

# **Round table on Facilities for Nuclear Science and its application**

- **From the long range plan of NuPECC**
- **Particular remarks for facilities not discussed by the other speakers**
- **Connection of European facilities with others worldwide**



- What is NuPECC
- What is the Long range plan of NuPECC and why?
- Who did produce this strategic document?



- The science in a nutshell
- The areas of research



- The facilities and the cutting edge technologies
- The recommendations
- ....the next step : the implementation

The European Expert Board  
for Nuclear Physics  
associated to ESF

**Representing  
about 6000 scientists**

**Members: 31 institutions  
from 21 countries  
JINR Dubna also joined**

**Main mission is**  
strategy at European scale  
for the field  
Nuclear Physics news (4/years 6000  
copies- 28 years)



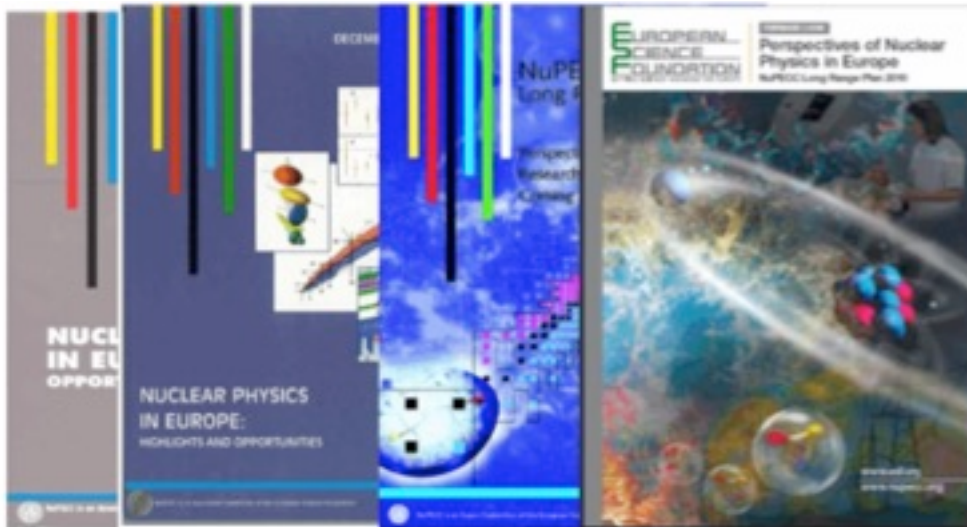
Observers : RIKEN Nishina center  
i\_THEMBA

LRP 1991

1997

2004

2010



2017

- The LRP **identifies opportunities** and priorities for the nuclear science in Europe
- The LRP **provides** the European Commission and national funding agencies with a **framework for coordinated advances** in nuclear science in Europe



**2016 beginning**

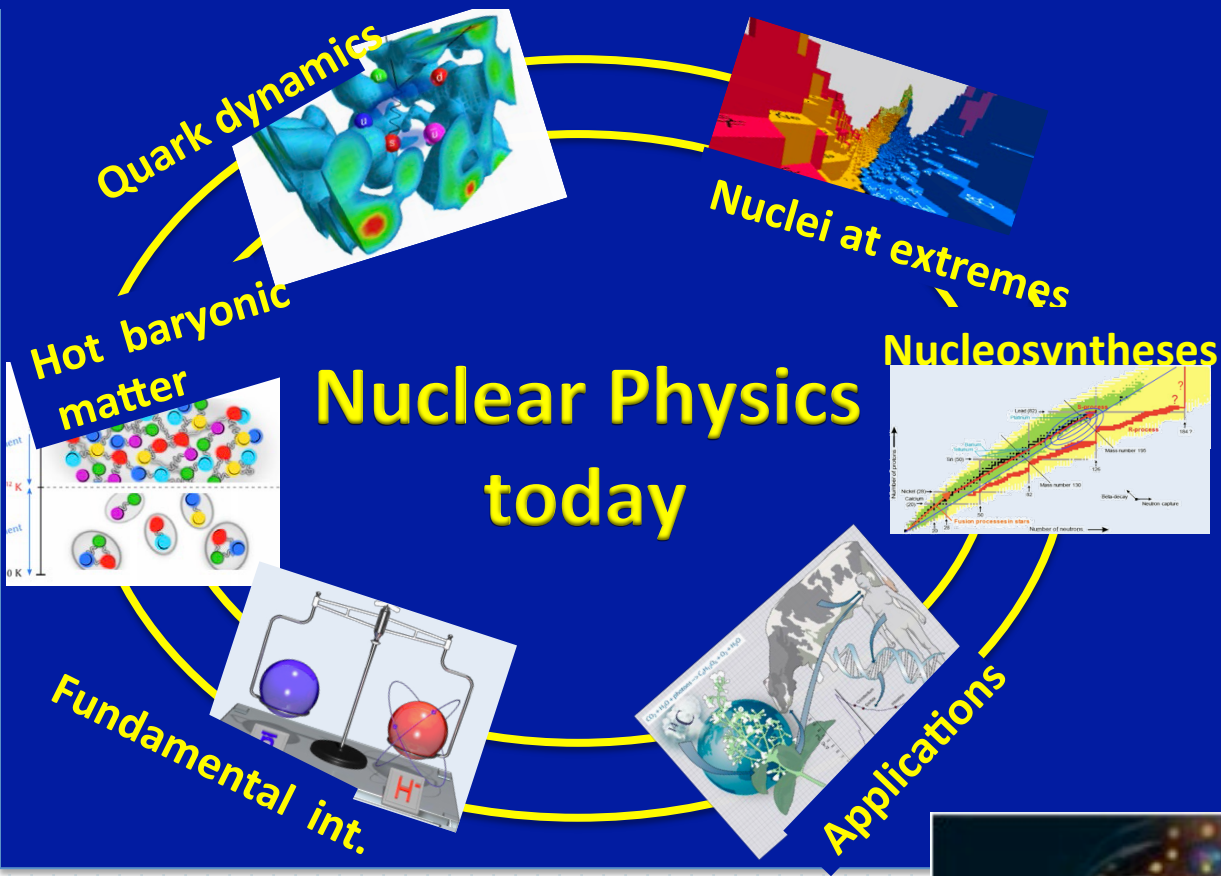
**Community working in the field :  
experts in experiments and theory**

