

Planar semiconductor Compton imaging using pulse shape analysis

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Position Sensitive Detectors 9
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Outline

- Motivation
- Compton camera principles
- Pulse shape analysis
- Initial result
- Silicon Detector
- Future work

Motivation

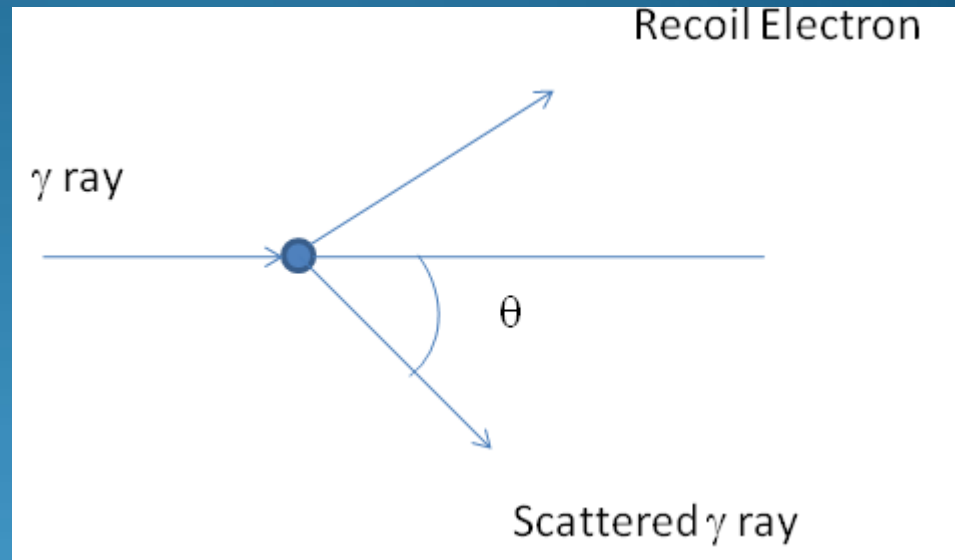
- Homeland security
- Nuclear decommissioning
- Existing systems are limited

Compton camera principles

Compton scattering

Major factors in Compton cameras:-

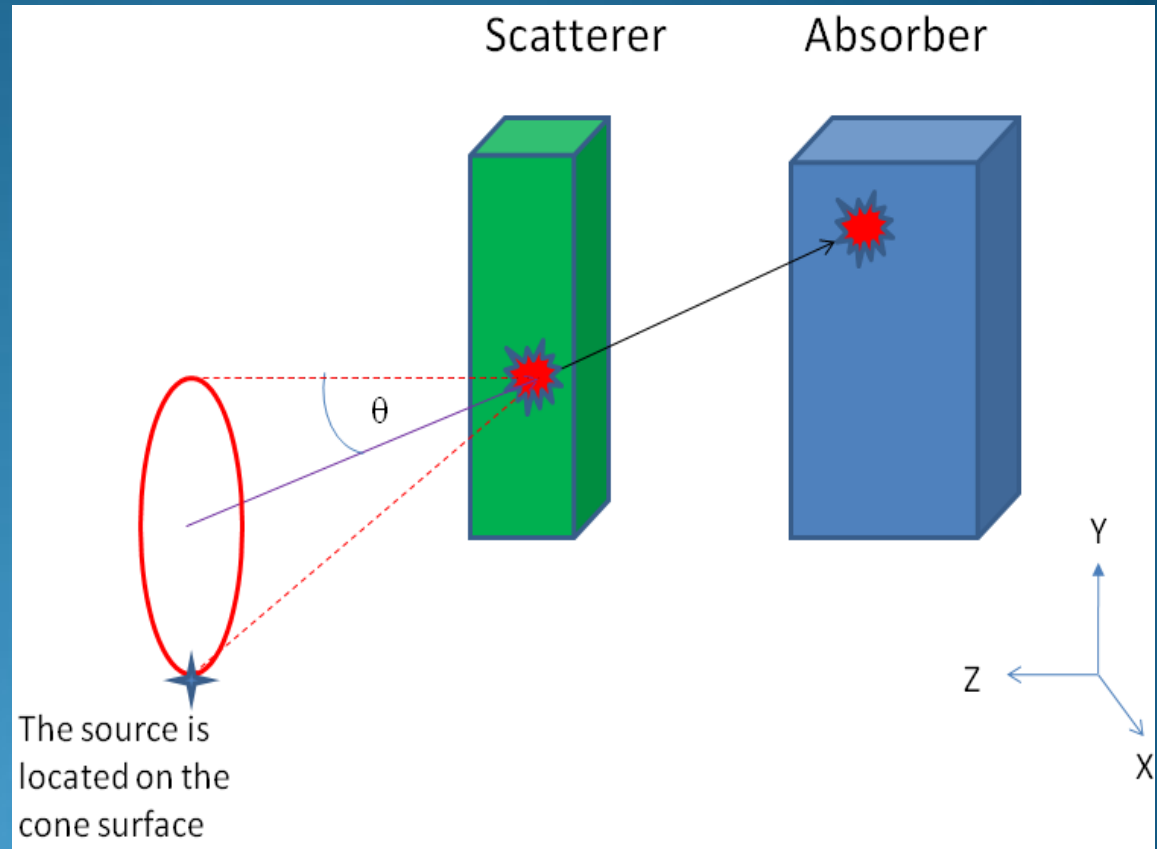
- Energy resolution
- Position resolution within the detector
- Doppler broadening



