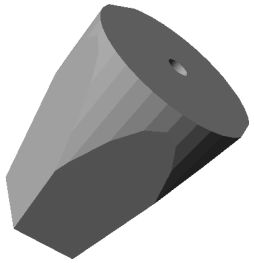
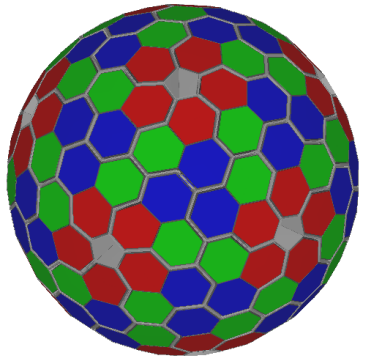
Digital Gamma-ray Spectroscopy

Frontiers of gamma-ray spectroscopy

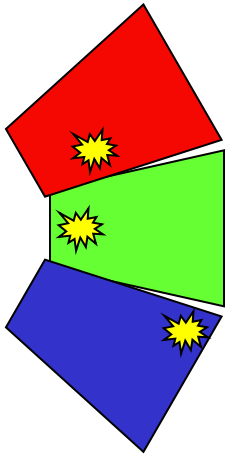


AGATA
GRETA

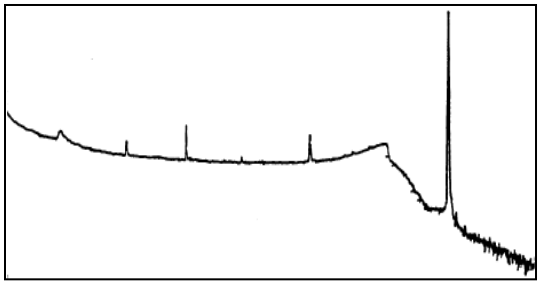


The AGATA Concept

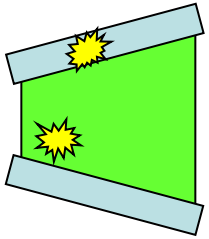
Without Compton suppression shields



Compton continuum. => Large peak to total ratio

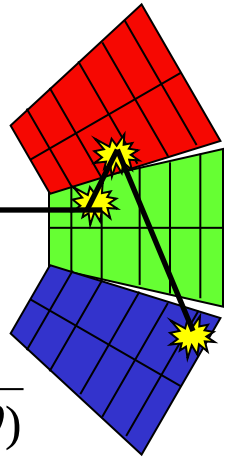


With BGO shielding



Less solid angle coverage => Big drop in efficiency

With highly segmented detectors



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

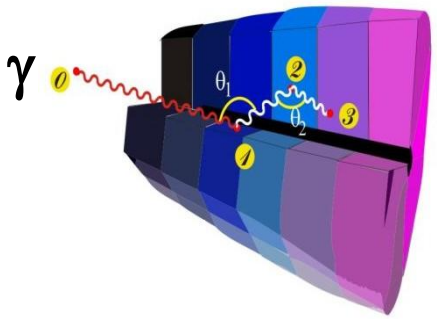
Path of γ-ray reconstructed to form full energy event
=> Compton continuum reduced
=> Excellent efficiency ~50% @1MeV
=> Greatly improved angular resolution (~1^0) to reduce Doppler effects

Ingredients of Gamma-Tracking

AGATA
ADVANCED GAMMA TRACKING ARRAY

1

Highly segmented HPGe detectors



2

Digital electronics to record and process segment signals

3

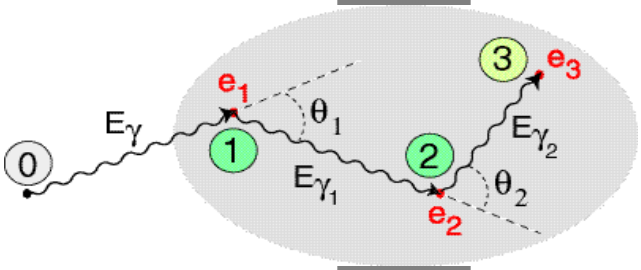
Pulse Shape Analysis to decompose recorded waves

4

Identified interaction

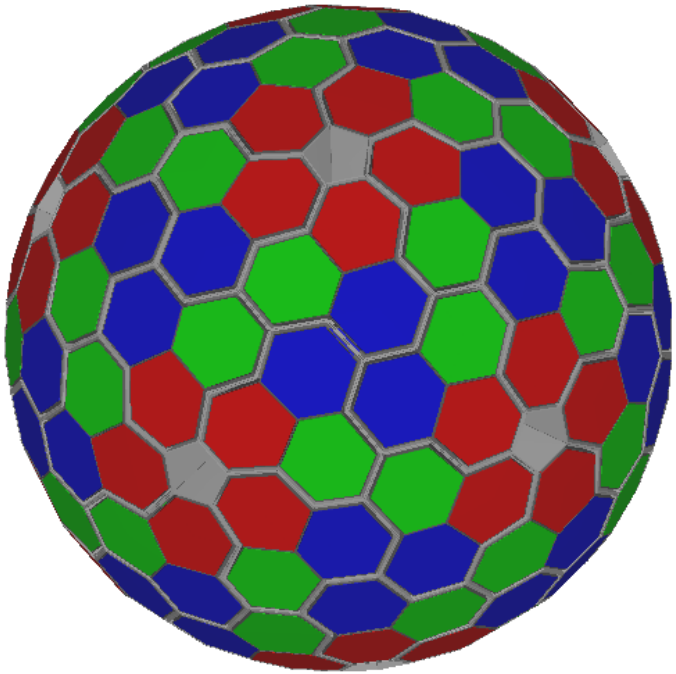
$(x,y,z,E,t)_i$

Reconstruction of tracks e.g. by evaluation of permutations of interaction points

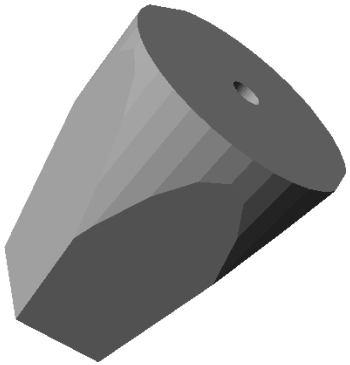


reconstructed γ-rays

AGATA : The configuration



Ge crystals size:
length 90 mm
diameter 80 mm

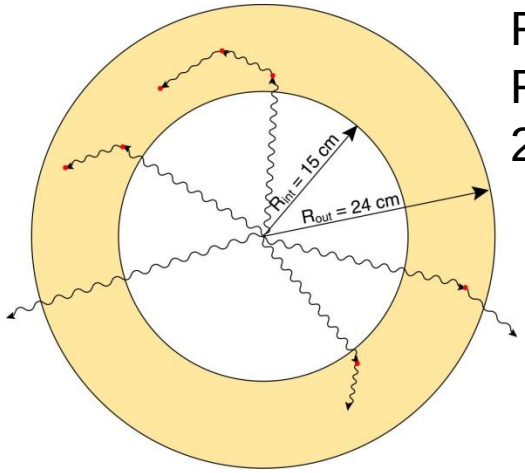


180 hexagonal crystals 3 shapes
60 triple-clusters all equal
Inner radius (Ge) 22 cm
Amount of germanium 310 kg
Solid angle coverage 80 %
Singles rate ~50 kHz
6480 segments

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

The "Standard" Germanium Shell

Idealized configuration to determine maximum attainable performance



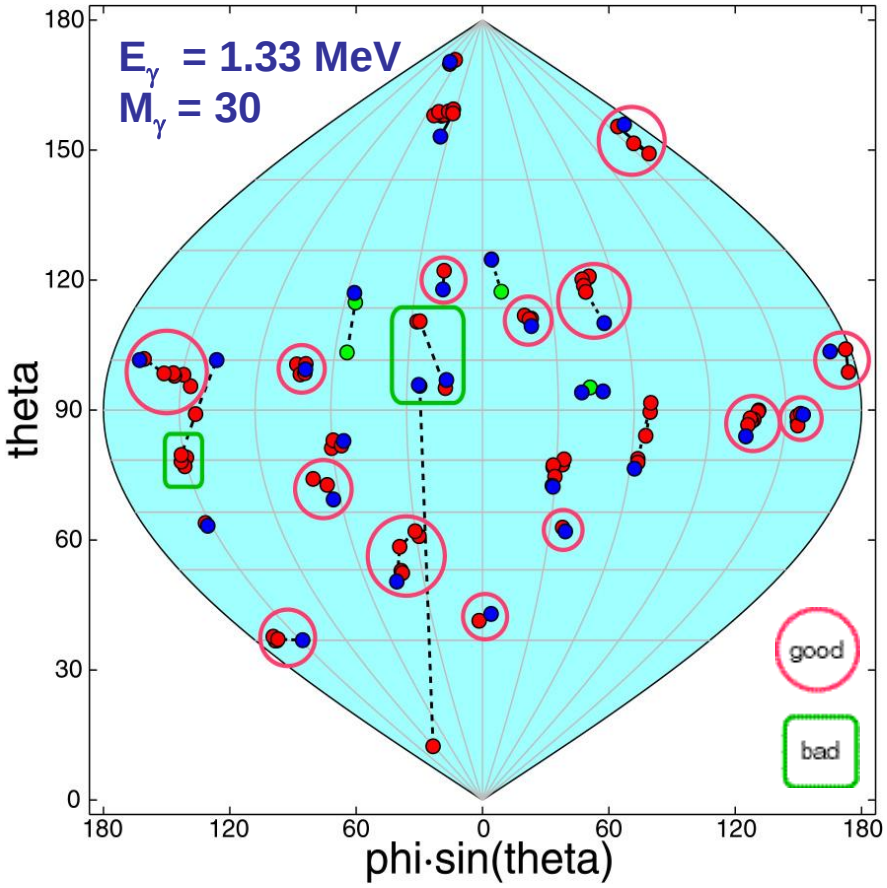
R_i = 15 cm
R_o = 24 cm
230 kg of Ge

M_γ= 1 → ε_{ph} = 65%
P/T = 85%

M_γ= 30 → ε_{ph} = 36%
P/T = 60%

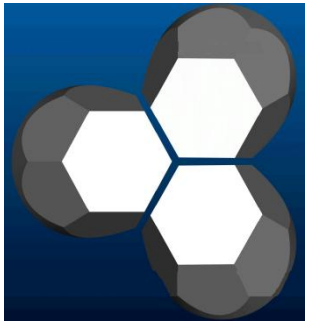
Assuming 5 mm Position Resolution

A high multiplicity event

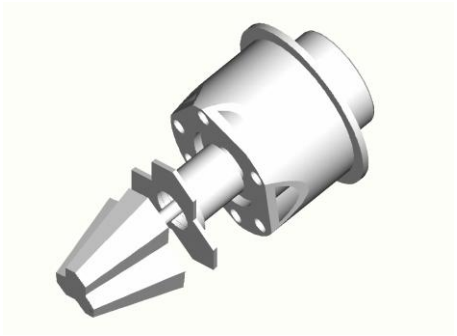


27 gammas detected -- 23 in photopeak
16 reconstructed -- 14 in photopeak

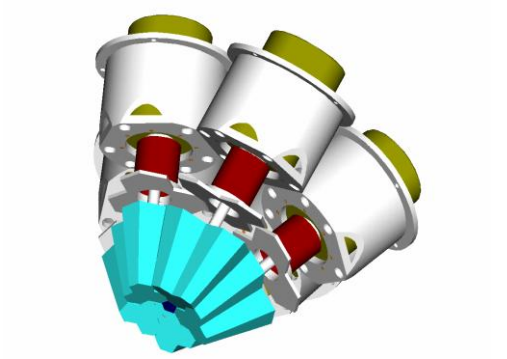
AGATA Design



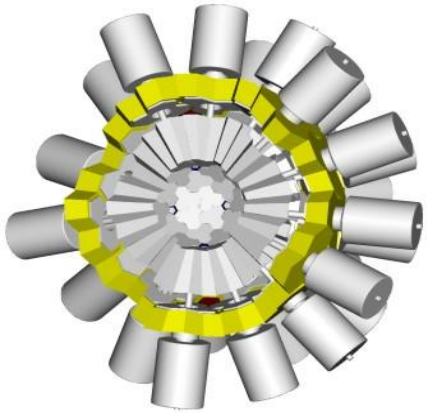
3 different asymmetric hexagonal shapes are used



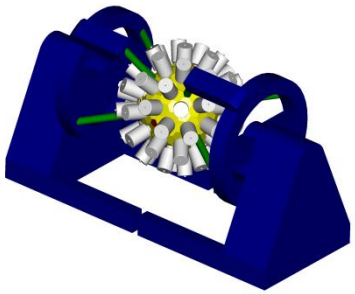
Triple cluster modular units in a single cryostat



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

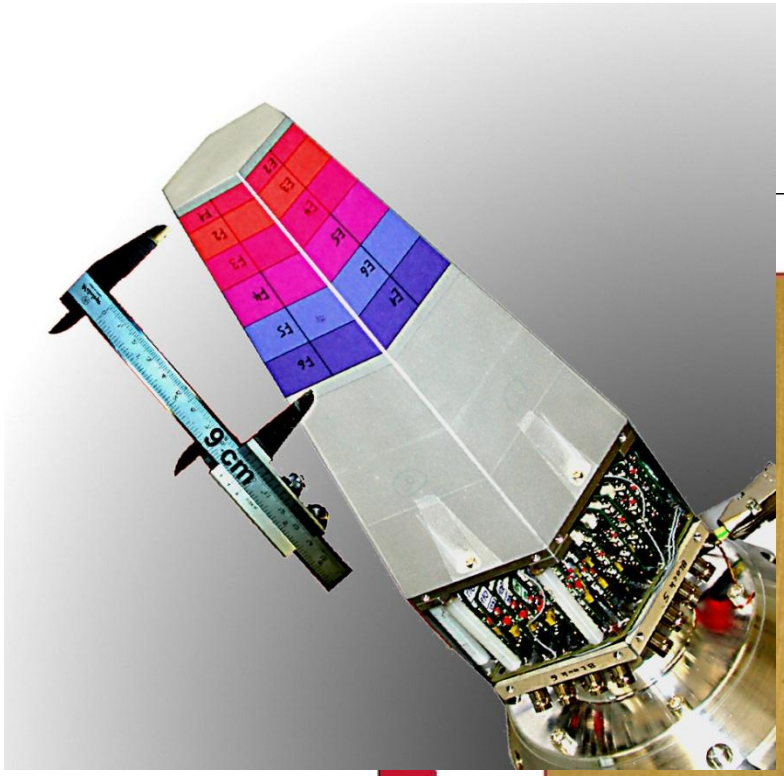


2π of complete d array

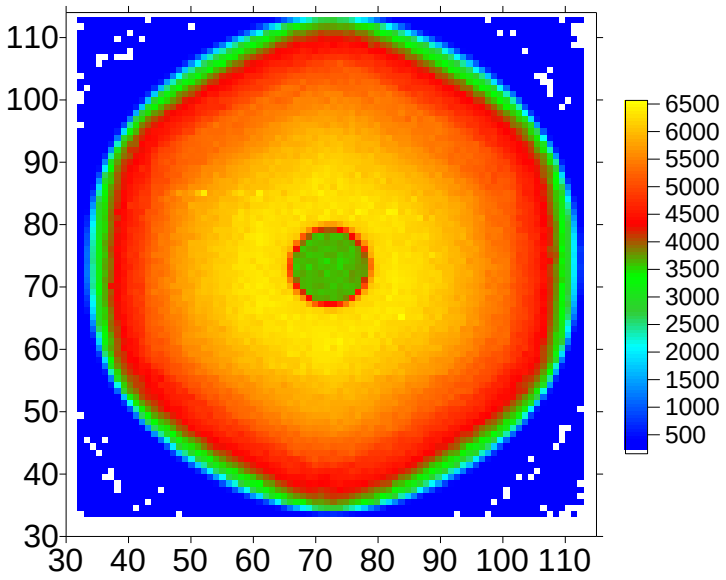


Completed array (6480 segments) with support structure

AGATA 1st symmetric cluster



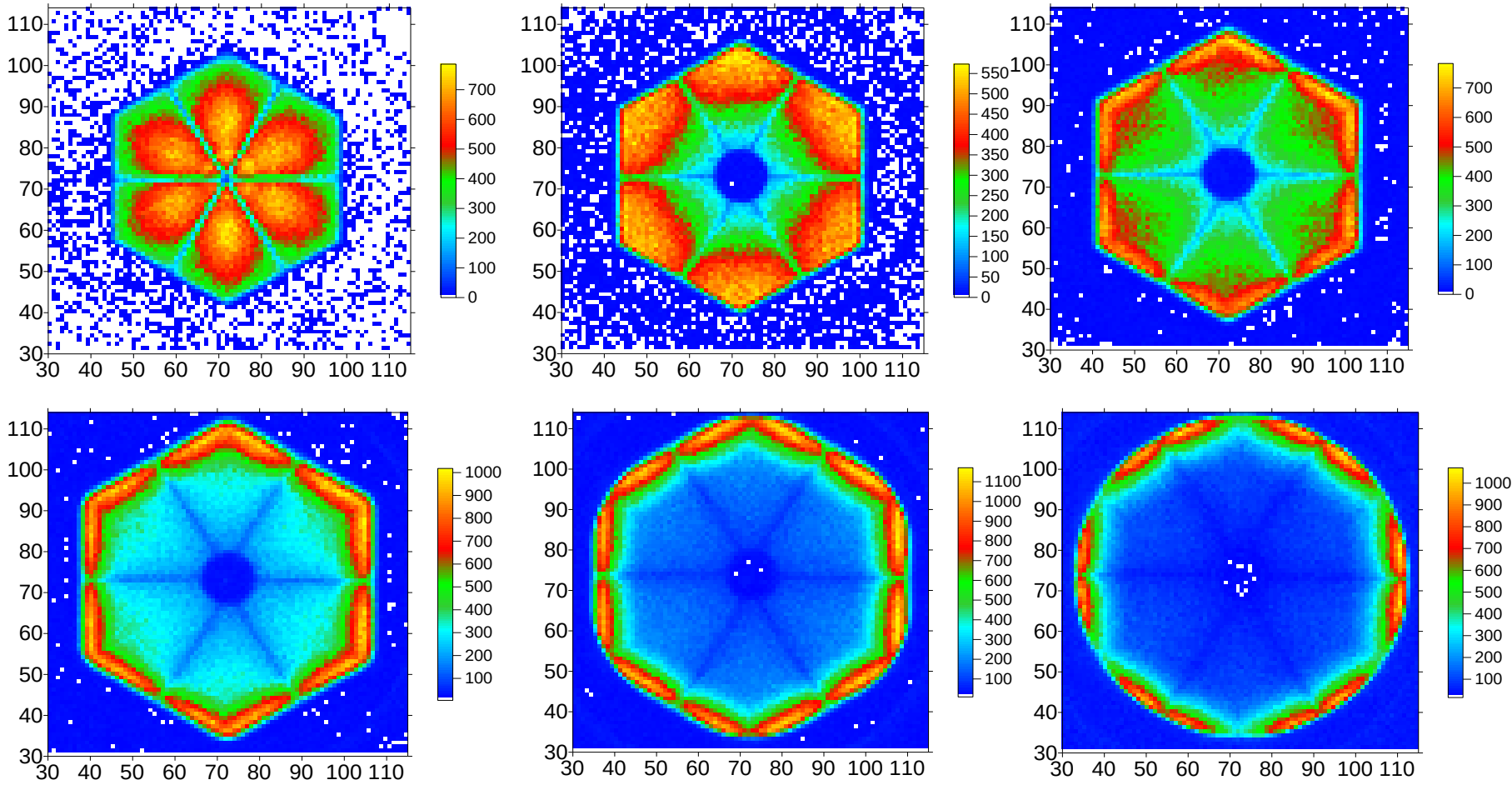
Cs-137 Singles Fine scan



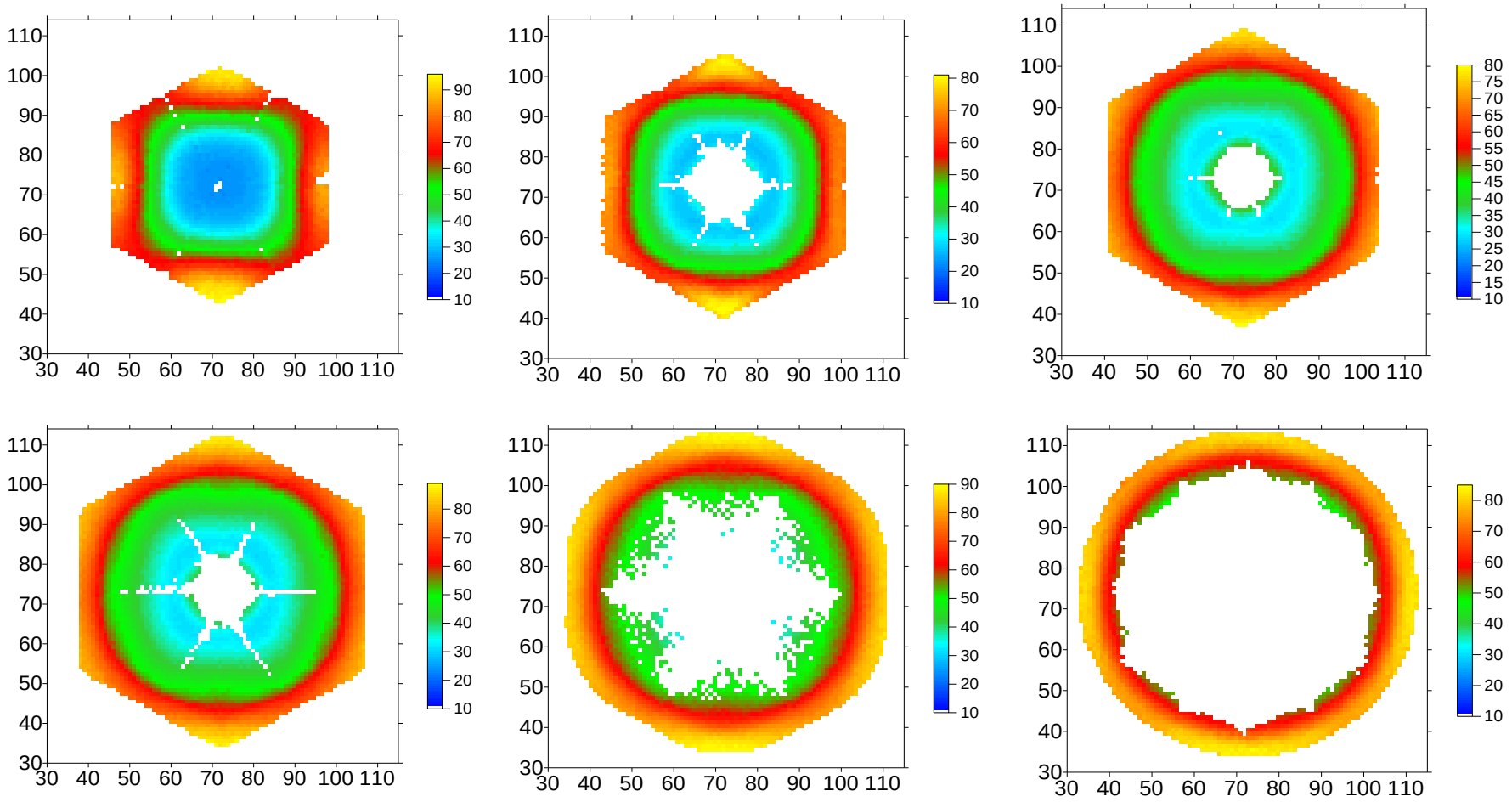
- 920MBq Cs-137 source
- 60 sec per position
- 1mm steps
- 1mm diameter collimator

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

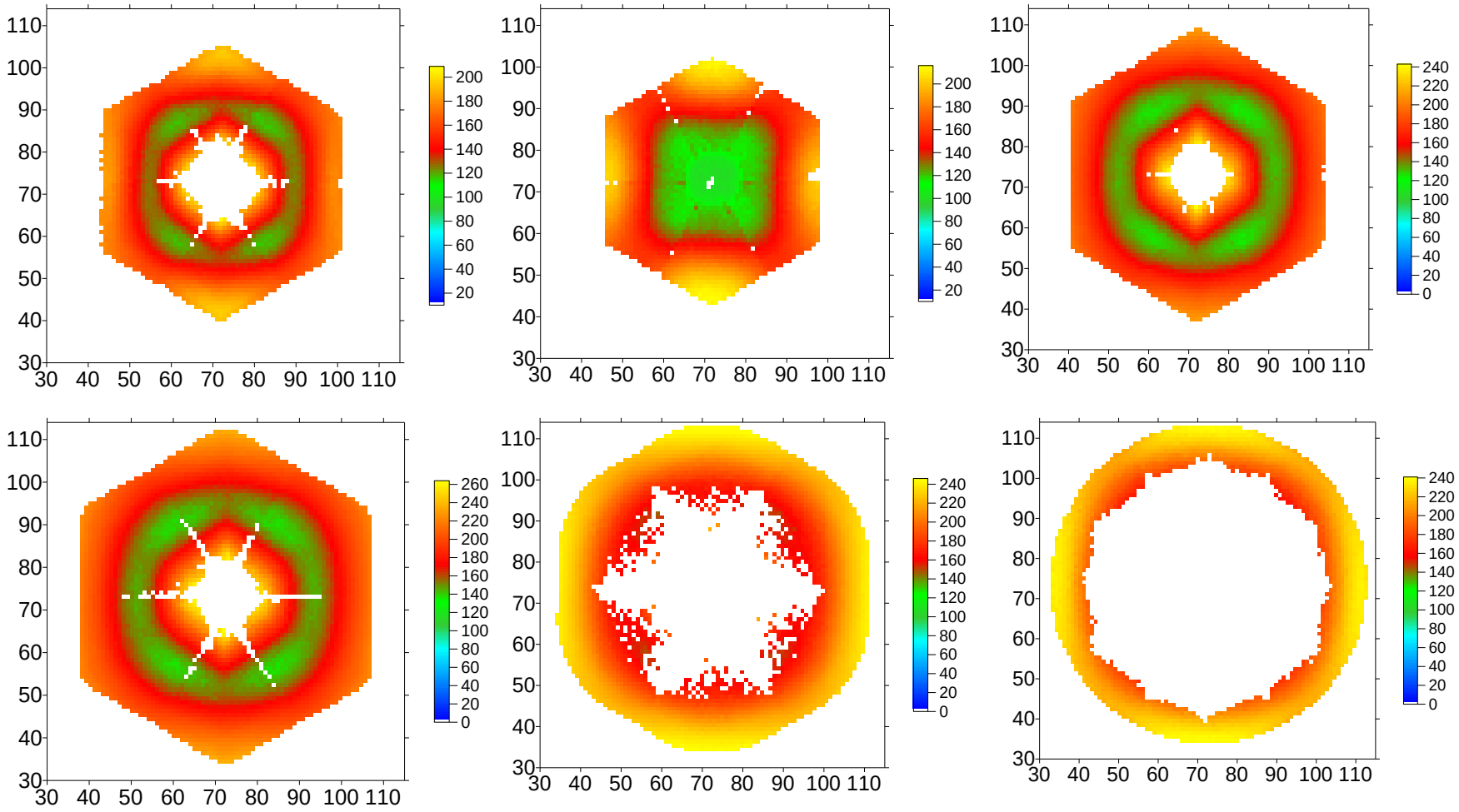
Core 662keV – Ring gated



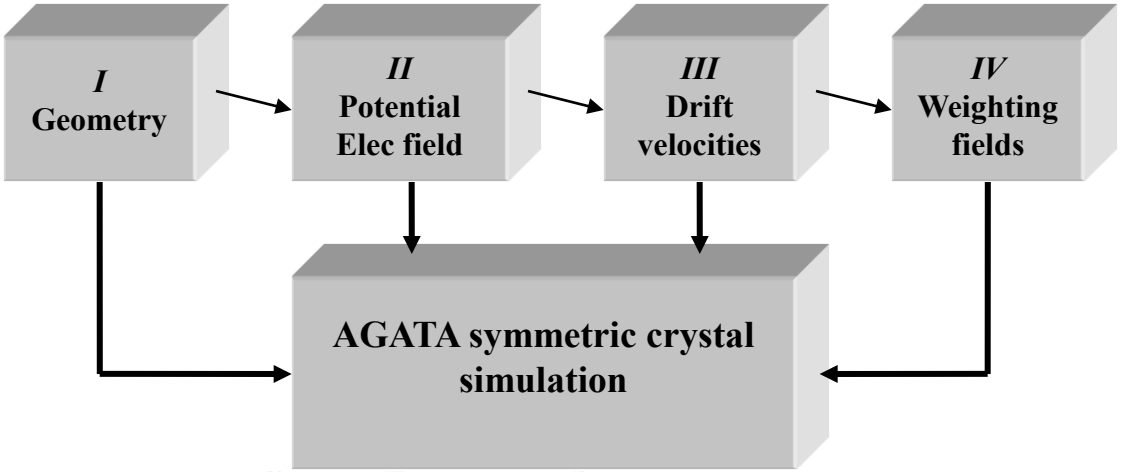
Core 662keV & Fold 1, Core T30



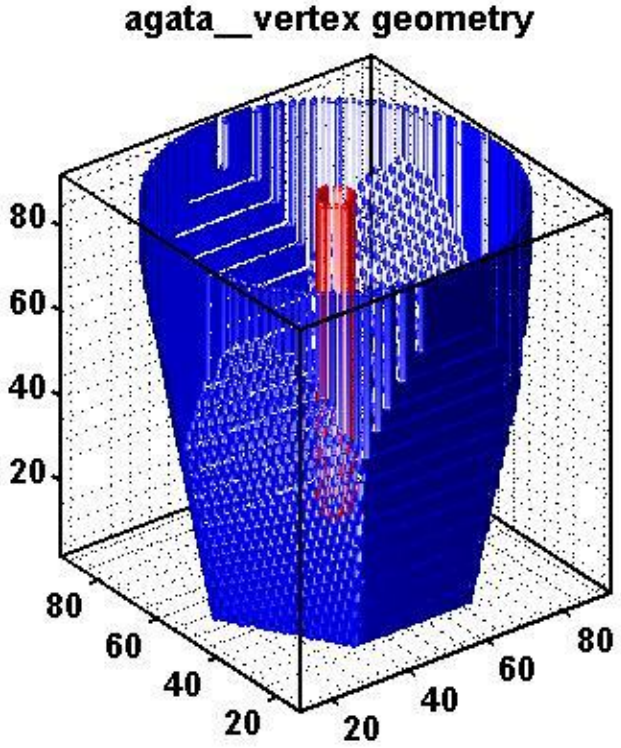
Core 662keV & Fold 1, Core T90

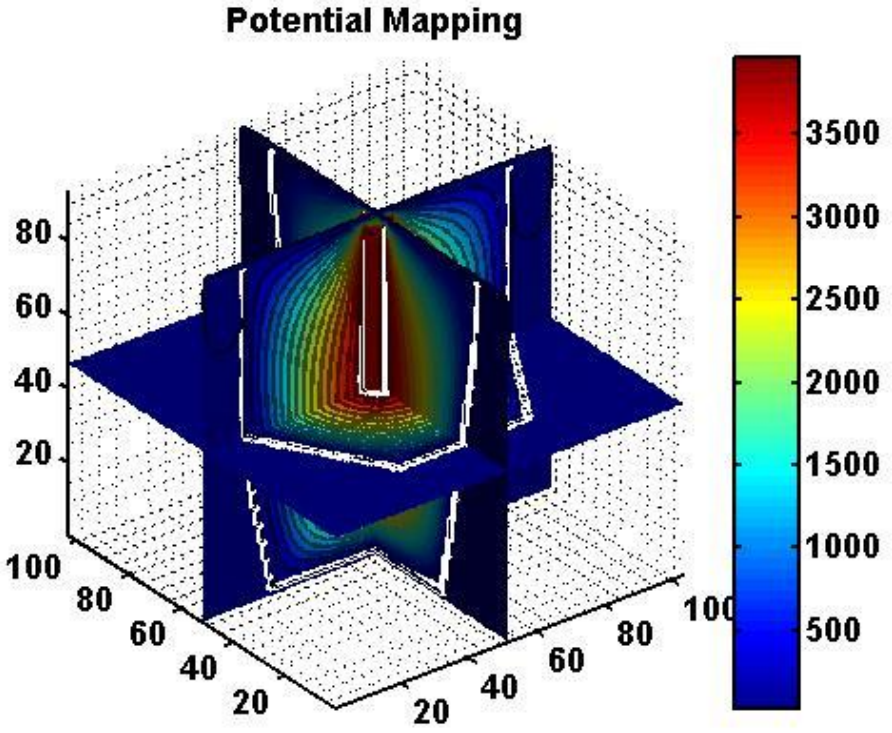


Electric Field Simulations : MGS

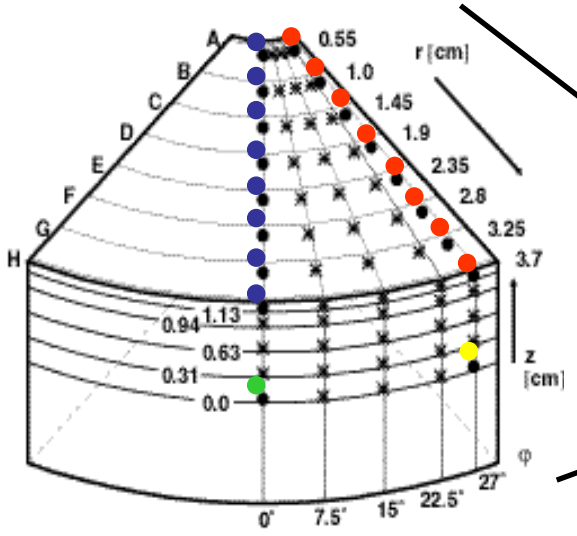


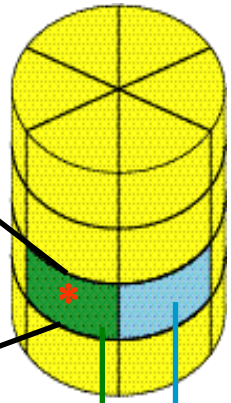
- Electric field simulations have been performed and details comparisons have been made with experimental pulse shape data.





Calculation of pulse shapes

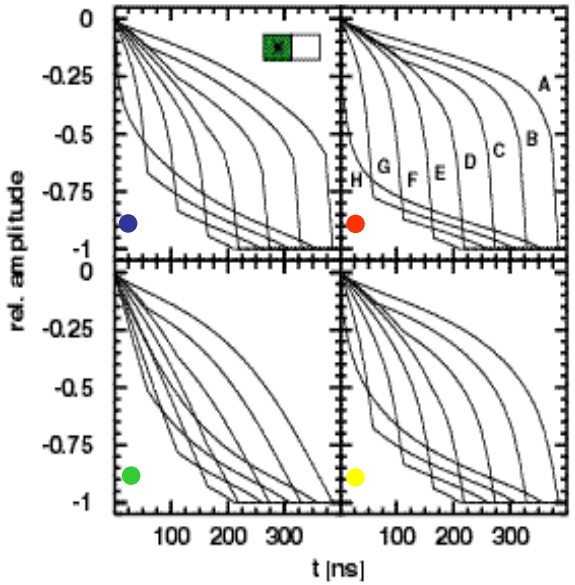


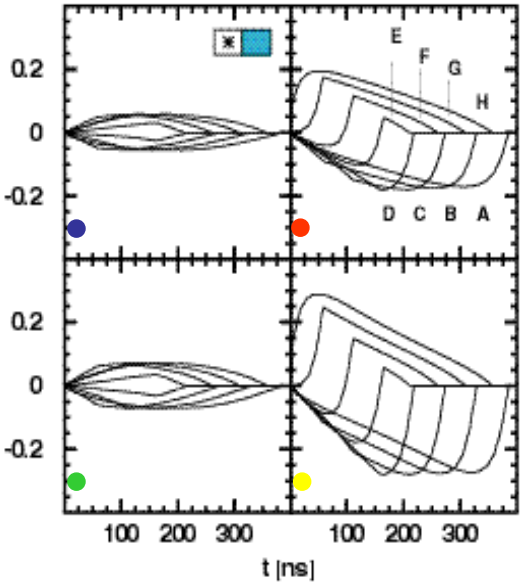


$$i_{e/h} = -q_{e/h} \cdot \bar{E}_W \cdot \bar{v}_{drift}(\bar{E})$$

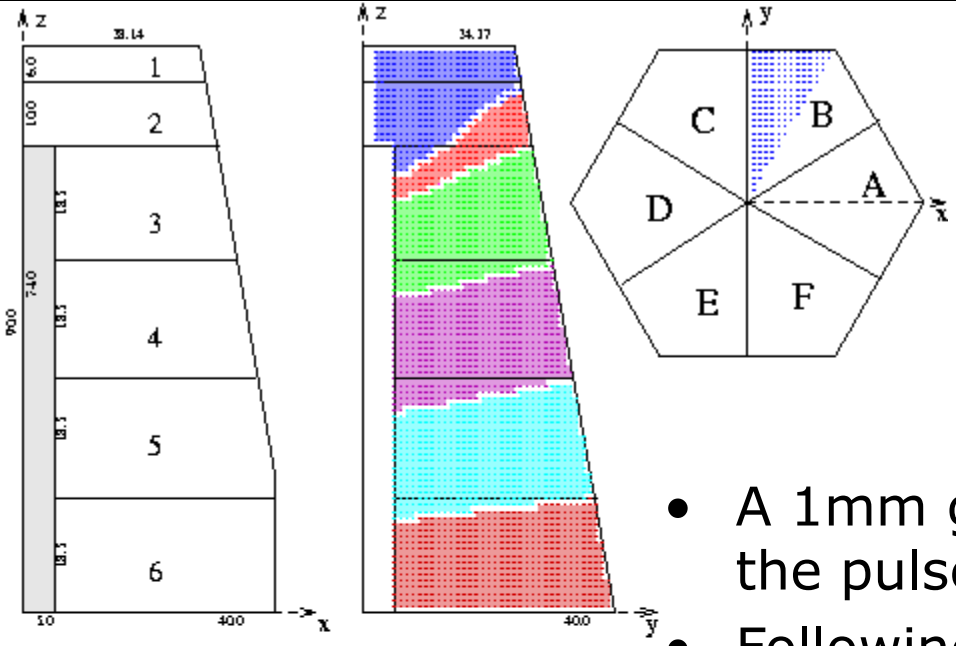
net charge signals

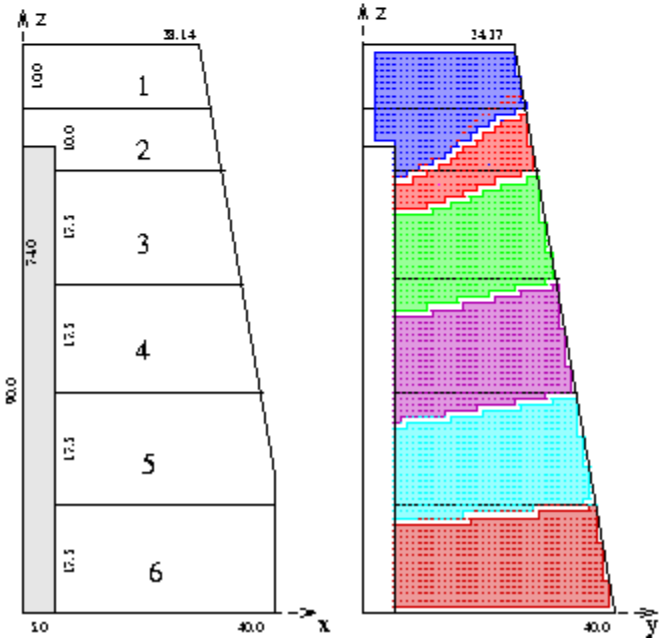
transient signals





Pulse shape database





- A 1mm grid was used to evaluate the pulse shapes.
- Following cylindrical symmetry arguments interactions only in seg. B $\rightarrow$ 25,000 grid points were used.
- Net and image charge considered.
- 662 keV photons from ^{137}Cs considered.

Sensitivity

- Total average sensitivity: $S = \sqrt{\chi_x^2 + \chi_y^2 + \chi_z^2}$

Charge collected at time t in segment i for interaction (x,y,z)

$$\chi_x^2 = \sum_i \sum_{t=0}^{Tp} \frac{(q_t, i(x,y,z) - q_t, (\delta x, y, z))^2}{2\sigma^2}$$

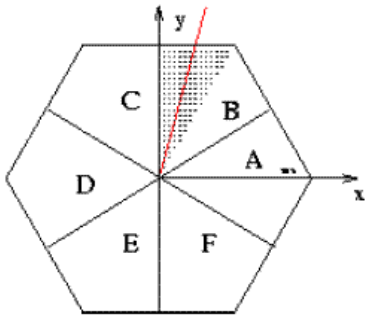
Noise factor 1% of total charge

Integration over time in steps of 1ns

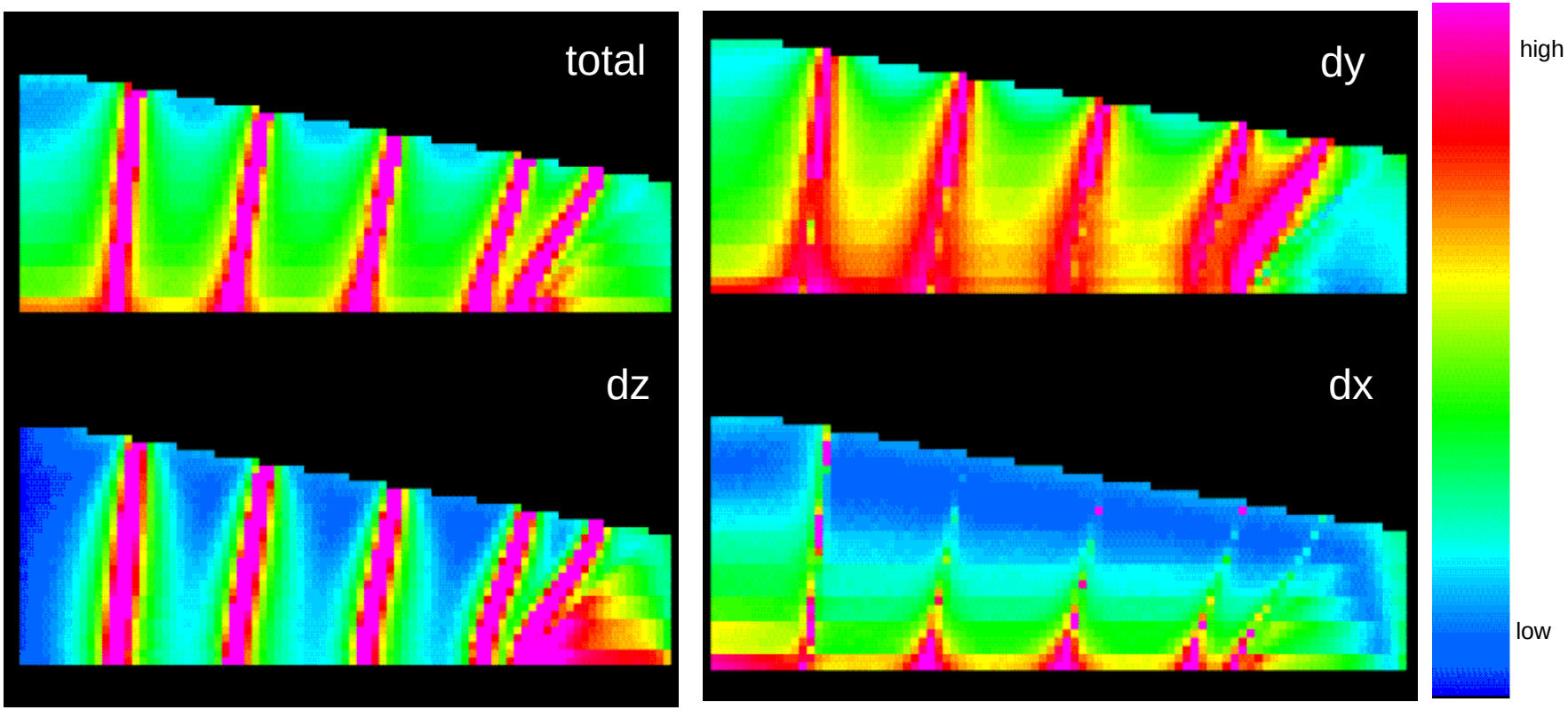
Segment that collects net charge and eight direct neighbours

- $\chi < 1$: Difference in signal is less than noise
- $\chi = 1$: Difference in signal is noise
- $\chi > 1$: Difference in signal is well above noise

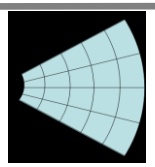
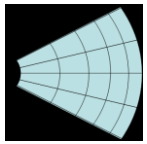
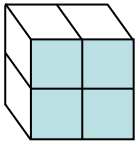
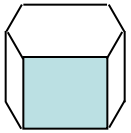
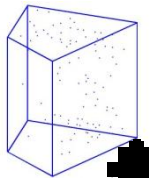
Sensitivity



- Demonstration of sensitivity: the position sensitivity peaks at the (effective) segment borders
- Regions near the outer surface between segment borders have the poorest sensitivity

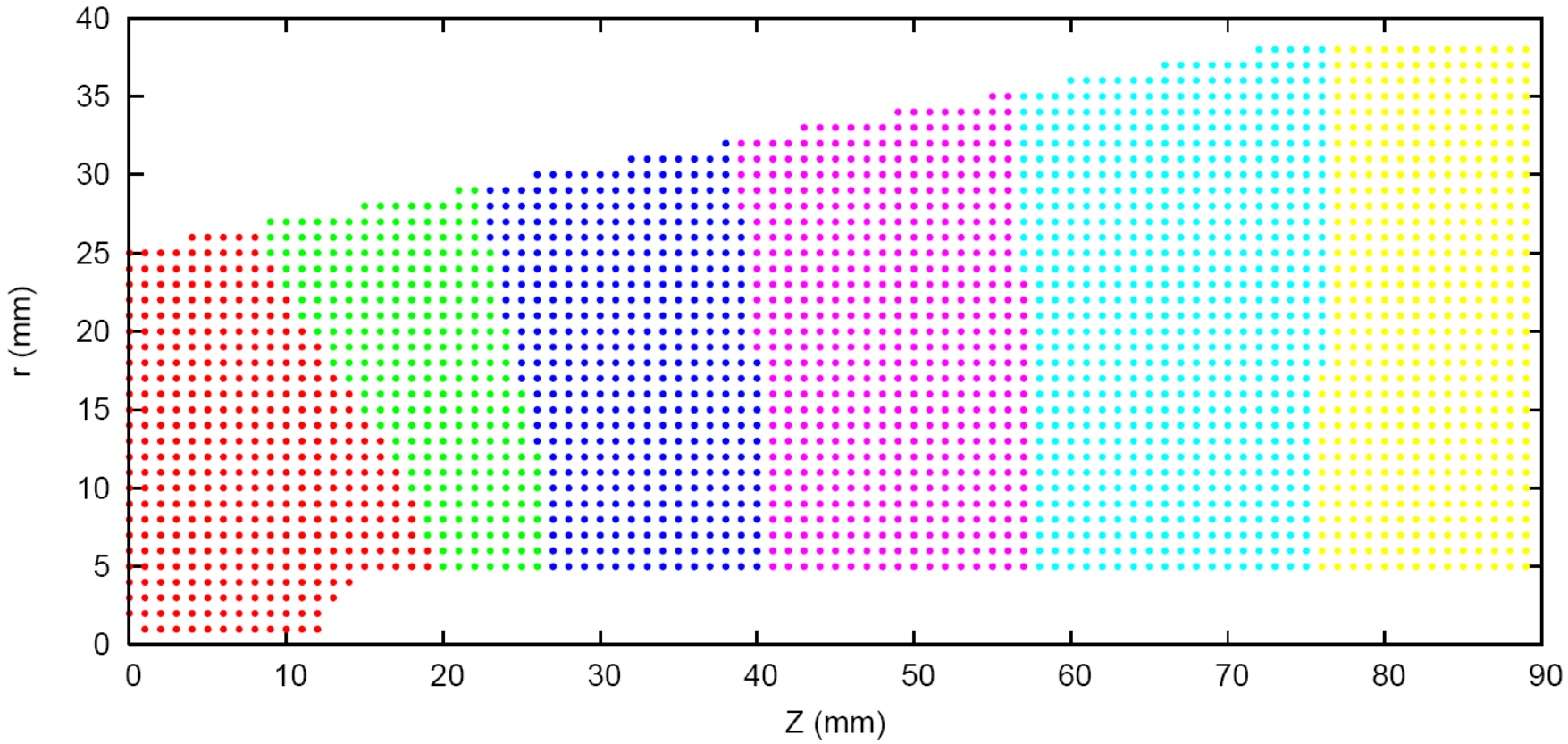


Which grid to choose ?

		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

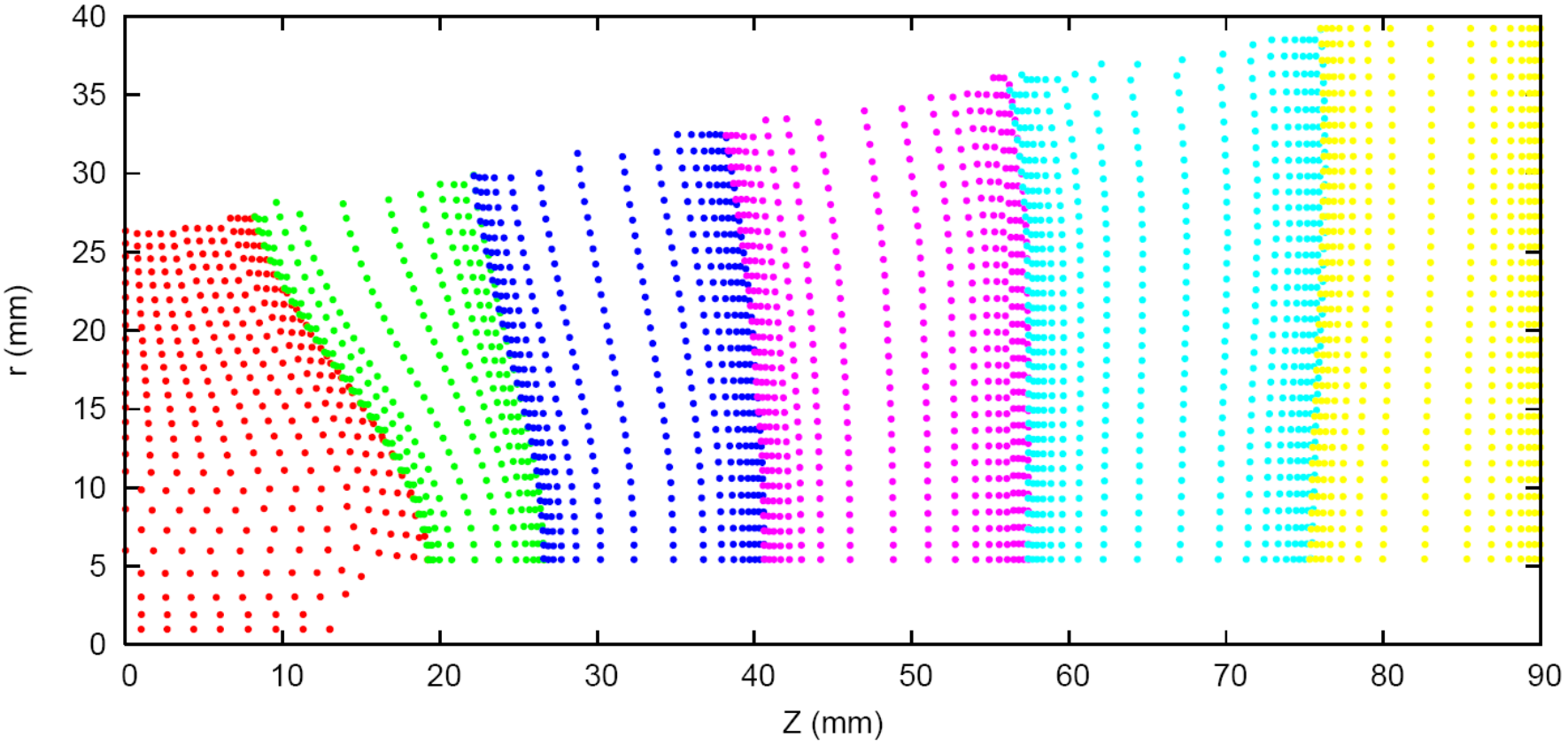
Cartesian Grid

- 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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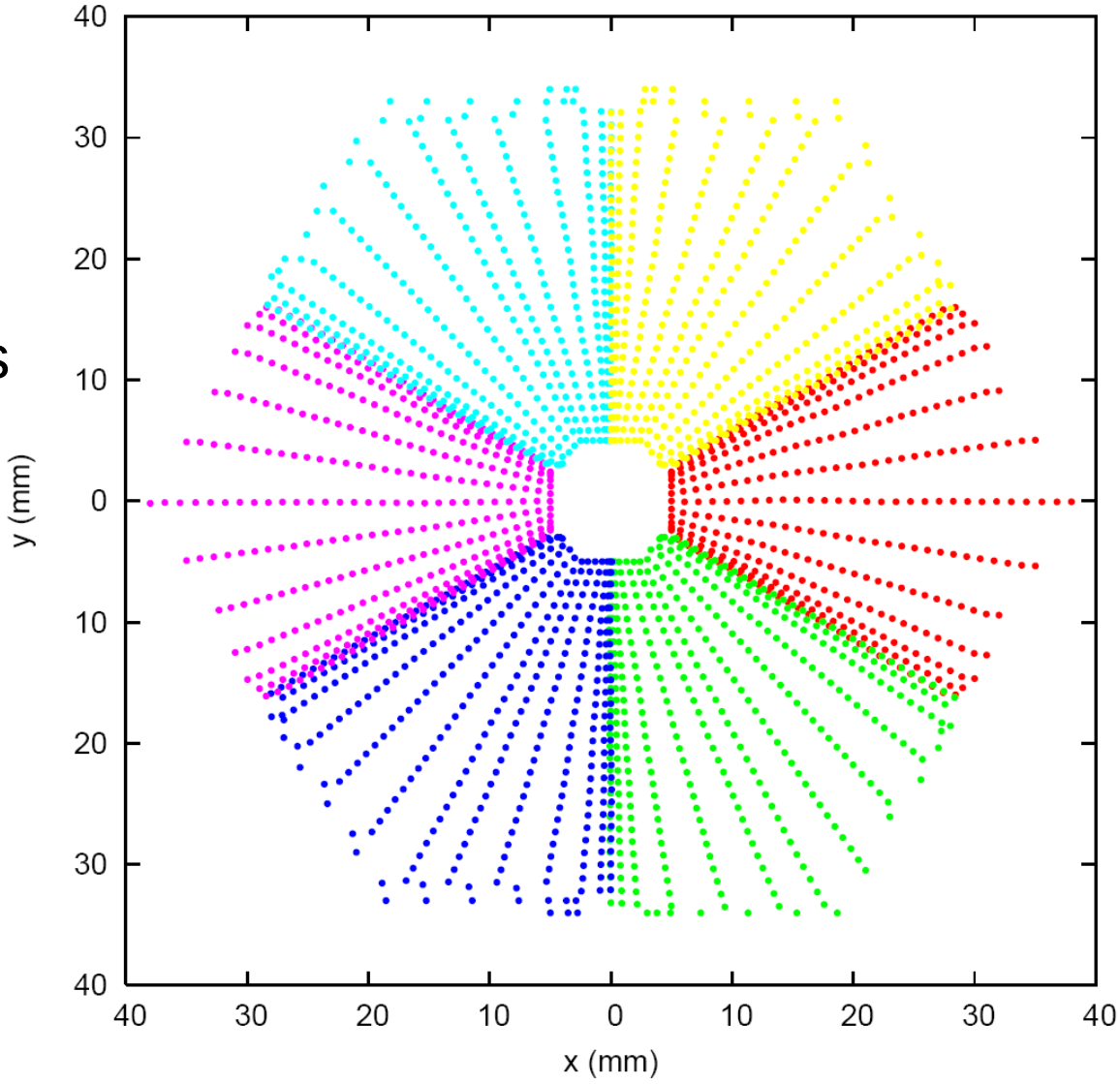
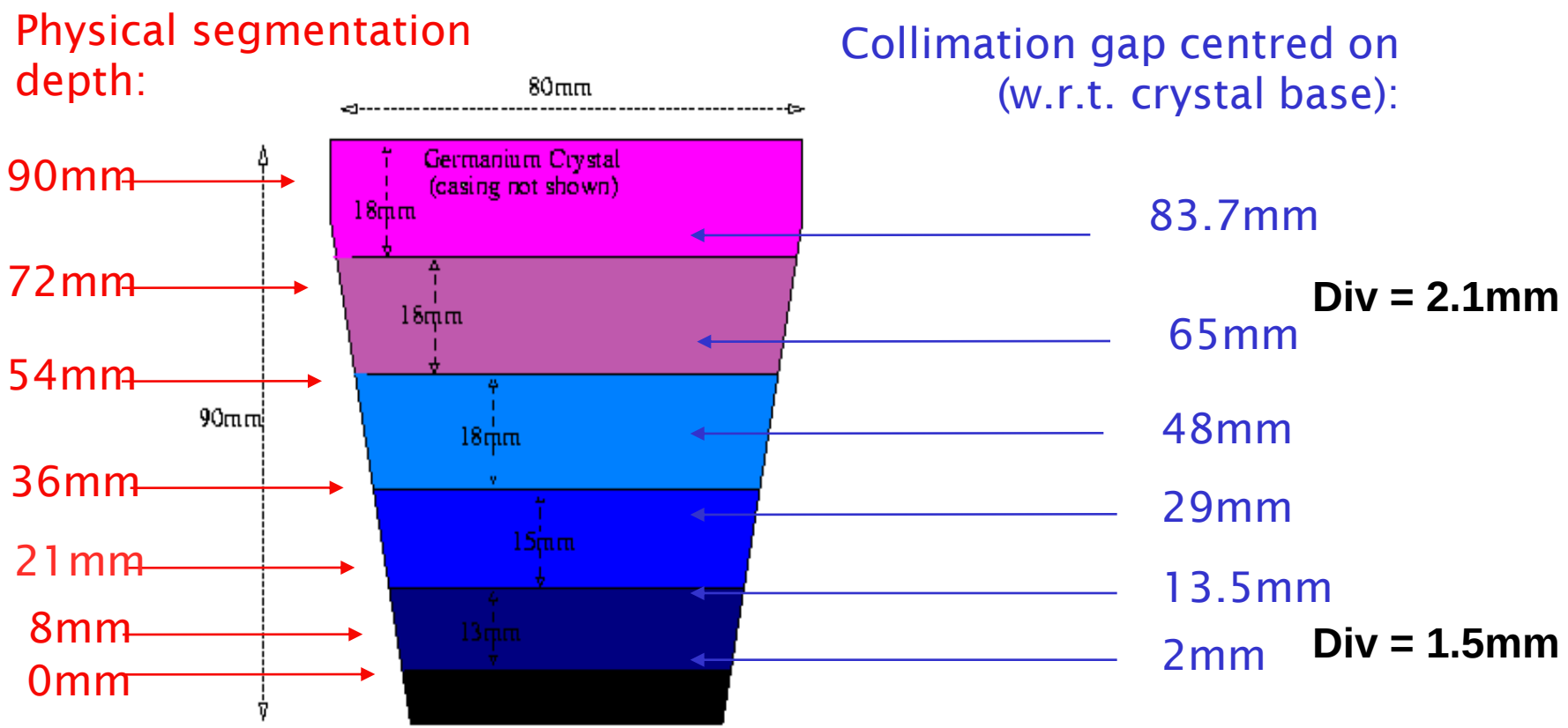
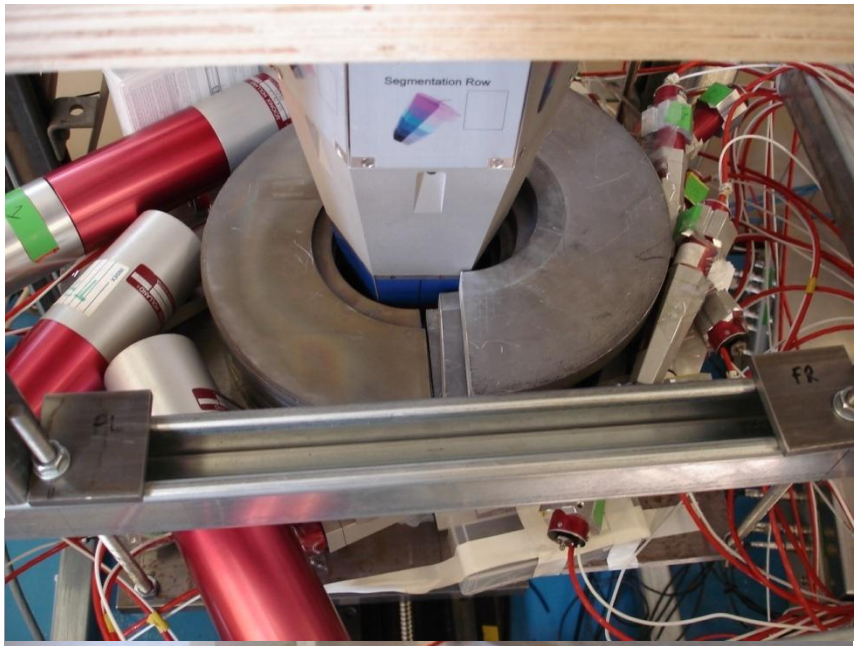
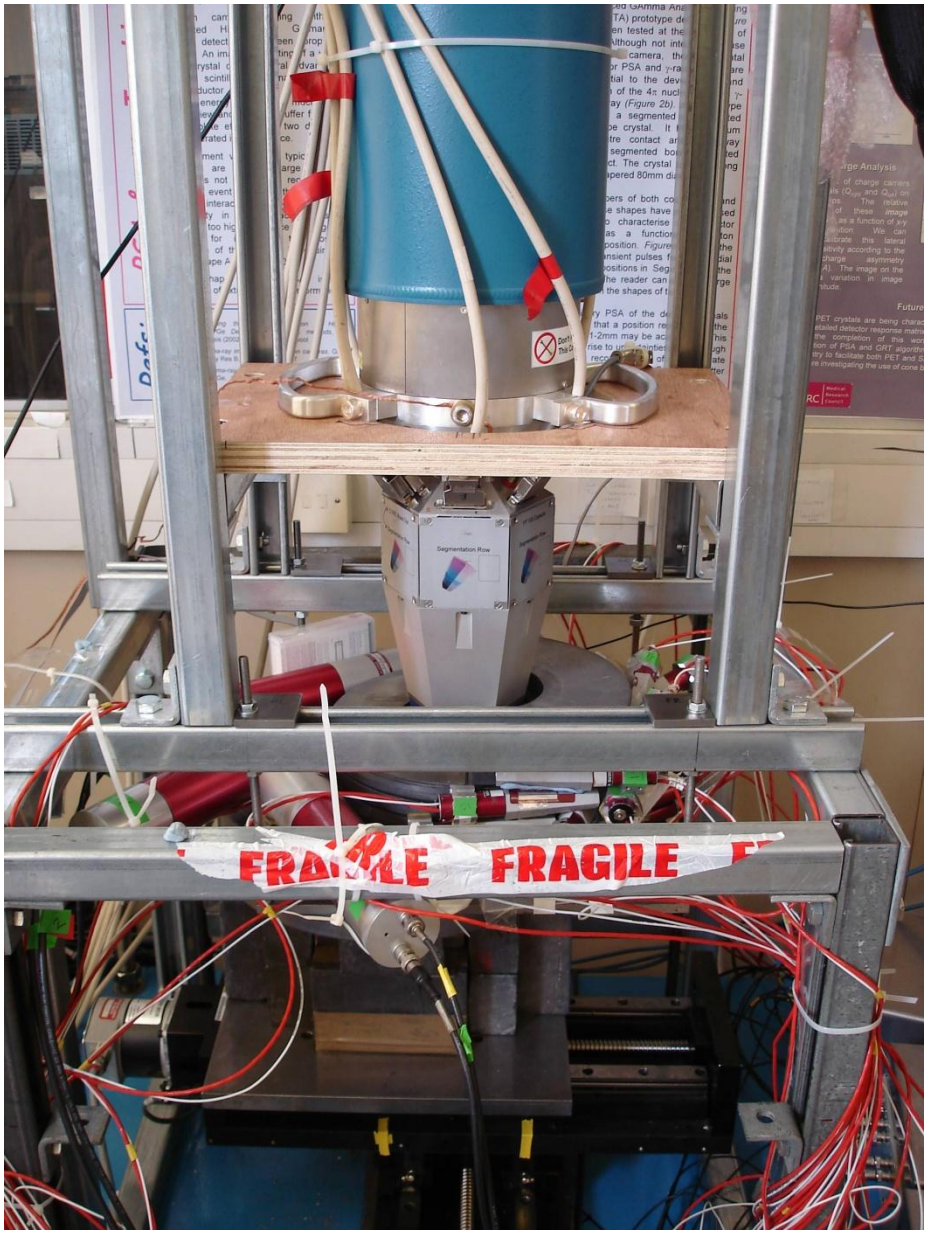


Coincidence scan: set up

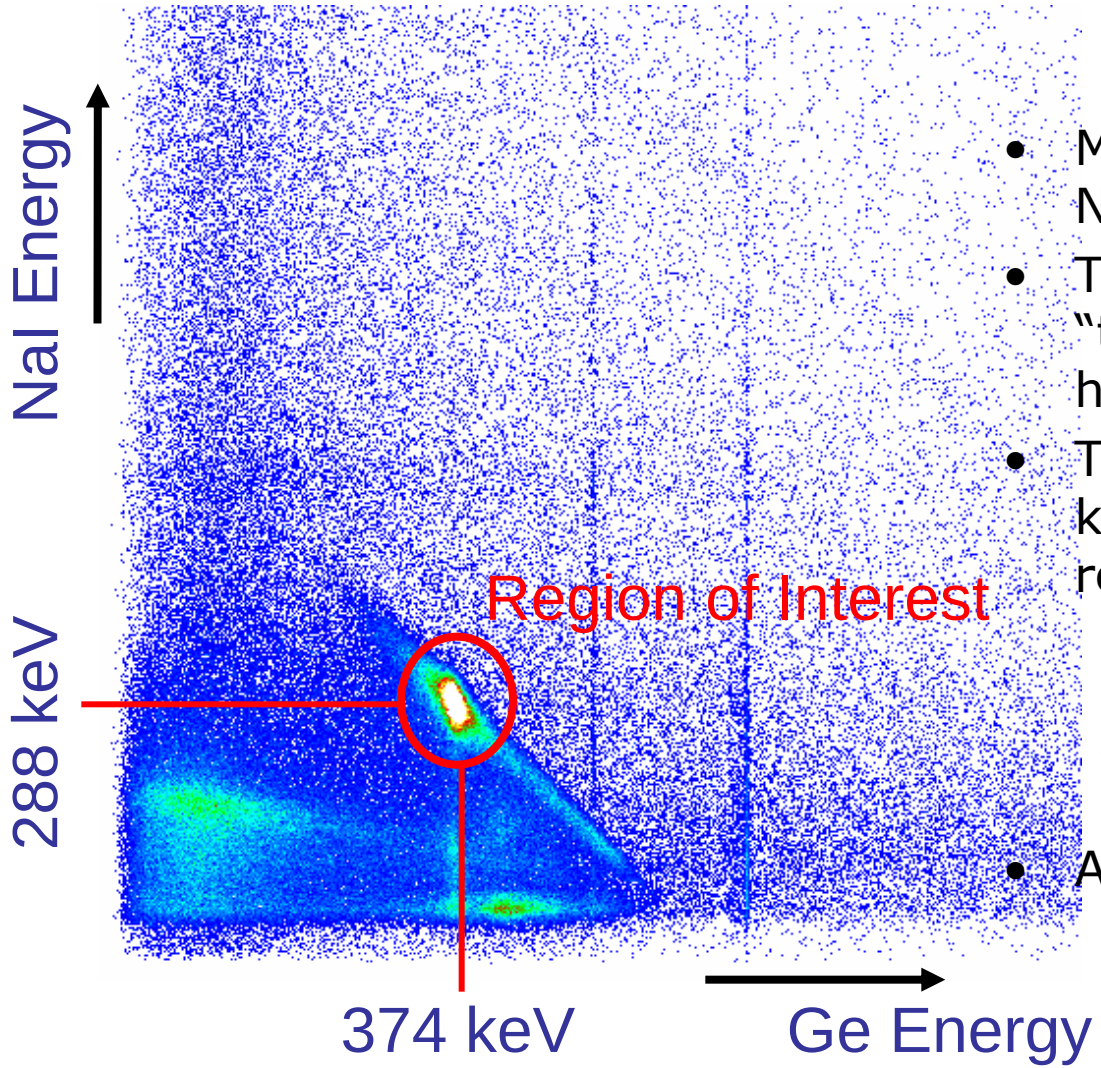


Coincidence scan: set up



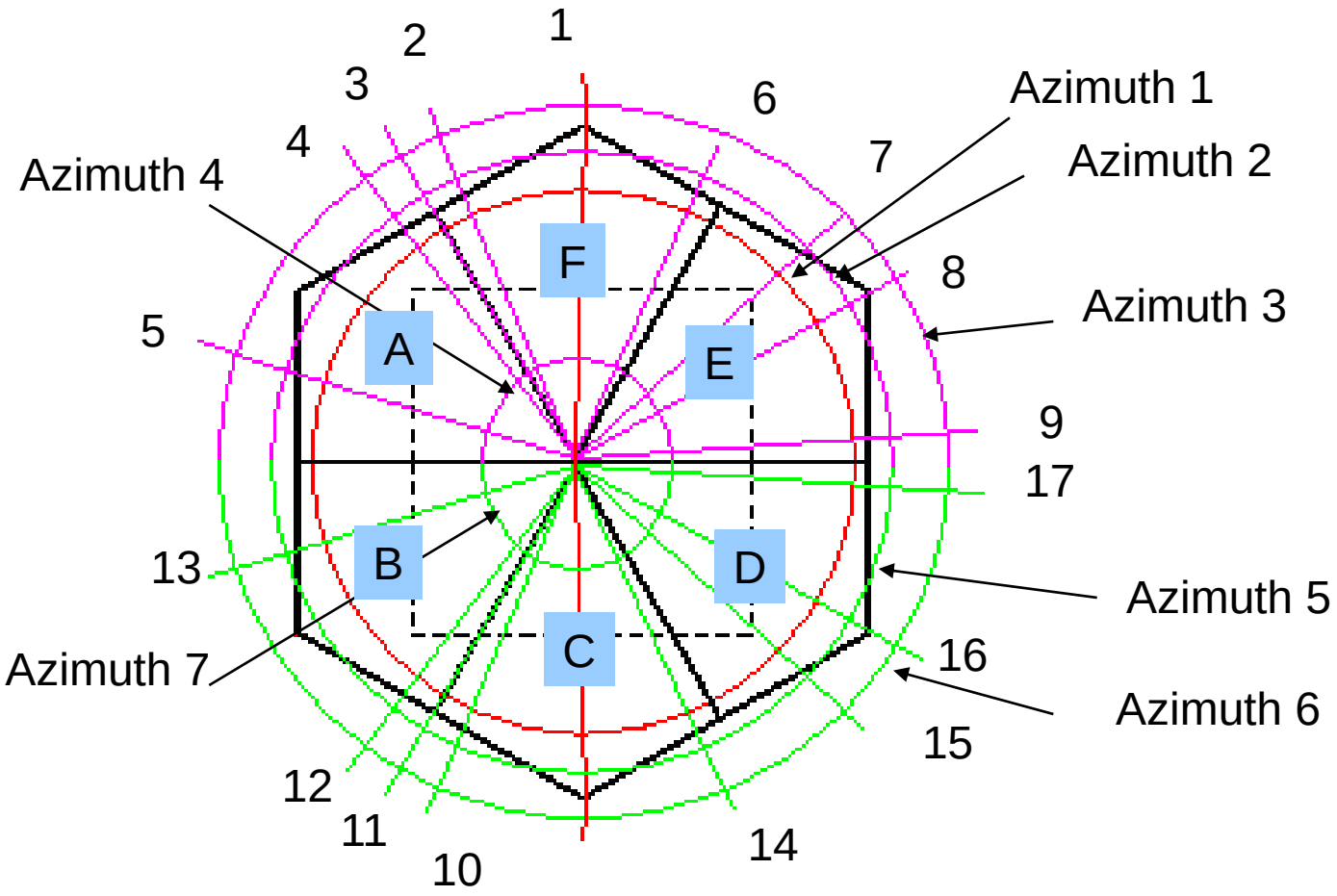


Coincidence results



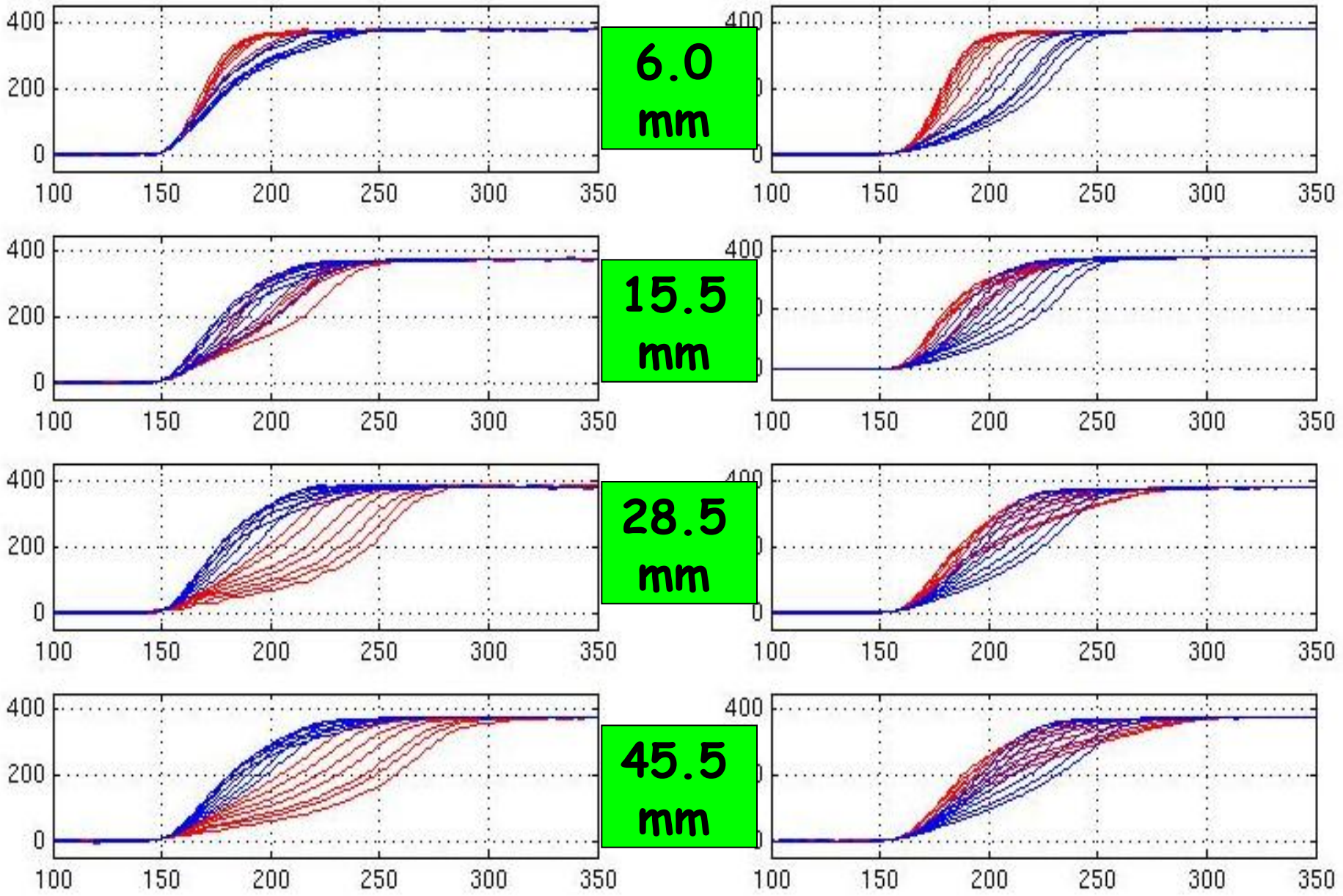
- Matrix of Ge energy vs Total NaI derived from Silena ADCs
- The region of interest for "true" coincidences is highlighted in red.
- The data was presorted to keep only the data in this region.
  - This leaves ~ 1.5Gb of data per line.
  - Gzip compressed into three 400Mb files.
- Available for download now.

Coincidence scan: plan



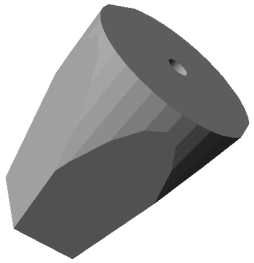
Segment pulses

Centre contact pulses



Digital Gamma-ray Spectroscopy

Frontiers of gamma-ray spectroscopy



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GRETA