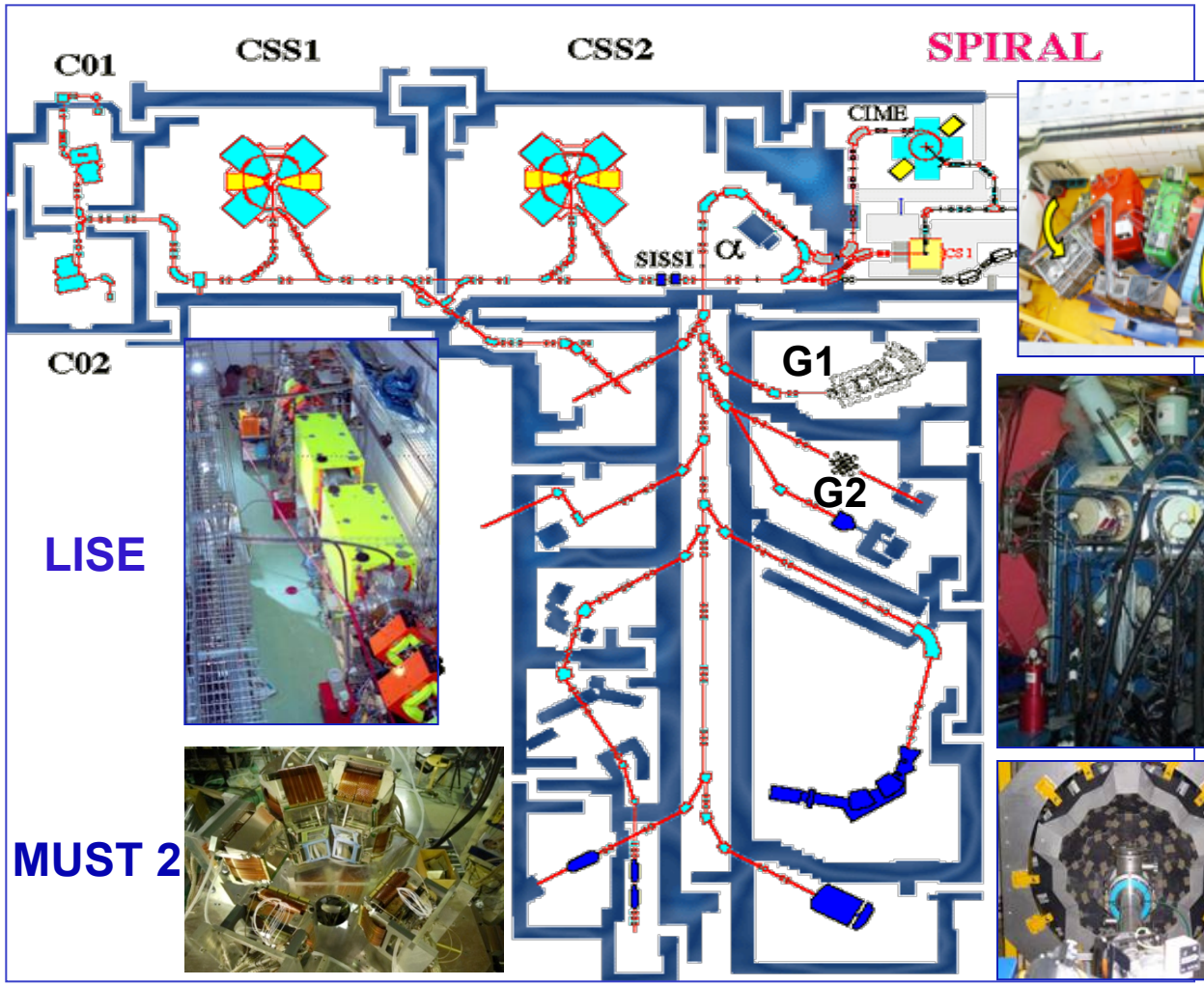
TNA GANIL

M. Lewitowicz
Deputy Director of GANIL

- **GANIL/SPIRAL1 beams and detectors**
- **Selected Physics Highlights**
- **Construction of SPIRAL2**
- **TNA & GANIL/SPIRAL1 operation 2013-2016**

www.ganil-spiral2.eu

GANIL accelerators and detectors



VAMOS

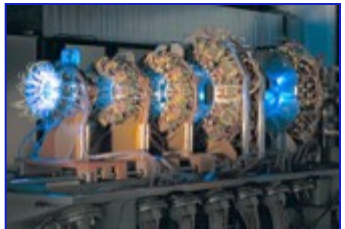
LISE

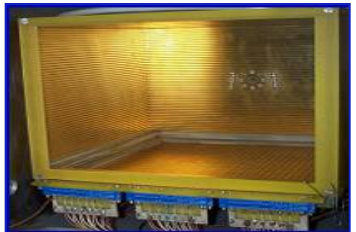
EXOGAM

MUST 2

n-Wall

INDRA



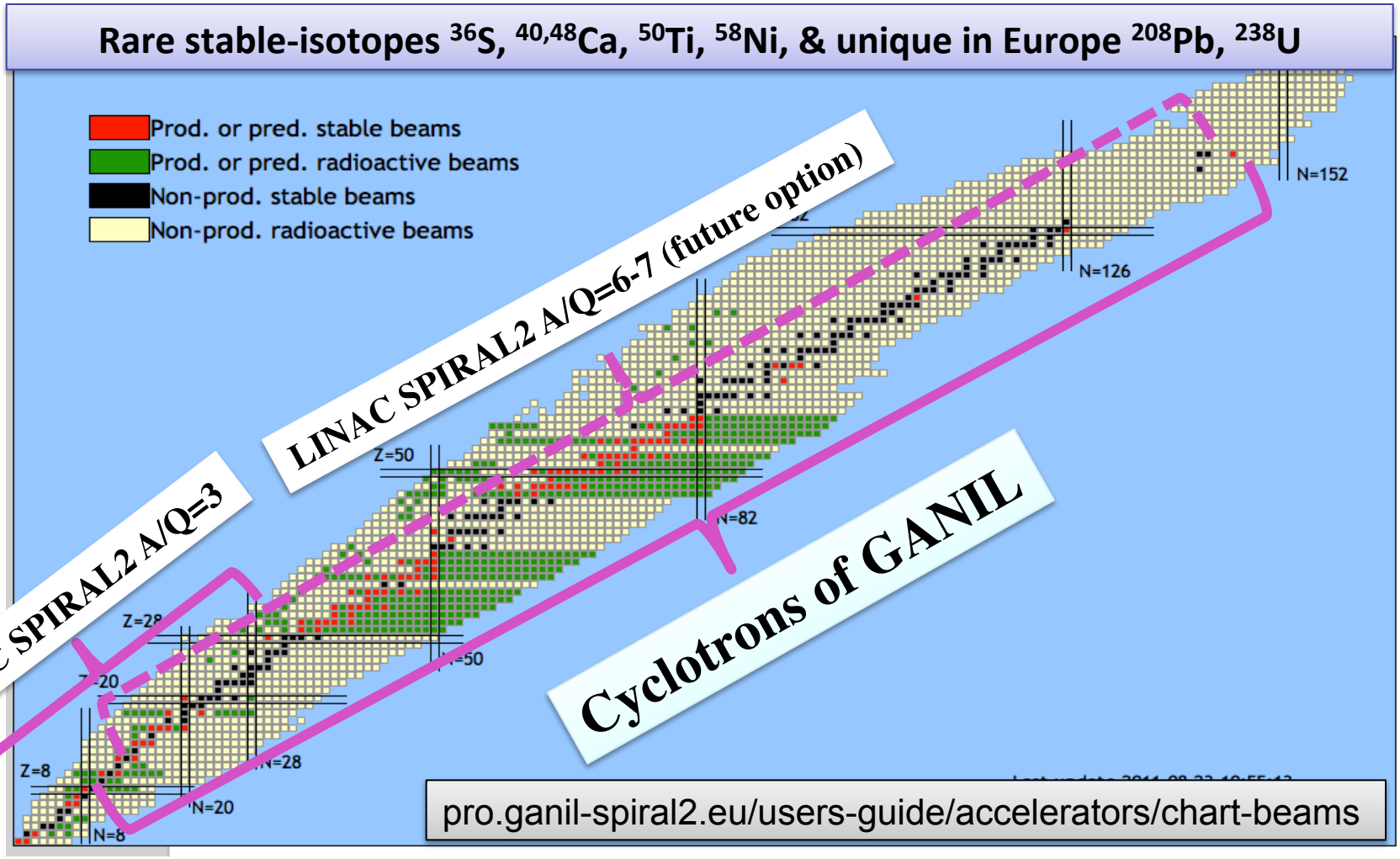


MAYA
TPC
ACTAR

Stable ion-beams of GANIL & LINAC SPIRAL2

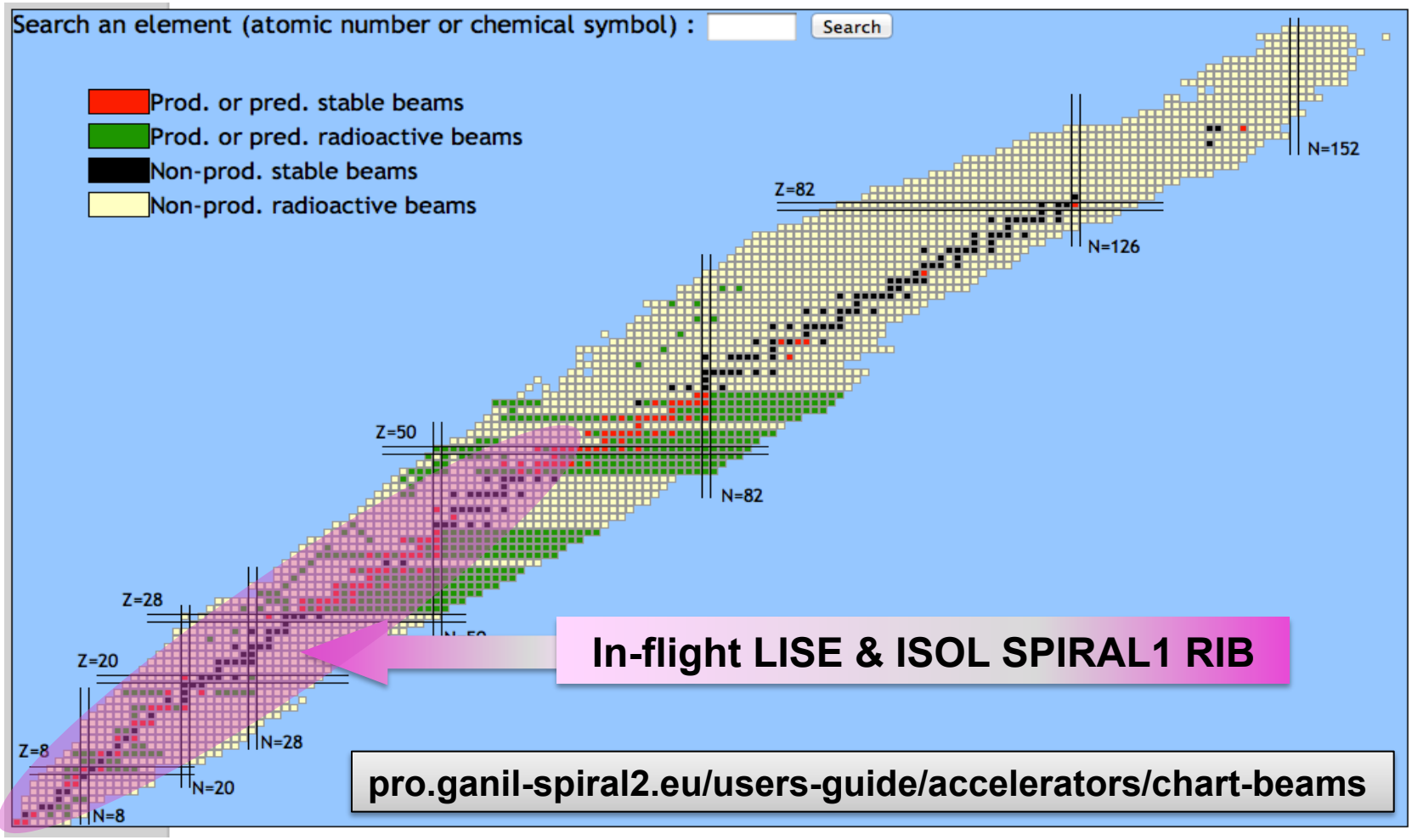
- **Cyclotrons: ≤10^{13} pps, du C à U, 1 MeV/n - 95 MeV/n**
- **LINAC SPIRAL2 (baseline project) ≤ 10^{15} pps, du n, p au Ni, 0.75 MeV/n – 15 MeV/n**

