A. Maj, J.P. Wieleczko

PARIS

Photon Array for studies with Radioactive Ion and Stable beams

http://paris.ifj.edu.pl

2nd COPIGAL WORKSHOP on Studies of Exotic Nuclei

June 4-6, 2012, Krakow, Poland

Organized by:

The Henryk Niewodniczański Institute of Nuclear Physics
Polish Academy of Sciences

COPIGAL participants in the PARIS project

Ch. Schmitt, ***GANIL*** **(*new French spokesperson*);**
J.P. Wieleczko, ***GANIL (French coordinator until 2011)***
GANIL: Ch. Schmitt, J.P. Wieleczko, M. Lewitowicz;
IPN Orsay: I. Matea, F. Azaiez, B. Genolini, G. Hull, P. Rossier, J. Bettane, I. Stefan, D. Beaumel, M. Niikura;
IPN Lyon: O. Stezowski;
IPHC Strasbourg: O. Dorvaux, S. Courtin, M. Rousseau, Finck, C. Beck, J. Dudek

A. Maj, ***IFJ PAN Kraków (Polish coordinator)***
IFJ PAN Kraków: A. Maj, M. Kmiecik, K. Mazurek, M. Ciemała, P. Bednarczyk, M. Ziębliński, B. Fornal, A. Czermak, M. Jastrząb, J. Grębosz; M. Krzysiek
SLCJ UW Warsaw: K. Hadyńska-Klek, P. Napiórkowski, M. Dudeło
UMCS Lublin: K. Pomorski

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

GANIL
SAC open session
October 19th, 2006

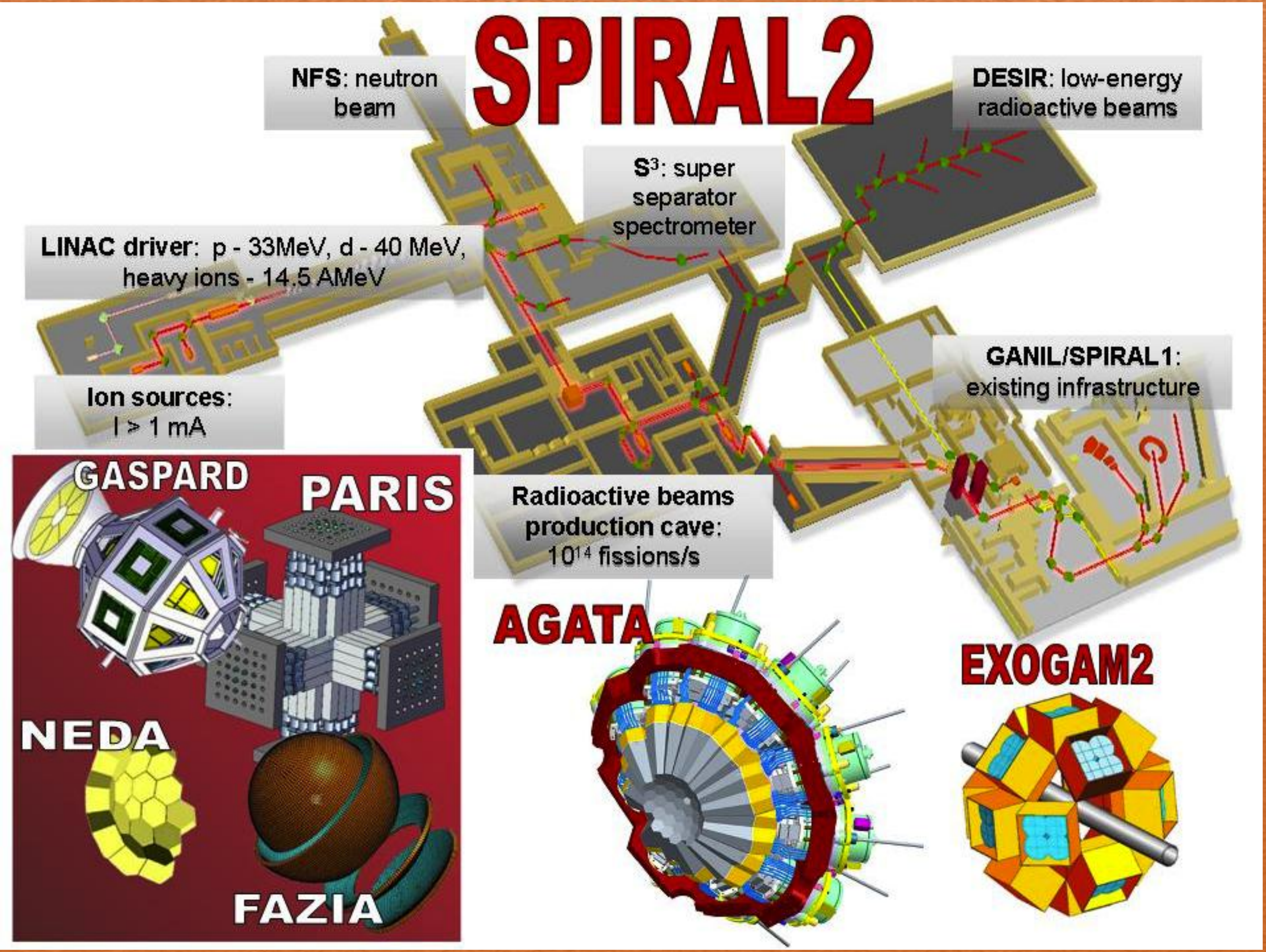
Letter of Intent for SPIRAL 2

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):*
Adam Maj, IFJ PAN Krakow, Adam.Maj@ifj.edu.pl
Jean-Antoine Scarpaci, IPN Orsay, scarpaci@ipno.in2p3.fr (
David Jenkins, University of York (UK), dj4@york.ac.uk

GANIL contact person
Jean-Pierre Wieleczko, GANIL, wieleczko@ganil.fr

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
Ion sources: I > 1 mA
GANIL/SPIRAL1: existing infrastructure
Radioactive beams production cave: 10¹⁴ fissions/s
GASPARD
PARIS
NEDA
FAZIA
AGATA
EXOGAM2

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 (after postacceleration)
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.

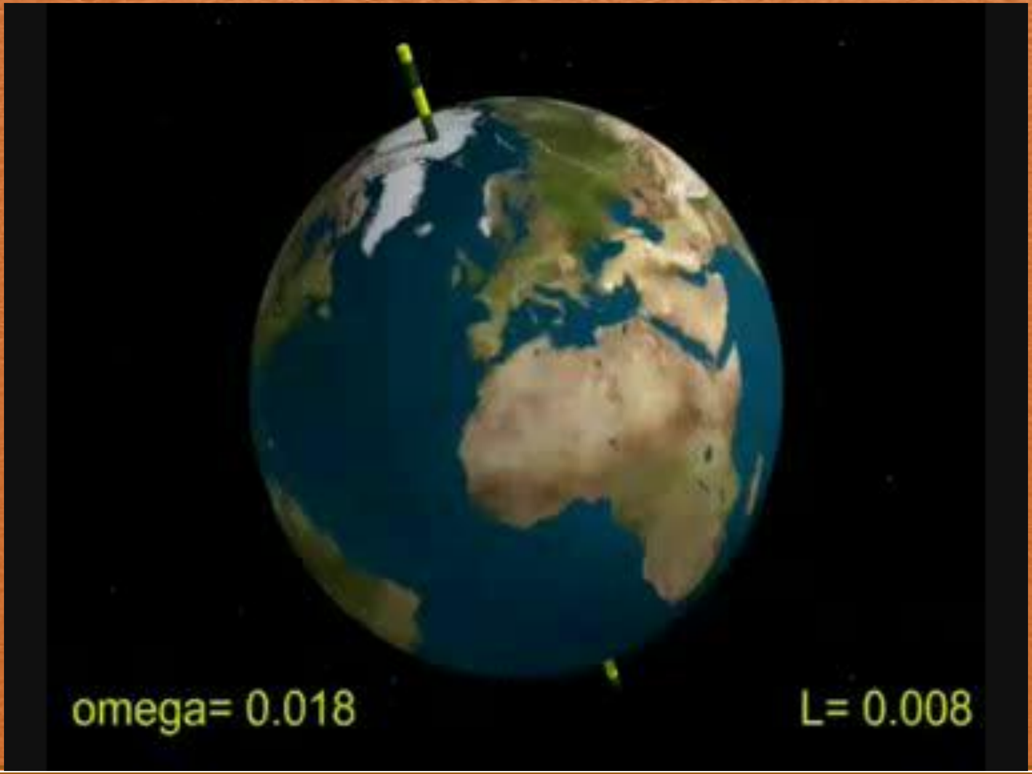
n) PDR in proton-rich nuclei with NEDA+PARIS
G. De Angelis et al.

