Present and future at GANIL

Héloïse Goutte
GANIL CEA/DSM-CNRS/IN2P3, Caen, France

On behalf of all my GANIL colleagues

Outline

- Statistics of the GANIL facility for 2010
- A few examples of physics studies and results @ GANIL
- Technical developments
- The SPIRAL2 project
- GANIL/SPIRAL1/SPIRAL2Timeline

Statistics of the GANIL facility for 2010

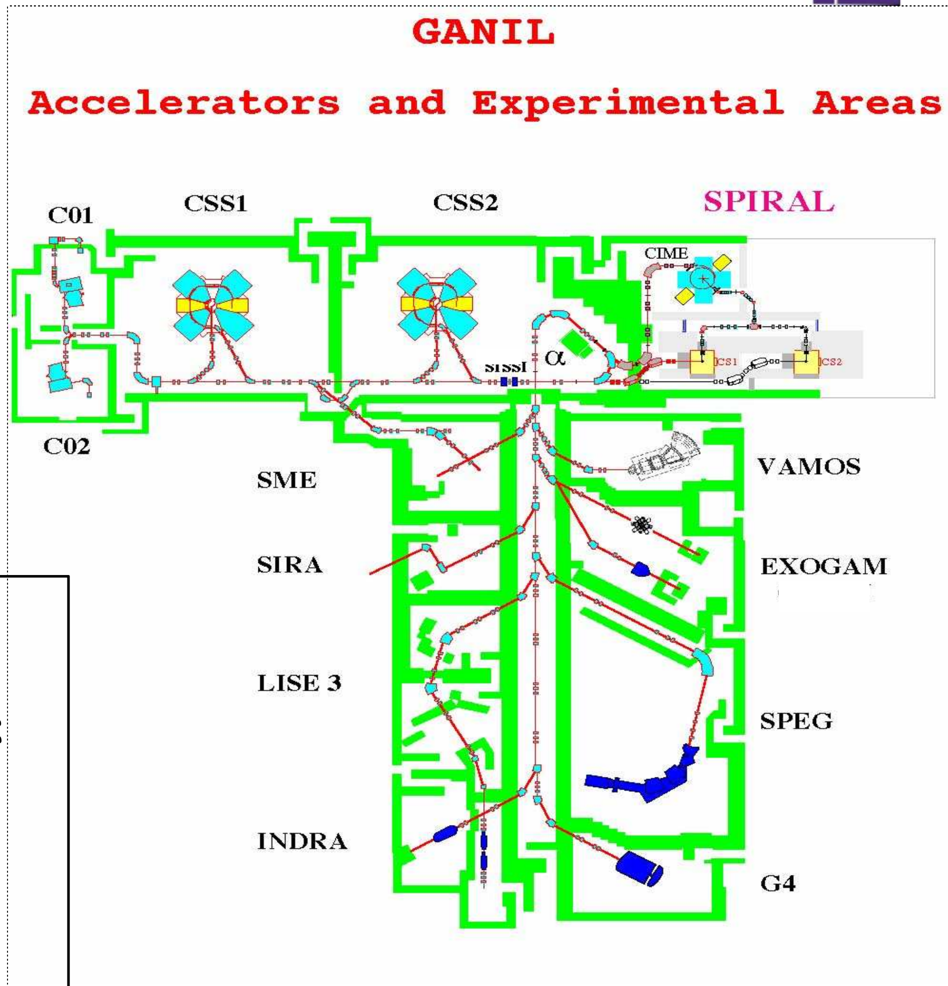
STABLE BEAMS

- from C to U
- energies up to 95 A.MeV
- intensities up to 2.10^{13} pps (6 kW)

RIB production schemes

- in-flight method : LISE
- ISOL method : SPIRAL

-high energy beams (pilot beam) (4-95 Mev/u) ,
-lowest energy beams are also delivered:
-medium (SME 4-10 MeV),
-low (IRRSUD 0.4-1 MeV)
- and very low (ARIBE a few keV) energy.



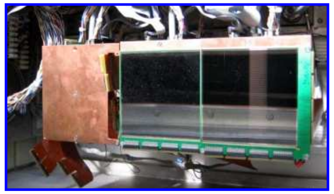
Up to 10000 hours of stable and radioactive beams per year (3-4 exp. simult.)

600 users/year (40% outside of France)
Staff 250 (10% physicists)

