A PET System Dedicated to Breast Cancer Imaging

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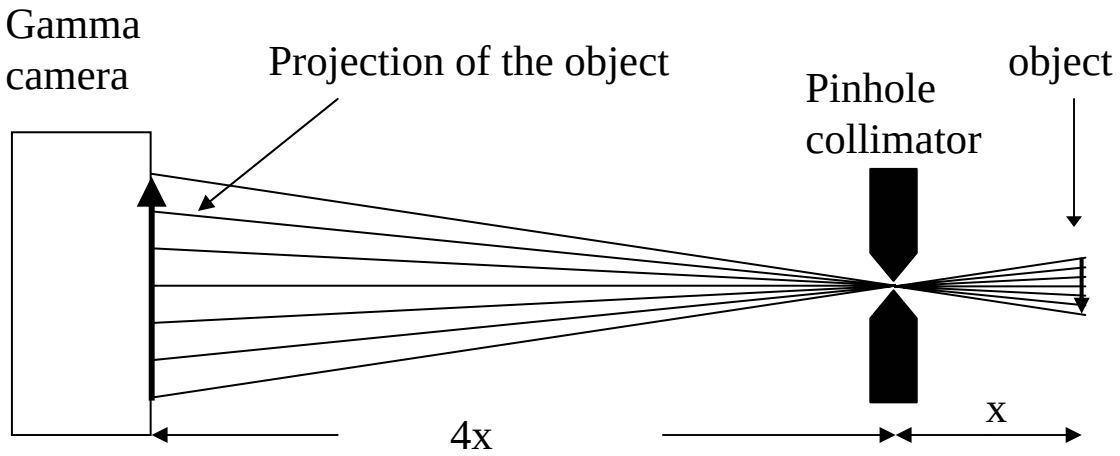
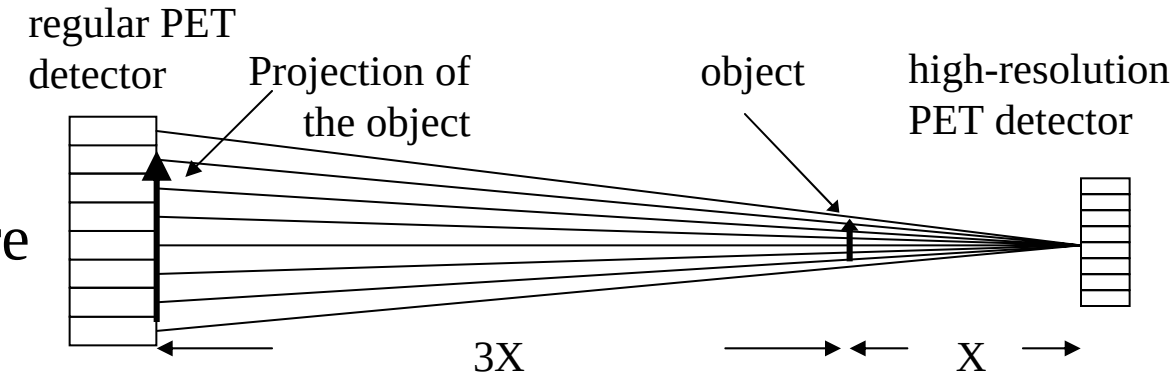
Pseudo-pinhole PET (PPP)

- Geometry learned from pinhole camera
- Image resolution limited by the pinhole size, not the camera resolution
- Regular PET detectors (left) are equivalent to a gamma camera
- High-resolution PET detectors (right) and coincidence detection are equivalent to multiple pseudo-pinhole





Proof of principle

- Detector 1 & 2: LSO crystals, 9x9 elements, 3x3x20 mm
- Sources: 2 glass tubes (Ø=1mm) filled with Cu-64, separated by 2mm (3.0mm C-to-C)
- Object to detector distance: 16.5 cm
- 12x12 elements of 1.51x1.51x10 mm LSO crystal in array 3
- Object to detector 3 distance: 5.5 cm

