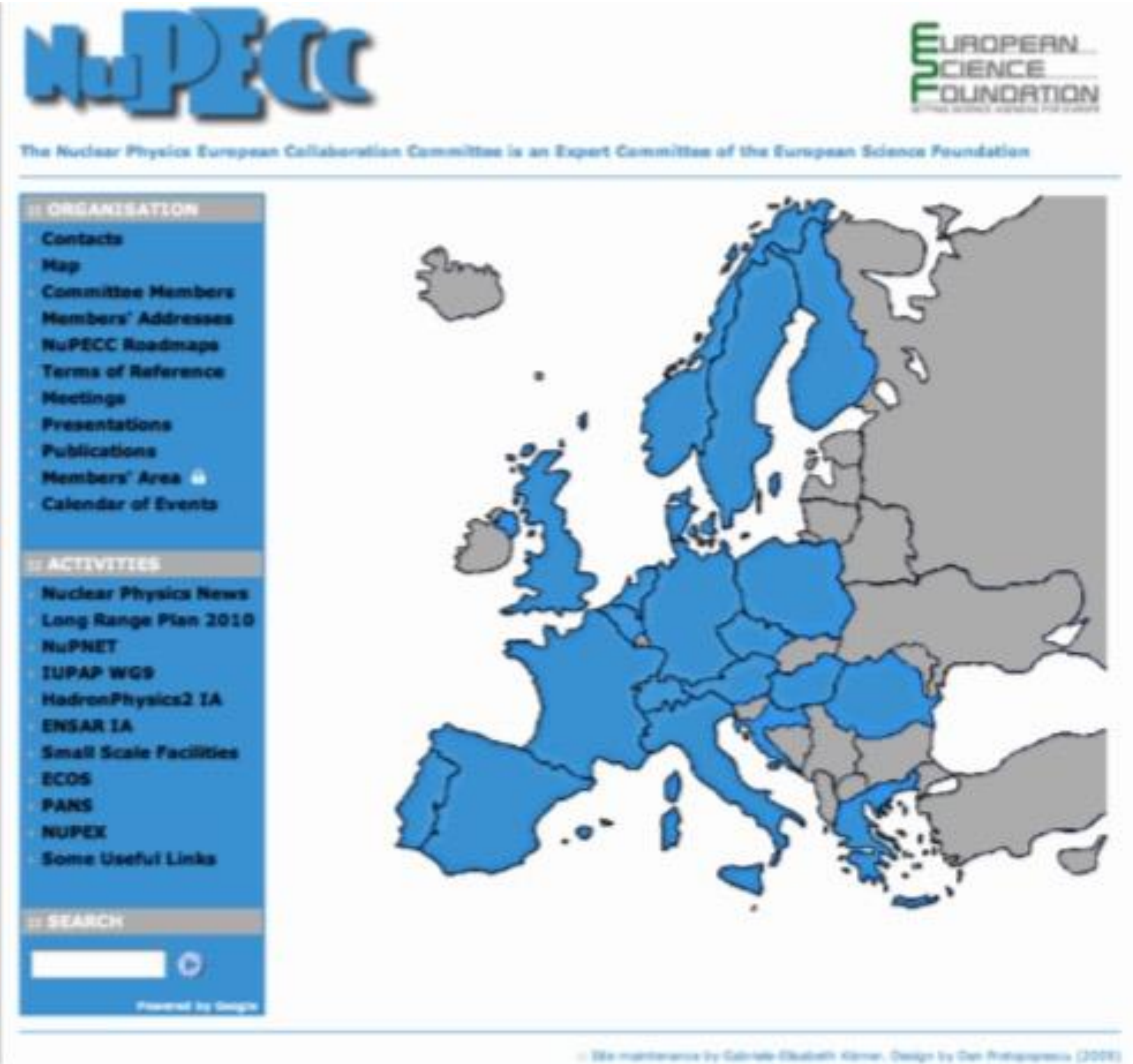
Status of the NuPECC Long Range Plan

Angela Bracco - Università di Milano and INFN
LNL, 10 October 2016



Joint Institute for Nuclear Research **Dubna-** Recently joined

Request from Turkey and Israel

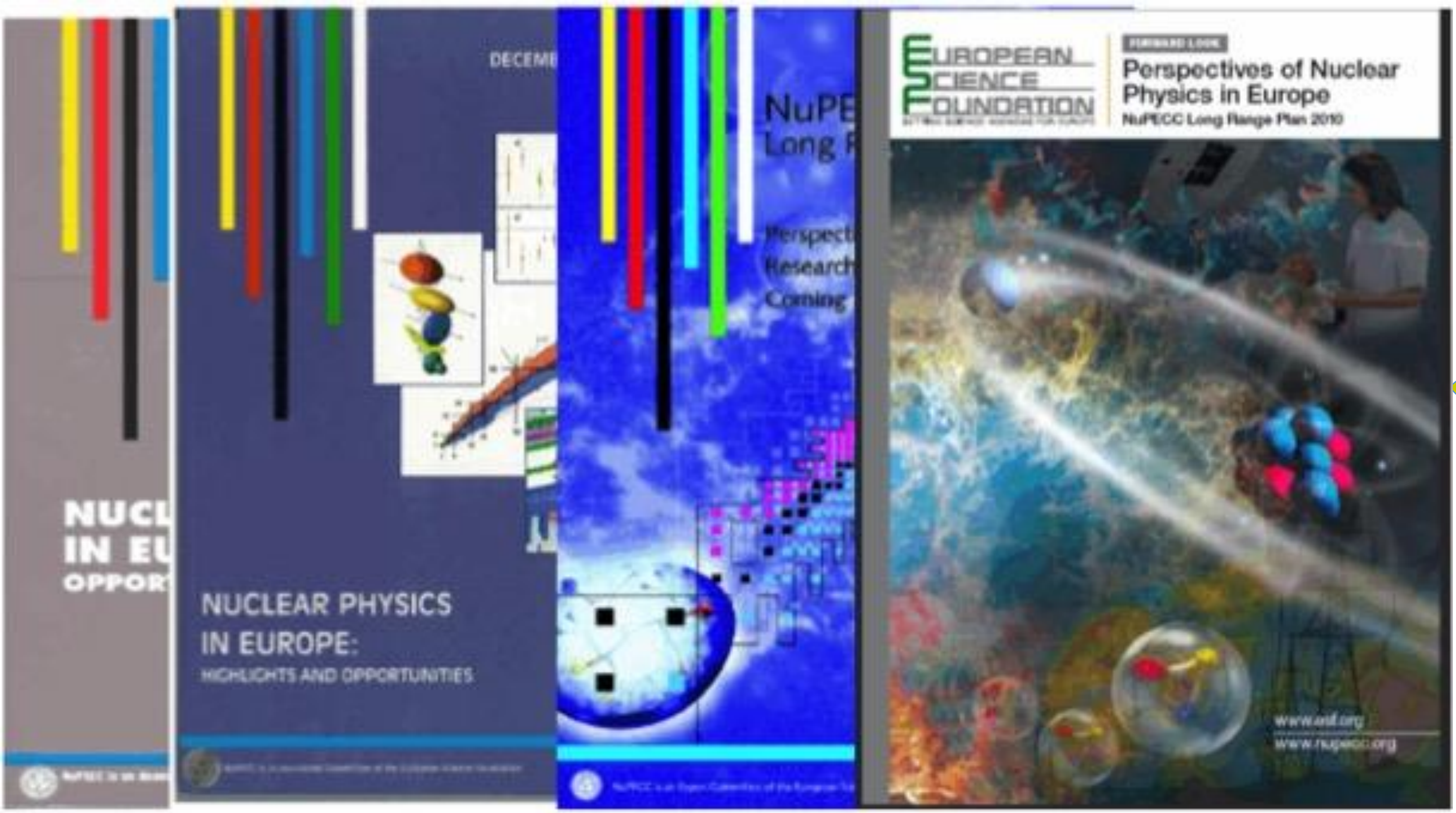
exchanges with

- AnPHA
- NSAC (mutual)
- Canada

+ ALAFNA

21 countries – 31 Members

Perspectives of Nuclear Physics in Europe



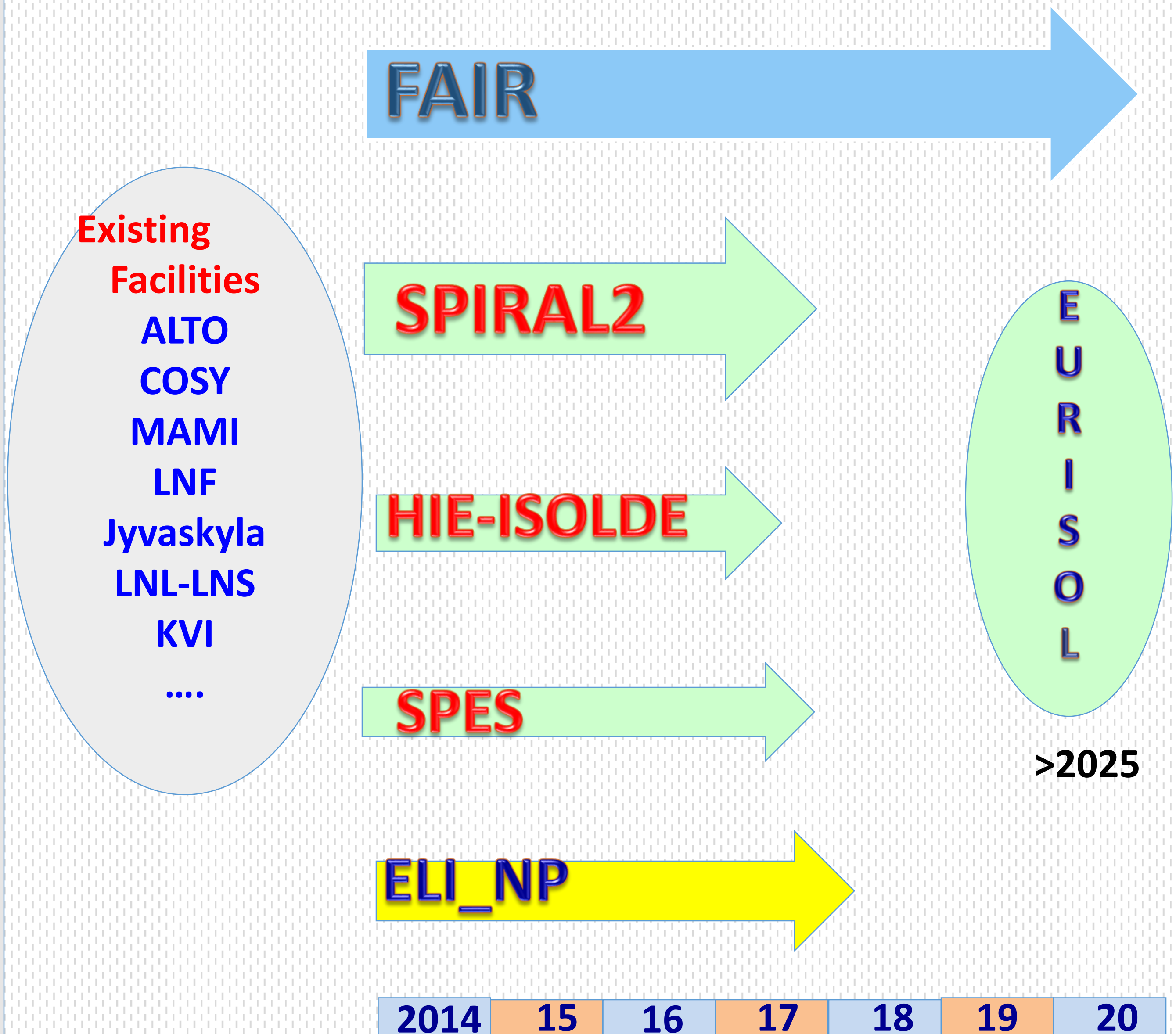
1991 1997 2004 2010

Volume
Brochure
video

NuPECC LRP (2010)

- FAIR and SPIRAL2 (ESFRI)
- HIE-ISOLDE and SPES
- ALICE at CERN
- Existing Laboratories + Luna
- Instrumentation (AGATA)
- Theory
- Applications
- New ESFRI fac.

New Facilities and Major upgrades



Shifts in time as compared with 2009

After 6 years a new Long range plan is needed

- The plans made in 2009 (published in 2010) are not yet fully realized –

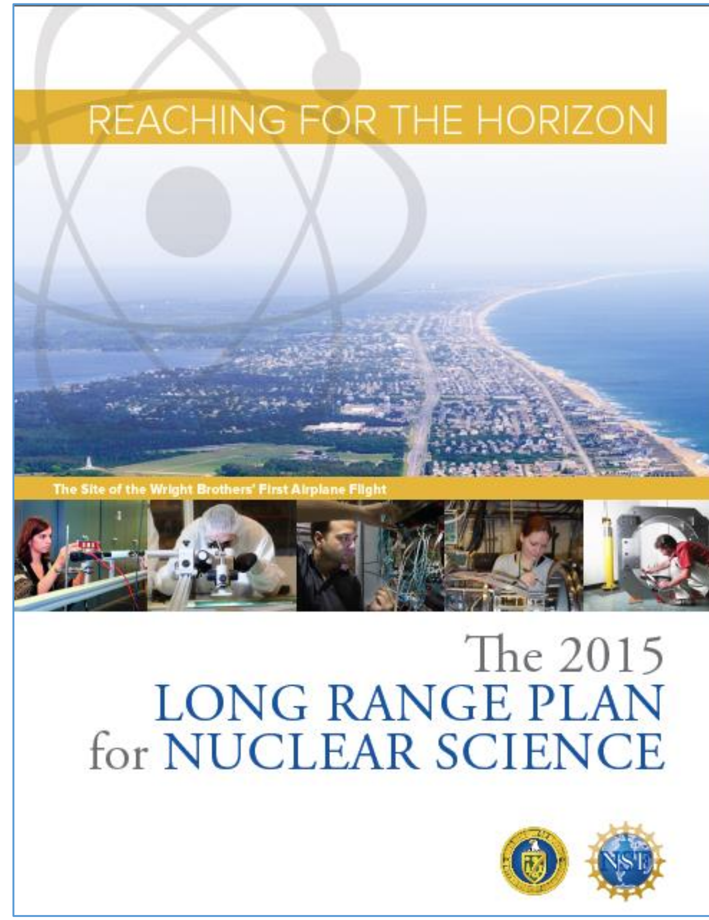
- Changes and delays in the original plans for major facilities are ongoing.

One needs urgently to :

- re-assess programmes at the present conditions and re-affirm the existing great interest on infrastructures under construction

- prepare the instrumentation (including theory) in view of the progress in science and of the changed timeline

The 2015 NSAC Long Range Plan
Reaching to the Horizons



Summary for U.S. Long Range Plan

- **The U.S. Nuclear Physics efforts are strong and moving forward rapidly.**

- **Capitalize on recent investments: CEBAF 12 GeV Upgrade, RHIC intensity upgrade and soon electron cooling, NSCL and ATLAS upgrades, and FRIB in the 2020's. There is exciting science ahead!**

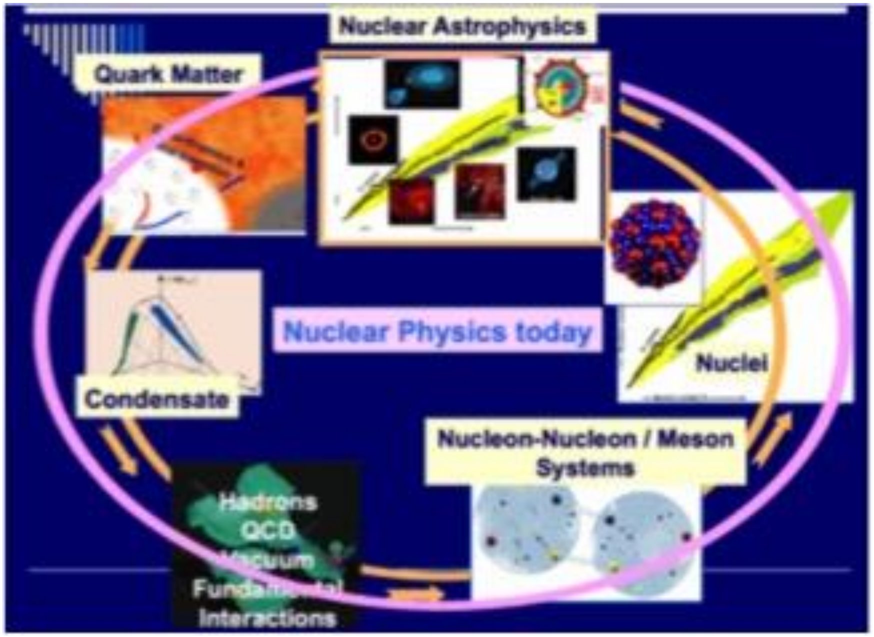
- **In the U.S. long range plan was created that will allow us to reach new horizons.**

Kitty Hawk- first flights Wright brothers

From Don. Geesaman

LRP 2016 - structure

- **One part of the volume on science and Facilities**
- **Summary and recommendations**
- **6 more detailed chapters** on the achievments and specific plans concerning the different themes of today Nuclear Physics