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.

Jacobi and Poincare shape transitions (+AGATA) *
(A. Maj, J. Dudek, K. Mazurek, Ch. Schmitt, S. Leoni, M. Kmiecik et al.)

Theoretical shapes of rotating gravitating body – the Earth

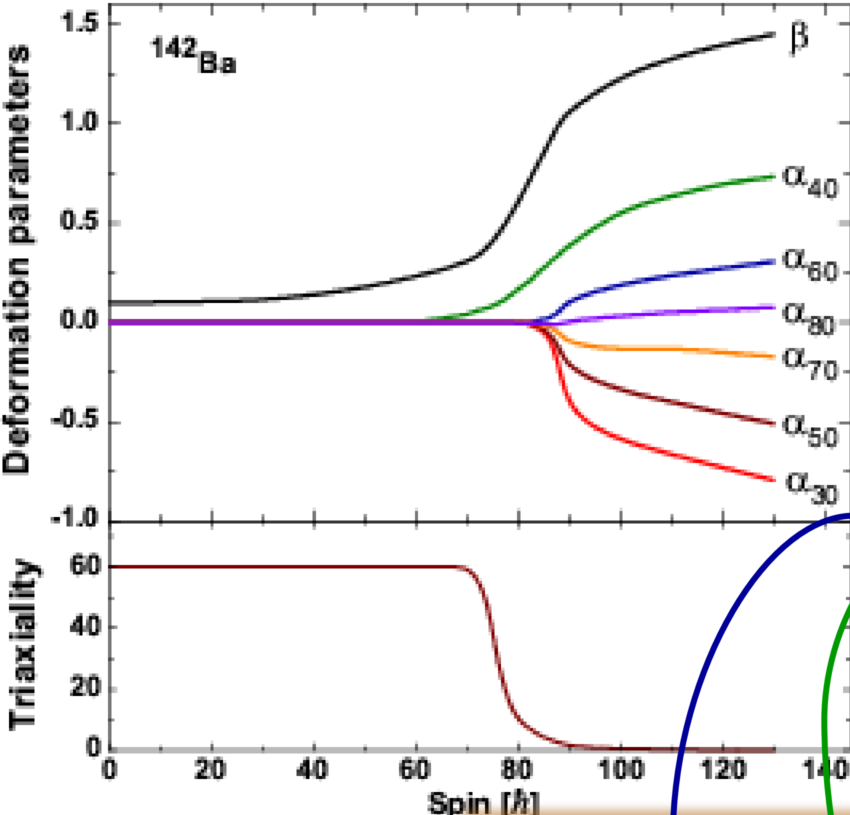


McLaurin, Jacobi and Poincare shapes

Such behaviour is expected also for rotating nuclei

Based on talk by Prof.. Etienne Ghys of the Unité de Mathématiques Pures et Appliquées de l'E.N.S. de Lyon
www.josleys.com/show_gallery.php?galid=313

Calculations based on LSD model

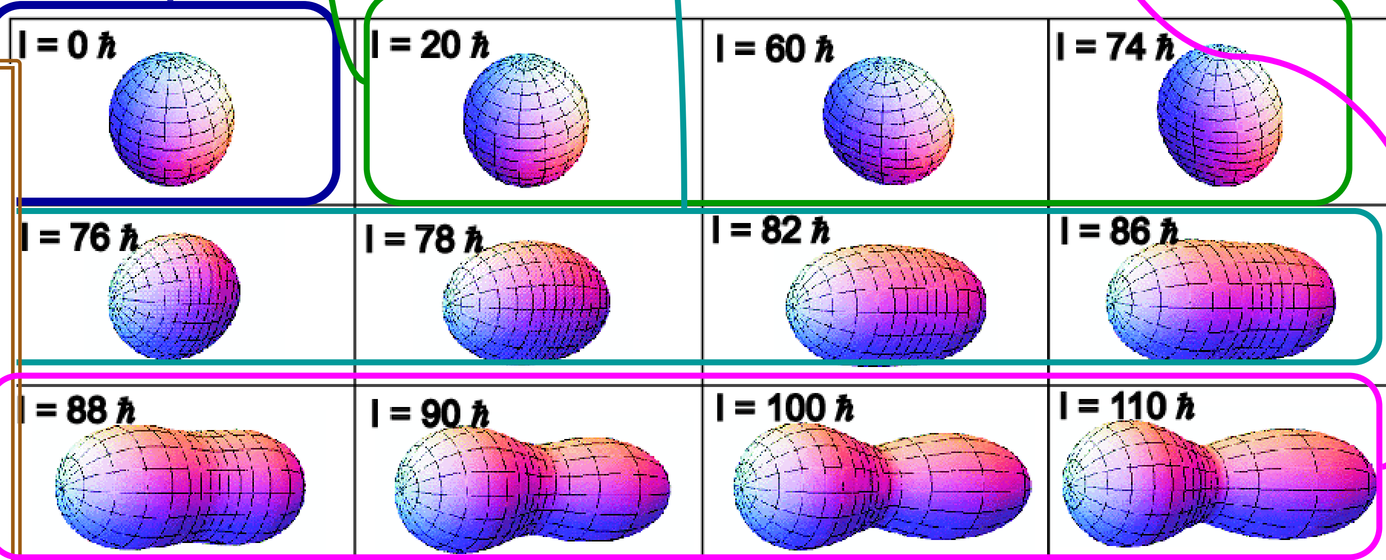


Sphere

Oblate (MacLaurin)

Elongated triaxial (Jacobi)

Octupole, left- right asymmetric (Poincare)



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

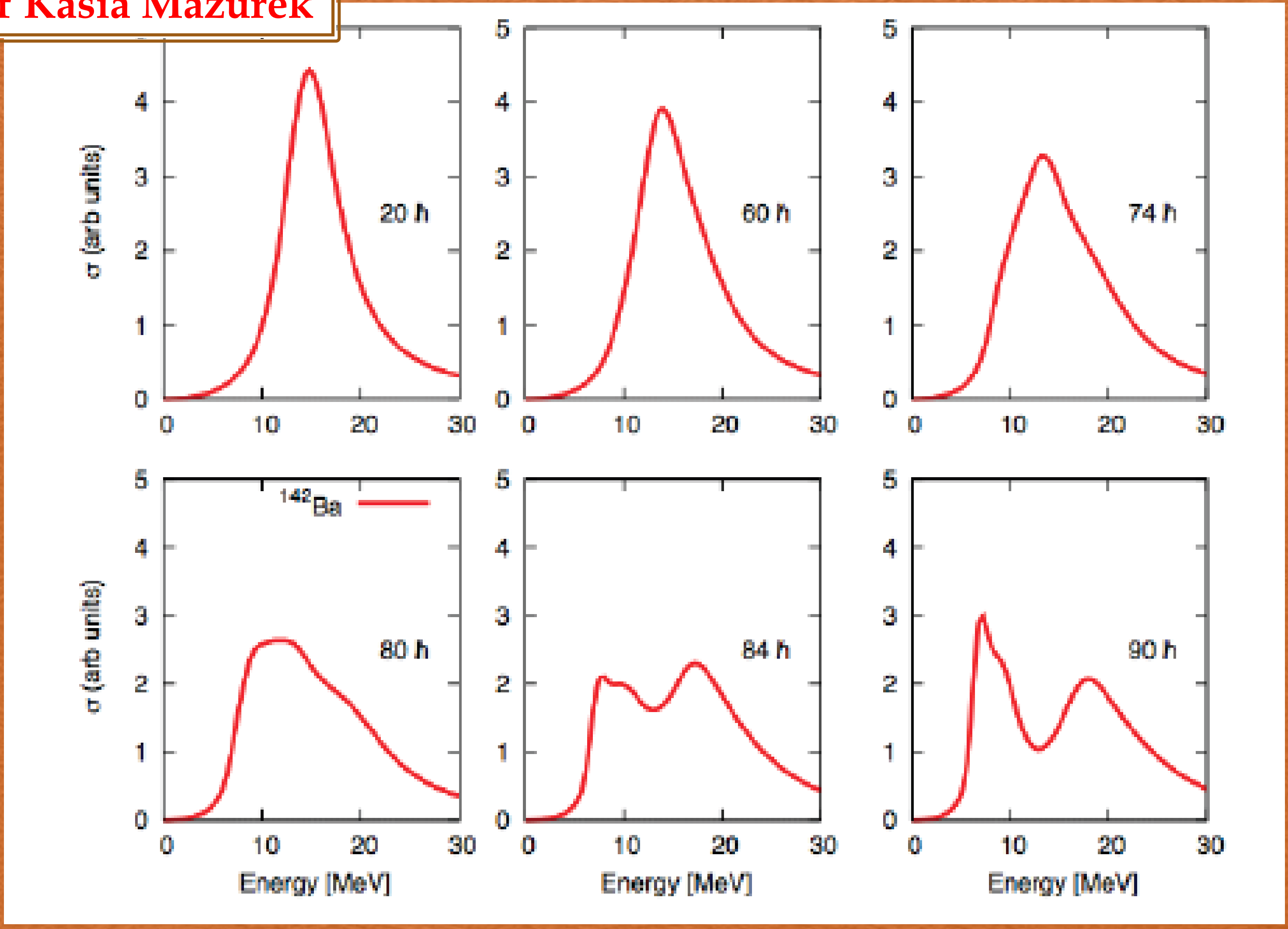
A.Maj *et al*. Int. J. Mod. Phys. E19, 532 (2010);
K.Mazurek *et al*., Acta Phys. Pol. B42, 471 (2011)

