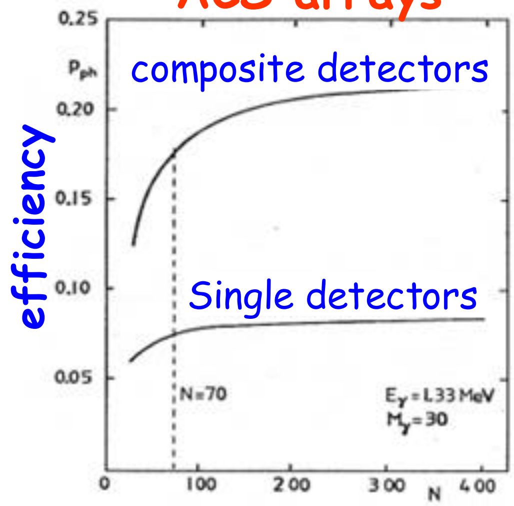
The Ultimate Ge Array: γ-ray tracking & PSA
AGATA & GRETA

FAIR
SPIRAL2
SPES
REX-ISOLDE
MAFF
EURISOL
HI-Stable

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

Harsh conditions!
Need instrumentation with

ACS arrays



High **efficiency**
High **sensitivity**
High **throughput**
Ancillary detectors

Conventional arrays will not be enough!

Present Arrays

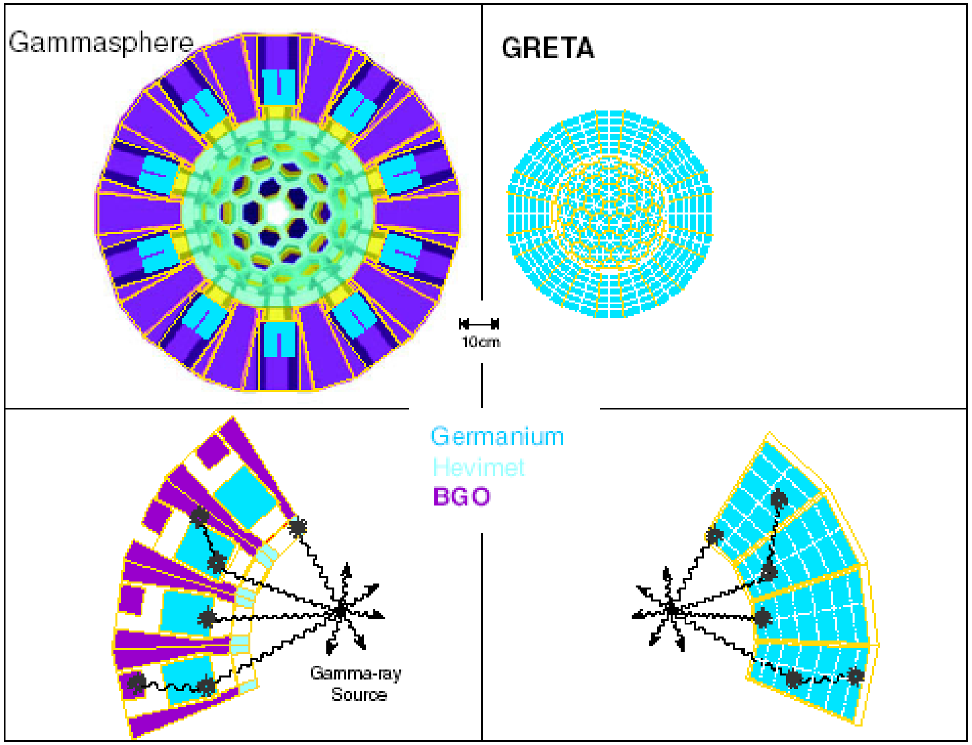
Large HpGe &
Anti-Compton shields

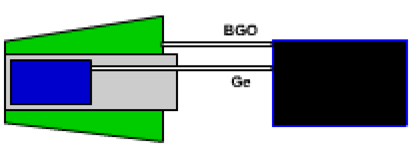
$\varepsilon \sim 10 — 5$ %
(M_γ=1 — M_γ=30)

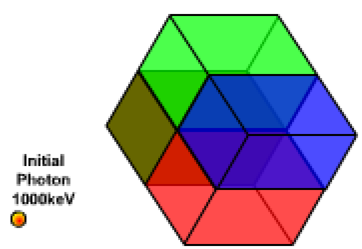
Future Arrays

Segmented Ge's
Tracking & PSA

$\varepsilon \sim 40 — 20$ %
(M_γ=1 — M_γ=30)







By removing ACS
it is possible to increase
the Ge solid angle

Ideal pure Ge shell:

ε_{ph}~ 60%
N=1000 to distinguish simultaneous γ's (M_γ ~ 20)

Prohibitive costs !!!

Tracking array:

Identify and track the interactions of all γ's even if several interact in one detector

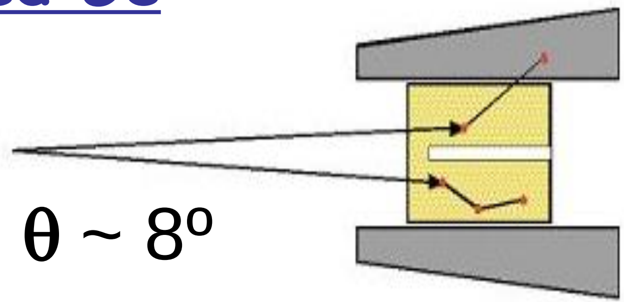
$\Rightarrow$ construction of array of 100 highly segmented Ge's

From conventional arrays to γ-ray tracking

Compton Shielded Ge

ε_{ph} ~ 10%
N_{det} ~ 100

Ω ~40%

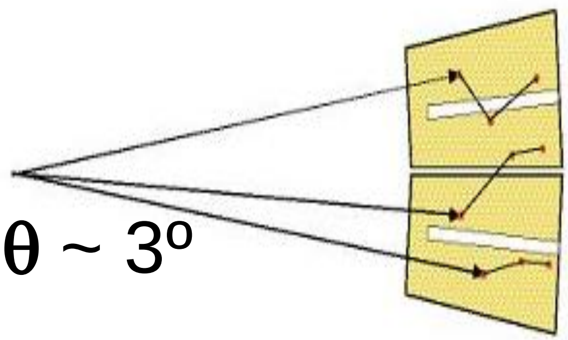


$\theta \sim 8^{o}$

Efficiency is lost due to the solid angle covered by the shield; poor energy resolution at high recoil velocity because of the large opening angle

Ge Shell

ε_{ph} ~ 50%
N_{det} ~ 1000



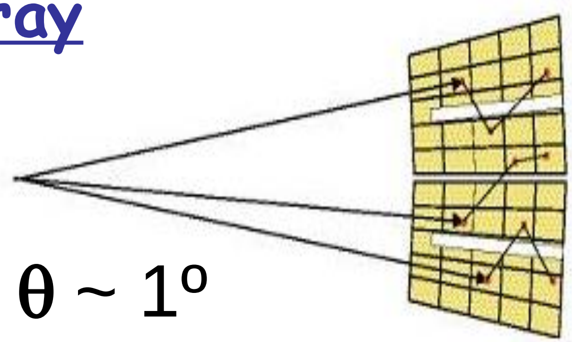
$\theta \sim 3^{o}$

Using only conventional Ge detectors, too many detectors are needed to avoid summing effects and keep the resolution to good values

Ge Tracking Array

ε_{ph} ~ 50%
N_{det} ~ 100

Ω ~80%

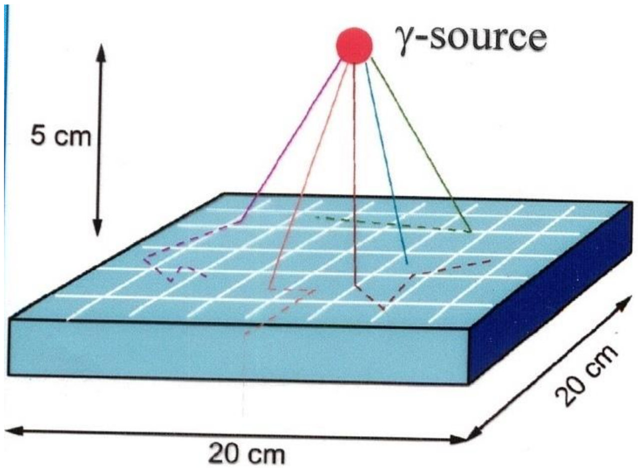


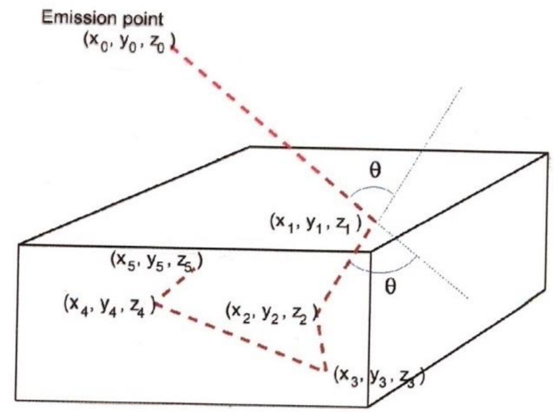
$\theta \sim 1^{o}$

The proposed solution:
Use the detectors in a non-conventional way!

AGATA and GRETA

Principle



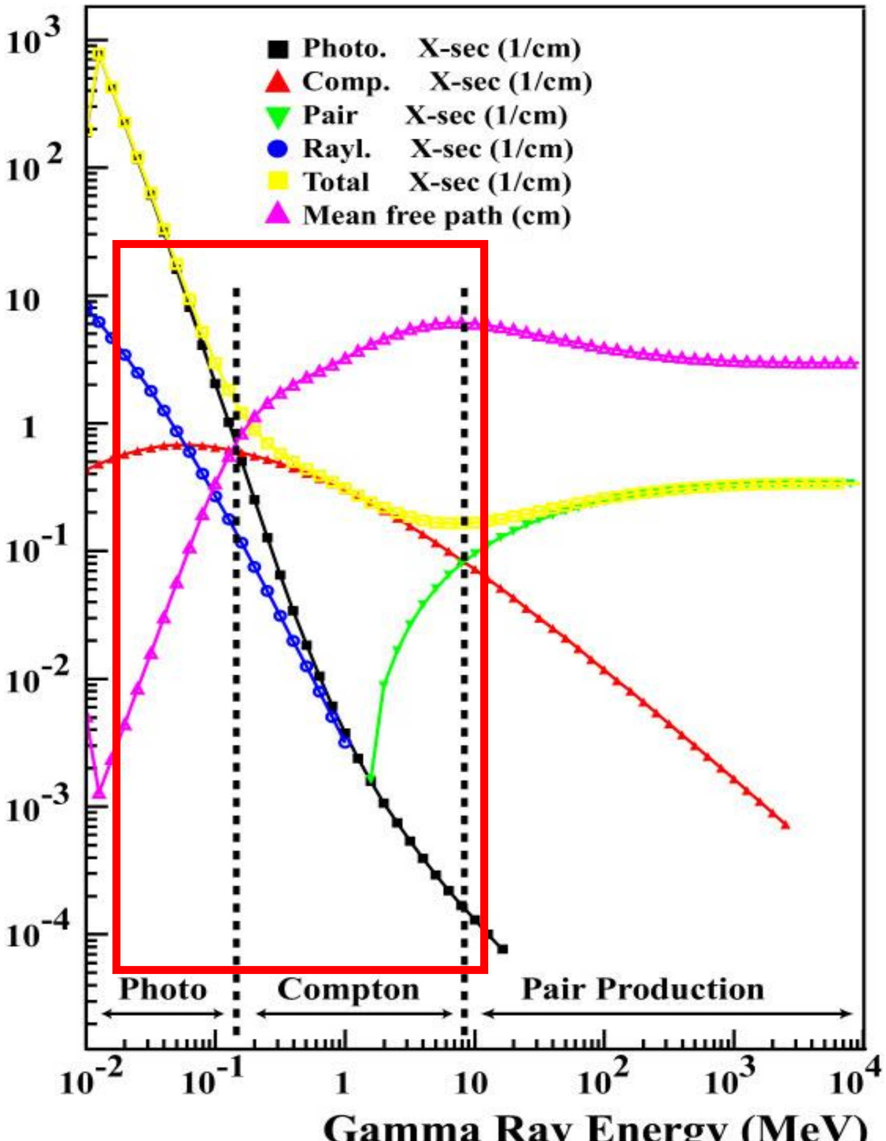


Information on **position of interactions** is used to

- reconstruct time order sequence
- original γ direction
- γ-ray energy

full tracking of γ-rays

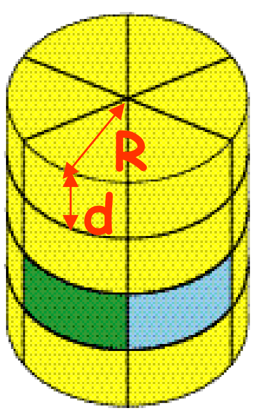
Interaction of photons in germanium



Mean free path determines size of detectors:

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(2 MeV)	~ 4.5 cm
λ(5 MeV)	~ 5.9 cm
λ(10 MeV)	~ 5.9 cm

typical segment size
d x R
1.5 cm x 3.6 cm



Tracking Principle

*determination of **individual γ-rays interactions***
*and **scattering sequence** in time order*

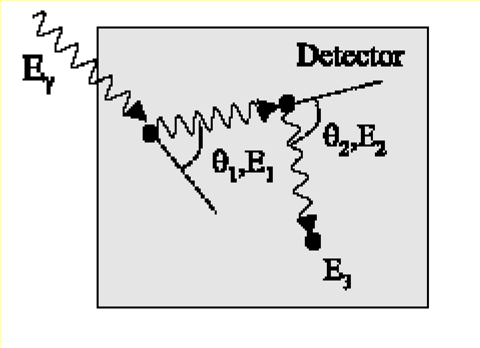
NOT possible with timing measurements:

interaction distance: $d \sim 1$ mm-1 cm
interval between interactions: $t = d/(c/\sqrt{\varepsilon_r \mu_r}) \sim (10^{-2}\text{-}10^{-3}\text{m})/(3\times10^8/(\sqrt{16\times100})\ \text{m/s})$
$=0.1\text{-}1.2$ ns

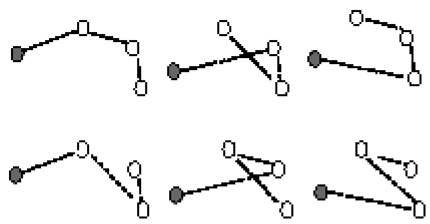
Ge time resolution: $\tau \sim 5$ ns $\gg t$

⇒ *individual interactions are seen in coincidence*

Solution: reconstruction of interaction path via **tracking algorithms** based on **i)** Compton scattering (dominant process), **ii)** pair production and **iii)** photoelectric interaction.



3! = 6 permutations



exact sequence is determined by Compton scattering laws

$$E'_\gamma = \frac{E_\gamma}{1+(E_\gamma/m_0c^2)(1-\cos\theta)}$$

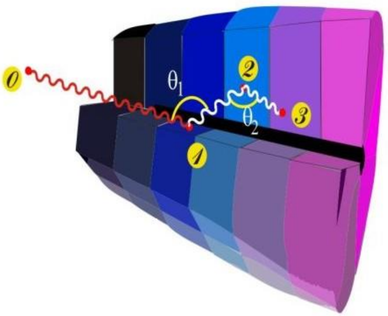
Required position resolution: 1-2 mm & Required energy resolution : 2-3 keV

➡ Position resolution is achieved with Pulse Shape Analysis

Ingredients of Gamma Tracking

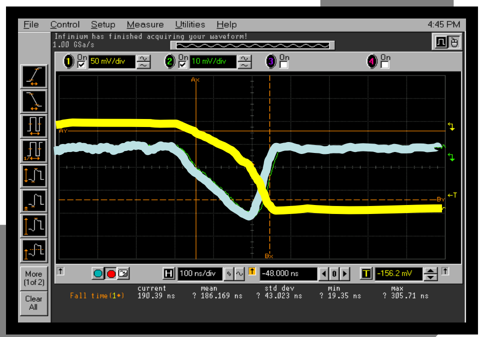
1

Highly segmented HPGe detectors



2

Digital electronics to record and process segment signals

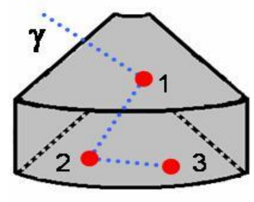


3

Pulse Shape Analysis to decompose recorded waves

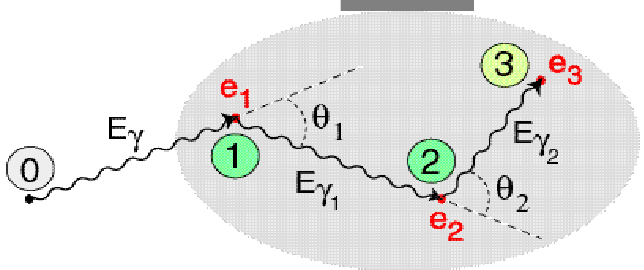
Identified interaction points

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



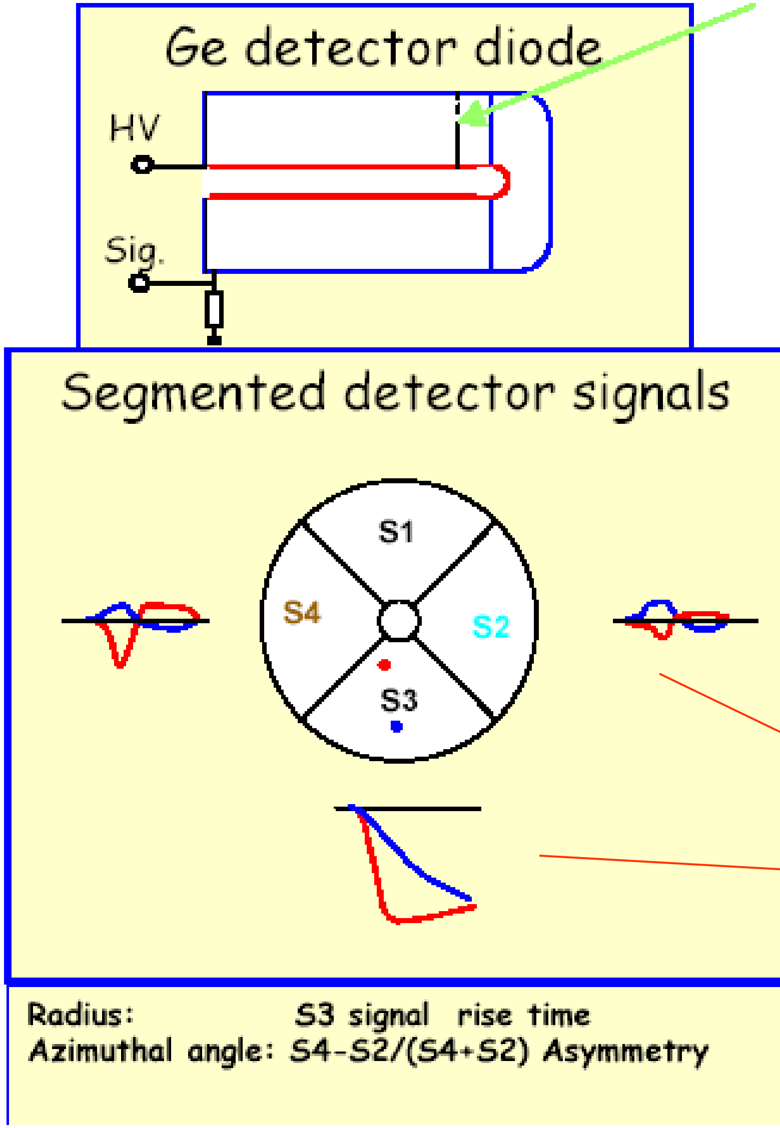
4

Reconstruction of tracks evaluating permutations of interaction points



Reconstructed gamma-rays

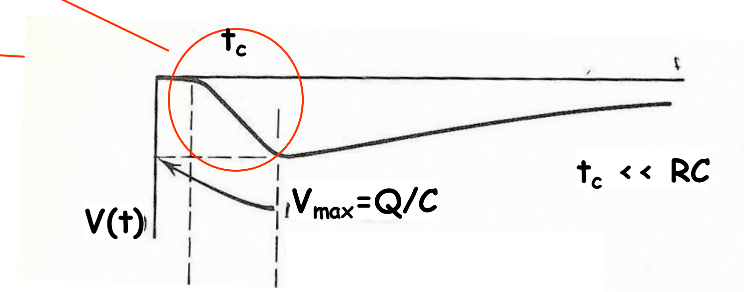
Pulse Shape Analysis (PSA)



The charge collection process induces signals with **Shapes & Amplitude** depending on the interaction point

detailed study of **preamplifier signals**

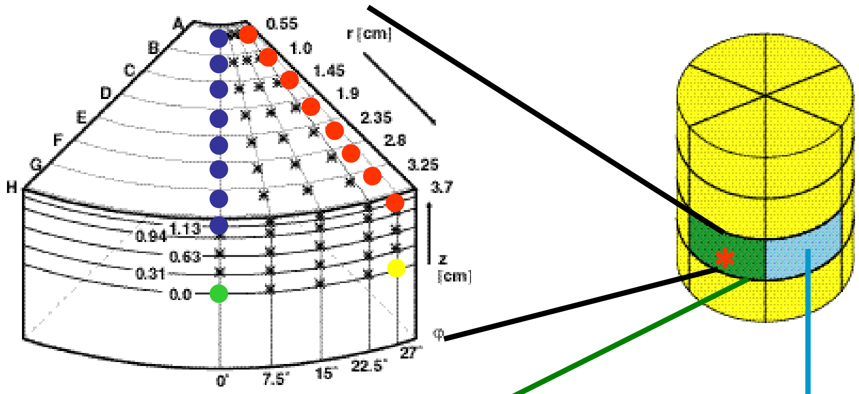
particularly the **leading edge**, which carries information on the charge collection time



Th. Kröll, NIM A 463 (2001) 227

Pulse Shape Analysis (PSA)

Analysis of **amplitude & shape** of recorded signals in each segment allows to determine the **3-dimentional position** of interaction point

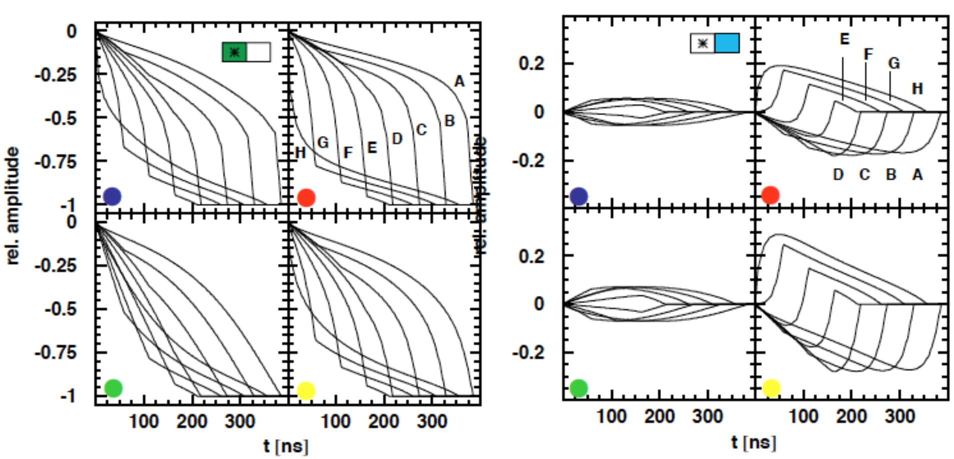


Procedure:

1. The charge collection process induces signals with **Shapes & Amplitude** depending on the interaction point
2. **Shapes & Amplitudes** can be calculated rather well using finite elements analysis
3. ***Genetic algorithms*** are used to determine points of interactions with ~2 mm precision

net charge signals ($Q \neq 0$)

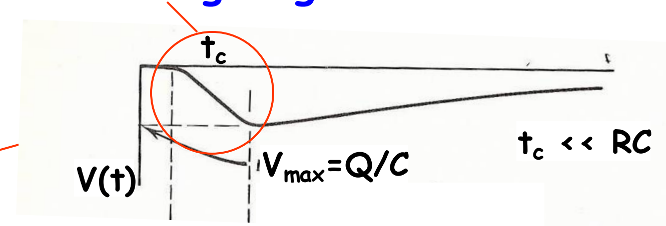
transient signals ($Q=0$)



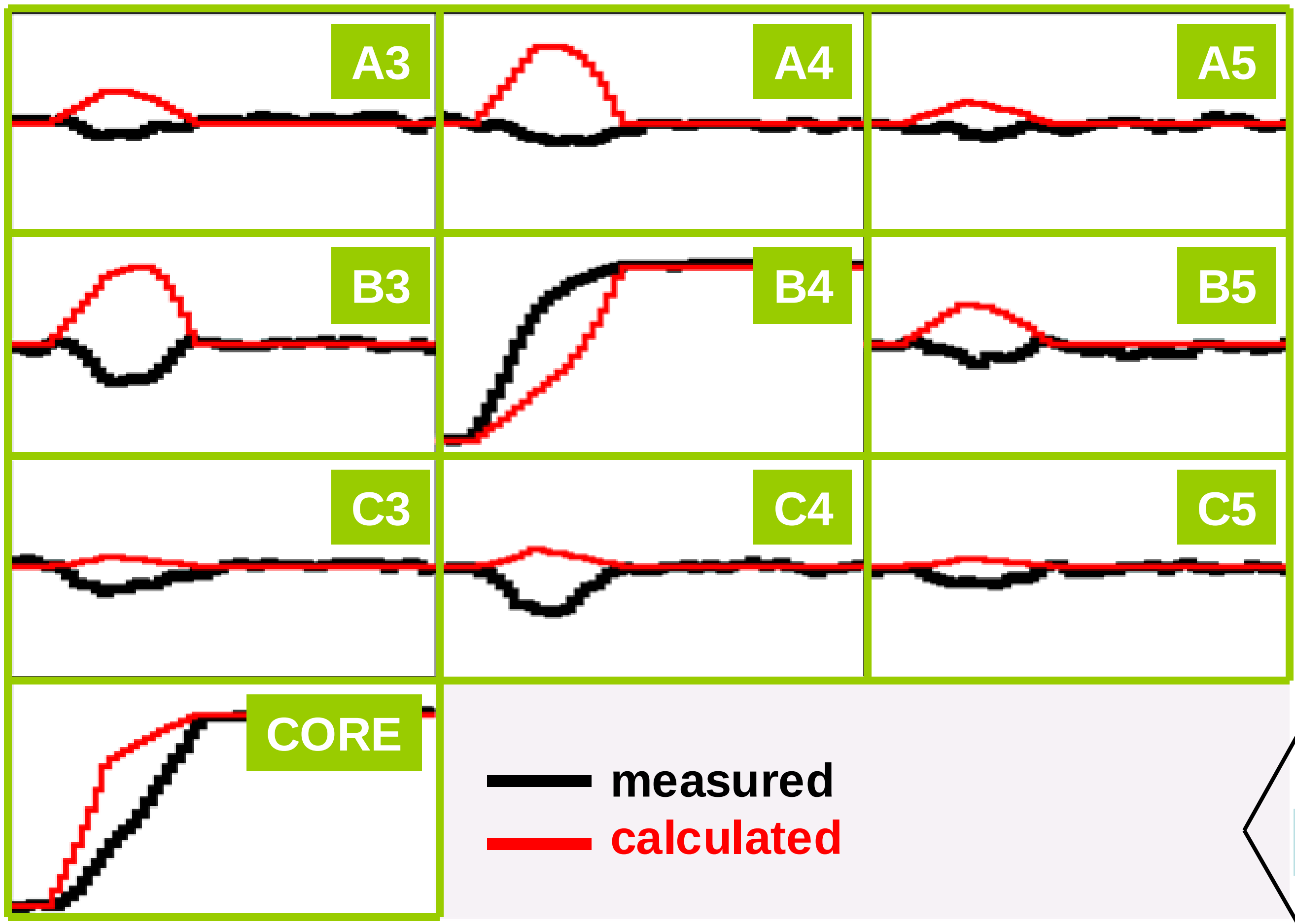
leading edge signals from PREAMP

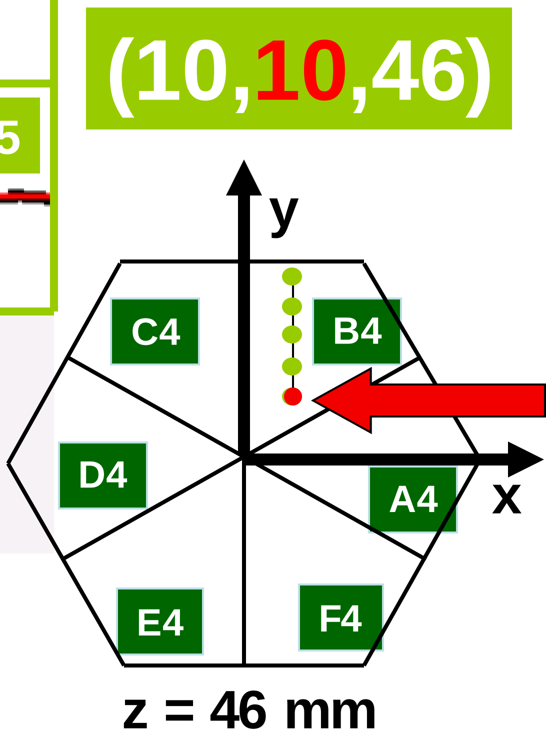
Digital electronics is needed to sample preamplifiers signals with fast ADC (100 MHz, 14 bits)

Only the subset of samples relative to the **leading edge** is transferred to ACQ



