Experimental study of *P*-parity nonconservation in the neutron resonance of ^{117}Sn

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Nonconservation of space parity has been detected in the 1.33-eV p resonance of ^{117}Sn. A value $\mathscr{P}(E_p) = (4.5 \pm 1.3) \times 10^{-3}$ has been obtained at the resonance for the ratio of the difference in the cross sections with opposite helicities $(\sigma_+ - \sigma_-)$ to their sum $(\sigma_+ + \sigma_-)$.

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Violation of space parity due to the interaction of neutrons with nuclei has been investigated in a number of papers. A difference in the total cross sections of unpolarized ^{117}Sn and ^{139}La nuclei for thermal neutrons polarized in the direction of the momentum and opposite to it has been recently detected[1,2] and the rotation of polarization of a neutron beam, which has the same nature and which occurs as a result of transmission through an unpolarized ^{117}Sn sample, has been measured. In the theoretical studies[3-5] the authors have analyzed the correlation between these parity-nonconserving effects and the p-wave resonances and obtained expressions for the energy dependence of these effects. It was mentioned in Ref. 5 that if these effects do not increase on approaching the resonance, then their explanation may require the introduction of new, space-parity-violating forces which exceed considerably the weak forces. Because of this situation, it has become important to perform an experiment in the region of the p resonance. Below, we describe a measurement of the difference in the total cross sections of ^{117}Sn nuclei near the 1.33-eV p resonance for neutrons polarized in the direction of their momentum and opposite to it.

The experiment was performed using the time-of-flight method on the J.I.N.R.

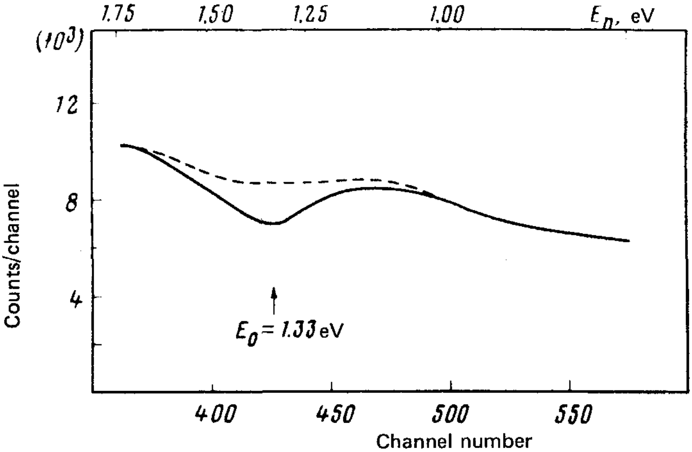

FIG. 1. Instrumental time-of-flight spectrum of neutrons transmitted through a 4-cm-thick ^{117}Sn target. The spectrum was obtained after 2 hours of measurements.

IBR-30 pulsed reactor with a path length of 58 m. The resonance neutrons were polarized by transmitting them through a polarized proton target. The longitudinal polarization of neutrons and its reversal were achieved by producing appropriate configurations of the guiding magnetic field. We have measured the transmission of a metallic tin (88% ^{117}Sn) sample 4.0 × 4.9 cm in area and a thickness with respect to the beam of ^{117}Sn nuclei $n = 1.3 \times 10^{23}$ cm^{-2}. The storage of time-of-flight spectra, the polarization monitoring and control of the experiment were accomplished by using a system with a small computer. The polarization was reversed after 40 sec. The direction of polarization of the proton target was reversed every two days of measurements in order to reverse the sign of the effect in question without changing the instrumental and geometric conditions of the measurements. The total time needed to collect the statistical data was 12 days.

One of the important advantages of the time-of-flight method in this experiment was the possibility of observing the energy dependence of the effect in the resonance and the ability simultaneously to control it in each off-resonance region. Figure 1 shows the region of the spectrum with the 1.33-eV resonance for one of the directions of polarization of the beam. The dashed curve represents the relative variation of the spectrum without a sample, which follows the measurement with a sample in the regions that are remote from the resonance. Figure 2 shows the experimental results for the region near the 1.33-eV resonance in the form of an energy dependence of the value

$$\epsilon = \frac{N_+ - N_-}{f_n (N_+ + N_-)}, \qquad (1)$$

where $N_\pm$ is the number of counts of the detector for neutron polarization in the direction of the momentum and opposite to it, and f_n is the beam polarization ($f_n = 0.6$). Each point in the resonance region was obtained by summing the counts in