Rare stable-isotopes ^{36}S, ^{40,48}Ca, ^{50}Ti, ^{58}Ni, & unique in Europe ^{208}Pb, ^{238}U



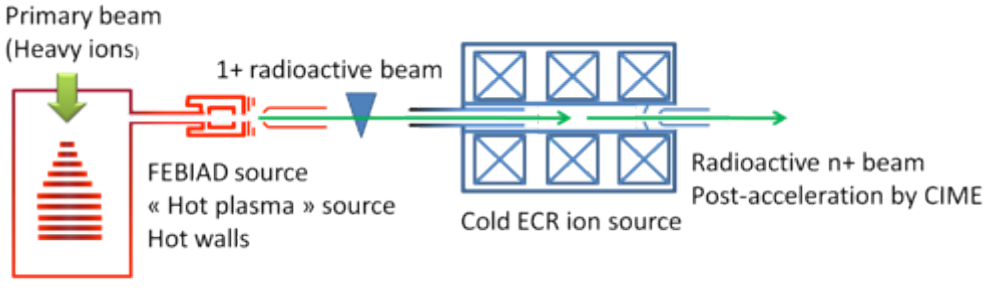
Radioactive Ion Beams GANIL/SPIRAL1

- **RIB by in-flight at LISE: few MeV/n to 50 MeV/nucl. (≈ 30% of beam time today)**
- **ISOL RIB from SPIRAL 1: ≤ 60keV et 1-15 MeV/nucl.**



SPIRAL 1 upgrade – New RIB

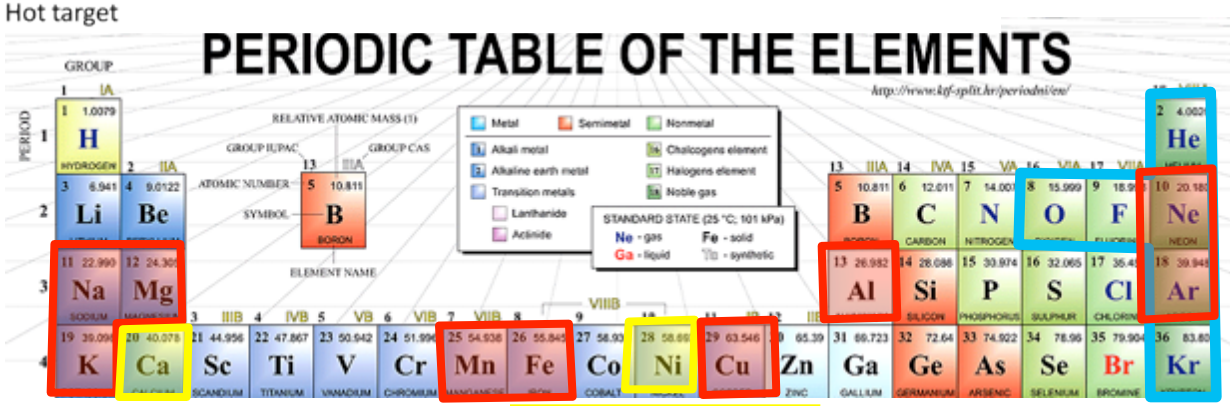
1+/n+ ionisation scheme



Metallic beams from a FEBIAD ion source

New FEBIAD source

SPIRAL Target



Ionised as radioactive beams

Ionized as stable beams

Existing beams at SPIRAL

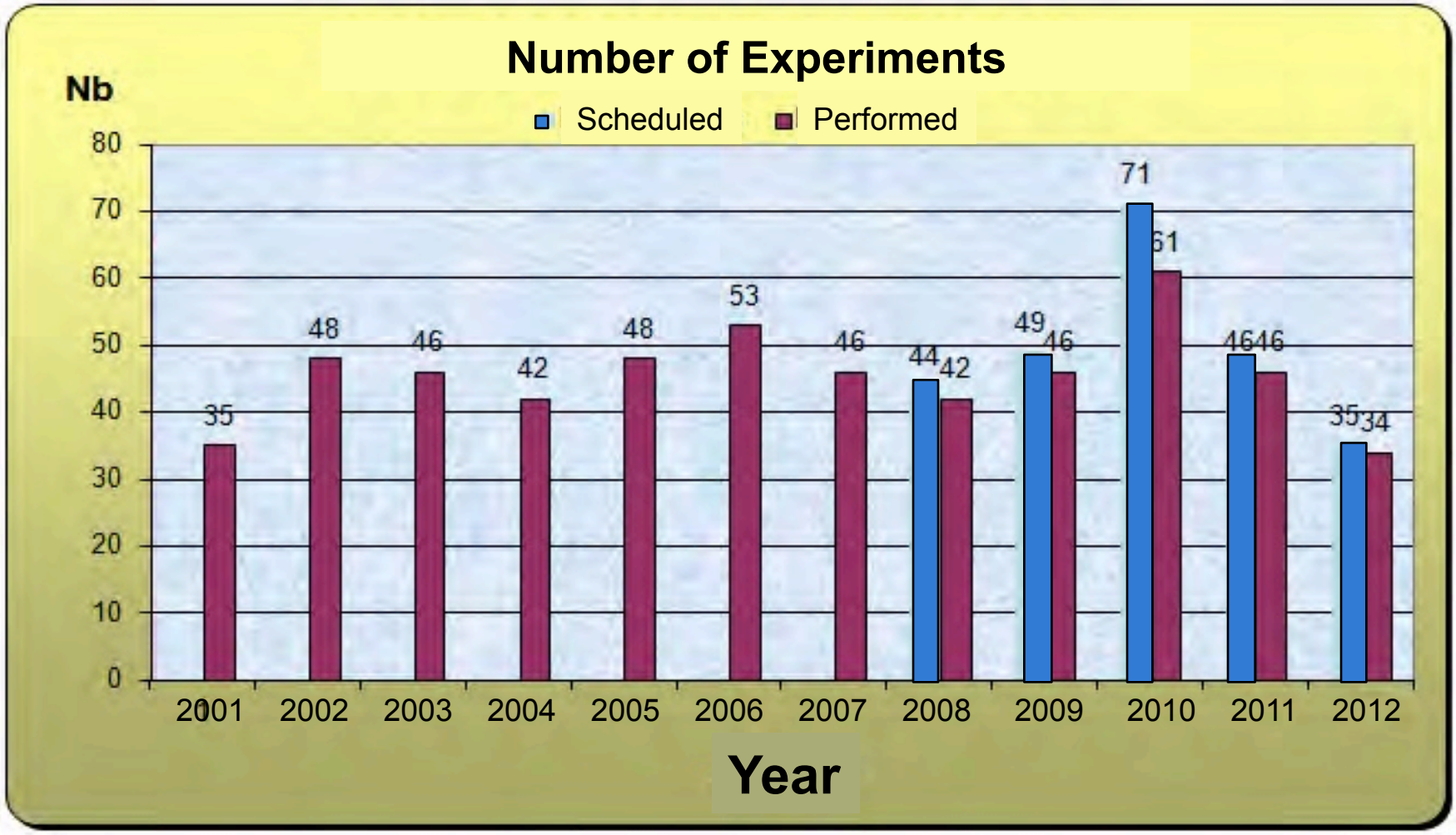
Most beams have projected intensities > 10^6 pps for 1.5kW primary beam power

New beams from FEBIAD (LIRAT, IBE): 2015
New beams from Booster (CIME energies): 2016

Today: 6 elements
after SPIRAL1 upgrade: 13 (15) elements

P. Delahaye at al.

Operation of the GANIL accelerators in 2012

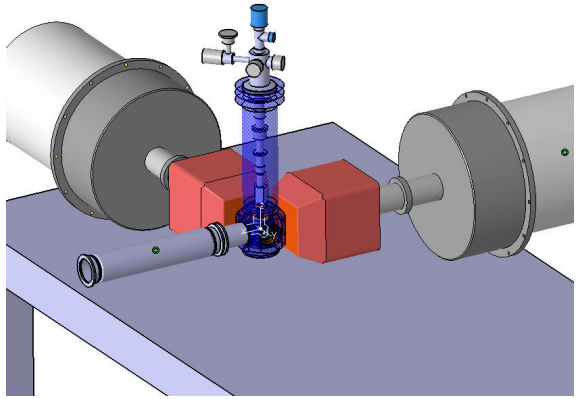


Only one experiment was not realised in 2012 due to a break-down of the CSS1 accelerator

Search for Super-screening effect in superconductor

P. Ujic et al.

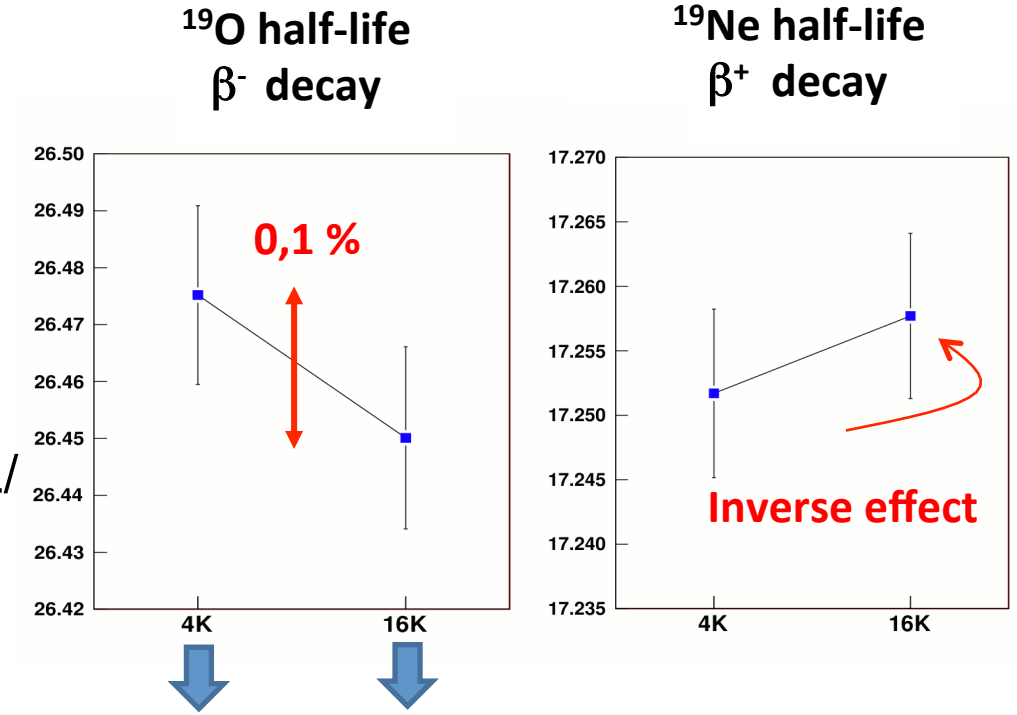
Collaboration CEA, CNRS, Serbia, Romania



