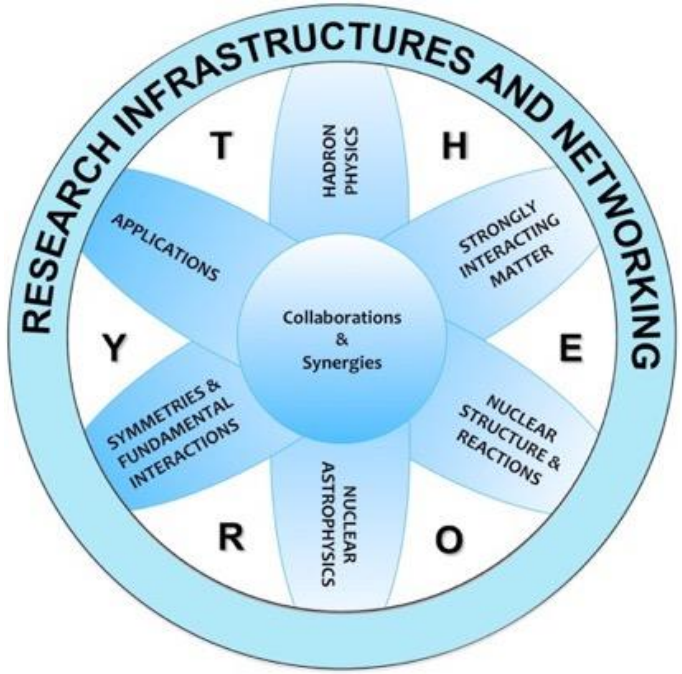
News from NuPECC

NuPECC Long Range Plan 2024
arXiv:2503.15575

Eberhard Widmann
NuPECC Chair
Marietta Blau Institute, Vienna

ANPhA Symposium
Academia Sinica, Taipei,
29 Nov 2025



www.nupecc.org

Nuclear Physics European Collaboration Committee (NuPECC)
Is the European Expert Board for Nuclear Physics
hosted by the European Science Foundation

Representing

> 5000 scientists

Composition:

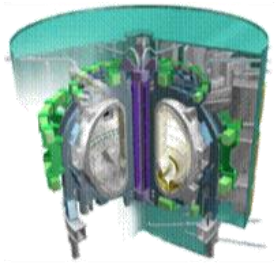
- 35 representatives from 23 countries (new: Slovakia, Slovenia, Ukraine), 3 ESFRI NP Infrastructures & ECT*
  - 4 associated members
    - CERN
    - Israel
    - iThemba Labs
    - Nishina Center
- 10 observers: ALAFNA, ANPhA, APPEC, CINP, ECFA, ESF, EPS-NPD, EPS-HEPPB, IAEA, NSAC

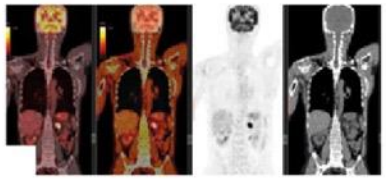
3 regular Committee meetings/y

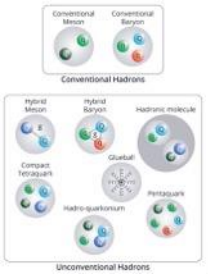
36 Years of NuPECC activities

https://nupecc.org

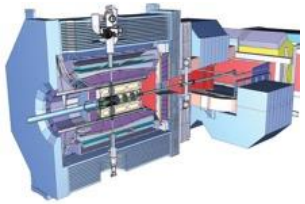
Nuclear Physics in Europe



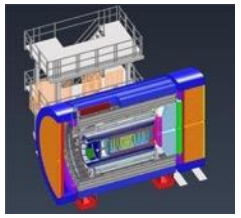




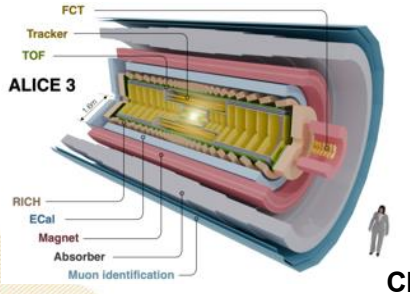
PANDA @ FAIR

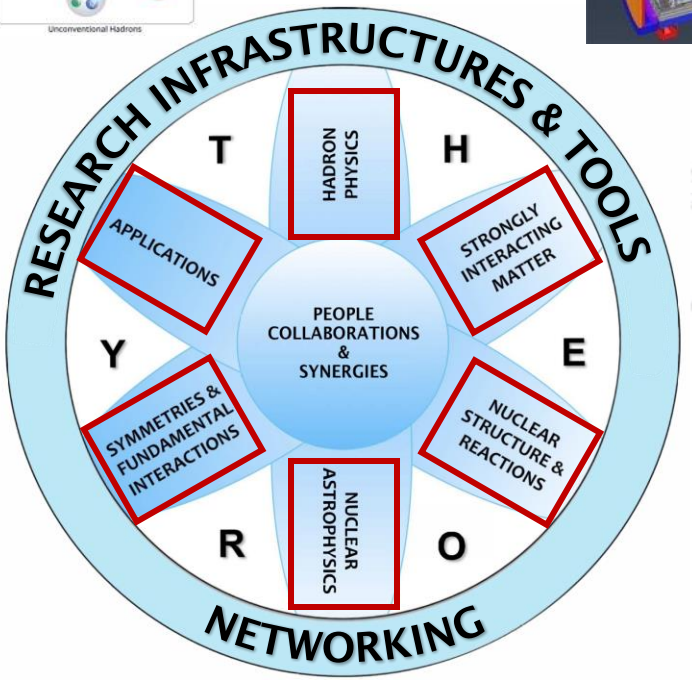


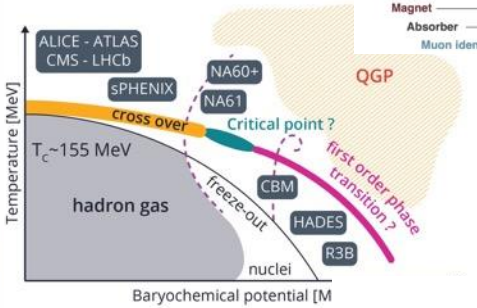
ePIC @ EIC



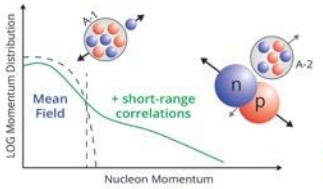
ALICE 3 @ LHC

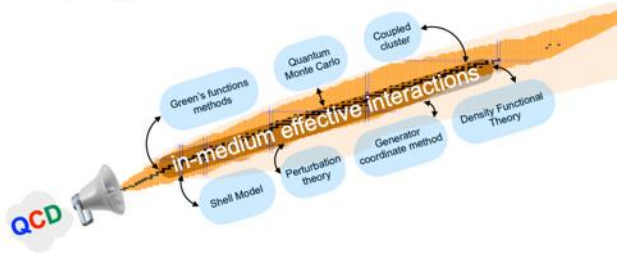


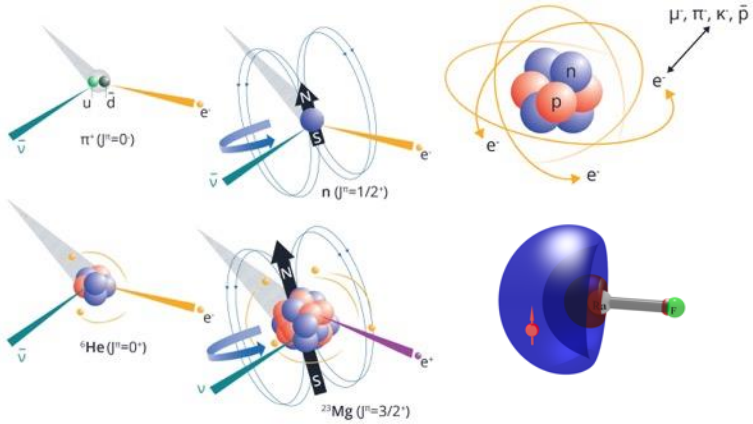


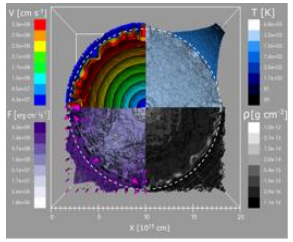


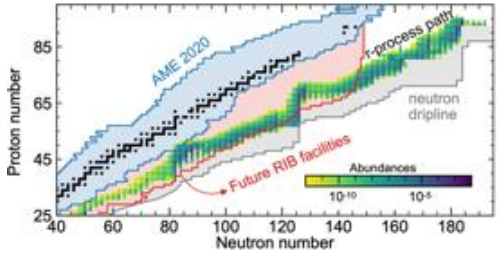
CBM @ FAIR





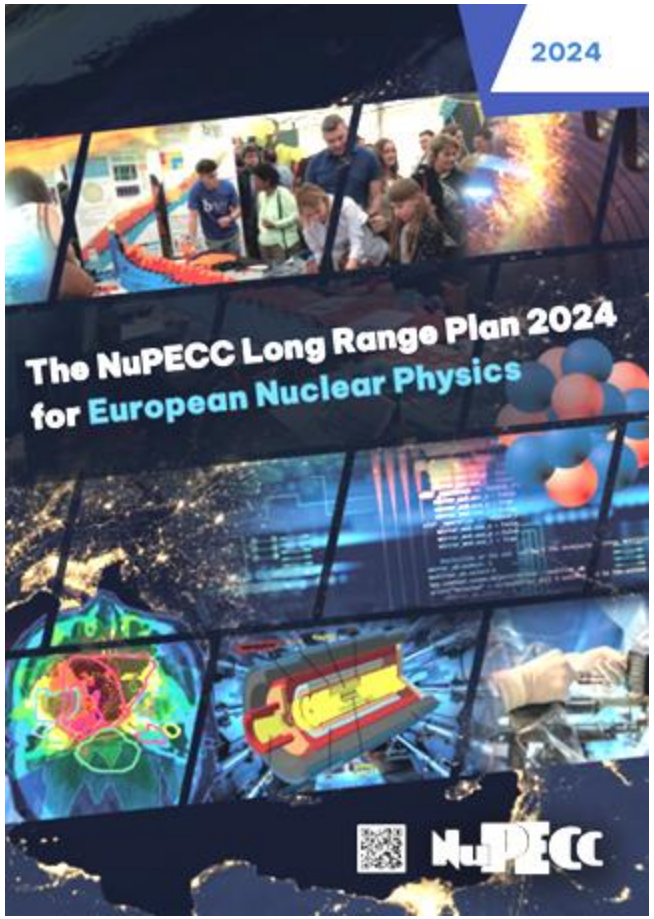






NuPECC Long Range Plan 2024

Prepared every ~7 years
Presentation in Brussels 19 Nov 2024
20 page brochure, 180 page full document
www.nupecc.org, arXiv:2503.15575



