The AGATA spectrometer

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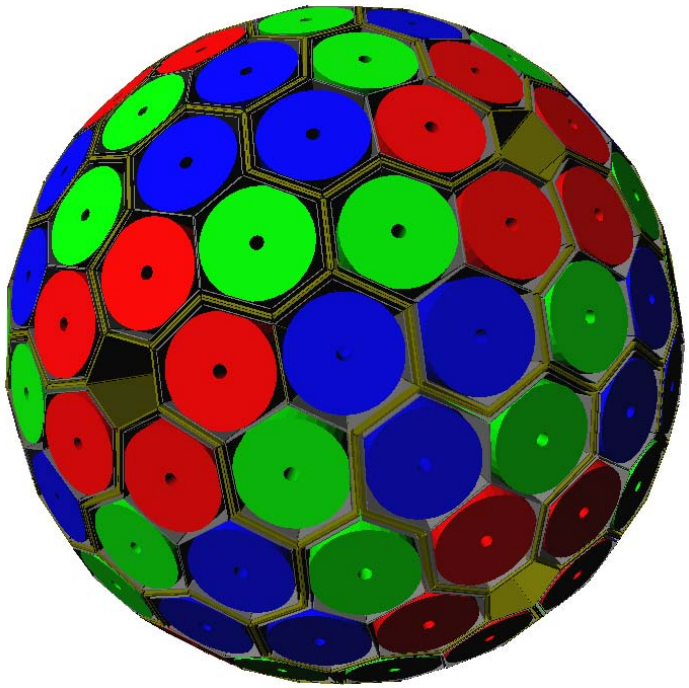
Nuclear Physics Group
Daresbury Laboratory

ECT* Gamma-Ray Spectroscopy in Europe, Present and Future Challenges 8-12th May 2006

AGATA

(Advanced GAmma Tracking Array)

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



Main features of AGATA

Efficiency: 43% (M_γ=1) 28% (M_γ=30)

today's arrays ~10% (gain ~4) 5% (gain ~1000)

Peak/Total: 58% (M_γ=1) 49% (M_γ=30)

today ~55% 40%

Angular Resolution: ~1° →

FWHM (1 MeV, v/c=50%) ~ 6 keV !!!

today ~40 keV

Rates: 3 MHz (M_γ=1) 300 kHz (M_γ=30)

today 1 MHz 20 kHz

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

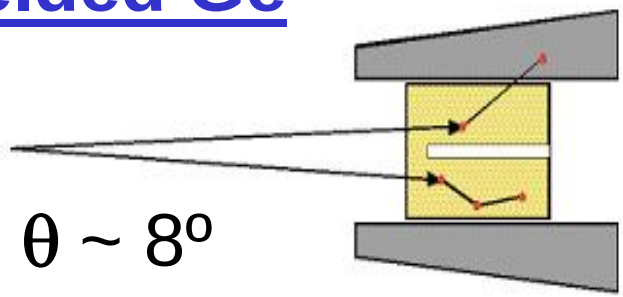
Idea of γ-ray tracking

Compton Shielded Ge

ε_{ph} ~ 10%

N_{det} ~ 100

Ω ~40%



θ ~ 8º

large opening angle means poor energy resolution at high recoil velocity.

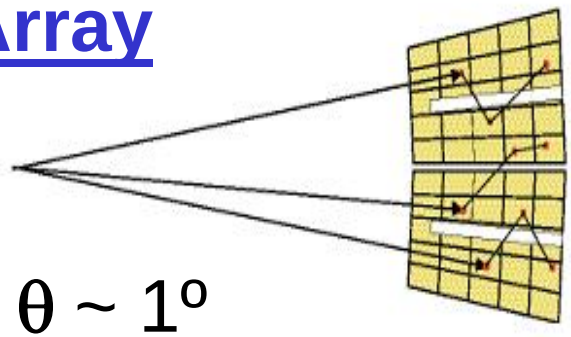
Previously we had to waste scattered gammas.
Technology is available now to track them..

Ge Tracking Array

ε_{ph} ~ 50%

N_{det} ~ 100

Ω ~80%



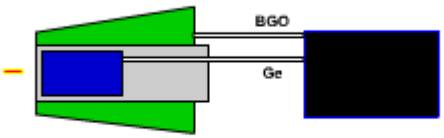
θ ~ 1º

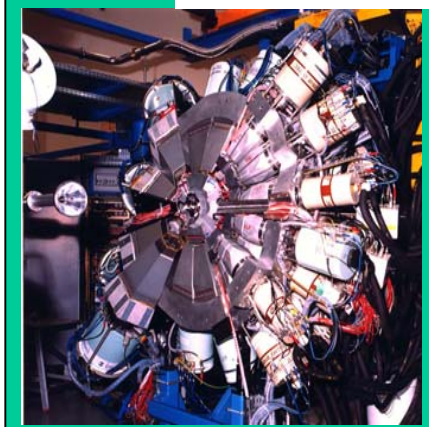
Combination of:

- segmented detectors
- digital electronics
- pulse processing
- tracking the γ-rays

Idea of γ-ray tracking

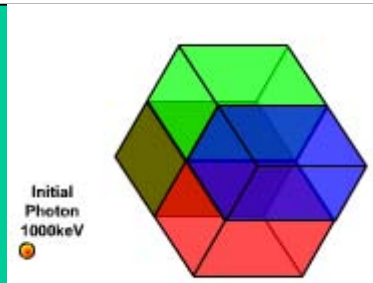
Large Gamma Arrays based on Compton Suppressed Spectrometers

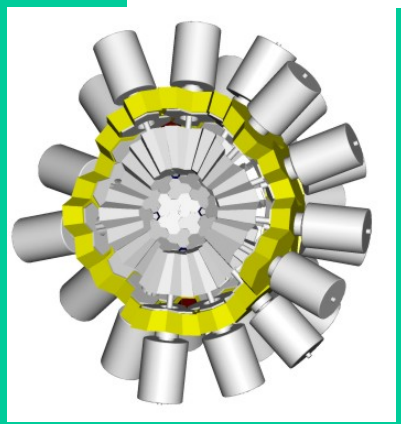


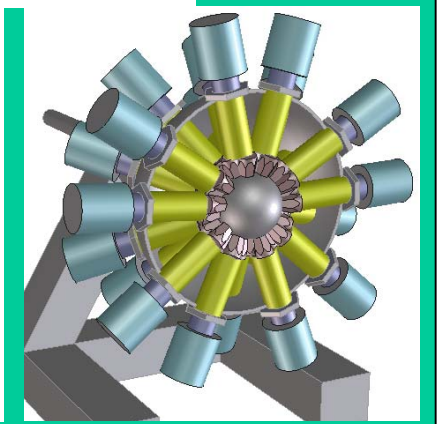


EUROBALL GAMMASPHERE

Tracking Arrays based on Position Sensitive Ge Detectors







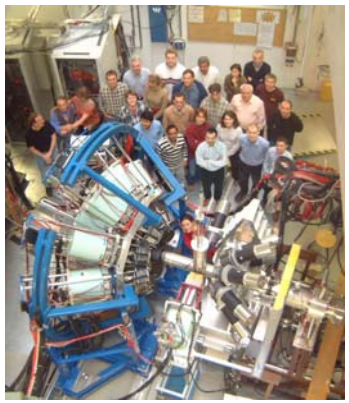
AGATA GRETA

ε ~ 10 — 5 %
(M_γ=1 — M_γ=30)

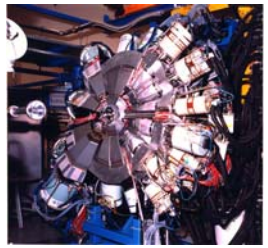
ε ~ 40 — 20 %
(M_γ=1 — M_γ=30)

Exogam, Miniball, SeGa: optimized for Doppler correction at low γ-multiplicitiy → ε up to 20%

Future Developments in Spectroscopy Instrumentation in Europe

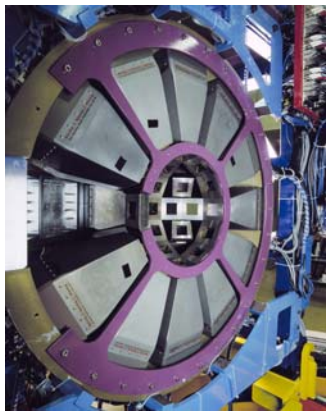


RISING, GSI



Euroball

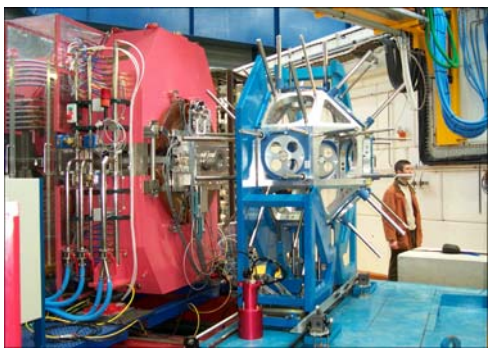
JUROGAM, GREAT, JYFL



CLARA, LNL

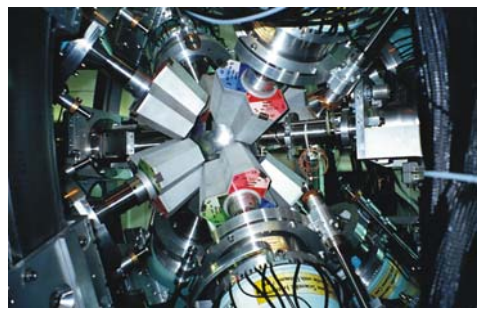
Radioactive beam spectroscopy

EXOGAM, SPIRAL, Ganil

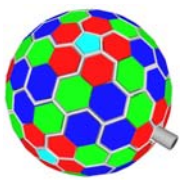


Segmentation
Encapsulation
Position
determination from
pulse shape analysis

MINIBALL, RexIsolde



•Gamma-ray tracking
TMR EU collaboration
AGATA



Tracking requires:

Good position determination from
Digital pulse processing

Previous/current projects:

EU Vth Framework TMR `Development of γ-ray tracking detectors' (6 EU countries)

Miniball and Exogam (European collaborations)

Mars, Italy

UK Instrumentation grant 'Digital Pulse Processing and γ-ray tracking' (Liverpool, Surrey, Daresbury)

GRETA, USA

Proved that position resolution can be achieved, tracking algorithms developed,
Highly segmented detectors developed

Next step

Build a sub array of few highly segmented detectors, prove tracking in real situations
Scale up to full array, fund full array

AGATA Europe 12 countries, 46 laboratories Research and Development Phase

Funding approved in France, Germany, Italy, UK, Sweden and turkey.

