The Henryk Niewodniczański Institute of Nuclear Physics
Polish Academy of Sciences

Adam Maj
IFJ PAN Krakow
for the PARIS collaboration

PARIS project - status and plans for first experiments

Plan of the talk

1. Introduction: ideas behind the PARIS project
2. Status of the project
3. First tests of the prototype
4. Planned first experiments
5. Summary and outlook

paris.ifj.edu.pl

Introduction:
ideas behind the PARIS project

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; M. Kmiecik: talk on possible Jacobi shapes in exotic nuclei

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):*
Adam Maj, IFJ PAN Krakow, Adam.Maj@ifj.edu.pl
Jean-Antoine Scarpaci, IPN Orsay, scarpaci@ipno.in2p3.fr *(E*
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

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

SPIRAL2

NFS: neutron beam

DESIR: low-energy radioactive beams

S^3: super separator spectrometer

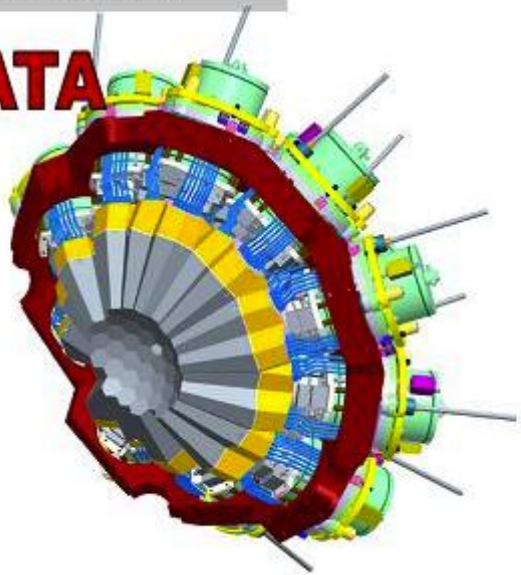
LINAC driver: p - 33MeV, d - 40 MeV, heavy ions - 14.5 AMeV

GANIL/SPIRAL1: existing infrastructure

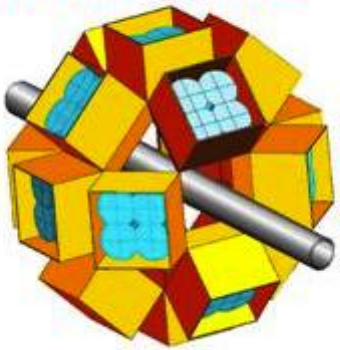
Ion sources: I > 1 mA

Radioactive beams production cave: 10^{14} fissions/s

AGATA



EXOGAM2



PARIS physics cases for SPIRAL2

* - flagship

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

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.

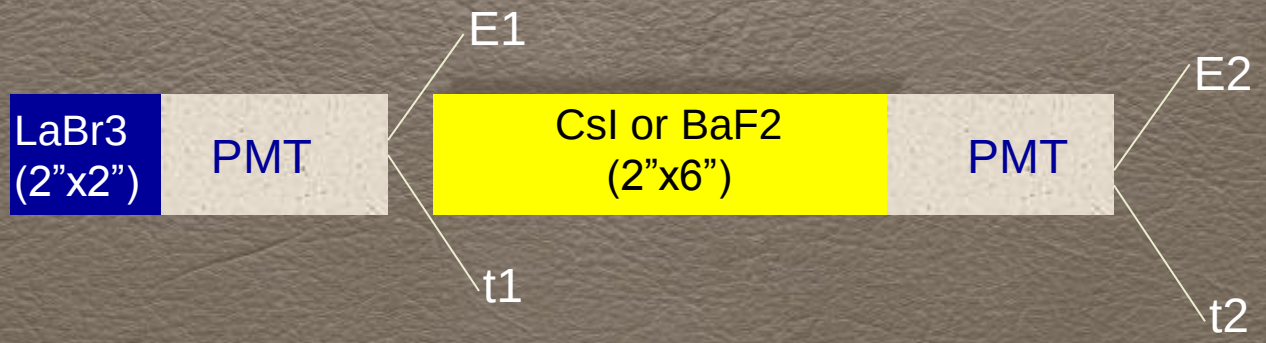
p) **Evolution of nuclear structure of ^{78}Ni and ^{132}Sn with ACTAR+PARIS**
G.F. Grinyer et al..

Main physics cases require that PARIS has to

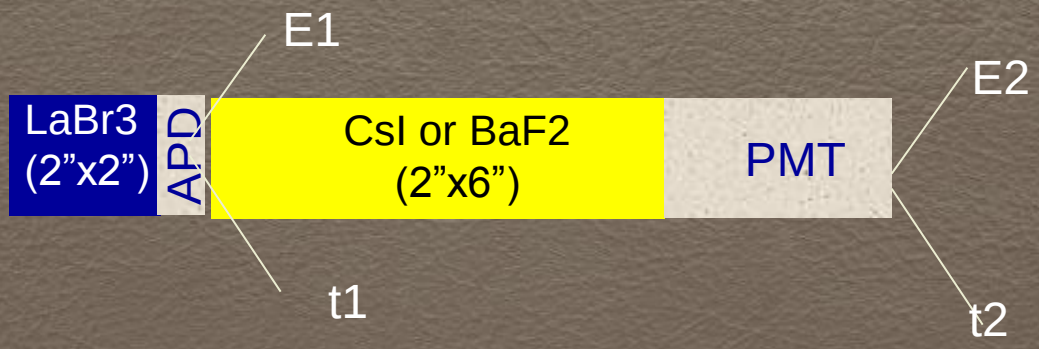
- be modular (to be connected with other detectors: **AGATA**, EXOGAM, **GALILEO**, GASPARD, **NEDA**, **FAZIA**, ACTAR, HECTOR/**HECTOR+**, EAGLE, ORGAM, CORSET...)
- have high granulation (multiplicity measurement, Doppler correction,...)
- have very high efficiency for high-energy γ-rays (~50 MeV)
- stand high count-rate (50MHz)
- have good timing resolution (<500 ps)
- have energy resolution as good as possible (2%)
- have some position sensitivity
- be transportable (SPIRAL2/GANIL will be the primary site, but experimental campaigns are planned also in other facilities: IPN Orsay, HIL Warsaw, CCB Krakow, **SPES**, HIE-ISOLDE, Mumbai)

4 POSSIBILITIES FOR A „GAMMA-TELESCOPE” ELEMENT

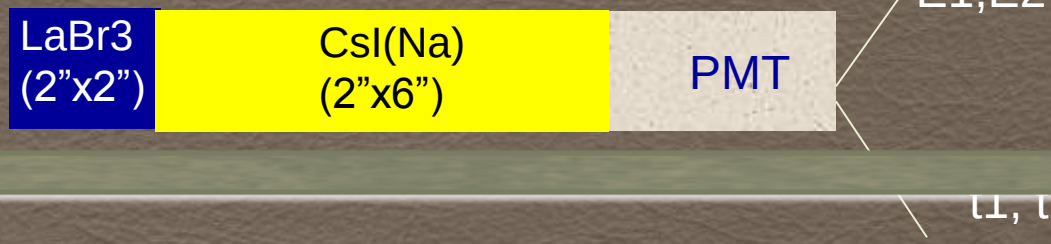
Possibility 1.



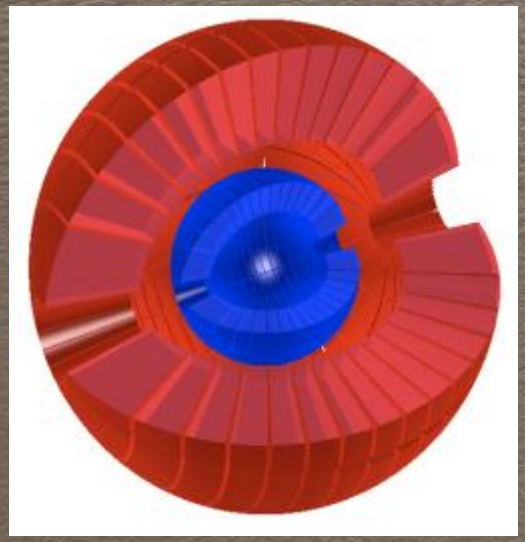
Possibility 2.



Possibility 3 – „phoswich”.



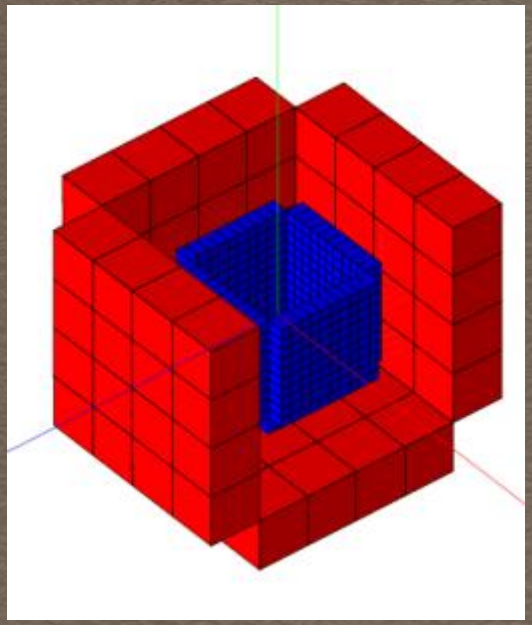
POSSIBLE GEOMETRIES of PARIS



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,…

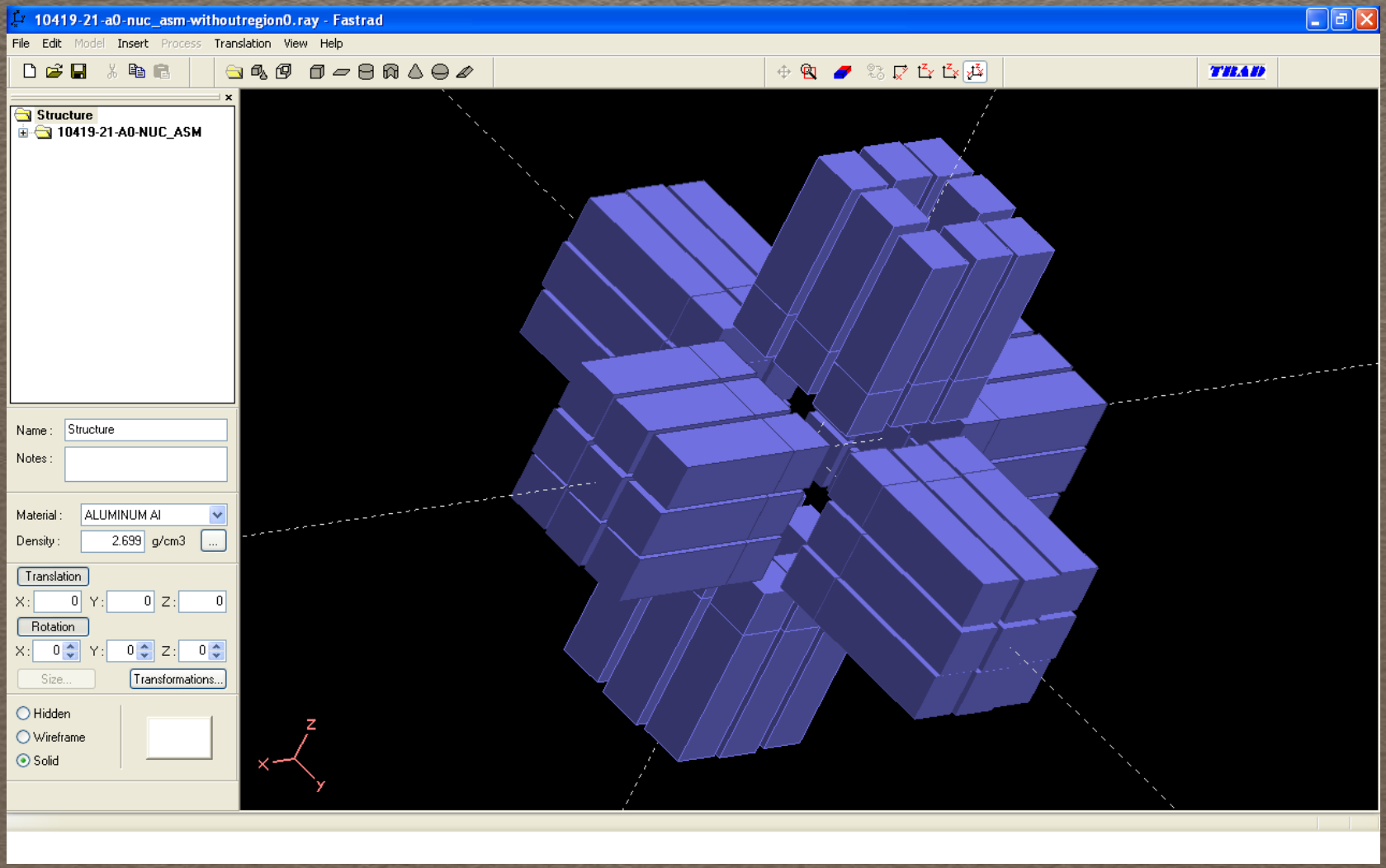


CUBIC (offering variable geometry):

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

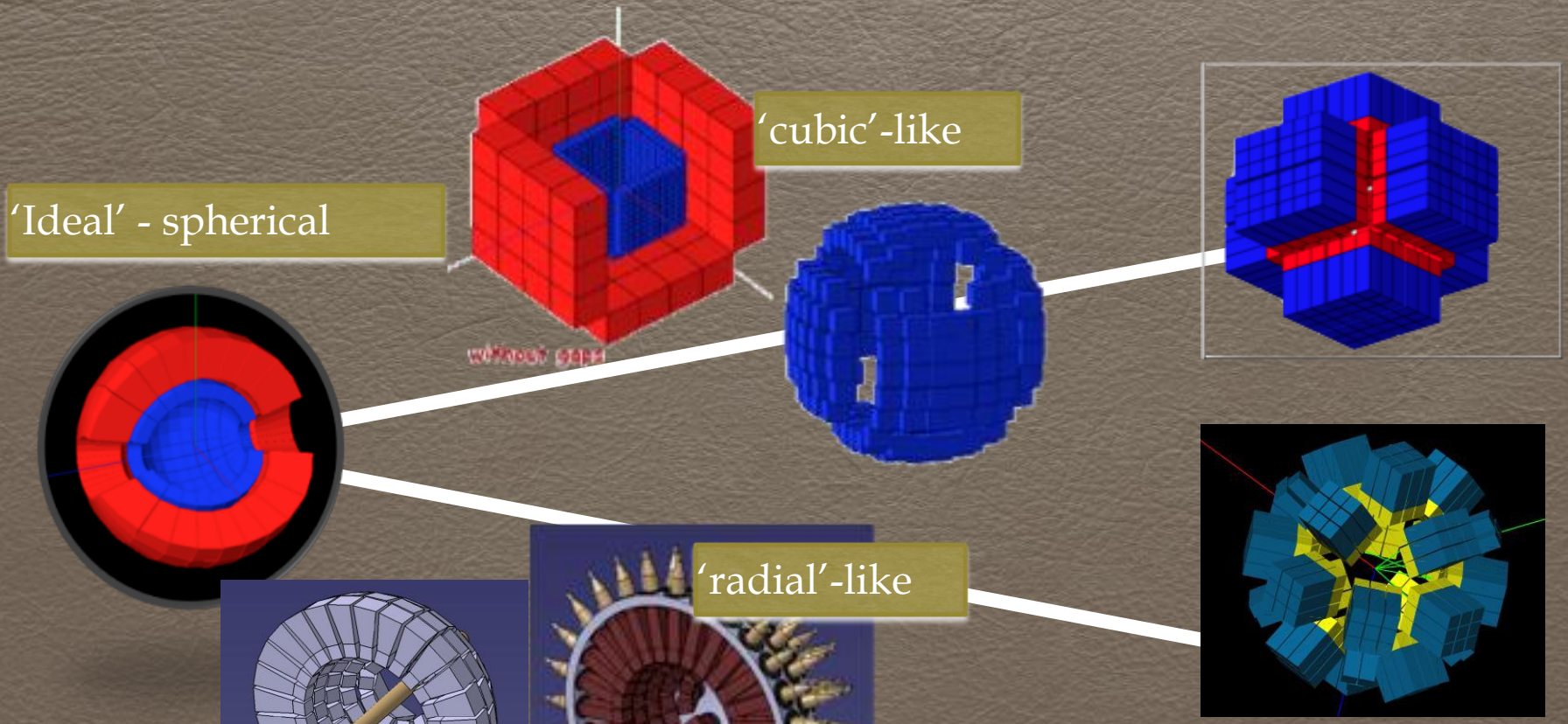
- : More complicated reconstruction, worse line shape, …

