The AGATA Spectrometer

Next generation Gamma-ray Spectroscopy

John Simpson

UNIVERSITY OF LIVERPOOL

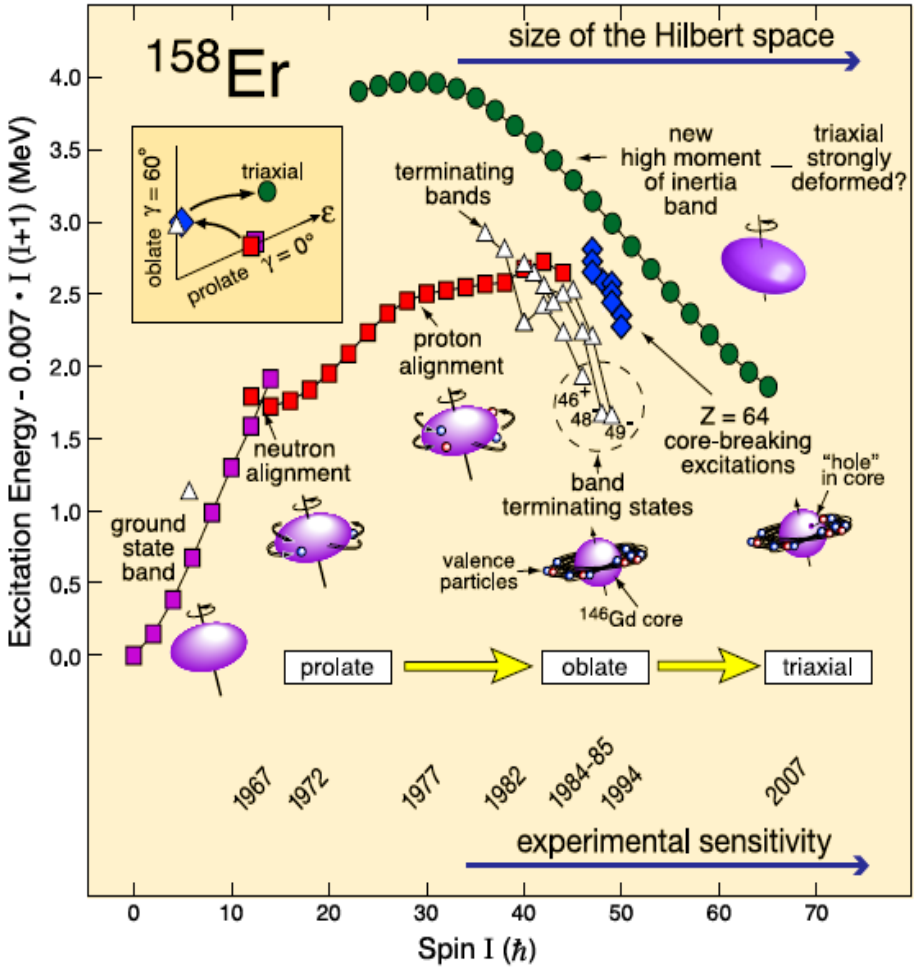
Science & Technology Facilities Council
Nuclear Physics Group

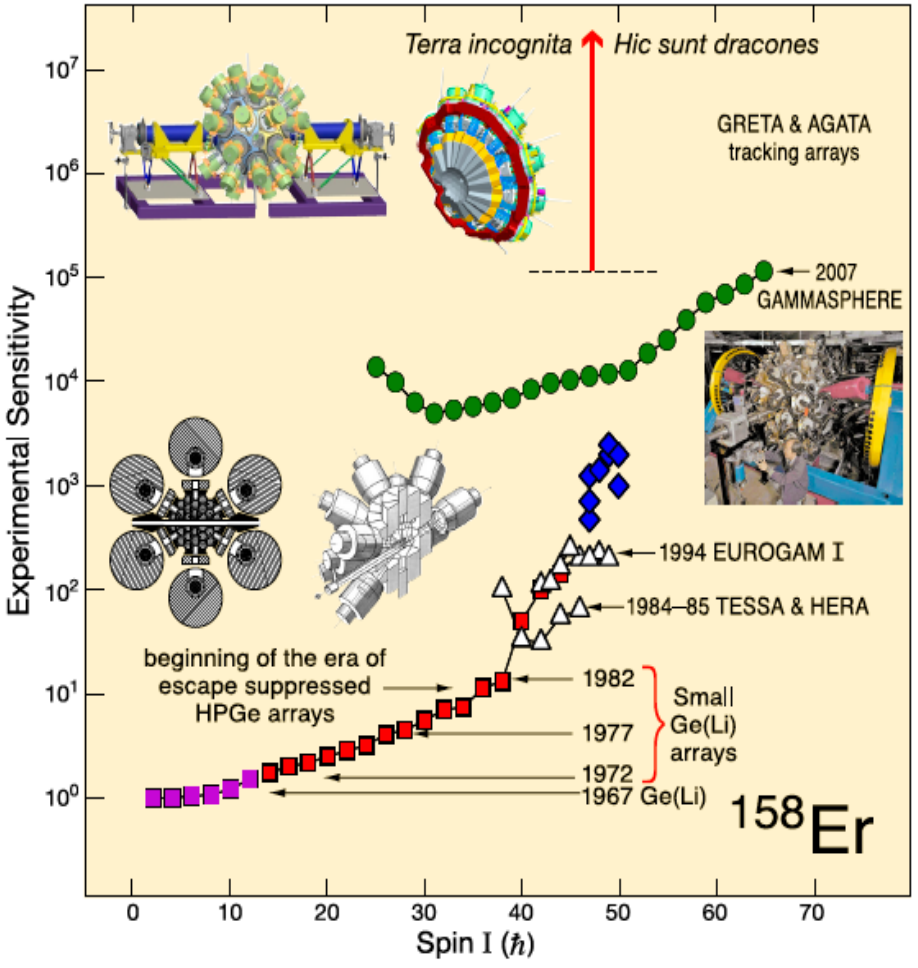
What is AGATA?

A precision instrument for Nuclear Structure

Evolution of Gamma-Ray Spectroscopy

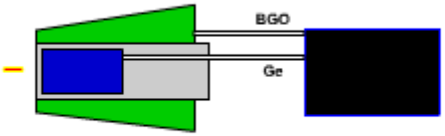
New Detector Systems ⟺ New Physics

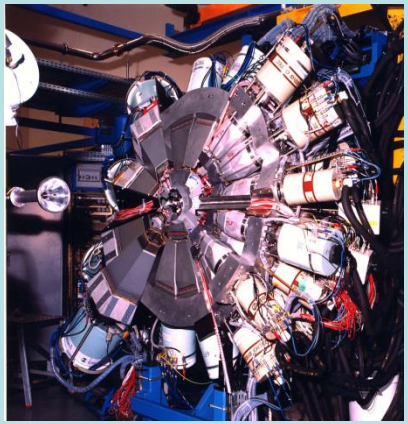




Idea of γ-ray tracking

Large Gamma Arrays based on Compton Suppressed Spectrometers



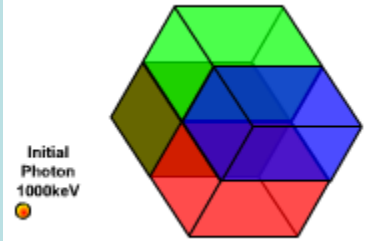


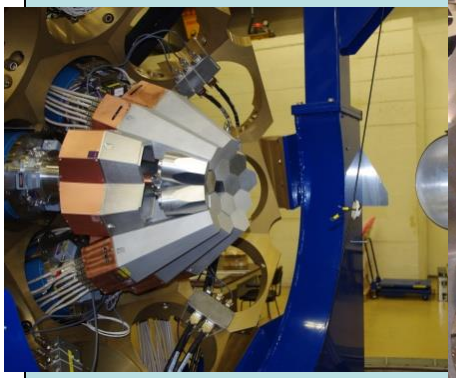
EUROBALL



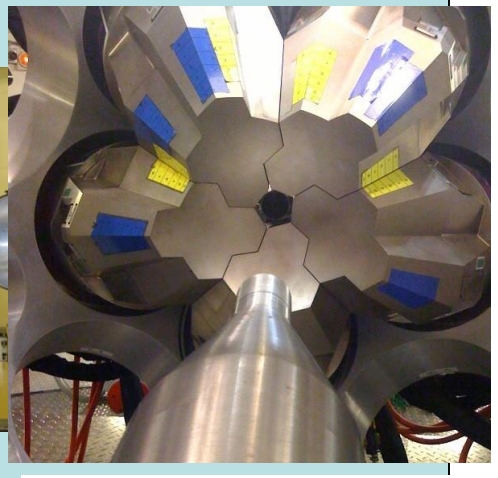
GAMMASPHERE

Tracking Arrays based on Position Sensitive Ge Detectors





AGATA



GRETINA/GRETA

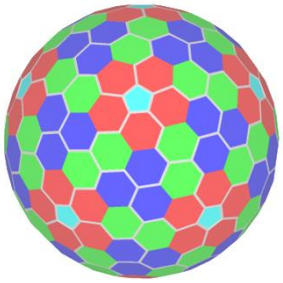
ε ~ 10 — 5 %
(M_γ=1 — M_γ=30)

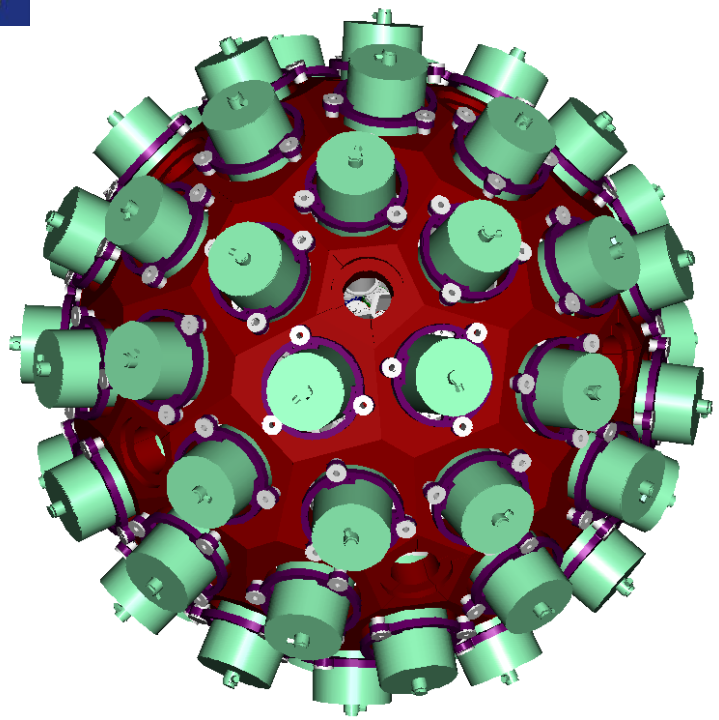
ε ~ 40 — 20 %
(M_γ=1 — M_γ=30)

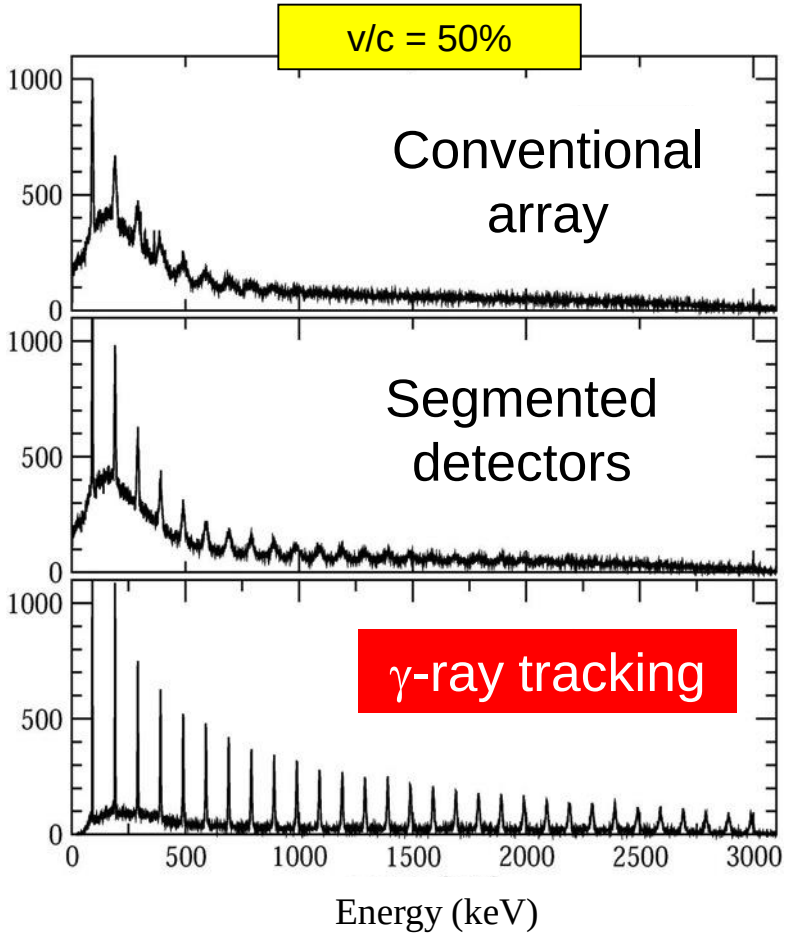
Huge increase in sensitivity

AGATA

(Advanced GAmma Tracking Array)



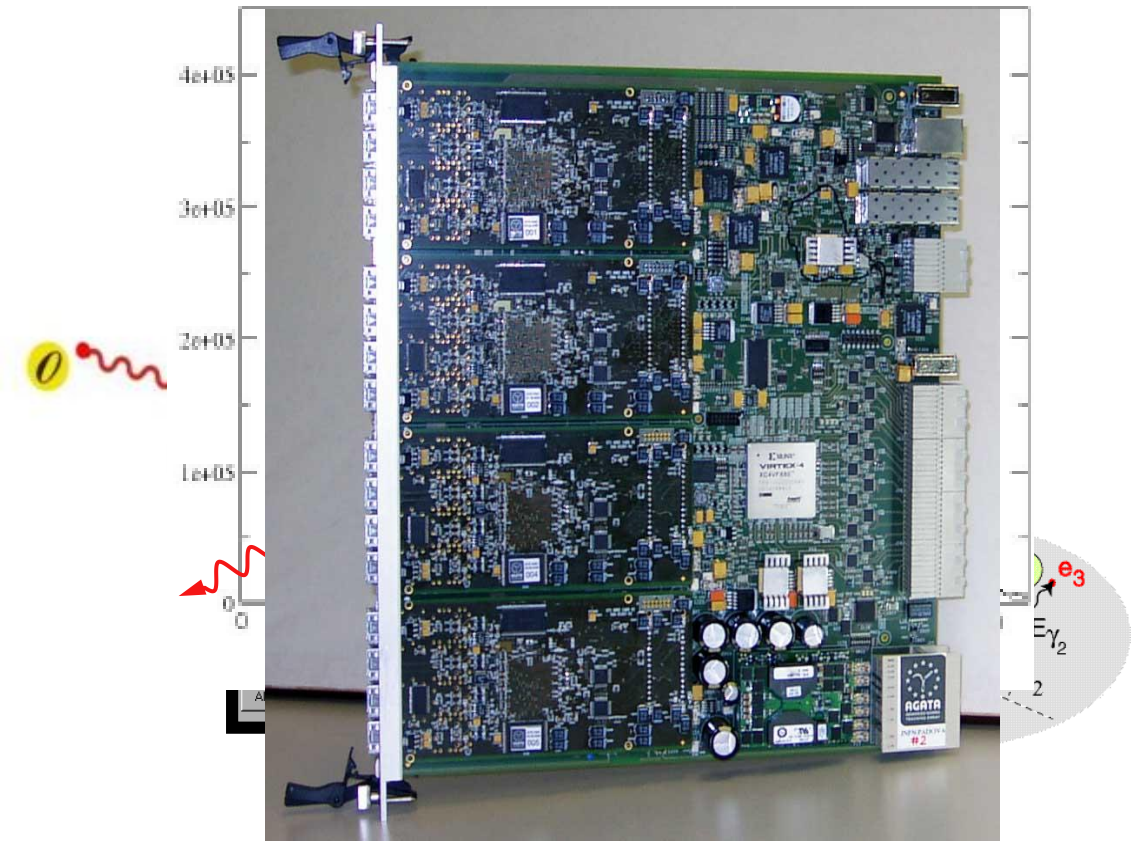




The innovative use of detectors (pulse shape analysis, γ-ray tracking, digital DAQ) will result in high efficiency (~40%) and excellent energy resolution, making AGATA the ideal instrument for spectroscopic studies of weak channels.