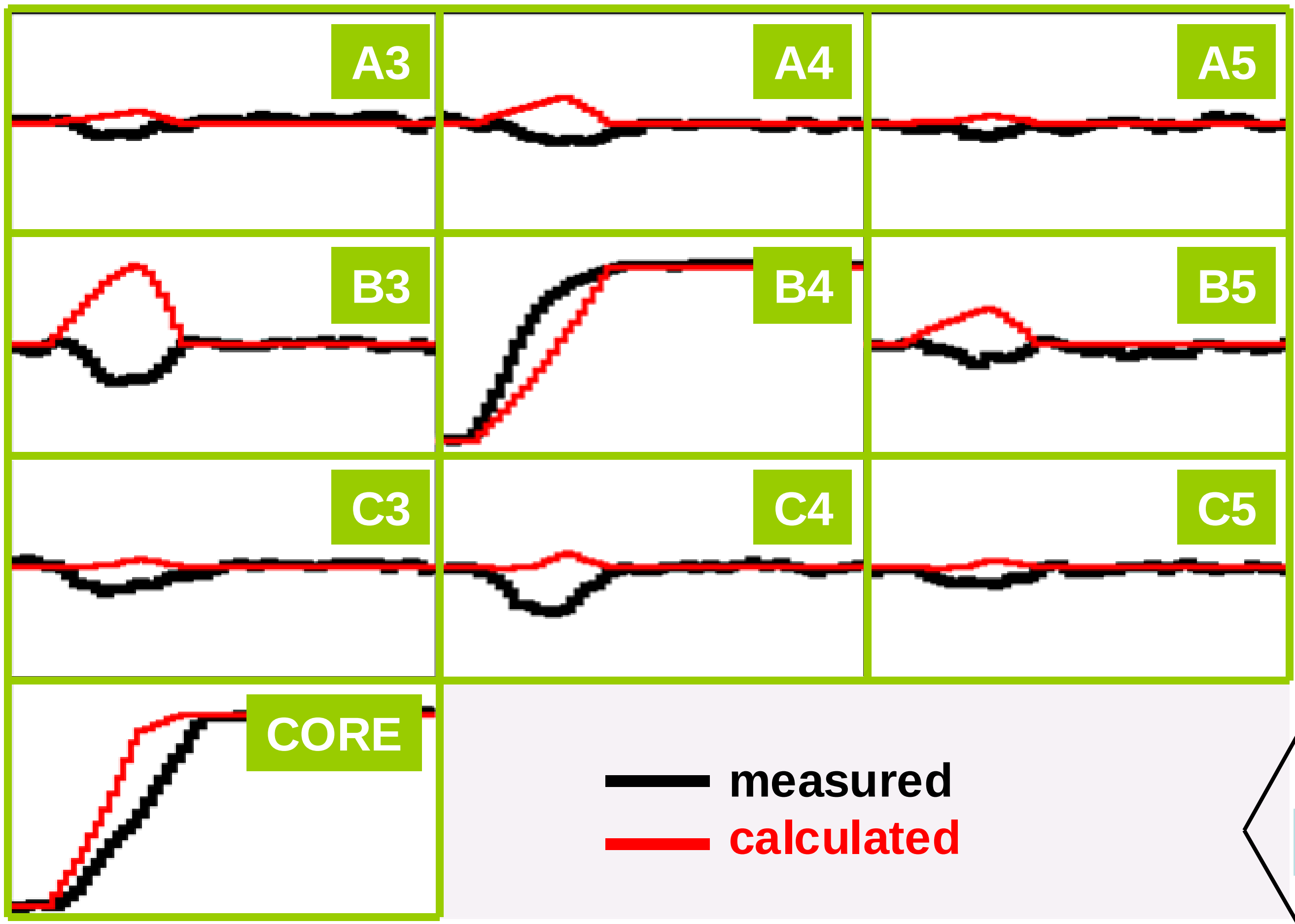
Pulse Shape Analysis concept



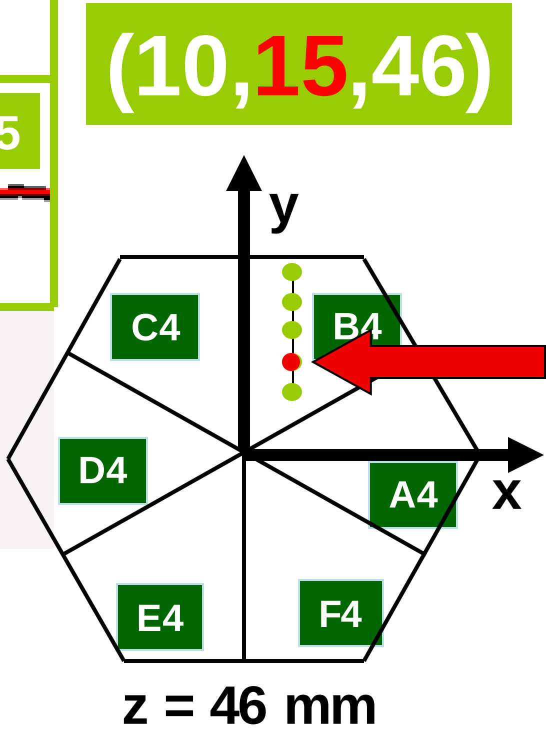


791 keV deposited in segment B4

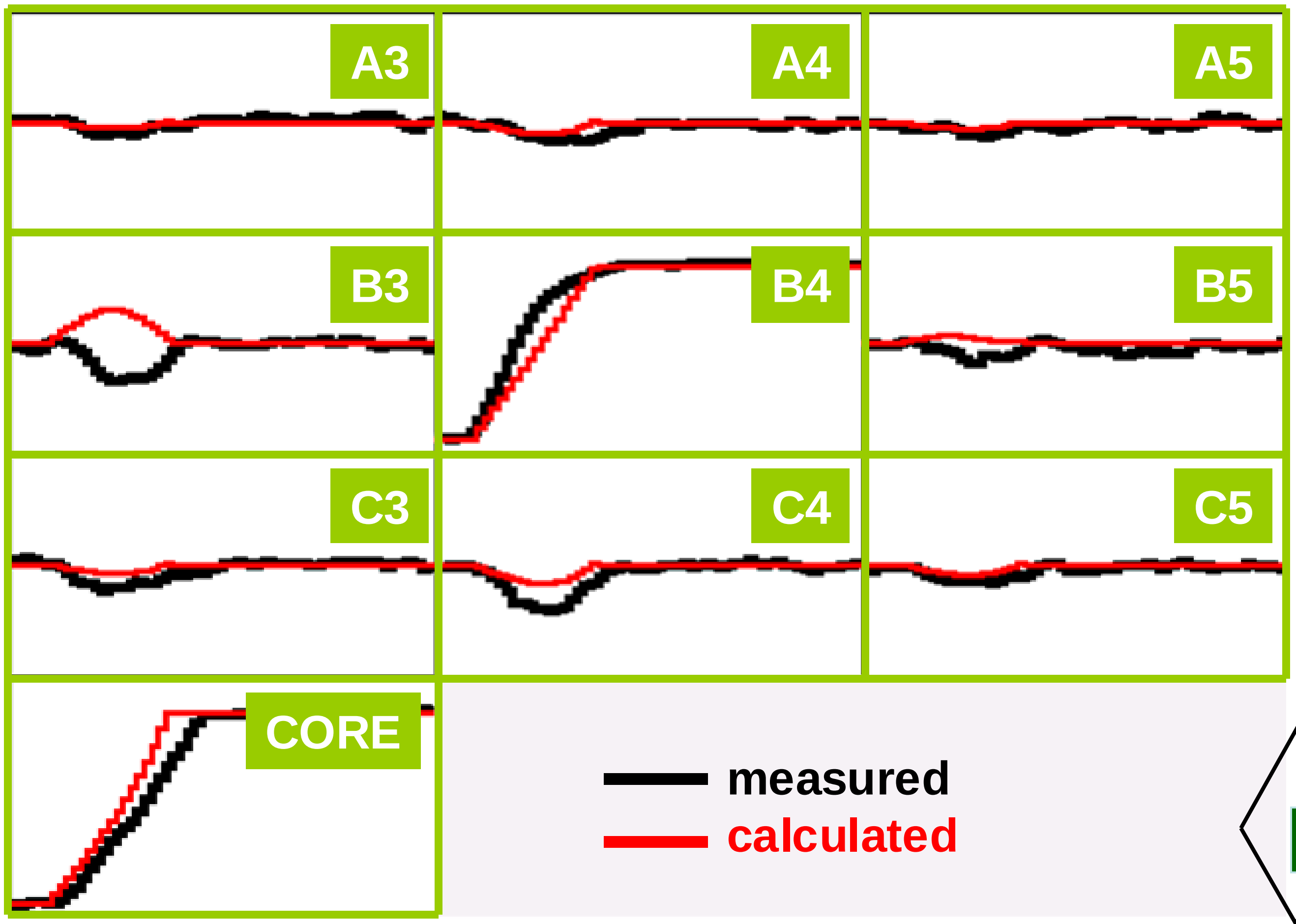
Pulse Shape Analysis concept



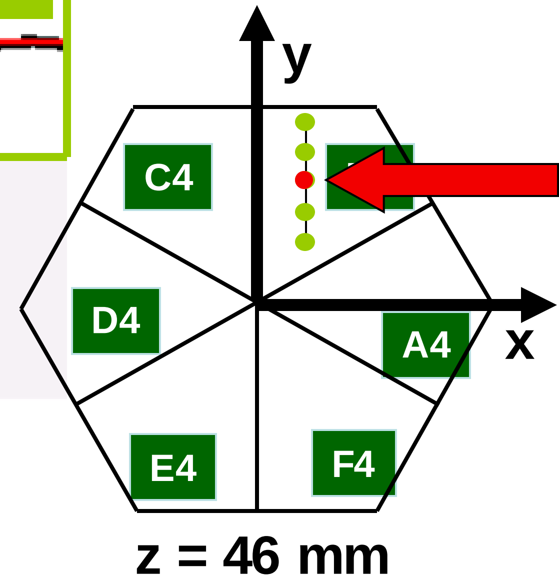
791 keV deposited in segment B4



Pulse Shape Analysis concept

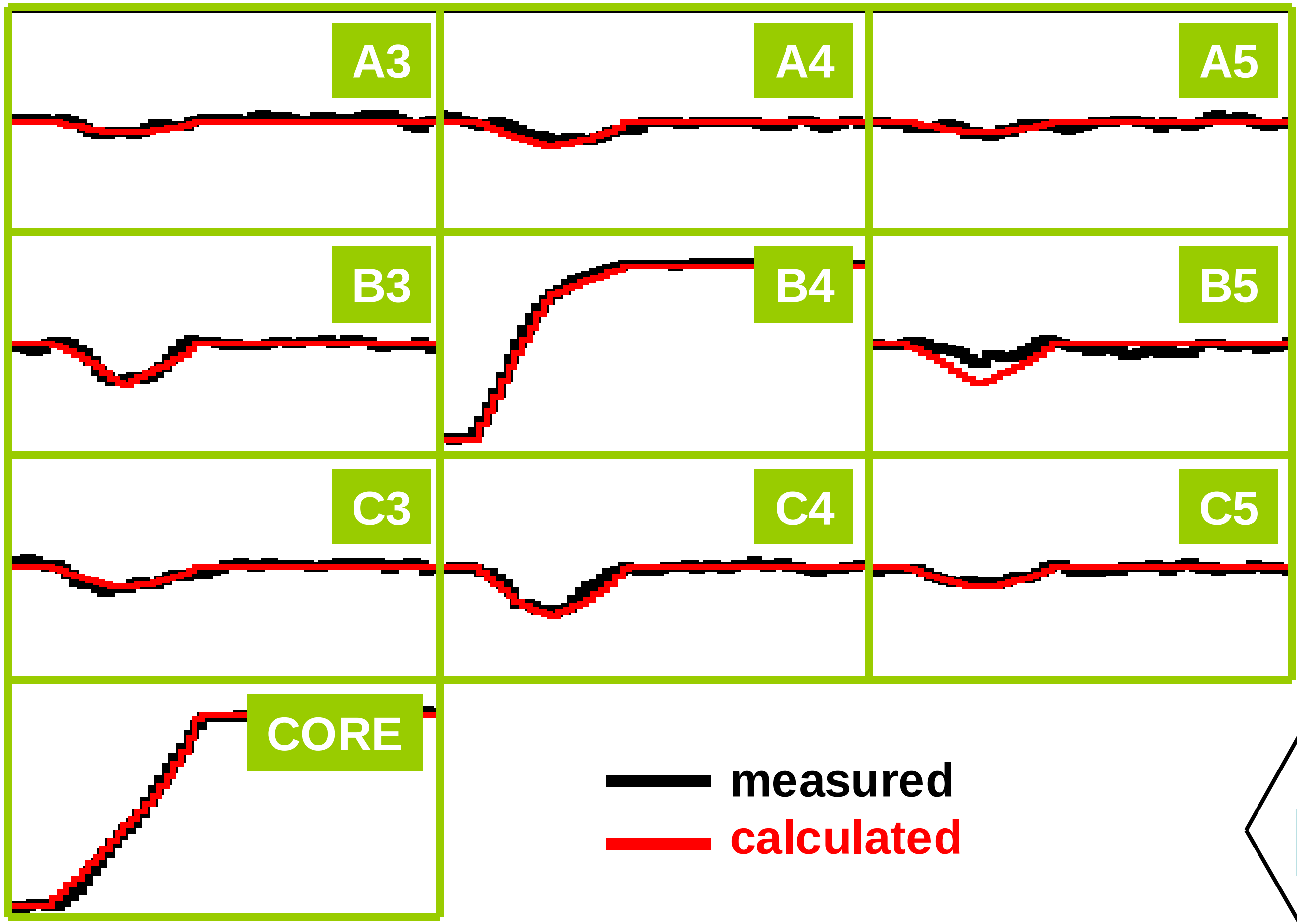


(10,20,46)



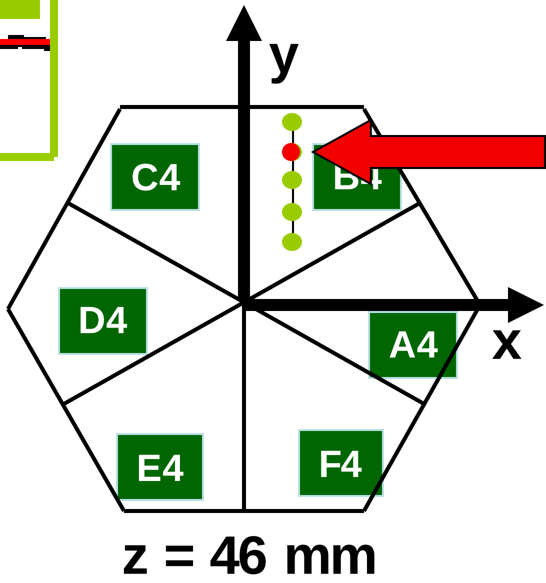
791 keV deposited in segment B4

Pulse Shape Analysis concept

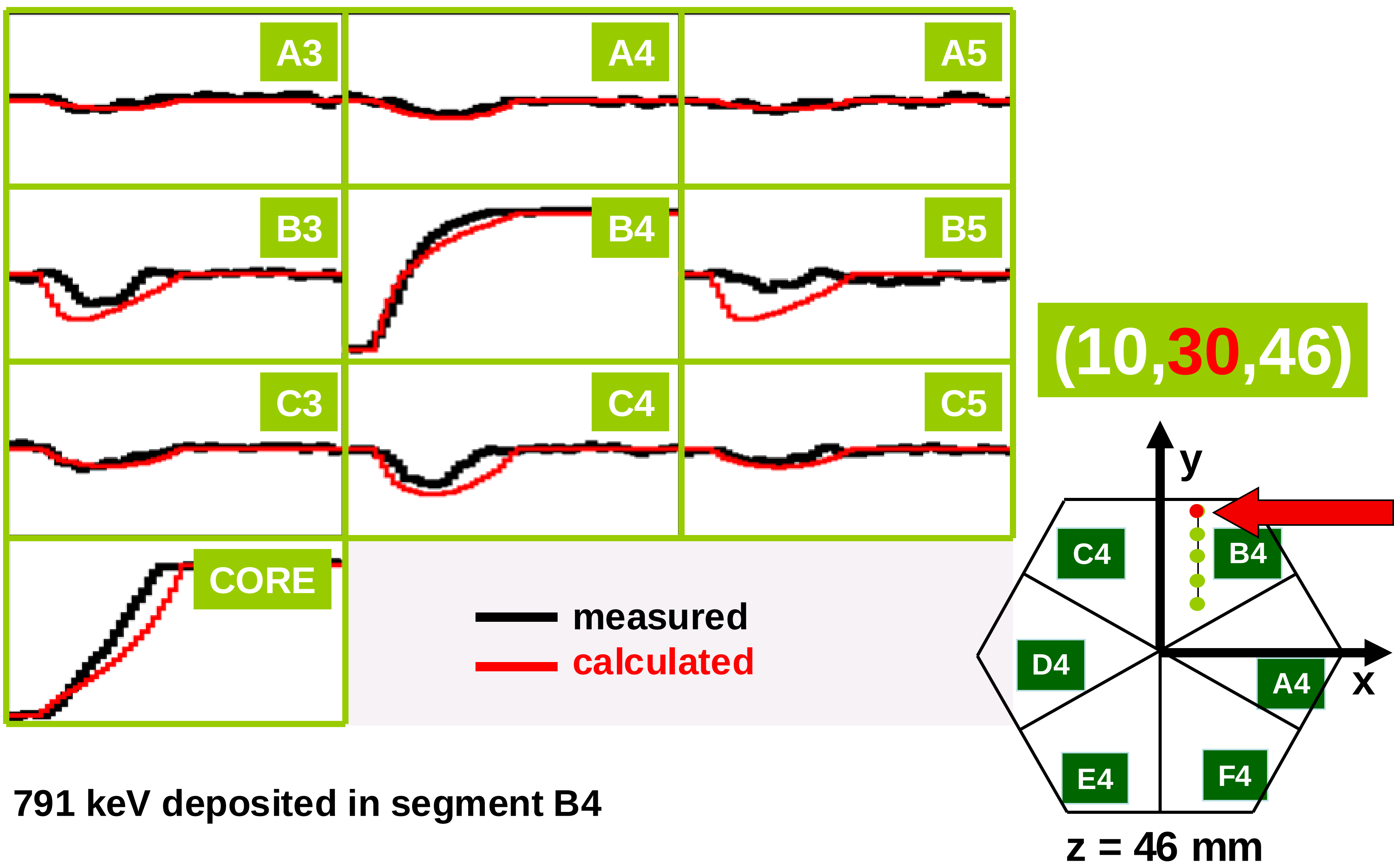


791 keV deposited in segment B4

(10,25,46)

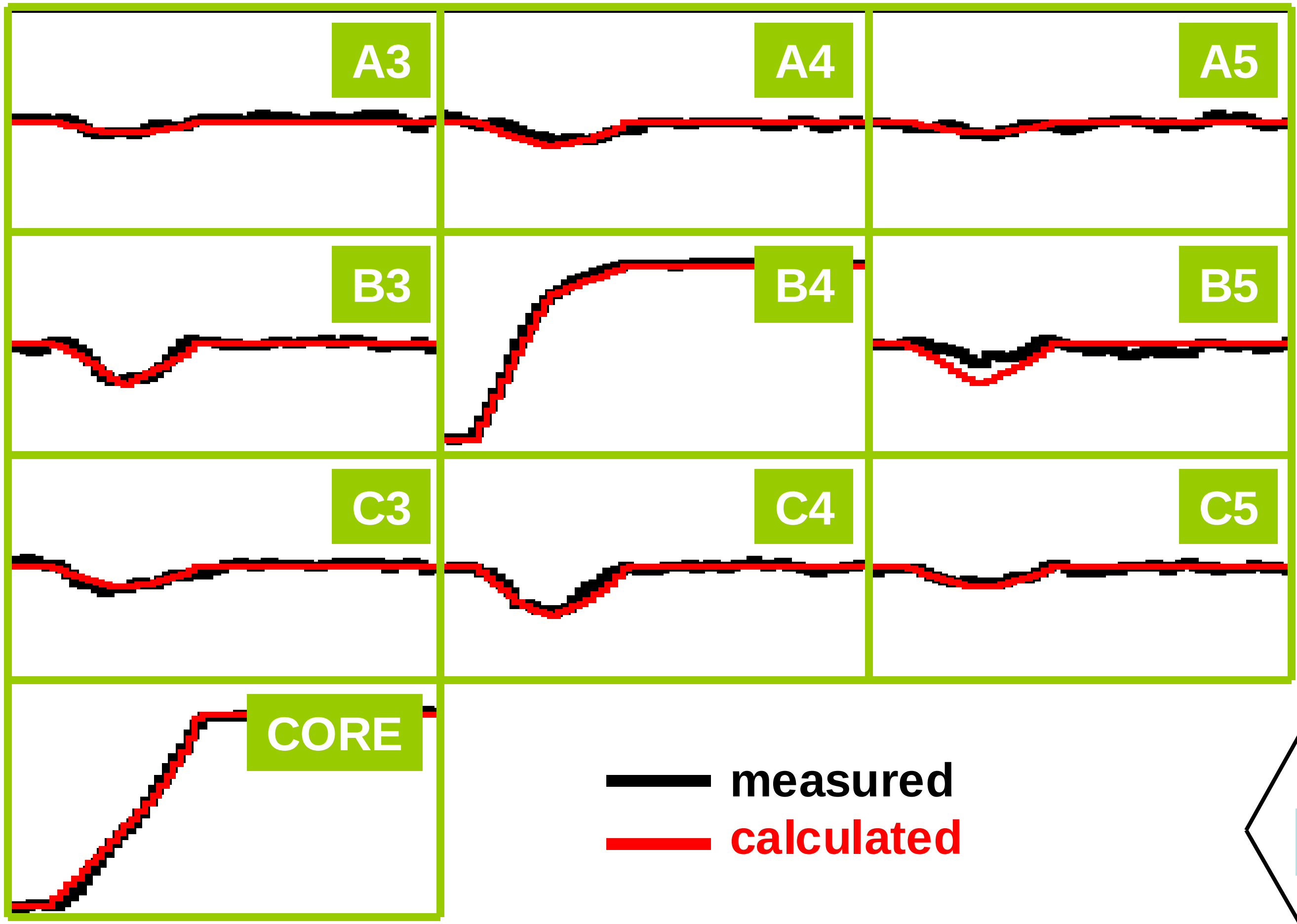


Pulse Shape Analysis concept



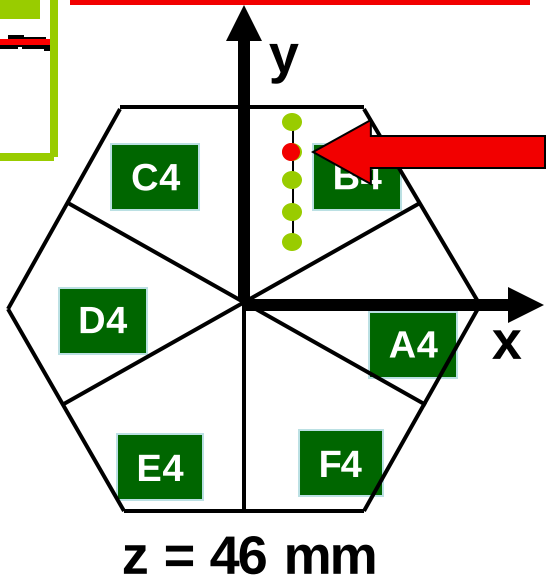
791 keV deposited in segment B4

Pulse Shape Analysis concept



Result of *Grid Search* Algorithm

(10,25,46)



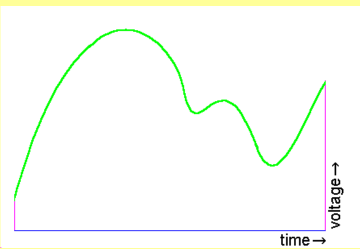
791 keV deposited in segment B4

Digitization of electronic signals

digitizing, or **digitization**, is the process of turning an analog (continous) signal into a digital representation of that signal (sequence of integers)

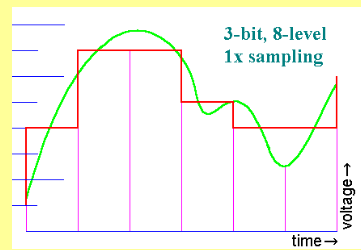
way of storing signals in a form suitable for transmission and computer processing

Analog signal:
continous variable

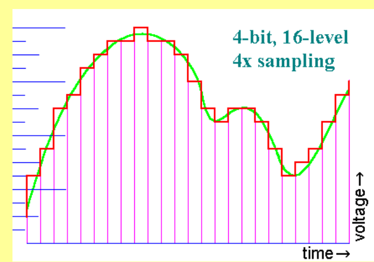


Digital signal:
discrete variable (sequence if integers)

Analog to digital conversion



low sample frequency



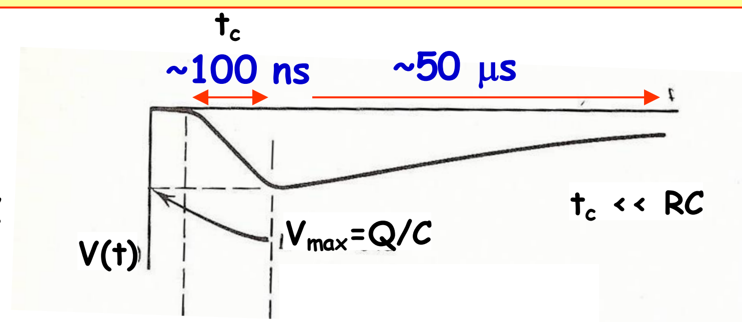
high sample frequency

Precision in digitization:

- sample frequency
- bits used to represent the integer

t_c = 100 ns = 10^{-7}s

Sample frequency ~ 100 MHz
14 Bits = 2^{14} = 16384

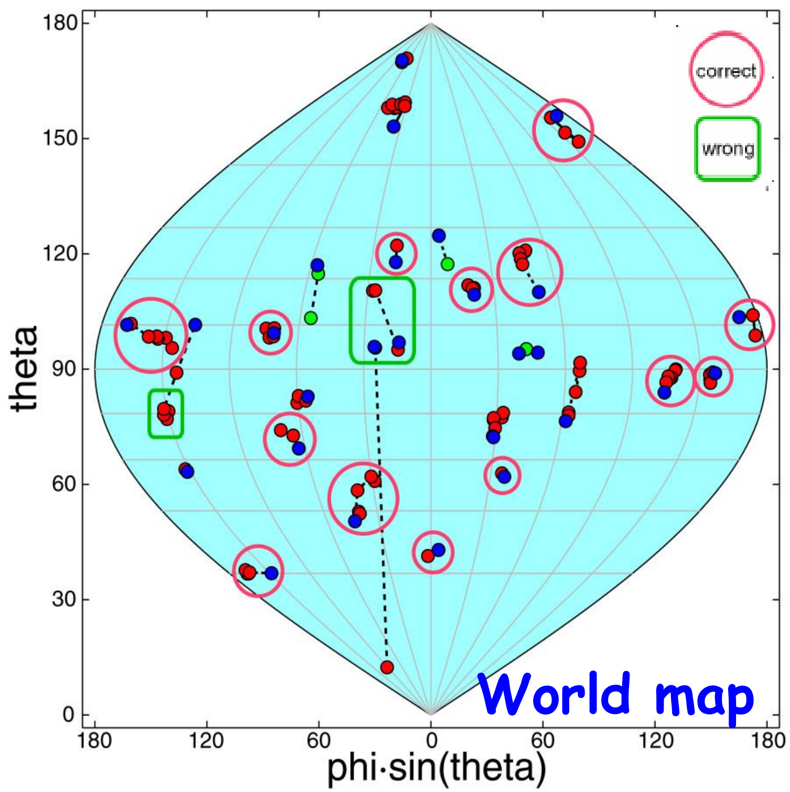


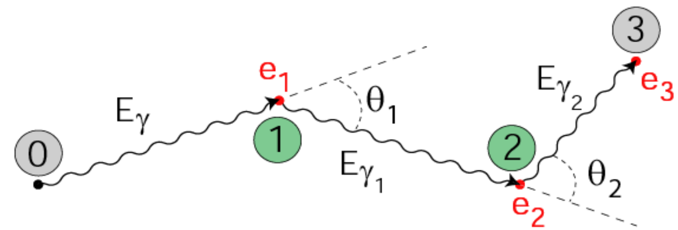
Analog signal
from **Ge** detector pre-amplifier

γ-ray tracking

Given the interaction points (PSA) one has to identify the sequence of interactions points belonging to each individual photon

A high multiplicity event
$E\gamma$=1.33MeV, $M\gamma$=30
in ideal Ge shell





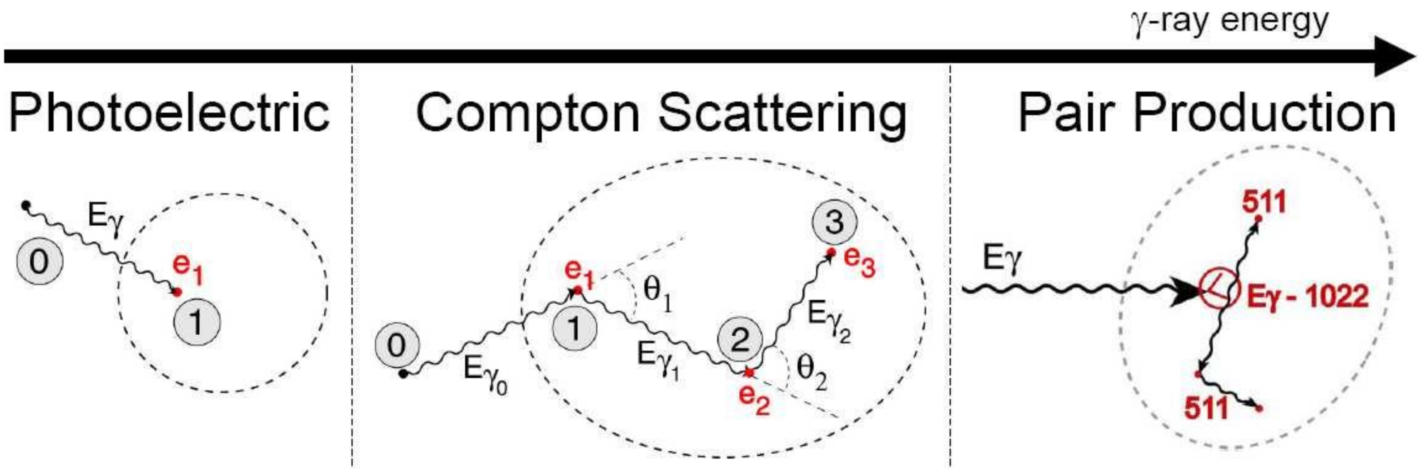
Basic formula is Compton scattering

Tough problem!
especially for high-multiplicity events

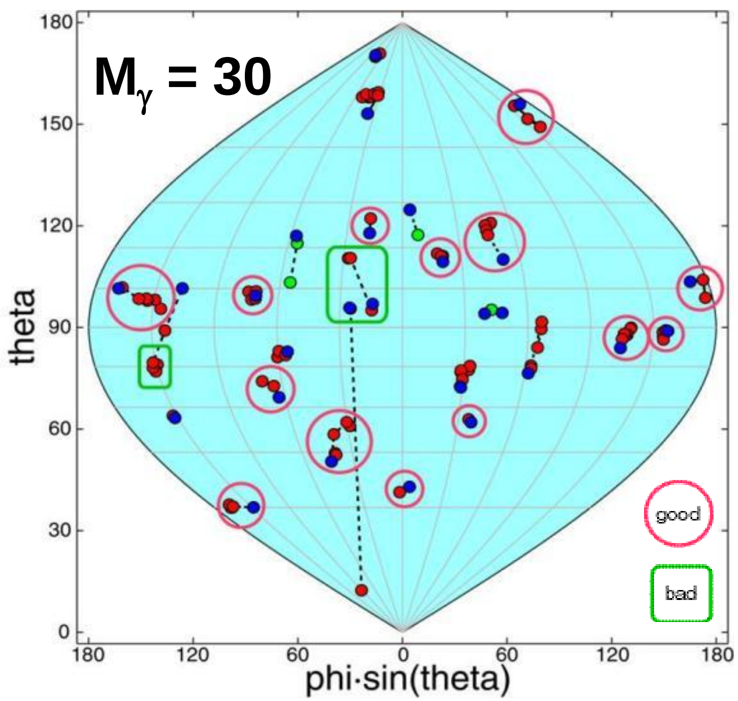
Tracking methods

1 – Cluster (forward) tracking
2 – Backtracking
3 – Other approaches
(fuzzy tracking, etc.)

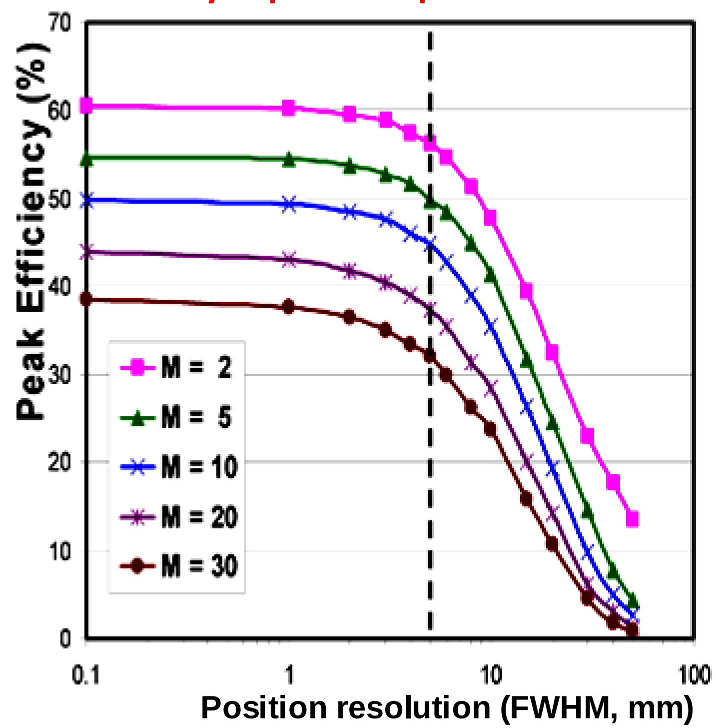
Reconstruction of 0.1÷10 MeV gammas

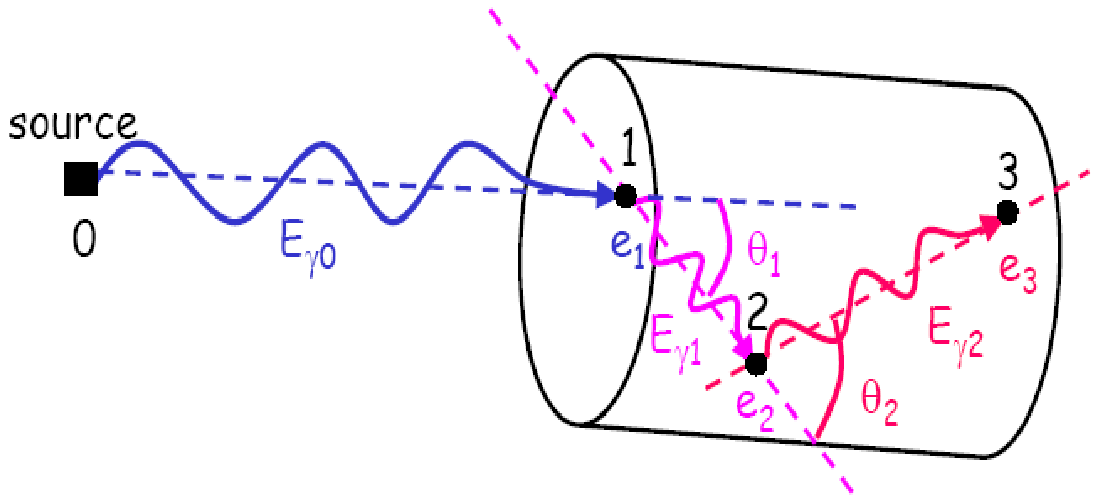


MC simulation of a high-multiplicity event



Efficiency depends on position resolution



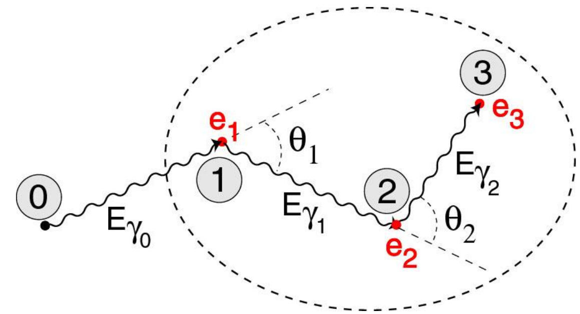

source
0
$E_{\gamma 0}$
1
e_1
θ_1
$E_{\gamma 1}$
2
e_2
θ_2
$E_{\gamma 2}$
3
e_3

Cluster tracking

(G.Schmid, 1999; mgt implementation by D.Bazzacco, Padova)

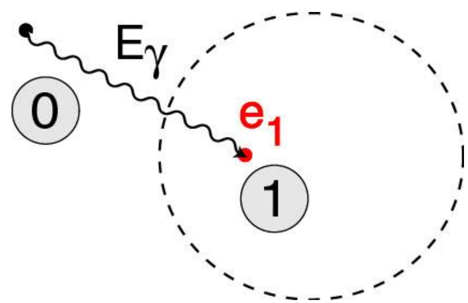
1. Create cluster pool => for each cluster, $E_{\gamma 0} = \sum$ cluster depositions

2. Test the 3 mechanisms

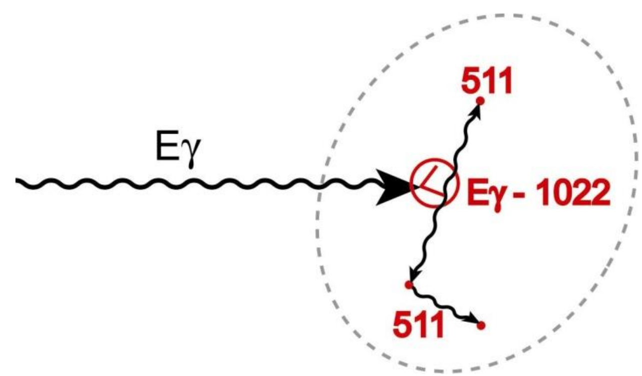


1. do the interaction points satisfy the **Compton** scattering rules ?

$$\chi^2 \approx \sum_{n=1}^{N-1} W_n \cdot \left(\frac{E_{\gamma'} - E_{\gamma'}^{Pos}}{E_\gamma} \right)_n^2$$



2. does the interaction satisfy **photoelectric** conditions (e_1,depth,distance to other points) ?



3. do the interaction points correspond to a **pair production** event ?

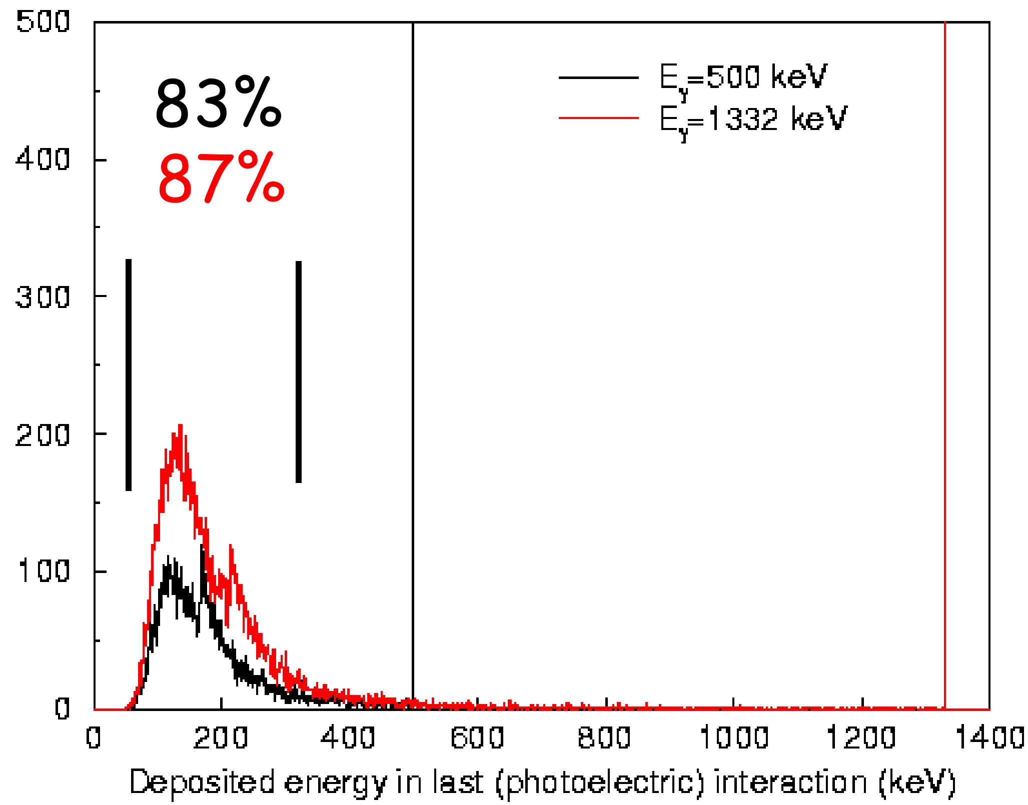
$$E_{1st} = E_\gamma - 2\, m_e c^2$$

3. Select clusters based on χ^2

Backtracking

(J. Van der Marel et al., 1999)

Photoelectric energy deposition is approximately independent of incident energy and is peaked around 100-250 keV

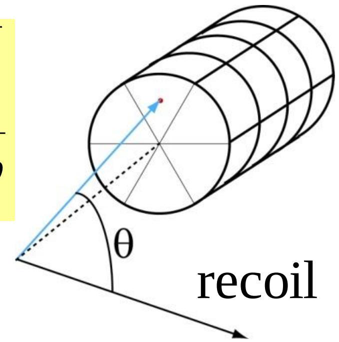


⇒ interaction points within a given deposited energy interval ($e_{min} < e_i < e_{max}$) will be considered as the last interaction of a fully absorbed gamma

⇒ trace back the interaction path on basis of Compton , ...

