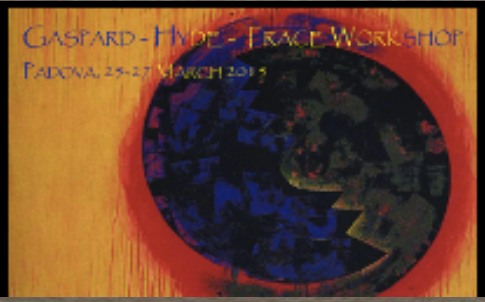
The Henryk Niewodniczański Institute of Nuclear Physics
Polish Academy of Sciences

PARIS

Adam Maj
IFJ PAN Krakow
for the PARIS collaboration

PARIS status



GASPARD-HYDE-TRACE Workshop 2015

25-27 March 2015 *Department of Physics and Astronomy - University of Padova*

Plan of the talk

1. Brief concept of the PARIS project
2. First tests of single detector and a cluster
3. Planned first experiments
4. Plans for integration with AGATA@GANIL
   Summary

paris.ifj.edu.pl

Brief concepts of the PARIS project

Original PARIS physics cases for SPIRAL2

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

b) Studies of shape phase diagrams of hot nuclei – GDR differential methods
$^{186\text{-}193}Os$, $^{190\text{-}197}Pt$
(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
$^{214\text{-}222}Ra$, $^{118\text{-}226}Th$, $^{229\text{-}234}U$
(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..

PARIS desing concepts:

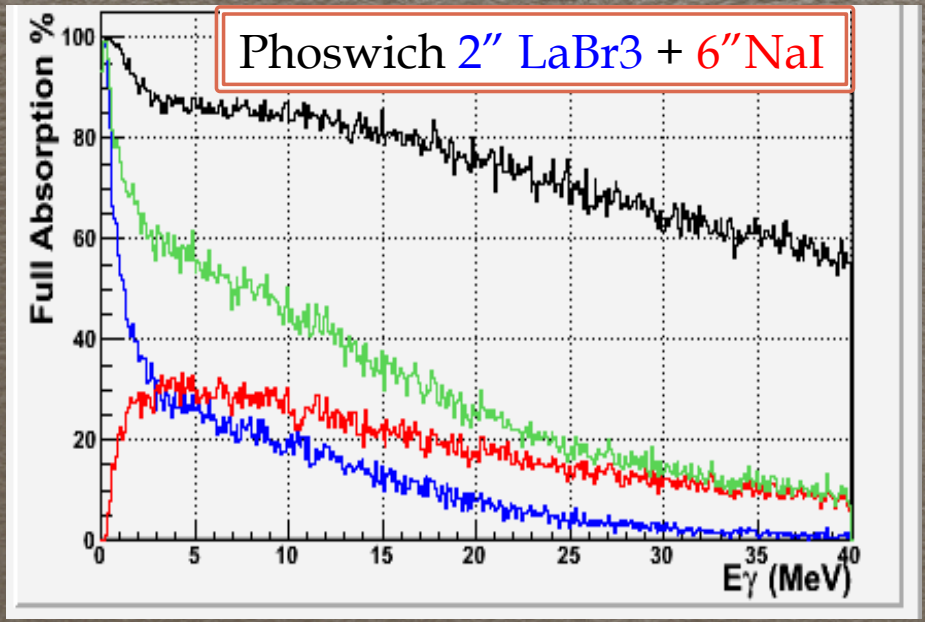
Design and build high efficiency detector consisting of 2 shells *(or 1 phoswich shell)* for medium resolution spectroscopy and calorimetry of γ-rays in large energy range

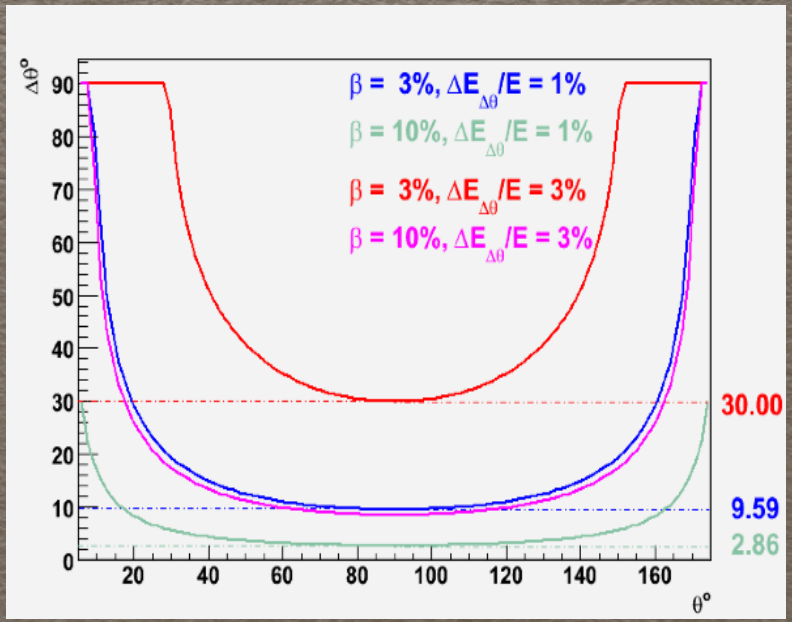
Inner sphere, highly granular, made of new crystals (LaBr3(Ce)), to be used as a multiplicity filter of high resolution, sum-energy detector (calorimeter), detector for the gamma-transition up 10 MeV with medium energy resolution. It may serve also for fast timing application.

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

O. Stezowski, M. Ciemala, M. Labiche et al..



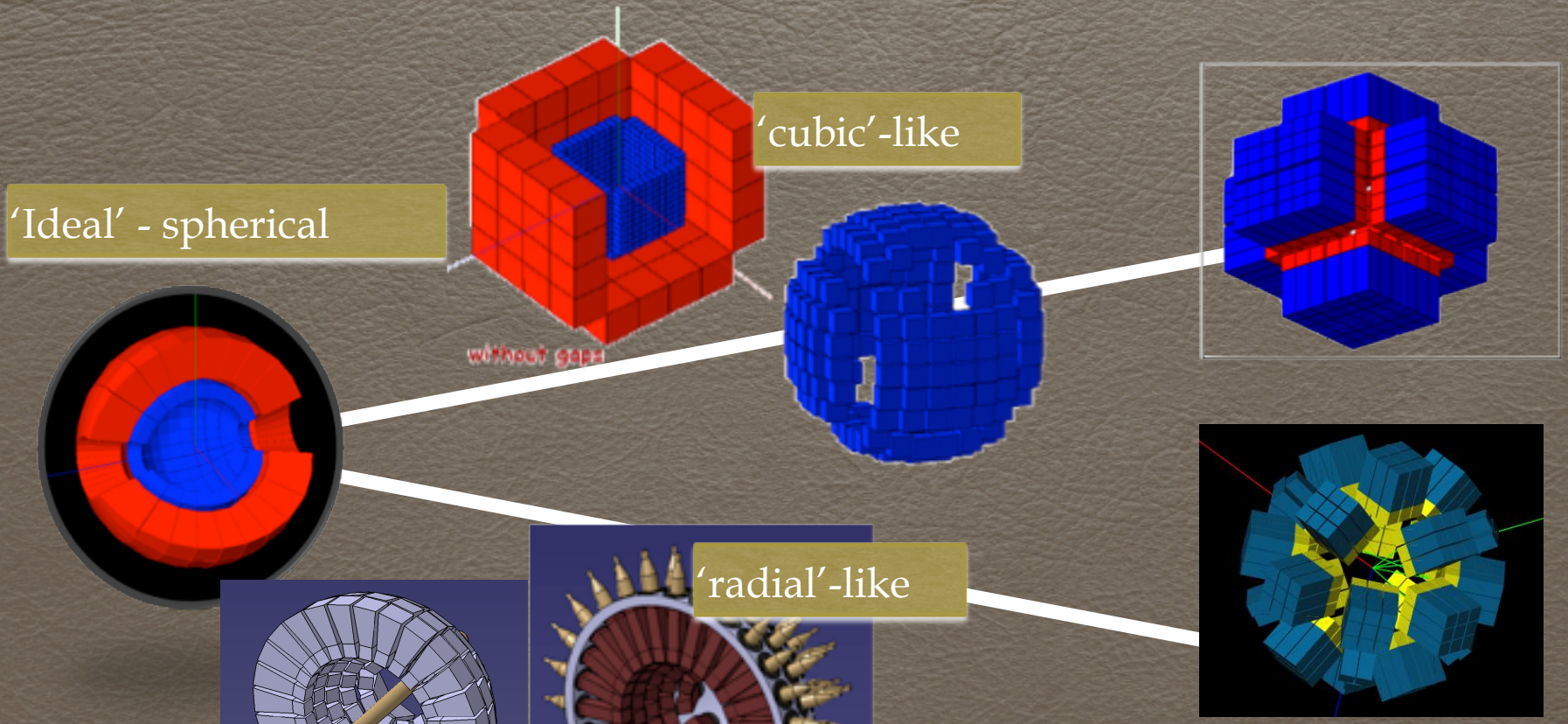


Extensive simulation studies have been performed to understand how γ–rays with energies from few keV up to 50 MeV are absorbed and recovered. Figure above is used for instance to determine the opening angle required to not spoil out the intrinsic LaBr3 resolution. All the considerations drive the ***design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

a phoswich 2″x2″x2″ LaBr3 followed by 2″x2″x6″ NaI.

placed at a reasonable distance (ca. 20 cm) from the target position it gives a ***4π array composed of ca. 200 of elements*** for optimal characteristics in ***non-relativistic domain*** (β < 10%).

Several geometries studied



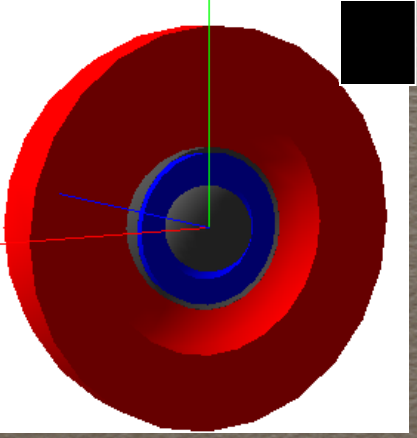
CONCLUSION:

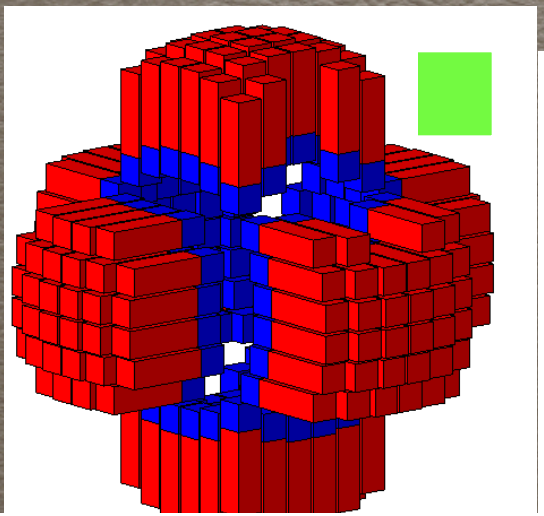
PARIS to be made of clusters:

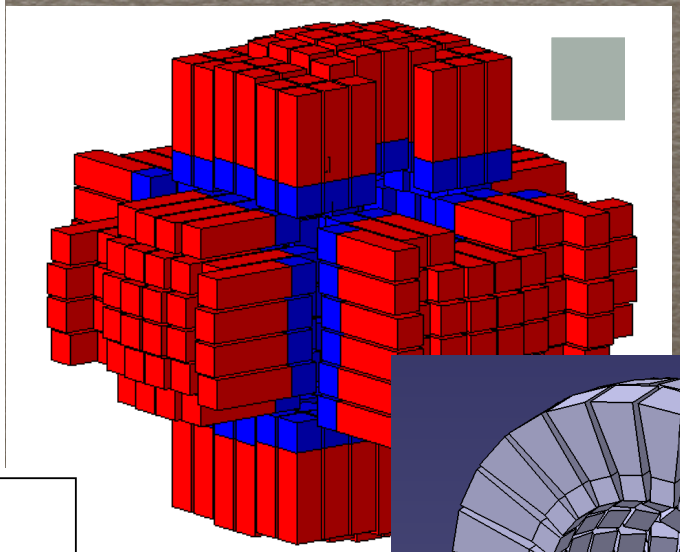
Cluster = *9 phoswiches*

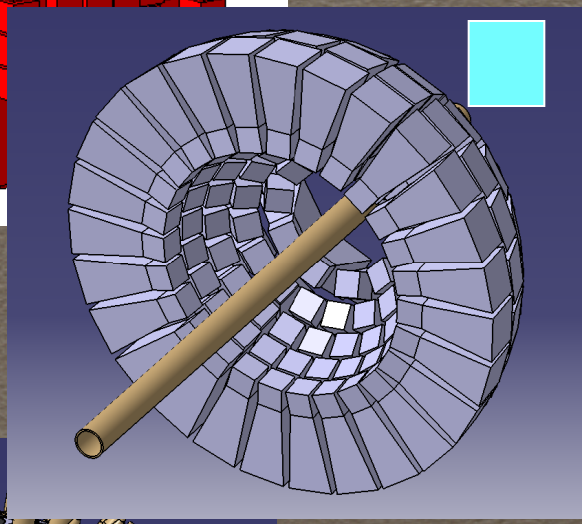
This allows *cubic* or *semi-spherical* geometry with 24 clusters (216 phoswiches)

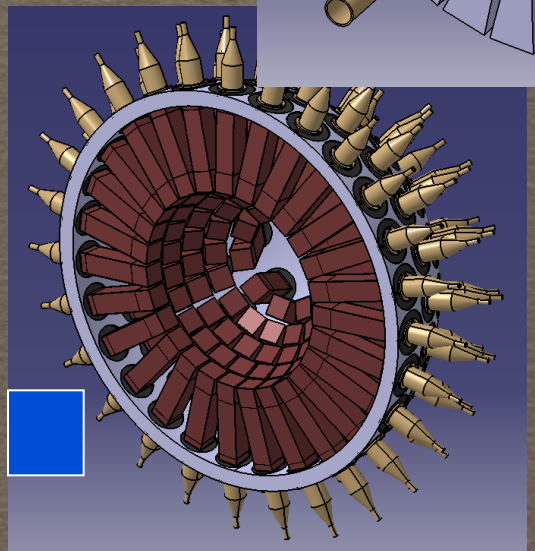
Cubic vs. Radial geometry

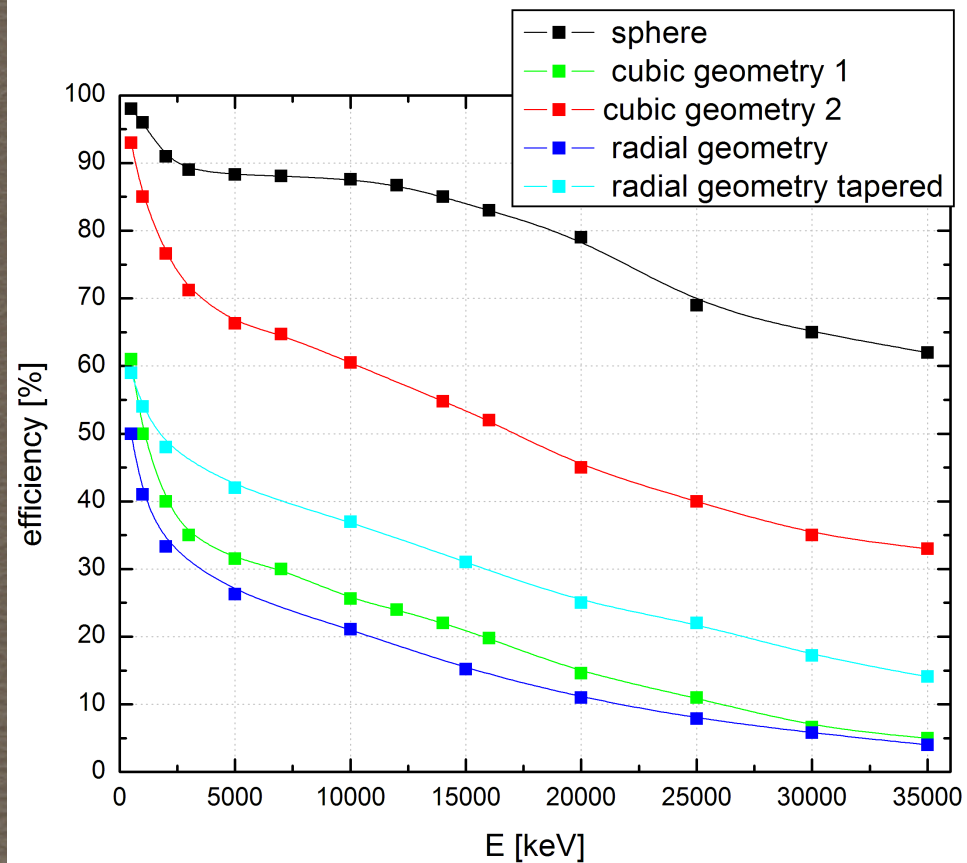












Institutions actively working for PARIS

POLAND (coord.: A. Maj): IFJ PAN Krakow, HIL Warsaw

FRANCE (coord.: I. Matea): INP3: IPN Orsay, IPHC Strasbourg, IPN Lyon; GANIL

INDIA (coord.: V. Nanal): TIFR Mumbai, BARC Mumbai, VECC Kolkata

UK (coord.: D. Jenkins): U. York, U. Surrey, STFC Daresbury, U. Manchester

ITALY (coord.: F. Camera): U. and INFN Milano, LNL Legnaro, LNS Catania

TURKEY (coord.: S. Ertürk): U. Istanbul, U. Nigde, U. Kayseri, U. Akteniz

BULGARIA (cord.: D. Balabanski) INRNE Sofia

ROMANIA (coord.: F. Negoita) IFIN-HH Bucharest

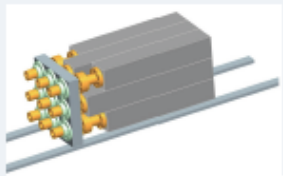
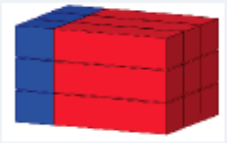
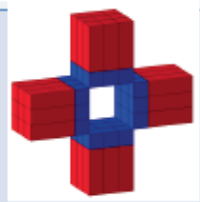
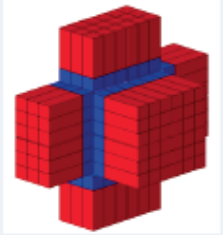
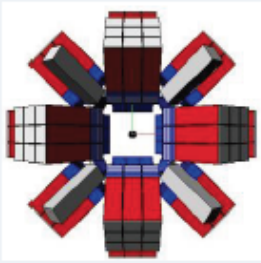
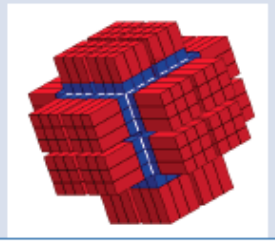
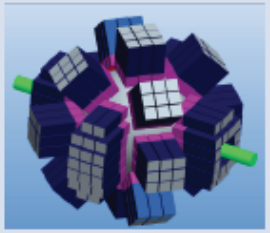
HUNGARY (coord.: Z. Dombradi) ATOMKI Debrecen

Status of the project

PARIS Demonstrator MoU and PARIS phases

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, UK, Turkey

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. wit AGATA and GASPARD Other exp.
Phase 4 **≈2019** **PARIS 4π**	≥24 clusters: ≥216 phoswiches	 	≈ 4 M€	**Only if Phase3 validated** Funds: PARIS consortiun Regular experimer in various labs

IPN Orsay

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AGATA@GANIL

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S3@GANIL

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CCB Krakow

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LNL/SPES

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SPIRAL2 phase2

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Partners of the PARIS Demonstrator MoU and their capital investment (2012-2015)