GANIL spectrometers and detectors

VAMOS

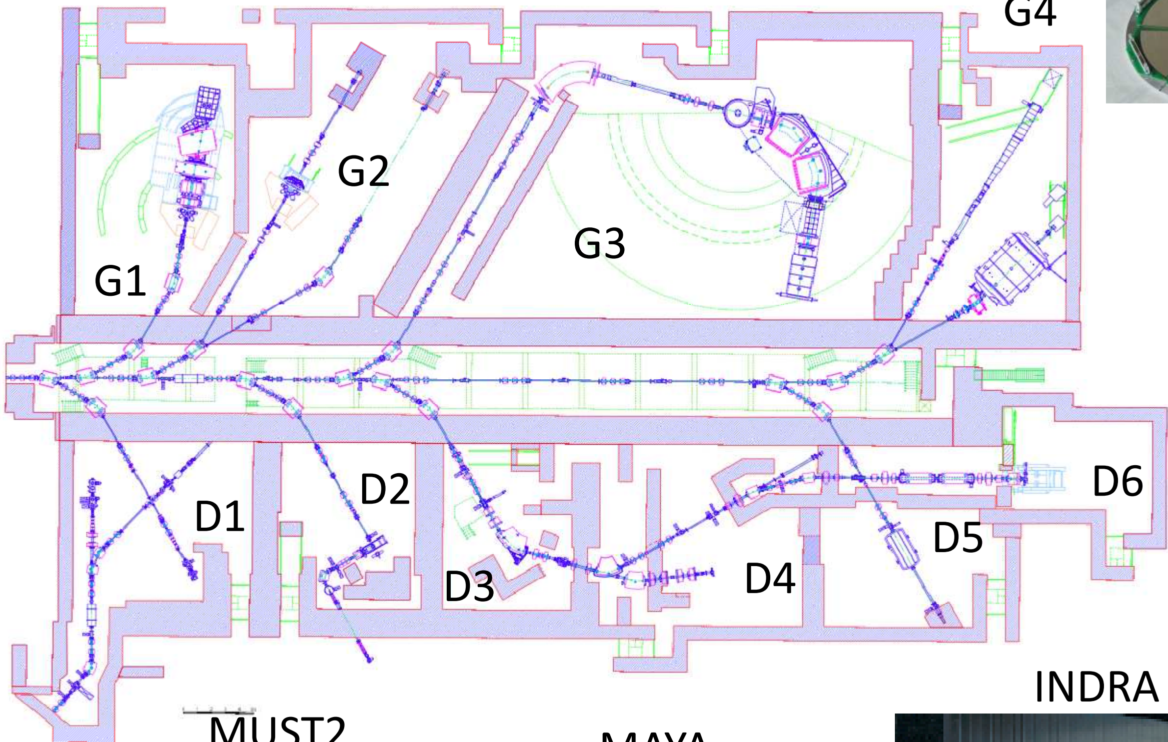
MUSETTE



TIARA

SPEG

EXOGAM2
EXOGAM & n-wall

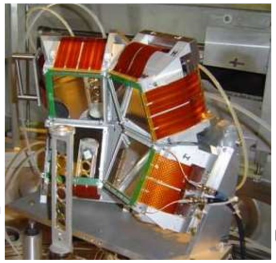


LISE 3

DIAMANT

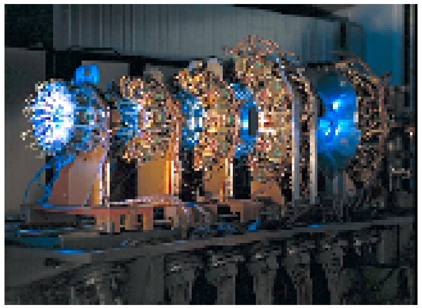
PLUNGER

MUST2

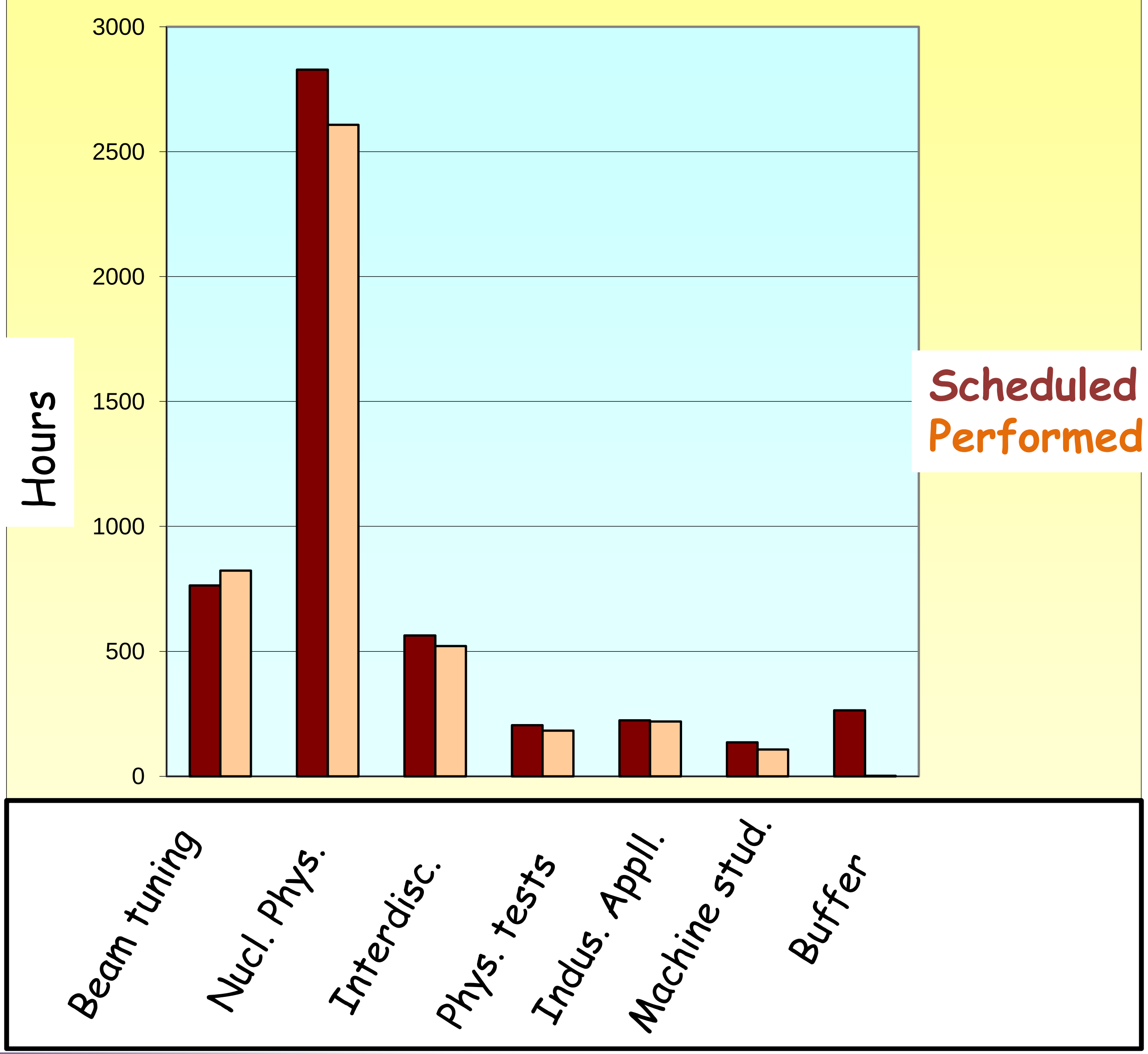


MAYA

INDRA



Statistics of the pilot beam for 2010 (as of Nov 29th)



From F. Chautard (SDA)

Physics studies and results @ GANIL

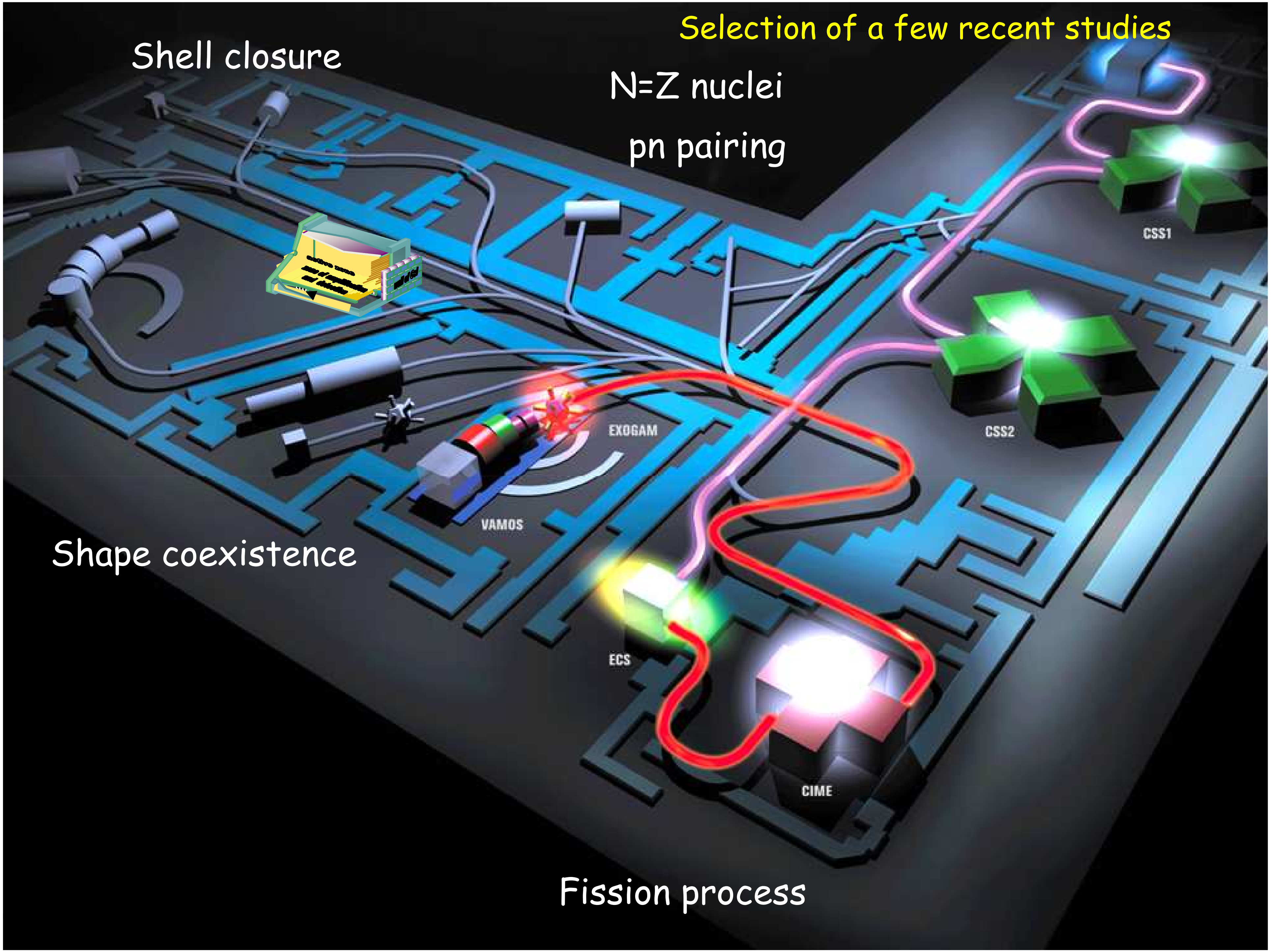
GANIL Physics cases

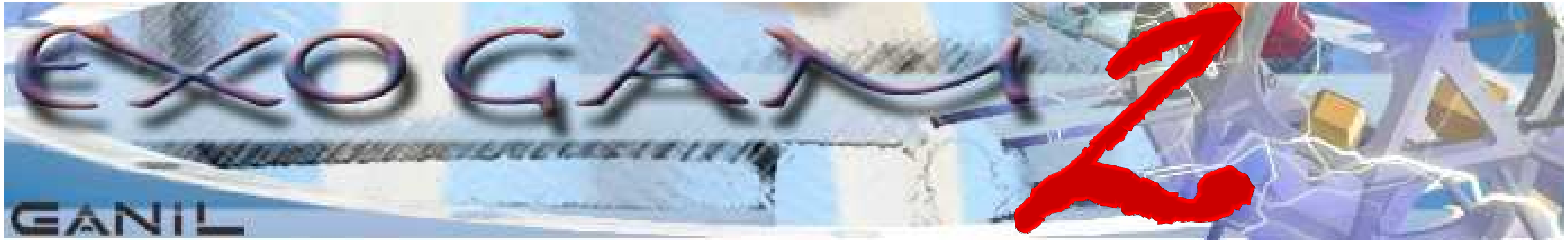
- Nuclear structure of stable and exotic nuclei
  - Ground state properties (existence, mass, deformation, spin …)
  - Excited states (energy, collectivity, *g*-factor …)
    - Single particle states
    - Shape isomers
  - Clustering
  - Loosely bound and unbound nuclei

- Astrophysics

- Fission reactions
- Lifetimes of SHE
- Fusion reaction
- Break-up
- Hot nuclei and nuclear matter; multifragmentation

- …

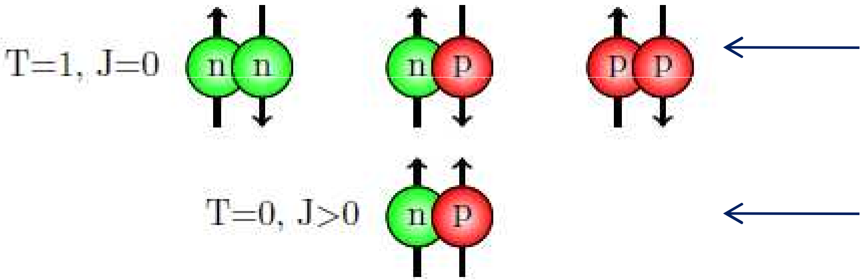

Selection of a few recent studies
Shell closure
N=Z nuclei
pn pairing
CSS1
EXOGAM
CSS2
VAMOS
Shape coexistence
ECS
CIME
Fission process



Study of the N=Z nucleus : ^{92}Pd

B. Cederwall et al. Nature, in press

New spin-aligned pairing phase in atomic nuclei inferred from the structure of ^{92}Pd



dominant up to mass 80

Predicted to play a major role as the mass increases

Difficult to prove because of very low cross section + problem of identification

Difficulties overcome through state-of-the-art apparatus with good detection efficiencies

+

Prolonged experimental running period

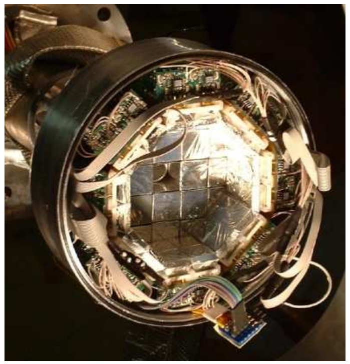
Heavy -ion fusion-evaporation reaction: ^{36}Ar ions on a ^{58}Ni target

