AGATA
The Advanced Gamma Ray Tracking Array

Dino Bazzacco, INFN Padova
on behalf of the AGATA collaboration

- Next "big" European 4π γ-array for NS studies at
  - Radioactive beam facilities: GSI, GANIL, SPES, … EURISOL
  - High intensity stable beam facilities: LNL, Jyväskylä, ...
- Based on years of worldwide R&D on γ-ray tracking
- Collaboration of 10 EU countries
  - Funded by national agencies and by EU
- Constructed in phases
  - Demonstrator 2003 · · · 2007
  - Phases of Full Array · · ·

Workshop on the Experimental Equipment for RIA, March 18-22, 2003, Oak Ridge

The AGATA Collaboration

- ***Bulgaria:*** Univ. Sofia
- ***Denmark:*** NBI Copenhagen
- ***Finland:*** Univ. Jyväskylä
- ***France:*** GANIL Caen, IPN Lyon, CSNSM Orsay, IPN Orsay, CEA-DSM-DAPNIA Saclay, IReS Strasbourg
- ***Germany:*** HMI Berlin, Univ. Bonn, GSI Darmstadt, TU Darmstadt, FZ Jülich, Univ. Köln, LMU München, TU München
- ***Italy:*** INFN/Univ. Padova, Milano, LNL, Firenze, Camerino, Napoli, Genova
- ***Poland:*** NINP & IFJ Krakow, SINS Swierk, HIL & IEP Warsaw
- ***Romania:*** NIPNE & PU Bucharest
- ***Sweden:*** Univ. Lund, KTU Stockholm, Univ. Uppsala
- ***UK:*** CLRC Daresbury, Univ. Brighton, Keele, Liverpool, Manchester, Paisley, Surrey, York

AGATA Organisation

Steering Committee **ASC**
Chair: Marcello Pignanelli, Milan
14 representatives of 10 EU countries

Management Board **AMB**
PM: John Simpson, Daresbury
7 Working Groups

Detector Module J.Eberth	Local Level Processing R.Krücken	Conceptual Design and Global Level Processing D.Bazzacco	Design and Infrastructure G.Duchêne	Ancillary Detectors and their Integration A.Gadea	Data Analysis J.Nyberg	EU Contact W.Korten

~20 Working Teams

R&D on γ-ray tracking

- MC simulations

  EGS4, MCNP, GEANT3 → GEANT4

- gamma-ray tracking algorithms

  Clusterization*, Backtracking,

  Forward Fuzzy Tracking, Probabilistic Tracking, …

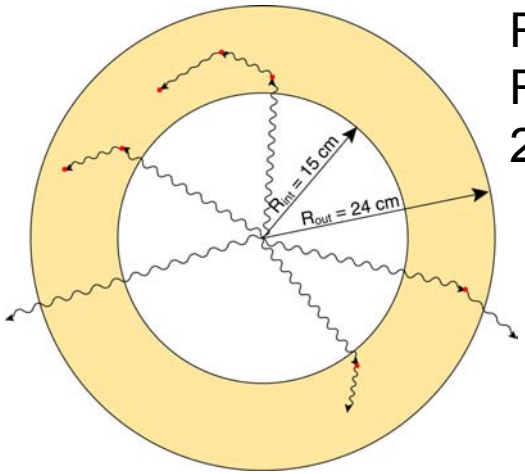
- Pulse Shape Analysis
- Segmented Ge detectors
- Electronics (→ in Electronics-III)