The effective energy resolution is maintained also at “extreme” v/c values

Gamma-ray tracking - how it works



Why do we need more efficiency?

Radioactive beams

FAIR
SPIRAL2
INFN LNL
SPES
HIE-ISOLDE

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

Harsh conditions
Need instrumentation with

High efficiency
High sensitivity
High throughput
Ancillary detectors

Conventional arrays will not suffice!

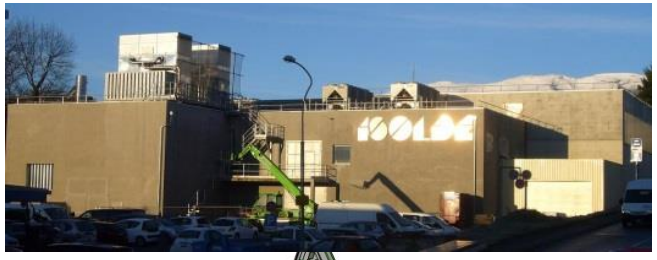
AGATA : 4π γ-array for Nuclear Physics Experiments
at major European accelerators providing radioactive and stable beams

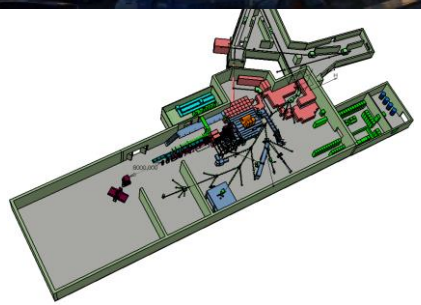


GSI/FAIR

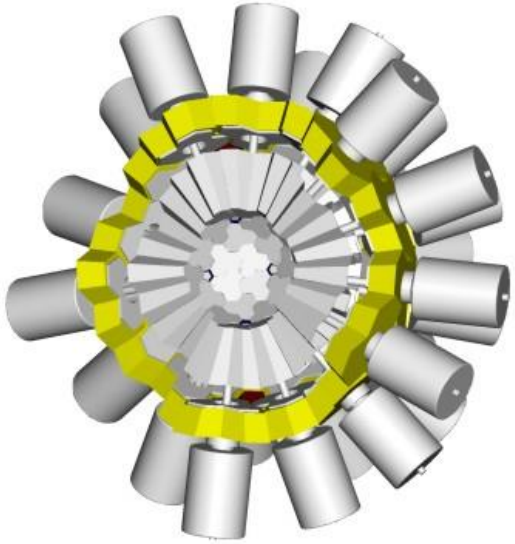


GANIL
SPIRAL 2

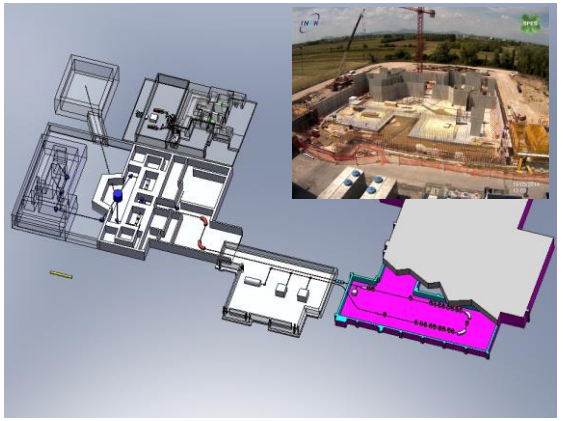




HIE-ISOLDE

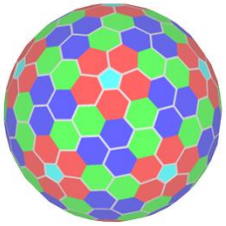


AGATA



LEGNARO/SPES

The AGATA Collaboration



Steering Committee Chairperson: Bo Cederwall KTH Stockholm

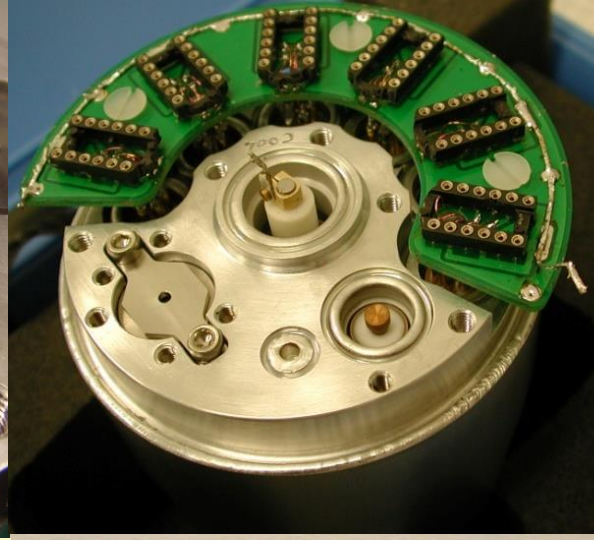
13 Countries
>40 Institutions

Bulgaria:	**Univ. Sofia**
Denmark:	**NBI Copenhagen**
Finland:	**Univ. Jyväskylä**
France:	**GANIL Caen, IPN Lyon, CSNSM Orsay, IPN Orsay, CEA-DSM-DAPNIA Saclay, IPHC Strasbourg, LPSC Grenoble**
Germany:	**GSI Darmstadt, TU Darmstadt, Univ. zu Köln, TU München**
Hungary:	**ATOMKI Debrecen**
Italy:	**INFN-LNL, INFN and Univ. Padova, Milano, Firenze, Genova, Napoli,**
Poland:	**NINP and IFJ Krakow, SINS Swierk, HIL & IEP Warsaw**
Romania:	**NIPNE & PU Bucharest**
Sweden:	**Univ. Göteborg, Lund Univ., KTH Stockholm, Uppsala Univ.**
Turkey:	**Univ. Ankara, Univ. Istanbul, Technical Univ. Istanbul**
UK:	**Univ. Brighton, CLRC Daresbury, Univ. Edinburgh, Univ. Liverpool, Univ. Manchester, Univ. West of Scotland, Univ. Surrey, Univ. York**
Spain:	**IFIC Valencia, IEM-CSIC Madrid, LRI Univ. Salamanca**



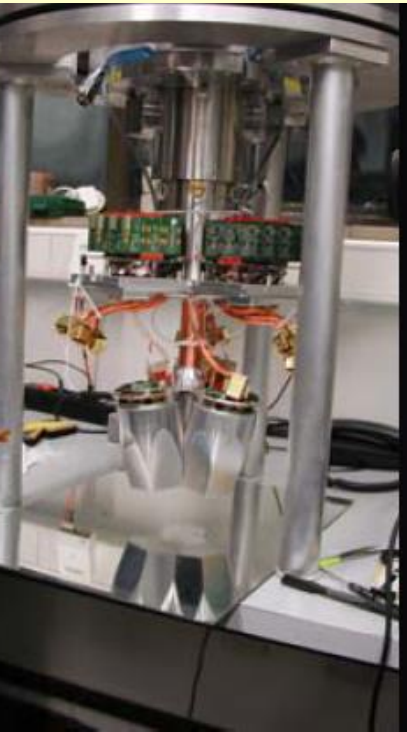


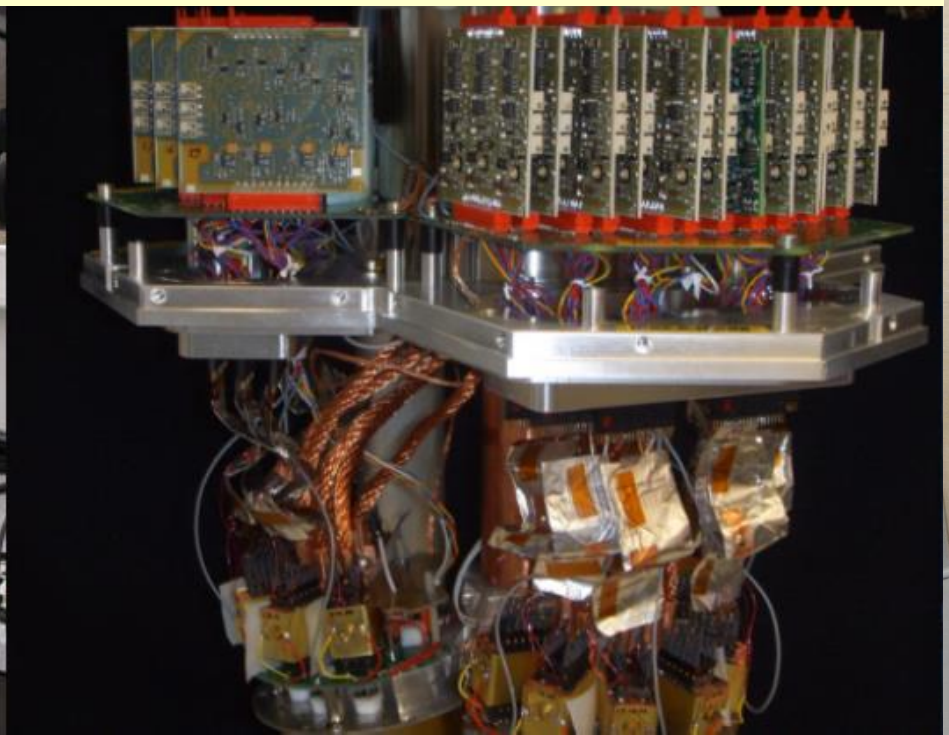




The AGATA triple detector

IKP Cologne, H.-G. Thomas (CTT Montabaur)

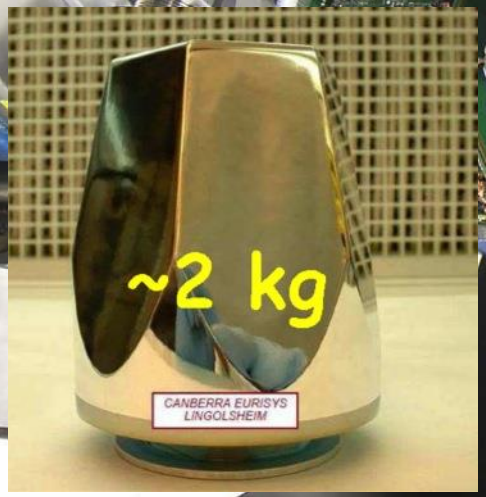






Asymmetric AGATA Triple Cryostat

- integration of 111 high resolution spectroscopy channels
- cold FET technology for all signals



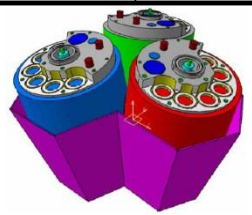
Segmentation plus
Digital Signal Processing
Results in 1mm^3 voxels
Excellent position resolution---tracking

AGATA Detector Status

Update: B. PIRARD - 1 September 2014

Detector data							
Detector number	Crystal number	Owner	Reference (OC)	Status	Comment	Last return	Planned dellivery
A001	73952	France (GANIL)	132250	OPERATION			
A002	74030	Germany (Munich)	134034	OPERATION			
A003	74009	UK (Liverpool)	131705	OPERATION			
A004	74095	Turkey (Ankara)	139339	OPERATION			
A005	73949	Sweden	140236	OPERATION			
A006	74096	Italy (INFN)	140526	OPERATION			
A007	74216	Italy (INFN)	146057	OPERATION			
A008	74108	Germany (IKP)	149843	OPERATION			
A009	74209	UK (Liverpool)	151694	OPERATION			
A010		Italy (INFN Milano)	173487	MANUFACTURING			1rst semester 2015
B001	74034	Italy (INFN Padova)	129986	OPERATION			
B002	73979	France (GANIL)	132250	OPERATION			
B003	74026	UK (Liverpool)	131705	OPERATION			
B004	74010	Turkey (Ankara)	139339	OPERATION			
B005	74065	Sweden	140236	CAT	Delivered in June 2014 - Waiting for CAT report		
B006	74076	Italy (INFN)	140526	OPERATION			
B007	74208	Germany (IKP)	149843	OPERATION			
B008	74212	Germany (IKP)	149843	OPERATION			
B009	74207	UK (Liverpool)	151694	AT CANBERRA (INVESTIGATION)	Damage on capsule	16/11/2012	TBD
B010	74202	Italy (INFN Milano)	154902	OPERATION			
B011	74203	Italy (INFN Legnaro)	156819	OPERATION			
B012	74217	France (IN2P3)	154132	OPERATION			
B013	74265	France (CEA Saclay nb 1)	157438	OPERATION			
C001	73899	Italy (INFN Padova)	129986	OPERATION			
C002	73951	France (GANIL)	132250	CAT	Delivered in December 2013 - waiting for report		
C003	74013	UK (Liverpool)	131705	OPERATION			
C004	74036	Turkey (Ankara)	139339	CAT	Delivered in November 2013 - waiting for report		
C005	74033	Sweden	140236	OPERATION			
C006	74115	Italy (INFN Legnaro)	146057	OPERATION			
C007	74164	Germany (IKP)	149843	OPERATION			
C008	74211	UK (Liverpool)	151694	OPERATION			
C009	74220	France (CEA Saclay nb 2)	157438	OPERATION			
C010	74222	Spain (IFIC)	158575	CAT	Delivered in June 2014 - waiting for report		
C011	74424	France (IN2P3)	168432	MANUFACTURING			September 2014
C012	74439	France (IN2P3)	168432	MANUFACTURING			October 2014
C013	74422	Spain (IFIC)	169330	CAT FAILED	Waiting for failure report + to be returned		
C014		Italy (INFN Milano)	173374	MANUFACTURING			1rst semester 2015

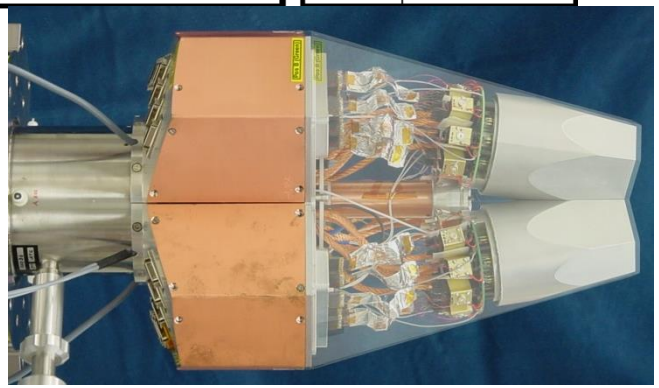
Capsules: 37 detectors ordered (~27 operational)



