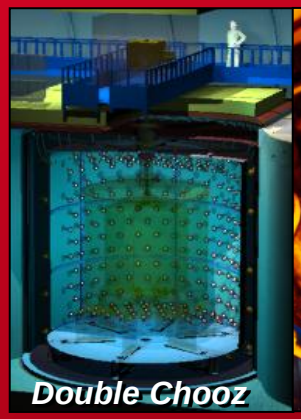
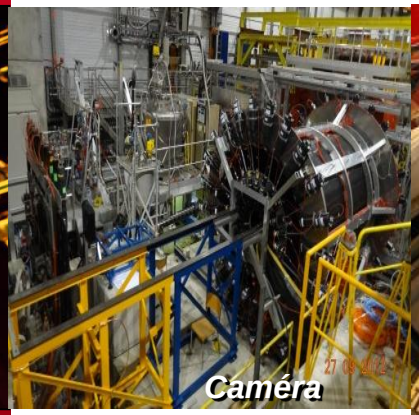
Irfu 2020 Plan
2008-2013 Report

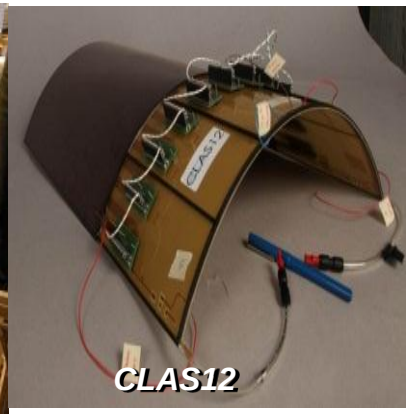
DE LA RECHERCHE À L'INDUSTRIE

SPHN

THE NUCLEAR PHYSICS DEPARTMENT







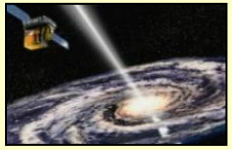
AERES Visit

Héloise Goutte

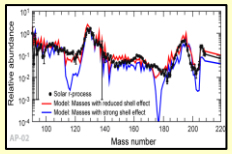
JANUARY 7TH TO 10TH 2014

IRFU ORGANIZATION WITHIN CEA

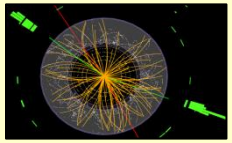
Institute of Research into the Fundamental laws of Universe



Astrophysics
Space technologies



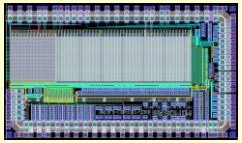
Nuclear Physics



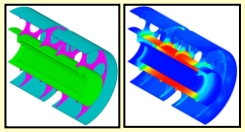
Particle Physics

Accelerators,
Supra. Magnets

Detectors, electronic,
computing

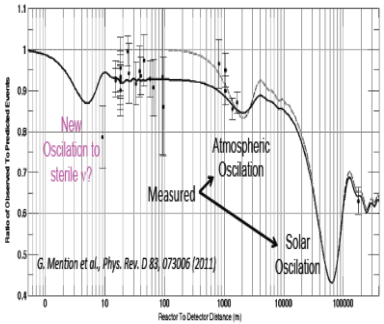


Systems engineering

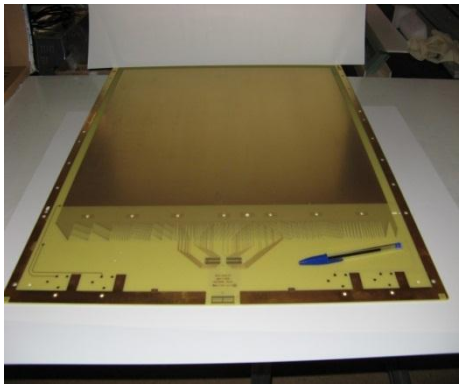


Our mission

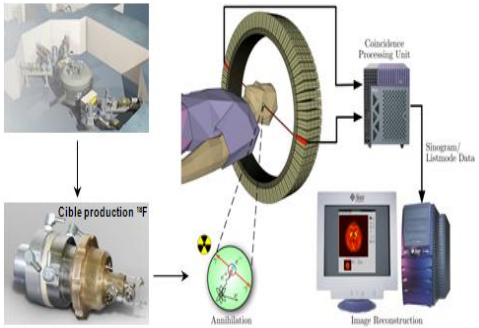
Discovery



Innovation



Service of society



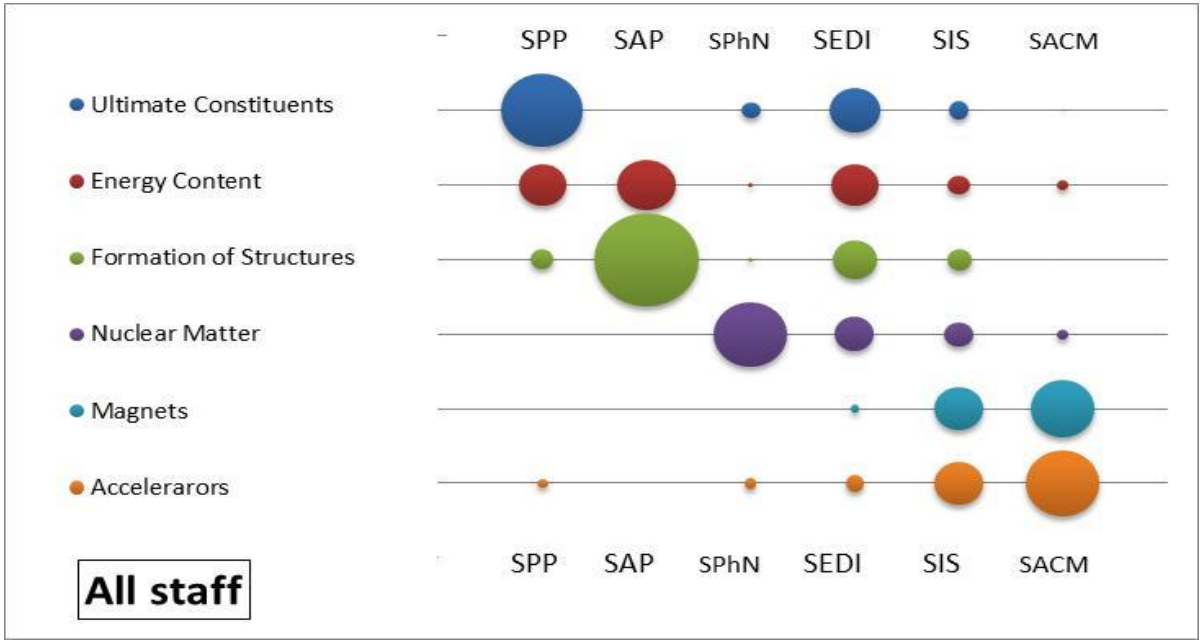
with SEDI, SIS, SACM

Training

Communication

Contributions to the strategic plans of Irfu

- Fundamental research

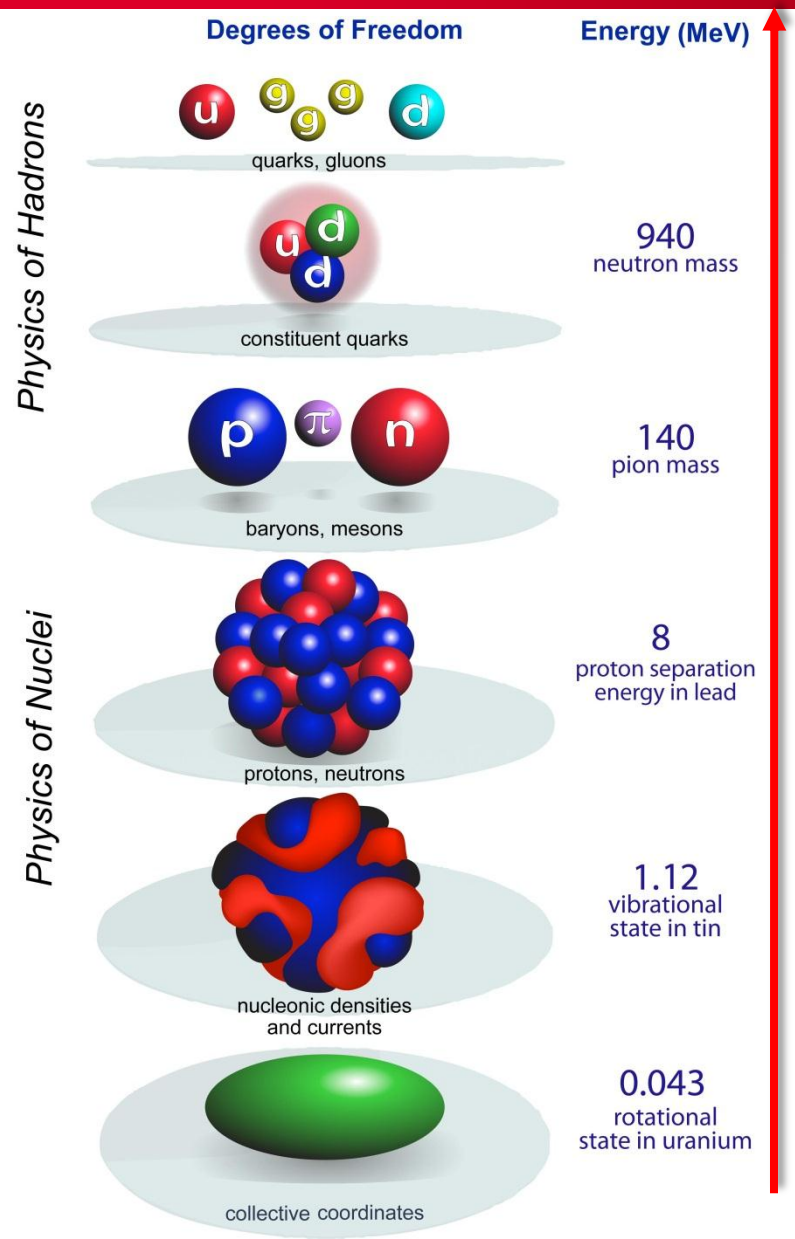


- What are nuclear matter self-organization processes ?

-What are the ultimate constituents of matter ? (neutrino's study)

- Expertise in the service of society.

