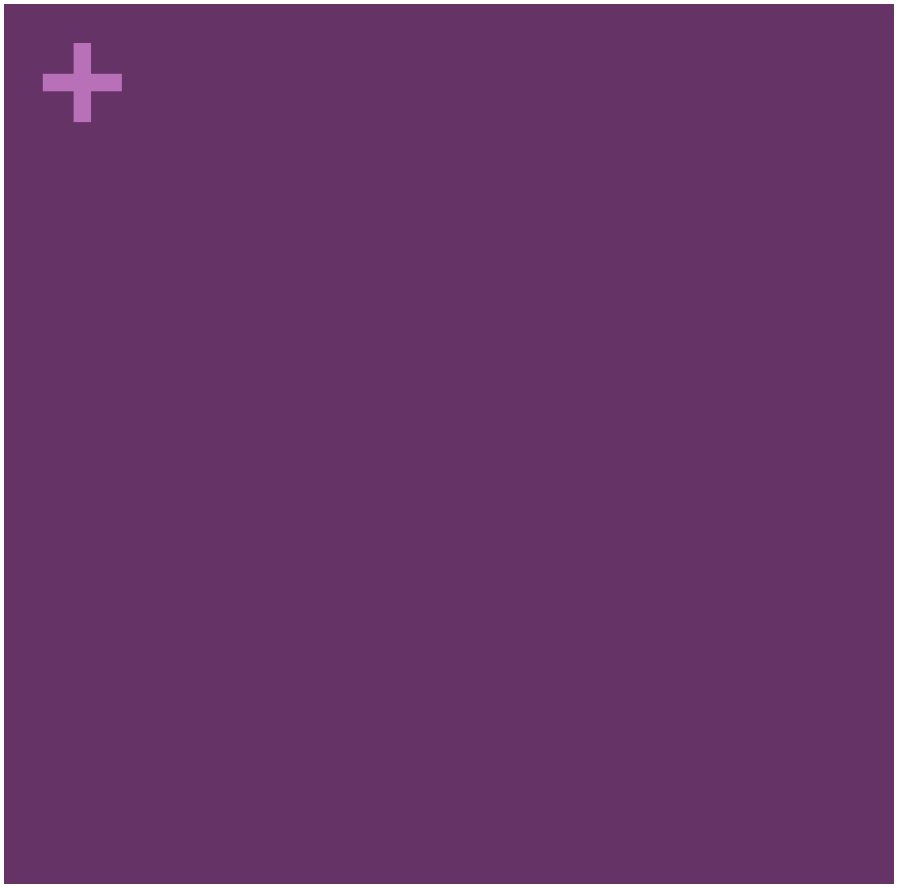


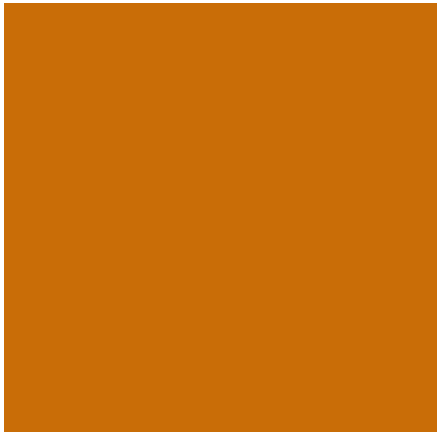


Pixelated CdTe Detectors to Overcome Intrinsic Limitations of Crystal Based Positron Emission Mammographs

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Voxel Imaging PET (VIP) Pathfinder Project
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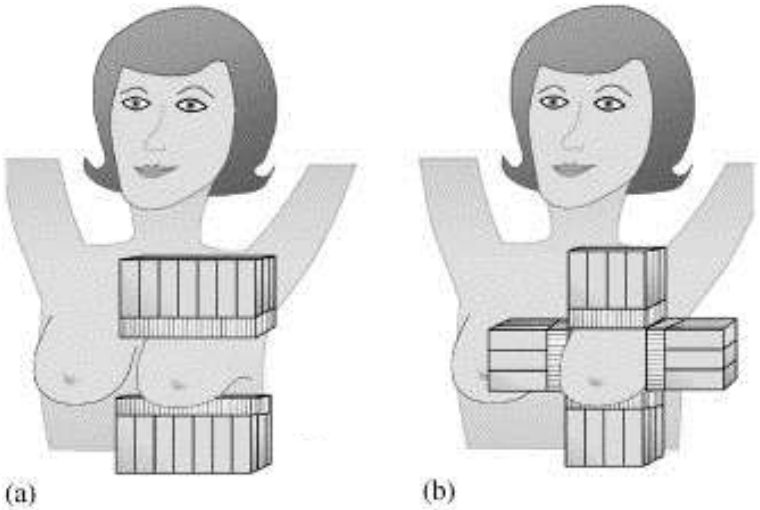
Outline

- State-of-the-art Positron Emission Mammography
- The VIP Novel Design
- Assessment of Expected Performance
- Discussion and Future Work

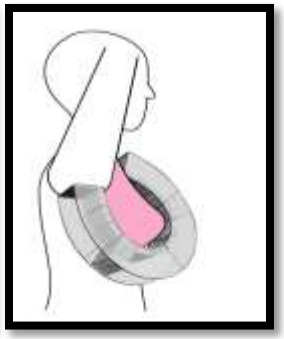
Overview of PEM Technique



courtesy of W. Moses, NIM Phys.A Volume 525, Issues 1–2, 1 June 2004, Pages 249–252