An experiment performed at GANIL/ SPIRAL with 2 beams

^{19}Ne / ^{19}O at 5.10^{5} pps 4 AMeV

Implanted in a cooled Niobium foil



Superconductor 4K 16K Metal

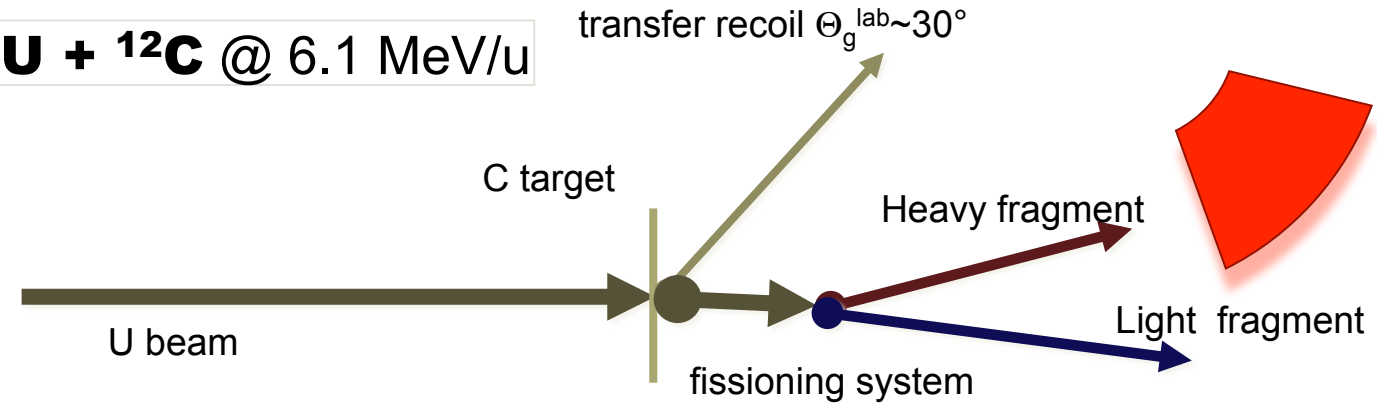
Conclusions:

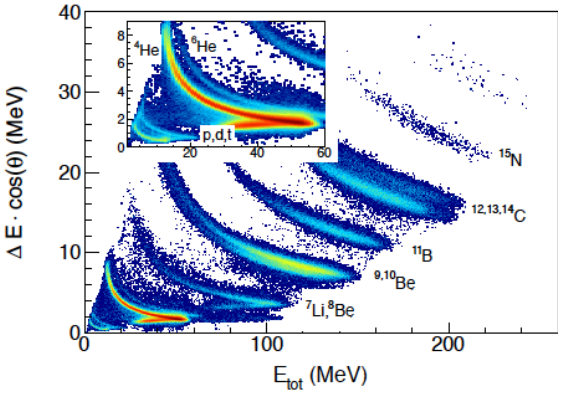
- **No super-screening observed**
- **Observed effect = 1.1 ± 0.9 % of the predicted value**
- **New method developed, possibility to go lower than 1/10,000 precision**
- **Impact on very accurate measurements – to be confirmed**

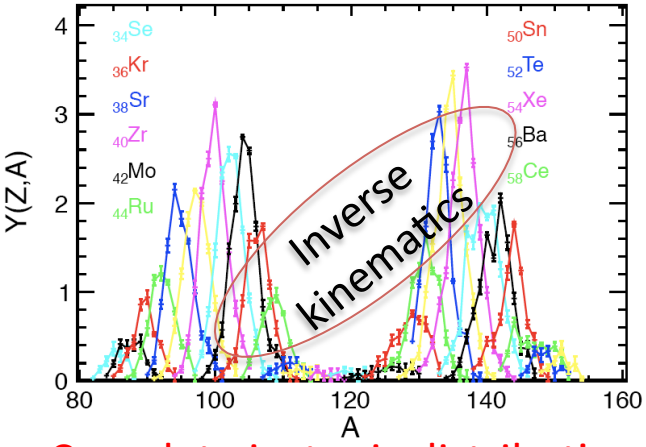
PRL 110, 032501 (2013)

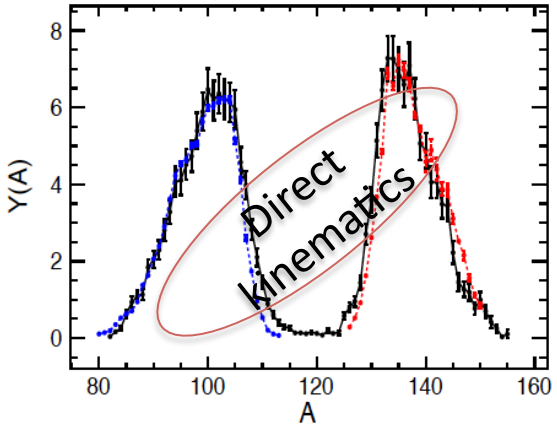
Study of fission yields and implications for SPIRAL2

^{238}U + ^{12}C @ 6.1 MeV/u







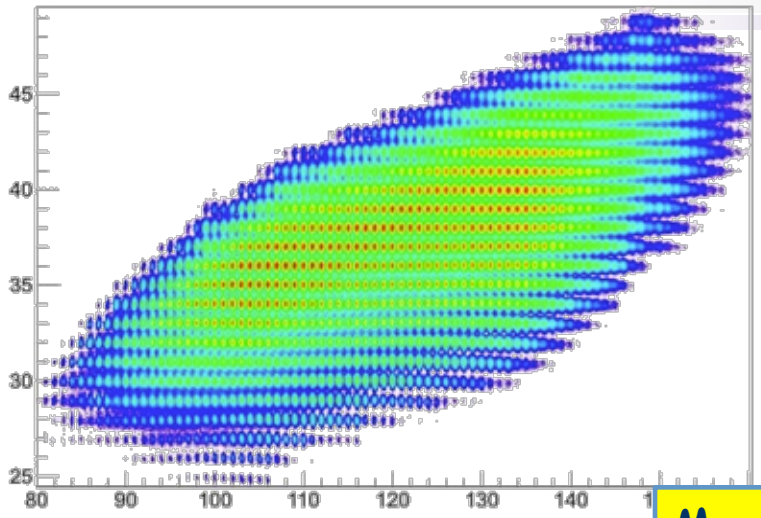


Complete isotopic distributions

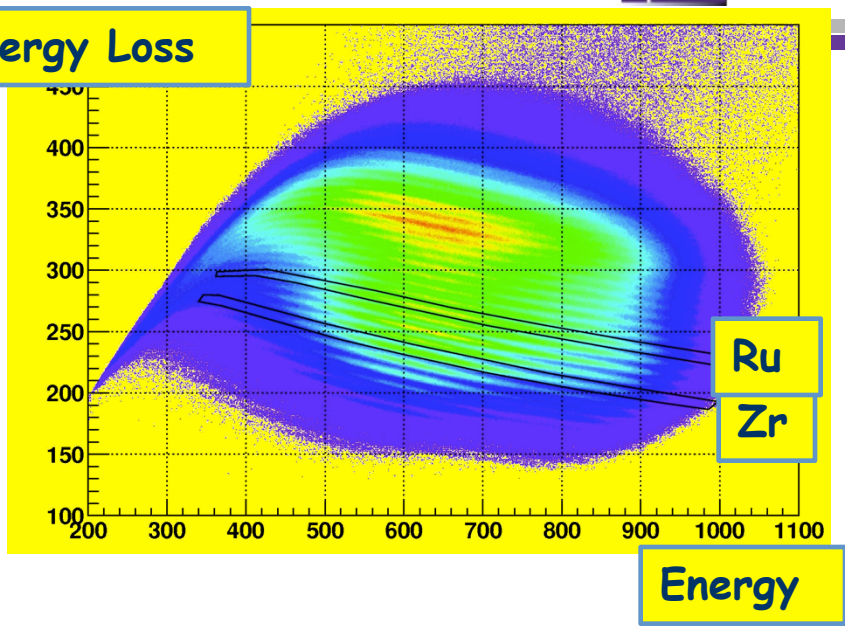
M. Caamaño et al., accepted PRC (2013)
Ph.D. O. Delaune (GANIL, 2012) Caen University
Referenced in the international database INIS.

Z, A & q identification at few MeV/nucleon

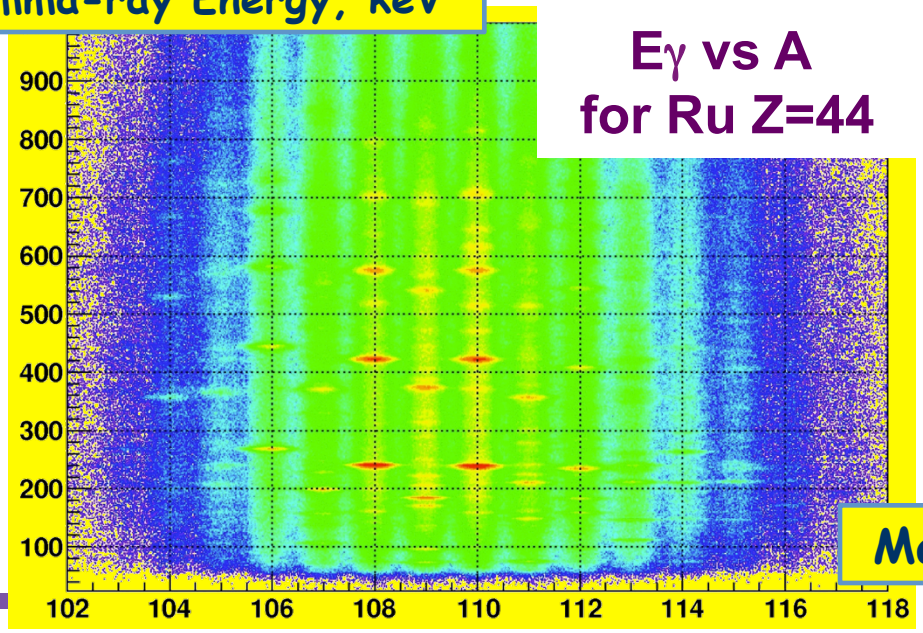
Charge State



Energy Loss

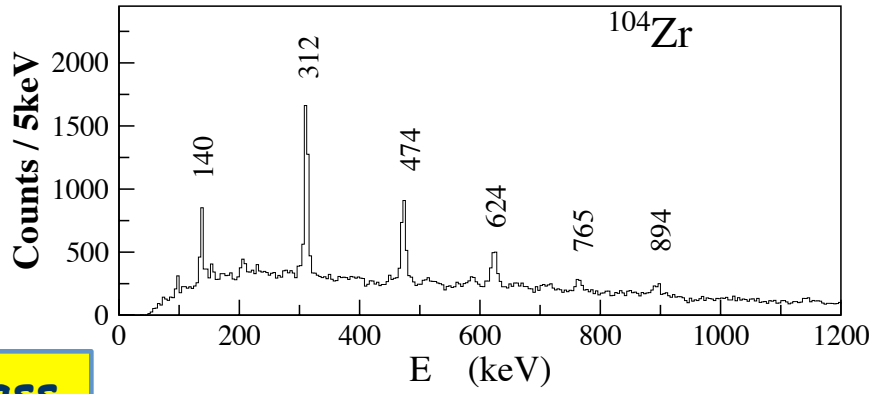


Gamma-ray Energy, keV



Eγ vs A for Ru Z=44

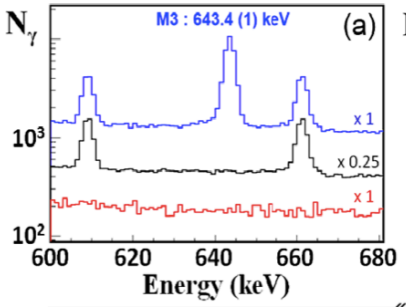
γ spectrum of ^{104}Zr (singles)

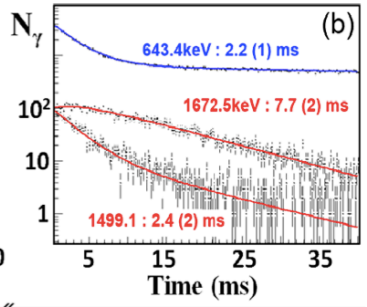


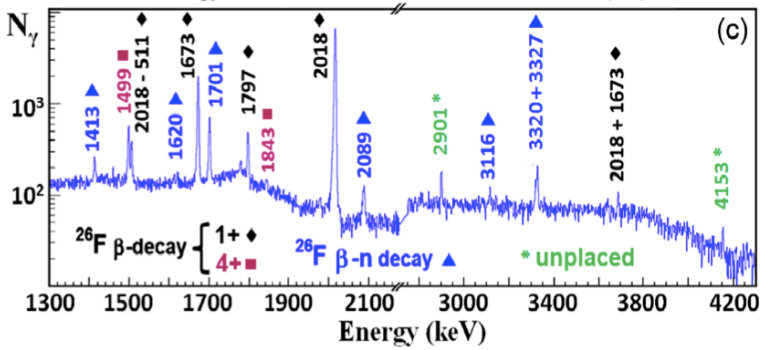
M. Rejmund at al.

