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NEW ATTEMPT TO DETERMINE THE FREE NEUTRON LIFE TIME BY IN-BEAM DETECTION OF DECAY ELECTRONS

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RESUME - Une mesure de la durée de vie du neutron est en préparation. Le nombre d'électrons se désintégrant par unité de temps ($\frac{\Delta N_e}{\Delta t}$) est obtenu en observant la désintégration d'un faisceau haché de neutrons froids passant à travers un compteur proportionnel à migration rempli de He^4 . Le nombre de neutrons susceptibles de se désintégrer (N_n) est obtenu par la mesure de l'activité d'un échantillon de Co^{59} absorbant totalement le faisceau de neutron ; $\lambda = \frac{1}{N_n} \left(\frac{\Delta N_e}{\Delta t} \right)$.

ABSTRACT - A measurement of the half life of the neutrons is in progress. Bursts of cold neutrons are passed through a 4He proportional counter (drift chamber) and the number ΔN_e of betas from the decaying neutrons are measured in 4π geometry during an interval Δt in the chamber. The total number N_n of neutrons per burst is determined by activation analysis of the ^{59}Co beam catcher, resulting in the decay constant $\lambda = \frac{1}{N_n} \left(\frac{\Delta N_e}{\Delta t} \right)$.

The importance of precise knowledge of the half life of the neutron is akin to that of the fundamental constants. Measurements of this quantity are of great importance to β decay theory and have far reaching consequences in cosmology /1/.

The following table summarizes the values of $|g_A/g_V|$ from the measurements of the life time τ_n of the neutron :

(1959)	Sosnovski	1.17 ± 0.019
(1972)	Christensen	1.243 ± 0.011
(1978)	Bondarenko	1.279 ± 0.006
(1980)	Byrne	1.230 ± 0.014
(1978)	Paul	1.255 ± 0.055
(1980)	Kosvintsev	1.287 ± 0.077

The angular correlation measurements are consistent together and lead to an averaged value :

$$g_A/g_V = 1.258 \pm 0.0085 /2/$$

in contrast to the inconsistency of the τ_n measurements. In the beta decay of nuclei the axial coupling constant g_A undergoes an extra renormalization due to the meson exchange current so that the value of g_A inferred from the neutron decay is used :

- to test the PCAC theory
- to calculate the Cabibbo angle

The g_A/g_V ratio of the coupling constants of the β decay can be written in term of the (ft) value of the $0^+ \rightarrow 0^+$ and neutron decay.

$$\frac{1 + 3(g_A/g_V)^2}{2} = \frac{(ft)_{0^+ \rightarrow 0^+}}{(ft)_{\text{neutron}}}$$

$$\text{where } (ft)_{0^+ \rightarrow 0^+} = 3084 \pm 1.9 \text{ s}$$

Thus the precision of the (ft) value of the neutron decay is actually limited by the measurements of the neutron half life.

The basic arrangement of our method is shown in fig. 1. A monochromator deflects neutrons under a right angle out of the cold neutron beam PN7. A double chopper assembly forms neutron bursts of about 25 cm length. The bursts enter a ^4He filled proportional counter which is layed out as a drift chamber. The activity of the ^{59}Co beam catcher is a measure for the number of neutrons per burst. The background can be measured when the burst travels outside of the counter. Fig. 2 illustrates the expected signal from the counter. The decay constant λ is given by

$$\lambda = - \frac{1}{N_n} \frac{\Delta N_n}{\Delta t}$$

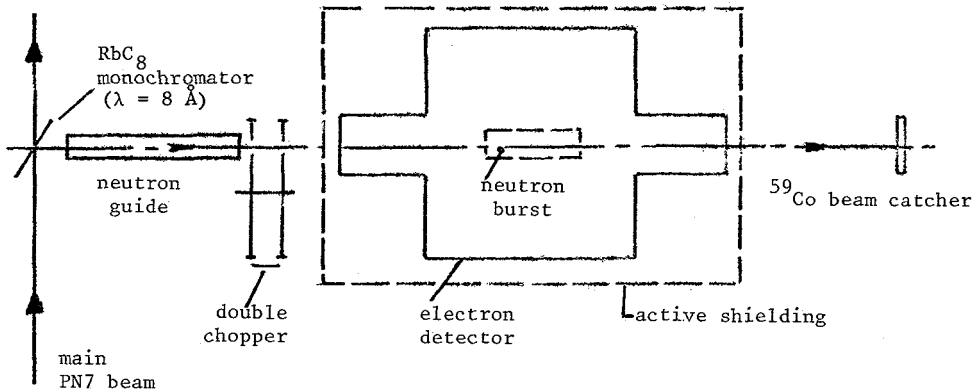


Fig. 1 - Scheme of the experimental set-up

The neutron beam

The neutron monochromator is made of a RbC_8 crystal of $3 \times 5 \text{ cm}^2$ size and deflects under a Bragg angle of $2\theta = 90^\circ$ a $\lambda = 8 \text{ Å}$ beam with a resolution of $\Delta\lambda/\lambda = 3\%$. The neutrons are guided and collimated by a bunch of parallel Pyrex tubes of $10 \text{ mm } \varnothing$. The flux at the exit of such a guide (divergency $\sim 0.5^\circ$) was measured as $\phi = 2.3 \times 10^6 \text{ n cm}^{-2} \text{ sec}^{-2}$. The double chopper, distant by 70 cm, will filter out higher orders of reflection and block the direct view to the monochromator (source of γ and e^- background).

