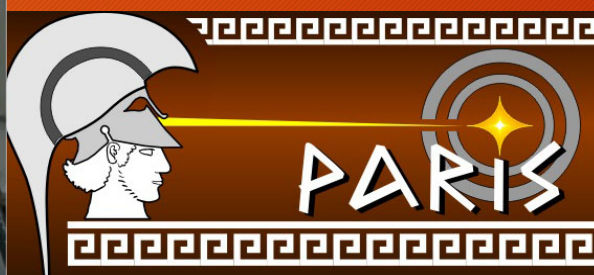




News from the PARIS Project Manager



Adam Maj
IFJ PAN Krakow
for the PARIS Collaboration

PARIS Collaboration Meeting
INFN Laboratori Nazionali di Legnaro
Aula Villi, 28-29 November 2019

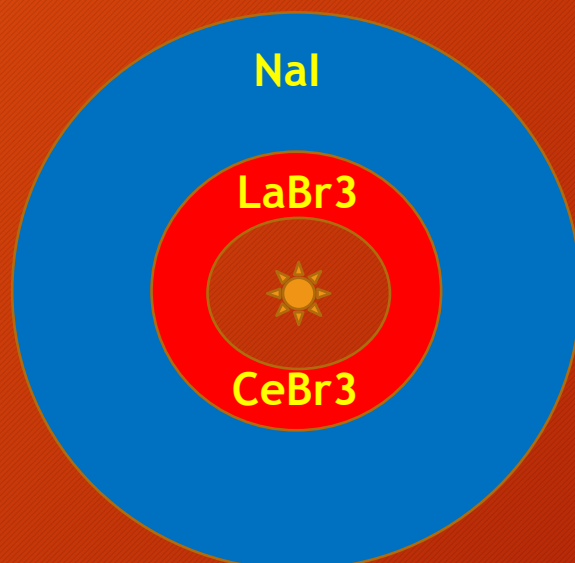
paris.ifj.edu.pl



PHOTON ARRAY FOR STUDIES WITH RADIOACTIVE ION AND STABLE BEAMS

PARIS design assumptions:

High efficiency ($\approx 4\pi$) gamma detector, based on new scintillation materials,
consisting of 2 shells
for medium resolution spectroscopy
and calorimetry of γ -rays in large energy range



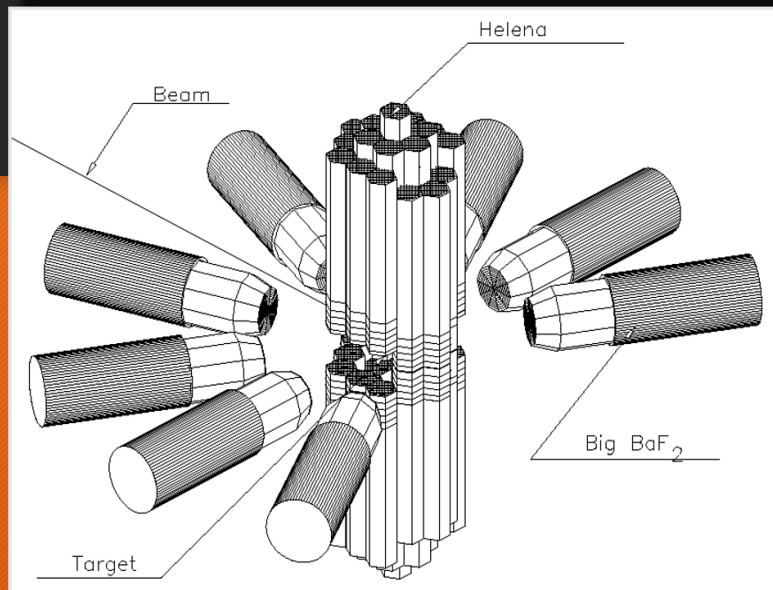
Inner sphere, highly granular, made of new crystals (LaBr3 or CeBr3), to be used as a gamma multiplicity filter, sum-energy detector (calorimeter), detector for the gamma-transition up to 10 MeV with medium energy resolution, fast timing.

Outer sphere, high volume conventional crystals (NaI), for high-energy photons, active shield for the inner shell.

2-shell 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

The idea of PARIS was developed jointly by physicists from Poland, France and Italy

Origin of the name **PARIS**



HECTOR+HELENA array, based on BaF₂ crystals
Successful series of experiments
In the **Milano-Krakow** -
(Copenhagen-Legnaro-
EUROBALL-RISING)
collaboration



PARIS main physics cases

HOT ROTATING NUCLEI

Jacobi and Poincare shape transitions (+AGATA)
Studies of shape phase diagrams of hot nuclei – GDR differential methods
Hot GDR in neutron-rich nuclei
Isospin mixing at finite temperatures
Links between GDR emission and SD/HD structure (+AGATA)
GDR and PDR built on isomeric states
Onset of chaotic regime (+AGATA)

A.Maj, J. Dudek, K. Mazurek, M. Kmiecik, A. Bracco, F. Camera, S. Leoni, I. Mazumdar, D.R. Chakrabarty, V. Nanal, M. Kicinska-Habior, M. Harakeh, P. Bednarczyk

COLLECTIVE MODES

PDR in neutron-rich and proton-rich nuclei (+GASPARD, NEDA)
Gamma -decay of GDR and GQR built on ground states

A.Bracco, A. Maj, D. Beaumel, I. Matea, F. Crespi, M. Kmiecik, M. Lewitowicz, M. Harakeh

REACTION MECHANISMS

Onset of multifragmentation and GDR (+FAZIA)
Reaction mechanism studied via gamma-rays
Heavy ion radiative capture
Nuclear astrophysics

J.P. Wieleczko, S. Santonocito, Ch. Schmitt, O. Dorvaux, S. Courting, D.G. Jenkins, S. Harissopulos

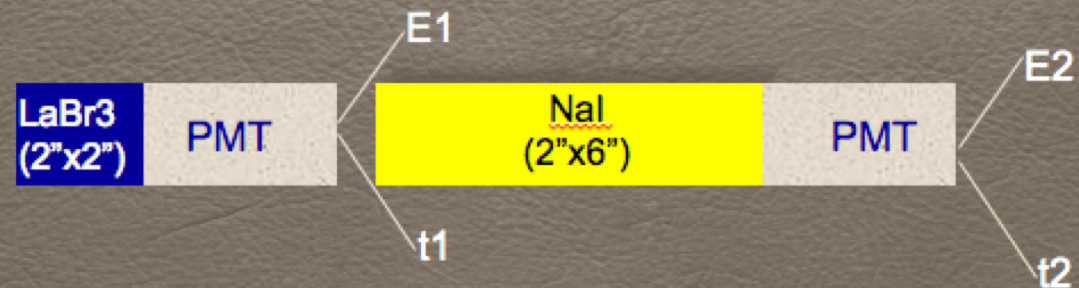
SHELL STRUCTURE

Multiple Coulex of SD bands in light nuclei
Relativistic coulex
Shell structure at intermediate energies (+LISE, S3, ACTAR)
Near barrier resonances

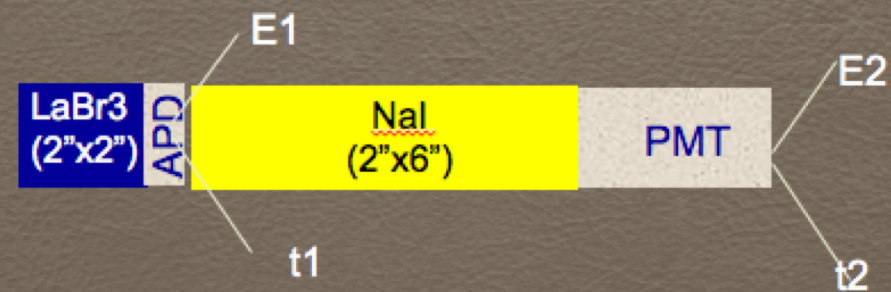
F. Azaiez, J. Stephan, B. Fornal, S. Leoni, P. Napiorkowski, P. Bednarczyk, A. Maj, Z. Dombradi, G. Grinyer, M. Ploszajczak

