Study of neutron-nuclear spin correlation terms with a polarized xenon target

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1. Introduction

A xenon (Xe) is interesting to measure a correlation term $\boldsymbol{s}\cdot\boldsymbol{I}$ of a neutron spin $\boldsymbol{s}$ and a target nuclear spin $\boldsymbol{I}$ with a polarized Xe target for a verification of a neutron optical theorem (NOPT). It has been observed the large parity non-conserving (PNC) effect at the p-wave resonance in neutron-nuclear reactions, and it polarizes up to 10^{-2}–10^{-1} at pressures of 10^{-1}–10^{0} atm by using a spin exchange optical pumping (SEOP) method. We plan to measure the neutron polarizing ability, spin dependent cross section and neutron spin rotation with polarized Xe, which are predicted to depend on neutron energy E_n strongly around resonance peaks. As the first step, we would measure the neutron polarizing ability at a 9.6 eV s-wave resonance peak of ^{129}Xe when unpolarized neutrons transmit through the polarized Xe cell.

2. Experiment

Fig. 1 shows the experimental apparatus in BL10. Pulsed neutron beams transmit through collimators, the Xe cell, a metal foil, and are counted by a position sensitive neutron detector (PSND) placed at 14.5 m position apart from the neutron source. For obtaining high count rates, the PSND consists of a Li glass scintillator and multi-anode photomultiplier tube (MAPMT) having 16×16 pixels with a 3×3 mm^2 pixel size. The metal foil is used to compensate time fluctuations of the detector by referring to a 5.2 eV resonance peak of ^{109}Ag. A ratio R between neutron transmissions with the polarized and unpolarized Xe cell is expressed as $R = \cosh(N\sigma l\rho P)$, where N, σ, l, P, and ρ denote a number density, neutron cross section, thickness, polarization and spin dependent parameter of Xe. The Xe cell is polarized by utilizing a SEOP system, where Xe gas is contained in a cylindrical glass cell with N_2 gas and Rb. Atomic spins of Rb are polarized by a resonance absorption of circularly polarized laser light, and Xe nuclear spins are polarized by spin exchange with polarized Rb atoms. Temperature inside an Al oven is kept between 340 K and 380 K for obtaining Rb vapor. The Xe polarization P is monitored by nuclear magnetic resonance (NMR) system.

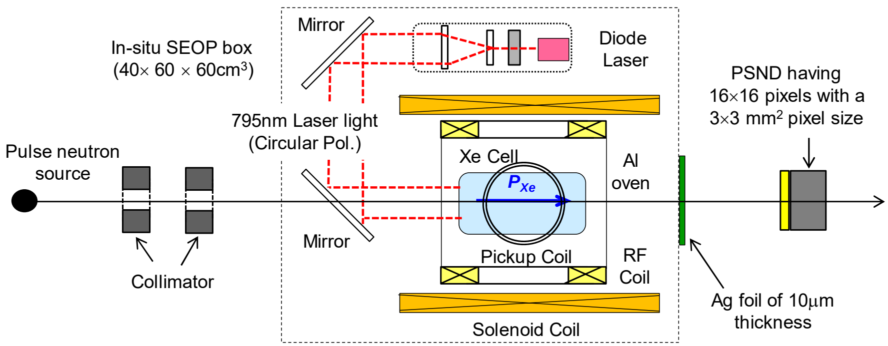

Fig. 1. Experimental apparatus for detecting neutron polarizing ability of Xe

3. Results

In the previous experiment of 2016B0146, we measured the ratio R $(=T_P/T_{U0})$ between neutron transmissions with the polarized cell at 343 K and unpolarized cell at room temperature, denoted by T_P and T_{U0}, with a cylindrical cell (cell-I) in 2.5 cm diameter and 5 cm long and containing the natural Xe gas of 3 atm pressure, and $\Delta R(=R-1)\approx 10^{-2}$ was obtained at the resonance peak of ^{129}Xe preliminary. In analyzing process, however, we noticed that it might be caused by the Doppler broadening (DB) effect due to temperatures difference between T_P and T_{U0} measurements. In the experiment of 2017B0016, three type transmissions were measured with the polarized and unpolarized cell at 358 K, and the unpolarized cell at room temperature, denoted by T_P, T_U and T_{U0}. We used another cell (cell-II) in 3.5 cm diameter and 10 cm long and containing the enriched ^{129}Xe gas of 1 atm which was predicted to be higher P because decrement of Xe gas pressure suppresses increment of Rb spin destruction due to effect of binary collisions. Fig. 2 (A), (B) and (C) represent T_U, T_{U0} as a function of neutron flight time t, and the ratio $R_D(=T_U/T_{U0})$ zooming in the 9.6 eV resonance peak along t axis. Fig. 3 (A), (B) and (C) represent T_P, T_U and $R_P(=T_P/T_U)$ zooming in the resonance peak. The shape of R_D having dips at both sides of the peak should be caused by the DB effect due to temperature difference. In contrast, the shape of R_P couldn't be explained by the DB effect only because it didn't have dips and both of T_P and T_U were measured at same temperature. Although a new NMR system for the cell-II operated in this experiment, P could not be decided by NMR signal because the NMR system had not been calibrated yet. If ΔR_P $(=R_P-1)\approx 0.02$ in Fig. 3 (C) is caused by P, the value of P would be 0.3 or 0.1 by assuming total angular momentum J=1 or J=0.

