A Silicon detector probe for high-resolution PET imaging

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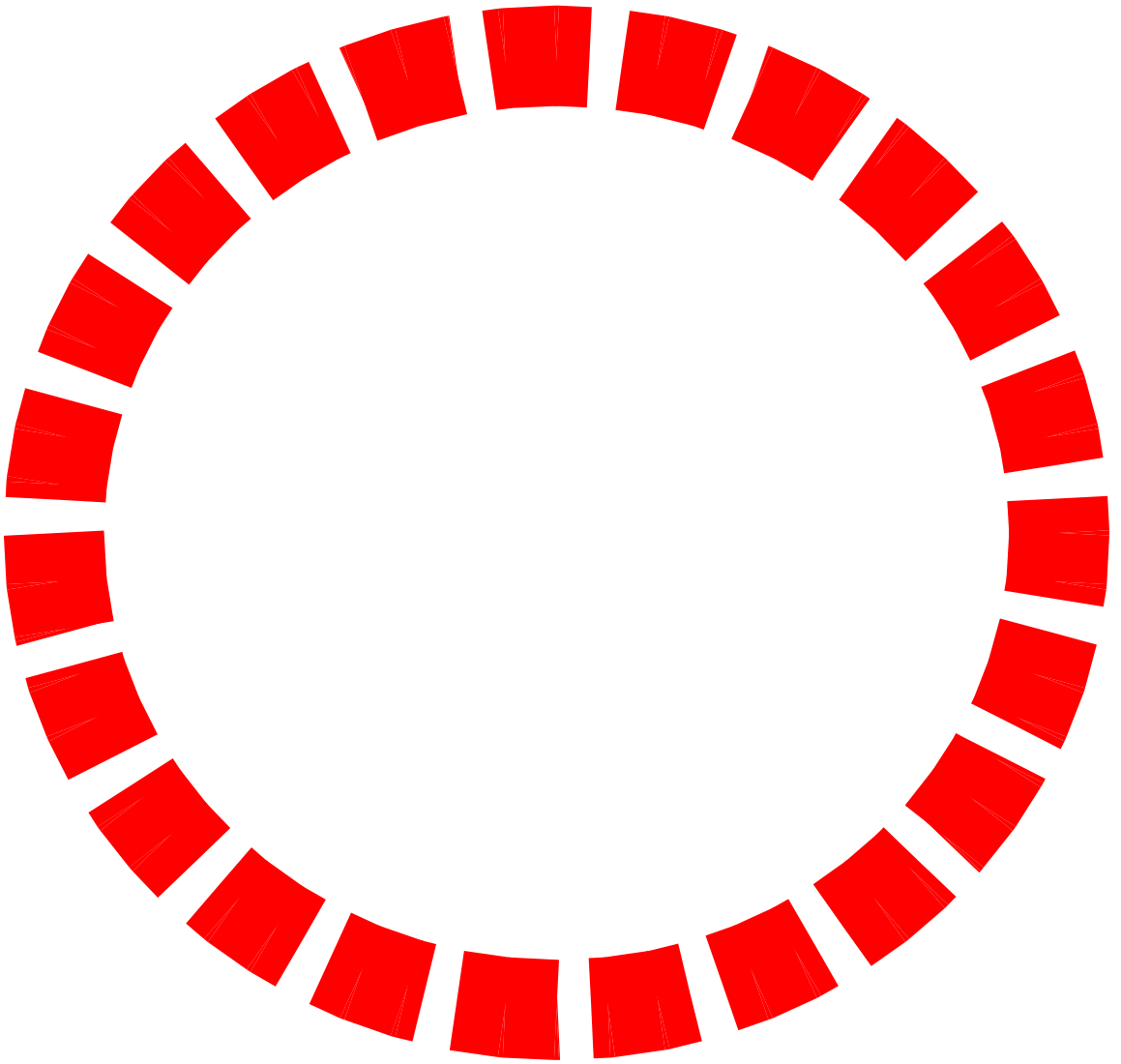
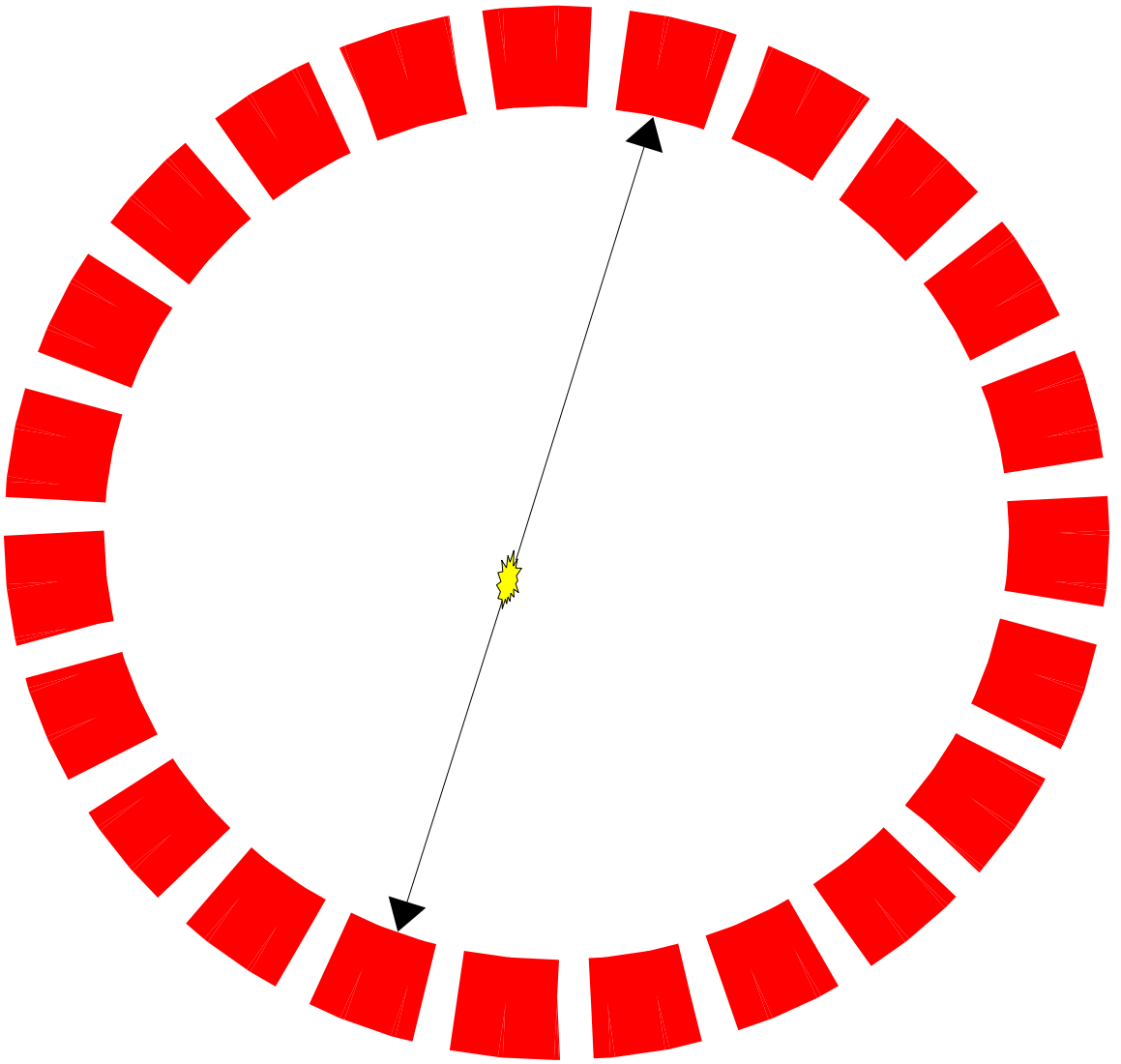
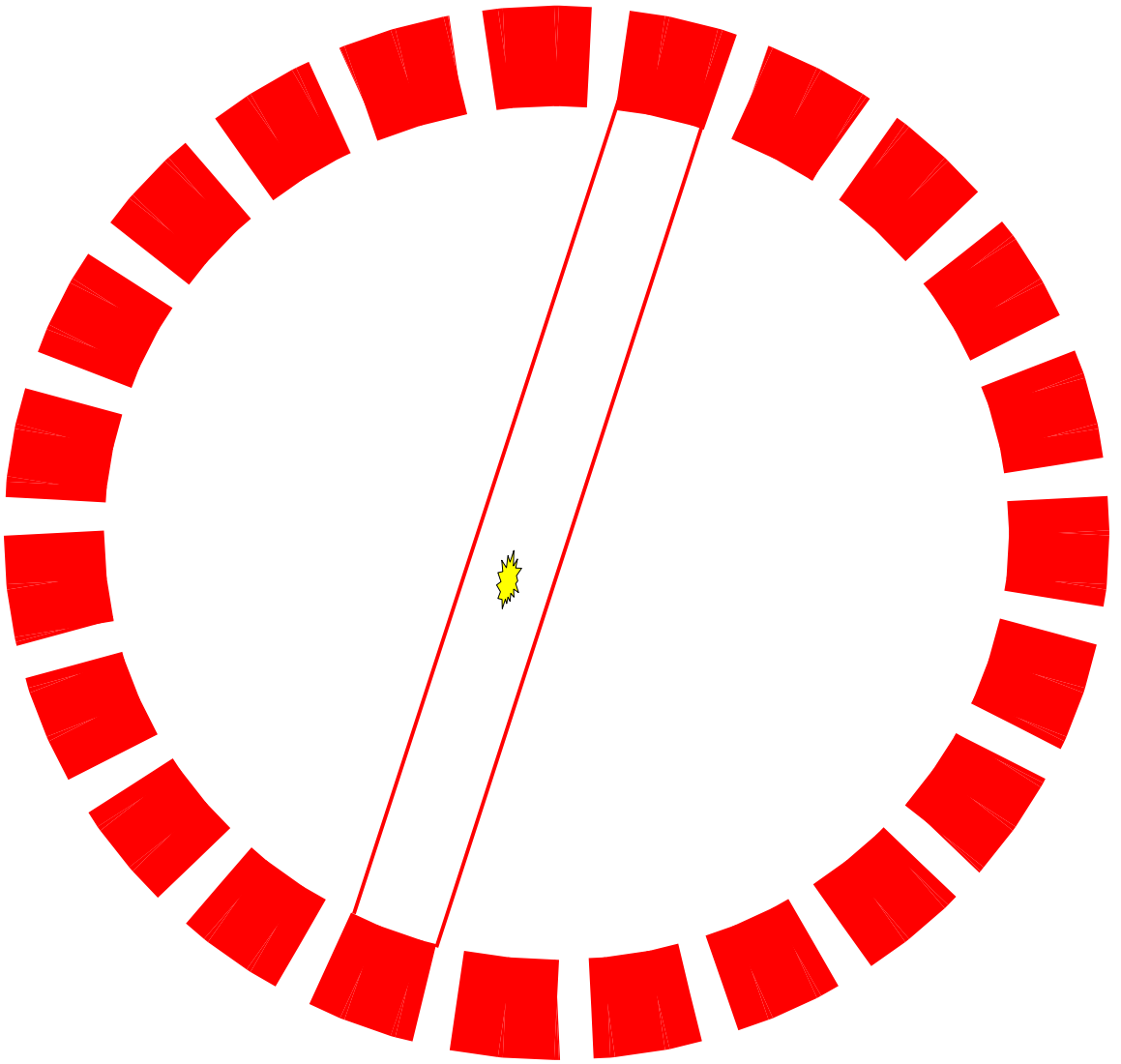
PET insert concept