CUBIC-LIKE GEOMETRY



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

Several geometries studied



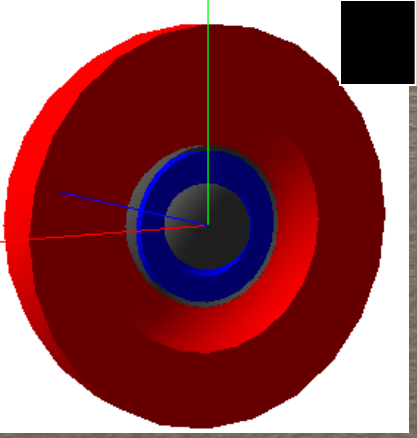
CONCLUSION:

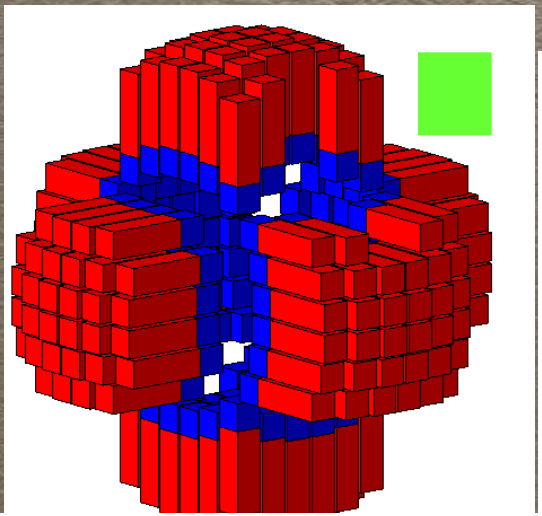
PARIS to be made of clusters:

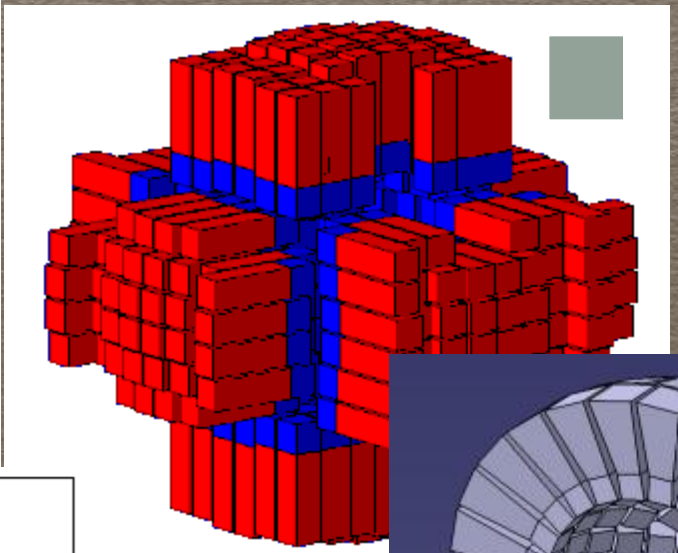
Cluster = *9 phoswiches*

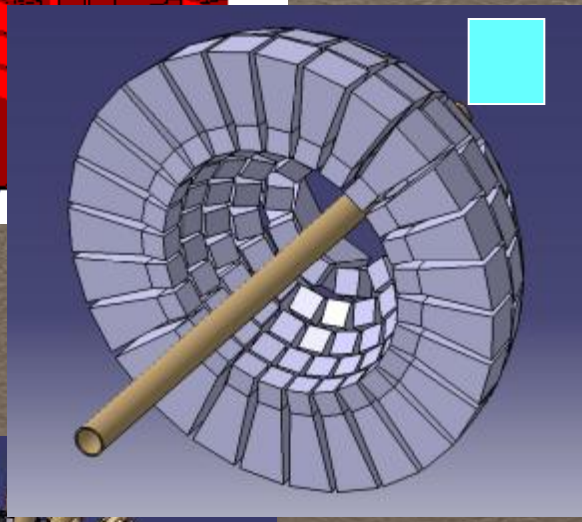
This allows *cubic* or *semi-spherical* geometry with 24 clusters (216 phoswiches)

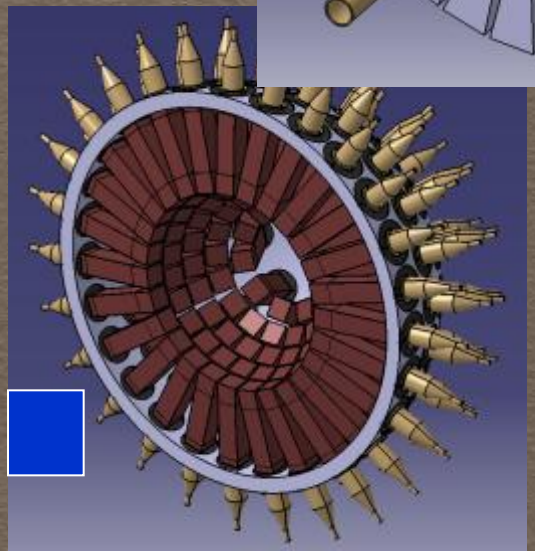
Cubic vs. Radial geometry

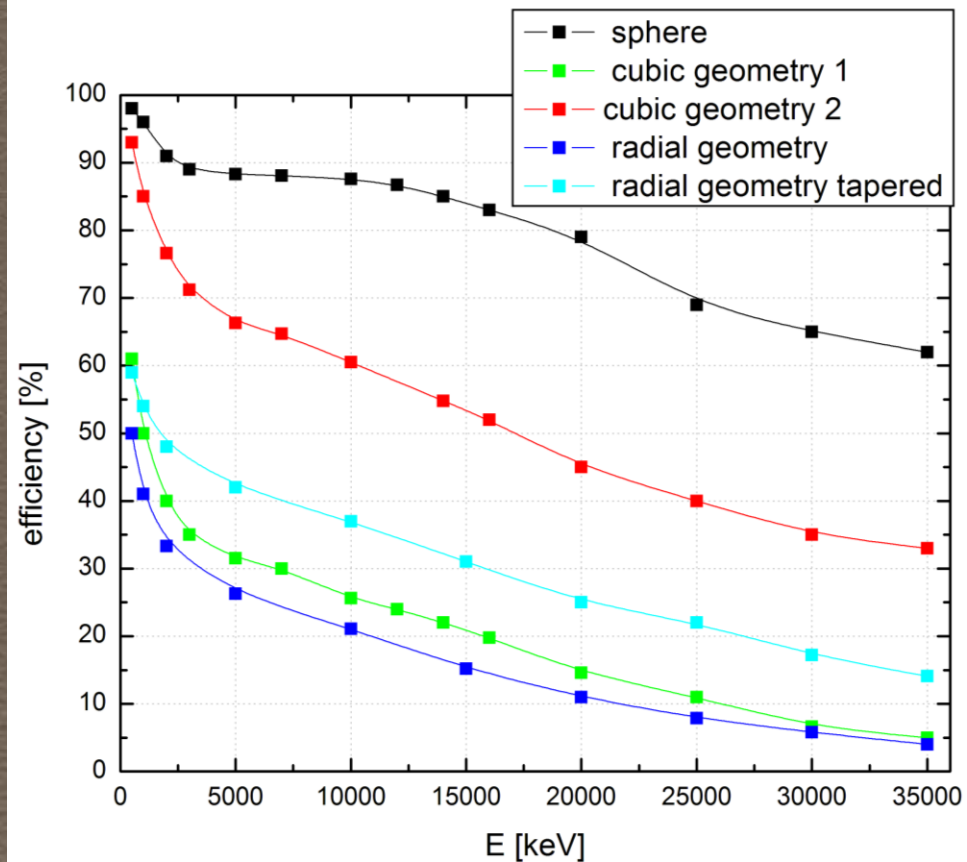






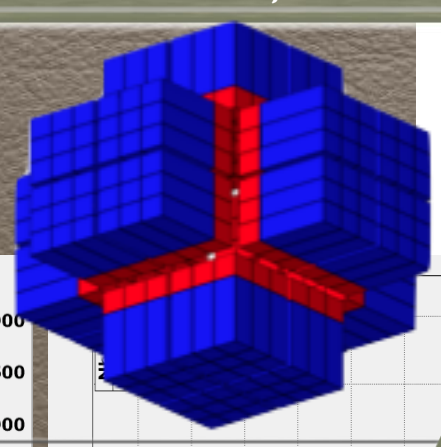


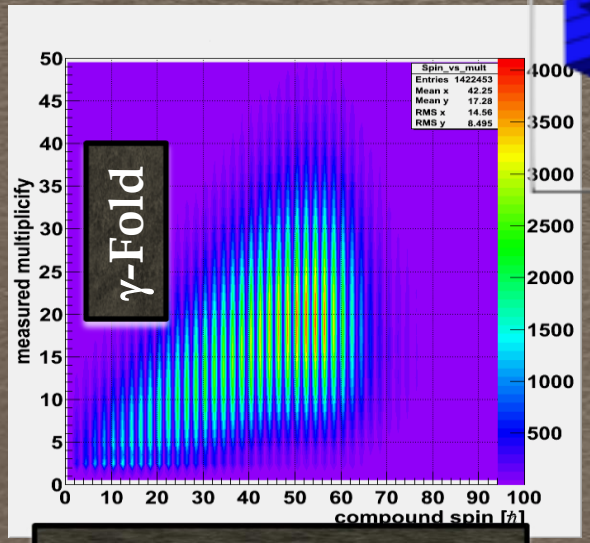


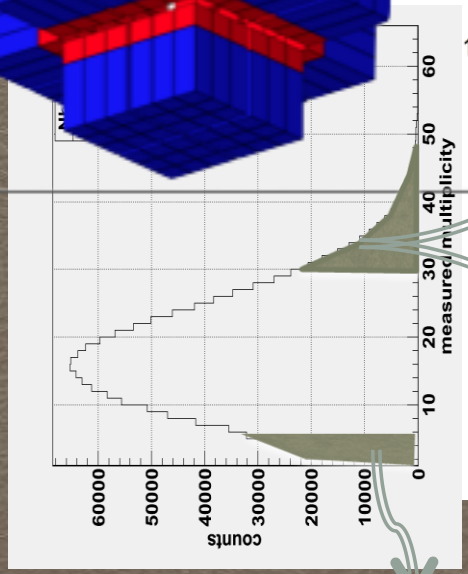


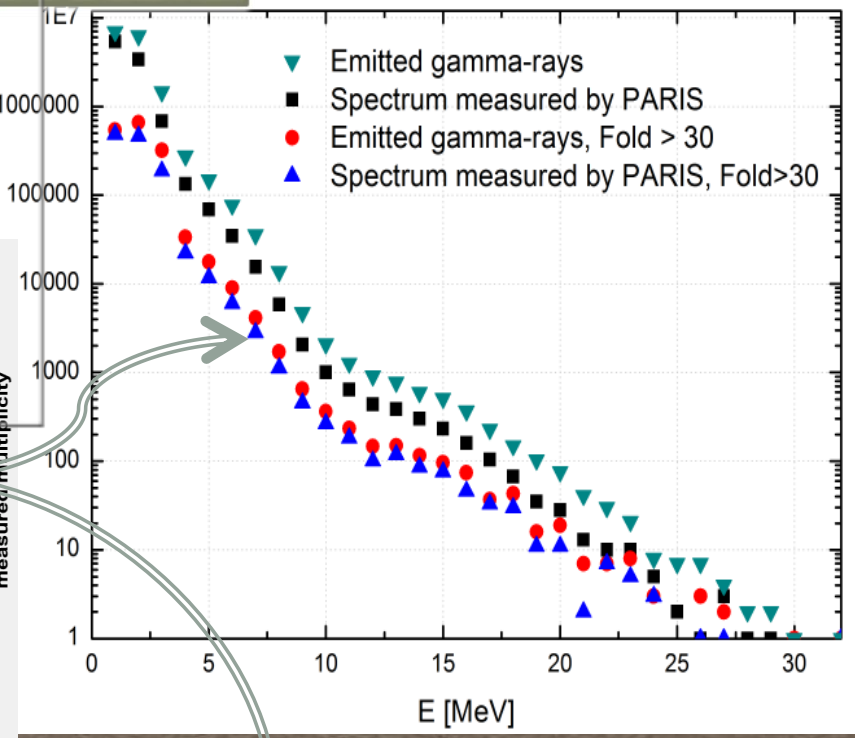
Event generator for PARIS based on MC Cascade (M. Ciemała, Ch. Schmitt, K. Mazurek, M. Kmiecik et al.)