Nuclear matter studies: the scientific context



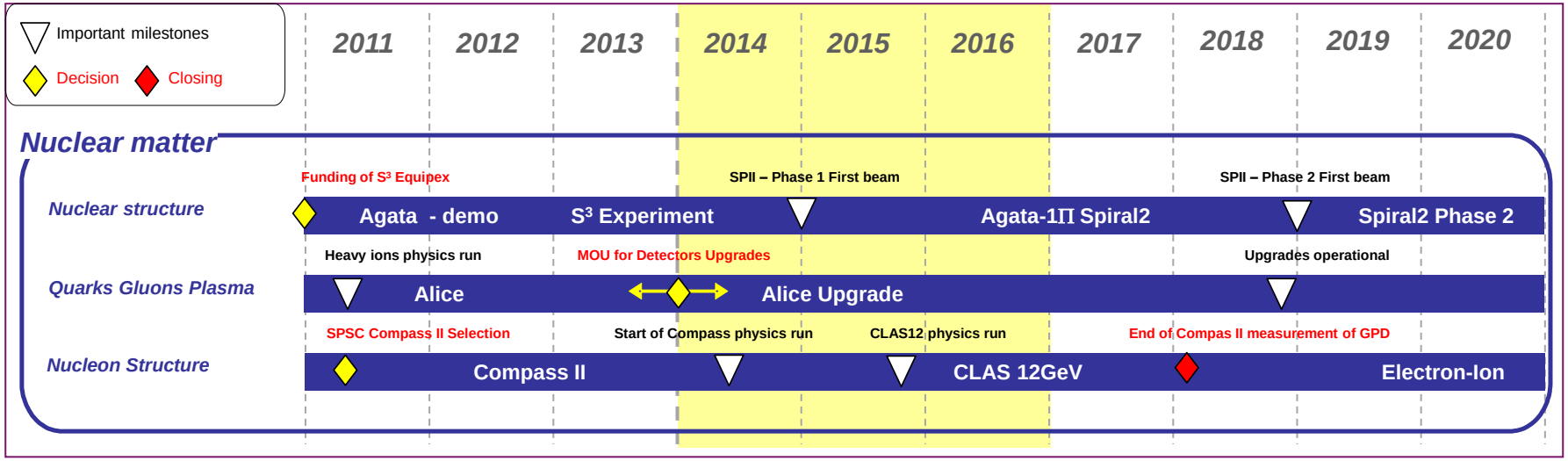
Hot and dense quark-gluon matter

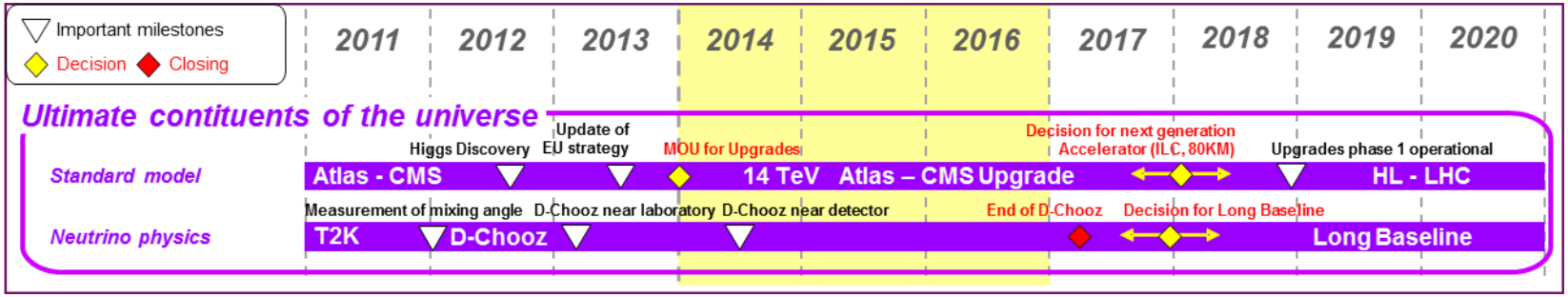
Hadron structure

Nuclear structure
Nuclear reactions

Applications of nuclear science

The Irfu's roadmap





The nuclear physics department

Head

Deputy

Secretariat

Technical support

Quark-gluon plasma

Nuclear structure

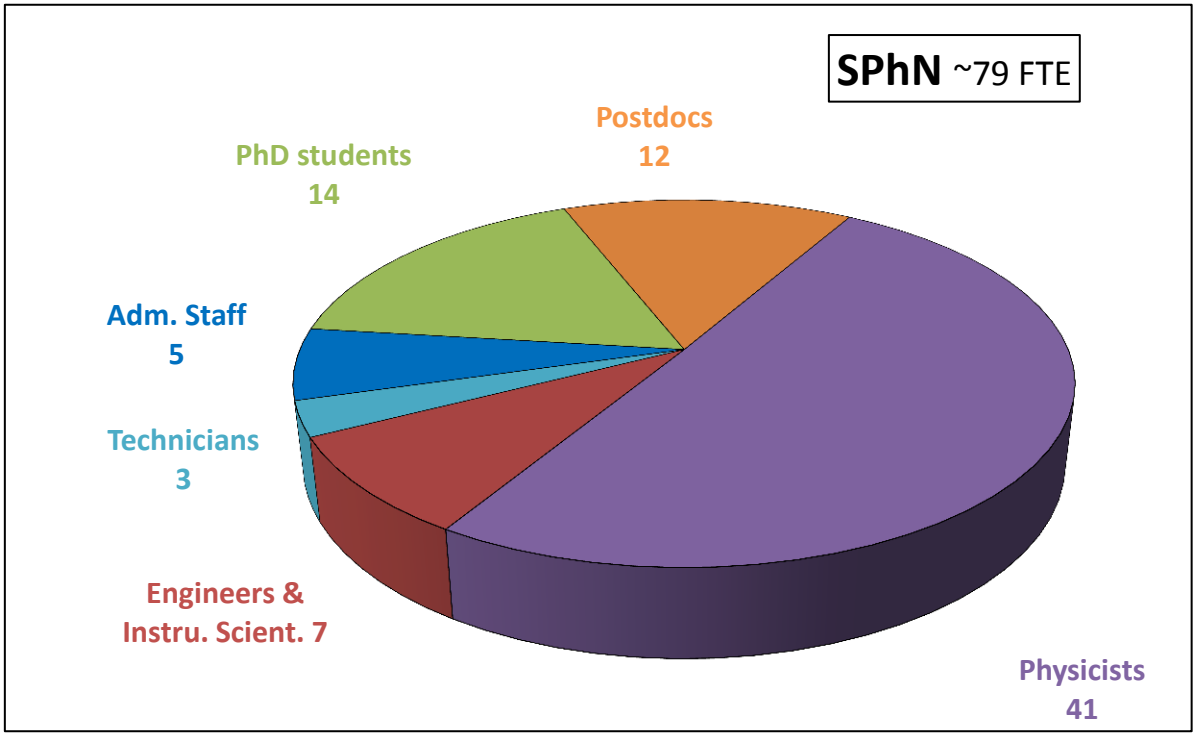
Nuclear reactions and applications

Structure of the nucleon

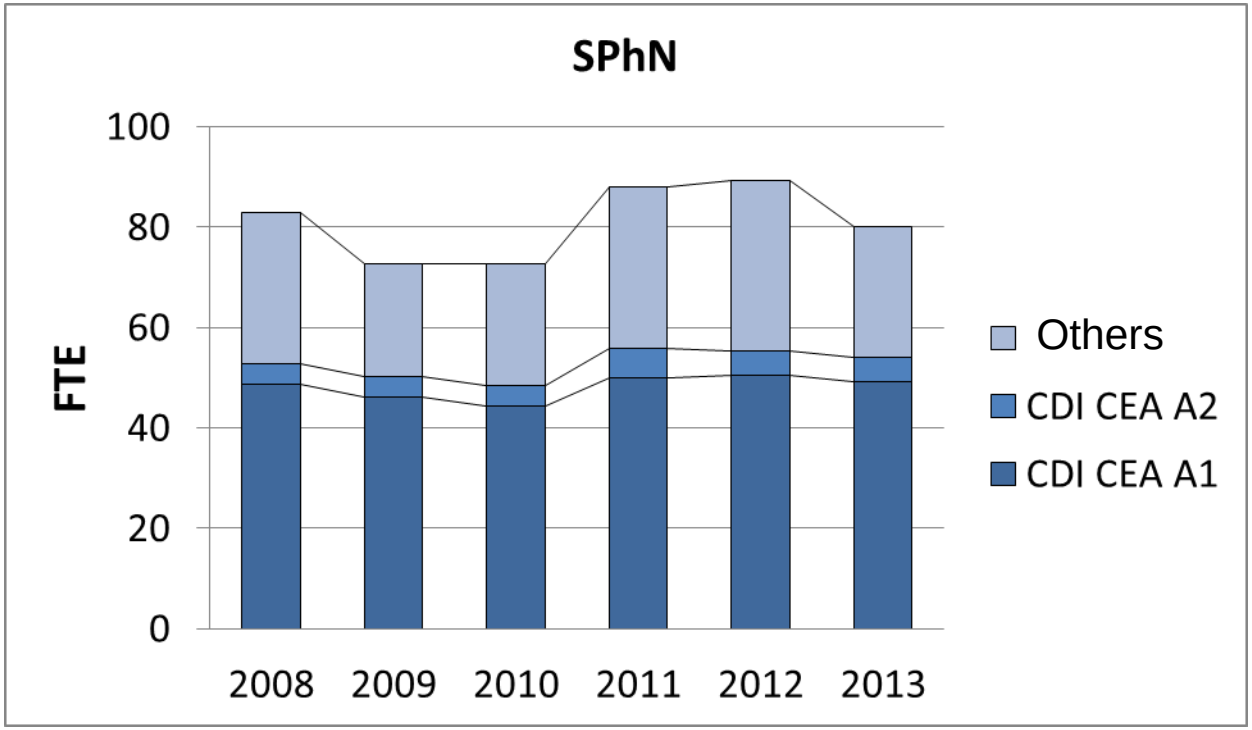
Expertise in design and decommissioning

Dec. 2013

The SPhN in numbers

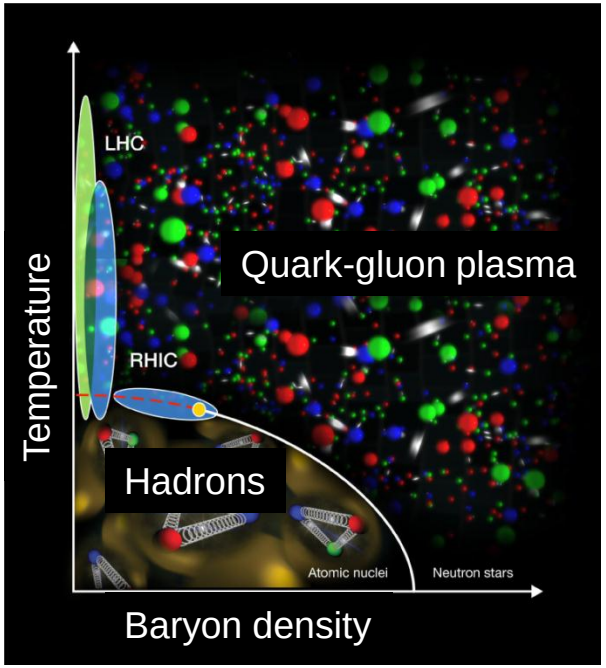


Evolution of the staff during the 2008-2013 period



- integration in 2011 of the department of nuclear expertise in design and decommissioning as a SPhN laboratory.

