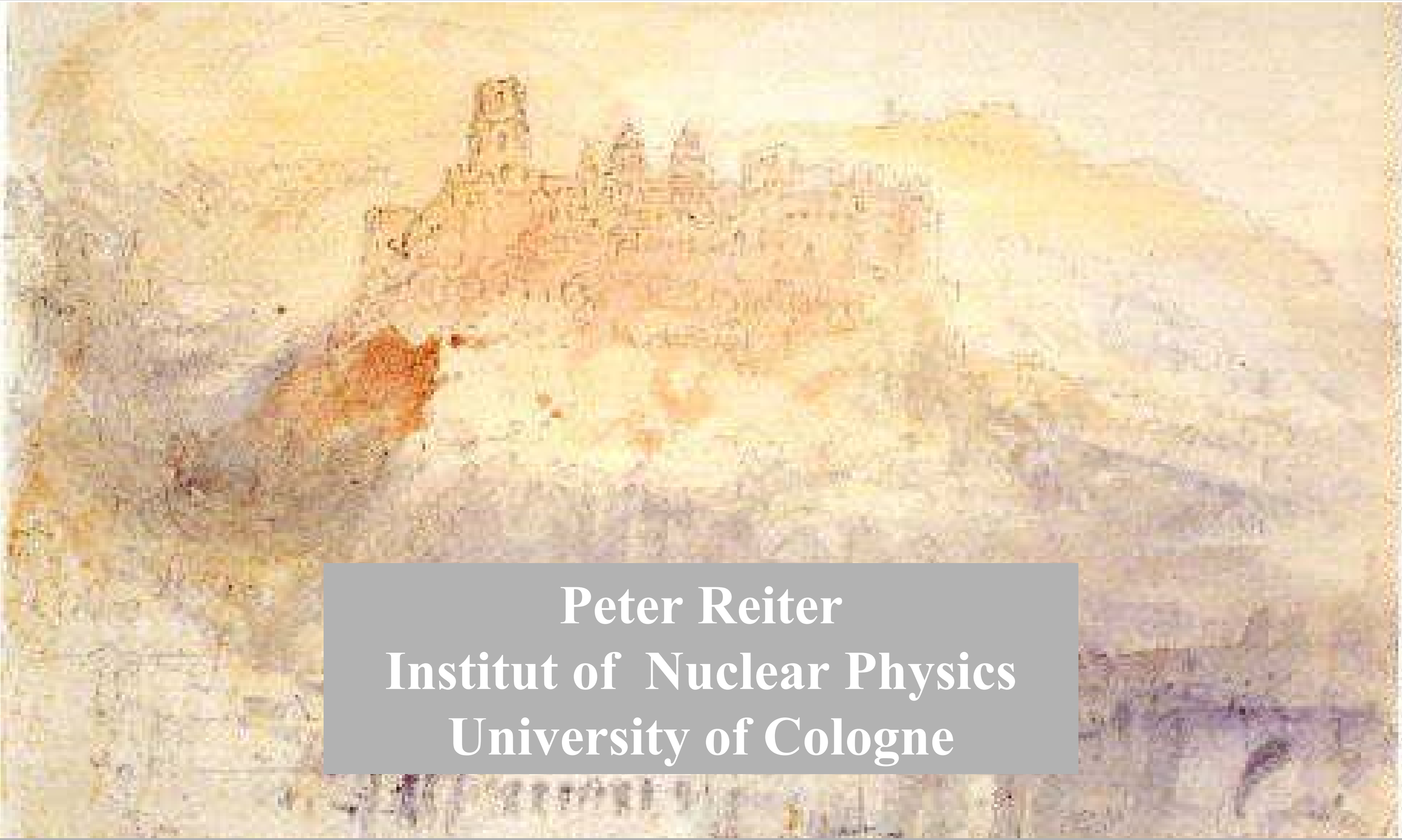
The AGATA project



Peter Reiter
Institut of Nuclear Physics
University of Cologne

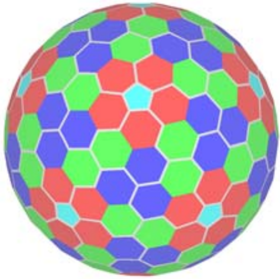
IRTG Fall School
Heidelberg, October 2006

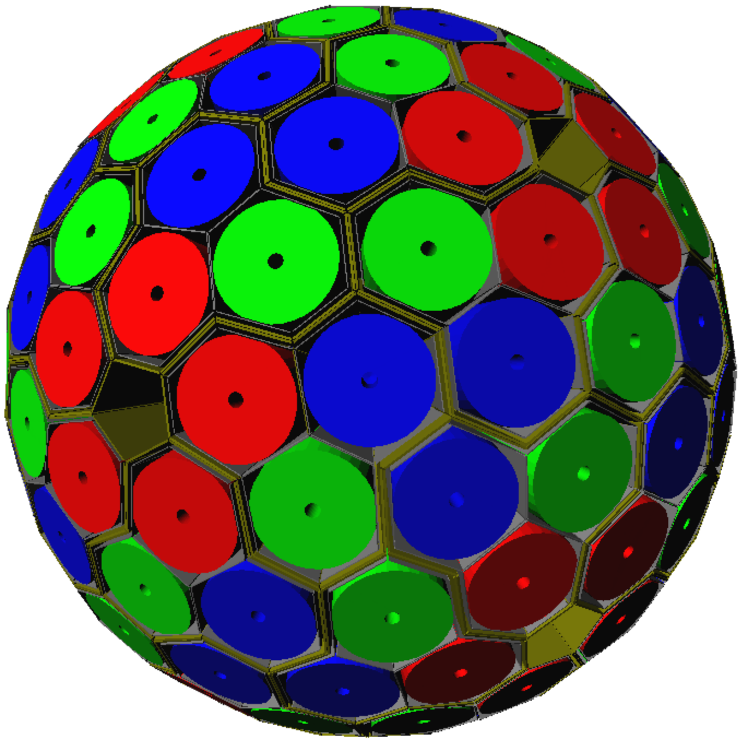
Outline

- introduction, physics motivation
- basics: γ-ray interactions, Ge detector
- ingredients of γ-ray tracking
- details on highly segmented detectors
- pulse shape analysis, position sensitivity
- concepts of γ-ray tracking
- the phases of AGATA

AGATA

(Advanced GAmma Tracking Array)



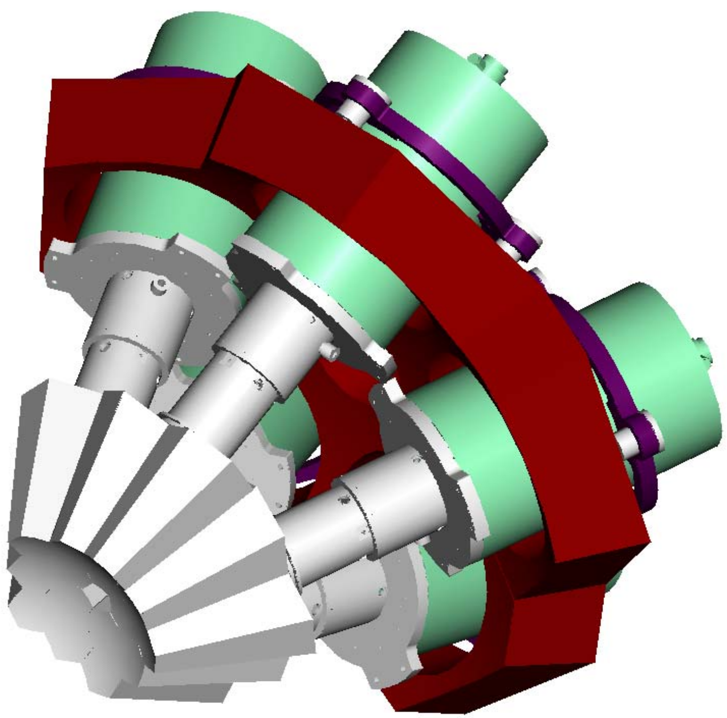


4π germanium shell	
180 hexagonal crystals	3 shapes
60 triple-clusters	all equal
Inner radius (Ge)	23.5 cm
Amount of germanium	362 kg
Solid angle coverage	82 %

Highly segmented Ge crystals
6480 segments

- 6660 high-resolution digital electronics channels
- Pulse Shape Analysis → position sensitive operation mode
- real time decomposition
  γ-ray tracking algorithms to achieve maximum efficiency
- Coupling to ancillary detectors for increased selectivity

The First Step:
The AGATA Demonstrator
Objective of the final R&D phase 2003-2008

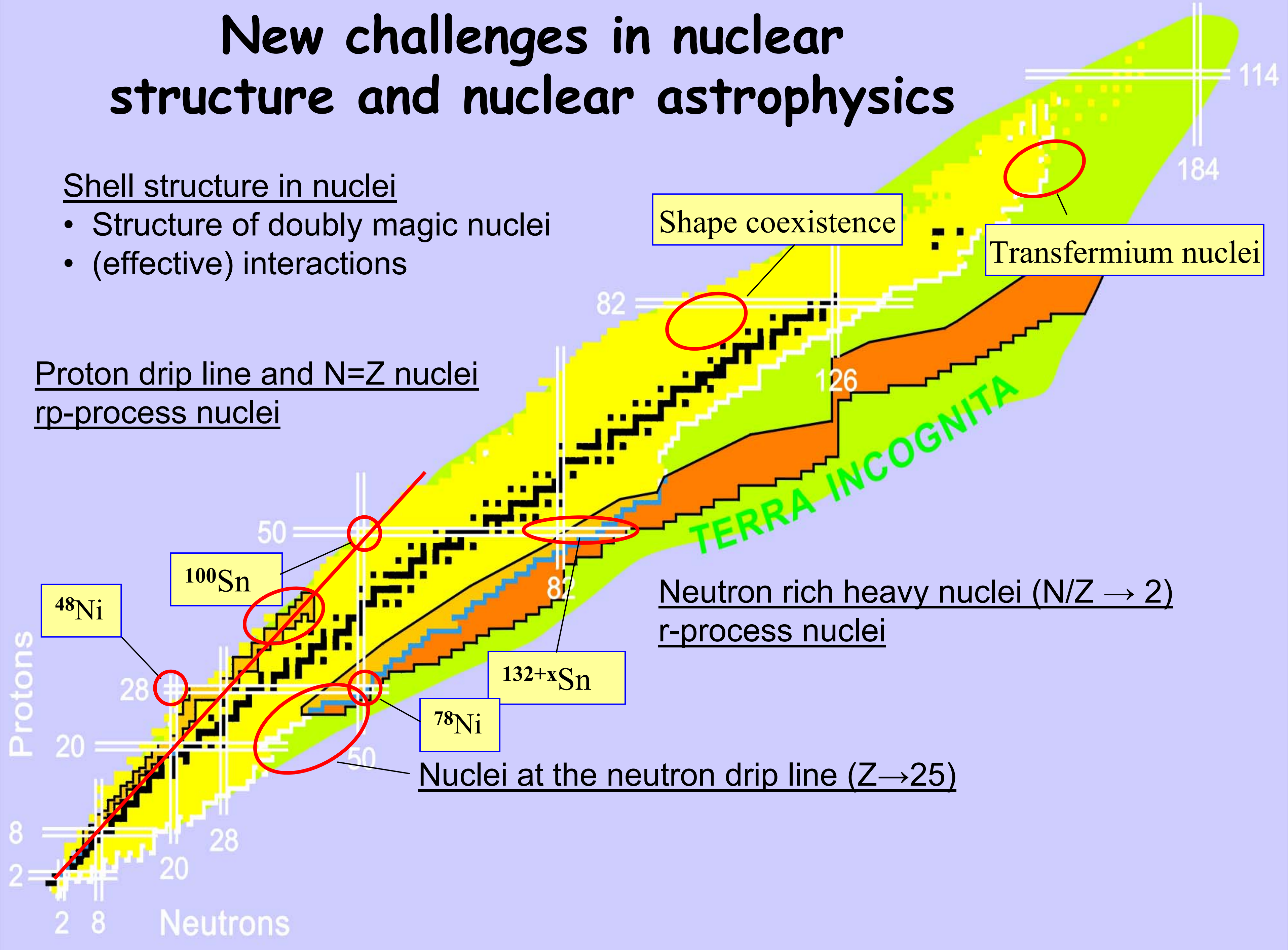


1 symmetric triple-cluster
5 asymmetric triple-clusters
36-fold segmented crystals
540 segments
555 digital-channels

Eff. 3 – 8 % @ $M_\gamma = 1$
Eff. 2 – 4 % @ $M_\gamma = 30$

Full ACQ
with on line PSA and γ-ray tracking
Test Sites:
GANIL, GSI, Jyväskylä, Köln, LNL

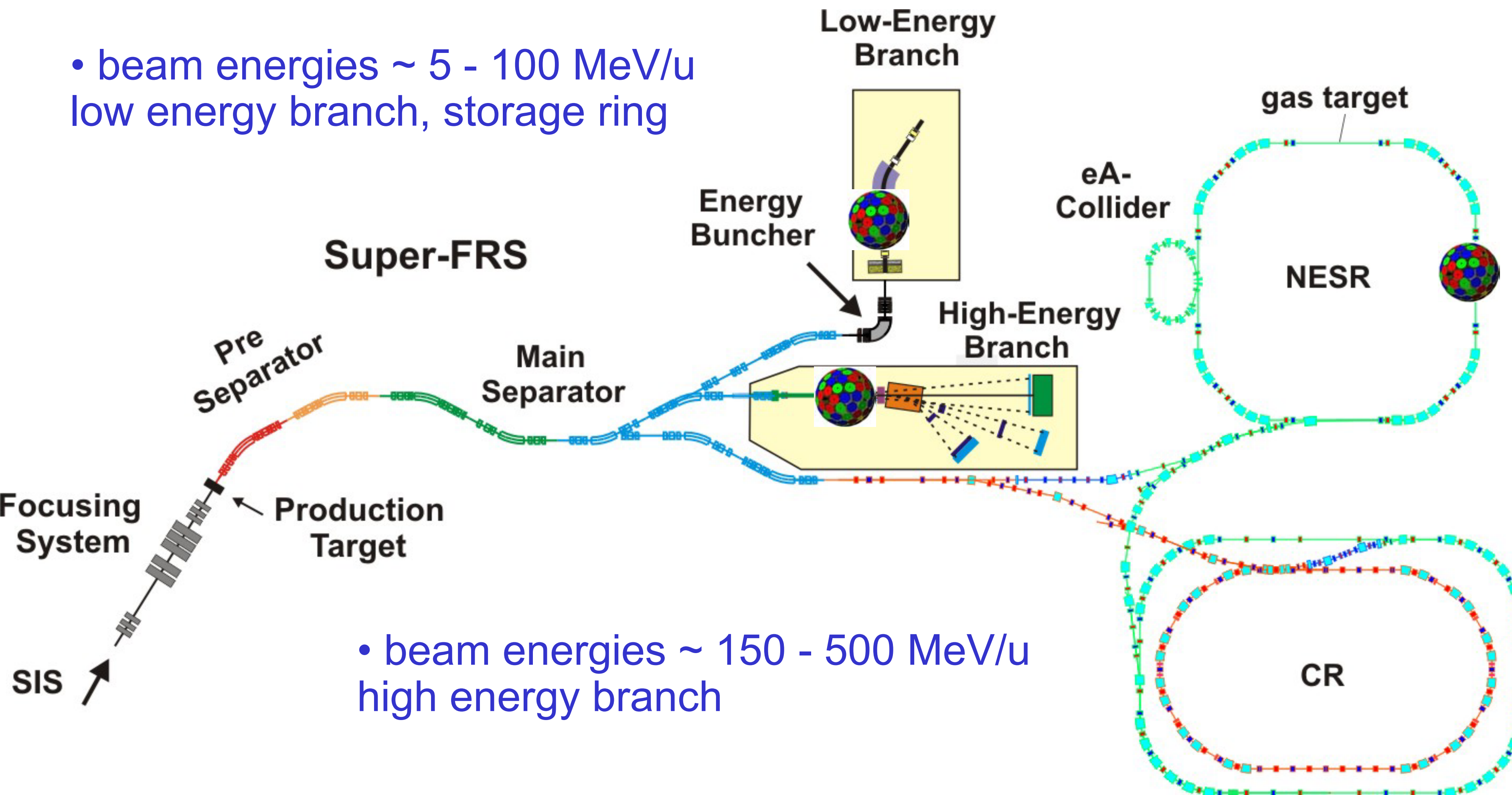
New challenges in nuclear structure and nuclear astrophysics



Future possibilities for AGATA at the FAIR NUSTAR facility

High resolution spectroscopy with secondary fragmentation products

• beam energies ~ 5 - 100 MeV/u
low energy branch, storage ring



• beam energies ~ 150 - 500 MeV/u
high energy branch

Advantages of γ-ray tracking

for instable beam experiments at high energies

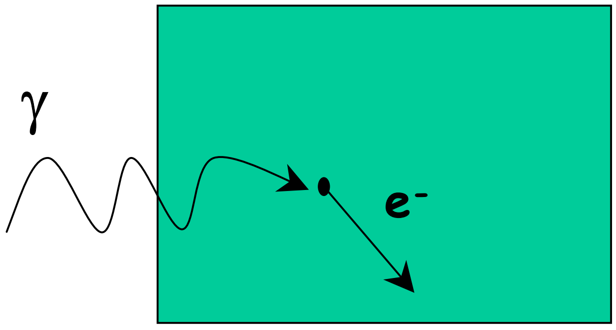
- High efficiency
- High position resolution
- High P/T

- low beam intensity
- large recoil velocity
  Doppler broadening

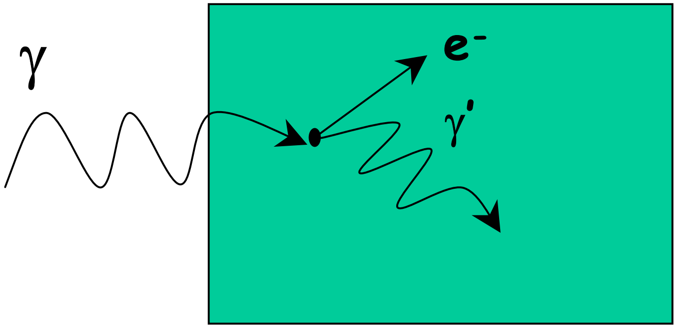
- High counting rate
- Background rejection

- background
  - atomic background
  - high energetic π..
  - beam composition
  - beam decays

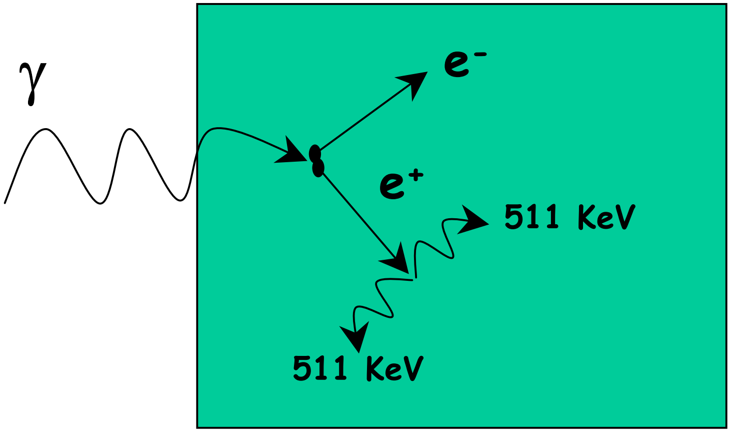
Reminder: interaction of γ-radiation with matter



