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NEUTRON ^{208}Pb SCATTERING AND THE ELECTRIC POLARIZABILITY OF THE NEUTRON

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Neutron transmission cross sections of ^{208}Pb were measured for four energies. These data were the basis to evaluate the electric polarizability of the neutron: $\alpha_n = (0.4 \pm 1.5) \cdot 10^{-3} \mathrm{fm}^3$ for $a_{ne} = -1.32 \cdot 10^{-3}$ fm and $\alpha_n = (-1.1 \pm 1.5) \cdot 10^{-3} \mathrm{fm}^3$ for $a_{ne} = -1.59 \cdot 10^{-3}$ fm.

The investigation has been performed at the Laboratory of Neutron Physics, JINR and in Garching Laboratory, Fed. Rep. Germany.

Рассеяние нейтронов на ^{208}Pb и электрическая поляризуемость нейтрона

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Полные нейтронные сечения ^{208}Pb измерены при четырех энергиях нейтронов. На основе полученных данных сделана оценка электрической поляризуемости нейтрона: $\alpha_n = (0{,}4 \pm 1{,}5) \cdot 10^{-3}$ фм^3 при $a_{ne} = -1{,}32 \cdot 10^{-3}$ фм и $\alpha_n = (-1{,}1 \pm 1{,}5) \cdot 10^{-3}$ фм^3 при $a_{ne} = -1{,}59 \cdot 10^{-3}$ фм.

Работа выполнена в Лаборатории нейтронной физики ОИЯИ и в Гархингской лаборатории, ФРГ.

The last attempts /1-3/ to measure the coefficient α_n of the neutron electric polarizability from precise measurements of the neutron total cross sections gave only the upper limits for the α_n value of $(1 \div 2) \cdot 10^{-3}$ fm^3 order. It is just on the level of theoretically expected meaning of α_n and the value for proton $\alpha_p = (1.07 + 0.11) \cdot 10^{-3}$ fm^3 /4/. So any define value of this fundamental constant is absent up to now.

The main difficulty in the works /1-3/ is the correct consideration for the neutron resonances, our knowledge of which is limited. Therefore, in this work instead of natural lead and bismuth used in /1-3/ we measured the total cross sections of double-magic ^{208}Pb which had very rare resonances.

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Table

Energy	1.26 eV	18.6 eV	128 eV	1970 eV
σ_t^{meas}, $10^{-24}cm^2$	11.441(5)	11.509(14)	11.503(16)	11.468(7)
σ_s^{corr}, $10^{-24}cm^2$	12.434(5)	12.494(14)	12.485(16)	12.443(7)

We had three metallic samples 8.7, 14.3 and 15.6 mm thick enriched with ^{208}Pb up to 97.3%, which had been used in different combination on the installations at three beams of the FRM reactor in Garching, West Germany. The methods of the measurement are described in /2,5/. The results for four energies of neutrons are listed in the Table as measured and corrected cross sections. The latter ones correspond only to s-wave potential scattering on ^{208}Pb and are obtained by subtracting from σ_t^{meas} small contributions of solid state effects, Schwinger scattering, other isotopes, p-wave neutrons and the contribution of two ^{208}Pb s-wave resonances. The resonance parameters of all lead isotopes were taken from /6/.

If we write /7/

$$\sigma_s^{corr} = \frac{4\pi}{k^2} \sin \delta_0 \sin(\delta_0 + 2\eta_0) \simeq \frac{4\pi}{k^2} \sin^2(\delta_0 + \eta_0) , \qquad (1)$$

where δ_0 is the phase shift of nuclear s-scattering,

$$\eta_0 = kZfa + k\alpha_n MZ^2e^2/(\hbar^2 R)(1 - \frac{\pi}{3} kR) ,$$

f is the atomic form-factor, $a = -\frac{A}{A+1} a_{ne}$, a_{ne} is a neutron-electron scattering length, R is the radius of the nucleus, so it is easy to obtain from (1) the following expression

$$\frac{\pi MZ^2e^2}{3\hbar^2}(k_1 - k_2)\alpha_n - Z(f_1 - f_2)a =$$

$$= \frac{1}{k_1}\arcsin\left(k_1\sqrt{\frac{\sigma_{s1}^{corr}}{4\pi}}\right) - \frac{1}{k_2}\arcsin\left(k_2\sqrt{\frac{\sigma_{s2}^{corr}}{4\pi}}\right) , \qquad (2)$$

where indices 1 and 2 refer to two different energies (note: $\delta_0 < 0$ and $0 < \eta_0 < |\delta_0|$).

For the evaluation of α_n now we can practically use only the energies 1.26 and 1970 eV. Then from equation (2) for the data taken from the table and considering the value of $a_{ne} = (-1.32 \pm 0.04) \times 10^{-3}$ fm [2,8] we have

$$\alpha_n = (0.4 \pm 1.5) \cdot 10^{-3} \text{ fm}^3; \tag{3}$$

in the case of $a_{ne} = (-1.59 \pm 0.04) \cdot 10^{-3}$ fm [1,9]

$$\alpha_n = (-1.1 \pm 1.5) \cdot 10^{-3} \text{ fm}^3. \tag{4}$$

These evaluations do not practically differ from the earlier ones [1-3], but they are more reliable, because of much smaller corrections on neutron resonances.

Now these investigations are in progress to achieve higher accuracy. Moreover, the measurement of a coherent scattering length of ^{208}Pb at the energy much less than 1 eV should permit one to have a new independent result for a_{ne} too.

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