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POLARIZABILITY OF NEUTRON FROM PRECISE NEUTRON MEASUREMENTS

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Almost thirty years passed since the idea of electrical polarizability of the neutron has been introduced and its experimental searches begun [1]. During this time the polarizability of the proton [2] and pion [3] was observed while the polarizability of the neutron has not been observed up to now. History and results of the neutron polarizability investigations are described in detail in the book [4]. The present report contains no new results and has a purpose to draw attention to one more experimental possibility omitted in [4].

The polarizability of a particle in the electrical field $\vec{\epsilon}$ results in the induced electrical moment $\vec{p} = \alpha\vec{\epsilon}$ that leads to a further interaction $H' = -\alpha\epsilon^2/2$. The coefficient α, which is a measure of polarizability, is very small ($\sim 10^{-42}$ cm^3) that causes difficulties of its experimental observation. It is found from the experiments on scattering of γ-rays and pions that for the proton $\alpha_p = (1.1 \pm 0.2)\cdot 10^{-42}$ cm^3 [2] and for the pion $\alpha_{\pi^-} = (0.68 \pm 0.14)\cdot 10^{-42}$ cm^3 [3].

The best estimates of an upper limit of the neutron - electrical - polarizability coefficient α_n were obtained from the analysis of the angular dependence of neutrons scattered by nuclei with a large charge Ze at keV energies. The anisotropy of this scattering is reduced essentially to the forward-backward scattering asymmetry which is characterized by the coefficient ω_1 in the expression for the differential cross section

$$d\sigma/d\Omega \sim 1 + \omega_1 P_1(\cos\theta) + \omega_2 P_2(\cos\theta) + \ldots$$

where θ is the scattering angle in the centre of mass system. As is shown in the work [5] the scattering asymmetry ω_1 has a simple energy dependence:

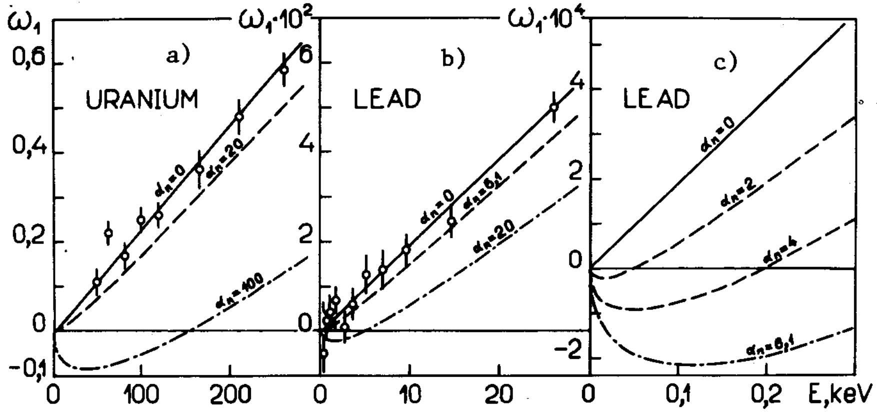
$$\omega_1 = aE - bE^{1/2}, \qquad (1)$$

where the first term corresponds to the pure nuclear scattering and the second one to the interference of nuclear scattering with an additional scattering due to polarizability of the neutron. For heavy nuclei $a \simeq 2$ MeV^{-1}, and b is defined by the quantities α_n, Z and nuclear scattering radius R':

$$b = 9.5\cdot 10^{-6}\,\frac{\alpha_n Z^2}{R'}\,\text{MeV}^{-1/2} \qquad (2)$$

(α_n is in units 10^{-42} cm^3, R' is in fm).

The figure demonstrates three stages of α_n evaluations using the ω_1 data and formulas (1) and (2). The energy dependence of ω_1 in the absence of polarizability is shown by solid lines, dot-dashed curves correspond to α_n estimates from previous experiments and dashed curves to α_n estimates which have been or can be obtained at the given stage.



At the first stage (part a) of the figure) the estimate $\alpha_n \sim 10^{-40} cm^3$ was known from the experiments with fast neutrons scattered at small angles /4/. The data on scattering asymmetry of the neutrons up to 300 keV for uranium nuclei allowed that estimate to decrease down to the limit $\alpha_n < 2\cdot 10^{-41} cm^3$ /5,6/. The second stage consisted in employing more slow neutrons (up to 26 keV) and in measuring ω_1 on the lead nuclei. It was done in the work /7/ (see part b) of the figure) where the new limit $\alpha_n < 6.1\cdot 10^{-42}$ cm^3 had been obtained.

For a further specification of α_n it is advisable to come to still lower energies of scattered neutrons at which the values of both terms of the expression (1) are comparable, the curve $\omega_1(E)$ is essentially nonlinear and crosses the abscissa axis. Part c) of the figure illustrates the situation with ω_1 for the lead nuclei at energies up to 300 eV. One may expect the measurements of ω_1 in this energy region will give at last a definite value of $\alpha_n \sim 10^{-42}$ cm^3. However, the corresponding experiment is highly difficult because the absolute error of the ω_1 measurements should not exceed $\sim 10^{-4}$. Besides a high statistical accuracy it is necessary to ensure an accurate taking into account of the background, especially of those neutrons which enter the detector after scattering on the sample and rescattering on surrounding materials and air.

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Самосват Г.С. E3-83-677
Поляризуемость нейтрона из прецизионных нейтронных измерений

Дан краткий обзор экспериментальных оценок коэффициента электрической поляризуемости нейтрона, основанных на измерениях асимметрии рассеяния килоэлектронвольтных нейтронов тяжелыми ядрами вперед-назад. Показано, что наибольшую чувствительность может обеспечить еще не реализованный прецизионный опыт с рассеянием нейтронов в диапазоне энергий ~1-300 эВ.

Работа выполнена в Лаборатории нейтронной физики ОИЯИ.

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Samosvat G.S. E3-83-677
Polarizability of Neutron from Precise Neutron Measurements

A short survey is given of the experimental evaluations of neutron-polarizability coefficient based on the measurement of keV forward-backward asymmetry of neutrons scattered by heavy nuclei. It is shown that the most sensibility can be provided by a precise experiment with the ~1-300 eV neutrons not yet realized.

The investigation has been performed at the Laboratory of Neutron Physics, JINR.

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