Fragmented GDR strength function

Evolution of GDR strength function for ^{142}Ba

K. Mazurek et al., to be published

More: talk of Kasia Mazurek

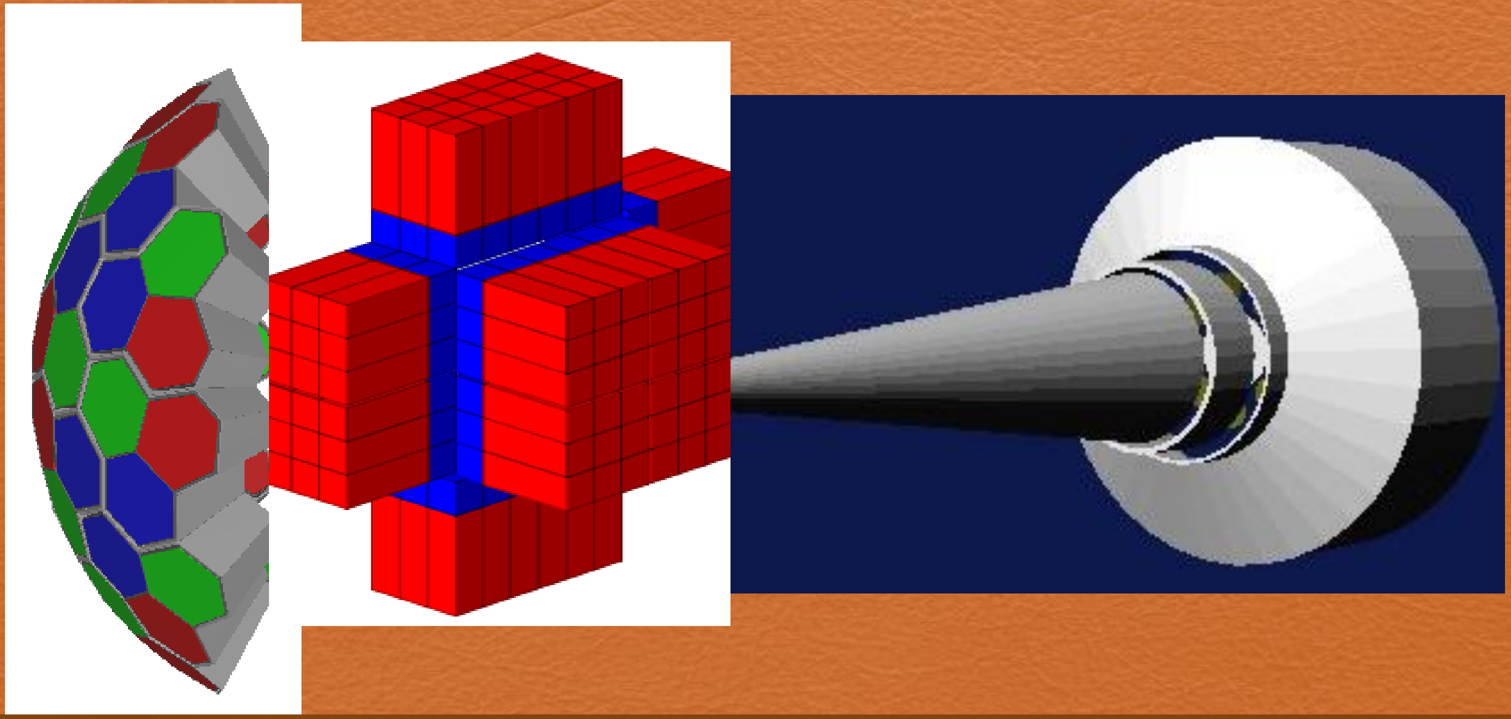


Study of collective modes of excitations in the neutron-rich Ba region via fusion-evaporation reactions

Spiral2 Day1-Phase2 LoI

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

More on physics: talk of Silvia Leoni
AGATA/EXOGAM2: talk of Gilles de France
RFD: talk of Piotr Bednarczyk



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

Main physics cases require that PARIS has to

- be transportable (SPIRAL2/GANIL will be the primary site, but experimental campaigns are planned in other facilities: ALTO, Warsaw, Krakow, SPES, HIE-ISLODE,…)
- be modular (to be connected with other detectors: AGATA, EXOGAM, 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 energy resolution as good as possible
- have some position sensitivity

PARIS organization at the beginning, to be rearranged soon

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

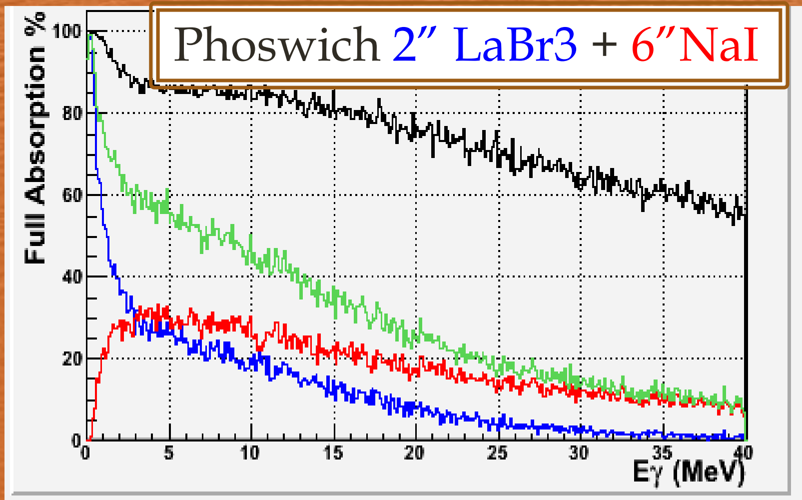
PARIS *Advisory* Committee
F. Azaiez (F) -chairman, D. Balabanski (BG), W. Catford (UK), D. Chakrabarty (India),
Z. Dombradi (H), S. Courtin (F), J. Gerl (D), D. Jenkins (UK) - deputy chairman,
S. Leoni (I), A. Maj (PL), I. Matea (F), Ch. Schmidt (F)

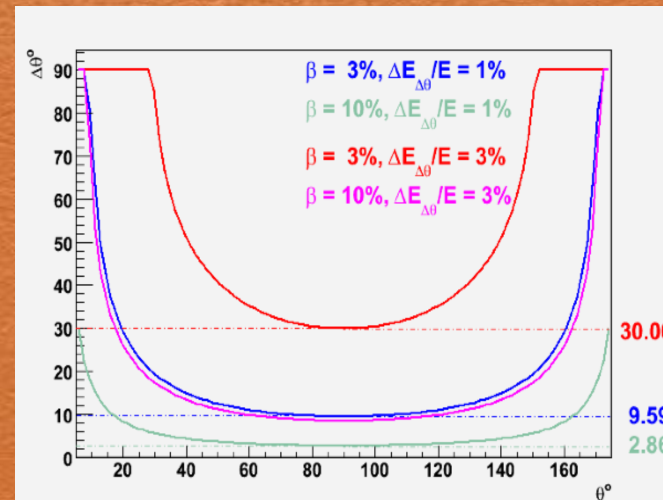
J. Pouthas – PARIS liaison to SPIRAL2 project management

Main PARIS Working Groups:

1. **Simulations WG:** O.Stezowski, Ch.Schmitt, M.Ciemała, M.Krzysiek, K.Mazurek, M.Labiche, D.R.Chakrabarty et al.
2. **Mechanical desing WG:** S.Courtin, D.Jenkins, J.Strachan, I.Matea, J.Bettane et al.
3. **Physics Cases WG:** Ch.Schmitt, I.Mazumdar, A.Maj, F.Azaiez, S.Leoni, M.Kmiecik, K.Mazurek, J.Dudek, K.Pomorski et al.
4. **Detector WG:** O.Dorvaux, I.Matea, J.Pouthas, G.Hull, M.Ziębliński, M.Ciemała, P.Napiorkowski, K.Hadyńska-Klęk, V.Nanal, I.Mazumdar, F.Camera et al.
5. **Electronics and DAQ WQ:** P.Bednarczyk, A.Czermak, M.Jastrząb, B.Genollini, M.Tripon, G.de France, S.Brambilla, M.Dudeło, J.Grębosz, D. Balabanski et al.