**Town meeting Darmstadt  
January 2017**

**Report  
June 2017**

**end 2017**

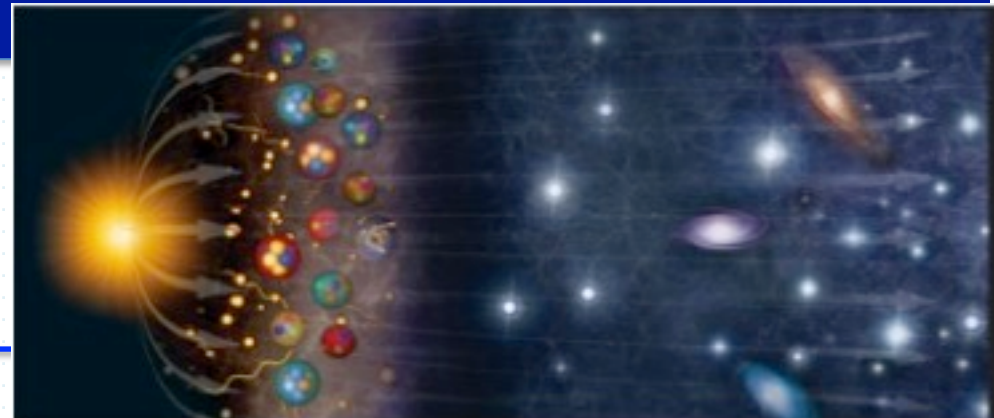
**Study of nuclear matter in all its forms  
and exploring their possible applications**



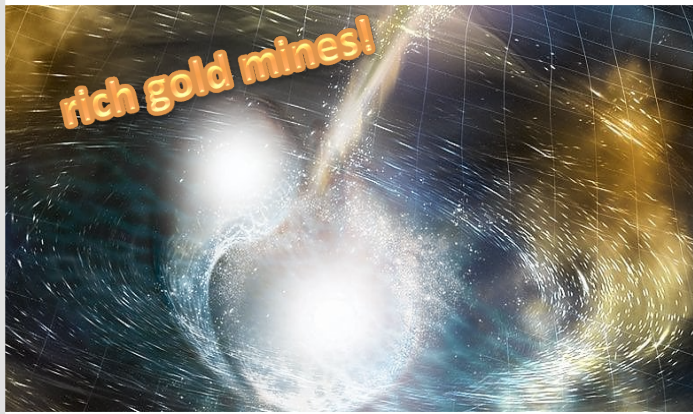
Nuclear physics  
is very broad !

Each area needs  
particular tools and  
technologies

Nuclear Physics with its different  
research domains addresses  
several key issues  
for the understanding of the  
different stages of the evolution  
of the universe

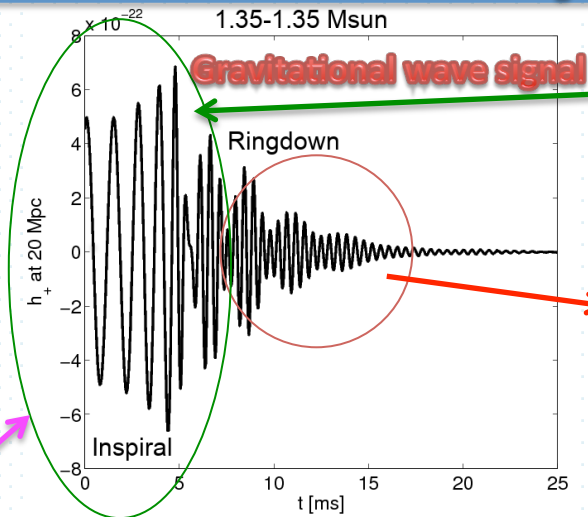


# Neutron star mergers: gravitational waves and production of heavy elements



The messengers from  
neutron star mergers :

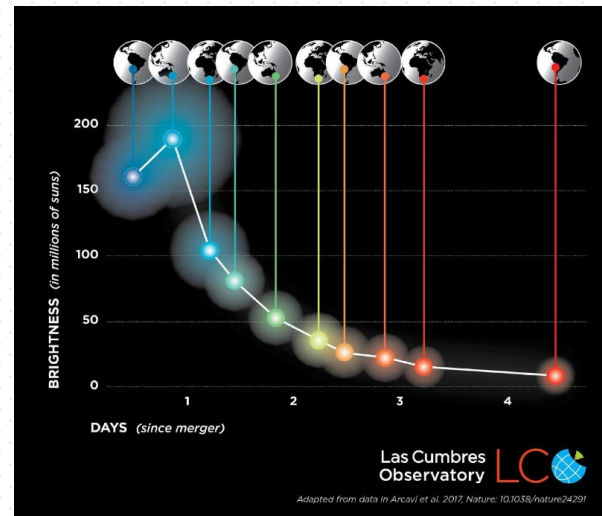
- Gravitational waves
- Electromagnetic signals characterizing the nuclei in the ejecta
- neutrinos



