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Measurement of Scattering Azimuthal Distribution of Polarized Gamma-Rays in Compton Scattering Using GAGG(Ce) Scintillator

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Recently, the measurement of gamma-rays polarization has increasingly become important for applications in various fields such as astrophysics measurements and medical imaging. One common method of gamma-rays polarization measurement is utilizing the formula of differential cross section in Compton scattering, $d/d = A + Bcos(2)$, where represents the scattering azimuth angle from polarization direction of gamma-rays, and others are constant values. In this study, we fabricated the gamma-rays polarization detector using $\mathrm{Gd_3(Ga,\,Al)_5O_{12}(Ce)}$ scintillator, in short GAGG, and measured the gamma-rays polarization in MeV range based on this method, assessing modulation and accuracy of this detector. The detector mainly consists of scatterer and absorber, each of which use GAGG array. This GAGG array is pixelated 8×8 with a single pixel size of 2.5 mm × 2.5 mm and a pitch of 0.7 mm. We used 1 piece of GAGG array with 4 mm thickness for scatterer, and 8 pieces with 9 mm thickness for absorber, and attached Multi-Pixel Photon Counter (MPPC) array on each GAGG array. In order to detect scattering azimuth angle, these 8 set of GAGG-MPPC arrays in absorber were placed 5 cm away from the scatterer in a circular pattern parallel to it. For polarized gamma-rays irradiation to scatterer, we used B1LU beamline in Ultraviolet Synchrotron Orbital Radiation Facility (UVSOR) with 6.6 MeV energy, which can control gamma-rays polarization. We irradiated 0°, 45°, 90°, and circular polarization gamma-rays to the center of the scatterer and acquired data on energy and location from MPPC via our FPGA and electric circuit system. Then we calculated the scattering azimuthal distribution and fitted with cosine function. As a result, the modulations, defined as $(N_{max} - N_{min})/(N_{max} + N_{min}\ )$, for 0°, 45°, 90° polarization were respectively 2.85%, 2.48%, 2.84%, which were close to the simulated result in Geant4, 1.71%, 1.59%, 1.94%. Also, we got relatively low phase errors from theoretical values as 4.11°, 4.19°, 13.2°. In summary, developed detector successfully detects the gamma-rays polarization and shows potential for the application especially in MeV range.

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