Adam Maj (IFJ PAN Kraków)
for the PARIS collaboration

The PARIS project - status and the next stepes

paris.ifj.edu.pl

Symposium
„The SHOGUN gamma-ray spectrometer"
RIKEN, February 4-5, 2011

PARIS — Photon Array for studies with Radioactive Ion and Stable beams

4-5-6th October, 2005 „Future prospects for high resolution gamma spectroscopy at GANIL" - Convenors : Bob Wadsworth and Wolfram Korten

WG „Collective modes in continuum" – convenors: Silvia Leoni & Adam Maj

Spiral2

GANIL
SAC open session
October 19th, 2006

Letter of Intent for SPIRAL 2

Title: High-energy γ-rays as a probe of hot nuclei and reaction mechanisms

Spokesperson(s) *(max. 3 names, laboratory, e-mail - please underline among them one corresponding spokesperson):*
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GANIL contact person
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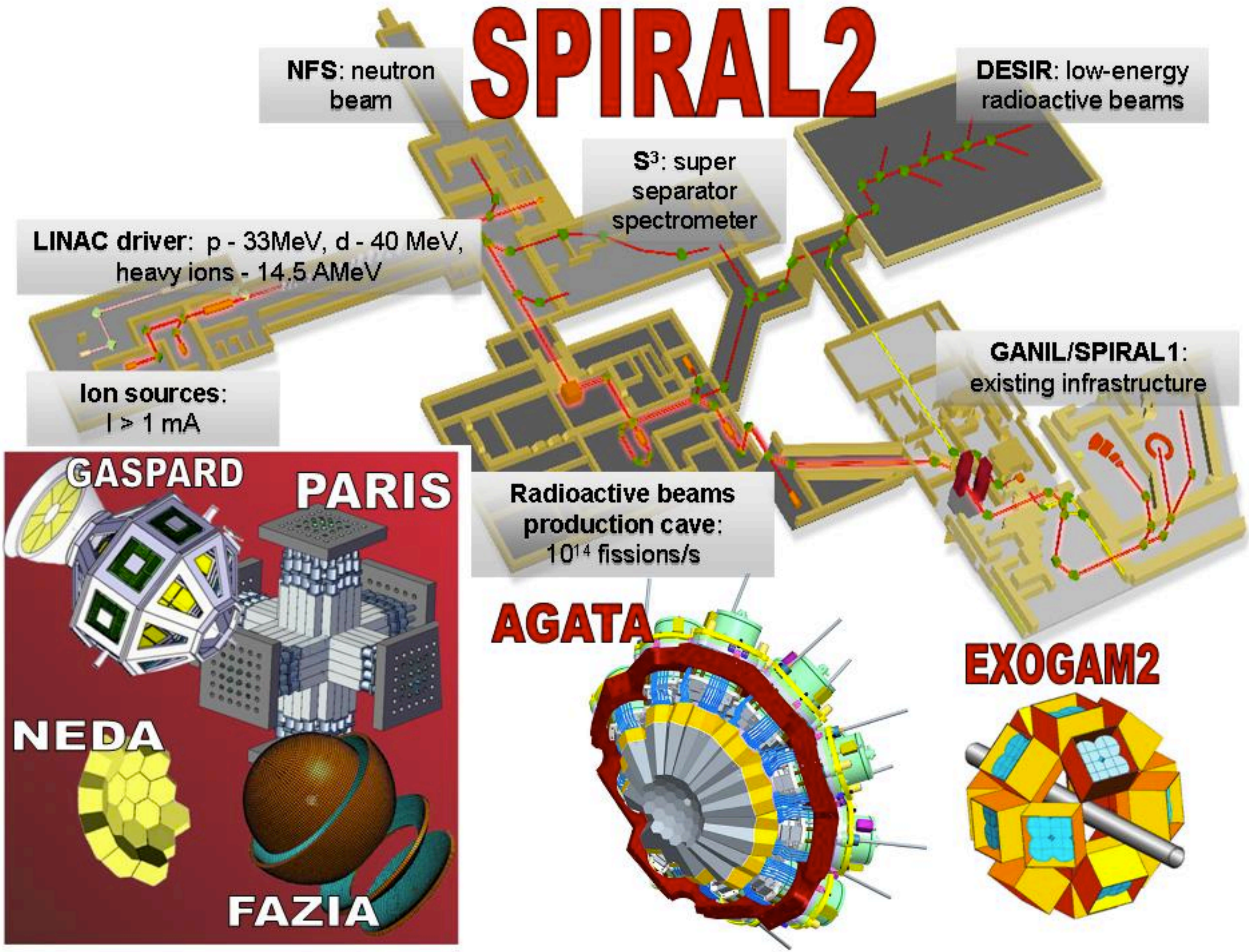
Aim:
to design and build efficient gamma calorimeter *PARIS*


SPIRAL2
NFS: neutron beam
DESIR: low-energy radioactive beams
S3: super separator spectrometer
LINAC driver: p - 33MeV, d - 40 MeV, heavy ions - 14.5 AMeV
GANIL/SPIRAL1: existing infrastructure
Ion sources: I > 1 mA
Radioactive beams production cave: 10^14 fissions/s
GASPARD
PARIS
NEDA
FAZIA
AGATA
EXOGAM2

PHYSICS CASE

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 (case mainly for FAIR and RIKEN)
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 S^3) *
30<A<150
(F. Azaiez, I. Stefan, B. Fornal et al.)

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

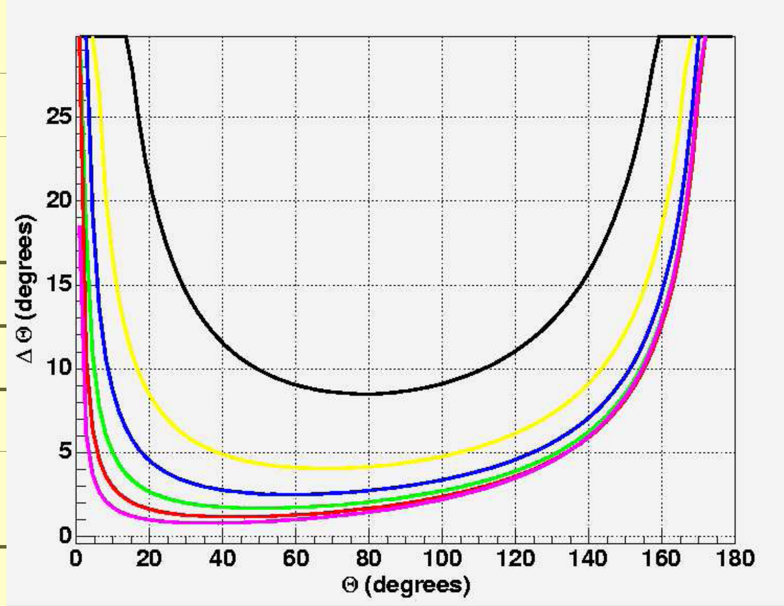
n) PDR in proton-rich nuclei with NEDA +PARIS
G. De Angelis et al.

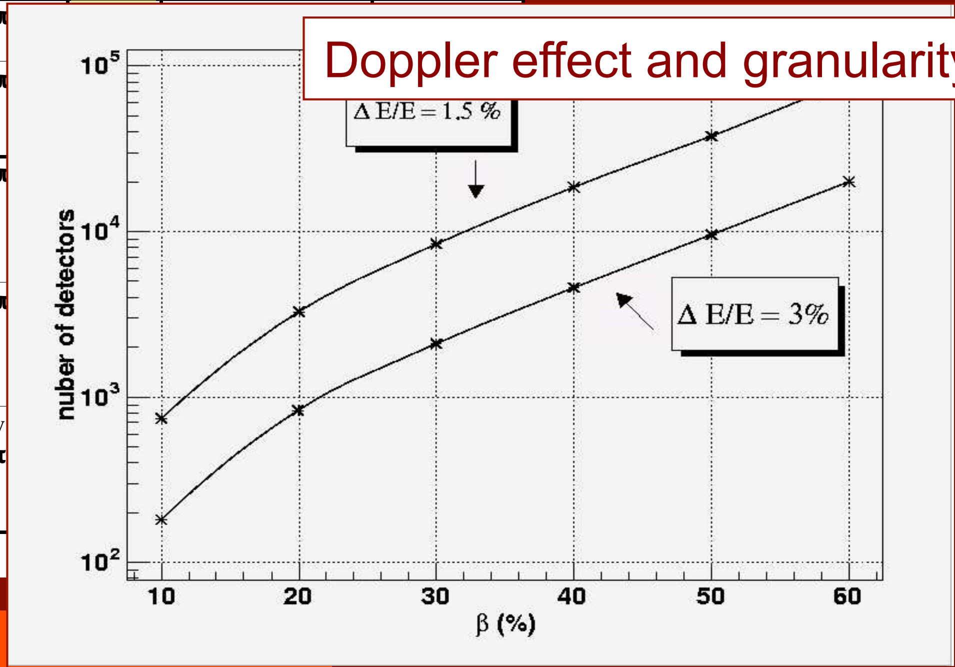
o) Onset of chaotic regime: PARIS +AGATA
S. Leoni et al.

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

Doppler effect and granularity

Physics Case	Recoil mass	v/c [%]	E_γ range [MeV]	$\Delta E_\gamma/E_\gamma$ [%]	$\Delta E_{sum}/E_{sum}$ [%]	ΔM_γ	Ω coverage
Jacobi transition	40-150	<10	0.1-30	4	<5	4	2π-4π
Shape Phase Diagram	160-180	<10	0.1-30	6	<5	4	2π-4π
Hot GDR in n-rich nuclei	120-140	<11	0.1-30	6	<8	4	2π-4π
Isospin mixing	60-100	<7	5-30	6	-	-	4π
Reaction dynamics	160-220	<7	0.1-25	6-8	<8	4	2π
Collectivity vs. multi-fragmentation	120-200	<8	5-30	5	-	-	2π
Radiative capture	20-30	<3	1-30	<4	5	-	4π
Multiple Coulex	40-60	<7	2-6	5	-	-	2π
Astrophysics	16-90	0.1	0.1-6	6	5	-	4π
Shell structure at intermediate energies (SISSI/LISE)	16-40	20-40	0.5-4	3	-	-	3π
Shell structure at low energies (separator part of S^3)	30-150	10-15	0.3-3	3	-	-	3π
Relativistic Coulex	40-60	50-60	1-4	4	-	1	Forw 3π





In our physics cases:
<β> ≈ 10%; ΔM/M<4 → **Granularity: 200-800**
ΔT: <1 ns; ΔEγ/Eγ: < 3%; high efficiency up to 15 MeV

PARIS has to

- be transportable (between different facilitiess)
- be modular (to be connected with other detectors: AGATA, GASPARD, NEDA, FAZIA, ACTAR ...)
- have high granulation (multiplicity measurement, Doppler correction,...)
- have very high efficiency for high-energy γ-rays
- have good timing resolution (<500 ps)
- have possibly good energy resolution

COLLABORATION

PARIS Management board
A. Maj - project spokesman;
D.G. Jenkins, J.P. Wieleczko, J.A. Scarpaci - deputies

PARIS *Advisory* Committee
F. Azaiez (F) -chairman, D. Balabanski (BG), W. Catford (UK), D. Chakrabarty (India), Z. Dombradi (H), S. Courtin (F), J. Gerl (D), D. Jenkins (UK) - deputy chairman, S. Leoni (I), A. Maj (PL), J.A. Scarpaci (F), Ch. Schmidt (F), J.P. Wieleczko (F)

Active working groups
1. Simulations (O. Stezowski et al.)
2. PARIS mechanical design scenarios (S. Courtin, D. Jenkins et al.)
3. Physics cases and theory background (Ch. Schmitt et al.)
4. Detectors (O. Dorvaux et al.)
5. Electronics (P. Bednarczyk et al.)
6. PARIS-GASPARD synergy (J.A. Scarpaci et al.)
7. Financial issues (J.P. Wieleczko et al.)
8. PARIS in FP7 projects (A. Maj, F. Azaiez et al.)

J. Pouthas – PARIS liaison to SPIRAL2 project management

Members of the Collaboration :

Give the list of participating institutions and names of collaborators.

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Nuclear Physics Group, The University of Manchester (UK): A. Smith
RIKEN Tokyo (JP): P. Doornenbal

40 institutions from 17 countries
≈ 100 physicists, engineers and PhD students

PARIS desing concepts:

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

Inner (hemi-)sphere, highly granular, will be made of new crystals (LaBr3(Ce)). The inner-sphere will 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.

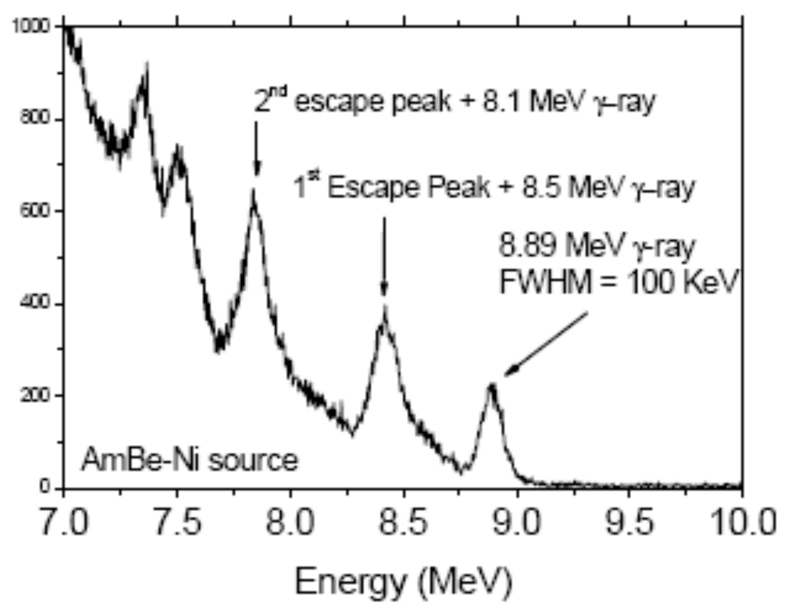
Outer (hemi-)sphere, with high volume detectors, could be made from conventional crystals (BaF2 or NaI). The outer-sphere will measure high-energy photons or serve as an active shield for the inner one.

2 shell concept, in addition to being more economic, shall help to discriminate a high-energy photon from a cascade of low energy gamma transitions in fusion evaporation reactions

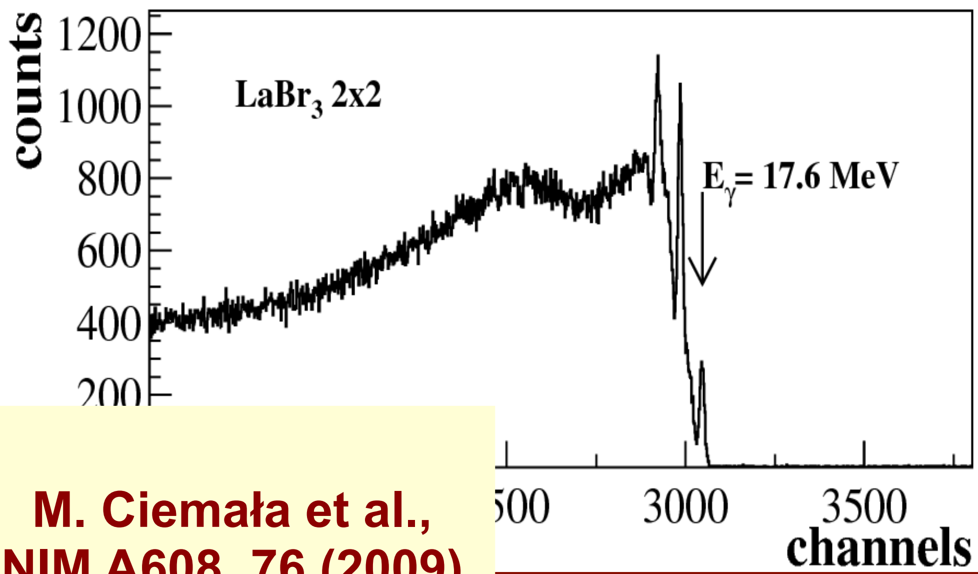
Why LaBr3?

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,worldwide interest, also in medical sector

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)

BASIC SIMULATIONS and DESIGNS

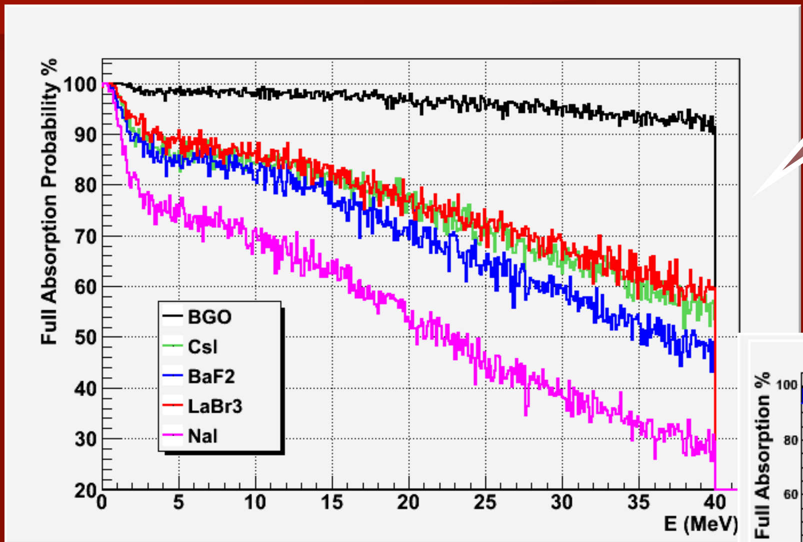
PARIS Geant4 simulation package devlopped
O. Stezowski, Ch. Schnitt – Lyon, M. Ciemala - Krakow

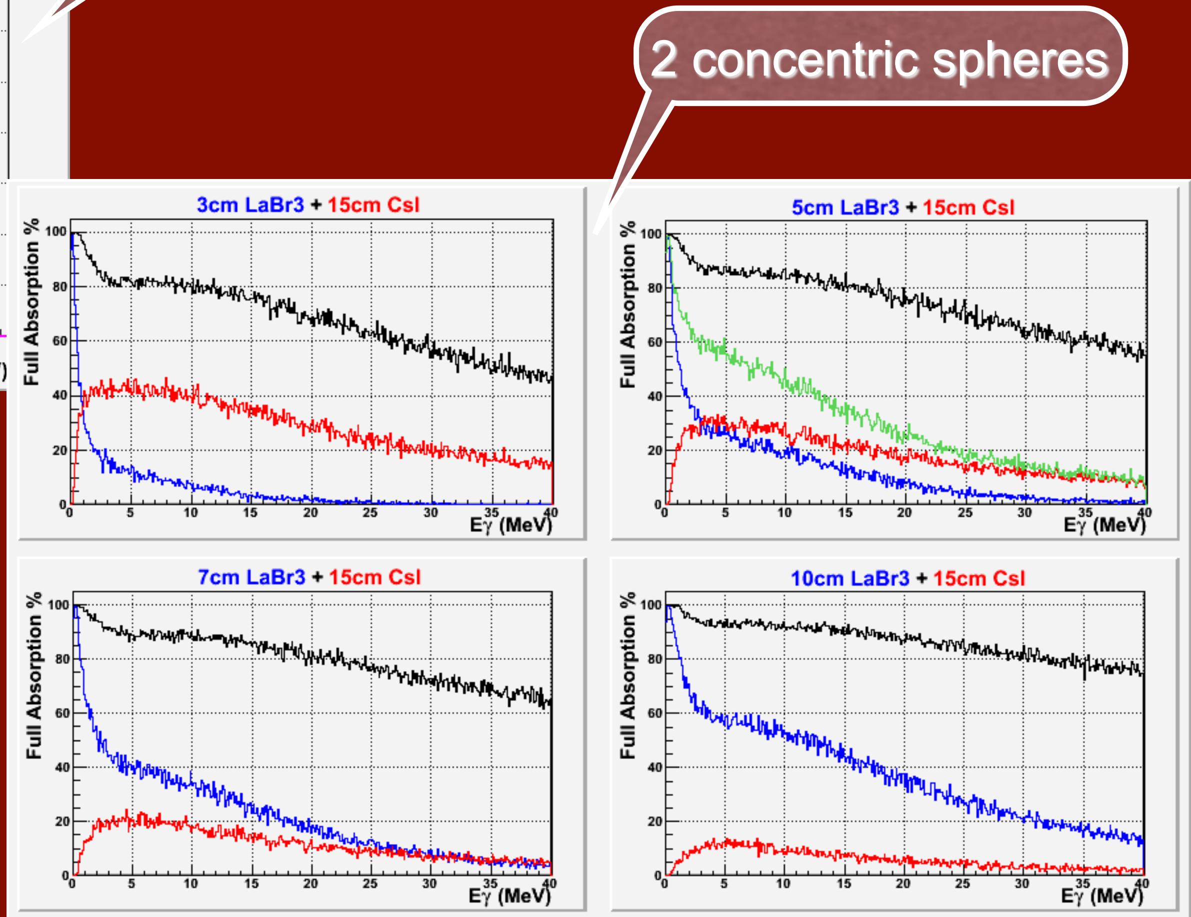
Conclusions from first (rather idealistic) stage of simulations

• The idea of **two concentric layers seems to be rather pertinent**, as suggested by the simulations: a) the percentage of fully absorbed events in one of the 2 shells has been found rather large; b) a two-shell design is relevant provided the inner shell is not too much absorbent. In this way, the inner shell fulfils its calorimeter job, while the outer layer is devoted to the detection of high-energy photons.

• The cubic geometry can provide economical solution for the 2-shell calorimeter.

