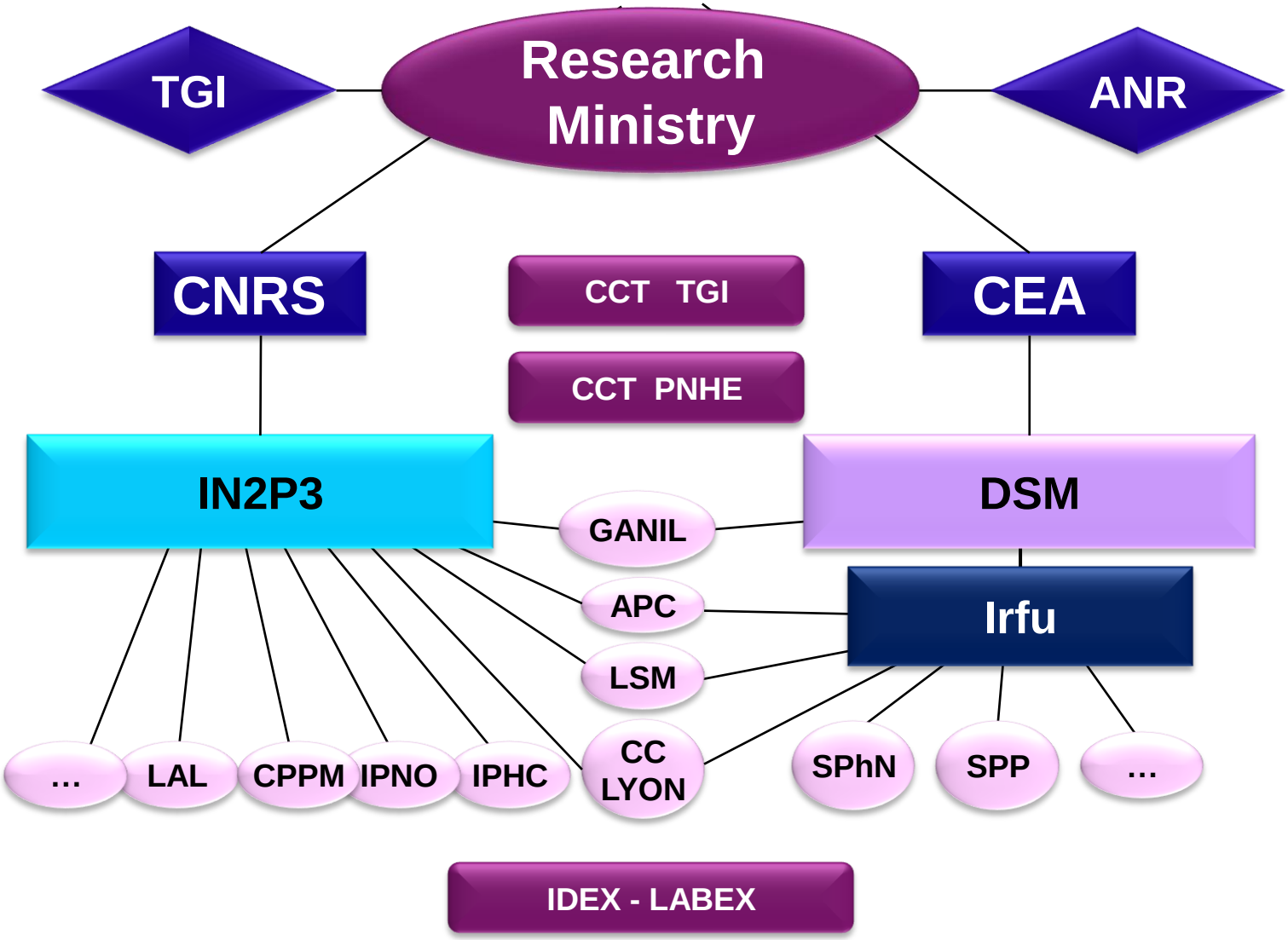
# Irfu 2020 Plan
## 2008-2013 Report

# FRENCH ORGANIZATION
# EX: NUCLEAR AND PARTICLE PHYSICS



- **Irfu: LARGE CEA INSTITUTE CREATED IN 1993: RESEARCH AND TECHNOLOGY**

- **EXPLORING THE FUNDAMENTAL LAWS OF UNIVERSE – EMPHASIS ON NΦ (OF THE NUCLEUS)**

  **GANIL – SPIRAL2**

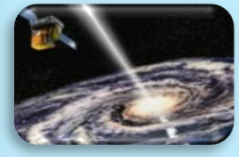
  **SPHN (GANIL, GSI, LEGNARO,…. JAPAN)**

- **GRANTS, SCIENTIFIC PRODUCTION AND POLICY ON HUMAN RESOURCES**

# Irfu: LARGE CEA INSTITUTE CREATED IN 1993
# RESEARCH AND TECHNOLOGY

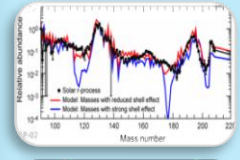

**Irfu**

## Institute of Research into the Fundamental laws of Universe

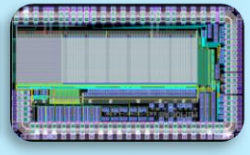


**SAp**: Astrophysics
Space technologies

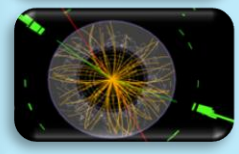
**SACM**: Accelerators,
Supra. Magnets



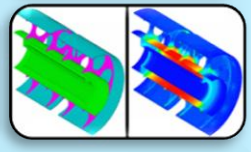
**SPhN**: Nuclear Physics



**SEDI**: Detectors,
electronic, computing

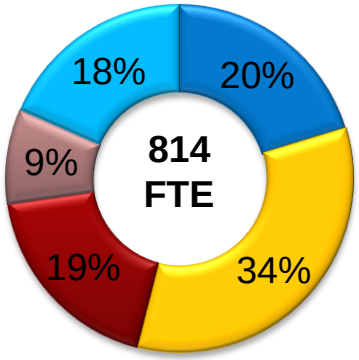


**SPP**: Particle Physics



**SIS**: Systems engineering

# Irfu: LARGE CEA INSTITUTE CREATED IN 1993
# RESEARCH AND TECHNOLOGY




**814 FTE**
**632/615 CDI/CDI-CEA**

- Physicists 165 FTE
- Engineers 274 FTE
- Technicians 152 FTE
- Adm. Staff 72 FTE
- PhD & Post Docs 150 FTE

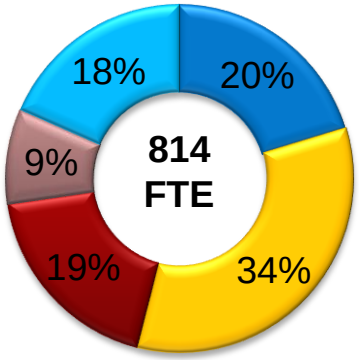
## Research & Technology

- Physics: Infinitely large & small
- Technology: Radiations

**Institute of Research into the Fundamental laws of Universe**

| | | | |
|---|---|---|---|
| 116 CDI 94 CDD | **SAp**: Astrophysics Space technologies | **SACM**: Accelerators, Supra. Magnets | 121 CDI 10 CDD |
| 56 CDI 29 CDD | **SPhN**: Nuclear Physics | **SEDI**: Detectors, electronic, computing | 125 CDI 11 CDD |
| 72 CDI 45 CDD | **SPP**: Particle Physics | **SIS**: Systems engineering | 97 CDI 8 CDD |

# LARGE CEA INSTITUTE CREATED IN 1993
# RESEARCH AND TECHNOLOGY

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**84 M€** (2012)
**54 M€ Gov. Subsidies**

- Gov. Subsidies 54 M€
- TGI & BA 12 M€
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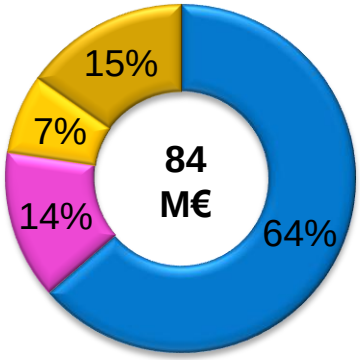


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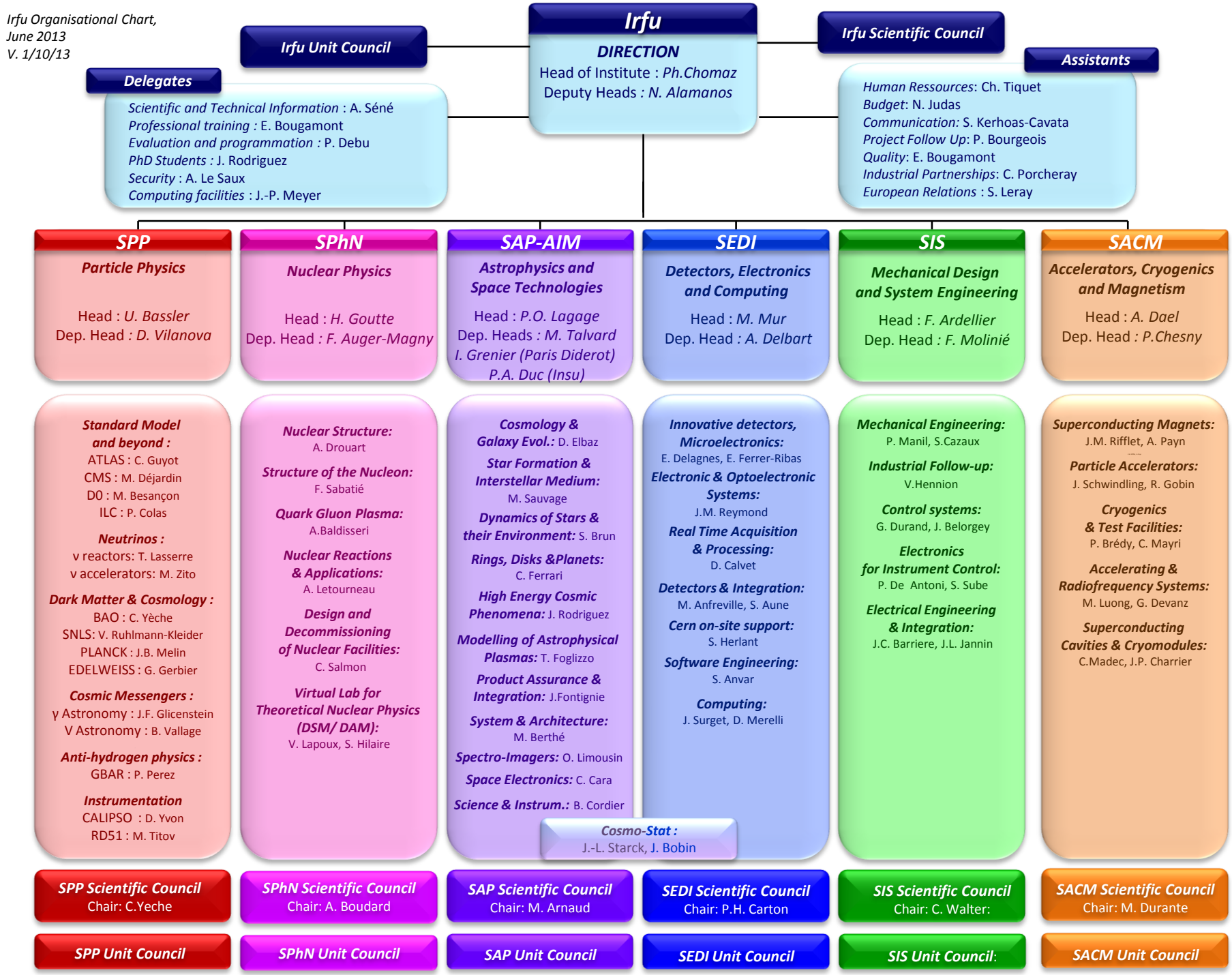
*Irfu Organisational Chart,*
*June 2013*
*V. 1/10/13*



Top

Adm.

Operation

# Irfu

**DIRECTION**
Head of Institute : *Ph.Chomaz*
Deputy Heads *: N. Alamanos*

**Irfu Unit Council**

**Irfu Scientific Council**

**Delegates**

*Scientific and Technical Information* : A. Séné
*Professional training :* E. Bougamont
*Evaluation and programmation :* P. Debu
*PhD Students :* J. Rodriguez
*Security* : A. Le Saux
*Computing facilities* : J.-P. Meyer

**Assistants**

*Human Ressources*: Ch. Tiquet
*Budget*: N. Judas
*Communication:* S. Kerhoas-Cavata
*Project Follow Up*: P. Bourgeois
*Quality*: E. Bougamont
*Industrial Partnerships*: C. Porcheray
*European Relations* : S. Leray

## SPP

***Particle Physics***

Head : *U. Bassler*
Dep. Head *: D. Vilanova*

***Standard Model and beyond :***
ATLAS : C. Guyot
CMS : M. Déjardin
D0 : M. Besançon
ILC : P. Colas

***Neutrinos :***
ν reactors: T. Lasserre
ν accelerators: M. Zito

***Dark Matter & Cosmology :***
BAO : C. Yèche
SNLS: V. Ruhlmann-Kleider
PLANCK : J.B. Melin
EDELWEISS : G. Gerbier

***Cosmic Messengers :***
γ Astronomy : J.F. Glicenstein
V Astronomy : B. Vallage

***Anti-hydrogen physics :***
GBAR : P. Perez

***Instrumentation***
CALIPSO : D. Yvon
RD51 : M. Titov

**SPP Scientific Council**
Chair: C.Yeche

**SPP Unit Council**

## SPhN

***Nuclear Physics***

Head : *H. Goutte*
Dep. Head *: F. Auger-Magny*

***Nuclear Structure:***
A. Drouart

***Structure of the Nucleon:***
F. Sabatié

***Quark Gluon Plasma:***
A.Baldisseri

***Nuclear Reactions & Applications:***
A. Letourneau

***Design and Decommissioning of Nuclear Facilities:***
C. Salmon

***Virtual Lab for Theoretical Nuclear Physics (DSM/ DAM):***
V. Lapoux, S. Hilaire

**SPhN Scientific Council**
Chair: A. Boudard

**SPhN Unit Council**

## SAP-AIM

***Astrophysics and Space Technologies***

Head : *P.O. Lagage*
Dep. Heads *: M. Talvard*
*I. Grenier (Paris Diderot)*
*P.A. Duc (Insu)*

***Cosmology & Galaxy Evol.:*** D. Elbaz

***Star Formation & Interstellar Medium:***
M. Sauvage

***Dynamics of Stars & their Environment:*** S. Brun

***Rings, Disks &Planets:***
C. Ferrari

***High Energy Cosmic Phenomena:*** J. Rodriguez

***Modelling of Astrophysical Plasmas:*** T. Foglizzo

***Product Assurance & Integration:*** J.Fontignie

***System & Architecture:***
M. Berthé

***Spectro-Imagers:*** O. Limousin

***Space Electronics:*** C. Cara

***Science & Instrum.:*** B. Cordier

***Cosmo-Stat :***
J.-L. Starck, J. Bobin

**SAP Scientific Council**
Chair: M. Arnaud

**SAP Unit Council**

## SEDI

***Detectors, Electronics and Computing***

Head : *M. Mur*
Dep. Head *: A. Delbart*

***Innovative detectors, Microelectronics:***
E. Delagnes, E. Ferrer-Ribas

***Electronic & Optoelectronic Systems:***
J.M. Reymond

***Real Time Acquisition & Processing:***
D. Calvet

***Detectors & Integration:***
M. Anfreville, S. Aune

***Cern on-site support:***
S. Herlant

***Software Engineering:***
S. Anvar

***Computing:***
J. Surget, D. Merelli

**SEDI Scientific Council**
Chair: P.H. Carton

**SEDI Unit Council**

## SIS

***Mechanical Design and System Engineering***

Head : *F. Ardellier*
Dep. Head *: F. Molinié*

***Mechanical Engineering:***
P. Manil, S.Cazaux

***Industrial Follow-up:***
V.Hennion

***Control systems:***
G. Durand, J. Belorgey

***Electronics for Instrument Control:***
P. De Antoni, S. Sube

***Electrical Engineering & Integration:***
J.C. Barriere, J.L. Jannin

**SIS Scientific Council**
Chair: C. Walter:

**SIS Unit Council:**

## SACM

***Accelerators, Cryogenics and Magnetism***

Head : *A. Dael*
Dep. Head *: P.Chesny*

***Superconducting Magnets:***
J.M. Rifflet, A. Payn

***Particle Accelerators:***
J. Schwindling, R. Gobin

***Cryogenics & Test Facilities:***
P. Brédy, C. Mayri

***Accelerating & Radiofrequency Systems:***
M. Luong, G. Devanz

***Superconducting Cavities & Cryomodules:***
C.Madec, J.P. Charrier

**SACM Scientific Council**
Chair: M. Durante

**SACM Unit Council**

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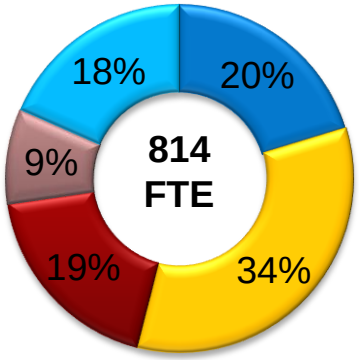