→ In beam test of detector & PSA

*For consistency, all quoted figures are from the Clusterization algorithm

The "Standard" Germanium Shell

Idealized configuration to determine maximum attainable performance



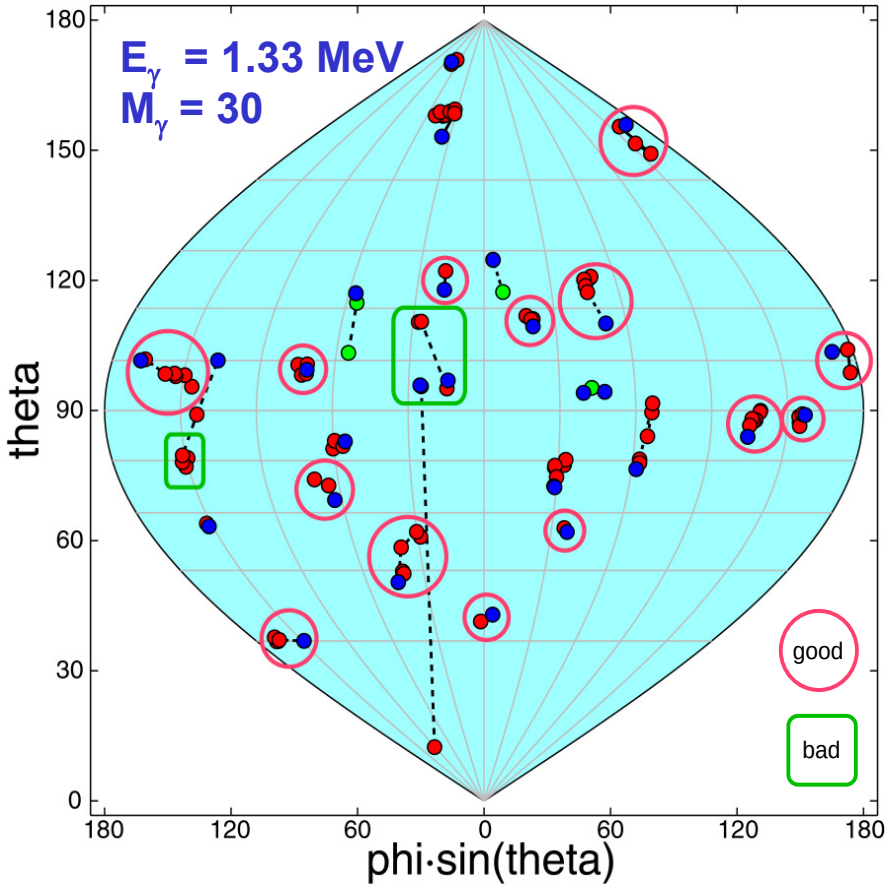
R_i = 15 cm
R_o = 24 cm
230 kg of Ge

M_γ= 1 → ε_{ph} = 65%
P/T = 85%

M_γ= 30 → ε_{ph} = 36%
P/T = 60%

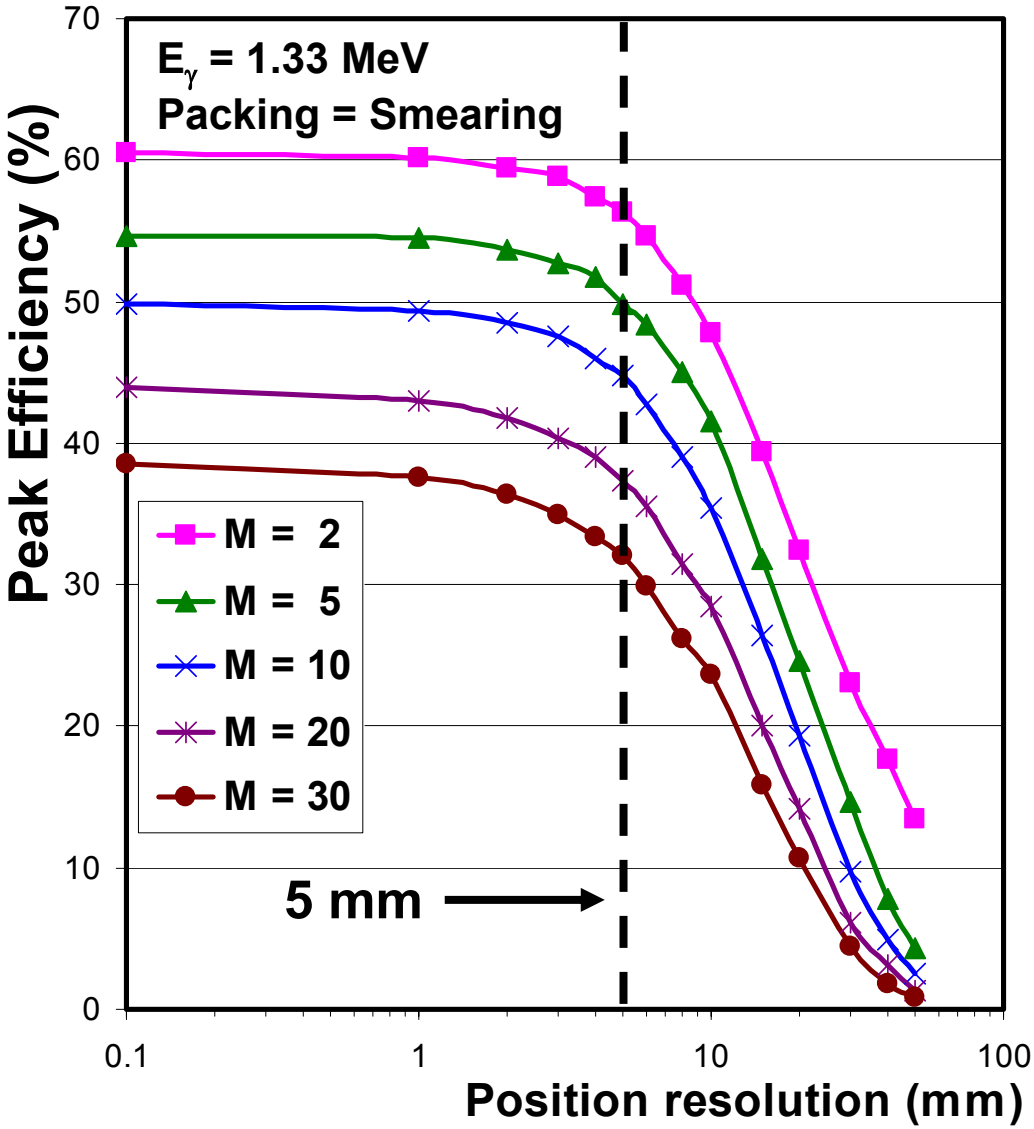
Assuming 5 mm Position Resolution

A high multiplicity event



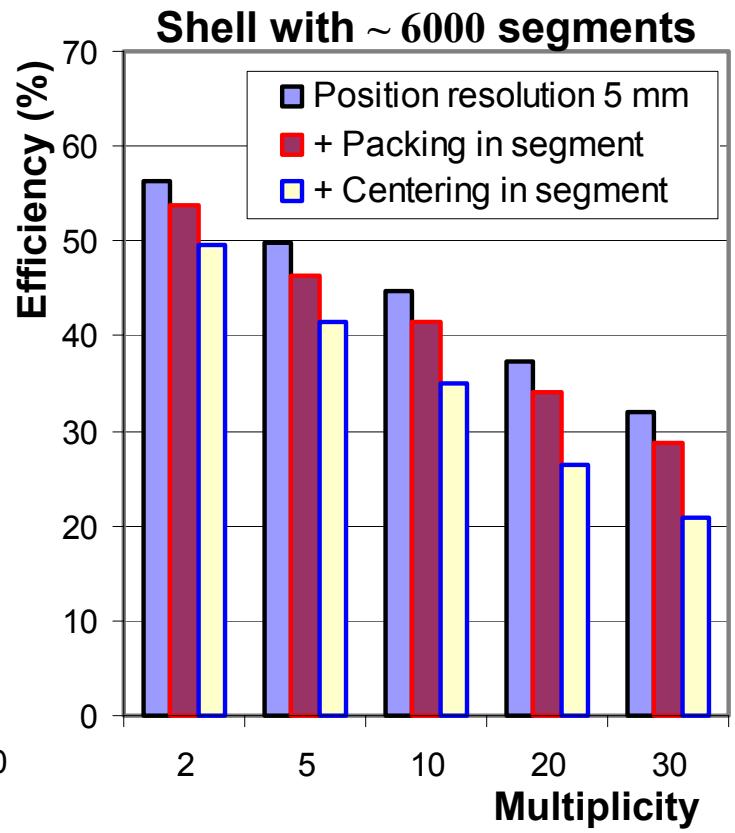
27 gammas detected -- 23 in photopeak
16 reconstructed -- 14 in photopeak

Effciency of Standard Ge Shell vs. Position Resolution and γ Multiplicity



The biggest losses are due to multiplicity (mixing of points), not to bad position resolution

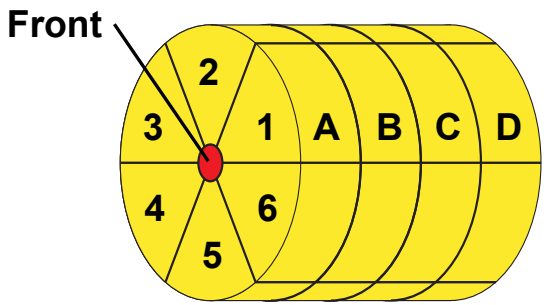
Improve tracking algorithms !!



Segmented Ge detectors & PSA

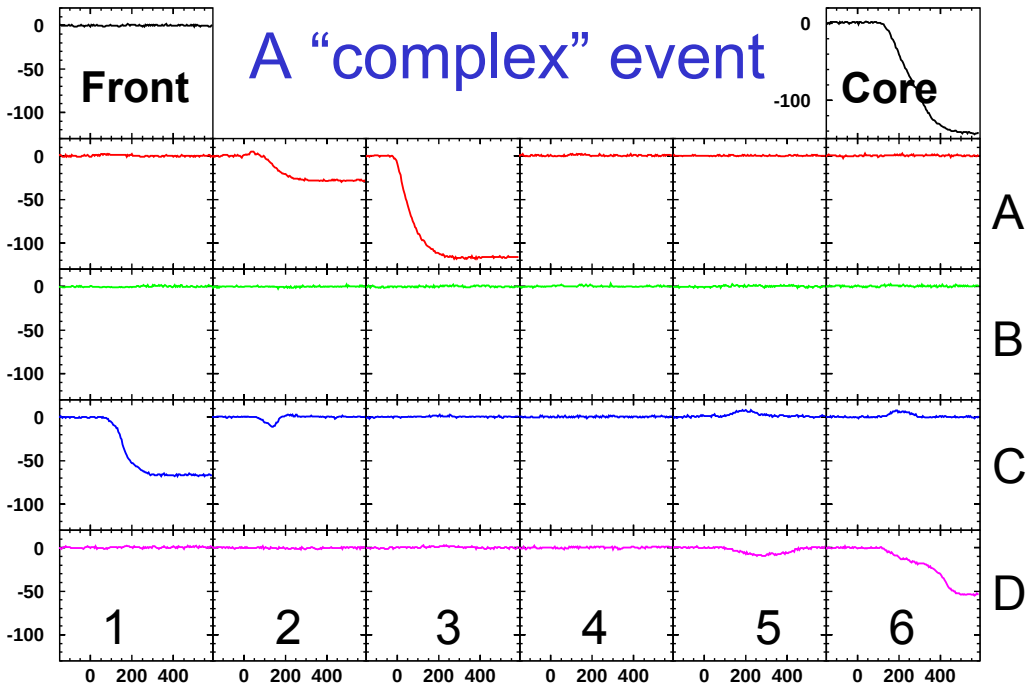
- Medium-fold segmentation
  - VEGA → 4-fold clover, large crystals
  - EXOGAM → 4-fold clovers
  - MINIBALL → 6-fold and 12-fold, hexaconical encapsulated
  - Liverpool → 6 x 2 -fold, cylindrical, inner segmentation
- High-fold segmentation
  - MARS → 25 fold cylindrical
  - TIGRE → 24 fold, 36 fold cylindrical
- Characterisation of detectors → A. Boston
- Pulse Shape Analysis Algorithms
  - GA → works fairly well but very slow
  - ANN → fast but rather impossible to train for complete detector
  - Wavelets based Pattern Recognition
    → being developed for realistic crystals

