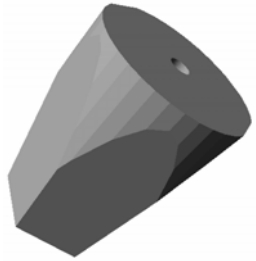
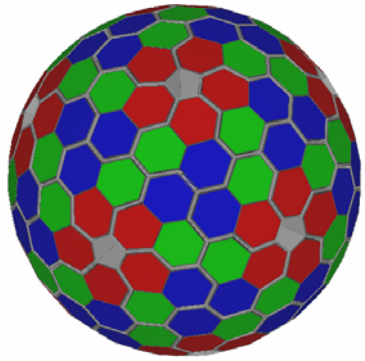
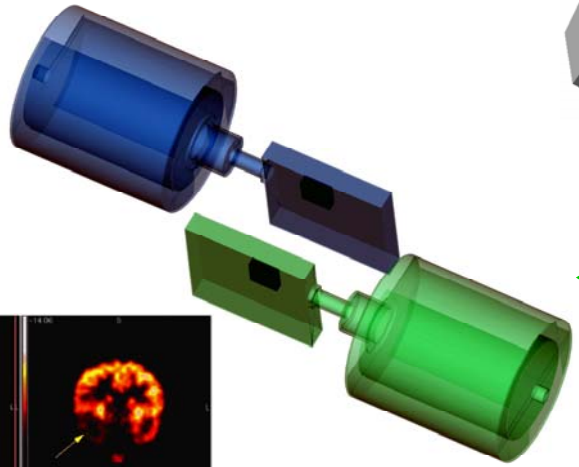
Digital Gamma-ray Spectroscopy & Imaging with Semiconductor detectors

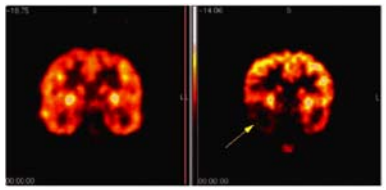
Frontiers of gamma-ray spectroscopy



AGATA
GRETA







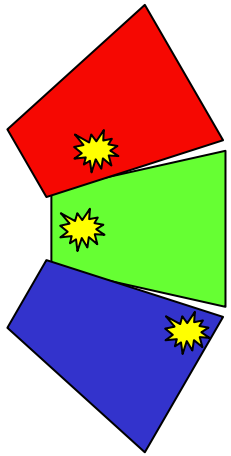
And its applications

Dr Andy Boston
ajboston@liv.ac.uk

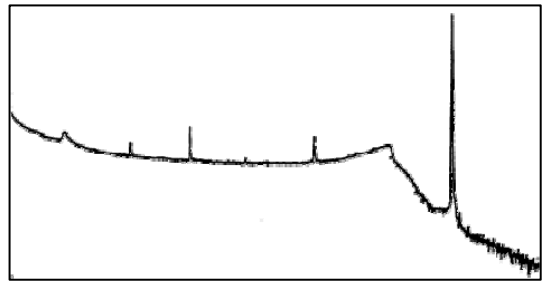
THE UNIVERSITY of LIVERPOOL

The AGATA Concept

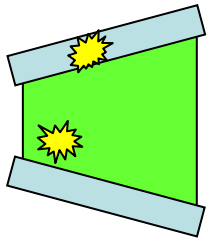
Without Compton suppression shields

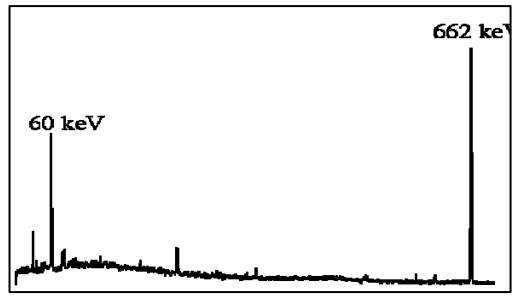


Compton continuum. => Large peak to total ratio



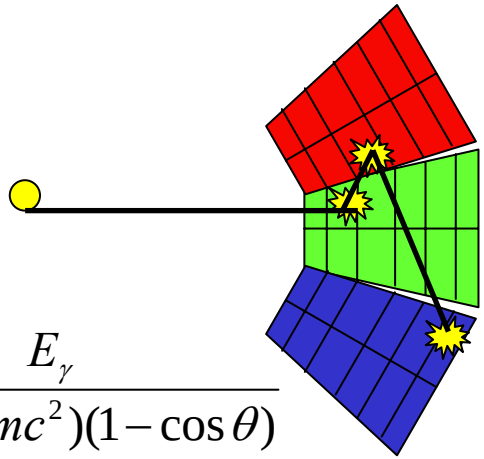
With BGO shielding





Less solid angle coverage => Big drop in efficiency

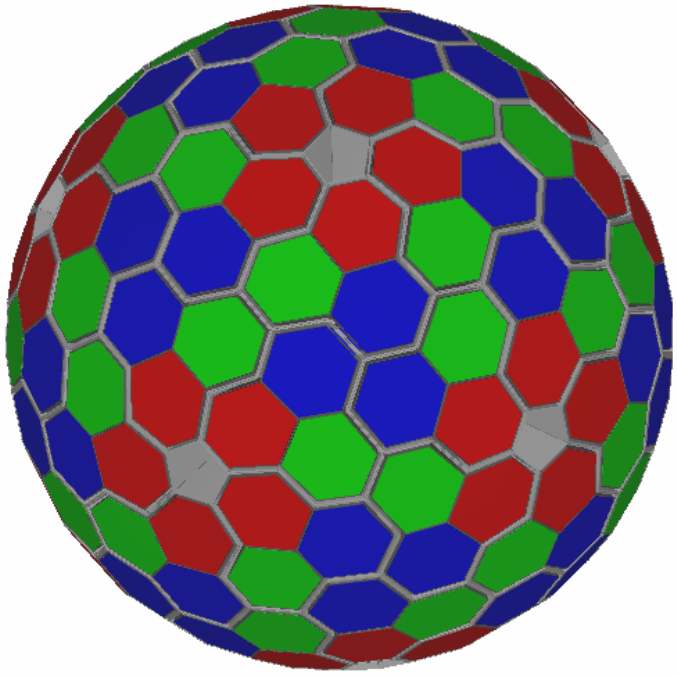
With highly segmented detectors



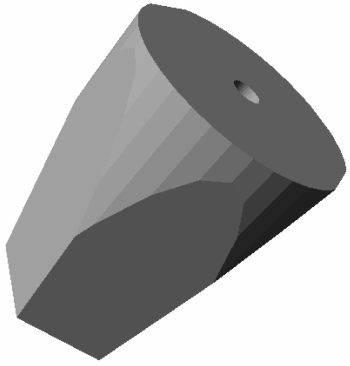
$$E_\gamma' = \frac{E_\gamma}{1+(E_\gamma / mc^2)(1-\cos\theta)}$$

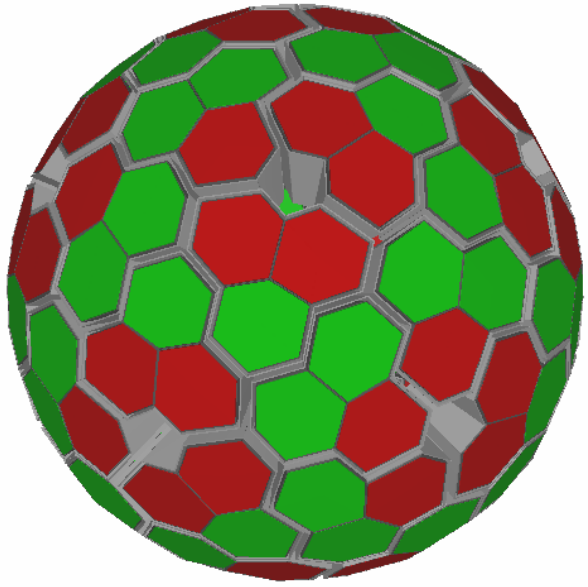
Path of γ-ray reconstructed to form full energy event
=> Compton continuum reduced
=> Excellent efficiency ~50% @1MeV
=> Greatly improved angular resolution (~1^0) to reduce Doppler effects

AGATA : Two candidate configurations



Ge crystals size:
length 90 mm
diameter 80 mm





180 hexagonal crystals	3 shapes
60 triple-clusters	all equal
Inner radius (Ge)	22 cm
Amount of germanium	310 kg
Solid angle coverage	80 %
Singles rate	~50 kHz
6480 segments	

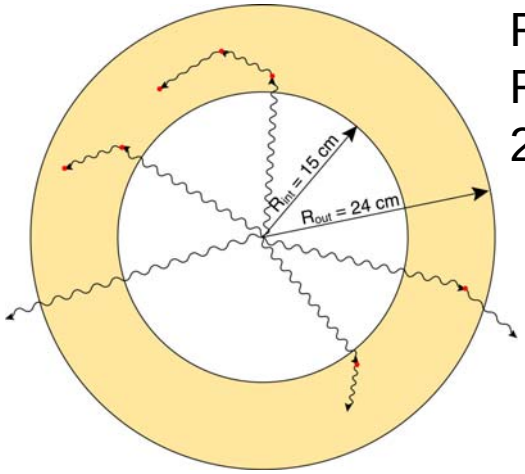
Efficiency: 40% (M_γ=1) 25% (M_γ=30)
Peak/Total: 65% (M_γ=1) 50% (M_γ=30)

120 hexagonal crystals	2 shapes
40 triple-clusters	2 shapes
Inner radius (Ge)	17 cm
Amount of germanium	220 kg
Solid angle coverage	74 %
Singles rate	~70 kHz
4320 segments	

Efficiency: 38% (M_γ=1) 21% (M_γ=30)
Peak/Total: 63% (M_γ=1) 47% (M_γ=30)

The “Standard” Germanium Shell

Idealized configuration to determine maximum attainable performance



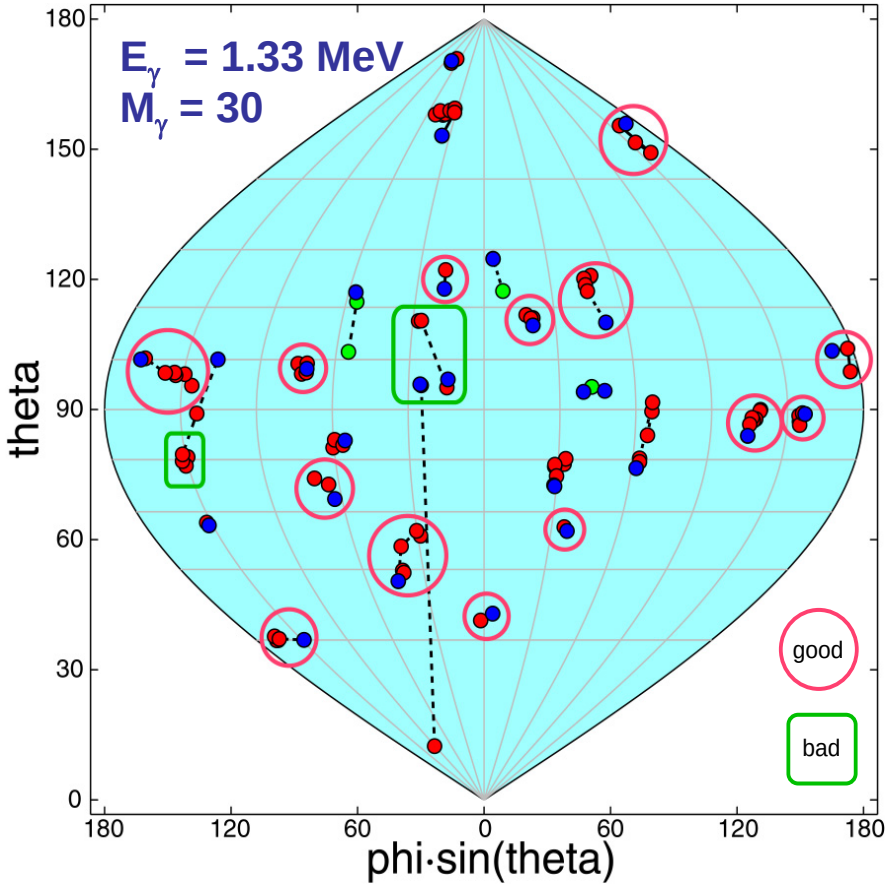
R_i = 15 cm
R_o = 24 cm
230 kg of Ge

M_γ= 1 → ε_{ph} = 65%
P/T = 85%

M_γ= 30 → ε_{ph} = 36%
P/T = 60%

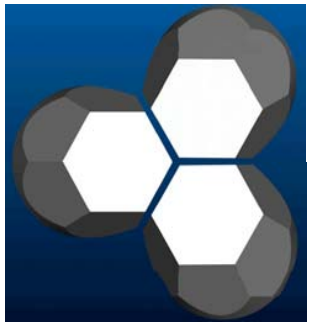
Assuming 5 mm Position Resolution

A high multiplicity event



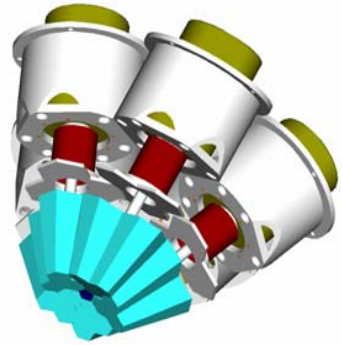
27 gammas detected -- 23 in photopeak
16 reconstructed -- 14 in photopeak

AGATA Design

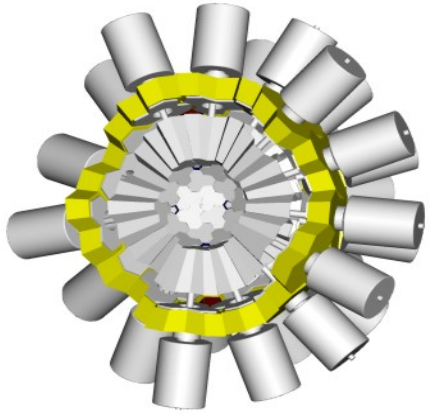


3 different asymmetric hexagonal shapes are used

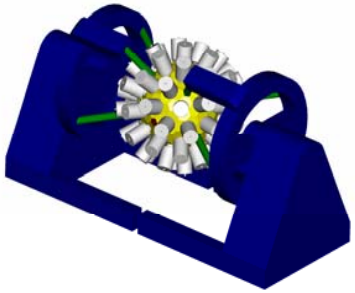
Triple cluster modular units in a single cryostat



The AGATA demonstrator: 5 triple clusters, 540 segments. Scheduled for completion 2008

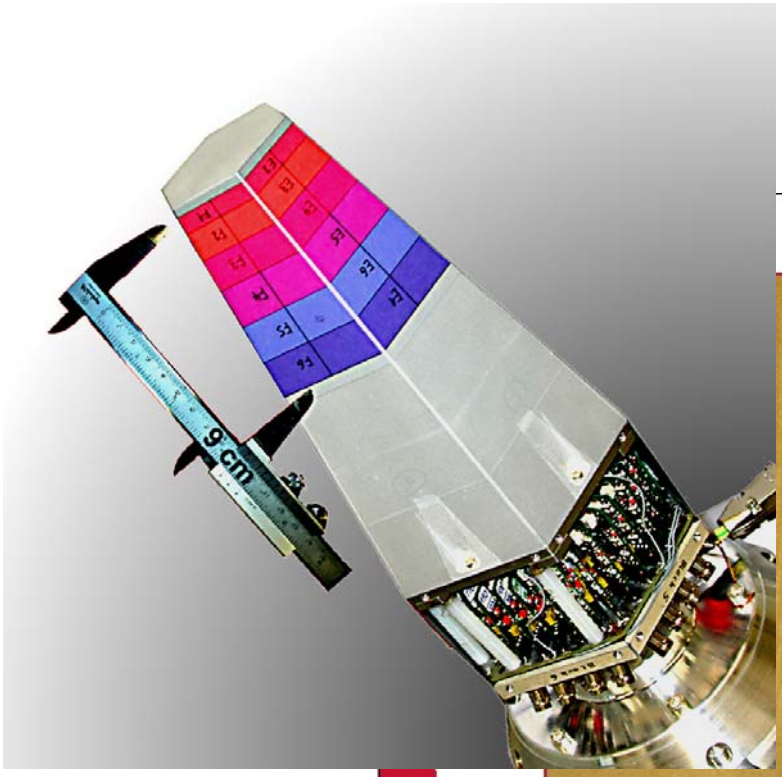


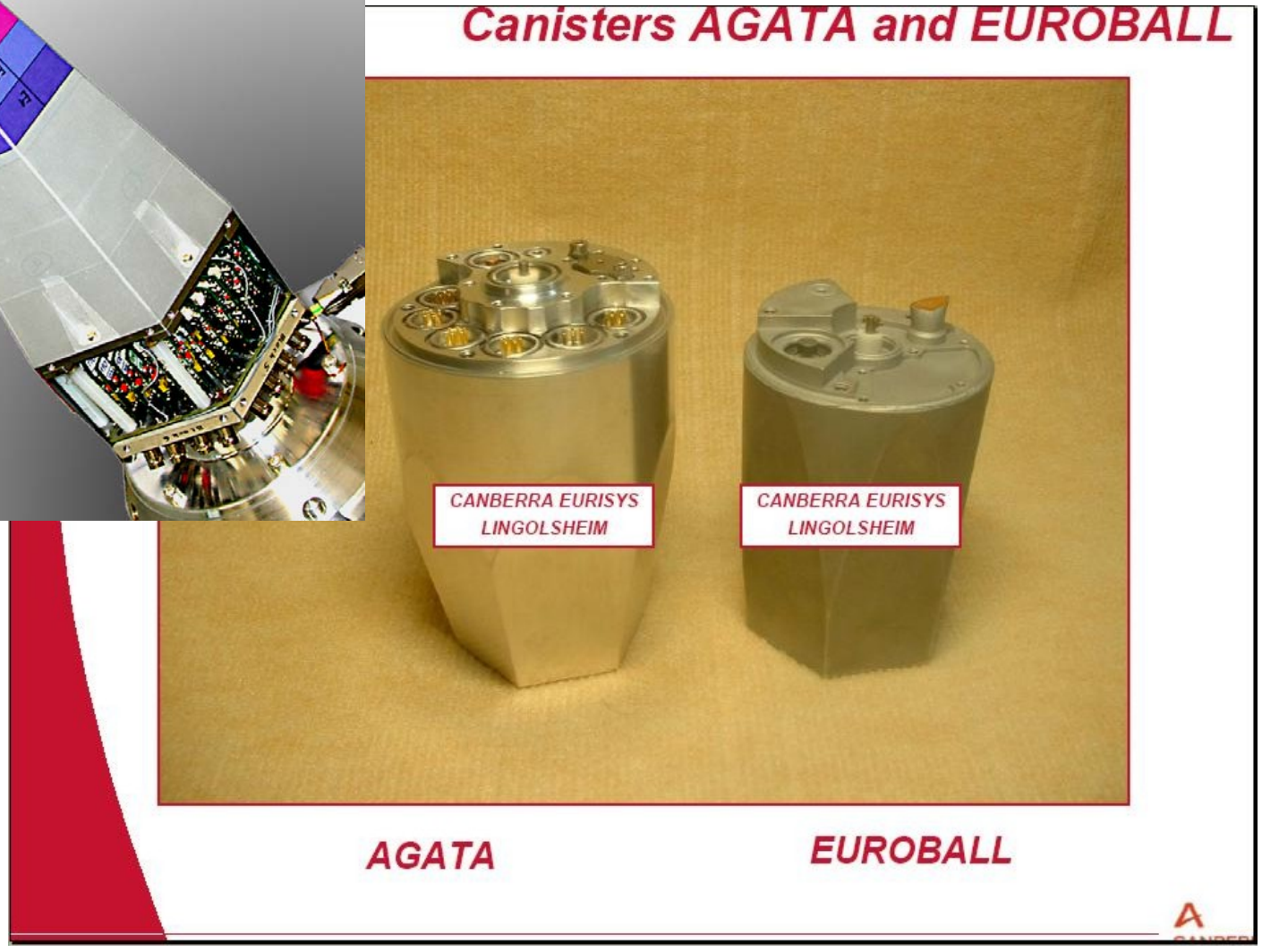
2π of complete d array



Completed array (6480 segments) with support structure

AGATA 1st symmetric cluster

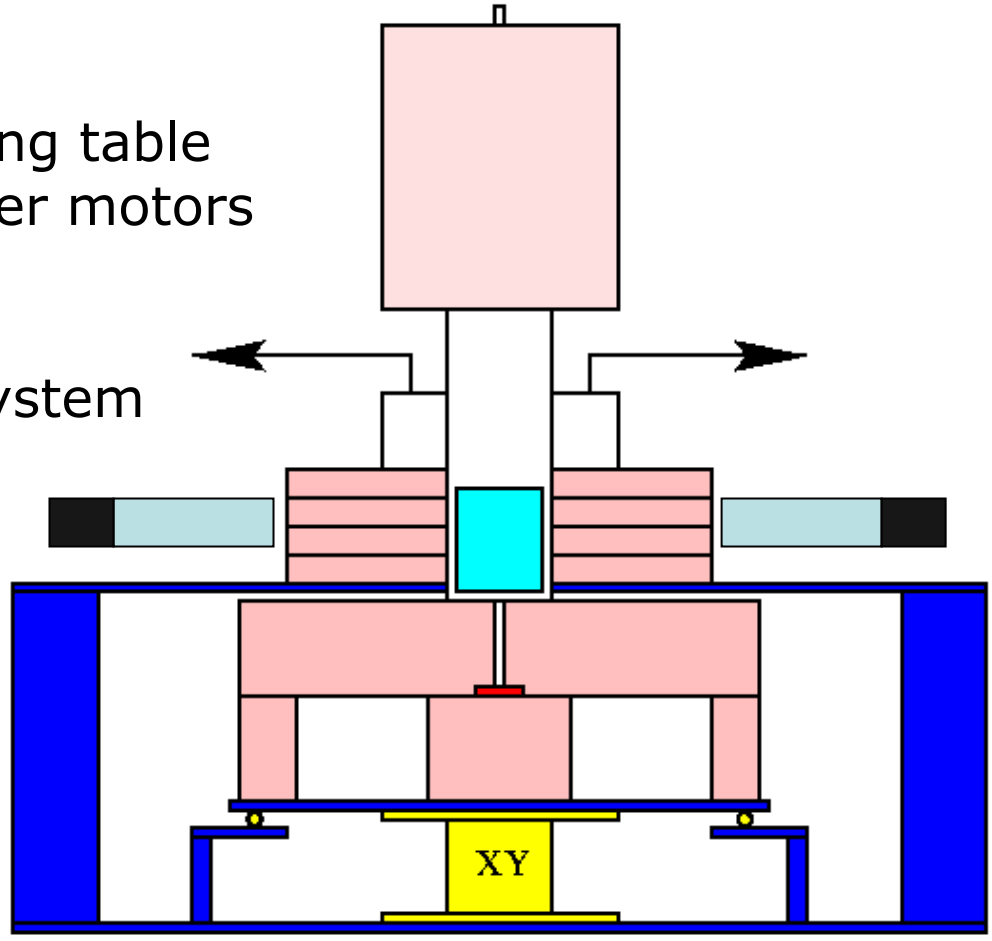




Automated Scanning Tables

Liverpool System

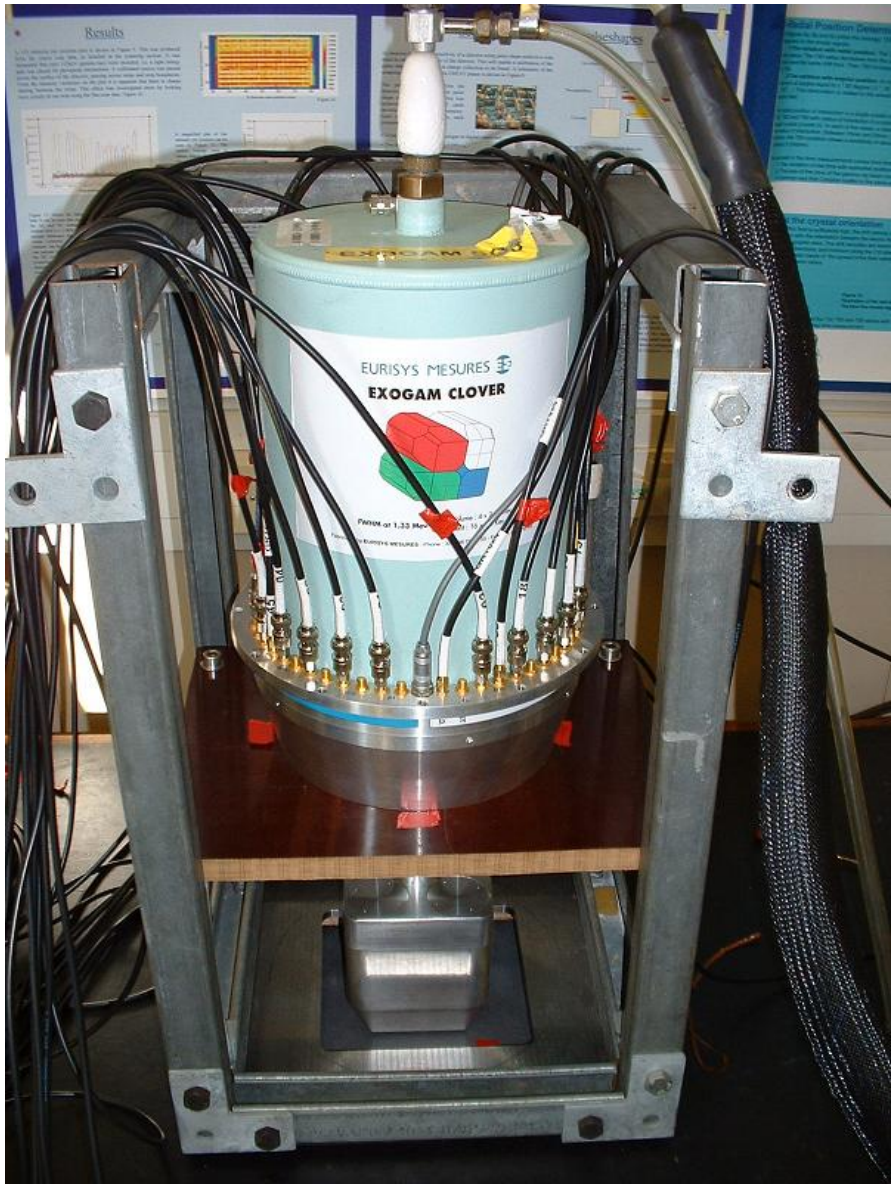
- Parker linear positioning table
- Pacific scientific stepper motors
- 920MBq ^{137}Cs
- 1 collimator
- Singles/coincidence system



Precise position calibration

“How well your basis fits your real data”

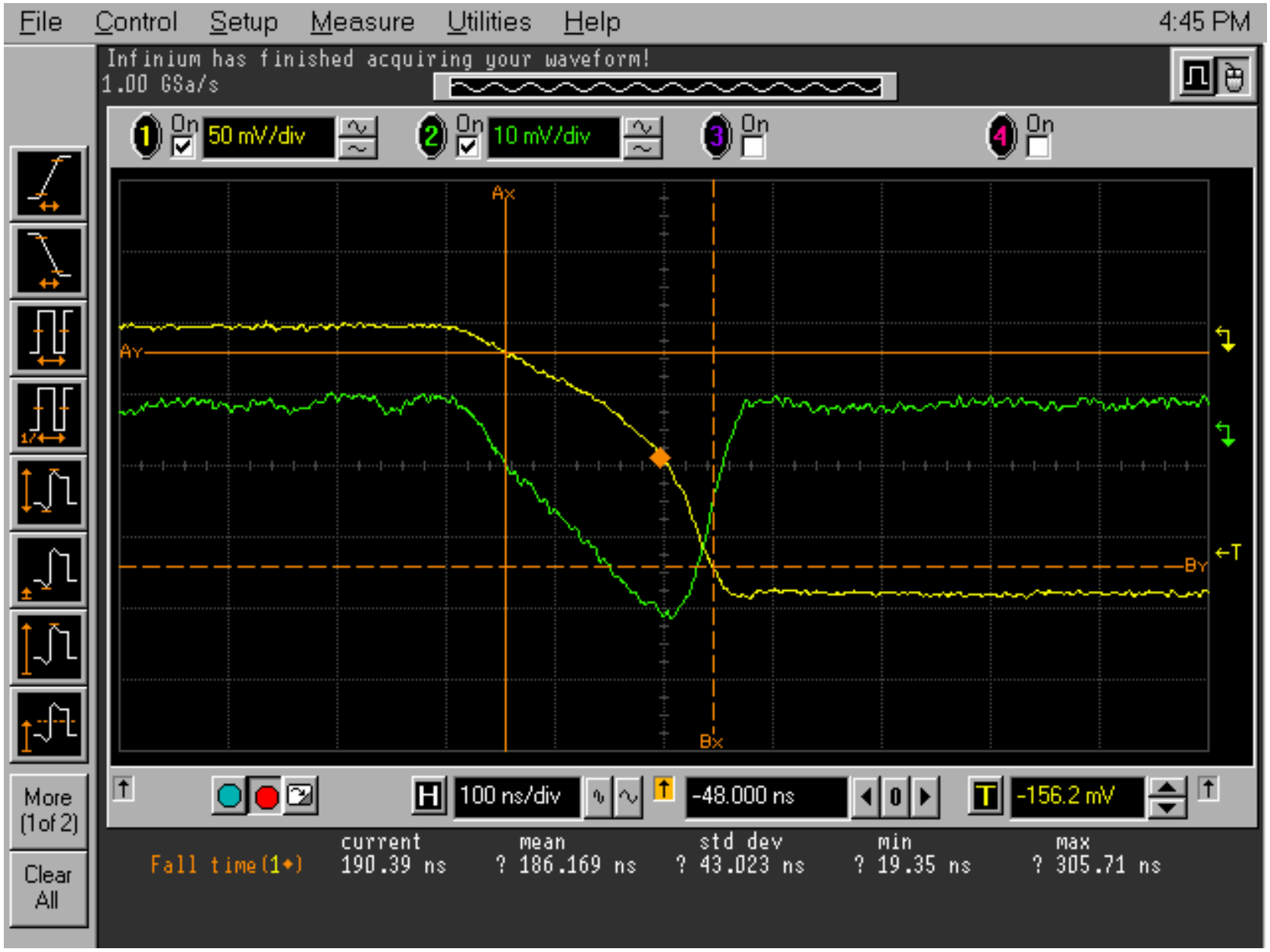
Liverpool Detector Scanning System



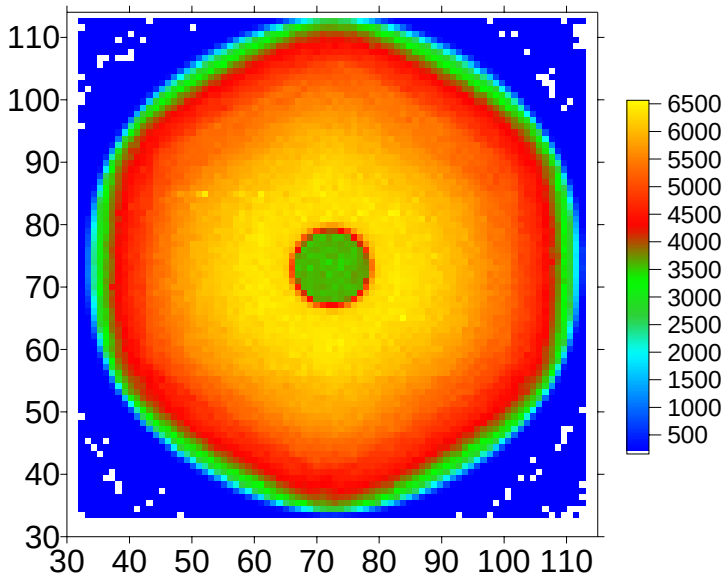
Data recorded using 14 bit 80Mhz digital electronics to disk.

Pulse shape analysis of detector response as a function of position.

Charge pulse response



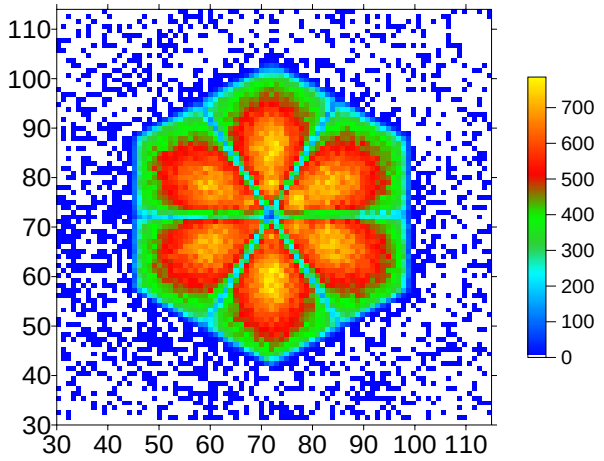
Cs-137 Singles Fine scan

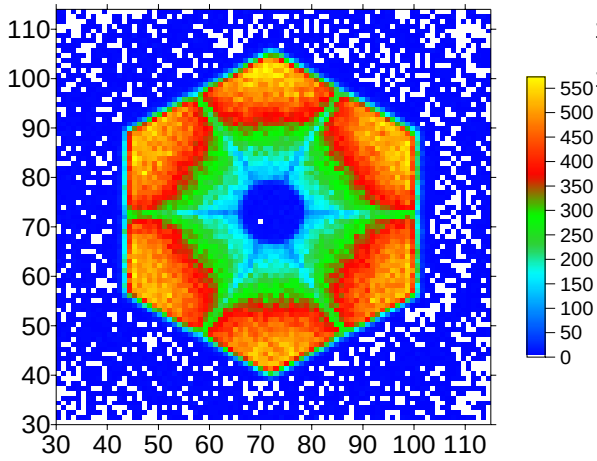


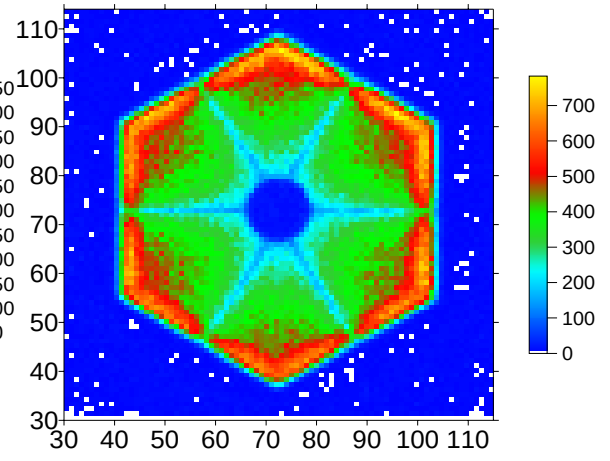
- 920MBq Cs-137 source
- 60 sec per position
- 1mm steps
- 1mm diameter collimator

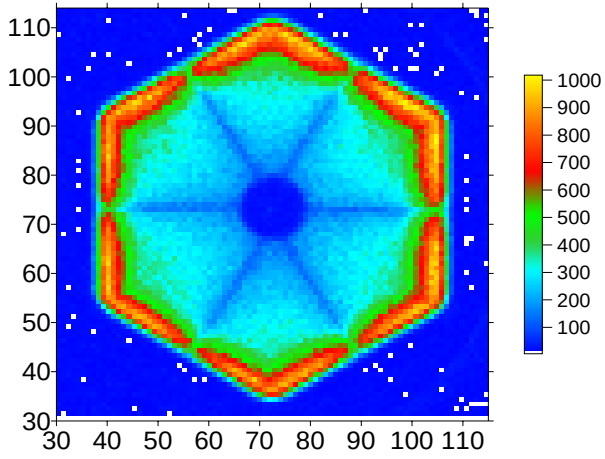
- Max count rate = 720 cps
- Background = 40 cps
- 600keV CFD threshold
- Accepted triggers = 120 cps
- 180GB pre-sorted data

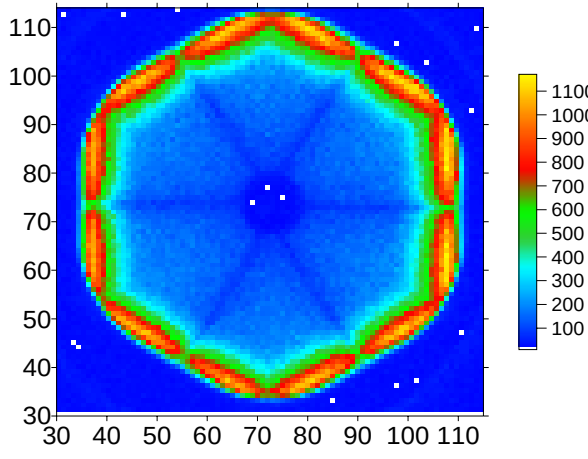
Core 662keV – Ring gated

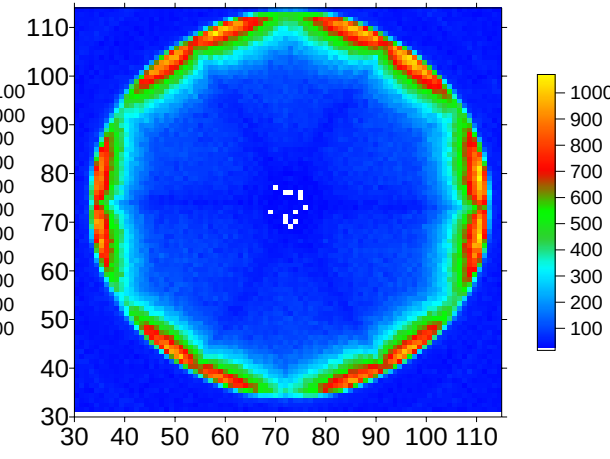




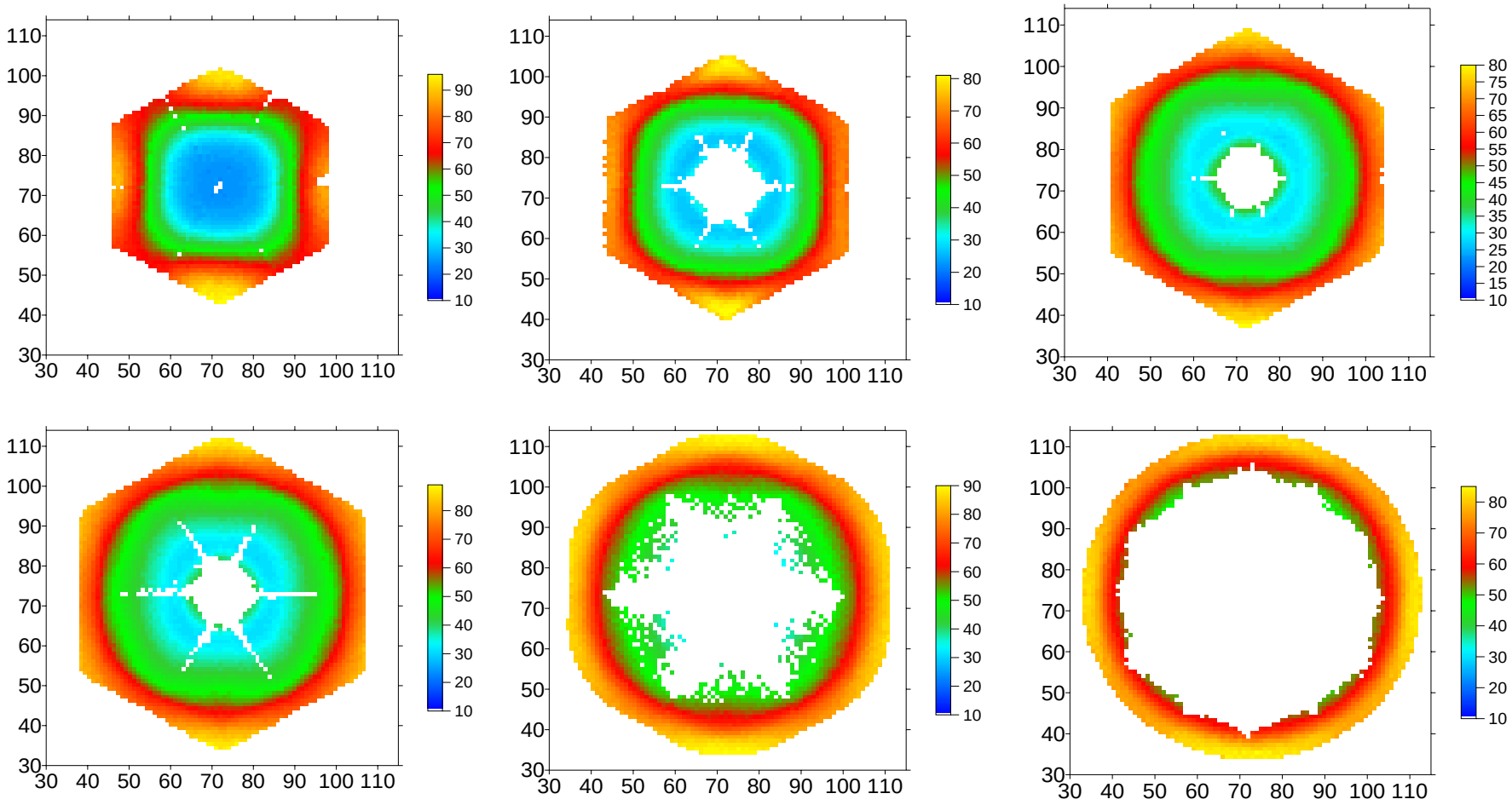




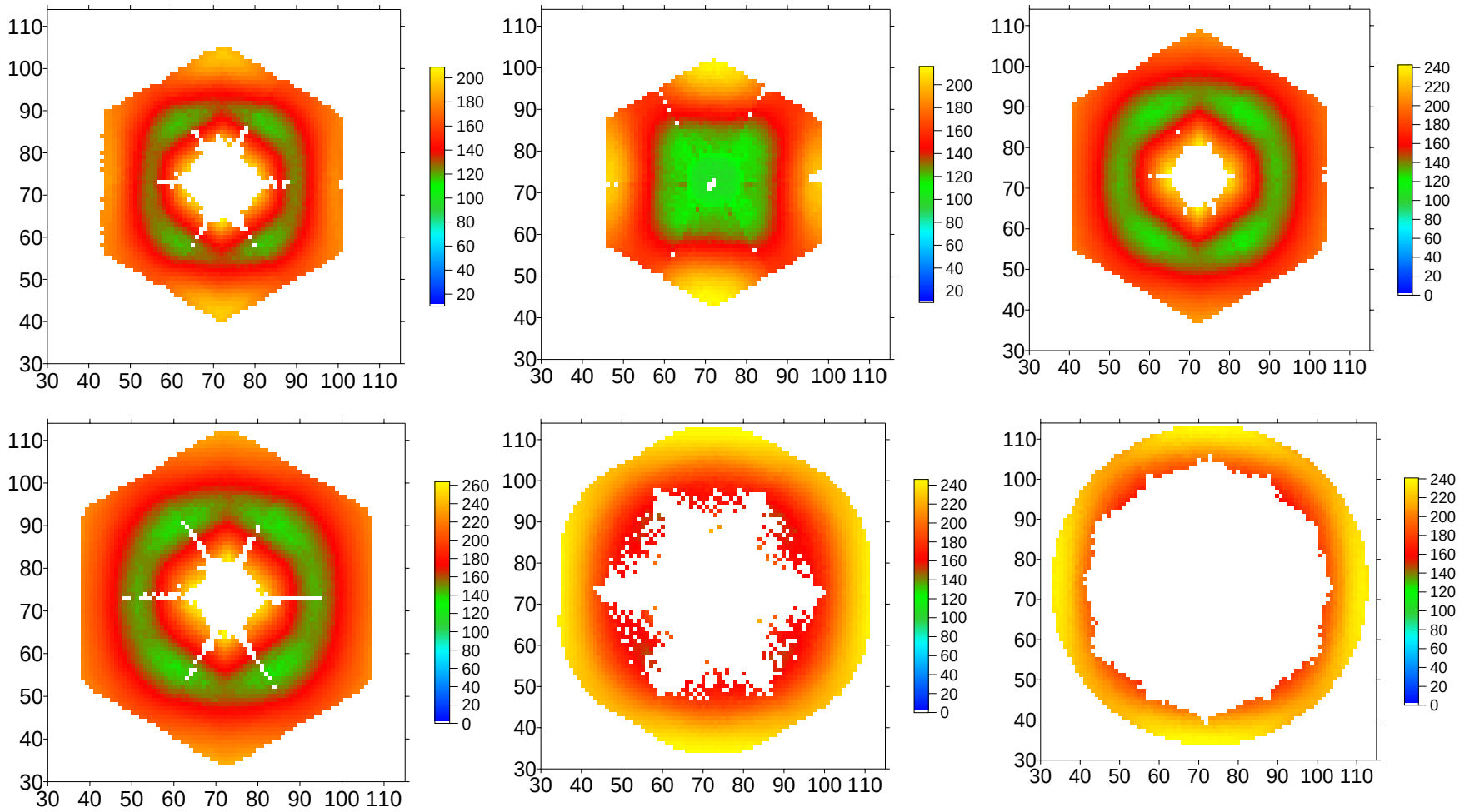




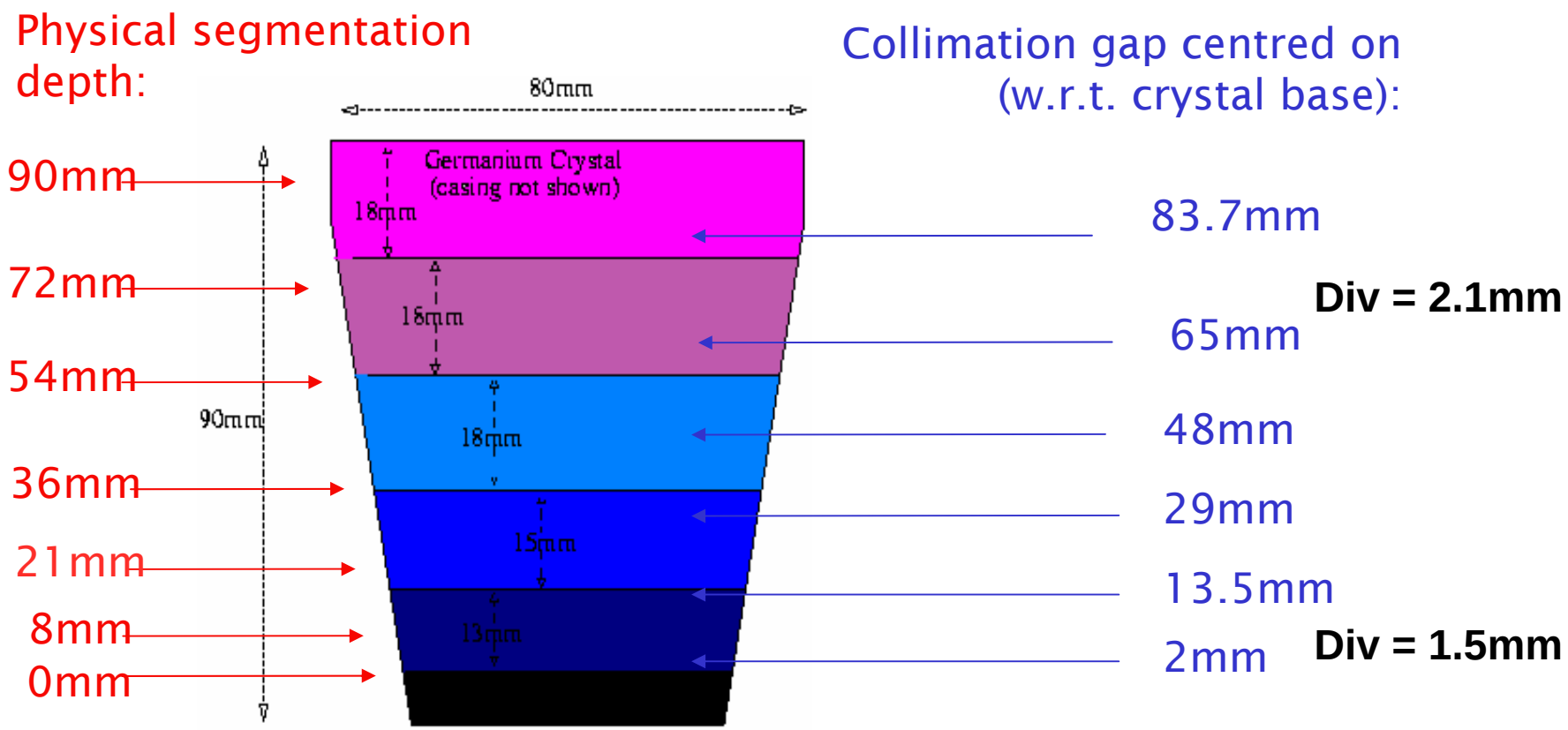
Core 662keV & Fold 1, Core T30



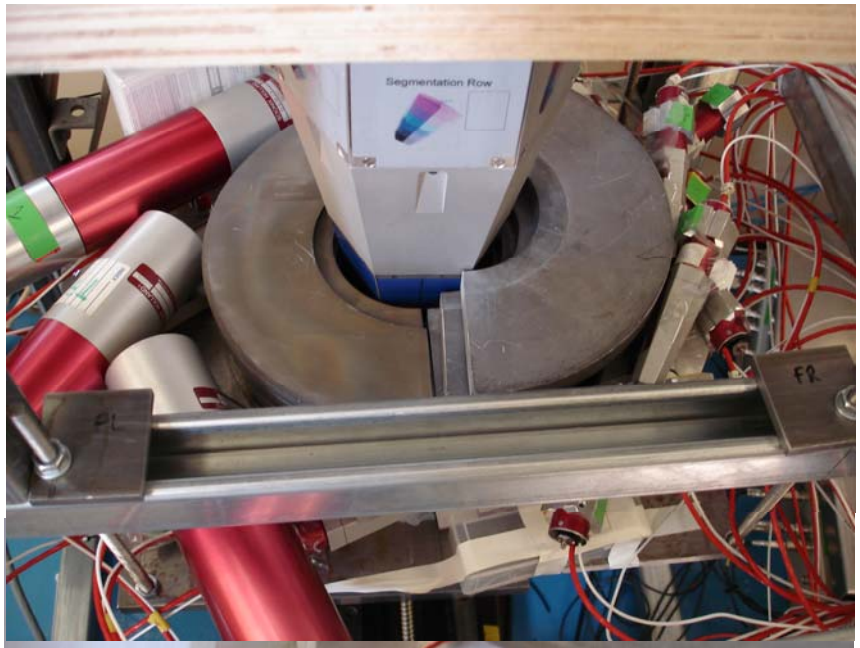
Core 662keV & Fold 1, Core T90

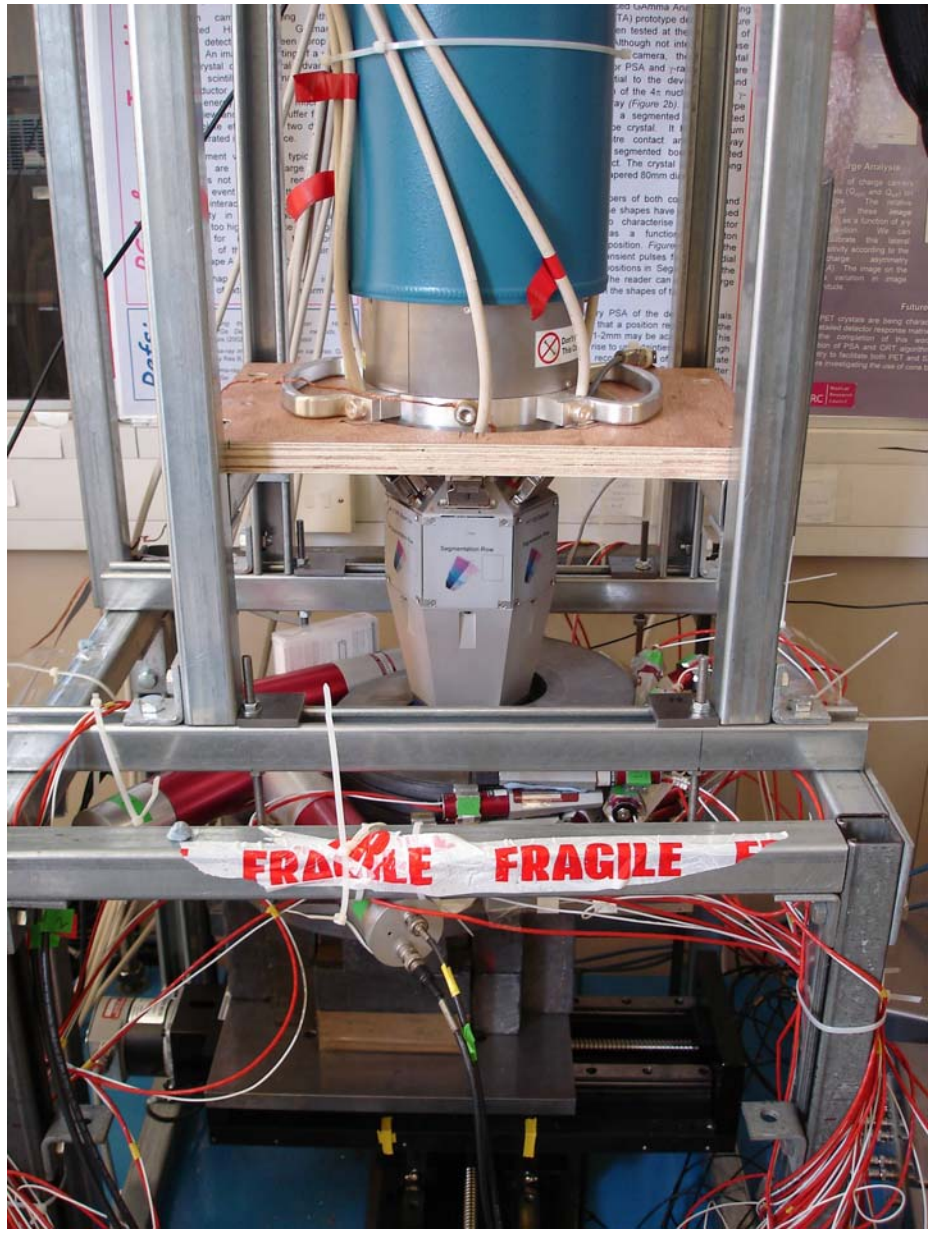


Coincidence scan: set up

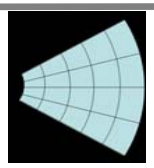
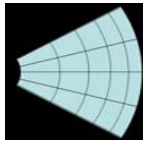
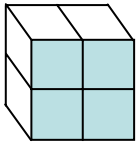
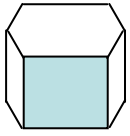
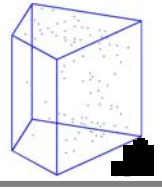


Coincidence scan: set up



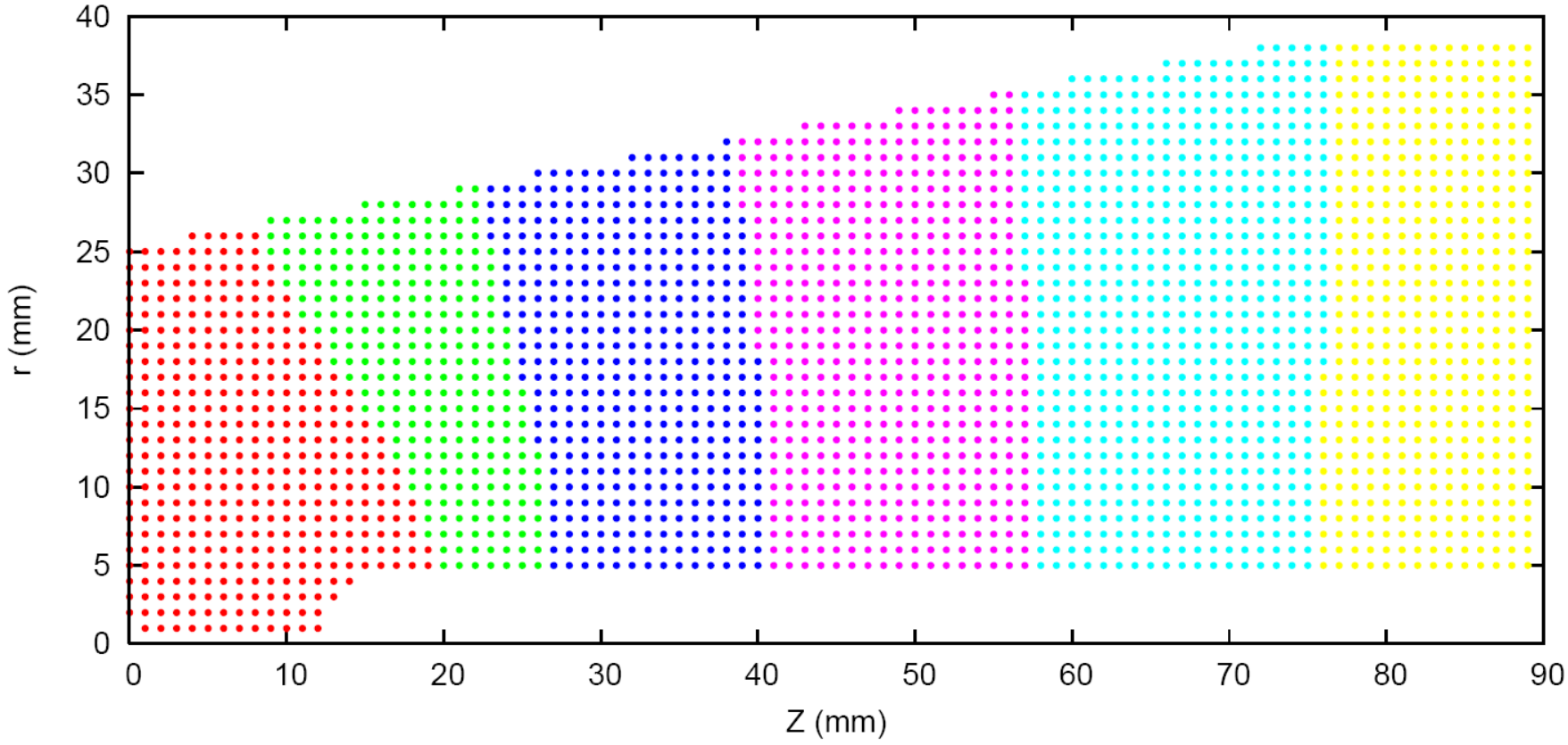


Which grid to choose ?

		advantages	drawbacks
	r,θ	cst. values of $t_{10\text{-}90}$… cylindrical	not homogenous
	$\sqrt{r},\theta$	cst. values of $t_{10\text{-}90}$… homogen., cylindr.	not the same *x*/*y* accuracy
	x,y,z	homogenous simple	not cylindrical large distances to grid
	hexagon, *z*	cylindrical compact	not compact in *z* not homogenous
	hexagonal compact	cylindrical maximum compacity	less “standard”
	Adaptive grid	optimum conditioning of the problem	not homogenous

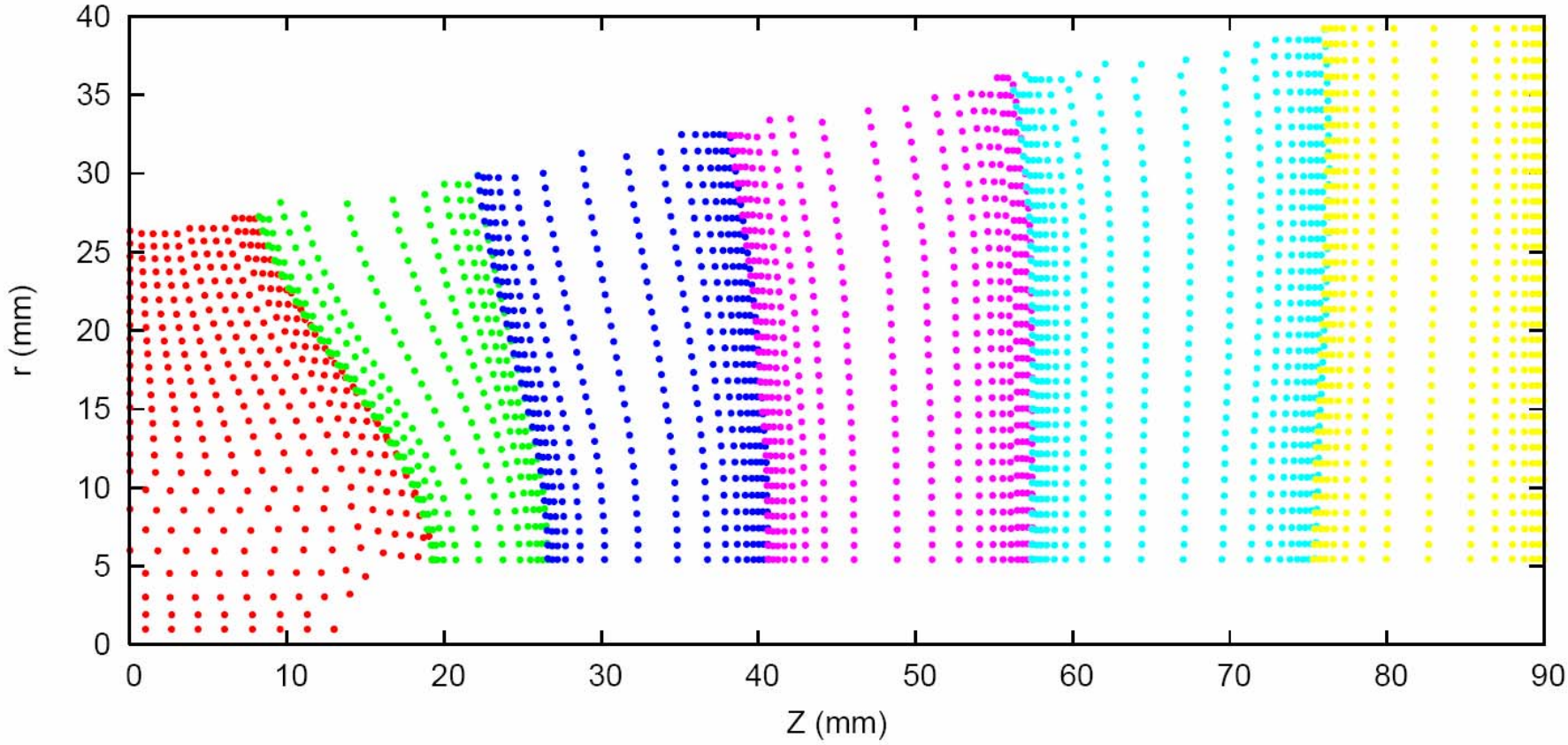
Cartesian Grid

- Different colors show active regions for the different segments



New Quasi-cylindrical Grid

- Different colors show active regions for the different segments
- Spacing is equidistant in sensitivity



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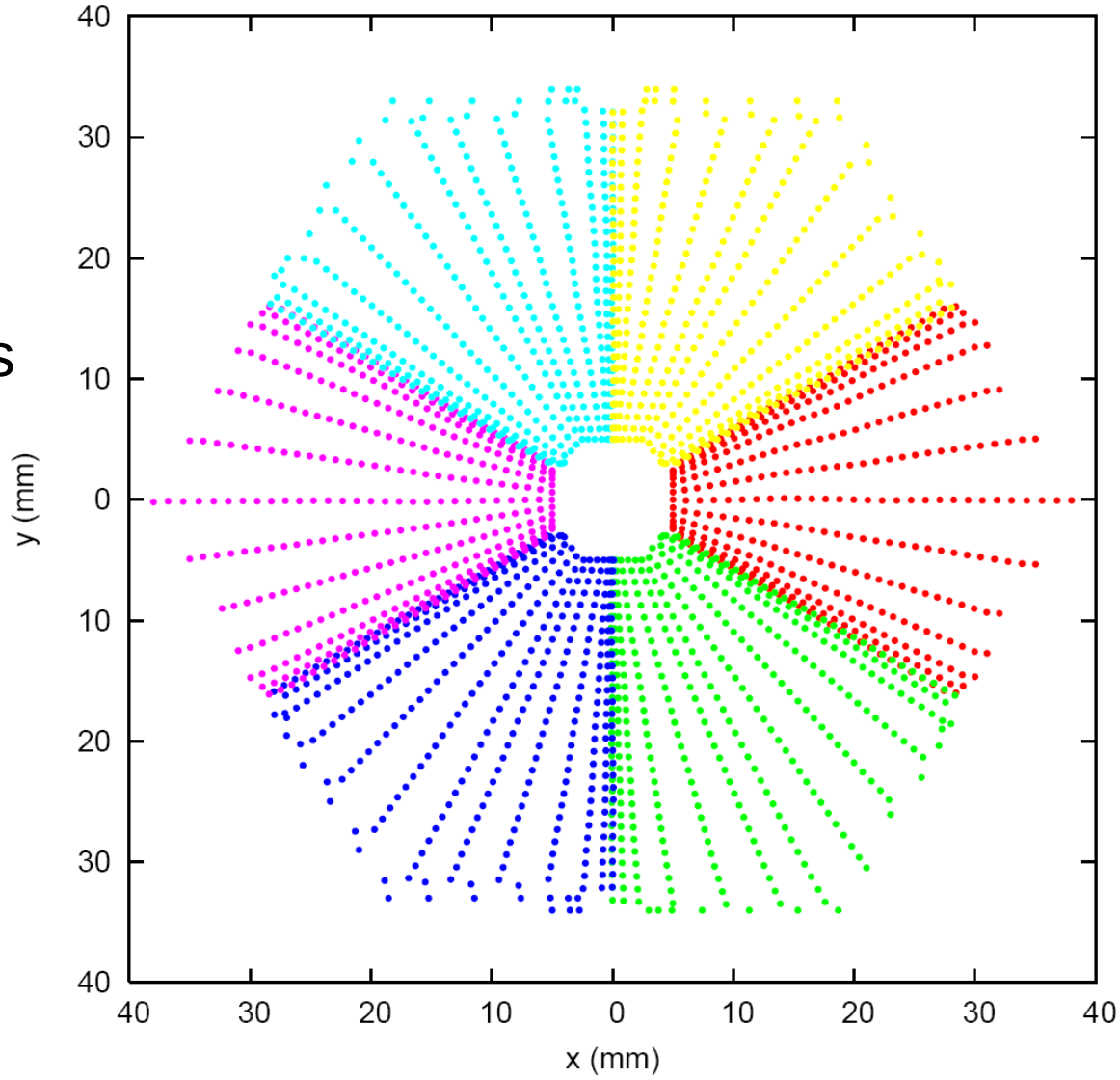
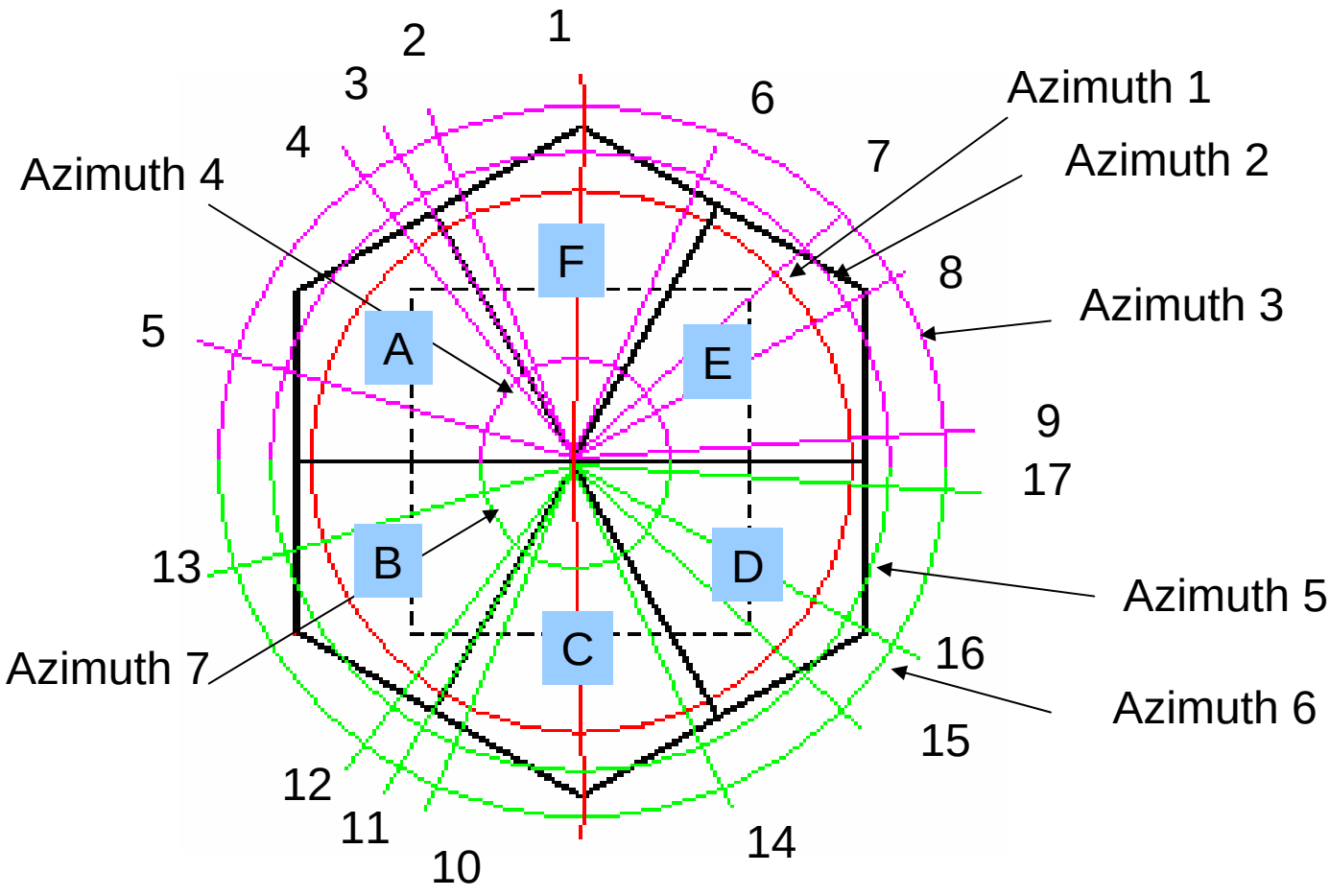
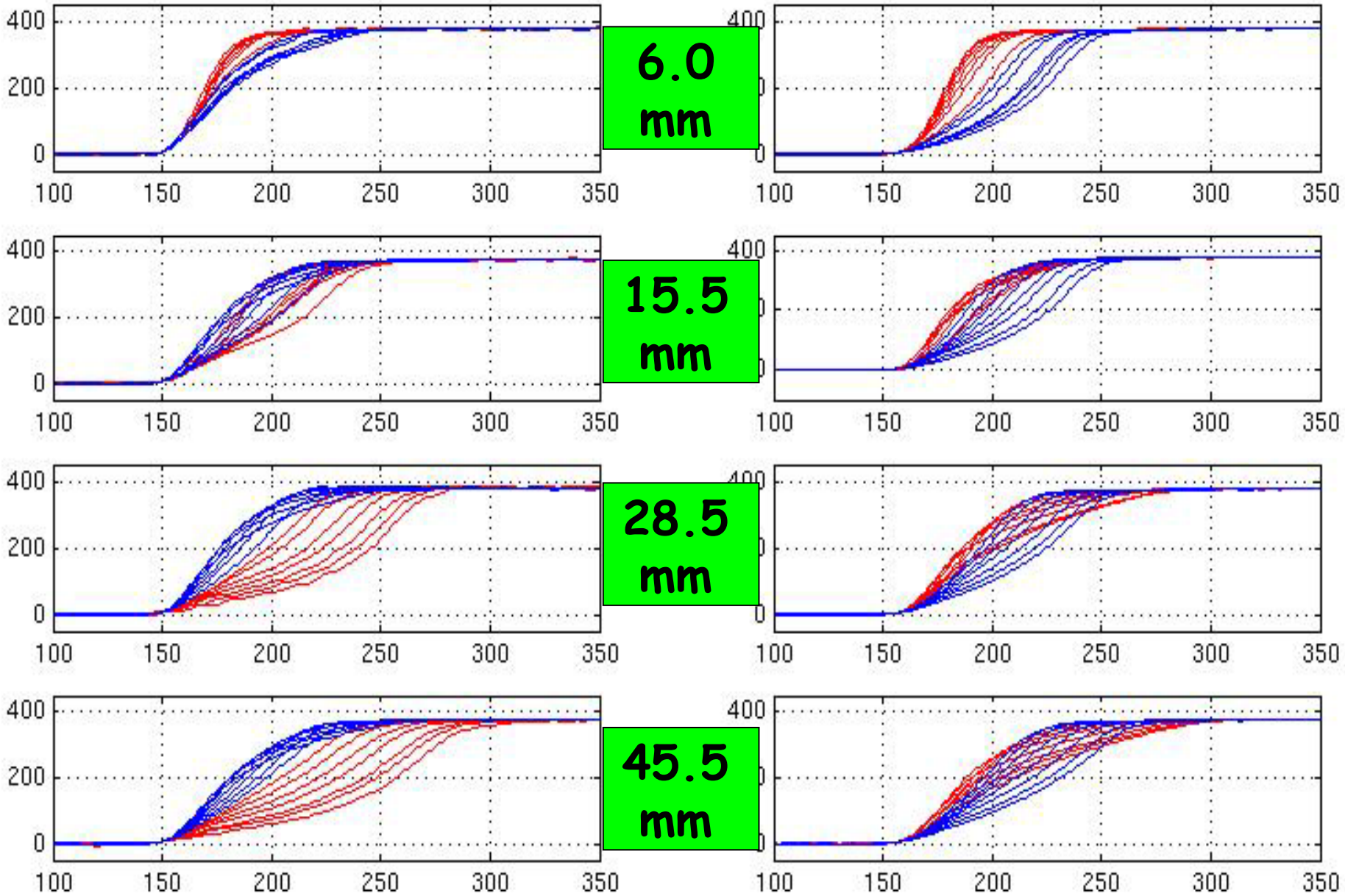


Coincidence scan: plan

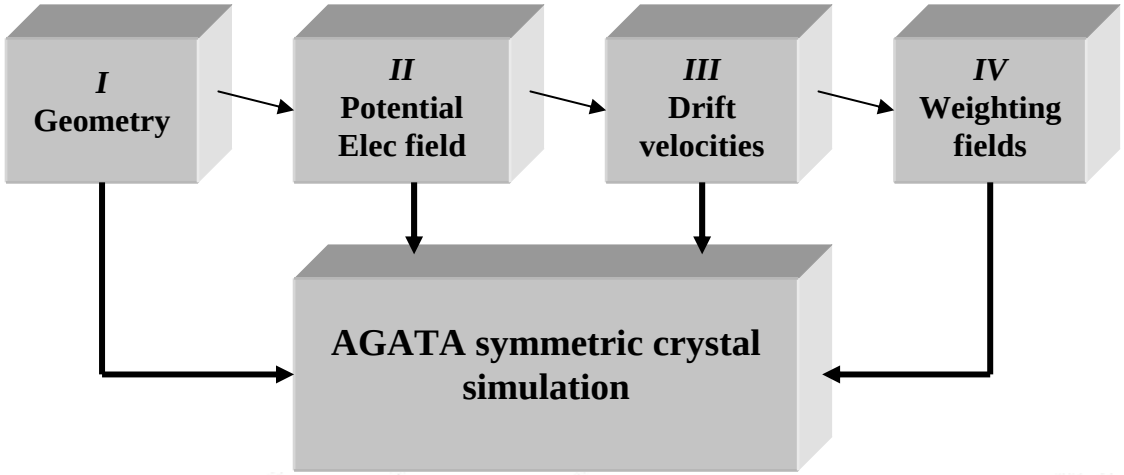


Segment pulses

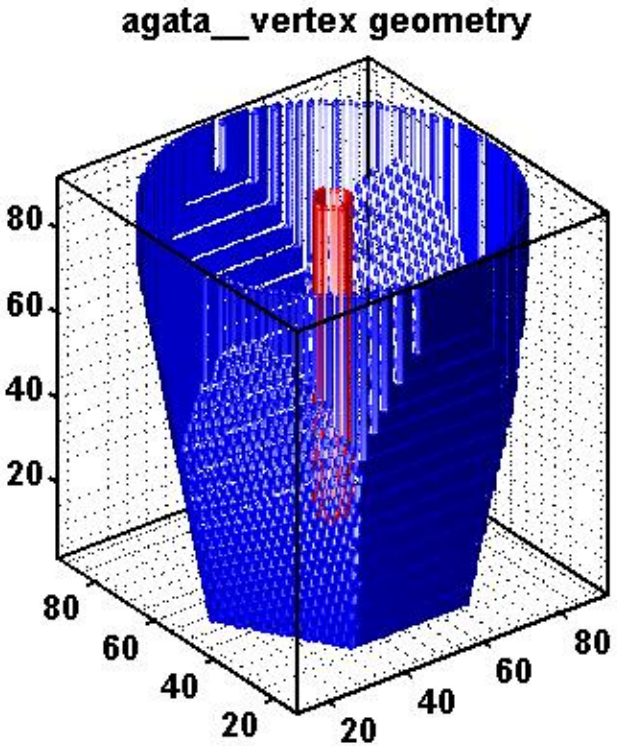
Centre contact pulses

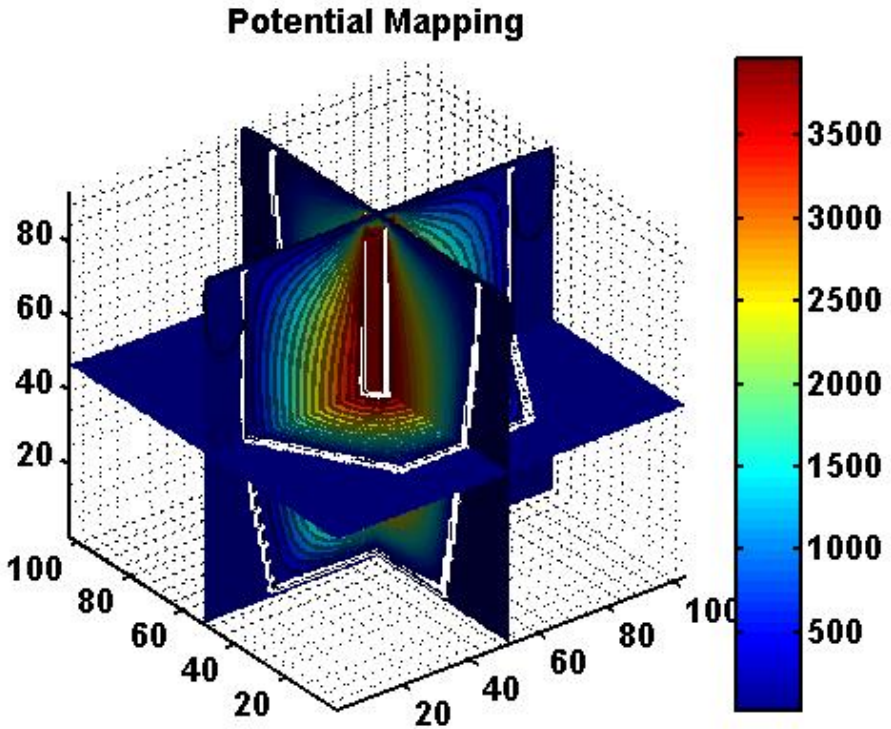


Electric Field Simulations : MGS

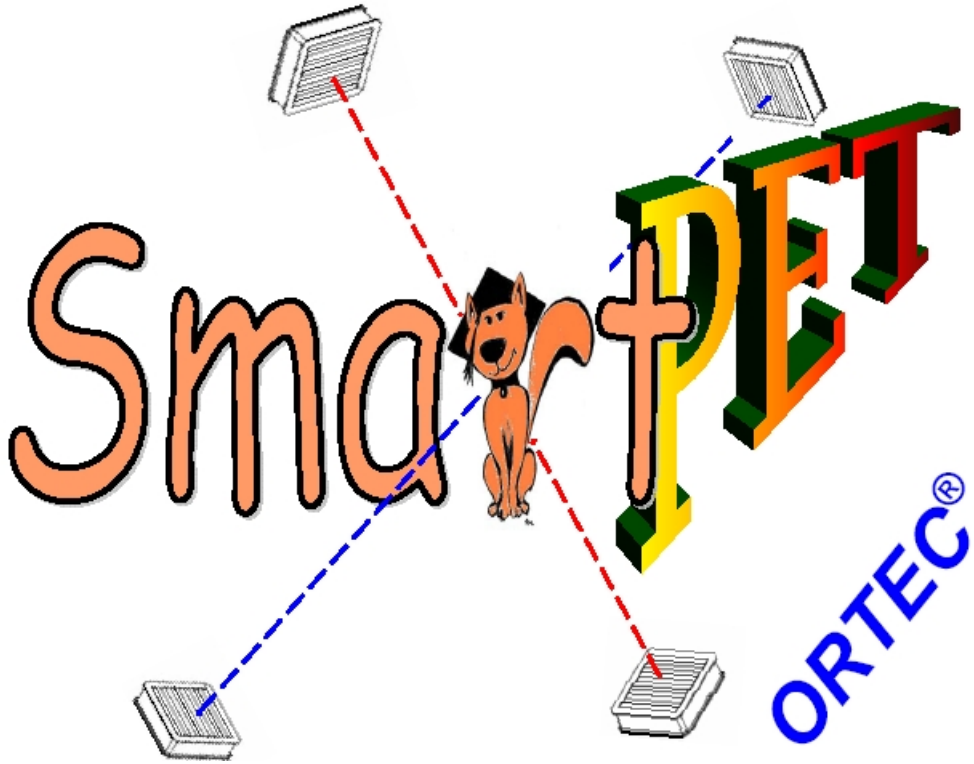


- Electric field simulations have been performed and details comparisons have been made with experimental pulse shape data.





The SmartPET Project



THE UNIVERSITY of LIVERPOOL

CCLRC

MONASH University

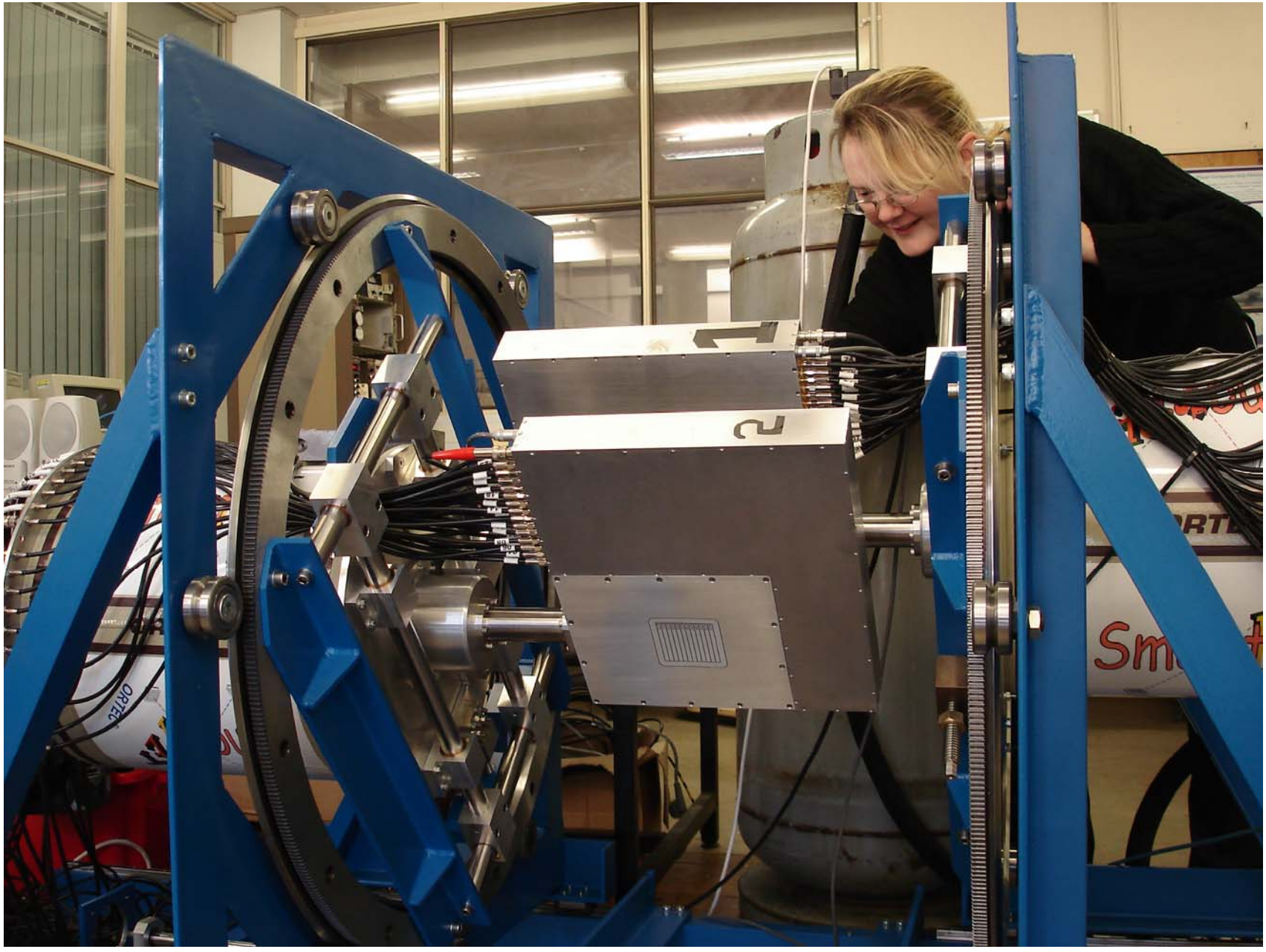
Andy Boston
ajboston@liv.ac.uk

EPSRC

MRC Medical Research Council

Digital Spectroscopy and Imaging

SmartPET December 2005



SmartPET detector depth response

"superpulse" pulse shapes for ^{137}Cs events versus depth

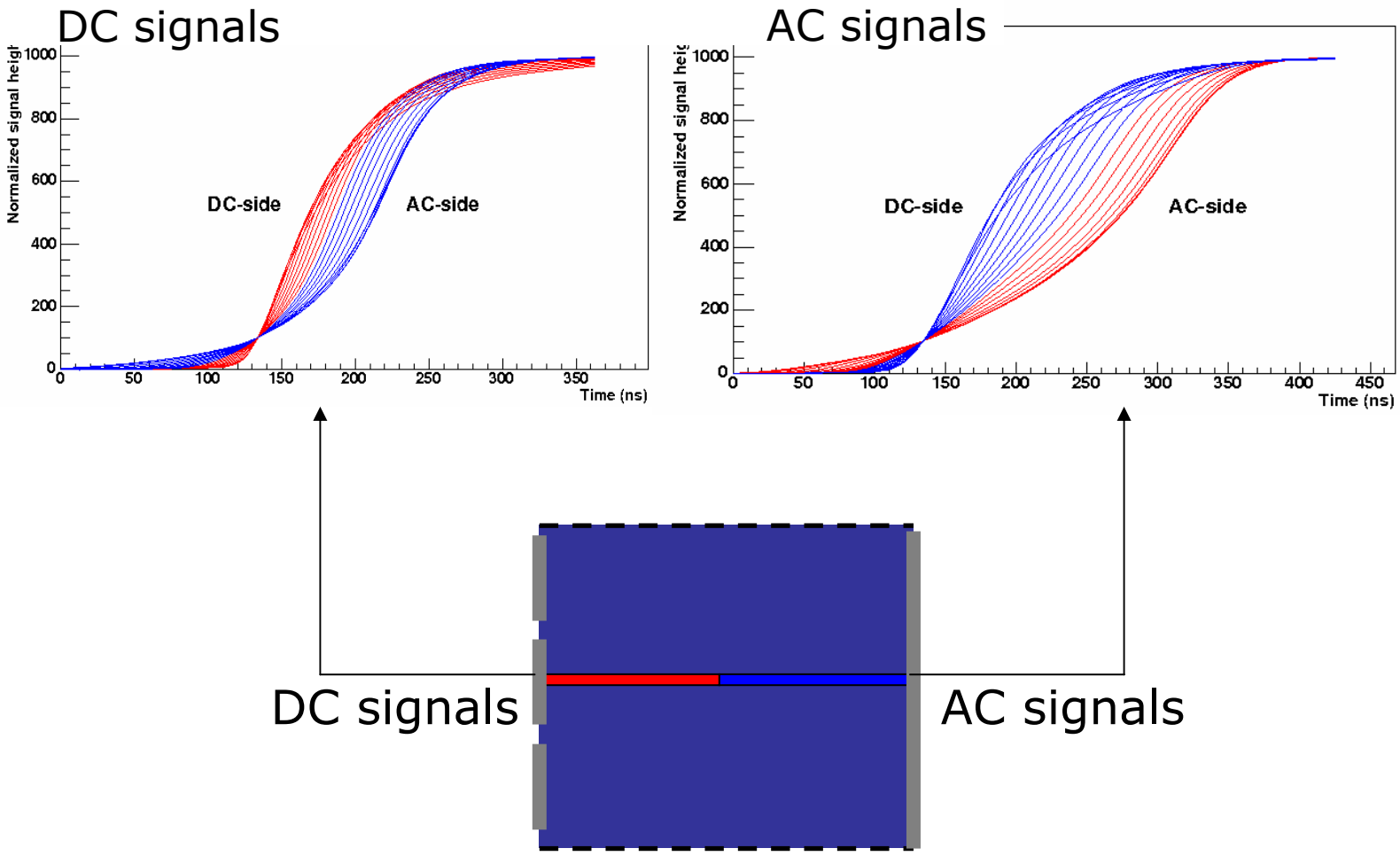


Image Charge Response

Image charge asymmetry varies as a function of lateral interaction position

- Calibration of asymmetry response

$$Asymmetry = \frac{Area_{left} - Area_{right}}{Area_{left} + Area_{right}}$$

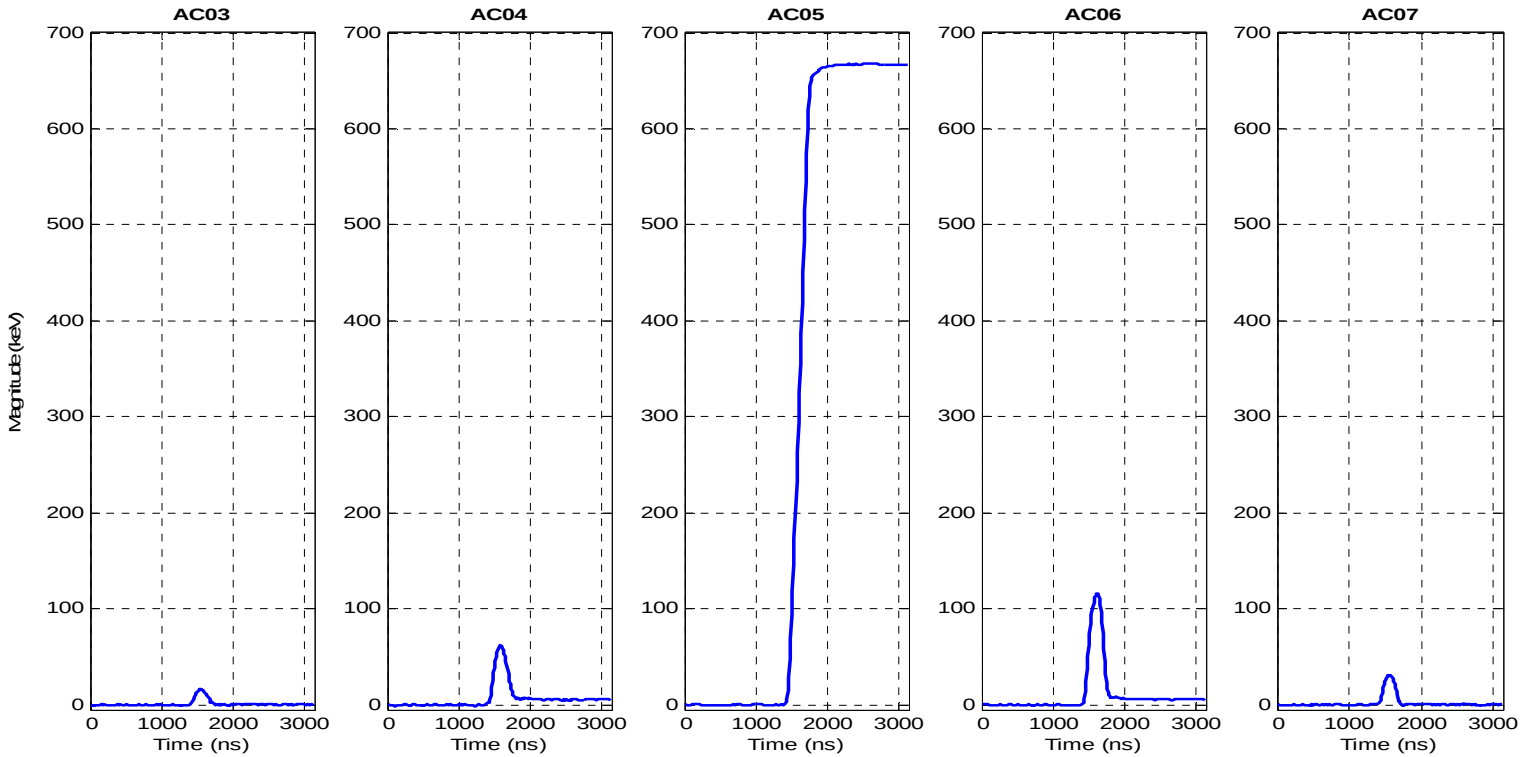
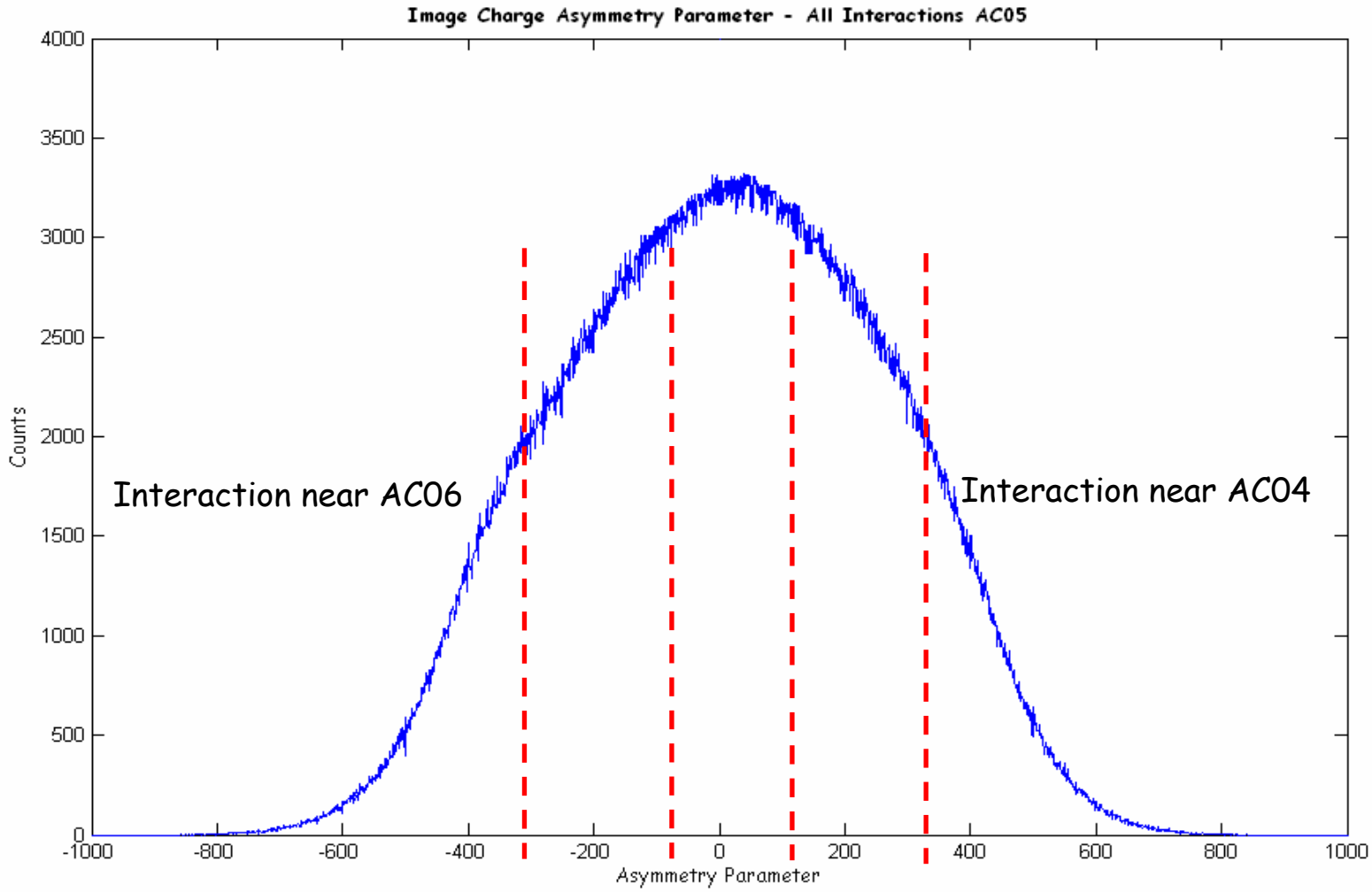


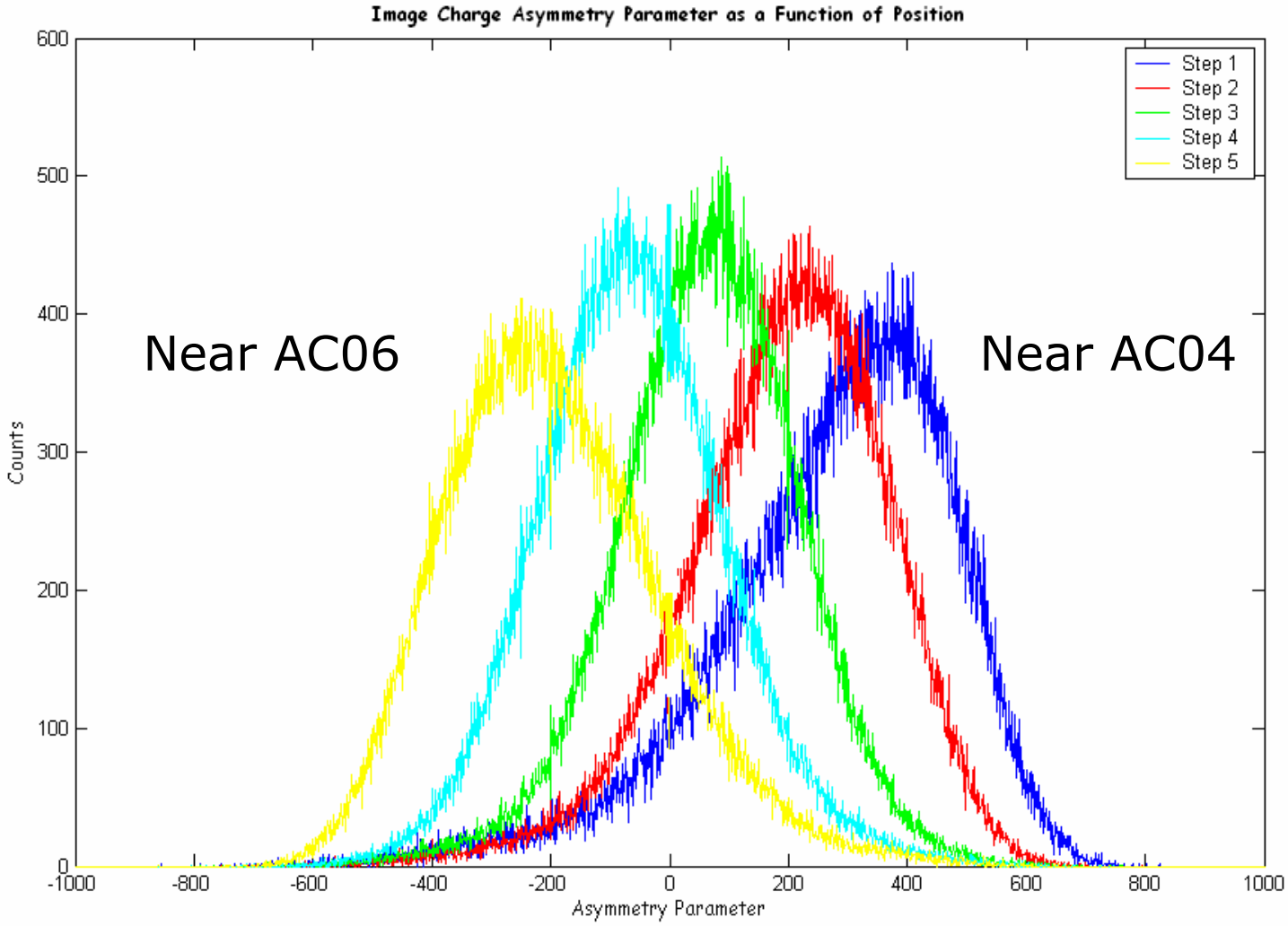
Image Charge Analysis



One approach to applying simple PSA is to split this distribution equally into five regions

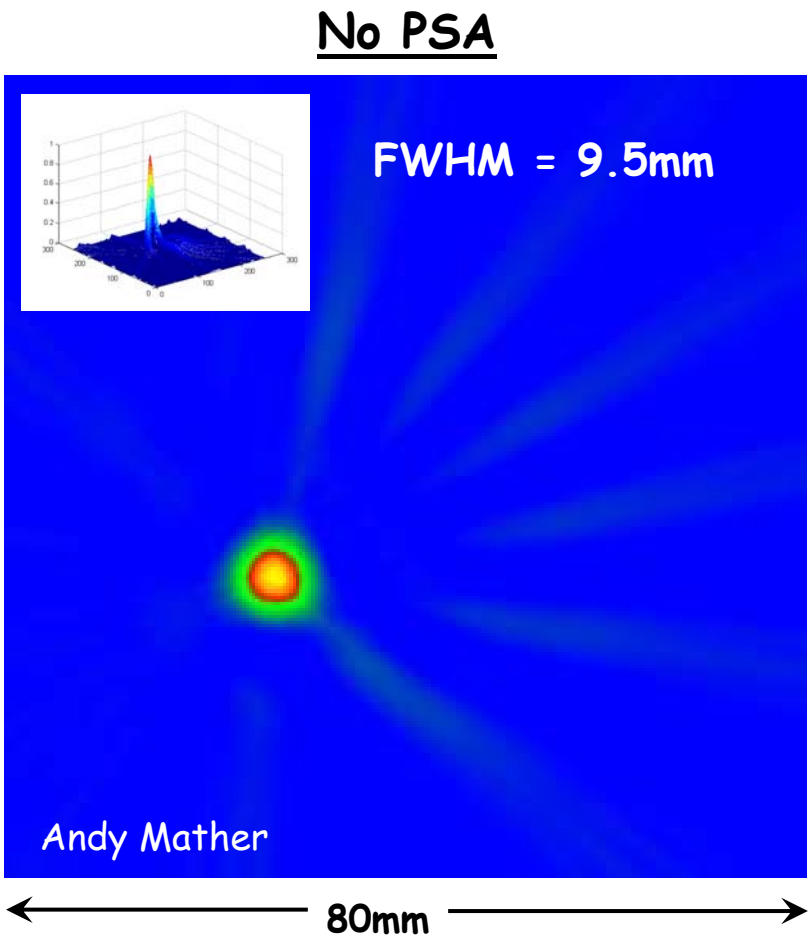
Image Charge Analysis

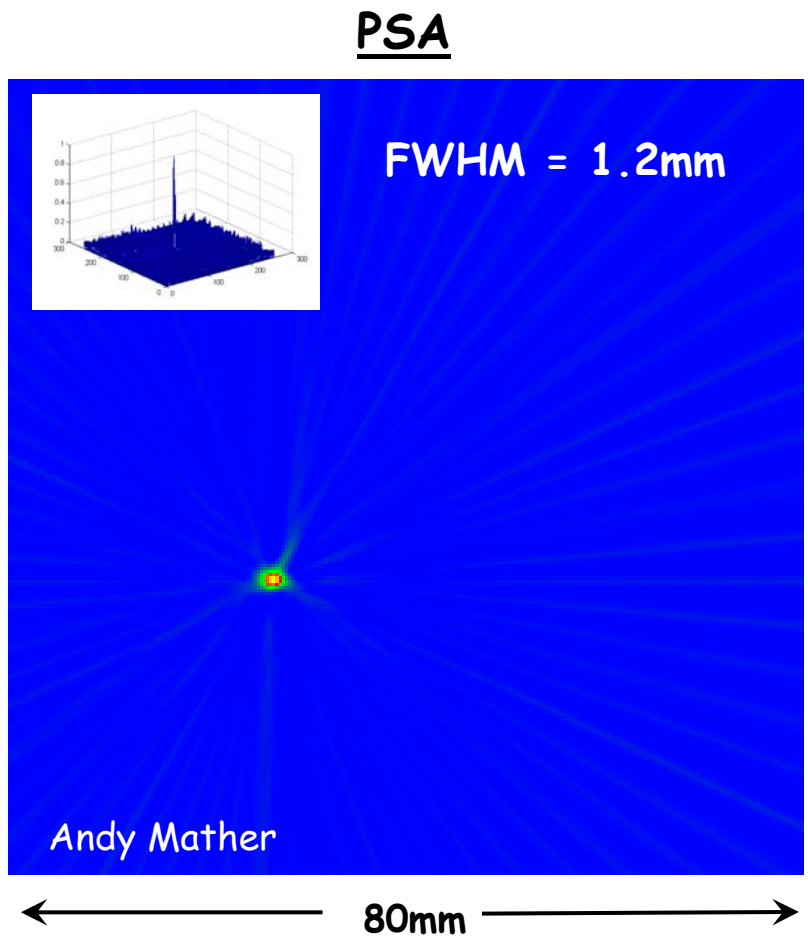
Asymmetry distribution as a function of scan (collimator) position (AC05)



Reconstructed Images

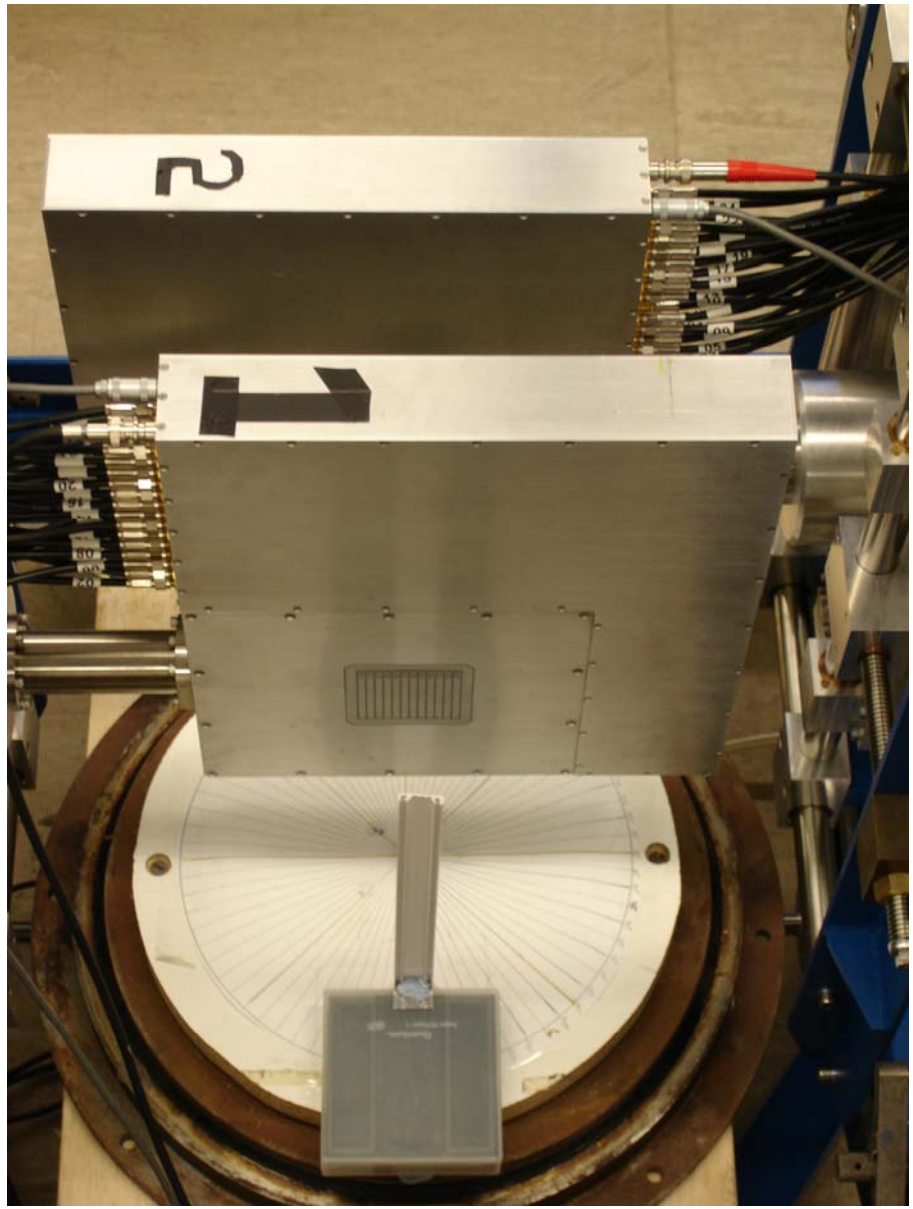
- Simple PSA techniques applied event-by-event
- Filtered Back Projection – ^{22}Na source



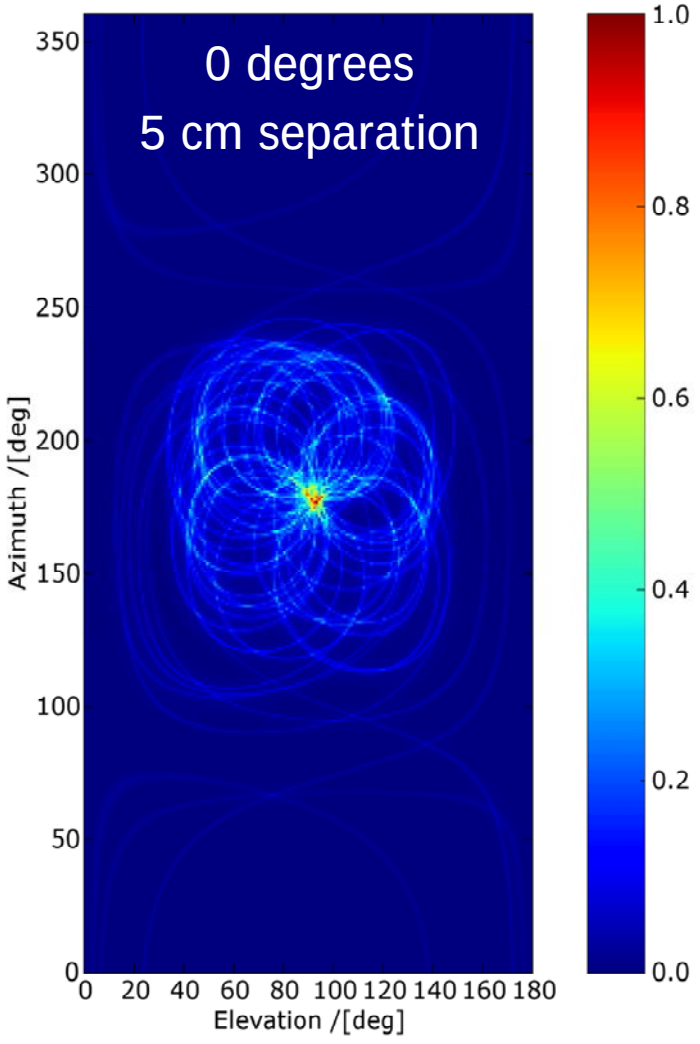


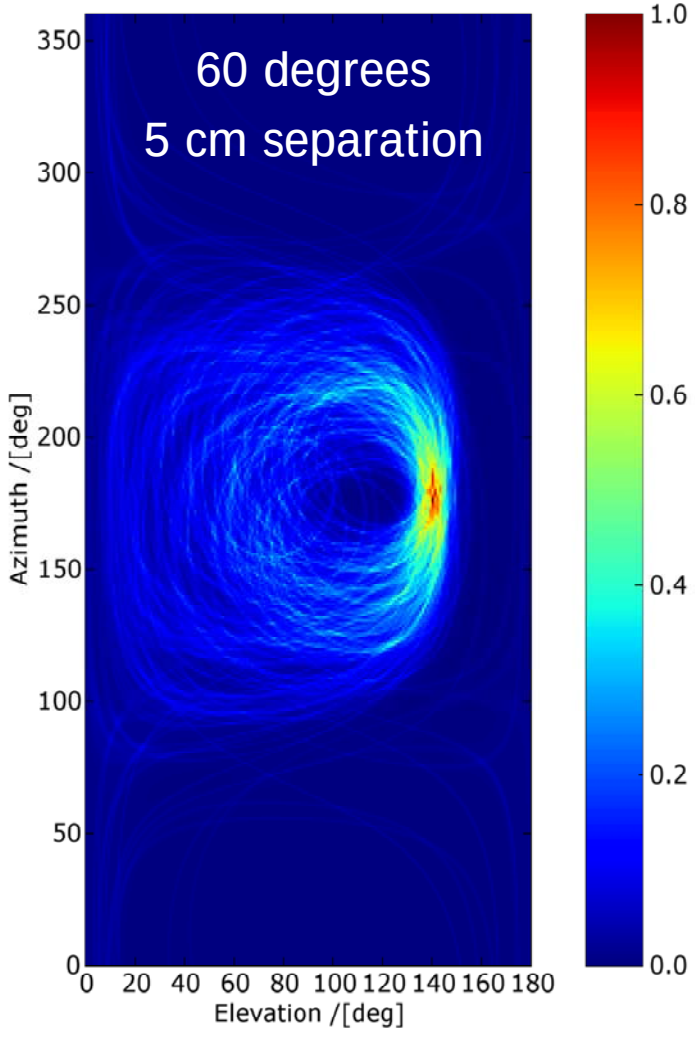
Compton Camera

- 10μCi ^{152}Eu
- 60mm from SPET1
- Source rotated
- Zero degrees in 15º steps up to 60º
- Detector separation
- 3 – 11cm in 2cm steps
- Gates set on energies
- 779, 1408keV
- 2 ^{22}Na sources at different x and y



Analytical method





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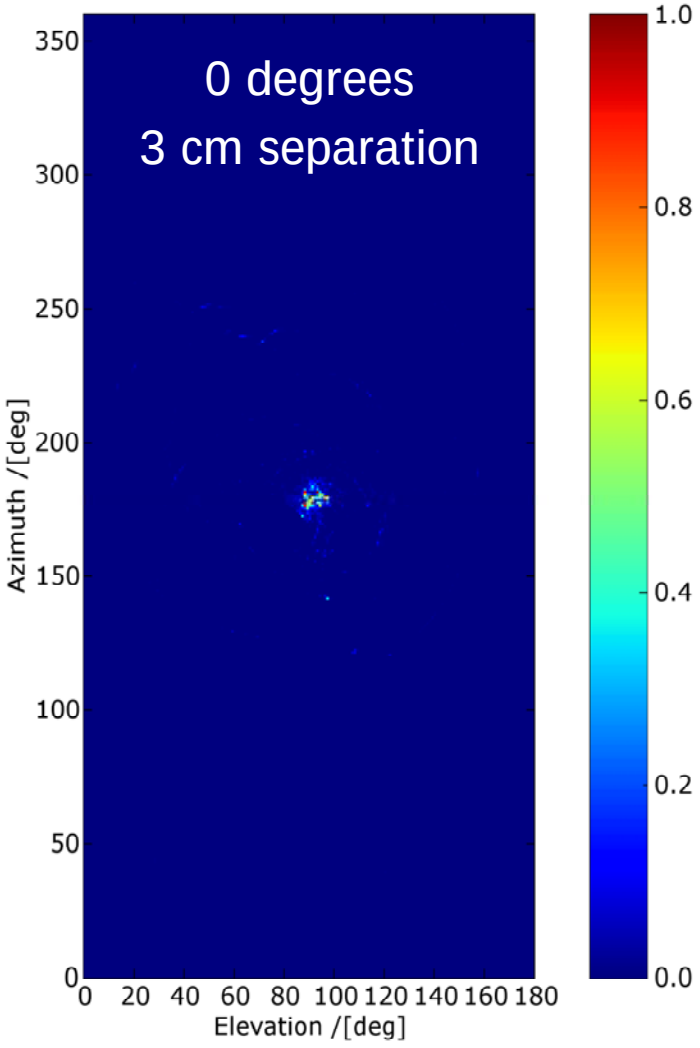
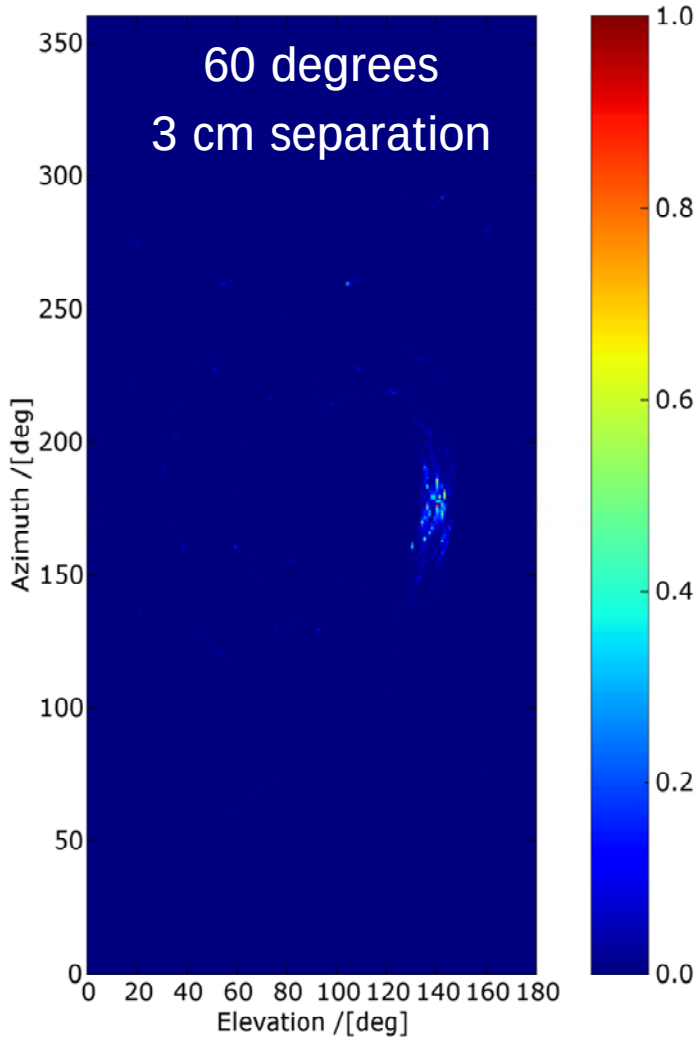
Iterative Method





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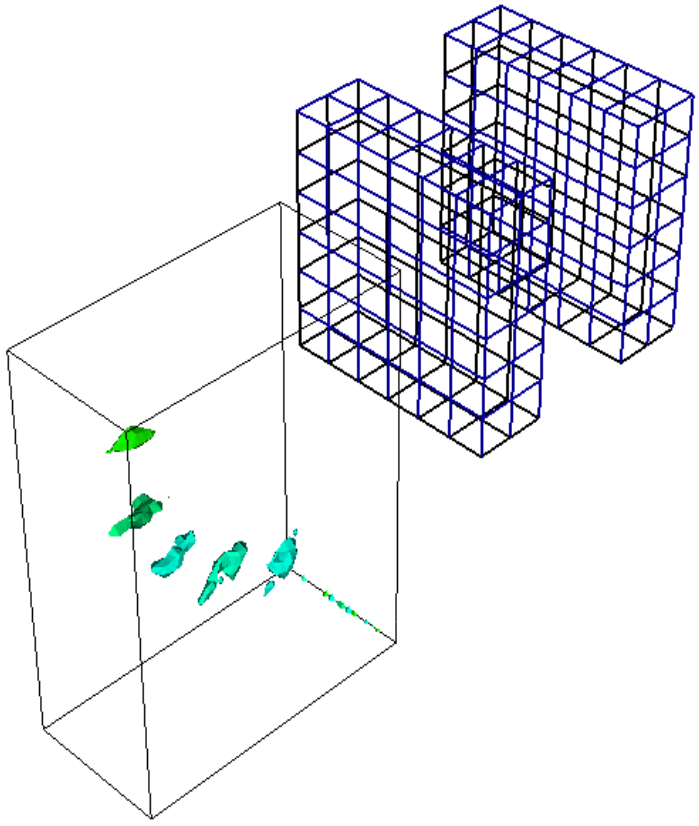
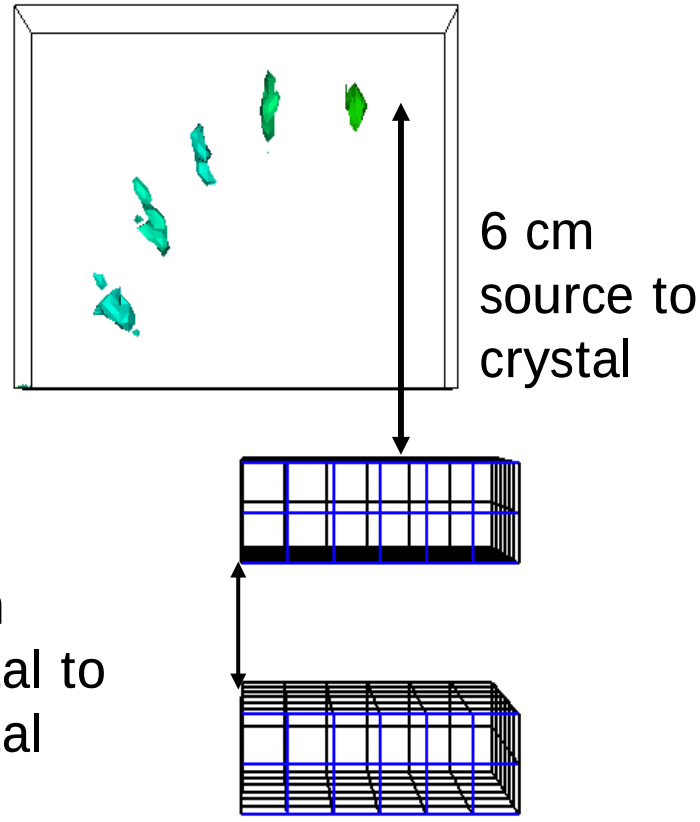
Compton Camera measurements (Ge/Ge)

E = 1408 keV





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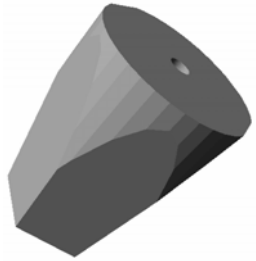
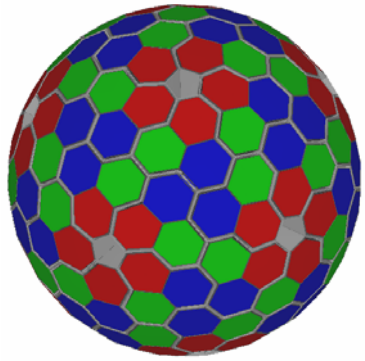
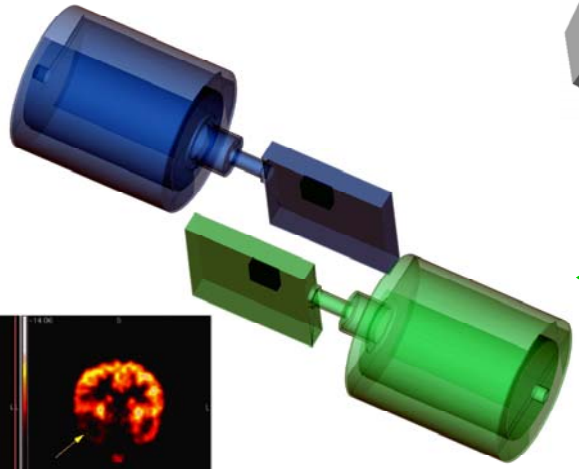
Digital Gamma-ray Spectroscopy & Imaging with Semiconductor detectors

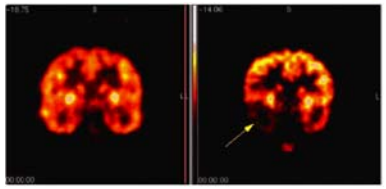
Frontiers of gamma-ray spectroscopy



AGATA
GRETA







And its applications

Dr Andy Boston
ajboston@liv.ac.uk

THE UNIVERSITY of LIVERPOOL