Design Optimization for a flat-panel PET scanner with DoI Capability

PROJECT MEFT

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Introduction

Cancer

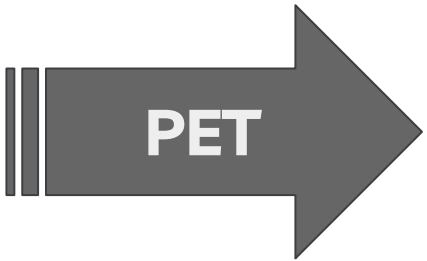
Cancer consists of more than 100 diseases defined by the uncontrolled growth of abnormal cells.

Proton therapy

Proton therapy is a cutting-edge cancer treatment that precisely targets tumors while minimizing damage to healthy tissues.

Range verification

Prompt Gamma (PG) and Positron Emission Tomography (PET) are the most promising techniques for range verification.



Positron **E**mission **T**omography

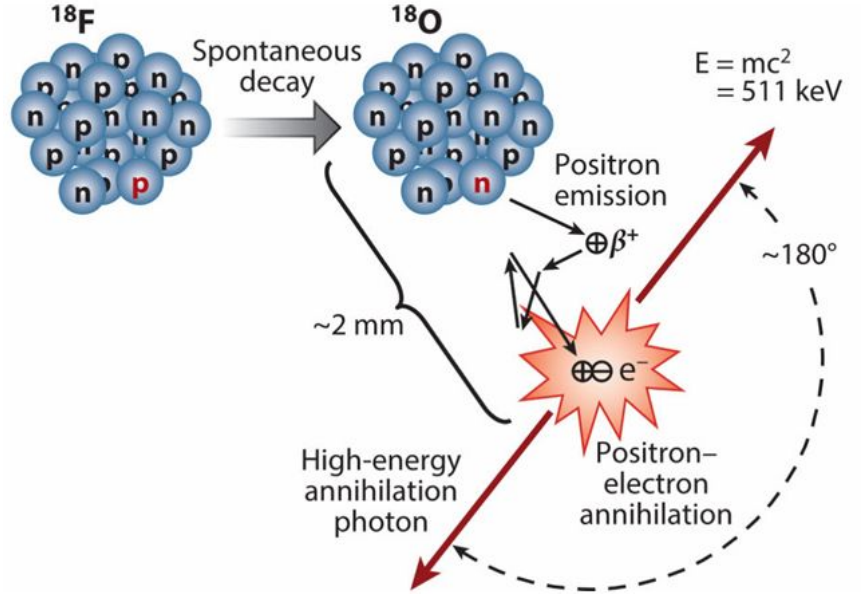


Figure 1. Annihilation coincidence detection.

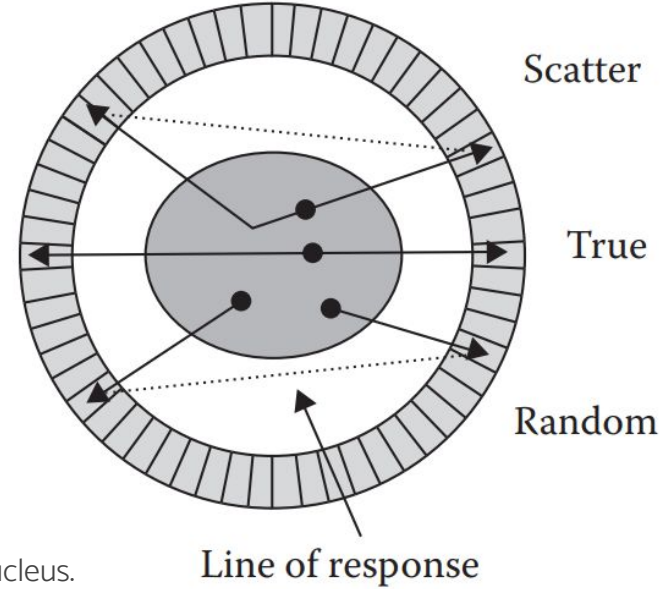


Figure 2. Types of coincidence event.

- PET imaging uses positron emission (β^+) from a neutron-deficient nucleus.
- Positron-electron annihilation produces two 511 keV gammas.
- PET scanners detect these gammas along a nearly straight path.

Fig 1: Vaquero, J. et al. "Positron Emission Tomography: Current Challenges and Opportunities for Technological Advances in Clinical and Preclinical Imaging Systems." In: Annual Review of Biomedical Engineering 17 (2015), pp. 385–414.
Fig 2: Flower, M.A. Webb's Physics of Medical Imaging. Boca Raton, Florida: Taylor Francis Group, 2nd ed., 2012.