NAVISCAN

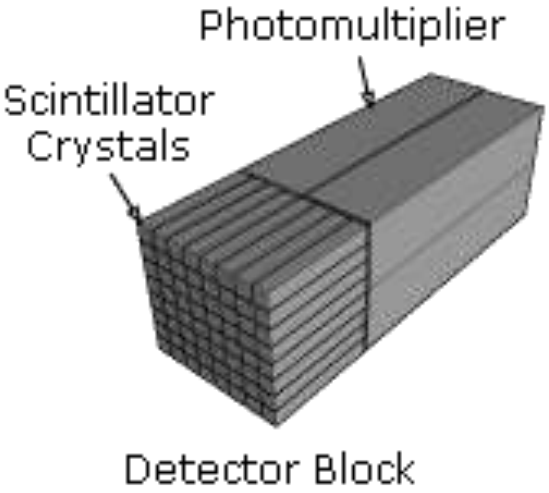
Clear PEM

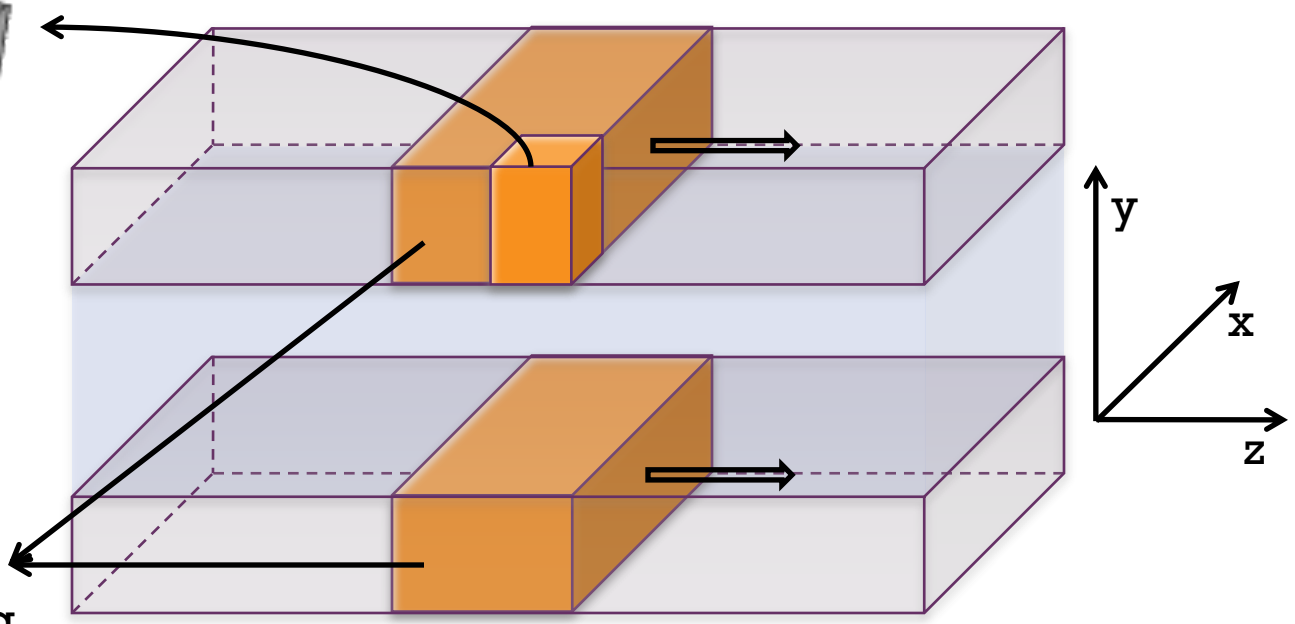


Yamada et al.

- A PEM is an organ dedicated PET scanner optimized for breast.
- Restricted FOV for higher cancer detection performance.
- Several designs based on scintillators proposed or developed.
- Coplanar design offers best cost/performance tradeoff.
- Increasing interest in PEM guided biopsy with coplanar devices.

Typical Coplanar PEM

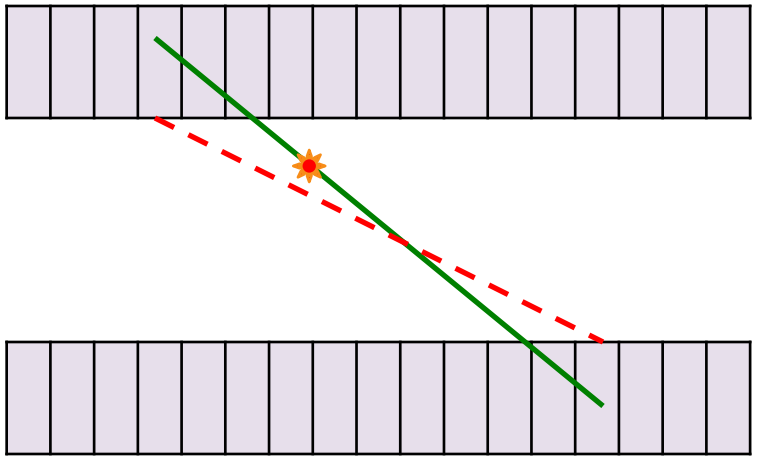




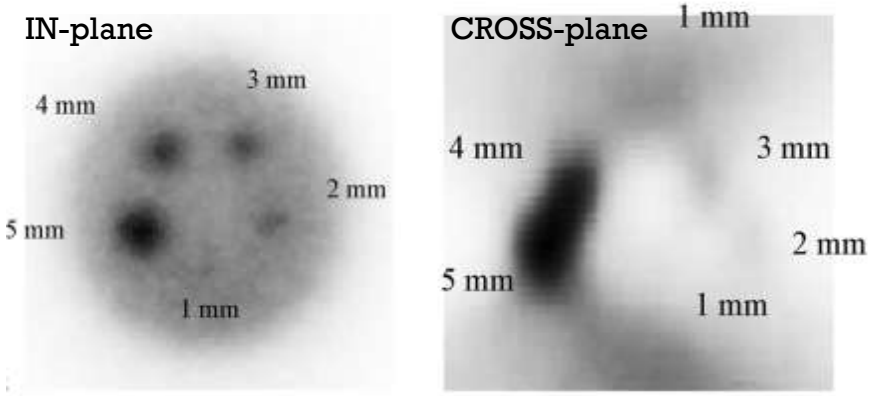
Active detector units mounted on two sliding heads for a complete scan of the FOV

typical FOV:
x = 200 mm
y = from 30 mm to 80 mm
z = 200 mm

Intrinsic Limitations of Crystal PEM



- Drawbacks of scintillating crystals:
  - poor energy resolution (6%-10%)
  - poor DOI resolution (≥6mm)
  - not compatible with MR if coupled to PMTs