Electron detection

The electron detector is a classical drift chamber filled at atmospheric pressure with a ^4He (95 %) CO_2 (5 %) gas mixture.

The ionization due to the β decay of the neutron is drawn by a convenient electrical field to the multiwires proportional part (MWPC) where the avalanches take place.

First measurements done with a prototype of the electron detector gave an efficiency close to 100 % for both the MWPC part and the drift part.

The fig. 3 shows a typical result obtained by a coincidence measurement of the chamber as a transmission counter and a scintillator.

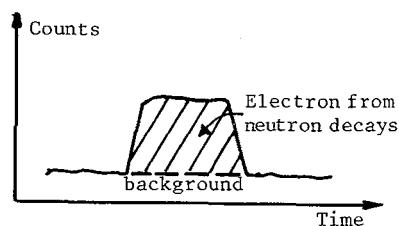


Fig. 2 - Time spectrum of the electron detector triggered by the chopper

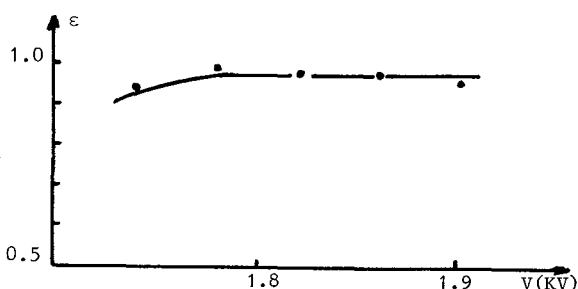


Fig. 3 - Efficiency of the MWPC as function of the applied high voltage

The cosmic rays and radiations from neighbouring experiments are screened by a veto signal from plastic scintillators surrounding the electron detector.

The elastically scattered neutrons in the ^4He gas may cause (n, γ) processes in the detector materials. The use of graphite for the electrode frames and for the cladding of the gas box, as well as the use of Zirconium wires limit this background contribution to less than 0.1 of the event rate. In order to avoid neutron captures in the counter itself the ^4He gas has to be free of ^3He ; the $^3\text{He}/^4\text{He}$ ratio must be smaller than 5×10^{-10} .

To suppress further the background, the path of the emitted electrons is recorded, thus the origin of the electron path can be located and sparking of individual wires recognized.

As the ionisation level is very low (0.25 keV/cm of gas) we also foresee to insert between the drift and the MWPC parts a gas preamplifier stage /3/.

Neutron flux measurement

For most of the neutron life time experiments done until now the neutron flux density had to be measured by rather delicate methods (transmission counter using ^3He or ^{10}B). For our arrangement the total number of neutrons is the relevant value which must be determined.

This measurement can be accomplished by absorbing all neutrons of a burst in a ^{59}Co sample of a thickness of 3 mm. The prompt γ -rays from the (n, γ) reaction are recorded in a Ge(Li) detector. The absolute efficiency ϵ of this arrangement can

be determined in replacing the beam catcher by a ^{60}Co sample of well-known activity. Thus the neutron flux measurement can be done also on-line :

$$\phi_n = \frac{n_\gamma}{\varepsilon_\gamma \cdot \eta_\gamma}$$

where n_γ are the detected events of a prompt γ line. η_γ is the intensity of this line per n capture as determined by a calibration measurement /4/. ε_γ is the efficiency at E_γ . A strong prompt γ line is observed at 1215 keV, which is close to the γ energies following the beta decay of ^{60}Co , thus $\varepsilon_\gamma \approx \varepsilon$ for this line.

In addition the accumulated neutron flux can be determined off-line with a high precision by activation analysis of the beam catcher, i.e. the produced ^{60}Co activity. In a preliminary stage of the experiment the neutron flux could also be determined by a ^6Li drifted glass scintillator as beam catcher.

Conclusion

Since the first measurement of the neutron half life, the general trend for neutron beam experiments went towards shorter half life values with improved technics. The present method, which differs vastly from those beam measurements, avoid some of the previous technical problems and will hopefully give a value with a high level of confidence.

/1/ Tayler R.J., Nature, vol 282 (Dec. 1979)

/2/ Wilkinson D.H., Progress in particule and nuclear physics 6 (1980) 325

/3/ Marchand P., Thesis LAPP Annecy le Vieux

/4/ Schreckenbach K., et al., Internal report ILL (Dec. 1981)