Scientific issues and our positioning
In the study of
The Quark and Gluon Plasma



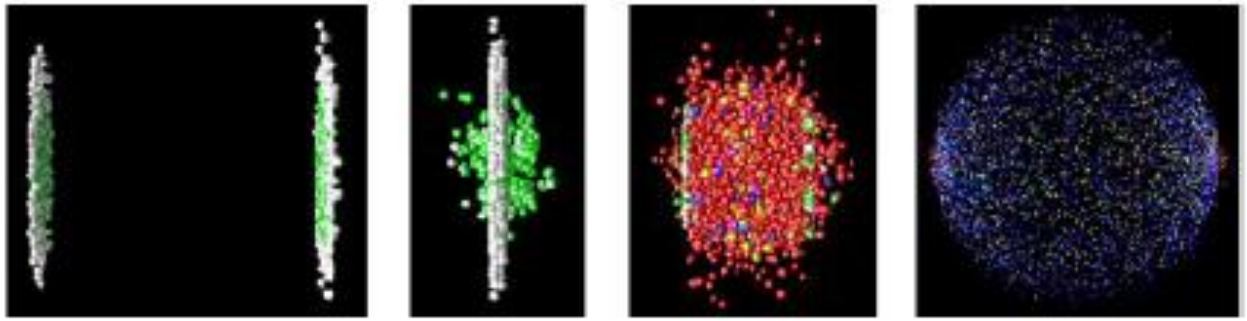
Quark - gluon plasma : burning questions !

- What is the nature of matter at ultra-high temperature and density ?

- Which are their microscopic degrees of freedom and excitations ?

- Which are the macroscopic transport properties and equation of state ?

Simulation URQMD

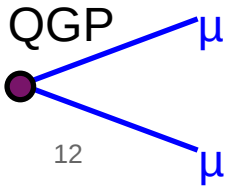


Initial conditions expansion Hadronization and freeze-out

Our positioning:

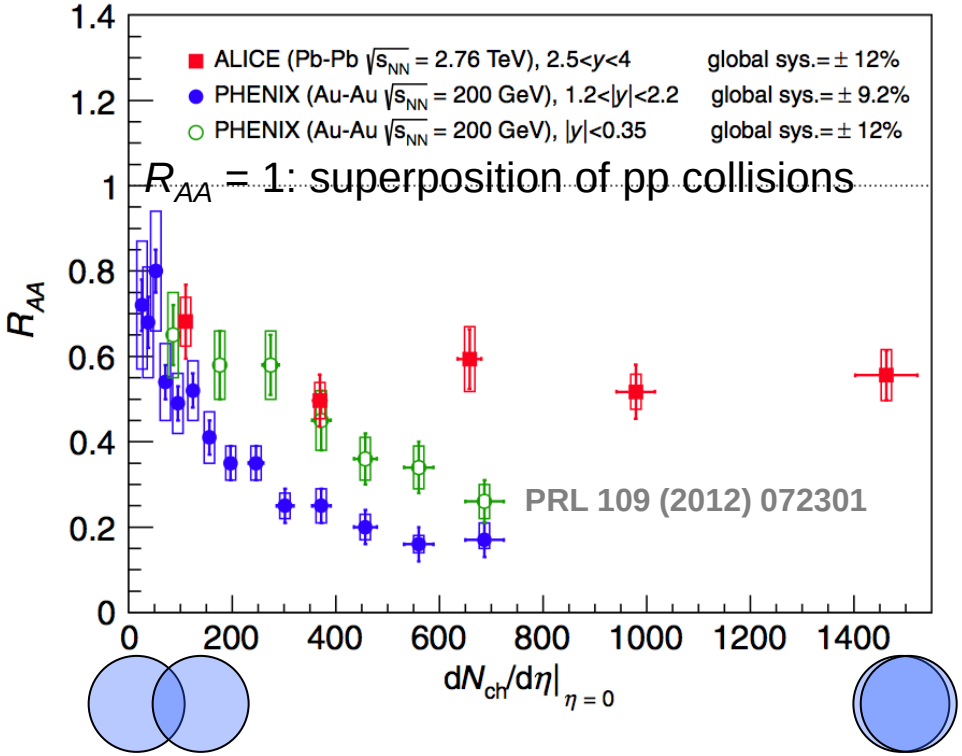
- Study of the J/Psi particles (a charm anti-charm pair) as probes of the QGP

- Detection of the J/Psi particles using the ALICE muon spectrometer



Recent highlight

R_{AA} : production of J/Psi in Pb-Pb versus pp collisions



From RHIC to LHC :

a QGP with a higher temperature but less suppression observed

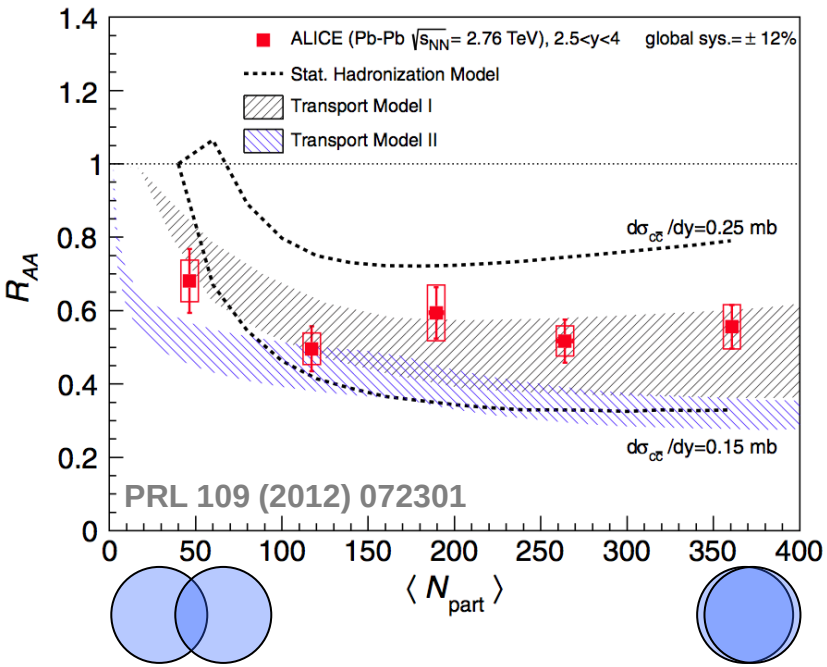
→ Recombination ?

<u>Publications:</u>

- R_{AA} : PRL 109 (2012) 072301, **Saclay coordinator of the paper committee**
- Reference pp : PLB 718 (2012) 295, phD thesis of C. Geuna
- Flow : PRL 111 (2013) 162301, postdoc H. Yang, **Saclay coordinator of the paper committee**

Recombination of c quarks ?

In qualitative agreement with the models including a fraction of J/Psi recombination



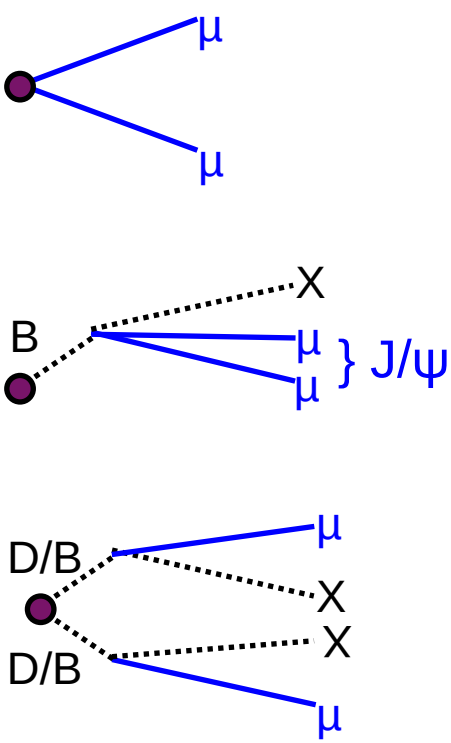
Firmer and quantitative conclusions are limited by

- Low statistic (in particular for the elliptic flow)
- An inclusive J/ψ measurement (contamination of the J/ψ coming from B)
- Uncertainties in the cross section of the c production

The MFT for the high luminosity @LHC (2018+)

MFT: Muon Forward Tracker :
to overcome the actual limitations
and broaden the spectrum of reachable physics

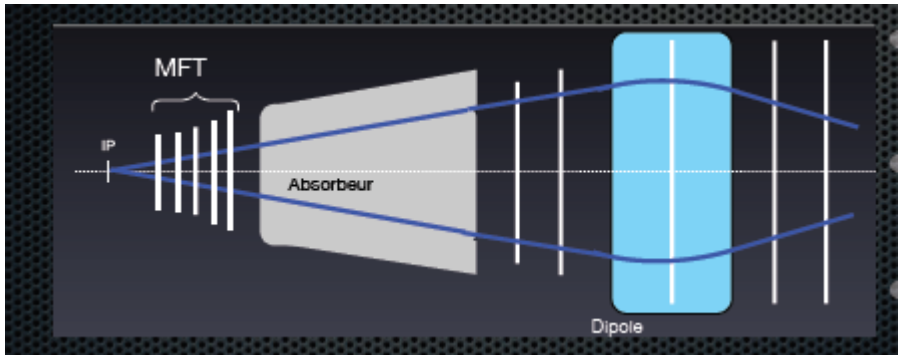
- Identification of secondary vertex to separate the different J/Psi contributions



Recombination ?