Cryostats/Clusters

8 Triple + 3 Double Clusters. 2 Triples arriving 2014

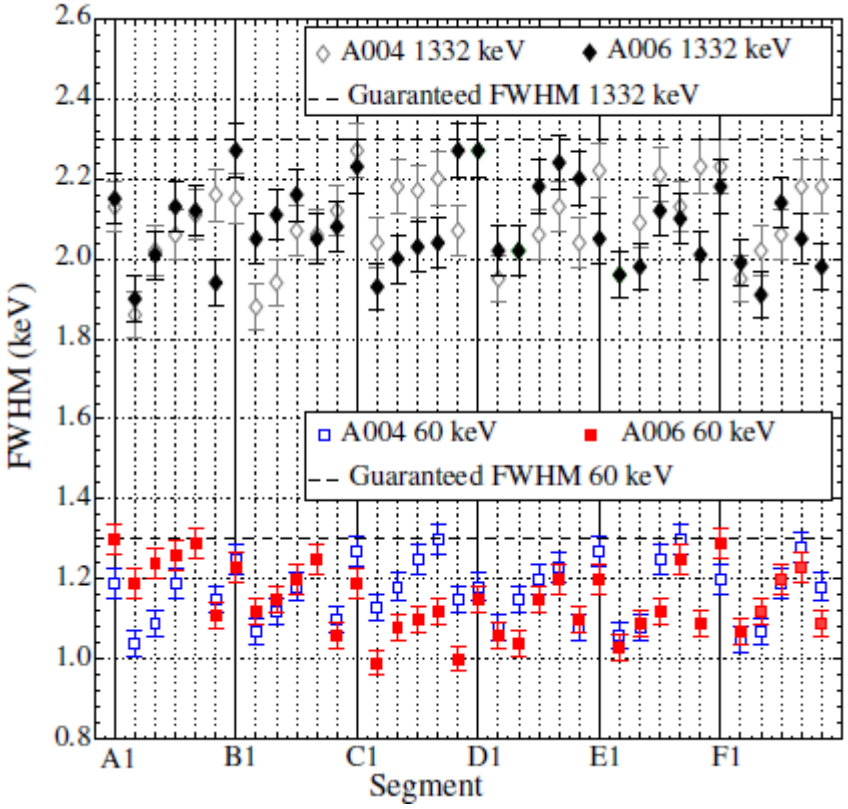
Ready to mount up to about 34 Capsules for 2015





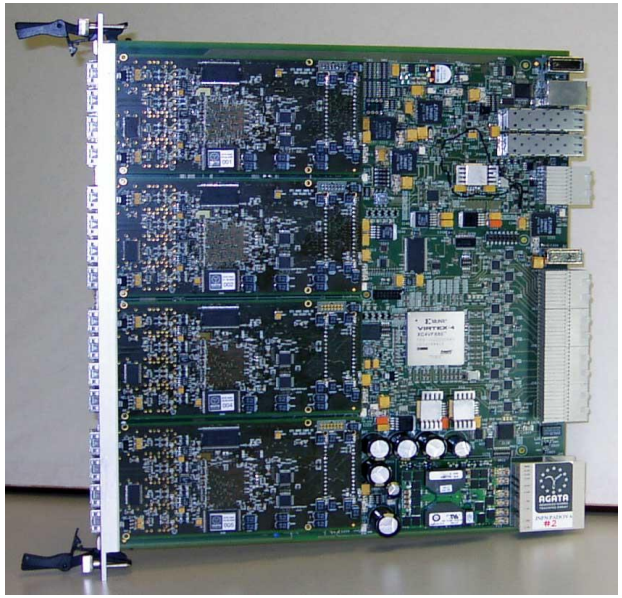
Detectors

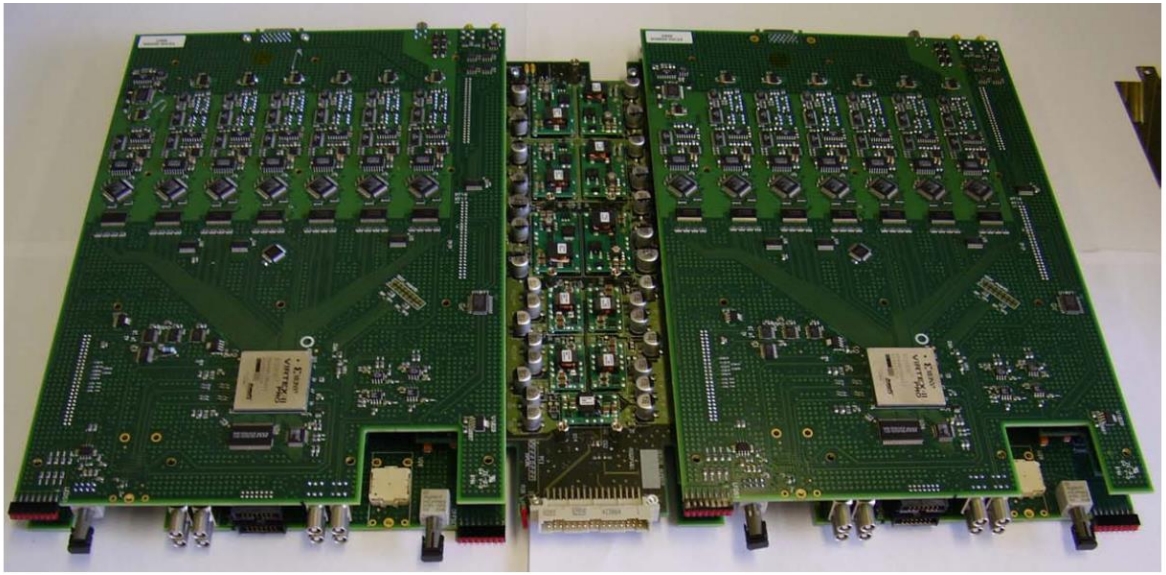
	Guaranteed	A004	A006
E_{Res}			
122 keV (keV)	≤ 1.35	1.17(9)	1.17(9)
1332 keV (keV)	≤ 2.35	2.19 (18)	2.09(17)
FWTM/FWHM	≤ 2.00	1.91(15)	2.00(16)
ϵ_{FEP} (%)		77.1(3.0)	78.2(3.0)



