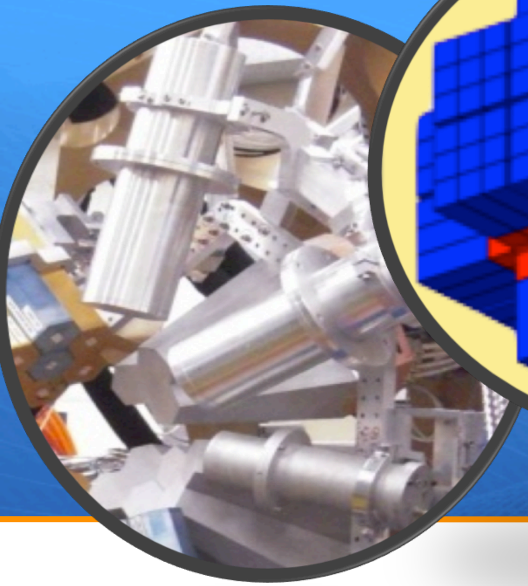
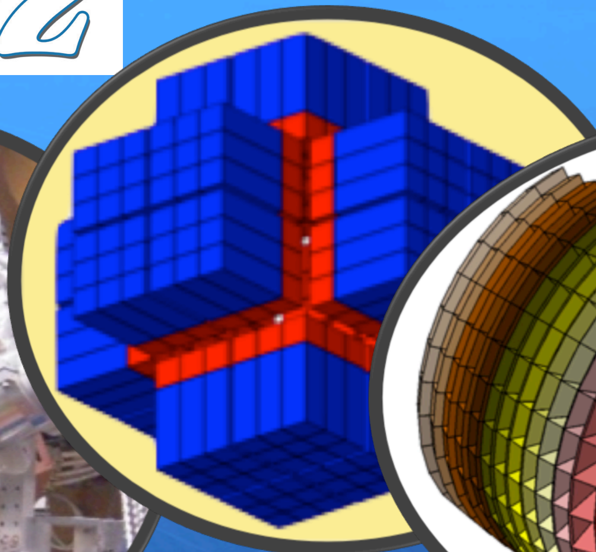
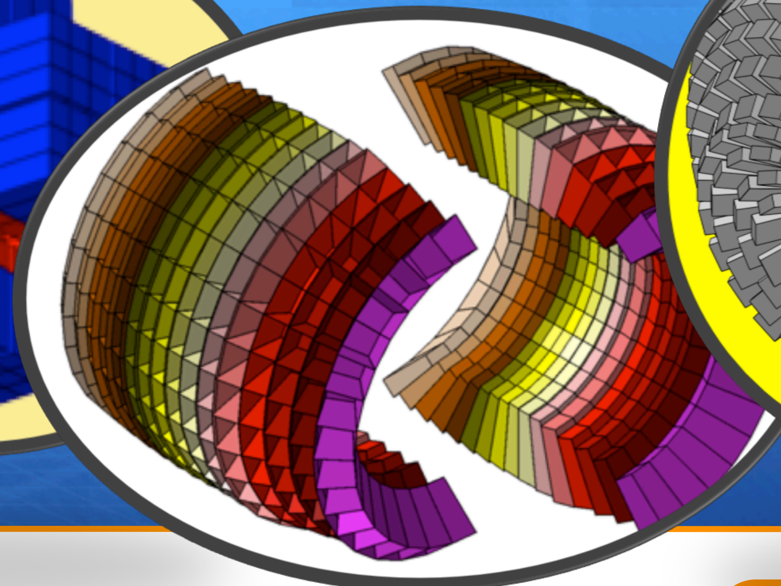
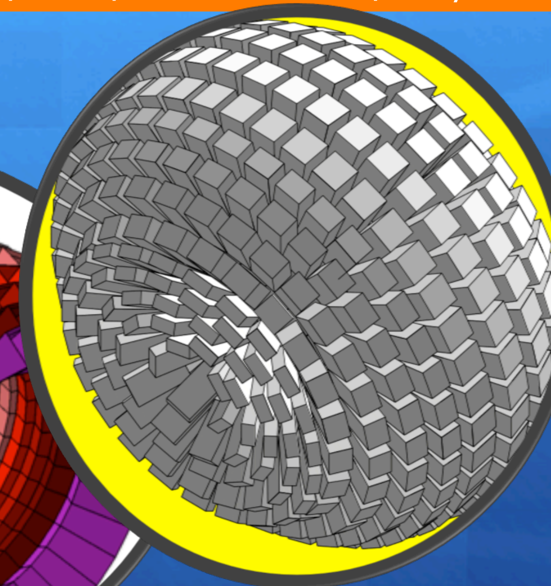
May 20th-25th, 2012; Abano Terme, Italy

# Novel large scintillator arrays for RIB facilities


**Adam Maj (IFJ PAN Kraków)** and
F. Camera (INFN Milano), H. Alvarez Pol (Santiago de Compostella),
P. Dornenball (RIKEN), O. Tengblad (Madrid)
*for the HECTOR, PARIS, CALIFA and SHOGUN collaborations*

# Plan of the talk

- Introduction: HECTOR and HELENA $BaF_2$ arrays
- Novel scintillators: LaBr3
- HECTOR$^+$ for SPES
- PARIS for SPIRAL2
- SHOGUN for RIKEN
- CALIFA array for R3B@NUSTAR at FAIR
- Synergies, GANAS@NupNet project
- Summary

Over last 30 years many scintaillator arrays, made of NaI or $BaF_2$, were constructed and succesfully used:

Cristall Ball (Heidelberg/GSI)

Spin Spectrometer (US)

TAPS (GANIL)

Chateu de Crystal (Strasbourg, GANIL)

MEDEA (Catania)

$BaF_2$ ball (Napoli)

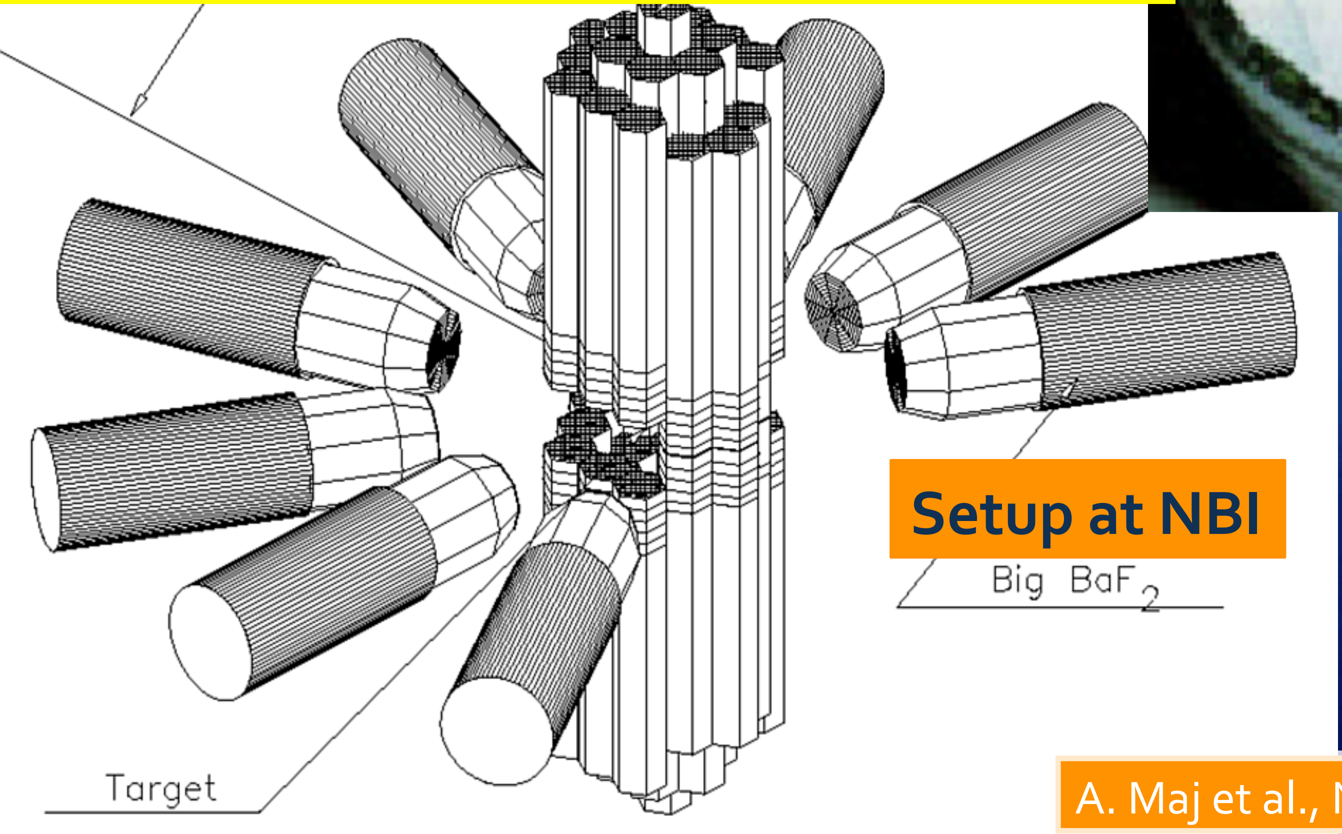
JANOSIK (Warsaw)

HECTOR (NBI, Grenoble, LNL, Argonne, GSI, ...)

# Introduction: HECTOR and HELENA $BaF_2$ arrays

# Built within
# Milano-Copenhagen-Krakow collaboration

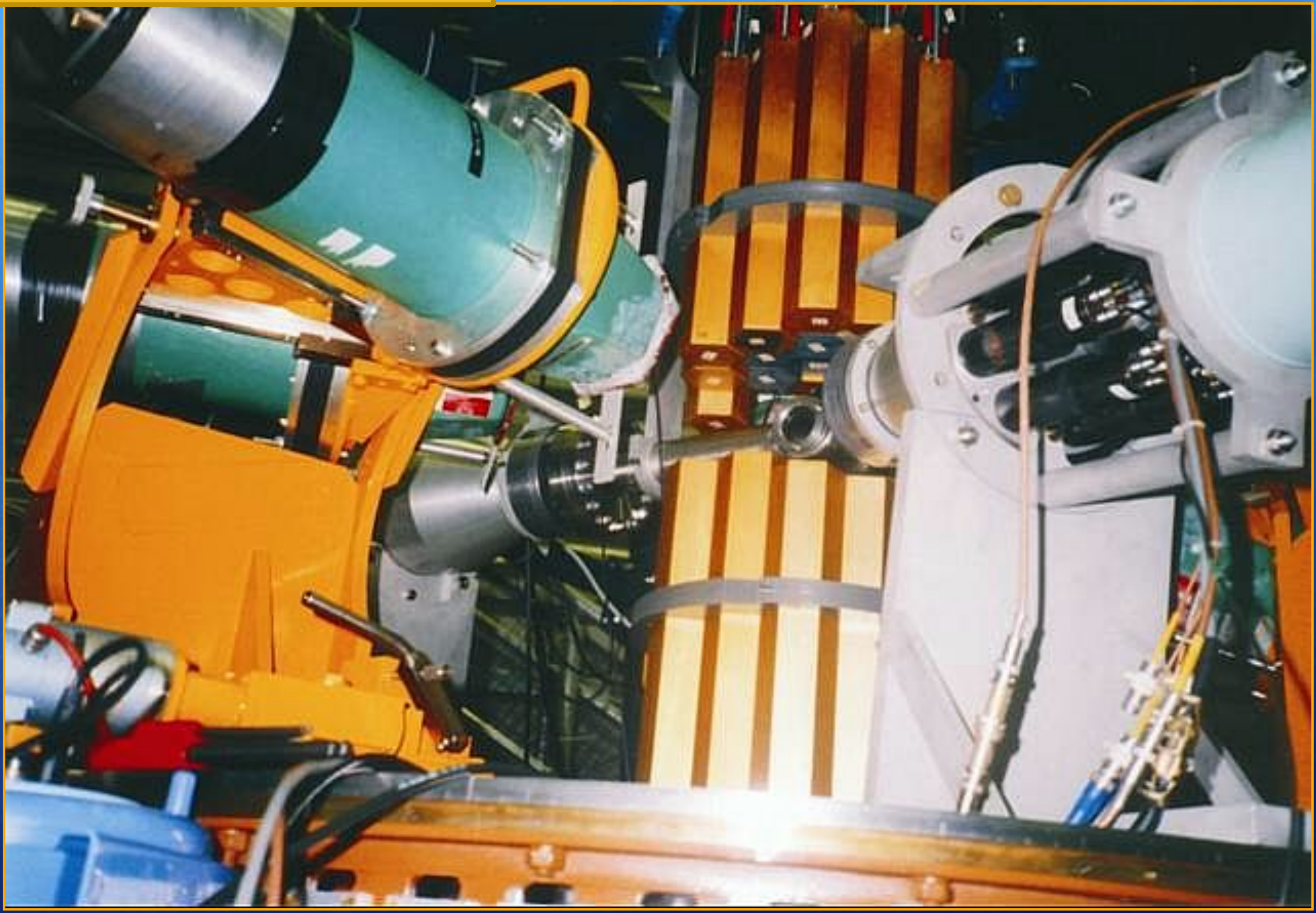
**HECTOR**: 8 big (14cm x 18cm) $BaF_2$ crystals
Time resolution <1 ns
Energy resolution = 11%
**HELENA (multiplicity filter and start signal)**:
38 small BaF2
Time resolution ≈ 500 ps



