

ProSPECTus

Next generation Single Photon Emission Computed Tomography

Nuclear Physics Group, Dept of Physics, University of Liverpool,
Nuclear Physics & Technology Groups, STFC Daresbury Laboratory,
MARIARC & Royal Liverpool University NHS Trust



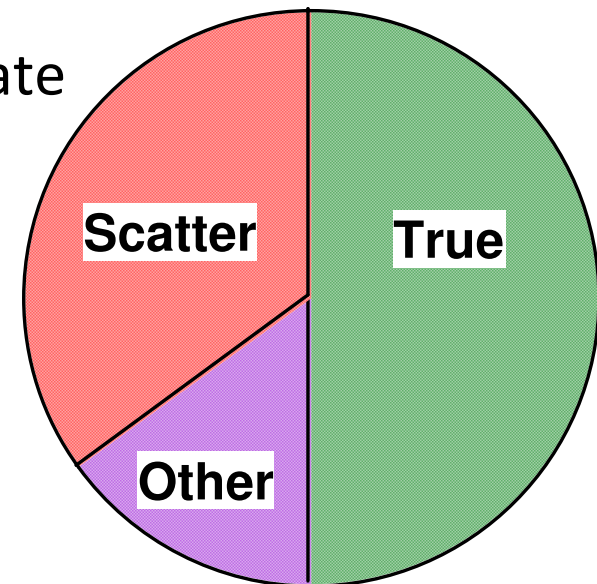
ProSPECTus: Project funding

- STFC funded the KE proposal through the Particle and Nuclear Physics Applied Systems Call (£1.1M) [Now CLASP]
- Challenge-led approach to maximize KE which will identifies novel uses of existing STFC funded skills and technologies
- Key nuclear physics input from internationally leading detector/instrumentation R+D from AGATA project
- The process involved Expressions of Interest (EOIs) followed by invite full application submission
- Focus on Security, Medical or Energy sectors

SPECT : Problems/Opportunities

Technical

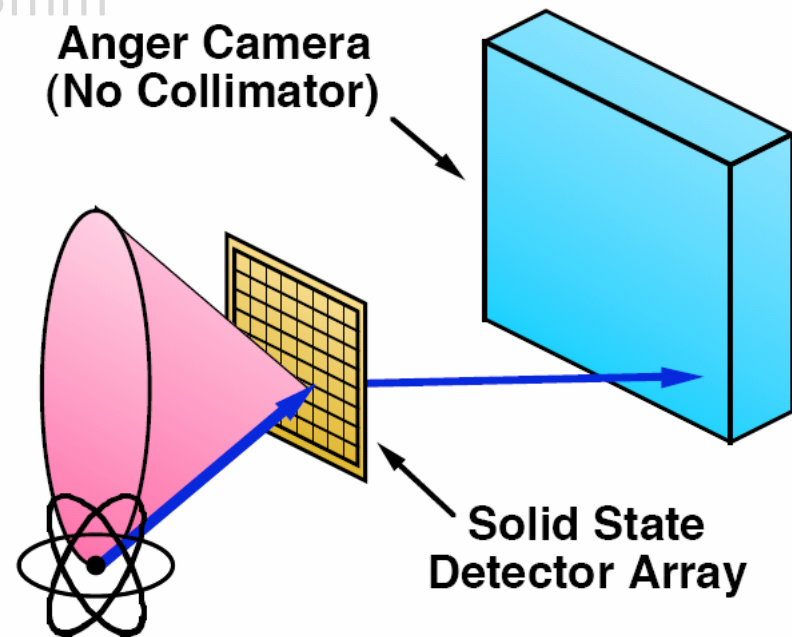
- Collimator Limits Spatial Resolution & Efficiency
- Collimator is heavy and bulky
- Energy of radioisotope limited to low energy
- NaI:Tl Dominant for >40 Years...
- MRI → Existing PMTs will not easily operate
- Would like to be able to image a larger fraction of events.



ProSPECTus: What is new?

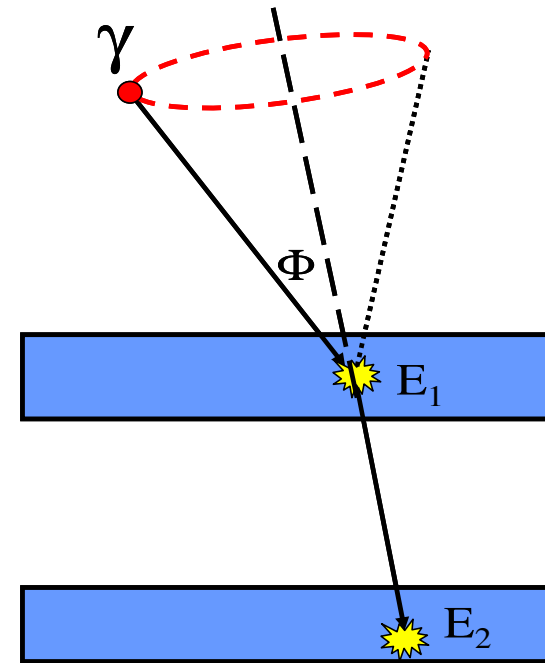
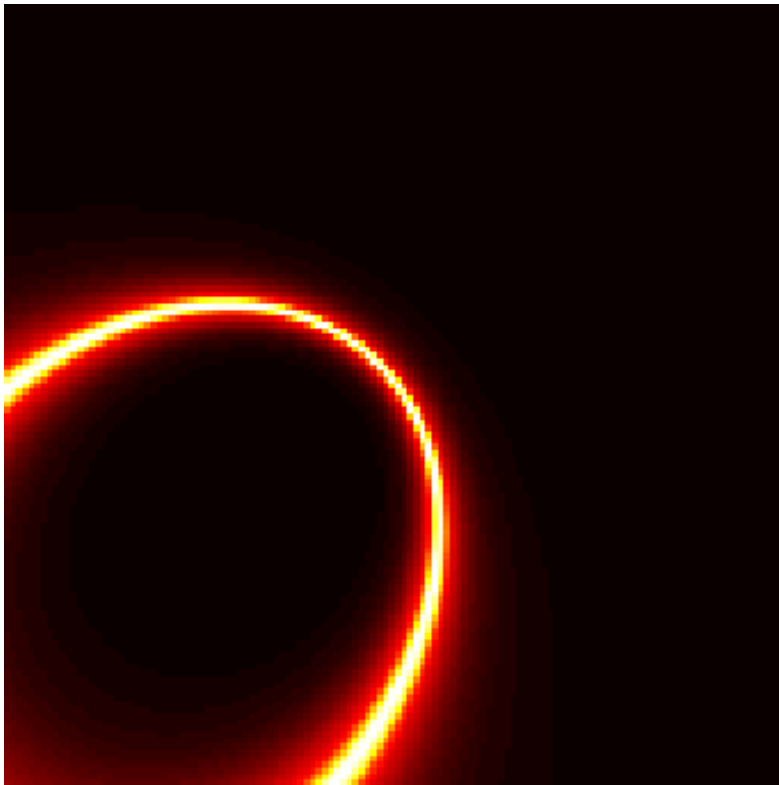
ProSPECTus is a Compton Imager

