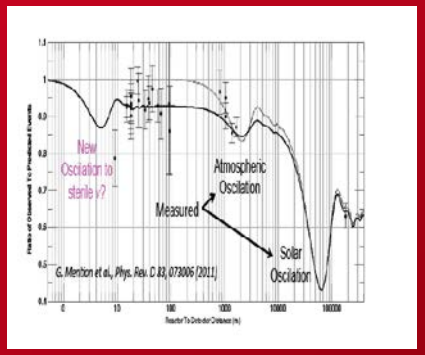
DE LA RECHERCHE À L'INDUSTRIE

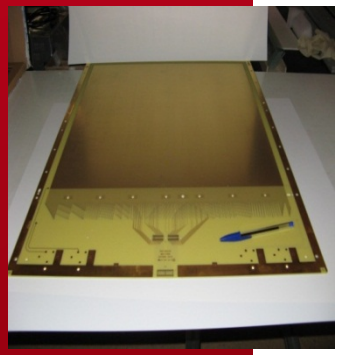
The Nuclear Physics Division

Irfu Scientific Council
January 2014

Discovery



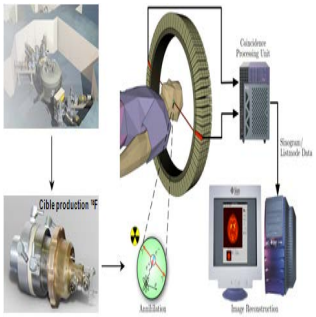
Innovation



Training

Communication

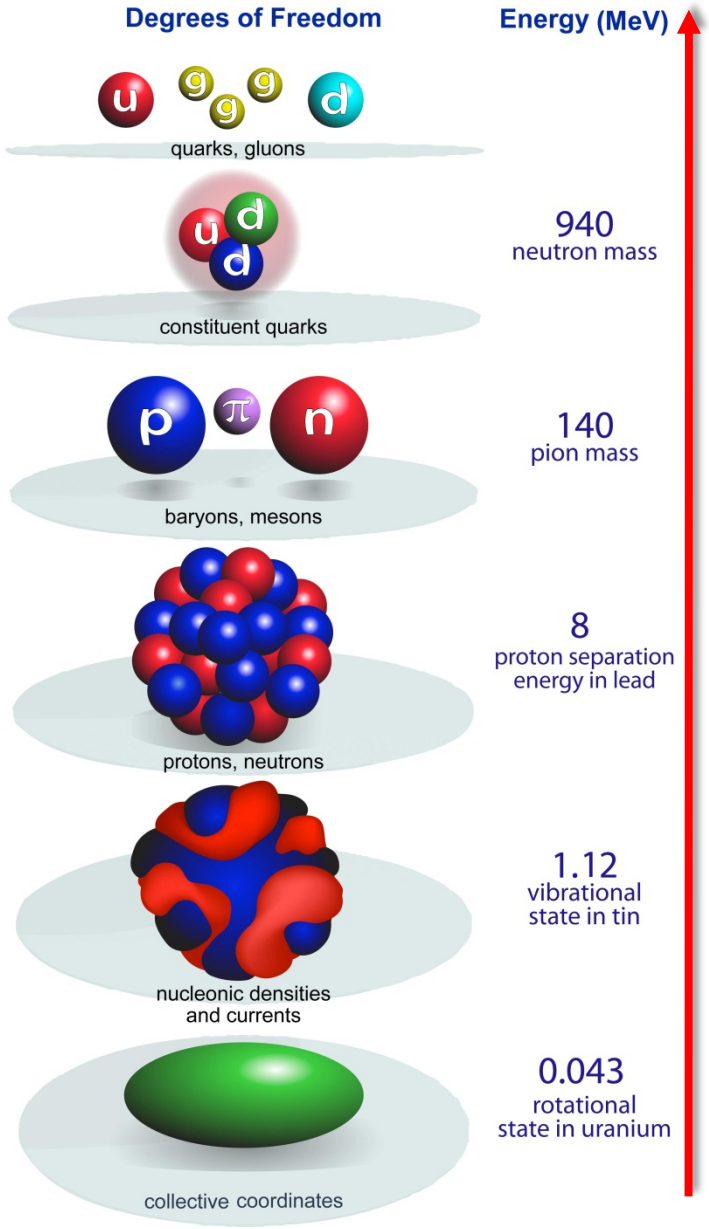
Service of society



With very close connections with SEDI, SIS and SACM

www.cea.fr

The scientific context



Hot and dense quark-gluon matter

Hadron structure

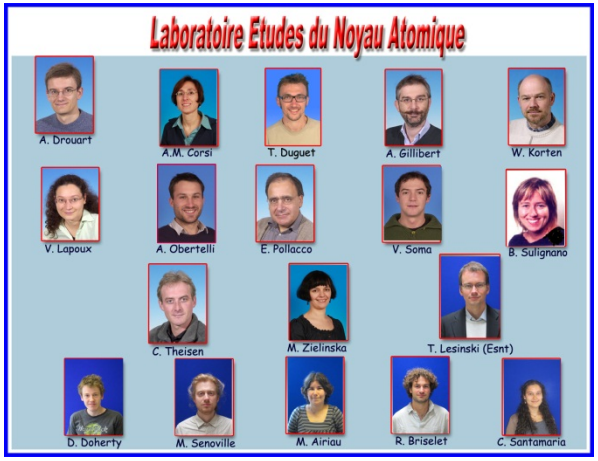
Nuclear structure

Nuclear reactions (study and applications)

Radioprotection … more related to physics projects

~~Security and dismantling~~

The nuclear physics division



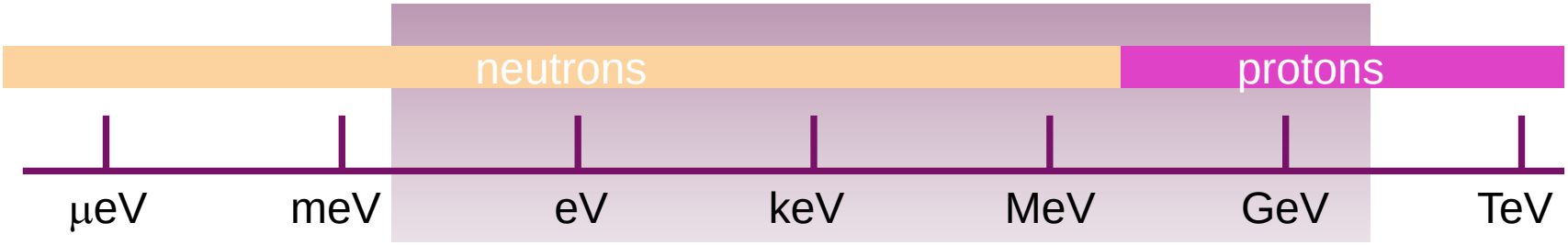
49 permanent staff

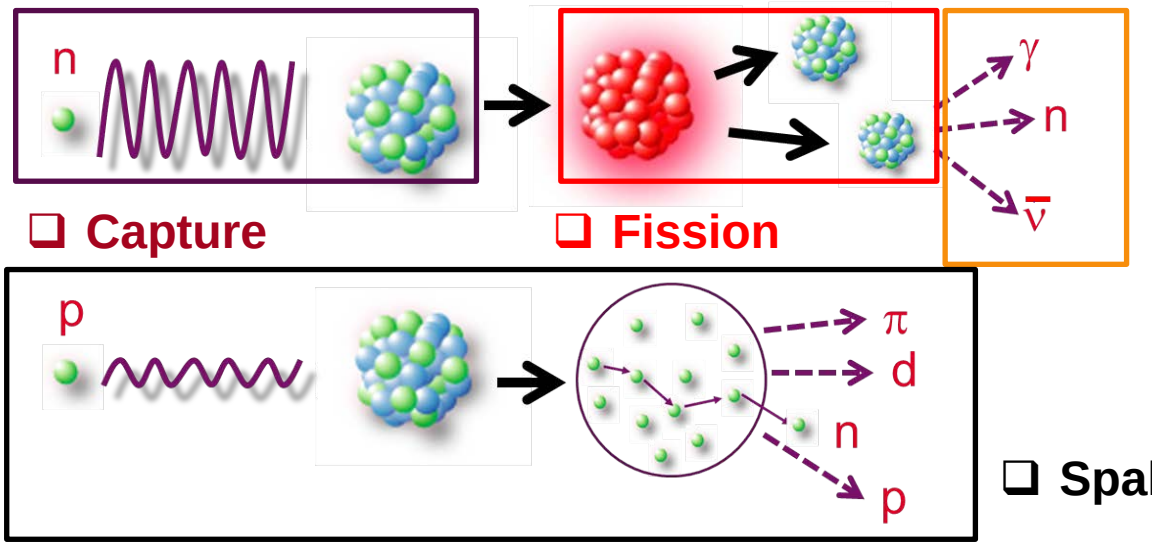
10 PhD
13 postdoc

- Creation of 4 thematic laboratories

Scientific issues and our positioning
In the study of
Nuclear Reactions

Scientific context





❑ **Capture**

❑ **Fission**

❑ **Beta-decay**

❑ **Spallation**

Two main objectives:

