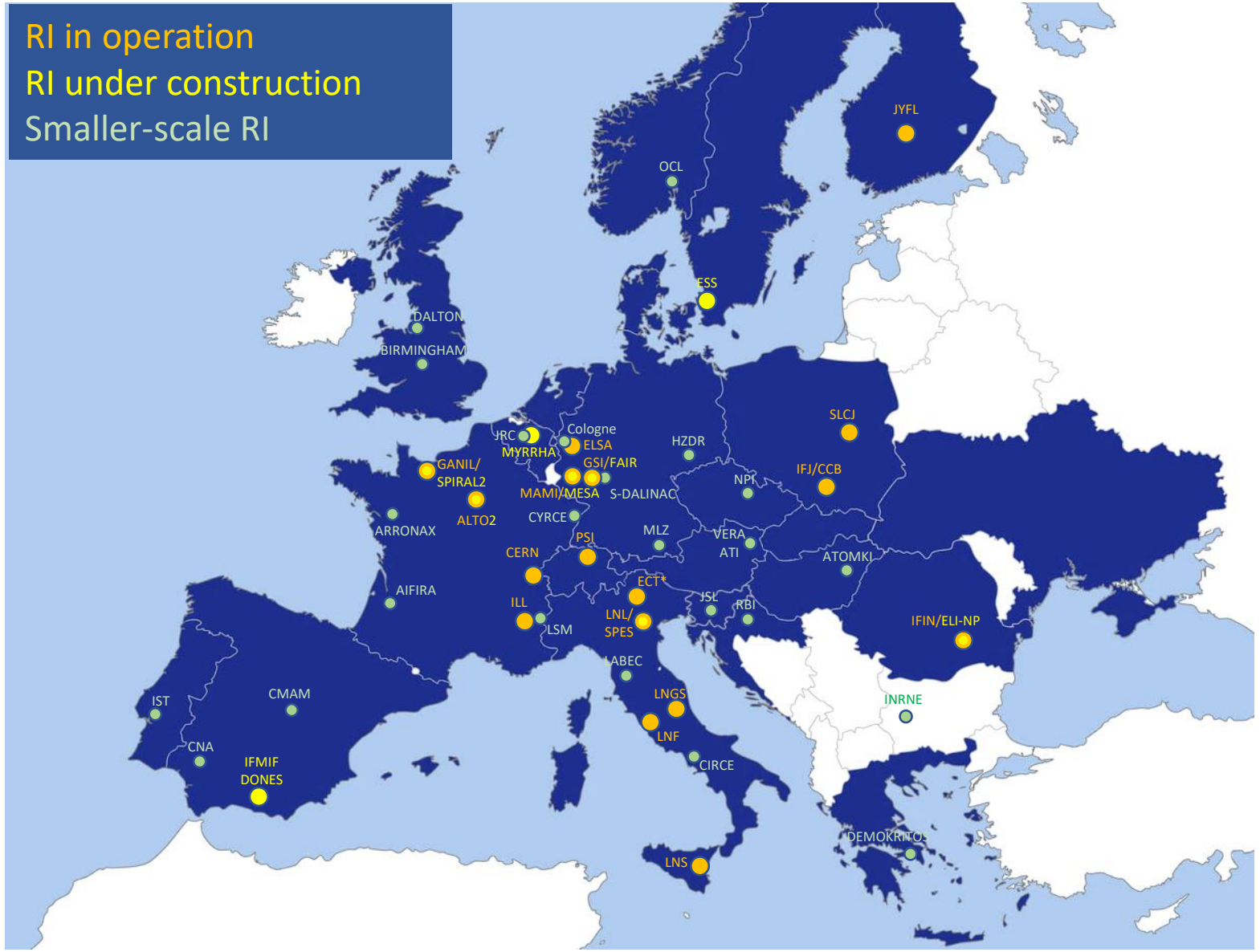
TWG-6: Research Infrastructures in the NuPECC LRP 2024

Outline

- Introduction to the TWG on RIs
- ESFRI facilities and CERN
- Large-scale facilities
  - Hadron and Heavy Ion Facilities
  - Lepton and Photon Facilities
- Small-scale facilities
- New facilities in Europe
- Facilities outside of Europe

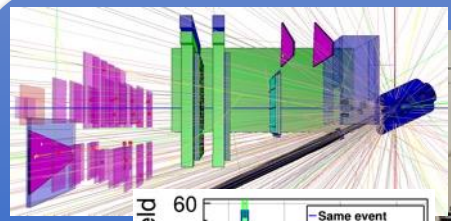
ESFRI: European Strategy Forum on Research Infrastructures

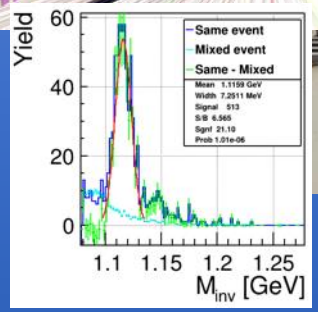


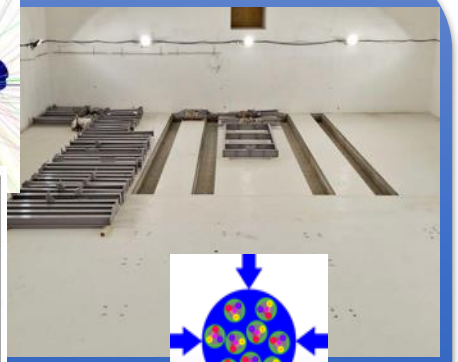
All FAIR pillars operational in the 2030s

APPA

CBM

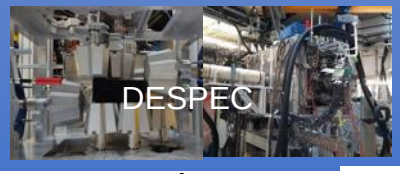


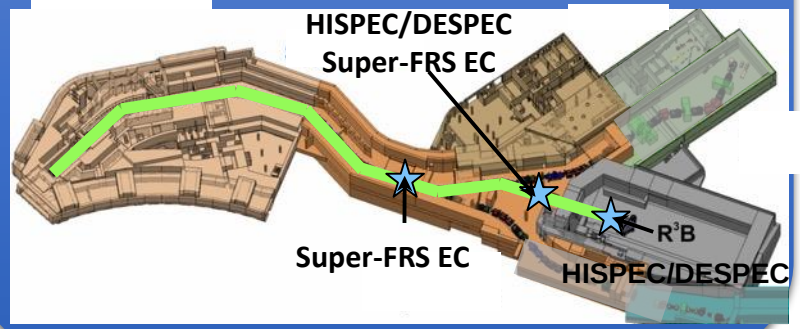




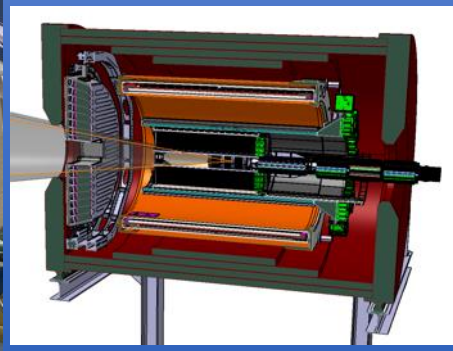
CBM

NUSTAR





PANDA



GANIL & SPIRAL2

"Vision to keep GANIL at the forefront of nuclear science globally for many decades to come"

International Expert Committee: Recommendations for the future of GANIL/SPIRAL2 (March 2022)

- **Construction of a facility for high-intensity Radioactive Ion Beams from fission and multi-nucleon transfer**
- **New post-accelerator for reacceleration of secondary beams up to 100 MeV/u**
- **Electron-RI beam scattering facility**

Extreme Light Infrastructure – Nuclear Physics

Short term (<5 years)

ELI-NP High power laser facility as an international user facility

Extreme light intensity (10 PW ⟹ 10^{23} W/cm²)

Extreme electric fields (10^{15} V/m)

Strong-field QED

- 10 PW laser + solid target → PW γ-source
- 10 PW laser + GeV LWFA electrons → Radiation reaction, Breit-Wheeler pairs, QED vacuum

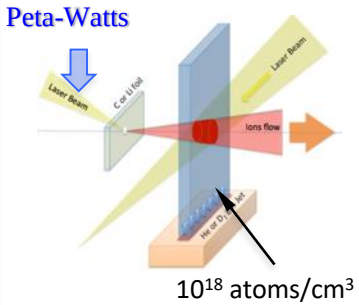
Extreme light pressures (Tbar)

Nuclear Physics with Lasers

10 PW radiation pressure acceleration of *dense* ion beams

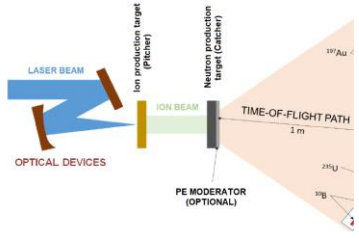
- Nuclear reactions in plasma
- Ultra-intense neutron source
- Neutron-rich nuclei

Study of electron screening factor in nuclear reactions of astrophysical interest



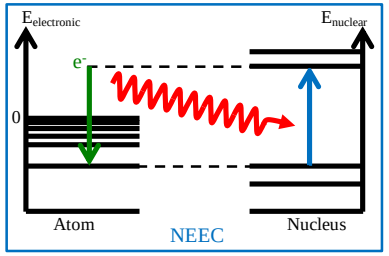
10^{18} atoms/cm³

High-intensity short-pulsed laser-driven neutron source



M.A. Millán-Callado et al., EPJ Web Conf. 239 (2020) 17012

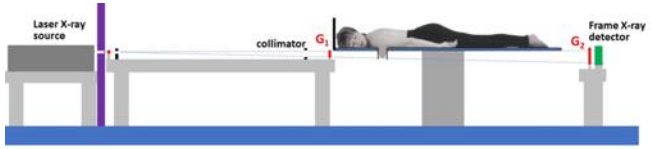
Nuclear lifetimes in plasma



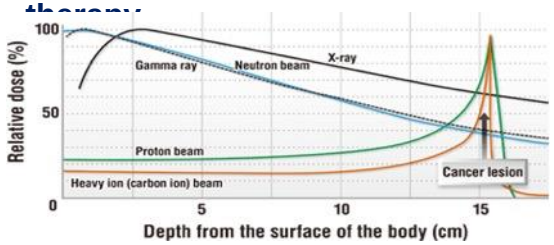
Medium term (5-10 years)