IN2P3 (France): 300 k€
GANIL (France): 180 k€
COPIN (Poland): 300 k€
TIFR/BARC/VECC (India): 180 k€
NIPNE Bucharest (Romania): 70 k€
INFN (Italy): 50 k€
York/Surrey (UK): ca. 40 k€
4 Universities in Turkey: 20 k€
INRNE Sofia (Bulgaria): 15 k€

Together: ca. 1.2 M€

Preliminary cost of the PARIS Demonstrator (5 clusters): ca. 1.1 M€

Since 2012 (after MoU was signed)
New organization of PARIS

PARIS Steering Committee (by nominations of the MoU partners):

- **IN2P3 France: F. Azaiez (chair)**
- **GANIL France: M. Lewitowicz**
- **COPIN Poland: B. Fornal**
- **India: V. Nanal (vice-chair)**
- **Italy: A. Bracco**
- **Romania: F. Negoita**
- **UK: D. Jenkins**
- **Turkey: S. Erturk**
- **Bulgaria: D. Balabanski**

A.Maj (Poland)
PARIS Project Manager

Working Groups and their Coordinators:

Geant4 simulation: **O. Stezowski** (Lyon)
Detectors: **O. Dorvaux** (Strasbourg)
Electronics and DAQ: **P. Bednarczyk** (Krakow)
Mechanical integrations: **I. Matea** (Orsay)
New materials: **F. Camera** (Milano)
Data analysis: **S. Leoni** (Milano)
New Physics case: **I. Mazumdar** (Mumbai)

GANIL campaign Spokesperson: C. Schmitt (GANIL)

PARIS Management Board:
PARIS Project Manager + WG coordinators

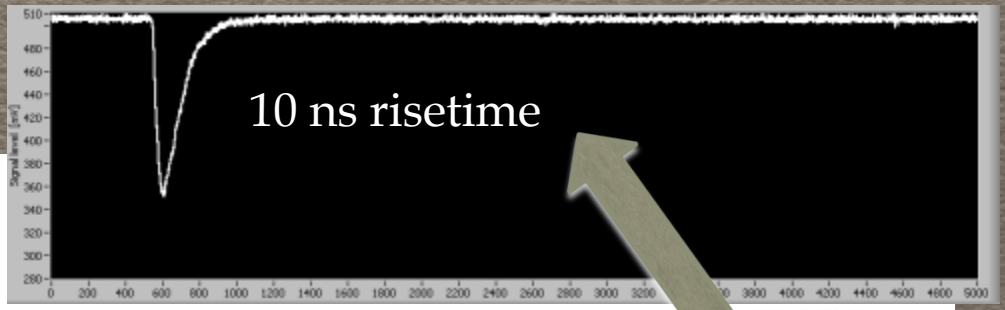
PARIS Collaboration Council was recently established

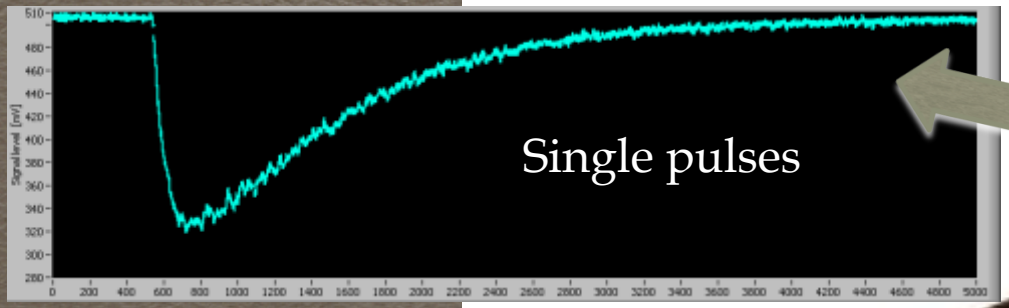
PARIS Collaboration Council:

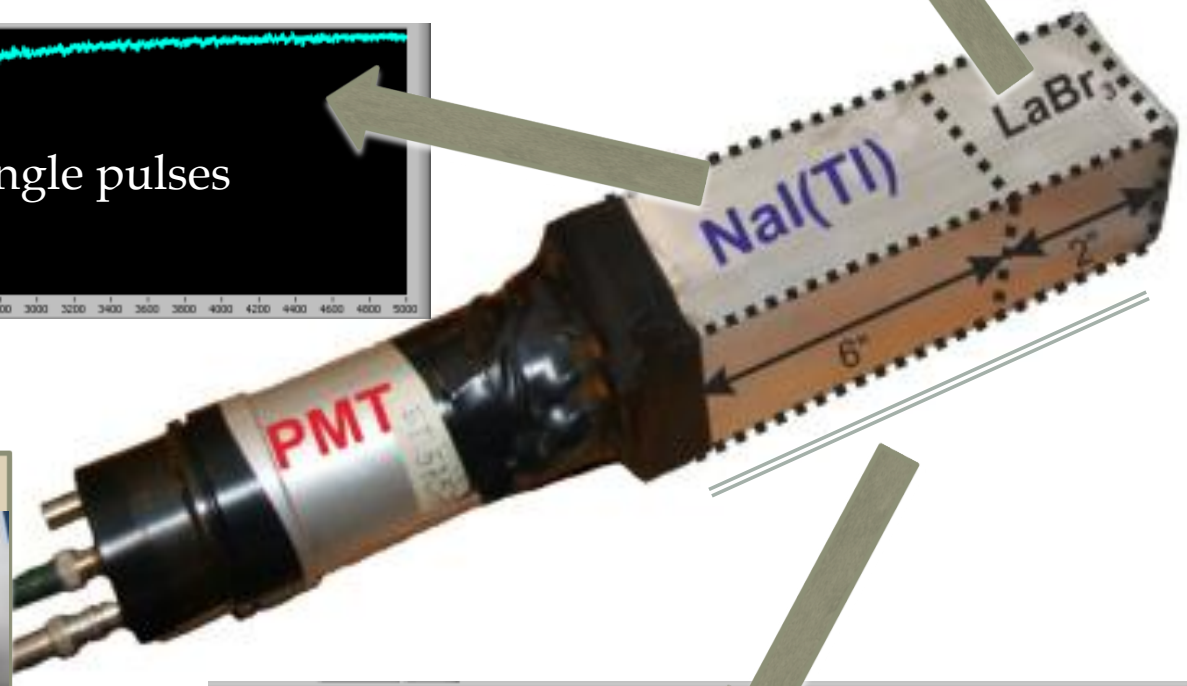
David Jenkins (University of York, UK) - chair and PARIS spokesman
Sudhee R. Banerjee (VECC Kolkata, India)
Franco Camera (INFN and University of Milano, Italy)
Wilton N. Catford (University of Surrey, UK)
Marco Cinausero (LNL Legnaro, Italy)
Sandrine Courtin (IPHC Strasbourg, France)
Zsolt Dombradi (ATOMKI Debrecen, Hungary)
Camille Ducoin (IPN Lyon, France)
Sefa Ertuerk (Nigde, Turkey)
Juergen Gerl (GSI, Germany)
Anil K. Gourishetty (IIT Roorkee, India)
Maria Kmiecik (IFJ PAN Krakow, Poland)
Suresh Kumar (BARC Mumbai, India)
Marc Labiche (STFC Daresbury, UK)
Vandana Nanal (TIFR Mumbai, India)
Pawel Napiorkowski (HIL Warsaw, Poland)
Marek Ploszajczak (GANIL, France)
Mihai Stanoiu (IFIN-HH Bucharest, Romania)
Jonathan Wilson (IPN Orsay, France)

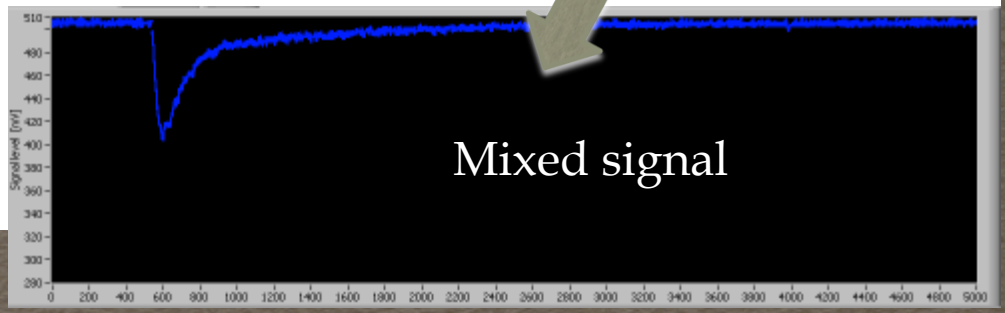
First tests of a single detector and a cluster

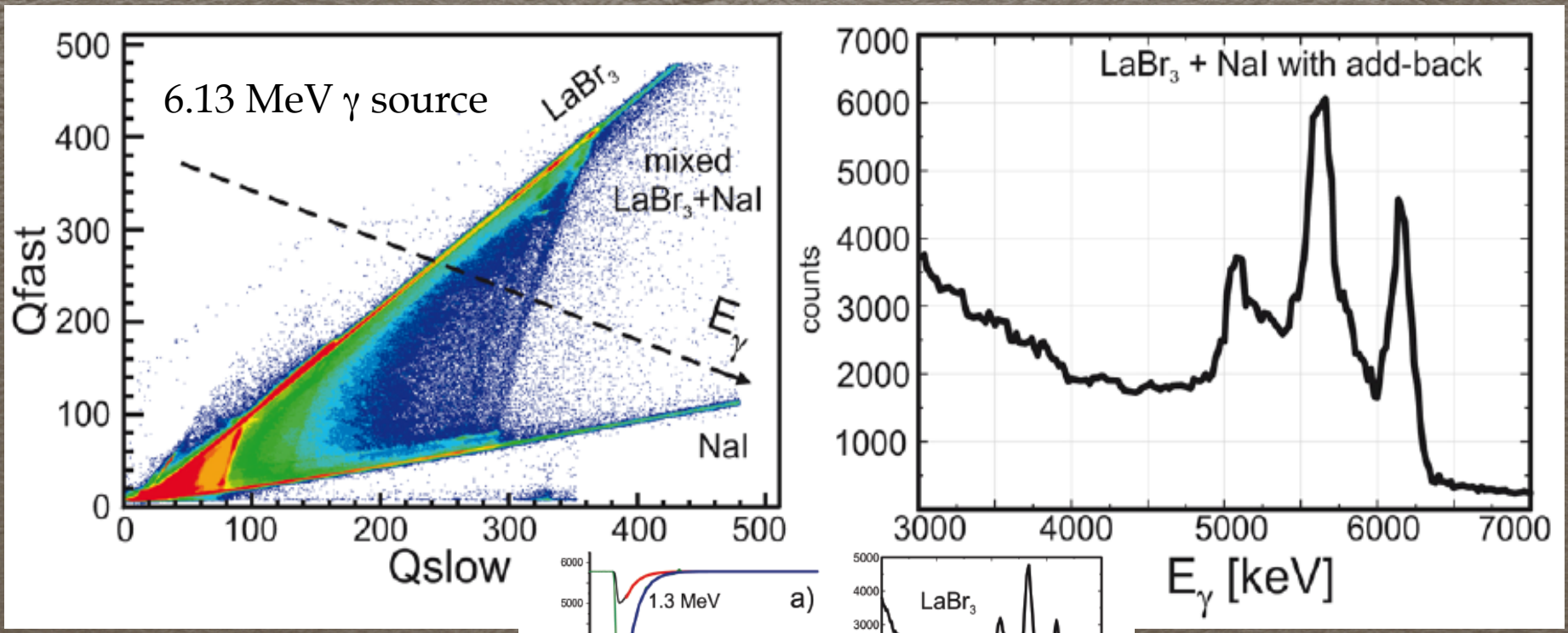
The PARIS PHOSWICH at work

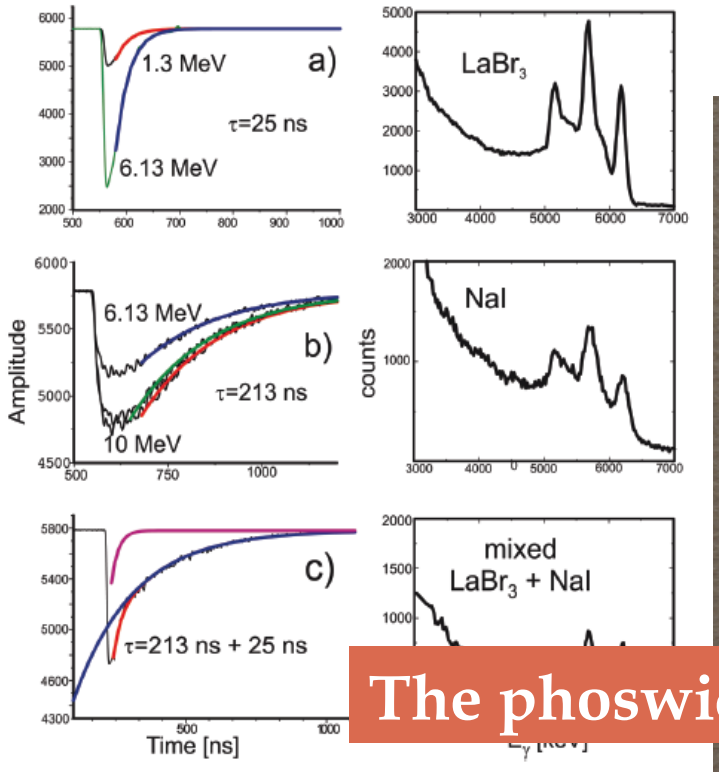












A test measurement at IFJ PAN, Kraków (2011) with BafPro module from Milano

- Sources
- proton beam

LaBr3 resolution (seen through 6" long NaI): ca. 4%

M. Zieblinski et al., Acta Phys.Pol. B44, 651 (2013)

The phoswich concept works!