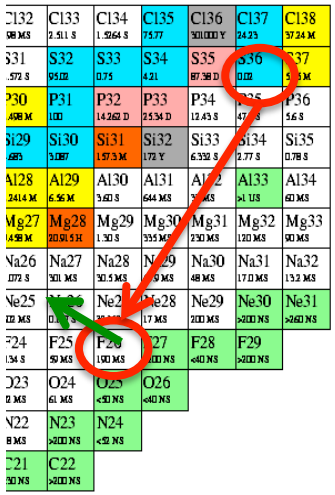
Spectroscopy of ^{26}F

A. Lepailleur, O. Sorlin et al., PRL 110 (2013)



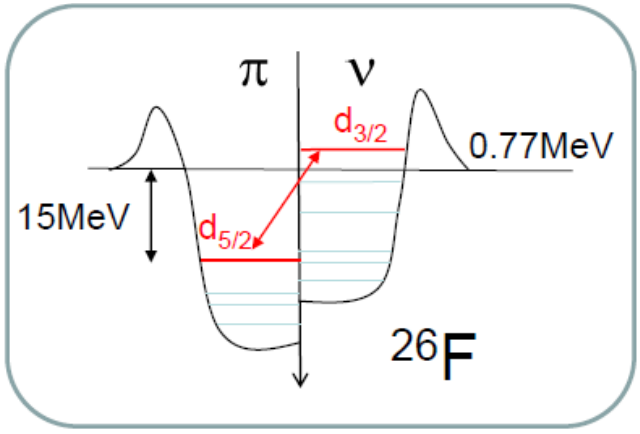


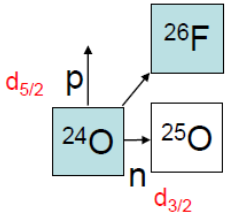




Production of exotic ^{26}F nucleus at LISE by fragmentation of a beam of ^{36}S

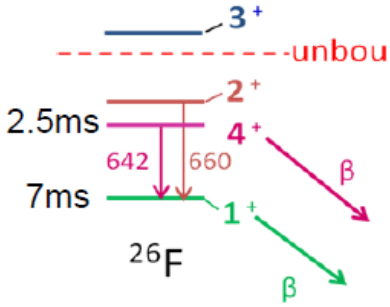
Observation of a new isomeric state decreasing by IT and beta to 26Ne.
New estimates of the gs mass of 26F
Important information on the p-n interaction at large isospin

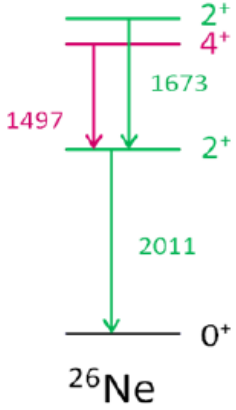




V^{pn} $(d_{3/2}d_{5/2})$

J=1,2,3,4

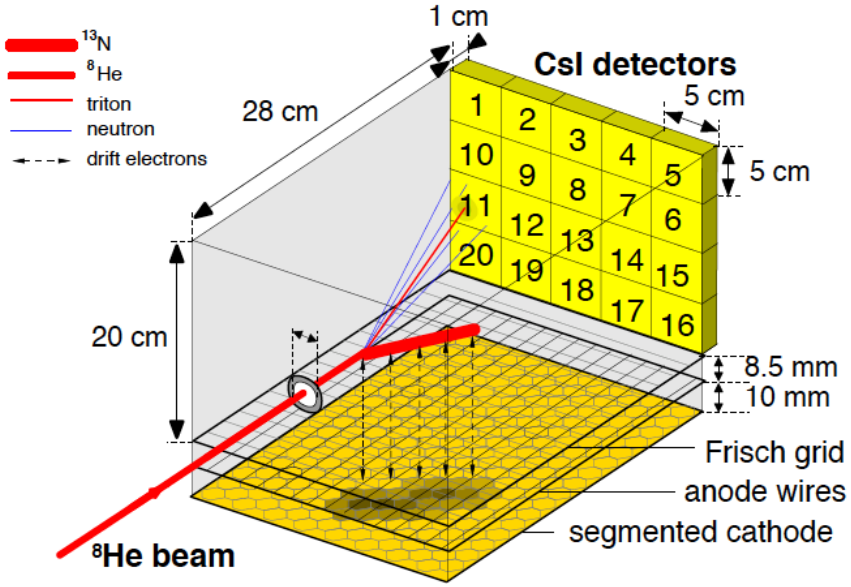




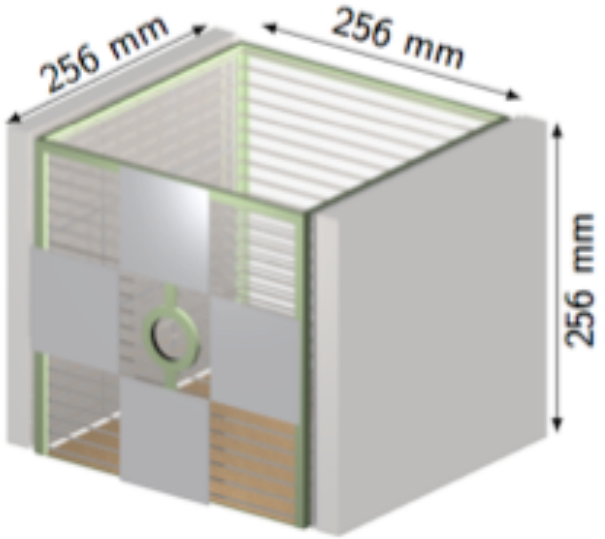
Conclusion:
The effective neutron-proton 0d5/2-0d3/2 force used in the calculations (shell model) must be reduced.

News : MAYA-ACTAR-TPC

MAYA



ACTAR-TPC



- Study of l'^{7}H Results coming soon! M. Caamaño, T. Roger et al.
- Technical developments allowing to use heavy and intense beams (up to Uranium) (relevant for Spiral2) ➔ JRA in ENSAR 2 (talk of G. Grinyer tomorrow)
- ERC ACTAR-TPC (G. Grinyer et al.) : nucleosynthesis and 2p radioactivity

Approved!

See also presentation of S. Bagchi

SPIRAL2 a national and EU priority

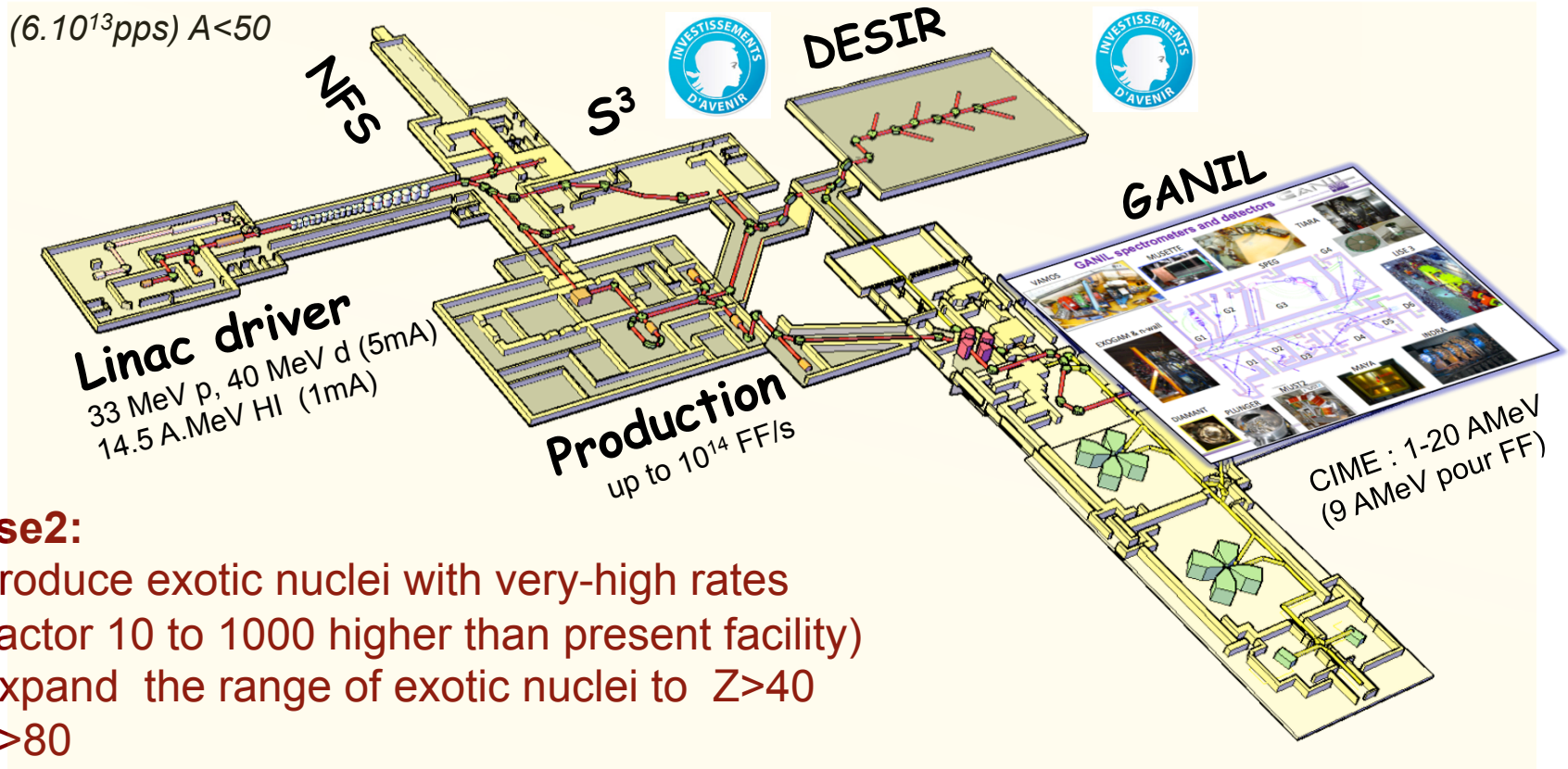
TGIR roadmap (rapport ministère 2012)

Phase1:

Increase the intensity of stable beams by a factor 10 to 100

10pμA (6.10^{13}pps) A<50

DESIR (low energy facility)



Phase2:

- Produce exotic nuclei with very-high rates (factor 10 to 1000 higher than present facility)
- Expand the range of exotic nuclei to Z>40 A>80

Investment :
Cost: 151,7 M€ & >23 M€ detectors

Post-acceleration of high intensity RIB through the CIME cyclotron to the curent GANIL facility

SPIRAL2 is on the list of the European Strategy Forum on Research Infrastructures (ESFRI)

Civil Construction

92 % of the concrete done (14000m³)