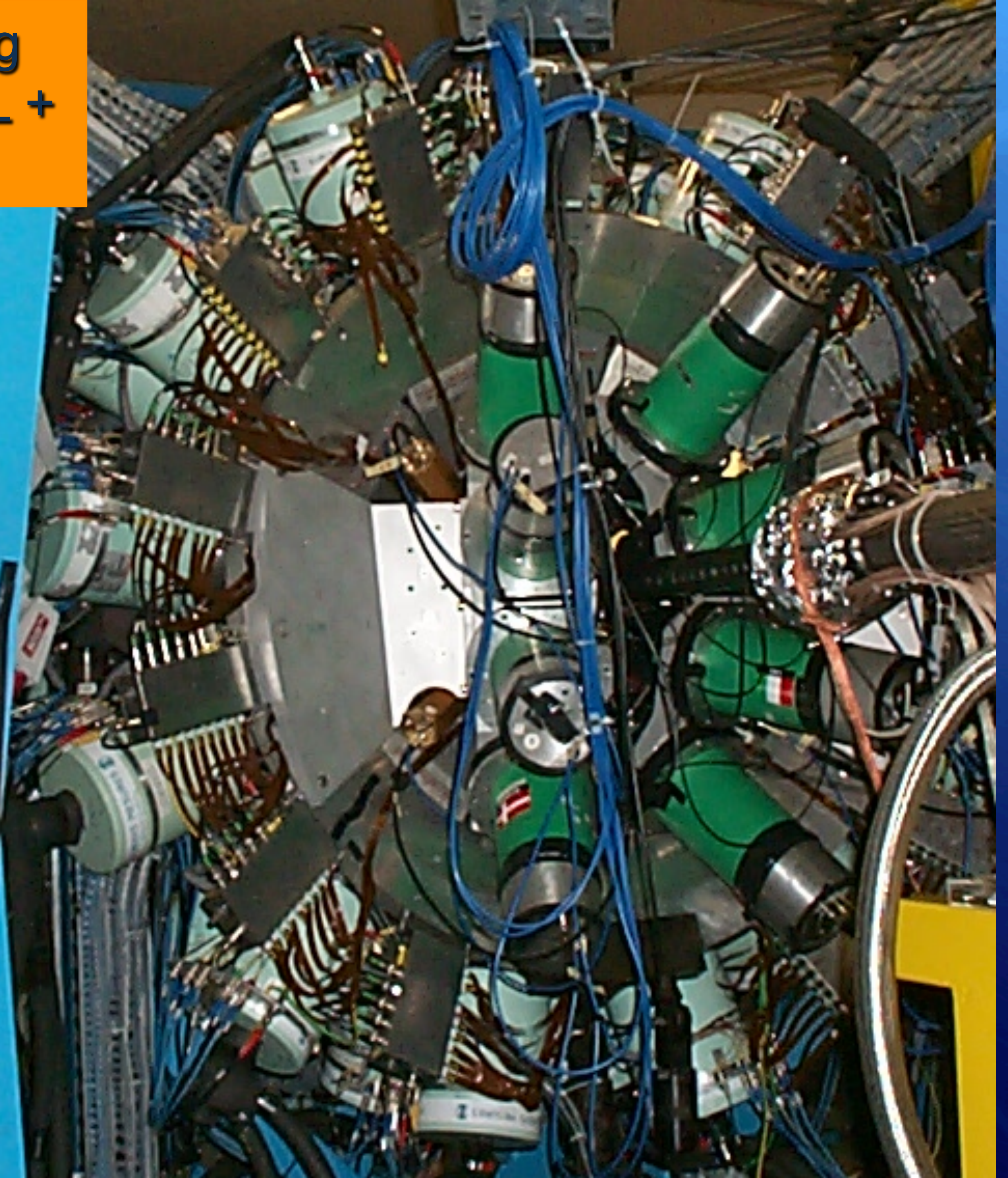

**Setup at NBI**

A. Maj et al., Nucl. Phys. A571 (1994) 185

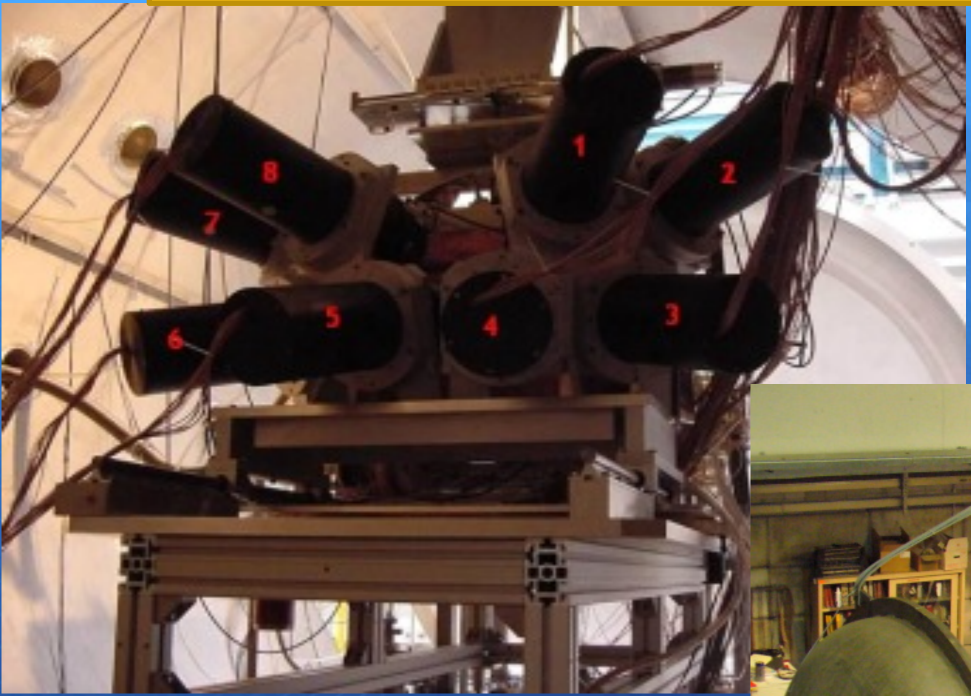
# HECTOR at LNL Legnaro

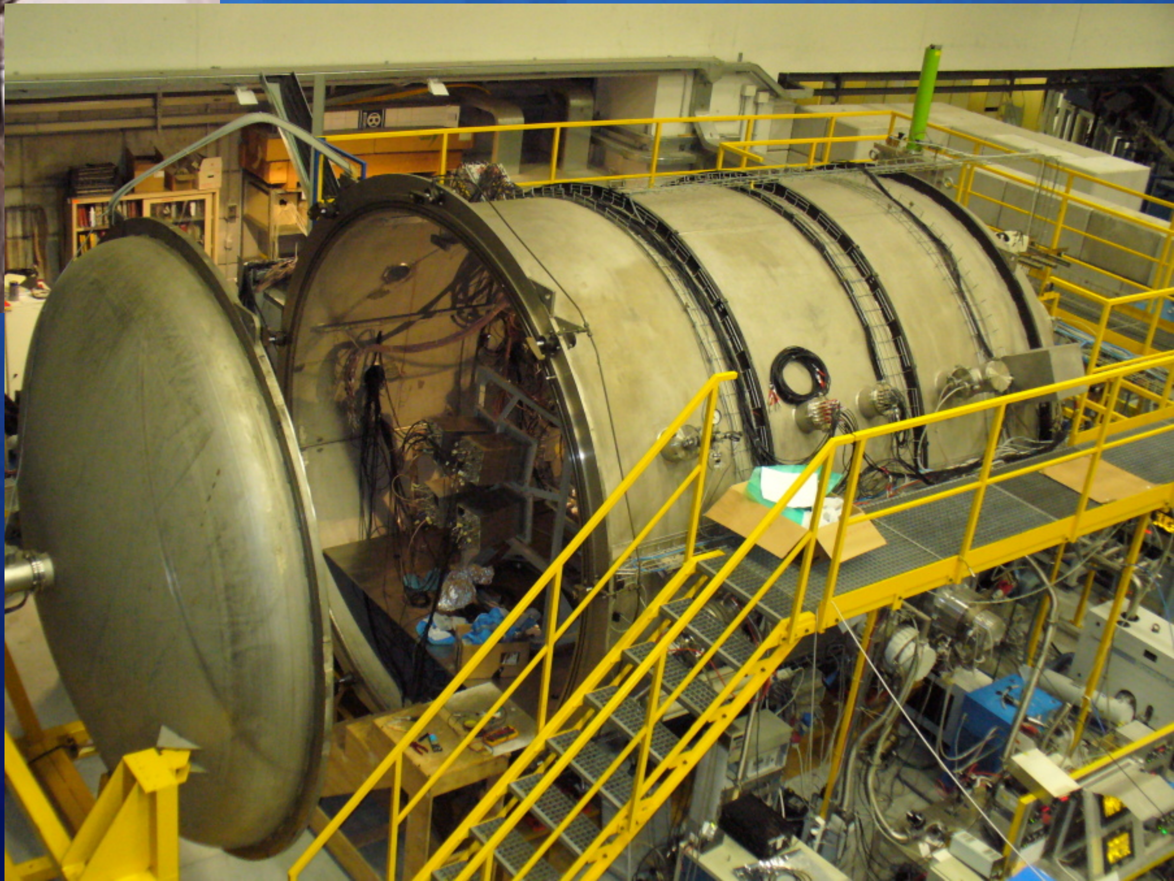


# Setup at IReS Strasburg HECTOR + EUROBALL + InnerBall + EUCLIDES

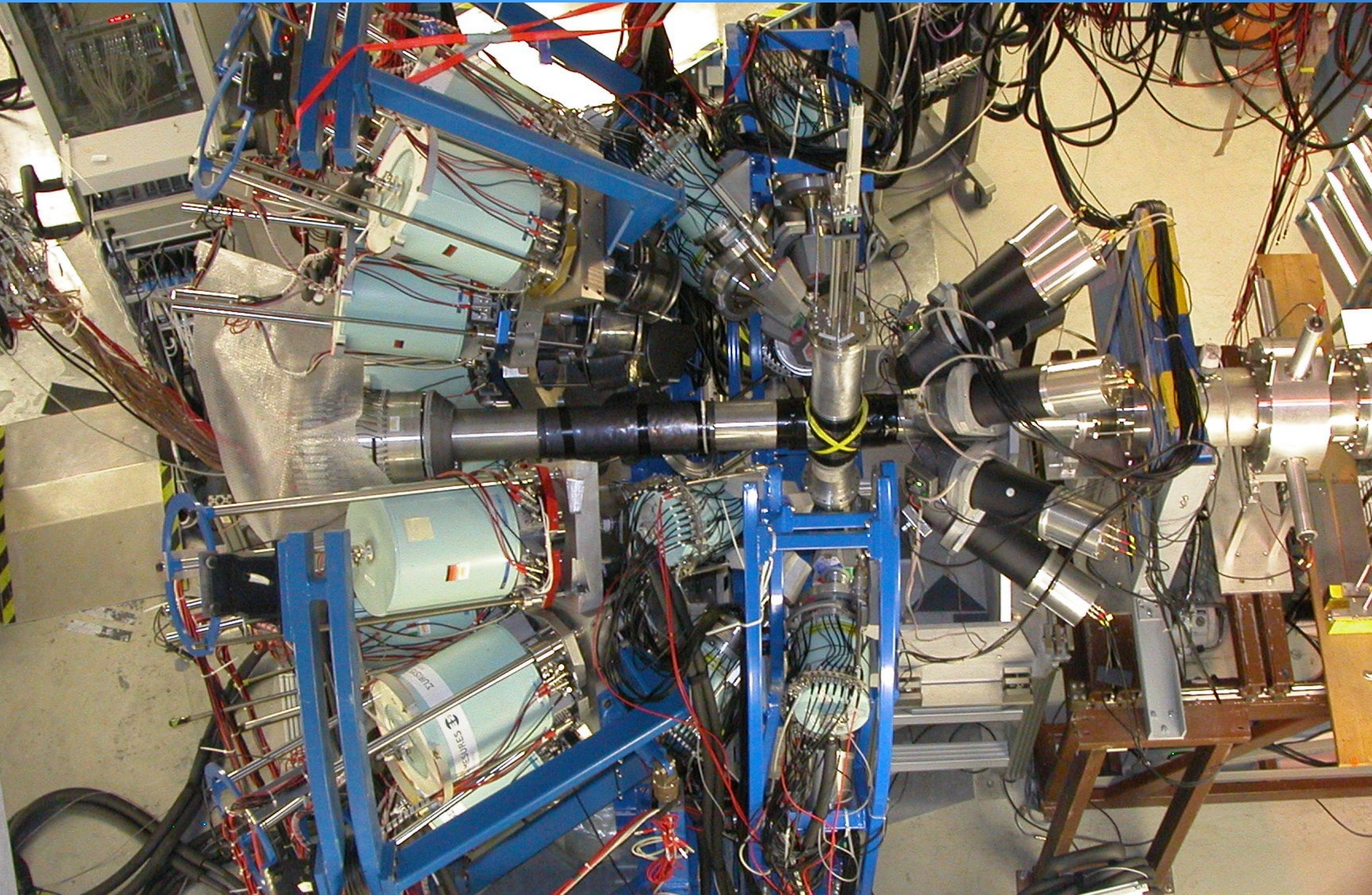


# HECTOR inside GARFIELD chamber at LNL Legnaro



# HECTOR with the RISING setup at GSI



## HECTOR selected main achievements:

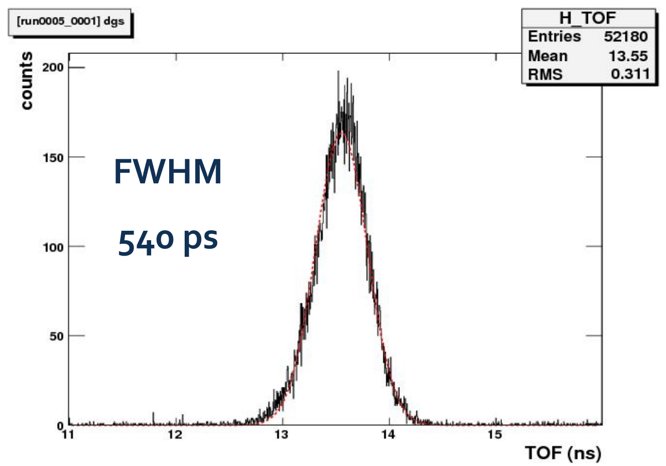
- A.Maj et al., "Phase Space Selection of the GDR gamma-ray emission from hot 162Yb nuclei", Phys. Lett. 291, 385 (1992)
- A.Bracco et al.,"Increase in width of the GDR in hot nuclei:shape change or collisional damping?" PRL 74, 3748 (1995)
- T.Tveter et al., "Collective Dipole Motion in highly excited 272Hs (Z=108) nuclei", PRL 76, 1035 (1996)
- F. Camera et al. "Probing the shape of hot 194Hg at high spins with the GDR decay in selected cascades", PRC 60, 014306 (1999)
- G.Benzoni et al., "Effect of E1 decay in the population of superdeformed structures", Phys. Lett. 540B, 199 (2002)
- A.Maj et al, "Evidence for the Jacobi shape transition in hot 46Ti", Nucl. Phys. A731, 319 (2004)
- M. Kmiecik et al., "Probing nuclear shape close to the fission limit with the GDR in 216Rn", Phys. Rev. C 90, 064317 92004)
- O. Wieland et al. "Search for the Pygmy Dipole Resonance in 68Ni at 600 MeV/u", PRL 102, 092502 (2009)
- A. Corsi et al., "Measurement of isospin mixing at a finite temperature in 80Zr via giant dipole resonance decay", Phys. Rec. C 84, 041304 (2011)

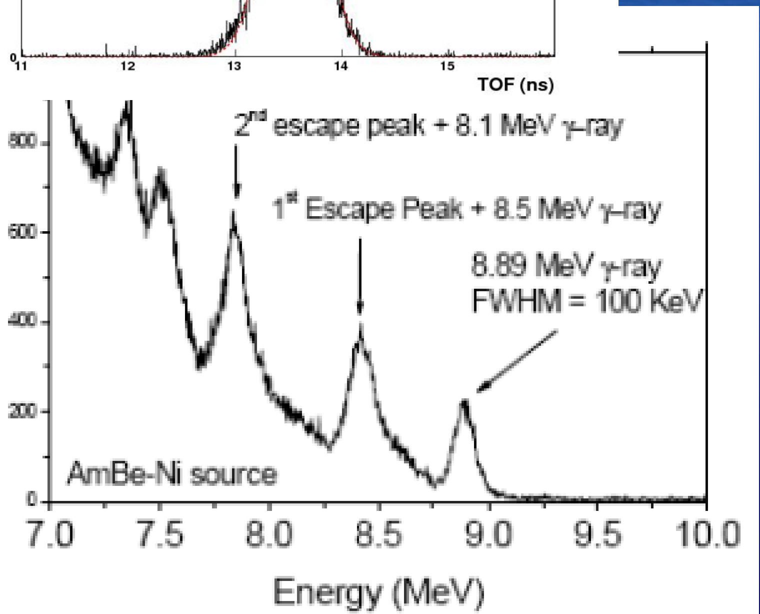
# Novel scintillators: $LaBr_3$

# LaBr3(Ce) from Saint Gobain

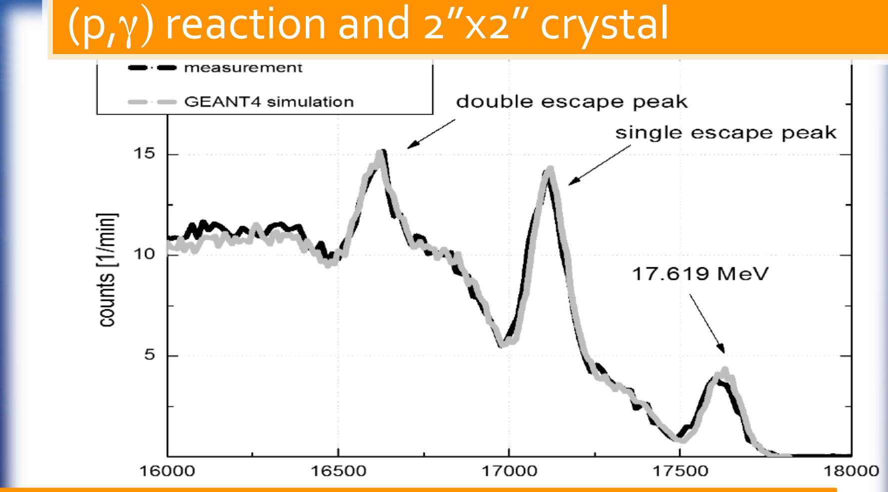
large light output (>60000 ph/MeV)
high efficiency (>60% up to 10 MeV)
→spectroscopy far from stability
energy resolution (3% at 662 keV, 0.6% at 18 MeV)
→spectroscopy far from stability
time resolution (~250 ps)
→discrimination against neutrons
fast light pulse decay (~16 ns)
→high counting rate capability
very good temperature stability

Milan group: Source and 3"x3" crystal



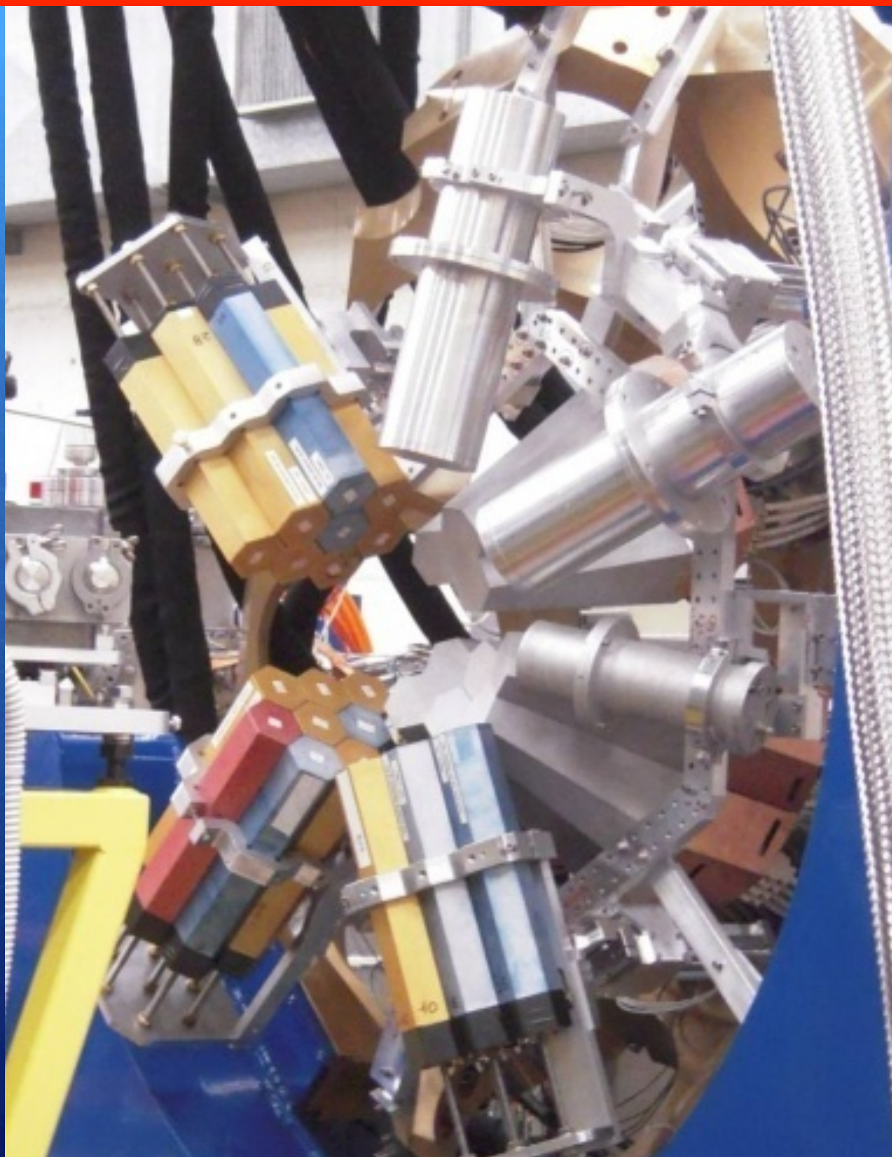

Debrecen-Sofia-Orsay-Krakow group: (p,γ) reaction and 2"x2" crystal



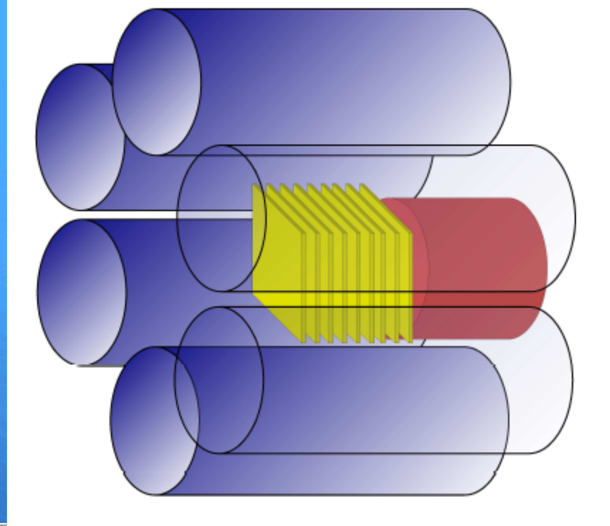

M. Ciemała et al., NIM A608, 76 (2009)

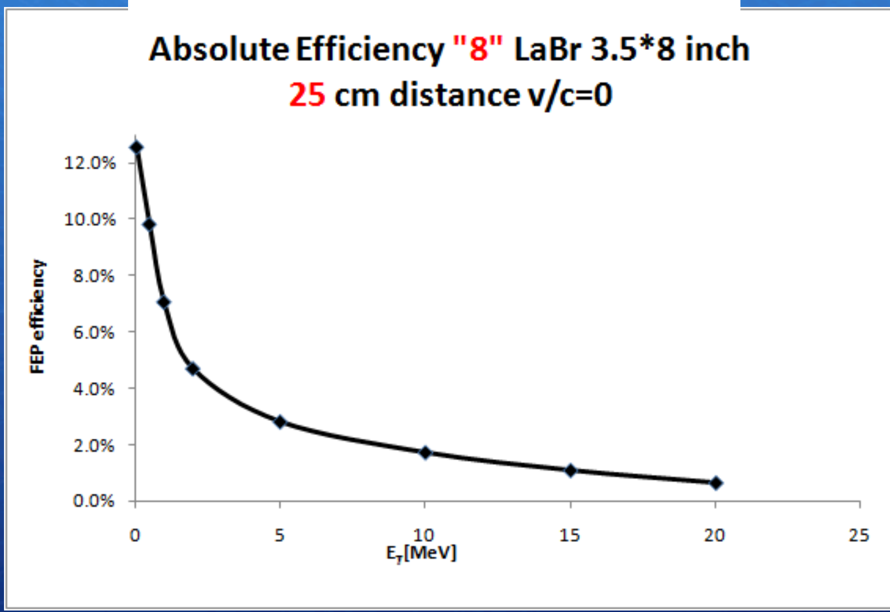
# HECTOR+ for SPES

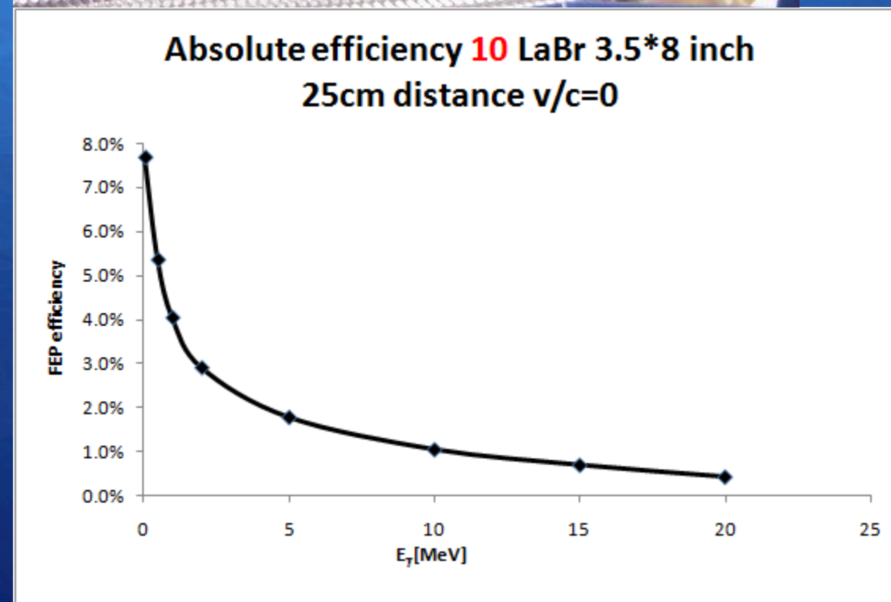
8 Large $BaF_2$ detectors from HECTOR were replaced by 10 large (9x20 cm) $LaBr_3(Ce)$ crystals




