NuPECC Long Range Plan

Marek Lewitowicz
Chair of NuPECC

TRIUMF Science Week - 2020

What is NuPECC ?

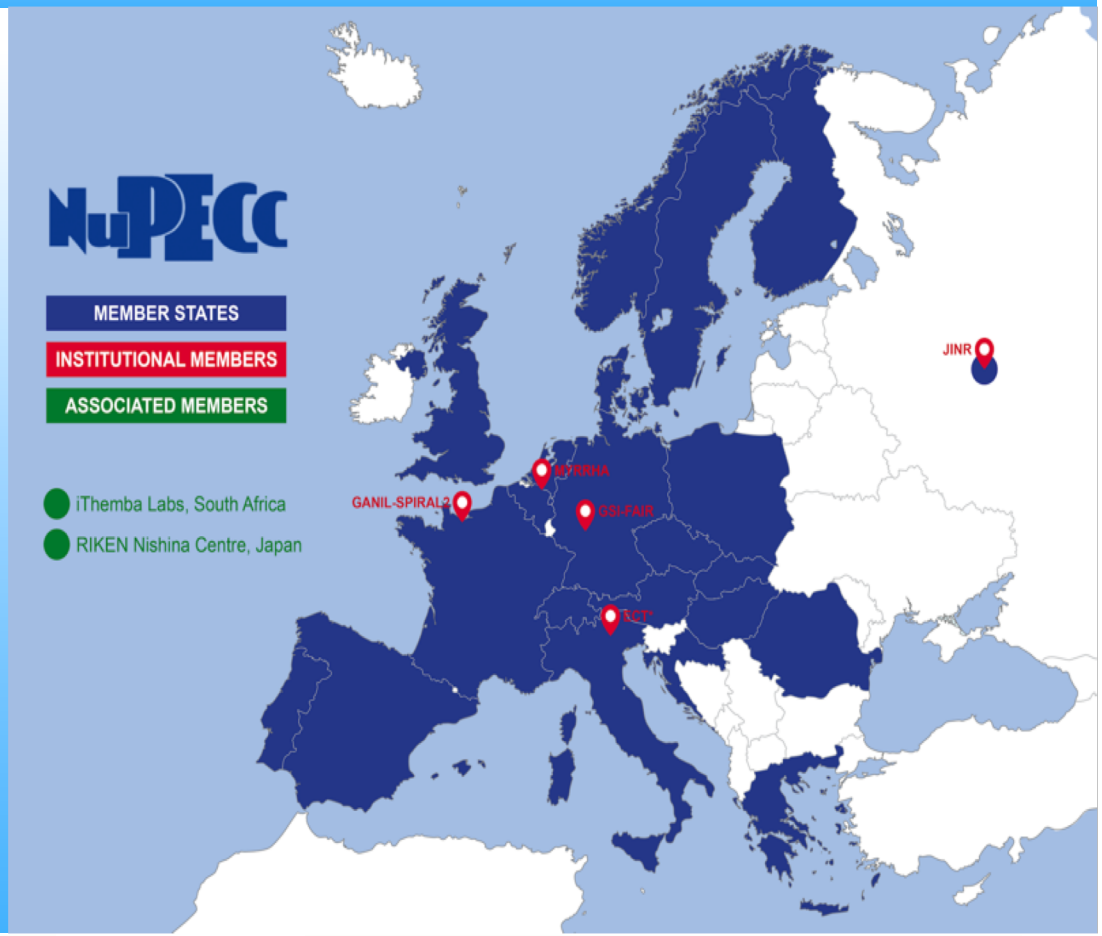
The European Expert Board for Nuclear Physics hosted by European Science Foundation

Representing

about 6000 scientists

Composition:

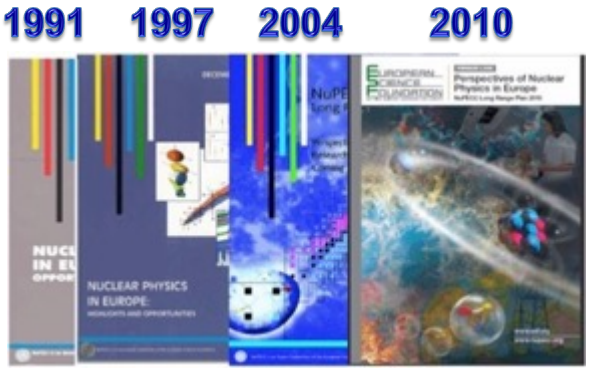
- 34 representatives from 21 countries, 3 ESFRI NP Infrastructures & JINR Dubna
- 3 associated members (Israel, iThemba Labs and Nishina Center)
- 9 observers (ESF, NPD/EPS, ECFA, NSAC, ANPhA, ALAFNA, CINP, IAEA, APPEC)



3 regular Committee meetings/y

30 Years of NuPECC activities

Long Range Plan organization & schedule



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

Community
200 experts
7 working groups

Town meeting in Darmstadt January 2017

Report June 2017

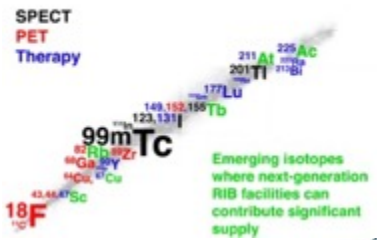
LRP presentation in Brussels Nov. 27, 2017

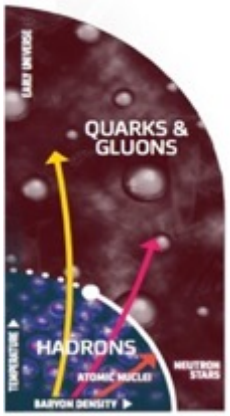
Beginning of 2016 → End of 2017

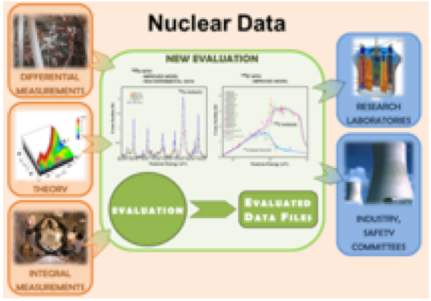
http://www.nupecc.org/lrp2016/Documents/lrp2017.pdf