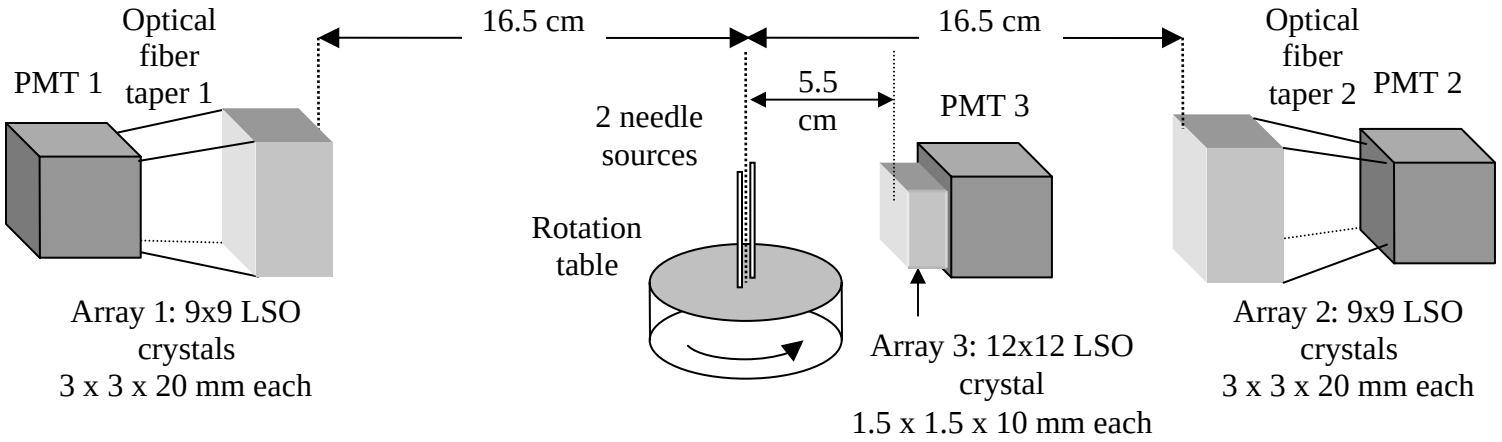


Image with the conventional geometry

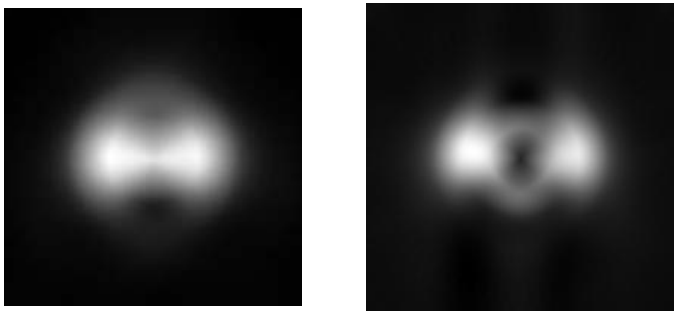
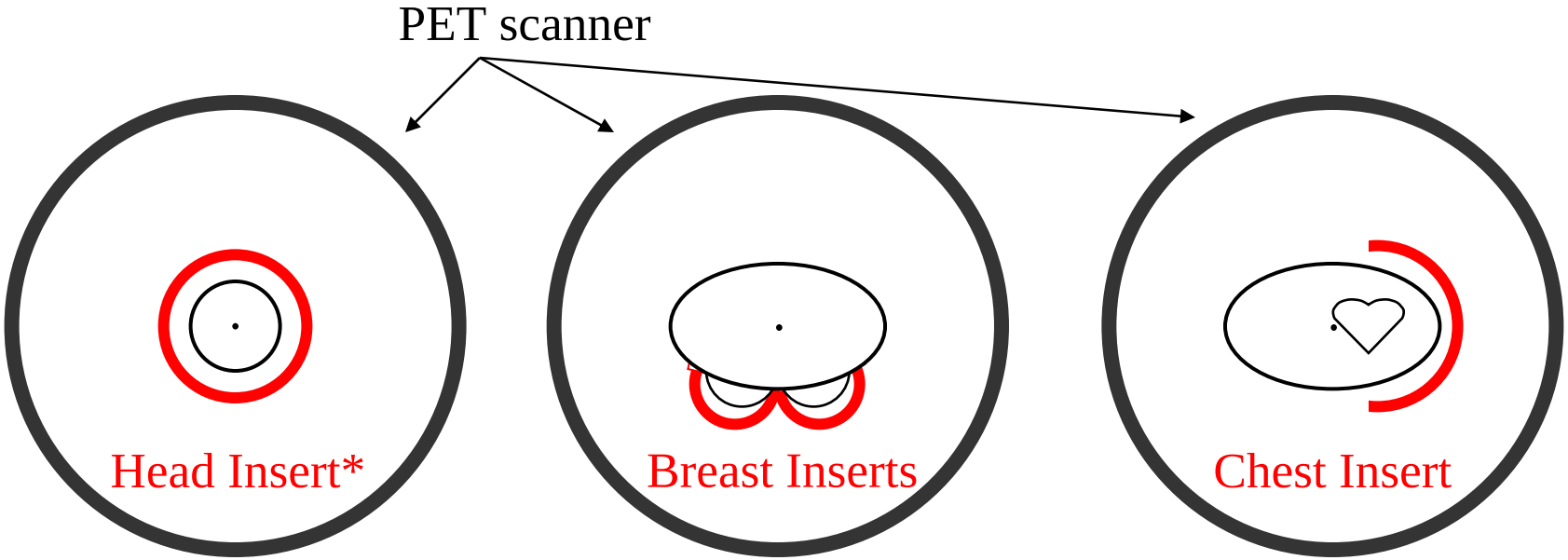