- Radical change → No mechanical collimator
- Utilising semiconductor sensors
- Segmented technology and existing electronics
- Position resolution 7-10mm → 2-3mm
- Sensitivity factor ~100 larger
- Simultaneous SPECT/MRI



Compton Imaging

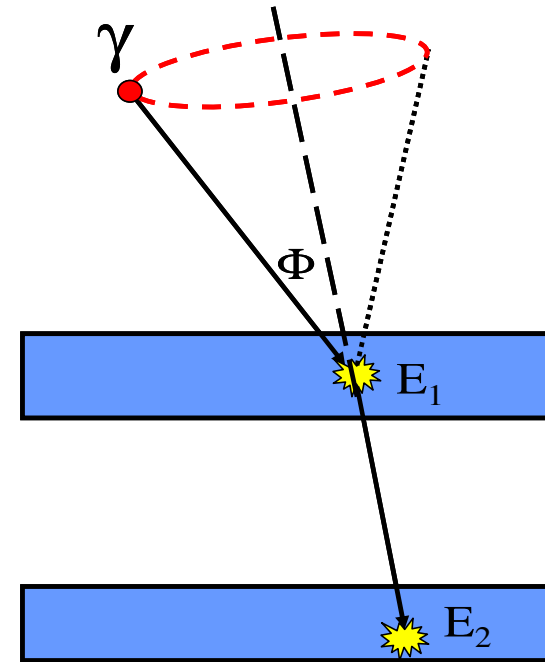
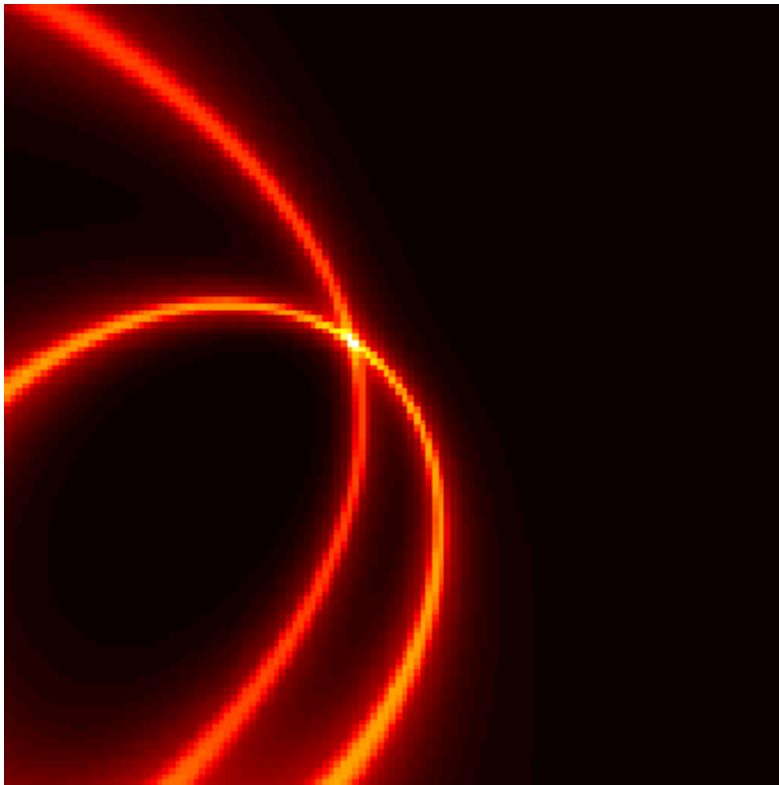
- Compton *Cones of Response* projected into image space