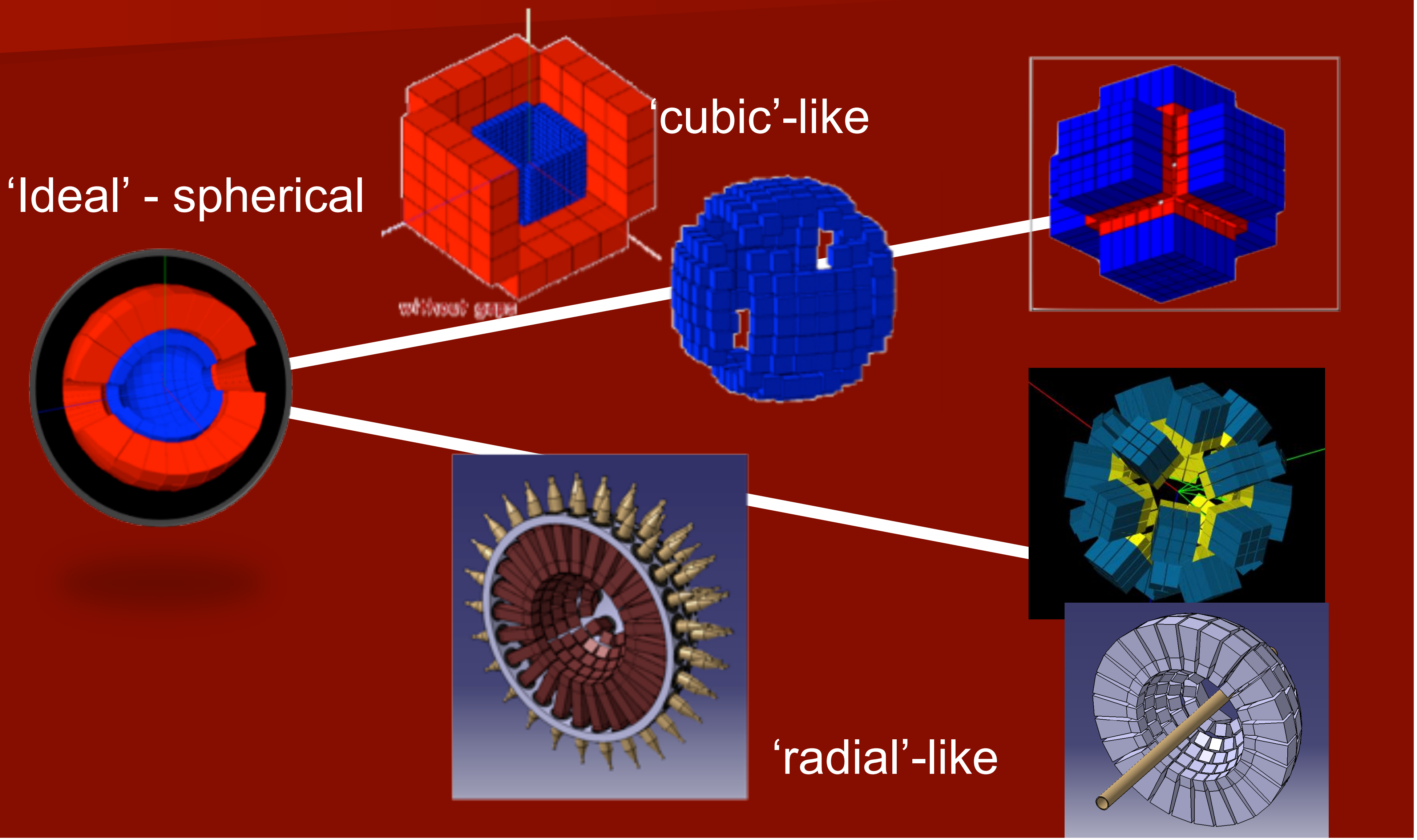
What we have learned



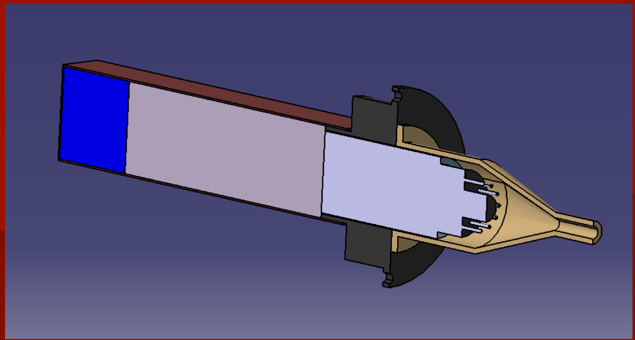


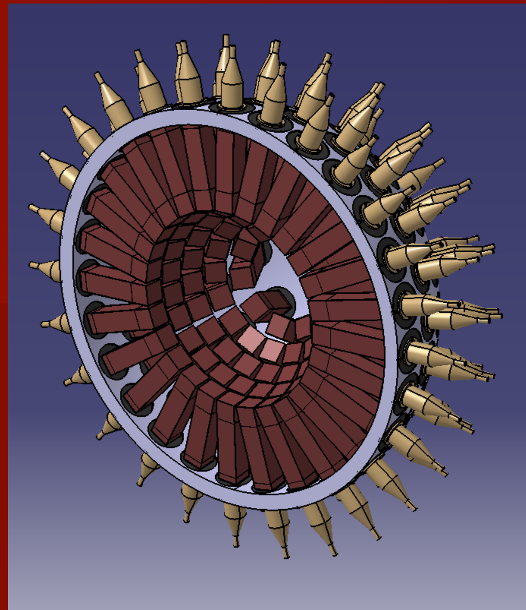
Two shells : OK
(+ reconstruction)

Several geometries studied

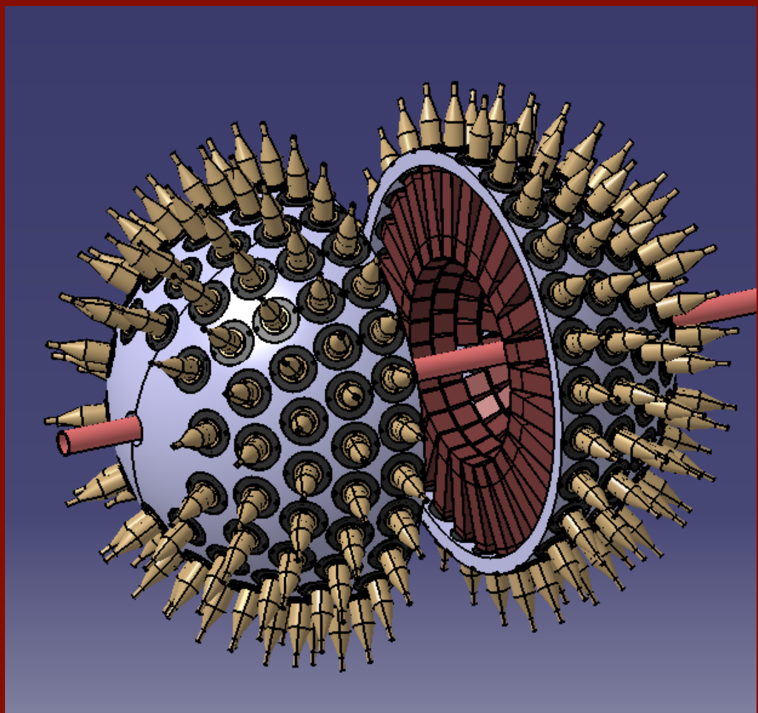


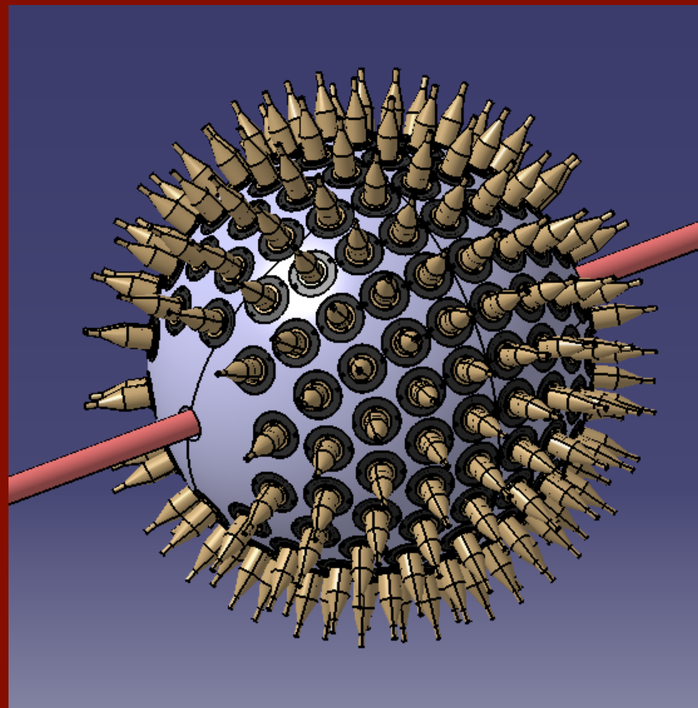
SPHERE-LIKE (RADIAL) GEOMETRY





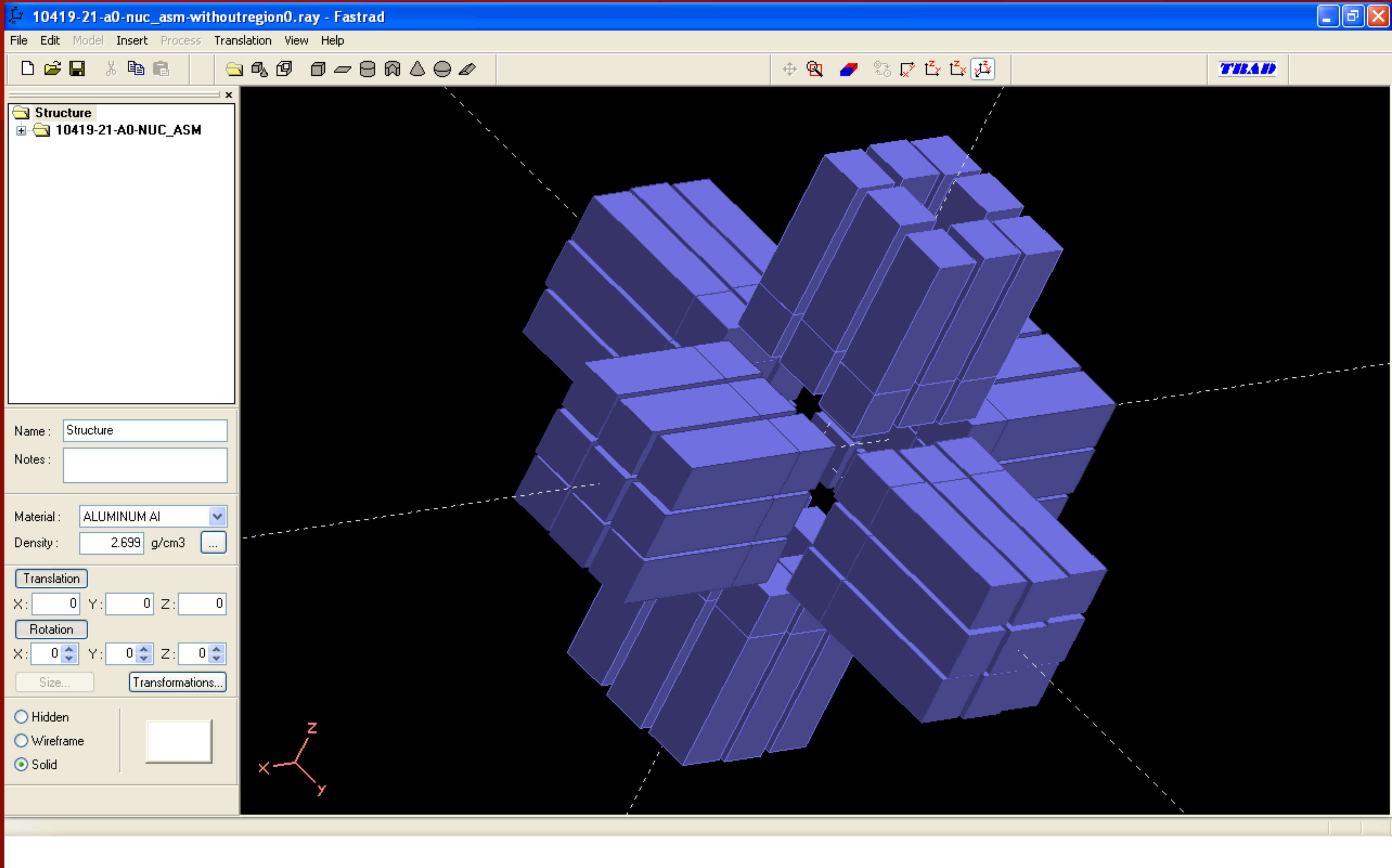
200 elements



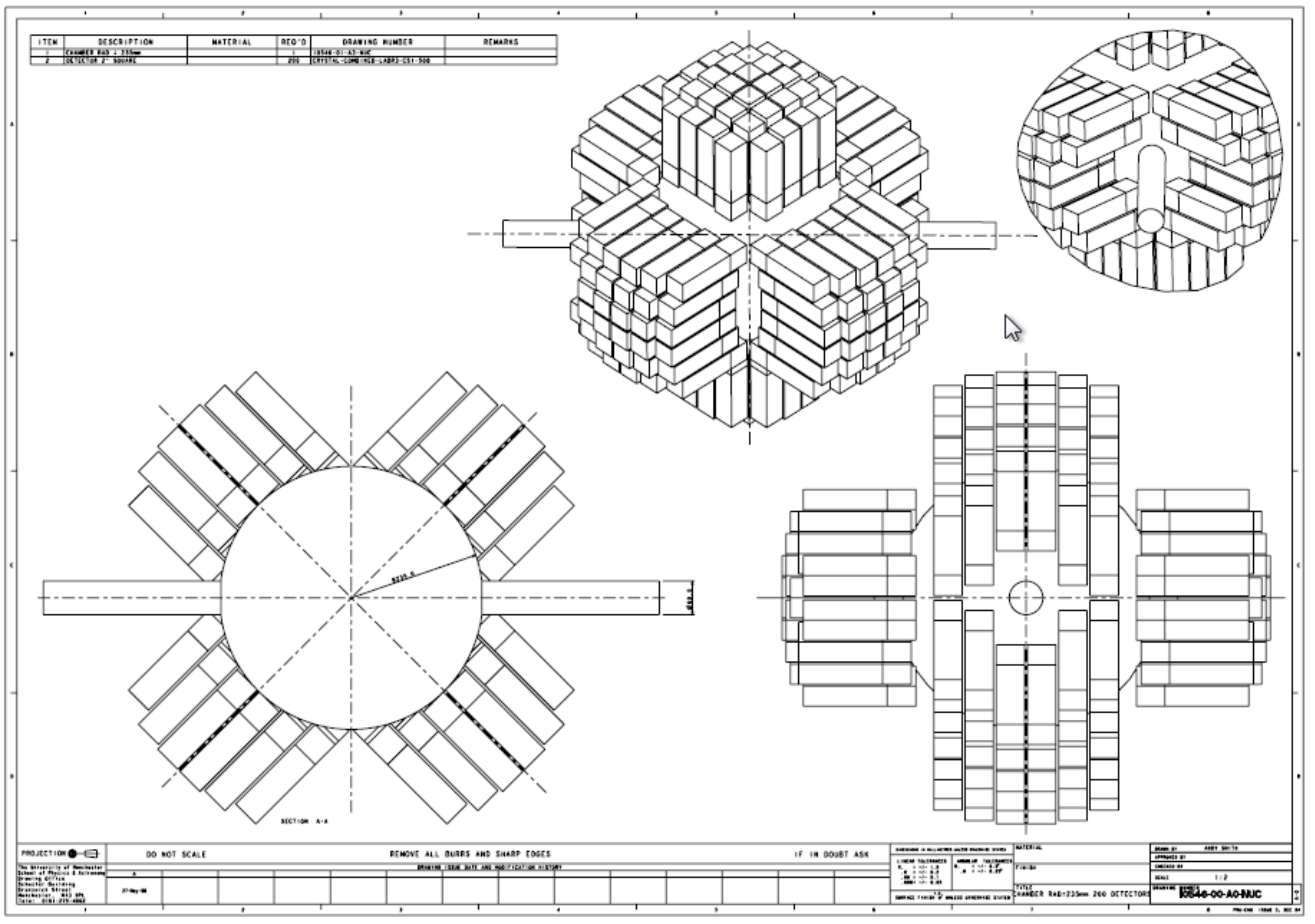


Various cubic designs exist for different inner radii and number of detectors (J. Strachan, A. Smith, S. Courtin, D. Jenkins et al.)

CUBIC-LIKE GEOMETRY



52 phoswitches - Labr3: 2”x2”x2” + CsI: 2”x2”x6” (15 cm inner radius)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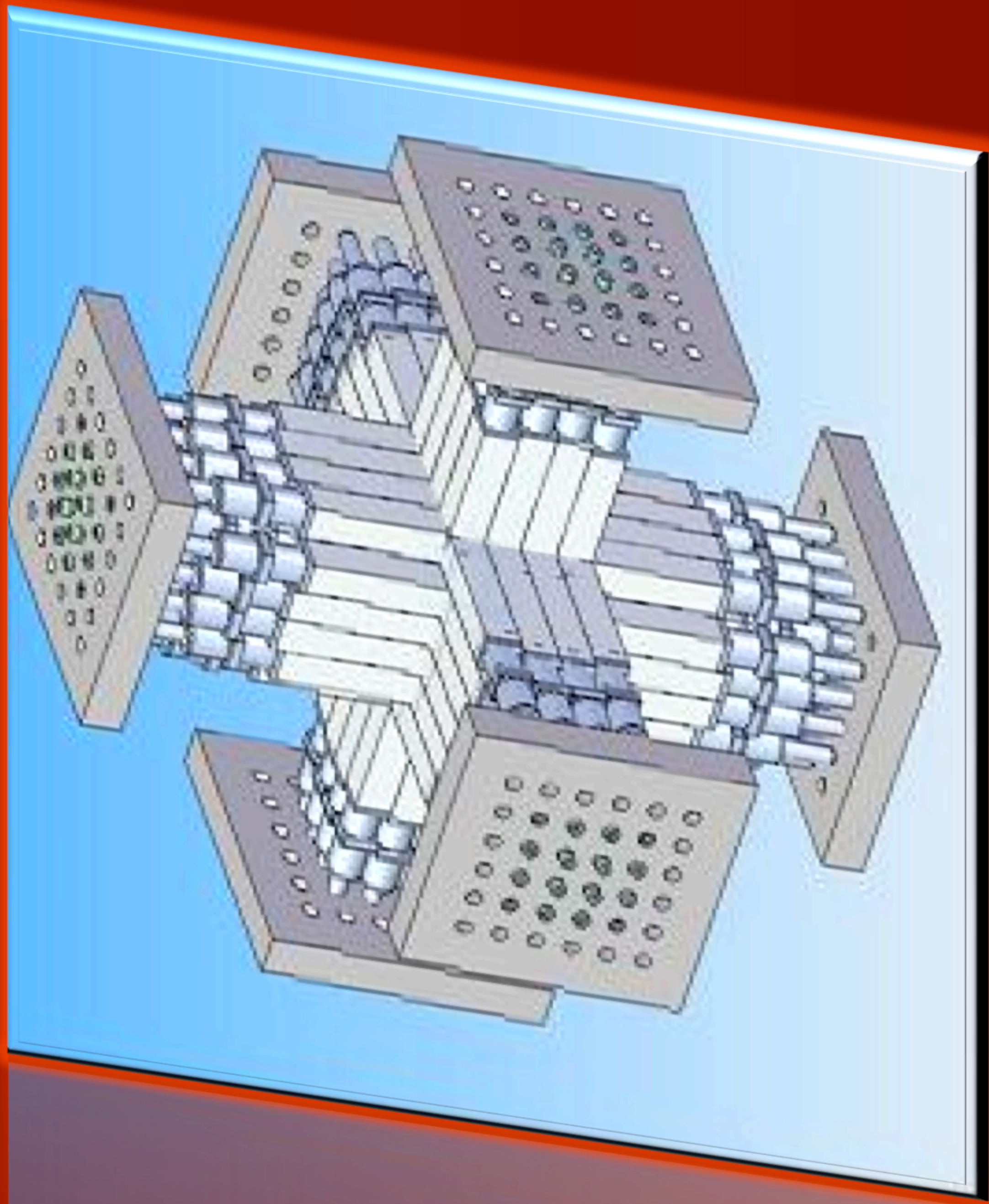
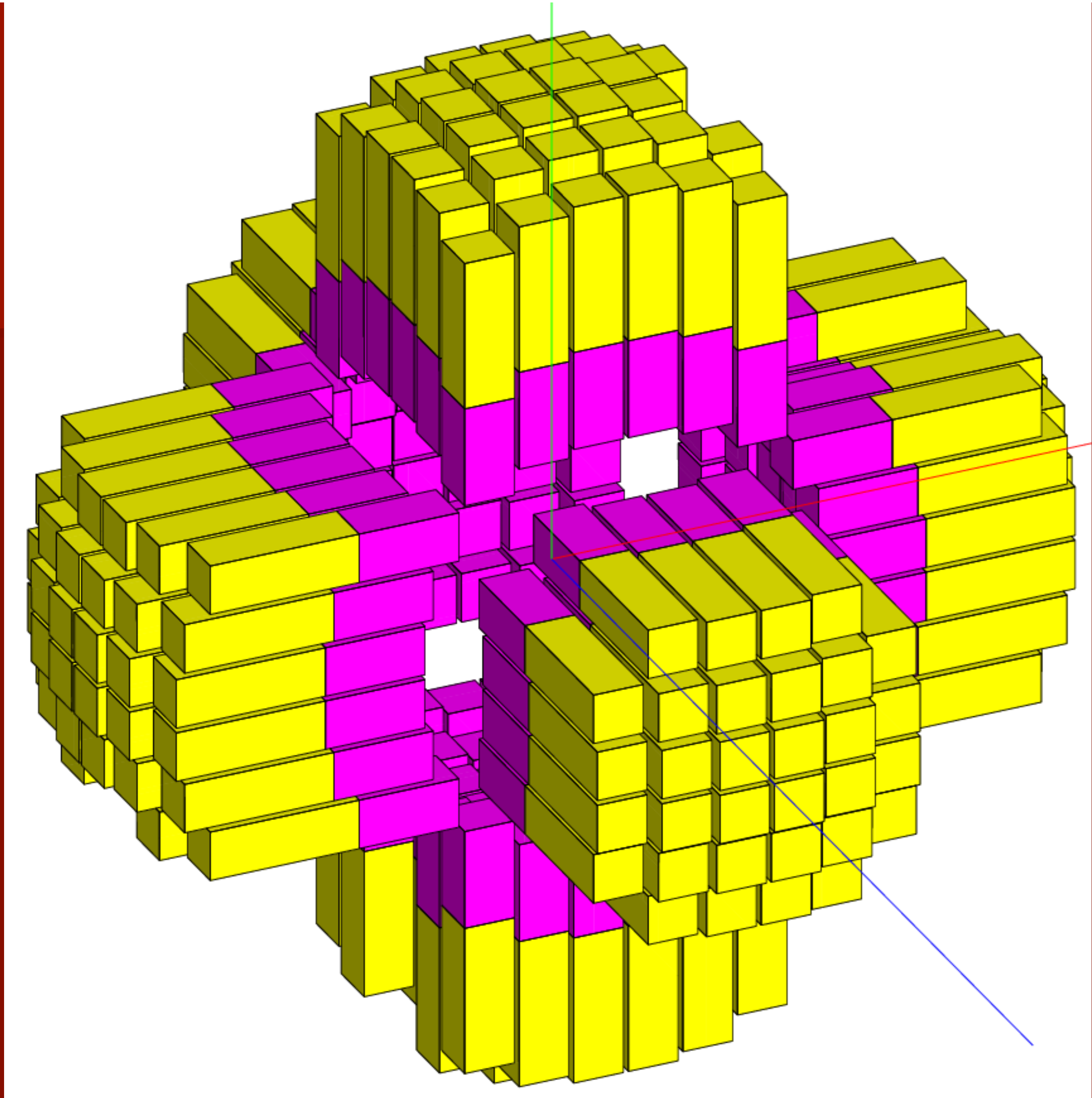
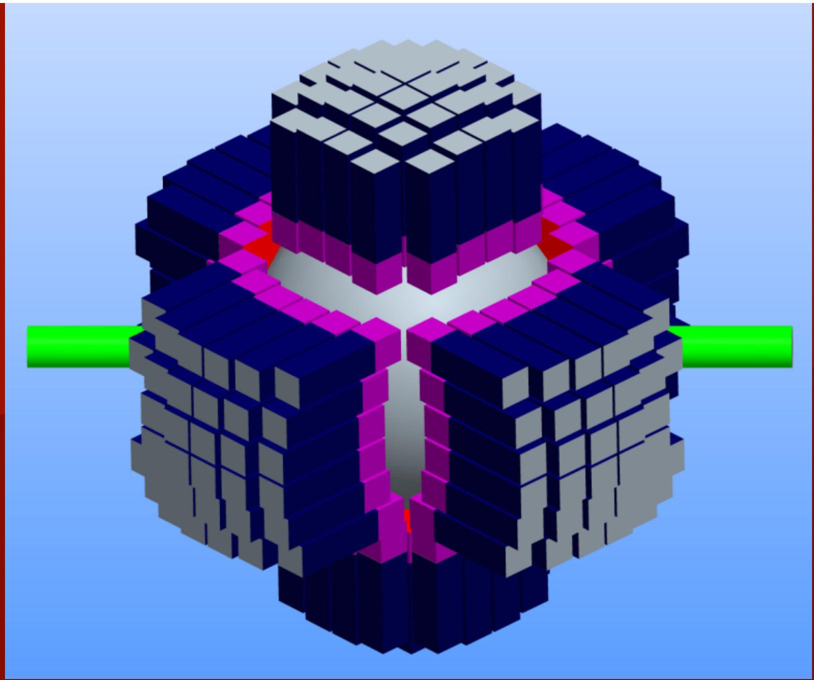


