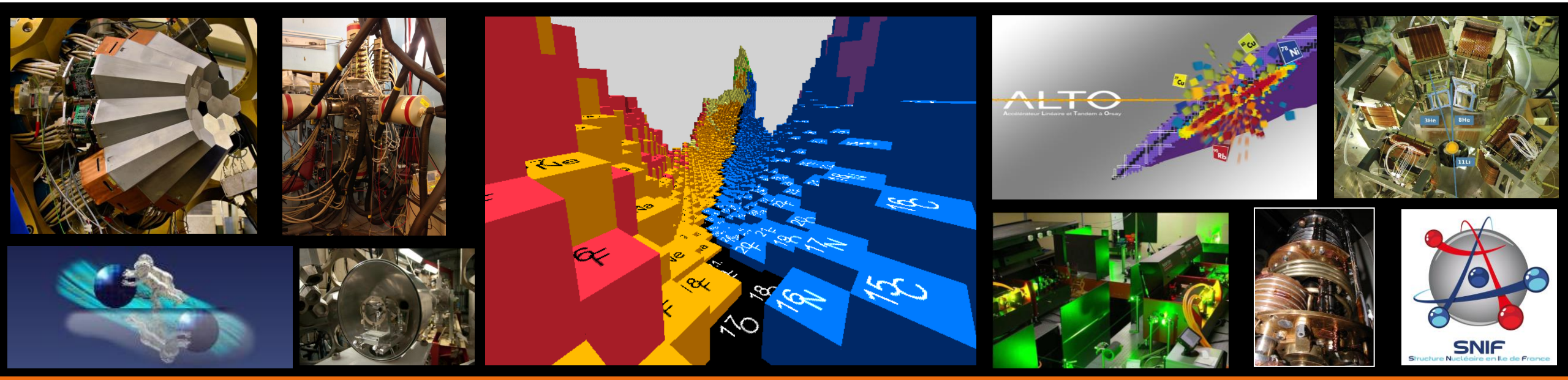
HCERES evaluation of Laboratoires de la vallée d'Orsay

CSNSM
IMNC
IPNO
LAL
LPT



Nuclear Structure & Dynamics

Speaker : David Verney
Contributors : SNO group (CSNSM), NESTER/NIM groups (IPN)

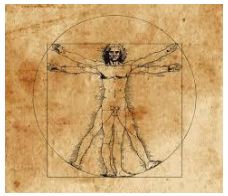
14-17 january 2019

Introduction to Nuclear Physics

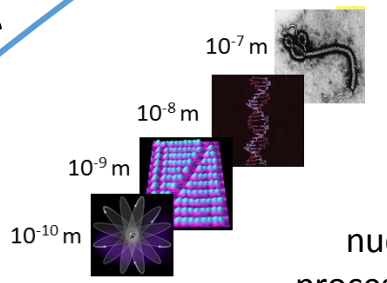
reduction

emergence
(the challenge of the XXIst century)

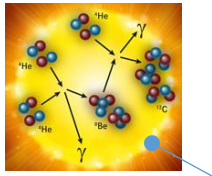
life & complexity



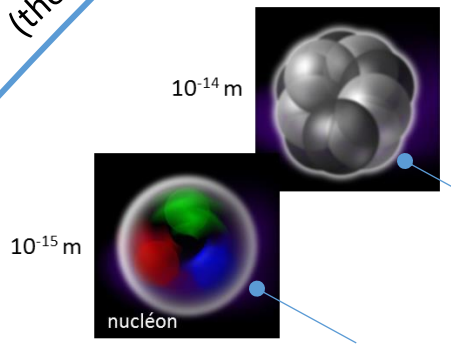
elemental diversity



nuclear processes and properties



nuclear astrophysics

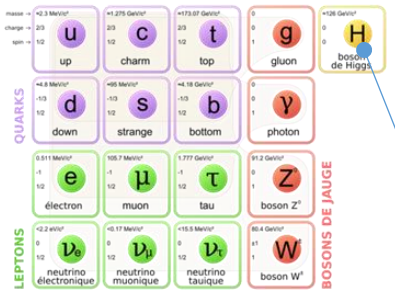


nucleons **in medium**
binding energy ≈ **MeV/u**

quarks & gluons **medium**
explains nucleon mass
≈ **1000 MeV**

Higgs process
explains mass of
quarks ≈ **5 MeV**

SU(3)×SU(2)×U(1)



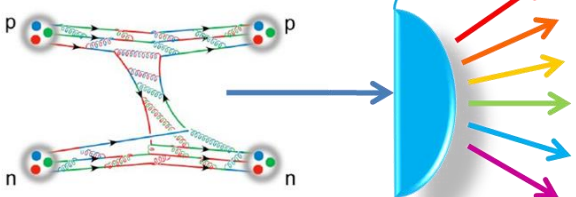
the origin of the mass of (≈90% of) visible universe:
due to **in-medium** (interacting) elementary particles

emergence nowadays theoretically addressed via **effective theories**
… we are experimentalists

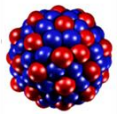
Introduction to Nuclear Physics

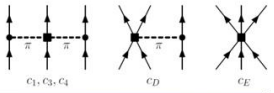
Nuclear interaction

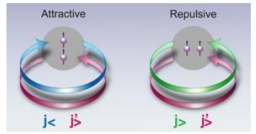
many-body problem

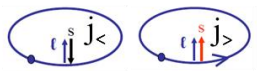


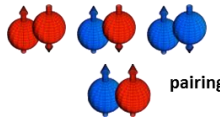
in medium





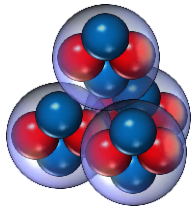




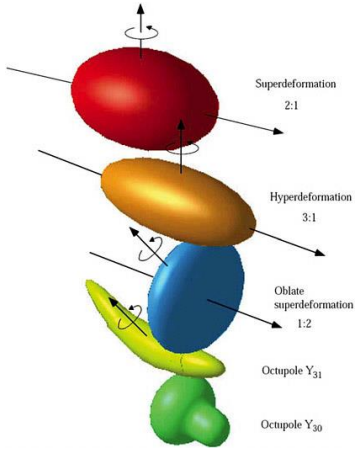


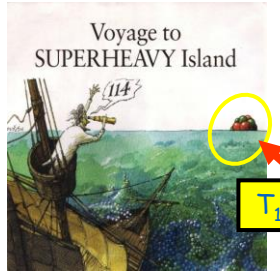
only possible strategy :
vary the *in medium* conditions
≡ explore 3 axes of the nuclide chart

emergence from an **experimental** point of view

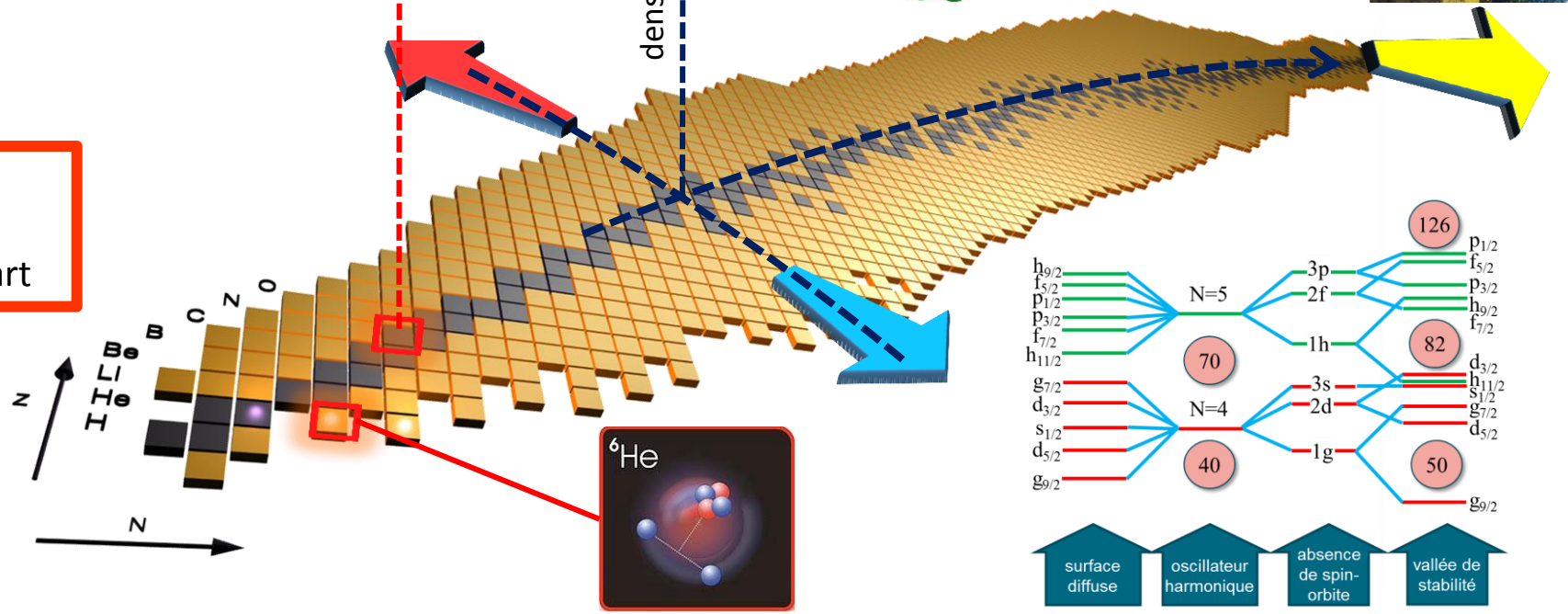


density, angular momentum





$T_{1/2}$ > 1 an



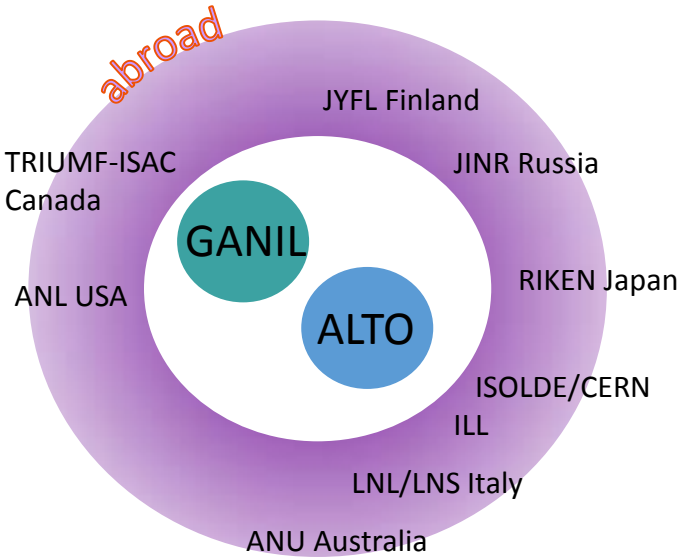
List of experiments/activities and laboratories

One single central question :
emergence at the microscopic scale

the discovery frontier (synthesis of new nuclei)

the precision frontier (network of observables)

Nuclear Spectroscopy : Orsay's field of excellence



laser spectroscopy

- ISOLDE/CERN : CRIS, COLLAPS
- ALTO : LINO (under construction)
- SPIRAL2/S3-LEB (under construction)

mass spectroscopy

- ISOLDE/CERN : ISOLTRAP
- TRIUMF/ISAC (Canada) : TITAN
- ALTO : MLL-Trap (under construction)
- SPIRAL2/DESIR (under construction)

particle and missing/invariant-mass spectroscopy

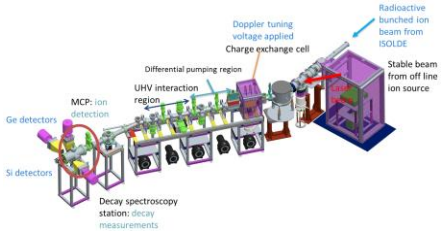
- GANIL : MUGAST, LISE, INDRA/FAZIA
- RIKEN (Japan)
- LNS (Italy): CHIMERA

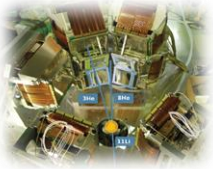
delayed/recoil spectroscopy

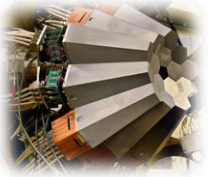
- ALTO : BEDO, TETRA, POLAREX
- GANIL : LISE
- JINR Dubna: GABRIELA
- SPIRAL2/S3: SIRIUS (under construction)

prompt γ-spectroscopy

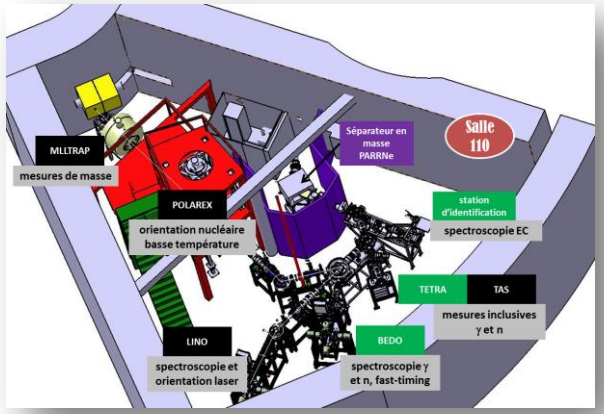
- ALTO : MINORCA, Nu-Ball
- GANIL : AGATA
- OUPS: lifetime measurements
- JYFL (Finland) : JUROGAM2, RITU
- ANL (USA) : GAMMASPHERE
- ILL : EXILL, FIPPS







List of experiments/activities and laboratories



a "builders" community —Orsay's NP hallmark—

detectors developments

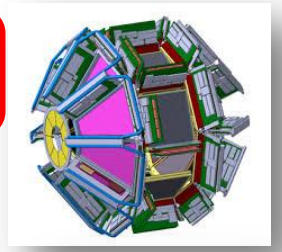
hall 110 instrumentation at ALTO:
BEDO, TETRA, POLAREX, LINO, MLL-Trap

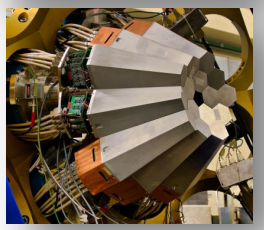
MUGAST towards GRIT

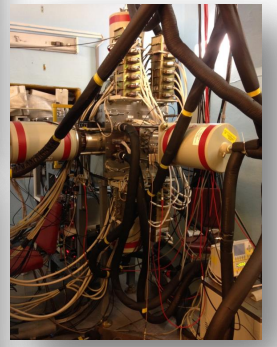
GABRIELA@Dubna, S3-REGLIS@SPIRAL2
S3-SIRIUS@SPIRAL2

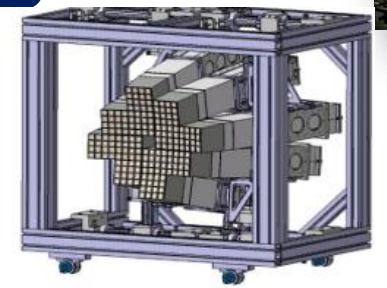
AGATA, OUPS, PARIS

FAZIA



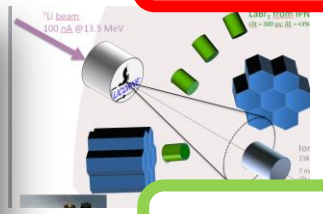






beam developments

ALTO ISOL-photofission



neutron beams:
LICORNE@ALTO

S3-LEB RIBs

Human resources

CNRS Research staff
- *Marlène ASSIE (CR)*
- *Alain ASTIER (CR)*
- *Didier BEAUMEL (DR)*
- *Yorick BLUMENFELD (DR)*
- *Isabelle DELONCLE (CR)*
- *Jérémie DUDOUET (CR) (2017-)*
- *Freddy FLAVIGNY (CR)*
- *Serge FRANCHOO (CR)*
- *Georgi GEORGIEV (DR)*
- *Jacques GUILLOT (CR)*
- *Karl HAUSCHILD (CR)*
- *Fadi IBRAHIM (DR)*
- *Dominique JACQUET (DR)*
- *Amel KORICHI (DR)*
- *François LE BLANC (DR)*
- *Joa LJUNGVALL (CR)*
- *Araceli LOPEZ-MARTENS (DR)*
- *Radomira LOZEVA (CR)*
- *David LUNNEY (DR)*
- *Marion MACCORMICK (CR)*
- *Brigitte ROUSSIERE (DR)*
- *Iulian STEFAN (CR)*
- *Daisuke SUZUKI (CR) (-2015)*
- *David VERNEY (DR)*
- *Jonathan WILSON (DR)*
- *Deyan YORDANOV (CR)*

University staff
- *Pierre DESESQUELLES (PR)*
- *Emmanuelle GALICHET (MCF)*
- *Carole GAULARD (MCF)*
- *Matthieu LEBOIS (MCF)*
- *Iolanda MATEA MACOVEI (MCF)*
- *Costel PETRACHE (PR)*
- *Stéphanie ROCCIA (MCF) (-2018)*

Senior research fellow
- *Giuseppe VERDE (2014-2017)*

Emeriti
- *Georges AUDI*
- *Bernard BORDERIE*
- *Chantale BRIANCON (-2015)*
- *Sydney GALES*
- *Marie-France RIVET (-2015)*

CNRS Technical staff (1)
- *Guillaume MAVILLA*

CNRS Secretarial staff (1)
- *Céline GAUBERT-ROSIER*

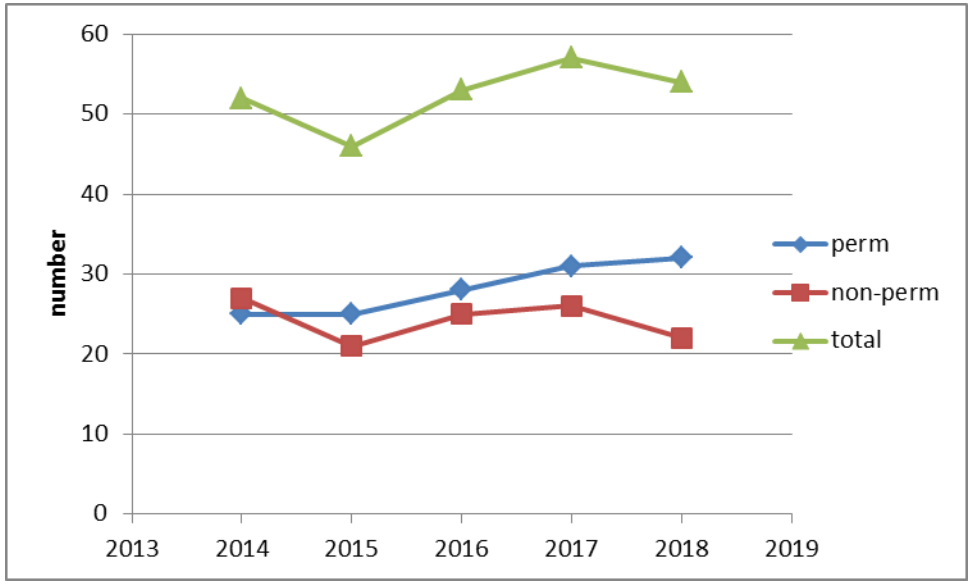
Post-doctoral fellows
- *M. BABO (2017-2019)*
- *P. CHAUVEAU (2016-2018)*
- *P. DUPRE (2012-2014)*
- *A. GOASDUFF (2012-2014)*
- *A. GOTTARDO (2013-2017)*
- *L. GRASSI (2016-2018)*
- *N. JOVANCEVIC (2018-2020)*
- *T. KONSTANTINOPOULOS (2012-2015)*
- *R. LI (2012-2015)*
- *E. MINAYA (2015-2017)*
- T. MORTENSEN (2013-2014)
- *M. NIIKURA (2013-2014)*
- *D. RALET (2015-2017)*

PhD students (def. year)*
- *P. GRANDEMANGE (2013)*
- *L. LEFEBVRE (2013)*
- *R. LEGUILLON (2013)*
- *A. ETILE (2014)*
- *V. MANEA (2014)*
- *A. CHOLLET (2015)*
- *S. KAIM (2015)*
- *T. ZERROUKI (2015)*
- *X. XING (2015)*
- *M. AIRIAU (2016)*
- *M.-C. DELATTRE (2016)*
- *M. KLINTEFJORD (2016)*
- *A. KUSOGLU (2016)*
- *B. LECROM (2016)*
- *K. REZYNKINA (2016)*
- *D. DELL'AQUILA (2017)*
- *J. GUILLOT (2017)*
- *A. LASHEEN (2017)*
- *L. OLIVIER (2017)*
- *C. PORTAIL (2017)*
- *A. BOUKHARI (2018)*
- *C. DELAFOSSE (2018)*
- *A. GEORGIADOU (2018)*
- *W. HUANG (2018)*
- *A. HUSSON (2018)*
- *I. MURRAY(2018)*
- *L. QI (2018)*
- *S. THOMAS (2018)*
- *M. MOUGEOT (2018)*
- *L. VASQUEZ (2018)*

PhD students (def. year)*
- *E. DUPONT (2019)*
- *P. LI (2019)*
- *B. LV (2019)*
- *V. ALCINDOR (2020)*
- *R. CHAKMA (2020)*
- *R. THOER (2020)*
- *M. SI (2021)*
- *G. HAEFNER (2021)*
- *L. LALANNE (2021)*
- *L. REN (2021)*
- *G. TOCABENS (2021)*
- *K. ZHANG (2021)*

