Search for P-odd asymmetry in the α emission in the capture of polarized thermal neutrons by ^{6}Li and ^{10}B nuclei

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Measurements by an integral method in a geometry ruling out an effect of a P-even left-right asymmetry have yielded limitations on the magnitude of the P-odd asymmetry in several reactions: $|a_p| < 1.4 \times 10^{-6}$ for the reaction ^{6}Li$(n,\alpha)^3$H, $|a_p| < 8 \times 10^{-6}$ for the reaction ^{10}B$(n,\alpha_0)^7$Li, and $|a_p| < 1.5 \times 10^{-6}$ for the reaction ^{10}B$(n,\alpha_1)^7$Li* (90% confidence level).

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A search was made in Refs. 1 and 2 for a P-odd correlation between the momentum of the α particle and the spin of the polarized thermal neutron in (n,α) reactions in ^{6}Li and ^{10}B nuclei: $W \sim 1 + a_p(\mathbf{s}_n, \mathbf{p}_\alpha)$, where $\mathbf{s}_n$ and $\mathbf{p}_\alpha$ are the unit vectors along the neutron polarization direction and along the momentum of the α particle. A P-even left-right asymmetry was observed: $W \sim 1 + a_{RL}\ \mathbf{s}_n \times [\mathbf{p}_n, \mathbf{p}_\alpha]$ (where $\mathbf{p}_n$ is a unit vector along the neutron momentum). The beam in these experiments was transverely polarized. If the polarization axis deviates from the direction toward the detector, the projection of a left-right asymmetry could imitate a P-odd asymmetry. The uncertainty in the orientation of the polarization axis, $\lesssim 3°$, places a limit on the order of 10^{-5} on the sensitivity to a P-odd asymmetry.

In the present experiments the background left-right asymmetry was suppressed further by taking the measurements with a longitudinally polarized beam, with 10 targets and 40 detectors along the beam axis (Fig. 1). In this geometry the detectors are relatively insensitive to a left-right asymmetry, and the magnitude of this asymmetry was suppressed further by orienting the polarization axis parallel to the beam axis ($\mathbf{s}_n \parallel \mathbf{p}_\alpha$) within an angle of less than 1°.

As in the earlier experiments, the detectors were gas-filled proportional chambers with wire electrodes. The gas pressure and the distance from the target to the detector were chosen for complete absorption of the heavy reaction products over this gap. The detectors, operated in an integrating regime, detected only the light reaction parts. The sensitive volume of each detector was partitioned into two parts; the outer part detected (in the study of the reaction $n + {}^{10}$B) only the α_0 line, which corresponds to the production of the ^{7}Li nucleus in the ground state, while the inner part detected a mixture of the lines α_0 and α_1, which are associated with the production of the ^{7}Li nucleus in an excited state (0.48 MeV), by analogy with Ref. 2. In the study of the reaction $n + {}^6$Li, the two volumes were combined.

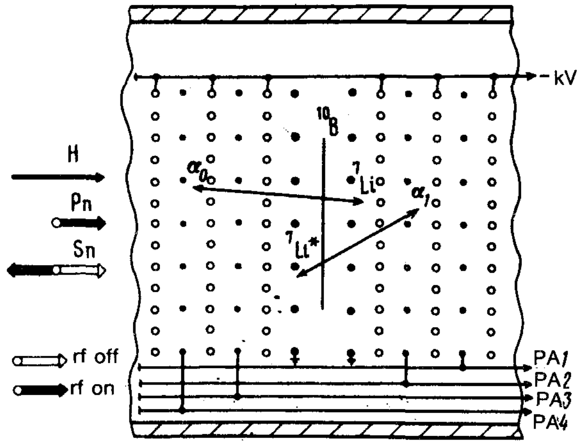

FIG. 1. One of the ten detecting modules in a common housing. The ^{10}B target is at the center. Open circles—High-voltage potential electrodes defining the sensitive volumes; points—signal electrodes [the corresponding electrodes are connected in parallel, and the resultant signal is fed to a single preamplifier (PA]; filled circles—electrodes of the purifying field. Shown at the left is the direction along which the neutron bema is incident and the neutron polarization direction with the rf field of the flipper turned on for the indicated direction of the guiding magnetic field H.