3 POSSIBILITIES FOR A „GAMMA-TELESCOPE” ELEMENT

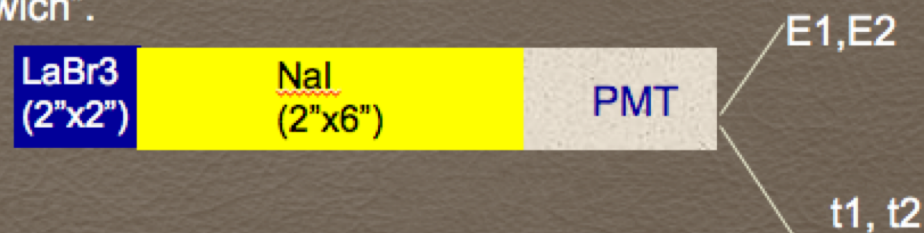
Possibility 1.



Possibility 2.

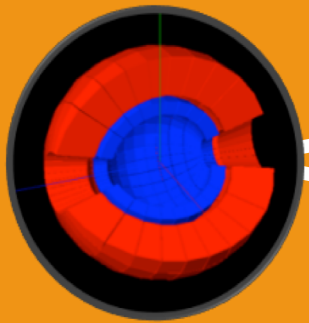


Possibility 3 – „phoswich”.

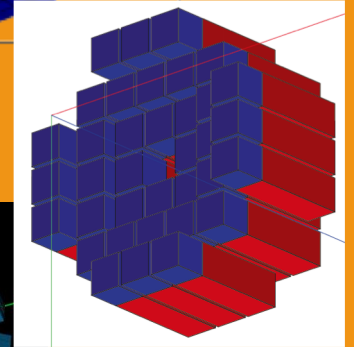
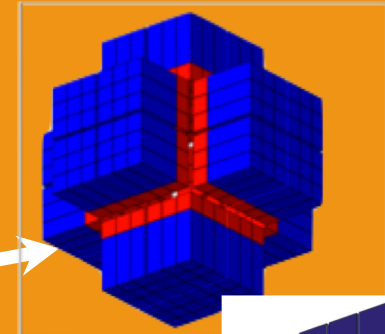
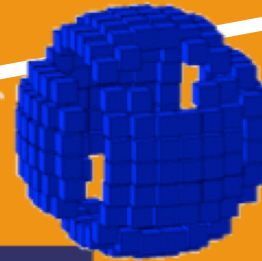
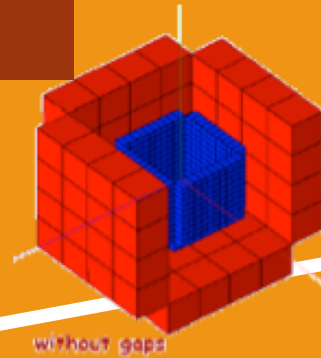


Several geometries studied

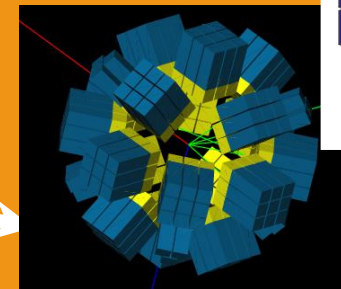
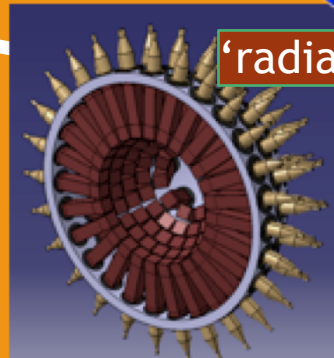
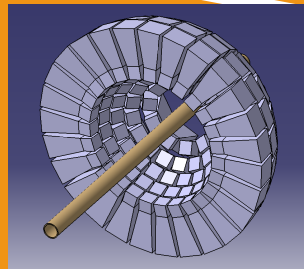
'Ideal' - spherical



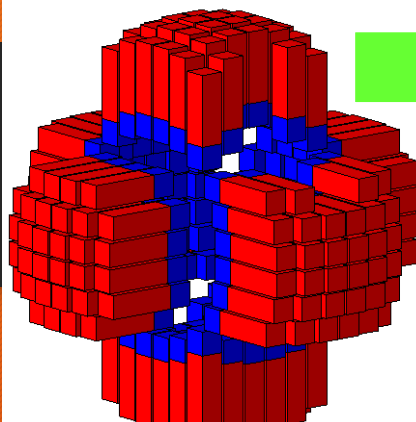
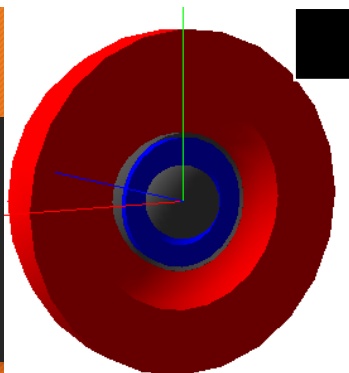
'cubic'-like



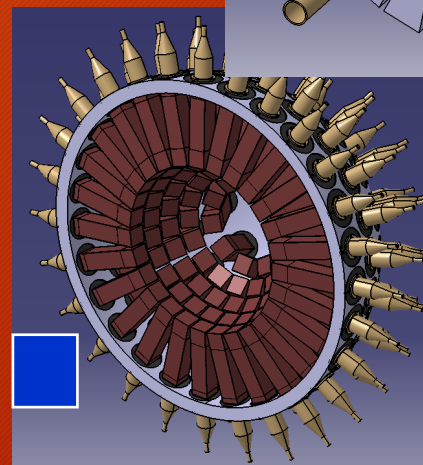
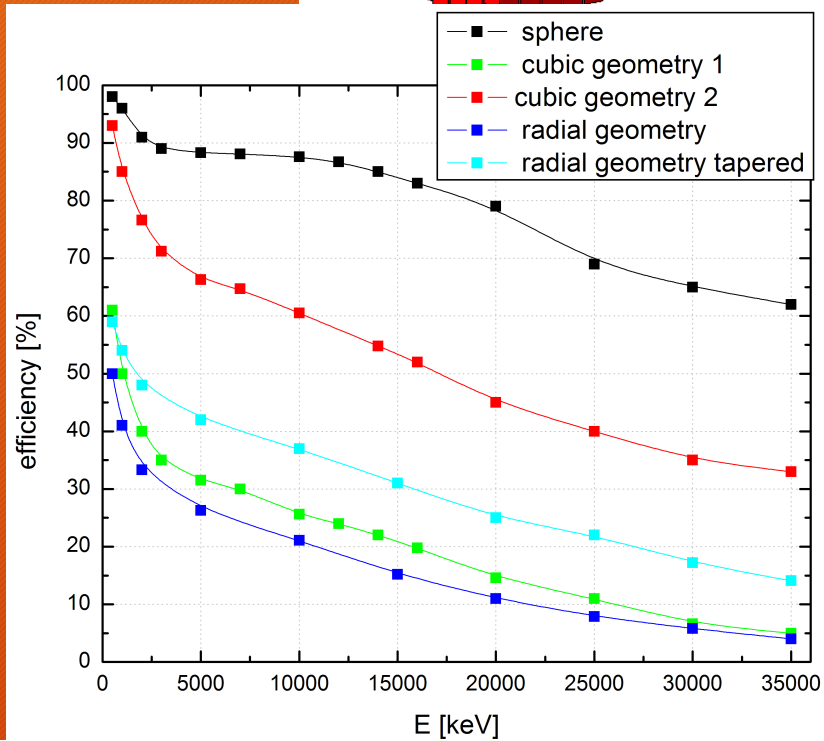
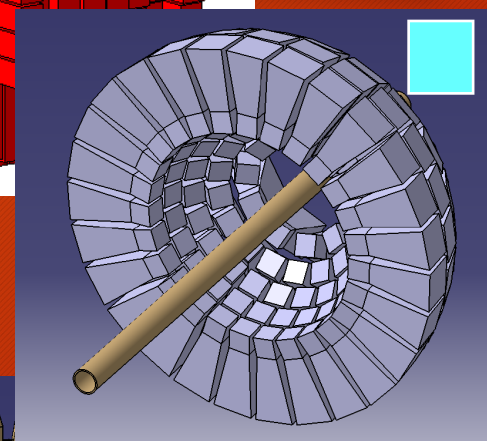
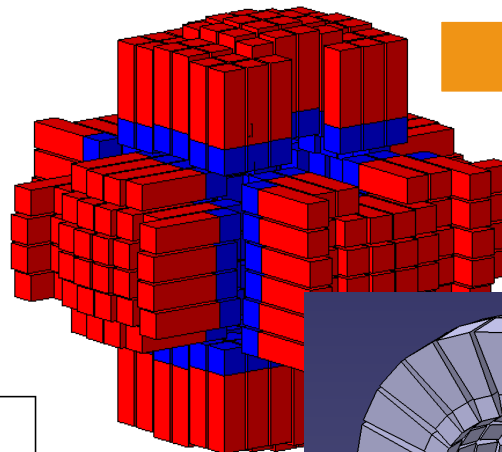
'radial'-like



