The NuPECC Long Range Plan

Angela Bracco - Università di Milano and INFN

CERN, 17 November 2017

Outline

- NuPECC mission
- The new long range plan
  the science
  facilities and recommendations
- ….few remarks on the world wide context
- Conclusion

The European Expert Board for Nuclear Physics

associated to ESF

Representing about 6000 scientists

Members: 31 institutions from 21 countries

JINR Dubna rather recently joined

In global context with

Member of WG9 of IUPAP

- AnPHA (Asia)
- NSAC (USA)
- Canada
- ALAFNA (south America)

Mission and activites

Nuclear **P**hysics **E**uropean **C**ollaboration **C**ommittee

founded **1988** by subscribing national research councils, who nominate nuclear scientists as their representatives.

Objective of NuPECC:

"To strengthen European collaboration in nuclear science through the promotion of nuclear physics and its trans-disciplinary use and application in collaborative ventures between research groups within Europe"

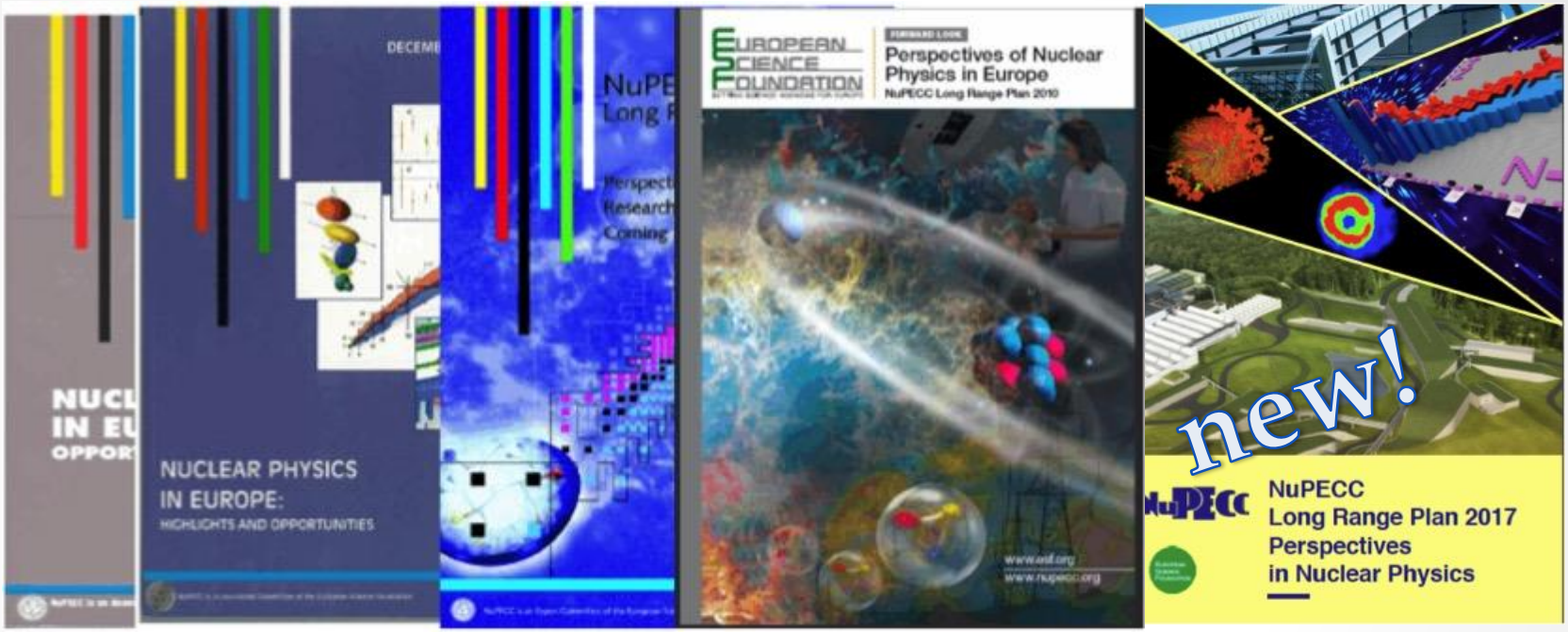
Major Tasks

- Advise Funding Agencies
- Identify key scientific issues – specific focus reports were issued
- **Develop Long Range Plan for Nuclear Science in Europe in a global perspective**

Nuclear Physics News (4 issues per year) – distributed worldwide

Perspectives of Nuclear Physics in Europe

LRP 1991 1997 2004 2010 2017



- The LPR **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

NuPECC town meeting in Darmstadt January 2017

Exciting discussions were triggered and conducted by the community at **town meeting** and working group meetings

NuPECC

Nuclear Physics European Collaboration Committee

NuPECC LRP2017 Town Meeting, Darmstadt January 11-13, 2017

Programme

Wednesday January 11, 2017	Thursday, January 12, 2017	Friday, January 13, 2017
8:00-9:00 Registration + Coffee		
9:00-9:15 Welcome	9:00-9:45 [Chair: Adam Maj] WG1: Nuclear Structure & Reaction Dynamics Elias Khan, John Simpson	9:00-10:40 [Chair: Jens I. Svend] International Context NSAC: Don Geesaman APPEC: [illegible]
9:15-9:45 Outline LRP2017: Angela Bracco	9:45-10:30 Discussion WG1	
	10:40-11:00 Coffee Break	
9:45-12:55 [Chair: Karlheinz Langanke] Future Large-Scale Facilities MSK: Paolo Giubellino (45+5) EURISOL-DF Facilities: - SPIRAL2: Marek Lewitowicz (12+3) - HIE-ISOLDE: Maria Borge (12+3) - SPES: Gianfranco Prete (12+3) EURISOL-DF: Marek Lewitowicz (12+3) ELI-NP: Sydney Gales (15+5) Dubna: Mikhail Itkis (12+3)	11:00-12:45 [Chair: Alex Murphy] WG4: Nuclear Astrophysics Gabriel Martinez Pinedo, Alison Laird	Panel discussion of overall recommendations, priorities & roadmap LRP2017 Steering Committee
	12:45-13:30 Discussion WG4	12:30-12:45 Summary and Conclusion: Angela Bracco
12:55-14:45 Lunch	12:30-14:00 Lunch	
14:45-16:45 [Chair: Helgi Rafelski] European Context EPPC: Giorgio Rossi (25+5) ENSAR2: Mahdoh M. Mostafa (25+5)	14:00-14:45 [Chair: Mark. Wilkinson] WG3: Symmetries & Fundamental Interactions Klaus Kirch, Klaus Blaum	https://indico.gsi.de/conferenceDisplay.py?confId=3177
14:45-15:30 [Chair: Bernd Krusche] WG2: Hadron Physics Diego Bettoni, Hartmut Wittig		
15:30-16:15 Discussion WG2	14:45-15:30 Discussion WG3	
16:15-16:45 Coffee Break	15:30-16:00 Coffee Break	
16:45-17:30 [Chair: Eugenio Nappi] WG5: Properties of Strong-Interaction Matter Silvia Masciocchi, François Gelis	16:00-16:45 [Chair: Nicolae Alexeyev] WG6: Applications & Societal Benefits Mona Dunlop, Alain Letourneau	
17:30-18:15 Discussion WG5	16:45-17:30 Discussion WG6	
18:15-20:00 Welcome Reception		

Eckhard Elsen for CERN

- Executive summary with **recommendations**

- Main features of existing and up-coming **facilities**
- 6 chapters on achievments and plans for the different themes defining **today Nuclear Physics**