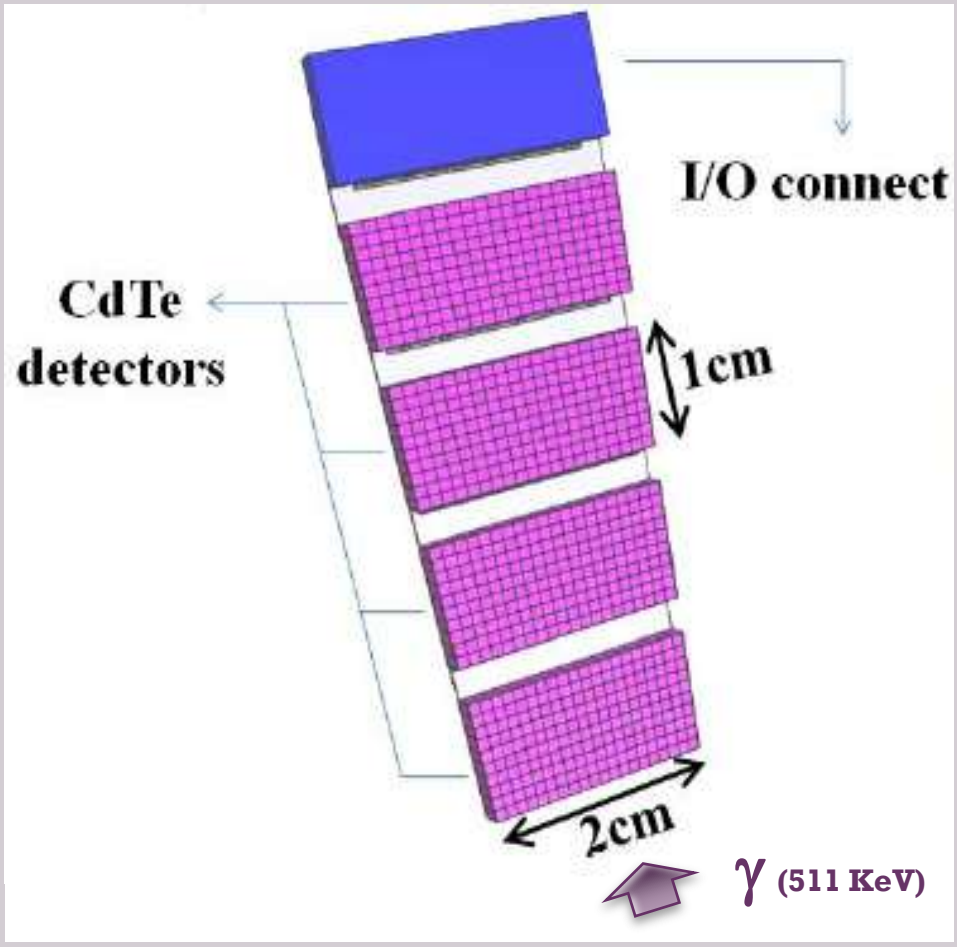


courtesy of W. Lou, IEEE trans. of nucl. sci., vol.. 57, Nno 1, February 2010

- Lack of DOI information is most stringent limitation:
  - poor CROSS-plane resolution
  - reduce ability of detecting small lesions

The VIP Novel Design

The VIP module

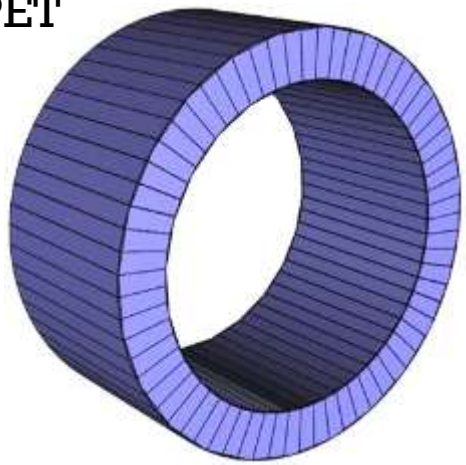


- 4 CdTe detectors (1cm x 2cm) mounted on ultra-thin layer (< 150 um of passive material).
- 200 pixels per detector with 1mm x 1mm x 2mm size.
- ~1.5% energy resolution at room temperature.
- Independent signal processing and readout per channel (1 mm^2 *smart-pixel* microchip).
- Stack modules to obtain any detector shape.
- Incoming photons facing 4cm CdTe.

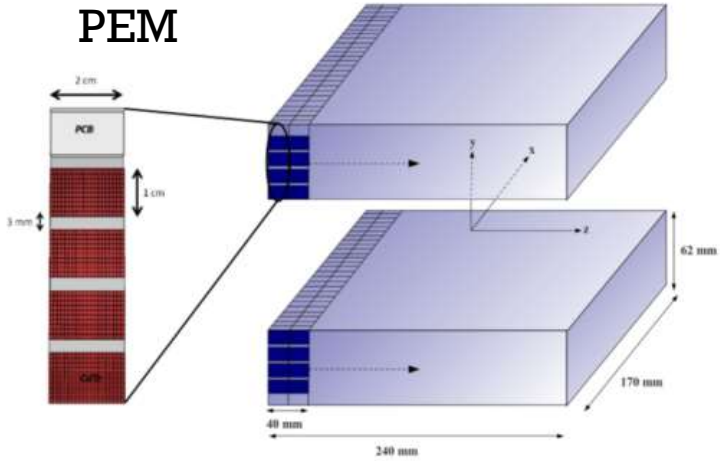
The VIP Project

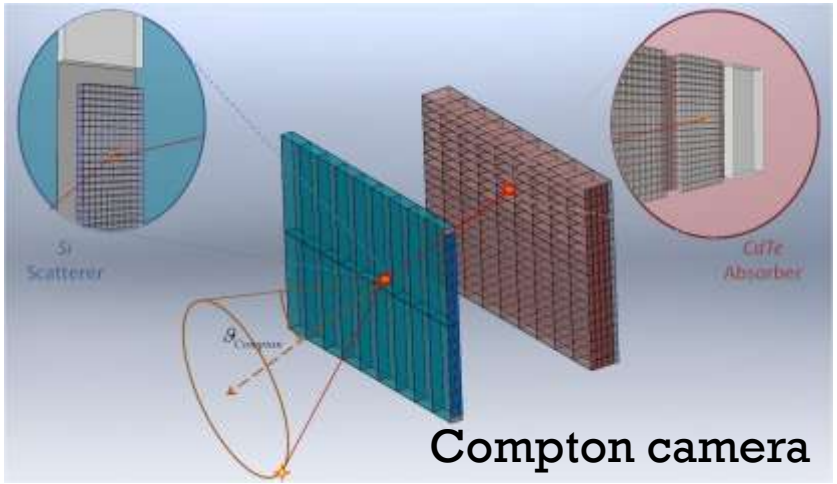
- The Voxel Imaging PET (VIP) Pathfinder project aims to prove the feasibility of using pixelated CdTe detectors in PET.
- VIP design offers:
  - high signal purity
  - superior spatial resolution
  - compatible with strong magnetic field
  - great flexibility for variety of applications