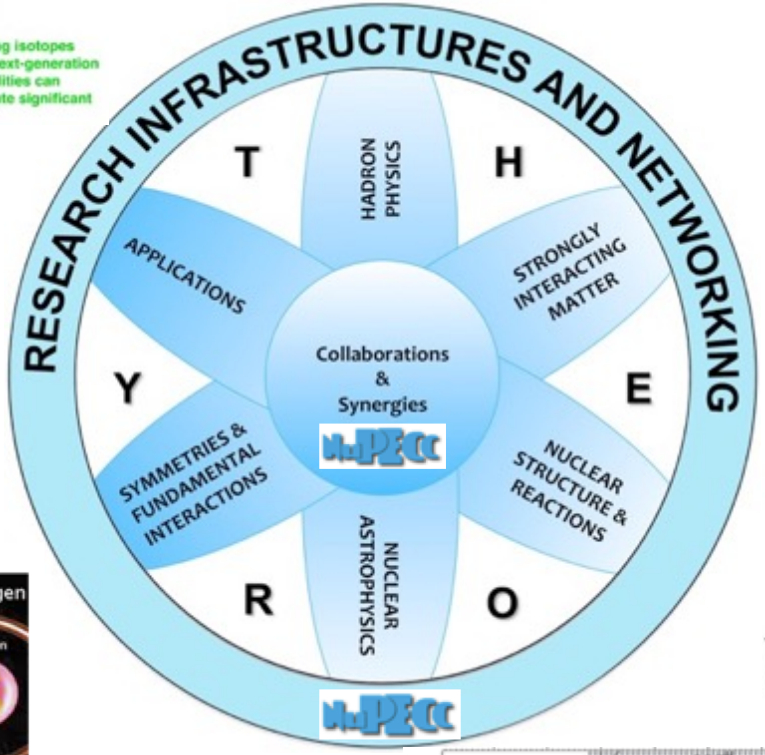
Nuclear Physics in Europe

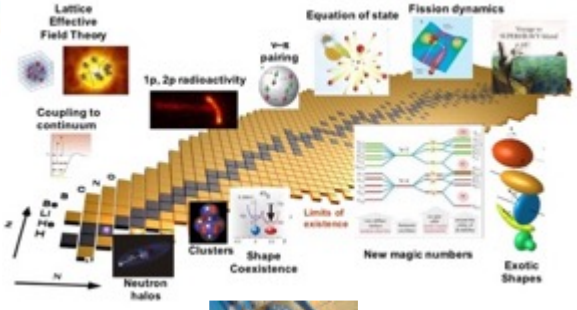
http://www.nupecc.org

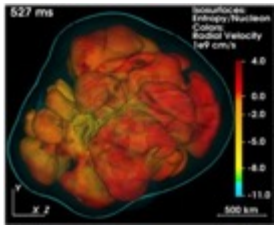


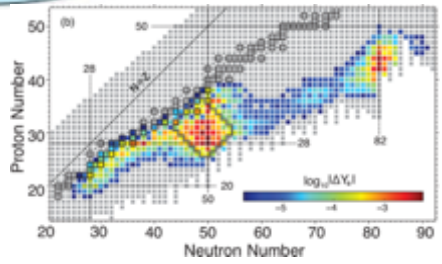






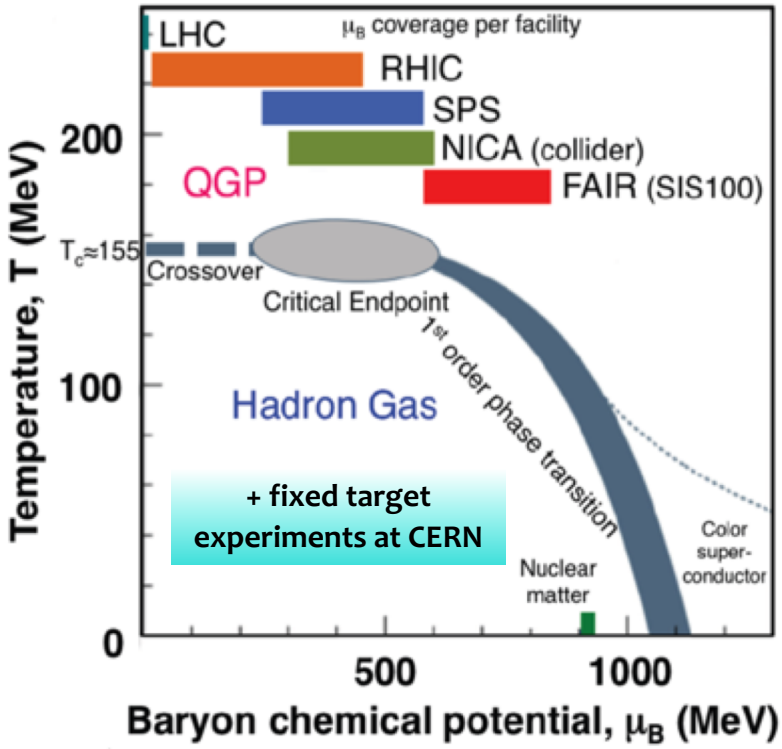


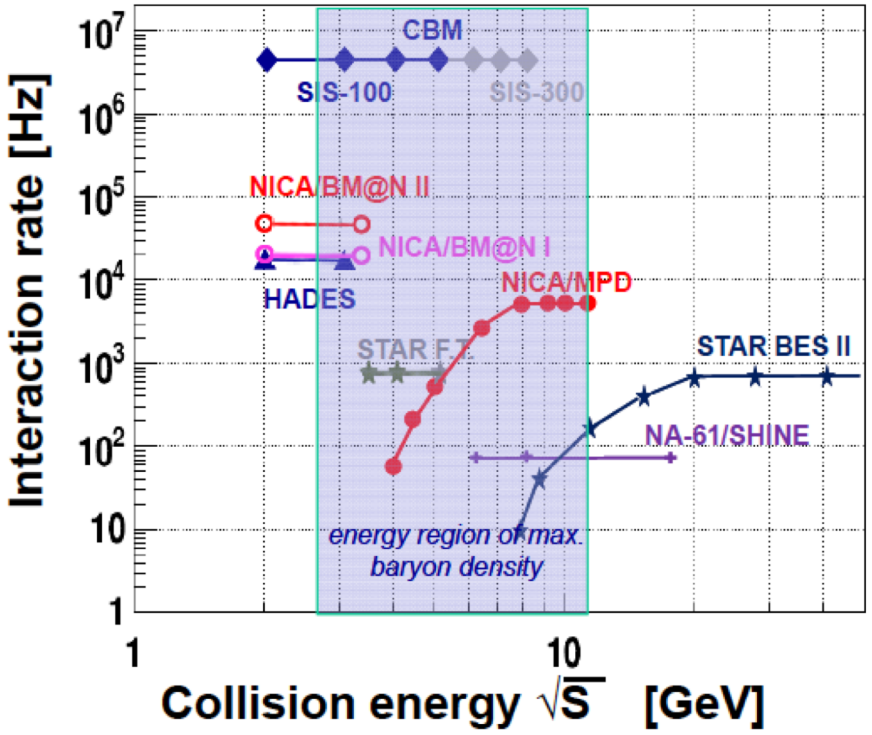




Hadronic Matter at the very extremes

- **What are the properties of nuclei and strong-interaction matter as encountered shortly after the Big Bang, in catastrophic cosmic events, and in compact stellar objects?**





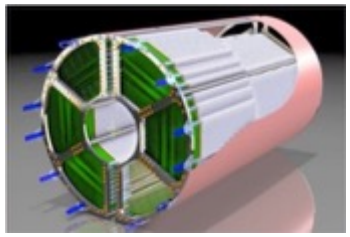
NuPECC LRP recommendation:
Fully develop synergies between ALICE, NICA, FAIR and fixed target experiments at CERN

The Physics of Hadrons

- How is mass generated in QCD and what are the static and dynamical properties of hadrons?
- How does the strong force emerge from the underlying quark-gluon structure of nucleons?

The proton

- discrepancies in measurements of the proton radius
- "proton spin puzzle"



High resolution experiments with antiprotons (PANDA) at FAIR to test QCD in detail

Main NuPECC LRP priority for this topic:

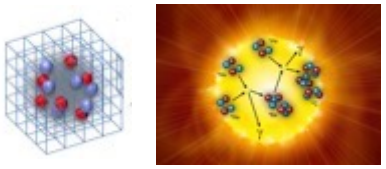
The antiproton programme at the FAIR/PANDA facility combined with programmes with polarised protons in Dubna (NICA) and those with lepton and hadron beams at existing facilities (MAMI, Bonn, INFN-Frascati, COMPASS).

European participation in the Electron–Ion Collider project in US under preparation

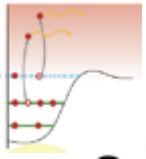
Structure of complex nuclei

- How does the complexity of nuclear structure arise from the interaction between nucleons?
- What are the limits of nuclear stability?