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

Evolution of the activities

- **End** of the activities on security and dismantling (departure of 4 people)
Repositioning of the nuclear and radioprotection expertize on design (2 departures)

- **Reinforcement** of the activities on neutronic measurements
  - -New experimental area N_Tof@CERN
  - -Saclay responsible of the commissioning and physics program @N_Tof (new)
  - -1person moving in (from NEA)

  Nucl. Data Sheets 119 (2014) 132

- **Focusing** (after 1 departure) of spallation reaction modelisation on
  - -light ion induced reactions PRC 90 054602 (2014)
  - -high energy
  - -uncertainty calculations (EURATOM Chanda project)

- **Reinforcement** of the collaborations with DEN and DAM on the modelisation of fission

  PRL 111, 242502 (2013)

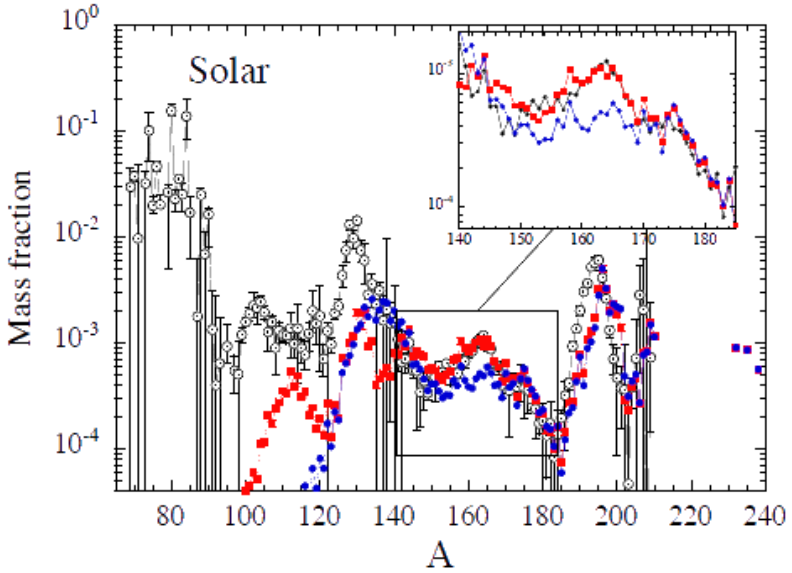
- **Continuity** of reactor's neutrinos activities : see talk of A. Letourneau

HIGHLIGHT: Fission in the heart of the nucleosynthesis (1/2)

None of the existing model of nucleosynthesis is able to explain the abundances of rare earth nuclei. Are the neutron stars good sites for the formation of these heavy elements ?

→ Need of the modelisation of the fission of a huge number of nuclei (2000), including drip-line nuclei

→ Use of a microscopic mean-field - based scission point model: SPY



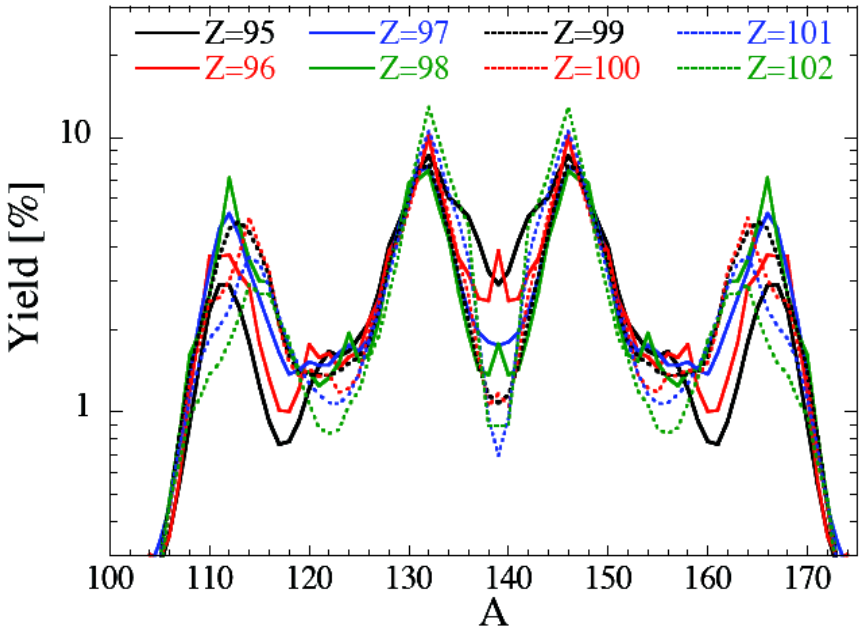
PRL 111, 242502 (2013)

White : Solar r-abundance distribution
Red : fission yields from SPY
Blue : fission yields from phenomenological fission model (GEF)

HIGHLIGHT: Fission in the heart of the nucleosynthesis (2/2)

- Nuclei with mass A=165 are predicted to come from the fission of A=278 nuclei

- Fission mass distributions of these nuclei are predicted to be 4-bumped distributions: unexpected and never observed experimentally confirmed by Hartree-Fock-Bogoliubov calculations of potential energy surfaces



SPY - Isobares A=278

PRL 111, 242502 (2013)

Perspectives (1/2)

Nuclear expertize on radioprotection:
Continuation of the current studies (CILEX, LIEBE…) and new prospective study on neutron sources at Saclay (in collaboration with LLB).

Modelisation of spallation reactions:
- Implantation of the strange degree of freedom in the cascade spallation code INCL for the production of strange particles and hypernuclei
- Introduction of theoretical tools for sensibility studies and/or error propagations (Chanda project)

Reactor's neutrinos :
Data taking with Nucifer (up to the shutdown of Osiris)
Building, setting up and commissioning of the STEREO detector (ANR Saclay P.I.)
Data analysis of Double Chooz.

See talk of A. Letourneau

Perspectives (2/2)

- Neutronic spectroscopy@ N_ToF:

-measurement of capture and fission cross sections of ^{233}U (2015) Saclay P.I.

-installation of the neutron beam position monitor (on going work)

- Fission :

- NFS@SPIRAL2 (2016) :

-development of the FALSTAFF detector for fission fragment identification Nucl. Data Shets 119 (2014) 346.

- finalization of the thick NFS convertor

- Modelisation: towards a more microscopic description (level densities)

- New item (with DEN) **:** Desexcitation of fission fragments (through the analysis of the EXIILL experiment)

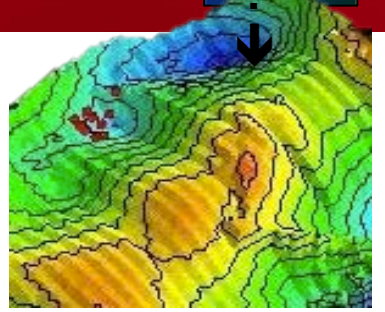
Scientific issues and our positioning
In the study of
Atomic nuclei structure

Physics topics

Along the tracks presented in 2013

Extreme in <u>deformation,</u>
in excitation energy

- Sudden onset of deformations
- Shape coexistence



- Stability of **<u>superheavy</u> elements**

<u>Exotic nuclei:</u>

- Evolution of shells and correlations away from the stability valley ?

- Position of the **drip-lines ?**

Human resources: 2 departures since 2013 and one recruitment in 2014

Topic 1: Exotic nuclei

- **MUST2 campaign@GANIL (2013-2014)** : Spectroscopy of exotic nuclei

2 experiments with Saclay P.I.

^{18}Ne (under analysis) and spectroscopy of 0^+ states in ^{72}Se (not conclusive)

- **MINOS@RIKEN (2014 -) :** Saclay P.I.