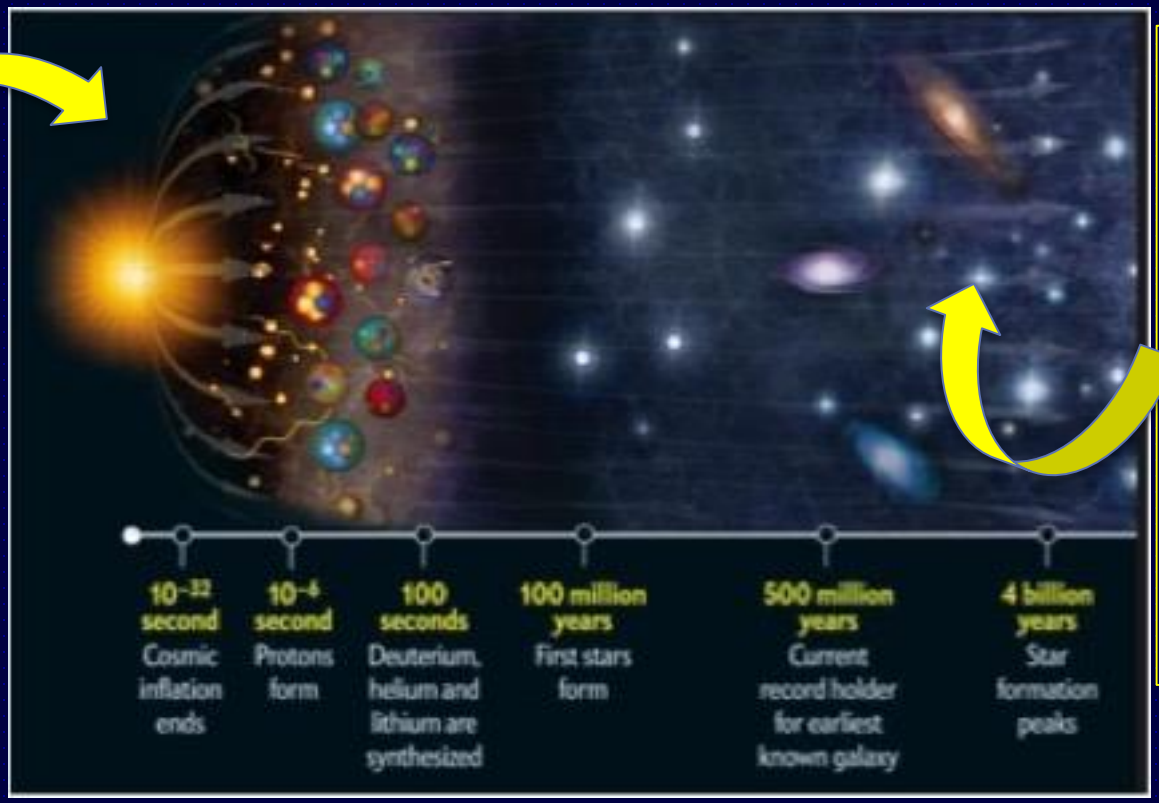
Nuclear physics today

Nuclear physics and the evolution of the Universe

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

QCD

QCD in hot compressed matter



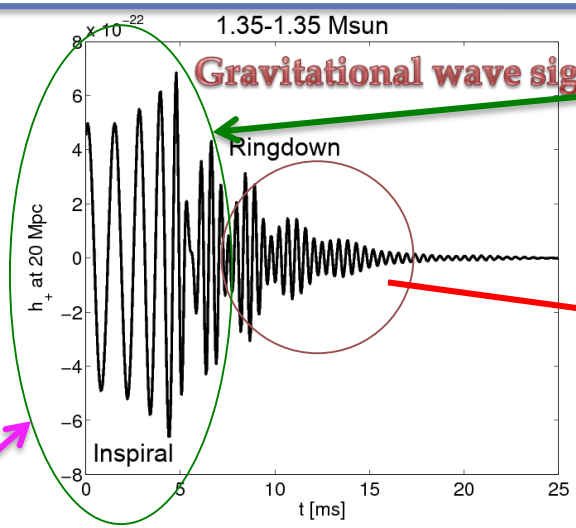
Nuclear structure
Nucleosynthesis

reactions for astrophysics

Compressed nuclear matter in neutron stars

To tackle the different problems one needs
a distributed approach and efforts : different accelerator types and energies

Neutron star mergers: gravitational waves and production of heavy elements



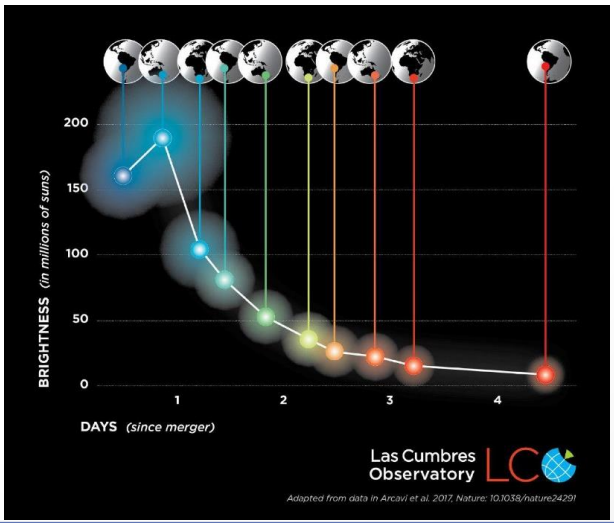
Neutron star mass

This depends on *Nuclear equation of state*

The messengers from neutron star mergers :

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

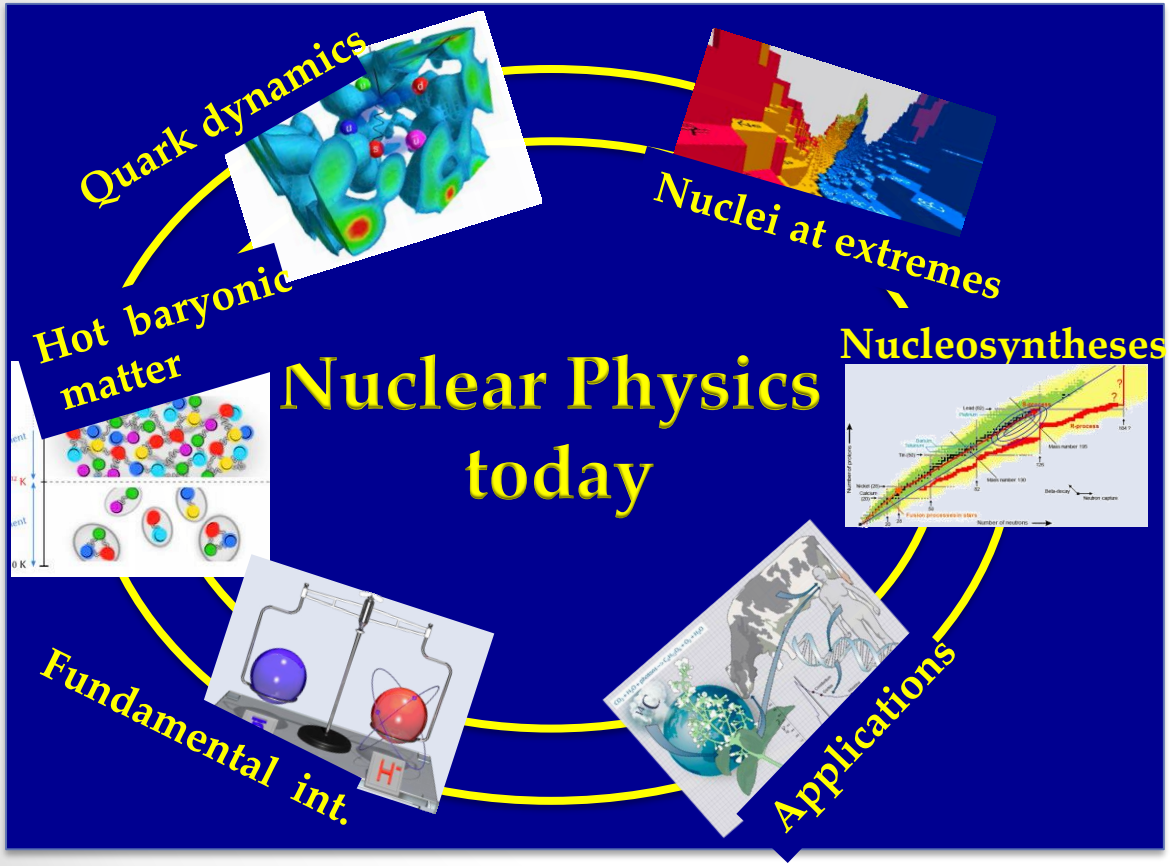
Gravitational wave emission seen together with electromagnetic signals