Visiting senior scientists
- *D. Balabanski (ELI-NP, Bucharest)*
- *A. Macchiavelli (Lawrence Berkeley National Laboratory)*
- *D. Hojman (Buenos Aires, Argentina) June-July 2014*
- *M.A Cardona (Buenos Aires, Argentina) June-July 2014*
- *B. Dimitrov (INRNE, Sofia) June-July 2014*
- *G. Gavrilov (INRNE, Sofia) June-July 2014*
- *D. Tonev (INRNE, Sofia) regular visitor*
- *A.E. Stuchbery (ANU, Canberra, Australia) regular visitor*
- *M. Yavahchova (INRNE, Sofia) regular visitor*
- *Yu. Penionzhkevich (FLNR-JINR, Dubna) regular visitor*
- *S. Lukyanov (FLNR-JINR, Dubna) regular visitor*
- *V. Smirnov (FLNR-JINR, Dubna) regular visitor*
- *Yu. Sobolev (FLNR-JINR, Dubna) regular visitor*
- *M. Niikura (Univ Paris Sud, invited professor) - May-June 2017*
- *M. D. Guiot (Turkey) April 2015 - October 2016*
- *C. Petrone (NIPNE-HH, Bucharest), February 2018*

integrated 5-year-period population:
111 individuals



*note:
3 PhD/HDR holder
(1.9 PhD/perm. staff)
in a 5-year period

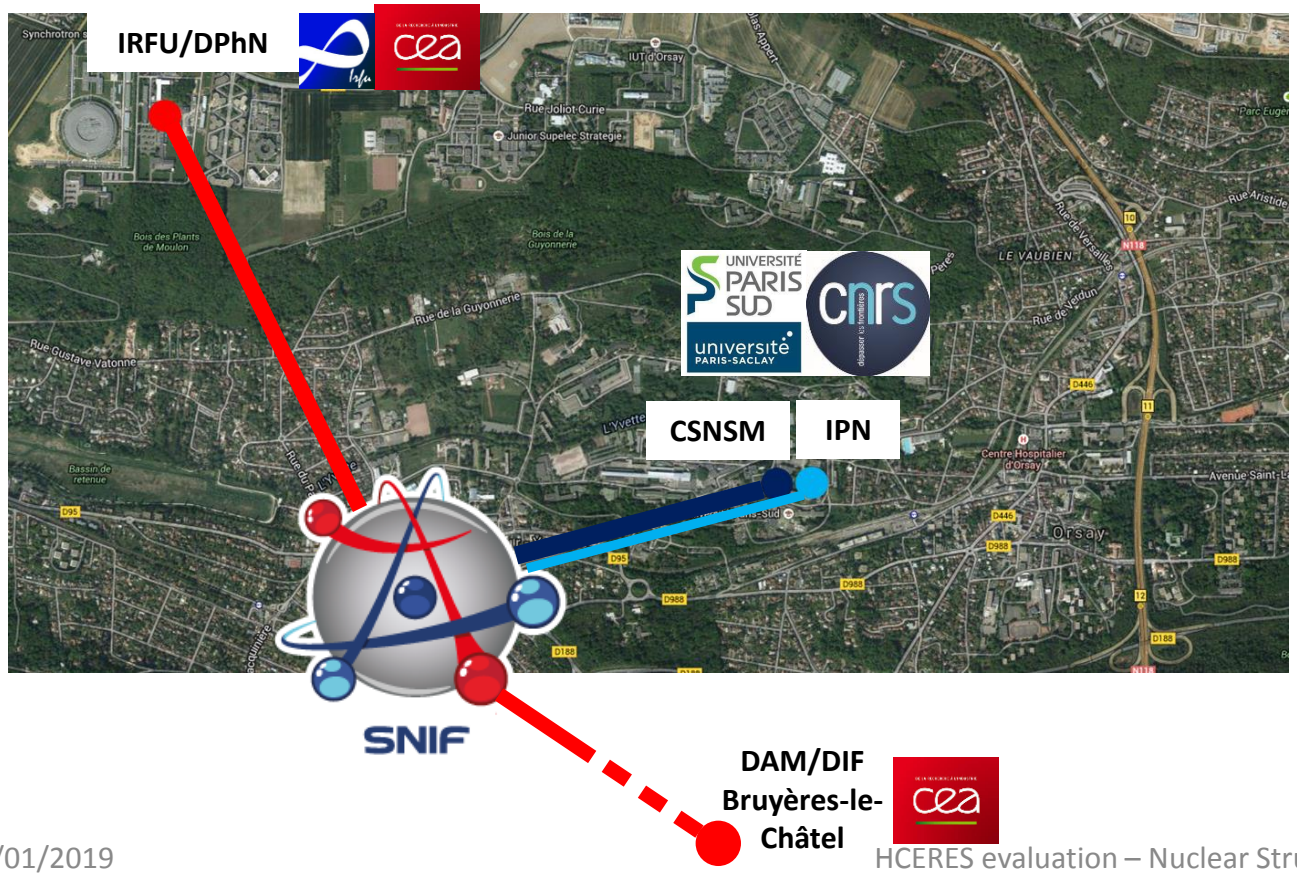
perm= CNRS + Univ.
non-perm= PhD
+research fellows
+emeriti

Link with local/national/international communities

A well locally/nationally/internationally integrated community

At the local level, organization around:

- The scientific forum SNIF (Nuclear Structure in Ile-de-France, gathering around 70 CEA, CNRS, UPSud nuclear physicists in Orsay-Saclay region)
- The P2IO LABEX
- The P2I Department of UPSaclay



At the national level, the community is structured by:

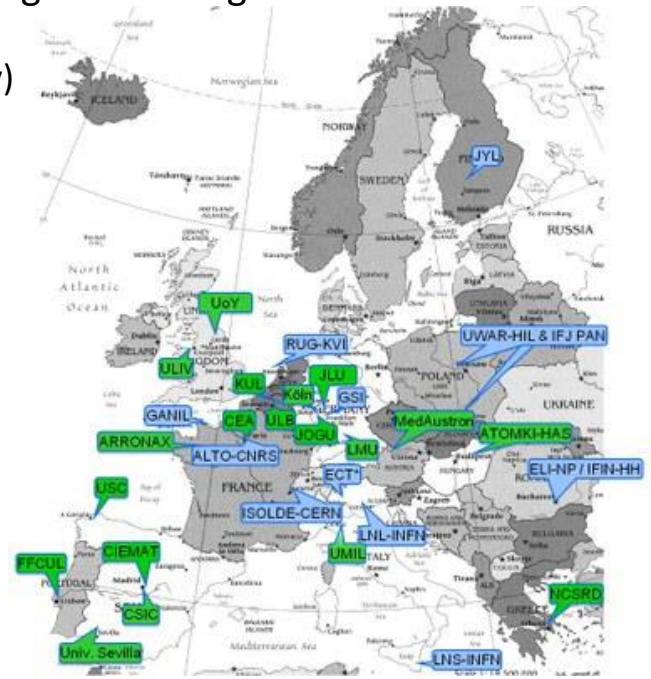
- IN2P3
- GANIL Users Community
- CNRS GDR RESANET (since 2018)

At the international level, strong networking:

- ENSAR2 European IA

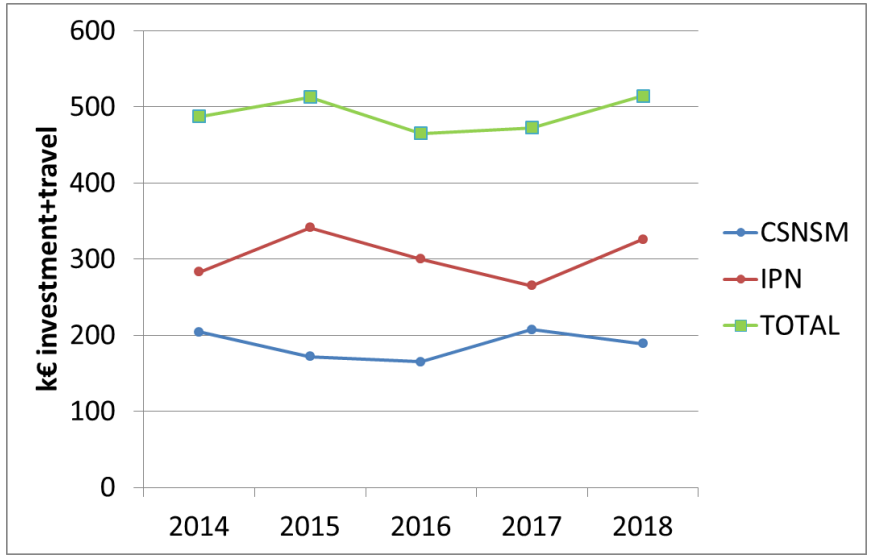
(ALTO is TransNational Acces facilty)

- future ERINS

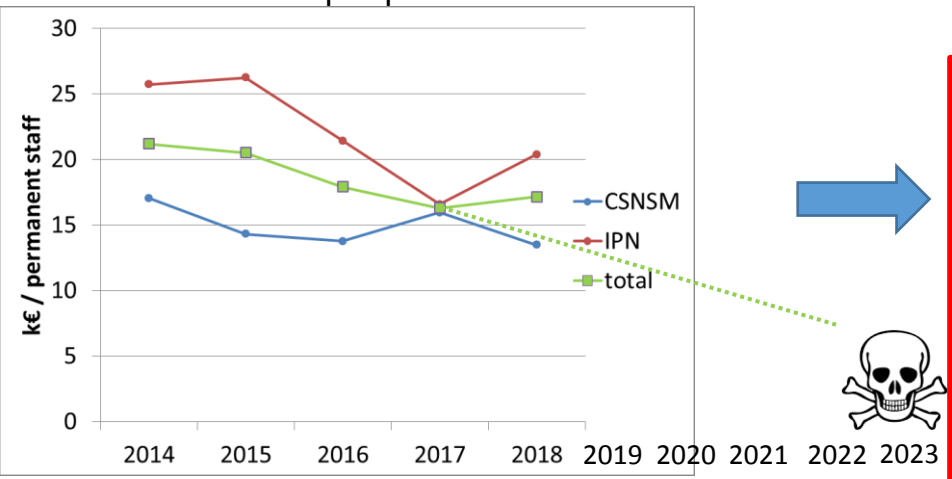


Financial support

IN2P3 funding



IN2P3 investment per permanent staff



Other funds :

National contracts
- ANR ANTION
- ANR PIPERADE
- ANR OASIS
- ANR POSITRAP
- ANR CLODETTE
- ANR CHYMENE
- ANR EXPAND
- French Embassy in Australia
- LIA FV-PPL France-Vietnam
- LIA COSMA France-Romania
- LIA COLLIGA France-Italy
- LIA COPIN France-Poland
- LIA France-RIKEN Japan
- PICS Russia Orsay-Dubna
- PICS Bulgaria
- PICS RIKEN
- IN2P3-JINR agreement (France-Russia)
- IN2P3-IFIN agreement (France-Romania)
- IN2P3-GSI agreement (France-Germany)

local grants
- SESAME Ile-de-France ReTIEN "Reaching Terra Incognita of Exotic Nuclei"
- U. Paris Sud ERM Grant

PIA grants
- EQUIPEX S3
- LABEX P2IO Highsp..
- LABEX P2IO Projet emblématique: "charting terra incognita"
- LABEX P2IO ½ PhD funding
- LABEX P2IO 2 post-doc fundings

European contracts
- ENSAR2 (TNA ALTO, various JRA's, NA's)

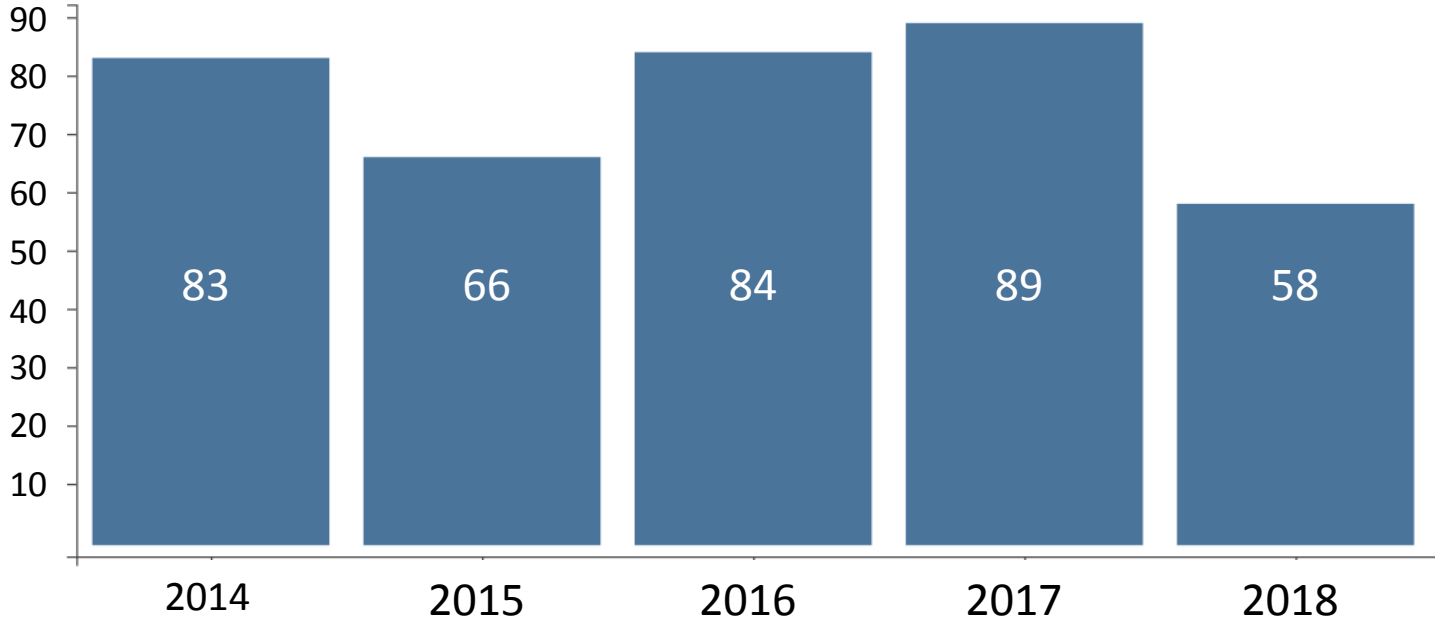
proposed analysis
- difference IPN/CSNSM mainly explained by investments on ALTO related projects (LINO, MLLTrap, **nu-ball** etc) + PARIS + GASPARD led by IPN's group
- IPN's group budget suffered more from the absence of travel money to go to GANIL, not supported any more by IN2P3
- incredible increase of the funding sources, each generally insufficient to achieve a given project, time is money and money is more and more time consuming
- A simple extrapolation of 2015-to-2017 trend would indicate vanishing support from IN2P3 by the end of next five-year plan.

Publications

Total Publications

381* Analyze

(* bottom value)



76 items published per year on the average
(including letters, articles, proceedings, reviews)

Source: Web of Science

Average citations per item

6,18

Sum of Times Cited

2 355

Without self citations

1 862

Citing articles

1 439 Analyze

Without self citations

1 234 Analyze

Prizes

- **A. Etilé (PhD student):** laureate of the L'Oréal-UNESCO For Women In Science Award – 2013
- **V. Manea (PhD student)**: Springer Thesis Prize – 2014
- **PhD students**: several poster/presentation prizes in international conferences
- **S. Galès**: Grand Prix Felix Robin French Physical Society (SFP) – 2014
- **S. Galès**: Chevalier dans l'Ordre National de la Légion d'Honneur – 2015
- **A. Lopez-Martens**: First Prize of the Joint Institute for Nuclear Research (Dubna, Russia) – 2015
- **K. Hauschild**: First Prize of the Joint Institute for Nuclear Research (Dubna, Russia) – 2015
- **S. Galès**: Fellow European Physical Society – 2016
- **F. Ibrahim**: First Prize of the Joint Institute for Nuclear Research (Dubna, Russia) – 2018
- **D. Verney**: First Prize of the Joint Institute for Nuclear Research (Dubna, Russia) – 2018

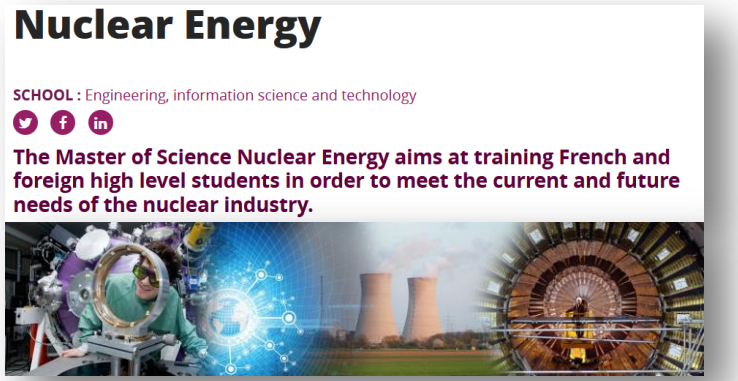
Joint Institute for Nuclear Research

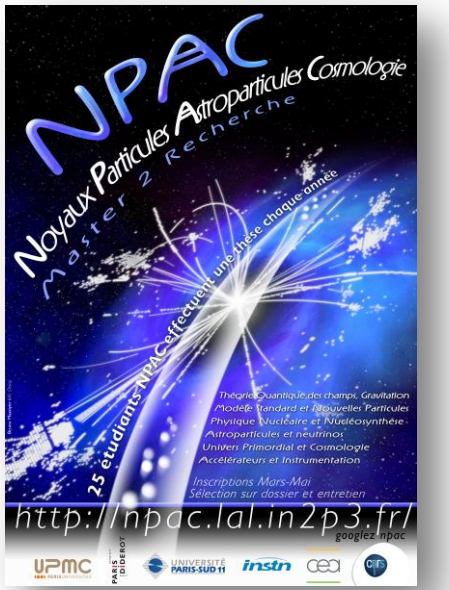
SCIENCE BRINGING NATIONS TOGETHER

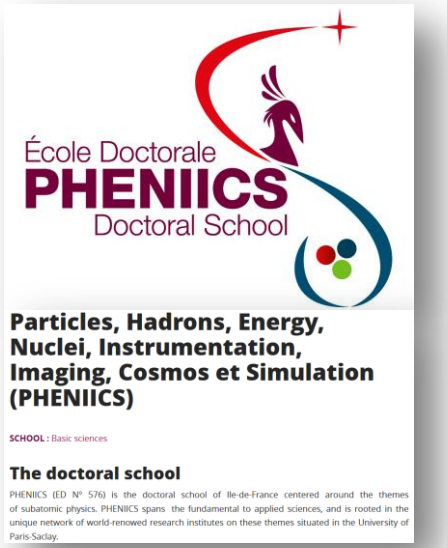
Teaching activities

- **7 University staff members (soon reduced to 5)**
- **+ classes taught by non-teaching CNRS staff members (2) at M2 and Doctoral School levels**
- **+ PhD students (almost 100%) have teaching duties**
- → from general physics at undergraduate level to specialized courses in subatomic physics

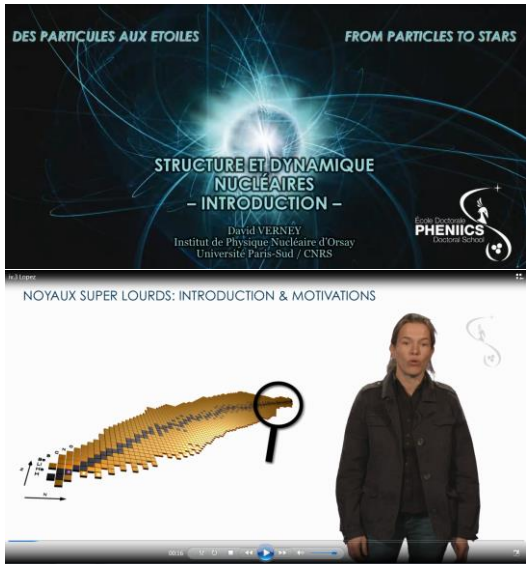
- **Academic responsibilities:**
  - **Co-Head:** Master-2 NPAC (Nuclei, Particles, Astroparticles, Cosmology)
  - **Co-Head**: Master-1&2 of Science Nuclear Energy
  - **Co-Head** : 1st year undergraduate (Licence Math-Physics-Computer science)
  - **Deputy Director:** Doctoral School n°576 "PHENIICS" (Particles, Hadrons, Energy, Nuclei, Instrumentation, Imaging and Simulations)
  - **Head**: several Teaching Units (Unités d'Enseignement)
  - **Membership**: Local and National University Councils (CCSU, CNU, UPSud Councils…)

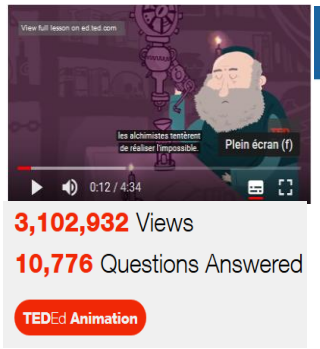






Outreach/Valorisation (+ scientific events organization)



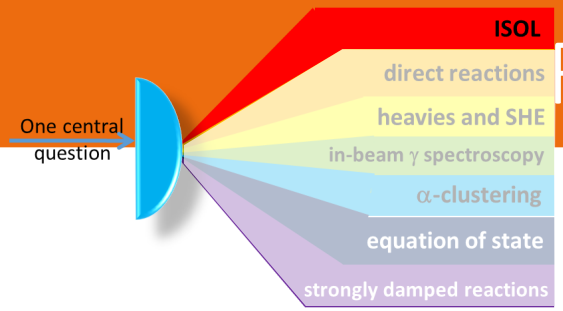


- **Organization** of the International Conference on Shapes and Symmetries in Nuclei from Experiment to Theory (yearly, Gif-sur-Yvette)

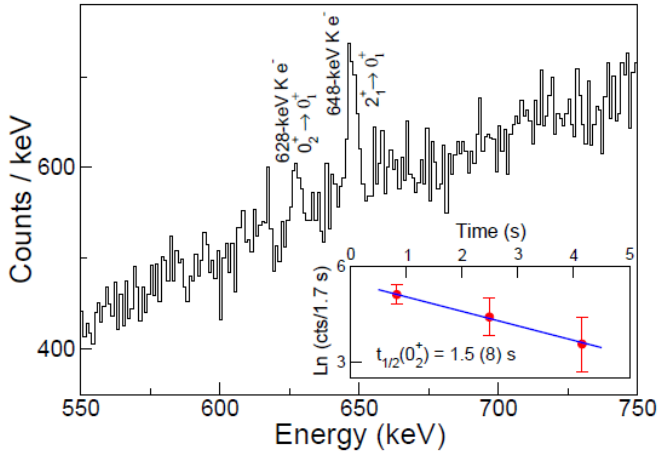
27 Countries, 130 participants (30 France, 12 Japan, 11 USA, 9 UK, 8 China, 7 Germany)
Physica Scripta Focus Issue celebrating the 40-year anniversary of the 1975 Nobel Prize in Physics to Bohr, Mottelson and Rainwater (http://iopscience.iop.org/article/10.1088/0031-8949/91/3/030301)

- **Organization** of various collaboration meetings (within ENSAR2, ALTO and AGATA related collaborations etc)
- **MOOC** "From particles to stars"
- **Outreach movie** TED Ed : Where does gold come from ?
- School **lecturing** and **organization**:
  - "Rencontres de Physique de l'infiniment grand à l'infiniment petit" (summer school at Orsay-Saclay campuses)
  - "De la physique aux détecteurs" & "Du détecteur à la mesure" (IN2P3 Instrumentation school for engineers and doctoral students)

Scientific achievements (2013 - 2018)



First evidence of shape coexistence in the ^{78}Ni region



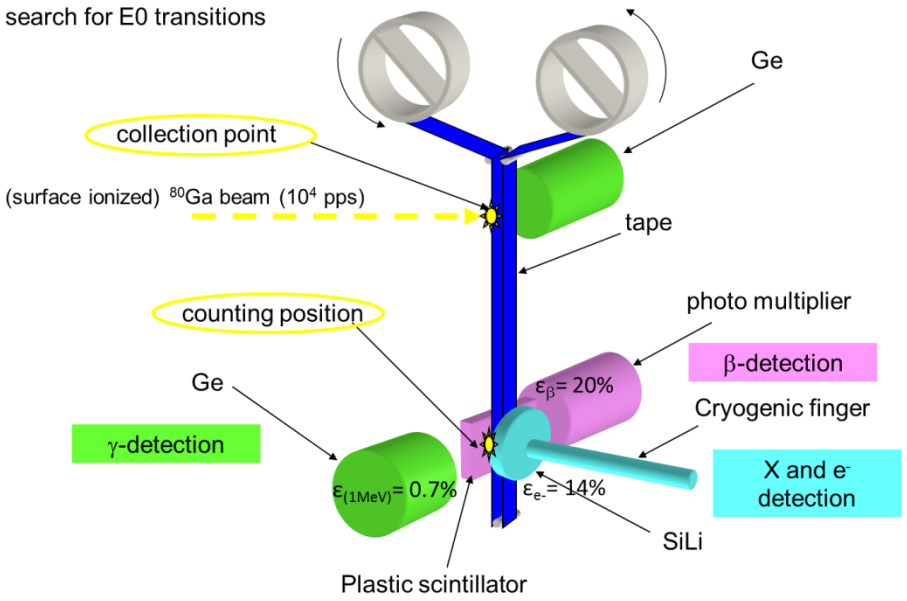
PRL 116, 182501 (2016) PHYSICAL REVIEW LETTERS week ending 6 MAY 2016