EXOGAM-NWall-DIAMANT:

The power of the coupling

EXOGAM: 11 Clovers with partial shield.
$\varepsilon_p\omega \sim 10\%$ for E_γ=1.3 MeV

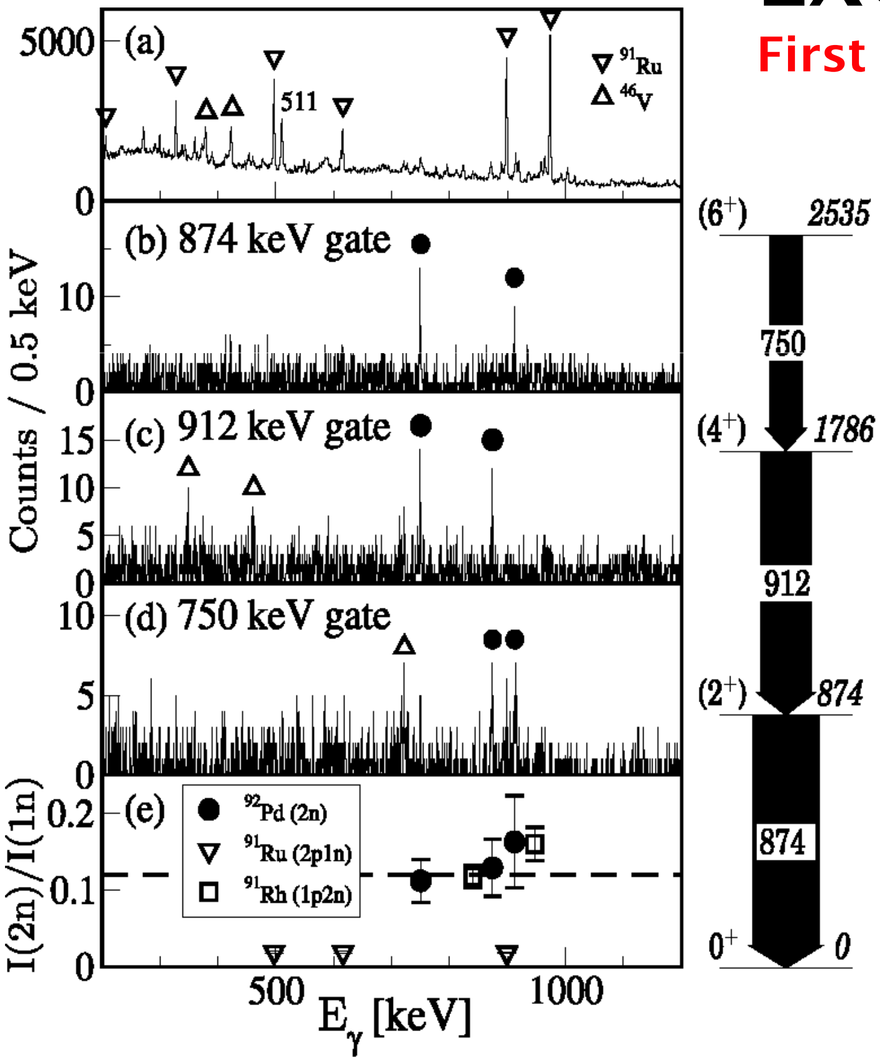
DIAMANT: 80 CsI(Tl) dets.
$e_{p \text{ or } \alpha} \sim 66\%$



The Neutron Wall: 50 liquid scintillator detectors. $e_{1n} \sim 23\%$

EXOGAM:

First identification of γ-rays in ^{92}Pd



- Three γ-rays firmly identified
- In coincidence with 2n
- Not in coincidence with charged particles
- Mutually coincident
- All possible contaminants excluded

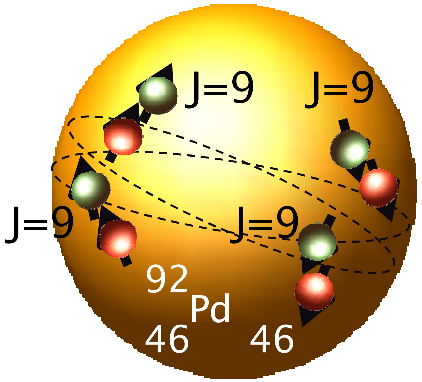
➔ Unambiguously assigned to ^{92}Pd

Production cross section ~ 0.5 mb

B Cederwall, F. Ghazi-Moradi, T Back, A Johnson, J. Blomqvist, E Clément, G. de France, R Wadsworth et al,

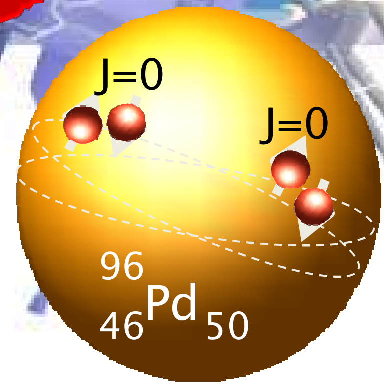
Nature, accepted for publication (2010)

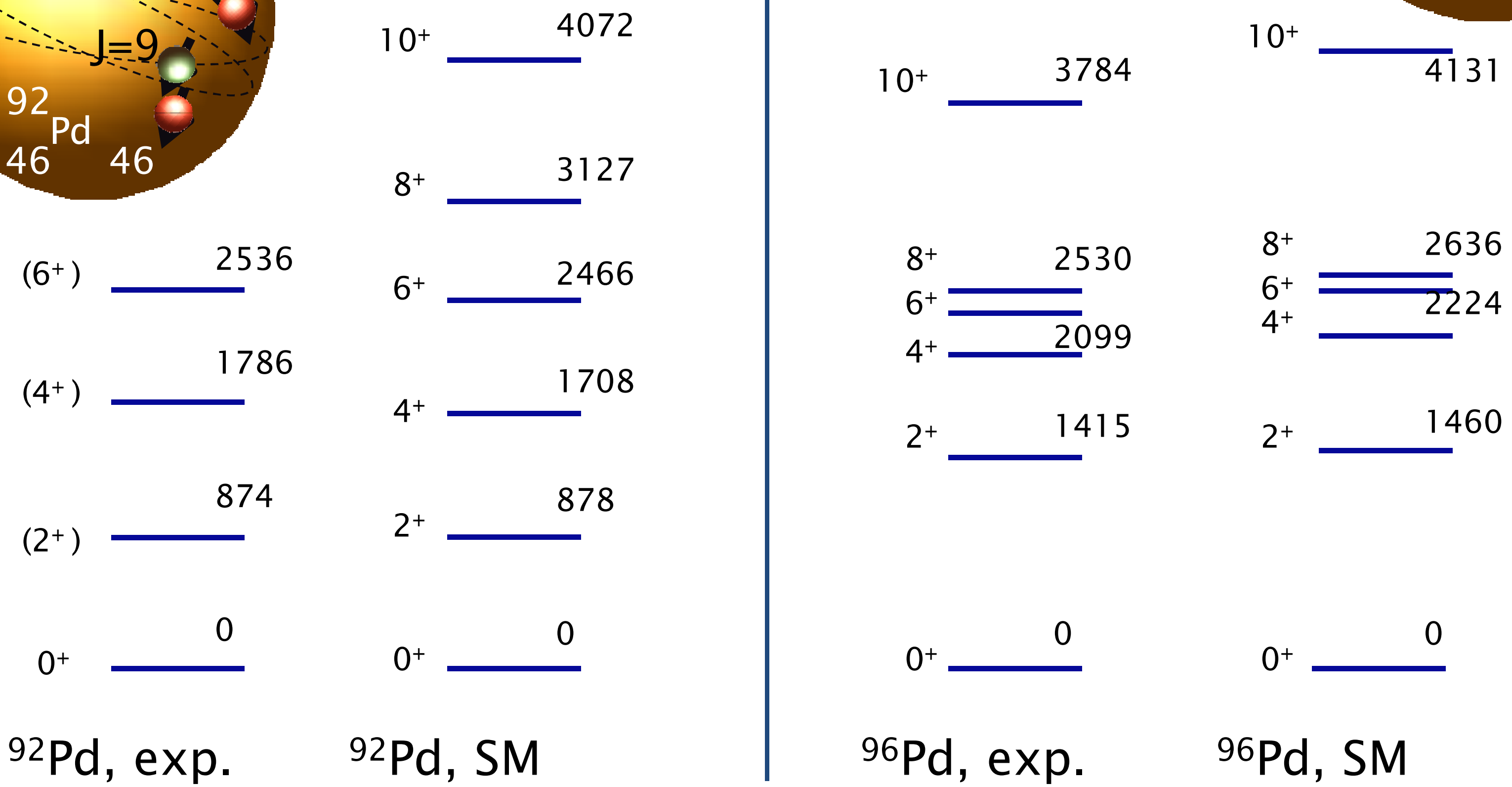
^{92}Pd: a new spin aligned np coupling scheme