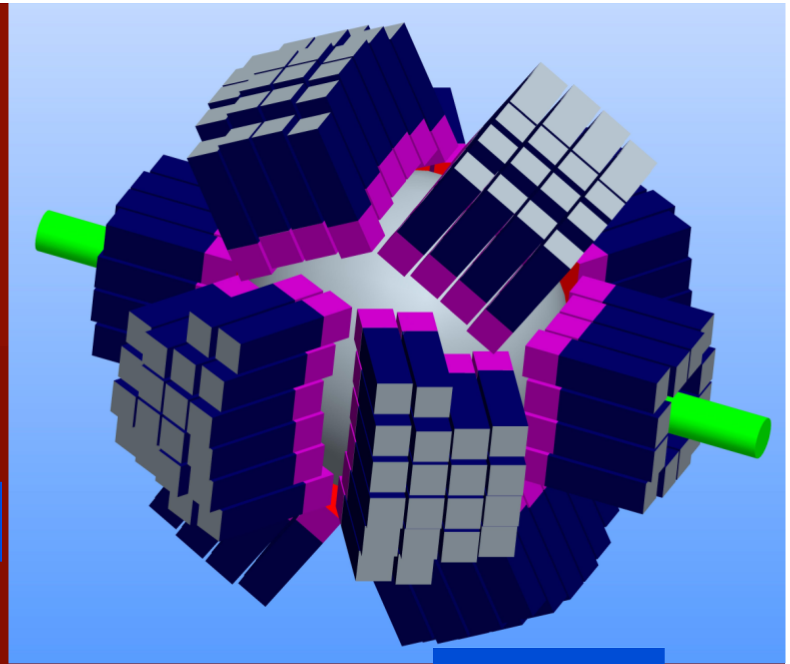


204 phoswitches - Labr3: 2”x2”x2” + CsI: 2”x2”x6” (23 cm inner radius)



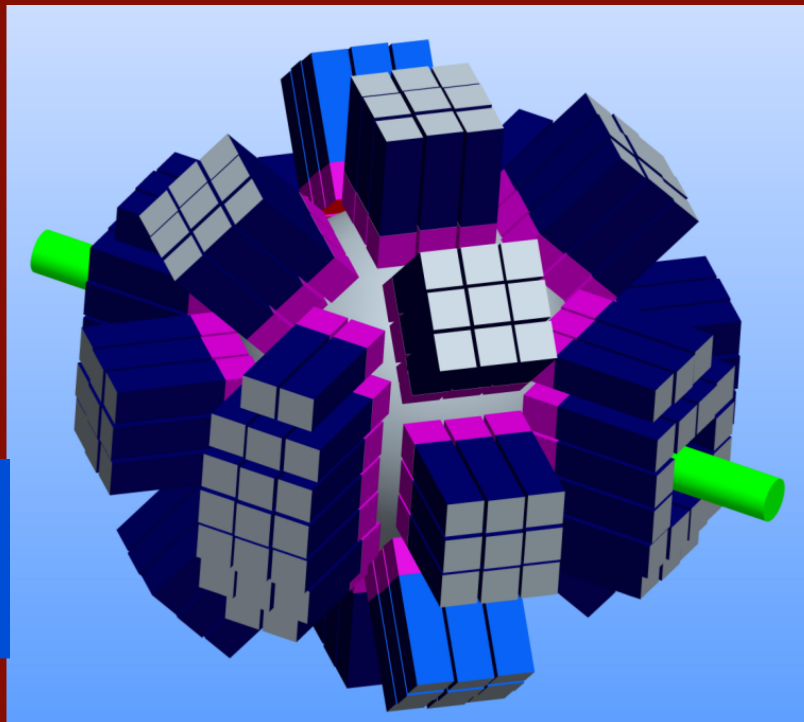
Cube
6 faces

200 elements

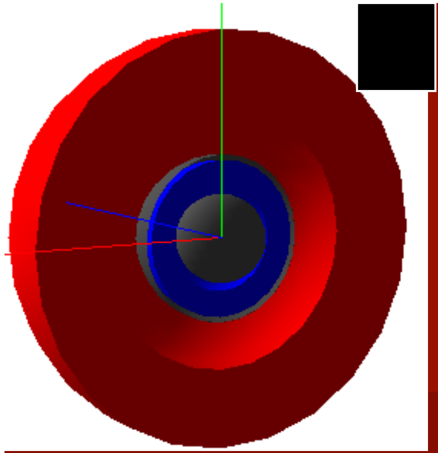


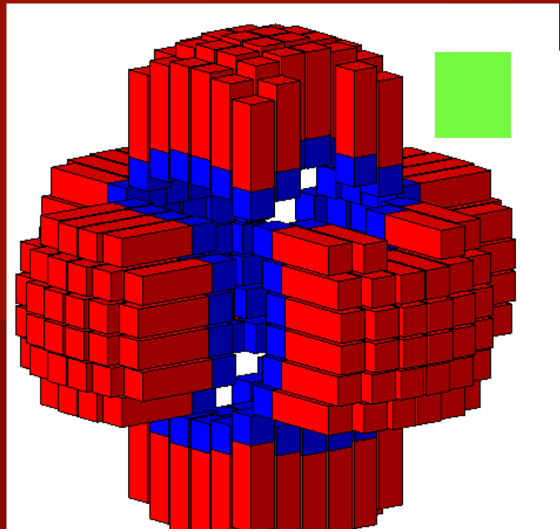
Decagon
10 faces

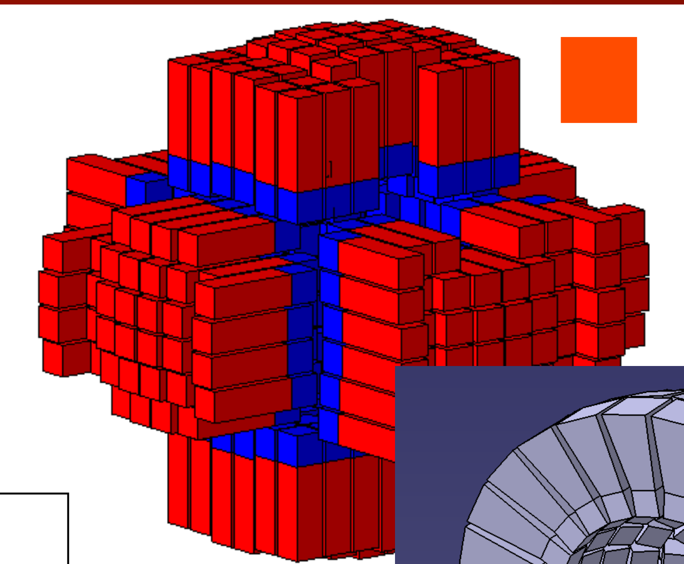
Octadegon
18 faces

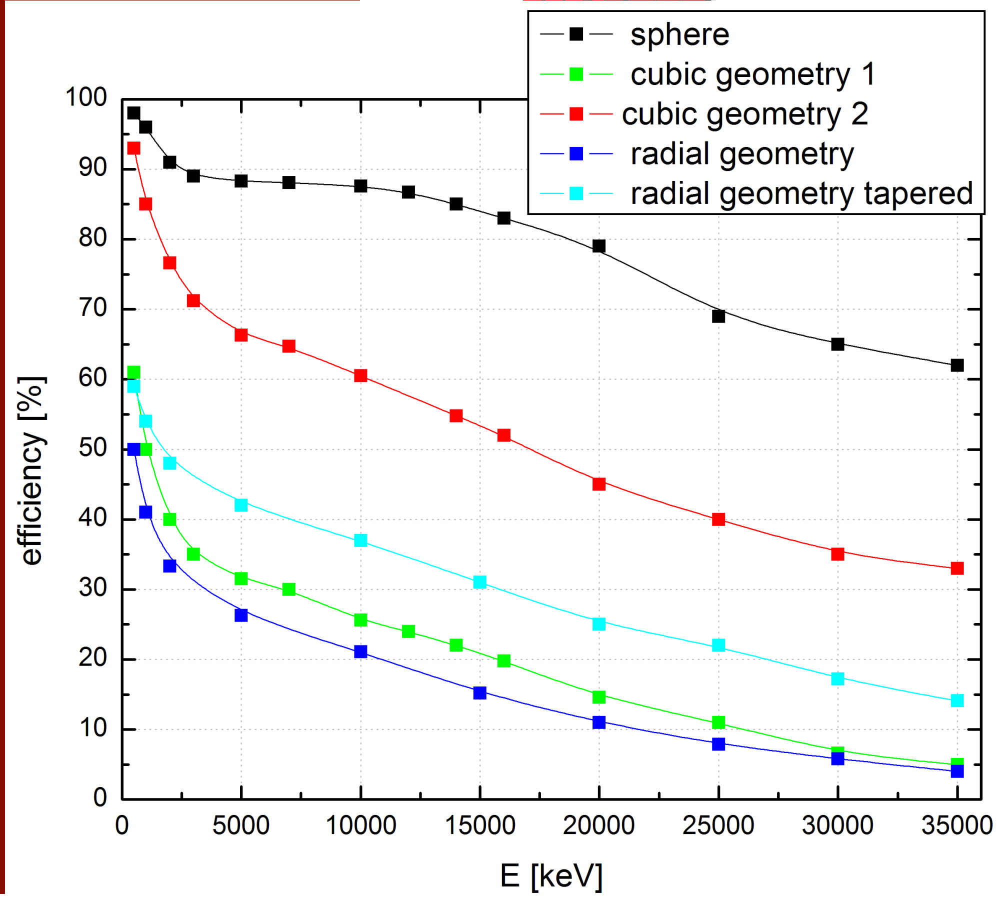


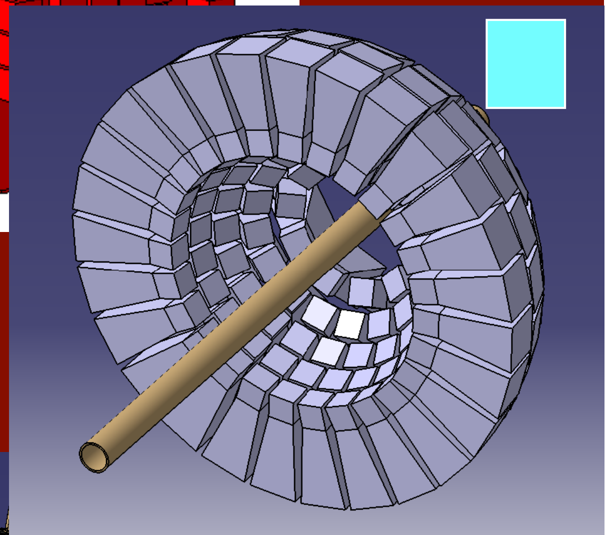
Cubic vs. Radial geometry

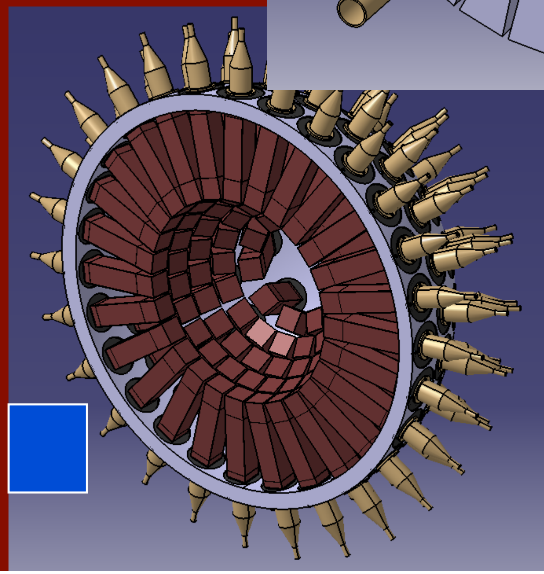




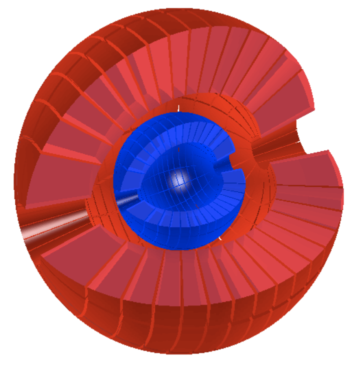








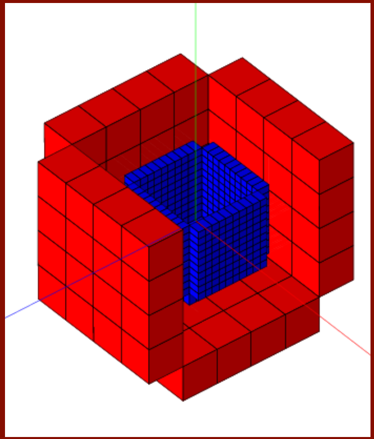
Pros an Cons of studied geometries



SPHERICAL (fix geometry, e.g. same as AGATA modules):

+ : highest efficiency, easy reconstruction, good line shape, compability with other spherical detectors,..

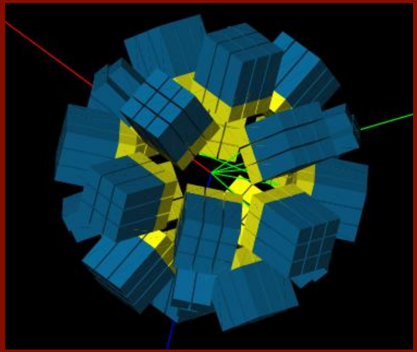
- : limited to one distance, high cost of a segment,…



CUBIC (offering variable geometry):

+ : high efficiency, adjustable to different distances, compatibility with many detectors, lower cost for a segment, easier mechanical support,

- : more complicated reconstruction, worse line shape,

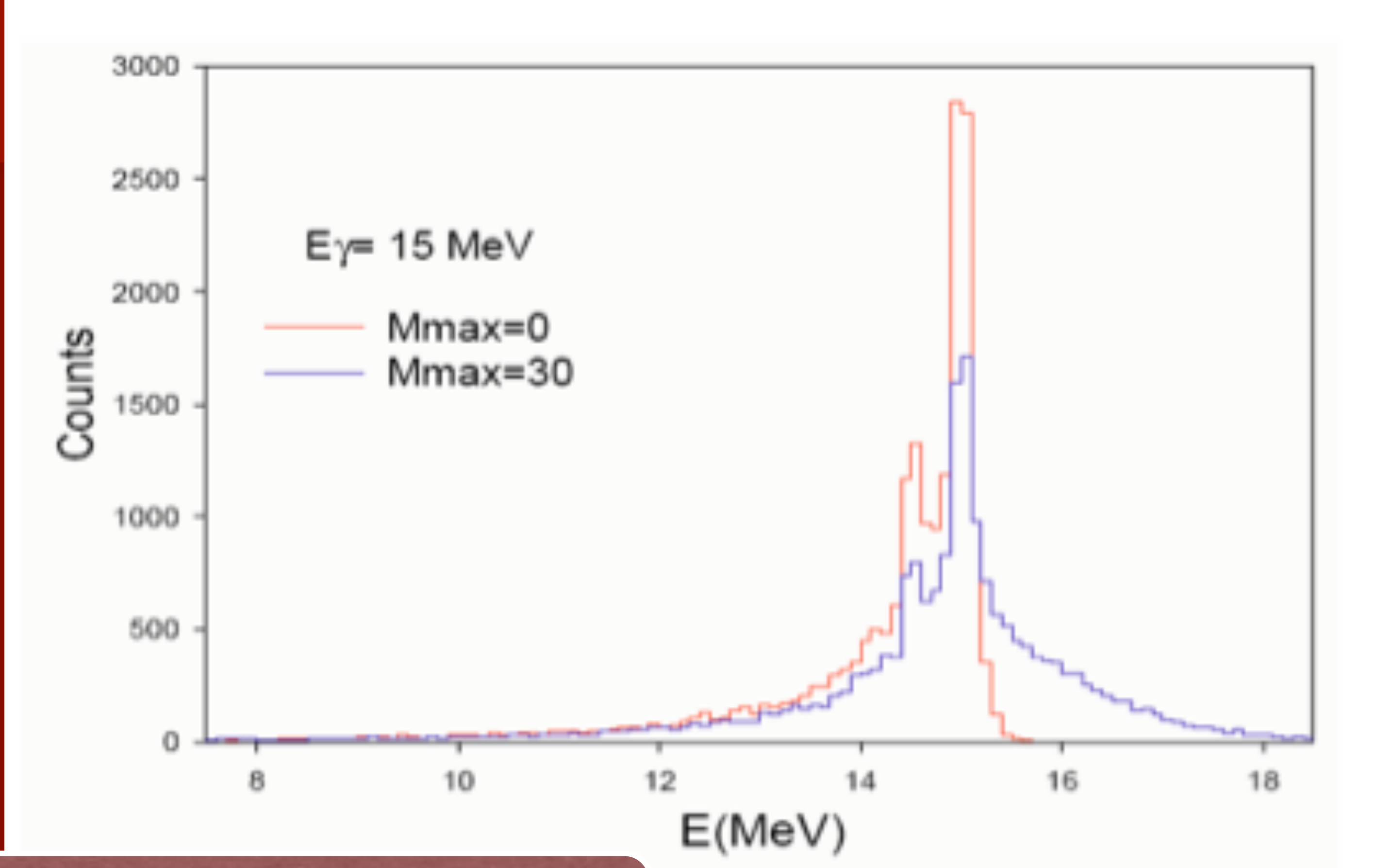


RADIAL (offering variable geometry):

+ : adjustable to different distances, compatibility with many detectors, lower cost for a segment, easier mechanical support, better line shape

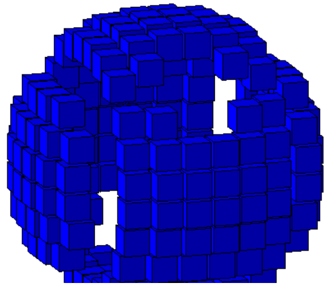
- : lower efficency,,

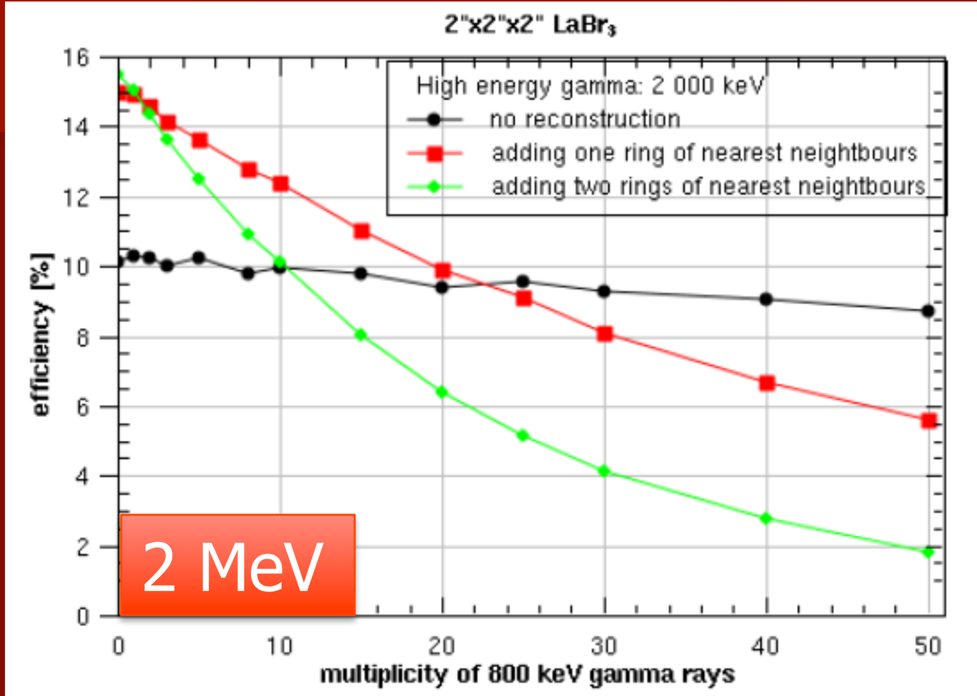
High-energy photon and pileups with low-energy transitions

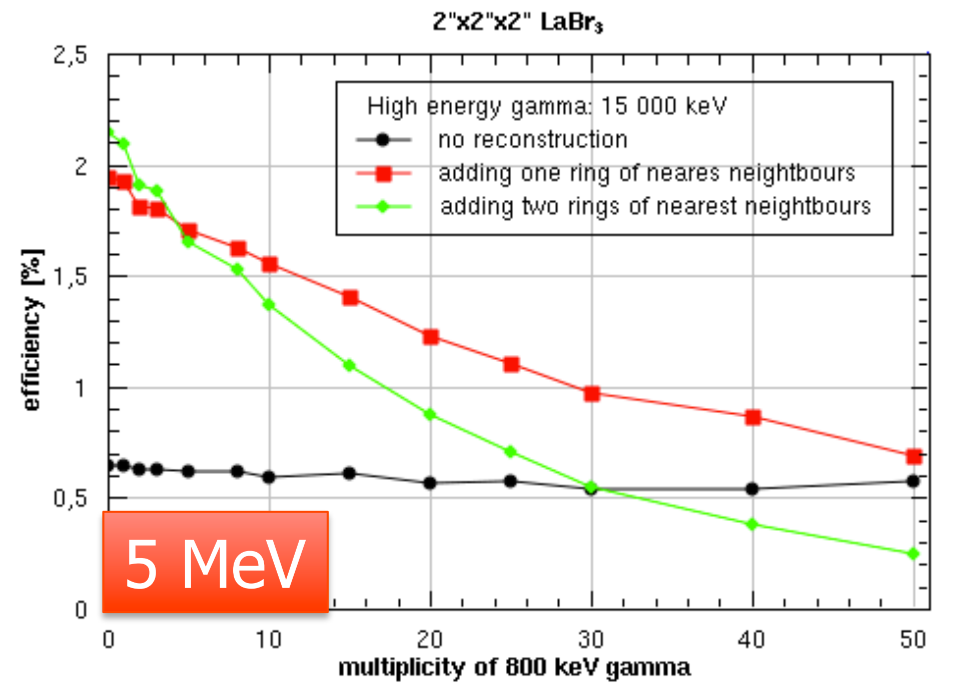


Separation of the two components :
no simple treatment
☛ algorithms needed !