PET

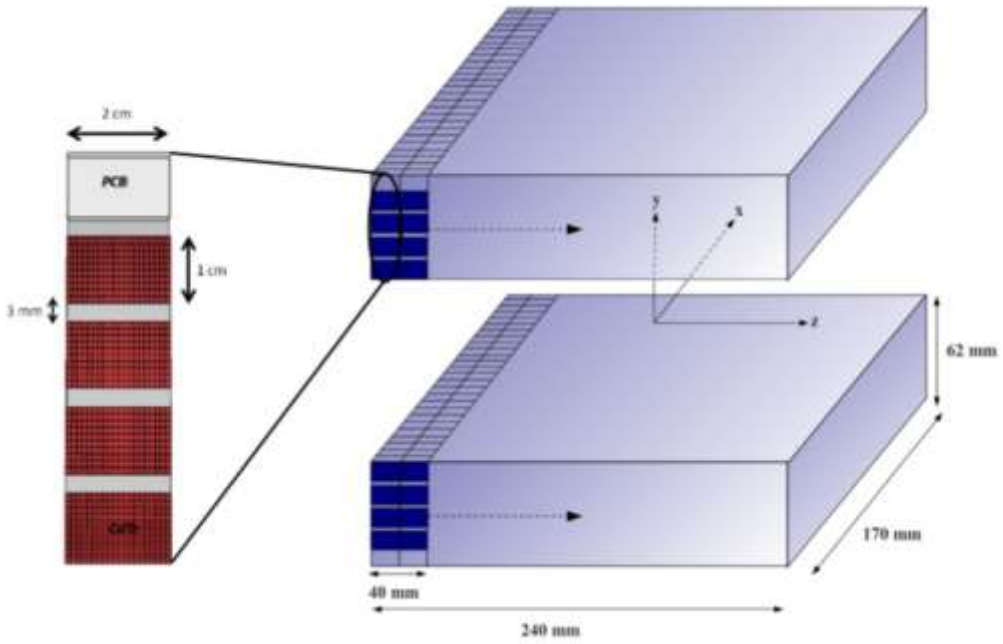


PEM





VIP Module in Coplanar PEM



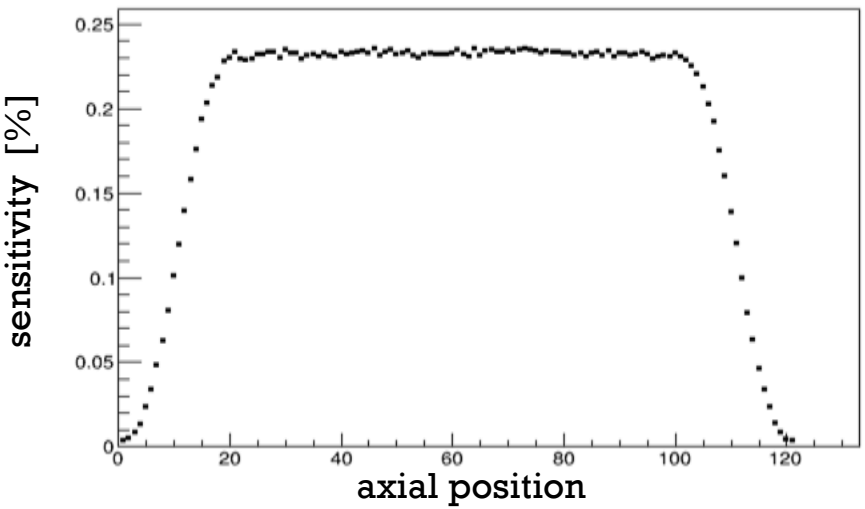
- Substitute crystals with VIP-module in typical dual head coplanar geometry.
- Stacked modules offer adequate stopping power with negligible passive material.
- Optimal application for VIP design due to limited size:
  - cost contained
  - limited number of channels

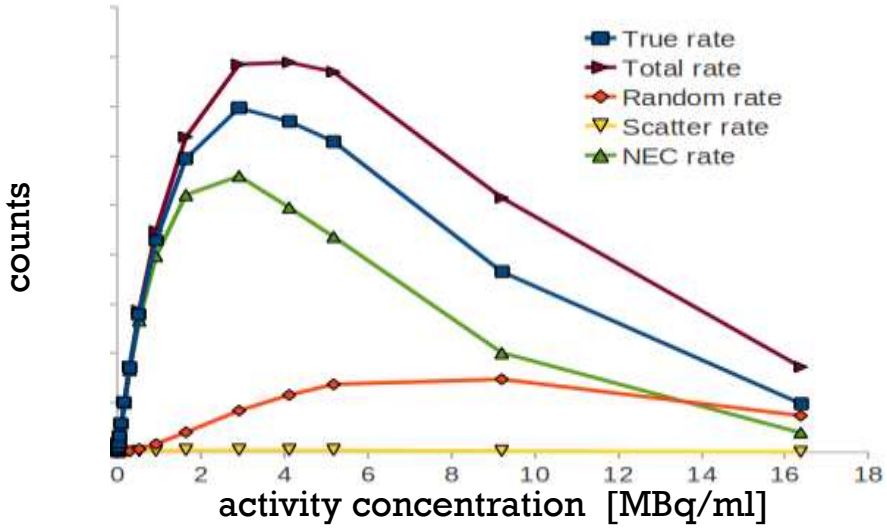
Simulation of VIP-PEM

System Specifics (see G.Ariño's poster n. 35)	
Voxel Size	1mm x 1mm x 2mm
Num of Channels	256000
Meas. Time per Channel	10 us
Dead Time per Channel	20 us
Coincidence Time Window	20 ns
Energy Resolution	1.57 %
Trigger Threshold	20 KeV

- VIP-PEM simulated with GAMOS (Geant4 based framework)
- List-mode event selection with off-line coincidence search.
- Images reconstructed with different algorithms for comparison:
  - FBP
  - OSEM
  - OE (see M. Kolstein's poster n. 84)

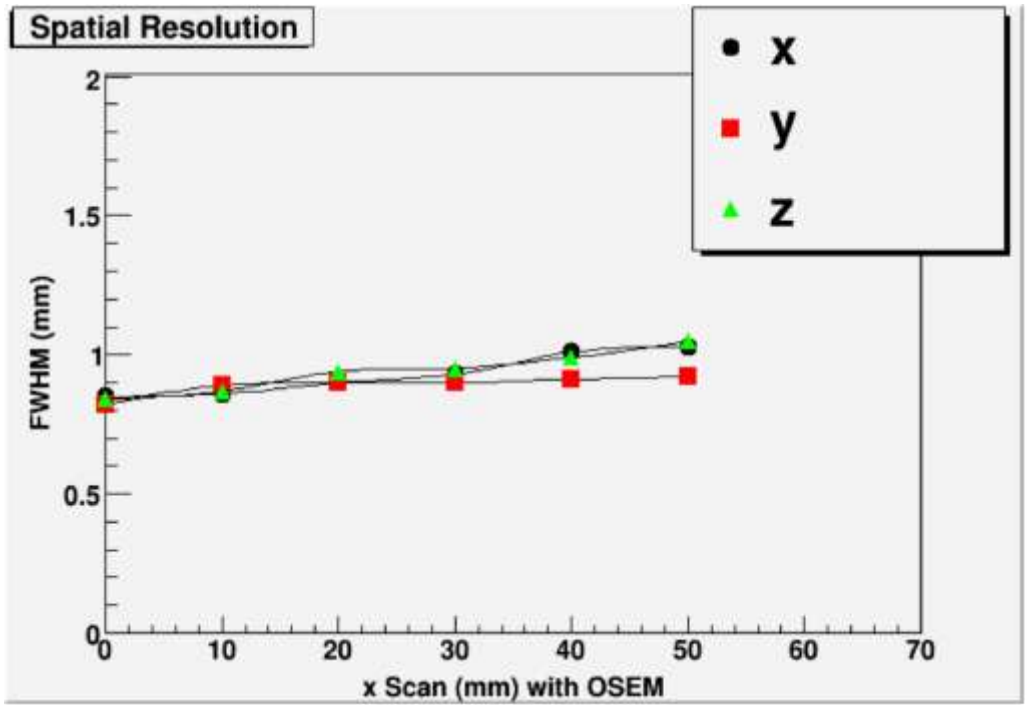
VIP-PEM Counting Performance





- VIP-PEM sensitivity of ~2 cps/kBq compatible with analogous scanners.
- Virtually noise-free data due to narrow energy selection window.
- Can operate at high activity.

