Why Liquid Xenon?

- Better energy resolution than LYSO
- Better spatial resolution than LYSO
- Better timing resolution/faster scintillation compared to LYSO
- Comparable stopping power to LYSO

A New Concept for Using Liquid Xenon in PET Imaging

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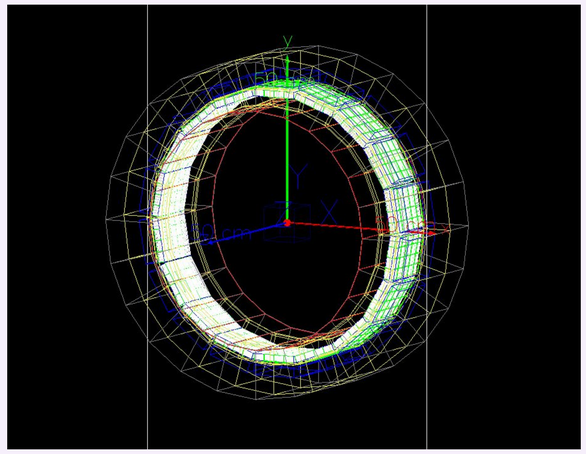
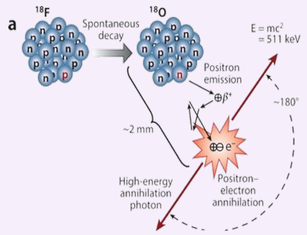
Science Fair 2026



Background & Motivation

What is PET?

• PET uses back-to-back 511 keV gamma photons to measure metabolic activity
• Current market standard is LYSO that has very good stopping power
• Parallax error and poor depth-of-interaction degrade image sharpness
• Need a detector with better energy & spatial performance → enter LXe



Creation of annihilation photons used in PET. Reproduced from Vaquero & Kinahan (2015).

Methods & Design

Methods:

- Used Opengate 10.0.0 to simulate detectors
- Digitised each material according to up-to-date research
- Used CASTor to reconstruct images with detector data

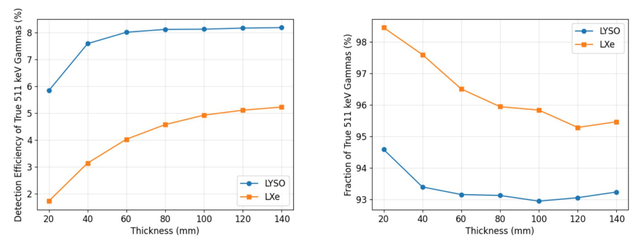
Design:

- Tested efficiency of crystals of varied thickness from 2-14 cm
- LXe was reconstructed with voxels of 1x1x1 cm^3
- Reconstructed image quality was assessed with 2D gaussian-fits.

$$f_{k+1}(r) = f_k(r) \frac{\sum_i p(i|r) \frac{y_i}{\sum_{r'} p(i|r') f_k(r')}}{\sum_i p(i|r)}$$

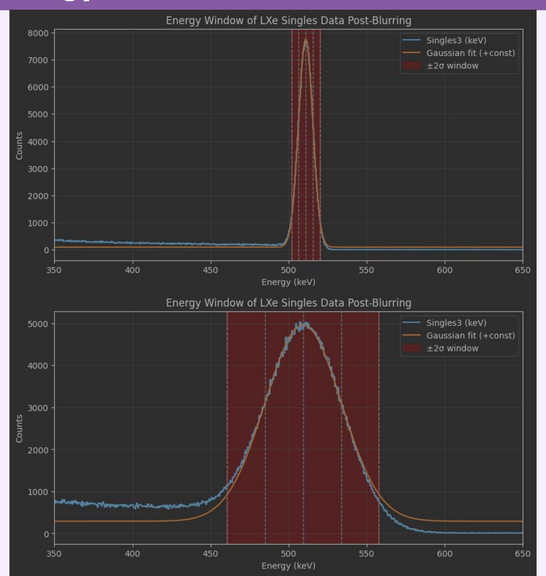
MLEM Update Rule
Iterative formula used for reconstruction

Results: Detection Efficiency



Left: Detection efficiency of true 511 keV gamma rays within the 2σ energy window centered at 511 keV for different radial thickness of the PET detectors.
Right: Fraction of true 511 keV gamma rays within the 2σ energy window.
Statistical uncertainties are smaller than the marker size; therefore, error bars are not shown.

Energy Window for LXe + LYSO



Analysis, Clinical Impact, and Future Work

Analysis

• The overall detection efficiency was lower for LXe compared to LYSO
• The better energy resolution of LXe made it easier to separate true 511 keV events from scattered ones
• LXe performed better during reconstruction, showing sharper results with less background noise.

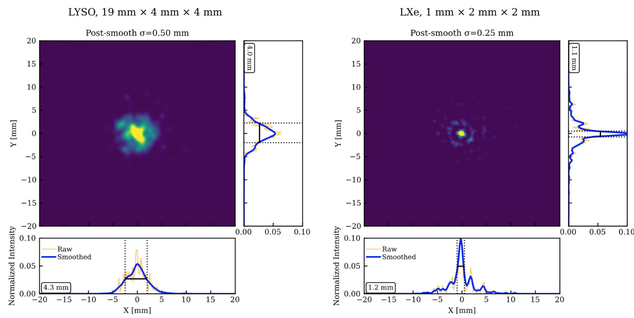
Clinical Impact

• Sharper images → earlier lesion detection
• Uniform LXe modules simplify calibration & manufacturing
• Lower patient dose & faster scans
• Potential hybrid modalities: PET+CT or PET+MRI

Future Work

• Future work should optimize the energy window instead of fixing a single ±2σ cut.
• Time of flight information could be incorporated to improve the resolution even more but is unlikely to return much better results
• Future work should reconstruct standardized phantoms in addition to point sources.

Results: Reconstruction



Reconstructed images from a simulated point-source for a LYSO-based PET system (Left) and an LXe-based PET system (right). Resolutions are determined by applying a 2D Gaussian fit to a smoothed reconstruction.