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

The Nuclear Physics domain

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



1) Hadron Physics

2) Phases of Strongly Interacting Matter

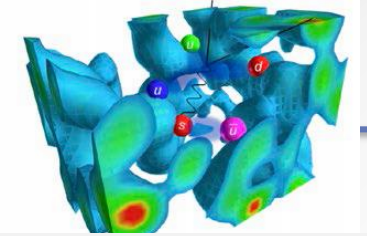
3) Nuclear Structure & Dynamics

4) NuclearAstrophysics

5) Fundamental Interactions

6) Nuclear Physics Tools & Applications

Working groups (with two coordinators and NuPECC liasons) have done an excellent job in preparing these 6 chapters!



Hadron Physics

- How is **mass generated in** QCD and what are the static and dynamical properties of hadrons?

- How does the **strong force** emerge from the underlying quark-gluon structure of nucleons?

Test of **non-perturbative QCD** to address particular aspects:

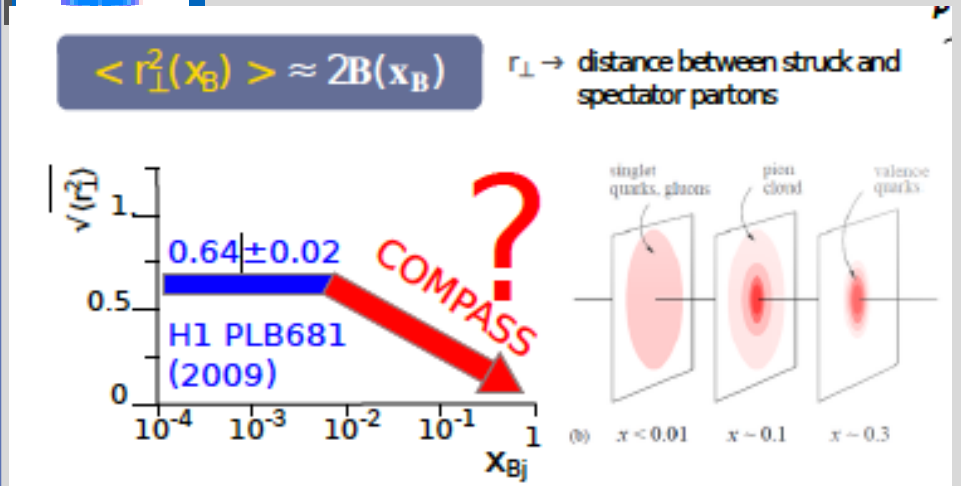
- the spatial quark distribution in p
- connection between quark dynamics and quantum numbers (spin and orbital angular momentum)
- spectroscopy and dynamics at different energy scales.

Needs:
large variety of complementary exp. in Nuclear Physics laboratories (electromagnetic, hadrons) designed for these questions

PANDA / FAIR antiprotons :
open issues in quarks dynamics of meson ad baryons with high resolution

COMPASS

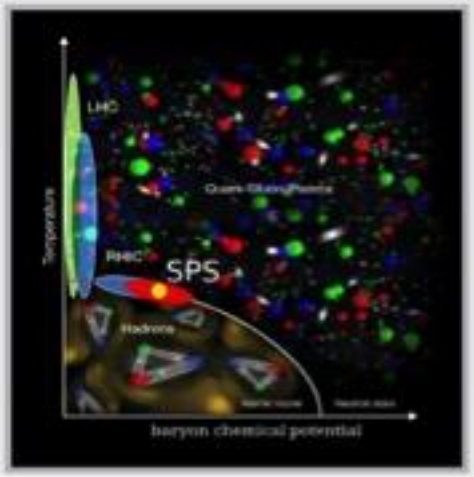
Transverse Nucleon Imaging



COMPASS "++" Opportunities beyond 2020

COMPASS has joined the CERN "Physics Beyond Colliders" Working Group

Properties of Strongly Interacting Matter at extreme conditions of temperature and baryon number density

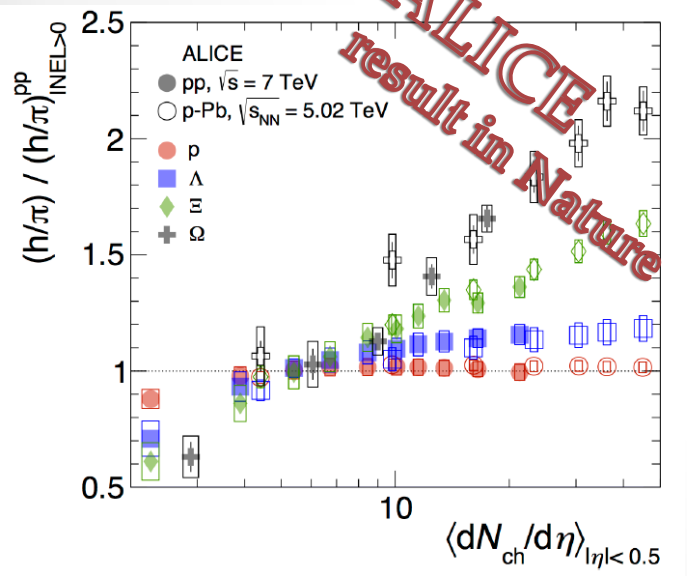


QGP turned into hadron few μs after BB. QGP not seen in astronomical observations and thus is recreated in the lab with HI within volumes of nuclear size.

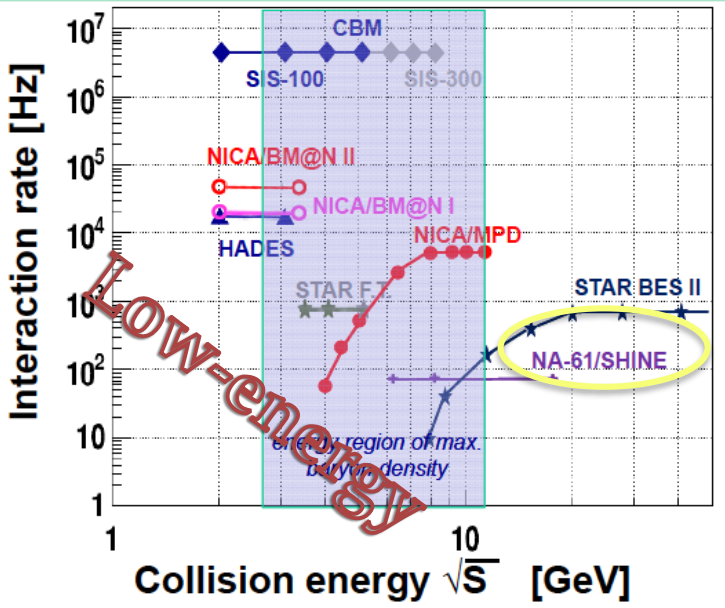
From QCD: above a critical energy density (0.3 GeV/fm^3) , a gas of hadrons undergoes a **deconfinement** (and chiral symmetry **restoration**)

ALICE devoted to study the different propeties (flow and particle production) of the QGP ---
Many Studies also at LHCb, ATLAS and CMS

