionization on distances of some hundreds microns. Quite independently from ČUDAKOV, D. H. PERKINS (2) following a suggestion of D. T. KING (1950) (*) made ionization measurements on a number of electron pair tracks with energies of $\sim 10^{11}$ eV. It follows from his measurements that for pairs of this order of magnitude this effect is measurable for distances $\lesssim 100\,\mu$m from the origin of the pair. In consequence of poor statistics on such length it was only possible to measure this effect as a mean effect for several pairs. PERKINS has performed these measurements for 7 pairs.

The aim of this letter is to report measurements of ionization on a single pair of energy probably higher than the pairs of PERKINS. The pair under discussion is the beginning of a large electron-photon cascade which at the distance of ~ 2.5 cascade units contains ~ 70 tracks of electrons of energies higher than 10^8 eV, from what we get roughly for the energy of the first pair some 10^{11} eV (3). On a length of 9540 μm the track is single. At this distance from the origin, an apparent trident of high energy is generated and the four particles form a single track for further se-

(1) A. E. ČUDAKOV: *Izw. Akad. Nauk USSR Ser. fiz.*, **19**, 651 (1955).

(2) D. H. PERKINS: *Phil. Mag.*, **46**, 1146 (1955).

(*) Unpublished.

(3) A. JURAK, M. MIĘSOWICZ, O. STANISZ and W. WOLTER: *Bull. de l'Acad. Pol.*, Cl. III, 369 (1955); M. MIĘSOWICZ, W. WOLTER and O. STANISZ: communicated at the Pisa Conference, June 1955.

Added in proof; The recent analisis of the electrons energy spectrum at the depth 2.5 c. u give for the energy of primary photons the value $(70^{+3.4}_{-2.6})\cdot10^{11}$ eV.

veral hundreds microns. We could only estimate the upper limit of the value of the projected angle of this pair as $1.7\cdot10^{-5}$ radians. Information about the energy of such pairs is very limited. We are able to measure only the projected angle of the pair. Besides, for distances of ~ 1 mm from the origin of the pair the separation of the electron tracks is essentially determined by multiple scattering (LOHRMANN (4)). In any case it is very probable that the opening angle of our pair is smaller than the value mentioned above. Assuming the equipartition of the energy we get from the formula of BORSELLINO (5) as a lower limit for the energy of the pair the value $\sim 10^{11}$ eV, which seems to be very underestimated.

As the measure of ionization we have taken the coefficient g of the exponential distribution of gap lengths after FOWLER and PERKINS (6). This distribution is given as $H=B\cdot e^{-gl}$ where H is the density of gaps of length greater than l and B is the blob density. The gap lengths were measured with a filar micrometer. There were carried out the following measurements of the distribution of gap lengths:

(*a*) For a relativistic electron (plateau) on the length of 1040 μm.

(*b*) for the investigated pair on the first segment of 260 μm from the origin of the pair.