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Physics topics

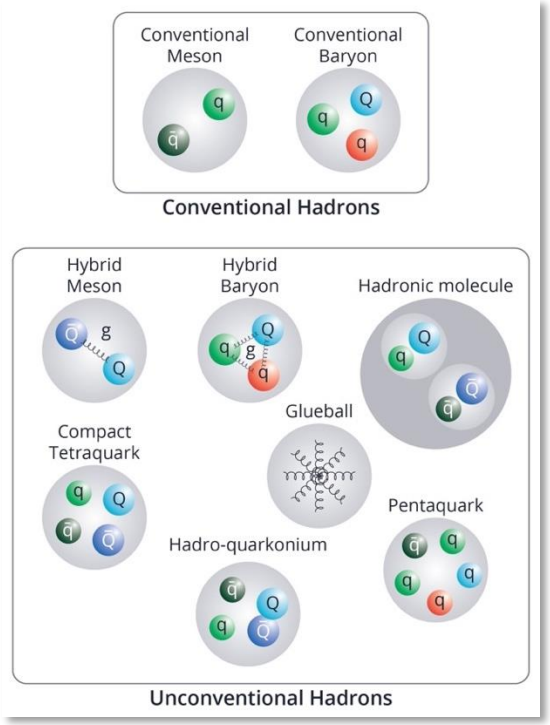
Hadron Physics

Key Questions & Goals

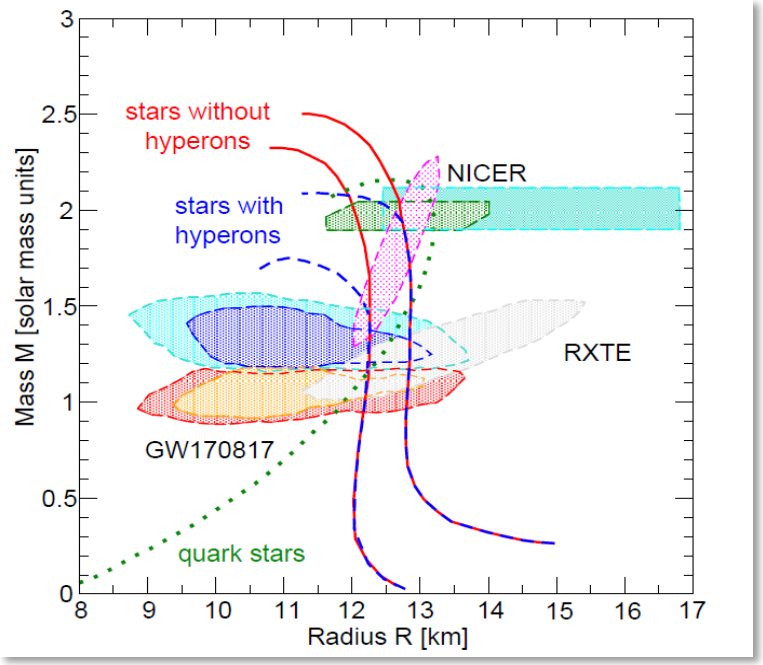
The goal of hadron physics is to understand the **rich and complex features** of the strong interaction. How does the major part of the **visible mass of the universe emerge** from the almost massless quarks? Can massless gluons form massive, exotic matter? What is the role of strong interactions in **stellar objects**, and in precision tests of the Standard Model?

Hadron Structure
Quarks and Gluons

Credit: https://www.bnl.gov/eic/goals.php



Valence content of conventional and exotic hadrons

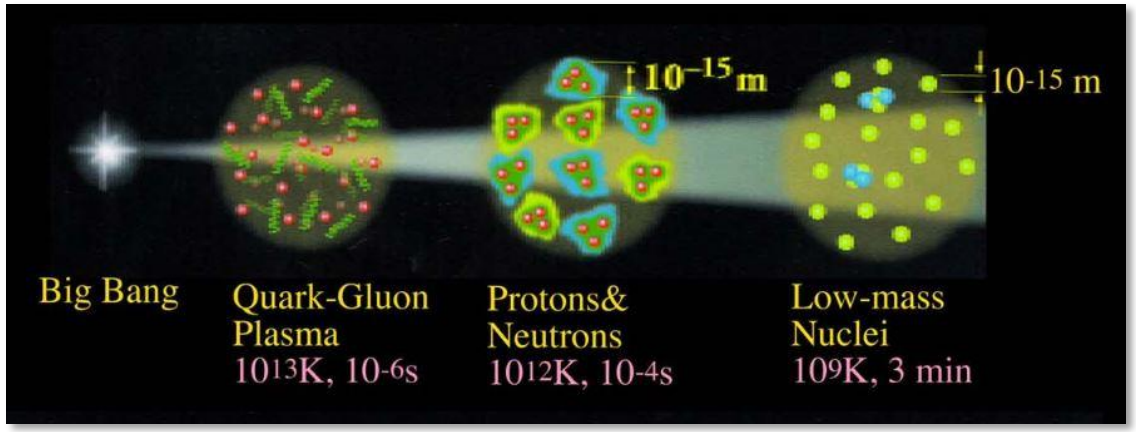


The blobs represent the mass and radius constraints from the gravitational wave detectors LIGO and Virgo, as well as NASA's Neutron star Interior ExploreR (NICER), while the dashed and solid lines represent the predictions obtained with various EoS models, with and without hyperons. Picture credit I. Vidana (Universita di Catania).

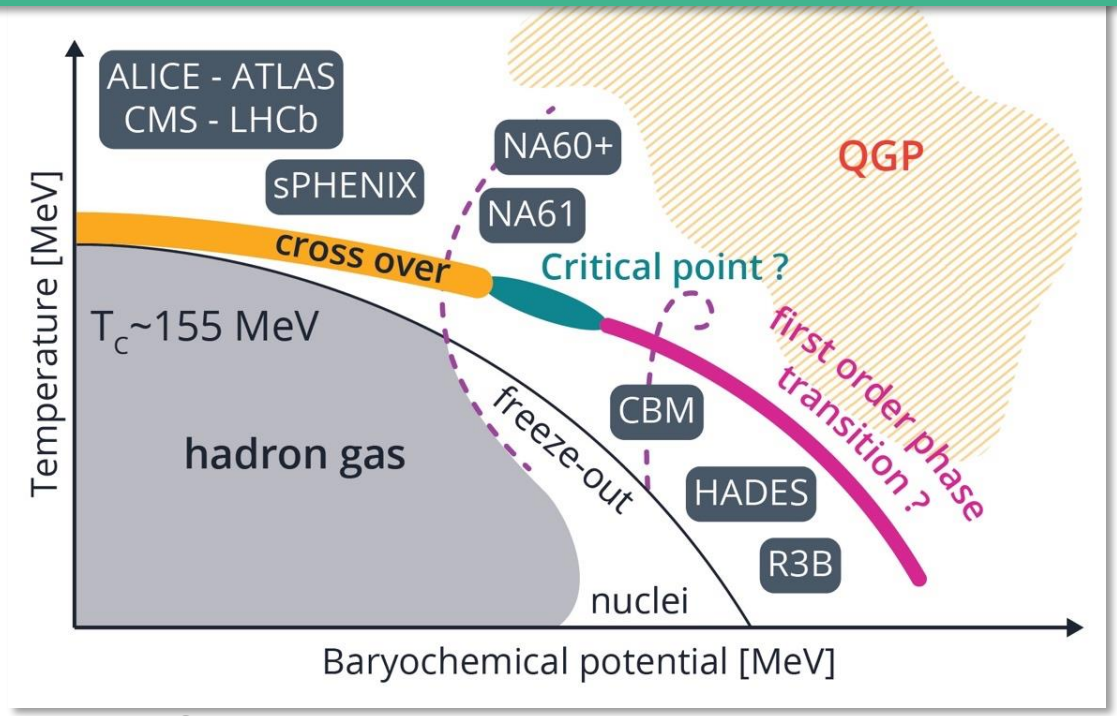
Strongly Interacting Matter at Extreme Conditions

Key Questions & Goals

What are the **properties of the quark-gluon plasma**, which is the qualitatively novel state of nuclear matter at extreme conditions of temperature and density?
Objectives: Discover in microscopic detail the **material properties** of the Quark Gluon Plasma at the **highest temperature** reached at the LHC at CERN and find the expected onset of the **first-order phase transition** at finite baryon density at FAIR in Darmstadt.



