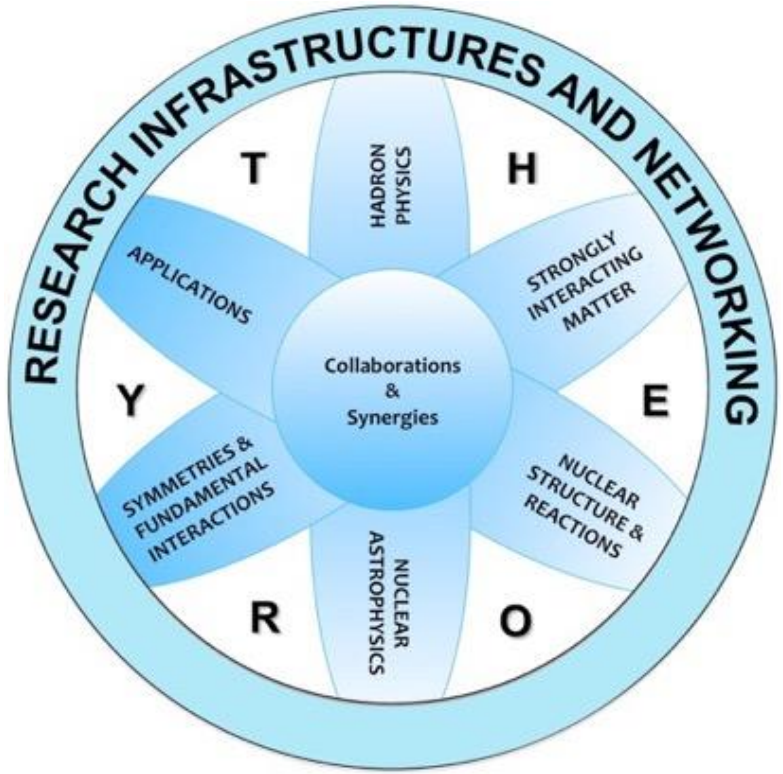
# NuPECC Report



## *Eberhard Widmann*

***Nuclear Physics European Collaboration Committee (NuPECC)***
***Deputy Chair / Chair Elect***
***Stefan Meyer Institute, Vienna***
***Slides contributed by Marek Lewitowicz***