- shell evolution and s[illegible]ematic search for 2^+ states energies (m[illegible]

- study of the str[illegible]e of halos and multi-nucleon correl[illegible]s in light nuclei (nov)

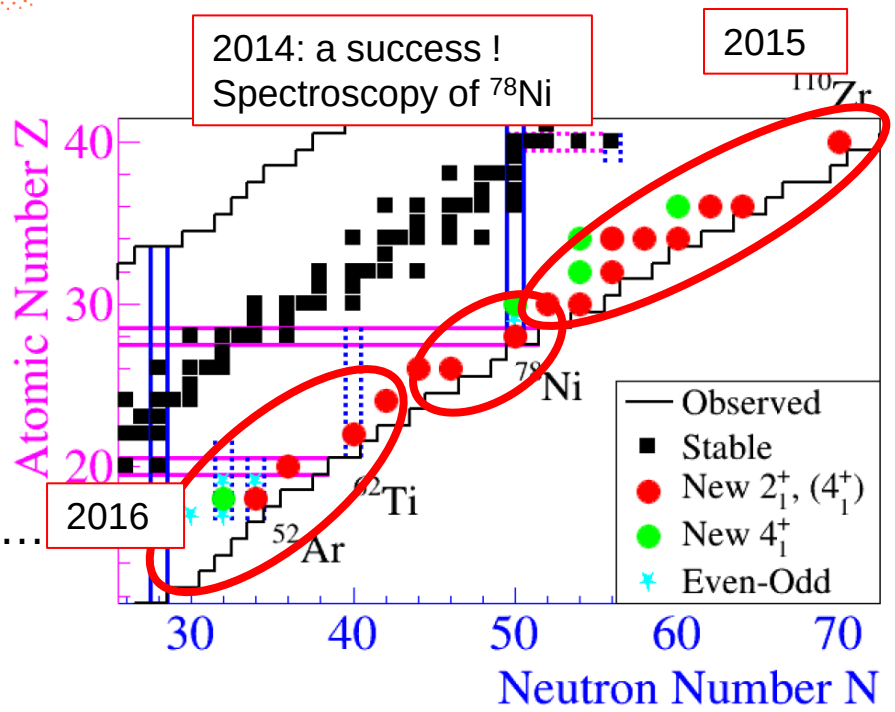
see talk of Anna Corsi

New cam[illegible]gns foreseen in 2015

+ associated technical developments:

GET electronics , cryogenic target Chymene …

(see talks of SEDI/SIS/SACM)



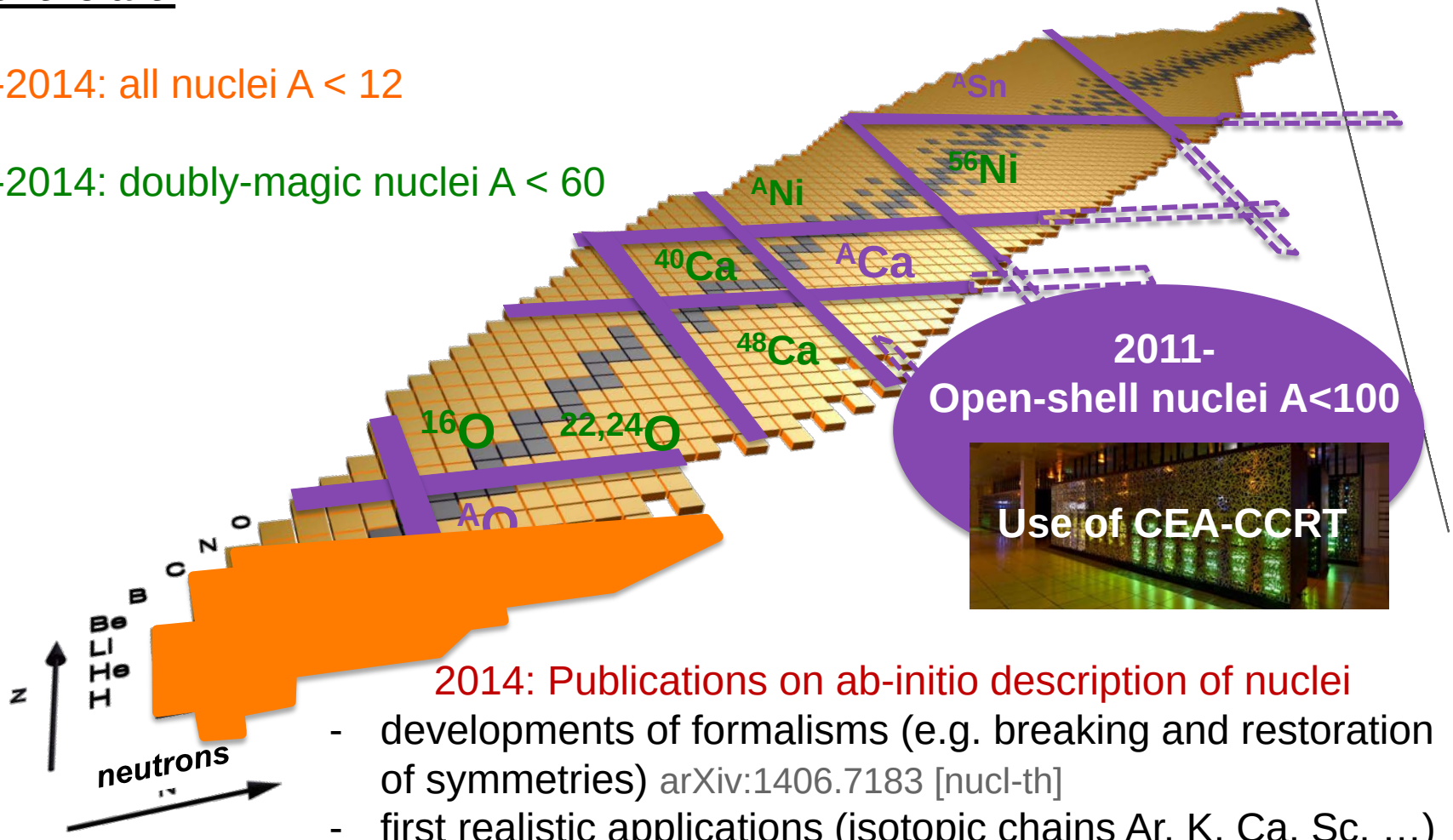
- **Theory**: ab initio description of medium-mass nuclei

HIGHLIGHTS: *Ab initio* methods for open-shell nuclei (1/2)

State of the art:

- 1980-2014: all nuclei A < 12

- 2003-2014: doubly-magic nuclei A < 60

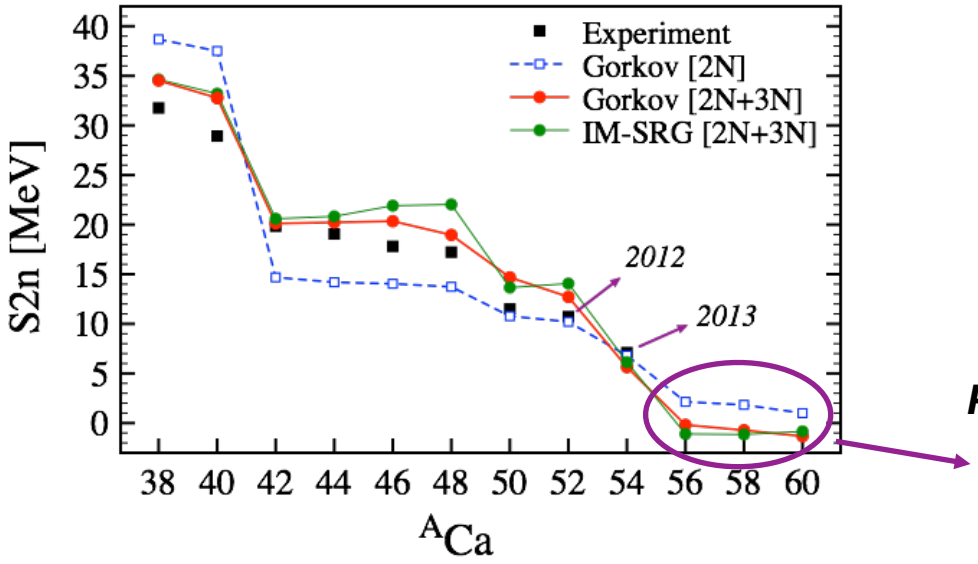


2014: Publications on ab-initio description of nuclei

- developments of formalisms (e.g. breaking and restoration of symmetries) arXiv:1406.7183 [nucl-th]
- first realistic applications (isotopic chains Ar, K, Ca, Sc, …) PRC89, 061301(R) (2014), PRC 90, 034321 (2014)

HIGHLIGHTS: First results with 2N+3N interactions (2/2)

Energy needed to remove two neutrons



Phys. Rev. C89, 061301(R) (2014)

Prediction of the drip line sensitive to 3N

Conclusions:

- Good overall description
- 3N forces essential

Near future: stronger collaborations with experimentalists for complete tests of structure observables (SPhN group and University of Leuven)

New responsibility: Professor @ K.U. Leuven

Topic 2: Nuclear deformations and shape coexistences

- **Data analysis and main publications:**
  - Collectivity of light Ge and As isotopes PRC 88, 044311 (2013)
  - Shape coexistence in n-deficient $^{182\text{-}188}$Hg isotopes PRL 112, 162701 (2014)
  - Lifetimes measurements in fission fragments and shape coexistence in $^{96\text{-}98}$Sr isotopes. (to be published)

→ Comparisons with shell model, interaction boson model and/or mean-field based calculations

- **New experiments** performed
  study of ^{100}Zr and ^{110}Ru @ ANL Argonne, Saclay co P.I.

