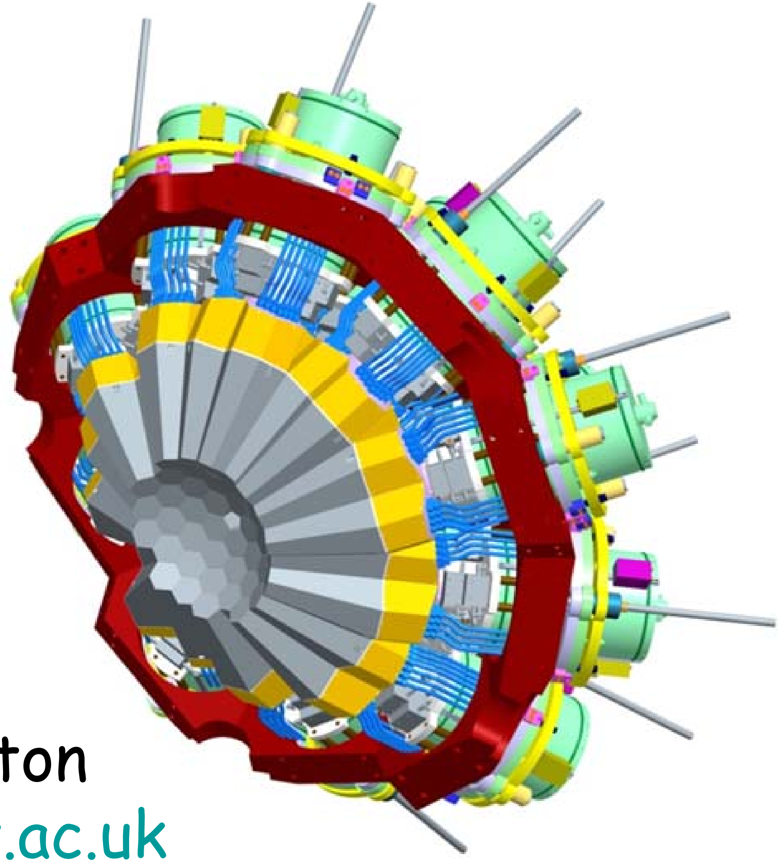
What the Advanced Gamma Tracking Array can do for us

Nuclear science in the 21st century

AGATA ADVANCED GAMMA TRACKING ARRAY

http://www.gsi.de/agata/



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UNIVERSITY OF LIVERPOOL

Science & Technology Facilities Council

The Advanced Gamma Ray Tracking Array

- Introduction: The AGATA project
- Current status of AGATA
  - towards the “demonstrator”
- Exploitation of AGATA
  - demonstrator and beyond

Next generation γ-ray spectrometer based on gamma-ray tracking

First “real” 4π germanium array ➔ no Compton suppression shields

Versatile spectrometer with very high efficiency and excellent spectrum quality for radioactive and high intensity stable beams

Experimental conditions and challenges

FAIR
SPIRAL2
SPES
REX-ISOLDE
EURISOL
ECOS

- Low intensity
- High backgrounds
- Large Doppler broadening
- High counting rates
- High γ-ray multiplicities

Need instrumentation

High efficiency
High sensitivity
High throughput
Ancillary detectors

Long Range Plan 2004
Recommendations and priorities

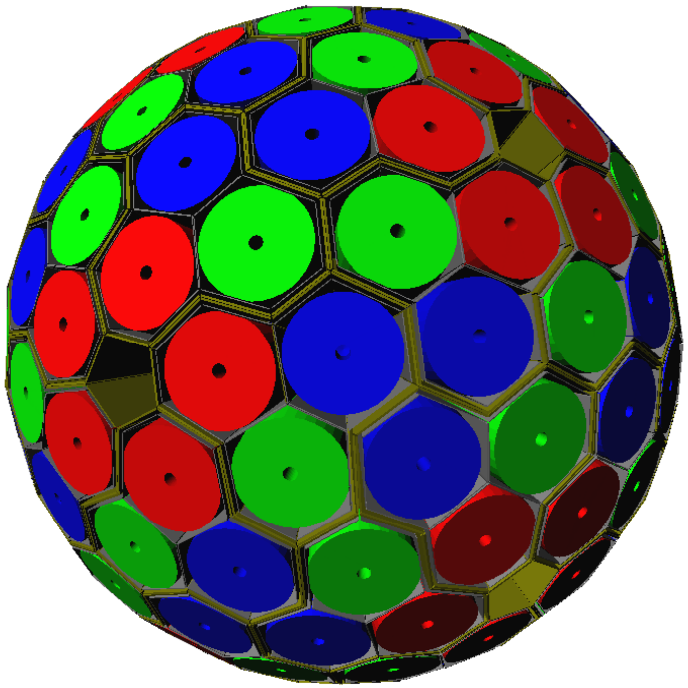
...

In order to exploit present and future facilities fully and most efficiently, advanced instrumentation and detection equipment will be required to carry on the various programmes.

The project AGATA, for a 4π-array of highly segmented Ge detectors for γ-ray detection and tracking, will benefit research programmes in the various facilities in Europe. **NuPECC gives full support for the construction of AGATA and recommends that the R&D phase be pursued with vigour.**

AGATA (Advanced GAmma Tracking Array)

4π γ-array for Nuclear Physics Experiments at European accelerators providing radioactive and high-intensity stable beams



Main features of AGATA

Efficiency: 43% (M_γ=1) 28% (M_γ=30)
today's arrays ~10% (gain ~4) 5% (gain ~1000)

Peak/Total: 58% (M_γ=1) 49% (M_γ=30)
today ~55% 40%

Angular Resolution: ~1° →
FWHM (1 MeV, v/c=50%) ~ 6 keV !!!
today ~40 keV

Rates: 3 MHz (M_γ=1) 300 kHz (M_γ=30)
today 1 MHz 20 kHz

- 180 large volume 36-fold segmented Ge crystals in 60 triple-clusters
- Digital electronics and sophisticated Pulse Shape Analysis algorithms allow operation of Ge detectors in position sensitive mode → γ-ray tracking

The AGATA Organisation

AGATA Steering Committee

Chairperson: W.Korten (and EURONS) Vice Chairperson: P.J. Nolan

G.deAngelis, 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, G.Duchêne, P. Reiter, A.Gadea, J.Nyberg, 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	Simulation and Data Analysis J.Nyberg

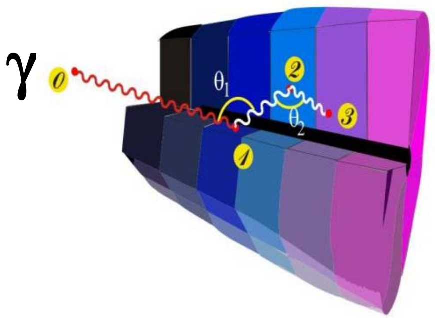
AGATA Teams

Detector and Cryostat A. Linnemann	Digitisation P.Medina	Data acquisition X.Grave	Mechanical design J.Strachan	Elec. and DAQ integration P. Bednarczyk	Gamma-ray Tracking A.Lopez-Martens
Preamplifiers A.Pullia	Pre-processing I.Lazarus	Run Control & GUI G.Maron	Infrastructure P.Jones	Devices for key Experiments N.Redon	Physics & exp. 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

Ingredients of γ-Tracking

1

Highly segmented HPGe detectors



2

Digital electronics to record and process segment signals

3

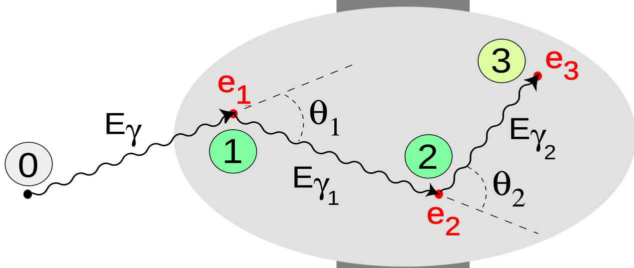
Pulse Shape Analysis to decompose recorded waves

Identified interaction

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

4

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



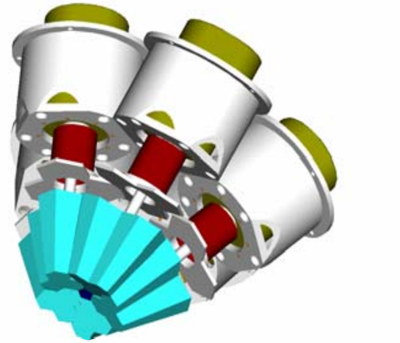
reconstructed γ-rays

AGATA PSD

AGATA array design

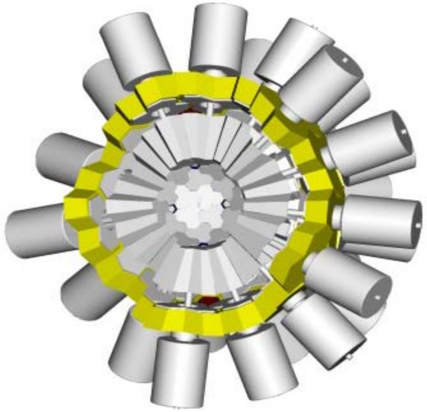
3 different asymmetric hexagonal shapes are used

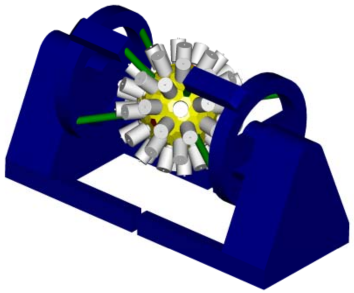
Triple cluster modular units in a single cryostat



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

2π of completed array





Completed array (6480 segments) with support structure

Ingredients of γ-Tracking

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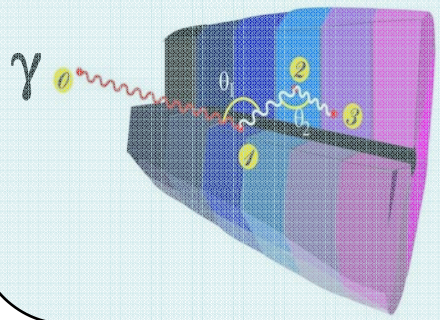
Highly segmented HPGe detectors