1) Hadron Physics
2) Phases of Strongly Interacting Matter
3) Nuclear Structure & Dynamics
4) Nuclear Astrophysics
5) Fundamental Interactions
6) Nuclear Physics Tools & Applications

LRP - Objectives

- **Review** status of the field

- Issue **recommendations** to advance
  The science
  Its applications in Europe

- Develop **action plan (roadmap) for:**
  Building new large-scale Research Infrastructures
  Upgrading existing Nuclear Physics facilities
  Collaborate closely with smaller scale facilities

- support **EU** projects (IAs, ERA-net ……)

- Put European Nuclear Physics into **global context**

−NSAC (DoE & NSF) in USA, ANPhA in Asia, ALAFNA in Latin America
−IUPAP and OECD Global Science Forum -

- Several meeting and worshops were organized by the working group members appointed by NuPECC and by the NuPECC liasons

The draft of their work was delivered and presented with oral presentation at the NuPECC meeting on October 7 in Vienna.

1) **Hadron Physics** *D Bettoni(Ferrara)* + *H. Wittig(Mainz)-*
2)**Phases of Strongly Interacting Matter** *S Masciocchi(GSI) + F Gélis(CEA Saclay)…*
3) **Nuclear Structure & Dynamics** *J Simpson (Daresbury) + E Khan (Orsay)*
4) **Nuclear Astrophysics** *G Martinez Pinedo(TU Darmstadt) + A Laird (York)*
5) **Fundamental Interactions** *K. Kirch (PSI) + K Blaum(MPI Heidelberg)*
6)**Nuclear Physics Tools & Applications** *M Durante (TIFPA Trento) +D. Letournau (Saclay)*

- **NuPECC has organized a special meeting in January to discuss the status of European Facilities**

WG3 Subgroups (SG)
Nuclear Structure and reaction dynamics

1. **Theory** (Christian Forssen and Achim Schwenk)

   Forssen, Gargano, Mora, Schwenk

2. **Nuclear structure** (Alexandre Obertelli)

   Bruce,Gargano, Dullman, Dombradi, Fornal,Forssen, Guttormsen Greenlees, Grevy,Jungclaus,Karpov,Kalantar,Leoni, Moro, Raabe, Rejmund, Obertelli,Pietralla, Riisager, Schwenk, Scheidenberger ,Ur

3. **Reaction Dynamics** (Antonio Moro)

   Karpov,Moro,Szilner,Ur

4. **The Nuclear Equation of State** (Giuseppe Verde)