MARS 25-fold segmented prototype

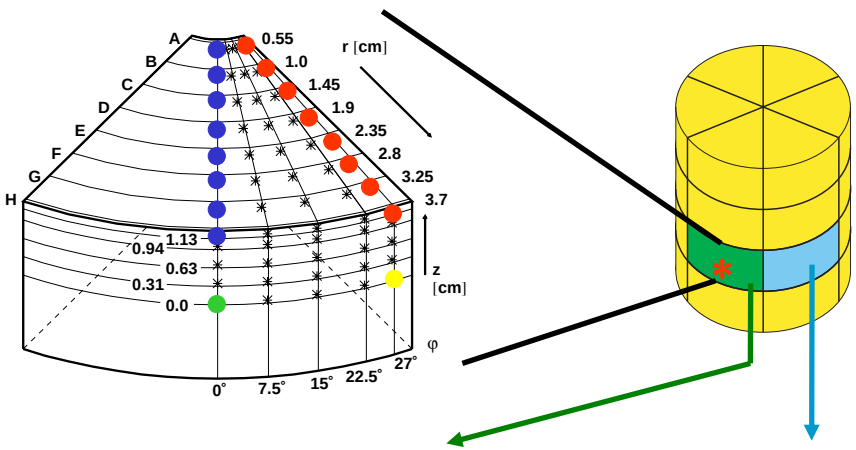


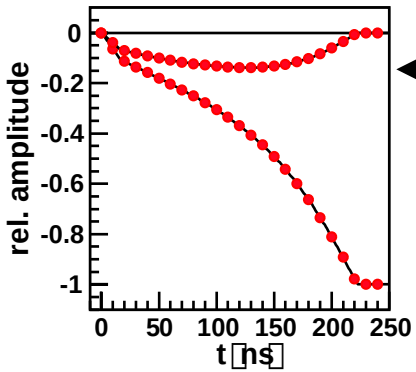
Length: 90 mm
Diameter: 72 mm
Efficiency ~ 80 %
6 × 4 + 1 segments

cold FETs for all segments; warm FET for core



Pulse Shape Calculations and Analysis by a Genetic Algorithm





measured signals

signals reconstructed from base

GA

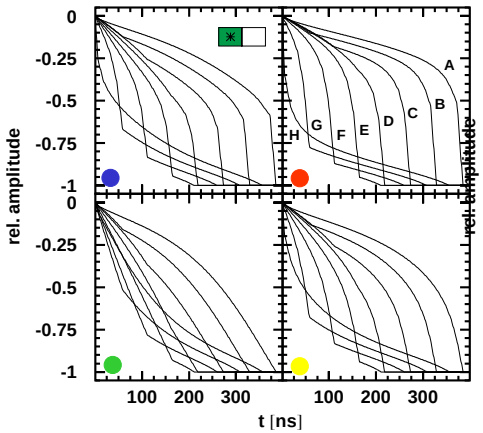
Sets of interaction points $(E; x,y,z)_i$

„fittest“ set

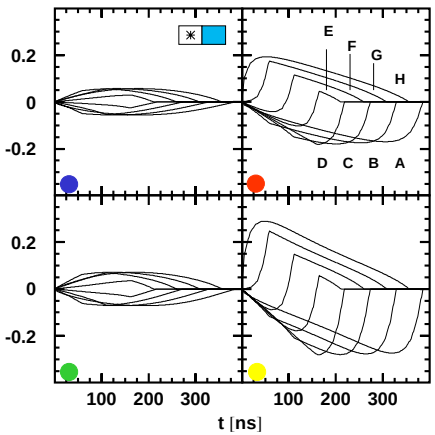
Base system of signals
measured or calculated

