Adam Maj (IFJ PAN Kraków)
for the PARIS collaboration

The PARIS Array - Status of the Project and Perspectives

paris.ifj.edu.pl

PARIS collaboration meeting
Strasbourg, January 12-14, 2011

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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Aim:
to design and build efficient gamma calorimeter
PARIS

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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STFC Daresbury (UK): J. Simpson, J. Strachan, M. Labiche
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

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.)

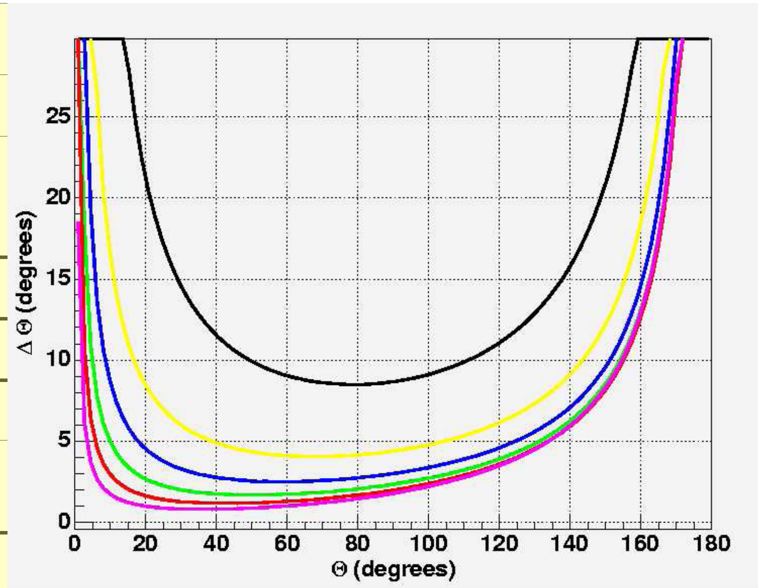
m) PDR studied with GASPARD+PARIS
D. Beaumel et al.

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

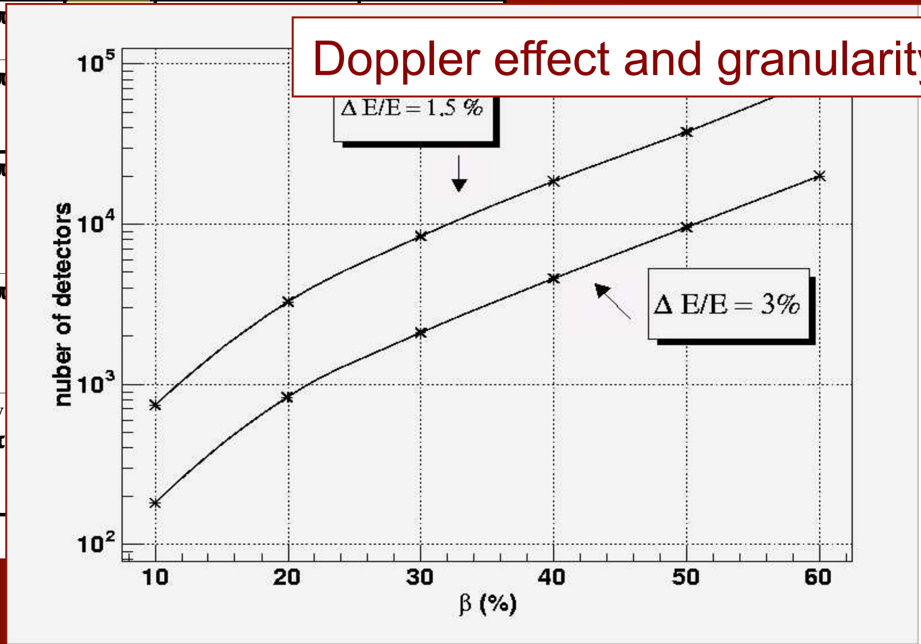
o) Onset of chaotic regime: PARIS +AGATA
S. Leoni et al.

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

Physics Case	Recoil mass	v/c [%]	E_γ range [MeV]	$\Delta E_\gamma/E_\gamma$ [%]	$\Delta E_{sum}/E_{sum}$ [%]	M_γ	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



Doppler effect and granularity



<β> ≈ 10%; ΔM/M<4 → **Granularity: 200-800**

ΔT: <1 ns; ΔEγ/Eγ: < 3%; high efficiency up to 15 MeV → **$LaBr_3$ scintillators**

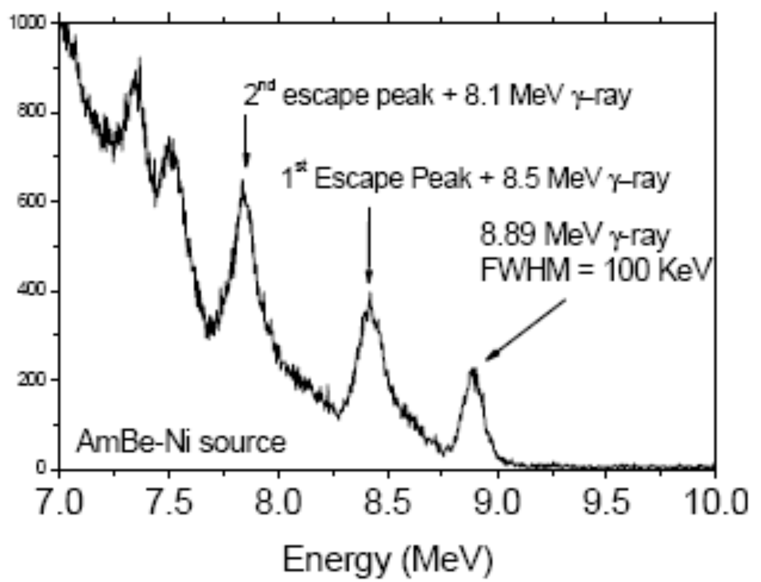
PARIS has to

- 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

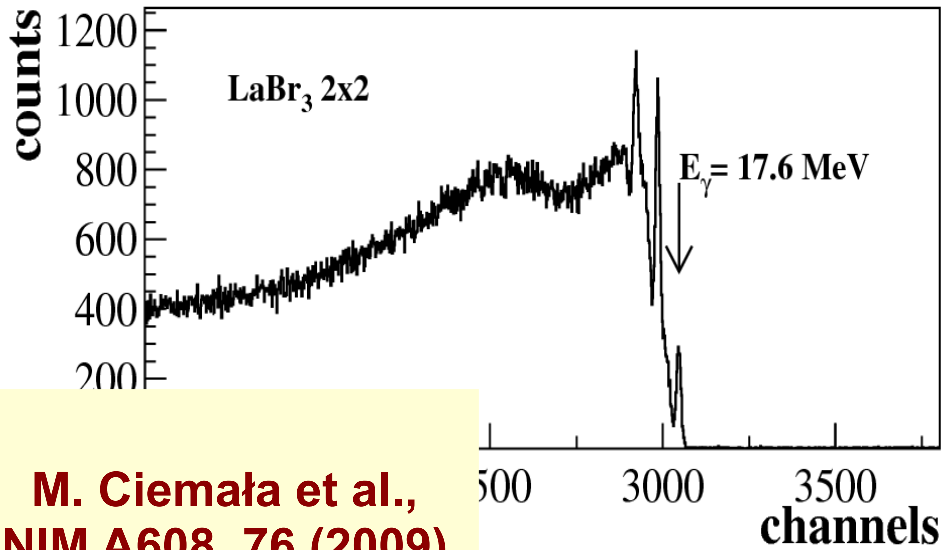
Why LaBr3?

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)

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 will serve also for fast timing application.

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

BASIC SIMULATIONS

PARIS GEANT4 software – **O. Stezowski,** Ch. Schmitt, M. Ciemała et al.
Great work done by the Simulation WG!

Conclusions from first (rather idealistic) stage of simulations (Stezowski et al..)

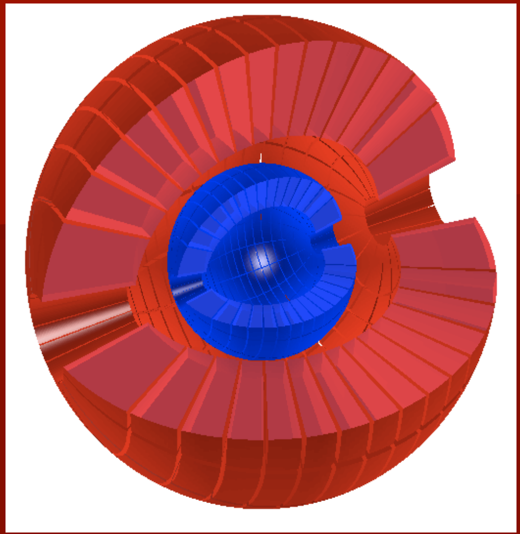
- The idea of **two concentric layers seems to be rather pertinent**, as suggested by the simulations: a) the percentage of fully absorbed events in one of the 2 shells has been found rather large; b) a two-shell design is relevant provided the inner shell is not too much absorbent. In this way, the 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.

More on Simulation Session

DESIGN

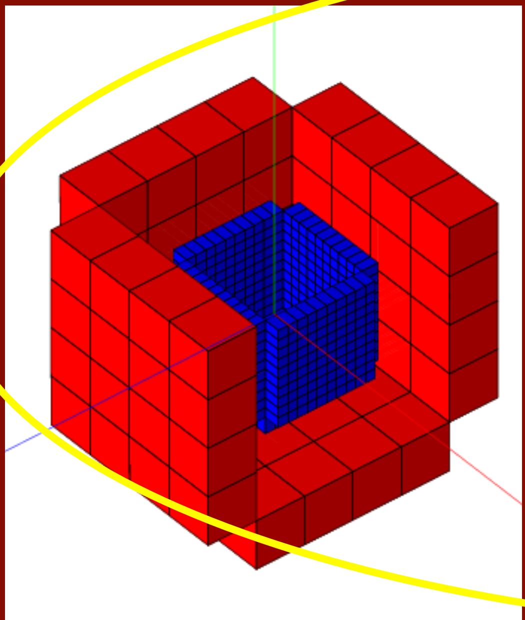
POSSIBLE GEOMETRIES of PARIS



SPHERICAL (e.g. same as AGATA modules):

