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PARITY NONCONSERVATION STUDY WITH A POLARIZED La TARGET

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I. Introduction

The discovery of parity nonconservation (PNC) with very large effects in p-wave neutron resonances [1] excited interest in such investigations. Several scientific groups in the USA, Japan, and Russia carried out experiments on the helicity dependence of neutron cross sections [2-5]. Correlation $(\vec{s}\vec{p})$ of the neutron spin $\vec{s}$ and momentum $\vec{p}$ were observed in all these experiments. The experimental effect ε_n in the transmission of longitudinally polarized neutrons through an unpolarized target may be expressed in a two-level approximation as:

$$\varepsilon_n = \frac{N_+ - N_-}{f_n(N_+ + N_-)} = n\sigma_0 P_n$$

$$P_n = \frac{2w_{sp}}{E_p - E_s}\sqrt{\frac{\Gamma_n^s}{\Gamma_n^p}}\cdot x,$$

$$x = \frac{\sqrt{\Gamma_{n1/2}^p}}{\sqrt{\Gamma_{n1/2}^p + \Gamma_{n3/2}^p}} = \frac{\gamma_{n1/2}^p}{\sqrt{\Gamma_n^p}} \qquad (1)$$

Here $N_\pm$ are the detector counts for neutrons with opposite helicities at a neutron polarization equal to f_n, n is the target thickness, σ_0 is the resonance cross section in the absence of polarization

$$\sigma_0 = \frac{\pi\lambda^2 g\Gamma_n\Gamma}{(E - E_p)^2 + \Gamma^2/4}$$

and w_{sp} is the matrix element of weak interaction.

According to the model of mixing states with opposite parity, an analogous effect must be in the correlation $(\vec{I}\vec{p})$ where $\vec{I}$ is the nucleus spin. Up to now, however, such experiments have not been carried out. One of the chief reasons is the difficulty in polarizing nuclei in comparison with the polarization of neutrons. The most interesting nucleus for such investigations, as well as for experiments with polarized neutrons and polarized nuclei, is lanthanum. This is connected with the very large PNC effect for this nucleus and with the proposed T-invariance violation study in p-wave neutron resonances.

Here we report the results of the PNC study in a $(\vec{I}\vec{p})$ correlation experiment.

Let us consider the transmission effect of unpolarized neutrons through a longitudinally polarized target on p-wave resonance. We will follow Bunakov and Gudkov [6]. The $(\vec{I}\vec{p})$ correlation was examined by Haase et al. [7] and Vanhoy et al. [8] but for us, it was more convenient to use the total neutron moment presentation which was used in previous papers. The forward scattering amplitude, which is connected with the weak interaction, may be written as a sum of substates multiplied by the population $w(m)$

$$A = \sum_m A_m w(m). \qquad (2)$$

Values $A_m^\pm$ have the form

$$A_m^+ = \frac{\sqrt{2}}{k}\frac{w_{sp}}{(s)(p)}\cdot\frac{\gamma_s^n m}{2I+1}\left(\gamma_{p1/2}^n + \gamma_{p3/2}^n\sqrt{\frac{2I+3}{I}}\right)$$

$$A_m^- = -\frac{\sqrt{2}}{k}\frac{w_{sp}}{(s)(p)}\cdot\frac{\gamma_s^n m}{2I+1}\left(\gamma_{p1/2}^n - \gamma_{p3/2}^n\sqrt{\frac{2I-1}{I+1}}\right), \qquad (3)$$

where k is the neutron wave number, and (s,p) refers to $(E - E_{s,p}) + i\Gamma_{sp}/2$, respectively. Signs $\pm$ refer to the spin of the compound states $I \pm 1/2$. After summation (2) we receive

$$A^{+} = f_N \frac{w_{sp}}{k(s)(p)} \cdot \frac{I\sqrt{2}\gamma_n^s}{2I+1}\left(\gamma^p_{n1/2} + \gamma^p_{n3/2}\sqrt{\frac{2I+3}{I}}\right)$$