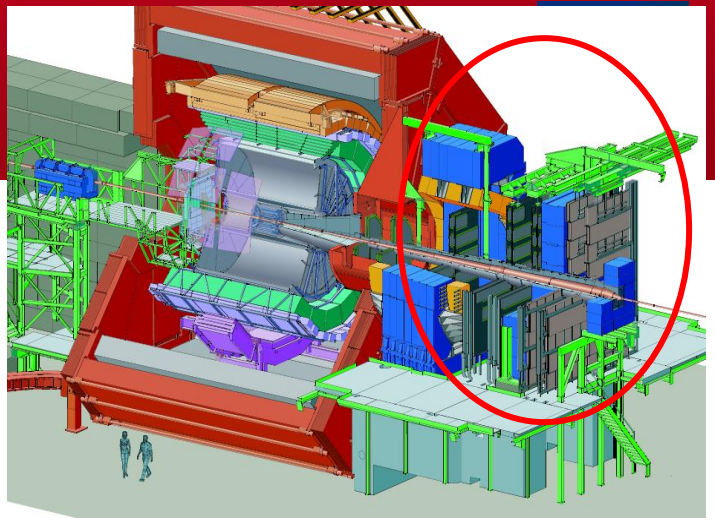
Measure of the B production

Production cross section of c



Accepted by the ALICE coll. : march 2013
Accepted by the LHCC: sept 2013

Responsibilities



- **Hardware, software, data analysis**

  - **Project leader of the ALICE muon spectrometer**
  - Coordinator of the ALICE muon tracking upgrade
  - Technical coordinator of the MFT
  - Convener of the physics analysis group $\Upsilon \rightarrow \mu\,\mu$
  - Responsible for the alignment and calibration
  - Members of many paper and review committees of the ALICE collaboration

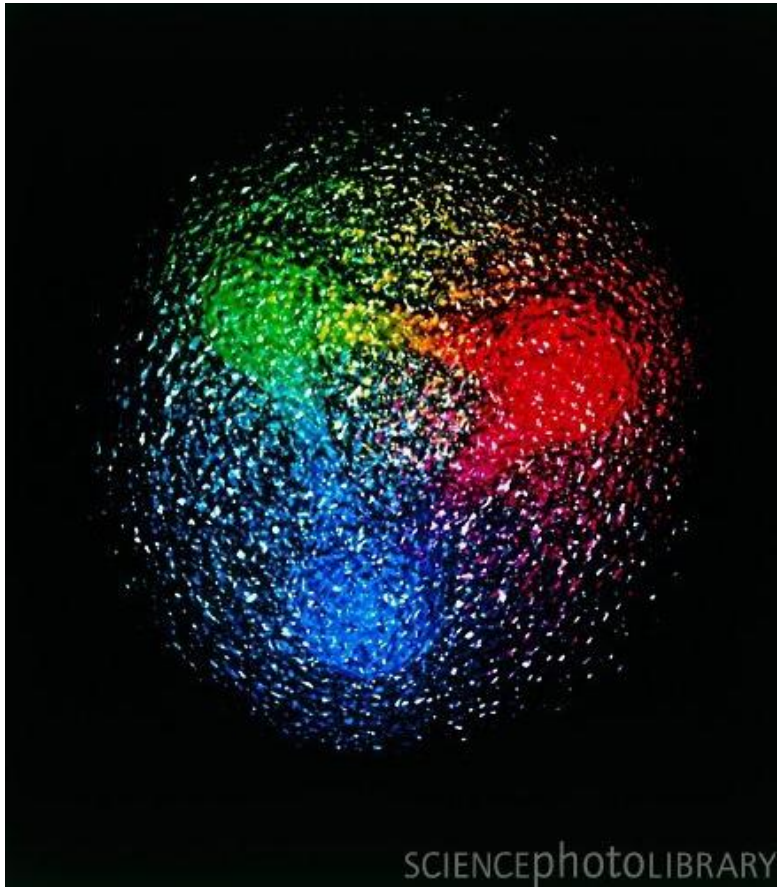
With SEDI

Scientific issues and our positioning

In the study of

The nucleon structure

Burning questions



- How hadrons are formed and interact from QCD degrees of freedom ?

→ Lattice QCD calculations

- How does the proton spin originates at the microscopic level ?

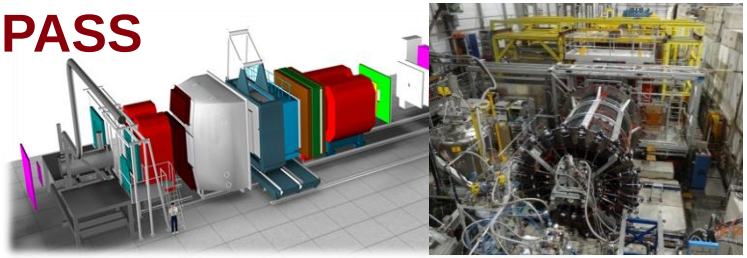
→ Measuring pertinent spin sum rules

- How does confinement manifests itself in the structure of hadrons ?

→ Space and momentum distributions of quarks and gluons inside a nucleon
→ Generalized Parton Distributions
→ Extracted through DVCS experiments
(Deep Virtual Compton Scattering)

The actors on two sites: CERN/COMPASS and Jefferson Lab/CLAS

COMPASS

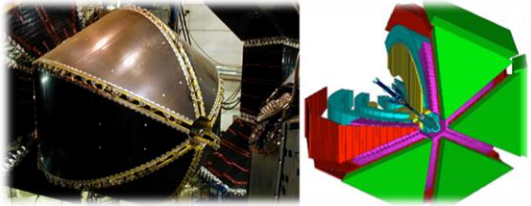


International Collaboration , ~220 members

Responsibilities in the collaboration:
Co- spokesperson of the coll., analysis coordinator., technical coordinators, members of the group leader board

Leadership : Longitudinal Spin program, DVCS
Funding: FP6, FP7, *ANR SPLAM*, ANR PARTONS, P2I, NSF

CLAS



International Collaboration, ~200 members

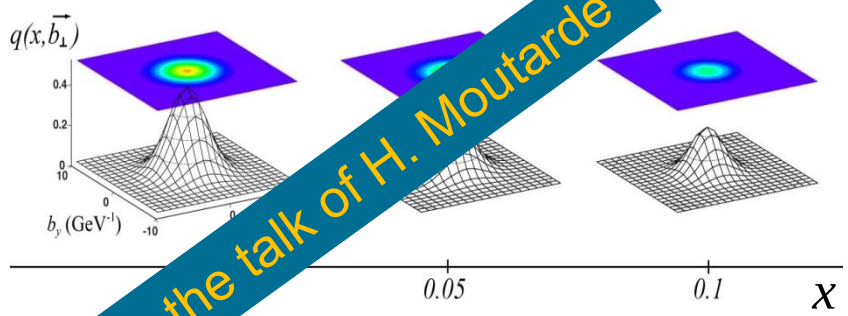
Responsibilities in the collaboration:
Spokesperson of exps., member of the steering committee, member of the user board

Leadership : DVCS, phenomenology
Funding: FP6, FP7, *ANR GPD@CLAS12*, ANR SPLAM, *ANR PARTONS*, P2I(O), DOE

Highlight on Nucleon 3D-imaging

A Software platform for Generalized Parton Distribution phenomenology
(ANR PARTONS, Saclay P.I.)

First realistic nucleon transverse profiles



Valence quarks: close to the center
Sea quarks: with a larger spatial extension

More details during the talk of H. Moutarde

Platform for the community:

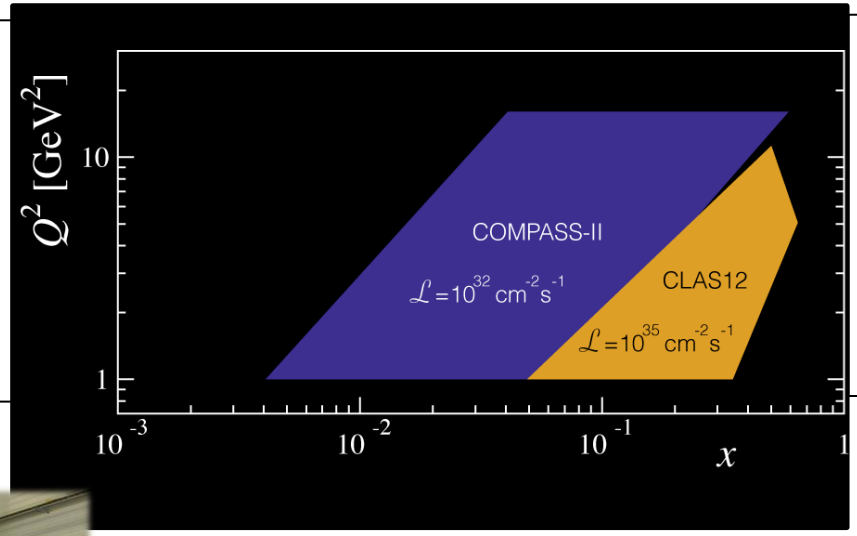
- GPD modeling
- GPD extraction from world experimental data
- Design of future experiments (JLab12/EIC)

A unique framework for 3D nucleon imaging

Short and mid terms– a coherent physics program

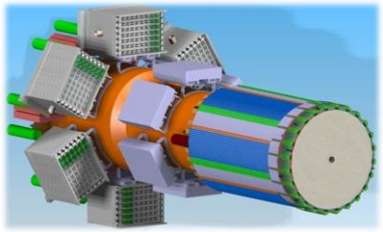
COMPASS-II

Muon beam
Energy: 160 GeV
Intermediate Luminosity
Sea quarks and gluons



CLAS12

Electron beam
Energy: 11GeV
High Luminosity
Valence quarks

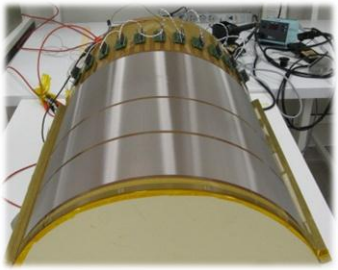


tracker

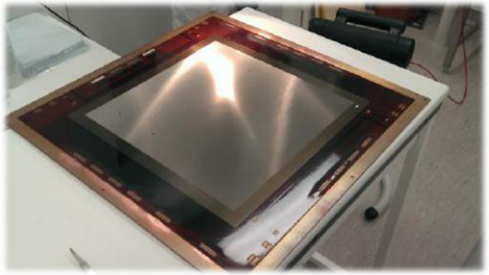
Camera

2012-14 : analysis, tech. devlpt …
2015-16 : data taking CLAS12
2016-17 : data taking COMPASS-II