**ANPhA Symposium**
**November 15, 2024**
**Institut for Modern Physics**
**Huizhou, China**



# What is NuPECC ?

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

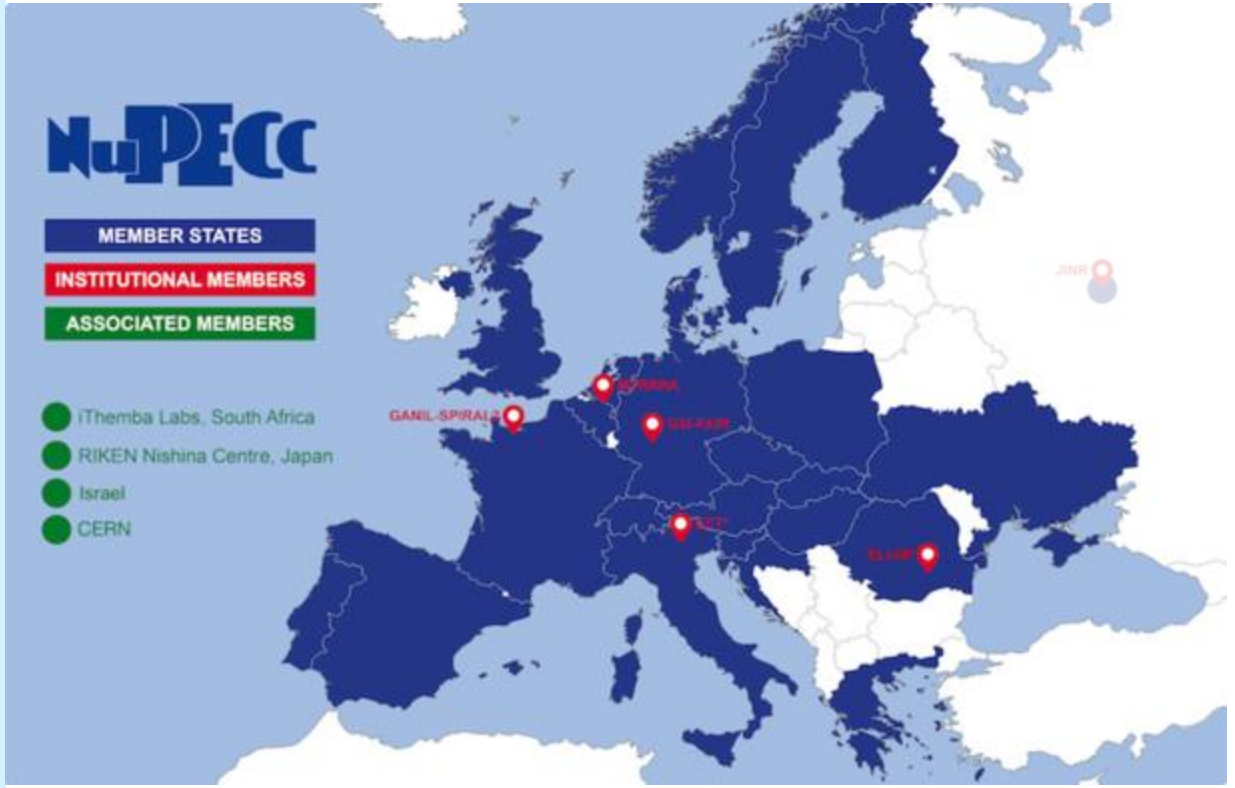
## Representing

> 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-HEPPD, IAEA, NSAC

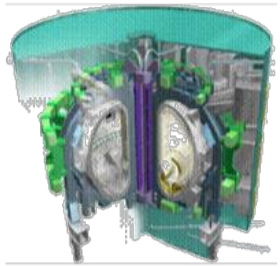
3 regular Committee meetings/y

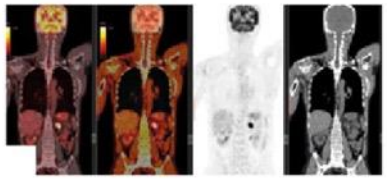


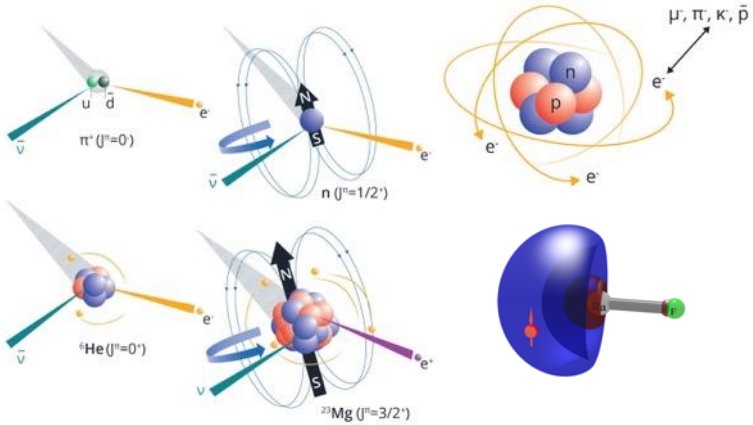

36 Years of NuPECC activities

https://nupecc.org

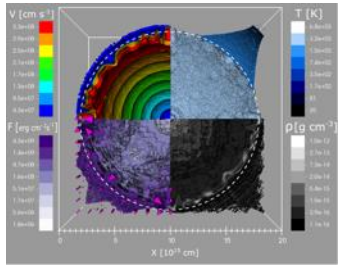
# Nuclear Physics in Europe

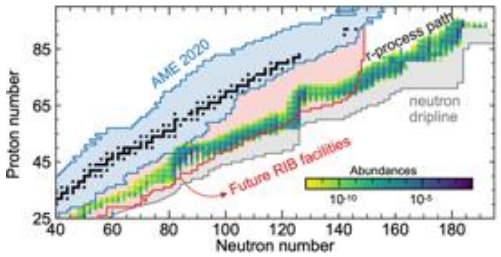


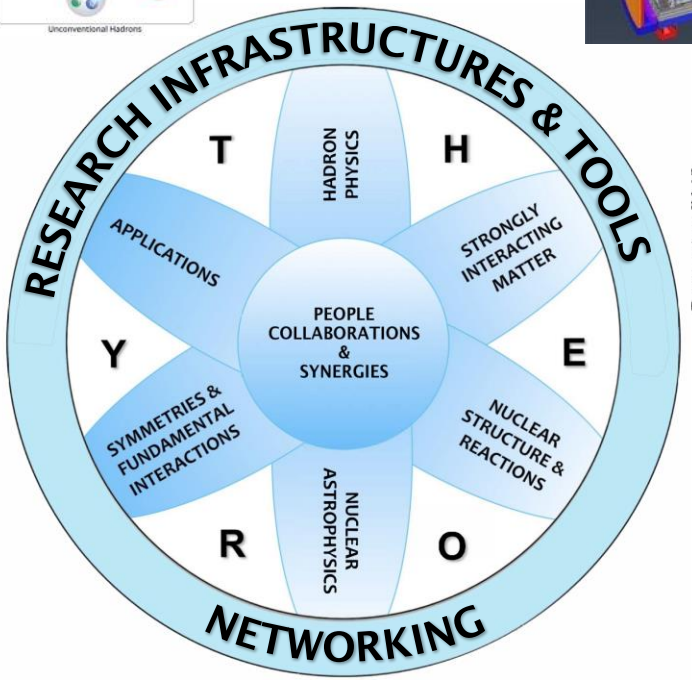


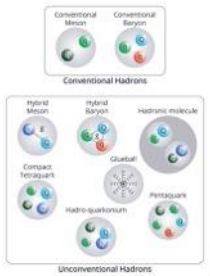




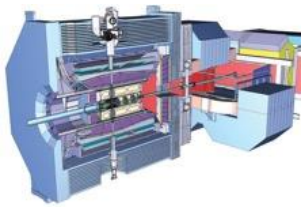




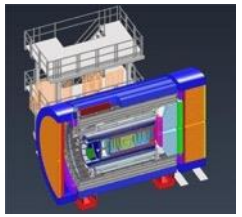



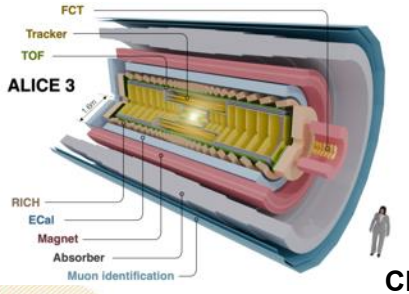

PANDA @ FAIR

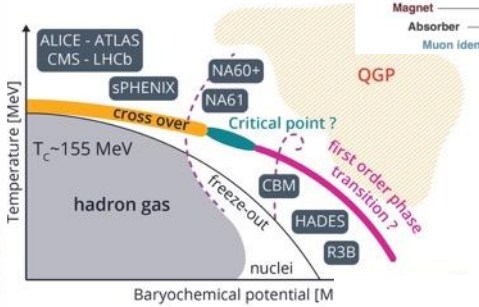


ePIC @ EIC

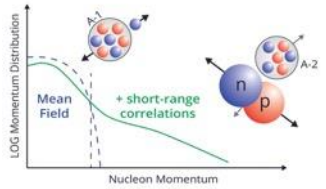


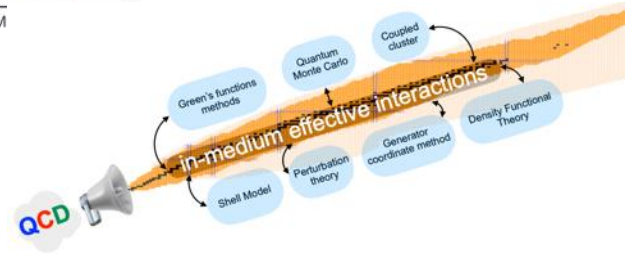
ALICE 3 @ LHC



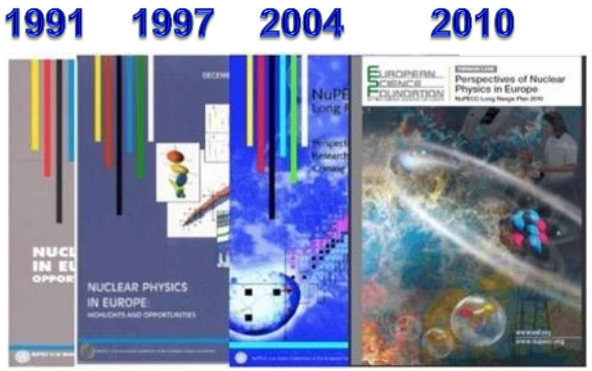




CBM @ FAIR

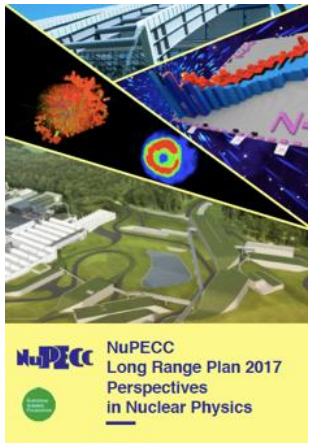


# Towards NuPECC Long Range Plan 2024




- **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**




**NuPECC LRP 2017**

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

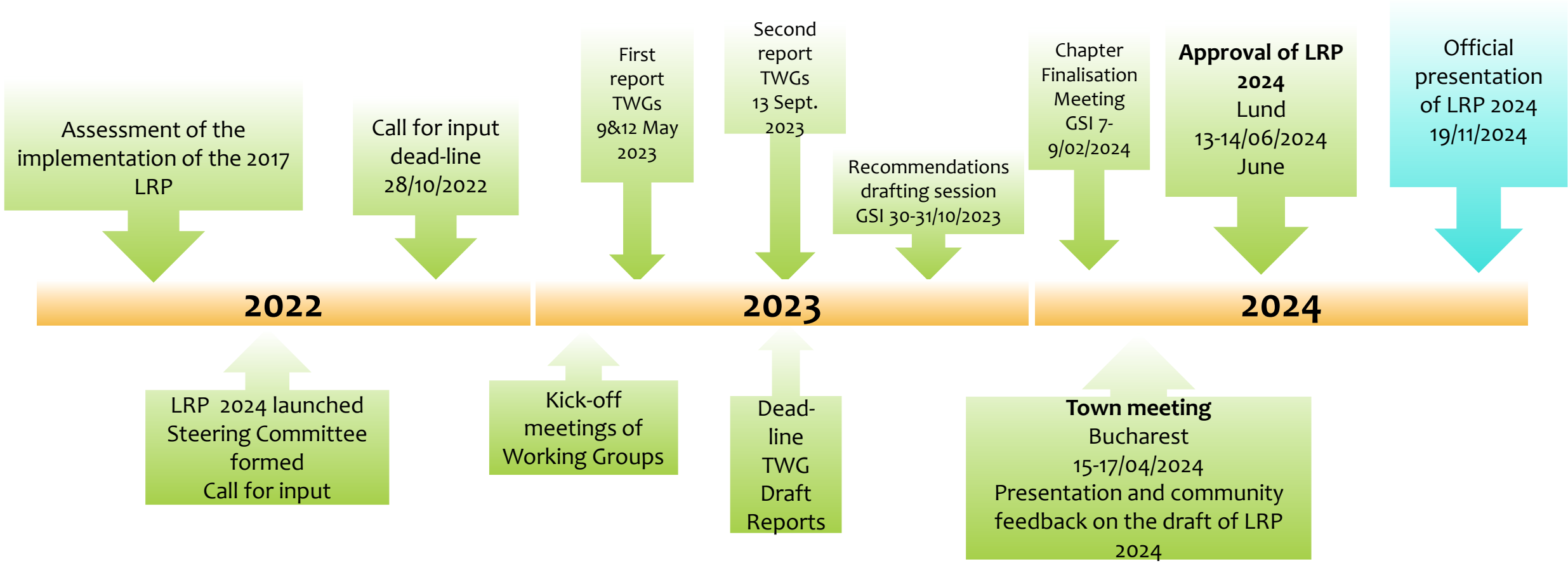
**Assessment of implementation of LRP 2017**