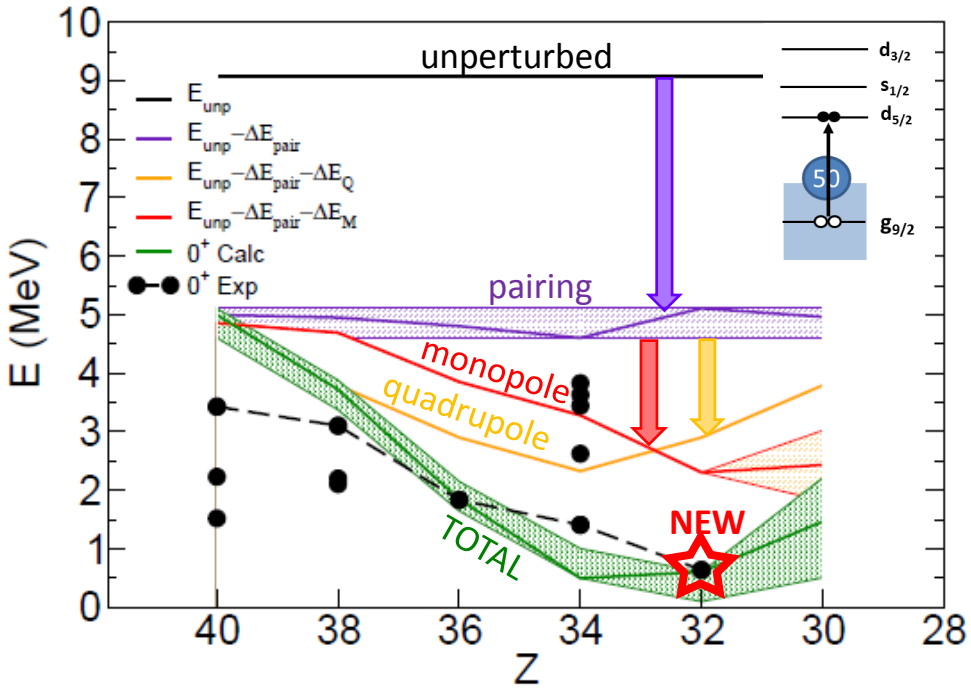
First Evidence of Shape Coexistence in the ^{78}Ni Region: Intruder 0_2^+ State in ^{80}Ge

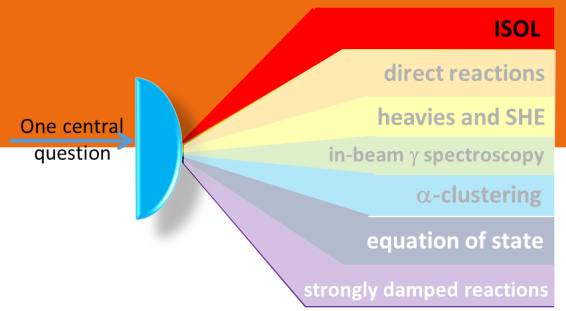
A. Gottardo,[1,*] D. Verney,[1] C. Delafosse,[1] F. Ibrahim,[1] B. Roussière,[1] C. Sotty,[2] S. Roccia,[3] C. Andreoiu,[4] C. Costache,[2] M.-C. Delattre,[1] I. Deloncle,[3] A. Etilé,[5] S. Franchoo,[1] C. Gaulard,[3] J. Guillot,[1] M. Lebois,[1] M. MacCormick,[1] N. Marginean,[2] R. Marginean,[2] I. Matea,[1] C. Mihai,[2] I. Mitu,[2] L. Olivier,[1] C. Portail,[1] L. Qi,[1] L. Stan,[2] D. Testov,[6,7] J. Wilson,[1] and D. T. Yordanov[1]

[1]*Institut de Physique Nucléaire, CNRS-IN2P3, Université Paris-Sud, Université Paris-Saclay, 91406 Orsay Cedex, France*

Experimental setup at the PARRNe online mass-separator - ALTO

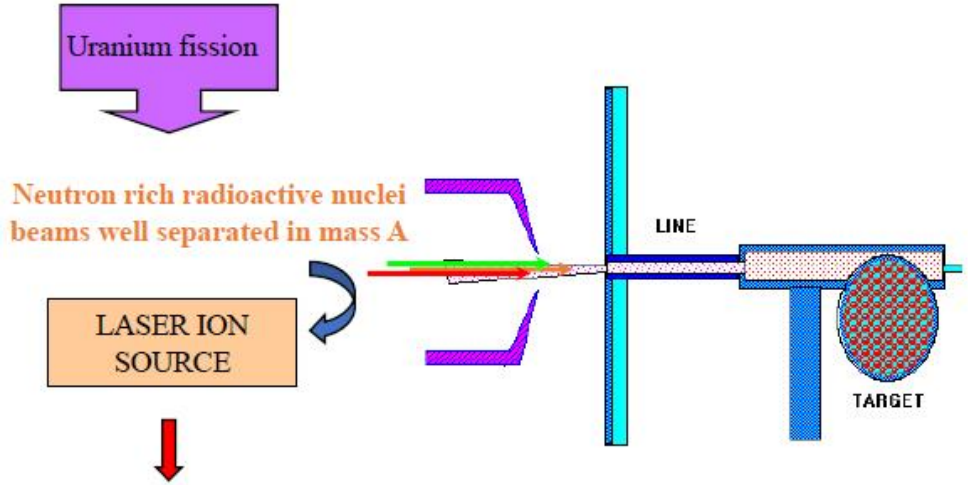


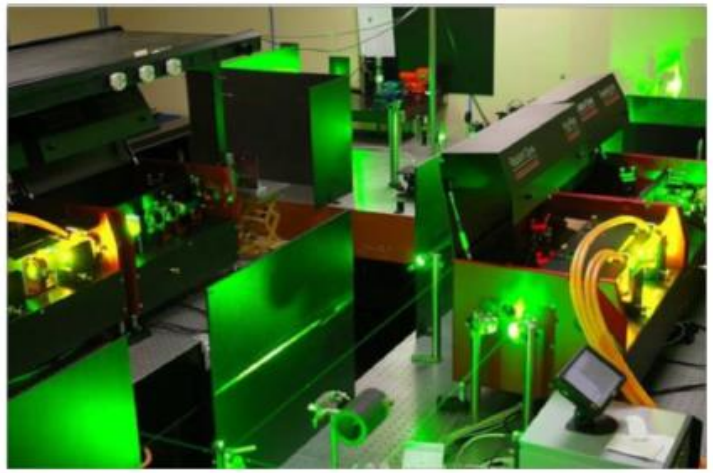




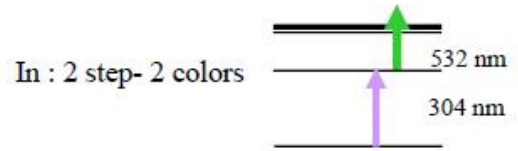
Laser ionized In isotopes record production

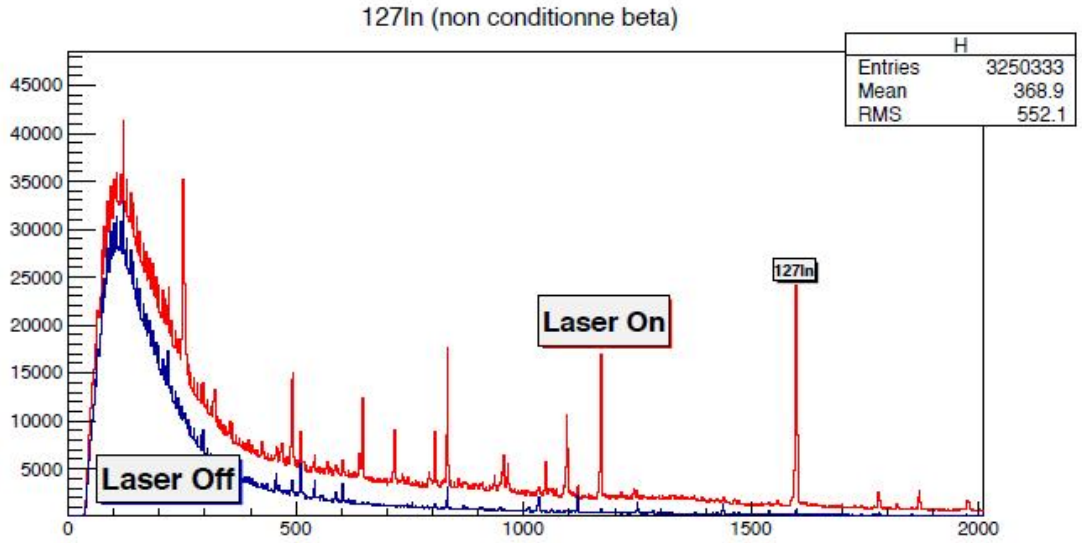
ALTO laser ion source



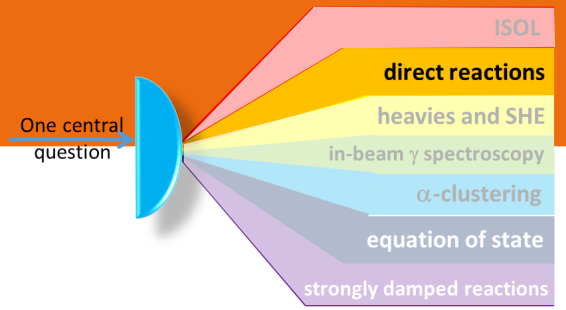


November 2018 : 10 days run at ALTO with indium beam





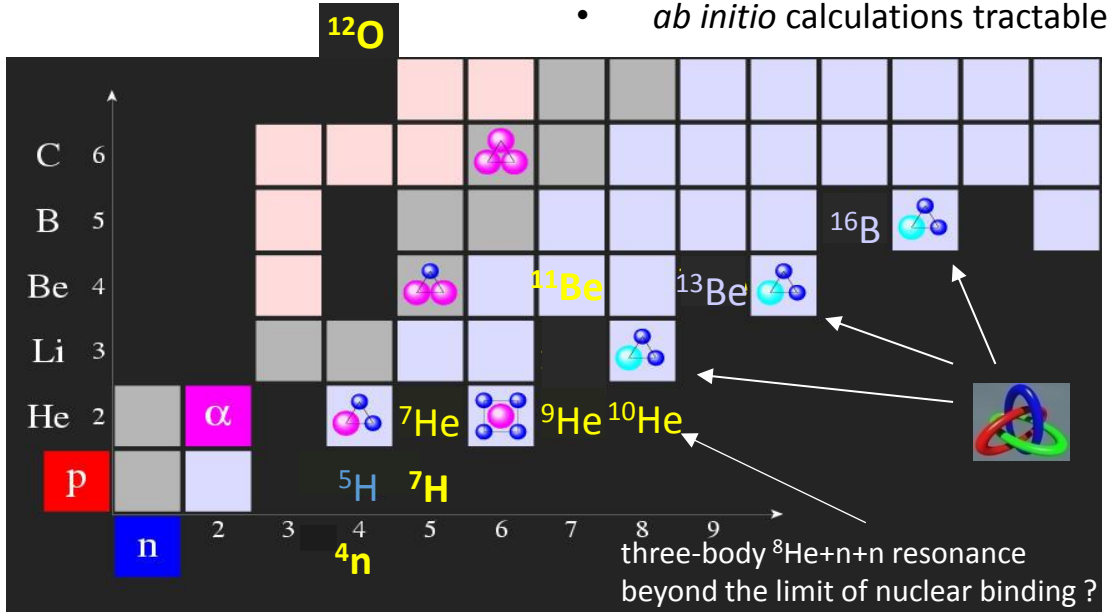
Efficiency : factor of **50**/surface ionisation



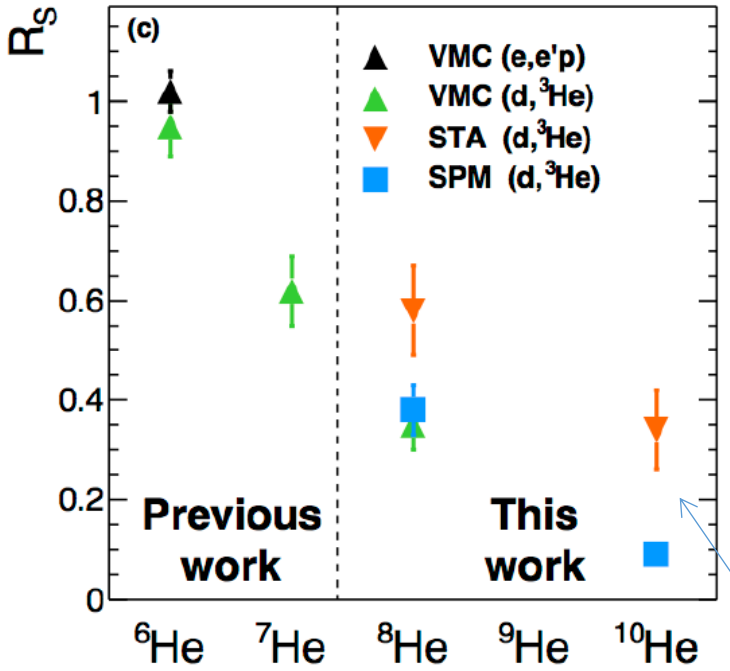
Nuclear overlaps near the dripline

Light exotic nuclei extensively studied by the group using Direct Reactions

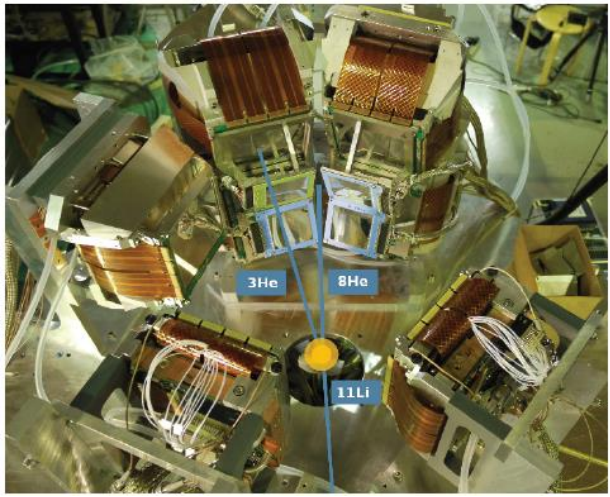
- Drip-line and beyond experimentally accessible
- Haloes, Molecular structures
- *ab initio* calculations tractable



$R_S = \sigma^{EXP} / \sigma^{CALC}$



9,11Li(d,3He) at 50 MeV/u



PRC92, 041302(R)(2015)

- observation of a new decay branch, ^{6}He + 4n,
- and of a puzzling reduction of the ^{11}Li(d,^{3}He)^{10}He cross section

→ challenges this view

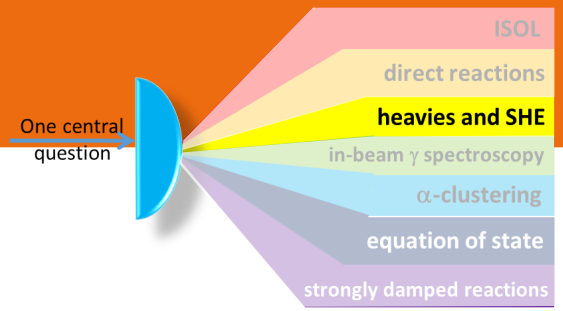
to be done:

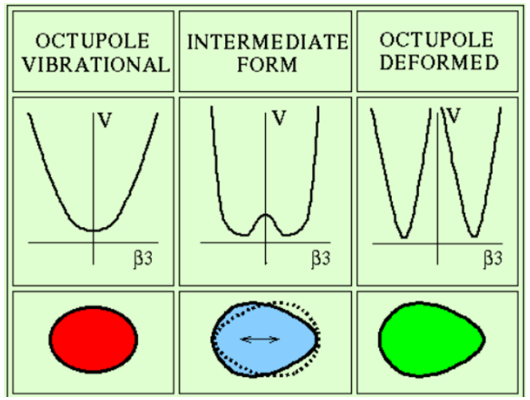
- Test of <Be|Li> overlaps: ^{12}Be(d,^{3}He) at GANIL/LISE --under analysis
- New data on ^{10}He from ^{14}Be(p,pα) --under analysis

Clear decreasing trend

Failure of *ab initio* VMC *overlaps ?*

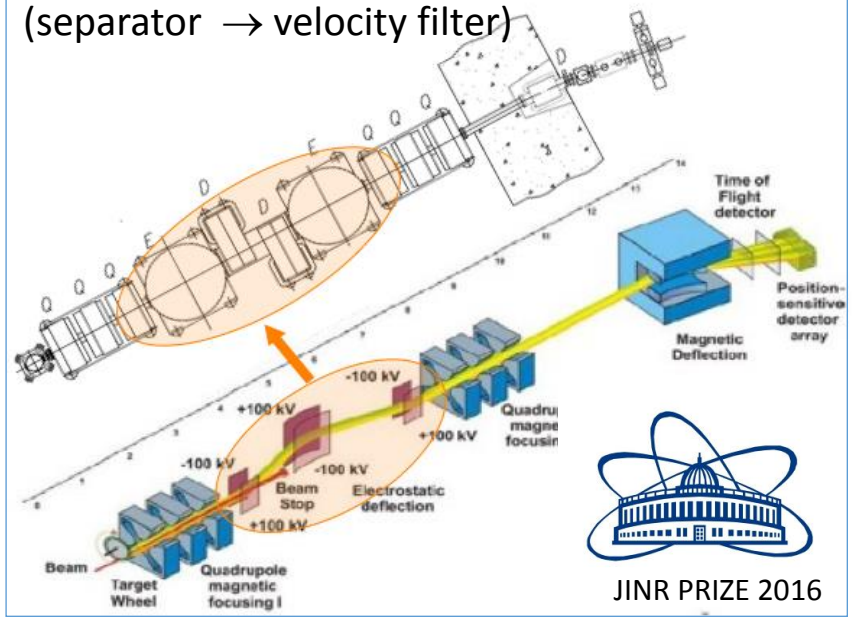
Spectroscopy of SHE with GABRIELA @ SHELS





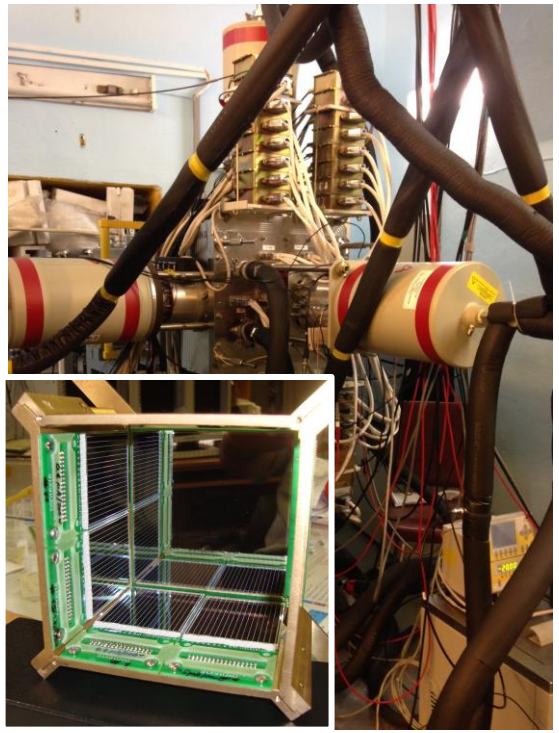
PhD thesis (2016)
and Phys. Rev. C 97 (2018) 054332

VASSILISSA → SHELS (2006-2013)
(separator → velocity filter)



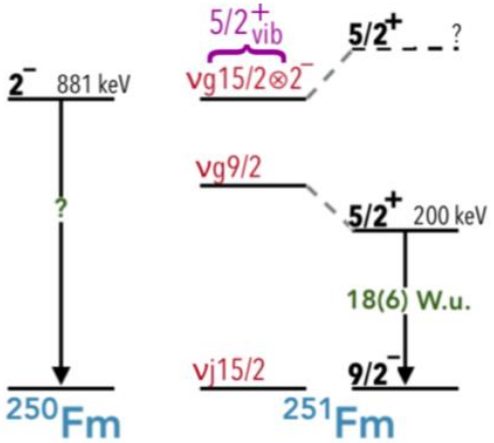
JINR PRIZE 2016

Upgrade of GABRIELA (2012-2016)



Commissioning (2016)

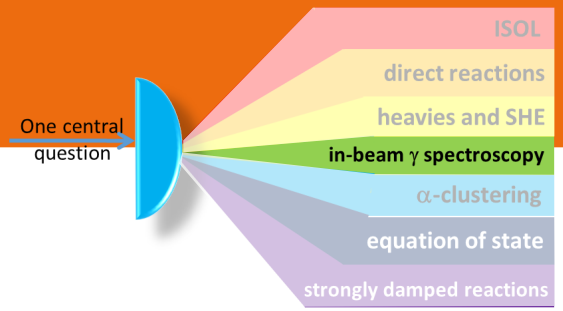
γ and ICE decay of the $5/2^+$ isomer in ^{251}Fm :
evidence for octupole collectivity



2017-2018: First physics campaigns

- p evaporation from ^{259}Db* (submitted)
- Decay properties of ^{257}Rf (to be published)
- Searh for isomers in ^{255}Rf (PhD thesis of R. Chakma)

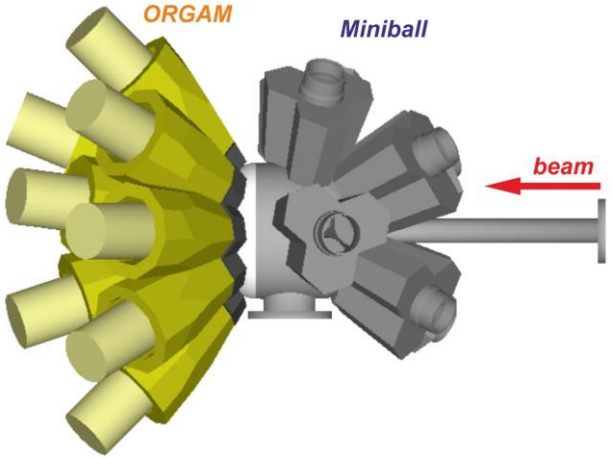
8-months long ν-ball campain at ALTO



MINORCA

(Miniball'N'ORgam CAmpaign)

(Joint SNO/NESTER effort already in 2014-2015)



- 15 ORGAM ***anti-Compton shielded*** efficiency 1.8% (at 1.3 MeV)
- 8 Miniball triple cluster detectors ***with addback*** efficiency : 6.3% (at 1.3 MeV)

→ total :8.1%

PRL 118, 222501 (2017) PHYSICAL REVIEW LETTERS week ending 2 JUNE 2017

Anomalies in the Charge Yields of Fission Fragments from the $^{238}U(n, f)$ Reaction

24 Clover Ge + BGO
10 Coaxial Ge + BGO
20 LaBr3 (FATIMA coll.)
ou 36 PARIS phoswich

UK-Fr loan pool

ν-ball experimental campaign

Nov. 2017-June 2018. 10 experiments > 3000 h of beam time

The ν-ball international collaboration

153 scientists from 16 nationalities and 37 institutions, among which 80 PhD students

the ν-ball spectrometer at ALTO

Innovations

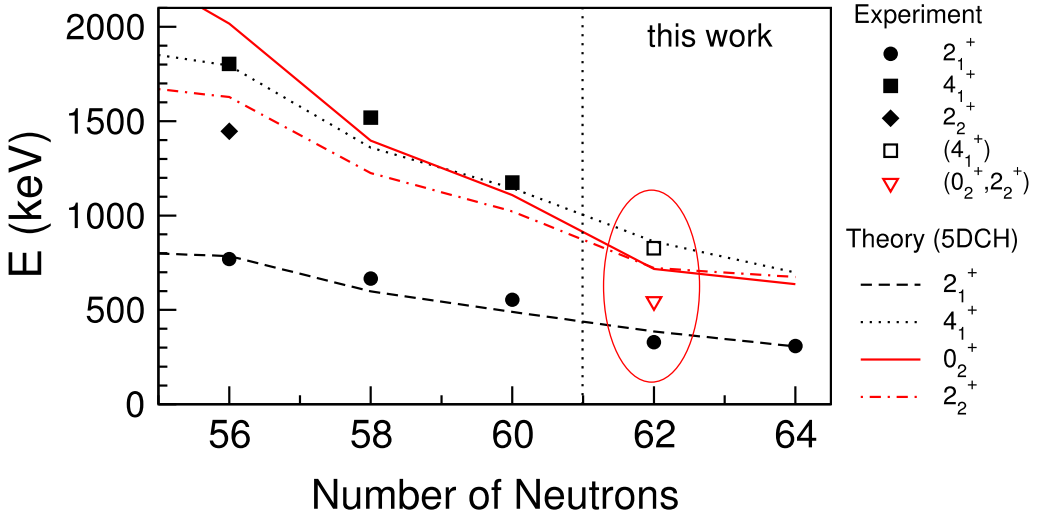
- ✓ hybrid spectrometer (Ge/LaBr3) high resolution, high efficiency
- ✓ On line with the LICORNE directional neutron source (pulsed n-beam, quasi monoenergetic)
- ✓ Calorimetry technique for reaction tagging
- ✓ fully digital DAQ, 200 channels
- ✓ Triggered or Triggerless modes

The discovery frontier: First spectroscopy of ^{98,100}Kr and ^{79}Cu

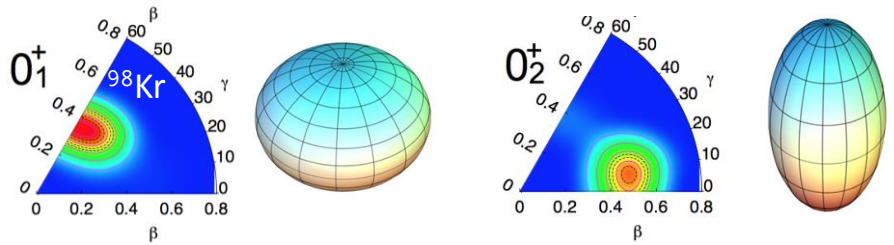
Collaboration SEASTAR: CEA/SPhN, RIKEN, FLUO, ….