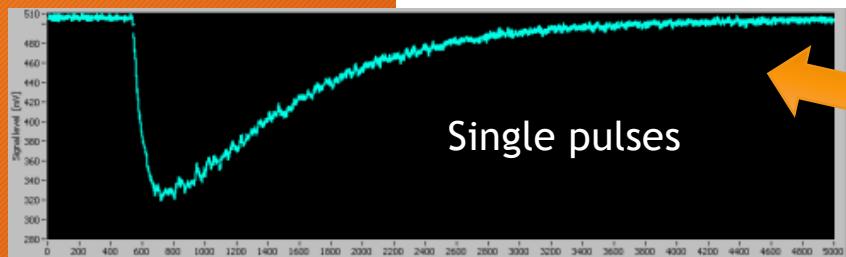
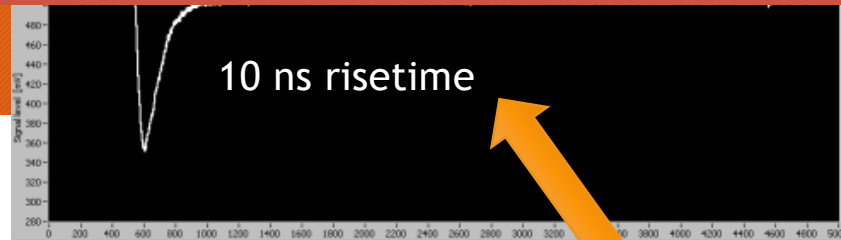
PARIS to be made of rectangular phoswiches
Arranged in clusters (9 phoswiches each)
This allows *cubic*, *wall* or *semi-spherical*
geometry with 24 clusters (216 phoswiches)



Cubic vs. Radial geometry



Phoswich tests

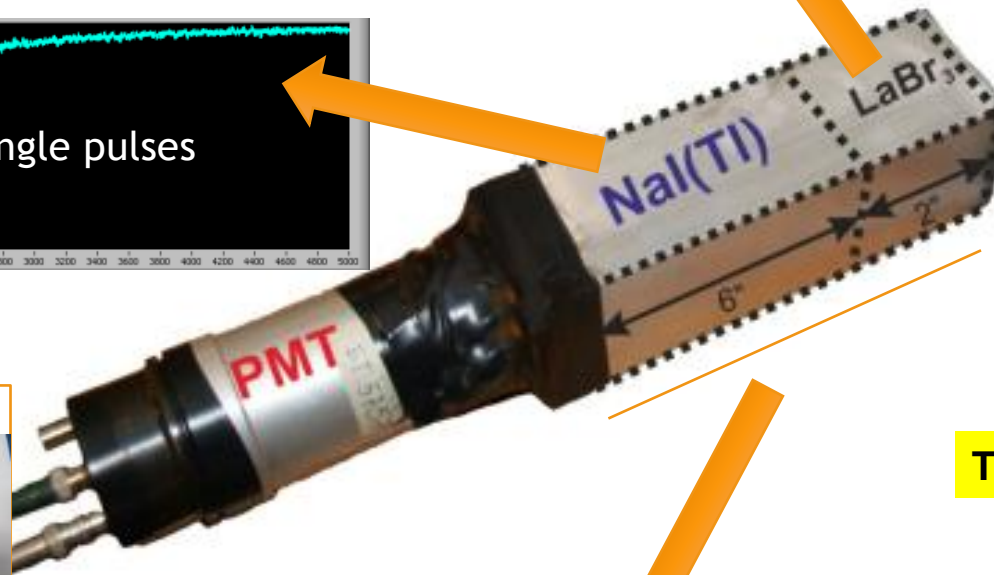


HAMAMATSU

Photomultiplier
Tube 光電子増倍管

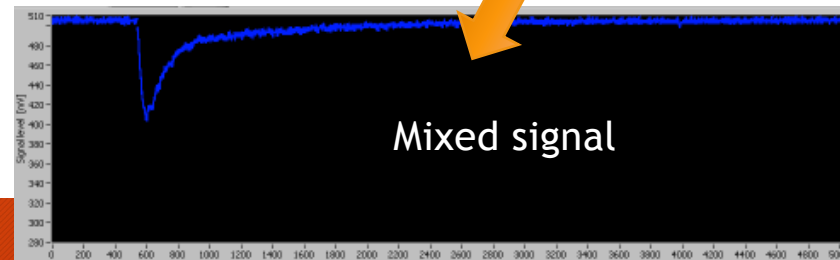
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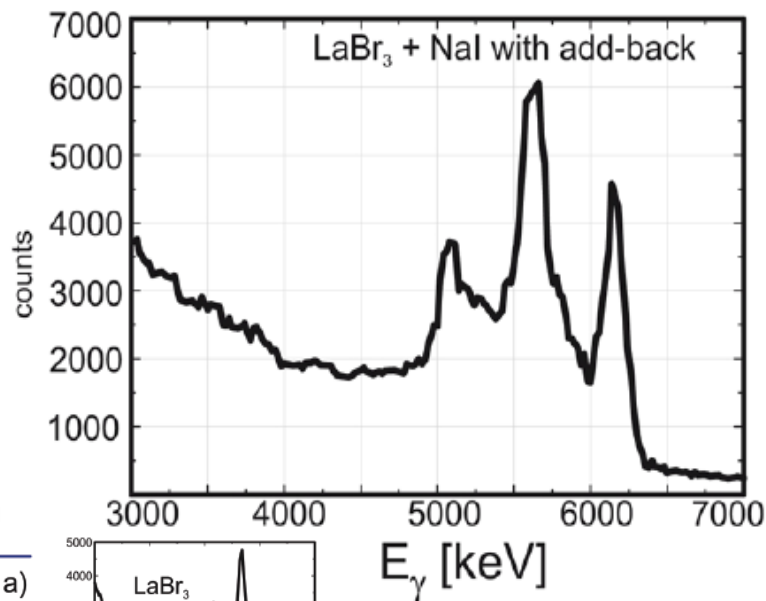
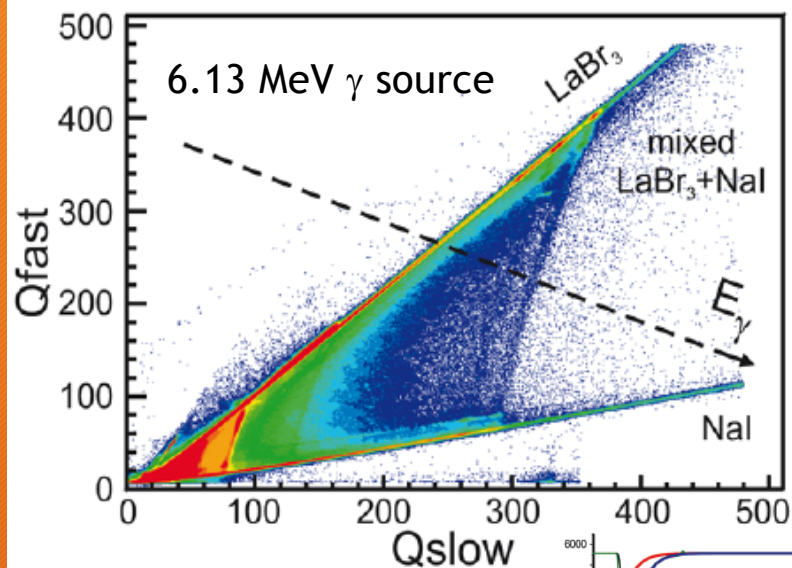
浜松ホトニクス株式会社