   Forssen, Guttormsen, Leoni, Kalantar, Schwenk, Ur, Verdi

5. **Facilities and instrumentation** (Stéphane Grevy)

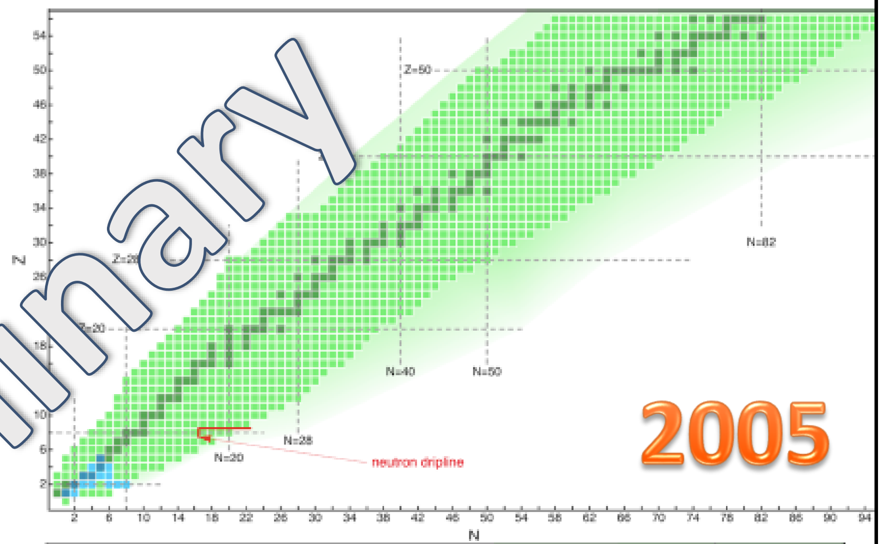
   Grevy, Kalandar, Leoni, Riisager, Scheidenberger , Szilner, Ur, Verde

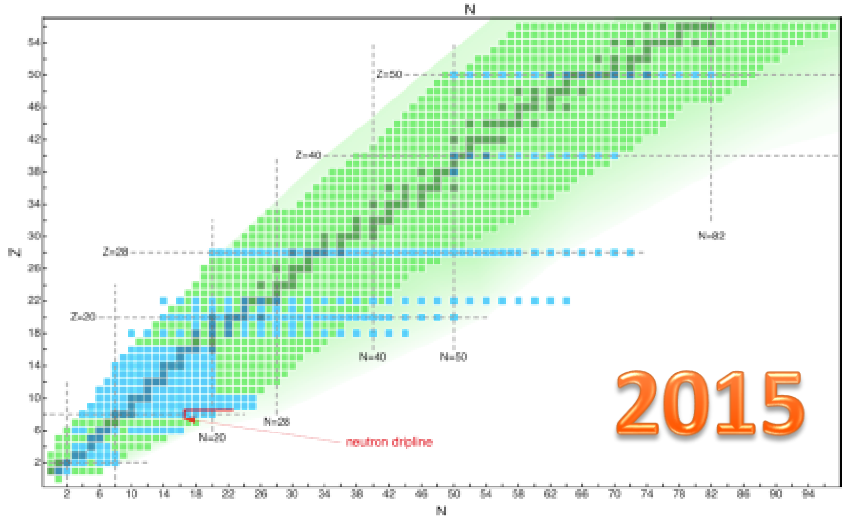
Theory in the Long Range Plan of NuPECC 2016-2017

Box 2. The reach of *ab initio* methods

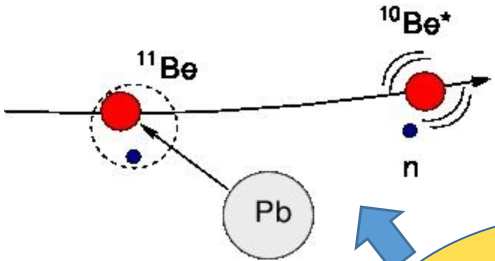
In recent years, *ab initio* computations of nuclei have advanced tremendously. This progress is due to an improved understanding of the strong interaction that binds protons and neutrons into nuclei, the development of new methods to solve the quantum many-body problem, and increasing computer performance. In the early decades, the progress of *ab initio* methods was approximately linear in the mass number *A* because the computing power, which increased exponentially according to the Moore's law, was applied to exponentially expensive numerical algorithms. In recent years, however, new generation methods, which exhibit polynomial scaling in *A*, have dramatically increased the reach. The figures show the chart of nuclei and the reach of *ab initio* calculations in 2005 (top) and 2015 (bottom). Nuclei for which *ab initio* calculations exist are highlighted in blue. Note that the figure is for illustrative purposes only and is based on a potentially non-exhaustive survey of the literature.

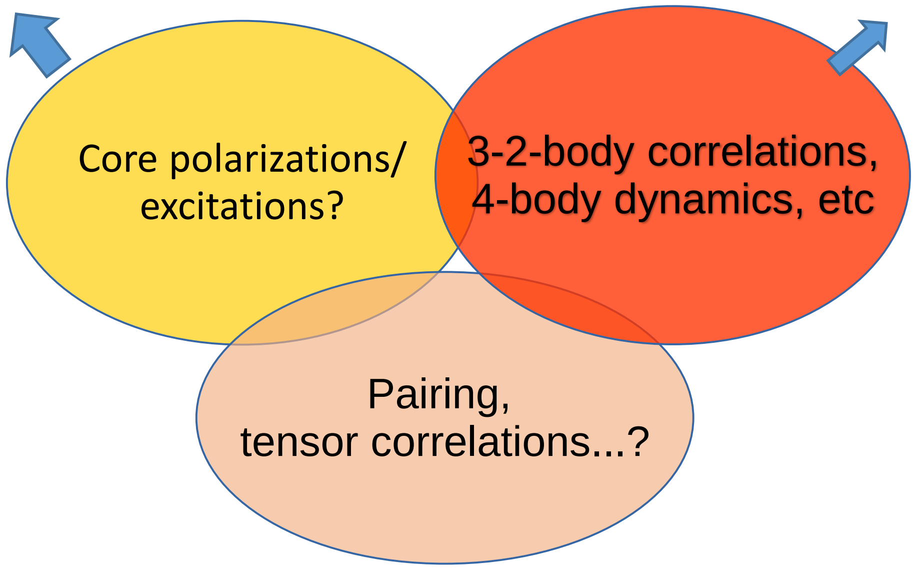
These recent developments allow employing *ab initio* many-body methods to perform dedicated tests of nuclear interactions and to answer what input is required to best constrain nuclear forces.