380 MeV ^{48}Ti on ^{40}Ca reaction

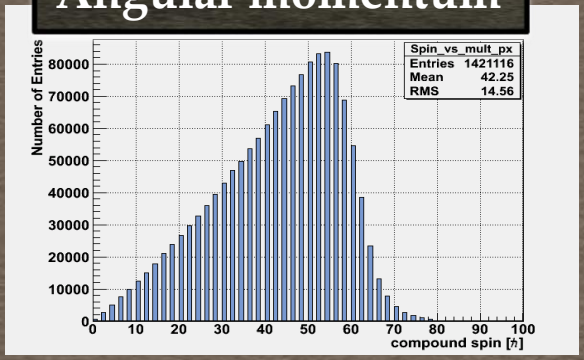




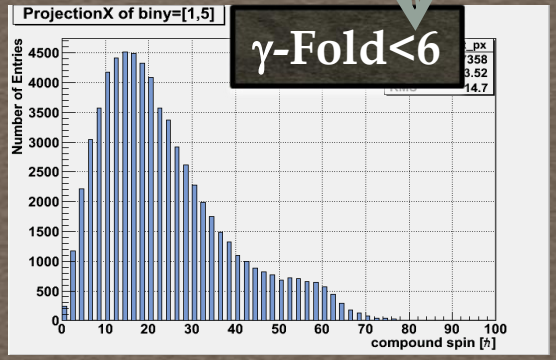




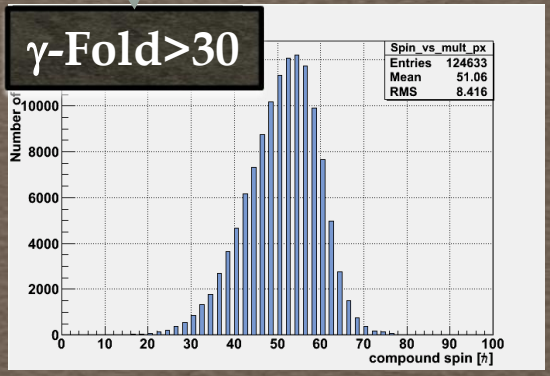
Angular momentum



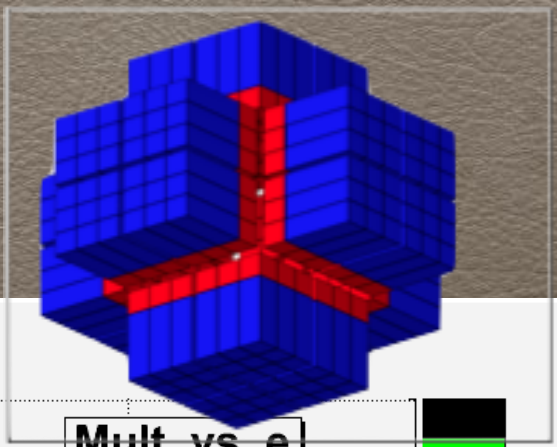
γ-Fold<6

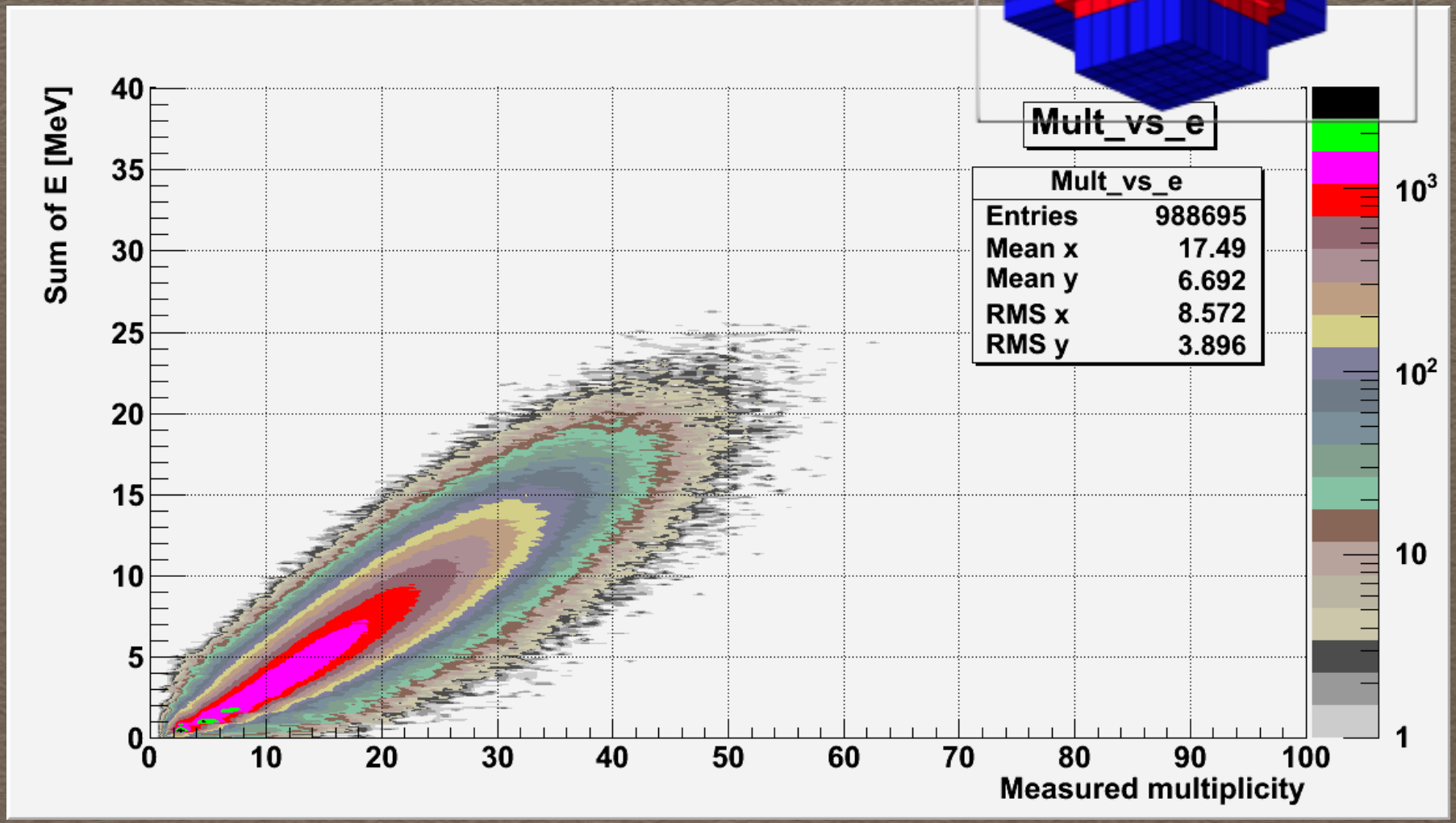


γ-Fold>30



Simulated PARIS response (H,K) for the gamma-decay of ^{88}Mo





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

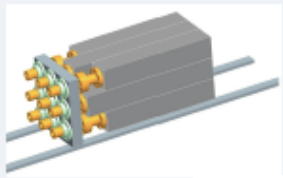
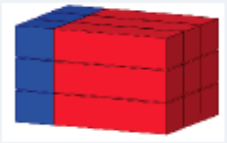
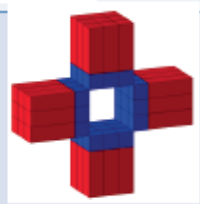
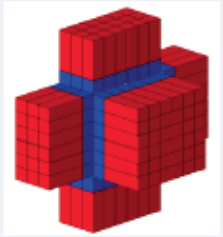
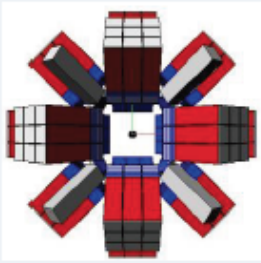
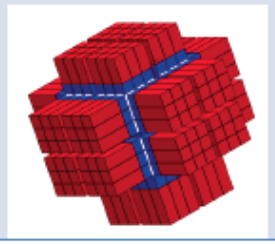
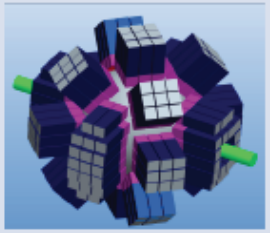
HUNGARY (coord.: Z. Dombradi) ATOMKI Debrecen

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)

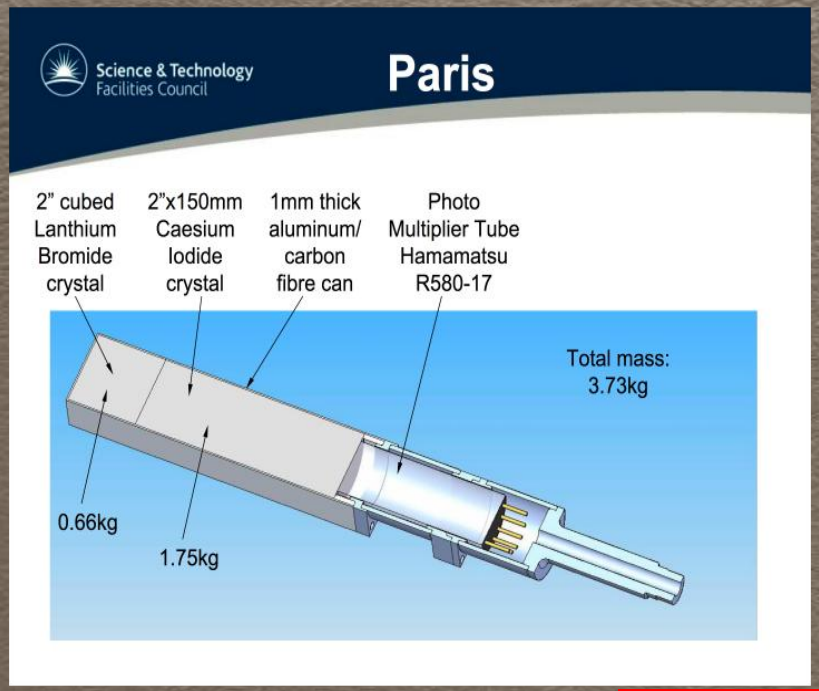
GANIL campaign Spokesperson: C. Schmitt (GANIL)

PARIS Management Board:
PARIS Project Manager + WG coordinators

PARIS Collaboration Council was recently established established

PARIS Collaboration Council:

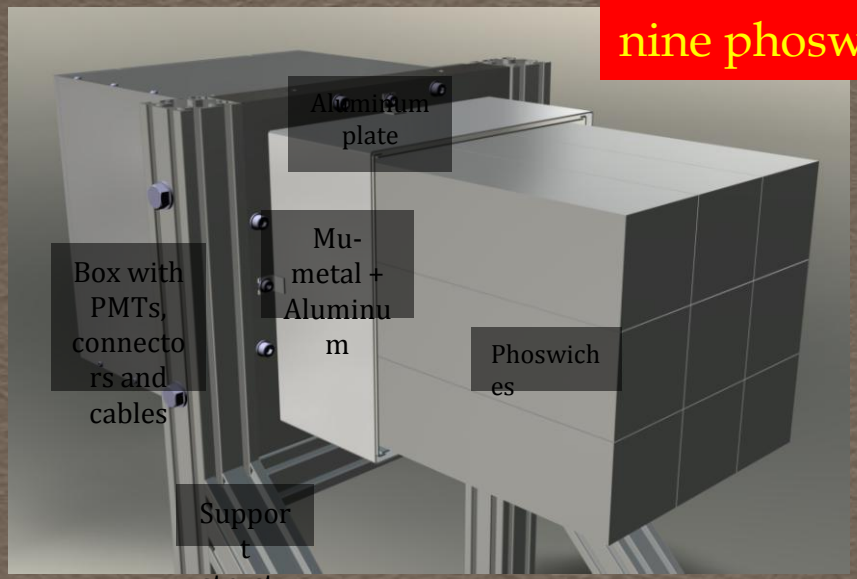
David Jenkins (University of York, UK) - chair and PARIS spokesman
Sudhee R. Banerjee (VECC Kolkata, India)
Franco Camera (INFN and University of Milano, Italy)
Wilton N. Catford (University of Surrey, UK)
Marco Cinausero (LNL Legnaro, Italy)
Sandrine Courtin (IPHC Strasbourg, France)
Zsolt Dombradi (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)

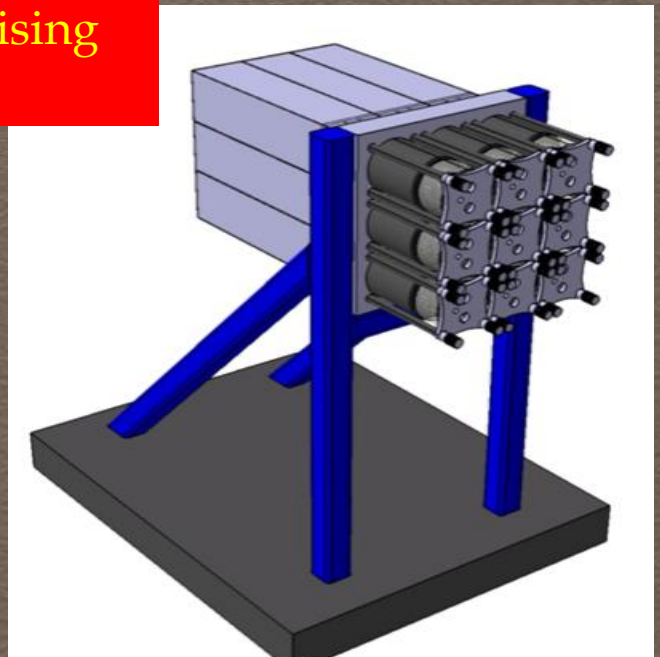


Designs made in IPN Orsay and in Daresbury

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

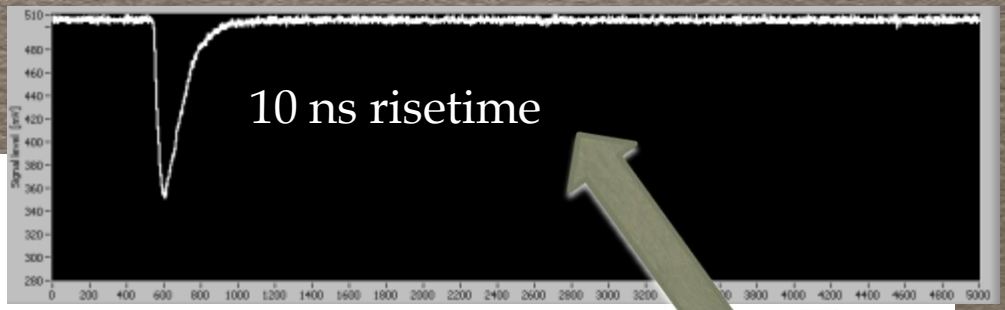
A cluster module comprising nine phoswich detectors