First in-beam test (Matea/Maj) , May 2013, Tandem-ALTO, IPN Orsay

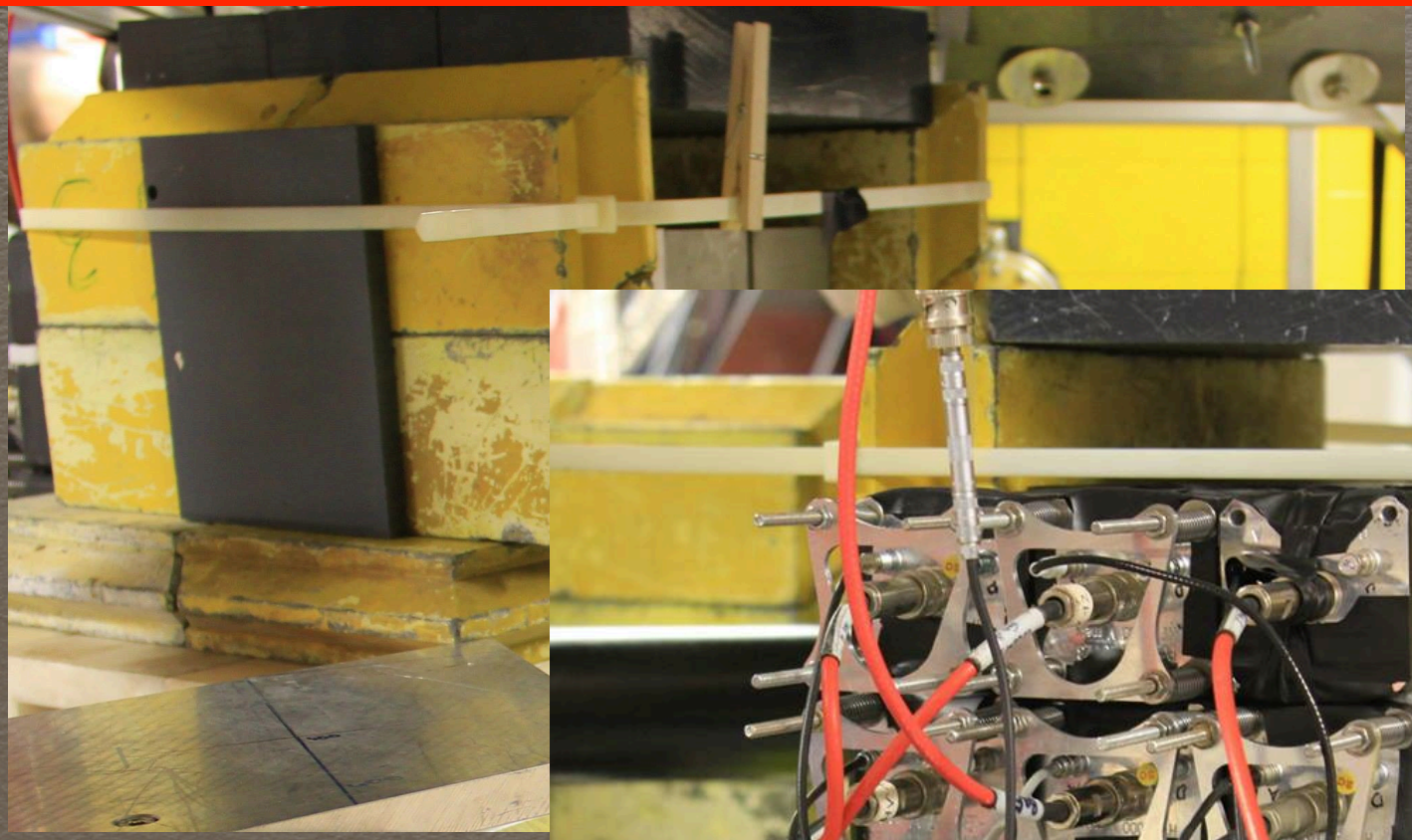
$^{11}B(p, \gamma)^{12}C$ at 7.2 MeV

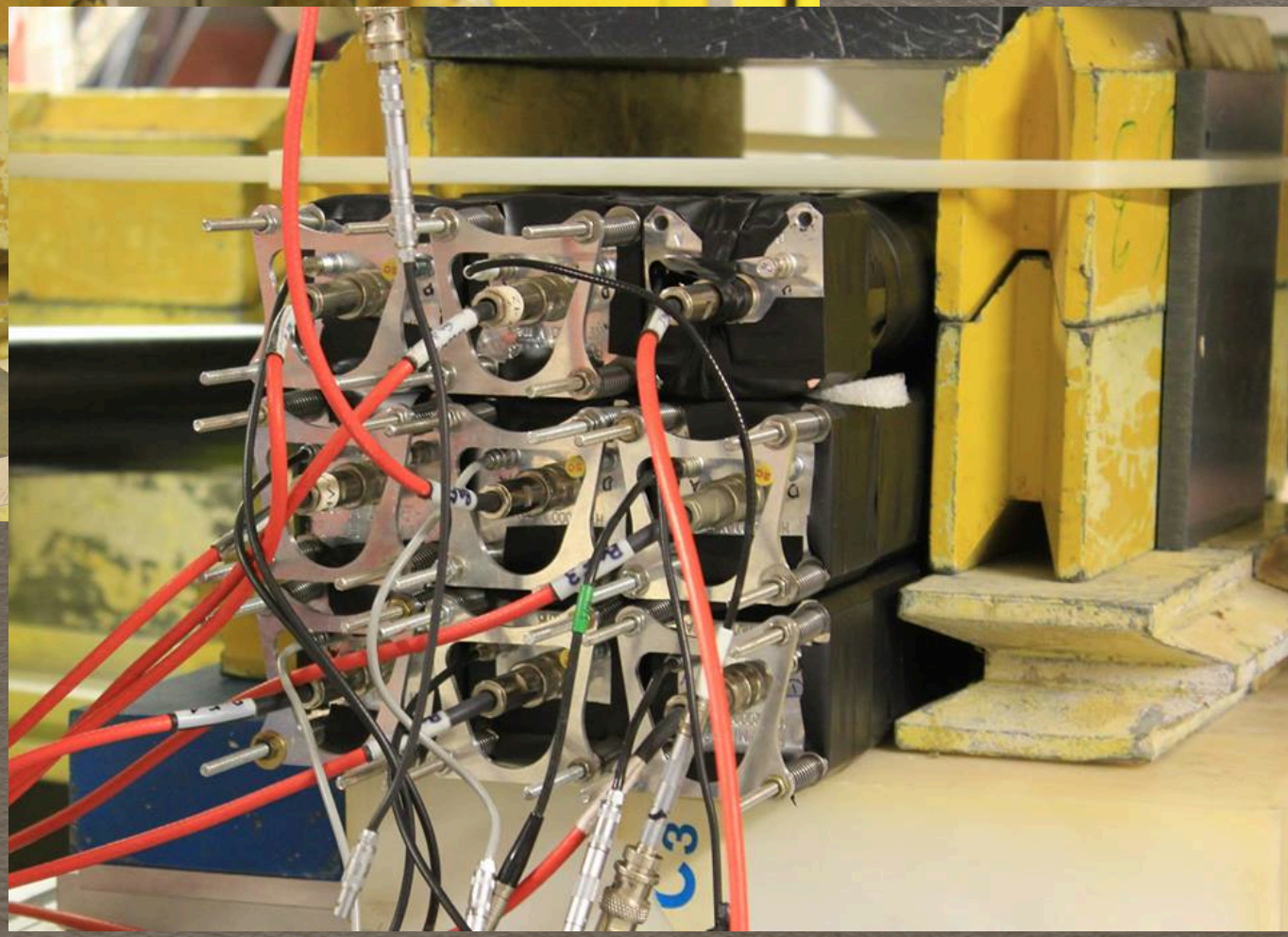
Eγ: …, 18.12 , 22.56 MeV

Goal:
testing addback capabilities at high energies

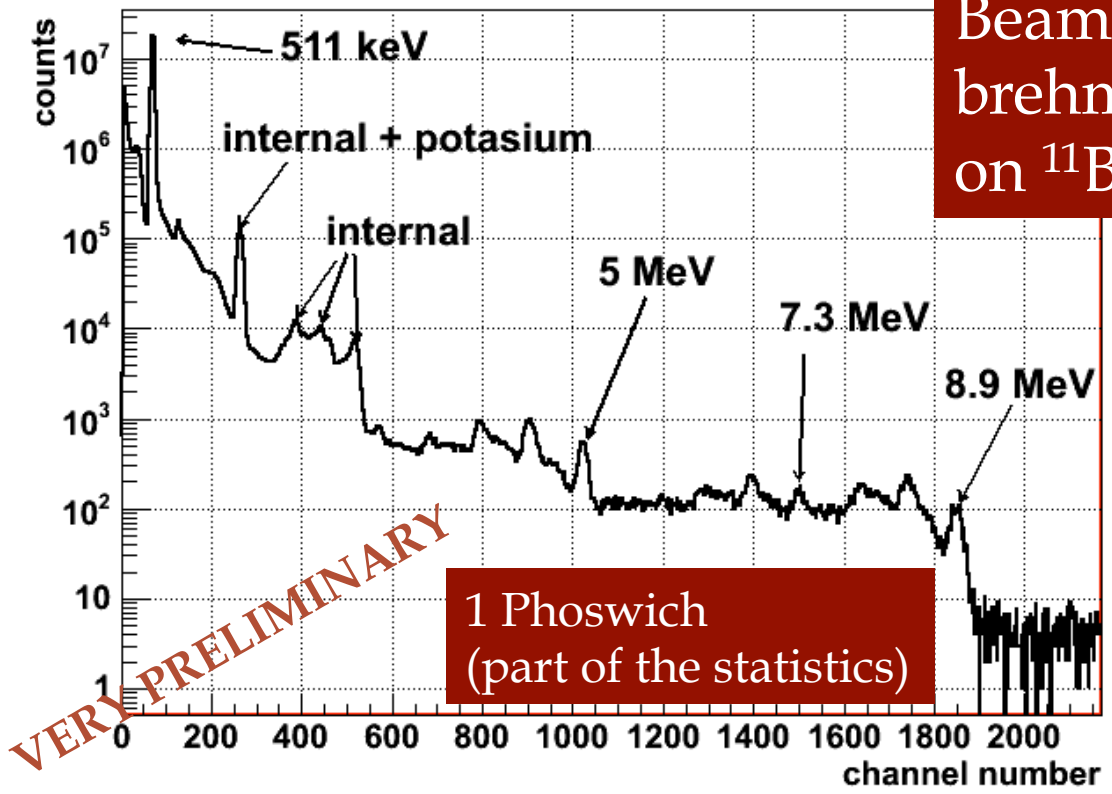
ELBE facility, Dreseden 10-12 December, 2013

Nuclear Resonance Fluorescence experiment (Mazumdar, Maj, Schwengner)



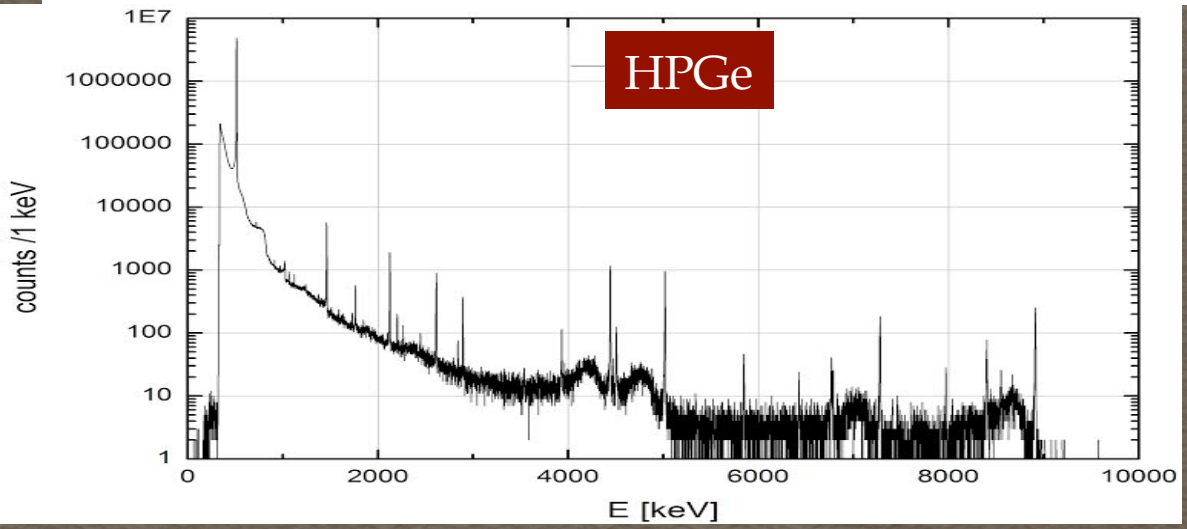


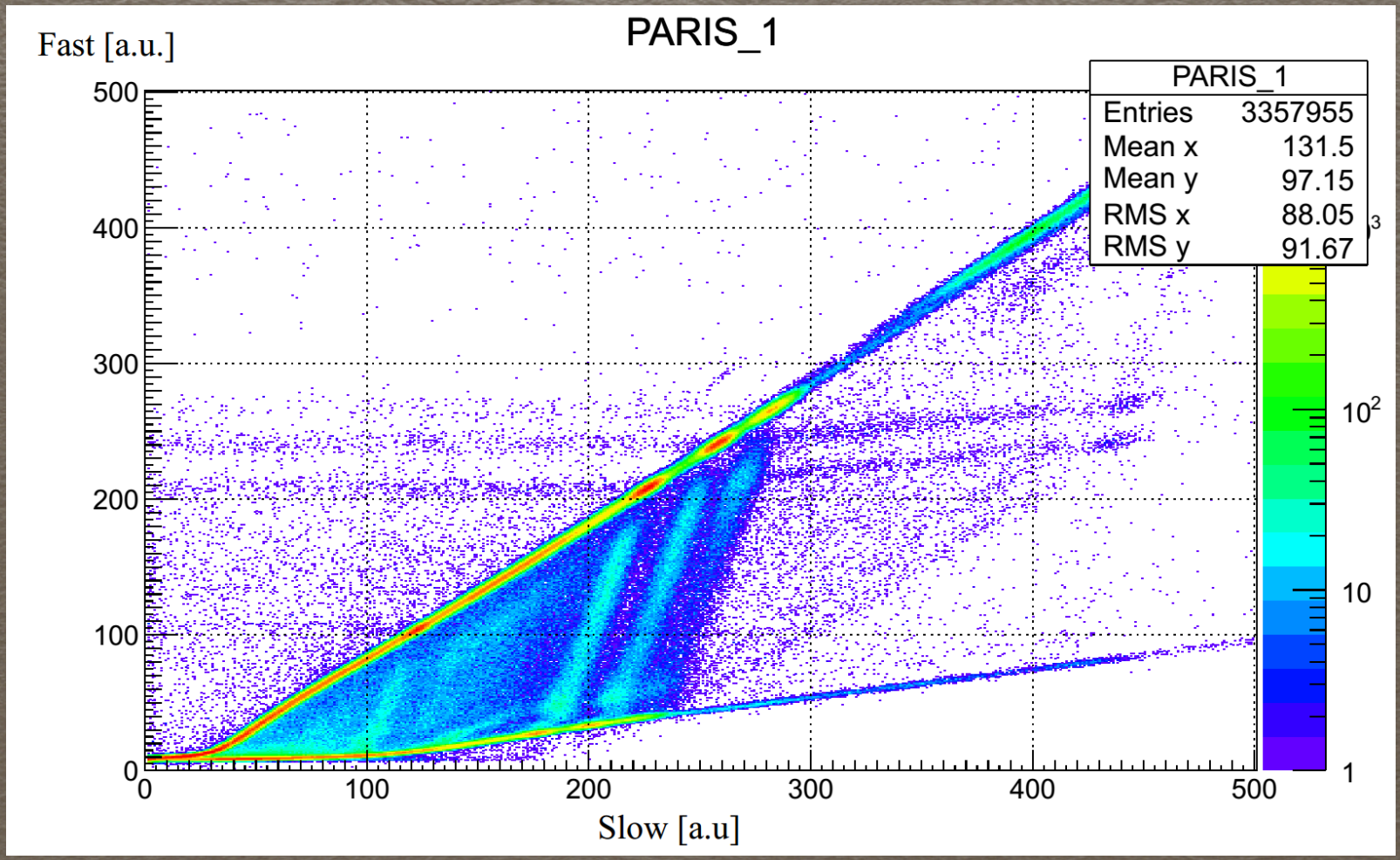
Beam 15 MeV electrons: brehmstallung gamma beam on ^{11}B target



VERY PRELIMINARY

1 Phoswich
(part of the statistics)

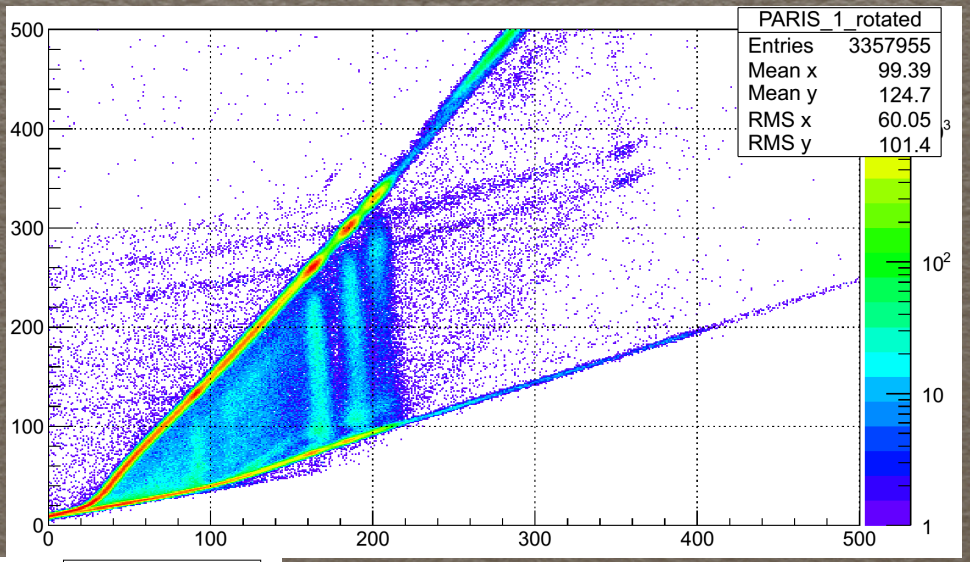


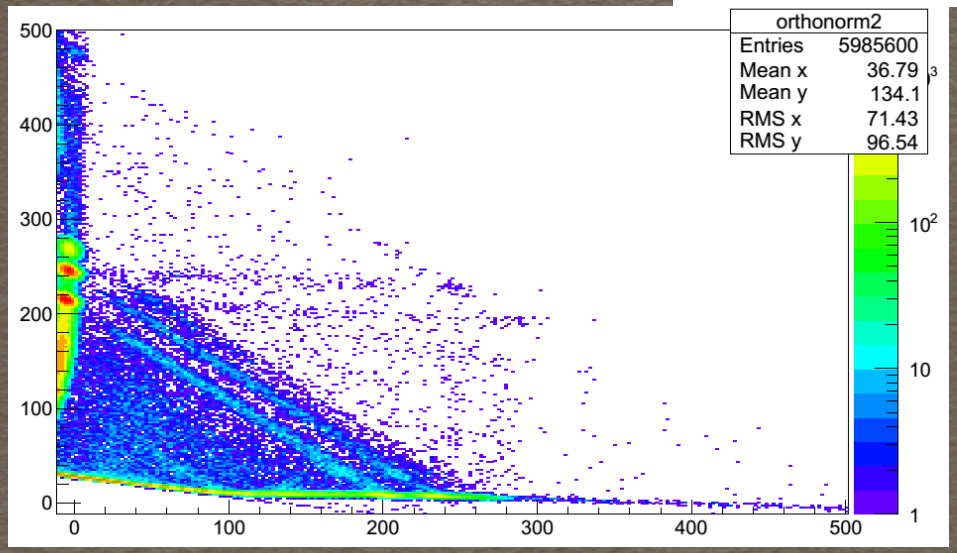


Analysis in progress:
B. Wasilewska, M. CIemała, A. Mentana, S. Brambilla et al..

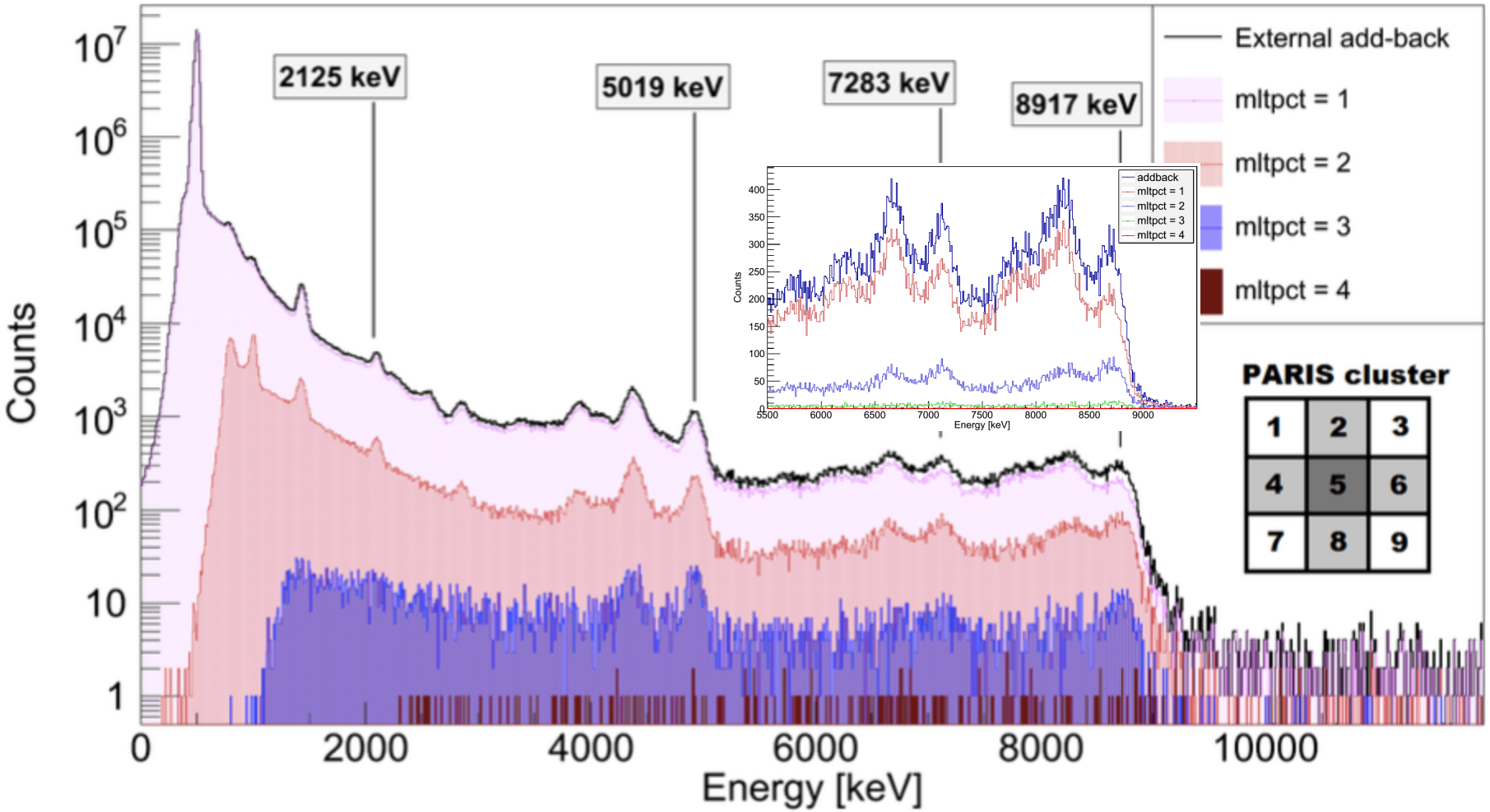
Orthonormalization & rotation

Rotation

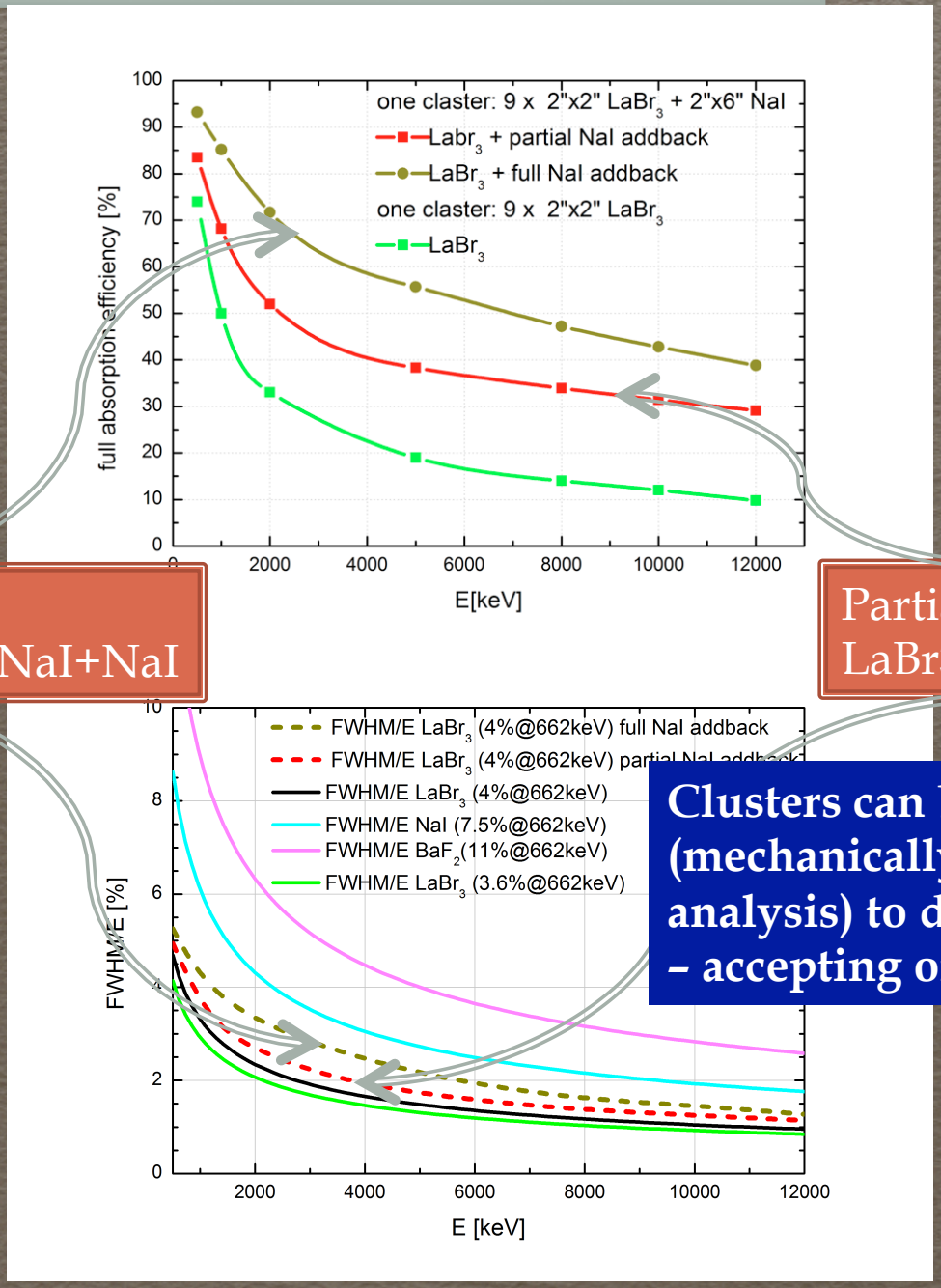


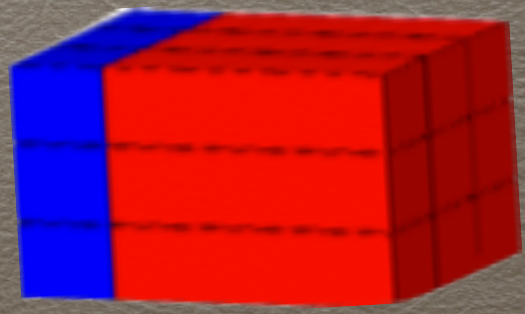


Orthonormalization


2125 keV
5019 keV
7283 keV
8917 keV
External add-back
mltpct = 1
mltpct = 2
mltpct = 3
mltpct = 4
PARIS cluster
1 2 3
4 5 6
7 8 9
Counts
Energy [keV]
addback
mltpct = 1
mltpct = 2
mltpct = 3
mltpct = 4