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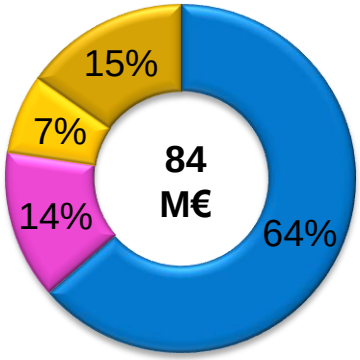
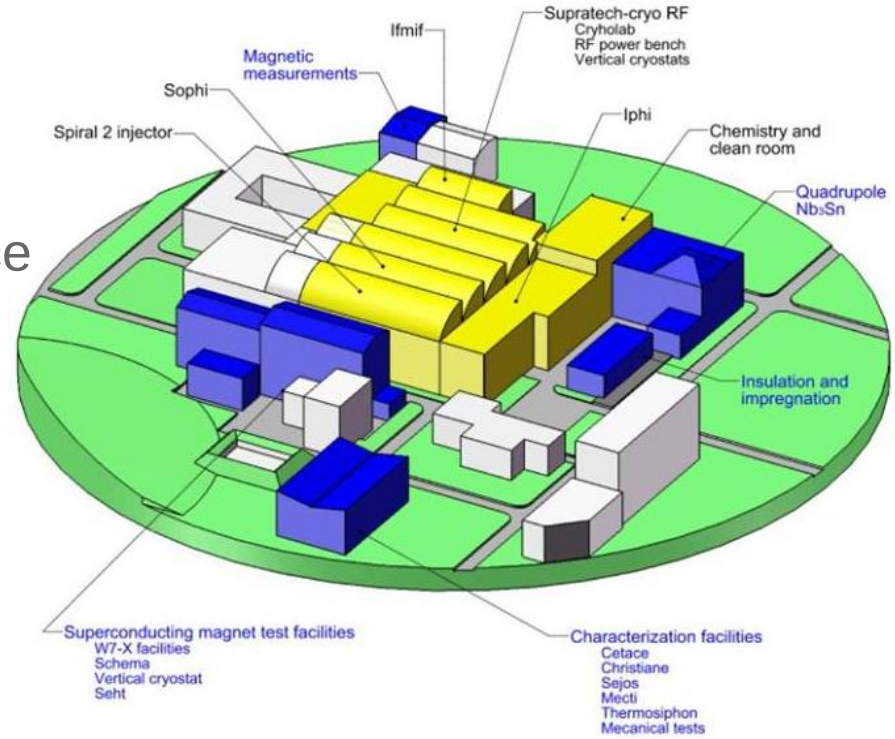
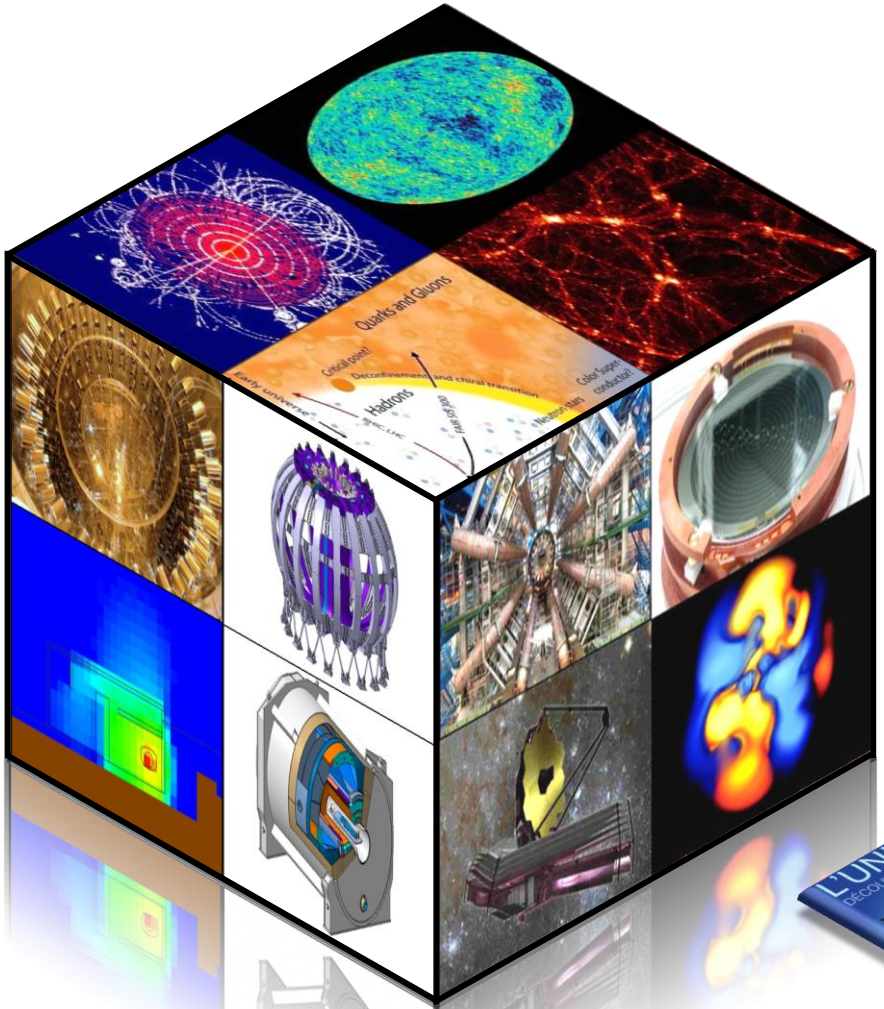



## Platforms Saclay & Orme

- 50 000 m², 130 M€
- Radiations Techno: Accelerators, Magnets, Space , Detection, computing




Quarks and Gluons
Critical point
Deconfinement and chiral transition
Color Superconductor
Hadrons
Early universe
Neutron stars
Today
RHIC, LHC

Irfu


L'UNIVERS
DÉCOUVREZ SES MYSTÈRES
ANNÉE MONDIALE DE L'ASTRONOMIE
2009

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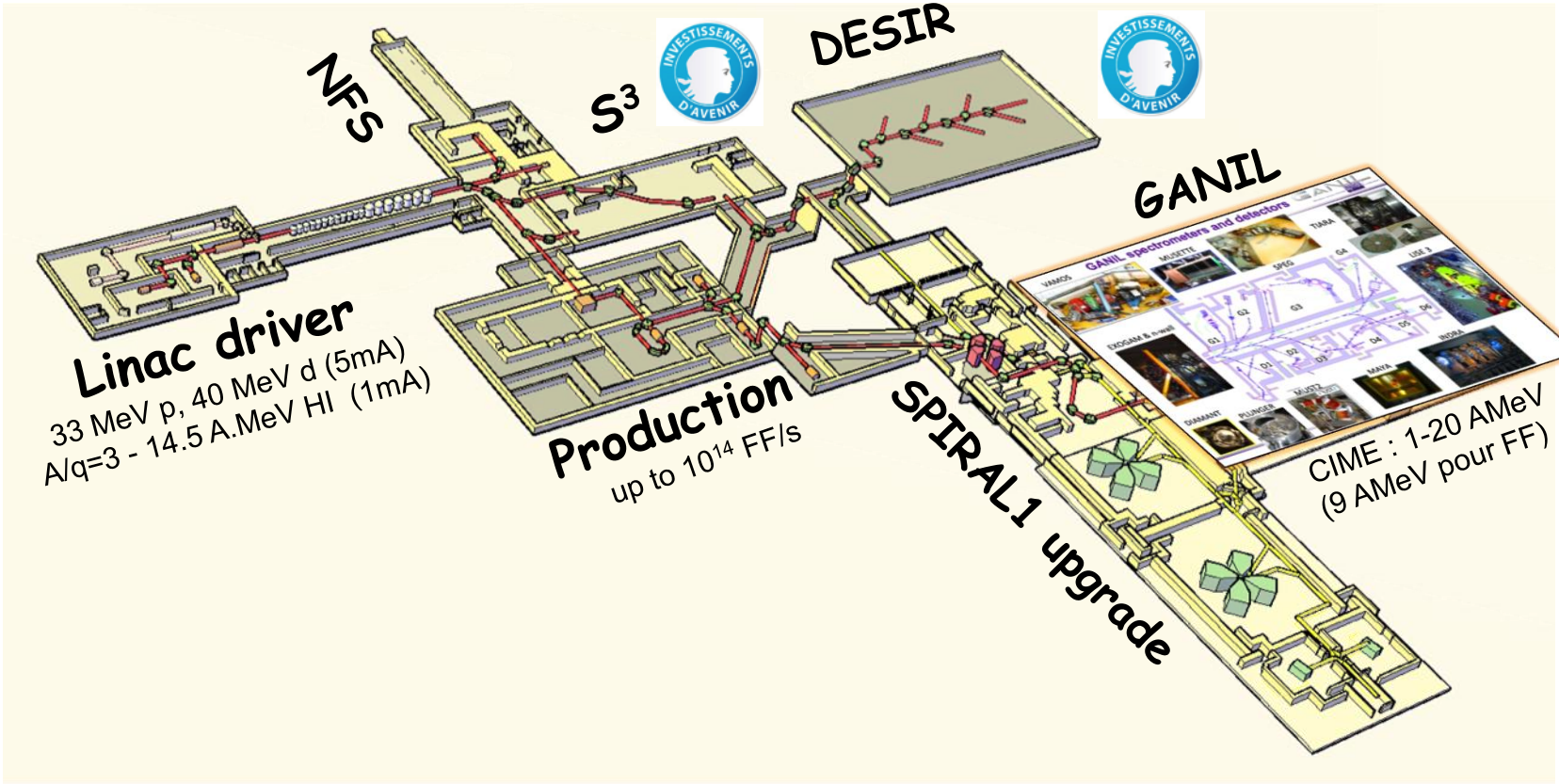
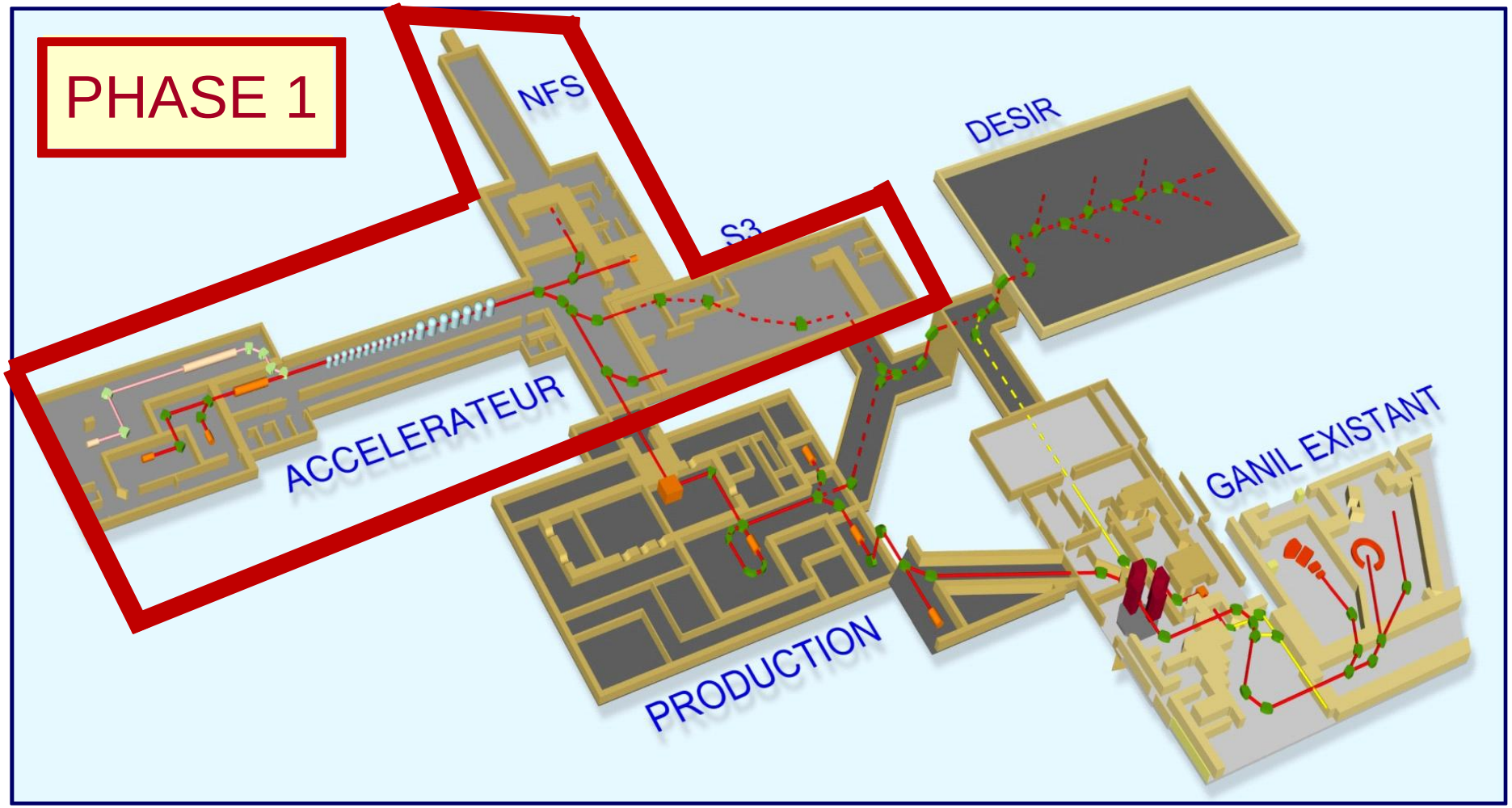
www.ganil-spiral2.eu

# A National & EU priority




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

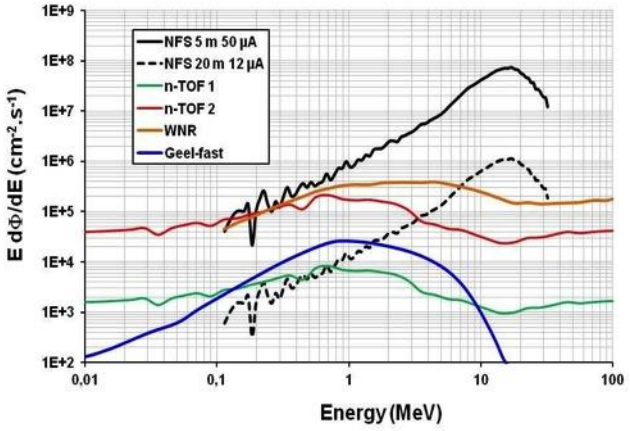
# SPIRAL2 Phase1 ready in 2015-2016



# 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



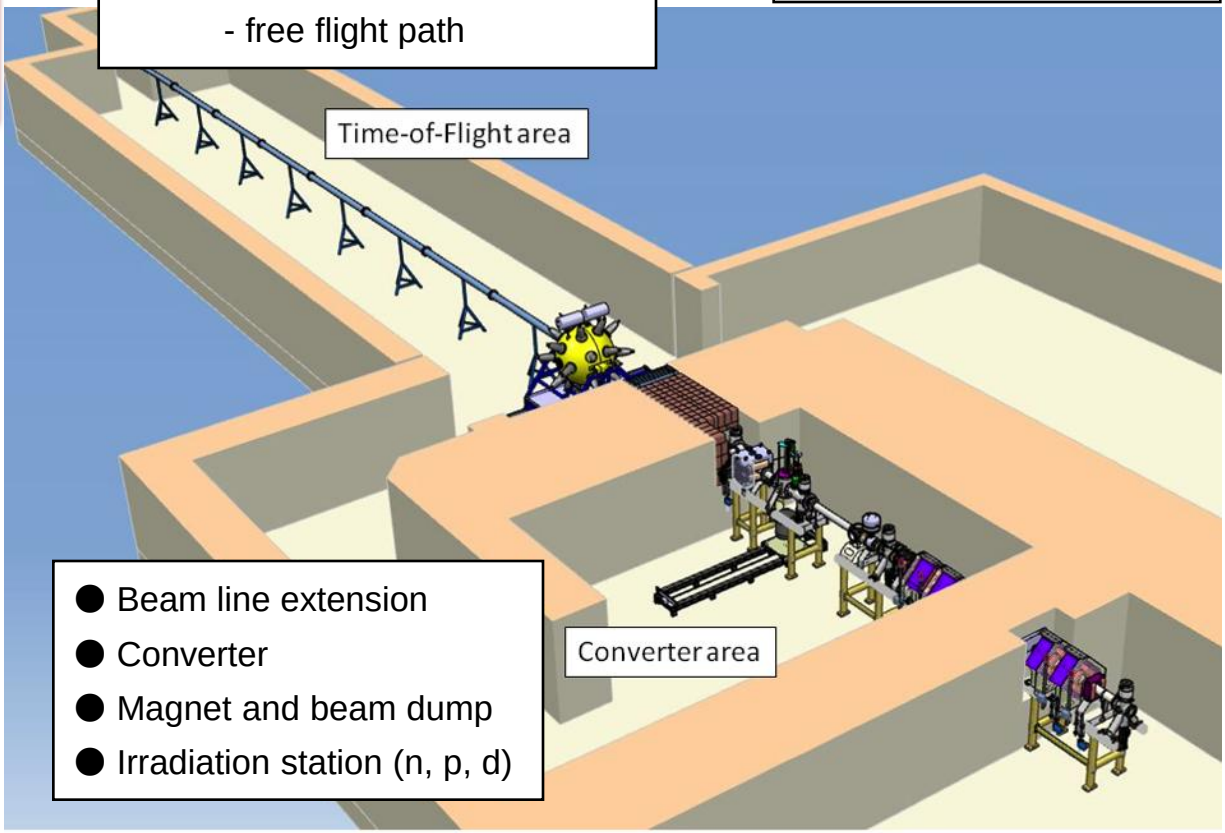

High intense neutron flux :
$\Phi > 1{,}5.10^{13}$ n/s in $4\pi$
Continuous or mono energetic spectra
Well collimated neutron beam