Photoelectric effect



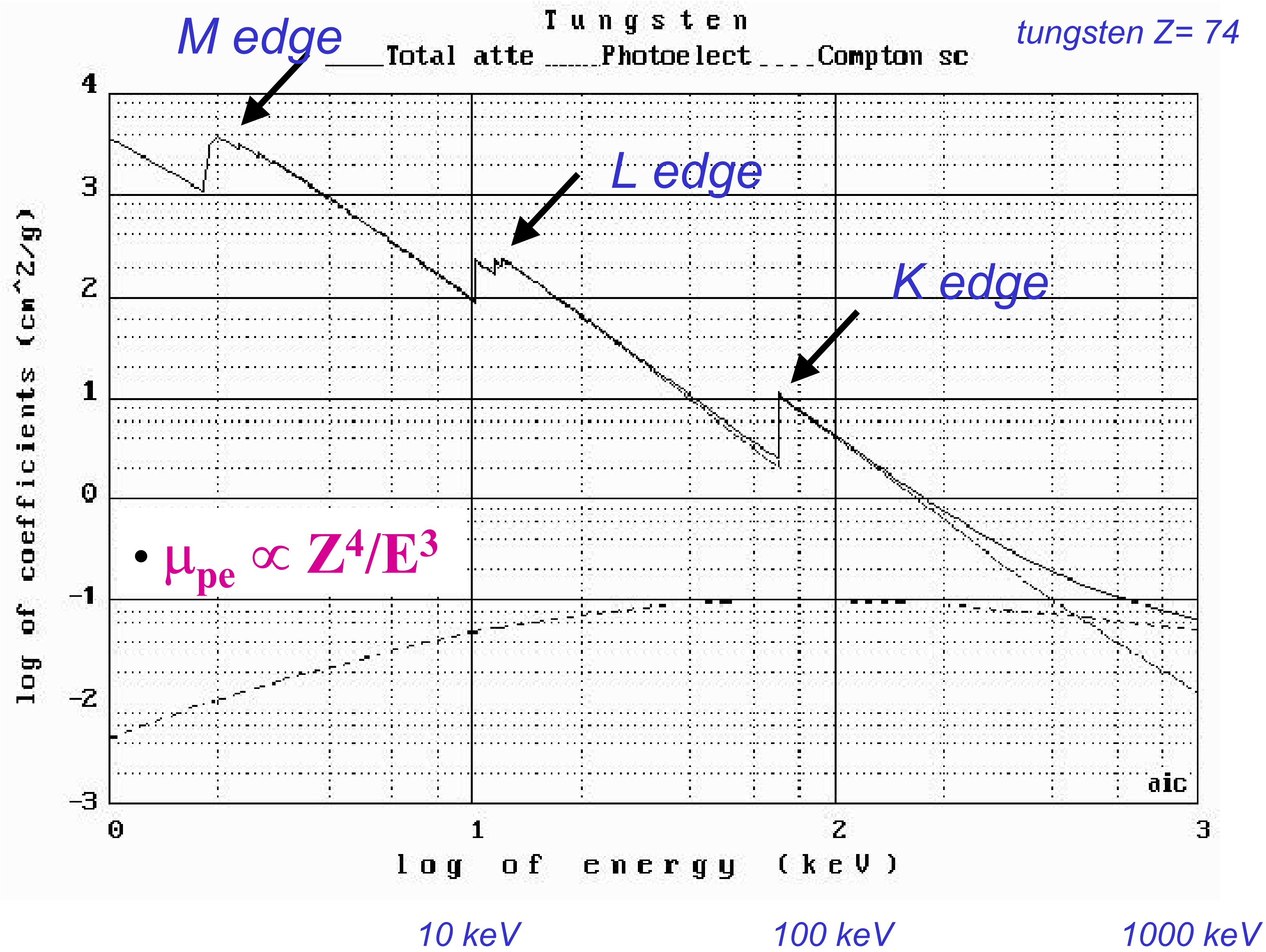
Compton scattering



Pair creation

Nuclear structure physics deals with typical γ-ray energies in the range 50 keV – 15 MeV.

at low energies photo effect



- $\mu_{pe} \propto Z^4/E^3$

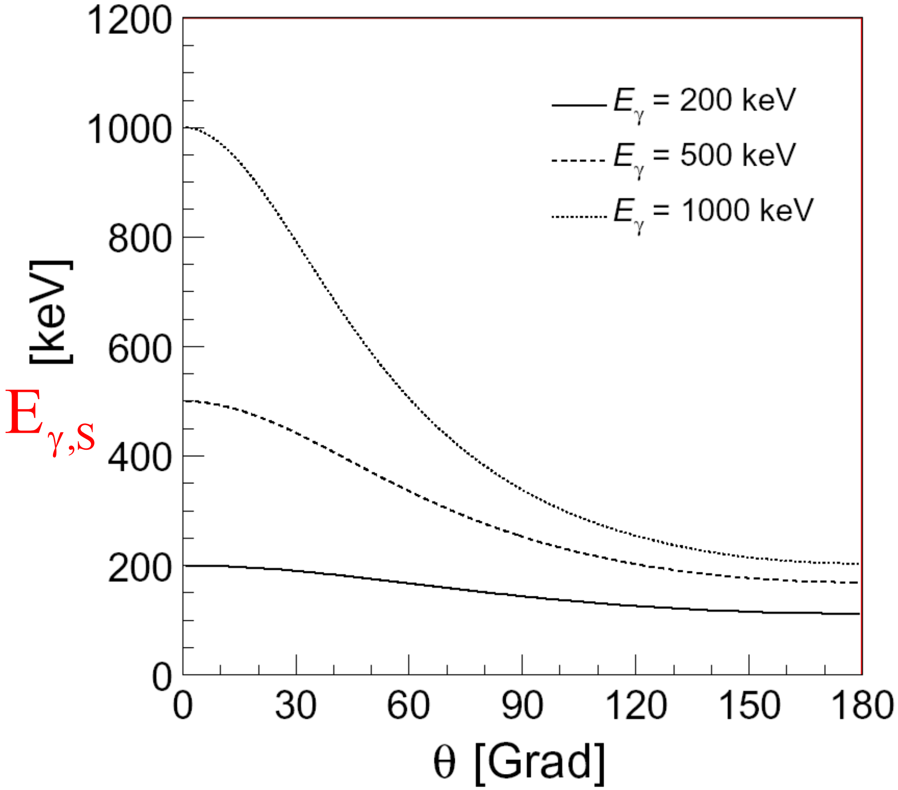
Compton scattering

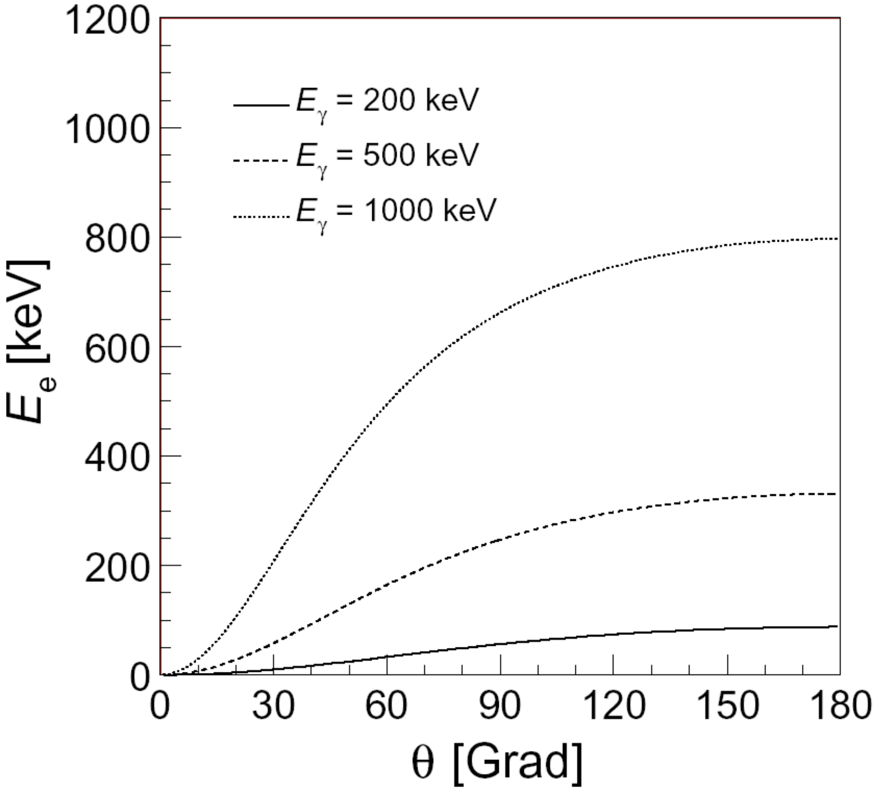
Energy conservation and spatial correlation

$$E_\gamma = E_{\gamma,S} + E_e$$

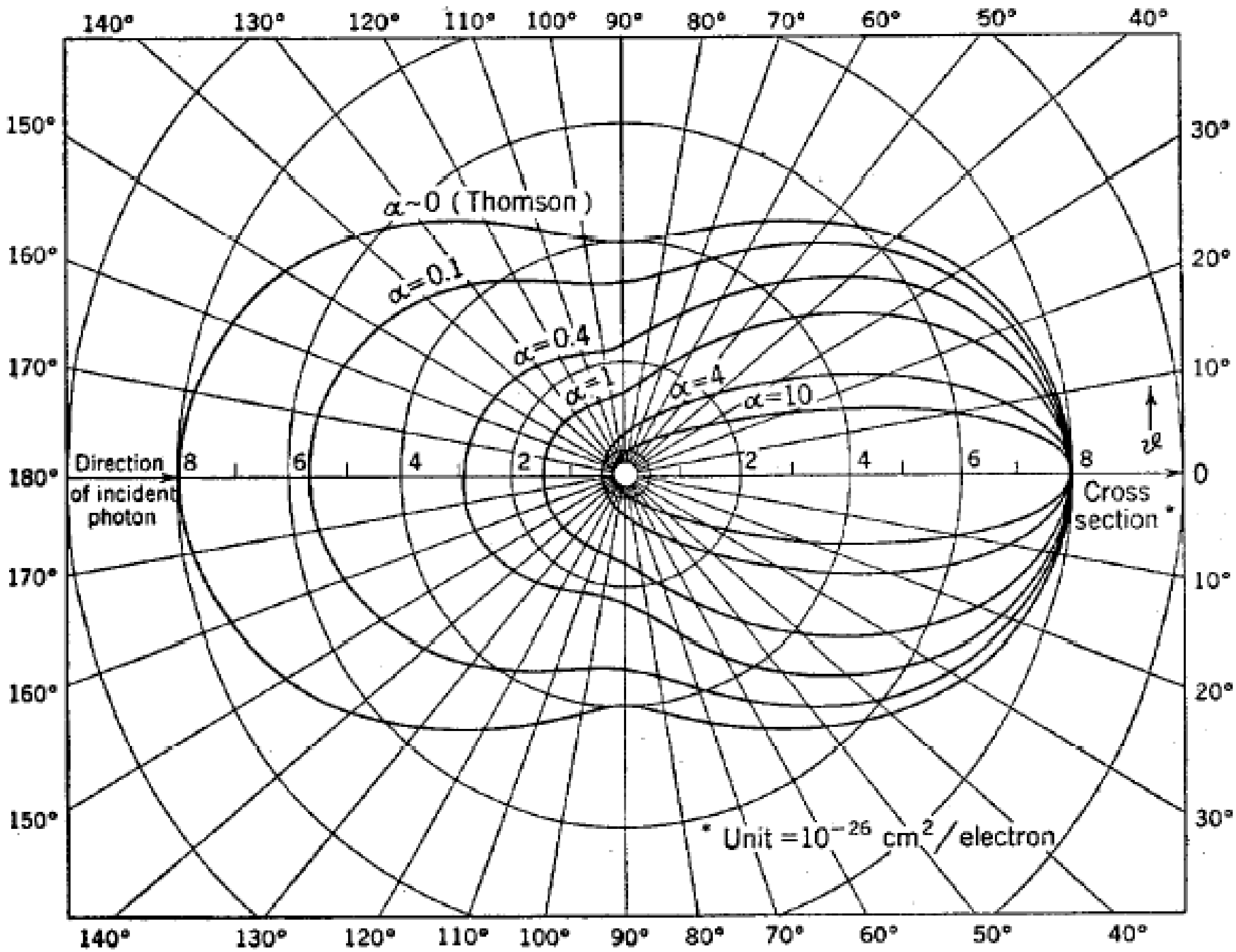
$$\frac{1}{E_{\gamma,S}} - \frac{1}{E_\gamma} = \frac{(1-\cos\theta)}{m_e c^2}$$

Crucial for
- *γ-ray tracking*
- *γ-ray imaging*

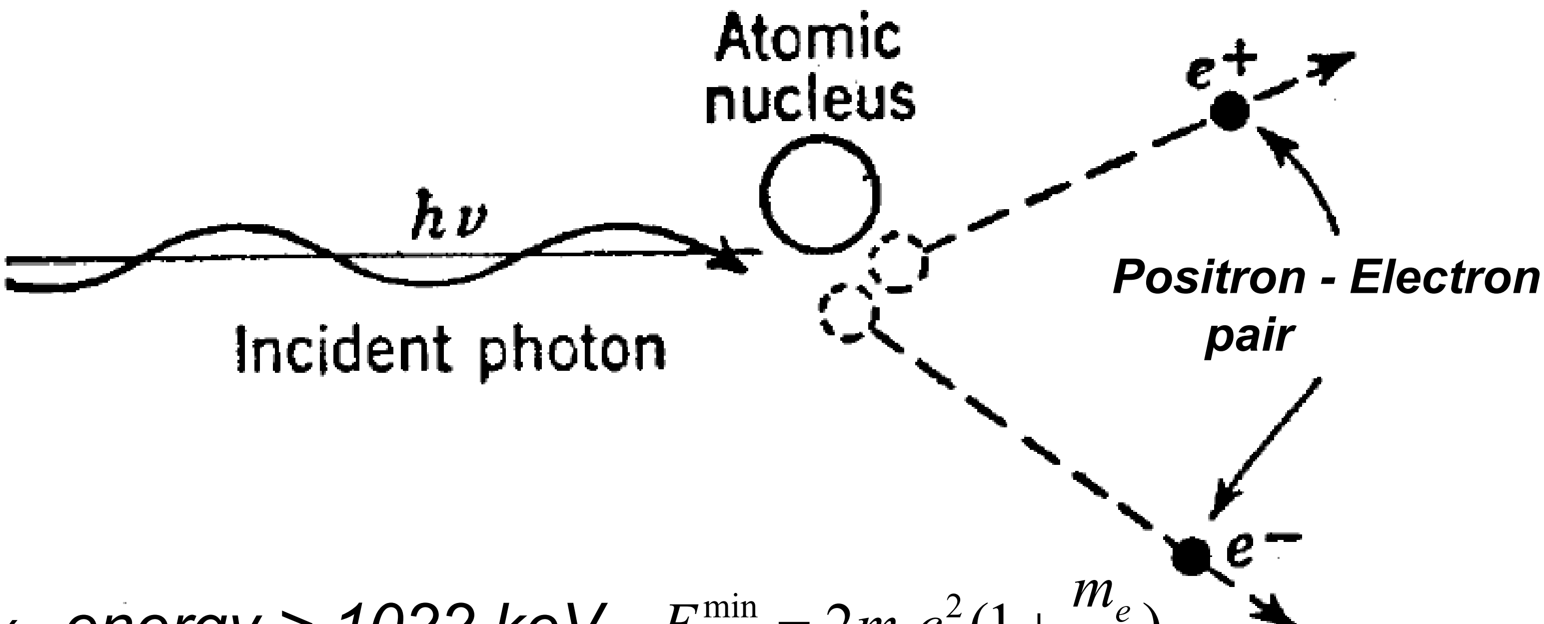




Klein-Nishina cross section



pair creation

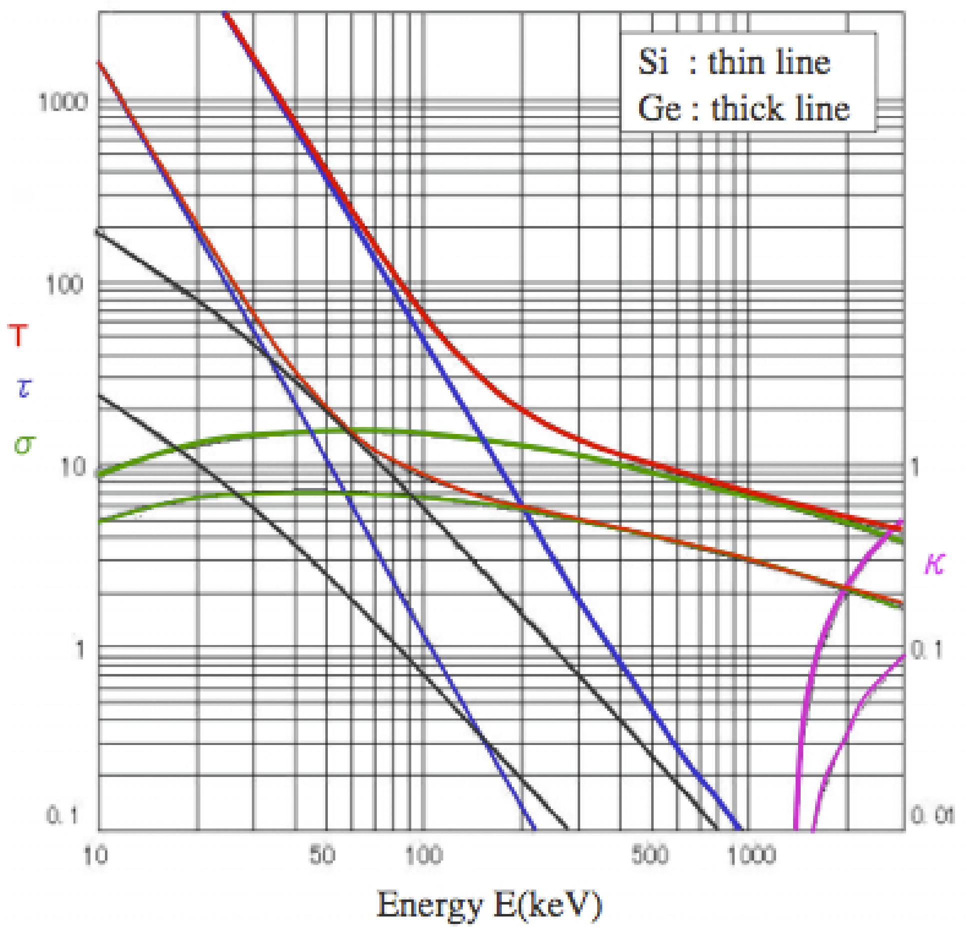


γ *- energy > 1022 keV,* $E_{\gamma}^{\min} = 2m_e c^2 (1 + \frac{m_e}{M})$

- *third particle momentum conservation*
- *electron positron annihilation* E_{γ}*=511 keV*
- $\mu_{PP} \propto Z^2$

Cross sections for interaction of γ-rays in matter

Germanium (Z=32, ρ=5.32 g/cm^3)
Silicon (Z=14, ρ=2.33 g/cm^3)



τ - photoelectric
σ - Compton
κ - Pair production
T - total

Mean free path :

$\lambda(E) = M_A/(N_{av}.\rho)\ .\ 1/\Sigma\sigma(E)$

for Ge:

λ(10 keV) ~ 55 μm

λ(100 keV) ~ 0.3 cm

λ(200 keV) ~ 1.1 cm

λ(500 keV) ~ 2.3 cm

λ(1 MeV) ~ 3.3 cm

λ(5 MeV) ~ 5.9 cm

Germanium detectors

Ge detectors enable very high energy resolution

$\Delta E/E = 0.16$ % at $E_\gamma = 1.33$ MeV

Major impact: γ-spectroscopy

energy resolution depends on

- *statistical fluctuations in number of charge carriers*

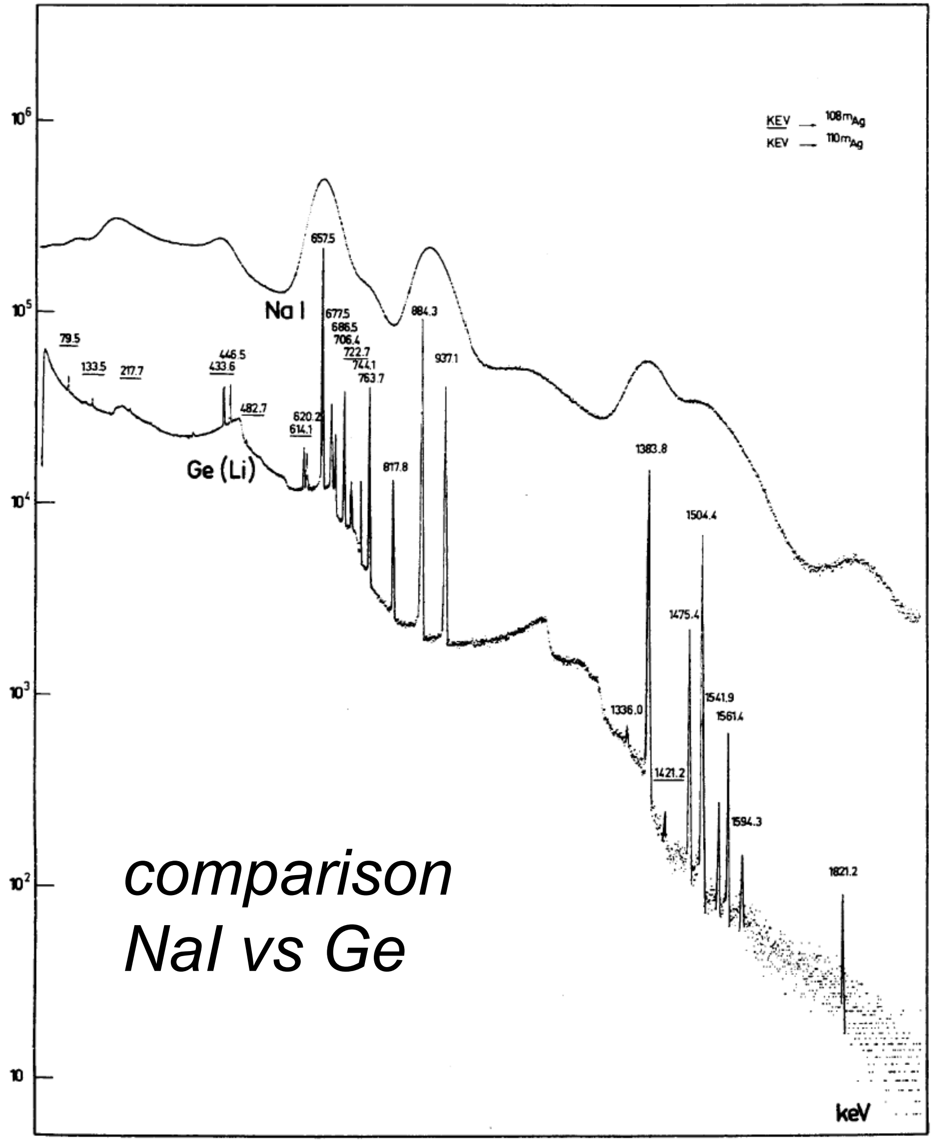
$$\sigma^2 = F\,\varepsilon\,E_\gamma$$

$\varepsilon = 2.96$ eV @ 77 K

Fano factor $F \sim 0.1$

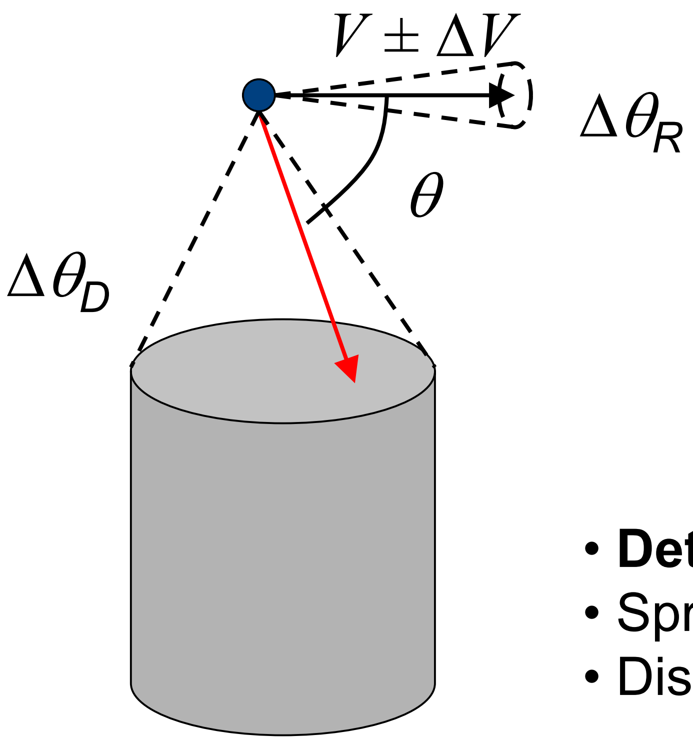
(not all the deposited energy goes to create e-h pairs)