**Project coordinator: Franco Camera**





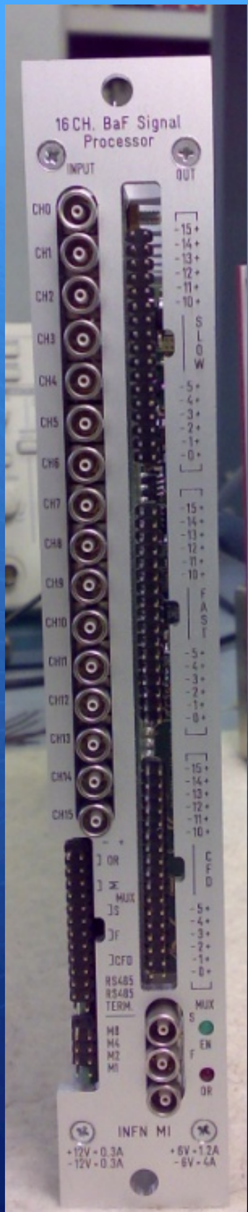




8 $LaBr_3$:Ce in barrel configuration
Solid angle covered ≈ 12.5 %
Absolute F.E.P. efficiency at 2 MeV ⇒ 5 %
Absolute F.E.P. efficiency at 10 MeV ⇒ 1.7 %

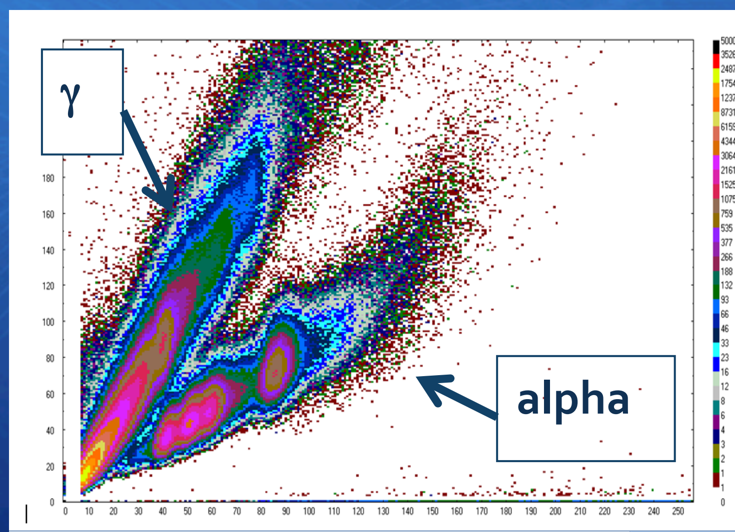
10 LaBr3:Ce in standard configuration
Solid angle covered ≈ 7.7 %
Absolute F.E.P. efficiency at 2 MeV ⇒ 3 %
Absolute F.E.P. efficiency at 10 MeV ⇒ 1 %

# PSA in $LaBr_3$:Ce and $LaCl_3$:Ce

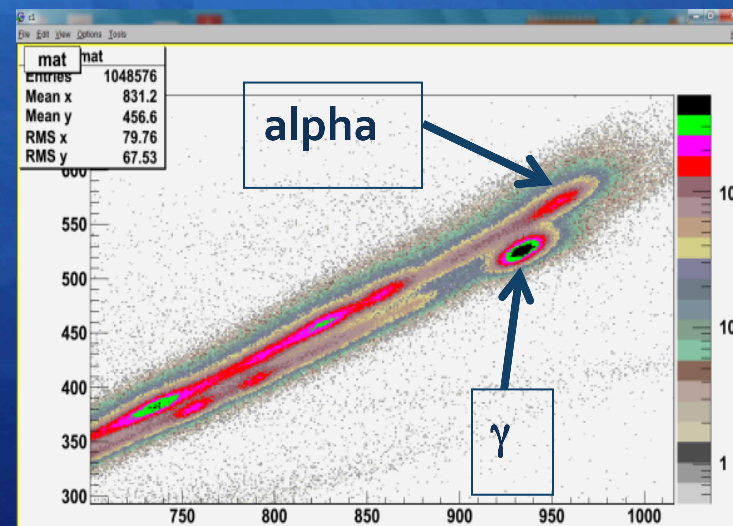
## BaFPro Nim module




16 channels of Shaping amplifier
16 channeld of CFD
16 Channer of peak stretcher for $BaF_2$ Fast component

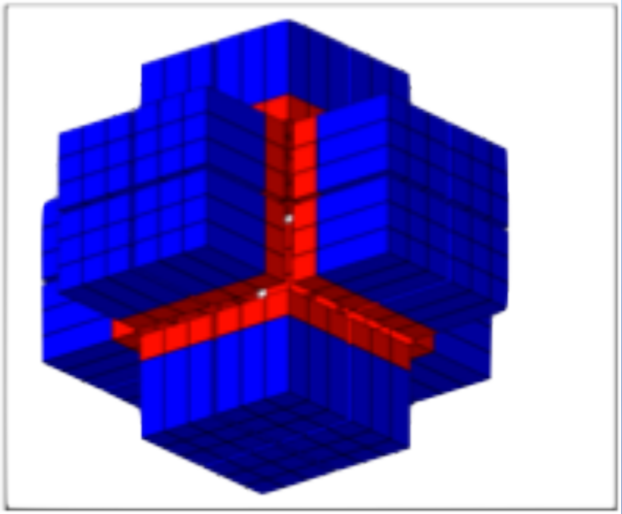



Fast vs Slow in a 2″x3″ $BaF_2$ detector




Fast vs Slow in a 3″x3″ $LaBr_3$:Ce detector

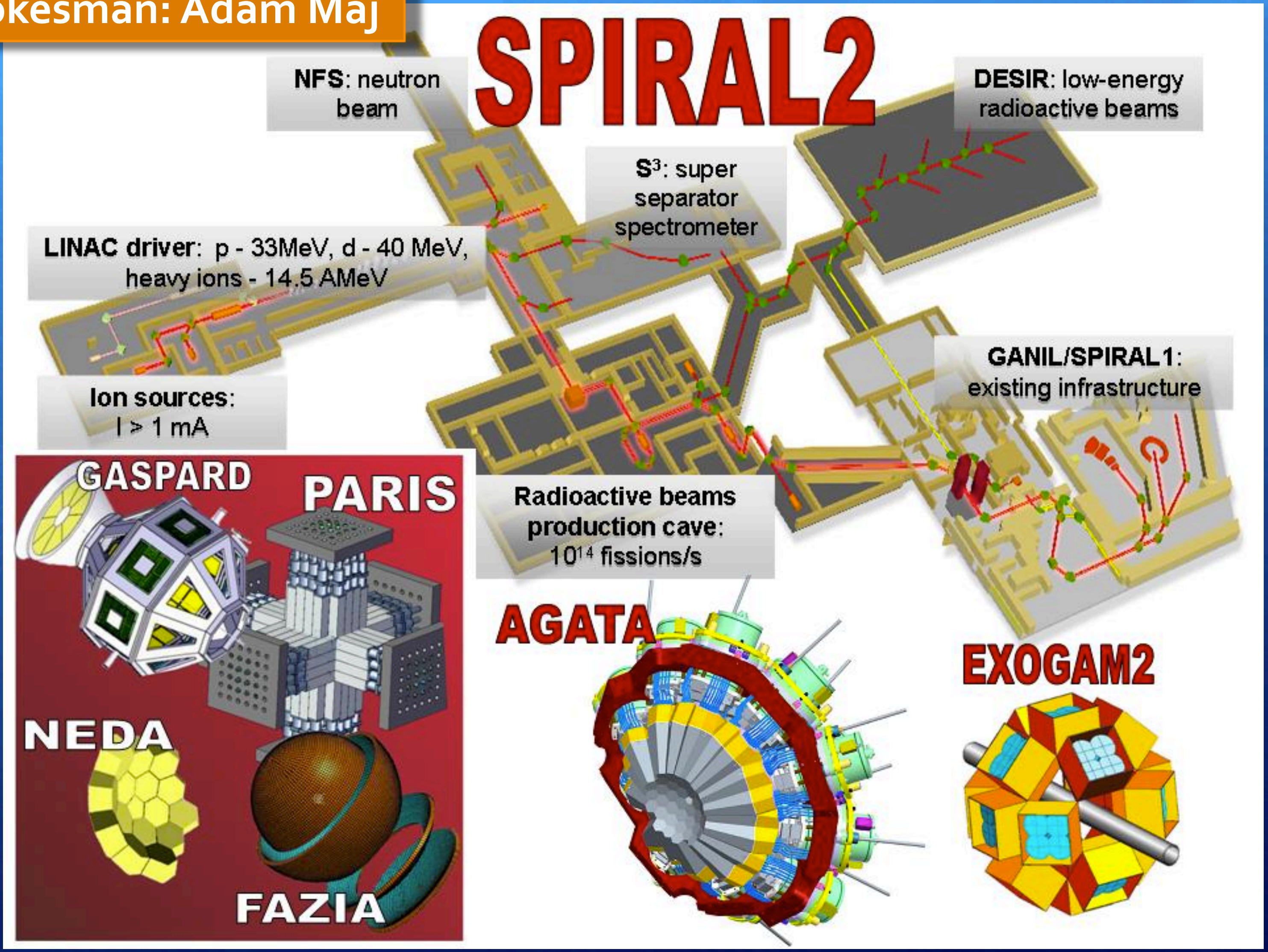
*F. Camera, Priv. Comm.*



http://paris.ifj.edu.pl

# PARIS for SPIRAL2

## PARIS project spokesman: Adam Maj




→ talk of Herve Savajols

# PARIS desing concepts:

**Design and build high efficiency detector consisting of 2 shells *(or 1 phoswich shell)* for medium resolution spectroscopy and calorimetry of γ-rays in large energy range**

- Inner sphere, highly granular, made of new crystals (LaBr3(Ce)), to be used as a multiplicity filter of high resolution, sum-energy detector (calorimeter), detector for the gamma-transition up 10 MeV with medium energy resolution. It may serve also for fast timing application.
- Outer sphere, with high volume detectors, made of conventional crystals (BaF2 or NaI), to be used for high-energy photons measurement or as an active shield for the inner shell..
- 2-shell or phoswich concept, in addition to being more economic, shall help to distinguish a high-energy photon from a cascade of low energy gamma transitions in fusion evaporation reactions

# PARIS physics cases for SPIRAL2

* - flagship

**a) Jacobi and Poincare shape transitions (+AGATA) ***
*$^{130-142}$Ba, $^{116-120}$Cd, $^{88-98}$Mo, $^{71}$Zn*
(A. Maj, J. Dudek, K. Mazurek et al.)

**b) Studies of shape phase diagrams of hot nuclei – GDR differential methods**
*$^{186-193}$Os, $^{190-197}$Pt*
(I. Mazumdar, A. Maj et al.)

**c) Hot GDR studies in neutron rich nuclei ***
(D.R. Chakrabarty, M. Kmiecik et al.)

**d) Isospin mixing at finite temperature**
*$^{68}$Se, $^{80}$Zr, $^{84}$Mo, $^{96}$Cd, $^{112}$Ba*
(M. Kicińska-Habior et al.)

**e) Onset of the multifragmentation and the GDR (+FAZIA)**
*120<A<140, 180<A<200*
(J.P. Wieleczko, D. Santonocito et al.)

**f) Reaction dynamics by means of γ-ray measurements**
*$^{214-222}$Ra, $^{118-226}$Th, $^{229-234}$U*
(Ch. Schmitt, O. Dorvaux et al.)

**g) Heavy ion radiative capture ***
*$^{24}$Mg, $^{28}$Si*
(S. Courtin, D.G. Jenkins et al.)

**h) Multiple Coulex of SD bands**
*36<A<50*
(P. Napiorkowski, F, Azaiez, A. Maj et al.)

**i) Relativistic Coulex (SPIRAL2 post-accelerated beams)**
*40<A<90*
(P. Bednarczyk et al.)

**j) Nuclear astrophysics (p,γ)**
**e.g.** *$^{90}$Zr*
(S. Harissopulos al.)

**k) Shell structure at intermediate energies (SISSI/LISE)**
*20<A<40*
(Z. Dombradi et al.)

**l) Shell structure at low energies (separator part of S³) ***
*30<A<150*
(F. Azaiez, I. Stefan, B. Fornal et al.)

**m) PDR studied with GASPARD+PARIS**
D. Beaumel et al.

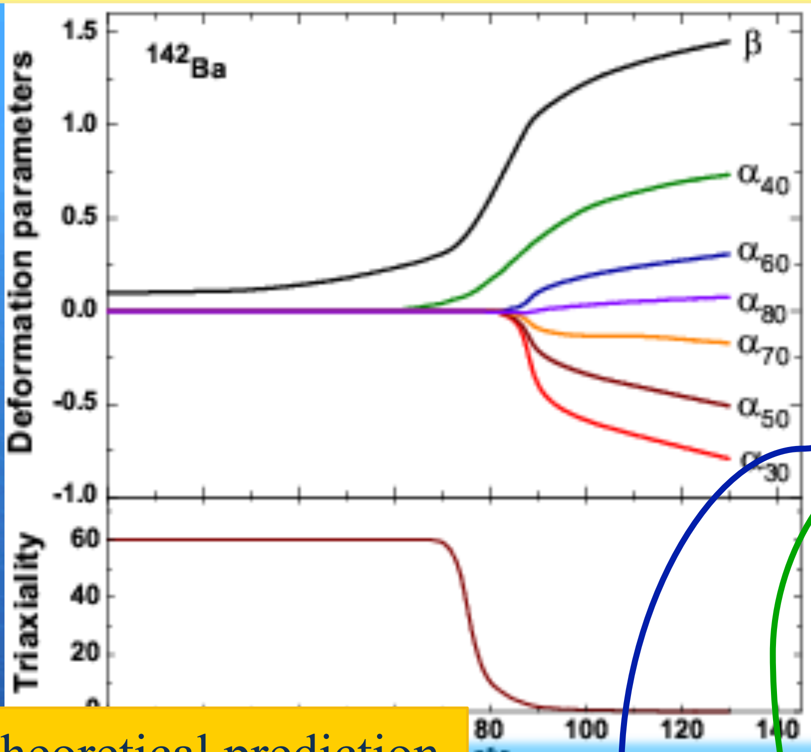
**n) PDR in proton-rich nuclei with NEDA +PARIS**
G. De Angelis et al.

**o) Onset of chaotic regime: PARIS +AGATA**
S. Leoni et al.

p) **Evolution of nuclear structure of $^{78}$Ni and $^{132}$Sn with ACTAR+PARIS**
G.F. Grinyer et al.

# Jacobi and Poincare shapes in exotic nuclei

Calculations based on LSD model (K. Mazurek et al.)




Sphere

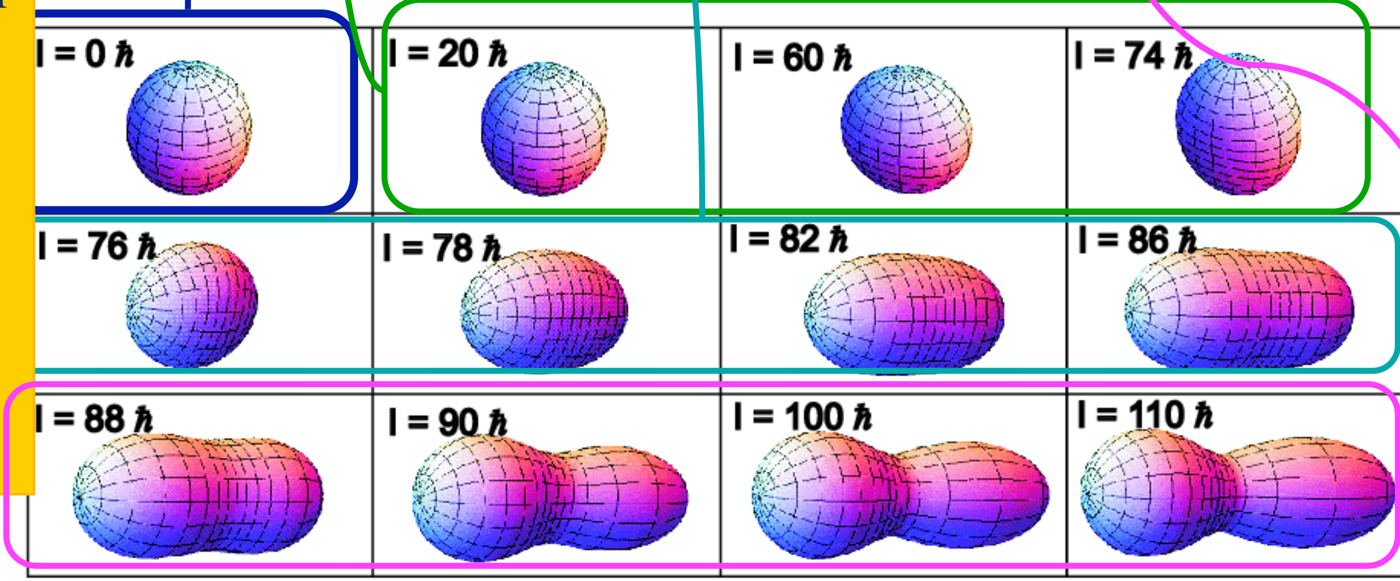
Oblate (MacLaurin)

Elongated triaxial (Jacobi)

Octupole, left- right asymmetric (Poincare)

Theoretical prediction *(for the first time)* of the Poincare shape transition in atomic nuclei

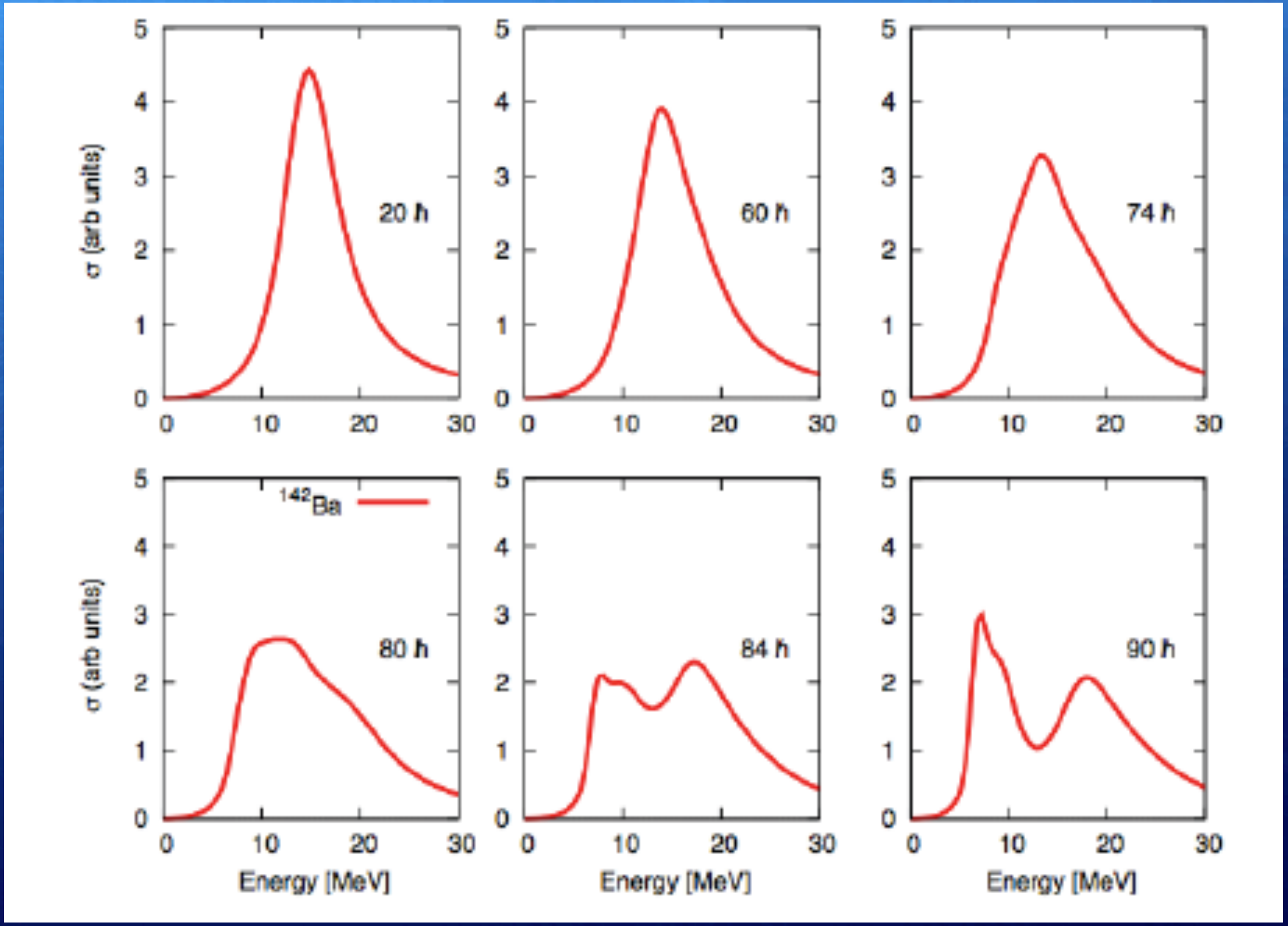
A.Maj *et al*. Int. J. Mod. Phys. E19, 532 (2010); K.Mazurek *et al*., Acta Phys. Pol. B42, 471 (2011)