Neutron star  
mass

This depends on  
the Nuclear  
equation  
of state

Gravitational wave emission  
seen together with electromagnetic signals



Time evolution  
determined by  
the radioactive  
decay  
of r-process  
nuclei  
(science drive of  
facilities with RIB)



# The Physics of hadrons

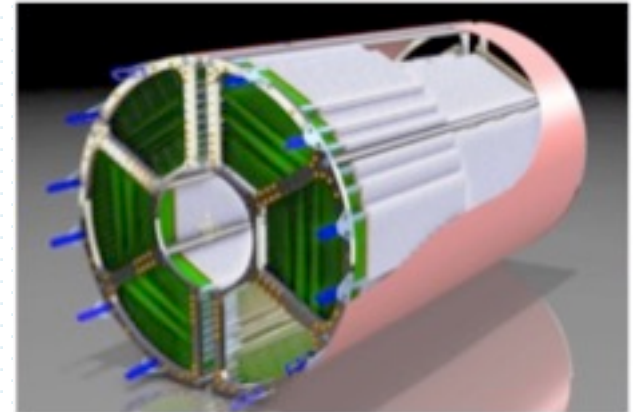
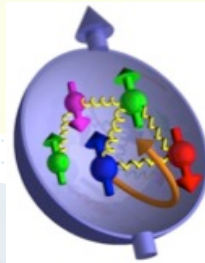
Origin of  
Mass

Strong force  
From quark  
Structure  
and  
dynamics

## The proton

Studies have uncovered discrepancies in the proton radius (using different techniques).

New experiment planned to explain this (one at Mainz-MESA) : new physics?

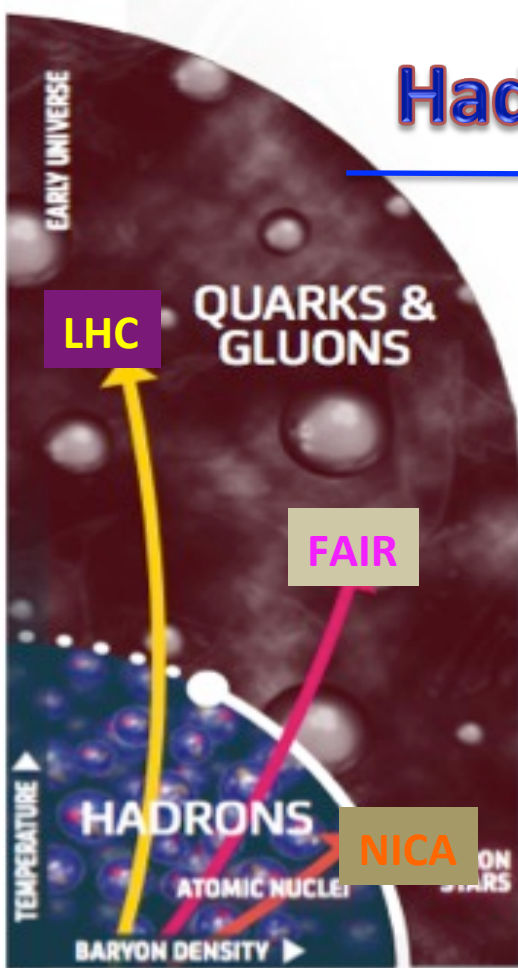


**High resolution** experiments with **antiprotons** (PANDA) at FAIR will address many issues to test in detail theory of QCD

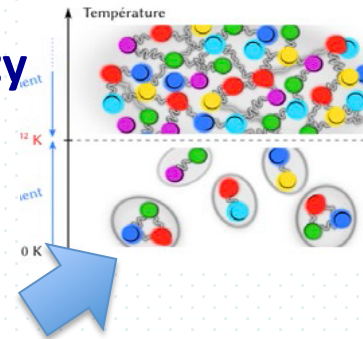




# Hadronic Matter at the very extremes



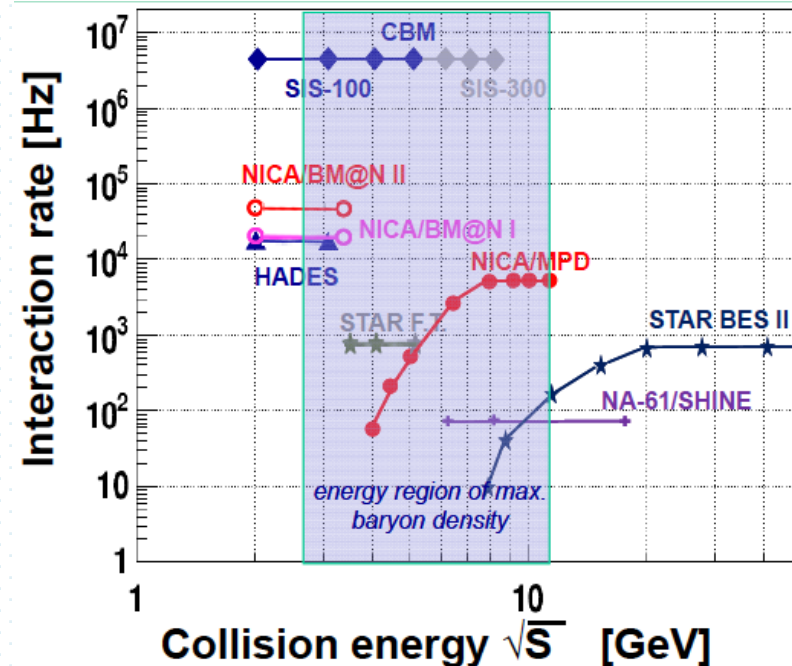
Matter at **very high temperature and density (QGP)** reveals the high energy processes that drove the **evolution of the universe after its birth.**  
(ALICE)