2017-2018 : first 3 D imaging



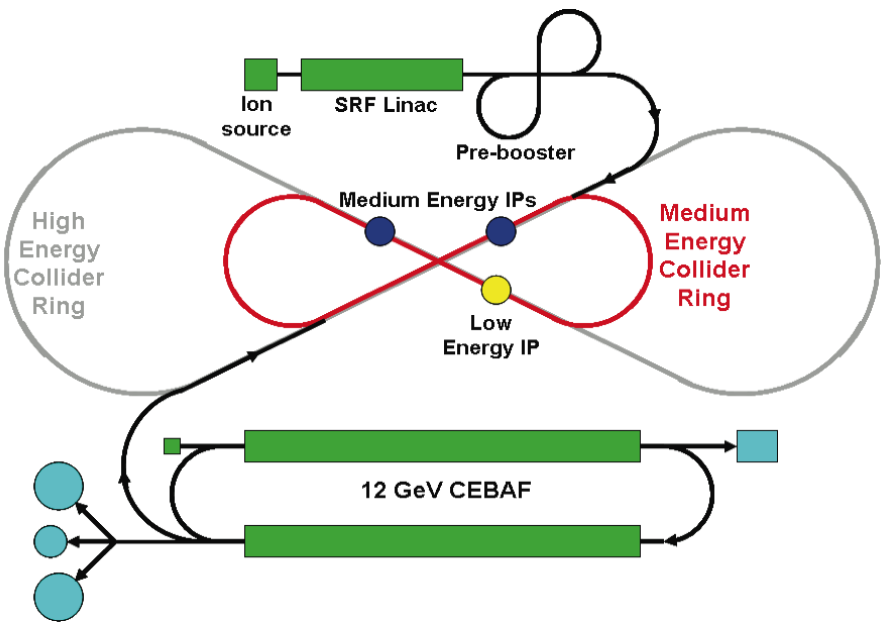
Bent tile



Pixellized micromegas

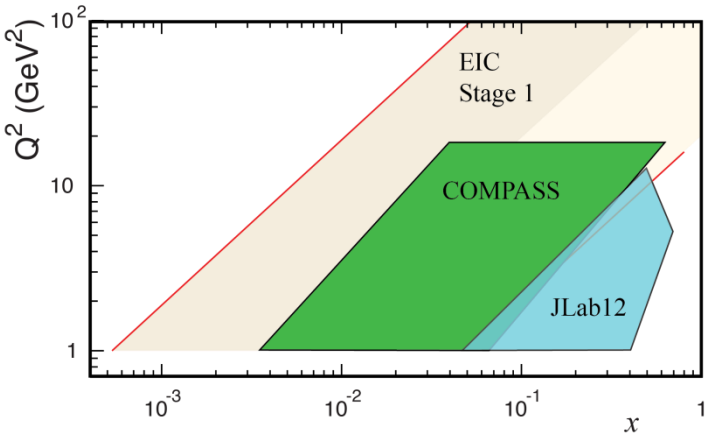
Long term– towards EIC an electron-ion collider

Stage1 : 5 GeV e^- on 100 GeV protons/nuclei
Target date : 2025



Jefferson Laboratory proposal

Participation of IRFU;
- Member of the steering committee
- Member of the White Paper writing committee



Technological development and interdisciplinary research

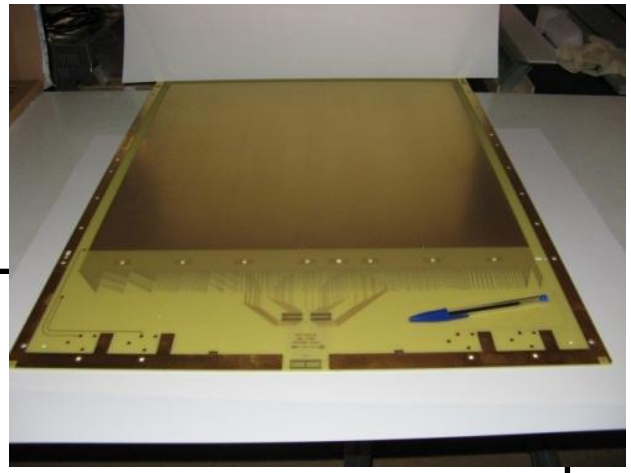
A multiplexed micromegas patented (2013)

→ easily adaptable to the flux of particles

→ well suited for micro channels, drift chambers and scintillators

→ can equip up to $p^2/2$ channels with only p electronic channels

Concept validated on a Micromegas 50x50 cm^2



Foreseen applications:

- Particle physics
- Homeland security
- Muonic tomography (collaboration with Institut de Physique du Globe)
- Archeology
- …