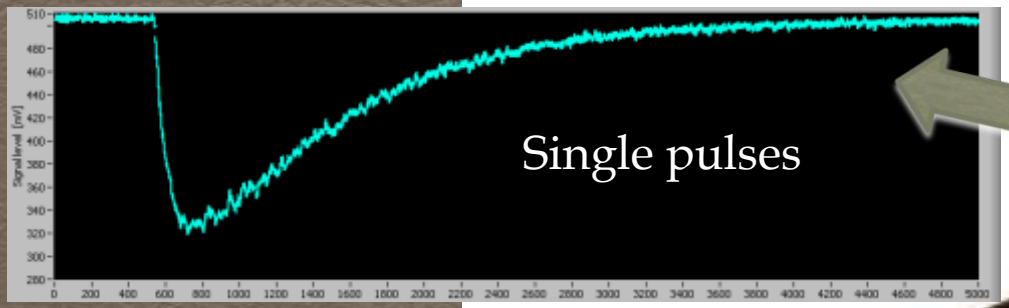


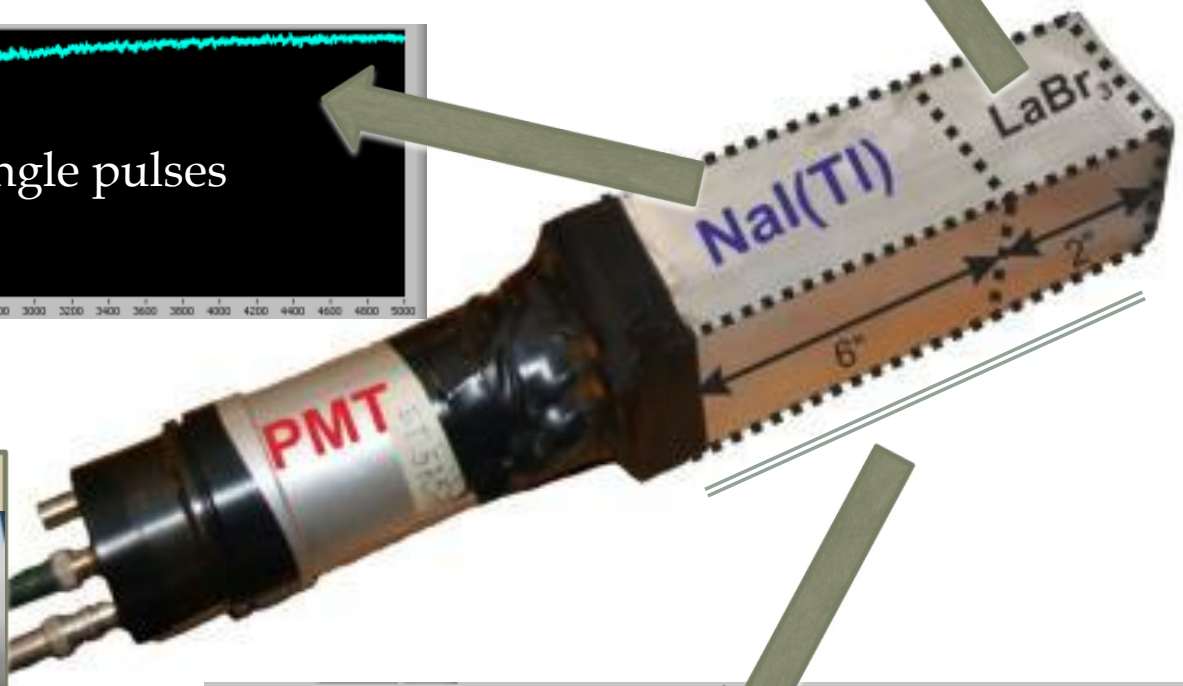


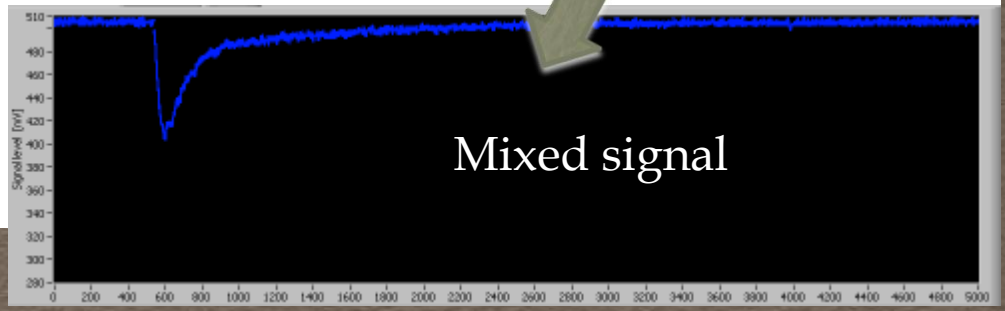
First tests of the prototype

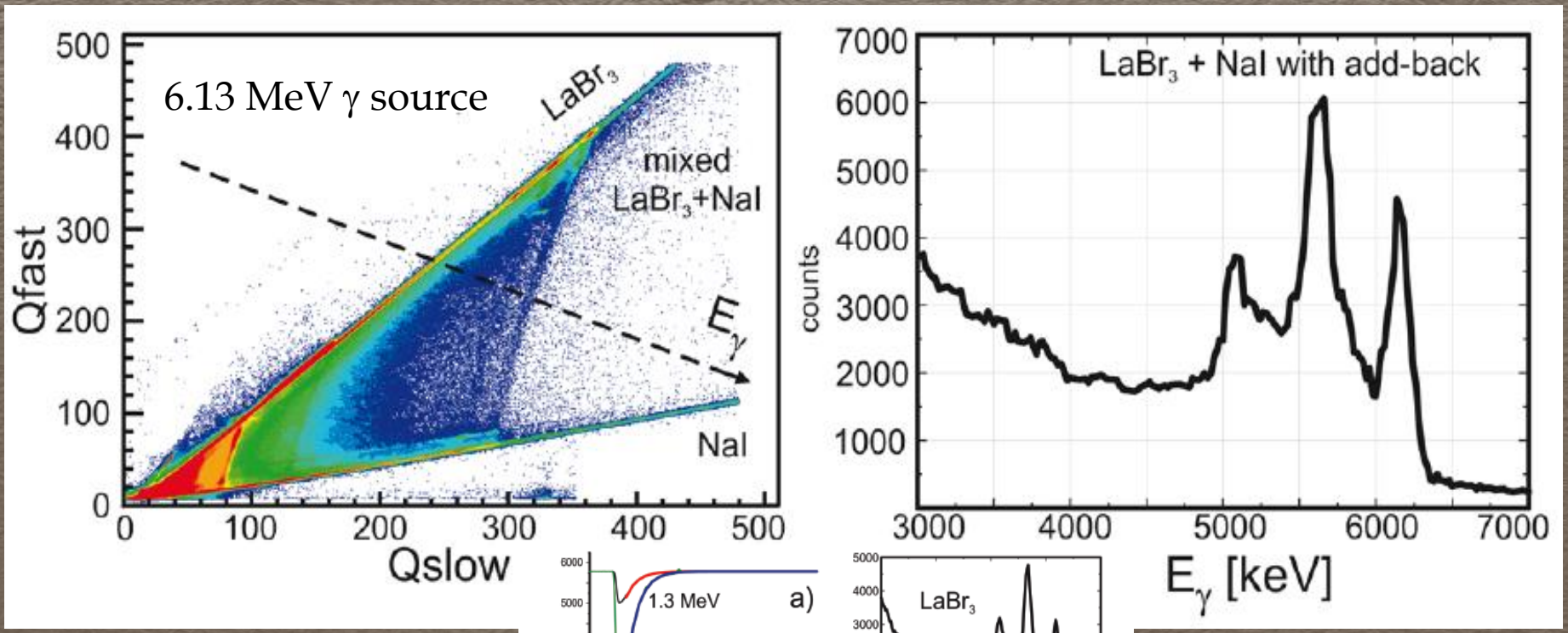
The PARIS PHOSWICH at work

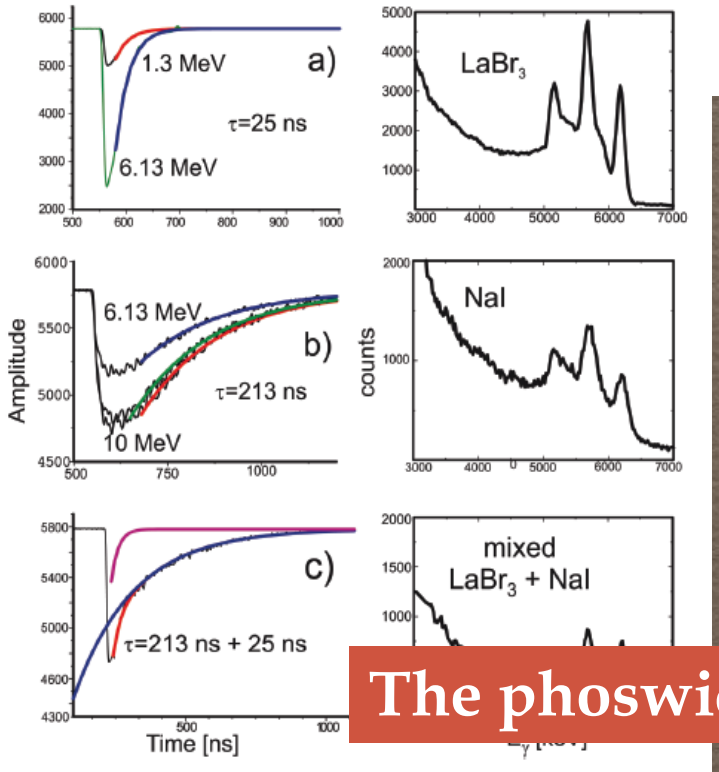












A test measurement at IFJ PAN, Kraków (2011) with BafPro module from Milano

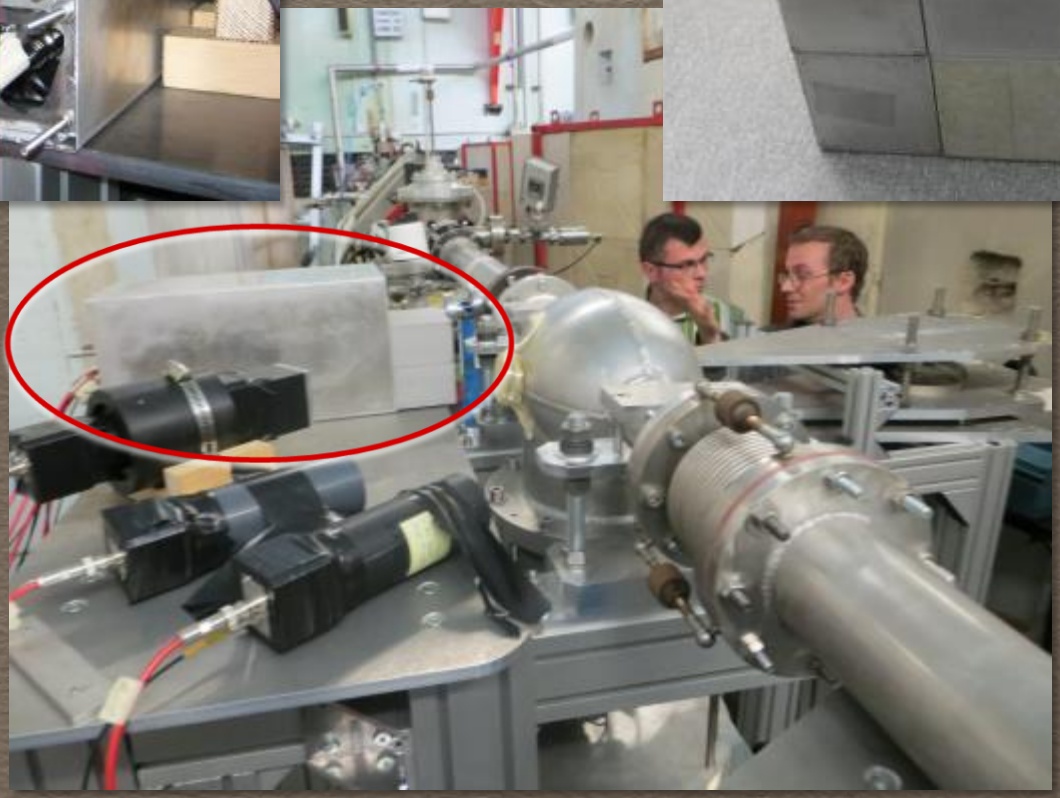
- Sources
- proton beam

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



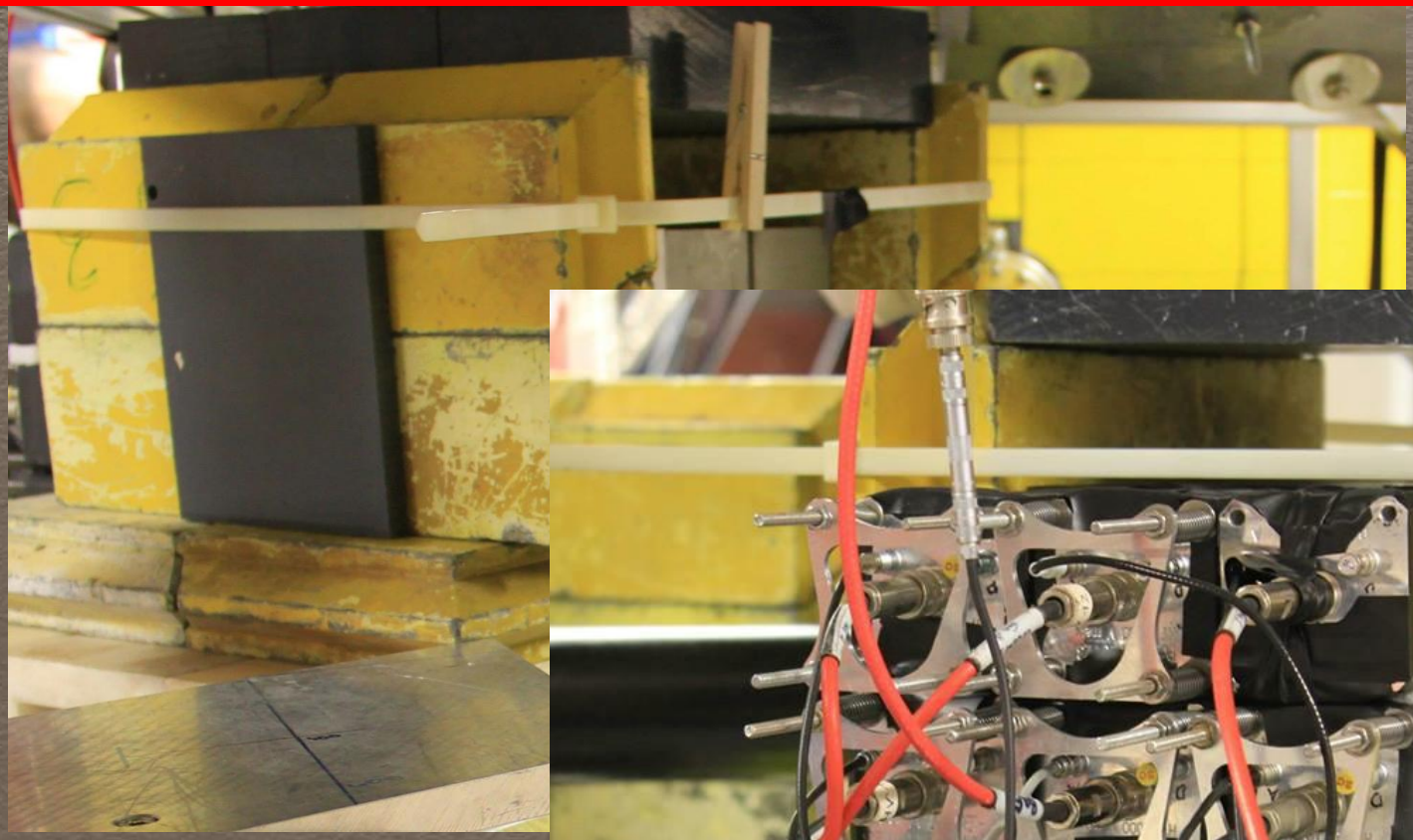
$^{11}B(p, \gamma)^{12}C$ at 7.2 MeV

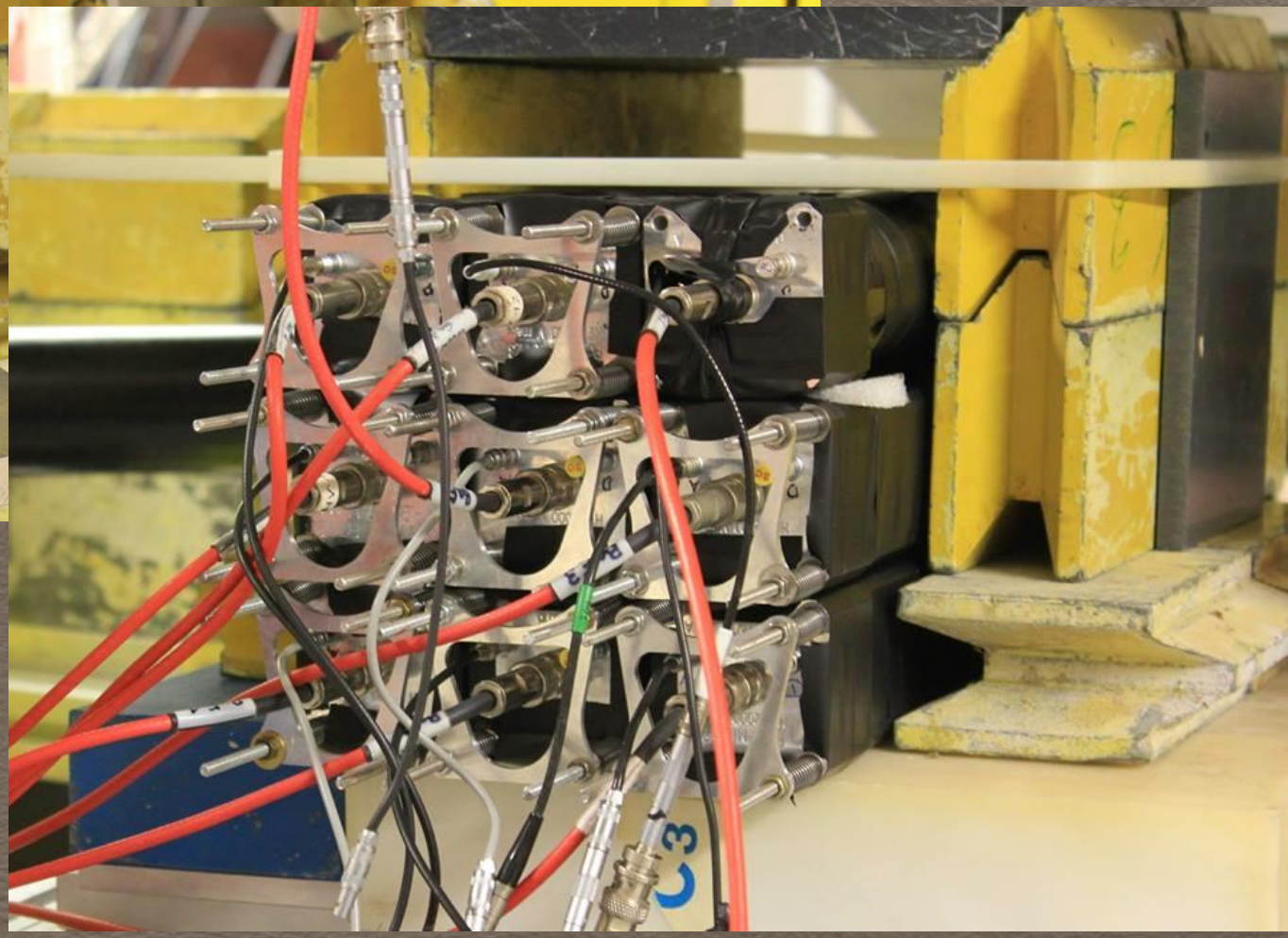
Eγ: …, 18.12 , 22.56 MeV

Goal:
testing addback capabilities at high energies

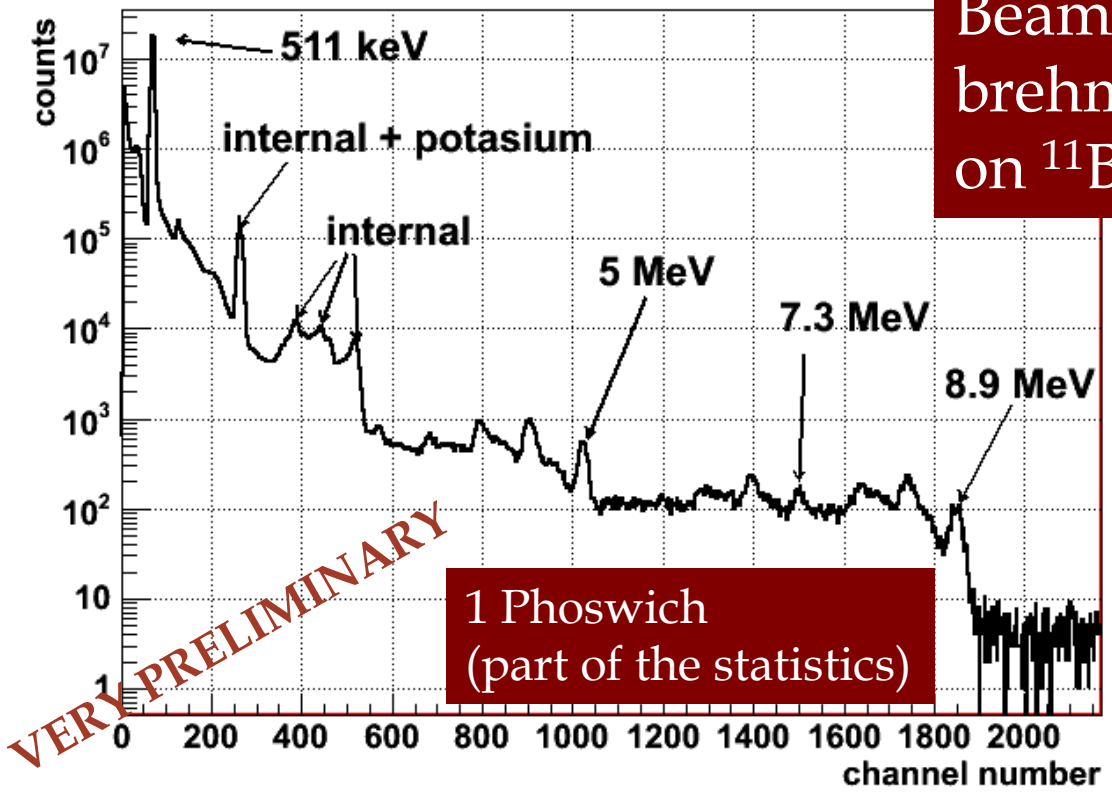
ELBE facility, Dreseden 10-12 December, 2013

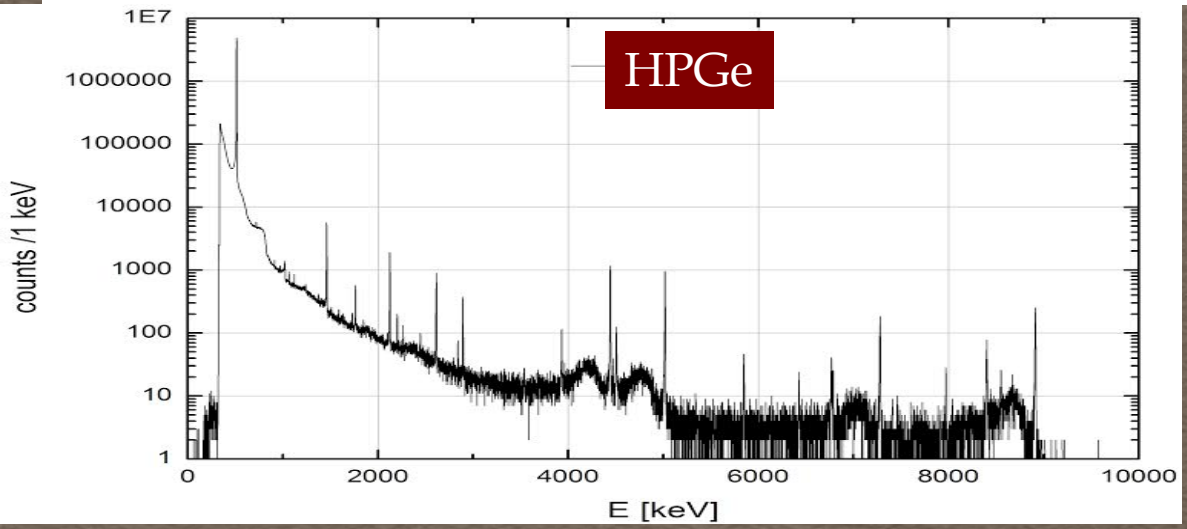
Nuclear Resonance Fluorescence experiment (Mazumdar, Maj, Schwengner)

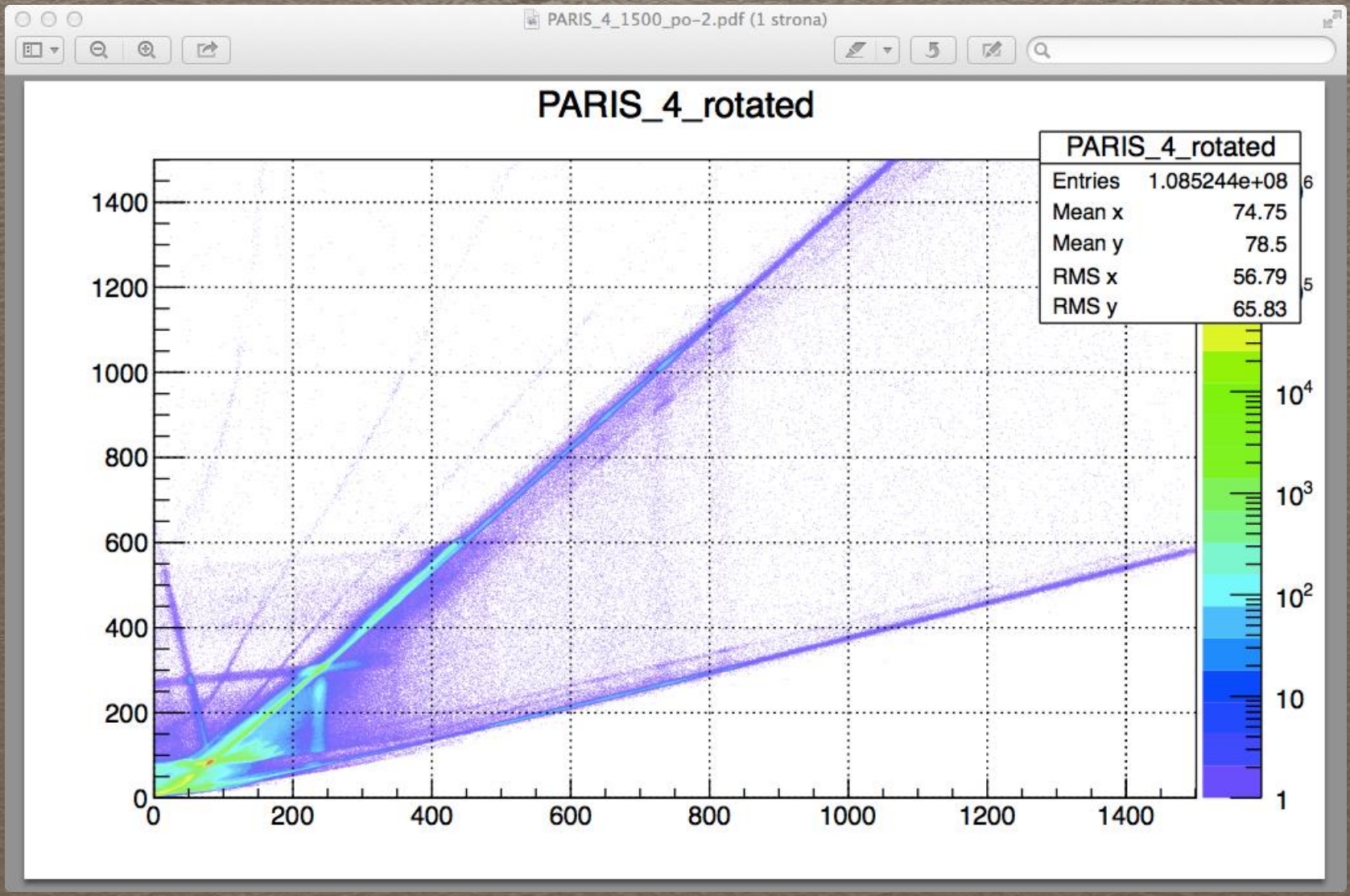




Beam 15 MeV electrons: brehmstallung gamma beam on ^{11}B target







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

Options of electronics for PARIS

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

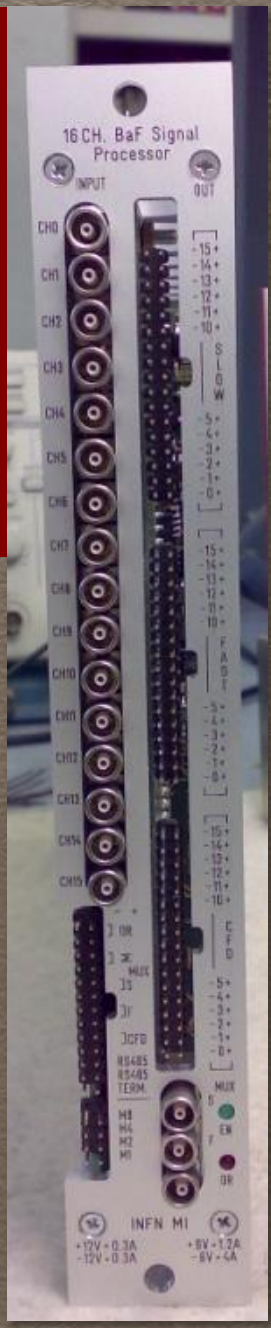
Implementation of the GTS interface into the NUMEXO2 VIRTEX 5 FPGA is currently being finalized.

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) Comercial digitizers (e.g. set of TNT4 digitizers from IPHC, Strasbourg, or ew V1730, 16 channel, 500 MS/s, 12/14 bit CAEN digitizer)

Require implementation of a digital alghoritm for timing

3) Analogue electronics based on
a) Milano "ParisPro" cards (S.Brambilla et al..)
b) Standard **QDCs**
+ **AGAVA**- integration with a GTS based DAQ (AGATA)



- **P**resently we have **16** Phoswiches: France 5, Poland 6 (incl. 2 from Krakow-Dubna cluster), India 2, Turkey 1, UK (2) ***(almost 2 clusters)***