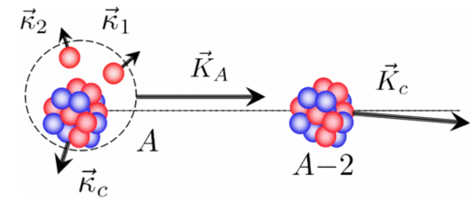


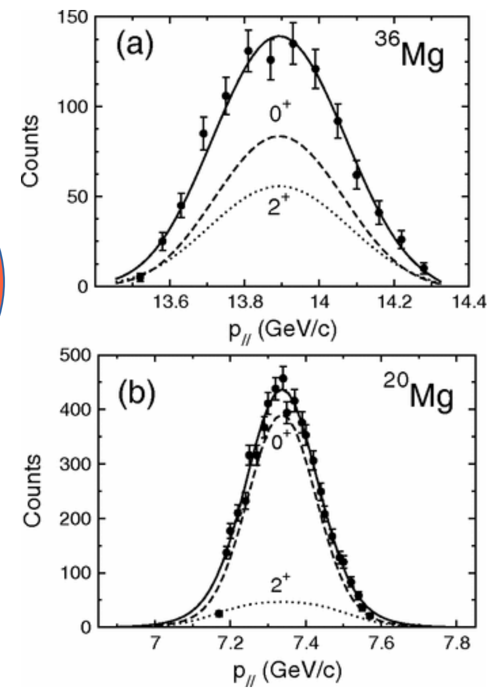


Interfacing structure with reaction observables



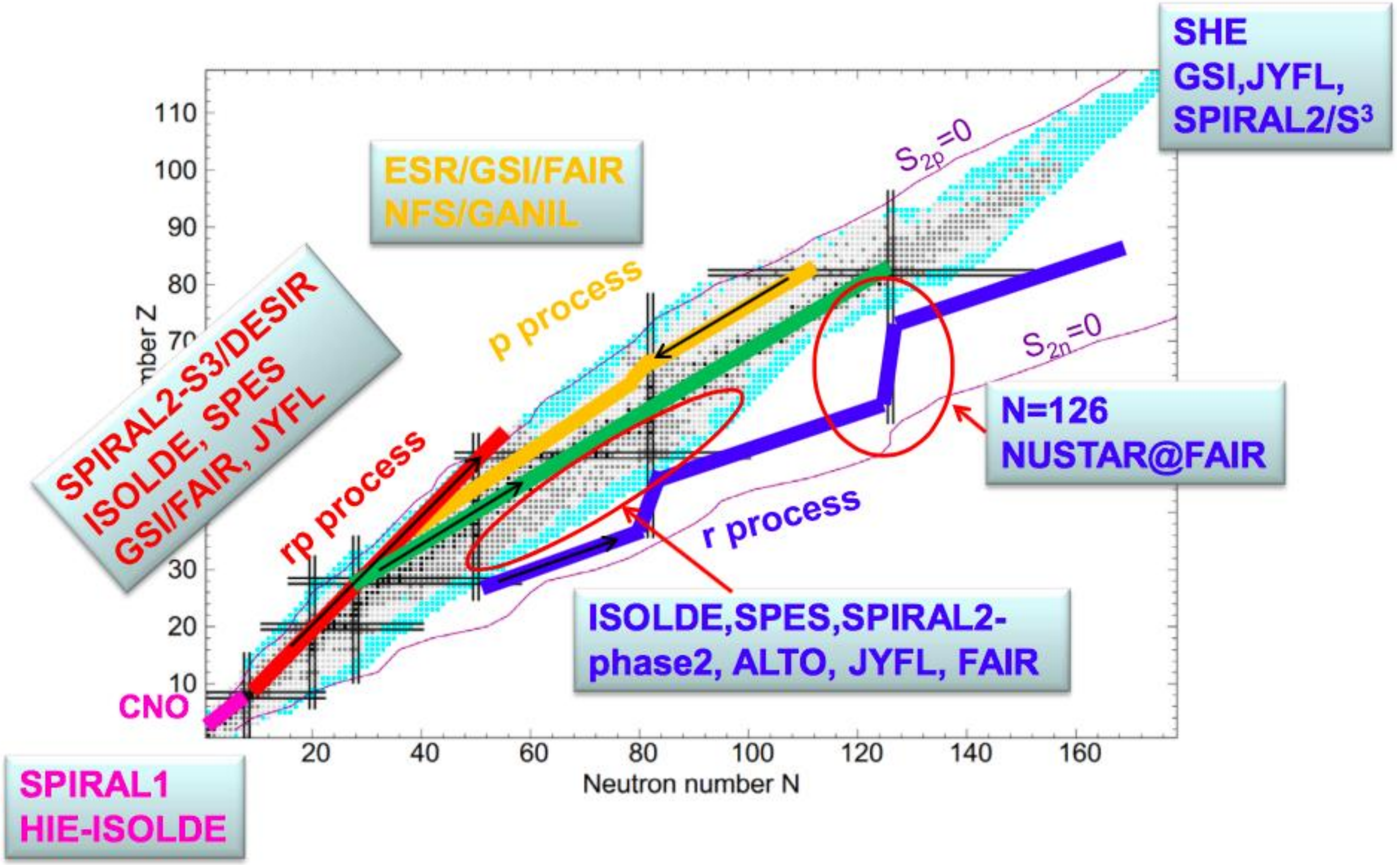






- Improvement of structure inputs in reaction frameworks.
- Understanding how structure phenomena (core polarizations, pairing & tensor correlations, etc.) show up in reaction observables.
- Exploring what structure information can be actually extracted from reaction observables: particles correlations, 2N transfer, etc

Nuclear Astrophysics: opportunities with RIB Beams



- Studies relevant to all explosive scenarios
- High quality (energy, time, etc.) radioactive beams for studying reaction cross sections (direct and spectroscopic measurements) at stellar energies
- Measurements away from stability crucial for testing models

SG5: Facilities and instrumentation (key questions, topics)

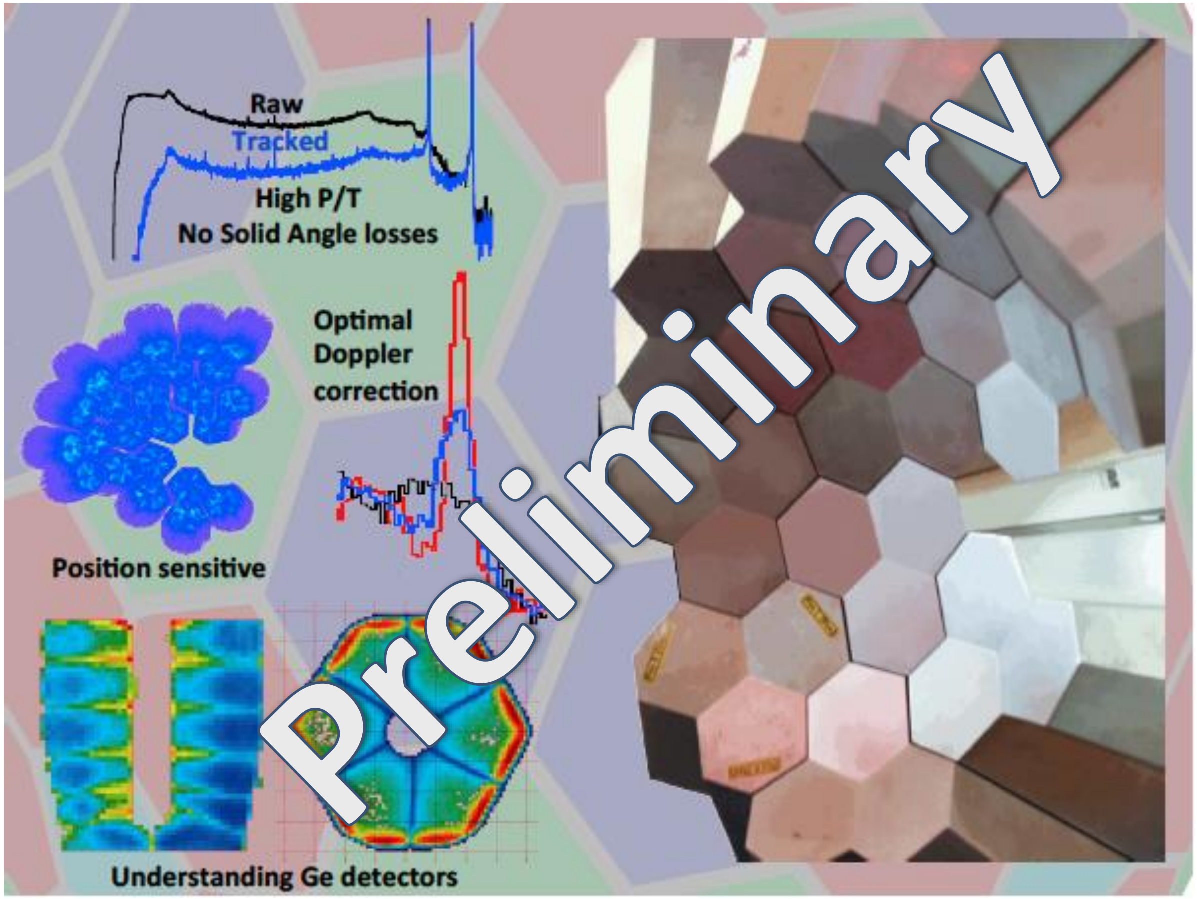
1) Accelerator/Reactor facilities

- **RIB Facilities**
- **Stable Ion Beam and others techniques**

2) Instrumentation

- **Separators, spectrometers and associated detection for the identification**
- **Detectors for structure and dynamic studies**
  - **Gamma detectors**
  - **Particle detectors**
  - **Neutron detectors**
  - **Active targets**
  - **Hadron spectrometers**
- **Storage rings**
- **Traps and Lasers**
- **Transverse Innovations**

AGATA in the Long Range Plan of NuPECC 2016-2017



- Currently, AGATA is being exploited at GANIL (until 2019) using its wide variety of stable and radioactive beams and site-specific spectrometers as well as state-of-the-art ancillary detectors for charged particles, neutrons and high-energy γ rays (see figure).

- From 2020 the collaboration plans to extend AGATA up to 40 units thus covering two thirds of 4π. **This array will be a key instrument at the next-generation facilities NUSTAR at FAIR, SPES at LNL and SPIRAL 2 at GANIL.**

Chapter on Applications

1.Energy applications

- 1.1 Next generation fission reactors
- 1.2 Accelerator driven sub-critical systems
- 1.3 Fusion reactors
- 1.4 Nuclear power sources for space applications
- 1.5 Future perspectives and recommendations

2. Health applications

- 2.1 Particle therapy
- 2.2 Imaging
- 2.3 Radioisotope production
- 2.4 Radioprotection

3. Environmental and Space applications

- 3.1 Climate and earth science
- 3.2 Environmental radioactivity
- 3.3 Space radiation

4. Societal applications

- 4.1 Heritage Science
- 4.2 Nuclear security and counter terrorism

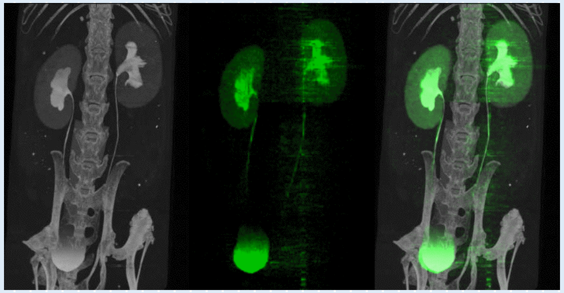
5. Cross-disciplinary impact in other domains

- 5.1 Material sciences
- 5.2 Atomic and Plasma physics

6. Summary and recommendations

2. Health applications

2.2 Imaging



- Spectral CT, including K-edge imaging, based on hybrid pixel detectors
- 3-photon cameras (gamma-PET)
- IGRT for particle radiosurgery using CBCT, online PET, particle radiography, prompt gamam or charged particle emission