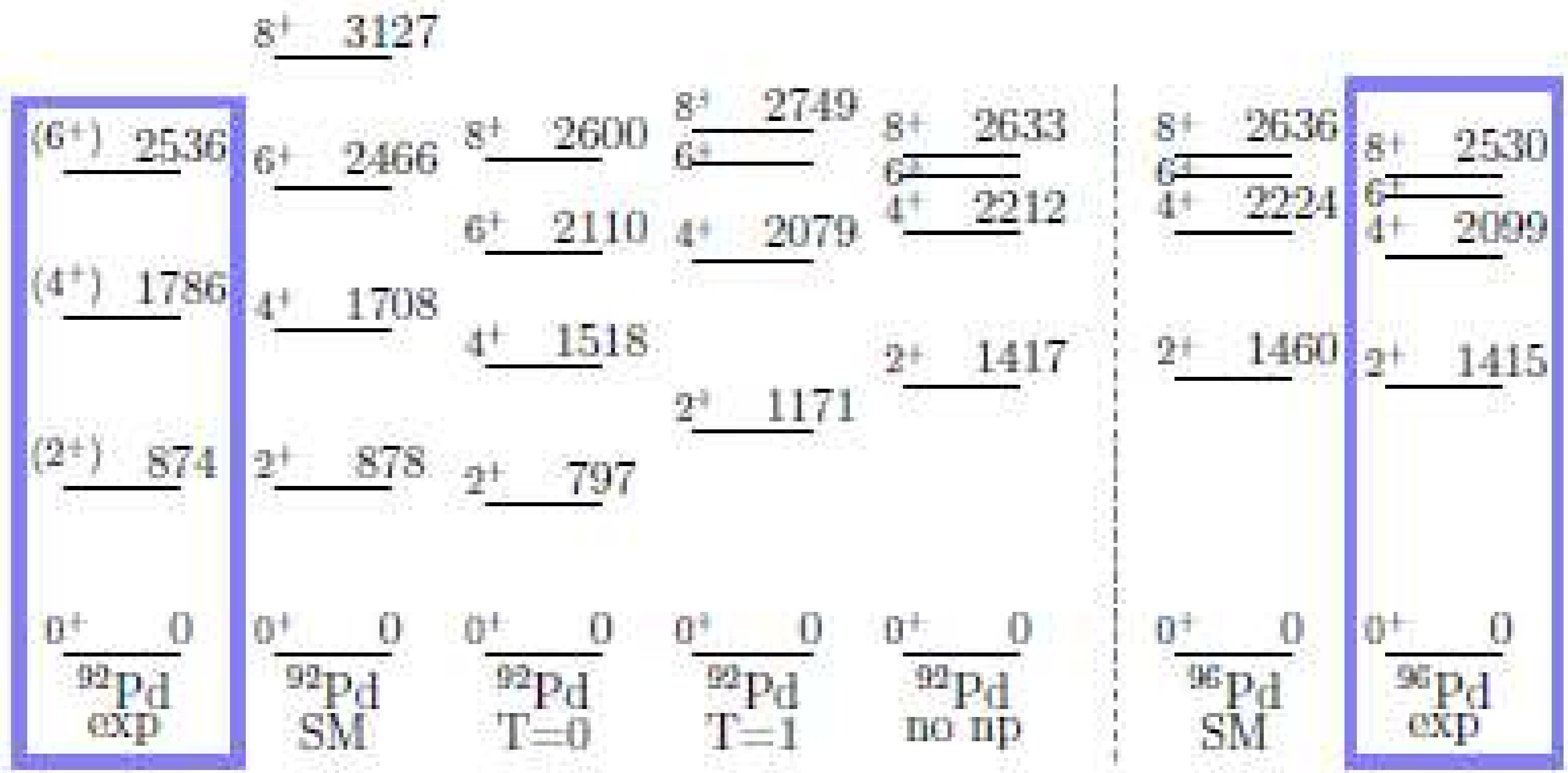
Spin-aligned pairing phase

Normal, anti-aligned pairing phase





Comparison with shell model calculations



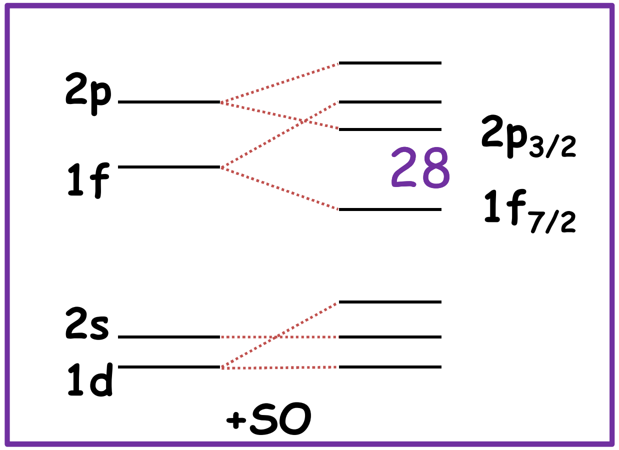
What's next ?

- what about deformation ?
    - measurement B(0+→ 2+) value using Coulomb excitation

- … other studies to elucidate the structural evolution of nuclei approaching 100Sn

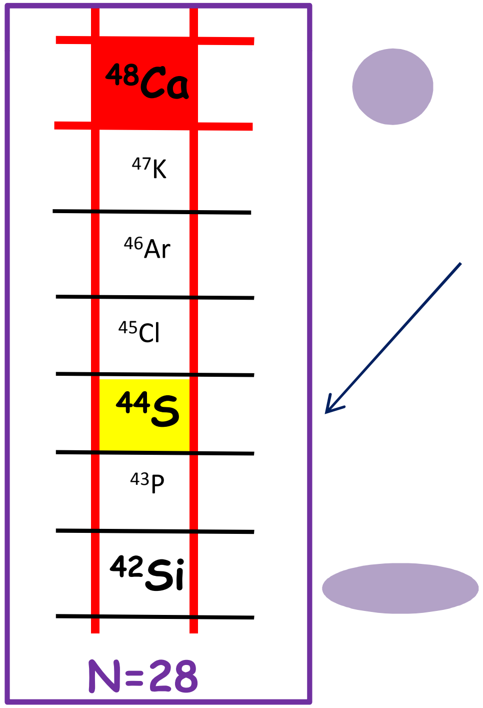
Prolate-Spherical Shape Coexistence at N=28 in ^{44}S

C. Force et al. , Phys. Rev. Let. 105, 102501 (2010)



Magic nuclei : → spherical

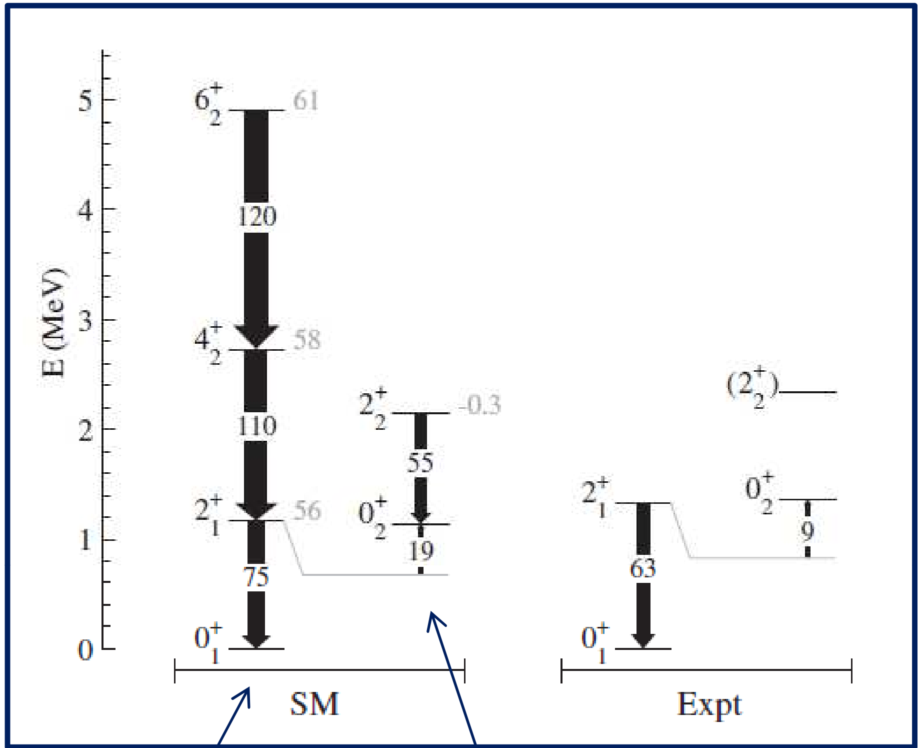
Magic nuclei due to SO gap:→ vulnerable to quadrupole excitations



Competition between ● and ⬬ expected

Study of ^{44}S using delayed γ and e^- spectroscopy

Prolate-Spherical Shape Coexistence at N=28 in ^{44}S



Rotational band
($\beta = 0.25$)

« Spherical » isomer

Exp results:

$E(0^+_2) = 1365$ (1) keV

$B(E2;\ 2^+_1 \rightarrow 0^+_2) = 8.4(26)\ e^2fm^4$

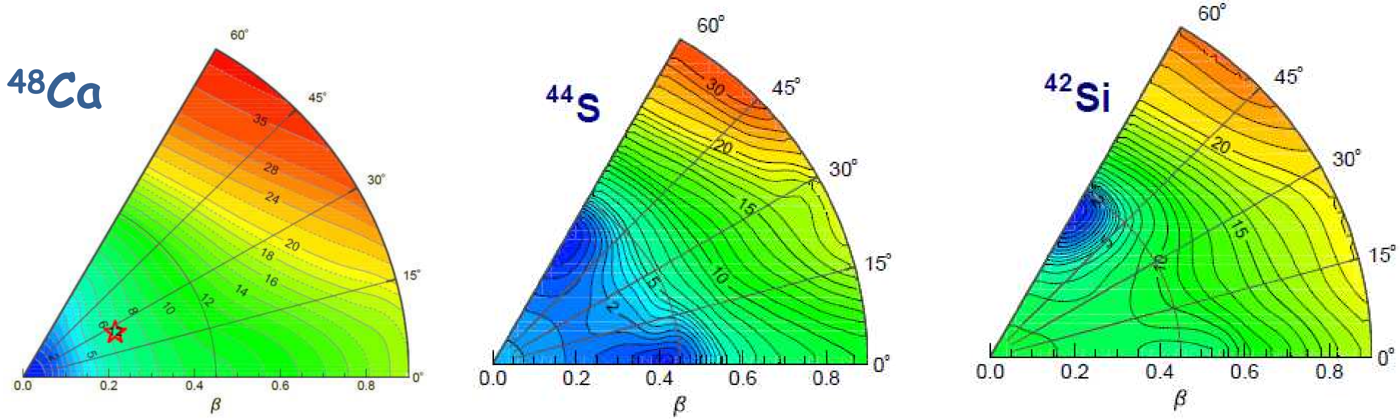
$\rho^2(E0;0^+_2 \rightarrow 0^+_1) = 8.7(7)\ 10^{-3}$

→Very small !!

