Low Energy Proton Detection via δ Electrons $^\diamond$

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The neutron life time τ can be determined in an ultra cold neutron(UCN) trap experiment by measuring the protons from the neutron β decay(maximum p energy $(T_p)_{max} = 752\,eV$) using a large area p detector. τ is the decay constant of the distribution dN_p/dt vs time t, if, after filling the UCN trap, all decay p(N_p) are collected, e. g., by a strong electric field, and focussed onto the detector.

There are several possibilities to measure the p: By means of low energy p impinging on a PIN diode biased with a reverse voltage of ca. 100 V, electron hole pairs(one pair/ 3.6 eV p energy) are produced, where, e. g., the e^- are collected yielding an energy proportional p detection signal. When the p are accelerated by an electric field to, e. g., 30 keV before hitting the PIN diode, $8.3 \cdot 10^3\,e^-$ are generated. The e^- noise of, e.g., the charge sensitive 32 channel preamplifier VA32C(company: ideas) is 140 + 26/pF yielding for a 1 cm^2 Siemens PIN diode(12 pF) 452 e^-, i. e., a signal/ noise ratio of 18. In order to reduce the capacity and noise for a large area detector, many small diodes must be read out separately, which is expensive.

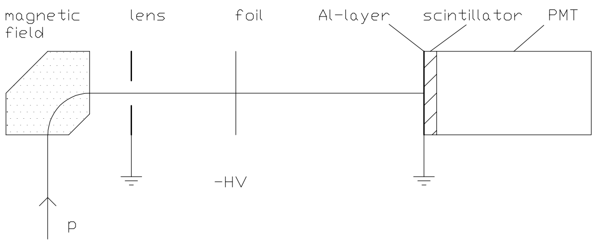

Fig. 1: Sketch of the experimental setup to measure p induced δ electrons produced at a C foil using a plastic scintillator and a photomultiplier(PMT)

Another means of low energy p detection is to measure p induced δ electrons. The method has been checked by a setup sketched in Fig. 1. From an ion source, p of, e.g., 18 keV, ≤0.01 pA, pass a grounded lens and are accelerated towards a 2 cm diameter $4\mu g/cm^2$ C foil at -12 kV voltage. Part of the δ electrons, which were produced by the p in the foil, are accelerated towards a grounded thin Al layer evaporated on a 0.4 mm thick 2 inch diameter plastic scintillator contacted by optical grease to a R329-02 photomultiplier tube(PMT, company: Hamamatsu). The number N_{e^-} of produced e^- per stopping power (-dE/dx) is $N_{e^-}/(-dE/dx) \approx 8/(keV/(\mu g/cm^2))$ yielding $N_{e^-} = 5$ with (-dE/dx)(30 keV p on C) = 0.63 keV/$(\mu g/cm^2)$. Since only the δ electrons, which were produced in the last 15 nm of the foil(C foil thickness 20 nm), are available at the rear foil surface, 3.8 e^- are accelerated to 12 keV each onto the scintillator, i. e., with 60 eV/photon, $4.52 \cdot 10^4$ eV e^- energy is transferred into 753 photons . Assuming a 20% light collection efficiency, 151 photons hit the Sb- Na- K-Cs PMT cathode producing at a 30% quantum efficiency 45 e^-. The PMT cathode e^- are multipied by 10^6 yielding a 362 μA current pulse of 20 ns duration, which has to be compared with a maximum PMT anode dark current of 40 nA corresponding to a signal/noise ratio of $9 \cdot 10^3$.

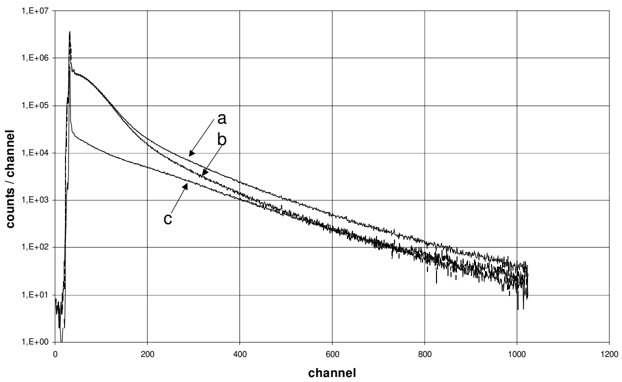

Fig. 2: e^- charge spectra from a -17 kV C foil, measuring time 100 s. a: With p impinging on the foil. b: Spectrum with background spectrum subtracted. c: Background spectrum of field emission e^-, no p

The bump in the measured e^- charge spectrum (Fig.2, curve b) is due to p induced δ electrons. Because of a field emission e^- background, especially at small charge(curve c), the δ e^- part is not separated from the background, which has to be reduced by an improved HV installation, e. g., by a polished foil holder. Moreover, a metal ring with a more negative potential than the C foil will be positioned after the foil (Fig. 3), in order to focus the emitted δ e^- electrostatically onto the scintillator, where the electric field along the rotational axis between foil and scintillator is always accelerating (Fig. 4).

$^\diamond$ The help and advice of many more people is greatly acknowledged

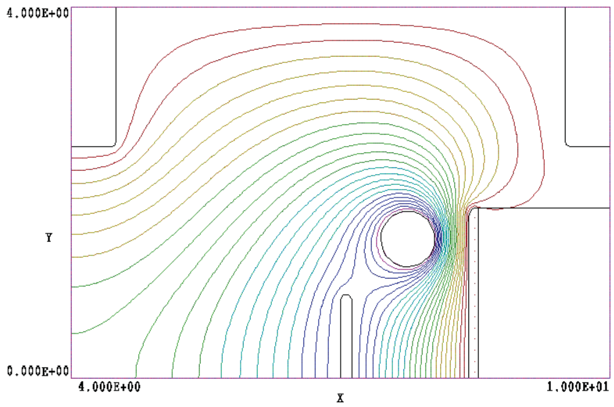

Fig. 3: Potential lines in the x- y plane with x being the axis of rotational symmetry, where the foil(x = 7 cm) is at -7 kV and the focussing ring at -8 kV

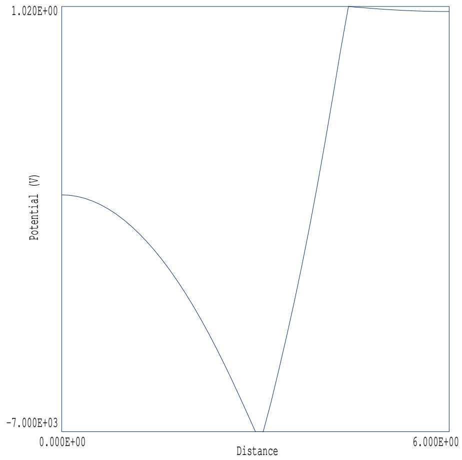

Fig. 4: Potential along the x axis(foil at x = 3 cm)