Reconstructed set of interaction points $(E; x,y,z)_i$

net charge signals

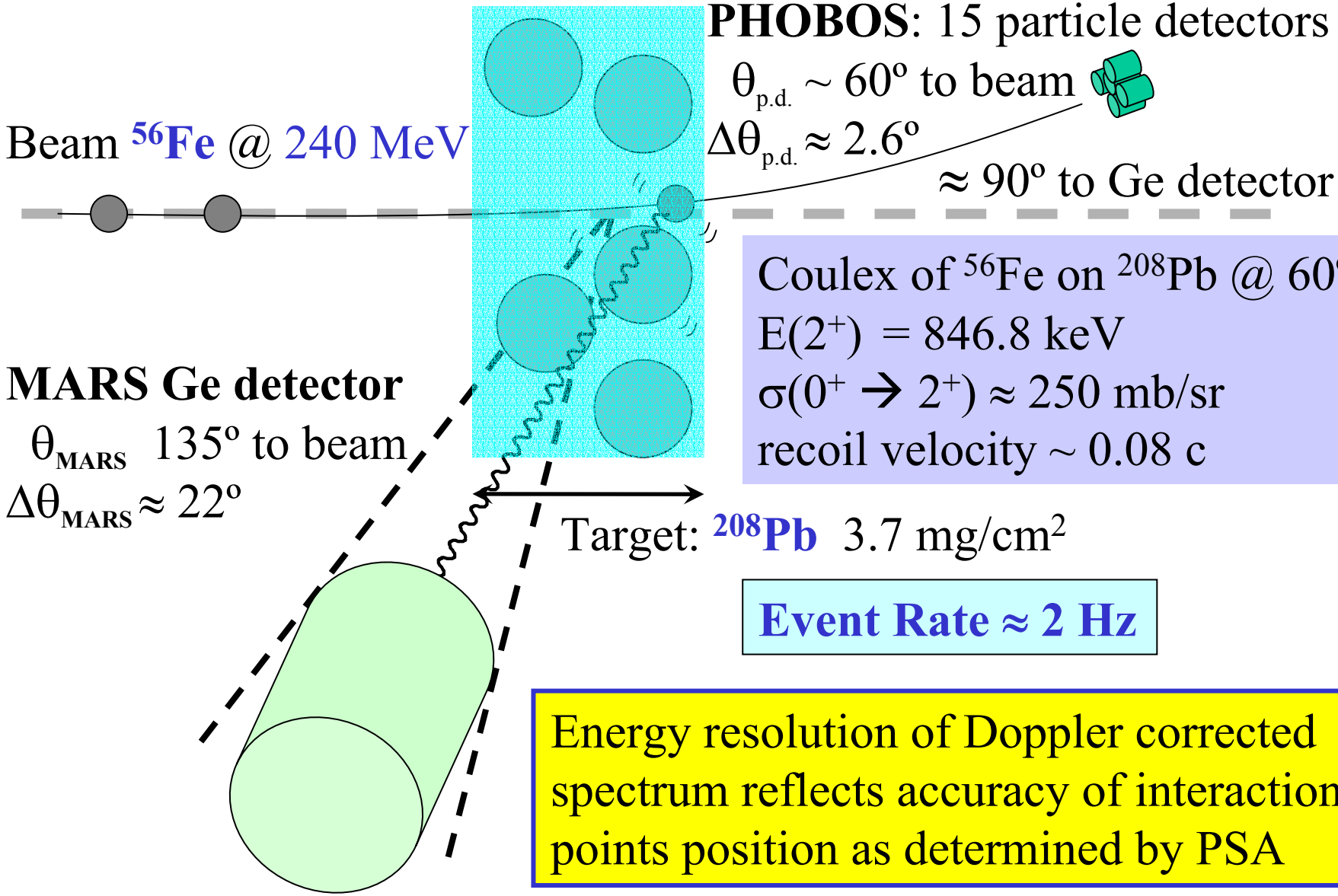


transient signals



Thorsten Kröll, LNL-TUM

In-beam test of PSA performance

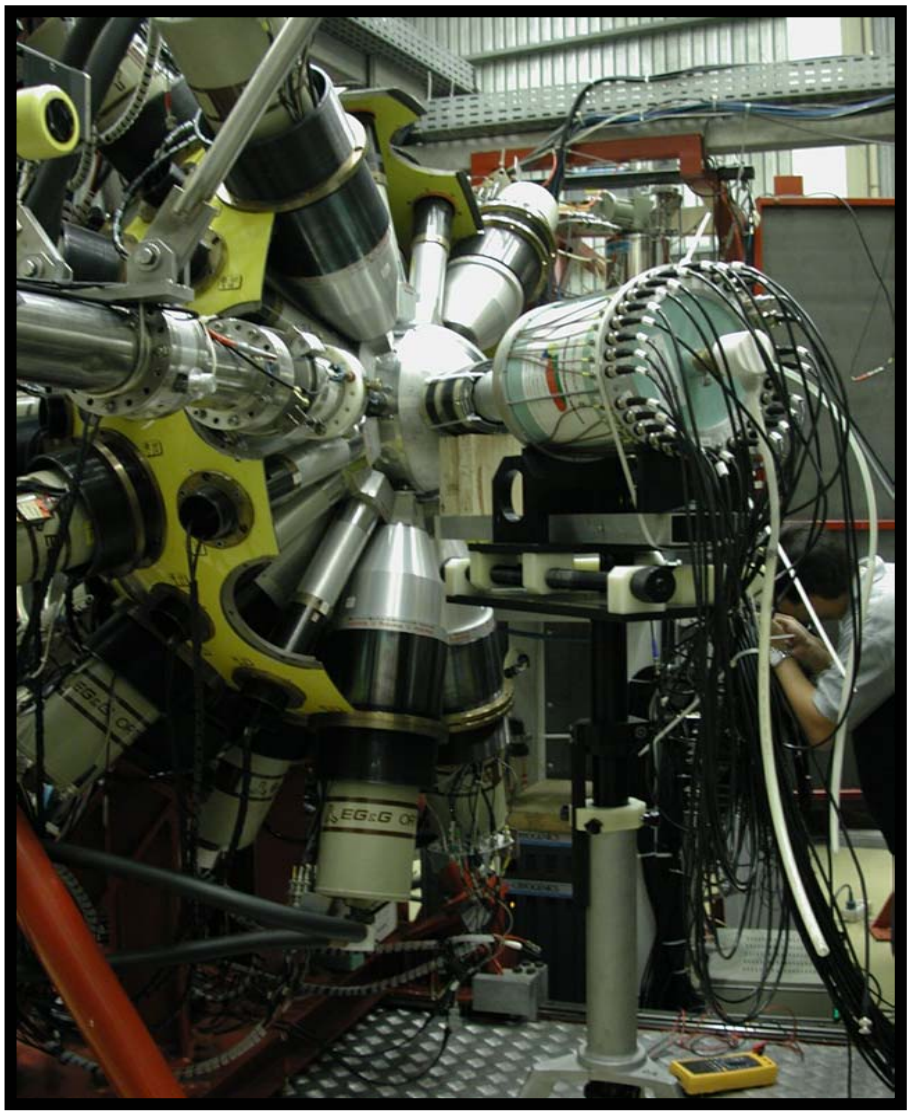


Coulex of ^{56}Fe on ^{208}Pb @ 60º
$E(2^+)$ = 846.8 keV
$\sigma(0^+ \rightarrow 2^+) \approx 250$ mb/sr
recoil velocity ~ 0.08 c

Event Rate ≈ 2 Hz

Energy resolution of Doppler corrected spectrum reflects accuracy of interaction points position as determined by PSA

MARS at GASP



DAQ of MARS

MC Simulation of Experiment

MARS: ϑ = 134.6° φ = 270.4° d = 17 cm

PHOBOS: ϑ = 53.1° φ = 216.5°

Beam: ^{56}Fe 240 MeV

Target: ^{208}Pb $\approx$ 3.7 mg/cm^2

→ Average $\beta \approx$ 7.4%

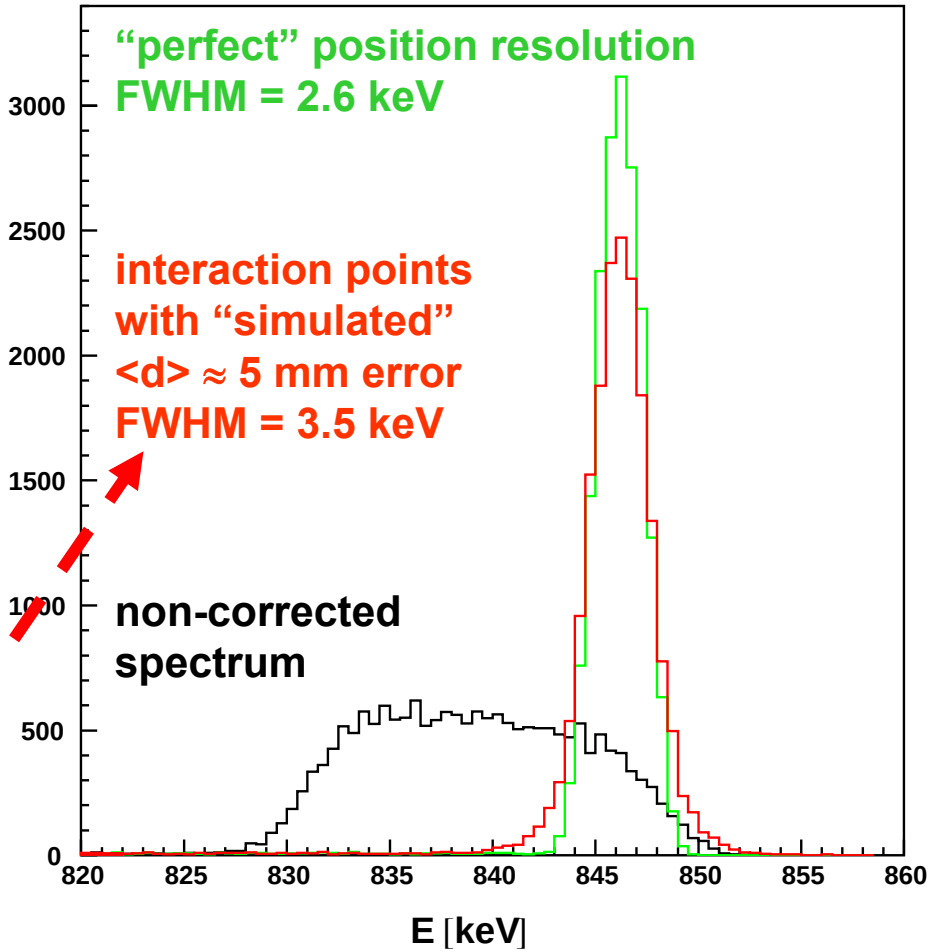
Effects considered in the simulation:

Opening angle of PHOBOS $\pm$ 1.3°

Target thickness

- dE/dx before and after scattering
- σ_{CLX} as function of energy

Beam spot $\pm$ 2 mm



"simulated" error obtained from reconstruction of simulated interactions points using a GA

Simulated resolutions have to be folded with intrinsic energy resolution of detector 2.2 keV @ 846.8 keV

Correction of Doppler Broadening

reconstruction of interaction points by a Genetic Algorithm

Expected final results:

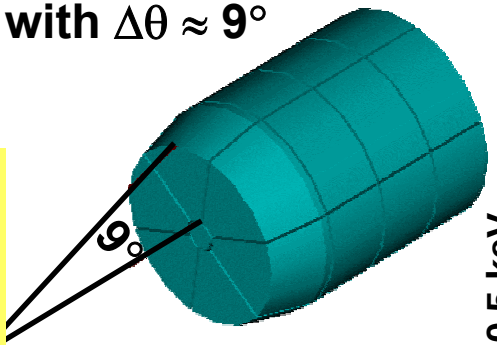
perfect tracking

➔ 3.4 keV

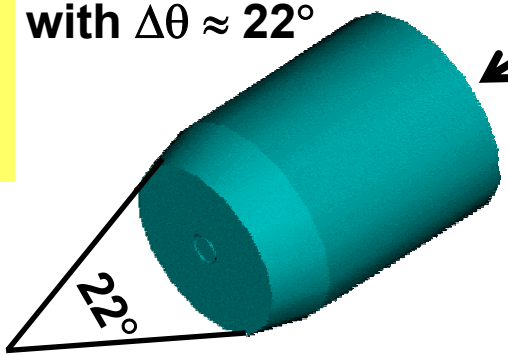
positional error
<d> ≈ 5 mm

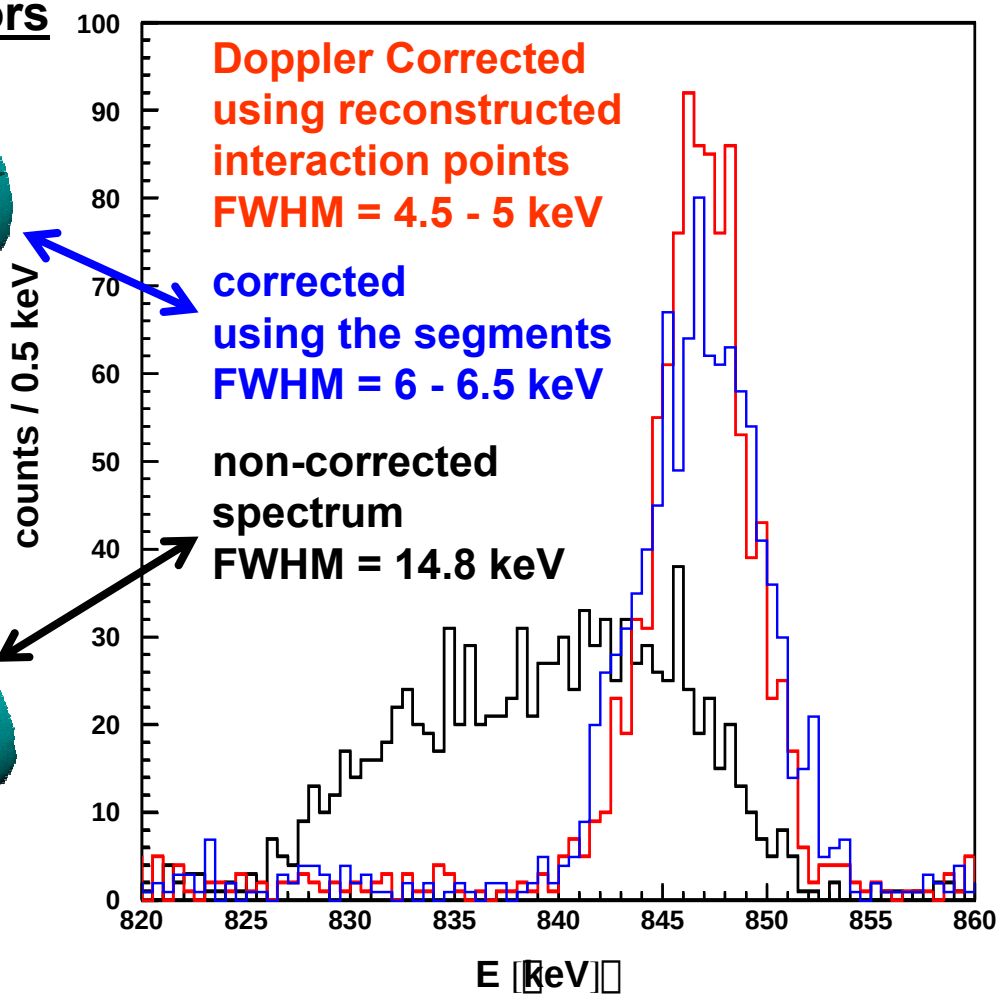
➔ 4.2 keV

24 individual detectors
with Δθ ≈ 9°



single detector
with Δθ ≈ 22°





Tapered detectors will perform better as most of the difficult front part is cut away

Analysis by Thorsten Kröll, LNL-TUM
Only 10% of data analyzed so far

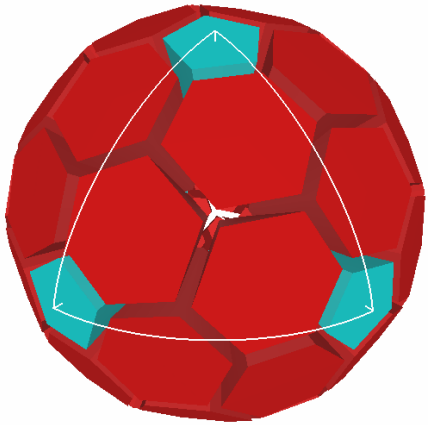
AGATA SPECS

Quantity	Specified for	Target Value
Photo-peak efficiency (ε_{ph})	E_γ = 1 MeV, M_γ = 1, $\beta < 0.5$ E_γ = 1 MeV, M_γ = 30, $\beta < 0.5$ E_γ = 10 MeV, M_γ = 1	50 % 25 % 10 %
Peak-to-total ratio (P/T)	E_γ = 1 MeV, M_γ = 1 E_γ = 1 MeV, M_γ = 30	60 - 70 % 40 - 50 %
Angular resolution ($\Delta\theta_\gamma$)	$\Delta E/E < 1\%$	better than 1°
Maximum event rates	M_γ = 1 M_γ = 30	3 MHz 300 kHz
Inner free space (R_i)		170 mm

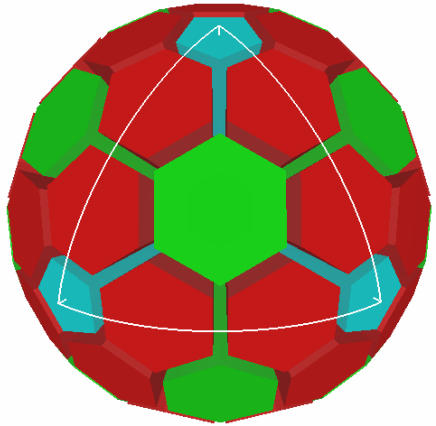
Detector requirements:

efficiency, energy resolution, dynamic range, angular resolution, timing, counting rate, modularity, angular coverage, inner space

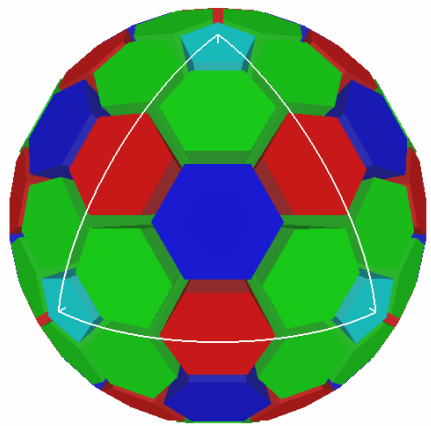
Geodesic Tiling of Sphere using 60–240 hexagons and 12 pentagons