Simulations for one cluster made of 9 phoswiches





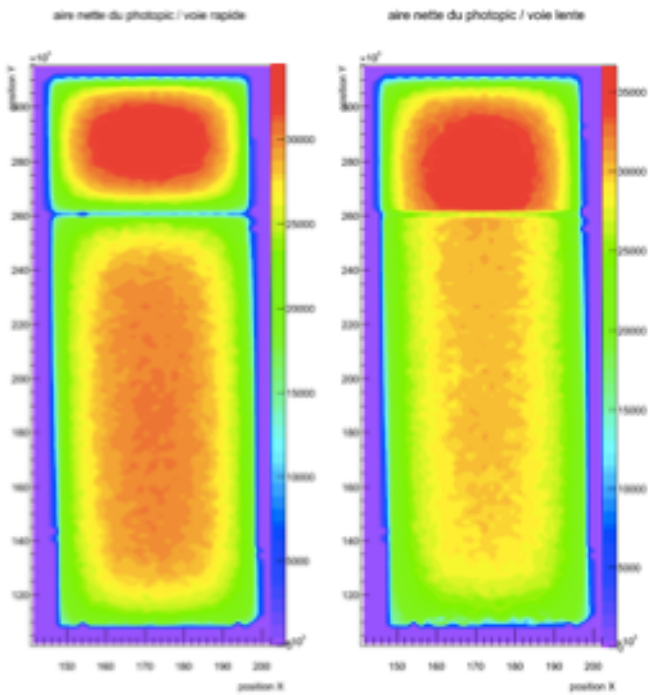
Full addback:
LaBr3+ LaBr3_NaI+NaI

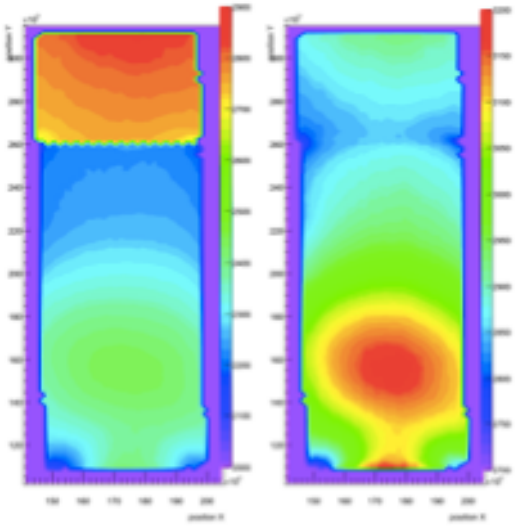
Partial addback:
LaBr3+ LaBr3_NaI

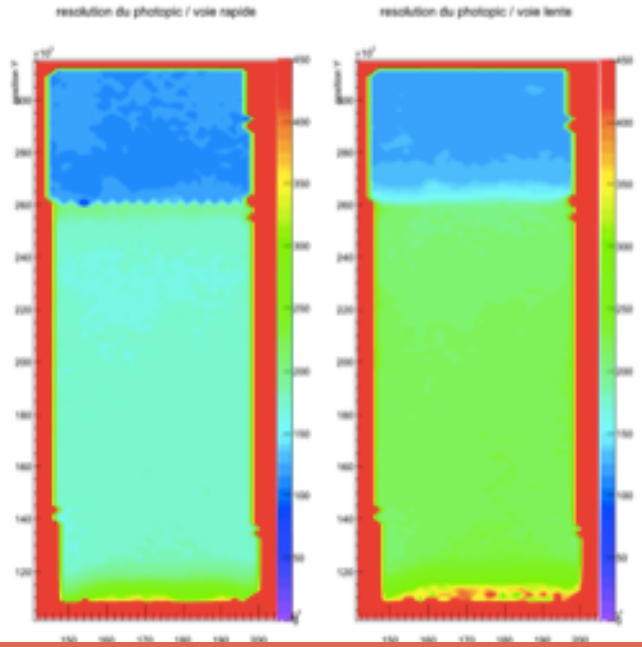
Clusters can be collimated (mechanically or in the off-line analysis) to depress the escape peaks – accepting only central phoswich hit

A example of scanning detector using the AGATA scanning table (1500 points)

IPHC Strasbourg
O. Dorvaux et al..

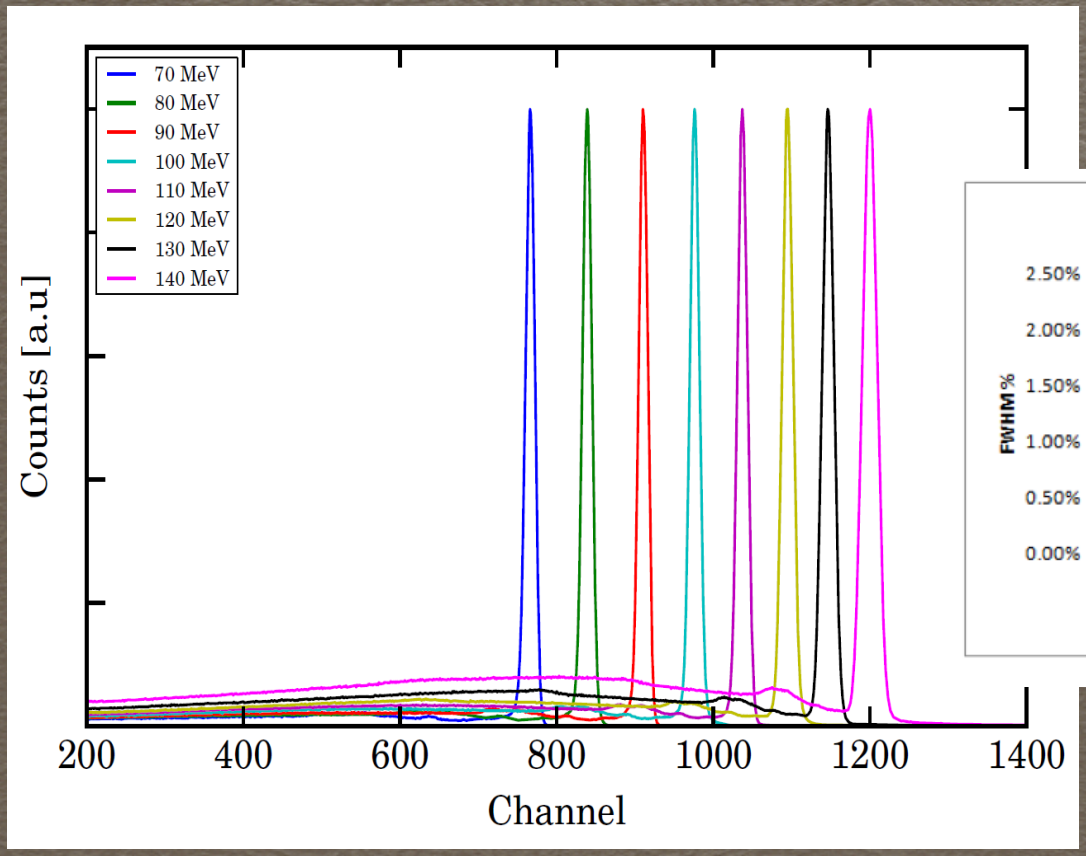


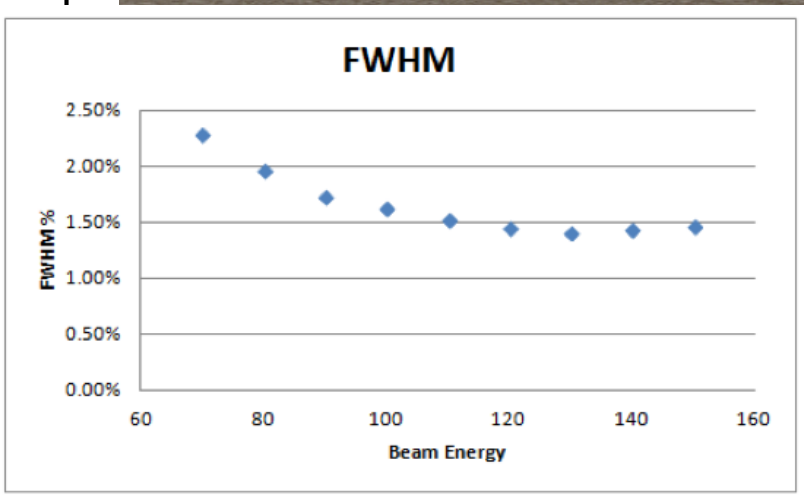




IPHC Strassbourg: Database of all PARIS phoswiches

First proton spectra from the Ti(p,p') reaction at proton beam energies 70-140 MeV measured at CCB Krakow with a $LaBr_3$ detector and PARIS phoswich





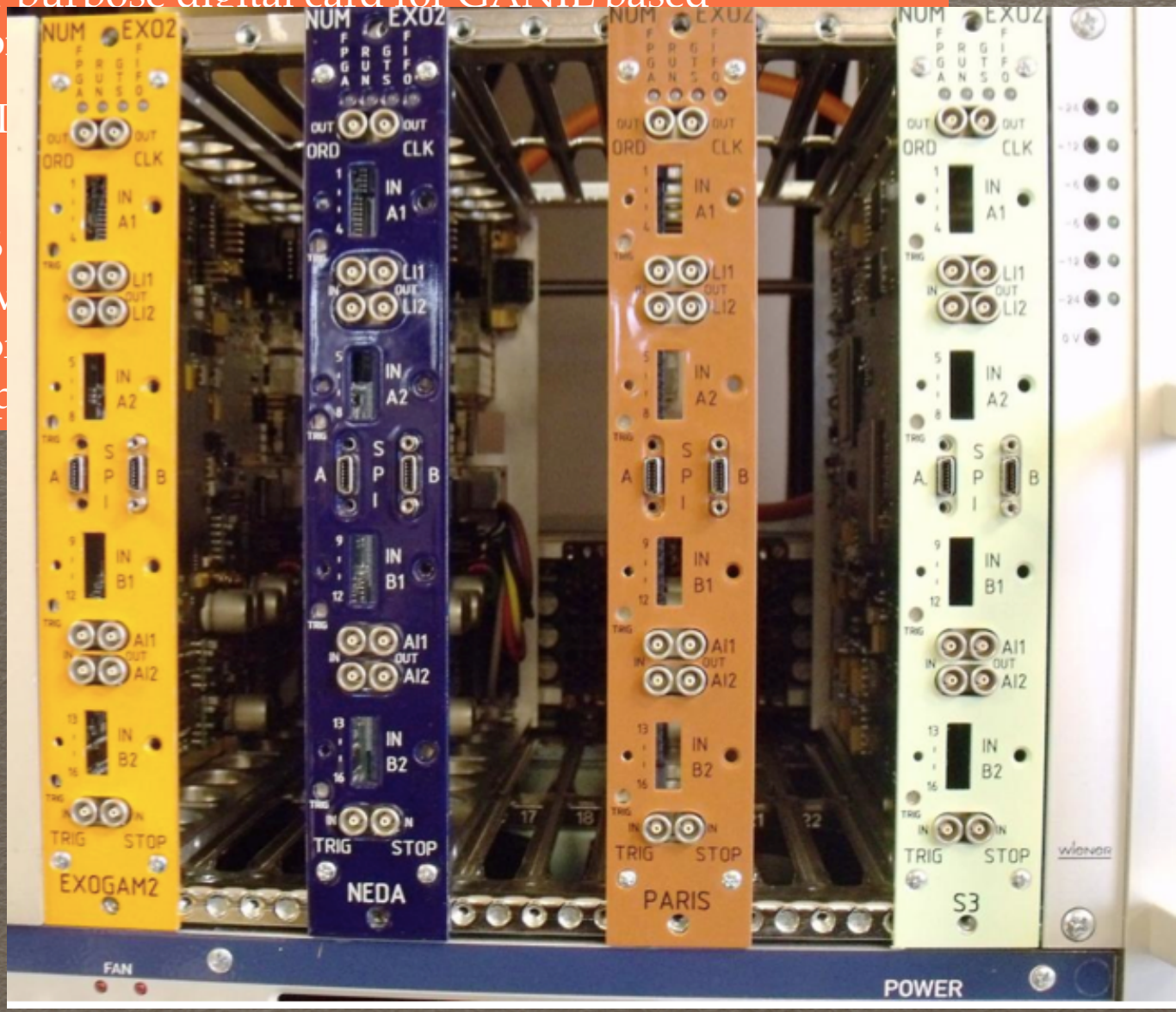
Spectra of protons at different beam energies measured with a 2" x 2" x 2" $LaBr_3$:Ce crystal at 5 deg. relatively to the beam axis. The spectra are normalized to have the same height of a proton peak.

Options of electronics for PARIS

1) NUMEXO2 - a general-purpose digital card for GANIL based experiments (collaboratio

Implementation of the GT currently being finalized.

A dedicated PARIS FADS designed. The digitizer w board. Implementation o Virtex6LX platform is in p



Options of electronics for PARIS

1) NUMEXO2 - a general-purpose digital card for GANIL based experiments (collaboration with EXOGAM2 and NEDA projects)

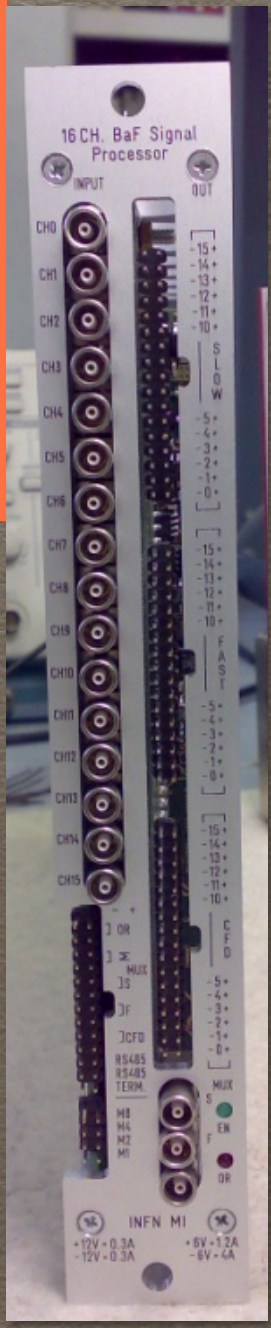
Implementation of the GTS interface into the NUMEXO2 VIRTEX 5 FPGA is currently being finalized.

A dedicated PARIS FADS front end electronics (mezzanine) is being designed. The digitizer will be integrated with the NUMEXO2 carrier board. Implementation of algorithms for on line PSA on the FPGA Virtex6LX platform is in progress.

2) **Analogue electronics** based on **Milano "PARIS_Pro"** cards (S. Brambilla et al.) + **AGAVA** interface (A. Czermak et al..):
Already tested in AGATA LNL and GSU camapigns!
Will be used fir first experiments with AGATA. (integrated to the VAMOS branch)

3) Comercial digitizers (e.g. V1730, 16 channel, 500 MS/s, 12/14 bit CAEN digitizer)

Require implementation of a digital alghoritm for timing



Planned first experiments

GANIL (AGATA campaigne *2016*
PARIS campaign manager: Ch. Schmitt)

- **Lifetimes in A=18 region (Leoni, Fornal, Ciemala): AGATA, VAMOS, Plunger (accepted)**

- **Discrete and continuum gamma-spectroscopy of hisj-spin states in 44Ti (P. Bednarczyk, A. Maj) AGATA+PARIS (+DIAMANT) (submitted)**

IPN/ALTO Orsay (PARIS campaign, *2015/2016*, PARIS campaigne manager: I. Matea)

Proposals submitted to Orsay PAC (under evaluation)

- M. Wiedeking - Coulomb Excitation of 14C
- P.J. Napiorkowski - Coulomb excitation of super-deformed band in 40Ca
- M. Lebois - Prompt gamma and neutron emission for 238U fast neutron induced fission as a function of incident neutron energy
- D. Montanari - Electromagnetic transitions between 12C+12C resonant states as a probe for clustering in 24Mg
- O. Kirsebom - A new probe of alpha-cluster structure in 12C
- A. Kozulin - Prompt γ-rays as a probe of nucleardynamics
- B. Blank - Measurement of the super-allowed branching ratio of 10C
- A. Gottardo - Study of β-delayed neutron emission in 83,84Ga,98Rb, 133In

CCB Krakow (2016/2017, campaign manager tbc)

- Studies of resonance states in nuclei using high-energy proton beam (Crespi, Kmiecik): HECTOR, PARIS, KRATTA, Ge_array
- Investigations of (p,2p) reactions in order to identify deep single-particle proton-hole states (Bracco, Fornal) HECTOR, PARIS, KRATTA
- Gamma-decay of GDR in proton induced fusion-eveporation reactions (Camera, Kmiecik) HECTOR, PARIS, KRATTA
- Investigation of proton induced spallation (Ch. Schmitt, D. Mancuzi): HECTOR, PARIS, KRATTA

HIL Warsaw

(1 experiment 2015?, more 2016/2017, campaign manager tbc)

- Coloumb excitations in A=40-50 nuclei (Napiorkowski, Bednarczyk): EAGLE +PARIS
- Radiative capture (D. Jenkins, D. Montanari) Eagle+PArIS

