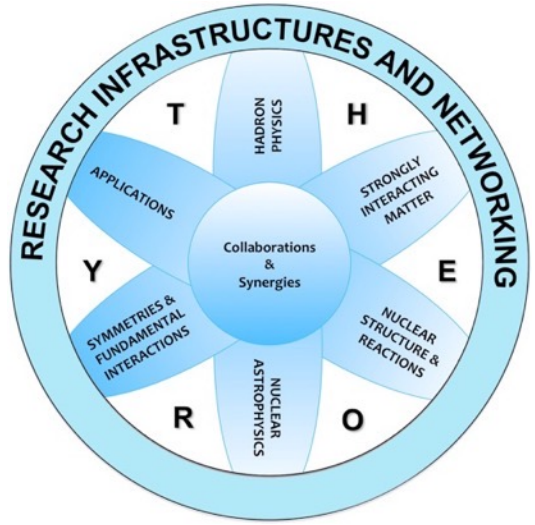
NuPECC Report
focused on the Update of ESPP

Marek Lewitowicz

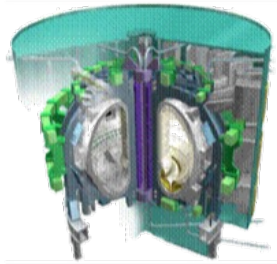
Nuclear Physics European Collaboration Committee (NuPECC)

