A 30-keV Proton Accelerator for Particle-detector Tests

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The detection of low-energy protons is very important for two new experiments on the neutron decay planned for FRMII. These are PENELOPE, a **p***recise* **e***xperiment on the* **ne***utron* **l***ifetime* **o***perating with* **p***roton* **e***xtraction* [1], and *aSPECT* for the determination of the electron-antineutrino correlation coefficient a in neutron decay. In order to test the proton detection with semiconductor and scintillation counters in the laboratory in a way as close as possible to the conditions expected for the experiment, a dedicated proton accelerator working in the fA region has been built.

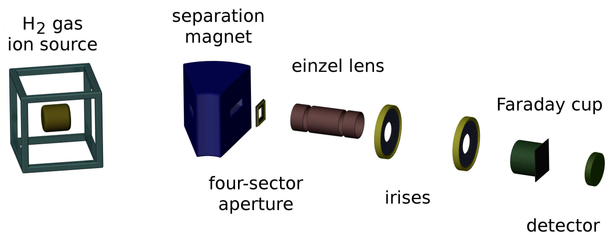

Fig. 1: Sketch of the proton accelerator. Further explanations may be found in the text.

The main components of the accelerator are shown in Fig. 1. A 10-mA ion source, operating with H_2 gas, delivers protons and H_2^+ ions (ratio 1:25). By an extraction voltage of up to 5 kV and an acceleration voltage of up to 30 kV the singly charged positive particles may gain energies of up to 35 keV. A dipole magnet ($B = 0..280\,\mathrm{mT}$) separates the protons from ions with differing q/m. A four-sector aperture behind this magnet allows beam definition and positioning. Next comes a three-element cylindrical einzel lens with the center electrode at positive potential V_m and the other two electrodes grounded. The focal length of this lens may be varied within a wide range by adjusting V_m. This allows to vary the beam size at the place of the detector further down-stream and hence the proton count rate within a very wide range down to about $30\,p/\mathrm{s}$ for a detector of 25 mm^2 area.

Remains the problem of suppressing an unwanted electron background. Electrons may be produced everywhere in the set-up by collisions of the heavy charged particles with beam tube walls and collimators, but only those generated behind the separation magnet can make it to the detector. Two irises with computer-controlled aperture (diameter 2..40 mm) are used to collimate the beam and stop the electrons created up-stream. Electrons originating at the edges of the iris diaphragms are deflected off the beam axis in cylindrical tubes put at +400 V. A removable Faraday cup with an electrometer is used for beam diagnostics.

The cold finger of a two-stage refrigerator may be employed for cooling the detector. Thus the temperature dependence of the scintillation efficiency of different crystals, e.g. CsI, or the noise behaviour of semiconductor detectors may be determined for temperatures between 10 and 300 K. At a second detector position a rotatable flange allows to measure the angular dependence of the detector efficiency in the range from -15° to +15° to the normal.

A useful feature of the accelerator set-up is the possibility to inject electrons parallel to the protons behind the einzel lens. Thus protons and electrons may be measured together to investigate the background expected from decay electrons in the future neutron-lifetime experiment.

First tests of the accelerator were very successful. Figure 2 shows spectra of 30-keV protons as taken with a $5 \cdot 5 \cdot 5\,\mathrm{mm}^3$ CsI(Tl) crystal and a Hamamatsu R329 photomultiplier. As may be seen, the noise level is remarkably small and production and detection is easily possible down to 30 protons/s.

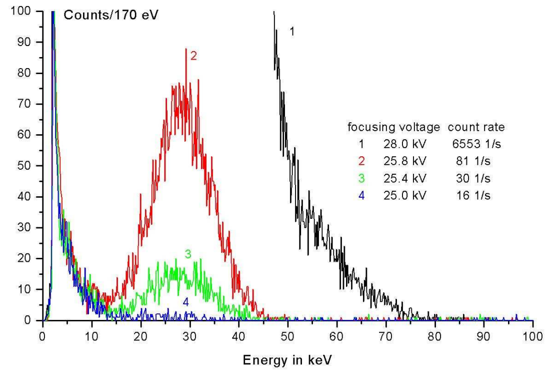

Fig. 2: Spectra of 30-keV protons produced by the accelerator and detected with a small CsI(Tl) scintillation counter. The different spectra correspond to different values for the focusing voltage and therefore to different count rates. Measuring time for each spectrum: 100 s. Further details are given in the text.

References

[1] I. Altarev *et al.*, this report, p.90.