Parity-violating asymmetry in the reactions $^6\text{Li}(n, \alpha)^3\text{H}$ and $^{10}\text{B}(n, \alpha)^7\text{Li}^* \rightarrow ^7\text{Li} + \gamma$

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Abstract We present two experiments measuring the parity-violating asymmetry (P-odd) of tritons emission in the reaction $^6\text{Li}(n, \alpha)^3\text{H}$ and $\gamma$-quanta emission in the reaction $^{10}\text{B}(n, \alpha)^7\text{Li}^* \rightarrow ^7\text{Li} + \gamma$ with polarized cold neutrons, aiming at estimation of the weak meson-nucleon coupling constants. These experiments started in the PNPI, Gatchina and continued in the ILL, Grenoble. We describe an integral method to measure P-odd asymmetry and the two experiments. The results of our measurements are: $\alpha^{6Li}_{P-odd} = (-8.8 \pm 2.1) \cdot 10^{-8}$ and $\alpha^{10B}_{P-odd} = (0.8 \pm 3.9) \cdot 10^{-8}$.

Keywords Slow neutrons · Weak interaction · Neutral currents

1 Introduction

The nucleon-nucleon (NN) weak interaction in nuclei is the only feasible way to study quark-quark neutral currents at low energy [1]. The conventional framework for its analysis has been a meson exchange model developed by Desplanques, Donoughue, and Holstein (DDH) [2, 3]. The parity violating (PV) NN interaction is described in this model by exchange of the lightest mesons: $\pi$, $\rho$, $\omega$. The strength of interaction is governed by six weak coupling constants: $f_\pi^2(h^0_{\pi})$, $h^0_{\rho,1,2}$,
$h^0_{\omega}$; superscripts denote isospin; the isovector couplings correspond to the neutral weak interaction. Significant contribution of the $f_\pi$ term to PV NN effects is expected at low energy. The objective of decades-long studies was to measure the weak meson-nucleon coupling constant; thus, one would link the meson-exchange mechanism with underlying physics. The field is overviewed in [4–6]. The observation of parity violation in proton-proton scattering is a manifestation of the charged weak current [7, 8]; the isoscalar couplings $h^0_\rho$, $h^0_\omega$ agree with the DDH “best values”. On the other hand, data on $f_\pi$ constant are discrepant: the DDH “best value” of $f_\pi$ is $4.6 \cdot 10^{-7}$; the $f_\pi$ obtained from $\gamma$-decay of $^{18}$F is compatible with zero ($-1.0 \cdot 10^{-7}$ $\leq f_\pi \leq 1.2 \cdot 10^{-7}$) [9, 10]; analysis of the $^{133}$Cs anapole moment [11] results to a value different from zero by several standard deviations ($f_\pi \approx 9 \cdot 10^{-7}$). In order to clarify the situation, one needs more relevant data. However, a number of points complicate the study. Thus, PV effects for bare nucleons and few-nucleon systems are small. In the situation, one needs more relevant data. However, a number of points complicate the study. Thus, PV effects for bare nucleons and few-nucleon systems are small.

Reactions with light nuclei ($A = 6 – 10$) look most promising to study the weak NN processes. Such nuclei can be described in the framework of cluster and multi-cluster models, if the excitation energy is $< 25 – 30$ MeV. Then the interaction of neutrons with them is considered as a few-nucleon reaction, influenced by the potential of one or a few $\alpha$-particles; thus the problem can be formulated in terms of constants of the meson-nucleon interaction. We investigate the P-odd asymmetry in the reactions $^6$Li$(n, \alpha)^3$H (asymmetry of triton emission) and $^{10}$B$(n, \alpha)^7$Li*, $^7$Li* $\rightarrow$ $^7$Li + $\gamma$ ($E_\gamma = 0.48$ MeV) (asymmetry of $\gamma$-quanta emission). The P-odd asymmetry coefficient for triton emission in $^6$Li$(n, \alpha)^3$H was calculated in [12] in terms of the $f_\pi$ and $h^0_\rho$ constants: $\alpha^{\text{P-odd}}_{^6\text{Li}} \approx -0.45 f_\pi + 0.06 h^0_\rho = -2.8 \cdot 10^{-7}$. The P-odd asymmetry coefficient for emission of $\gamma$-quanta in the reaction $^{10}$B$(n, \alpha)^7$Li*, $^7$Li* $\rightarrow$ $^7$Li + $\gamma$ was calculated in [13]: $\alpha^{\text{P-odd}}_{^{10}\text{B}} = 0.16 f_\pi - 0.028 h^0_\rho - 0.009 h^1_\rho - 0.014 h^0_\omega - 0.014 h^1_\omega \approx 1.1 \cdot 10^{-7}$. Here, the DDH “best values” are used for numerical estimates.

A measurement of the asymmetry coefficients for these two reactions would allow us to derive constants corresponding to the neutral and charged current interactions.

2 Experimental technique

In order to collect $> 10^{16}$ events for reasonable time and to suppress eventual false effects we used an integral method of the P-odd asymmetry measurement proposed by Lobashev [14, 15] and developed in the PNPI [16–18]. The experiments were performed using the high intensity polarized cold neutron beam at the PF1B (ILL, Grenoble, France). The total flux of polarized neutrons was equal $(4 – 5) \cdot 10^{10}$ s$^{-1}$. Further beam characteristics can be found in [19].

Incident neutrons were mainly absorbed in the samples providing count rate of $\approx 10^{10}$ s$^{-1}$. Resulting current in the detector circuit was proportional to the energy deposited by secondary particles averaged over the accepted emission angles. The spin direction of polarized neutrons was periodically inverted by an adiabatic spin flipper [20]. If the P-odd asymmetry exists, the output signal is modulated with the flipper switching frequency. Hence, the P-odd asymmetry is equal $\alpha = (I_+ - I_-)/(I_+ + I_-)$, where $I_\pm$ is the detector current for different neutron spin directions.