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

**Launched in May 2022 in Madrid**


**NuPECC LRP 2024**

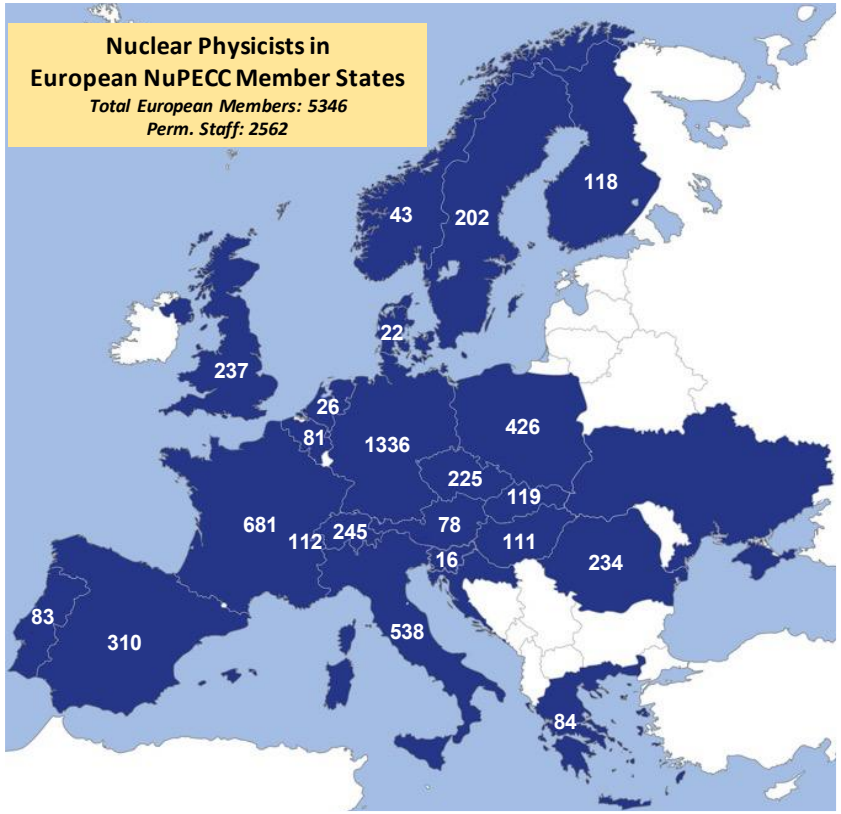
# NuPECC LRP2024 Timeline




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

# Nuclear Physics in Europe – two pillars

## Nuclear Physics Workforce in Europe



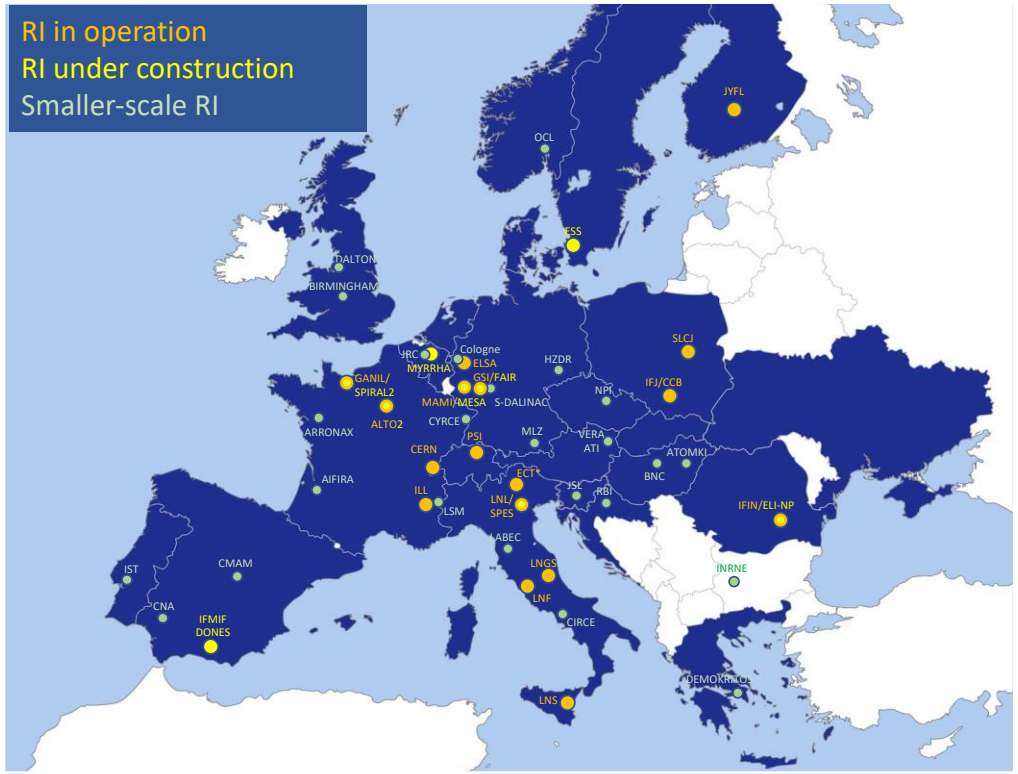

**5346** - total number of Nuclear Physicists (Exp. & Theory) in the European NuPECC Member States and the Associated Member CERN

**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*

# Hadron Physics

## *Recommendations (experiments)*

**Support of existing facilities and experiments:**

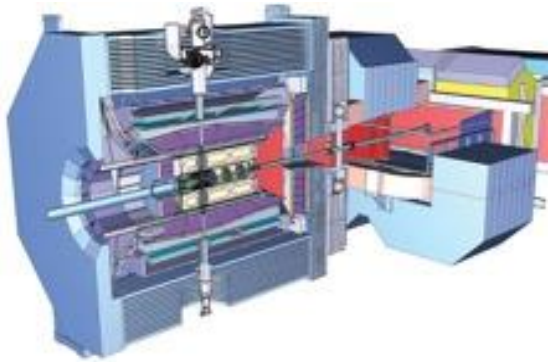
- **AMBER** at **CERN**
- **ELSA** in Bonn**, HADES** at GSI**, MAMI** and **MESA** in Mainz, Germany
- **Jefferson Laboratory** in Newport News, USA

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

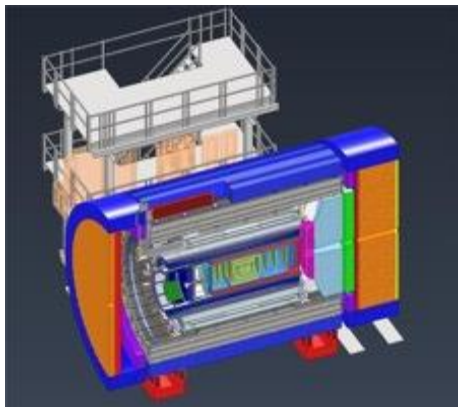
**Future flagship facilities and experiments:**

- 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.

**PANDA @ FAIR**



**ePIC @ EIC**



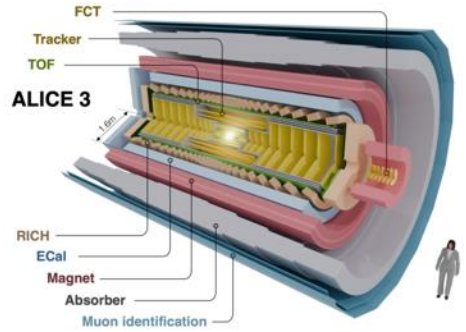
# Strongly Interacting Matter at Extreme Conditions

## *Recommendations (experiments)*

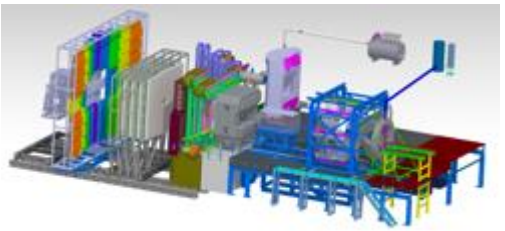
- **Future flagship facilities and experiments**
  - **ALICE 3** at **CERN**
  - **SIS-100** at **FAIR** and the realization of the **CBM** experiment
  - **CERN LHC** after 2035 (Run 5 and 6), the **LHCb Upgrade2** and the fixed-target setup **NA60+** detector at the **SPS**

- **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

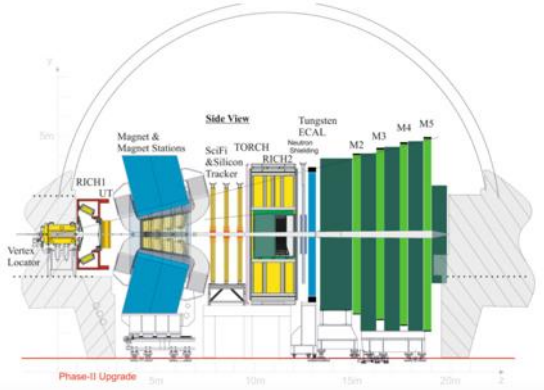
**ALICE 3 @ LHC**




**CBM @ FAIR**

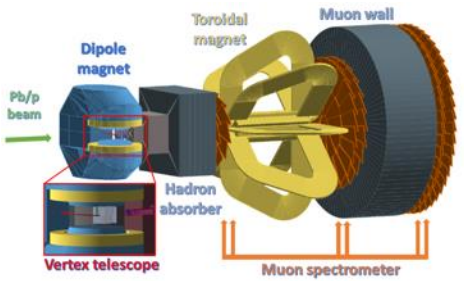


**LHCb Upgrade II**




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

**NA60+**




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

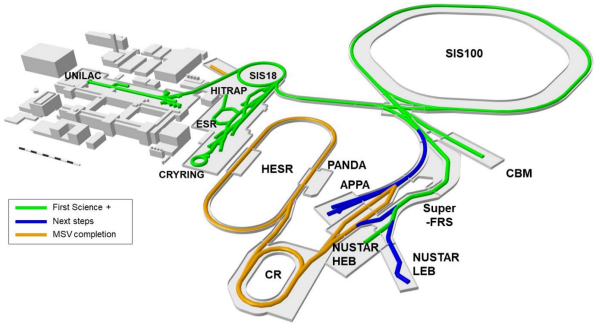
# Nuclear Structure and Reaction Dynamics