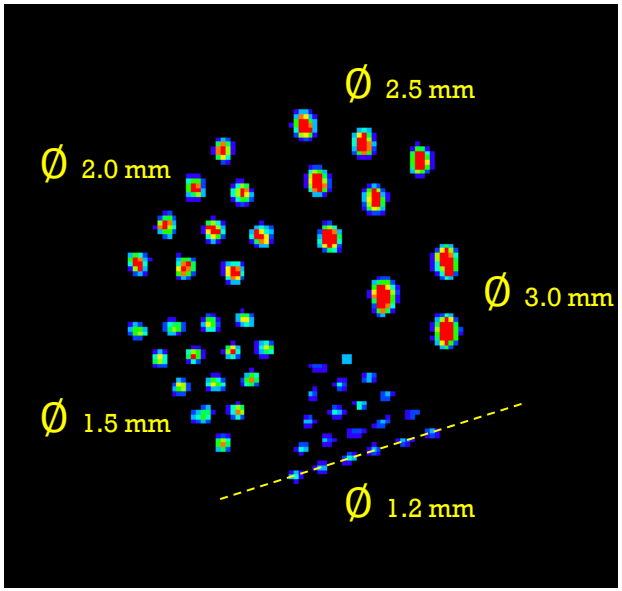
VIP-PEM Spatial Resolution

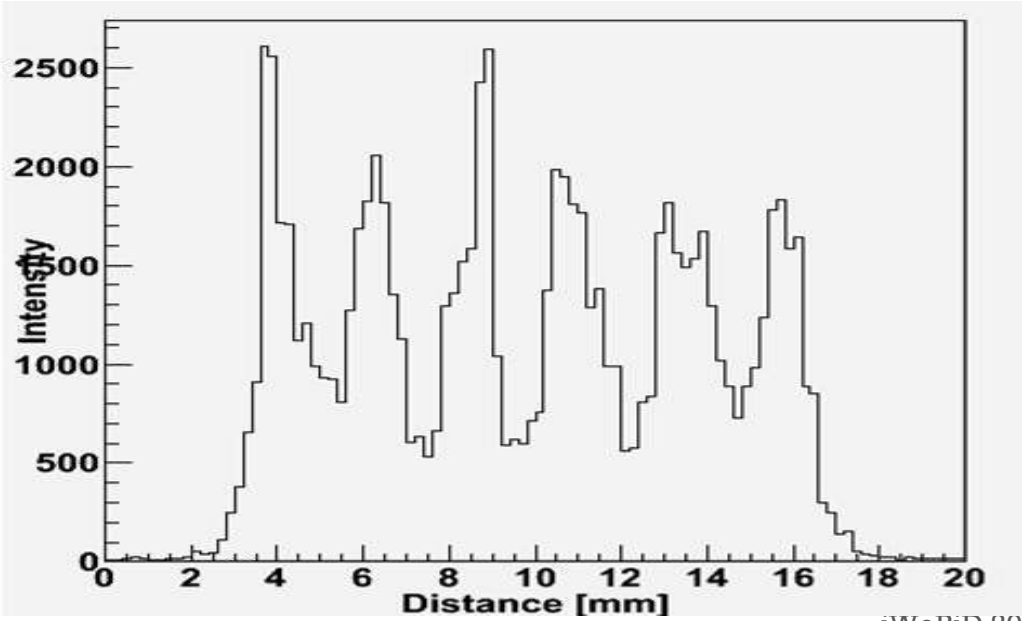


- Excellent spatial resolution along all directions.
- Expected a 2 times better IN-plane PSF with respect to analogous crystal PEMs.
- Expected 8 times better CROSS-plane PSF with respect to analogous crystal PEMs.

VIP-PEM Image Quality:
IN-plane Derenzo Phantom

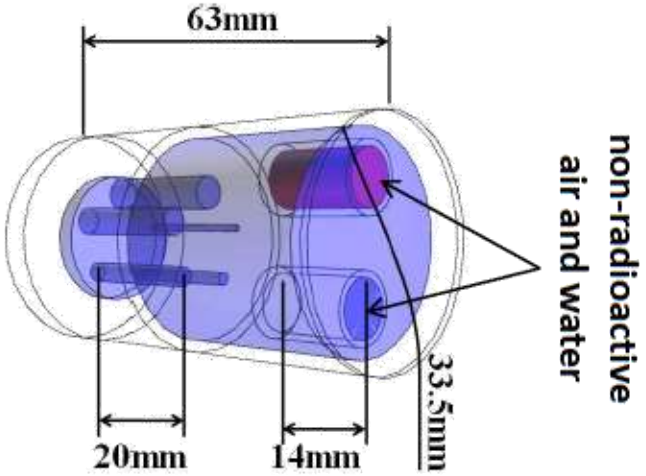
- Image of a typical Derenzo phantom.
- High-contrast/high-resolution down to smallest rods (Ø 1.2 mm).
- Image reconstructed with OE algorithm.

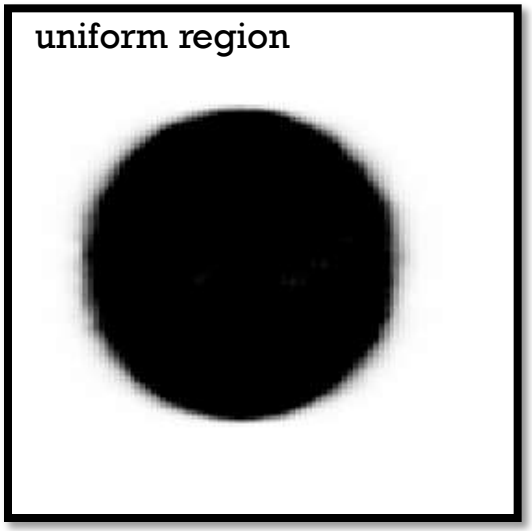


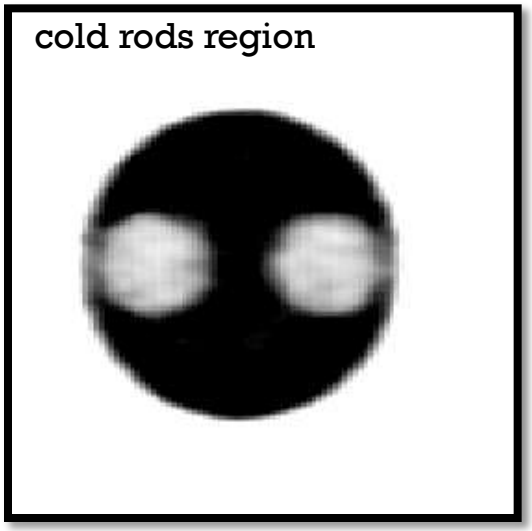


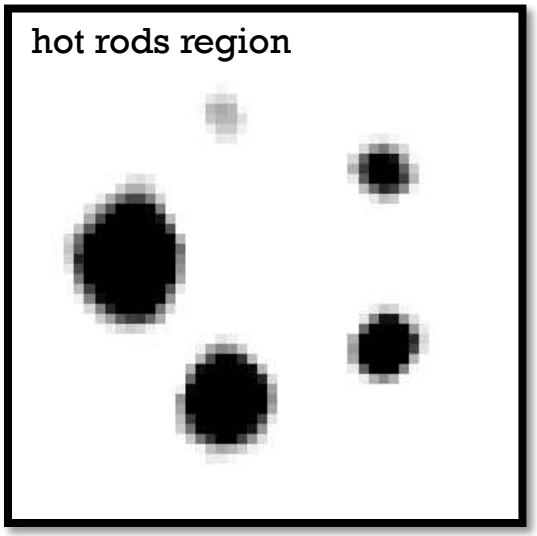
VIP-PEM Image Quality:
IN-plane Sections of NEMA Phantom

- Images of cylindrical NEMA NU4 2008 phantom for small PET evaluation.
- Excellent quality IN-plane sections.
- Images reconstructed with OSEM.