Applications of High–Power

Interferometric phase contrast X–ray imaging



Laser-driven C-ions for hadron therapy

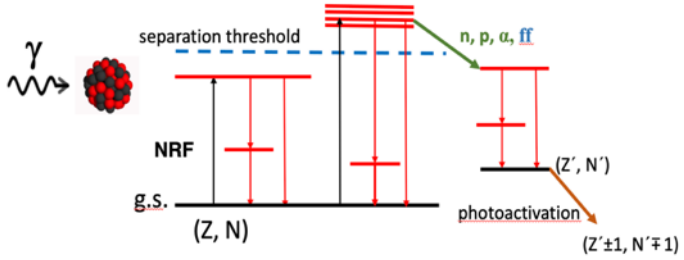


Nuclear Photonics with Gamma

ELI-NP Gamma Beam System: E_{max} = 19.5 MeV, Rel. bwd < 0.5%, SPD > 5000 ph/s/eV

Physics Case

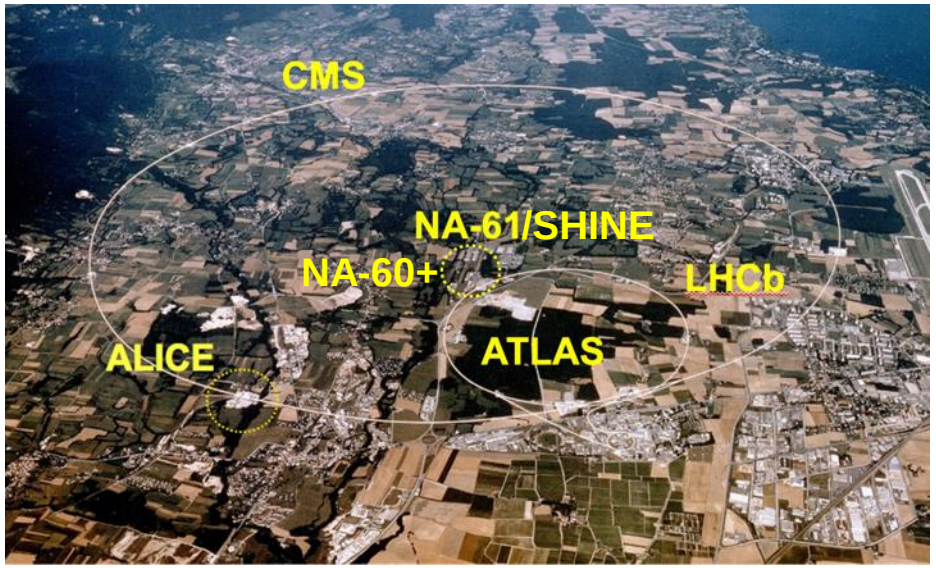
- Nuclear structure, PDR/GDR
- Photonuclear reactions and Photofission
- Nuclear astrophysics and nucleosynthesis

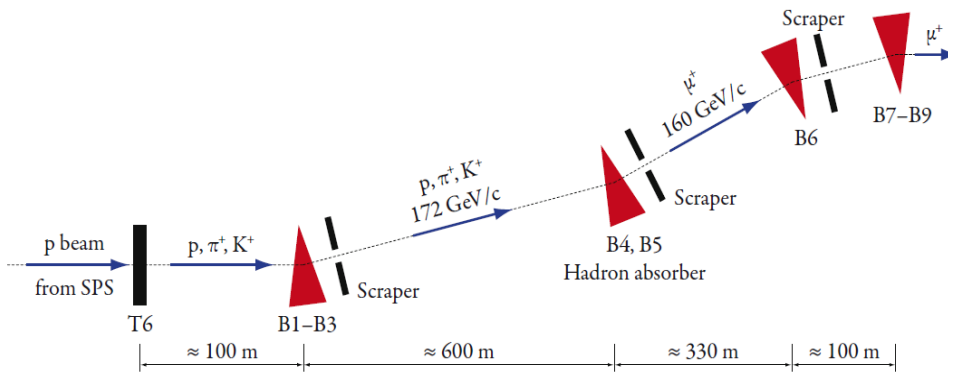


Applications

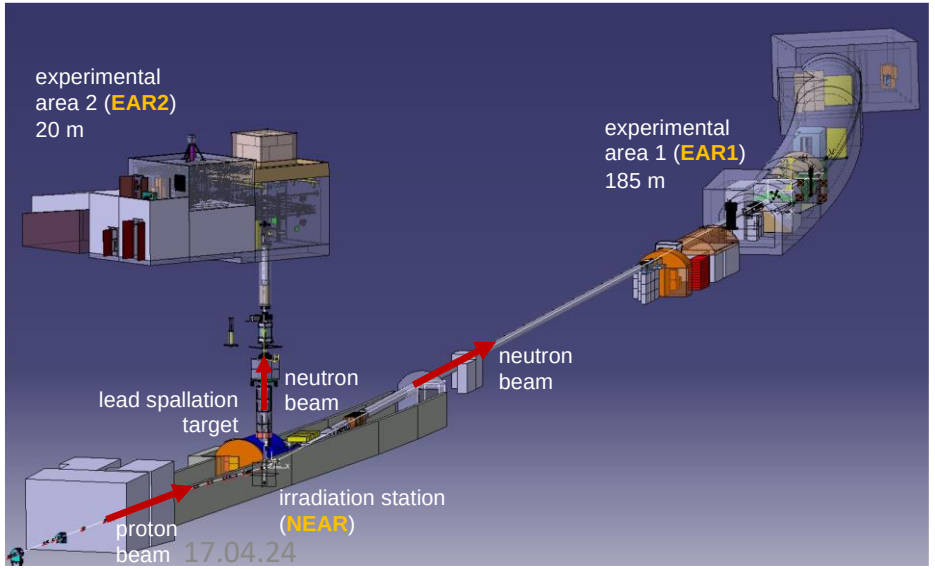
- Non-destructive analysis
- Material studies with positrons
- Generation of radioisotopes of medical interest