Feb 2011

May 2011

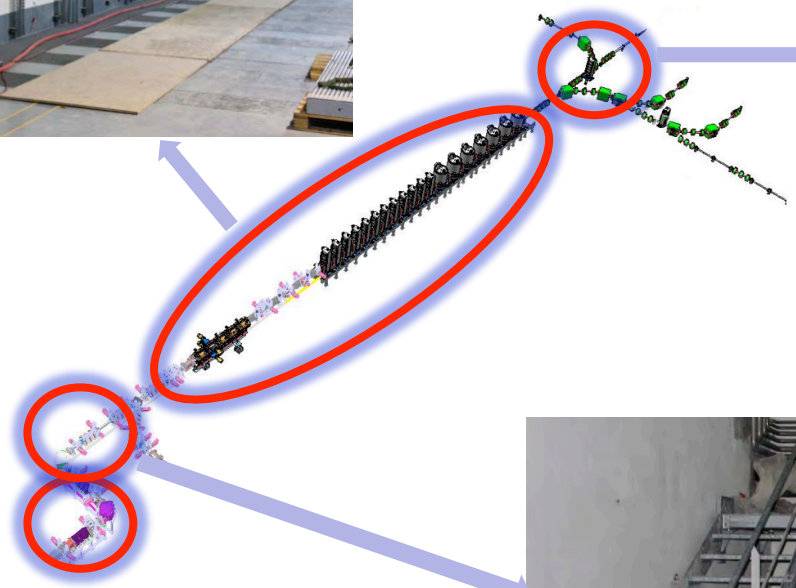
Oct 2011

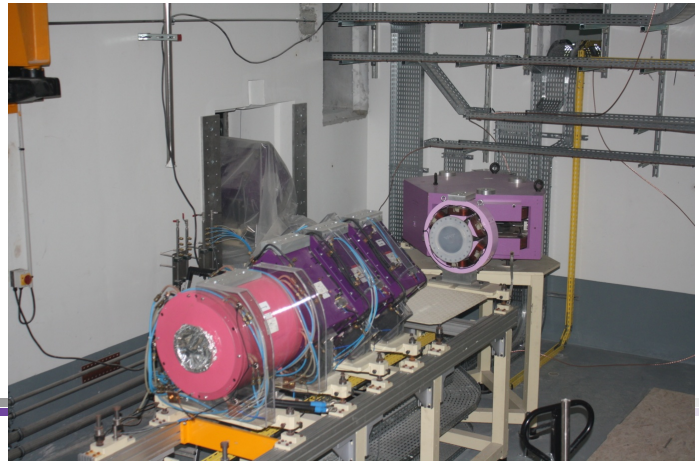
May 2012

Oct 2012

March 2013

Installation is going on

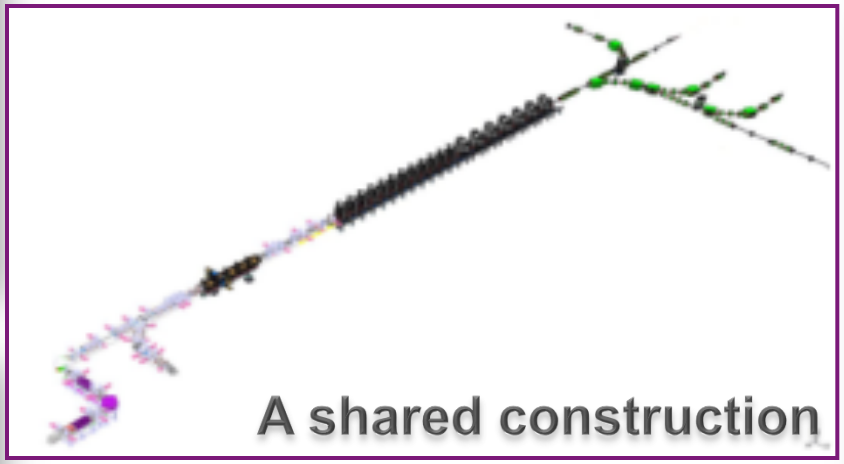




May 2013

Phase 1

HI beam line



d & p beam line

RFQ

Cold Box

Cryomodule A

Cryomodule B

Phase 1

HI beam line

A

d & p b

B

- ✓ Decree of SPIRAL2 Phase 1 signed by Prime Minister on May 8th 2012
- ✓ Operation permit expected by Mid 2014

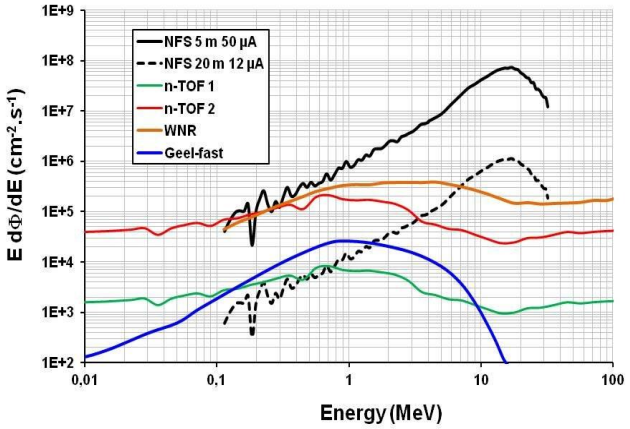
SPIRAL2 Phase1 schedule :

✓ Installation of the first equipment	➔December 2012
✓ Start of the RFQ installation	➔ September 2013
✓ Start of the Cryomodule installation	➔ November 2013
✓ **RFQ/BTI first beams**	➔ **June 2014**
✓ LINAC cool down	➔ July 2014
✓ **First Linac beams**	➔ **December 2014**

Neutrons For Science

NFS Physics case (11 LoIs)

- Fission reactors of new generation
- Fusion technology
- Studies related to hybrid reactors (ADS)
- Basic data for evaluated data bases
- Nuclear medicine and biology
- Development of new detectors



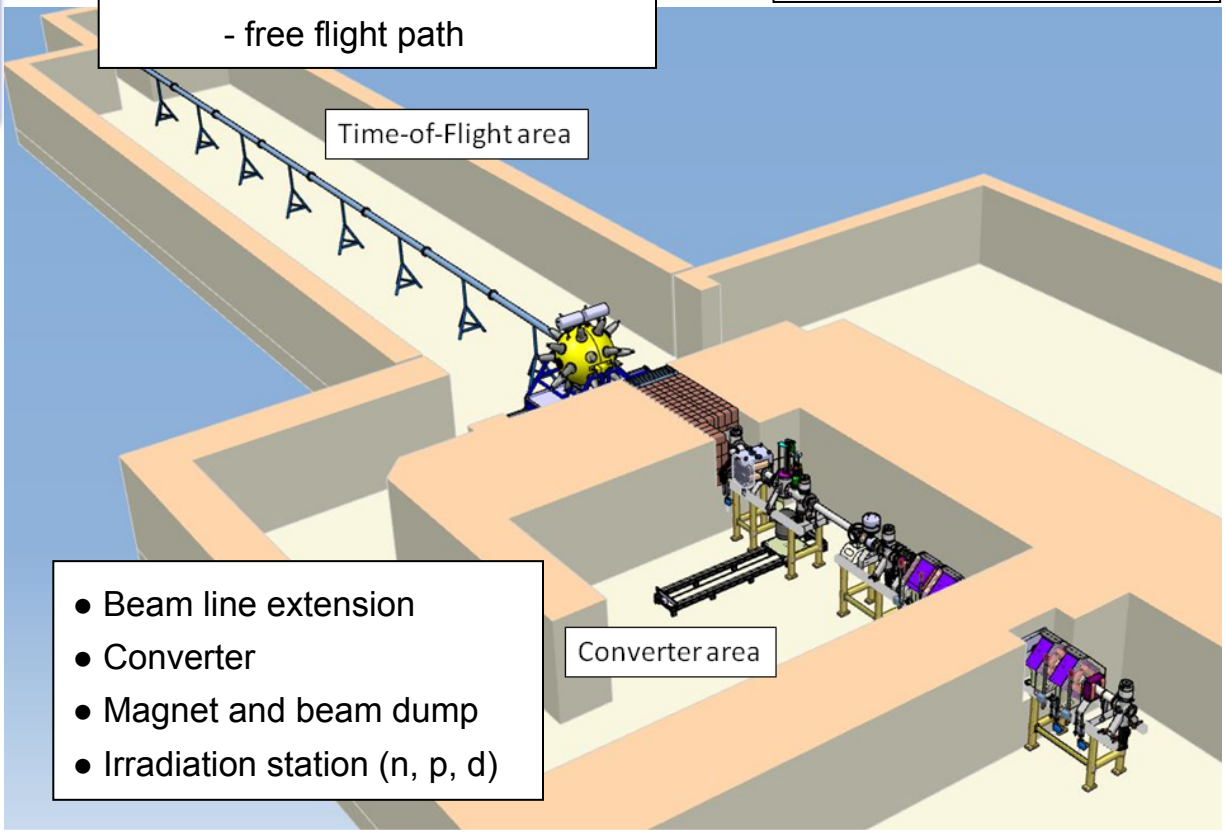
High intense neutron flux :
$\Phi > 1{,}5.10^{13}$ n/s in 4π
Continuous or mono energetic spectra
Well collimated neutron beam

First experiment in 2014

- Beam at 0°
- Collimator ↔ beam quality
- Size (L x l) ≈ (28m x 6m)
  - TOF measurements
  - free flight path

I < 50 µA
P < 2 kW

Use of radioactive samples
A< 1 GBq for thin layers
A< 10 GBq for thick samples



- Beam line extension
- Converter
- Magnet and beam dump
- Irradiation station (n, p, d)

Neutrons For Science

NFS Physics case (11 LoIs)

- Fission reactors of new generation
- Fusion technology
- S
- B
- N
- D

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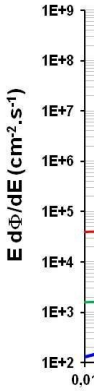

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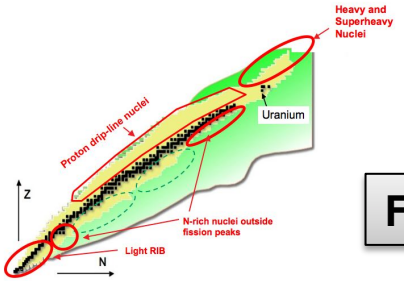
First experiment in 2014

cea
cnrs IN2P3 Les deux infinis
UPPSALA UNIVERSITET
KIT Karlsruhe Institute of Technology

S3

S3 Physics case (16 LoIs)

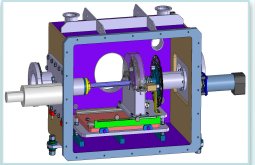
- VHE – SHE elements
- Proton drip-line and N=Z
- Nuclear astrophysics
- Atomic physics



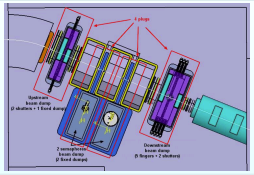
GANIL spiral2
laboratoire commun CEA/DSM CNRS/IN2P3

First experiment in 2015

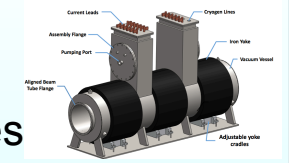
High power Rotating targets including actinides