Benefits of γ-ray tracking
(Doppler Correction)

$$E_\gamma = E_{\gamma 0}\frac{\sqrt{1-\left(\frac{v}{c}\right)^2}}{1-\frac{v}{c}\cos\theta}$$



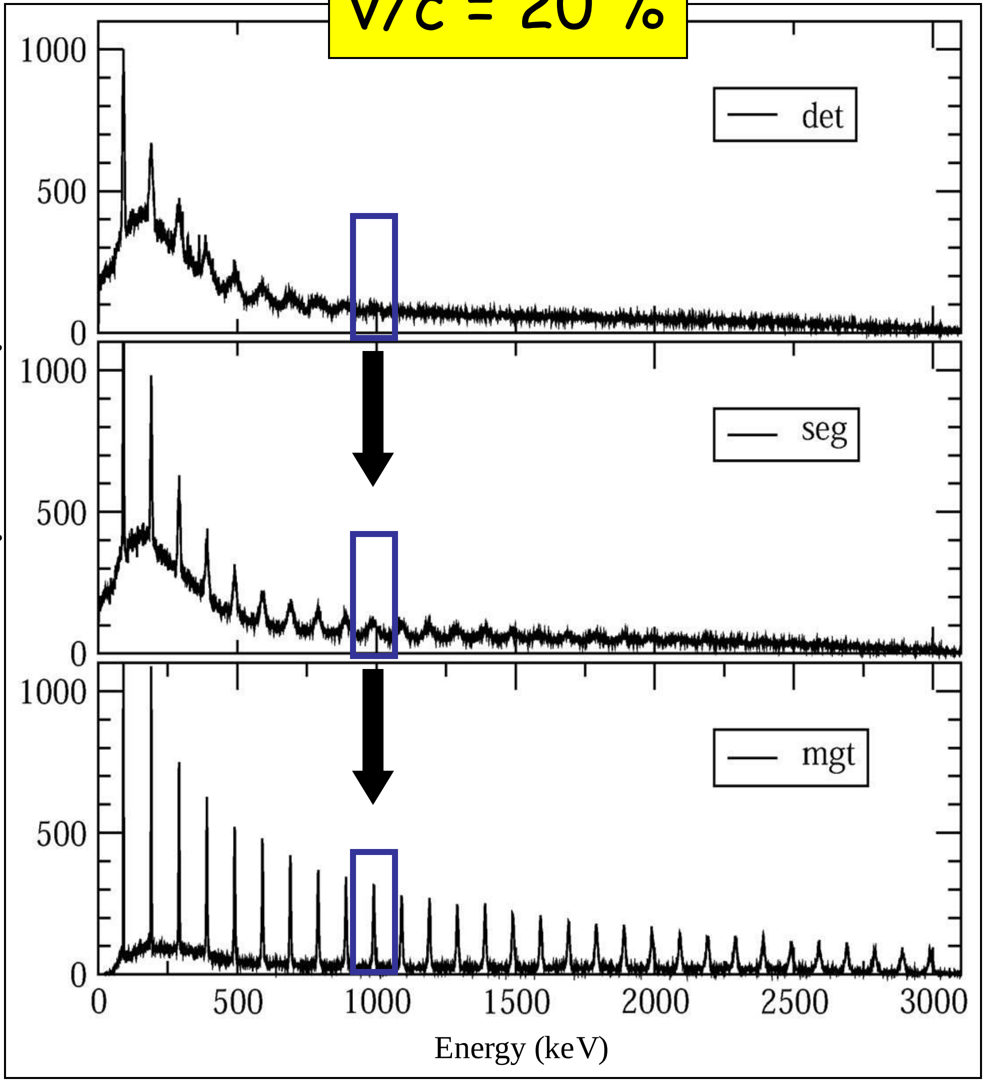
scarce

Definition of the photon direction

Doppler correction capability

good

v/c = 20 %



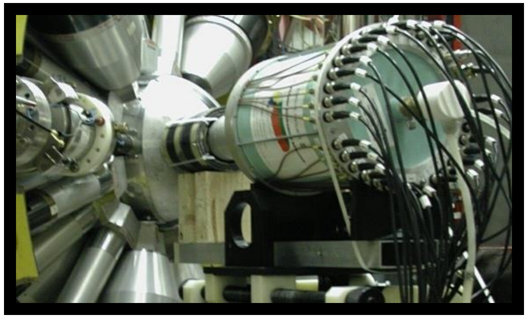
Detector

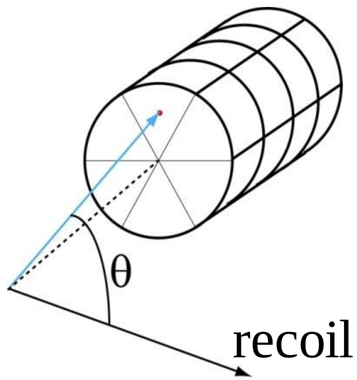
Segment

Pulse shape analysis
+
tracking γ

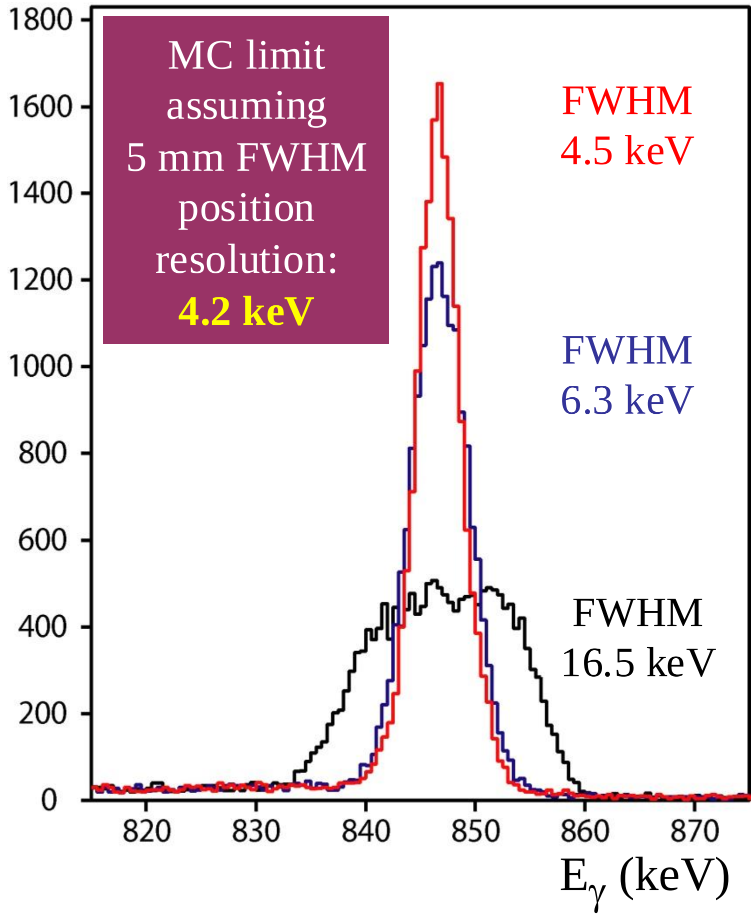
In-beam test of PSA: MARS detector (6x4+1) segments

Coulex. of ^{56}Fe at 240 MeV on ^{208}Pb, **v = 0.08c**





$$E_\gamma^{CM} = E_\gamma^{Lab} \frac{1-\beta\cos(\theta)}{\sqrt{1-\beta^2}}$$



Corrected using points determined with a Genetic Algorithm

Corrected using center of segments → 24 detectors with $\Delta\theta \approx 9°$

Corrected using center of crystal → one detector with $\Delta\theta \approx 22°$

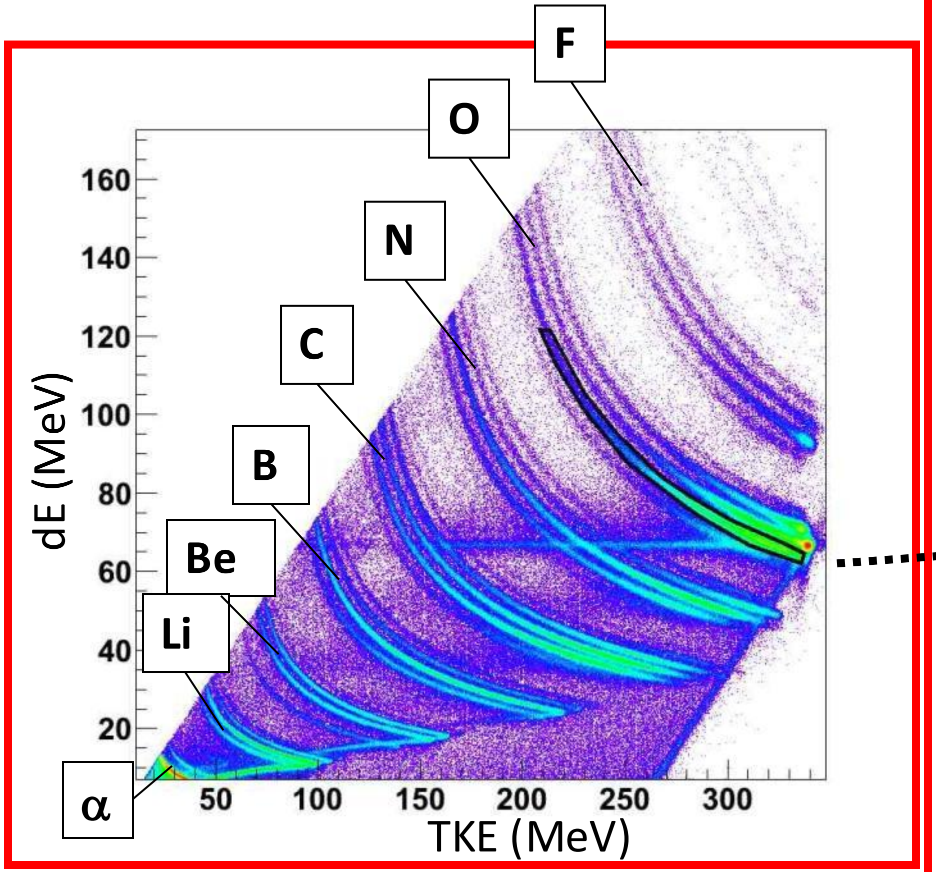
Position resolution → 5 mm FWHM

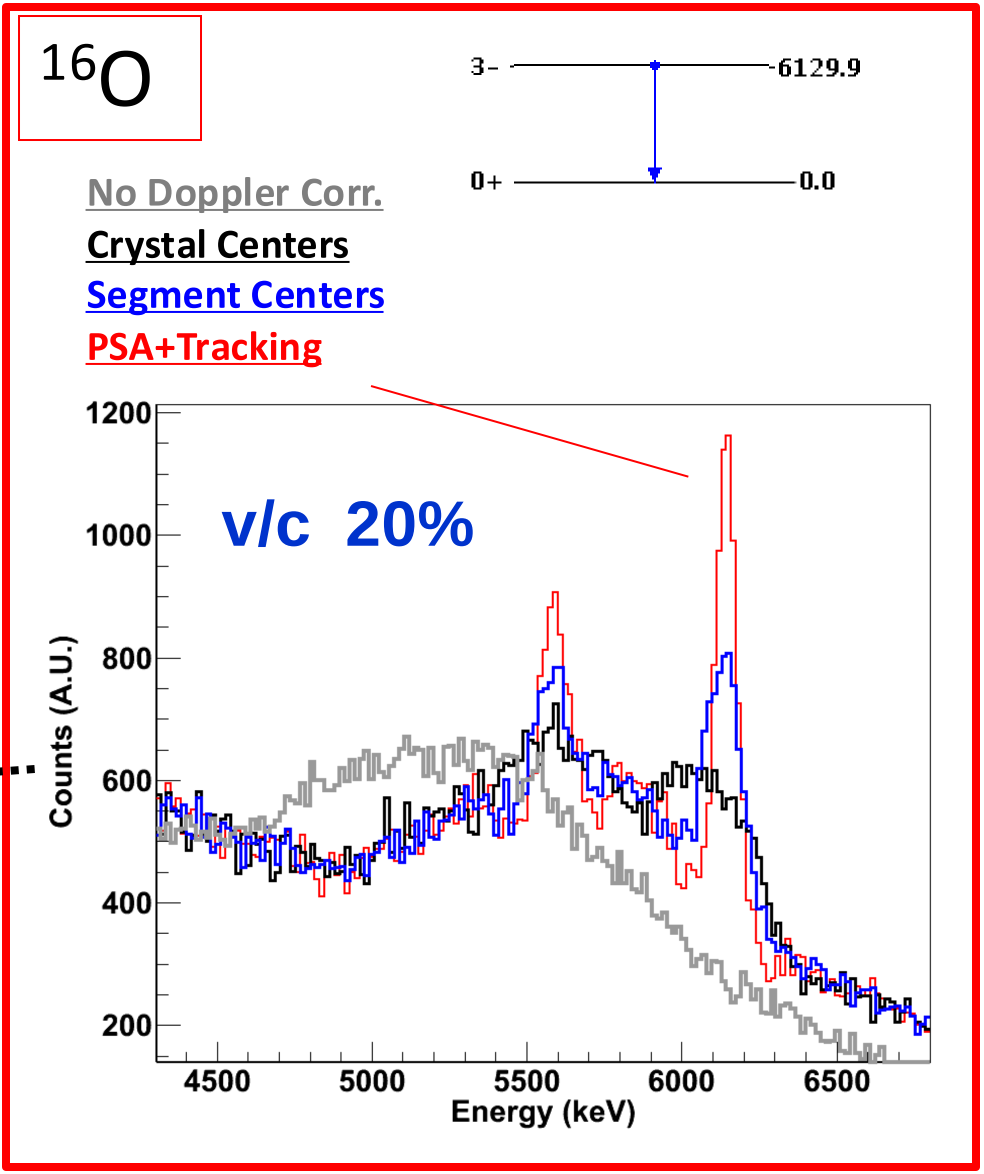
Similar result from an experiment done with the GRETA detector

Doppler Correction Capability, “large” v/c

inelastic scattering ^{17}O @ 20 MeV/u on ^{208}Pb

Recoils detected in TRACE



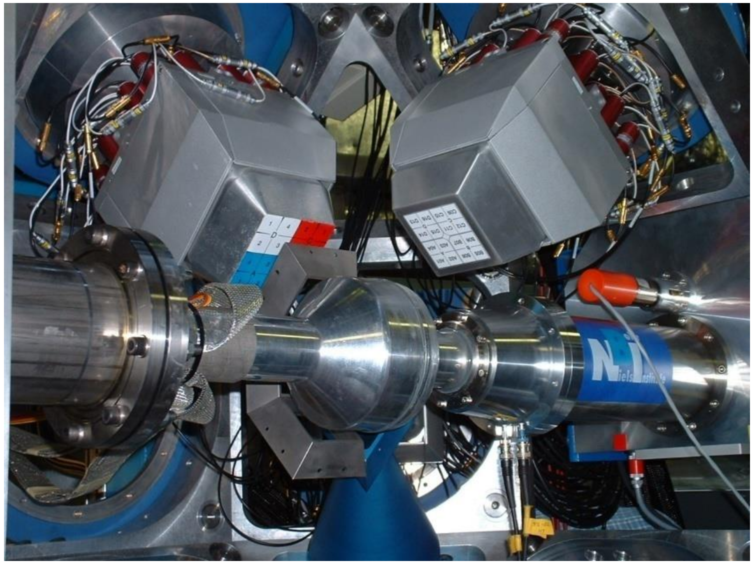


F. Crespi, Milano

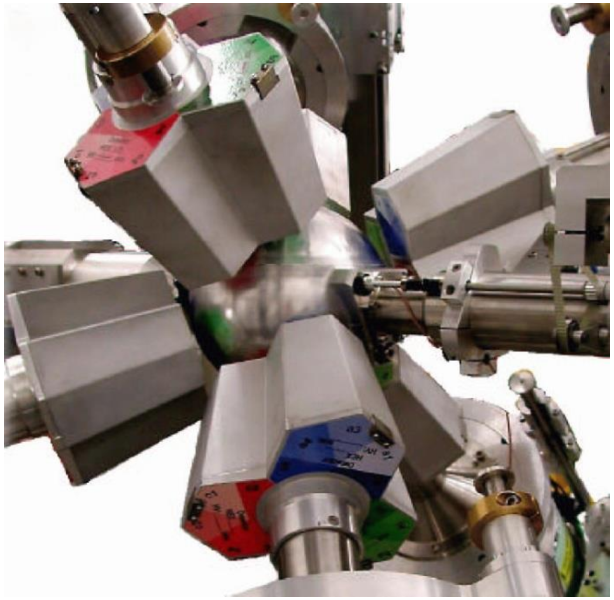
Arrays of segmented Ge detectors

(for Doppler correction)

EXOGAM segmented clovers
with 4x4 fold segmentation



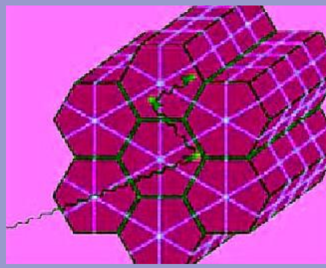
MINIBALL triple-clusters
with 6 and 12 fold segmentation

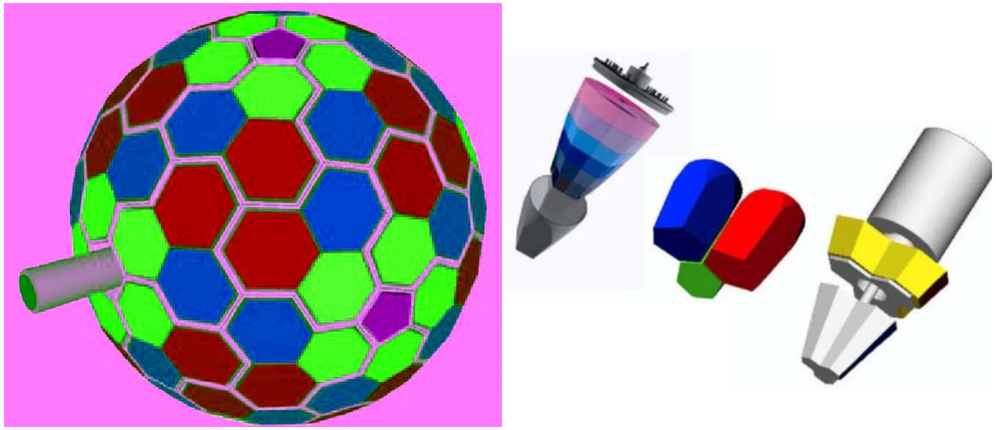


Segmented Germanium Array (SeGA)
with 32-fold segmentation

AGATA
Advanced Gamma Tracking Array

based on
position sensitive Ge





192 segmented Ge detectors
(36 segments each) ⇒ 6780 segments

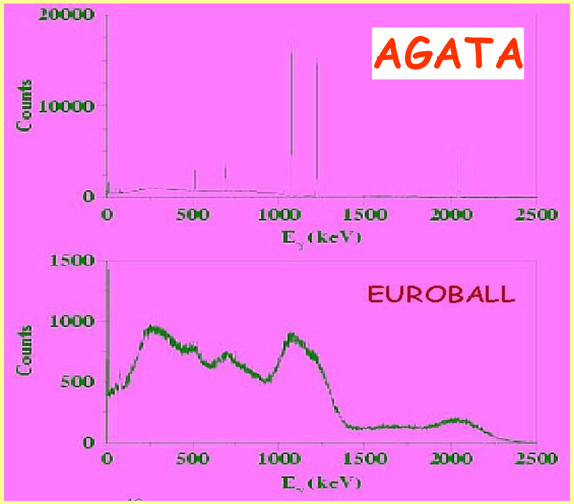
180 hexagonal Ge in 60 triple clusters
12 pentagonal Ge

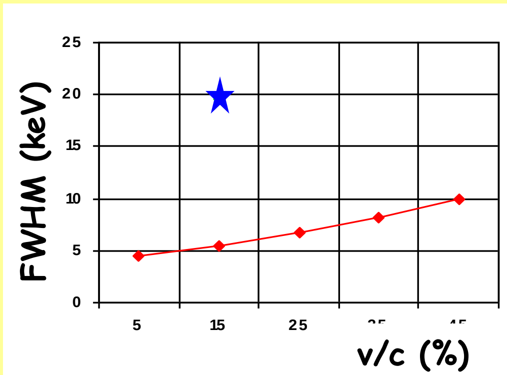
2.5 tons

R_{inner} = 17 cm, R_{outer} = 26 cm
$\Omega \approx 77\%$

$\varepsilon \approx 40\%$ ($M\gamma$=1), 20% ($M\gamma$=30)
P/T ≈ 65% ($M\gamma$=1), 50% ($M\gamma$=30)
FWHM ≈ 1 keV (1 MeV, source)
≈ 6 keV (1 MeV, v/c ≈50%)
instead of 40 keV at present !!

Count rate ~ 3 MHz - 300 kHz



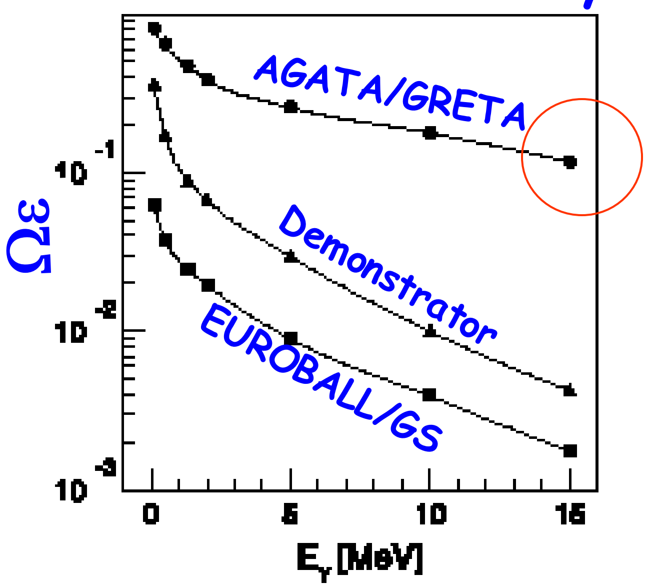


- **Digital electronics** (to record and process segments signals)
- **Pulse Shape Analysis** (to extract position and energy of interaction)
- **Tracking Analysis** (to reconstruct γ-rays tracks from interaction points)

Construction ≈ 8 y, Cost ≈ 40 M€

Tracking array performances

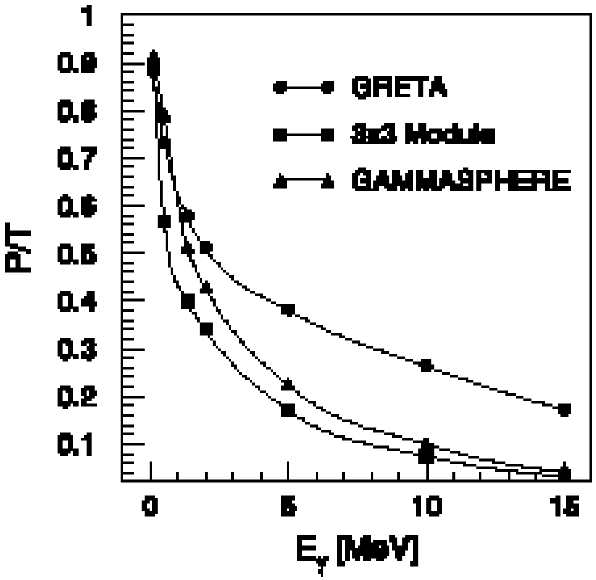
absolute efficiency



comparable with scintillators arrays

n vs. γ discrimination ?

possibly from different clustering of signals



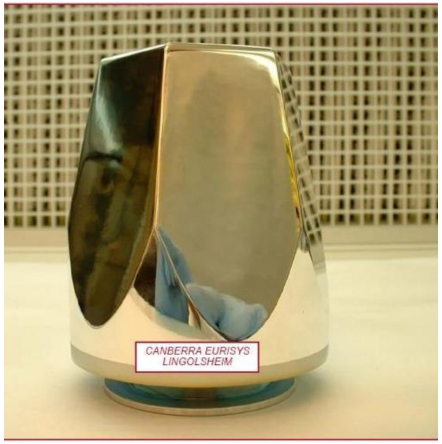
Calculations for 1 γ ray and NO tracking

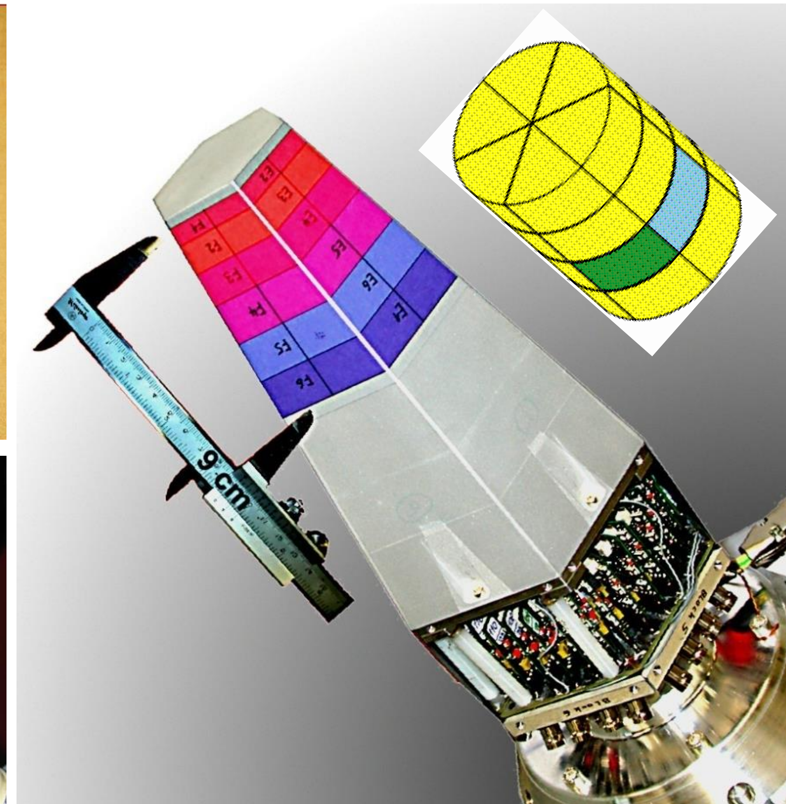
Event rates will be increased by factor 20:

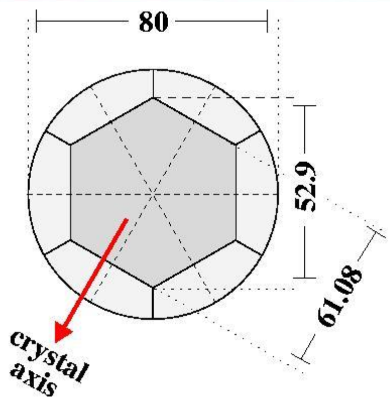
~ 3 MHz (M_γ = 1) - 300 kHz (M_γ = 30)

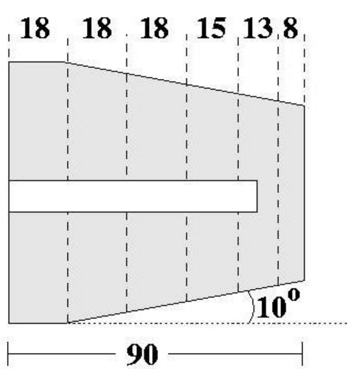
as a consequence of <u>shorter processing time</u> & <u>increased number of segments</u>

AGATA/GRETA Prototypes









Encapsulation

0.8 mm Al walls

0.4 mm spacing

MINIBALL-style cryostat

used for acceptance tests

"standard" preamplifiers

36-fold segmented, encapsulated detector

AGATA Cryostats

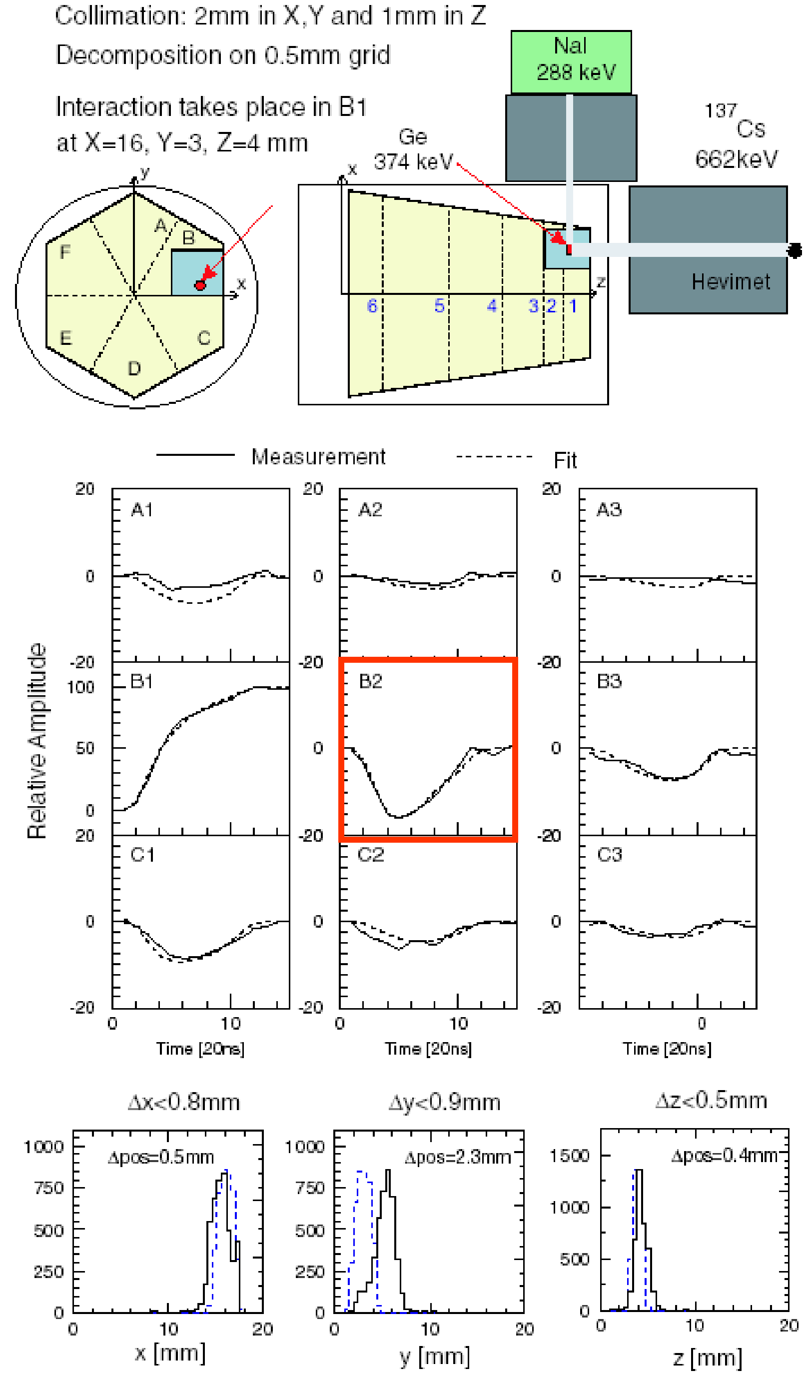
Köln September 2005:
1° Triple-cluster test

Individual, for tests

Triple, for experiments

differential-output preamplifiers with fast reset
of saturated signals (Milano/Ganil, Köln)

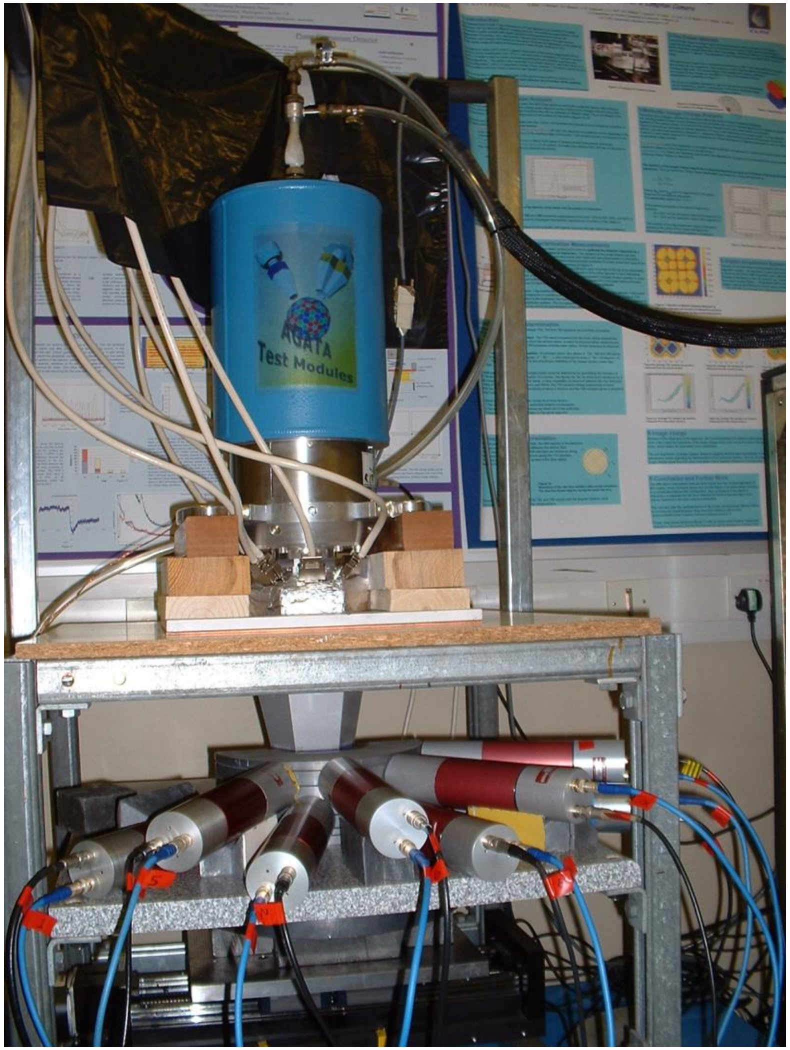
AGATA detector scanning



Full scan in 1 mm^3 grid almost impossible

→ define characteristic points

to calibrate calculations



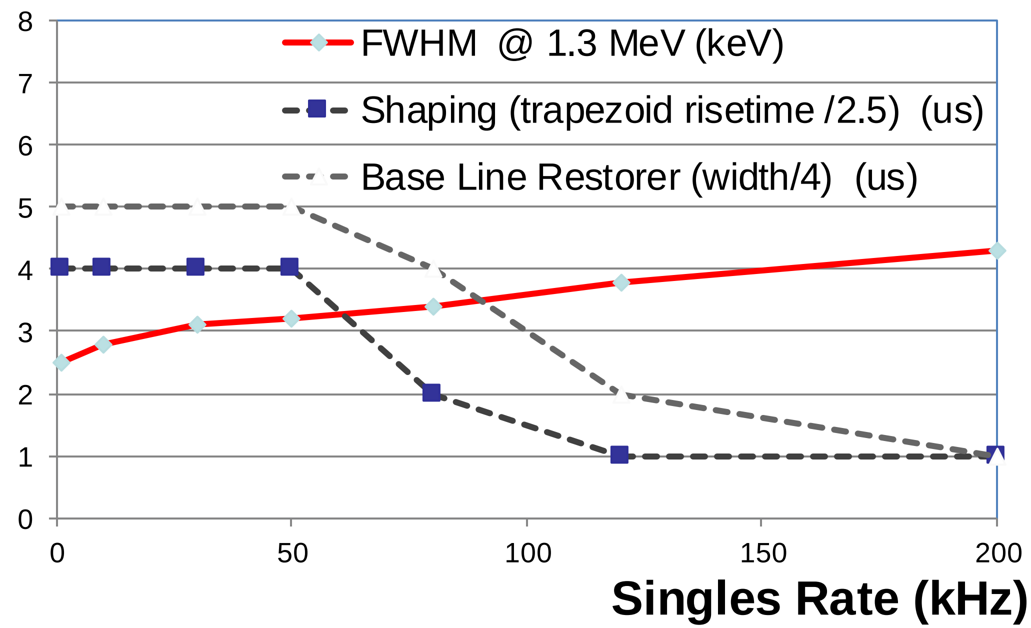
Liverpool coincidence setup
with multileaf collimator

Other system being developed
at CSNSM Orsay and GSI

High Count Rate Performance

- The detection efficiency of AGATA is, so far, provided by a small number of crystals.
- Experiments want to collect big statistics ➔ need to run at high singles rates (> 50 kHz).
- Digital Signal Processing allows to work at rates “impossible” with analogue electronics.
- Under these “extreme” conditions, the performance of the detectors is still acceptable.