Image with the proposed geometry

Application-specific inserts for PET

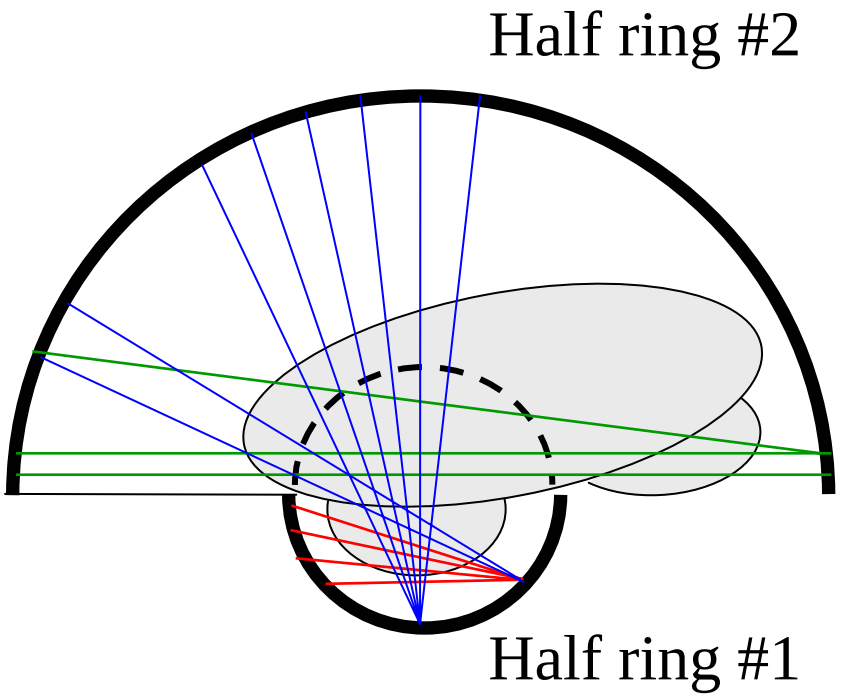


* Poster M10-72

- Currently developing insert for head and neck
- Evaluate the feasibility of a dedicated breast PET system using a similar geometry

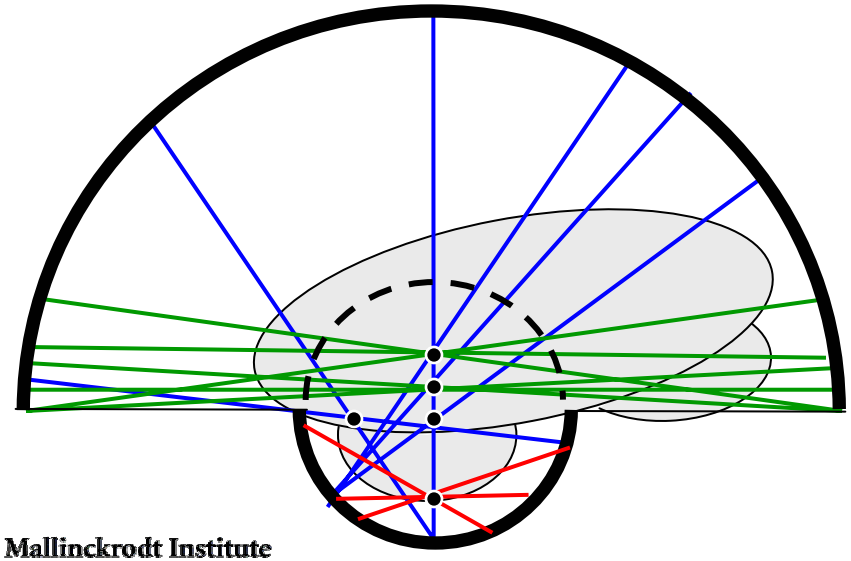
A Breast PET System

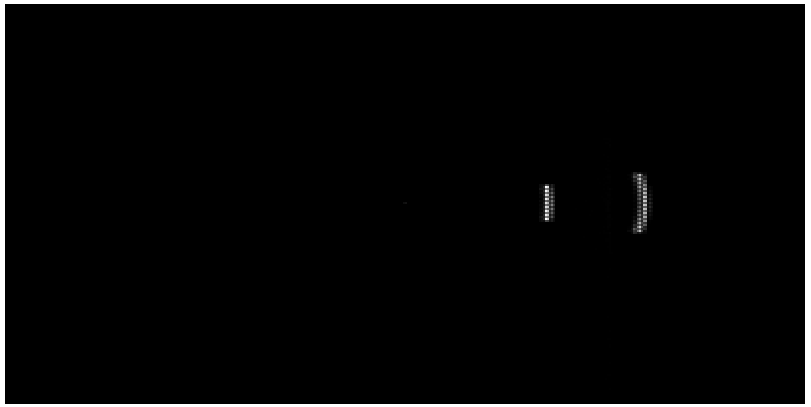
- Half ring #1 consists of high-resolution detectors
- Half ring #2 consists medium-resolution low-cost detectors
- Image resolution is limited by intrinsic resolution of detectors in half ring #1