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

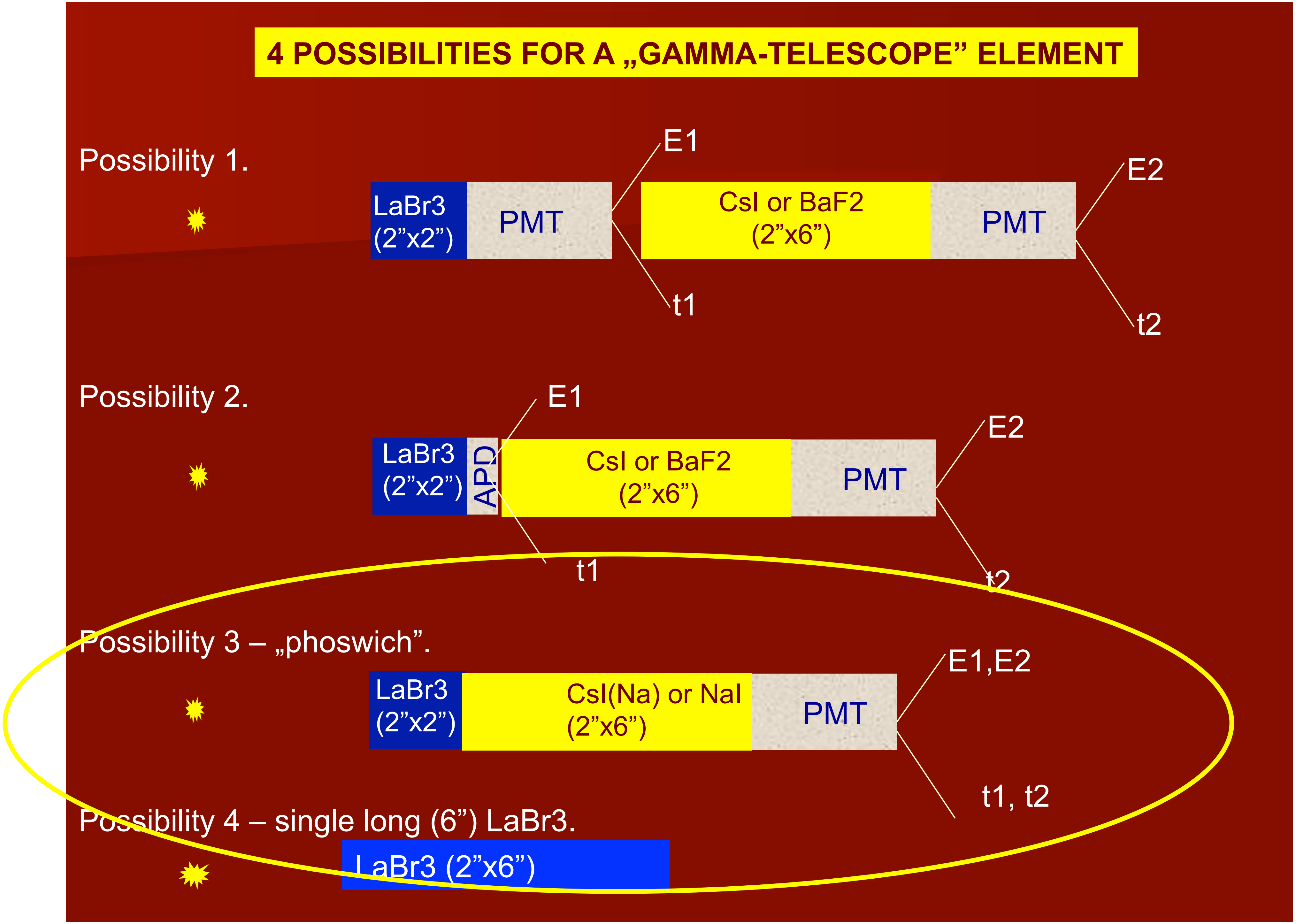
- : Limited to one distance, high cost of a segment,…



CUBIC (offering variable geometry):

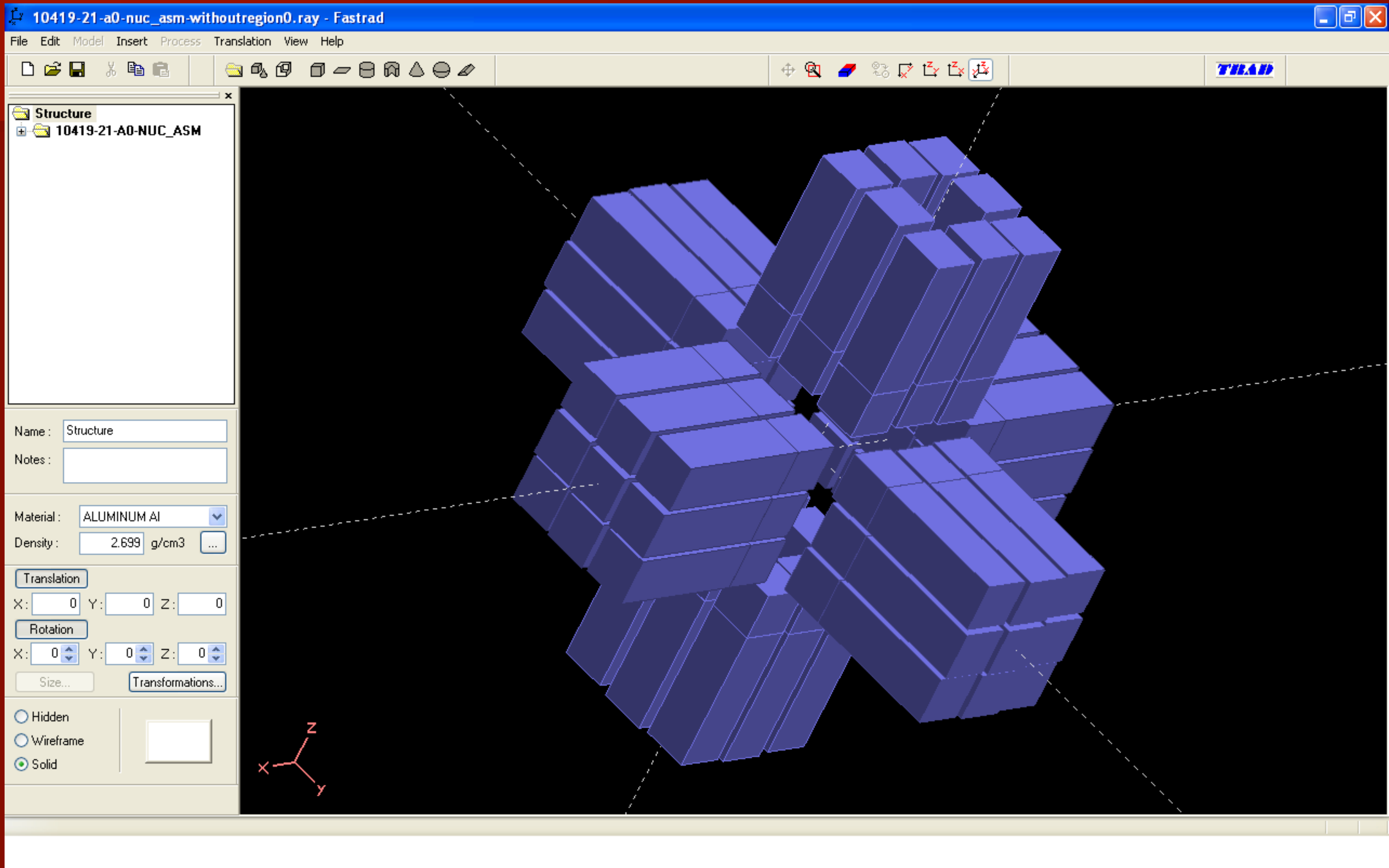
+ : adjustable to different distances, compatibility with many detectors, lower cost for a segment, easier mechanical support,

- : More complicated reconstruction, worse line shape, …

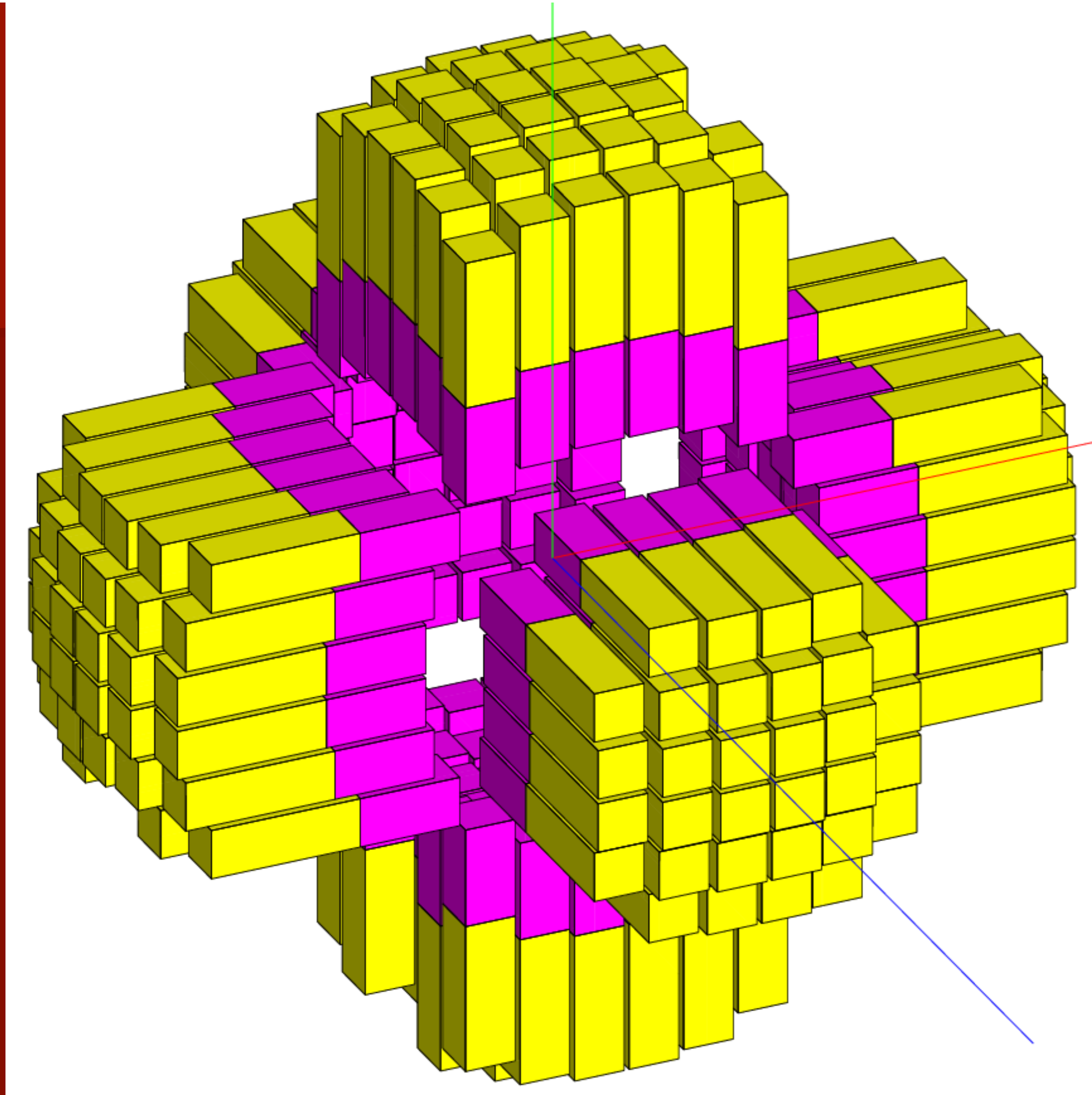

4 POSSIBILITIES FOR A „GAMMA-TELESCOPE” ELEMENT
Possibility 1.
LaBr3
(2”x2”)
PMT
E1
t1
CsI or BaF2
(2”x6”)
PMT
E2
t2
Possibility 2.
LaBr3
(2”x2”)
APD
E1
t1
CsI or BaF2
(2”x6”)
PMT
E2
t2
Possibility 3 – „phoswich”.
LaBr3
(2”x2”)
CsI(Na) or NaI
(2”x6”)
PMT
E1,E2
t1, t2
Possibility 4 – single long (6”) LaBr3.
LaBr3 (2”x6”)