First experiment in 2015

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

**I < 50 µA**
**P < 2 kW**

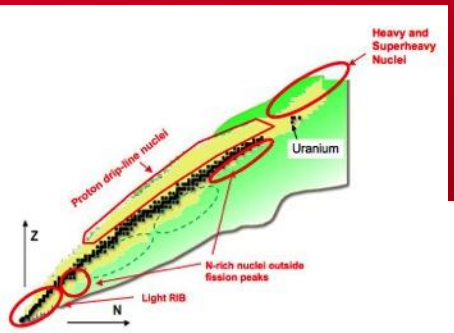
Use of radioactive samples
A< 1 GBq for thin layers
A< 10 GBq for thick samples




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

**S3 Physics case (16 LoIs)**

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




**First experiment in 2016**

**Acceptance:**

➔ ± 60 mrad in X and ± 80 mrad Y

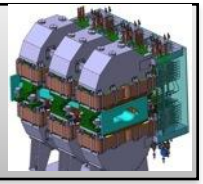
➔Bρ acceptance +/- 10%

➔5 charge states transmitted

$^{58}Ni+^{46}Ti \not\rightarrow {}^{100}Sn + 4n$

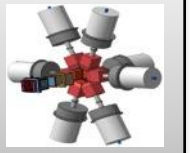
➔⊗M/M = 420 & 55% transmission

Beam dump & Movable fingers

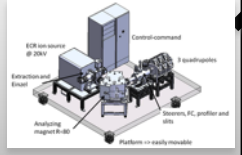


High power Rotating targets including actinides

Implantation-decay station at the mass dispersive plan *SIRIUS*

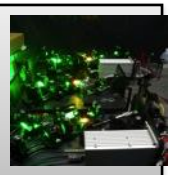


FISIC setup Fast Ion Slow Ion Collisions *ANR FITFISC*



Large acceptance SC Multipoles

Low Energy Branch *ANR REGLIS³*



***DESIR***

# Civil Construction

*100 % of the concrete done (14000m³)*

Feb 2011

May 2011

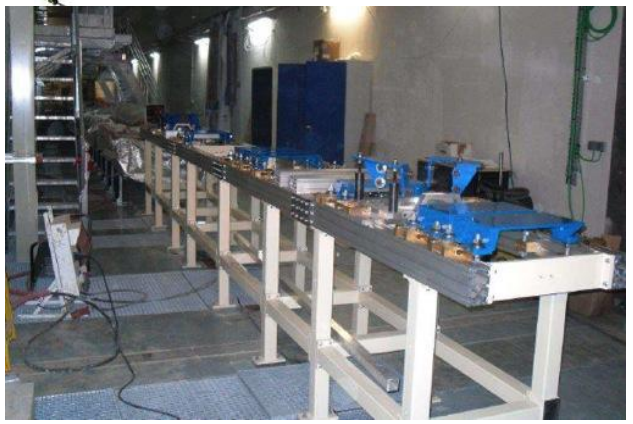
Oct 2011

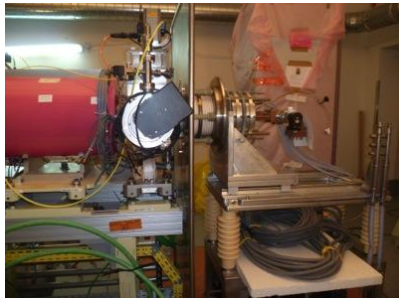
May 2012

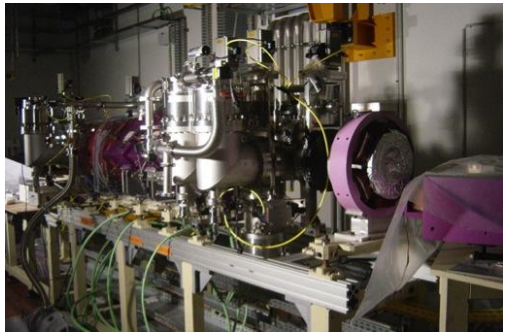
Oct 2012

Jan 2014

# Installation is going on







# SPIRAL2 Phase1+ by 2018-2019?

PHASE 1

NFS

DESIR

ACCELERATEUR

PRODUCTION

GANIL EXISTANT

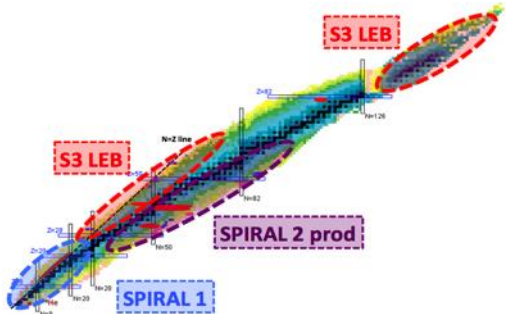
DESIR

**First experiment 2018 - 2019**

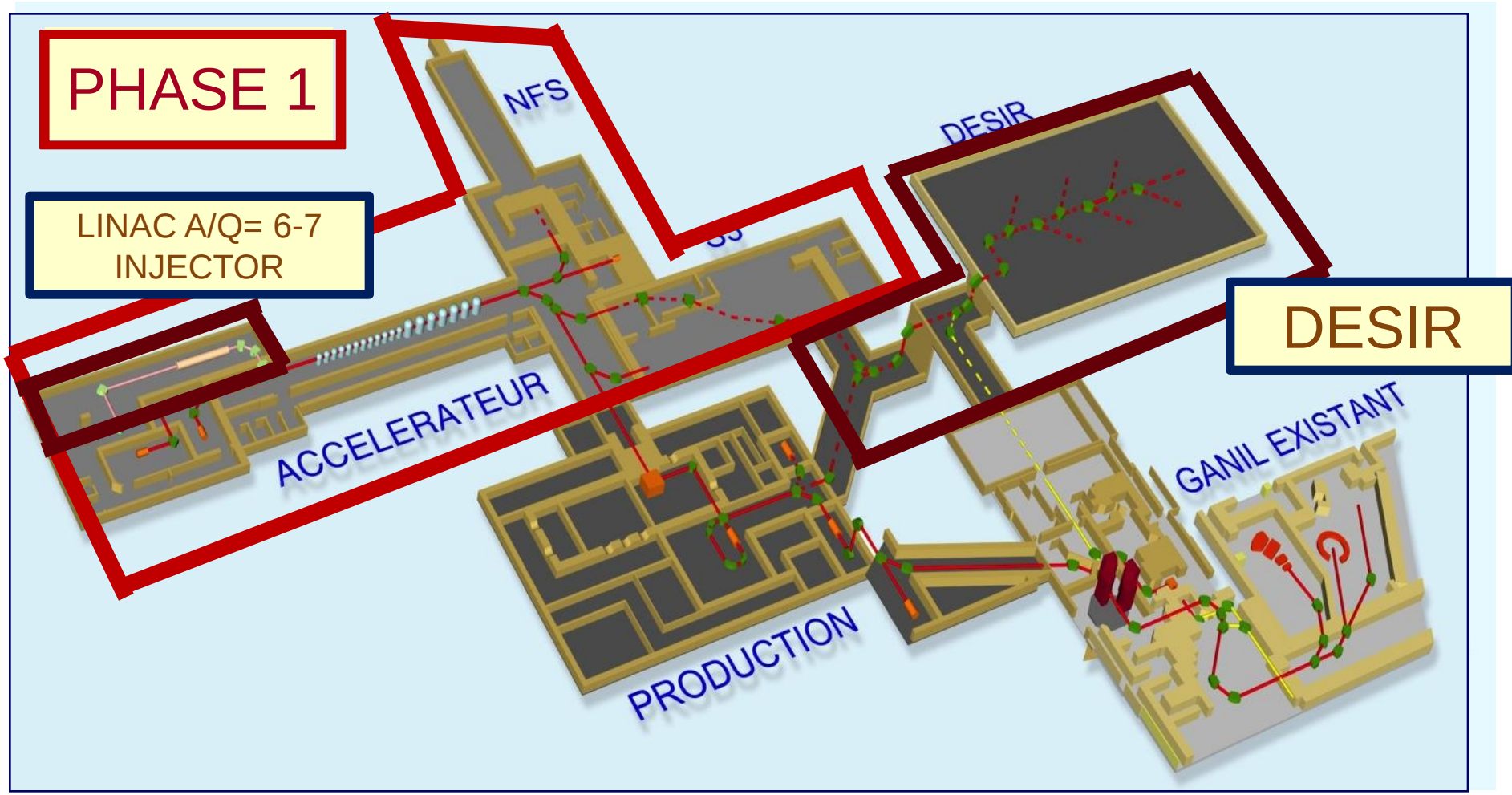
120 physicists, 35 institutions, 15 countries
Bertram Blank – CENBG France (Project leader)
Jean Charles Thomas – GANIL France (EQUIPEX)

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

- **SPIRAL1 (light n-deficient nuclei from beam/target fragmentation)**
- **S3 (fusion-evaporation products, refractory elements)**



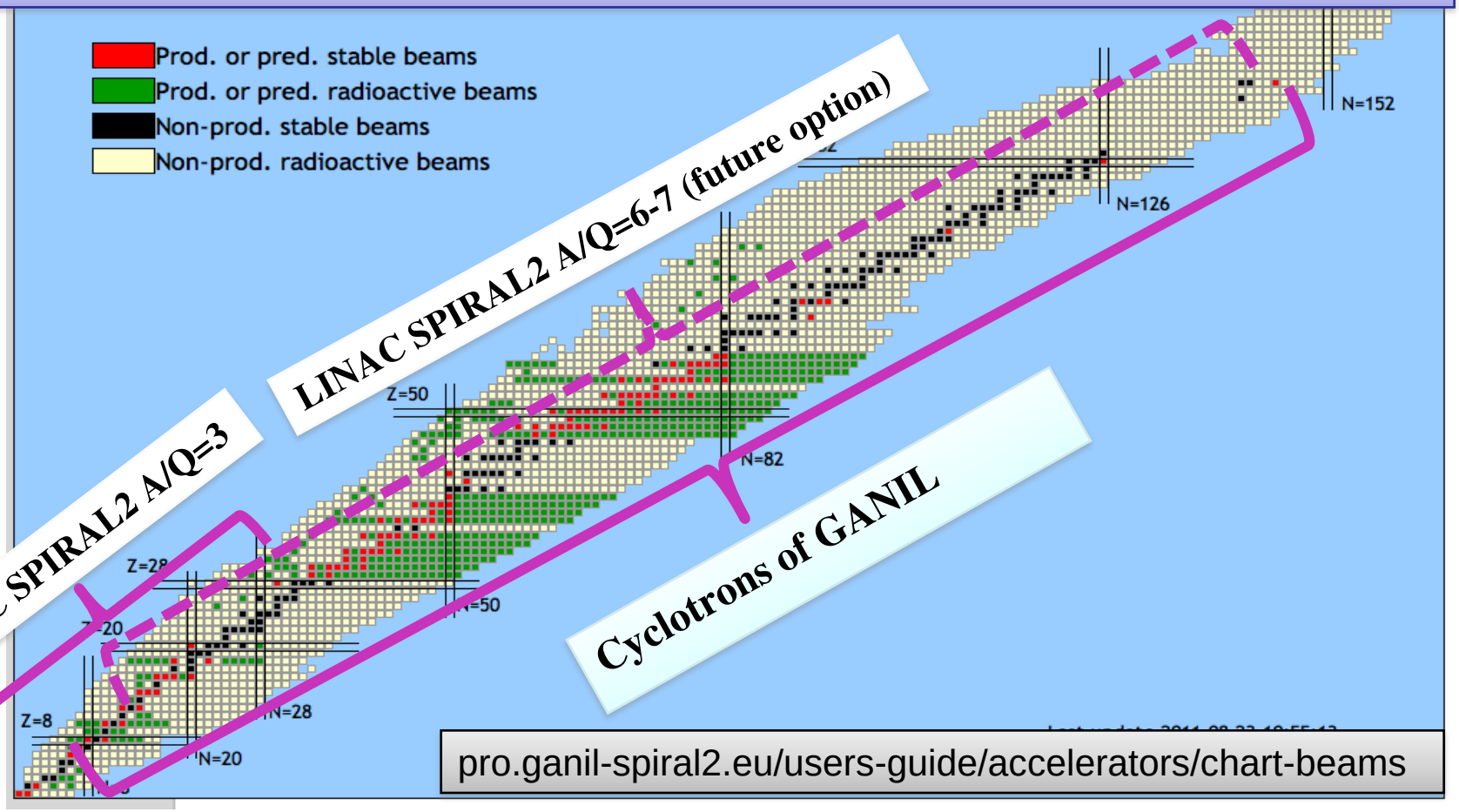
# SPIRAL2 Phase1++ by 2018-2019?



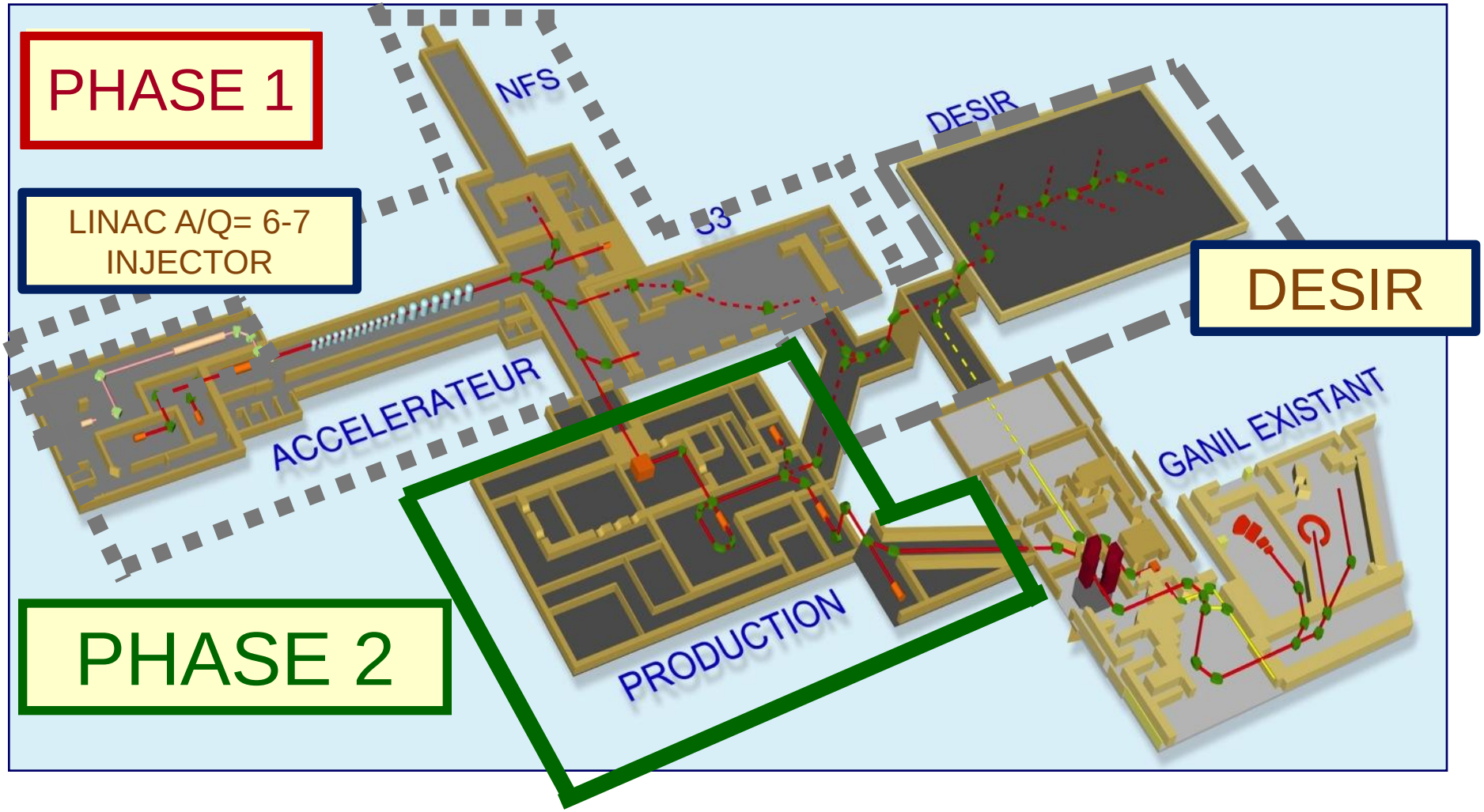
# Stable ion-beams of GANIL & LINAC SPIRAL2