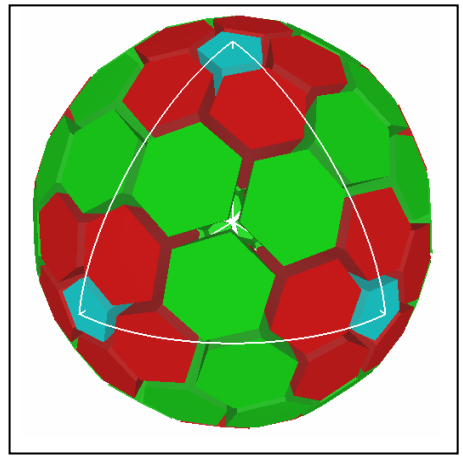
60



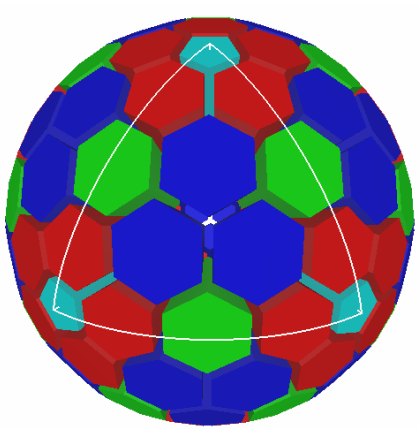
80



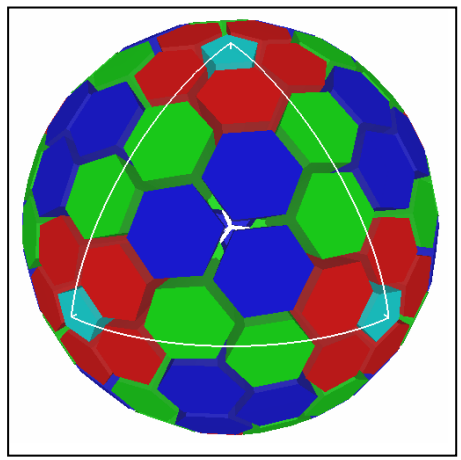
110



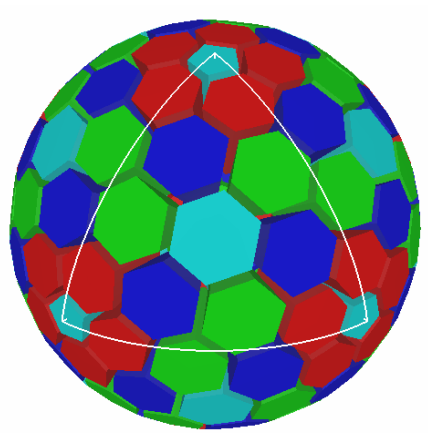
120



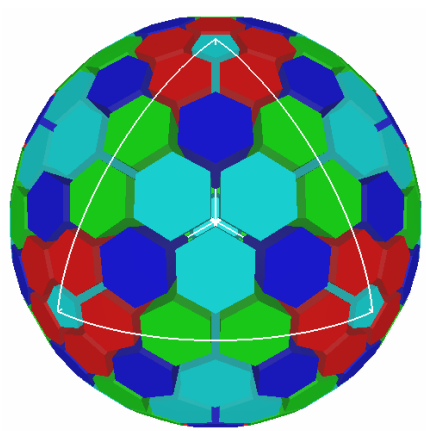
150



180

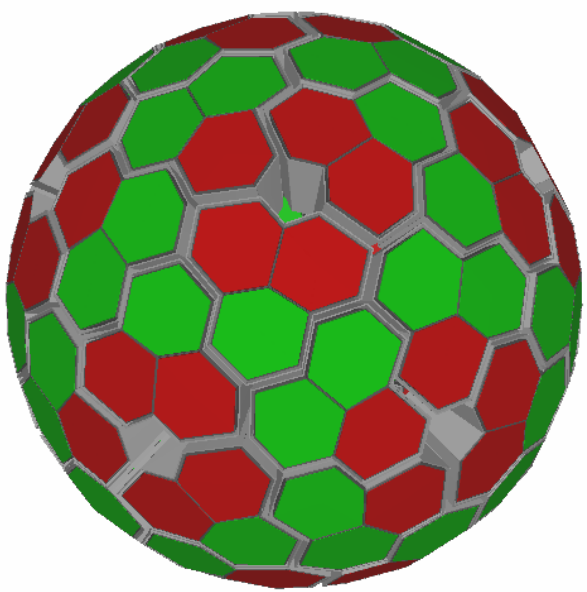


200

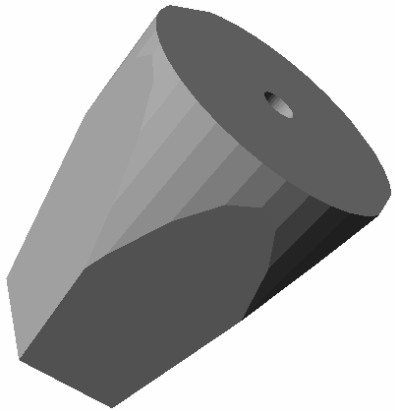


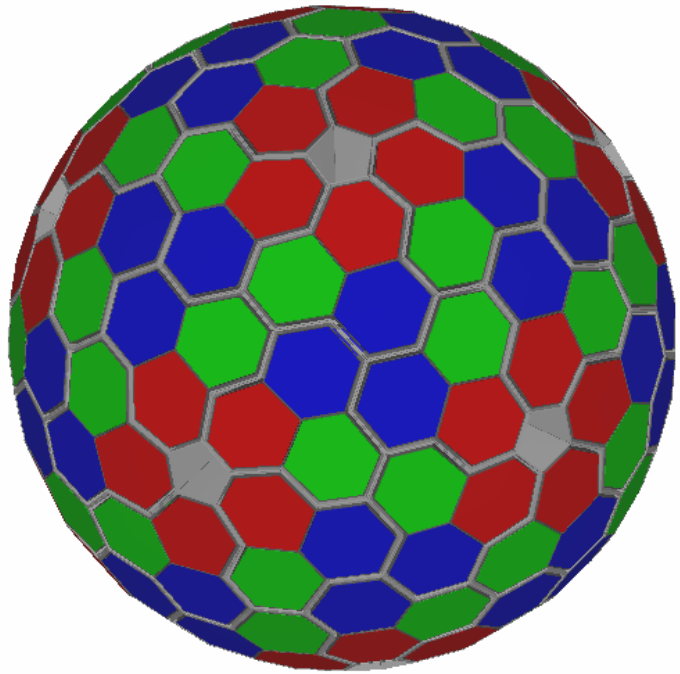
240

Two candidate configurations



Ge crystals size:
length 90 mm
diameter 80 mm





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)

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	

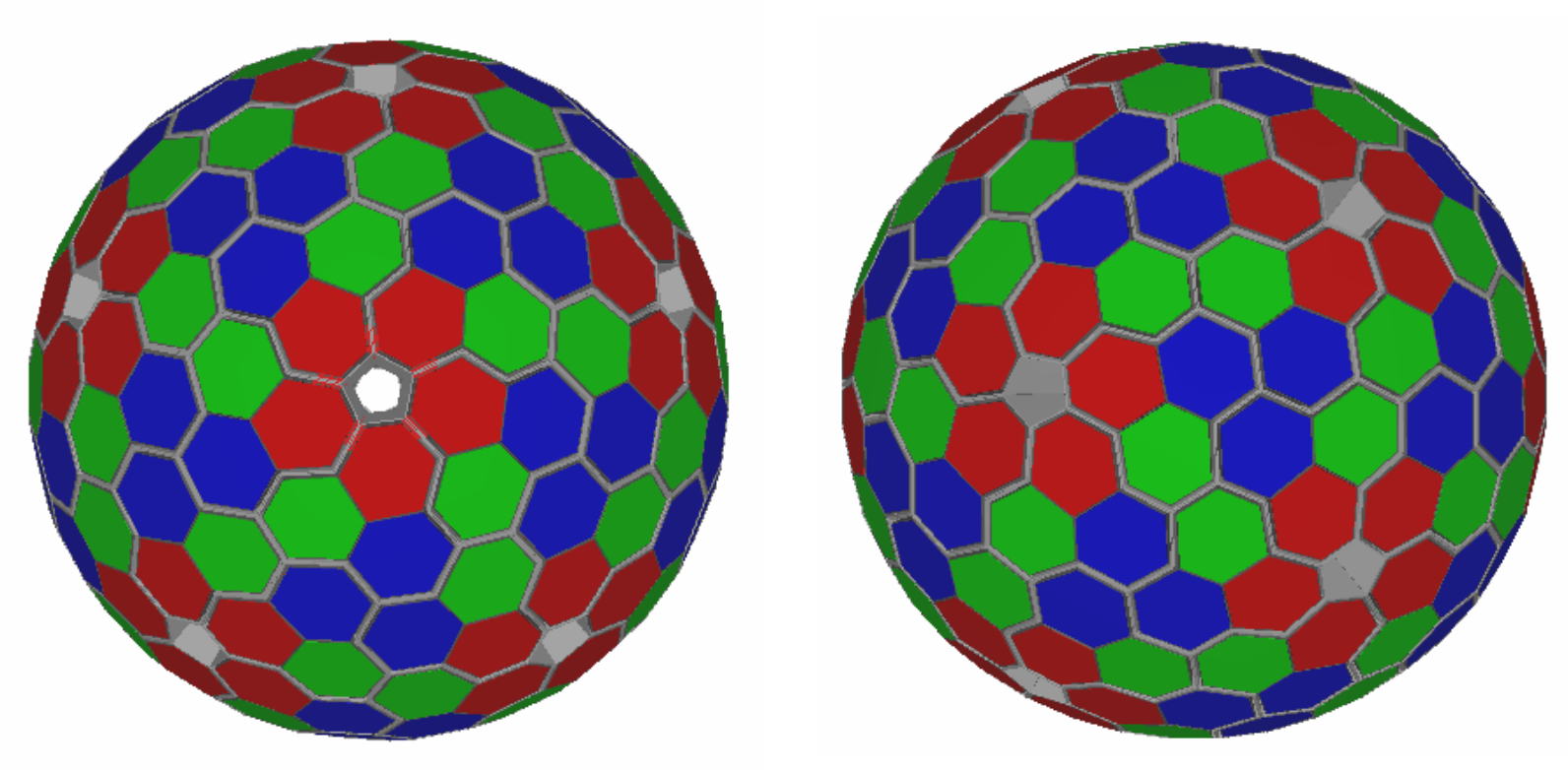
Efficiency: 40% (M_γ=1) 25% (M_γ=30)
Peak/Total: 65% (M_γ=1) 50% (M_γ=30)

Comparison of the 2 configurations

Number of crystals	120	180
Solid Angle (%)	74	80
ε_{ph} / PT at M = 1 (%)	38 / 63	40 / 65
ε_{ph} / PT at M = 1 (%)	21 / 47	25 / 50
Inner free space (cm)	16	21*
Angular resolution		better
Counting rate (kHz)	70	50
Number of clusters / types	40 / 2	60 / 1
Rings of clusters	3-7-10-10-7-3	5-10-15-15-10-5
Angular coverage of rings	irregular	very regular
Electronics channels	4440	6660
Cost	nn M €	30 % higher ?