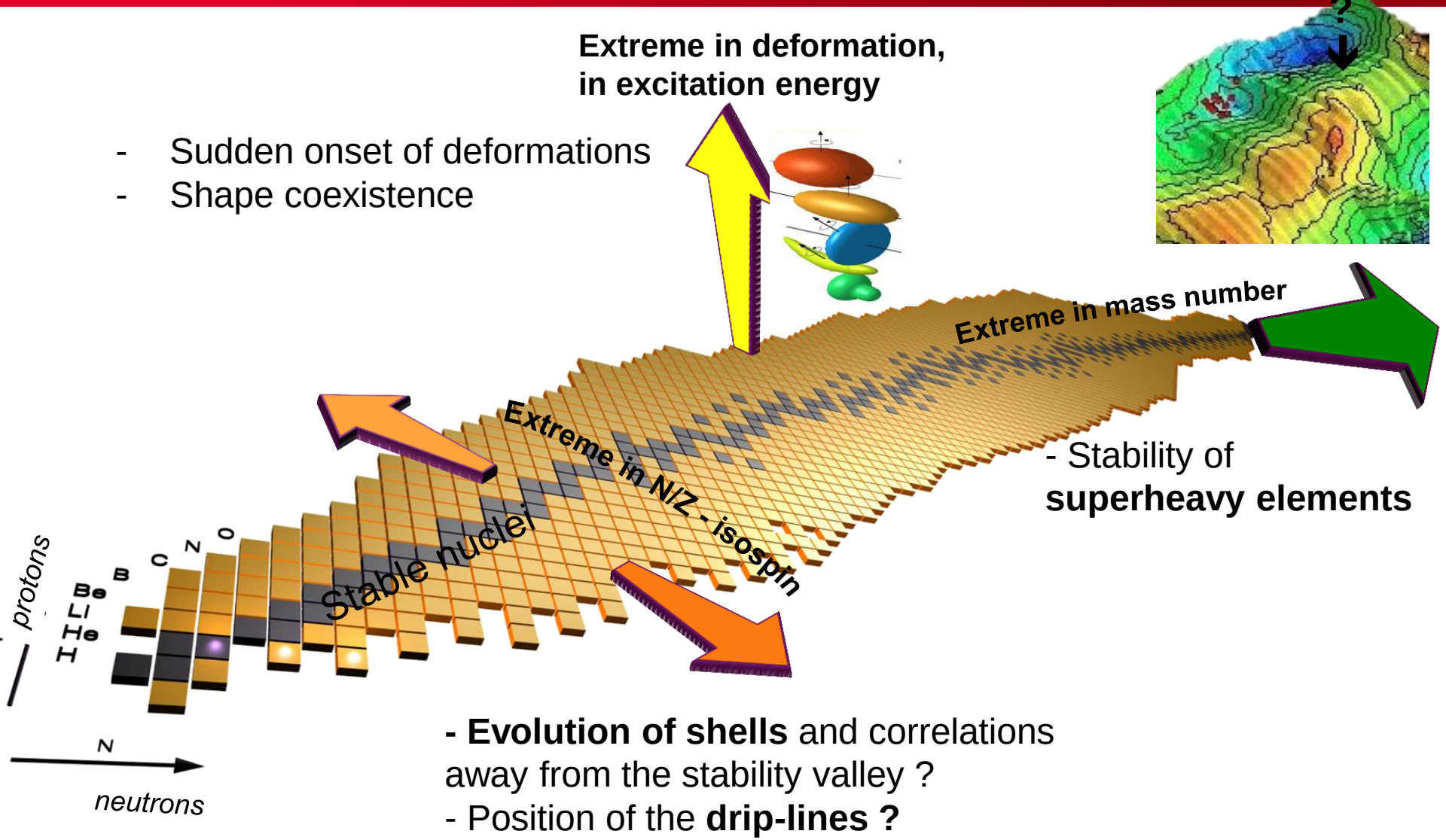
with SEDI@Irfu

Scientific issues and our positioning

In the study of

The nuclear structure

Nuclear structure at the extremes: burning questions



- 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 ?**

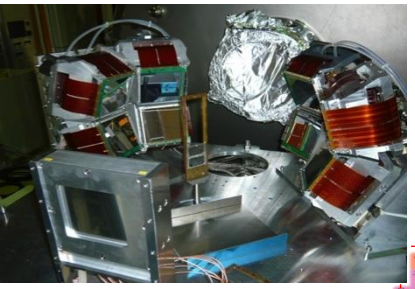
Shell effects evolution

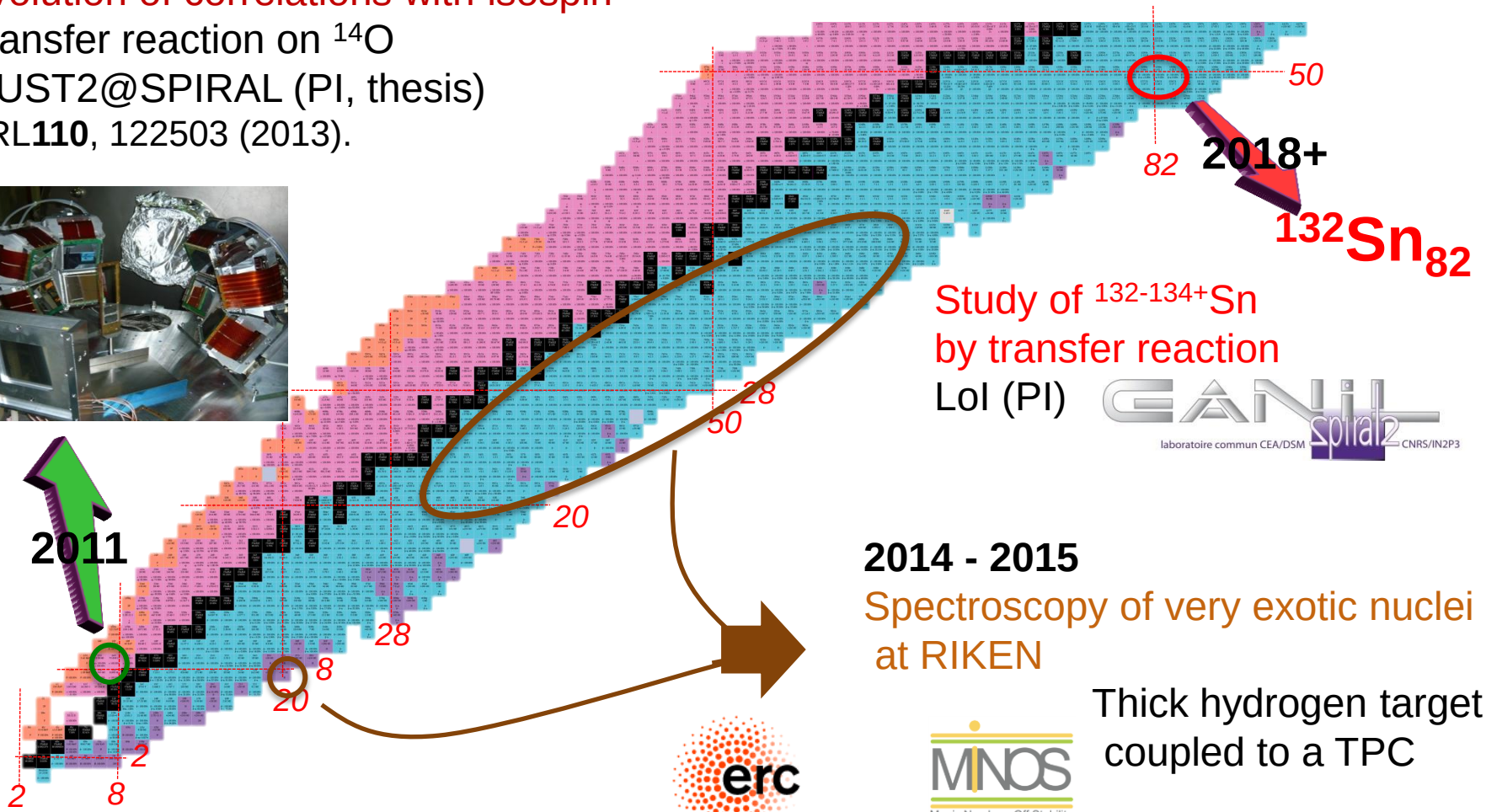
Evolution of correlations with isospin

Transfer reaction on ^{14}O

MUST2@SPIRAL (PI, thesis)

PRL**110**, 122503 (2013).





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

LoI (PI)

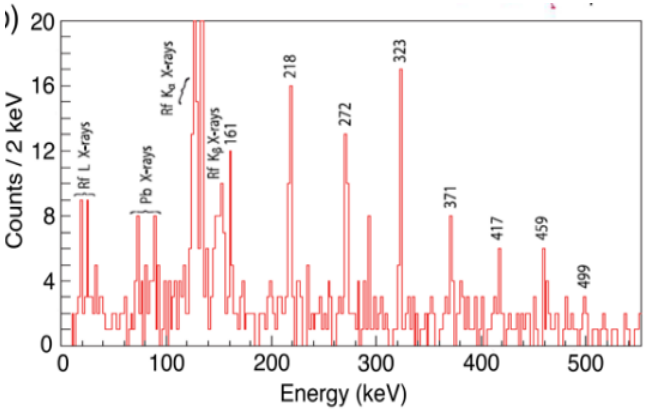
2014 - 2015

Spectroscopy of very exotic nuclei at RIKEN

Thick hydrogen target coupled to a TPC

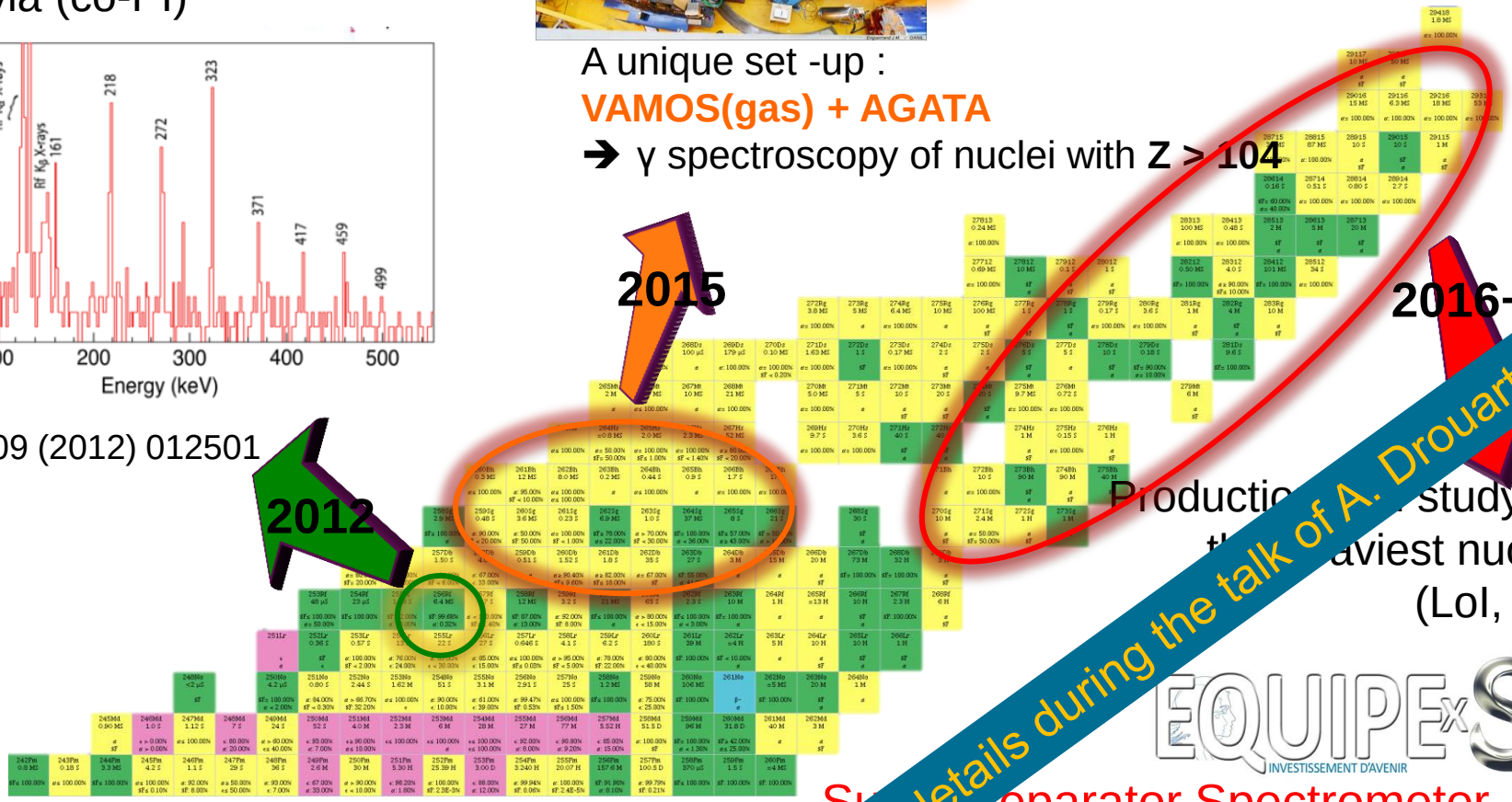
Towards a superheavy island of stability

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**



Productio[illegible] study of t[illegible]aviest nuclei (LoI, PI)

More details during the talk of A. Drouart

EQUIPEx S3 INVESTISSEMENT D'AVENIR

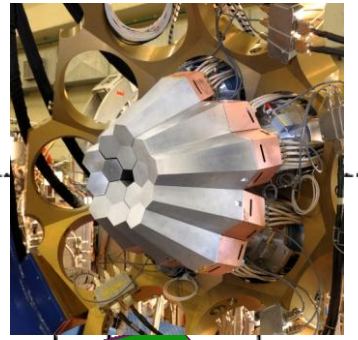
Su[illegible] Separator Spectrometer
[illegible]eader of the project

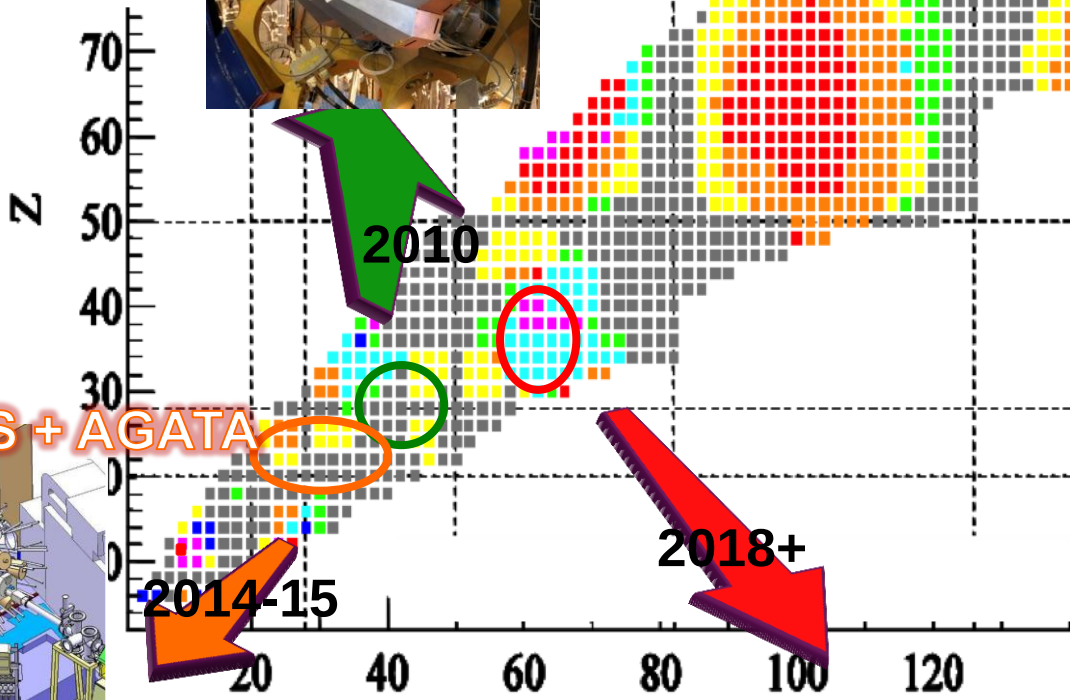
Shapes and collectivity

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

PRC 87, 054302 (2013)