GRETA U.S.A. Funded for development modules GRETINA U.S.A. Funded for 30 crystals

The AGATA Collaboration

MoU 2003 Research and Development

Bulgaria:	Sofia
Denmark:	Copenhagen
Finland:	Jyväskylä
France:	GANIL, Lyon, Orsay, Saclay, Strasbourg
Germany:	Berlin, Bonn, GSI, Darmstadt, Jülich, Köln, München
Hungary:	Debrecen
Italy:	Padova, Milano, LNL, Firenze, Camerino, Napoli, Genova
Poland:	Krakow, Swierk, Warsaw
Romania:	Bucharest
Sweden:	Lund, Stockholm, Uppsala
Turkey:	Ankara, Istanbul
UK:	Daresbury, Brighton, Liverpool, Manchester, Paisley, Surrey, York

AGATA Organisation

AGATA Steering Committee

Chairperson J.Gerl, Vice Chairperson, W.Korten (and EURONS)

G.deAngelis, A.Atac, F. Azaiez, D.Balabanski, D.Bucurescu, B.Cederwall, 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, J.Eberth, A.Gadea, R.Krücken, J.Nyberg

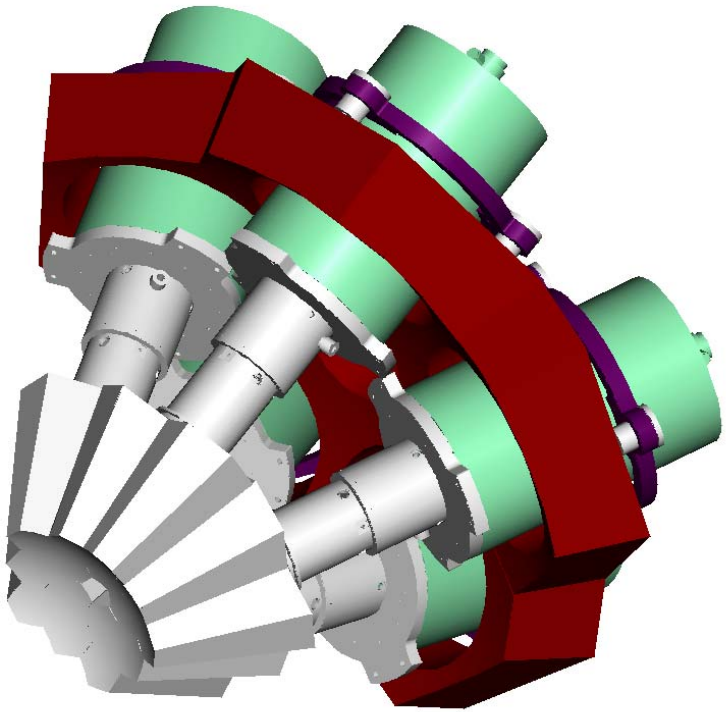
AGATA Working Groups

Detector module J.Eberth	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

AGATA Teams

Detector and Cryostat A. Linnemann	PSA R.Gernhaeuser/ P.Desesquelles	Digitisation P.Medina	Mechanical design K.Fayz/J.Simpson	Elec. and DAQ integration Ch. Theisen	Gamma-ray Tracking A.Lopez-Martens
Preamplifiers A.Pullia	Detector Characterisation A.Boston	Pre-processing I.Lazarus	Infrastructure P.Jones	Devices for key Experiments N.Redon	Physics & expt. simulation E.Farnea
		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 J. Valiente Dobon	Data analysis O.Stezowski
		Run Control & GUI G.Maron			

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

Cost ~ 7 M €

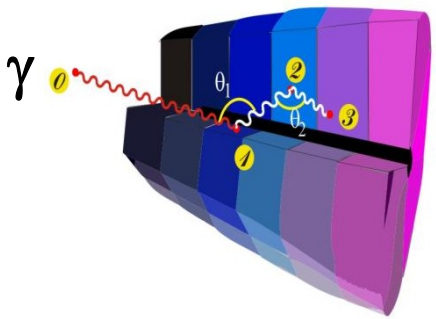
The AGATA
RESEARCH and DEVELOPMENT PHASE

- **Develop 36 fold segmented encapsulated detector of right shape**
- **Develop cryostat for groups "clusters" of these detectors**
- **Develop digital electronics (700 channels)**
- **Finalise signal algorithms for energy, position and time**
- **Develop tracking algorithms**
- **Build demonstration unit to prove tracking in real situations**
- **Write technical proposal for full array**

Ingredients of γ-Tracking

1

Highly segmented HPGe detectors



2

Digital electronics to record and process segment signals

3

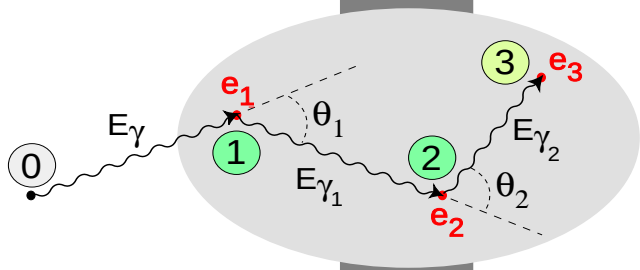
Pulse Shape Analysis to decompose recorded waves

4

Identified interaction

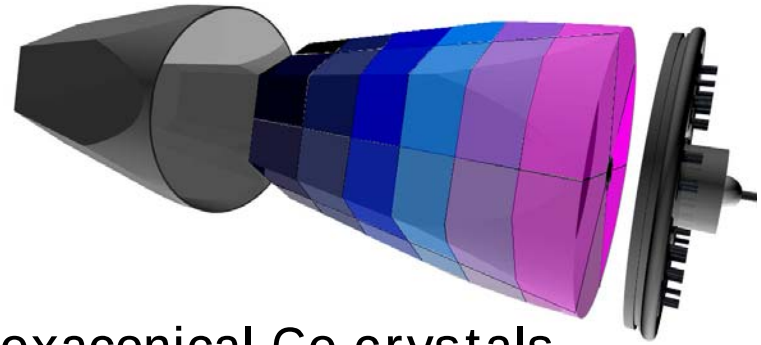
$(x,y,z,E,t)_i$

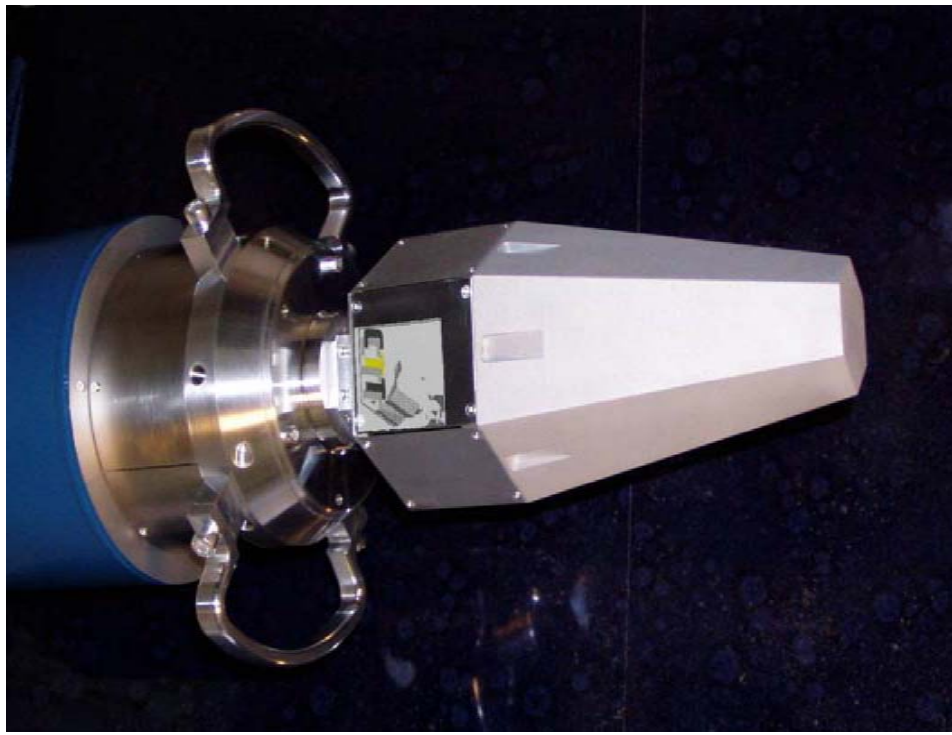
Reconstruction of tracks e.g. by evaluation of permutations of interaction points



reconstructed γ-rays

AGATA Detectors



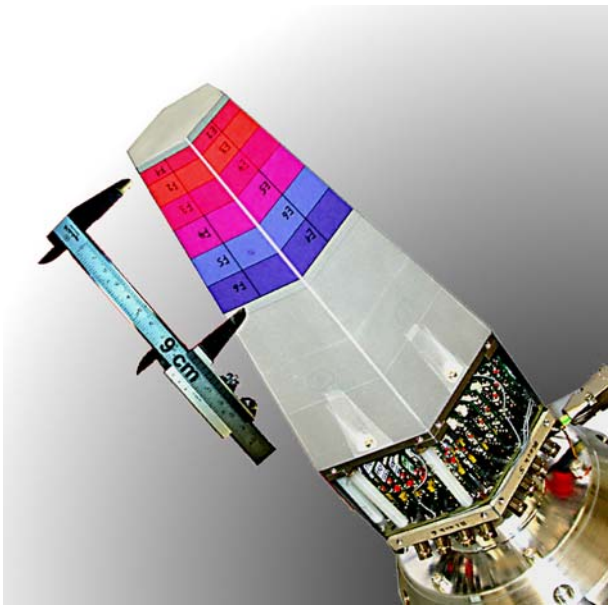


Hexaconical Ge crystals
90 mm long
80 mm max diameter
36 segments
Al encapsulation
    0.6 mm spacing
    0.8 mm thickness
37 vacuum feedthroughs