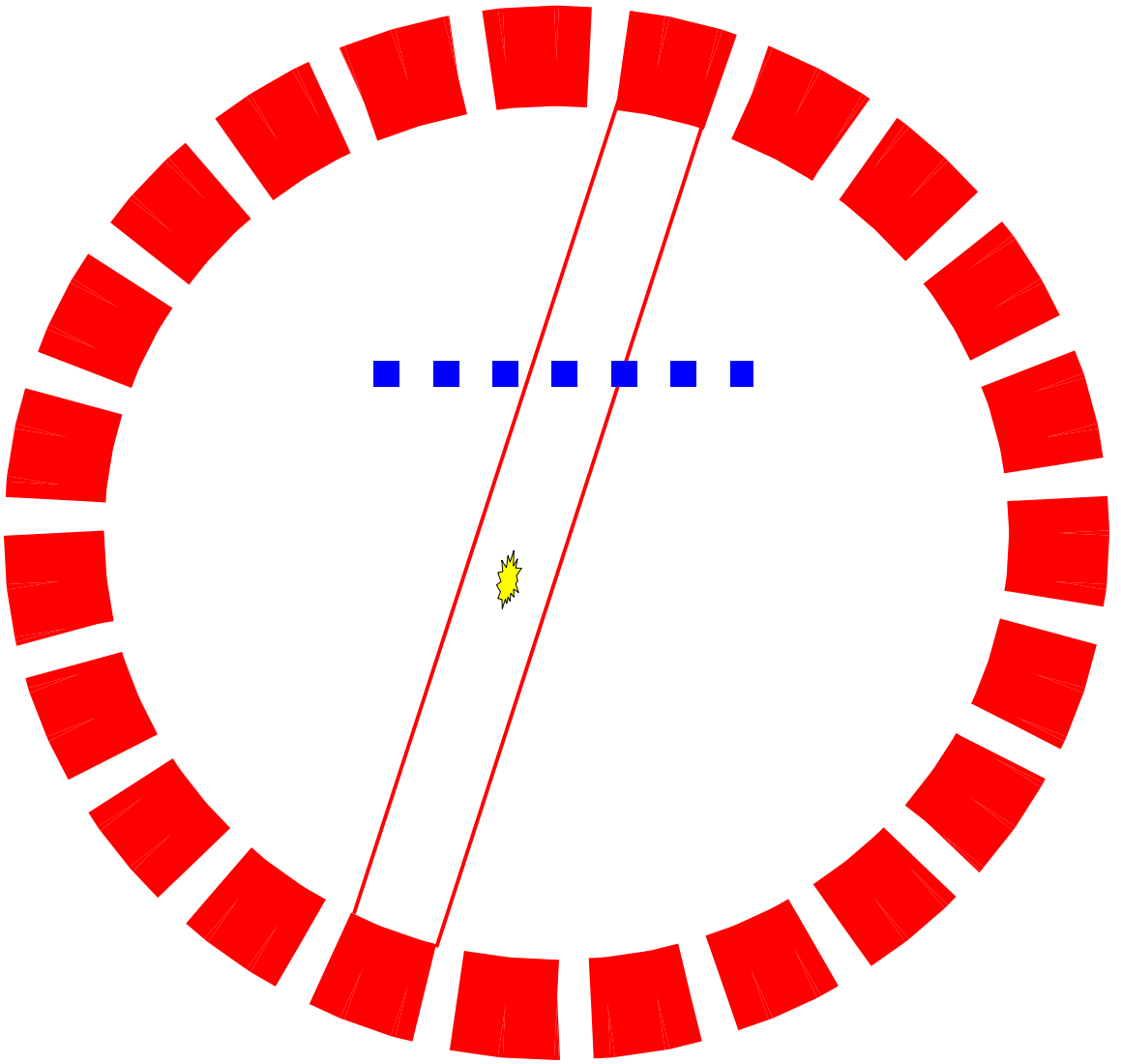
PET insert concept



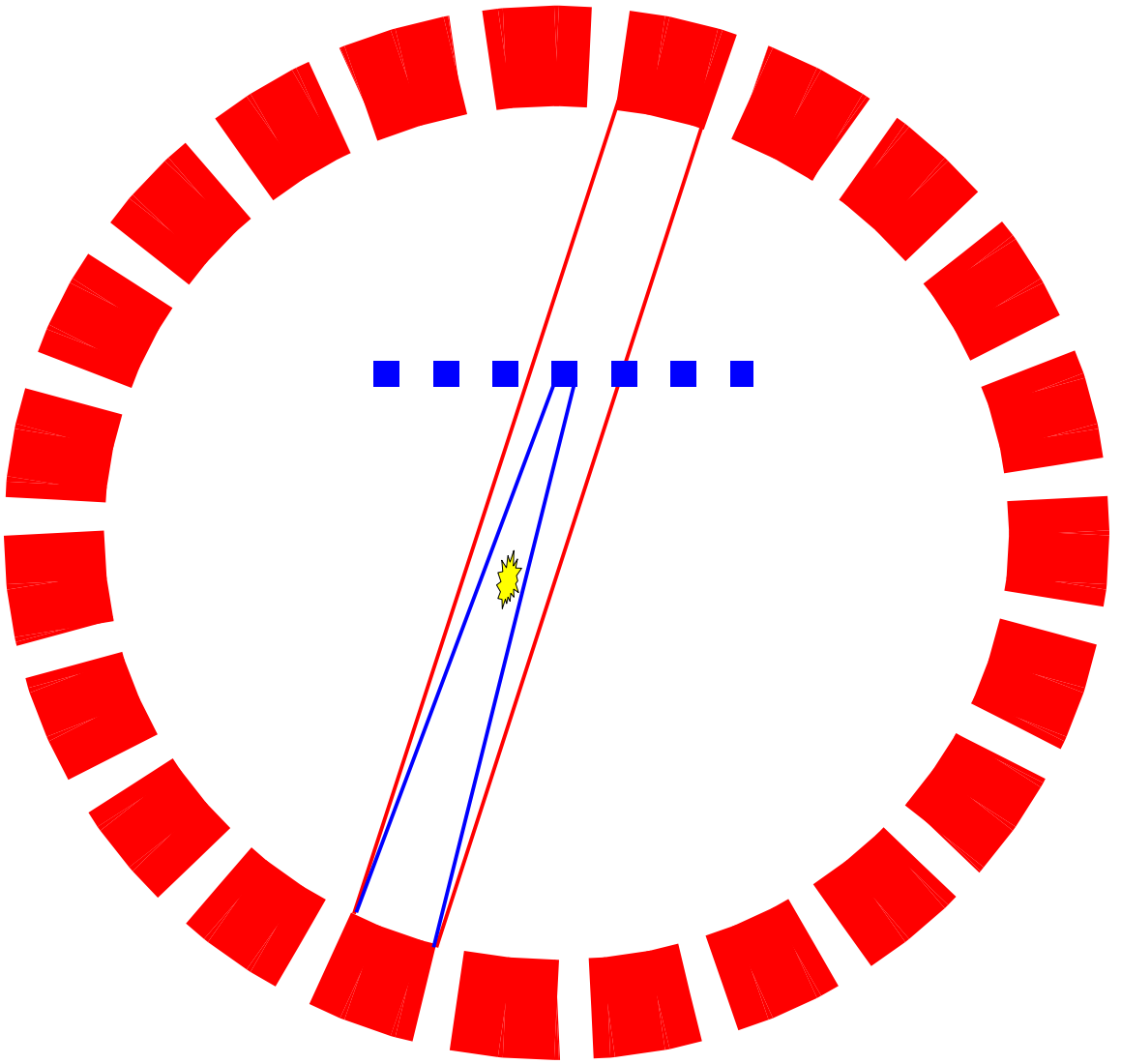
PET insert concept



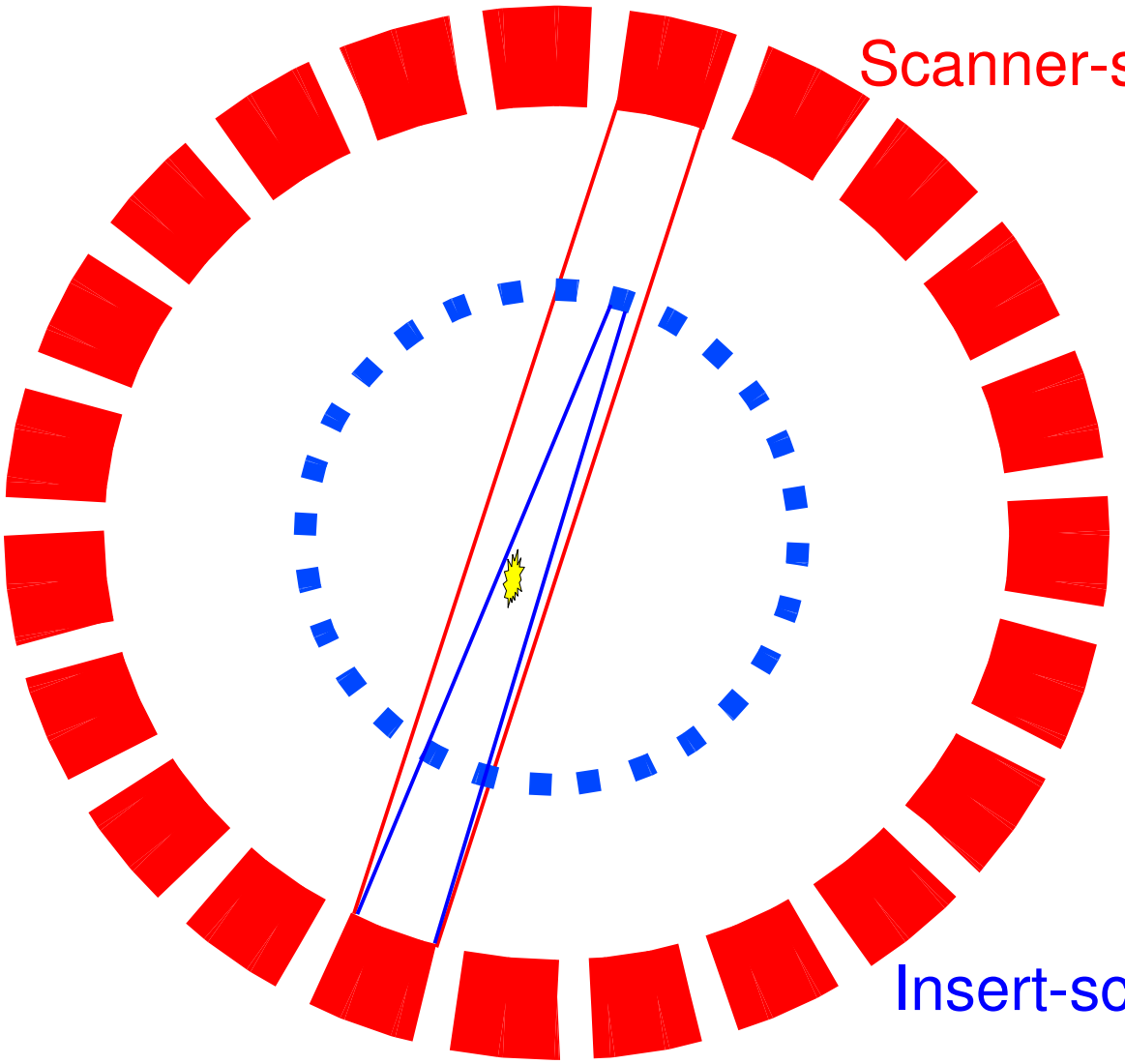
PET insert concept



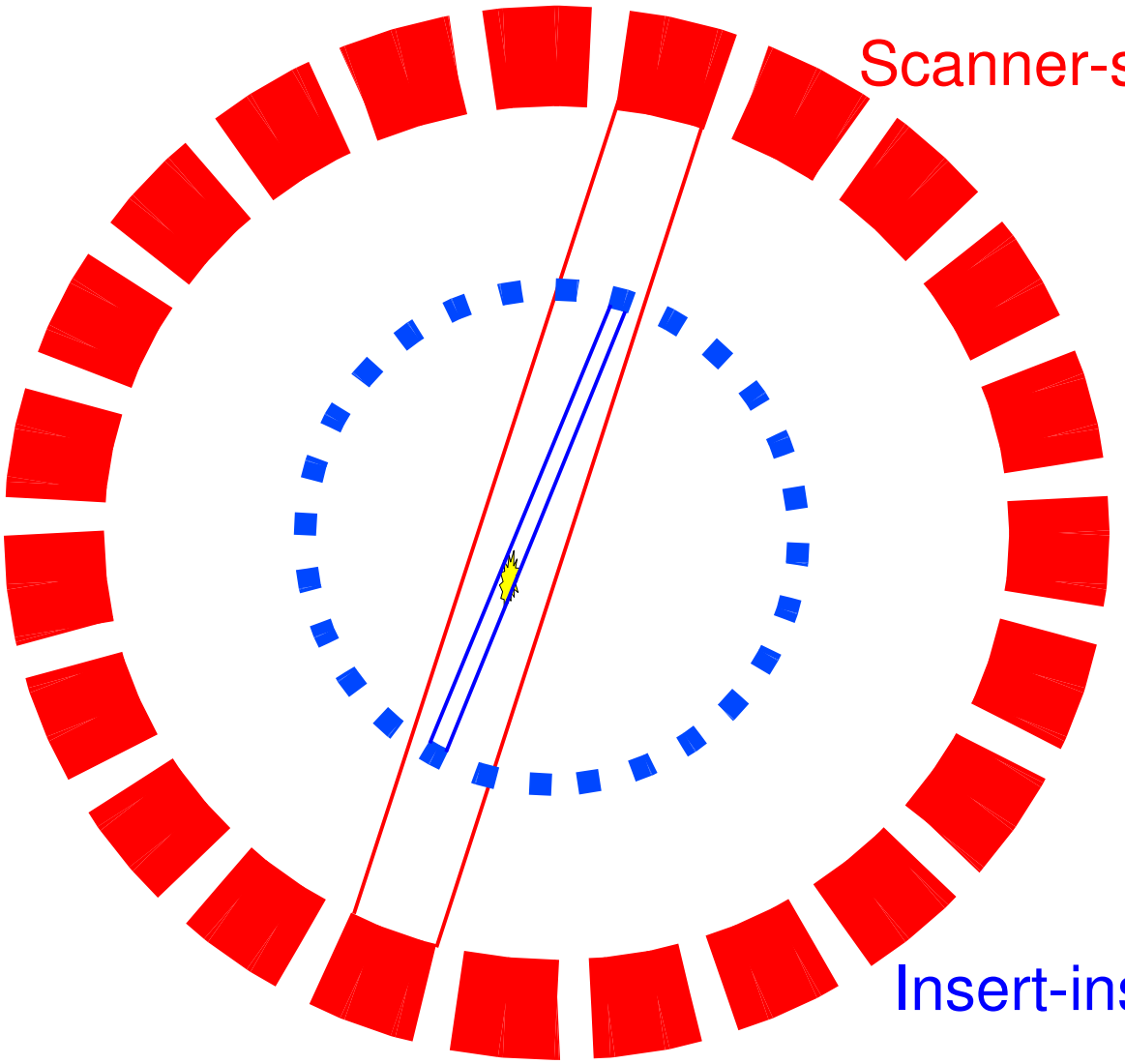
PET insert concept



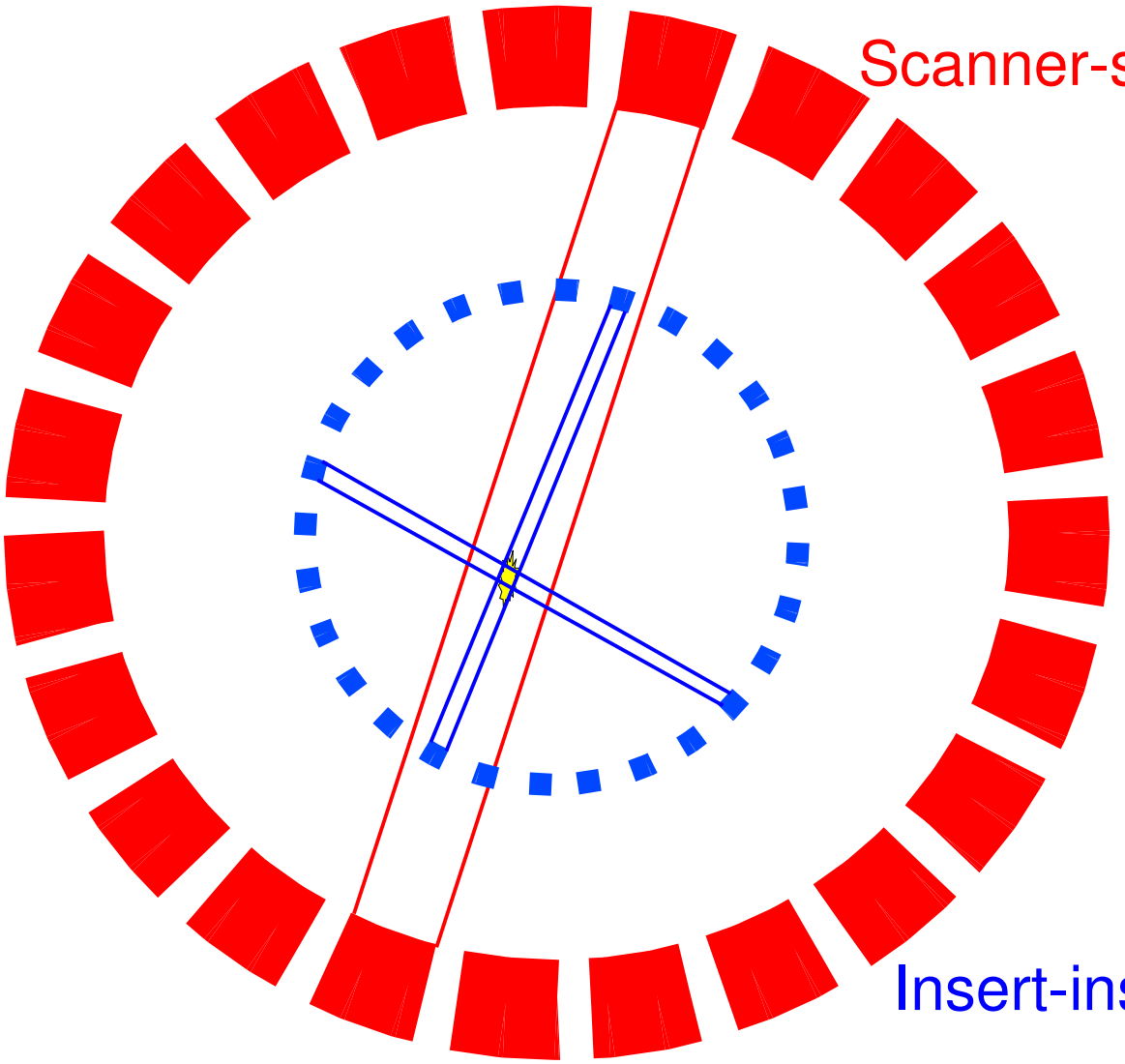
High-resolution inserts: ring geometries



High-resolution inserts: ring geometries



High-resolution inserts: ring geometries



High-resolution inserts: ring geometries

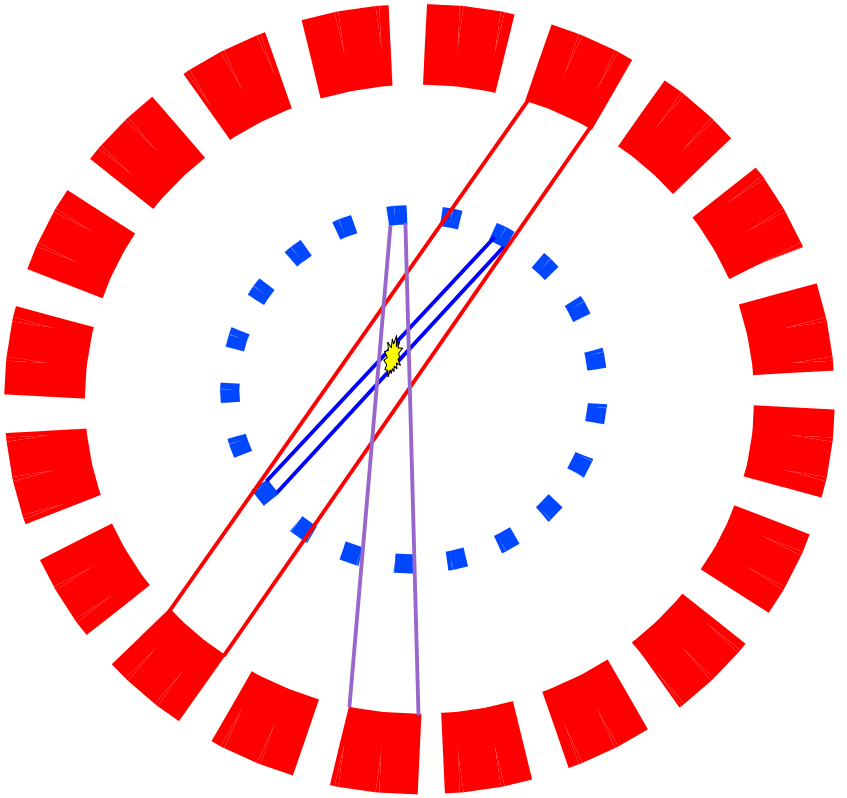
Improved spatial resolution observed through a decrease in FWHM.

Simulation studies:

- Clinical scanner + LSO insert[1]:
  - ~ 64 % insert-insert events
- Small animal scanner + Si insert[2]:
  - ~ 85 % insert-insert events
  - ~ 45 % insert-scanner events

Experimental prototypes:

- Small animal scanner + LSO insert[3]:
  - ~ 33 - 41 % insert-insert events
  - ~ 17 - 23 % insert-scanner events
- Clinical PET-CT + LSO insert[4]:
  - ~ 40 - 50 % insert-insert events

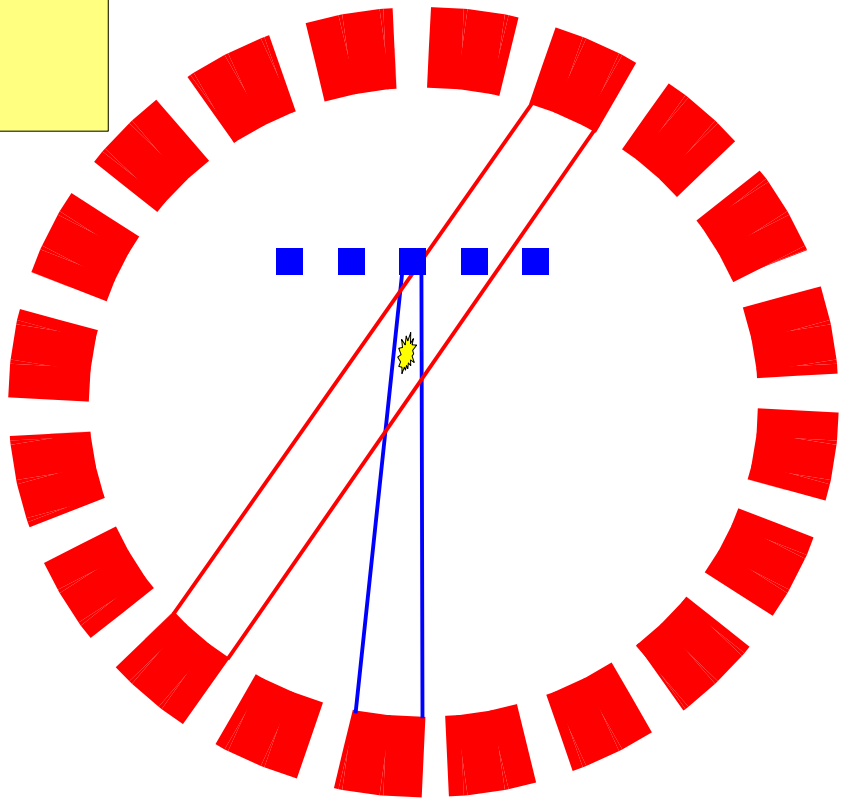


1. Janecek M. et al (2006)
2. Park S.J et al (2007)
3. Wu H. et al (2008)
4. Wu H. et al (2008)

High-resolution inserts: “probe” geometries

Advantages:

- More straight forward to adapt to an existing PET scanner.
- Focus on target region close to the face of the detector.
- Flexibility (adaptive imaging possible).
- More cost effective.