- Additional **7** were ordered: France 6, Italy 1

- There are founds available for next **8**: Poland 3, Romania 3, India:2

- So at the end of 2014 PARIS collaboration should have at least (this depends on SaintGobain) 34 phoswiches: **3.5 clusters**

- For the AGATA (mid 2015) campaigne at GANIL we will have 4 clusters

- 5th cluster: end 2015/beginning 2016

Planned first experiments

So far considered non-SPIRAL2 PARIS physics cases

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

- Lifetimes in A=18 region (Leoni, Fornal, Ciemala): AGATA, VAMOS, Plunger
- SD bands at high spins in the Ca region (Bednarczyk, de France): AGATA, Diamant
- SD bands in A=80 region (Cederwall): AGATA, Diamant

IPN/ALTO Orsay (PARIS campaign manager: I. Matea)

- Dynamics of heavy-ion collisions around the Coulomb barrier (Schmitt, Dorvaux): ORGAM, CORSET
- Measurements of prompt γ–rays in neutron-induced fission (Wilson, Matea): LICORNE, ORGAM
- *… others will come after dedicated Workshop, organized by D. Jenkins and I. Matea later this year*

CCB Krakow

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

HIL Warsaw

- Coloumb excitations in A=40-50 nuclei (Napiorkowski, Bednarczyk): EAGLE

So far considered non-SPIRAL2 PARIS physics cases

LNL/SPES Legnaro

- 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

4 examples will follow…

a) GANIL AGATA campaign: end 2015-2017

Lifetime measurements of excited states in neutron-rich C and O isotopes:a stringent test of the three body forces with the *AGATA+PARIS+VAMOS+Plunger* setup {S. Leoni (Milano), B. Fornal (Krakow), M. Ciemała (GANIL)}

Different Microscopic Calculations start to become available in A = 20 mass region

Ab initio: No-Core Shell Model (NCSM) or Multi-Body Perturbation (MBPT) with NN or NNN

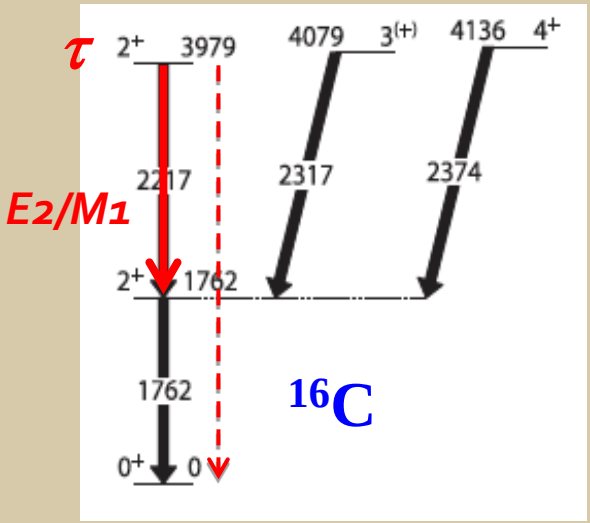
Shell Model: Empirical or realistic effective interactions