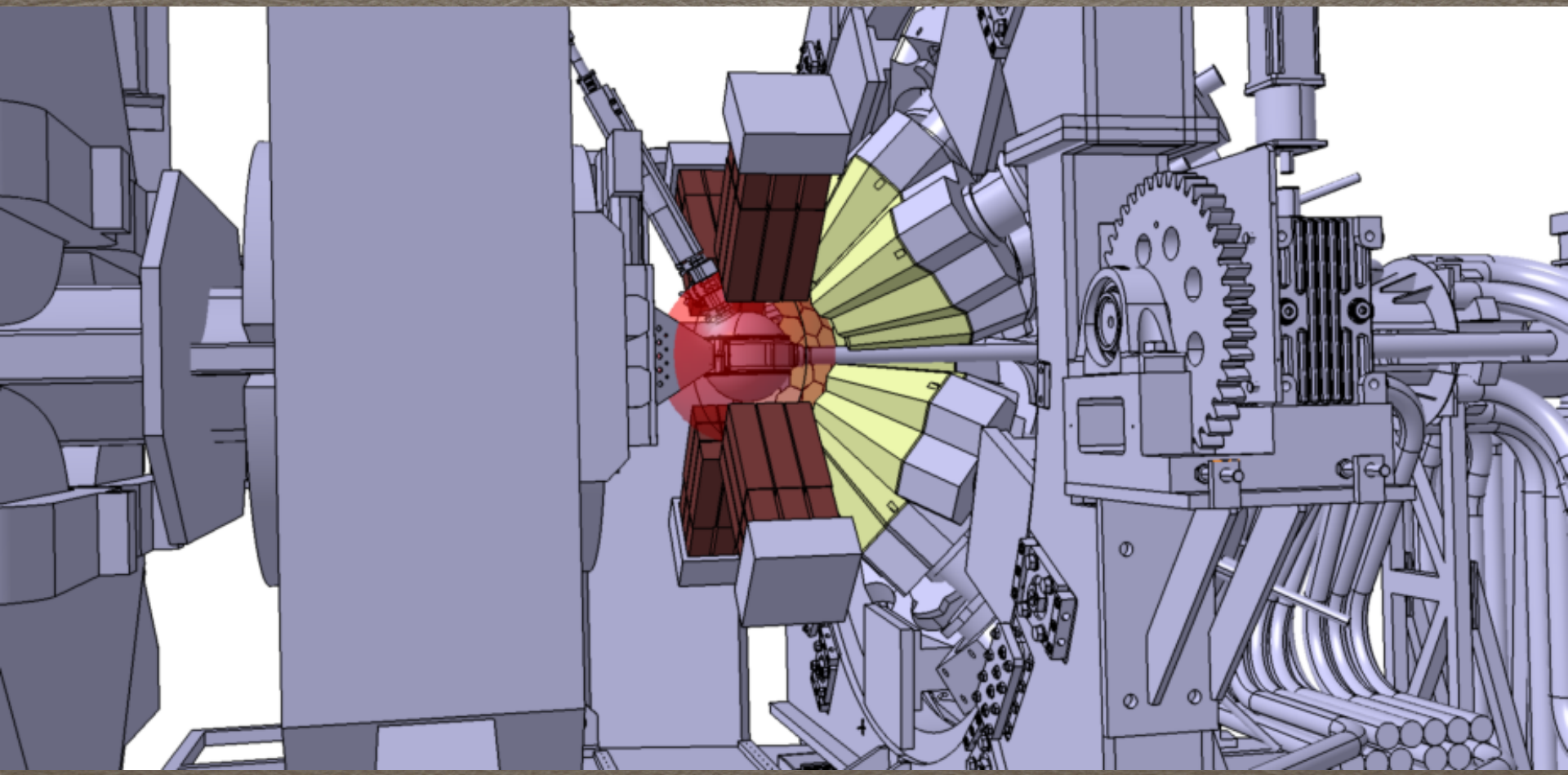
LNL/SPES Legnaro (*2018?*)

- GDR decay of hot rotating nuclei in A=130 mass region (Maj, Leoni): GALLILEO, RFD
- Measurement of Isospin Mixing in N=Z medium mass nuclei (F. Camera): HECTOR+, GALLILEO
- Measurement of the Dynamical Dipole emission and the symmetry term of the EOS (F. Camera, G. Casini): HECTOR+, fusion_evaporation det.
- Entry distributions for fragments produced in deep- inelastic collisions with stable and radioactive beams (Królas)
- Coulomb excitation tagged by beta decay: The onset of deformation in the n-rich Y isotopes (Kmiecik, Benzoni, Suzuki) GALILEO
- Heavy-ion binary reactions as a tool for detailed gamma spectroscopy in exotic regions (Leoni, Maj): PRISMA, GALILEO
- High-spin gamma ray spectroscopy of heavy, octupole deformed Ac and Fr nuclei produced in fusion evaporation reactions with the intense A~90 Rb radioactive beams at SPES (Bednarczyk): GALILEO

Mechanical coupling of 4 PARIS clusters to AGATA with VAMOS will be done using EXOGAM frame

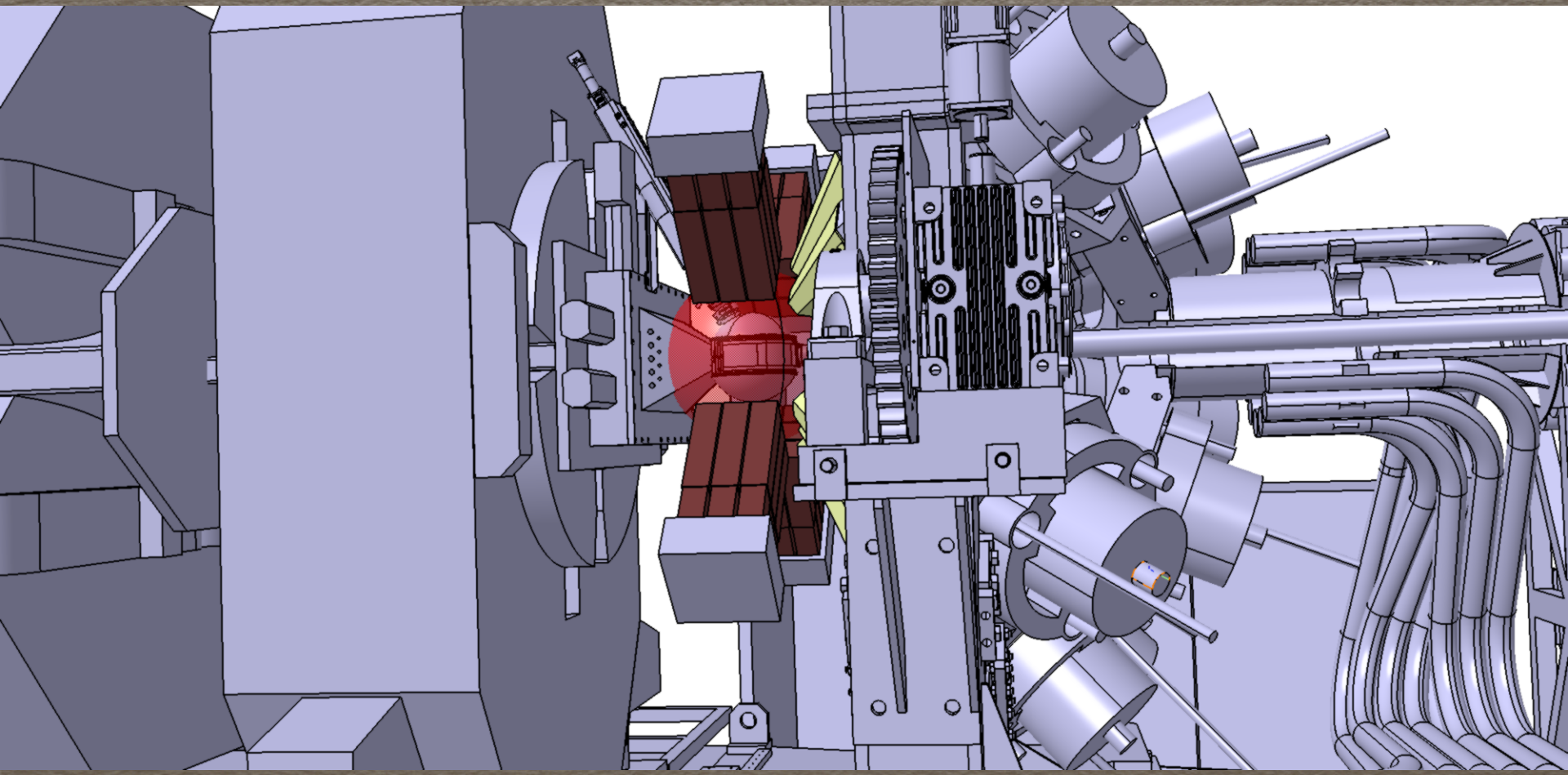
PARIS detectors are at 23 cm distance from target

PARIS and VAMOS and AGATA @GANIL



Standard geometry:
4 PARIS clusters at 23 cm from the target

PARIS and VAMOS and AGATA @GANIL



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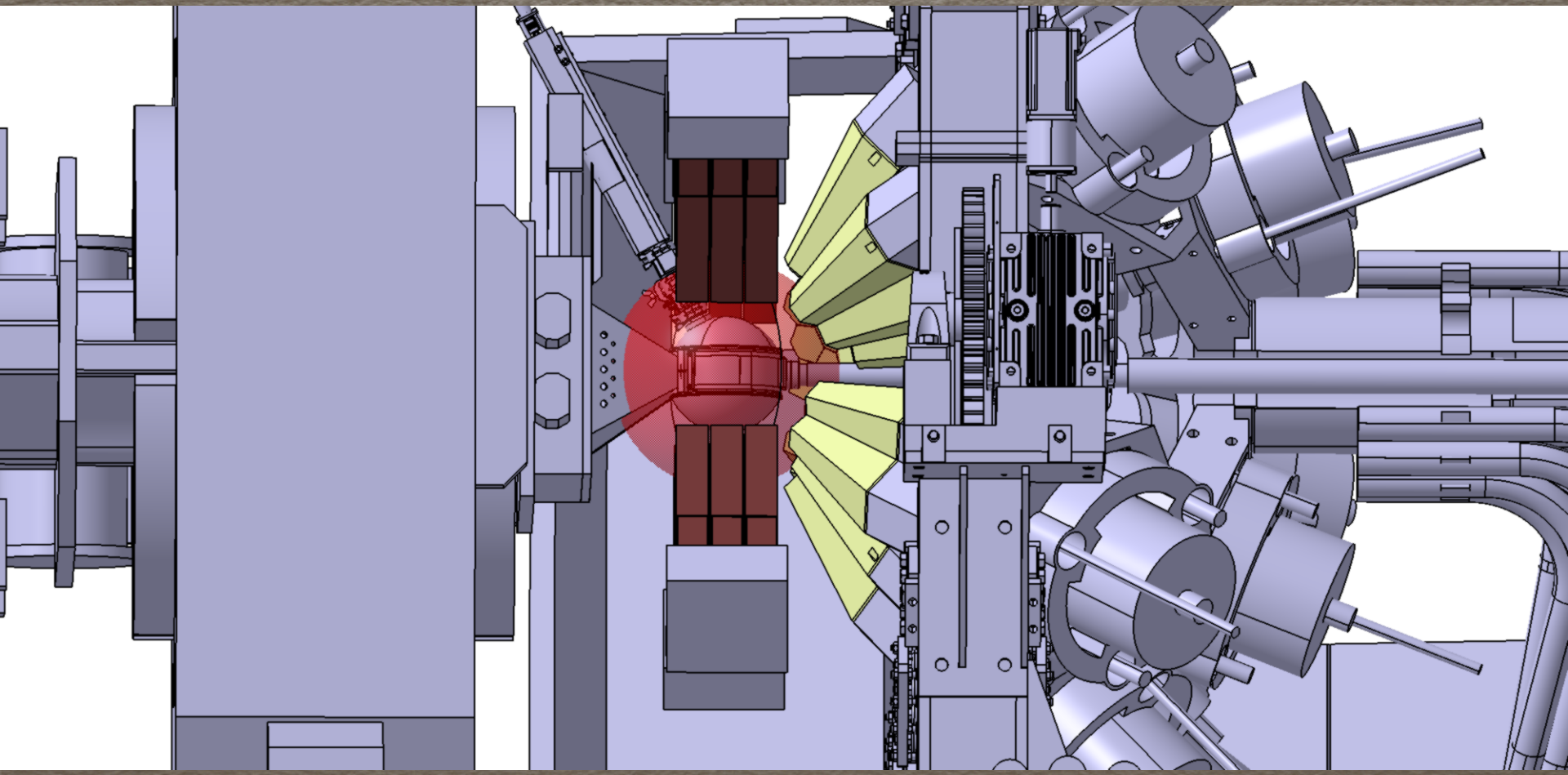
PARIS and VAMOS and AGATA @GANIL



Standard geometry:
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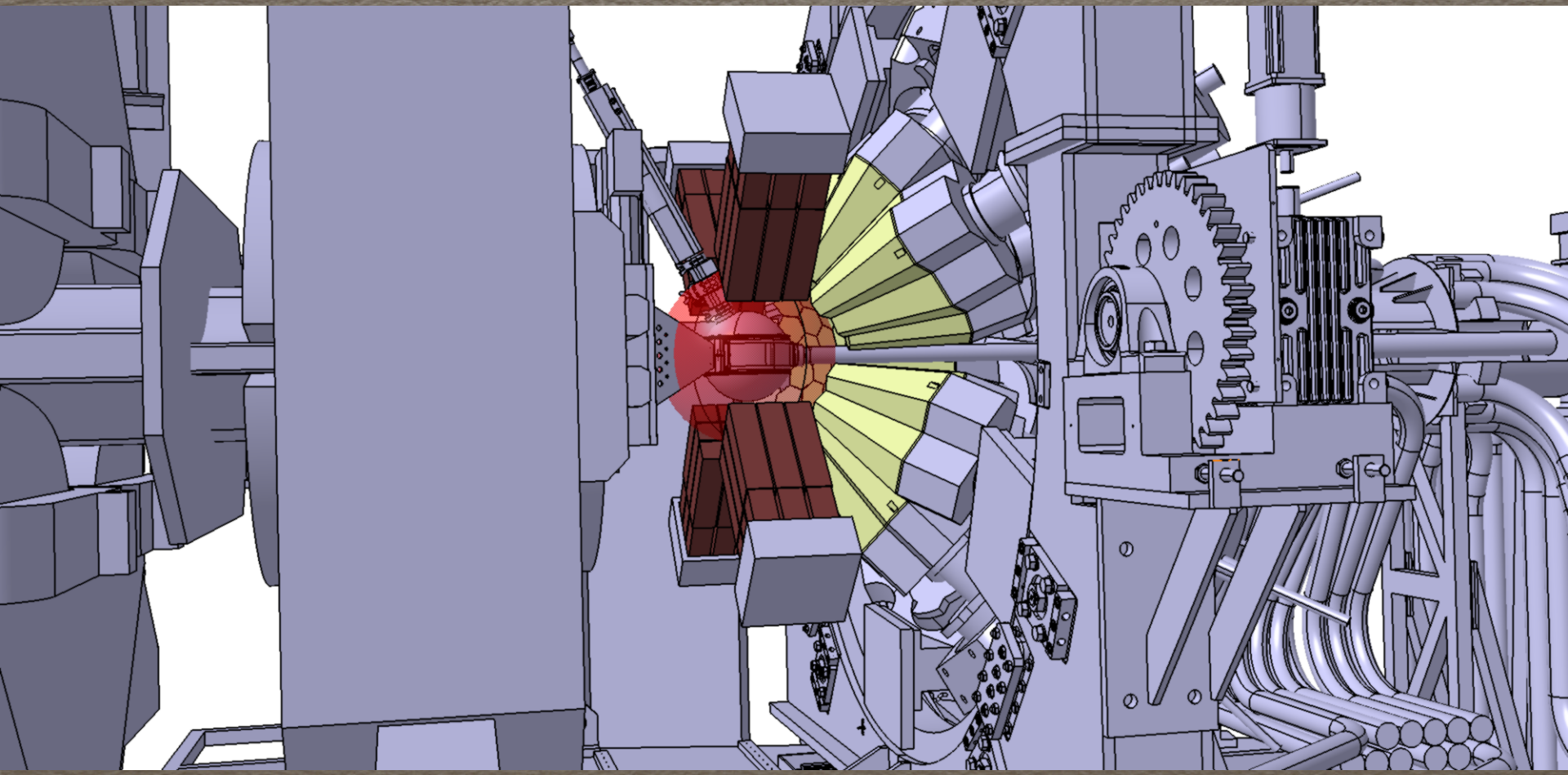
PARIS and VAMOS and AGATA @GANIL



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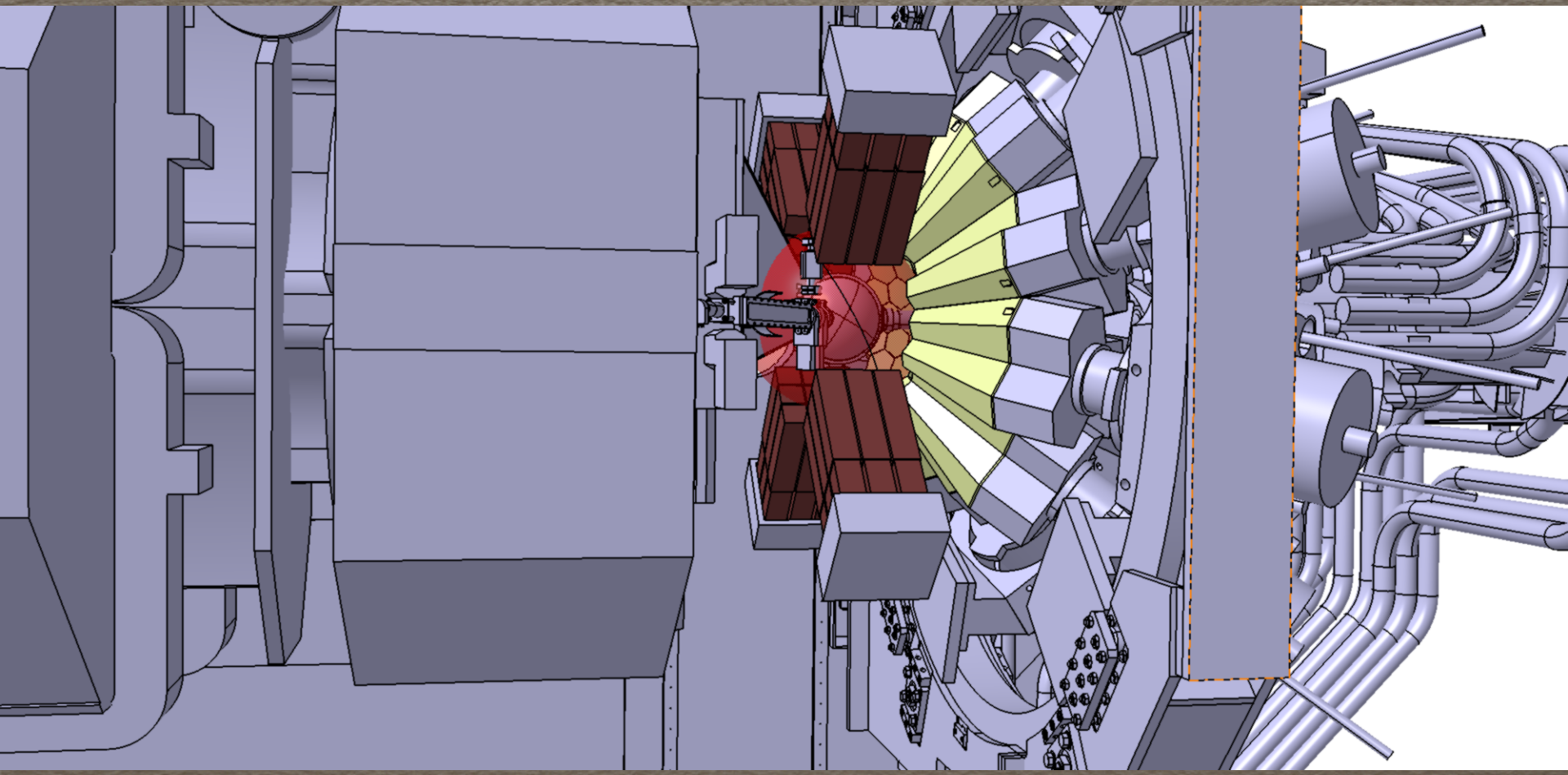
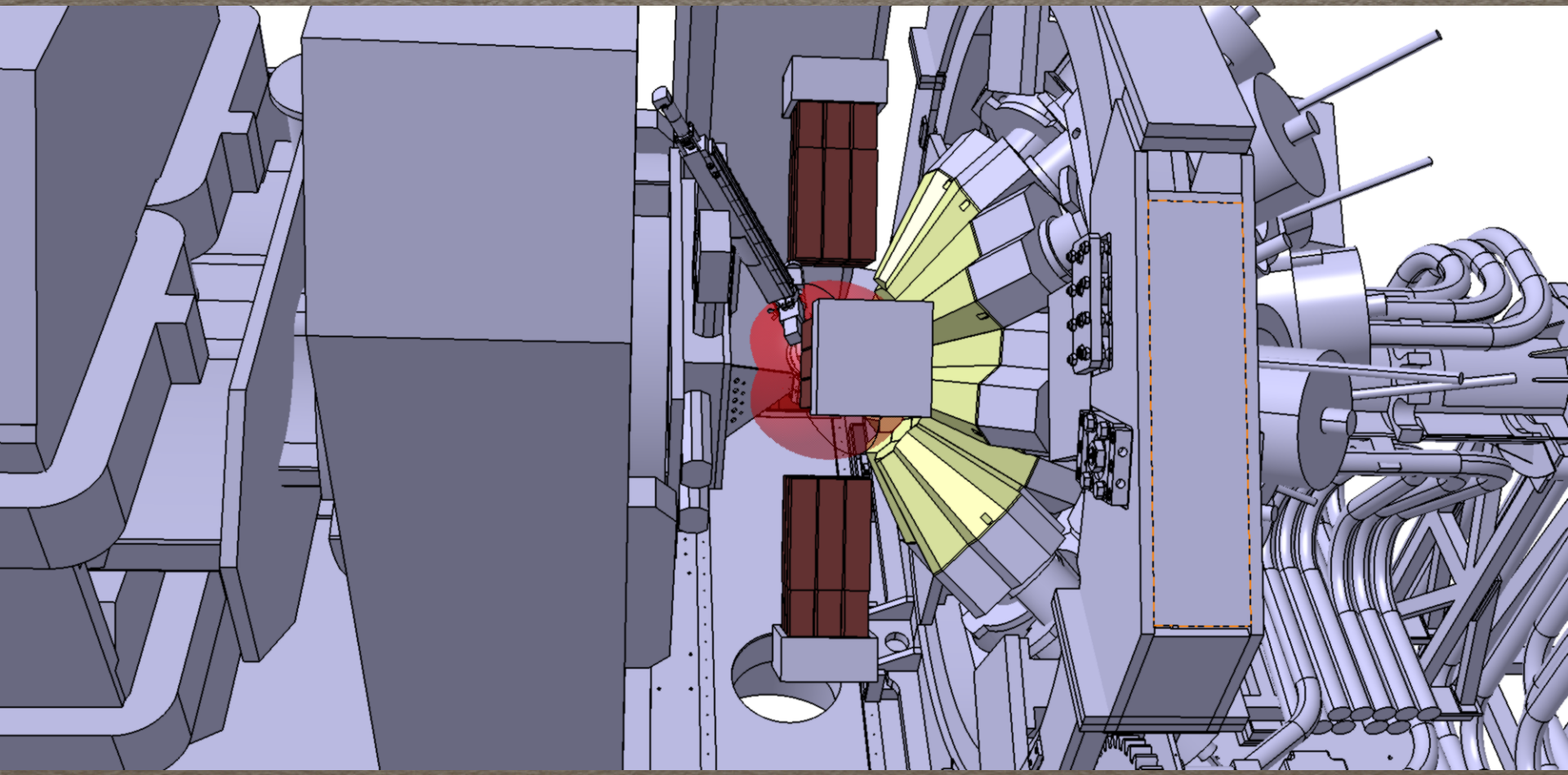
PARIS and VAMOS and AGATA @GANIL