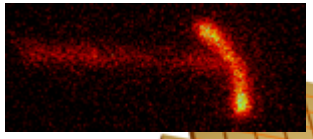
Lattice Effective Field Theory



Coupling to continuum



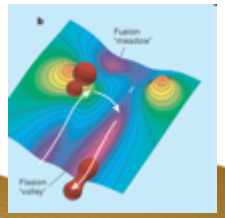
1p, 2p radioactivity

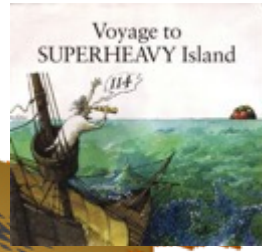


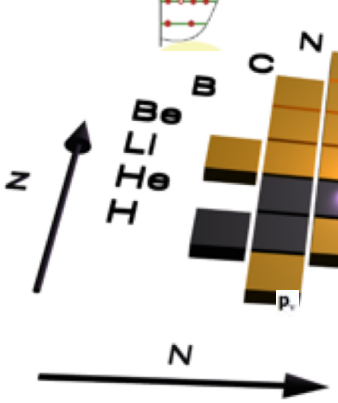
ν–π pairing

Equation of state

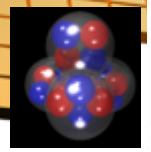
Fission dynamics



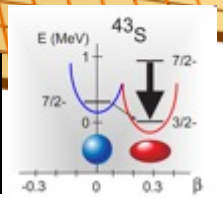




Neutron halos

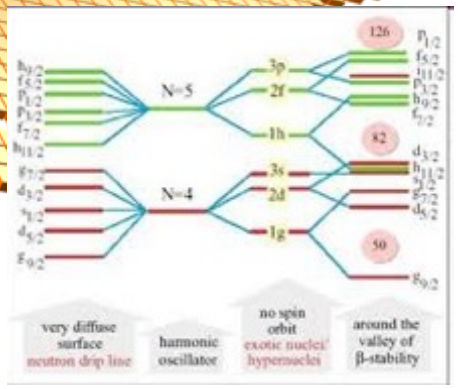


Clusters

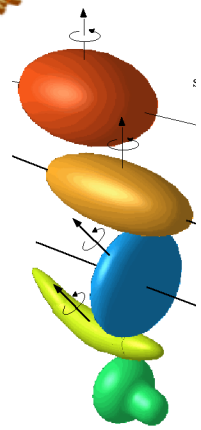


Shape Coexistence

Limits of existence



New magic numbers



Exotic Shapes

Main NuPECC LRP recommendation:
Construction of FAIR/NUSTAR, ISOL Facilities, ELI-NP and full AGATA array

AGATA Tracking array for gamma spectroscopy

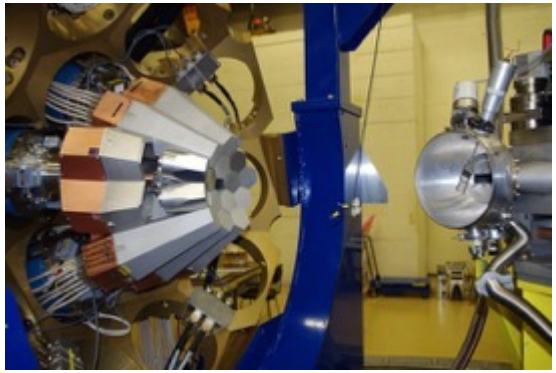
High-sensitivity for nuclear structure of exotic nuclei – used in several EU laboratories

2010 → 2011 LNL, Italy
5TC (15 detectors)

→ 2012 → GSI, Germany
6TC+3 DC (22 detectors)

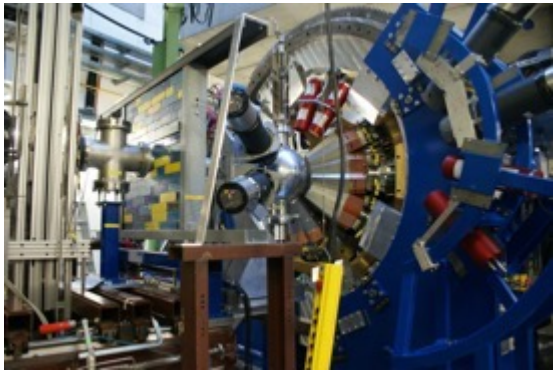
→ 2014 → GANIL, France
15TC (45 detectors)

→ 2021 -> LNL



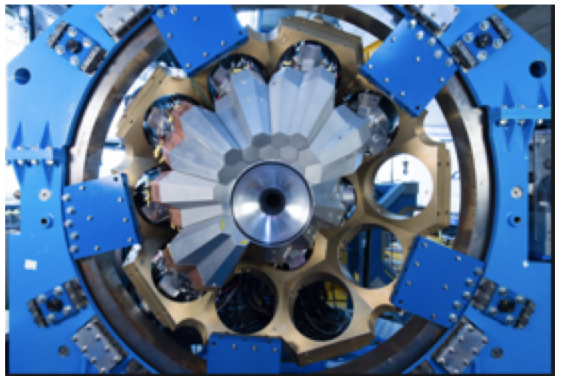
AGATA Demo. + PRISMA

Total Eff $_{Nominal}$. ~2.6%



AGATA @ FRS

Total Eff. (β=0.5) ~ 10%



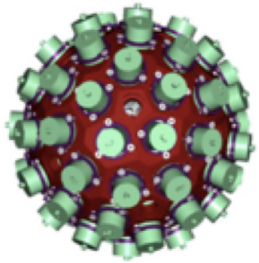
AGATA @G1

Total Eff ~ 8% to 14%

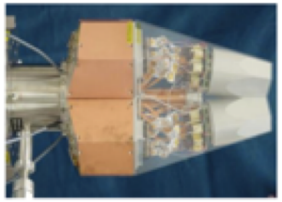
→ 60 detectors by 2020

AGATA array: A powerful traveling instrument - its construction has to proceed in the next years up to 4π coverage (60 triple clusters = 160 detectors) !