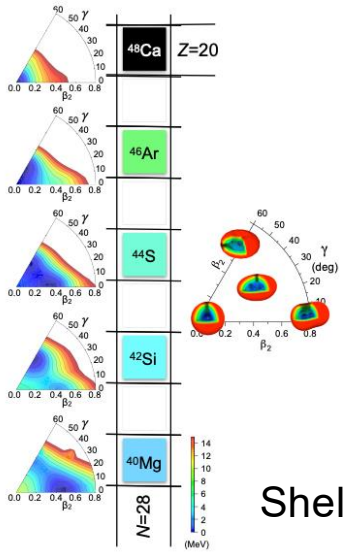
Mahnaz Q. Haseeb, *Introduction to Quark Gluon Plasma*, 2009



Nuclear Structure and Reaction Dynamics

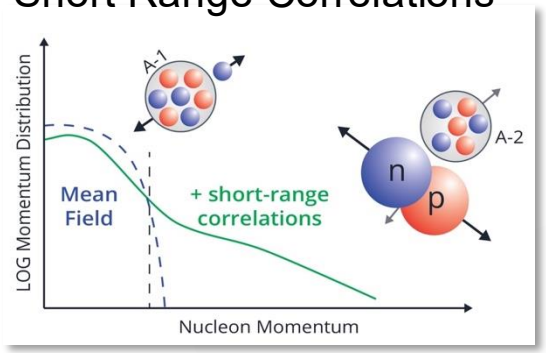
Key Questions & Goals

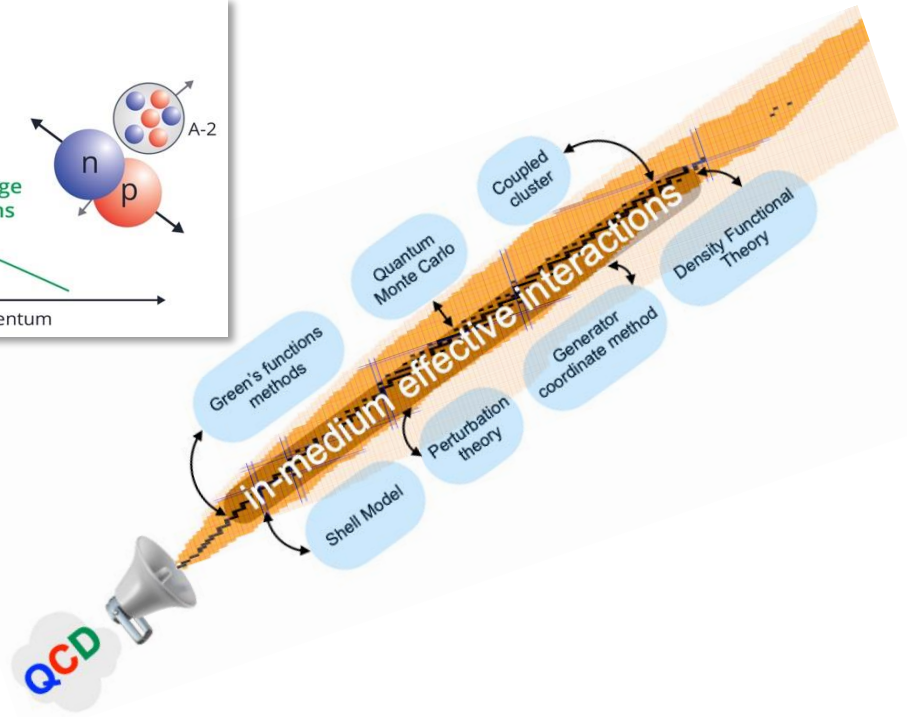
The main goals of Nuclear Structure and Reaction Dynamics in the next decade will be to answer the following questions: How do nuclei and nuclear matter **emerge** from the underlying fundamental interactions? What is the limit of nuclear existence and which phenomena arise from **open quantum systems**? How do nuclear **shells** evolve across the nuclear landscape, what kind of **shapes** can nuclei take, and what is the role of nuclear **correlations**? What are the mechanisms behind nuclear **reactions** and nuclear **fission**?



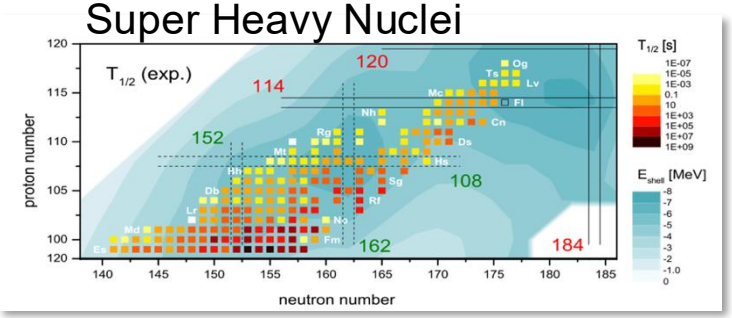
Shell Evolution

Short Range Correlations

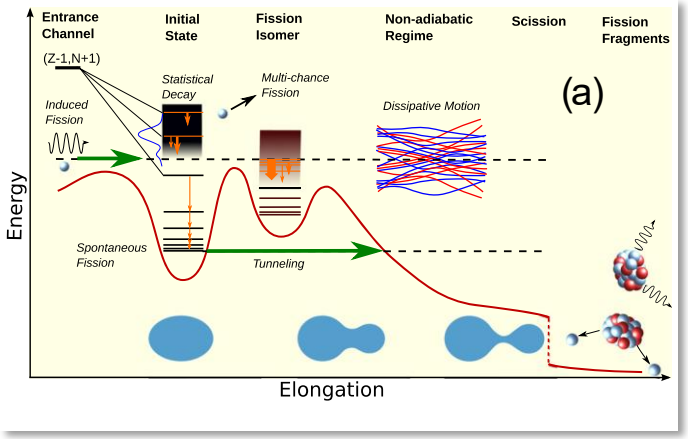




Super Heavy Nuclei



Fission of nuclei

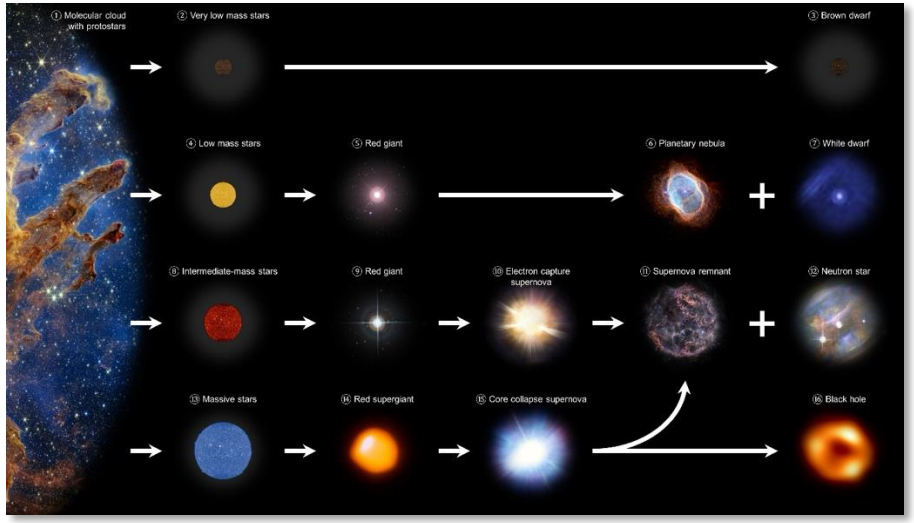


Nuclear Astrophysics

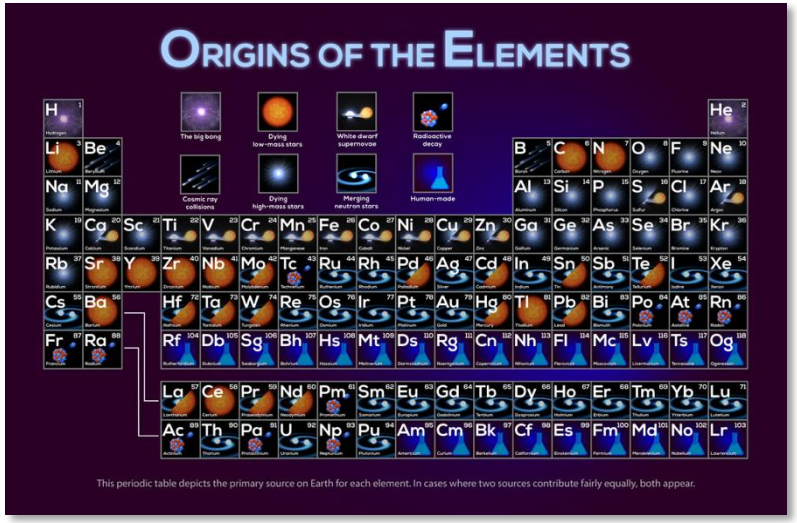
Key Questions & Goals

Nuclear astrophysics is the study of nuclear processes in **astrophysical objects** such as stars, covering the wide range of physical scenarios found in space. The key research questions are: How can we better understand the **synthesis of heavy elements** and the **chemical evolution** of the visible universe? What is the nature of matter in the **extreme conditions of compact astrophysical objects** such as mergers or pulsars?
Gravitational wave telescopes have opened a new window to astrophysics. These **multi-messenger** studies need a nuclear physics foundation (ex. equation of state of nucl. matter)

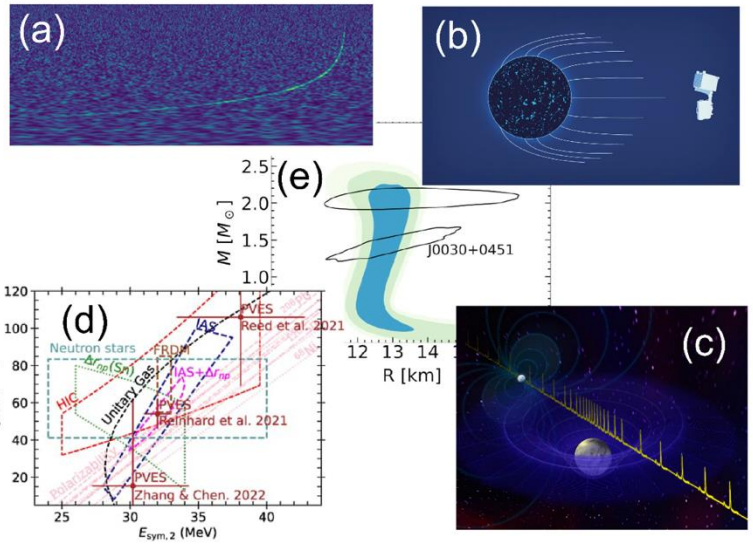
Stellar evolution for low-, intermediate - mass and massive stars



Origin of the Elements



Neutron stars and Equation of State



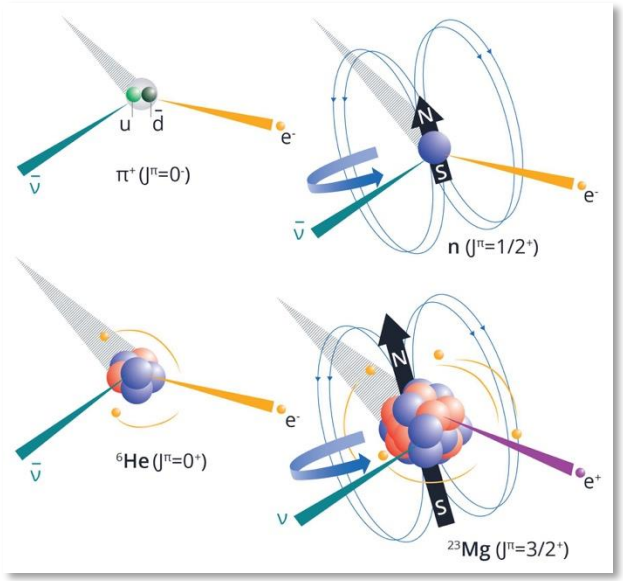
(See LRP2024 for details)