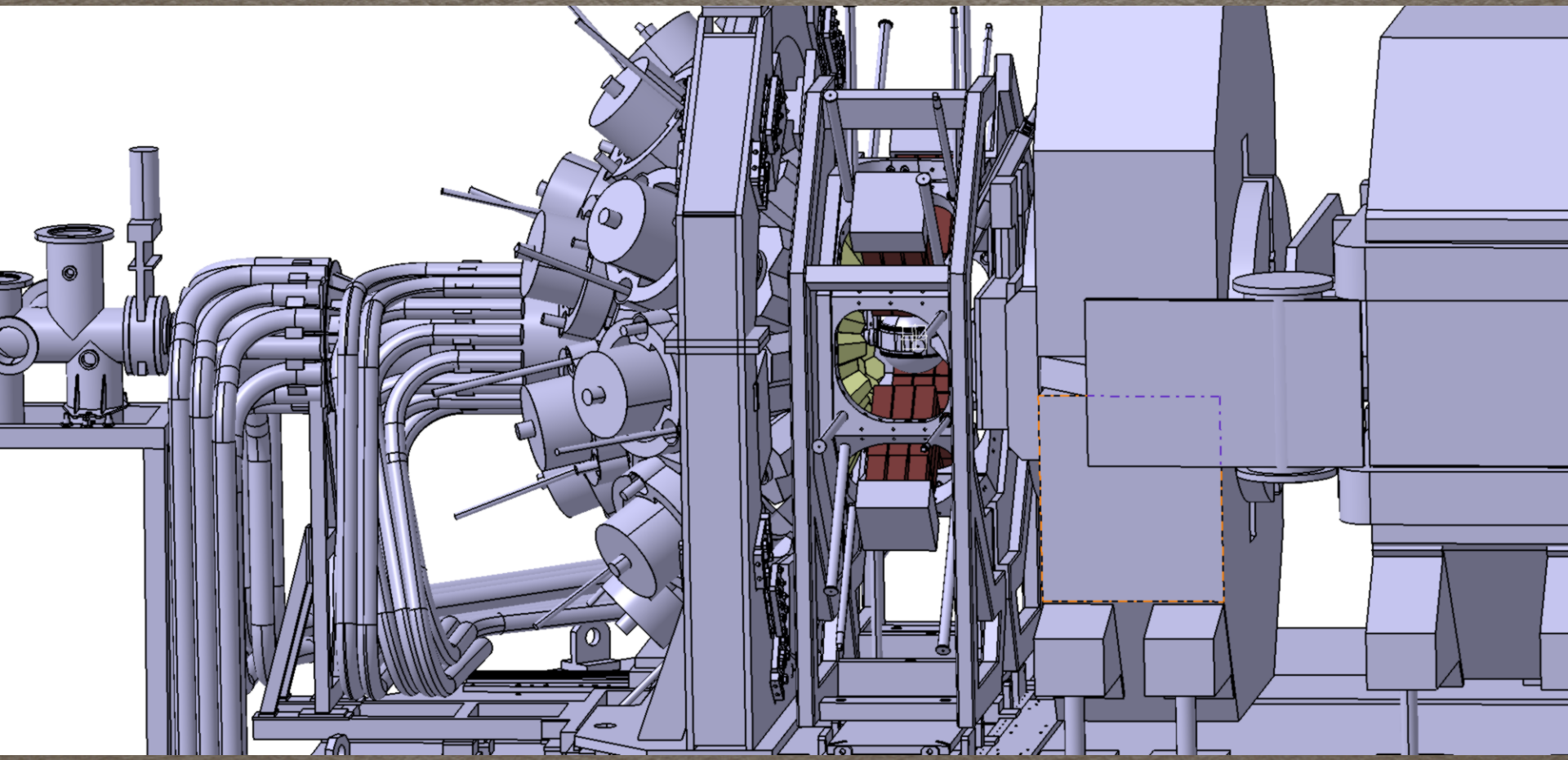
Standard geometry:
4 PARIS clusters at 23 cm from the target

PARIS and VAMOS and AGATA @GANIL



Standard geometry:
4 PARIS clusters at 23 cm from the target

PARIS (in EXOGAM frame) and VAMOS and AGATA @GANIL



Standard geometry:
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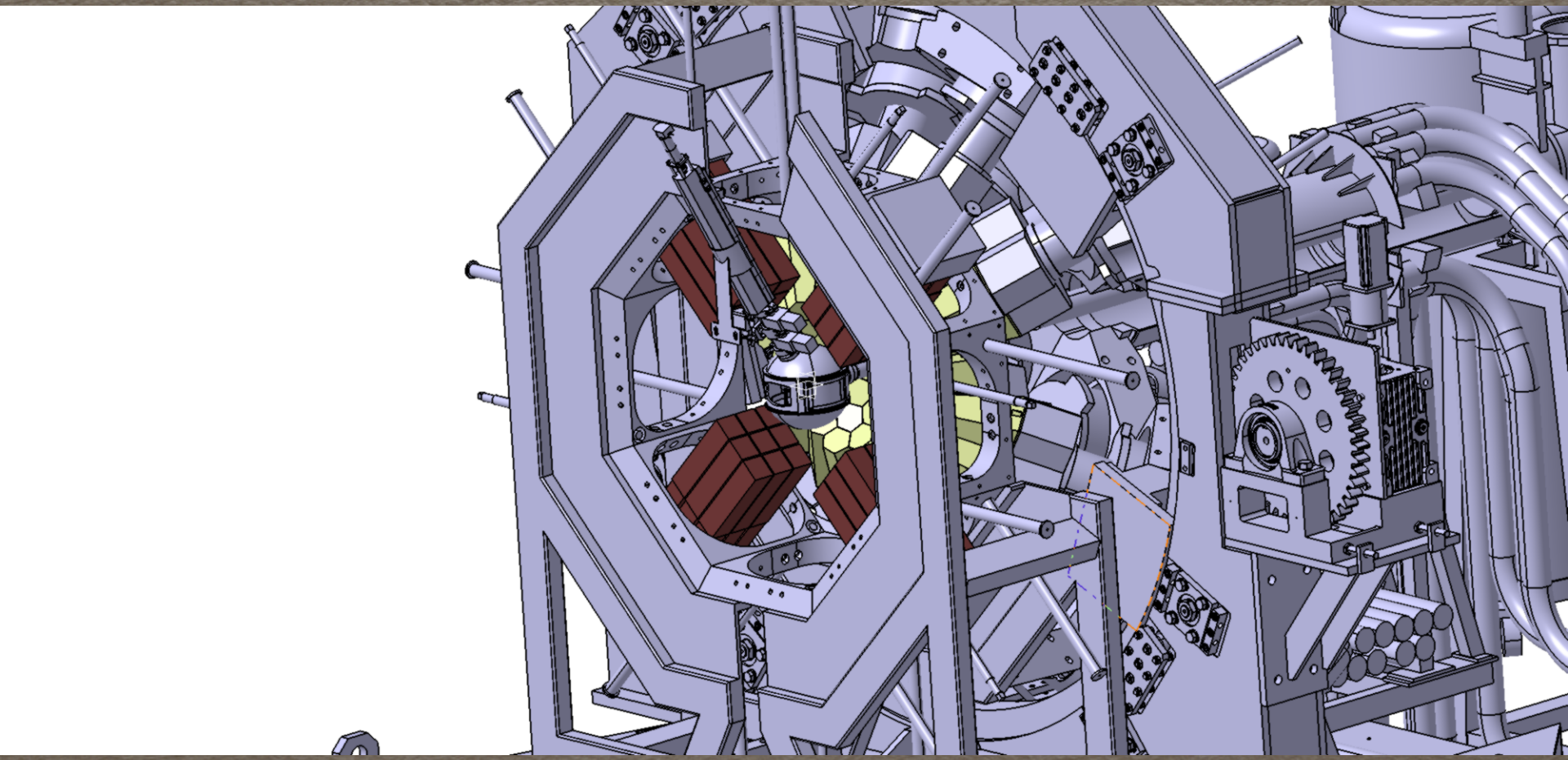
PARIS (in EXOGAM frame) and VAMOS and AGATA @GANIL



Standard geometry:
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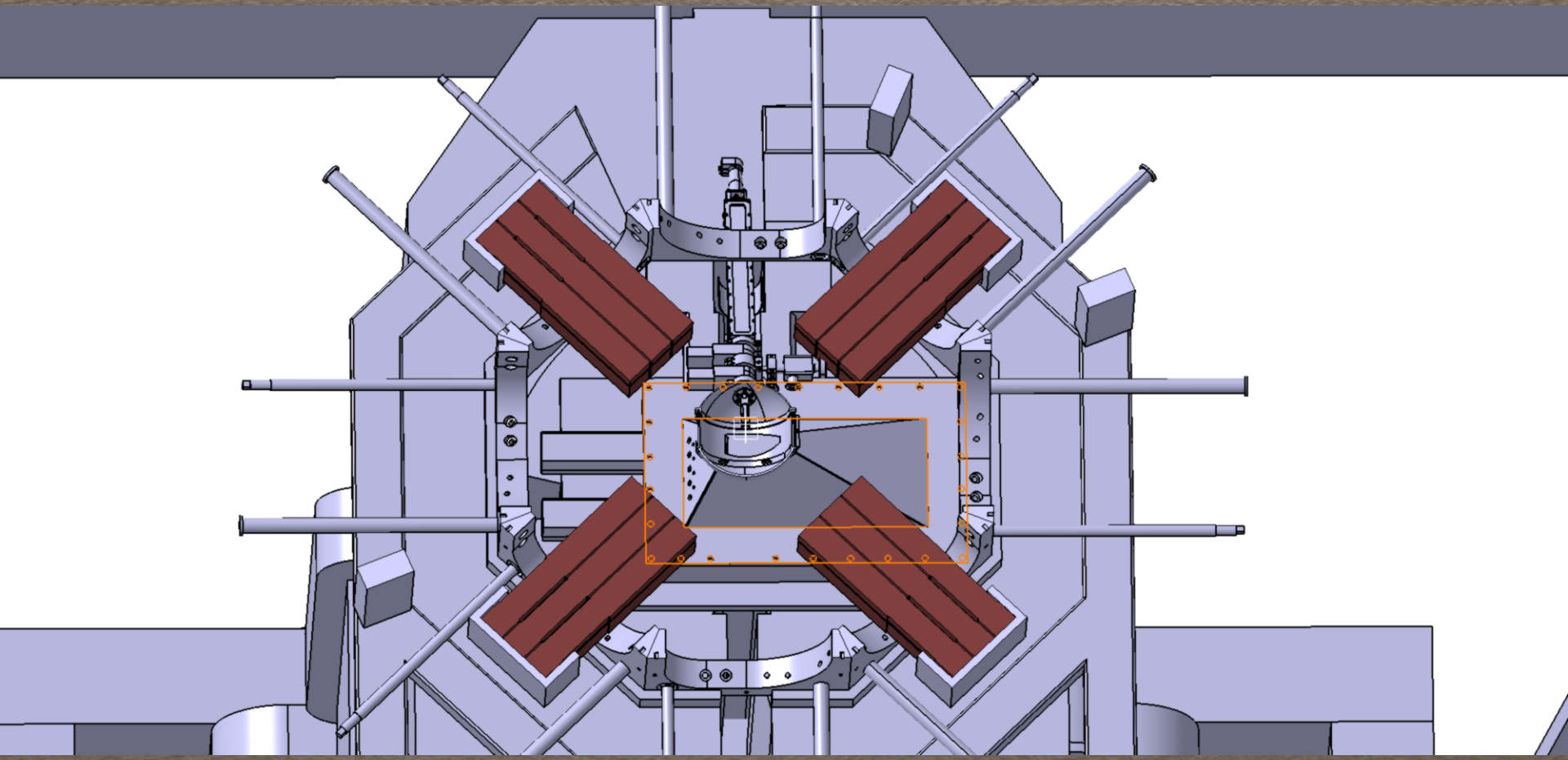
PARIS (in EXOGAM frame) and VAMOS and AGATA @GANIL



Standard geometry:
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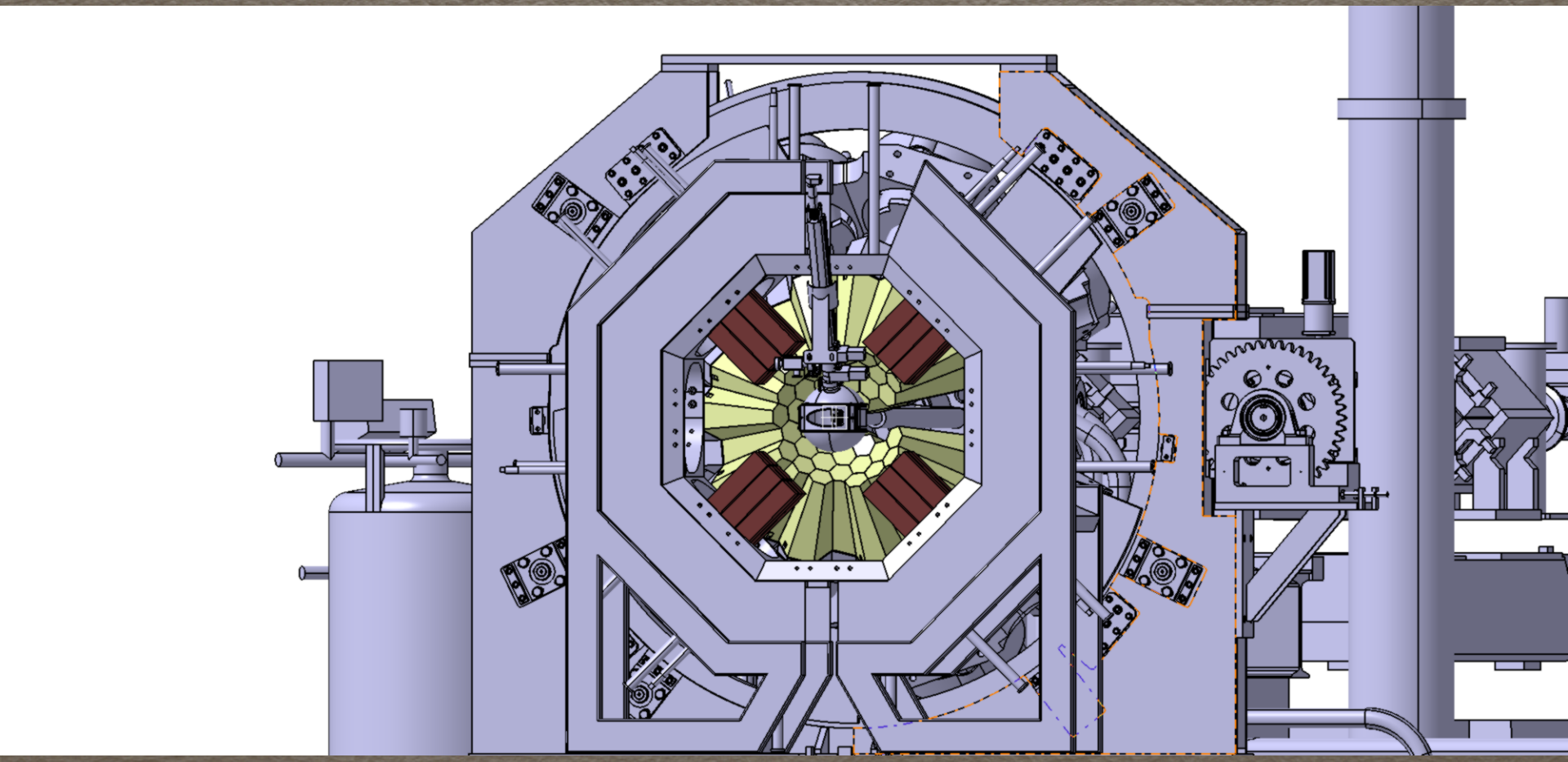
PARIS (in EXOGAM frame) and VAMOS and AGATA @GANIL