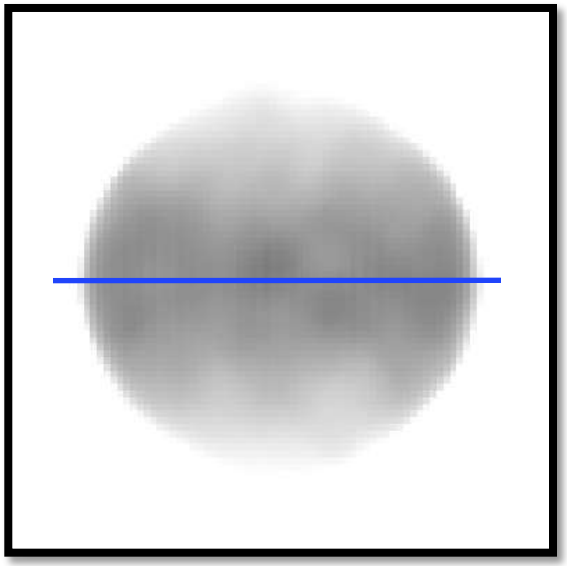


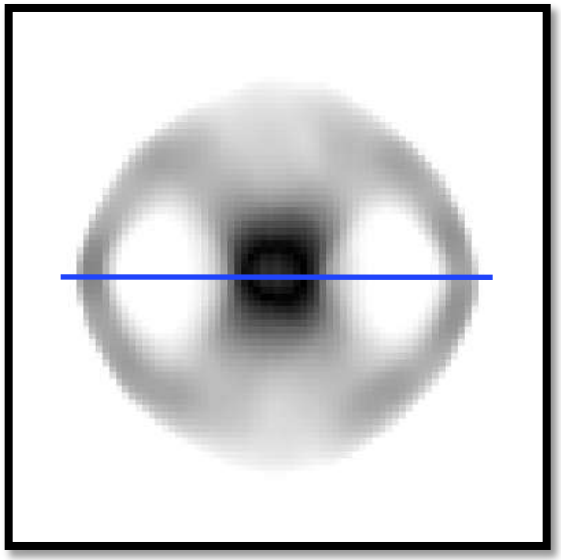


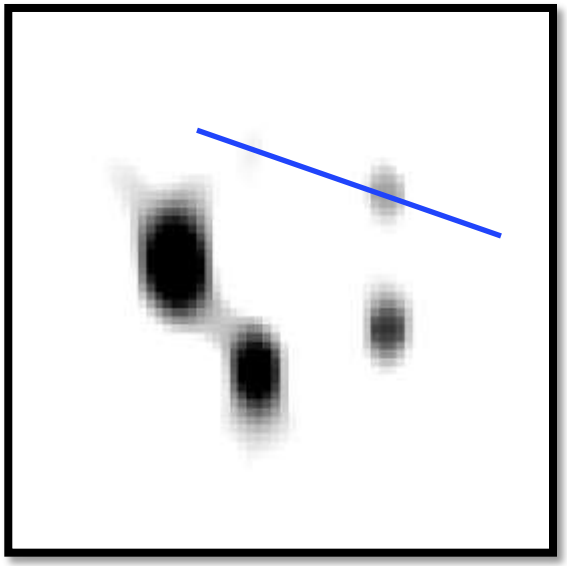


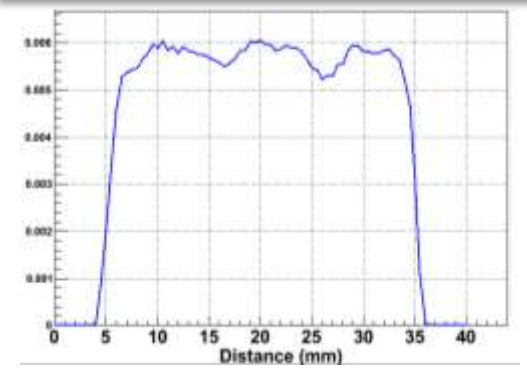


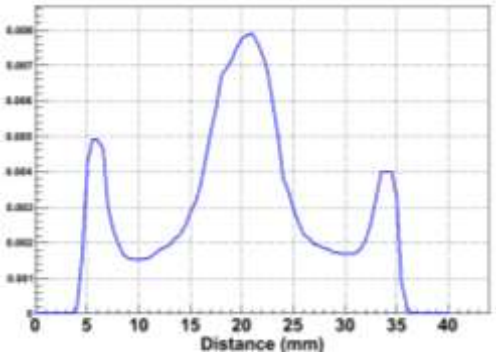
VIP-PEM Image Quality:
CROSS-plane Sections of NEMA Phantom

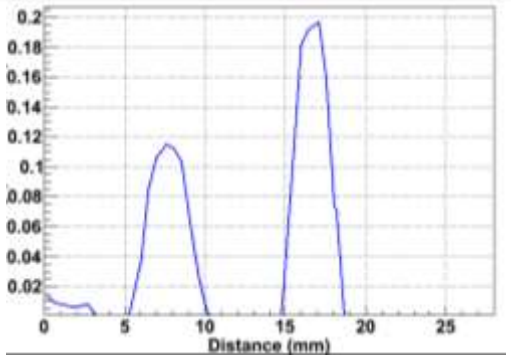








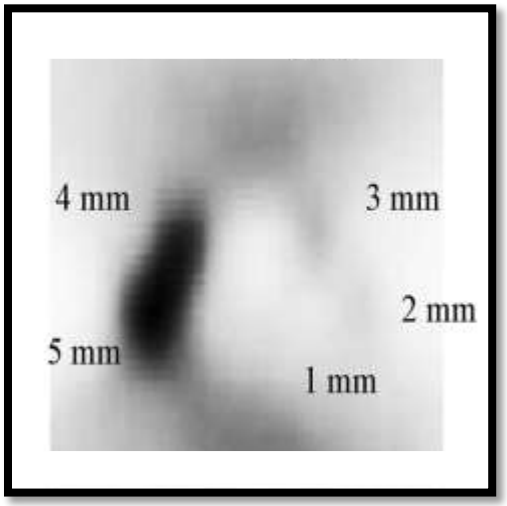




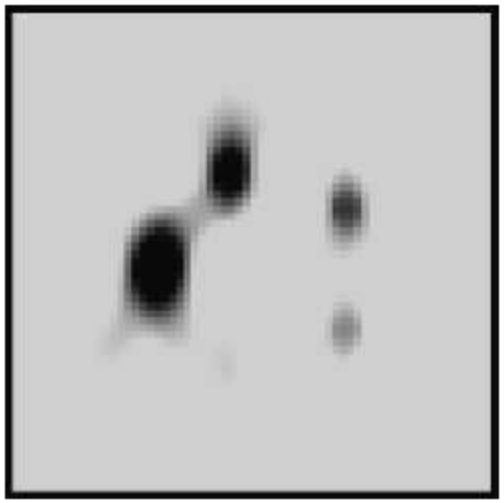
Discussion

- Simulation results indicate VIP modular design based on pixelated CdTe as excellent solution to overcome current limitations of crystal PEMs.
- VIP-PEM has the potential to provide unprecedented image quality and resolution in all directions.
- VIP-PEM optimal solution for:
  - <4mm tumor size detection.
  - PEM guided biopsy.
  - MR-PEM hybrid systems.