Two Sources Method

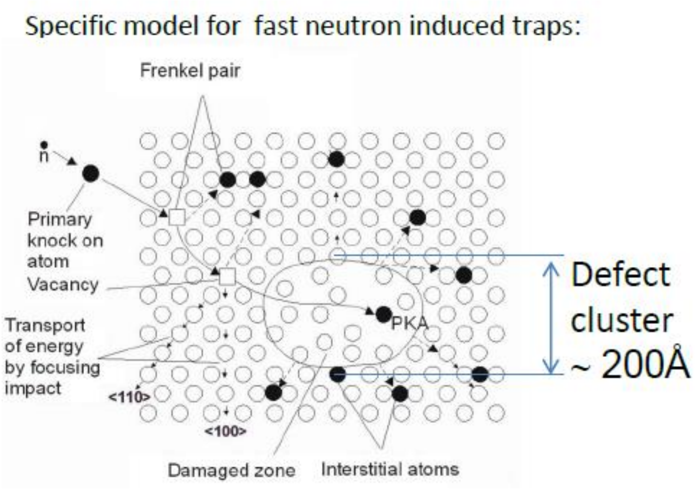


- A limit exists, due to pileup of the signals which exhausts the dynamical range of the FADC. Can counteract this by reducing the gain of the preamplifiers, but then energy resolution is a bit worse also at low counting rate.
- However, running at high singles rates has consequences …

AGATA: Neutron Damage

- **Flux of fast neutrons** from the reaction scales with the counting rate
  → ***10-15 times more*** *fast neutrons/s than in the past*

- **Result: accelerated neutron damage**



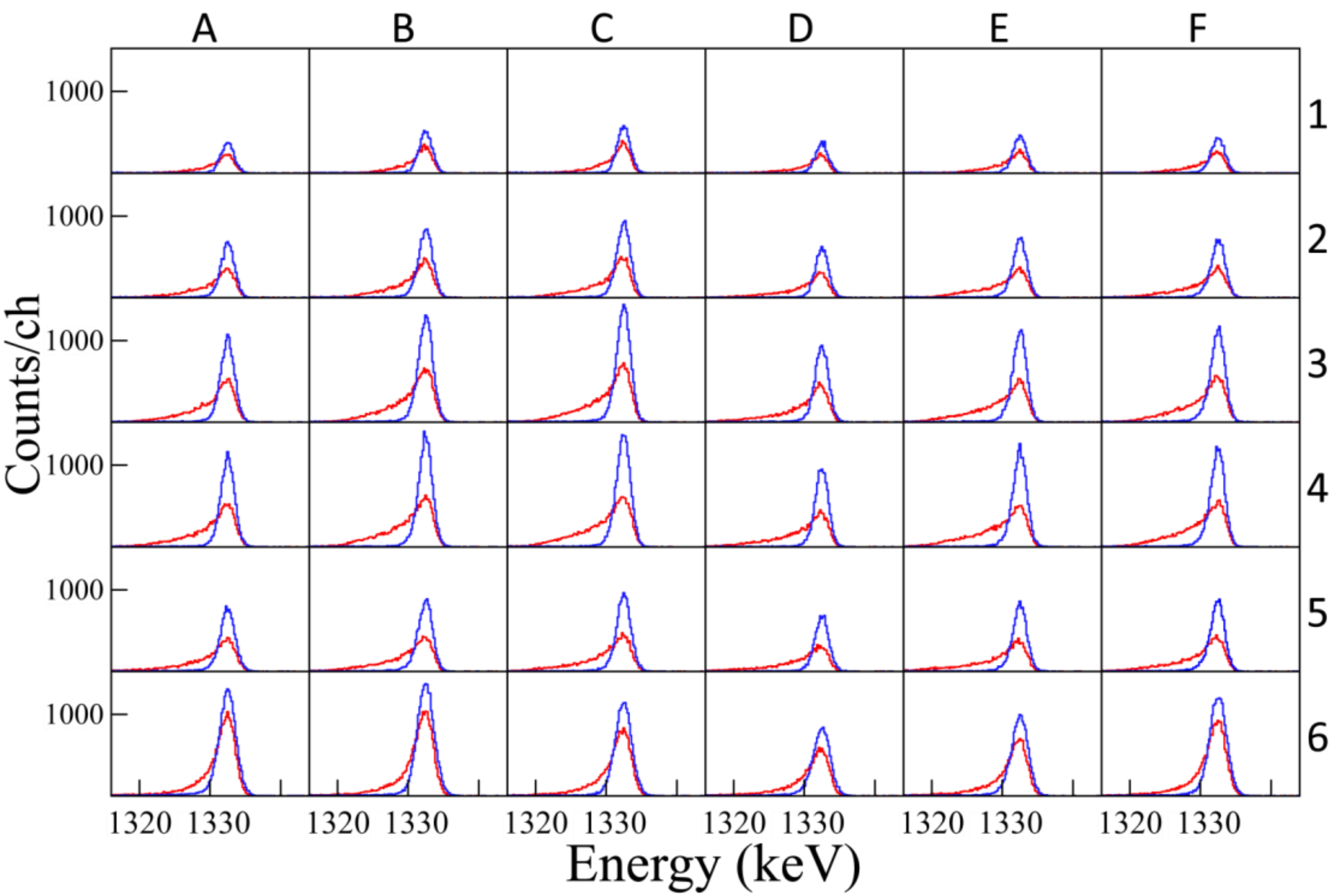
- **Effect:**

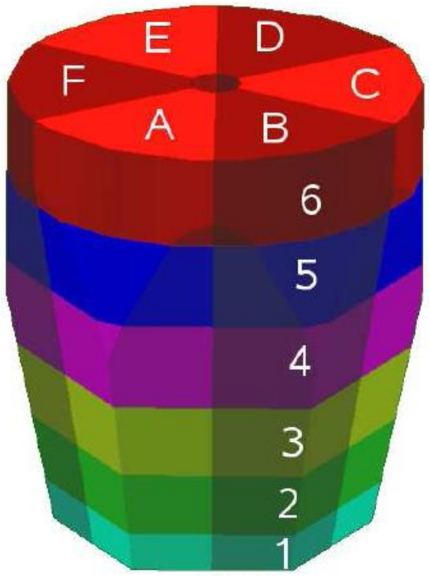
  increased hole trapping
  slight reduction of pulse amplitude
  → *no significant change in pulse shape*

  Energy resolution of Core is degraded only slightly
  Energy resolution of Segments is degraded significantly
  Pulse shape analysis is almost insensitive to neutron damage
  PSA provides the information to correct OFF-LINE for this effect

- **Real recovery of neutron damage**: *ANNEALING* the detectors
  → ***Risky operation*** *which can be delayed by the PSA-based corrections*

Neutron damage: shape of the 1332 keV line





Blue: April 2010 → FWHM(core) ~**2.3 keV** FWHM(segments) ~**2.0 keV**

Red: July 2010 → FWHM(core) ~**2.4 keV** FWHM(segments) ~**3 keV**

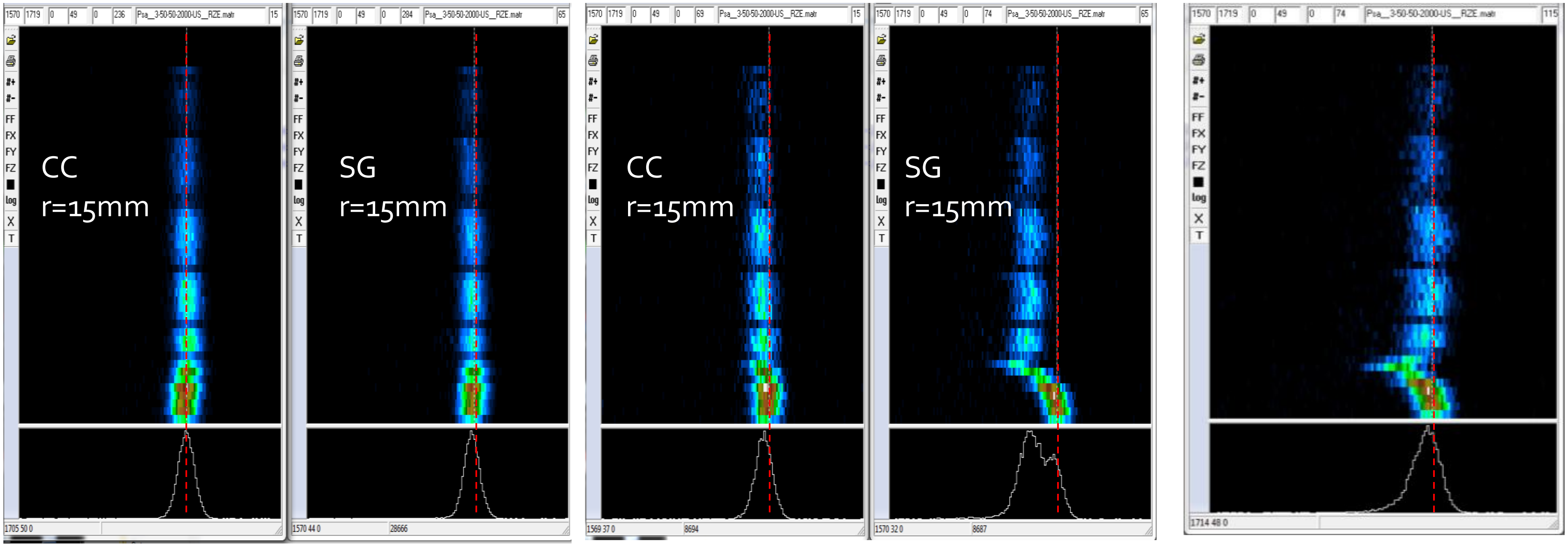
Damage after 3 high counting-rate experiments (**3 weeks of beam at 30-80 kHz singles**)

Worsening seen in most of the detectors; more severe on the forward crystals;

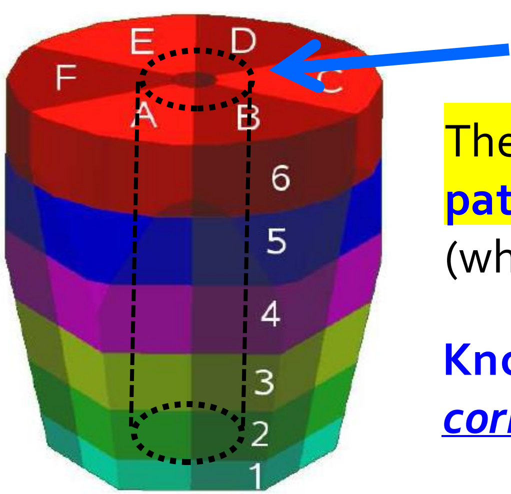
segments are the most affected, cores almost unchanged (as expected for n-type HPGe)

Crystal C002

April 2010 **July 2010** **→ corrected**



The 1332 keV peak as a function of crystall depth (z) for interactions = 15mm



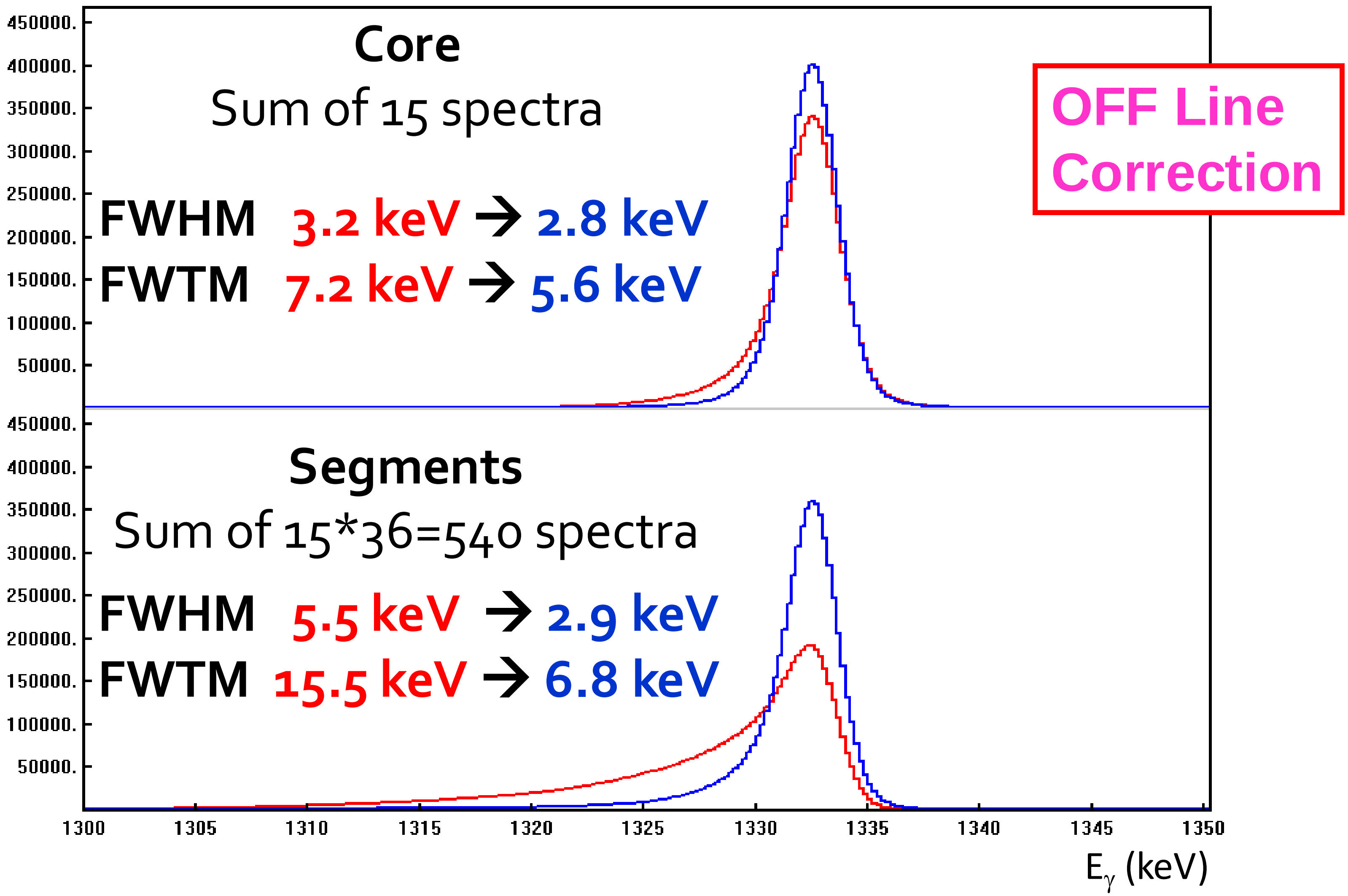
The **charge loss** due to neutron damage is **proportional to the path length** to the electrodes. The **position** is provided by the **PSA** (which is barely affected by the amplitude loss).

Knowing the path, the *charge trapping can be modeled and corrected away* (Bart Bruyneel, IKP Köln)

Energy resolution at the end of the LNL campaign

Before and ***After*** charge-trapping correction

cold detectors …

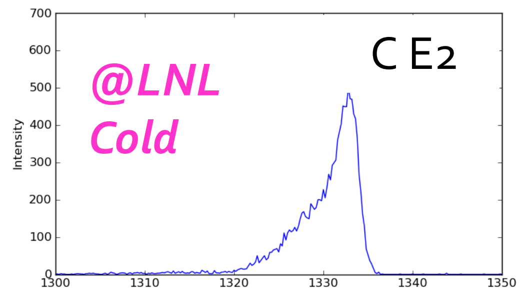


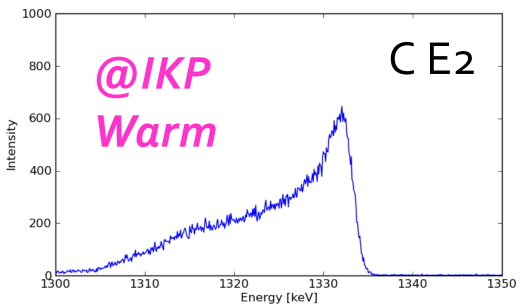
Undamaged detectors: FWHM ~2.5 keV, FWTM ~4.8 keV

Real Recovery: Crystal Annealing

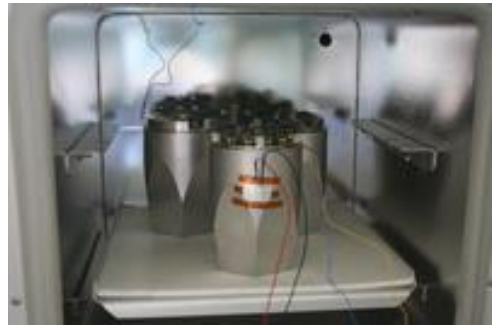
courtesy of P. Reiter (IKP)

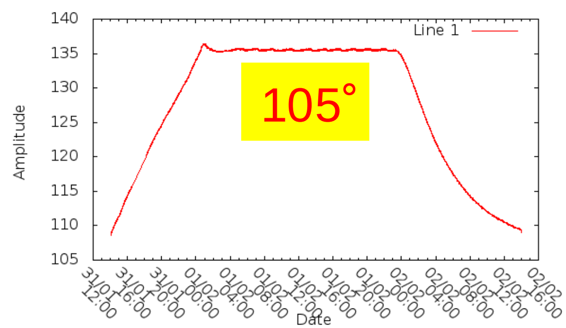
ATC 1 detector



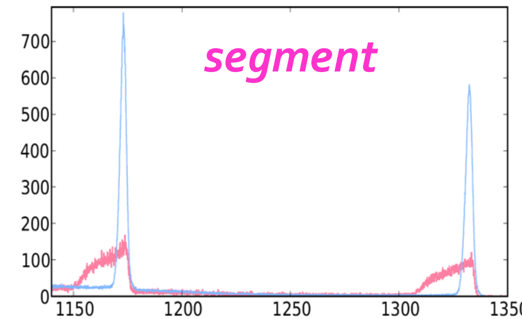


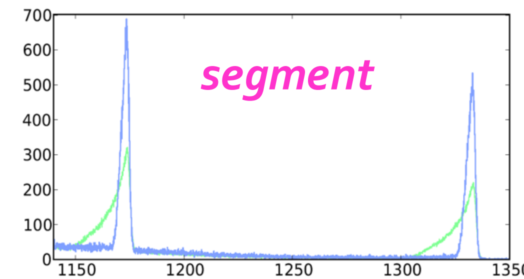
ANNEALING

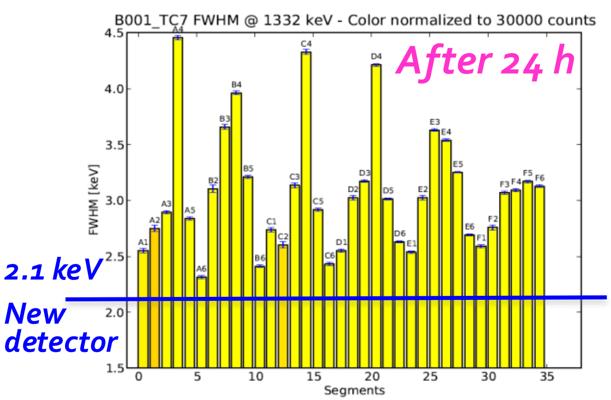


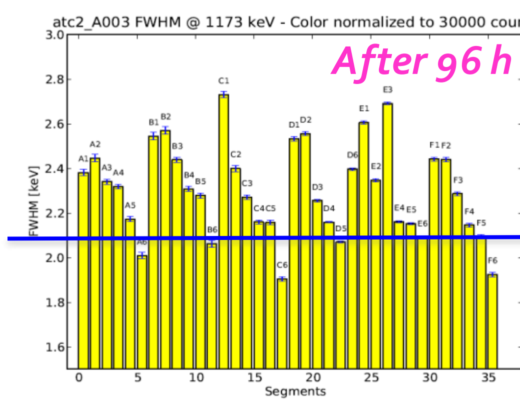


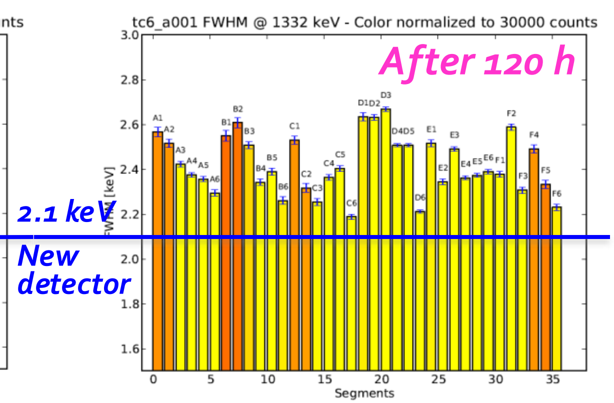
After 24 h Annealing





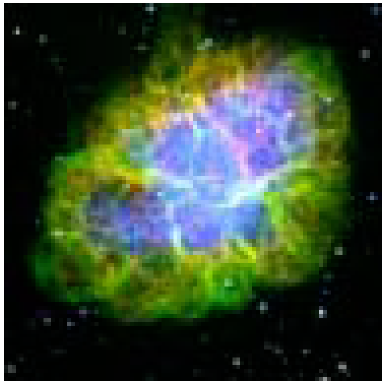






→ 120 hours of annealing do not recover from neutron damage @ 1.3 MeV

Impact on applied research



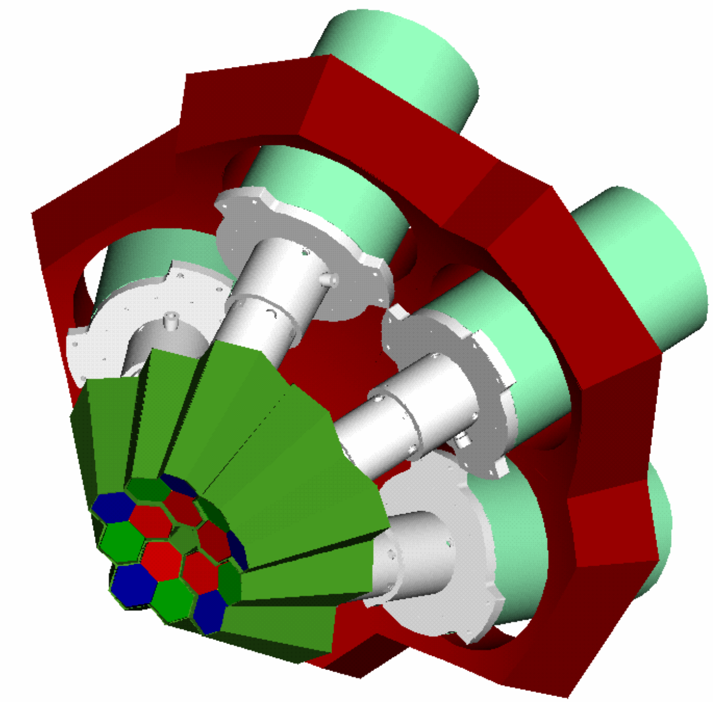
- High Energy Astrophysics
- Biomedical Research
- National Security
- Industrial non destructive asessments

Medicine: ultra-low radiation (full body scan)

The First Step:

The AGATA Demonstrator

Objective of the final R&D phase 2003-2008



$\Omega \sim 1/3\ \pi - 2/3\pi$

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

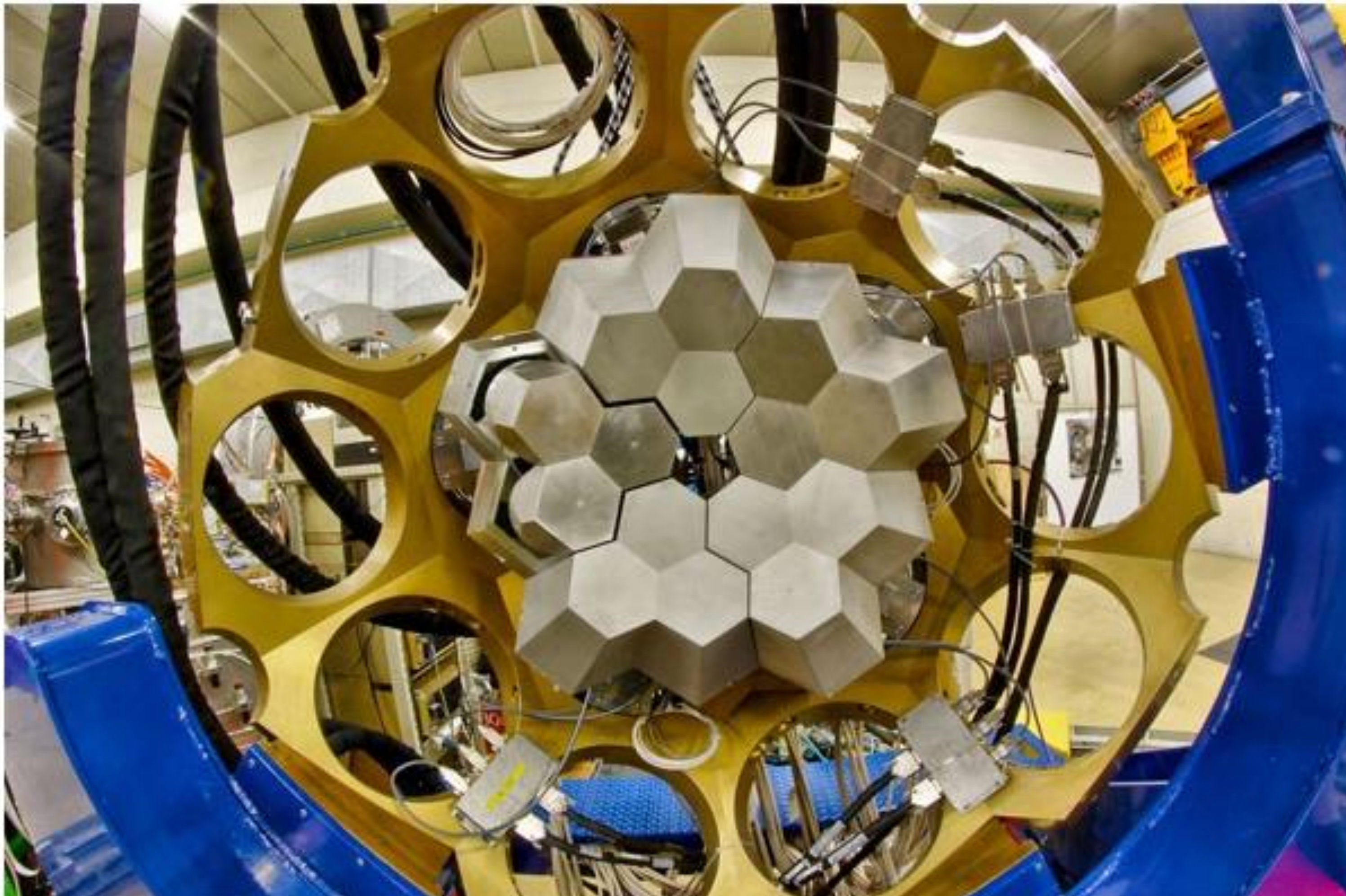
Test Sites:

LNL, GANIL, GSI, Jyväskylä, Köln

2007-2008: Commissioning & 1st physics Campaign @ LNL with PRISMA spectrometer

ADVANCED GAMMA TRACKING ARRAY

9th April 2010 – Legnaro National Laboratory INFN



9th April 2010 – Legnaro National Laboratory INFN


AGATA
Advanced Gamma Tracking Array
the future begins today
INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro
science is part of our culture
www.lnl.infn.it

A CRYSTAL BALL FOR STRANGE EXOTIC NUCLEI

WHERE IT'S LOCATED

Istituto Nazionale di Fisica Nucleare

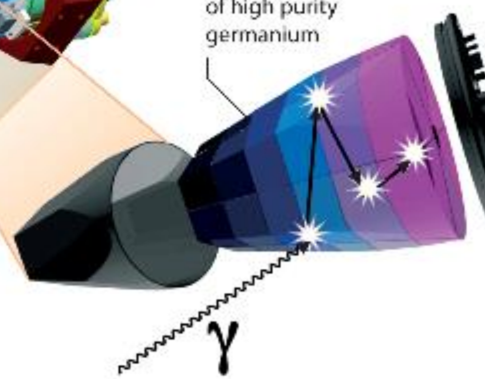
AGATA ADVANCED GAMMA TRACKING ARRAY

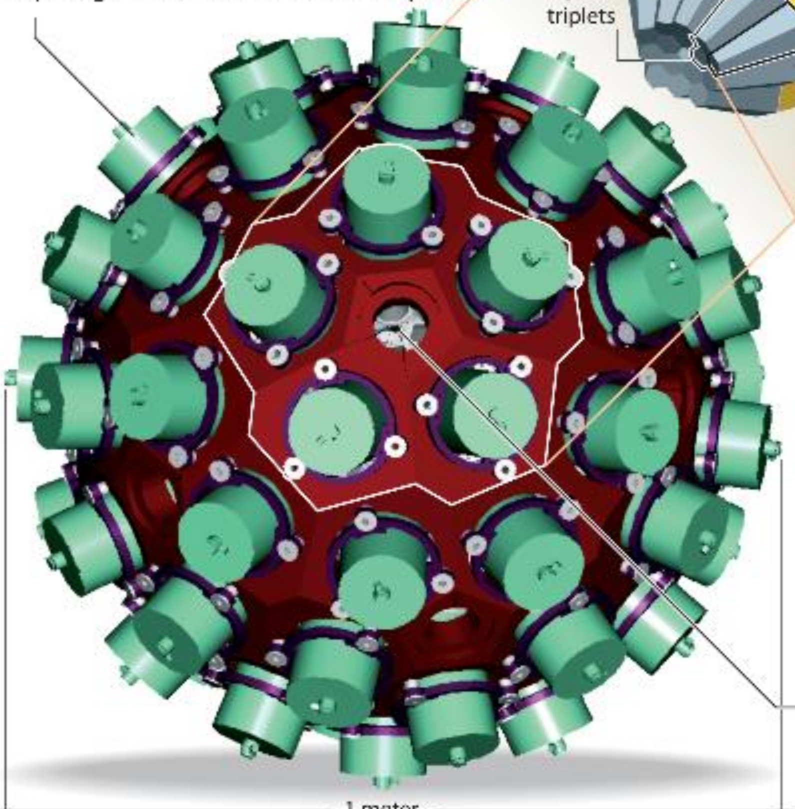
National Laboratories of **Legnaro** (LNL) of the Istituto Nazionale di Fisica Nucleare (INFN)

WHAT IT WILL CONSIST OF

Agata (Advanced Gamma Tracking Array) will be a new generation detector of gamma rays, that is, high energy photons.

It will consist of a sort of hollow sphere composed of 180 hexagonal crystals of pure germanium assembled in triplets.



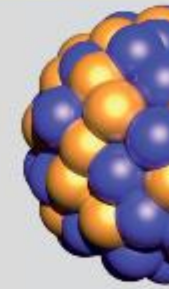


Sophisticated technology will allow tracks of gamma rays within the crystal to be reconstructed to calculate the trajectory of the incident gamma ray

The events that will be tracked by this experiment are those produced by the interaction of accelerated beams on a target located at the centre of the apparatus.

WHAT IT WILL BE USED FOR

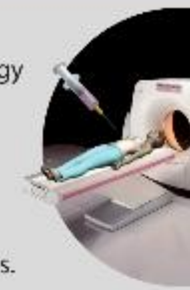
Nuclear Physics: to study the properties of the nuclear force in nuclei that do not exist on Earth.



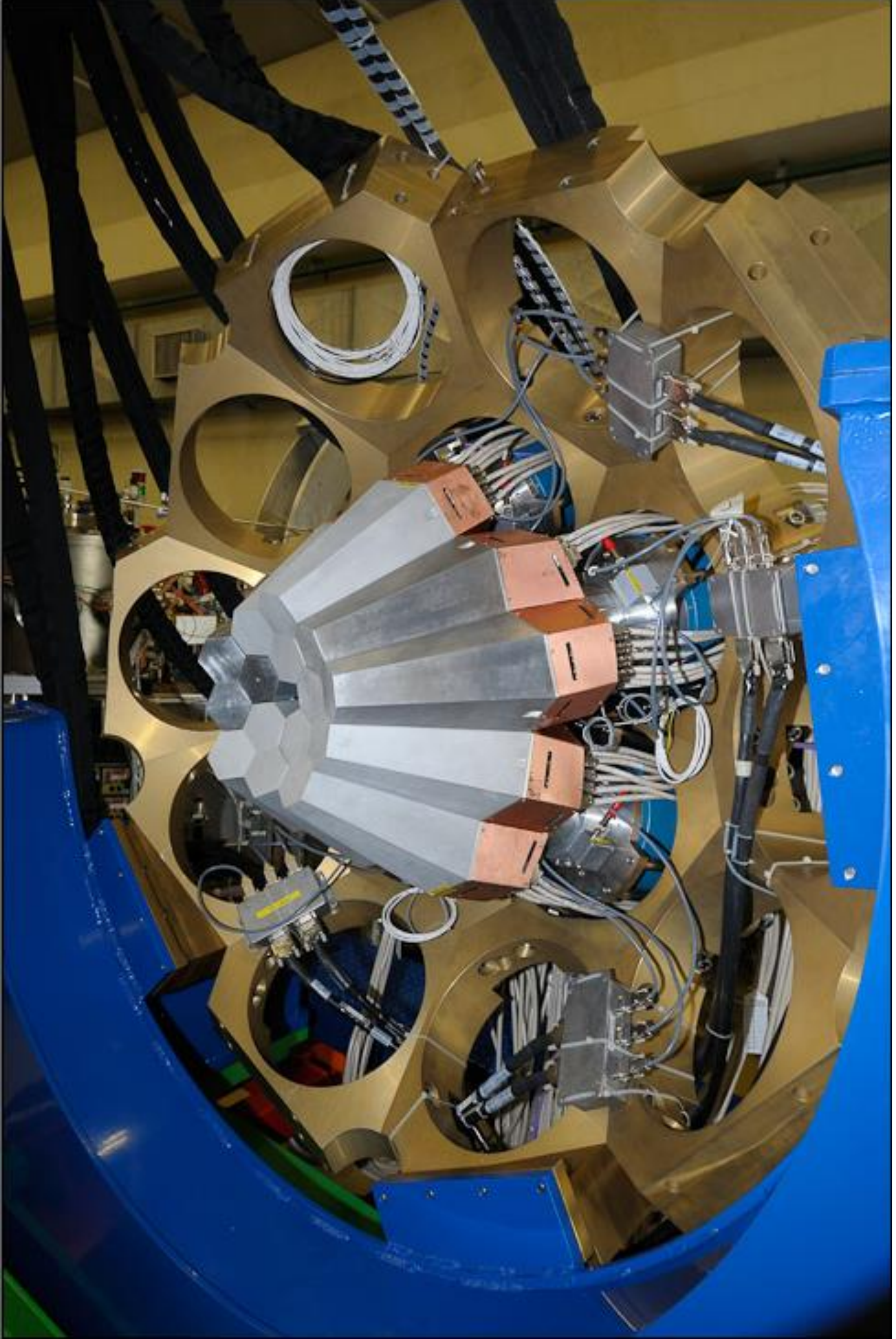
Astrophysics: to investigate that which occurs in stars by performing laboratory studies on the nuclei that are normally produced by the reactions that occur in stars.

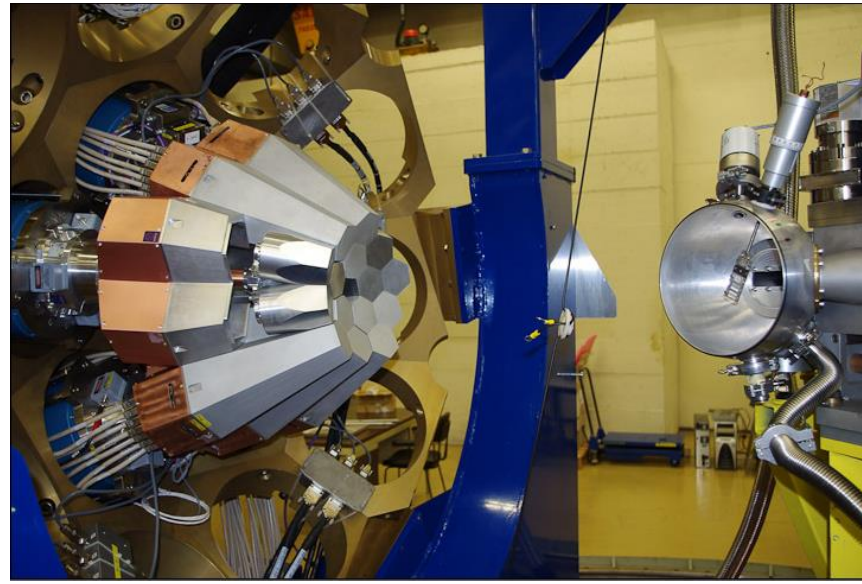
FUTURE APPLICATIONS

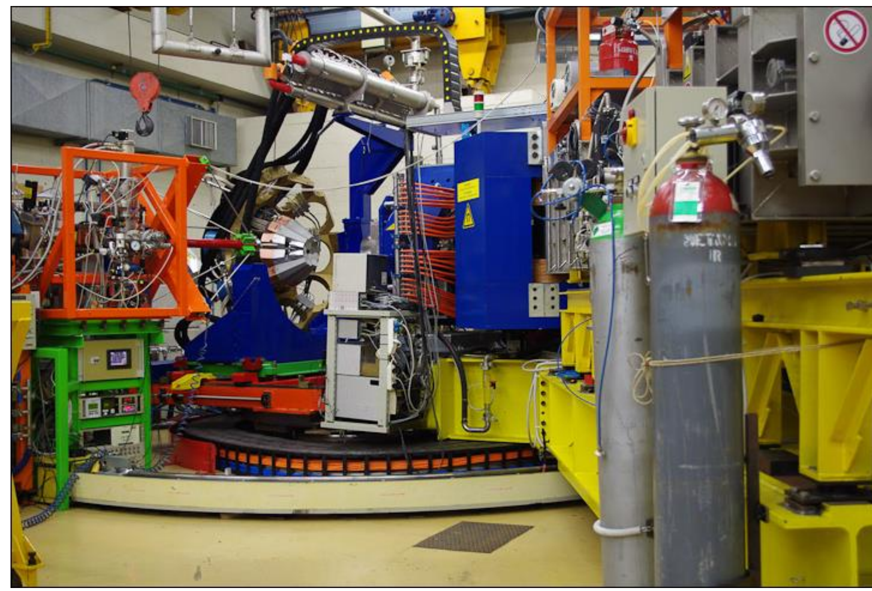
Medical Imaging: the developed technology could allow diagnostic tests such as PET and SPECT to be more accurate and rapid and to require a lower dose of radioactive drugs.