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

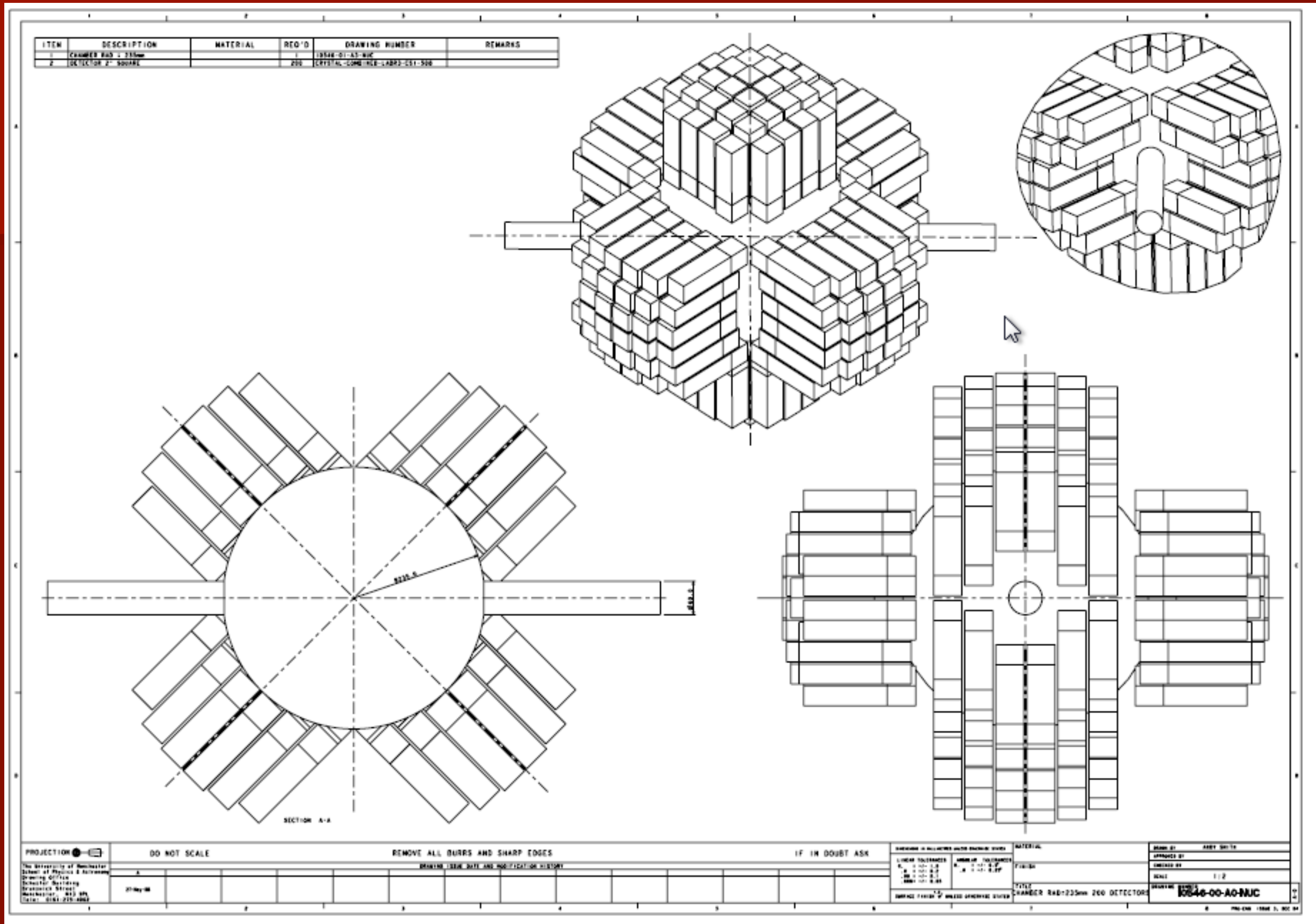
CUBIC-LIKE GEOMETRY



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



204 phoswitches - Labr3: 2”x2”x2” + CsI: 2”x2”x6” (23 cm inner radius)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MATERIAL
REQ'D
DRAWING NUMBER
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DO NOT SCALE
REMOVE ALL BURRS AND SHARP EDGES
IF IN DOUBT ASK
DRAWING ISSUE DATE AND MODIFICATION HISTORY
LINEAR TOLERANCES
MATERIAL
FINISH
TITLE
CHAMBER RAD=235mm 200 DETECTORS
SCALE
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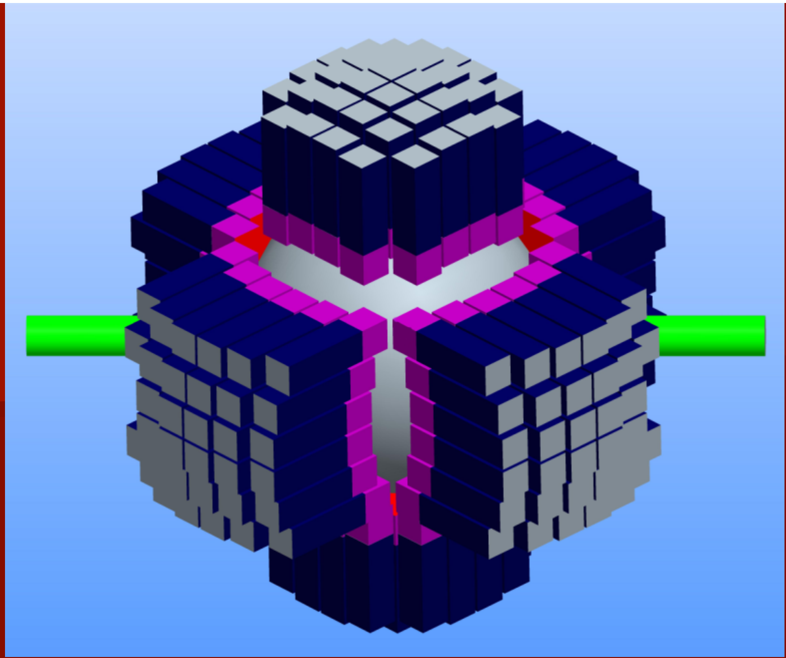
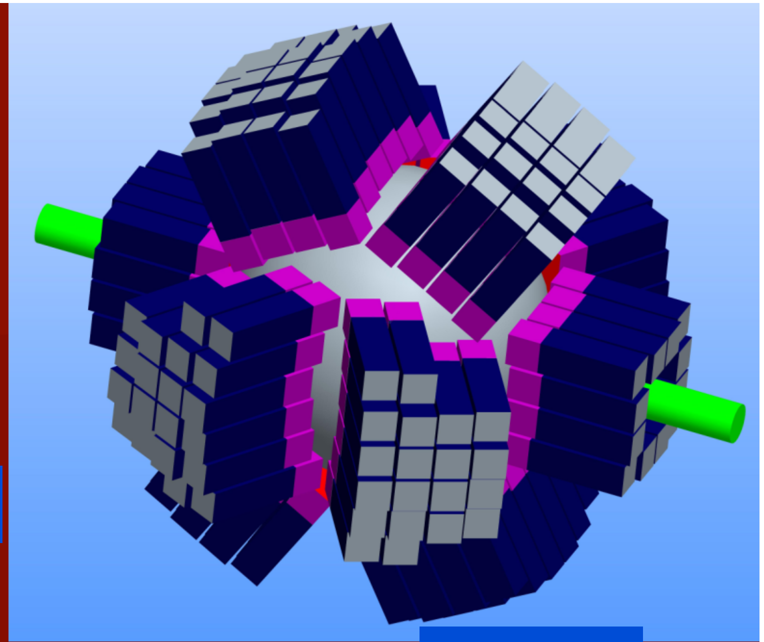
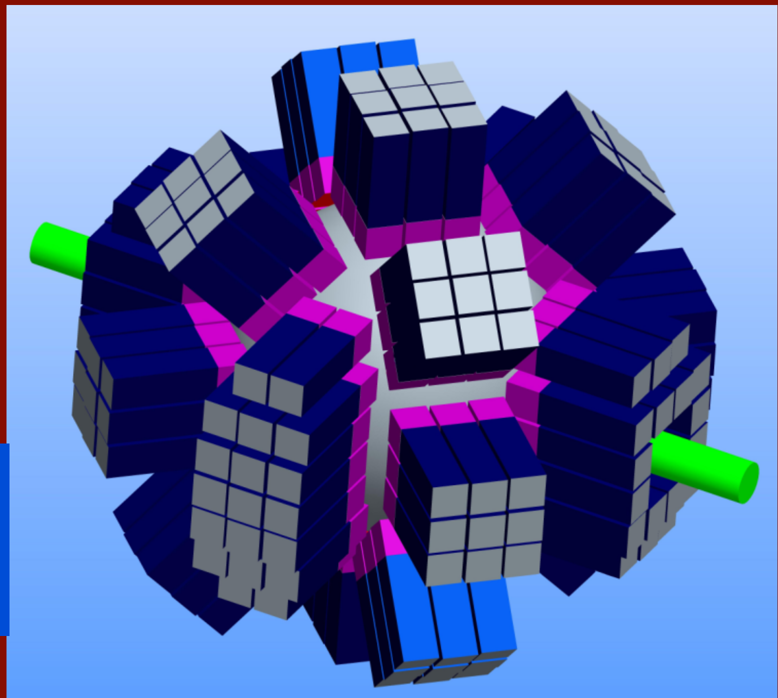