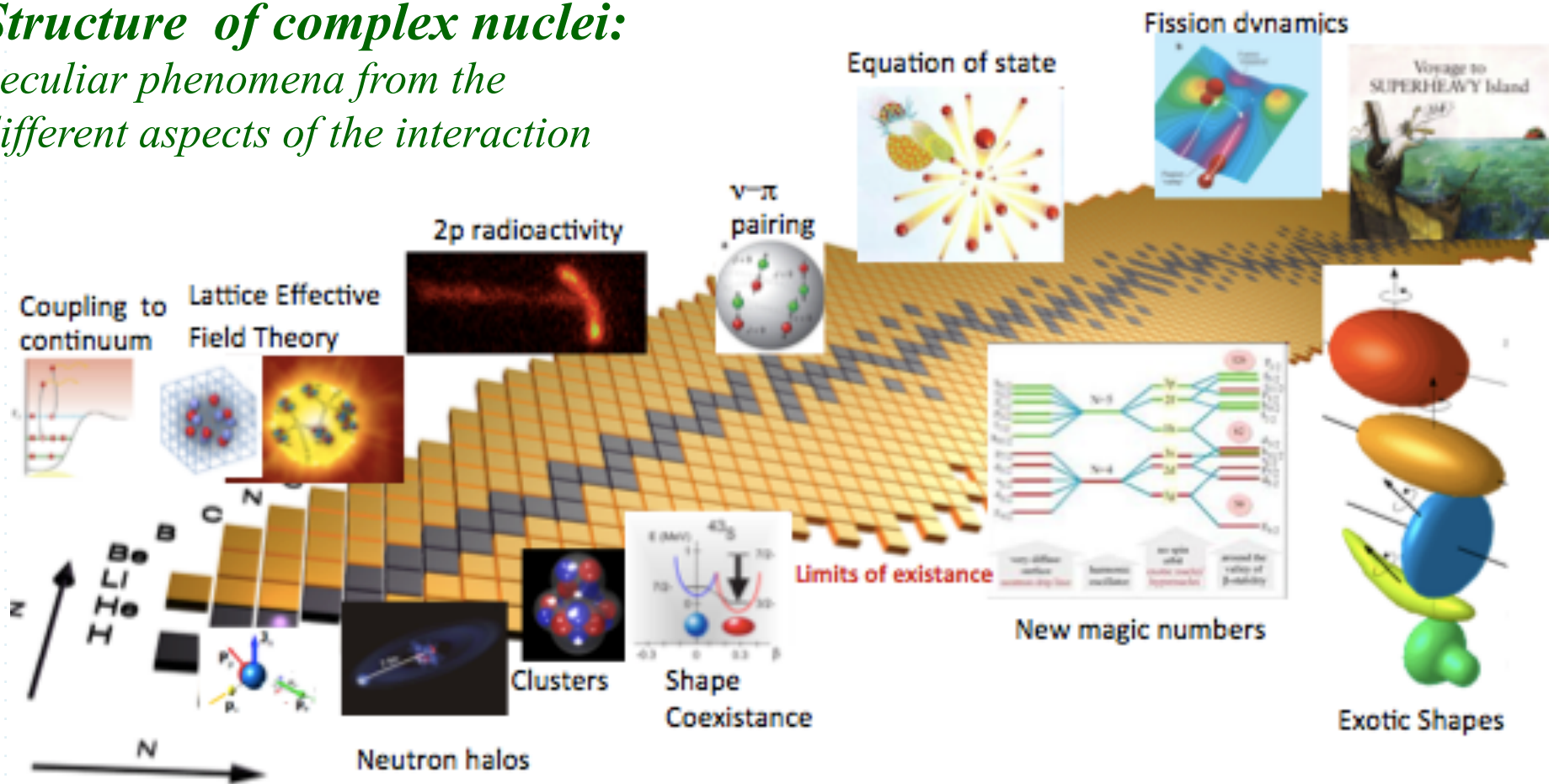
signals from **deconfinement** and chiral symmetry **restoration**

QGP turned into hadron few  $\mu$ s after BB.  
It is not seen in astronomical observations and thus is recreated in the lab with HI

Its very exotic nature is found in massively **compressed stellar corpses : neutron stars**



# Structure of complex nuclei: peculiar phenomena from the different aspects of the interaction



Search and UNDERSTAND regular and simple patterns in the structure of complex nuclei  
By characterizing nuclei under EXTREME conditions ( $E^*, J, T$ ):  
amplify different aspects of the interaction

**Nuclear structure is needed for astrophysics, double beta decay and other domains ....**

# Nucleosyntheses (nuclear structure and reactions information)

a large effort involving

from small scale accelerators .....

to very large infrastructures

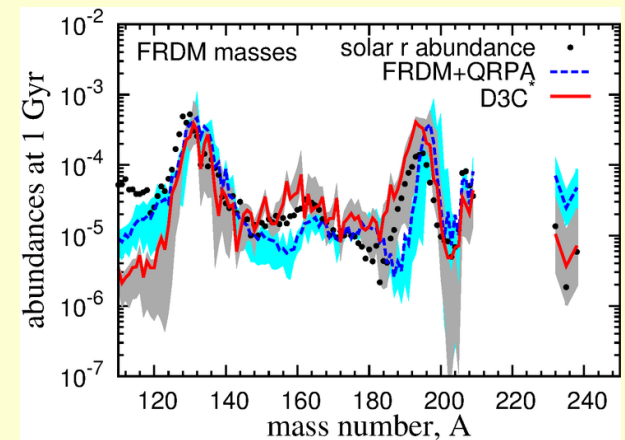


In particular at **small scale** accelerators :

- BBN and fusion reaction in stars for light nuclei nucleosynthesis
- reactions for energy generation

Medium to heavy nuclei

Nucleosynthesis- neutron rich

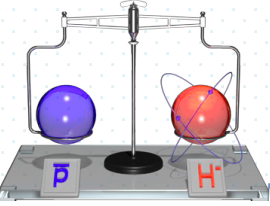


**Scientific programs at :**

- FAIR
- SPIRAL2- ISOLDE-SPES
- ELI\_NP
- Heavy factory (Dubna)
- .....