Symmetries and Fundamental Interactions

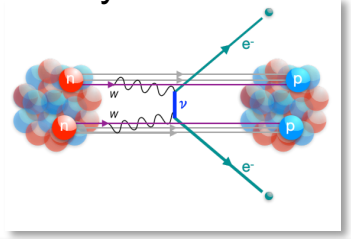
Key Questions & Goals

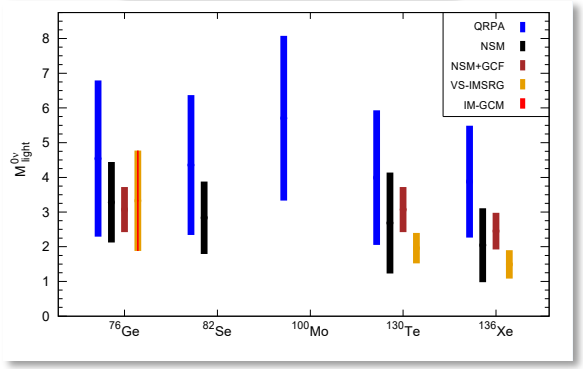
Symmetries, referred to as the invariance of the laws of physics under a given transformation, play a fundamental role in physics. They can be studied by powerful **low-energy probes**. As such, precision measurements are **complementary** to collider searches for new physics. Pioneering techniques are under development to **produce, manipulate, cool and trap** a diverse range of particles, including radioactive nuclei, neutrons, antiprotons, pions, muons, exotic atoms, and highly charged ions.

Examples of beta decays used to probe the weak interaction

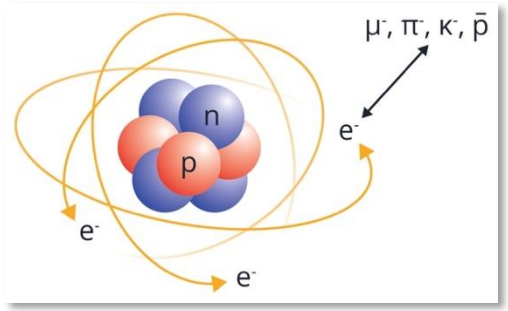


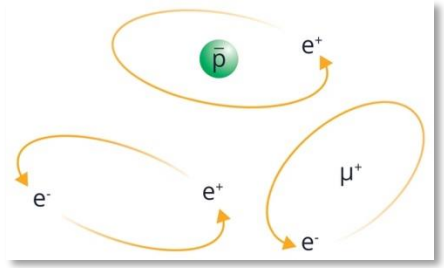
Neutrinoless double-beta decay research

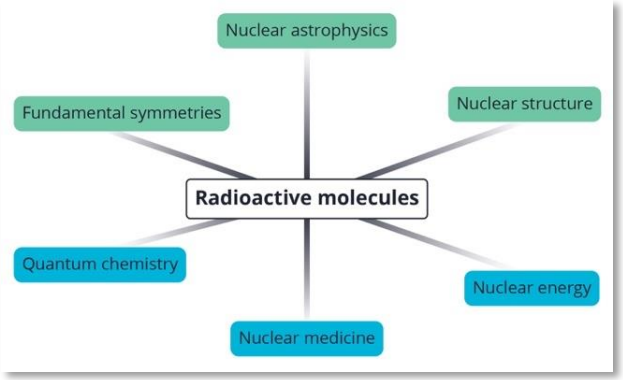




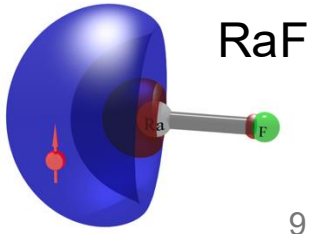
Exotic atoms







Schematic representation of the radium monofluoride (RaF) molecule



Applications and Societal Benefits

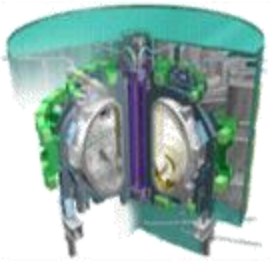
Key questions & Goals

How might nuclear physics strengthen its role in society's **sustainable development**?
The United Nations Sustainable Development Goals (SDGs) call to action for all governments across the globe, but also a call for all research communities to contribute. The nuclear science community contributes to all SDGs but more specifically, it directly addresses some of these goals (#3 Good health and well-being, #7 Affordable and clean energy, #9 Industry, innovation and infrastructure, #13 Climate action) or indirectly (#4 quality education, #5 gender equality, #10 reduced inequalities) through innovative and collaborative approaches. Nuclear science must critically assess where it can contribute to them and engage fully in such opportunities.

Recommendations

- Improving **nuclear data**, including both the measurement and the evaluation of nuclear data is needed to support research in the fields of energy, health, space, and material science.
- **Capacity building**: in radiochemistry and radiobiology maintaining nuclear application competencies, developing the landscape of smaller-scale facilities, in coordination with the large-scale facilities.
- New generations of nuclear energy sources and the management of nuclear waste through partition and transmutation, depend on sustained technological developments in the present facilities, as well as the completion of **MYRRHA** and **IFMIF-DONES.**
- Upscaling the production capacity of novel medical radionuclides: **MEDICIS** separator at CERN, the expansion of the EU **PRISMAP** project, and the completion **ISOLPHARM** at SPES, **ISOL@MYRRHA**, **IMPACT-TATTOOS** at PSI, and **SMILES** at Subatech
- Completion of the first galactic cosmic ray simulator in Europe at GSI/FAIR
- The installation of a high-energy **AMS** in Europe (>10 MV) is recommended.
- Isotope-sensitive techniques in **environmental, heritage, and material science**: sustained operation of research reactors

AI nuclear clock



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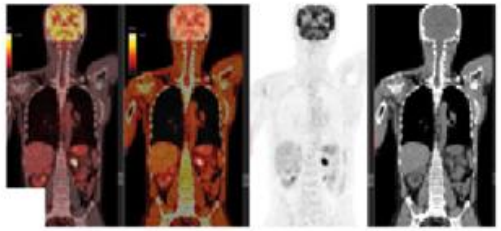
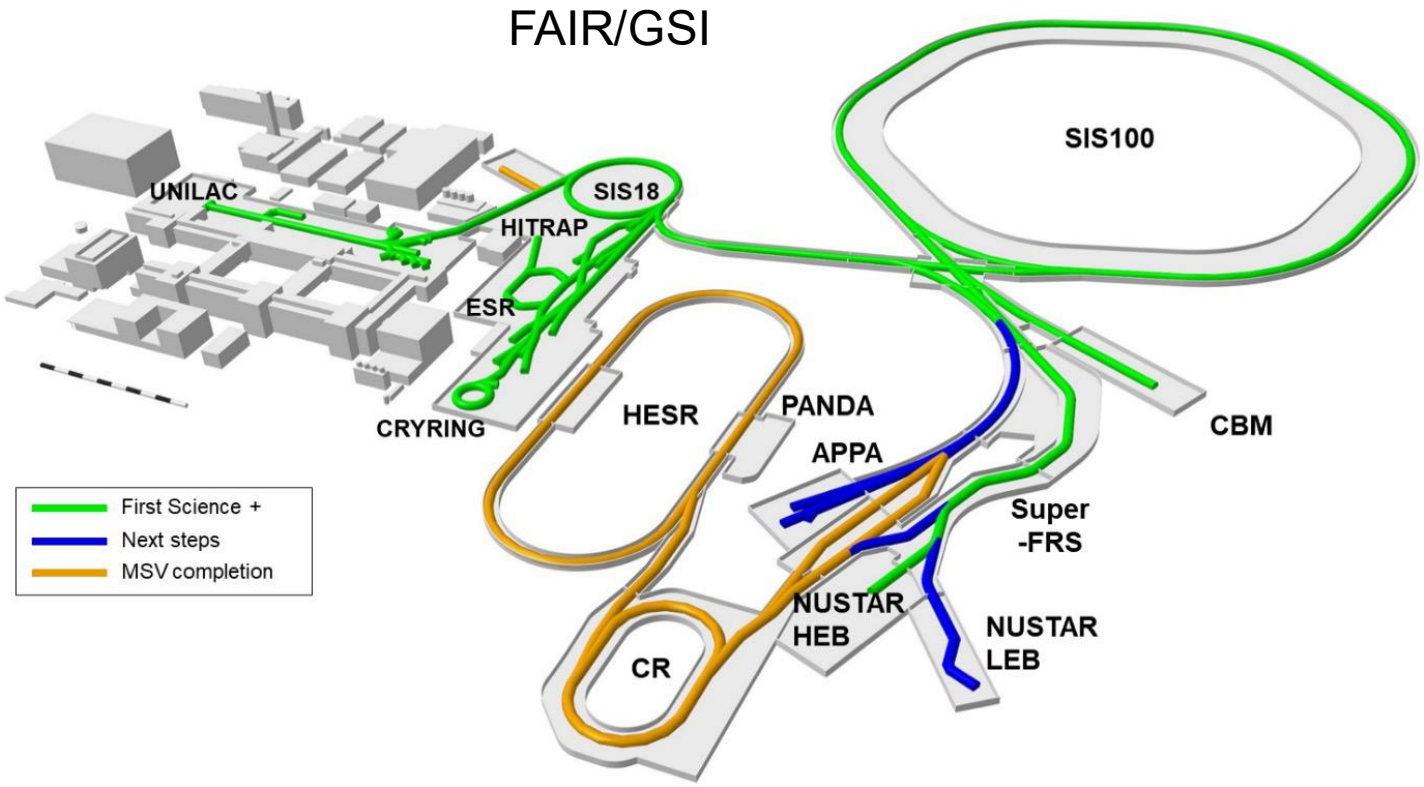


A PET–CT scan of the human body.