- *incomplete charge collection*
- *electronics*



(J.Cl. Philippot, IEEE Trans. Nucl. Sci. NS-17/3 (1970) 446)

Doppler broadening



Doppler shift

$$E_\gamma = E_0 \frac{\sqrt{1-\frac{V^2}{c^2}}}{1-\frac{V}{c}\cos\theta}$$

Doppler broadening

$$\Delta E_\gamma = E_0 \frac{V}{c} \sin\theta \, \Delta\theta$$

- **Detector opening angle $\Delta\theta_D$**
- Spread in recoil velocity ΔV
- Distribution in the recoil velocity direction $\Delta\theta_R$

acurate determination of velocity V (ancillary device) and θ

semiconductor detectors

Parameter	Si	Ge	Others
Dielectric constant	12	16	CdTe InSb HgI_2 GaAs
Electron-hole pair E energy gap	3.76 [eV] 1.1 [eV]	2.96 [eV] 0.7 [eV]	CdS GaP
Mobility e / hole(+)	1350 / 480 [cm^2 /Vs]	3900 / 1900 [cm^2 /Vs]	@ [~ 300 K]
e / hole(+)	20,000 / ~10,000	40,000 / > 50,000	@ [~ 90 K]

38,500 +/- 300/ [100]/[111]
61,500 +/- 300 [100]/[111]

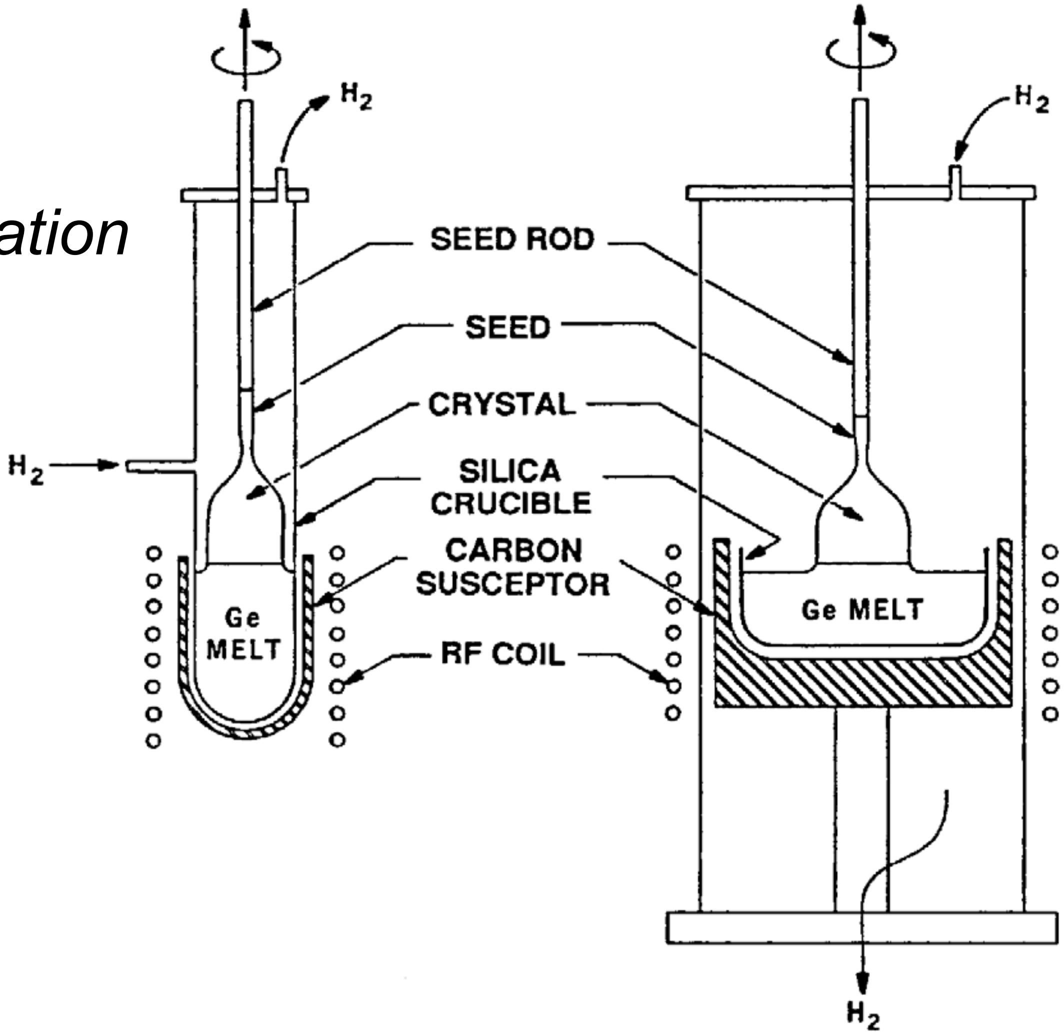
Ge-Detektoren

Thickness of depletion zone

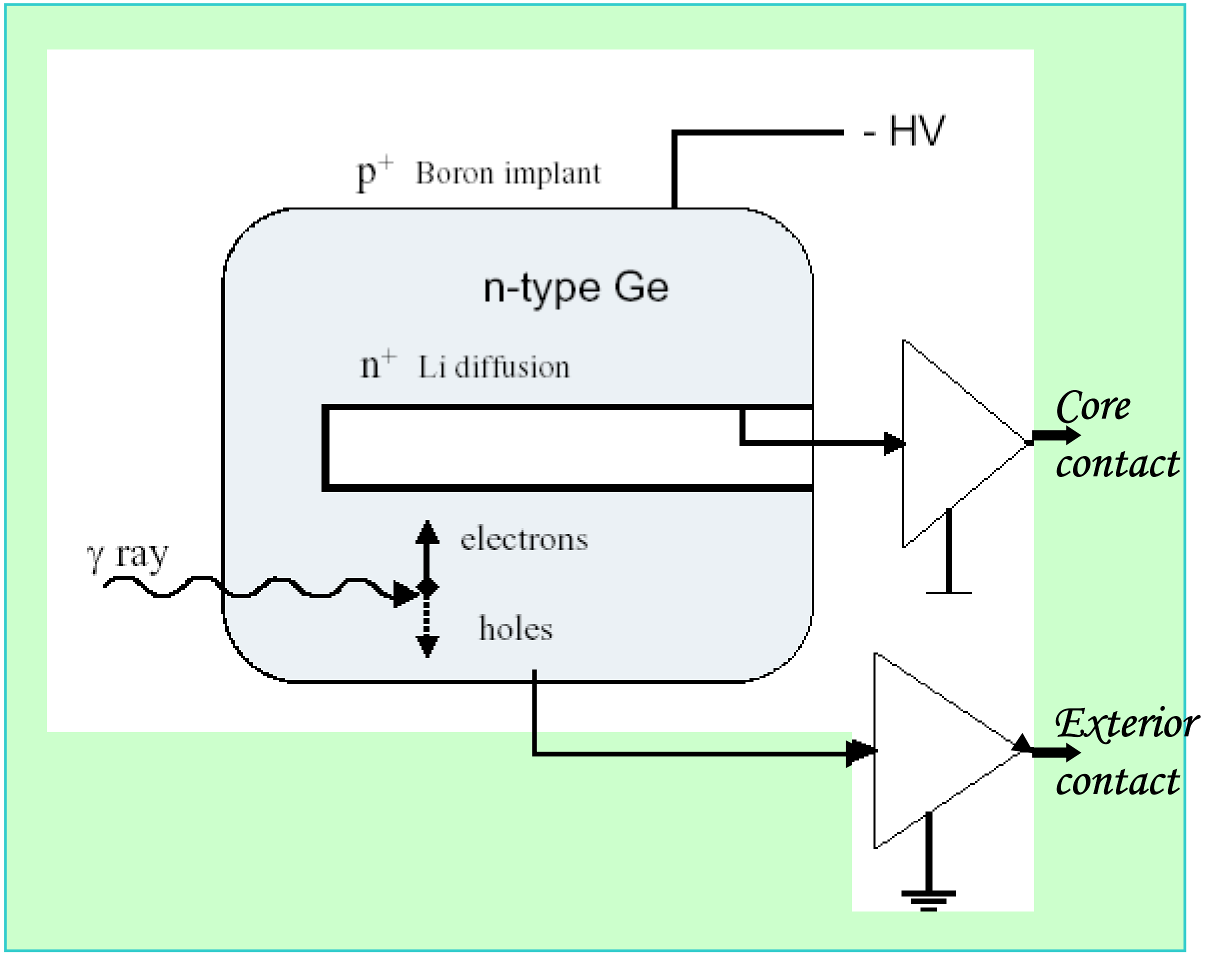
$$W = \sqrt{\frac{2\varepsilon V_b}{eN}}$$

V_b *reverse bias voltage*
N net impurity concentration
Ge: N~10 $^{-12}$ *per atom*

production of
High-purity germanium
enables detectors
of large single crystals
with 8 cm diameters

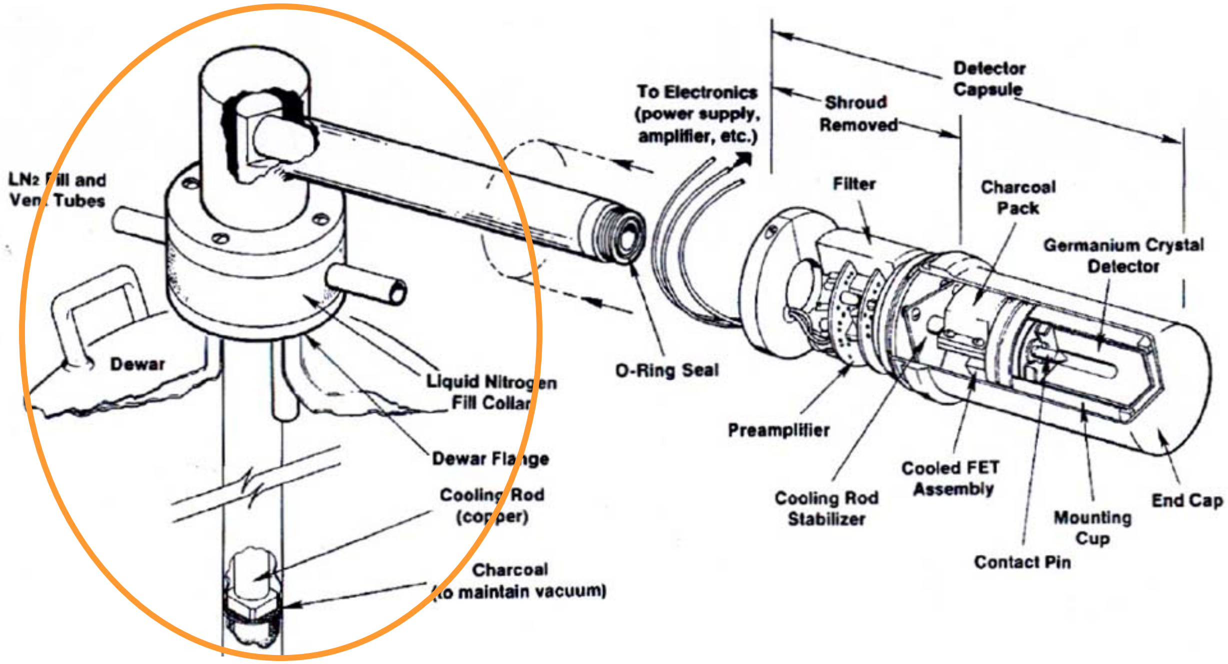


typical configuration of a HP-Ge Detector



- *Standard n-type*
- *Intrinsic HP-Ge*
- *Closed end*
- *Co-axial structure*

Standard Ge-detector



Thermally activated charge carriers in the conduction band:

density at room temperature ~ 2.5 10^{13} cm^{-3} for Ge

~ 1.5 10^{10} cm^{-3} for Si

To reduce the number of free charge carriers:

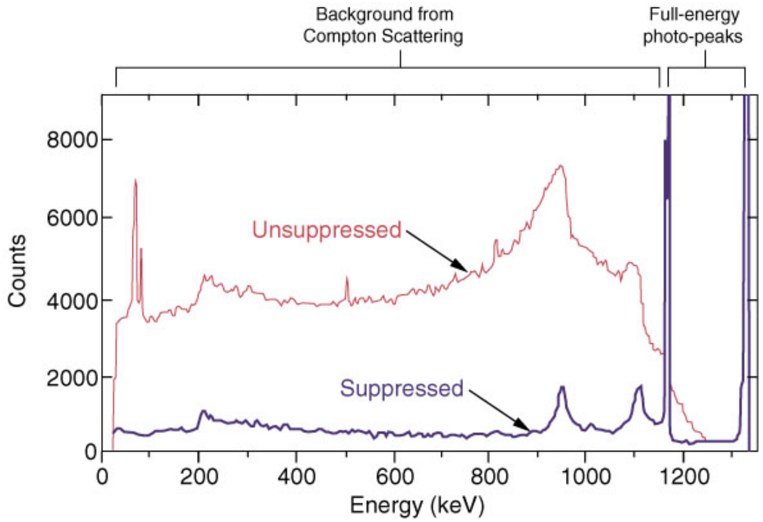
=> for Ge, cool crystal with LN_2 - 77K

Ge-spectrometers

GAMASPHERE at ANL
110 HPGe detectors

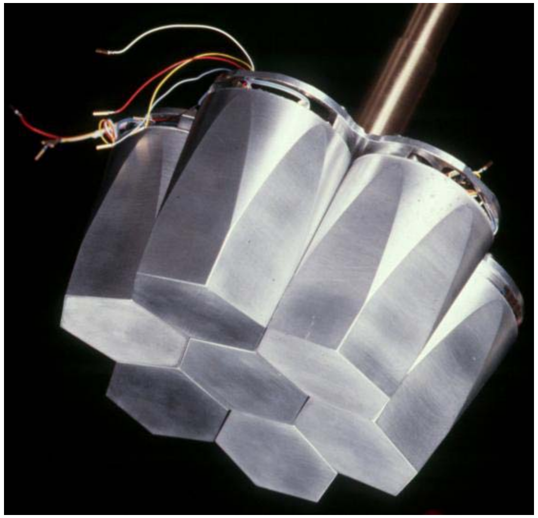
- Granularity

- Anti-Compton shield (BGO)
photo peak/total ~ 0.6

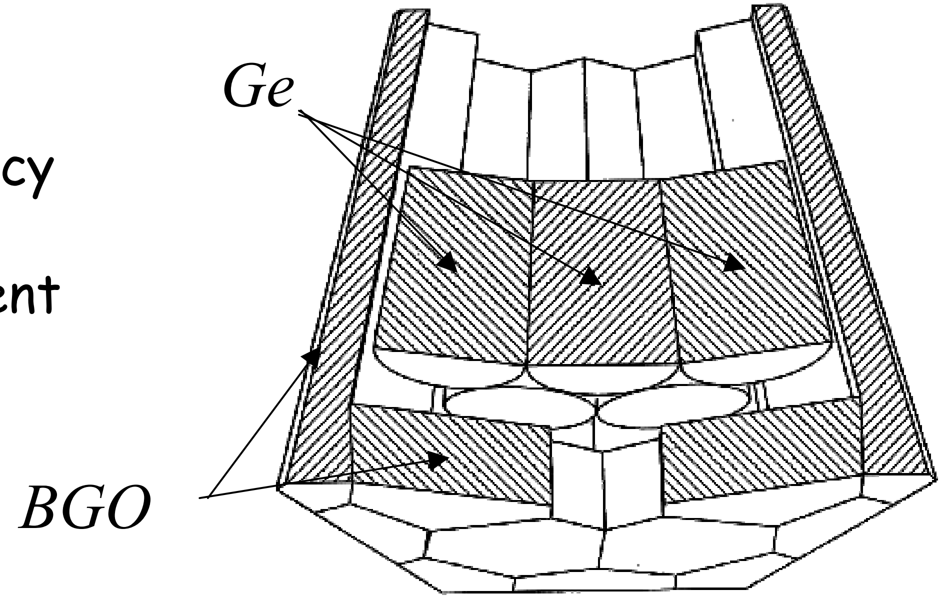


Developments: composite Ge-detectors

• efficiency is limited by size of single Ge crystal



Composite CLUSTER detector
- seven large hexagonal tapered Ge detectors
- encapsulated Ge crystals
- closely packed in a common cryostat
- common BGO escape-suppression shield



- increased total-absorbtion efficiency
- at 5 MeV the efficiency is doubled
- highest peak to total ratio 61 percent

Development: University of Cologne, FZ-Jülich, EURISYS

SPI spectrometer

Composite, encapsulated Ge detectors currently used in space applications:

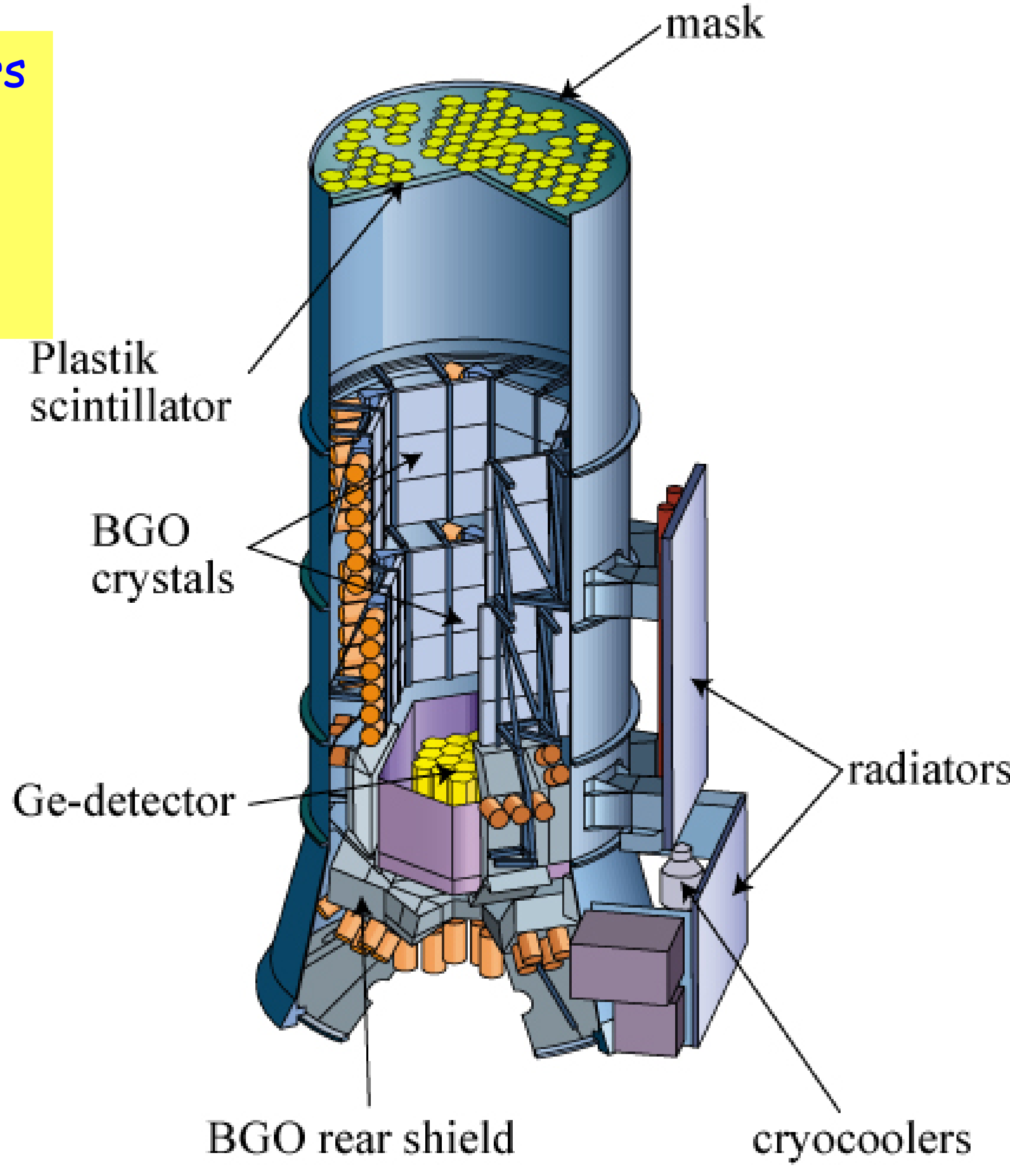
- INTEGRAL
- MARS Odyssee

SPI at INTEGRAL

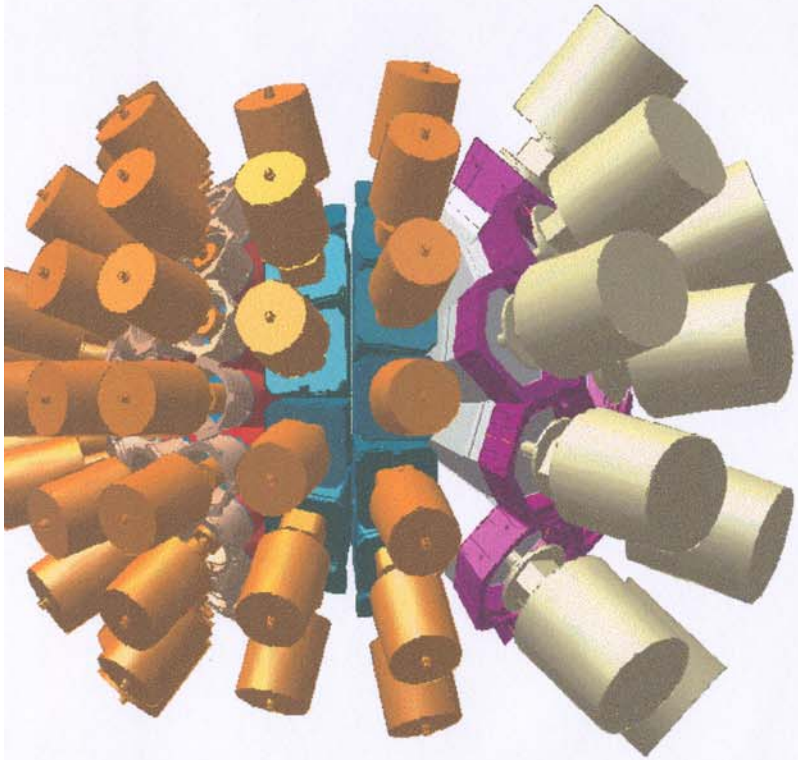
19 hexagonal encapsulated Ge-crystals

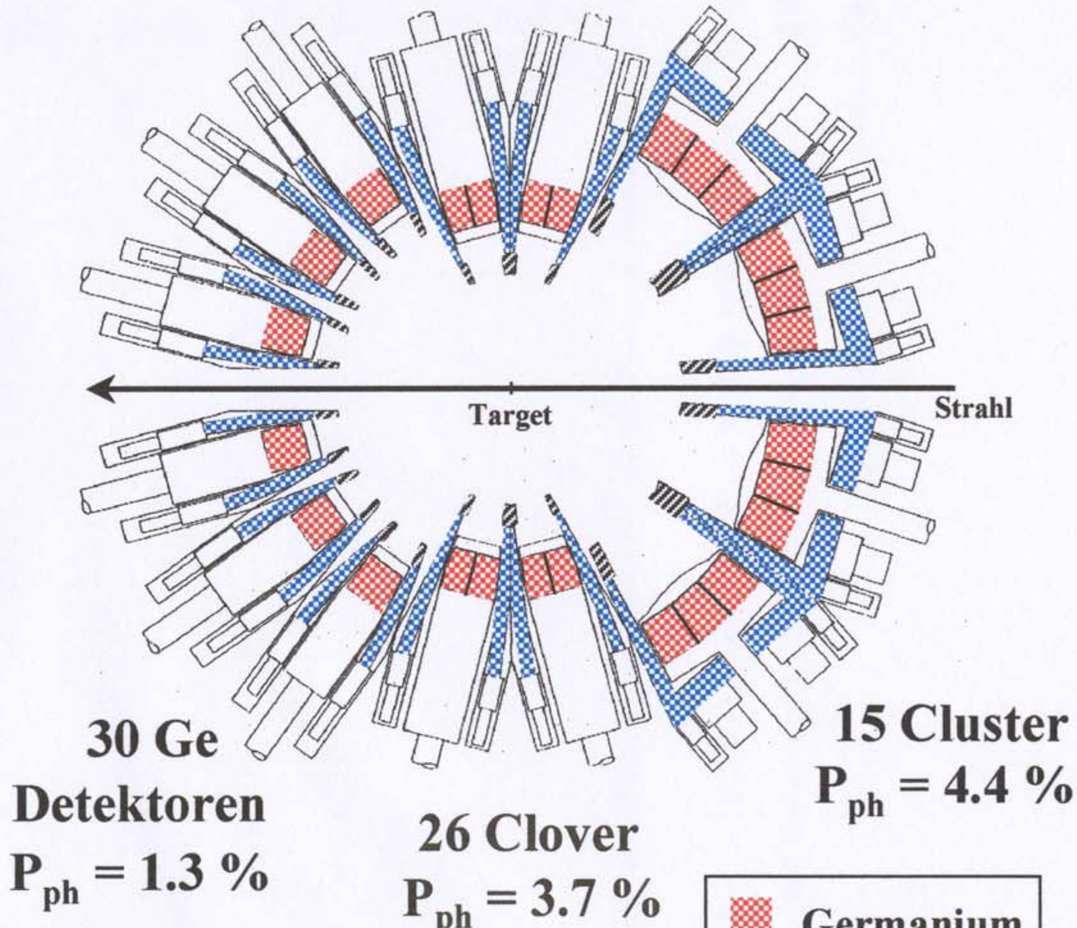
cooled to about 85 K by electrical cooling system

background suppression by a massive anticoincidence BGO shield



EUROBALL-Spektrometer

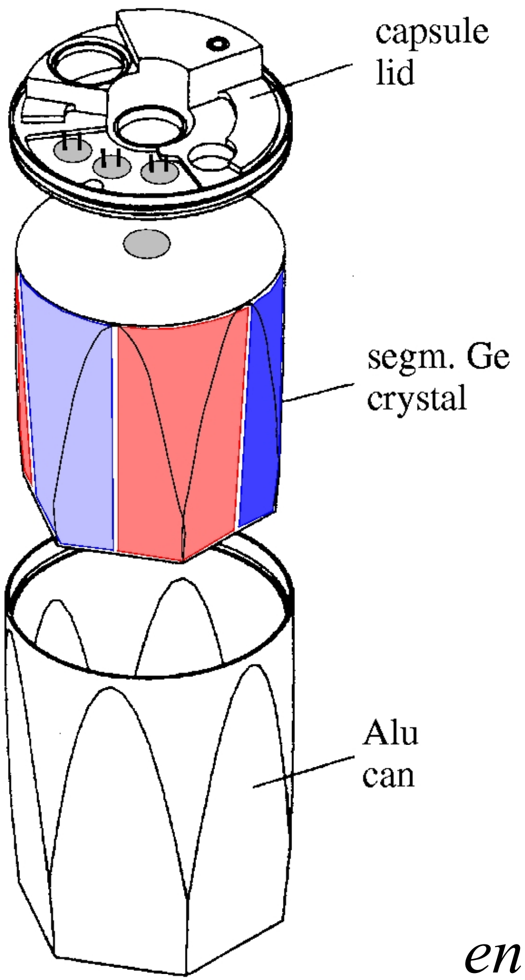


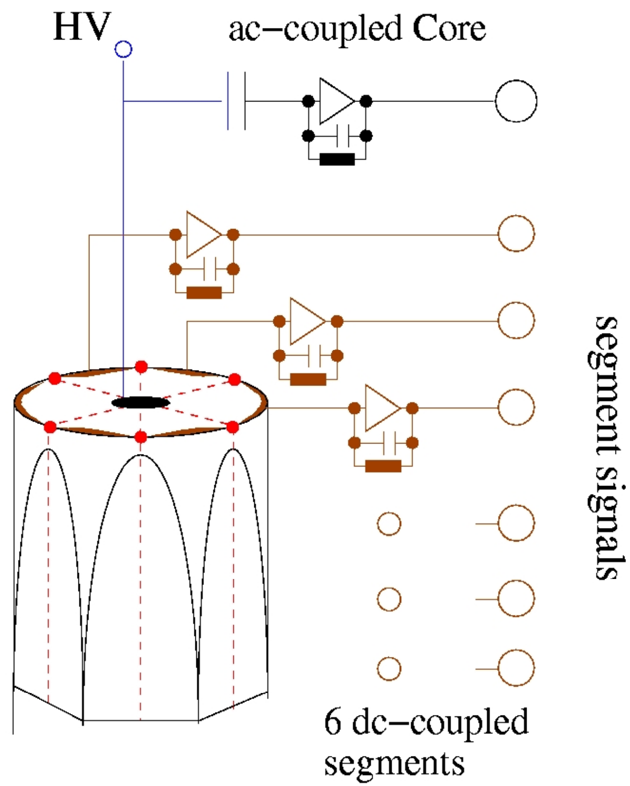


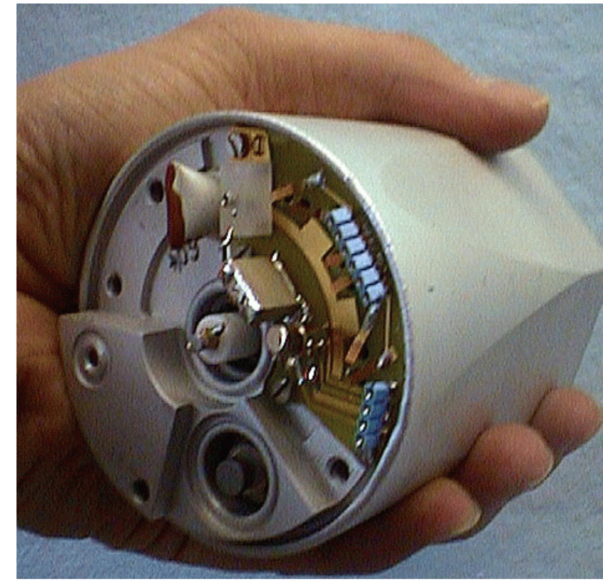
239 single Ge crystals

EUROBALL, GAMMASPHERE provide highest detection sensitivity especially for high multiplicity and rare decays

segmented Ge-detectors







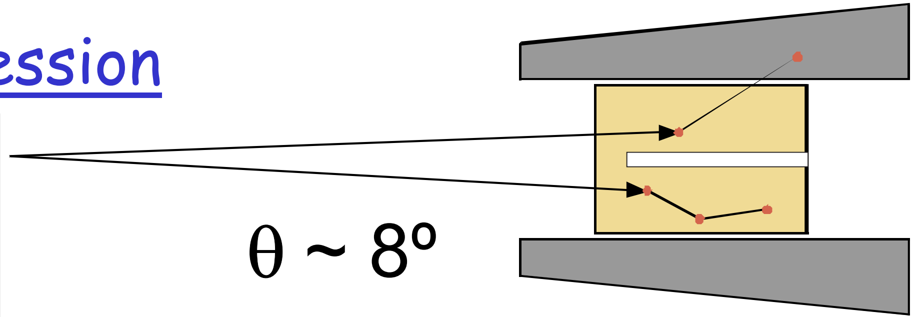
encapsulated, six-fold segmented HP Ge detectors
24 detectors at REX-ISOLDE, CERN

Idea of γ-ray tracking

Compton supression

ε_{ph} ~ 10%

N_{det} ~ 100

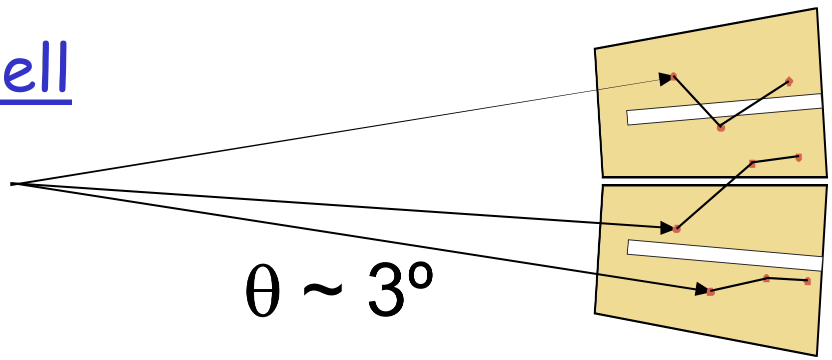


Larger openeing angle means lower energy resolution at large velocities

Germanium Shell

ε_{ph} ~ 50%

N_{det} ~ 1000

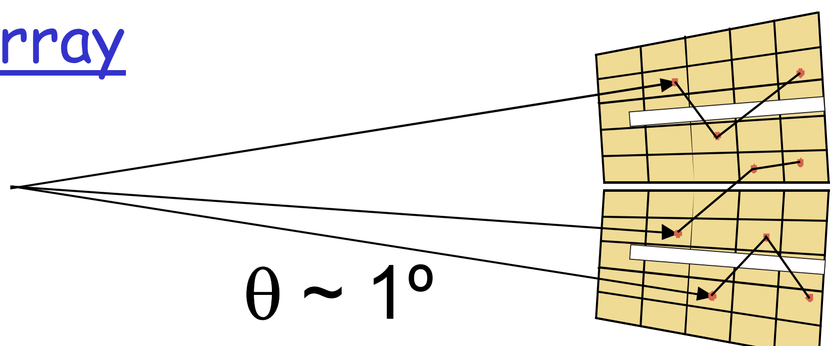


Too many counters at large distance (to reduce multiple hits)

Ge Tracking Array

ε_{ph} ~ 50%

N_{det} ~ 100



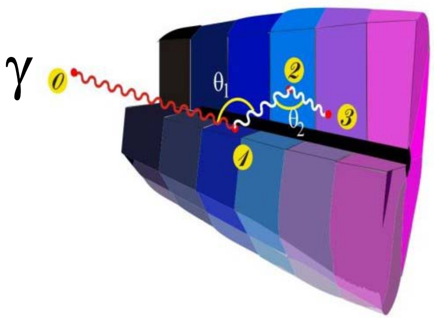
Combination:

- Segmented crystals
- Digital Electronics
- Pulse-shape analysis
- Tracking of γ-rays

Ingredients of γ-Tracking

1

Highly segmented HPGe detectors



2

Digital electronics to record and process segment signals

3

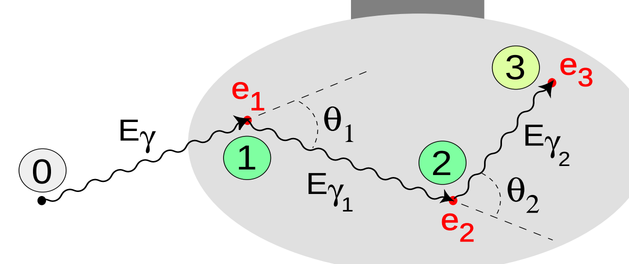
Pulse Shape Analysis to decompose recorded waves

Identified interaction

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

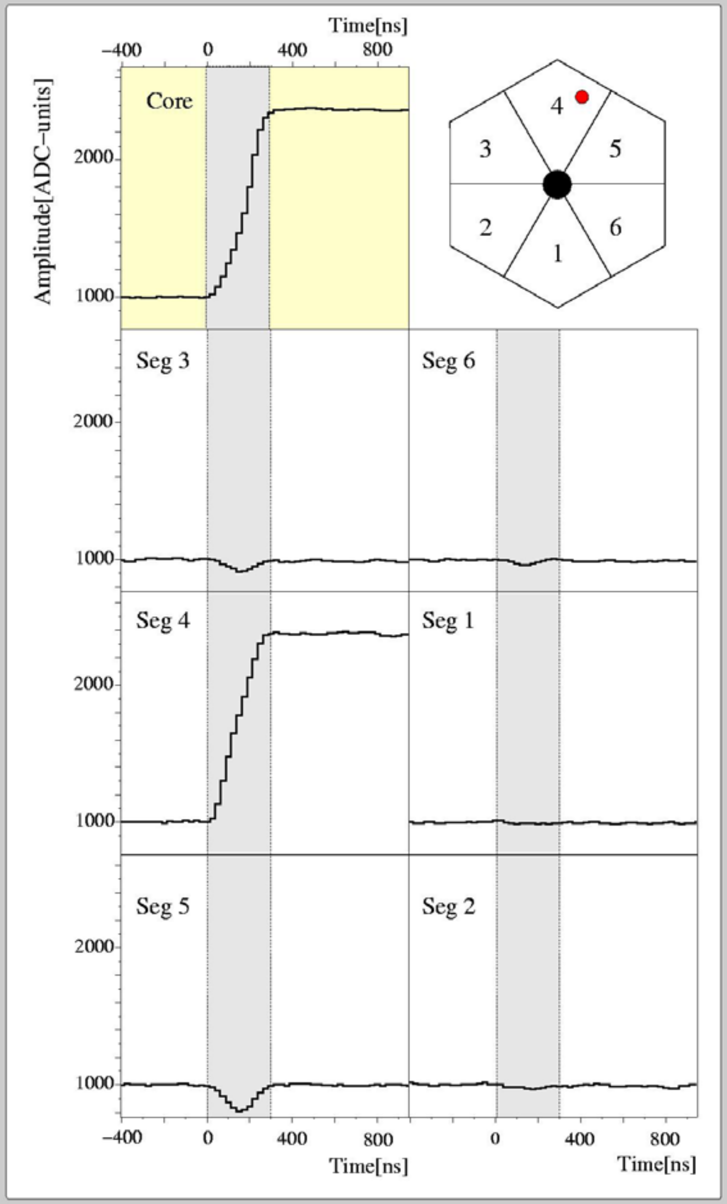
4

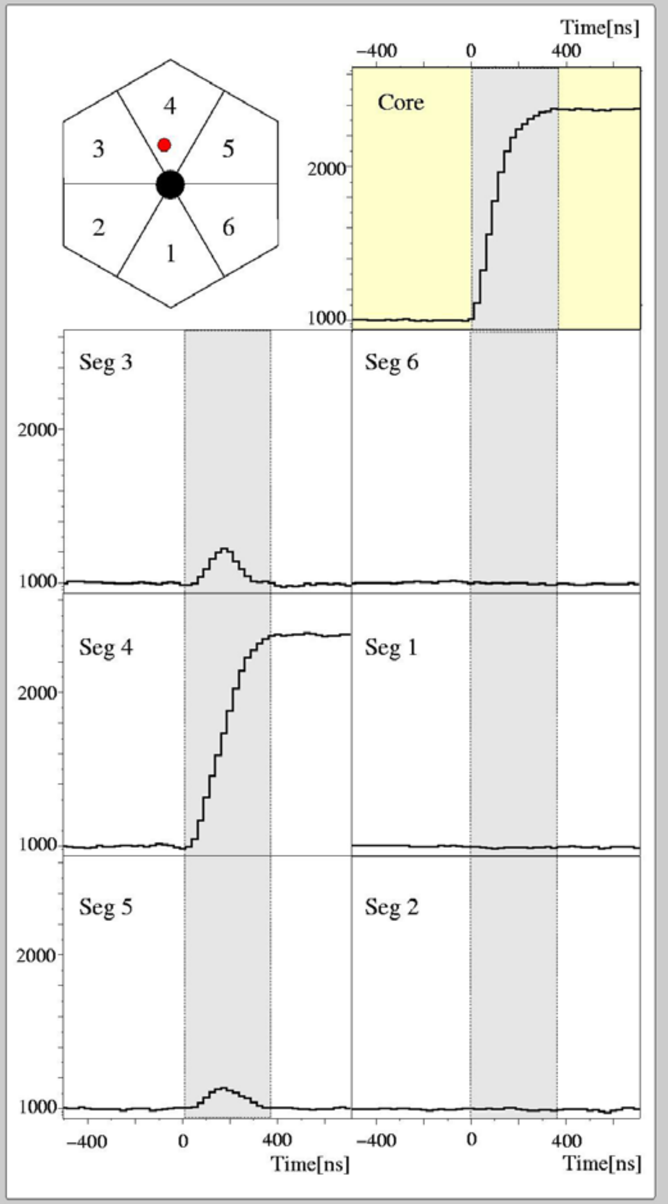
Reconstruction of tracks e.g. by evaluation of permutations of interaction points



reconstructed γ-rays

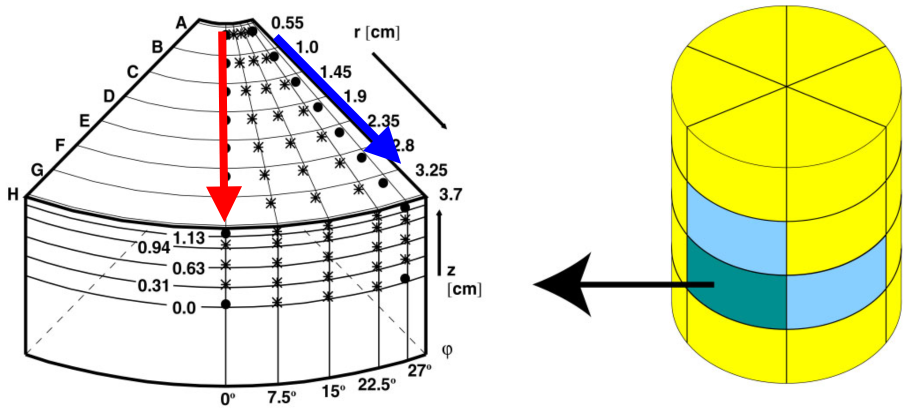
Pulse shapes & position sensitivity
Example MINIBALL 6 fold segmented detector