LaBr₃ or CeBr₃

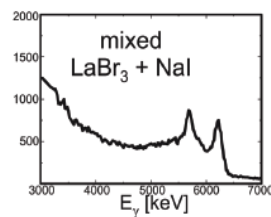
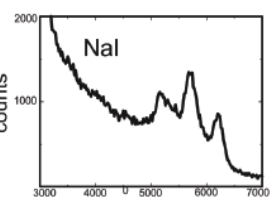
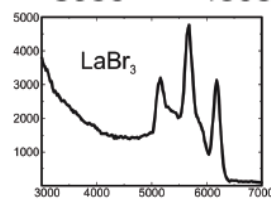
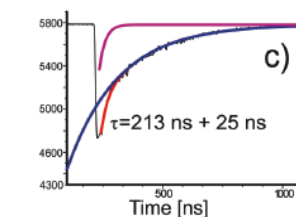
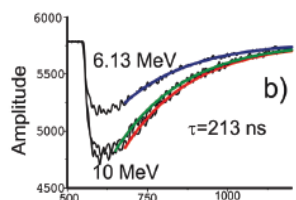
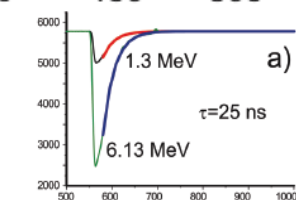
The PARIS PHOSWICH at work





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

- Sources
- proton beam



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

The phoswich concept works !

**Other tests:
Strasbourg, Orsay,
Milano, Warsaw,
Mumbai**

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

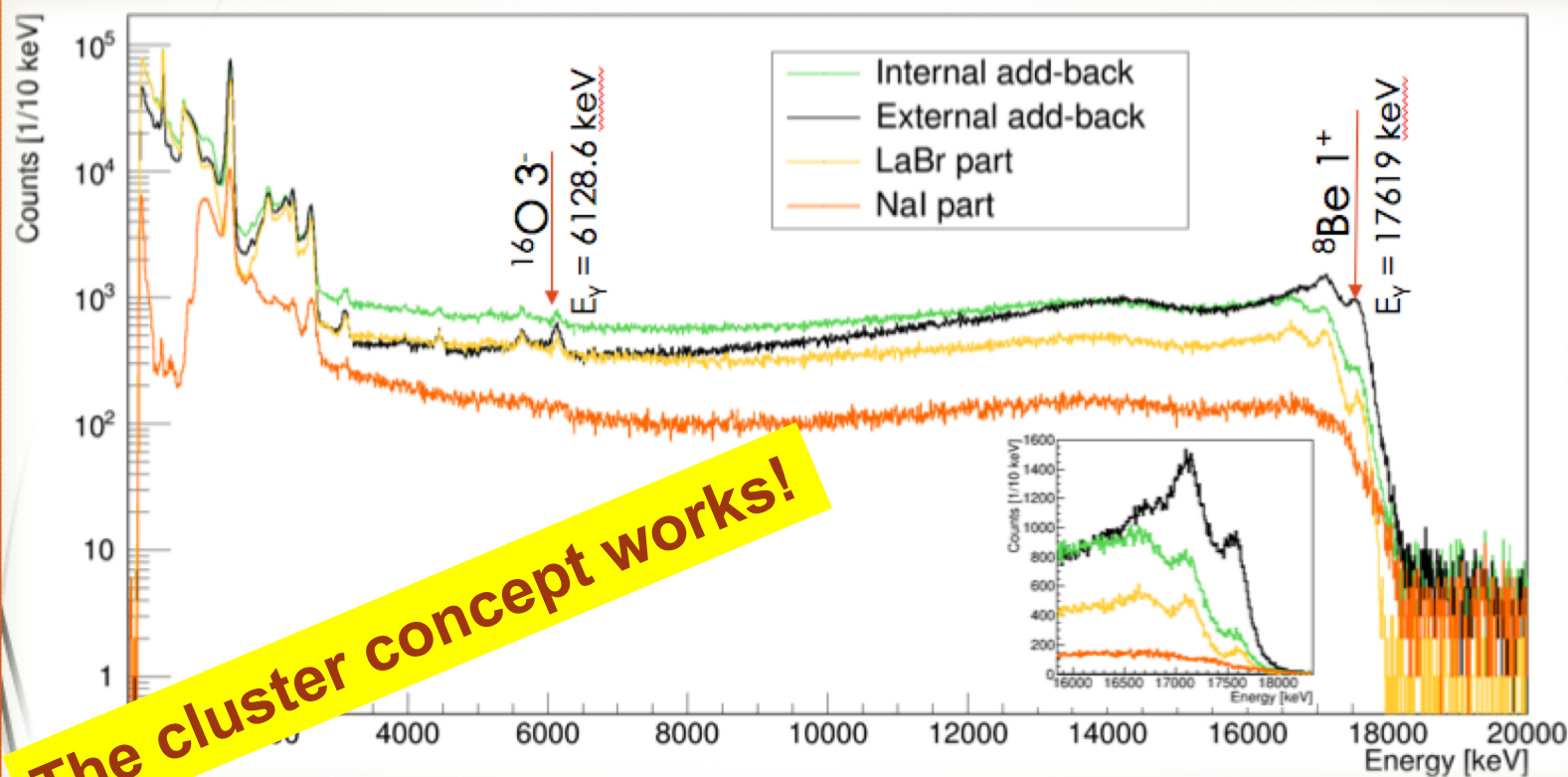
First PARIS cluster



Cluster tests were performed in
IPHC Strasbourg, IPN Orsay, IFJ PAN Krakow, TIFR Mumbai,
ELBE Rosendorf, INFN Milano, ATOMKI Debrecen
using sources and beams

Cf. talk by O. Dorvaux

Exp. in ATOMKI Debrecen – March 2017
(p,gamma) – reaction on LiBO target
Testing **PARIS cluster add-back** with high-energy gamma-rays