PRL 118, 242501 (2017) PHYSICAL REVIEW LETTERS week ending 16 JUNE 2017

Shape Evolution in Neutron-Rich Krypton Isotopes Beyond $N = 60$: First Spectroscopy of ^{98,100}Kr



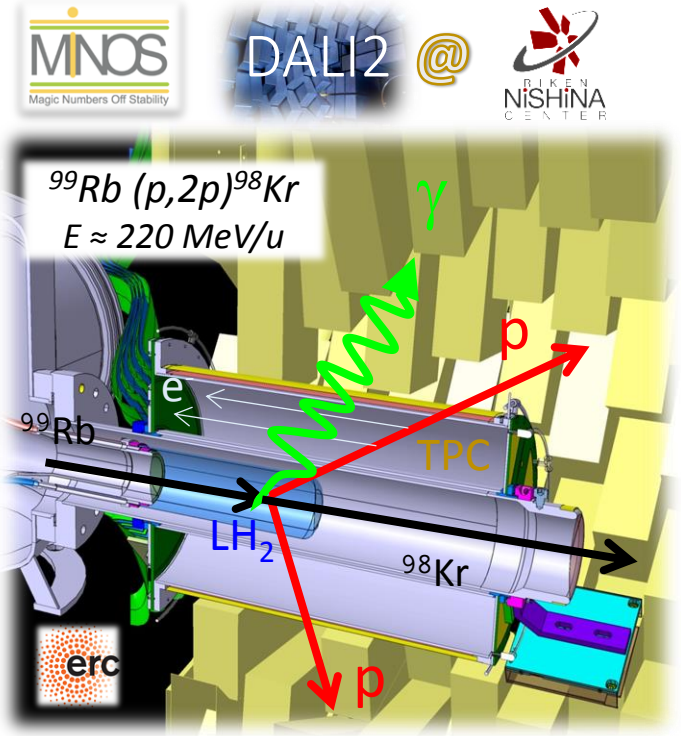
Interpretation: Subtle competiton between coexisting shapes

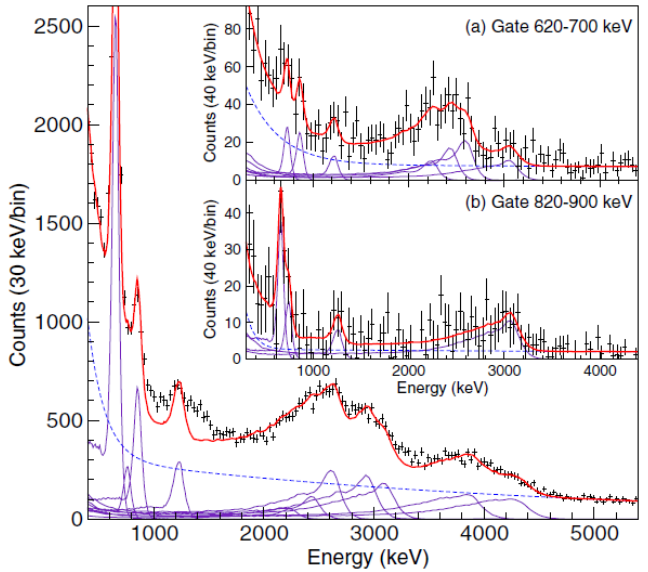


Calc. (int. Gogny D1S): J. P. Delaroche et al. (CEA/DAM), T. Rodriguez (U. Madrid),

PRL 119, 192501 (2017) Selected for a Viewpoint in Physics PHYSICAL REVIEW LETTERS week ending 10 NOVEMBER 2017

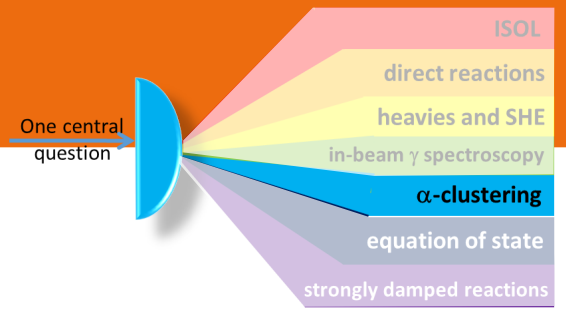
Persistence of the $Z = 28$ Shell Gap Around ^{78}Ni: First Spectroscopy of ^{79}Cu





γ-ray spectrum of ^{80}Zn(p,2p)^{79}Cu

α-clustering in self-conjugate nuclei revealed



Selected for a Viewpoint in *Physics*
PRL 119, 132501 (2017) PHYSICAL REVIEW LETTERS week ending 29 SEPTEMBER 2017

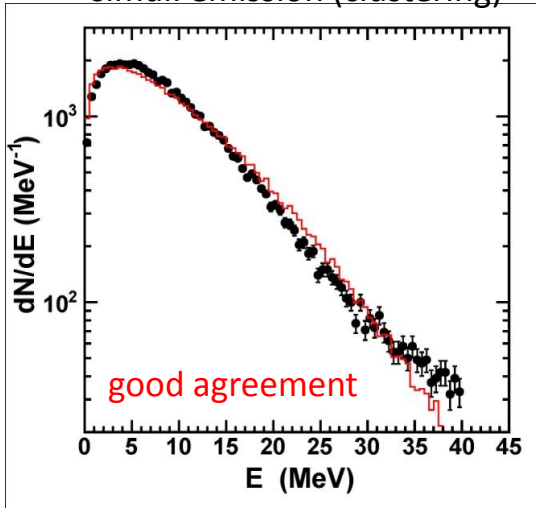
High-Precision Probe of the Fully Sequential Decay Width of the Hoyle State in ^{12}C

Contents lists available at ScienceDirect
Physics Letters B
www.elsevier.com/locate/physletb
Physics Letters B 755 (2016) 475–480

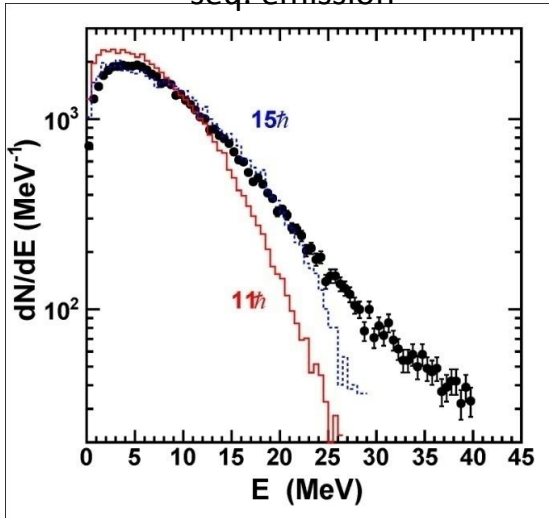
experiment

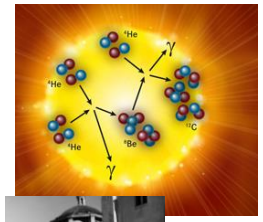
Alpha energy spectrum in the $^{16}O^*$ ref. frame
$^{16}O^*$ from ^{40}Ca fragmentation (<E*> = 52 MeV)

simul. emission (clustering)



seq. emission





Hoyle state

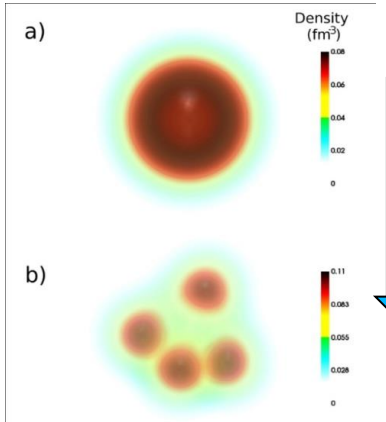
Alpha clustering from
excited expanding self-conjugate nuclei
(^{16}O, ^{20}Ne, ^{24}Mg)

theory

- Constrained Hartree-Fock-Bogoliubov model
- Constrained self-consistent relativistic Hartree Bogoliubov (RHB) model

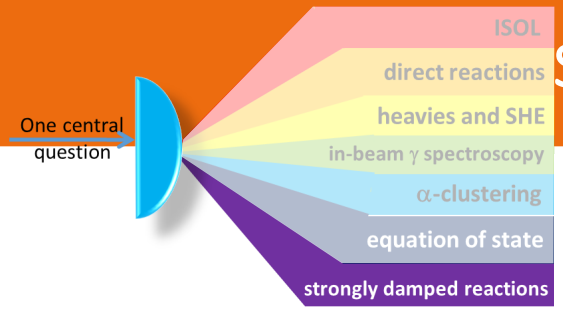
both by imposing radial deformation

PRL 111 (2013) 132503
PRC 89 031303(R) 2014



$^{16}O^*$
$E^* \approx 60$ MeV

FIG. 3: (Color online) Self-consistent intrinsic nucleon density of ^{16}O for a radius constrained to 3.32 fm (a) and 3.34 fm (b).

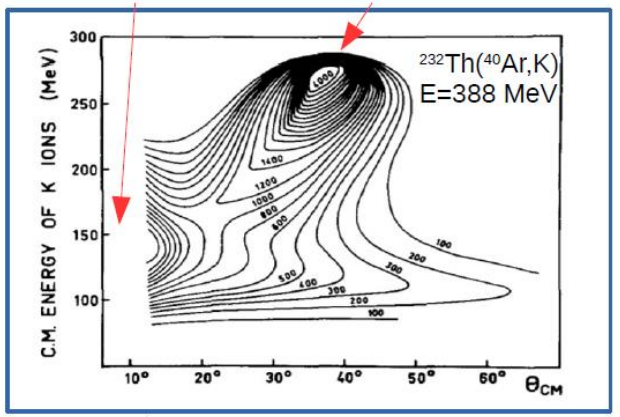


Survival of neutron-rich quasi-projectiles towards 0° in deep-inelastic collisions

Contents lists available at ScienceDirect
Physics Letters B
www.elsevier.com/locate/physletb
Physics Letters B 779 (2018) 456-459

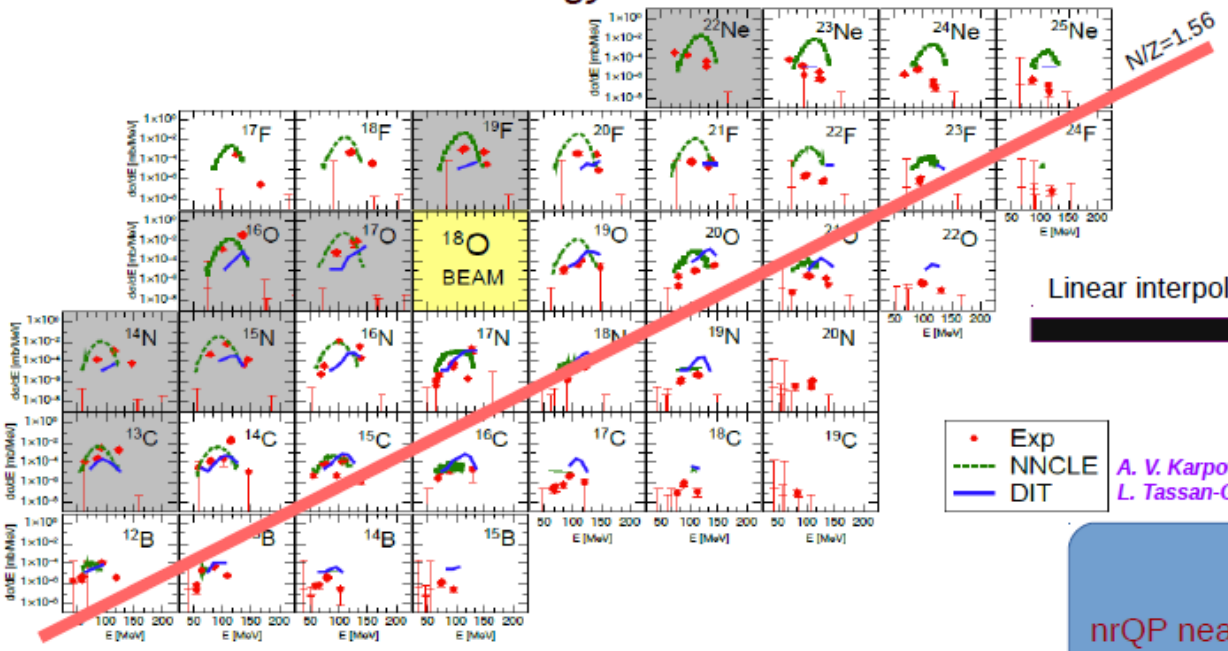
Neutron-rich nuclei produced at zero degrees in damped collisions induced by a beam of ^{18}O on a ^{238}U target

Possible second maximum — Maximum cross-section



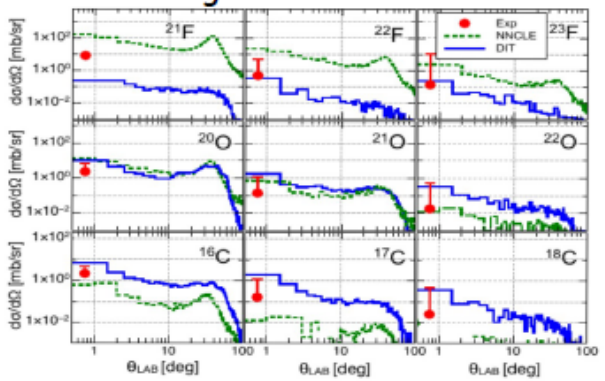
J. Wilczynski, PLB 47B (1973) 484

Kinetic energy distribution



Linear interpolation

Angular distribution



A. V. Karpov, PRC 96, 024618 (2017)
L. Tassan-Got, NPA 524 (1991) 121

Conclusion

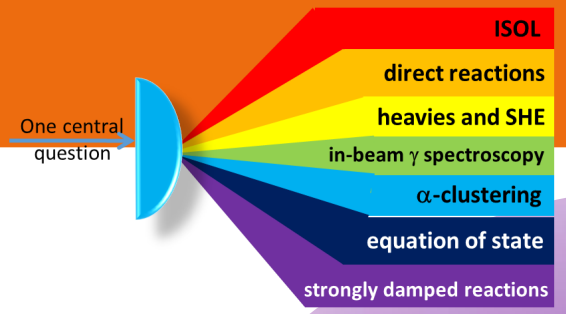
0° is a maximum for nrQP production
nrQP near the beam competition between 0° & grazing angle

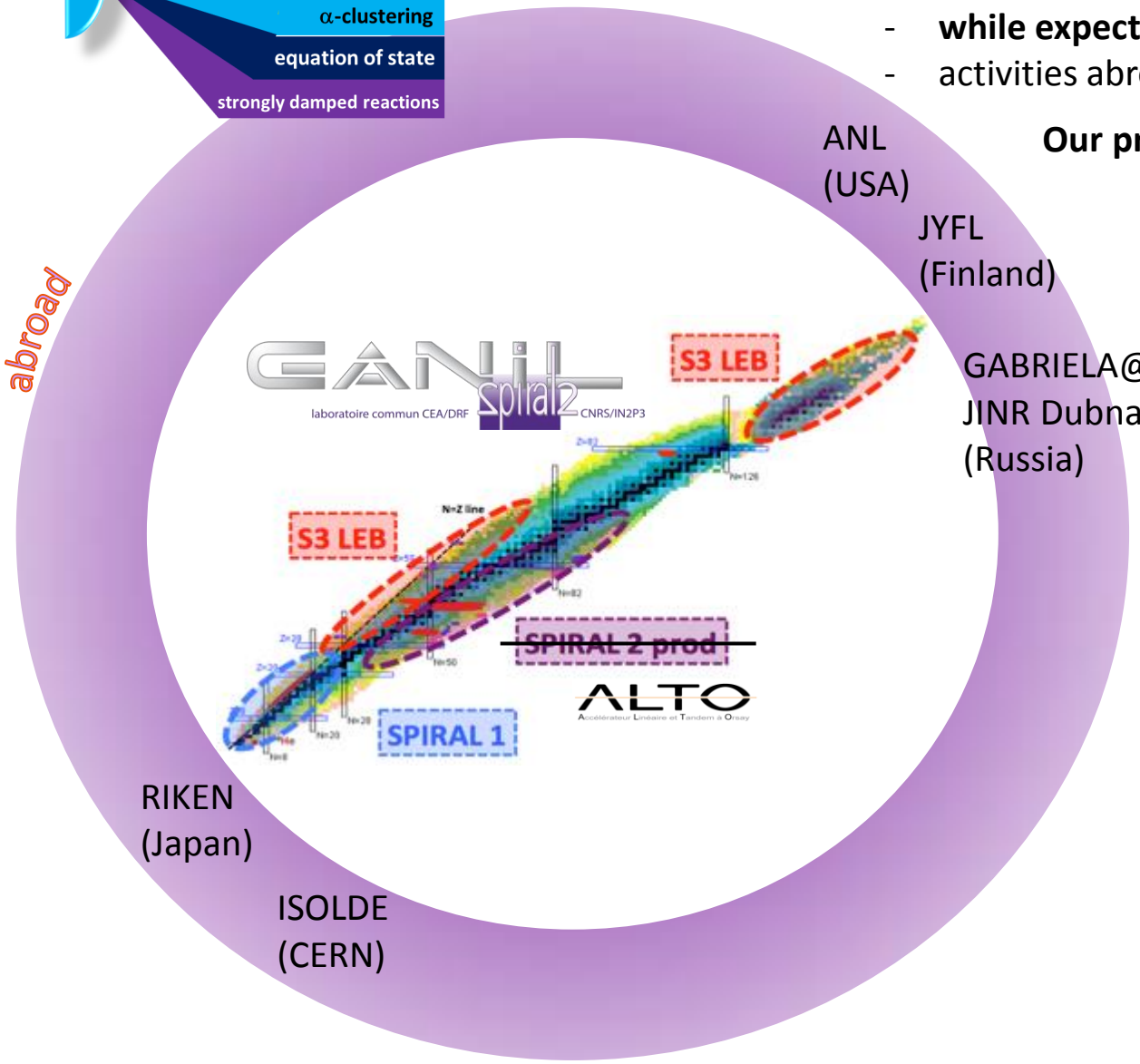
Practical application:

Linag (high beam intensities)+ S3 (high resolution 0° spectrometer) @ GANIL

Project (2018 – 2023 and longer term future)

2018-2023 Orsay NP's roadmap





- **while expecting for SPIRAL2/S3 operational**
- activities abroad where Orsay's NP community has leadership: must be pursued

Our priorities:

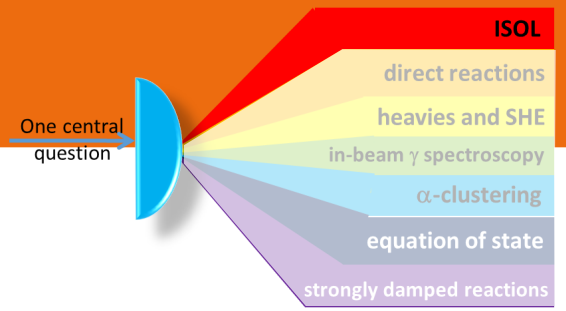
- Online commissioning of the new experimental setups at ALTO (MLLTrap, LINO, POLAREX)
- ALTO's reliability enhancement: the ALTO2.0 project
- Contribution to the development of S3-LEB **in synergy** with the development of ALTO (a CNRS researcher will be hired on that topic on 01/10/19),

- ensure the success of the forthcoming AGATA+MUGAST campaign at GANIL

- continue our commitment to the development of AGATA → contribution to AGATA white book
- (includes enhanced collaboration with GRETINA's community)

- SHE spectroscopy program at ANL, at Dubna, at Jyväskylä, paving the way towards S3
- (contributing to the development of SIRIUS)

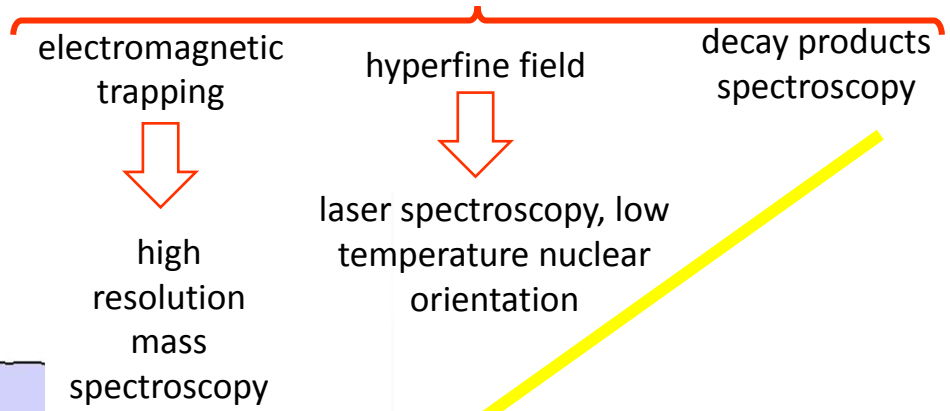
ALTO: second phase of equipment



Instrumentation prepared within a long-term strategy for low-energy ISOL physics at SPIRAL2-DESIR