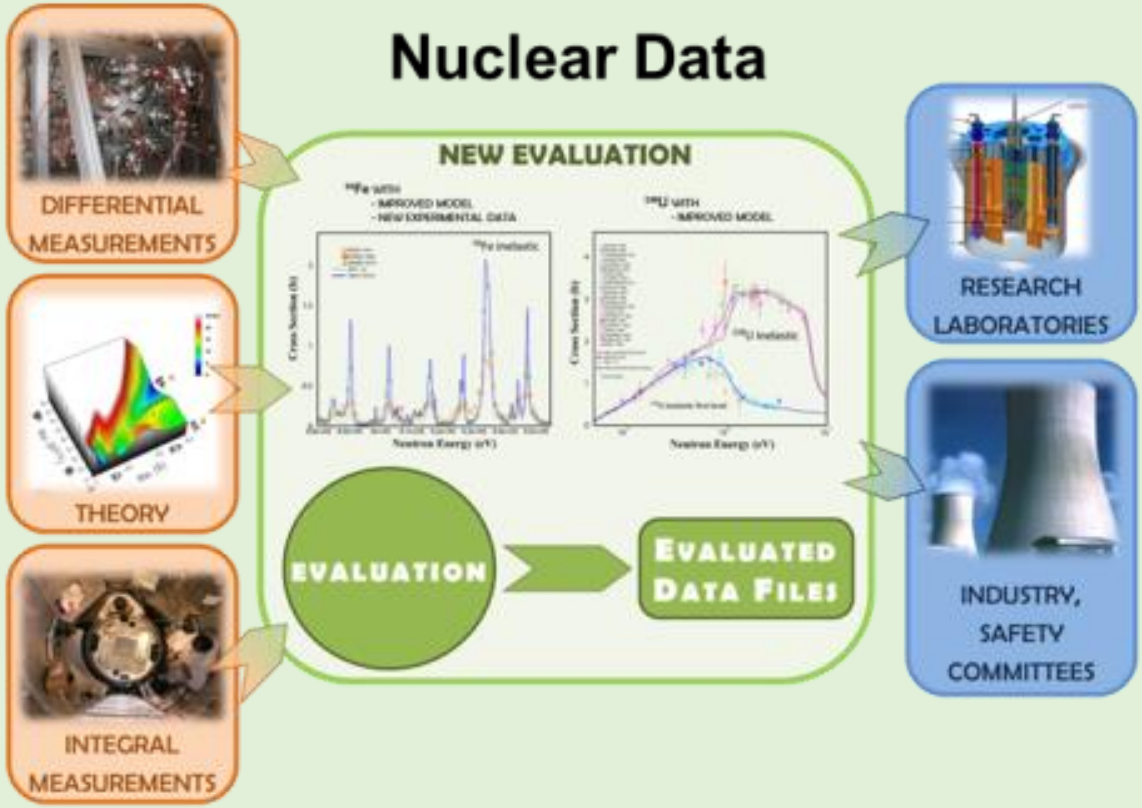
2.3 Radioisotopes

- Therapy (radioimmunotherapy)
- Theranostics (with nanoparticles)
- Production: need increasing, R&D required
- Purity: Physical separation (replicing chemical) based on mass separators like ISOLDE

2.4 Radioprotection

MELODI

Nuclear Data

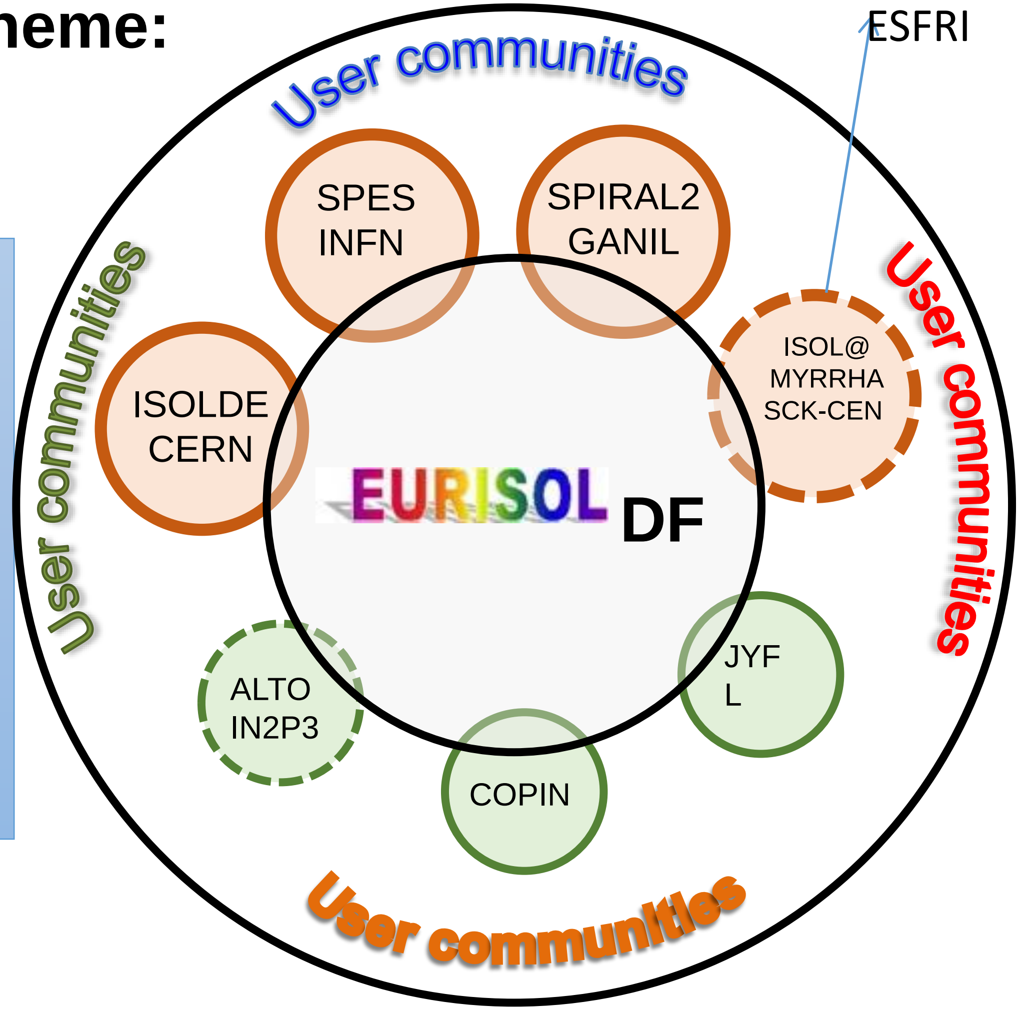


In absence of predictive and reliable models able to describe nuclear reactions with the accuracy needed to fulfill the requirements imposed by nuclear systems in operation, Nuclear Data are the key ingredients in the simulation codes to assess the performance of innovative nuclear systems in normal and accidental conditions. Indeed, any calculation or simulation of the behavior of a nuclear system, and its safety limits, heavily relies on the production and transport of neutrons, photons, charged particles and recoil nuclei. Improving the accuracy of neutron-induced reaction cross section data for a variety of isotopes and over a wide range of energies is, for example, fundamental for the neutronics of the core and the production of radioactive elements. Similarly, improvements in the accuracy of fission yields and decay data are necessary to calculate the energy deposition inside the fuel element, the decay heat in case of urgent stopping and to predict the evolution and assess the safety of spent nuclear waste. An important part of the activity is related to nuclear data evaluation, with complete uncertainty and covariance analysis needed, as well as compilation and continuous maintenance of nuclear data libraries as the JEFF European library.

ISOL FACILITIES

EURISOL – Distributed Facility (DF) Initiative

Proposed EURISOL-DF scheme:



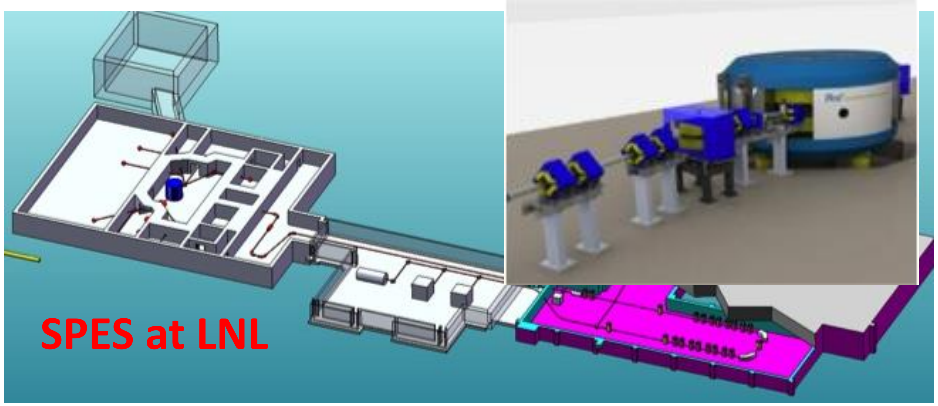
- **EURISOL Science Case & Experiments**
  - Dedicated beamtime for EURISOL-DF experiments
  - Dedicated EURISOL-DF Scientific Council & PAC
- **R&D for EURISOL**
  - Dedicated Technical Advisory Committee
- **Legal entity (ERIC,…)**

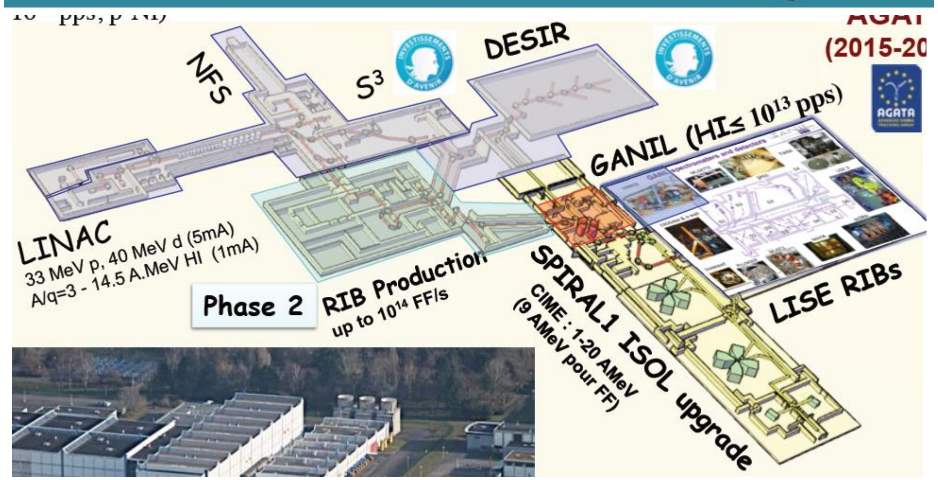
Main and Satellite facility structure

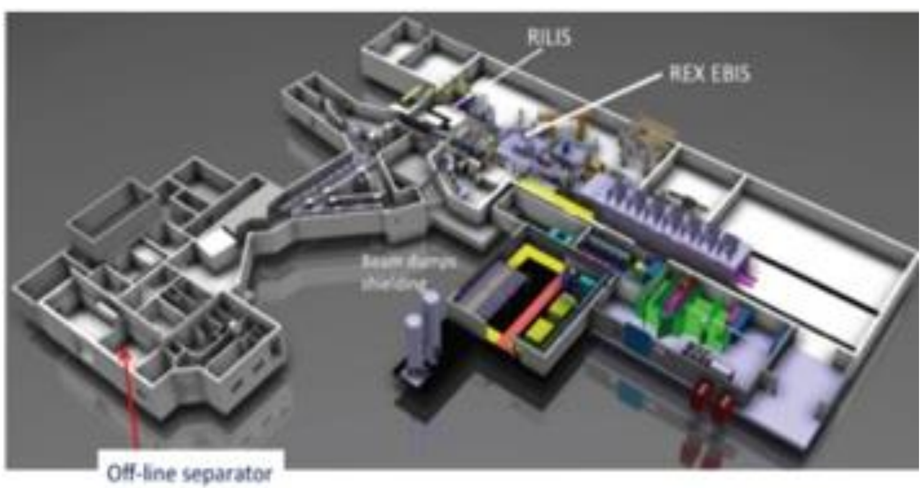
Interaction with EURISOL JRA in ENSAR 2 and EURISOL User group

