Demonstration of nuclear gamma-ray polarimetry based on a multi-layer CdTe Compton Camera†

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The systematic study of nuclear levels with spin-parity assignments is essential to understand structural changes of nuclei. Linear polarization measurements have been applied to determine the electromagnetic character of γ-ray transitions, however the measurements have been limited due to the low efficiency of Compton polarimeters. The multi-layer cadmium-telluride (CdTe) Compton camera[1,2] can be a highly efficient γ-ray polarimeter with high position sensitivity and detection efficiency.

In the present work, we demonstrated γ-ray polarimetry using a multi-layer CdTe Compton camera by using partially polarized 847-keV γ-rays produced by the inelastic reaction of ^{56}Fe(p, $p'\gamma$). The schematic of the measurement is shown in Fig. 1. An iron foil of 10 μm was irradiated with the 3.0-MeV proton beam provided by the RIKEN Pelletron accelerator.[3] The detector was placed perpendicular to the beam axis, where the high degree of polarization is expected. The distance between the target and the front side of the first layer was set to 18.0 cm. In order to obtain the reference data, a segmented Ge detector (CNS-GRAPE[4]) was placed on the opposite side of the Compton camera.

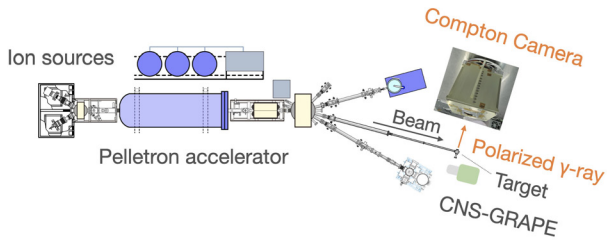

Fig. 1. Schematic view of the experimental setup.

The degree of polarization (P) of incoming γ-rays was determined by comparing the azimuthal angular distributions of the measurement and simulated calculation. The modulation curve for the 847-keV γ ray is shown in Fig. 2. The curve was obtained by taking the ratio of the measured- and the simulated-azimuthal angular distribution with the obtained degree of polarization. The curve was fitted with the function $A(1 + Q' \cos 2(\phi - \phi_0))$, where A, Q', and ϕ_0 are the fitting parameters. Q' is called modulation factor, which is proportional to the degree of polarization.

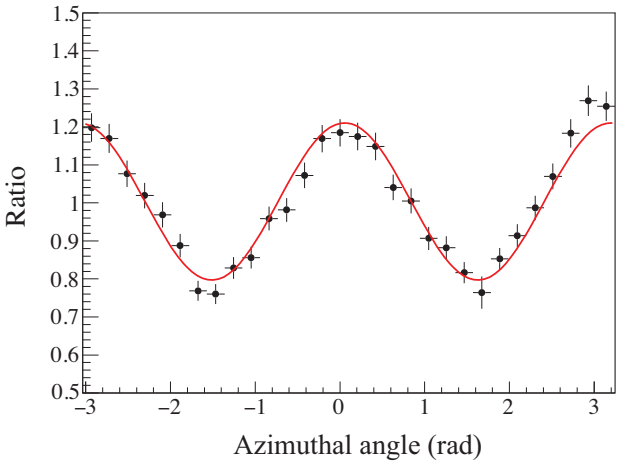

Fig. 2. Modulation curve for the 847-keV γ-ray transition. The black dots and red line correspond to the experimental data and the fitted line.

In the present work, we obtained $Q' = 0.203(9)$ with $P = 0.57(4)$. The polarization sensitivity for 100% polarized photons was estimated to be $Q = Q'/P = 0.35(4)$ at 847 keV. The remarkably high sensitivity and high-detection efficiency are expected to play an important role for γ-ray polarimetry in nuclear spectroscopy.

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