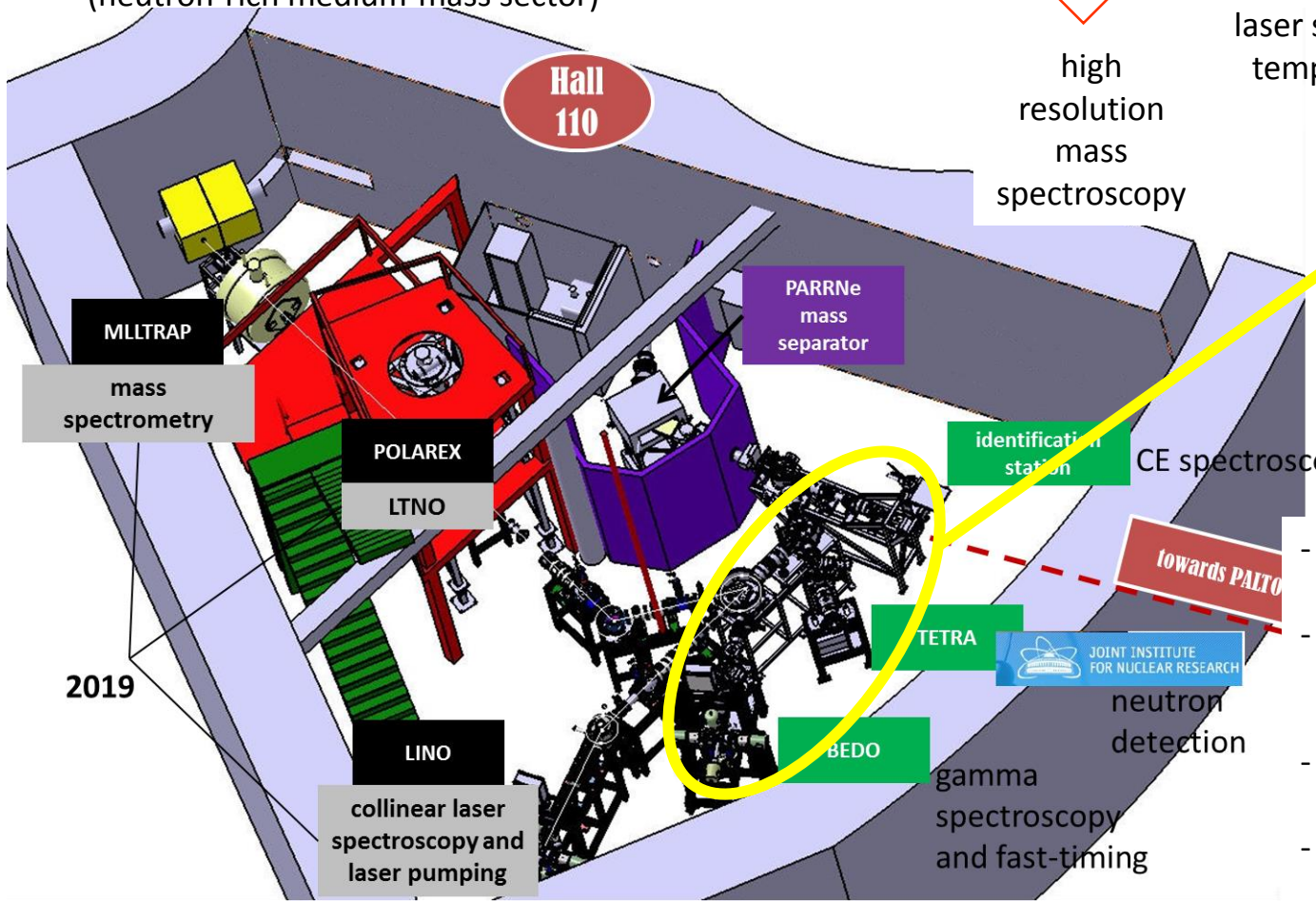
→ALTO plays a key/renewed role in the context of the sine-die postponing of the phase 2 of SPIRAL2 (neutron-rich medium-mass sector)

3 families of ISOL based measurements



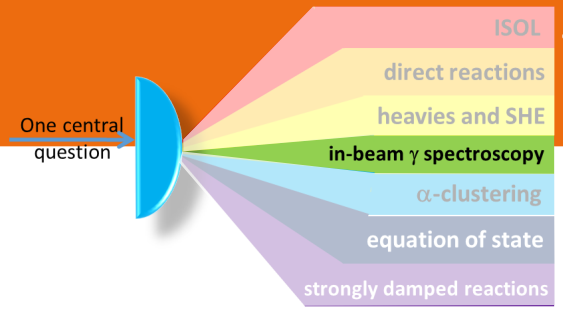
« charting terra incognita »

« reaching terra incognita »

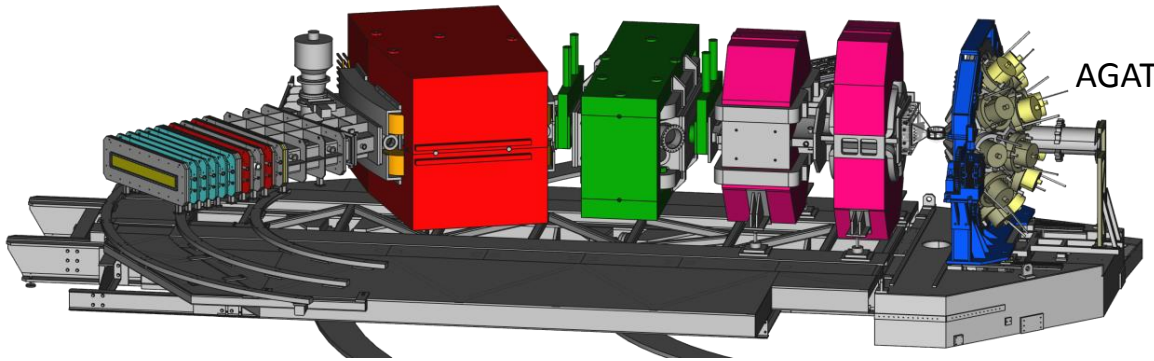


- **full exploitation of the ALTO RIB capabilities**
- finalization of the “terra incognita”and “ReTIEN” related projects : POLAREX, MLL-Trap, LINO
- New beams developments (ISOL fusion-evaporation, molecular beams)
- **reinforced synergy with SPIRAL2/S3-LEB**

Towards the AGATA+MUGAST campaign at GANIL



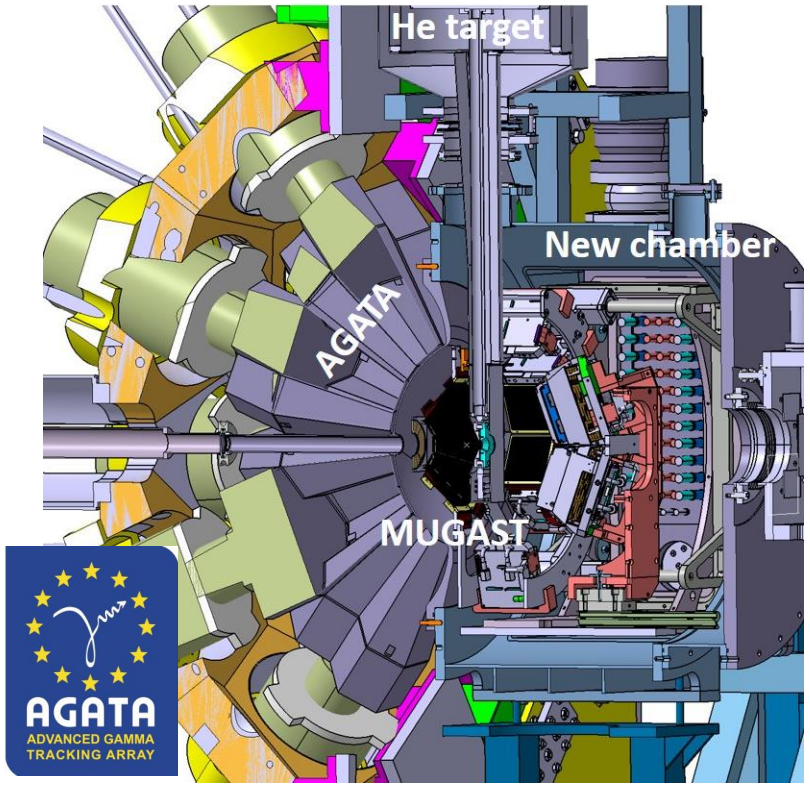
Campaign starting in april 2019



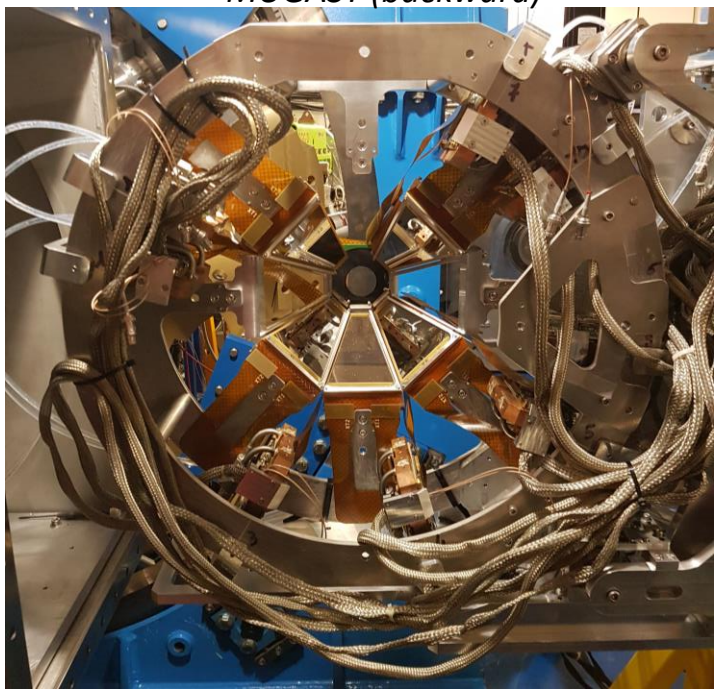
AGATA@VAMOS (GANIL)

- New Spiral 1 beams (low energy)
- AGATA
  . very **high energy resolution**
  . good efficiency : **~10%** at 1.3 MeV in 2019 @ **18cm**
  (depending on number of clusters)
- MUGAST
  . **one-layer of Silicon backward** & 90 deg.
  → **well-suited for stripping measurements**
- VAMOS : large acceptance spectrometer at 0 degree
- Unique coupling with ^{3,4}He cryogenic target
- About 3000 Si channels + 40 AGATA det.
- Intermediate step toward full GRIT array

Reaction	Spokesperson	
$^{15}O(^{6}Li,d)^{19}Ne$	C. Diget, N. de Séréville	Approved
$^{14}O(p,p')$	I. Stefan, F. de Oliveira	
$^{19}O\ (d,p)\ ^{20}O$	E. Clément, A. Goasduff	
$^{46}Ar(^{3}He,d)^{47}K$	A. Gottardo, M. Assié	
$^{56}Ni(d,p)^{57}Ni$	F. Flavigny, O. Sorlin	LoI
$^{56}Ni(^{3}He,p)^{58}Cu$	M. Assié	
^{69}Cu, ^{46}Ar, $^{49\text{-}50}Sc$ (t,^{4}He)	S. Bottoni	

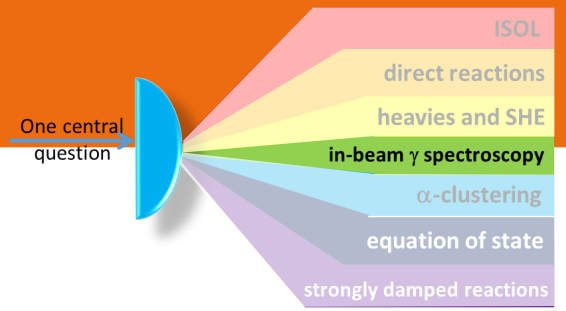


MUGAST (backward)



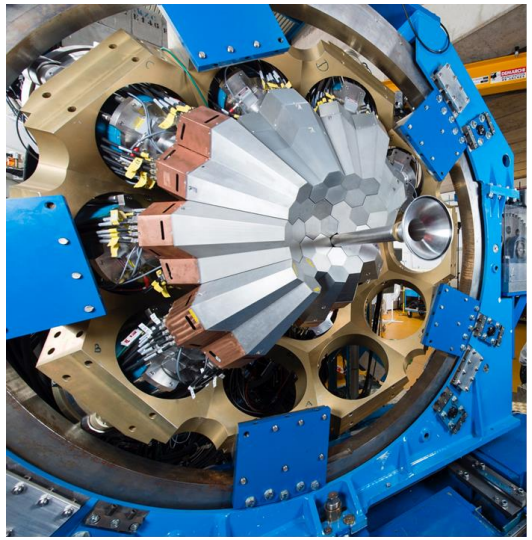
New Trapezoidal DSSDs of GRIT

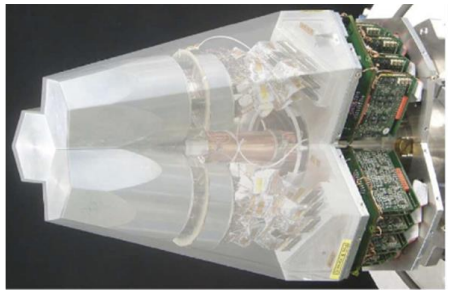
Orsay NP pushing forward AGATA



ADVANCED GAMMA TRACKING ARRAY

40 institutions
350 collaborators





Efficiency (Mγ=1 [30]):	35% [23%]
Today's arrays	10 % [5%]
Peak/Total (Mγ=1 [30]):	55% [46%]
Angular resolution 1°	
FWHM (1 MeV v/c=50%)	6 keV
Today's arrays	40 keV
Rates : 3 MHz (Mγ=1)	300 kHz (Mγ=30)
Today 1 MHz	20 kHz

-180 large volume 36-fold segmented Ge crystals in 60 triple-clusters
-Digital electronics and sophisticated Pulse Shape Analysis algorithms

Allow operation of Ge detectors in position sensitive mode γ-ray tracking

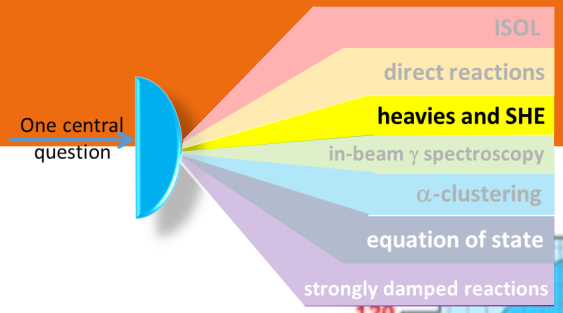
- FLUO's researchers are team leaders for:
  - Data processing,
  - Hard/software DAQ Support,
  - Data Analysis and Tracking,
  - Data distribution and reprocessing,
  - AGATA Performance

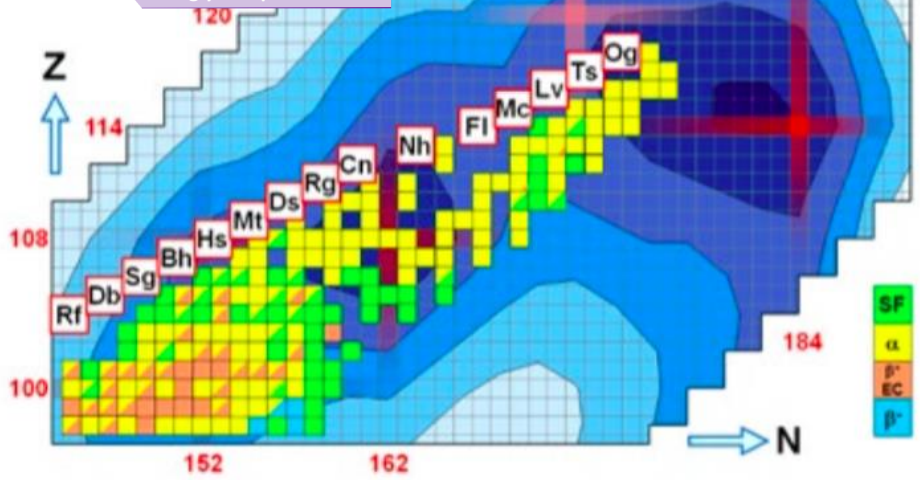
- Improvements of tracking code are on going at FLUO → still much to be done

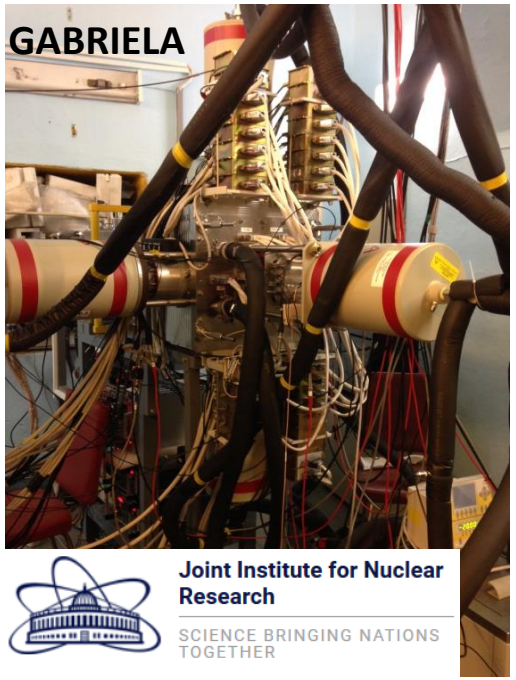
- AGATA-GRETA collaboration has been set by FLUO →Sharing experience between AGATA and GRETINA/GRETA

- **AGATA white book inputs : including physics case involving coupling to GRIT**

Heavy and SHE perspectives



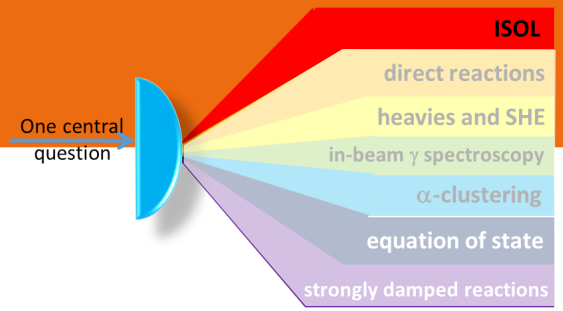




S3 SPIRAL2

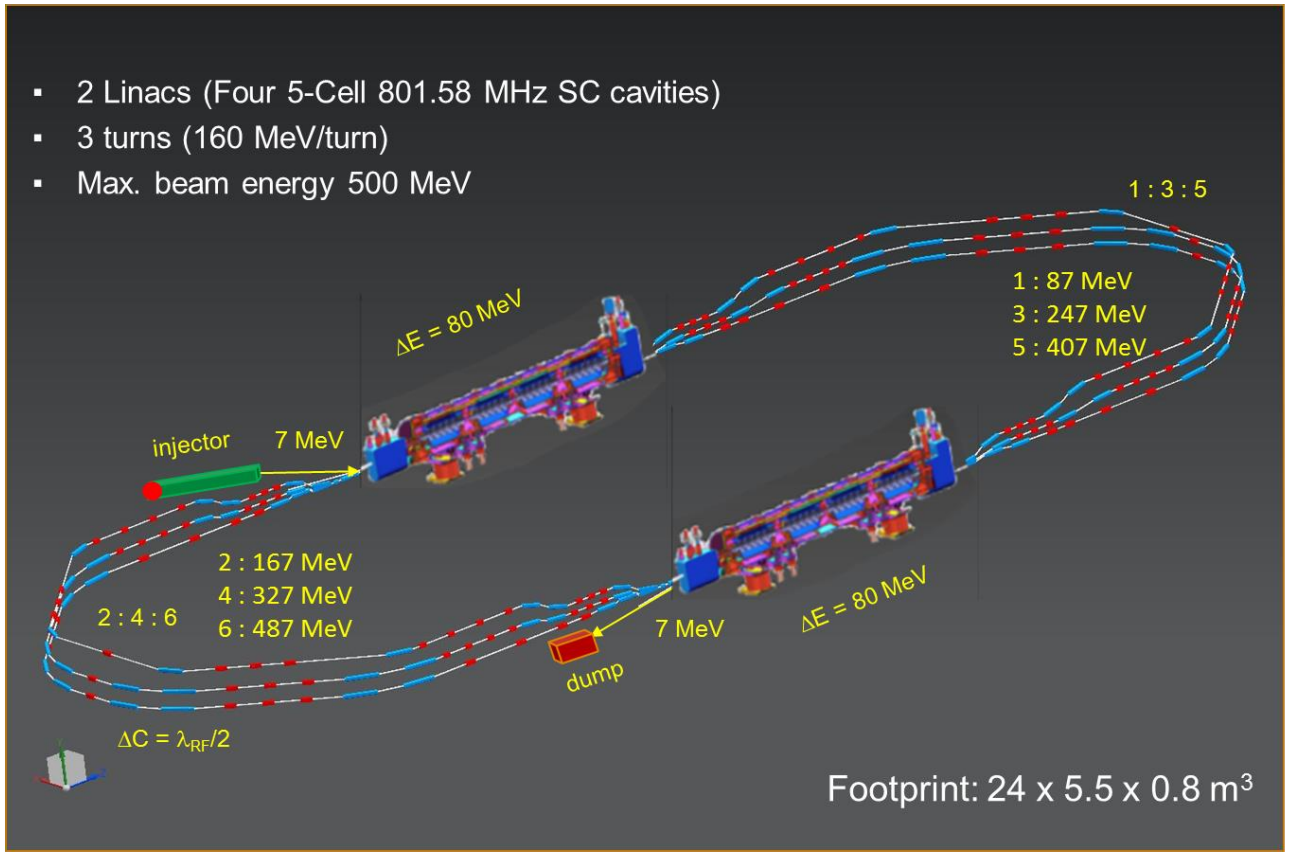
- Operation and digitalization of **GABRIELA@SHELS**
- Opportunity @SHF: **Xray fingerprinting** of the heaviest nuclei
- Commissioning and day 1 experiments of **SIRIUS@S3** (CEA, GANIL, IPHC, FLUO): 2 LoI submitted on the search for the dripline in No isotopes and high-K isomer properties of ^{256}Rf
- Commissioning of **MLLtrap@ALTO & transfer to DESIR**
- Lifetime measurements & fine structure alpha spectroscopy of heavy nuclei
- Physics campaign at ANL with **AGFA+Gammasphere** physics starting in 2019
- **AGATA white book** project: measurement of fission barriers and gamma-ray strength function in super heavy nuclei