→ No mixing between 0^+_1 and 0^+_2

→ shape isomer

Comparaisons with shell model calculations F. Nowacki



→ Rather poor agreement with results from mean-field based approaches. Generator Coordinate Method (GCM) , collective Hamiltonian

→ General feature of 0_2^+ states of collective approaches
J.P. Delaroche et al., Phys. Rev. C 81 014 303 (2010)

→ Introduction of the coupling between collective modes and individual excitations

Towards a microscopic derivation of a non adiabatic Schrodinger equation

PhD work of R. Bernard (CEA Bruyères)

Nuclear state

$$\left|\Psi(t)\right\rangle = \sum_i \int dq\, f_i(\{q\},t)\left|\Phi_i(\{q\})\right\rangle,$$

i= intrinsic excitations

q=collective coordinate

Generalized Hill-Wheeler equation

$$\sum_i \int dq \left(\left\langle \Phi_j(q')\right|\hat{H}\left|\Phi_i(q)\right\rangle - i\hbar \frac{\partial}{\partial t}\left\langle \Phi_j(q') \middle| \Phi_i(q)\right\rangle\right) f_i(q,t) = 0.$$

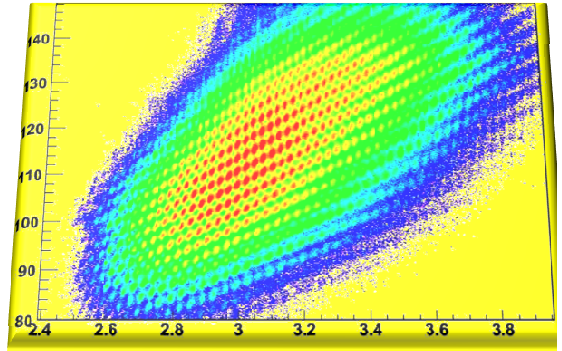
The same approach would be also very useful to describe reaction mechanism in particular the fission process, where single particle excitations are predicted to play an important role.

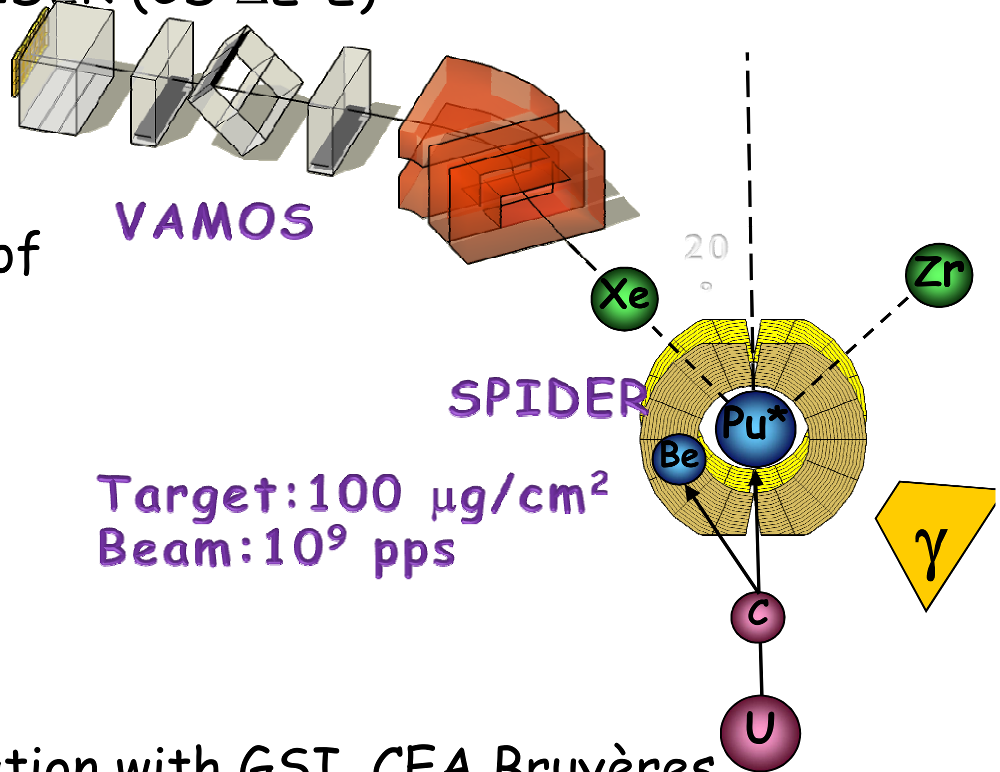
Collaboration: CEA Bruyères, GANIL, Livermore

Study of Fission of Actinides

Fission induced by transfer reactions

- Inverse kinematics (U+C)
- Fission fragments identified in VAMOS
- Light particles identified in SPIDER (CD ΔE-E)

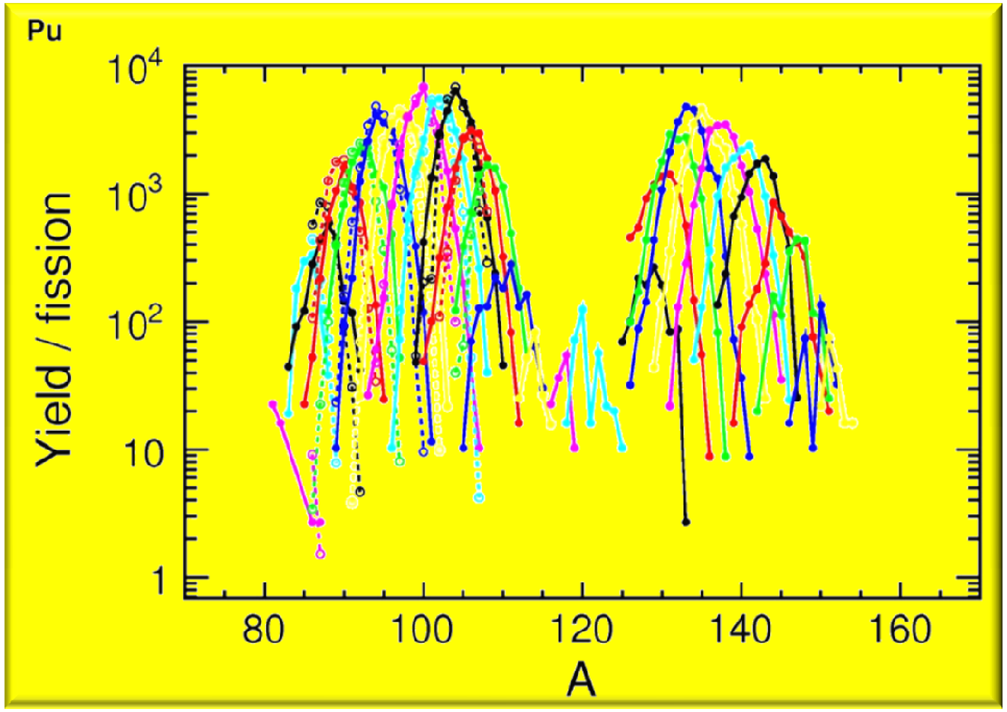




- Complete isotopic distributions of fission fragments
- Different fissioning systems
- Controlled excitation energy

Lead by Fanny Rejmund, in collaboration with GSI, CEA Bruyères, IK TU, IPNO, CENBG, Univ. Santiago de Compostella

Results: theoretical and experimental improvements

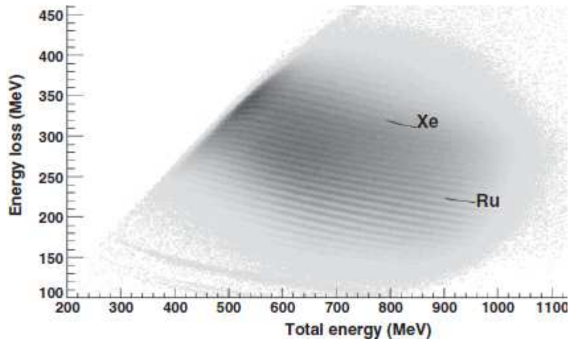


F. Rejmund et al

W. Younes (Livermore, US) in coll. with GANIL and CEA Bruyères

+ Prompt γ-ray spectroscopy of isotopically identified fission fragments
A. Shrivastava et al., Phys. Rev. C 80 051305(R) (2009)

Examples of technical developments of the existing GANIL



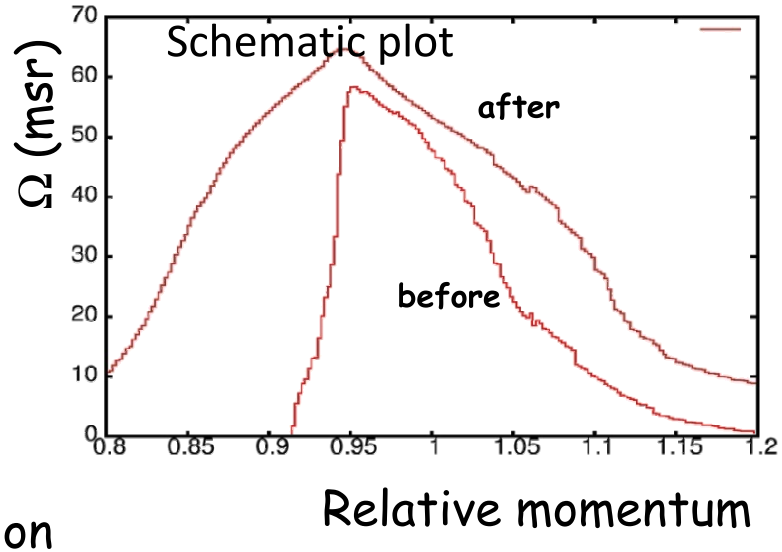
Upgrade of VAMOS

Characterization of the large acceptance spectrometer

NIMA 593 343 2008

Proof of gas-filled operation mode @ VAMOS zero degree operation with high-intensity beams

