Panel Detectors in PET Imaging: Leveraging TOF-DOI for High-Quality Performance

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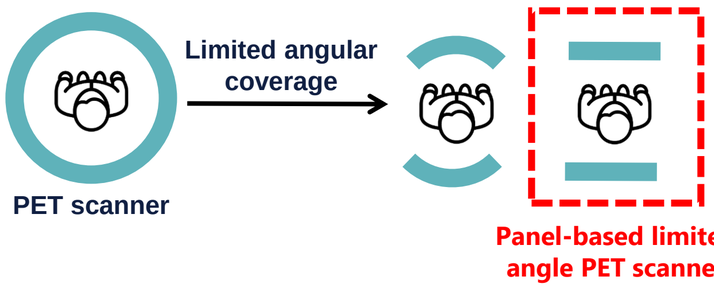
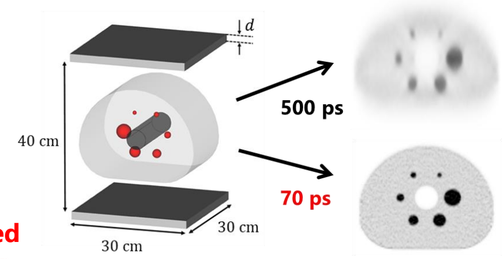
Introduction

- Traditional PET scanners employing a full-ring design have proven invaluable in clinical diagnosis and research, however, they are not without limitations.
- As a general design, it's evident that the ring geometry, with its relatively large radius, may not be the optimal choice for detector placement across all applications.
- TOF also enables reduced angular sampling → novel geometries
- The flat-panel design allows PET detectors to be positioned close to the patient, aiming to enhance sensitivity and spatial resolution through improved geometric coverage and reduced non-collinearity blurring





Why Flat Panel PET Detectors?

Flexibility → adjustable FOV and sensitivity

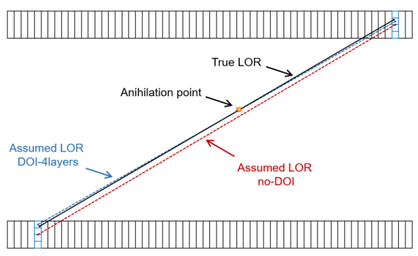
Mobility → portable or bedside PET imaging

Modularity → multi-organ/total-body PET scanner

Accessibility → reduced manufacturing cost and complexity

Simulation study

- Monte Carlo simulation → GATE software
- Reference scanner → **Siemens Biograph Vision**
- MLEM image reconstruction → CASToR software
- Depth of Interaction (DOI)
  → 2,4,8,16-layer DOI configurations using 20 mm long crystals



Specifications of scanners used in the simulation

	2-panel system	Reference scanner
Scintillator	L(Y)SO	LSO
Crystal size	3 x 3 x 20 mm	3.2 x 3.2 x 20 mm
Geometry	Panel: 30 x 30 cm	Ring, diameter: 78 cm
Axial field of view	30 cm	26.3 cm
Energy resolution	10%	10%
Energy window	435 – 585 keV	435 – 585 keV
Coincidence time resolution	200 ps, 70 ps	214 ps
Coincidence time window	2 ns	4.7 ns