- Cyclotrons: ≤ $10^{13}$ pps, from C to U, 1 MeV/n - 95 MeV/n
- LINAC SPIRAL2 (baseline project) ≤ $10^{15}$ pps from p to 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**



# SPIRAL2 PHASE 2 by 2022?



# GANIL/SPIRAL2 facility

## Phase1

Increase the intensity of stable beams by a factor 10 to 100 + High intensity neutron source

*10pμA (6.10$^{13}$pps) A<50*

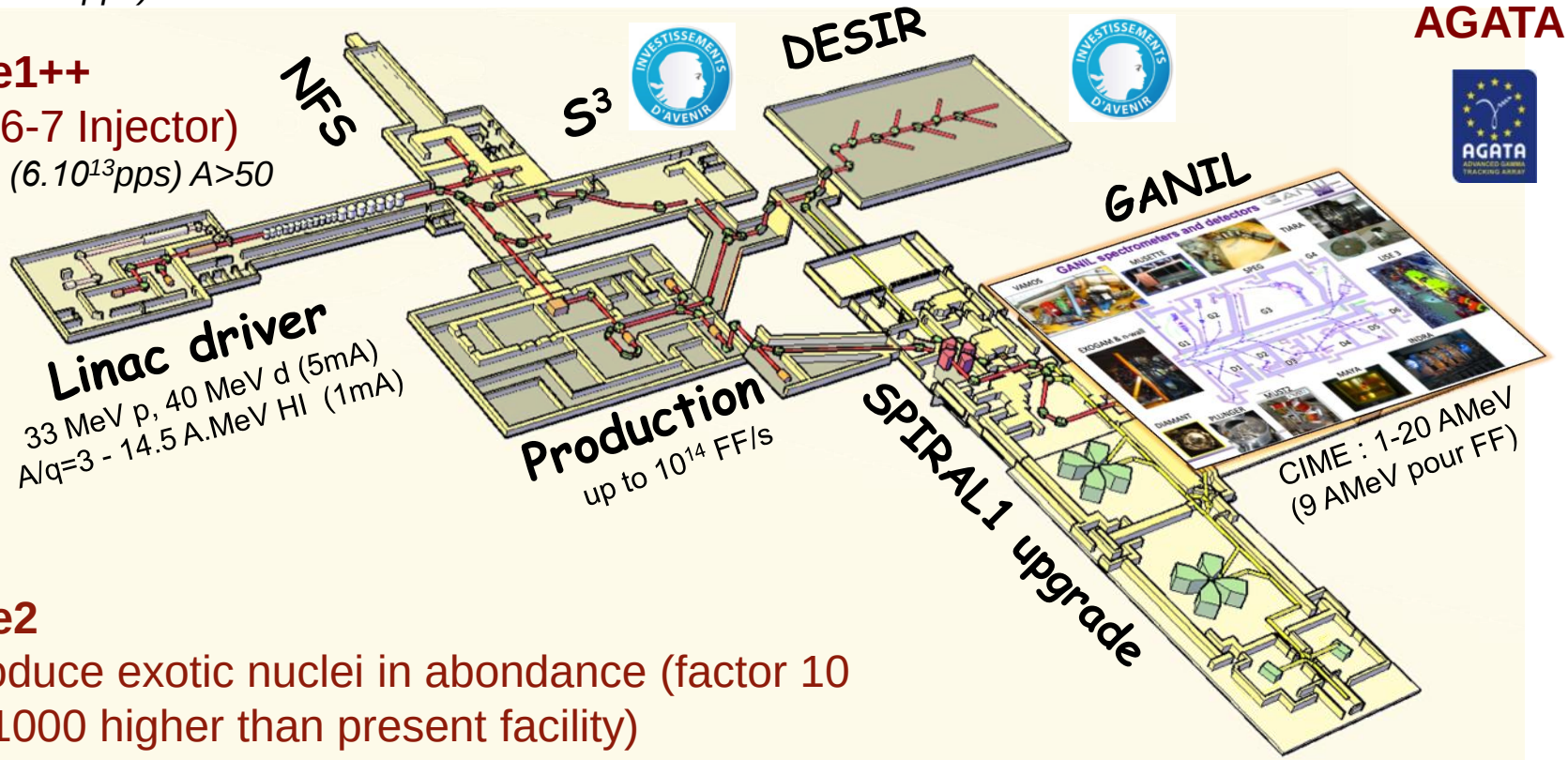
## Phase1++

(A/Q=6-7 Injector)

*≥10pμA (6.10$^{13}$pps) A>50*

## DESIR Phase1+

(low energy facility)




## Phase2

- Produce exotic nuclei in abondance (factor 10 to 1000 higher than present facility)
- Expand the range of exotic nuclei to A>80
- Post-acceleration of high intensity RIB

## SPIRAL1 Upgrade

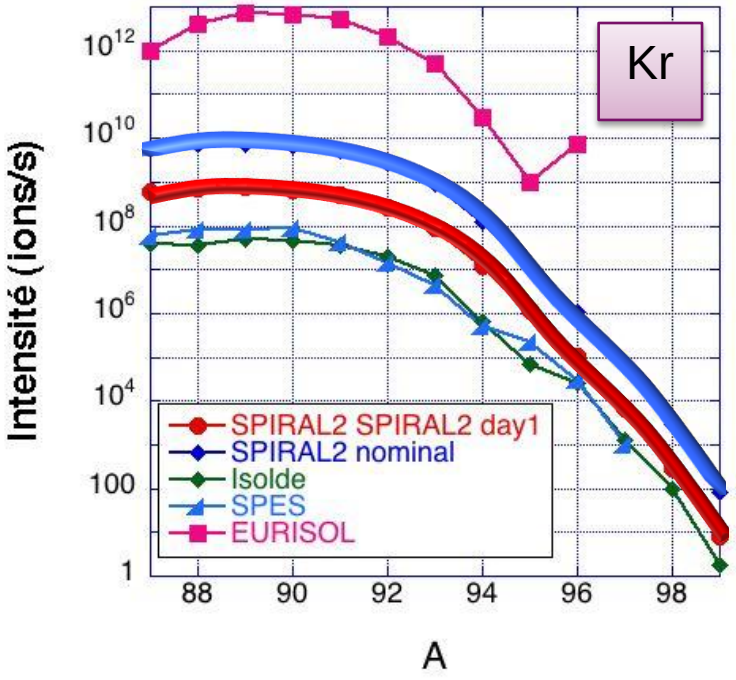
New light n-deficient nuclei from beam/target fragmentation

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

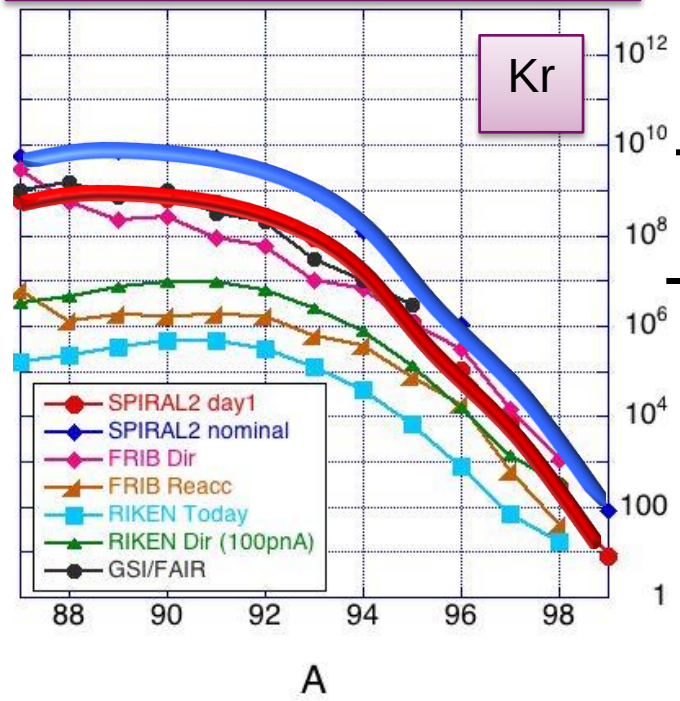
# SPIRAL 2: ADVANCED ISOL RIB FACILITY

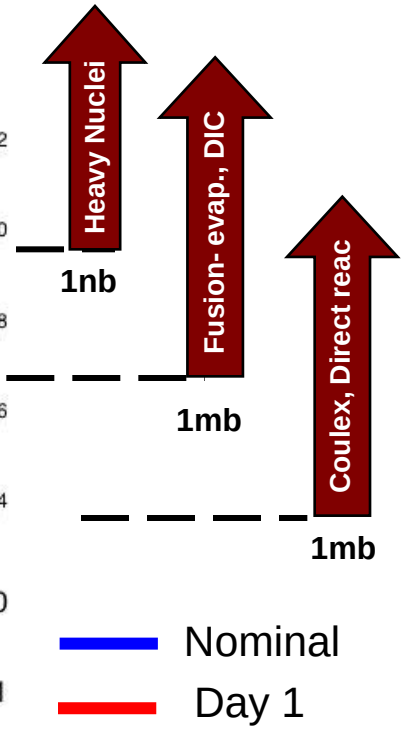
## SPIRAL 2: Experiments with RIB at low cross sections and very exotic nuclei at few MeV/nucleon

SPIRAL2 – ISOL facilities




SPIRAL2 – In flight facilities




**ISOL RIB beams:**

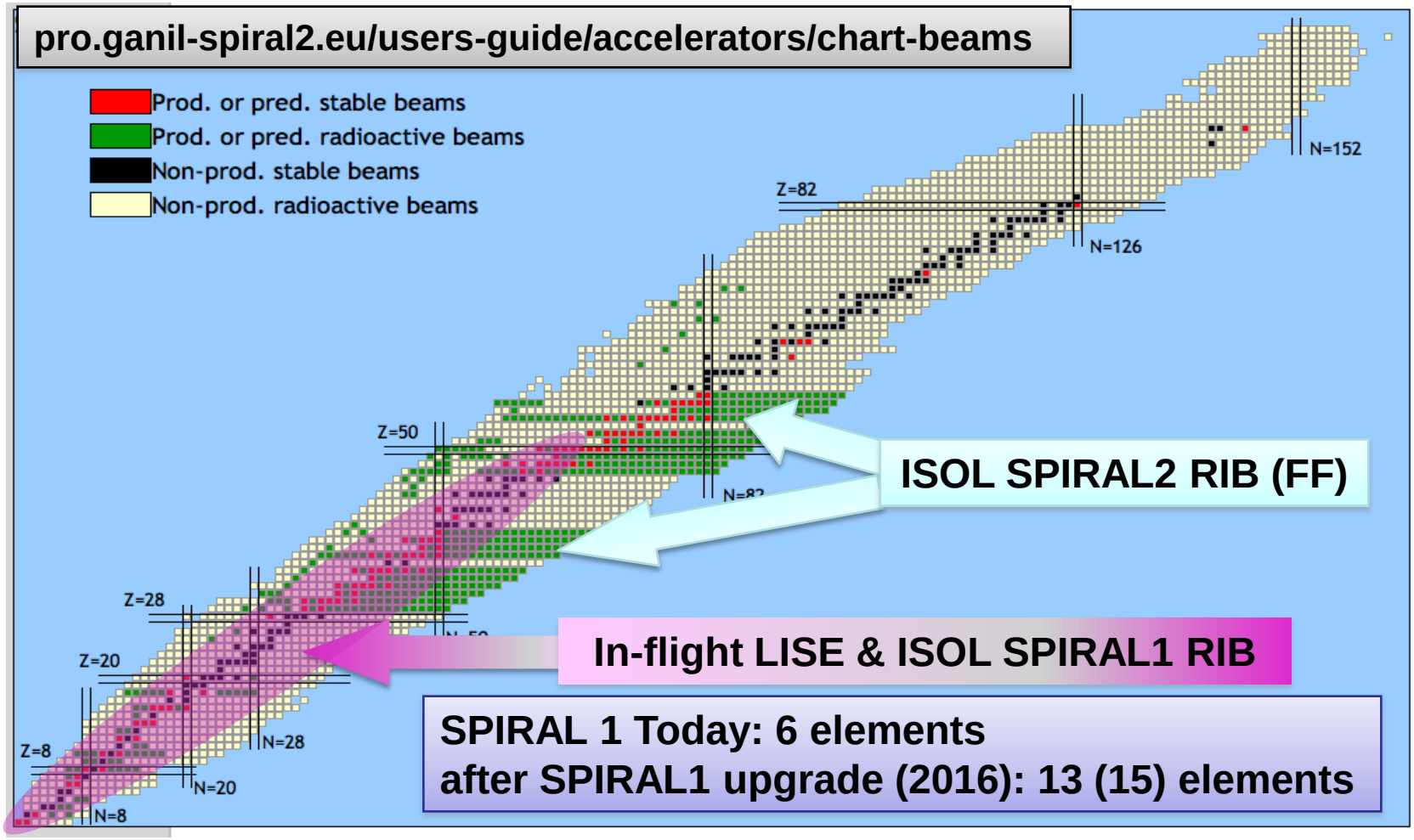
- high intensity, optical quality & purity

**Versatility:**

- light & HI, high-intensity stable-ion & RIB
- Multi-beam capabilities,
- Months of beam-time
- World-class arrays & detectors

# Radioactive Ion Beams GANIL/SPIRAL1&2

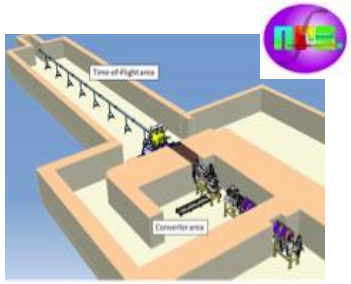
- **RIB by in-flight at LISE: few MeV/n to 50 MeV/nucl.**
- **ISOL RIB from SPIRAL 1 & SPIRAL 2: ≤ 60keV et 1-15 MeV/nucl.**



# GANIL/SPIRAL2 *mid-term* roadmap

## Start the scientific program with SPIRAL2 in 2015

- Commissioning and operation of SPIRAL2 Phase 1
- First experiment with NFS in 2015
- First experiment with $S^3$ in 2016

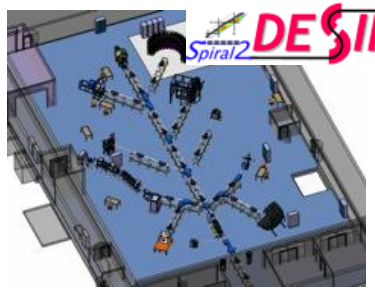




## Exciting scientific program with AGATA@GANIL in 2014-2016 (- 2018?)

- New SPIRAL1 RIBs (9 new elements, tens of isotopes)

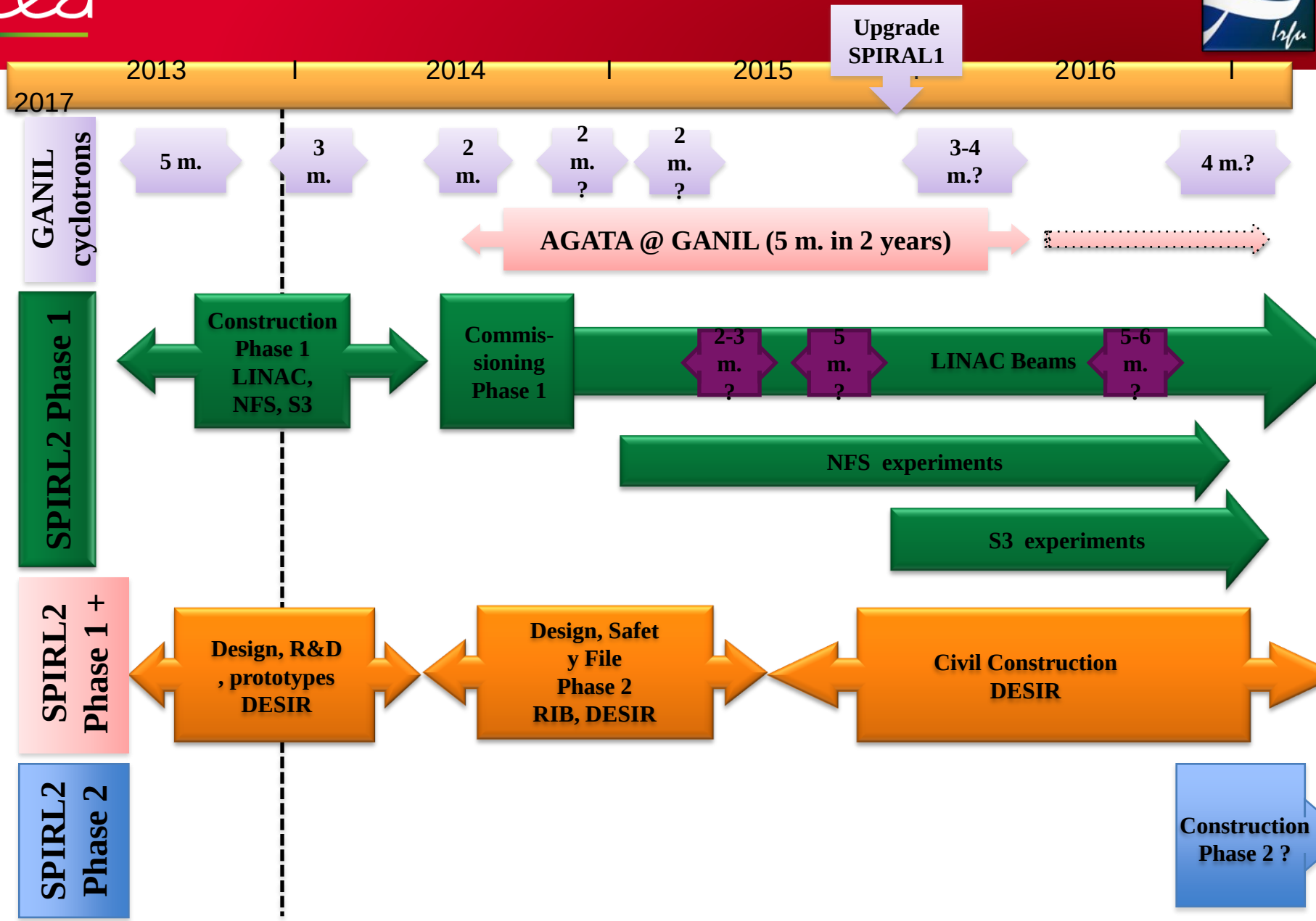
## Start the scientific program with DESIR by 2018