The measurements were carried out in the beam of polarized thermal neutrons from the VVR-M reactor at the Leningrad Institute of Nuclear Physics; the beam intensity was $6 \cdot 10^7$ n/s. The measurement procedure was similar to that of Ref. 2. We used synchronous detection of the changes in the current flowing through the proportional chambers upon a change in the sign of the polarization of the neutron beam. The beam polarization was changed by an adiabatic rf flipper, so that it was possible to independently change the sign of the observed effect while changing the direction of the static guiding magnetic field in the target region. Spurious effects associated with the operation of the flipper were eliminated by subtracting the results measured for two directions of the guiding field, thereby doubling the effect of interest. To cancel the fluctuations in the intensity of the neutron beam, a signal proportional to the reactor power was subtracted during the data analysis.

The ^{6}Li targets were ^{6}LiF films 3.5 mg/cm^2 thick deposited on an Al substrate 5.5 μm thick. The target surface was covered with a second similar foil. Targets of elemental ^{10}B were synthesized by deposition on a Ti substrate. In the first series of measurements we used six Ti(100)-B(120)-Ti(100) targets; in a second series we used ten Ti(200)-B(160)-Ti(20)-B(160)-Ti(200) targets (the numbers in parentheses are the film thickness in micrograms per square centimeter). The detector was filled with a mixture Ar + 15% CO_2 to a pressure of 1.7 ata in the experiments with ^{6}Li or with a mixture of He + 5% Ar + 5% CO_2 in the experiments with ^{10}B.

The contribution of the α_0 line to the mixture of the α_0 and α_1 lines detected by the detectors (in the reaction in ^{10}B) was determined by calculations based on the measured ratio of currents produced by α particles in the inner and outer detectors. We also subtracted a correction for the finite size of the detectors. The results of these calculations were compared with the magnitude of the left-right asymmetry measured during bombardment of one of the targets by a vertically polarized beam, directed perpendicular to the chamber axis.

Measurements were carried out in three 10-day cycles—one cycle with the ^{6}Li target and two with the ^{10}B target.

For the coefficient of the P-odd asymmetry in the reaction $^6\mathrm{Li}(n,\alpha)^3\mathrm{H}$, taking into account the correction for the solid angle of the detector, $\langle \cos\theta \rangle = 0.86$, and that for the degree of polarization of the neutron beam, $P_n = 0.95$, we find the value $0.07 \pm 0.80 \times 10^{-6}$ or $|a_p|(^6\mathrm{Li})| < 1.4 \times 10^{-6}$ (90% confidence level).

The P-odd asymmetry in the reaction $^{10}\mathrm{B}(n,\alpha_{0,1})^7\mathrm{Li}$ was measured in two cycles. In the last cycle we doubled the winding density of the potential electrodes which defined the sensitive volumes in the detectors in order to improve their screening properties. In the first cycle the contribution of the α_0 line to the current in the outer and inner detectors was 0.57 and 0.12; in the second cycle, it was 0.90 and 0.14, respectively. In each case we determined the asymmetry coefficients for each α-particle line from the measurements in both groups of detectors. After making corrections for $\langle \cos\theta \rangle$, we found the weighted-average values $a_p^0(^{10}\mathrm{B}) = 0.21 \pm 0.34 \cdot 10^{-5}$ and $a_p^1(^{10}\mathrm{B}) = 0.35 \pm 0.68 \times 10^{-6}$ or $|a_p^0(^{10}\mathrm{B})| < 8 \times 10^{-6}$ and $|a_p^1(^{10}\mathrm{B})| < 1.5 \times 10^{-6}$ (90% confidence level).

These results are in approximate agreement with the lower limit of the estimate $a_p \sim 10^{-5}$–10^{-6} found in Ref. 3. The accuracy of the present experiments is limited by the intensity of the neutron beam.

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