HADES NICA CBM NA61/SHINE for properties at the onset (neutron stars)
AFTER fix target under exploration

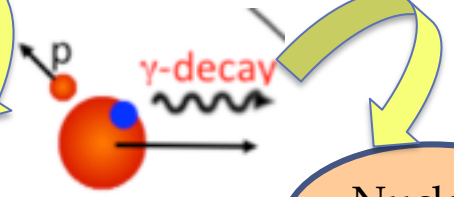


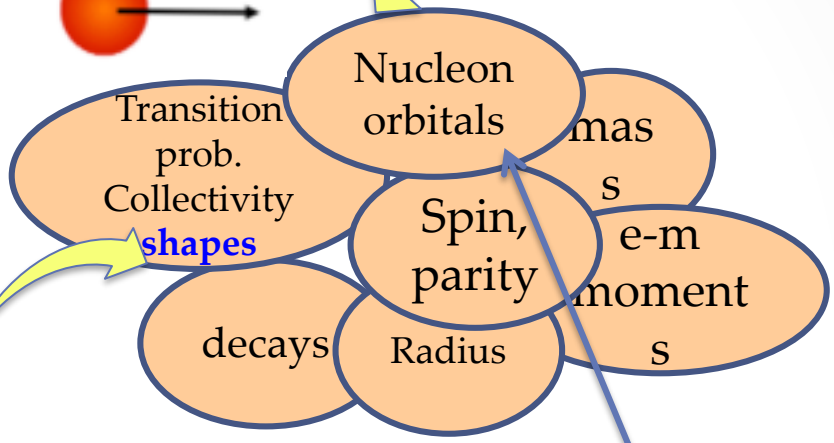
Enhanced production of multi-strange hadrons not only in p-Pb also in high-multiplicity p-p collisions



Nuclear structure and reaction dynamics

- Where are the **limits of stability** and what is the heaviest element?
- How does **nuclear structure evolve** (also with T and L) and what shapes can nuclei adop ?
- How **complex** are nuclear excitations?
- How do **correlations** appear in dilute neutron matter ?
- What is the density and isospin dependence of the **nuclear equation of state** ?





discovery frontier (new isotopes, new elements, etc.), and moreover measure the **different nuclear properties**

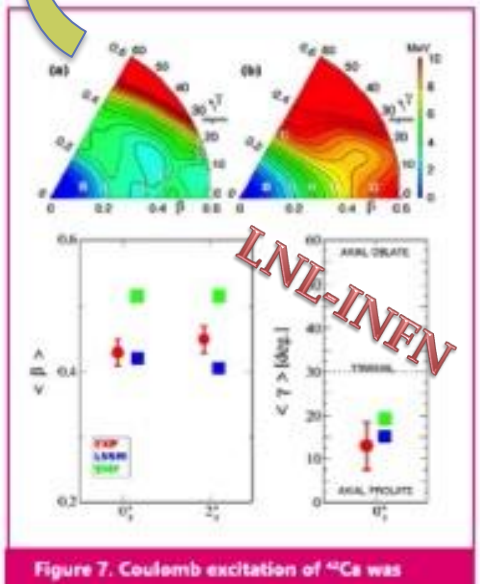
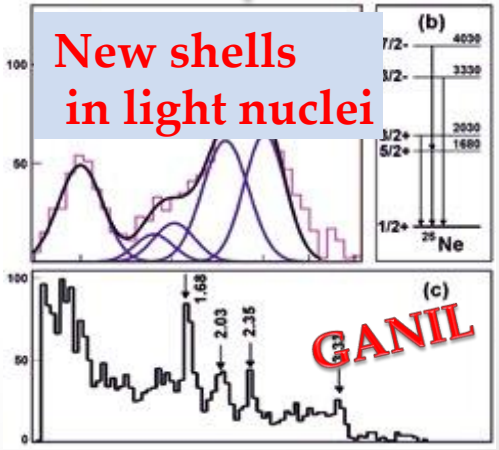


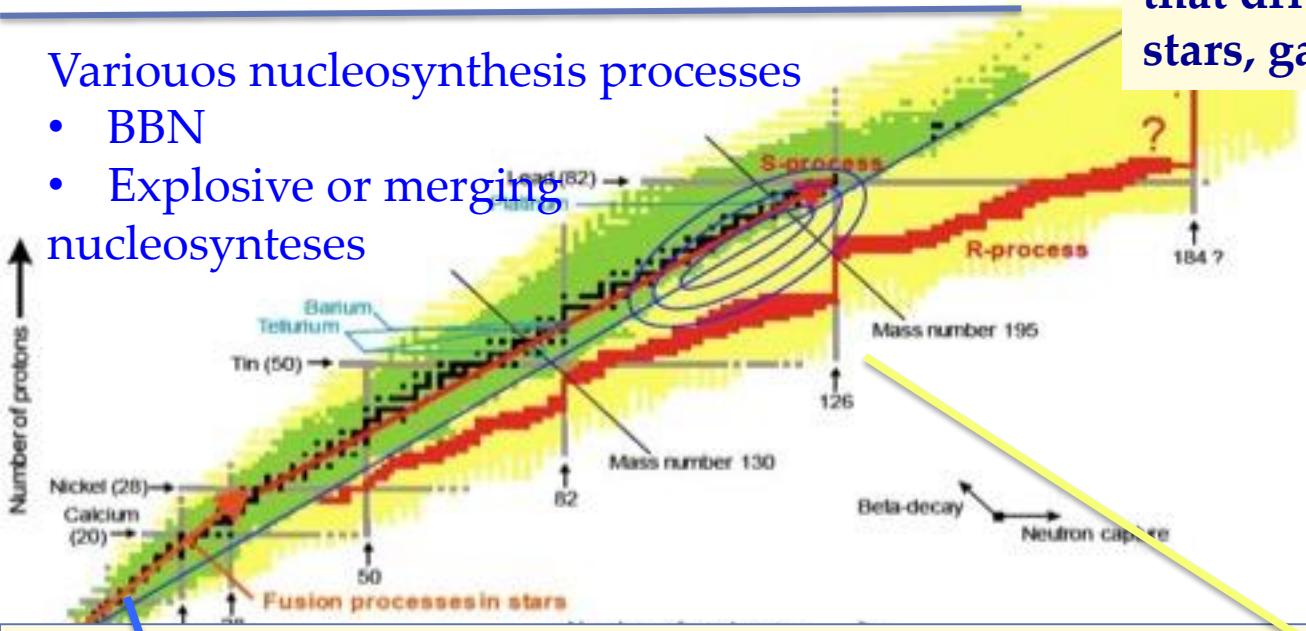
Figure 7. Coulomb excitation of ^{42}Ca was



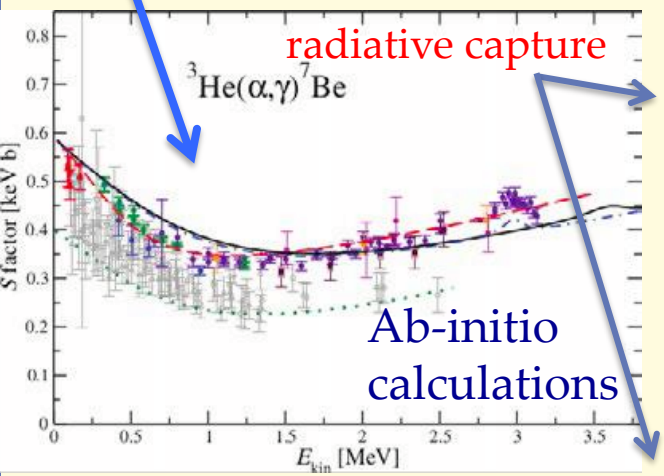
Nuclear astrophysics

What are the nuclear processes that drive the evolution of the stars, galaxies and the Universe?