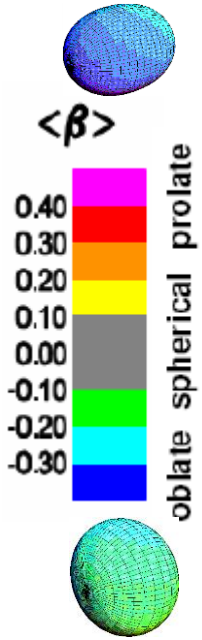
AGATA
@
Legnaro





Hint for static octupole deformation in ^{224}Ra

Nature 497 (2013), 157



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

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

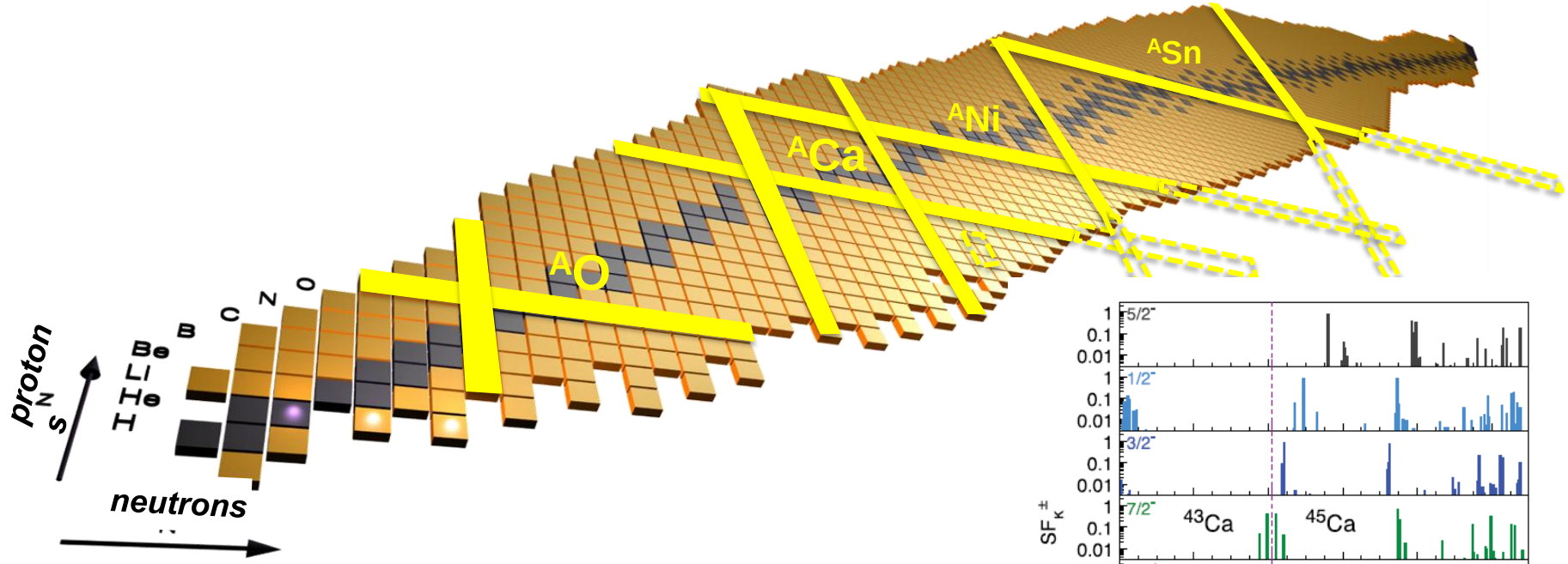
Theoretical challenges

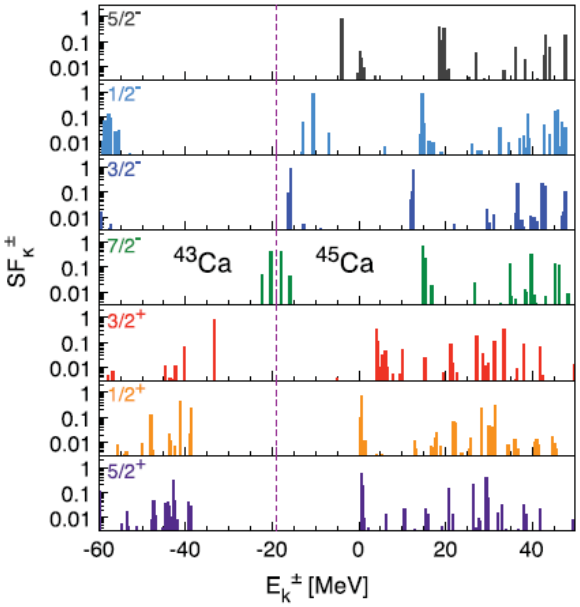
ESNT; a virtual lab for theoretical nuclear physics (CEA DAM/DSM)

- 100 visitors/year
- 5 workshops /year

First ab initio calculations for medium mass semi-magic nuclei

Self-consistent Gorkov Green's functions theory

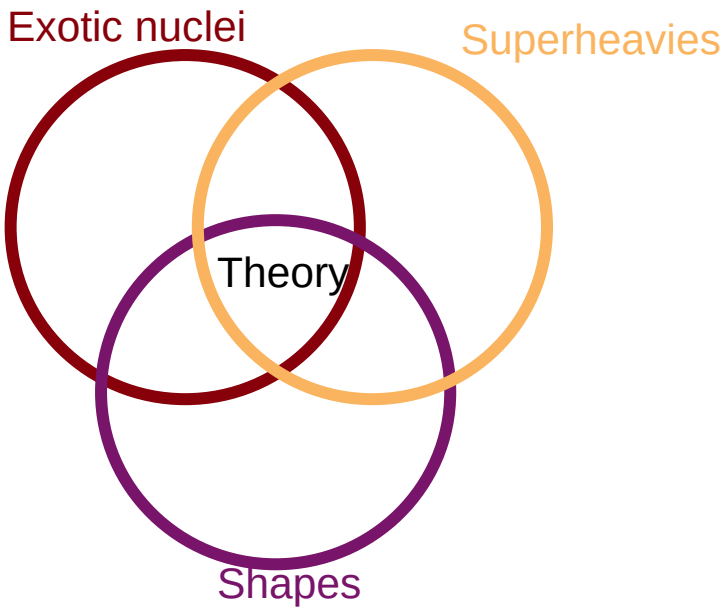




→ Use of high performance computers (GENSI)
→ Important for the description of exotic nuclei to be produced (SPIRAL2 …)

PRC 87, 011303(R) 2013.

Funding and responsibilities



Acknowleged projects:

ANR Funding:

- MUSETT (2006-2009)
- GET (2009-2013)
- CHYMENE (2011-2015)

Leader in research programs:

- P.I. : **Ganil**, GSI, ILL, **Jyväskylä**, LNL, **RIKEN,**
- Spokesperson of 4 LoI @ **Spiral2**

Scientific issues and our positioning
In the domain of
Nuclear reactions

Fundamental studies and societal challenges

A twofold objective:

- To understand and predict the elementary reaction mechanism's
- To meet the needs of various applications by providing nuclear data, models and instrumentation.

Burning applicative issues

- Nuclear energy
  - Fission experiments at **ILL** and in the future at **NFS@SPIRAL2**
  - Theoretical description of the fission process
  - Capture cross sections measurements at **n_TOF**

- Nucleosynthesis
  Measurements (N_TOF) and simulation (fission) for **r- and s-process**

- Non- proliferation and monitoring of reactors
  - Antineutrino' s flux measurement : **Nucifer** experiment
    (with CEA/DAM under IAEA auspices)

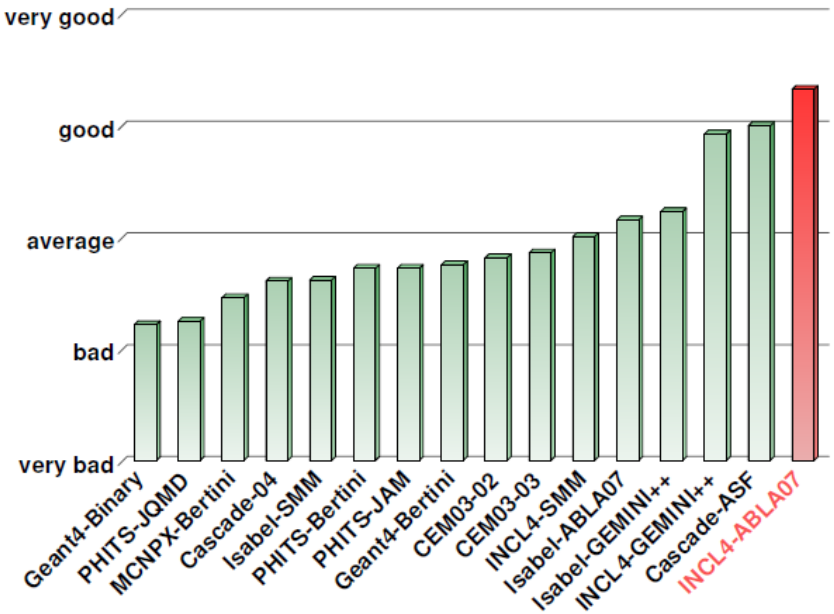
- Non-destructive interrogation of packages or nuclear wastes
  - Photo-fission experiments @Bruyères le Chatel (with CEA/DAM)

- Medical applications
  - Spallation calculations for **radio-isotopes production and hadrontherapy**

- Design and decommissioning of nuclear installations
  - Safety studies, **radiological calculations, waste studies**

Spallation simulation highlights

INCL, developed in collaboration with Liège University



IAEA benchmark of spallation Models (2009)

www-nds.iaea.org/spallation

prediction of residual nuclei production rates

Implementation into high-energy transport codes: MCNPX, GEANT4, PHITS

Ongoing extensions to : light ion, high energy and hyper nuclei

Burning fundamental topics

These applicative researches often address fundamental problems:

- Influence of structure properties on the dynamical process ?

  fission yields, isomers, resonant states …

- Uncertainties evaluations ?

- Existence of a fourth neutrino state ?