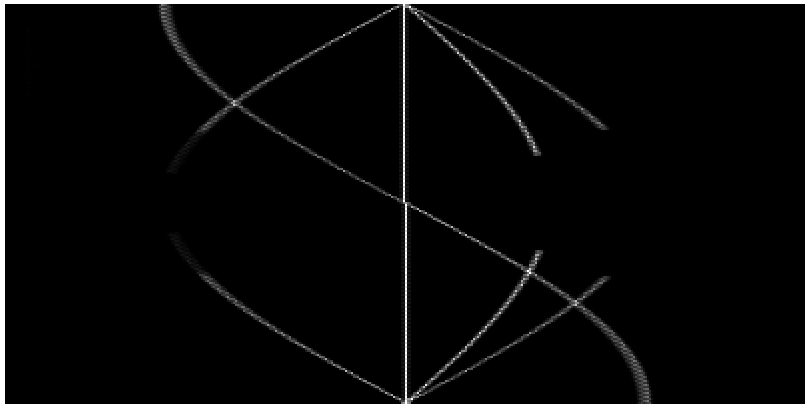


Sampling issue

- Potentially usable imaging FOV is the full circular region with the small radius that enclose a breast, chest wall, and internal lymph nodes
- coincidences may be detected by large half-ring alone (LL), small and large half-rings (SL), and small half-ring alone (SS).

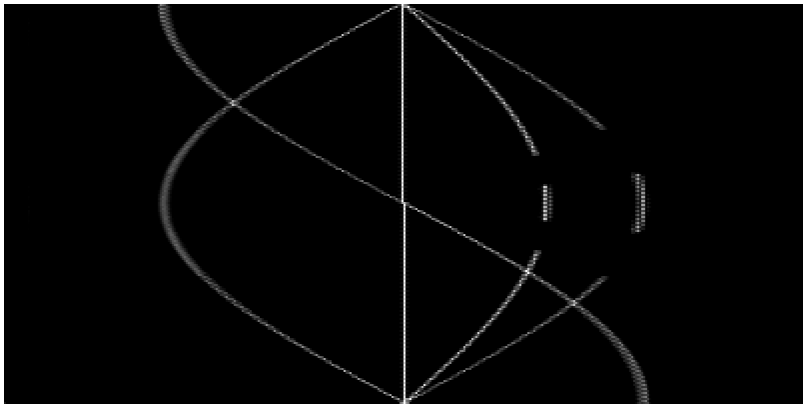


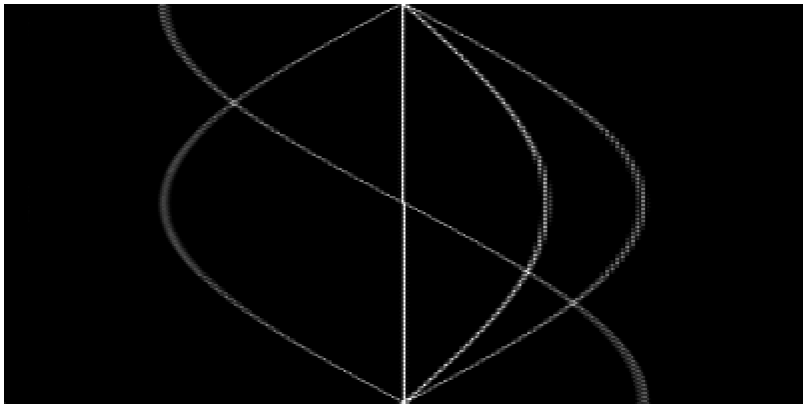




Combined sinogram for complete sampling

- Combined sinogram (LL, SL, SS) provides complete sampling for lower half of imaging FOV.
- The farther away above the middle plane, the less complete the sampling
- Image may still be obtained from the incomplete sinogram through statistical reconstruction methods