LRP 2024 Recommendations for NP Infrastructures

FAIR facility, Darmstadt, Germany

- The first phase of the international **FAIR** facility is expected to be operational by 2028, facilitating experiments with SIS100 using the High-Energy Branch of the Super-FRS, the CBM cave and the current GSI facilities. Completing the full facility including the **APPA**, **CBM**, **NUSTAR** and **PANDA** programs will provide European science with world-class opportunities for decades and is highly recommended.



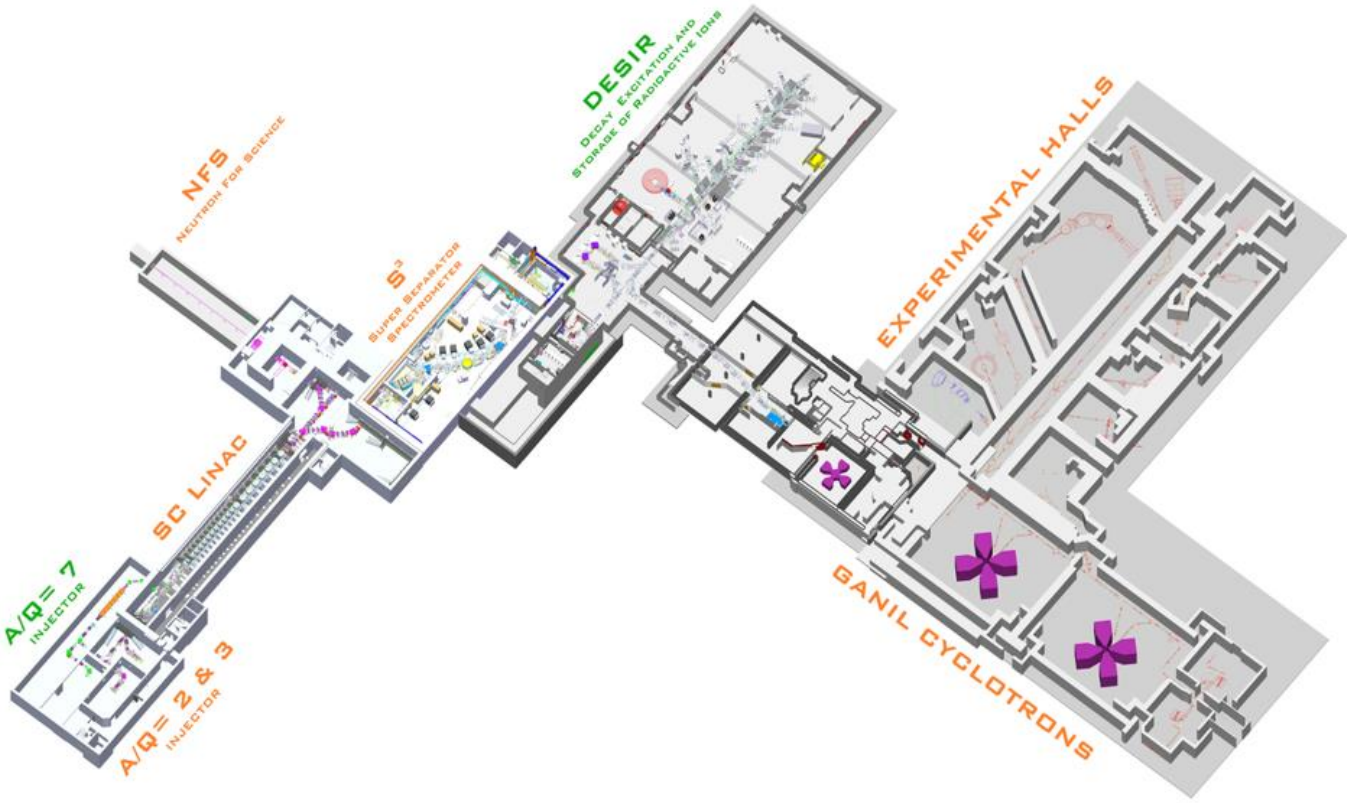
LRP 2024 Recommendations for NP Infrastructures

GANIL/SPIRAL2 facility, Caen, France

ESFRI

- At **GANIL/SPIRAL2** the Super-Separator Spectrometer **S³** is in an advanced stage of completion and the low-energy **DESIR** facility and heavy-ion injector **NEWGAIN**, will be operational from 2027/28. The refurbishing of the cyclotrons will ensure their operation for the next decades. Timely completion and full exploitation of these GANIL/SPIRAL2 projects are recommended. The future evolution of the infrastructure towards a very high-intensity reaccelerated RIB facility of up to 100 MeV/u should be actively planned.

GANIL/SPIRAL2 France



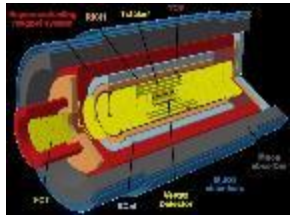
LRP 2024 Recommendations for NP Infrastructures

CERN Nuclear Physics facilities and experiments

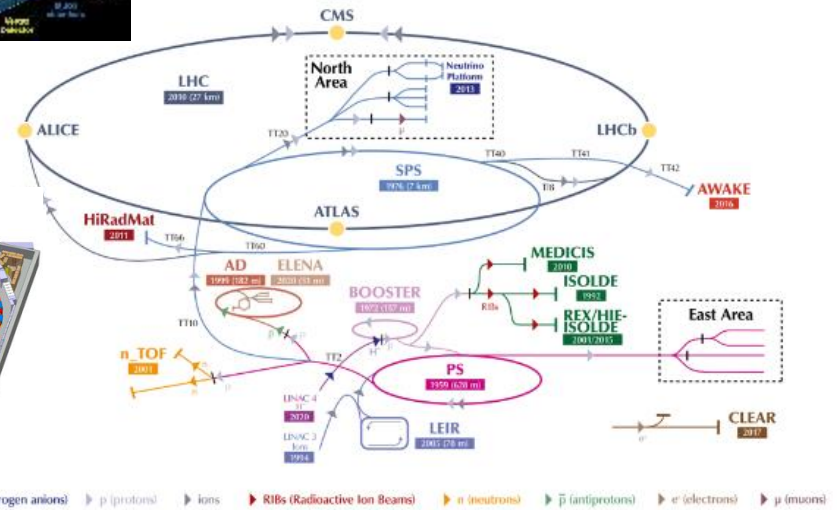
- Nuclear physics opportunities at **CERN** constitute a world-leading research . The construction of **ALICE 3** as part of the **HL-LHC** plans is strongly recommended. Continued support for exploitation and new developments are recommended to maximise the scientific output of **ISOLDE**, **n_TOF**, **SPS fixed-target program** and **AD/ELENA**. As the roadmap for the post-LHC future of CERN is developed, a strategy should be prepared to secure future opportunities for continuing world-leading nuclear-physics programmes that are unique to CERN.

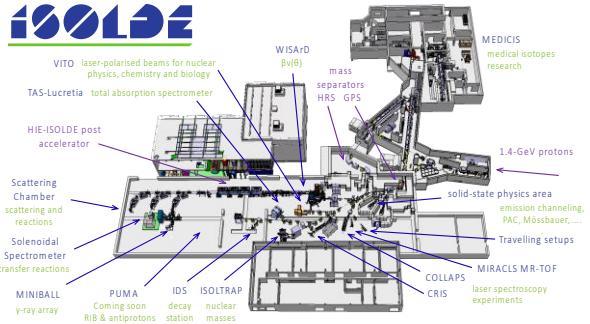
-> NP contributions to the ongoing Update of the Strategy for Particle Physics

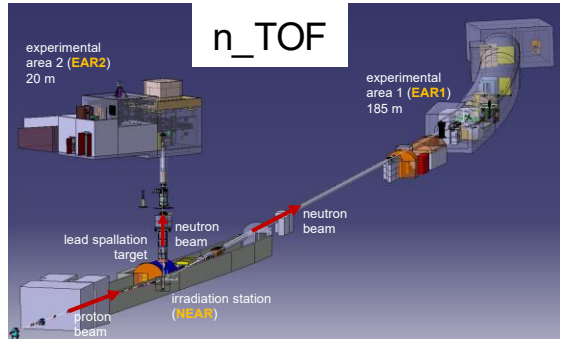
ALICE 3



AD/ELENA







Nuclear Science - People and Society

Key Questions & Goals

Fundamental nuclear science and curiosity-driven research is a rich area of knowledge and development with a broad range of applications and impact on our society. To further develop this pool of knowledge for future generations, however, we must not only explore these areas of knowledge, understanding and development, but communicate them to – and develop them jointly with – the next generations, through **outreach**, **education** and **training**.

Recommendations

- Outreach: We recommend that funding agencies, national and international bodies, and the community of European nuclear physicists emphasise the critical societal investment inspiring the public about nuclear science and its impacts

- Education: We recommend that national educational accreditation bodies, funding agencies, universities and educational institutions, in collaboration with the community of European nuclear physicists work to embed nuclear science across all levels of education, highlighting its interdisciplinary nature and impact

- Training: We recommend that the community of European nuclear physicists in collaboration with funding bodies and other stakeholders resource and support the training of new generations of nuclear scientists, … technical and engineering staff as well as interdisciplinary researchers

Binding Blocks initiative in UK

Training at EURO-LABS facilities

Nuclear Science - People and Society

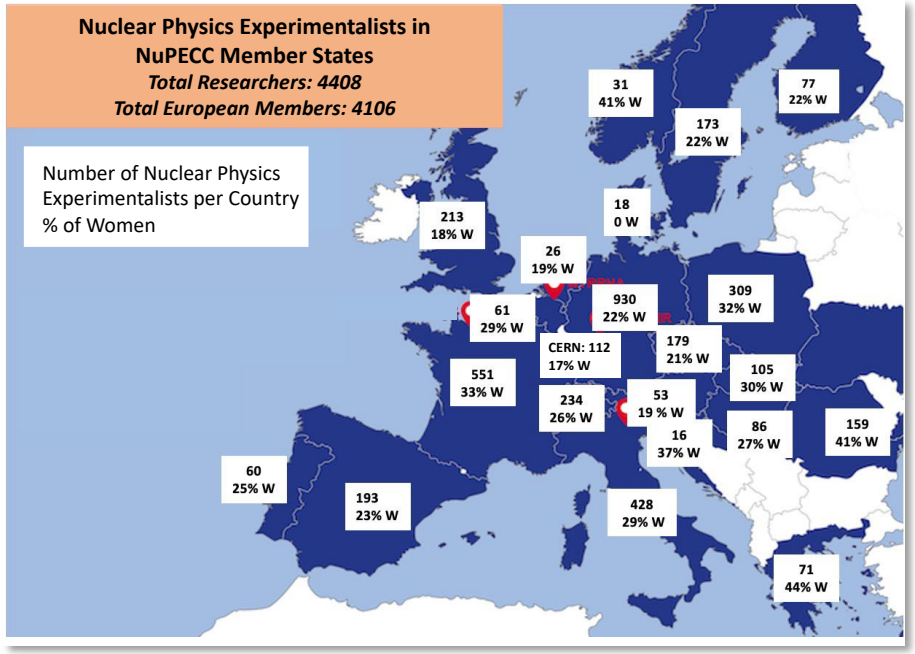
Key Questions & Goals

The **diversity** and **gender** balance in the nuclear physics community should be a mirror of the European society we live in.
Early career researchers (**ECR**) provide the backbone of the different research areas of the nuclear physics community. Further efforts are necessary to inspire and offer opportunities to – particularly – the next generations of scientists, enhancing the impact of nuclear physics and the broader nuclear sciences on people and society.