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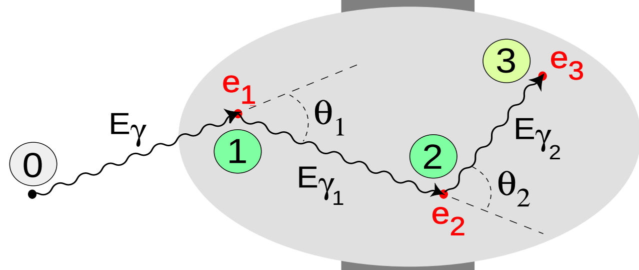
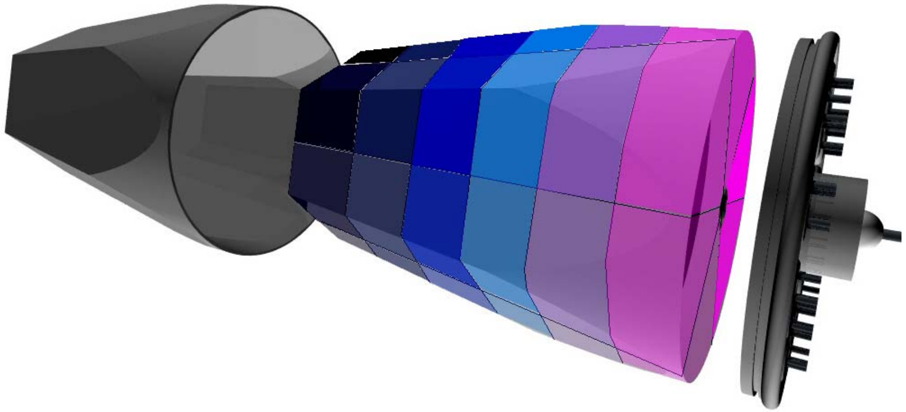
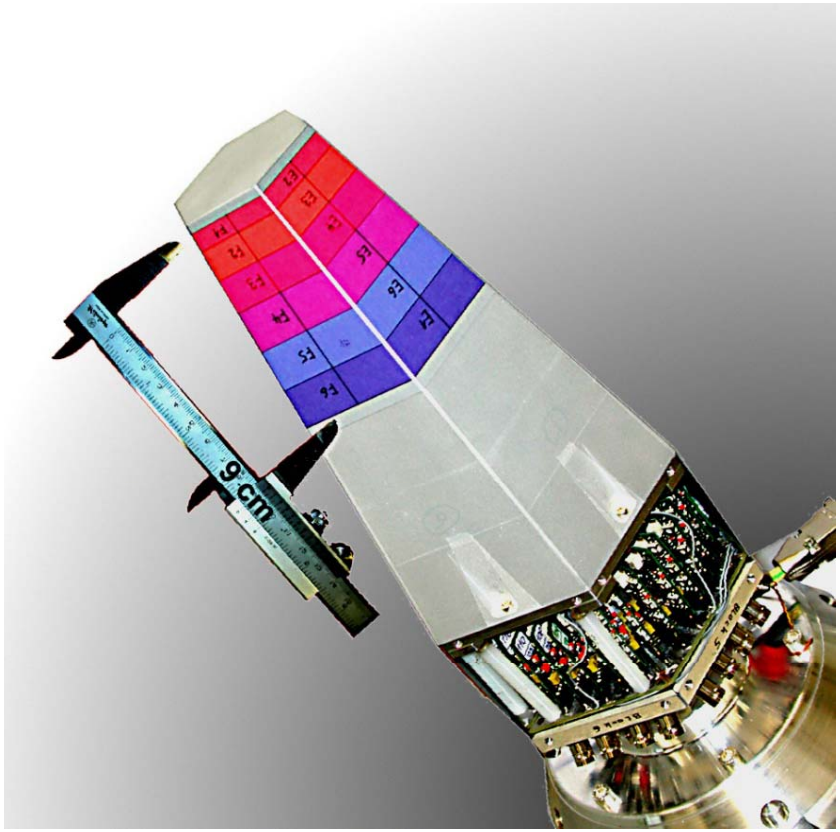


reconstructed γ-rays

AGATA 1st symmetric capsule



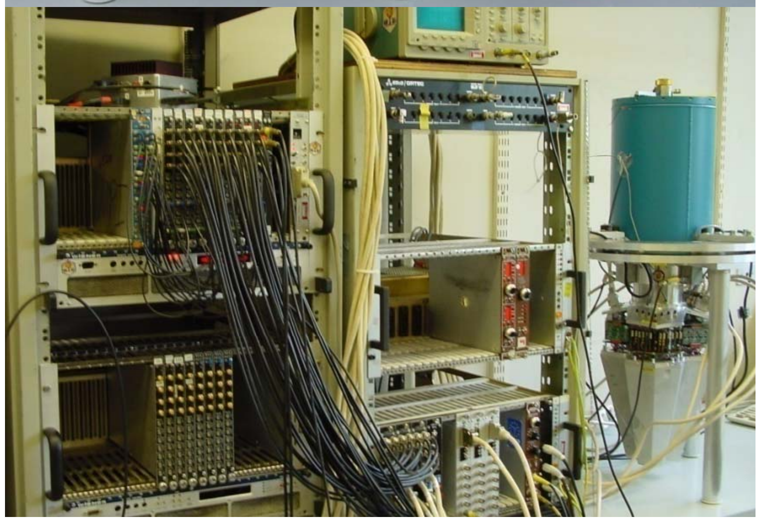


Hexaconical Ge crystals
90 mm long
80 mm max diameter
36 segments
Al encapsulation
- 0.6 mm spacing
- 0.8 mm thickness

37 vacuum feedthroughs

AGATA detector status

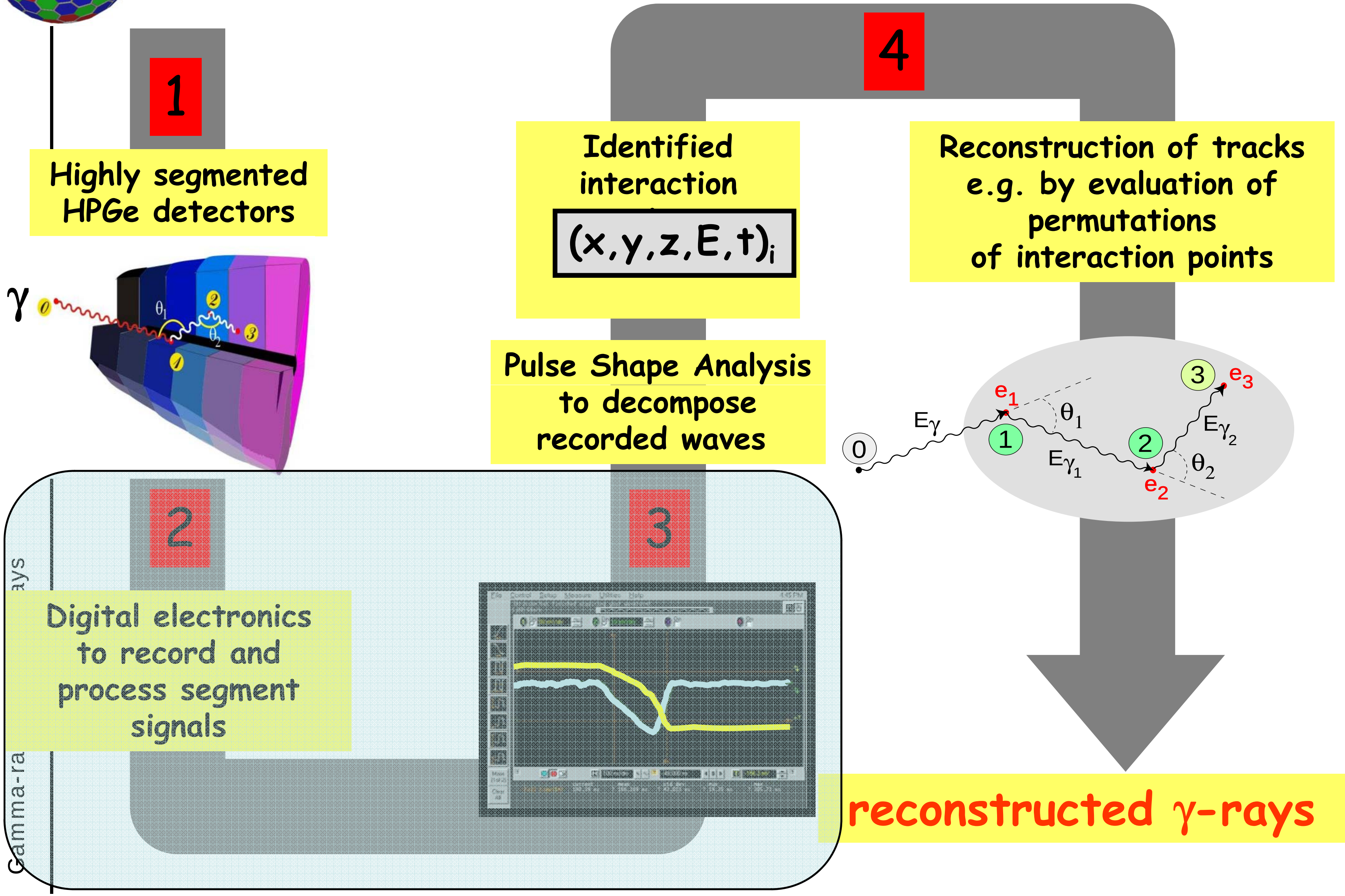
- Symmetric detectors
  - 3 delivered
- Asymmetric detectors
  - 19 ordered (9 accepted, 4 in test, 2 not accepted, 4 to be delivered)
- Preamplifiers available
  - Core (Cologne);
  - Segment (Ganil & Milano)
- Test cryostats for characterisation
  - 5 delivered
- Triple cryostats
  - 5 ordered
  - 1 complete, 2 being assembled, 2 ordered