a) Segmentation (≈200) already helps

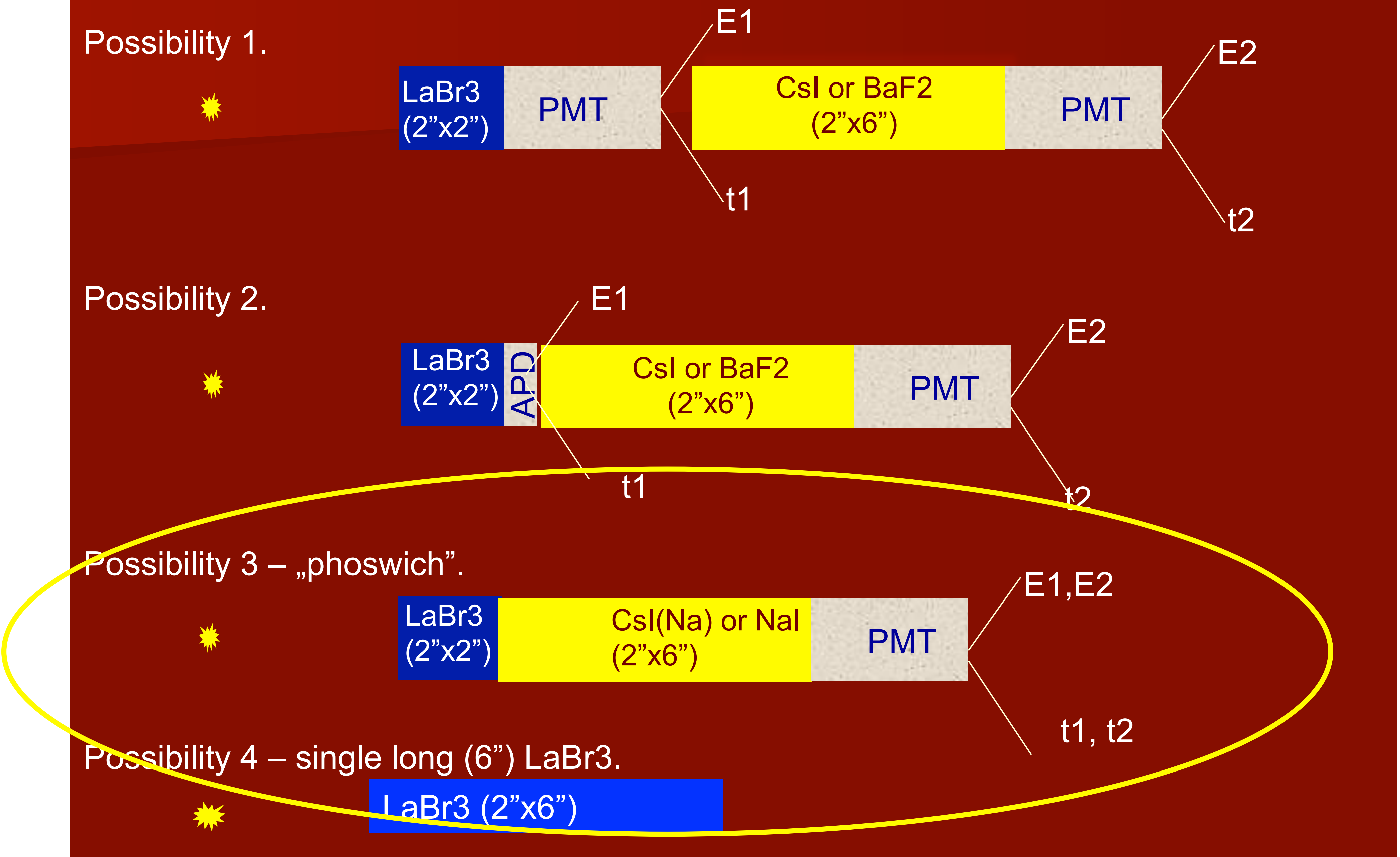




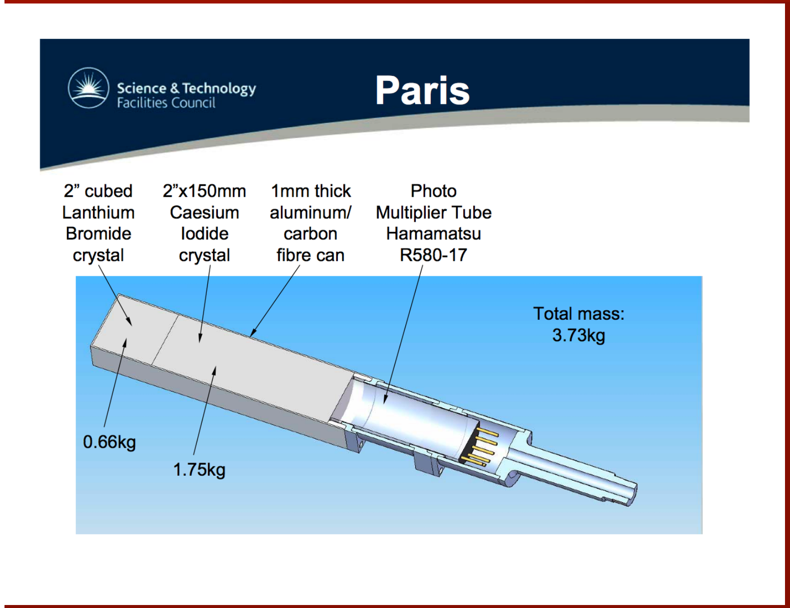


b) 2 layers (e.g. Phoswich) seem to help much more – work on algorithms in progress

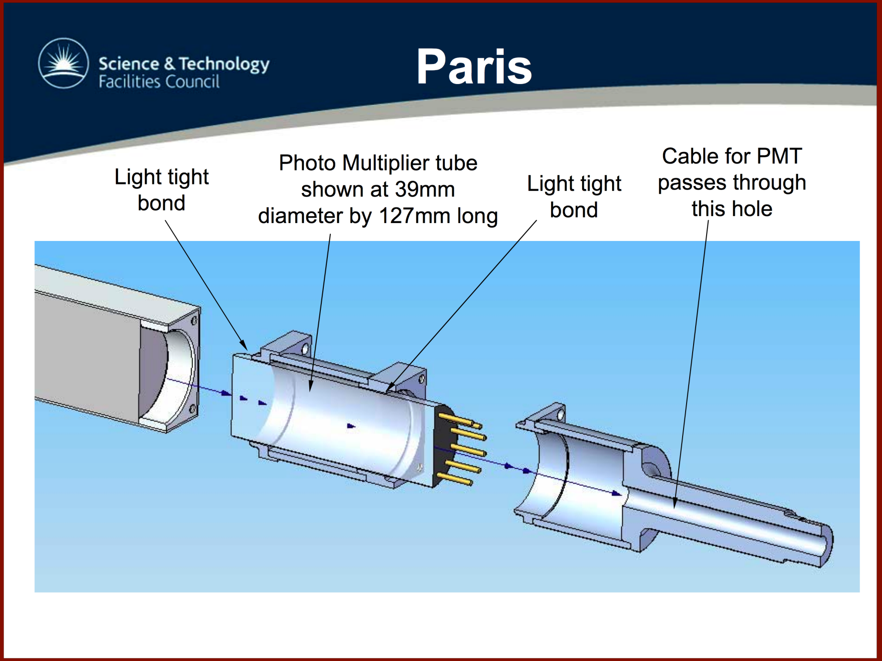
4 POSSIBILITIES FOR A „GAMMA-TELESCOPE” ELEMENT



Phoswich design



Pros:
Composite detector gives sensitivity over wider range of gamma ray energies
No space lost between crystals

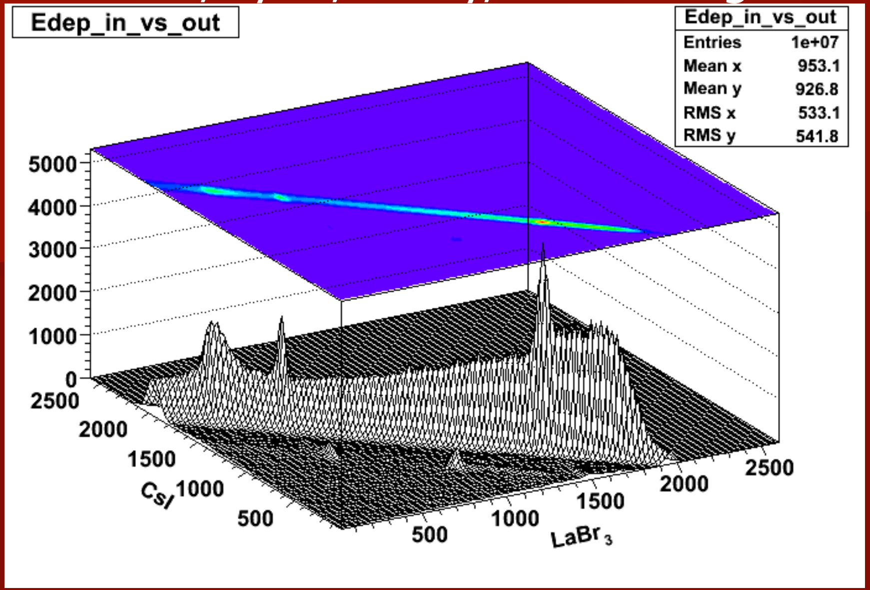


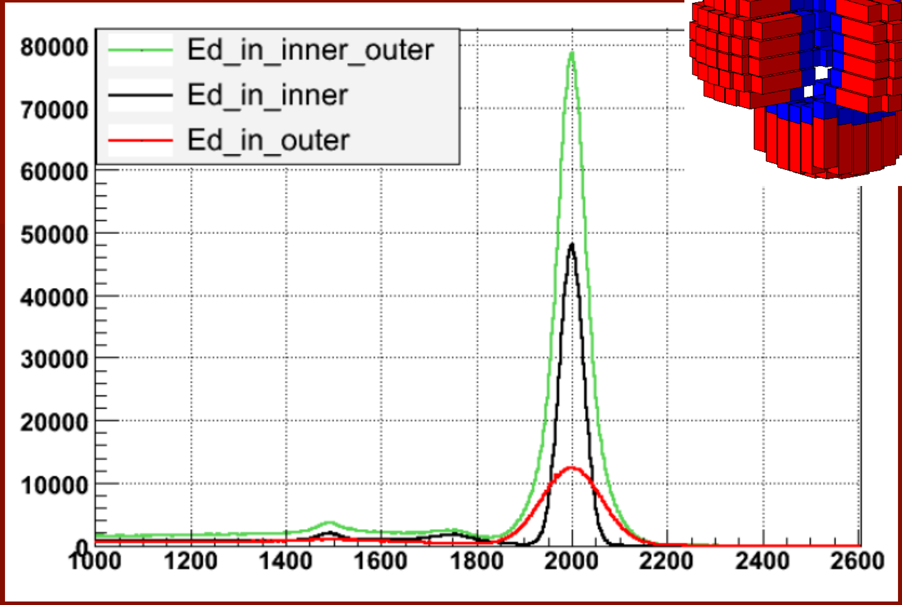
To test:
Does it work?
Is it mechanically stable?
Does it provide needed energy resolution?
How does it respond to charged particles and neutrons?

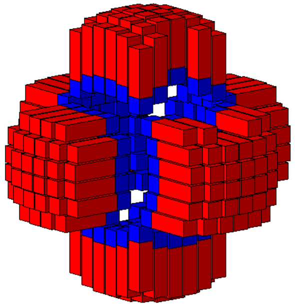
Science & Technology Facilities Council
Paris
2" cubed Lanthium Bromide crystal
2"x150mm Caesium Iodide crystal
1mm thick aluminum/ carbon fibre can
Photo Multiplier Tube Hamamatsu R580-17
Total mass:
0.66kg
1.75kg
Science & Technology Facilities Council
Paris
Light tight bond
Photo Multiplier tube shown at 39mm diameter by 127mm long
Light tight bond
Cable for PMT passes through this hole
Science & Technology Facilities Council
Paris
Detectors can be slid forwards and backwards

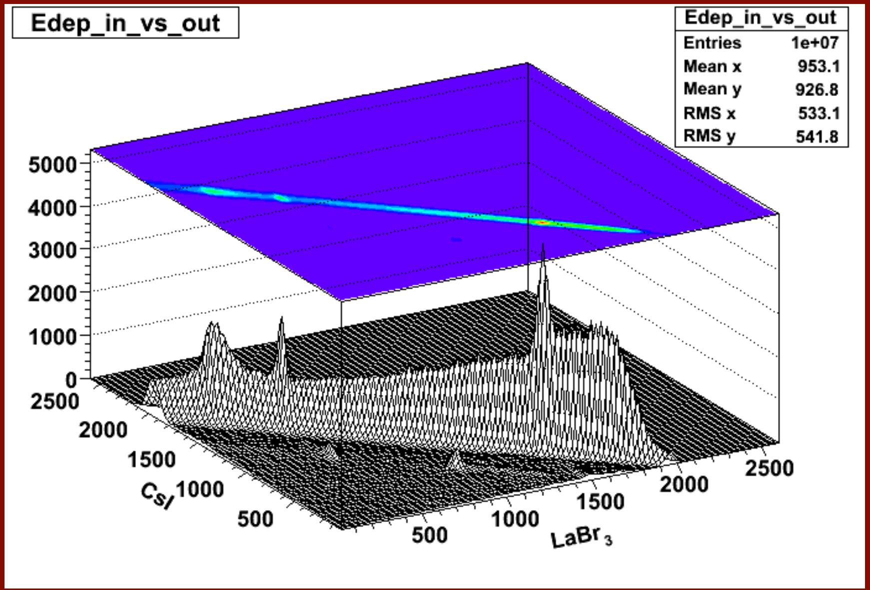
Phoswich (2"LaBr3+6"CsI) Cube simulations

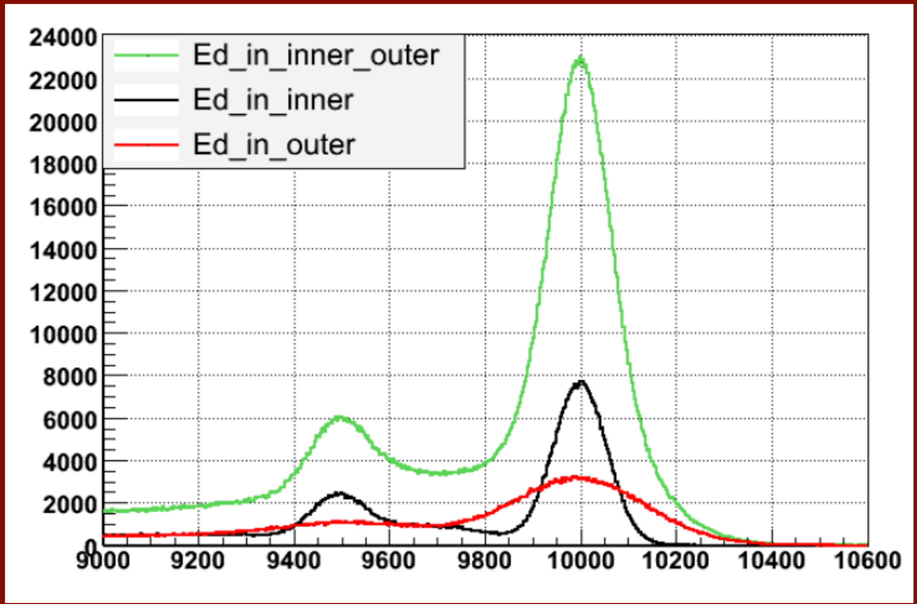
Krakow, Lyon, Orsay, Strasbourg

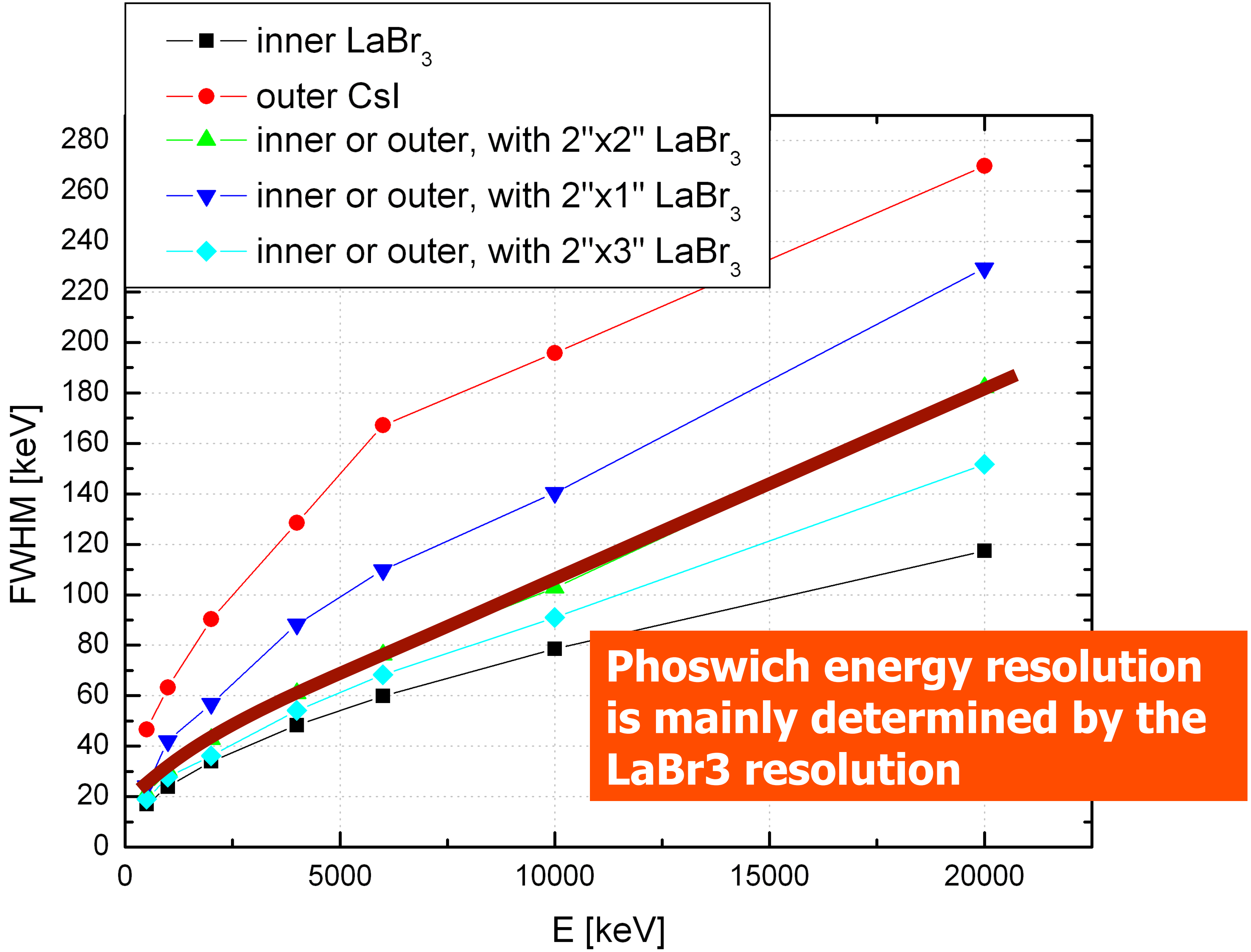




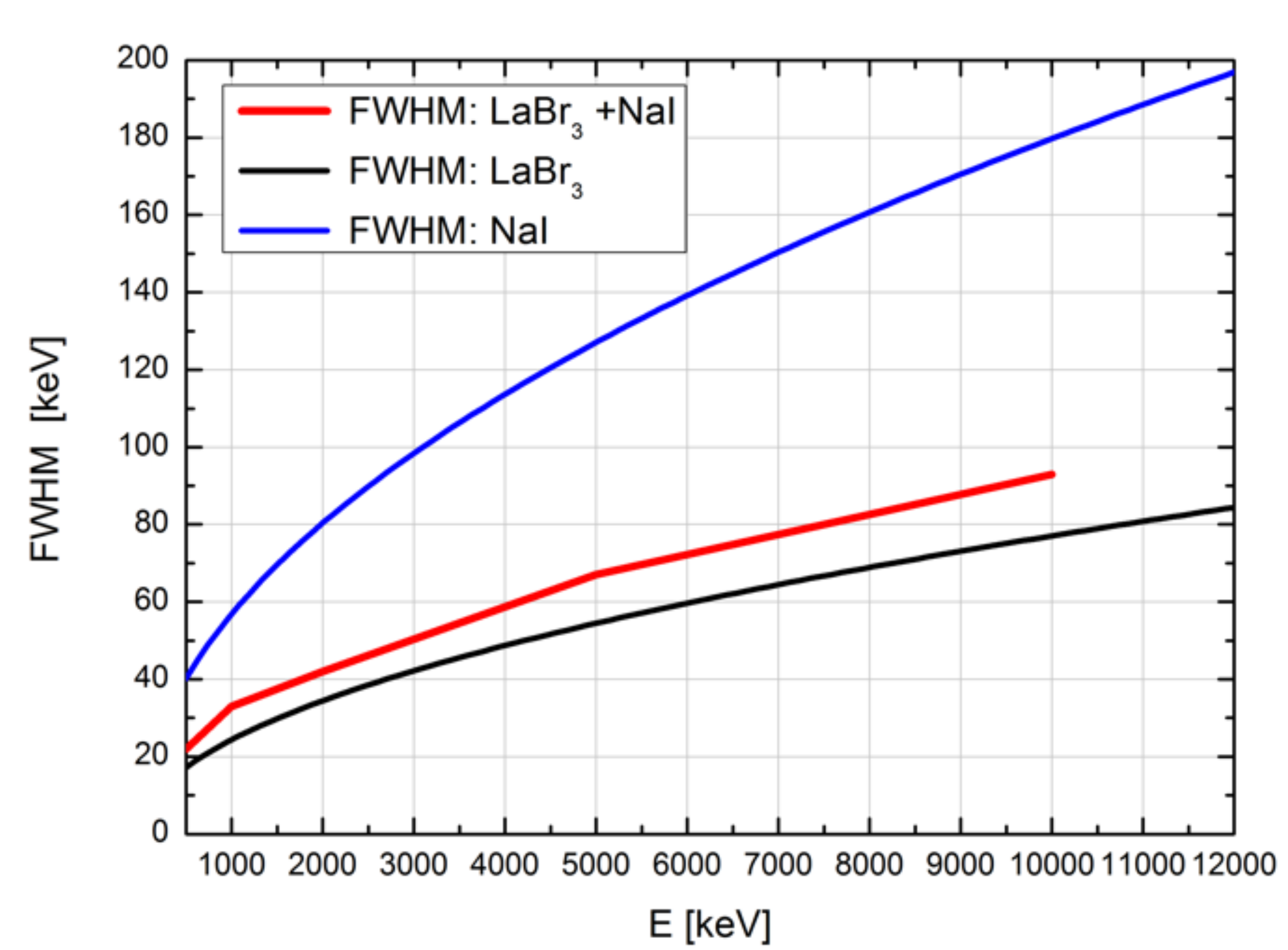







inner LaBr3
outer CsI
inner or outer, with 2"x2" LaBr3
inner or outer, with 2"x1" LaBr3
inner or outer, with 2"x3" LaBr3
FWHM [keV]
E [keV]
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
0
5000
10000
15000
20000
Phoswich energy resolution is mainly determined by the LaBr3 resolution