Nuclear physics at PERLE@Orsay

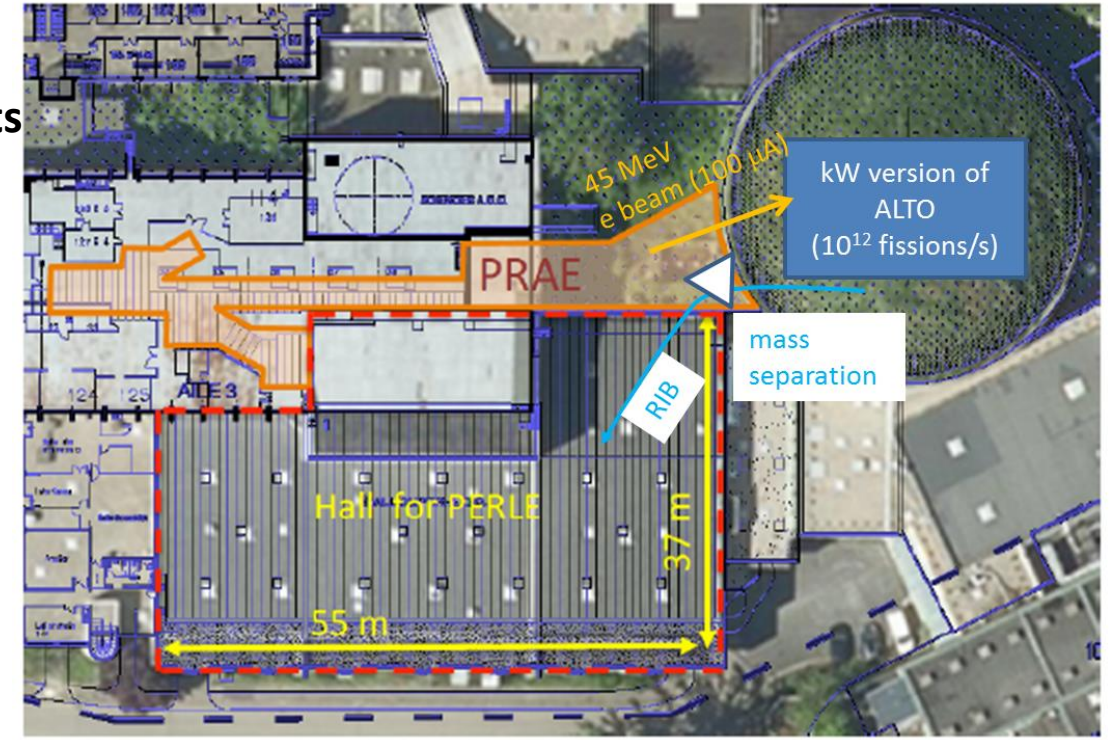


seize the opportunity of PERLE@Orsay for electron scattering off RIBs experiments

The PERLE@Orsay configuration

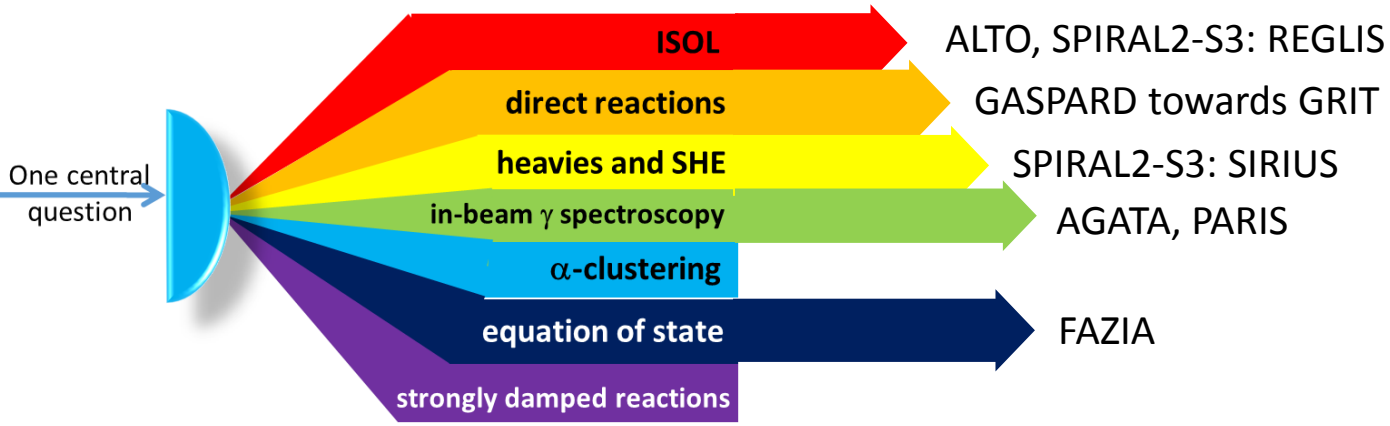


Courtesy W. Kaabi (LAL Orsay)
(LHeC/FCC-eh and PERLE Workshop, 27-29 June 2018, Orsay, France)



the Orsay PERLE-based project DESTIN
[DEep STructure Investigation of (exotic) Nuclei]
for the time being just an idea…
European NP community around this idea is being gathered
→ proposal of an NA in ERINS (successor of ENSAR2 IA)

RH evolution in the next five years



-1(7) • Retirements : 1CR (direct reactions component) – around or beyond 5 years: 3 DR and 3 emeriti possible departures

-3 • Departure : 1 MCF (2018, ISOL component), 1 PR, 1 CR (in-beam γ-spectroscopy component)

+1 • Recruitment : 1CR (instrumentation S3-LEB & ALTO) 2019

-3(9)

immediate needs

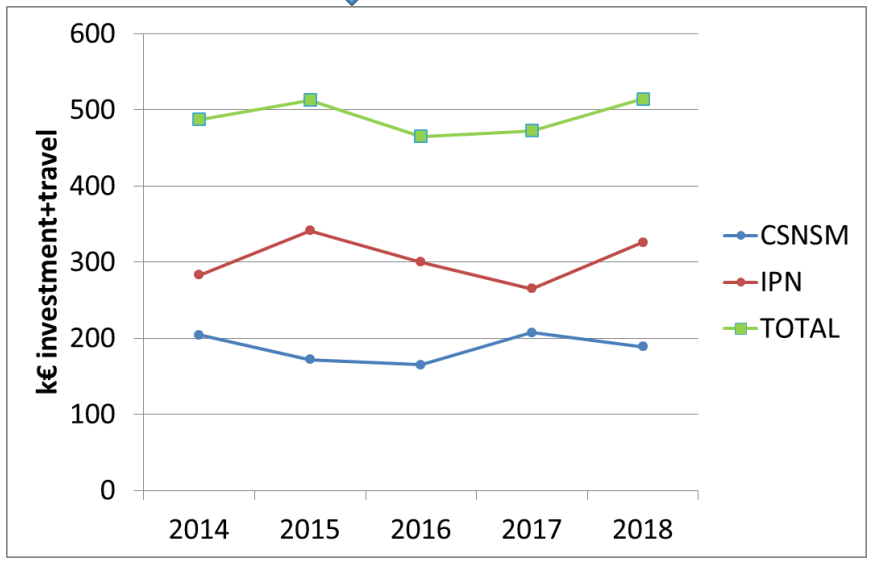
CNRS : **ISOL:** 1 IR Laser, 1 CR accelerator technologies ISOL related

direct reactions: replacement of 1 departures

University: **ISOL-platform and subatomic physics teaching:** 1 MCF

Expectation on financial support

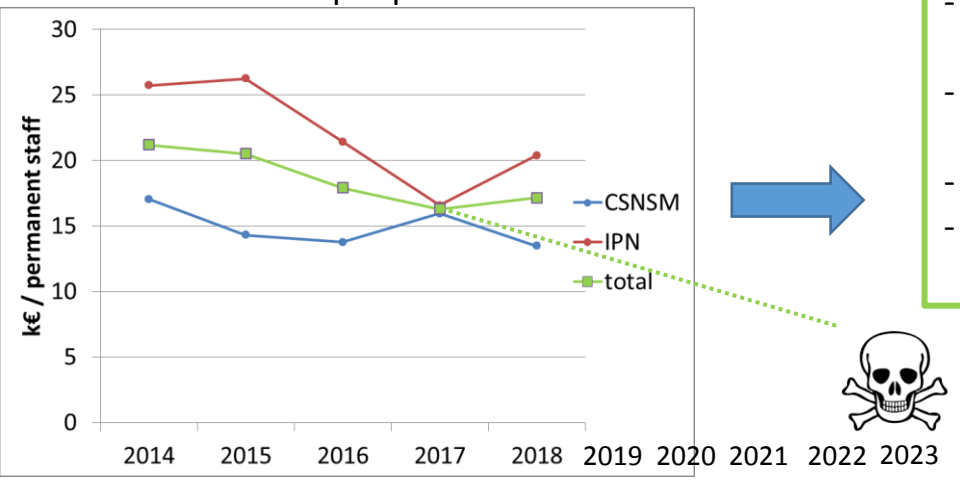
IN2P3 funding → Other funds : over fragmented



proposed analysis (reminding)

- difference IPN/CSNSM mainly explained by investments on ALTO related projects (LINO, MLLTrap, **nu-ball** etc) + PARIS + GASPARD led by IPN's group
- IPN's group budget suffered more from the absence of travel money to go to GANIL, not supported any more by IN2P3
- incredible increase of the funding sources, each generally insufficient to achieve a given project, time is money and money is more and more time consuming
- A simple extrapolation of 2015-to-2017 trend would indicate vanishing support from IN2P3 by the end of next five-year plan.

IN2P3 investment per permanent staff



Expectations:

- support for Post-doc's and PhD's from IN2P3 too low
- IN2P3 investment money per permanent staff shows a dramatic trend between 2015 and 2017, it is interpreted (by us) as due to limited interest of IN2P3 management to our field
- total IN2P3 allocation in 2018 to FLUO's NP teams is around 60% of the one granted at the beginning (around 2010) of the previous five-year period
- 2018 budget: an exception or a new hope for next five-year period?
- → we request a reevaluation of the relative weight of nuclear physics in IN2P3 activities and an improvement in the quality of dialogue with our funding agencies in general.

SWOT analysis

STRENGTHS

- Number of projects under our leadership
- Local Research Infrastructure (ALTO)
- Excellent culture and results in PhD formation
- Very strong network of national and international relations
- Rather successful with grant calls

WEAKNESSES

- Number of Post-doc's & PhD's
- Dwindling financial resources
- Fragmentation of the financial support with no coherent scientific strategy behind (limited interest of IN2P3 management to the field)

OPPORTUNITIES

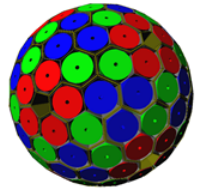
- lab unification in Orsay Valley
- University Paris Saclay
- PERLE@Orsay
- Strong implantation in different international installations: GANIL, RIKEN, ISOLDE/CERN, JINR
- unique Local Research Infrastructure (ALTO)

THREATS

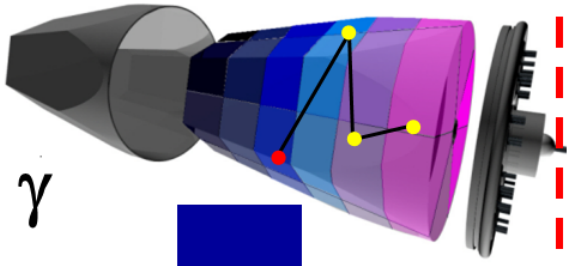
- Chronic dwindling of financial resources
- Ambitious project of the community - Spiral 2 phase 2 suspended
- Number of project per number of persons in the group
- Limited or difficult access to technical resources for small-to-medium scale projects within the future merged Orsay Lab. (more fear than threat ?)
- Limited visibility in University Paris Saclay

Backup

Gamma Tracking Array Concept



Highly segmented HPGe detectors



Synchronized digital electronics to digitize (14 bit, 100 MS/s) and process the 37 signals generated by crystals

Event building time-stamped data

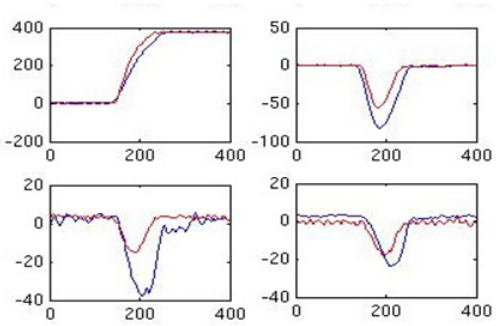
Global level

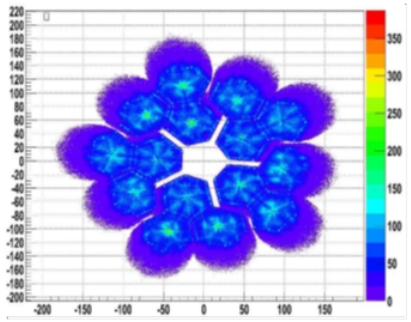
Local level

Energies, times, interaction points

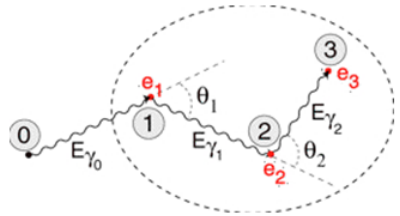
$(x,y,z,E,t)_i$

Pulse Shape Analysis of the recorded waves





Reconstruction of γ-rays from the hits



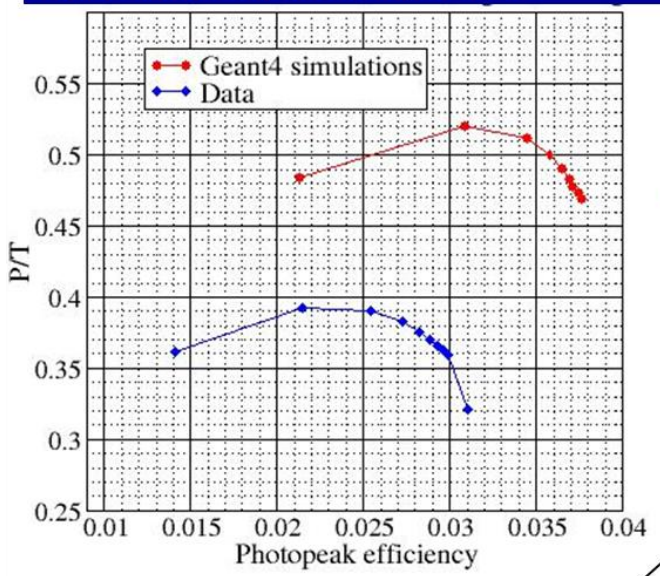
Analysis & correlation with other detectors

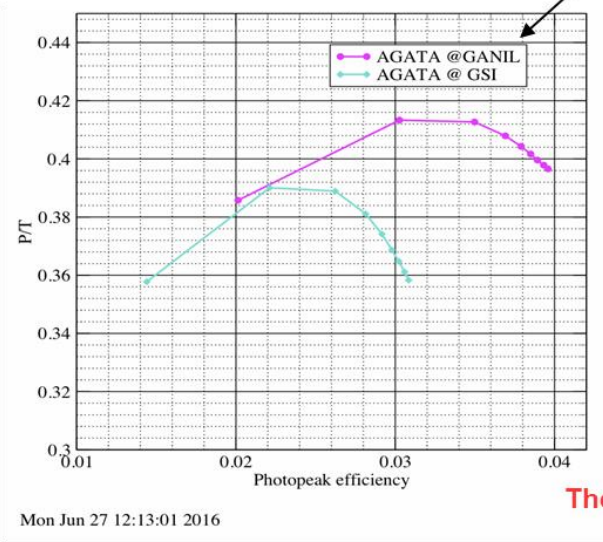
HARDWARE

SOFTWARE

Improve the performance of AGATA : CSNSM is involved !

GEANT4 simulations versus measurements
A. Korichi et al, NIM872(2017)80





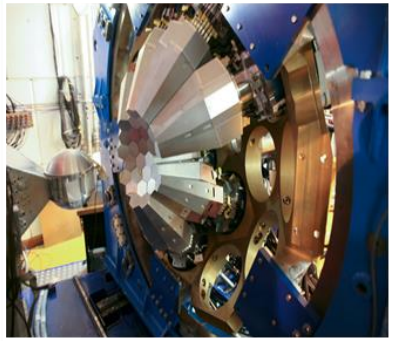
Improvments of tracking code are on going at CSNSM But !
The main issue comes from PSA/basis fidelity

Issues with PSA to be understood and fixed
for a better performance of AGATA
ANR OASIS (CSNSM) : R&D

-a better determination of the interaction positions within the detectors

-correctly assign the number of interactions inside a detector segment

However, the specs P/T and efficiency can only be achieved with the full 4π array
From 21 to 30 crystals the effect is clear and not linear !

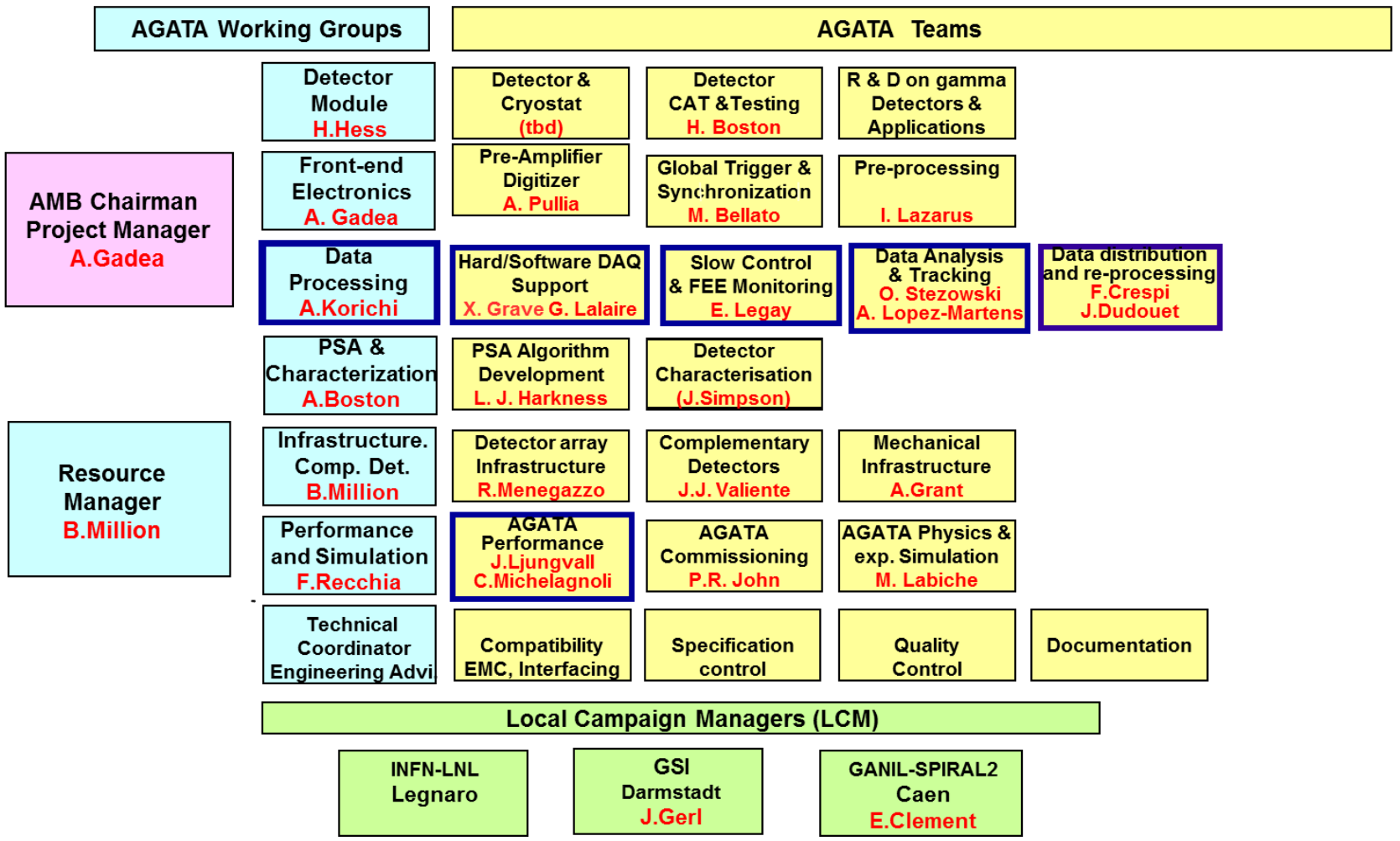


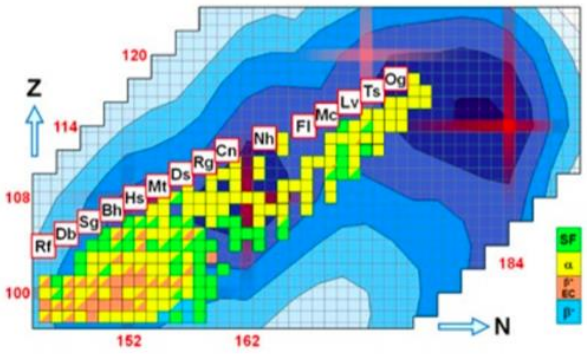
AGATA-GRETA collaboration has been set by CSNSM
Sharing experience between AGATA and GRETINA/GRETA
Devote effort to understand the limitations and explore ways to improve the current performance for more physics output

The common collaboration meetings/synergies are valuable for EU/CSNSM and USA

AGATA Management Board and Teams

A. Gadea (Project Manager)
A. Boston, B. Million, A. Korichi, F. Recchia, H.Hess, P. Reiter (ASC) and W.Korten (ACC).
J. Gerl (LCM-GSI), E. Clement (LCM-GANIL)





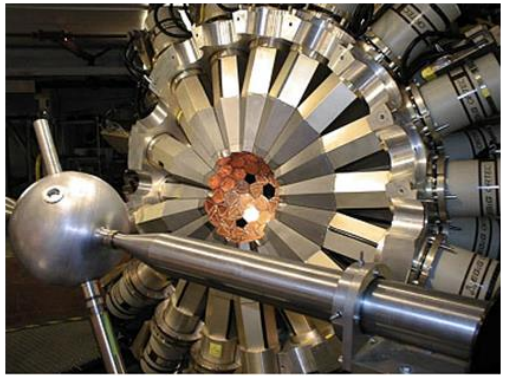
per heavy elements studies at

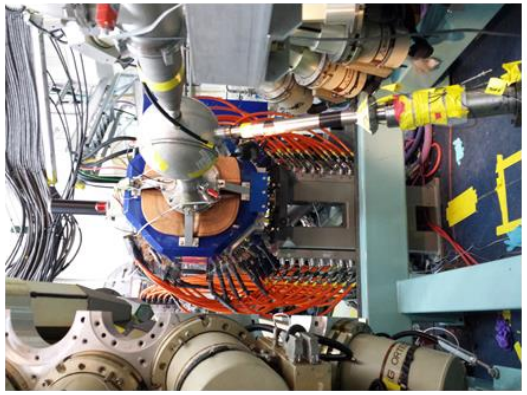
AGFA (Argonne Gas Filled Analyser)
Gammasphere & focal plane decay station