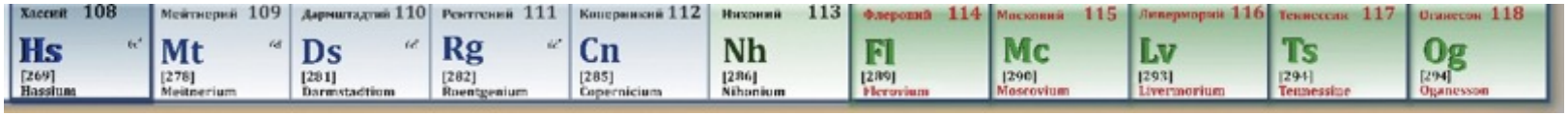
AGATA 4π



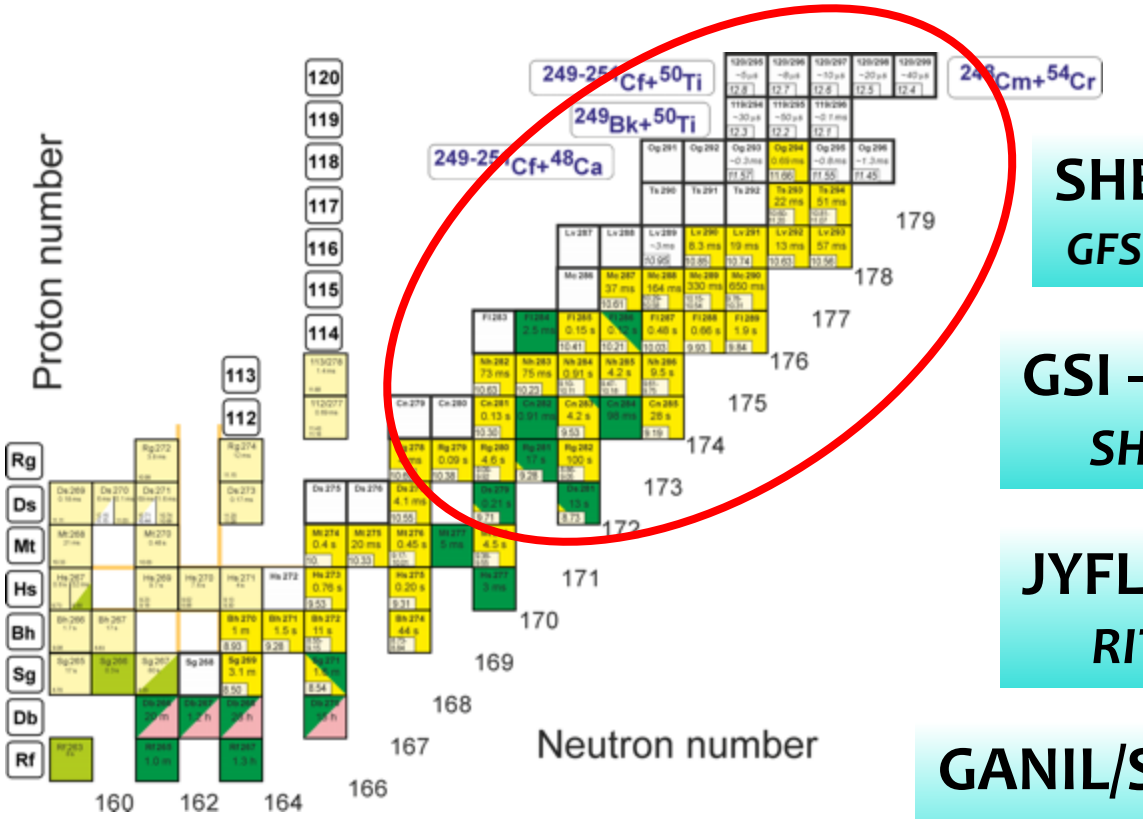
Tripple Cluster



Study of Heavy and SH nuclei



10 out of 11 elements discovered at GSI and JINR



Scientific programs at:

SHEF – Dubna
GFS II & III, SHELS
— *Commissioning*

GSI – Darmstadt
SHIP & TASCA
— *Taking data*

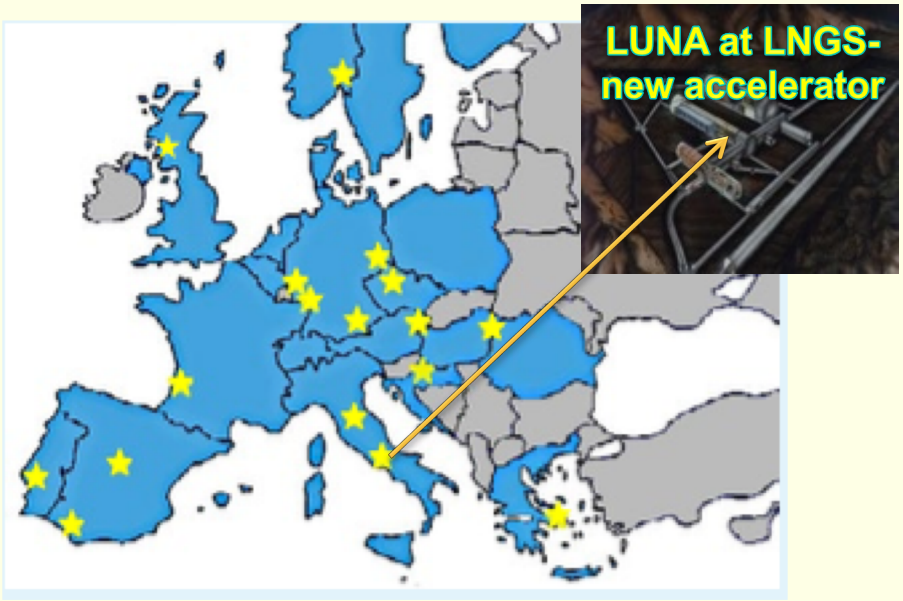
JYFL – Jyväskylä
RITU & MARA
— *Taking data*

GANIL/SPIRAL2 – Caen
S3 & VAMOS GFS
— *Commissioning of LINAC*

Nucleosynthesis (nuclear structure and reactions information)

Strong support for a large effort

involving small scale accelerators …… & large infrastructures



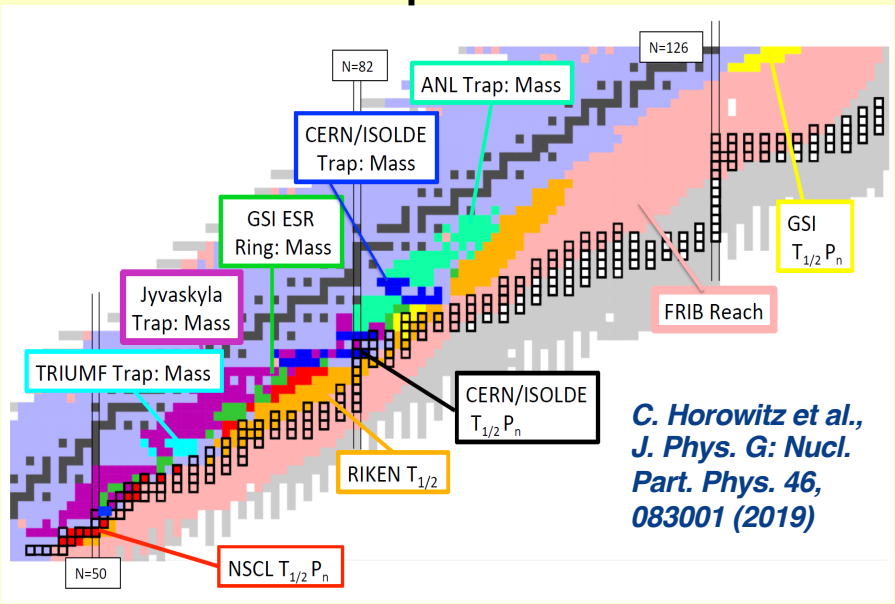
In particular at smaller scale accelerators :

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

LUNA, LNS, ALTO,…

Nucleosynthesis of medium to heavy nuclei

Example: Mass measurements & r-process



C. Horowitz et al., J. Phys. G: Nucl. Part. Phys. 46, 083001 (2019)

Scientific programs at :