# Fragmented GDR strength function

## Evolution of GDR strength function for $^{142}Ba$

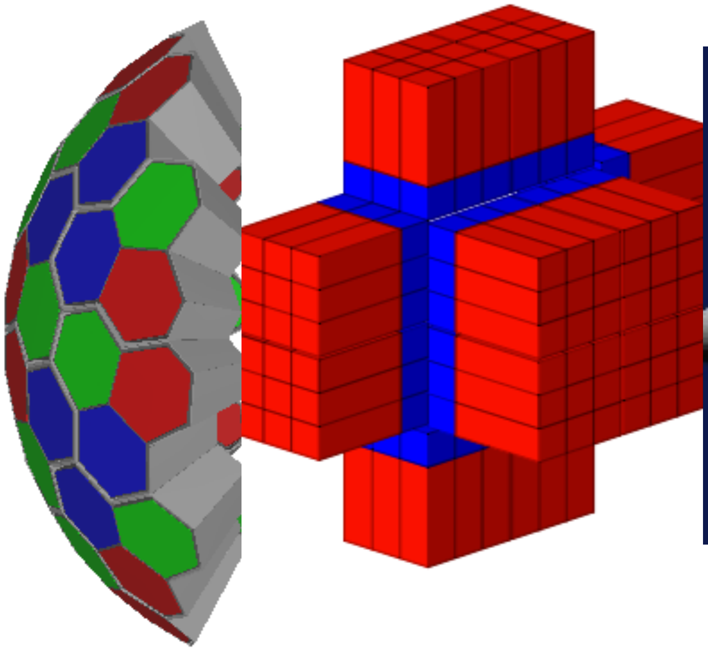
K. Mazurek et al., to be published

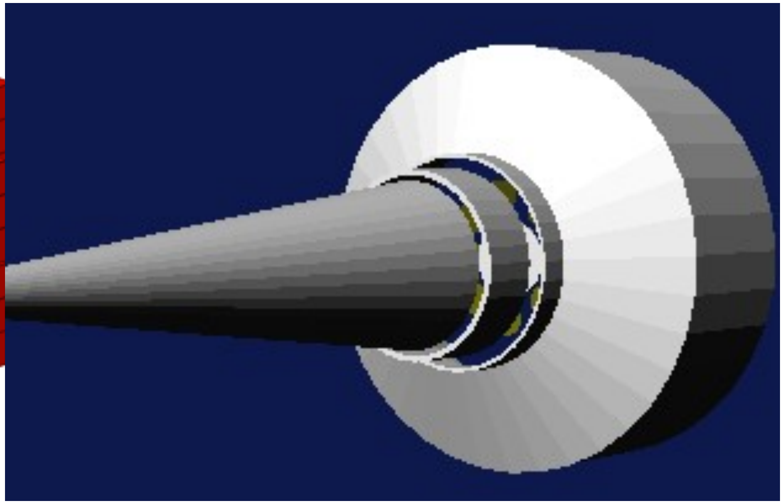


# Study of collective modes of excitations in the neutron-rich Ba region via fusion-evaporation reactions

***Spiral2 Day1-Phase2 LoI***

Adam Maj (Kraków), Silvia Leoni (Milano) - spokespersons
Christell Schmitt - GANIL Liaison





Experiment will require efficient aray for discrete γ-rays (AGATA/EXOGAM), recoil detector (e.g. VAMOS or Krakow RFD) and very efficient detector for high-energy photons: PARIS

| Physics Case | Recoil mass | v/c [%] | $E_\gamma$ range [MeV] | $\Delta E_\gamma/E_\gamma$ [%] | $\Delta E_{sum}/E_{sum}$ [%] | $\Delta M_\gamma$ | Ω coverage | ΔT [ns] | Ancillaries | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Jacobi transition | 40-150 | <10 | 0.1-30 | 4 | <5 | 4 | 2π-4π | <1 | AGATA HI det. | High eff. Beam rej. |
| Shape Phase Diagram | 160-180 | <10 | 0.1-30 | 6 | <5 | 4 | 2π-4π | <1 | HI det. | High eff. Differential method Beam rej. |
| Hot GDR in n-rich nuclei | 120-140 | <11 | 0.1-30 | 6 | <8 | 4 | 2π-4π | <1 | HI det. | Beam re. |
| Isospin mixing | 60-100 | <7 | 5-30 | 6 | - | - | 4π | <1 | HI det. | High eff. Beam rej. |
| Reaction dynamics | 160-220 | <7 | 0.1-25 | 6-8 | <8 | 4 | 2π | <1 | n-det. FF det. | Complex coupling |
| Collectivity vs. multi-fragmentation | 120-200 | <8 | 5-30 | 5 | - | - | 2π | <1 | LCP det. HI det. | Complex coupling |
| Radiative capture | 20-30 | <3 | 1-30 | <4 | 5 | - | 4π | <1 | HI det. | High eff. |
| Multiple Coulex | 40-60 | <7 | 2-6 | 5 | - | - | 2π | <5 | AGATA CD det. | Complex coupling |
| Astrophysics | 16-90 | 0.1 | 0.1-6 | 6 | 5 | - | 4π | <1 | Outer PARIS shell as active shield | High eff. Back-ground |
| Shell structure at intermediate energies (SISSI/LISE) | 16-40 | 20-40 | 0.5-4 | 3 | - | - | 3π | <<1 | SPEG or VAMOS | High eff. Low $I_{beam}$ γ−γ coinc |
| Shell structure at low energies (separator part of $S^3$) | 30-150 | 10-15 | 0.3-3 | 3 | - | - | 3π | <<1 | Spectrometer part of $S^3$ | High eff. Low $I_{beam}$ γ−γ coinc |
| Relativistic Coulex | 40-60 | 50-60 | 1-4 | 4 | - | 1 | Forward 3π | <<1 | AGATA HI analyzer | Ang. Distr. Lorentz boost |

In our physics cases:

<β> ≈ 10%; ΔM/M<4 → **Granularity> 200 (at the distance of 20 cm)**

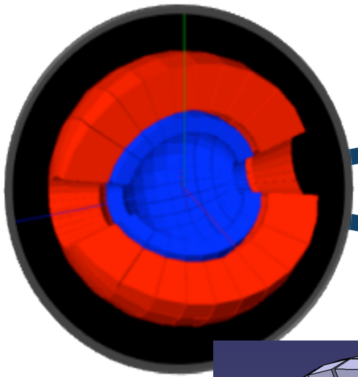
ΔT: <1 ns; ΔEγ/Eγ: < 3%; high efficiency up to 15 MeV

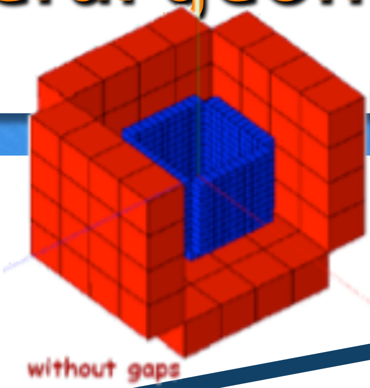
# PARIS has to

- be transportable (between different facilities: SPIRAL2, ALTO, SPES, Warsaw, Krakow, TIFR Mumbai, ELI-NP, HIE-ISOLDE,…)
- be modular (to be connected with other detectors: AGATA, GASPARD, NEDA, FAZIA, ACTAR, HECTOR+)
- have high granulation (multiplicity measurement, Doppler correction,…)
- have very high efficiency for high-energy $\gamma$-rays
- have good timing resolution (<500 ps)
- have energy resolution as good as possible
- have some position sensitivity

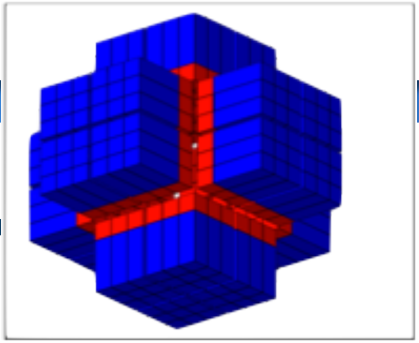
# Several geometries studied

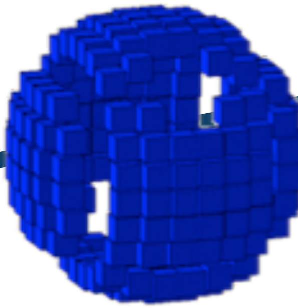
'Ideal' - spherical

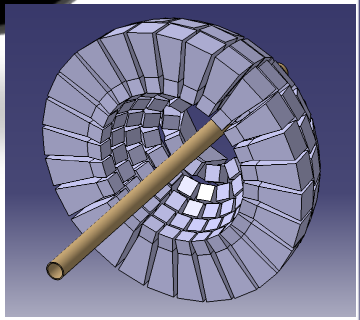


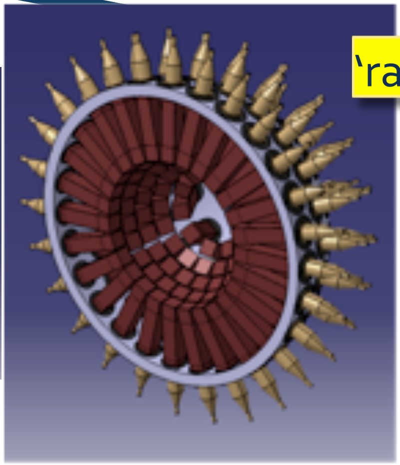



'cubic'-like

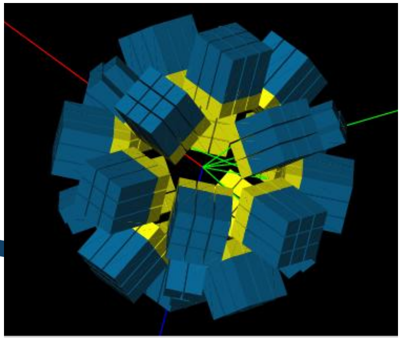








'radial'-like

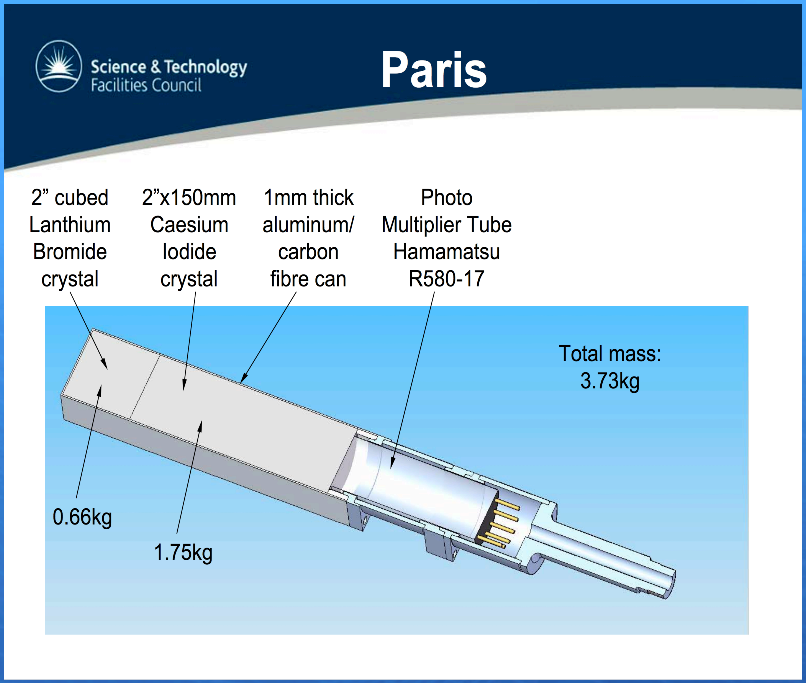


**CONCLUSION:**

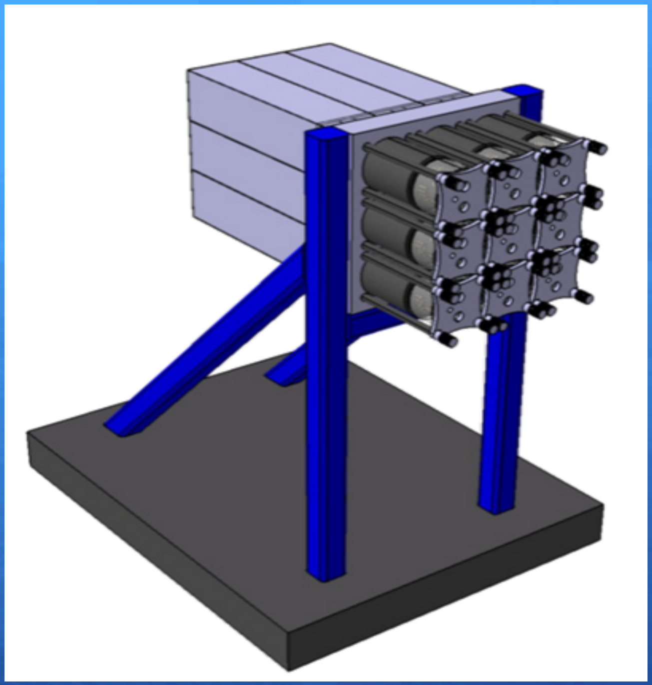
***PARIS*** to be made of ***clusters***:

1 ***cluster*** = 9 ***phoswiches***

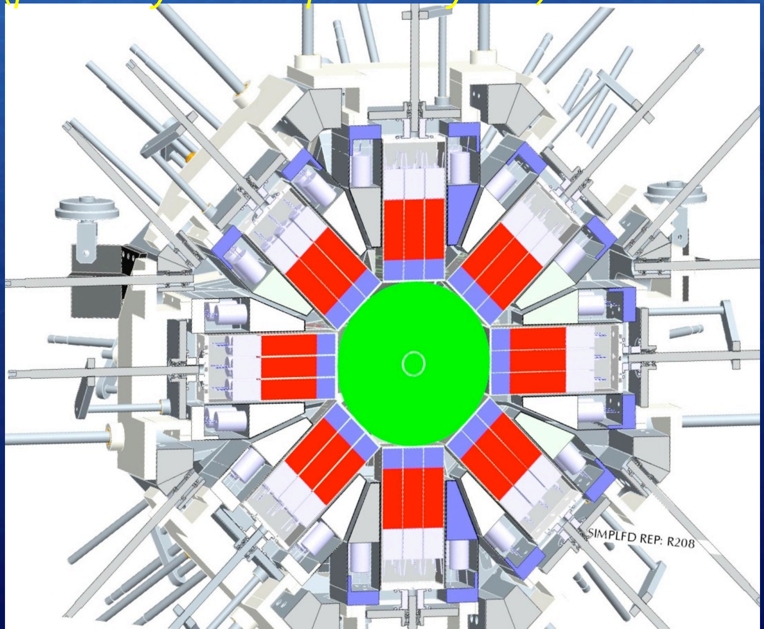
This allows for ***cubic*** or ***radial-like*** geometry




*Initial concept of a phoswich detector element (presently CsI is replaced by NaI)*



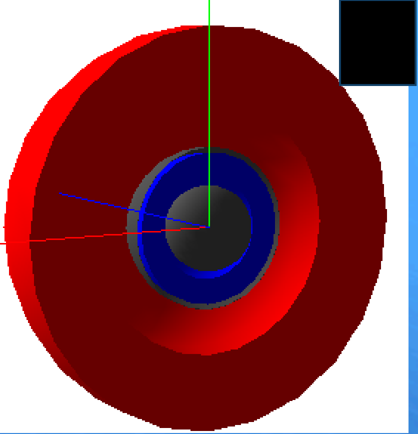
*A cluster module comprising nine phoswich detectors*