Improved spatial resolution

Simulation studies:

Small animal scanner + LSO (DOI) probe[1]:

~ 60 % probe-scanner events

MADEIRA system:

~ 50 % insert-scanner events

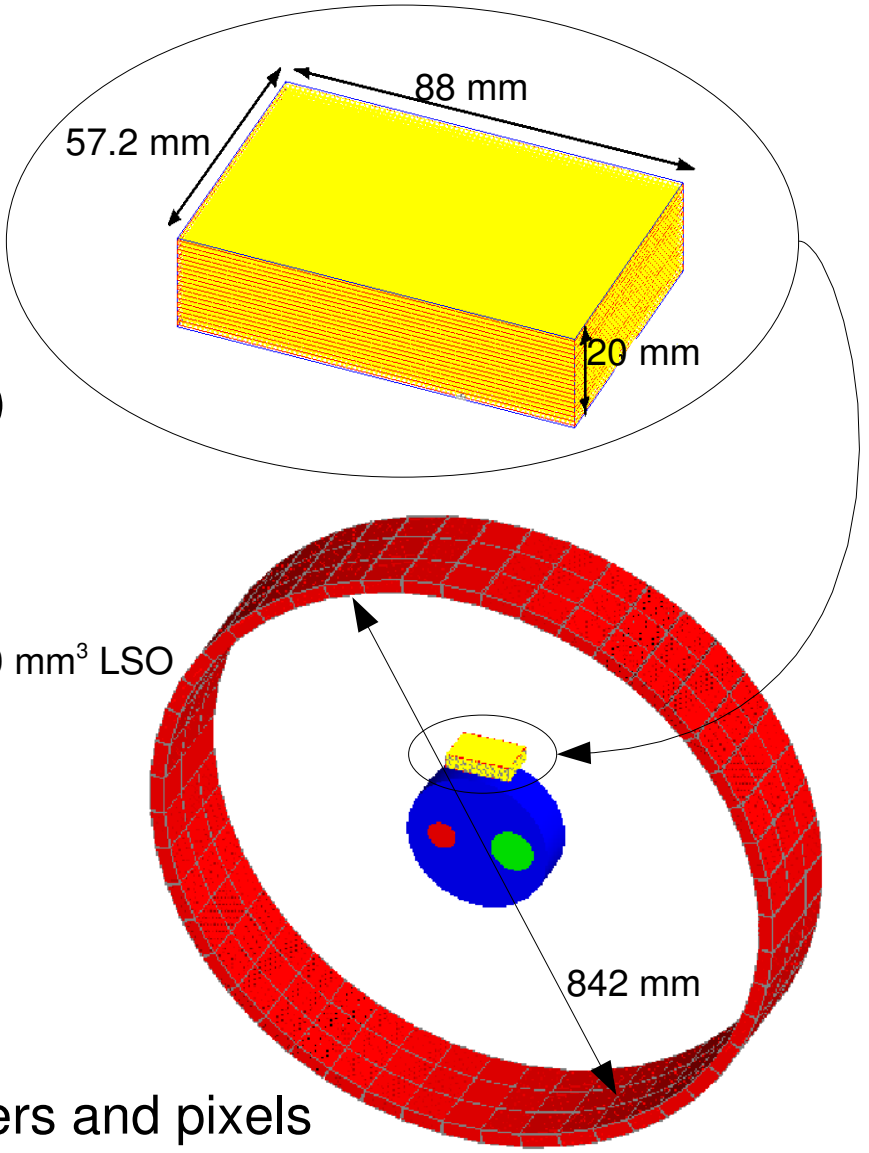
1. Zhou J. et al (2009)

The MADEIRA geometry

<u>The MADEIRA probe:</u>

Finely pixelated silicon detectors

- Good spatial resolution
- Good energy resolution (event classification)
- Robust and compact
- Functions in magnetic fields
- Mature technology



<u>Monte Carlo simulations (GATE):</u>

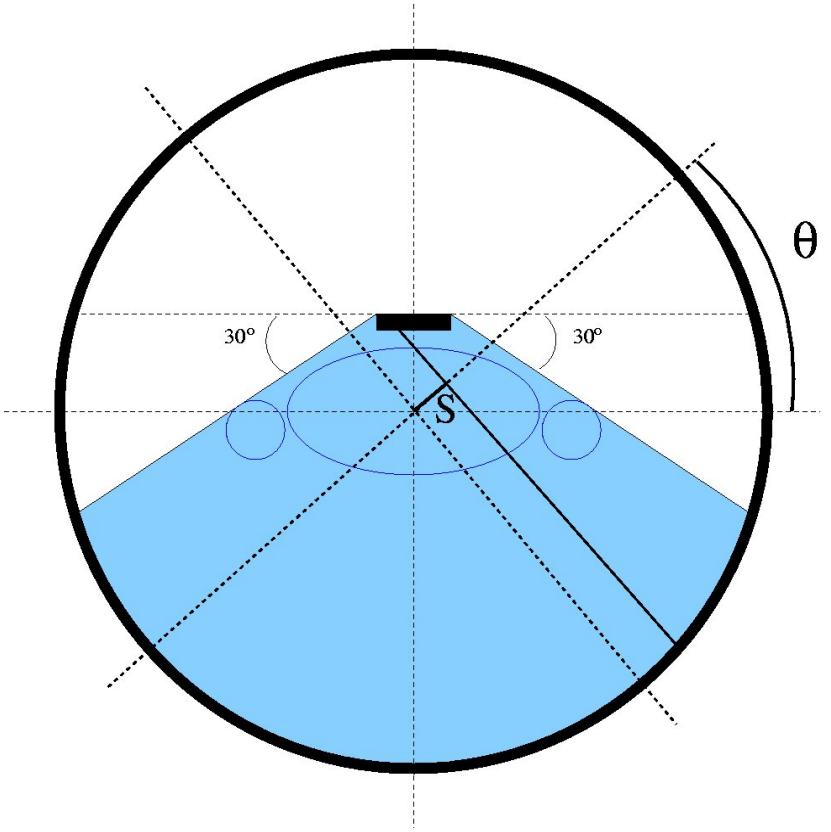
- 10 layers of Si (1 mm thick, 1mm spacing)
- 1x1 mm^2 pixels in 80 x 52 arrays
- Scanner modeled on Siemens Biograph64
- Experimental probe prototype has fewer layers and pixels

Possible clinical application

- High resolution in localized ROI – Breast cancer imaging
- PET in mammography – An a ccurate tool
  - Primary tumor detection
  - Axillary staging
  - Defining extent of cancer
  - Therapy response monitoring
- High resolution may be beneficial for a number of these tasks

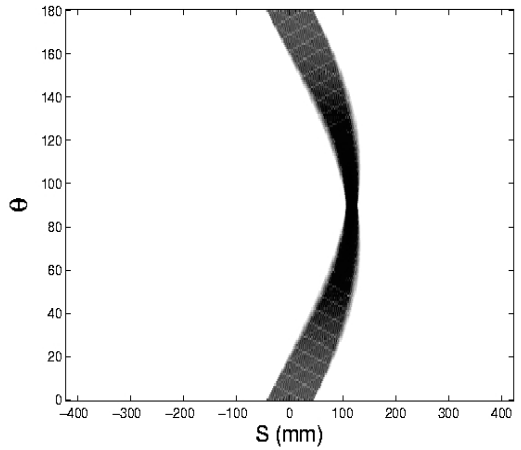
Nature of the probe-ring data

- High resolution
- Limited angular coverage
- To be used to enhance ring-ring data
- Limited FOV
  - Other data can be "cut out"

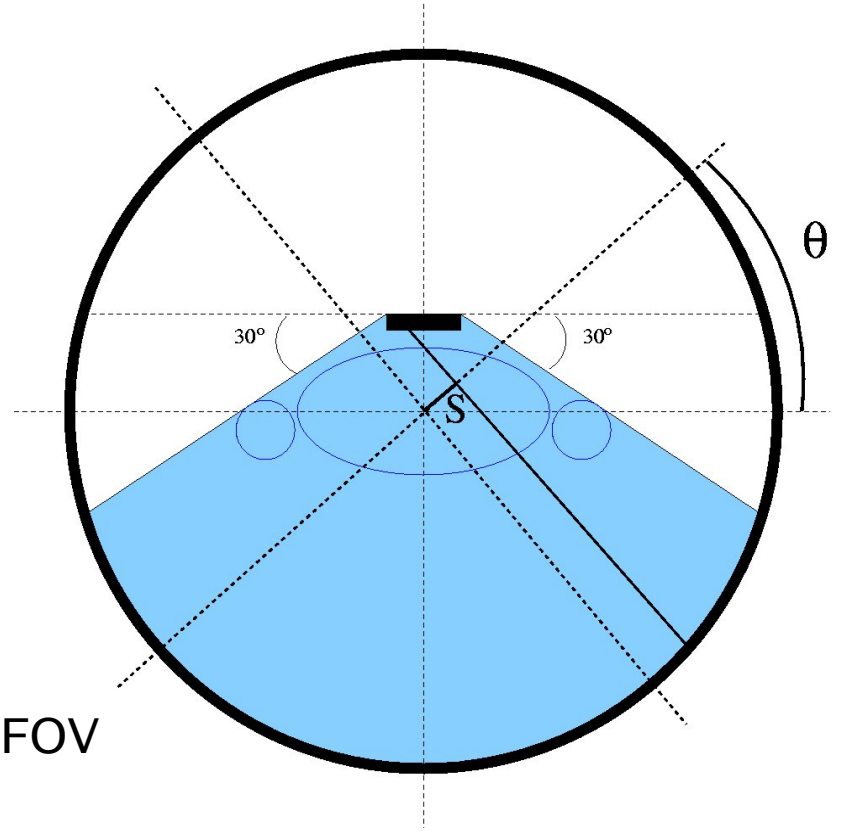


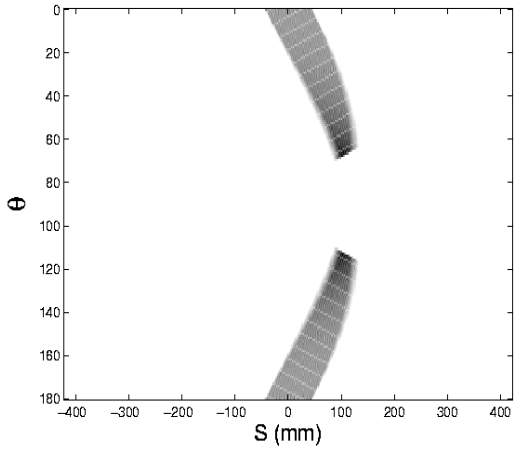
Nature of the probe-ring data

In Radon space:



Full probe-ring FOV

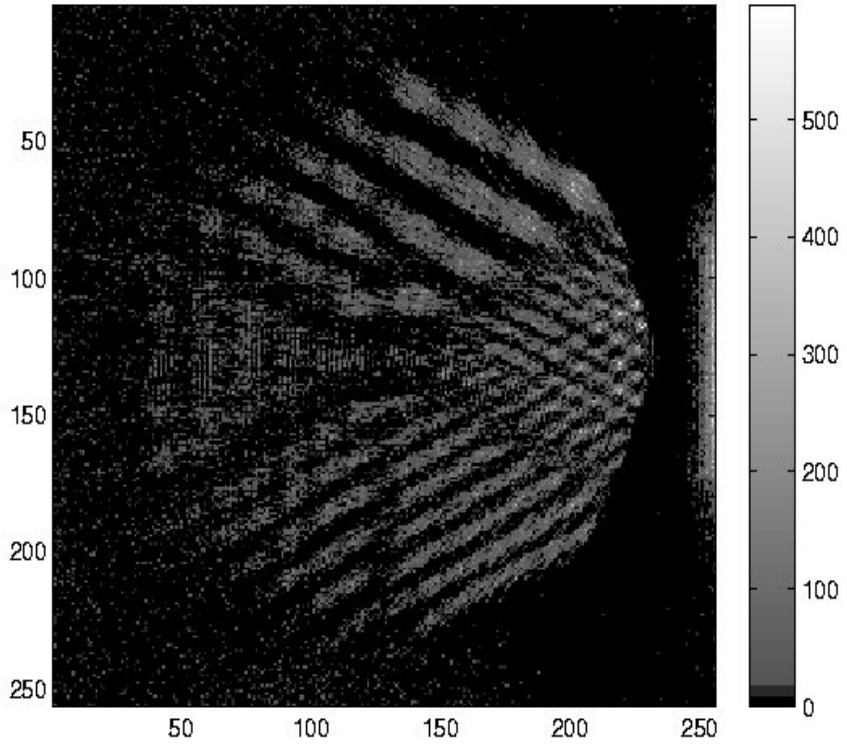


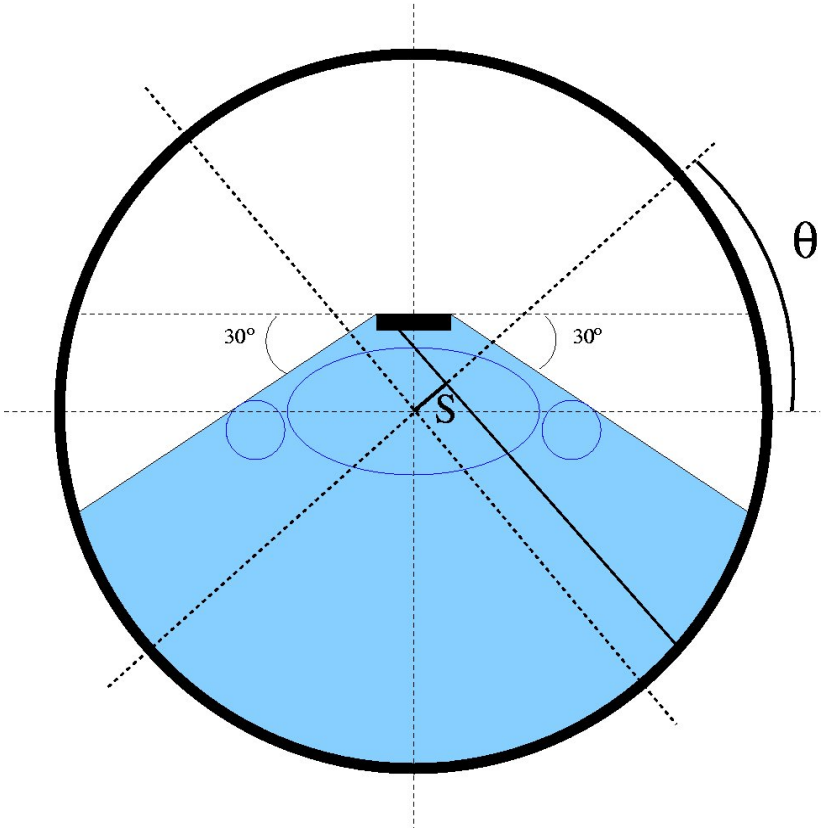


Limited probe-ring FOV

Nature of the probe-ring data

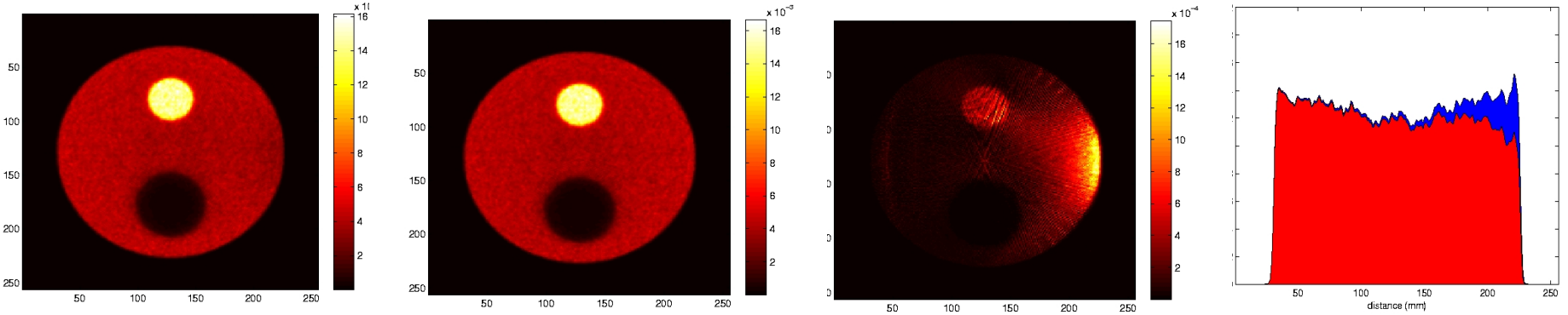
In image space:





System modeling and image reconstruction

- ML-EM
  - Abundance of possible measurements-> list-mode

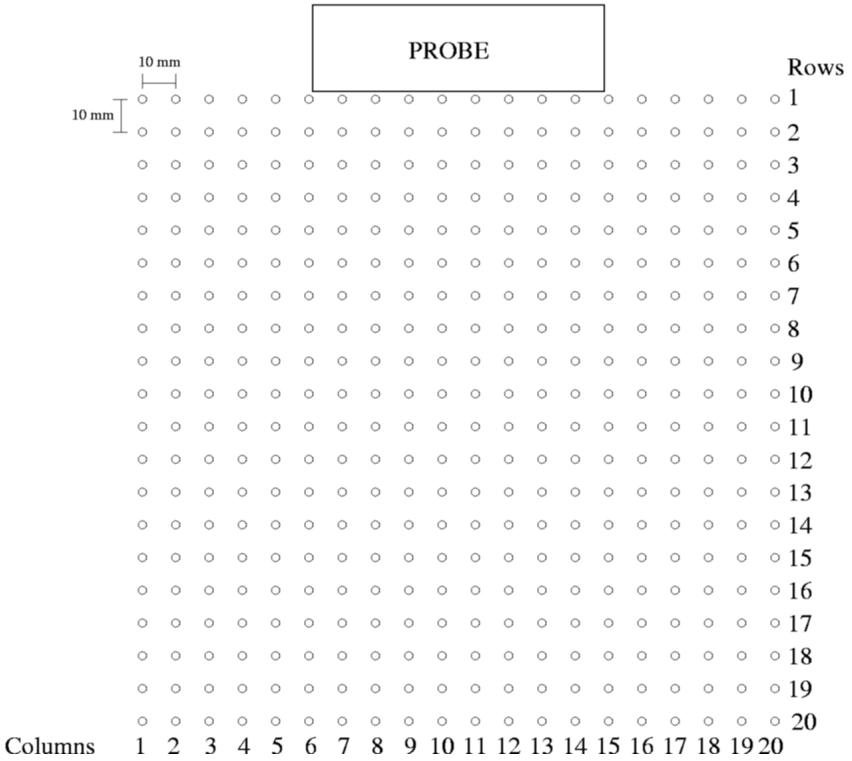


  - No correction corrected difference image profiles

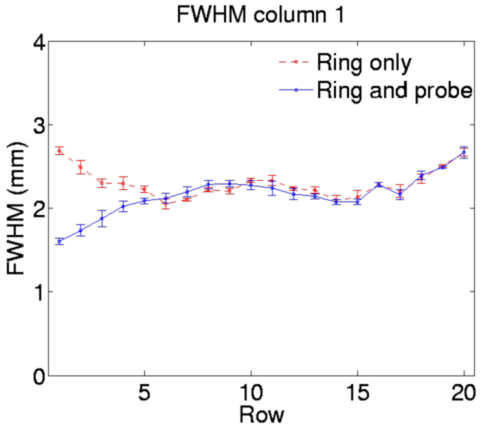
- Probe attenuation effects
  - SM elements weighted by Siddon length through probe
  - Applied in only in Sensitivity correction, cancels elsewhere
  - Successful in ring-ring and probe-ring images, fails in combined image

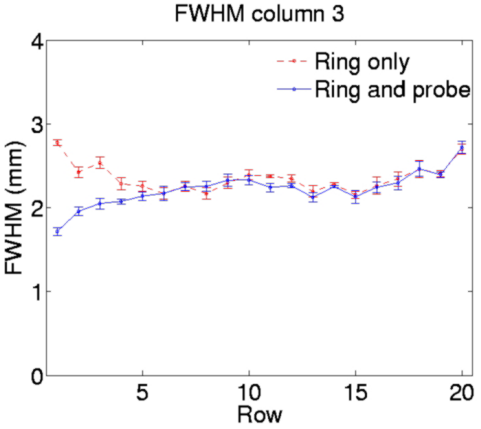
Spatial resolution

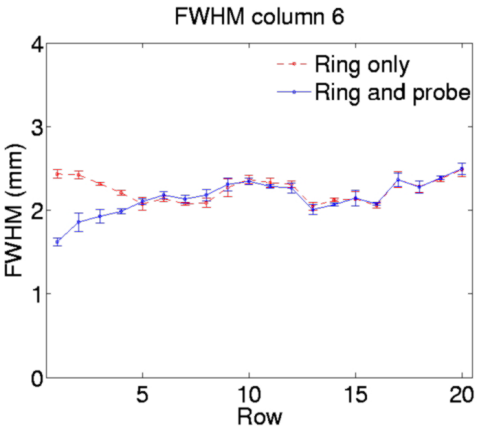
- System IRF non-isotropic, shift variant
  - Probe-ring LORs are fan-shaped
- Grid of points simulated
  - ...on low background (non-negativity, cold spot bias)

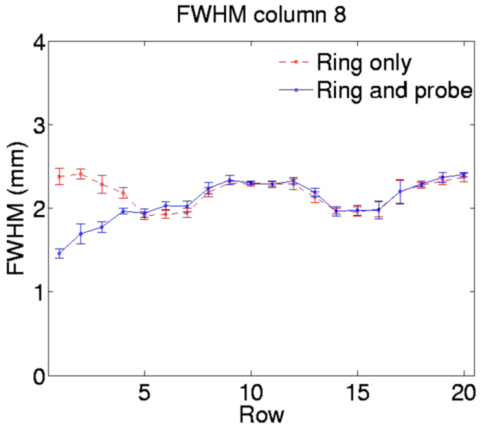


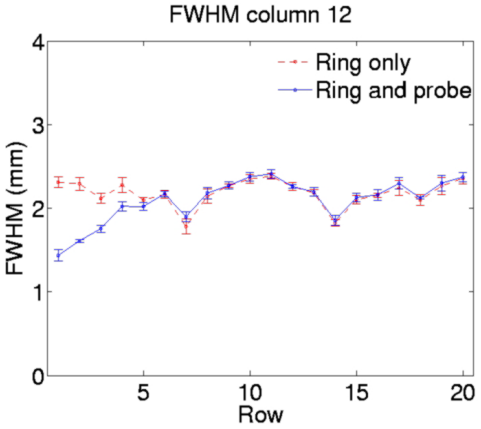
Resolution perpendicular to the probe surface