- **FAIR**
- **ISOLDE-SPES-JYFL**
- **GANIL**

Support for Nuclear Theory

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

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

Computing infrastructures

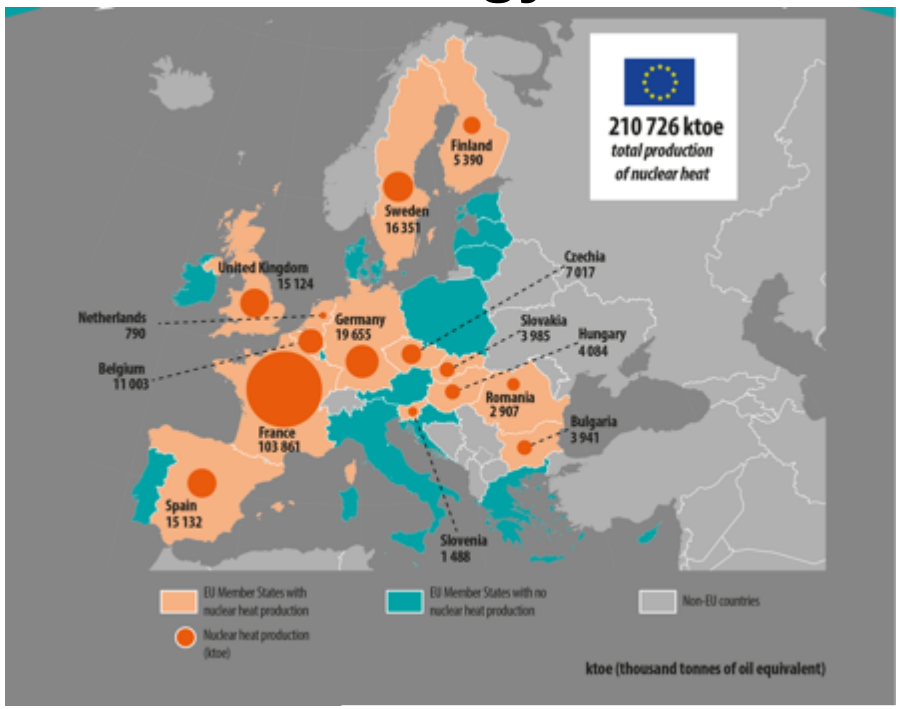
With continued major conceptual and computational advances, nuclear theory plays a crucial role in shaping existing experimental programmes.

- **Provide platforms for scientific exchange and training of theorists**
- **Increase the work force and strengthen collaborations and accessibility in the area of high-performance computing.**

New: Quantum computing initiatives – ECT*, EU Quantum Flagship
European Open Science Cloud (EOSC) – ESCAPE project

Energy applications

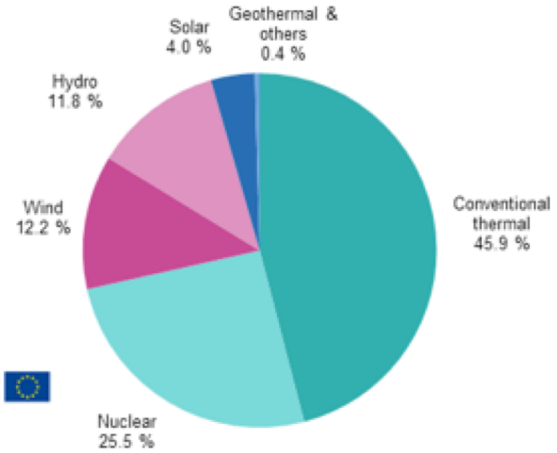
Nuclear Energy in EU



In 2018, nuclear plants generated 25,5 % *(15% in Canada in 2017)* of the electricity produced in the European Union, with nuclear reactors operating in 14 Member States

128 nuclear power reactors (119 GWe)
Under construction: 4 reactors in EU + 10 in Russia and Belorussia

Electricity production by source, EU-28, 2018 (%)



eurostat

First phase of MYRRHA ADS facility under construction

ESFRI

IFMIF-DONES - test facility for fusion materials under design

Recommendations for European Nuclear Physics facilities

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

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

GANIL/SPIRAL2
ISOLDE, SPES,
JYFL

Support for the full exploitation of existing and emerging facilities.

ELI-NP
NICA, SHEF
MYRRHA
IFMIF-DONES

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

Support to the completion of AGATA in full geometry.

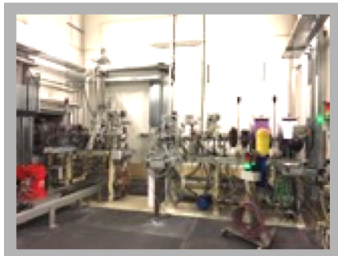
FAIR Facility

- **ESFRI Landmark**
- **Top priority for European Nuclear Physics Community**
- **Driver for Innovation in Science and Technology**