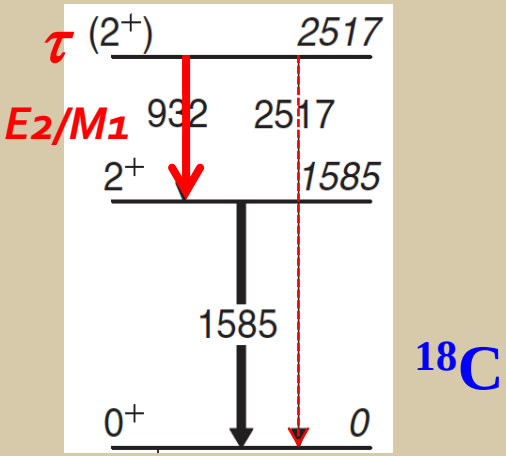
Lifetimes of 2+ states in $^{16\text{-}18}$C and $^{20\text{-}22}$O

		Results of calculations (with various interactions)				
ucleus	Excited state	tau [ps] (SM USDA)	tau [ps] (*ab initio* MBPT NN)	tau [ps] (*ab initio* NCSM NN)	tau [ps] (*ab initio* NCSM NNN)	Experiment [ps]
^{20}O	2^+_1	10.7	10.3			10.70(40)
	2^+_2	0.22 ↔	0.026			-
^{22}O	2^+_1	0.65	0.68			0.69(28)
	2^+_2	0.46 ↔	0.03			-
^{16}C	2^+_1			24		11.4(10) - 18.3(50)
	2^+_2			0.23 ↔	0.08	< 4
^{18}C	2^+_1			19.4		22.4(3.5)
	2^+_2			2.2 ↔	1.1	< 4.6

τ = 30 fs – 10's ps

of the second 2^+: *Sensitivity to Microscopic Models and details of NN interactions*



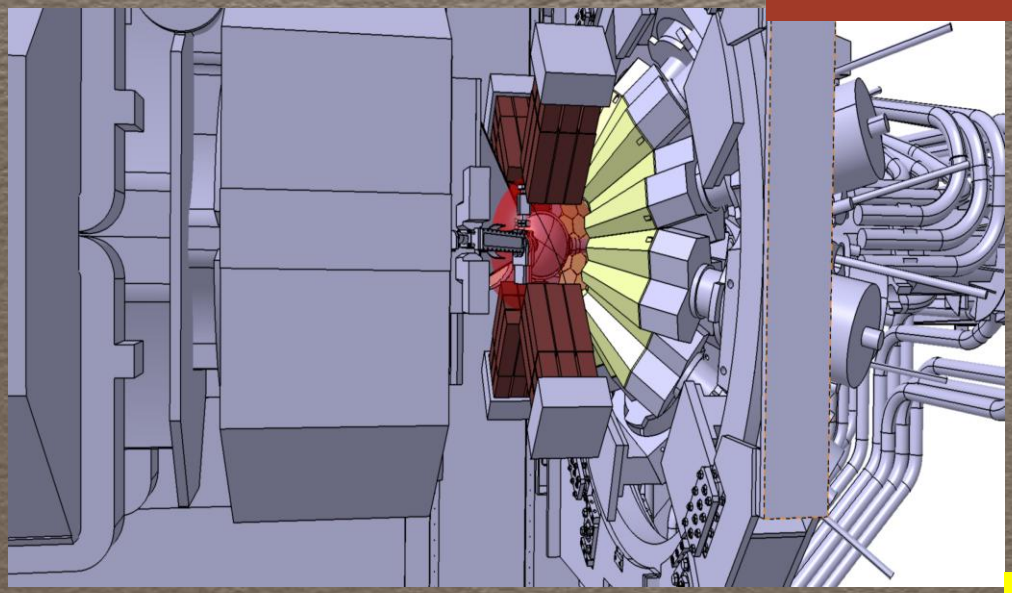


1. *Lifetimes of Excited states* *(DSAM and Plunger)*
2. *Decay Branchings* *(PARIS, high efficiency)*
3. *E2/E1 Mixing Ratio* *(AGATA angular distributions)*

→ ***B(E2), B(M1) transition probabilities***
Test of wave functions

EXPERIMENTAL SETUP

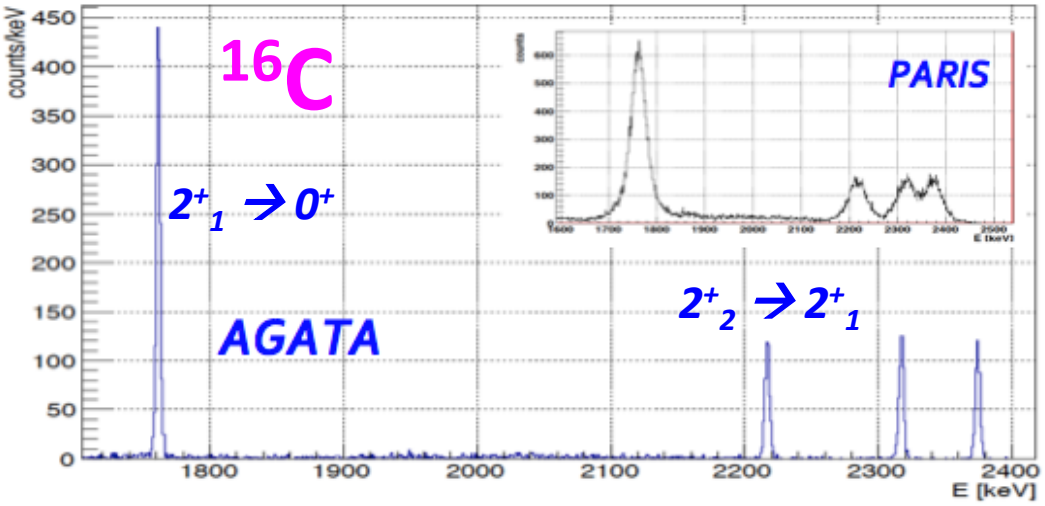
reaction: 18O (141 MeV) on 238U (10 mg/cm2)
Multi-nucleon transfer



AGATA *(8TC+5TC)*
PARIS-Demonstrator
(4 Clusters) @ 90°, 23 cm
VAMOS *@ 45°*
PLUNGER *(Cologne)*

Simulations for ^{16}C, a -2*p* product

AGATA@GANIL Simulations Package



v/c ≈ 12%
(E_{kin},θ_{LAB}) from GRAZING

VAMOS Transmission ≈ 30 %
ℰ(AGATA) @ 1.8 MeV = 5.2 %
ℰ(PARIS) @ 1.8 MeV = 6 %

See talk of
Michał Ciemała
on Thursday

b) IPN Orsay: mid 2015

Prompt gamma-rays in neutron-induced fission

J. Wilson, I. Matea (Orsay)

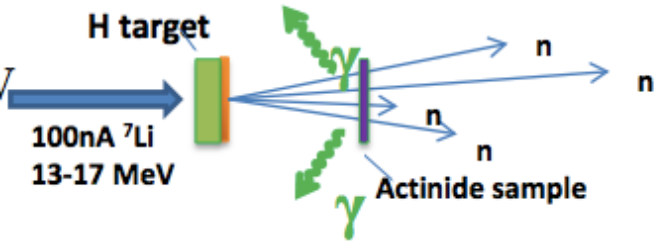
- Fundamental interest:
  - ✓ What governs the A, Z, E, ϑ, deformation of the fission partition ? (role of macroscopic and microscopic effects)
  - ✓ Process of angular momentum generation at scission
  - ✓ How are E* and L shared between the 2 fragments ?
  - ✓ n/γ-ray emission competition

γ-rays are most direct signature! (M_γ, E_γ^{sum})

- Applications: Control heating in reactors
  - 10% of heat comes from γ-rays: → safety of the core reactor
  - Benchmark calculations need data on spectral shape, E_γ and M_γ → on HIGH PRIORITY LIST of NEA/OECD:

- Uniqueness of the n-beam LICORNE facility@IPNO:

Intensely focused mono-energetic [0.5-4]MeV n-source (10^7 n/s/sr) → higher n intensity on target and lower background



- Considered set-up: PARIS demonstrator + ...
  - ✓ Several LaBr3 (IPNO/IRMM) and Ge(BGO) available @ IPNO
  - ✓ Fission-fragment detection in ionisation chamber

... Use PARIS as n detector ?

c) CCB Krakow: 2018-2019

Gamma-decay of collective modes (PDR, GQR,…) in different stable nuclei excited in proton-induced reactions

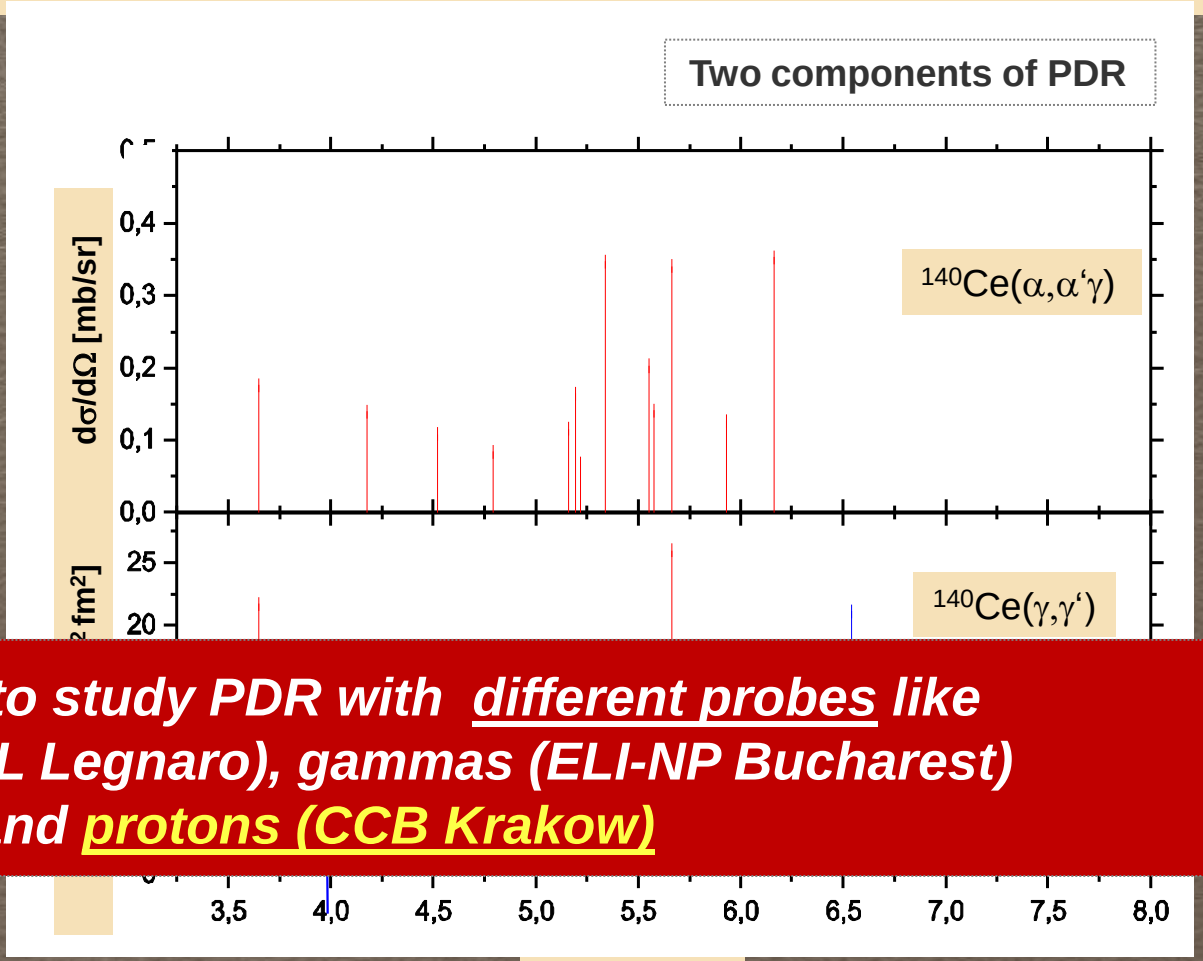
F. Crespi(Milano), M. Kmiecik (Krakow)

New facility: Cyclotron Center Bronowice (IFJ PAN Krakow)
70-230 MeV protons for cancer therapy and basic research

Eye therapy room, 2 gantries and small exparimental hall

Why to measure PDR in stable nuclei?

- Several microscopic models are able to reproduce qualitatively the experimental data, but the interpretations of the mode are different
- Different probes (gamma, alpha, HI, ..) excite different components of the PDR



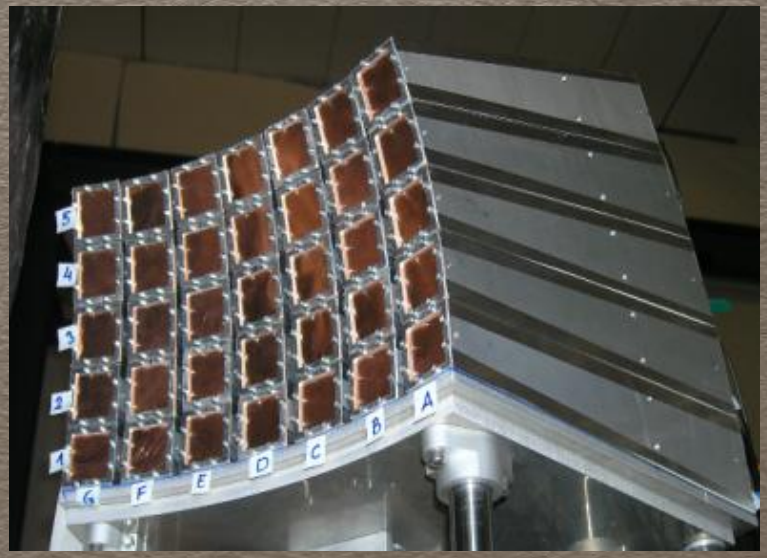
Further need to study PDR with <u>different probes</u> like heavy ions (LNL Legnaro), gammas (ELI-NP Bucharest) and <u>protons (CCB Krakow)</u>