$$\cos \phi = 1 - m_e c^2 \left(\frac{1}{E_2} - \frac{1}{E_1 + E_2} \right)$$

Compton Imaging

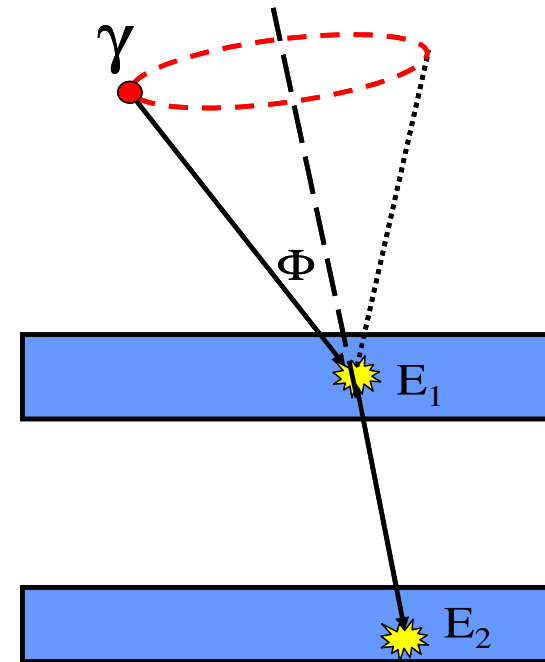
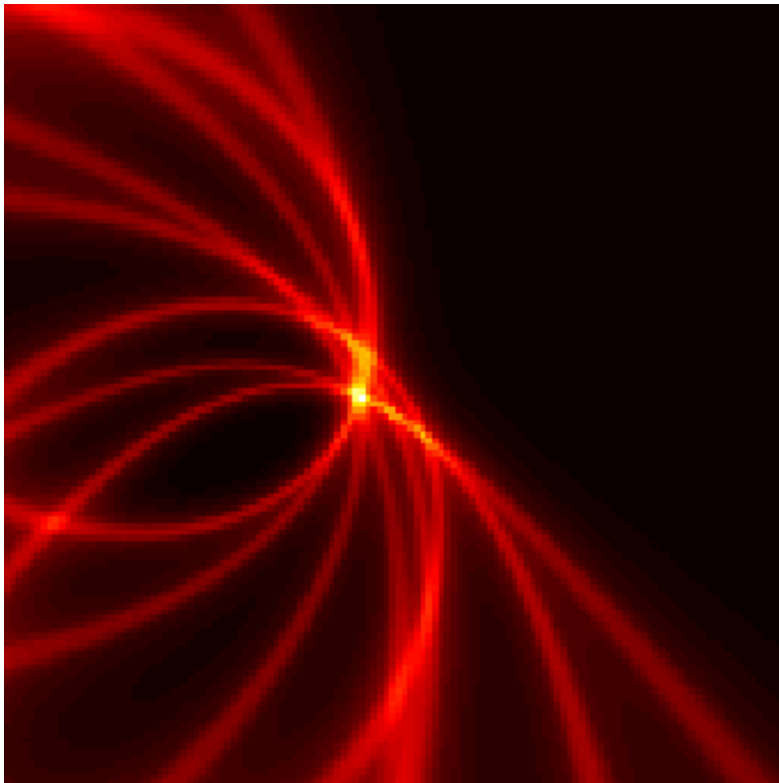
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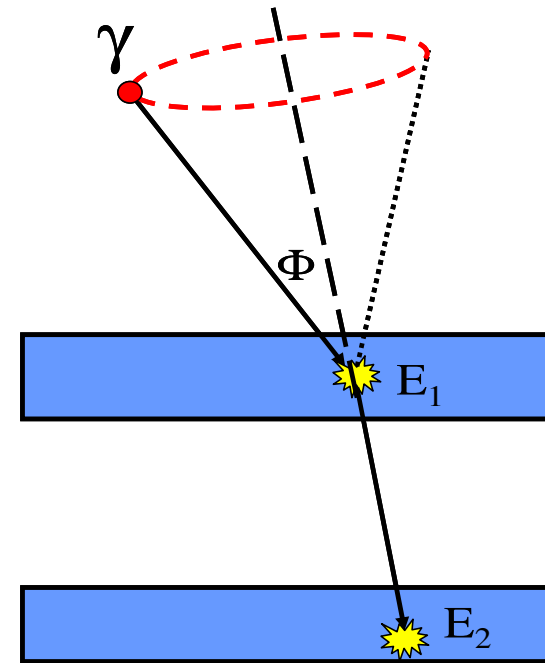
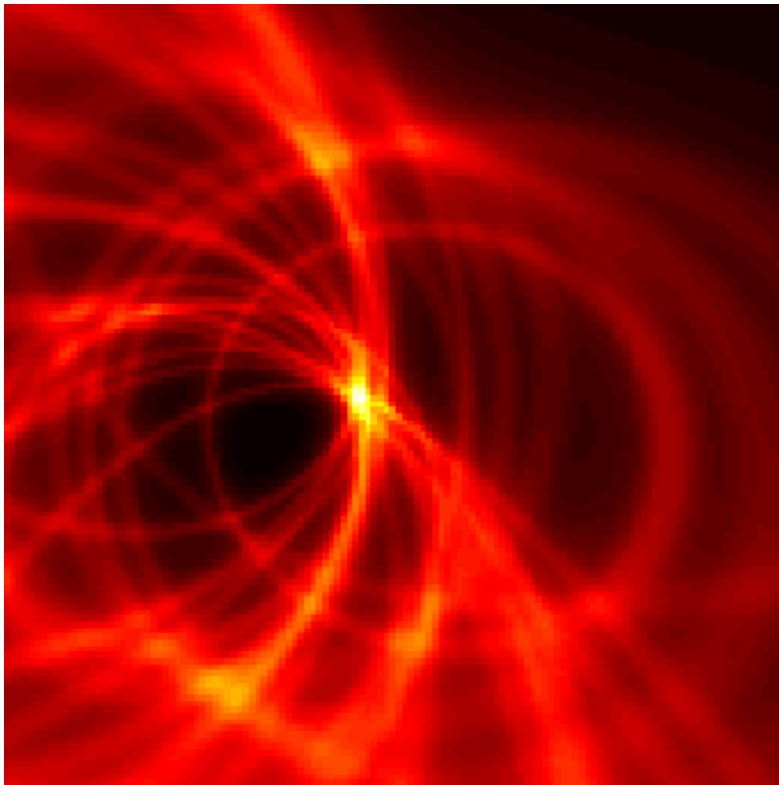
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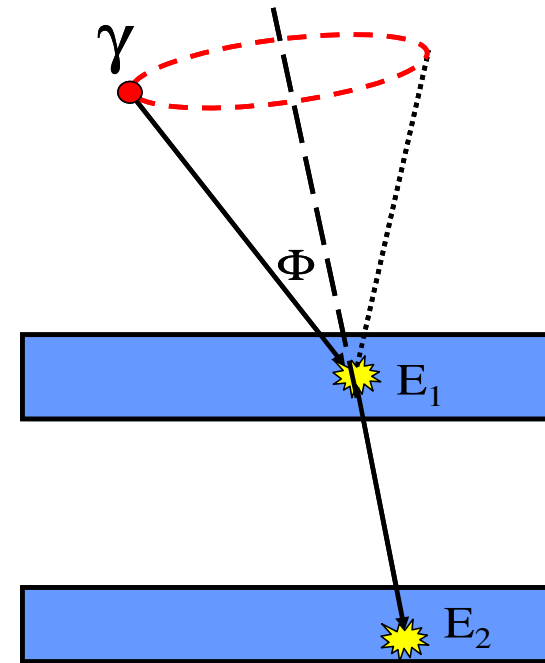
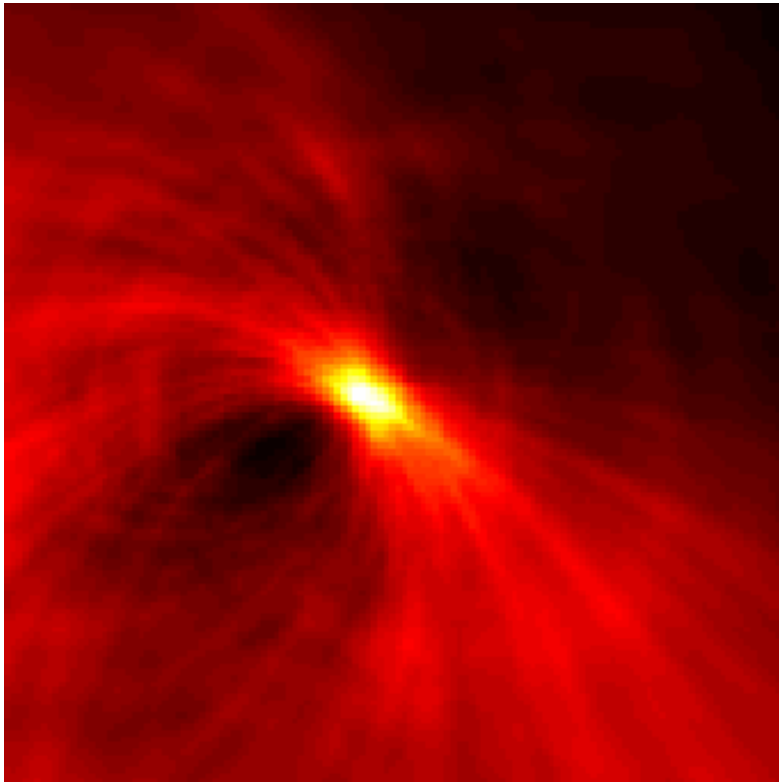
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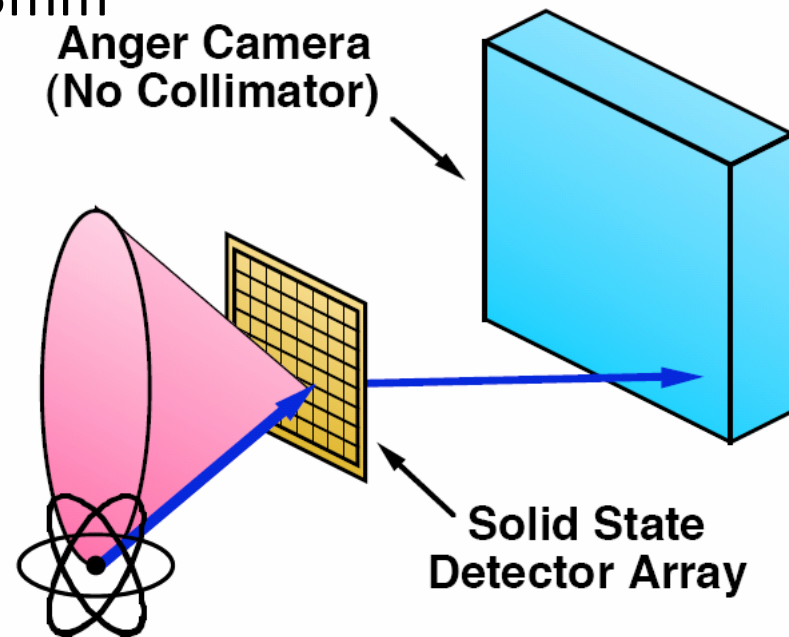


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ProSPECTus: What is new?