Status of FAIR Project: Civil Construction

Curtesy of Paolo Giubellino

Roadmap NP facilities



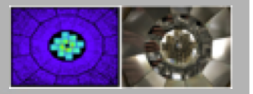
NFS

S3

DESIR

AGATA
VAMOS

FAZIA
INDRA



HI SC LINAC

SPIRAL2 Phase 1

SPIRAL2 Phase 2
under discussion

SPIRAL1

0 10 20 30 40 50 m

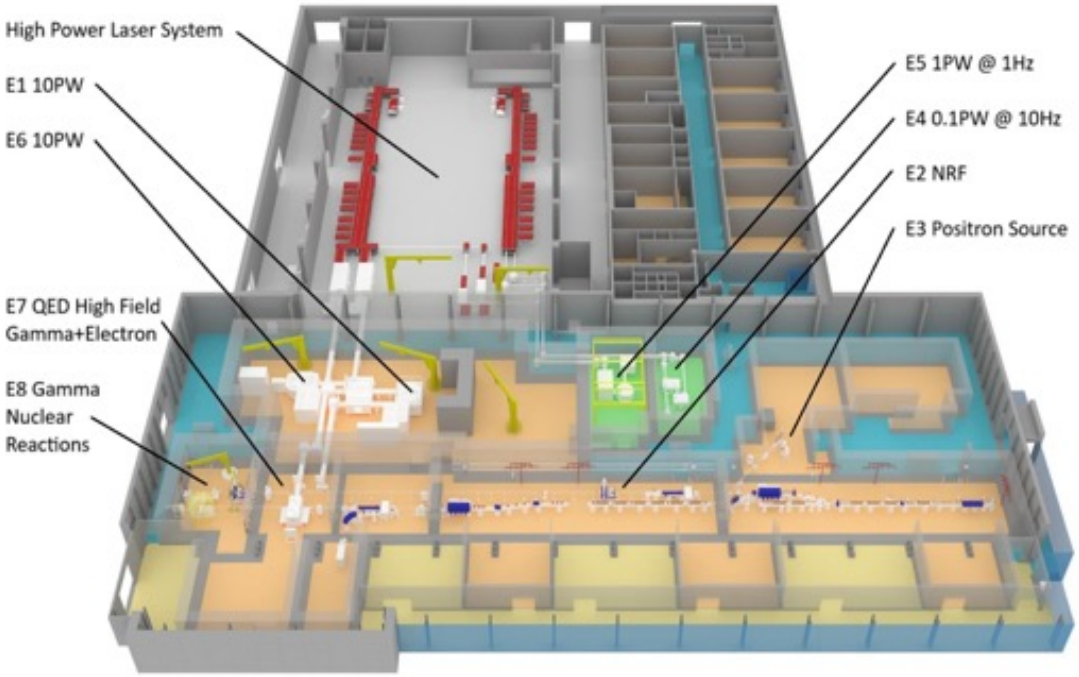
5mA 14-20 MeV/n light and heavy ions

First SPIRAL2 experiments in 2020

Courtesy of Navin Alahari

Future development of the facility under discussion

Roadmap NP facilities



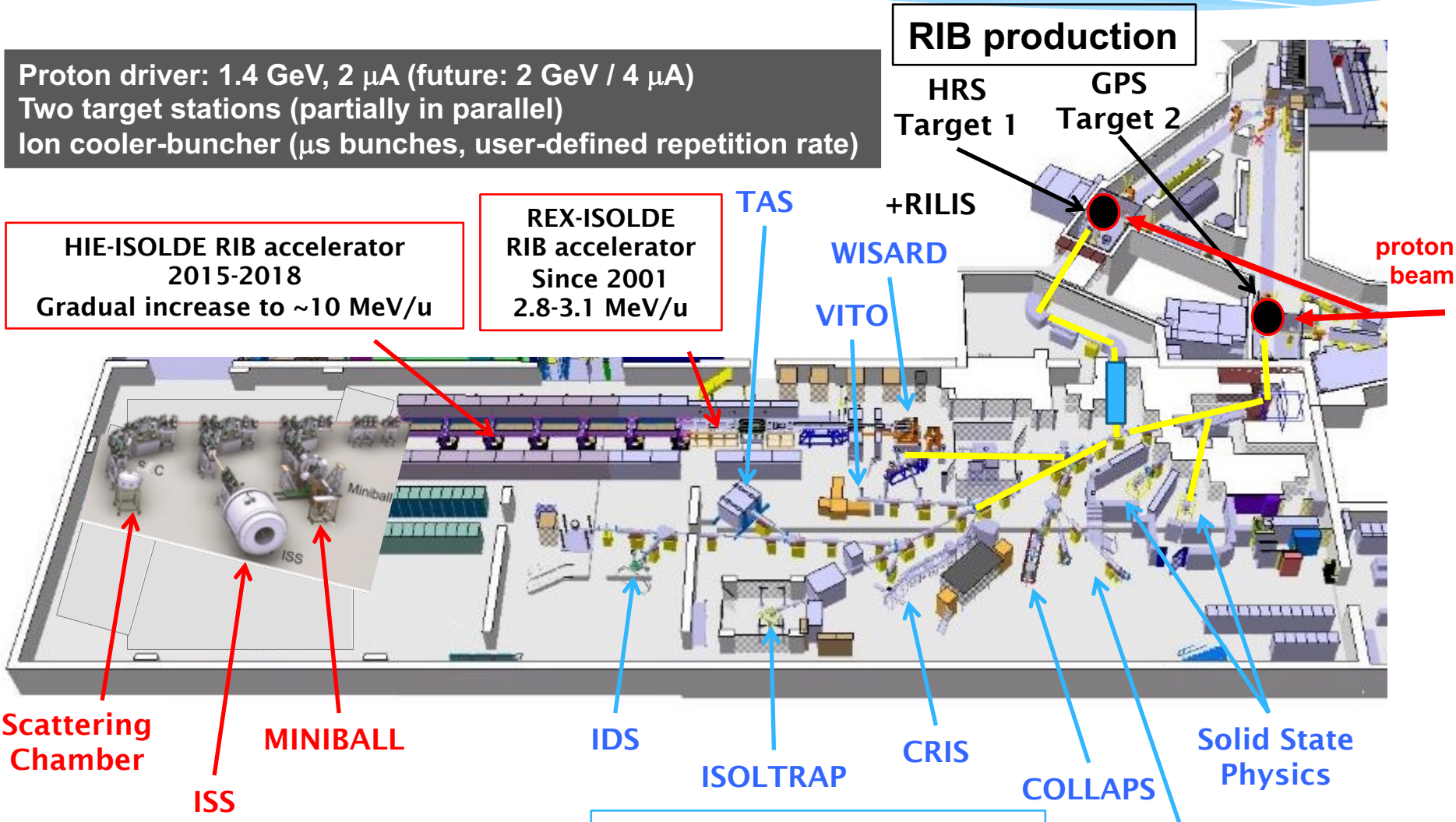
The nominal power of 10 PW laser system was achieved in March 2019, making HPLS from ELI-NP the most powerful laser in Europe

20MeV Gamma beams expected by 2022

Courtesy of Dan Gabriel Ghiță & Ionel Andrei

CERN/ISOLDE facility

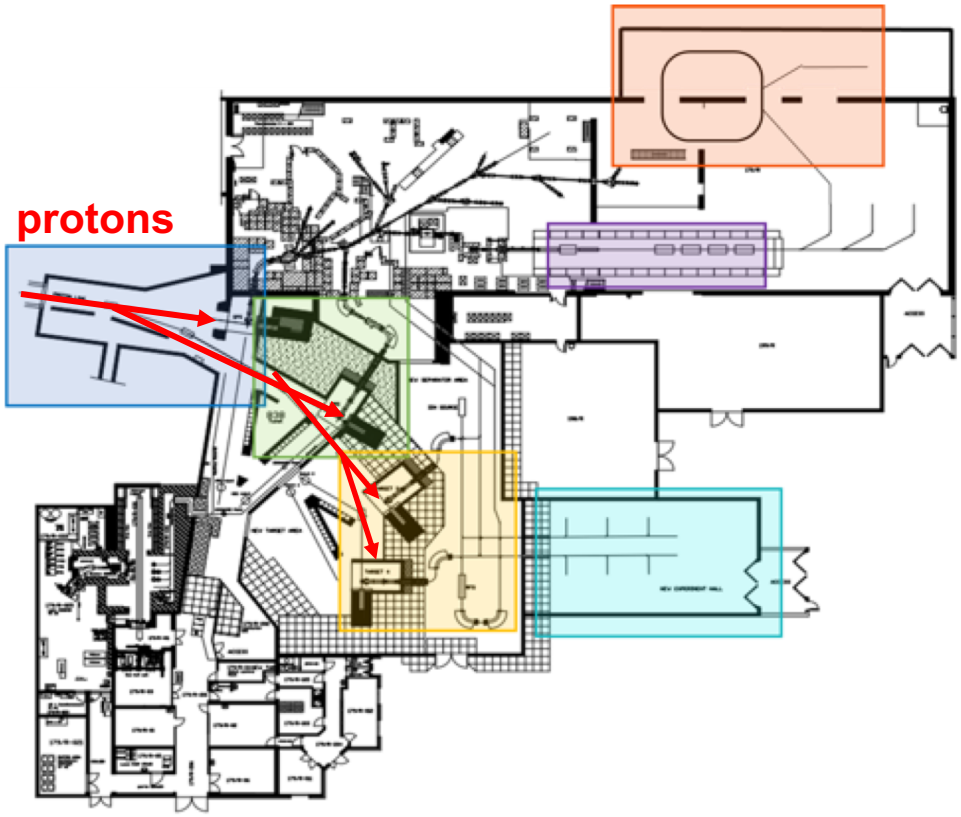
Proton driver: 1.4 GeV, 2 μA (future: 2 GeV / 4 μA)
Two target stations (partially in parallel)
Ion cooler-buncher (μs bunches, user-defined repetition rate)



ISOLDE: A Laboratory Report, JPG44 (2017)

Courtesy of G. Neyens

A possible layout of an extended ISOLDE (colors are new/upgrades) :