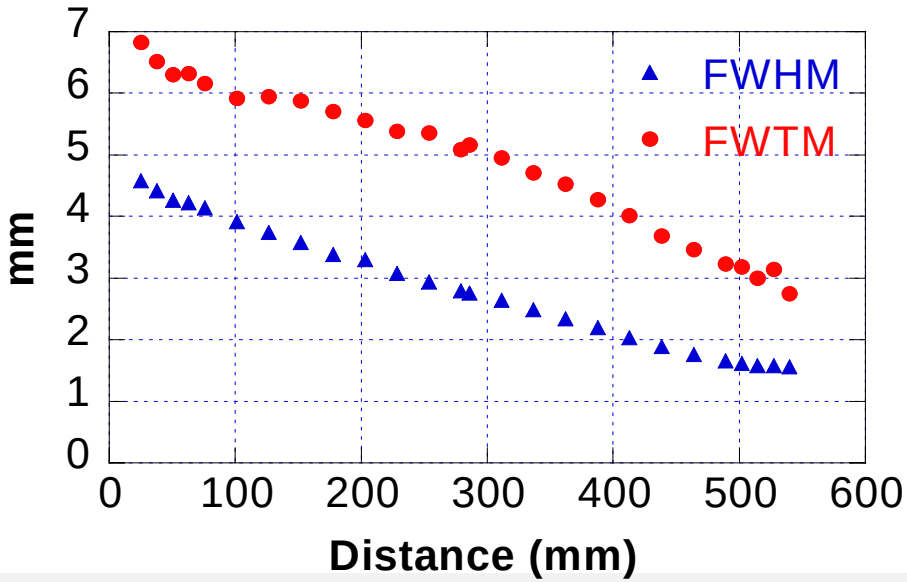


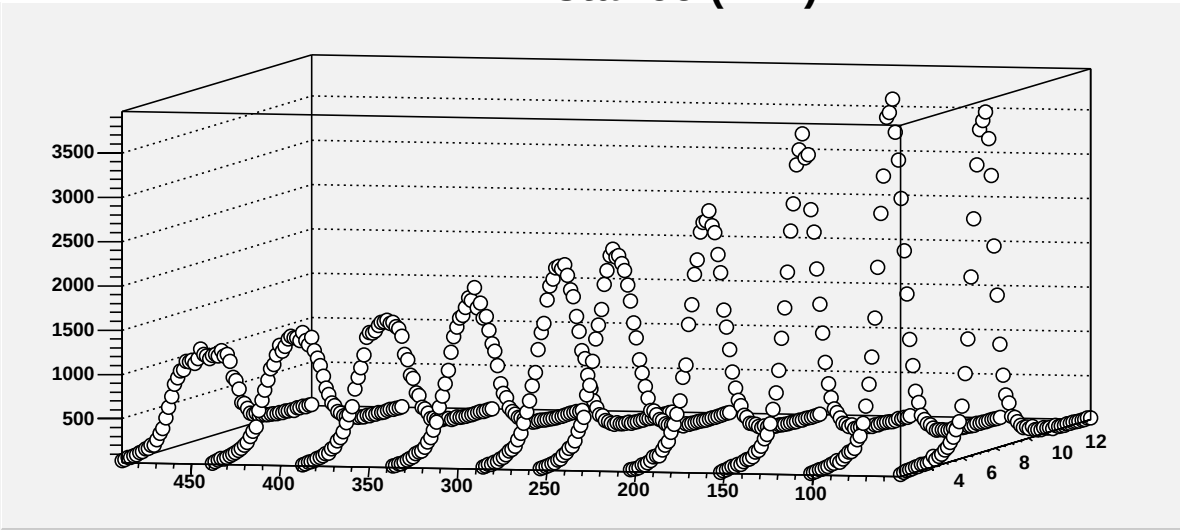


- Increase the angular coverage of the upper half ring can also fill the missing data

Coincidence detection profile

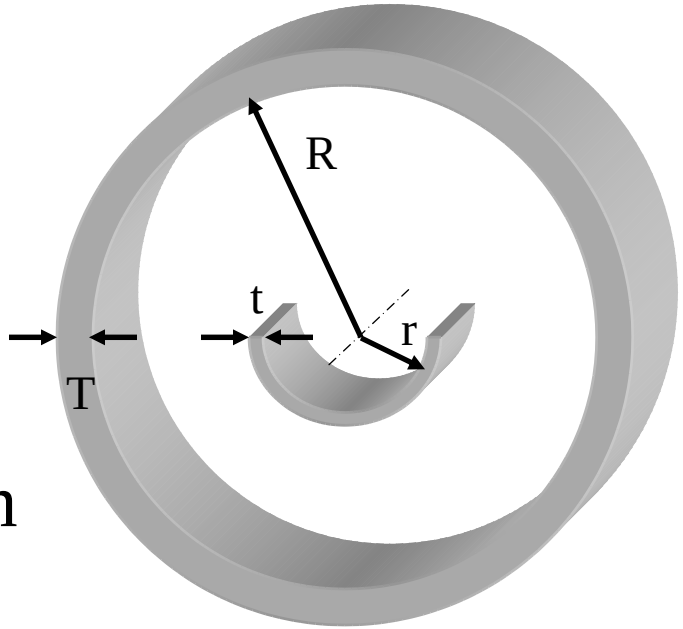
- Measured with a ^{22}Na point source (0.5 mm diameter) stepping across a pair of LSO detectors
- Left: 4.8 x 4.8 x 10 mm LSO array
- Right: 1.6 x 1.6 x 10 mm LSO array
- Distance between arrays is 560 mm





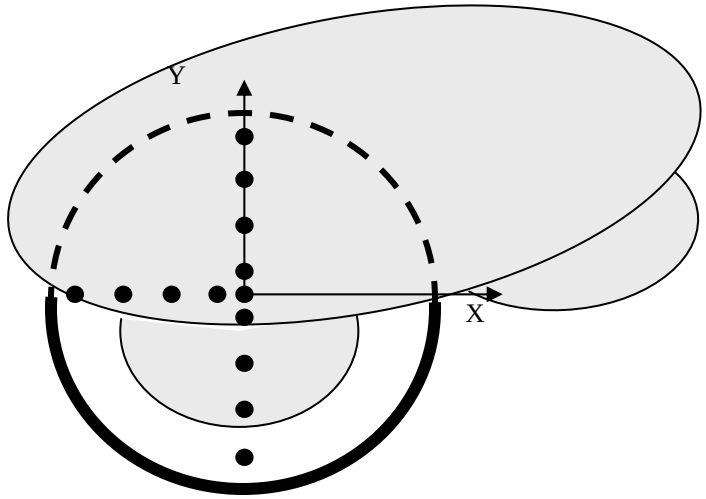
Simulation study

- SimSET package was modified to support a half ring detector module coexist with a cylindrical module.
- LSO crystal for both modules
- Energy resolution = 18%
- R = 41.25 cm, r= 15.27 cm,
- T = 2.5 cm, t = 2.0 cm
- Acollinearity enabled
- Crystal pitch: 4.3 mm and 1.6mm
- 2- or 4-layer DOI detector in high resolution half ring