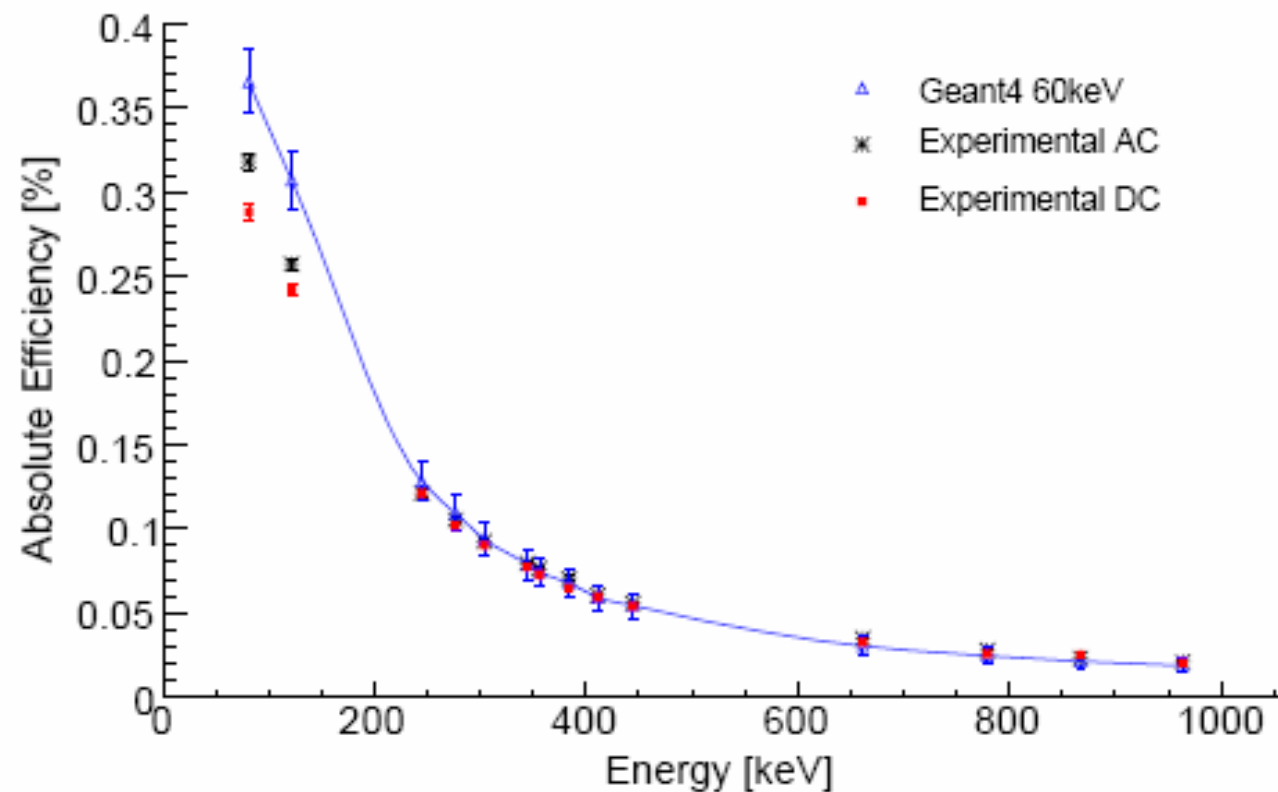
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Specification: Geant4 Simulations

- GEANT4 toolkit used to model proposed detectors
- Validated against existing SmartPET experimental data
- Extended to model various Compton camera configurations
- Energy and position used to generate images and examine efficiency
- Ge detector simulation

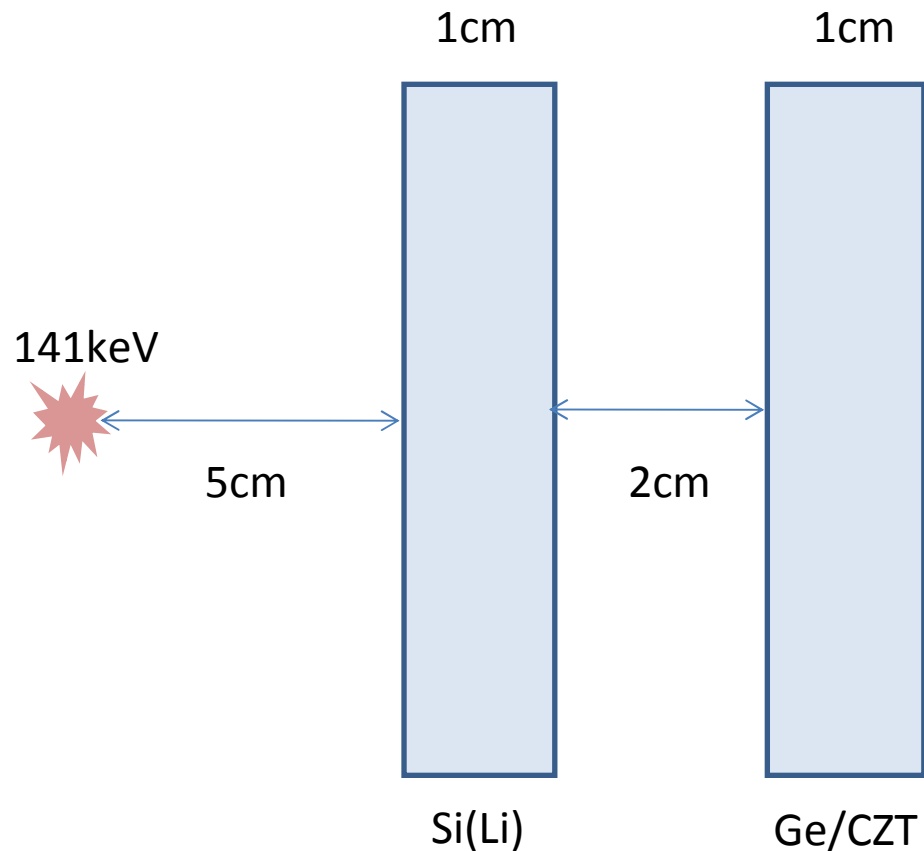


Optimisation of Geometry

- Maximise reconstructable events
- Categorise as % incident : single/single, absorbed, coincident
- % single/single events most simple to reconstruct

- Scatter detector: high Compton scattering cross-section at 141keV: Si(Li) and HPGe
- Absorber detector: high probability of photoelectric absorption at 141keV: CZT, HPGe and CsI

Optimum Configuration



- Total Coincident $\sim 3.49\%$
- SPECT $\sim 0.035\%$ (1×10^{-4} collimator)
- Factor of ~ 100

Event Type	%
Single / Single	2.23
Single / Multiple	0.33
Multiple / Single	0.61
Multiple / Multiple	0.04
Not absorbed	0.28

Experimental factors



- Energy resolution of detectors
- Position resolution of detectors
- Doppler broadening in various detector configurations

