Intrinsic depth of interaction resolution study using dual-ended readout of LYSO crystals

Hui Huang[1], Haonan Li[1], Yongfeng Yang[1], Zheng Liu[1]

[1]*Paul C. Lauterbur Research Center for Biomedical Imaging, Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen, China*
Corresponding Author Email: zheng.liu@siat.ac.cn

Depth-of-interaction (DOI) information is essential for mitigating parallax errors in small-diameter, high-resolution PET systems, including small-animal, brain, and breast scanners [1-3]. The objective of this study is to systematically investigate and disentangle the effects of inter-crystal reflector properties, irradiation beam width, and inter-crystal scattering on DOI resolution in dual-ended readout pixelated scintillator detectors, in order to reliably assess the intrinsic DOI performance.

In this work, two high-resolution dual-ended readout PET detector modules based on 28 × 28 LYSO crystal arrays (0.75 × 0.75 × 10 mm^3) were systematically investigated, employing $BaSO_4$ and E60 inter-crystal reflectors, respectively. Crystal identification, energy resolution, and DOI performance were evaluated for both detectors. To disentangle intrinsic detector behavior from external influences, controlled irradiation experiments with varying beam widths were conducted, combined with energy-window selection and inter-crystal scatter rejection. A crystal-wise geometric beam-width correction was further implemented to extract the intrinsic DOI resolution.

Both detectors achieved clear crystal separation across the full array. Within the 400 – 650 keV energy window, the average DOI resolutions were 1.92 mm FWHM with $BaSO_4$ reflectors and 1.75 mm FWHM with E60 reflectors. The measured DOI resolutions under different irradiation beam width and the effectiveness of the correction procedure are illustrated in Fig 1. After successive energy-window selection, inter-crystal scatter removal, and beam-width correction, the intrinsic DOI resolution of the E60-based detector converged to approximately 0.80 mm, approaching the physical limit imposed by the 0.75 mm crystal pitch. This study establishes a practical correction framework for extracting intrinsic DOI performance and provides experimental evidence that sub-millimeter DOI precision is achievable in fine-pitch LYSO arrays using dual-ended readout.

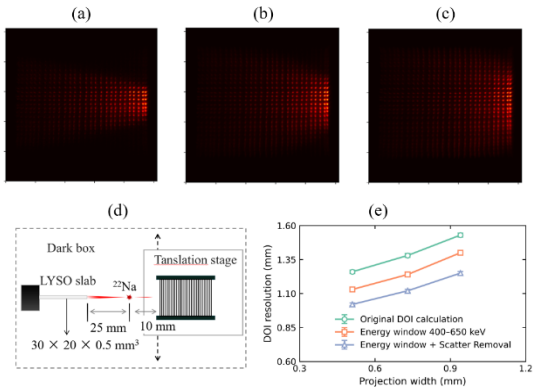

Fig. 1 (a–c) Crystal identification maps of the 28 × 28 array under three irradiation geometries; (d) OI resolution measurements acquired at different source-to-detector distances; (e) DOI resolutions under the three irradiation beam widths using all events, the 400–650 keV window, and additional scatter removal.

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