- $S^3$ low energy beams
- New SPIRAL1 RIBs



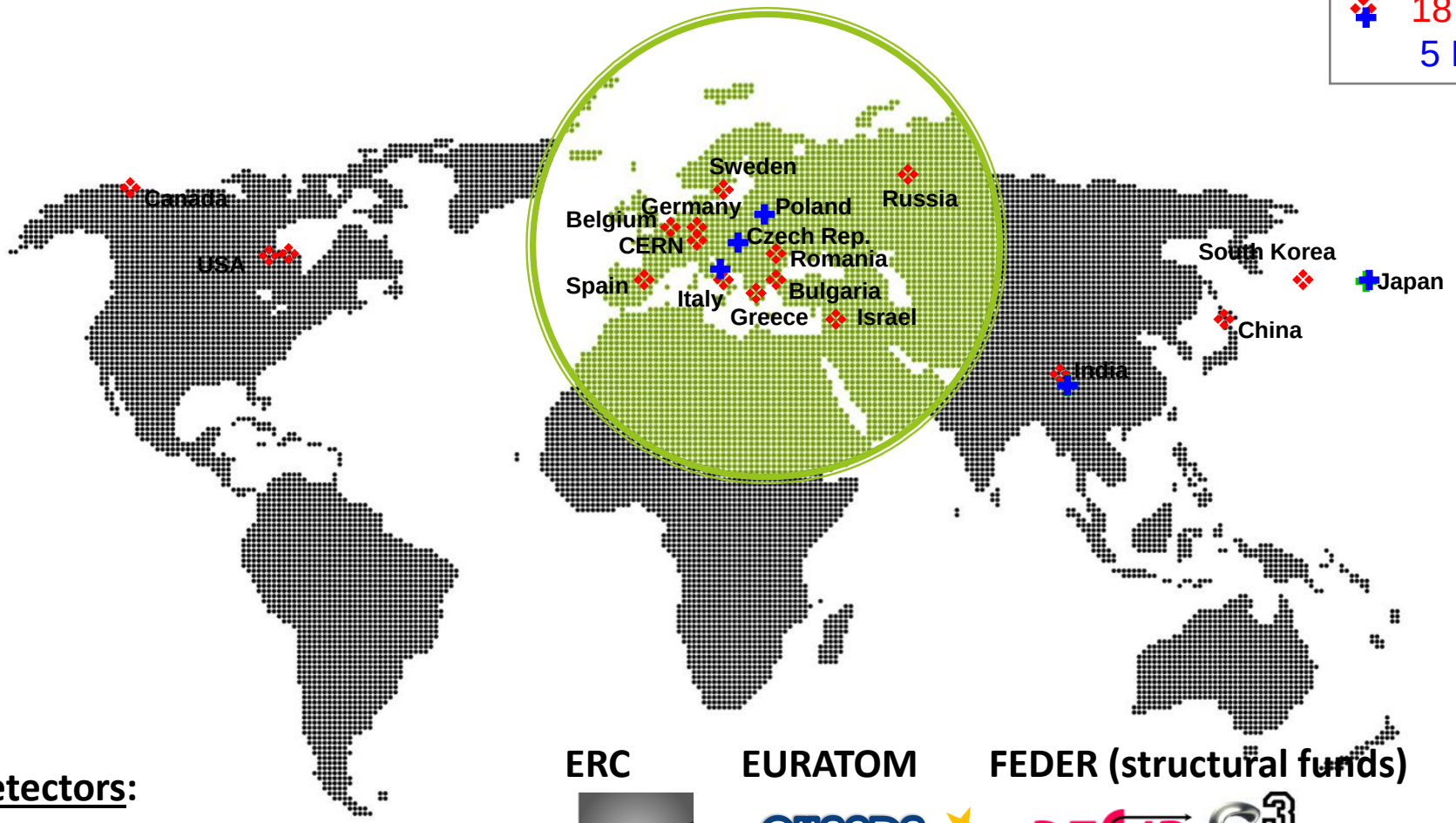

## Get green light for the construction of Phase 2 in the coming few years

# Timeline GANIL & SPIRAL2



# International Collaborations GANIL/SPIRAL2

**EU FP7:** ENSAR, CRISP, LANNET, MAGNEC




**ERC** **EURATOM** **FEDER (structural funds)**

**Detectors:**

MoUs: FAZIA, NFS, NEDA, PARIS

Collaboration agreements: Instr. Coord. Committee (ICC), EXOGAM2, DESIR (DECA), ACTAR TPC

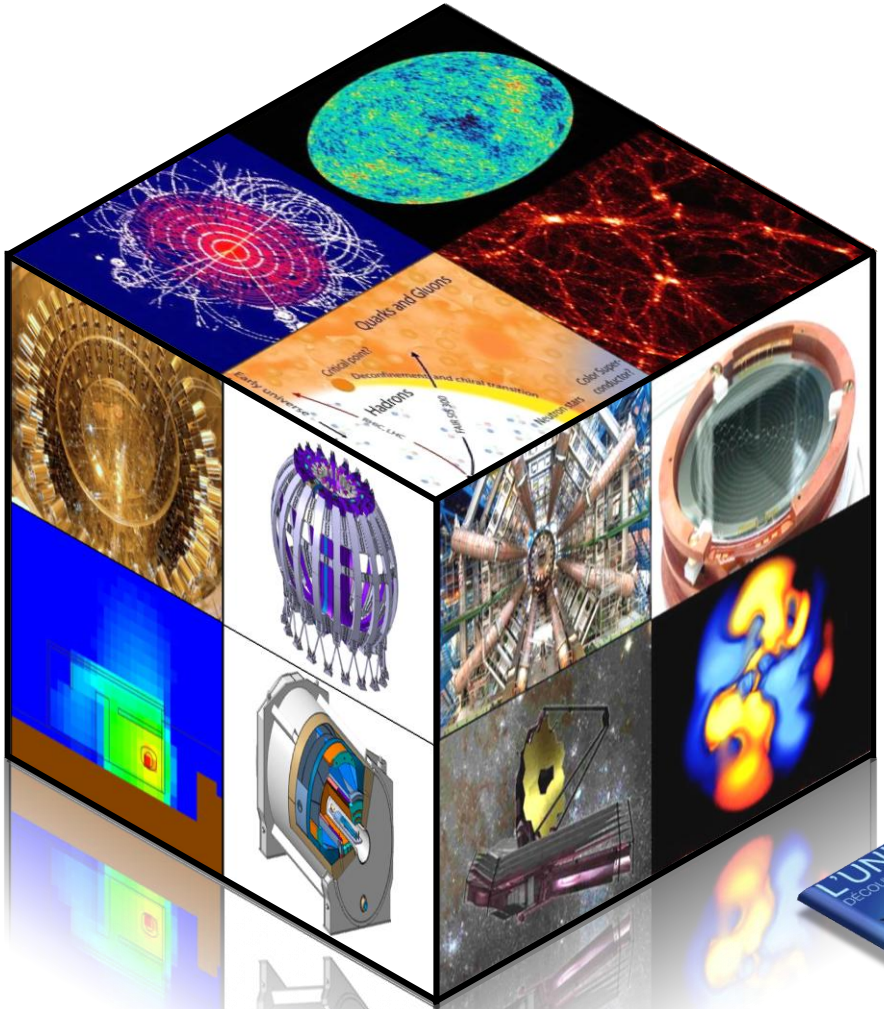
# Remarks

**Commissioning of SPIRAL2 LINAC from autumn 2014**
**First experiments at SPIRAL2 Phase 1 with NFS in 2015 and S3 in 2016**
The goal: produce first high-quality physics results soon after commissioning

**SPIRAL 2 Phase 1+ +**
The goal: construct DESIR (Low-energy RIB from S3 and SPIRAL1) and the second injector for the SPIRAL2 LINAC by 2018-2019

**Exciting scientific program with AGATA@GANIL (≥28 weeks of beam time in 2014-2016) with stable-ion and new RIB from SPIRAL 1**
A possibility to extend the AGATA campaign to 2017 & 2018 with about 20 additional weeks of beamtime

**A possibility to include international members in the GANIL/SPIRAL2 legal structure in 2015**


Quarks and Gluons
Critical point
Deconfinement and chiral transition
Color Superconductor
Hadrons
Early universe
Neutron stars
Today
RHIC, LHC

Irfu


L'UNIVERS
DÉCOUVREZ SES MYSTÈRES
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2009

- Irfu: LARGE CEA INSTITUTE CREATED IN 1993: RESEARCH AND TECHNOLOGY

- EXPLORING THE FUNDAMENTAL LAWS OF UNIVERSE – EMPHASIS ON NΦ (OF THE NUCLEUS)

  GANIL – SPIRAL2

  **SPHN (GANIL, GSI, LEGNARO,…. JAPAN)**

- **GRANTS, SCIENTIFIC PRODUCTION AND POLICY ON HUMAN RESOURCES**

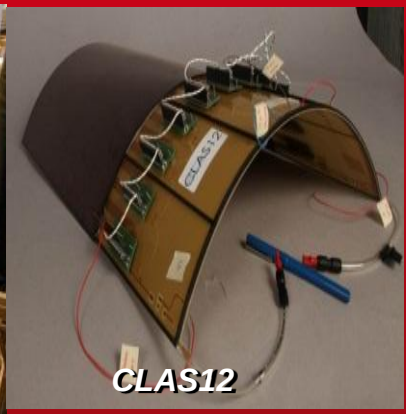
Irfu


Double Chooz


ALICE


Caméra


Must2

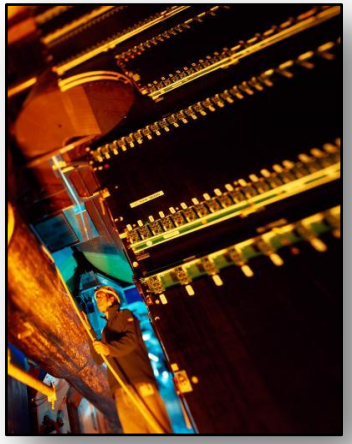

CLAS12

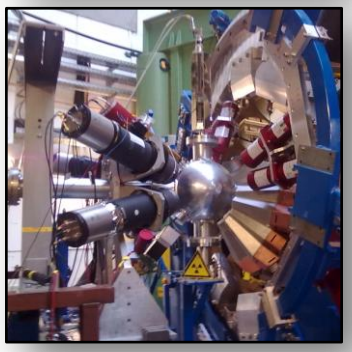
Commissariat à l'énergie atomique et aux énergies alternatives
Centre de Saclay | 91191 Gif-sur-Yvette Cedex

Etablissement public à caractère industriel et commercial | RCS Paris B 775 685 019

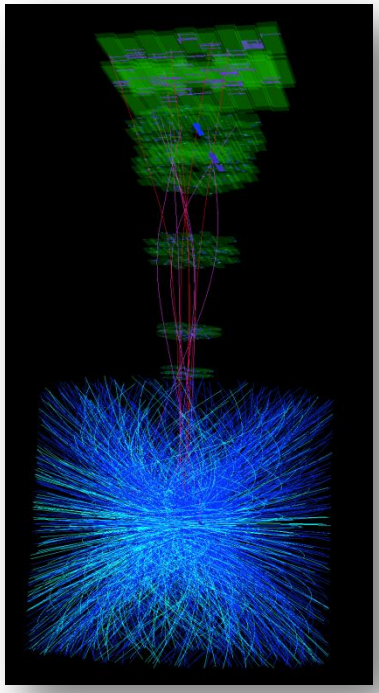
Direction des Sciences de la matière
Institut de Recherche sur les lois Fondamentales de l'Univers
Direction

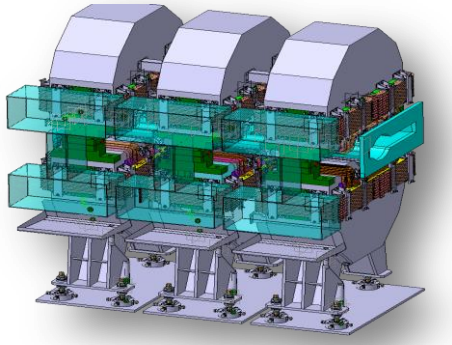
# STRUCTURES OF NUCLEAR MATTER
# 2008 – 2013 PROGRESSES AND HIGHLIGHTS



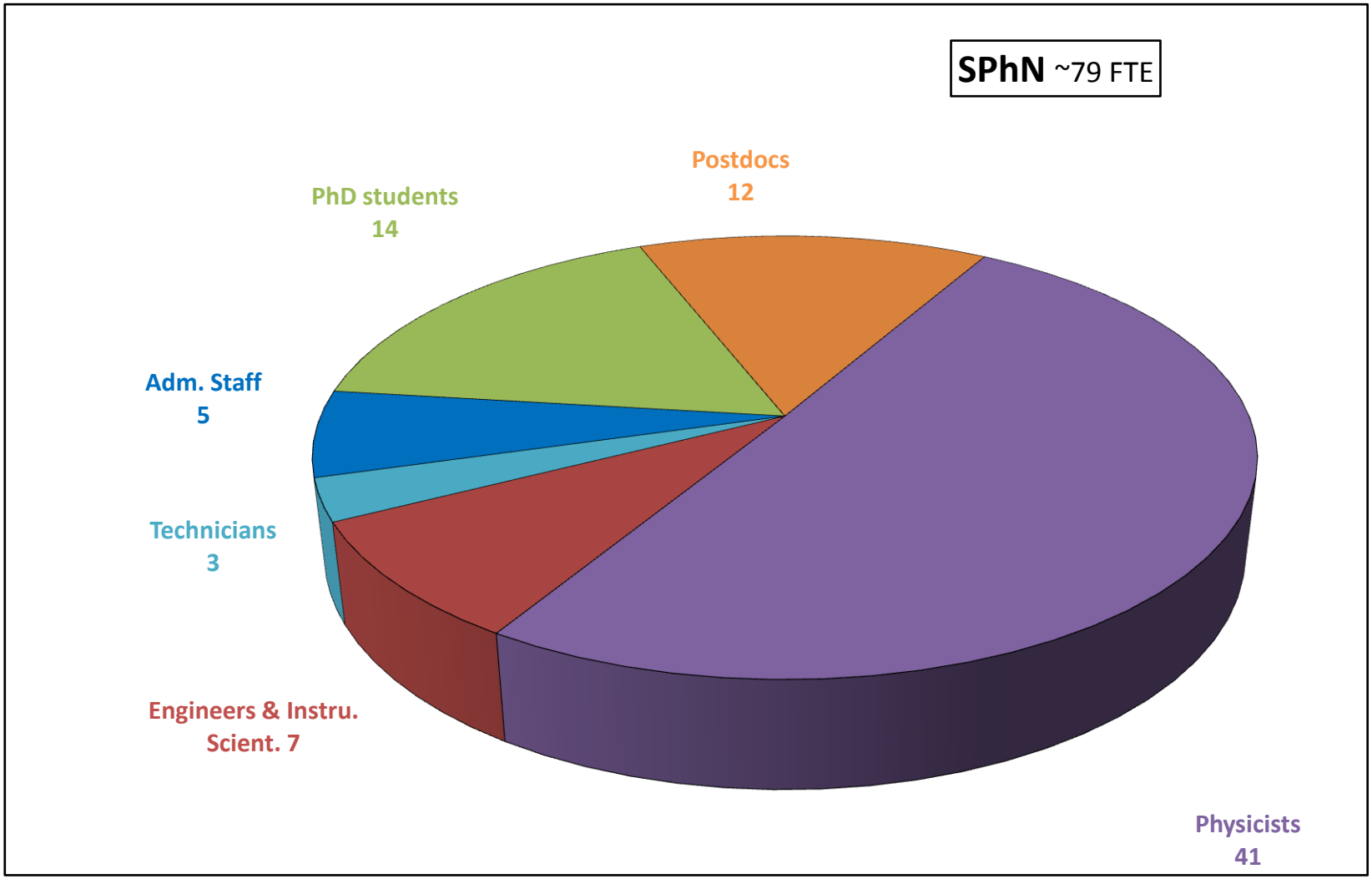


- **ALICE probe QGP**
  - Important CEA contribution
    Di-muon arm
  - Screening and Flow of J/Psi
- **Quarks and gluon in Hadrons**
  - COMPASS and the spin puzzle
  - COMPASS-2 and GPD
    (Parton distributions)
  - R&D CLASS12
- **Nuclear forces and structures**
  - SPIRAL2 construction
    Major contribution to LINAC and S3
  - Revolutionary ab-initio approaches
  - Study of exotic nuclei
    GANIL and Riken, MINOS ERC project
  - Deformation and super-heavies
    Important contribution du AGATA detector