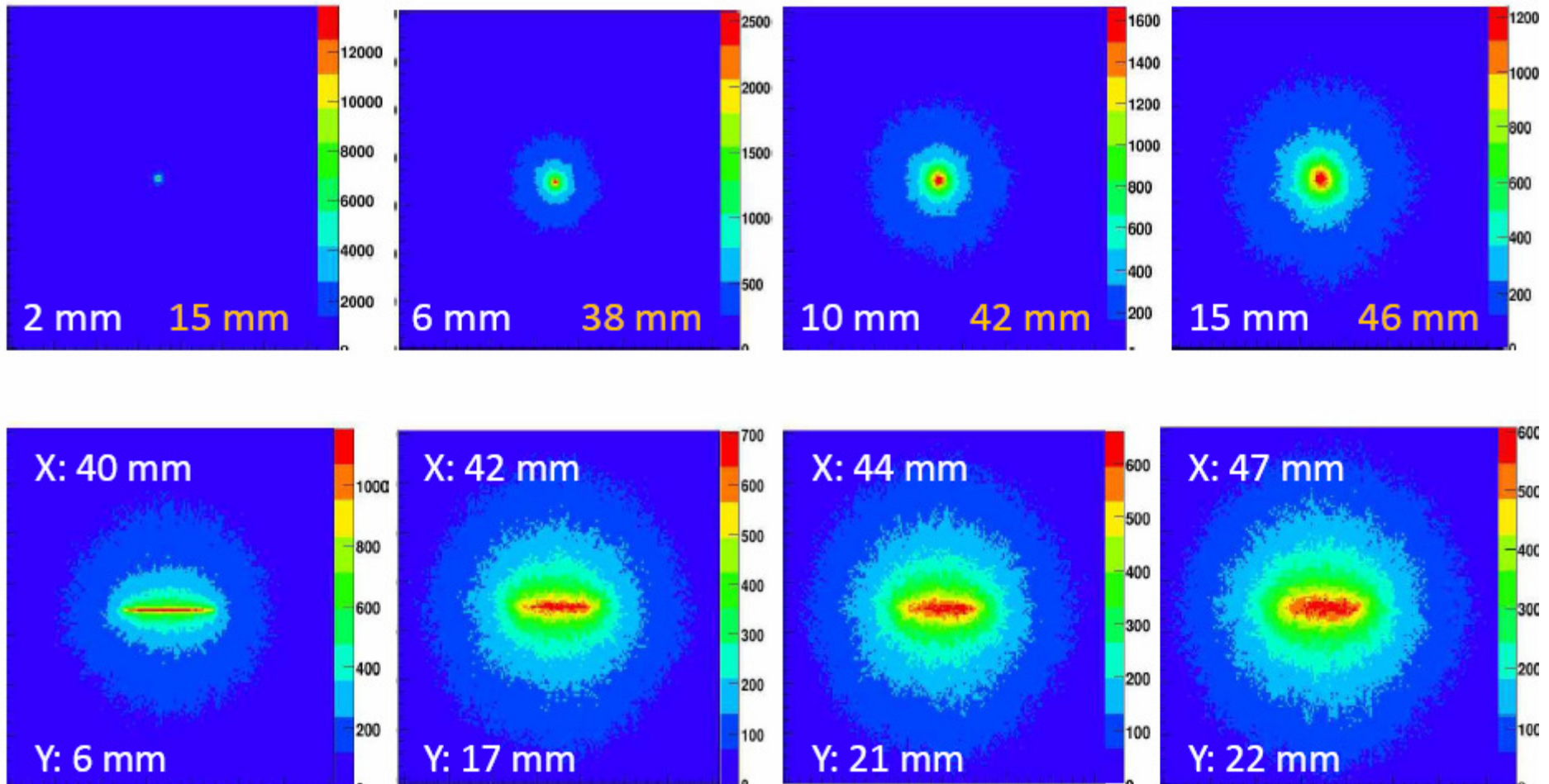
Image performance

“Perfect”

+Doppler Broadened

+Pos Res 1mm

+Energy Res 2keV



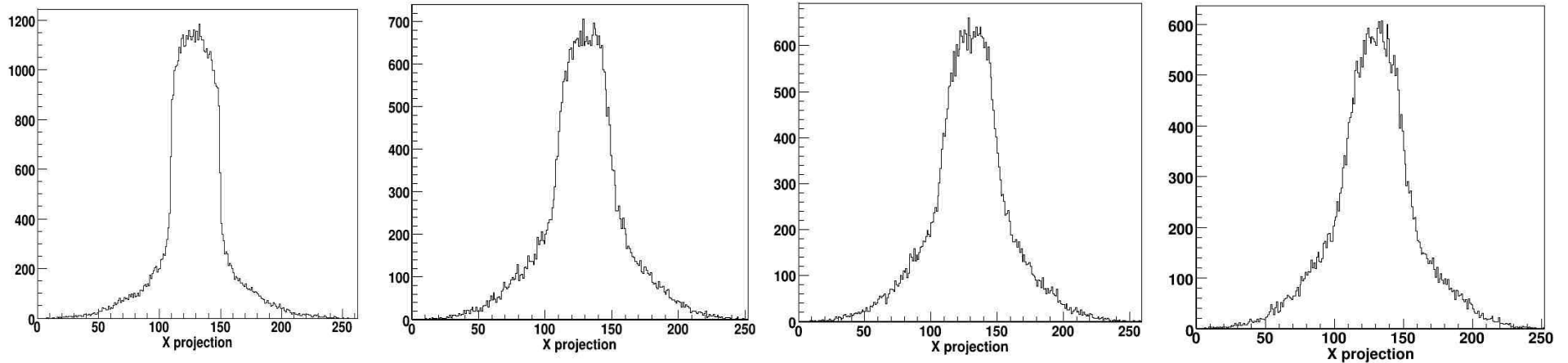
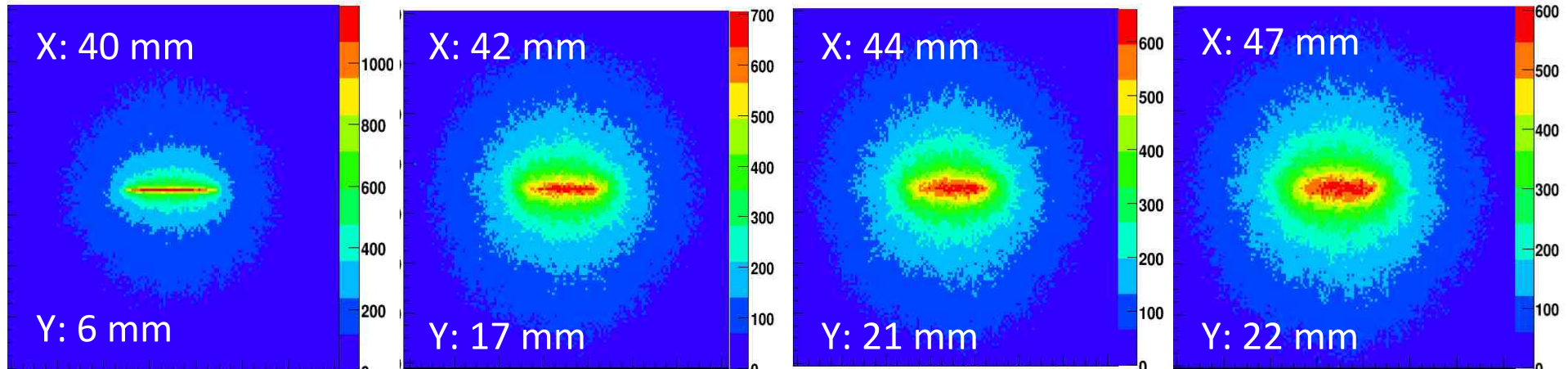
Line Source Images