# Symmetries and Fundamental interactions



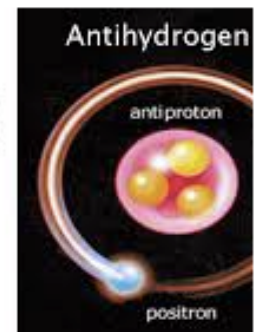
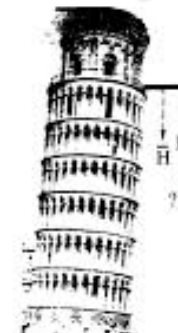
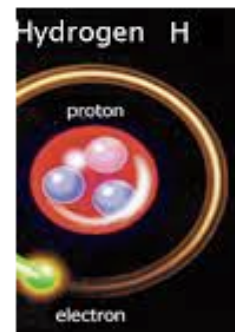
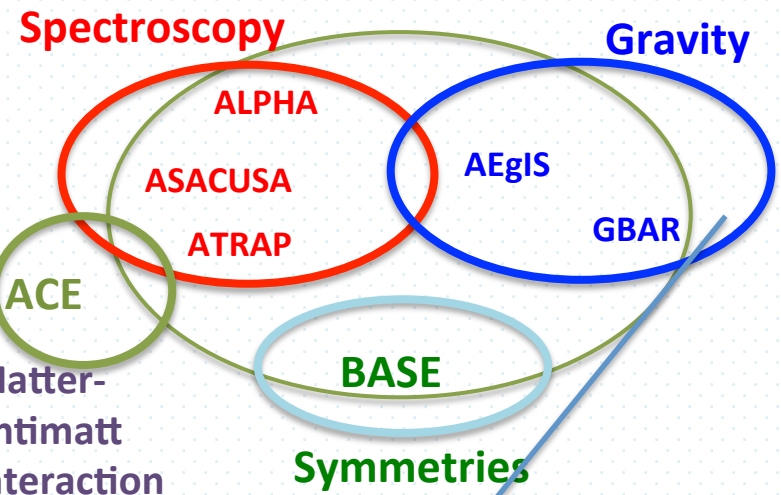
- **High precision** studies at low energies to test **interactions** and **symmetries**
- Complementary to experiments at the highest energies and offer **sensitivities to new effects beyond the Standard Model**

Among them :

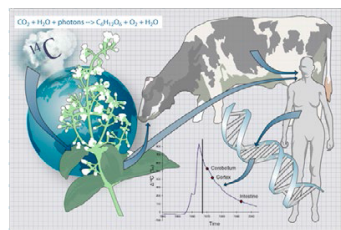
- EDM of the Neutron
- Symmetries in antimatter (antihydrogen)
- **Electron and neutrino correlations for the weak interaction**

## More and colder antiproton in ELENA

Experiments at AD  
(antiproton and antihydrogen)





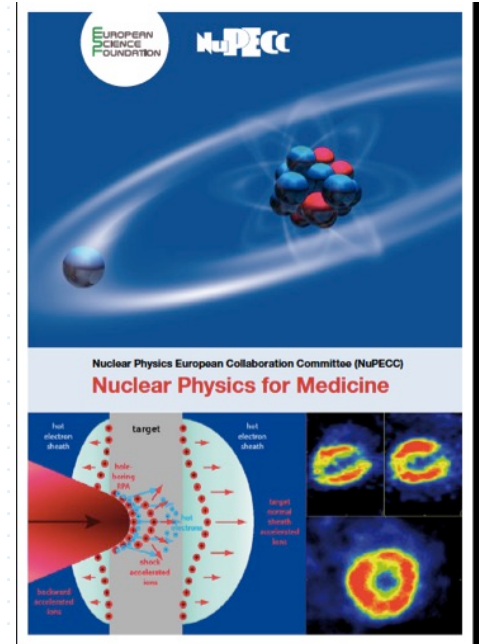


# Applications and societal benefits

**Applications** from basic Nuclear Physics Research have a **large impact on everyday life.**

**Society benefits** from basic Nuclear Physics research (knowledge on nuclear structure, decay, nuclear reactions) in areas as:

- nuclear medicine,
- energy, environment
- cultural heritage
- nuclear stewardship and security.



**A report on  
Nuclear Physics  
For medicine  
Released in  
2014 by NuPECC**

# The facilities



Because of its nature  
(different beams of different  
energies )  
and different sizes of  
specialized set-ups,  
the activities in Nuclear physics  
are distributed in several  
laboratories

See short descriptions in LRP

LRP concerns the several facilities in the field of Nuclear science  
(of different size and types) in Europe . **NuPECC enhances their  
coordination and connections**