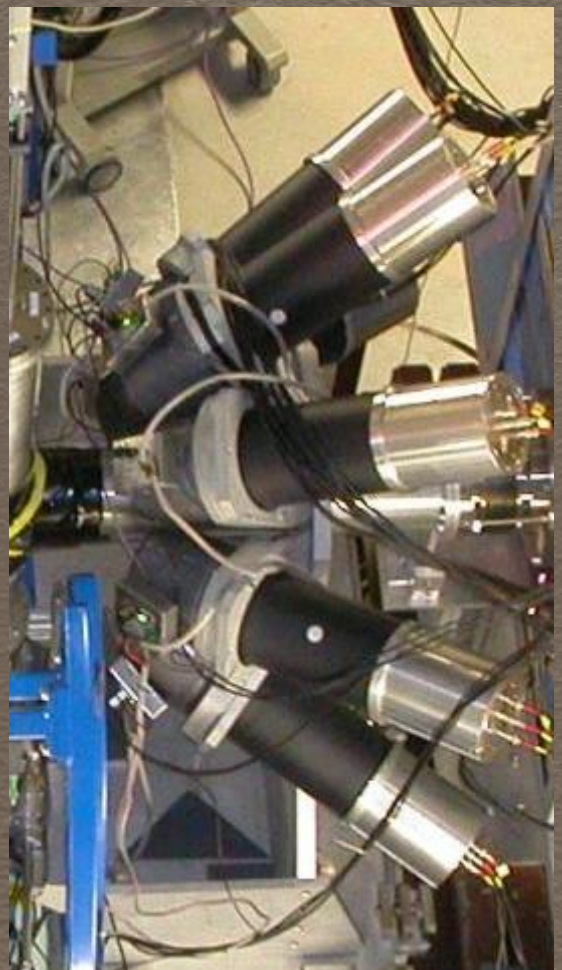
cf. talk of N. Tsoneva and A. Schwenk

D. Savran et al., Phys. Rev. Lett. 97(2006) 172502

Gamma-ray setup setup

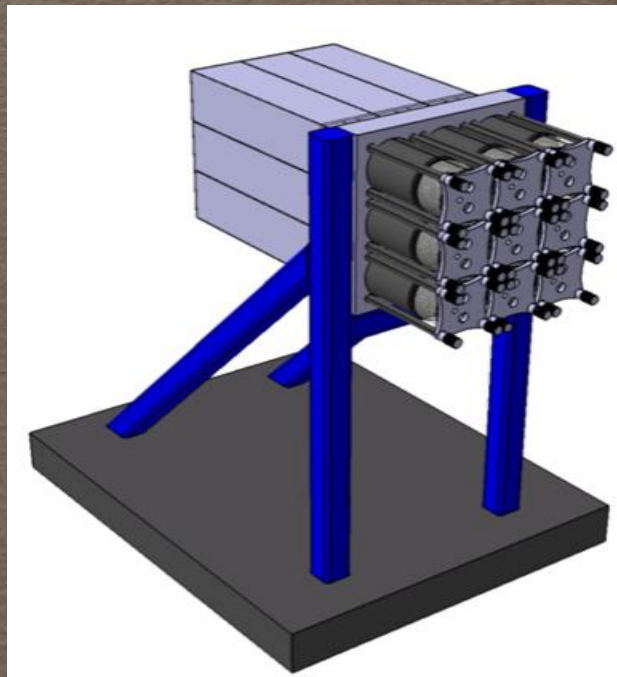
1. **KRATTA** array (CsI telescopes) at forward direction to measure the energy of inelastically scatter protons in order to reconstruct the excitation energy (resolution ca. 1%) and select excitation energy bins





2. **HECTOR** array to measure high energy gamma-rays

3*. **PARIS** Demonstrator for PDR measurements with high-resolution, in coincidence with KRATTA



4*. **Germanium array**

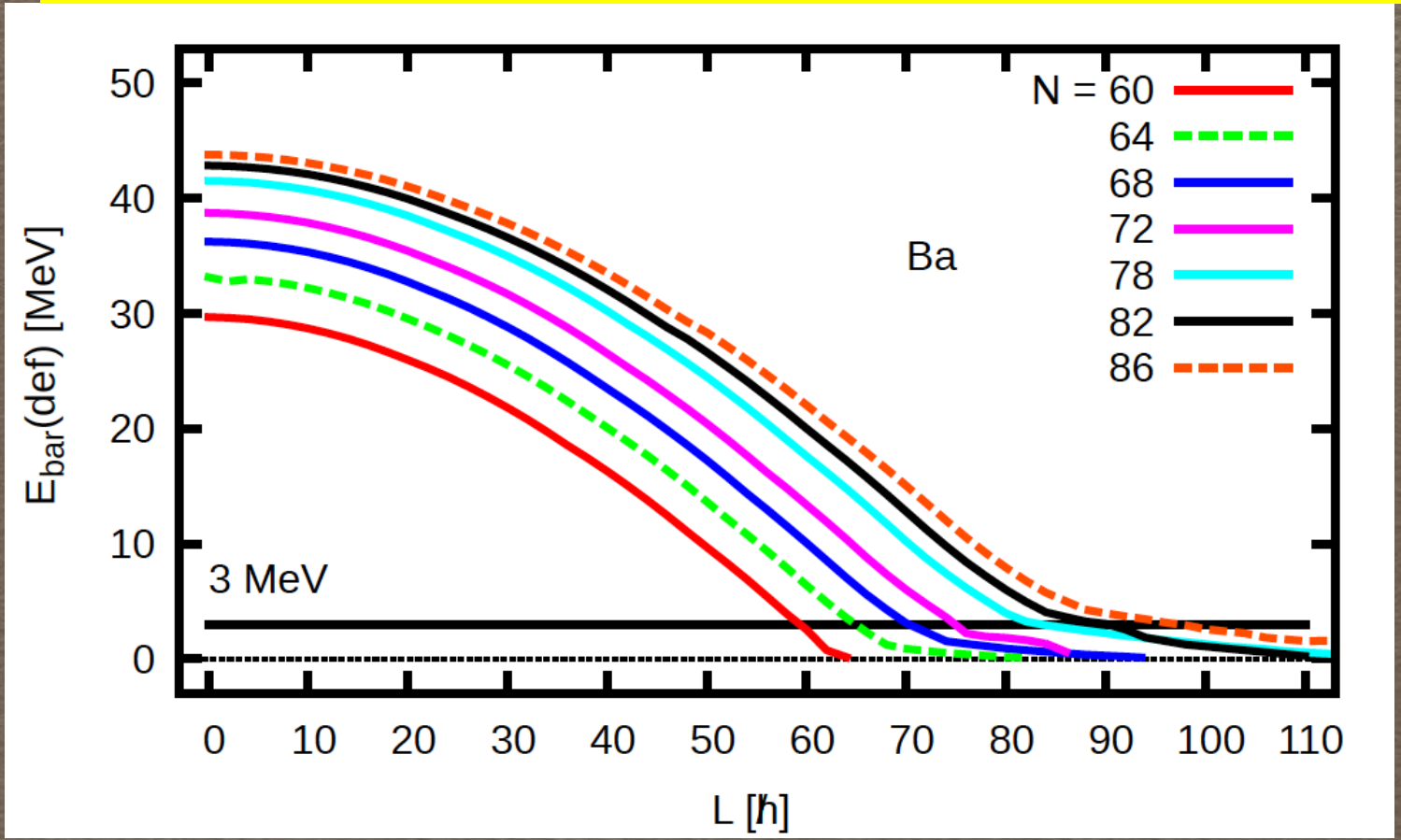
* - *in dedicated campaigns*

d) LNL Legnaro: 2019-2020 and SPIRAL2 phase2 (2020+)

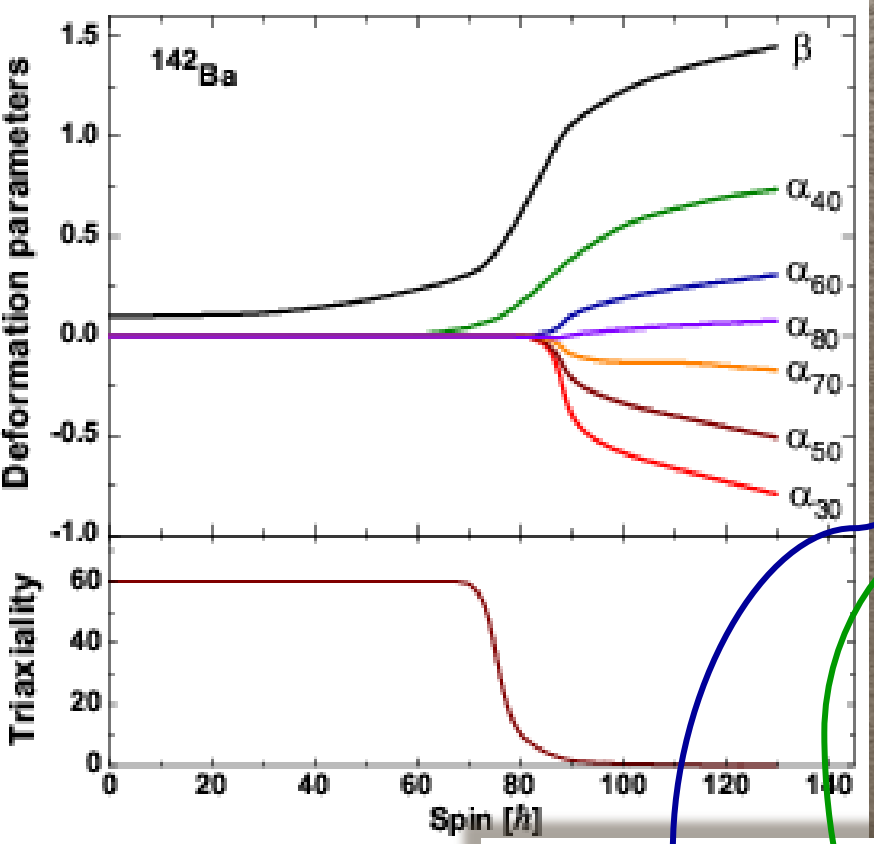
Search for Poincare shape transitions at high spins in neutron-rich nuclei produced in fusion-evaporation reactions at SPIRAL2 or LNL Legnaro/SPES

(A. Maj, S. Leoni)

With RI beams extremely high spins can be reached in fusion-evaporation reactions



Poincare shape transitions (e.g. in ^{142}Ba produced in ^{94}Kr on ^{48}Ca reaction)

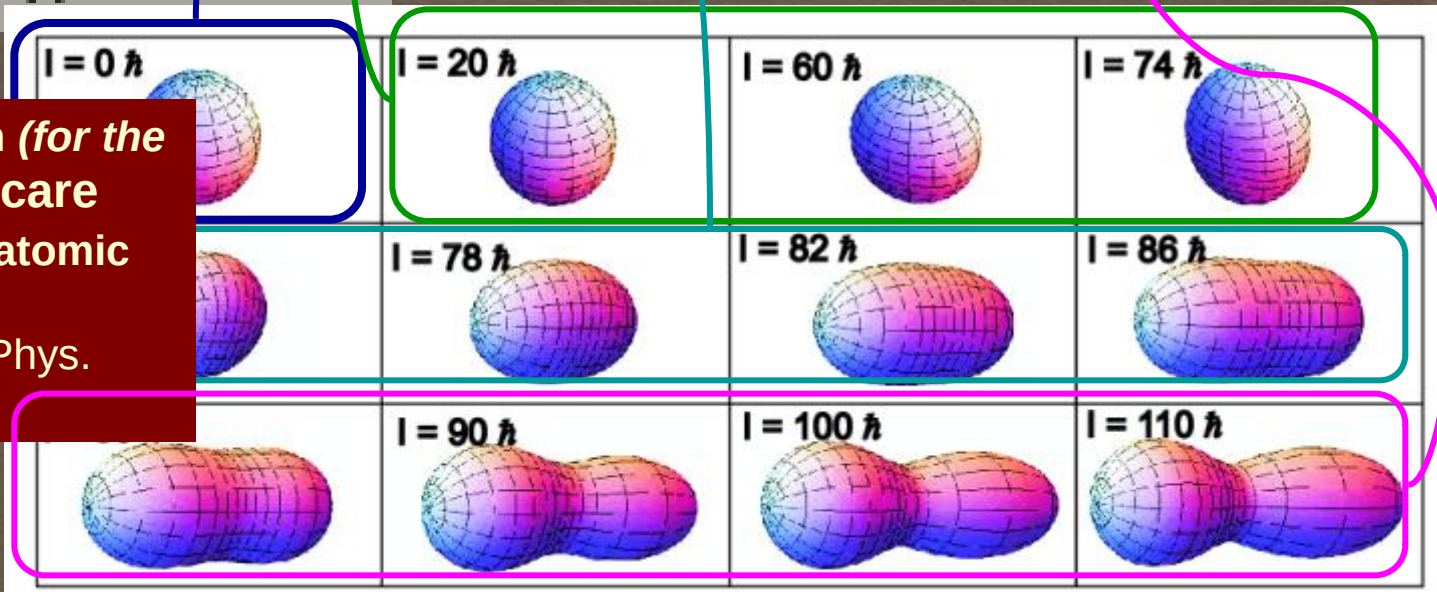


Sphere

Oblate (MacLaurin)

Elongated triaxial (Jacobi)

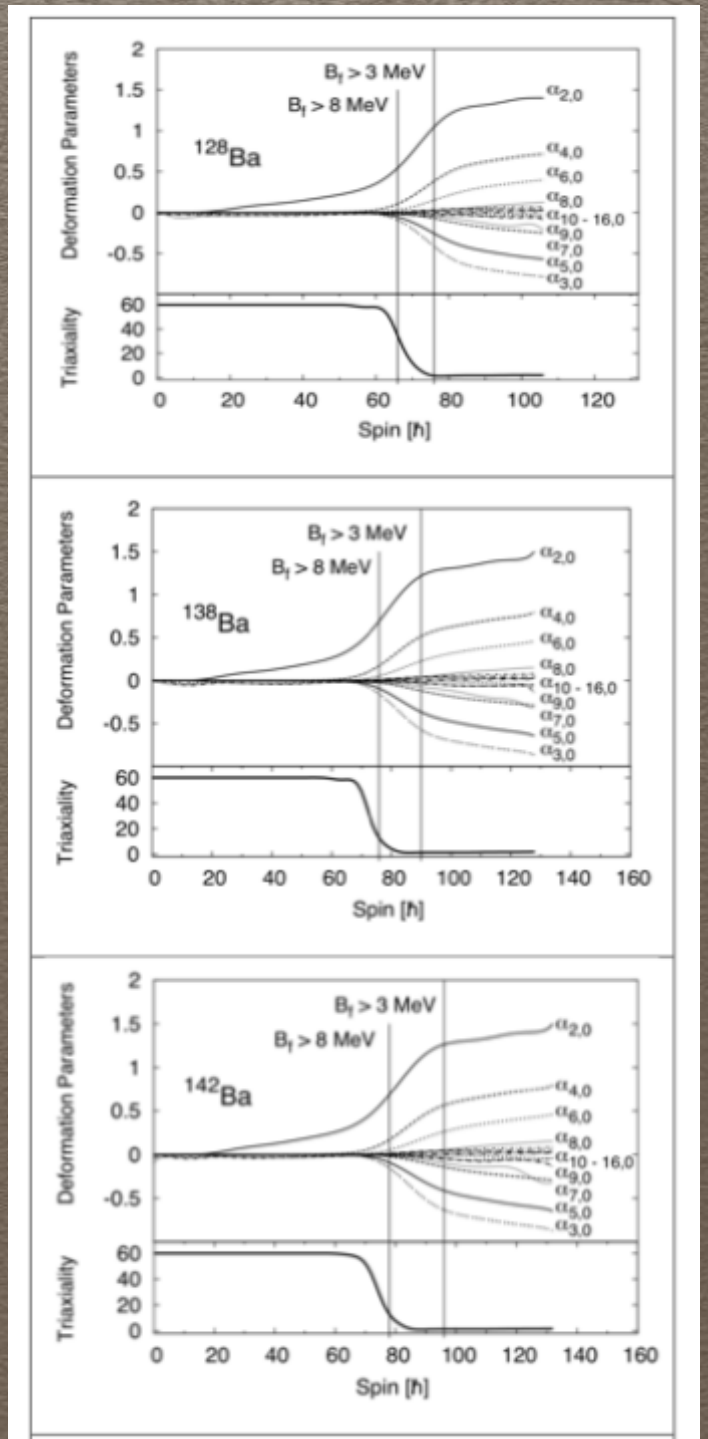
Octupole, left- right asymmetric (Poincare)



