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Measurement of angular correlations in positronium decay using GaGG scintillator matrices with single-side readout by silicon photo-multipliers

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Gamma-ray polarization is of prime interest in many areas of physics. One particular is biomedical imaging with positron emission tomography (PET). Two orthogonally polarized, entangled gamma-rays are emitted in an event of para-positronium annihilation thus they are strongly correlated. When they undergo Compton scattering, the initial correlation dominantly results in their orthogonal azimuthal scattering. This correlation can be used in PET as an additional criterium for distinguishing a true coincidence event from the background where such correlation is lacking. In a previous study we showed a moderate azimuthal correlation could be observed via Compton scattering in system of two 4x4 Lutetium Fine Silicate (LFS) scintillation matrices. The goal of the present study is to increase the detector sensitivity to azimuthal correlation, where one of the important parameters is the energy resolution. Hence, we measured azimuthal correlations of annihilation quanta with two 8x8 matrices of Gadolinium Aluminum Gallium Garnet doped with Cerium (GaGG:Ce). Each detector matrix contains 64 crystals of size 3 mm x 3 mm x 20 mm and it is read-out by a single Silicon Photo-multiplier (SiPM) array, with one SiPM matching one pixel. The studied single-side readout concept keeps the modules compact and cost-efficient on a large scale. Coincidence events were recorded using a Na-22 source placed between the modules and the mean energy resolution at 511 keV was 9.7% ± 0.5% and 11.3% ± 0.7% for the two modules, respectively. We clearly identified and reconstructed the Compton scattering events and we observe the excess of orthogonally scattered gammas over the ones with the parallel azimuthal angles. We present the measured azimuthal modulation factors for several kinematic selection criteria and different inter-pixel distances and we compare them to previous findings with 4x4 LFS scintillators. Finally, we discuss the perspective of using the presented concept in PET.

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