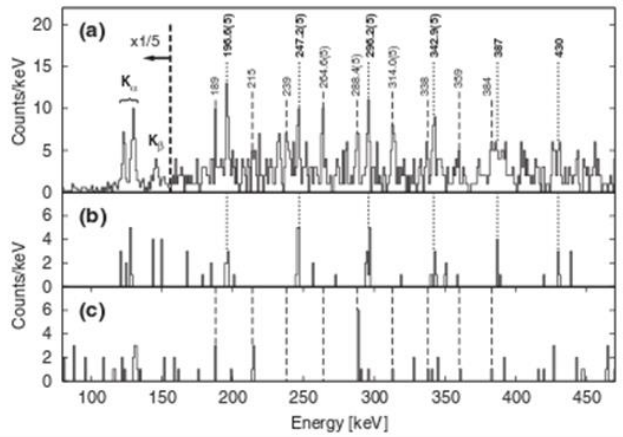
Argonne NATIONAL LABORATORY

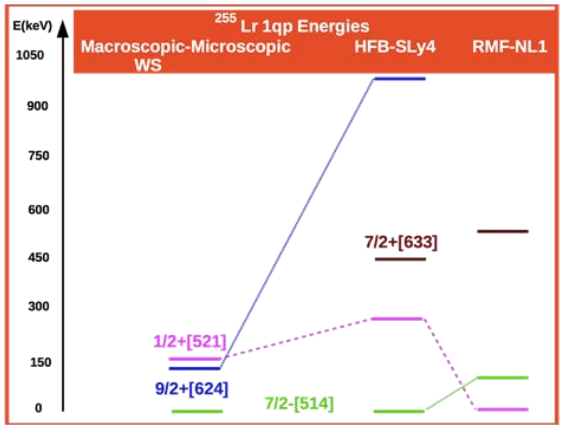
In-beam/deacy γ-ray Spectroscopy and calorimetry

In-beam spectroscopy of ^{255}Lr: information on a shell gap at Z=114 for super-heavy elements









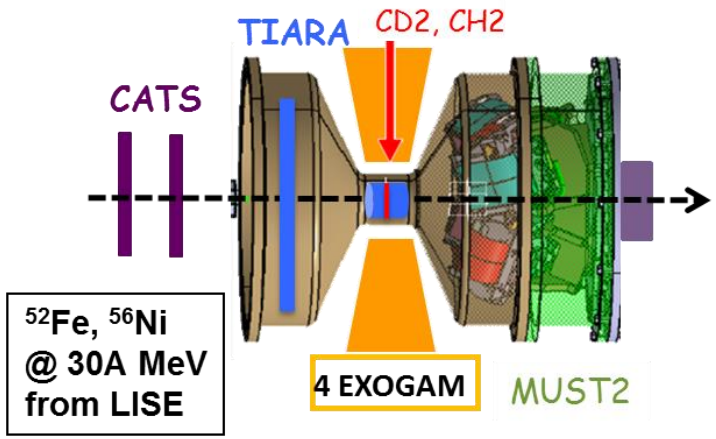
Single gamma-ray spectrum in delayed coincidence with recoils.
(b) Sum of recoil-gated γγ coincidence with transitions marked by ...
(c) same as (b) but for transitions marked by ---
S. Ketelhut et al, PRL 102(2009)212501 (JYFL- Finland)

Future experiment at ANL ^{209}Bi(^{48}Ca,2n)^{255}Lr (A. Korichi et al,)
Improvment by a factor of 8 compared to JYFL is expected

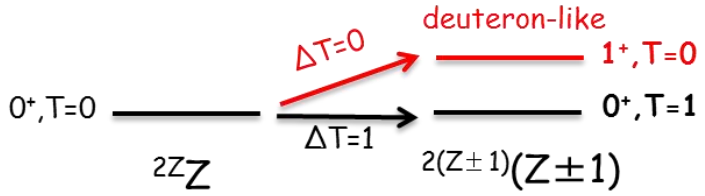
Other approved experiments will also be carried out : ^{251}Md,^{253,254}No, ^{254,256}Rf

Collaboration : CSNSM, ANL, LBNL, Umass Lowel,JYFL, GANIL, IPNL, IPHC

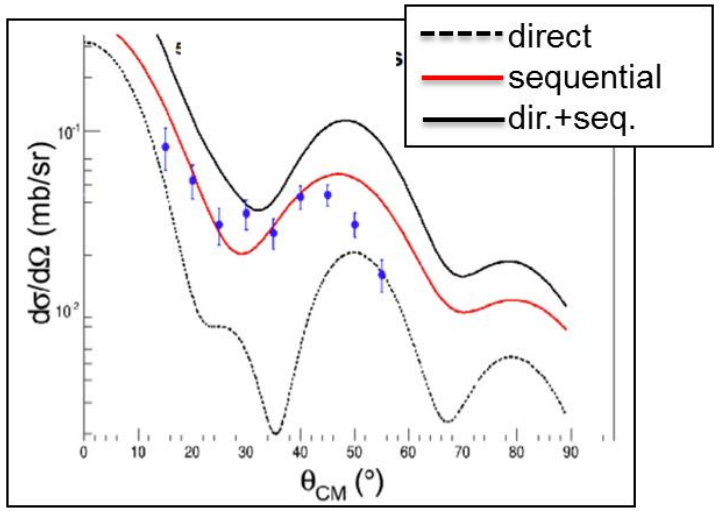
The elusive isoscalar np pairing : the case of the fp shell



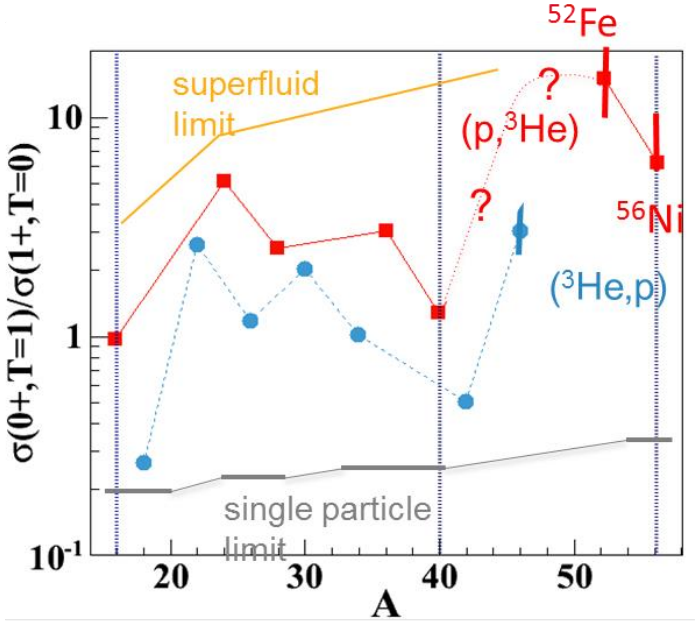
^{56}Ni (doubly magic) and ^{52}Fe (open-shell) have been investigated at GANIL through 2N-transfer reactions with a particle-gamma coincidence set-up.



➡ **Angular distribution for ^{54}Co g.s.**



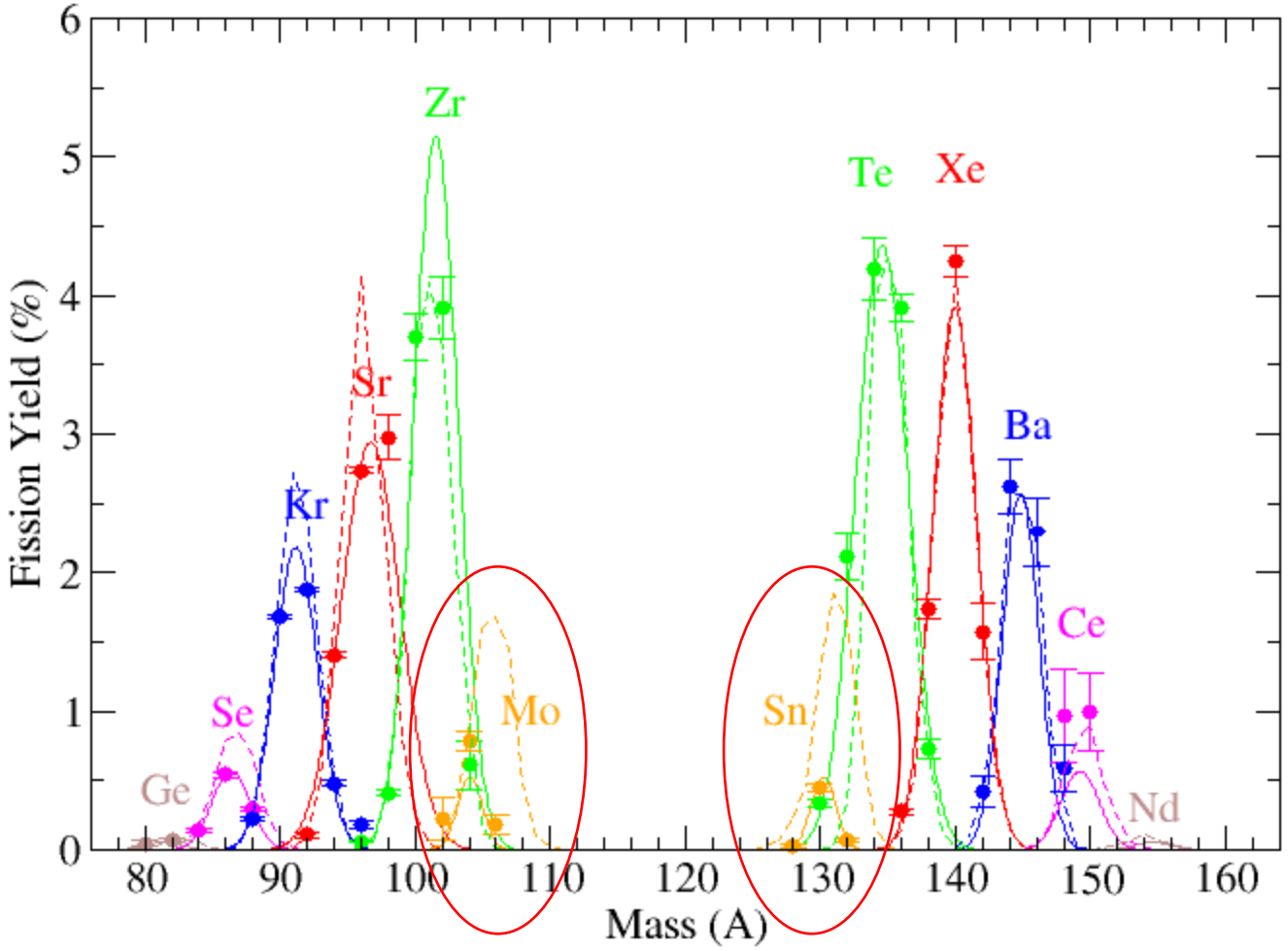
DWBA calculation (J. Guillot)



➡ **Isoscalar pairing weak in the fp shell hindered by spin-orbit effects**

Anomalies in the Charge Yields of Fission Fragments from the 238U(n,f) Reaction

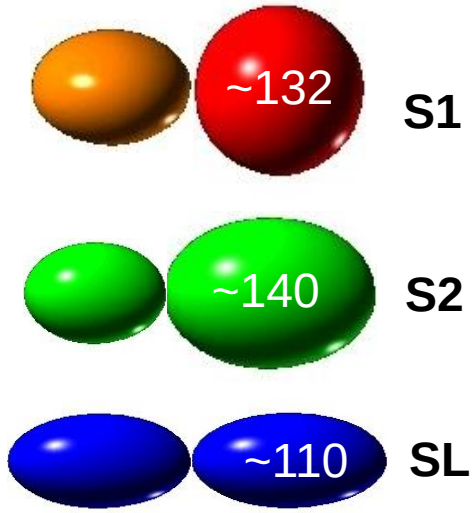
J. N. Wilson et al. Phys. Rev. Lett. 118, 222501 (2017)



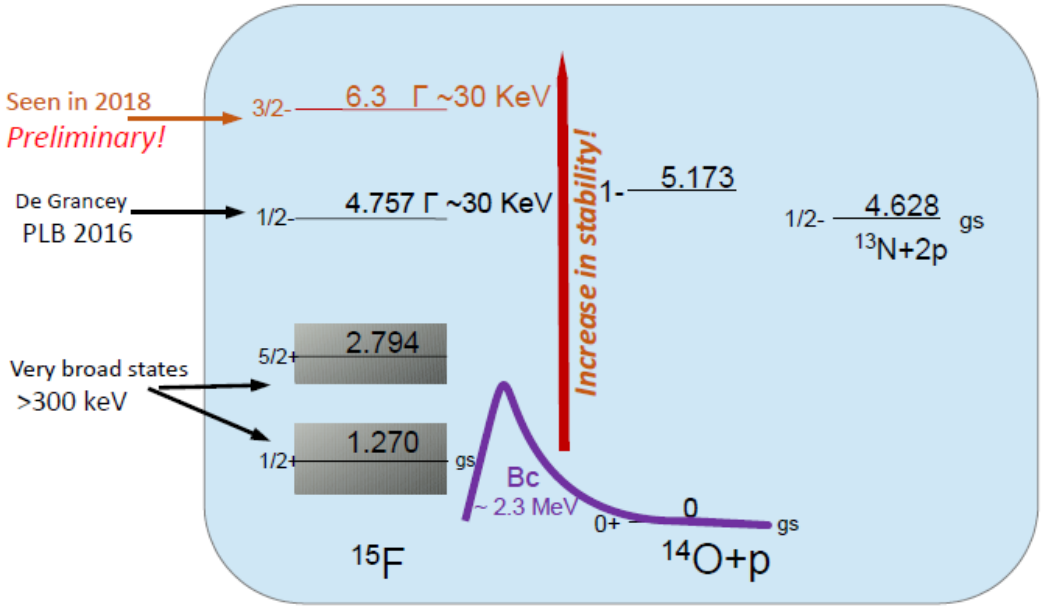
Interpretation:

Spherical shell effects in the nascent fragments (S1) become much less important!

Fission modes



The case of ^{15}F

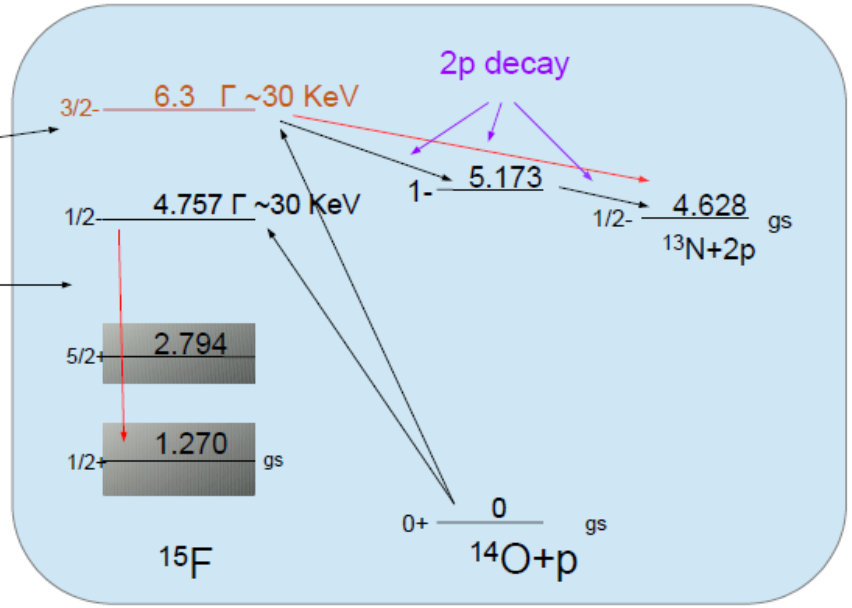


- 2nd&3rd excited states x10 times more stable (explained by the particular strucure of ^{15}F)
- 2nd state Halo configuration => large spatial expansion => high gamma decay probablity. GSM calculation ->the fastest on the nuclear chart (^{11}Be is measured to have the fastest E1 gamma decay)
- 2p decay favored

Study in 2019:

Measure the 2p decay

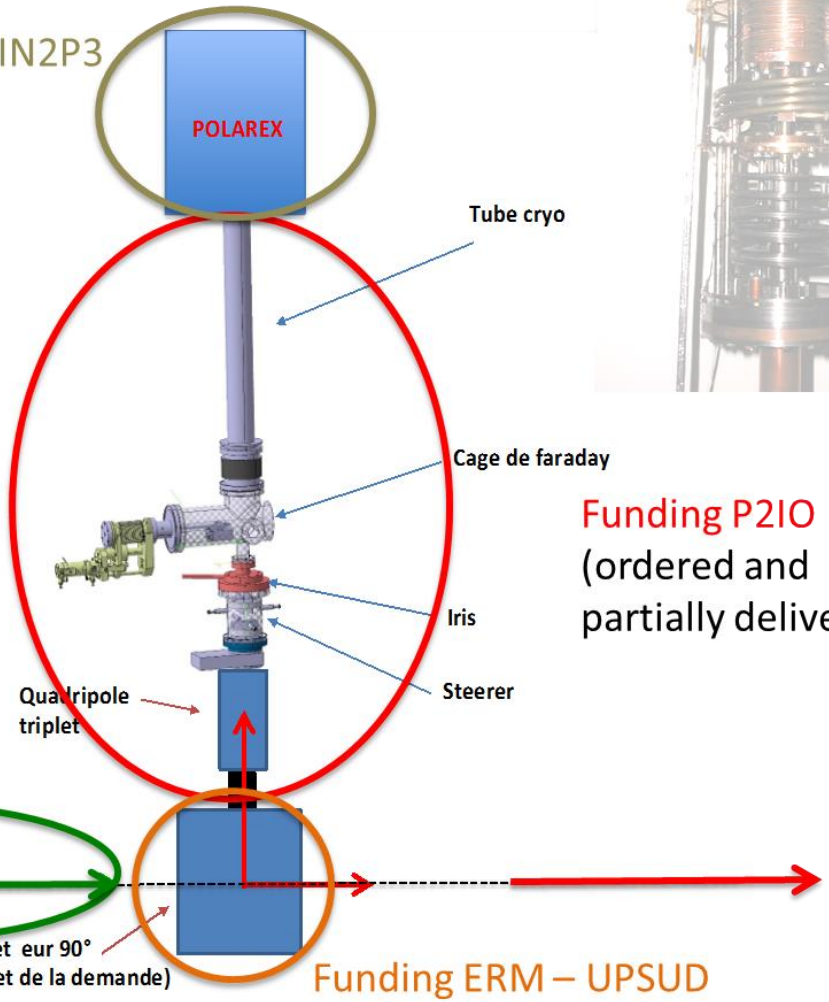
Measure the gamma decay from 1/2-



Understand the gain in stability and the implications

POLAREX : On Line Nuclear Orientation
Low temperature (7 mk) + High magnetic field (10-100 T) + Neutron rich beam

Funding ANR + IN2P3
(installed)



Funding P2IO
(ordered and
partially delivered)

Funding SESAME – Ile de France
(Order beginning 2019)

ALTO Beam

NIMA 859 (2017) + proceedings
Off-line measurement ^{139}Ce beginning 2019
On-line commissioning end 2019

Funding ERM – UPSUD
(delivered)

ALTO
Accélérateur Linéaire et Tandem à Orsay

Evolution of the well known « spherical » magic numbers far from stability :

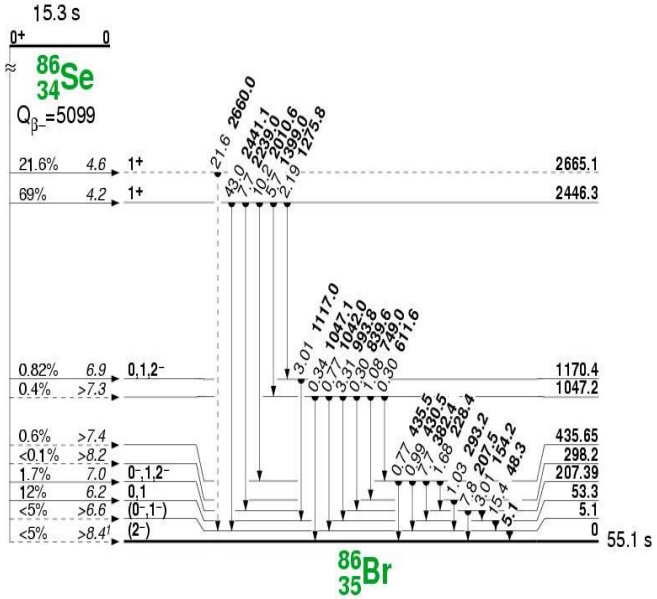
→ There are already evidences of shell strength decrease (masses)

- ➢ γ-spectroscopy from β-decay of ^{86}Se :
  - measurement of J^{π} for 1st excited states

    (by A. Astier et al. accepted by PAC ALTO)

- ➢ POLAREX :

  measurement of μ(^{86}Br)



Results:
- Two independent measurements of J^{π}
- Access to residual interaction energies for various π-ν configurations

Evolution of the well known « spherical » magic numbers far from stability

- Determination of J^{π} (g.s.) = $3/2^-$ or a $5/2^-$?
  $\Rightarrow$ It entirely depends on the proton behavior, since proton lies in the *fp* orbits for which very scarce information is known.
  $\Rightarrow$ Help in the description of the structure of the supposed doubly-magic ^{78}Ni (same N=50)

- How to get ^{83}As at ALTO since it is not produced ?
  from β-decay of implanted ^{83}Ge ($T_{1/2}$ = 1.855 s).
  [feasible thanks to the suitable half-life of ^{83}As ($T_{1/2}$ = 13.4 s)]

Evolution of the well known « spherical » magic numbers far from stability

- Determination of J^{π} (g.s.) = $3/2^-$ or a $5/2^-$?
  $\Rightarrow$ It entirely depends on the proton behavior, since proton lies in the *fp* orbits for which very scarce information is known.
  $\Rightarrow$ Help in the description of the structure of the supposed doubly-magic ^{78}Ni (same N=50)

- How to get ^{83}As at ALTO since it is not produced ?
  from β-decay of implanted ^{83}Ge ($T_{1/2}$ = 1.855 s).
  [feasible thanks to the suitable half-life of ^{83}As ($T_{1/2}$ = 13.4 s)]

Rencontres d'été de physique de l'infiniment grand à l'infiniment petit

- **Objectif** :

transmettre à des étudiants en physique de <u>niveau L3 ou équivalent</u>, notre savoir et notre expérience autour des thématiques de recherche : physique des particules, physique nucléaire, astrophysique, cosmologie, physique spatiale, instrumentation associée et accélérateurs, applications (médicales, Machine Learning, etc.).