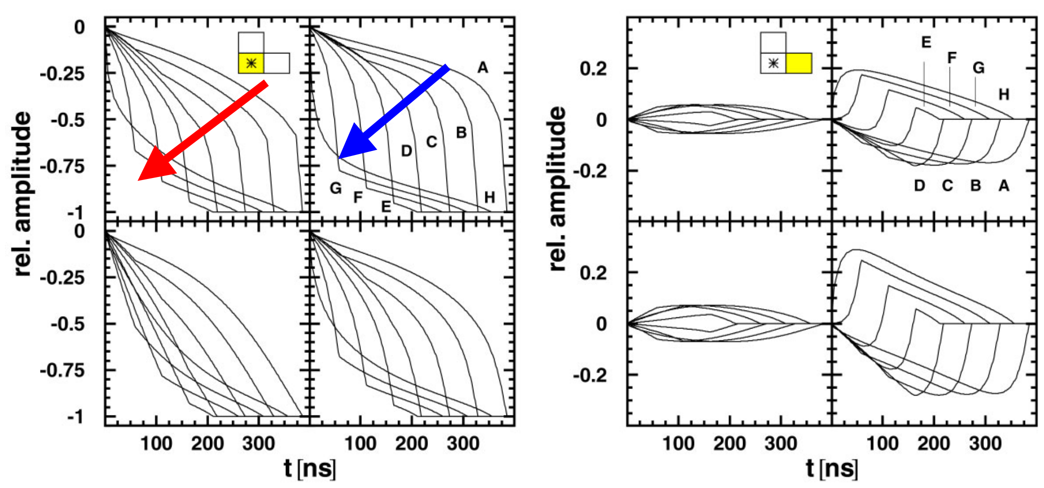




Position determination through Pulse-shape Analysis

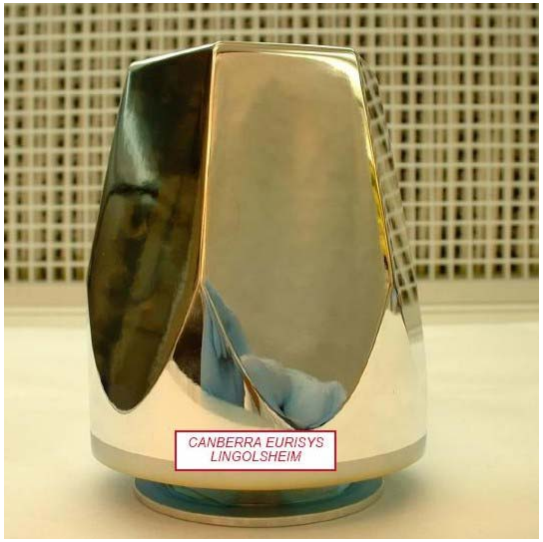
Calculated signals for true coaxial detector



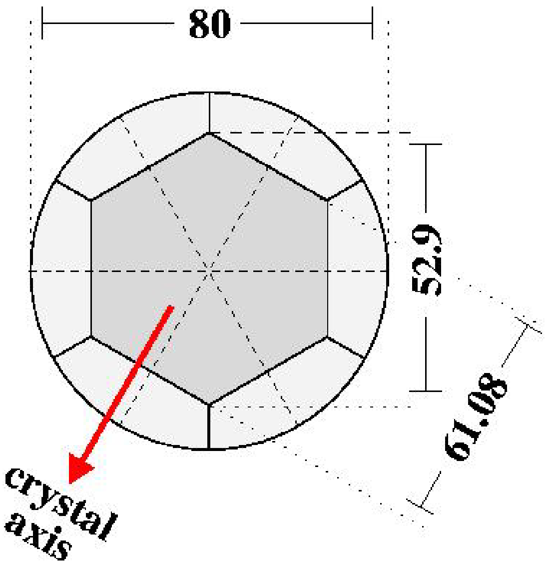


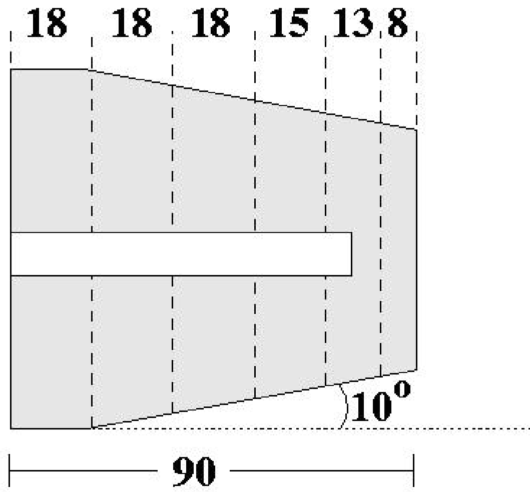
net charge signals　*mirror charge signals*

AGATA detector first prototype

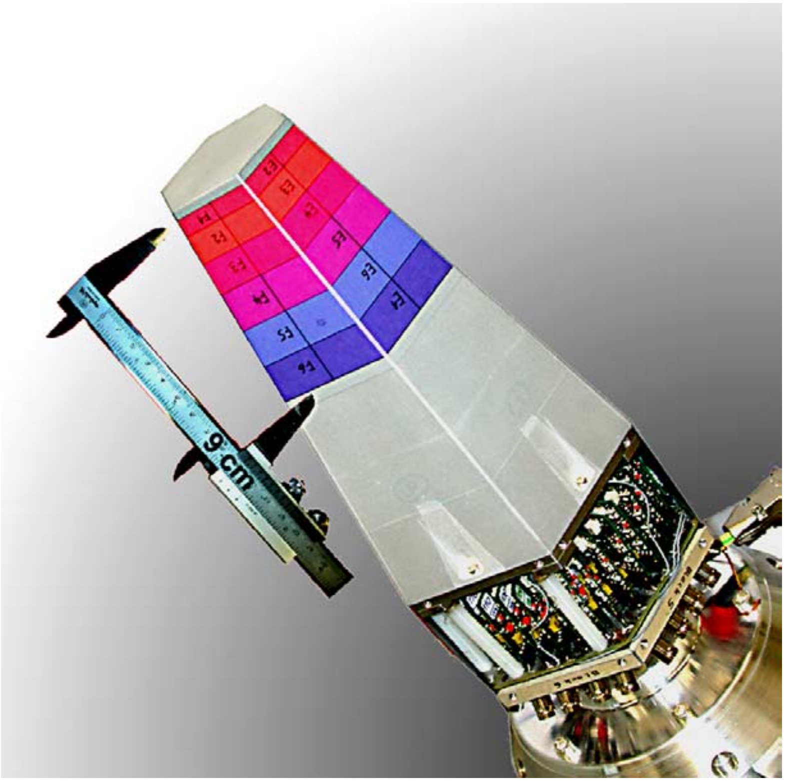


Hexaconical Ge crystals
90 mm long
80 mm max diameter
36 segments
Al encapsulation
    0.6 mm spacing
    0.8 mm thickness
37 vacuum feedthroughs





AGATA first prototypes



First results within specs:

Energy resolution:
36 outer contacts
0.9-1.1keV at 60keV
1.9-2.1keV at 1.3MeV

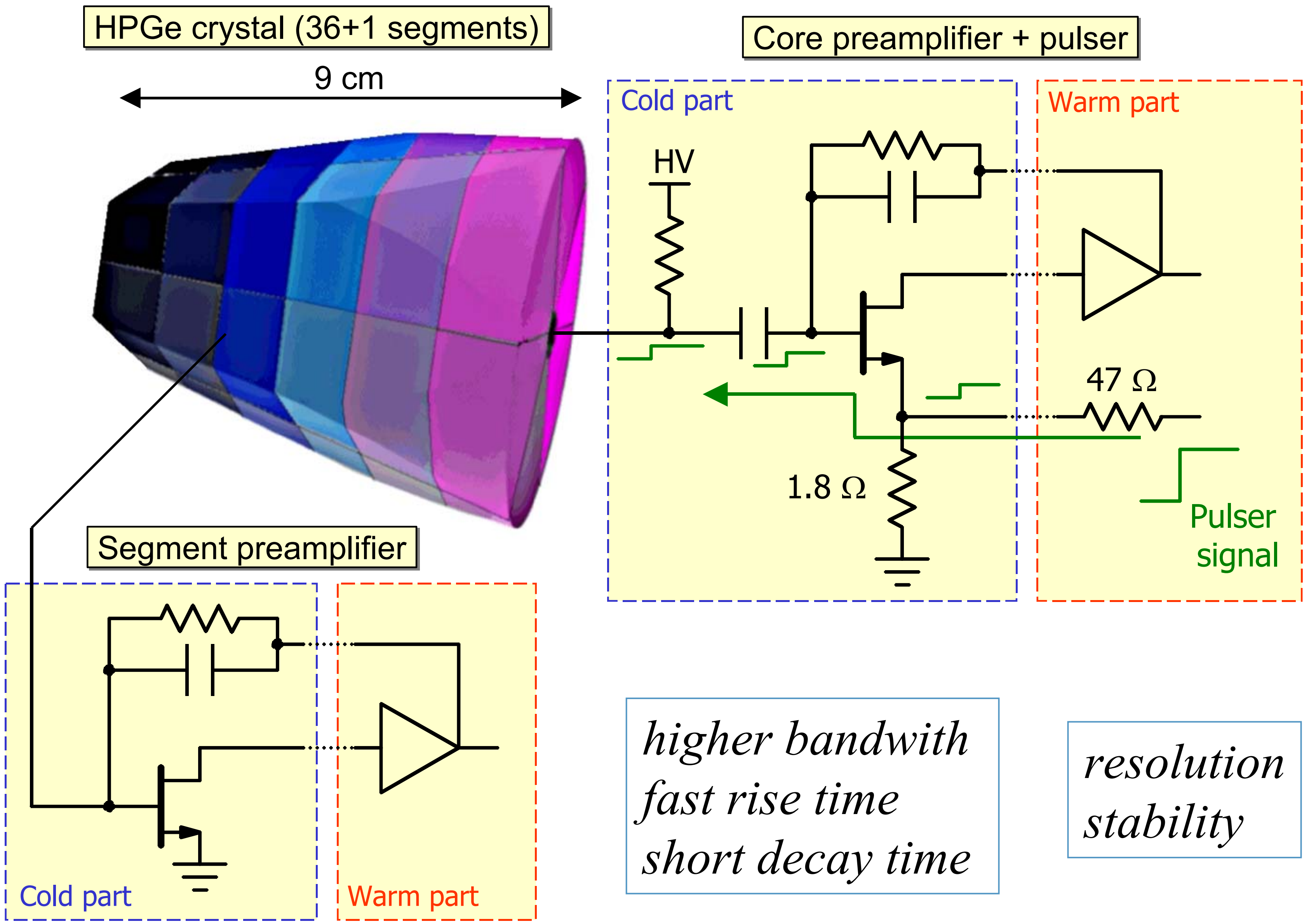
Core
1.2keV at 60keV
2.1keV at 1.3MeV

Cross talk less than 10^{-3}

Dedicated cryostat:
Internal layout as in triple cryostat,
optimised for minimum crosstalk,
cold FET's, low power (23 mW/FET)
Heko preamp, single ended output

No.	Delivered	accepted
1	May 04	July 04
2	May 04	July 04
3	Dec 04	Feb 05

AGATA pre-amplifier signal

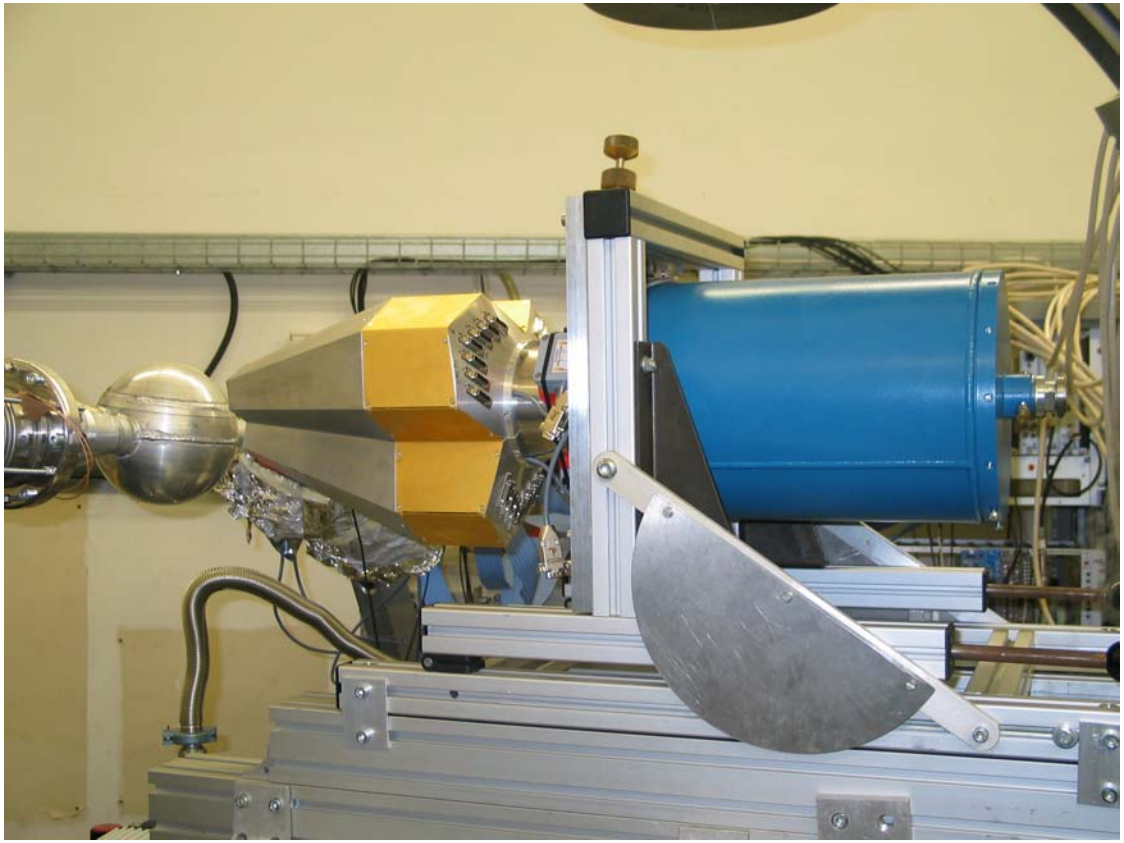


higher bandwith
fast rise time
short decay time

resolution
stability

AGATA triple cluster detector

3 encapsulated crystals
111 preamplifiers with cold FET
~230 vacuum feedthroughs
LN_2 dewar, 3 litre, cooling power ~8 watts



In-beam test
tandem accelerator
University of Cologne
September 2005

d(^{47}Ti,^{48}Ti)p @ 2.3 MeV/u
^{48}Ti at β=6%
triple cluster
plus annular Si detector

pulse shape is determined by:

- electric field geometry and strength
- impurity concentration
- crystal orientation
- charge carrier mobility
- preamplifier characteristics
- cross talk

thesis work by B. Bruyneel

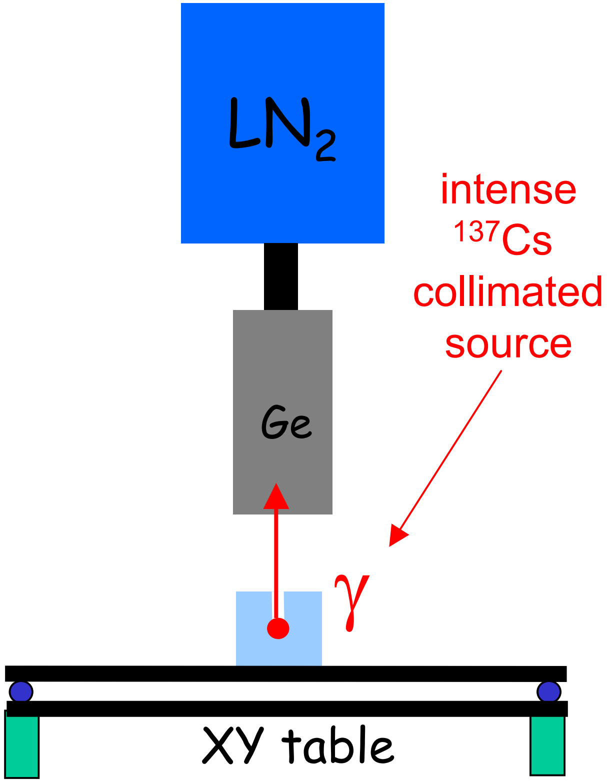
Detector characterization

- Singles scan:

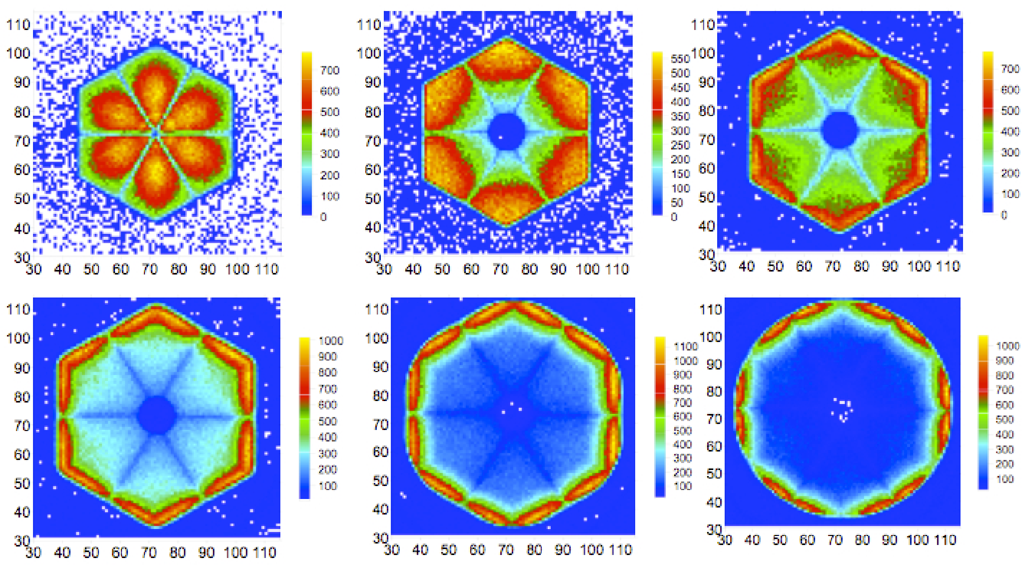
Location of crystal & segment boundaries

General survey of sensitive volume

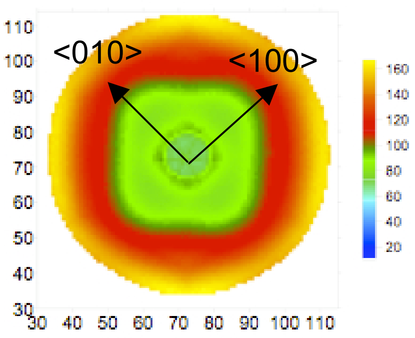
Check of lattice orientation



Core intensity map vs depth



T60 core



Detector characterization

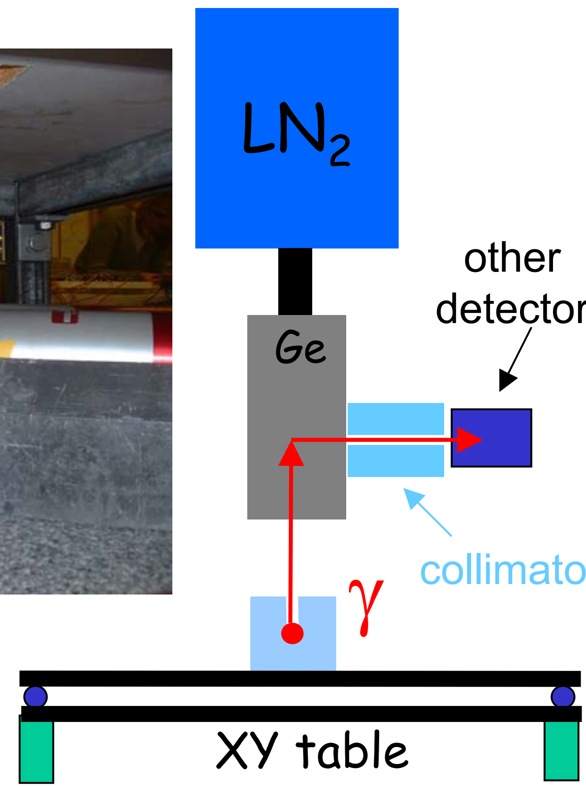
- Coincidence scan:

Mapping of signals as a function of interaction position

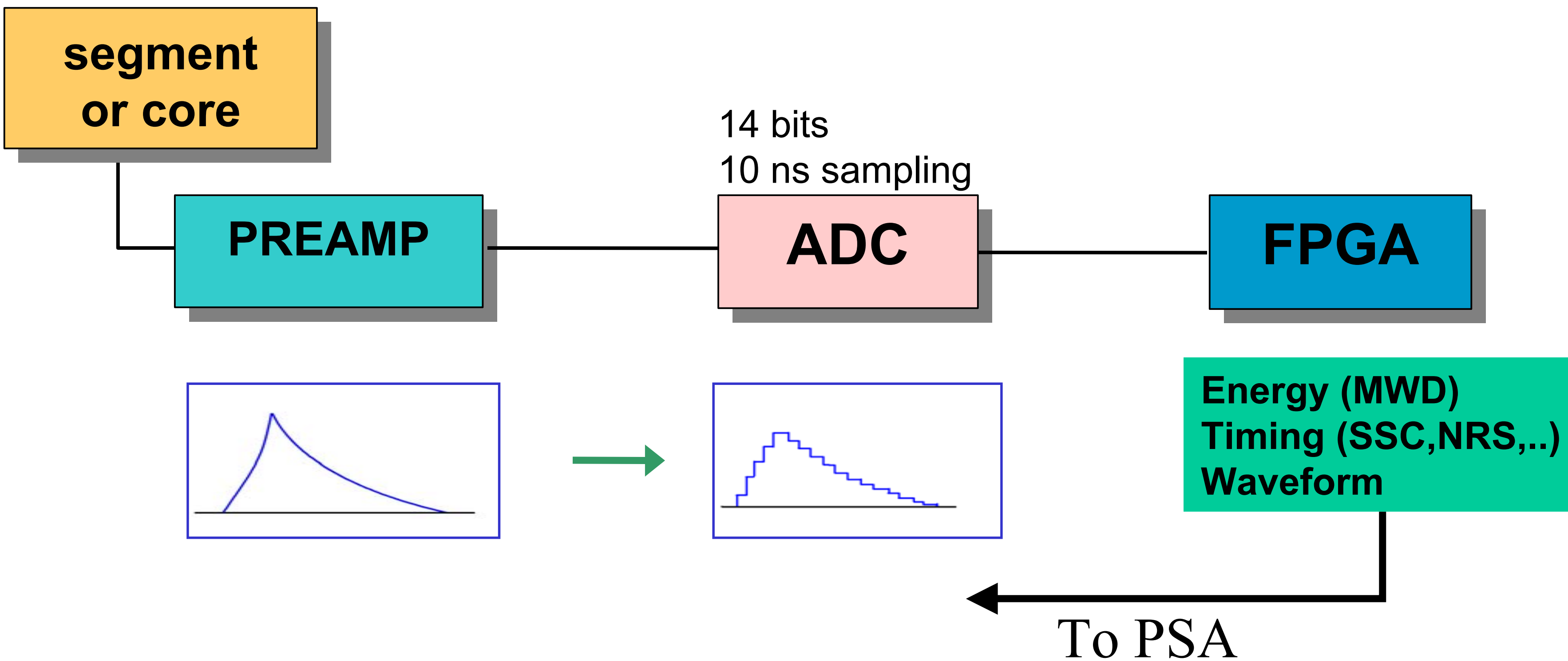
=> pulse shape database

=> comparison with simulations

Liverpool coincidence setup with multileaf collimator



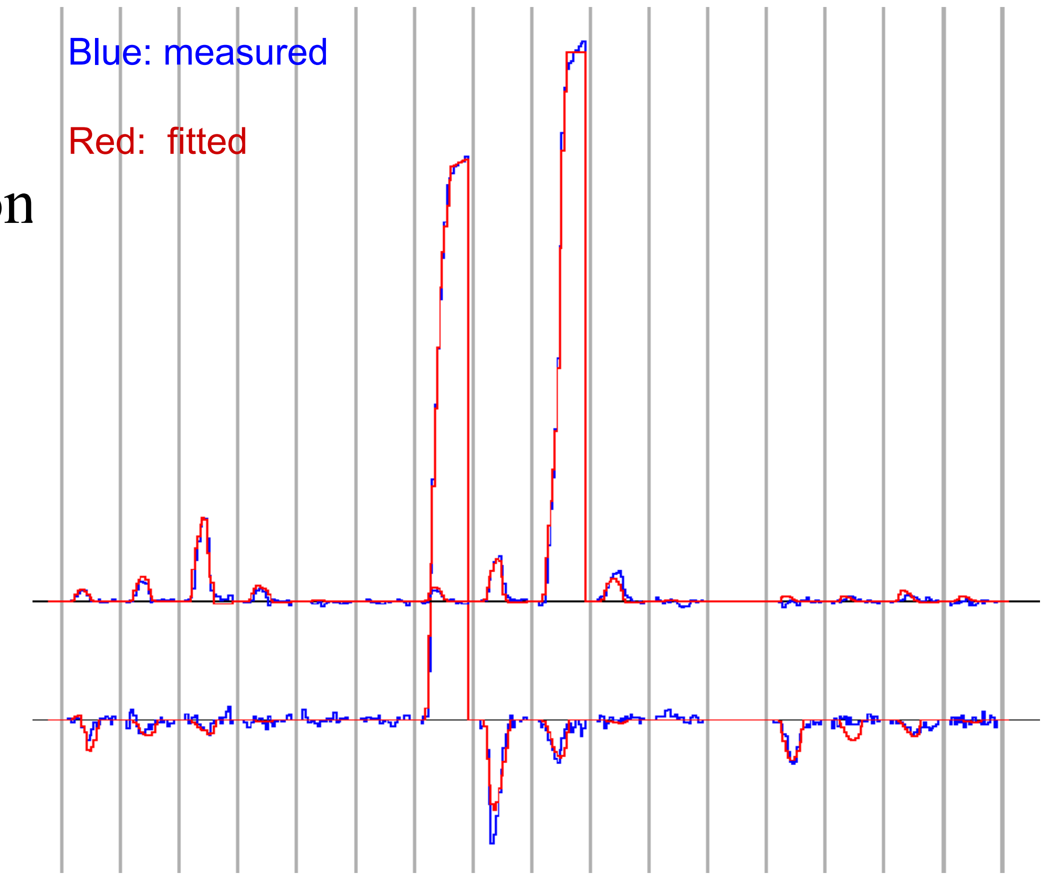
Digitization and preprocessing in AGATA



Pulse shape analysis

Expand measured signals in terms of base signals and determine expansion coefficients

$$S_{exp} = \sum a_i S_i^{base}$$



Methods under investigation

-Least Squares Method

-Adaptive Grid search

-Matrix Method

-Genetic algorithms

-Artificial Neural network

-Wavelet decomposition

Verifying the quality of PSA

- From simulations and calculations
- From experimental data with defined position
  - Scanning tables and coincidence methods with well collimated, strong radioactive sources can provide ~mm^3 precision
- In-beam experiments with fast moving nuclei
  - Doppler shift correction depends on determination of gamma-emission angle, which depends on position of first interaction point

AGATA triple detector test experiment

Main characteristics of the setup

Extreme inverse reaction:

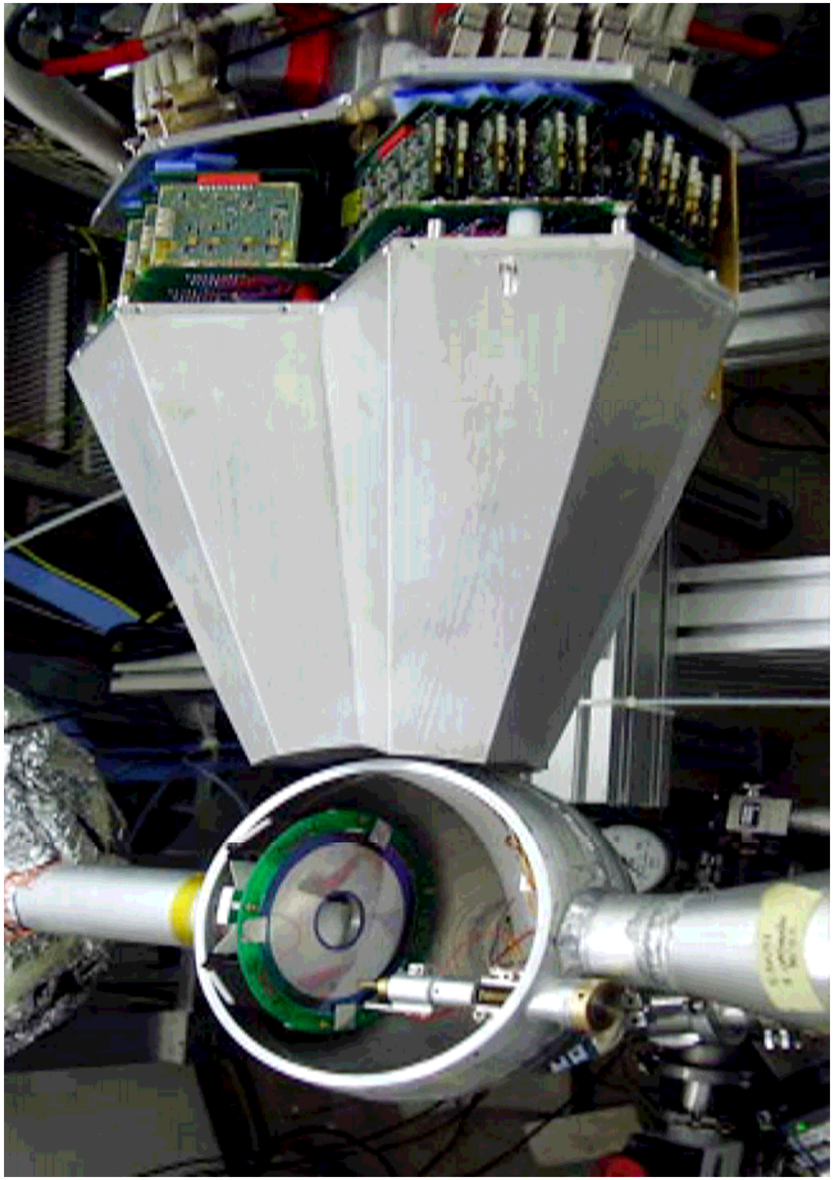
d(^{48}Ti,^{49}Ti)p E_{beam}=100 MeV

Kinematic measured

Segmented Si detector:

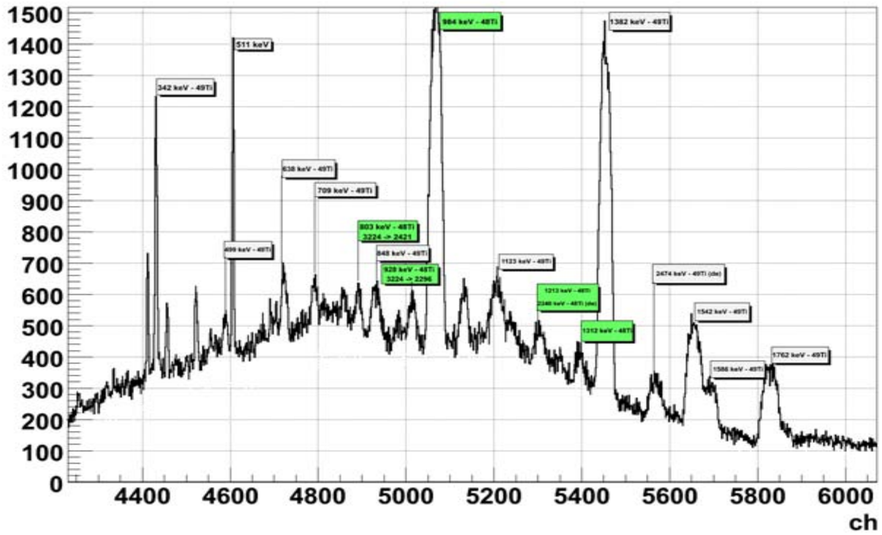
32 rings, 64 sectors

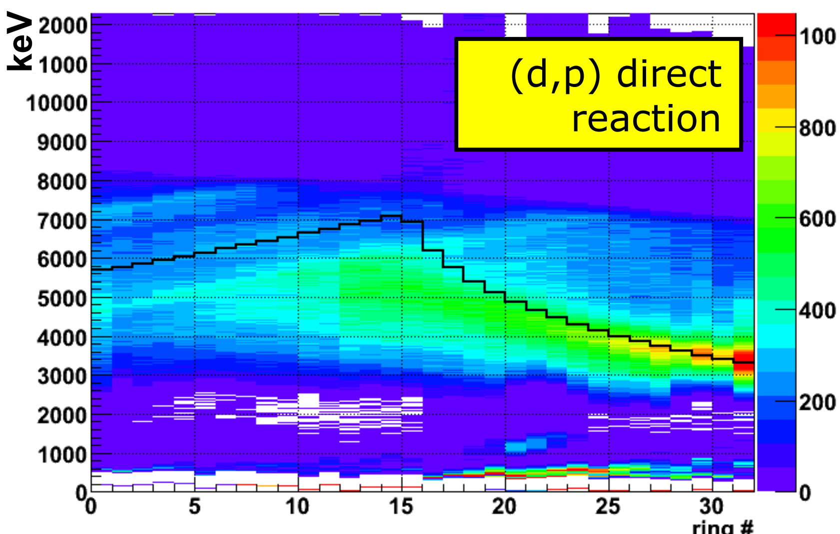
DSSSD thickness 300 μm



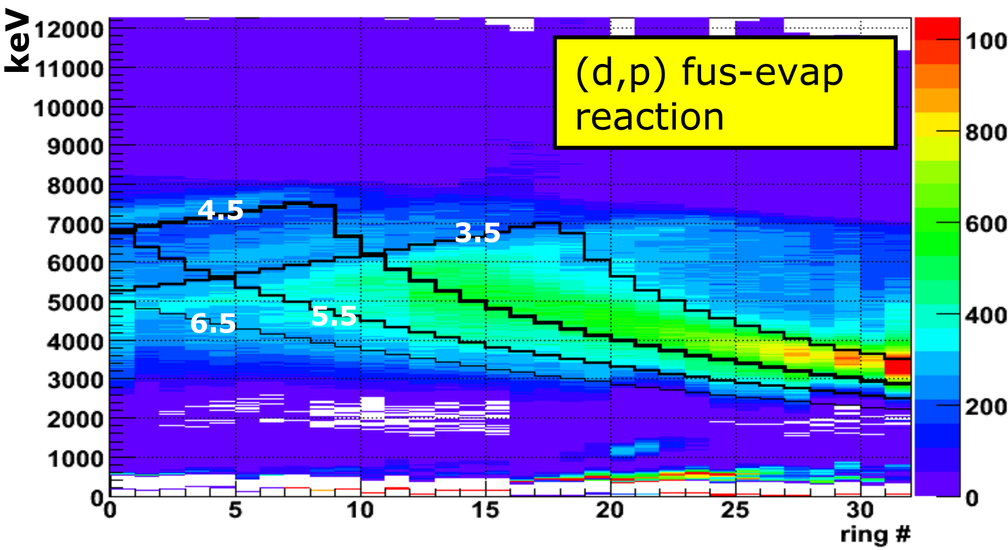
Channel identification: $^{48}Ti(d,p)^{49}Ti$

Gammas from ^{49}Ti and ^{48}Ti



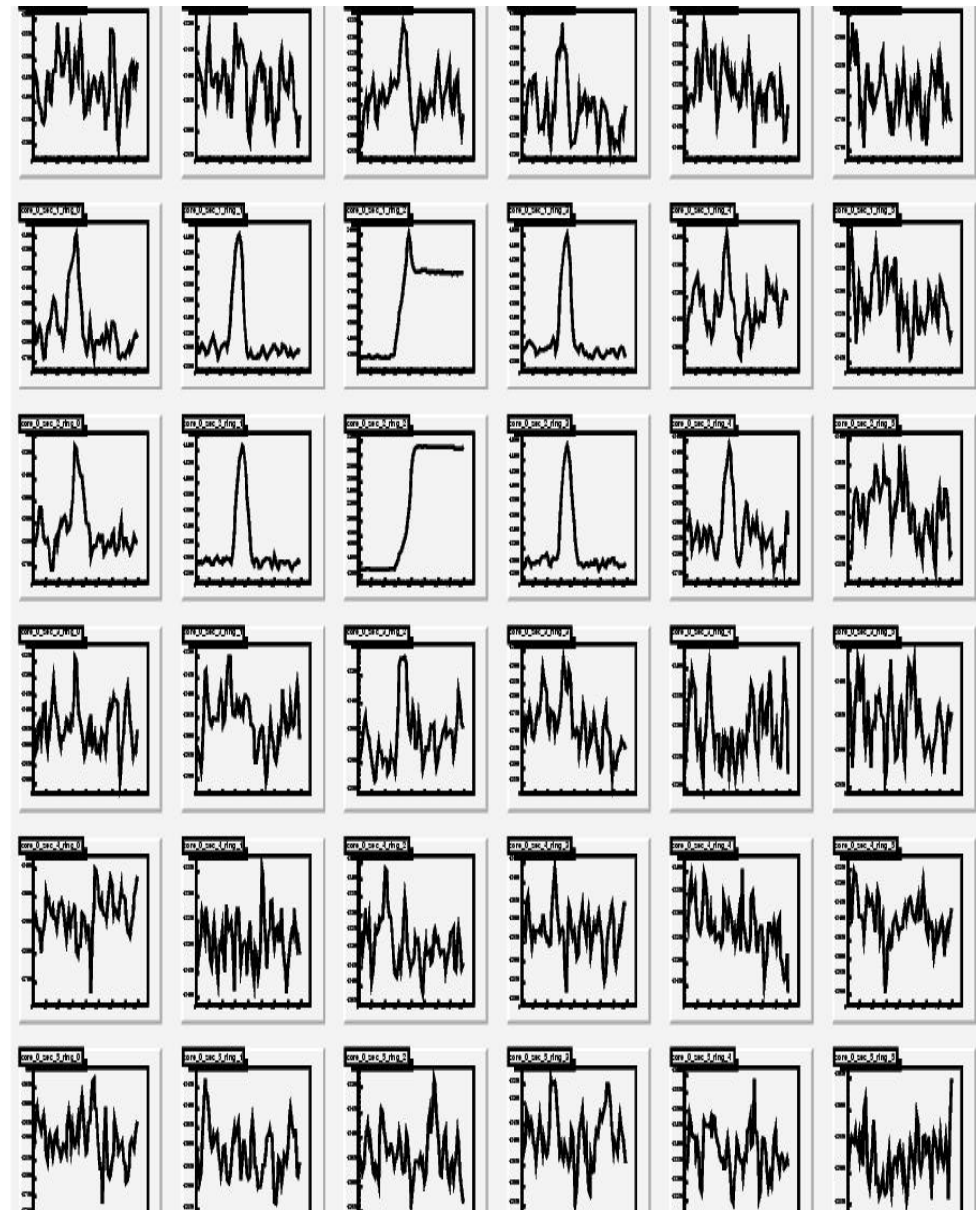


Gate on γ 1382 keV



Gate on γ 1382 keV

traces



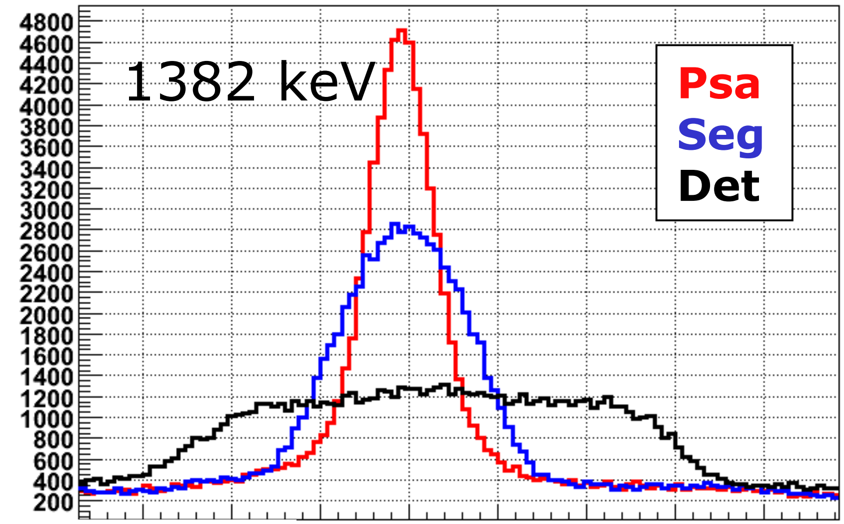
- 2 μs long, sampled at 40 MHz. 3*(36 segments+core)=111 traces.
- Noise contribution often comparable to

  mirror-charge amplitudes
- Before PSA traces have to be:
  1. Normalised
  2. Time aligned