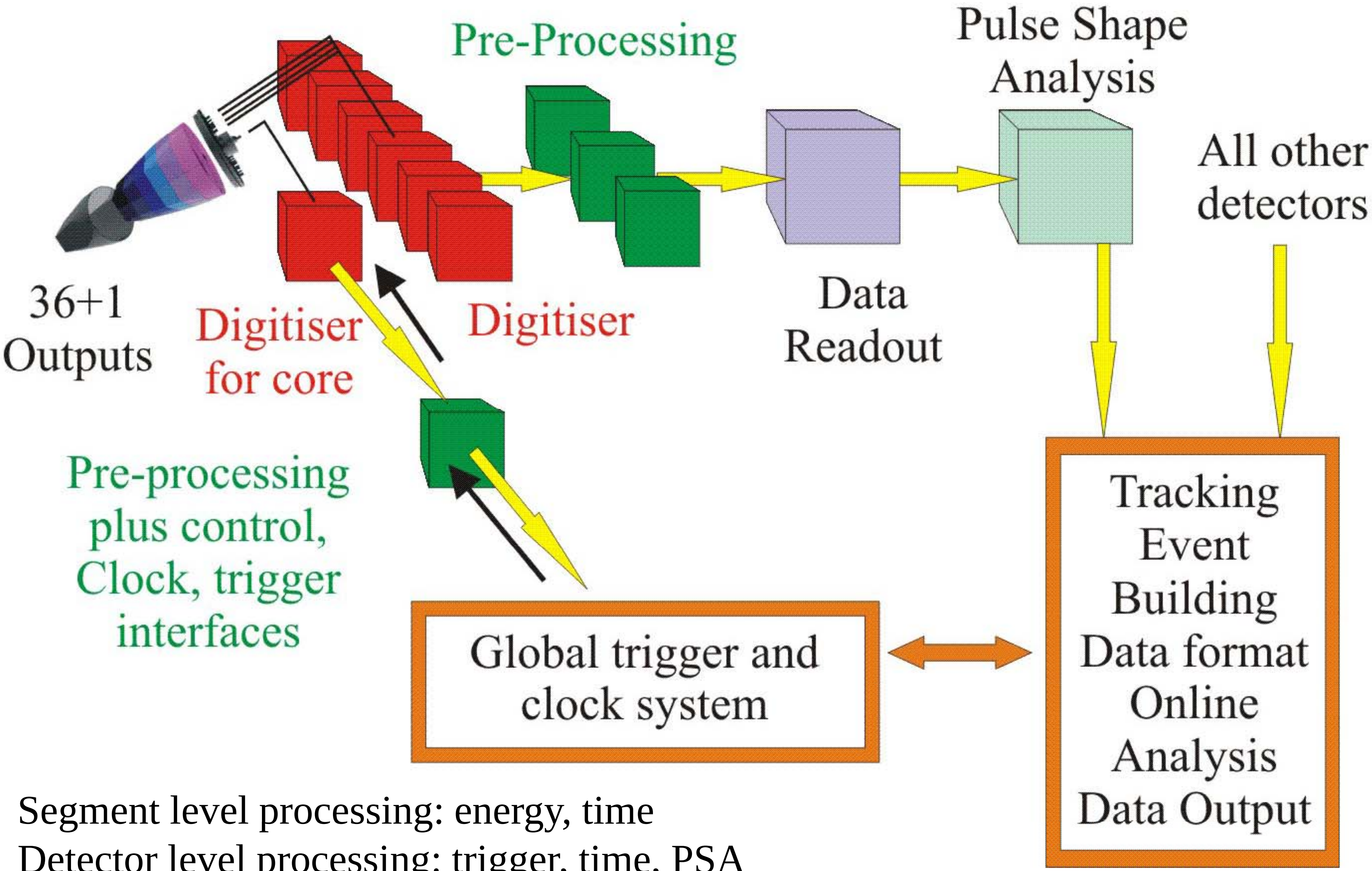
Triple Cluster Energies: Single vs Triple

Resolution 60keV line | Resolution 1.33MeV line

Ingredients of γ-Tracking



Schematic of the Digital Electronics and Data Acquisition System for AGATA



Segment level processing: energy, time

Detector level processing: trigger, time, PSA

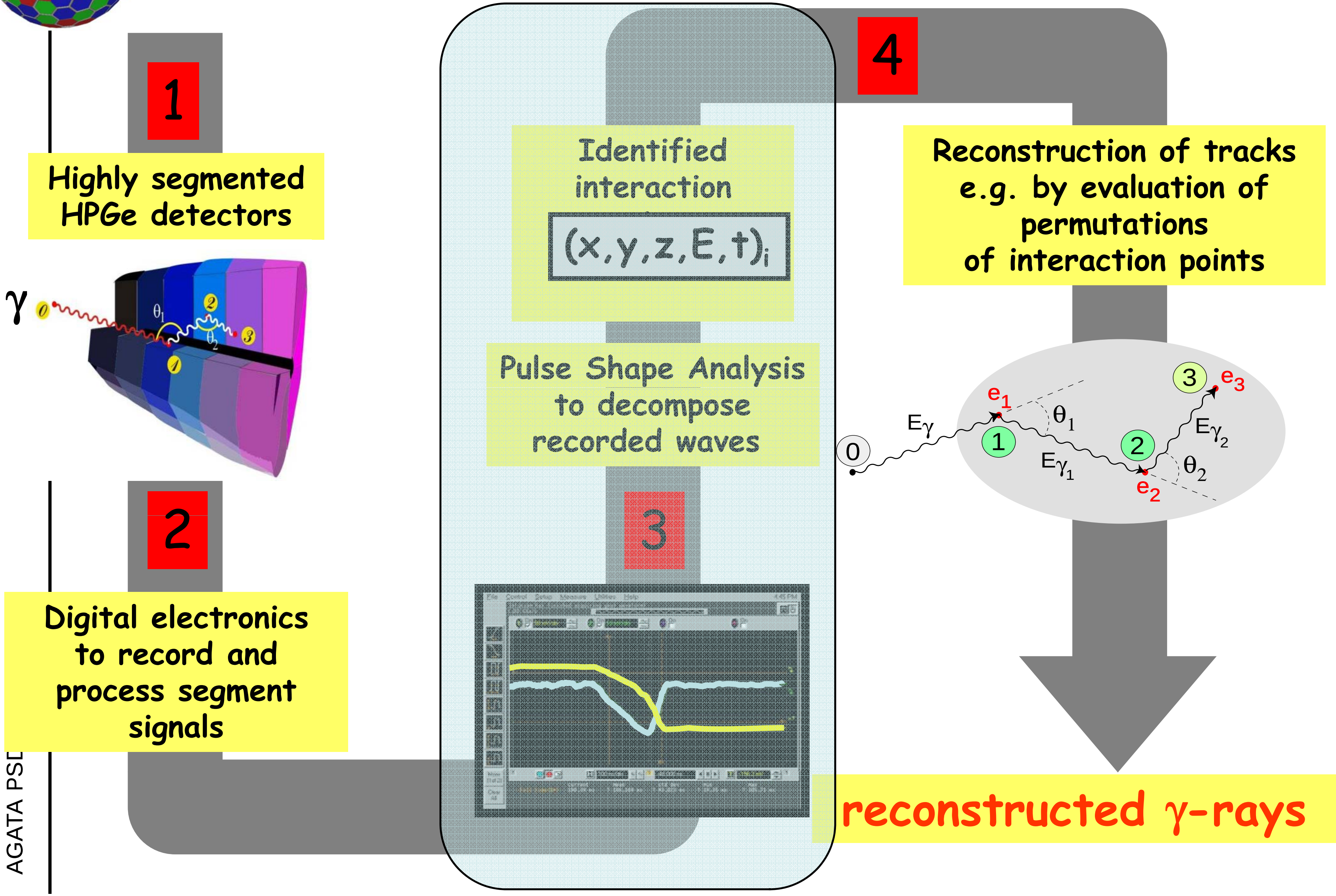
Global level processing: event building, tracking, software trigger, data storage

AGATA Digitiser Module

36+1 channels, 100 MhZ, 14 bits
(Strasbourg - Daresbury – Liverpool)

- Mounted close to the Detector 5-10 m
- Power Dissipation around 400W
- Water Cooling required
- Tested in Liverpool (December 2006)
- Production in progress (for 18 modules)