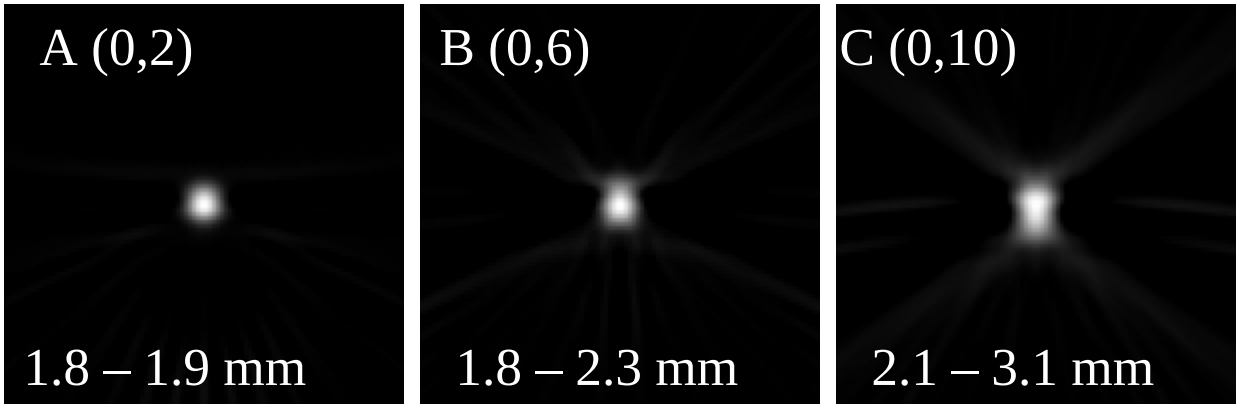
Evaluation of image resolution

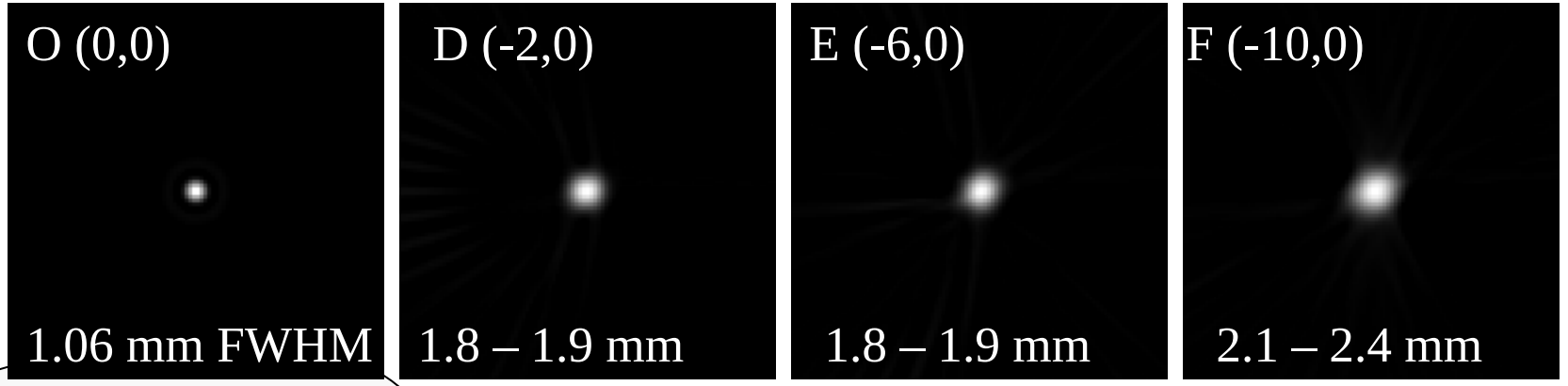
- A point source of 1mm in diameter was simulated at 0, 2, 6, and 10 cm from CFOV along the -X, -Y and +Y directions
- Positron range effect not simulated

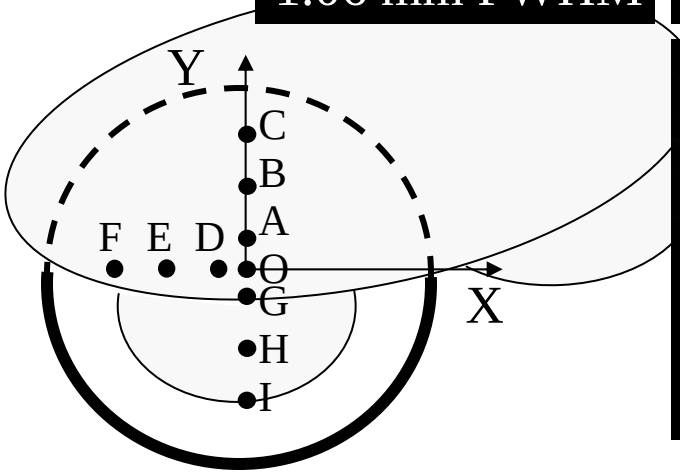


Point source w/ 4-layer detector

(1.6 x 1.6 x 5mm each)