# Transnational access within EU projects



**ENSAR2**

## Nuclear structure reactions and applications

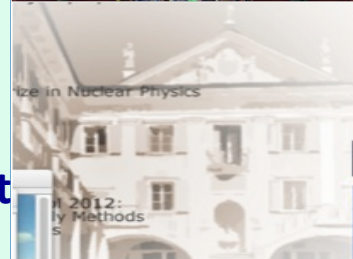
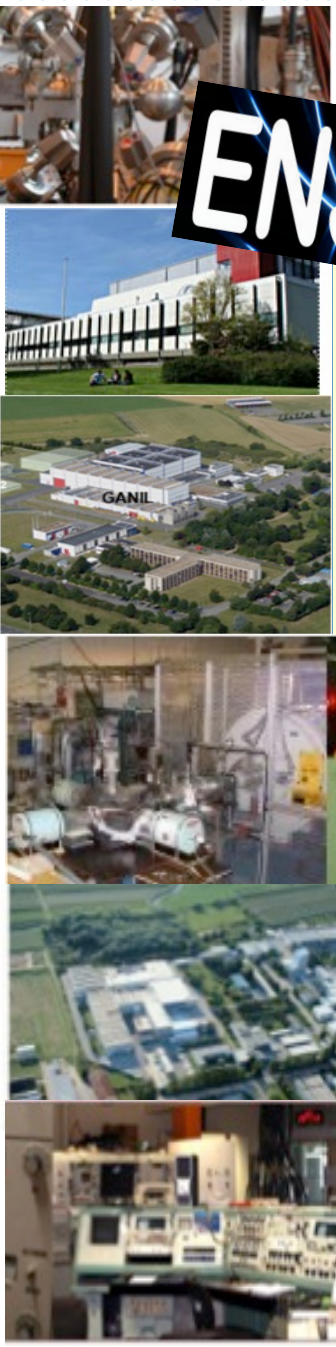
- GANIL (France)
- LNL-LNS (Italy)
- ISOLDE (CERN)
- JYFL (Finland)
- ALTO (CNRS, France)
- GSI (Germany)
- KVI (The Netherlands)
- NLC (HIL/IFJ PAN, Poland)
- IFIN-HH/ELI-NP (Romania)
- ECT\* (Italy)

## Hadron physics with hadronic and electromagnetic probes

- CERN (LHC, COMPASS, fixed target)
- GSI/FAIR (Germany)
- LNF, Frascati Italy
- MAMI, Mainz Germany
- ECT\*, Trento Italy
- ELSA, Bonn Germany
- COSY, Julich Germany



**HadronPhysics**

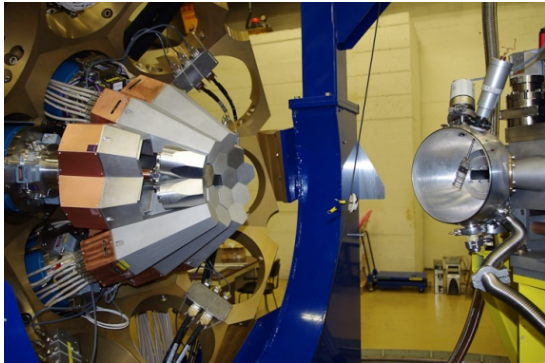




# Tracking array for gamma spectroscopy

## High-sensitivity for nuclear structure of exotic nuclei – used in several laboratories

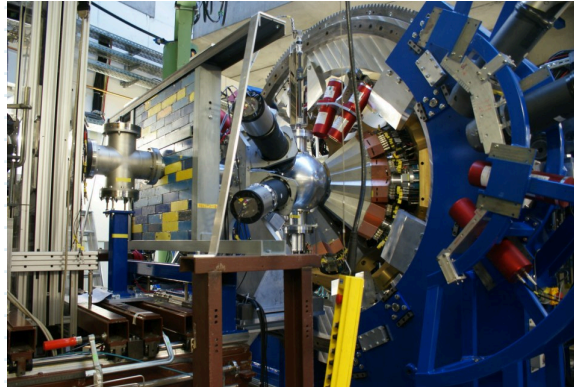
2010 → 2011  
LNL : 5TC



**AGATA D.+PRISMA**

Total Eff<sub>Nominal</sub> ~2.6%

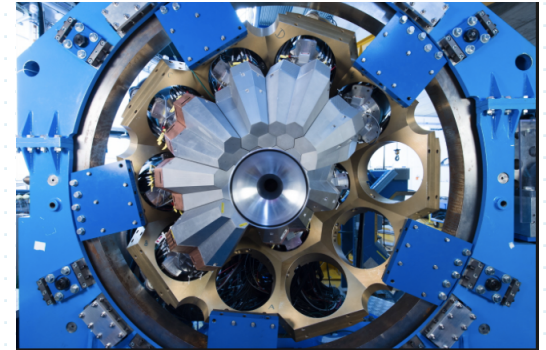
2012 → GSI/FRS  
6TC+3 DC



**AGATA @ FRS**

Total Eff. ( $\beta=0.5$ ) ~ 10%

2014 → GANIL/SPIRAL1  
15TC

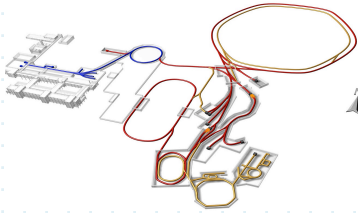


**AGATA @G1**

Total Eff ~ 8% to 14%

A **powerful traveling instrument** - its construction has to proceed  
in the next years!