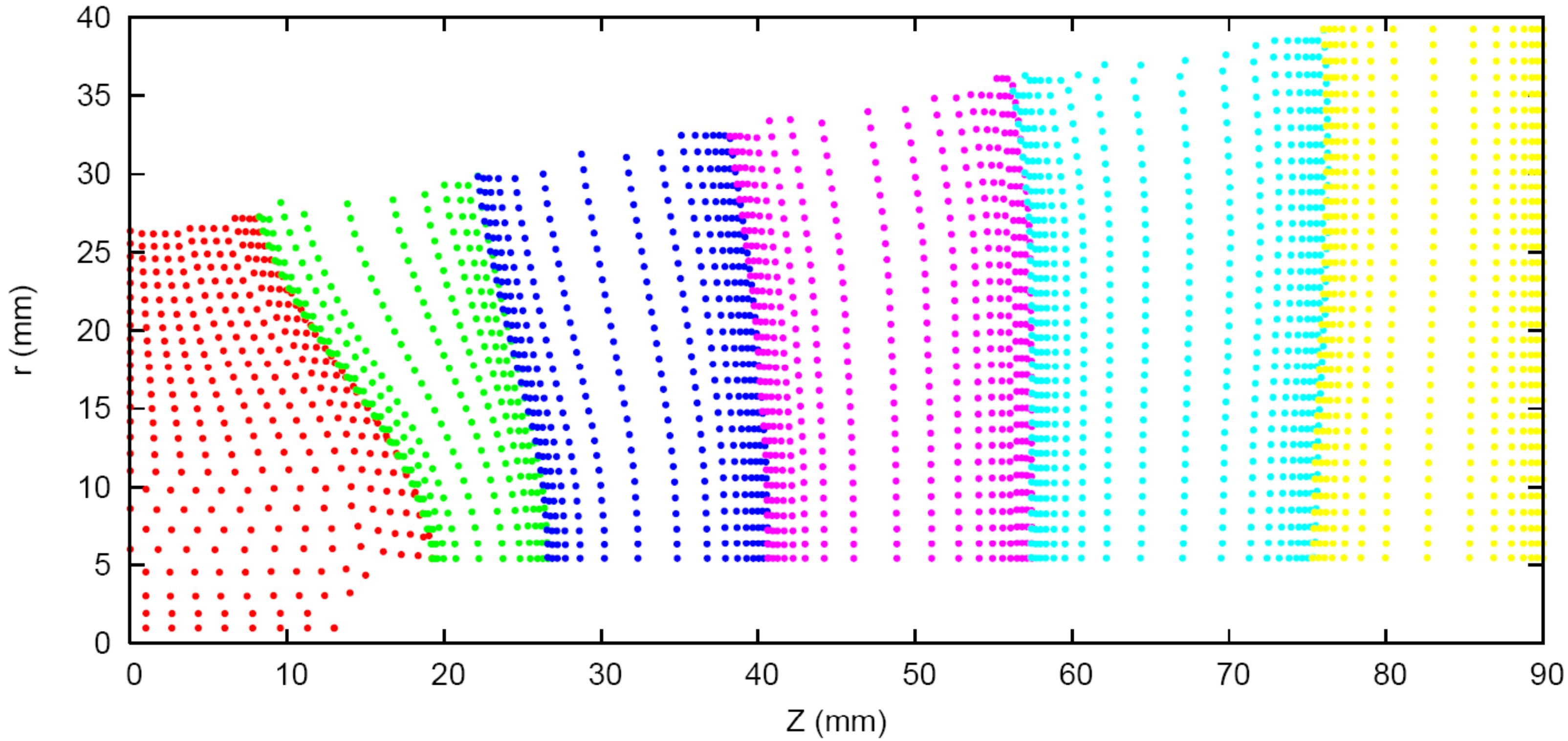
Ingredients of γ-Tracking



AGATA PSD

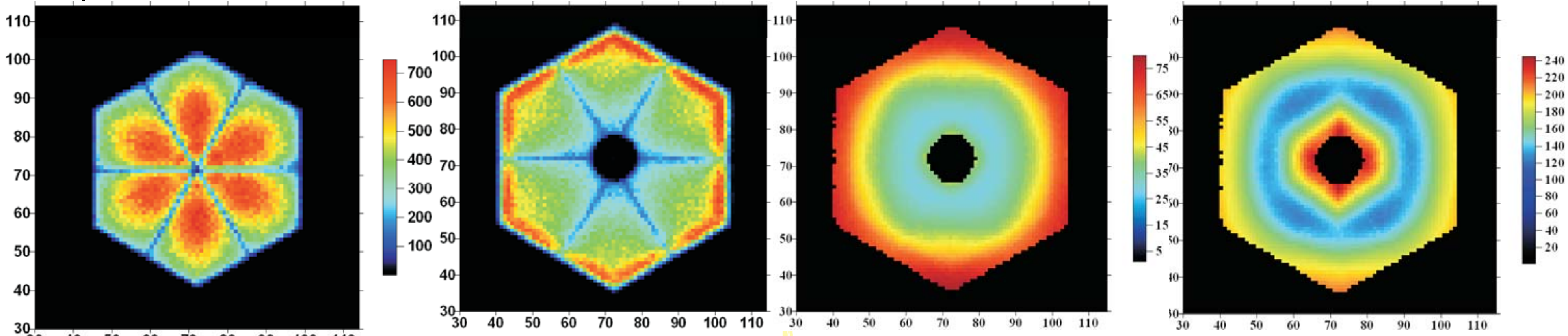
Detector Characterisation and PSA

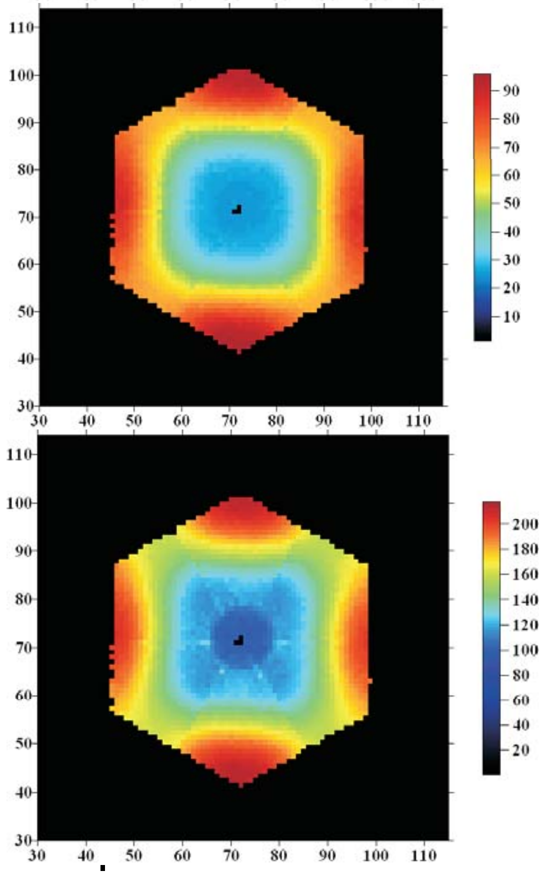
- Calibrate detector response function
- Comparison of real and calculated pulse shapes
- Coincidence scan for 3D position determination
- Validate codes

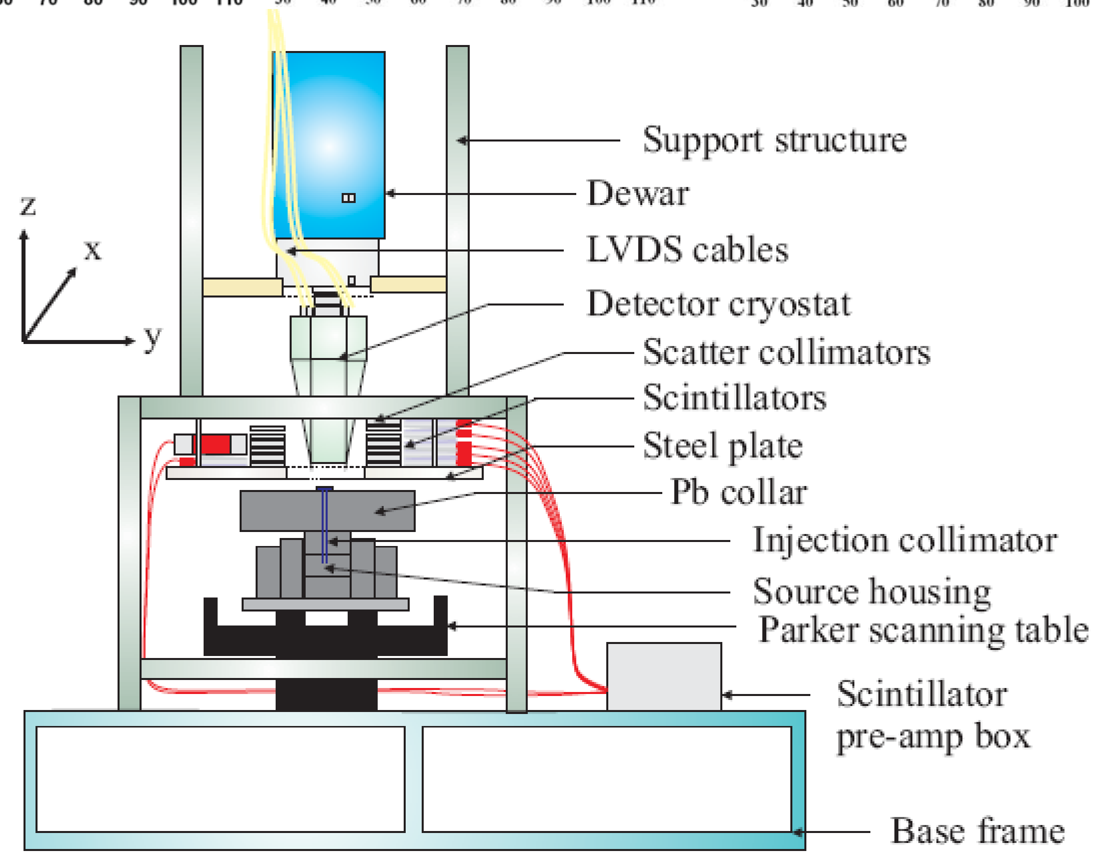


"How well your basis fits your real data"