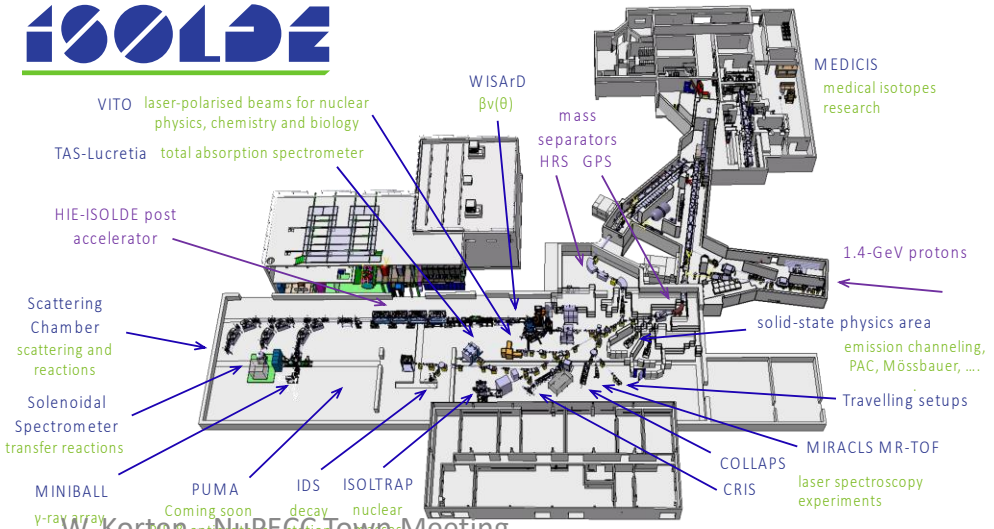
CERN: LHC, SPS-M2, ISOLDE, n_ToF, AD

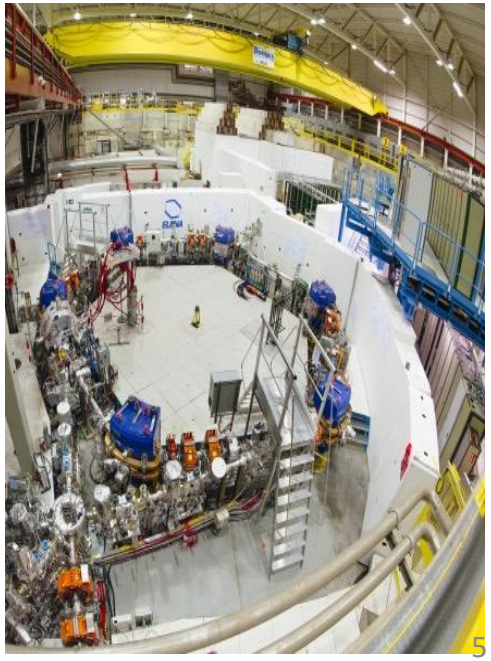




AMBER
MUonE
NA64-μ







Research Infrastructures in the NuPECC LRP 2024

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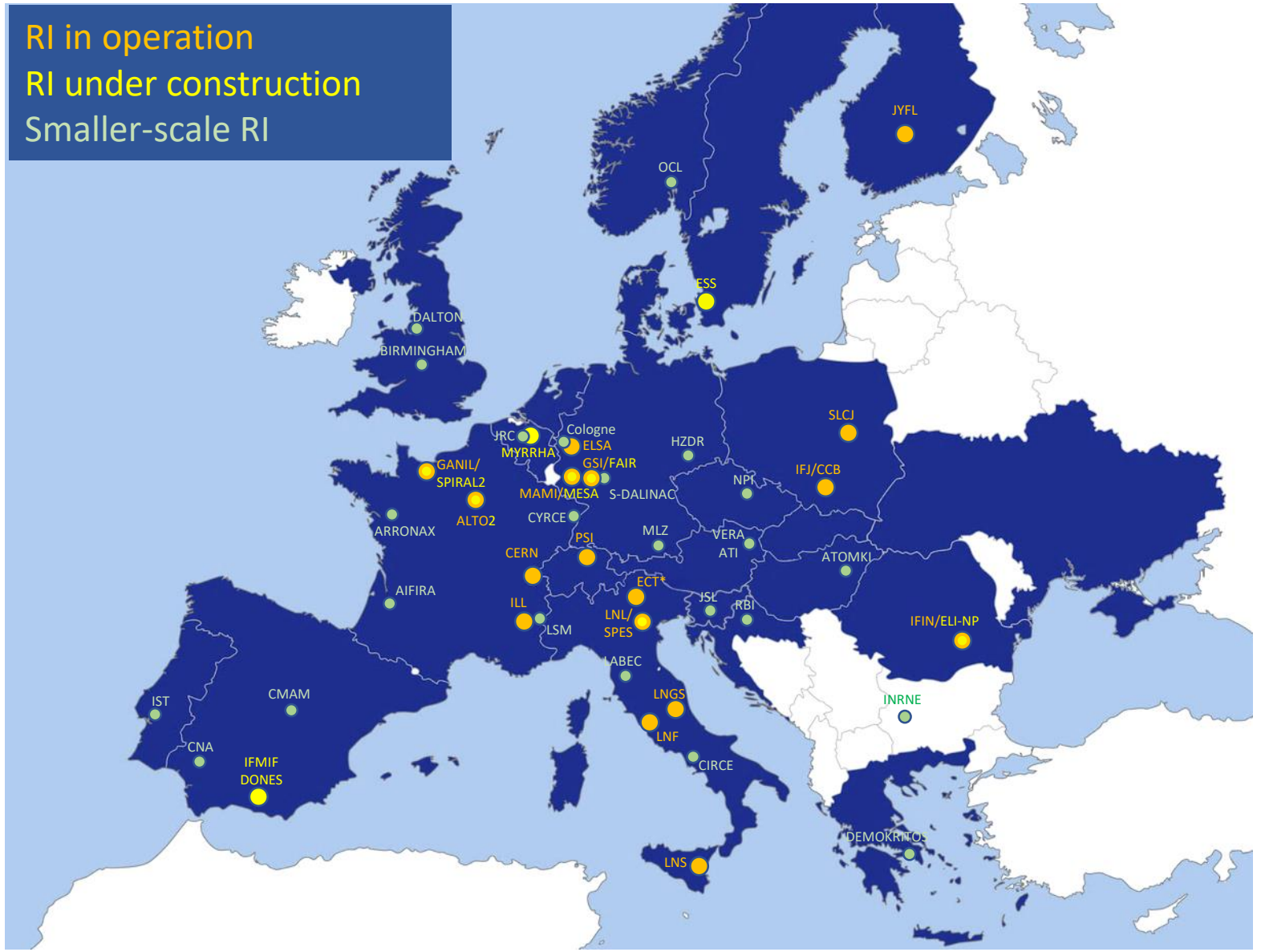


"Horia Hulubei" National Institute for R&D in Physics and Nuclear Engineering

Research infrastructure for fundamental nuclear physics **and** applications

Short term (<5 years) developments of the International laboratory of IFIN-HH

TANDEM Accelerators

9 MV upgrades:

- New injector system
- Beamline upgrade
- Dedicated set-up for proton irradiation and novel material

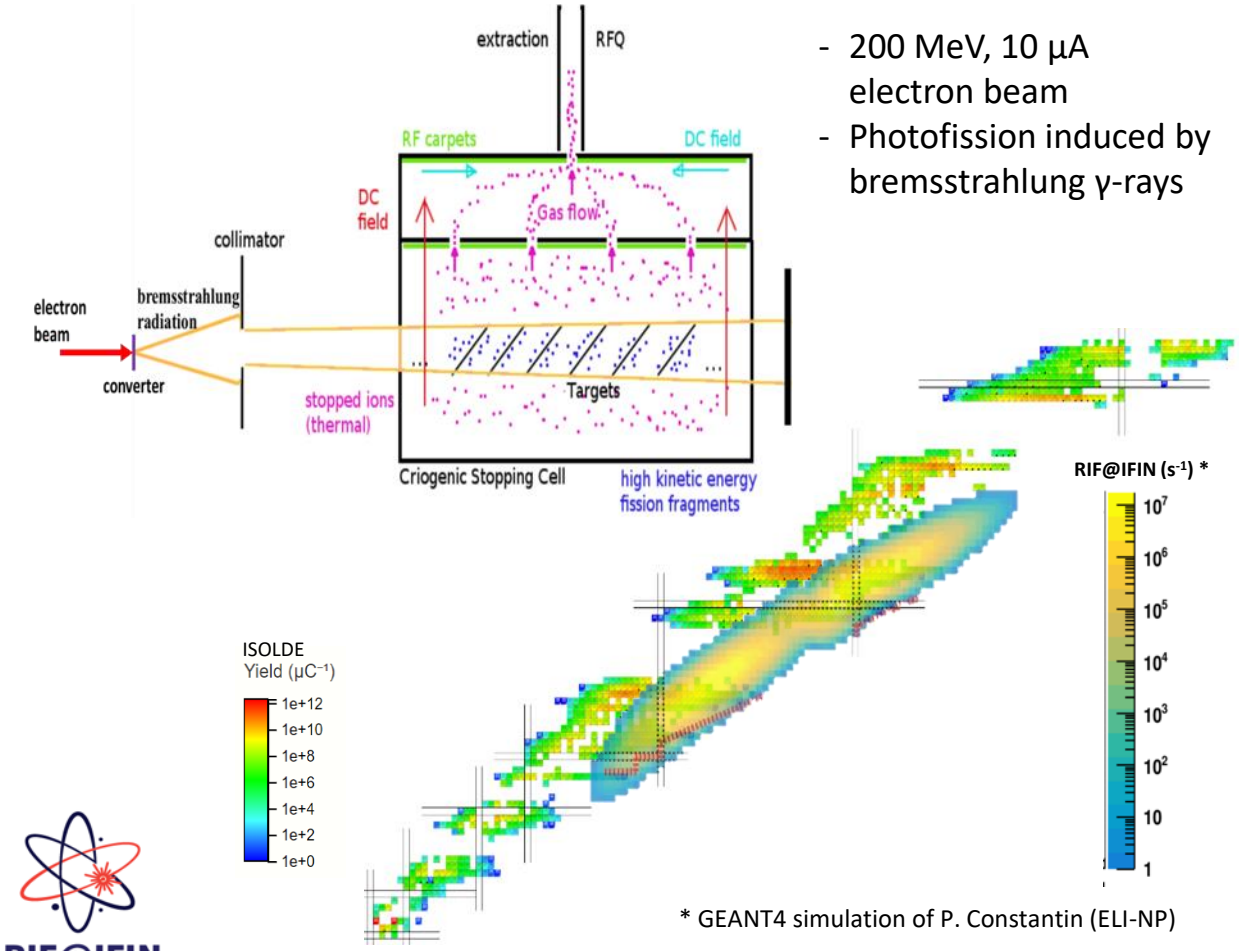
1 & 3 MV upgrades:

- Detection of nuclear polluting sources
- ^{10}B detection for nuclear decommissioning
- Time-of-Flight Elastic-Recoil-Detection Analysis

Medium-Long term (5-10 years and beyond)

Proposal for a Radioactive Ion Facility RIF@IFIN-HH

- 200 MeV, 10 μA electron beam
- Photofission induced by bremsstrahlung γ-rays



1. New fundamental research topics : **Nuclear spectroscopy with RIBs**
2. **Solid state physics with RIBs**
3. Production of **radioisotopes for medical research** (e.g: ^{47}Sc, ^{67}Cu)

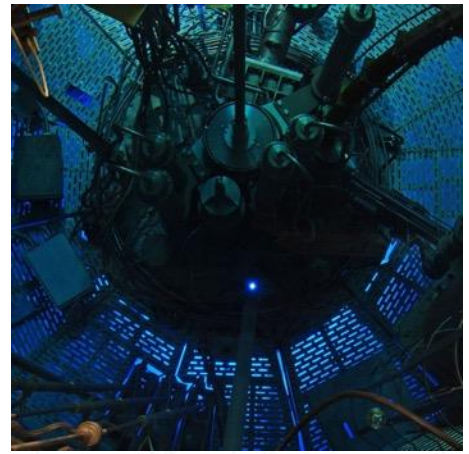
Institut Laue Langevin (ILL)

World-leading facility for thermal to ultra-cold neutrons

- User facility, priorities de facto driven by user proposals / LoI
- Strongest NP focus among all thermal/cold neutron facilities
- ENDURANCE upgrade project concluded
  - 42 instruments operating, 3 more to be commissioned,
  - “Harvest time”: optimum operation rather than new build

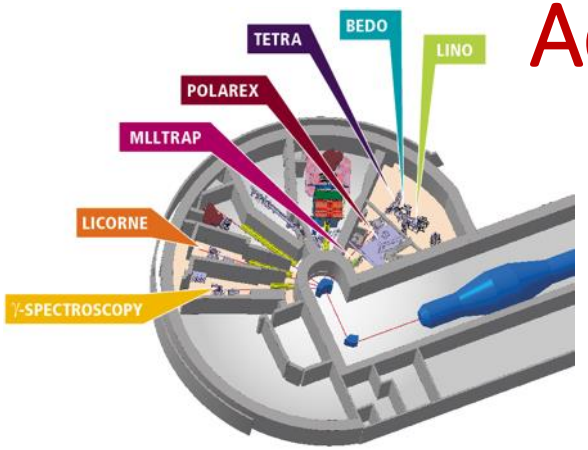
Specifically for Nuclear and Particle Physics (NPP):

- high flux irradiation position: increase of capacity and capability by additional beamtube and hot cell
- UCN: commissioning of SuperSUN and PanEDM (experiment)
- Coherent antineutrino scattering: RICOCHET (experiment)
- FIPPS: new beamline, more space, diamond detectors
- LOHENGRIN: nuclear moment measurement setup



IJCLAB/ALTO

Accélérateur Linéaire et Tandem à Orsay



https://alto.ijclab.in2p3.fr/

Short term < 5 years

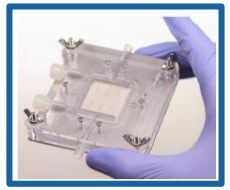
- **Sustainability & Reliability** : mainly for the RIB part, desired return of the R&D
- **Environment** : National and international landscape. Setting up a common strategy GANIL / SPIRAL2.

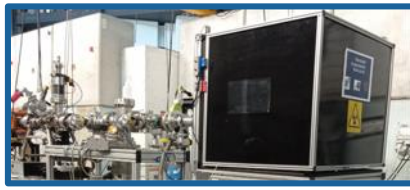
Medium term 5 – 10 years

- **Valorization** : Greater openness to industry and education. Dedicated chamber for irradiation with ions from protons to ^{197}Au. New features for the irradiation (bigger surfaces, long temperature range). Dosimetry system integrated.
- **Physics** : Clear definition of the physics program (low energy RIB and beams, nuclear reactions with the Tandem) for the next years.
- **Multidisciplinary :** Development of a **reference facility for hadron therapy** research at IJClab in collaboration with the IP2I and the LPSC.