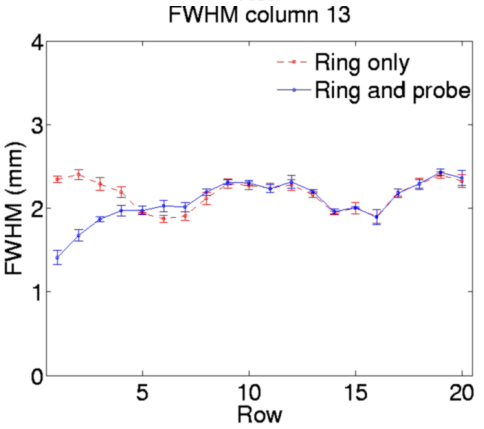


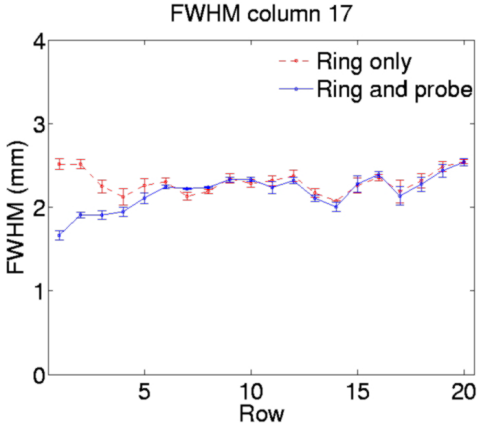


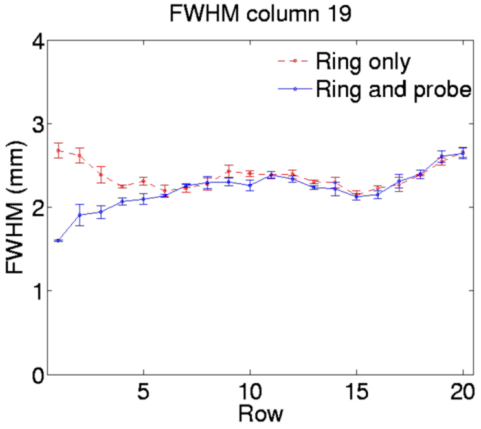


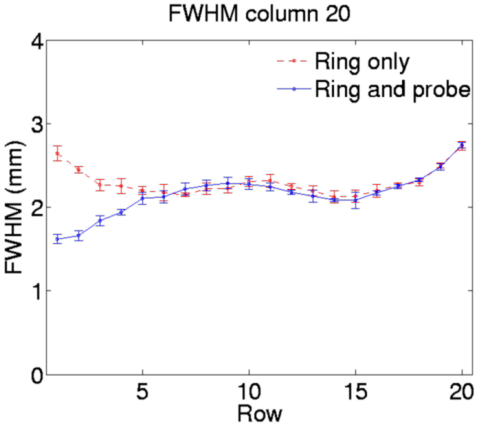




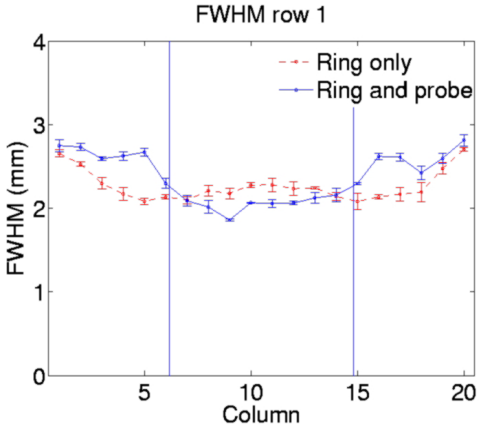


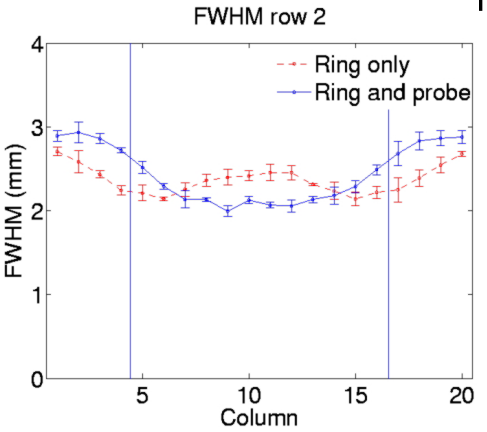


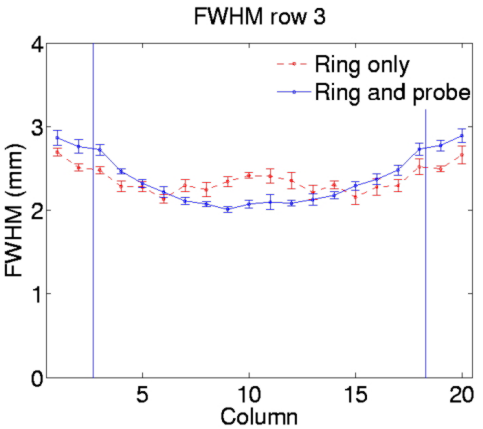


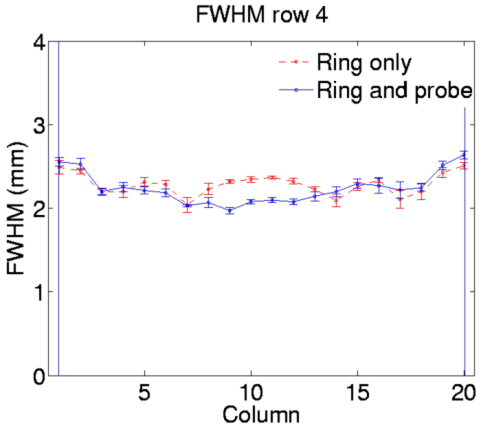


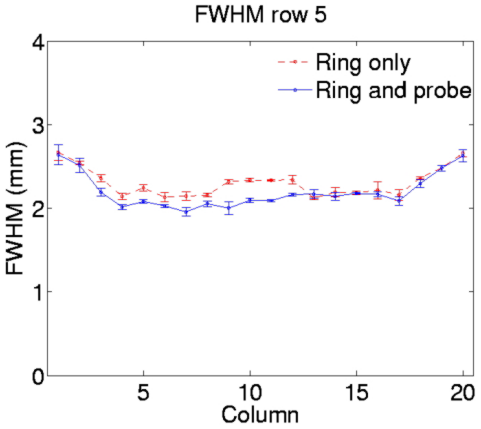
Resolution parallel to the probe surface

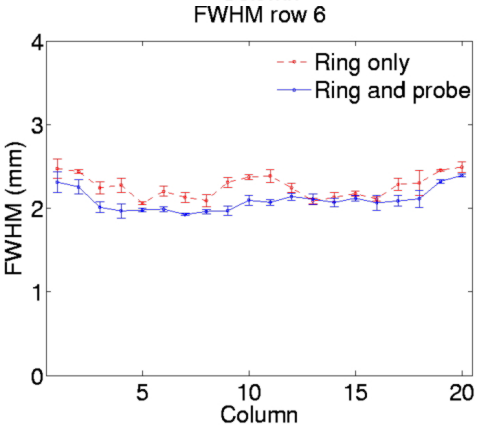


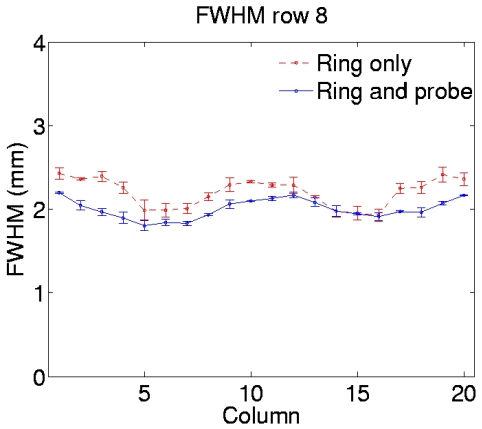


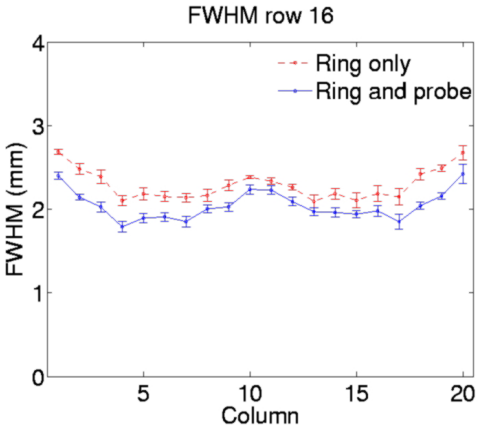












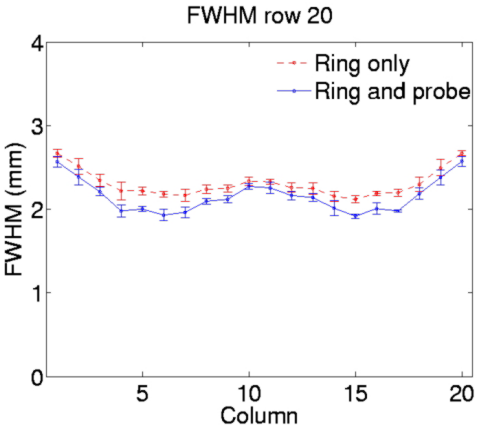


Image studies

- Resolution phantom
  - Small derenzo inserts measuring 4.8, 4.0, 3.2, 2.4, 1.6 and 1.2 mm in diameter

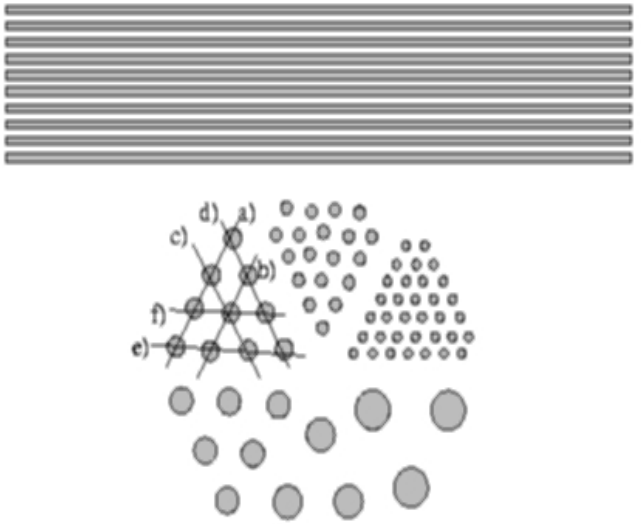
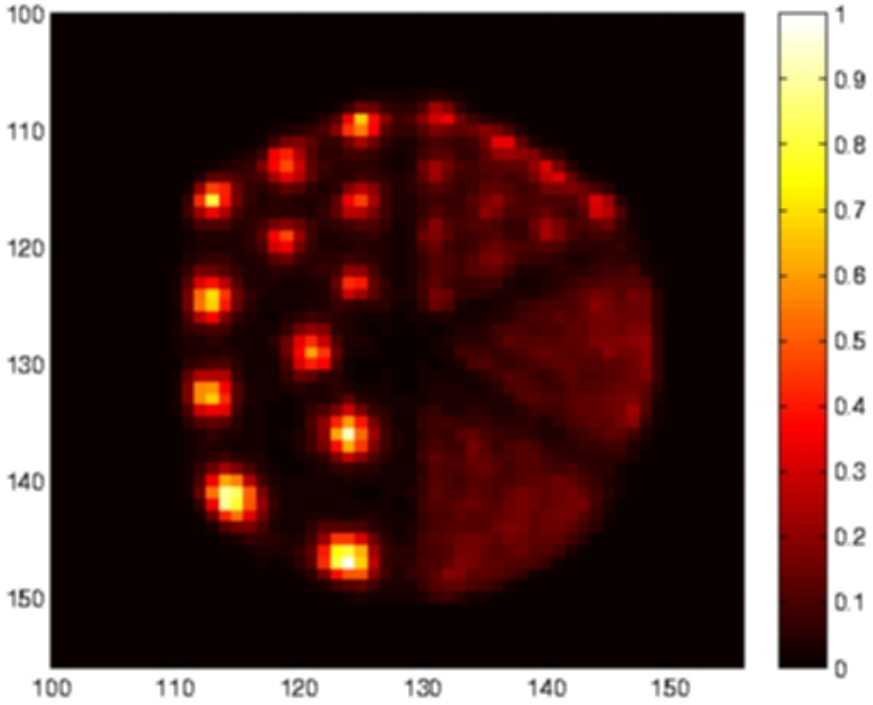
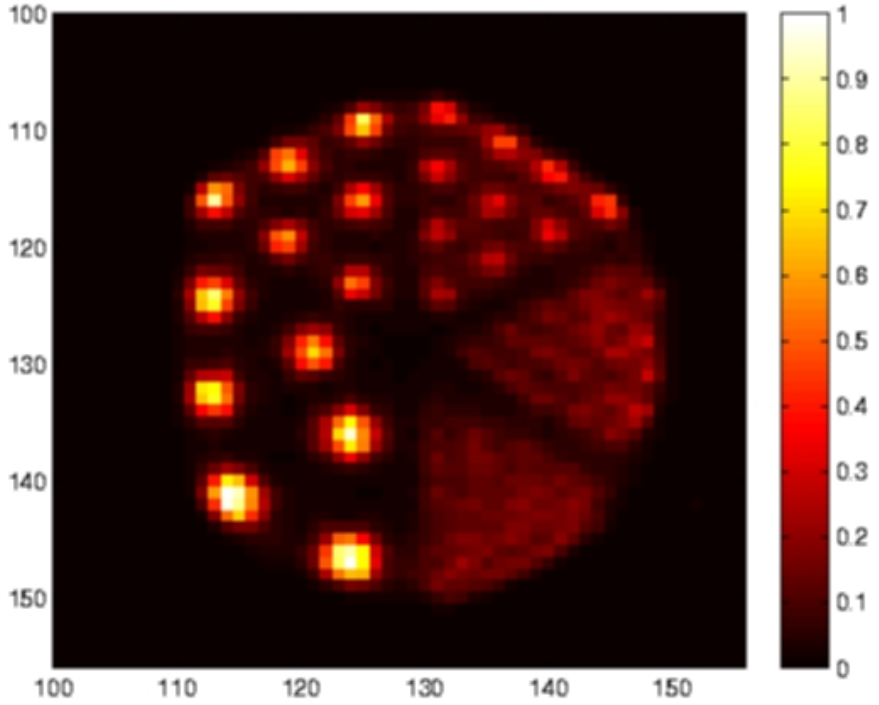