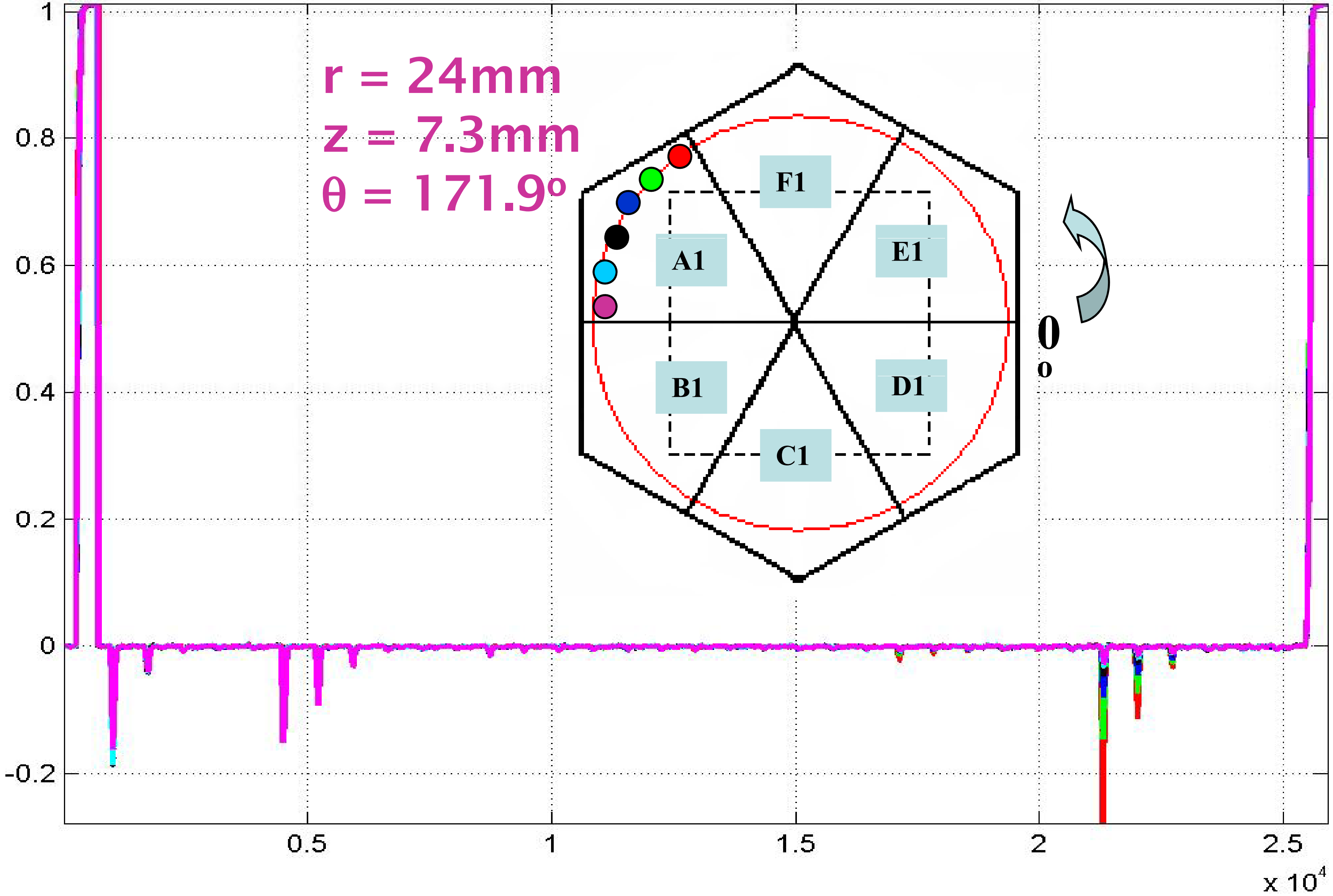
AGATA detector scanning





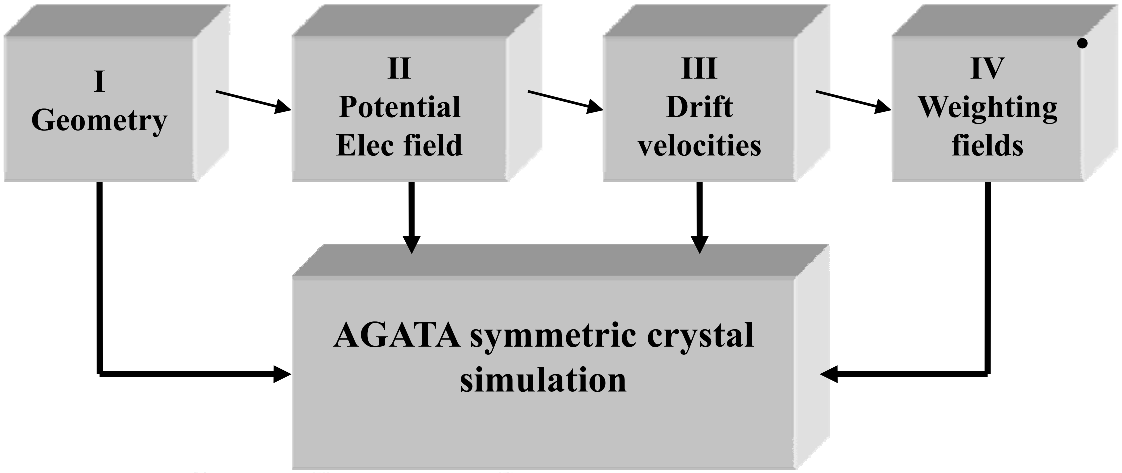


Azimuthal detector sensitivity

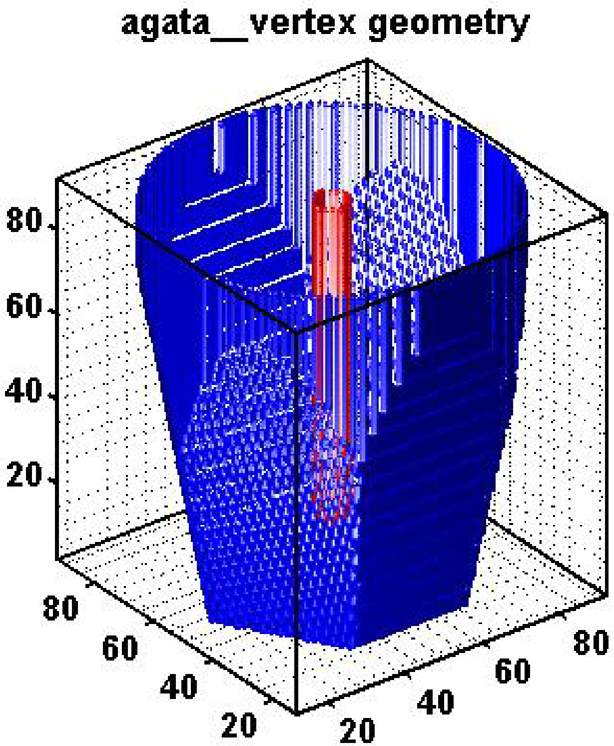


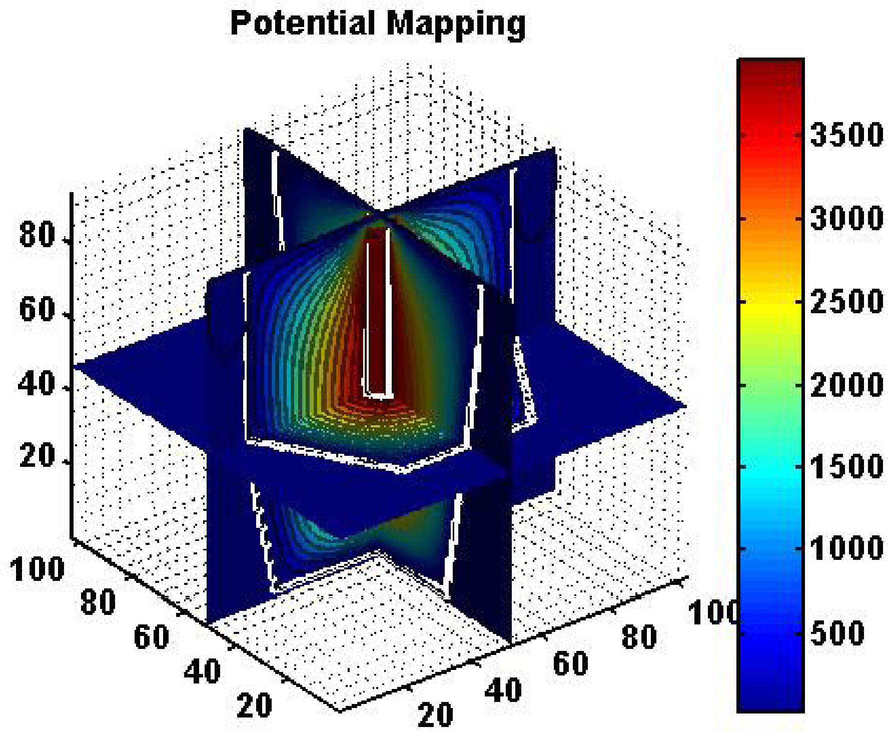
AGATA PSD8 Glasgow

Electric Field Simulations : MGS

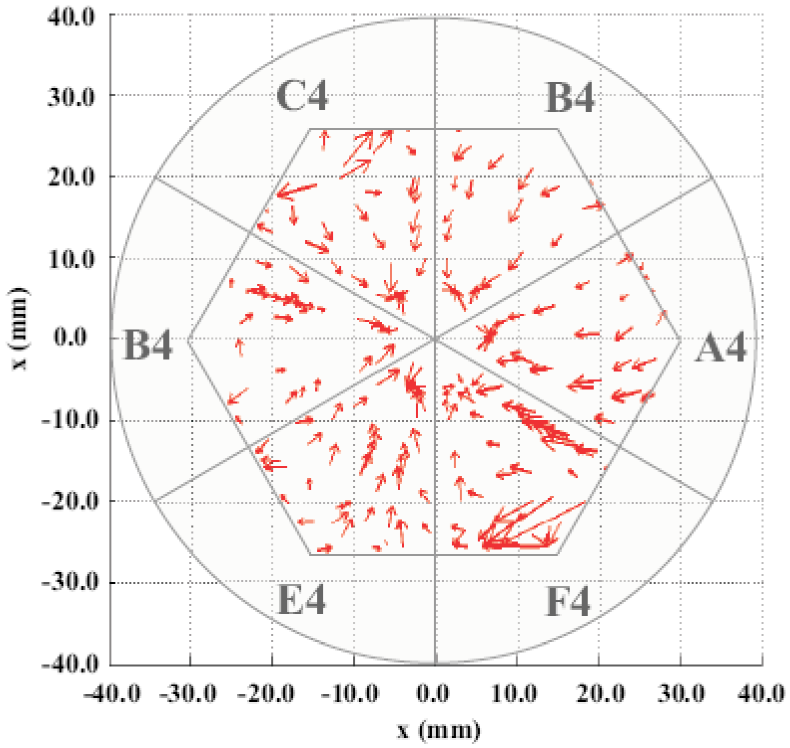


- Electric field simulations have been performed and detailed comparisons have been made with experimental pulse shape data.