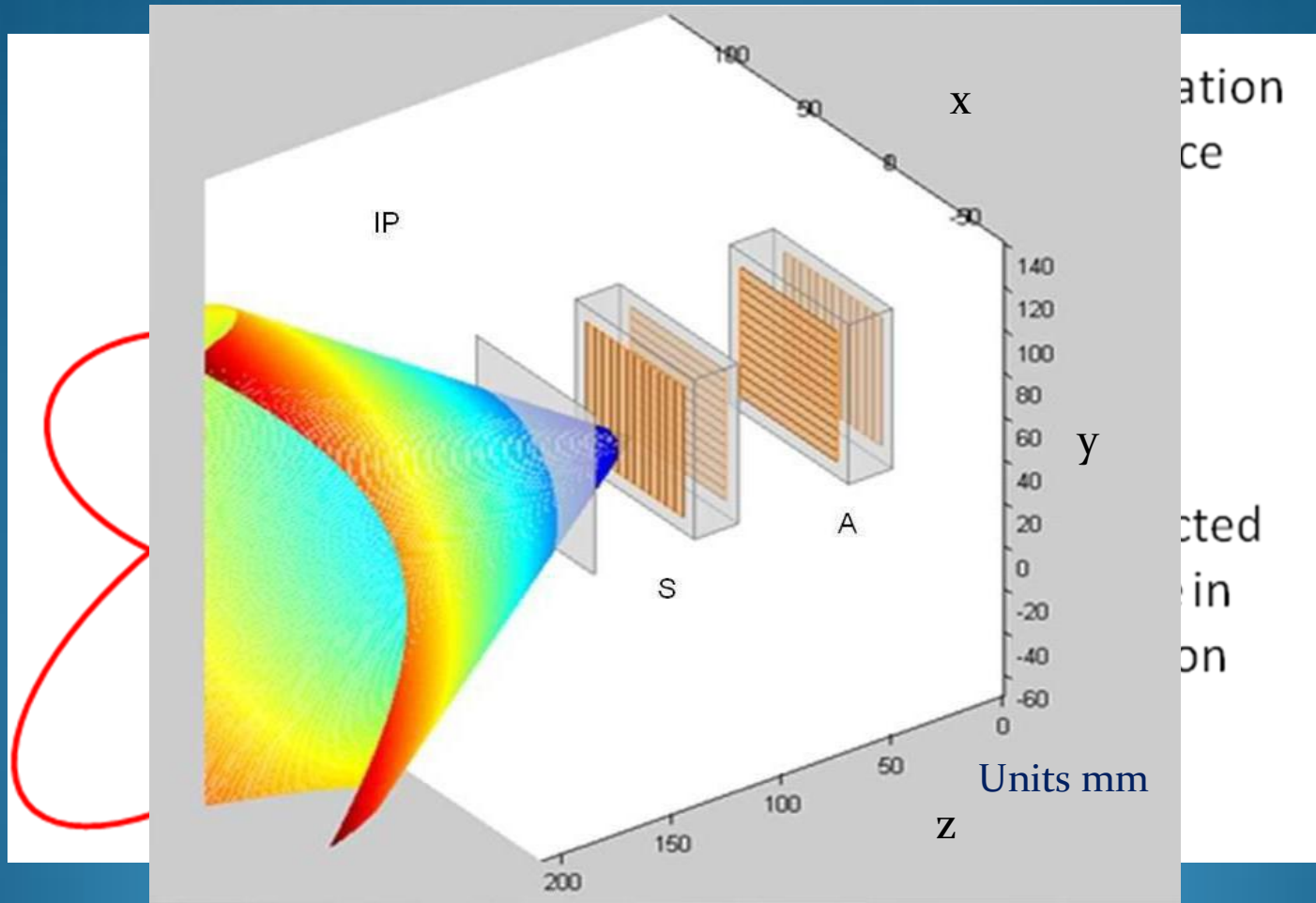
$$E_{\gamma}' = \frac{E_{\gamma}}{1 + \frac{E_{\gamma}}{m_0 c^2} (1 - \cos \theta)}$$

Compton camera

- Compton camera made up from two detectors, scatter detector and absorber.
- Energy of the incident gamma ray can be found by adding the energy deposited in both detectors.
- The position of interaction within the detectors are used to fix the cone apex.
- Opening angle of the cone is calculated using the Compton scattering formula.
- The source lies somewhere on the surface of the cone.

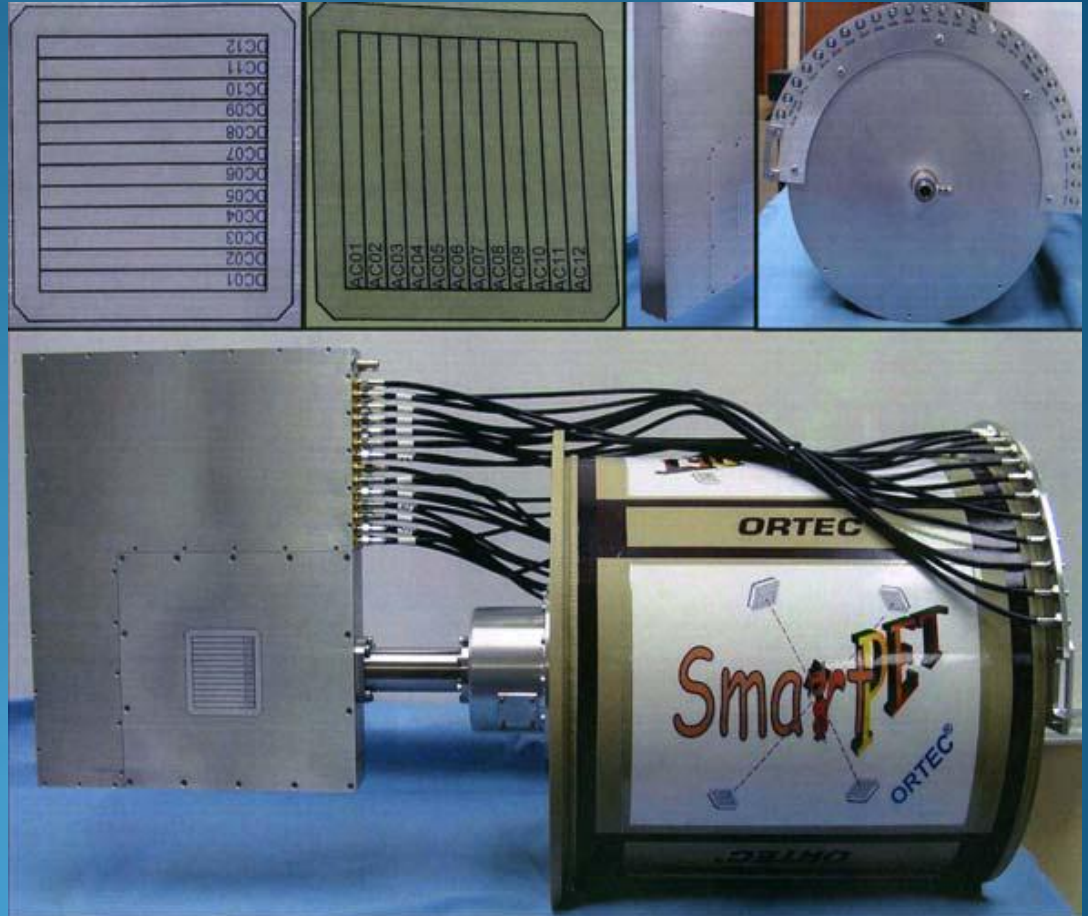


Compton image reconstruction



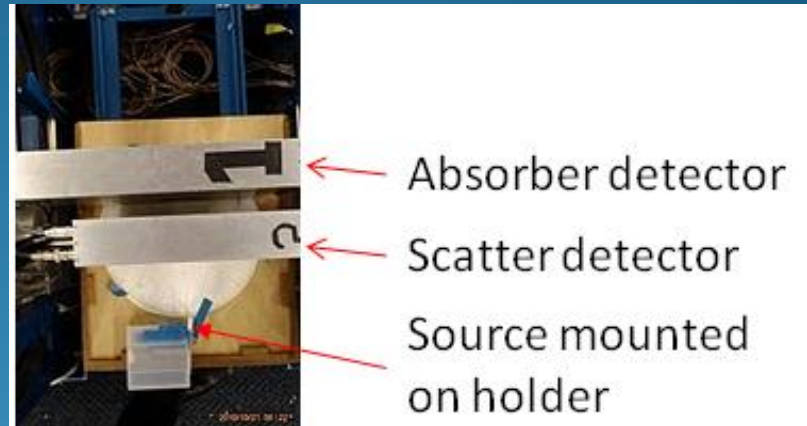
Detectors used

- Two high purity germanium double sided strip detectors manufactured by Ortec with an active area of 60x60x20mm.
- 24 strips per detector, 12 on each side giving 144 voxels of 5x5x20mm.
- Individual charge sensitive preamplifiers for each channel.
- The preamplifier outputs are digitised through CAEN V1724 cards.
- Typical energy resolutions of 2 to 3keV are seen at 662keV for all strips of both detectors.



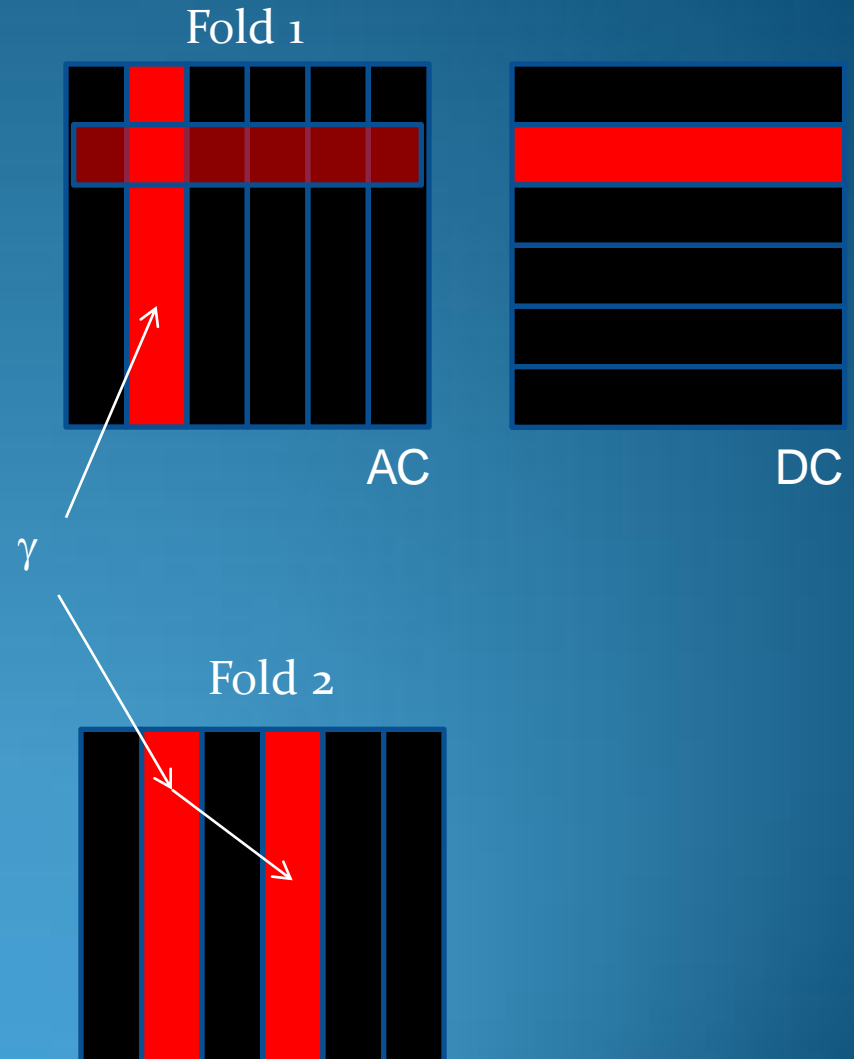
Detector and source positions

- Detectors are mounted 5.5cm apart with the centres aligned.
- Separation chosen as a compromise between data collection time and final image resolution.
- A ^{137}Cs point source of 0.26MBq activity was positioned 5cm away from the centre of the scatter detector.
- Trigger on a coincident event between both detectors within a 100ns time window.



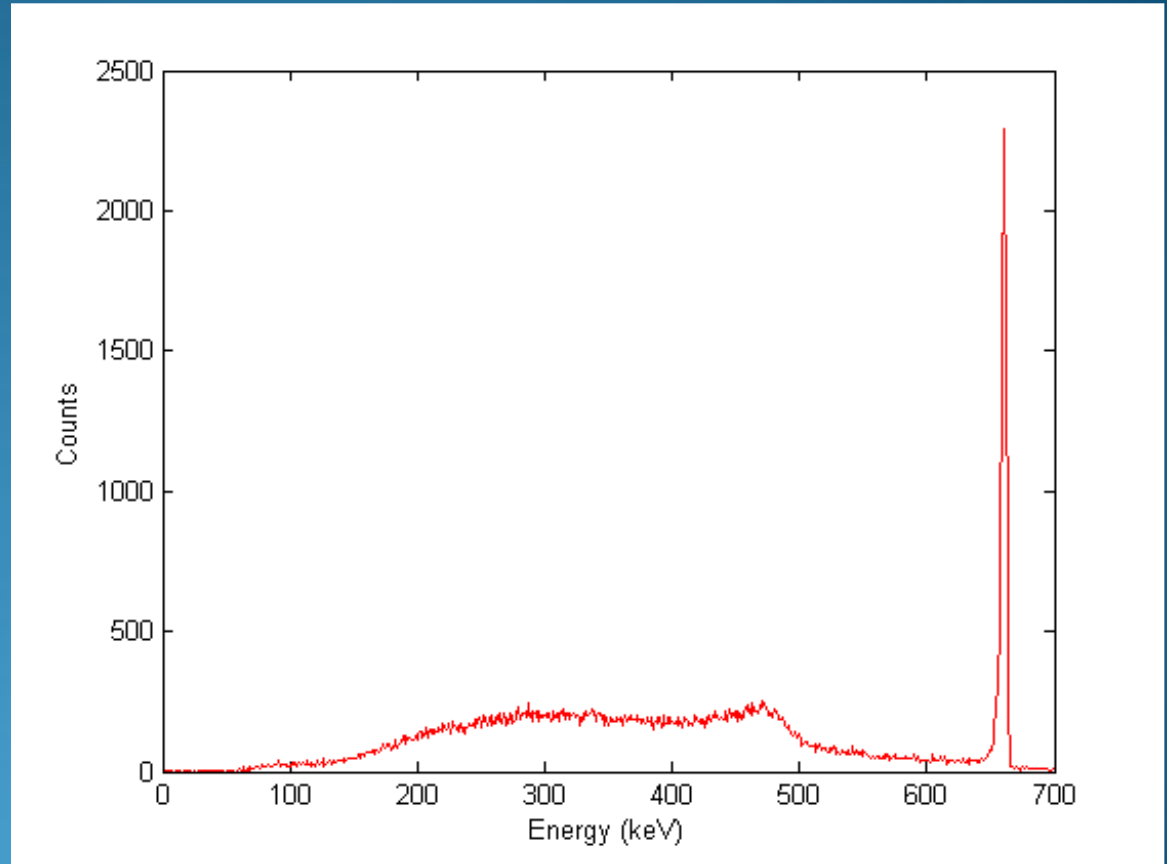
Data selection: Fold

- Single interactions within the scatter detector and subsequently the absorber detector are needed for reconstruction.
- Fold is the number of strips which contain energy for one side of the detector.
- Only fold one events from both sides of both detectors are selected.
- Each event selected will now only have interacted within one voxel of each detector.



Data selection: Addback

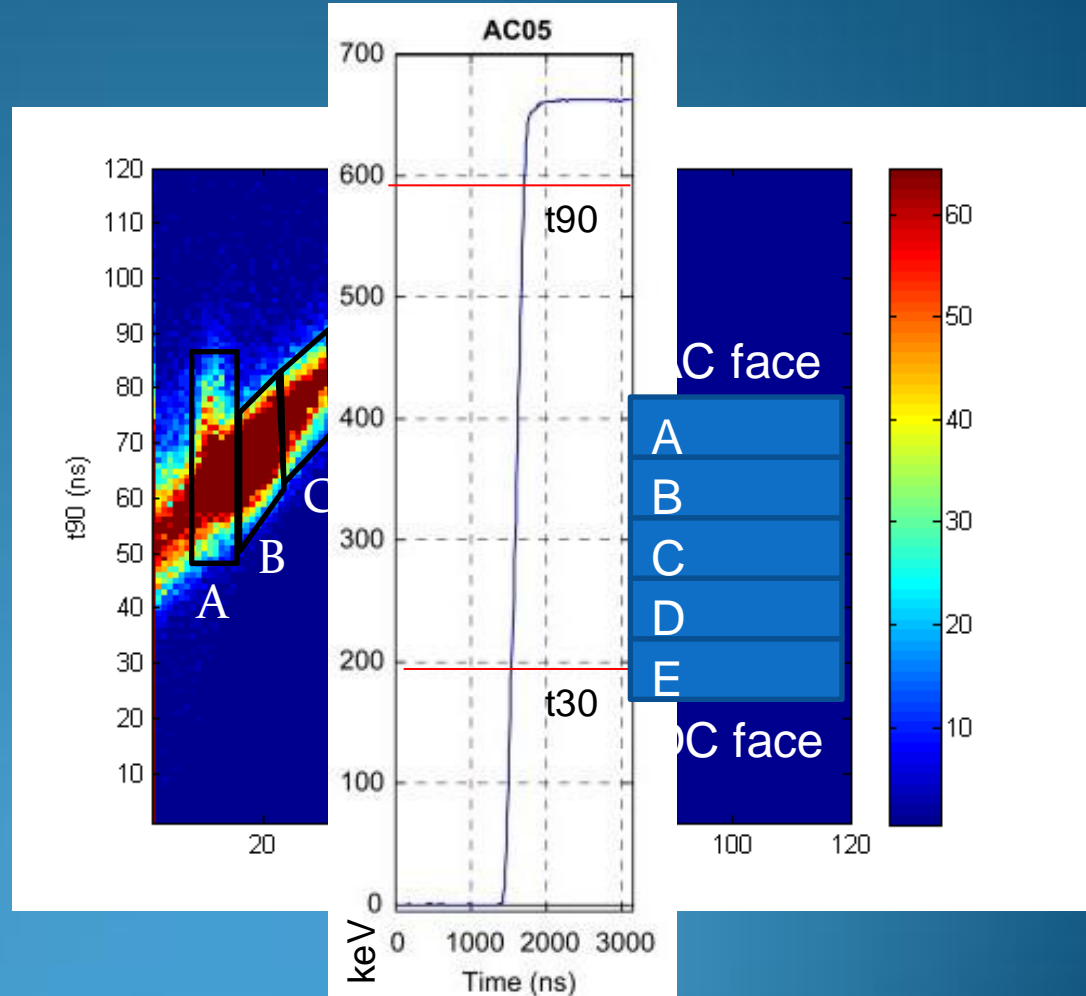
- Less energy is deposited in the scatter detector than the absorber.
- A spectrum can be created using the fold selected events.
- The photopeak seen in this spectrum can be used to identify the source.
- Only events within the photopeak of interest will be reconstructed.
- Here the ^{137}Cs 662 keV photopeak can be seen clearly with an energy resolution of 3.7keV.



Pulse shape analysis (PSA)