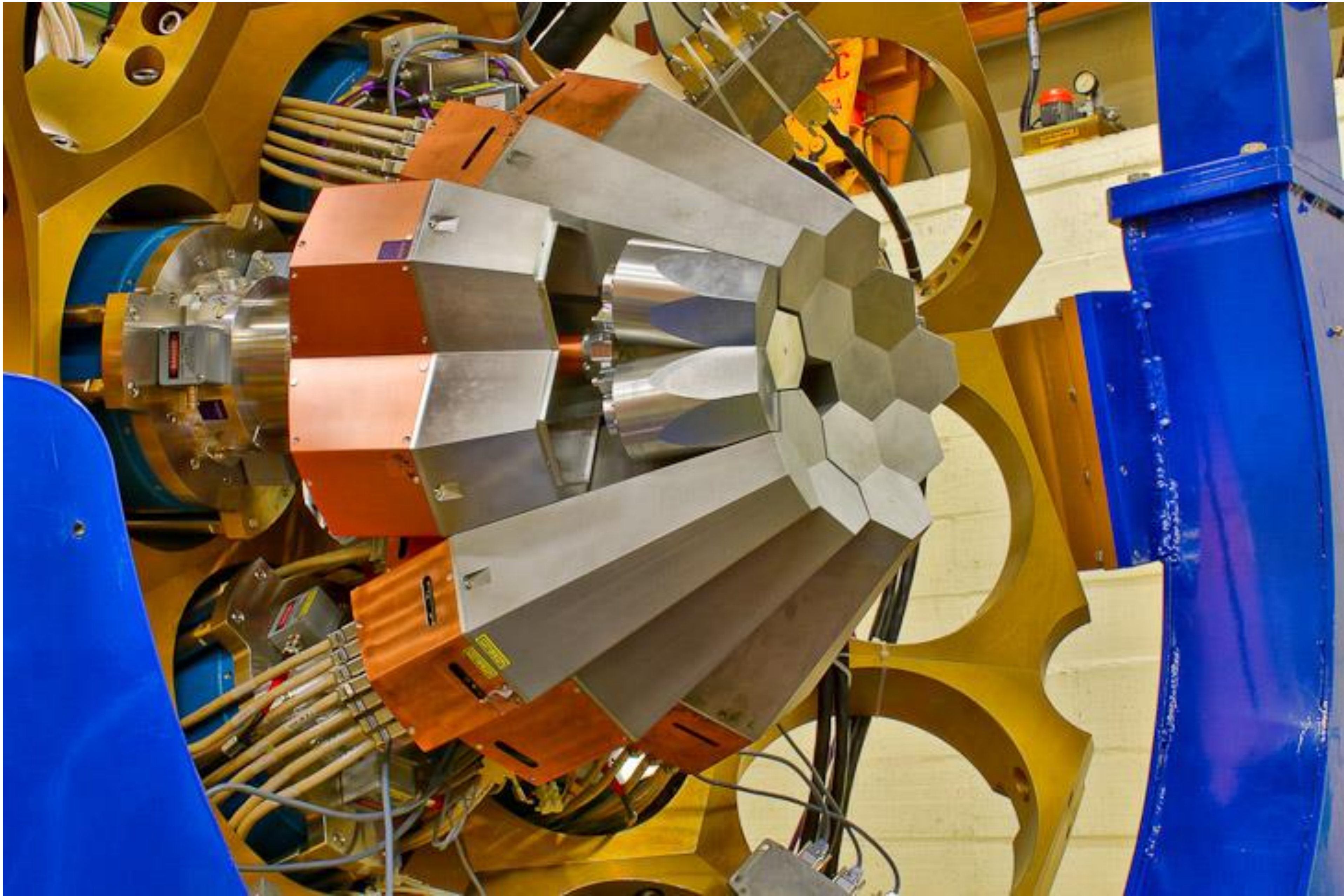


Security: This technology could increase the effectiveness of security controls on radioactive materials, for example in transport cargoes.



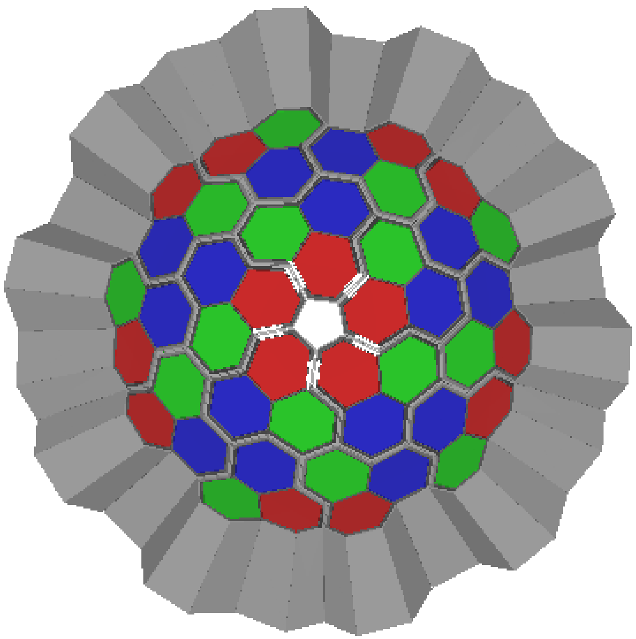




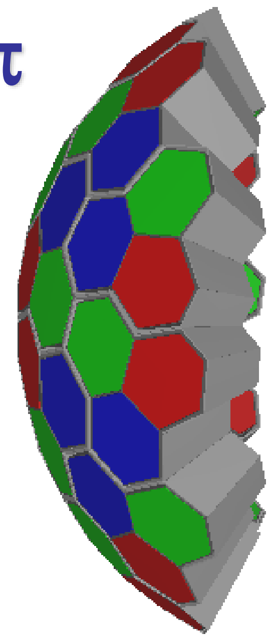


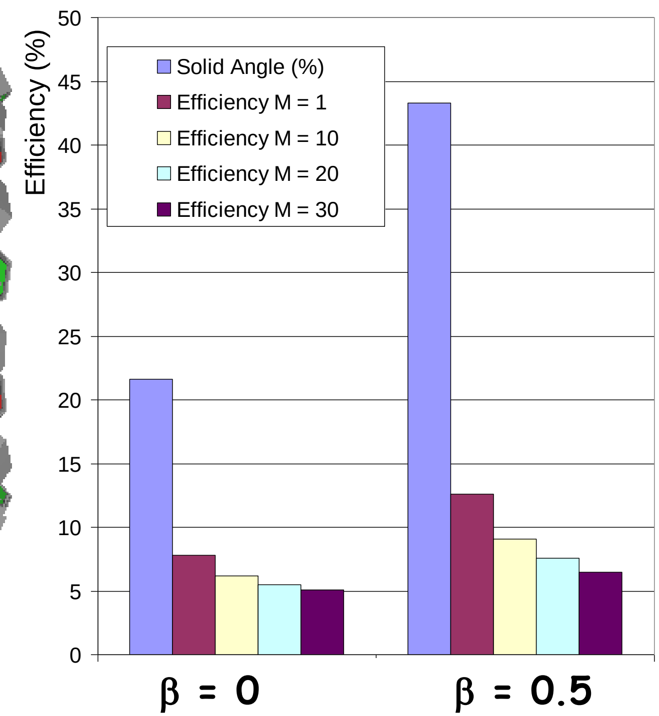
The Phases of AGATA 2

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, …

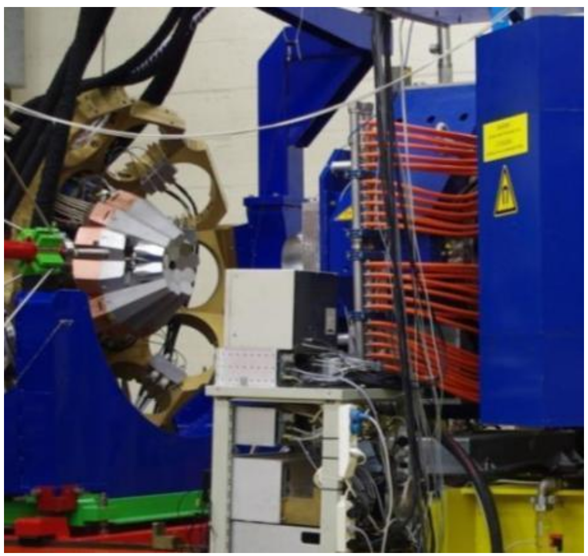
From the Demonstrator to AGATA 1π

Plans for the next few years

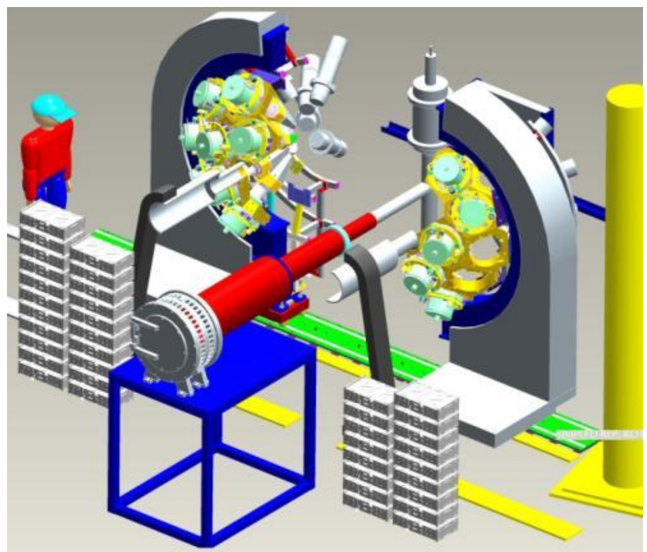
LNL: 2010-2011
15 crystals (5TC)
Total Eff. ~6%

GSI: 2012-2013
25 crystals (5DC+5TC)
Total Eff.~10%

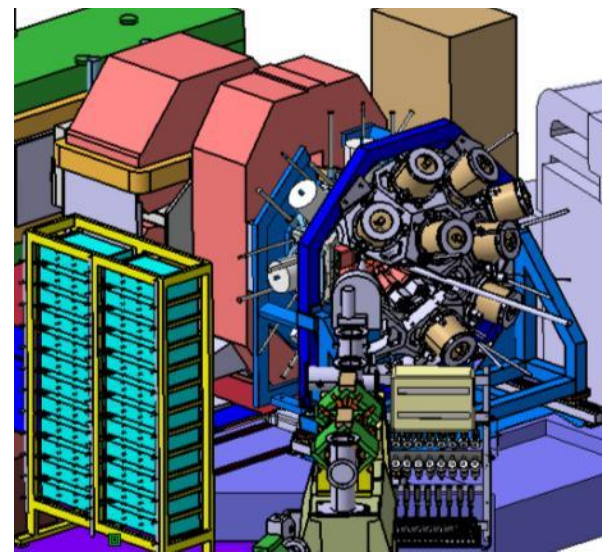
GANIL: 2014-2020
45 crystals (15 TC)
Total Eff. ~15%



Demonstrator + PRISMA
"backward"



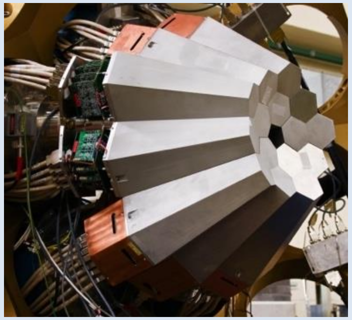
AGATA + FRS
"forward"



AGATA+VAMOS
"backward"

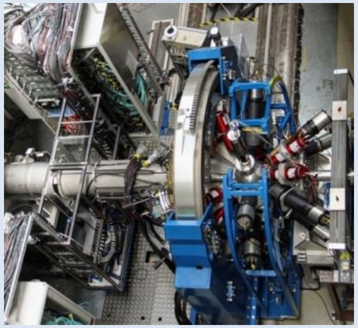
Progress of the AGATA array

2010-2012
Legnaro, Italy
Intense stable beams
15 detectors



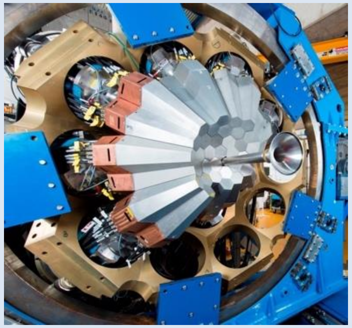
AGATA Demonstrator + PRISMA at LNL

2012-2014
GSI, Germany
Fast fragmentation beams
25 detectors



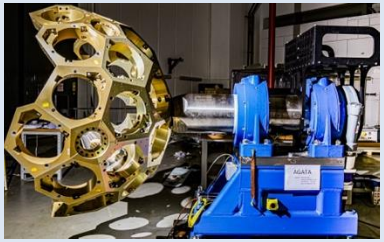
AGATA at GSI

2014- 2021
GANIL, France
ISOL and stable beams
approaching 1π (45)



AGATA at GANIL

2021--
LNL, Italy
Stable beams
SPES radioactive beams



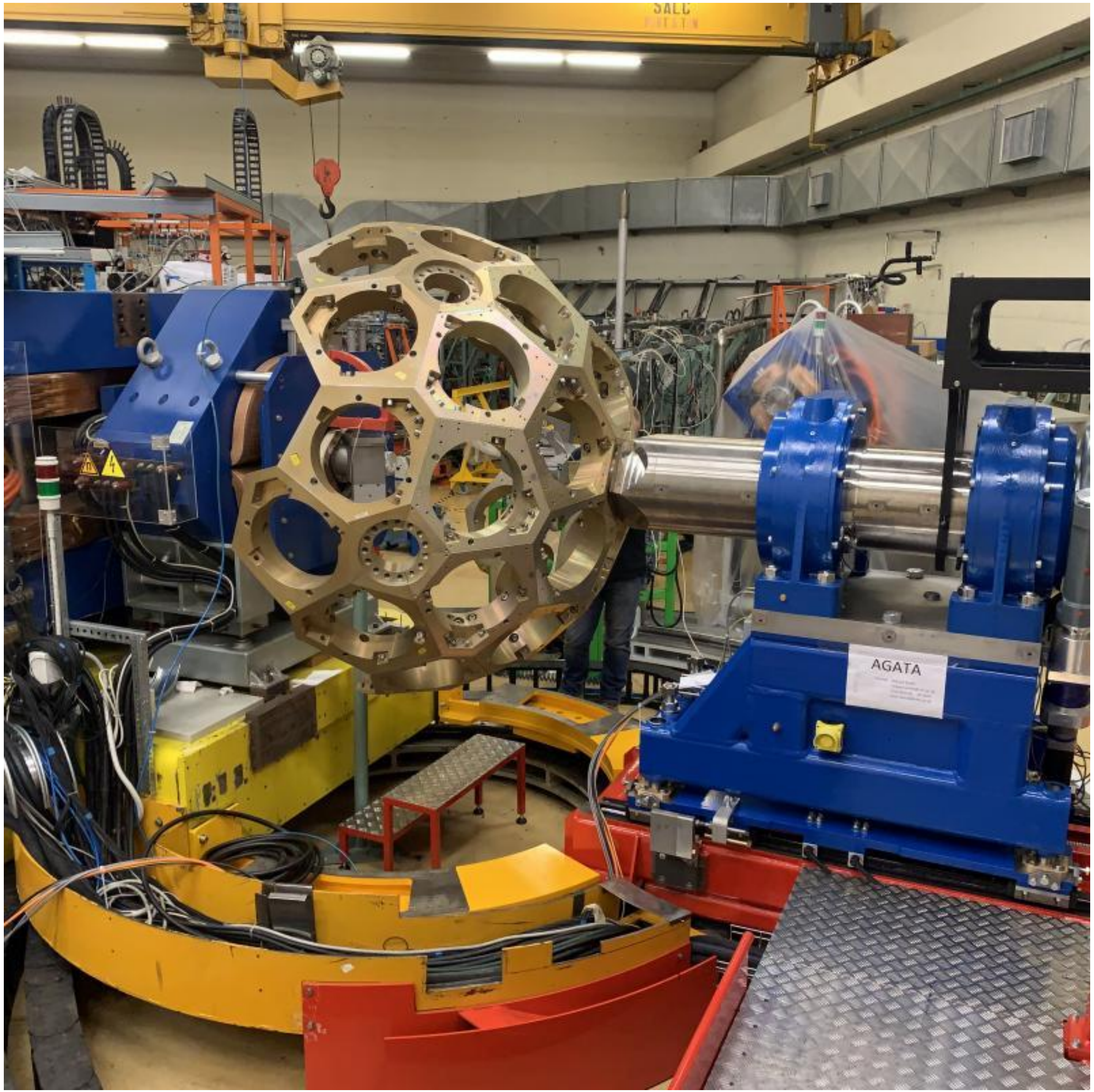
AGATA at LNL

AGATA
ADVANCED GAMMA TRACKING ARRAY

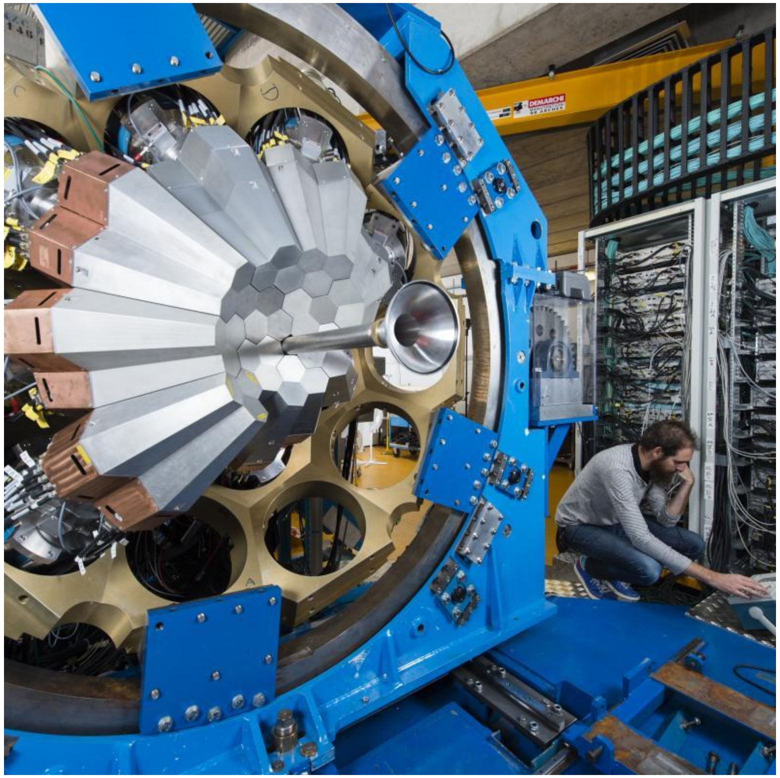
New AGATA campaign at Legnaro-INFN

Spring 2022 →

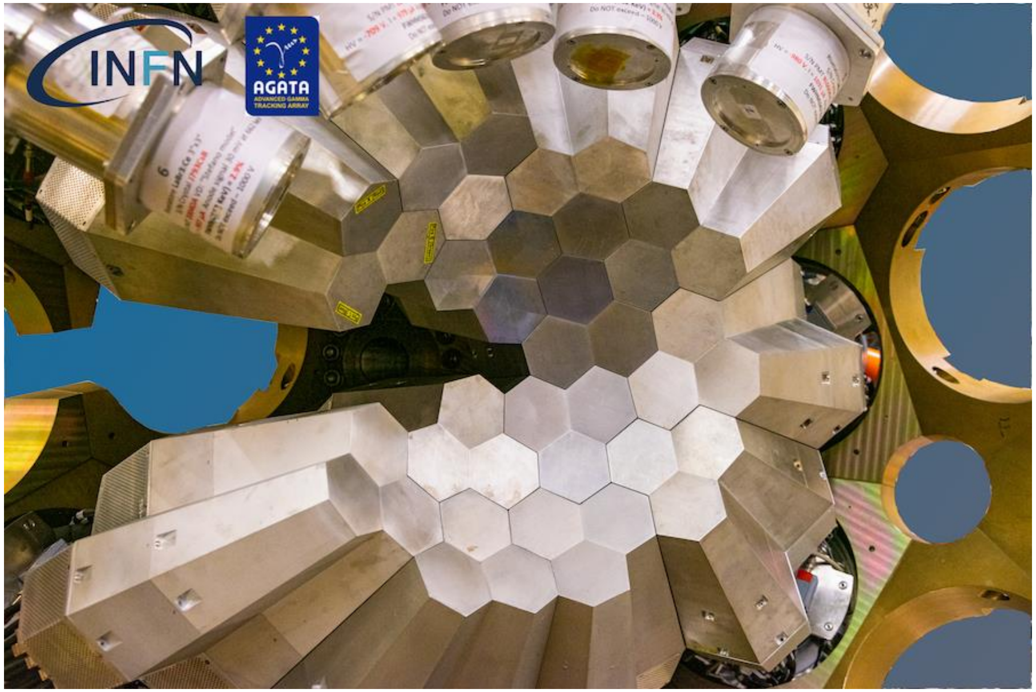
Use with stable and radioactive beams (SPES facility)



AGATA at GANIL (2021)



AGATA at Legnaro (17.10.22)



AGATA 10(+2) Years Celebration

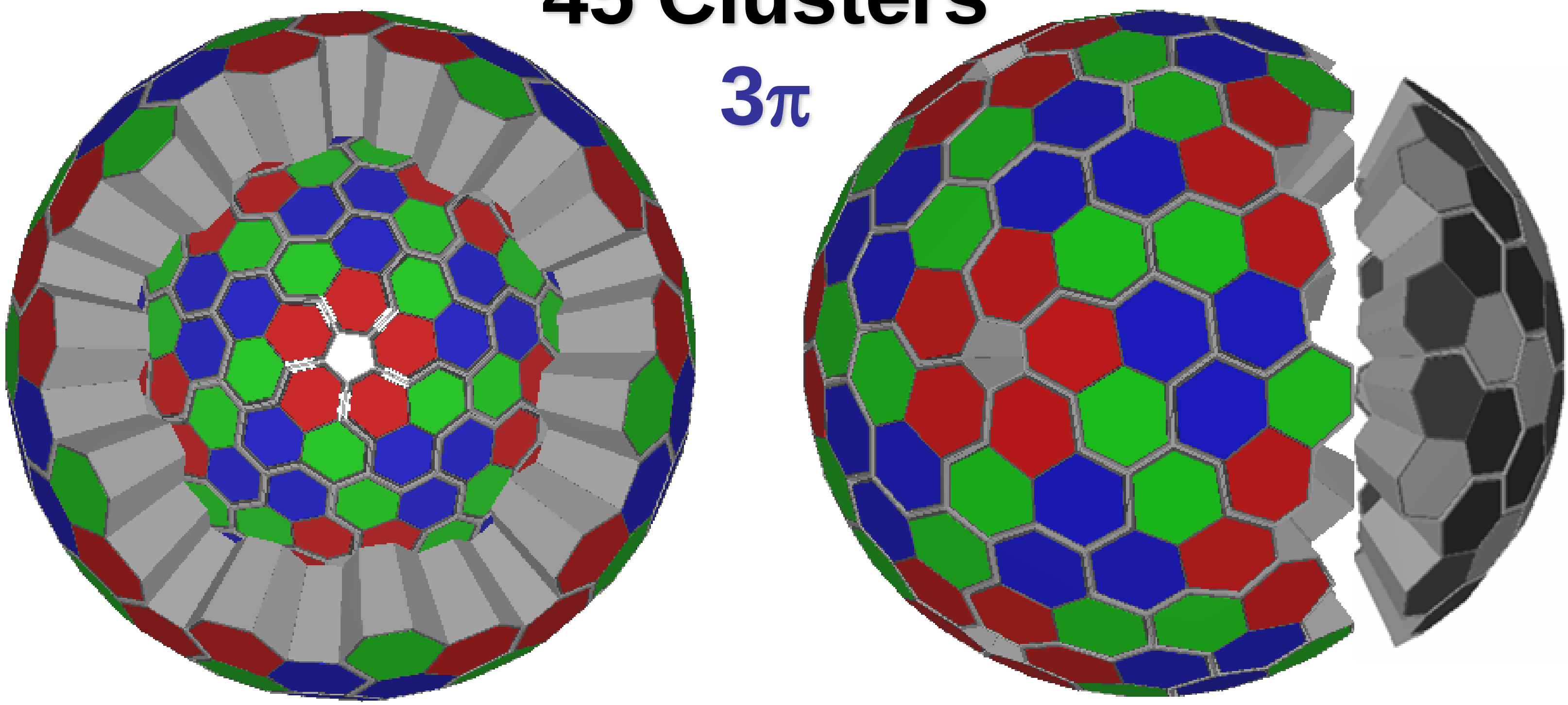
9th June 2022

https://agenda.infn.it/event/30956/

The Phases of AGATA

45 Clusters

3π



Ideal instrument for FAIR / EURISOL

Also used as partial arrays in different labs

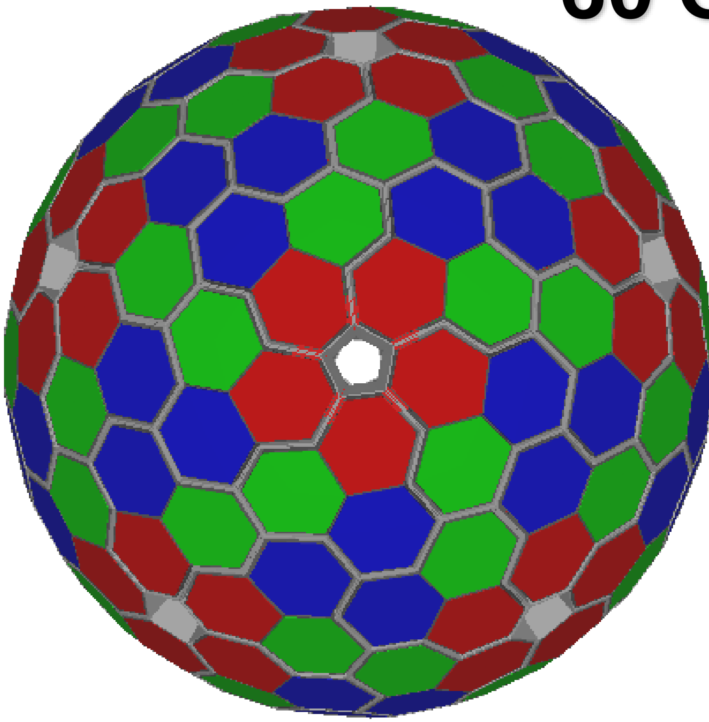
Higher performance by coupling with ancillaries

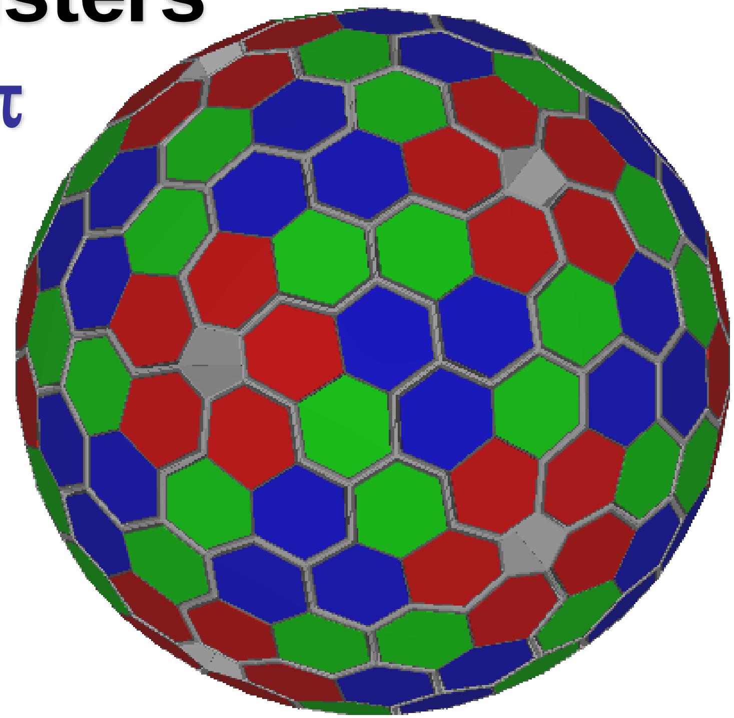
Ready by 2030

The Phases of AGATA 4

60 Clusters

4π



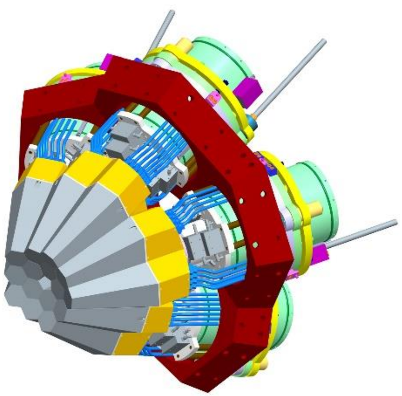


Full ball, ideal to study extreme deformations
and the most exotic nuclear species
Most of the time used as partial arrays
Maximum performance by coupling to ancillaries

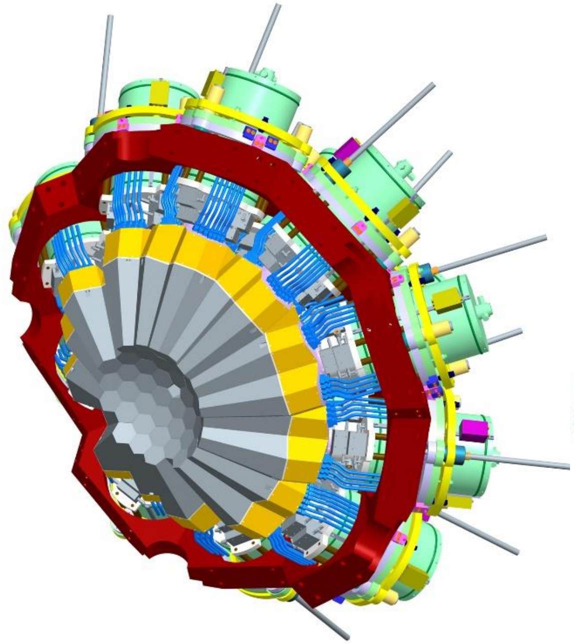
Ready by 20.. ??