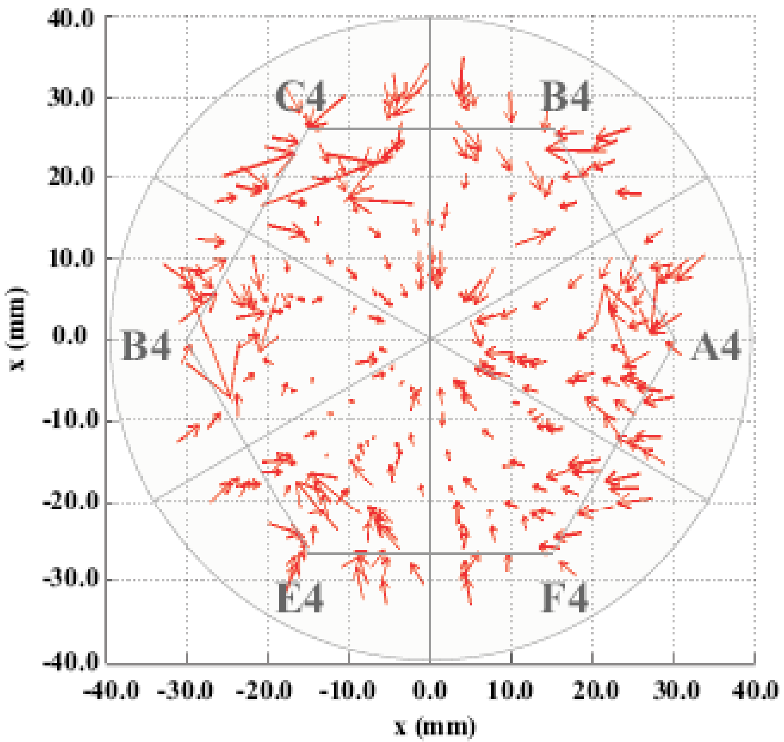




Experiment vs Theory Performance



a) Displacement vectors, z = 4.8±0.3mm



a) Displacement vectors, z = 48.8±0.9mm

Depth (mm)	Ring	Min Displacement (mm)	Max Displacement (mm)	<Displacement (mm)>
4.2±0.3	1	0.1±0.4	11.9±0.4	2.2±0.4
15.7±0.3	1	0.2±0.6	17.3±0.6	2.7±0.6
48.8±0.3	4	0.1±0.7	17.0±0.7	2.6±0.7

Status of the PSA

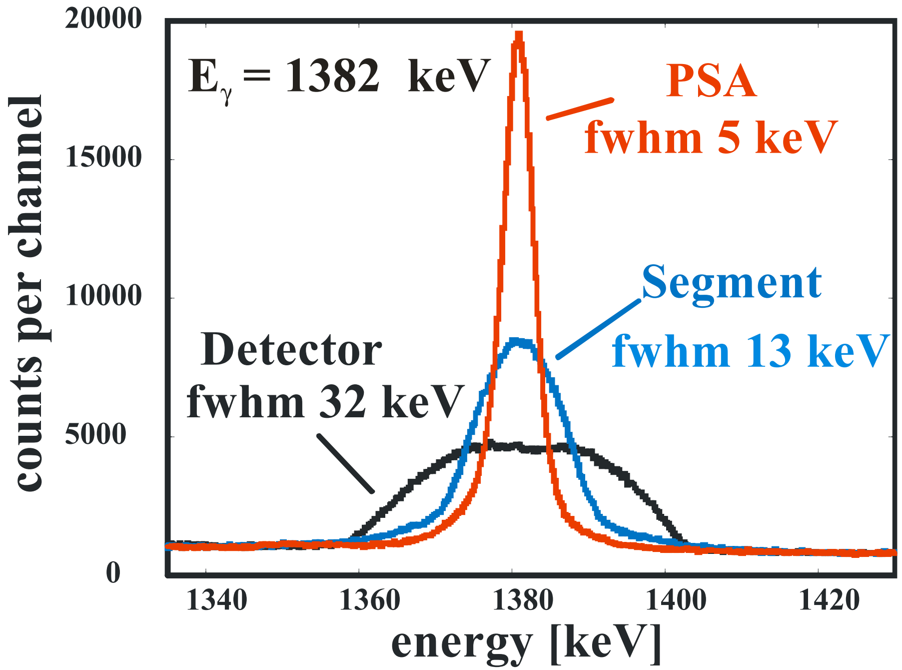
3 types of codes:

- Whole crystal with multi-hits per segment
  - Genetic algo. (Padova, Munich)
  - Swarm algo. (Munich)
  - Adaptative grid search (Padova)
  - Matrix method (Orsay)
- Single-hit in one segment
  - Binary search (Darmstadt)
  - Neural network (Munich, Orsay)
- Determination of the number of hits
  - Recursive subtraction (Milan)
  - Matrix method (Orsay)

Pulse-Shape Analysis: current status

Results from the analysis of an in-beam test with the first triple module, e.g. Doppler correction of gamma-rays using PSA results

d(^{48}Ti,p)^{49}Ti, v/c ~6.5%



Results obtained with *Grid Search* PSA algorithm (R.Venturelli et al.)

Position resolution ~4.4mm

Ingredients of γ-Tracking

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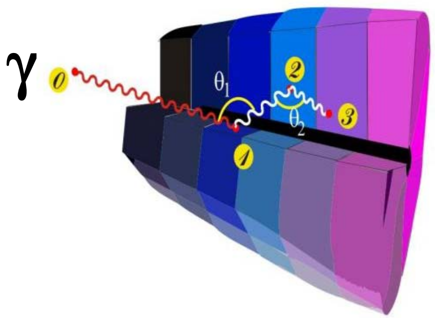
Highly segmented HPGe detectors



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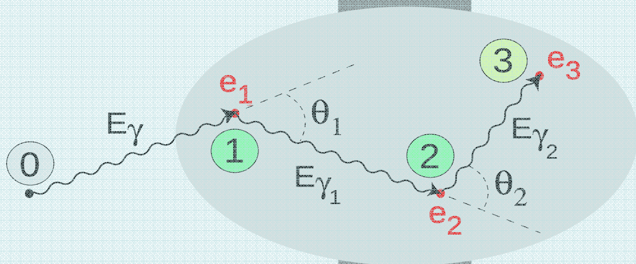
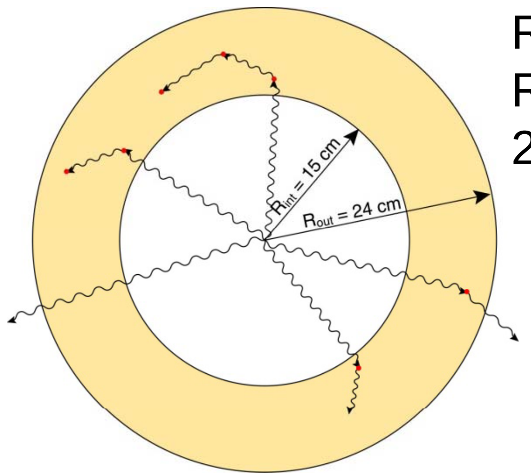