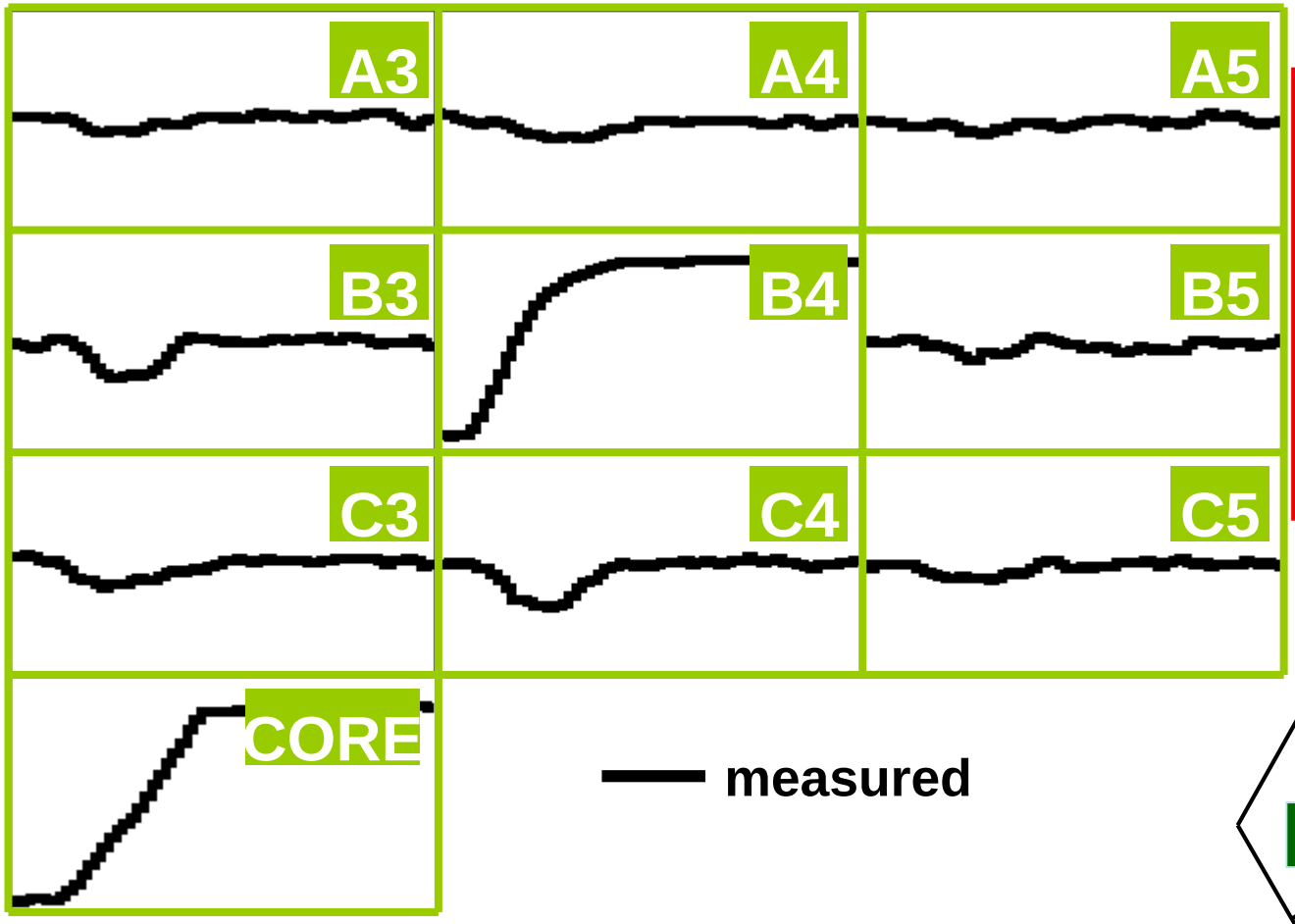
AGATA EDAQ

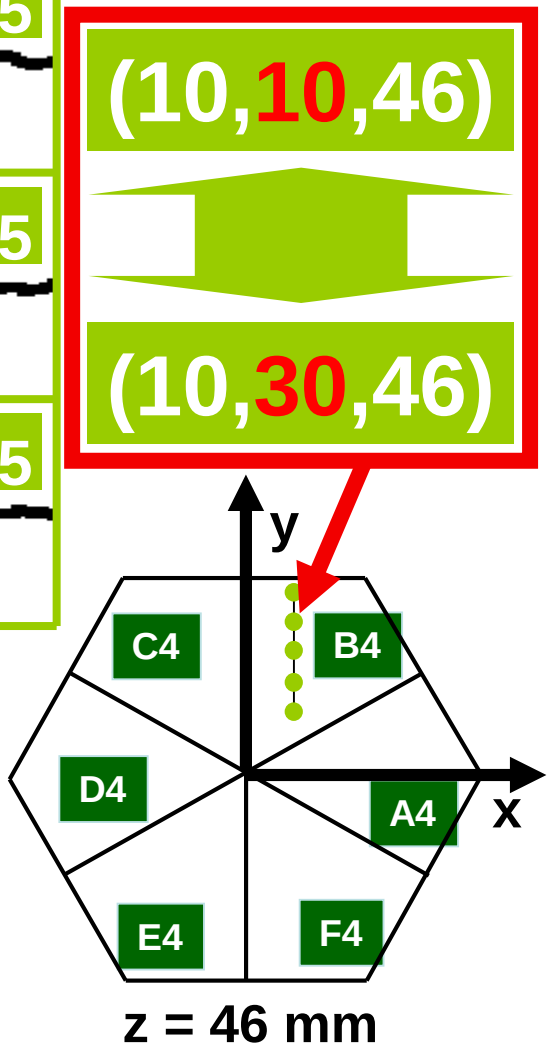






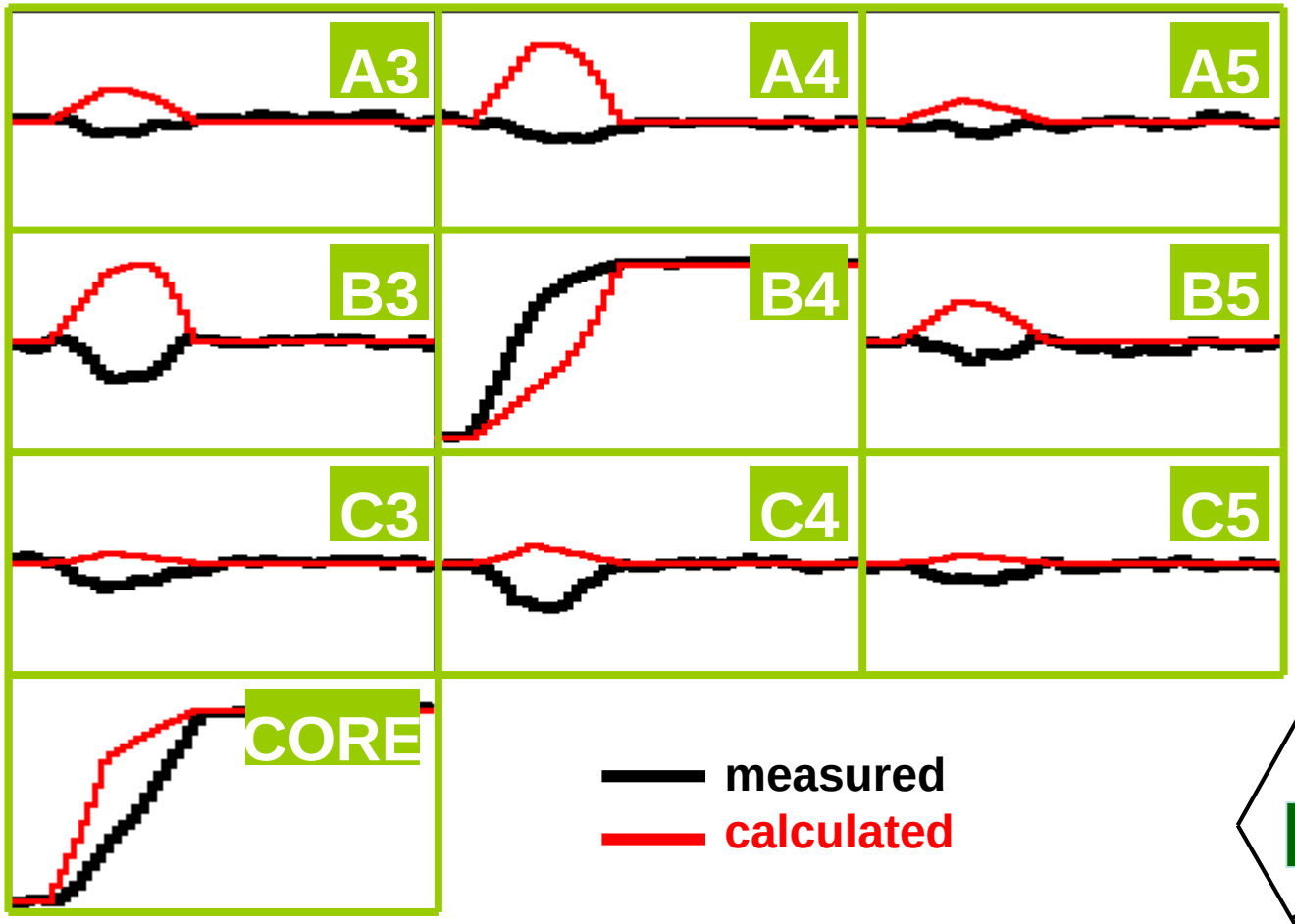
Pulse Shape Analysis concept



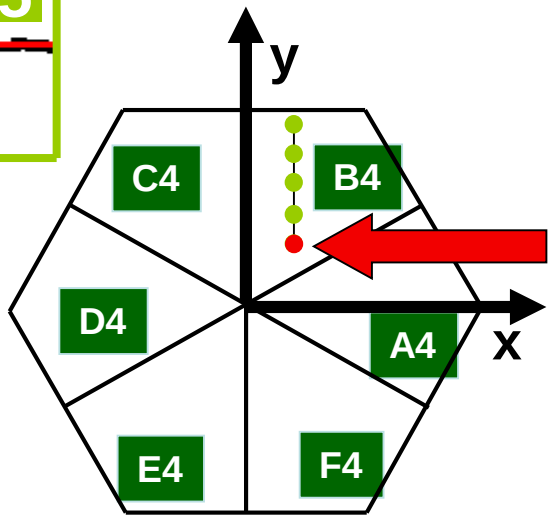


791 keV deposited in segment B4

Pulse Shape Analysis concept



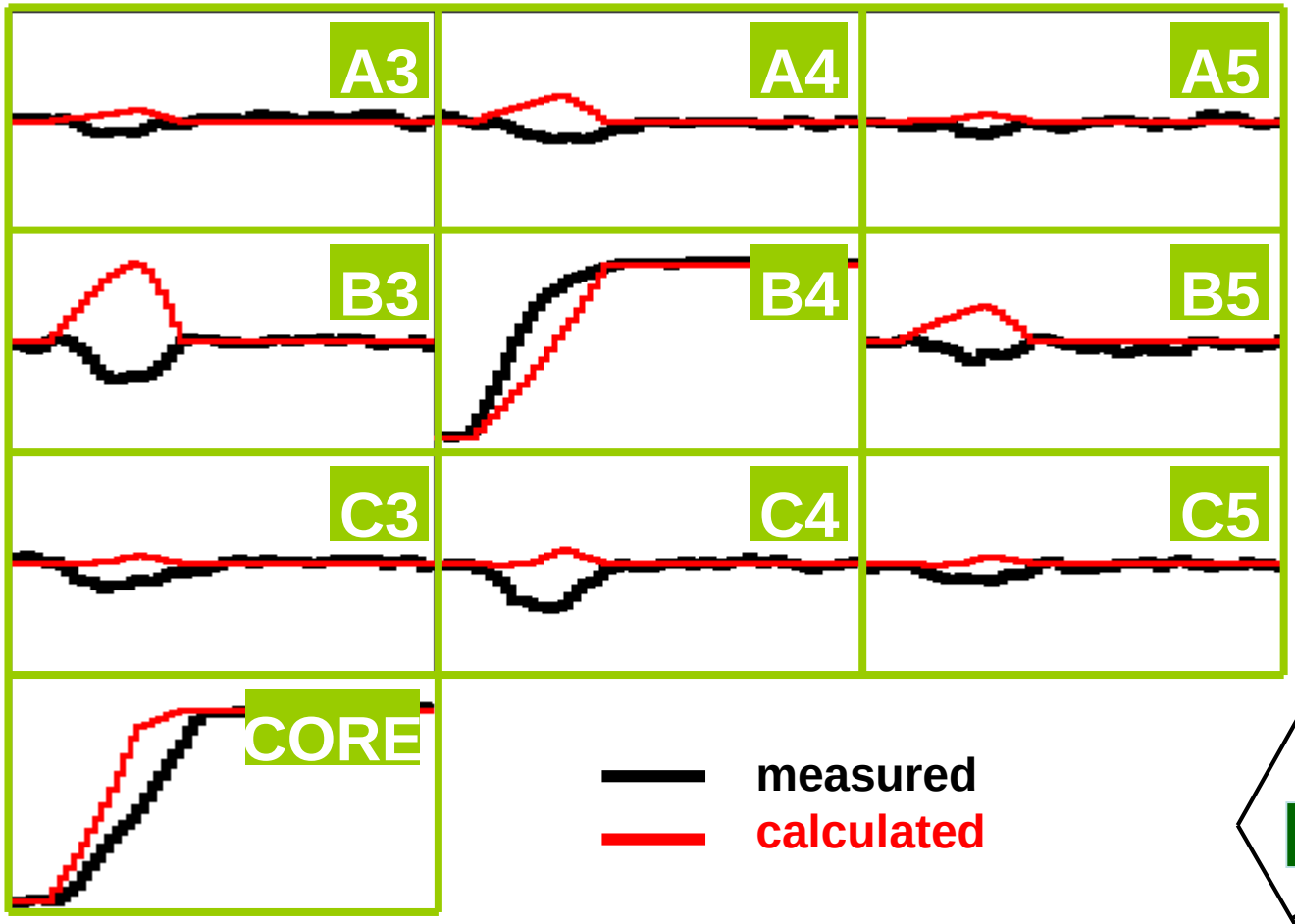
(10,10,46)



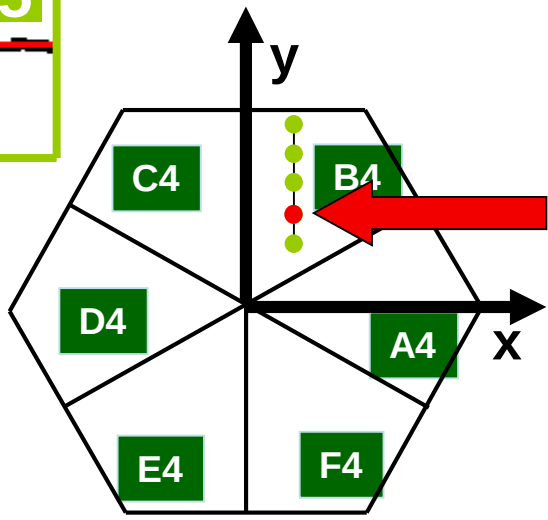
z = 46 mm

791 keV deposited in segment B4

Pulse Shape Analysis concept



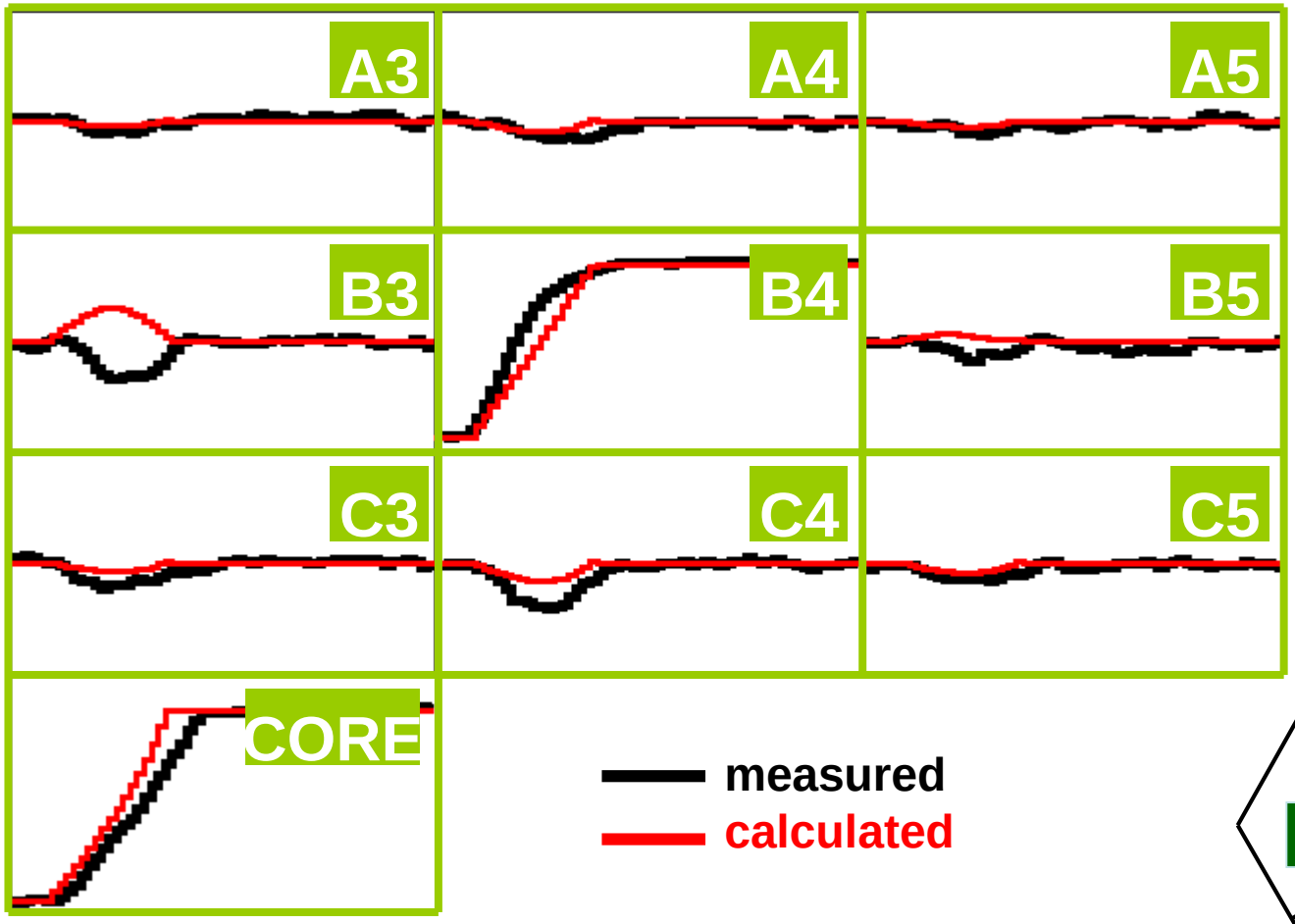
(10,15,46)



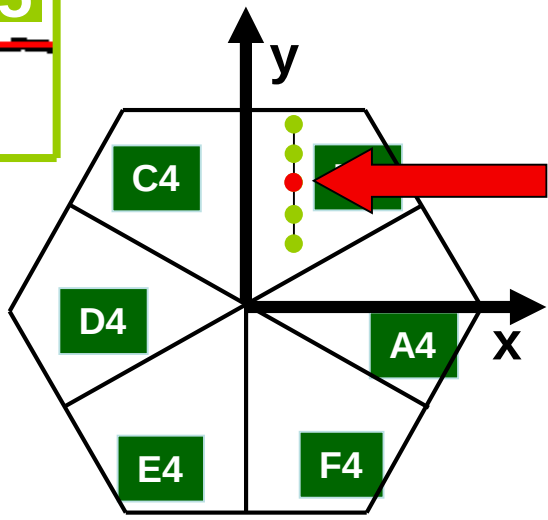
z = 46 mm

791 keV deposited in segment B4

Pulse Shape Analysis concept



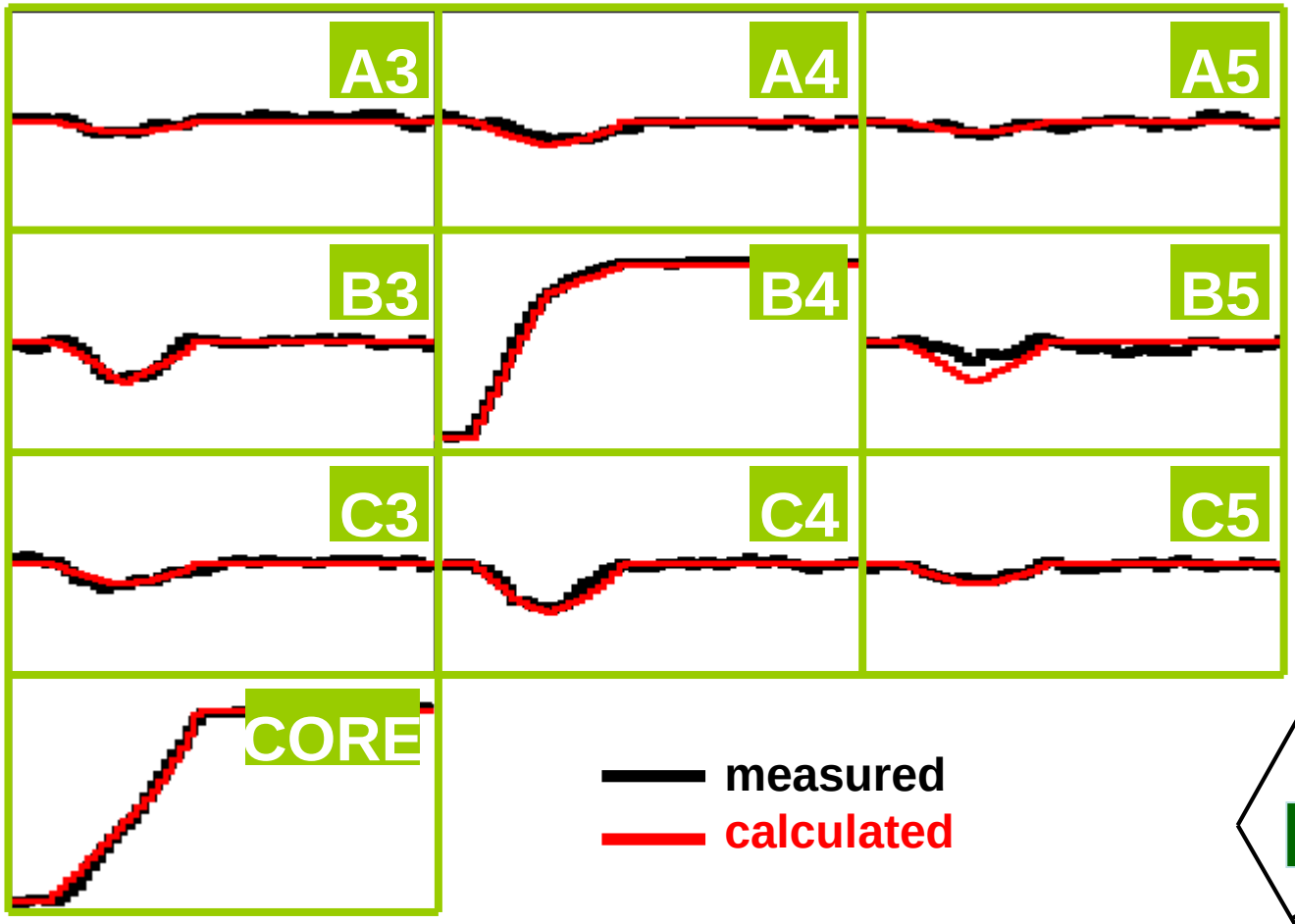
(10,20,46)