B. Wasilewska et al.,
paper in preparation



Status

PARIS Organization

Cf. talk by B. Fornal

PARIS Steering Committee

- IN2P3 France: F. Farget, O. Dorvaux
- GANIL France: M. Lewitowicz
- COPIN Poland: B. Fornal (dep.chair)
- India: V. Nanal (chair)
- Italy: A. Bracco
- Romania: M. Stanoiu
- UK: W. Catford
- Turkey: S. Erturk
- **Dubna: Y. Pienionzkievich**
- **GSI: J. Gerl**

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)

Data analysis: S. Leoni (Milano)

New materials: F. Camera (Milano)

New Physics case: I. Mazumdar (Mumbai)

PARIS Management Board:

PARIS Project Manager + WG coordinators

PARIS Project Manager

(nominated by PSC)

A. Maj (Poland)

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)

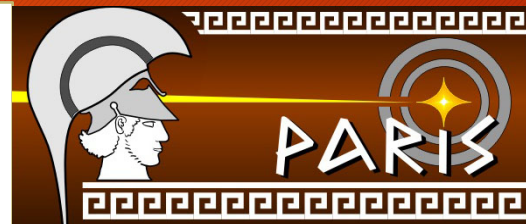
Mihai Stanoiu (IFIN-HH Bucharest, Romania)

Jonathan Wilson (IPN Orsay, France)

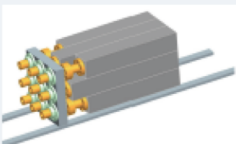
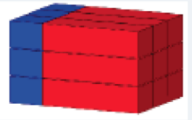
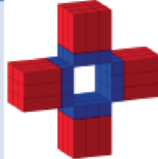
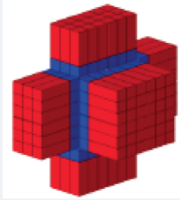
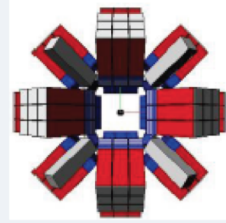
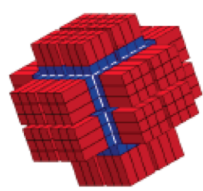
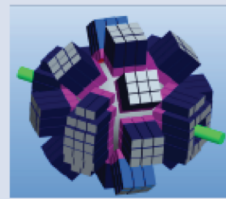
New chair (2018-2020)
Franco Camera (Milano)

PARIS Demonstrator MoU (2011-2015...) 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), 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 2017 PARIS Demonstrator	4 clusters: 36 phoswiches			1100 k€	Only if Phase1 validated Funds: MoU Ph1Day1 exp@S
Phase 3 2022 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 2025? PARIS 4π	≥24 clusters: ≥216 phoswiches			≈ 4 M€	Only if Phase3 validated Funds: PARIS consortium Regular experimer in various labs

IPN Orsay
·
AGATA@GANIL
·
S3@GANIL
·
CCB Krakow
·
LNL/SPES
·
SPIRAL2 phase2
·

By November 2018 PARIS collaboration had 4 clusters:

3 LaBr₃_NaI clusters (produced by Saint Gobain)

1 CeBr₃_NaI cluster (produced by Scionix)

So the goal of the original MoU on PARIS Demonstrator was achieved

Recently PSC decided to extend the PARIS Demonstrator MoU until 2021

with the goal to reach at least 8 clusters (33% of 4π)

Total cost: ≈ 1.9 M€

New partners:

JINR Dubna and GSI

The extension of the MoU was already signed by all partners

Next steps

Presently PARIS collaboration possesses 5 clusters

New orders for 2019/2020:

GANIL: 5 phoswiches

IN2P3: 6 phoswiches

Poland: 2 phoswiches

Italy: 6 phoswiches

Dubna: 1 phoswich

India: ?

So we will have at least 7 clusters by the end of 2020.



First experiments

First experimental results



GANIL (France)

Performed:

- S. Leoni, B. Fornal, M. Ciemala et al., "Lifetimes in A=18 region measured with PARIS", (PARIS: 2 clusters + 2 large LaBr3), AGATA, VAMOS, Plunger (July 2017) *Cf. talk by S. Ziliani*

Accepted, but not yet performed:

- P. Bednarczyk, A. Maj et al., "Investigation of a high spin structure in ^{44}Ti via discrete and continuum γ -spectroscopy with AGATA, PARIS (4 clusters) and DIAMANT"
- B. Fornal, S. Leoni, M. Ciemala et al., "Gamma decay from near-threshold states in ^{14}C : a probe of clusterization phenomena in open quantum systems" (AGATA, PARIS, NEDA, DIAMANT, DSSD)
- R. Lica, O. Sorlin et al., "Study of deformed and spherical 2^+ states via Coulomb excitation and first time measurement of PDR in ^{34}Si " (LISE-PARIS-EXOAM2) *Cf. talk by M. Stanoiu*
- Ch. Schmidt, M. Lewitowicz et al., "PARIS for study of fission at VAMOS" *Cf. talk by M. Lewitowicz*

Under discussion:

Combining PARIS to AGATA

First experimental results



IFJ PAN Krakow (Poland)

Performed:

- M. Kmiecik, F. Crespi, B. Wasilewska et al. „Studies of resonance states in nuclei using high-energy proton beam in p,p' reactions at forward angles with HECTOR, PARIS, KRATTA (2017, 2018, 2019 and to be continued in 2020)

*Cf. talks by M. Kmiecik
and B. Wasilewska*

Accepted and ongoing:

- S. Leoni, B. Fornal, N. Cieplicka et al., „Study of M4 resonance decay in ^{13}C ”
Cf. talk by N. Cieplicka
- A. Bracco, B. Fornal „Investigations of (p,2p) reactions in order to identify deep single-particle proton-hole states”: HECTOR, PARIS, KRATTA
- Ch. Schmidt, D. Mancusi, B. Kamys et al., „Investigation of proton induced spallation with HECTOR, PARIS, KRATTA”

First experimental results



ALTO IPN Orsay (France)

Performed:

- I. Matea, J. Wilson, M. Ciemala et al. „PARIS cluster response to fast neutrons”
- E. Kozulin, I. Harca, E. Vardaci et al. “Prompt γ -rays as a probe of nuclear dynamics” (2017)
- M. Lebois, Q. Liqiang et al. “Prompt gamma and neutron emission for ^{238}U fast neutron induced fission as a function of incident neutron energy” (2017)
- M. Kmiecik, F. Crespi, J. Wilson et al., „Feeding of low-energy structures in ^{188}Pt of different deformations by the GDR decay: the nuBall array coupled to PARIS” (June 2018)

Cf. talk by M. Ciemala

- I. Matea et al., „PDR studies in very neutron rich nuclei around $N=50$ shell closure through beta-decay” (2019)

Cf. talk by I. Matea

Accepted:

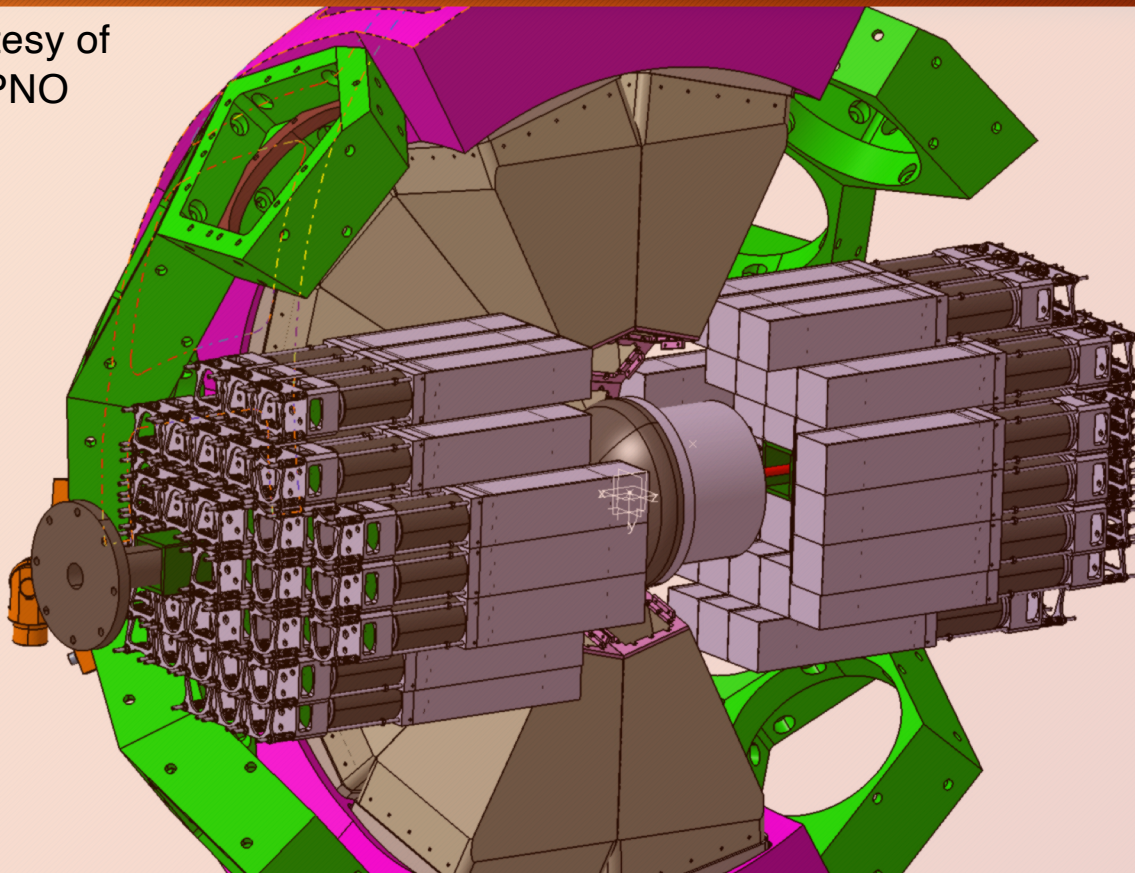
- P.J. Napiorkowski et al., „Coulomb excitation of super-deformed band in ^{40}Ca ” (2019)
- M. Babo, A. Gottardo et al., “ ^{81}Zn ground-state spin determination from pandemonium free beta-delayed spectroscopy of ^{81}Ga ” (2019)
- A. Oberstedt, “Measurement of prompt gamma ray spectra from the reaction $^{233}\text{U}(n,f)$ ” (2019)



Perspectives

nuBall2 campaign: possibility to couple 72 PARIS detectors

Drawings: courtesy of
C. Legalliard, IPNO



Cf. talk by J. Wilson

AGATA@LNL (2022?) - call for Lols to be presented March 25-26, 2019

Preliminary list of Lols AGATA+PARIS in LNL:

*Cf. talks by F. Camera
and by G. Gosta*

- Measurement of Isospin Mixing (F. Camera et al.,)
- GDR feeding of SD states (G. Benzoni)
- Gamma and Particle Decay of Giant Resonances Excited by Inelastic Scattering of 170 ions at 20 MeV/A (F. Crespi et al.)
- Onset of collectivization/clusterization in Oxygen neutron-nuclei (S. Leoni, B. Fornal et al.)

ITALY

- Lifetime measurements of excited states in neutron-rich C isotopes: a test of the three-body forces (M. Ciemala, B. Fornal, S. Leoni et al.)
- The search for Jacobi shape transitions in hot rotating nuclei from the Mo-Ba region (M. Kmiecik, A. Maj et al.)
- Study on single-particle structure of pygmy dipole resonance (M. Krzysiek et al.)
- Investigation of a high spin structure in the vicinity of ^{44}Ti via discrete and continuum γ -spectroscopy with AGATA+EUCLIDES+RFD and PARIS detectors (P. Bednarczyk et al.)

POLAND

Cf. talk by M. Matejska-Minda

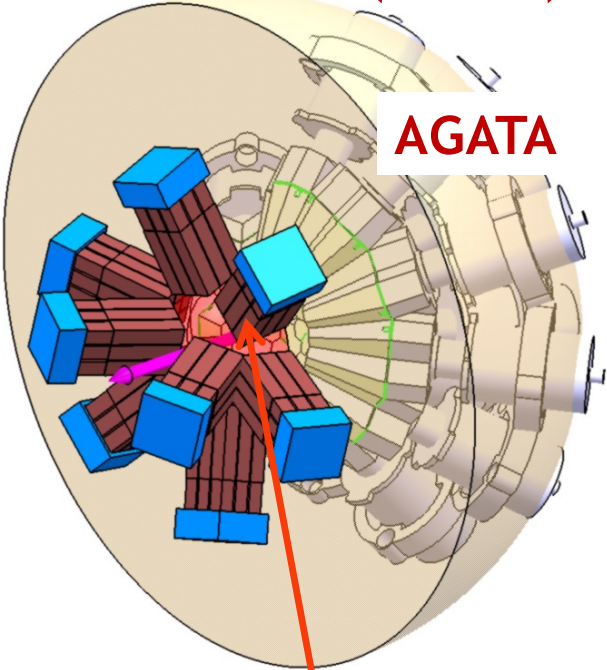
- Coulomb excitation of the super-deformed structures in $A \sim 40$ mass region (AGATA+SPIDER+PARIS) (K. Hadynska-Klek et al.)
- Study of the isovector giant dipole resonance in hot superheavy nuclei (M. Vanderbrouck et al.)