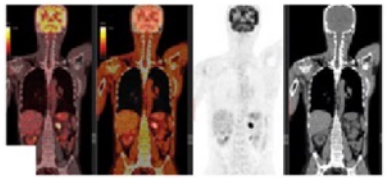
GANIL

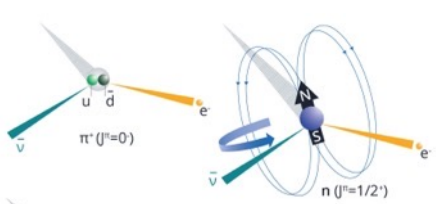
ECFA
November 14, 2024
CERN

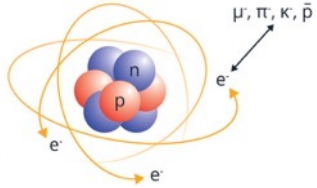


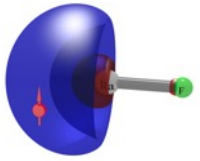
Nuclear Physics in Europe

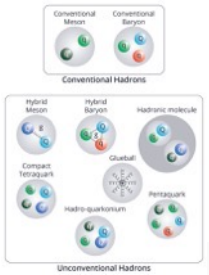




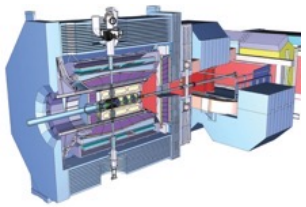




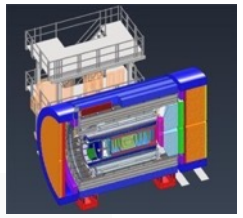




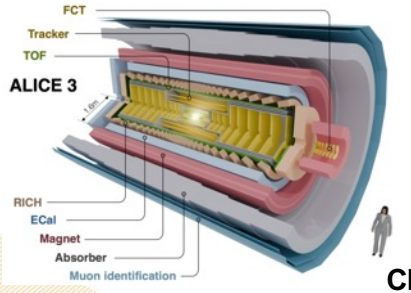
PANDA @ FAIR

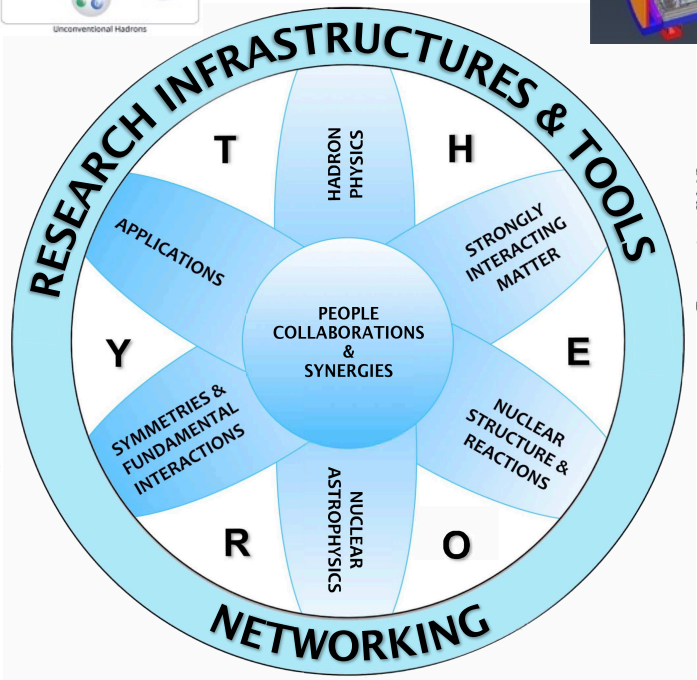


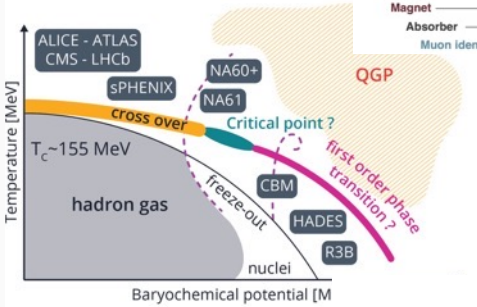
ePIC @ EIC



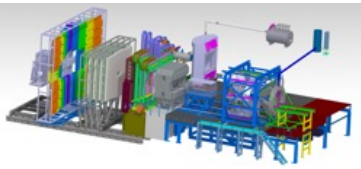
ALICE 3 @ LHC

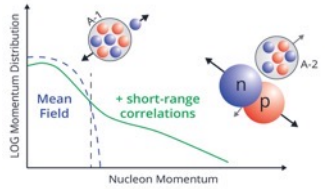


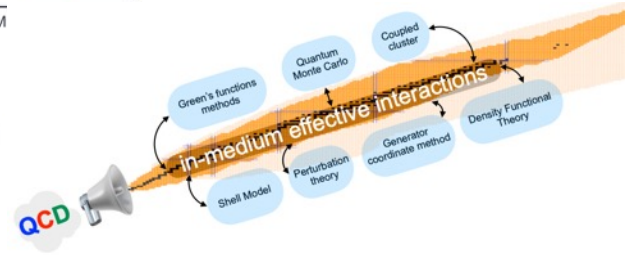


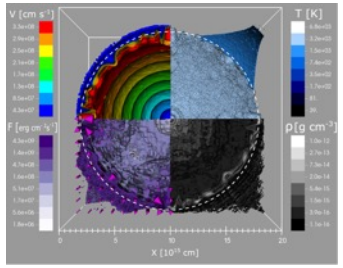


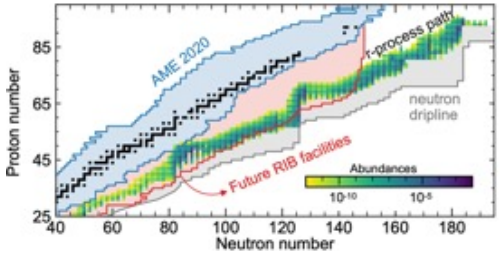
CBM @ FAIR





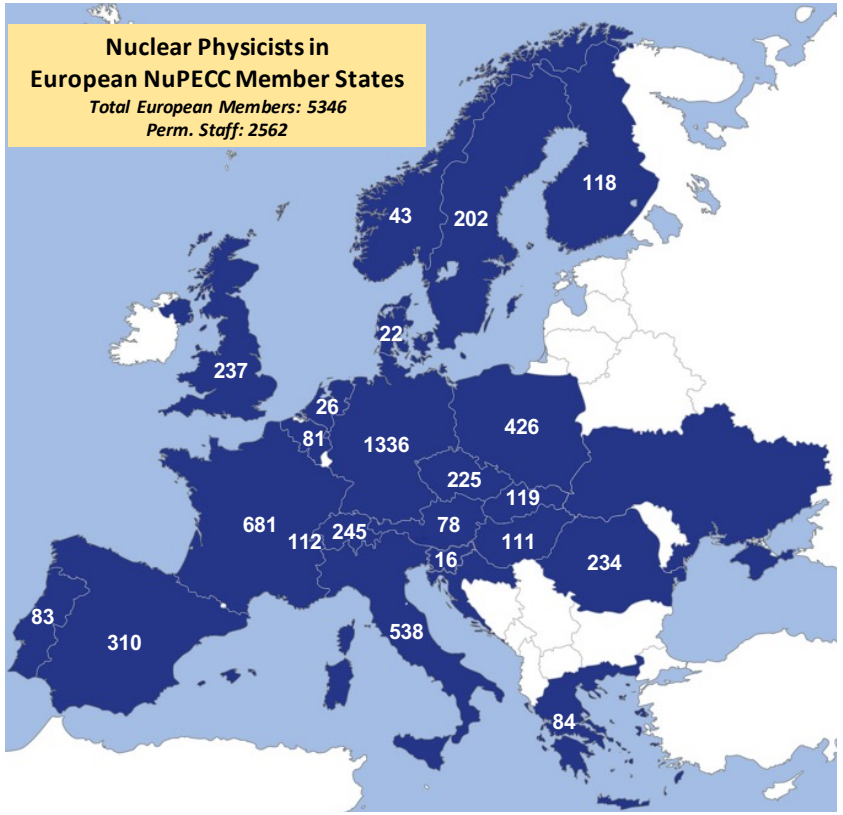






Nuclear Physics in Europe – two pillars

Nuclear Physics Workforce in Europe



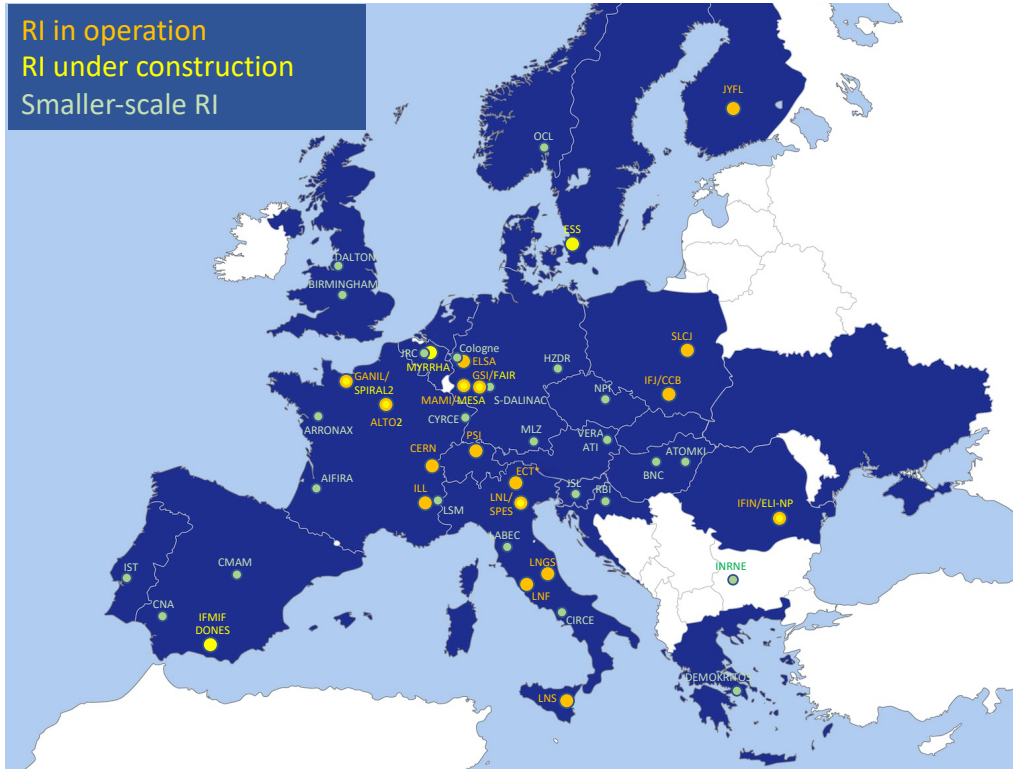
5346 - total number of Nuclear Physicists (Exp. & Theory) in the European NuPECC Member States and the Associated Member CERN

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

Previous Update of the ESPP and Nuclear Physics

Update of the European Strategy for Particle Physics 2020

Strategy Statements

5. Synergies with neighbouring fields

a) A variety of research lines at the boundary between particle and nuclear physics require dedicated experiments and facilities. Europe has a vibrant nuclear physics programme at CERN, including the heavy-ion programme, and at other European facilities. In the global context, a new electron-ion collider, EIC, is foreseen in the United States to study the partonic structure of the proton and nuclei, in which there is interest among European researchers. Europe should maintain its capability to perform innovative experiments at the boundary between particle and nuclear physics, and CERN should continue to coordinate with NuPECC on topics of mutual interest.

Deliberation Document

The synergies between particle and nuclear physics are driven by the ambition to achieve first-principle understanding of strong dynamics based on QCD. In addition, they share similar experimental tools. The CERN baseline programme includes not only the ISOLDE and n_TOF facilities but also the heavy-ion programme at the SPS and the LHC. Future European facilities such as FAIR, NICA and ESS envisage research programmes that are of interest to particle physics. The nuclear physics roadmap in Europe is coordinated by the Nuclear Physics European Collaboration Committee (NuPECC) and there are well established communication lines between the nuclear and the particle physics communities. NuPECC has expressed strong support for the extension of the heavy-ion programme into the HL-LHC era and beyond, should a high-energy hadron collider be built at CERN in the future. Electron-proton colliders, such as LHeC or FCC-ep, with the option of including ion-targets, are also of interest to NuPECC, which is preparing a support statement for the participation of Europe in the Electron-Ion Collider in the United States.