For 2”LaBr3+6”NaI should be even better



DETECTOR TESTING

PARIS detectors tests

Orsay, Strasbourg, York, Krakow, Warsaw

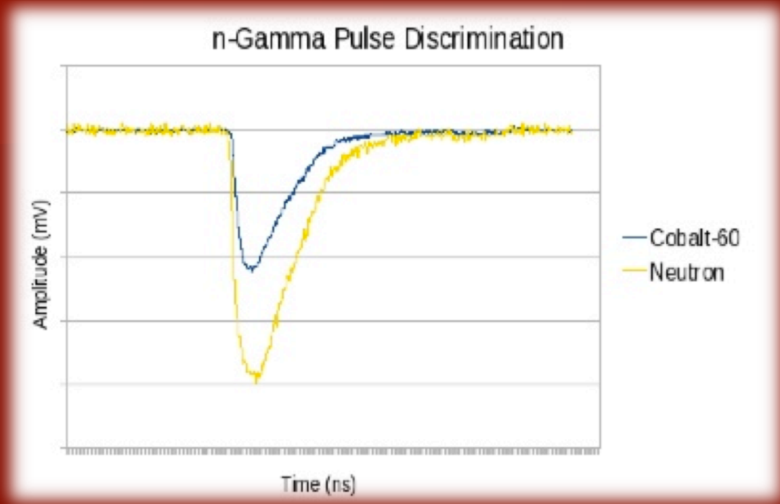
We purchased from Saint Gobain, using SP2PP and PROVA funds, following detectors:

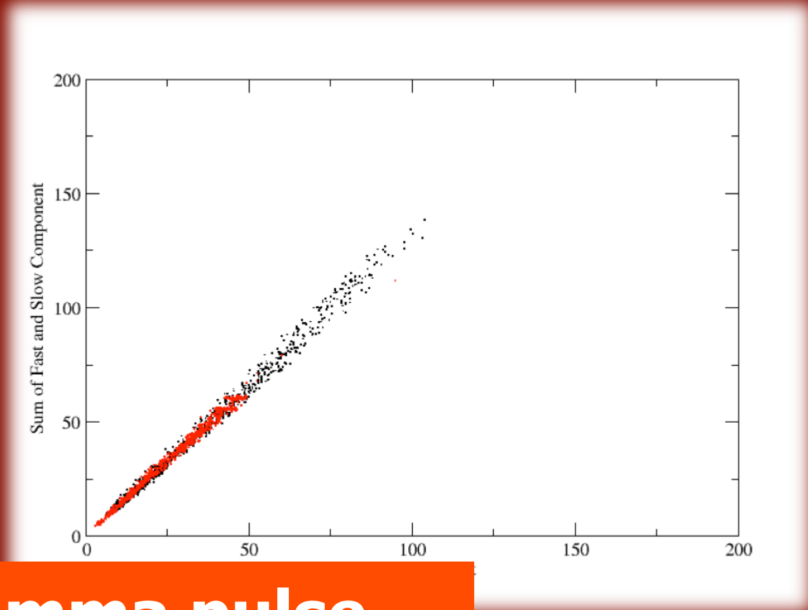
- Cubic 1″x1″x2″ LaBr3(Ce)
- Cubic 2″x2″x2″ LaBr3(Ce)
- Cubic 2″x2″x4″ LaBr3(Ce)

- Cylindrical phoswich 1″x2″ LaBr3(Ce)+1″x6″ CsI
- Cylindrical phoswich 1″x2″ LaBr3(Ce) + 1″x6″ NaI

Energy resolution of single cubic $LaBr_3$ the same as cylindrical ones

Neutron/gamma discrimination (York group)

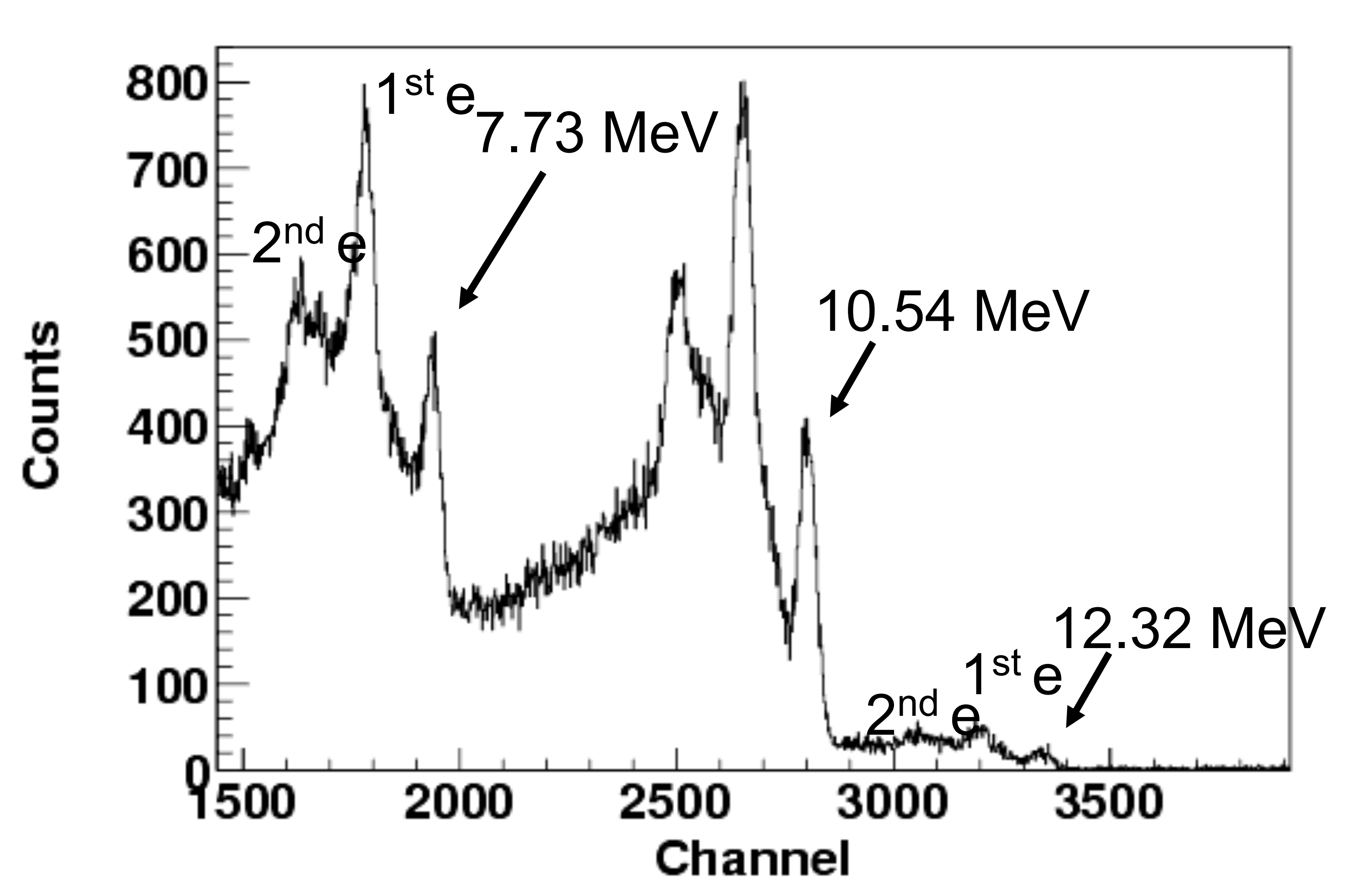




No possibility for neutron-gamma pulse discrimination – only by TOF

Strasbourg testL QDC spectrum: 4”LaBr

$^{27}Al(p,\gamma)^{28}Si$ @ E_L = 767 keV (^{28}Si E* = 12.32 MeV)



Preliminary phoswich test results

- Cubic Phoswich: 1”x1”x2” LaBr3 + 1”x1”x6” CsI(Na)

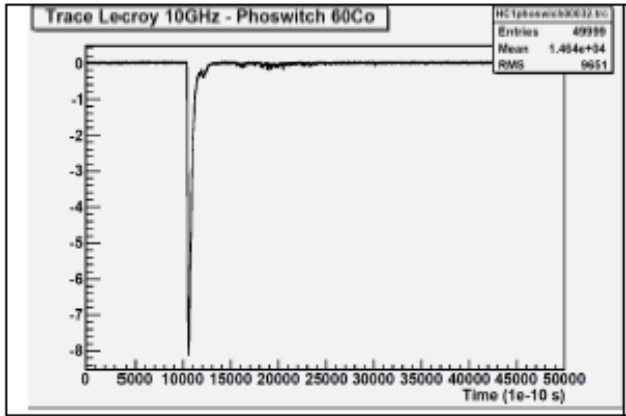


Fig. 4a: Signal corresponding to the event which deposited energy only in LaBr3

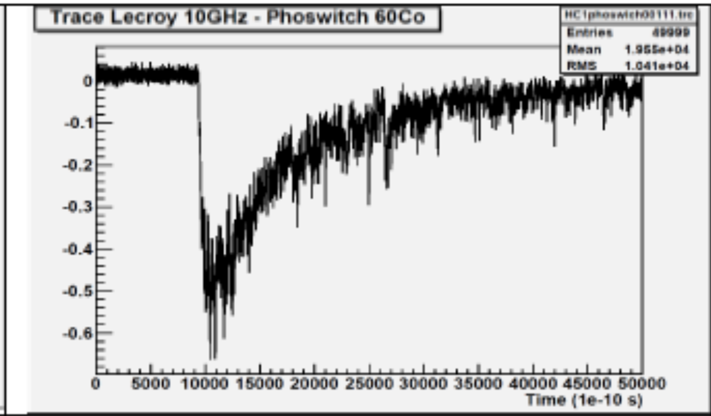


Fig. 4b: Signal corresponding to the event which deposited energy only in CsI(Na)

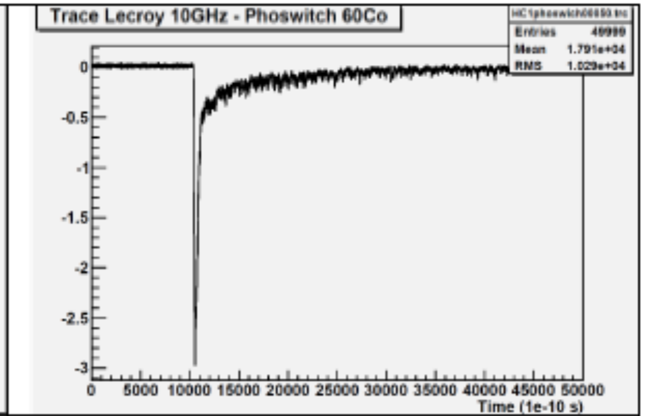


Fig. 4c: Signal corresponding to the event which deposited energy in both crystals

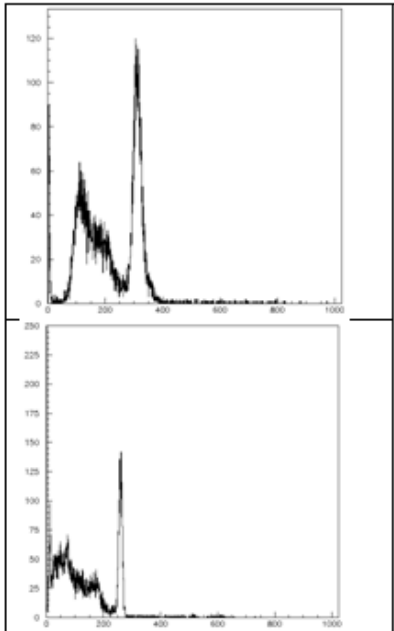


Fig. 5a: Spectra for ^{137}Cs for the events, when the whole energy is deposited in LaBr3 (bottom) and

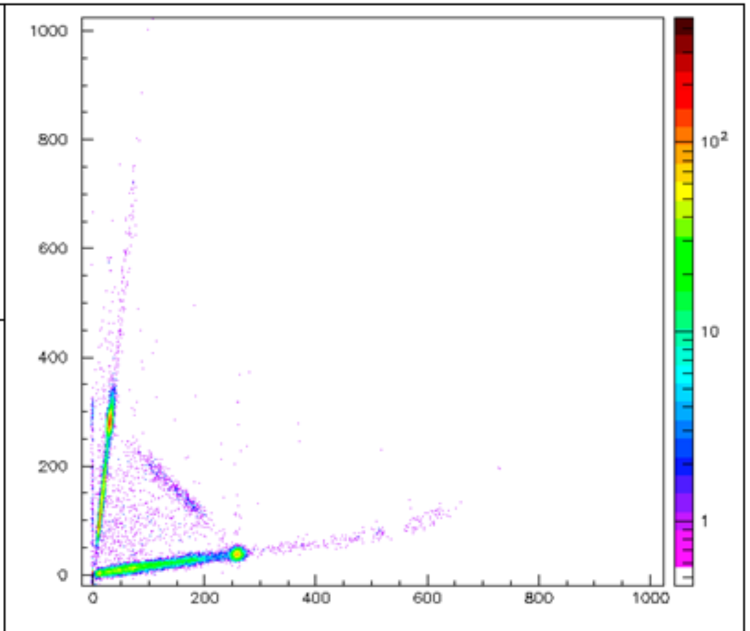
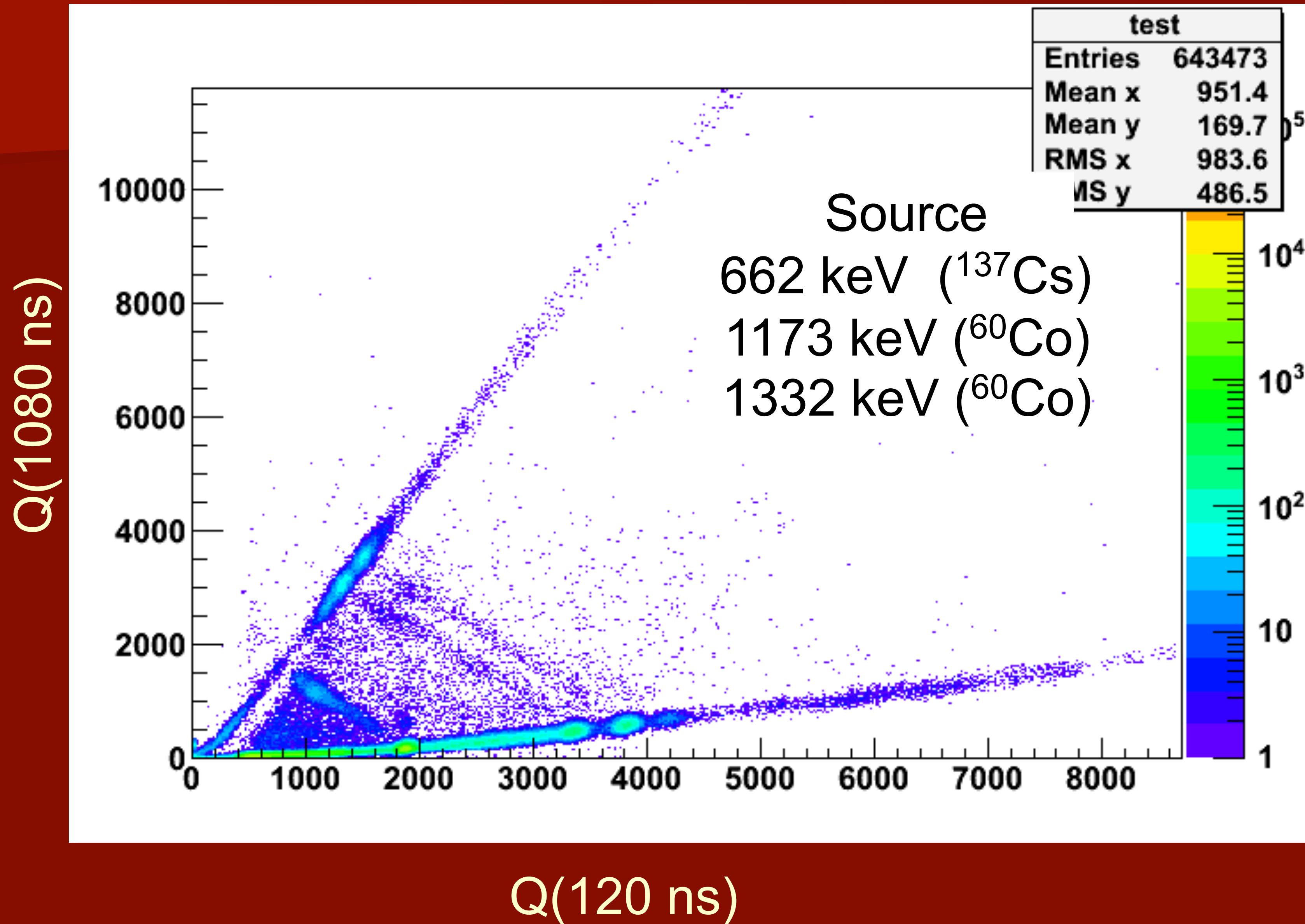


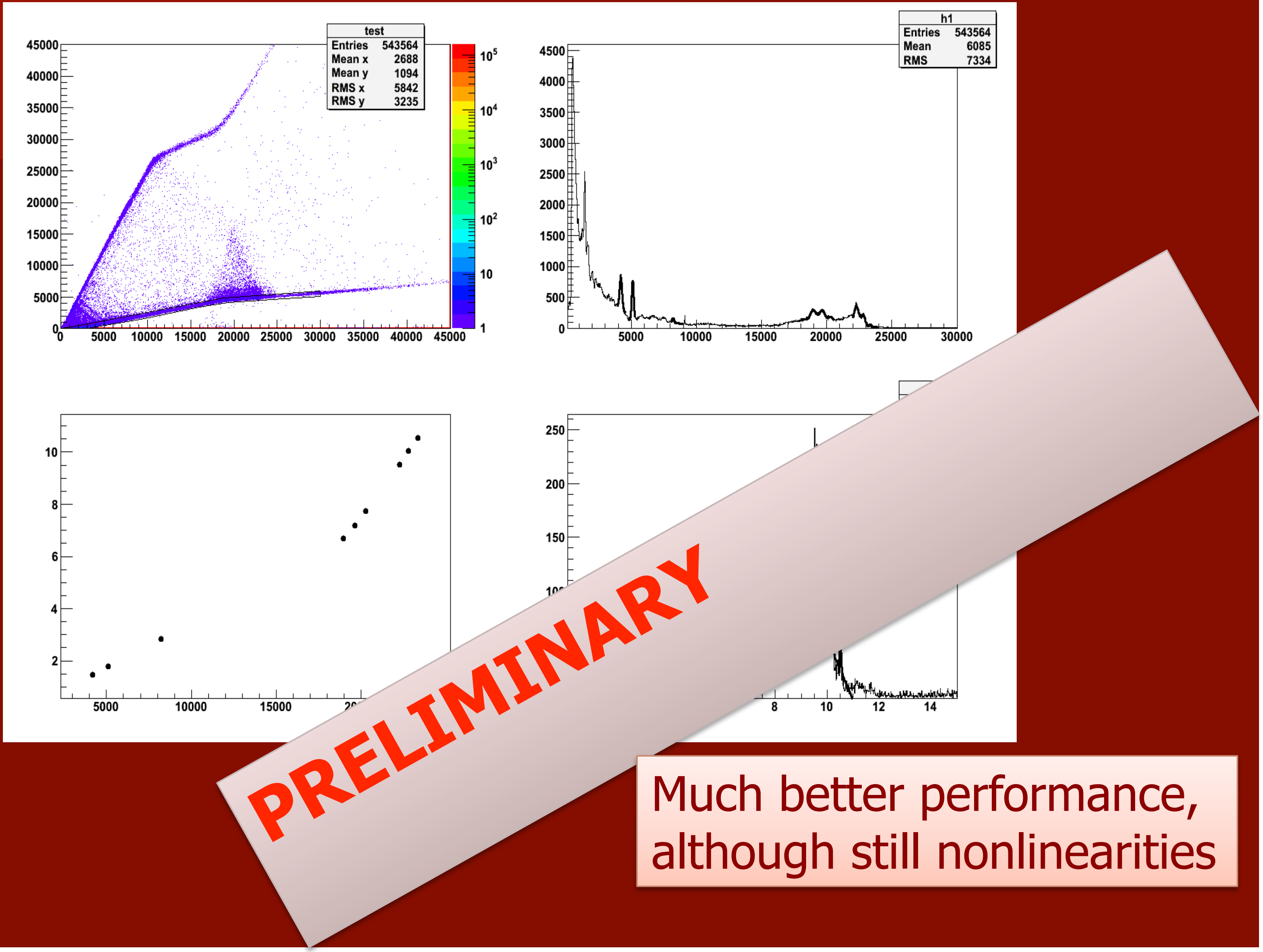
Fig.5b: Correlation plot between events deposited in LaBr3 (x-axis) and CsI (y-axis), when the detector was exposed to 661 keV gamma radiation from ^{137}Cs source

Phoswich concept seems to work, but problems with linearity and high counting rate

LaBr3+ NaI phoswich: sources test

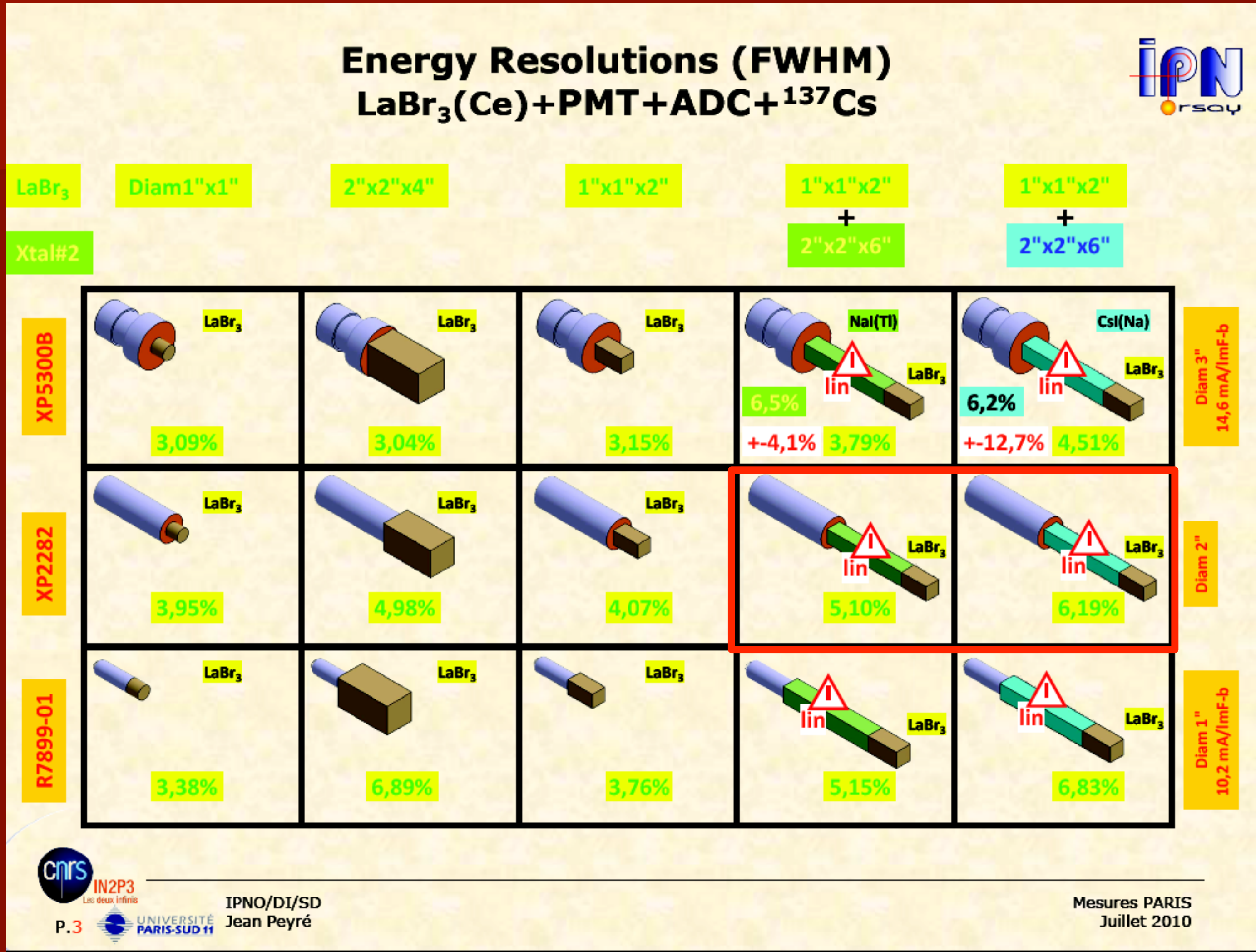


LaBr3+ NaI phoswich: in-beam



Much better performance, although still nonlinearities

Pwoshwich tests performed at Orsay



Resolution is very dependant on the size and type of PM

-> In beam test has to be repeat with new PM.