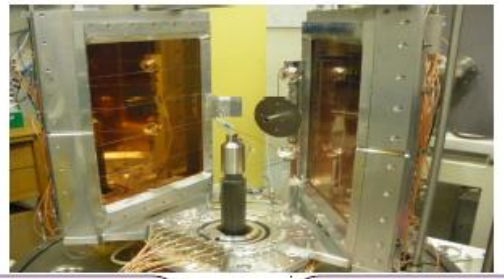
→ 2 semaines de cours, visites, débats et séminaire

2013 : présence de Serge Haroche

2019 : 9ème édition avec Gérard Mourou pour partager son prix Nobel avec nos étudiants

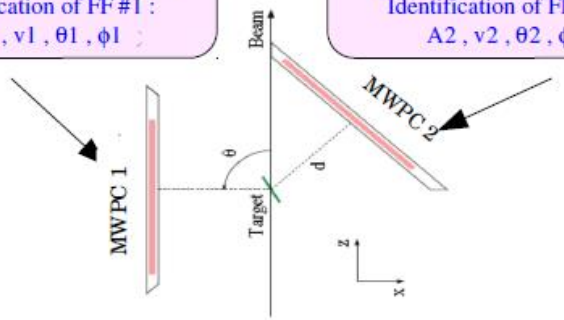
Evidence for the Role of Proton Shell Closure in Quasifission Reactions from X-Ray Fluorescence of Mass-Identified Fragments

$^{48}Ti + ^{238}U$ 5.75 MeV/A (Canberra)



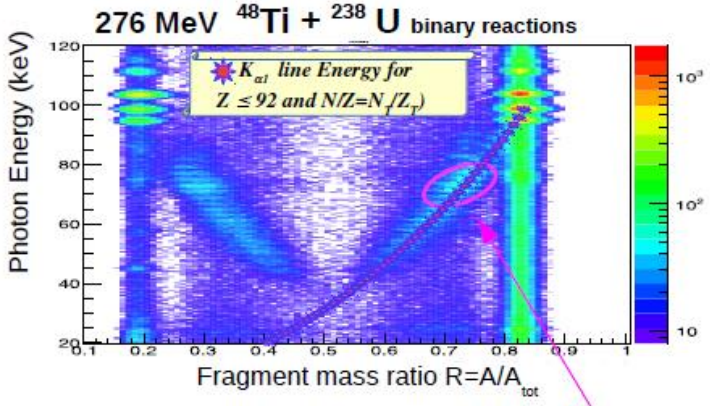
Multi-wire proportional counter
Large solid angle ;
large angular correlations
Identification of FF #1 :
A1 , v1 , θ1 , ϕ1

Multi-wire proportional counter
Large solid angle ;
large angular correlations
Identification of FF #2 :
A2 , v2 , θ2 , ϕ2



3 Ge planar detectors
Large solid angle (~1sr)
Low energy threshold

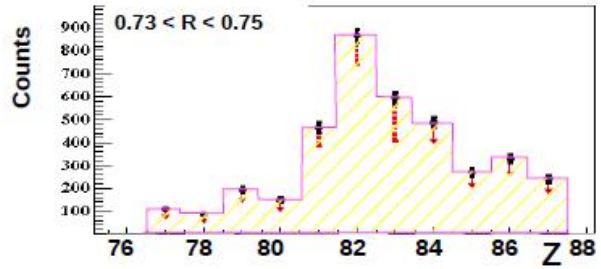
Fragment characteristic X-rays
↳ Z identification of the fragments



Combined with mass

→ Information on the ratio N/Z of the fragments
↳Nucleon exchange along the different trajectories

→ **Shell closure effect** Z vs N



The PERLE@Orsay project

PERLE is a high current, multi-turn ERL facility (900 MeV),

designed to study and validate main principles of the Large Hadron Electron Collider (LHeC: 60 GeV)

LHeC would use a 3-pass energy recovery, recirculating linac with 20 GeV per pass and a current of about 10 mA; the RF frequency would be 802 MHz

The Orsay realization of PERLE (called **PERLE@Orsay**) is a smaller version (500 MeV) with the same design challenges and the same beam parameters:

Target Parameter	**Unit**	**Value**
Injection energy	MeV	7
Electron beam energy	MeV	500
Normalised Emittance $\gamma\varepsilon_{x,y}$	mm mrad	6
Average beam current	mA	20
Bunch charge	pC	500
Bunch length	mm	3
Bunch spacing	ns	25
RF frequency	MHz	801.58
Duty factor		CW

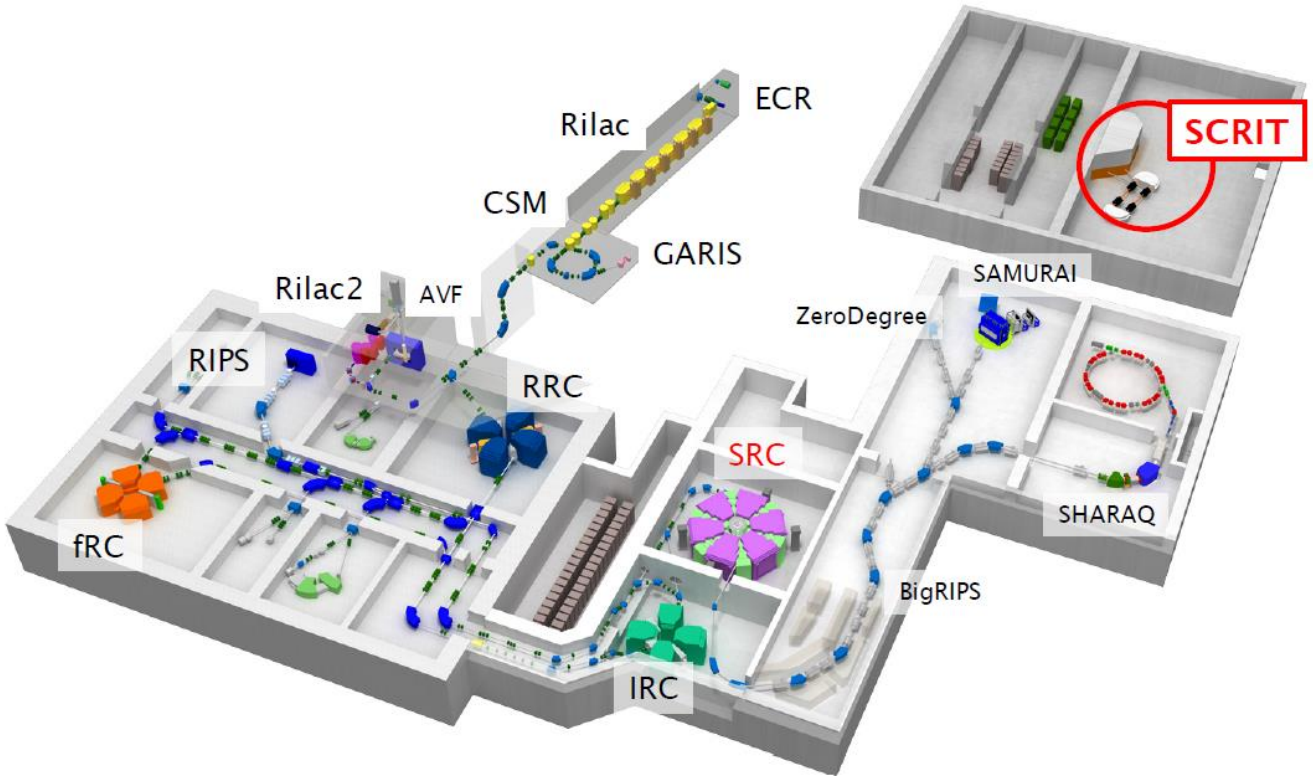
Courtesy W. Kaabi (LAL Orsay)
(LHeC/FCC-eh and PERLE Workshop, 27-29 June 2018, Orsay, France)

Only one existing e-RIB-scattering setup: SCRIT (Self-Confining Radioactive Ion Target)

T. Suda, M. Wakasugi, T. Emoto, K. Ishii, S. Ito, K. Kurita, A. Kuwajima, A. Noda, T. Shirai, T. Tamae, H. Tongu, S. War and Y. Yano,
"First Demonstration of Electron Scattering Using a Novel Target Developed for Short-Lived Nuclei,"
Physical Review Letters **102** (10) (2009).

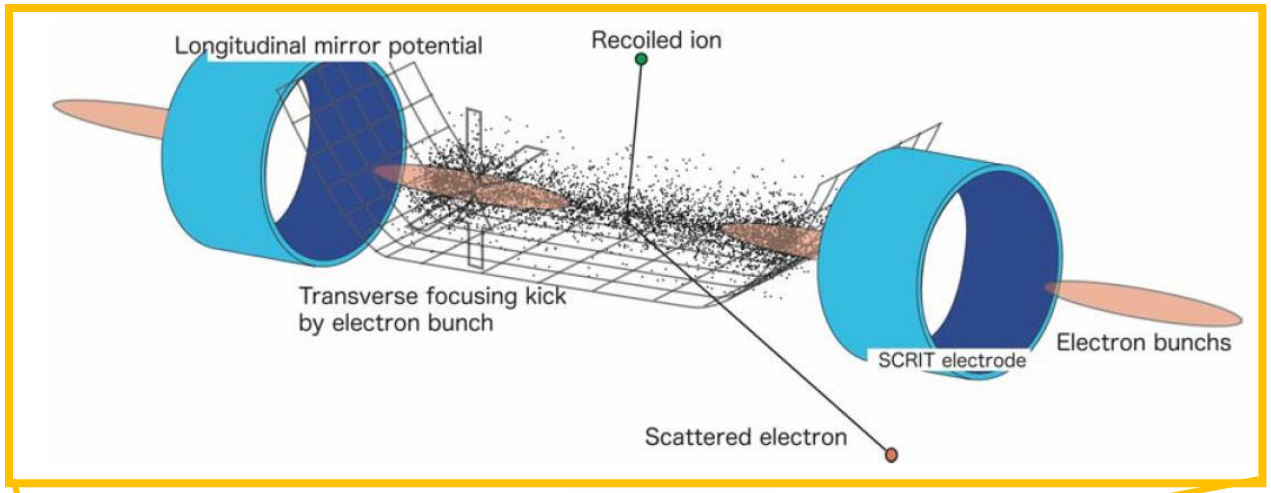
M. Wakasugi, T. Emoto, Y. Furukawa, K. Ishii, S. Ito, T. Koseki, K. Kurita, A. Kuwajima, T. Masuda, A. Morikawa, M. Nakamura, A. Noda, T. Ohnishi, T. Shirai, T. Suda, H. Takeda, T. Tamae, H. Tongu, S. Wang, and Y. Yano,
"Novel internal target for electron scattering off unstable nuclei,"
Physical Review Letters **100** (16) (2008).

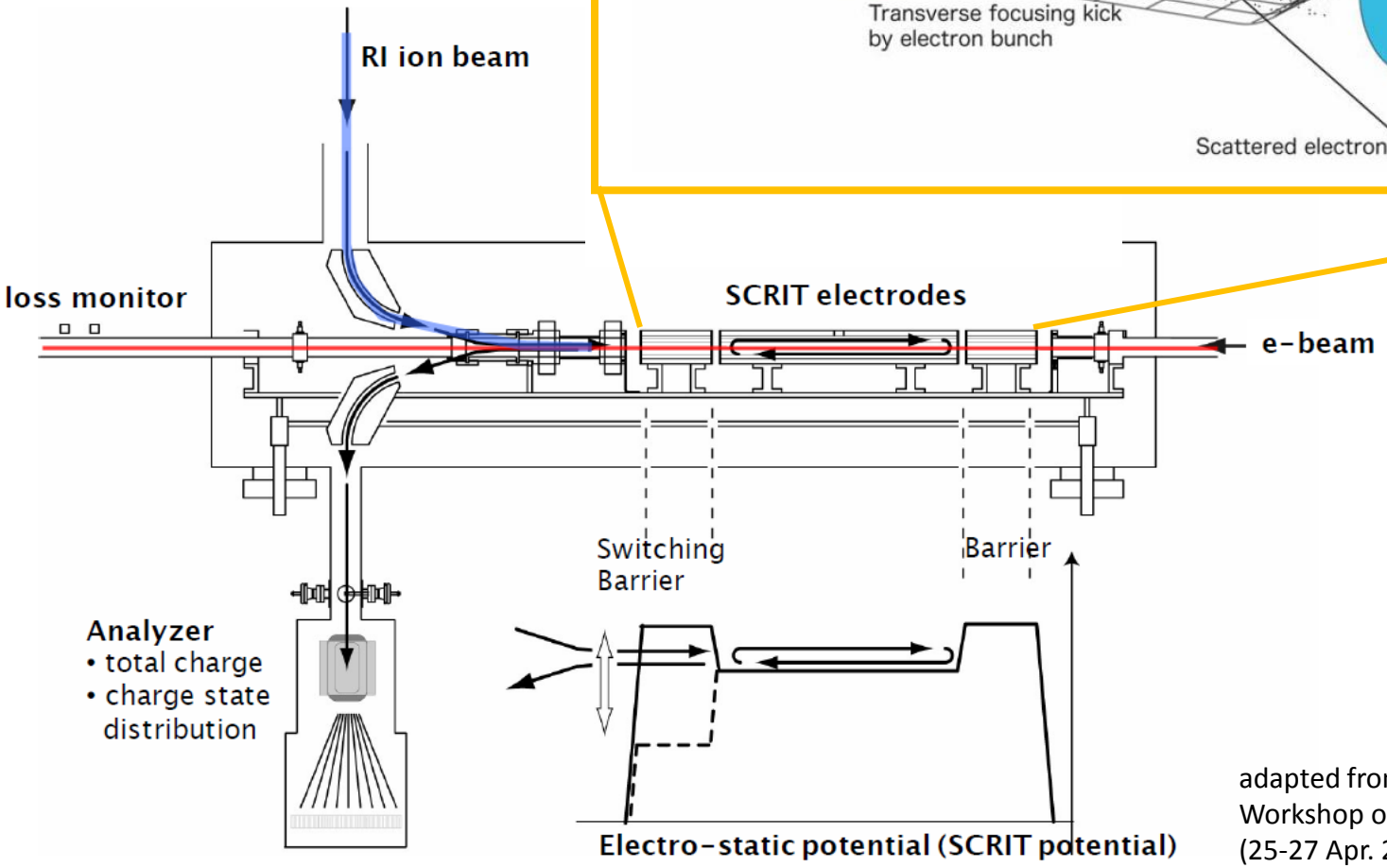
Location of the SCRIT Facility in the RIKEN RI Beam Factory



taken from : M. Wakasugi
Workshop on e-Ion collision
at CEA Saclay
(25-27 Apr. 2016)

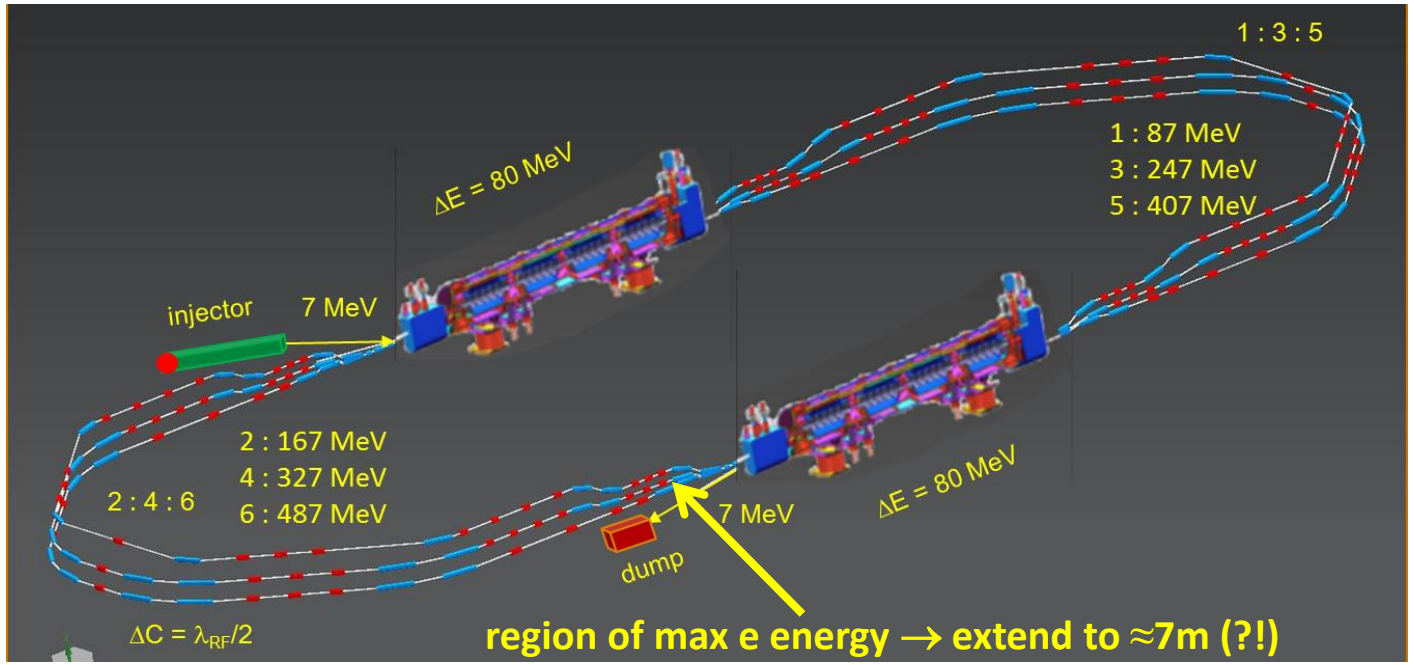
Only one existing e-RIB-scattering setup: SCRIT (Self-Confining Radioactive Ion Target)





adapted from : M. Wakasugi
Workshop on e-Ion collision at CEA Saclay
(25-27 Apr. 2016)

injection of ALTO-like RIBS into the ERL



Largely inspired by the pioneering SCRIT example

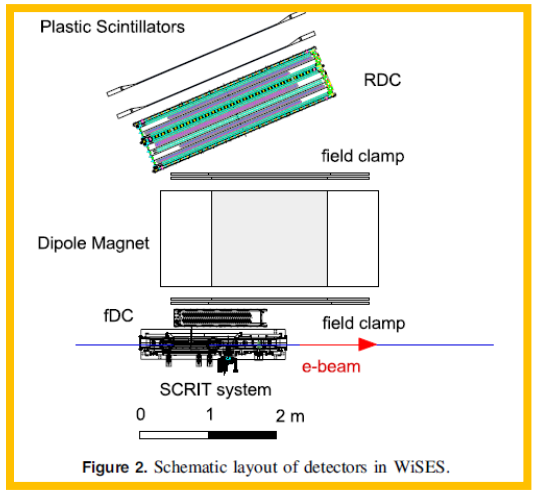
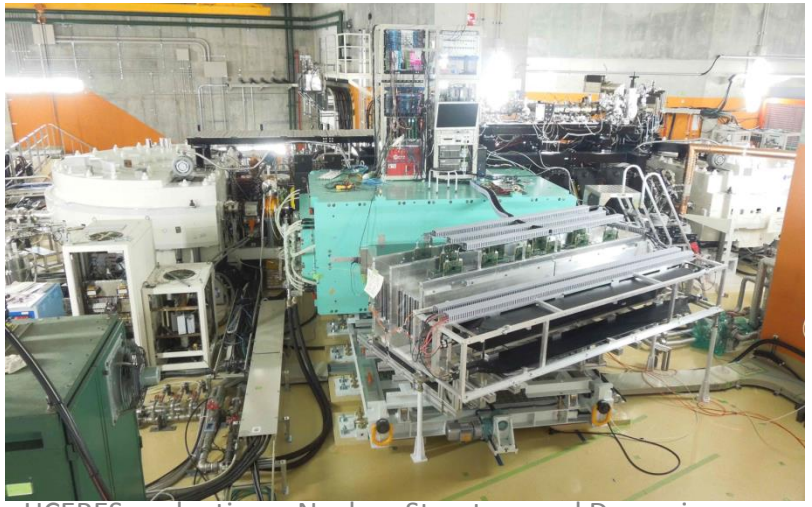


Figure 2. Schematic layout of detectors in WiSES.



T Ohnishi et al Phys. Scr. T166 (2015) 014071

The DESTIN project

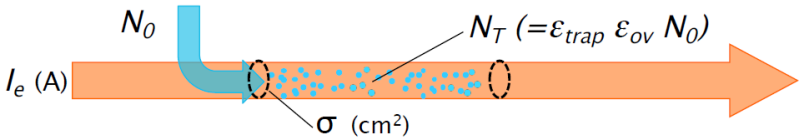
Chancé et al (CEA Saclay) **ETIC** project within GANIL-2025 (2015)
calculations within ERL hypothesis :

I_e=200 mA N_A=10^6 trapped ions: $\mathcal{L} \simeq 10^{29}$ should be achieved

based on

[A.N. Antonov et al., Nucl. Instr. and Meth. A **637** 60 (2011)] ELISE project GSI

Achievable luminosity

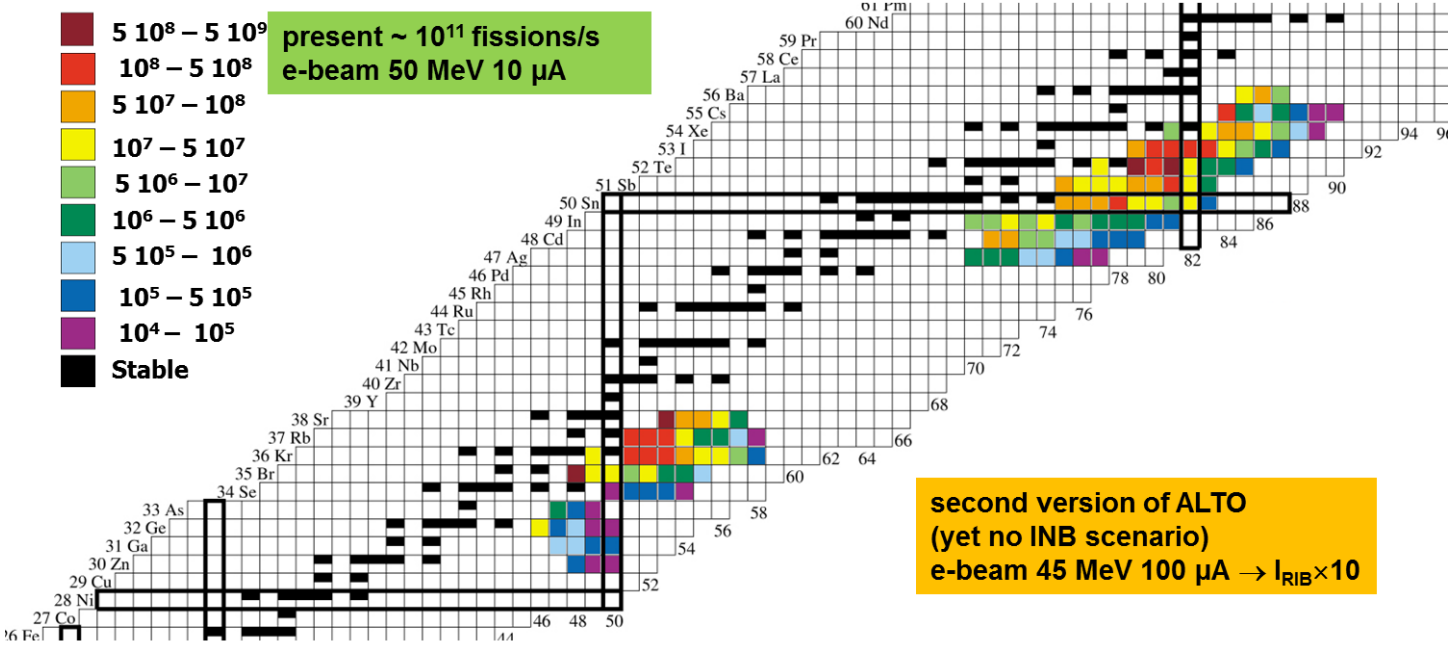


$$L \sim \frac{I_e/e \quad N_T}{\sigma} \ /(\mathrm{cm^2 s})$$

PERLE@Orsay : 20 mA $\rightarrow \mathcal{L} \simeq 10^{28}$ is *probably* achievable for a **10^6** trapped RI population **on the principle**

but the dynamical e-beam-RI coupling should be investigated : first time with a ERL time structure
e-beam instabilities ? impact on ERL operation ?

Production pps



The DESTIN project : physics case

stable targets already used T. Suda, H. Simon [Progress in Particle and Nuclear Physics 96 (2017) 1]

radioactive targets envisioned with DESTIN