Varioous nucleosynthesis processes
- BBN
- Explosive or merging nucleosynteses



Interplay of:
- **nuclear structure**
- **Nuclear decays**
- **half-lifes**
- **nuclear reactions**
- **Nucler masses**



Primordial ^{7}Li Nucleosyntesis

^{7}Be(n,α)^{4}He

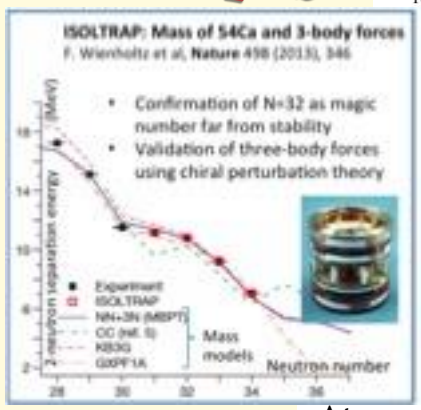
nTOF

^{8}B neutrinos for solar model and data from

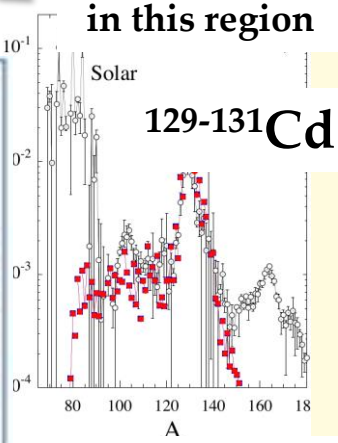
The lowest energy at
LUNA –LNGS
LUNA MV in the next years

ISOLDE

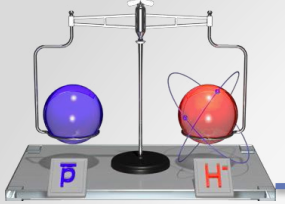
Nature pub



mass data favour Core Colapse Supernova in this region



Atanasov, PRL115 (2015) 232501



Symmetries and Fundamental interactions

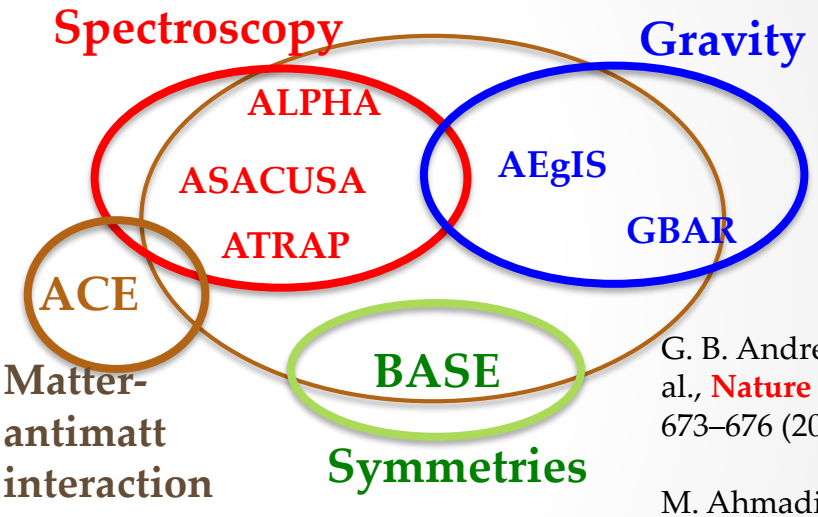
- **High precision** studies at low energies to **test interactions and symmetries**
- Complementary to experiments at the highest energies and offer **sensitivities to new effects beyond the Standard Model**

Among them :

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

More and colder antiproton in ELENA From 2017

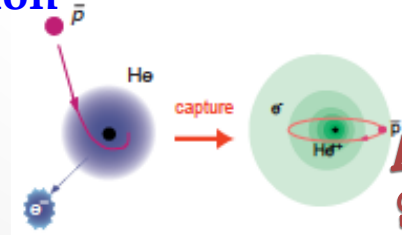
Experiments at AD
(antiproton and antihydrogen)



G. B. Andresen et al., Nature 468, 673–676 (2010)

M. Ahmadi et al., Nature 541, 506–510 (2017)

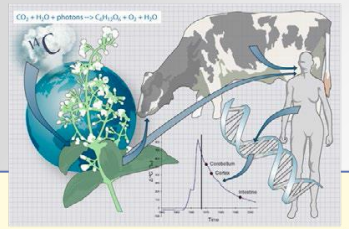
ASACUSA results ($\bar{p}He^+$ spectroscopy)



By comparing the calculated and experimental $\bar{p}He^+$ frequencies, the ratio $M_{\bar{p}}/m_e$ can in principle be determined to a fractional precision of $<1 \times 10^{-10}$

ASACUSA Science pub

M. Hori *et al.*,
Science 04 Nov 2016: Vol. 354, Issue 6312, pp. 610-614
DOI: 10.1126/science.aaf6702

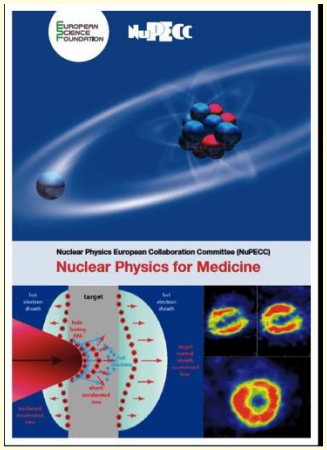


Applications and societal benefits

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

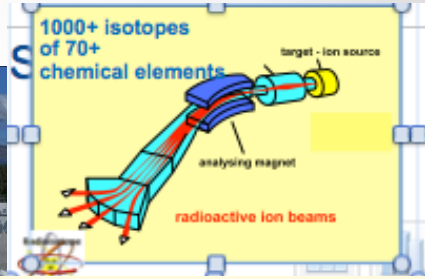
Society benefits from basic Nuclear Physics research (knowledge on nuclear structure, decay, nuclear reactions) in areas as:

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



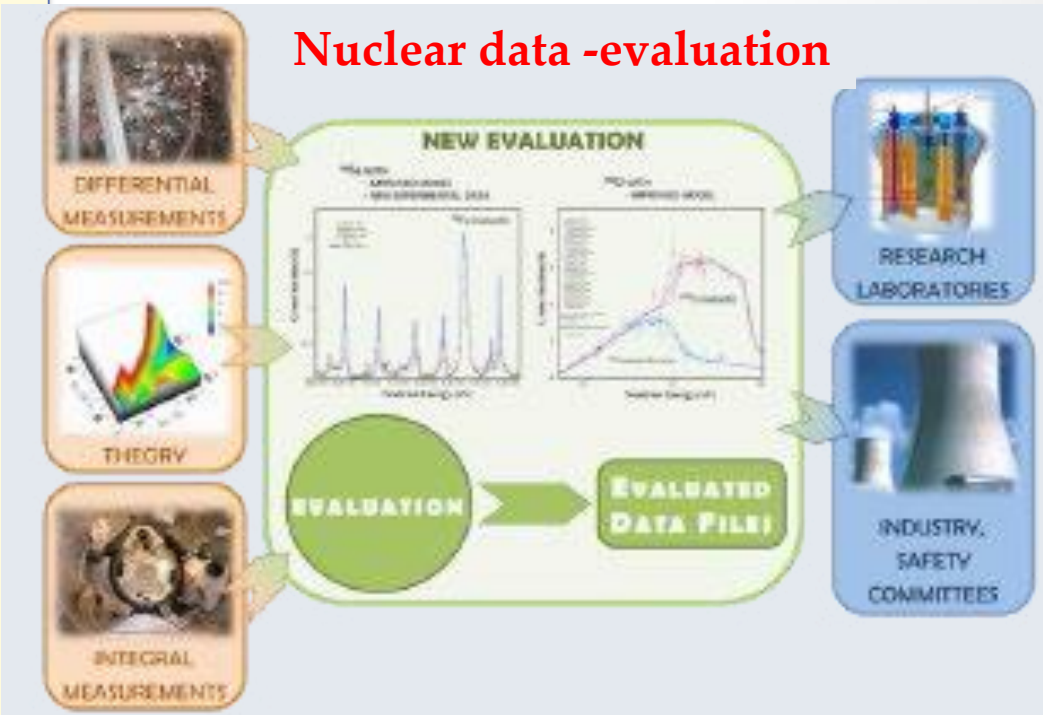
A report on Nuclear Physics For medicine Released in 2014 by NuPECC