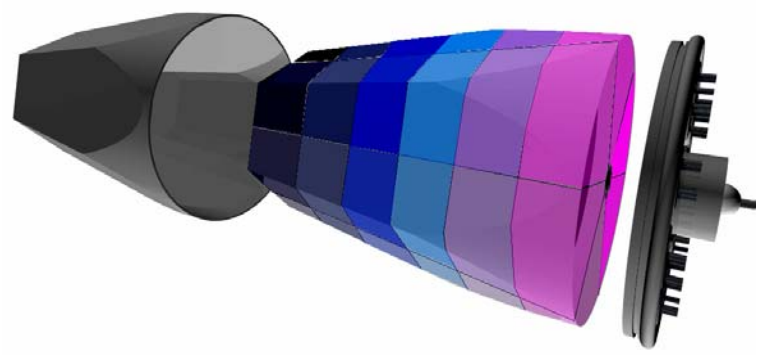
To reduce cost of germanium, A-180 could be squeezed to similar size as A-120.
Efficiency reduces also but all nice symmetries remain; smaller crystals simplify PSA .

The Phases of AGATA-180

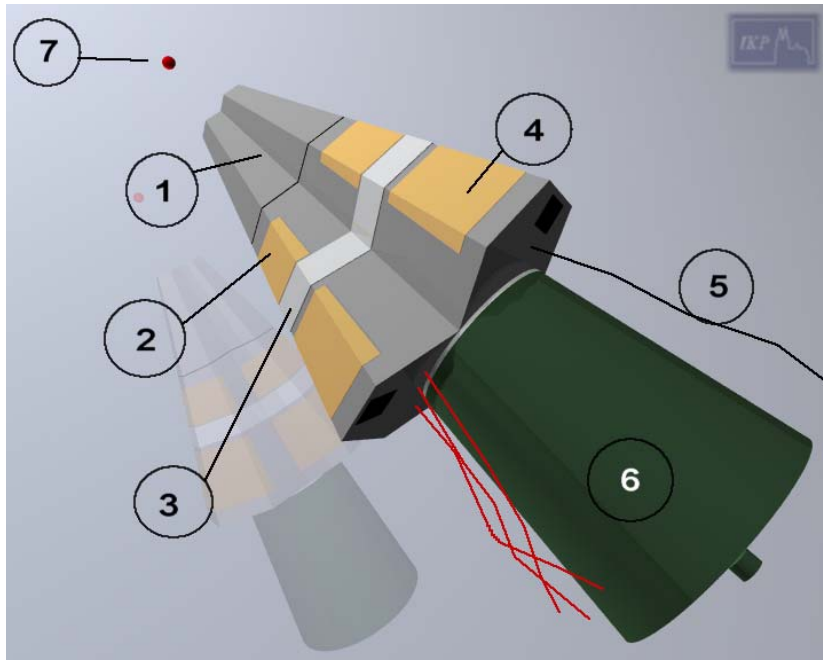


4π Array

AGATA Detectors



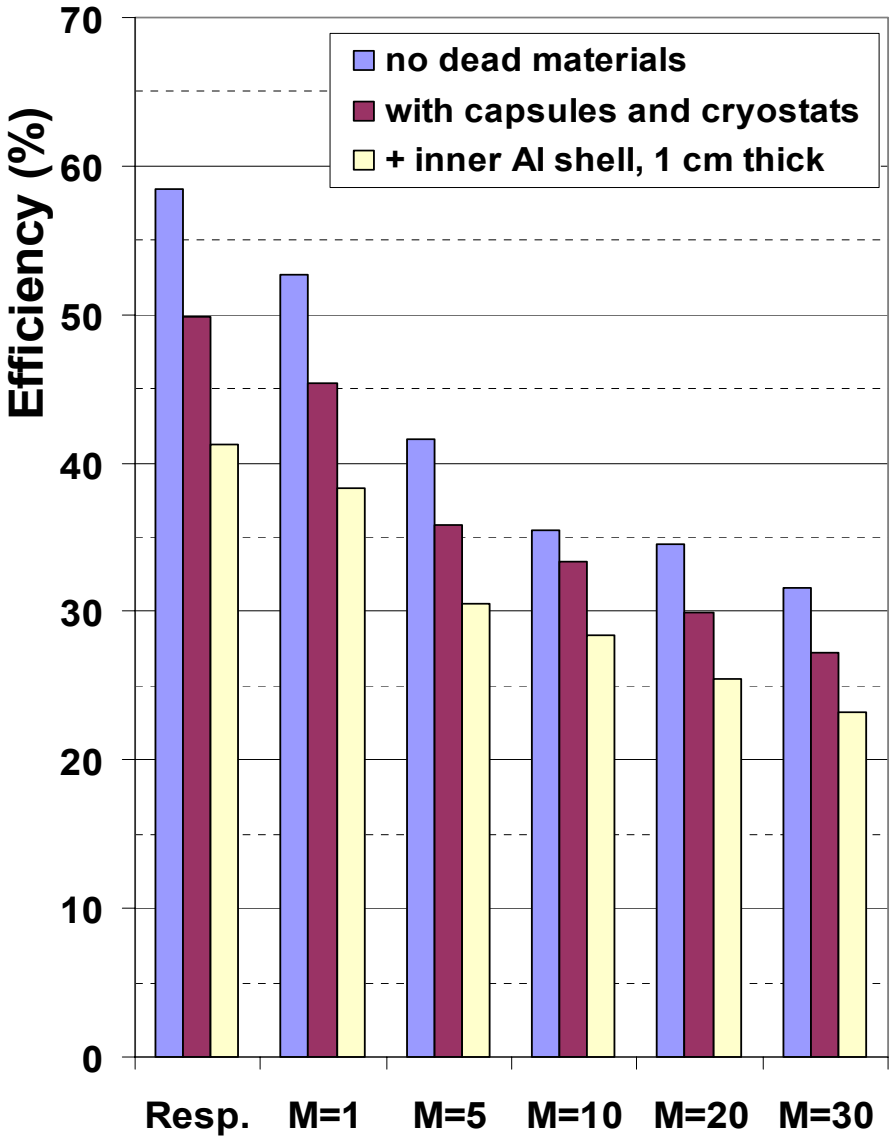
Hexaconical Ge crystals
90-100 mm long
80 mm max diameter
36 segments
Al encapsulatation
    0.6 mm spacing
    0.8 mm thickness
37 vacuum feedthroughs



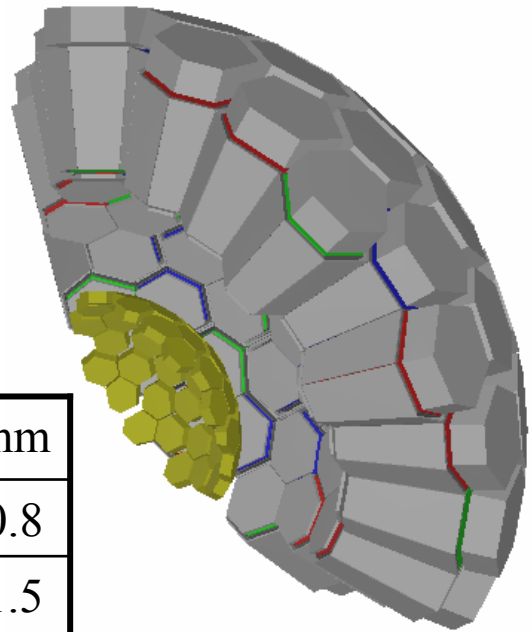
3 encapsulated crystals
111 preamplifiers with cold FET
~230 vacuum feedthroughs
LN_2 dewar, 3 liter, cooling power ~6 watts

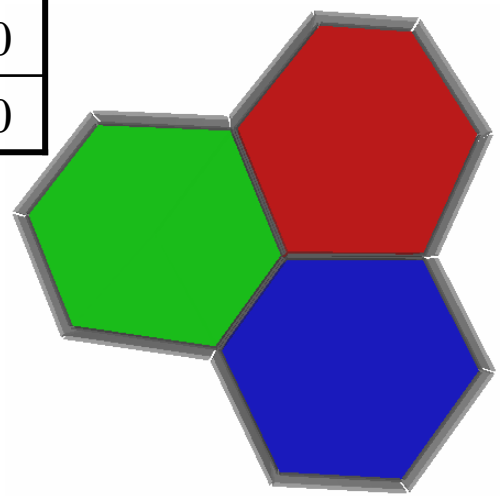
Italy&Germany ordering 3 symmetric encapsulated crystals.
Cryostat will be built by CTT in collaboration with IKP-Köln
Cluster ready by mid 2004