Cube
6 faces

200 elements

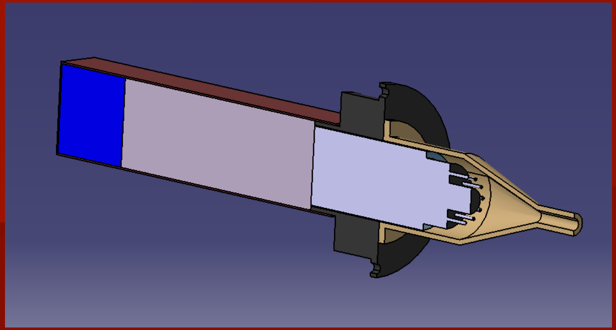


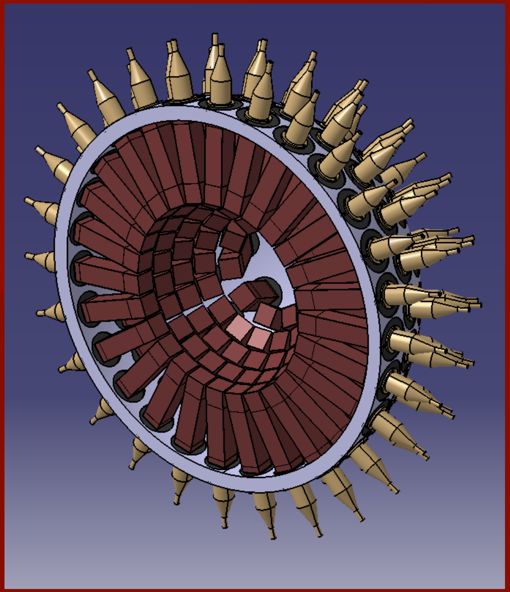
Decagon
10 faces



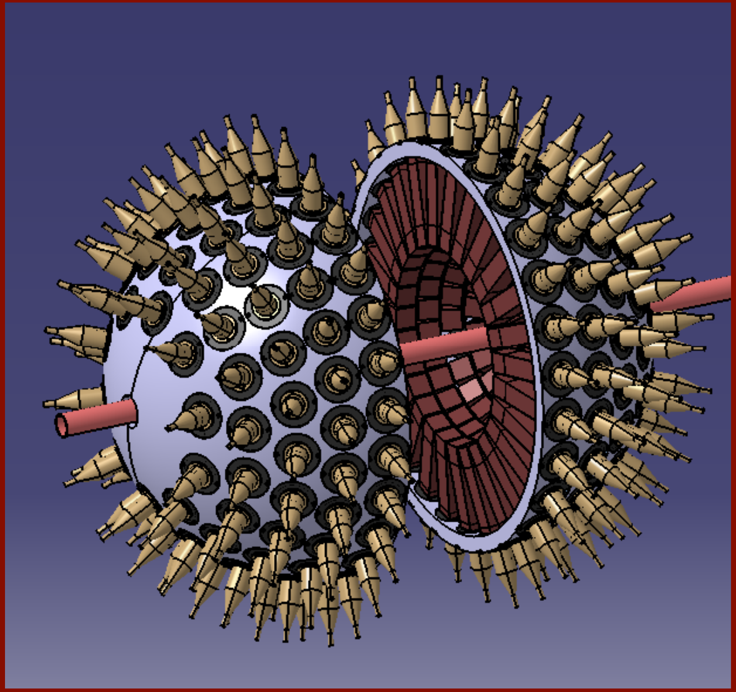
Octadegon
18 faces

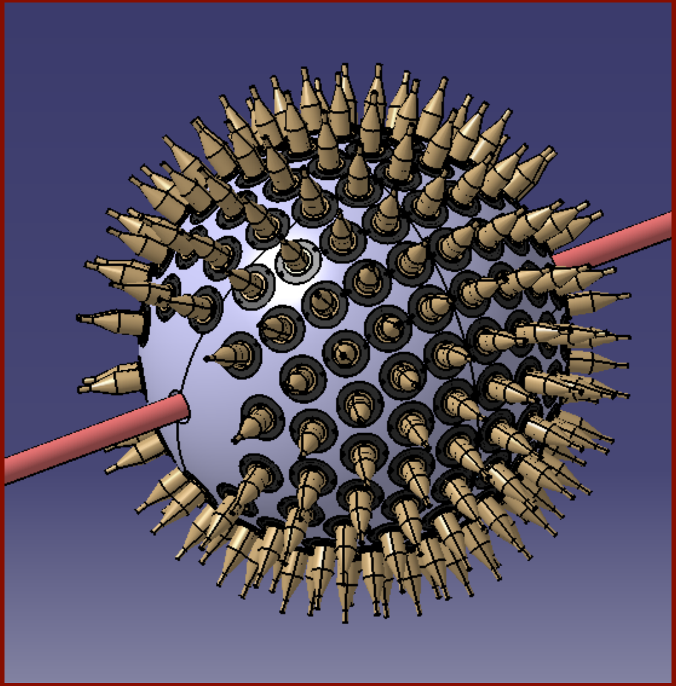
SPHERE-LIKE (RADIAL) GEOMETRY



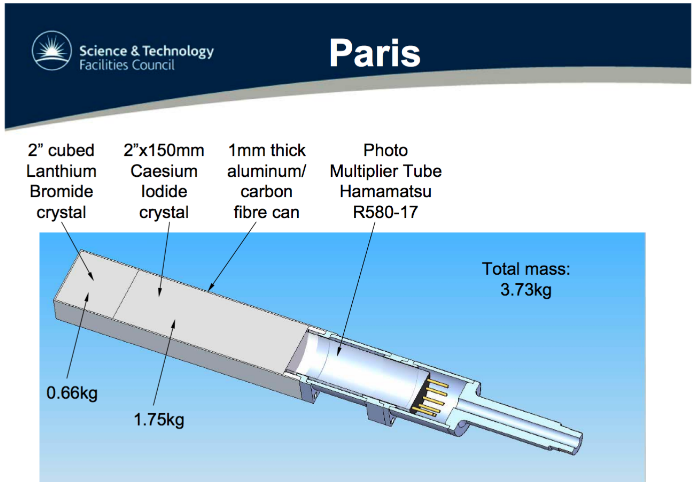


200 elements

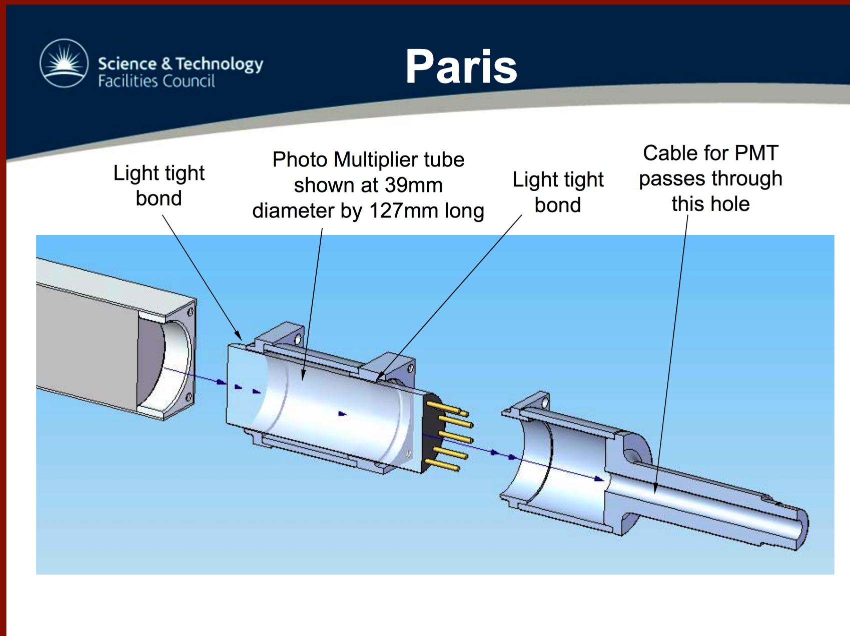




Phoswich design

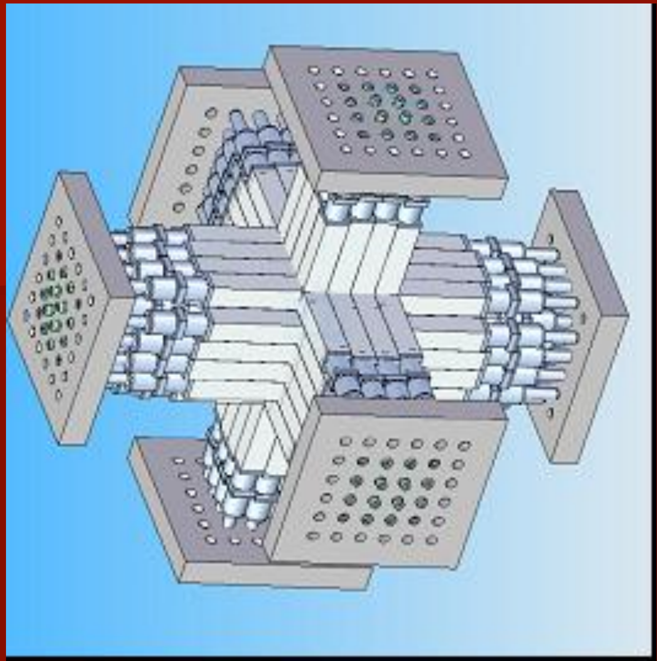


Pros:
Composite detector gives sensitivity over wider range of gamma ray energies
No space lost between crystals



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



More on Design and Mechanis Session

DETECTOR TESTING

PARIS detectors tests

Orsay, Strasbourg, York, Krakow, Warsaw

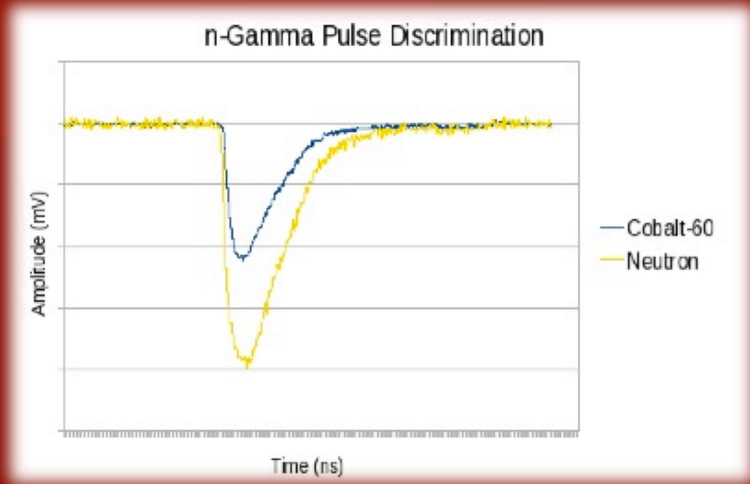
We purchased from Saint Gobain, using SP2PP and PROVA funds, following detectors:

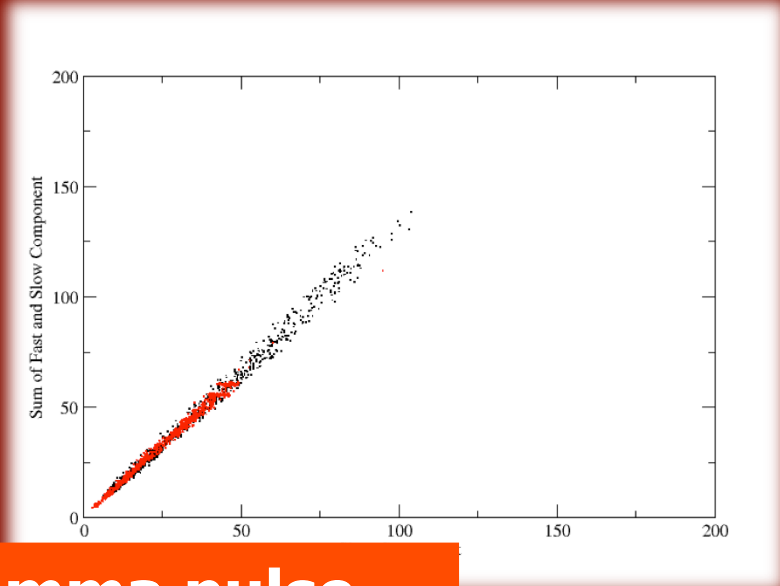
- Cubic 1”x1”x2” LaBr3(Ce)
- Cubic 2”x2”x2” LaBr3(Ce)
- Cubic 2”x2”x4” LaBr3(Ce)

- 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)

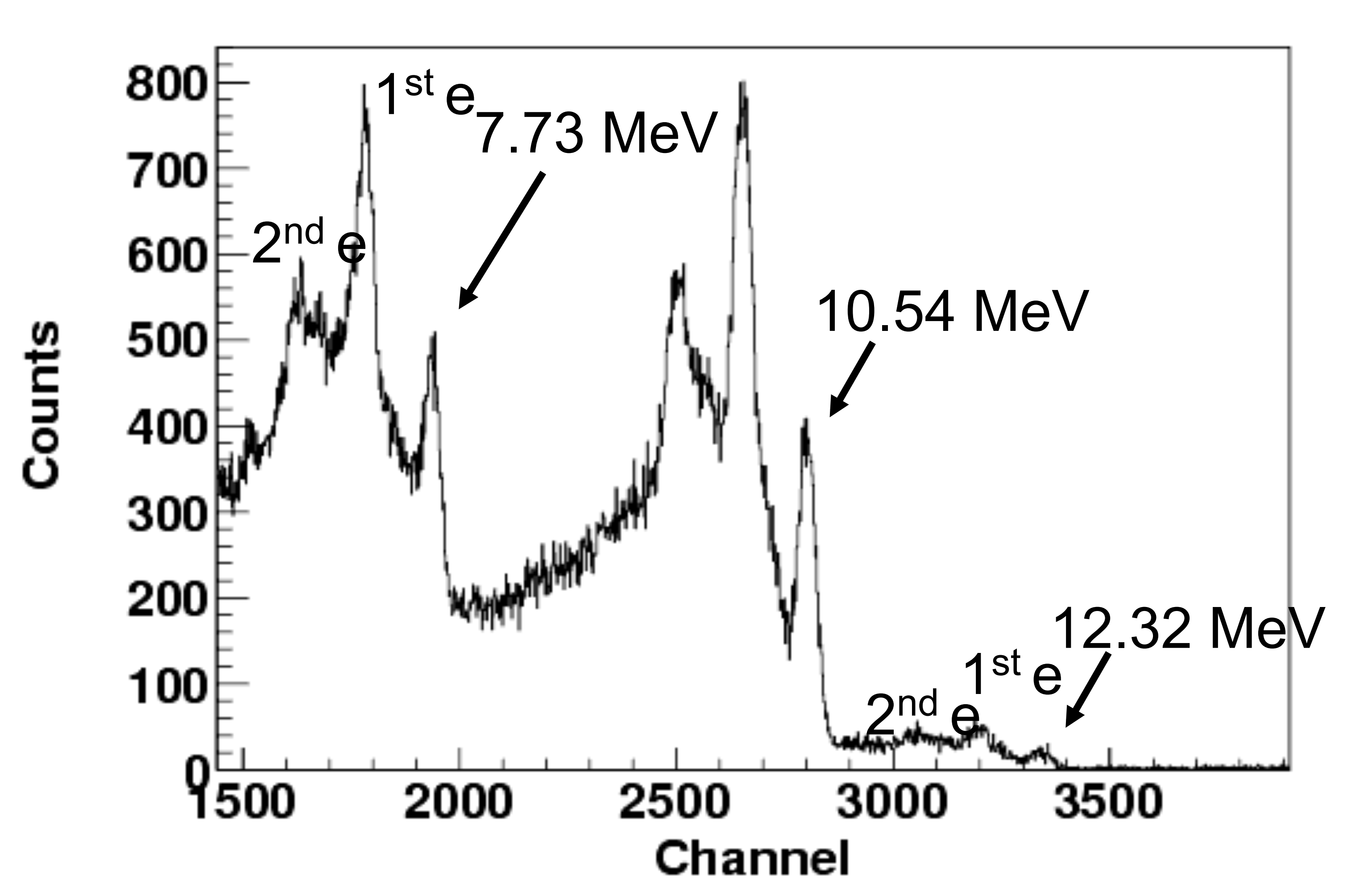




No possibility for neutron-gamma pulse discrimination – only by TOF

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)

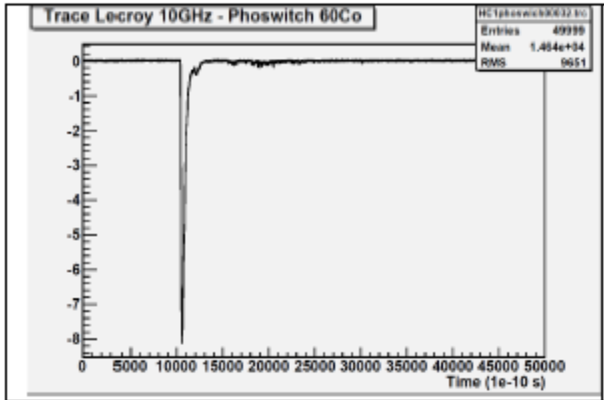


Fig. 4a: Signal corresponding to the event which deposited energy only in LaBr3

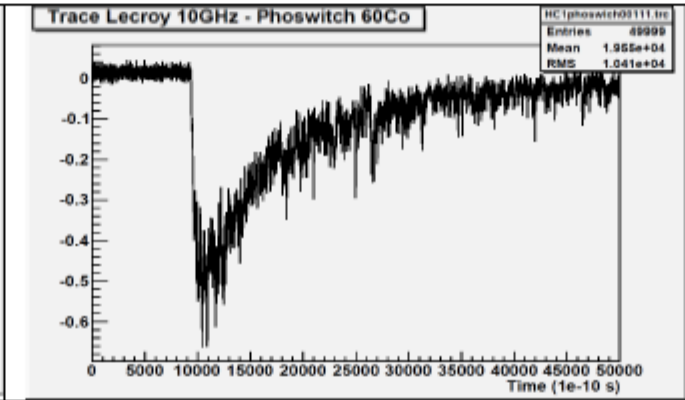


Fig. 4b: Signal corresponding to the event which deposited energy only in CsI(Na)

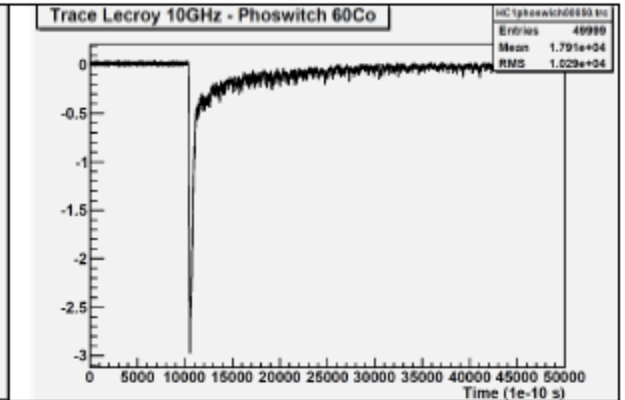


Fig. 4c: Signal corresponding to the event which deposited energy in both crystals

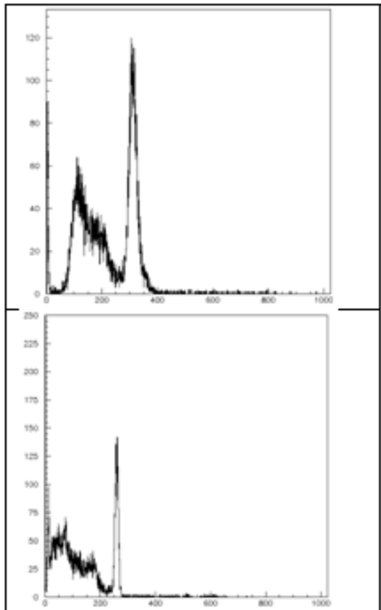


Fig. 5a: Spectra for ^{137}Cs for the events, when the whole energy is deposited in LaBr3 (bottom) and