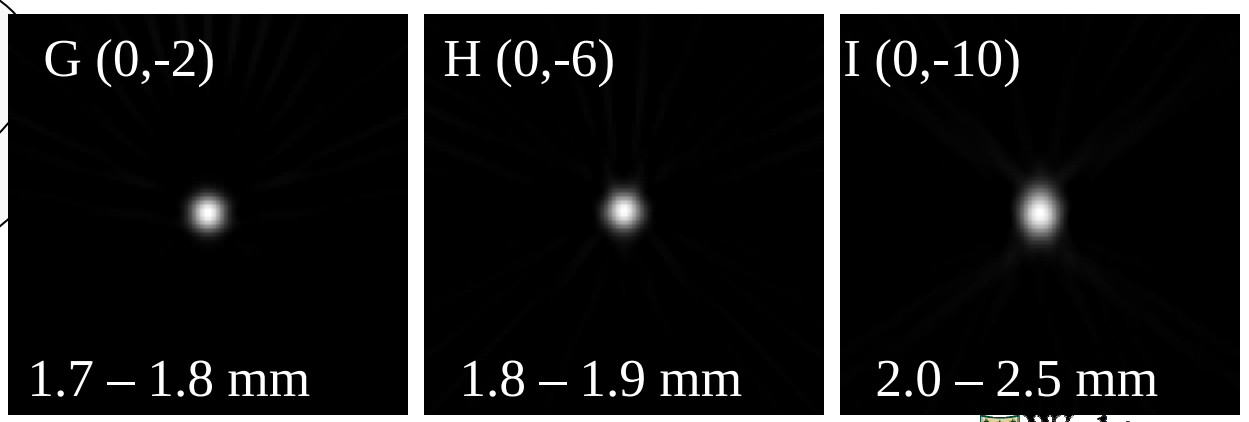
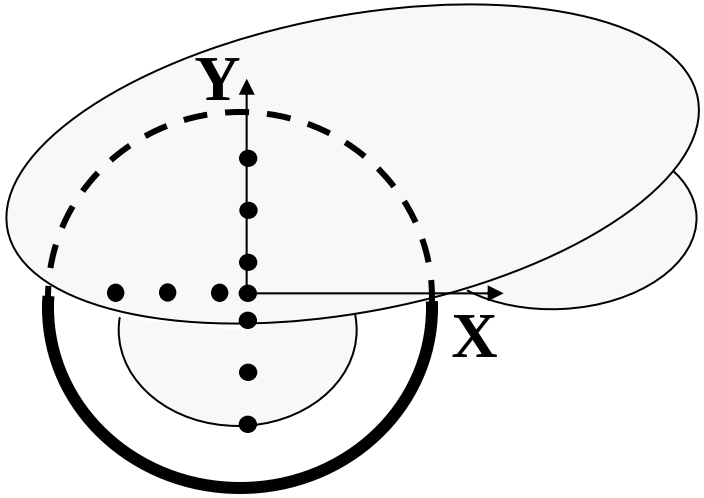
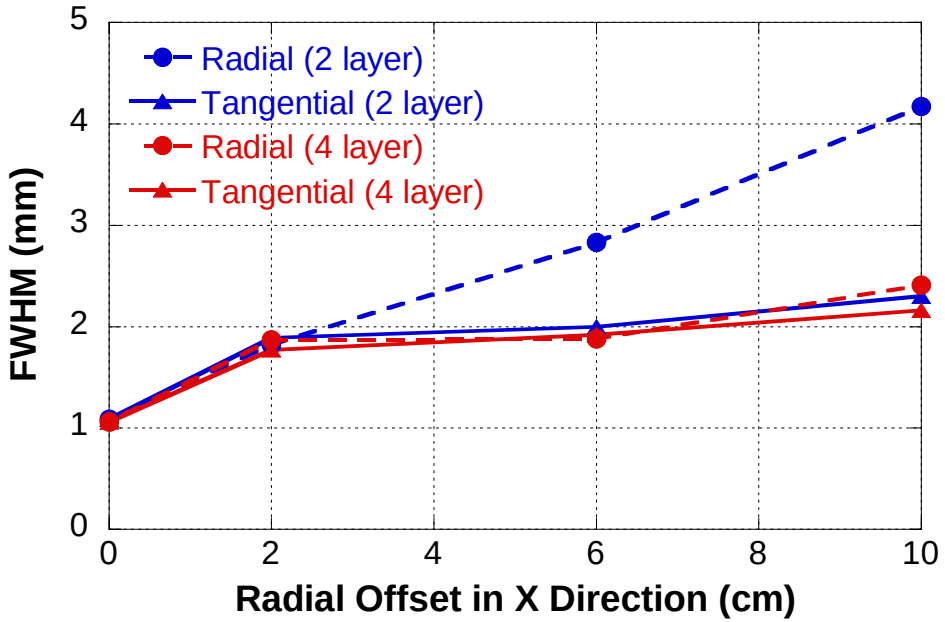
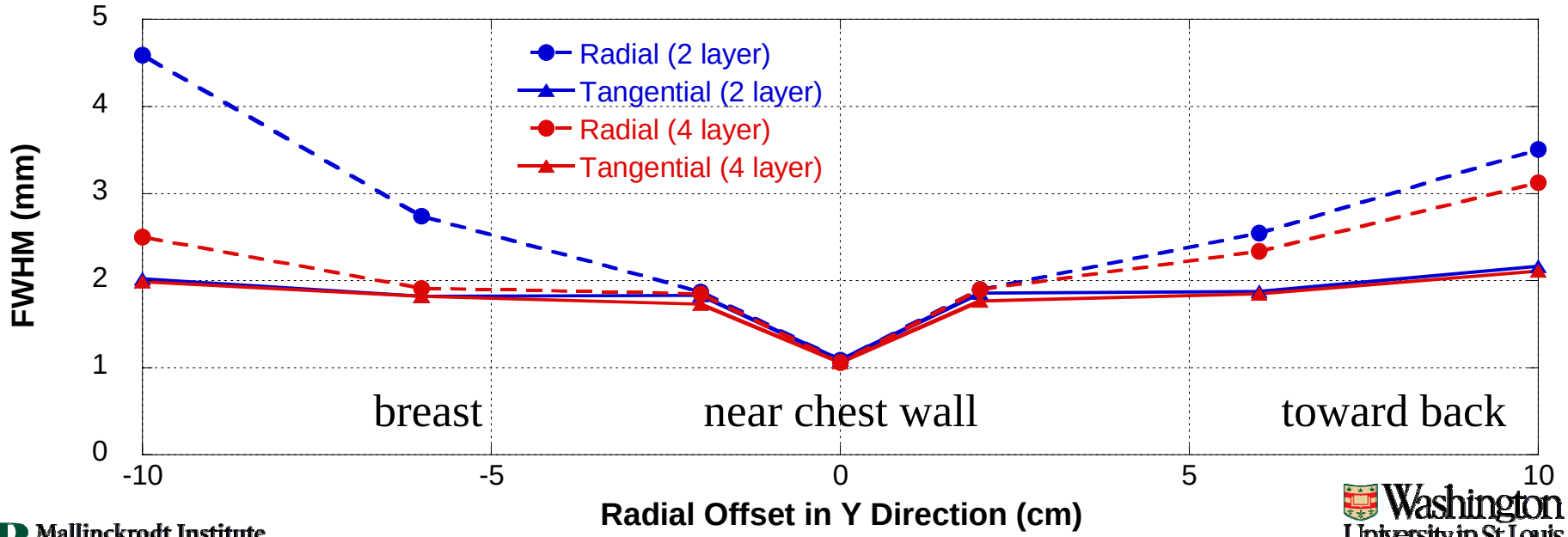