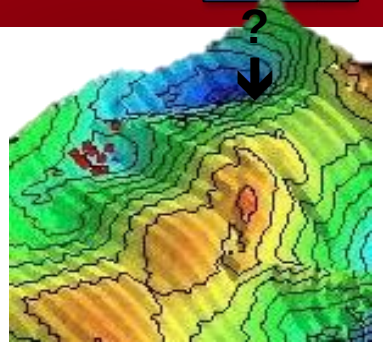




# The SPhN in numbers

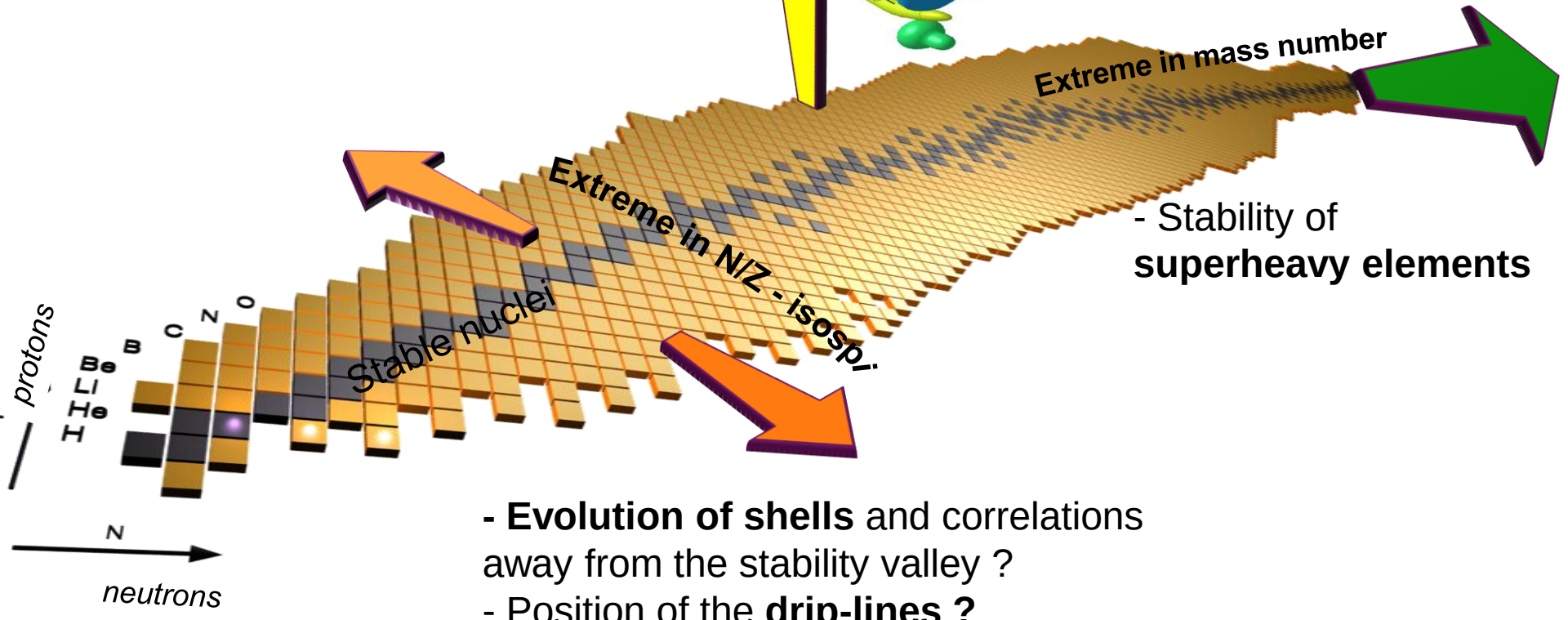


# Nuclear structure at the extremes: burning questions




**Extreme in deformation, in excitation energy**

- Sudden onset of deformations
- Shape coexistence



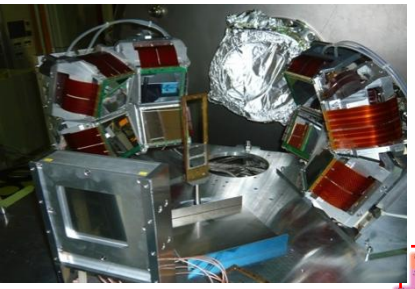

- Stability of **superheavy elements**

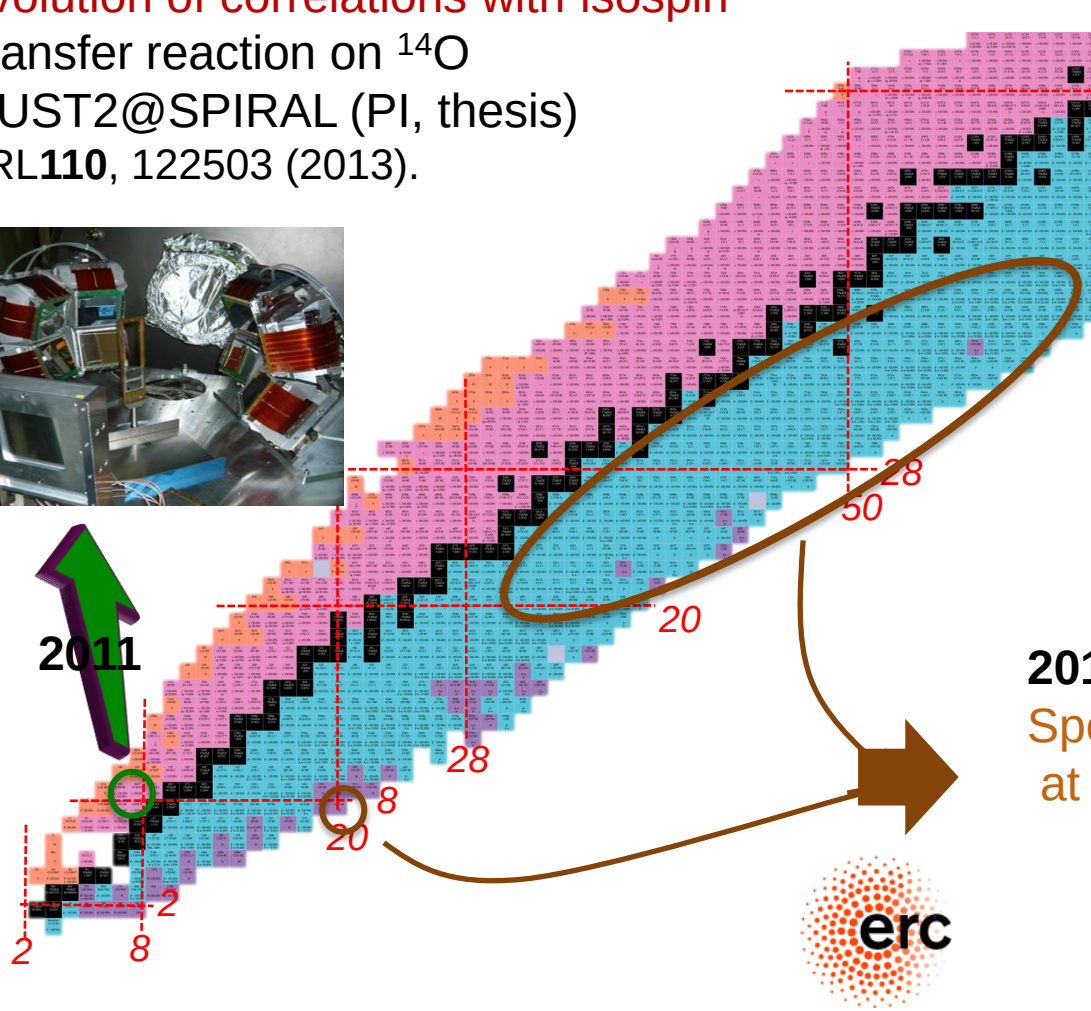
**- Evolution of shells** and correlations away from the stability valley ?
- Position of the **drip-lines ?**

# Shell effects evolution

## Evolution of correlations with isospin

Transfer reaction on $^{14}$O
MUST2@SPIRAL (PI, thesis)
PRL**110**, 122503 (2013).






Study of $^{132\text{-}134+}$Sn
by transfer reaction
LoI (PI)

GANIL spiral2
laboratoire commun CEA/DSM — CNRS/IN2P3

**2014 - 2015**

Spectroscopy of very exotic nuclei
at RIKEN

erc

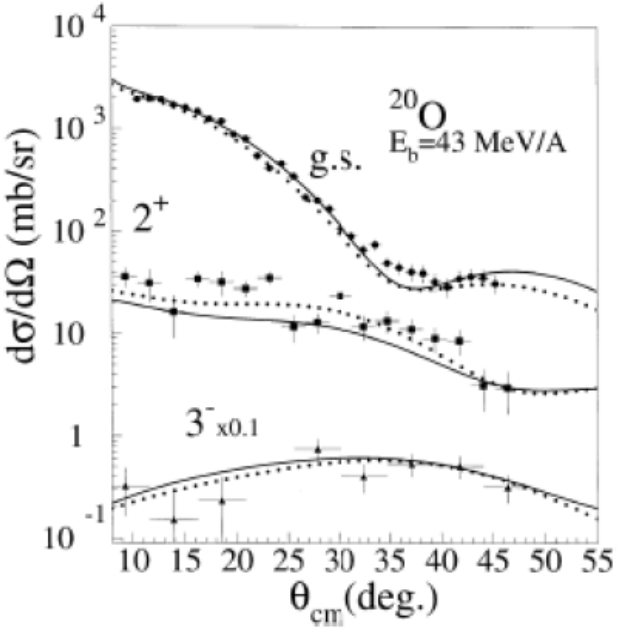
MINOS
Magic Numbers Off Stability

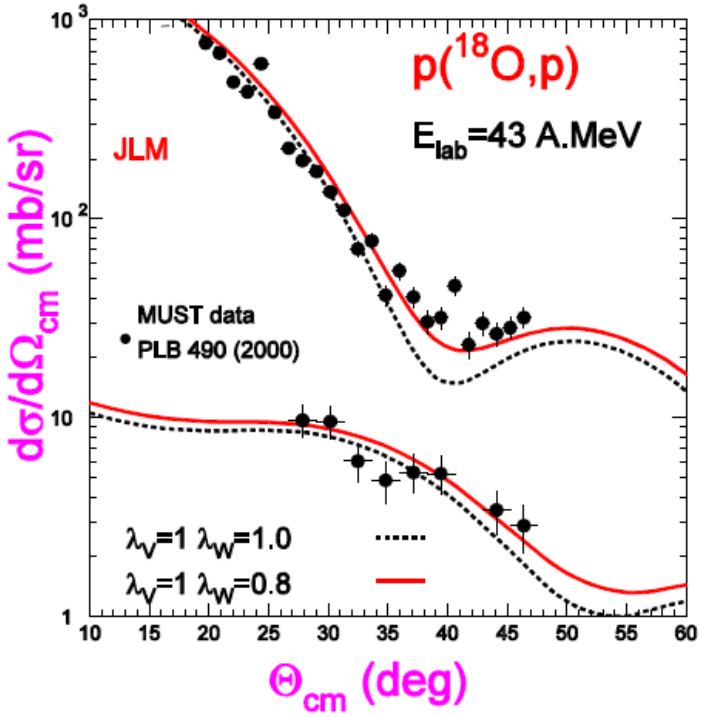
Thick hydrogen target
coupled to a TPC and
a micromegas

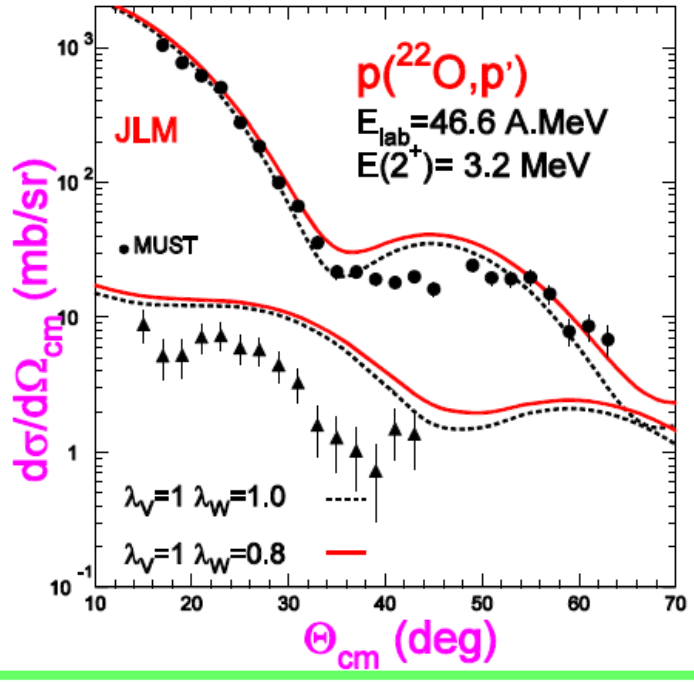
# Examples of OMP analysis for $^{18,20,22}$O(p,p)

MUST data @GANIL:
$^{20}$O PLB **490**, 45 ('00) ;
$^{22}$O PRL **96,** 012501 ('06)

JLM analysis (Vlx) using HFB/Sly4 densities from E Khan et al.

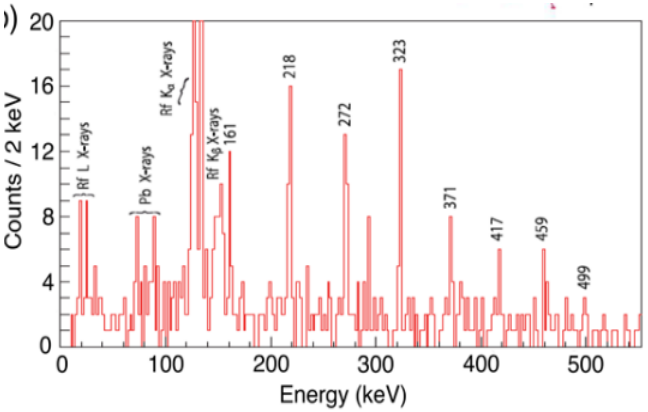


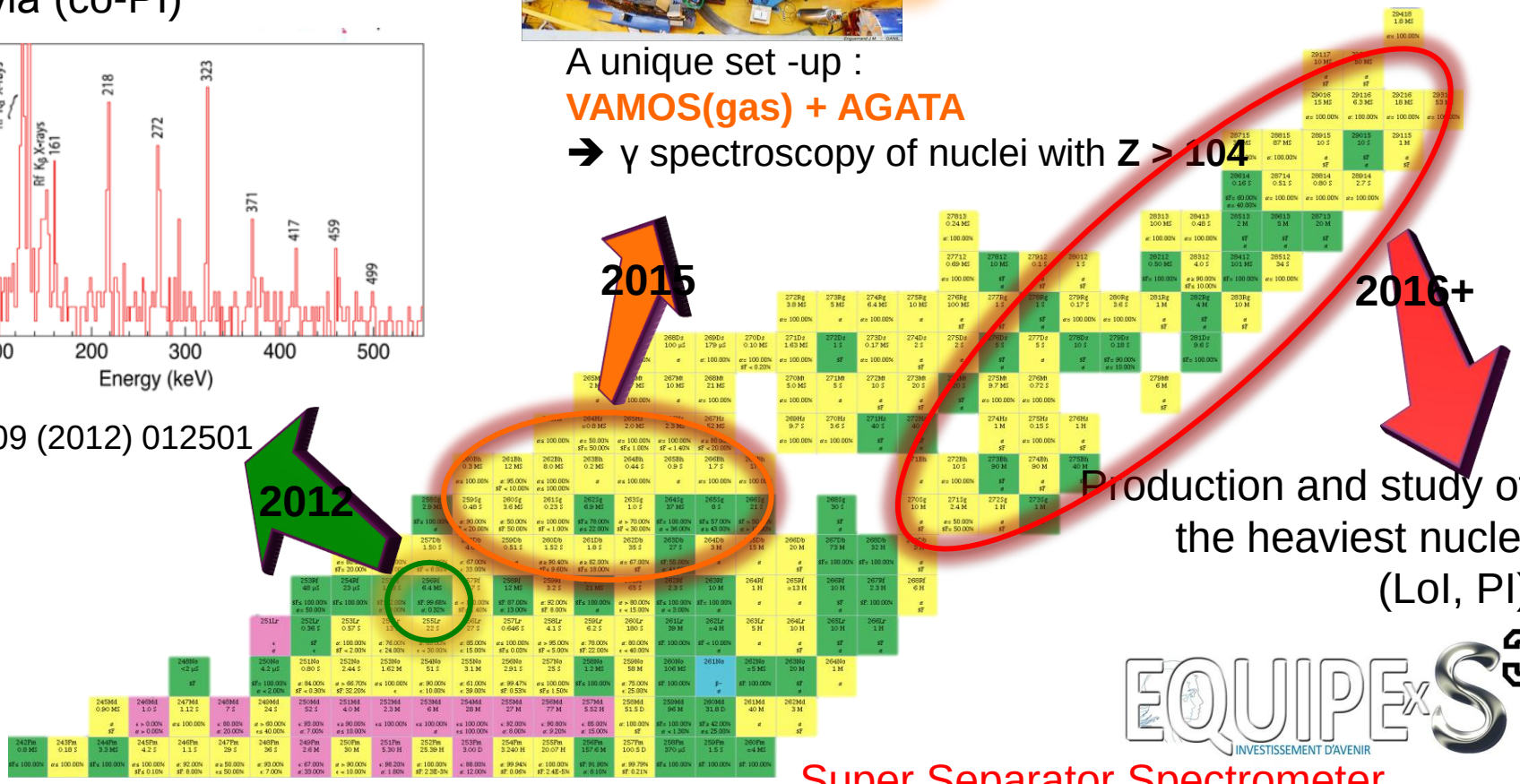
# Towards a superheavy island of stability