Present Update of the ESPP and Nuclear Physics

The European Strategy Group

Invitees: President of CERN Council, one representative from each of the Associate Member and Observer States, one representative from the European Commission, the Chairs of APPEC, NuPECC and ESFRI, the members of the Physics Preparatory Group.

Remit of the European Strategy Group (ESG)

The Strategy update should also indicate areas of priority for exploration complementary to colliders and for other experiments to be considered at CERN and at other laboratories in Europe, as well as for participation in projects outside Europe.

National inputs to the ESPP update: ECFA guidelines

It would thus be most useful if the national inputs explicitly included the preferred prioritisation for non-collider projects. Specific questions to address:

c) To what extent should CERN participate in nuclear physics, astroparticle physics or other areas of science, while keeping in mind and adhering to the CERN Convention? Please use the current level and form of activity as the baseline for comparisons.

NuPECC Long Range Plan 2024 for European Nuclear Physics

Official presentation on Nov. 19, 2024 in Brussels

Recommendations related to ESPPU

- ✓ Hadron Physics
- ✓ Strongly Interacting Matter at Extreme Conditions
- ✓ Nuclear Structure and Reaction Dynamics
- ✓ Nuclear Astrophysics
- ✓ Symmetries and Fundamental Interactions
- ✓ Applications and Social Benefits
- ✓ Nuclear Physics Tools –
  - ✓ Detectors and experimental techniques
  - ✓ Computing, Artificial Intelligence, Machine Learning and Quantum Computing
- ✓ Open Science and Data
- ✓ Infrastructures

Recommendations (experiments)

Support of existing facilities and experiments:

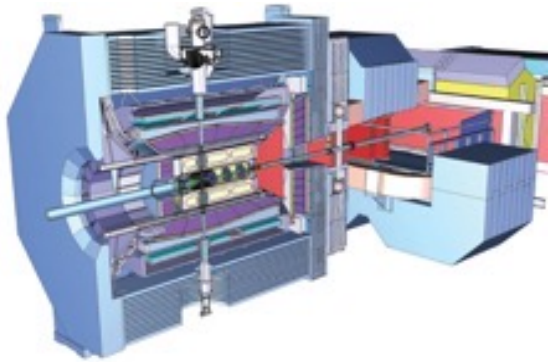
- **AMBER** at **CERN**
- **ELSA** in Bonn, **HADES** at GSI, **MAMI** and **MESA** in Mainz, Germany
- **Jefferson Laboratory** in Newport News, USA

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

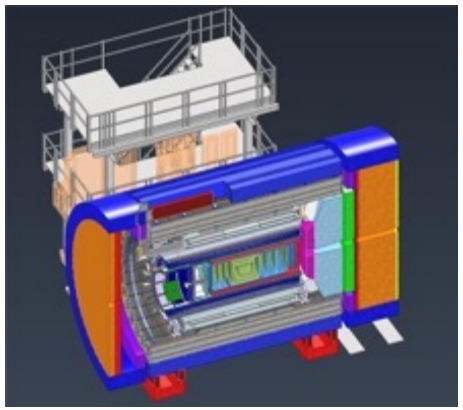
Future flagship facilities and experiments:

- 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



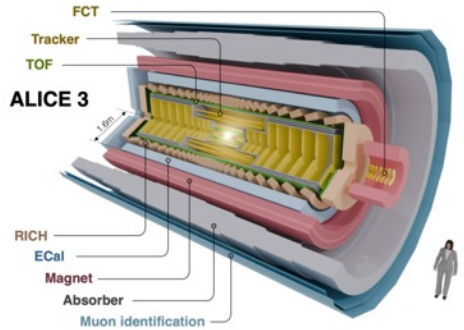
Strongly Interacting Matter at Extreme Conditions

Recommendations (experiments)

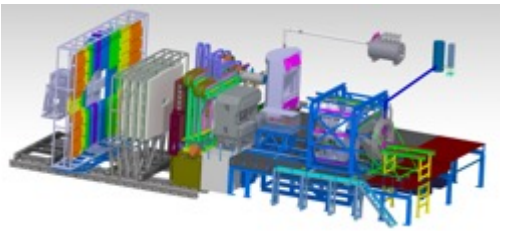
- **Future flagship facilities and experiments**
  - **ALICE 3** at **CERN**
  - **SIS-100** at **FAIR** and the realization of the **CBM** experiment
  - **CERN LHC** after 2035 (Run 5 and 6), the **LHCb Upgrade2** and the fixed-target setup **NA60+** detector at the **SPS**