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

AGATA Prototypes

- Symmetric detectors
  - 3 ordered, Italy, Germany
  - 3 delivered
  - Acceptance tests in Koln
  - work very well



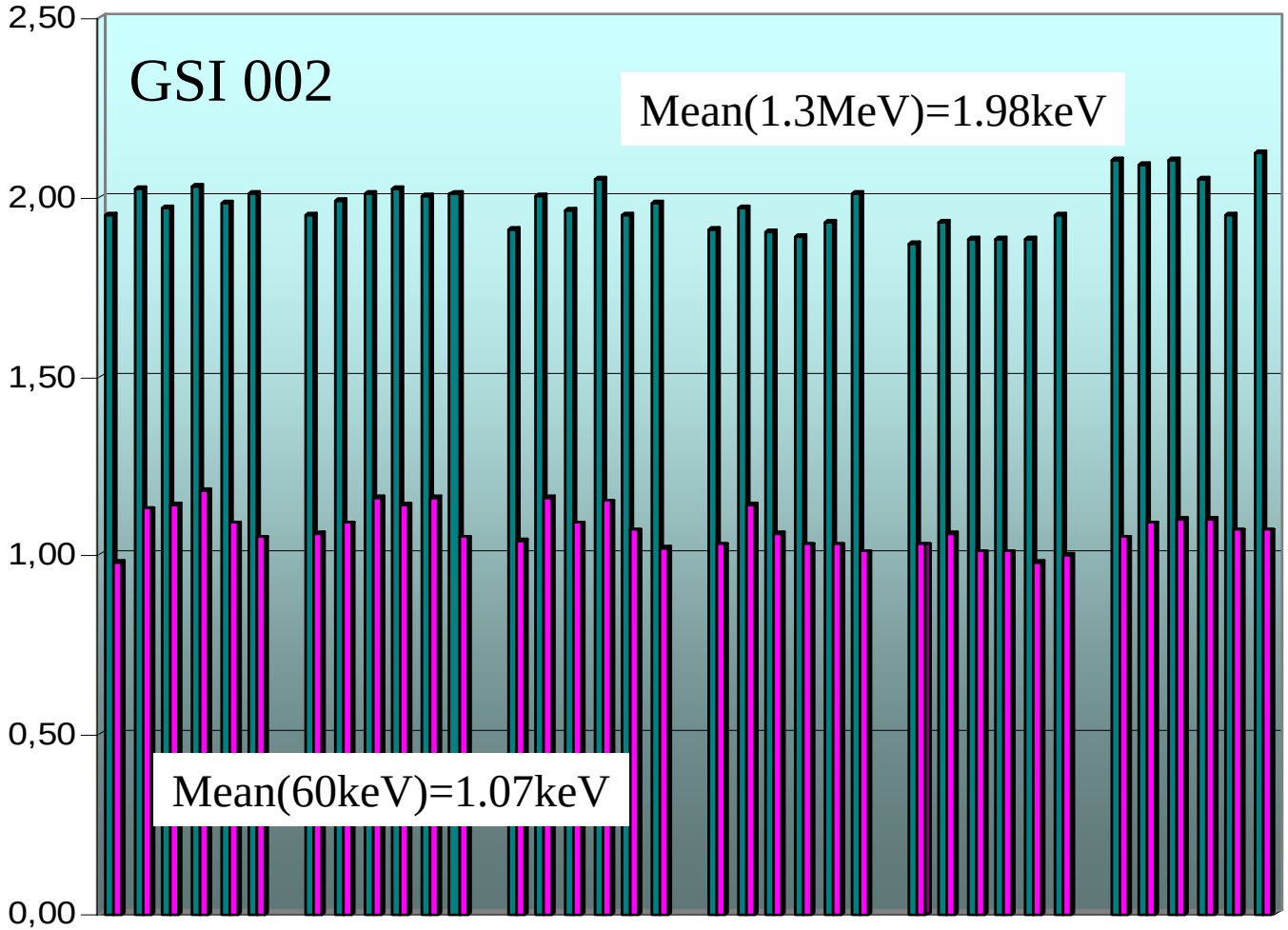
Results very good:

36 outer contacts
0.9-1.1keV at 60keV and 1.9-2.1keV at 1.3MeV

Core
1.2keV at 60keV and 2.1keV at 1.3MeV

Cross talk less than 10^{-3}

Acceptance tests on prototypes



Core FWHM:
at 1.3MeV : 2.08keV
at 122keV : 1.19keV

AGATA Prototypes

Scan of first in Liverpool done

Assembly of triple cryostat (CTT)

Cluster in beam test Cologne

Second Scan in progress at Liverpool

First triple cryostat in Cologne

Asymmetric detectors for the 180 geometry

- 9 ordered in 2004
- 6 to be ordered in 2006
- 4 delivered, 2 specification not reached
- 1 accepted, 1 to be tested

