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Advanced optical simulation study on the spatial resolution of a thick monolithic PET detector

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The intrinsic spatial resolution of clinical positron emission tomography (PET) detectors is ~ 3 - 4 mm. A further improvement of the resolution using pixelated detectors will not only result in a prohibitive cost, but is also inevitably accompanied by a strong degradation of important performance parameters like timing, energy resolution and sensitivity. Therefore, it is likely that future generation high resolution PET detectors will be based on continuous monolithic scintillation detectors. Monolithic detectors have attractive properties to reach superior 3D spatial resolution while outperforming pixelated detectors in timing, energy resolution and sensitivity.

In this work, optical simulations including an advanced surface reflection model, allow us to investigate the influence of three parameters on the spatial resolution: silicon photomultiplier (SiPM) pixel size, photon detection efficiency and the number of channels used to read out the SiPM array. A lutetium-yttrium oxyorthosilicate (LYSO) crystal with dimensions 50x50x16 mm3 coupled to an SiPM array is calibrated and a nearest neighbor algorithm is used to position events. Findings show that the tested parameters affect the spatial resolution resulting in 0.40 - 0.66 mm full width at half maximum (FWHM). Best resolution could be obtained with smaller SiPM pixels, higher PDE, and an individual channel readout. However, it was shown that combining channels by adding their signals can significantly reduce the amount of readout channels while having small or no significant impact on the resolution. The mean depth of interaction estimation error is 1.6 mm. This study demonstrates the ultimate spatial resolution that can be obtained with this detector without being constrained by practical limitations of experimental setups. In the future these optical simulations may be used as a more precise and fast method to obtain calibration data for real monolithic detectors.

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