FRANCE

Further experimental cases at SPES, also using PARIS-ACTAR

Cf. talk by A. Mentana

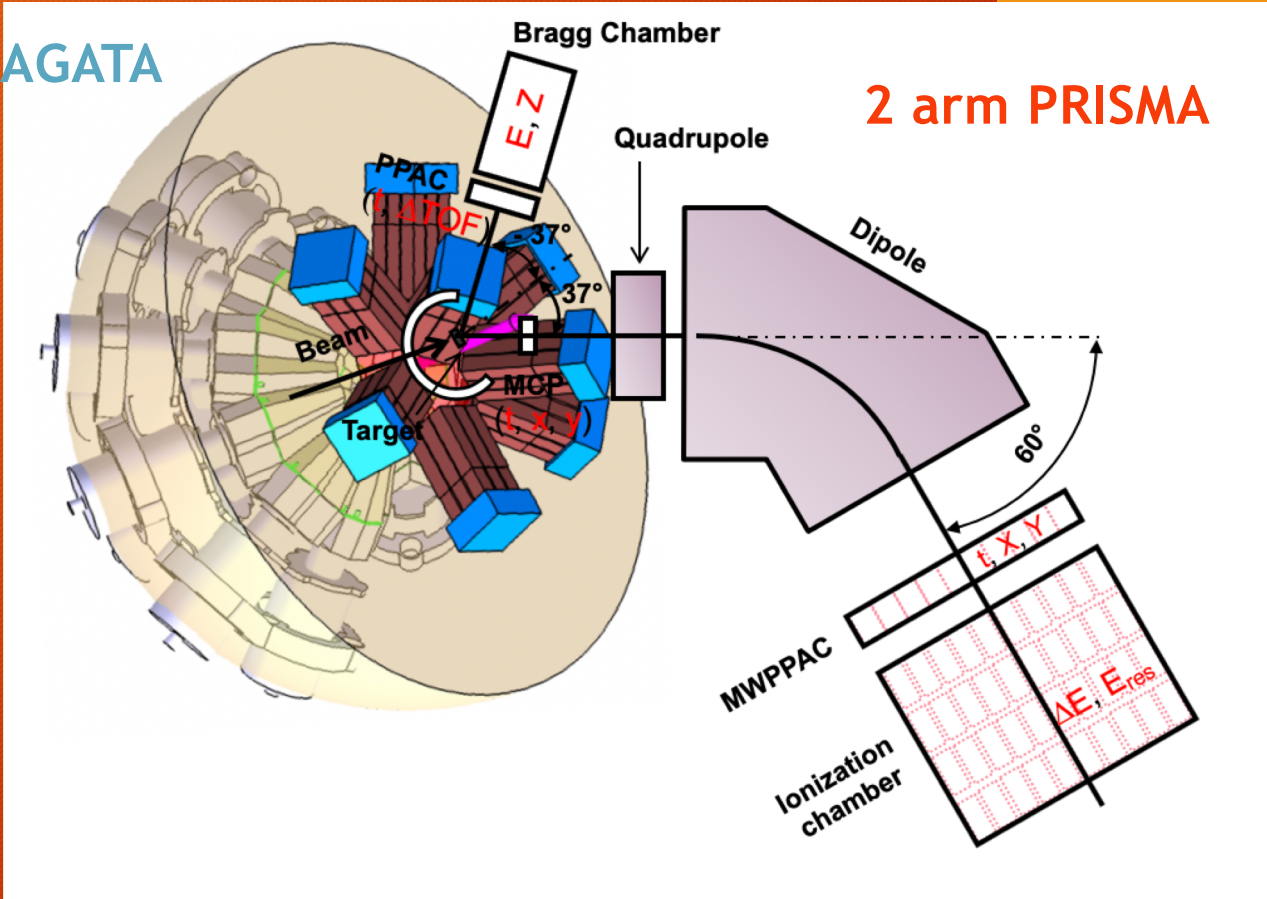
PARIS + HECTOR+ (+CLYC)



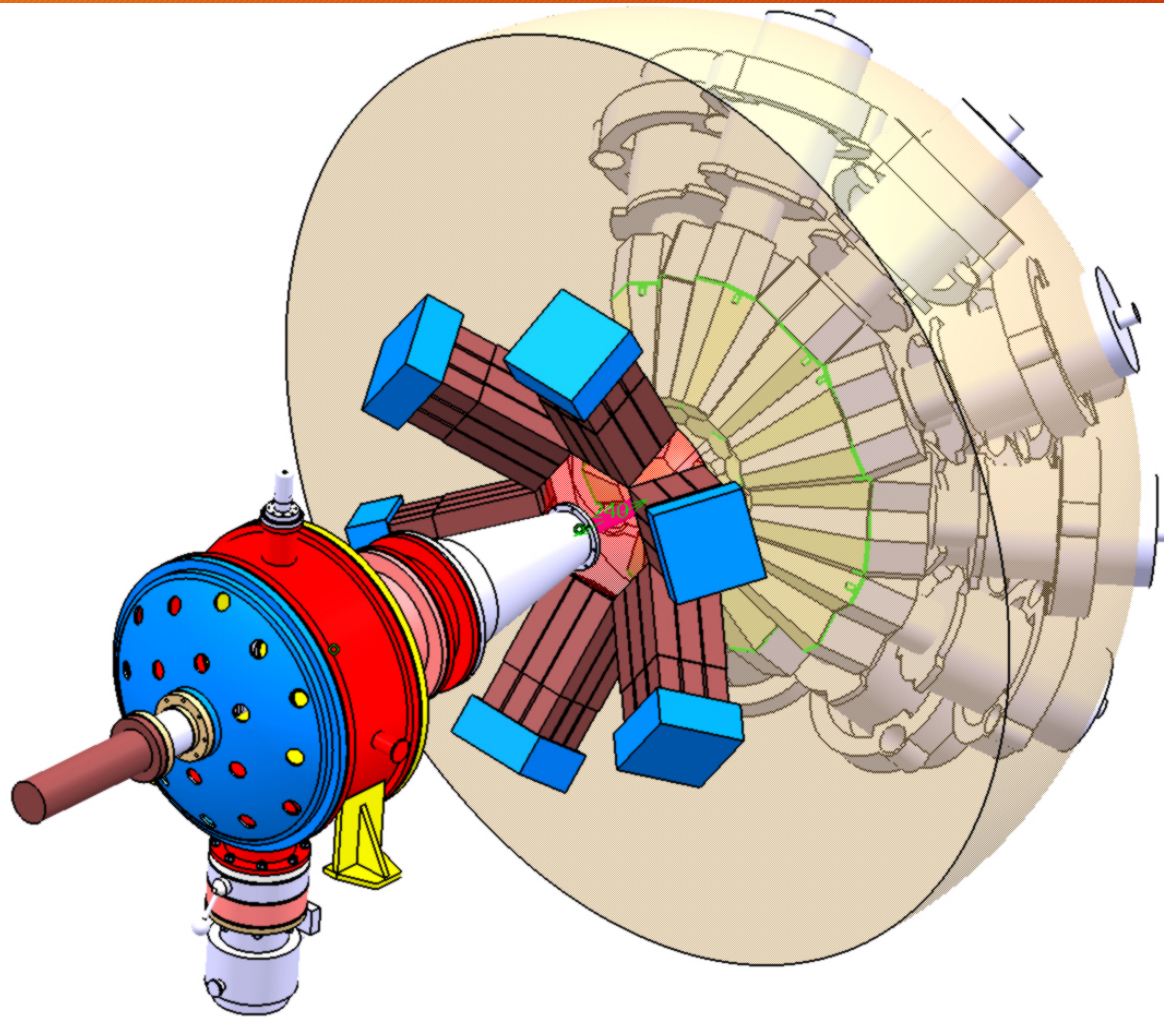
AGATA

EUCLIDES or TRACE

PARIS + LaBr₃



AGATA+PARIS + HECTOR+ RFD





Perspectives for a **PARIS** campaign in **HISPEC/DESPEC@FAIR** (2023...)

Cf. talk by J. Gerl



Perspectives for a **PARIS** campaign in **Warsaw Heavy Ion Laboratory** (2023...)

*Cf. talks by P. Napiorkowski
and K. Hadynska-Klek*

Perspectives for a **PARIS** campaign in **India** (2023...)

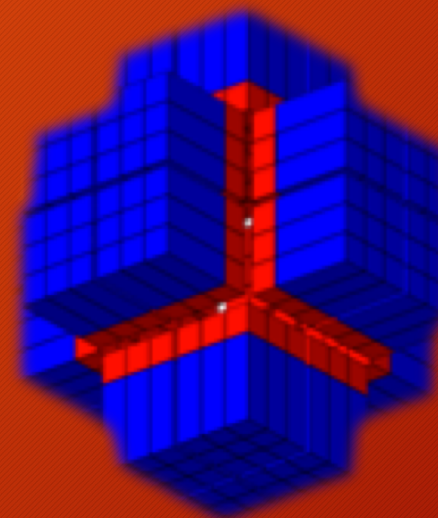
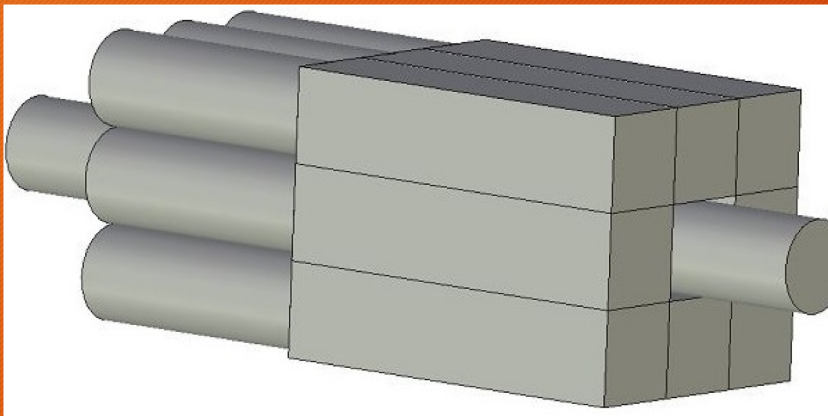
*Cf. talks by R. Palit
and M. Supriya*

PLANS for JINR DUBNA

E.g.
EXPERIMENTAL STUDIES OF TOTAL REACTION CROSS-SECTIONS for
REACTIONS with EXOTIC BEAMS (e.f. ${}^6,{}^8\text{He}$ and ${}^9,{}^{11}\text{Li}$)
Y. Pienionzkievich, Y. Sobolev et al.