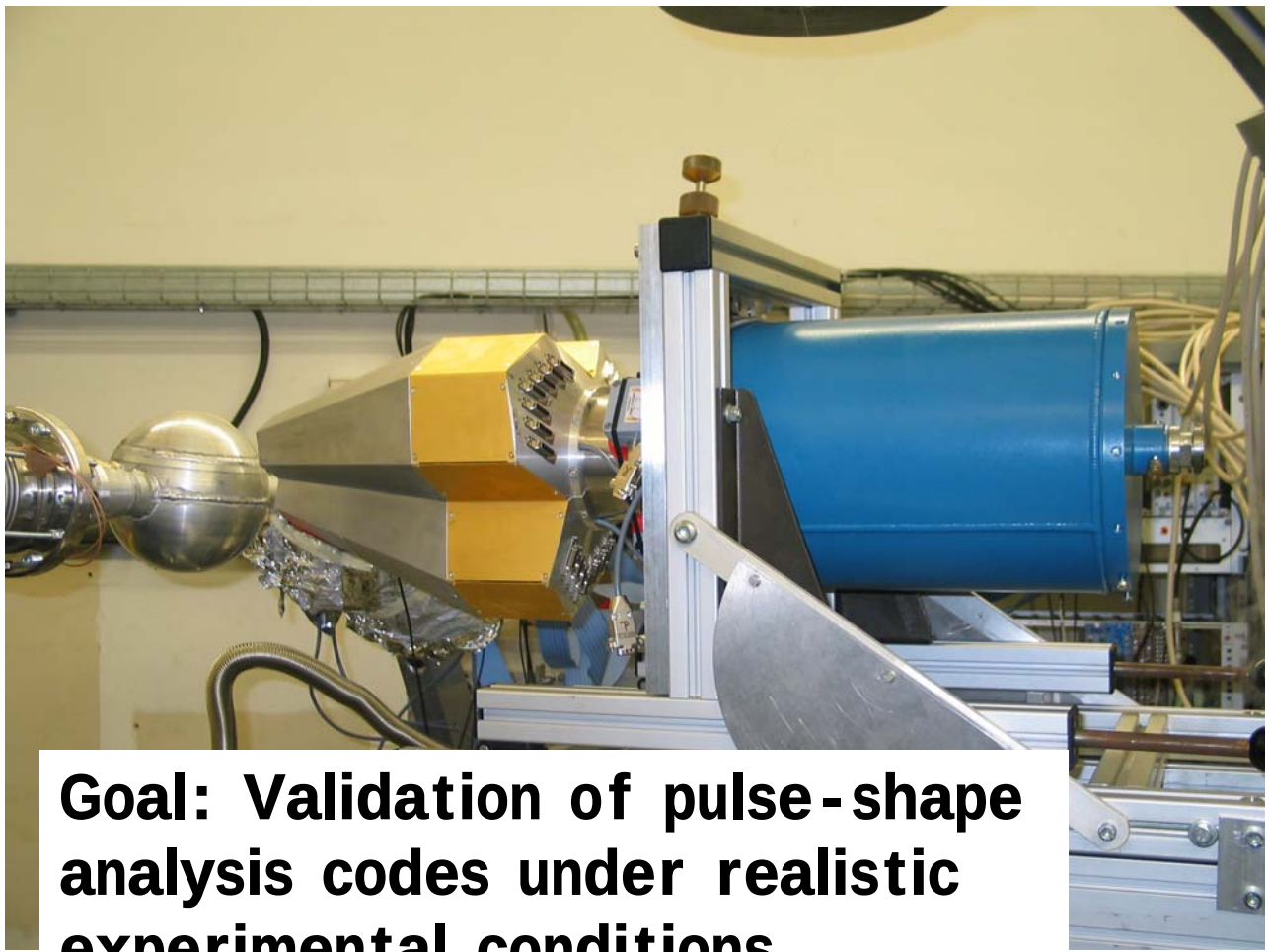
In-beam test

University of Cologne 29th August-11th September 2005

d(^{47}Ti,^{48}Ti)p @ 2.3 MeV

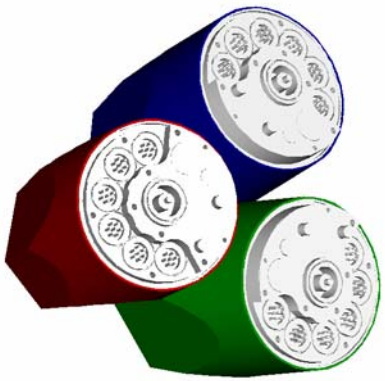
^{48}Ti at 6%

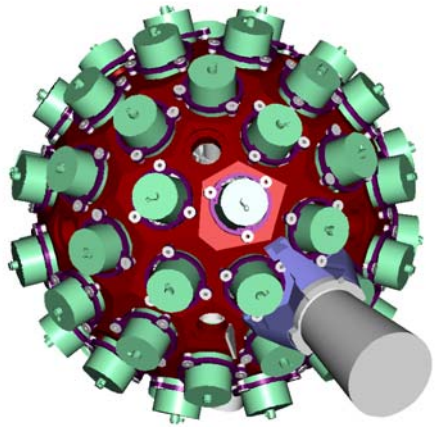
Triple symmetric cluster plus annular Si detector set-up

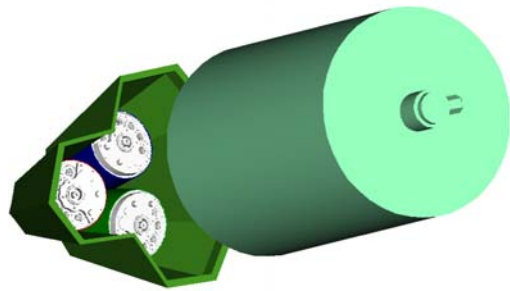


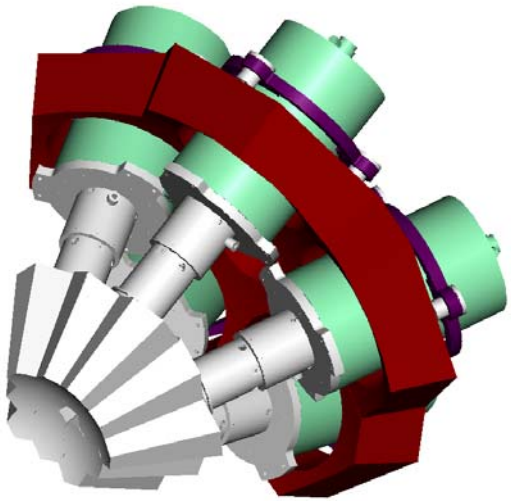
Goal: Validation of pulse-shape analysis codes under realistic experimental conditions