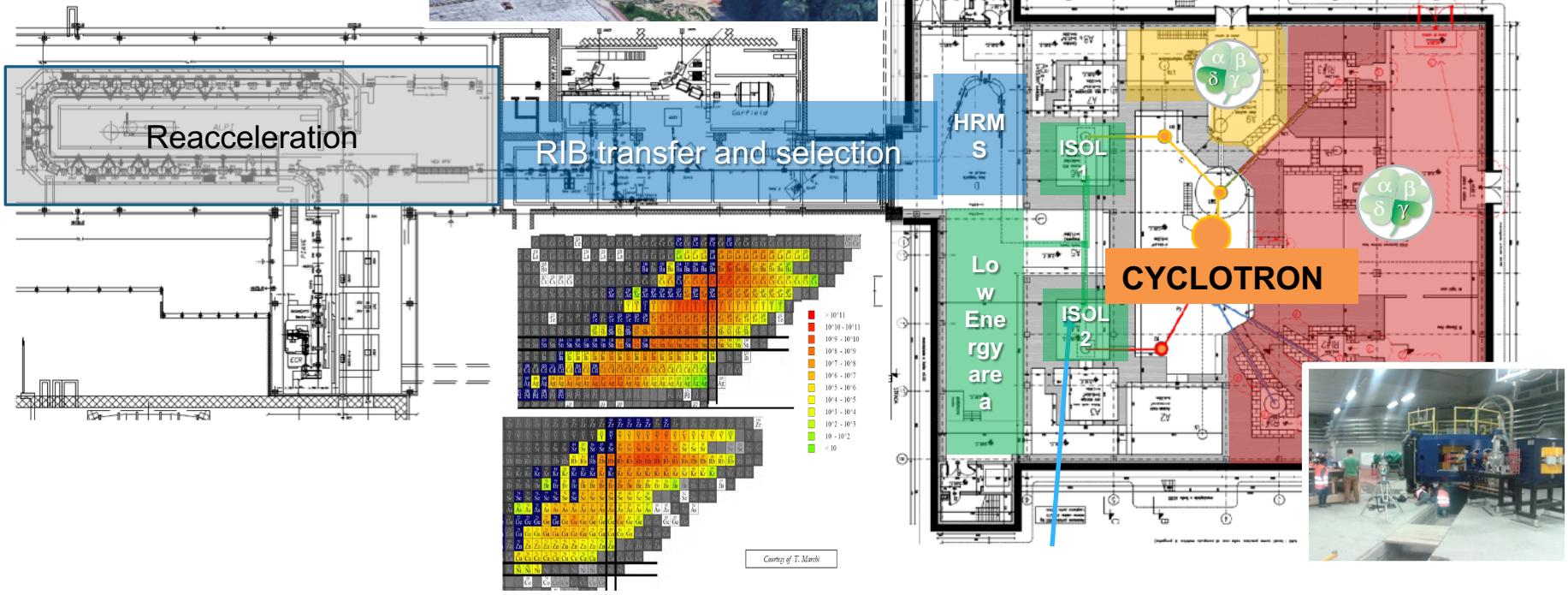
Courtesy of G. Neyens

The EPIC project comprises of 6 key upgrades (in no particular order):

- The addition of two new target stations and a high resolution mass separator
- Improvement of the existing beam dumps
- Provide 2 GeV protons to ISOLDE
- The addition of a second experimental hall
- Installation of a storage ring beyond the HIE-ISOLDE post accelerator
- An upgrade of the non-superconducting part of HIE-ISOLDE (REX-part)

SPES Facility at LNL, Italy

Neutron production area (NEPIR)



RIB reacceleration:

- new RFQ
- ALPI

≥ 2023

1/20.000 Mass separator (Beam Cooler + HRMS)
Elettrostatic beam transport
Charge Breeder (n+)
1/1000 mass separator

by 2023

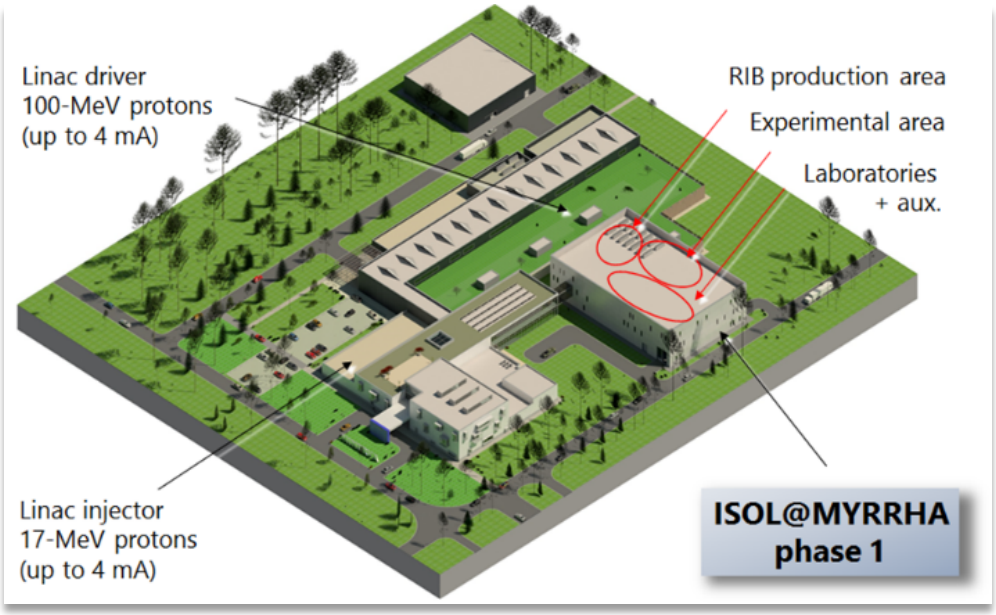
ISOL bunkers
1/200 mass separator
low energy experimental area

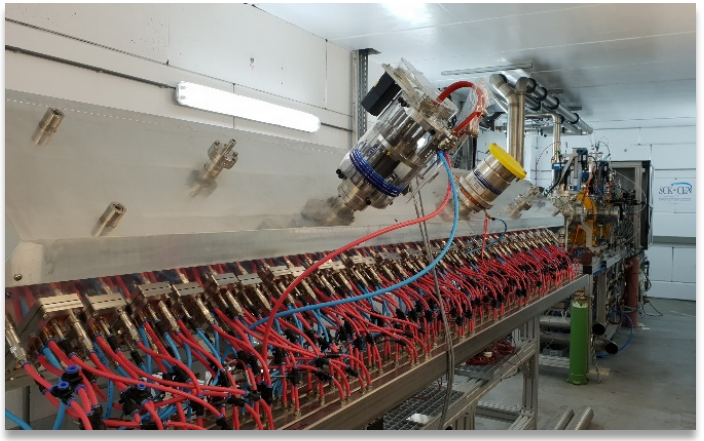
by 2022

Radioisotopes production area (LARAMED)