reconstructed γ-rays

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%

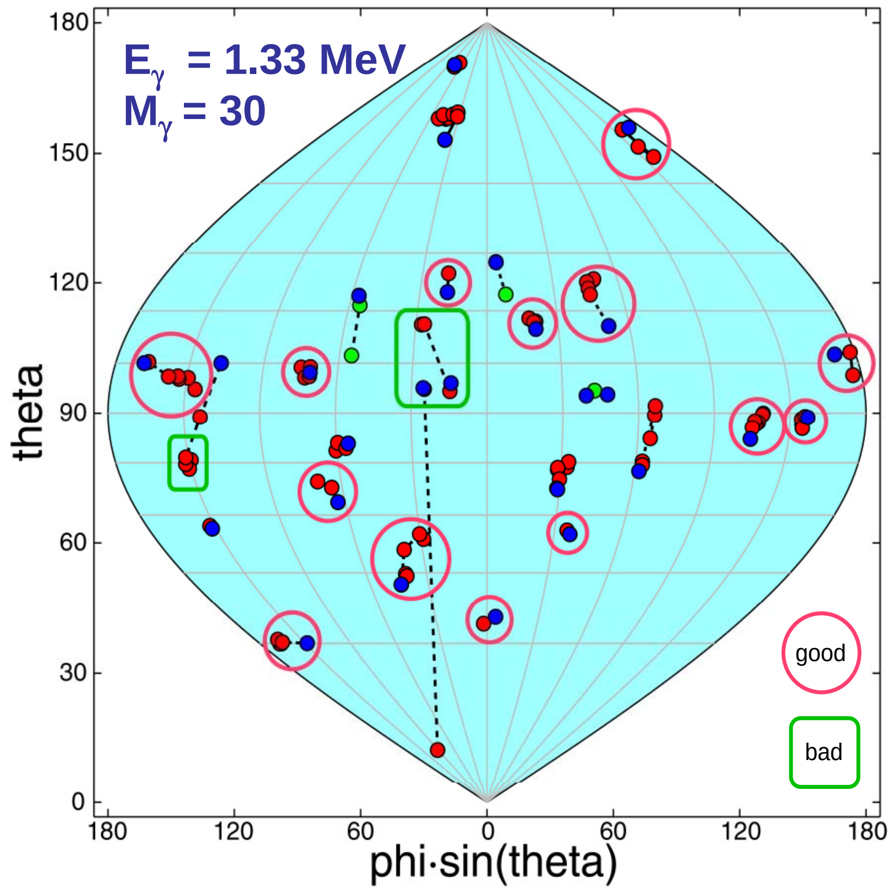
P/T = 85%

M_γ = 30 → ε_{ph} = 36%

P/T = 60%

Assuming 5 mm Position Resolution

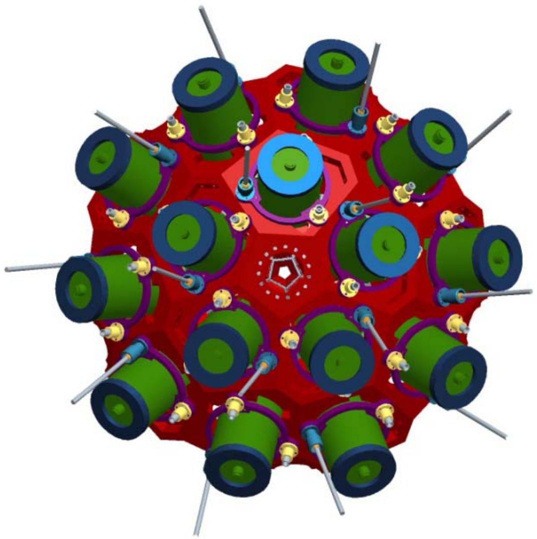
A high multiplicity event

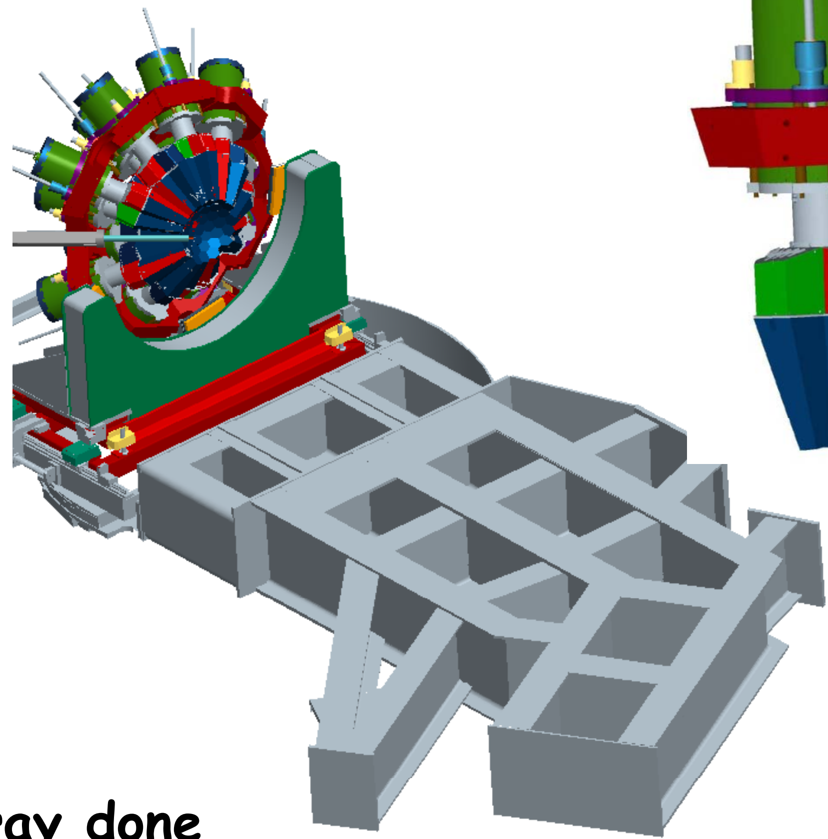


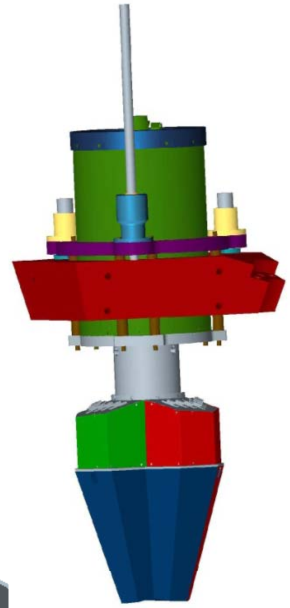
27 gammas detected -- 23 in photopeak

16 reconstructed -- 14 in photopeak

AGATA Design and Construction







180 geometry defined
Conceptual design of 180 array done
Specifications of infrastructure parts done
Design of AGATA demonstrator for LNL complete
Flanges manufactured
Assembly in LNL, complete

Objective of the final R&D phase 2003-2008

1 symmetric triple-cluster

5 asymmetric triple-clusters

36-fold segmented crystals

540 segments

555 digital-channels

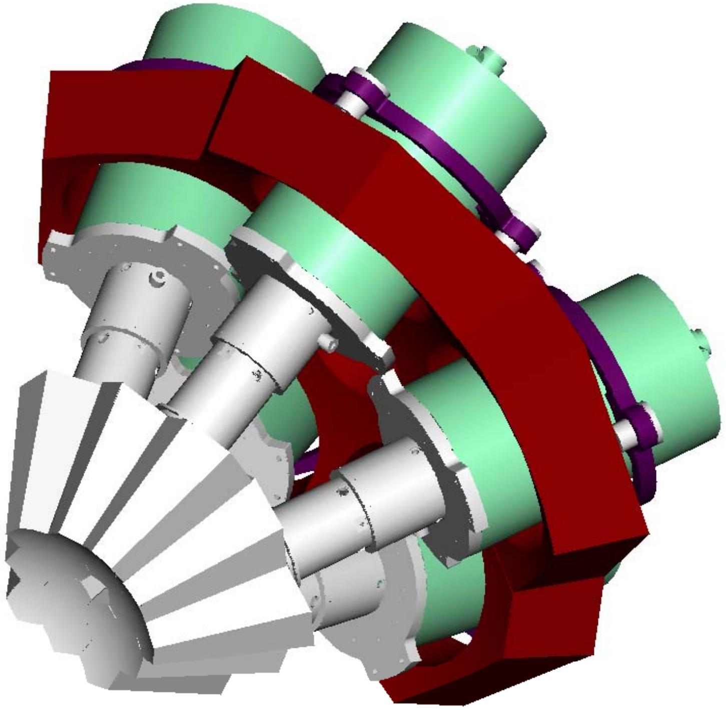
Eff. 3 – 8 % @ M_{γ} = 1

Eff. 2 – 4 % @ M_{γ} = 30

Full ACQ

with on line PSA and γ-ray tracking

Cost ~ 7 M €



Commissioning Preliminary Plan

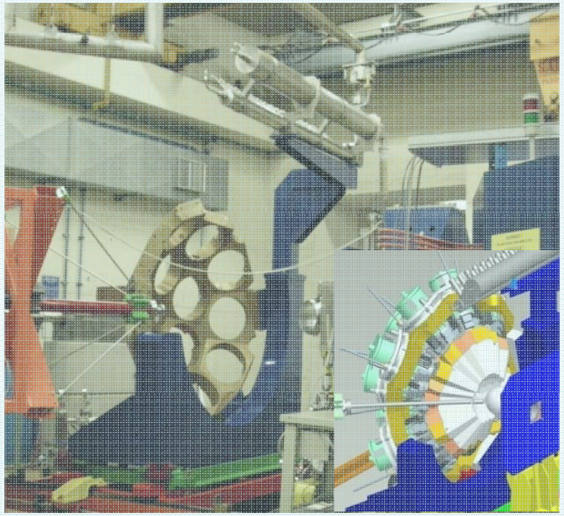
- **Phase 0:** commissioning with radioactive sources starting when detectors and electronics are available (even partially).
- **Phase 1:** easy test with tandem beams with no ancillary detectors. Radiative capture or fusion-evaporation reactions with light targets in inverse kinematics.
- **Phase 2:** test with a "simple" ancillary detector with limited number of parameters (DANTE). Coulomb excitation reactions with medium mass beams (A<100) in inverse kinematics.
- **Phase 3:** test with PRISMA with multi-nucleon transfer reactions and at high multiplicity with appropriate ancillaries.