Crystal PEM



VIP-PEM



Future Work

- Ongoing effort of the VIP group on three fronts:

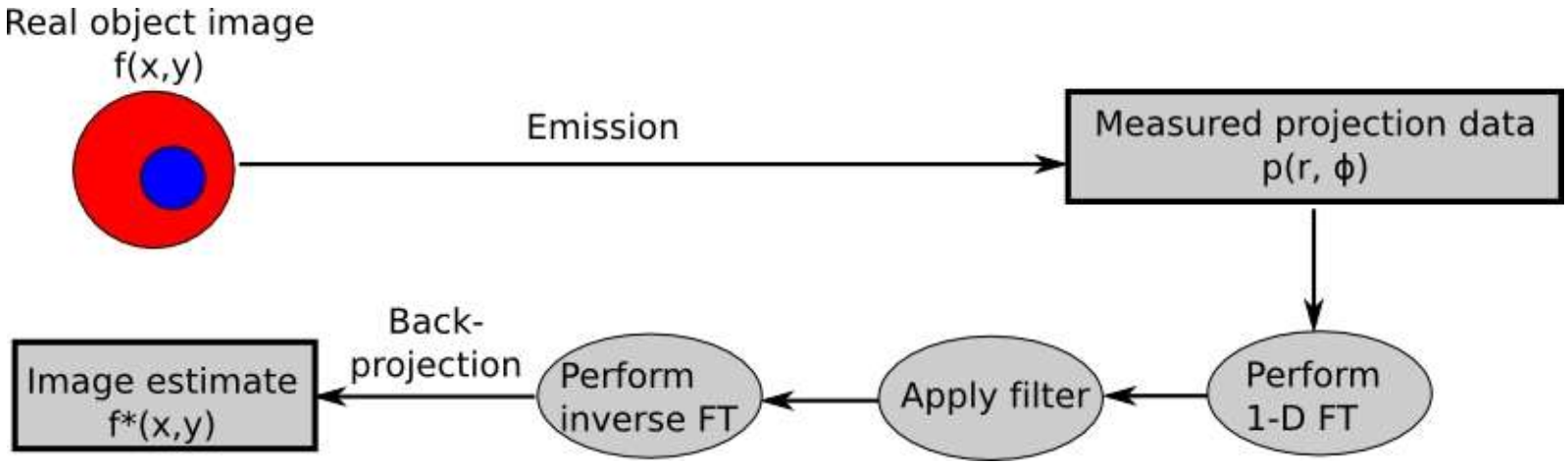
1. Development of the VIP smart-pixel for individual channel signal processing.
2. Development and testing of small dual-head prototype.
3. Optimization of image reconstruction algorithms.

➔ Project goal deadline: early 2015

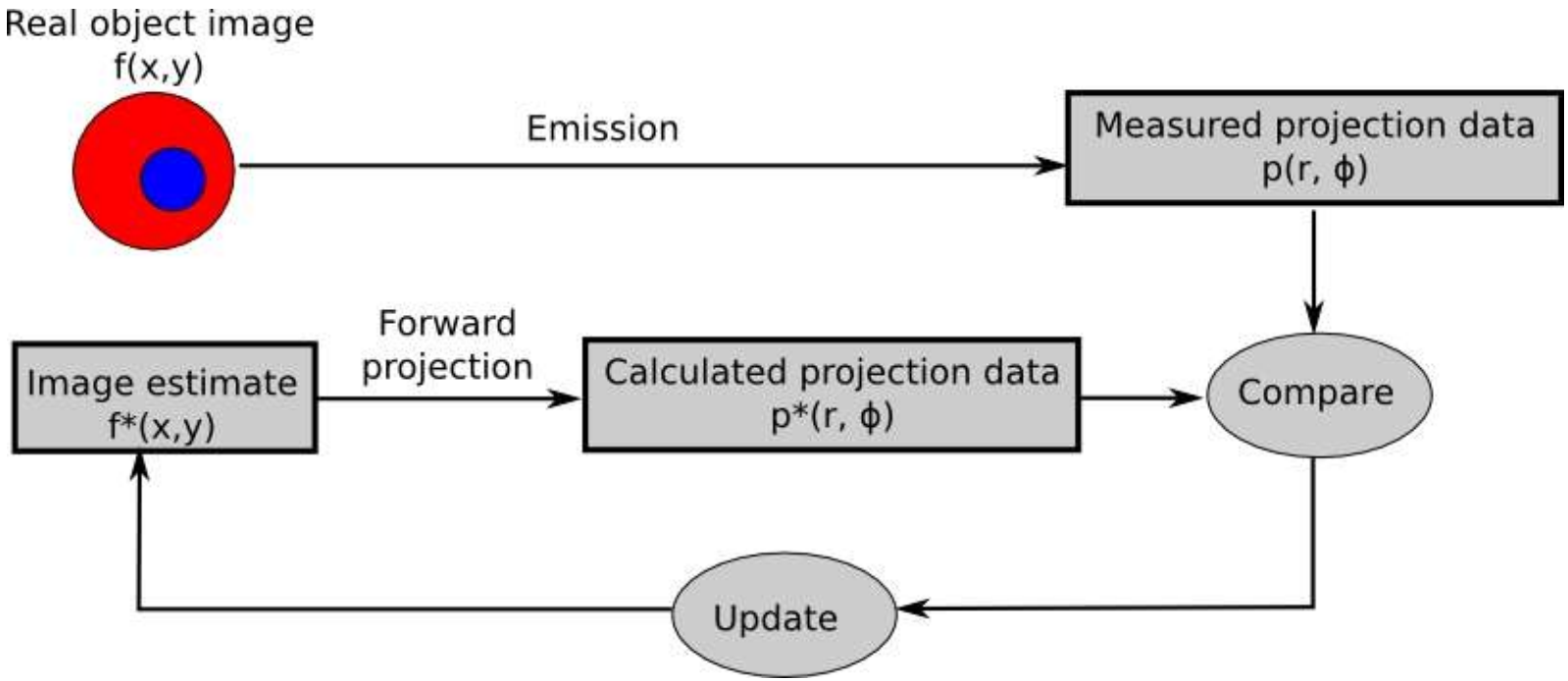
STAY TUNED!