- **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

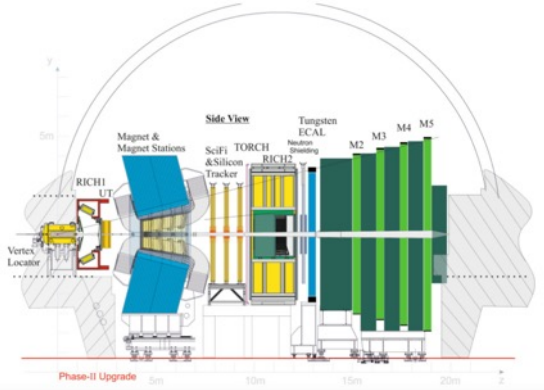
ALICE 3 @ LHC



CBM @ FAIR

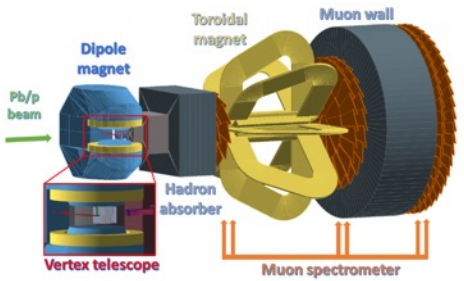


LHCb Upgrade II



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

NA60+



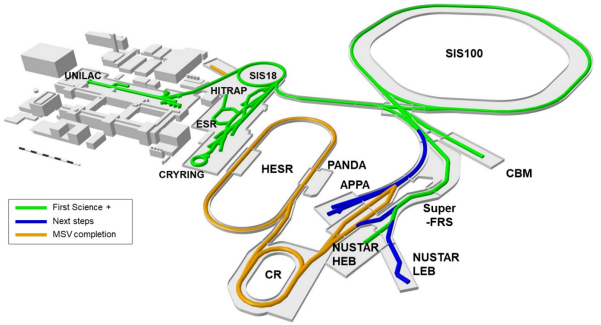
Credit: https://na60plus.ca.infn.it

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

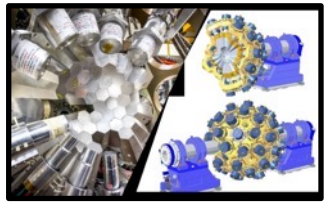
- **Future flagship facilities and experiments**
  - **FAIR** facility (with Low-Energy-Branch)**, SPIRAL2, SPES, ELI-NP, ISOL@MYRRHA,** and **ISOLDE** upgrades
  - Future rings at **FAIR** and **HIE-ISOLDE are recommended**

FAIR

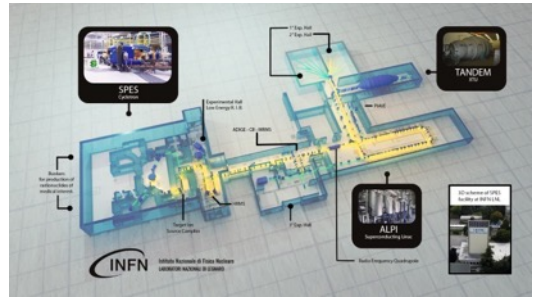


GANIL/SPIRAL2 France

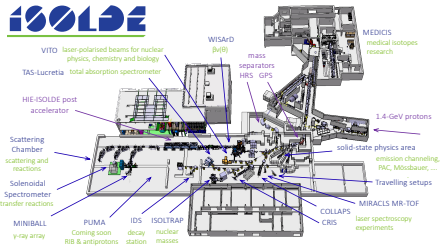
AGATA



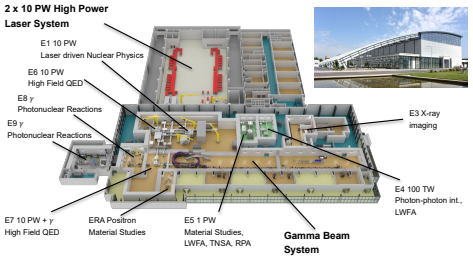
SPES/LNL Italy



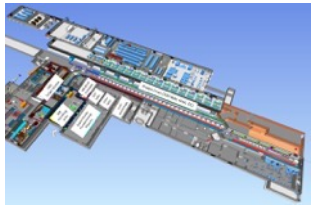
ISOLDE CERN



ELI – NP Romania



ISOL@MYRRHA Belgium



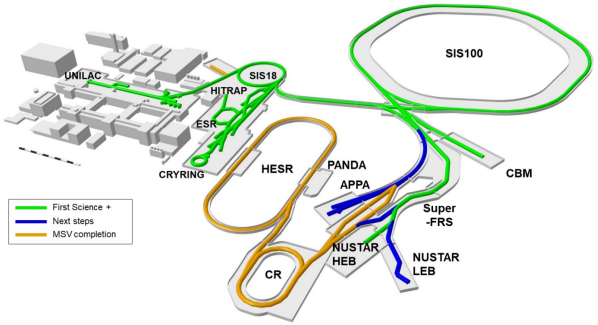
Recommendations (experiments)