- **AGATA**

New responsibility: lecturer on « Nuclear Physics; experimental part », MASTER2 level in Orsay

AGATA

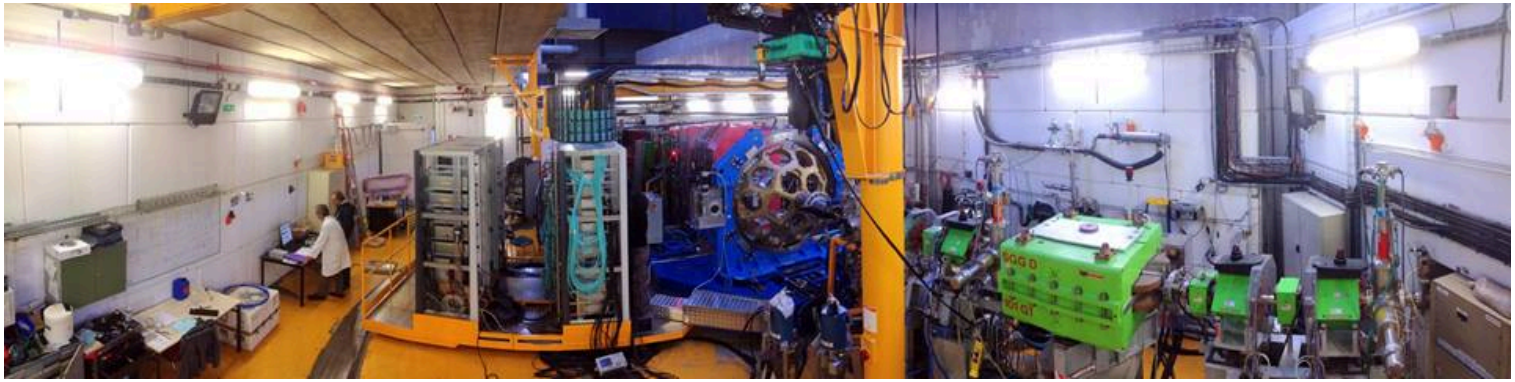
- **Legnaro campaign 2010-2011**: 8 scientific publications and more to come

Saclay P.I: lifetime measurements in heavy zinc isotopes

C. Louchart *et al.*, Phys. Rev. C **87**, 054302 (2013)

-GSI campaign: 8 experiments done and 0 from Irfu

- 2014: Installation@ GANIL



Our physics cases for the AGATA campaign@GANIL(2015-2018):

- Lifetime measurements of fission fragments (to be submitted in 2015).
- Heavy nuclei (VAMOS-GFS 2017-2018)
- Coulex experiments with Spiral1upgrade

+ technical responsibilities ; detectors and infrastructure (see talks from SEDI/SIS)

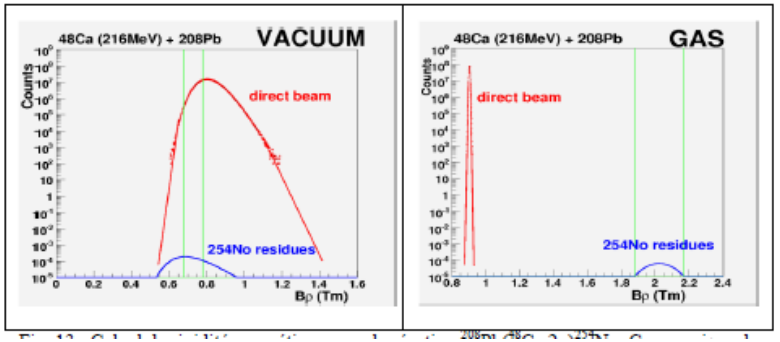
Topic 3: Heavy and superheavy nuclei

- Spectroscopy experiments in odd nuclei @ **Jyväskylä** (Saclay P.I)
  2013-2015 : ^{249}Md, ^{251}Md, ^{250}No
- Fission lifetime measurements @ GANIL (Saclay co-P.I.)

Projects @ GANIL-SPIRAL2

- **Vamos-Gaz Filled** (foreseen in 2017 with AGATA) : project launched, Saclay project coordinator

NIM A 747 (2014) 69 Separator for fusion evaporation reactions



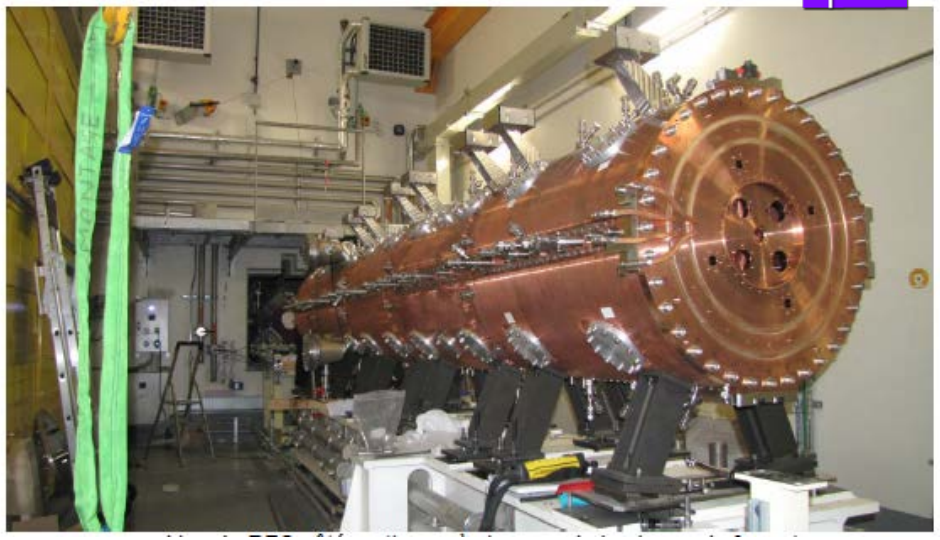
- **S3:** Equipex Saclay co-leader (foreseen in 2017)
  Saclay P.I. of the LoI « Production and study of the heaviest nuclei

technical responsibilities ; detectors , and spectrometer designs
(see talks from SEDI/SIS/SACM)

Perspective in nuclear structure

- Participation in the prospective group GANIL-SPIRAL2 2025

  - First proton beam extracted at SPIRAL2 from the d source (from IRFU).
  - SPIRAL2 Phase2 frozen



- Discussions on the future physics program to come in the next Scientific and Technical Council of SPhN (CSTS) in February

Perspectives in nuclear structure: future tracks to be discussed in Feb in SPhN

Heavy nuclei:

- Experiments @ Jyväskylä for spectrsocopy of transfermium isotopes
- Program @GANIL:
  - Vamos Gaz Filled (2017)
  - S3 (2017+) : Irfu Project leader and P.I. of the LoI «Superheavy »

Deformed nuclei:

- Lifetime of excited states: AGATA@GANIL
- Study of shapes by coulomb excitation (existence and octupole): start of HIE ISOLDE, ALTO, Caribu@ANL

Exotic nuclei:

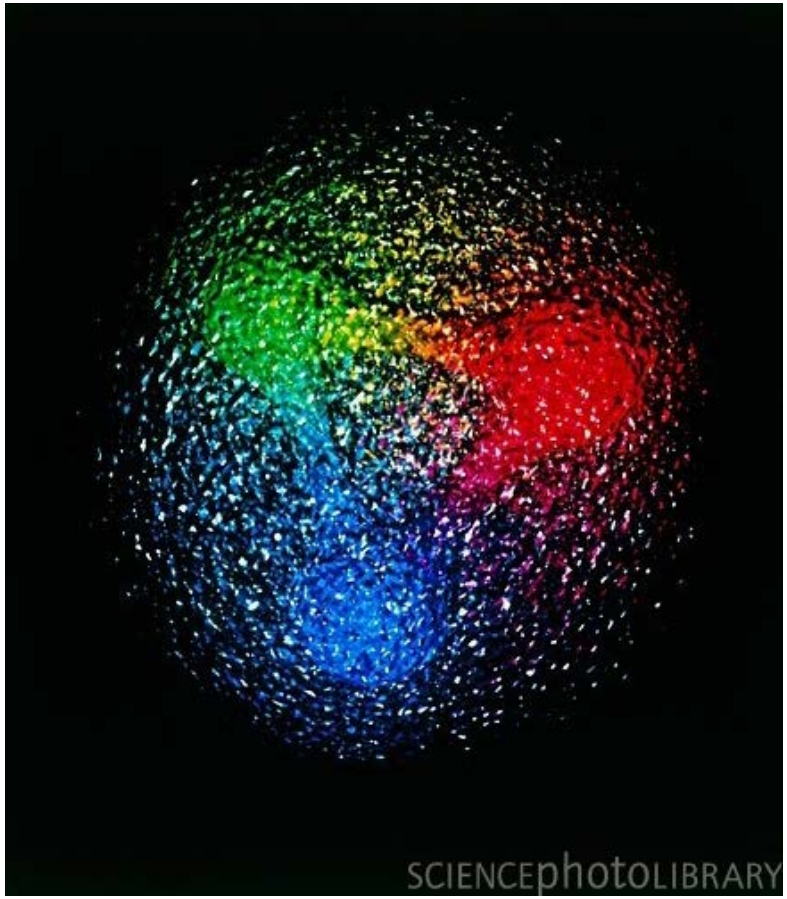
- Very exotic nuclei:

Pursuit of the program @ RIKEN (2015 campaign + ANR submitted for 2016+)
Tracks for the future include hypernuclei (e.g. R3B, FAIR, RIKEN)
Instrumentation: MINOS, cryogenic target (Chymene …)

-Detailled spectroscopy by direct reaction
SPIRAL2Phase2 frozen;
Reflexion for the future (HIE ISOLDE, RIBS@RIKEN …) :
Instrumentation : Must2, Astrobox, cryogenic target (Chymene …)

Scientific issues and our positioning
In the study of
The Nucleon Structure

Scientific issues and our positioning



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

→ Theoretical modelisation

- 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 (Deeply Virtual Compton Scattering)

- **Experiments on two sites**: COMPASS@ CERN and CLAS12@Jefferson Laboratory

- **Theory:** Lattice QCD and modelisation based on quantum field theory

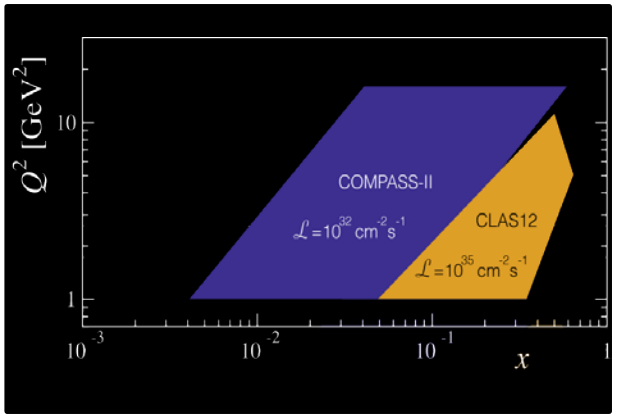
Short and mid terms:a coherent physics program

Along the tracks presented in 2013

COMPASS 2

Muon beam
Energy: 160 GeV
Sea quarks and gluons

2012: test of DVCS
2014: Preliminary results Released
2016-17: DVCS exp.
Saclay P.I.
2015 and 2018 :
new interest expressed**:**
TMD distributions



JLAB

Electron beam
Energy: 11GeV
Valence quarks

2013-16: analysis of Hall A DVCS exp.

2014: start of JLab12 era
2016-17: CLAS12 DVCS exp
Saclay P.I.

Responsibilities: - co-spokesperson of the COMPASS collaboration,
- analysis coordinator of COMPASS (new)
- run group leader in Hall B @JLab

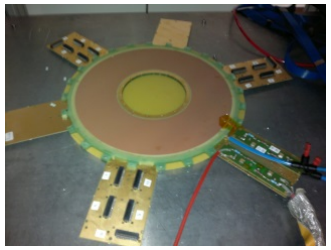
Human resources: two departures in 2013-2014 and one open position for 2015

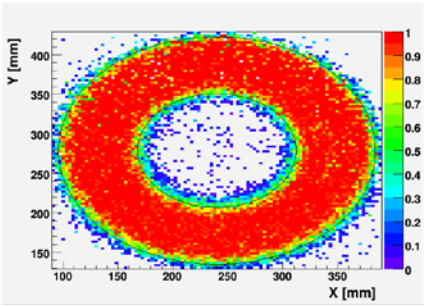
Technical developments

CLAS12:

State-of-the art technology for the tracker:

→ Resistive Micromegas





Barrel and Forward Micromegas

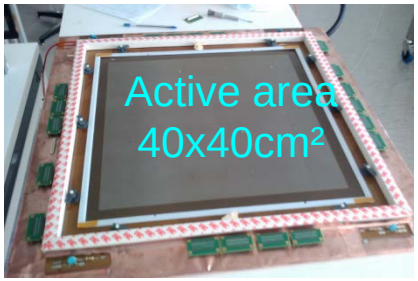
Prototypes realized, production to start

→ Delivery in 2015-16

COMPASS2:

New hybrid pixelized micromegas detectors

Production at ELVIA company



→ Installation at COMPASS in 2015

New responsibility: lecturer on “Gaseous Detectors”, Master2 in Orsay

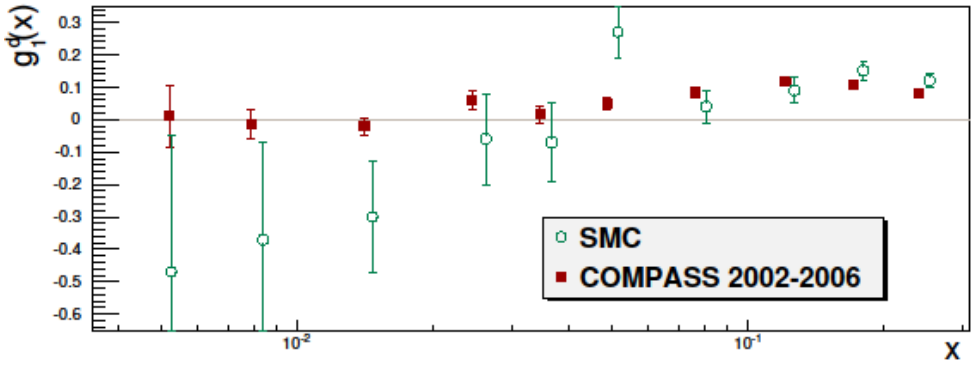
Data analysis (main contributions)

COMPASS :

3 COMPASS Releases :

- spin asymmetry at low x
- fragmentation functions
- pion multiplicities

to be published in 2015



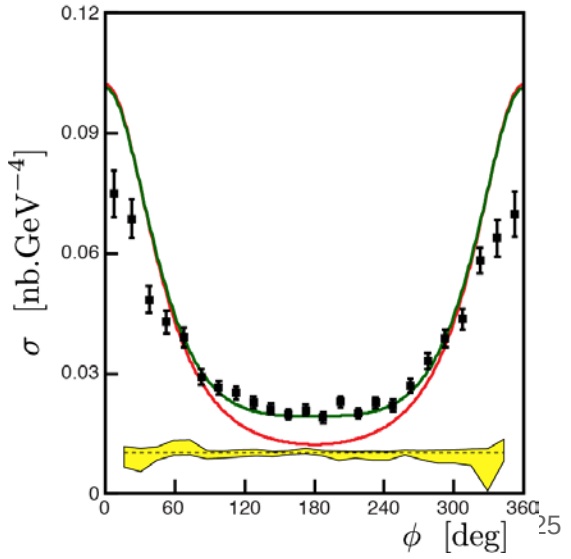
→ Much improved accuracy for the extraction of the spin fraction carried by quarks

JLab:

New analysis of DVCS 2004

Better background subtraction
→ Kinematic domain enlarged

treatment of higher order QCD corrections
→ Better description of data
to be published in 2015

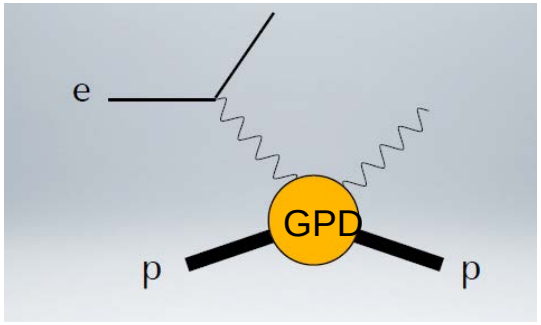


(close connection between theory and experiment)

A Platform for 3D nucleon tomography

A platform for the community (ANR PARTONS, Saclay P.I.) **:**

- GPD modeling
- GPD extraction from world experimental data
- Input for the design of future experiments (JLab12/EIC)