Long term > 10 years

- **Physics :** Application of R&D on UC_x targets and molecular beams for production of new low energy RIB
- **Multidisciplinary** : Contribute to the network of irradiators on a national scale.





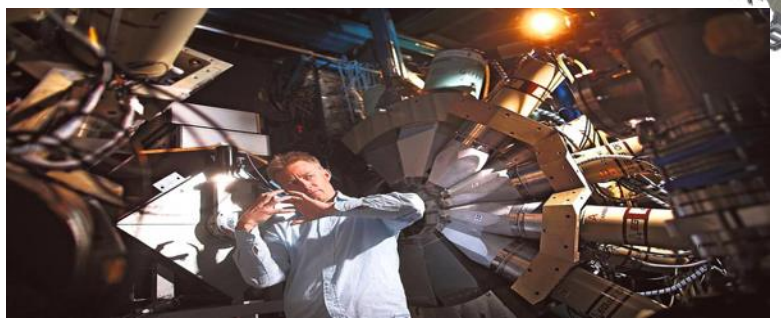
JYFL Accelerator Laboratory

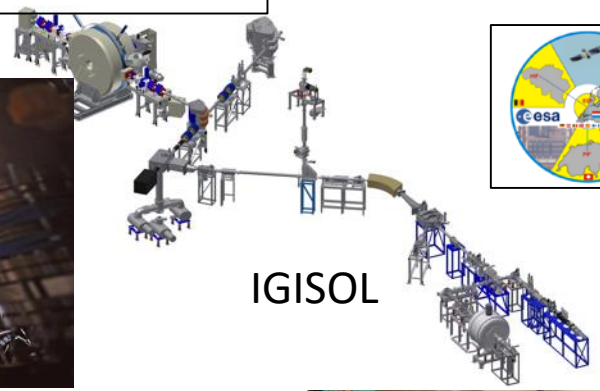
Short term < 5 years:

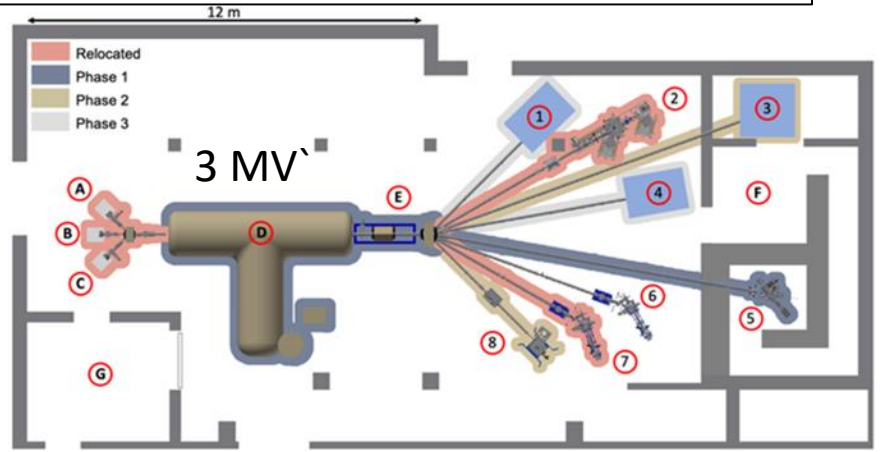
- Final commissioning of MCC30
- Commissioning of **MARA-LEB**
- Installation of 3 MV platform
- Expand radioisotope production
- Commercial services as contracted

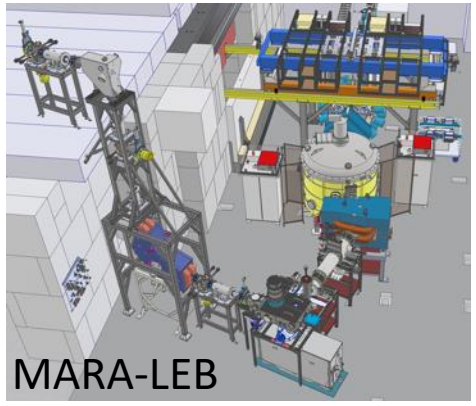
Medium term 5-10 years:

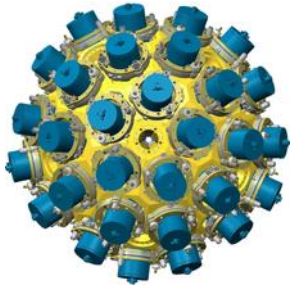
- Hosting AGATA ?
- K130: RF upgrade to solid state technology
- New beamlines for 3 MV platform (incl. neutrons)











Laboratori Nazionali del Gran Sasso

Future Plans at LNGS for Nuclear Astrophysics:

- Short term:
  - Exploit **LUNA-400** (H and He beams 50-400 keV) with on going studies on hydrogen and helium burning
  - **New 3.5 MV facility (H, He and C beams 0.3 - 3.5 MeV):** $^{14}N(p,\gamma)^{15}O$ and $^{22}Ne(\alpha,n)^{25}Mg$
- Medium term:
  - $^{12}C + ^{12}C$: nucleosynthesis and energy production in carbon burning.
    - New array of NaI detectors coupled to HPGe detector under construction
  - $^{13}C(\alpha,n)^{16}O$: neutron sources for the s-process (nucleosynthesis beyond Fe)
  - **Refurbishment of the LUNA-400 accelerator** to become part of the Bellotti Ion Beam Facility.
    - will allow to study reactions in a broad energy range (e.g. $^{14}N(p,\gamma)^{15}O$, $^{13}C(\alpha,n)^{16}O$, $^{10/11}B+\alpha$)
- Long term:
  - Study of $^{12}C(\alpha,\gamma)^{16}O$
    - New cutting-edge detectors to measure the total cross section with high detection efficiency needed

Laboratori Nazionali di Legnaro (LNL)

Medium-term plan

A new phased approach for the **SPES project** that will allow a timely delivery of the successive milestones of the project:

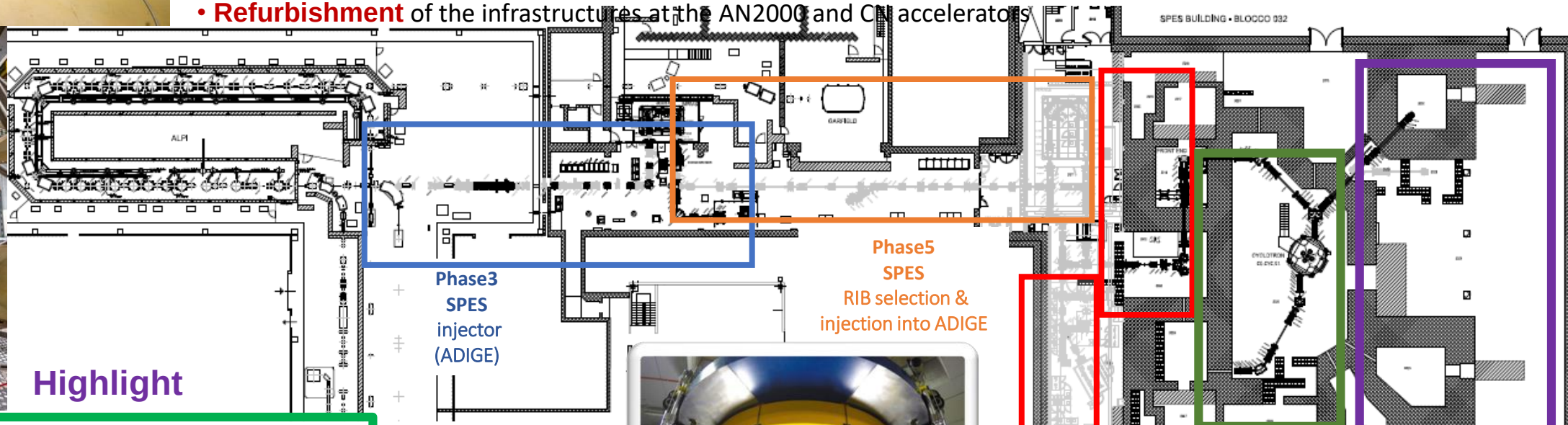
- Routine operation of the **SPES cyclotron**
- Commissioning of the **ISOL low-energy radioactive beams**
- Implement facility for **producing radionuclides** for medicine
- Complete the **ADIGE new injector** and **RFQ** for ALPI (replacing PIAVE)
- Commissioning of **post-accelerated radioactive beams**

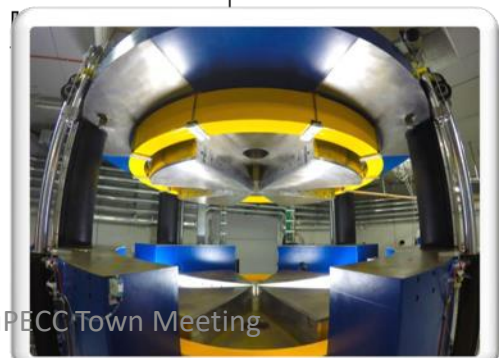
• Construction of New Data Centre to upgrade **AGATA DAQ infrastructure** and the upgrade of the **LNL Tier-2 Data Centre**

• **Refurbishment** of the infrastructures at the AN2000 and CN accelerators

Highlight

AGATA campaign at LNL (since April 2022)
28 + 3 (commissioning) experiments performed
>5300 hours beam on target for AGATA