Standard geometry:
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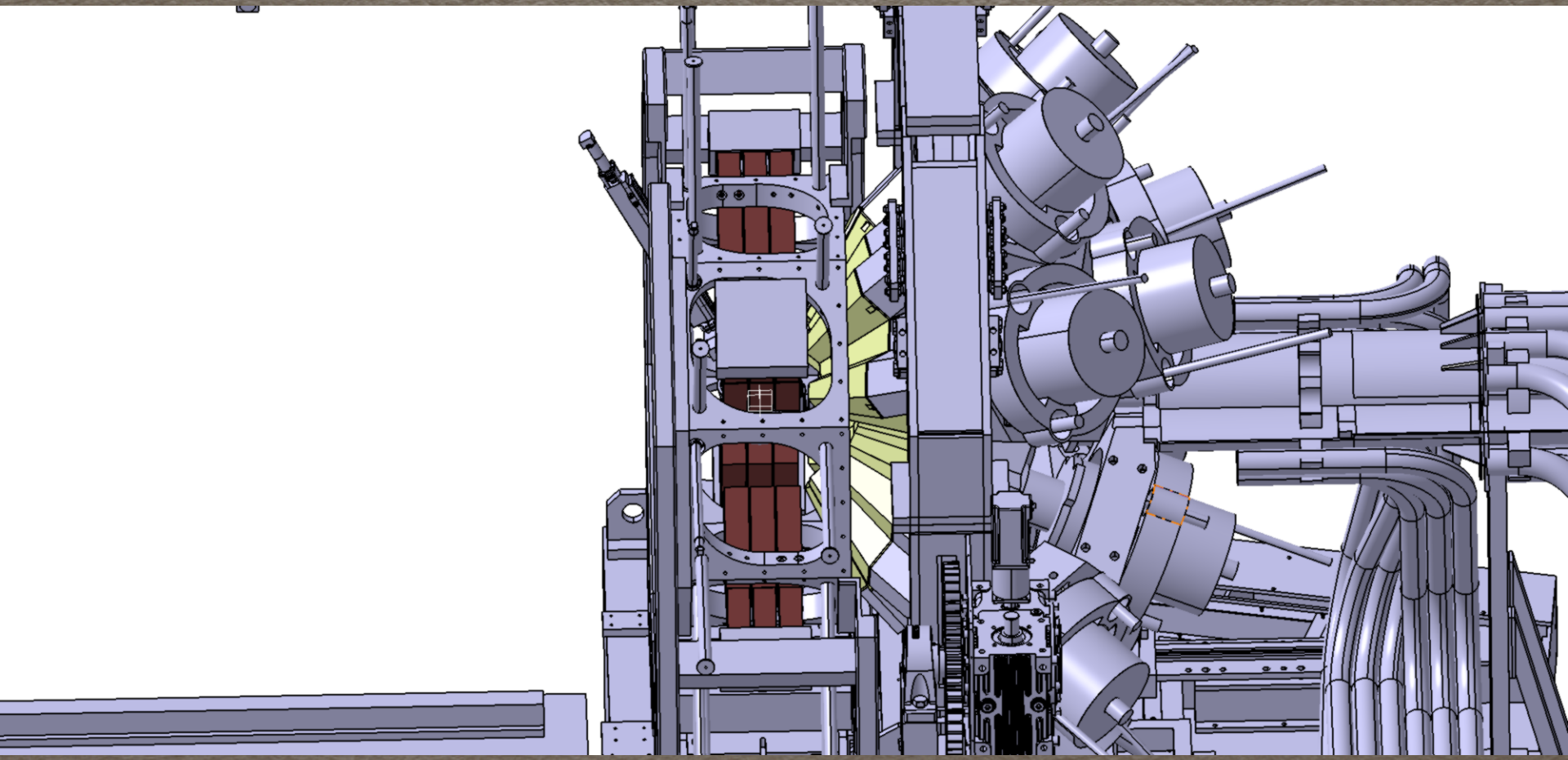
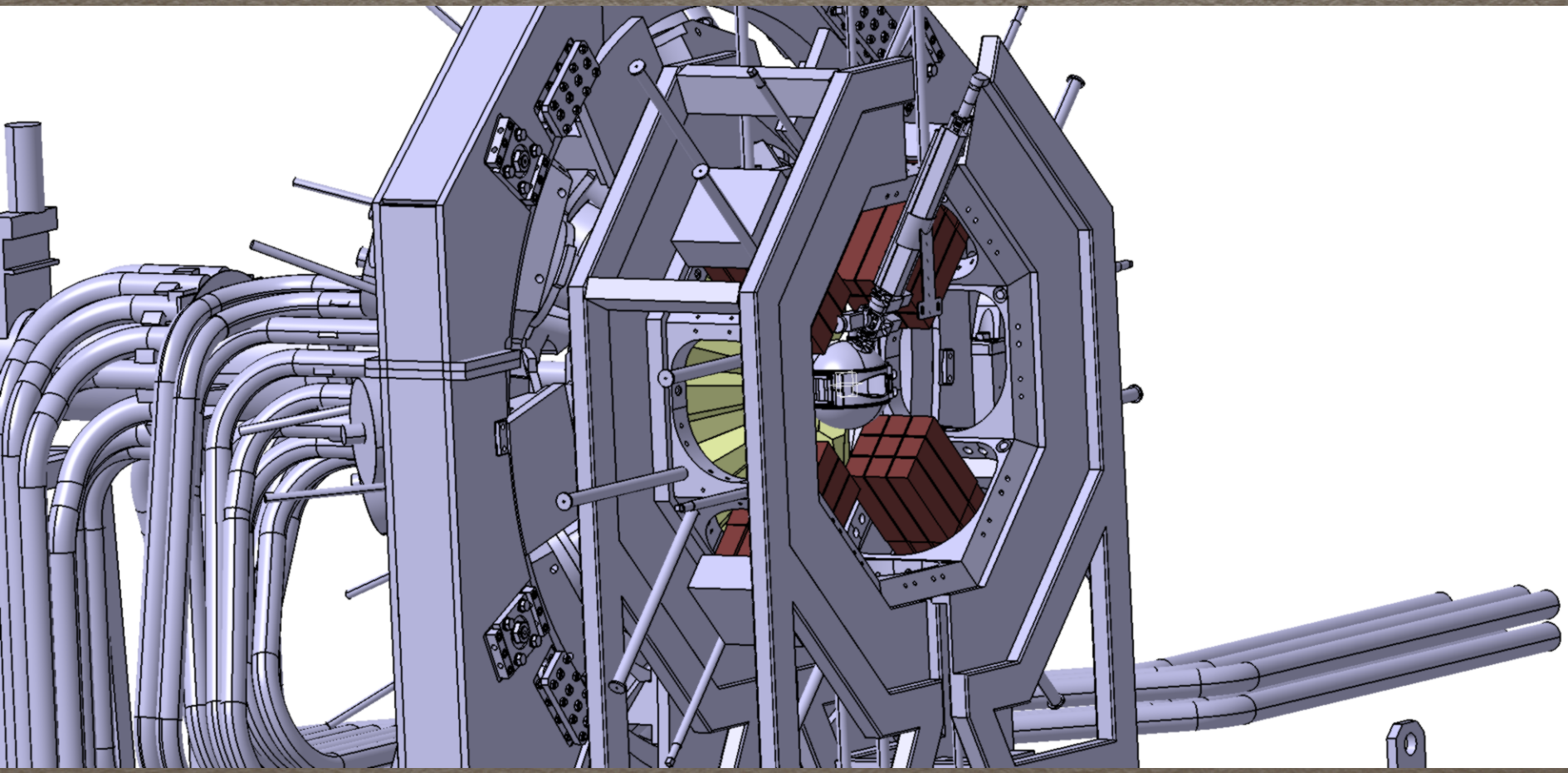
PARIS (in EXOGAM frame) and VAMOS and AGATA @GANIL



Standard geometry:
4 PARIS clusters at 23 cm from the target

PARIS (in EXOGAM frame) and VAMOS and AGATA @GANIL



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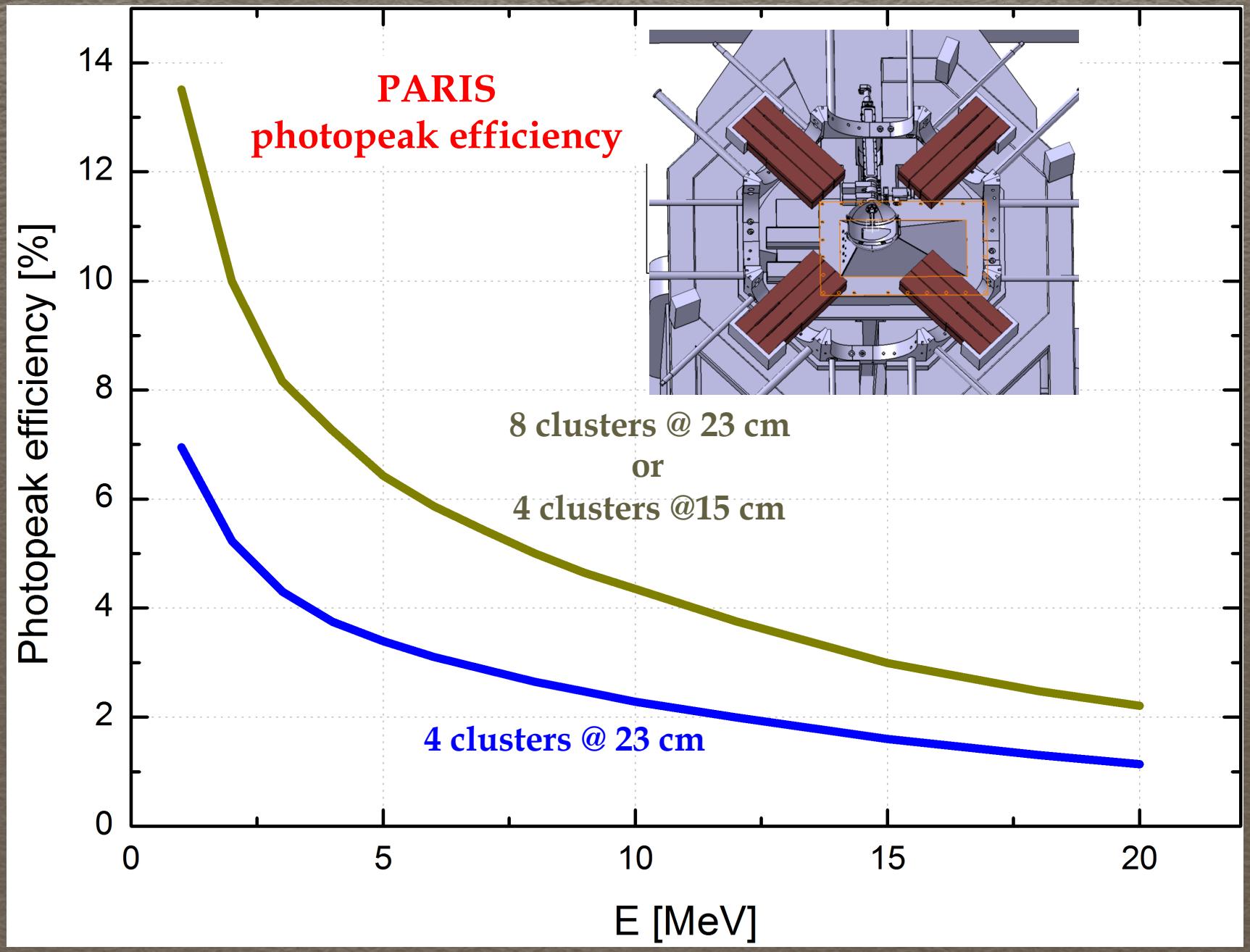
4 PARIS clusters at 23 cm from the target

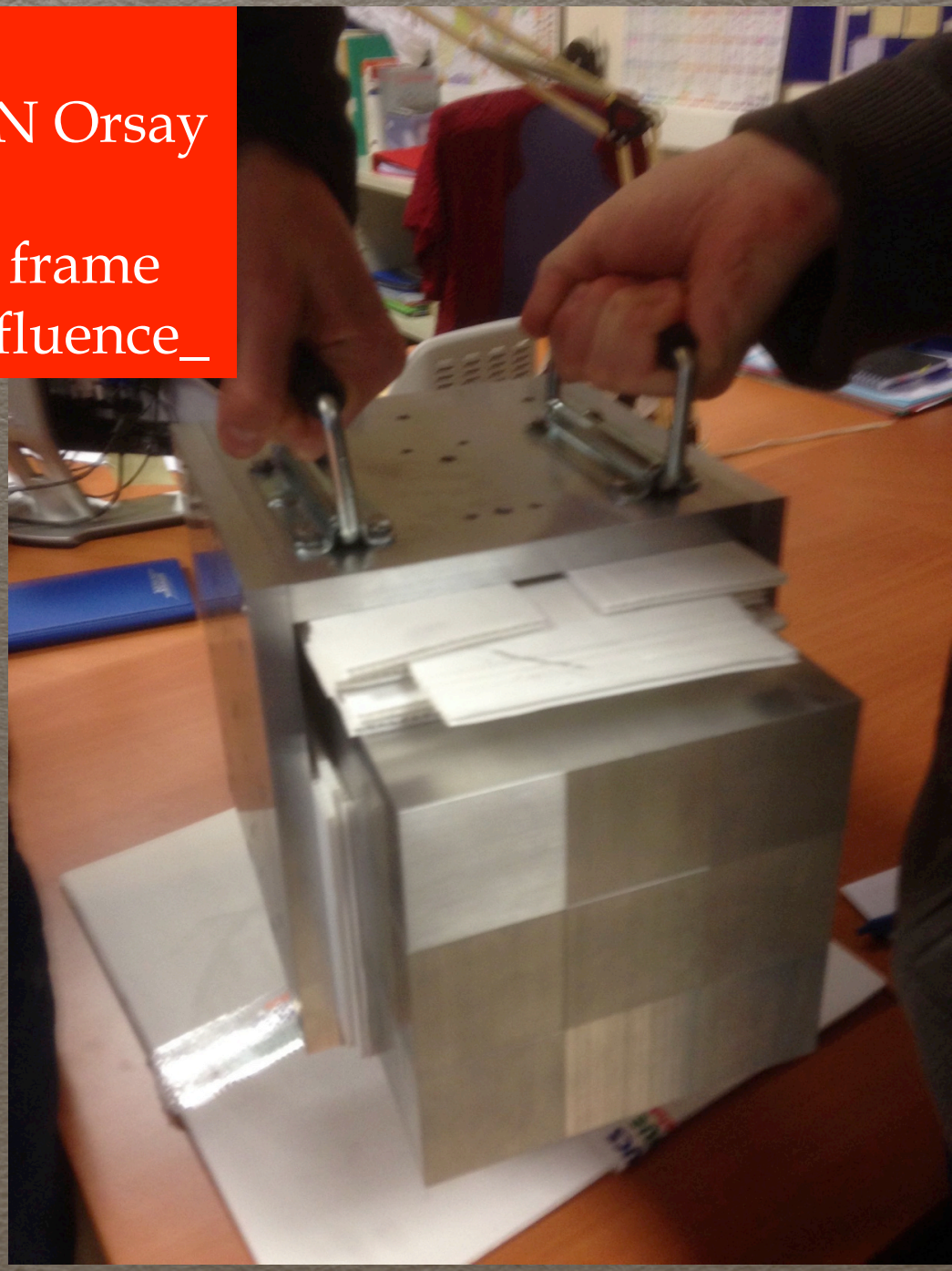


Simulations: Michal Ciemala

Cluster holding structure

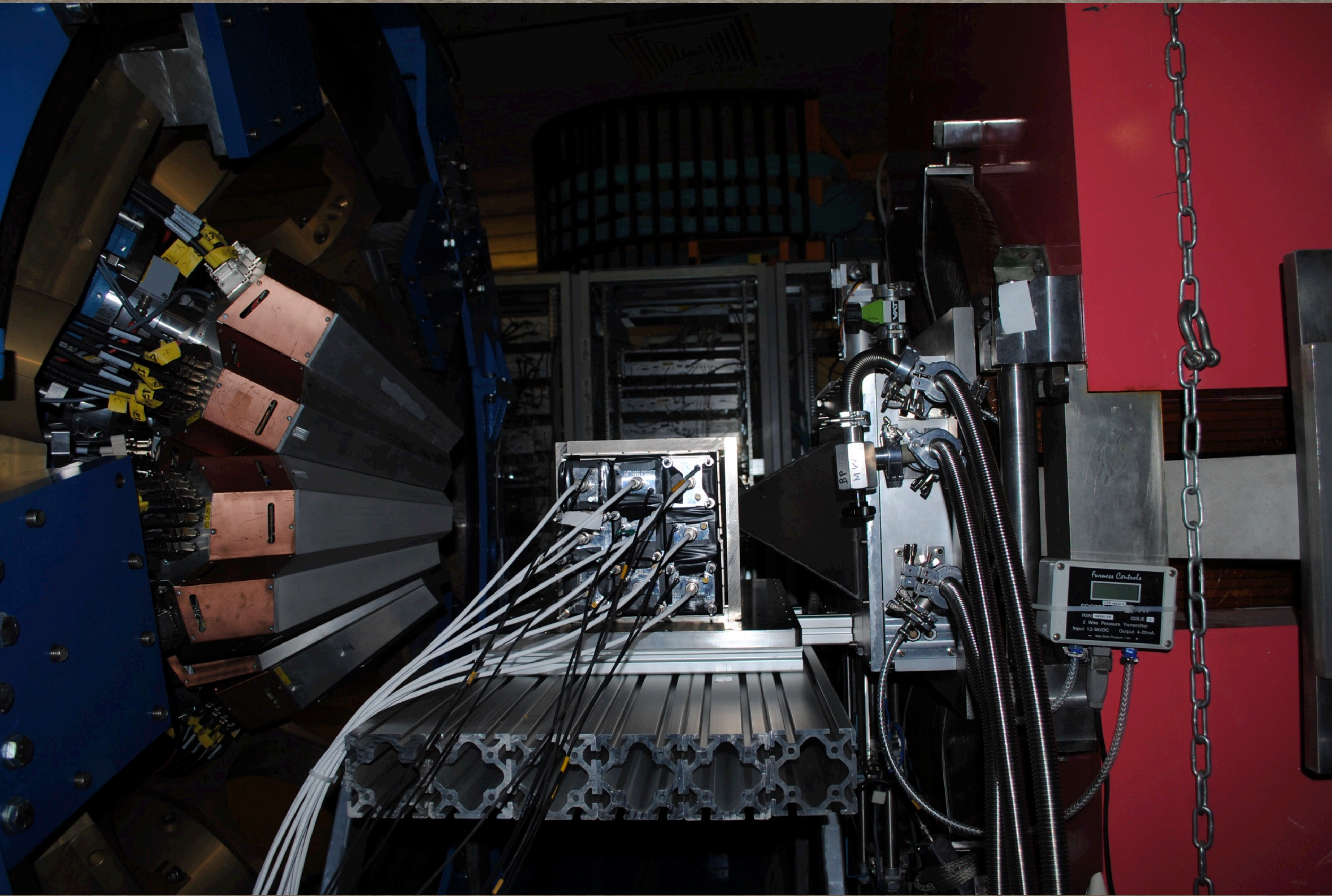
Designed and produced by IPN Orsay

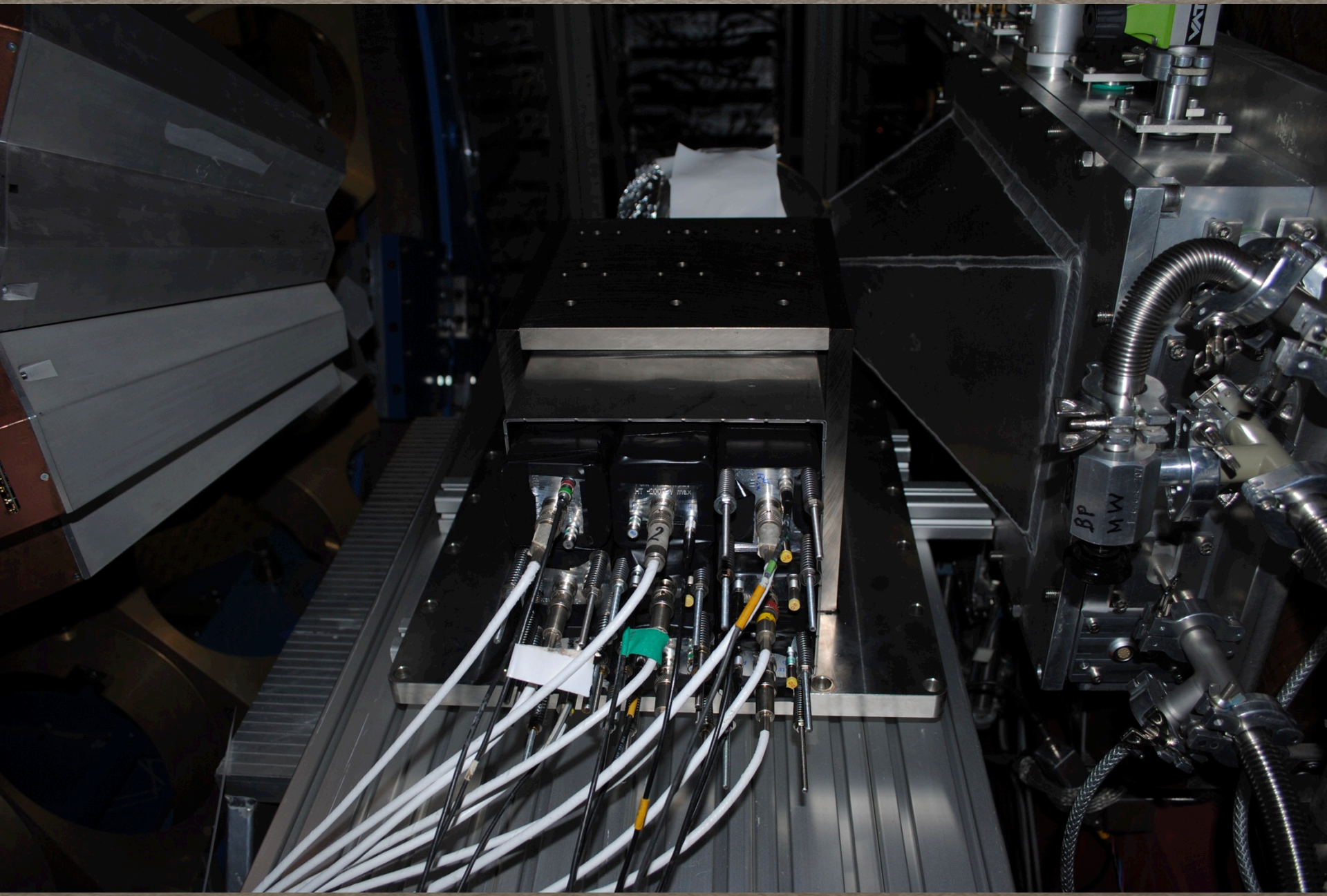
It will connected to EXOGAM frame (after test of magnetoc field influence_