- Theoretical developments and publications

  PRB 741 (2015) 190

  PLB 737 (2014) 23

- Relations with experiments: predictions delivered for DVCS observables for COMPASS, HERMES and JLab

  1 PRL submitted

Perspectives:

- Development of a community of developers and users
- Delivery of the simulation codes for the 3D tomography end of 2015
- Visualization interface in 2016

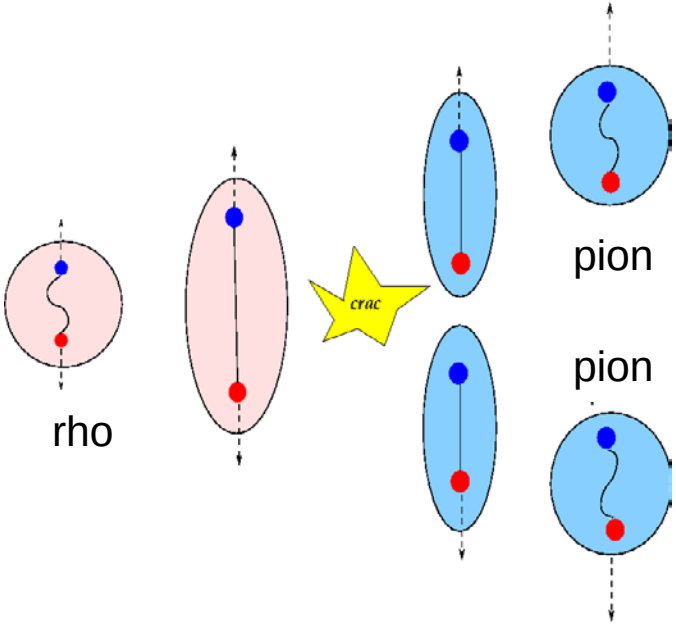
HIGHLIGHT: Lattice QCD calculations

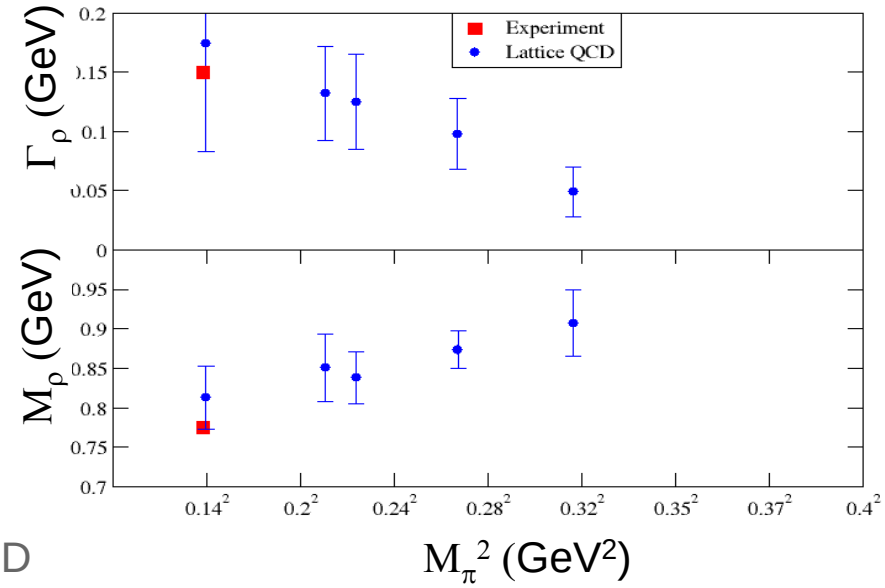
Breakthrough: Calculation of the mass and of the width of the rho meson

Use of super-computing ~ 30 Millions CPU hours on BlueGene-Q IDRIS (France) and Julich (Germany)
BMW collaboration

Two feats:

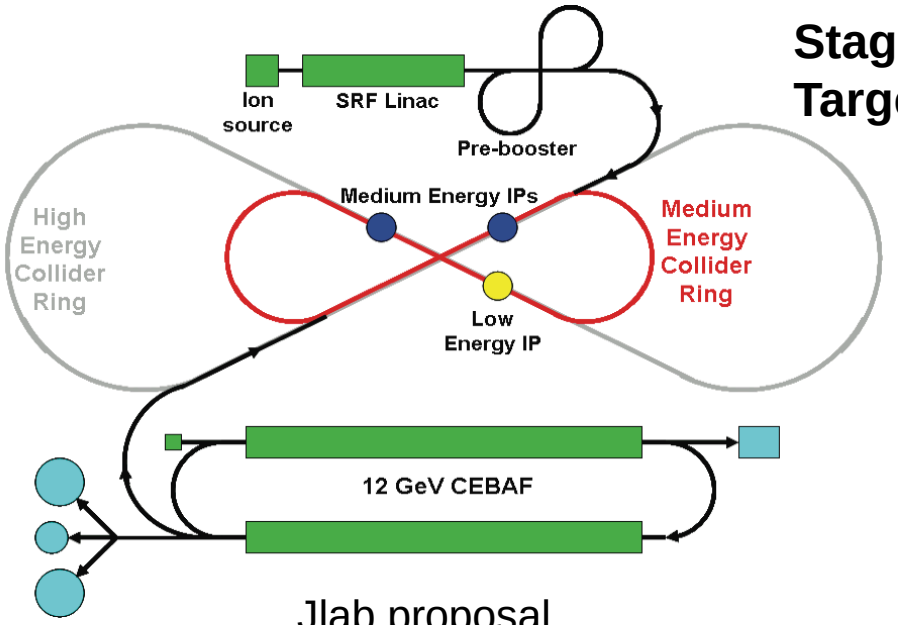
- calculations with physical quark masses
- and calculations of the width on a finite size lattice



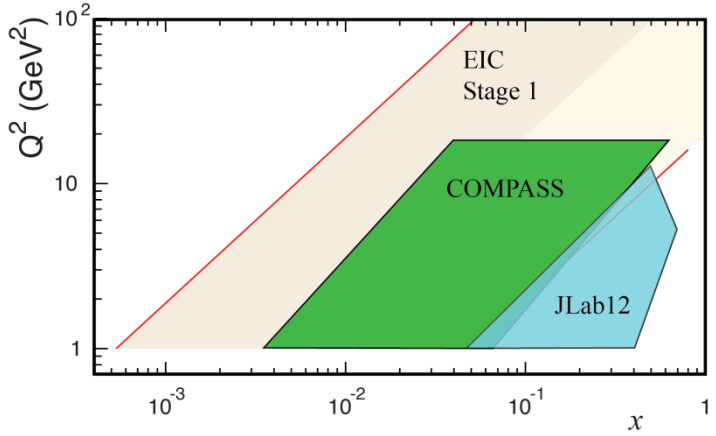


Th. Métivet et al. to be submitted in Phys Rev. D

Long term– towards EIC: an electron-ion collider



Jlab proposal



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

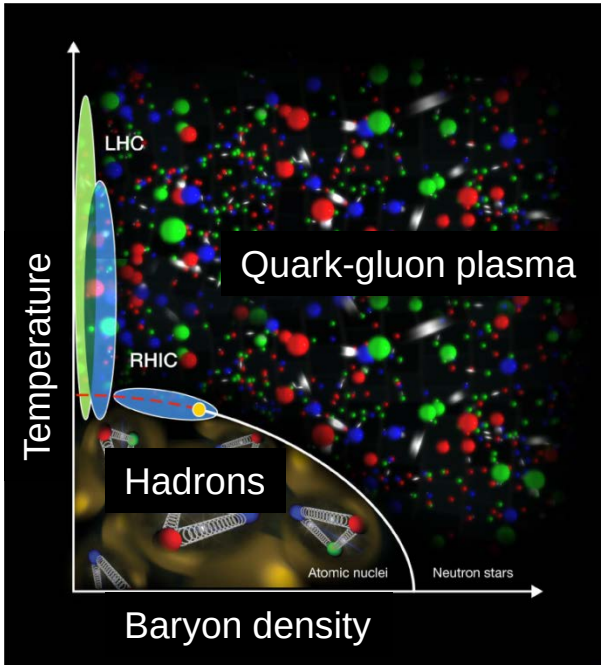
→ An ambitious project that aggregates the high energy nuclear physics communities