http://www.eurisol.org/eurisol_df/

Project to be submitted for the 2018 update of the ESFRI roadmap





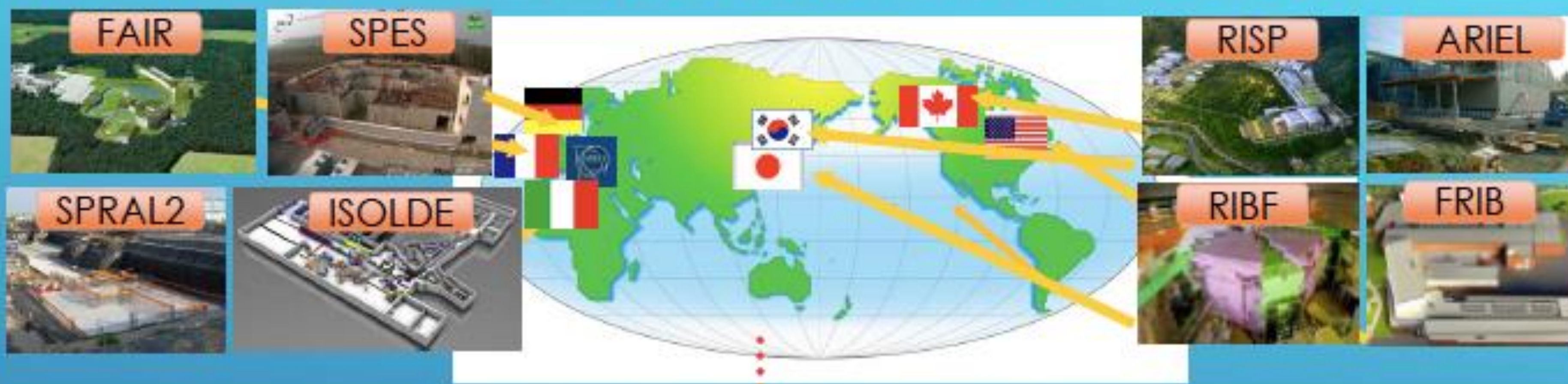


For the Distributed-Facility

Important aspects to be considered :

- Maturity of the projects
- Common developments and specific features and roles of each site
- Why we need in Europe such an organization to progress in this science

…. .the worldwide situation ….and Eurisol_DF



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
RIBF	Exp start					Complete								RIBF2 ???							
FAIR	Const.												1st Exp		Complete						
FRIB							Const.							1st Exp		Complete					
ARIEL		Const							1st Phase					Complete							
GANIL		Const										Exp		Complete							
SPES						Const					Exp		Complete								
ISOLDE							Const		4 MeV		10 MeV		Complete								
RISP									Const.				1st Exp		Complete						

European Strategic Forum Research Infrastructures

- NuPECC, APECC , CERN ….are observers and gave inputs for **STRATEGY REPORT ON RESEARCH INFRASTRUCTURES -** March 10 2016

http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri

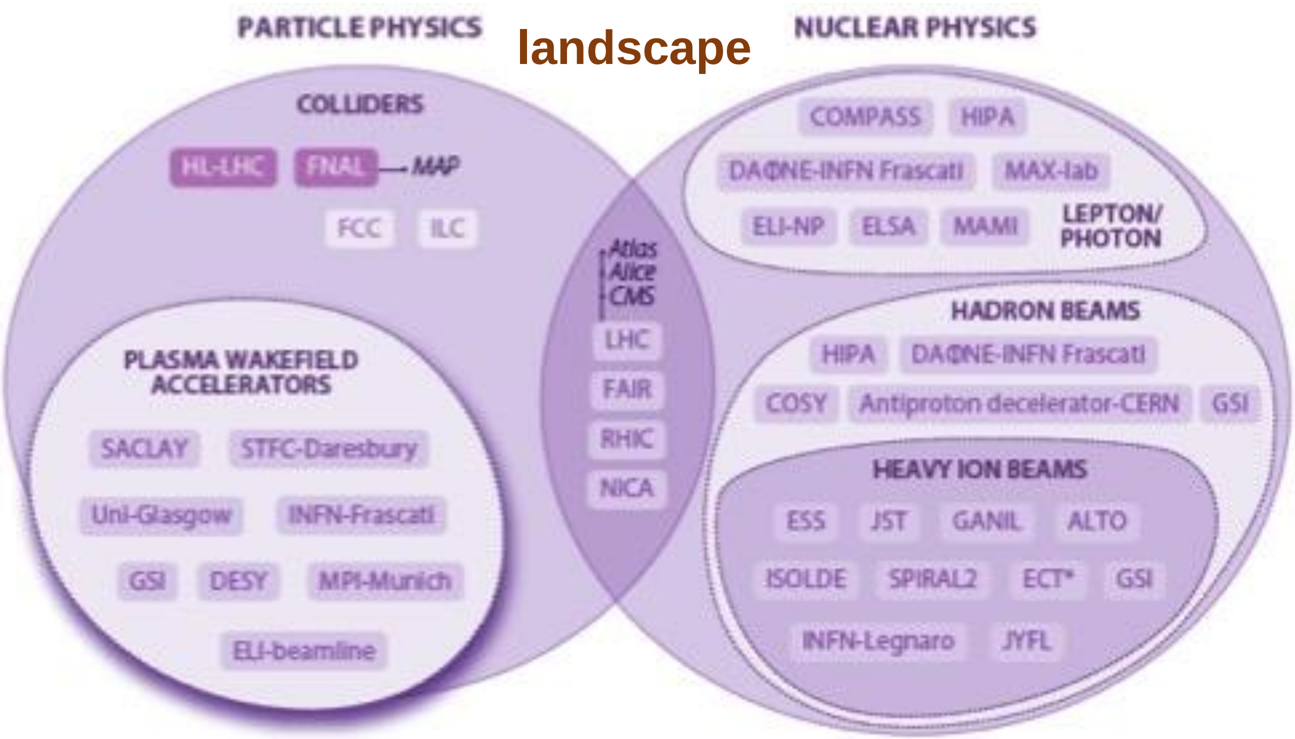
Landmark Facilities

– FAIR -→ synergies with NICA at JINR

– SPIRAL2

– ELI_NP

landscape



In 2018 the list will be updated – a proposal from NP is in preparation

Next meetings of ESFRI to update the list in 2018

- **The procedure will be launched in October 2016 at Cape Town (South Africa) during the ICRI conference**.

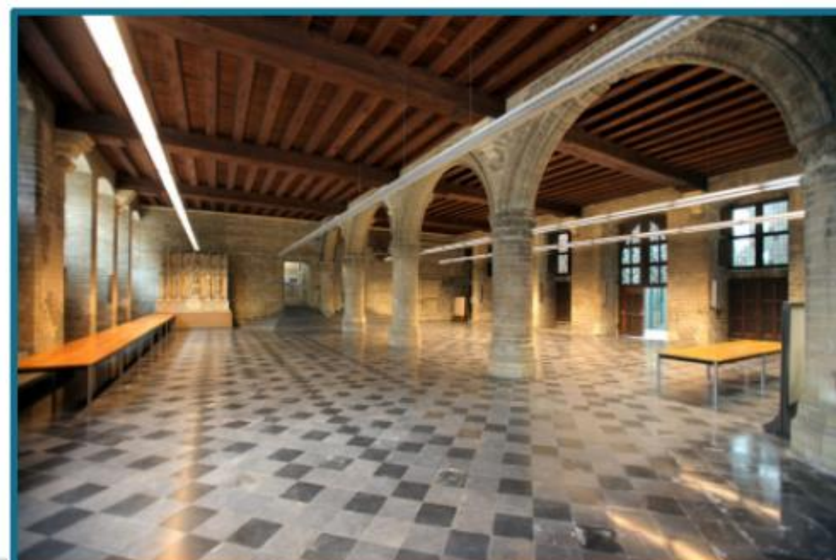
The International
Conferences on Research Infrastructures (ICRI) 2016 is co-organised by the South African Department of Science and Technology (DST) and the European Commission.