Simulation vs Experiment (d,p) channel

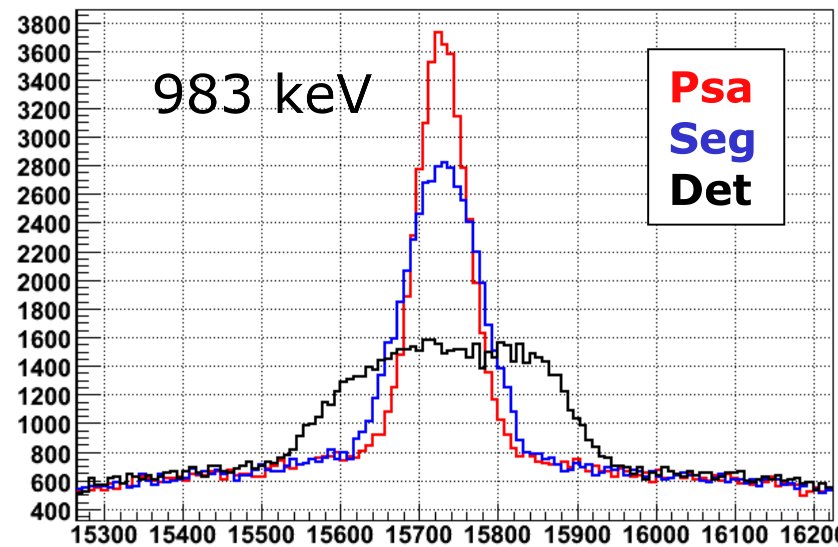
REACTION CHANNEL: (d,p)

	Experiment	Simulation
	FWHM	FWHM
Detector	32 keV	35 keV
Segment	11.1 keV	12 keV
PSA	5.5 keV	5.0 keV



REACTION CHANNEL: (C,C’)

	Experiment
	FWHM (keV)
Detector	18
Segment	6.8
PSA	4.5



position resolution

Peak broadening sources

$$E_\gamma^{CM} = E_\gamma \frac{1-\beta\cos(\theta)}{\sqrt{1-\beta^2}} \qquad (\beta,\ \theta \text{ and } E_\gamma \text{ in Lab frame})$$

$$\left(\Delta E_\gamma^{CM}\right)^2 = \left(\frac{\partial E_\gamma^{CM}}{\partial\theta}\right)^2 (\Delta\theta)^2 + \left(\frac{\partial E_\gamma^{CM}}{\partial\beta}\right)^2 (\Delta\beta)^2 + \left(\frac{\partial E_\gamma^{CM}}{\partial E_\gamma}\right)^2 (\Delta E_\gamma)^2$$

$$\left(\Delta E_\gamma^{CM}\right)^2 = \left(E_\gamma \frac{\beta\sin\theta}{\sqrt{1-\beta^2}}\right)^2 (\Delta\theta)^2 + \left(E_\gamma \frac{(\beta-\cos\theta)}{\left(1-\beta^2\right)^{\frac{3}{2}}}\right)^2 (\Delta\beta)^2 + \left(\frac{1-\beta\cos\theta}{\sqrt{1-\beta^2}}\right)^2 (\Delta E_\gamma)^2$$

- **Position resolution for the first gamma interaction**
- Beam emittance
- Target thickness

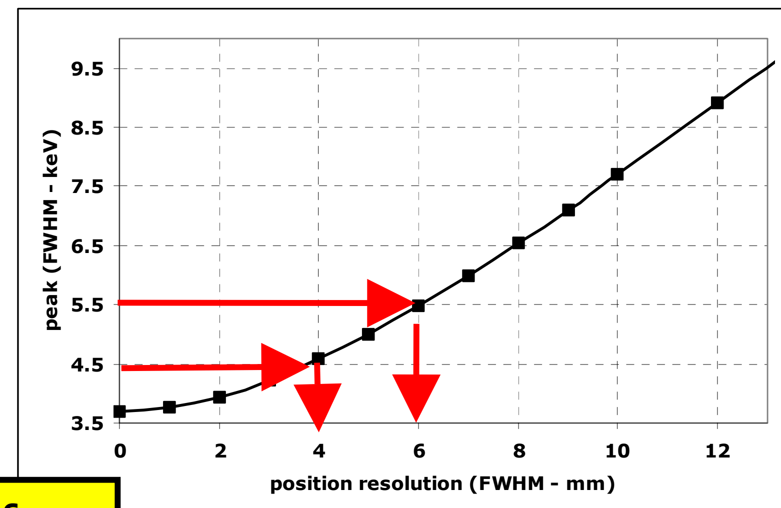
- Target thickness

- Intrinsic resolution

Contribution of **position resolution** of PSA can be **isolated**

Energy resolution: 4.5 - 5.5 keV FWHM

Spatial resolution: 4 - 6 mm FWHM



Preliminary results!

Aim of tracking

Read for each event the list of deposited energies and positions of all the interactions points in AGATA

e_1, x_1, y_1,z_1
e_2, x_2, y_2,z_2
……………….
e_n, x_n, y_n,z_n

Result of PSA

Disentangle the interaction points i.e reconstruct individual photon trajectories and write out photon energies, incident and scattering directions

$\mathbf{E_1}$, $(\theta,\phi)_{inc-1}$, $(\theta,\phi)_{sc-1}$
$\mathbf{E_2}$, $(\theta,\phi)_{inc-2}$, $(\theta,\phi)_{sc-2}$
……………………..
$\mathbf{E_i}$, $(\theta,\phi)_{inc-i}$, $(\theta,\phi)_{sc-i}$

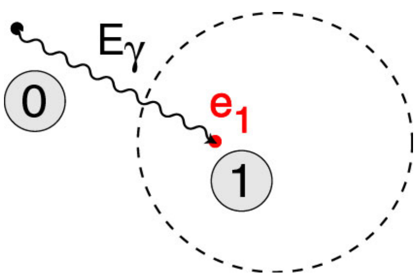
Result of γ-ray tracking

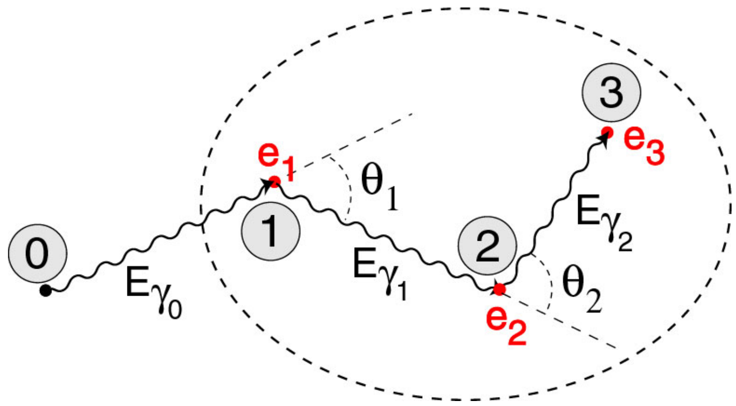
Processes in Germanium

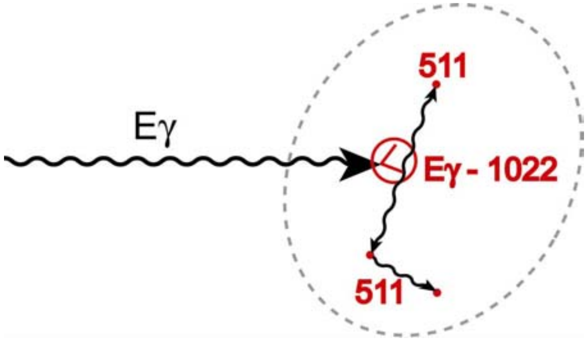
~ 100 keV ~1 MeV ~ 10 MeV

γ-ray energy →

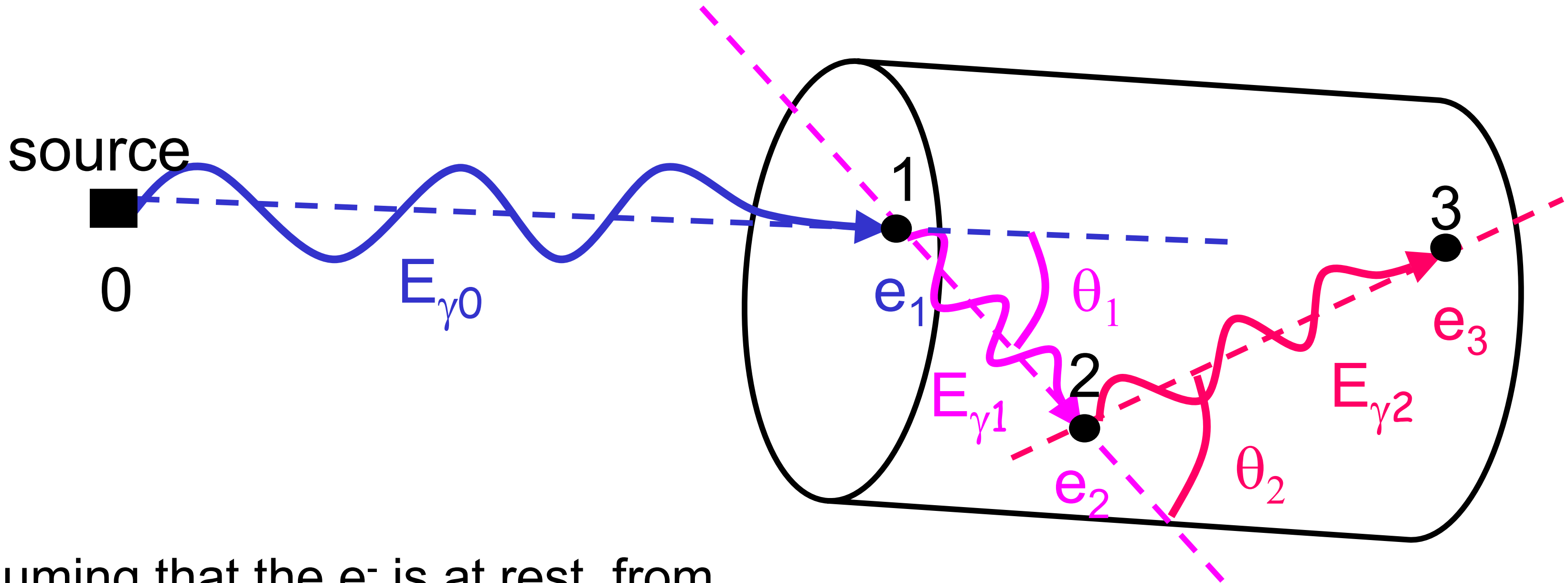
Photoelectric | **Compton Scattering** | **Pair Production**







Compton scattering



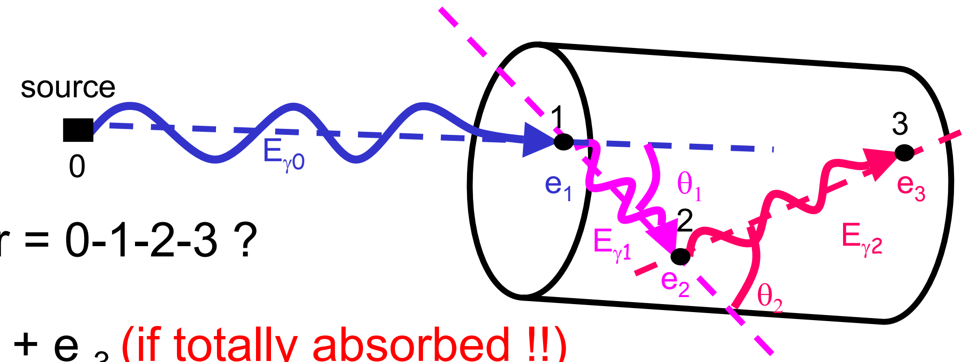
assuming that the e^- is at rest, from conservation of energy & momentum:

incident energy at i

$$\cos(\theta_i) = 1 - m_e c^2 \left(1/E_{\gamma i} - 1/E_{\gamma(i-1)}\right)$$

scattered energy at i = $E_{\gamma(i-1)} - e_i$

Compton scattering rules



Is the event complete ? Is track order = 0-1-2-3 ?

Original photon energy: $E_{\gamma 0} = e_1 + e_2 + e_3$ (if totally absorbed !!)

1) from source + interaction positions :

$$\cos(\theta_1) = \frac{\overrightarrow{01} \cdot \overrightarrow{12}}{|\overrightarrow{01}| \cdot |\overrightarrow{12}|} \Rightarrow E_{\gamma 1,pos}$$

from energy deposition + incident energy:

$$E_{\gamma 1} = E_{\gamma 0} - e_1$$

2)

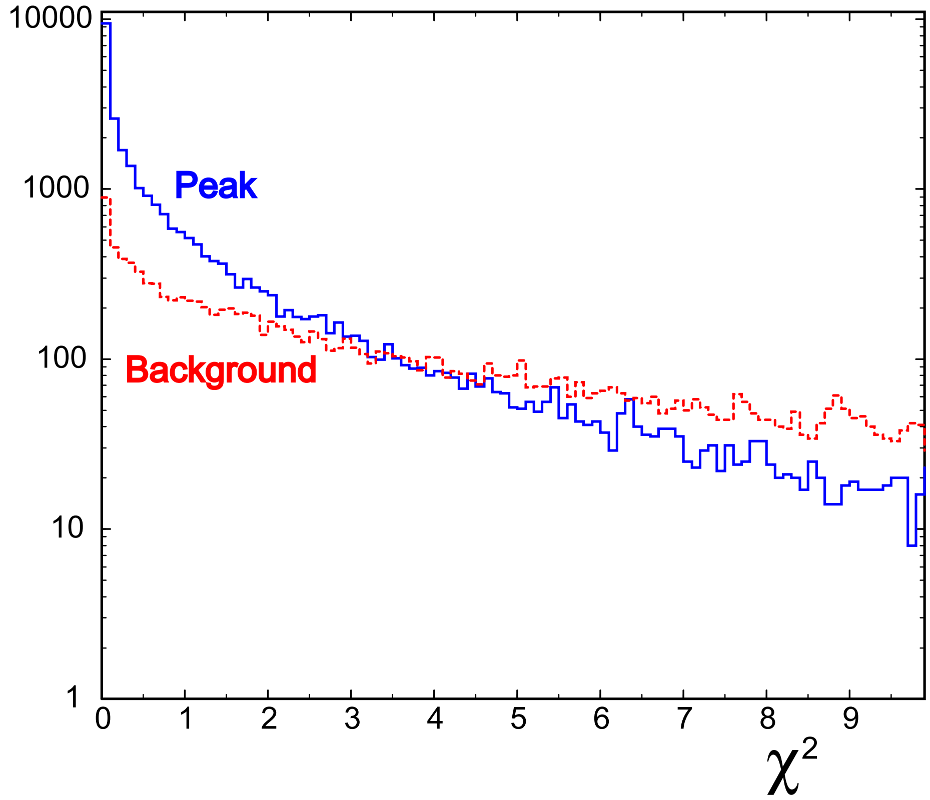
$$\cos(\theta_2) = \frac{\overrightarrow{12} \cdot \overrightarrow{23}}{|\overrightarrow{12}| \cdot |\overrightarrow{23}|} \Rightarrow E_{\gamma 2,pos}$$

$$E_{\gamma 2} = E_{\gamma 1} - e_2$$

Track order = Permutation with best

$$\chi^2 = \sum_{n=1}^{2} \left[\frac{E_{\gamma n} - E_{\gamma n,pos}}{\sigma_E} \right]^2$$

Identification is not 100% sure



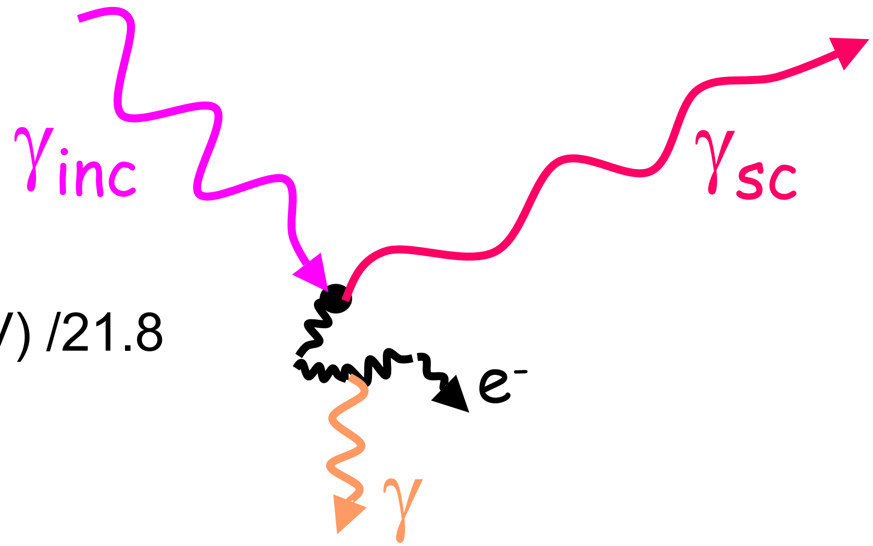
Distribution for 10^5 transitions (at $E\gamma$= 1.0 MeV) detected in the standard spherical shell.

=> spectra will always contain background

=> Acceptance value determines the quality of the spectrum

What limits tracking performance ?

- Interaction position $\neq$ position of energy deposition



$\sigma_{ion}/\sigma_{Brem} \sim E_{e-}$ (MeV) /21.8

- Electron Momentum Profile

- Rayleigh scattering (relevant at low gamma energies and end of track)
  => change in incident direction

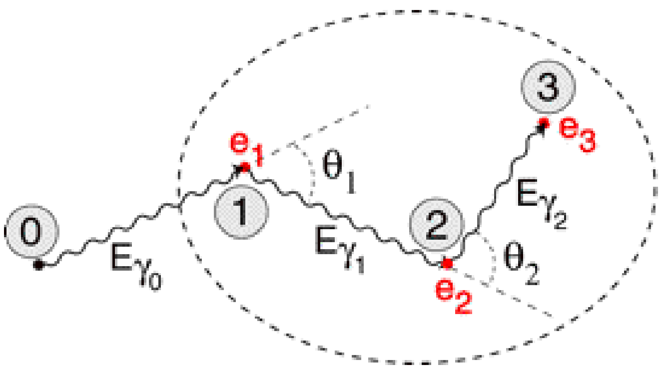
Forward tracking

- Forward peaking of Compton scattering (Klein-Nishina)
- Clusterisation of interaction points in (θ,ϕ) space
- Create cluster pool => for each cluster, $E_{\gamma 0}$ = sum of energy depositions in the cluster
- Find most probable sequence of interaction points for each cluster

- Which sequence satisfies best the Compton scattering rules ?

$$L = \prod_{n=1}^{N} P_n \exp^{-\left[\frac{E_{\gamma n} - E_{\gamma n,pos}}{\sigma_E}\right]^2}$$

Probability for Compton or photoelectric interaction and for travelling a given distance in Germanium



