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A COINCIDENCE-TYPE ION-ELECTRON CONVERTER DETECTOR WITH LOW BACKGROUND FOR LOW-ENERGY PROTONS

By

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In the last years a series of measurements on weak-interaction in neutron decay has been performed using the coincidence detector developed by O. BENKA. A short description of this detector will be presented with special emphasis on the problem of counting low-energy protons. Special care was taken in order to ensure the detection efficiency being independent of particle energy.

1. Introduction

In the last years a series of measurements on weak-interaction in neutron decay has been performed. The essential work was the precise measurement of the energy spectrum of the recoil protons from free-neutron decay [1, 2]. For this purpose, the detecting device (developed by O. BENKA [3]) should have a very high counting efficiency for the low-energy protons ($T_{\mathrm{max}} = 751{,}4$ eV) under consideration. Special care had to be taken in order to ensure the detection efficiency being independent of the particle energy at the detector entrance [3, 4].

2. Requirements and layout

According to the neutron decay measurement, the detecting device has to fulfil the following requirements (see also [2, 4]):

1) to focus protons onto a converter foil (at $U_B \approx 25$kV) independent of their primary energies T at the detector entrance (50 eV $\leq T \leq$ 750 eV);

2) to ensure a counting probability independent of the primary energy T of the protons;

3) to discriminate against counting of heavy ions (from residual gas, etc.);

4) to keep the background low (for a typical radiation-background of 1mr/h) and independent of energy setting.

On this basis, O. BENKA has developed a coincidence type ion-electron converter detector consisting of four distinguishable units [3]:

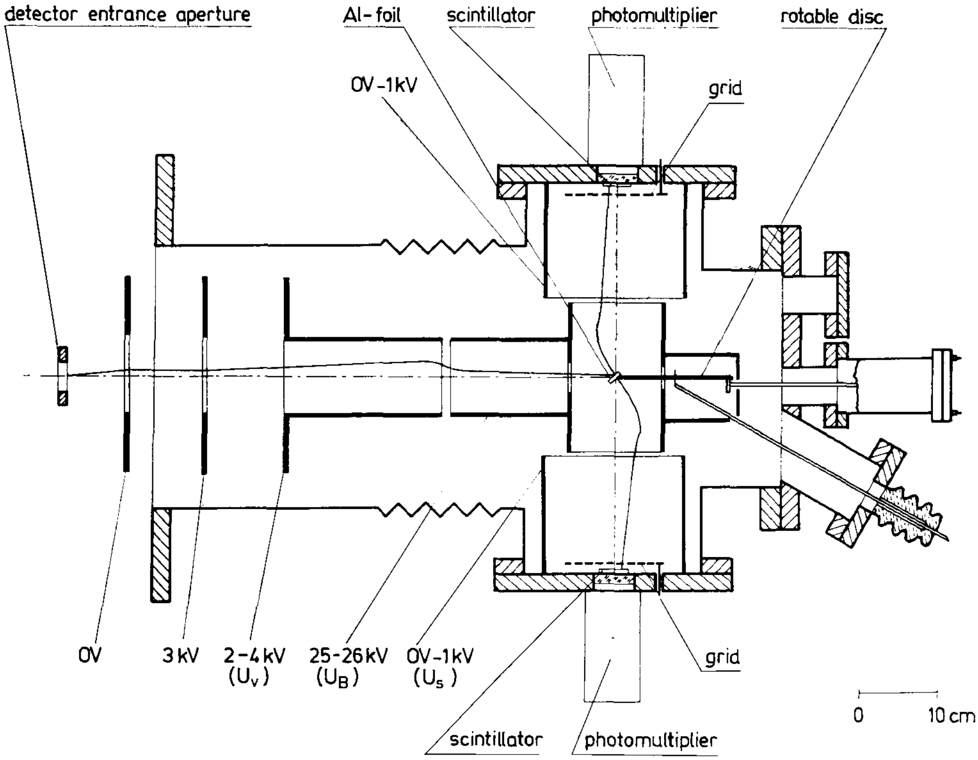

Fig. 1. Ion-electron converter detection system (all potentials given are negative with respect to ground potential).