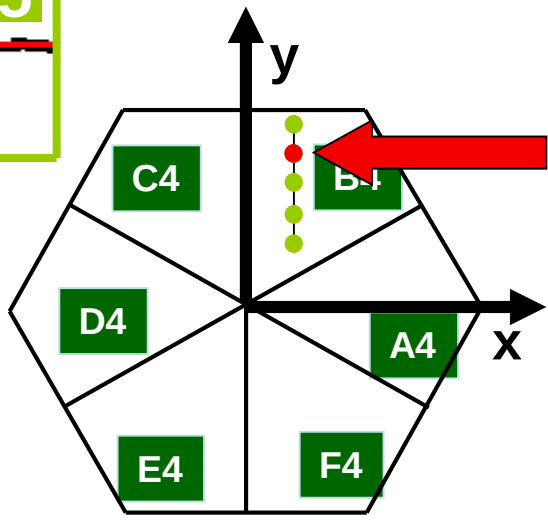
z = 46 mm

791 keV deposited in segment B4

Pulse Shape Analysis concept



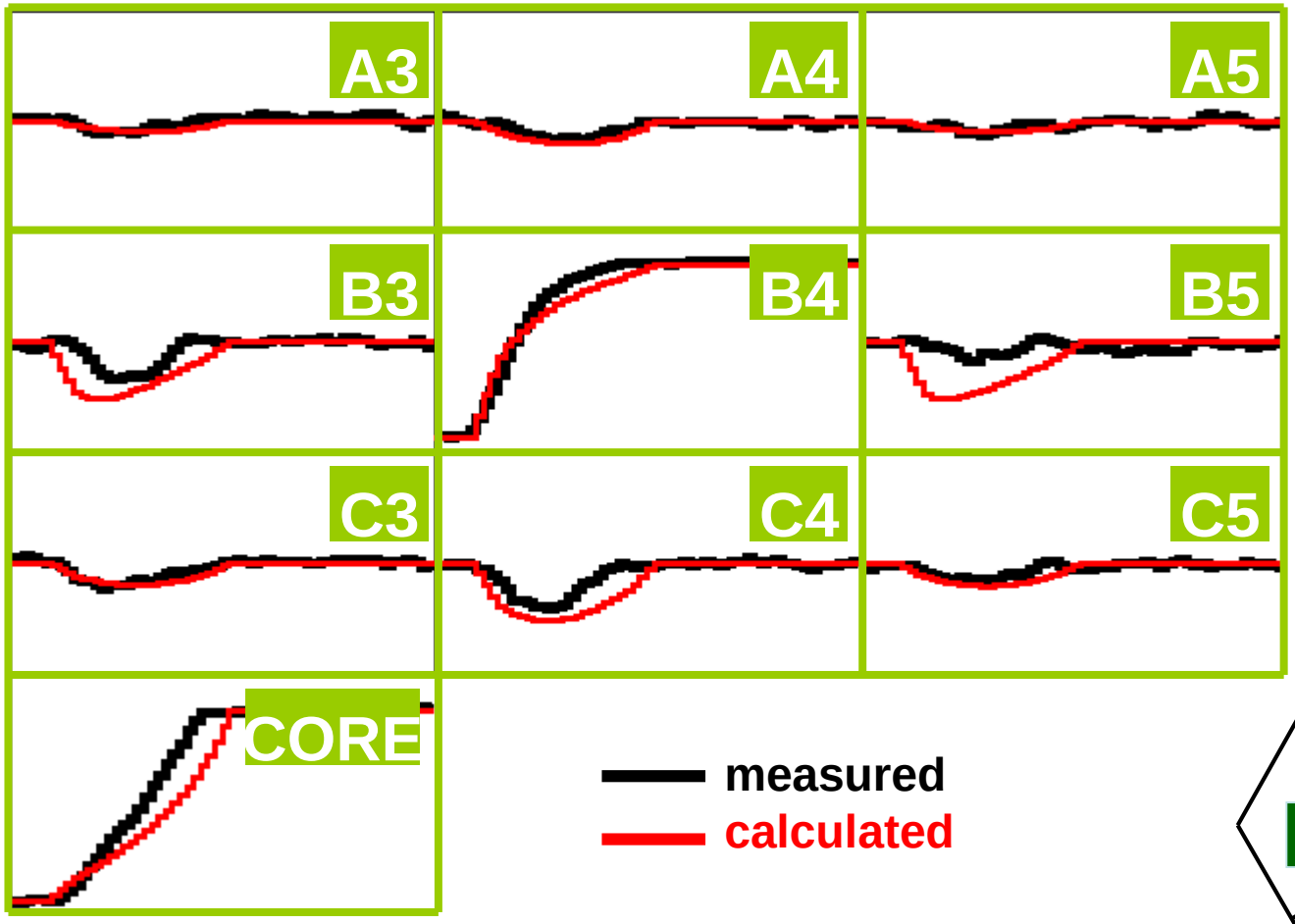
(10,25,46)



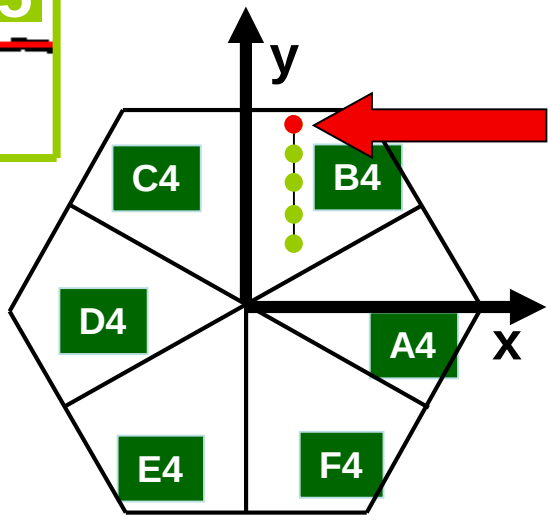
z = 46 mm

791 keV deposited in segment B4

Pulse Shape Analysis concept



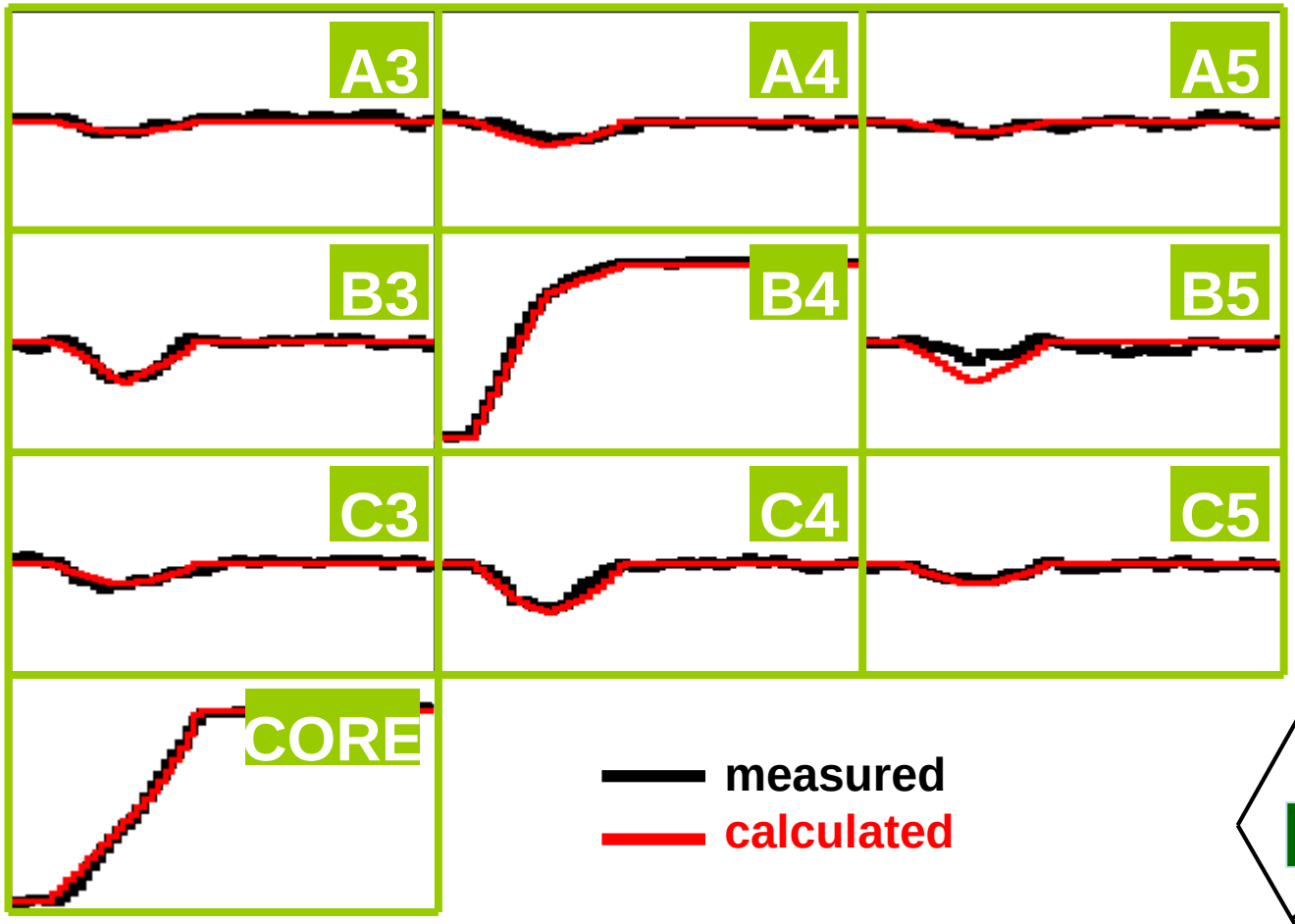
(10,30,46)



z = 46 mm

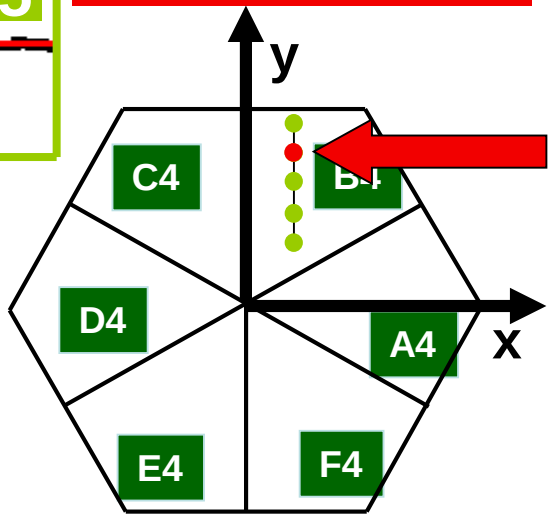
791 keV deposited in segment B4

Pulse Shape Analysis concept



Result of *Grid Search* algorithm

(10,25,46)



z = 46 mm

791 keV deposited in segment B4

Pulse Shape Analysis, Tracking & Characterization

Pulse Shape Analysis: Two PSA codes are available.

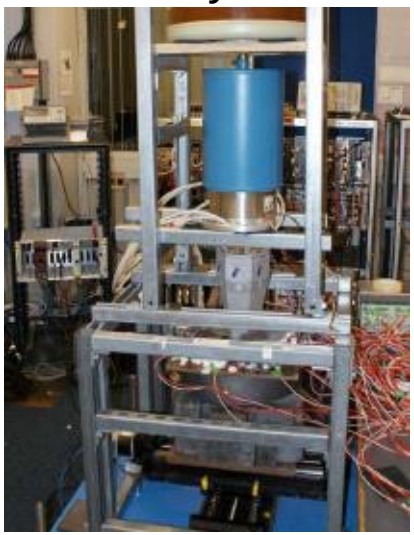
•*Adaptive Grid Search algorithm*: Single interaction in a segment.

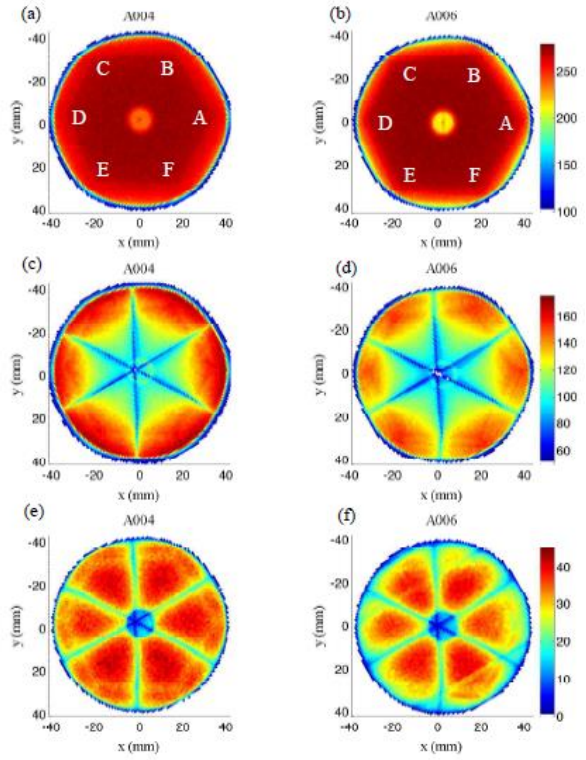
•*Particle Swarm algorithm:* implemented in test form for single interactions in up to 5 segments, Multiple interactions in a segment under test.

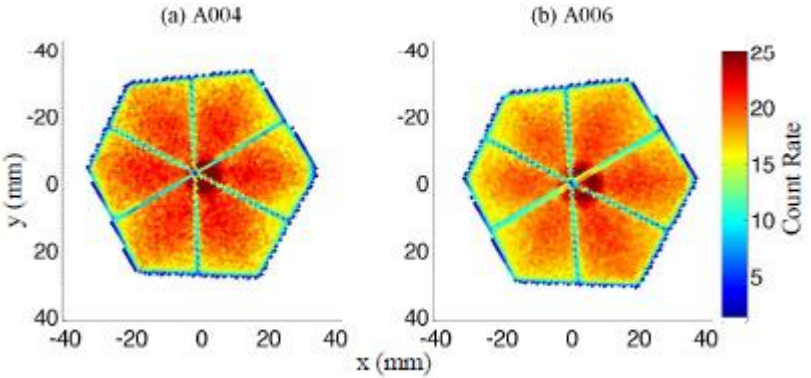
Pulse shape Library, Validation by characterization

Position resolution of <4 mm (FWHM)

Detector Characterization: Scanning tables
University of Liverpool scanned 3 symmetric capsules/crystals
2 asymmetric crystals
Singles and coincidence scanning