## *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**

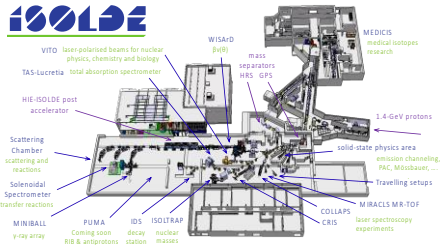
**FAIR**



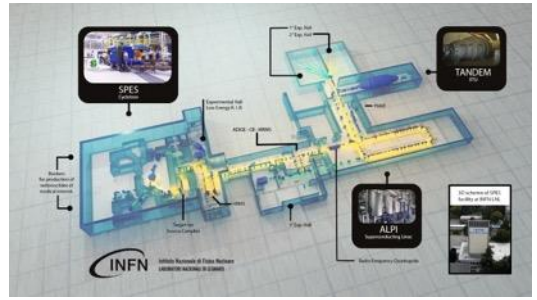

**GANIL/SPIRAL2 France**


**AGATA**

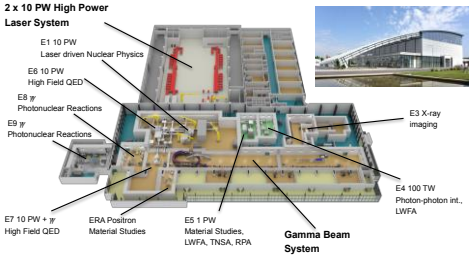
**ISOLDE CERN**



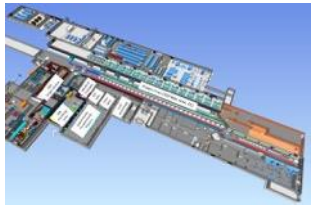

**SPES/LNL Italy**




**ELI – NP Romania**




**ISOL@MYRRHA Belgium**



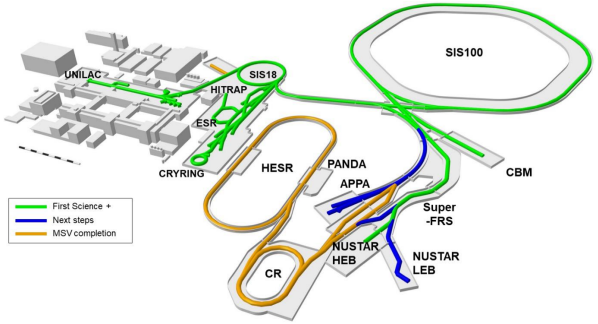
## *Recommendations (experiments)*

- 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

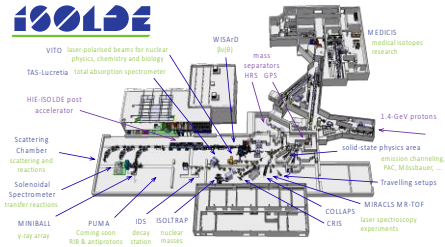
- **Future flagship facilities and experiments**
  - We strongly recommend the completion of Radioactive Beam Facilities in Europe, in particular the **Super-FRS** at FAIR, including the Low-Energy-Branch, the **upgrade of ISOLDE**, and **SPIRAL2**
  - A large (> 10 MV) **Atomic Mass Spectrometry** system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

**FAIR**




**GANIL/SPIRAL2 France**


**ISOLDE CERN**

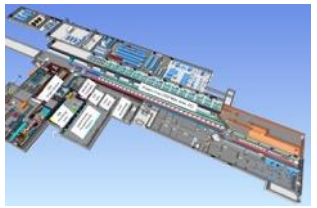


## *Recommendations (experiments)*

- **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.

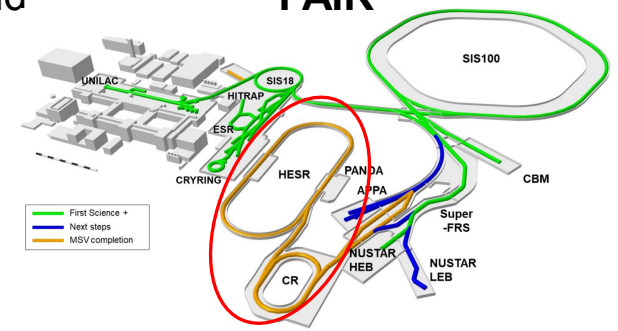
- **Future flagship facilities and experiments**
  - Specialization of upcoming Radioactive Ion Beam facilities such as **ISOL@MYRRHA** and **DESIR at GANIL-SPIRAL2** should be regarded as an opportunity not to be missed
  - At **ESS,** a fundamental neutron physics beamline should be installed
  - The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

**ISOL@MYRRHA Belgium**



**GANIL/SPIRAL2 France**


**FAIR**



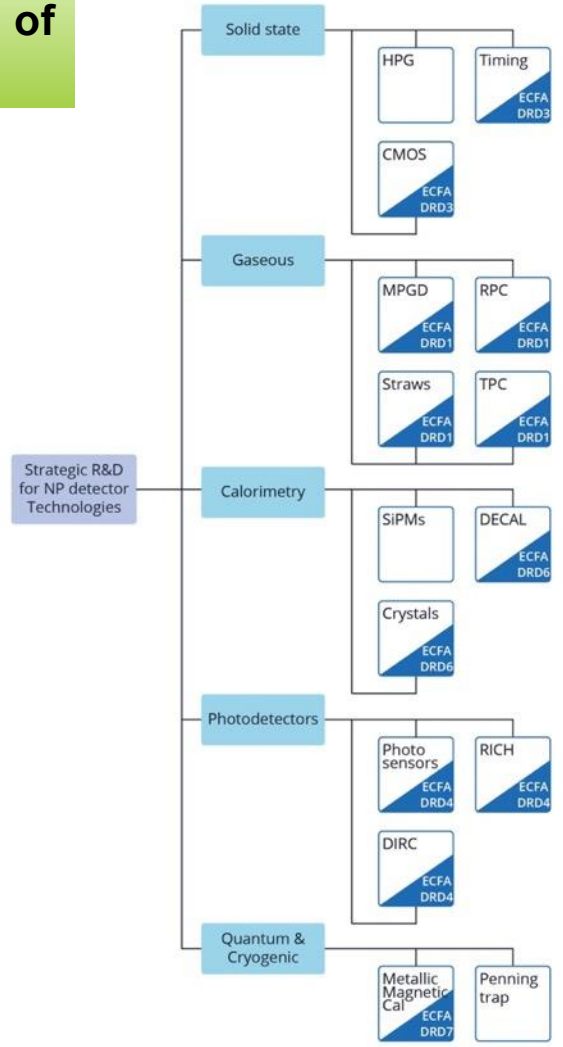
# Nuclear Physics Tools - Detectors and experimental techniques

## Key Questions & Goals

**Advancement in the understanding of fundamental physics is intimately related to progress in the development of tools for experimental and theoretical investigations. These tools are used for detector R&D, detector operation, data acquisition and analysis, theoretical interpretation of experimental results and genuine theoretical developments.**

## Recommendations

- Elaboration of a **roadmap for detector R&D dedicated to the specific needs of low-energy nuclear physics and applications in radiation monitoring and heritage science** must be supported.
- **Strengthening of the collaborative effort in developing cutting-edge detector technology** for identified applications in accelerator experiments with respective activities in high-energy particle physics and other adjacent research fields.
- Enhance precision and efficiency in **high-resolution laser spectroscopy and mass spectrometry**, to study the structure of rare isotopes and test fundamental symmetries.
- Establish infrastructures to **ensure the provision of stable and radioactive targets**, such as **a dedicated mass separator** for providing radioactive samples and targets – **foreseen to be built at PSI**
- Secure a strategic **supply of stable enriched isotopes** for fundamental research and applications as is the case for the installation of a **European Electro-Magnetic Ion Separation facility**, providing material of the highest enrichment in rare stable isotopes.
- To develop **novel efficient neutron detectors** to replace those based on $^{3}$He.



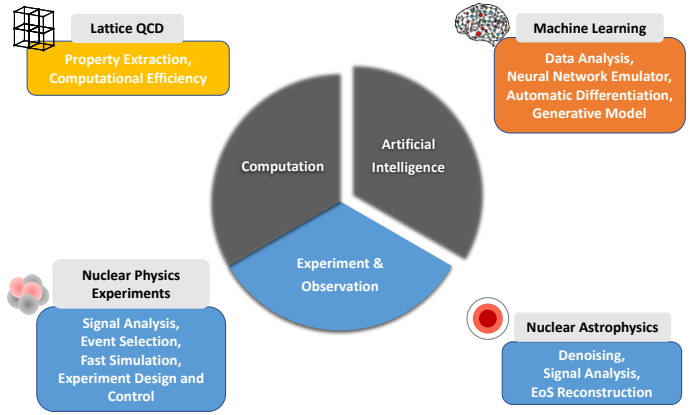
# Nuclear Physics Tools – Computing, Artificial Intelligence, Machine Learning and Quantum Computing

## Key Questions & Goals

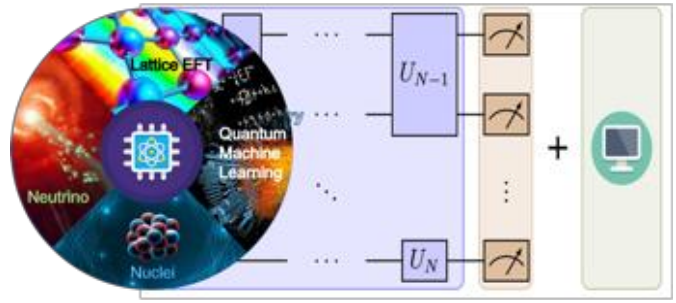
**The tremendous progress in the field of nuclear physics has led to the pressing need for appropriate numerical tools aimed at addressing the most relevant experimental, theoretical and technological challenges, such as those encompassed by the Joint ECFA-NuPECC-APPEC (JENA) initiatives. To this end, the advent of algorithms based on Machine Learning (ML) and Artificial Intelligence (AI) techniques, and the fast progress in the field of Quantum Computing (QC) has opened an entire new world of possibilities.**

## Recommendations

- Provide **long-term career perspectives for software developers** in the field
- **Facilitate and strengthen access for nuclear physics researchers to large High Performance Computing centres**
- Develop research into explainable AI; **Enhance transparency and interpretability in scientific AI applications in nuclear physics and adjacent fields.**
- Facilitate **access to quantum platforms**.
- Establish a **European network on quantum activities related to nuclear physics**.