# Recommendations



**Complete urgently the construction of the ESFRI flagship FAIR and develop and bring into operation the experimental programme of its four scientific pillars APPA, CBM, NUSTAR and PANDA.**

**Support for construction, augmentation and exploitation of world leading ISOL facilities in Europe.**

**Support for the full exploitation of existing and emerging facilities**

**Support for ALICE and the heavy-ion programme at the LHC with the planned experimental upgrades.**

**Support to the completion of AGATA in full geometry**



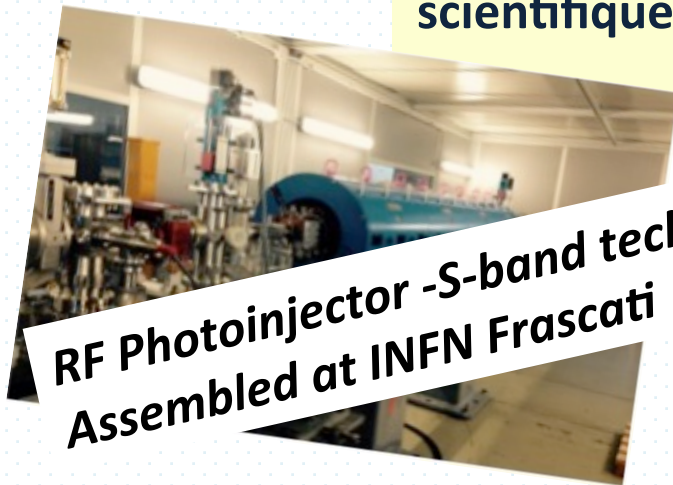
In Bucharest :  
one pillar of the distributed  
facility ELI ( in the ESFRI list)

# Up-coming Facilities

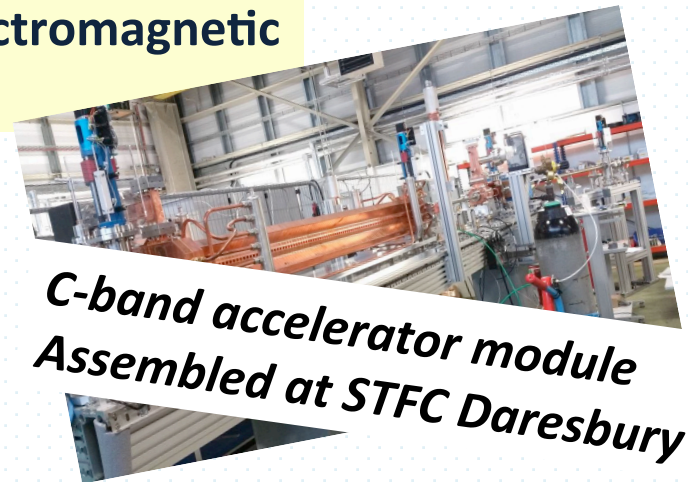
- 1) Ultra-short High power  
laser pulse  
(25fs) 2 X10 PW, 1/mn
- 2) GAMMA beams high flux ,  
monochromatic,  $\Gamma \sim 10^{-3}$  ,  
E= 0.2-19 MeV

Nuclear astrophysics-Nuclear structure-applications – start in 2019-20

Experimental set ups under construction-  
scientific program with electromagnetic  
probes unique



RF Photoinjector -S-band technology  
Assembled at INFN Frascati



C-band accelerator module  
Assembled at STFC Daresbury

## Support for Nuclear Theory



FONDAZIONE  
BRUNO KESSLER



European Centre  
for Nuclear Theory  
and related areas  
Eu Centre  
in Trento (Italy)

**25 years celebrated  
This week!!**



The IBM Blue Gene/Q system JUQUEEN with 5.9 Pflops peak performance at the computing center of the Forschungszentrum Jülich