The heaviest ever studied:
$^{256}$Rf
Jyväskylä (co-PI)




PRL 109 (2012) 012501


A unique set -up :
**VAMOS(gas) + AGATA**
➔ γ spectroscopy of nuclei with **Z > 104**




Production and study of the heaviest nuclei (LoI, PI)

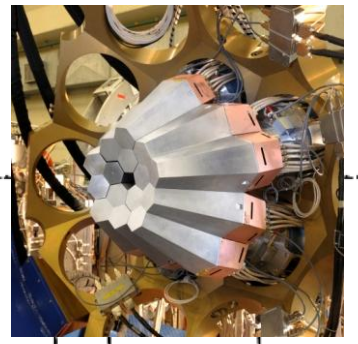
EQUIPEX S3 INVESTISSEMENT D'AVENIR

Super Separator Spectrometer
Co-leader of the project

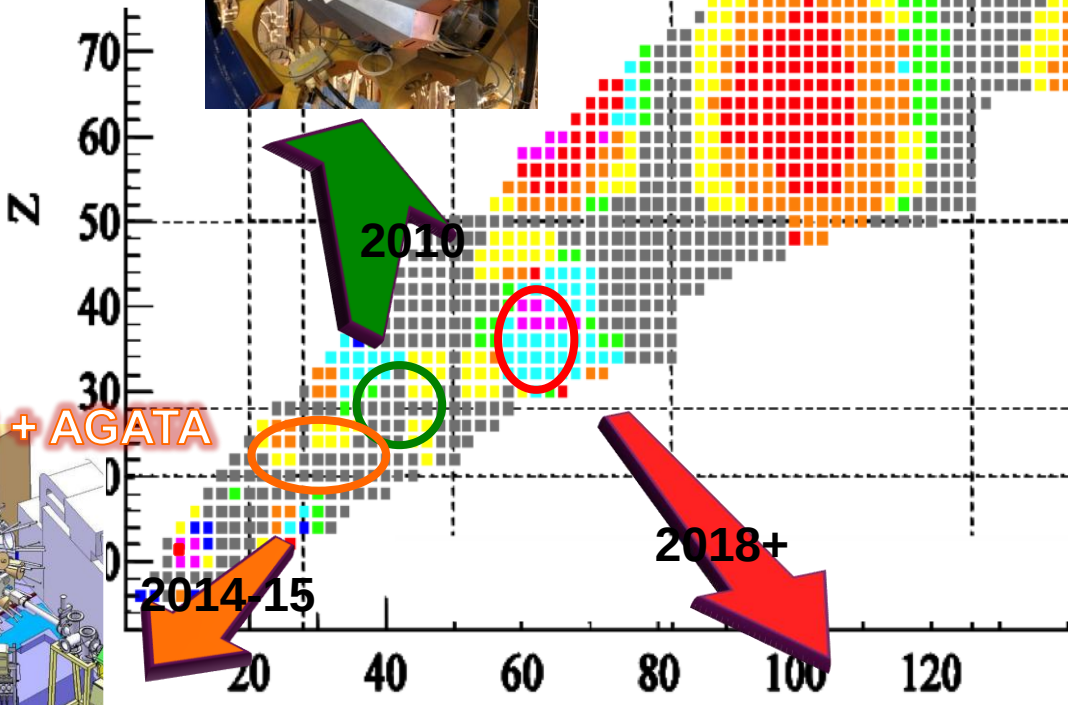
# Shapes and collectivity

Collectivity in $^{70\text{-}74}$Zn
Legnaro (PI, Thesis)

PRC 87, 054302 (2013)



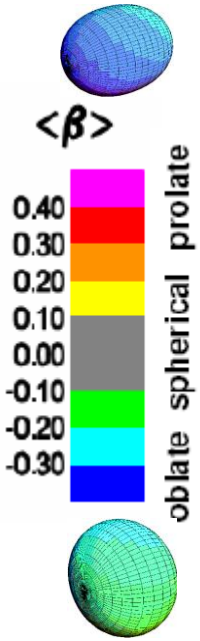
AGATA @ Legnaro






Hint for static octupole deformation in $^{224}$Ra

Nature 497 (2013), 157




Shape transition $^{94\text{-}96}$Kr

GANIL laboratoire commun CEA/DSM Spiral2 CNRS/IN2P3

Shape coexistence in fission fragments and rare earth
AGATA 1π @ Ganil

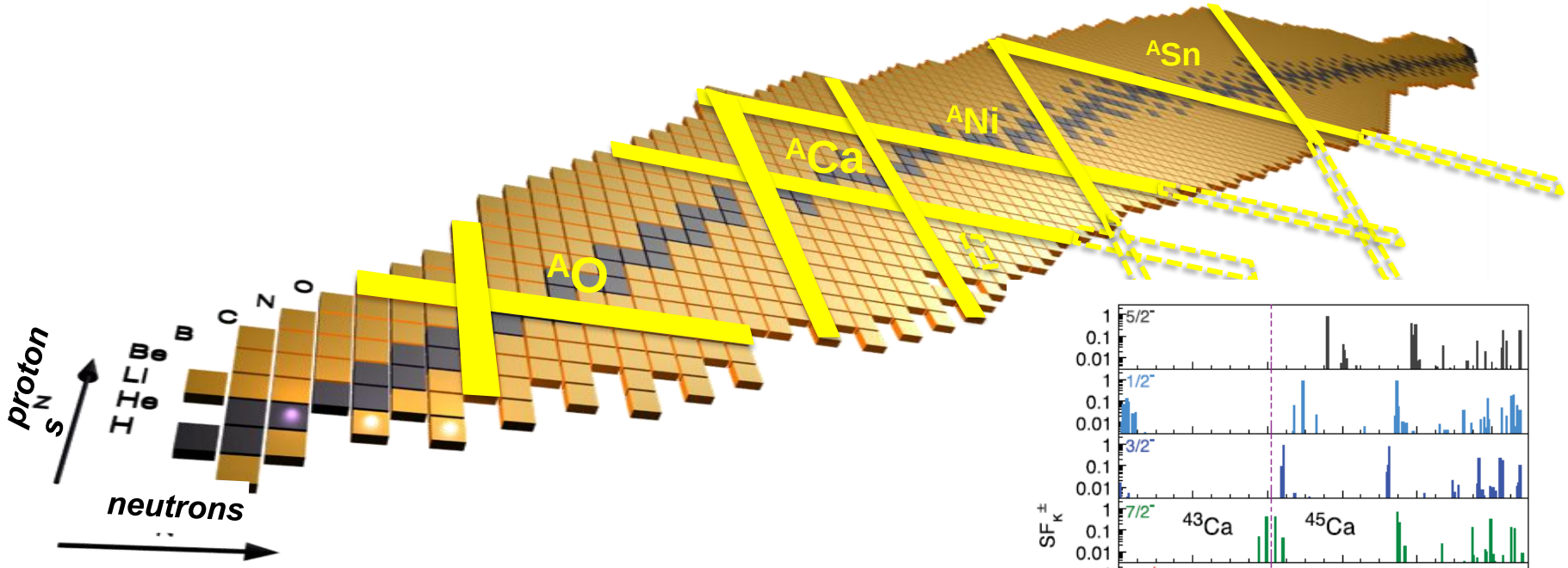
# Theoretical challenges

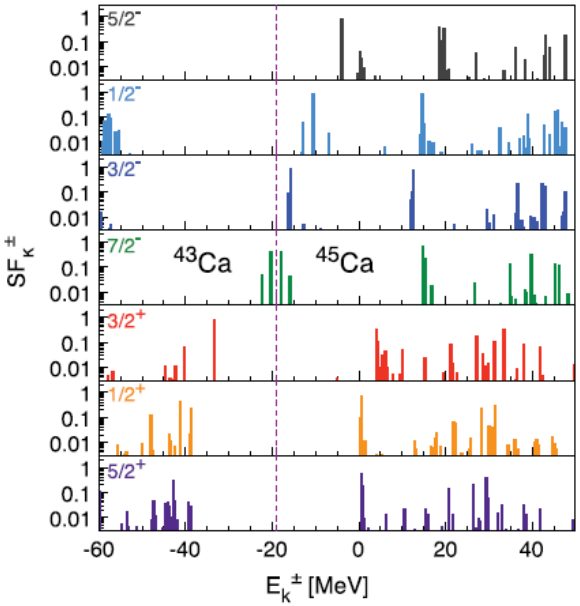

ESNT; a virtual lab for theoretical nuclear physics (CEA DAM/DSM)

- 100 visitors/year
- 5 workshops /year

**First ab initio calculations for medium mass semi-magic nuclei**

*Self-consistent Gorkov Green's functions theory*

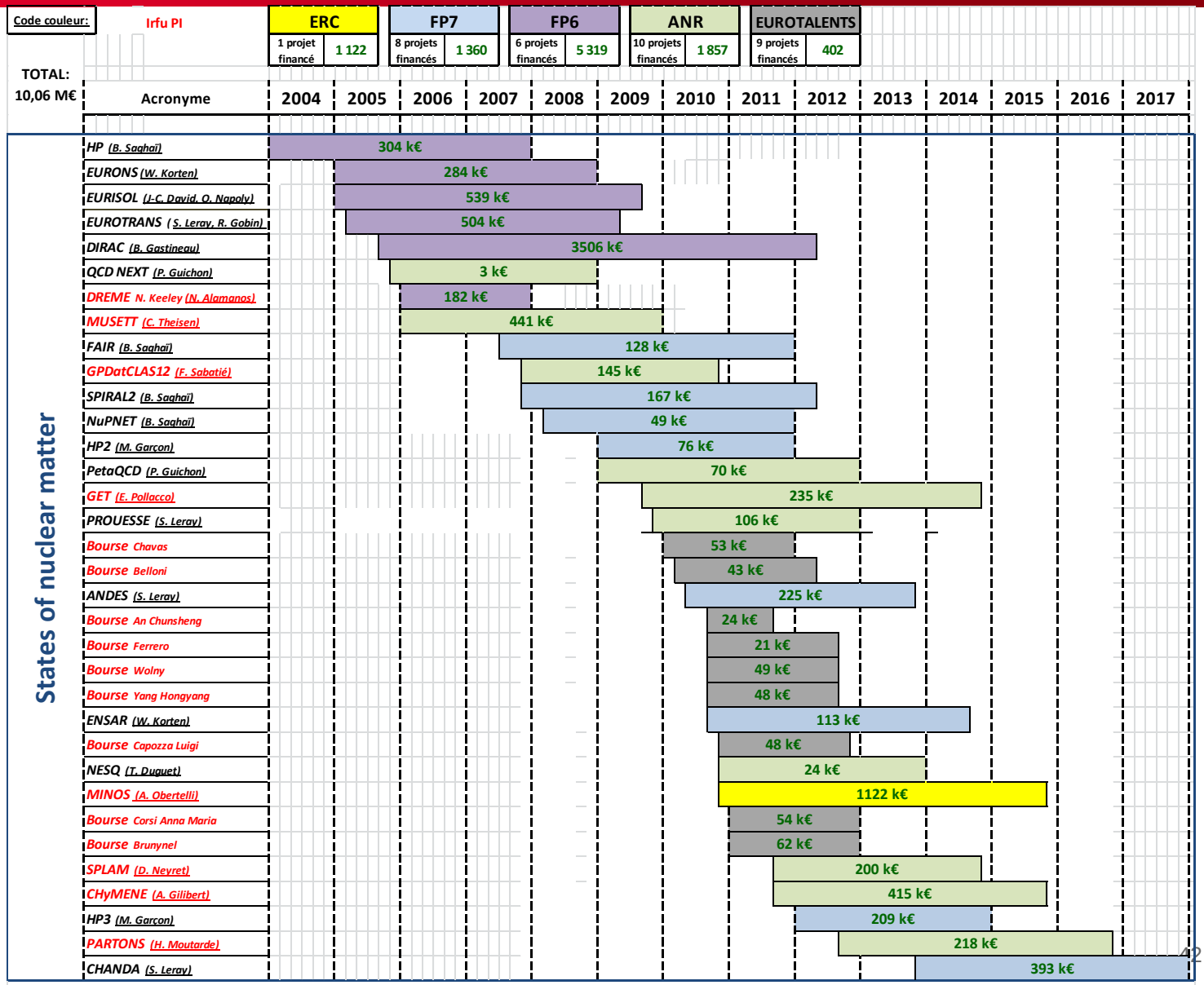


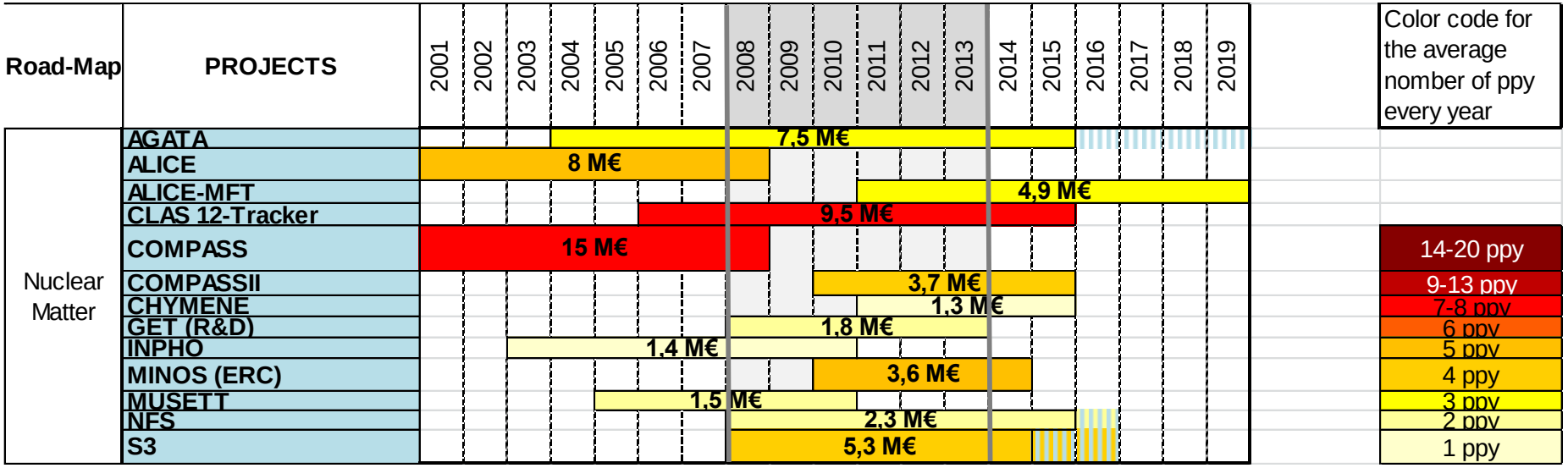

→ Use of high performance computers (GENSI)
→ Important for the description of exotic nuclei to be produced (SPIRAL2 …)

PRC 87, 011303(R) 2013.

# National and european grants

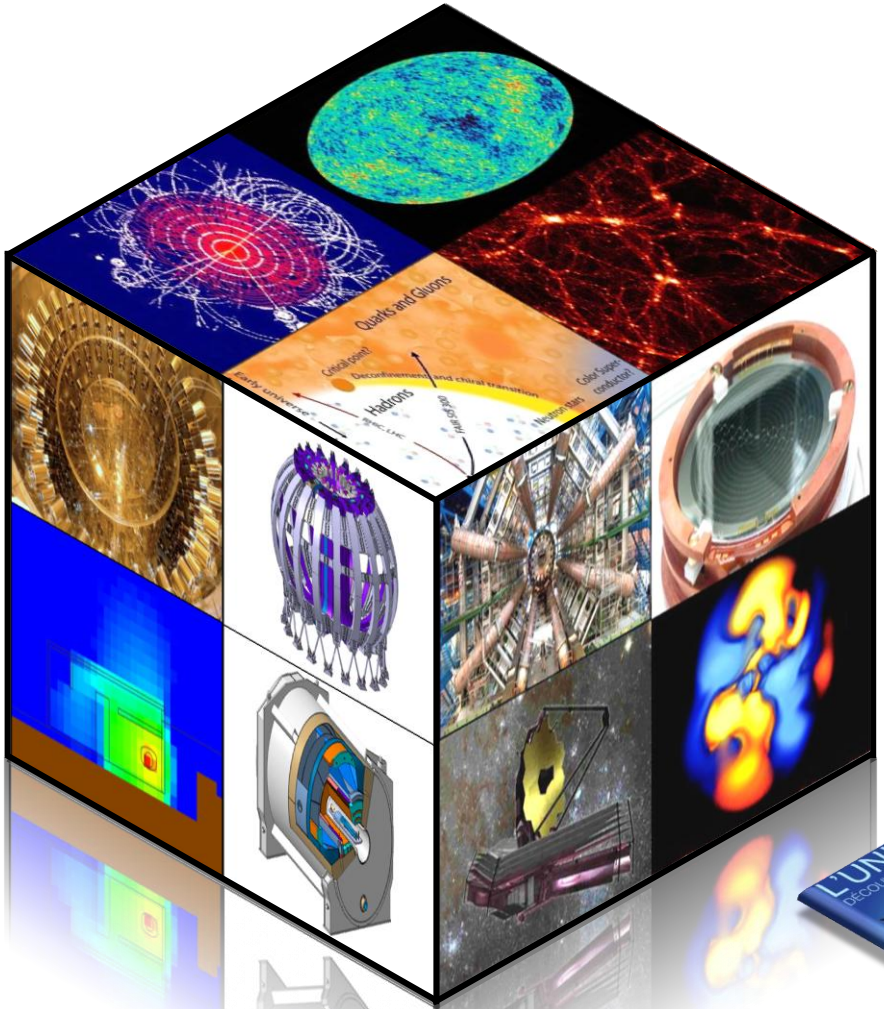


# Projects running between 2008 and 2013




In the short term, many new facilities and upgrades will start.

