Highly-efficient γ-ray linear polarization measurement by multi-layer CdTe Compton Camera

S. Go,[*1] Y. Tsuzuki,[*2,*3,*1] Y. Ichikawa,[4,*1] T. Ikeda,[*1] N. Imai,[*5] K. Imamura,[*1] M. Niikura,[*1] D. Nishimura,[*6,*1] R. Mizuno,[*2,*1] S. Takeda,[*3,*1] H. Ueno,[*1] S. Watanabe,[*7,*3,*1] T. Y. Saito,[*5] S. Shimoura,[*5,*1] S. Sugawara,[*6,*1] A. Takamine,[*1] H. Yoneda,[*1] and T. Takahashi[*2,*3,*1]

Linear-polarization measurements of photons are typically applied to determine the electromagnetic character of gamma-ray transitions. However, the measurement has not been applied in the wide range of nuclei because it needs to measured the azimuth and polar scattering angle of Compton Scattering events. As for the performance for the polarimeter, a figure of merit was proposed as:[1)]

$$F = \epsilon Q^2, \tag{1}$$

where ϵ is the efficiency of the detector to measure Compton-scattering events and Q is the polarization sensitivity of the polarimeter. The development of the γ-ray polarimeters which has a sufficient figure of merit is important for the linear polarization measurements on rare isotopes.

Therefore, we implement a multi-layer semiconductor Compton Camera,[2,3)] which has been developed originally for the X- and gamma-ray observatory in space, for the linear polarization measurement. The detector consists of 20-layer pixelated cadmium telluride. The thickness of each layer is 0.75 mm and the effective area of 51.2×51.2 mm^2 is pixelated into 16×16. The detector measured the intensity distribution of Compton-scattering events of γ ray as a function of azimuth angle.

To demonstrate the capability of measuring the linear polarization for sub-MeV γ-ray, the experiment was conducted at the RIKEN Pelletron facility in May 2022. The performance as a polarimeter was investigated with polarized γ-ray.[4)] The iron target foil of 10 μm was irradiated with the proton beam energy around 3.1 MeV. The first excited 2^+ state of ^{56}Fe was populated by the proton inelastic reactions. The azimuth angle distribution of 847-keV γ ray were measured by the detector placed at 90° degrees to the beam direction. The segmented Ge detector (CNS-GRAPE[5)]) with a lead collimator was also placed at 90° to the beam direction to measure the axial asymmetry of scattered radiation as described in Ref. 6).

The intensity distribution of Compton scattering events as a function of azimuth angle obtained by the Compton Camera is shown in Fig. 1. The curve was obtained by calculating the ratio of the experimental and simulated azimuth angle intensity for polarized and unpolarized photons, respectively. The known electric character of the γ-ray was successfully confirmed. Further analysis to quantify the polarization sensitivity and figure of merit of the polarimeter is in progress.

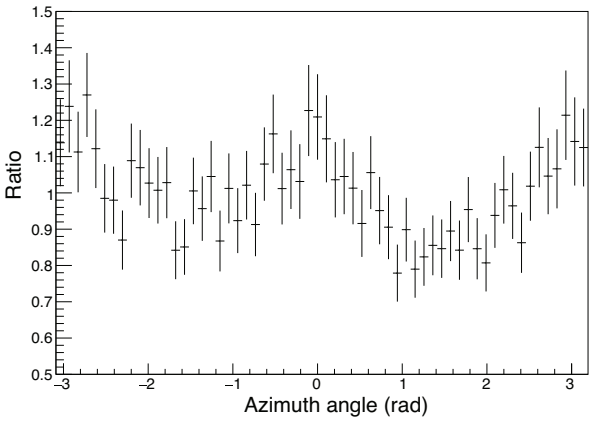

Fig. 1. Intensity distribution of Compton scattering events of the 847-keV γ-ray as a function of azimuth angle.

References

1) B. A. Logan *et al.*, Nucl. Instrum. Methods Phys. Res. **108**, 603 (1973).
2) T. Takahashi, Nucl. Phys. B (Proc. Suppl.) **134**, 191 (2004).
3) S. Watanabe *et al.*, Nucl. Instrum. Methods Phys. Res. A **505**, 118 (2003).
4) J. Simpson *et al.*, Nucl. Instrum. Methods Phys. Res. **204**, 463 (1983).
5) S. Shimoura *et al.*, Nucl. Instrum. Methods Phys. Res. A **525**, 188 (2004).
6) P. A. Butler *et al.*, Nucl. Instrum. Methods Phys. Res. **108**, 497 (1973).

*1 RIKEN Nishina Center
*2 Department of Physics, University of Tokyo
*3 Kavli Institute for the Physics and Mathematics of the Universe, Institutes for Advanced Study
*4 Department of Physics, Kyushu University
*5 Center for Nuclear Study, University of Tokyo
*6 Department of Physics, Tokyo City University
*7 Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency