AGATA: Gamma-ray tracking in segmented HPGe detectors

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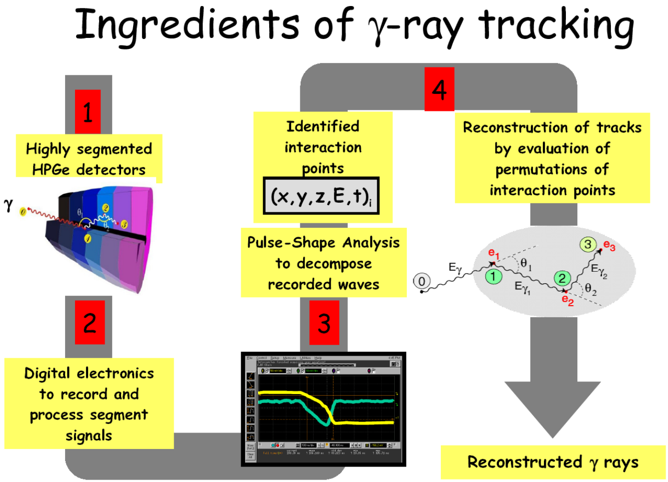
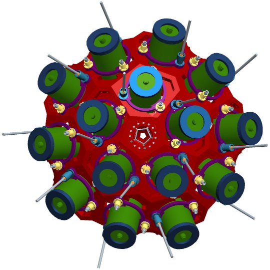
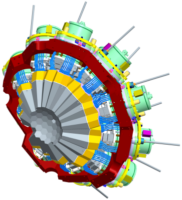
Overview


Ingredients of γ-ray tracking
1
Highly segmented HPGe detectors
γ
2
Digital electronics to record and process segment signals
3
Pulse-Shape Analysis to decompose recorded waves
Identified interaction points
(x,y,z,E,t)$_i$
4
Reconstruction of tracks by evaluation of permutations of interaction points
0
1
2
3
E_γ
E_{γ_1}
E_{γ_2}
e_1
e_2
e_3
θ_1
θ_2
Reconstructed γ rays

AGATA - The Advanced Gamma Tracking Array





- Now: 4th revolution in nuclear structure. RIB facilities for studies of exotic nuclei. Weak γ-ray signals, hard to detect.
- AGATA: When completed a 4 π spherical array of HPGe detection
- The full array will consist of 180 crystals in three different asymmetric hexaconical shapes in 60 triple clusters (TC)
- Energy range 5 keV - 20 MeV

AGATA - The Advanced Gamma Tracking Array

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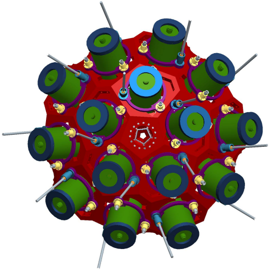
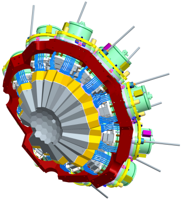
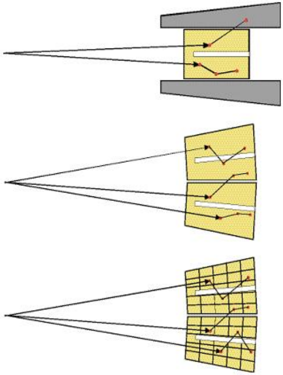




- To greatly increase energy resolution, efficiency and solid angle coverage novel techniques of γ-ray tracking will be implemented
- Efficiency:
  43 % ($M_\gamma = 1$, gain ~ 4)
  28 % ($M_\gamma = 30$, gain ~ 1000)
- Movable between different laboratories:
  2008, 5 TC at LNL, Italy
  $\rightarrow$ 2010, 10 TC at GANIL
  $\rightarrow$ 2012, 20 TC at GSI
  $\rightarrow$???

AGATA - Detector unit



- Previously used BGO shields create lots of dead material
- Discarding escaped events heavily reduces efficiency

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- Removing BGO shield increase solid angle and efficiency
- Problems with angular resolution and energy summing
- Many detectors needed

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- Instead, a system based on γ-ray tracking
- No dead material
- High efficiency
- Good position resolution

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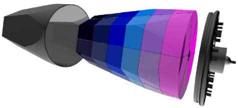
AGATA - Detector unit



- HPGe crystals manufactured by Canberra. Electrically segmented in 6 x 6 azimuthal and depth segments + 1 core segment.
- Size of the crystals: 8 cm diameter before shaping, 10 cm length
- Most equipment built and developed by the collaboration (cryostat, preamp, digitizers, HV, mezzanines, etc.)
- All segment pulse shapes sampled by 14 bits and 100 MHz, 400 W water cooled ADC
- Pulse shapes sent to computer farm for PSA, tracking, merging...

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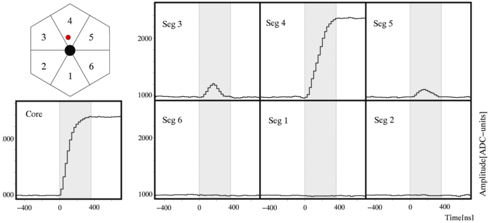
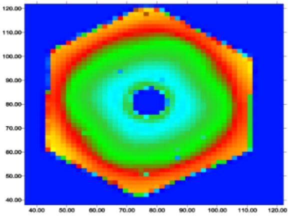
PSA - Position determination





- Segmentation does not give high enough granularity
- Exact interaction position through pulse shape analysis
- Azimuthal position from mirror charge asymmetries
- Radial position from pulse rise times

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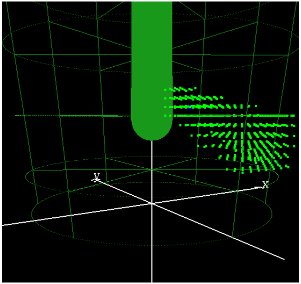
Position

Tracking

Commissioning experiment

Conclusions

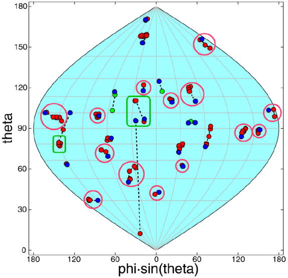
PSA - Algorithms



- Grid search
- Database of pulse shapes ($\approx$ 750 Mb) stored in memory
- Compare pulse shapes with database and minimize χ^2
- Works great for single hit. Worse performance for double hit.
- Calculate: Fast process but not trivial. Complicated geometry gives complicated electric field
- Scanning: Extremely slow process but gives true pulse shapes. Also gives mirror charge asymmetries and rise times necessary for calculations
- Does pulse shapes differ significantly between crystals?

Tracking - Principles

Two complemetary algorithms implemented: Backtracking (which I will not talk about) and Clusterisation or Forward tracking



Forward tracking

- Preliminary identification of clusters of interaction points
- All possible scattering angles within a cluster compared against the Compton scattering formula
- In general, more efficient than backtracking

Tracking - Principles

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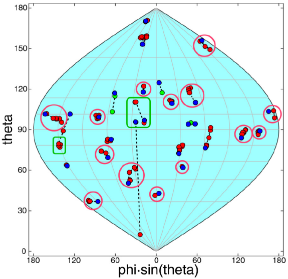

Forward tracking

- Preliminary identification of clusters of interaction points
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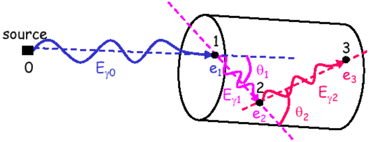
Forward tracking - an example



1. Choose a first and second point (i, j)
2. Calculate energy remaining after first interaction as $E_{\mathrm{s,e}} = E_{\mathrm{tot}} - e_i$
3. Calculate energy remaining according to Compton formula $E_{\mathrm{s,p}} = \frac{E_{\mathrm{tot}}}{1+E_{\mathrm{tot}}/m_{\mathrm{e}}(1-\cos\theta)}$
4. Repeat for all permutations. Correct when $E_{\mathrm{s,e}} \approx E_{\mathrm{s,p}}$.
5. Start over with found interaction point as new source.

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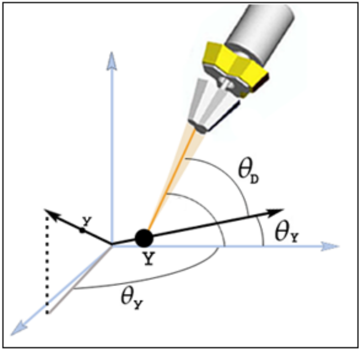
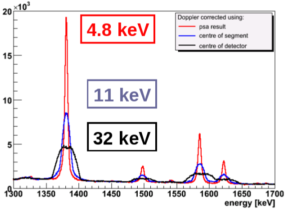
Commissioning - In-beam measurement of position resolution

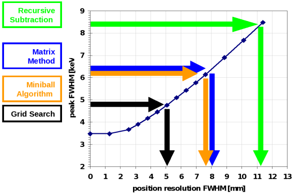


- One of the commissioning experiments at LNL would be to measure position resolution of one triple cluster.
- The idea is to use FWHM contribution of Doppler shifts

$$W_{\text{tot}}^2 = W_{\text{int}}^2 + W_{\text{rec}}^2 + W_{\Delta\theta}^2$$

Commissioning - Old strategy for position resolution

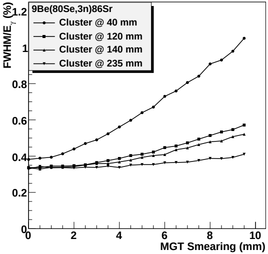




(Francesco Recchia)

- 2005 at Cologne
- Energy resolution 4.8 keV gives position resolution of 5 mm using grid search PSA
- Monte Carlo dependency where input parameters not at all well determined (beam spot and dispersion, detector positioning)
- Ancillary DSSSD detector made analysis time consuming

Commissioning - New strategy for position resolution



- No ancillaries!
- Same detector at different distances
- Only difference the angular resolution (once distance uncertainties and count rate effects corrected for)
- Comparing distances gives position resolution of detector + PSA + tracking
- Only experimental information involved!

$$p^2 = \frac{1}{k^2}\left(\Delta E^2_{\mathrm{close}} - \Delta E^2_{\mathrm{far}}\right)\left(\frac{1}{d^2_{\mathrm{close}}} - \frac{1}{d^2_{\mathrm{far}}}\right)^{-1}$$

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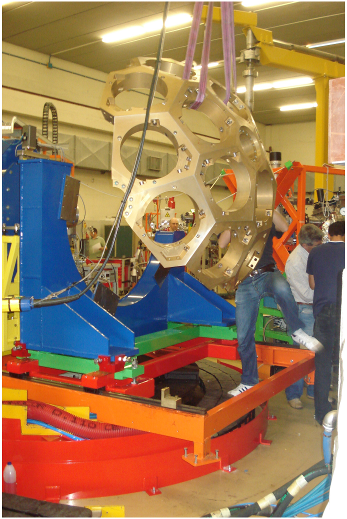
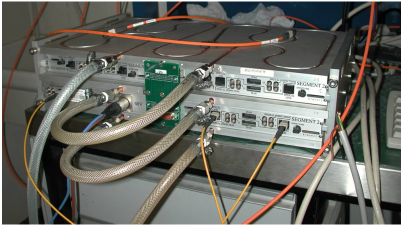
The real thing...





Collaboration and Contact

Bulgaria, Denmark, Germany, Hungary, Italy, Finland, France, Poland, Romania, Sweden, Turkey, UK

AGATA Steering Committee
Chairperson W. Korten (and EURONS), Vice Chairperson P.J. Nolan,
G. de Angelis, A. Atac, F. Azaiez, D. Balabanski, D. Bucurescu, B. Cederwall, J. Gerl,
J. Jolie, R. Julin, W. Meczynski, M. Pignanelli, G. Sletten, P.M. Walker

AGATA Management Board
J. Simpson (Project Manager)
D. Bazzacco, A. Gadea, G. Duchêne, J. Nyberg, P. Reiter, Ch. Theisen

AGATA Working Groups

Detector module P. Reiter	Front end processing D. Bazzacco	Data acquisition Ch. Theisen	Design and Infrastructure G. Duchêne	Ancillary detectors and integration A. Gadea	g-ray tracking, simulation and data analysis J. Nyberg

AGATA Teams

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Preamplifiers A. Pullia	Pre-processing I. Lazarus	Run control & GUI G. Maron	Infrastructure P. Jones	Devices for key experiments N. Redon	Physics & event simulation E. Farnea
Detector characterisation A. Boston	Global clock and trigger M. Bellato		R&D on gamma detectors D. Curien	Impact on performance M. Palacz	Detector data base K. Hauschild
	PSA R. Gernhaeuser/ P. Desesquelles			Mechanical integration J. Valiente Dobon	Data analysis O. Stezowski

www.gsi.de/agata/