- 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

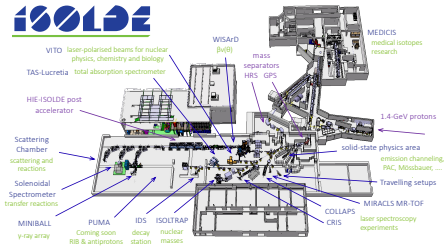
- **Future flagship facilities and experiments**
  - We strongly recommend the completion of Radioactive Beam Facilities in Europe, in particular the **Super-FRS** at FAIR, including the Low-Energy-Branch, the **upgrade of ISOLDE**, and **SPIRAL2**
  - A large (> 10 MV) **Atomic Mass Spectrometry** system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

FAIR



GANIL/SPIRAL2 France

ISOLDE CERN

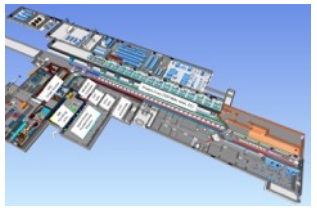


Recommendations (experiments)

- **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.

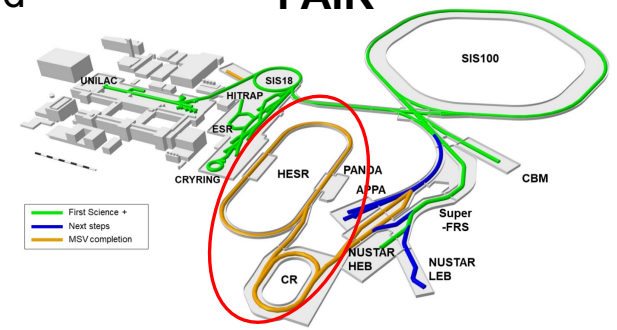
- **Future flagship facilities and experiments**
  - Specialization of upcoming Radioactive Ion Beam facilities such as **ISOL@MYRRHA** and **DESIR at GANIL-SPIRAL2** should be regarded as an opportunity not to be missed
  - At **ESS,** a fundamental neutron physics beamline should be installed
  - The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

ISOL@MYRRHA Belgium



GANIL/SPIRAL2 France

FAIR



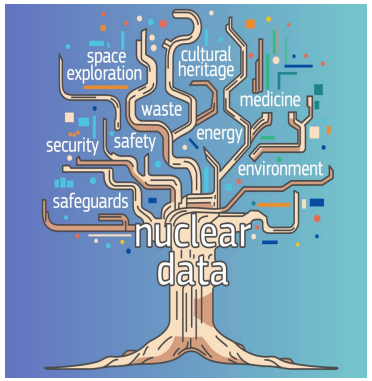
Applications and Societal Benefits

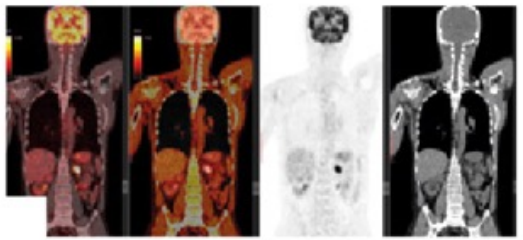
Key Questions & Goals

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.

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 materials 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 materials science: sustained operation of research reactors




A PET–CT scan of the human body.

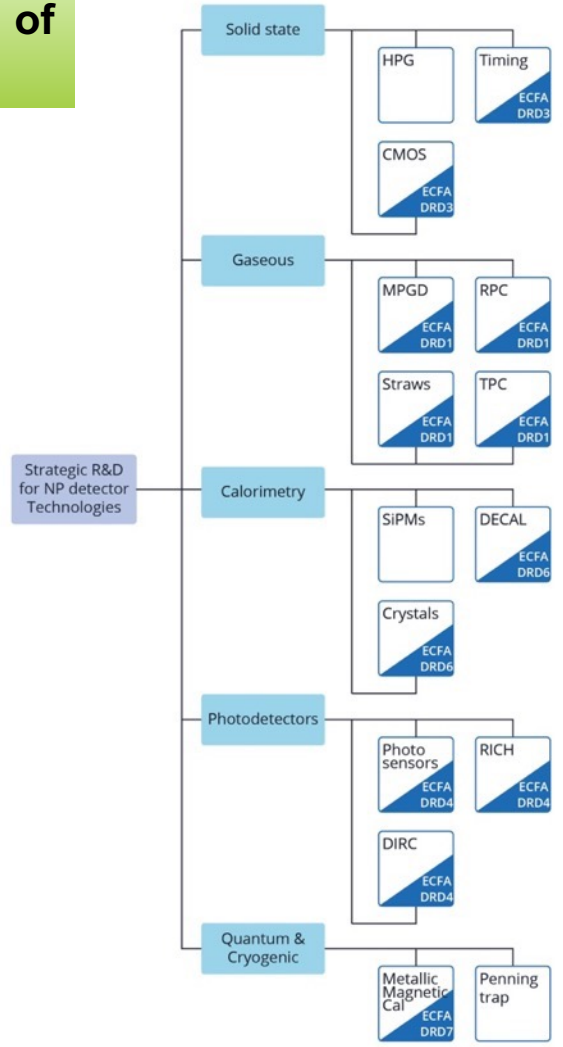
Nuclear Physics Tools - Detectors and experimental techniques

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.