**ML application in nuclear physics**




**Quantum Comp. in nuclear and particle physics**

# Open Science and Data

## Key Questions & Goals

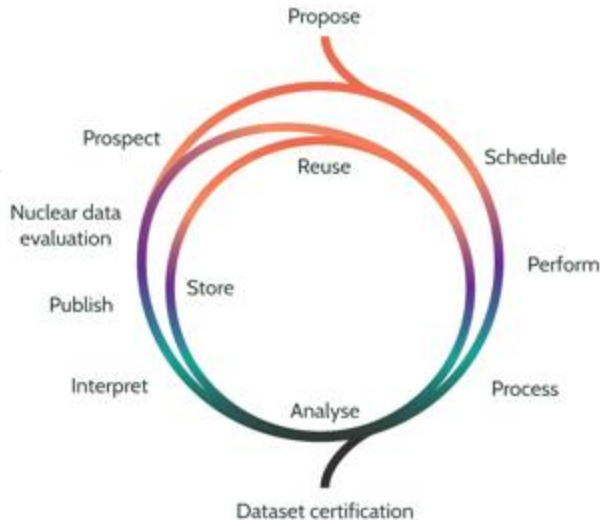
**Open science and Findable, Accessible, Interoperable, Reusable (FAIR) data offer an important opportunity for the nuclear physics community to uphold the highest research standards and enhance its societal impact, by treating the scientific production process as a strategic asset.**

## Recommendations

The results of the **ESCAPE** and **OSCARS** EU projects should be fully deployed by and for the nuclear physics community.

**Importance of Joint ECFA-NuPECC-APPEC (JENA) activities is underlined**

- The **creation and adoption of open science policies and guidelines** … as well as **promoting best practices** within individual institutes and research infrastructures should be strongly encouraged.
- **Creation of coordination bodies to pursue standardization of the Data Life Cycle** to ensure data FAIRness should be supported.
- Combine forces of the European nuclear physics research and applications communities to **establish a comprehensive European nuclear data program** with well-defined priorities defined by stakeholders and sustainable funding to fulfil the needs in nuclear structure and dynamics, astrophysics and applications.
- …

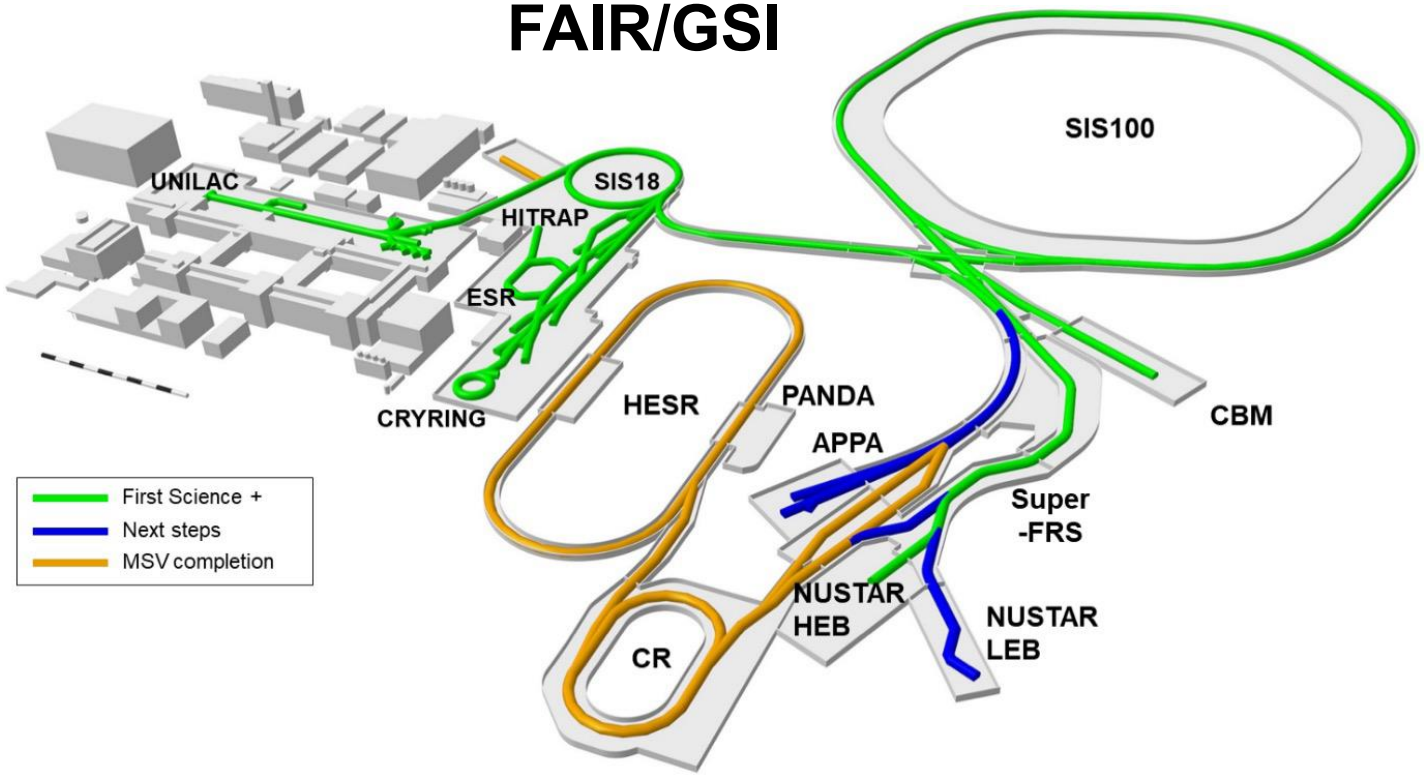



*Data life cycle in nuclear physics*

## FAIR facility, Darmstadt, Germany

ESFRI

- **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.**



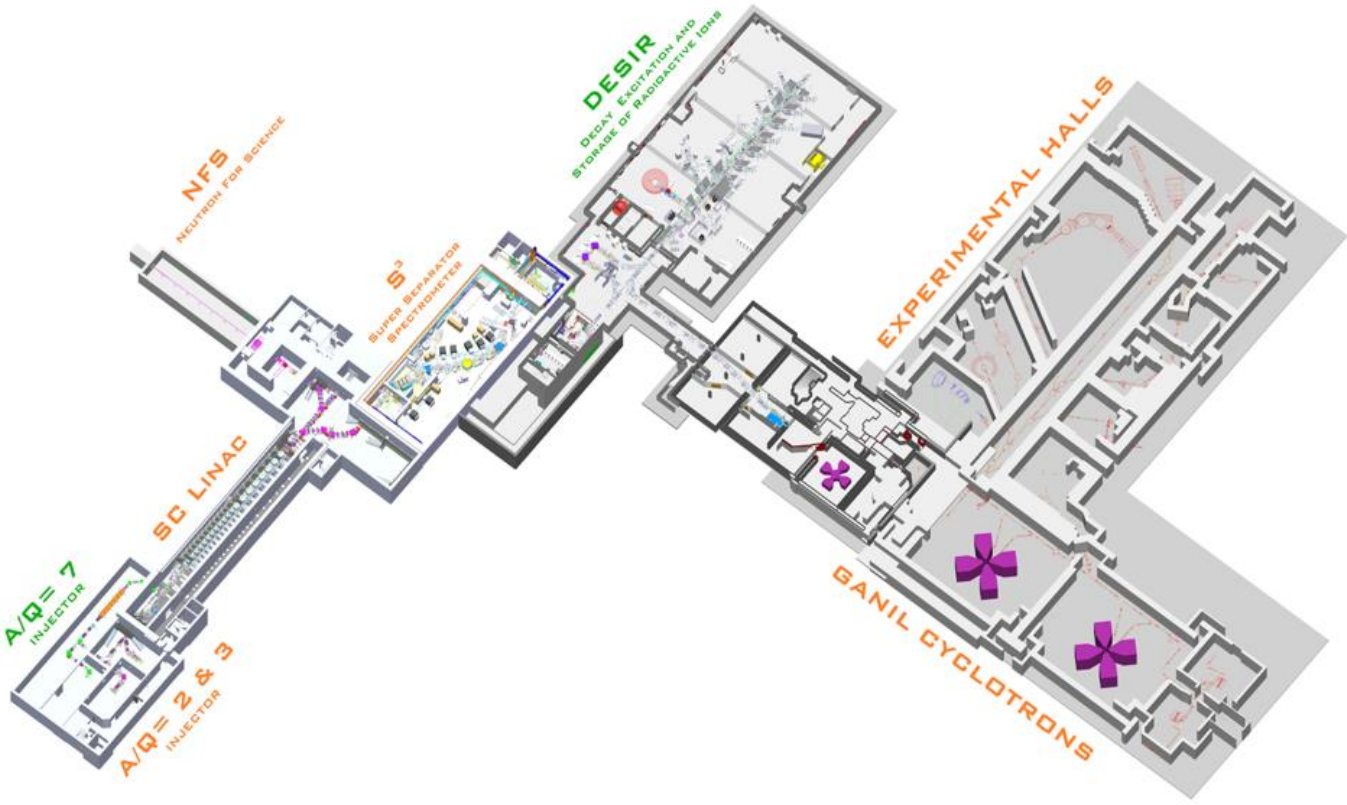
# LRP 2024 Recommendations for NP Infrastructures