1) Ion focusing and acceleration system
2) Ion electron converter: Al-foil
3) Electron focusing and acceleration system
4) Scintillation-detector:
   a) Scintillator, glass window, photomultiplier
   b) Pulse-discriminator and coincidence-device

The principle of this system can be seen in Fig. 1.

3. Description

The protons ($T = 50$ to 750 eV) entering the detector are accelerated by a four electrode lens to a final energy T_f of approximately 25 keV and focused onto a thin converter foil (Al-foil). In order to keep the final energy T_f independent of the primary proton energy T, the acceleration voltage U_B has to be varied accordingly: $U_B = (T_f - T)/e$.

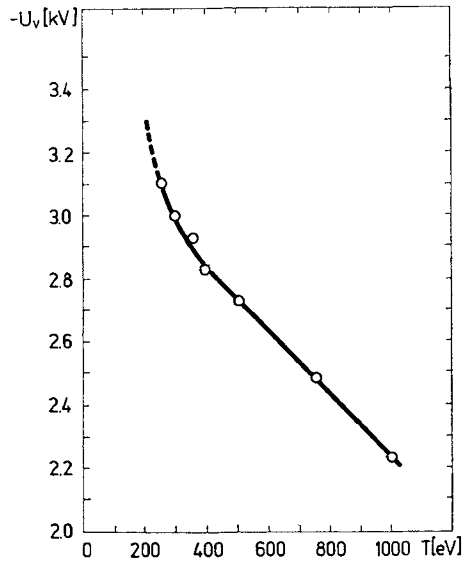

Fig. 2. Variable voltage U_v vs proton energy T (for $U_B = 25$ kV)

An optimum focusing of the protons on the converter foil was attained by varying the potential U_v of the third electrode (see Fig. 1) between -2 and -4 kV according to a calculated and experimentally tested function of the proton energy (see Fig. 2).

The accelerated protons penetrate the converter (20—40 μg/cm^2 Al-foil) which is inclined by 45° with respect to the proton flight path, and eject secondary electrons from both sides of the foil (electron yield γ at 25 kV $\approx$ 6.5 electrons/proton). These electrons are accelerated and focused by two cylinder-lenses onto two thin scintillator foils (NE 102 A), mounted on glass windows with a potential U_s of 0 — 1 kV applied. (To ensure a constant detection efficiency, also the impinging energies of the electrons at the scintillators have to be kept independent of the primary energy T. For this purpose, the potentials U_s of the scintillator surfaces — covered with a conducting Al-layer — are regulated accordingly). Two photomultipliers (RCA 8575) are optically coupled to these windows. Only coincident counts of the two detectors are accepted as proton events.

The thickness of the converter foil is chosen in order to stop heavier particles (e. g. residual gas ions) of comparable energies (see Fig. 3), thus preventing coincidences (mass-discrimination). To suppress background signals from secondary ions, originating from scintillator surfaces, grids at a moderate positive potential U_B with respect to the scintillator surfaces are used (see Fig. 4).

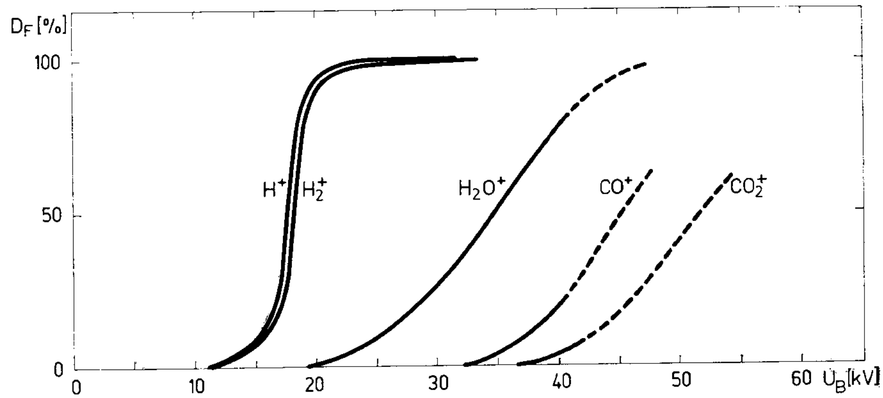

Fig. 3. Transmission D_F of a 25 μg/cm^2 Al-foil for various ions vs acceleration voltage U