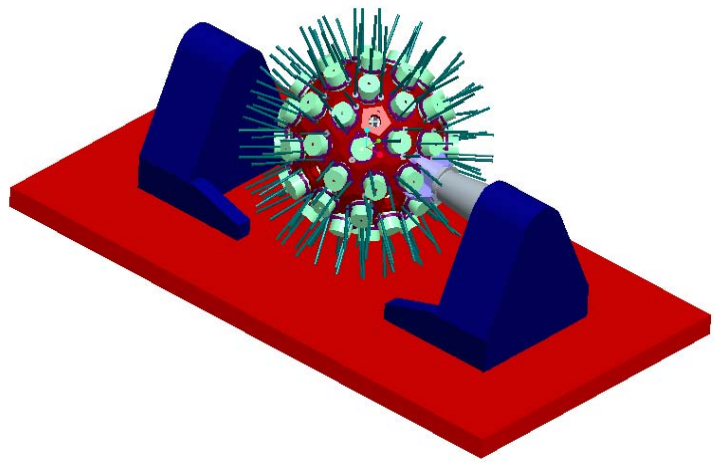
AGATA Design and Construction



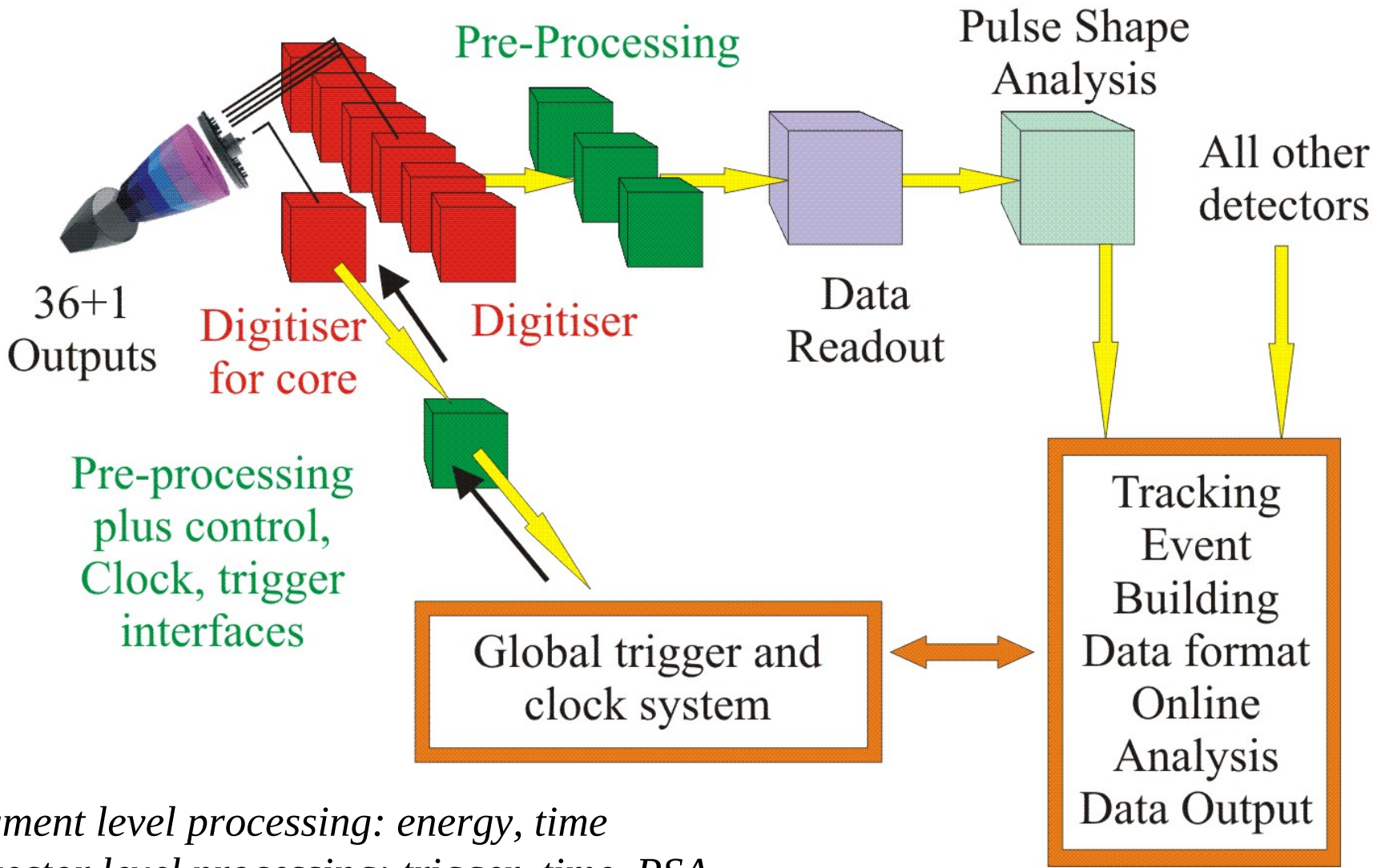






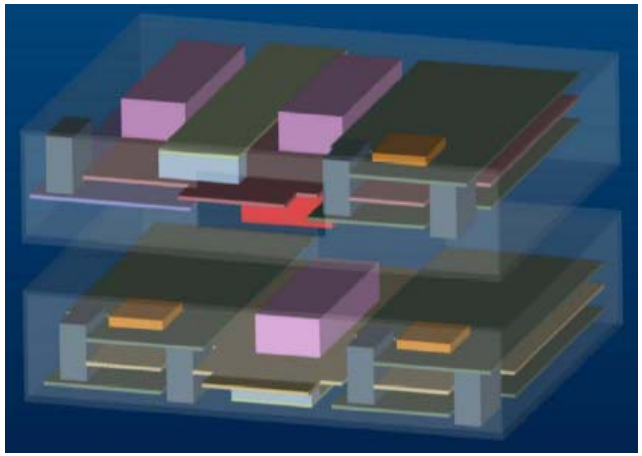


Schematic of the Digital Electronics and Data Acquisition System for AGATA



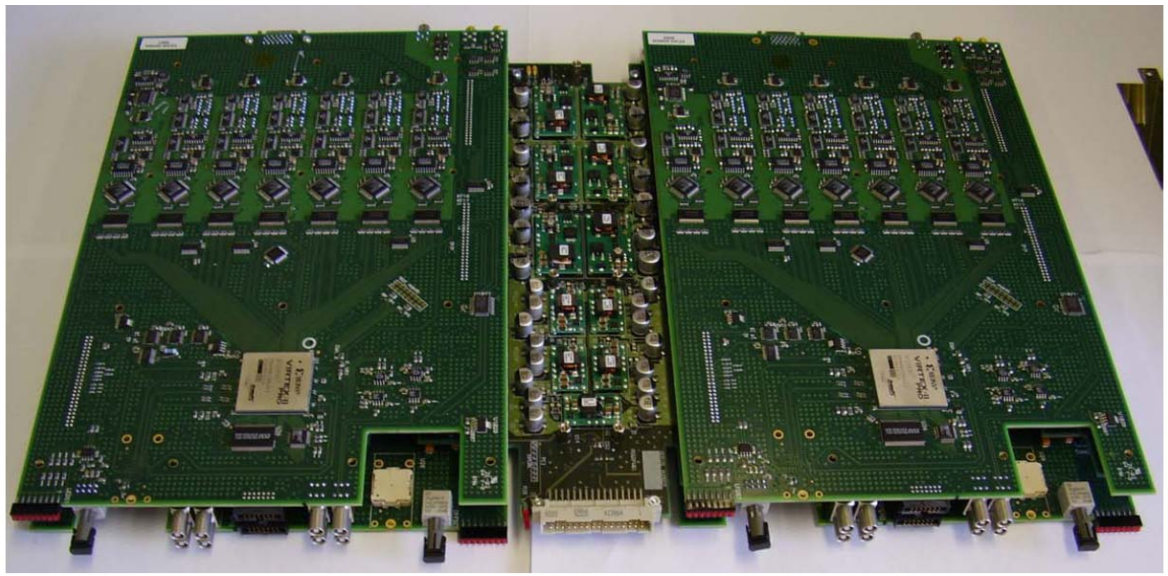
Segment level processing: energy, time
Detector level processing: trigger, time, PSA
Global level processing: event building, tracking, software trigger, data storage

Digitiser module
36+1 channels, 100 Mhz, 14 bits
(Strasbourg - Daresbury – Liverpool)



2 boxes per crystal

- **Mounted close to the Detector** ***5-10 m***
- **Power Dissipation around** **400W**
- **Water Cooling**

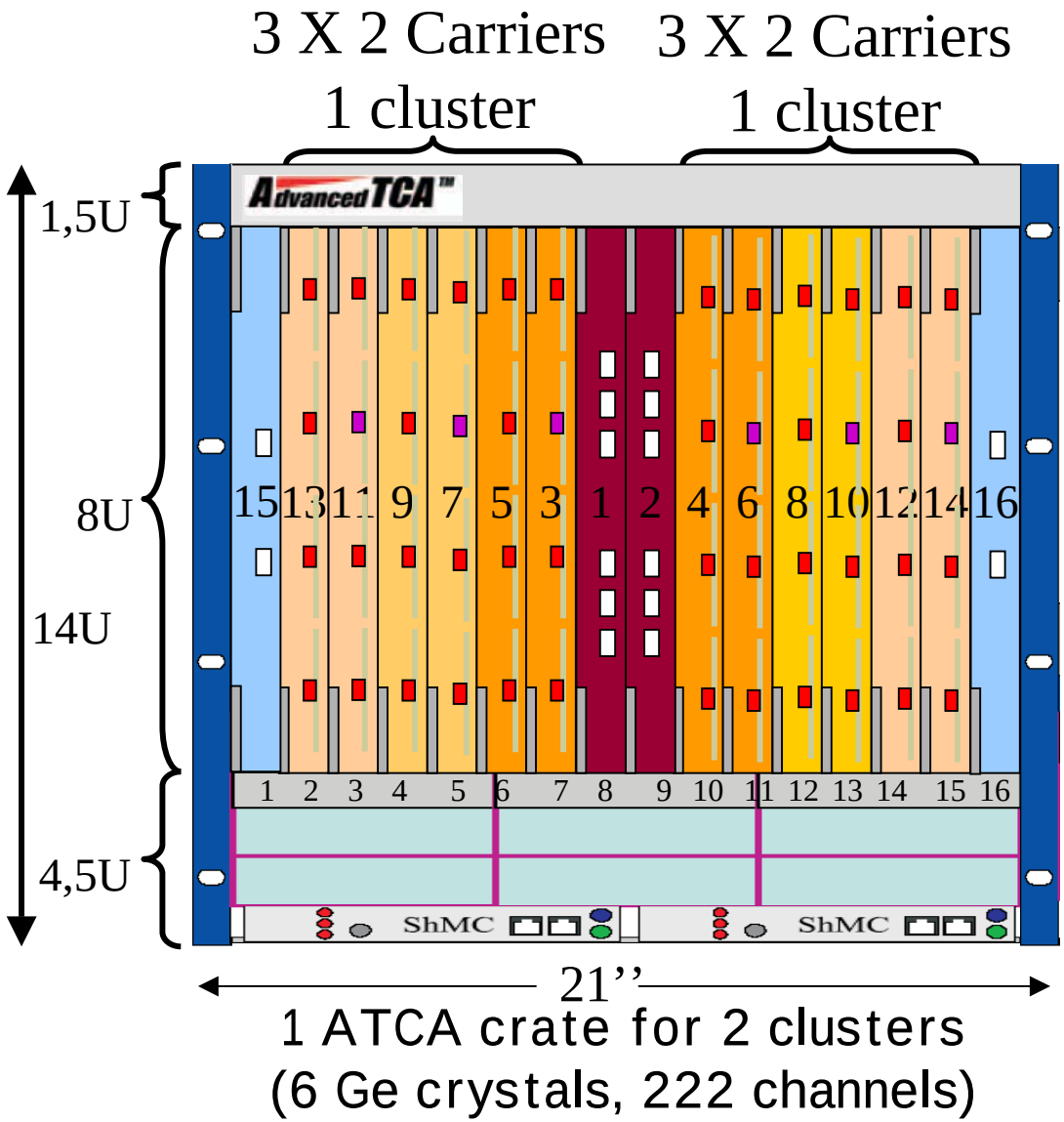


Prototype Segment Board

Data Link Test

- Pseudo Random Sequence using 16 bits. All six channels operating.
- Transmit Alignment data, then start sequence. Each channel different start.
- Receive using XC2VP20 board. Alignment, load first word, then shift and check against new data. Output statistics and status to terminal every 5 seconds.
- All six channels run well. Average two data faults per channel per 24 hours over Five days. Sensitive to clock distribution from LeCroy generators.

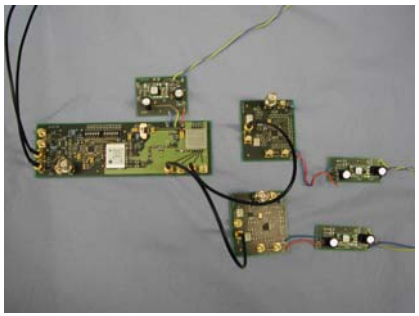
Pre-processing modules (E,T, hits, …) (Orsay – Daresbury)



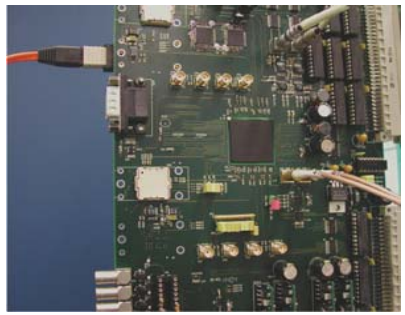
ATCA standard :
"full mesh" communication with Gbit Ethernet or PCIexpress switches