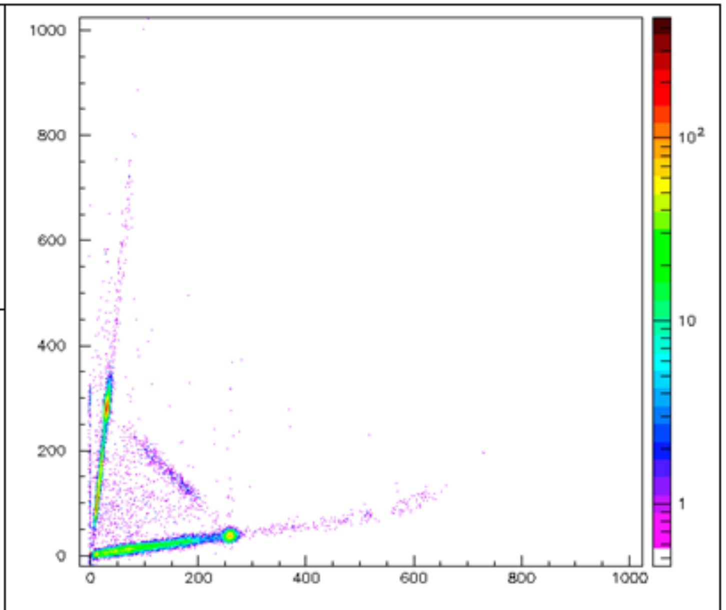
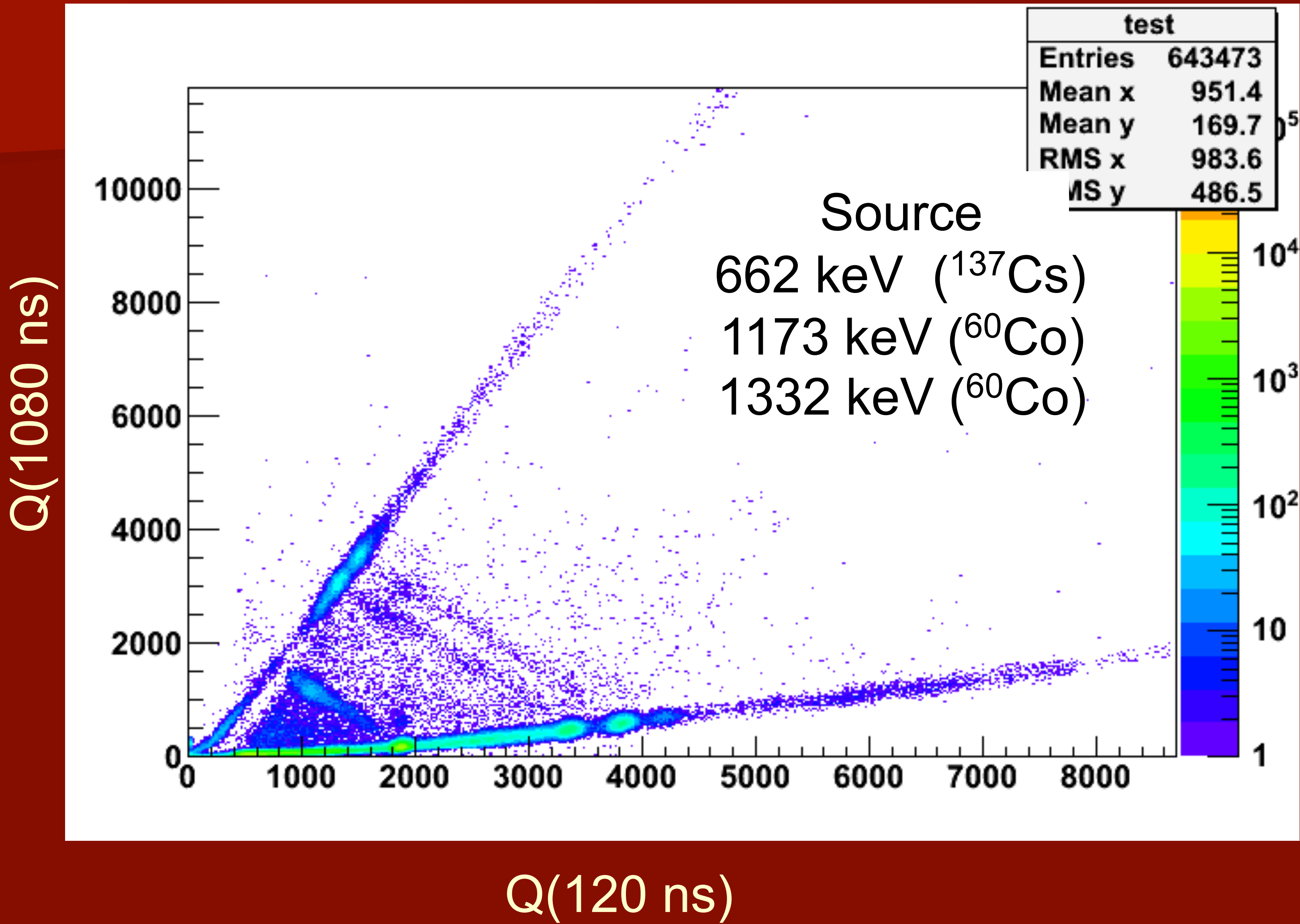


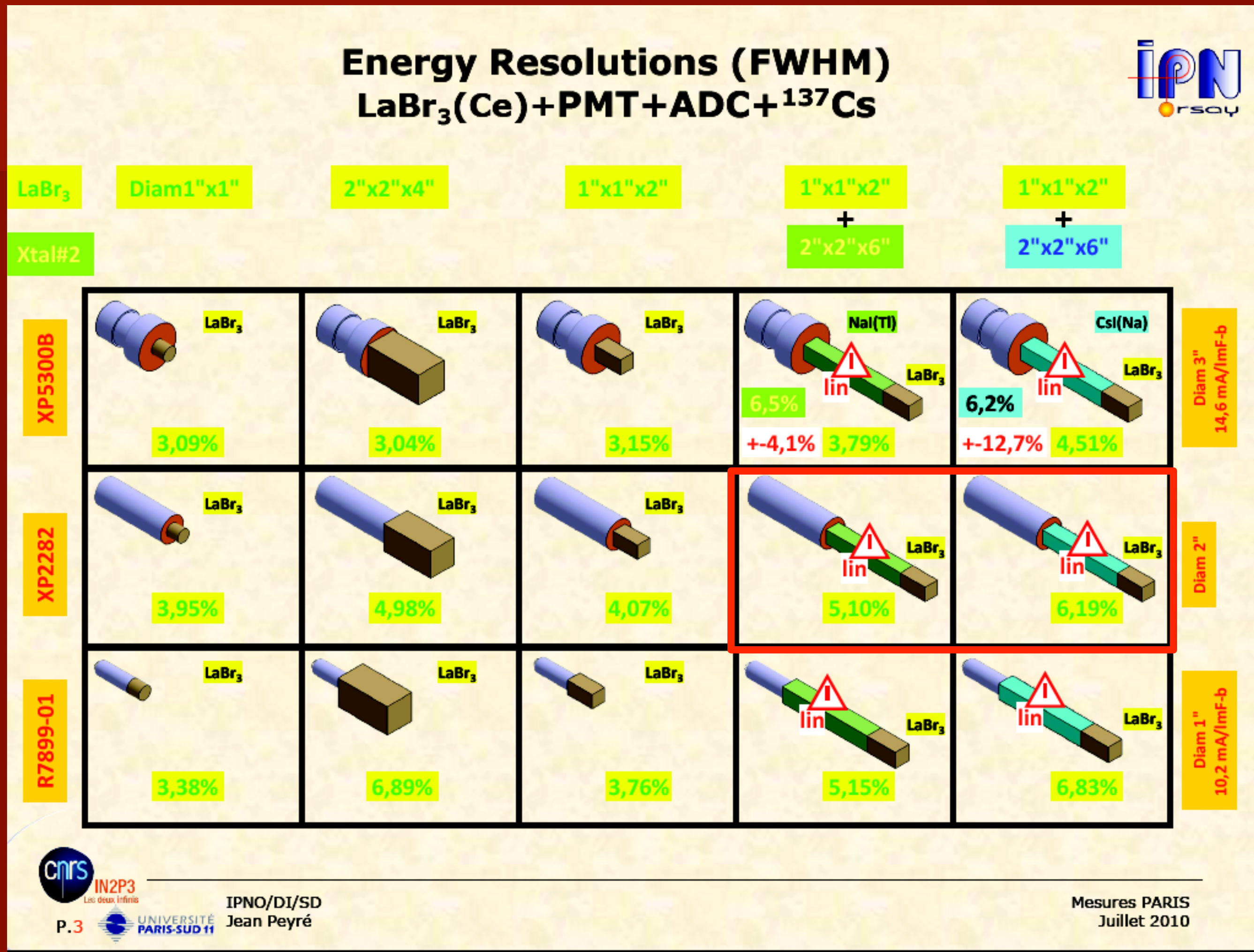
Fig.5b: Correlation plot between events deposited in LaBr3 (x-axis) and CsI (y-axis), when the detector was exposed to 661 keV gamma radiation from ^{137}Cs source

Phoswich concept seem to work

Qslow/ Qfast PWNaI: sources



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

More on Detectors Session

Electronics

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

SPIRAL2 committees:
ICC (Instrumentation Coordination Committee chaired by A. Maj & F. Azaiez
ICC FEE WG coordinator: Michel Tripon (GANIL)
ICC DAQ WG coordinator: Bruno Raine (GANIL)
Adam Czermak (Krakow) represents PARIS in the FEE WG
Xavier Grave (Orsay) represents PARIS in the DAQ WG

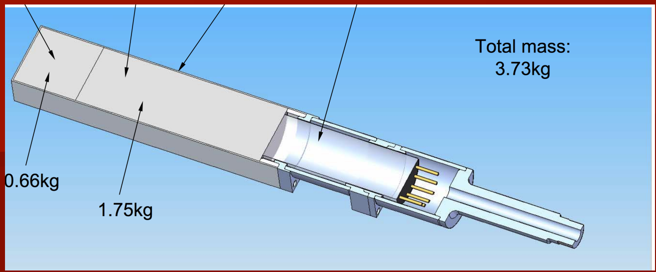
- Clock distribution, time stamping and trigger system:
-Two systems are emerging: GTS and MUTANT
- EXOGAM2, PARIS, NEDA will (most probably) implement the GTS.

More on Electronics Session

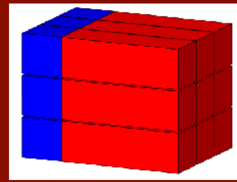
WHAT NEXT?