Recommendations

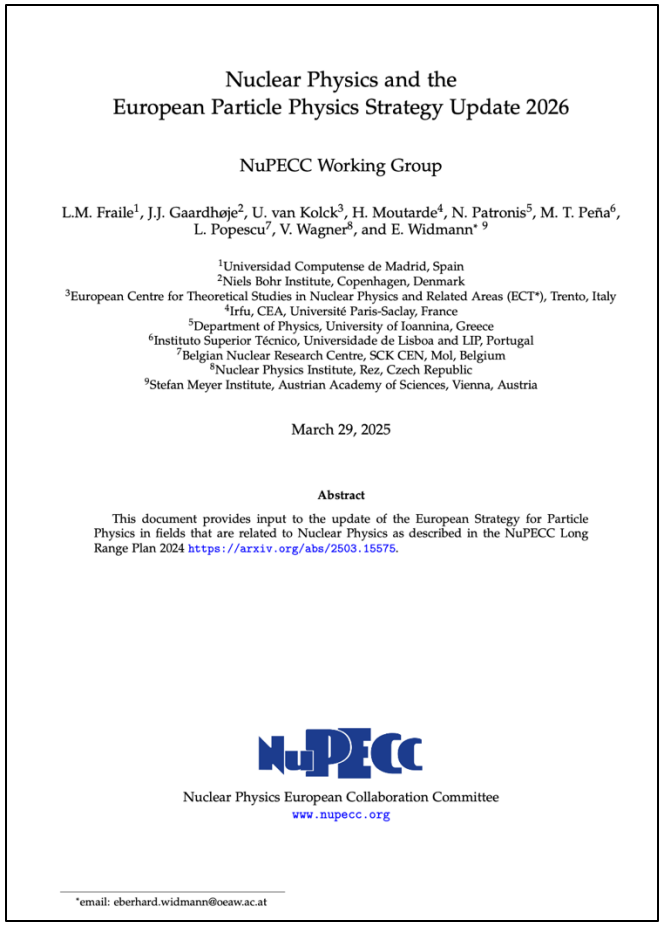
- Diversity: We recommend that the network of research organisations, funding agencies, as well as scientific collaborations and conference committees should sign up to and promote a diversity charter, such as the one prepared by NuPECC together with APPEC and ECFA.
  …identify a body in Europe that takes charge of collating and providing an overview of the monitoring of diversity across nuclear science in Europe

- Careers: We recommend that equitable and inclusive career development is further prioritised by stakeholders across the European nuclear physics community, giving recognition and visibility to the critical contributions of early career researchers (ECR), as the future of nuclear physics and its impact on society
  - support tenure track programs giving highly qualified ECR the opportunity to lead their own group and establish scientific independence (e.g. permanent staff position openings for ECR, European Research Council Starting Grants)



The map shows the community of experimental researchers within NuPECC. For each Country the total number and the ratio of women are given.

NuPECC input to ESPPU



Nuclear Physics and the
European Particle Physics Strategy Update 2026

NuPECC Working Group

L.M. Fraile[1], J.J. Gaardhøje[2], U. van Kolck[3], H. Moutarde[4], N. Patronis[5], M. T. Peña[6], L. Popescu[7], V. Wagner[8], and E. Widmann*[9]

[1]Universidad Computense de Madrid, Spain
[2]Niels Bohr Institute, Copenhagen, Denmark
[3]European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*), Trento, Italy
[4]Irfu, CEA, Université Paris-Saclay, France
[5]Department of Physics, University of Ioannina, Greece
[6]Instituto Superior Técnico, Universidade de Lisboa and LIP, Portugal
[7]Belgian Nuclear Research Centre, SCK CEN, Mol, Belgium
[8]Nuclear Physics Institute, Rez, Czech Republic
[9]Stefan Meyer Institute, Austrian Academy of Sciences, Vienna, Austria

March 29, 2025

Abstract

This document provides input to the update of the European Strategy for Particle Physics in fields that are related to Nuclear Physics as described in the NuPECC Long Range Plan 2024 https://arxiv.org/abs/2503.15575.

Nuclear Physics European Collaboration Committee
www.nupecc.org

*email: eberhard.widmann@oeaw.ac.at

European Strategy Update
EUROPEAN STRATEGY FOR PARTICLE PHYSICS

- Contribution edited by selected experts
  - #103 of 263
    https://indico.cern.ch/event/1439855/contributions/
  - Available at arXiv:2504.04100
  - Participation in European Strategy Group (EW)

Contents

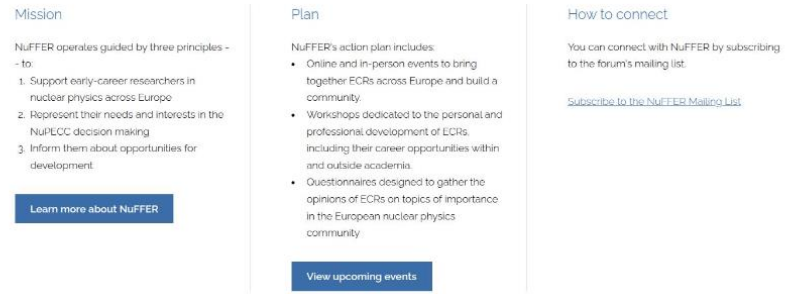
JENAS Symposia

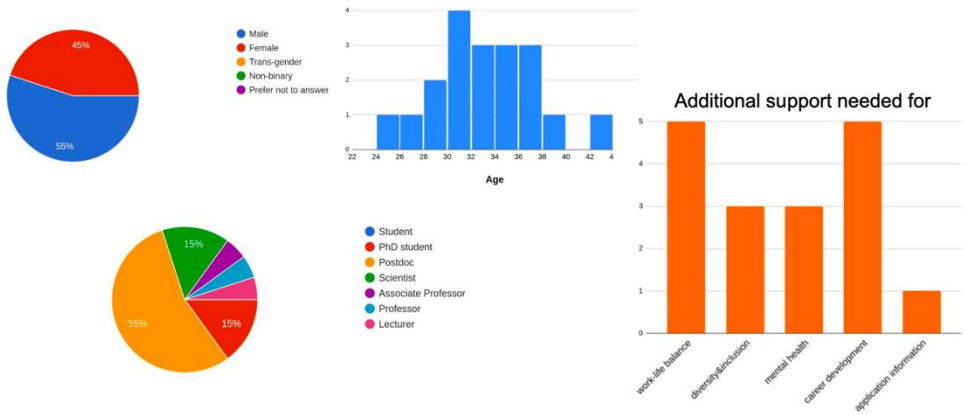
- *Joint ECFA NuPECC APPEC* activities
- Orsay, FR 2019
- Madrid, ES 2022
- Didcot, UK 2025
- Large attendance
- Excellent presentation of topics of joint interest
- Meeting with funding agencies
  - Main focus 2025: *JENA white paper on federated computing*
- *JENAS 2028*

A NuPECC Forum For Early career Researchers

- Established in 2024
  - Chair: Annika Thiel
  - Co-chair Michail Athanasakis-Kaklamanakis
  - First activities: by-laws, survey
- Kick-off meeting during EuNPC
  - Caen 26 Sep 2025

- https://nuffer.web.cern.ch/





Thank you

Implementation of the NuPECC LRP2024

- NuPECC Task Force (directors of the NP ESFRI infrastructures) meetings with the funding agencies of the Member Countries to promote the LRP and encourage its implementation

  9 Task Force meetings in 2017-2022

  Task Force meetings in 2023-2025:

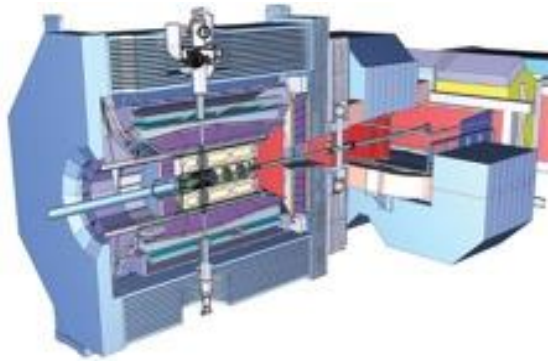
  - Belgium in Brussels on 31/01/2023
  - Slovenia in Ljubljana on 15/03/2023
  - Austria in Vienna on 21/04/2023
  - Germany in Bad Honnef on December 5th, 2024
  - France in Strasbourg , 11/06/2025
  - *Meetings in Slovakia, Hungary, Romania, Finland and Sweden 2025 - 2026*

- Use and cite the LRP2024 in the applications for funding of new projects, collaborations, EU and national grants!
- Make the LRP2024 recommendations known among the nuclear physics community
- Apply for and ensure the support of EU for nuclear physics: next EC calls!