AGATA is operated under a Memorandum of Understanding

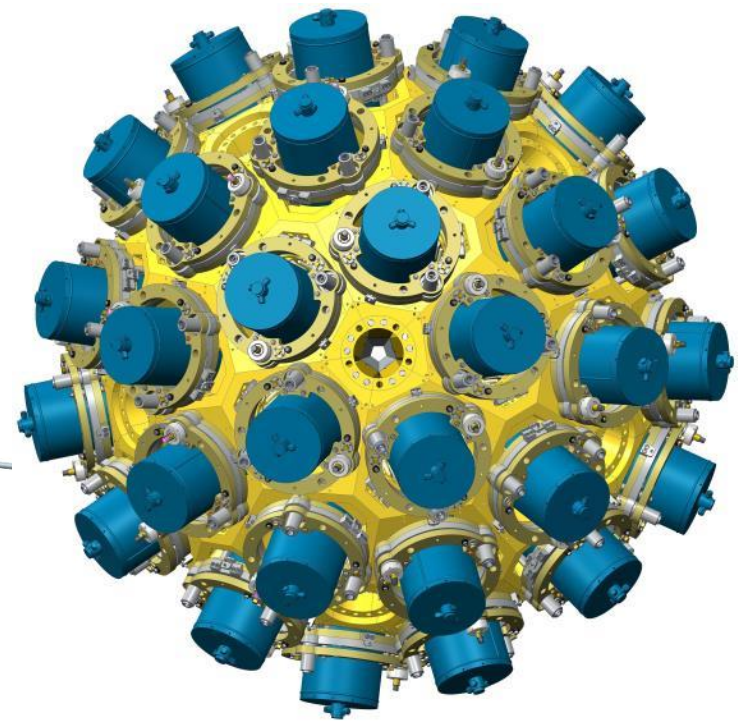
I MoU
AGATA 15
Demonstrator
2003-



II MoU
AGATA 60
2021-2030



III MoU
AGATA 180 = 4π



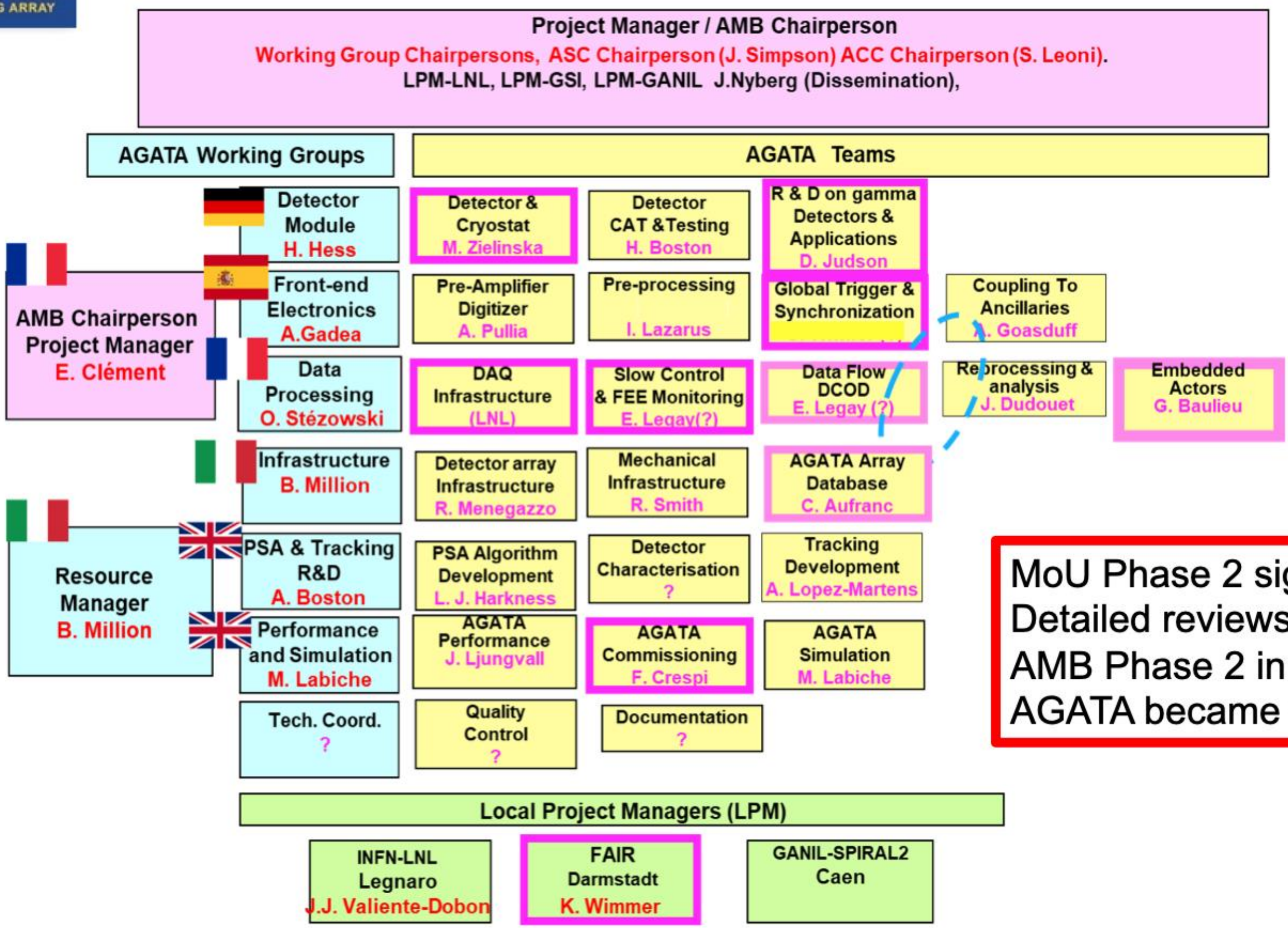
AGATA Collaboration – September 2021

WEB PAGE: https://www.agata.org

13 Countries
~40 Institutions

Bulgaria:	Univ. Sofia
Finland:	Univ. Jyväskylä
France:	GANIL Caen, IP2I Lyon, IJC Orsay, IPHC Strasbourg, DRF/IRFU Saclay,
Germany:	GSI Darmstadt, TU Darmstadt, Univ. zu Köln
Hungary:	ATOMKI Debrecen
Italy:	INFN Firenza, Lagnaro, Milano, Padova
Poland:	IFJ PAN Krakow, University of Warsaw (HIL)
Spain:	CSIC-Universidad de Valencia, Instituto de Fisica Corpuscular.
	Universidad de Valencia, Escuela Tecnica Superior de Ingenieria
	CSIC, Instituto de Estructura de la Materia, Madrid
	Universidad de Salamanca, Laboratorio de Radiaciones Ionizantes.
Sweden:	Lund Univ., KTH Royal Institute of Technology Stockholm, Uppsala Univ, Stockholm Univ.
Turkey:	Univ's Ankara, Istanbul, Kocaelli, Bitlis Eren
UK:	Univ's Brighton, Edinburgh, Liverpool, Manchester, West of Scotland, Surrey, & York,
	UKRI-STFC Daresbury
Romania:	IFIN-HH Bucharest
Slovenia:	Ljubljana

AGATA Organization Structure – November 2021



MoU Phase 2 signed by major countries
Detailed reviews successfully passed in 2020
AMB Phase 2 in place
AGATA became a « IR » in France

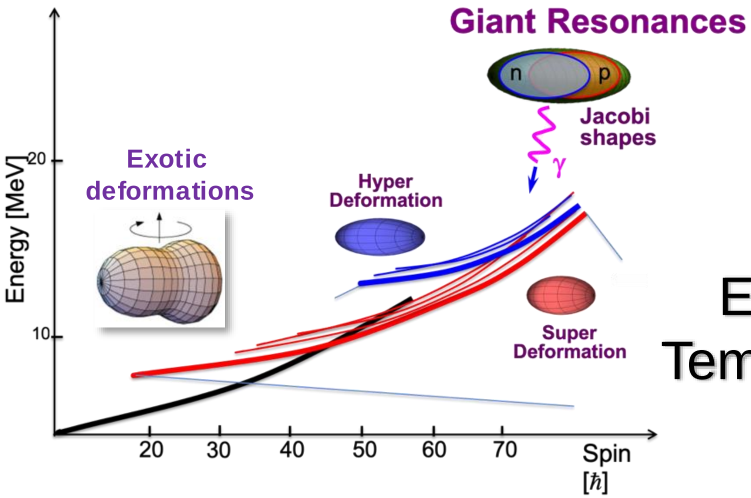
Long Range Plan 2004, 2017 and 2024
Recommendations and priorities

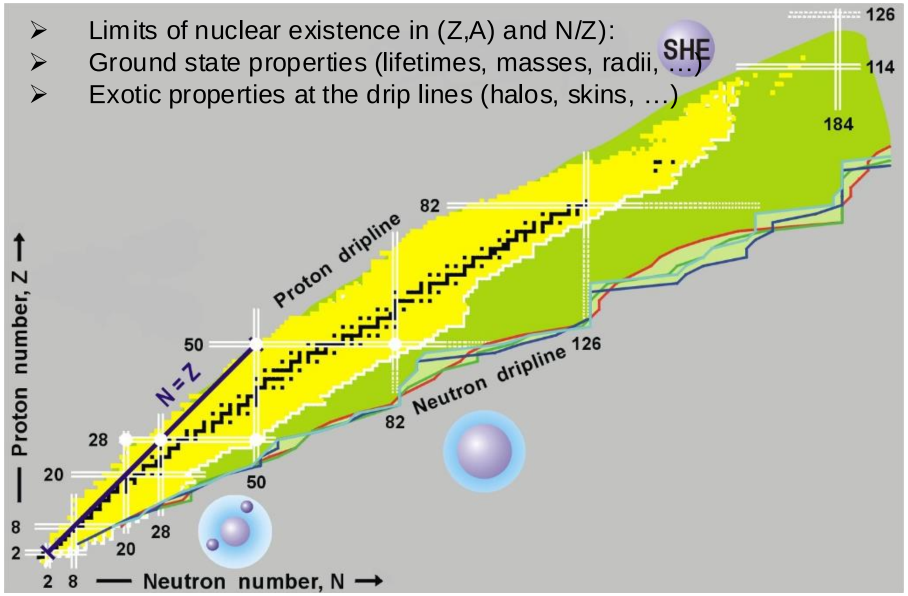
…

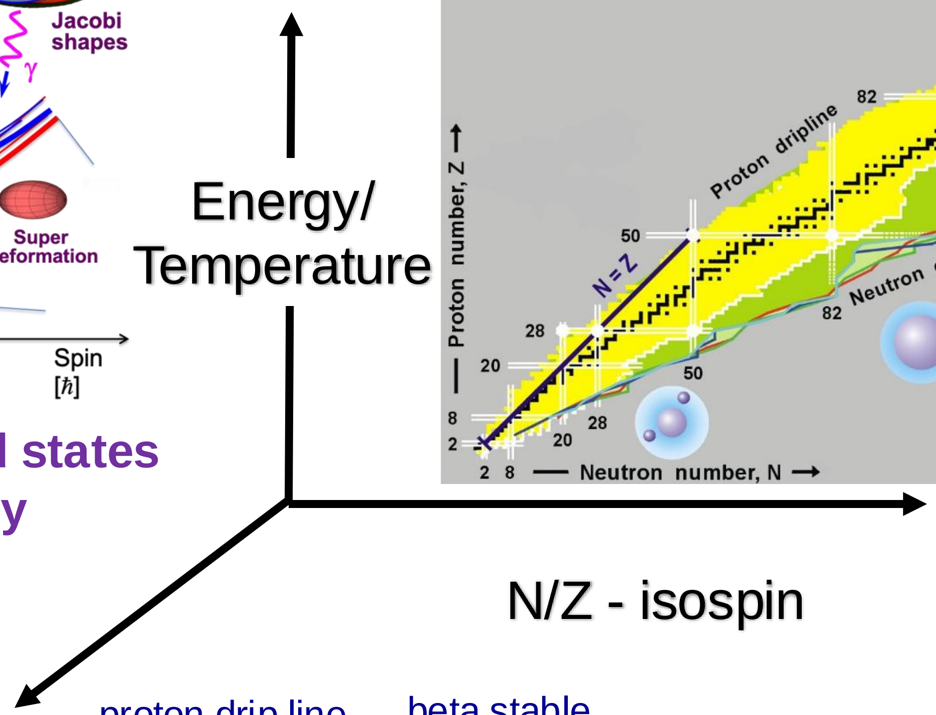
In order to exploit present and future facilities fully and most efficiently, advanced instrumentation and detection equipment will be required to carry on the various programmes.

The project *AGATA*, for a 4p-array of highly segmented *Ge* detectors for g-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.**

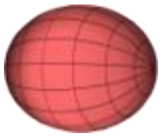
AGATA physics case
Challenges in Nuclear Structure Physics

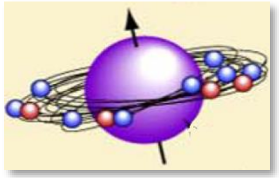


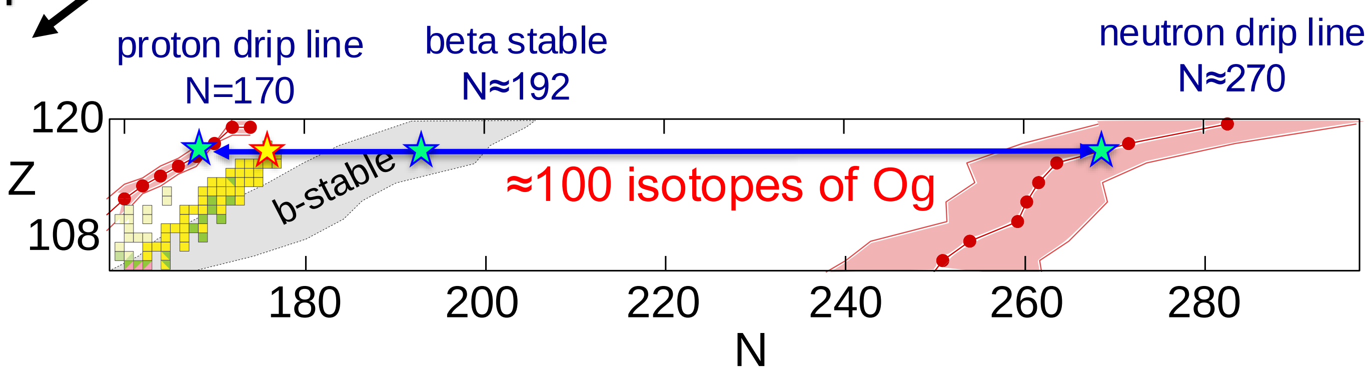




Properties of excited states
→ γ-ray spectroscopy







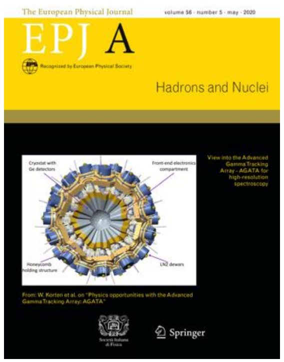
AGATA Science White Book

[Physics opportunities with the Advanced Gamma Tracking Array: AGATA | SpringerLink]

May 2020

AGATA Science White Book

Physics opportunities with the Advanced Gamma Tracking Array: AGATA | SpringerLink



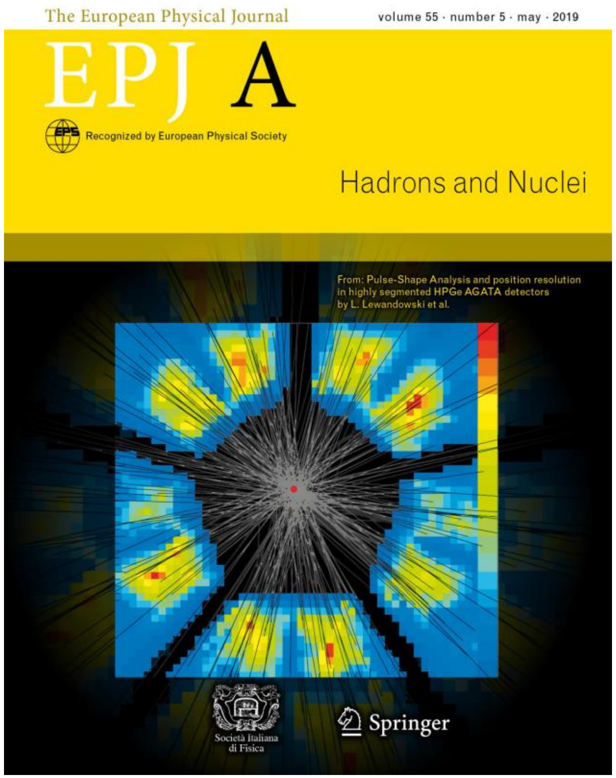
Common Physics Working Group
W. Korten (chair)
Gilbert Duchene (co-chair)
Facility Working Group: CERN/ISOLDE
Magdalena Zielińska (chair)
Peter Reiter (co-chair)
Facility Working Group: GANIL/SPIRAL1/SPIRAL2
Bo Cederwall (chair)
Emmanuel Clément (co-chair)
Facility Working Group: GSI/FAIR
Andrea Jungclaus (chair)
Magdalena Górska (co-chair)
Facility Working Group: JYFL
David Jenkins (chair)
Paul Greenlees (co-chair)
Facility Working Group: LNL/SPES
Silvia Leoni (chair)
José Javier Valiente Dobón (co-chair)

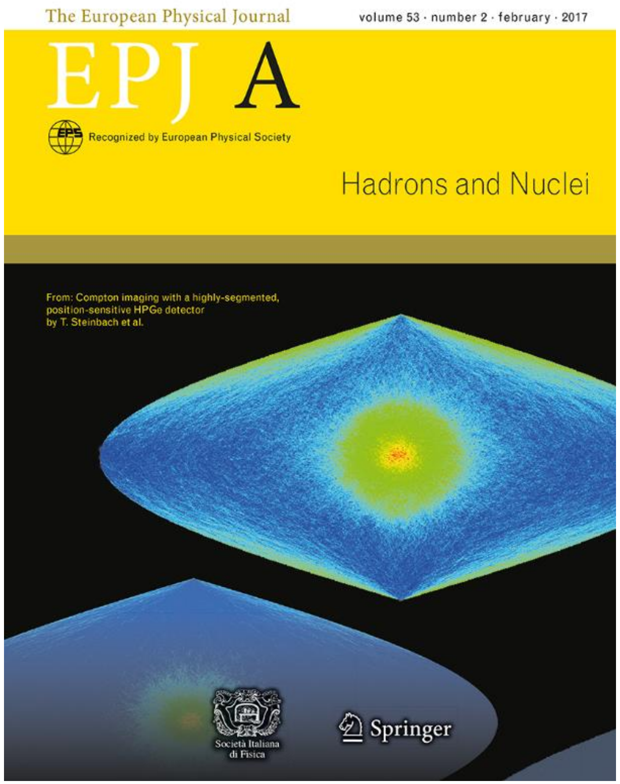
Many people contributed

AGATA scientific results: technical publications

85 scientific publications (10 PRL/PL)
108 technical publications
66 PhDs, 18 Masters, 9 Diplomas, 11 Bachelor, 1 Licentiate (6/10/21)

https://www.agata.org/





EPJ A

2023 Impact factor **2.6**

Hadrons and Nuclei

10 most recent | All issues | Topical Collections | Reviews | Letters | Viewpoints & Perspectives | Code Papers

The European Physical Journal A
AGATA: Advancements in Science and Technology

Nicolas Alamanos, Maria Jose Garcia Borge, Angela Bracco, Emmanuel Clement, Andres Gadea, Wolfram Korten
Silvia Leoni and John Simpson

FOCUS ISSUE: 15 papers on Science and Technology of AGATA

https://epja.epj.org/component/toc/?task=topic&id=1878

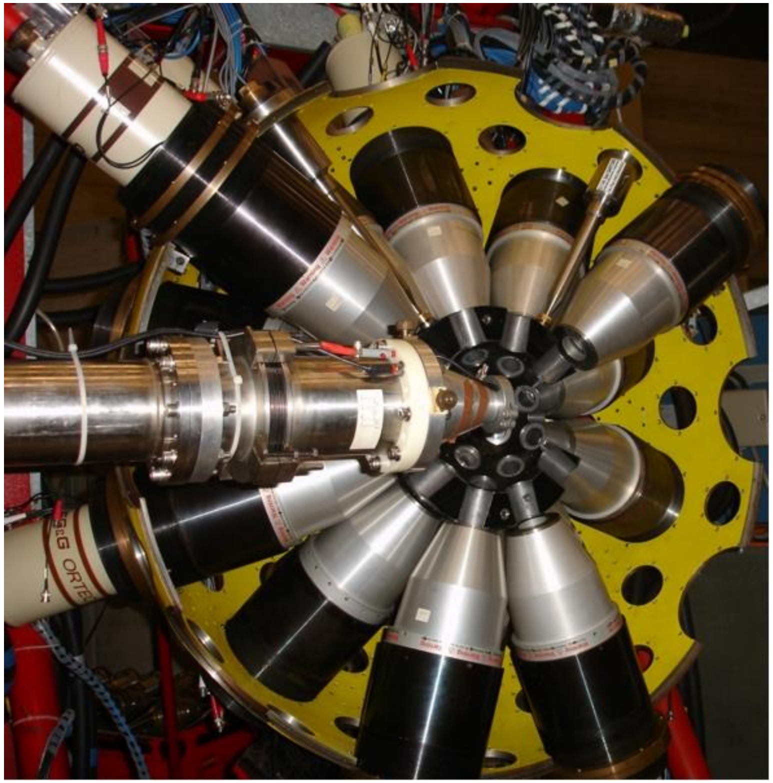
Lesson Learned from AGATA …

The GALILEO Project at
INFN-Legnaro National Laboratory

Legnaro-Padova-Milano-Firenze
+ European Collaborators

Gamma–ray spectroscopy at LNL

a brief history



GASP – 1992

40 HPGe (80%) + AC

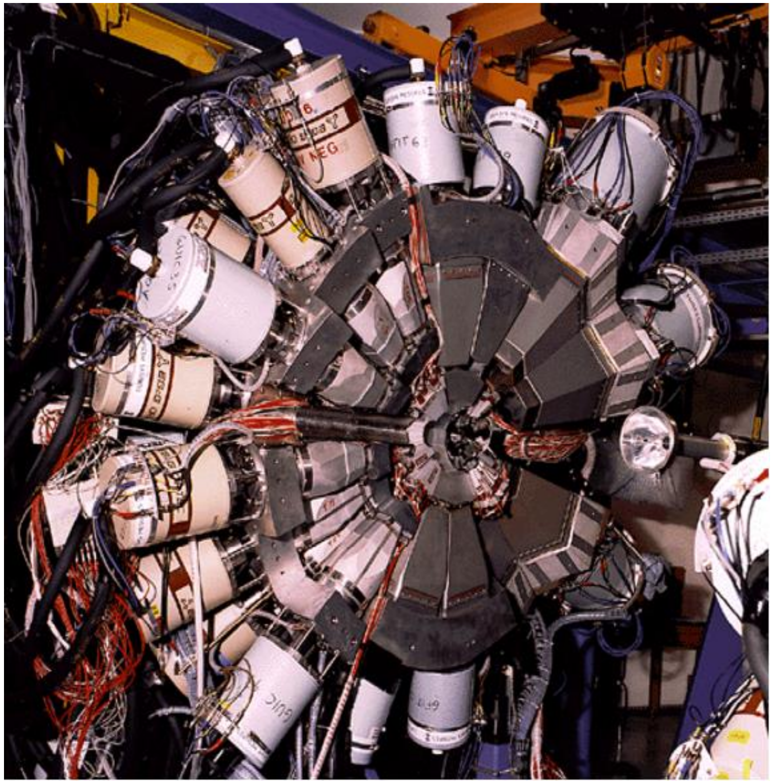
ε_{ph} (1.3MeV) ~ 3% (@ 27 cm)
~ 6% (@ 22 cm)

P/T ~ 60%

high–spin states populated in fusion–evaporation reactions

Gamma–ray spectroscopy at LNL

a brief history



EUROBALL – 1997–1998
European Collaboration

15 cluster detectors + AC
26 clover detectors + AC
30 tapered detectors + AC

ε_{ph} (1.3MeV) ~ 9%
P/T ~ 50

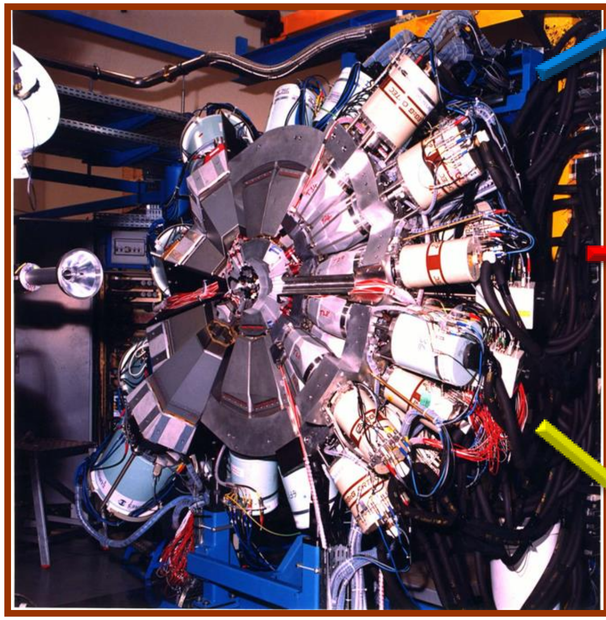
high–spin states populated in fusion–evaporation reactions

Gamma–ray spectroscopy at LNL

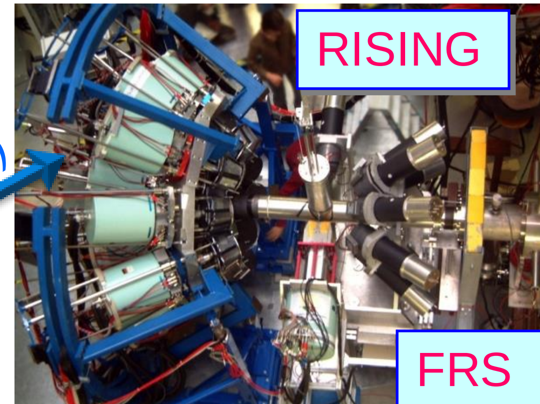
EUROBALL
Legacy

a brief history

EUROBALL



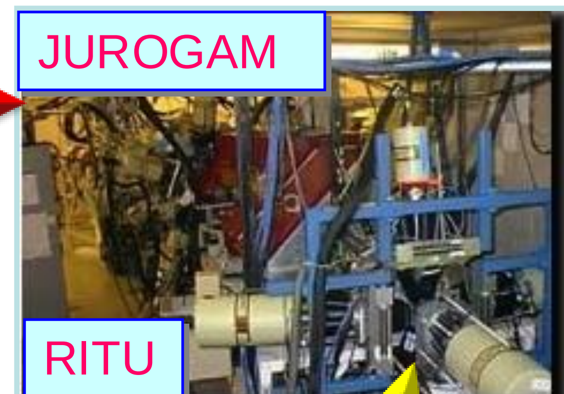
cluster (15)



ERIK
A

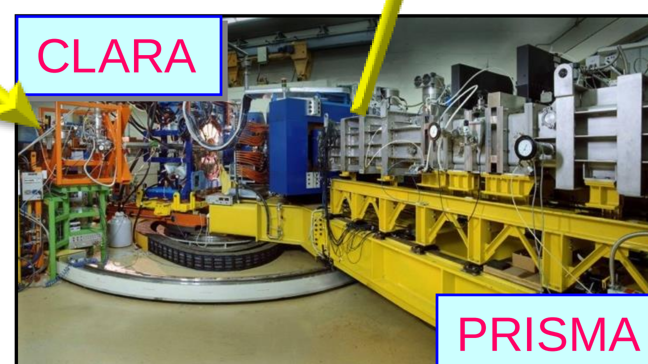
GALILE
O

tapered
(30)



ORGAM

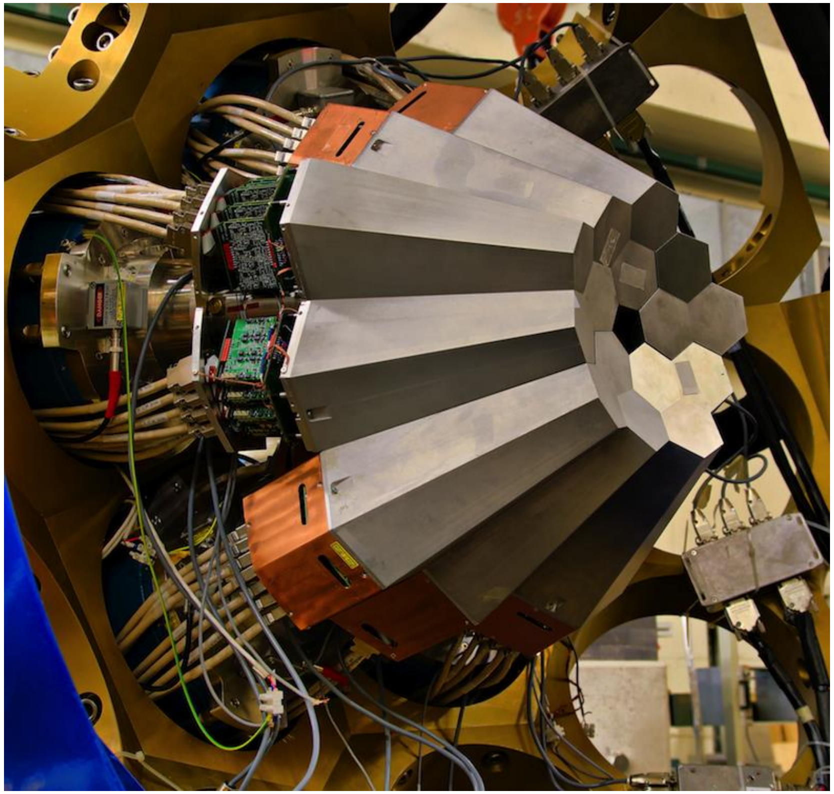
clover (26)



European Gammapool Owners
Committee

Gamma–ray spectroscopy at LNL

nowadays



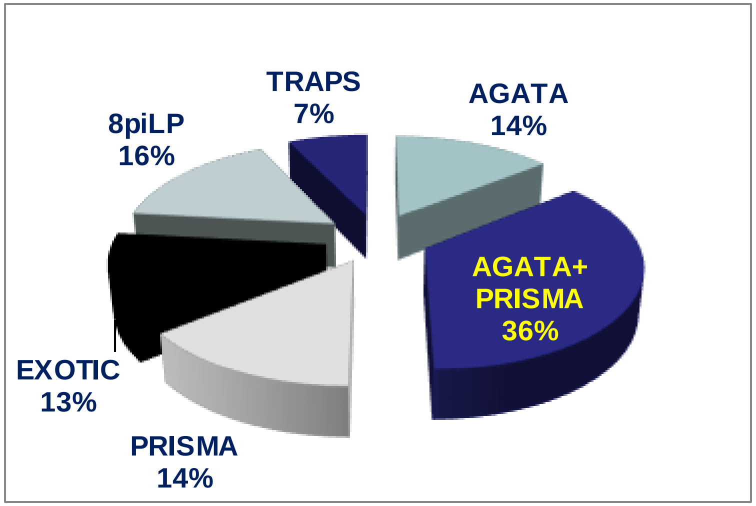
AGATA D – 2010
European Collaboration

5 triple cluster detectors
segmented detectors
tracking array

ε_{ph} (1.3MeV) ~ 6%

Coupled to the PRISMA
magnetic spectrometer up to end 2011

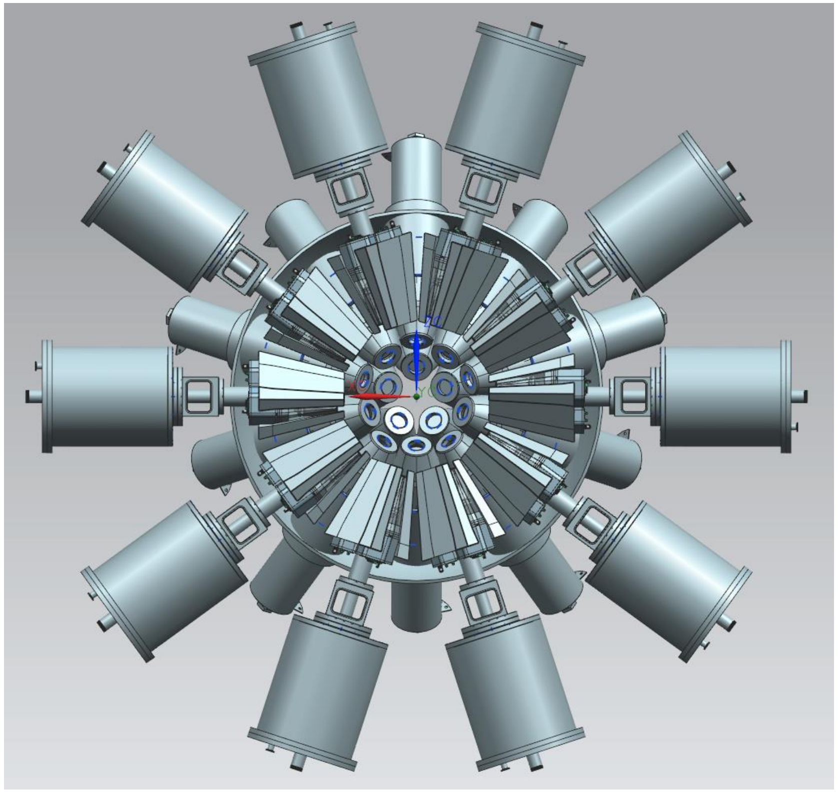
Beam time distribution
Sept. 28, 2011 – Mar. 14, 2012



Gamma–ray spectroscopy at LNL

GALILEO – 2012-→

new gamma–ray array



European Collaboration

take advantage of the recent technical developments for AGATA

preamplifiers, digital sampling, preprocessing, DAQ

→ **high counting rates (50 kHz/det)**

use of existing detectors

EB cluster detectors capsules

GASP detectors

→ **high photopeak efficiency**

use beam facilities at LNL

Tandem, ALPI, PIAVE – stable

SPES – RIB

→ **production of new nuclei**

Physics Case for GALILEO at LNL (spanning the entire Nuclear Chart)

- structure of N~Z nuclei
- isospin symmetry
- study of neutron–rich nuclei
- exotic decay of high–spin states
- nuclear structure close to ^{100}Sn
- cluster and highly deformed states in sd–shell nuclei
- giant resonances and warm rotations
- symmetries and shape–phase transitions in nuclei
- shape coexistence in neutron–deficient nuclei
- g–factor measurements
- measurement of astrophysical interest cross sections – surrogate NR method

The GALILEO array

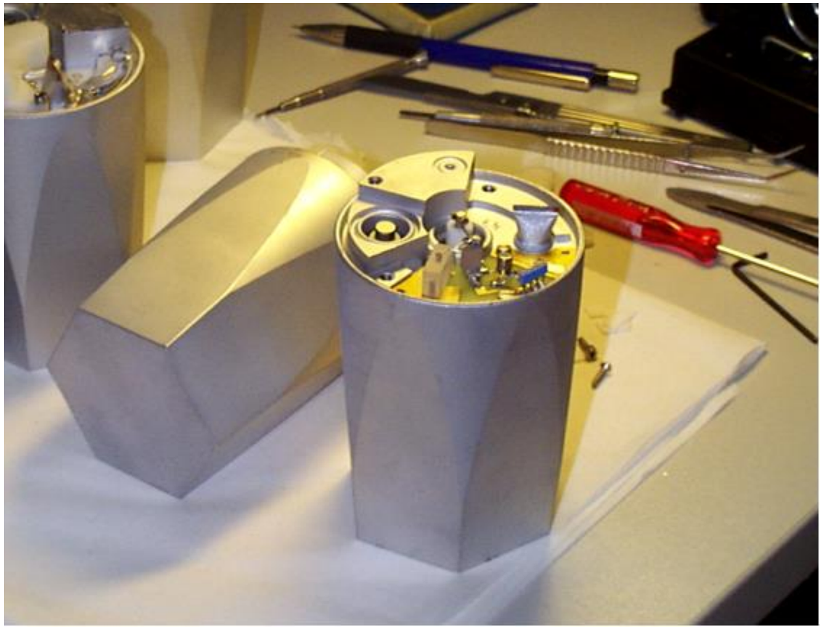
- Main ingredients
  - the capsules of the EUROBALL cluster detectors
  - the GASP tapered detectors

The capsules of the EB cluster detectors

15 x 7– cluster detectors (GSI–RISING array)
- encapsulated n–type HPGe detectors
- FWHM < 2.4 keV @ 1332.5 keV
- ε_{int} ~60% @ 1332.5 keV

common cryostat
HV/LV/FE independent

→ **New triple cryostat**



The GASP tapered detectors

40 n–type HPGe detectors

FWHM < 2.4 keV @ 1332.5 keV

ε_{int} ~80% @ 1332.5 keV

P/T ~ 25% (^{60}Co source)

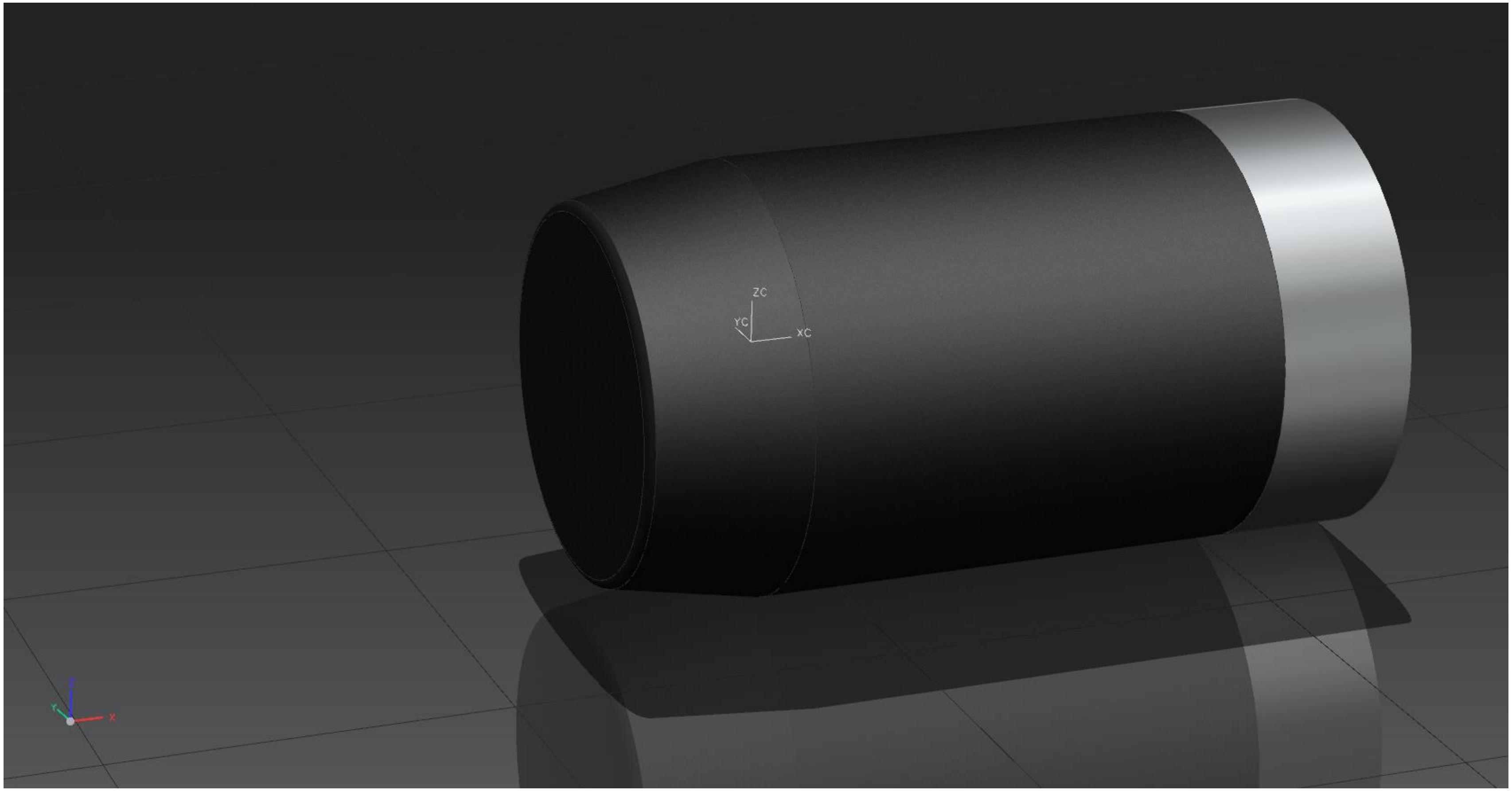
40 BGO anti–Compton shields

P/T ~ 60% (^{60}Co source)