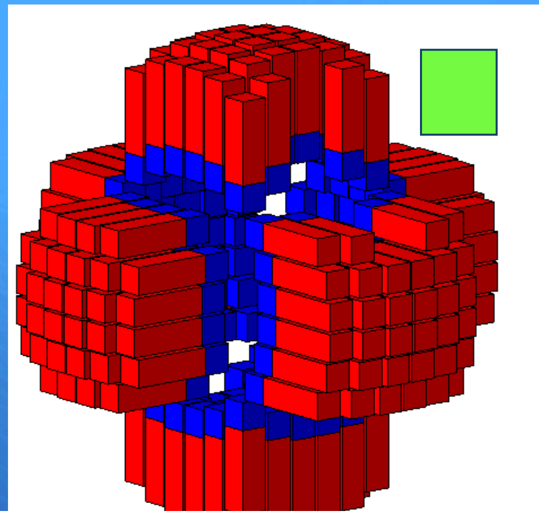


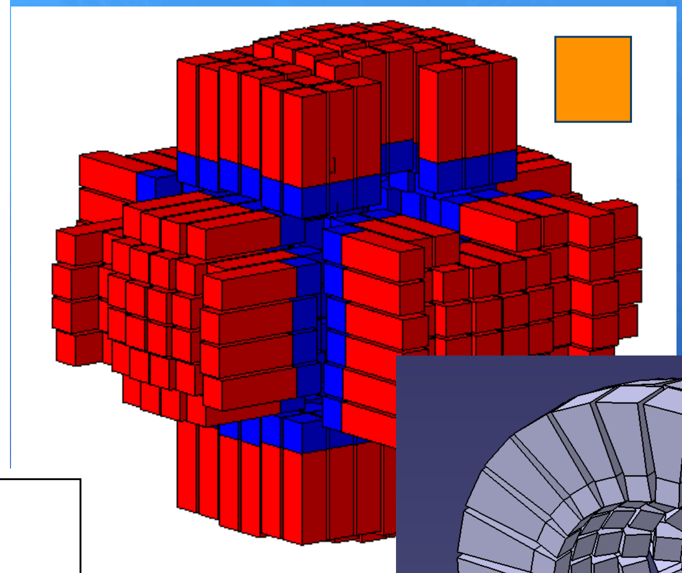

*Clusters of phoswich detectors arranged in a radial geometry*

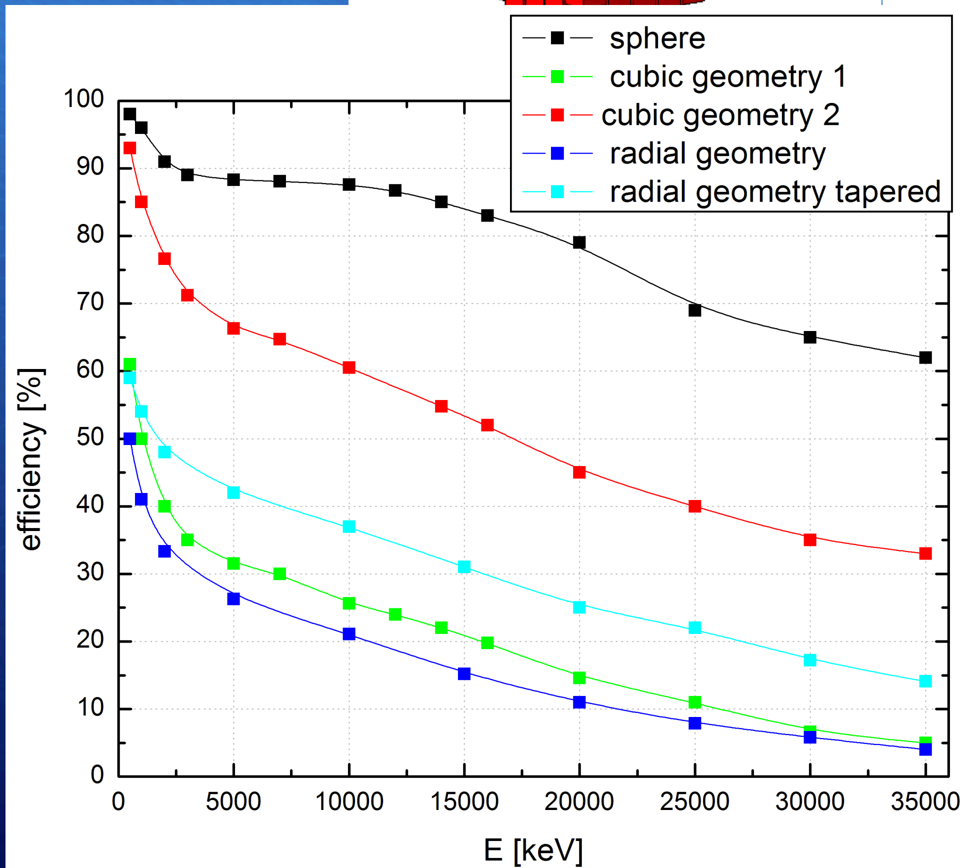
Designs made in IPN Orsay and Daresbury

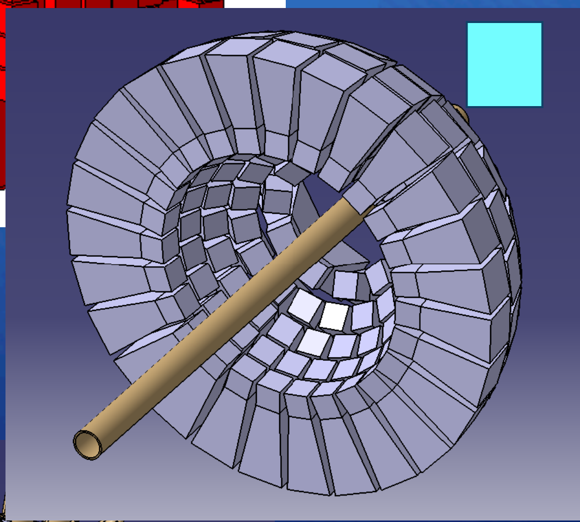
# Cubic vs. Radial geometry

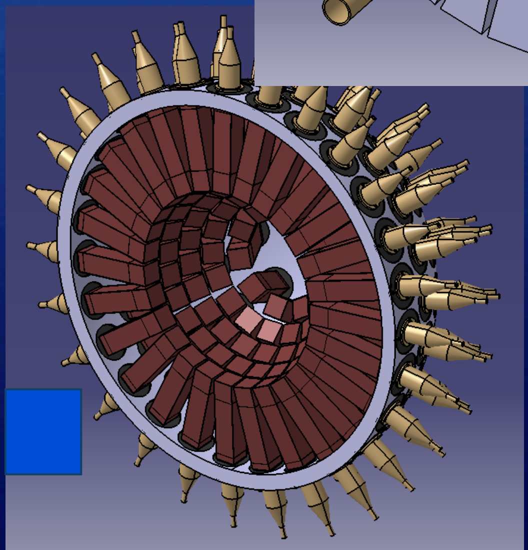




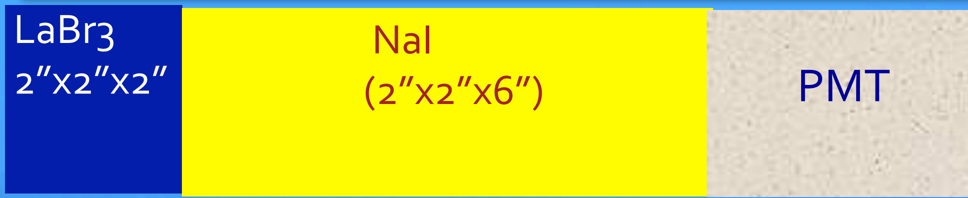




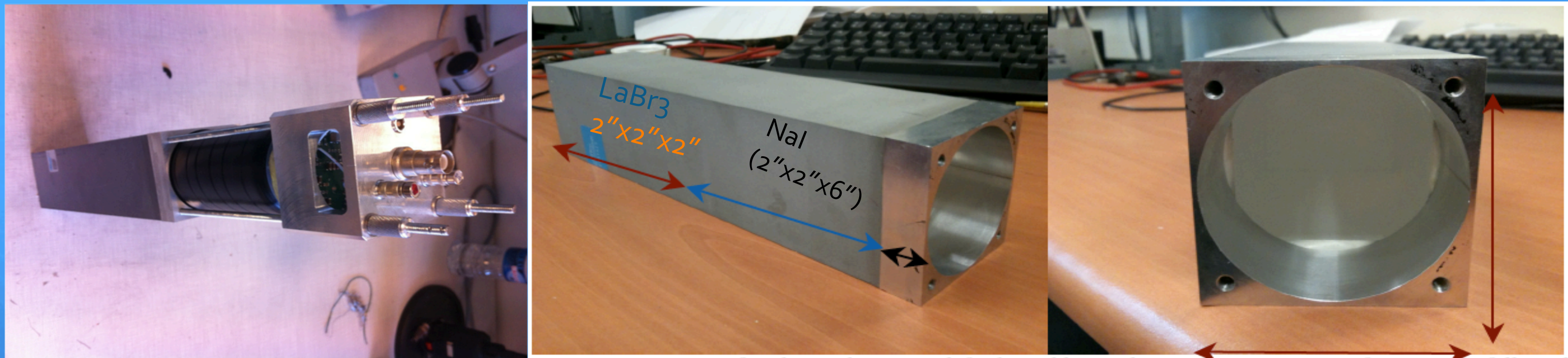



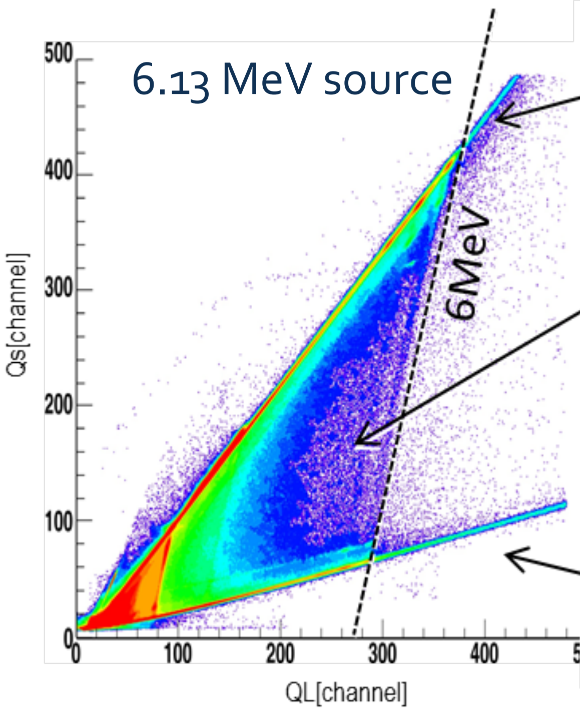


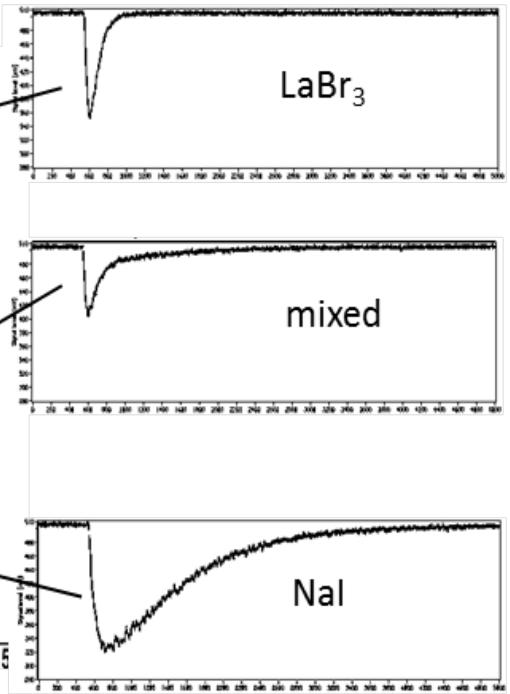
# Basic element: a phoswich $LaBr_3$+NaI

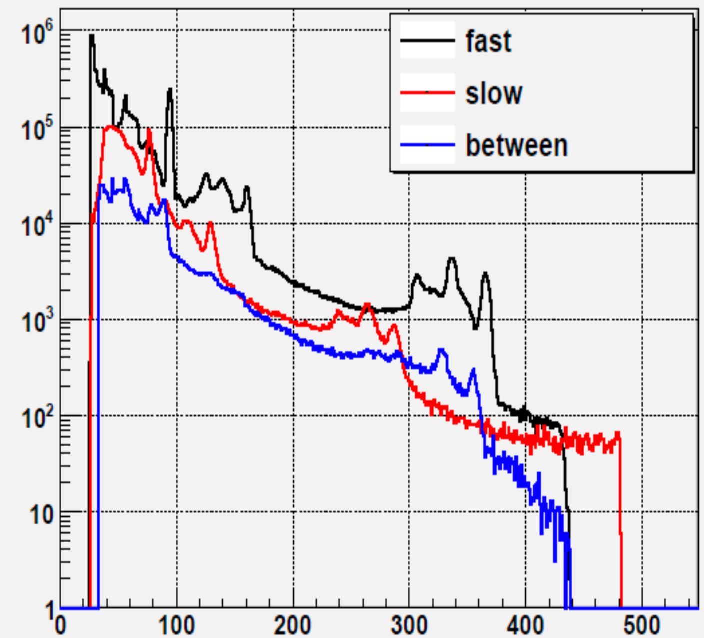



5 prototypes were ordered from Saint Gobain:
1 to Orsay, 1 to Strasbourg, 3 to Krakow

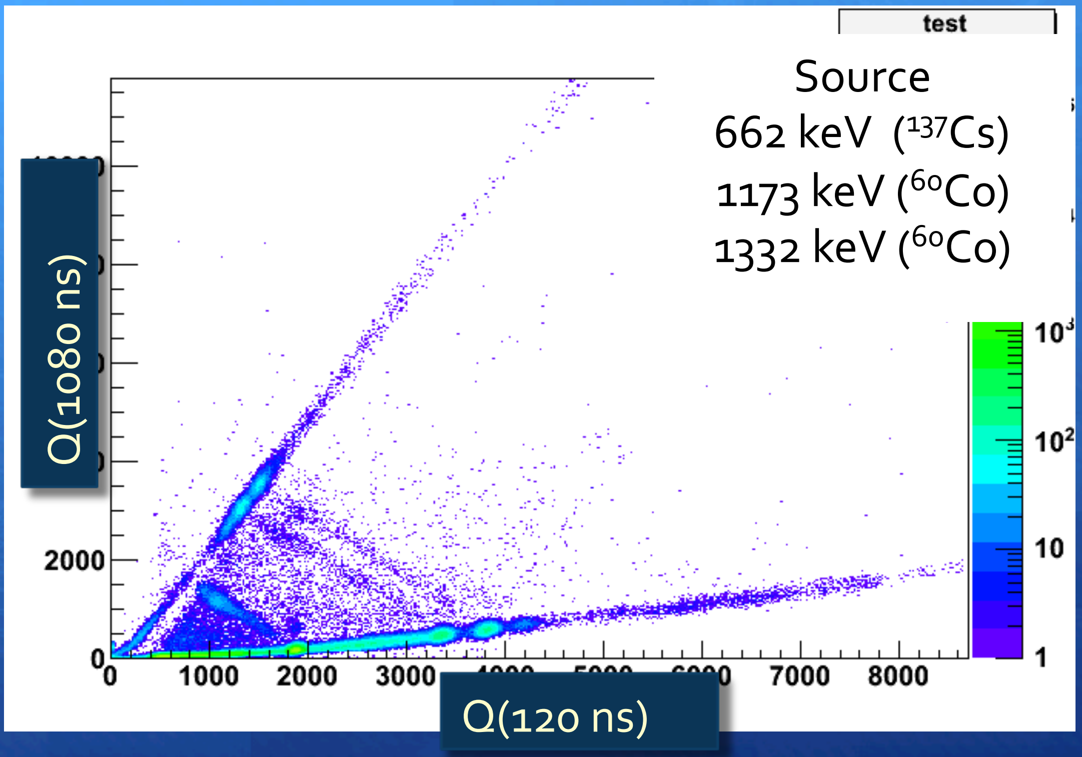


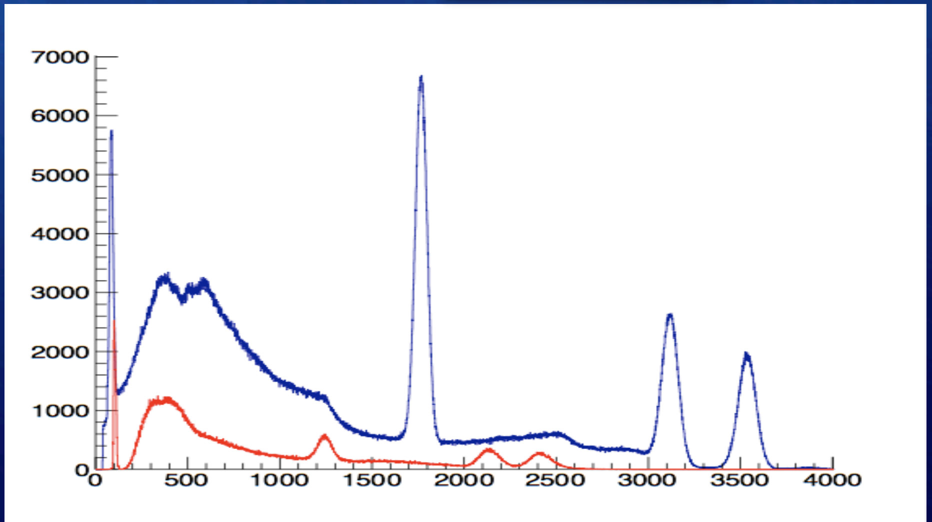




*Left: 2D plot plot for a phoswich detector obtained for a 6MeV gamma source using a Milano BaF processor card. The steep strip representing the fast pure LaBr3 signals is well separated from the flat distribution related to much slower NaI pulses, mixed events are seen in between. Middle: shapes of the corresponding signals. Right: Spectra obtained with a gate of fast (LaBr3 only), slow (NaI only) and mixed events.*




$LaBr_3$ $\Delta E/E \approx 4\%$



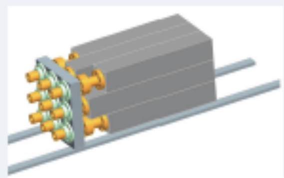
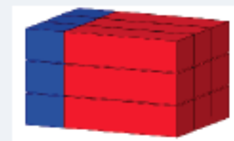
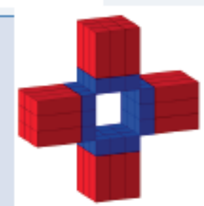
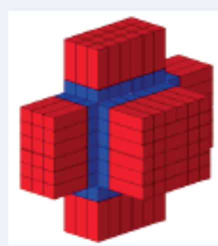
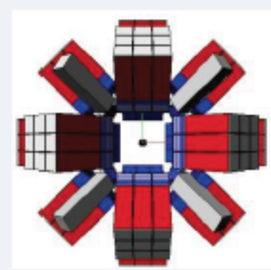
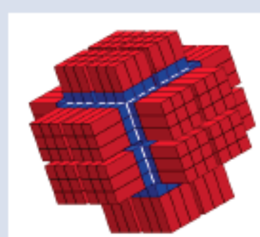
# Collaborating groups from:

**POLAND**: IFJ PAN Krakow, HIL Warsaw *(consortium COPIN)*
**FRANCE**: IPN Orsay, IPHC Strasbourg, IPN Lyon, GANIL
**INDIA**: TIFR Mumbai, BARC Mumbai, VECC Kolkata
**UK**: U. York. U. Surrey, STFC Daresbury, U. Manchester
**BULGARIA**: INRNE Sofia
**ROMANIA**: IFIN-HH Bucharest
**ITALY**: INFN and University Milano, LNL Legnaro, LNS Catania
**TURKEY**: U. Nigde, U. Istanbul, U. Sebahattin Zaim, U. Akdeniz
**HUNGARY**: ATOMKI Debrecen

# PARIS Demonstrator MoU

MoU on PARIS Demonstrator (Phase 2) was prepared and agreed to be signed by
IN2P3 (France), COPIN (Poland), GANIL/SPIRAL2 (France), TIFR/BARC/VECC (India), IFIN HH (Romania), INFN (Italy), Bulgaria, U. York (UK), Turkey
U. Surrey (UK) and Hungary might sign soon, too.
Since more than 3 partners already signed it (underlined), the MoU is effective.

## PARIS phases and cost estimates

| | | | | |
|---|---|---|---|---|
| *Phase 1*<br>**2011/2012**<br>PARIS cluster | 1 cluster:<br>9 phoswiches |   | 250 k€ | **Decided**<br>Funds: SP2PP, ANR, Orsay, Strasbourg, Kraków, Mumbai<br><br>Tests in-beam and with sources |
| *Phase 2*<br>**2015**<br>**PARIS Demonstrator** | 5 clusters:<br>45 phoswiches |  | 1100 k€ | **Only if Phase1 validated**<br>Funds: MoU<br><br>Ph1Day1 exp@S3 |
| *Phase 3*<br>**2017**<br>**PARIS 2π** | 12 clusters:<br>108 phoswiches |   | ≈ 2 M€ | **Only if Phase2 validated**<br>Funds:<br>MoU, PARIS consortium<br><br>Ph2Day1 exp. with AGATA and GASPARD<br>Other exp. |
| *Phase 4*<br>**≈2019**<br>**PARIS 4π** | ≥24 clusters:<br>≥216 phoswiches |   | ≈ 4 M€ | **Only if Phase3 validated**<br>Funds:<br>PARIS consortium<br><br>Regular experiments in various labs |

# SHOGUN for RIKEN

# Next generation gamma spectrometer for fast (200 MeV/u) beams in RIKEN

**SHOGUN project spokesman: Pieter Dornennball**

**S** cintillator based

**H** igh-res**O**lution

**O**

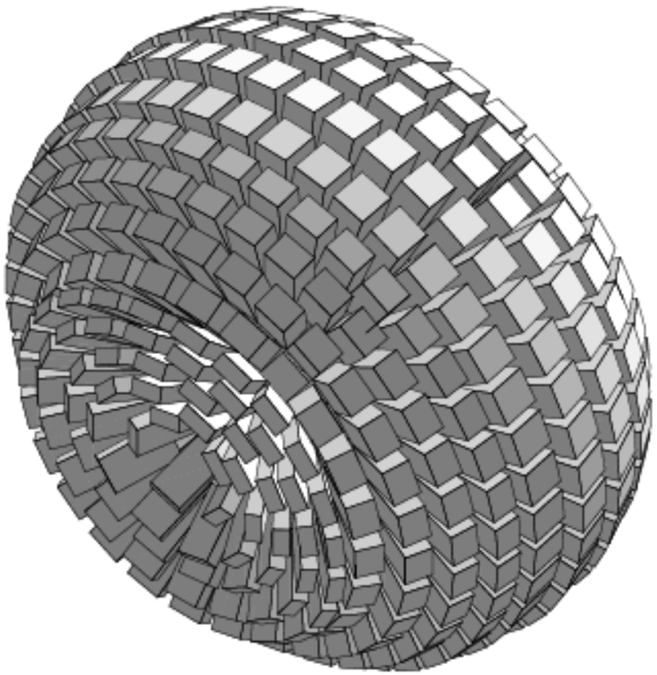
**G** amma-ray spectrometer for

**U** nstable

**N** uclei

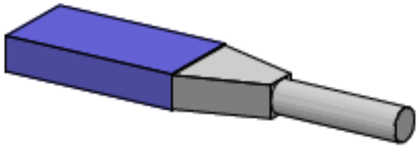
- $LaBr_3$ based $\gamma$-ray spectrometer optimized for **in-beam** $\gamma$-ray spectroscopy at **RIBF beam energies**
- Small $\theta$ angular coverage per crystal
- Construction proposal (H. Scheit *et al.*) accepted by NP-PAC in Dec. 2009 (no funding)
- Received three prototype crystals in 2011, just started to test them