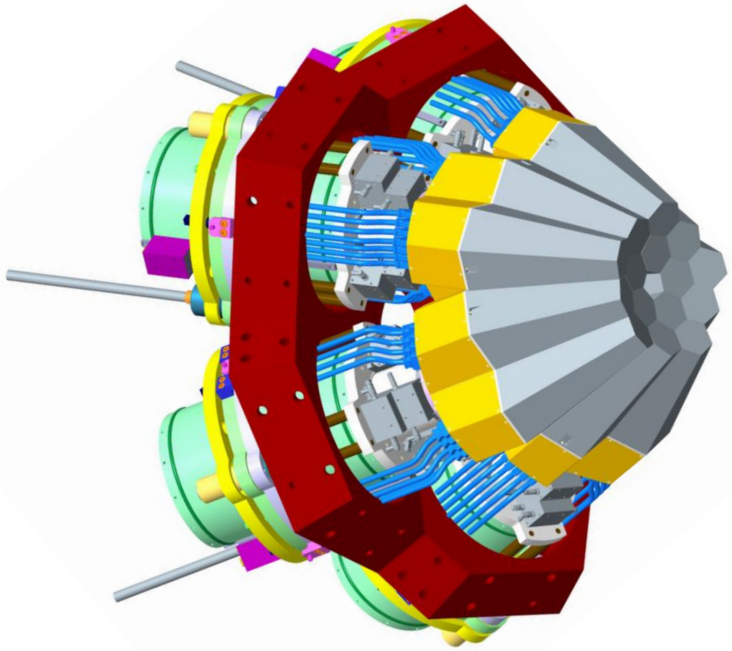


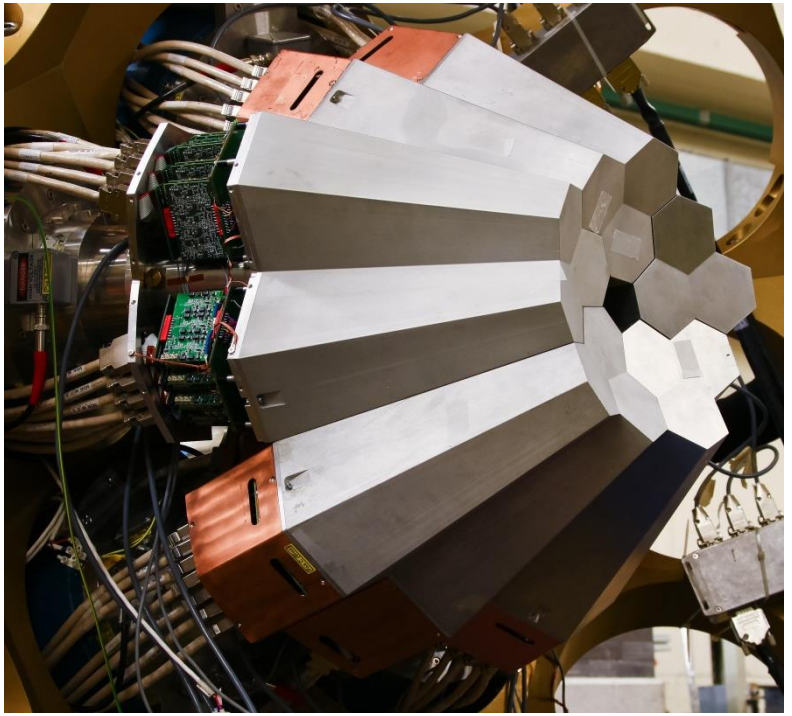




The AGATA Demonstrator

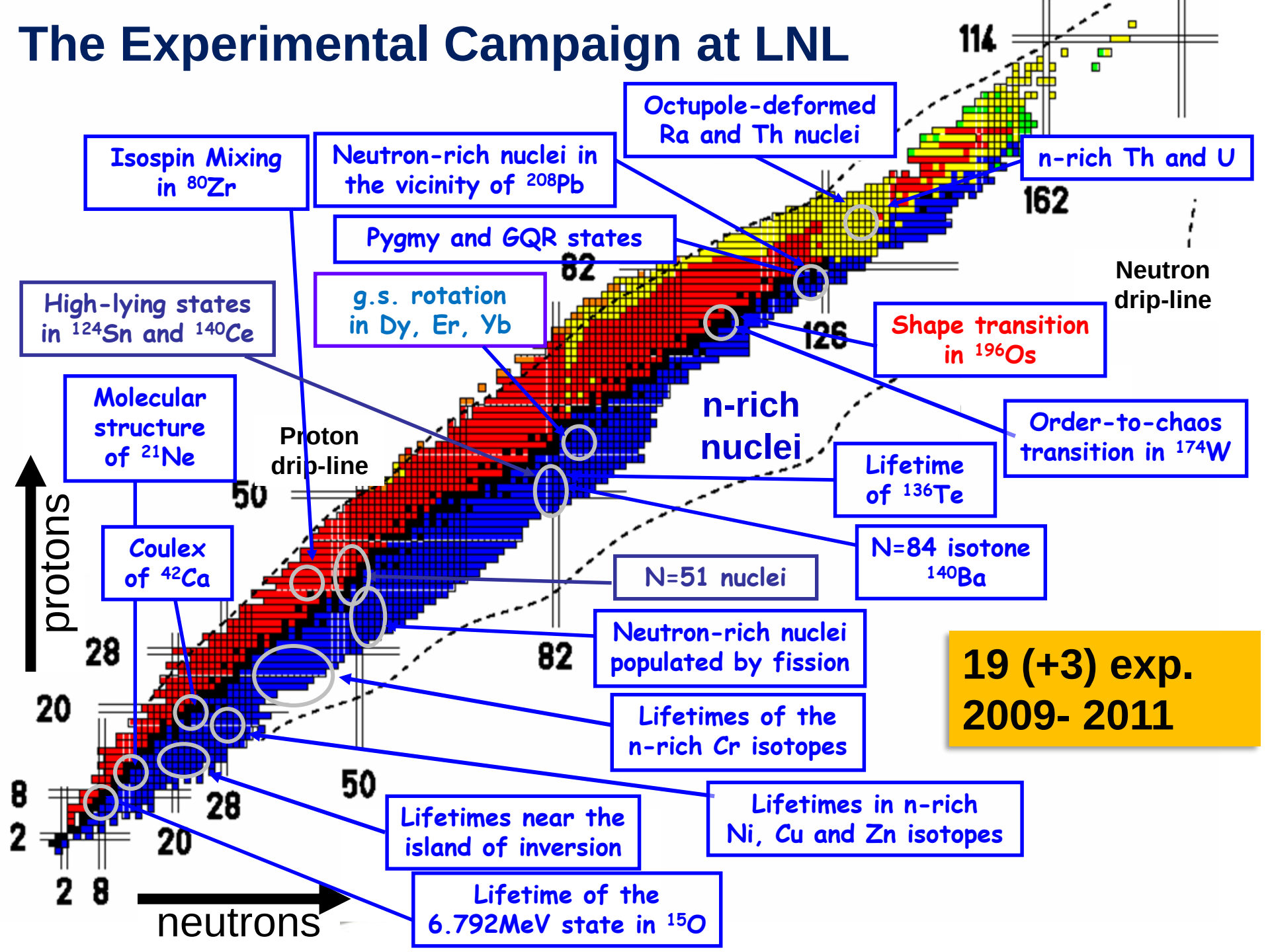
Objective of the final R&D phase 2003-2008





From Design to Reality

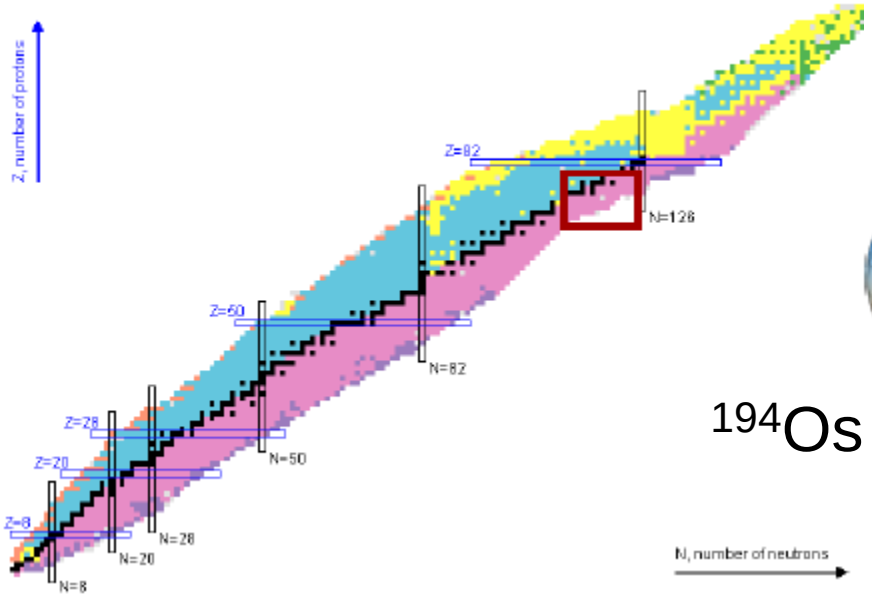
The Experimental Campaign at LNL

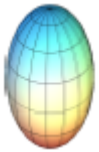


19 (+3) exp.
2009- 2011

Study of shape transitions in the neutron-rich Os isotopes

Philipp John et al.,

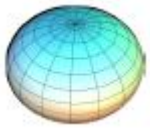




^{194}Os prolate

^{196}Os

?

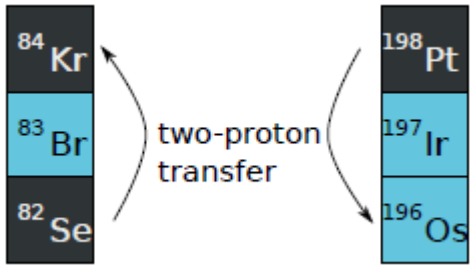


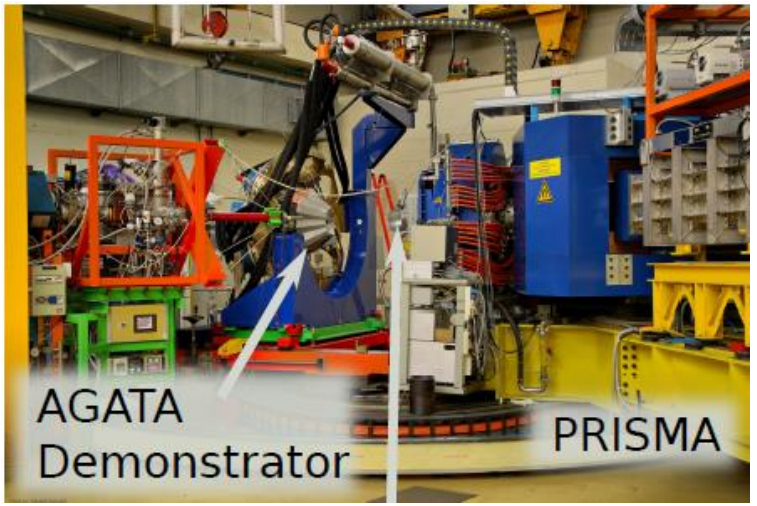
^{198}Os oblate

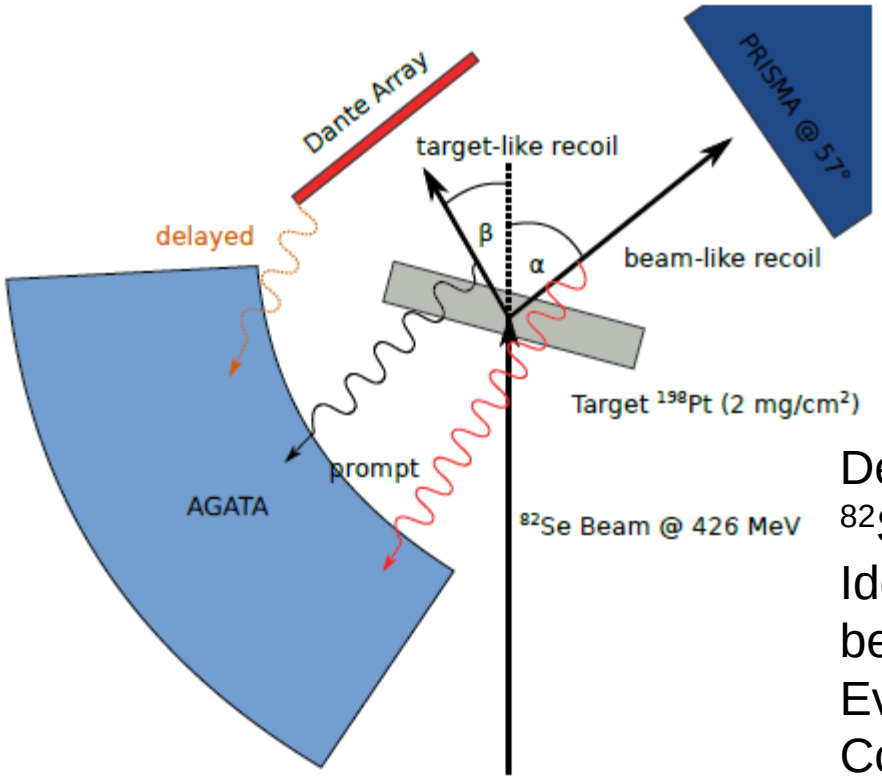
Nuclear shape changes
Across a chain of Os isotopes
Extreme neutron-rich nuclei
No spectroscopic information on ^{196}Os

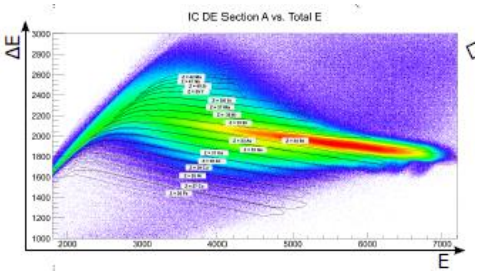
Study of shape transitions in the neutron-rich Os isotopes





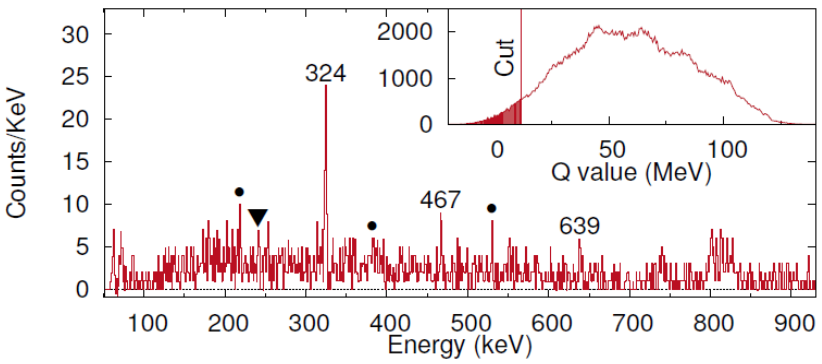




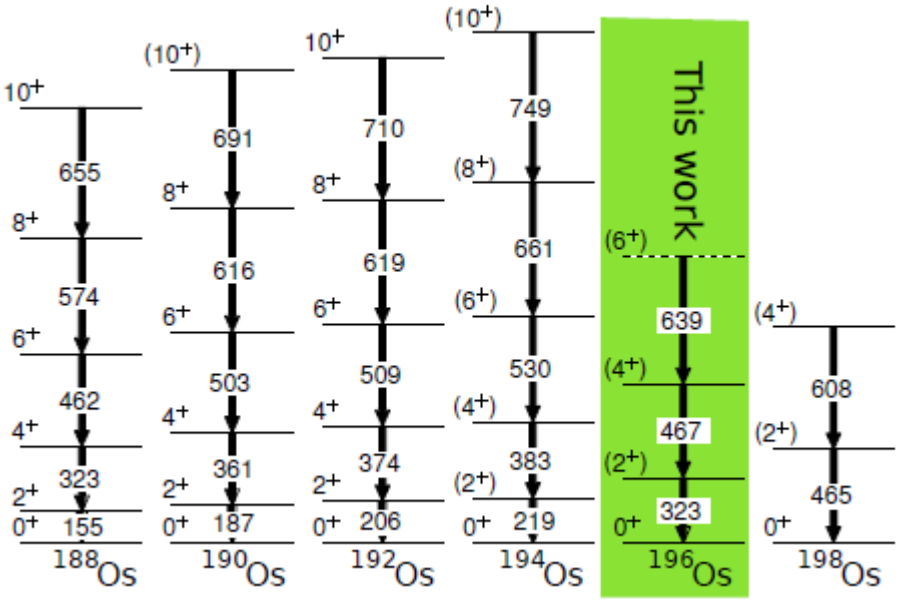


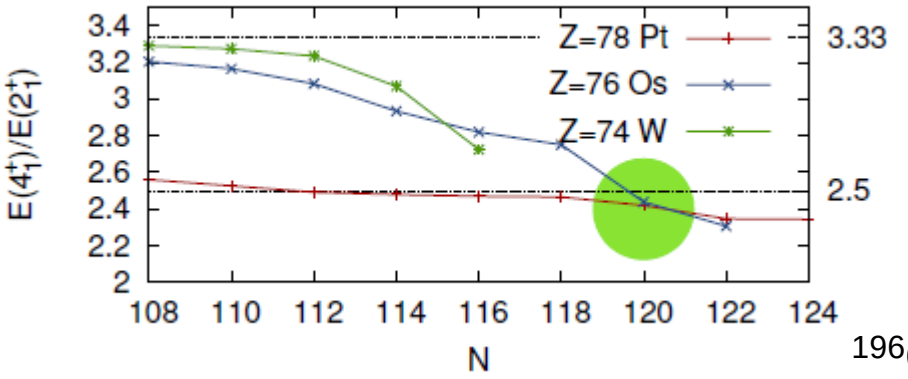
Deep inelastic reaction
^{82}Se on ^{198}Pt target
Identification of mass and charge of beam like recoils
Event by event Doppler correction
Construct angle and velocity of target like ions