Depth of interaction

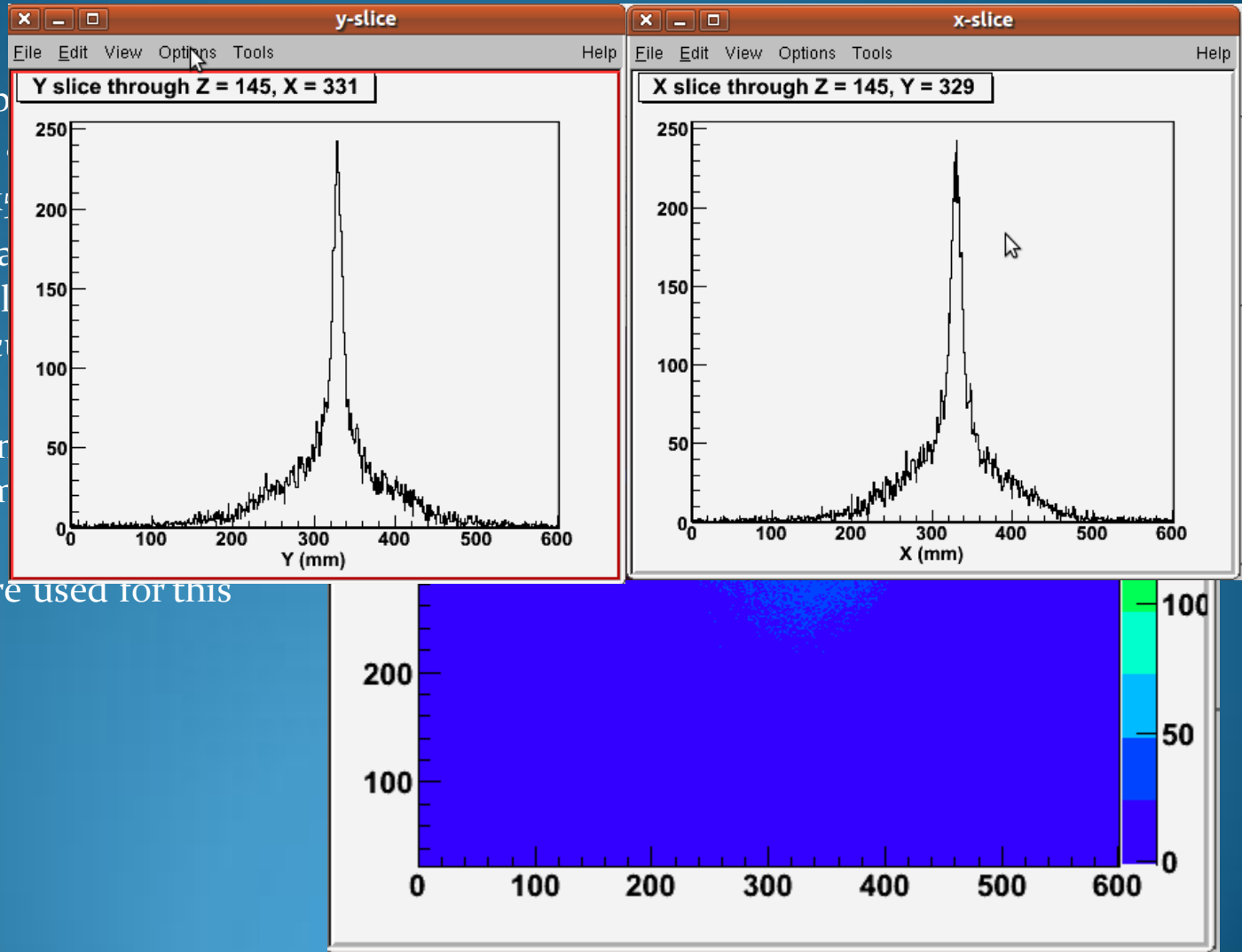
- Typical charge collection times of 200ns are seen with the detectors used.
- Risetimes are dependant upon the time taken for charge carriers to be collected at their respective contacts.
- 30% of the total rise time provides information on the primary carrier (t_{30}).
- 90% of the total rise time provides information on the complete charge collection (t_{90}).
- Plotting t_{30} against t_{90} for all events on one side of one detector a depth of interaction can be measured.
- Voxel size reduced to 5x5x4mm after 5 regions are selected.