# Replacement of preent DALI2 array with LaBr3 based array For beam energies ca. 200 MeV/u (v/c=50%)



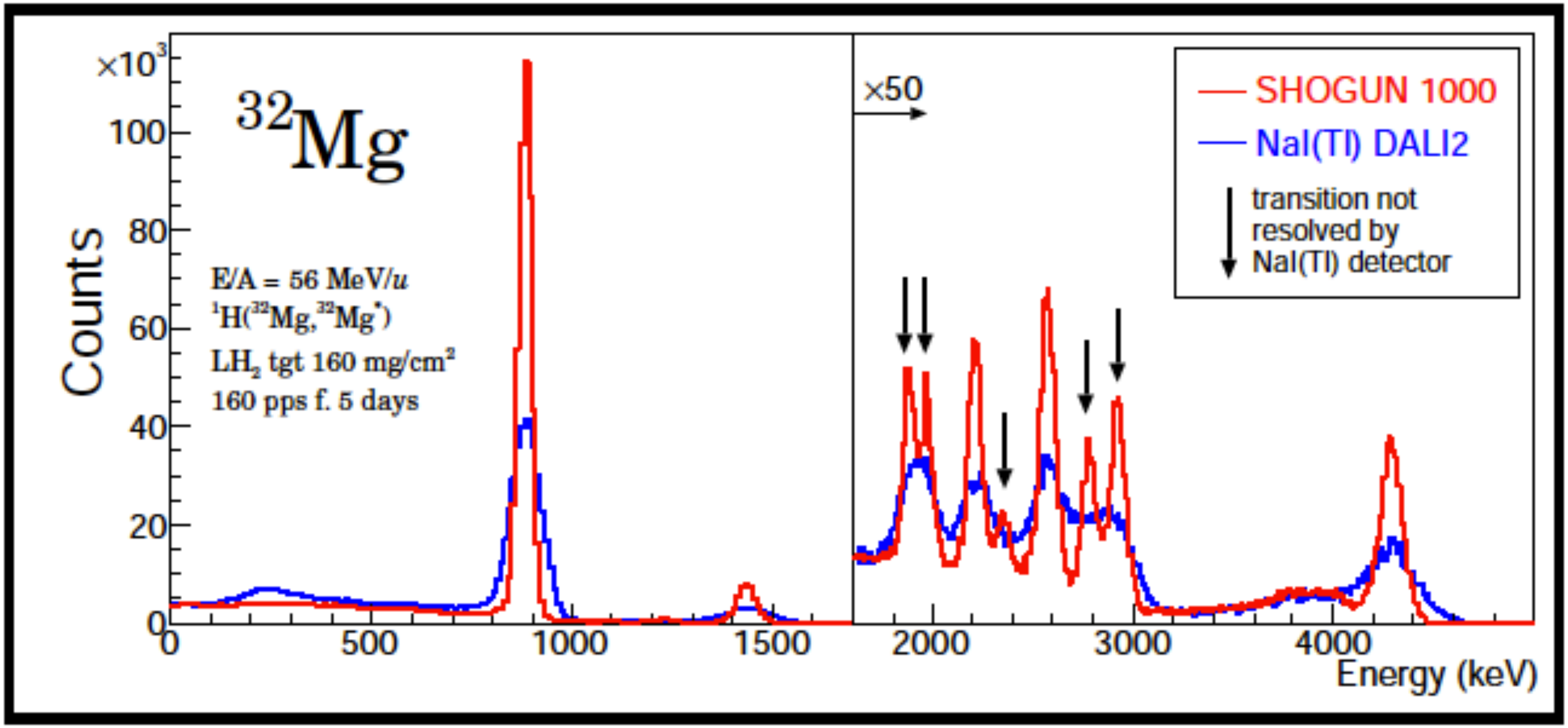
| | $\frac{\Delta E}{E}$ (%) | $\epsilon_\gamma$ (%) | $\epsilon_{\gamma\gamma}$ (%) |
|---|---|---|---|
| NaI(Tl) DALI2 | 10.0 | 23.5 | 5.5 |
| RISING | 1.9 | 2.8 | 0.08 |
| SHOGUN 1000 | **3.2** | **35.0** | **12.2** |

$8 \times 4 \times 1.5\ \mathrm{cm}^3$



- □ 1000 Crystals in single-, double- and triple-housings
- □ $4\pi$ configuration could be completed by FY2016-17

# Simulations: DALI2 and SHOGUN



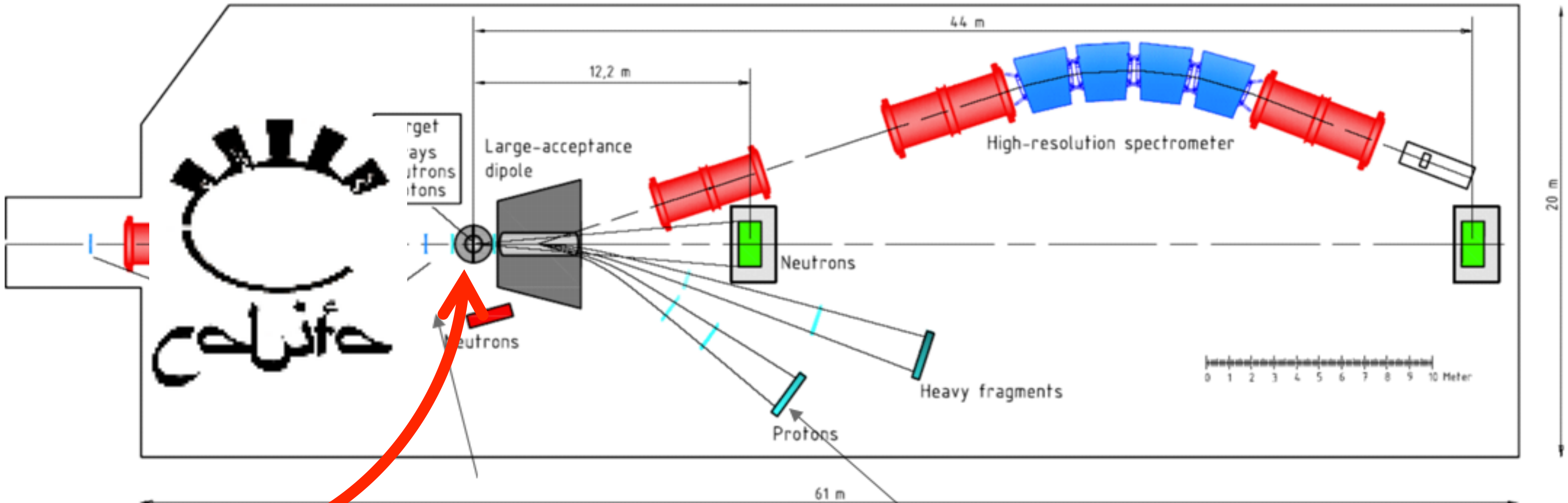

Simulation based on experimental data of
S. Takeuchi *et al.*, Phys. Rev. C 79, 054319 (2009)

**Other physics cases for DALI/SHOGUN→talk of Walter Henning**

# CALIFA for R3B@NUSTAR at FAIR

# R$^3$B: Reactions with Relativistic Radioactive Beams

More than 300 scientists from institutions in 23 countries




***R$^3$B (Reactions with Radiactive Relativistic Beams):***

- Beam, proton and fragment ToF & tracking detectors.
- Silicon arrays around target for recoils.
- **Large acceptance** superconducting dipole.
- **High resolution** neutron detectors.
- **High efficiency** calorimeter/gamma spectrometer.

***R$^3$B Physics programs comprehends:***

- Knockout: shell structure, resonances, ...
- QFS: structure functions, correlations, ...
- Total absorption: halo nuclei, nuclear radius, ...
- Elastic scattering: nuclear density, ...
- EM excitations: transition strengths, ...
- Fission: structural and dynamic properties, ...
- Spallation, fragmentation, multifragmentation, ...

http://www.gsi.de/forschung/kp/kp2/collaborations/R3B

→talk of Thomas Nilsson

# CALIFA project spokesperson: Lola Cortina

## CALIFA: the $R^3B$ calorimeter and gamma spectrometer

***CALIFA: the R3B CALorimeter for In Flight detection of γ rays and high energy charged pArticles.***

*CALIFA Working group (stablished since 2005):*

- **Conceptual & mechanical design**: Univ. Santiago de Compostela, Univ. Vigo.
- **Crystal and photosensors**: Univ. Santiago de Compostela, Univ. LUND, IEM-CSIC, Univ. Chalmers.
- **Simulations**: Univ. Santiago de Compostela, Univ. LUND, IEM-CSIC, Univ. Lisboa, EMMI-GSI.
- **Electronics**: T.U. München, IEM-CSIC, Univ. Santiago de Compostela.
- **Slow control**: T.U. Darmstadt, IEM-CSIC, T.U. München.
- **DAQ**: GSI, T.U. München (Common task within $R^3B$).

Univ. Santiago de Compostela (Spain)

Univ. LUND (Sweden)

Univ. Vigo (Spain)

Univ. Lisbon (Portugal)

T. U. München (Germany)

ExtreMe Matter Institute (Germany)

Univ. Frankfurt (Germany)

Univ. Chalmers (Sweden)

IEM - CSIC (Spain)

T. U. Darmstadt (Germany)

GSI Helmholtzzentrum für Schwerionenforschung (Germany)

CALIFA project spokesperson: Lola Cortina

## What makes CALIFA an unique instrument?

***The CALIFA requirements comprise:***

- Intrinsic **photopeak efficiency: 40% up to E = 15MeV** projectile frame.
- A γ **ray sum energy resolution:** $\Delta(E_{Sum})/<E_{Sum}> \sim 10\%$ for 5 γ rays of 3 MeV.
- A γ **ray energy resolution:** $\Delta E/E \sim 5\text{-}6\%$ (FWHM) for 1 MeV γ rays.
- **Calorimeter** for high energy light charged particles (LCP): up to 320 MeV in Lab.
- **LCP energy resolution:** $\Delta E_p/E_p < 1\%$ up to 300 MeV.
- Proton – γ ray **separation**: for 1 to 30 MeV.

***… and additionally CALIFA should offer:***

- The appropriate volume coverage, surrounding the reaction chamber and the inner (silicon) tracker detectors.
- A reduction of dead layers to increase efficiency.
- A solution to the problems associated to the particular γ ray kinematics.
- A reasonable cost.

**Detector based on the use of performant scintillation crystals and photosensors system**

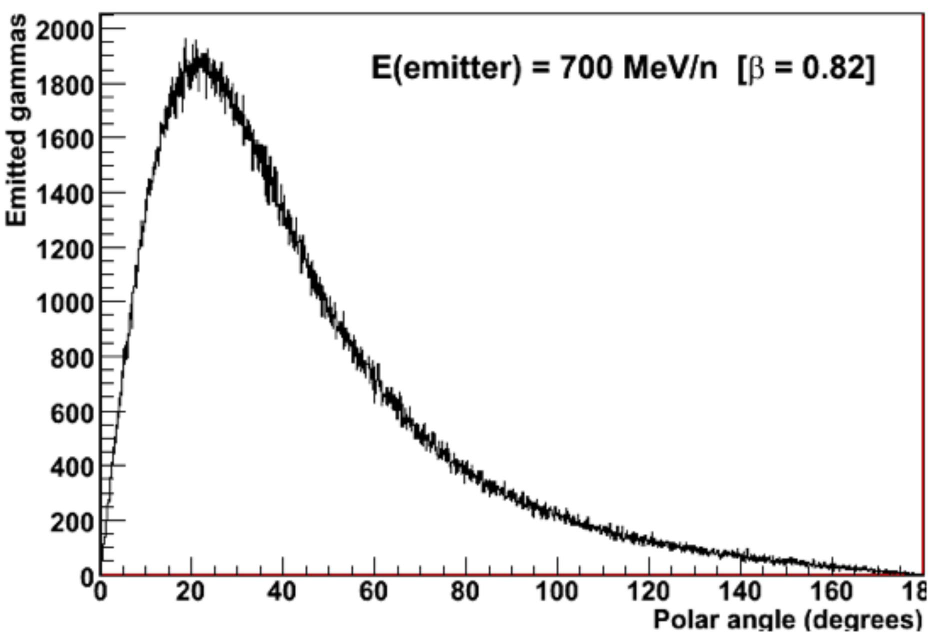
# What makes CALIFA an unique instrument?

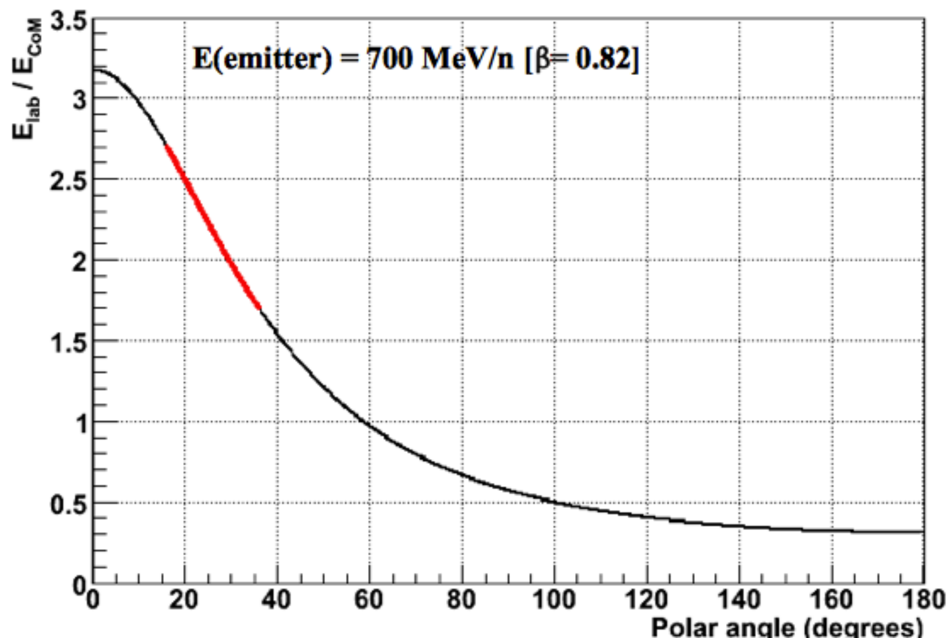
***Note the particular kinematics due to the relativistic fragments:***

- The **Lorentz boost shifts** the γ rays energy up to x3 in forward direction (at 700 A MeV).
- The γ rays energy reconstruction depends strongly on the polar angle resolution.
- A large polar angle **granularity** is requested to **correct** the Doppler broadening.
- An enhanced forward emission, peaked around 23 degrees (for β~0.82).

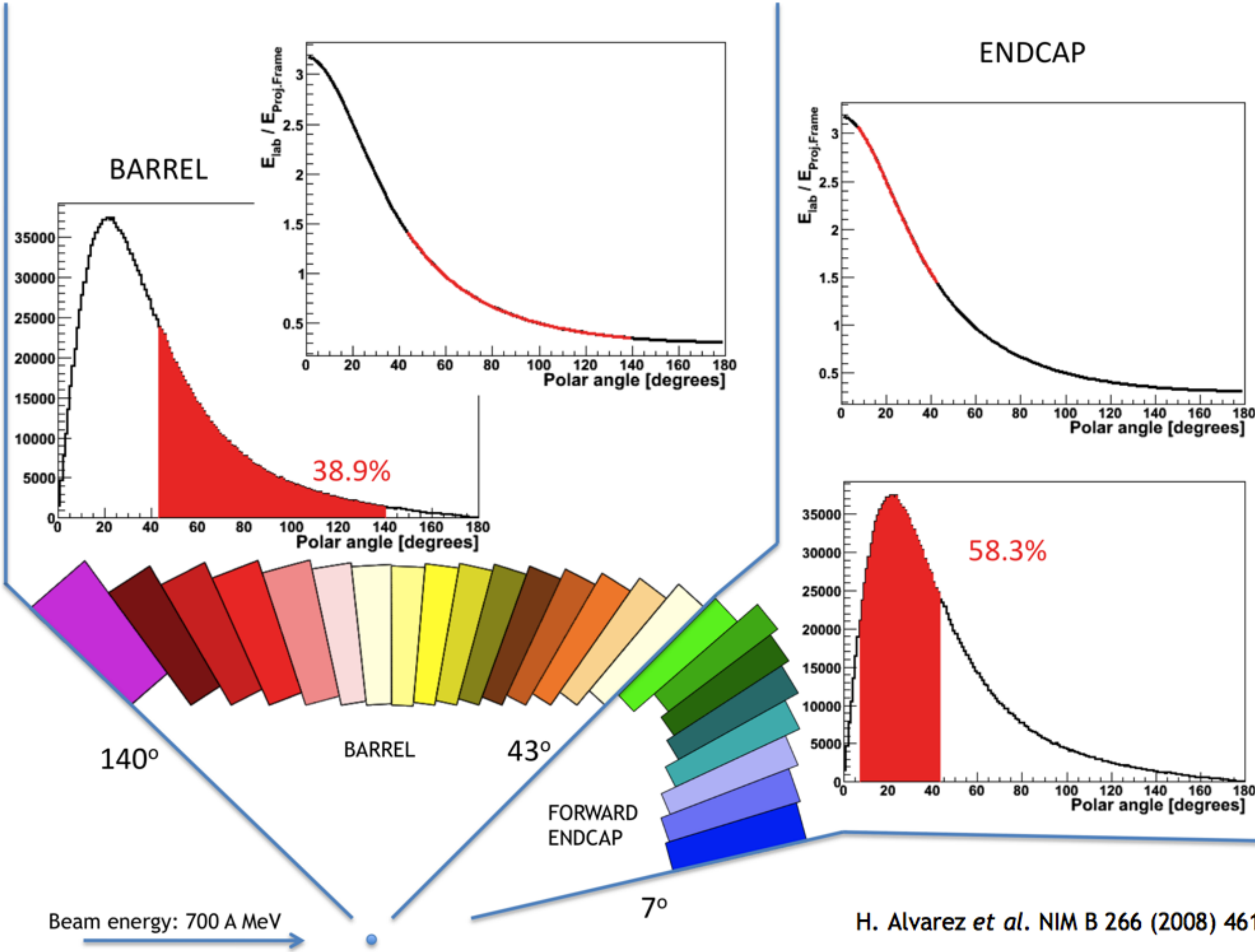
***… then, the $R^3B$ Calorimeter should feature:***

- A **sufficient granularity in polar angle** for a reasonable γ ray energy reconstruction.
- A suitable set of crystal lengths at different polar angles.
- A compact size, without gaps to increase the efficiency, no escape lines from target.
- A small number of different crystal types, a careful consideration of the mechanical design...