Study of shape transitions in the neutron-rich Os isotopes

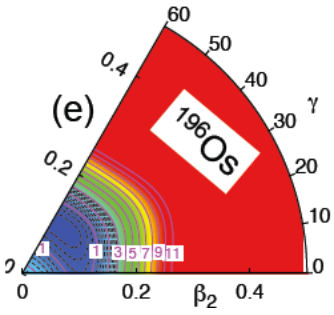


Yrast band of ^{196}Os measured for the first time





E(4⁺)/E(2⁺) ratio close to expected for a gamma-soft nucleus



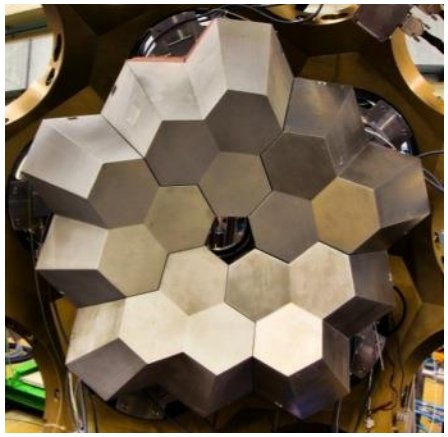
^{196}Os is a transitional nucleus

PHYSICAL REVIEW C 90, 021301(R) (2014) P.R. John et al.,
Shape evolution in the neutron-rich osmium isotopes: Prompt γ-ray spectroscopy of ^{196}Os

AGATA's Deployment

Intense stable beams

2010 → INFN LNL
15 detectors

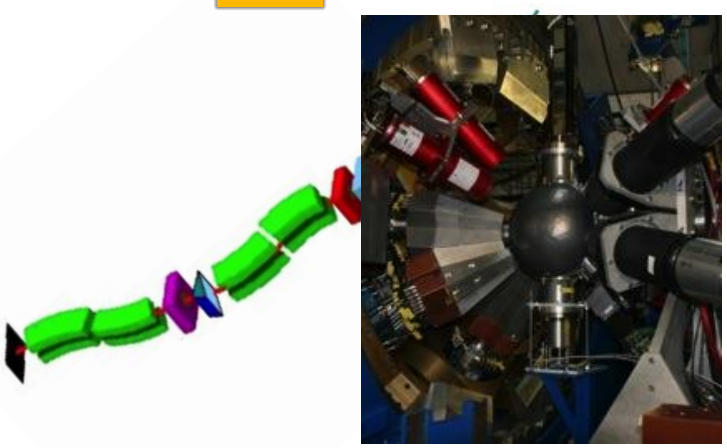


AGATA D.+PRISMA

Total Eff $_{Nominal}$. ~2.6%

Fast Fragmentation beams

2012 2014→ GSI/FAIR
25 detectors

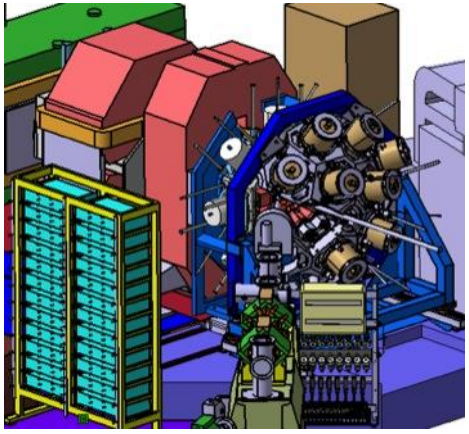


AGATA @ FRS

Total Eff. (β=0.5) ~ 10%

ISOL and stable beams

2014- 16→ GANIL/SPIRAL
45 detectors

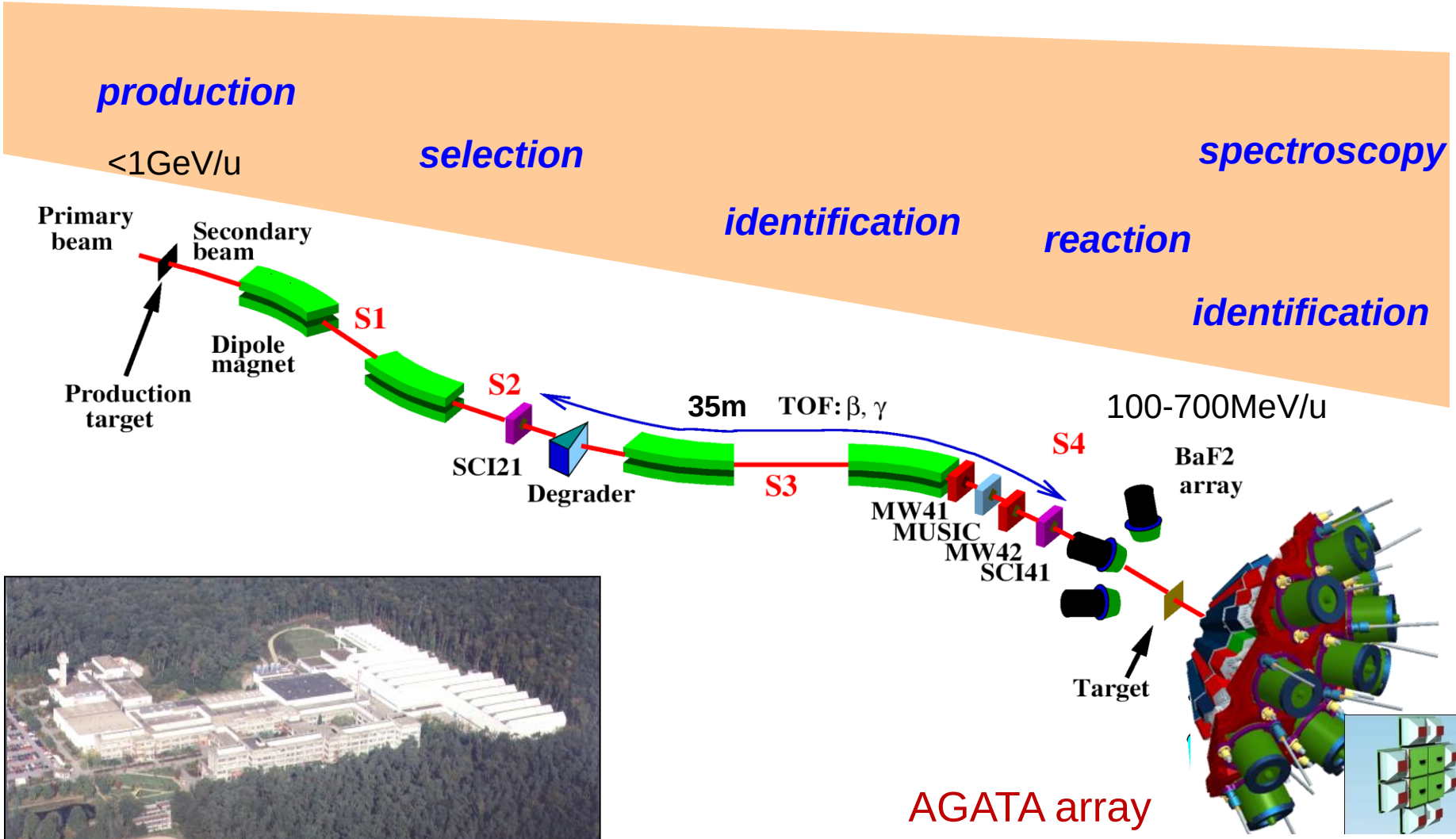


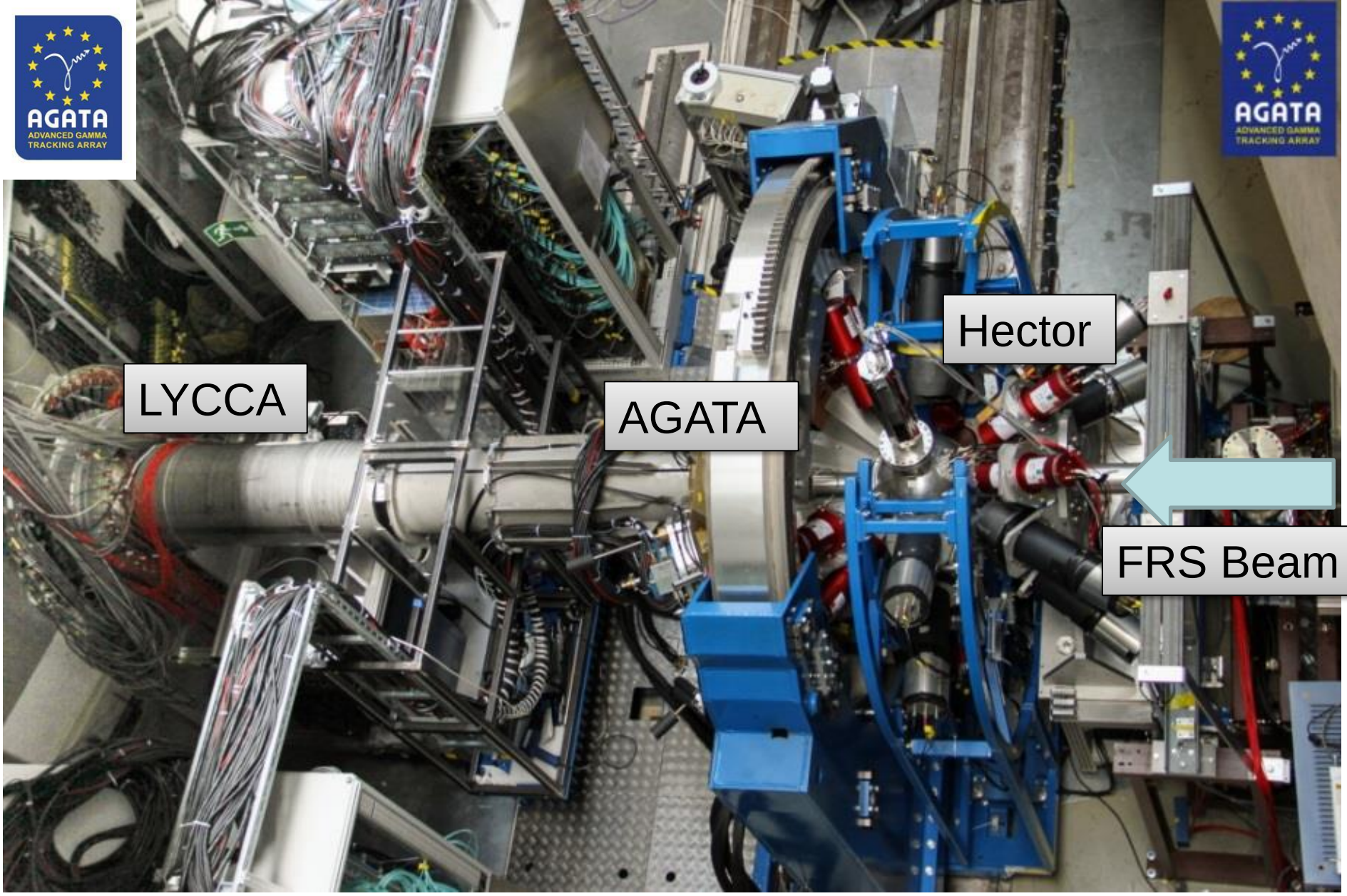
AGATA @GANIL

Total Eff ~ 8% to 14%

AGATA set-up at GSI

In flight high resolution γ-spectroscopy at the FRS



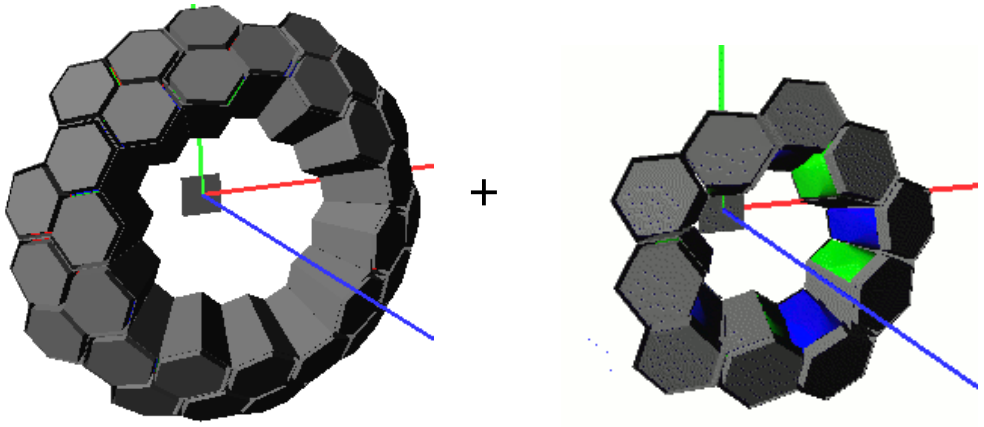


AGATA set-up at GSI

AGATA performance at GSI

Challenge: FRS beam size

High recoill velocities, forward focussed



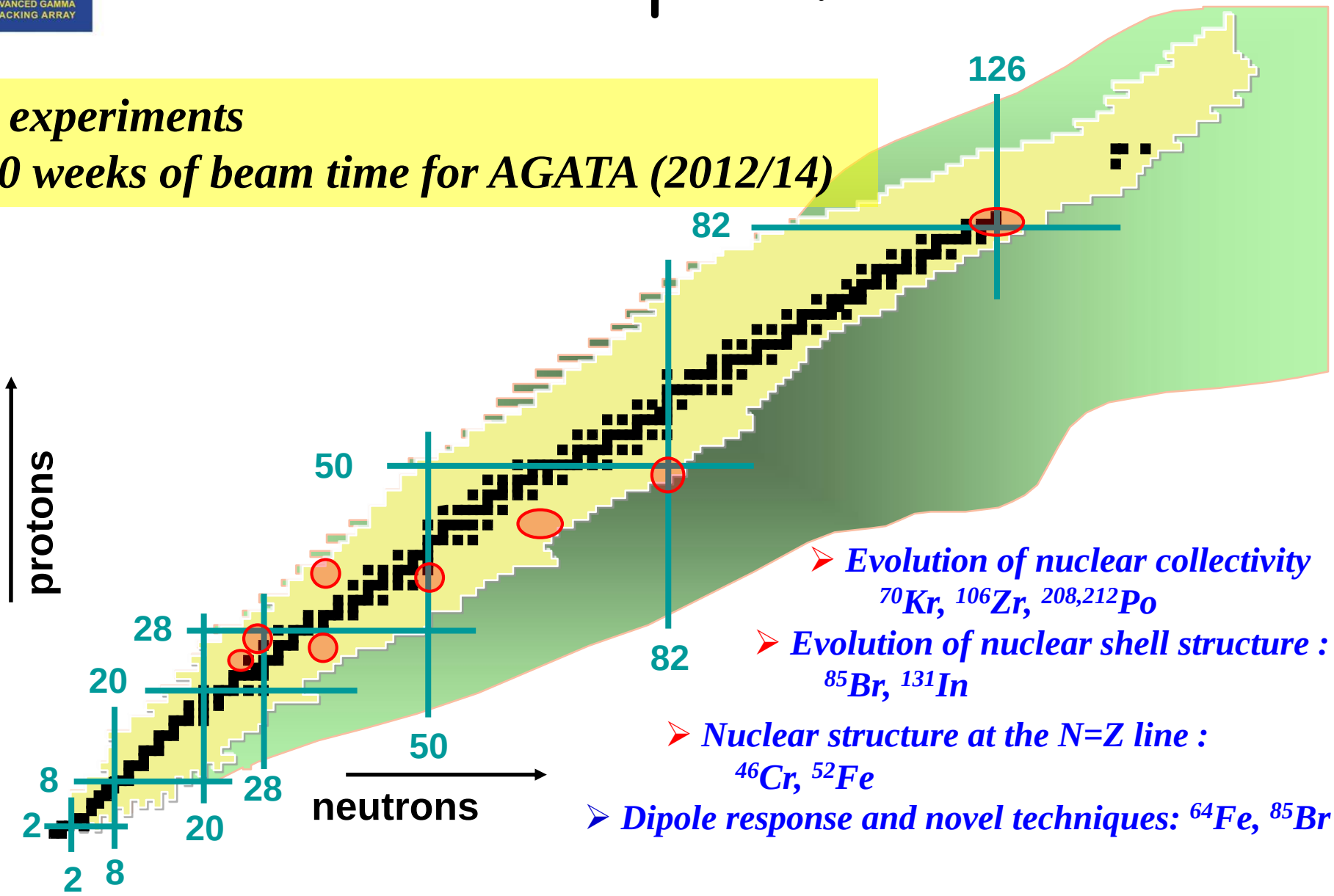
10 triple Cluster + **5 double** Cluster