NIM A 621 558 2010

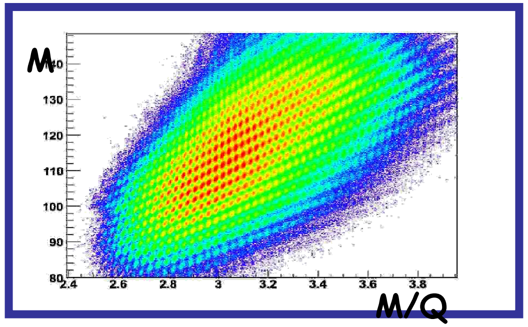


Upgrade of the detection system (2008-2011)

Dispersion-independent large acceptance

Doubling momentum acceptance

(Doubling detector size), trajectory reconstruction



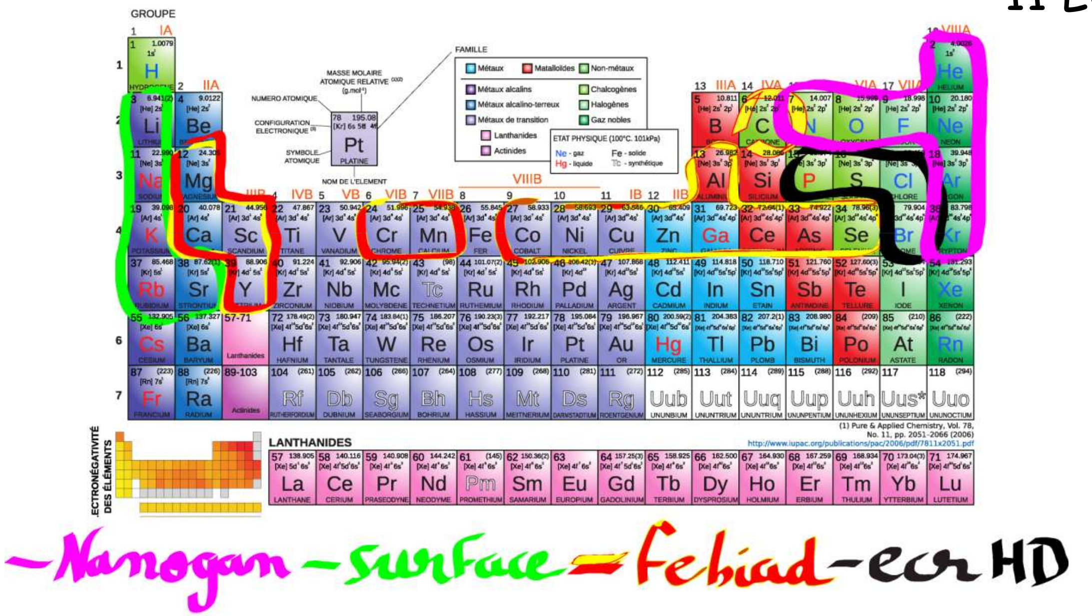
Better resolution in mass Adding a MWPPAC start detector ($\Delta M/M$ ~1/170 to <1/250)

SPIRAL 1 upgrade

laboratoire commun CEA/DSM CNRS/IN2P3

Extending the range of SPIRAL 1 capabilities
1+ N+ with more universal sources

Developments based on a global call
11 LOI March 2010 meeting of the PAC



FEBIAD as first priority

Already existing beams
$^{19}Ne^{1+}$, $^{35}Ar^{1+}$

Modifying the target configuration
^{118}Xe, ^{120}Xe, ^{15}C

Alkali beams
$^{8}Li^{1+}$, $^{21}Na^{1+}$, $^{37}K^{1+}$, ^{38}K

Metallic beams
$^{25}Al^{1+}$, ^{28}Mg, $^{39}Ca^{1+}$, $^{41}Sc^{1+}$, ^{68}Se

Non metallic beams
$^{29}P^{(1+/n+)}$, ^{30}P, $^{31}S^{1+}$, $^{33}Cl^{(1+/n+)}$

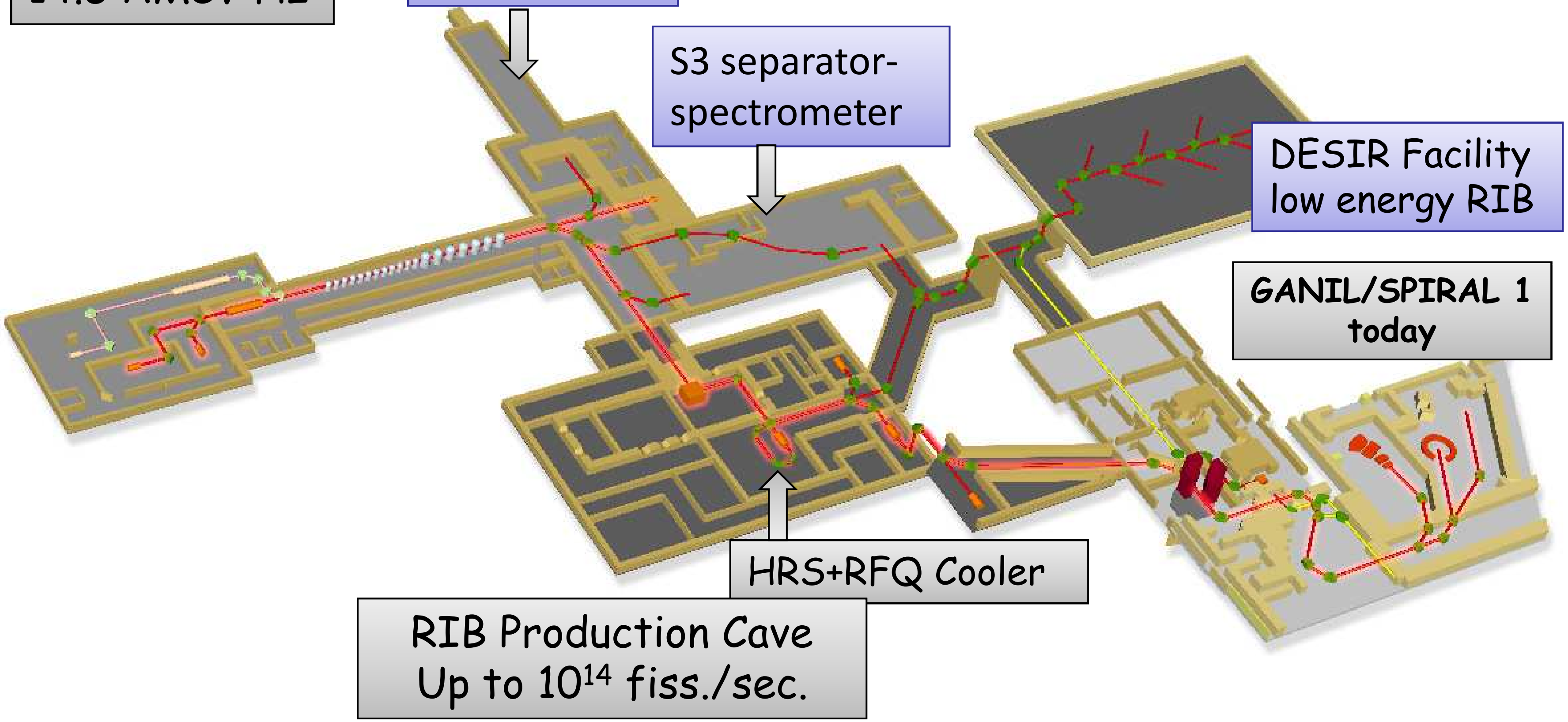
Mid 2012: 1^{+} beams
Mid 2013: Post-accelerated beams

The SPIRAL2 project

GANIL/SPIRAL1/SPIRAL2 facility

GANIL Beam time: 35 weeks/y (600users)
SP2 Beam time: 44 weeks/y
ISOL RIB Beams: up to 53 weeks/y
Up to 50 % more users: 800-900
First experiments 2013

LINAC:
33MeV p
40 MeV d
14.5 AMeV HI



2 RIB + 3 Stable-ion beams (ARIBE, IRRSUD, SME) **-> 5 experiments in parallel**


136 M€
2006-2012
Construction in 2 Phases
IN2P3
Phase 2 2014
RIB production Building
& DESIR
Phase 1 Fall 2012
Accelerator & S3, NFS
GANIL
Civil construction: 2010 – 2012
Phase 1 permit granted
11Oct 2010
Investment (with 10% contingencies): 136 M€
CNRS, CEA, Local Region
Total cost: 196 M€ (136+60 Manpower)
In the investment budget 26M€ are expected to come from EU and international partners