Responsibility of Saclay;
- Member of the writing committee of the white paper

DOE- NSAC 2014/2015 Long range plan to be discussed in 2015

→ will shape the future of hadronic physics

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

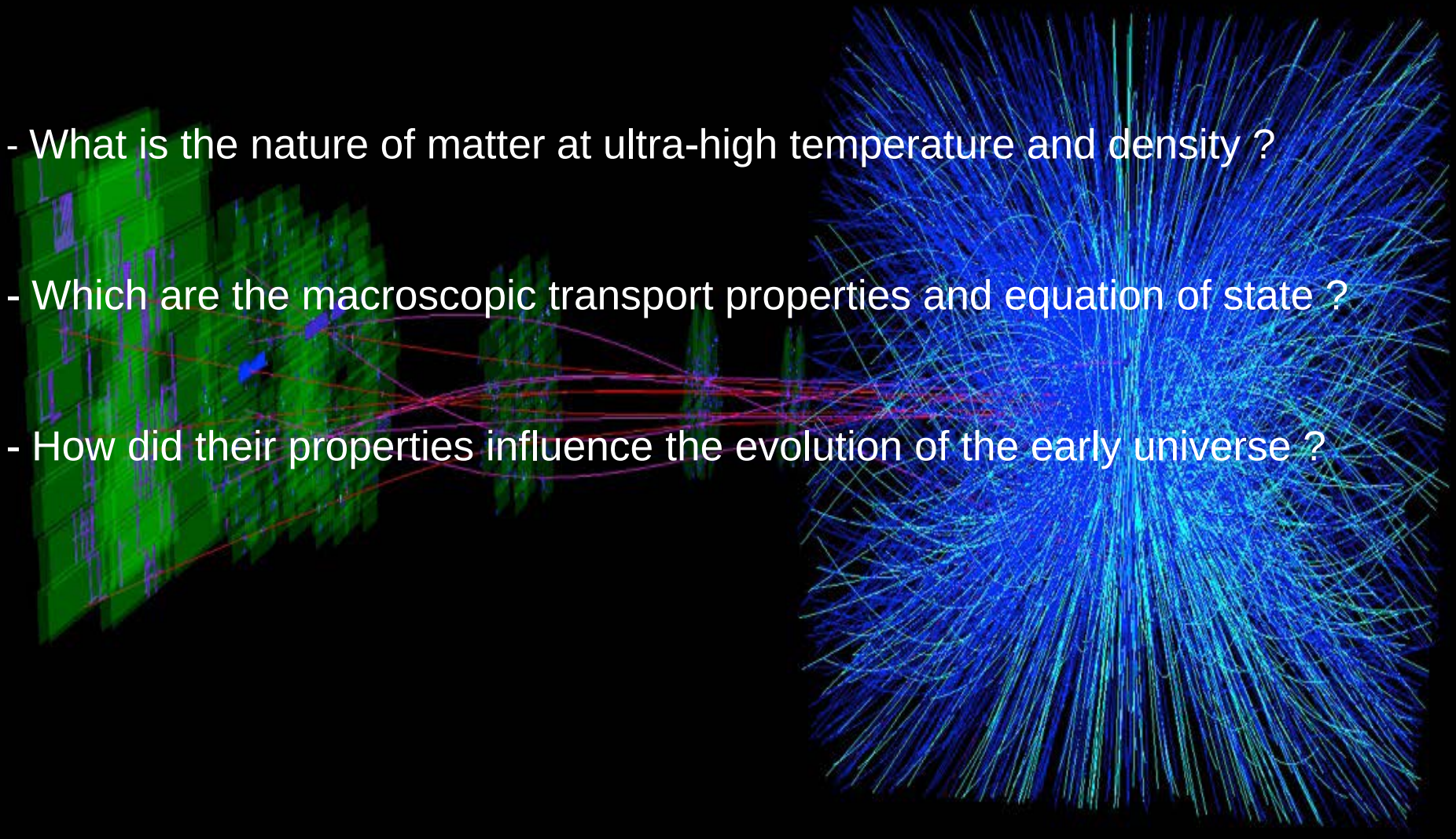


QGP: fundamental questions

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

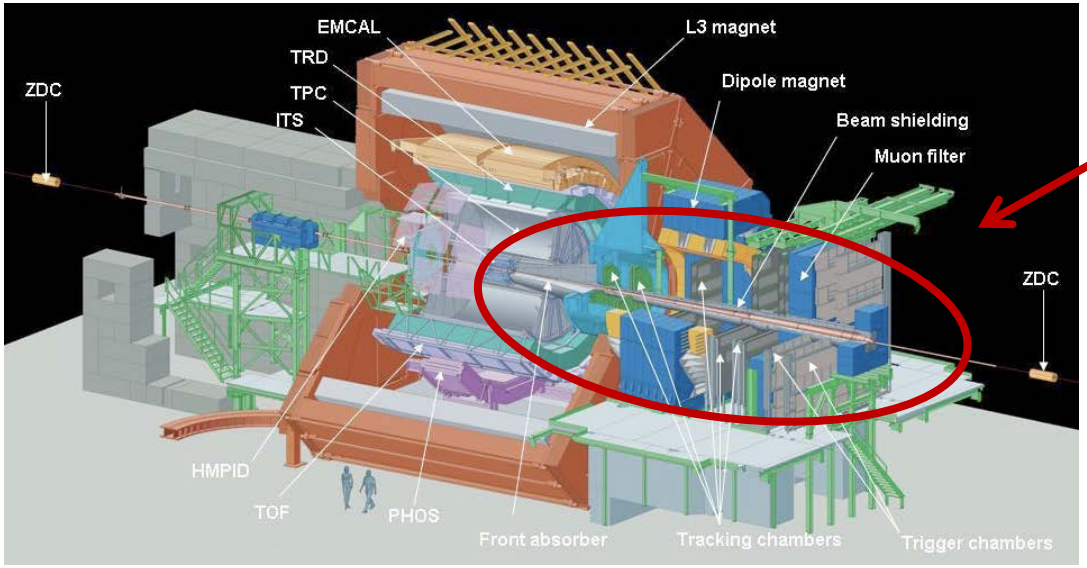
- Which are the macroscopic transport properties and equation of state ?

- How did their properties influence the evolution of the early universe ?



Our positioning

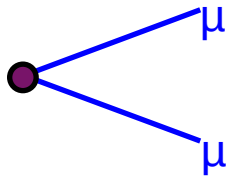
Heavy ion collisions ALICE @ CERN



Muon spectrometer

Our positioning: along the tracks presented in 2013

- Study of the quarkonia (quark anti-quark pairs) as probes of the QGP
- Detection of the quarkonia using the ALICE muon spectrometer
- Responsibility: Saclay Project Leader of the Muon Spectrometer



Scientific production since last Scientific Council

- **Data taking** : p-Pb collisions at 2.76 TeV (2013)

- **Data analysis** : Pb-Pb (2011), p-p (2011-2012) and p-Pb (2013)

New responsibility

Convener of the Physics Working Group Dileptons and Quarquonia

- Υ suppression in Pb-Pb: probing the QGP
  PLB 738 (2014) 361 Saclay analysis coordinator

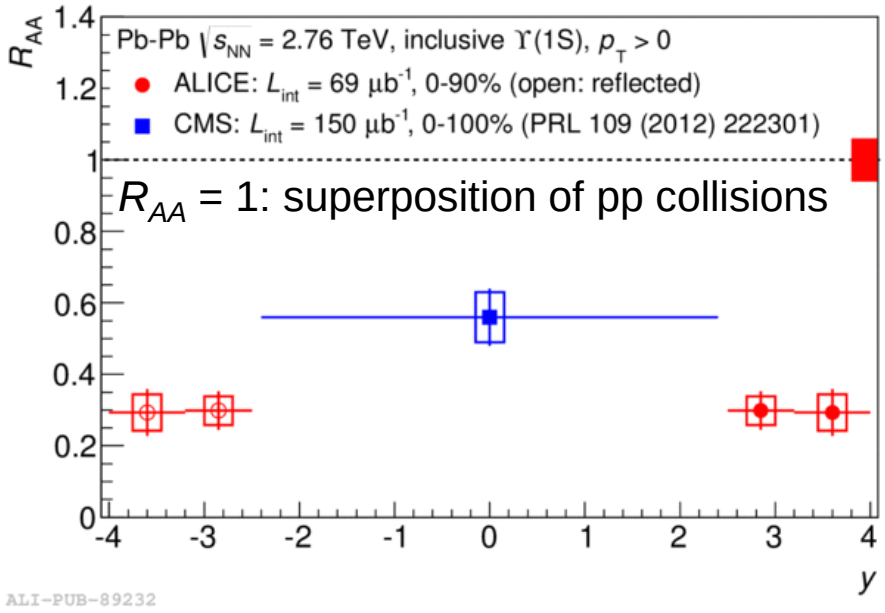
- quarkonia production in p-p: testing production model
  EPJ. C 74 (2014) 2974 Saclay one the analysis coordinator
  and member of the writing committee