“Perfect”

+Doppler Broadened

+Pos Res 1mm

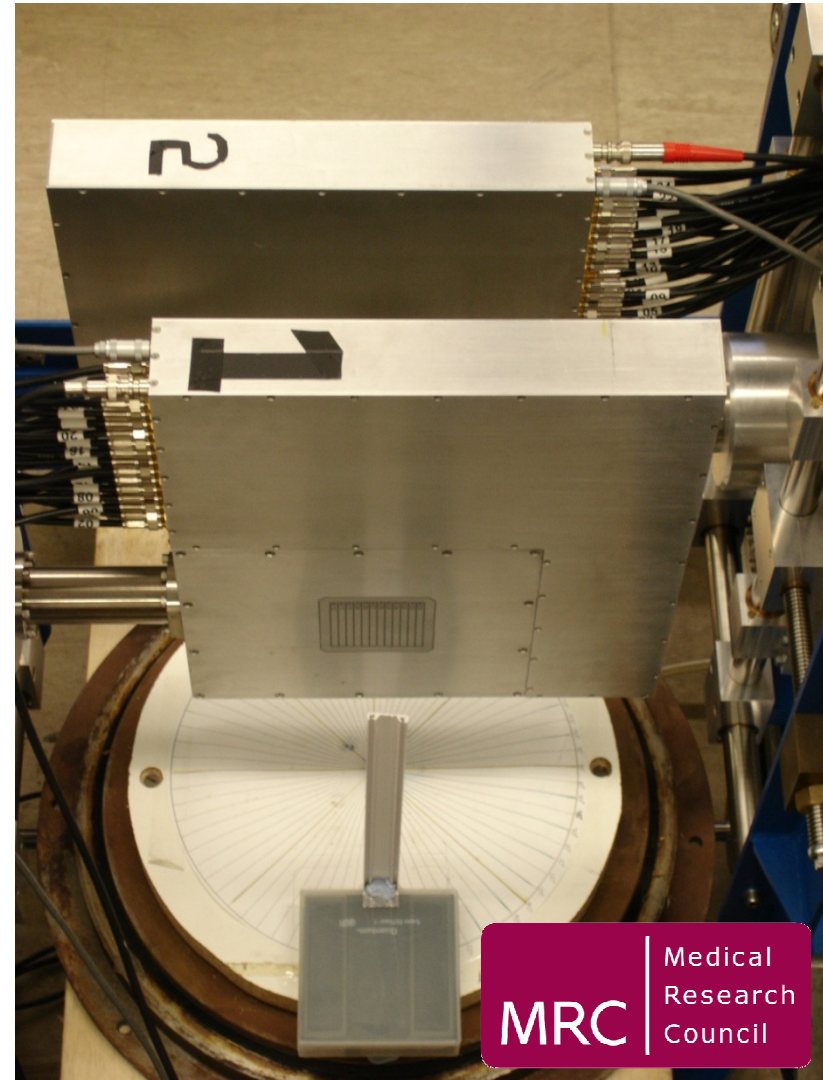
+Energy Res 2keV



Source 1: 141 keV (9,3,3) 4 cm long on a (14x14) cm grid

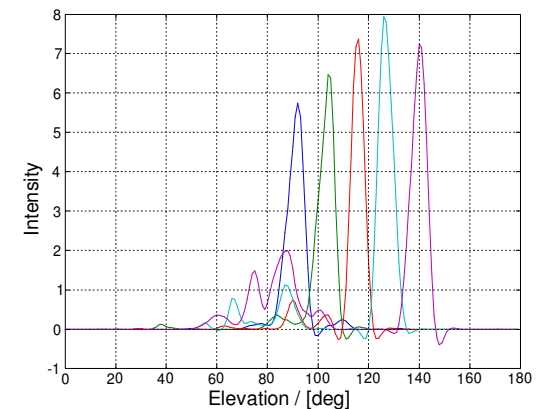
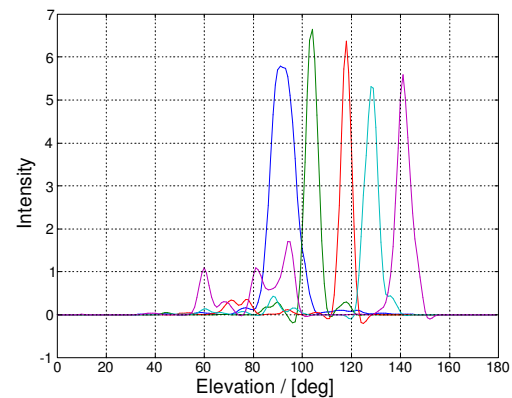
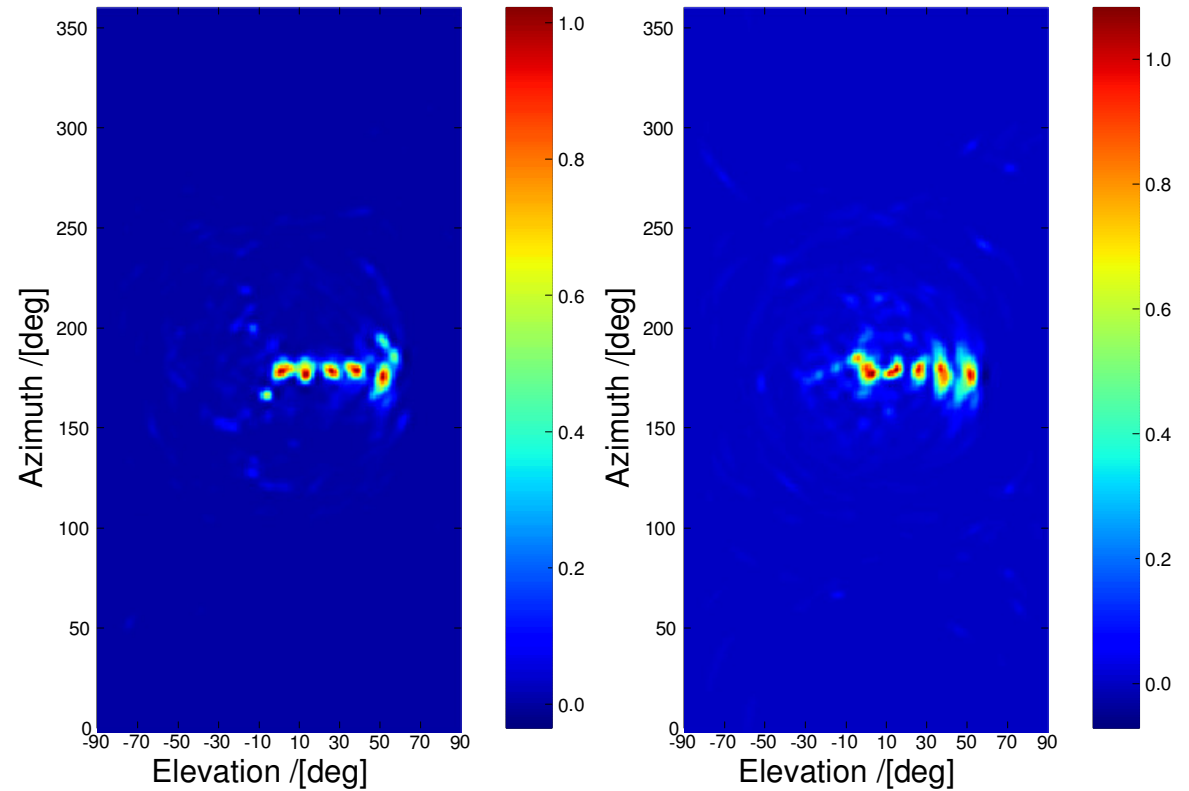
SmartPET: Previous track record