Segment preprocessing mezzanine for 6 channels

TOOLS

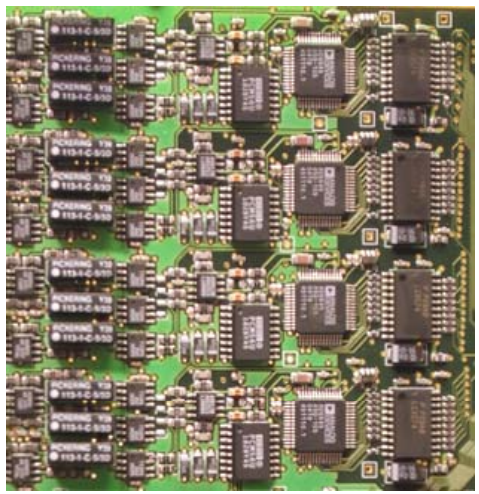


Clock Distribution

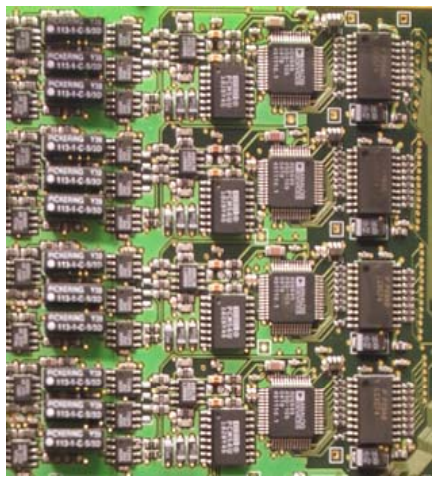


Trial Laser Board

Slow Control
Comunication Tests Board

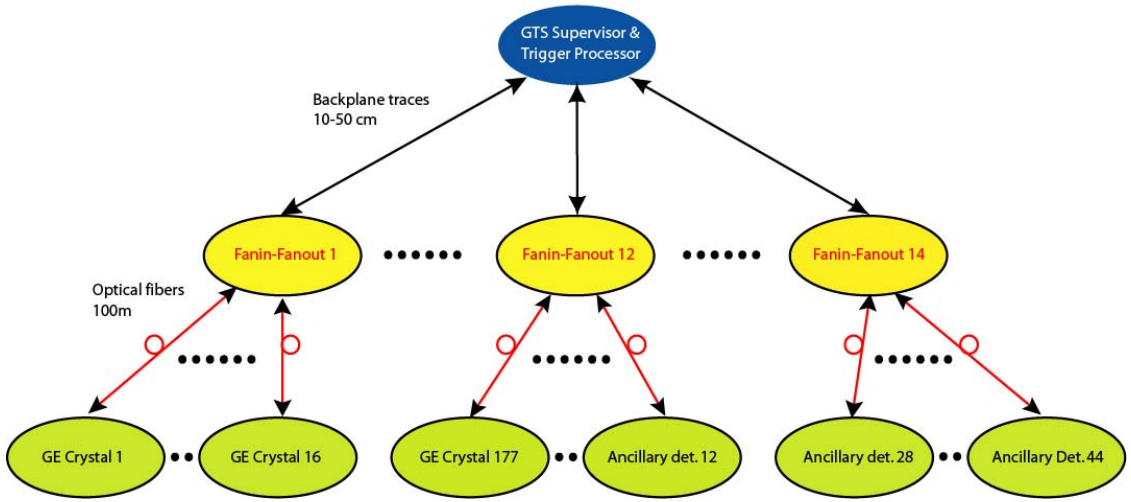


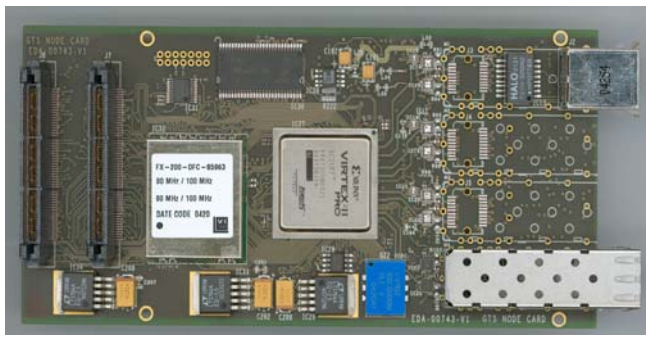
TNT2 FADC



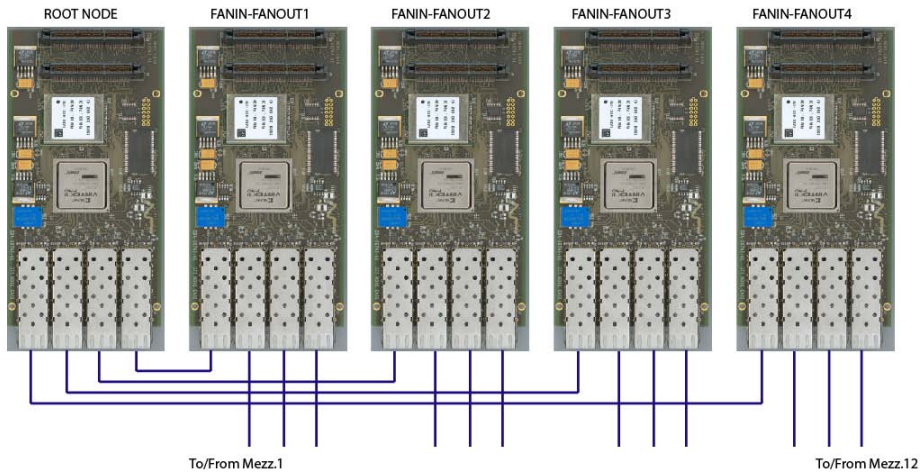
Waveform Generator
6x16 bits 400MHz (2006)

Global Trigger System (GTS)
(Padova – Legnaro)





GTS Pre-Proc. mezzanine
One per detector
(also for ancillaries)



Trigger processor layout
For up to 12 detectors

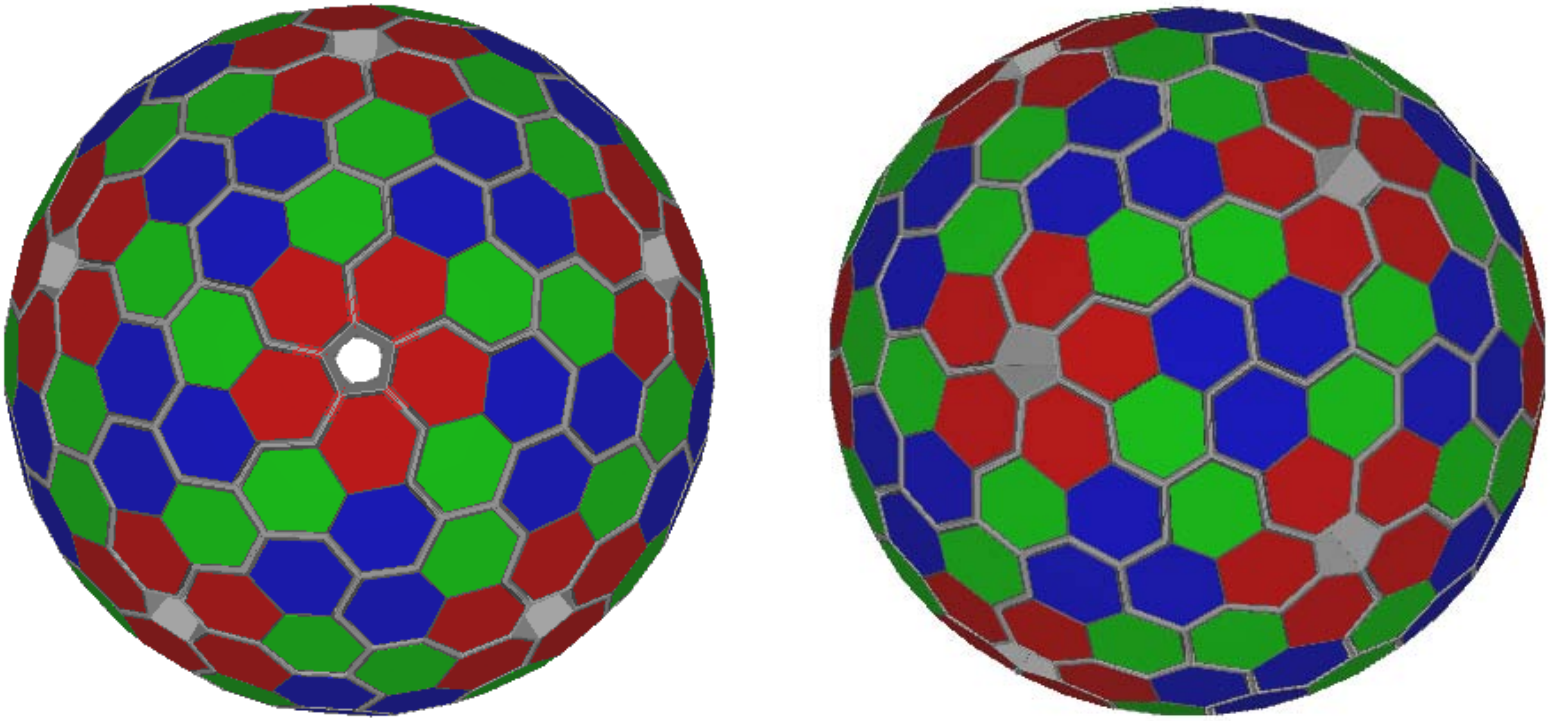
Status of the AGATA project

- Next steps
  - General discussion at the next AGATA week: Liverpool, June 6-9
  - Characterising the first prototype Ge detectors
  - Testing the first electronics and DAQ prototype boards
- Milestones and deliverables for 2006
  - Ge detector prototype characterized
  - Pulse-shape analysis algorithms optimised
  - Gamma-ray tracking algorithms optimised
  - Electronics and DAQ prototypes
- Ready for Demonstrator by fall 2007

Status and Evolution

- Demonstrator ready in 2007
- Next phases discussion 2005-2006
- New LoI for construction phase 2005
- New MoU and bids for funds in 2007
- Start construction in 2008
- Rate of construction depends on production capability
- Stages of physics exploitation, facility development

The Phases of AGATA-180

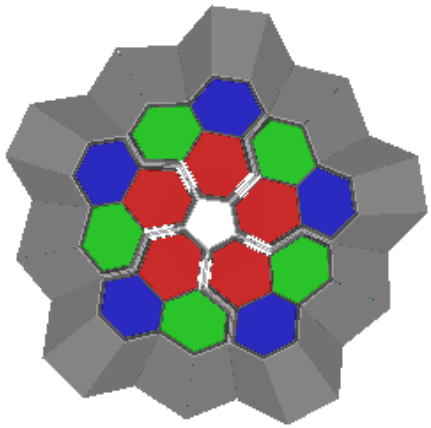


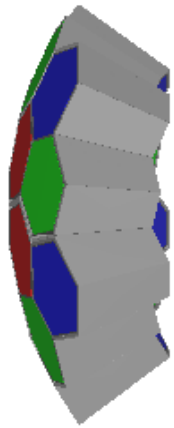
4π Array

The Phases of AGATA 1

5 Clusters 2007

Demonstrator





Peak efficiency

3 – 8 % @ $M_\gamma = 1$

2 – 4 % @ $M_\gamma = 30$

Replace/Complement

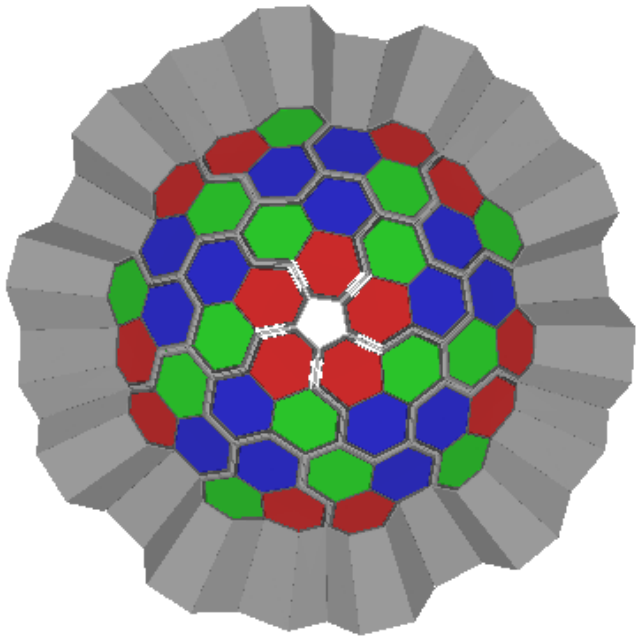
Main issue is Doppler correction capability
→ coupling to beam and recoil tracking devices