PARIS collaboration meeting, February 2012, Bormio



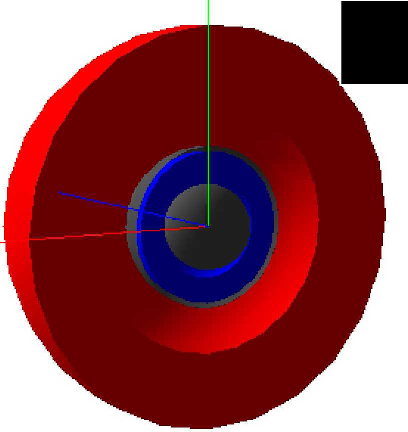


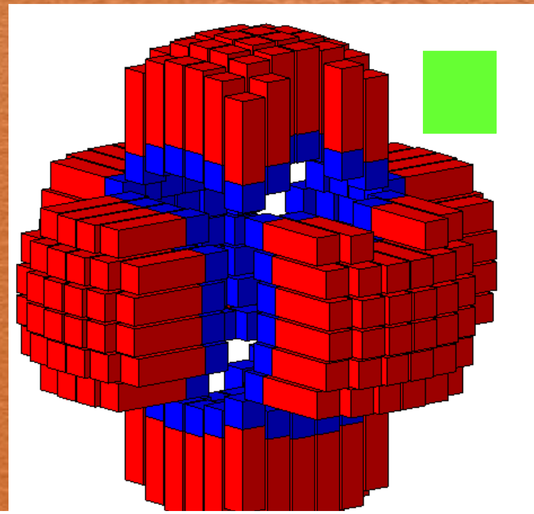
Extensive **simulation studies** have been performed to understand how γ–rays with energies from few keV up to 50 MeV are absorbed and recovered. Figure above is used for instance to determine the opening angle required to not spoil out the intrinsic LaBr3 resolution. All the considerations drive the ***design of the basic element*** of PARIS as composed of

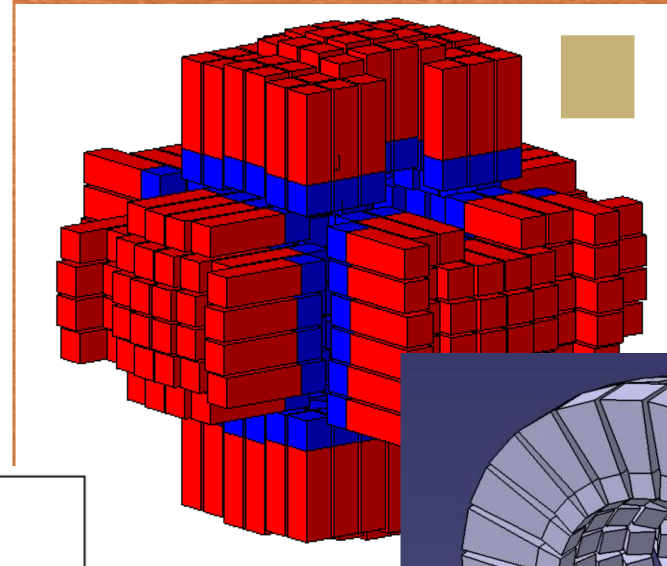
2″x2″x2″ LaBr3 followed by 2″x2″x2″ NaI.

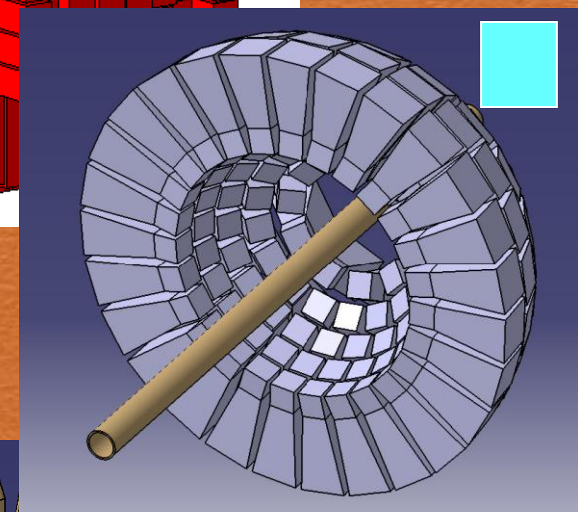
Placed at a reasonable distance from the target position it gives a ***4π array composed of few hundred of elements*** for optimal characteristics in ***non-relativistic domain*** (β < 10%).