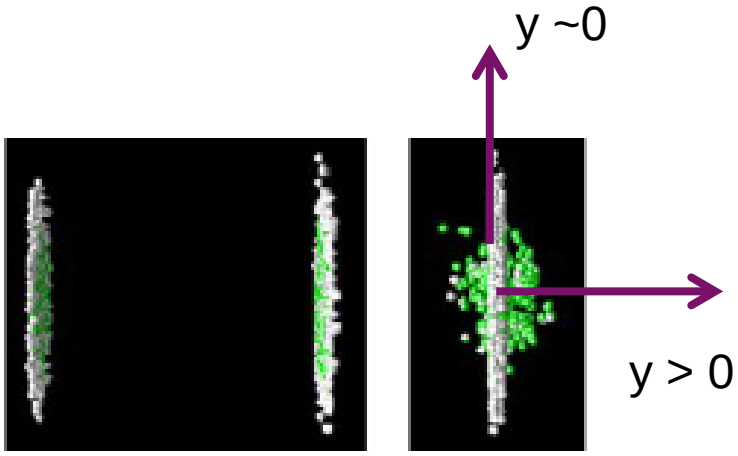
- quarkonia production in p-Pb : addressing cold nuclear matter effects
  PLB 740 (2015) 107 Saclay analysis coordinator and leading author

- **Development of theoretical models for cold nuclear effects in p-Pb**
  EPJC 73 (2013) 2427, Physical Review C 88 (2013) 047901

HIGHLIGHT: Puzzling comparisons between ALICE and CMS results

R_{AA} : production of Υ in Pb-Pb versus pp collisions





Pb-Pb collision

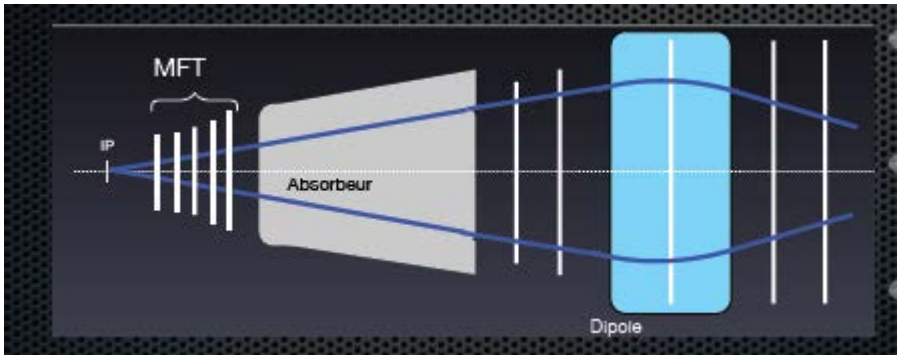
Stronger suppression at forward rapidity than at mid rapidity !!

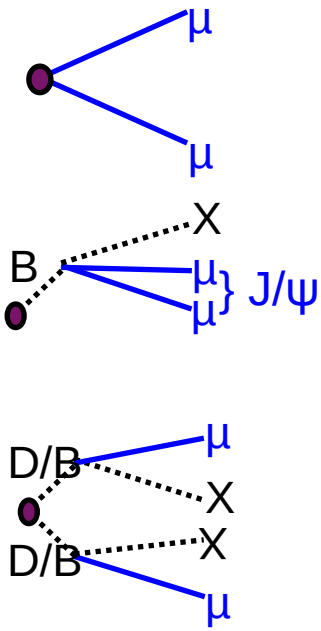
- Although smaller or similar energy density expected at forward than at mid rapidity
- Not reproduced by the model
- Role of recombination ?
- Role of cold nuclear effects ?

The Irfu involvement in the ALICE upgrade (2018+)

- **Muon tracking electronics upgrade**
  - Responsibility: Saclay coordinator of the muon chamber electronics upgrade
  - 2015 milestone: validation of the SAMPA chip
  - TDR accepted by LHCC in 2014 and MoU to be signed in 2015

- **Muon Forward Tracker (MFT):**
  - Responsibility: Saclay (SEDI) technical coordinator of the MFT
  - Saclay involved in the pixel sensor and in the ladder construction
  - TDR sent to LHCC and MoU to be signed in 2015





Innovative developments and interdisciplinary projects

- Hypernuclei
- Antiproton's production, storage and use for exotic nuclei production
- Cryogenic targets for laser-driven acceleration
- Muon tomography

Muon tomography

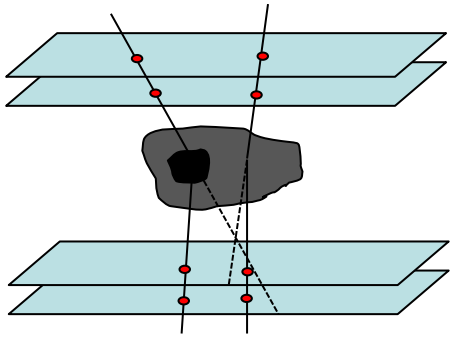
- Passive imaging using the natural cosmic muon rays

Technology based on multiplexed micromegas (patent 2012)

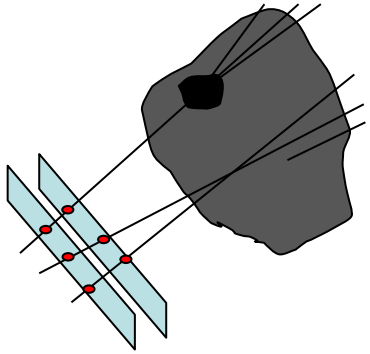
CLAS12 spinoff

- 2 working modes

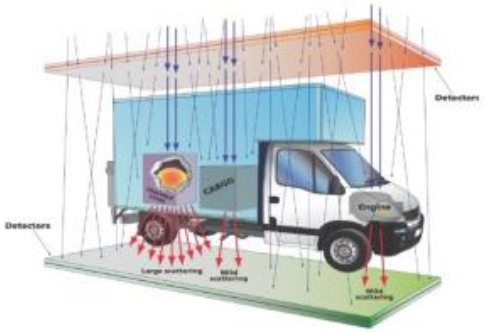
→ by deflection



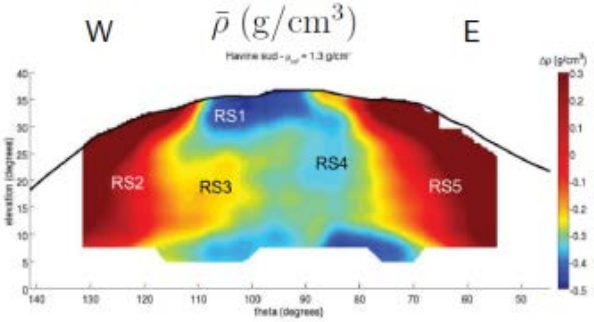
→ by absorption



Application*: homeland security*



Application*: volcanology, archeology, mining exploration*



Muon tomography: results and future milestones

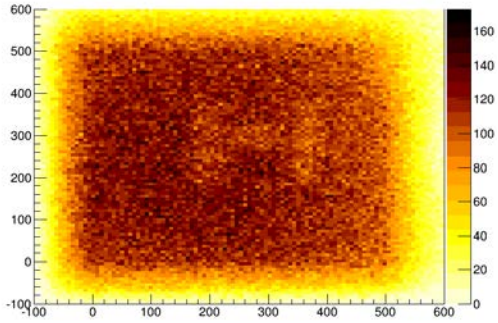
M-cube (financed by NRBC-E): demonstrator for detection of nuclear matter

- 2014: design, building and test of 5 prototypes
- 2015: assembly of the gantry and detection times measurements for different configurations (collaboration with DRT)

WaTo (Water Tower): muon telescope for a dynamic picture of the Saclay water tower

→ To validate the use of micromegas outdoors for potential applications in volcanology, archeology …

- 2014: 1st tests of tomography with lead bricks
- 2015: 1 month of data taking



Communication,
Training
Outreach

Initiatives, projects …

ESNT (CEA DSM-CEA DAM): Espace de Structure et réactions Nucléaires Théorique (5– 6 workshops and ~ 100 visitors per year)

- Celebration of the 10th anniversary (dec. 2014)
- Directors expressed support for the future

Stronger interaction with LARSIM : Laboratoire de Recherche sur les Sciences de la Matière now localized in the same builing:

→ organization of joint workshops: (this week) *"Sub-determination, incompleteness, incommensurability : the thought of the limits"*

Strongest involvement in the labex P2IO

<u>new responsibility</u>: member of the steering committee

Future

Under discussion within Irfu; development of an exhibition hall devoted to communication in the SPhN building in Orme les Merisiers

Trainees (classe de 3ième) dec. 2014