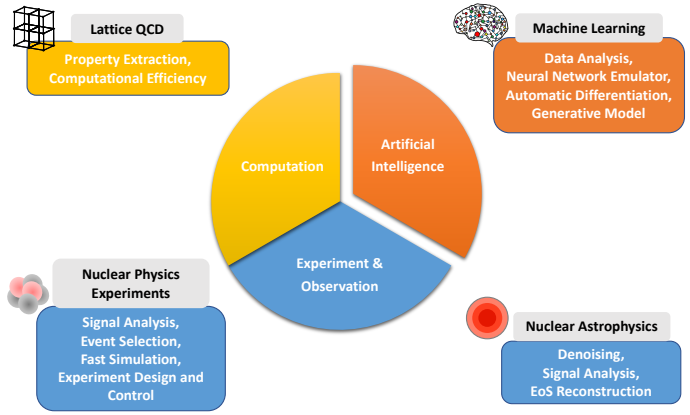
Nuclear Physics Tools – Computing, Artificial Intelligence, Machine Learning and Quantum Computing

Key Questions & Goals

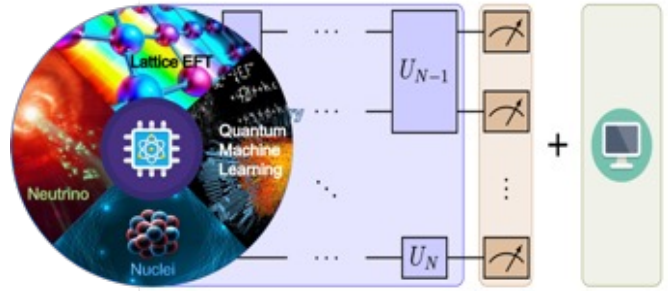
The tremendous progress in the field of nuclear physics has led to the pressing need for appropriate numerical tools aimed at addressing the most relevant experimental, theoretical and technological challenges, such as those encompassed by the Joint ECFA-NuPECC-APPEC (JENA) initiatives. To this end, 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

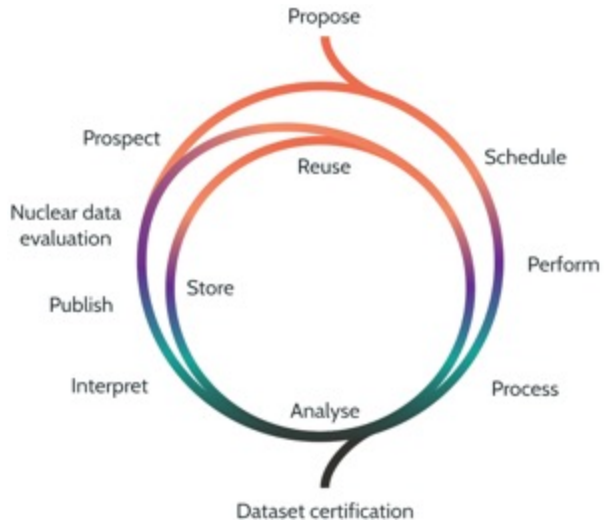
Open science and Findable, Accessible, Interoperable, Reusable (FAIR) data offer an important opportunity for the nuclear physics community to uphold the highest research standards and enhance its societal impact, by treating the scientific production process as a strategic asset.