Hadron Physics

Recommendations (experiments)

PANDA @ FAIR

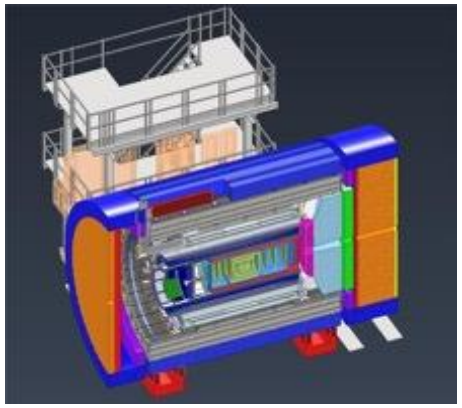


Support of existing facilities and experiments:

- **AMBER** at CERN
- **ELSA** in Bonn, **HADES** at GSI**, MAMI** and **MESA** in Mainz, Germany
- **Jefferson Laboratory** in Newport News, USA

Furthermore, we recommend the support of ongoing hadron physics activities at the multi-purpose facilities Belle II, BESIII and those at the LHC.

ePIC @ EIC



Future flagship facilities and experiments:

- We recommend the expedited realisation of the antiproton experiment **PANDA**, and the support of European groups to contribute to the electron-ion experiment **ePIC**. By virtue of their different beam species and energy regimes, PANDA and ePIC will explore complementary physics aspects.

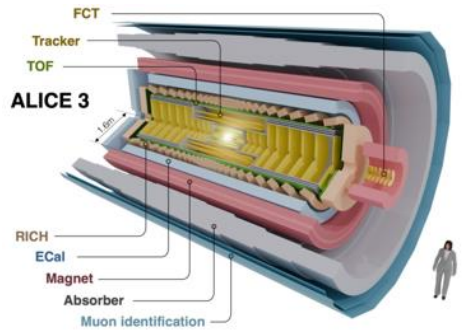
Strongly Interacting Matter at Extreme Conditions

Recommendations (experiments)

- **Future flagship facilities and experiments**
  - **ALICE 3** at **CERN**
  - **SIS-100** at **FAIR** and the realization of the **CBM** experiment
  - **CERN LHC** after 2035 (Run 5 and 6), the **LHCb Upgrade2** and the fixed-target setup **NA60+** detector at the **SPS**

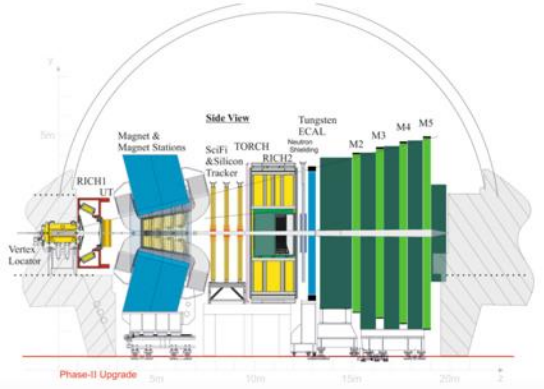
- **Support of existing facilities and experiments**
  - Maximise scientific output from the significant investment in current detector upgrades at the **LHC**
  - **HADES** and **R3B** at **SIS-18/SIS-100**, should receive full support.
  - The exploitation of **NA61** at **SPS** should receive full support

ALICE 3 @ LHC



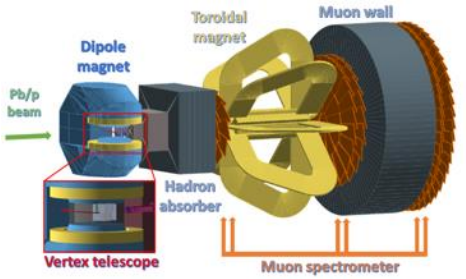
CBM @ FAIR

LHCb Upgrade II



Credit: Framework TDR for the LHCb Upgrade II CERN-LHCC-2021-012 ; LHCB-TDR-023

NA60+

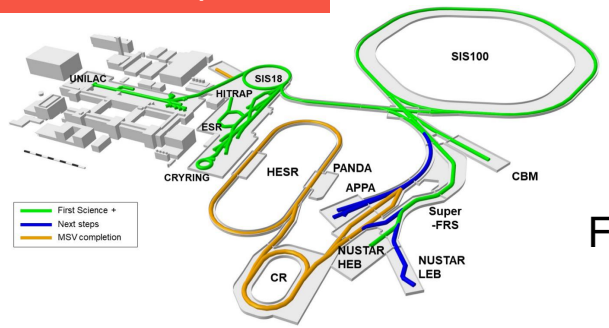


Credit: https://na60plus.ca.infn.it

Nuclear Structure and Reaction Dynamics

Recommendations (experiments)

- Support of existing facilities and experiments
  - To ensure complementarity in experimental programs, it is essential to strongly support *large- and small-scale facilities* which guarantee access to the whole community
  - The coordinated effort amongst the ISOL facilities in Europe … will secure the leading position of Europe
  - The full completion of the European flagship gamma spectrometer AGATA-4π (with ancillaries) is mandatory
- **Future flagship facilities and experiments**
  - **FAIR** facility (with Low-Energy-Branch), **SPIRAL2**, **SPES**, **ELI-NP**, **ISOL@MYRRHA**, and **ISOLDE** upgrades
  - Future rings at **FAIR** and **HIE-ISOLDE**



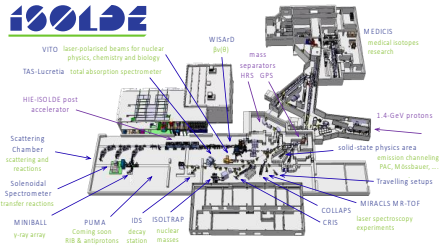
FAIR

GANIL/SPIRAL2 France

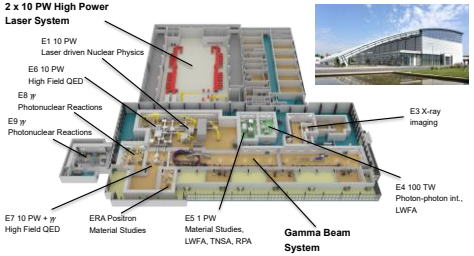
SPES/LNL Italy

AGATA

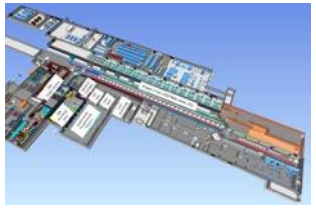
ISOLDE CERN

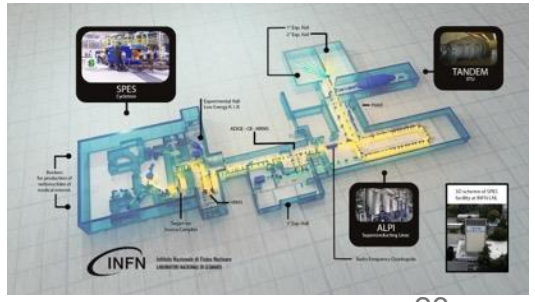


ELI – NP Romania



ISOL@MYRRHA Belgium





Nuclear Astrophysics

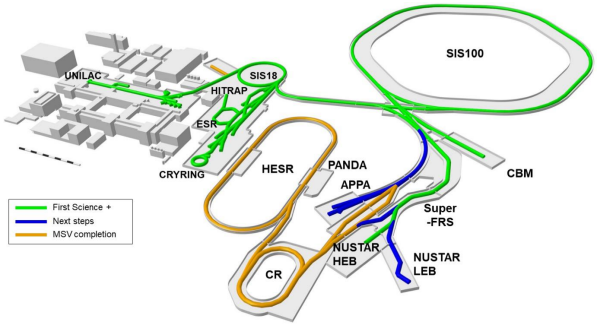
Recommendations (experiments)

- We recommend to strengthen nuclear astrophysics **networks** in Europe (e.g. ChETEC-INFRA) and to make them sustainable.

- Support of existing facilities and experiments
  - Small-scale facilities are key for nuclear astrophysics research and should be supported
  - European underground laboratories (**LNGS Bellotti** Ion Beam Facility and **Felsenkeller)** are essential
  - CRYRING and ESR storage rings at FAIR, which open important new physics cases, and n_TOF at CERN should be fully exploited

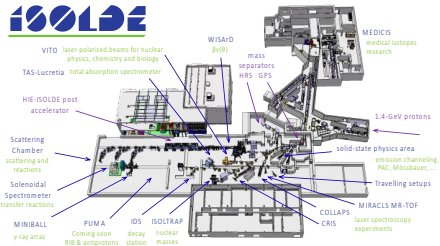
- **Future flagship facilities and experiments**
  - We strongly recommend the completion of Radioactive Beam Facilities in Europe, in particular the Super-FRS at FAIR, including the Low-Energy-Branch, the upgrade of ISOLDE, and SPIRAL2
  - A large (> 10 MV) **Accelerator Mass Spectrometry** system is currently missing in Europe