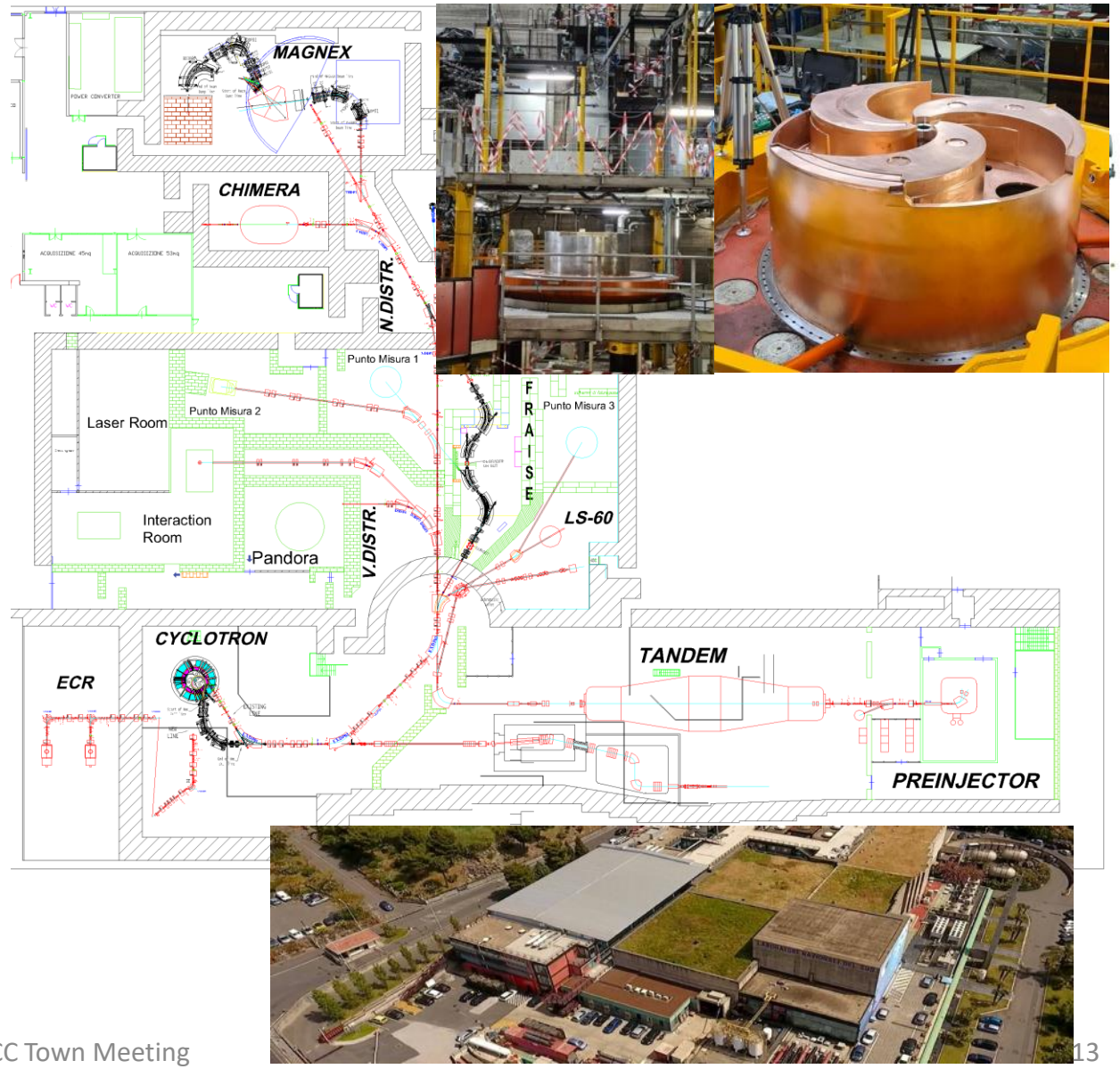


Laboratori Nazionali di Sud (LNS)

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud

Medium-term plan of LNS :

- Upgrade of the K800 superconducting cyclotron (POTLNS phase): Intensity increase through new beam extraction by charge-state stripping.
- Complete **FRAISE**, the new fragment separator for radioactive beams.
- Exploit the **PANDORA** and **NUMEN** experiments concerning studies in nuclear structure, astrophysics and fundamental interactions.
- Updates and upgrades of the Tandem accelerator and the experimental facilities.
- Installation of a **high-power laser** for medical physics as basis for **I-LUCE** and exploit its opportunities for Nuclear Physics experiments, Industrial applications and Material studies.



National Laboratory of Cyclotrons (NLC)

- a two-center facility in Poland

Cyclotron Center Bronowice IFJ PAN Kraków

Proteus C-235 cyclotron
protons 70-230 MeV

AIC-144 cyclotron
protons 60 MeV

Research program

- gamma decay of giant resonances and other states in the continuum via (p,p') reaction
- dynamics of few-nucleon systems
- in-beam testing of detectors
- irradiations with high-intensity protons
- investigations of the clinical efficacy of proton therapy for selected tumours

Upgrade plans

- polarized He-3 targets
- upgrade of BINA detector (proton polarization measurements)
- new fully digital DAQ system
- fully automatized scanning table for irradiation purposes
- new irradiation lines for testing the FLASH irradiation technique

Heavy Ion Laboratory Univ. of Warsaw

U-200P cyclotron
beams: B to Ar; 2-10 MeV/A

PETrace cyclotron
***p* 16 Mev; *d* 8 MeV**

Research program

- nuclear structure using Coulomb excitation
- nuclear reaction studies (Coulomb barrier distribution)
- radiobiology
- radioisotopes production
- particle detectors development and testing

Upgrade plans

- development of heavier beams toward nickel
- construction of a vertical beam facility for radiobiology
- capillary line connecting the PETrace and U-200P cyclotrons to accelerate radioactive, short-lived isotopes

Paul Scherrer Institute

Projects & facilities:

- **IMPACT**: realise HIMB (first beam 2028) and TATTOOS (first beam 2030)
- **UCN**: replacement of central solid deuterium unit to provide reliable and improved user operation
- **SINQ**: feasibility study “North Guide Hall”
- Proton Irradiation Facility and other test beam options

HIPA proton accelerator:

- Upgrade of RF cavity 5 in ring cyclotron
- Infrastructure refurbishment

Experiments:

- Successful measurements by ongoing experiments **MEG-II, Mu3e, n2EDM**
- Upcoming experiments **muEDM** and **PIONEER**
- Active experimental program with direct nuclear physics implications: **HyperMu, muX, QUARTET, MONUMENT/OMC4DBD**

R&D efforts in detectors and electronics

IMPACT project: Isotope and Muon Production using Advanced Cyclotron and Target technologies

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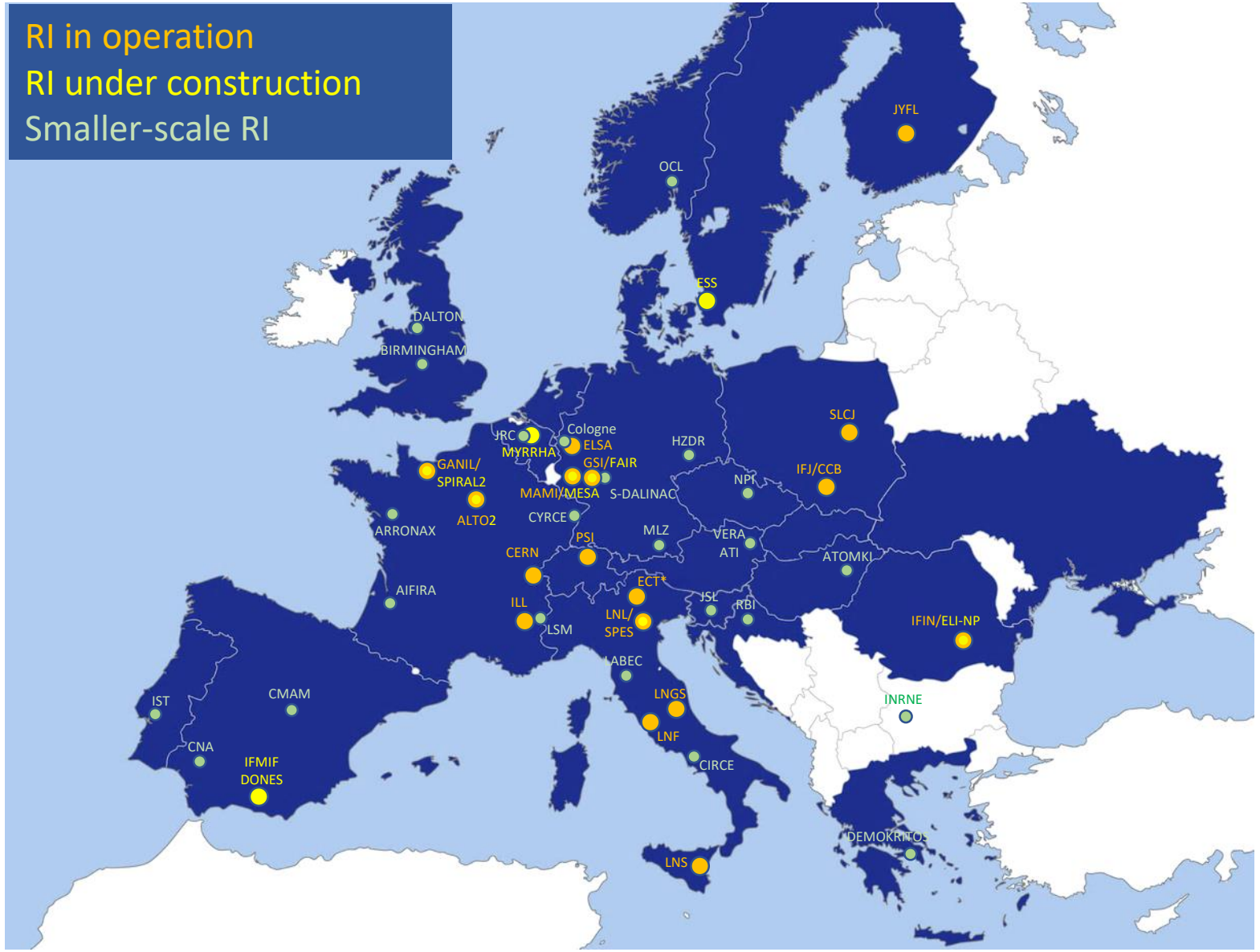
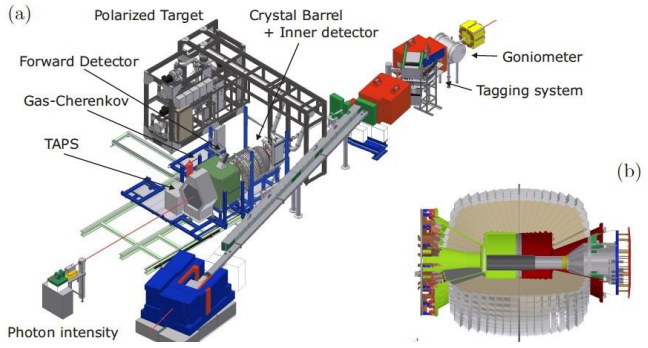