## GANIL/SPIRAL2 facility, Caen, France

ESFRI

- **At GANIL/SPIRAL2 the Super-Separator Spectrometer $S^3$ 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**



# CERN Nuclear Physics facilities and experiments

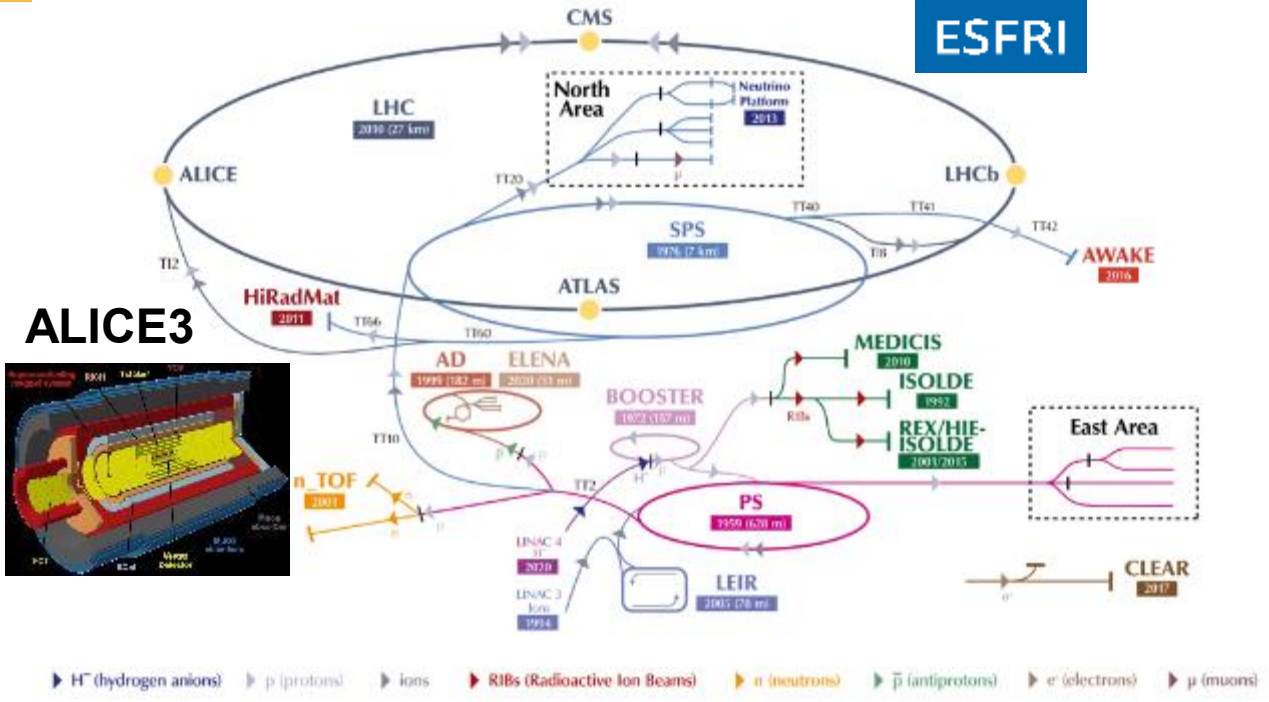
- **Nuclear physics opportunities at CERN constitute a world-leading research . The construction of ALICE 3 as part of the HL-LHC plans is strongly recommended. Continued support for exploitation and new developments are recommended to maximise the scientific output of ISOLDE, n_TOF, SPS fixed-target 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.**

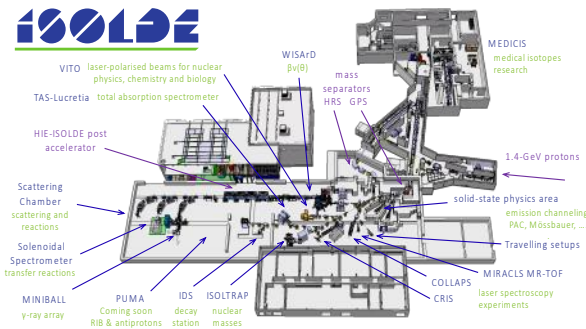
**-> NP contributions to the ongoing Update of the Strategy for Particle Physics**

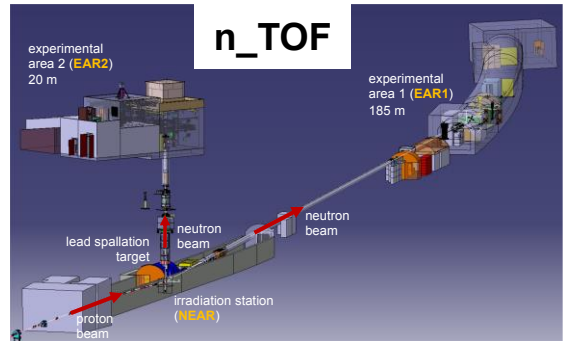
ESFRI

ALICE3





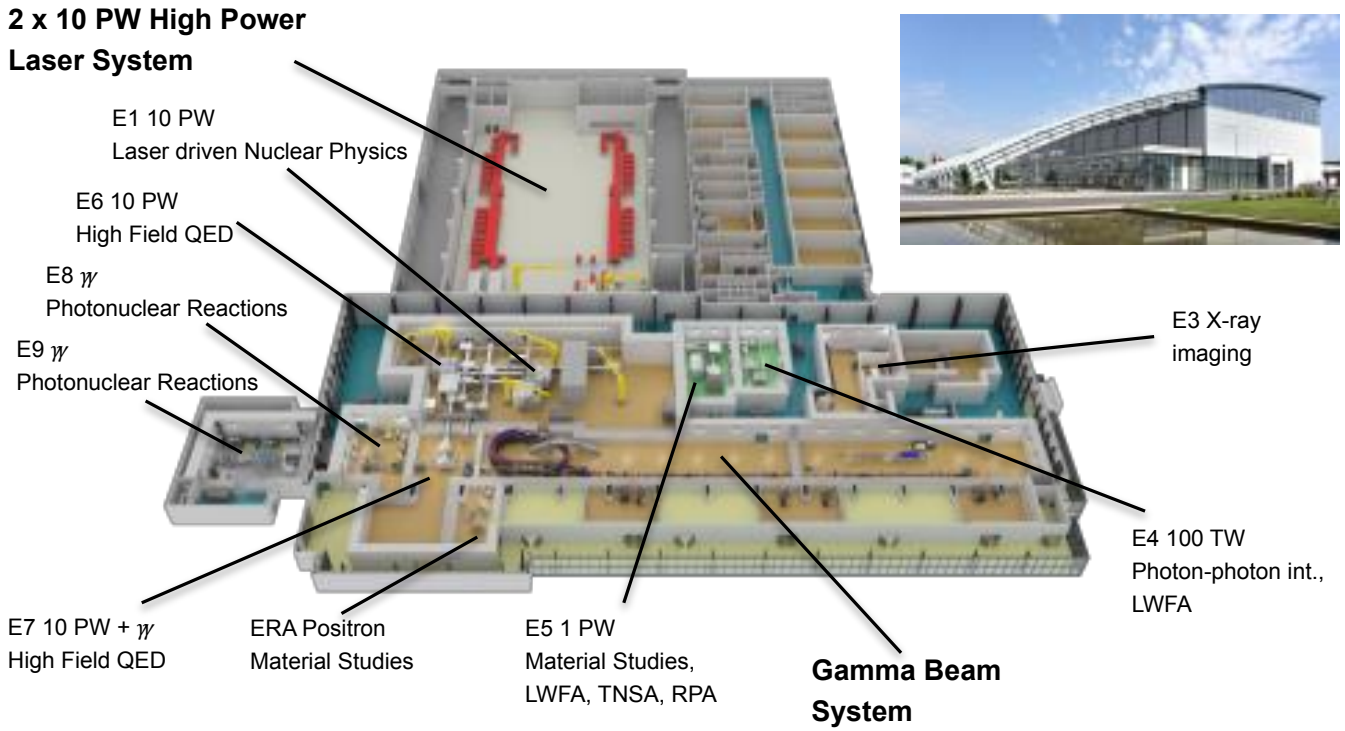



# Extreme Light Infrastructure - Nuclear Physics, Magurele, Romania

ESFRI

- **At ELI-NP studies will focus on addressing key topics, such as laser-driven ion and electron acceleration. Implementing the gamma beam system to achieve the full completion of the facility to allow breakthrough results in the field of nuclear photonics is of high importance and is strongly recommended.**