Image studies

- Resolution phantom



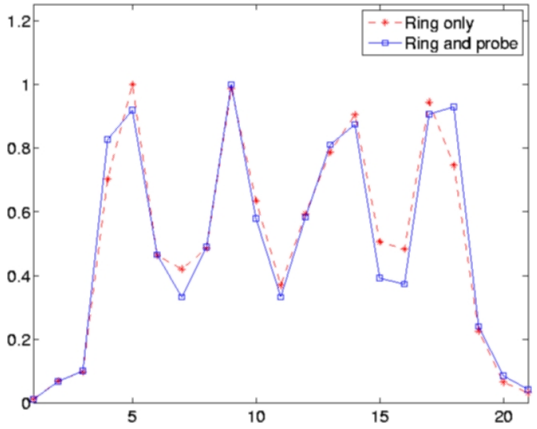
Ring only

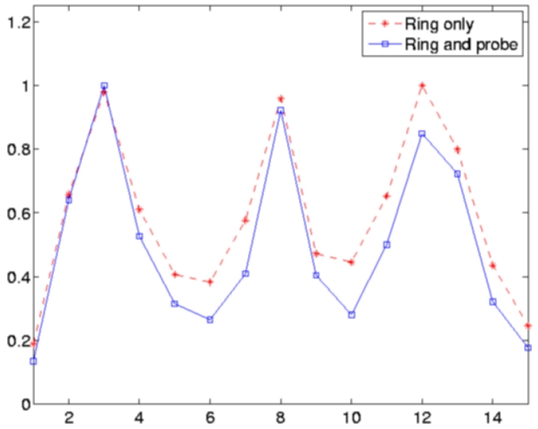


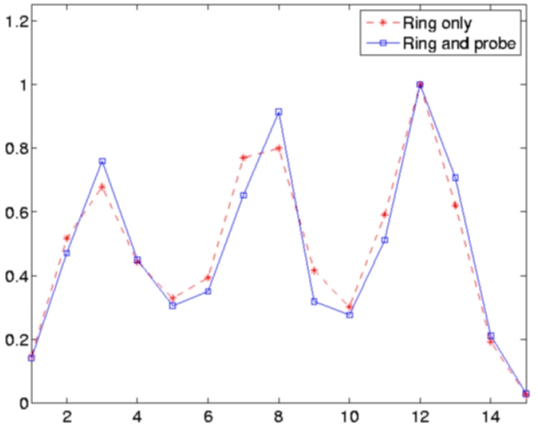
Ring and probe

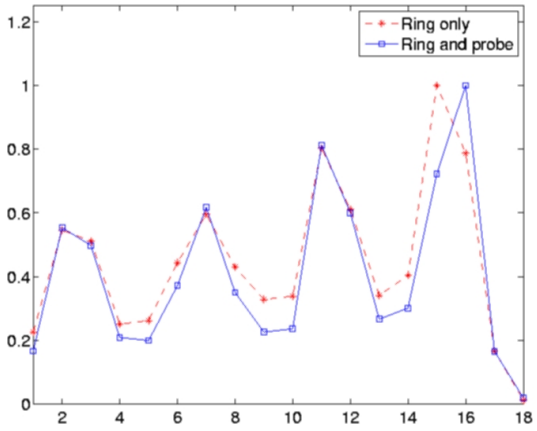
Image studies

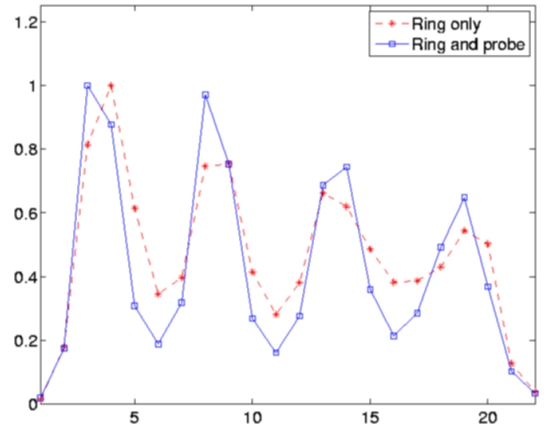
- Resolution phantom











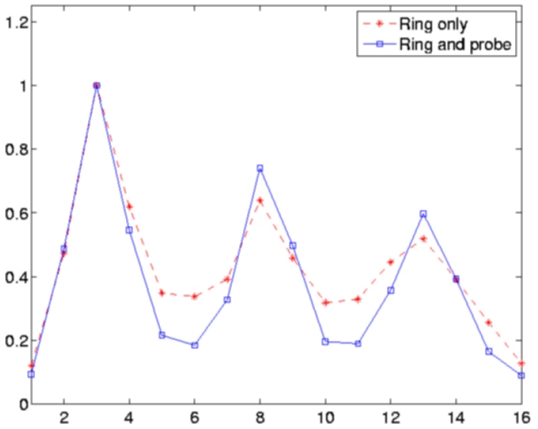


Image studies

- Resolution phantom
  - Now the probe closer to the ROI

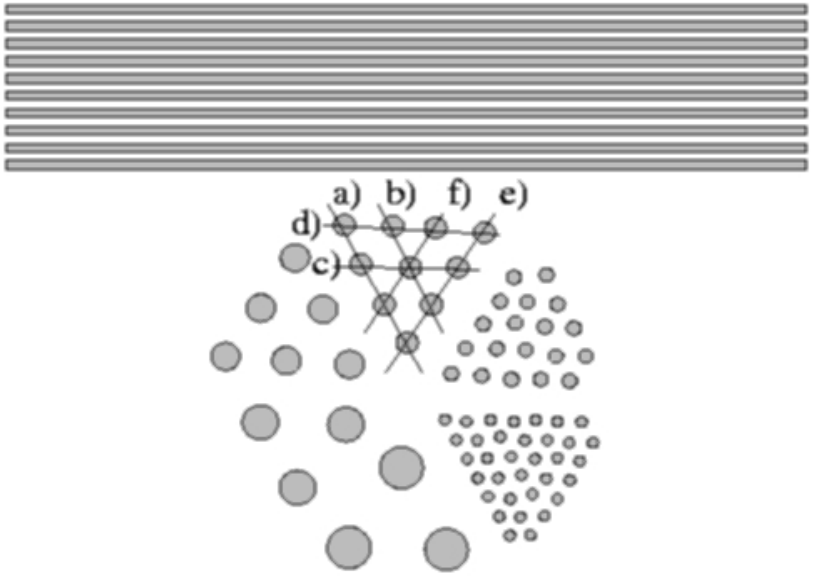
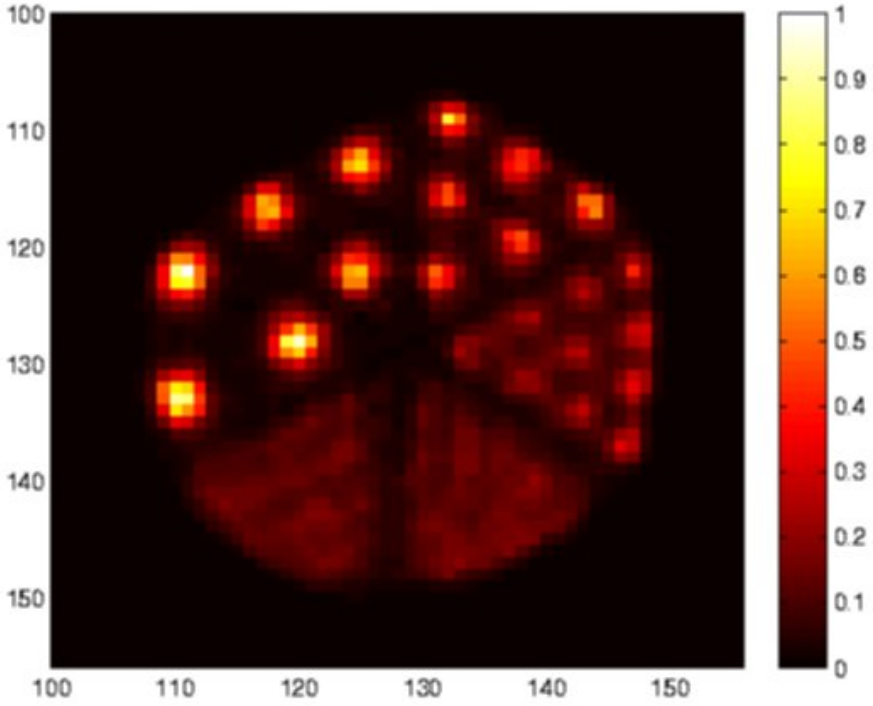
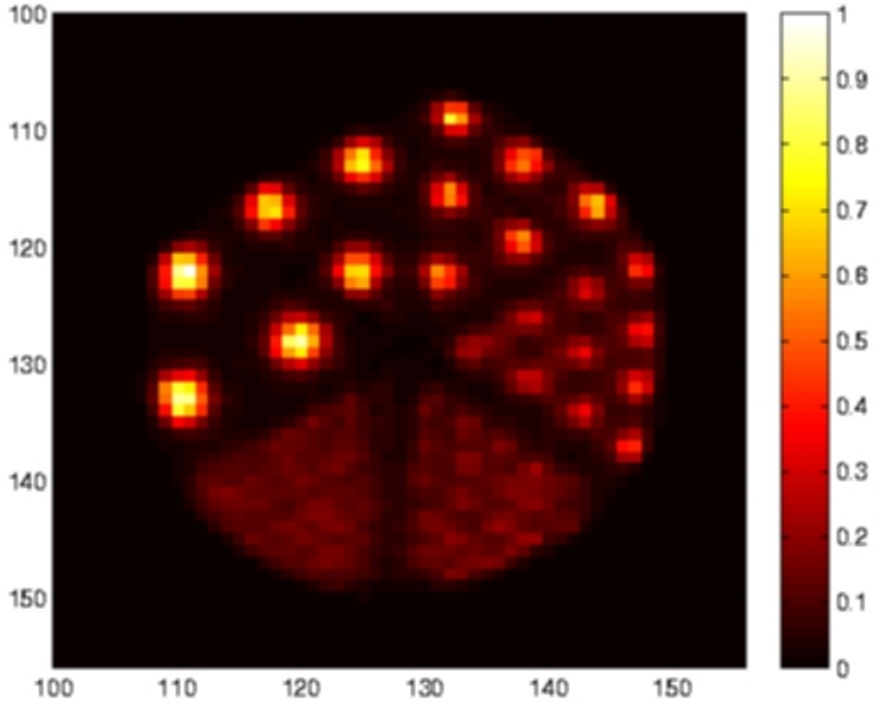