CERN Contributions t o medical applications



Exploitation of competence from ISOLDE

Nuclear data -evaluation



FACILITIES

Perspectives of Nuclear Physics in Europe

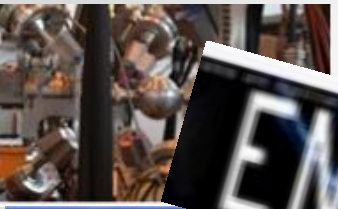
Because of its nature
(different beams of different energies and different sizes of set ups)

the activities in Nuclear Physics are carried out in several laboratories

NuPECC long range plan **contains the future plans of the existing and and planned facilities**

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

Trasnational access within EU projects



ENSAR

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)

HadronPhysics

Hadron physics with hadronic and electromagnatic probes

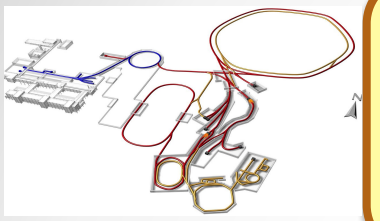
- CERN (LHC, COMPASS, fixed ta

- GSI/FAIR (Germany)
- LNF, Frascati Italy

- MAMI , Mainz Germany
  ECT*, Trento Italy

ELSA, Bonn Germany
COSY, Julich Germany

Recommendations



Complete urgently the construction of the ESFRI flagship FAIR and develop and bring intooperation the experimental programme of itsfour 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

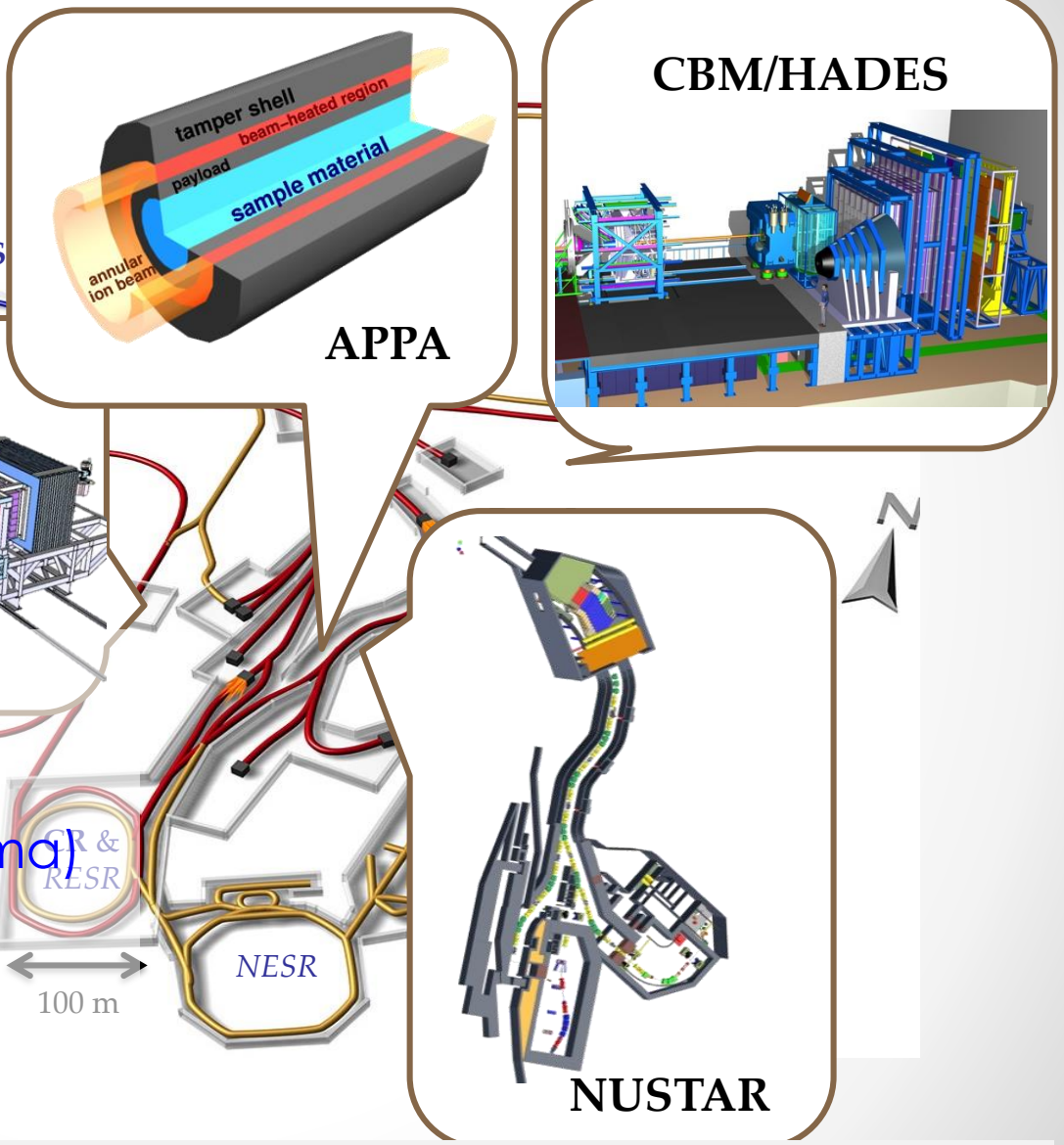
Support for ALICE and the heavy-ion programme at the LHC with the planned experimental upgrades.