Sensitivity and NECR

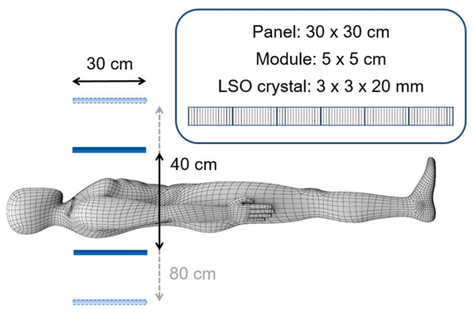
PetVison project

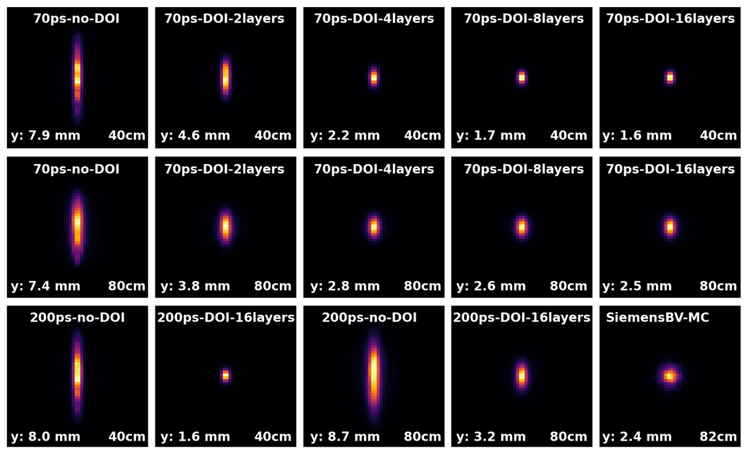
Develop a flexible, modular PET scanner based on two planar, opposite detector panels with exquisite TOF resolution.

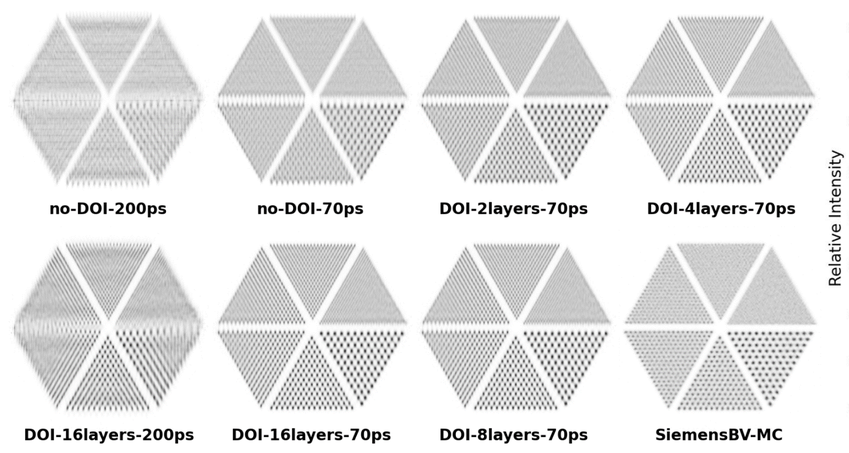
https://petvision.org

Spatial resolution

- Point source (1 cm, 0, 0)
- Derenzo phantom – hot rods
- Voxel size: 0.5 mm







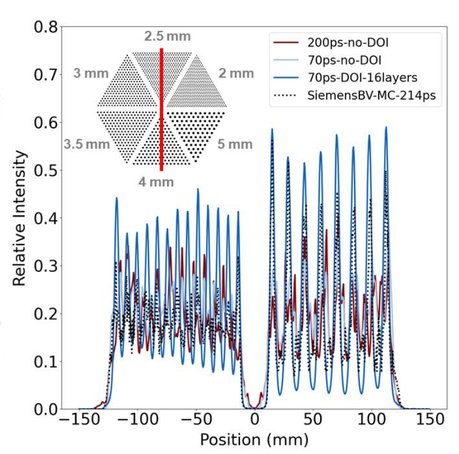
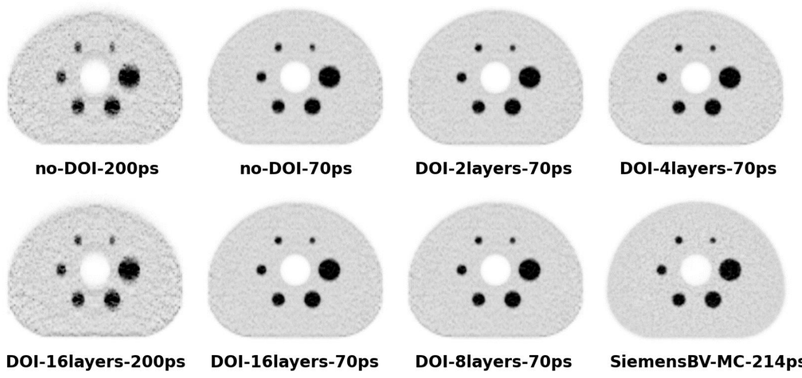
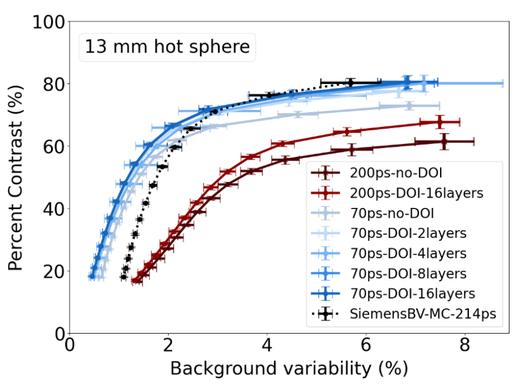