Highlight: reactor antineutrino anomaly

Double Chooz;
Collaboration: 40 institutes In close collaboration with SPP:

Improvement of the calculations to predict the antineutrino spectrum emitted by a reactor:
- treatment of all known β-decay transitions, fission yields
- time-evolution of the fission yields
- full propagation of the uncertainties

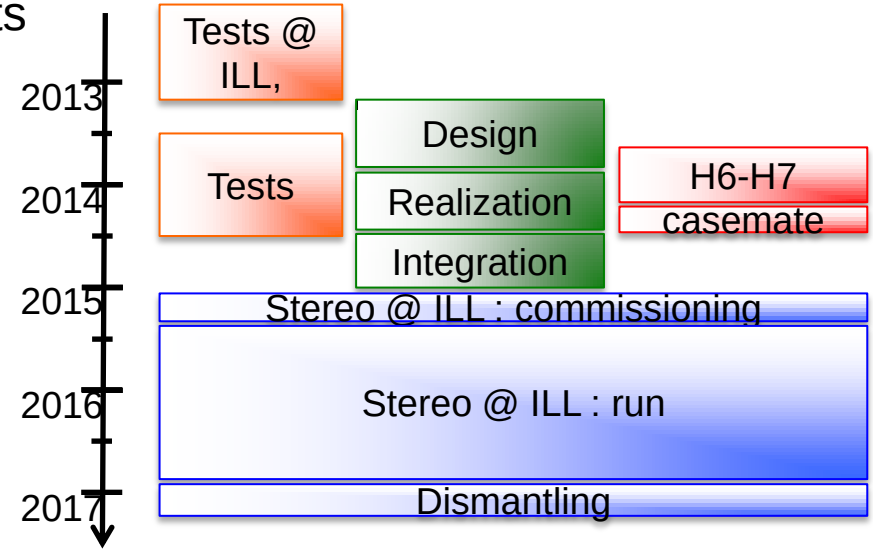
Phys. Rev. C83, 054615, 2011

→Reanalysis of past short-baseline experiments

→ A possible indication for the existence of a 4th neutrino

→ **The STEREO project (ANR grant)@ILL**

Coll; SPP, LPSC, LAPP, ILL, MPI, Univ. Rabat

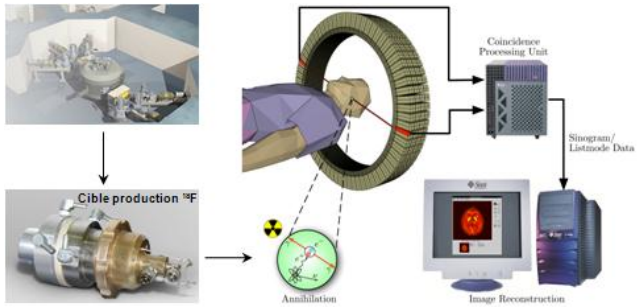


Funding and responsibilities

Main responsibilities; member of expert groups IAEA, OCDE/NEA, ANCRE. GEDEPEON Scientific council, coordinators of WP for FP7 projects

Funding's from national and european grants

FP7 : ENSAR, ANDES, CHANDA
French consortium: Gedepeon
Labex P2IO , ANR Prouesse



LOTUS

Design and dismantling of nuclear facilities:

Contracts outside Irfu

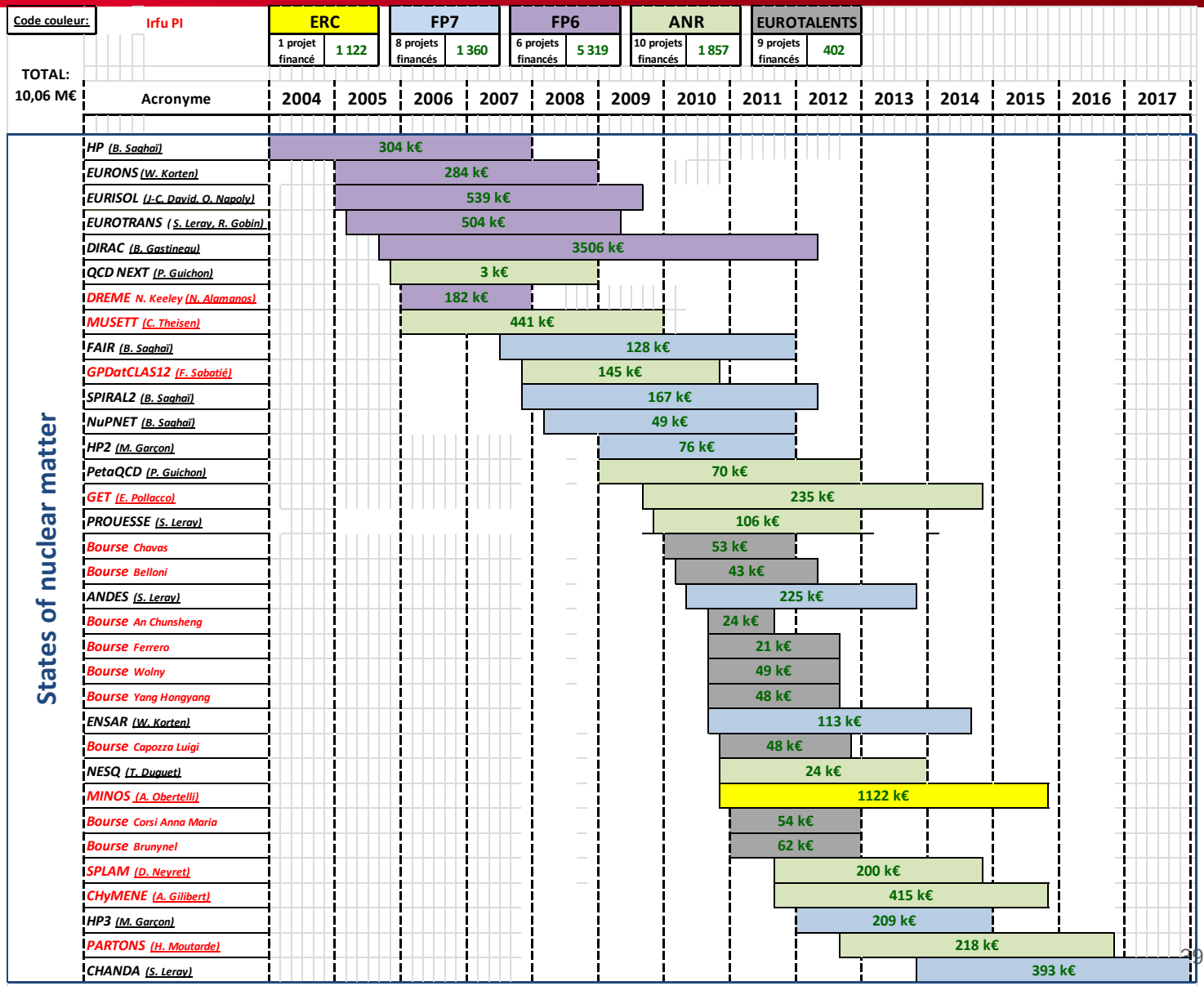
High power laser: LOA, PETAL, UHI100, CILEX
Medical: CPO, LOTUS
Reactors G1, Phenix, Phebus
Accelerator's : CEMHTI (Orleans), SIRIUS (LSI), Tandem (CEA DAM)
Dismantling and waste management: nuclear installations of radioactive facilities of Saclay

Conclusion and perspectives

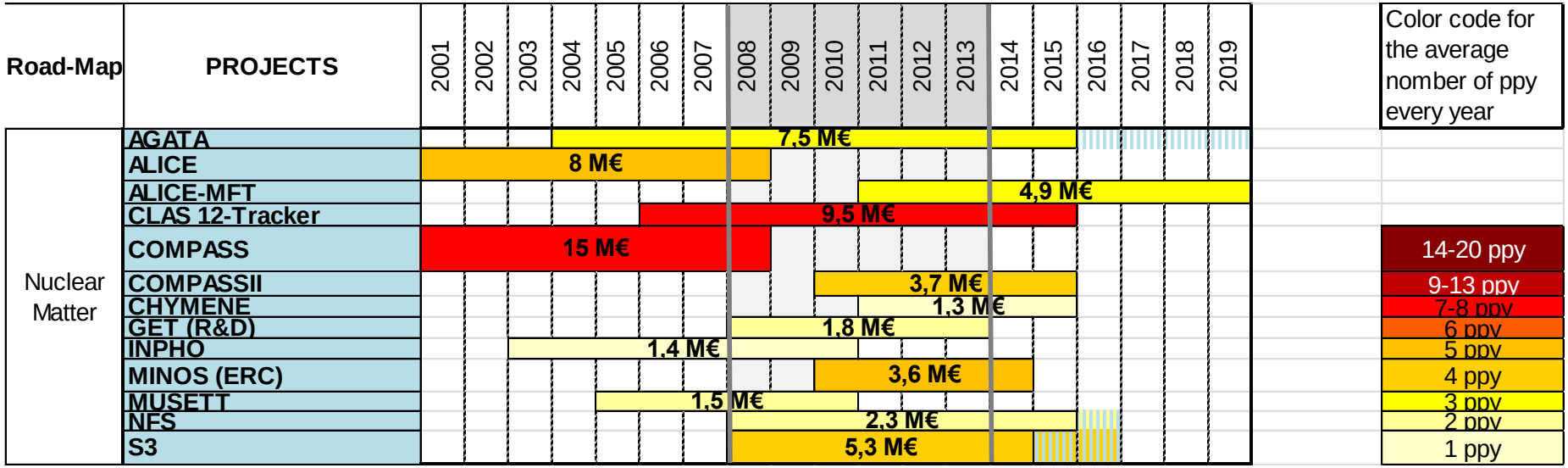
- One of the central strengths of our Department; the different areas of research and applications feed and complement each other

We are actively preparing the future !

National and european grants



Projects running between 2008 and 2013

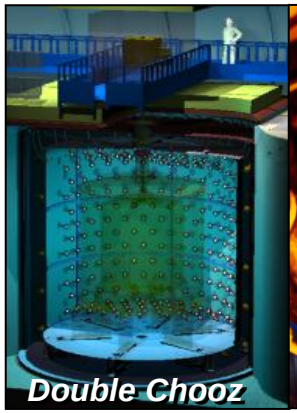


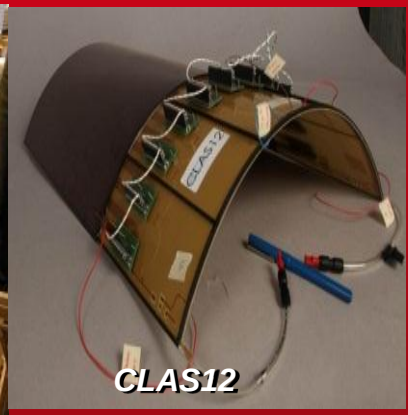
Conclusion and perspectives

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

Very promising results in perspective !

Irfu





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Institut de Recherche sur les lois Fondamentales de l'Univers
Direction