PARIS as a gamma calorimeter*



*) Under financial support by grant of
Plenipotentiary of the Government of the Poland Republic to JINR
(Project leaders: Yu. Pienionzkievich, A. Maj)

P. Bednarczyk, S. Brambilla, O. Dorvaux, M. Jastrzab, A. Czermak, P. Napiorkowski

Options of electronics for PARIS

1) **NUMEXO2** - a general-purpose digital card for GANIL based experiments (collaboration with **EXOAM2** 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.):

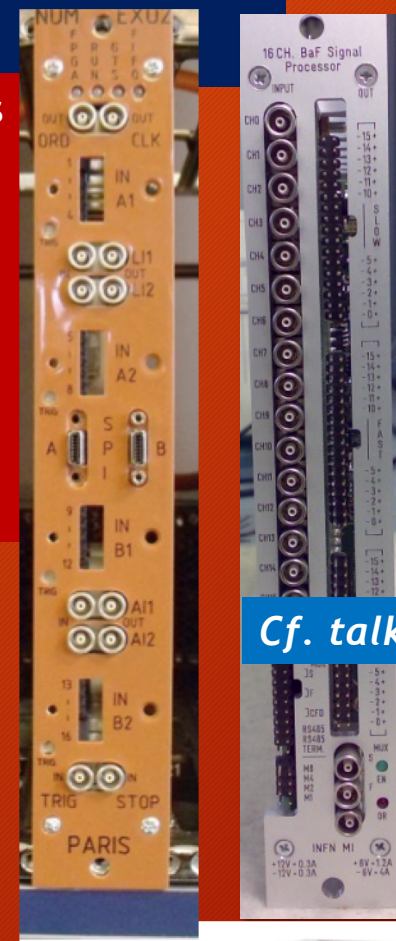
Already tested in AGATA LNL and GSU campaigns!

**Will be used for first experiments with AGATA.
(integrated to the VAMOS branch)**

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

Tested in Krakow, July 2015 - works very well (good time resolution, time resolution - 0.7ns, low deadtime)

4) **Occasionally other local digitizers** (e.g. FASTER in IPN Orsay)



Cf. talk by P. Bendarczyk



Publications, Master thesis, Ph.D. Thesis

- A. Maj et al., The Paris Project, Acta Physica Polonica B 40 (2009) 565,
- C. Ghosh, V. Nanal, :Characterization of PARIS LaBr₃(Ce)-NaI(Tl) phoswich detectors up to Egamma~22 MeV,” Journal of Instrumentation 11 (2016)
- B. Wasilewska, M. Kmiecik, A. Maj et al., „The First Results from Studies of Gamma Decay of Proton-induced Excitations at the CCB Facility:, Acta Phys. Pol. B48, 635 (2017)
- B. Wasilewska et al. Acta Phys. Pol. 2019 (in print)
- B. Dey, C Ghosh, S. Pal, V Nanal, R.G. Pillay, K.V. Anoop, M.S. Pose, „Neutron response of PARIS phoswich detector”, arXiv:1708.06346, to appear in Advanced detectors for Nuclear, High energy and Astroparticle physics (Springer Nature Singapore Pvt Ltd, 2018)
- Q. Liqiang et al. (exp, in Orsay), submitted,
- I. Harca et al. (exp. In Orsay), in final stage of preparation
- B. Wasilewska (ELBE treests), in final stage of preparation
- B. Wasilewska et al., (ATOMKI tests), to be prepared
- M. Ciemala, I. Matea, J. Wilson (test of PARIS at Licorne), in preparation

Ph.D's:

- C. Ghosh (2017), TIFR
- A.Mentana (2018), Milano, delivered
- B. Wasilewska, PhD Krakow, 2018
- Q. Liqiang (2018?) IPN Orsay

SUMMARY

paris.ifj.edu.pl

The concepts of PARIS phoswich (LaBr_3+NaI , CeBr_3+NaI) and PARIS cluster of 9 phoswiches, were proved to work according to expectations based on simulations

Results from the first PARIS experiments done in GANIL, IPN Orsay and CCB at IFJ PAN Krakow, are coming and are promising

PARIS, either standalone or coupled to other detectors, performs well

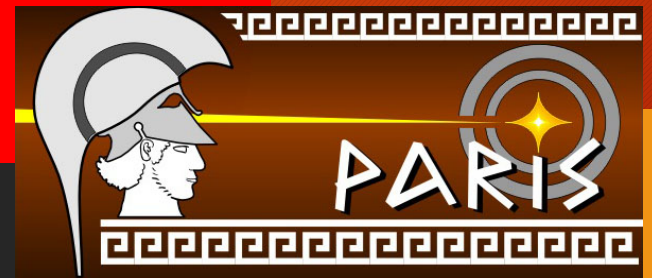
At present PARIS possesses 5 clusters. Extension of the MoU till 2021 (at least 8 clusters) is signed by all the partners

GSI (HISPEC/DESPEC) and JINR Dubna are parties in the new MoU

PARIS campaigns are planned in IPN Orsay (nuBall), GANIL (LISE), LNL Legnaro (AGATA), IFJ PAN Krakow, TIFR Mumbai, **FAIR and Dubna**

Question: *Is there any interest to use PARIS in the EXPERT initiative (PARIS+GADAST)?*

Acknowledgements



- M. Ciemala, M. Kmiecik, B. Wasilewska, B. Fornal, P. Bednarczyk, M. Zieblinski (IFJ PAN Kraków)
- P. Napiorkowski, M. Kicińska-Habior, K. Hadyńska-Klęk, ... (HIL Warsaw)
- A. Bracco, S. Leoni, S. Brambilla, F. Crespi, F. Camera (University of Milano)
- O. Dorvaux, C. Schmitt, S. Kihel (IHPC Strasbourg)
- M. Lebois, L. Qi, J. Wilson, I. Matea (IPN Orsay)
- M. Lewitowicz, E. Clement, A. Lemasson (GANIL)
- V. Nanal, C. Gosh, B. Dey, I. Mazumdar et al. (India)
- D. Jenkins et al. (York),
- M. Stanoiu (Bucharest)
- A. Krasznahorkay (Debrecen), R. Schwengner (Rosendorf), J. Gerl (GSI), Y. Pieniozkievich (JINR)
- PARIS, AGATA, VAMOS and LICORNE collaborations
- Technical staff of IPN Orsay, IFJ PAN Krakow, GANIL Caen, ATOMKI Debrecen
- Saint Gobain and Scionix
- *H2020 project ENSAR2 (TNA support), **COPIGAL and POLITA collaboration projects**, Polish NCN grants*