$$A^{-} = -f_N \frac{w_{sp}}{k(s)(p)} \cdot \frac{I\sqrt{2}\gamma_n^s}{2I+1}\left(\gamma^p_{n1/2} - \gamma^p_{n3/2}\sqrt{\frac{2I-1}{I+1}}\right) \qquad (4)$$

where f_N is the nuclear polarization. Through the optical theorem we can go to the weak interaction cross section

$$\sigma = \frac{4\pi}{k}\operatorname{Im} A .$$

The experimental effect in the transmission of unpolarized neutrons through a longitudinally polarized target on p-wave resonance for $J=I+1/2$ can be expressed as

$$\varepsilon_N = \frac{N_p - N_a}{f_N\left(N_p + N_a\right)} = n\sigma_0 P_N ,$$

$$P_N = -\frac{2\sqrt{2I}}{I+1} \cdot \frac{w_{sp}}{\left(E_p - E_s\right)} \cdot \sqrt{\frac{\Gamma_n^s}{\Gamma_n^p}} \cdot \left(x + y\sqrt{\frac{2I+3}{I}}\right) \qquad (5)$$

where $y = \gamma^n_{p3/2}\big/\sqrt{\Gamma^p_n}$, n is the target thickness, $N_{a,p}$ refer to neutron detector counts of antiparallel and parallel $\vec{I}$ and $\vec{p}$. Note that $x^2 + y^2 = 1$ is by definition.

In the search for the $(\vec{I}\vec{p})$ correlation it is also useful to find the exact value of matrix element w_{sp}. It is obvious from Eq.(1) that to extract w_{sp} we should know the value and sign of the x-normalized amplitude of the neutron width for the total neutron moment $j=1/2$. Comparison of P_n from Eq.(1) and P_N from Eq.(5) can be made in the form of the ratio

$$\frac{P_n}{P_N} = -\frac{I+1}{\sqrt{2I}} \cdot \frac{x}{x + y\sqrt{(2I+3)/I}} . \qquad (6)$$

It is easy to see that measurement of both correlations $(\vec{I}\vec{p})$ and $(\vec{s}\vec{p})$ make it possible to determine the values of x and y and consequently the matrix element w_{sp}.

2. Measurement of PNC effect with Polarized Lanthanum

The experiment was carried out on the POLYANA installation [9] (Fig. 1). For polarization of *La* nuclei a brute force method was used because there was no other good method for polarization of a large sample (about 2 kg). The investigated metallic lanthanum sample was placed inside a ^3He-^4He dilution refrigerator in the longitudinal magnetic field H=1 T of an iron magnet. The sample of *La* was a set of metallic plates of 10×4.8 cm^2 and thickness 0.9 cm. Six such plates gave a total thickness of n=1.37×10^{23} nucl/cm^2. Transmitted neutrons were detected by a large ^3He ionization detector located 30 m from the IBR-30 pulsed neutron source.

The first measurements showed problems with the target temperature [10]. A very large metallic sample in a magnetic field and in intensive neutron and gamma ray beams had a temperature of about 0.13 K. After improvement of the thermal contact we obtained a temperature about 0.07 K in this present experiment and the nuclear polarization $f_N = 0.0065$.

The total time of measurement was about 100 hours. During this time the direction of nuclear polarization was changed 4 times by switching the current in the magnet.

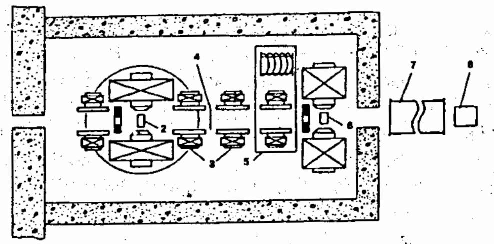

Figure 1. Experimental arrangement of the POLYANA spectrometer. 1 - IBR-30 neutron source, 2 - dynamically polarized proton target, 3 - neutron polarization guide field magnets, 4 - current sheet, 5 - interchangeable magnets of guide field, 6 - polarized lanthanum target, 7 - neutron guides, 8 - neutron detector.