EURISOL DF 2016

- 18-21 October 2016
- Leuven
- Expecte attendance: ≥ 200 participants

Promotiezaal KU Leuven
(385 places)

Jubileumzaal: coffee breaks, reception,
lunch and poster session(s)

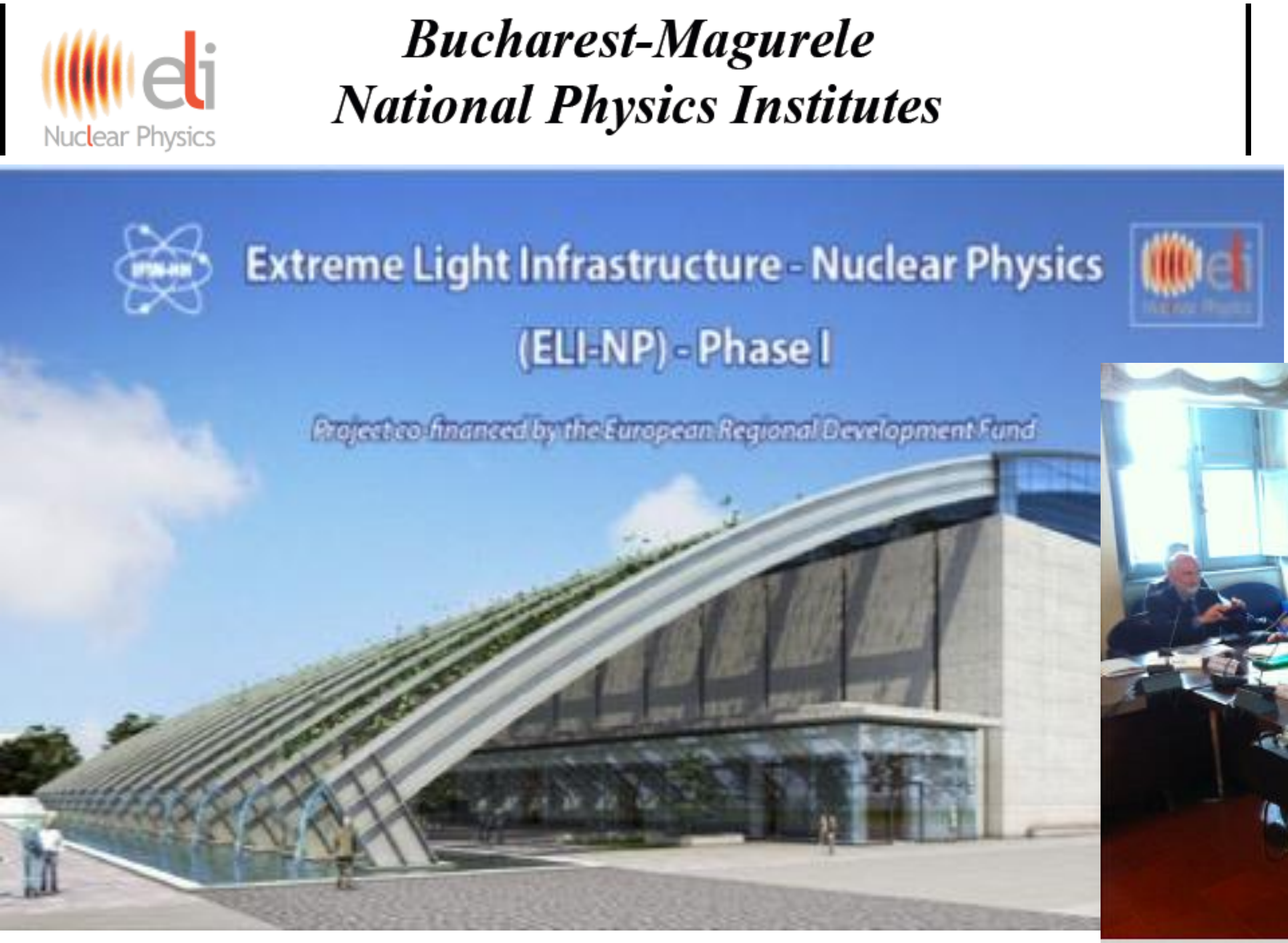


Future Facilities- NuPECC LRP 2010

- **The inclusion of Nuclear Physics programmes at the multi-purpose facilities ELI and ESS.**

ELI (distributed facility)
ESFRI ROAD MAP
see ESFRI Report 2010

ELI-NP within the Rumanian pillar



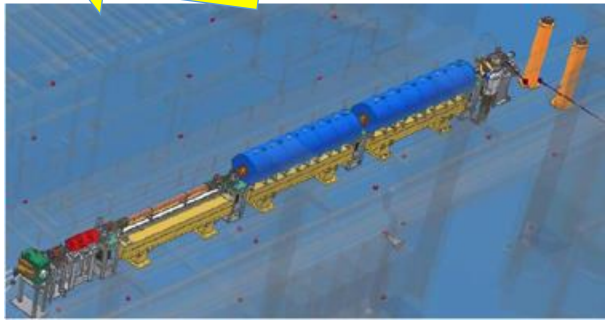
ELI-Nuclear Physics

Large equipments:

- *Ultra-short pulse high power laser system, 2 x 10PW maximum power*

  0.5% band width 10^4 photons/eVs.
- ***Gamma beam**, high intensity, tunable energy up to 20MeV, produced by **Compton scattering of a laser beam on a 700 MeV electron beam produced by a warm LINAC***

Competitor of
higs.tunl.duke

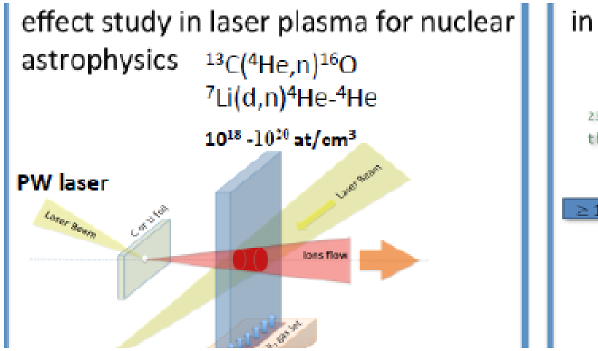


Buildings: 33000sqm total

Experiments:

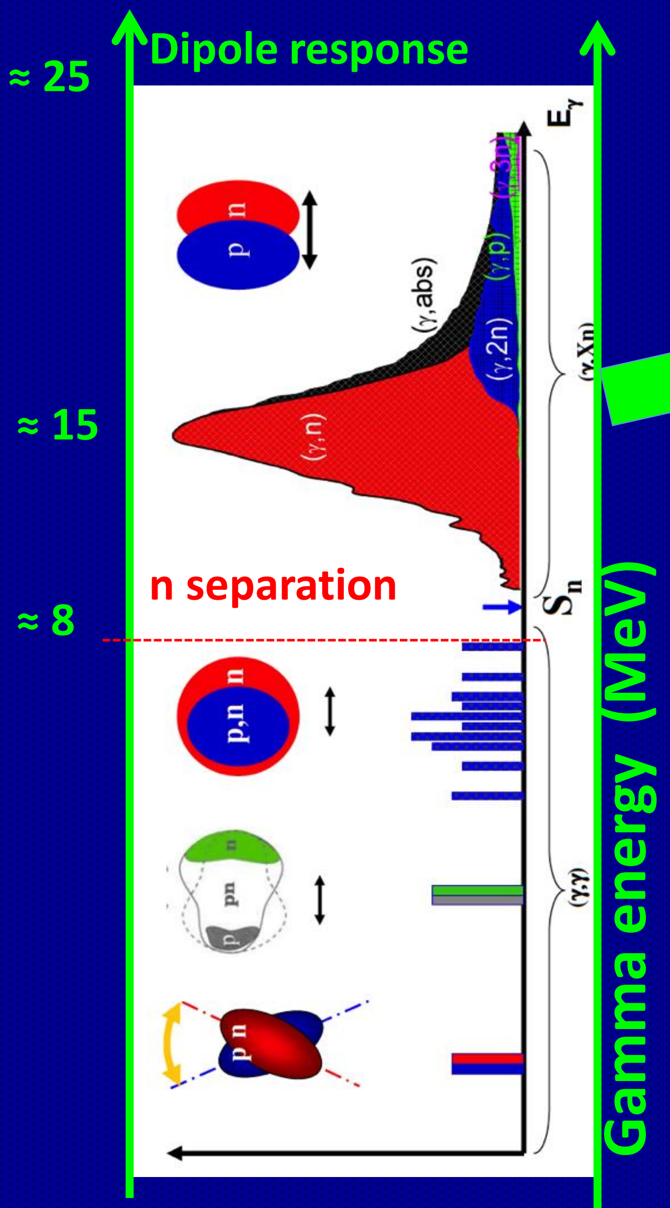
- *8 experimental areas,*

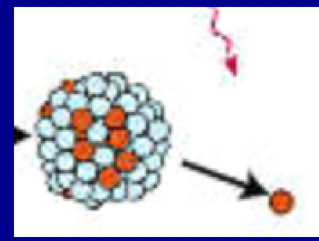
  Interaction chambers, Beam transportation
- *8 auxiliary laboratories*
- ***Nuclear Structure- Nuclear Astrophysics and Applications***

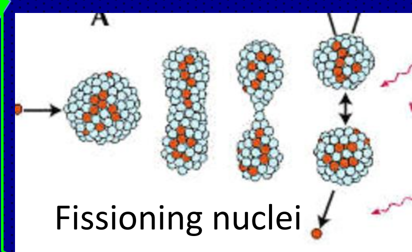


Peak brilliance
photons/s·mm^2·mrad^2·0.1%bwd 10^{20}–10^{23}

Electromagnetic excitation of nuclei by γ beams







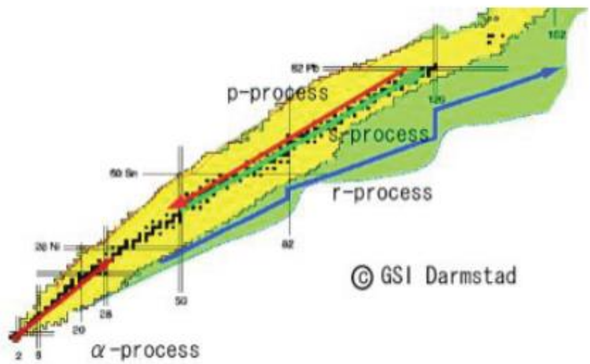
- nuclear structure of collective modes- exclusive data
- Order -chaos cohexistance
- Reaction rates for astrophysics
- Rare isotopes production

- Detailed nuclear structure
- M1 transition important for neutrino interaction
- Nucleosyntheses r and s processes
- Fission barrier and high deformations

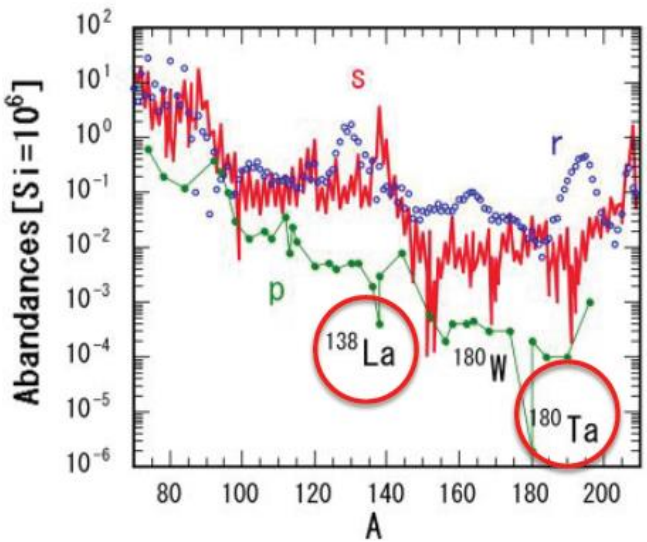
Nucleosynthesis of very rare isotopes

P-process nucleosynthesis

Photonuclear reactions play a major role.