## ELI - NP

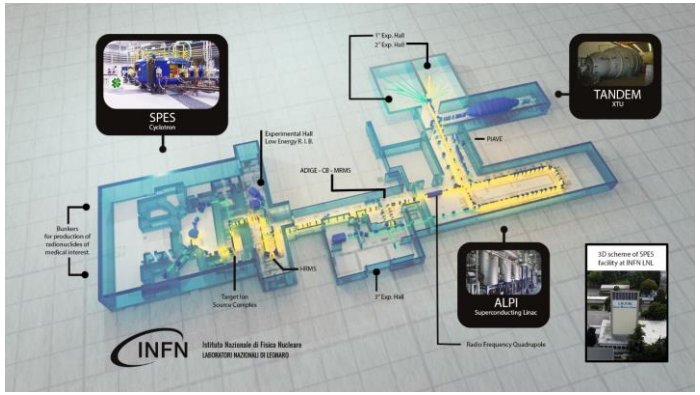


# ISOL radioactive ion beam facilities

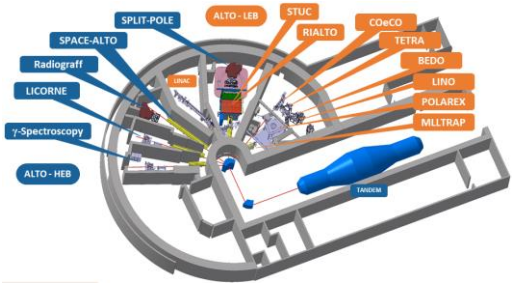
- **Timely completion of the SPES a facility and continuing coordinated efforts in developing the ALTO, IGISOL, ISOLDE, SPES, and SPIRAL ISOL facilities in Europe, will be key to maintaining their world-leading position in many areas of radioactive isotope science and are strongly recommended. Extending these efforts towards future facilities, such as ISOL@MYRRHA, TATTOOS@PSI, and RIB@IFIN, together with the development of common instrumentation, will secure the European leading position for radioisotope production, separation, and acceleration techniques, and create new avenues for the future and should therefore be actively pursued.**

**-> EURO-LABS**

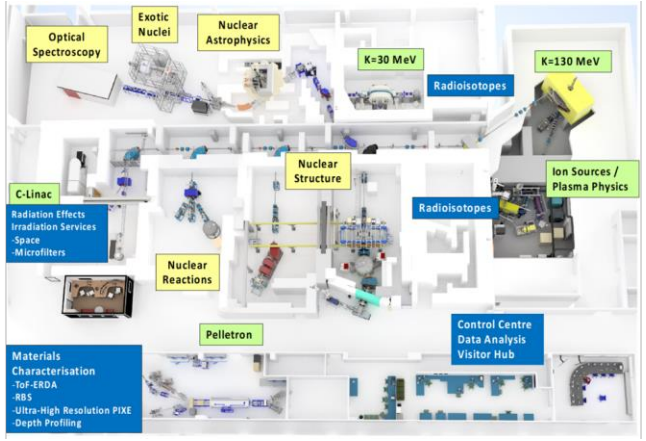
## SPES/LNL Italy



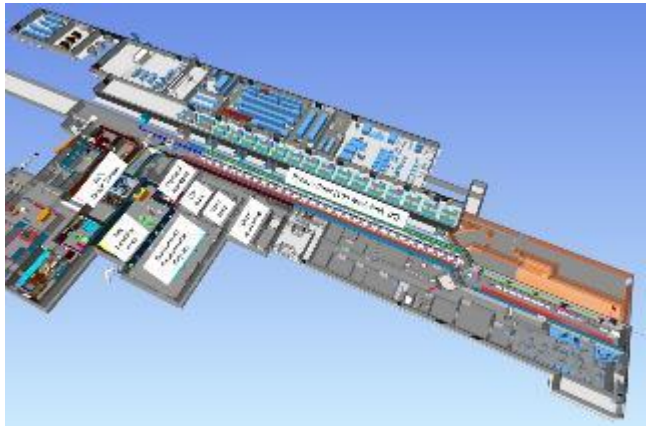

## ALTO/IJCLab France




## IGISOL/JYFL Finland




## ISOL@MYRRHA Belgium



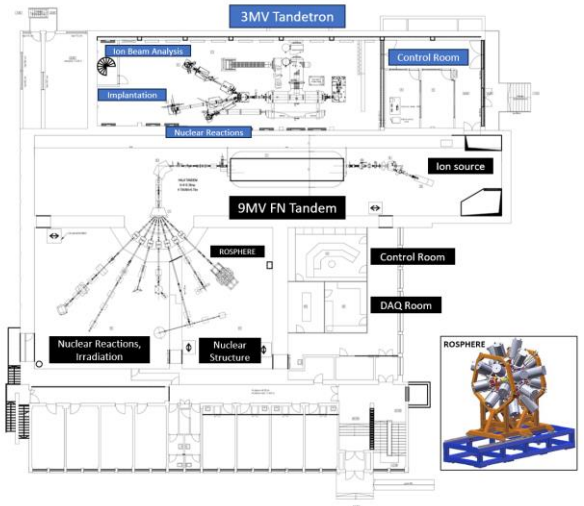
# LRP 2024 Recommendations for NP Infrastructures

## Stable Ion Beam facilities

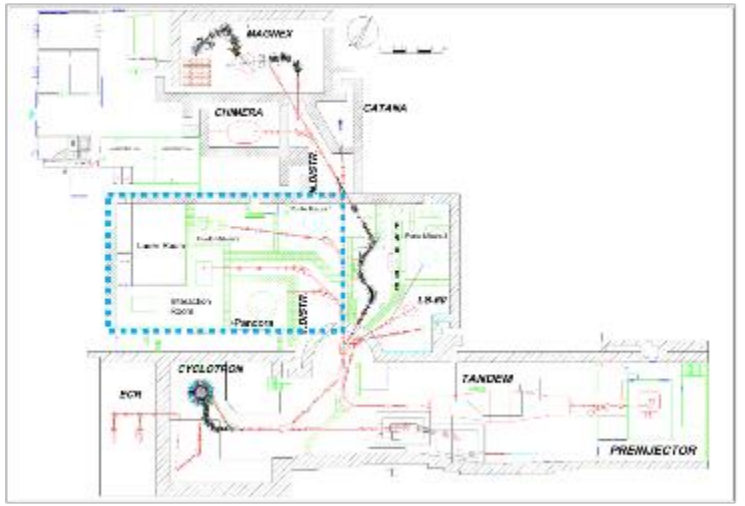
- **Large-scale stable beam facilities, such as FAIR/GSI, GANIL/SPIRAL2, IFIN, JYFL-ACCLAB, LNL, LNS, NLC (SLCJ and IFJ-PAN), and smaller ones, such as tandems, underground facilities and AMS systems, should be optimally exploited. Developments of novel and more intense beams and capabilities are also recommended to open new opportunities for basic science and applications. It is recommended that synergies between all these facilities, irrespective of size, be reinforced.**

**-> EURO-LABS**

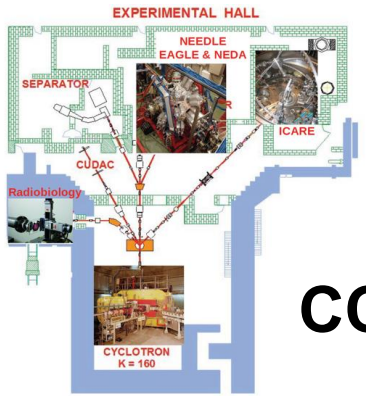
**IFIN-HH Romania**




**LNS Italy**

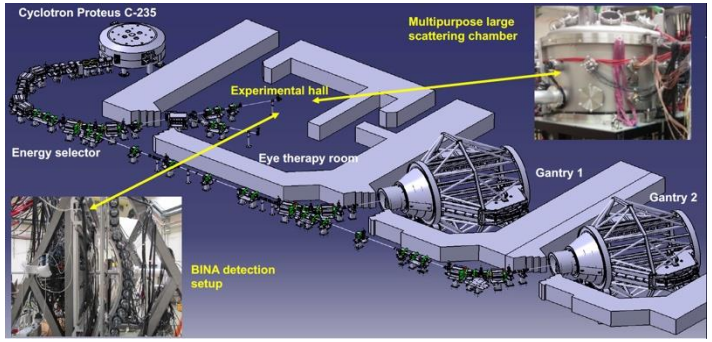



**NLC Poland**




**SLCJ**

**CCB**



## AGATA European gamma tracking array

- **It is strongly recommended to complete the AGATA gamma tracking array to its full configuration as a key instrument for studying atomic nuclei in both stable and radioactive ion beam facilities.**