Image Quality

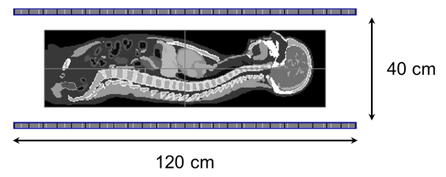
- 4:1 contrast, 4 min, voxel size: 1.6 mm

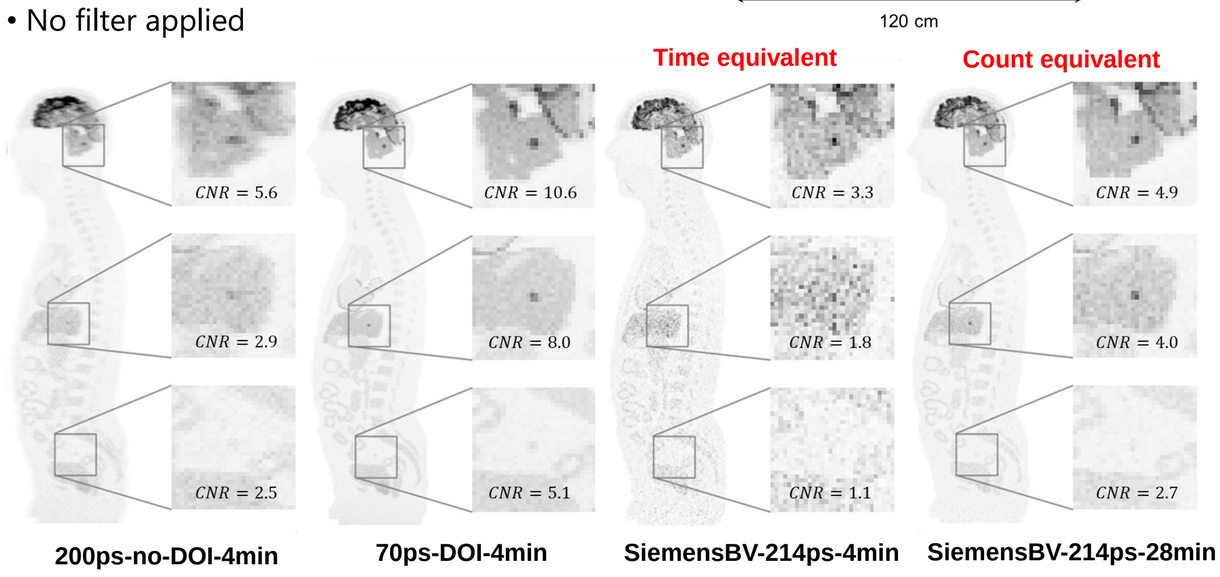




Large panels

- **120 x 60 cm** (4 x 2 small panels)
- Highly anatomically detailed phantom (XCAT)
- Matrix: 330 × 200 × 90, voxel size: 3 mm
- No filter applied





Conclusion

- A relatively compact 2-panel PET system can achieve image quality comparable to clinical scanners while utilizing approximately **four times less detector material**.
- While TOF is crucial to compensate for limited angular sampling, DOI adds an extra dimension to improving image quality by mitigating the parallax error and enhancing spatial resolution beyond that of commercially available whole-body PET scanners.
- Its **mobility** and **flexibility** enable novel applications, including bedside imaging and ICU diagnostics, as well as imaging in positions such as sitting or standing.
- The **modularity** of panel detectors offers the potential to construct cost-effective, high-performance long axial field-of-view PET systems.