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#9-78 Positron Emission Tomography imaging using polarization-correlated annihilation quanta measured by single-layer Compton polarimeters

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Positron emission tomography is an important medical diagnostic tool that exploits the process of positron annihilation with an electron in a patient's tissue, resulting in two gamma-ray photons with 511 keV energy and opposite momenta. The two annihilation photons are also entangled in their polarizations, specifically, their polarizations are mutually orthogonal, a property not yet utilized by conventional PET devices. This property could potentially be used as an energy-independent handle for background noise rejection that lacks this correlation, thus enhancing the image quality. We developed a novel type of PET scanner demonstrator, capable of measuring the correlations in the polarization of the entangled annihilation quanta, offering for the first time the opportunity to test the possibility of image quality and sensitivity improvement with respect to standard devices that are based on photoelectric detection. The scanner consists of four detector modules mounted on an annular construction capable of precise rotation around the annihilation source at different diameters. The detector modules are single-layer Compton polarimeters, consisting of 16x16 square matrices, assembled of four 8x8 matrices of scintillating crystals, either GAGG:Ce or LYSO:Ce, read out by silicon photomultipliers on one side, using the TOFPET2 ASIC read-out system for data acquisition. The crystals are 20 mm long, and detector modules mounted opposite one another have identical matrix pitches of 3.2 mm and 2.2 mm, respectively. This setup allows the emulation of 16 trans-axial PET rings, with the possibility of determining and reconstructing the polarization correlations of the annihilation quanta by measuring their azimuthal Compton scattering angles. The scanner was tested at University Hospital Centre Zagreb with sources with clinically relevant activities: Ge-68 line sources (1.6 mm active diameter, ~45.5 MBq) and small animal NEMA phantom (NU 4-2008, initial activity of Ga-68 ~400 MBq). After data acquisition and analysis, the obtained list-mode data is fed to OMEGA image reconstruction software. The images are reconstructed using the Ordered Subsets Expectation Maximization (OSEM) algorithm and analyzed in MATLAB. We will report on the scanner's properties and present the reconstructed images of Ge-68 line sources and NEMA phantom filled with Ga-68. The results demonstrate it is possible to image sources using only entangled gamma photon pairs which undergo Compton scattering in the detectors. The spatial resolution, evaluated by imaging the Ge-line sources was ~4 mm for the photoelectric events and ~8.5 mm for the polarization-correlated events, respectively. The signal-to-random-background ratio achieved using polarization-correlated events shows an improvement of up to 40% compared to only photoelectric events. We will discuss the potential of further imaging signal-to-background improvements through measurements of the correlated quanta at different activities.

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