A novel method to enhance Positron Emission Tomography detector performance

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Introduction: Positron emission tomography (PET) systems with time-of-flight (TOF) capability have received significant attention in recent years since they improved images signal-to-noise ratio, allowing lower exposure rates for patients. Current commercial systems (e.g., Biograph Vision Quadra PET/CT (Siemens Healthineers)) achieved a 214 ps timing resolution. Timing resolution of less than 30 ps could further improve imaging quality and accelerate imaging reconstruction. Currently, timing resolution is mainly limited by the optical photon (emitted after a gamma interaction in the crystals system) time spread inside the detectors. Here, we propose a statistical method to mitigate their spread by using the interaction position between the gamma and scintillator using optical Monte Carlo simulations in the opensource software GATE.

Methods: The crystal bulk and optical properties (refractive index, stopping power, scintillation yield, decay time) and geometry influence the optical photon spread before detection. Consequently, we separately tested five different materials, four thicknesses (9, 12, 15 and 18 mm), and one cross-section (3 x 3 mm2). We irradiated the material with 511 keV gammas which emitted either scintillation photons (~40 ns) and prompt Cherenkov photons (~10 ps). We grouped them into different bins according to their depth of interaction (DOI). We tested two bin sizes (1 and 3 mm). Cherenkov detection time stamps in each bin were corrected for the DOI time walk and histogrammed to obtain the DOI-corrected detection time distribution, which was characterized by the full width at half of the maximum (FWHM).

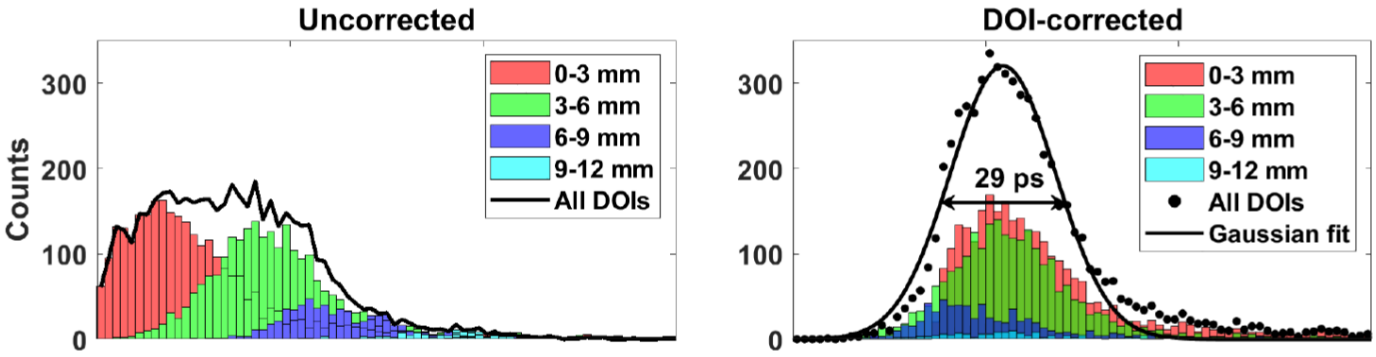

Figure 1: Example of a (left) non corrected and (right) DOI-corrected Cherenkov photons' detection time distribution.

Results: Thanks to the DOI correction, the Cherenkov photons' detection time FWHM was reduced to 26 ps (Figure 1), corresponding to a lower optical time spread. The corrected timing depended on the DOI bin size, scintillator thickness and material properties.

Discussion & Conclusions: DOI corrected Cherenkov photons' timing performance showed promising results and could lead to increased TOF-PET image quality.