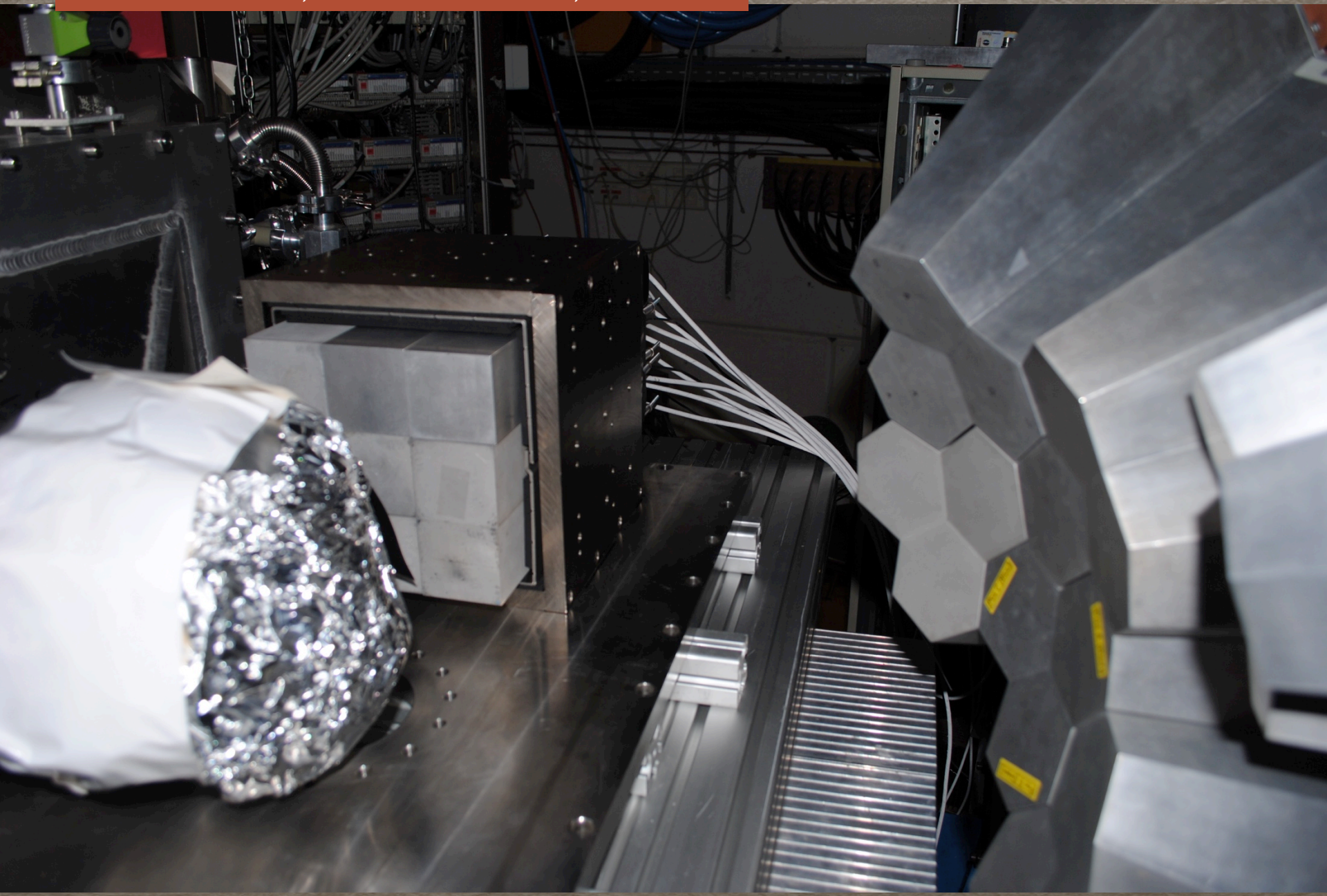
PARIS detector exposed to VAMOS magnetic field

M. Ciemała, O. Dorvaux, S. Kihel et al.

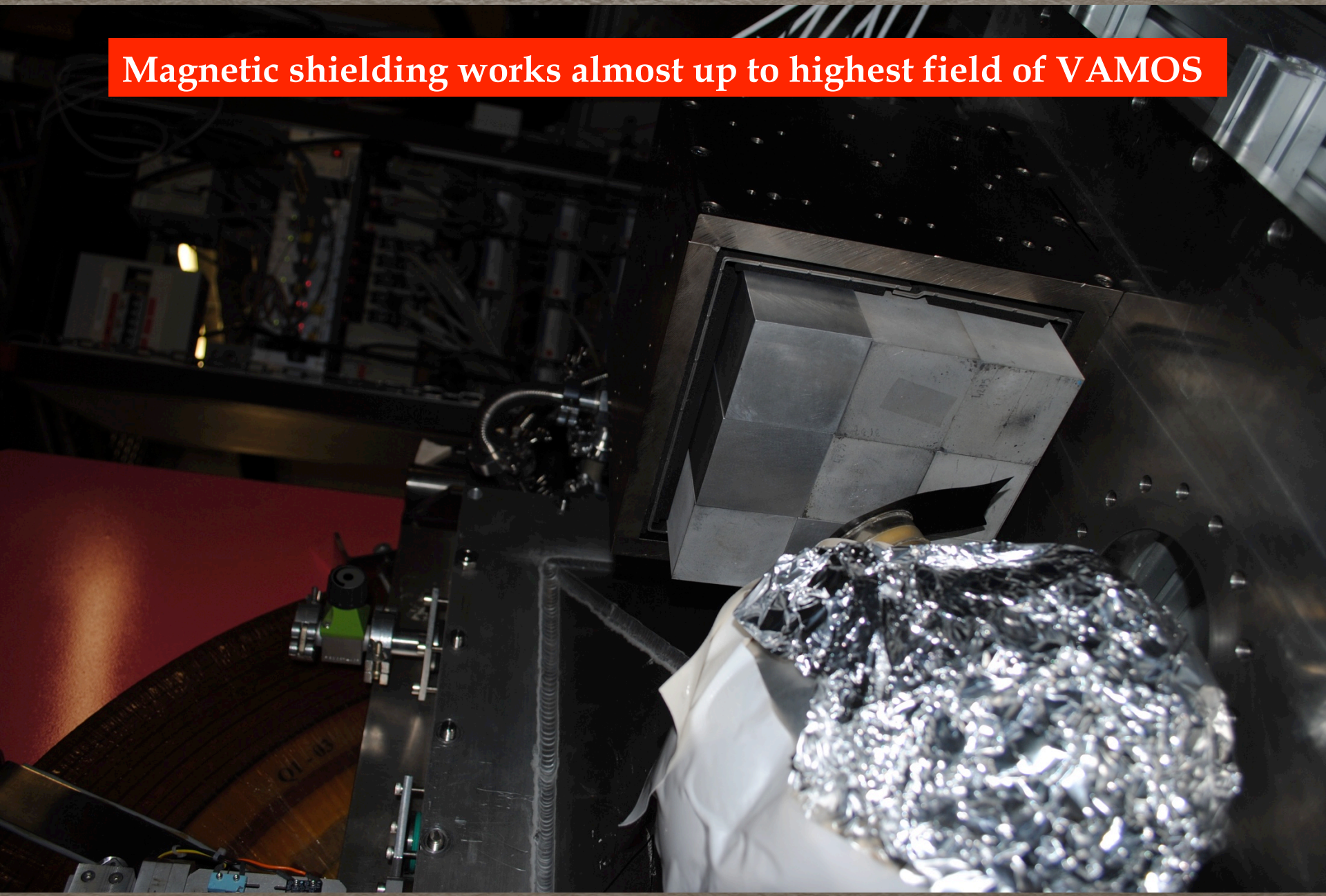

Furness Controls
RSN
ISSUE
2 Wire Pressure Transmitter
Input 12-36VDC Output 4-20mA


BP
MW

1 mm mu-metal, 1 mm aluminium, 1 cm iron



Magnetic shielding works almost up to highest field of VAMOS



Murphy law: If everything goes smoothly with PARIS…

Newest delay in delivery PARIS phoswich detectors !!!

Saint Gobain announced in January that the phoswiches produced recently by them are having problems with getting worse resolution after treatment. They decided to hold the production (and reparation of the old ones) until solution is found.

In the recent discussion with SG theuyoffer to make new phoswich, in which LaBr3 and NaI are hermetically sealed and separated by a thin light-guide.

Alternative solutions (2 separate detectors: LaBr3 with SiPM and NaI with PM) are under investigations.

There will be a delay in construction of the PARIS array.

PARIS construction time line

Within PARIS Demonstrator MoU

- **Presently PARIS has 17 phoswiches (5 of them are sent to SaintGobain for replacements/repair, be back probably mid 2015)**
- **>9 additional phoswiches were ordered (to be delivered probably in 2015/2016)**
- **End of 2016: probably 4 clusters; Analoque electronics PARIS-Pro implemented, mechanical integration to AGATA ready**
- **In 2016: NUMEXO2 electronics verified**

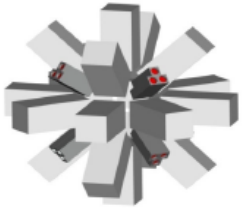
End of PARIS Demonstrator MoU

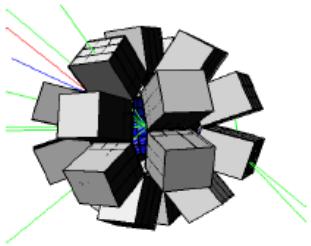
2016: New PARIS 2π MoU to be agreed and signed

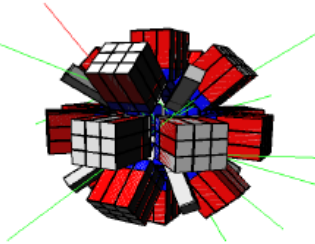
- **2018** (probably)**: 8 clusters**
- **2019:** (hopefully) **12 clusters (2π PARIS)**

And what about PARIS+GASPARD?

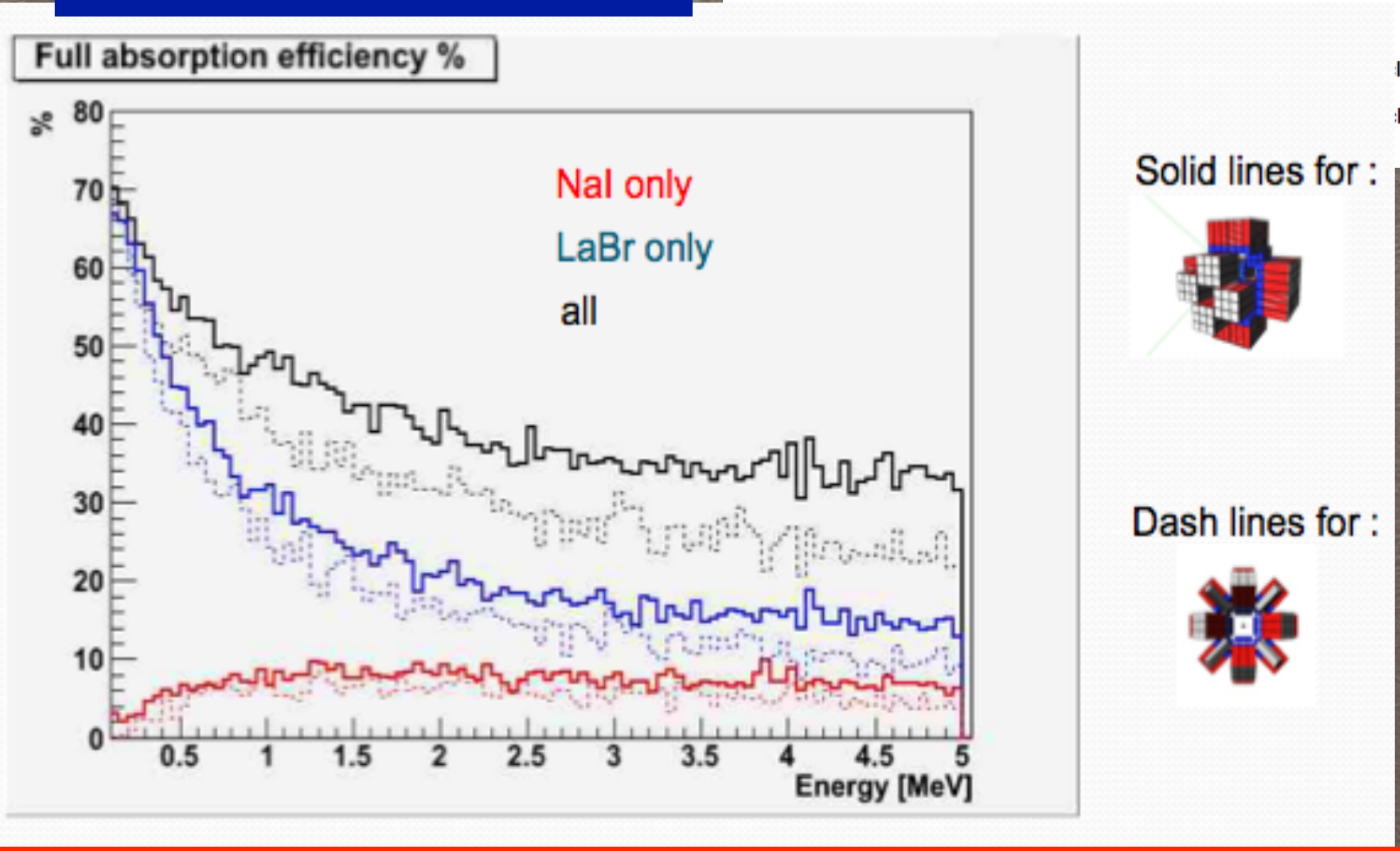
Simulations: Marc Labiche et al..







PARIS168
lusters + 6 phoswich
R = 208 mm
lusters in main ring)



Solid lines for :

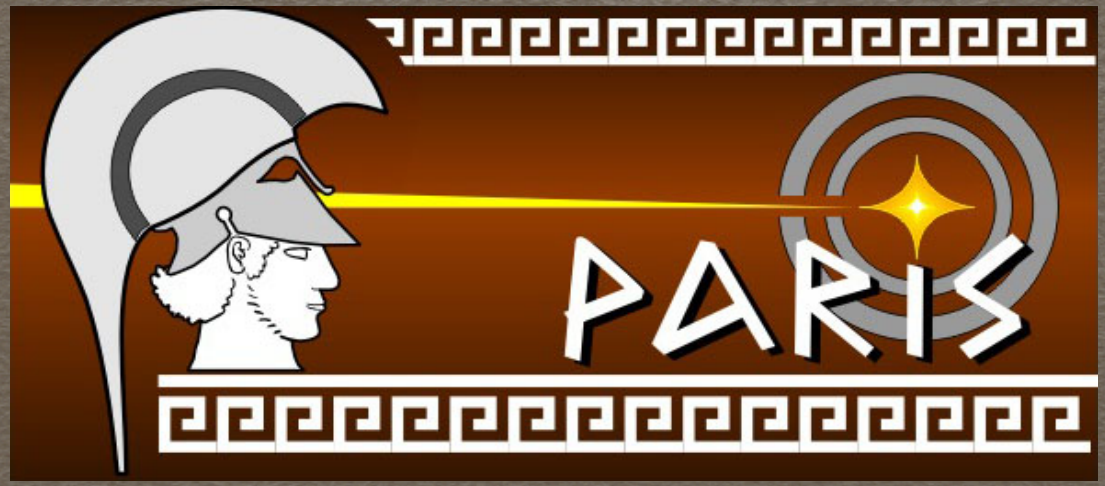
Dash lines for :

Time to prepare real proposals for GANIL/SPIRAL2, IPN Orsay or LNL Legnaro?

Summary

- LaBr3+NaI phoswich is a viable solution for the elements of the PARIS calorimeter, in terms of it meeting the requirements for energy and timing resolution
- Presently we explore the performance of a cluster of 9 phoswich detectors. Source and in-beam testing of this cluster were done recently.
- Holding structure with magnetic shield for 1 cluster done and being tested
- Electronics for AGATA experiments based on analoque PARIS-Pro + AGAVA, data stream via VAMOS branch
- The next phase will be to complete the PARIS Phase2 (Demonstrator) of 5 clusters, each of 9 phoswich detectors. ***(Some delays possible, due to the delays in delivery time of phoswiches)***
- First physics experiments are coming (AGATA@GANIL, IPNO Orsay, Krakow/Warsaw, LNL Legnaro) – *maybe with GASPARD?*

Thanks to: P. Bednarczyk, M. Kmiecik, B. Fornal, K. Mazurek, B. Wasilewska, M.Krzysiek, M.Zieblinski, M.Jastrzab, A. Czermak – IFJ PAN Krakow; F.Azaiez, I.Matea – IPN Orsay; O.Dorvaux, S. Kihel – IPHC Strasbourg; M.Ciemała. Ch. Schmitt – GANIL; D. Jenkins – York; M. Labiche – Daresbury; A.Bracco, S.Leoni, F.Camera, S.Brambilla, B.Million, O.Wieland, A. Giaz – Milano; P.Napiorkowski, K.Hadynska-Klęk – HIL Warsaw; V.Nanal, I.Mazumdar – TIFR Mumbai; and many others



PARIS technical meeting „**PARIS Weekend**”
Milano, April 23-24, 2015

The 5th International Conference on

"COLLECTIVE MOTION IN NUCLEI UNDER EXTREME CONDITIONS"

September 14–18, 2015 Kraków, Poland

14-18 September, 2015

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