# CALIFA conceptual design

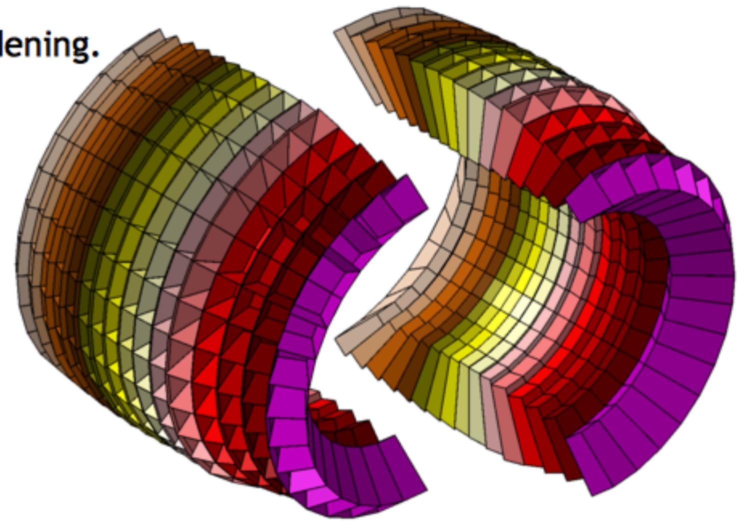


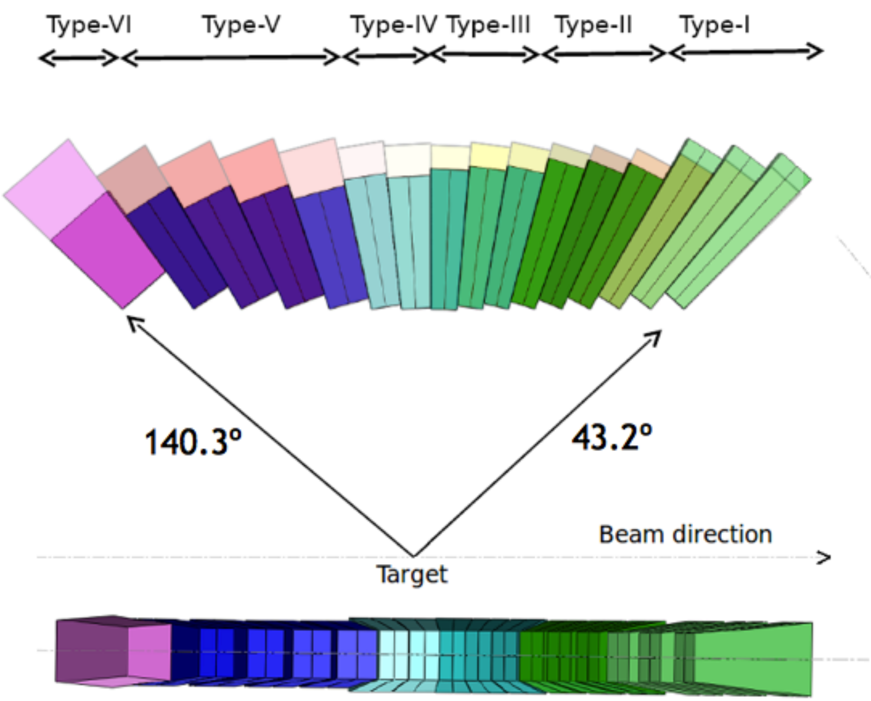

H. Alvarez *et al.* NIM B 266 (2008) 4616-4620

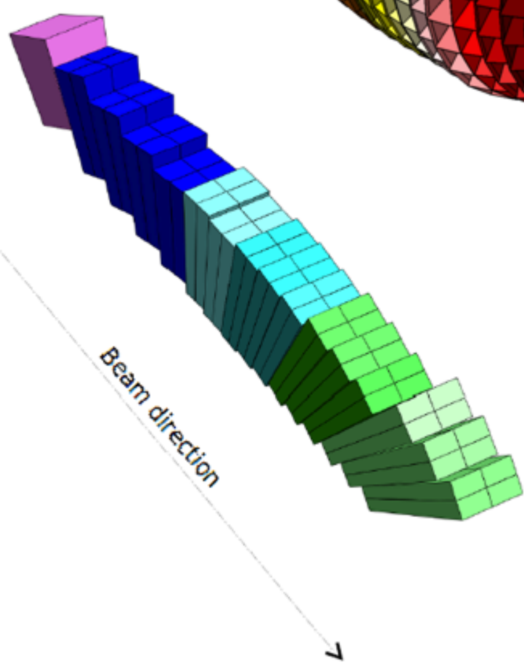
# CALIFA BARREL design (V8.11)

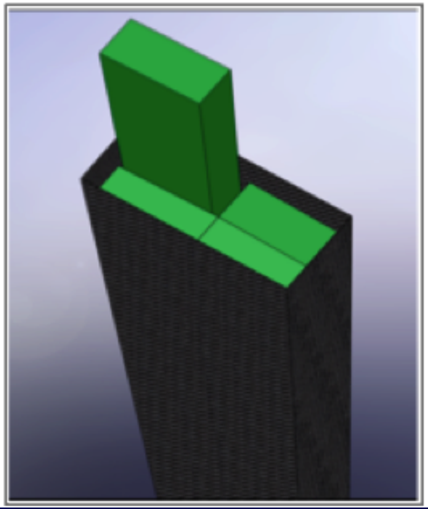
***The CALIFA BARREL design comprises:***

- A set of finger-like CsI[Tl] crystals with LAAPD readout.
- Sufficient granularity to ensure a reduced Doppler broadening.
- The length of the crystals secures QFS proton detection.
- Very thin carbon fiber alveoli in a honeycomb.
- A compact 1 $m^3$ detector.





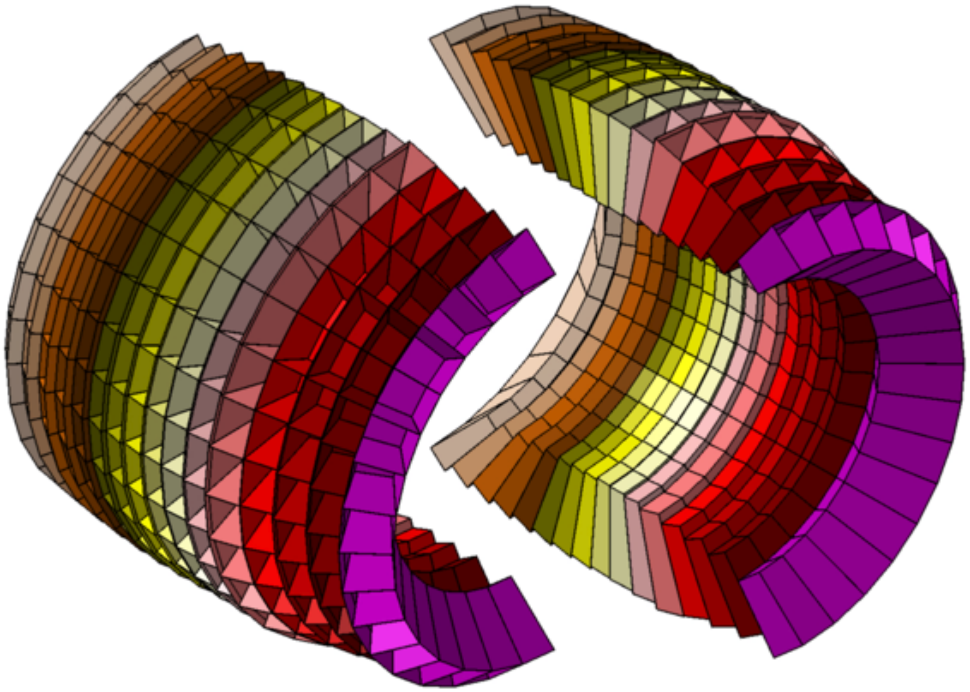



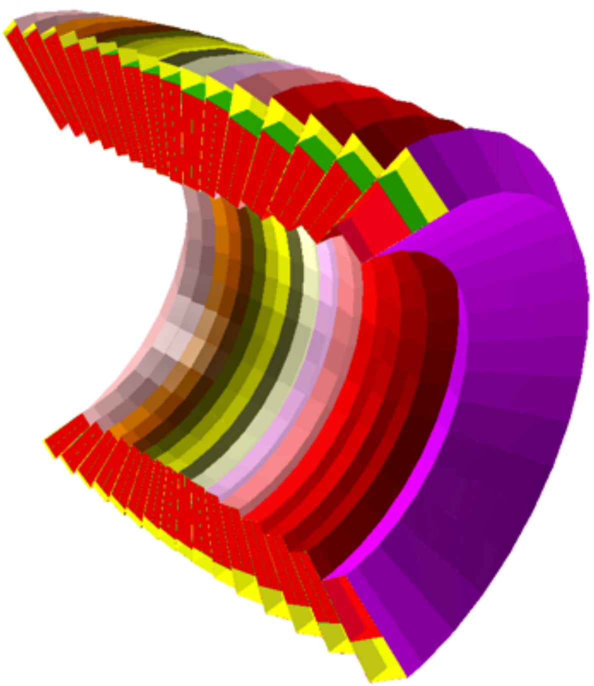
# CALIFA BARREL simulation

| | |
|---|---|
| **Crystals** | **1952** |
| Crystals per ring | 64 (32) |
| Crystals by polar direction | 31 |
| Crystals by alveolus | 4 (1) |
| Alveoli | 512 |
| Alveoli by ring | 32 |
| Alveoli by polar direction | 16 |

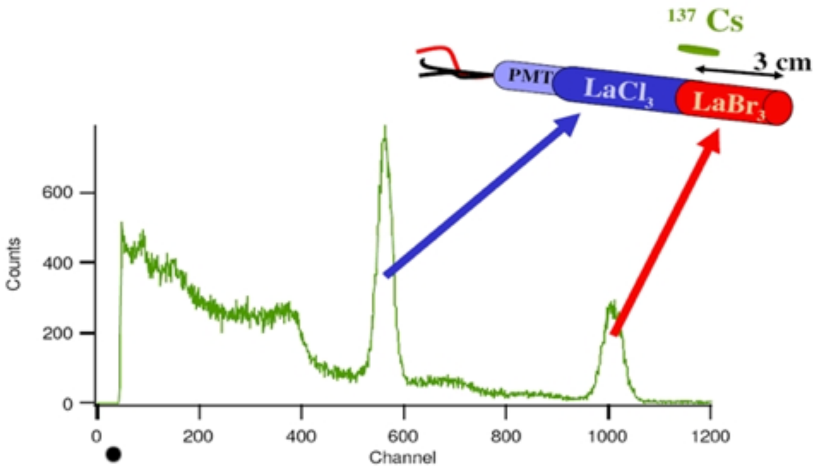
***Complete inventory of matter in simulation:***

- **Crystals, variable thickness wrapping**
- **Alveoli (also variable thickness), spacers, tabs, ...**
- **Inner components (chamber, inner detectors, ...)**

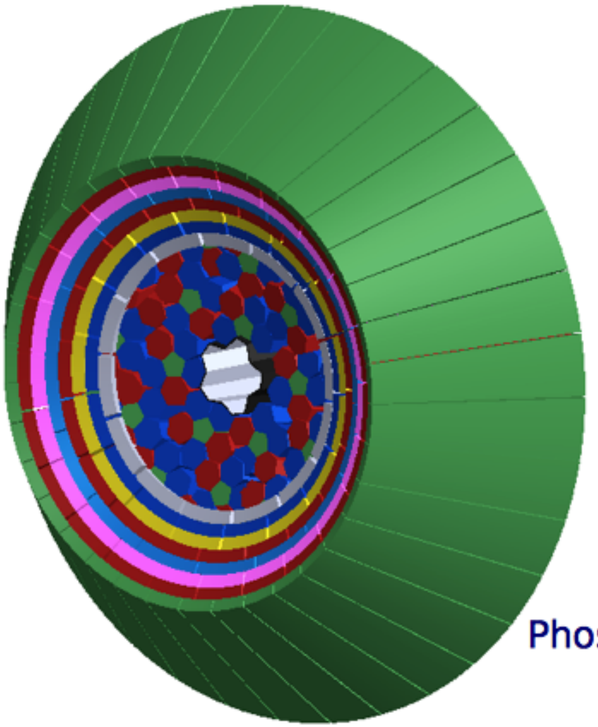




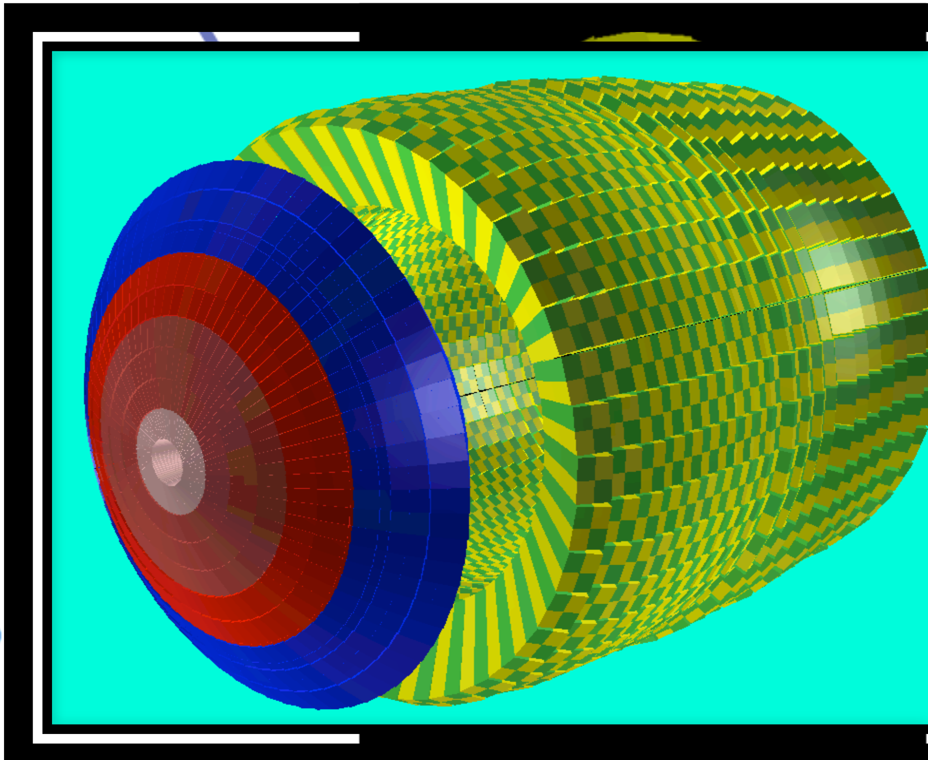
# Other CALIFA elements in simulation



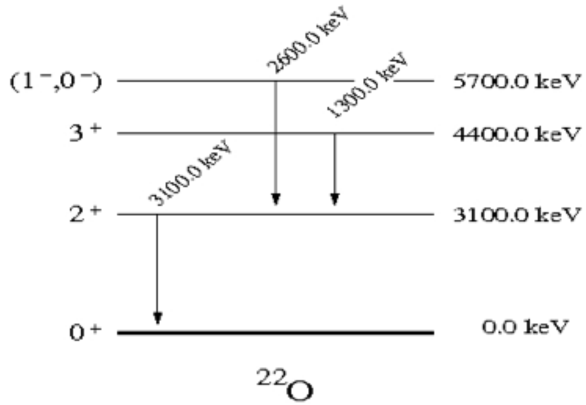

| Crystals | 736 |
| --- | --- |
| Crystals per ring | 64 (32) |
| Crystals by polar direction | 12 |
| Crystals by alveolus | 8 (7) |
| Alveoli | 96 |
| Alveoli by ring | 32 |
| Alveoli by polar direction | 3 |



Phoswich Endcap

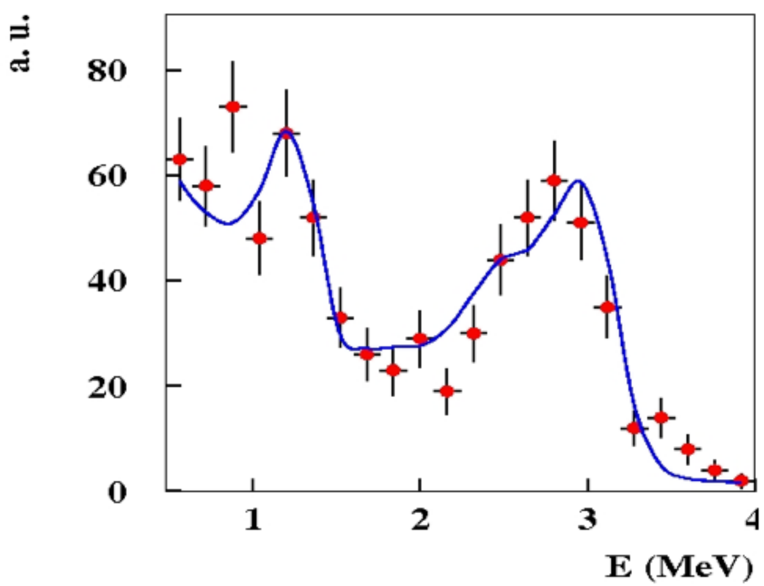


# Selected Physical cases: γ ray spectroscopy

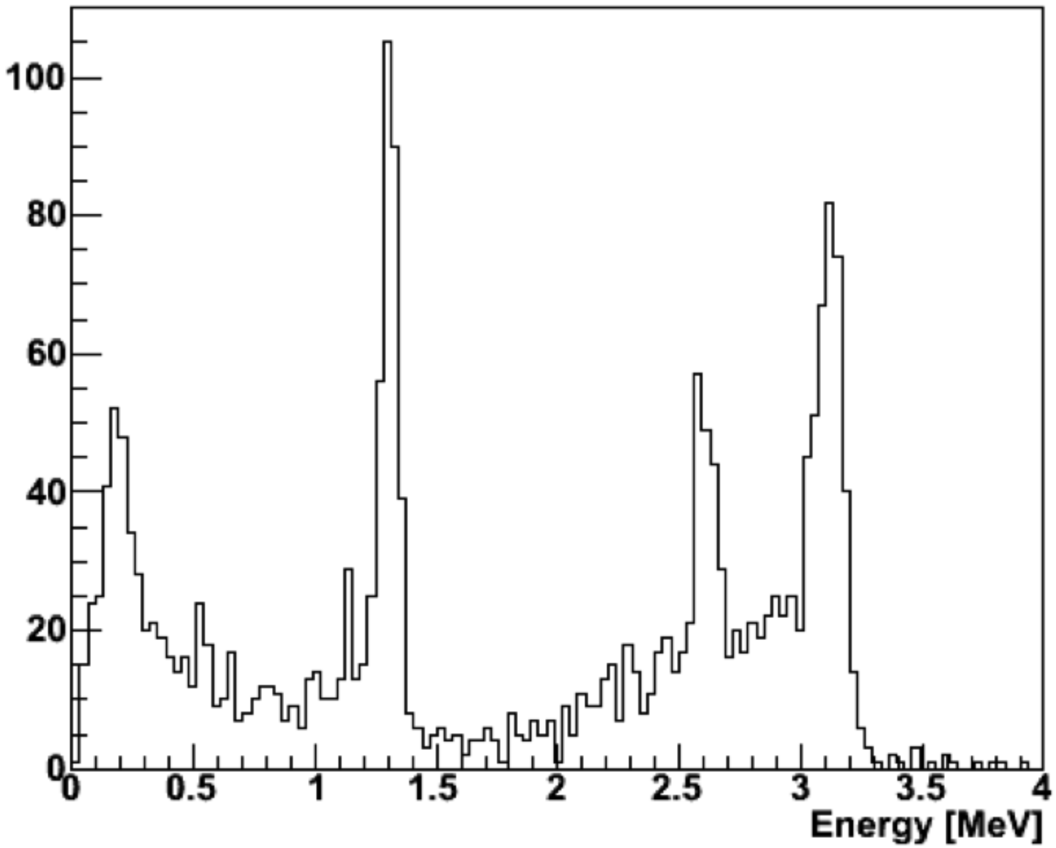



***CALIFA BARREL as a high resolution spectroscopy: the $^{22}O$ nucleus.***

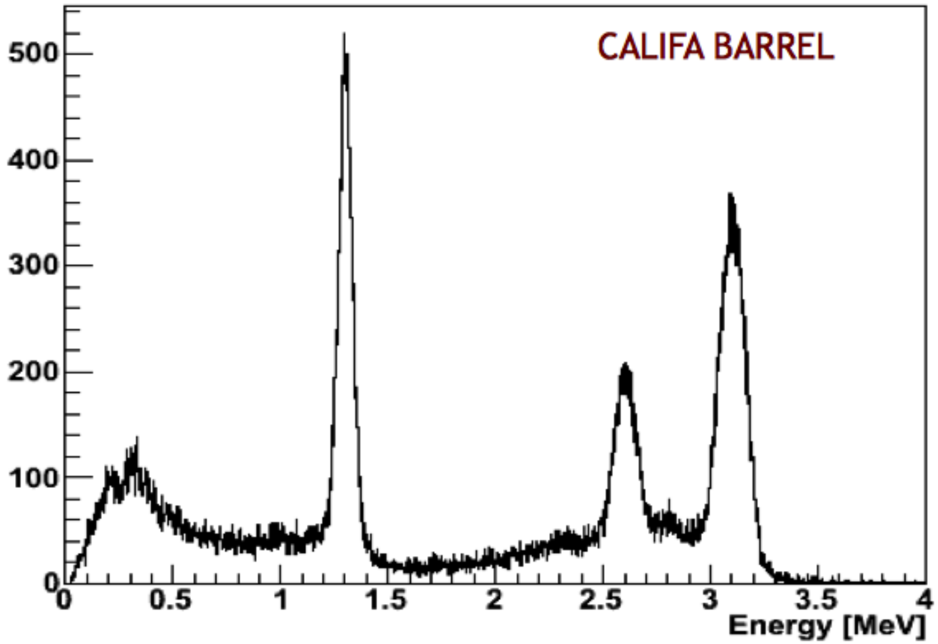
- Experimental spectra obtained with NaI detectors at FRS:GSI.
- CALIFA BARREL spectra mimics the statistics to demonstrate the high resolution expected in nuclear spectroscopy.