3. Results

The data processing consisted, first, in the extraction of σ_0 for the 0.75 eV resonance by a fit of the transmission spectrum. The neutron source resolution and Doppler broadening were included in σ_0. At that fit, resonance parameters $g\Gamma_n$ = 3.8 × 10^{-8} eV and Γ=0.035 eV were obtained. Then to extract the value of $f_N P_N$ we fitted the transmission effect (5) with the obtained resonance parameters. The transmission effect (5) and fit are shown in Fig. 2. The final result is

$$f_N P_N = (-1.8 \pm 0.5)\cdot 10^{-3},$$

where the accuracy includes both statistical and systematic errors.

Substitution of $P_n = 0.095$ from previous measurements [9] and I=7/2 for *La* into Eq. (6) gives

$$\frac{x}{x + 1.7y} = -0.37 \pm 0.11;\ |x| = 0.42 \pm 0.07,\ |y| = 0.91 \pm 0.03 .$$

These parameters and the value of $w_{sp} \cdot x = 1.67$ meV obtained from P_n measurements gives $w_{sp} = 4$ meV.

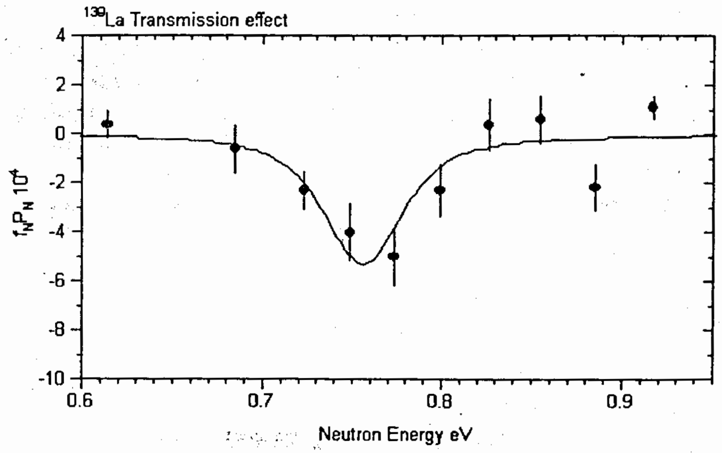

Figure 2. ^{139}La transmission effect and fit

4. Conclusion

In conclusion we should point out that a set of different measurements of neutron interactions with *La* nuclei has been performed at Dubna. Beside parity violating effects in the 0.75 eV p-wave resonance with polarized neutrons, and the above described measurement with polarized lanthanum, we have measured the total *La* cross sections in the 0.5 - 20 eV region and the polarized cross section in polarized neutron transmission through a polarized *La* target [11]. At the present time, we are preparing a new experiment to measure the polarized cross section near the 0.75 eV resonance in polarized neutron transmission through a polarized *La* target to extract x and y with better accuracy.

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5. References

1. V.P. Alfimenkov et al. Pisma Zh. Exp. Teor. Fiz. 34 (1981) 308; 35 (1982) 42
2. V.P. Alfimenkov et al. Nucl. Phys A398 (1983) 93
3. Y. Masuda et al. Nucl. Phys A504 (1989) 269
4. S.A. Birjukov et al. Yad. Fiz. 45 (1987) 1511
5. J.D. Bowman et al. Phys. Rev. Lett. **65** (1990) 1192
6. V.E.Bunakov and V.P.Gudkov Zeitscht. Phys . **303** (1981) 28
7. D.G.Haase et al. Hyperf. Interact. **43** (1988) 127
8. J.R.Vanhoy et al. Zeitscht. Phys . **A333** (1989) 229
9. V.P.Alfimenkov et al. Yad. Fiz. 54 (1991) 1489
10. V.P.Alfimenkov et al. In Proc. of The Second International Workshop on Time Reversal Invariance and Parity Violation in Neutron Reactions. 4 - 7 May, 1993, Russia (World Scientific, Singapore, 1994) 84
11. V.P.Alfimenkov et al. Yad. Fiz. 57 (1994) 1926

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