Backup Slides

Filtered Backprojection



Expectation-Maximization Algorithm

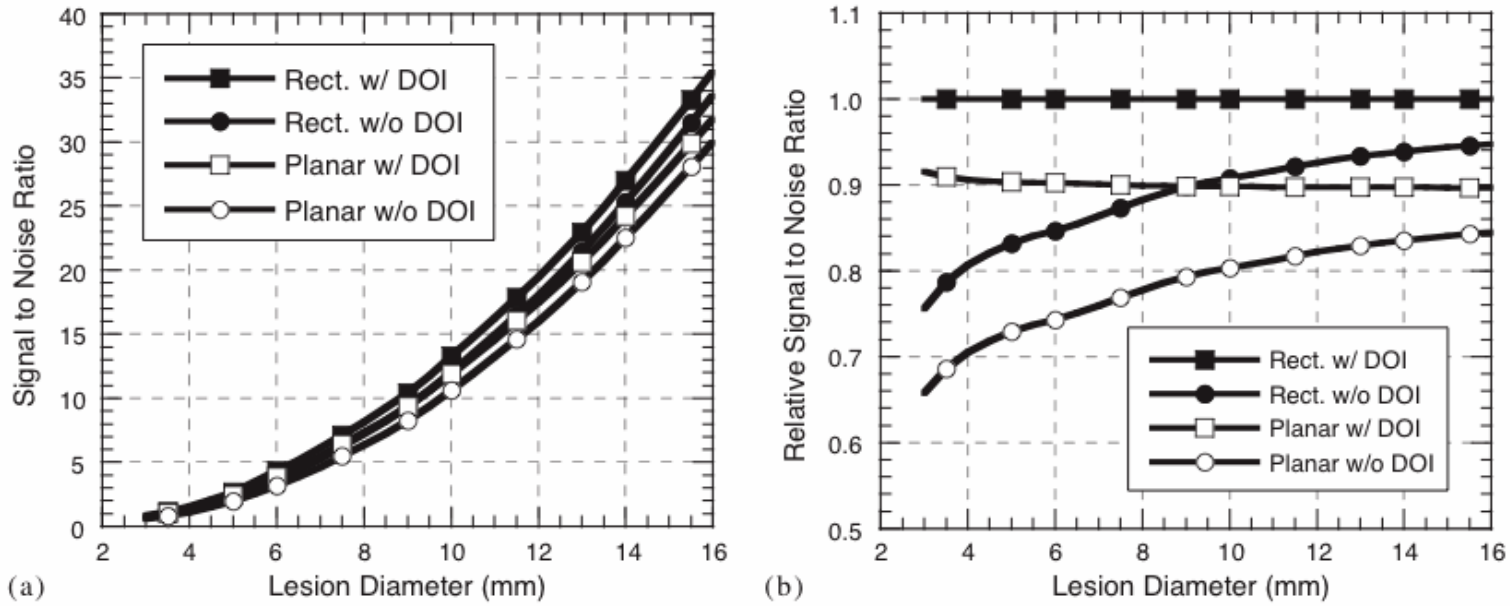


Origin Ensemble Algorithm

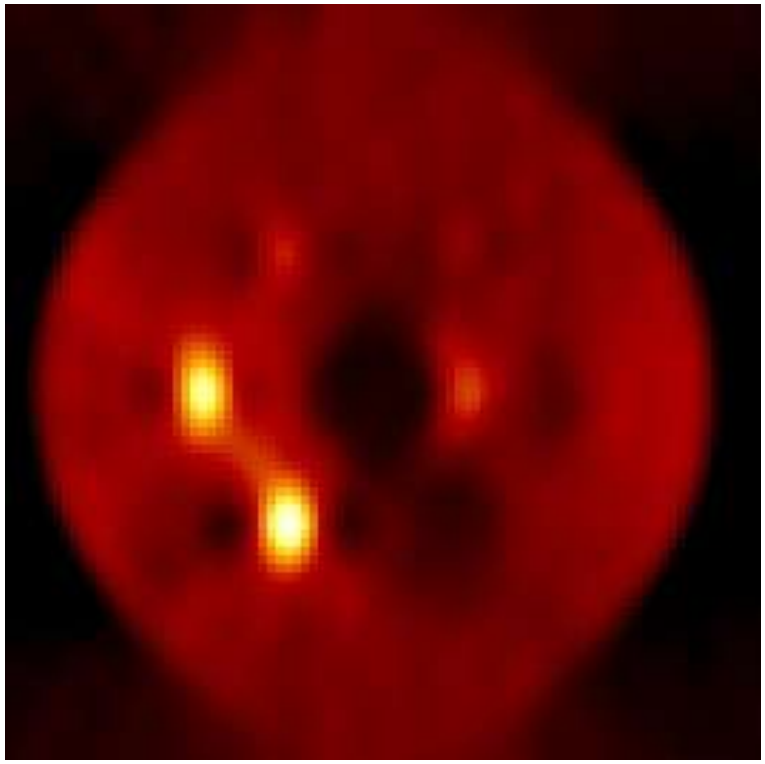
- See M. Kolstein's poster "Modeling, Simulation, and Evaluation of Compton Camera Based on Pixelated Solid-State Detector"

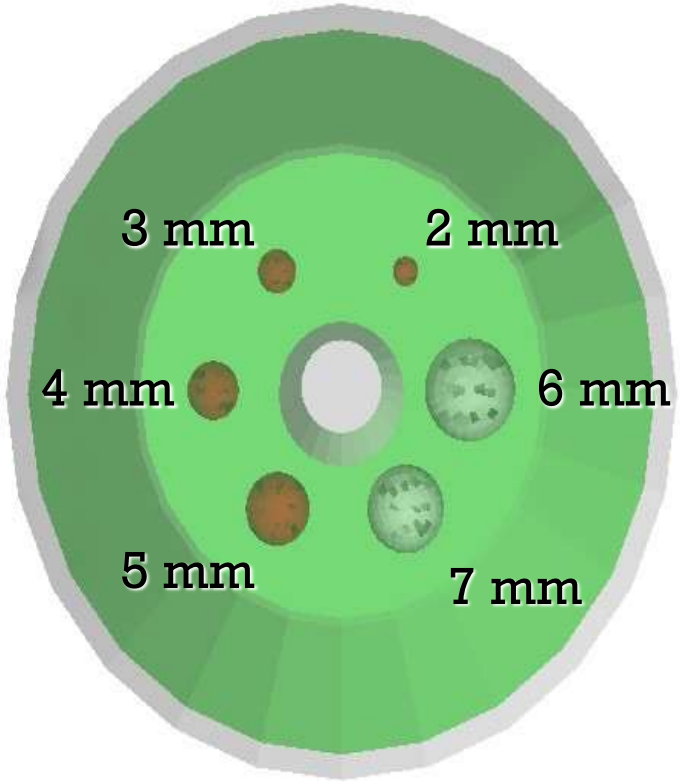
DOI Impact on Tumor Detectability

W.W. Moses, J. Qi / Nuclear Instruments and Methods in Physics Research A 527 (2004) 76–82



Torso Phantom Scan preliminary results with low stat





Sphere-to-background activity ratio: 8:1