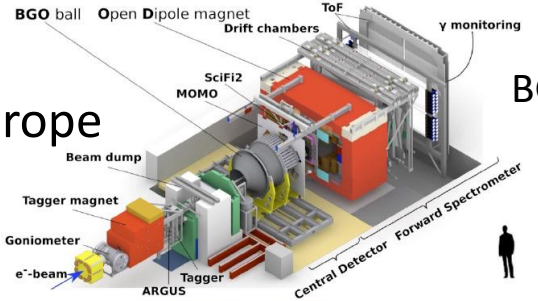
Electron Stretcher Accelerator (U. Bonn)

3.2 GeV electron accelerator ELSA, Bonn

University Accelerator with the highest energy in Europe

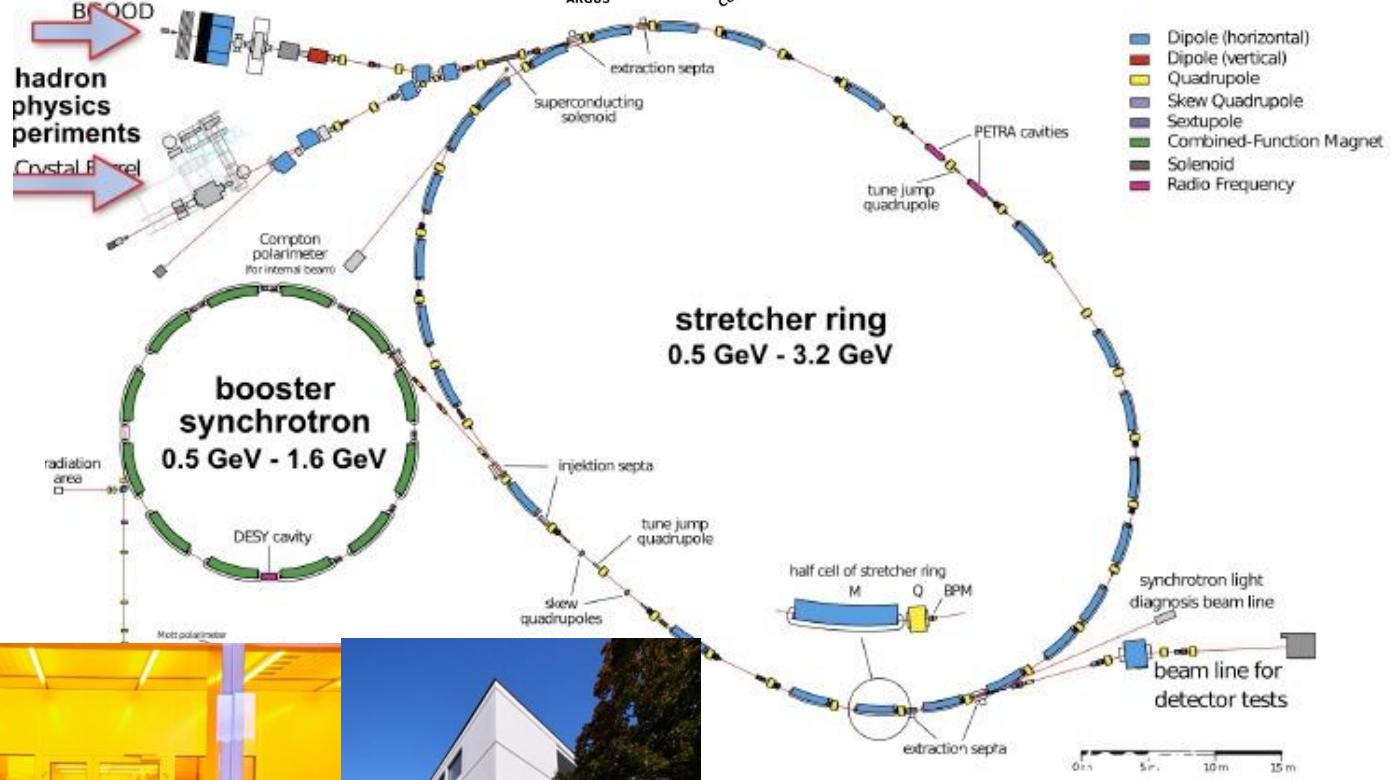
CBELSA





BGO-OD

Polarised beam
Polarised target



Plans and priorities:

- Provide high-energy **tagged photon beam**
- Exploit hadron physics experiments BGO-OD & CBELSA
- Major upgrades and hadron physics program with **polarized electron beams**
- New center for detector physics (FTD) Test beam for detector development
- New irradiation station with dose rates up to 40 MGy/s using E=1.2 GeV e^-

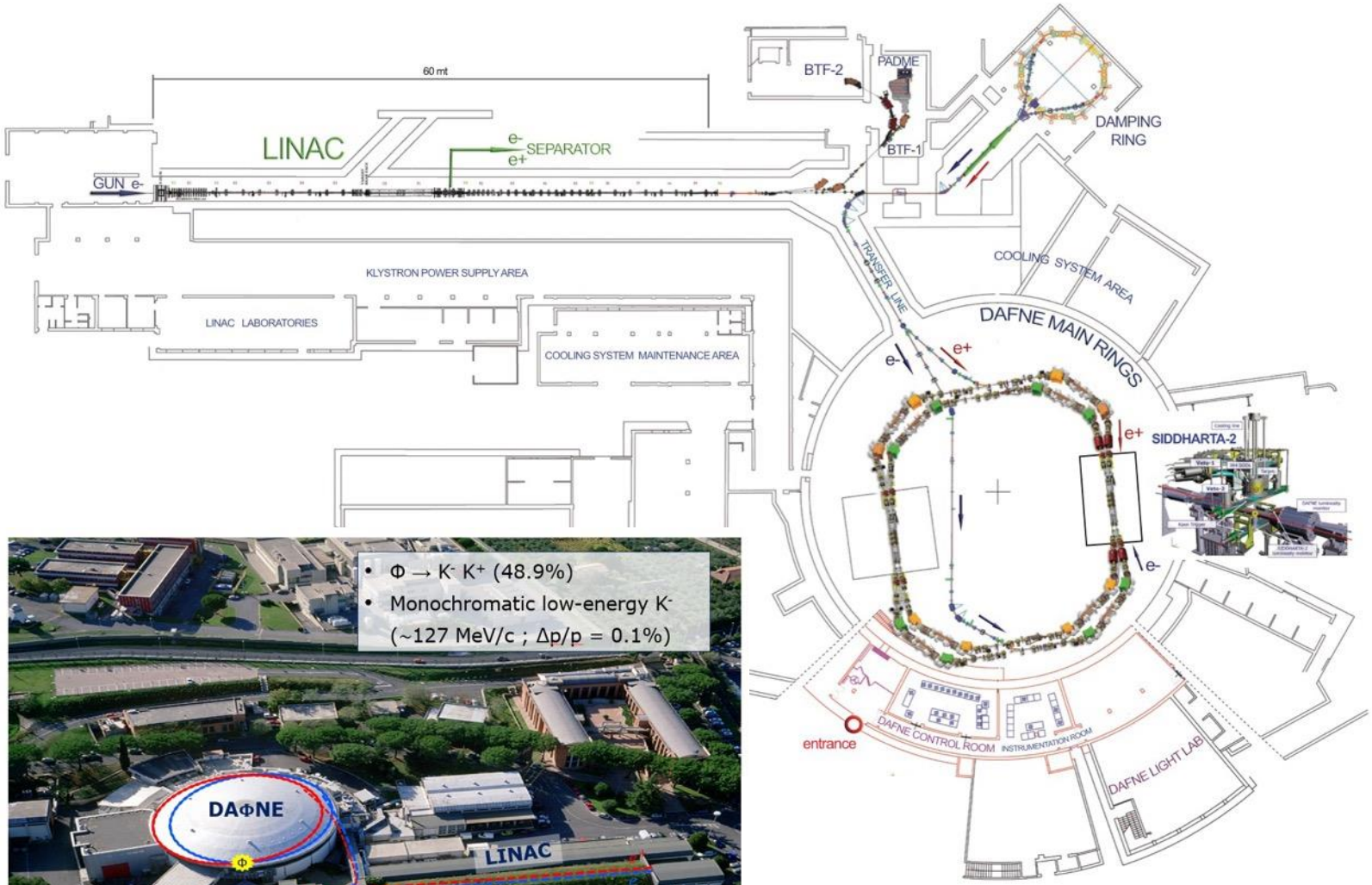
FTD

Laboratori Nationali di Frascati (LNF)

DAΦNE: electron-positron collider could be maintained as **synchrotron radiation** facility

SIDDHARTA-2 will complete the first measurement of **kaonic deuterium** X-ray transitions

SPARC_LAB: High-brightness electron beam driving a free electron laser for **plasma-wave-based acceleration** as seed for the new infrastructure **EUPRAXIA**



MAMI Electron Accelerator (U. Mainz)