5 Doubles provide almost 50% of the efficiency



AGATA experiments

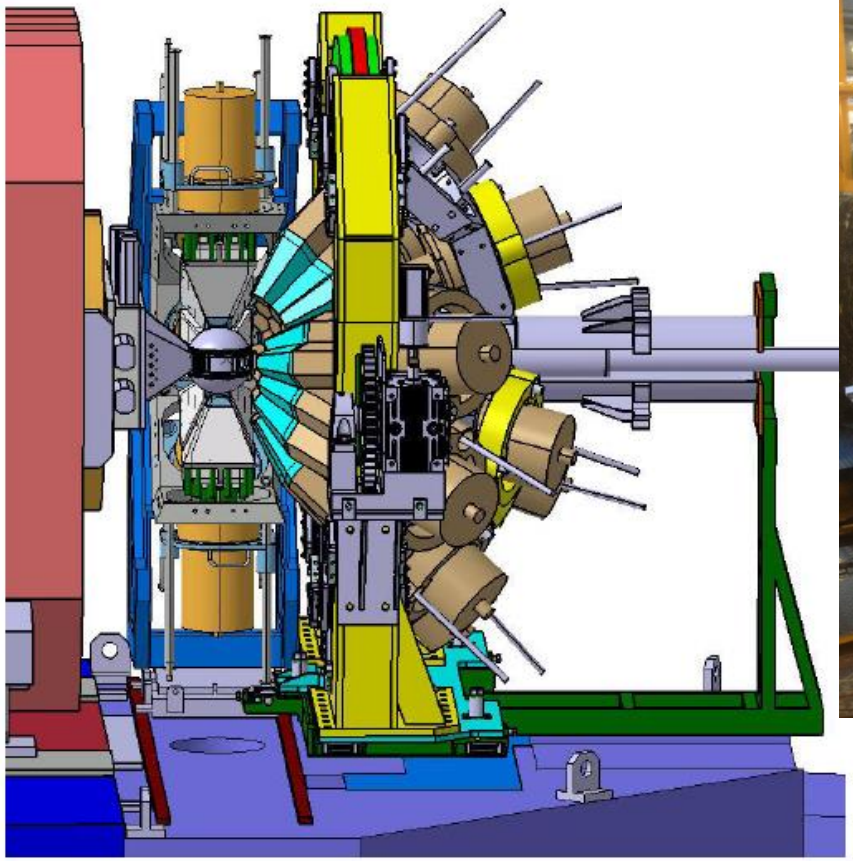
8 experiments
10 weeks of beam time for AGATA (2012/14)



- ***Evolution of nuclear collectivity***
  ^{70}Kr, ^{106}Zr, ^{208,212}Po
- ***Evolution of nuclear shell structure :***
  ^{85}Br, ^{131}In
- ***Nuclear structure at the N=Z line :***
  ^{46}Cr, ^{52}Fe
- ***Dipole response and novel techniques: ^{64}Fe, ^{85}Br***

Next AGATA Campaign: GANIL 2014-(2016)

Installation in progress



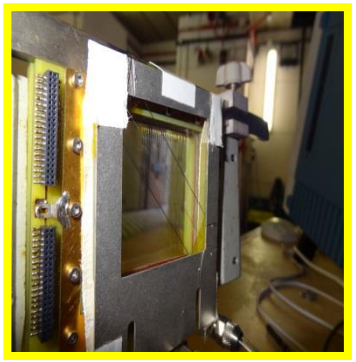


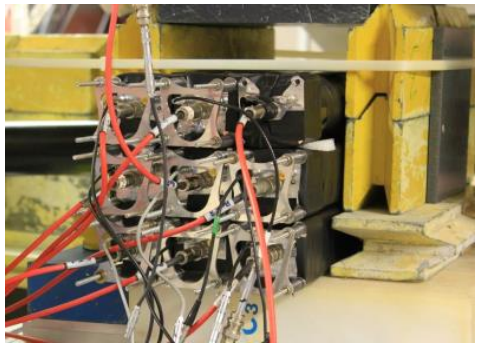
47 Lol's presented as Physics cases for the AGATA campaign in GANIL
AGATA to be used together with VAMOS, EXOGAM2, PARIS, NEDA, DIAMANT, MUST2, FATIMA.
The campaign will start with a dedicated run with AGATA and VAMOS
Expect 9-10 triple cluster at start up in March 2015

Ancillary Detectors

In 2015-2016

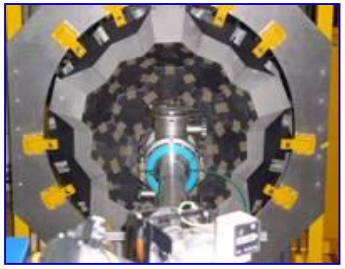
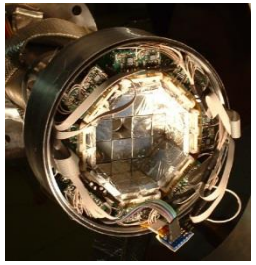
VAMOS vacuum mode
EXOGAM2
Plungers (OUPS& Cologne)
PARIS & FATIMA



From 2016

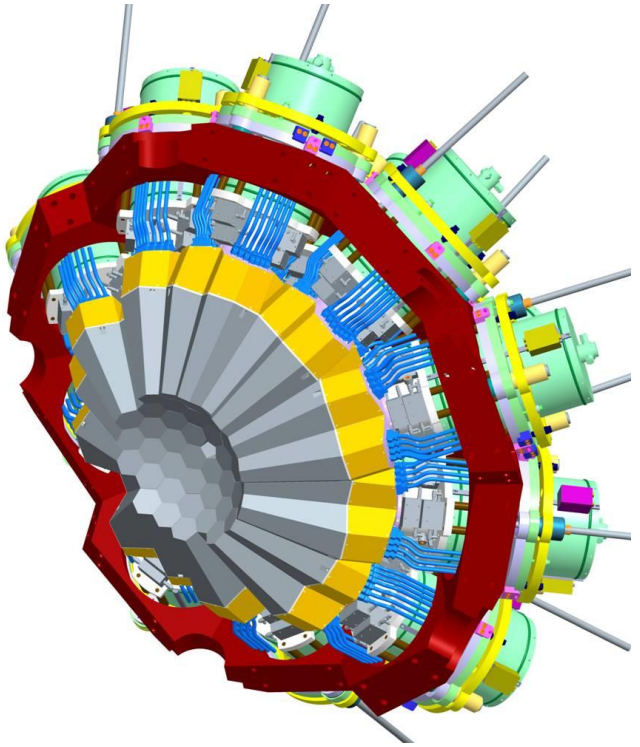
VAMOS Gas-filled
NEDA/NWALL (after Galileo campaign)
DIAMANT
MUST2/GASPARD

The AGATA Phase 1

Objective of phase 1 (2010-2015)



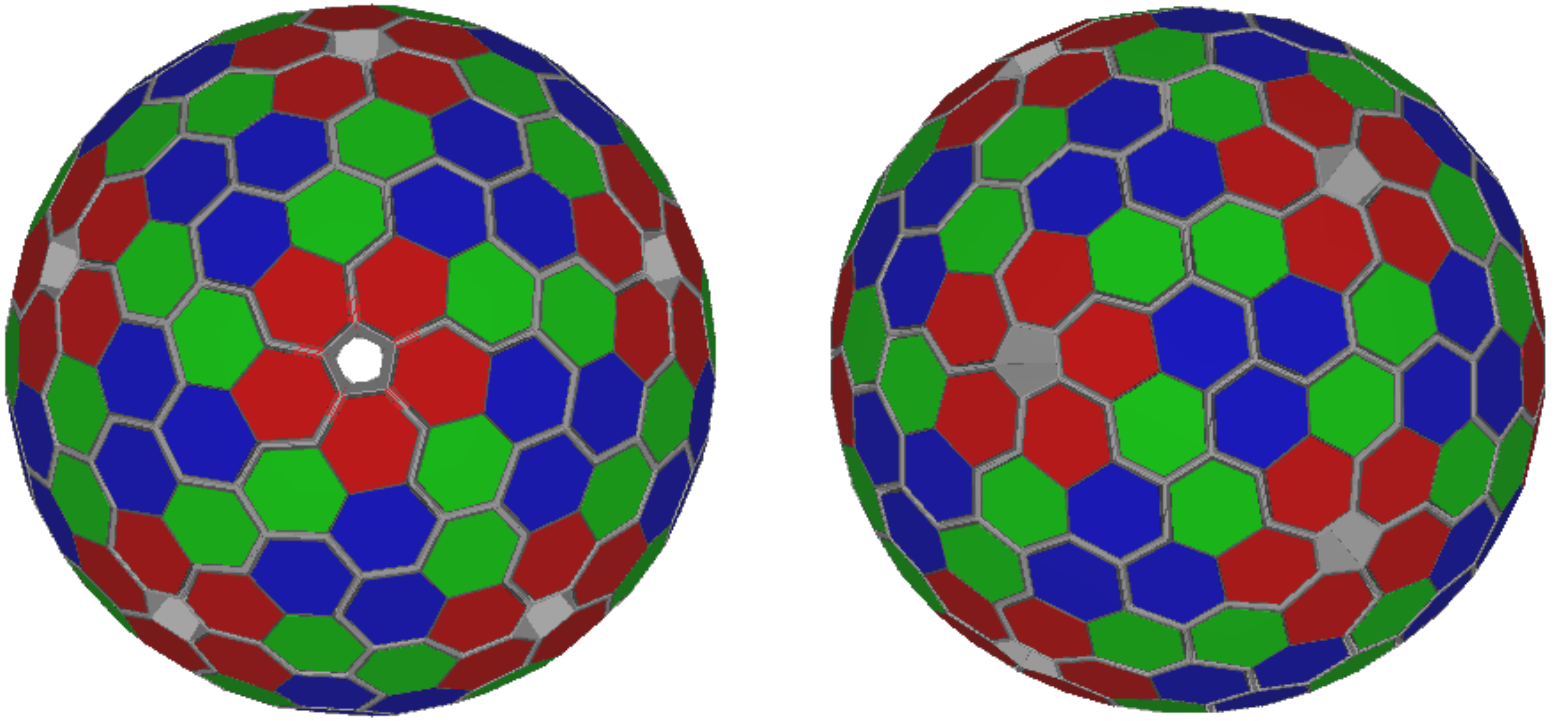


AGATA > 1π

- Phase 1 → 20 triple Clusters (60 Detectors)
- The first "real" tracking array

To be used at **FAIR-HISPEC**, **SPIRAL2-GANIL**, **SPES-LNL …**
Coupled to spectrometers, beam tracker, LCP arrays …

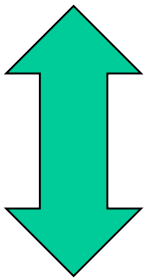
The Phases of AGATA-180



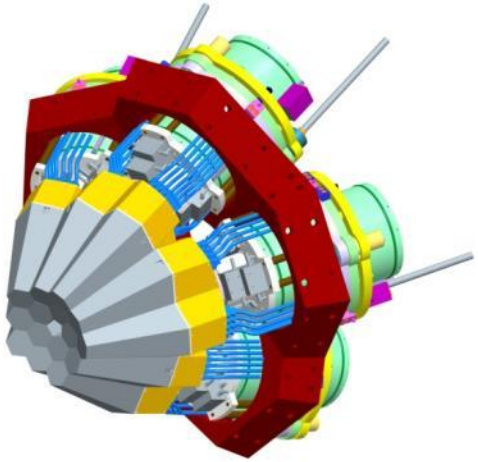
4π Array

KNOWLEDGE EXCHANGE and IMPACT

Scientific Research



Applications



e.g. AGATA
Gamma-ray Tracking
Imaging







AGATA and Applications

Direct application in medical and security areas



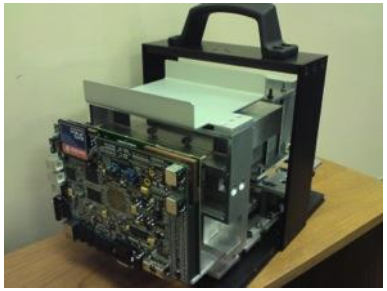


PROSPECTUS

- Novel SPECT imaging system.

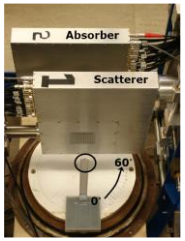
PORGAMRAYS / PGRIS

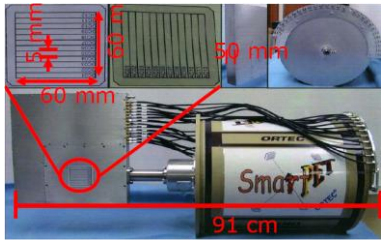
- Hand-held radiation identification and location device

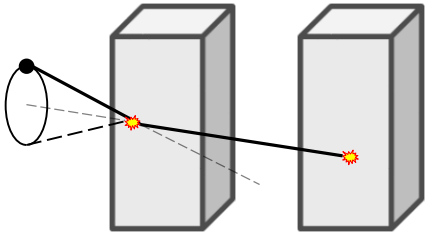


SMARTPET

- Novel Small Animal PET system

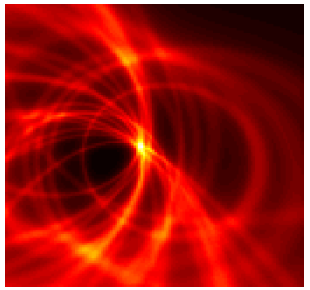






Compton Camera systems
Andrew Boston

Low background systems
Paul Nolan



SUMMARY

- AGATA operational
  - Campaigns at Legnaro and GSI
  - Installation at GANIL
- Continual increase in detectors (electronics) ---60 ….
- Science results emerging
- Impact in applications

Nuclear Instruments and Methods in Physics Research A 668 (2012) 26–58, Akkoyun et al.,

http://npg.dl.ac.uk/agata_acc/index.html

Acknowledgements

AGATA – Advanced Gamma Tracking Array
Nuclear Instruments and Methods in Physics Research A 668 (2012) 26–58

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THANKS