Conclusion on the performance:

•Long pure LaBr3 gives very good resolution and reasonable linearity

•LaBr3+CsI do not perform satisfactory

•Phoswich concept in case of LaBr3+NaI seems to work

•Further test on resolution and linearity needed

Electronics

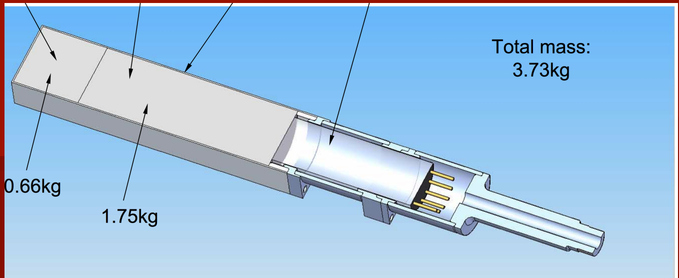
- Designing the HV supply – Sofia
- Digital Electronics – GANIL, Strasbourg, Krakow, Orsay, Mumbai, Daresbury, York
- DAQ – GANIL, Orsay, Krakow

PARIS will go for digital electronics
Triggering system: GTS (same as EXOGAM2 and AGATA)
Common NUMEXO2 card, own Flash ADC with FPGA

WHAT NEXT?

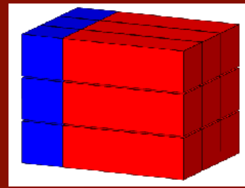
Proposed next steps

1. Detailed tests of phoswich



2. Purchasing – Testing

PARIS PROTOTYPE

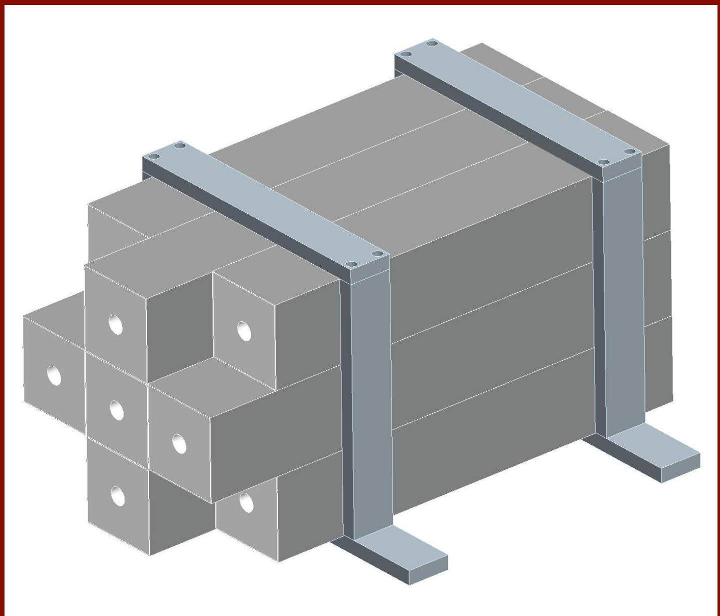


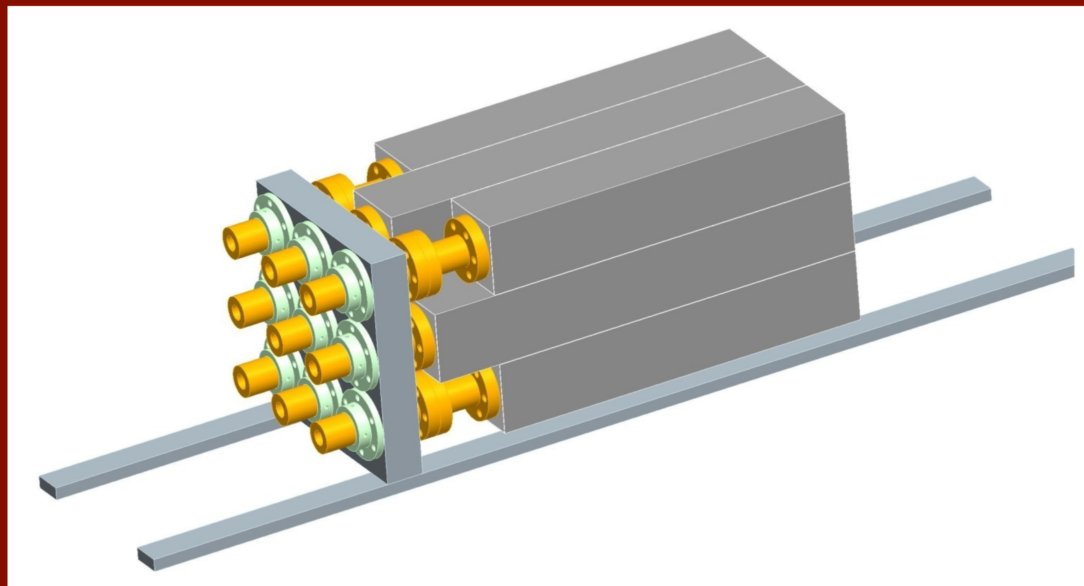
a CLUSTER of 9 LaBr+NaI phoswiches;

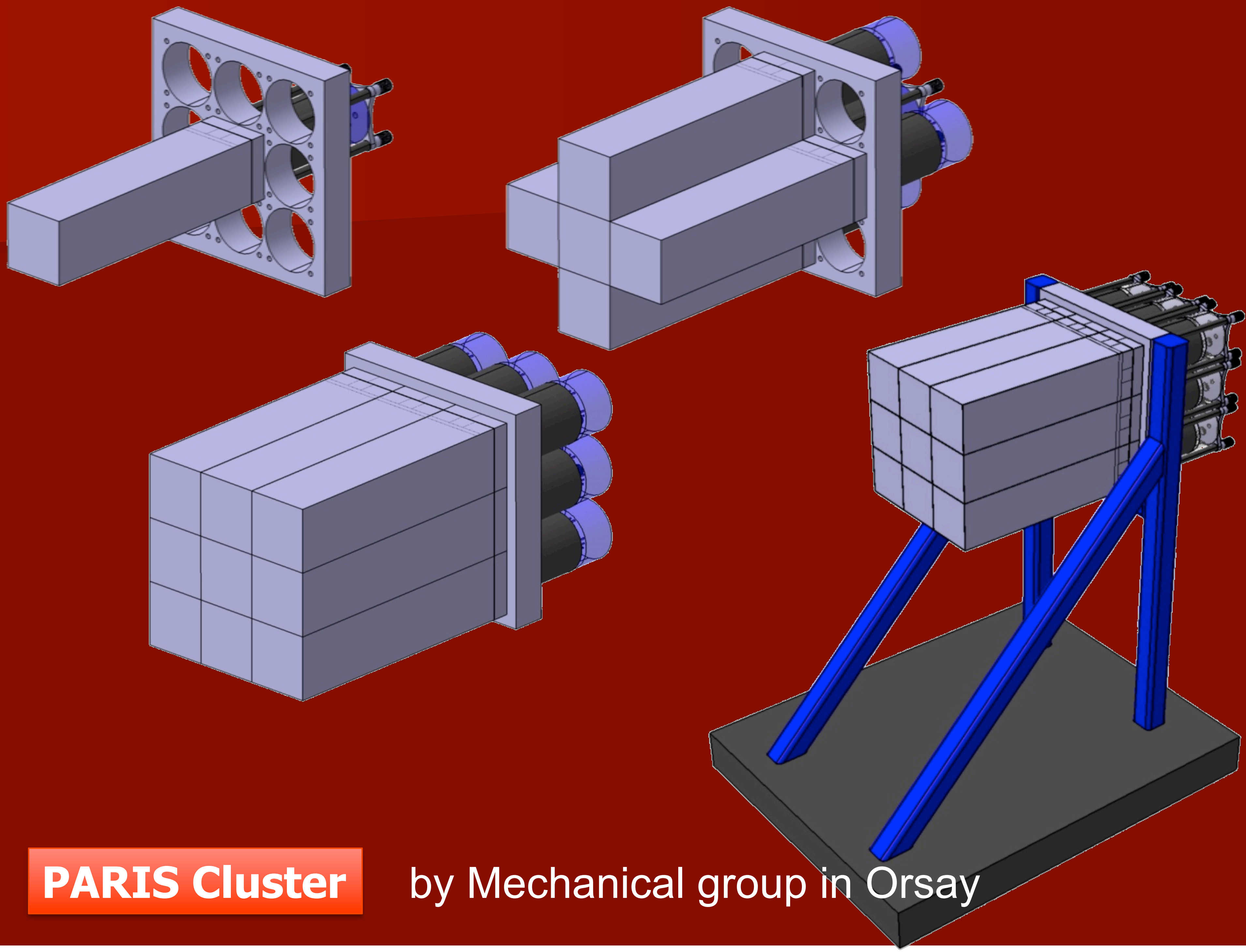
2 ordered by Orsay and Strasbourg

3 ordered by Krakow

4 to be ordered by Mumbai



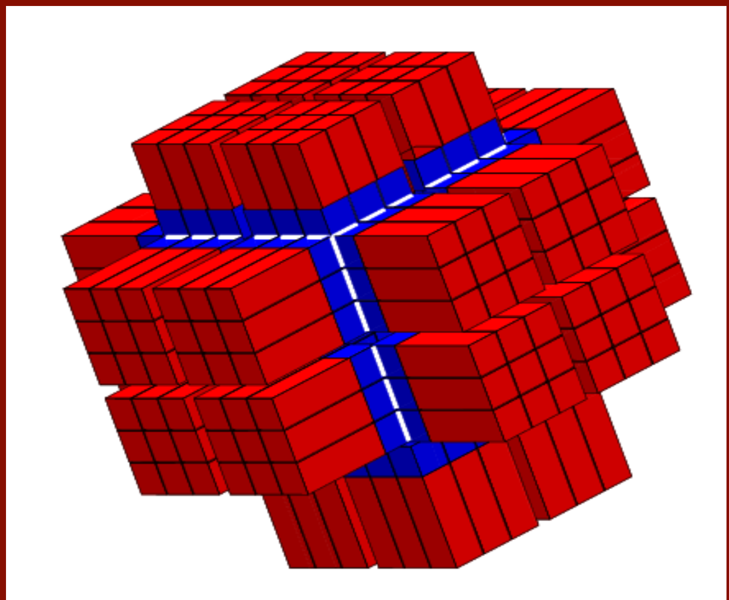


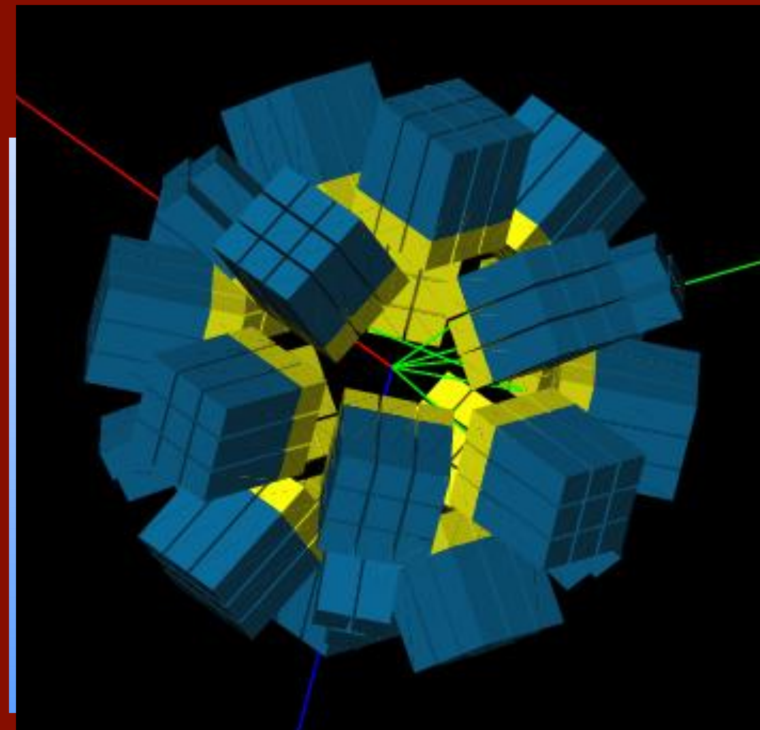


PARIS Cluster by Mechanical group in Orsay

3. After testing prototype decide if:
phoswich or pure LaBr3 or hybride of both types

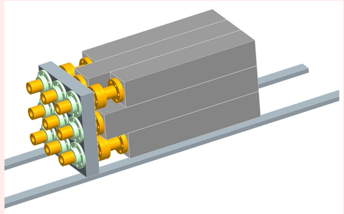
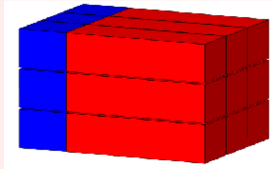
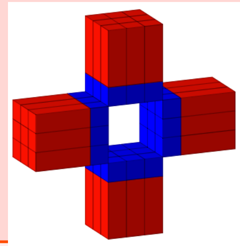
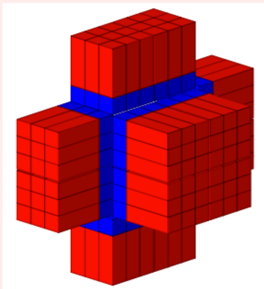
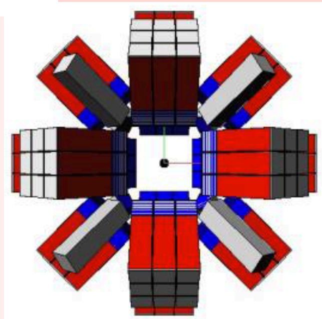
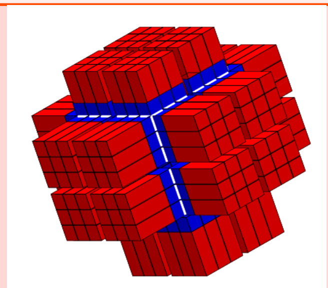
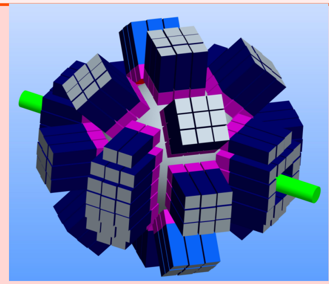
4. Sign **MoU** between partners and purchase/assembly clusters into
a)PARIS DEMONSTRATOR (1π);
b) full 4π ***PARIS array***.
It can be arranged either in **cubic** or **radial geometry.**





Such arrangement will be compatible with other detectors,
e.g. AGATA, GASPARD, NEDA, FAZIA,...

PARIS phases and costs

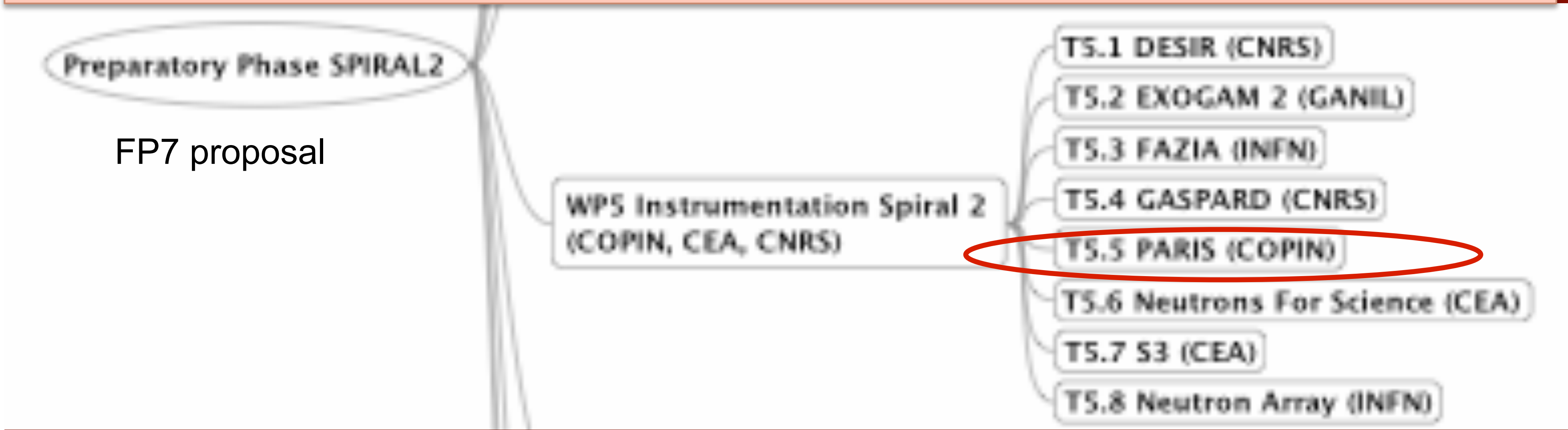
Phase 1 **2011** **PARIS Prototype**	1 cluster: 9 phoswiches	 	k€	**Decided** Funds: SP2PP, ANR, Orsay, Strasbourg, Kraków, Mumbai Tests in-beam and with sources
Phase 2 **2013** **PARIS Demonstrator**	4 clusters: 36 phoswiches		k€	**Only if Phase1 validated** Funds: MoU Ph1Day1 exp@S3
Phase 3 **2015** **PARIS 2π**	12 clusters: 108 phoswiches	 	M€	**Only if Phase2 validated** Funds: MoU, PARIS consortium Ph2Day1 exp. with AGATA and GASPARD Other exp.
Phase 4 **≈2017** **PARIS 4π**	≥24 clusters: ≥216 phoswiches	 	M€	**Only if Phase3 validated** Funds: PARIS consortium Regular experiments in various labs

Indicated costs are approximations only. Include cost of LaBr3+NaI phoswiches, PMs, HV, electronics and mechanics. It is assumed that phoswich solution will work.

FOUNDING

1. ANR PROVA

2. PARIS in the FP7 SPIRAL2 Preparatory Phase project



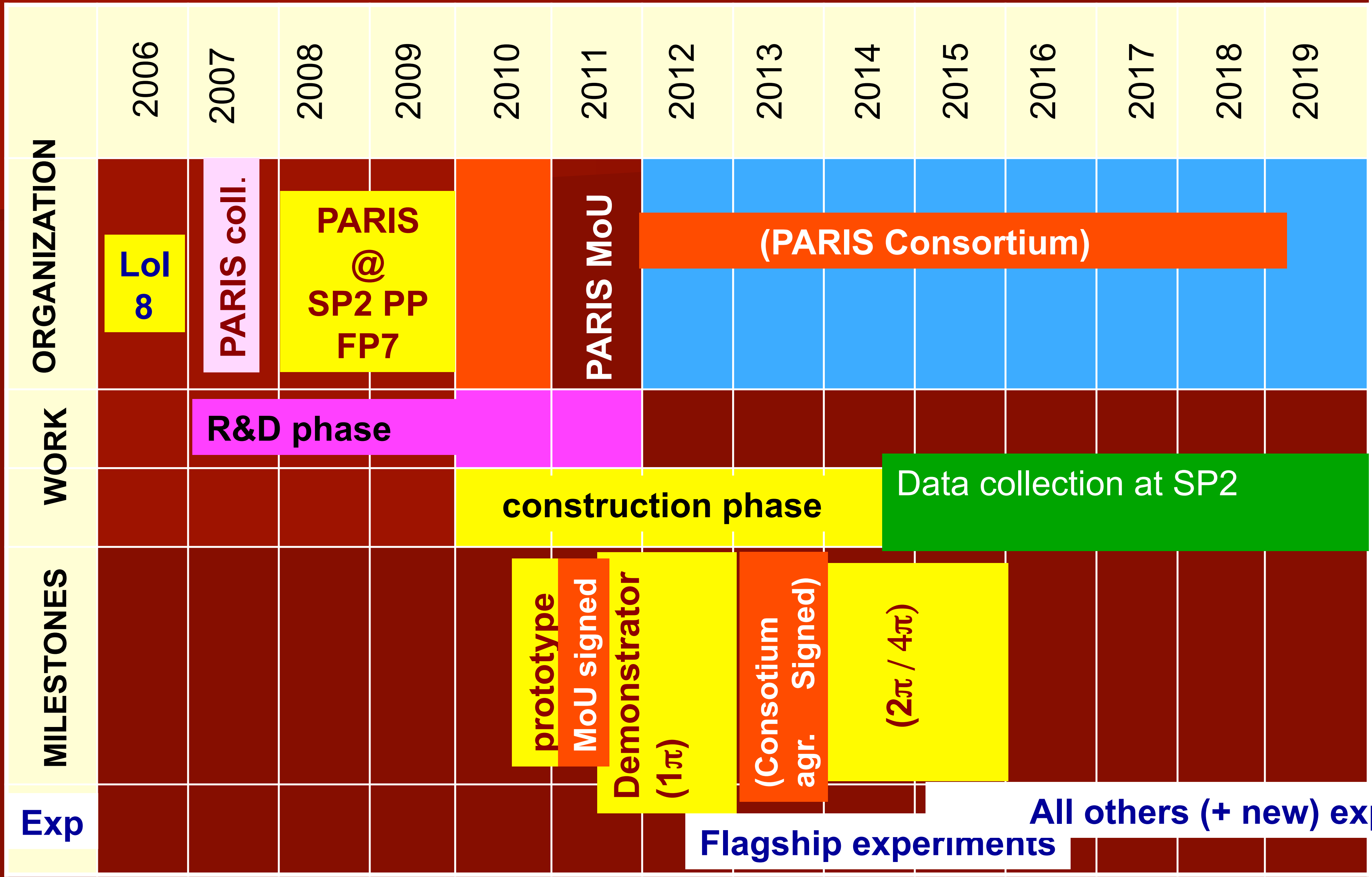
Main goals: Design and construct PARIS prototype
Sign MoU between partners of PARIS collaboration

~250 kEuro

Frame for common preparation with **EXOGAM2 (+Agata Demonstrator**).