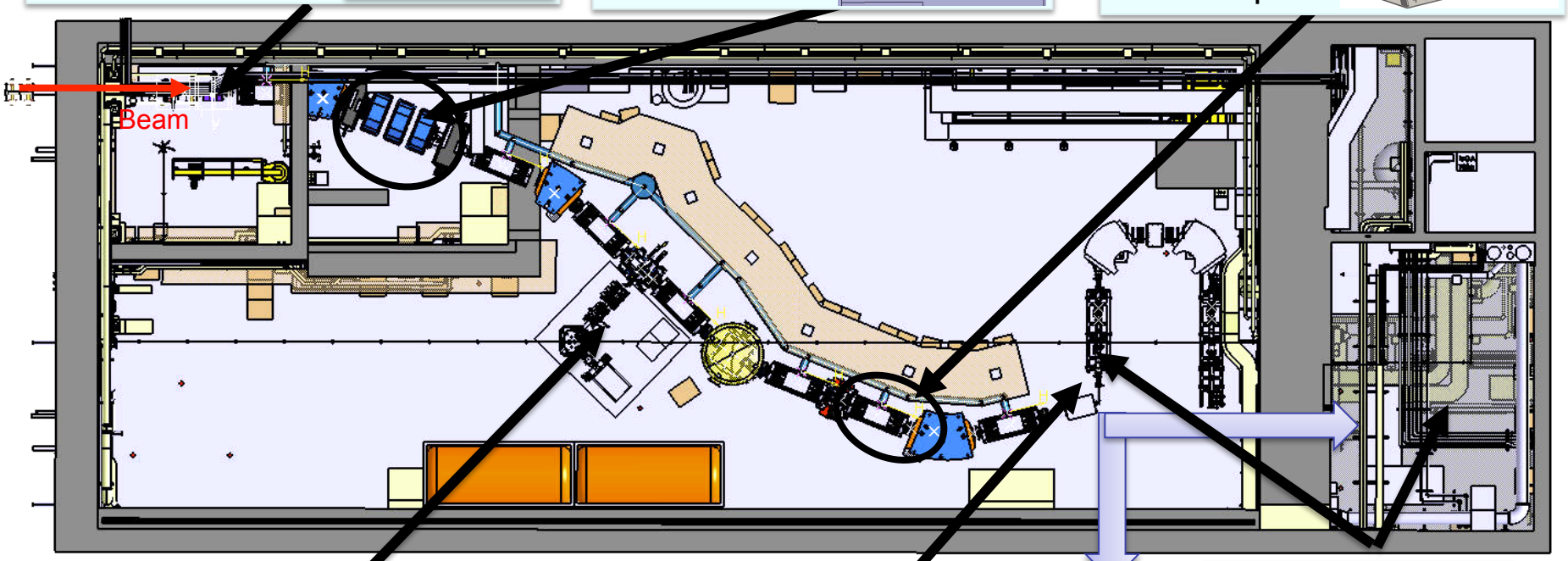


Beam dump & Movable fingers

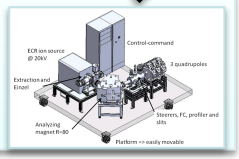


Large acceptance SC Multipoles

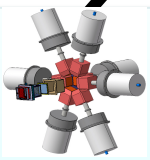




FISIC setup Fast Ion Slow Ion Collisions

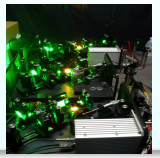


Implantation-decay station at the mass dispersive plan



DESIR

Low Energy Branch



GANIL spiral2 laboratoire commun CEA/DSM CNRS/IN2P3 · cnrs IN2P3 Les deux infinis · Irfu - CEA Saclay Institut de recherche sur les lois fondamentales de l'Univers · Argonne NATIONAL LABORATORY · IMSP Institut des NanoSciences de Paris · KATHOLIEKE UNIVERSITEIT LEUVEN · INVESTISSEMENTS D'AVENIR

S3

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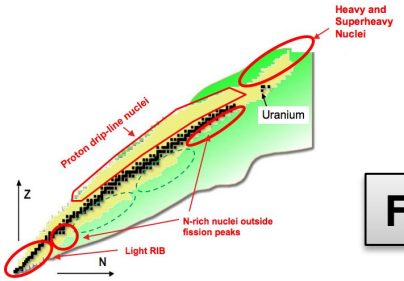

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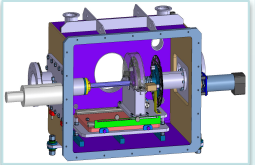
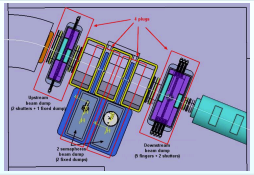
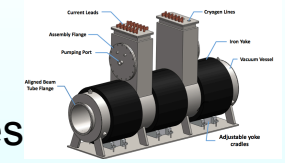


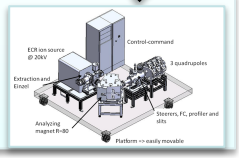
Beam dump & Movable fingers



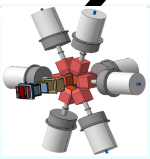
Large acceptance SC Multipoles



FISIC setup Fast Ion Slow Ion Collisions

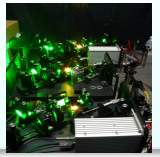


Implantation-decay station at the mass dispersive plan



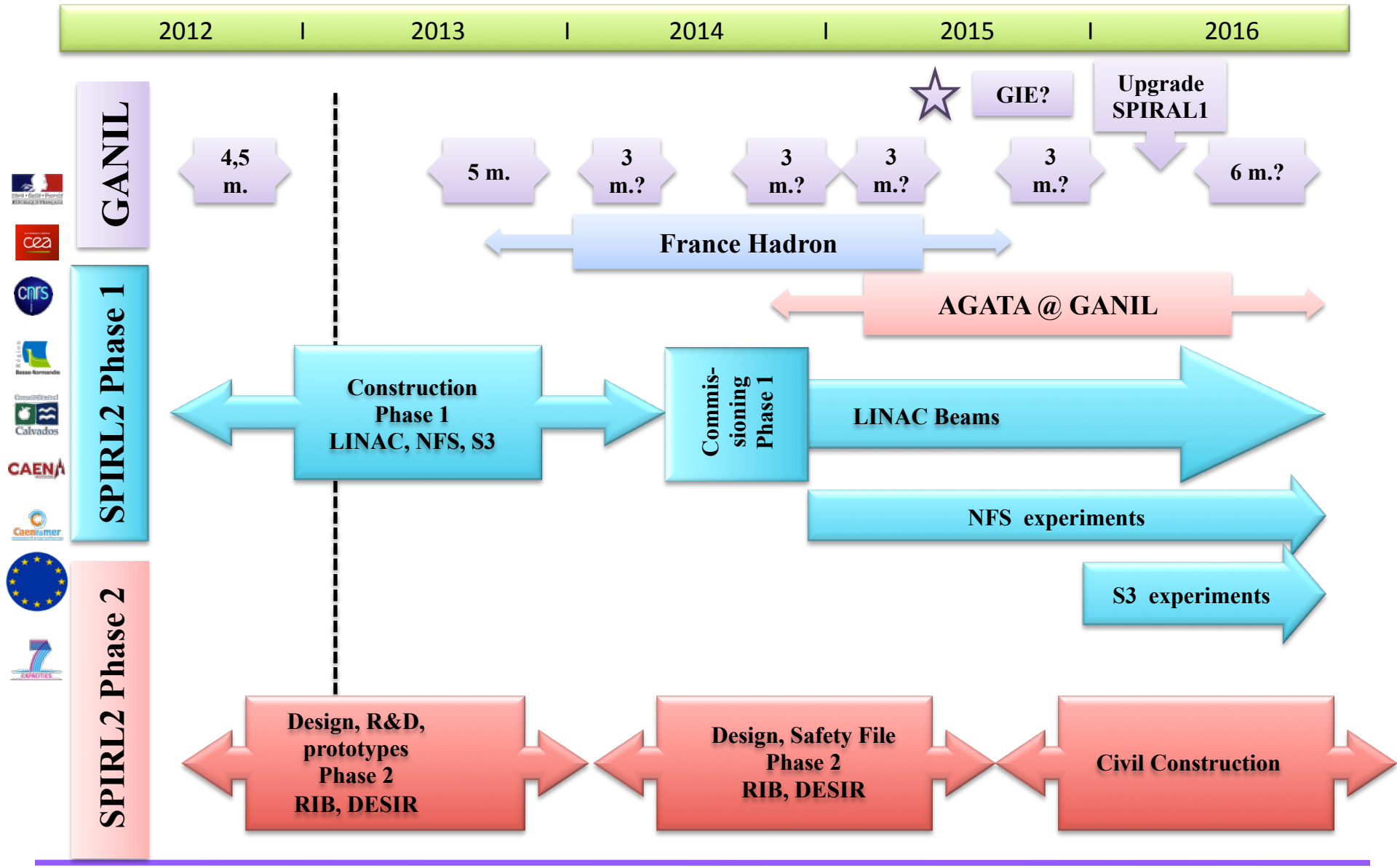
DESIR

Low Energy Branch



GANIL spiral2 laboratoire commun CEA/DSM CNRS/IN2P3 — cnrs IN2P3 Les deux infinis — Irfu CEA Saclay Institut de recherche sur les lois fondamentales de l'Univers — Argonne NATIONAL LABORATORY — IMSP Institut des NanoSciences de Paris — KATHOLIEKE UNIVERSITEIT LEUVEN — INVESTISSEMENTS D'AVENIR

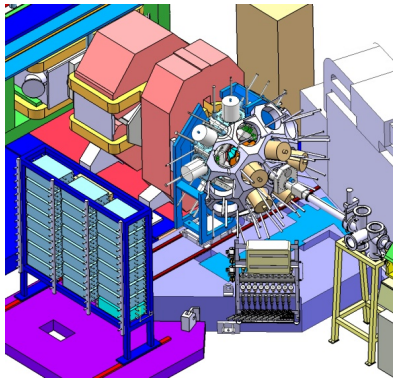
Timeline GANIL & SPIRAL2

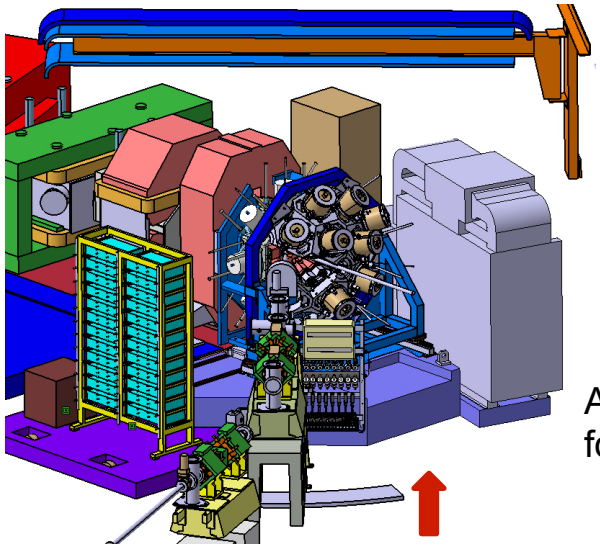


AGATA 1π 15 Triple Clusters at GANIL 2014 - 2016

Total Eff. ≤ 15% at 1.3 MeV, M=1

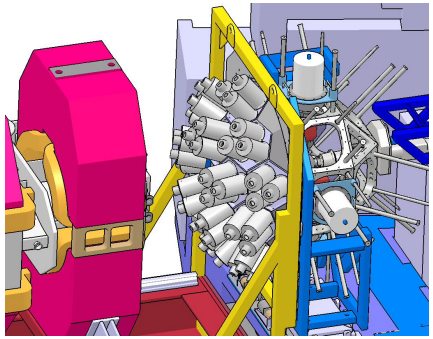
At 0° as separator (vaccum/gas-filled)



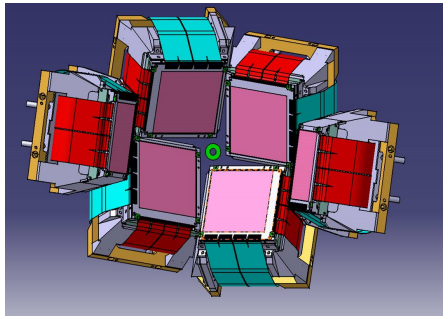


Angles >10 deg
for fission & MNT

n-wall



MUST II

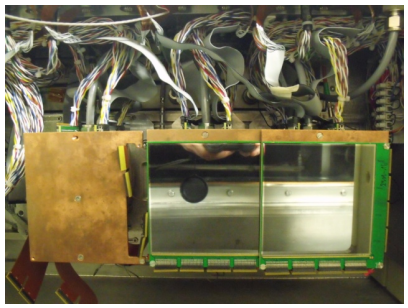


+ Cryogenic target

In G1 coupled to VAMOS (+ EXOGAM2): SIBs, RIBs

- *Charged particle array for transfer reaction MUST2/TIARA : (d,p) etc … program with SIB and RIB*
- *Charged particle array for prompt tagging : DIAMANT*
- *Charged particle array for Recoil Decay Tagging : MUSETTE*
- *Neutron detectors: n-wall*
- *Scintillators : BaF2 array, LaBr3*
- *Future detector : NEDA (n) , GASPARD (MUST2-like), PARIS (LaBr3)*

MUSETTE



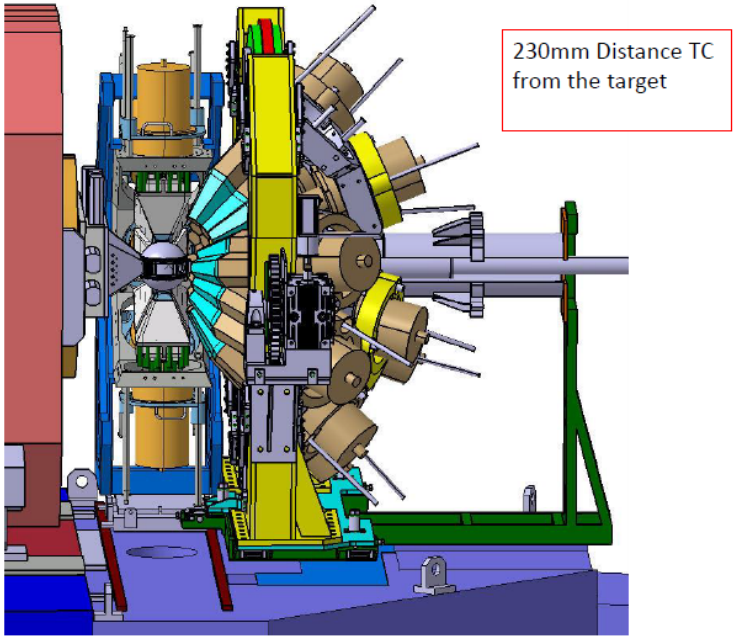
E. Clément et al.