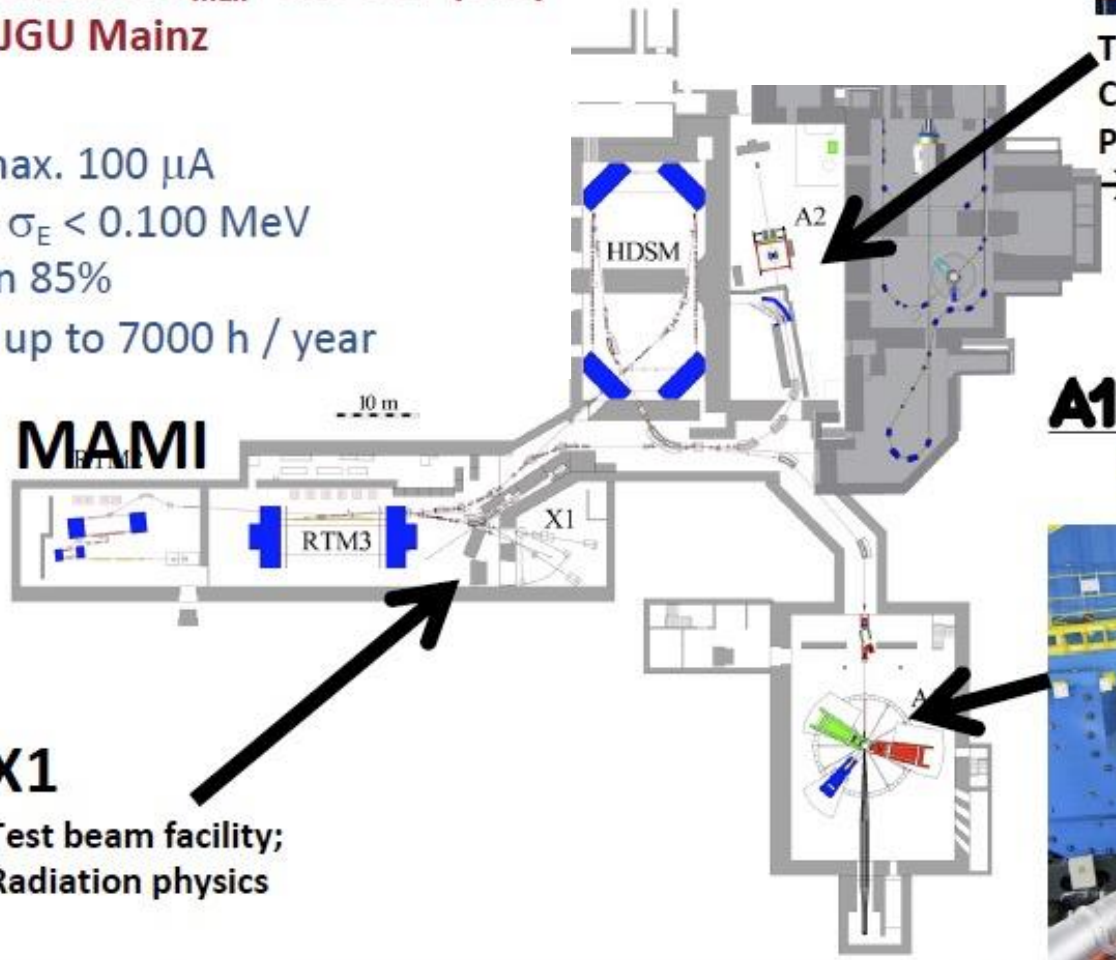
Plans and priorities:

- Major hadron physics program with **polarized electron beams**
- Parity violating nuclear physics program
- Upgrade of instruments
- Test bench for MESA

Electron Accelerator E_{max} =1.6 GeV (CW) operated at JGU Mainz

Hallmarks

- Intensity max. 100 µA
- Resolution σ_E < 0.100 MeV
- Polarization 85%
- Reliability: up to 7000 h / year



Tagged Photon Scattering (A2 hall)
Crystal Ball / TAPS calorimeters;
Polarized frozen-spin target
→ currently at Univ. Bonn

Electron scattering (A1 hall)
High resolution Magnetic spectrometers

X1
Test beam facility;
Radiation physics

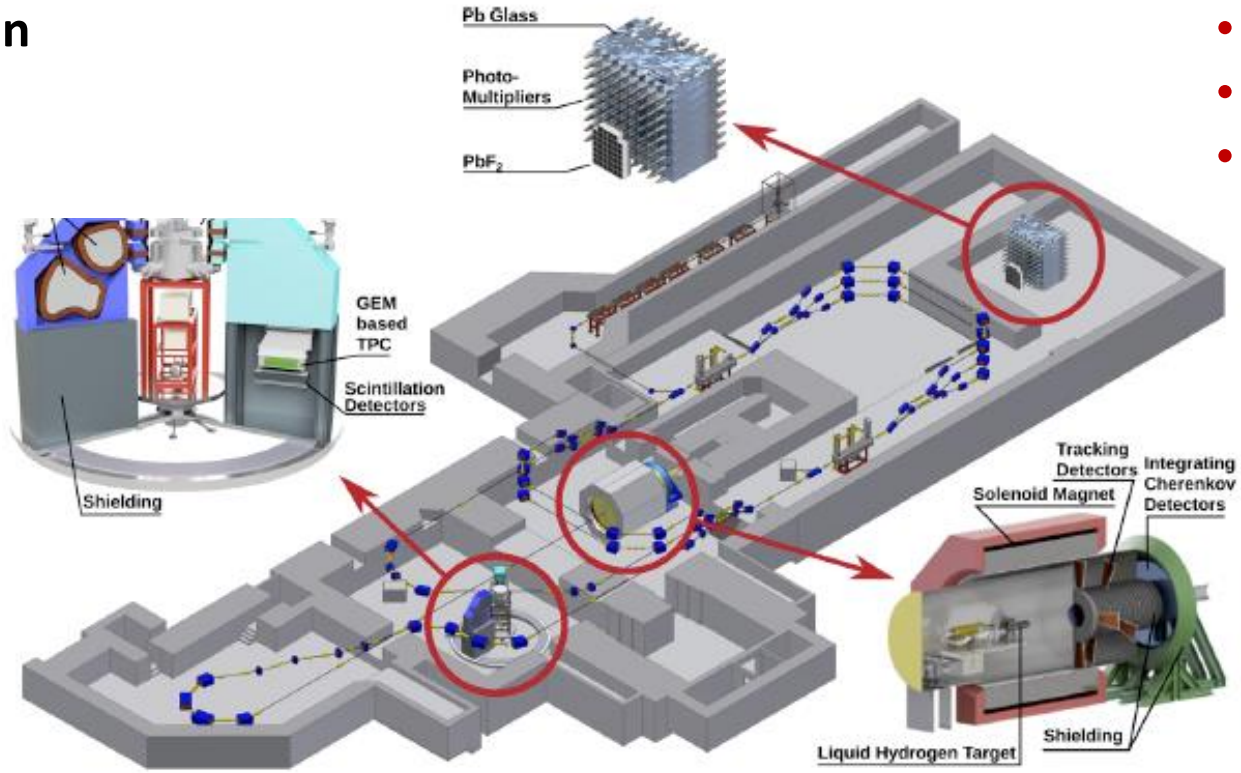
PRISMA+

MESA - Mainz Energy-recovering Superconducting Accelerator

MESA
Mainz
Energy-recovering
Superconducting
Accelerator

Plans and priorities:

- New accelerator installation
- First and **only ERL operation** for physics experiments
- Start of operation in 2025
- Major physics program in hadron- nuclear, particle- , and Astrophysics
- Planned upgrade to 10 mA electron current



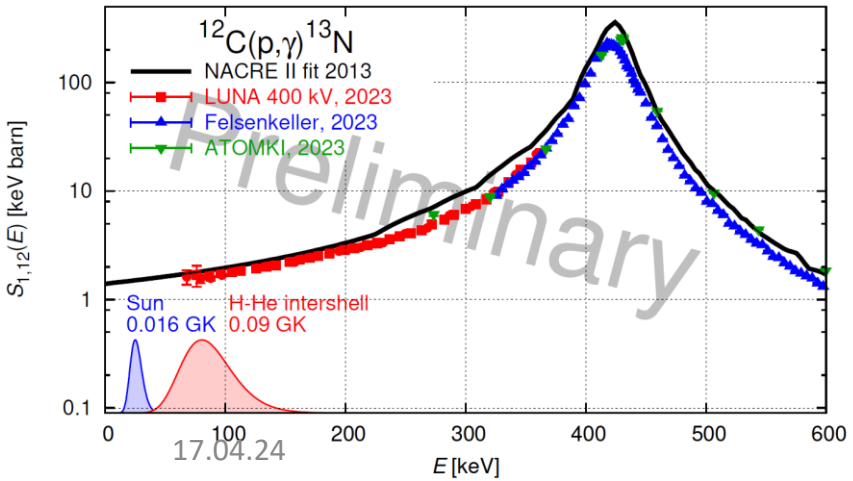
Planned experiments:

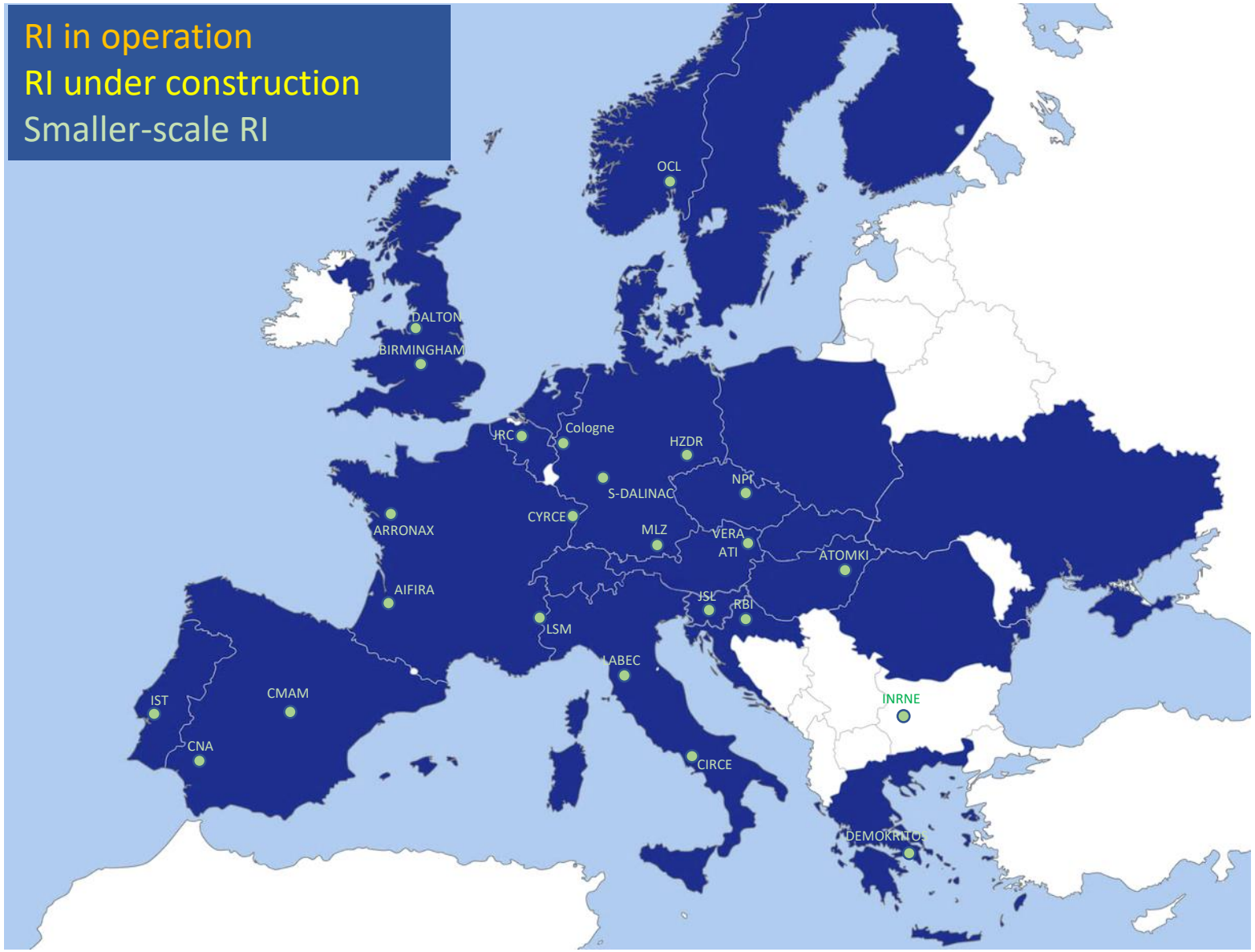
- **MAGIX** (ERL mode)
- **Dark MESA** (beam dump)
- **P2** (extracted beam mode)