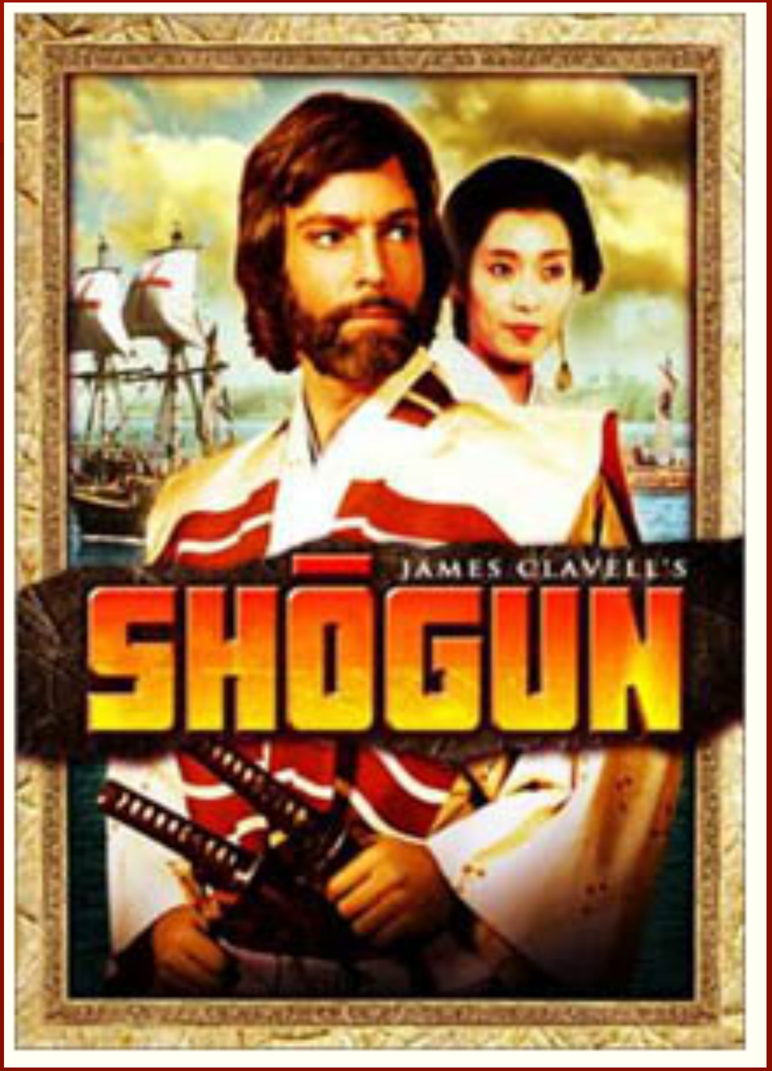
3. In preparation applications for funds from ministry/funding agency in Poland, Bulgaria, India and UK.

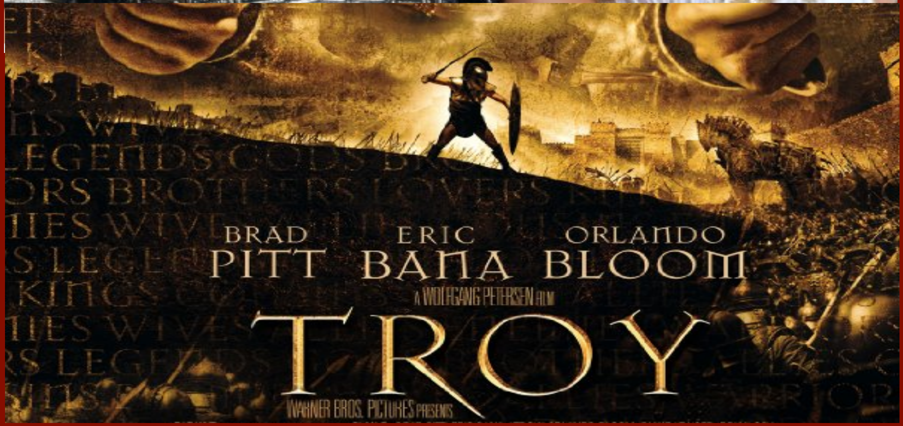
Preliminary TIME SCHEDULE



CONCLUSION

SHOGUN and **PARIS**: similar ideas, goals, challenges and passions...





Good perspectives for fruitful collaboration!

One of the Physics Cases

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

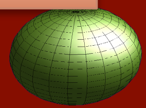
A. Maj[a], K. Mazurek[ac], M. Kmiecik[a], P. Bednarczyk[a], M. Ciemala[a], B. Fornal[a], W. Meczynski[a],
J. Grebosz[a], J. Styczeń[a], M. Zieblinski[a] et al.,
S. Leoni[b], A.Bracco[b], G.Benzoni[b], F. Camera[b], F.C.L. Crespi[b], N. Blasi[b], B. Million[b],
O. Wieland[b], P.F. Bortignon[b], G. Colò[b], E. Vigezzi[b] et al.,
Ch. Schmitt[c], J.P. Wieleczko[c], M. Lewitowicz[c], G. de France[c], M. Rejmund[c],
N. Alahari[c], E. Clement[c] al.,
F. Azaiez[d], I. Matea[d], I. Stefan[d], M. Niikura[d], D. Beaumel[d], A. Korichi[d], A. Lopez-Martens[d] et al.,
O. Stezowski[e], N. Redon[e], D. Guinet[e], G. Lehaut[e] et al.,
J. Dudek[f], O. Dorvaux[f], S. Courtin[f], M. Rousseau[f], G. Duchene[f], D. Curien[f], Ch, Beck[f] et al.,
D.R. Chakrabarty[g], V. Nanal[g], I. Mazumdar[g] et al.,
T. Dossing[h], B. Herskind[h] et al.,
G. De Angelis[i], D.R. Napoli[i], J.J. Valiente-Dobon[i] et al.,
D. Bazzacco[l], E. Farnea[l], S.M. Lenzi[l], S. Lunardi[l], D. Mengoni[l], C. Ur[l], F. Recchia[l] et al.
A. Gadea[m], T.Hüyük[m] et al.,
J. Simpson[n] et al.,
W. Korten[o] et al., A. Goergen[p] et al.,
D. Jenkins[q], R. Wadsworth[q] et al.,
M. Palacz[r], G. Jaworski[r], K. Hadynska-Klek[r], P. Napiorkowski[r], K. Wrzosek-Lipska[r] et al.,
A. Atac[s] et al.,

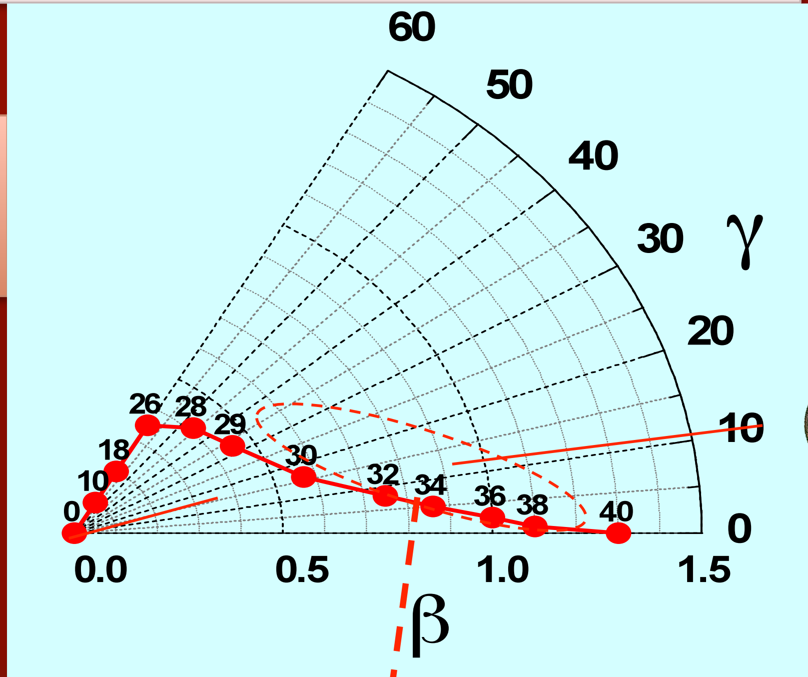
and the PARIS-EXOGAM-AGATA collaborations

1. Jacobi shape transition in nuclei
(oblate to very elongated prolate)

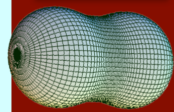
Euroball + HECTOR experiment in Strasbourg

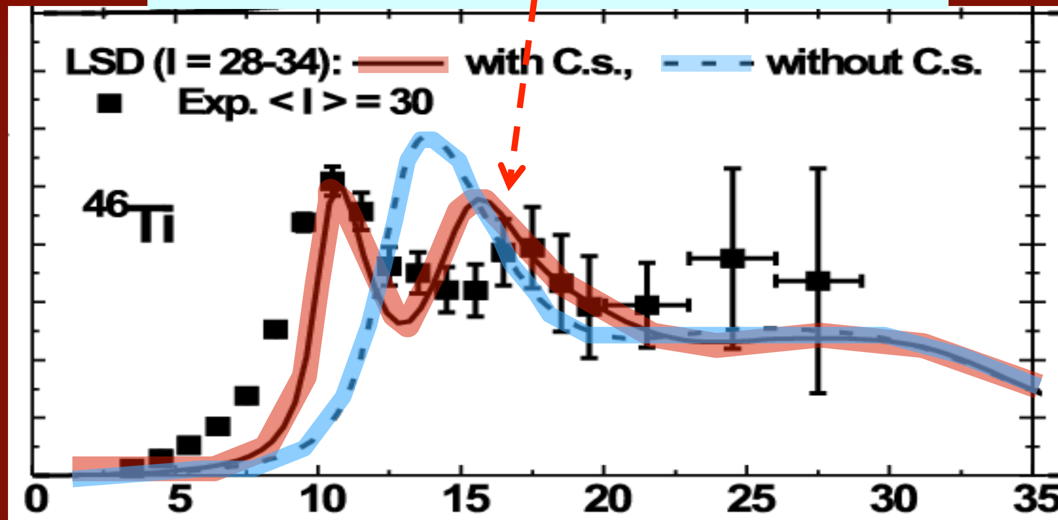
I=20





I=34



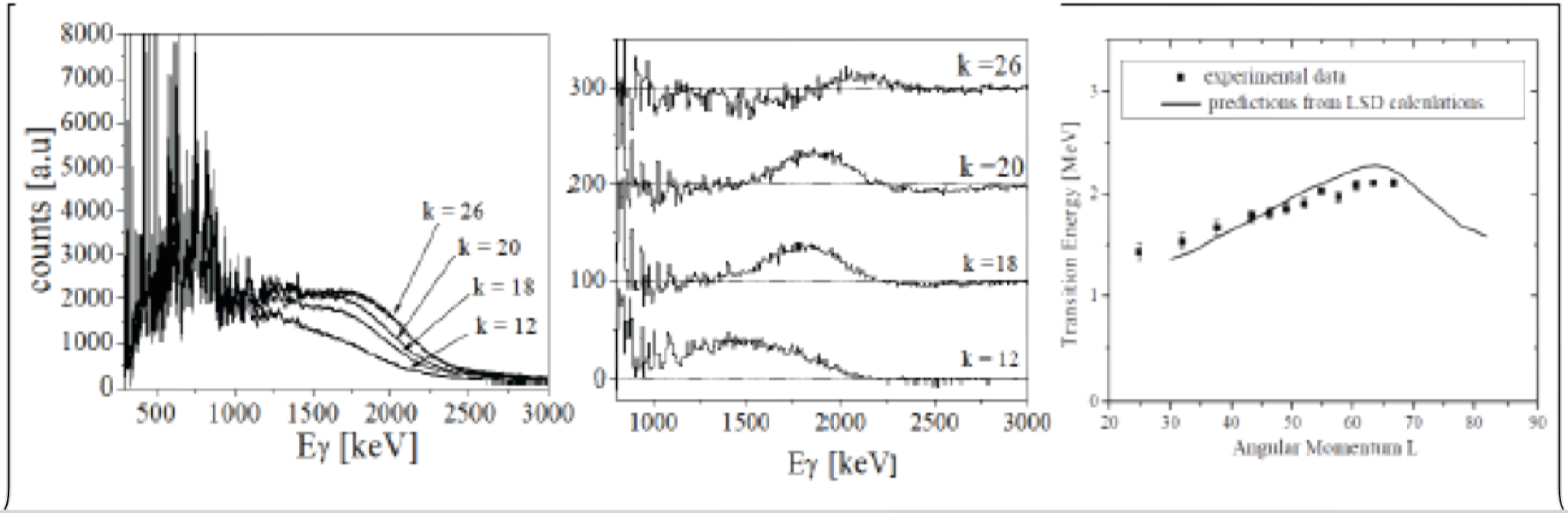


A. Maj et al, Nucl. Phys. A731 (2004) 319 ; M. Kmiecik et al., Acta Phys. Pol. B36, (2005) 1169

2. Giant back-bending of „E2-bump”

Results for ^{128}Ba* from the „Hyperlong Hyperdef” experiment, EUROBALL IV, Strasbourg, B. Herskind et al.

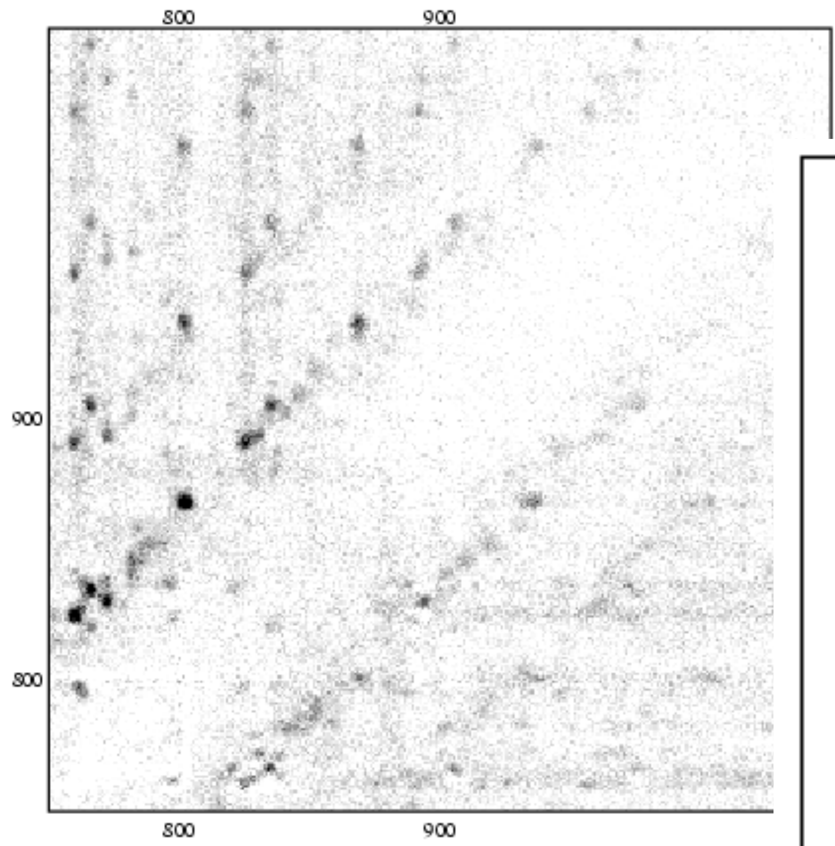
^{64}Ni + ^{64}Ni -> ^{128}Ba (@255 and 260 MeV bombarding energy)

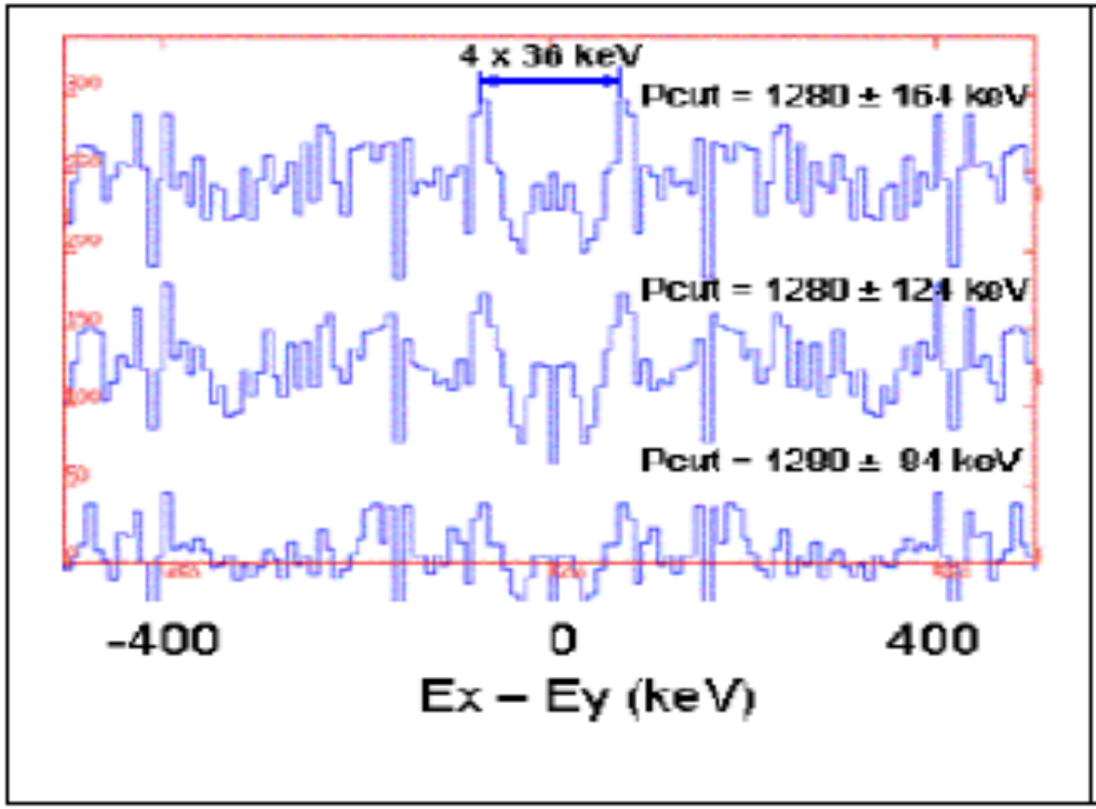


G. Benzoni (Milano), Ph.D. Thesis, unpublished

3. Ridge-Valley Structure and Hyperdeformation

In ^{128}Ba* gamma-decay spectra clear signature of warm rotation and hyperdeformation in continuum, but no evidence of discrete hyperdeformation





B. Herskind et al., Act. Phys. Pol. B38 (2007)1421;
B. Herskind et al., Phys. Scr. T125 (2006)108.

What are the shape changes of hot rotating neutron-rich nuclei?

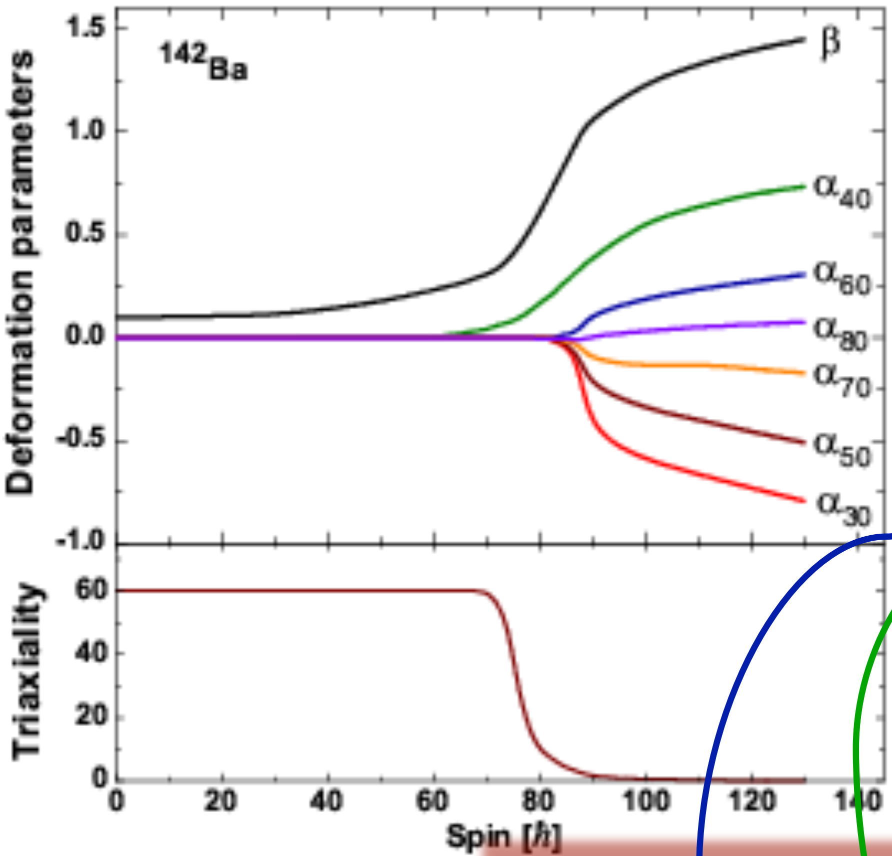
New calculations based on the LSD model, allowing odd-rank deformation parameters (α_{30}, α_{50}, α_{70}) be free:

K. Mazurek, J. Dudek et al., Acta Phys. Pol. (2011) in print

A.Maj, K. Mazurek, J. Dudek, M. Kmiecik, D. Rouvel "Shape evolution at high spins and temperatures: nuclear Jacobi and Poincare transition", J. Mod. Phys. E19 (2010) 53

e.g. ^{142}Ba (Z=56, N=86)

Lublin-Strasbourg liq.Drop (LSD) model by K. Pomorski and J. Dudek, PRC67 (2003) 044316

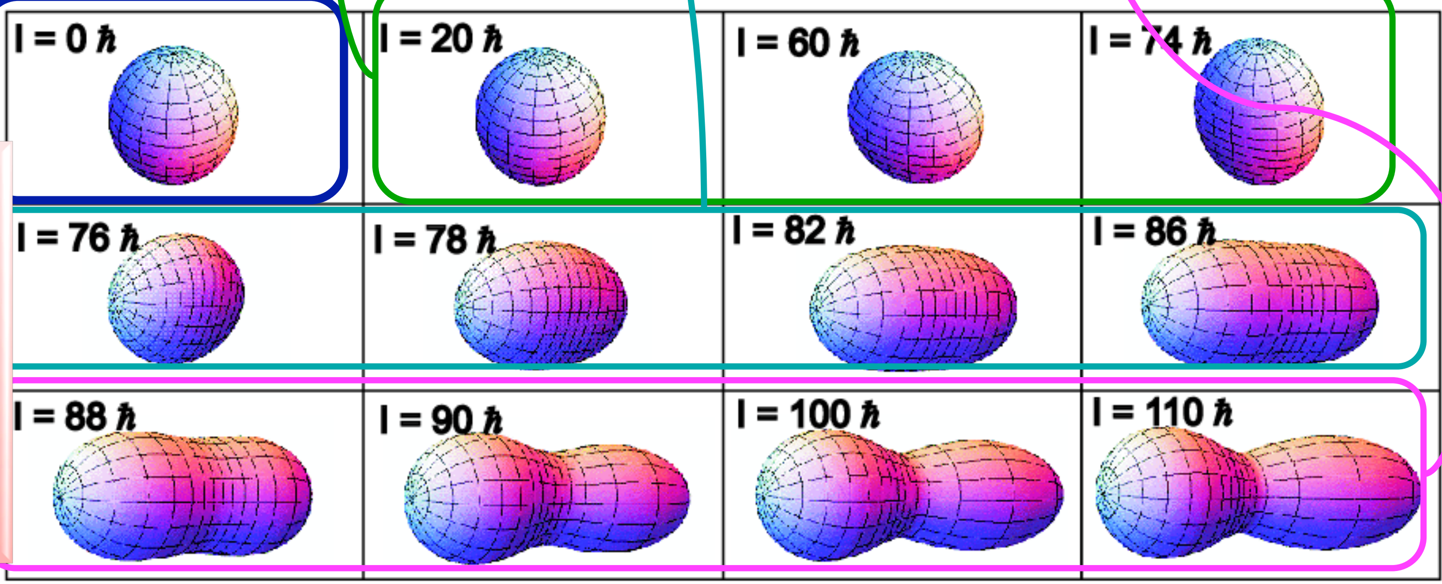


Sphere

Oblate (MacLaurin)