- Accept or reject clusters on the basis of Nth root of likelihood

G. Schmidt *et al.,* Nucl. Instr. Methods 430 (1999) 69

Forward tracking

- Ideal 4π shell

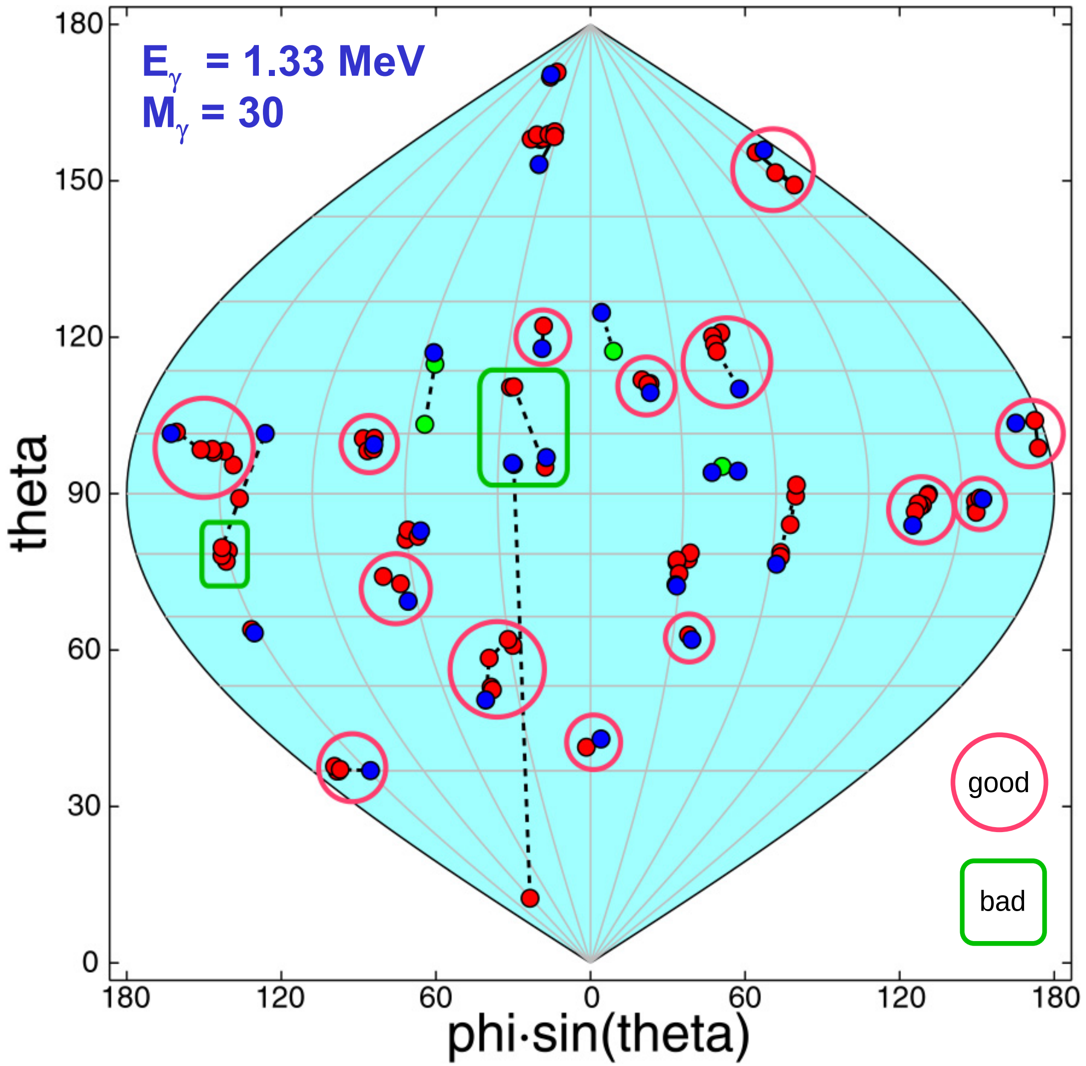
16 reconstructed

14 in photopeak

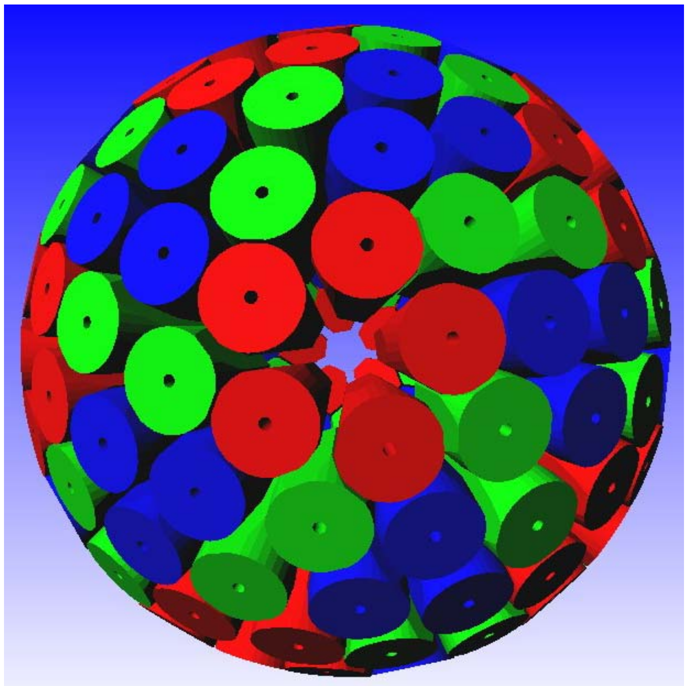
Backtracking

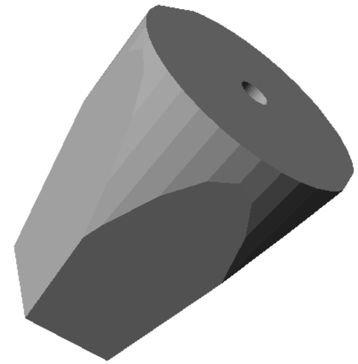
is disfavored

A.Lopez-Martens *et al.*,
Nucl. Instr. Meth. A 533 (2004) 454



The 4π 180 detector Configuration





Ge crystals size:
length 90 mm
diameter 80 mm

180 hexagonal crystals	3 shapes
60 triple-clusters	all equal
Inner radius (Ge)	23.1 cm
Amount of germanium	362 kg
Solid angle coverage	82 %
Singles rate	~50 kHz
6480 segments	

Efficiency: 43% (M_γ=1) 28% (M_γ=30)
Peak/Total: 58% (M_γ=1) 49% (M_γ=30)

http://agata.pd.infn.it/documents/simulations/comparison.html

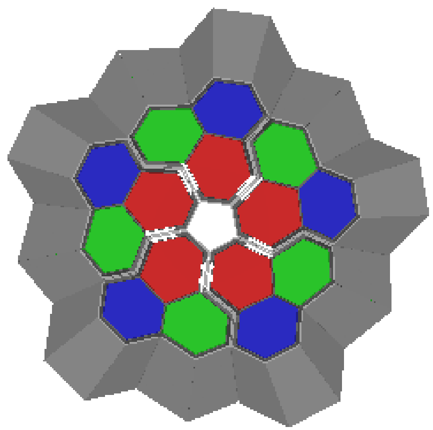
The Phases of AGATA

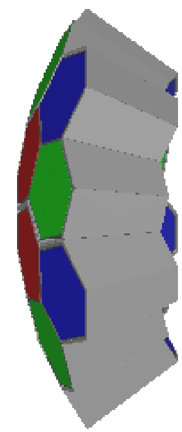
1

5 Clusters

2008

Demonstrator





Peak efficiency
3 – 8 % @ $M_\gamma = 1$
2 – 4 % @ $M_\gamma = 30$

Replace/Complement

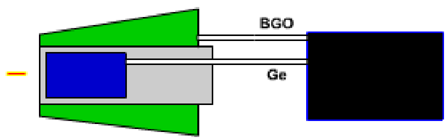
GSI	FRS	RISING
LNL	PRISMA	CLARA
GANIL	VAMOS	EXOGAM
JYFL	RITU	JUROGAM

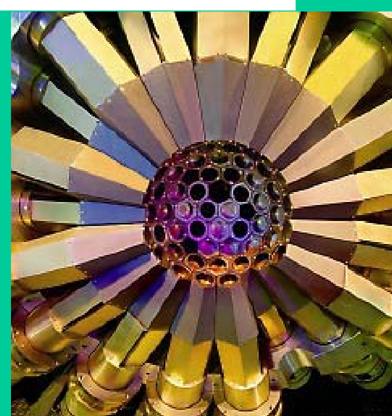
Main issue is Doppler correction capability → coupling to beam and recoil tracking devices

Improve resolution at higher recoil velocity
Extend spectroscopy to more exotic nuclei

Summary

Large Gamma Arrays based on Compton Suppressed Spectrometers





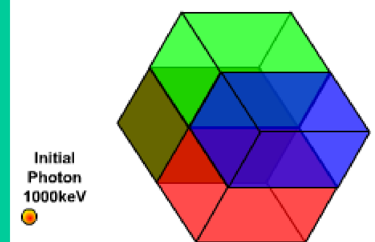
EUROBALL

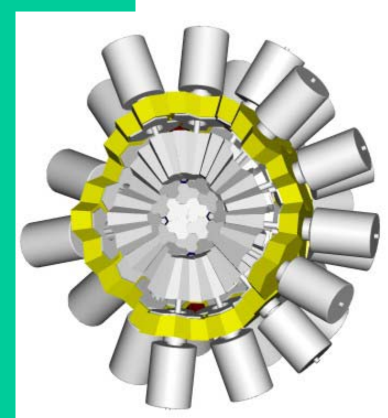
GAMMASPHERE

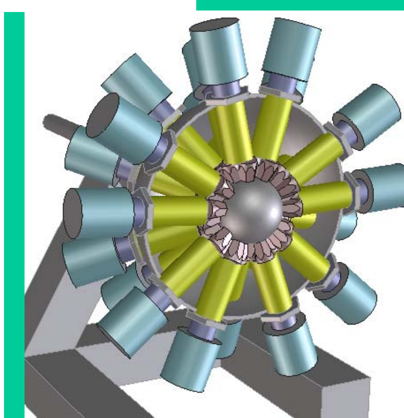
$\varepsilon \sim$ **10 — 5 %**

(M_γ=1 — M_γ=30)

Tracking Arrays based on Position Sensitive Ge Detectors







AGATA

GRETA

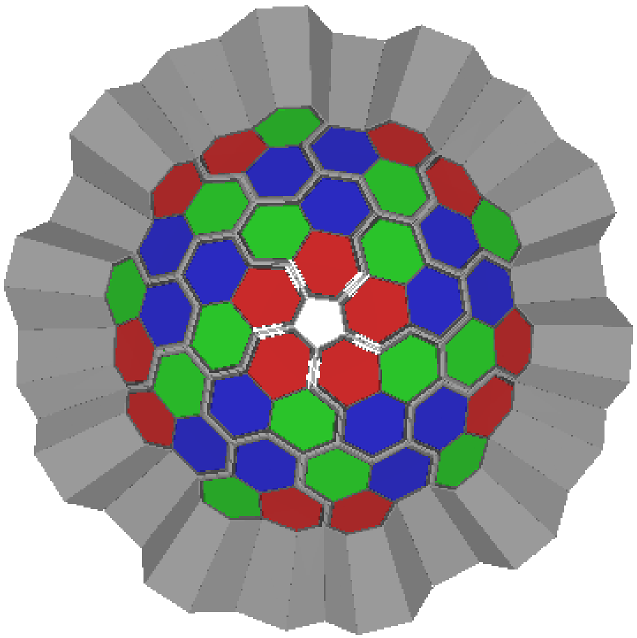
$\varepsilon \sim$ **40 — 20 %**

(M_γ=1 — M_γ=30)

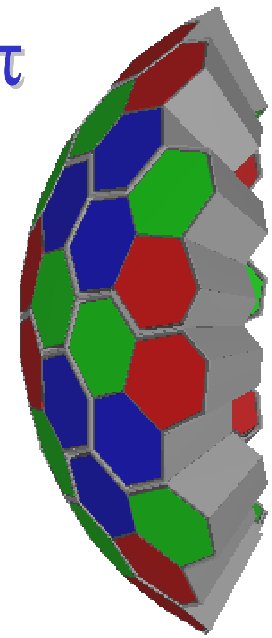
The Phases of AGATA

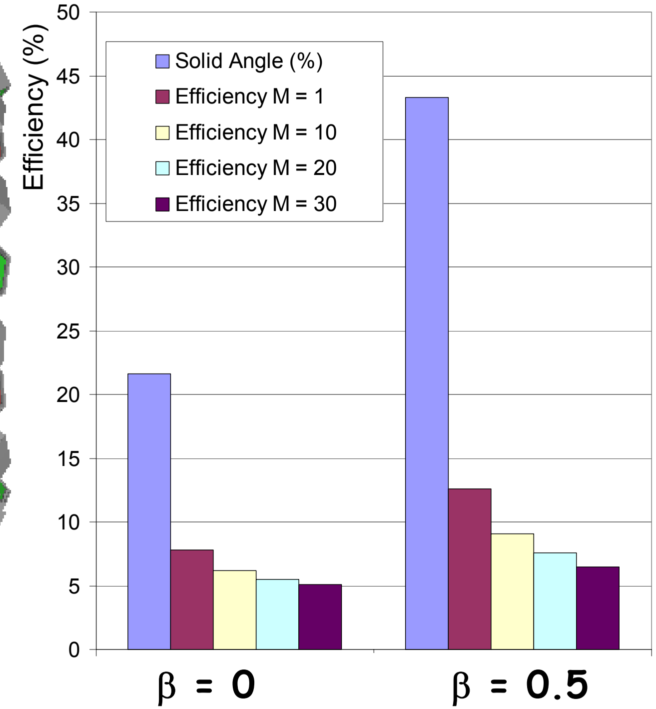
2

15 Clusters



1π





The first "real" tracking array

Used at **FAIR-HISPEC**, **SPIRAL2**, **SPES**, **HI-SIB**

Coupled to spectrometer, beam tracker, LCP arrays …

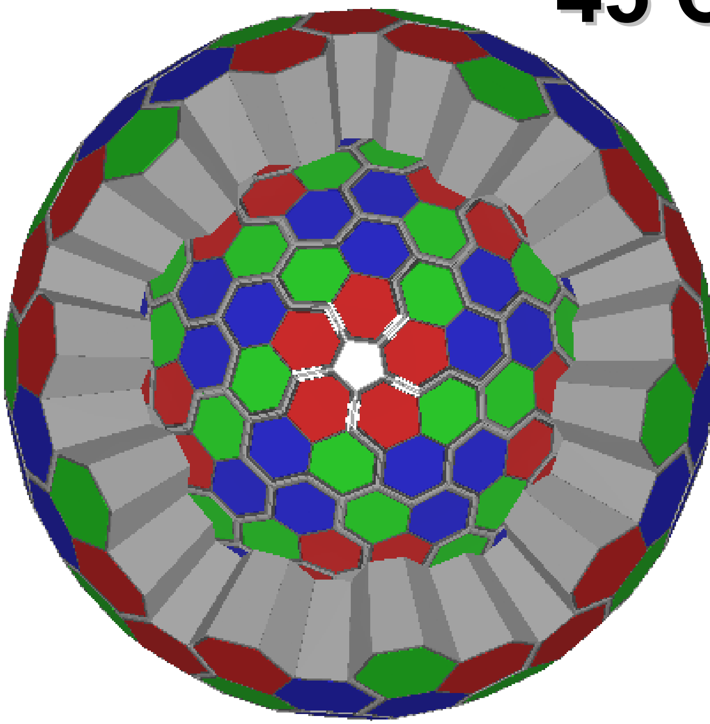
Spectroscopy at the N=Z (^{100}Sn), n-drip line nuclei, …

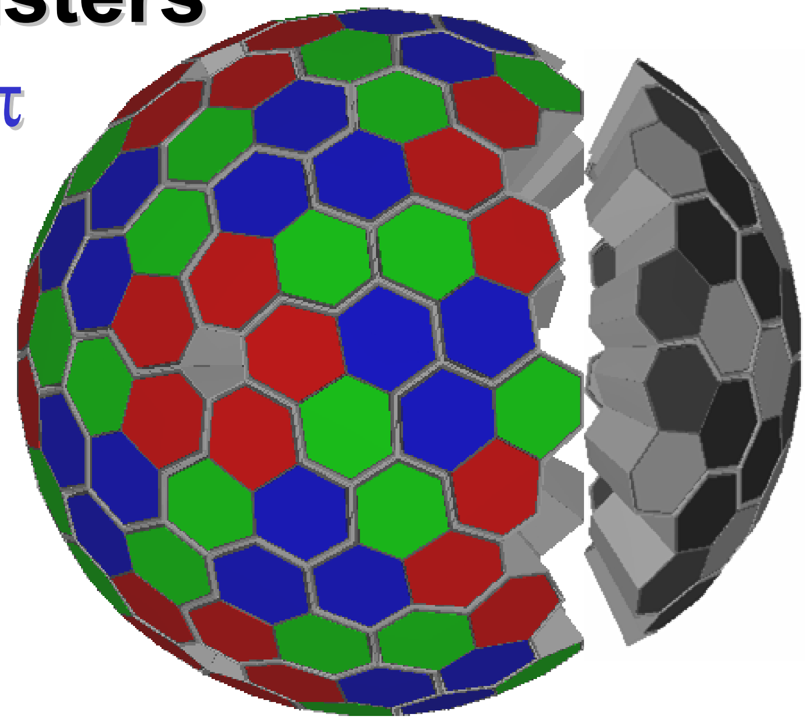
The Phases of AGATA

3

45 Clusters

3π





Efficient as a 120-ball (~20 % at high γ-multiplicity)

Ideal instrument for FAIR / EURISOL

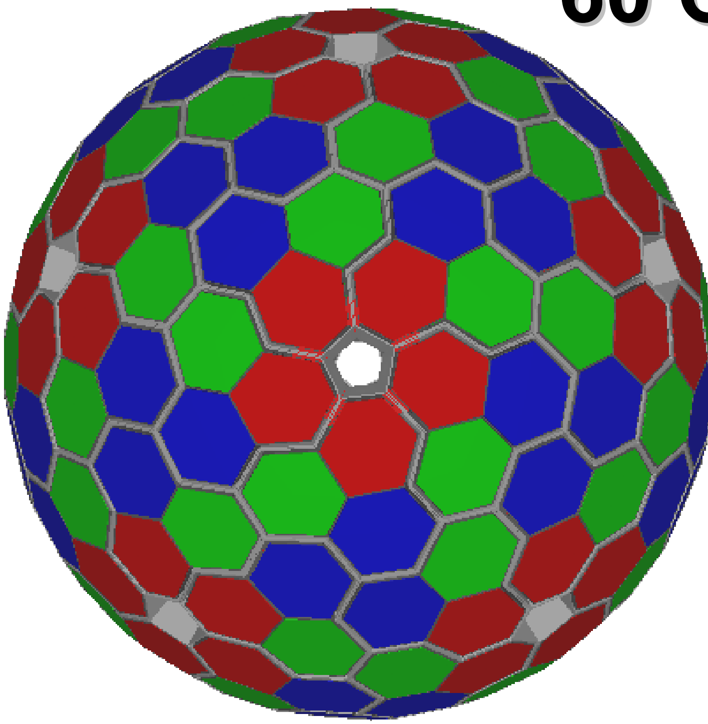
Also used as partial arrays in different labs

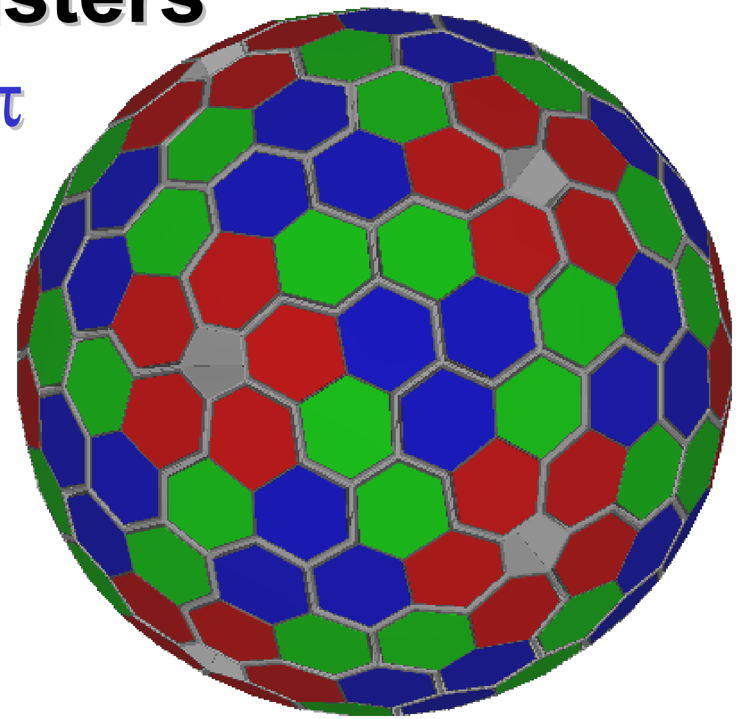
Higher performance by coupling with ancillaries

The Phases of AGATA

60 Clusters

4π





Full ball, ideal to study extreme deformations and the most exotic nuclear species

Most of the time used as partial arrays

Maximum performance by coupling to ancillaries

The AGATA Collaboration
Memorandum of Understanding 2003 Research and Development

Bulgaria: Univ. Sofia

Denmark: NBI Copenhagen

Finland: Univ. Jyvaskyla

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. zu Köln, LMU München, TU München

Italy: INFN & Univ. Firenze, INFN & Univ. Genova, INFN Legnaro, INFN & Univ. Napoli,
INFN & Univ. Padova, INFN & Univ. Milano, INFN Perugia, Univ. Camerino

Poland: NINP and IFJ Krakow, SINS Swierk, HIL & IEP Warsaw

Romania: NIPNE & PU Bucharest

Sweden: Chalmers Univ. of Technology Göteborg, Lund Univ.,
Royal Institute of Technology Stockholm, Uppsala Univ.

UK: Univ. Brighton, CLRC Daresbury, Univ. Keele, Univ. Liverpool, Univ. Manchester,
Univ. Paisley, Univ. Surrey, Univ. York

Turkey Ankara, Istanbul

Hungary Debrecen

AGATA Organisation

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G.deAngelis, A.Atac, D.Balabanski, D.Bucurescu, B.Cederwall, D.Guillemaud-Mueller, J.Jolie, R.Julin, W.Meczynski, P.J.Nolan, M.Pignanelli, G.Sletten, P.M.Walker

AGATA Management Board

J.Simpson (Project Manager)

D.Bazzacco, G.Duchêne, P. Reiter, A.Gadea, W.Korten, R.Krücken, J.Nyberg

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Detector module P. Reiter	Detector Performance R.Krücken	Data Processing D.Bazzacco	Design and Infrastructure G. Duchêne	Ancillary detectors and integration A.Gadea	Simulation and Data Analysis J.Nyberg	EURONS W.Korten

AGATA Teams

Detector module	Detector Performance	Data Processing	Design and Infrastructure	Ancillary detectors and integration	Simulation and Data Analysis	EURONS
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Preamplifiers A.Pullia		Pre-processing I.Lazarus	Infrastructure P.Jones	Devices for key Experiments N.Redon	Physics & expt. 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	
		Data acquisition X.Grave		Mechanical Integration vacant	Data analysis O.Stezowski	
		Run Control & GUI G.Maron				