- Two planar germanium detectors were configured.
- Data was reconstructed using both analytical and iterative reconstruction algorithms



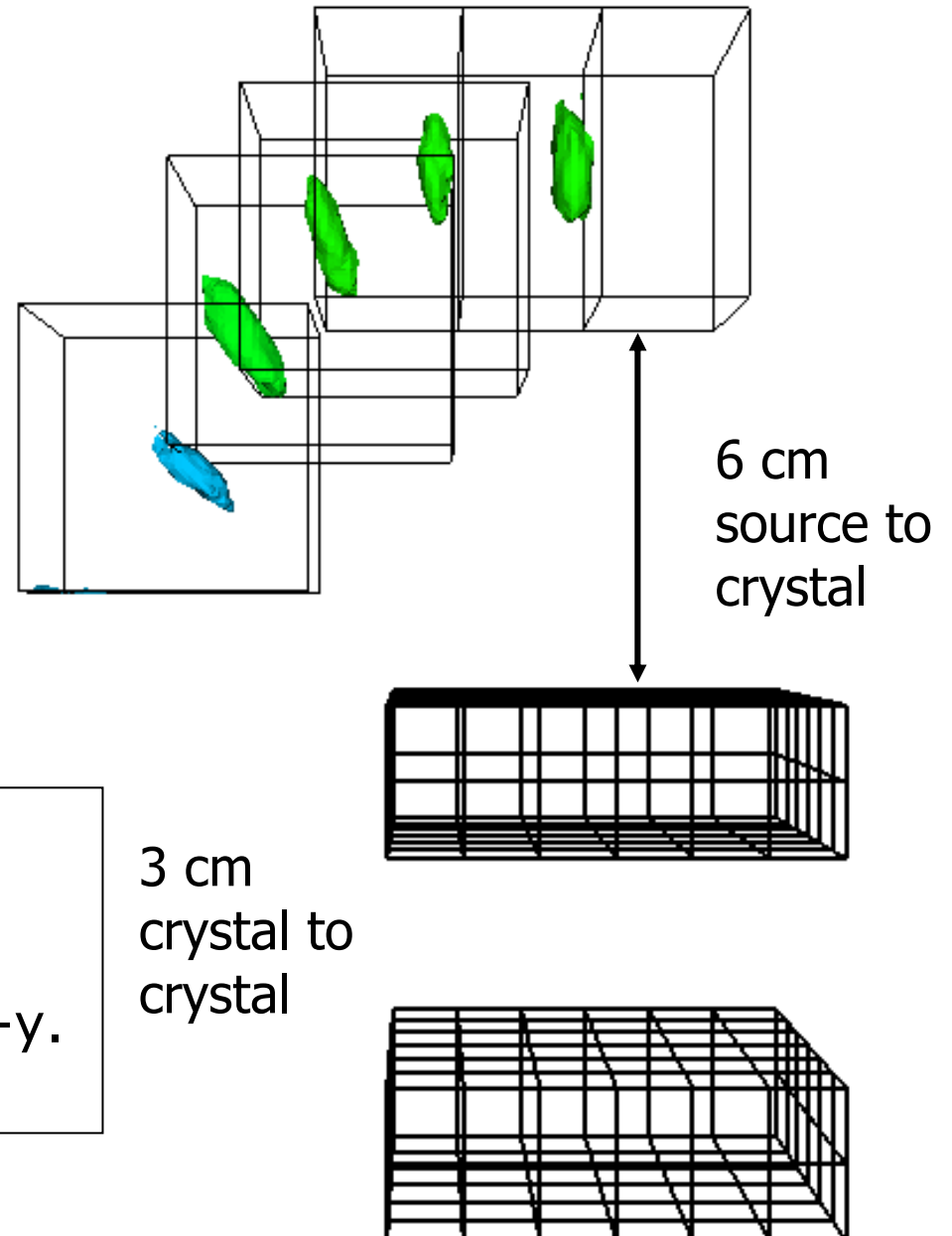
Compton Imaging with HPGe

- 30mm & 50mm separation between scatterer & analyser.
- 1.6cm separation between points
- FWHM \sim 8mm



Compton Imaging with HPGe

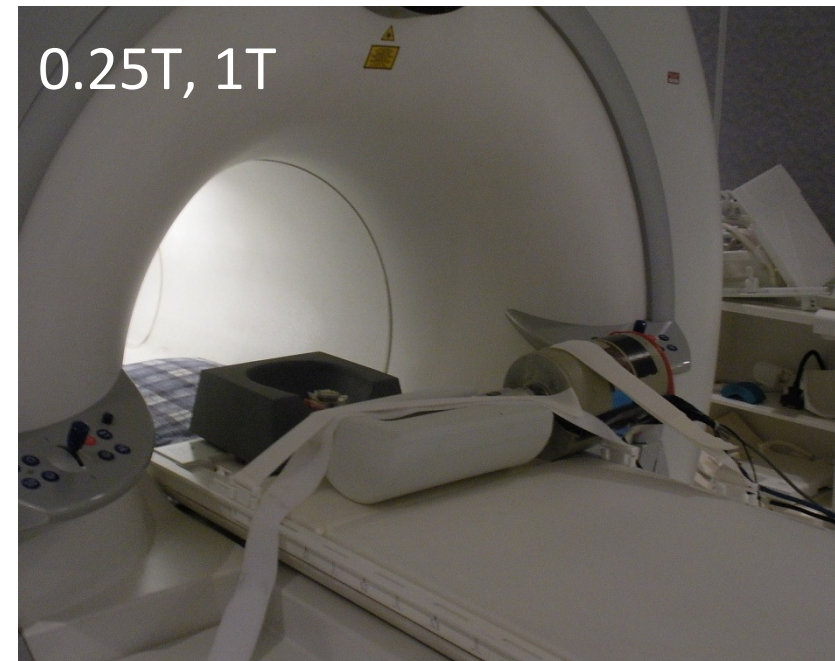
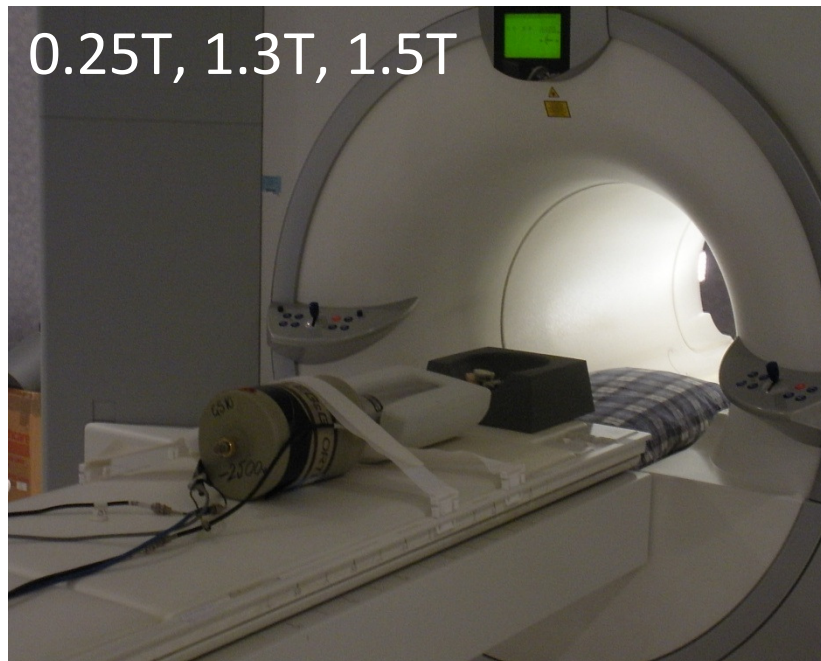
- ^{152}Eu point source imaging.
- 30 keV gate on 1408 keV.
- 30mm detector separation with 1.6mm position resolution.
- Single interactions in each detector.