Elongated triaxial (Jacobi)

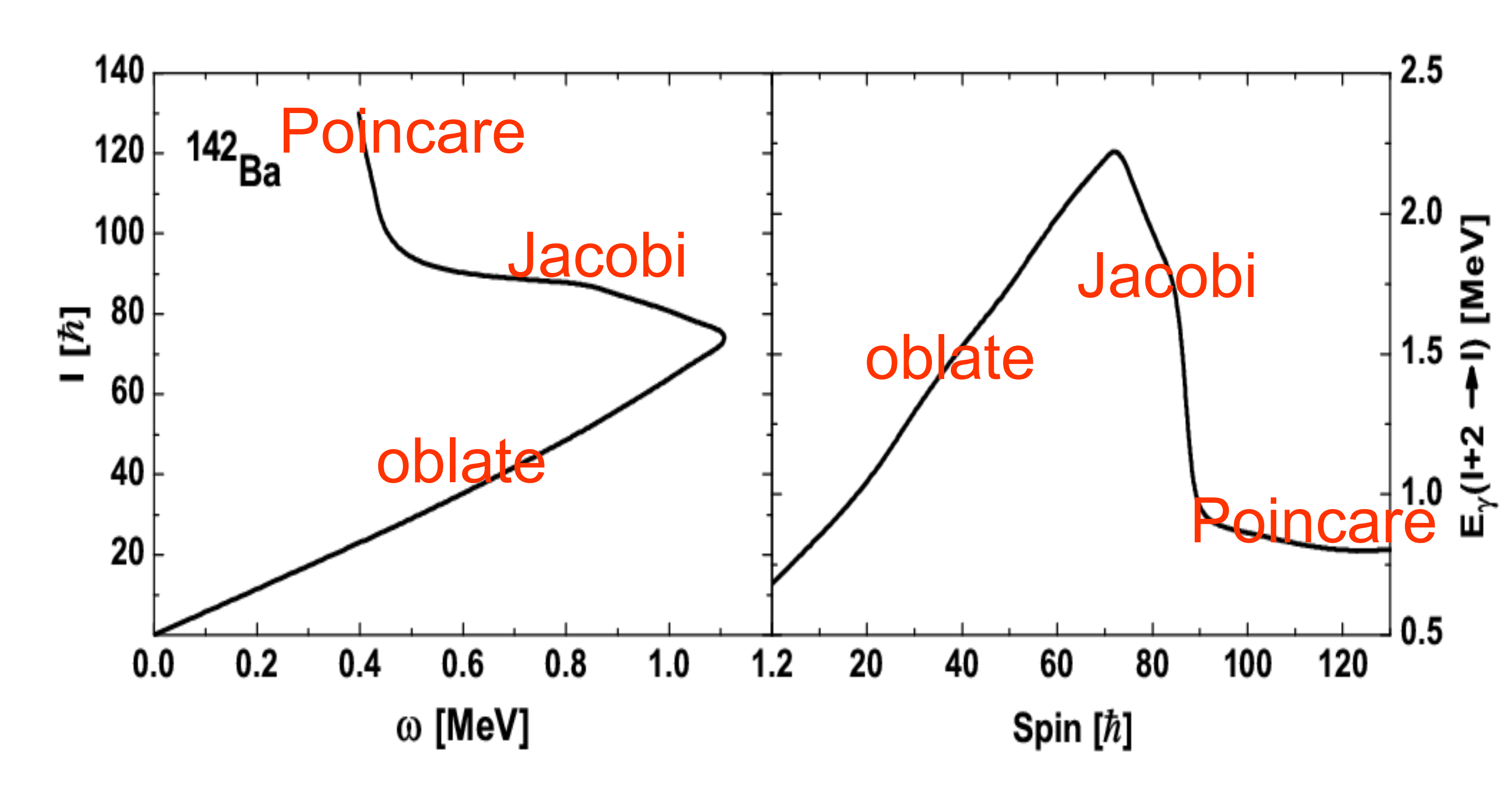
Octupole, left-right asymmetric (Poincare)



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

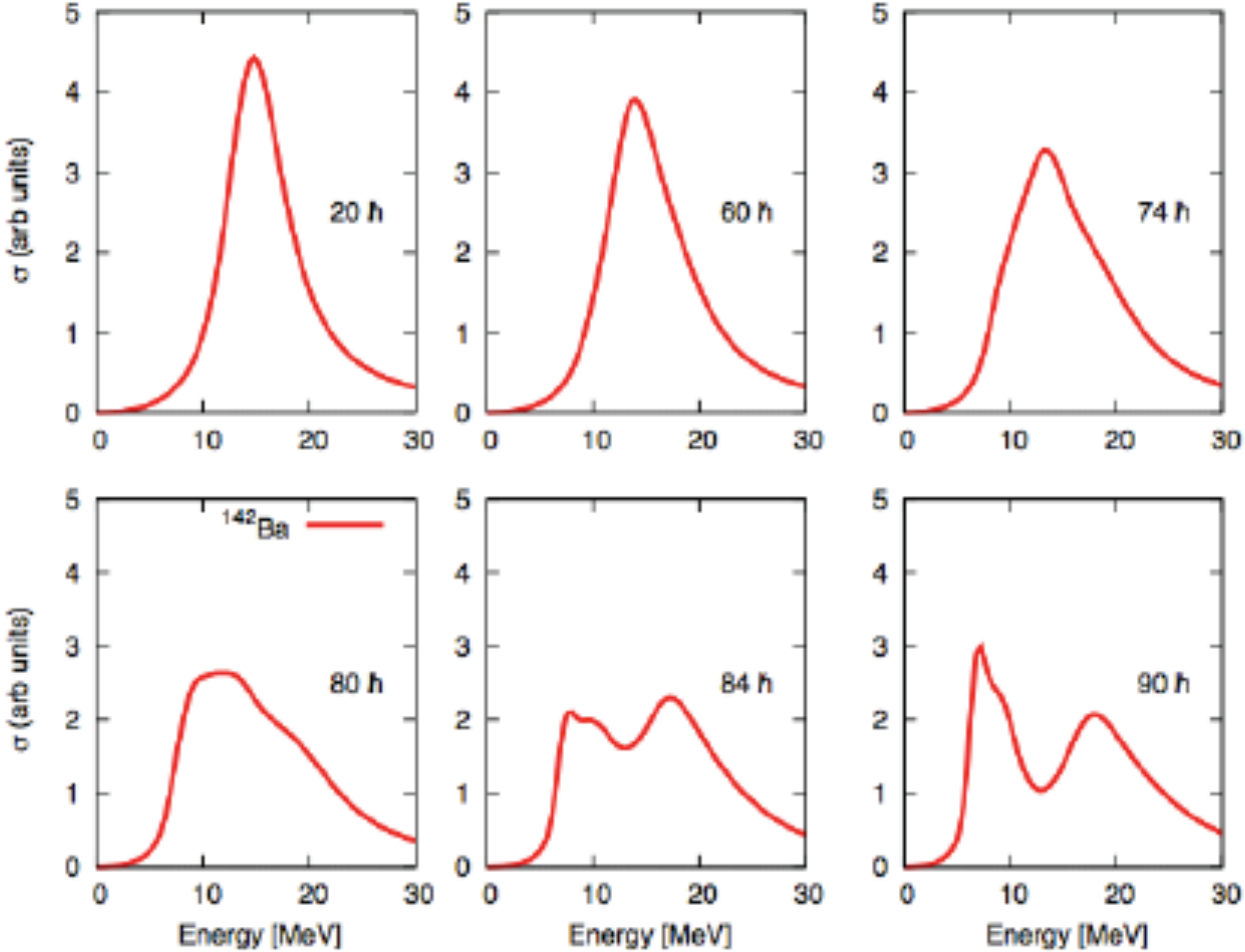
Evidence for Jacobi and Poincare shape transition:

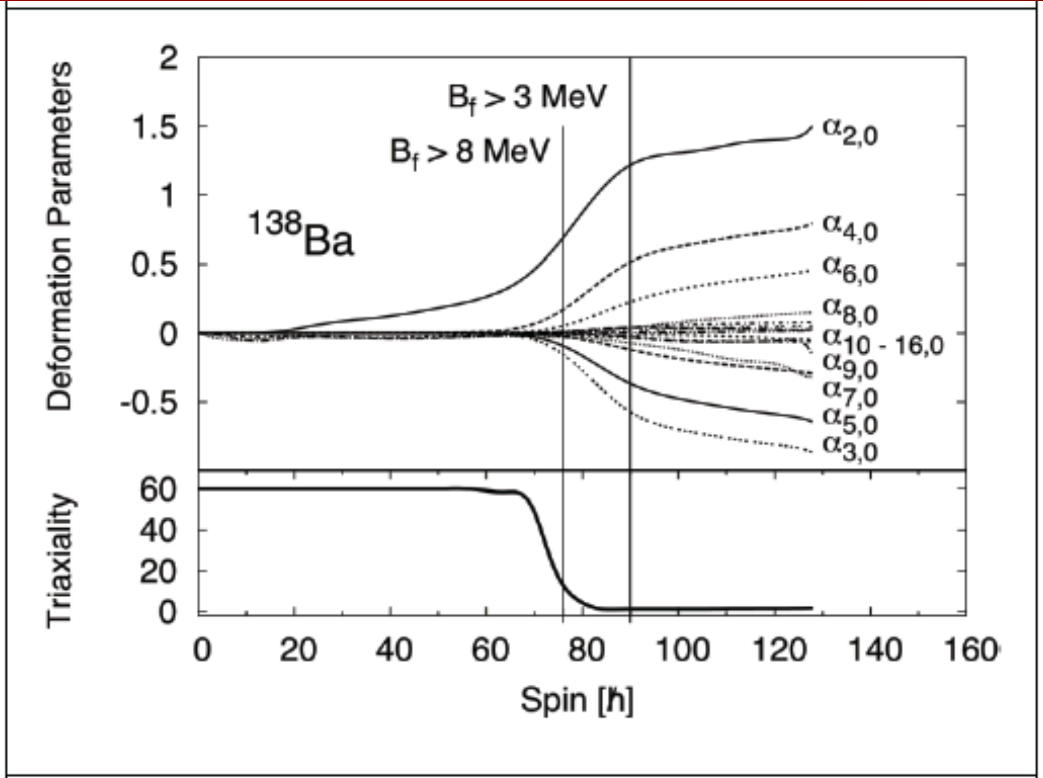
- Mass symmetric (Jacobi) or asymetric (Poincare) fission
- Specific giant back-band curves
- Fragmented GDR strength function



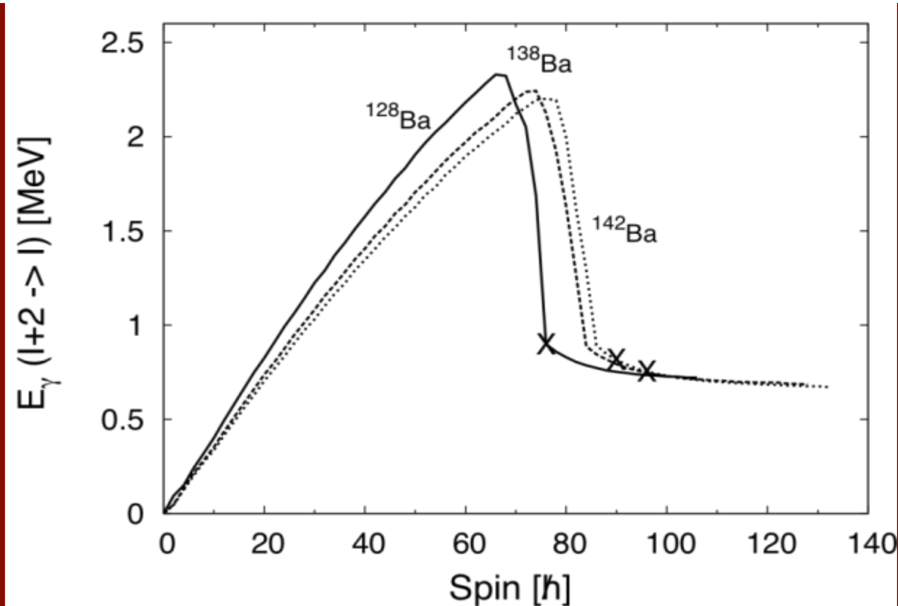
K. Mazurek et al.

Evolution of GDR strength function for ^{142}Ba
K. Mazurek et al., to be published





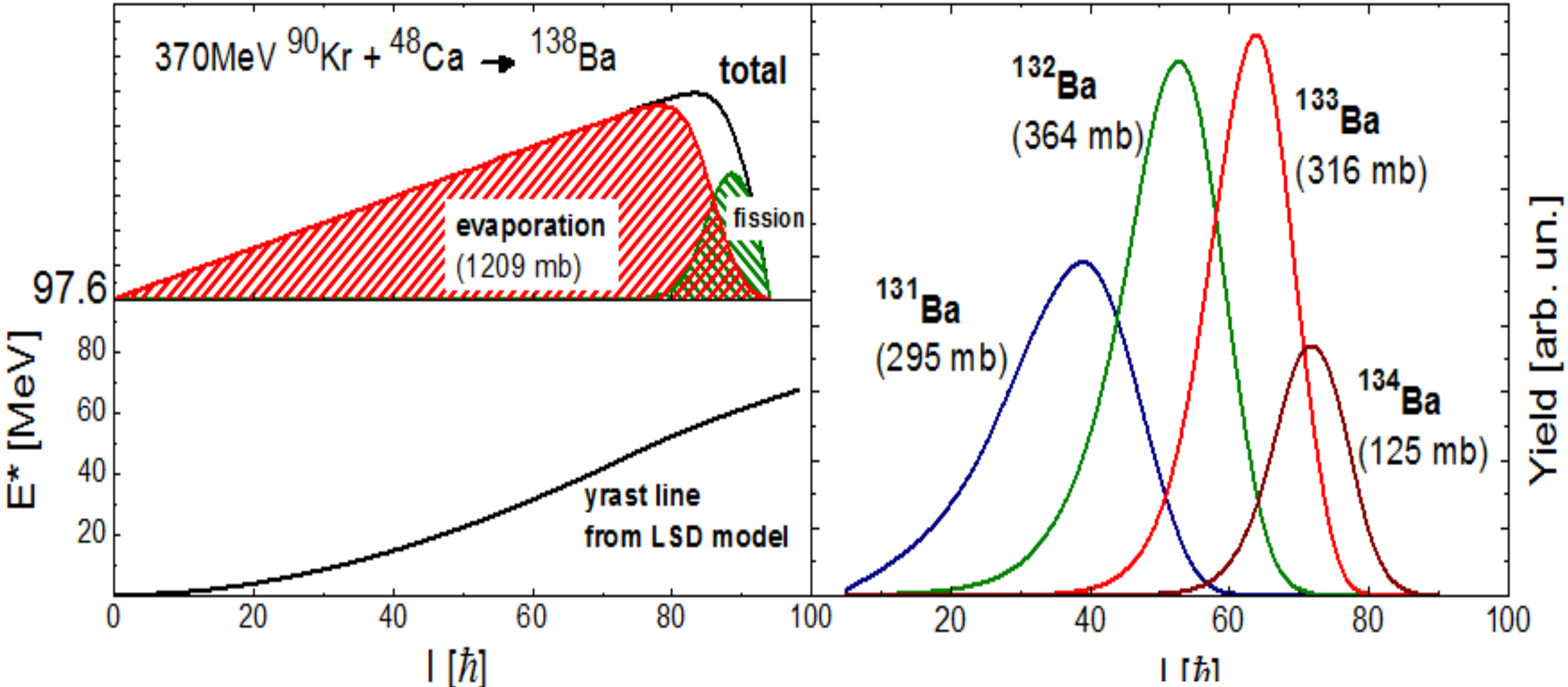
^{138}Ba also good candidate for obervation of Jacobi and Poincare shape transitions



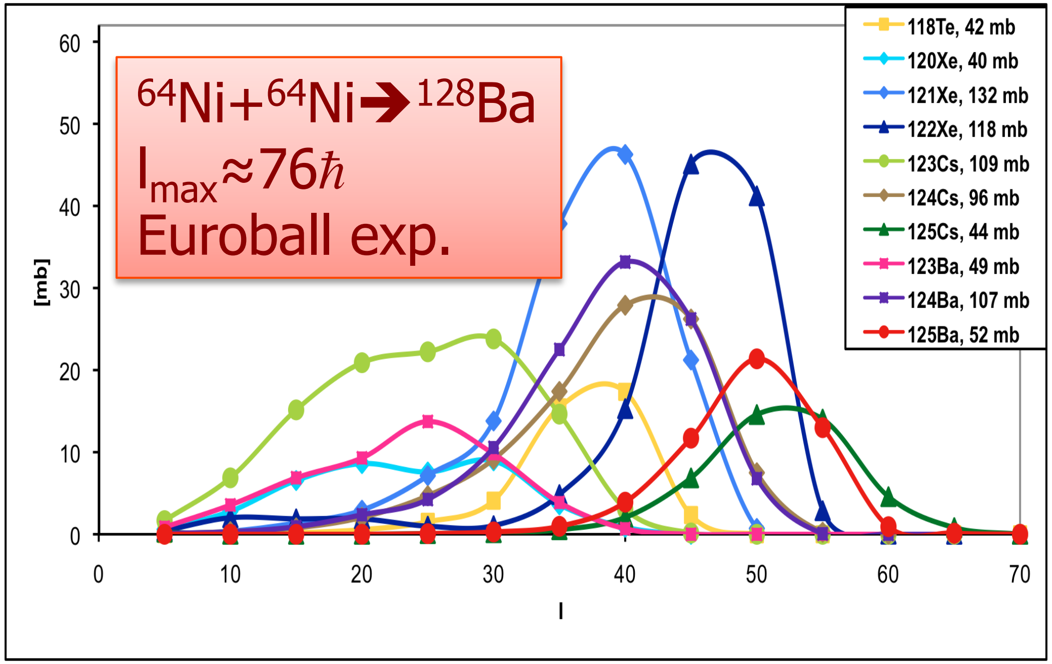
We propose a step approach:

Day-1) At the first stage of SPIRAL2 the reaction **^{90}Kr** (with intensity of **5×10^8 pps** and ~4 MeV/A) on **^{48}Ca** target will be used to populate the compound nucleus **^{138}Ba*** at maximum spin around 90 $\hbar$.

Day-2) At a later stages (Phase2-Day2) even more neutron-rich systems, as e.g. **^{142}Ba*** will be reached by the use of the **^{94}Kr** beam, with similar intensity.



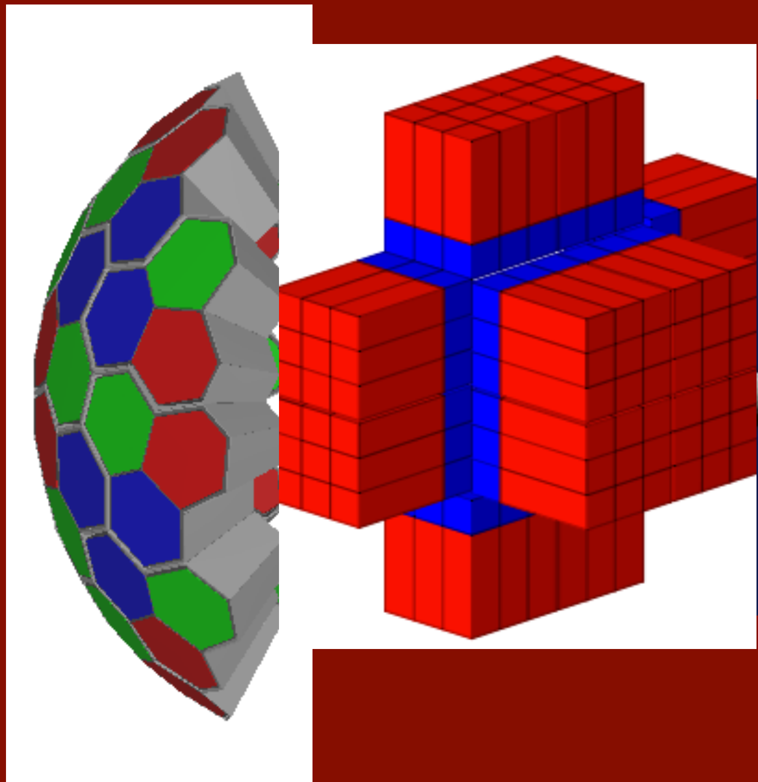
370MeV 90Kr + 48Ca → 138Ba
total
evaporation
(1209 mb)
fission
97.6
E* [MeV]
yrast line
from LSD model
I [ħ]
132Ba
(364 mb)
133Ba
(316 mb)
131Ba
(295 mb)
134Ba
(125 mb)
Yield [arb. un.]

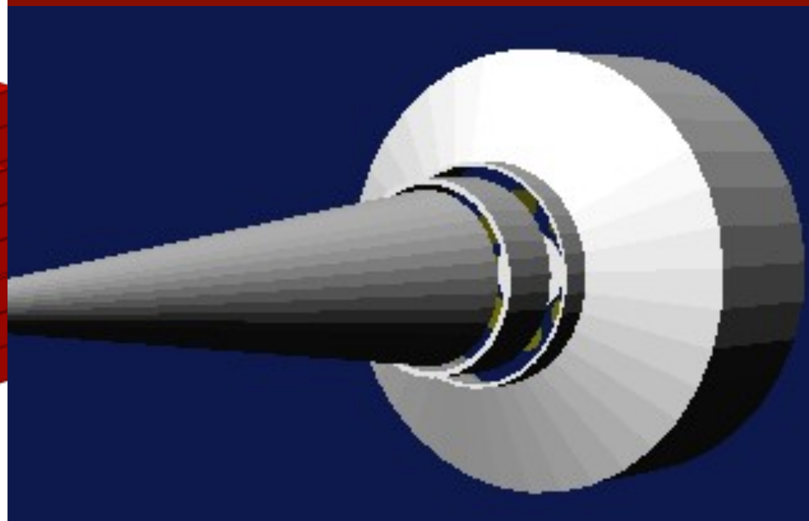


64Ni+64Ni→128Ba
Imax≈76ħ
Euroball exp.
[mb]
I
118Te, 42 mb
120Xe, 40 mb
121Xe, 132 mb
122Xe, 118 mb
123Cs, 109 mb
124Cs, 96 mb
125Cs, 44 mb
123Ba, 49 mb
124Ba, 107 mb
125Ba, 52 mb

Experimental setup

- The experimental setup will require the coupling of the **AGATA/EXOGAM2** array to the 2π **PARIS** scintillator array, plus a detection system for the beam rejection and selection of the evaporation residues, such as **RFD: Recoil Filter Detector**.





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どうもありがとう

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