D. Cortina *et al*. Phys. Rev. Lett. 93 (2004) 062501

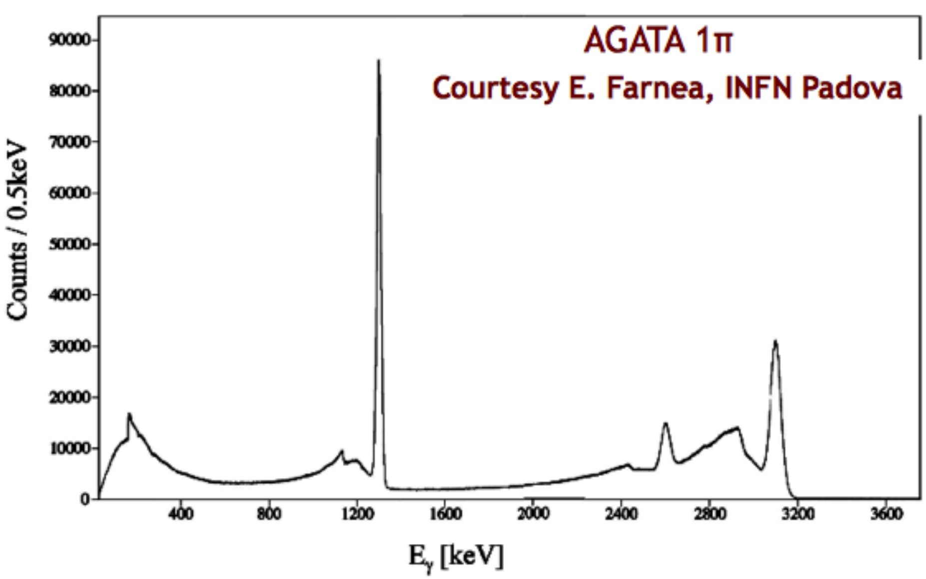


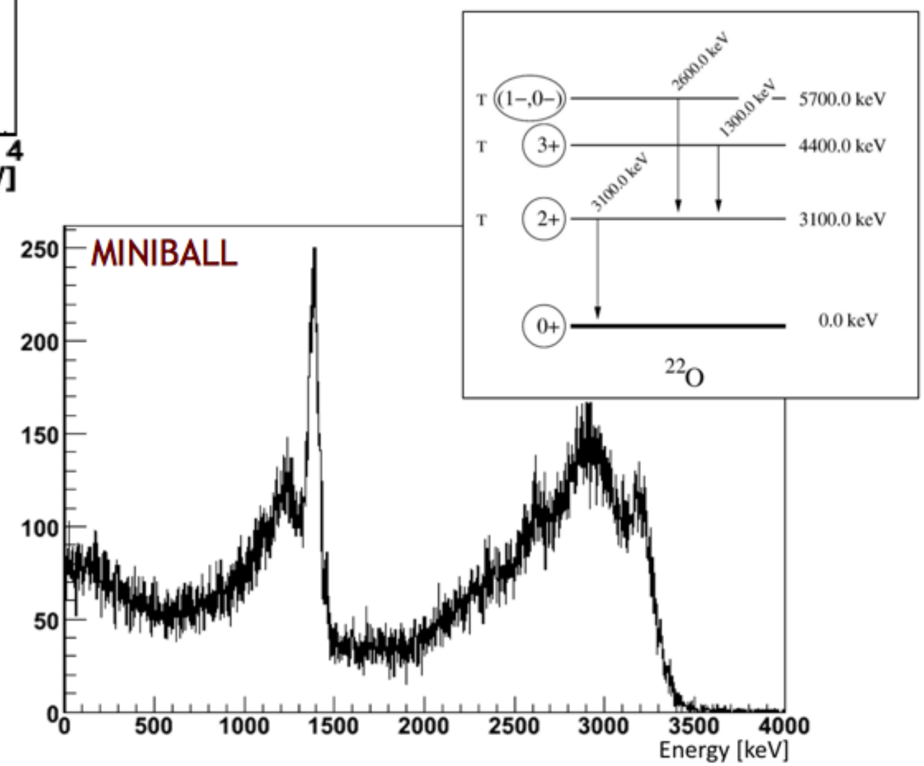
# Selected Physical cases: γ ray spectroscopy

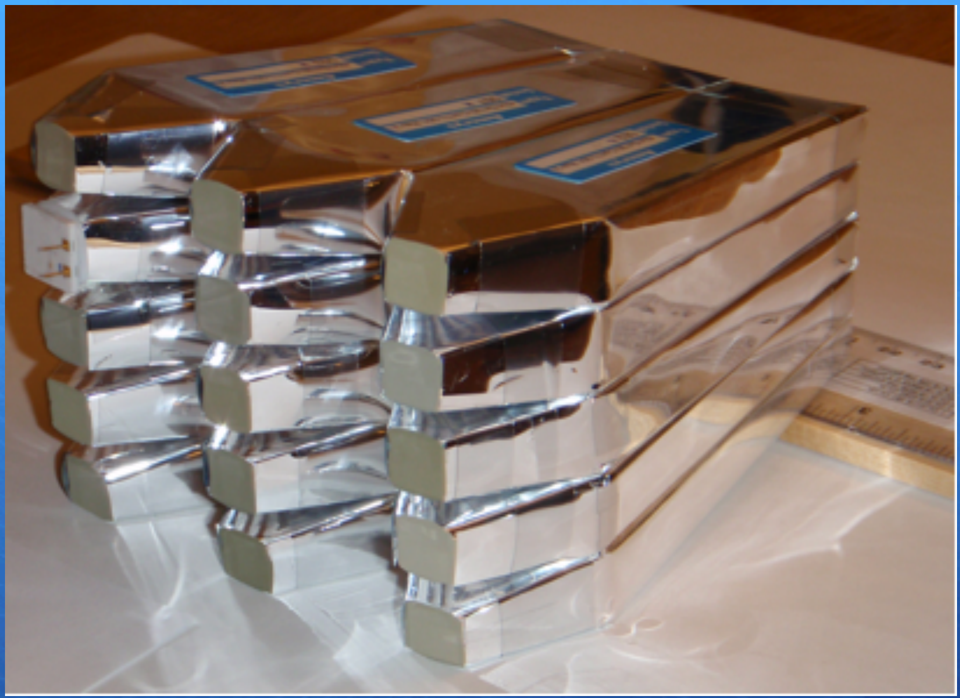


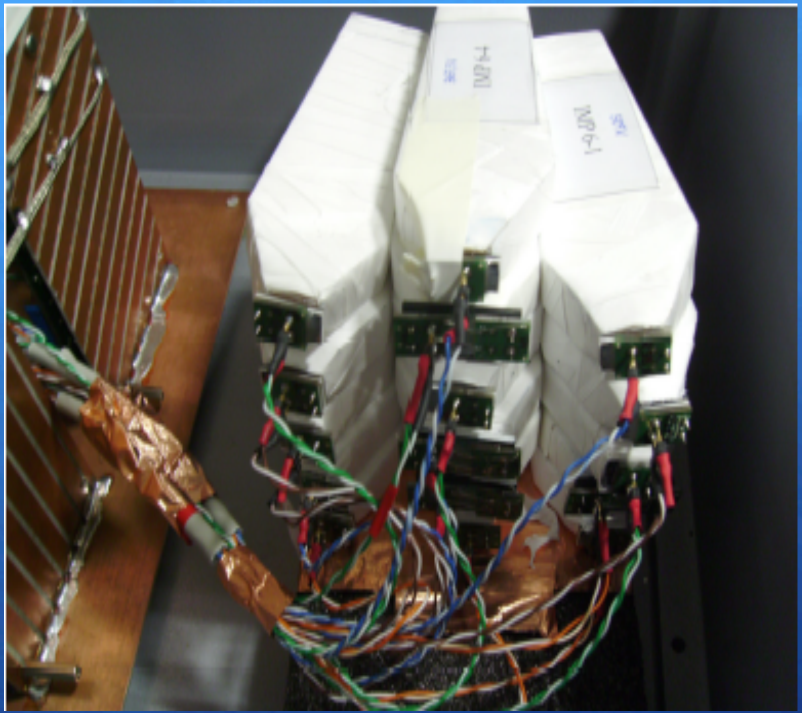

***Comparing with other Ge-based solutions:***

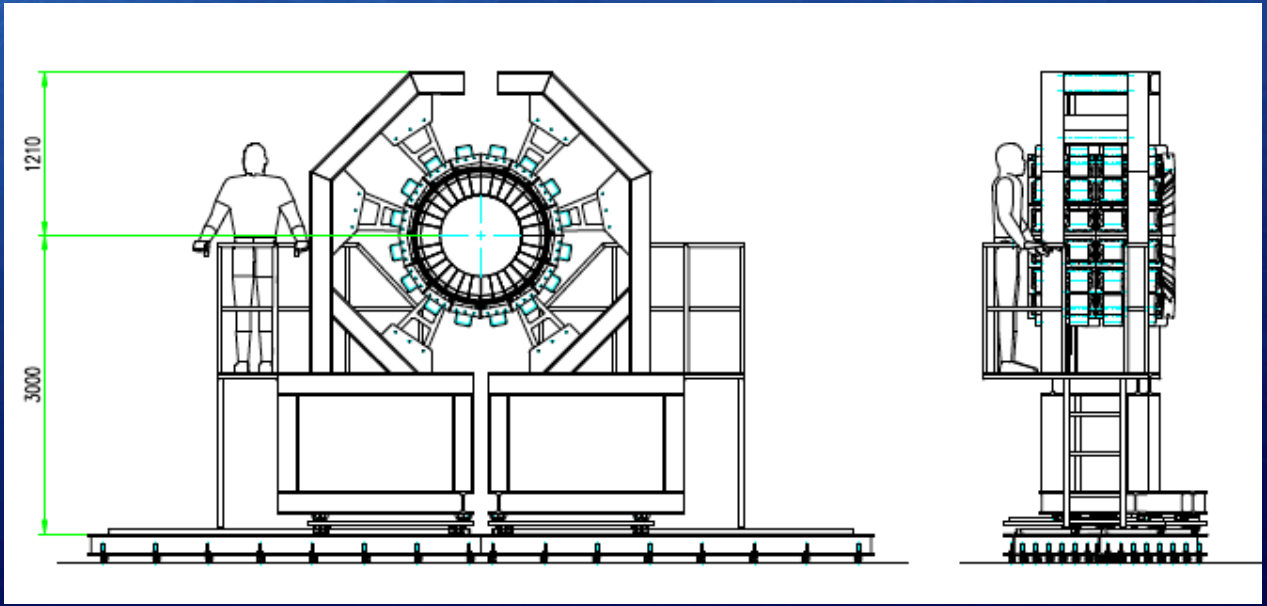
- MINIBALL Ge Array (G4 sim., see setup details in P. Maierbeck *et al*, Phys. Lett. B 675(2009)22).
- AGATA 1π (G4 sim.).



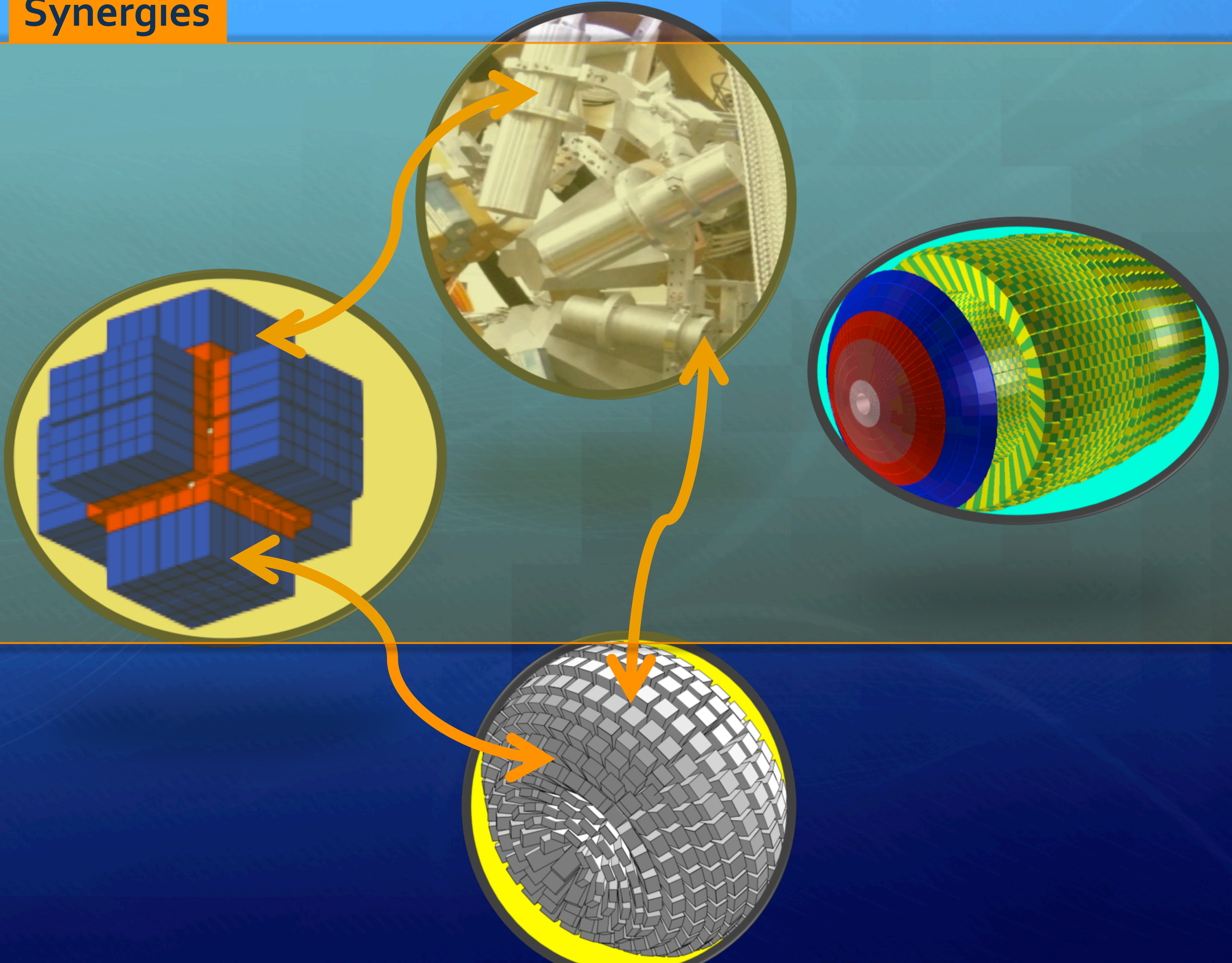


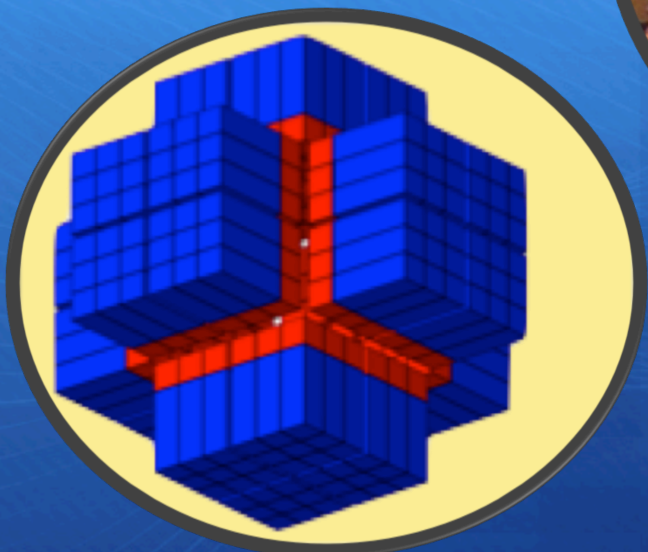


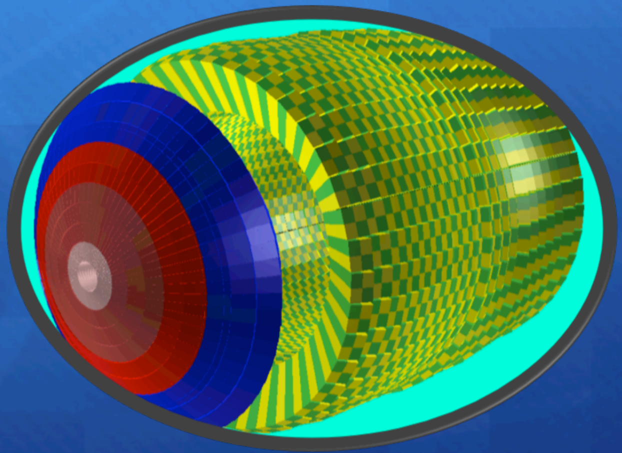

1210
3000

# Synergies, GANAS@NupNet project

## Synergies







# GANAS
# GAmma detection with New Advanced Scintillators
# NupNet Project

GANAS coordinator: Olof Tengblat

ERA-NET for Nuclear Physics Infrastructures

## GANAS Project, ca. 1.2 M€, for 3 years

| | | | |
|---|---|---|---|
| 1: | IEM-CSIC | Madrid Spain | Olof.tengblad@csic.es |
| 2: | USC | Santiago de Compostela, Spain | d.cortina@usc.es |
| 3: | IPNO | Orsay, France | matea@ipno.in2p3.fr |
| 4: | IPHC | Strasbourg, France | Marc.rousseau@iphc.cnrs.fr |
| 5: | TUM | Germany | Roman.Gernhaeuser@ph.tum.de |
| 6: | U. Giessen, Germany | (Jürgen Gerl) | Christoph Scheidenberger |
| 7: | IFJ PAN Krakow, | Polish Academy of Sciences, | Adam.Maj@ifj.edu.pl |
| 8: | U. Warszawa, Poland | (Pawel Napiorkowski ) | pjn@slcj.uw.edu.pl |
| 9: | INRNE | Bulgaria | Balabanski@inrne.bas.bg |
| 10: | U. York | UK | david.jenkins@york.ac.uk |
| 11: | INFN U. Milano , Italy | | franco.camera@mi.infn.it |
| 12: | GANIL | (Christelle Schmitt) | schmitt@ganil.fr |

| | | | | | |
|---|---|---|---|---|---|
| WP0 | coordination,networking | Spain | IEM-CSIC | Olof Tengblad |
| WP1 | New Scintillator Materials | France | IPNO | Gulia Hull |
| WP2 | Photosensors | UK | U.York | David Jenkins |
| WP3 | Pulse Shape Analysis | Germany | TUM | Roman Gernhaeuser |
| WP4 | Position Sensitivty in Large Crystals & Applications | Italy | INFN U.Milan | Franco Camera |
| WP5 | Segmented Scintillator Arryas | Poland | IFJ PAN Krakow | Maria Kmiecik |

| | **Spain** | | **France** | | | **Germany** | | **Poland** | | **Bulgaria** | **UK** | **Italy** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1 - IEM | P2 - USC | P3 - IPNO | P4 - IPHC | P12 - GANIL | P5 - TUM | P6 - Giessen | P7 - IFJ PAN Krakow | P8 - U. Warszawa | P9 - INRNE | P10 - U.York | P11 - INFN | tot |
| WP0 | 10 | 10 | 5 | 5 | | 15 | 11 | 8 | 5 | 5 | 5 | 10 | 89 |
| WP1 | | | 34 | | | | | | 10 | 9 | | | 53 |
| WP2 | | 57 | | 30 | | 90 | | | | 9,25 | 30 | | 216,3 |
| WP3 | 55 | | | | | 140 | | 25 | 25 | | | | 245 |
| WP4 | | | | | | | 72 | 15 | | | 13 | 40 | 140 |
| WP5 | 57 | 55 | | | 25 | | 72 | 80 | 45 | | | | 334 |
| OH | | | 6 | | | 44 | 31 | 22 | 15 | 1,75 | 53 | | 172,8 |
| tot | 122 | 122 | 45 | 35 | 25 | 289 | 186 | 150 | 100 | 25 | 101 | 50 | *1250* |

Money to WP0 means travel and attending workshops

OH= Over Head

# Summary

- The new scintillator materials, as LaBr3, brought new dynamics in designing new large scintillator arrays for the radioactive ion beam facilities
- **HECTOR+** array, made of 10 large LaBr3, is ready to be used
- **PARIS** concept of LaBr3+NaI phoswich detectors is validated, MoU for Phase 1 signed
- **SHOGUN**, made of LaBr3 is a the development phase
- **CALIFA** is almost ready for construction
- Synergies between these detectors established (thanks to NupNet project)
- New physics cases for those arrays and for RIB facilities (SPIRAL2, NUSTAR@FAIR, SPES, RIKEN, HIE-ISOLDE) are prepared

Many thanks to all active members of the HECTOR, HECTOR+, PARIS, SHOGUN and CALIFA collaborations

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