FAIR



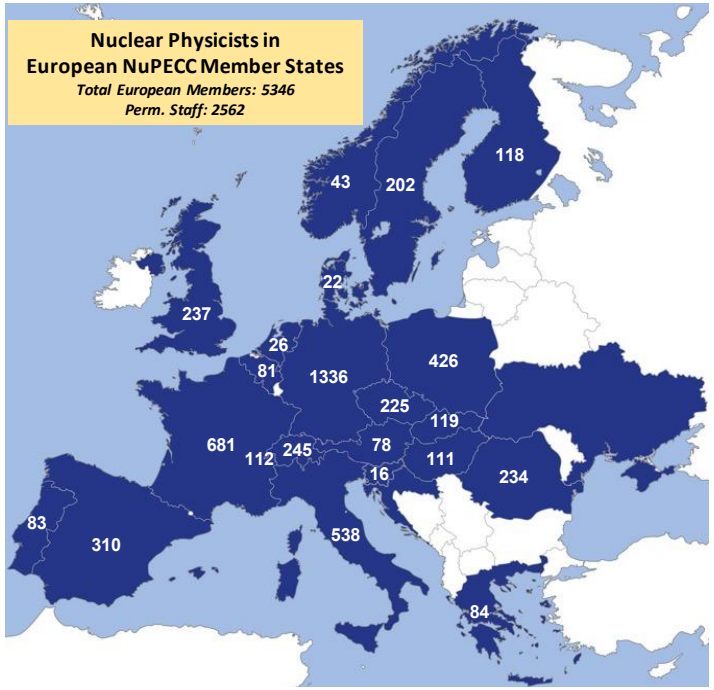
GANIL/SPIRAL2 France

ISOLDE CERN



Nuclear Physics in Europe – two pillars

Nuclear Physics Workforce in Europe



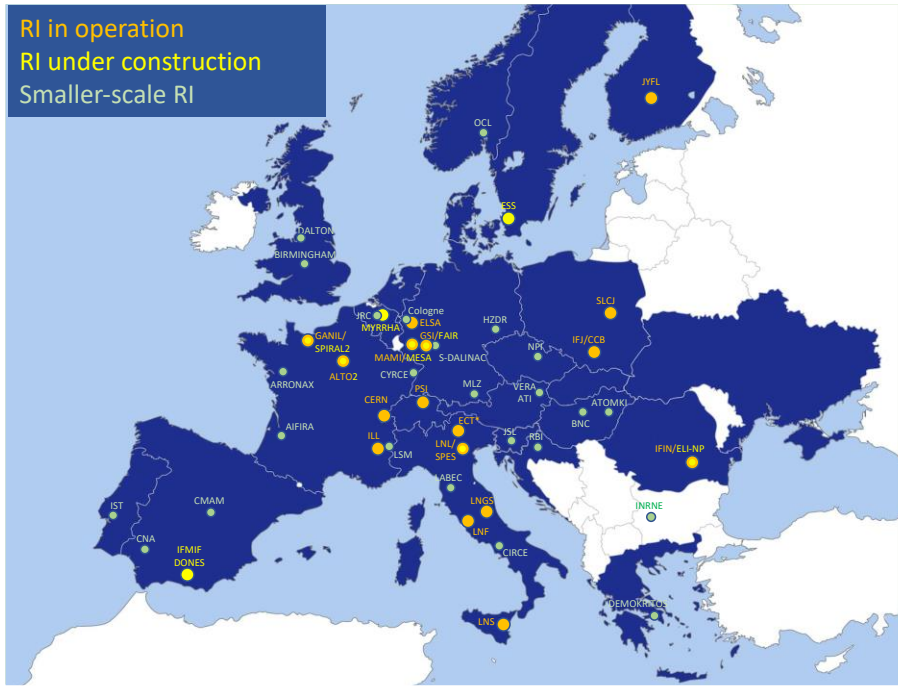
5346 - total number of Nuclear Physicists (Exp. & Theory) in the European NuPECC Member States and the Associated Member CERN

2546 – permanent staff

2800 – PhD students and non-permanent staff

From NuPECC 2021& 2023 surveys

European Landscape of Nuclear Physics Infrastructures



All infrastructures are multidisciplinary !

Taking data > 30;
Under construction or upgrade ≥ 9

From NuPECC LRP 2024

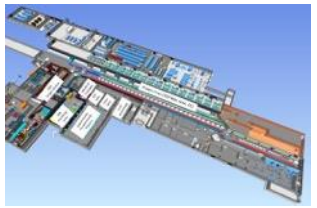
Symmetries and Fundamental Interactions

Recommendations (experiments)

- Support of existing facilities and experiments
  - The multidisciplinary research infrastructures **ILL**, **FRM-II** and **PSI** provide unique opportunities. Operation of ILL should be ensured beyond 2033.
  - Continued support for **ESR**, **CRYRING** and **HITRAP** at GSI/FAIR, and high-energy **EBITs** in other labs
  - The **AD/ELENA** physics program at CERN should be strongly supported
  - Customised instrumentation and beam time availability should be guaranteed for fundamental tests at **RIB facilities** like ISOLDE, GANIL-SPIRAL2, and JYFL-ACCLAB/IGISOL
  - Multiple and **complementary experimental searches** for neutrino-less double beta decay have to be encouraged as they can reach into the inverted hierarchy in the next decade.

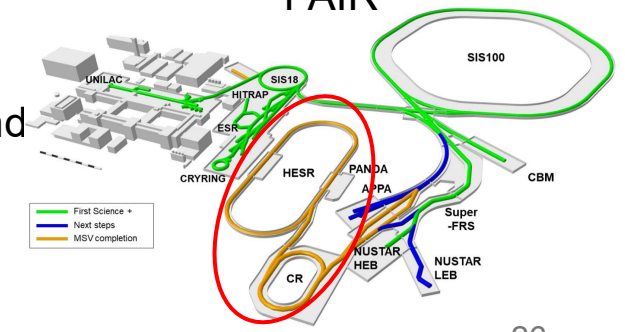
- **Future flagship facilities and experiments**
  - Specialization of upcoming Radioactive Ion Beam facilities such as **ISOL@MYRRHA** and **DESIR at GANIL-SPIRAL2** should be regarded as an opportunity not to be missed
  - At **ESS**, a fundamental neutron physics beamline should be installed
  - The realisation of future **CR** and **HESR** at FAIR should be vigorously pursued

ISOL@MYRRHA Belgium



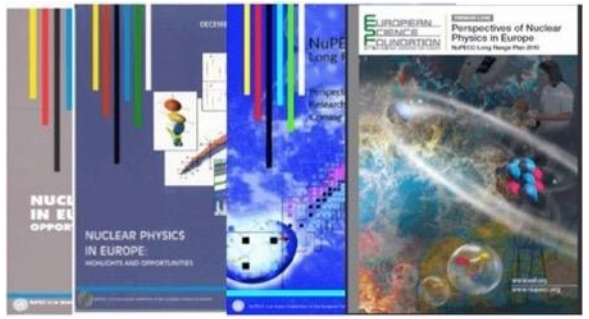
GANIL/SPIRAL2 France

FAIR



Towards NuPECC Long Range Plan 2024

1991 1997 2004 2010



NuPECC LRP 2017

https://www.nupecc.org/lrp2016/Documents/lrp2017.pdf

- The LRP identifies opportunities and priorities for nuclear science in Europe
- The LRP provides national funding agencies, European Strategy Forum on Research Infrastructures and the European Commission with a framework for coordinated advances in nuclear science in Europe

Assessment of implementation of LRP 2017

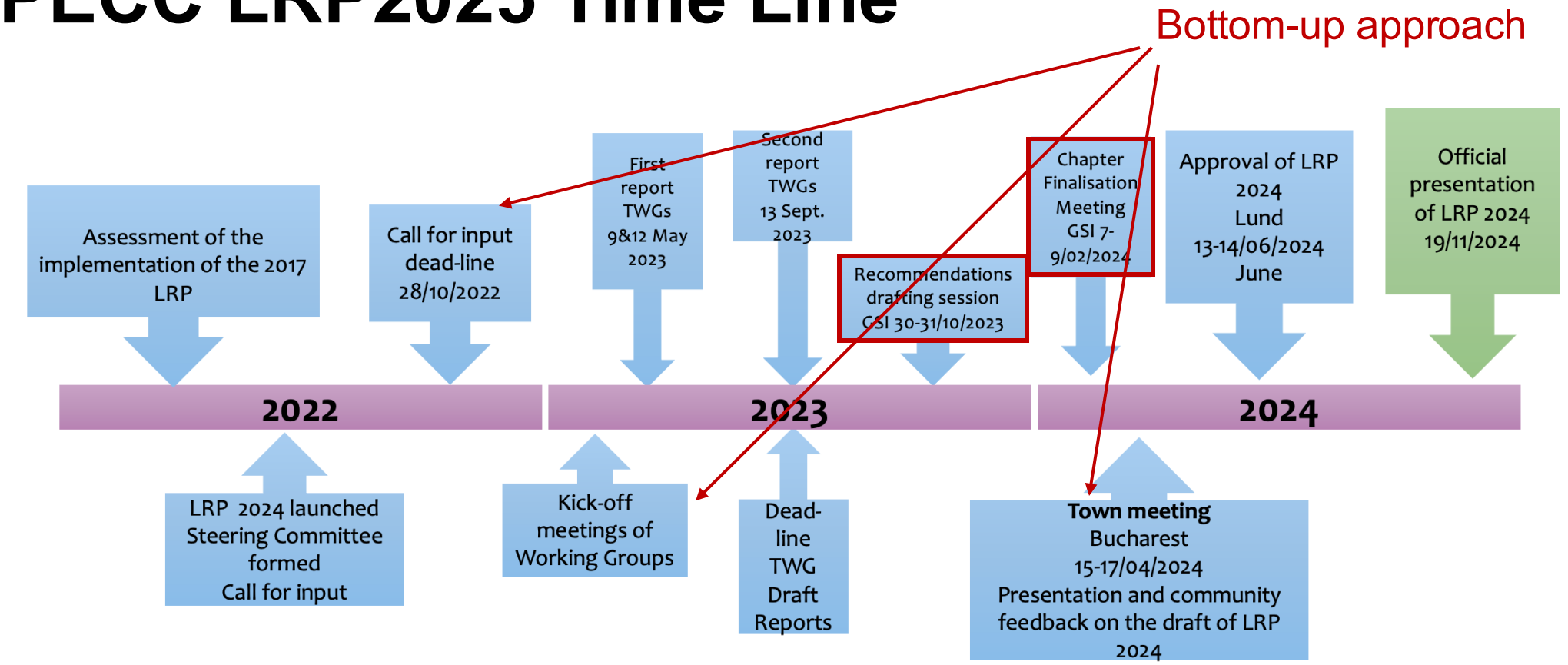
https://www.nupecc.org/2017_LRP_Assessment_of_Implementation_final.pdf

Launched in May 2022 in Madrid

NuPECC LRP 2024

arXiv:2503.15575

NuPECC LRP2025 Time Line



29 members of the Steering Committee
159 contributions from the community
10 Thematic Working Groups with 266 conveners, NuPECC members and contributors

NuPECC Long Range Plan 2024

University Foundation Bruxelles

Presentation in Brussels 19 Nov 2024

- Brochure: 20-page summary and recommendations
  - Targeted at public and decision makers
  - Available in print
- Full report
  - Text approved in Lund meeting Jun 2024
  - 180+ pages pdf version available Nov 2024
- Executive Summary of the LRP2024 is available on the NuPECC Web site
  https://www.nupecc.org/lrp2024/Draft_Executive_Summary_LRP2024.pdf
- The PDF web version version of the full text is available at arXiv:2503.15575
- Printed version available on request