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)

Also ligther isotopes of Ba are showing the Poincare transitions

(K. Mazurek et al.,
Acta Phys.Pol. B42, 471 (2011))



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

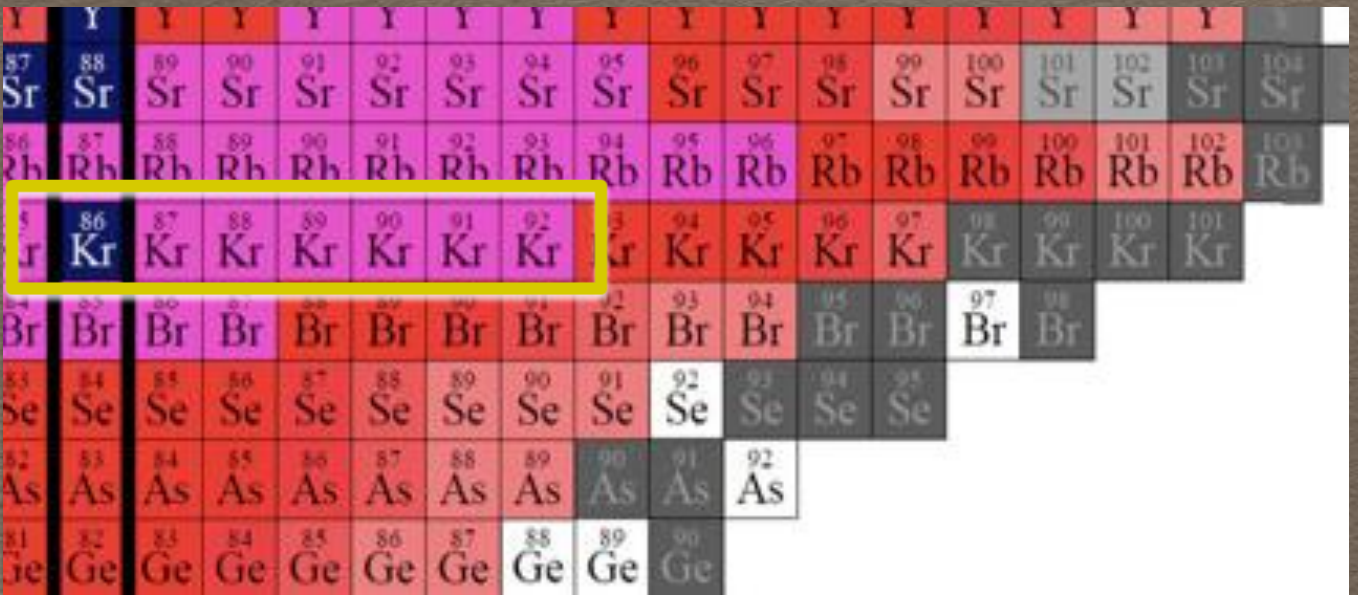
Spiral2 Day1-Phase2 LoI

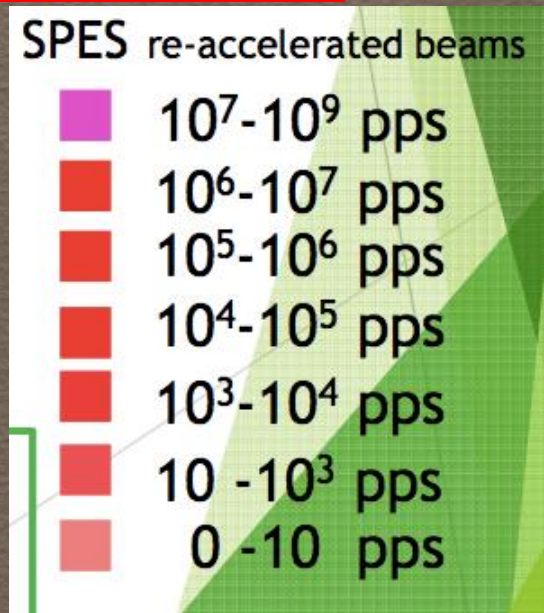
Adam Maj (Kraków), Silvia Leoni (Milano) - spokespersons
Christell Schmitt - GANIL Liaison
and the PARIS collaboration

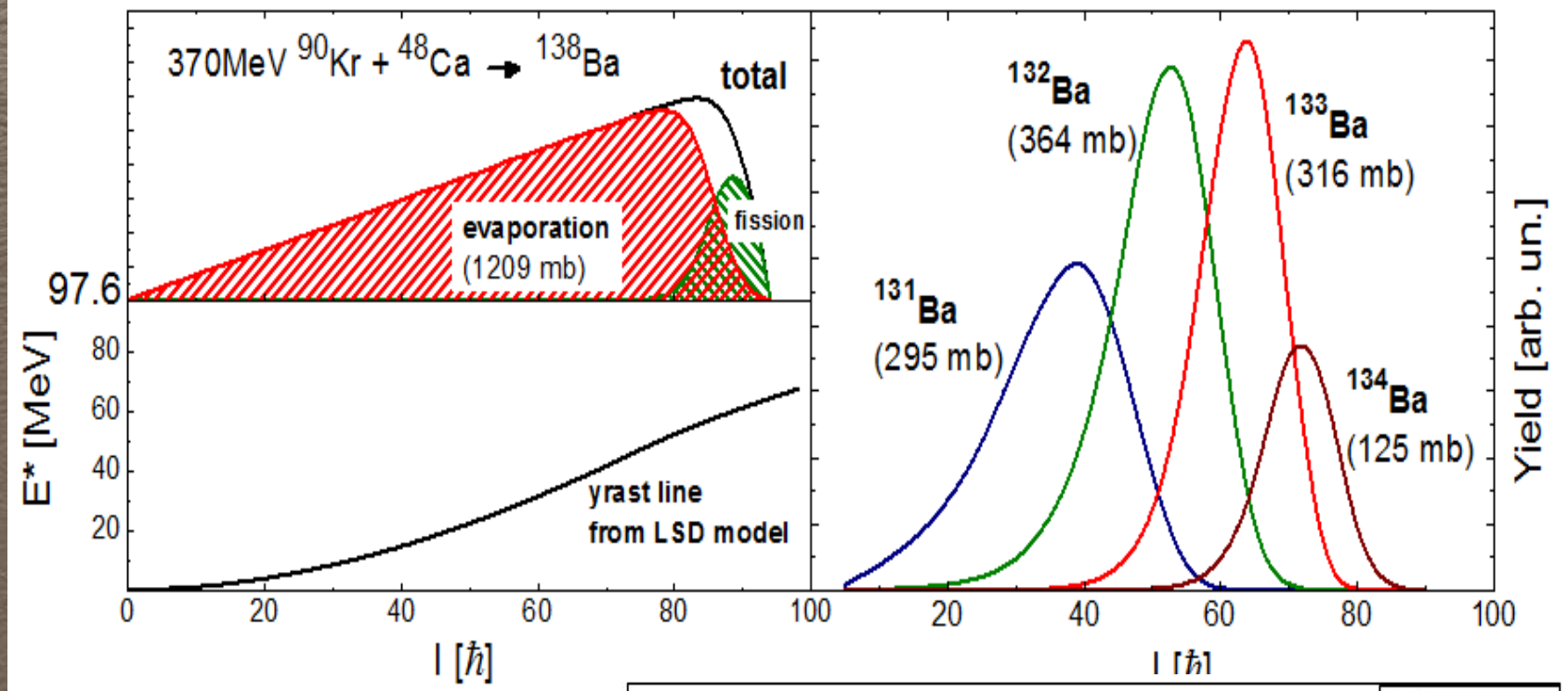
Day-1) At the first stage of SPIRAL2 the reaction **^{90}Kr** (with intensity of **5x10^{8} pps** and ~4 MeV/A) on **^{48}Ca** will be used to populate the compound nucleus **^{138}Ba*** at maximum spin around 90 $\hbar$.

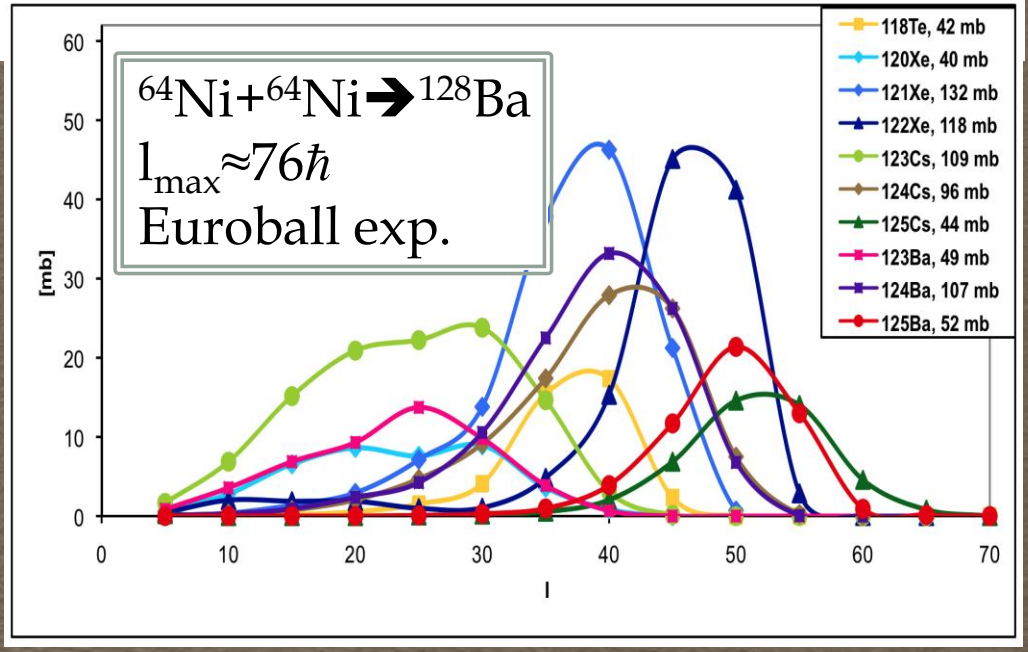
Day-2) At a later stage (Phase2-Day2) the even more neutron-rich system **^{142}Ba*** will be reached by the use of the **^{94}Kr** beam, with similar intensity.

Day 1 experiments could be done also at SPES with $^{86\text{-}92}$Kr beams



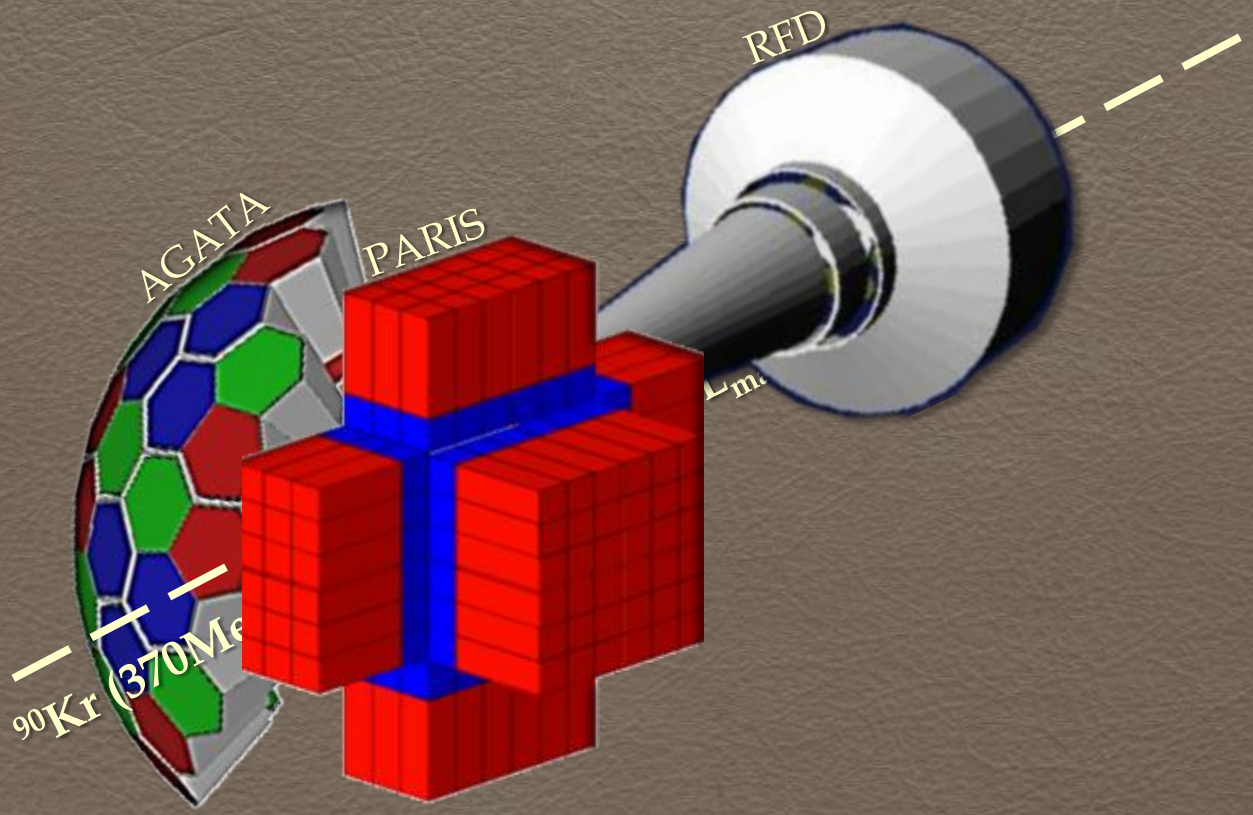



370MeV ^{90}Kr + ^{48}Ca → ^{138}Ba
total
evaporation
(1209 mb)
fission
97.6
yrast line
from LSD model
E* [MeV]
I [ħ]
^{132}Ba
(364 mb)
^{133}Ba
(316 mb)
^{131}Ba
(295 mb)
^{134}Ba
(125 mb)
Yield [arb. un.]


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

Experiment will require efficient

- **aray for discrete γ-rays (AGATA/EXOGAM/GALILEO),**
- **recoil detector (VAMOS, RFD)**
- **detector for high-energy photons: PARIS**



Summary and outlook

- 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.
- The next phase will be to complete the PARIS Phase2 (Demonstrator) of 5 clusters, each of 9 phoswich detectors
- First physics experiments are coming (GANIL, IPNO, Krakow, LNL)
- **PARIS project is progressing quite well**

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.Courtin – IPHC Strasbourg; Ch.Schmitt, M.Ciemała – GANIL; D. Jenkins – York; 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

Adam.Maj@ifj.edu.pl

ZAKOPANE CONFERENCE ON NUCLEAR PHYSICS

Extremes of the Nuclear Landscape — *August 31 - September 7, 2014*

Organized by
The Henryk Niewodniczański Institute of Nuclear Physics
Polish Academy of Sciences, Kraków, Poland

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Zakopane Schools
of Physics

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- from low lying shell model states to collective excitations at extreme spins and temperatures,
- from light to superheavy nuclei,
- from exotic proton drip-line nuclei to very neutron rich nuclear systems,
- new opportunities and challenges arising at the radioactive ion beam facilities
- role of today's nuclear structure research in the understanding of astrophysical processes and its influence on other disciplines.

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The 5th International Conference on

"COLLECTIVE MOTION IN NUCLEI UNDER EXTREME CONDITIONS"

September 14–18, 2015 Kraków, Poland

14-18 September, 2015

comex5.ifj.edu.pl

Testing the scinitillators from the PARIS, HECTOR+ and CALIFA collaborations with the proton beam (March 2013)

Layout of the beam delivery at CCB