Image resolution

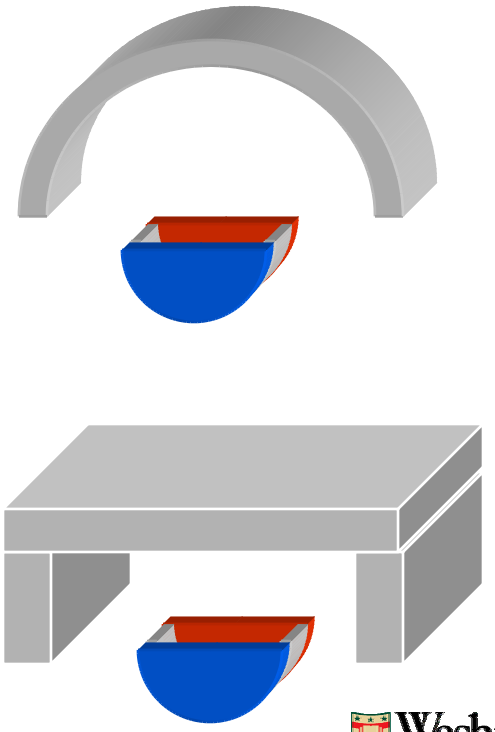






Sensitivity of the device

- Sensitivity is 7.8% at CFOV if the axial extent of the small and large half-rings are 3.8 cm and 10.8 cm, and drops to 5.4% toward the edge of the small half ring.
- The sensitivity can be improved if:
  - Ring diameters are further reduced
  - Two planar detectors are added to enclose the breast from the axial directions
  - The upper half ring is substituted by 3 planar detectors that are positioned closer to the patient body with large solid angle coverage



Conclusions

- The proposed PET system can provide high resolution and high sensitivity for breast imaging.
- Imaging FOV includes full breast, internal and/or axillary lymph nodes.
- Dynamic imaging is possible
- May be combined with a stereotactic biopsy station
- Lots of challenges to overcome

Future works

- Monte Carlo simulation to optimize the detector design and system parameters.
- Develop high-resolution detector with DOI capability
- Develop image reconstruction techniques that include the non-uniform detector response.
- Develop correction techniques such as normalization, attenuation correction, scatter correction, etc.
- Build a prototype system
- Clinical evaluation of the effectiveness of the system

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