Carbon Fiber End–Cap – Demonstration

Research and Development at LNL

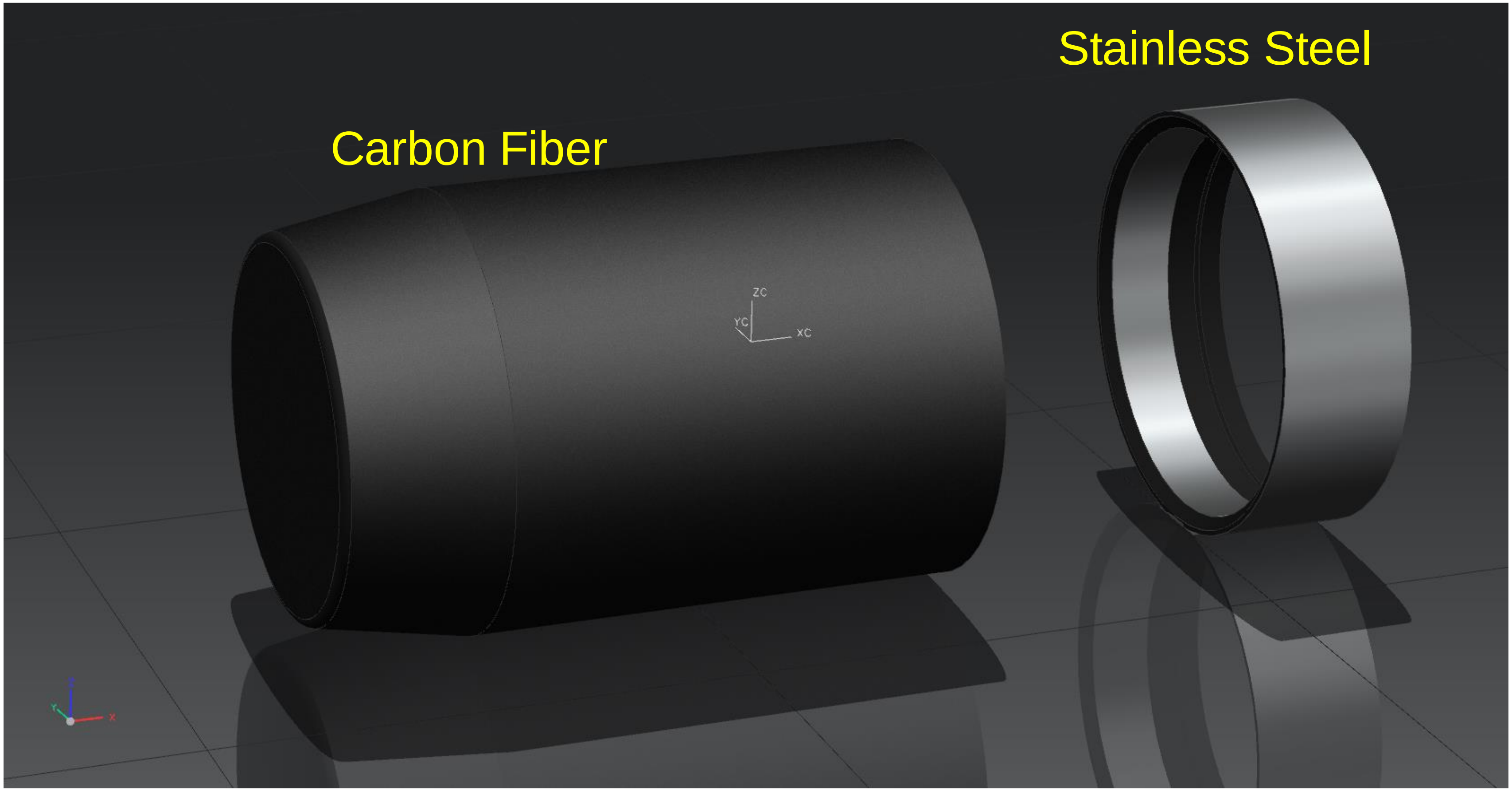
GASP detector end–cap



Carbon Fiber End–Cap – Demonstration

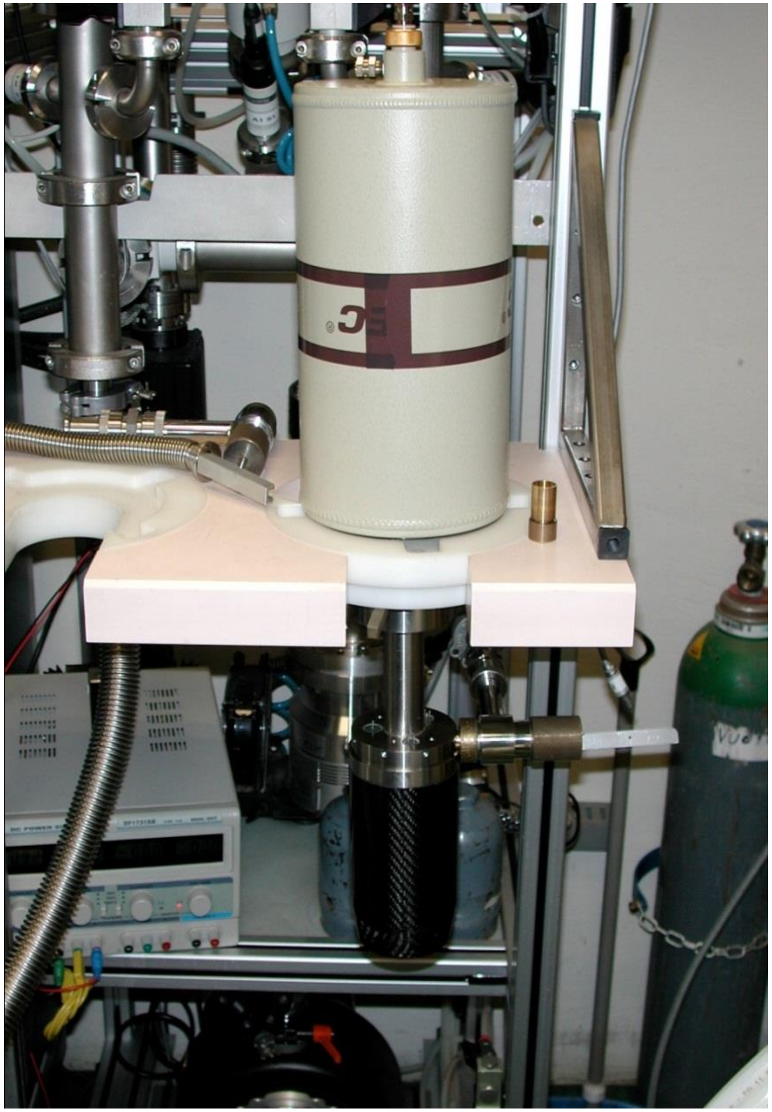
Research and Development at LNL

GASP detector end–cap



Carbon Fiber End–Cap – Demonstration

GASP detector end–cap



<u>NO GOOD Vacuum !!!</u>

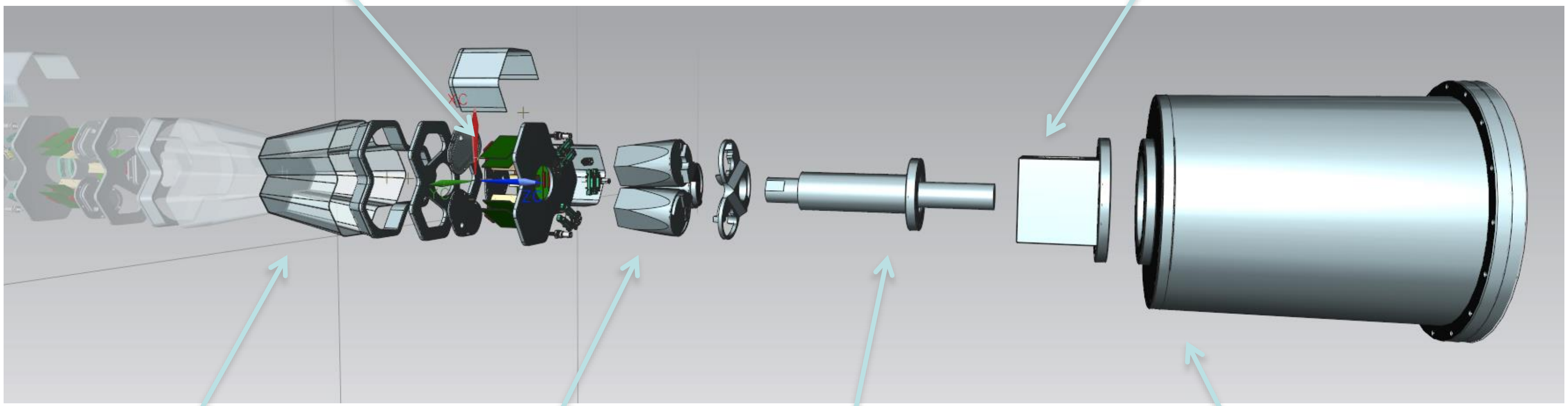
Mass analysis (water)

– <u>fiber storage (-18^{o}C)</u>

The triple cryostat

front–end electronics (warm part)

Zeolites container



end–cap in Carbon fiber

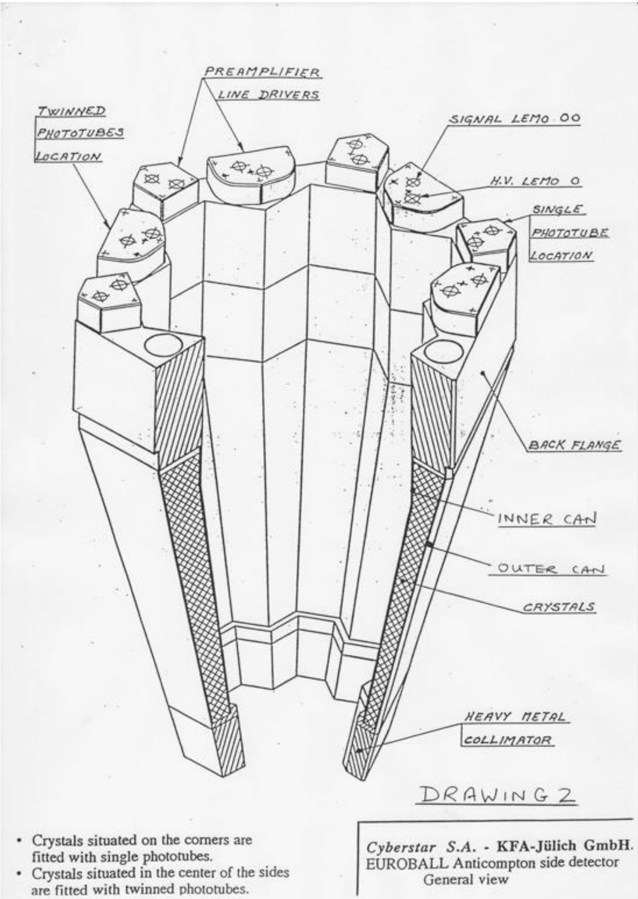
capsules

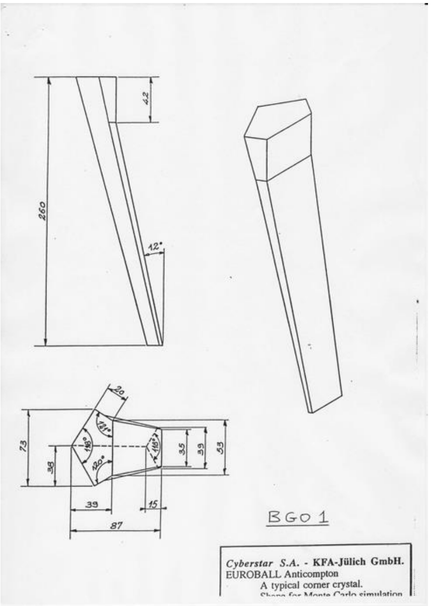
cold finger

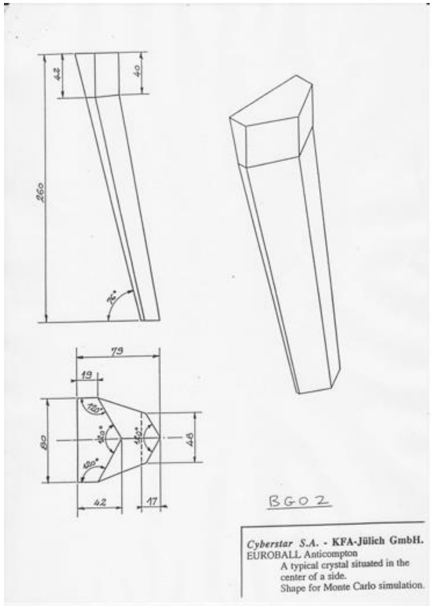
dewar

A new design

The Anti-Compton shield for the triple cryostat

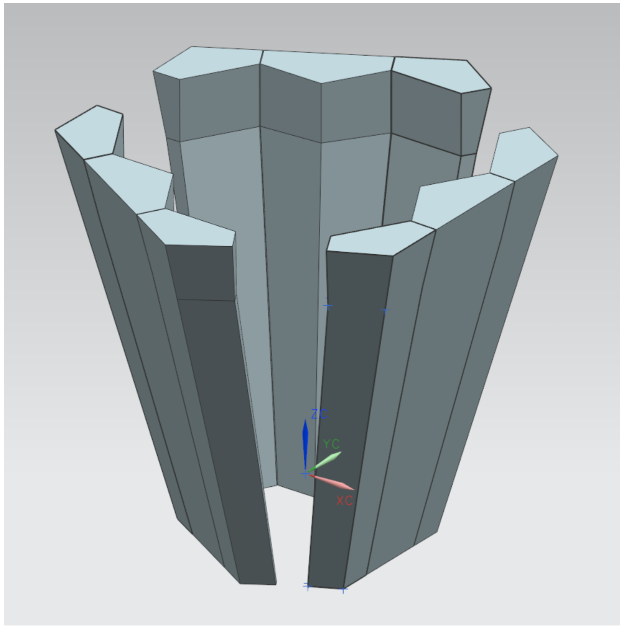


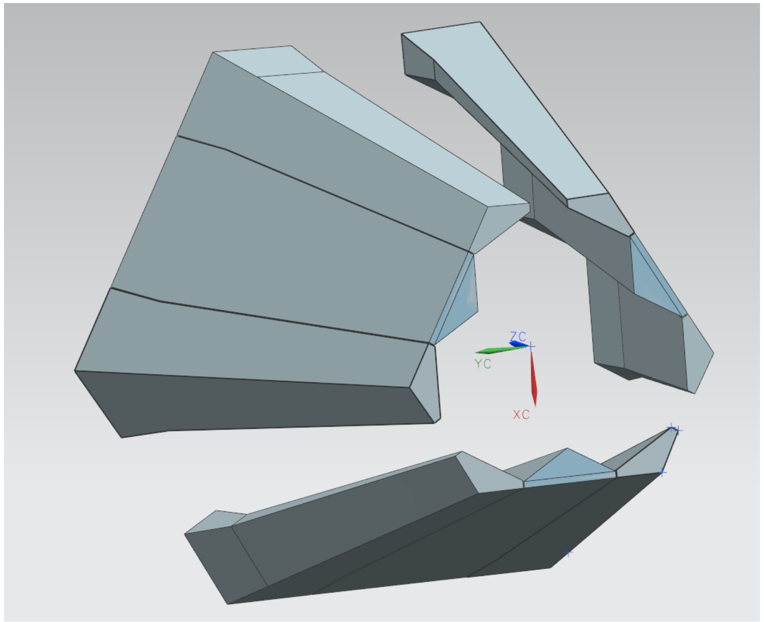




Investigated the possibility to re–use the single BGO crystals from the EUROBAL cluster anti–Compton shields

Anti–Compton shield for GALILEO

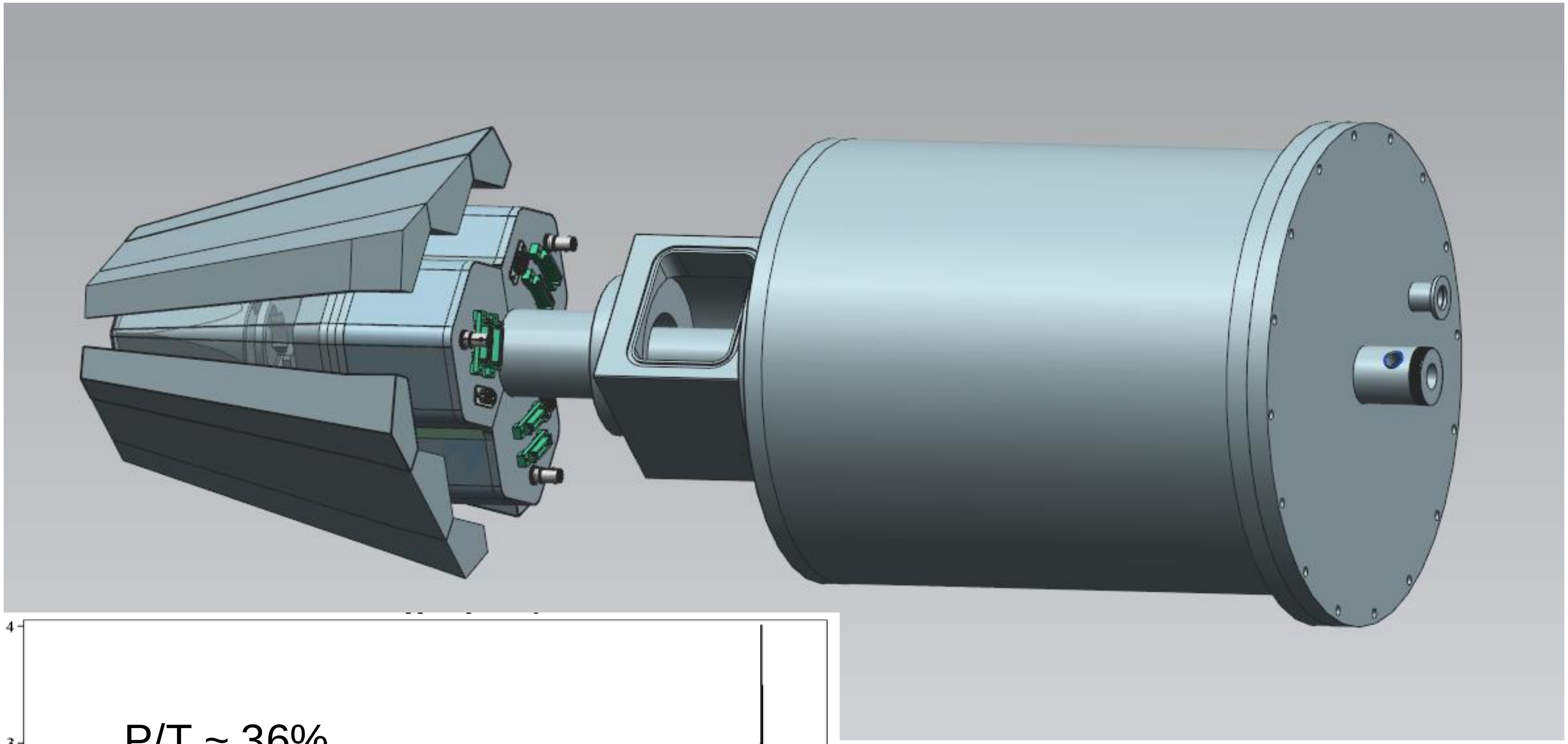


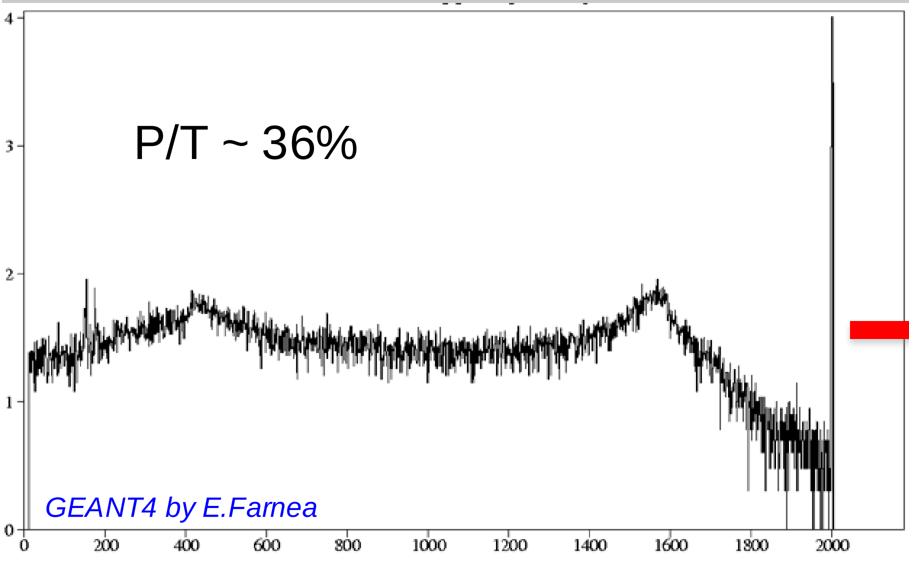


- Construction of the triple cluster AC shield out of the individual crystals of the original EB cluster shield
  → <u>one can build only one new shield from the original one</u>

- safely dismounting the crystals and phototubes
  → manufacturing by external company

Assembled triple cluster detector

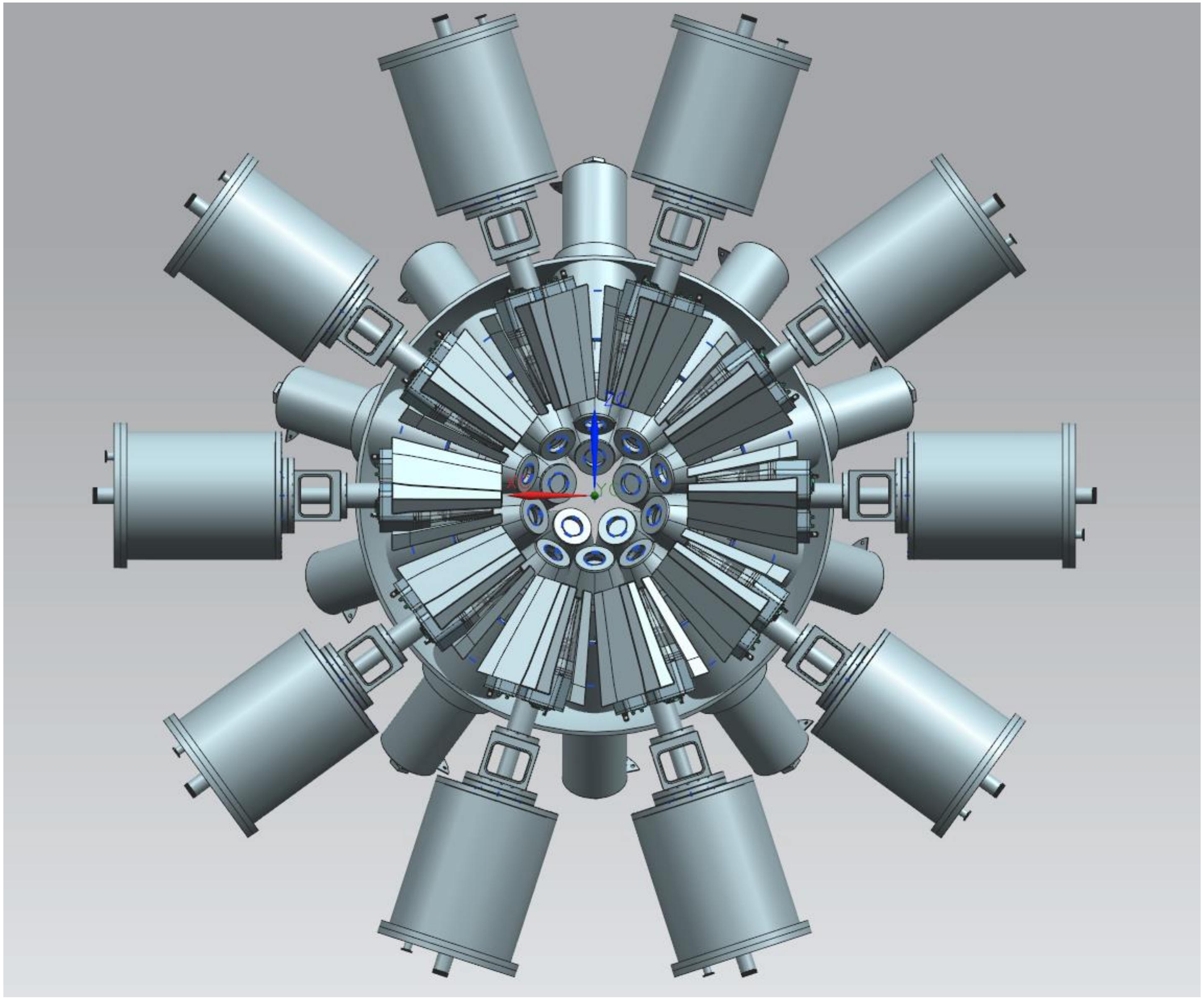




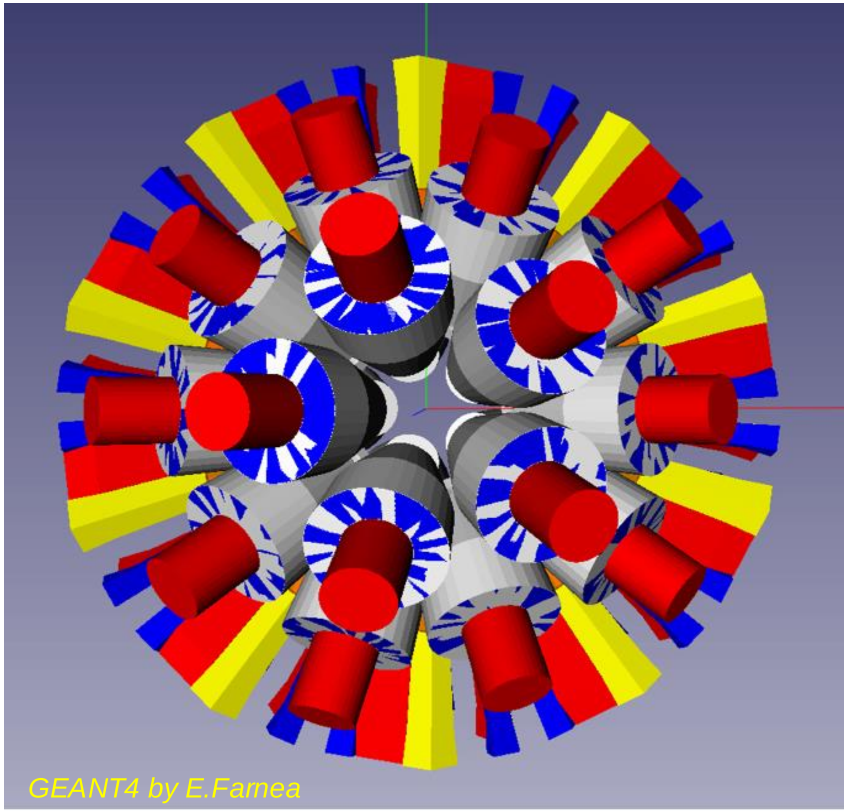
Need of shared suppression among neighboring detectors to improve P/T

Mounting of the triple clusters

FIRST OPTION: in a 90° ring



GALILEO – GEANT4 Simulation



Mixed configuration

30 GASP detectors @ 22.5cm

5	5	5	5	5	5
29°	51°	59°	121°	129°	151°

10 triple cluster @ 24cm

90°

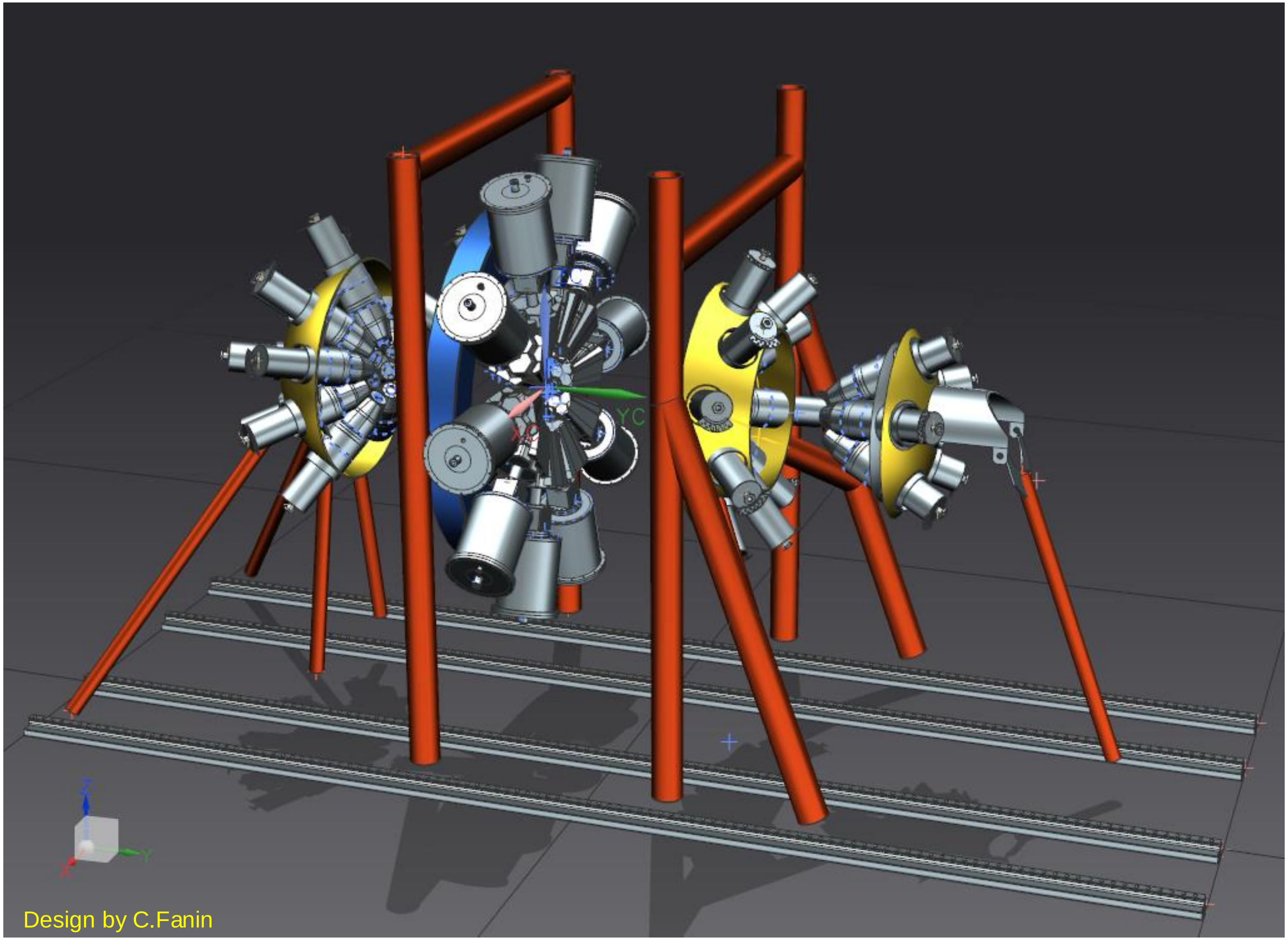
Definition of the new triple cluster detectors

- symmetrical coverage of the solid angle (ang. distr., DSAM)
- good granularity
- at 90° detectors have relatively lower solid angle aperture
- anti–Compton shields
  - for GASP detectors already available
  - for the triple clusters new AC shields
- Limited impact on the array performance when dismounting the first ring of detectors to allow insertion of ancillary detectors