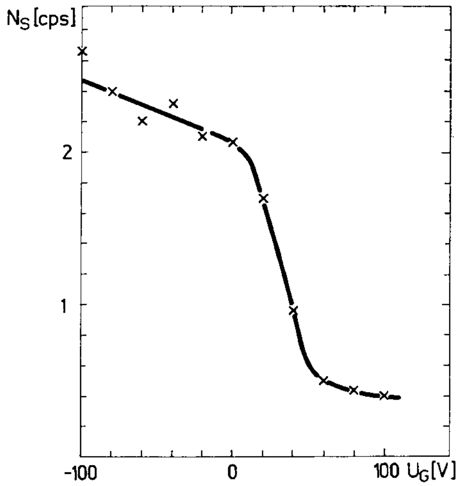

Fig. 4. Variation of background counting-rate N_S with grid voltage U_G

The dependences of the background on the acceleration voltage U_B and the gamma-dose rate D_{Ir} of an Ir^{192}_{77}-source are shown in Figs. 5 and 6. The coincidence background at $U_B = 25$ kV and 1mr/h γ-background amounted to approx. 0.1 counts/sec. The detecting device is able to measure proton counting rates of 0.1 cps to 2.10^5 cps.

To allow a variety of measurements, six foils of different sizes and thicknesses are assembled on a rotable disk (at acceleration potential) which can be moved by a rotary feedthrough.

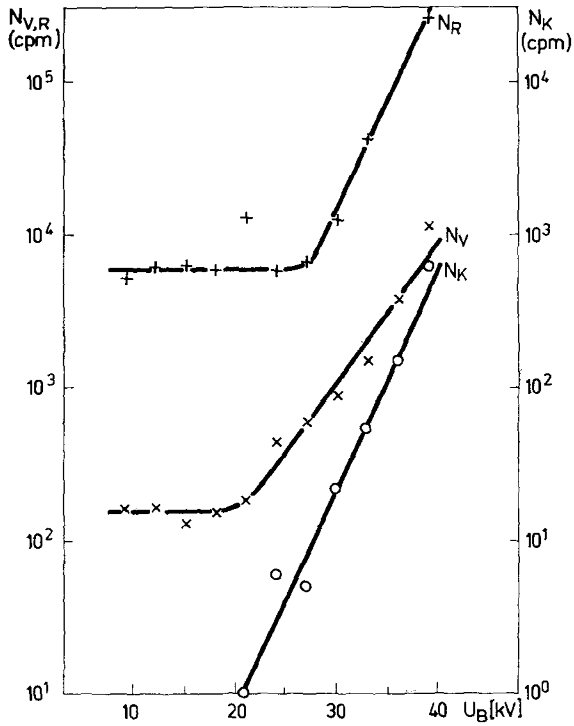

Fig. 5 Single-channel backgrounds N_V and N_R (V: scintillator seeing frontside of the foil; R: scintillator seeing back-side of the foil), and coincident background N_K as a function of acceleration voltage U_B

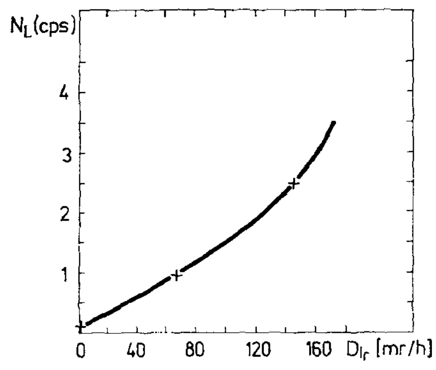

Fig. 6. Background N_L vs gamma-dose rate D_{Ir} (Ir^{192}_{77})

4. Results

By means of the detecting device described, a series of precision measurements of the energy spectrum of recoil protons following free-neutron decay has been performed, using an evacuated longitudinal beam-tube of the

ASTRA reactor. Proton spectra were measured from 150 to 750 eV, typical counting rates (at 7 MW reactor power) were 0.1 to 3 cps. Evaluating the results of the spectra measured with optimum precision, we obtained $|g_A/g_V| = 1.259 \pm 0.017$ for the ratio of the coupling constants. A more detailed description of this basic experiment can be found in [2].

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