Proposed next steps

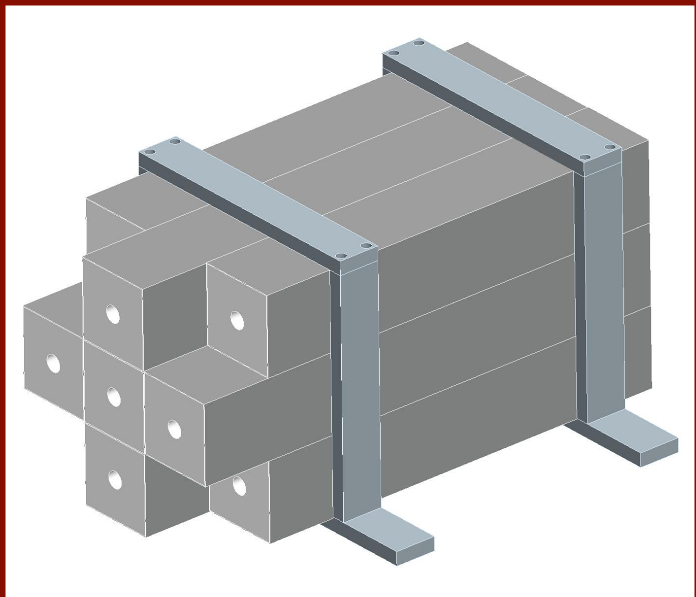
1. Detailed tests of phoswich

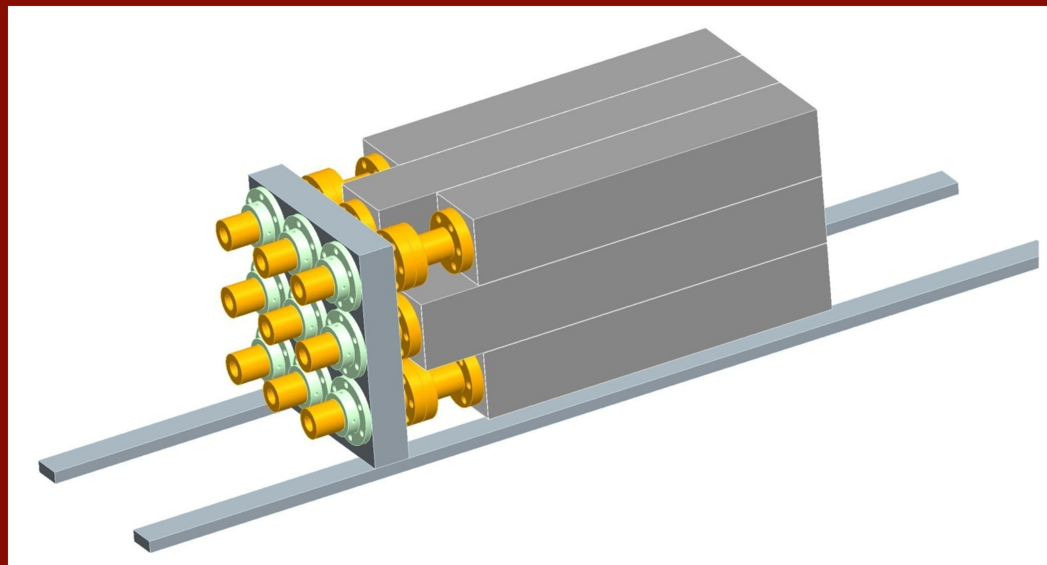


2. Purchasing – Testing
PARIS PROTOTYPE
made of 2 CLUSTERs:

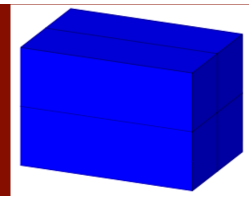


a) of 9 LaBr+NaI phoswiches;
2 ordered by Orsay and Strasbourg
3 ordered by Krakow
4 to be ordered by Mumbai



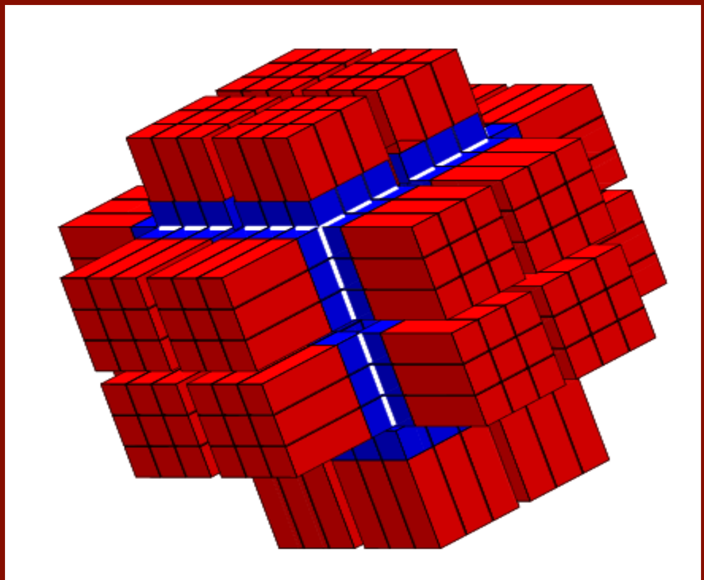


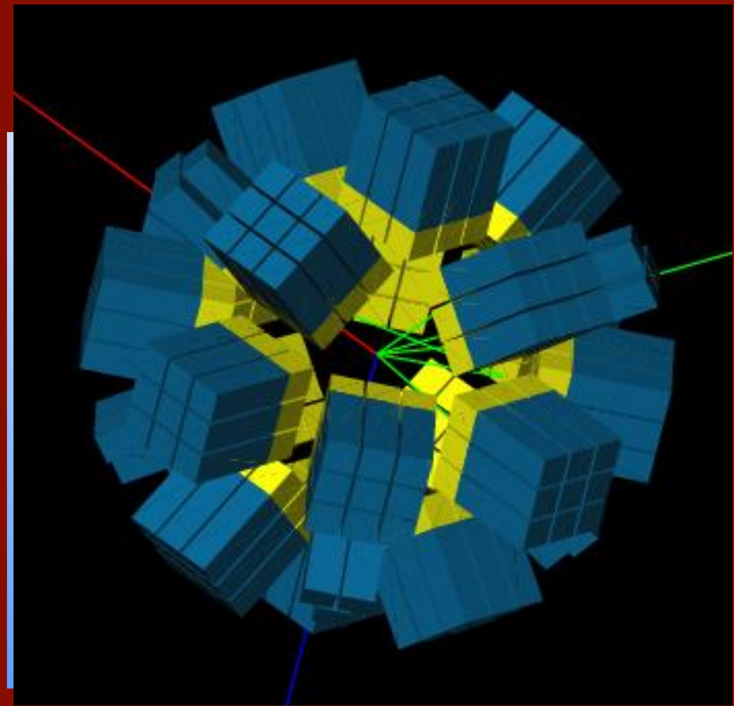
b) of 9 single LaBr3 crystals 6” long



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

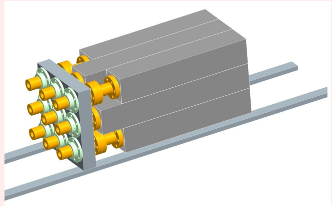
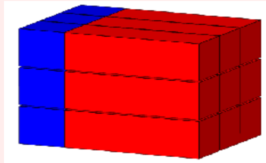
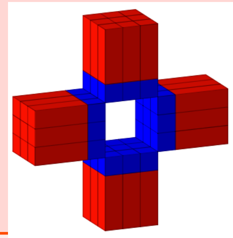
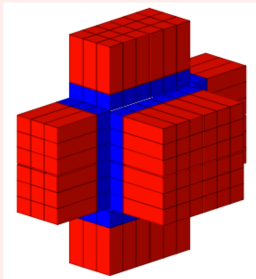
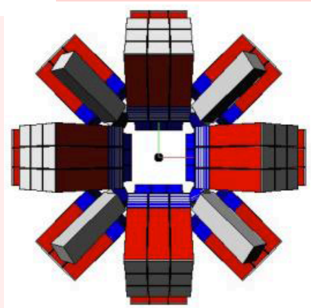
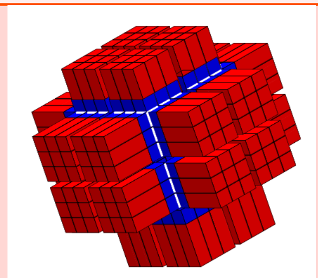
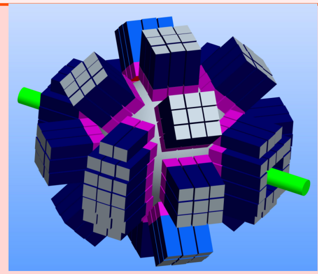
4. Sign **MoU** between partners and purchase/assembly clusters into
a)PARIS DEMONSTRATOR (1π);
b) full 4π ***PARIS array***.
It can be arranged either in **cubic** or **radial geometry.**





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	 	220 k€	**Decided** Funds: SP2PP, ANR, Orsay, Strasbourg, Kraków, Mumbai Tests in-beam and with sources
Phase 2 **2013** **PARIS Demonstrator**	4 clusters: 36 phoswiches		800 k€	**Only if Phase1 validated** Funds: MoU Ph1Day1 exp@S3
Phase 3 **2015** **PARIS 2π**	12 clusters: 108 phoswiches	 	2.2 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	 	≈ 4 M€	**Only if Phase3 validated** Funds: PARIS consortium Regular experiments in various labs

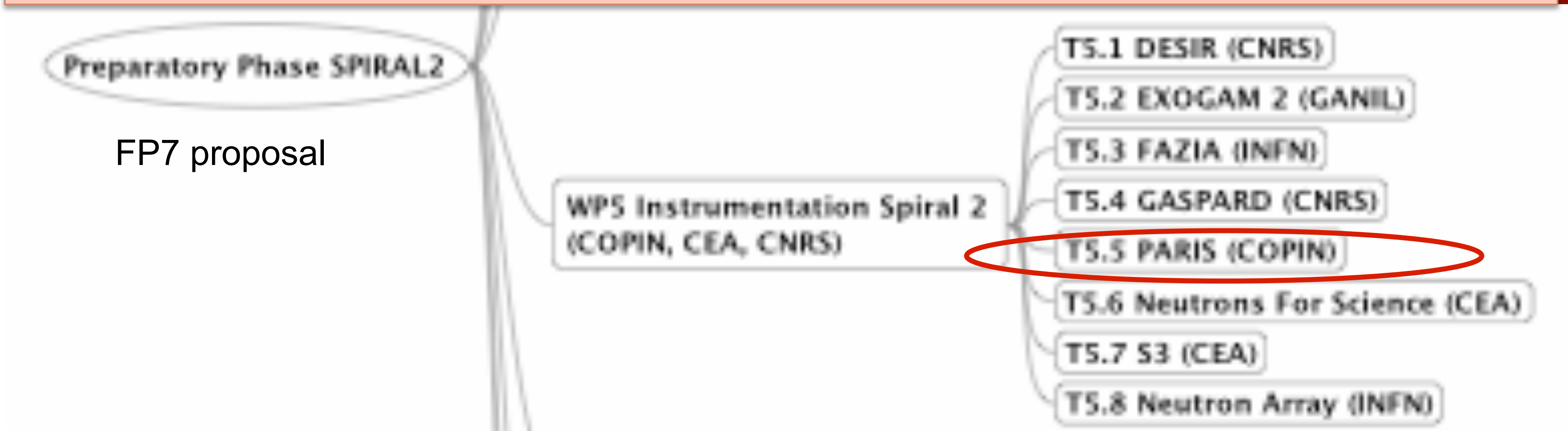
Indicated costs are approximations only. Include cost of LaBr3+NaI phoswiches, PMs, HV, electronics and mechanics. It is assumed that phoswich solution will work.

*) To be approved by PARIS MB in Jan.2011

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)**.