Very promising results in perspective !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Critical point
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  GANIL – SPIRAL2

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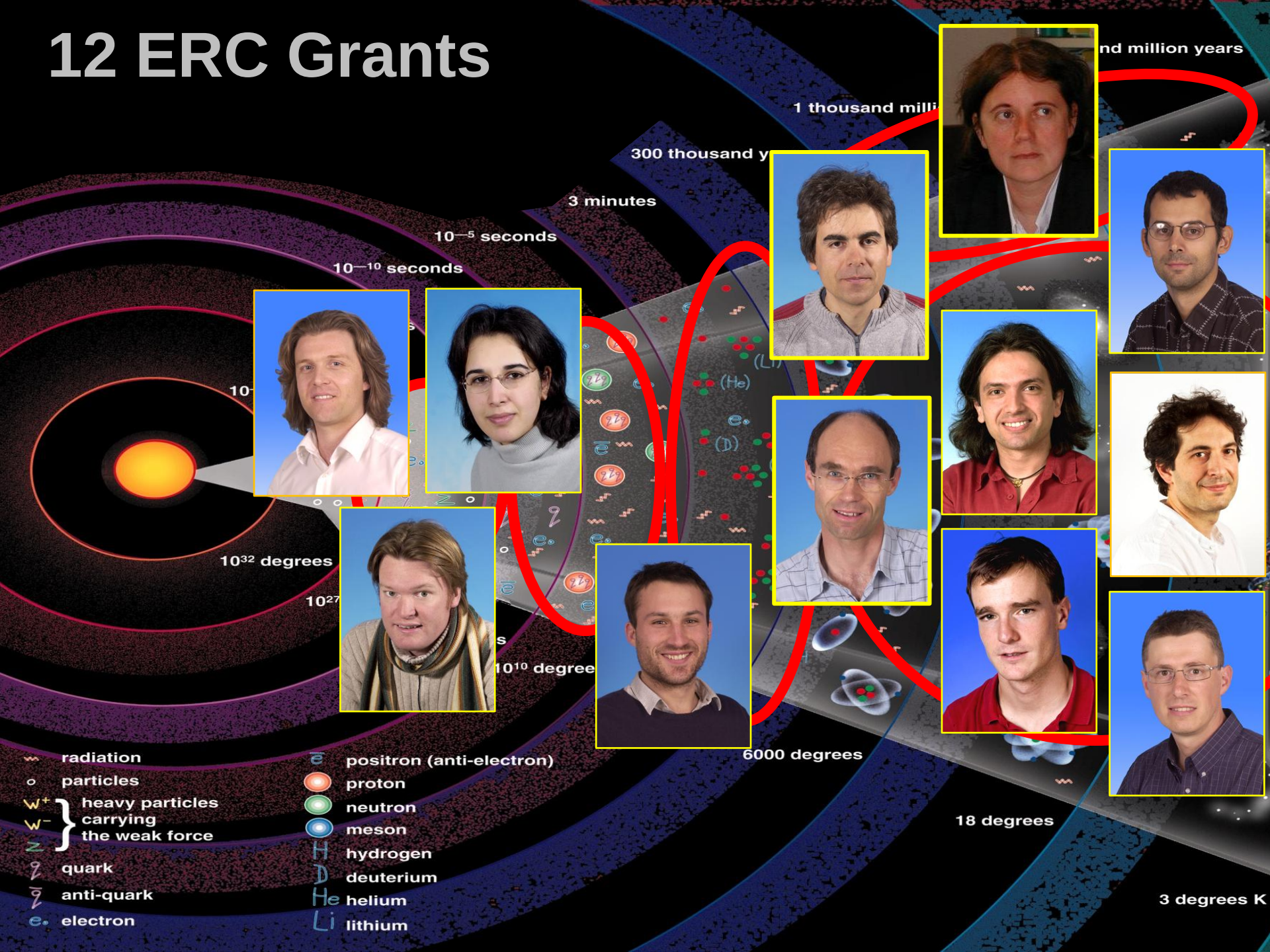
- **GRANTS, SCIENTIFIC PRODUCTION AND POLICY ON HUMAN RESOURCES**

# 12 ERC Grants



# BENCHMARK ON ERC WITHIN FRANCE

## Large proportion of French ERC

| Subatomic Physics | | |
|---|---|---|
| | FTE Physicists | ERC |
| France | 1100 | 7 |
| CEA/Irfu | 120 | 4 |
| | 11% | 57% |

| Astrophysics | | |
|---|---|---|
| | FTE Physicists | ERC |
| France | 800 | 23 |
| CEA | 41 | 8 |
| | 5% | 35% |

# LEVEL OF INTERNATIONAL RELATIONS

| | |
|---|---|
| 92 | Responsibilities in conference organisation |
| 221 | Mandates international scientific boards |
| 305 | Operational responsibilities in international collaborations |
| 105 | responsibilities in international oversight and steering of research |

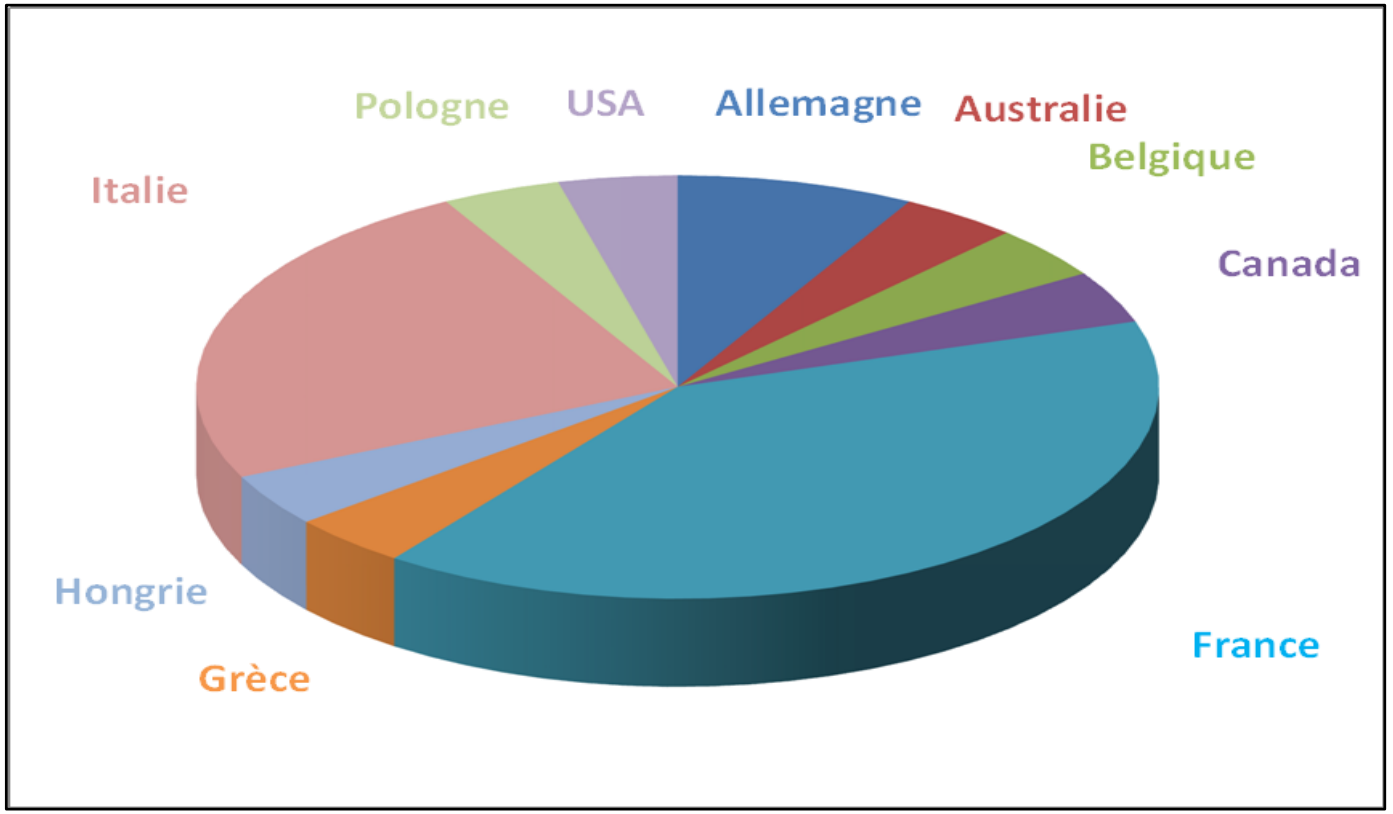
- **Formal participation at European an global**
  - Organisations : CERN (chair of Dir. Meetings, member of RRB's and committees), ESA et ESO
  - Board of ESFRI facilities: CTA, ESS, X-FeL, GANIL
  - Coordination boards: APEC/ASPERA, NUPECC/NUPNET, OECD/APIF

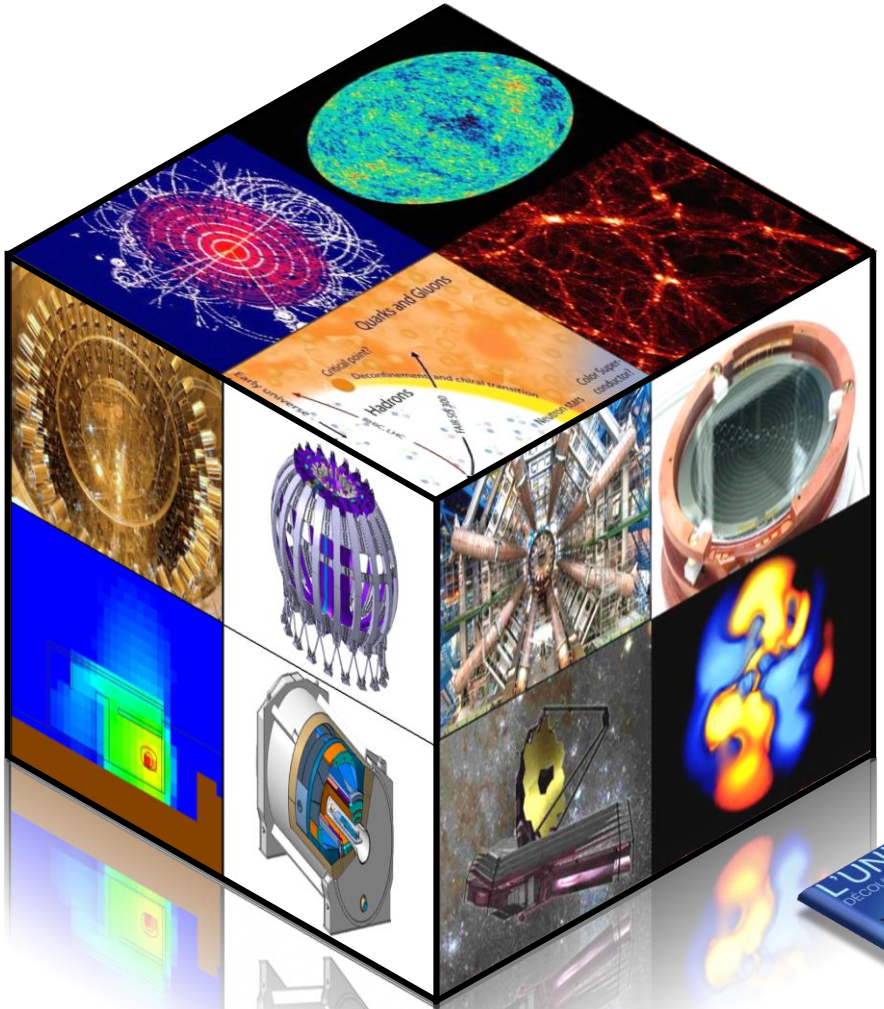
- **Bilateral connexions (regular meetings)**
  - USA : DOE, NSF,NASA
  - Japon : JAEA, KEK, Riken
  - Europe : BMBF, STFC, INFN
  - Israel : Soreq

# PERFORMANCES
# SCIENTIFIC PRODUCTION

| Performance indicators (2008 – mi-2013) | |
|---|---|
| **154** | **Permanents Physicists** (mean FTE) |
| 4 063 | Articles (rang A) |
| 388 | *PRL, Nature* et *Science* |
| 322 | Cited more than 50 times |
| 108 | Cited more than 100 |
| 81 900 | citations, ie 7 citations per article and per an |
| 12 | % articles in the top 1%, 2% in the top 0,1% |
| 1608 | Oral presentations in conferences (2008-2012) |
| 92 | Responsabilities in conference organisation |
| 223 | PhD thesis |
| 140 | Habilitations to lead researches |
| 352 | Years of post-docs |
| 150 | Contrats of researche (ANR, FP7, .. ;) |
| 12 | ERC grants including 3 *advanced* |
| 37 | Awards and distinctions |
| 221 | Mandates international scientific boards |
| 305 | Operational responsabilities in international collaborations |
| 15 | Editorial responsabilities |
| 105 | responsabilities in international oversight and steering of research |

- **International attractiveness**
  - Origin of PhD of the 25 physicists hired on a permanent contract

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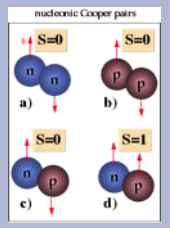
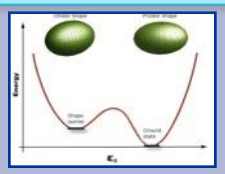
L'UNIVERS
DÉCOUVREZ SES MYSTÈRES
ANNÉE MONDIALE DE L'ASTRONOMIE
2009

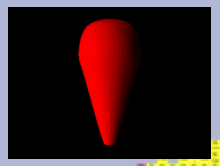
# Physics case for the AGATA campaign in GANIL

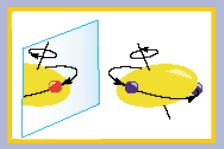
Workshop February 2013 : **47** LoI (**669** days of beam requested)

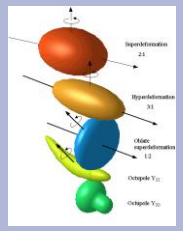
PAC April 2014: **26** proposals for the first AGATA campaign (**242** days requested)

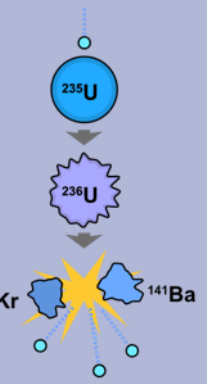


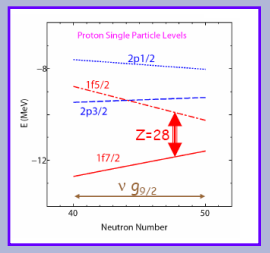



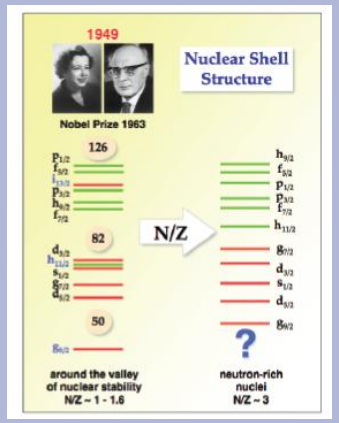









$^{256}$Rf
$^{254}$No
Cm,Bk
Cf,Es
$^{238}$U
$^{194}$Pb
$^{176}$Hg
Sm,Pm
$^{206}$Hg
$^{102}$Sn
Dy,Er,Yb
$^{100}$In
Ru, Pd
Xe,Te
$^{80}$Zr
Zr, Mo
$^{132}$In
$^{77}$Y
$^{75}$Sr
Zr, Sr
$^{78}$Ni
$^{80}$Zn
$^{63}$Ge
$^{68}$Ni,Fe,Co,Cu
$^{46}$Ti
$^{38}$K
$^{34}$Ar
$^{46,48}$Ca
S,Cl,Ar,K
Ne,Na

*Courtesy of Silvia Lenzi*