Spatial **R**esolution and **DoI** Capability in **PET**

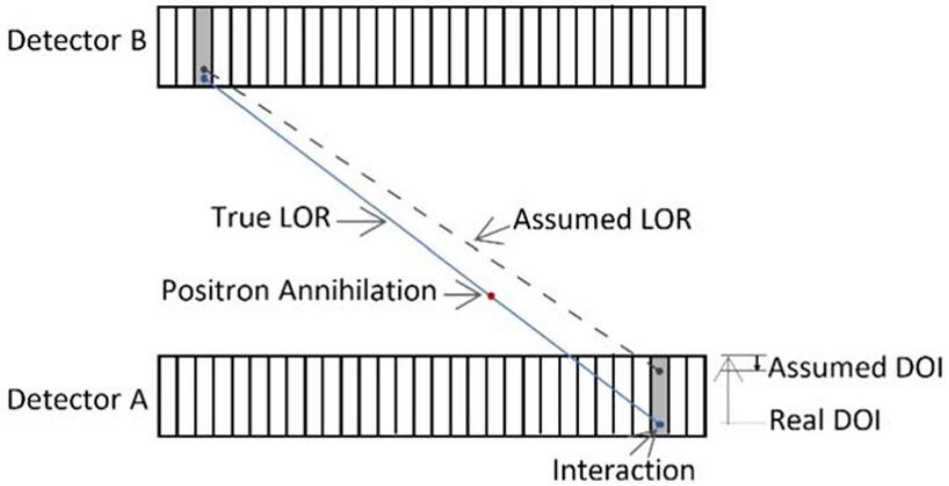
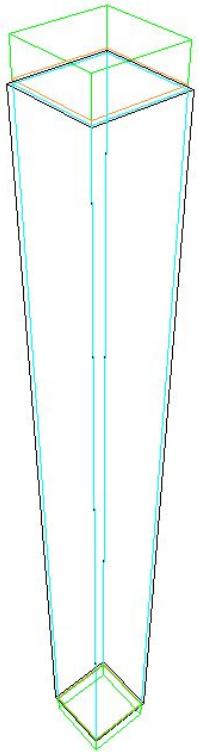


Figure 3. Sketch showing parallax error from an oblique LOR without DoI: dashed line represents assumed LOR, solid line represents true LOR with DoI.

- SR is the minimum distance at which two point sources can be distinguished in an image.
- Factors affecting SR include positron range, gamma non-collinearity, and DoI.
- The DoI indicates the exact location of gamma interaction within the detector crystal.
- Single-positioning can cause parallax errors from oblique gamma rays, distorting the LOR.

Fig 3: Mohammadi, I.. et al. "Minimization of parallax error in positron emission tomography using depth of interaction capable detectors: methods and apparatus". In: Biomed.Phys.Eng.Express 5 (2019), p. 062001.

Project Goal



Objective 1

Develop a simulation model of a basic scanner detection unit, comprising a LYSO scintillator, 3 x 3 x 30 mm^3, encapsulated with ESR film, and two SiPMs sensors, using the ANTS3 toolkit.

Objective 2

Determine the DoI resolution by testing different crystal sizes and encapsulation approaches.
Validation of the model with experimental data collected from UT Austin.

Objective 3

Characterize the resolution and image distortion of the optimized scanner across the entire field of view.

Project Methods

- The analysis of the DoI evaluated the impact of lateral surface roughness.
- The model will incorporate wavelength-resolved photon transport and SiPMs' wavelength-dependent PDE.
- The DoI will be parameterized based on the normalized signal difference between the sensors.
- Resolution will be compared in XYZ coordinates, with and without DoI correction.

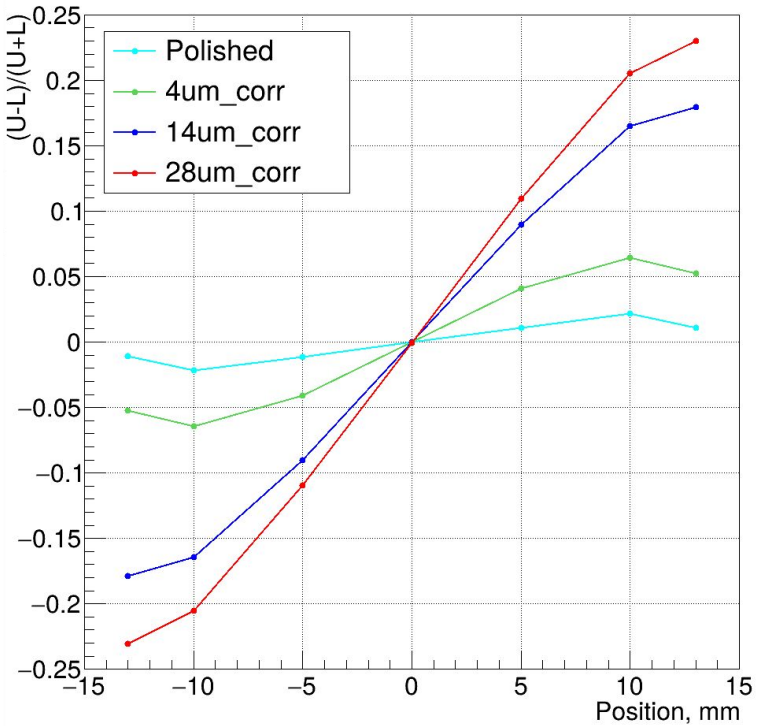


Figure 7. Preliminary model made by the collaboration. The (U-L)/(U+L) represents the normalized signal difference between the upper ("U") and lower ("L") sensors. Position (in mm) is the distance between the sides inside the crystal, with 0 at the center. The four curves correspond to a polished surface and three roughness levels (4 μm, 14 μm, and 28 μm).

THANK YOU!

Does anyone have any questions?

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