The earliest possibility to run in-beam tests is Dec.2008

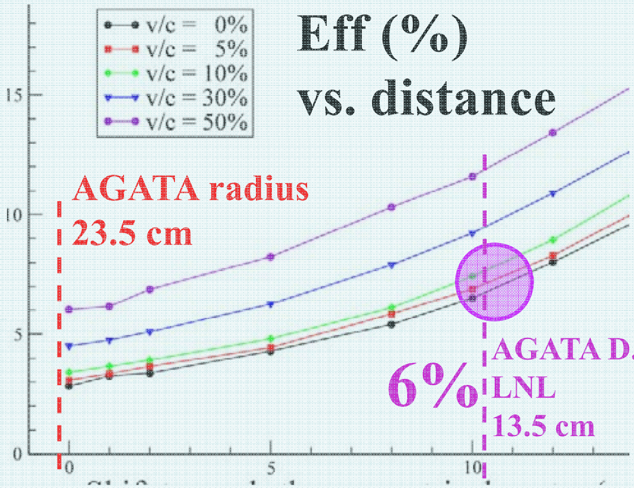

AGATA Demonstrator at PRISMA

AGATA Experimental Program

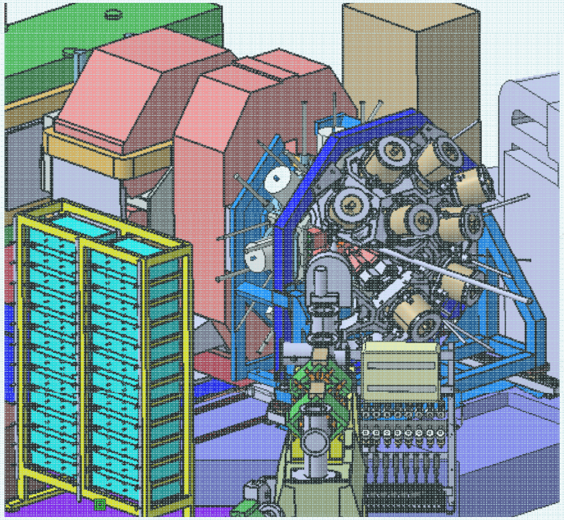
2008 → LNL
6TC



AGATA D. + PRISMA



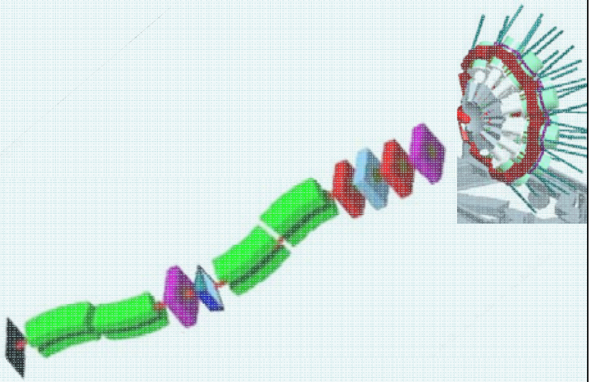
2010 → GANIL/SPIRAL
≥ 8TC



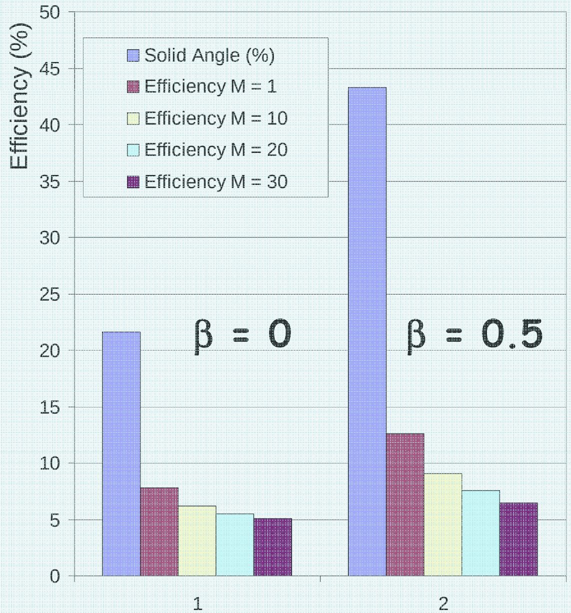
AGATA + VAMOS

AGATA D. ≥8TC
EXOGAM 8 seg.
Clovers
Total Eff. > 10%
Setup works also as
Compton Polarimeter

2012 → GSI / FRS
~15TC (1π)



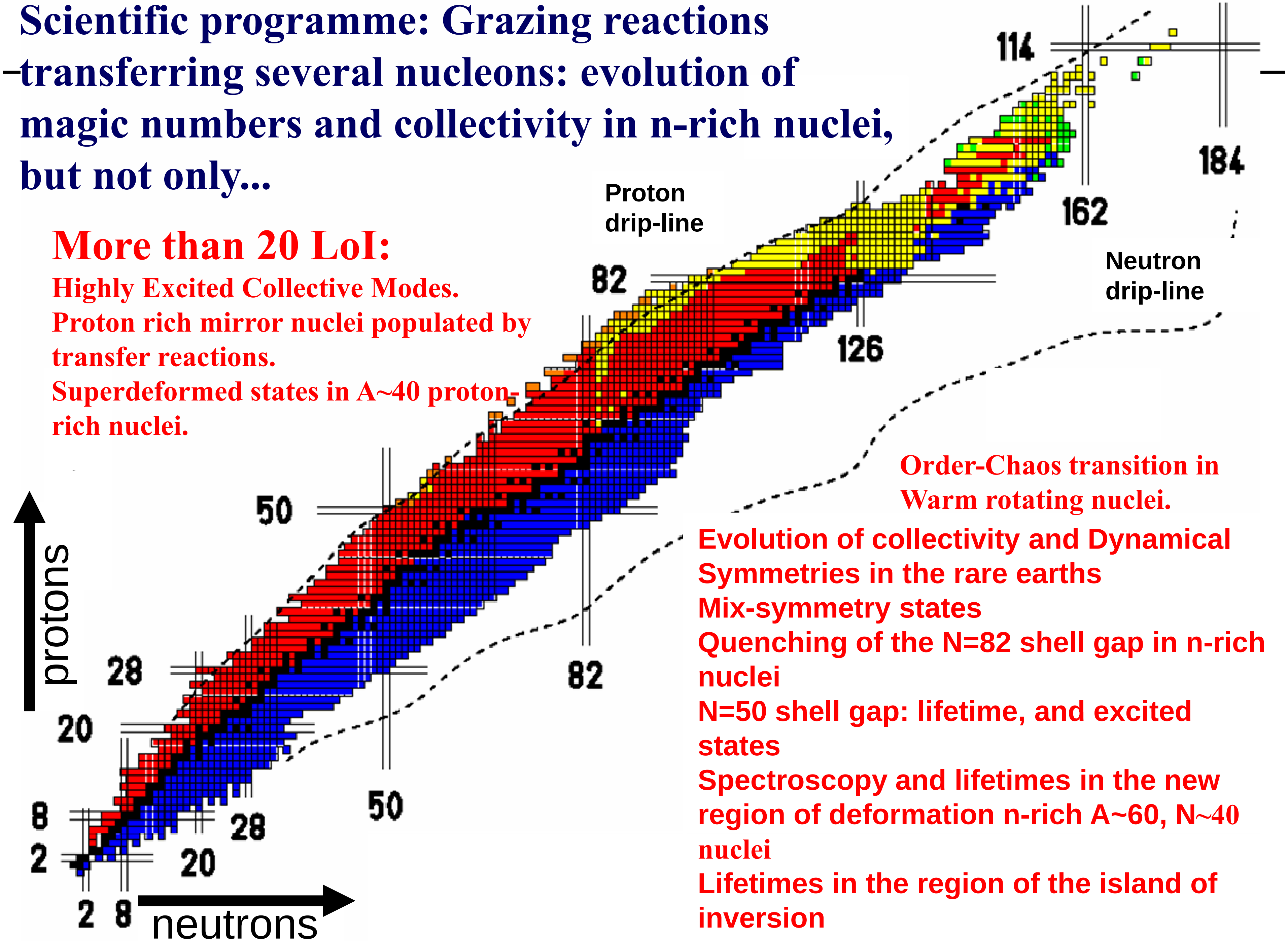
AGATA @ FRS



Scientific programme: Grazing reactions transferring several nucleons: evolution of magic numbers and collectivity in n-rich nuclei, but not only...

More than 20 LoI:

Highly Excited Collective Modes.
Proton rich mirror nuclei populated by transfer reactions.
Superdeformed states in A~40 proton-rich nuclei.



Order-Chaos transition in Warm rotating nuclei.

Evolution of collectivity and Dynamical Symmetries in the rare earths
Mix-symmetry states
Quenching of the N=82 shell gap in n-rich nuclei
N=50 shell gap: lifetime, and excited states
Spectroscopy and lifetimes in the new region of deformation n-rich A~60, N~40 nuclei
Lifetimes in the region of the island of inversion

AGATA demonstrator at GANIL (~2010/11)

Main physics opportunities:

- Spectroscopy of heavy elements towards SHE
- Gamma-ray spectroscopy of neutron-rich nuclei populated in Deep Inelastic Reaction (with the GANIL specific aspects)
- Gamma-ray spectroscopy with reactions at intermediate energies (up to 50 A.MeV)
- Classical high-spin physics and exotic shapes

Range of beams, fragmentation, SPIRAL, direct beam line

AGATA "post-demonstrator" array at GSI-FRS (~2012/13)

Main physics opportunities:

Gamma-ray spectroscopy with reactions

- at relativistic energies (> 50 A.MeV)

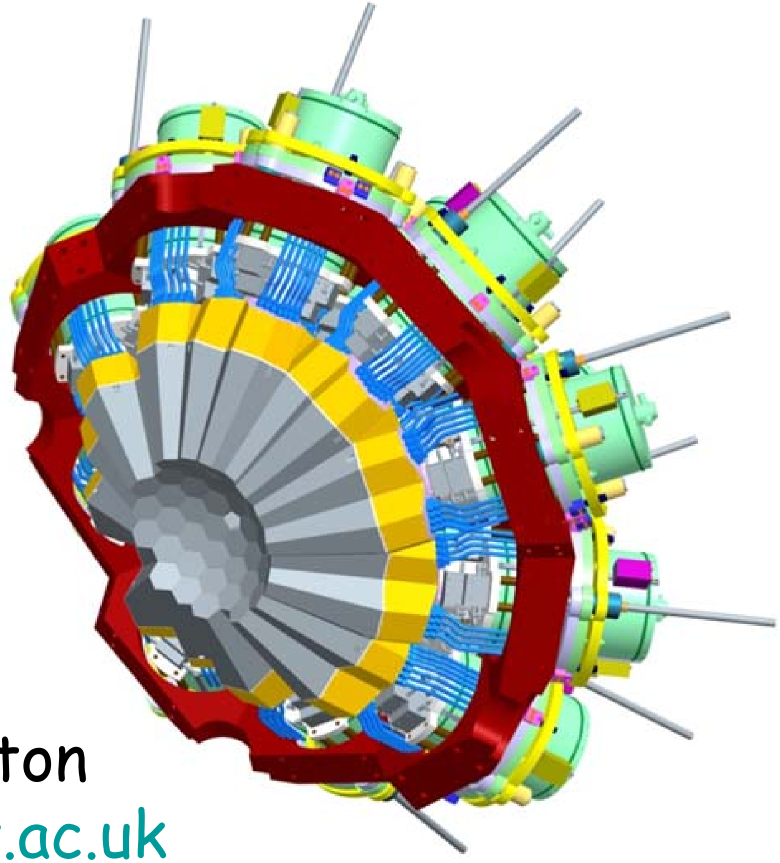
  Coulomb excitation, few nucleon removal etc.

- with slowed-down beams (10-20 A.MeV)

  direct reactions, inelastic scattering


FAIR

What the Advanced Gamma Tracking Array can do for us
Nuclear science in the 21st century



http://www.gsi.de/agata/

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