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.
- …



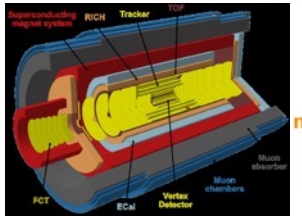
Data life cycle in nuclear physics

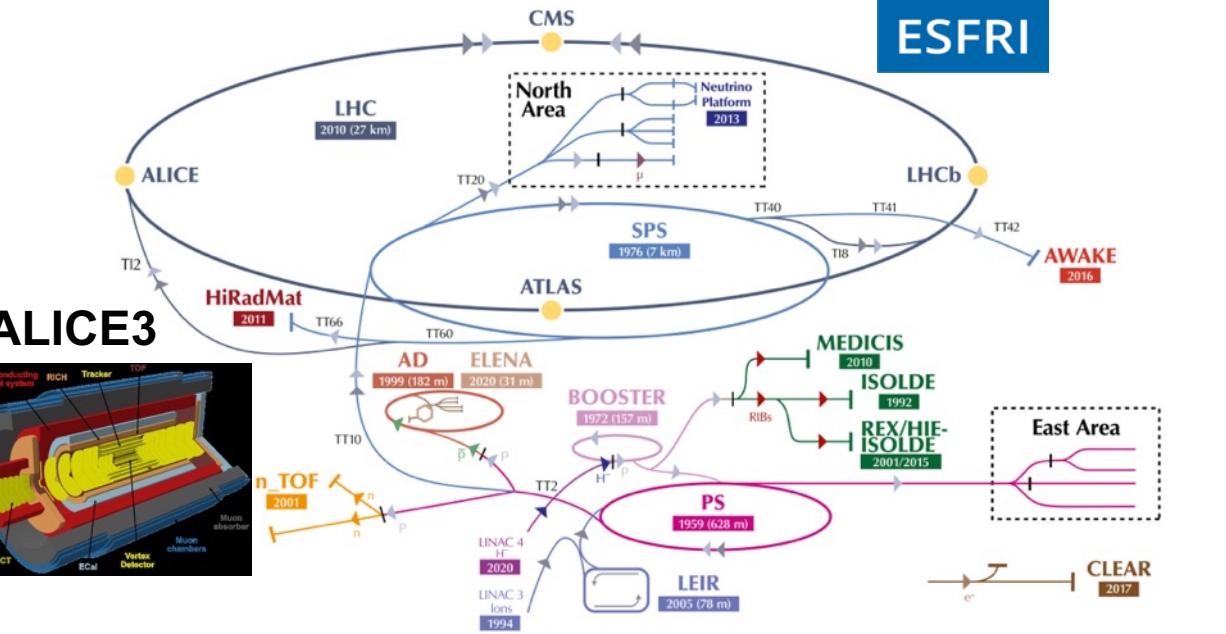
CERN Nuclear Physics facilities and experiments

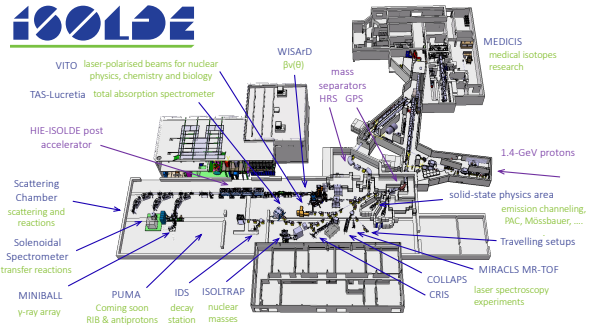
Nuclear physics opportunities at CERN constitute a world-leading research. The construction of ALICE 3 as part of the HL-LHC plans is strongly recommended. Continued support for exploitation and new developments are recommended to maximise the scientific output of ISOLDE, n_TOF, SPS fixed-target program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

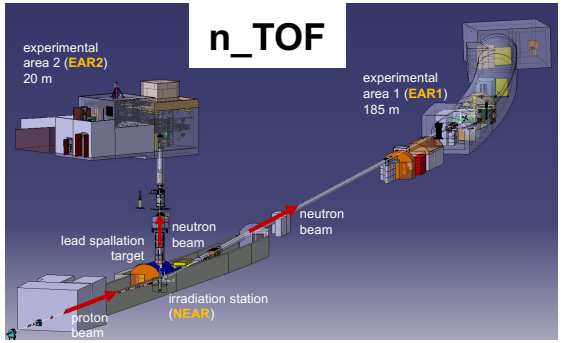
ESFRI

ALICE3









NuPECC & Nucl. Phys. input to ESPPU 2024-26

- **General input by NuPECC will be prepared similar to the previous update of ESPP**
  - **Recommendations from NuPECC Long Range Plan 2024 that concern facilities and research fields with overlap to EPPSU**
  - **Coordinated by Eberhard Widmann (NuPECC Chair from Dec. 5, 2024)**
- **Input from communities expected**
  - **Heavy ion physics**
  - **AD/ELENA**
  - **ISOLDE**
  - **n_TOF**


Nuclear physics and the
European Particle Physics Strategy Update 2018

Country input (info received so far)

- Austria: together with particle phys. community
- France IN2P3 & Irfu joint input
- Netherlands: together with PP
- Spain: together with PP or separately, tbc.
- Sweden: together with PP

…

- **Warm thanks to ECFA for the fruitful collaboration over the last 7 years**
- **Special thanks to the present and past ECFA Chairs:**
  - **Paris, Karl and Jorgen for all joint actions and fruitful discussions**
- **I believe that initiatives of APPEC, ECFA and NuPECC (JENAS, EoI, Computing, Diversity Charter,…) will help in making our future projects happen**
- **Many thanks to the CERN directorate for joining NuPECC as the Associated Member during my mandate and supporting the joint activities**