Image studies

- Resolution phantom



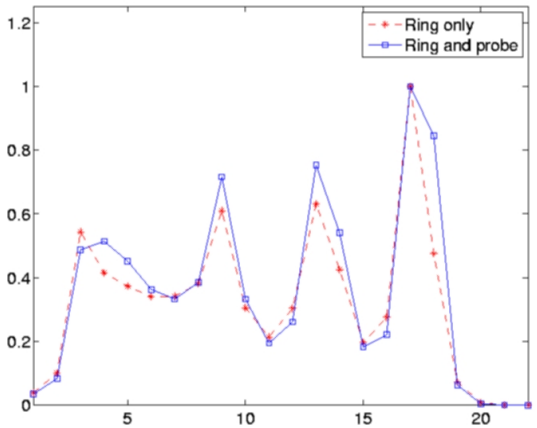
Ring only

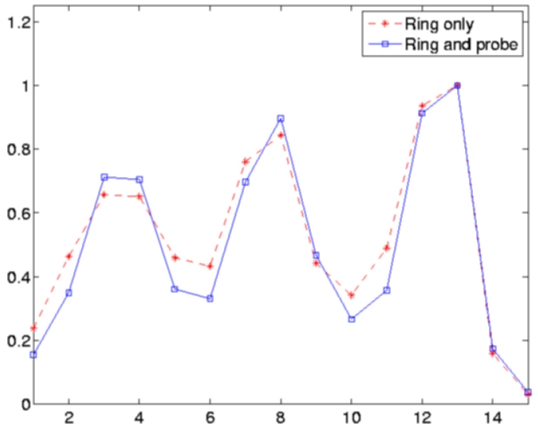


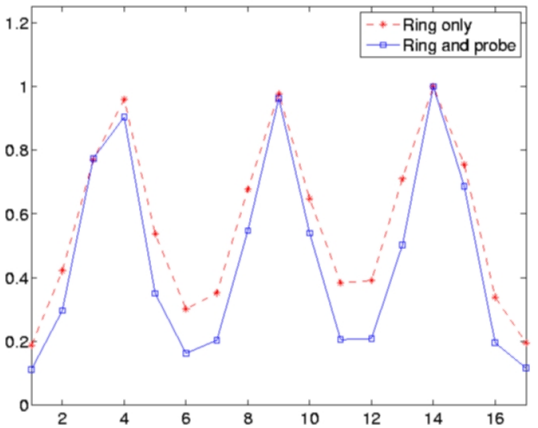
Ring and probe

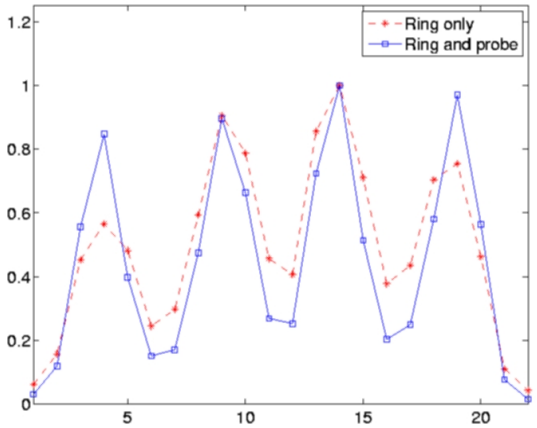
Image studies

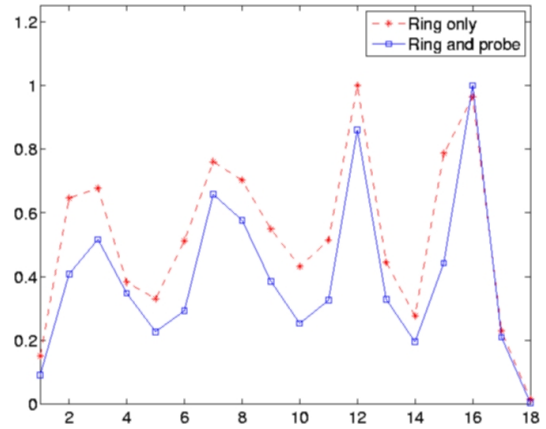
- Resolution phantom











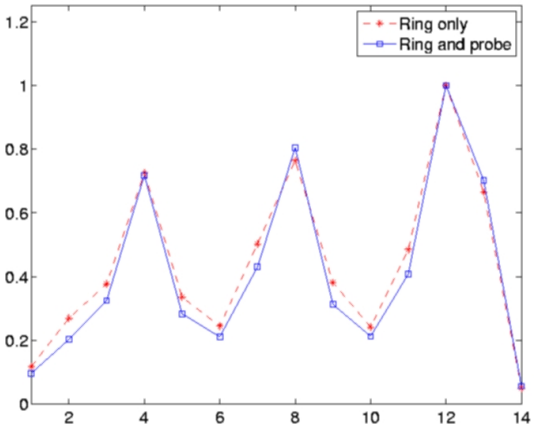


Image studies

- Mammography application
  - Breast phantom
  - Three hot lesions (3 mm diameter) on a uniform background, varying distances from probe
  - 8:1 uptake ration

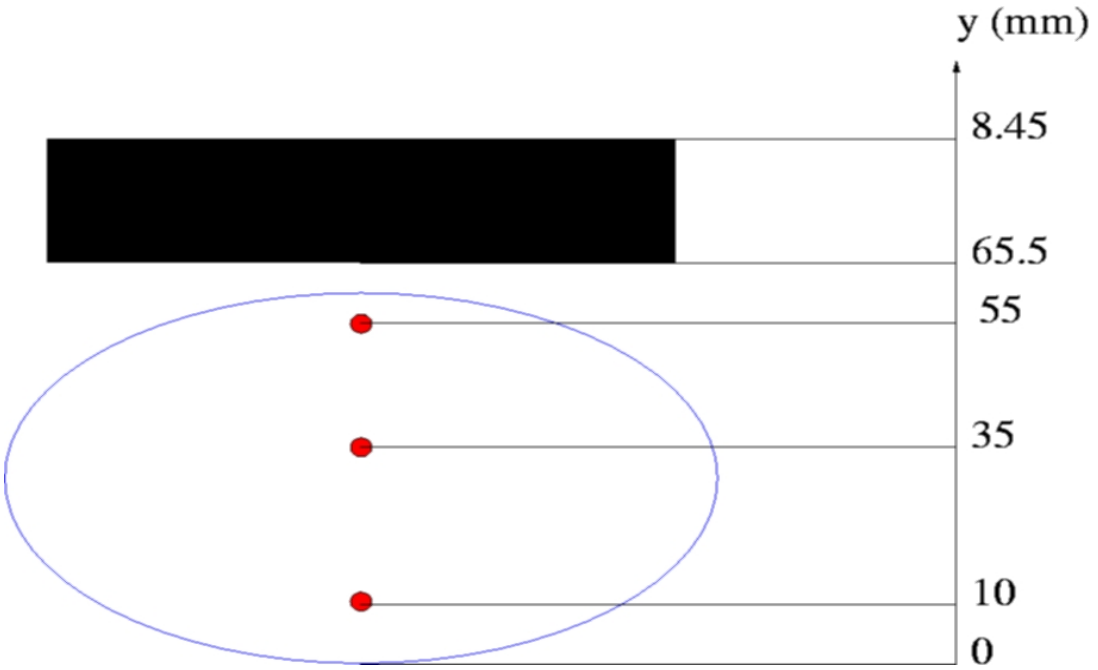
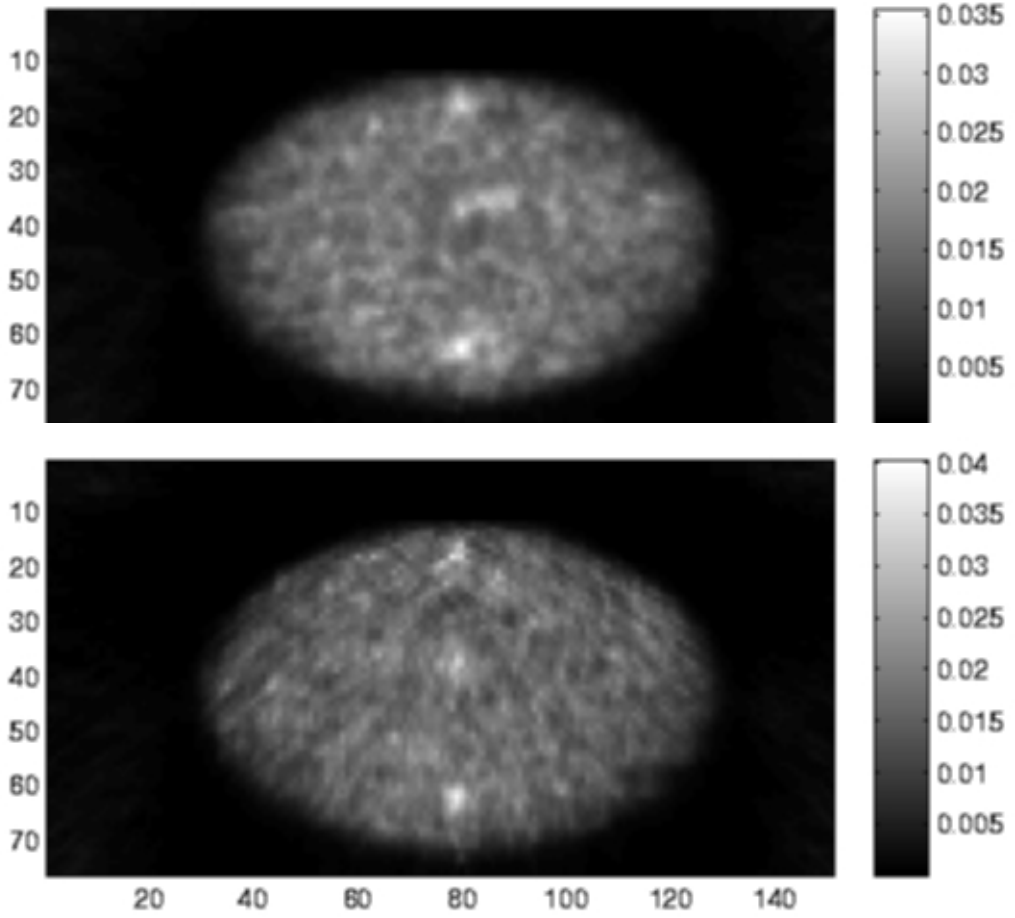


Image studies

- Mammography application
  - Post reconstruction filtering (gaussian, FWHM = 1 mm)

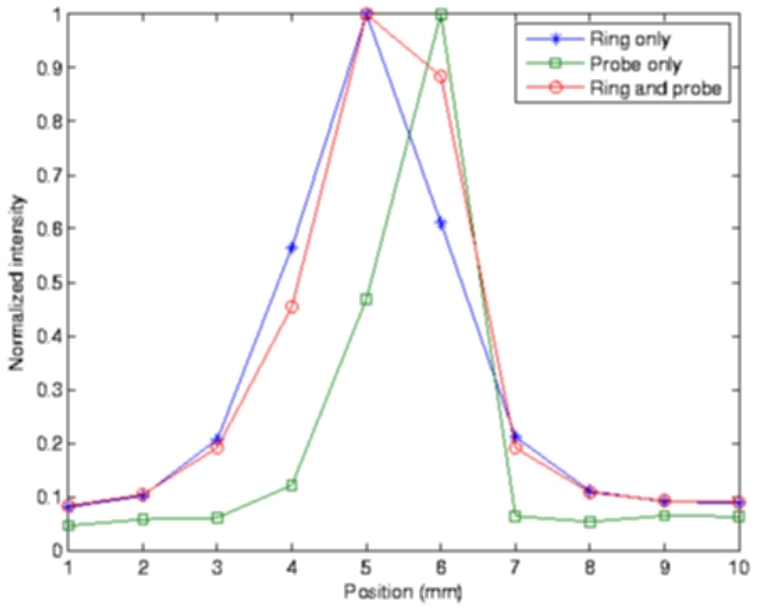


Conclusions

- High-resolution PET-probe system presented
- IRF comparison show resolution improvement in ROI close to the probe
- Imaging studies using resolution phantom show improvement
- Application to mammography motivated by breast phantom imaging study

Thank you for your attention!

- FWHM not realistic, only for comparison
  - Scattering will affect results
  - Probe can be used to remove scattering events
- Loss of resolution at top corners of FOV -> DOI



Discussion

- FWHM not realistic, only for comparison
  - Scattering will affect results
  - Probe can be used to remove scattering events
- Loss of resolution at top corners of FOV -> DOI
- Room for improvement
  - Better model –DO I, sampling for finer grid
  - Sensitivity correction
  - Compton camera –incr ease sensitivity