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

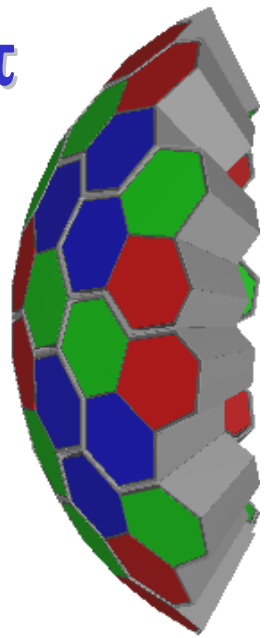
Improve resolution at higher recoil velocity
Extend spectroscopy to more exotic nuclei

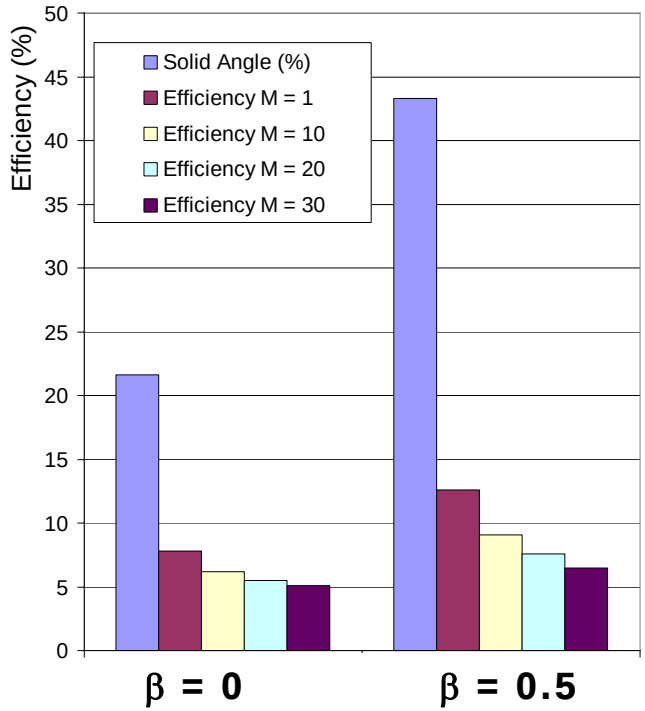
The Phases of AGATA 2

15 Clusters



1π





The first "real" tracking array

Used at **FAIR-HISPEC**, **SPIRAL2**, **SPES, ECOS**

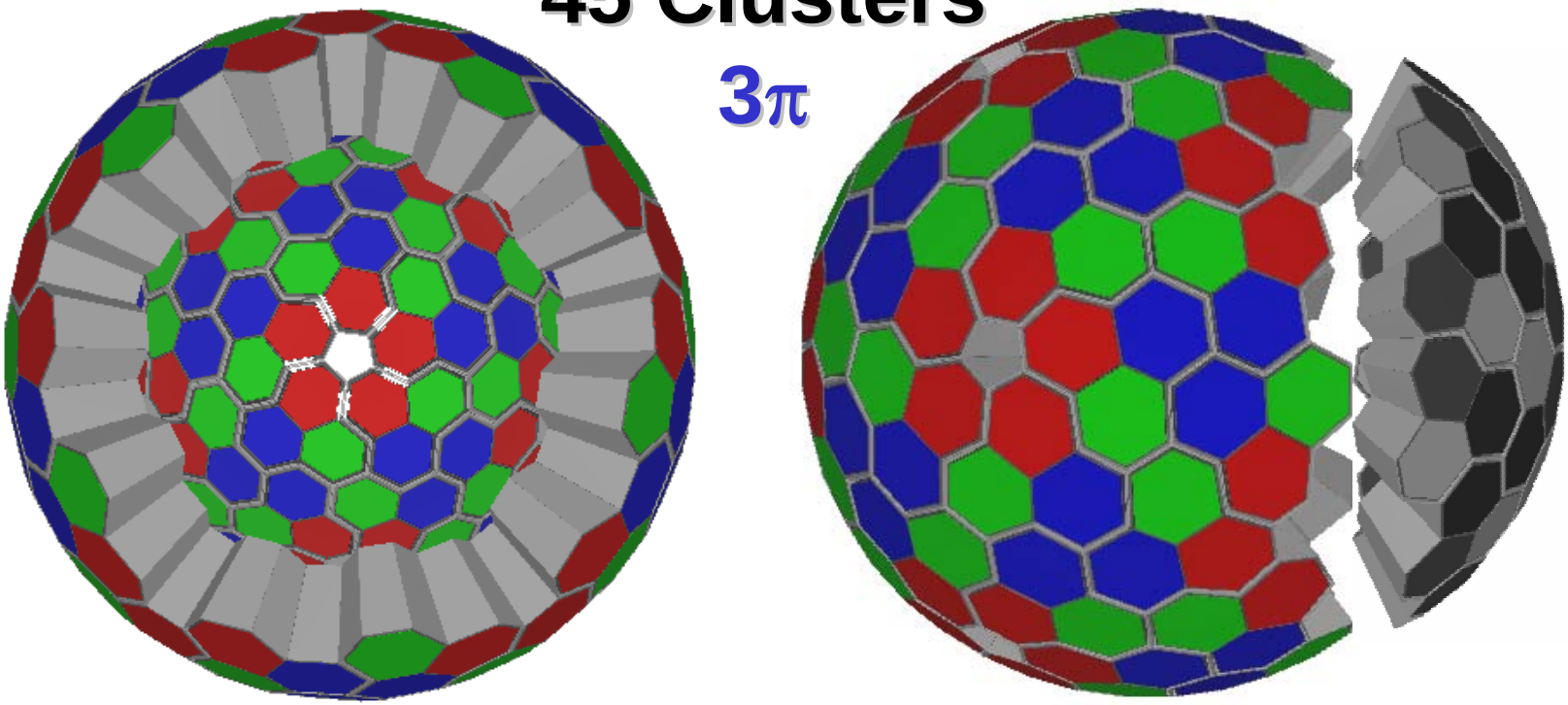
Coupled to spectrometer, beam tracker, LCP arrays …

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

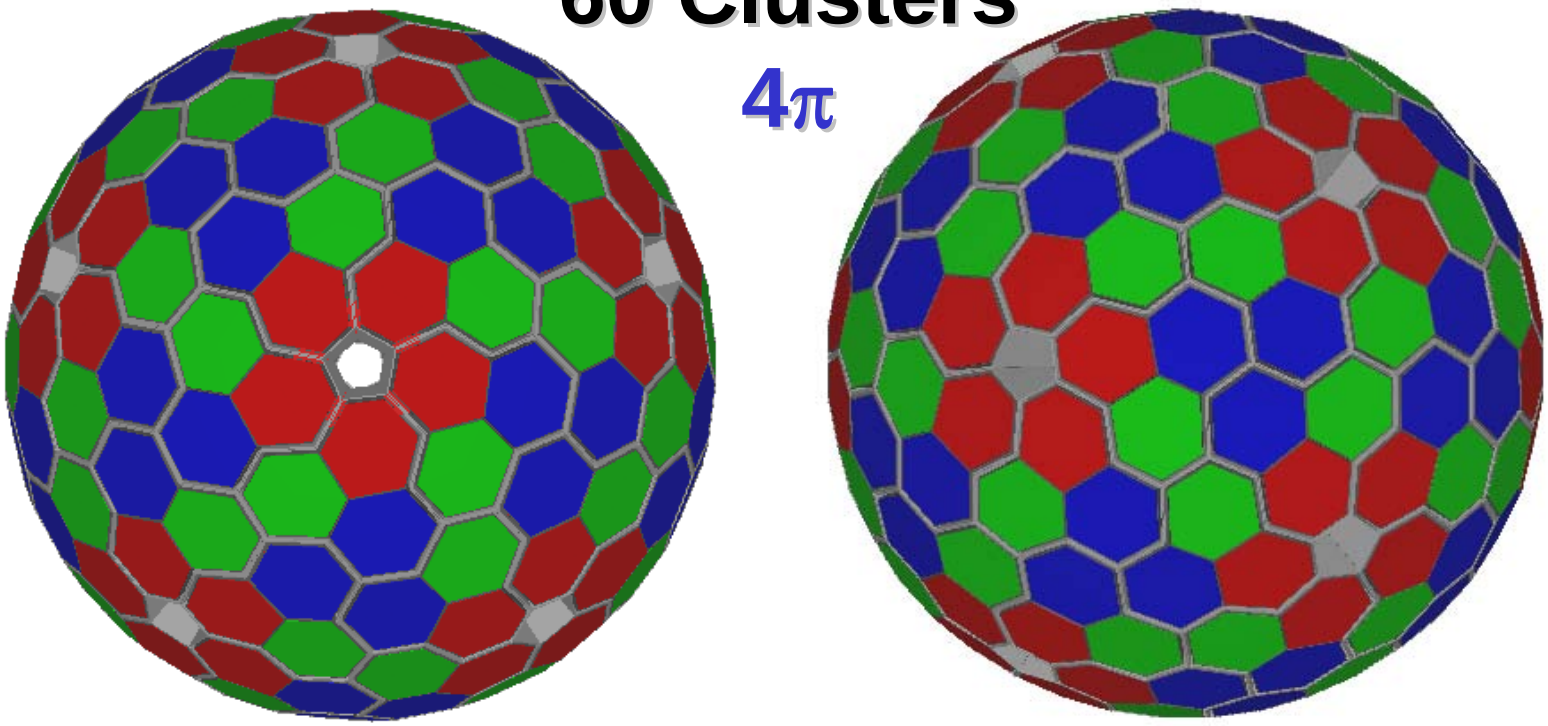
Also used as partial arrays in different labs