Super Separator Spectrometer

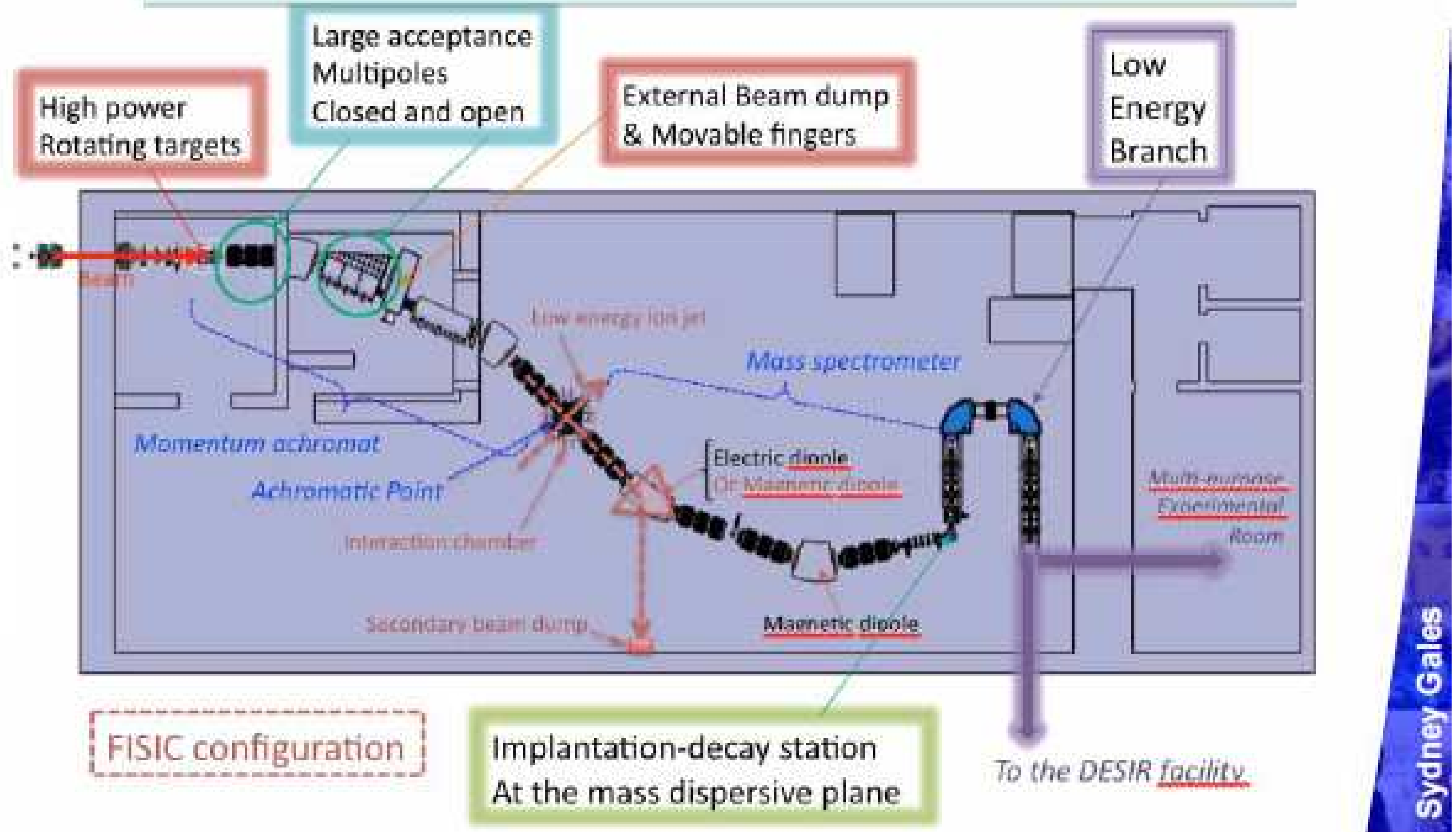
104 physicists, 30 institutions, 12 countries

Spokespersons:

Hervé SAVAJOLS – GANIL, France

Antoine DROUART – Irfu/SPhN (CEA), France

Jerry A. NOLEN – Argonne National Laboratory, USA



Sydney Gales

S3 LoI Physics objectives

Proton Dripline & N=Z nuclei

LoI_Day1_6, LoI_Day1_8, LoI_Day1_9
LoI_Day1_11, LoI_Day1_17

- Single-Particle structure
- Development of Collectivity
- Shape coexistence

LoI_Day1_3, LoI_Day1_4, LoI_Day1_18

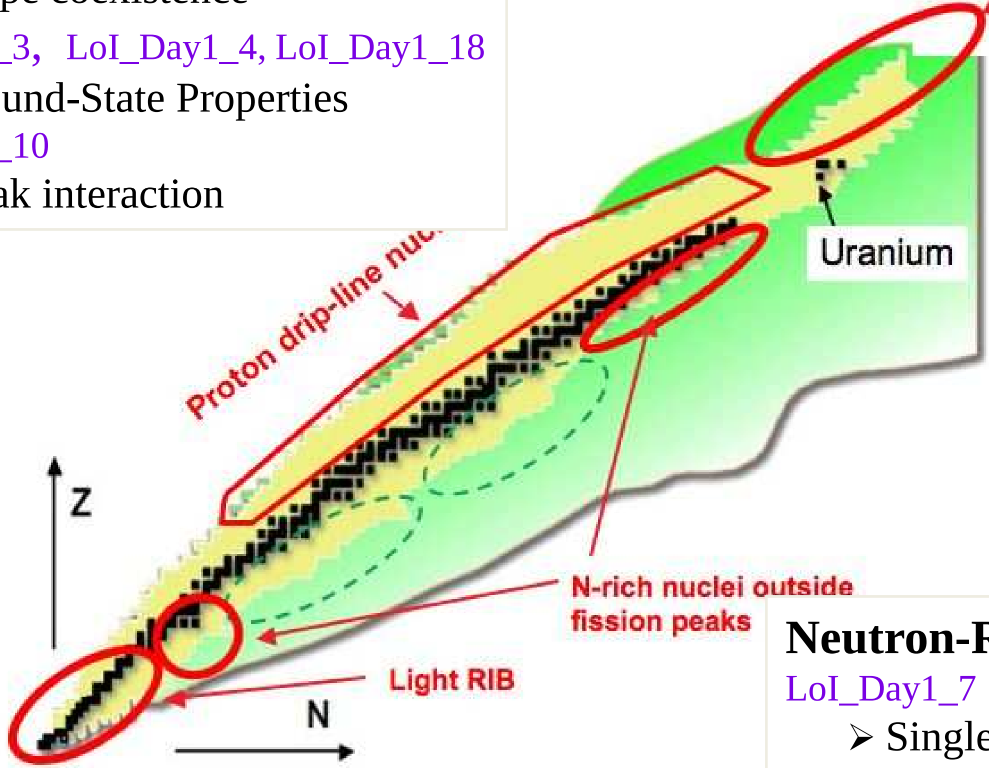
- Ground-State Properties

LoI_Day1_10

- Weak interaction

FISIC project

LoI_Day1_1



Heavy and Superheavy Elements

LoI_Day1_2

- Synthesis
- Spectroscopy and Structure

LoI_Day1_5

- Ground-State Properties

Neutron-Rich Nuclei

LoI_Day1_7

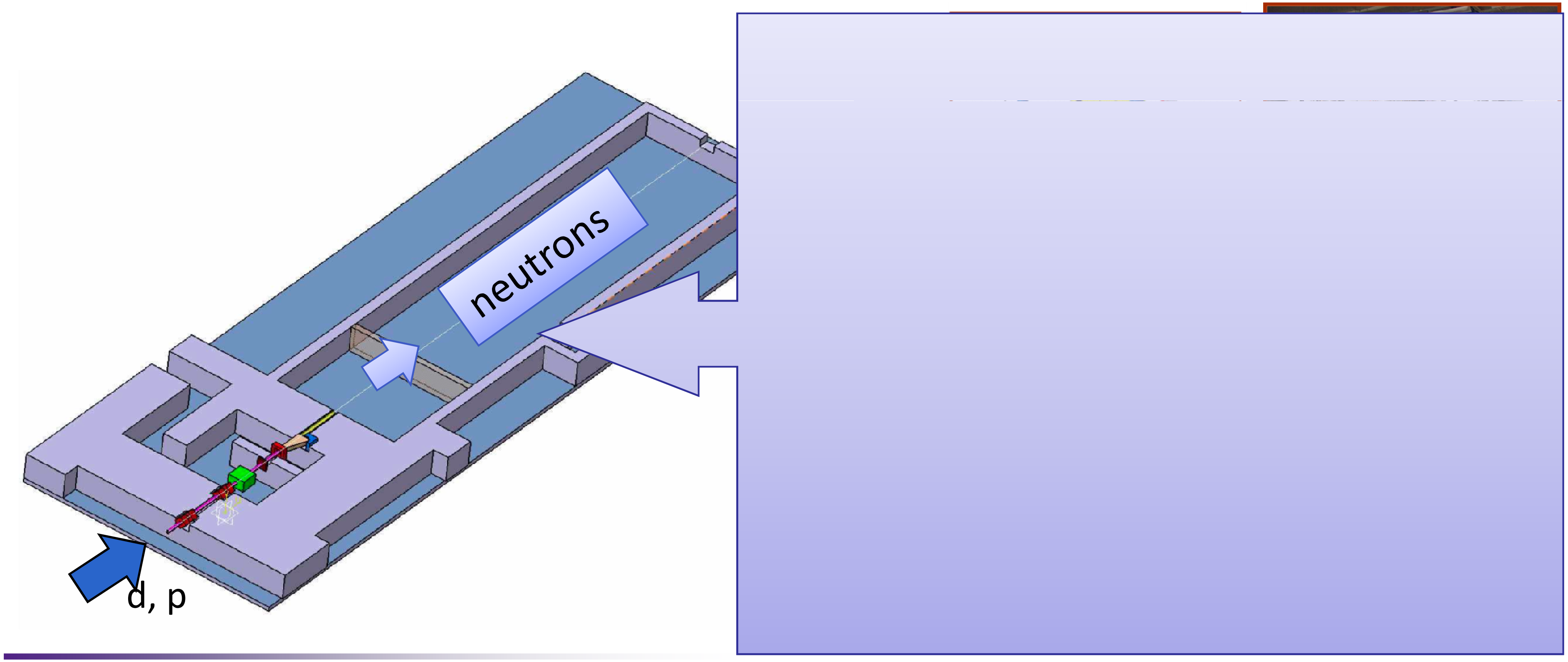
- Single-Particle structure
- Quenching of Shell Gaps

- 13 LoIs submitted
- LoIs signed by 170 physicists
- Requested beam time : 380 days !!!