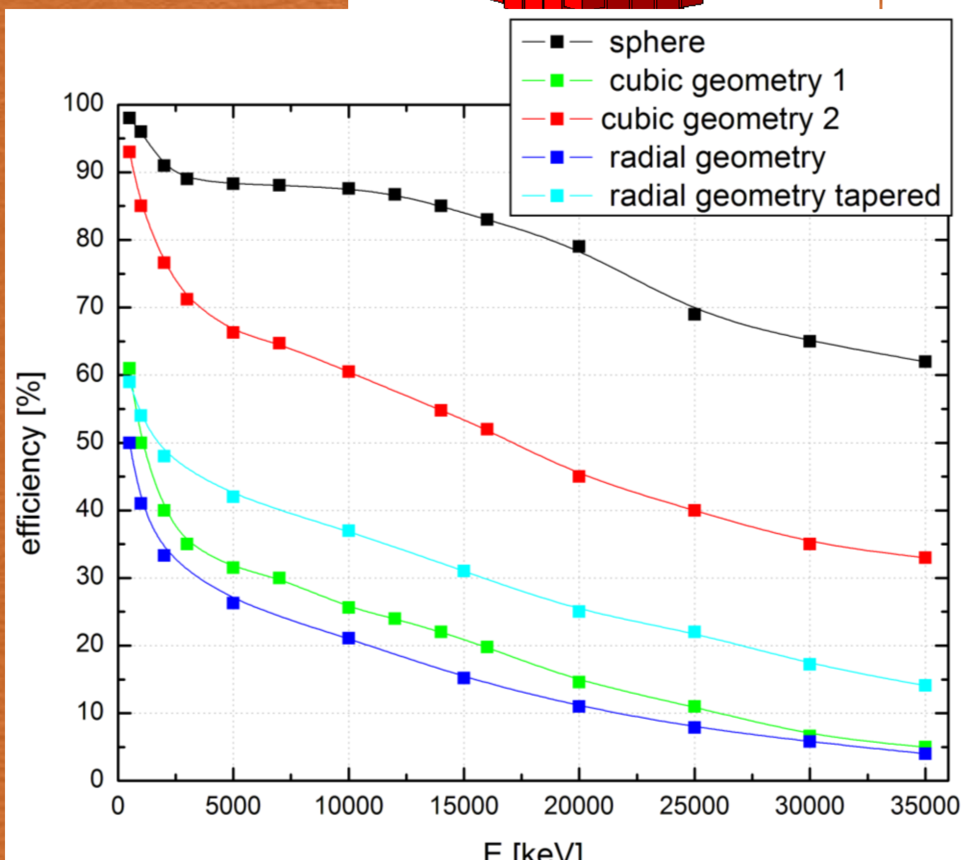
Cubic vs. Radial geometry

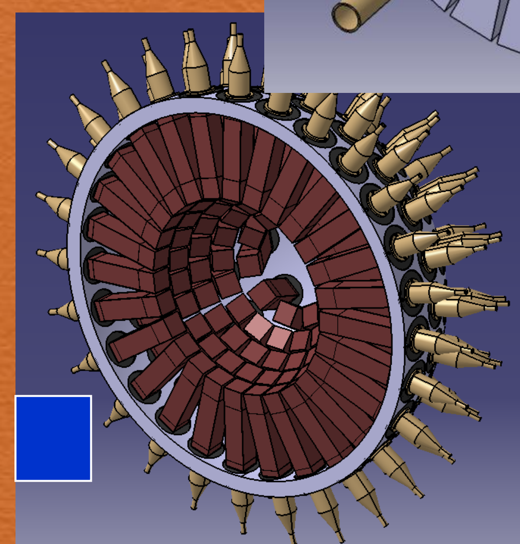






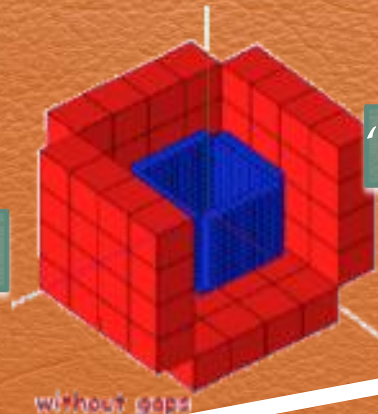




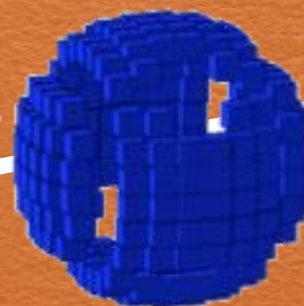


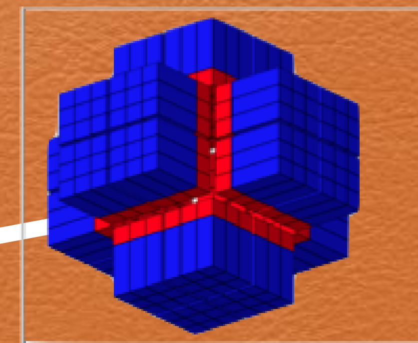
Several geometries studied

'Ideal' - spherical

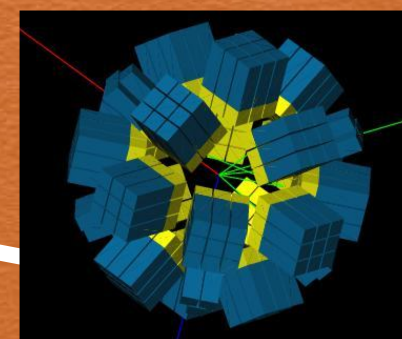


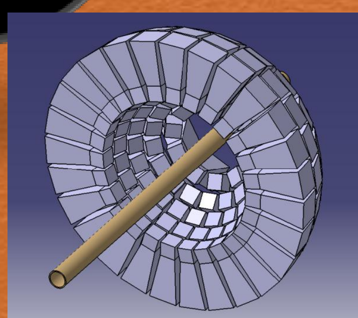
'cubic'-like

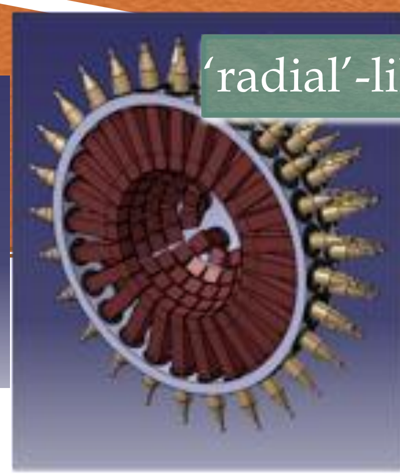




'radial'-like





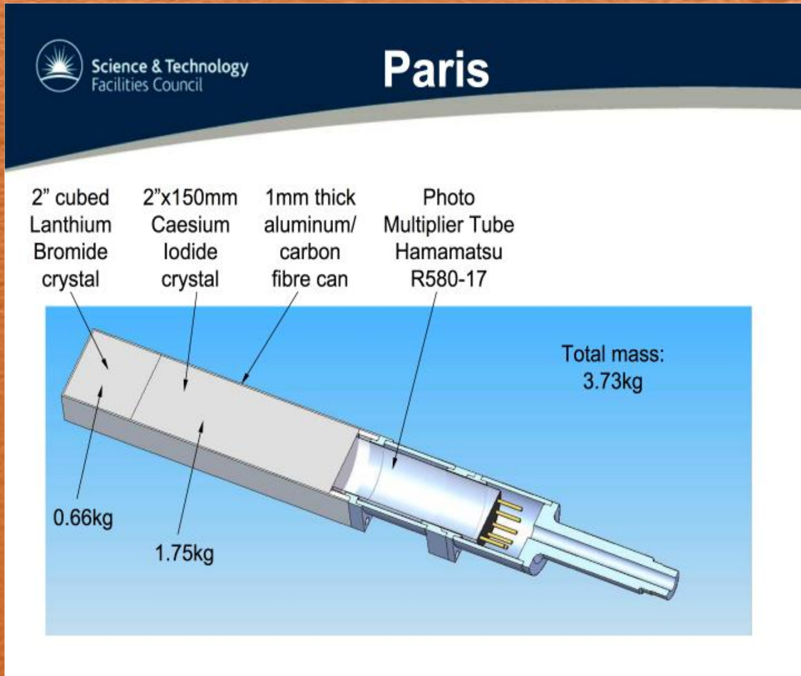


CONCLUSION:

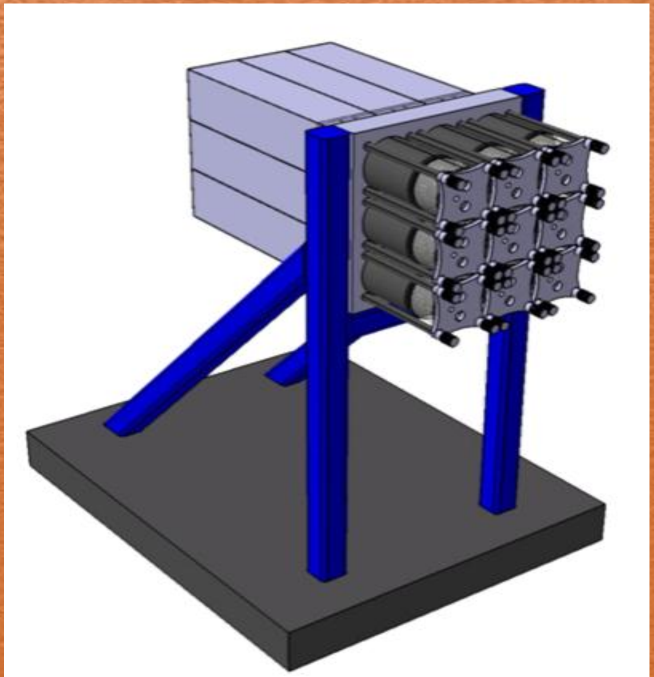
PARIS to be made of clusters:

Cluster = 9 *phoswiches*

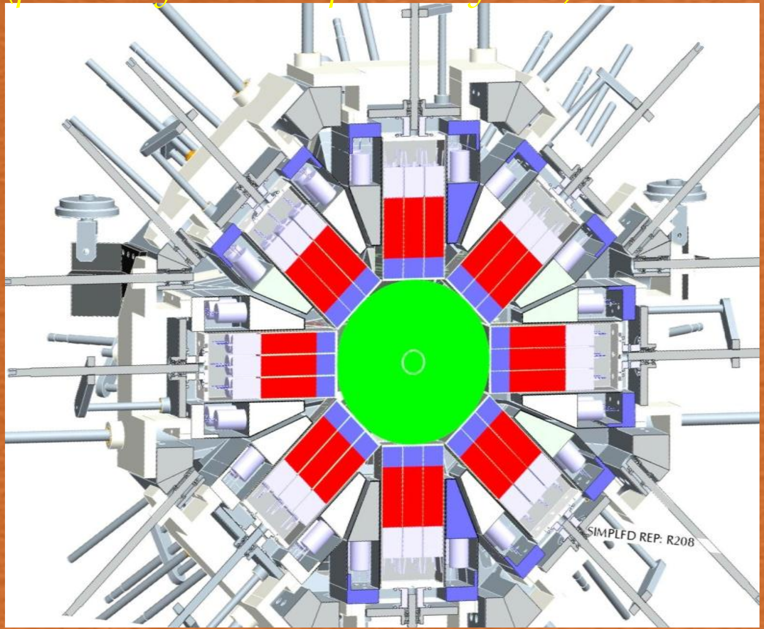
This allows *cubic* or *semi-spherical* geometry with 24 clusters (216 phoswiches)