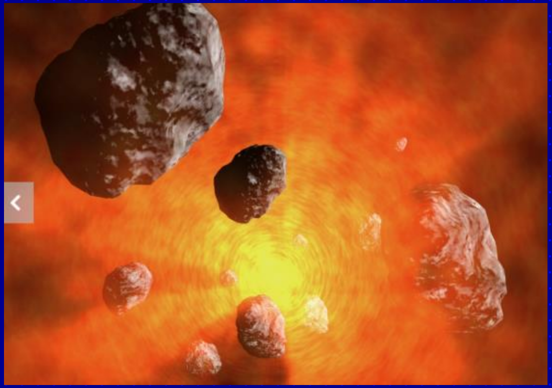


35 neutron-deficient rare isotopes

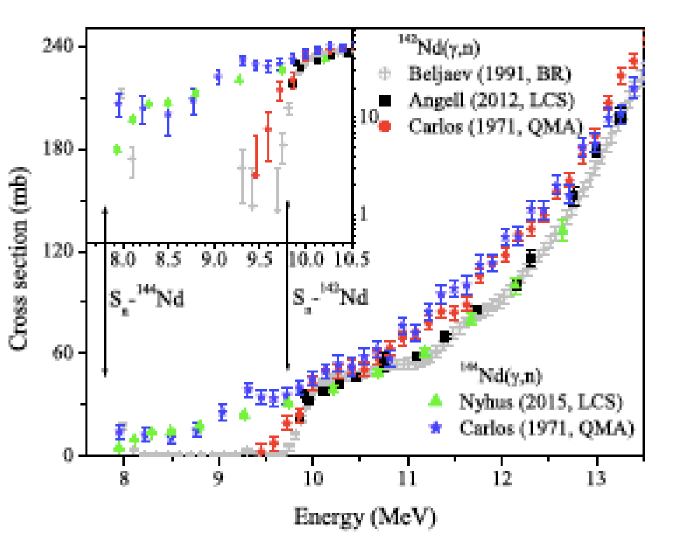


180Ta(γ,n)179Ta

138La(γ,n)137La



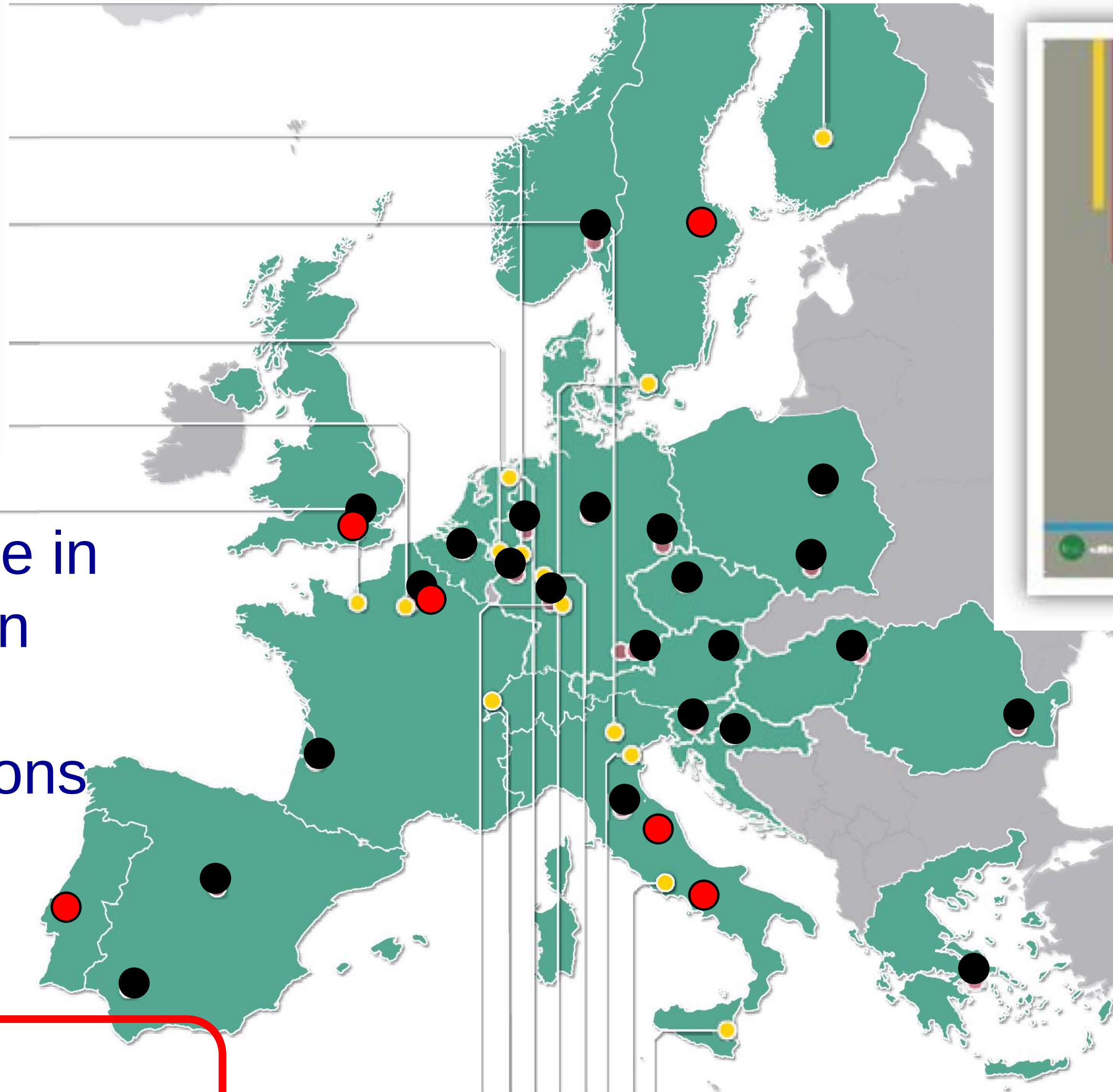
Abundances from meteorites presosal grain and geochemical analysis

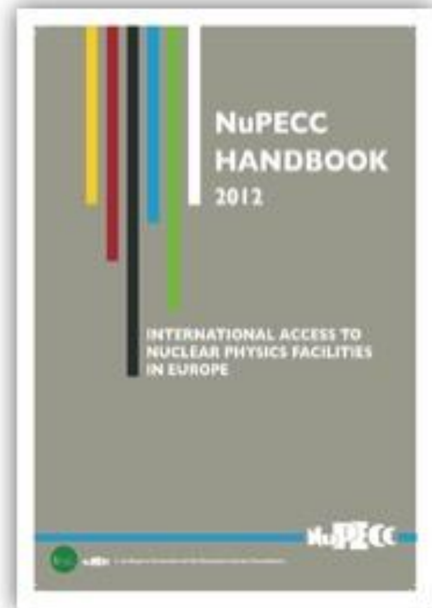


The need is to measure accurately (γ,n) at threshold

Small scale facilities

European Small-scale Accelerator Facilities





Specific role in
- Education
- R&D
- Applications

European Networ
Accelerato
ENSAR2

30 small scale facilities

LUNA AT LNGS-NEW ACCELERATOR

LUNA site

LUNA MV
(approved)
$U_{terminal}$ = 350 – 3500kV
I_{max} = 500μA (on target)
ΔE = 0.7keV
Allowed beams: H^+, ^4He, ^{12}C

LUNA 1
(1992-2001)
50 kV

LUNA 2
(2000 – …)
$U_{terminal}$ = 50 – 400kV
I_{max} = 500μA (on target)
ΔE = 0.07keV
Allowed beams: H^+, ^4He, (^3He)

Nuclear reactions at stellar energies
for nucleosynthesis-
star evolution, energy production

At the position of ICARUS
Start with beams of the new accelerator in 2018

INTERNATIONAL COOPERATIONS

EUROPEAN SCIENCE FOUNDATION

NuPECC

INSTITUTE for NUCLEAR THEORY

USA

ECT*

FONDAZIONE BRUNO KESSLER

Technische Universität München

TECHNISCHE UNIVERSITÄT DARMSTADT

RIKEN

Japan

NAOJ

National Astronomical Observatory of Japan

APCTP

Asia Pacific Center for Theoretical Physics

Korea

JINR Dubna

Russia

ITP

Chinese Academy of Sciences

China

Final remarks….

Nuclear Physics is in general a very vital field

The new facilities under constructions for nuclear physics will engage the community for several years-

Delays in the construction !!!
The community needs to push for the realization of the scientific objectives with no further delays
and to update and reformulate them when needed

NuPECC is preparing the next LRP
This will play a role for Nuclear science in giving it the deserved visibility towards the funding agencies and towards other communities in the international general landscape

Town meeting for LRP of NuPECC

at GSI

11-13 January 2017