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Implementation of the annihilation gamma-ray polarizations in Positron Emission Tomography

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Positron emission tomography (PET), is a profound imaging technique that exploits features of positron annihilation, where two back-to-back gamma photons emitted with 511 keV energies are detected in coincidence. In the current PET systems, only the photoelectric interaction of the gamma photons is considered, and their Compton scattering is assumed to have a parasitic effect. Since the annihilation photons have orthogonal polarizations, simulations have shown its potential use to improve image quality by suppressing the random background which lacks this correlation. In this way, one could discern true coincidences from false ones and improve the signal-to-noise ratio of the reconstructed image. To test this hypothesis, we developed and commissioned a PET device that utilizes single-layer Compton polarimeters which can reconstruct azimuthal correlations of the annihilation quanta. The single-layer Compton polarimeter detector modules contain scintillator matrices that are read out by silicon photomultipliers. Four such detector modules are mounted on an aluminum ring, capable of rotation around the source. Each detector module consists of four 8x8 crystal (GAGG:Ce and/or LYSO:Ce) matrices with either 2.2 mm or 3.2 mm pitch. Through rotation, they establish 16 trans-axial rings with a total of 1024 pixels. This PET device has been tested with clinically relevant sources at the University Hospital Centre Zagreb. We will report on the device's polarimetric performance and characteristics with various clinical sources and reconstructed images. We shall also discuss the potential use of the Maximum Likelihood analysis method to improve the polarimetric sensitivity of the detectors.

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