Support to the completion of AGATA in full geometry

Facility for Antiproton and Ion Research

FAIR

To to realize in phases-
phase 0 on going using GSI



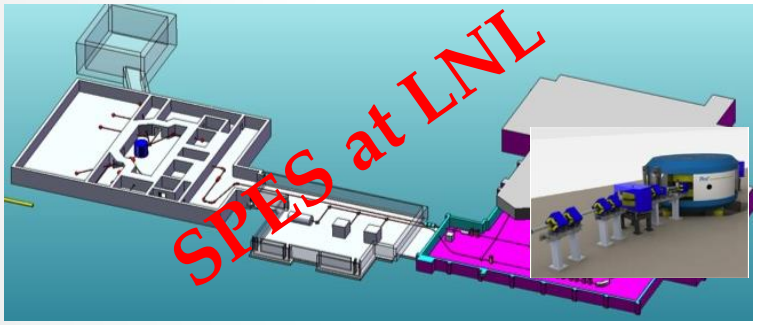
- Conception

of FAIR 4 scientific pillars

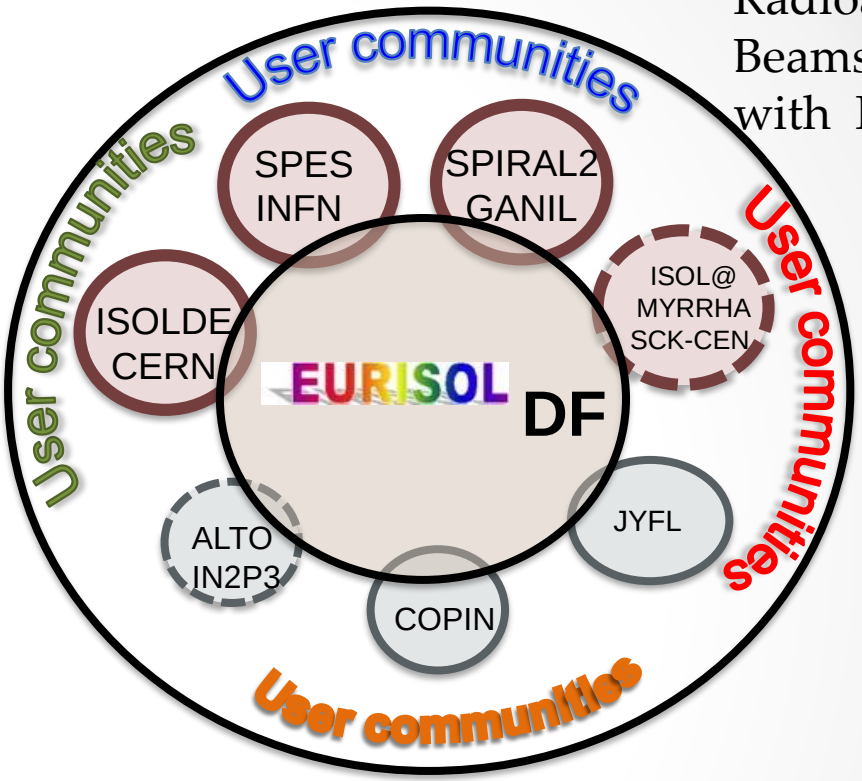
- APPA (atomic and plasma)
- CBM
- NUSTAR
- PANDA

Large facility covering all thematics in the nuclear physics domain

The ISOL Facilities



Radioactive Beams with ISOL



- A **distribute laboratory** for radioactive beams:
- **More exotic beams** available
- **Coordination of competences** to face EURISOL technologic challenges for the future
- **Joint effort** to manage the activity at European level

To be submitted for application in the ESFRI list

Up-coming Facilities

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

1) Ultra-short High power laser pulse (25fs) 2 X1O PW

2) GAMMA beams high flux , monochromatic, Γ ~qqs10^{-3} , E= 0.2-19 MeV

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

NICA at JINR

NICA **-commissioning in 2019**
◎sNN = 4-11 GeV heavy ions L~10^{27} cm^{-2} c^{-1} (Au)
p↑ (d↑) of ◎sNN up to 26 (13) GeV **L ~ 10^{32} cm^{-2} c^{-1}**

QCD test and hot barionic matter
synergies with FAIR

SHE factory at JINR

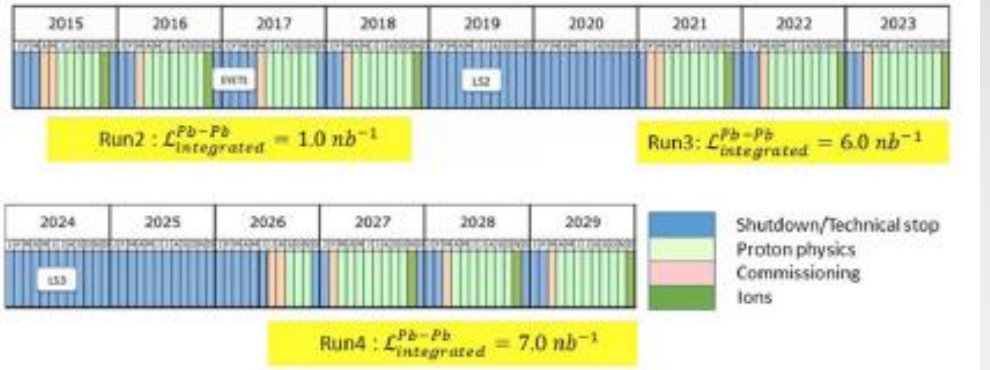
^{48}Ca 10^{14} pps

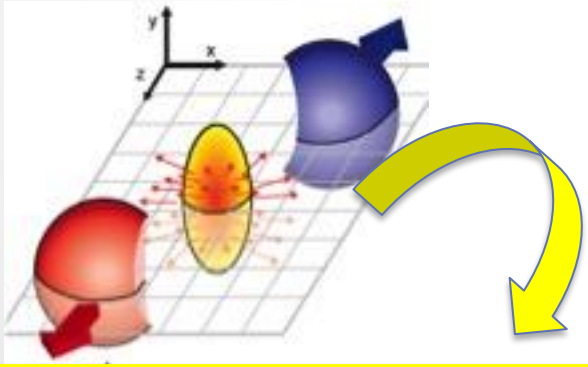
Experiments for σ<100 fb :
- Synthesis of new SHE….(Z = 119, 120)
- Study of decay properties of SHE

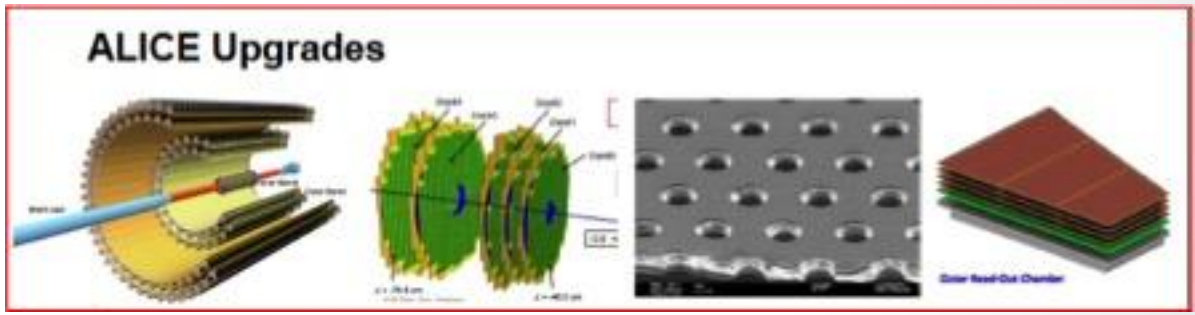
First exp 2018

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

- **Run-3 and Run-4: 2021-29**
  - ➡ $\sqrt{(s_{NN})}$ = 5.5 TeV
  - ➡ L_{int} > 10 nb^{-1}
  - ➡ Major experiment upgrades







- Correlations and fluctuations
- Jet structure
- γ-jet and Z-jet correlations
- Low-mass dileptons
- (Anti-)(hyper-)nuclei

- Charm and beauty energy loss and degree of thermalization in the medium
- Charm production mechanism(s)
- Charm elliptic flow (in-medium hadronization or at phase boundary)

Support to the completion of AGATA in full geometry

Coupling with ancillaries is essential point

AGATA represents the **state-of-the-art detector** in gamma-ray spectroscopy for a broad programme in ***nuclear structure, nuclear astrophysics and nuclear reactions.***

AGATA will **be exploited at all of the large-scale radioactive and stable beam facilities**.

AGATA will be realised in phases goal of completing the phase 1 with 20 units by 2020.

