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3DΠ: A Novel Total-Body PET Scanner Using Xenon-Doped Liquid Argon Scintillator with SiPM-based Photosensors

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The 3DΠ scanner is a Total-Body (TB), Time Of Flight (TOF), Positron Emission Tomography (PET) imaging device that utilizes silicon photomultiplier-based technology and a Xenon-doped Liquid Argon (LAr) scintillator. The scanner has an axial field-of-view (AFOV) of 200 cm and consists of 9 double-sided concentric rings of SiPM panels. The addition of Xenon doping to the LAr scintillator suppresses the long-lifetime component of the scintillation light, allowing for higher data rates and potentially higher patient doses, if needed for a specific application. This is due to the faster de-excitation process in the LAr-Xenon mixture, which allows for direct energy transfer and emission of Xenon light, compared to traditional fluorescence processes involving wavelength shifters (WLS). Moreover, studies have shown that lowering the operating temperature of SiPMs to match the temperature of LAr significantly reduces the dark count rate within the SiPM.

The 3DΠ scanner project is a medical imaging application of the ongoing research and development efforts of the DarkSide collaboration, which is focused on direct dark matter particle searches using LAr targets. The 3DΠ monte carlo simulation package has been derived from the DarkSide simulation package, which is based on the Geant4 toolkit. The main objective of our study was to evaluate the performance of the 3DΠ scanner using established NEMA NU 2–2018 standards for spatial resolution, sensitivity, image quality, count rate performance, and timing resolution.

The sensitivity of the 3DΠ scanner was measured to be 564.02 kcps/MBq at the center of the scanner. The noise-equivalent count rates (NECRs) were found to be 1.5 Mcps at a concentration of 5.3 kBq/mL, and increased to 3 Mcps at a concentration of 21.2 kBq/mL. The TOF resolution was measured as 160 ps. These preliminary results indicate that the system performance of the 3DΠ scanner is comparable to, if not better than, other commercial scanners.

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