Ongoing synergy with **NEDA and GASPARD**

Discussion are going on with **FAZIA. ACTAR** and **VAMOS** groups

Polish Ministry Roadmap (to be released soon)

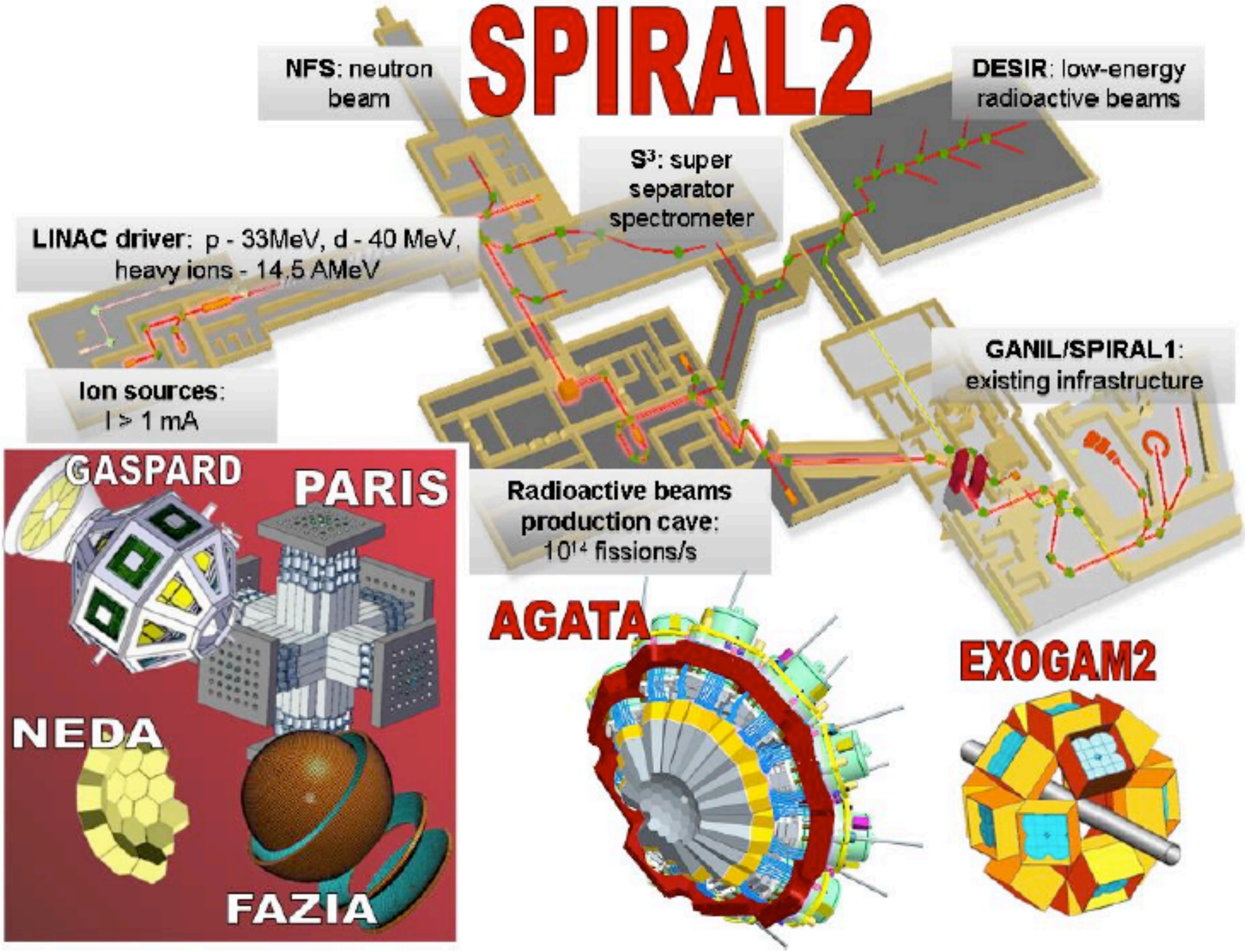
SPIRAL2

SPIRAL2 is a new European facility to be built at GANIL laboratory in Caen, France. The project aims at delivering stable and rare isotope beams with intensities not yet available with present machines, and at developing state-of-the-art instrumentation for studying exotic nuclei. SPIRAL2 will reinforce the European leadership in the field of nuclear physics based on exotic nuclei. It will provide better insight into the table of nuclides, thereby fostering the discovery of new properties of matter, it will contribute to the physics of nuclei far from stability as well as nuclear fission and fusion based on the collection of unprecedented detailed basic nuclear data, to the production of rare radio-isotopes for medicine, to radio-biology and to material science. The SPIRAL2 project is an intermediate step towards EURISOL, the most advanced nuclear physics research facility presently imaginable and based on the ISOL principle. It is expected that the realization of SPIRAL2 will substantially increase the know-how of technical solutions to be applied not only for the radioactive beam facility project EURISOL, but also in the projects of other European and world research facilities.

The Polish contribution concerns both experimental and theoretical areas of SPIRAL2. Experimentally, Polish partners design and build the state-of-the-art instrumentation, in particular the new generation gamma-ray calorimeter PARIS – an international project proposed and led by Polish scientists. Theoretically, they develop the state-of-the-art frameworks, based on the nuclear energy density functional theory and complex-energy shell model to guide the research program at SPIRAL2 and interpret experimental discoveries.

Polish coordinator: Institute of Nuclear Physics, Polish Academy of Sciences, in Cracow (IFJ PAN)

Fig. 1) SPIRAL2 with novel instrumentation



NUPNET

On 15 October 2010 at CNRS headquarters, representatives of 18 funding institutions from 14 European countries voted upon the "list of topics" for NuPNET's first call for proposals.

Elaborated within Work Package 4 “Launching joint activities at a transnational level” under the leadership of José Benlliure (MICINN, Spain) after consultation of all NuPNET member institutions, this list had first been approved of by the NuPNET Co-ordination Committee and then proposed to the NuPNET Governing Council for a common decision.

After an interesting final discussion on 15th October, the vote was performed and the result unanimous: indeed all 18 funding agencies agreed to launch NuPNET’s first call with the following topics:

<u>1st topic: R&D on new detector technologies in nuclear physics</u>.

*** Gamma and neutron detection technologies based on new scintillation materials and new photo-sensors (APDs, SiPMs…).**

* Silicon and micropatterned gas tracking detectors (GEM, Micromegas): low and high energy applications.

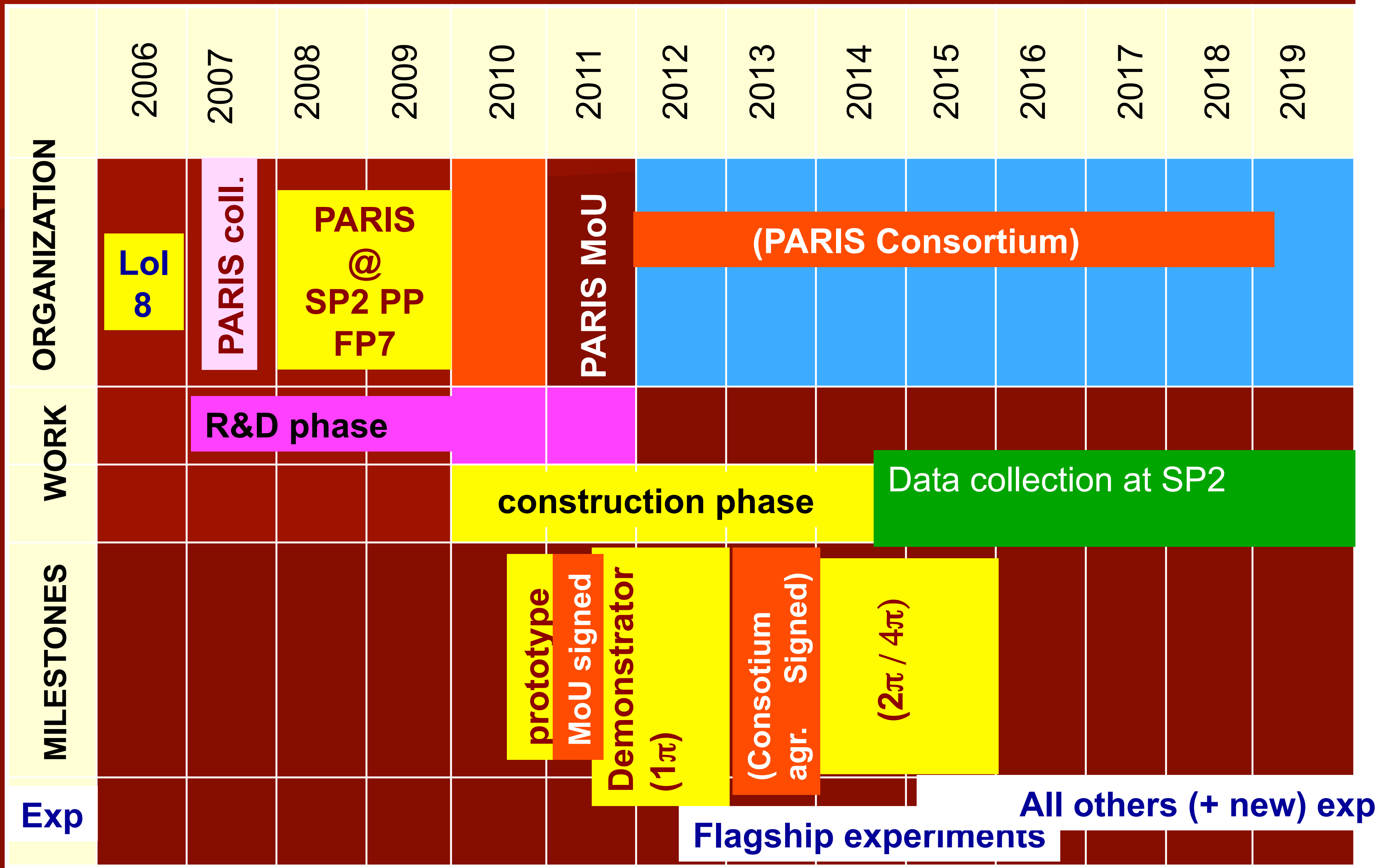
* Large-area diamond detectors for beam monitoring or timing.

These technologies are important for the nuclear research infrastructures selected in the ESFRI list: FAIR and SPIRAL2.

<u>2nd topic: R&D on Eurisol technologies: accelerator components, target and ion sources.</u>

<u>3rd topic: Targeted action on nuclear structure and reactions theory.</u>

Preliminary TIME SCHEDULE



Themes for this PARIS collaboration meeting:

1) Approve the PARIS phases
2) Decide schedule of the prototype test
3) Decide the way of developing electronics (e.g. NUMEXO2 + own digitizer?)
4) Mechanics for the prototype (cluster of 9 phoswiches)
5) Decide on the realistic simulations and gamma-ray tracking algorithms for PARIS based on phoswiches
6) ....

7) Advisory Committee Meeting (led by Faical Azaiez) MoU between PARIS partners