Higher performance by coupling with ancillaries

The Phases of AGATA 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

Commissioning and first phases

- Bids to host demonstrator presented to community at IReS in November 2005
- ASC in January 2006 accepted these bids.
- Decision to site demonstrator at Legnaro for commissioning in 2007
- First physics campaign at Legnaro in 2008
- Further campaigns (from 2009) at GANIL, GSI, ILL, …
- LoI for construction phase signed in 2005
  to allow bids for new funds from 2006 (D, …)
- MoU for AGATA construction ready in 2007
- Start construction in 2008, 1π in possible in 2011
- Support in FP7?

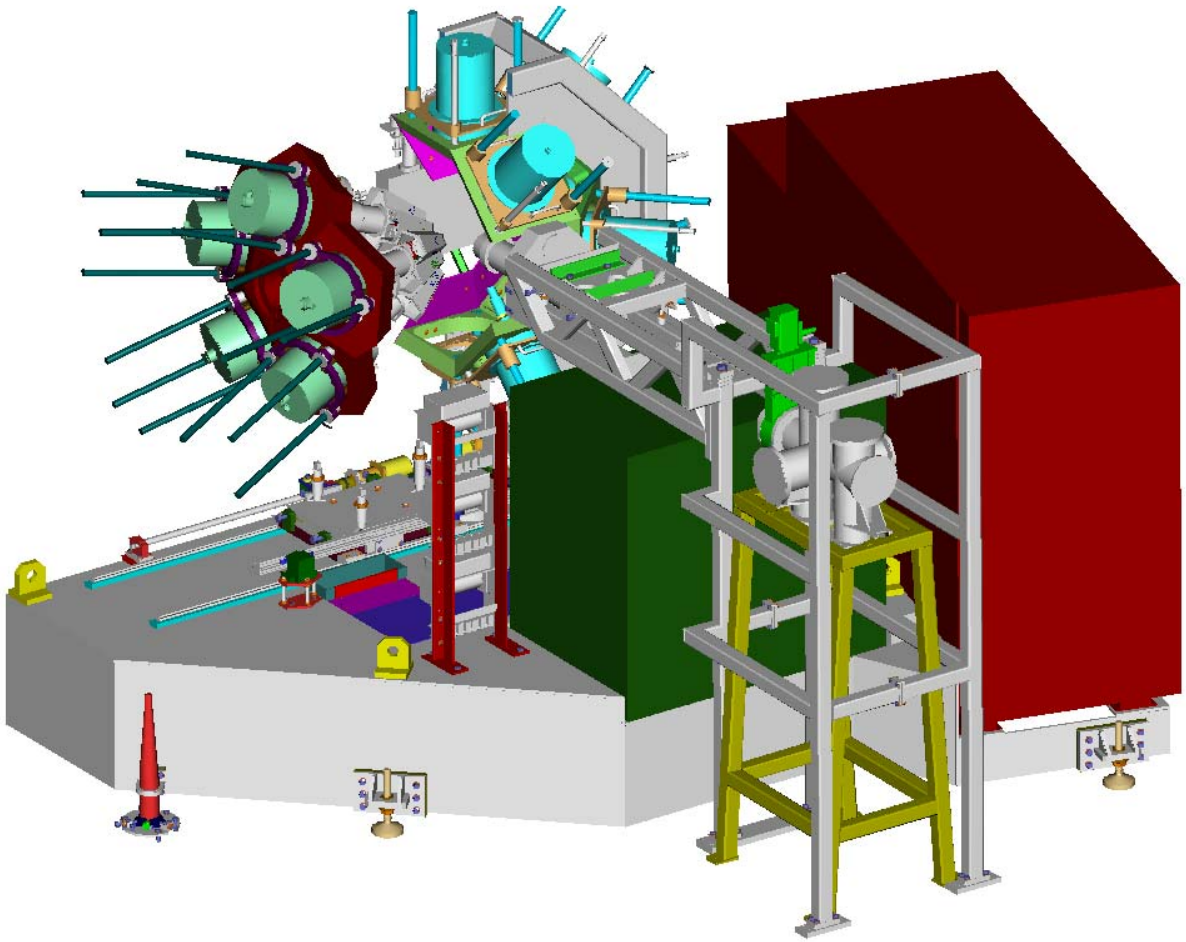
Commissioning of the Demonstrator

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

2nd half of 2007

AD + PRISMA (ADP)
LEGNARO
6 weeks beam time agreed with LNL
Collaborative effort
Followed by a physics programme

AGATA + VAMOS + EXOGAM
GANIL



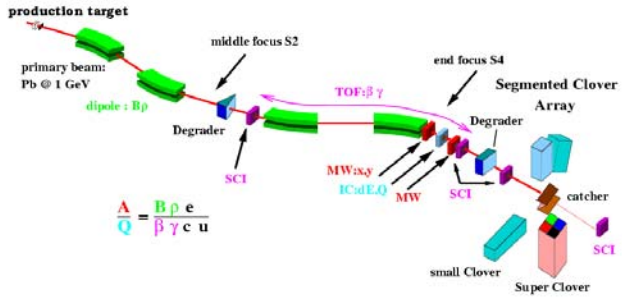
Range of beams, Fragmentaion, SPIRAL I, II, direct beam
N-rich nuclei, high spins, SHE

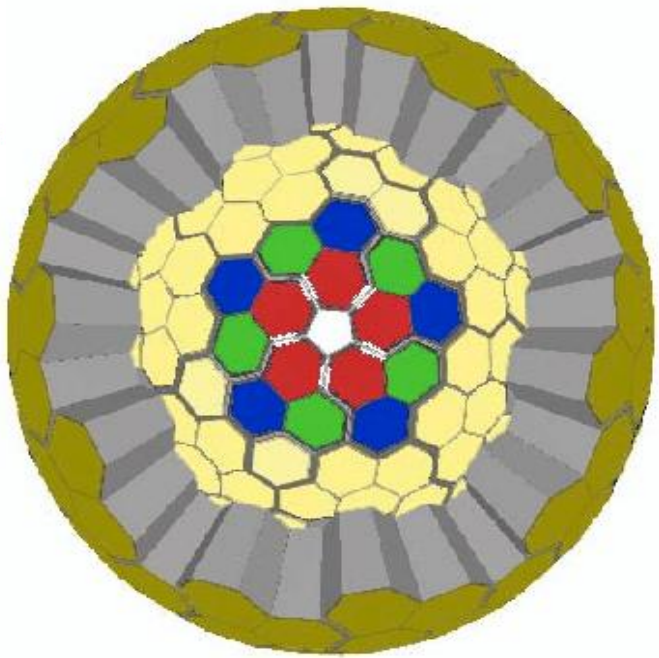
Experimental opportunities for in-beam spectroscopy at GSI-FAIR:

Intermediate energies (50-200 MeV/u):

AGATA demonstrator -> 1 π (+RISING) ~2010

FRS-SFRS





Experimental methods:

- Coulomb excitation
- knock-out
- fragmentation

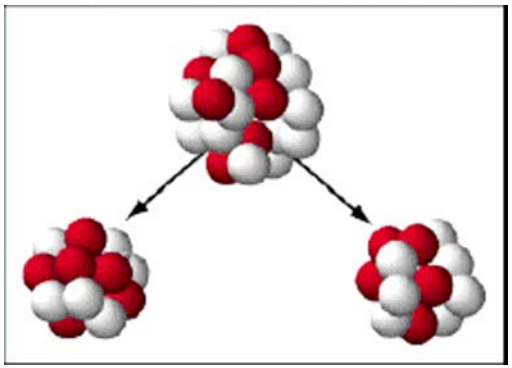
Beam intensities: $10^1 ... 10^5$ particle/s

(target: ~300 mg/cm^2)

Concentrate on the unique features of GSI-FAIR

AGATA @ ILL

Fission fragment, n-γ spectroscopy



Huge number of nuclei (many new)
γ-γ-γ coincs,
n-rich A 80-95 nuclei, nuclei near ^{132}Sn, fission process

The Fourth AGATA Week

6-9th June 2006

Liverpool

http://ns.ph.liv.ac.uk/agata/

All welcome

Talks from last AGATA week:
http://ireswww.in2p3.fr/ires/workshops/agata_week/

AGATA web page

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

The Management

Thanks