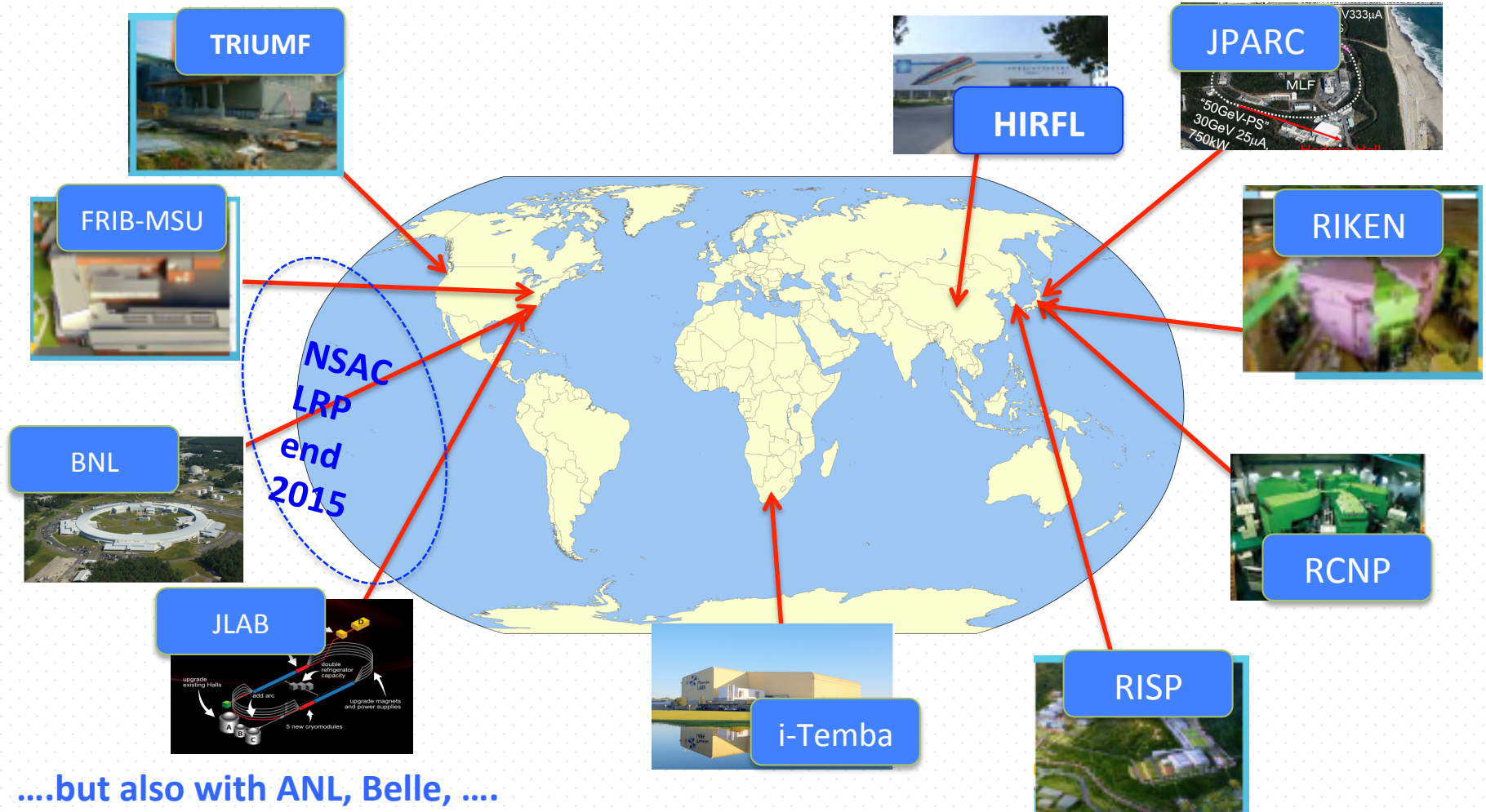
Computing  
infrastructures

Perform R&D programmes for  
possible future facilities

Training the next generation of  
nuclear scientists



# ....connections with laboratories outside Europe



## European Users

and joint technical developments and contributions with European Laboratories and Institution (collaborations for EIC in USA)

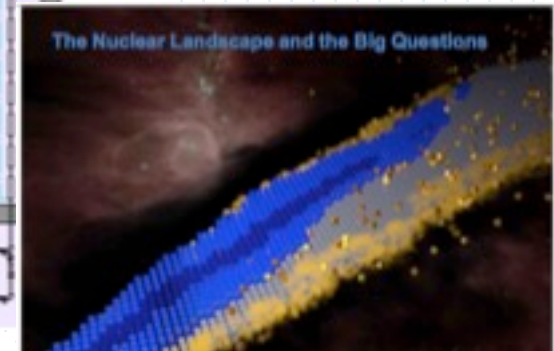
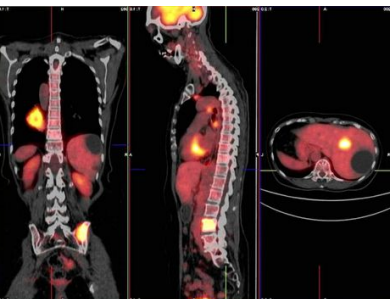
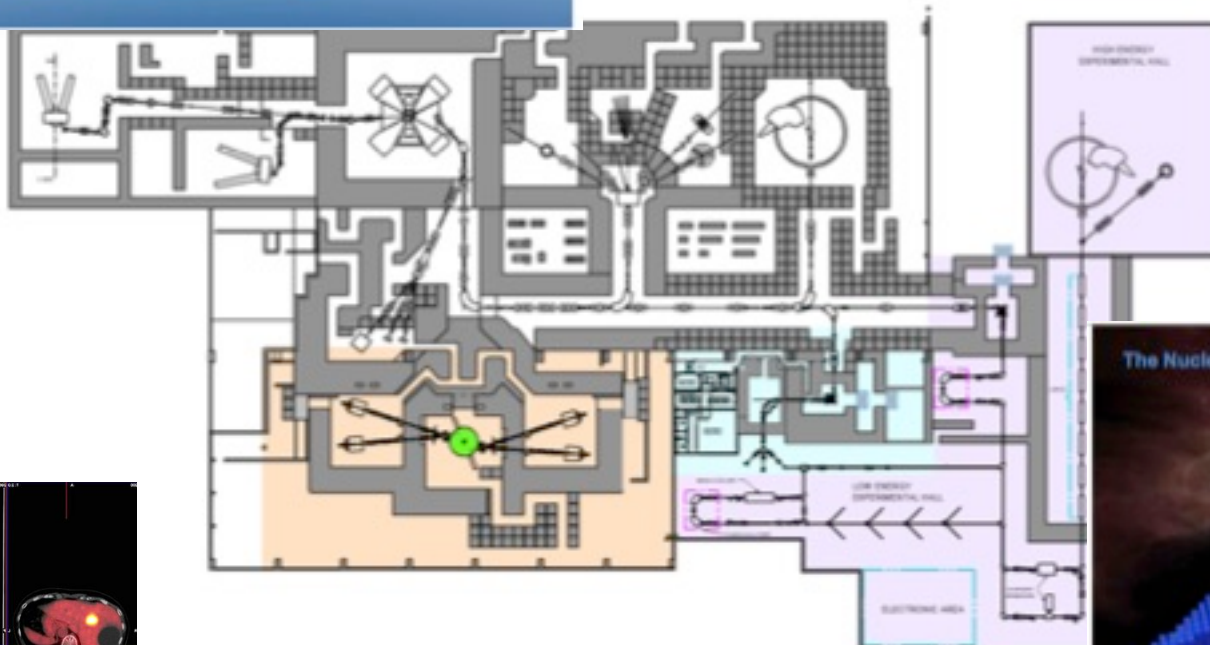
experiments at these facilities provide complementary information.

# i-Temba

i-Temba



**A new cyclotron**  
**For production of radioisotope**  
**For medicine and for**  
**basic science**





- ◆ **Build** .....the new
- ◆ **Support** existing (all sizes) and emerging facilities
- ◆ **Carry out** R&D Program –training

Programme at laboratories based on an integrated approach for:

- ✧ **Basic science:** the building block of our world
- ✧ **Applications:** the best use of nuclear techniques for the benefit of society

