A 30-keV Proton Accelerator with Low Flux for Particle-Detector Tests

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The detection of low-energy protons is crucial for two experiments on neutron decay planned for FRM II, PENeLOPE as a precise experiment on the neutron lifetime operating with proton extraction [1] and aSPECT [2] for the determination of the electron-antineutrino angular-correlation coefficient a in neutron decay. In order to test the detection of these protons with semiconductor or scintillation counters at proton fluxes and energies as close as possible to those expected during the main experiments, a dedicated **p**roton **a**ccelerator, working down to the **f**emtoampere **f**lux region was built: *paff*. This device can also be used to perform systematic tests for the experiment on the bound-beta decay of the neutron [3].

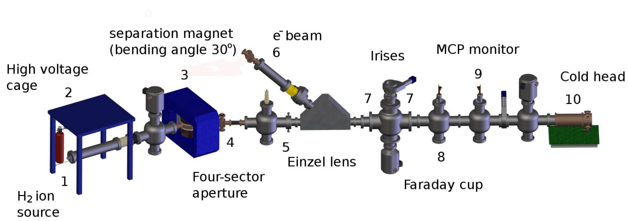

Fig. 1: Sketch of the proton accelerator. The detectors to be tested are mounted in position 10.

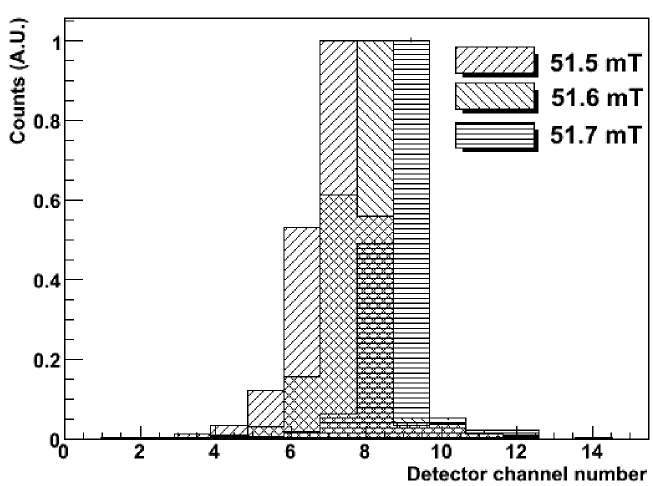

Fig. 2: Scan of the Si- strip detector.

The main parts of the accelerator [4] are shown in Fig. 1. The setup and the characterization measurements were finished. An MCP detector, consisting of two plates in chevron geometry with a diameter of 40 mm has been added to monitor the beam at currents between 10^{-13} and 10^{-18} A. An inner anode of 20 mm diameter and a ring shaped anode (inner diameter 22 mm, outer diameter 40 mm) allow a rough check of beam position and size. A Faraday cup is used to measure currents between pA and mA. Both, Faraday cup and MCP, are used to fix, fine tune, and control the beam hitting the detectors further downstream. The monitoring devices may be moved into and out of the beam; thus different detectors may be measured under the same beam conditions. A cold head at the end of the accelerator allows to cool these detectors down to temperatures of about 10 K. As it is placed in a vacuum chamber that may be separated from the rest of the set-up, detectors may be changed without interfering with the accelerator operation.

One of the first applications was to test the position sensitive silicon strip detector of aSPECT (strip width 0.9 mm, pitch 1 mm). For this task the beam was collimated to 2 mm diameter and moved from left to right through some strips of the detector by changing the B field in 0.1 mT steps. The result is shown in Fig. 2. First tests have been performed to determine the temperature dependence of the efficiency of the scintillation crystals for the large-area PENeLOPE proton counter. In Fig. 3 the quantum efficiency of CsI(Tl) is plotted against the crystal temperature. It was measured using an ^{241}Am source and a crystal of $5 \cdot 5 \cdot 5\,\mathrm{mm}^3$ connected to the cold head. The crystal was coupled to a lucite light guide viewed by a Hamamatsu photomultiplier that was held at room temperature. The result is compared in the Figure with values from earlier measurements [5]. The next step is now to prove - with protons - the increase of light output with decreasing temperature for pure CsI down to liquid-nitrogen temperatures [6], followed by a systematic study down to 10 K, the working temperature of the PENeLOPE proton counter. The light output of CsI at such a low temperature has never been investigated. This work is supported by the German BMBF and by Deutsche Forschungsgemeinschaft (grant PA 762/5-2).

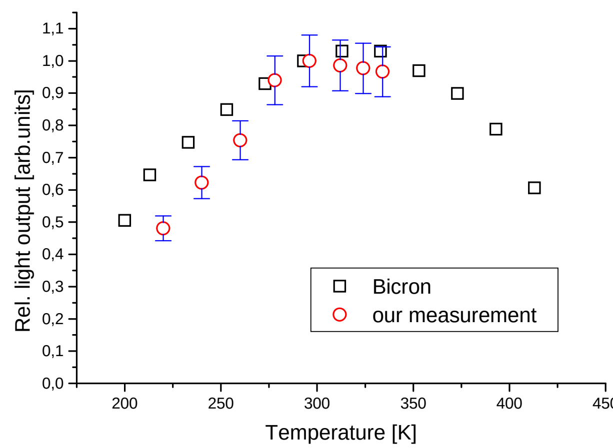

Fig. 3: The efficiency of CsI(Tl) as a function of the temperature. The error bars correspond to a relative error of 8%, the typical uncertainty of the energy calibration.

References

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