Dead Materials and Inner Detectors



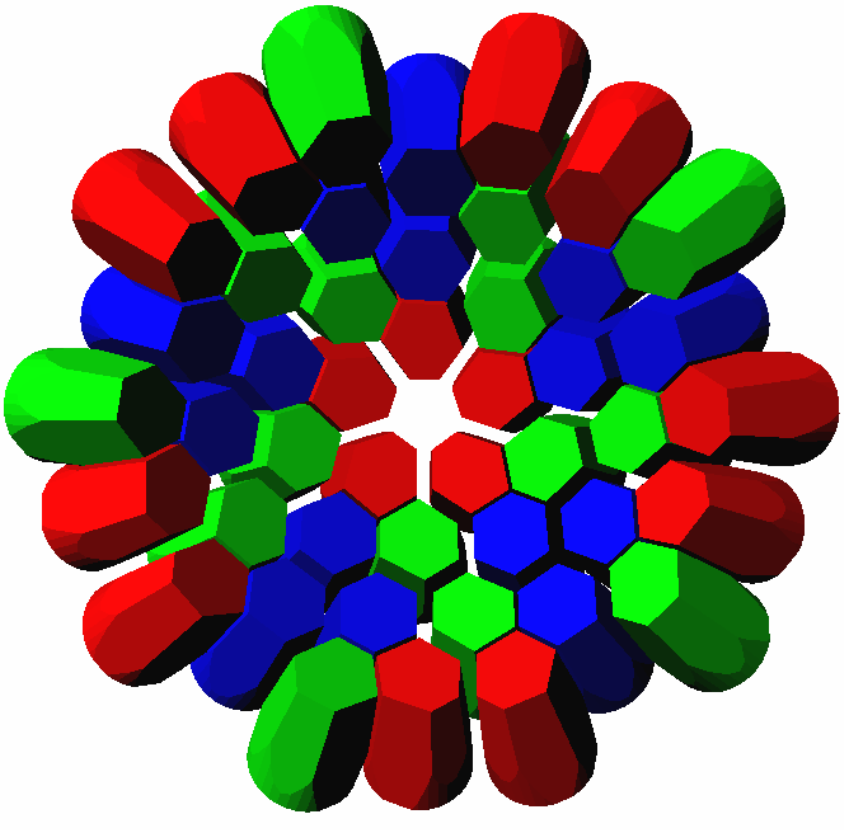
Thickness of	mm
Capsule side	0.8
Cryostat side	1.5
front	3.0
back	30
Inner “ball”	10

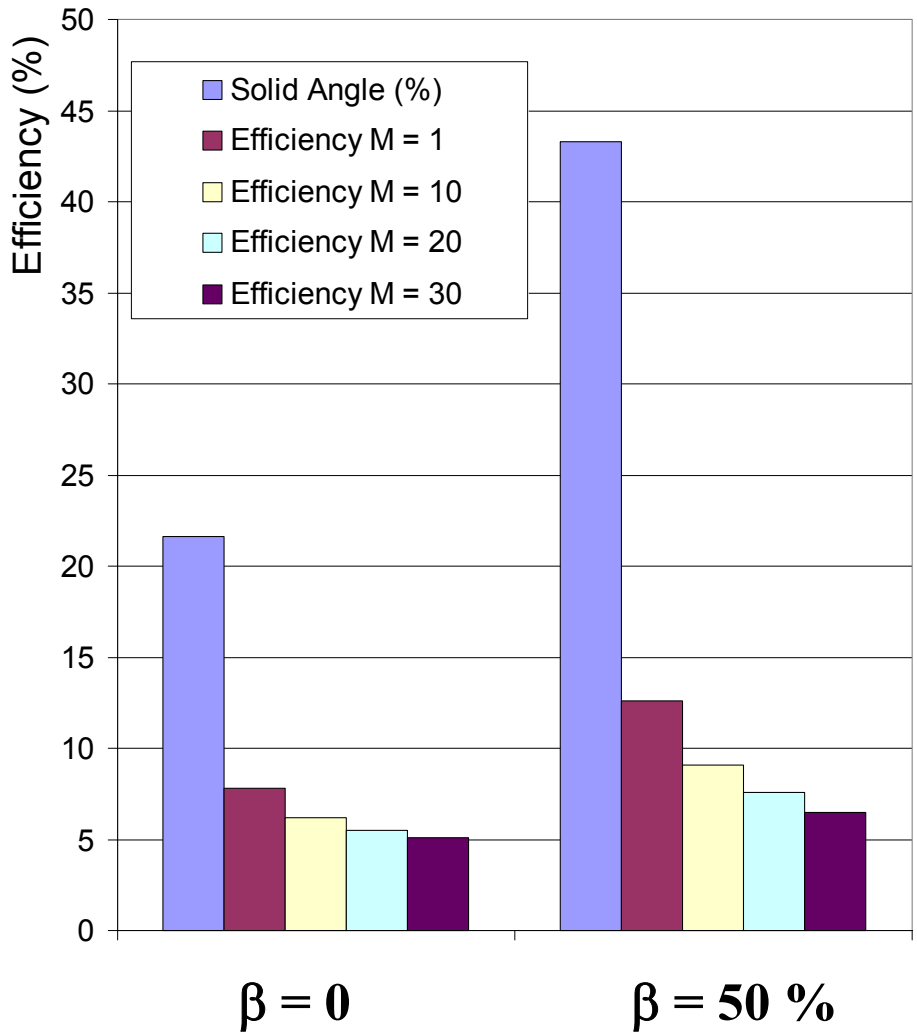




Starting to build AGATA

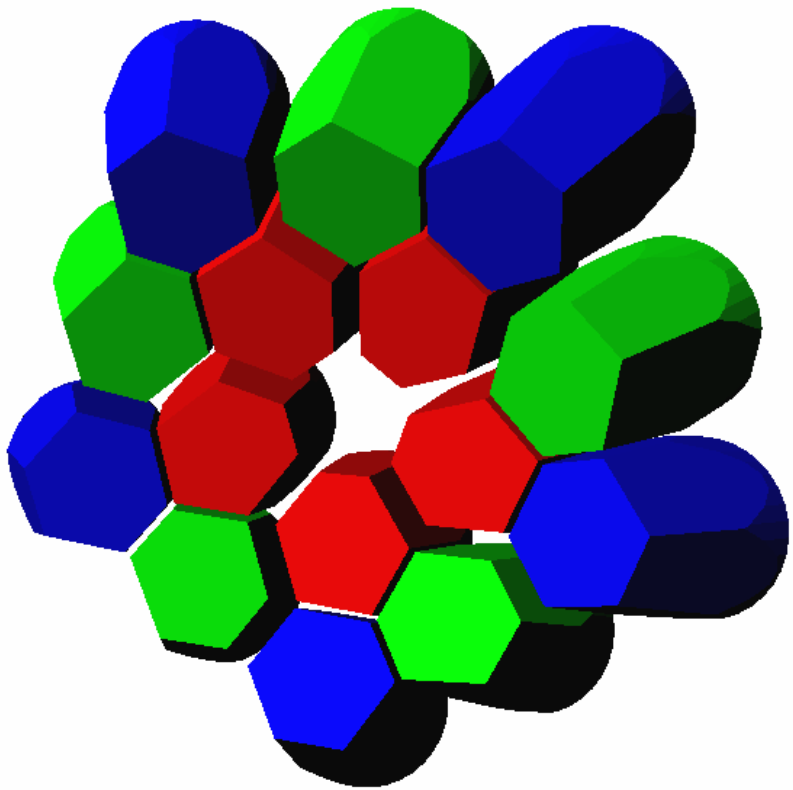
The Forward Quadrant with 45 crystals in 15 triple-clusters





The First Step:
The AGATA Demonstrator

Objective of the final R&D phase 2003-2007



1 symmetric triple-cluster

5 asymmetric triple-clusters

36-fold segmented crystals

540 segments

555 digital-channels

Eff. 3 – 8 % @ $M_\gamma = 1$

Eff. 2 – 4 % @ $M_\gamma = 30$

Full ACQ

with on line PSA and γ-ray tracking

Test Sites:

GANIL, GSI, Jyväskylä, Köln, LNL

Cost ~ 7 M €