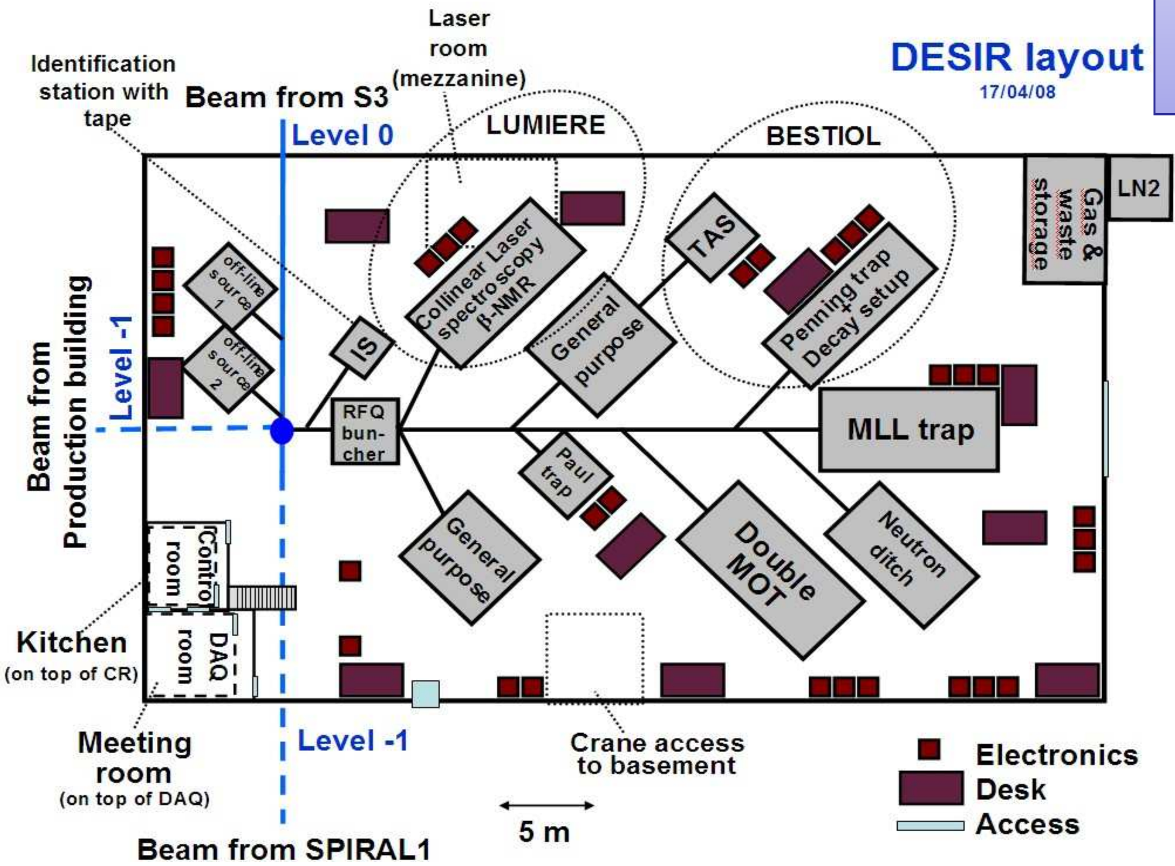
Neutrons For Science (NFS) ; LoI Physics objectives

- **Fission fragment distributions** (yields, and angular distributions) and **neutron emission** LoI_Day1_12, LoI_Day1_15

- **Cross section measurements** ((n,xn), p and d activation) LoI_Day1_13, LoI_Day1_14, LoI_Day1_16



DESIR Facility



Topics:

- nuclear fine structure
- charge radii & moments
- masses, ion-purification
- weak interaction studies

Tools:

- keV RI Beams
- decay spectroscopy
- laser spectroscopy
- ion / atom trapping

DESIR time-line:

- design: 2007 - 2010
- construction: 2012-13
- commissioning: 2014-15

A large-scale project related to nuclear structure and dynamics like SPIRAL2 requires a large-scale theoretical support.

Day1
Experiment and Theory
@SPIRAL2

discussion and exchange between theory and experimental groups toward joint efforts for the preparation, future analysis and interpretation of results of the day-one experiments.

two-day's meeting on June 24 and June 25 2010at GANIL
at the occasion of the SAC meeting which evaluates the LoIs for day-one SPIRAL2 Phase1 experiments.

FUSTIPEN
French –U.S. Theory Institute for Physics with Exotic Nuclei

FUSTIPEN Inauguration
and
First FUSTIPEN Workshop
« Bridging the Atlantic with Exotic Isotope Physics »

January, 18-19, 2011, GANIL, Caen, France

-to bring together scientists from both sides of the Atlantic with common interests in the physics of exotic nuclei.

GANIL/SPIRAL1/SPIRAL2 Timeline

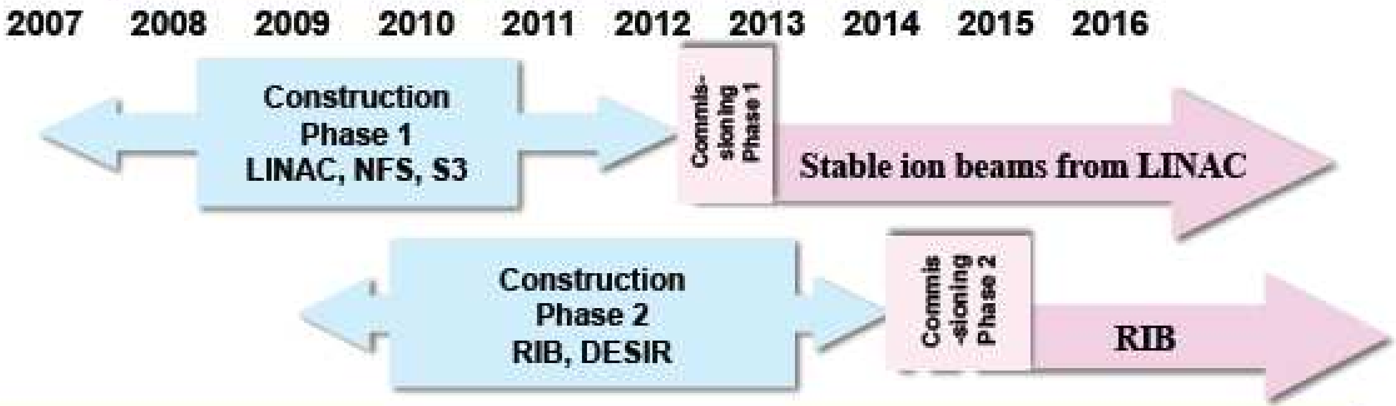
Existing GANIL

2011: 3 periods of running (*~4113 hours*):

March 18	–	May 15	run 1
May 23	-	July 27	run 2
August 29	–	October 16	run3

2012 : running during 1/3 of the year is forecasted

SPIRAL 2 timeline



M. Lewitowicz 30/11/10

Safety Aspects Construction

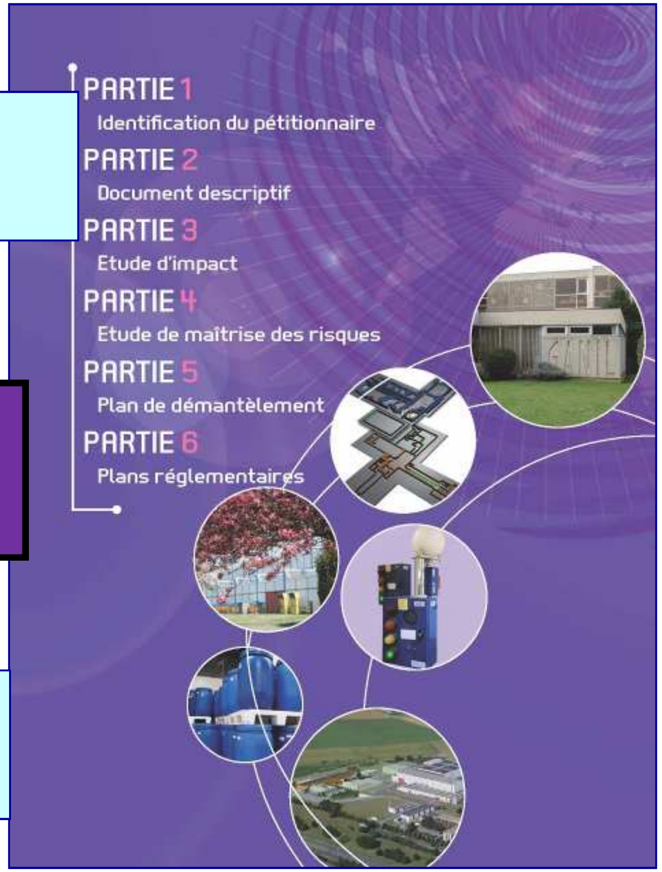
April 2009 :
Safety files sent to authorities

July 2009 :
Construction permit Phase 1 requested

From 14th June to 15th July 2010
Public enquiry

11th October 2010
Permit of construction delivered

Beginning of 2011
Site preparation – Ground breaking



Thanks for your attention !!!