Cone beam reconstruction
with 10 iterations.
~8mm image resolution x-y.

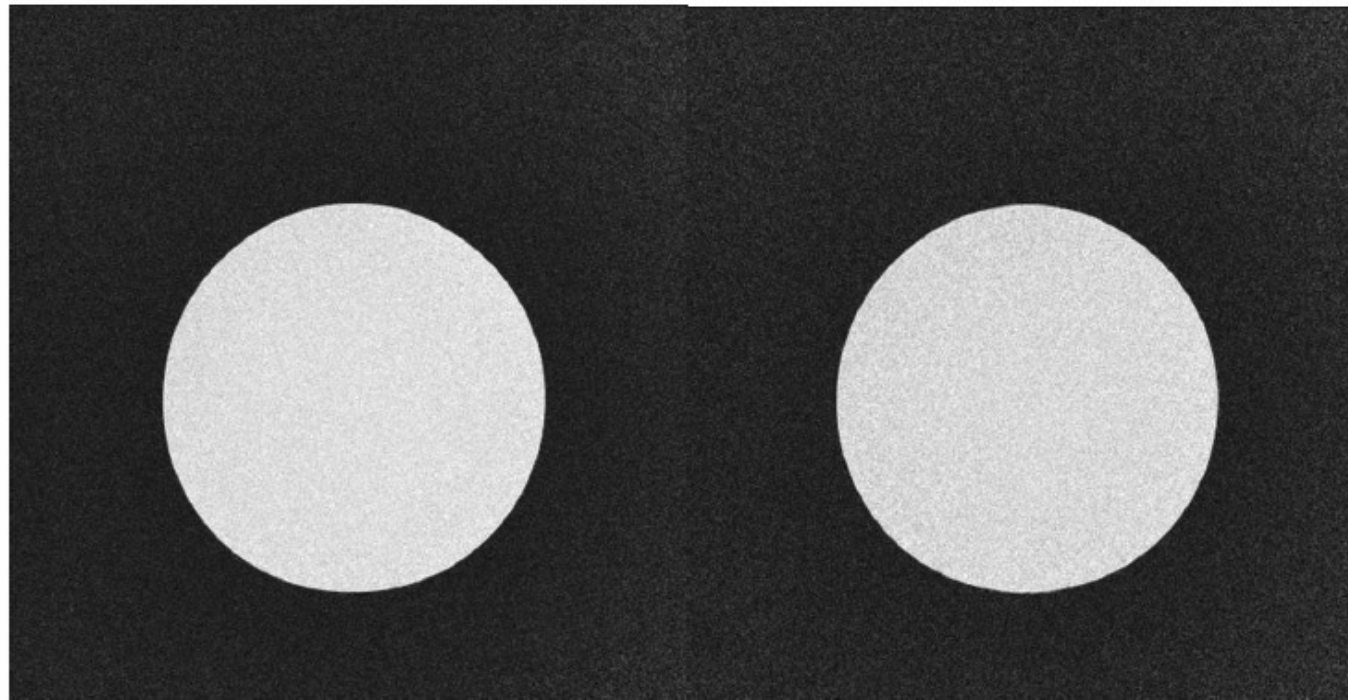
B field measurements

- TESSA unsegmented n-type coaxial HPGe
- TIGRE 6 x 4 segmented n-type coaxial HPGe
- Data acquired at MARIARC for 2 B field orientations, longitudinal (left) and transverse (right)
- Pulser and Sources: ^{137}Cs , ^{133}Ba , ^{60}Co (80keV- \rightarrow 1332keV)



MRI imaging

Preliminary analysis of MRI images acquired with the detector at the entrance of the bore (b) show that the detector does not degrade the MRI performance. FLASH images and TSE MRI images were acquired. Image (a) is when there is no detector present.



(a)

(b)

FLASH - Fast Low Angle Shot TSE - Turbo Spin Echo

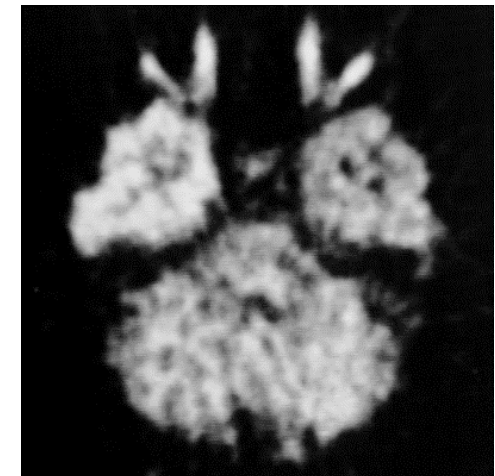
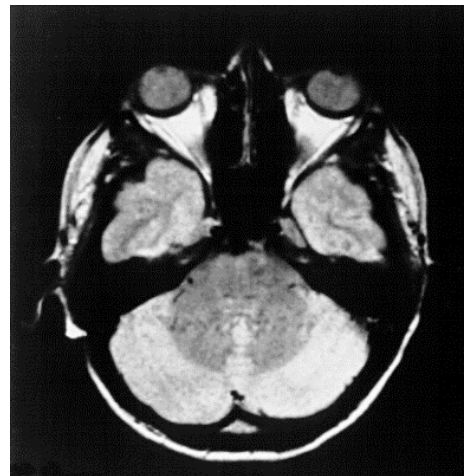
ProSPECTus : The Implication

Patient benefits:

- Earlier and more effective diagnosis of tumours (higher probability of effective treatment).
- Higher sensitivity offering the scope for shorter imaging time (more patients through one machine per day) or lower doses of radio pharmaceuticals.
- Cardiac and brain imaging
- Image larger patients

SPECT/MRI:

- Functional/Anatomical
- Image co-registration



ProSPECTus

Next generation Single Photon Emission Computed Tomography

Largest Nuclear Medicine market

100 x imaging sensitivity

Factor 2 -3 increase in position resolution

Earlier and more effective diagnosis of tumours

Higher patient throughput

SPECT/MRI

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