Best Company Cyclotron
70 MeV – 500 μA proton beam tested

MYRRHA ADS project phase 1/MINERVA at SCK Belgium

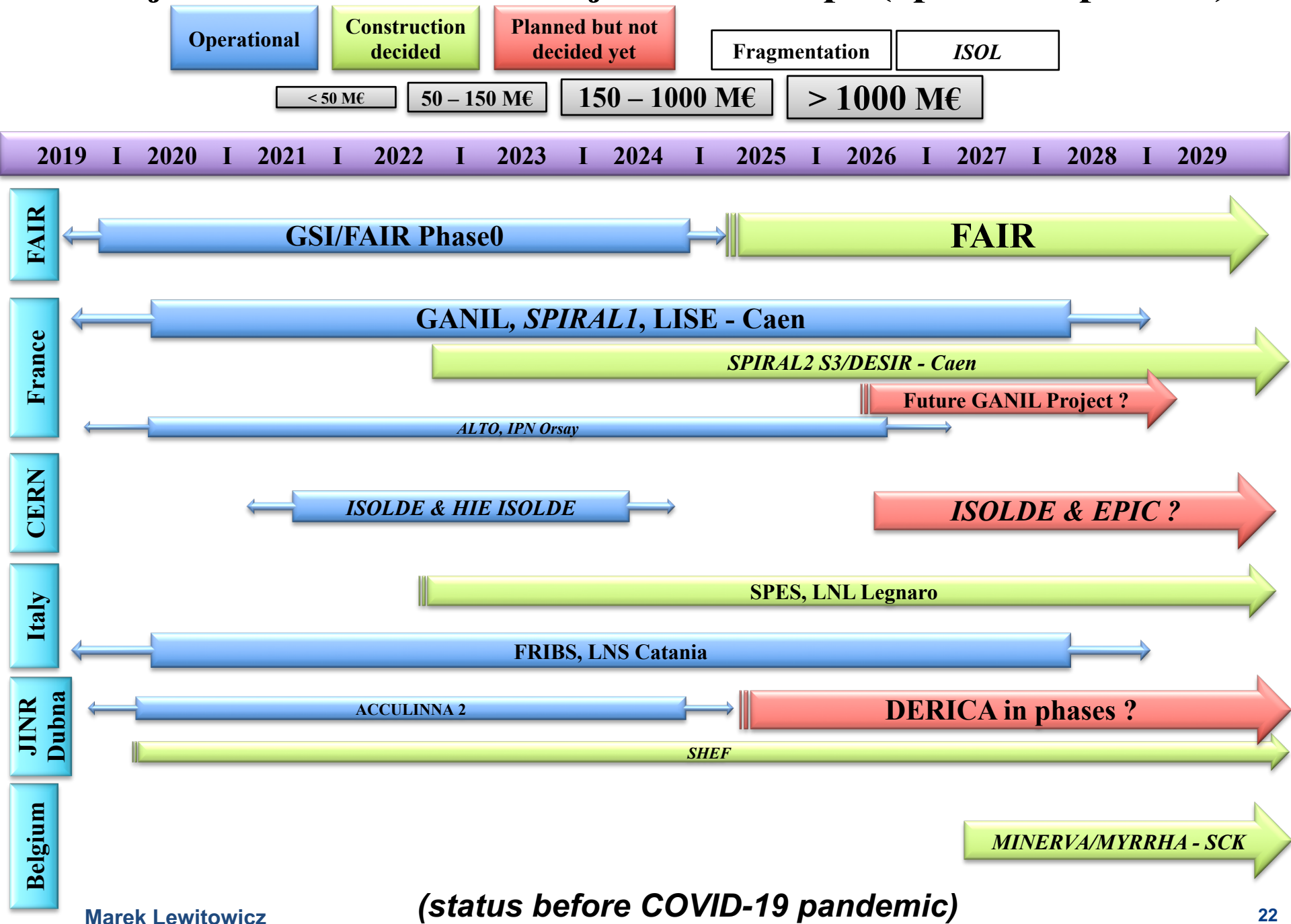




- Accelerator in Phase 1 = a subset of the MYRRHA accelerator
- Beam sharing allows for parallel activities :
  - feeding the PTF hosting **the ISOL** system (ISOL@MYRRHA phase 1)
  - commissioning the linac for **reliability evaluation**
  - irradiation capabilities for the **fusion** community
- Layout is compatible with Linac extension to 600 MeV
- Conceptual Design of the PTF – to be finalized in 2019
- **First Radioactive Ion Beams expected by 2027**

Courtesy of Lucia Popescu

Major RIB Facilities & Projects in Europe (operation periods)



(status before COVID-19 pandemic)

NuPECC LRP

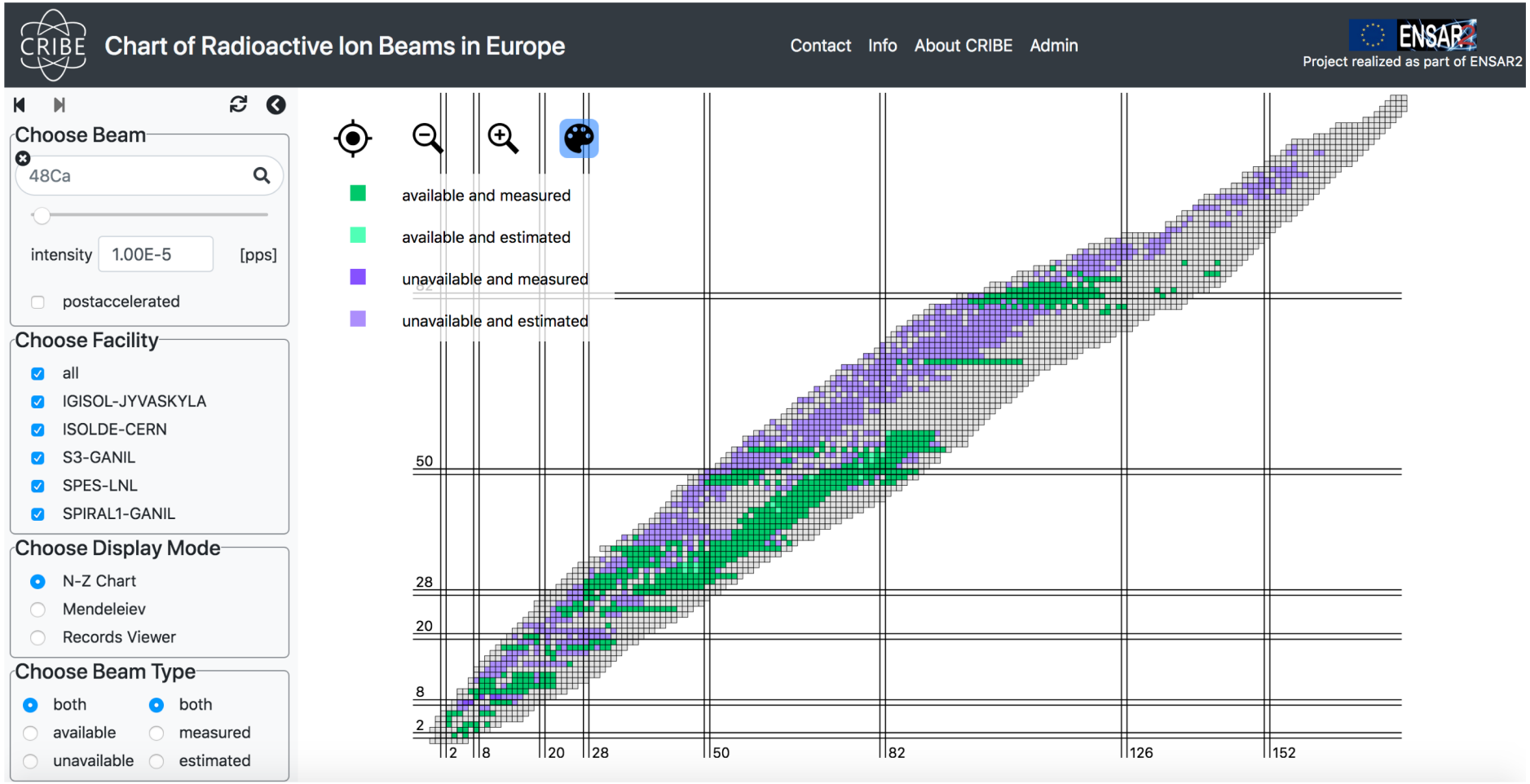
- **The 2017 NuPECC Long Range Plan defined an ambitious strategy for European Nuclear Physics**
- **NuPECC efforts to transform the LR Plan into reality -> Task Force meetings**
- **Development of a global international approach to nuclear science in collaboration with IUPAP, NPD/EPS, ECFA, ApPEC, NSAC (US), ANPhA (Asia), ALAFNA (S. America), CINP (Canada)**

Joint activities of ECFA, APPEC & NuPECC (particle, astroparticle and nuclear physics)

- **Joint "JENAS" seminar**
- **European Strategy for Particle Physics**
- **Diversity Charter**
- **Recognition of young scientists**

Thank you for your attention

ISOL Radioactive Ion Beams in Europe



Integrating community with EU projects

Support for users and facilities





ENSAR2

Nuclear structure reactions and applications

Contract 2016-2020 (10M€)

Coord. Muhsin Harakeh
GANIL

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

HadronPhysics

Hadron physics STRONG-2020

Contract 2019 -2023 (10M€)

Coord. Barbara Erazmus
IN2P3/CNRS

- CERN
  LHC & fixed target exp.
- GSI/FAIR (Germany)
- LNF, Frascati (Italy)
- MAMI, Mainz (Germany)
- ECT*, Trento (Italy)
- ELSA, Bonn (Germany)
- COSY, Jülich (Germany)