4. Conclusion

We noticed that $\Delta R \approx 10^{-2}$ obtained with the cell-I in the previous experiment might be caused by the DB effect due to temperature difference. For demonstrating it, R_D and R_P were measured with the cell-II. The shape of R_D in Fig. 2 (C) was consistent roughly with evaluation by the DB effect. In contract, we consider that the shape of R_P in Fig. 3 (C) should be caused by P. Although we also attempted to measure R_D and R_P with the cell-I and its calibrated NMR system for checking the previous result, enough statistics couldn't be obtained because beam operation terminated more than half a day during this measurement. Preparation for verifying the values of R_P are in progress.

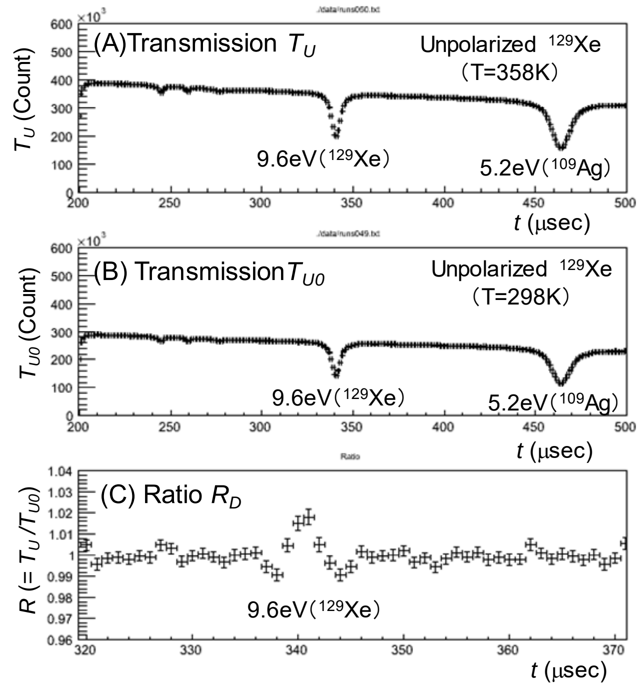

Fig. 2 (A) T_U and (B) T_{U0} with unpolarized Xe at 358 K and 298 K as a function of t, and (C) R_D $(=T_U/T_{U0})$ zooming in 9.6 eV resonance peak along t axis.

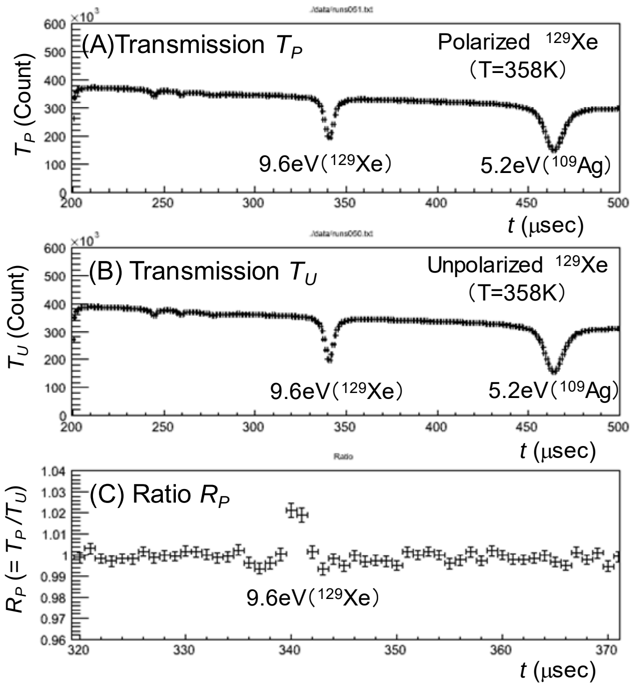

Fig. 3 (A) T_P (B) T_U with polarized and unpolarized Xe at 358 K, as a function of flight time t, and (C) $R_P(=T_P/T_U)$ zooming in 9.6 eV resonance peak along t axis.