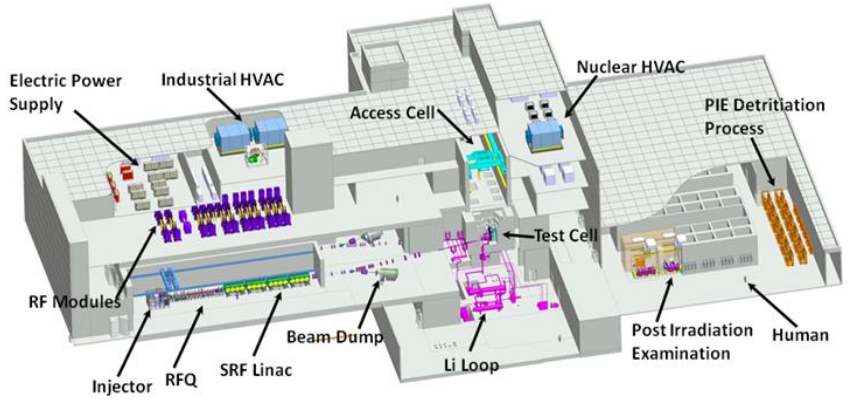
**AGATA**

## Neutron facilities

- **Neutron facilities are playing a significant role in nuclear fundamental research and applications, producing unique and valuable experimental outcomes. The new NFS facility, located at SPIRAL2, is now providing a highly intense neutron flux of fast neutrons, attracting a broad scientific community. It is crucial and strongly recommended to maintain the operation of exceptional neutron facilities like ILL and n_ToF at CERN. ESS facility and the future infrastructure IFMIF-DONES will provide advanced tools for interdisciplinary research and their unique capabilities to serve advances in nuclear physics should be explored.**

### ILL France

### IFMIF-DONES Spain

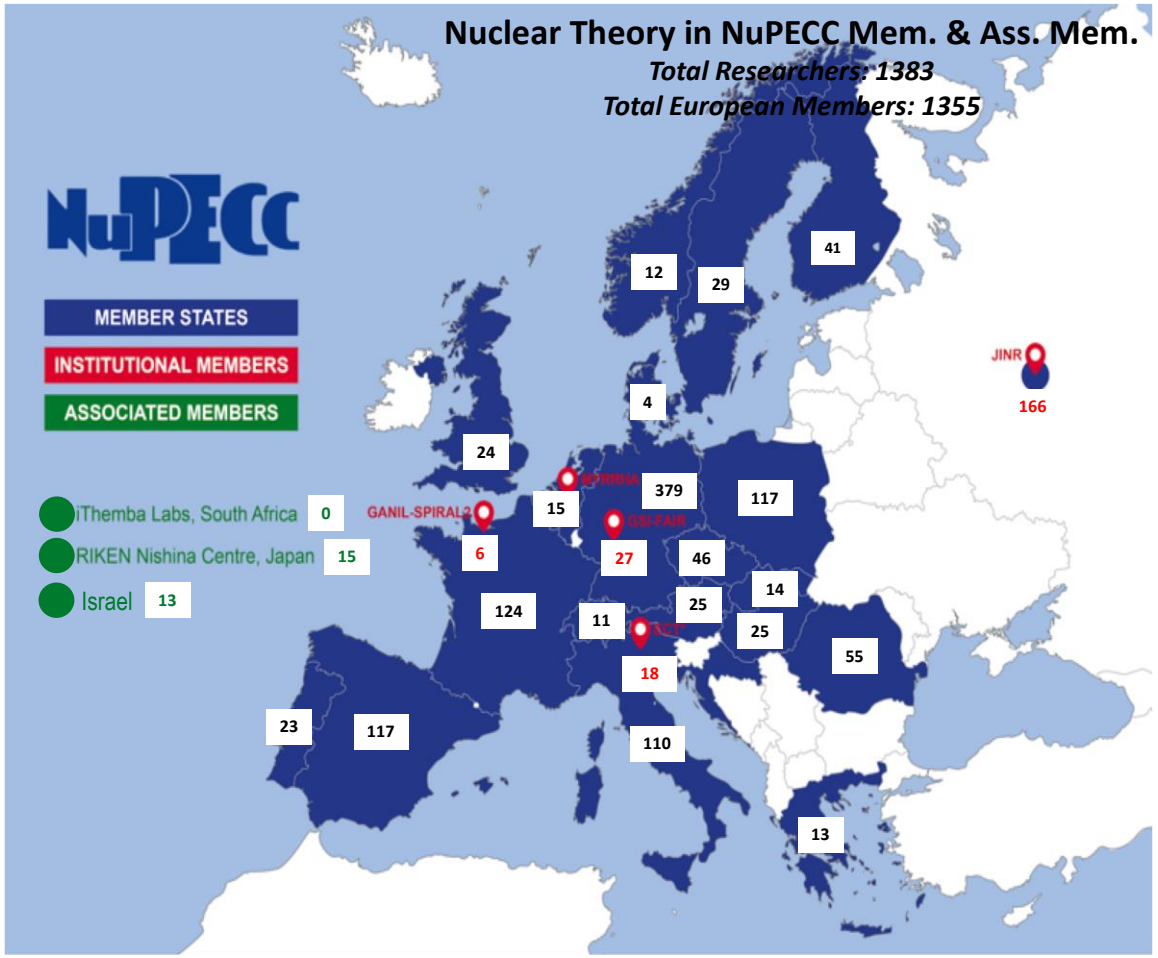


# LRP 2024 Recommendations for NP Infrastructures

## Theory centres

- **Theory centres and groups should be strongly supported throughout Europe, in particular the European Centre for Theoretical Studies (ECT*, Trento, Italy), which is a unique European centre dedicated to theoretical nuclear physics in the broadest sense. A stronger pan-European support which will ensure that ECT* activities continue to play a strategic role in the development of nuclear physics in Europe is recommended.**

**-> EURO-LABS**




*From NuPECC 2021 survey*

**ECT***

# Nuclear Physics and Society



- 17 Sustainable Development Goals (SDGs) by United Nations
- The nuclear science research community contributes to all of the 17 SDGs
- #7 energy, #3 health, and #9 space: *NP & applications*
- #4 high-quality education, #5 gender equality, #10 decreased disparities, #12 responsible consumption and production, and #13 climate action: *education*
- #2 zero hunger, #6 clean water, #14 life below water, and #15 life on land: *applications like tracer methods*
- #11 sustainable cities, #12 responsible consumption*: nuclear waste*
- #16 peace: *non-proliferation*
- #17 partnership: *collaboration*

# 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**

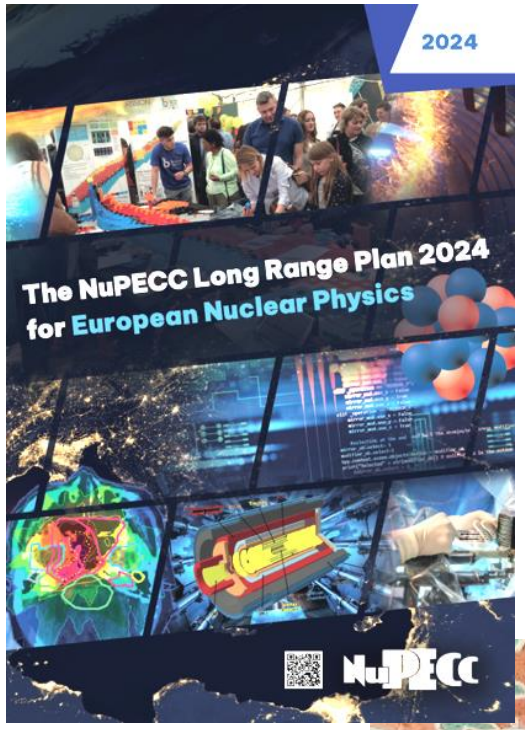
  9 Task Force meetings in 2017-2022

  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
  - *Scheduled for December 5th, 2024: Germany in Bad Honnef*
  - *Meetings in Slovakia, Hungary, Romania, and Sweden by 2025*

- **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!**

# LRP2024 publication process




University Foundation Bruxelles

## *NuPECC Long Range Plan 2024*

### *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
  - Editing and layouting close to finished
  - 180+ pages pdf version available
- Video link will be provided
- Executive Summary of the LRP2024 is available on the NuPECC Web site
  https://www.nupecc.org/lrp2024/Draft_Executive_Summary_LRP2024.pdf
- The PDF version of the full document will be available on the NuPECC Web site soon