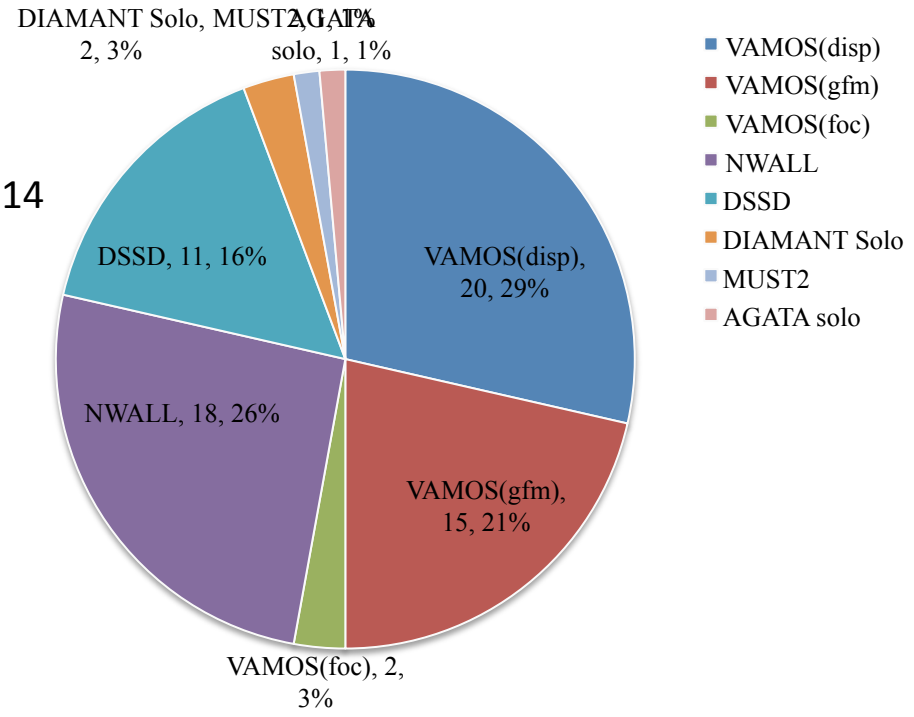
News : AGATA@GANIL

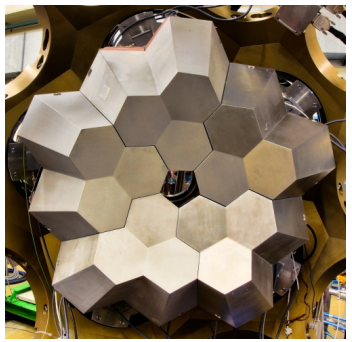
Workshop February 2013 : 47 LoI (669 days of beam requested)

75% stable beams CSS1, 25% RIB SPIRAL 1

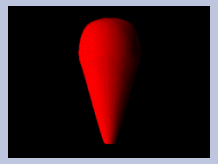
Installation of AGATA at GANIL from March 2014

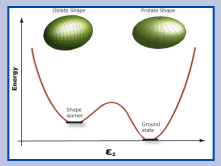


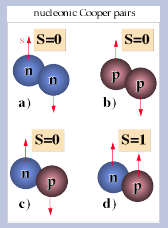


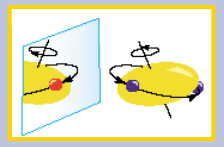


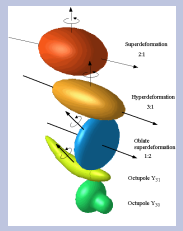
Physics cases for the AGATA campaign in GANIL

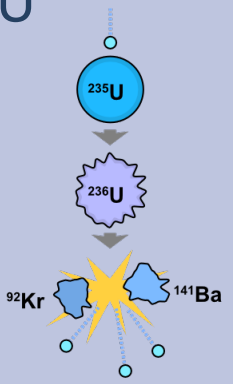


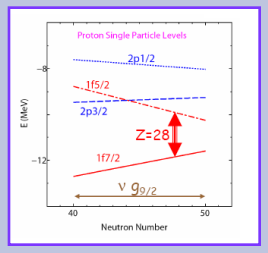


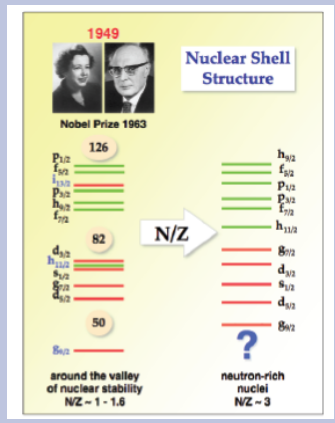






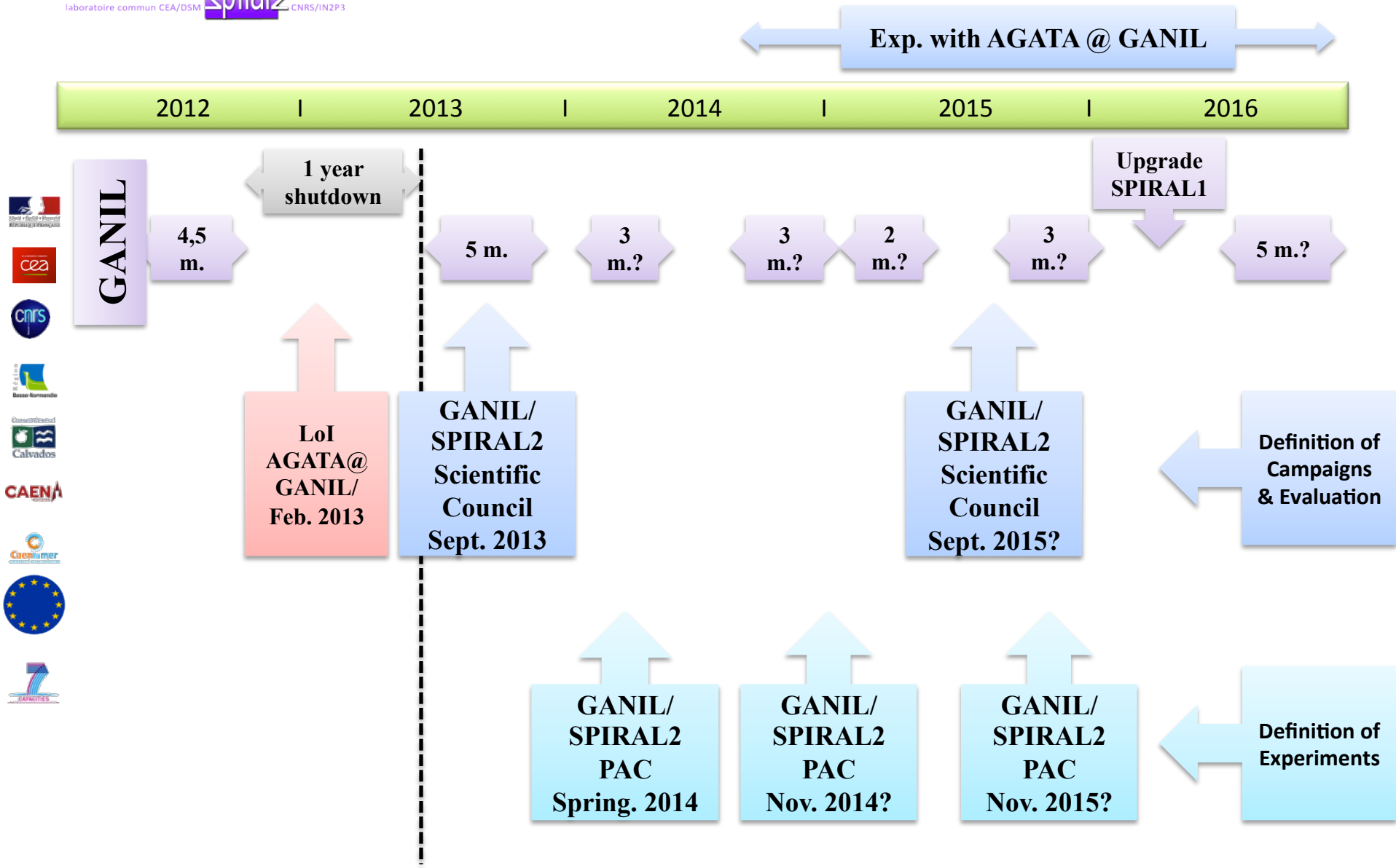






256Rf
254No
Cm,Bk
Cf,Es
238U
194Pb
176Hg
Sm,Pm
206Hg
102Sn
Dy,Er,Yb
100In
Ru, Pd
Xe,Te
80Zr
Zr, Mo
77Y
132In
75Sr
Zr, Sr
78Ni
80Zn
63Ge
68Ni,Fe,Co,Cu
46Ti
38K
46,48Ca
34Ar
S,Cl,Ar,K
Ne,Na

AGATA@GANIL Campaign



Conclusion

Great opportunities for an exciting physics program at GANIL/SPIRAL1/SPIRAL2 and with AGATA@GANIL in the end of ENSAR and during the future ENSAR 2

Beginning of operation of SPIRAL2 Phase 1 with NFS from the beginning of 2015 and S3 from the beginning of 2016

≥ 5 month/year of beam at GANIL cyclotrons in 2014-2016
Operation with upgraded SPIRAL1 with delivery of new radioactive beams from 2016

Commitment of GANIL to host of AGATA until end of 2016 with ≥ 6 months of beam = about 32+/-3 experiments
A possibility to extend the AGATA campaign to 2017

-> Increased request for TNA GANIL in ENSAR 2

TNA GANIL

after 32 months

TNA	Number of beam hours promised -full contract	Number of beam hours 01/09/2010 - 30/ 09/2012	Estimated number of Users - full contract	Number of Users 01/09/2010 - 30/ 09/2012	Estimated number of days - full contract	Number of days 01/09/2010 - 30/ 09/2012	Estimated number of projects - full contract	Number of projects 01/09/2010 - 30/ 09/2012	Total amount for T&S - full contract	Amount for T&S 01/09/2010 - 30/ 09/2012	Amount for other direct costs - full contract (AGATA)	Amount for other direct costs (AGATA) 01/09/2010 - 30/ 09/2012	Access costs - full contract	Access costs 01/09/2010 - 30/ 09/2012
GANIL	3500	3237	280	199	3200	2436	40	21	338 800€	191 500€	80 000€	0€	350 000€	323 700€

Search for Super-screening effect in superconductor

P. Ujic et al.

Collaboration CEA, CNRS, Serbia, Romania

An effect predicted a long time ago

MAY 15, 1936 PHYSICAL REVIEW page727 VOLUME 49

A Note on the Possible Effect of Screening in the Theory of Beta-Disintegration

M. E. Rose, *Institute for Advanced Study, Princeton, N. J.*

(Received March 23, 1936)

The present paper considers the possibility that screening by the atomic electrons has an appreciable effect on the energy distribution of β-particles emitted by heavy nuclei. A general formula is derived from which it is possible to conclude that the effect of screening is negligible. This result is also derived by another method. Finally, an explicit calculation based on the model of a charged sphere is shown to lead to the same conclusion.