Support for Nuclear Theory

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

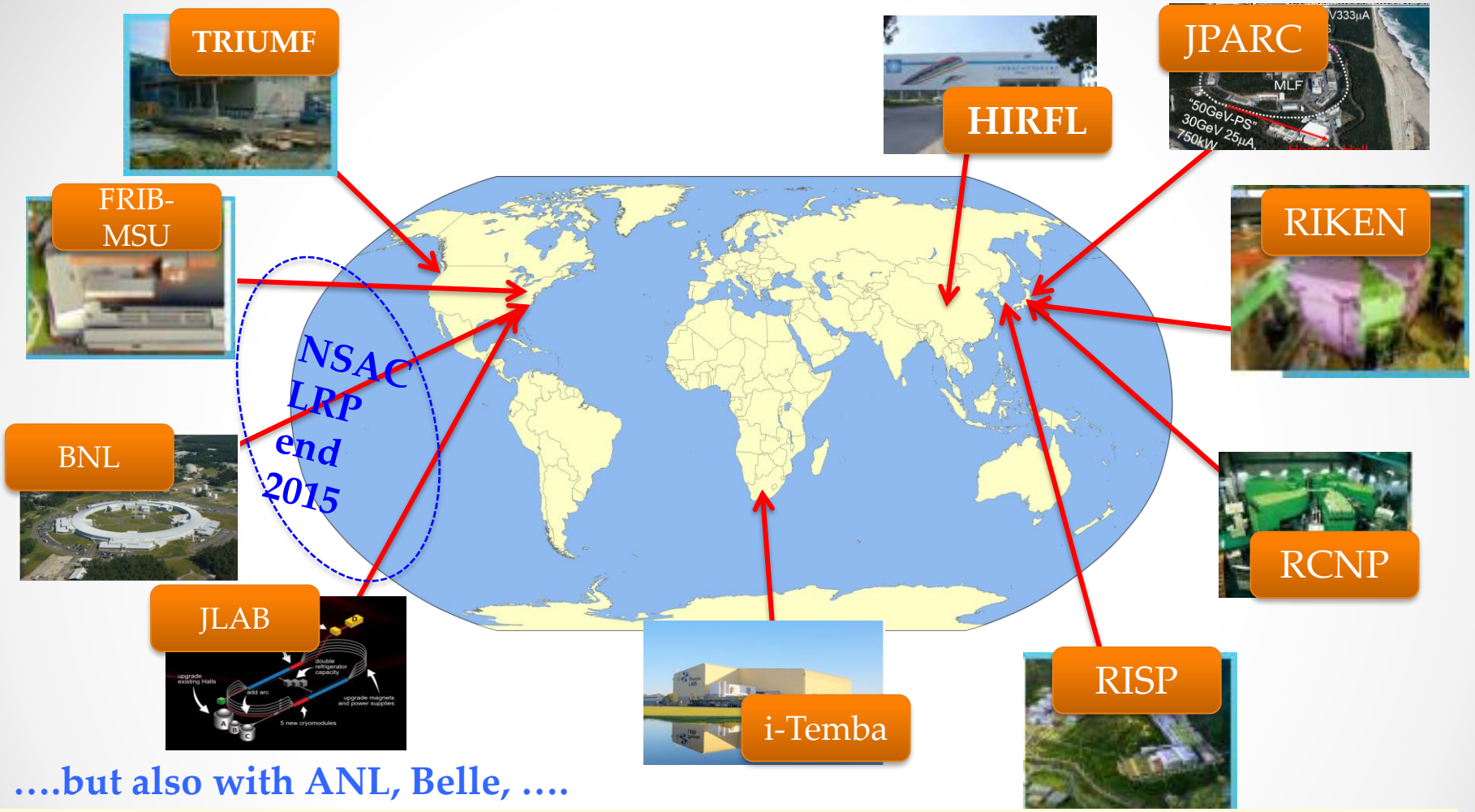
The IBM Blue Gene/Q system JUQUEEN with 5.9 Pflops peak performance at the computing center of the Forschungszentrum Jülich

Computing
infrastructures

Perform R&D programmes for possible future facilities

Training the next generation of nuclear scientists

….links/collaborations with labs outside Europe



….but also with ANL, Belle, ….

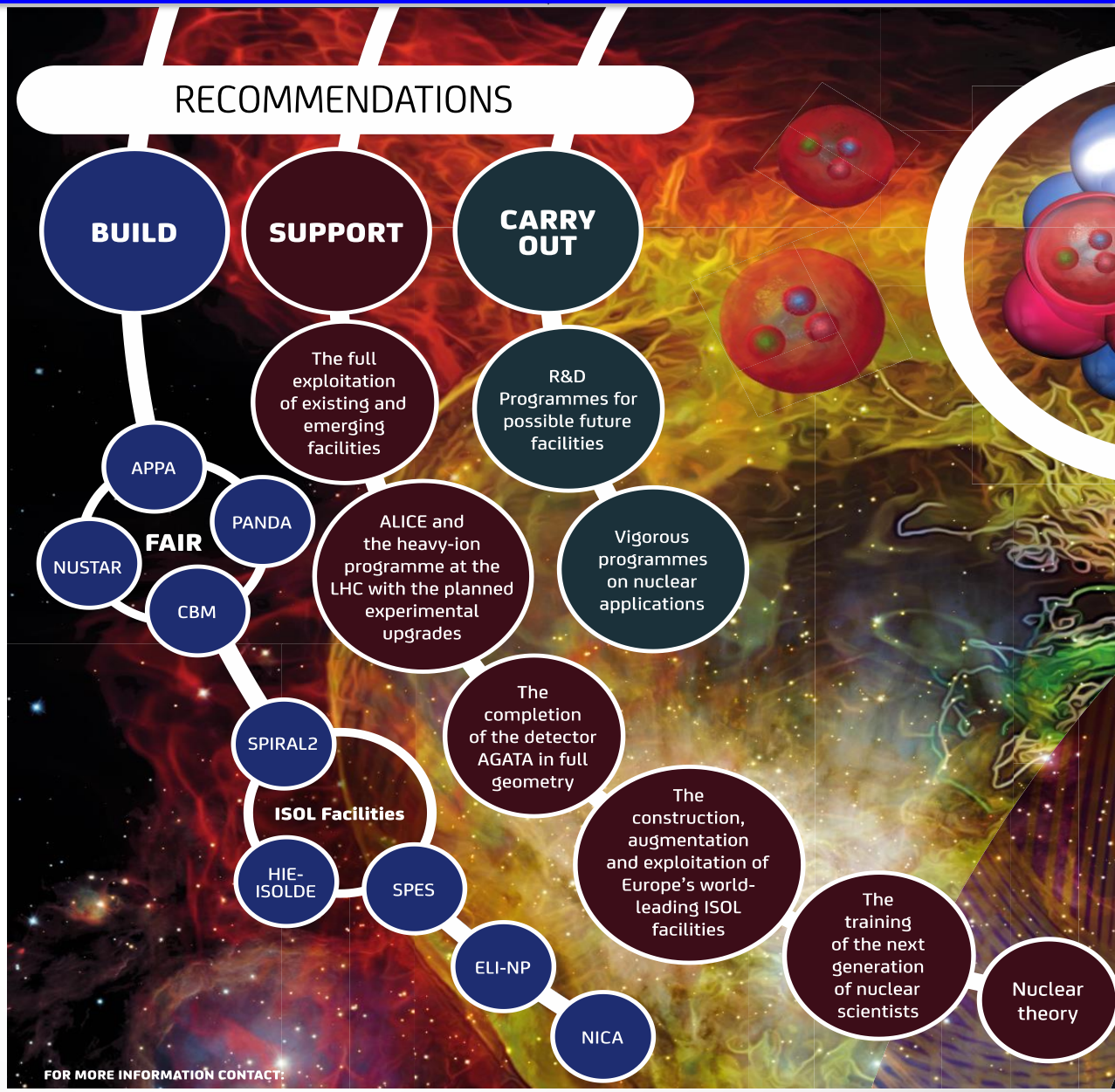
European Users
and joint technical developments with European Laboratories and Institutions
(collaborations for EIC in USA)
experiments at these facilities provide complementary information.

…in summary our NuPECC recommendations

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

Programme 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



Summary and Final Remarks….

Nuclear Physics is and remains to be a very vital field.
Exciting science world wide – Europe has strong impact

NuPECC LRP plays a role in giving it the deserved **visibility** towards the funding agencies (aligning their strategy to it) and other communities in the international general landscape (e.g. ESFRI).
Recommendations are made **to enhance European leadership**

European Facilities – are key players – strong engagement and support to them have been and **will be essential** for important achievements in nuclear physics

Presentation of the Long Range Plan 2017 of NuPECC

brochure

Perspectives in Nuclear Science and its application