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



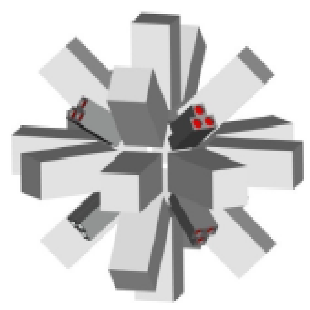
A cluster module comprising nine phoswich detectors



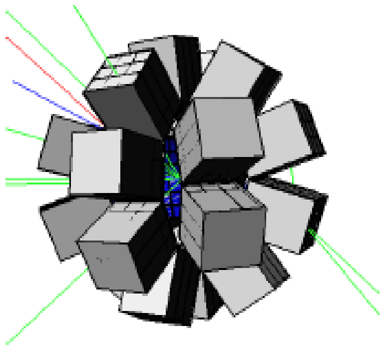
Clusters of phoswich detectors arranged in a radial geometry

Designs made in IPN Orsay and Daresbury

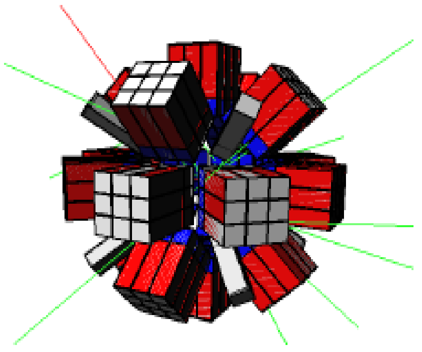
Geometries for PARIS+GASPARD



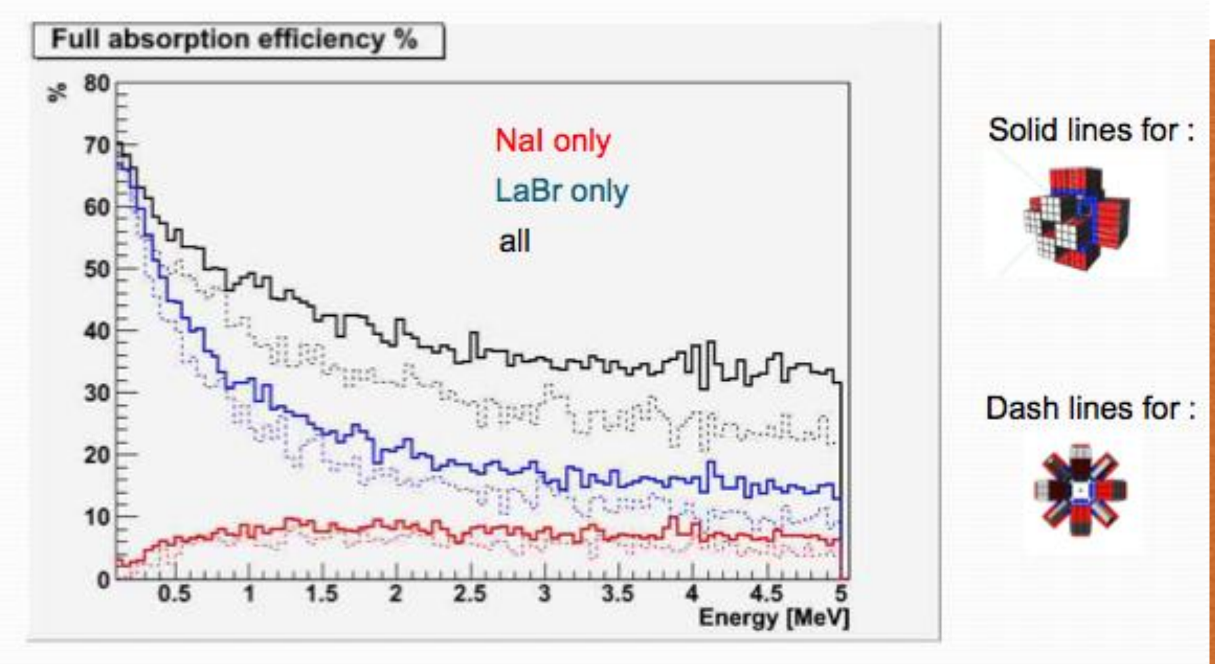
PARIS180
18 clusters + 18 phoswich
R = 235 mm
(8 clusters in main ring)



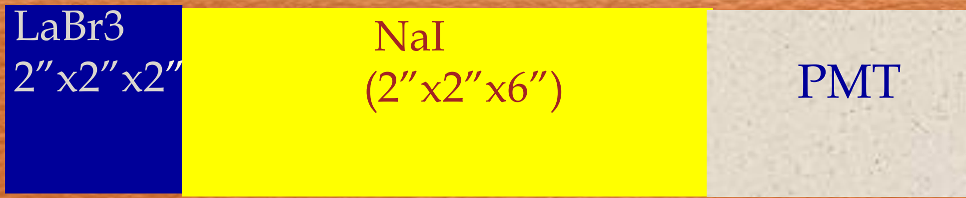
PARIS234
26 clusters
R = 235 mm
(10 clusters in main ring)



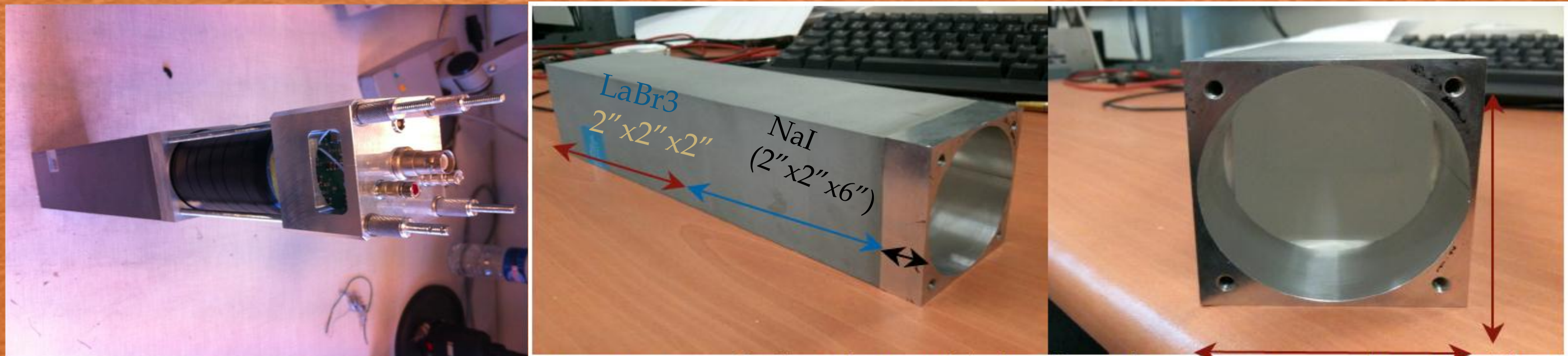
PARIS168
18 clusters + 6 phoswich
R = 208 mm
(8 clusters in main ring)