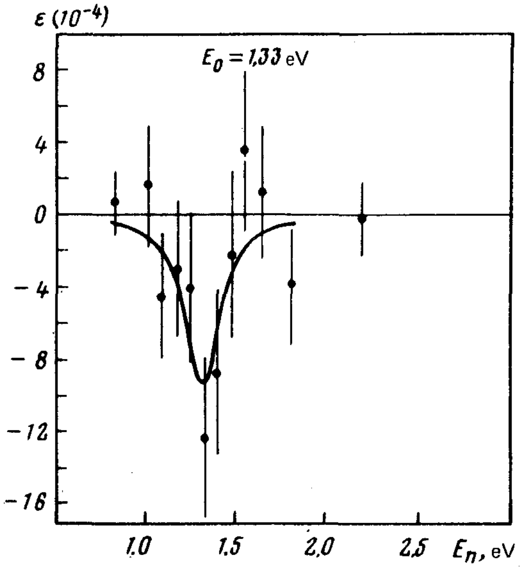

FIG. 2. Dependence of ϵ on the neutron energy in the region of the p-wave 1.33-eV resonance.

the 0.08-eV interval; this is slightly larger than the width of the resolution function, which is equal to about 0.06 eV in our case. The average value of ϵ in the off-resonance regions (0.05–0.7 eV and 2.2–8 eV) does not go outside the limits of statistical error, 0.9×10^{-4}.

We have also measured the parameters of the p resonance, which must be analyzed further: $E_p = (1.33 \pm 0.01)$ eV, $g\Gamma_p^n = (1.90 \pm 0.15) \times 10^{-7}$ eV, and $\Gamma_p = (0.23 \pm 0.02)$ eV. The fact that the radiative width of the p-wave resonance of ^{117}Sn is three times larger than that of the s-wave resonance ($\Gamma_s \approx 0.08$ eV) is of interest in itself in neutron spectroscopy.

It was shown in Ref. 3 that the resonance cross section of neutrons with different helicities $\sigma_\pm$ is related to the standard resonance cross section σ by the following relations:

$$\sigma_\pm = \sigma(E)\,[\,1 \pm \mathcal{P}(E)\,]\,; \quad \mathcal{P}(E) = 2\alpha\,(\Gamma_s^n / \Gamma_p^n)^{1/2}, \tag{2}$$

where α is the coefficient of mixing of the levels with respect to parity, and Γ_s^n and Γ_p^n are the energy-dependent neutron widths of the mixed s and p levels. The effect in question in our case is

$$\epsilon(E) = -\,n\sigma(E)\,\mathcal{P}(E_p). \tag{3}$$

An absence of a noticeable effect outside the resonance allows us to assume that the observed effect is due to the resonance part of the cross section.

On the basis of this assumption we found that $\mathcal{P}(E_p) = (4.5 \pm 1.3) \times 10^{-3}$, using the method of least squares and Eq. (3). The curve in Fig. 2 corresponds to the behavior of the effect with the given value of the parameter $\mathcal{P}$.

Since the measured thermal capture cross section for ^{117}Sn is much larger than the cross section calculated from the resonances with a positive energy, we can expect that there is a negative s level nearby with an energy E_s, whose impurity accounts for the observed effect.

To calculate the mixing coefficient α according to Eq. (2), we must know the neutron width of the s level Γ_s^n. Since its exact value cannot be determined, we shall limit ourselves to the estimate of α and use the average value of the reduced neutron width $2g\Gamma_s^n = 1.0$ meV, which was determined from the data of Ref. 6. This gives an estimated value $\alpha = 4 \times 10^{-5}$, correct only to an order of magnitude, since the neutron width Γ_s^n can differ from the average width by several factors.

We shall compare the data of Ref. 2 with our results. We can make such a comparison because of the energy dependence of parity nonconservation, which was analyzed in Ref. 4. According to the results of this study, we obtain the following sufficiently rigorous relation, which relates the values of $\mathcal{P}(E)$ for $E \ll E_p$ and $\mathcal{P}(E_p)$ for the p-resonance energy to the capture cross sections for the same energies:

$$\frac{\mathcal{P}(E)}{\mathcal{P}(E_p)} = \frac{\sigma(E_p)}{\sigma(E)} \left(\frac{\Gamma_p}{2E_p}\right)^2 \left(1 + \frac{E_p}{|E_s|}\right). \tag{4}$$

Substituting in Eq. (4) the values $\mathcal{P}(E) = 1.6 \times 10^{-5}$ and $\sigma(E) = 1.1$ b obtained in Ref. 2 and those determined by us $\mathcal{P}(E_p)$, $\sigma(E_p) = 1.61 \pm 0.16$ b, and Γ_p, we can see that the ratio on the left-hand side of Eq. (4) is approximately one-third that on the right-hand side. It should be noted that the thermal cross section $\sigma_T = 2.6 \pm 1.0$ in Ref. 6 eliminates the indicated difference. Unfortunately, Kolomensky *et al.*[2] did not describe the procedure for measuring $\sigma(E)$ and did not give the error of the cross section or the energy. The existence of a p resonance in the negative energy region, which accounts for the opposite-sign effect, can be considered the hypothesis that explains the deviation of the energy dependence of the effect from the predicted dependence.

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