Initial results

Compton image with depth of interaction

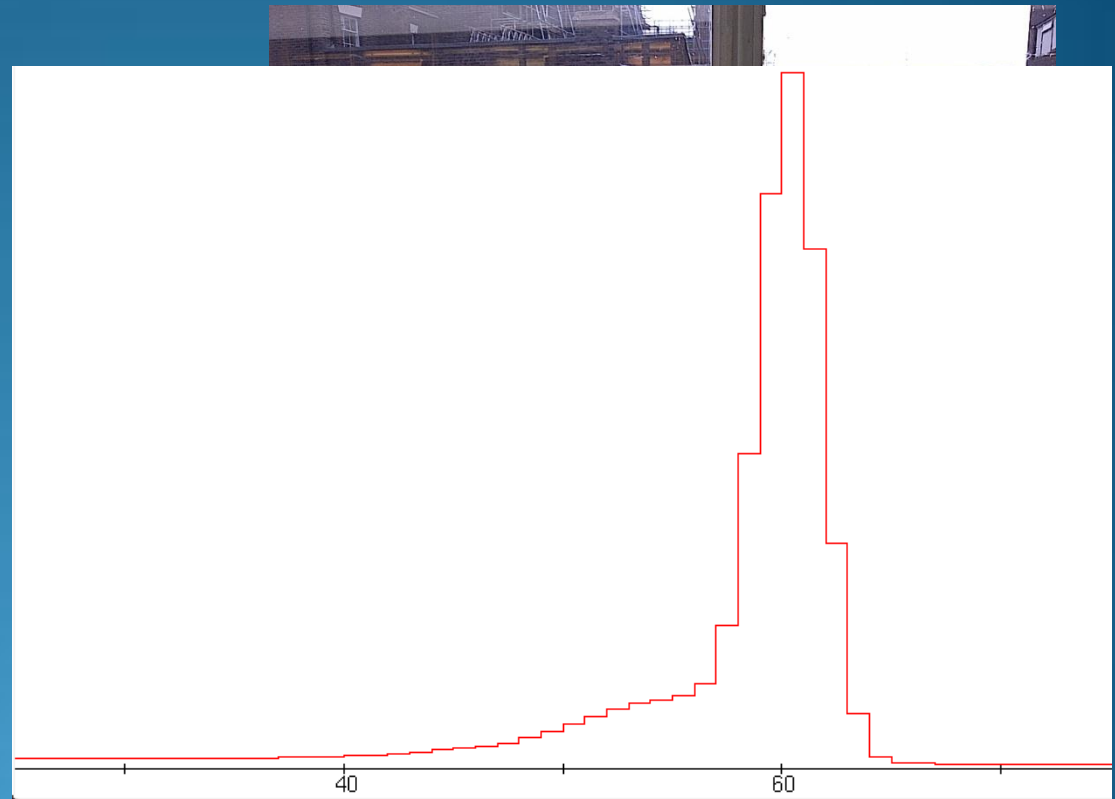
- Image with depth of interaction PSA
- Voxel size 5x5x9
- Resolution is approximately full maximum of a cone in X and Y axis.
- Approximate in-plane resolution is 19mm in X and 17mm in Y.
- 5558 cones were used for this reconstruction.



Silicon detector

Silicon Detector

- Manufactured by Canberra.
- Mechanically cooled.
- Circular wafer, 8mm thick with an active diameter of 66mm.
- Double sided strip detector, with 13 strips per side of varying sizes.
- 26 charge sensitive pre amplifiers.
- Average energy resolution across all strips is 1.5 keV at 60 keV.
- One strip is non functional.
- Raster scans have been completed on both detector faces and the edge.



Energy
(keV)



Future work

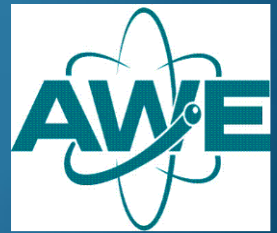
Future work

- Asymmetry pulse shape analysis will be applied to the data.
- New firmware is being tested for the CAEN V1724s.
- Compton data will be collected with the silicon detector acting as the scatter detector.
- A 5mm thick HPGe detector will be scanned and tested to provide an additional scatter detector opening the possibility of a three detector Compton camera system.
- Tests onsite at Aldermaston.



Contributors

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Data flow

| | Counts | % total | % accepted | % F(1,1,1,1) |
|--------------|---------|---------|------------|--------------|
| Total | 1952163 | | | |
| Accepted | 947188 | 48.52 | | |
| F(1,1,1,1) | 208550 | 10.68 | 22.02 | |
| Photopeak | 14289 | 0.73 | 1.51 | 6.85 |
| Imaged (PSA) | 5558 | 0.28 | 0.59 | 2.67 |

Analogue results (collection time vs image resolution)

| Detector separation (cm) | FWHM X (mm) | FWHM Y (mm) | Cones per second |
|--------------------------|-------------|-------------|------------------|
| 3 | 24 | 22 | 22 |
| 5 | 17 | 19 | 12 |