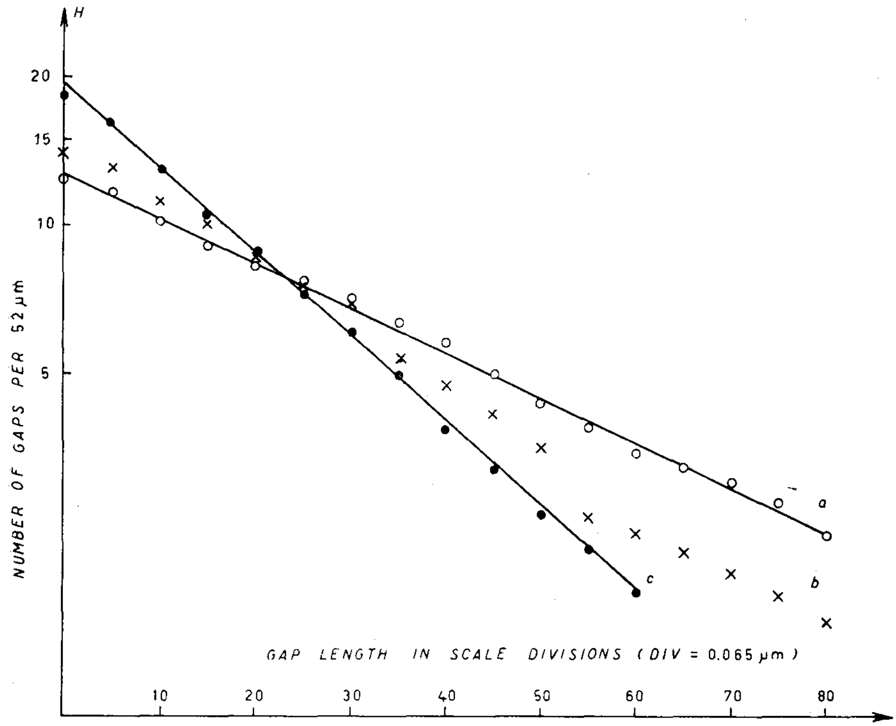

Fig. 1. – Gap length distributions on tracks of: *a*) a relativistic electron (plateau); *b*) the investigated pair (0 ÷ 260 μm); *c*) the investigated pair (260 ÷ 1560 μm).

(4) E. LOHRMANN: *Nuovo Cimento*, **2**, 1029 (1955).

(5) A. BORSELLINO: *Phys. Rev.*, **89**, 1023 (1953).

(6) P. H. FOWLER and D. H. PERKINS: *Phil. Mag.*, **46**, 587 (1955).

(c) For the investigated pair in the segment of track between 260 and 1 560 μm.

These distributions are shown on Fig. 1.

The investigated tracks were so long as compared with the « dip » that the gap length could be measured simply along the track. From these measurements the following values for the coefficient g of exponential gap length distribution can be obtained:

g-values per scale division ($=0.065$ μm)	
Relativistic electron (plateau)	0.021 ± 0.001
High energy pair near the origin ($0 \div 260$ μm)	0.028 ± 0.004
High energy pair far from the origin ($260 \div 1560$ μm)	0.039 ± 0.002

The values of errors are calculated as $1/\sqrt{N_B}$ where N_B is the number of blobs. In order to examine whether the g values were not influenced by local differences in development of the emulsion, control measurements of g were carried out for a long relativistic track nearly parallel to the track of the pair at a distance of ~ 50 μm on a length of ~ 1000 μm including the neighbourhood of the pair origin. On all segments of the track of 260 μm length, the same value of g was obtained within the limits of statistical errors. On Fig. 2.

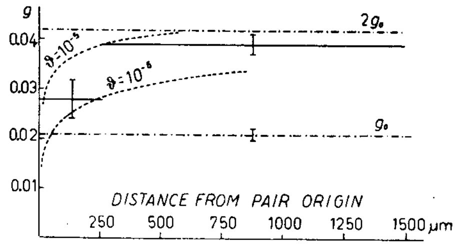

Fig. 2. – —— the values of g determined on two segments of track; –·–·– the values g_0 (plateau ionization) and $2g_0$; ···· the curves of Čudakov for opening angle of the pair $\vartheta = 10^{-5}$ and $\vartheta = 10^{-6}$ radians.

are given the values of g for two segments of the pair. On the same figure the curves of ČUDAKOV for opening angles $\vartheta = 10^{-5}$ and $\vartheta = 10^{-6}$ radians are shown. If the observed effect of the diminishing of ionization near the origin of the pair is really caused by the unlike charges of negaton and positon then we can use this effect for the estimation of the opening angle of the pair which is very valuable because of difficulties in measurements of this angle in any other way. It follows from Fig. 2 that the value obtained in this way for the opening angle does not contradict with the value estimate from the energy development of the cascade and the Borsellino formula.