Beta Decay theory

$$f(Z',Q)\ t = \frac{cte}{\left|M_{if}\right|^2}$$

Fermi function

The lifetime of a radioactive nucleus depends on the electron cloud and thus on its environment.

Predicted effect of a few %? but significant for some applications.

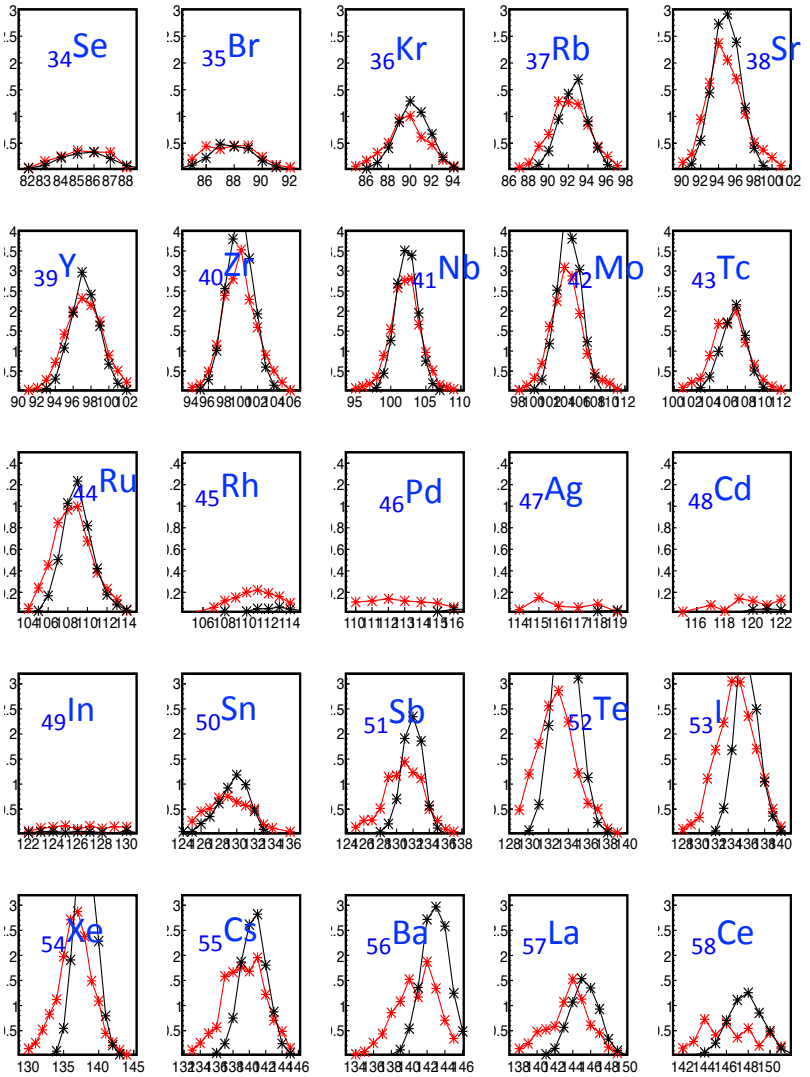
Super-screening predicted in a superconductor.

Possible consequences: **1) Waste disposal (shorter lifetime)**

2) Fundamental physics (as a systematic error)

3) Astrophysics (correction of the reaction rate)

Implications for SPIRAL2



The code of SPIRAL2 (GANPROD) is used to reproduce the data obtained VAMOS.

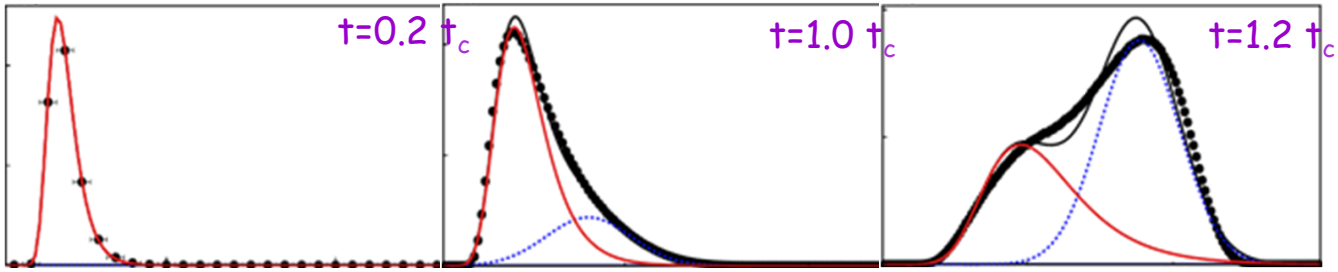
Significant differences emerged in the area of heavy fragments

M. Fadil, F. Farget
Work in progress

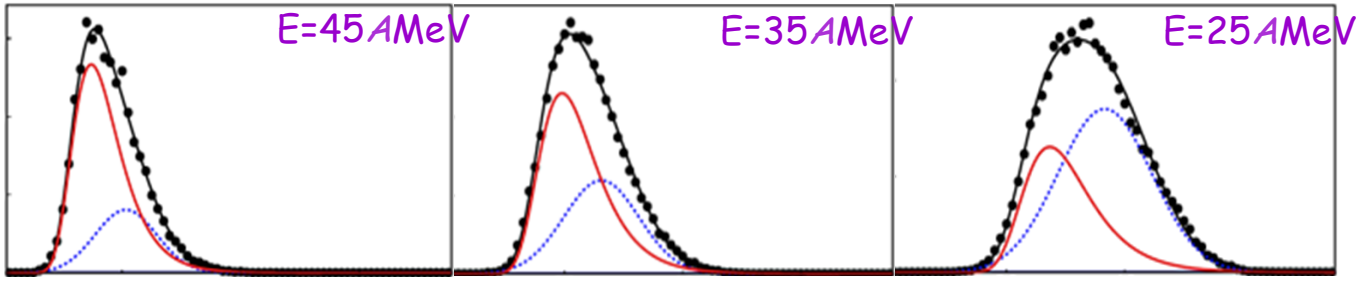
Multifragmentation : la distribution en charges comme horloge temporelle

D. Gruyer, J. Frankland et al., 172701 PRL 110 (2013)

Indra: 129Xe + Sn collisions - Observation of multiple nuclear fragments
Multifragmentation
What is its nature? First order transition?
Difficulty of identifying quantitative phase transition
Search for parameter order: the size of the largest fragment
Model used: aggregation from a "soup" of nucleons



La distribution de la taille du plus grand cluster évolue en fonction du temps



The distribution of the size of the largest charged fragment

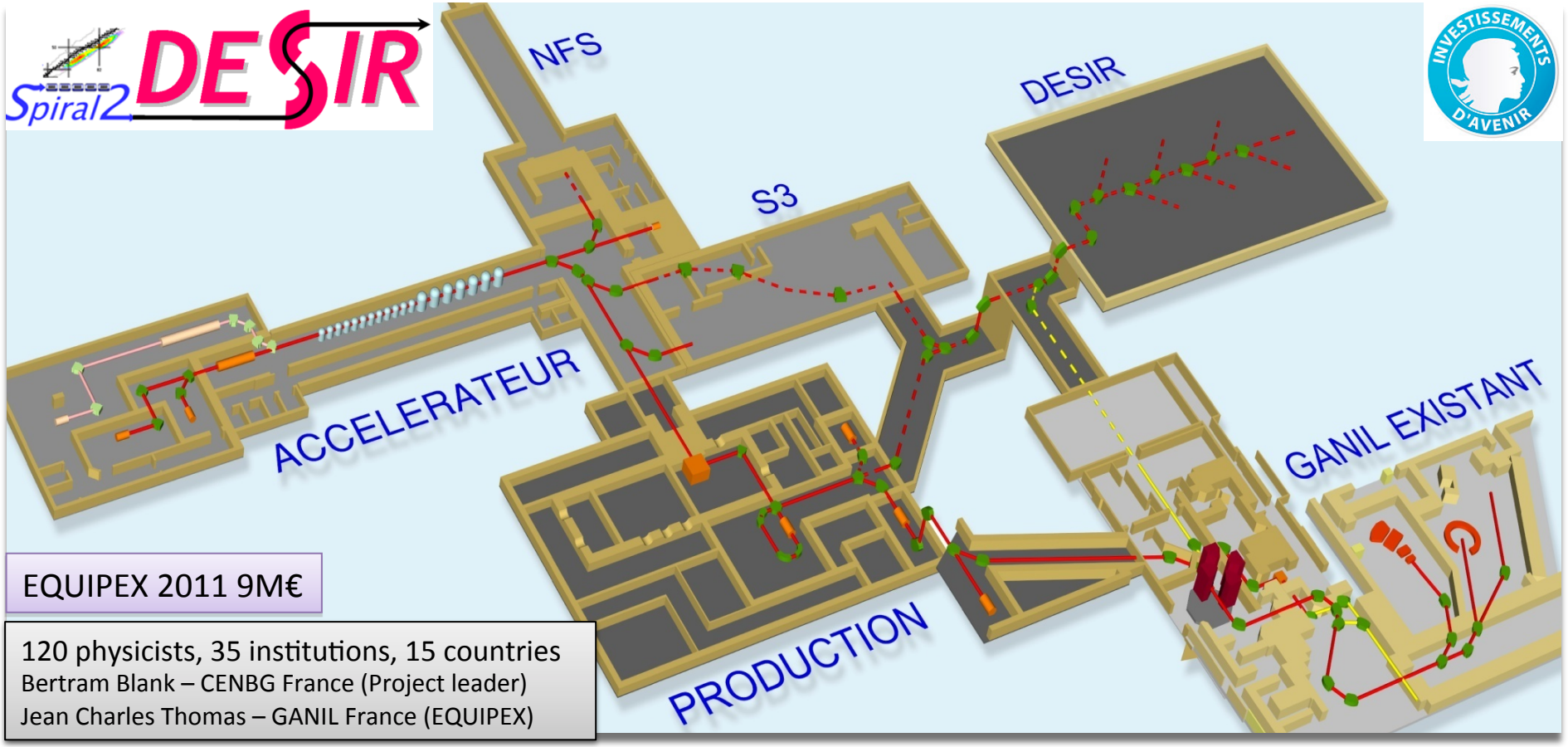
The similarities between the model and the data indicate that the time scale decreases with increasing bombardment energy

High-energy Beam Operation of the GANIL accelerators in 2012

- **Operation time: 2865 hours** *(4151 h)**
- **Beam time delivered: 4053 h** *(5204 h)*
  - High energy beams (CSS2): 2865 h *(3251 h)*
    - SPIRAL1/GANIL beam time sharing 31% *(17%)* / 69% *(83%)*
  - Beam development: 31 h *(164 h)*
- **Accelerated Beams**
  - Stable ion-beams: 22 *(36)*
  - RIB from SPIRAL: 4 *(1)* (^{14}O, ^{35}Ar, ^{24}Ne, ^{8}He)
- **Experiments: 34** *(46)*

** in italics numbers for 2011*

The DESIR facility at SPIRAL2

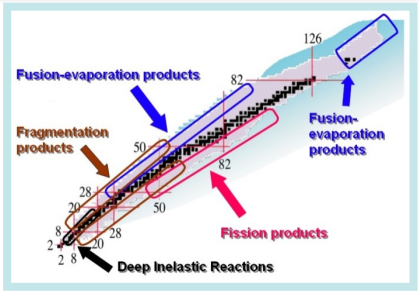


EQUIPEX 2011 9M€

120 physicists, 35 institutions, 15 countries
Bertram Blank – CENBG France (Project leader)
Jean Charles Thomas – GANIL France (EQUIPEX)

High quality 1+ RIB of 10 to 60 kV from:

- **SPIRAL1** (light n-deficient nuclei from beam/target fragmentation)
- **SPIRAL2** (n-rich fission fragments, transfer and fusion-evaporation products)
- **S3** (fusion-evaporation products, refractory elements)



First experiment mid 2018

DESIR experimental hall & associated detectors

DECA Agreement

DECA collaboration
14 owners of equipments
Commitment: ~5 M€
50% from EU partners