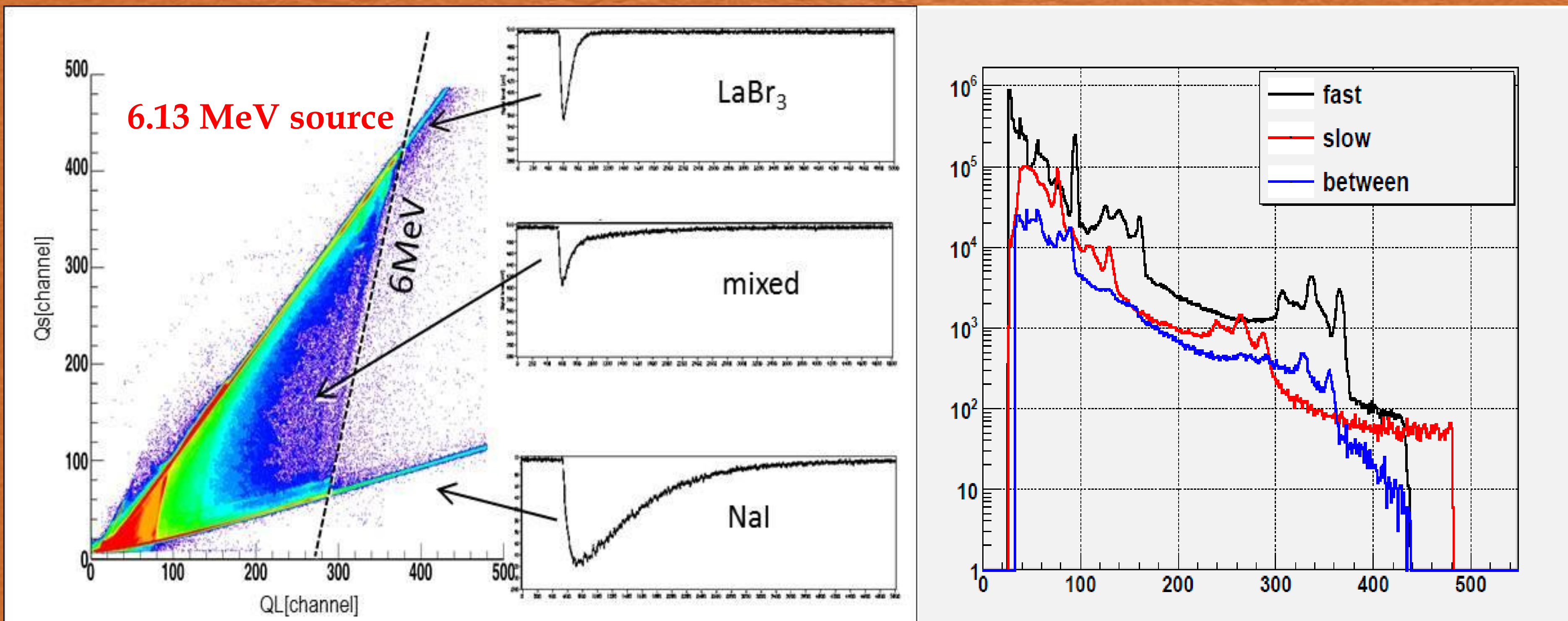


Basic element: a phoswich LaBr3+NaI

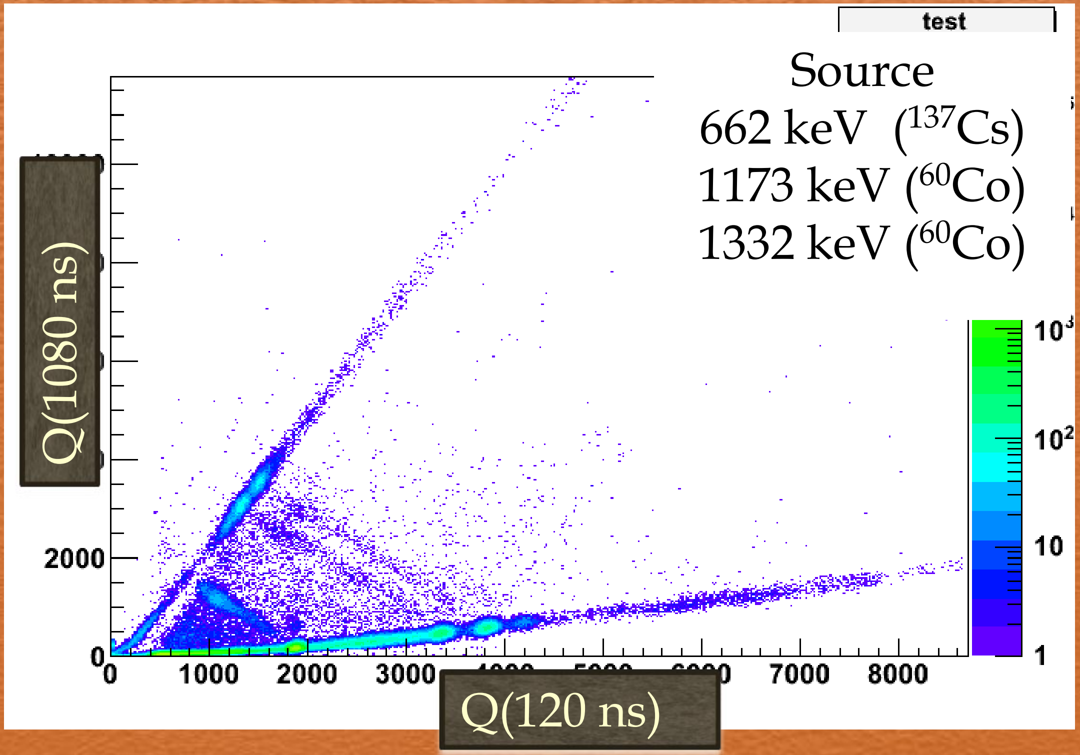


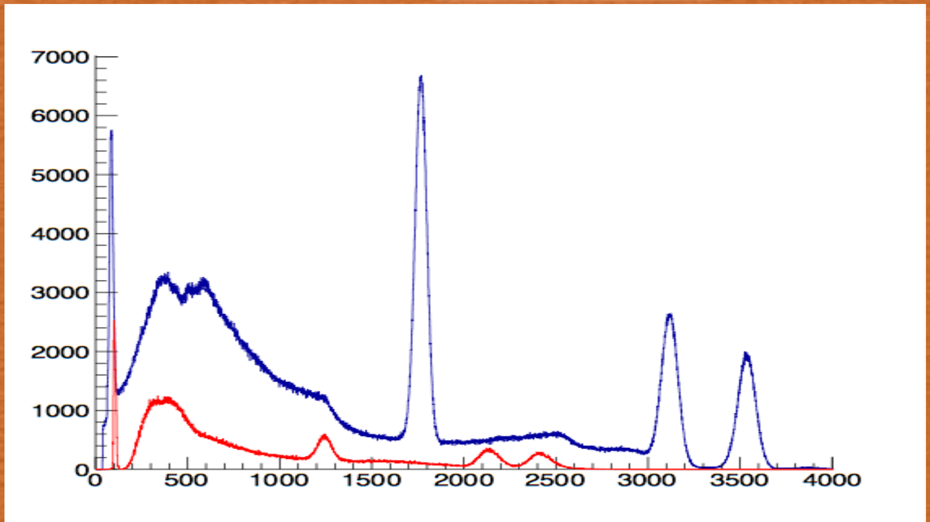
5 prototypes were ordered from Saint Gobain
1 to Orsay, 1 to Strasbourg, 3 to Krakow





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.





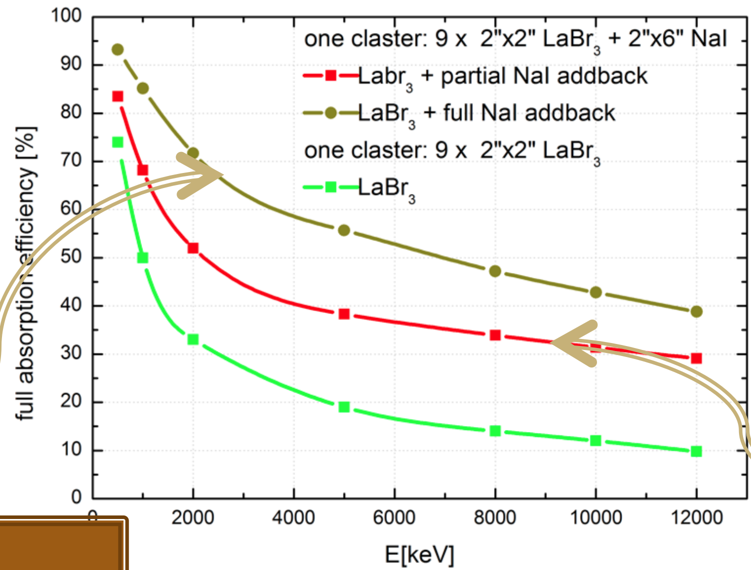
$LaBr_3$ $\Delta E/E \approx 4\%$

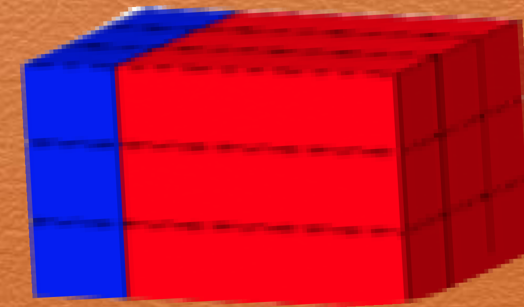
Phoswich tests results

:

Phoswich/ PMT	Energy resolution (%)					Energy Gated Timing Resolution (ps)		Linearity
	@662keV			@1332keV		@511keV	@1.1-1.4MeV	^{137}Cs, ^{60}Co
	St. Gobain	$LaBr_3$	NaI	$LaBr_3$	NaI			
IFJ PAN A0_207/ XP3292B	4.1	4.0	~11 side	2.9 side	6.0 side	710	530	Very good
IFJ PAN A0_209/ XP3292B	4.3	4.1	8.9 side	3.0 side	5.6 side	770	580	Very good
IPNO/ R7723-100	4.5	4.3	6.5-7 side	3.3		500	400	Very good
IPHC/ R7723-100	4.8	4.7	7.5-8	3.4	5.3			Very good
Single cubic 2"x2" Labr3/ XP3292B	*3.6*	*3.6*	*X*	*2.8*	*X*	*520*	*370*	*Very good*

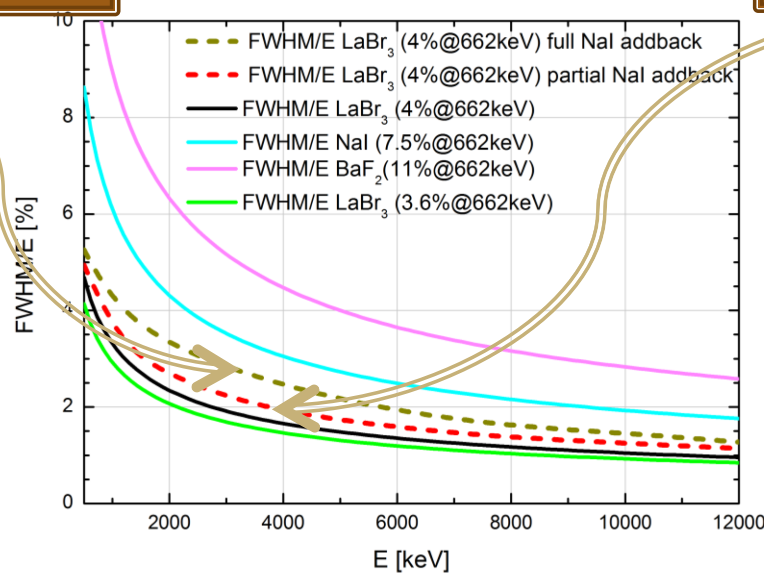
Simulations for one cluster made of 9 phoswiches



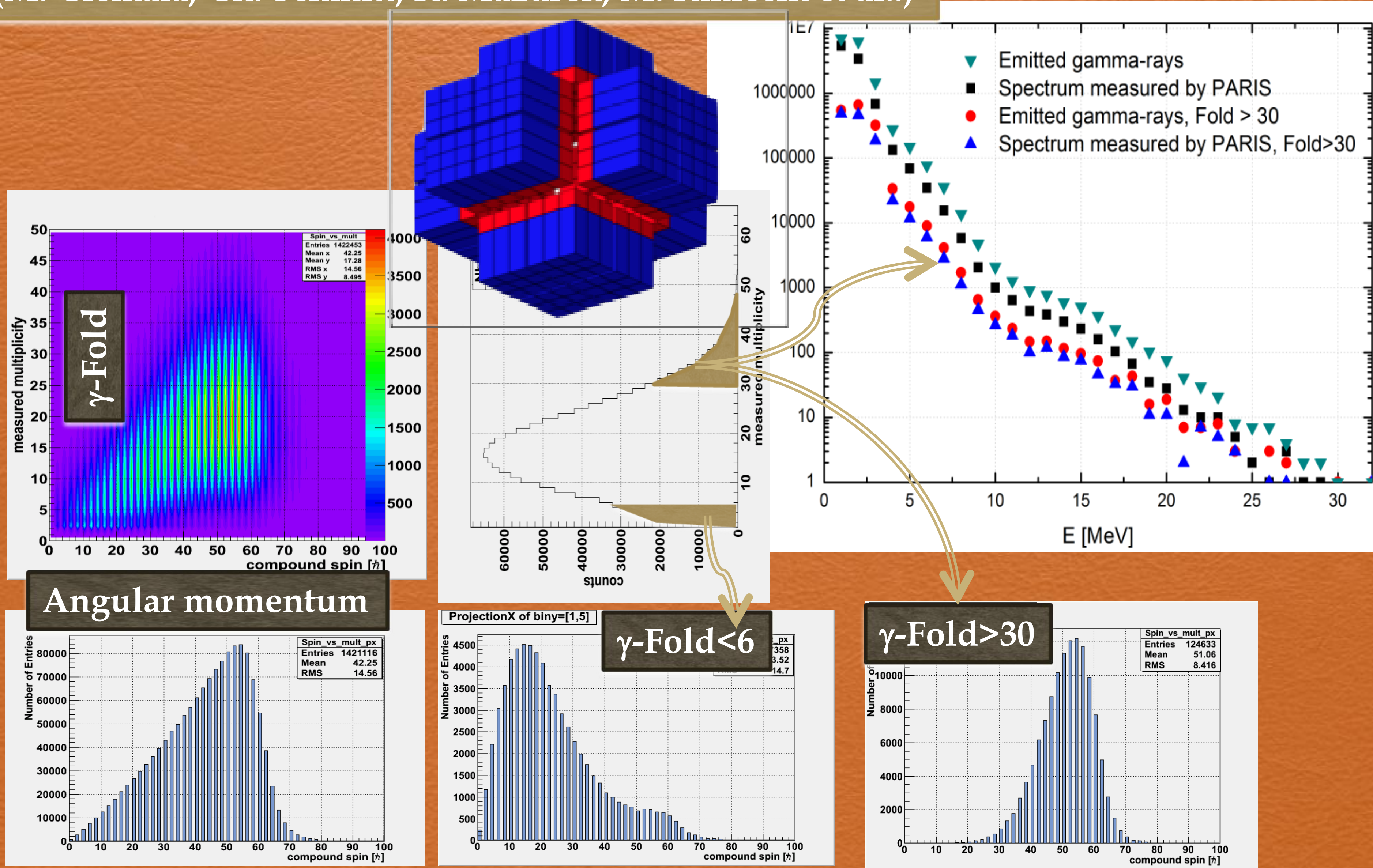


Full addback:
LaBr3+ LaBr3_NaI+NaI

Partial addback:
LaBr3+ LaBr3_NaI



Event generator for PARIS based on MC Cascade
(M. Ciemała, Ch. Schmitt, K. Mazurek, M. Kmiecik et al..)



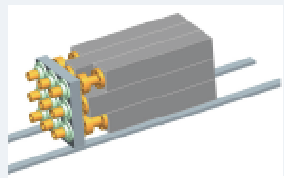
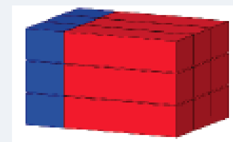
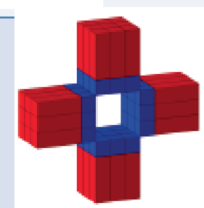
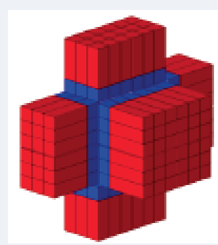
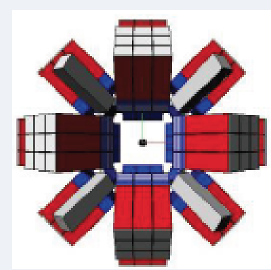
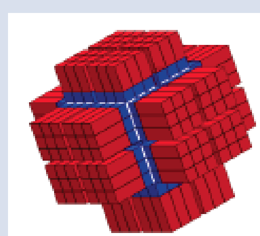
PARIS Demonstrator MoU

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

Signature of the PARIS Demonstrator MoU

Other activities:

- Puls shape analysis: electronics for PARIS shall be based on NUMEXO2 solution (synergy with EXOGAM2 and NEDA)
- Simulation software for GASPARD and PARIS
- Common physics cases with GASPARD and with NEDA in preparation
- Work started do adapt the Krakow RFD to PARIS at SPIRAL2 beams experiments

SUMMARY

- LaBr3+NaI phoswich is a viable solution for the elements of the eventual PARIS calorimeter, in terms of it meeting the requirements for energy and timing resolution
- The next step is to explore the performance of a cluster of 9 phoswich detectors. Source and in-beam testing of this cluster will proceed soon
- The next phase will be the PARIS Phase2 (Demonstrator) of 5 clusters, each of 9 phoswich detectors.
- The MoU for the Phase 2 (PARIS Demonstrator) has been worked out and already signed by some partners, including GANIL, IN2P3 and COPIN

More info on PARIS: http://paris.ifj.edu.pl