ε_{ph} ~ 8%   P/T ~ 50%

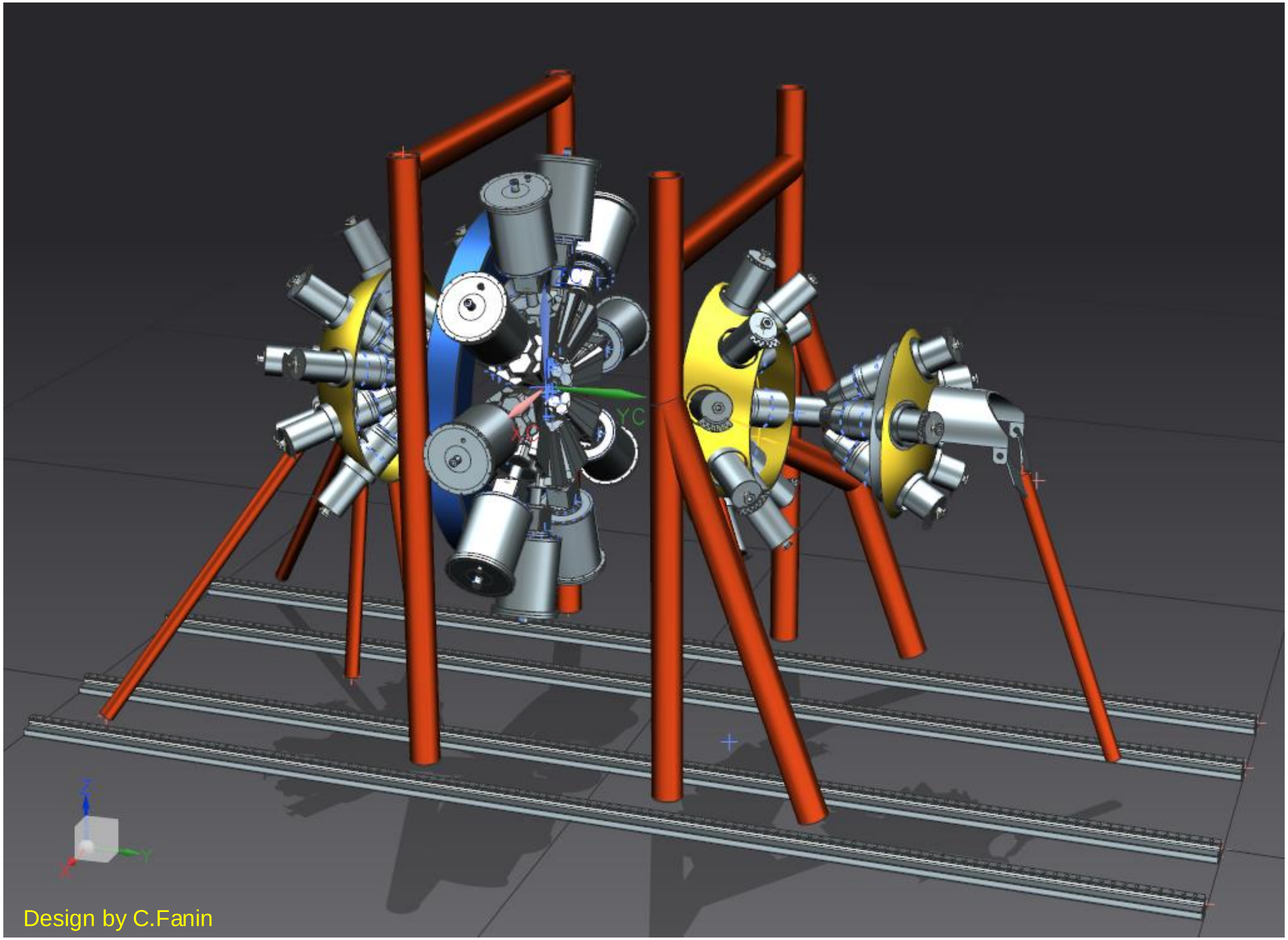
Holding structure of the array

FIRST OPTION: TRIPLE CLUSTER in a 90° ring



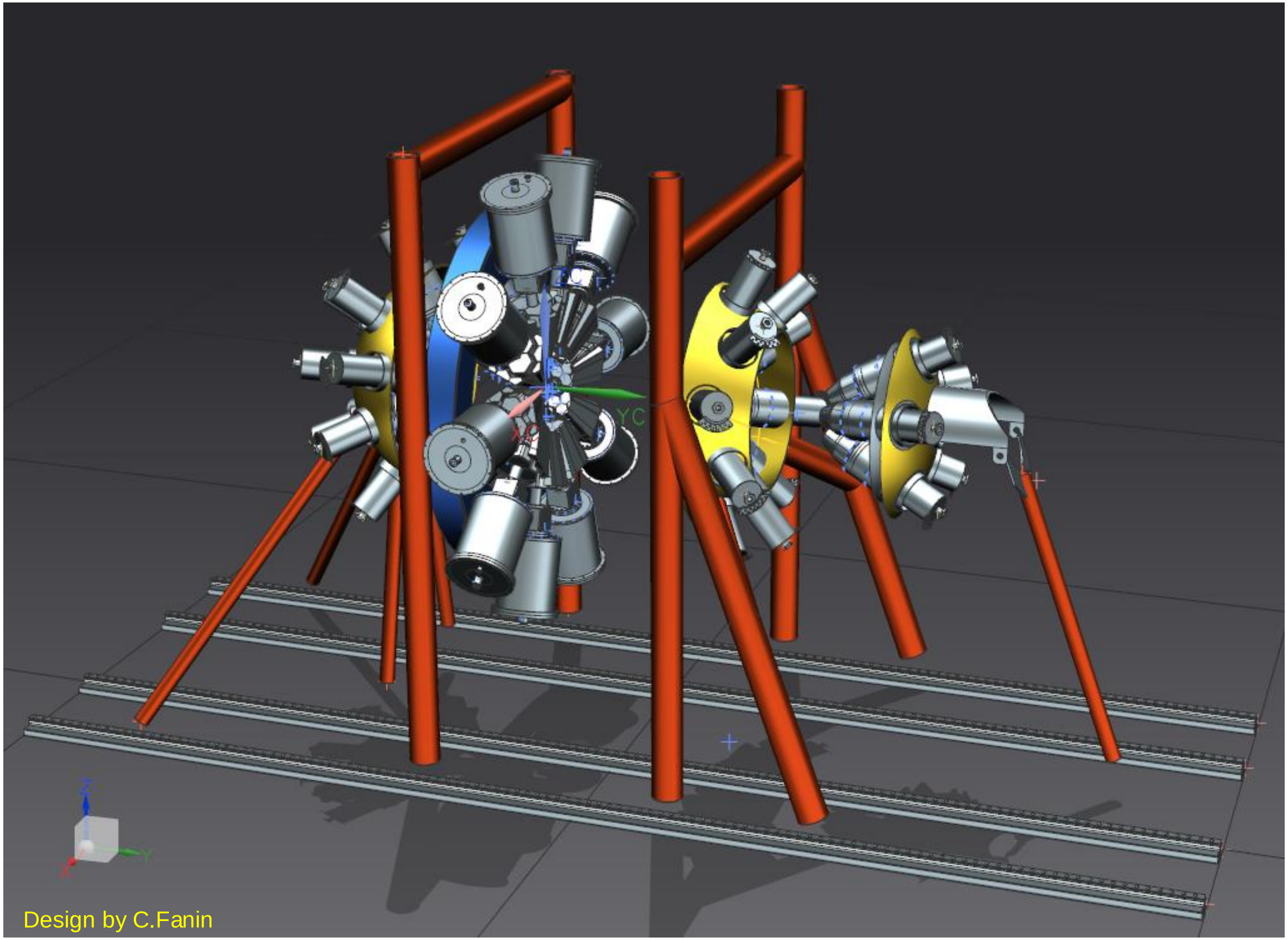
Holding structure of the array

FIRST OPTION: TRIPLE CLUSTER in a 90˚ ring



Holding structure of the array

FIRST OPTION: TRIPLE CLUSTER in a 90° ring



Holding structure of the array

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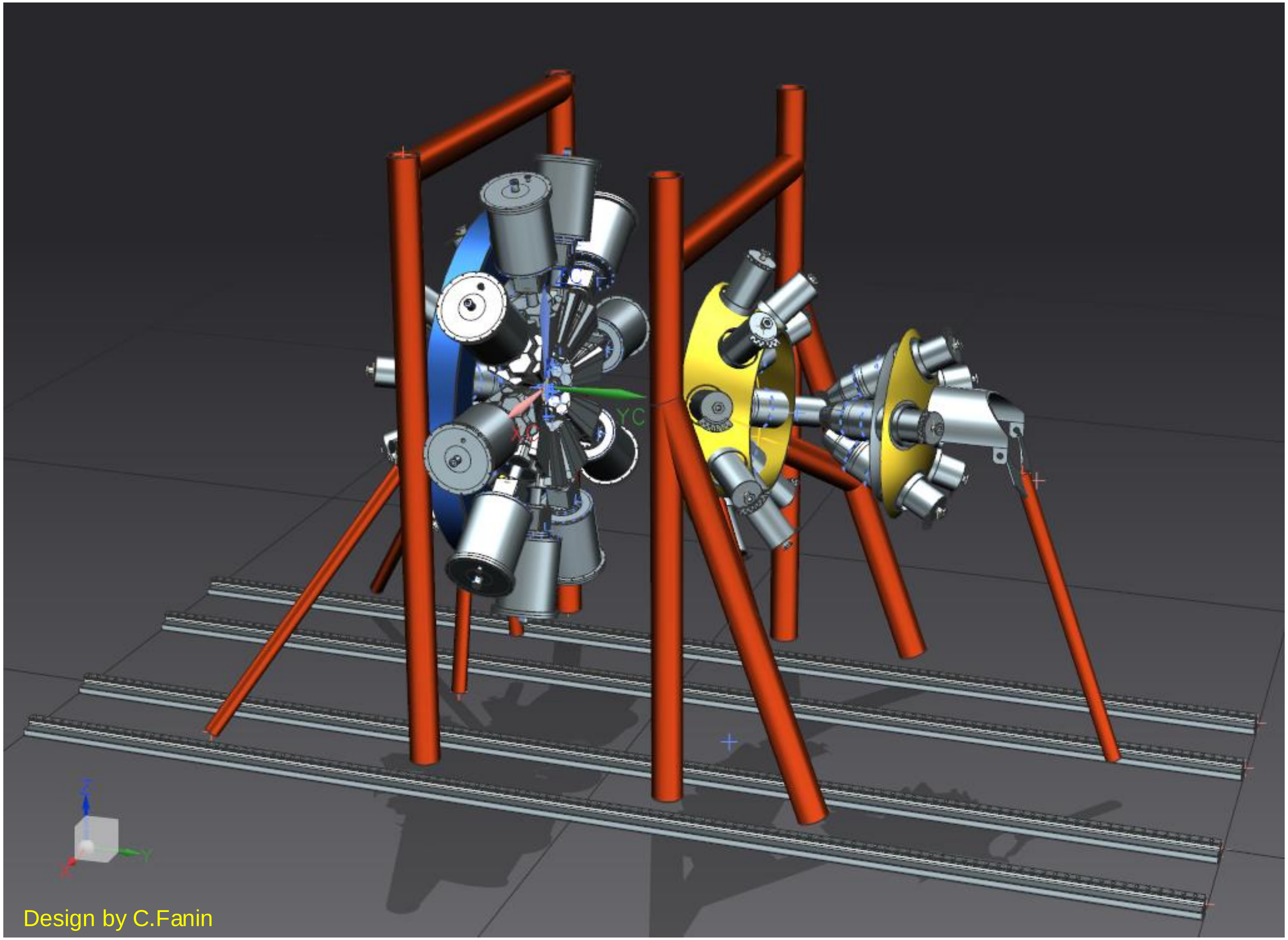

Holding structure of the array

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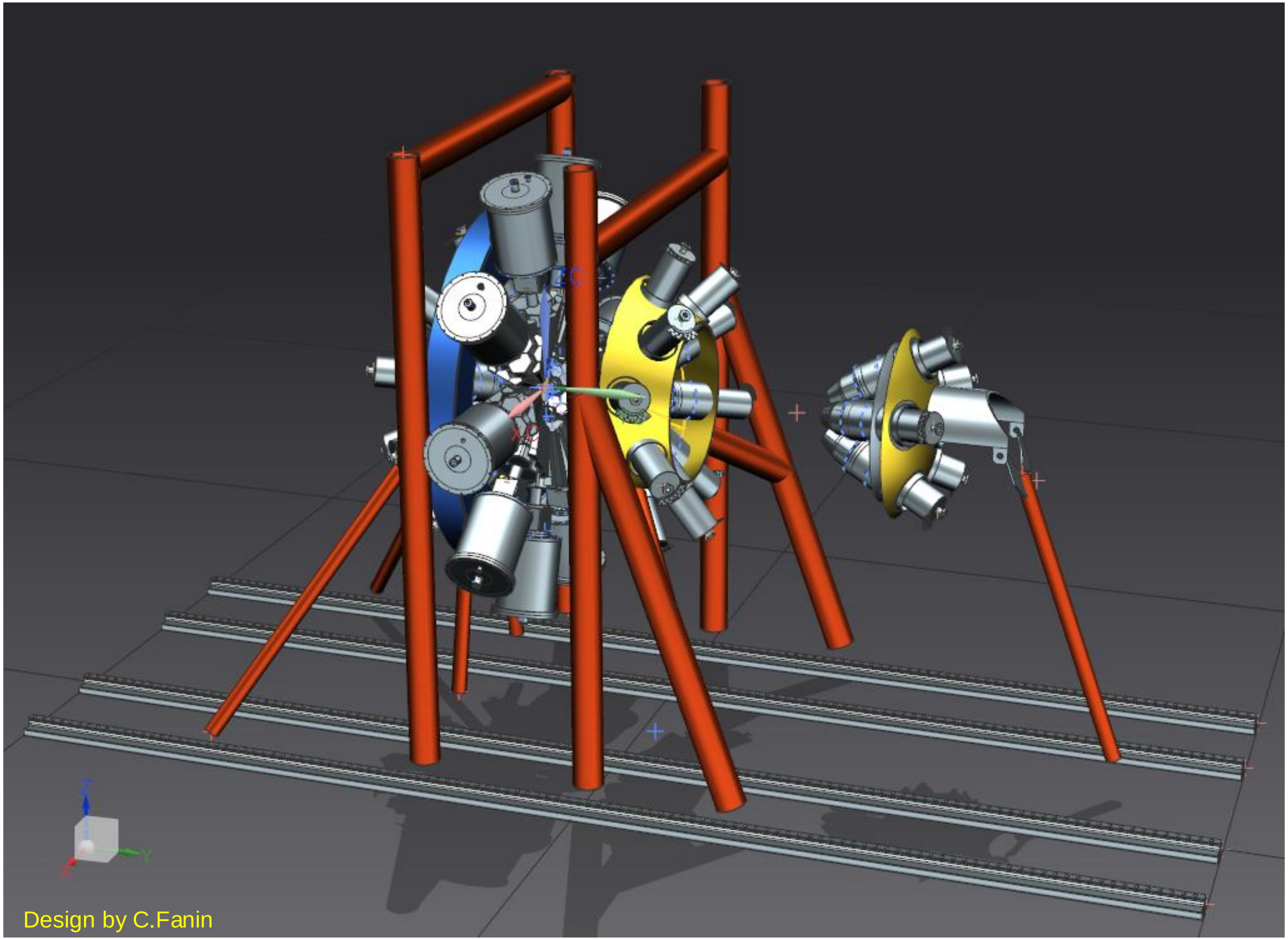
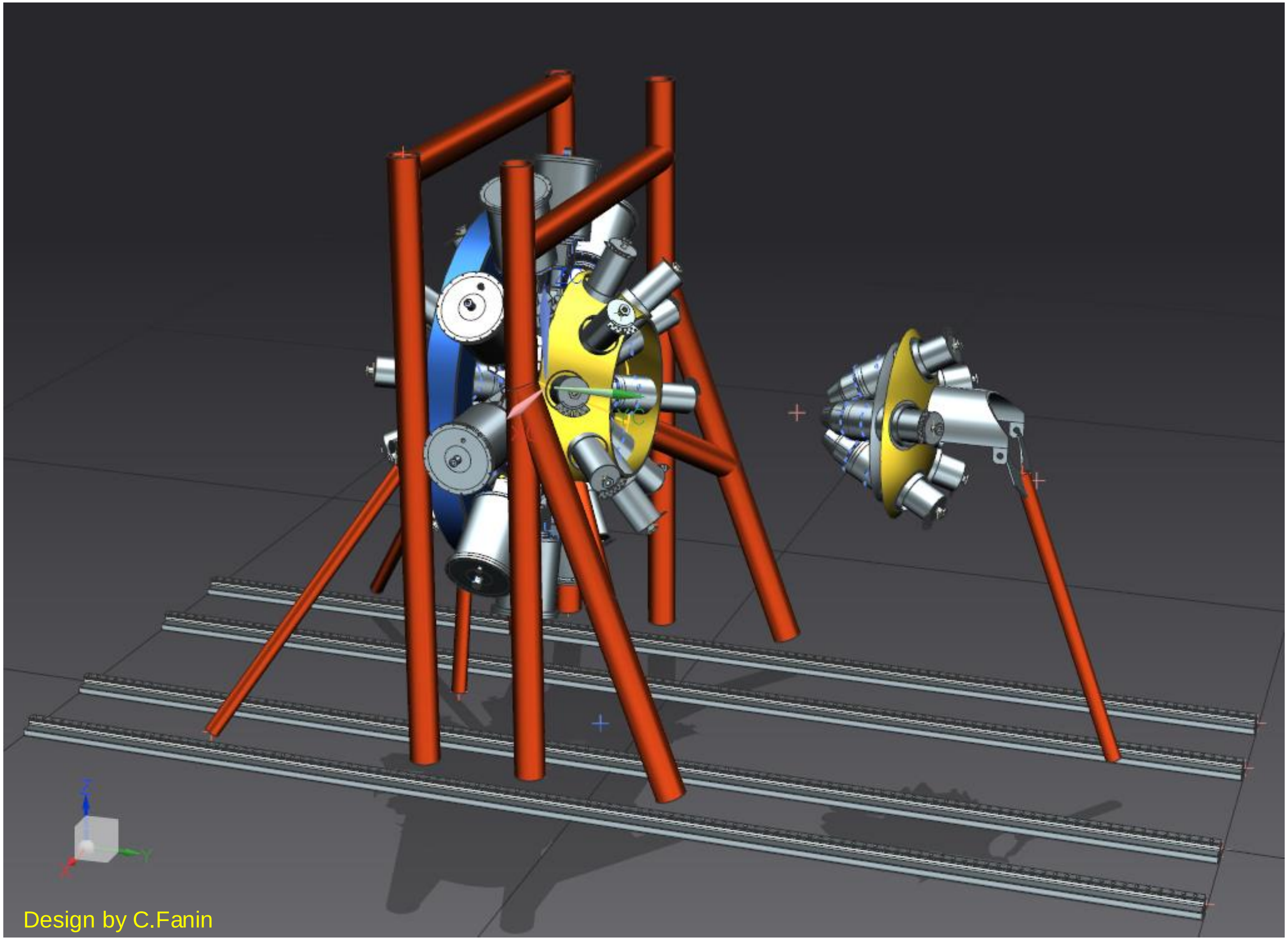


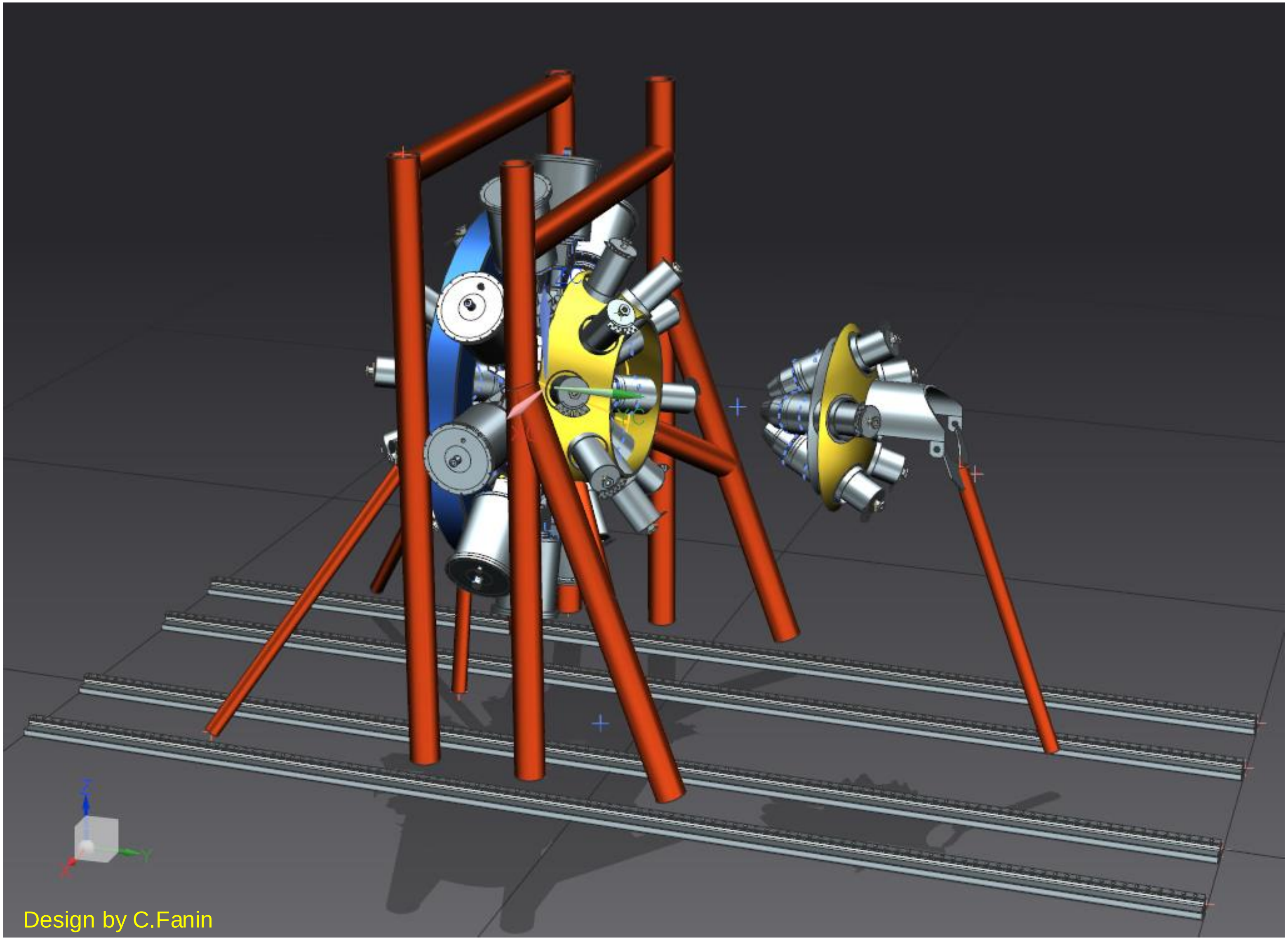
Holding structure of the array

FIRST OPTION: TRIPLE CLUSTER in a 90° ring



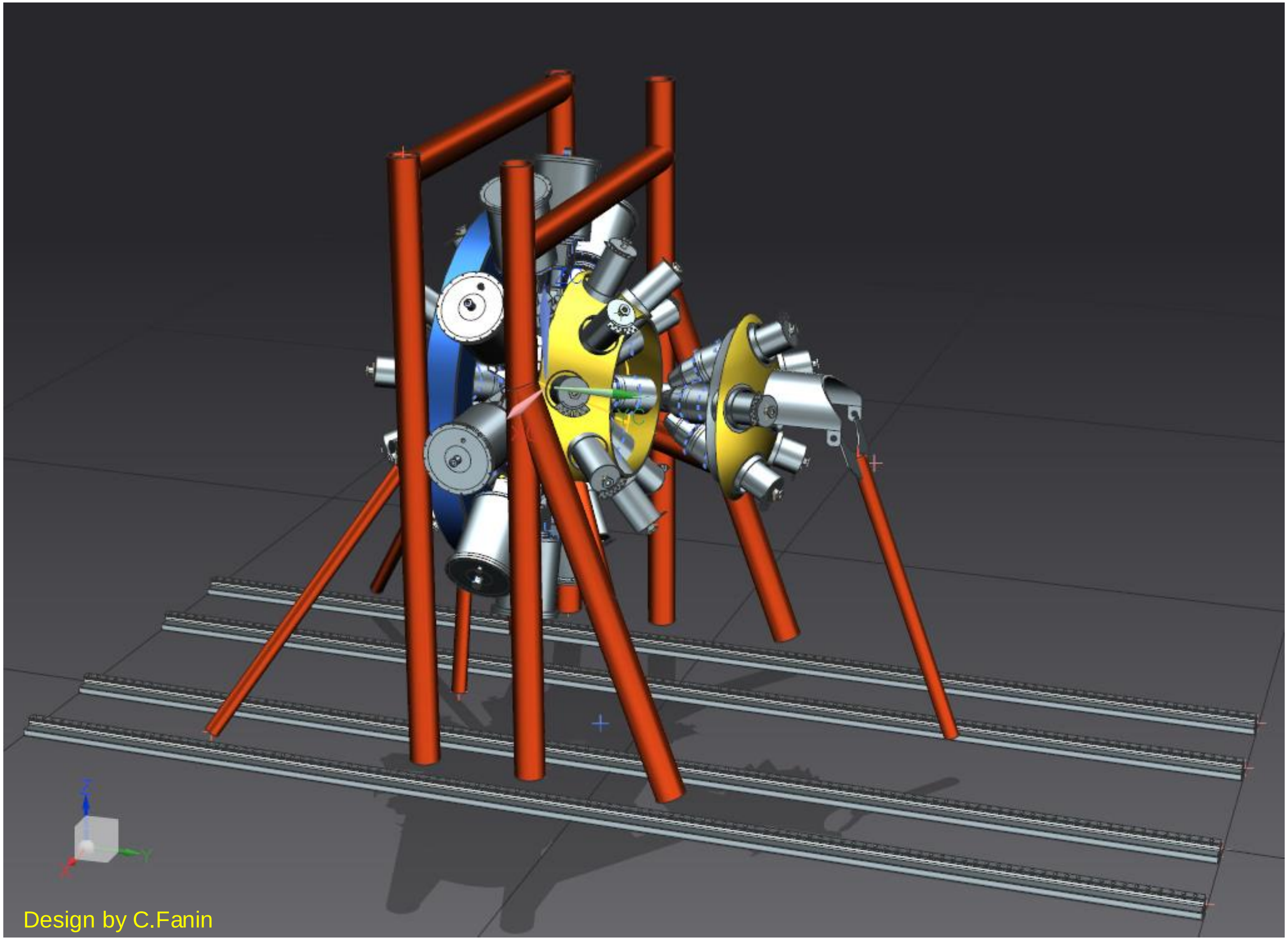
Holding structure of the array

FIRST OPTION: TRIPLE CLUSTER in a 90° ring



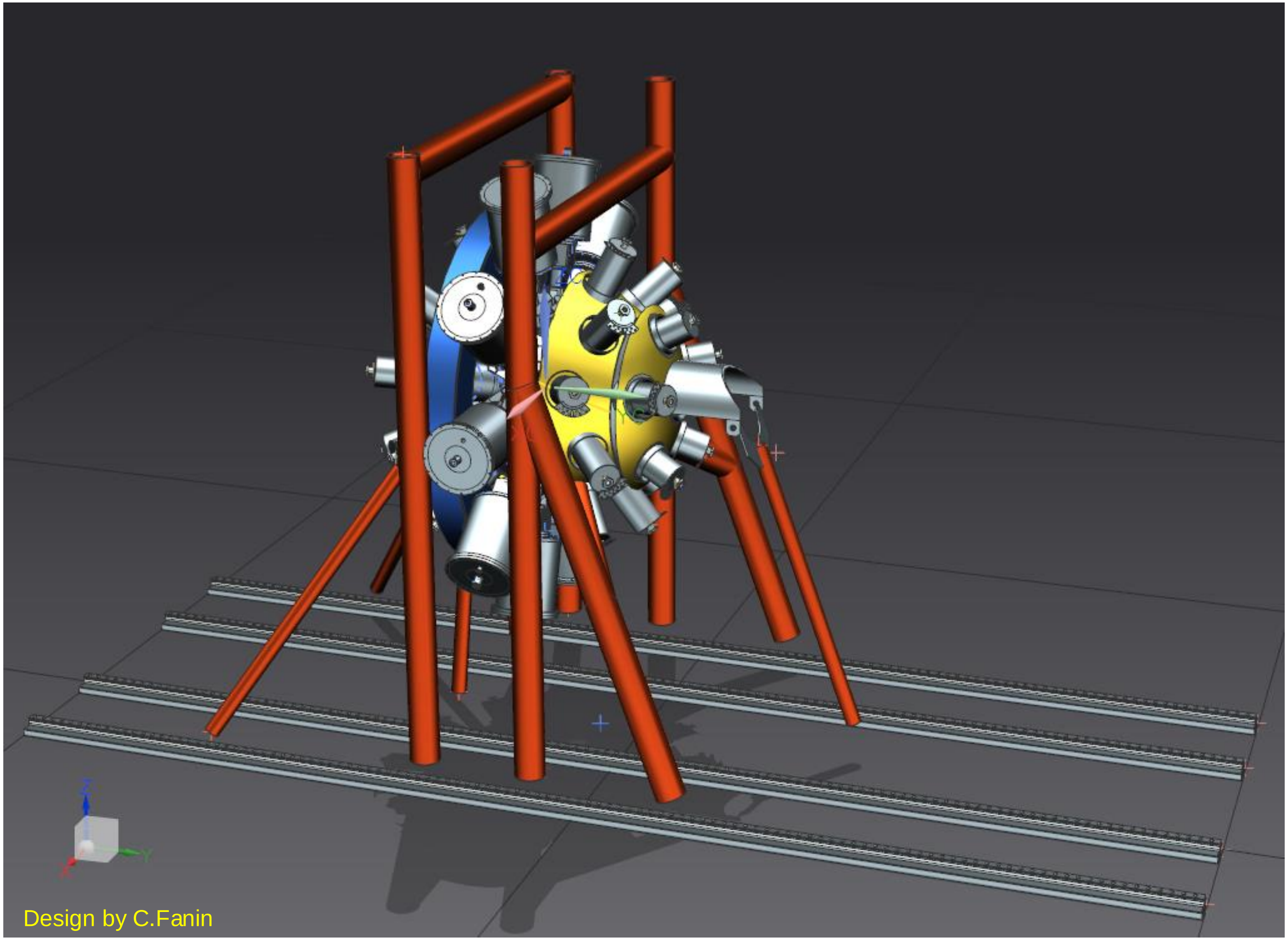
Holding structure of the array

FIRST OPTION: TRIPLE CLUSTER in a 90° ring



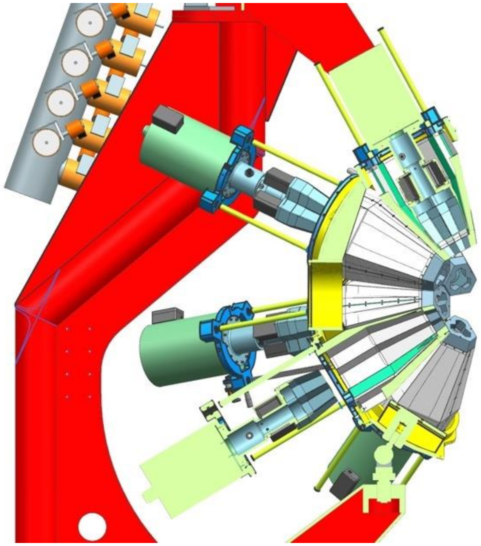
Holding structure of the array

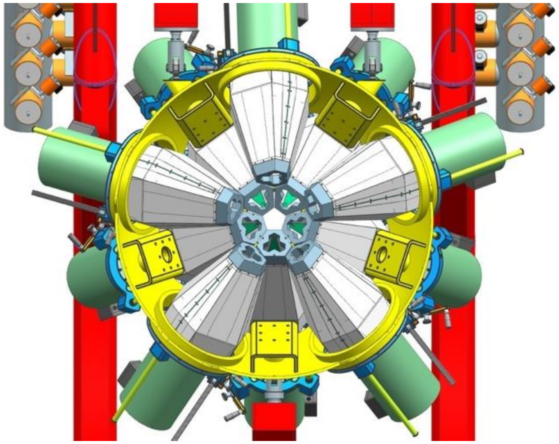
FIRST OPTION: TRIPLE CLUSTER in a 90° ring

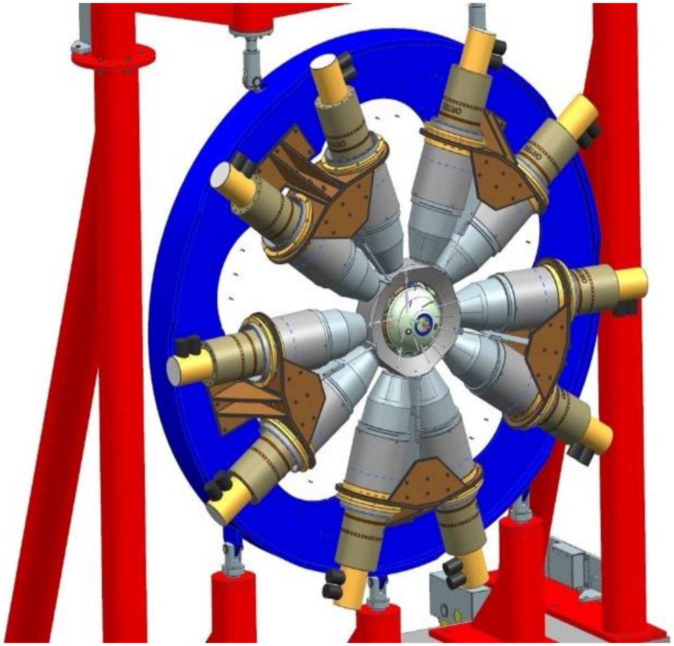


Present GALILEO Configuration

GASP at 90°　, GALILEO TRIPLE Cluster Backward

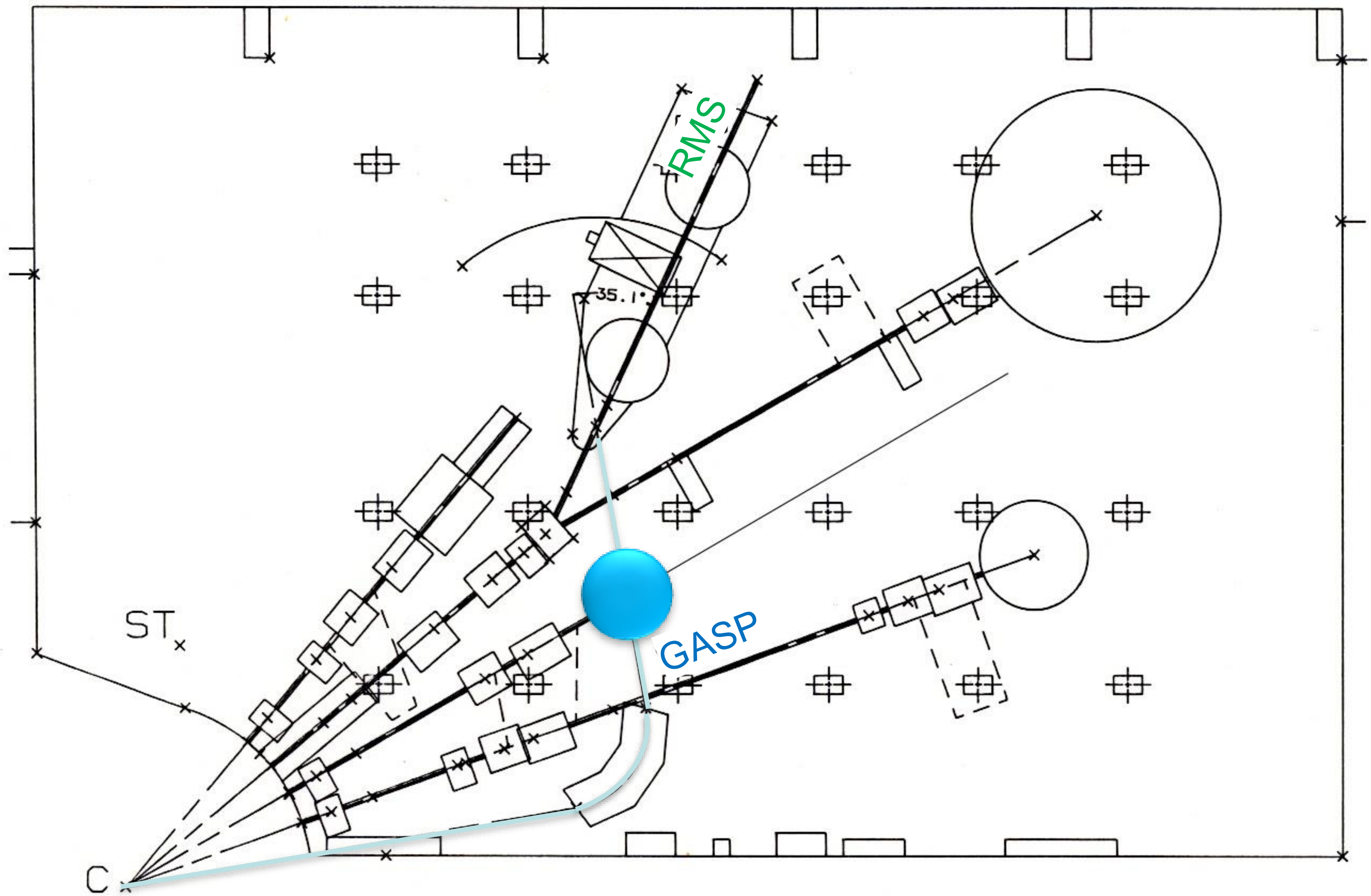






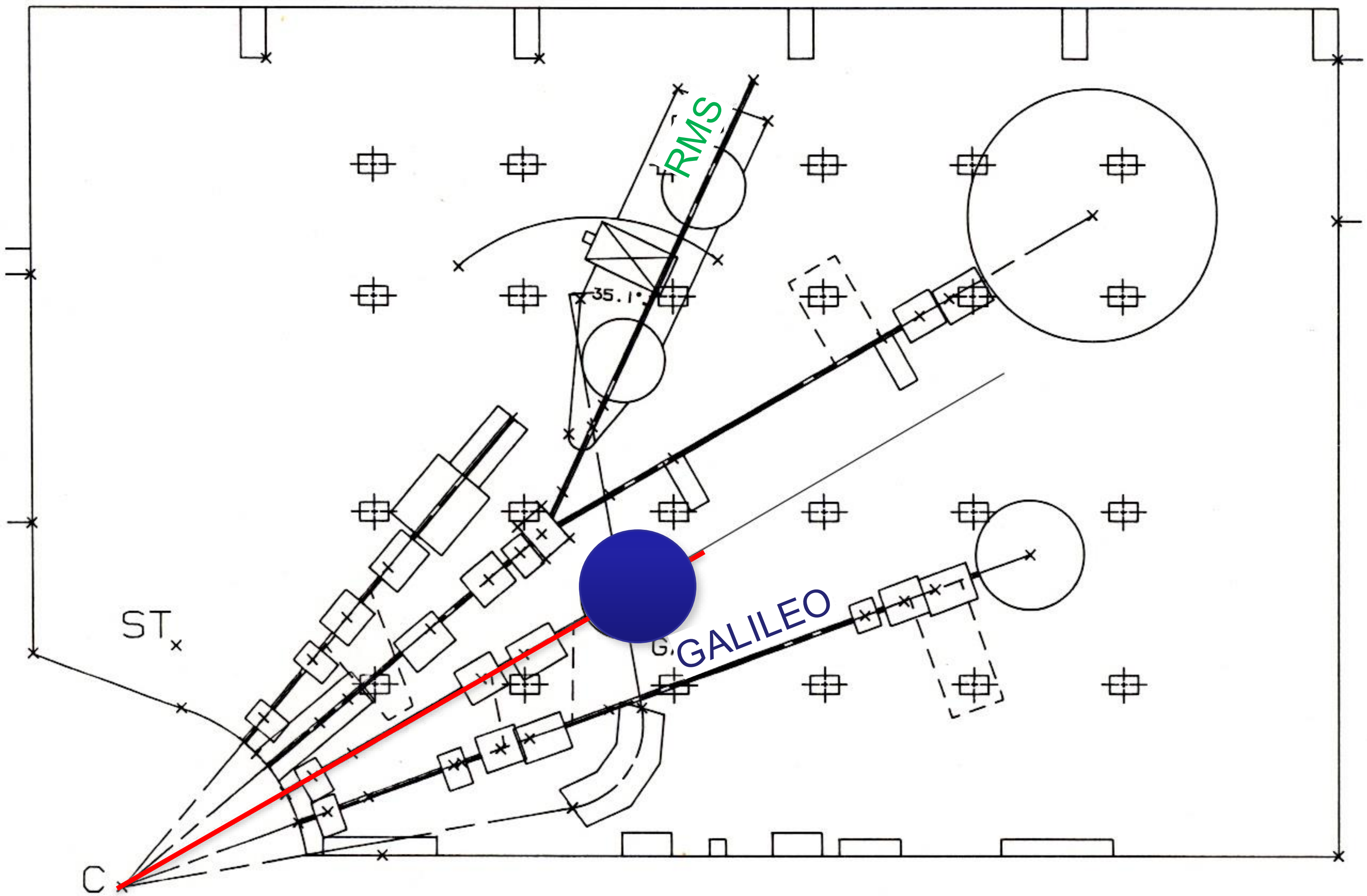
FIRST Campaign
with GALILEO TRIPLE CLUSTER
in Spring 2021

GALILEO – location at LNL



Experimental Hall II – replacing GASP

GALILEO – location at LNL



Experimental Hall II – replacing GASP

Possibilità di tesi Strumentali su Ge detectors in collegamento a progetto AGATA e ancillari

- Magistrali
- Triennali

rivolgersi a Silvia Leoni