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Measurement of angular correlation of (n,gamma) reaction with polarized neutrons

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Large enhanced P violation in a nuclear resonance reaction has been observed by using a polarized neutron beam. Enhanced CP violation is predicted to exist within the same nuclear reaction. We are now preparing to supply a polarized neutron beam for a CP violation search experiment. In the enhancement process of CP violation, we assume that the P violation of the compound nuclear state doesn't depend on the final state. However this assumption has not been verified yet. We plan to verify the assumption by measuring the ^{139}La(n,γ) reaction with a polarized neutron beam at J-PARC MLF BL04. The supplied neutron beam will be polarized by using ^{3}He spin filter, which will be installed into BL04. We present the states of development for ^{3}He spin filter and study of the equipment in BL04.

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1. Motivation

The current universe cannot be understood by CP violation in standard theory. We aim to search for CP violation in compound nuclei. When neutrons are incident on target nuclei, the scattering amplitude can be described as

$$f = A + B\sigma \cdot \hat{I} + C\sigma \cdot \hat{k} + D\sigma\left(\hat{I} \times \hat{k}\right) \tag{1.1}$$

where σ and $\hat{k}$ are the neutron spin and momentum, $\hat{I}$ is nuclear spin of the target. D $\neq 0$ suggests CP violation via CPT theorem. To measure P violation, polarized neutrons and a non-polarized target are needed, while a CP violation measurement requires both the neutrons and target to be polarized. Fig.1. shows the concept of measurement of P- and CP violation. P violation enhanced by 10^6 times has been observed in compound nuclear reactions. If enhancement of P violation occurs in the nucleus, the CP violation is also enhanced. It is given as

$$\Delta\sigma_{\mathrm{CP}} = \kappa(J)\frac{W_{\mathrm{T}}}{W}\Delta\sigma_{\mathrm{p}} \tag{1.2}$$

where $\Delta\sigma_{\mathrm{CP}}$ and $\Delta\sigma_{\mathrm{P}}$ are the CP- and P violating cross section, and W_{T} and W express the CP- and P violating matrix elements. The $\kappa(J)$ is an enhancement factor[1]. It is necessary to precisely measure P violation as a pre-measurement step for CP violation.

Figure 1: Conceptual diagram of measurement of P- and CP violation

2. P violation measurement

We will measure the P violation in nuclei with the highest precision by using high a intensity neutron beam at J-PARC on BL04. ^{139}La with low neutron resonance energy and large asymmetry is used for the target nucleus. The energy of the p-wave resonance of ^{139}La is $(7.5 \pm 0.1) \cdot 10^{-1}$ eV and asymmetry of cross-section is $(7.3 \pm 0.5) \cdot 10^{-2}$[2]. Highly polarized neutron and optimum target thickness are required. According to the theory of compound nuclei [3], it is thought that P violation occurs without depending on the final state, yet there is no example verified. This verification is also important in showing the validity of the compound nucleus model. By further increasing the statistics, it becomes possible to measure the final state dependence of P violation. In order to measure this, it is necessary to detect gamma rays emitted by the (n,γ) reaction.

3. Experimental setup

First, unpolarized neutrons are polarized with a ^{3}He spin filter from the beam line upstream. After that, polarized neutrons irradiate the target. At that time, gamma rays emitted by (n,γ) reaction are measured with 4π germanium detectors, and the neutrons transmitted through the target is measured with a transmission detector. Fig.2. shows this experiment setup.

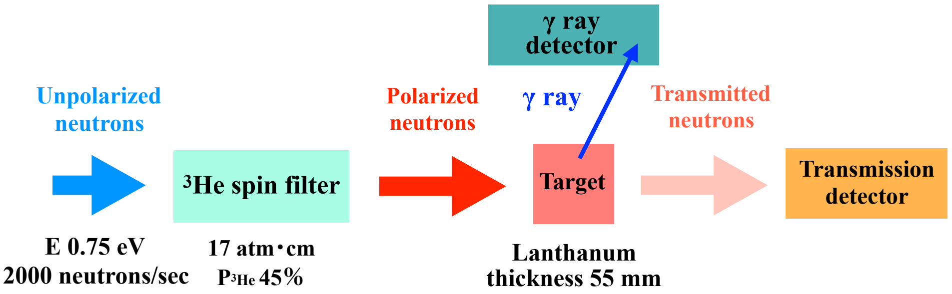

Figure 2: Setup for P violation measurement

4. Estimation

When we try to measure P violation, the optimum thickness of the target is determined by the cross-section and the polarization ratio of the neutrons. Fig.3. shows the relationship between the thickness of lanthanum and required neutrons when P violation is measured with an accuracy of 10%. Fig.3. shows that when the thickness of the target is small, it is difficult for neutrons and target nuclei to interact with each other, and thus many neutrons are required, while as the target becomes thicker, the amount of permeation decreases and it is difficult to accurately measure the asymmetry. Table1. shows experimental conditions. The optimum thickness of lanthanum is 55 mm when P violation is measured with an accuracy of 10%. However, when we use a thick lanthanum like this, we measure a blurred angular distribution due to scattered neutrons in the target. Therefore, it is considered good to use as thin of a target as possible.

Neutron intensity	2000 neutrons/sec
Polarization of ^{3}He	45%
Neutron polarization	20%
Neutron transmission	65%
Effective thickness	17 atm cm

Table 1: Parameters in the experiment

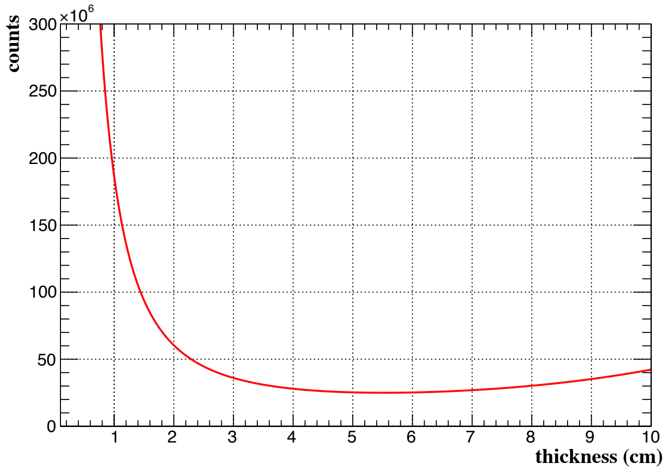

Figure 3: Relationship between ^{139}La thickness and required neutrons

5. Conclusion

Final state dependence of P violation has not been measured yet. In the case of ^{139}La, it takes 3.5 hours beam time to measure the asymmetry with an accuracy of 10%. The optimum target thickness is 5.5 cm. In addition, when discussing the final state dependence, we need to consider the effect of scattering.

6. Acknowledgments

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