Small(er)-Scale Research Infrastructures

Importance for the community:

- Often act as national facilities and provide local community with training opportunities
- Widely spread in many countries
- Low(er) investment/running costs
- Possibility of long(er) experiments
- Fast response for industrial demands
- Open access based on scientific excellence with program committees and TNAs
- Combination of different beams/techniques

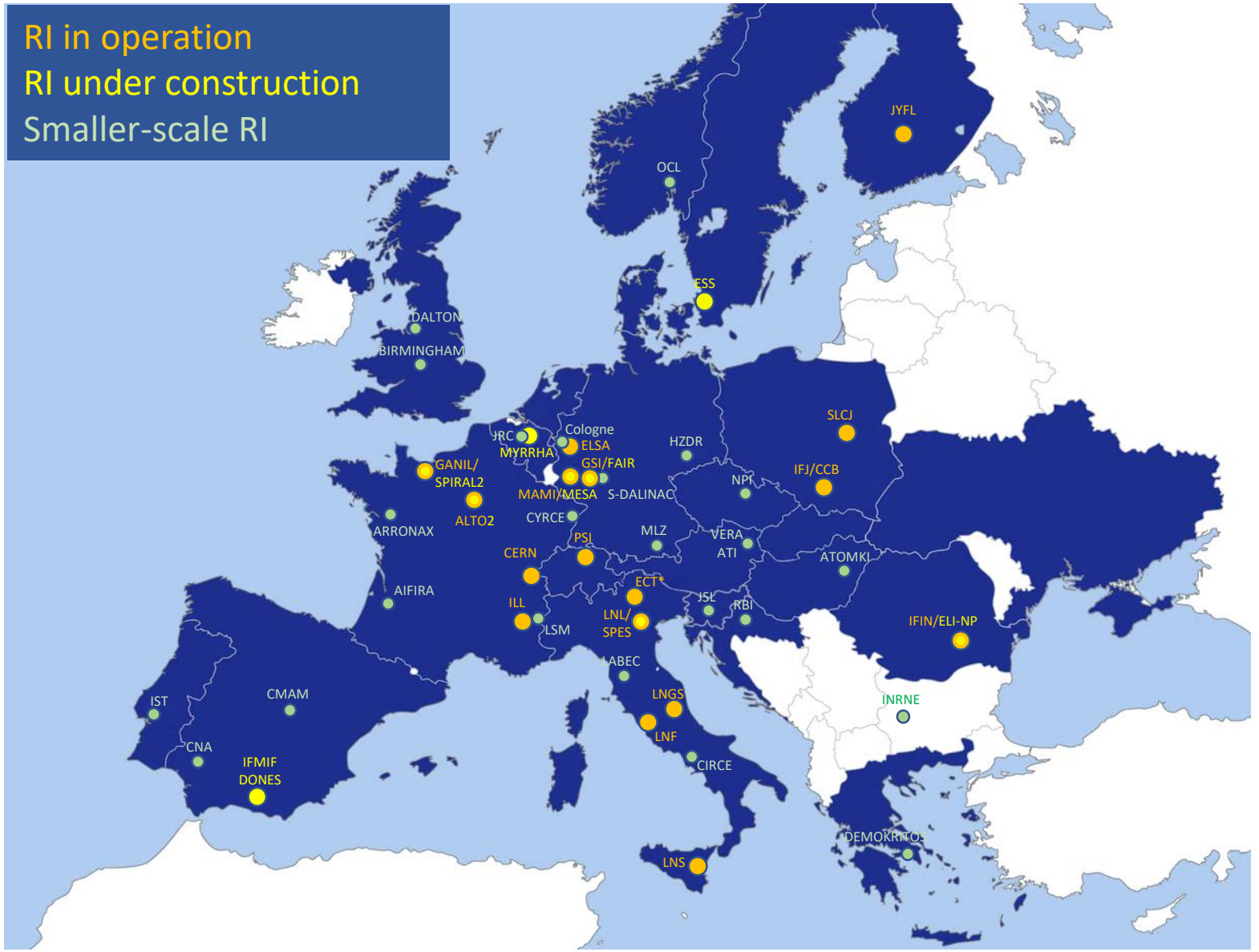




Research Infrastructures in the NuPECC LRP 2024

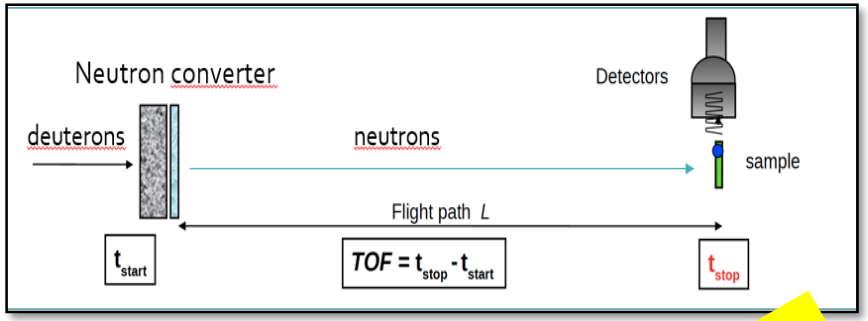
Outline

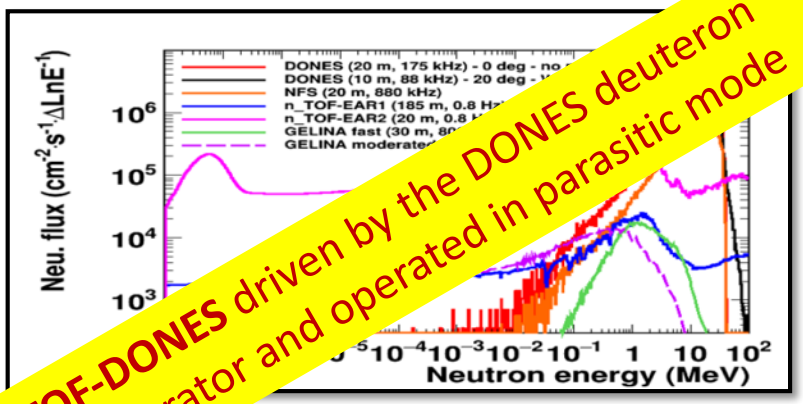
- Introduction to the TWG on RIs
- ESFRI facilities and CERN
- Large-scale facilities
  - Hadron and Heavy Ion Facilities
  - Lepton and Photon Facilities
- Small-scale facilities
- **New facilities in Europe**
- **Facilities outside of Europe**



New facilities in Europe

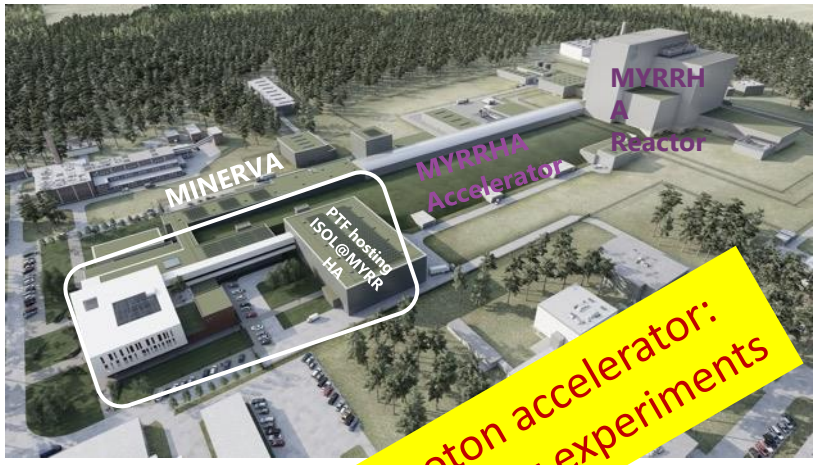
IFMIF-DONES & TOF DONES

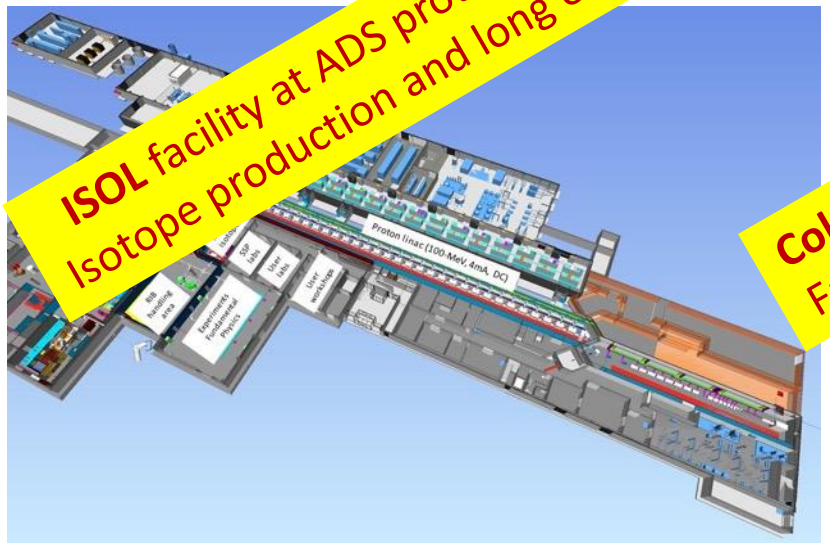




TOF-DONES driven by the DONES deuteron accelerator and operated in parasitic mode

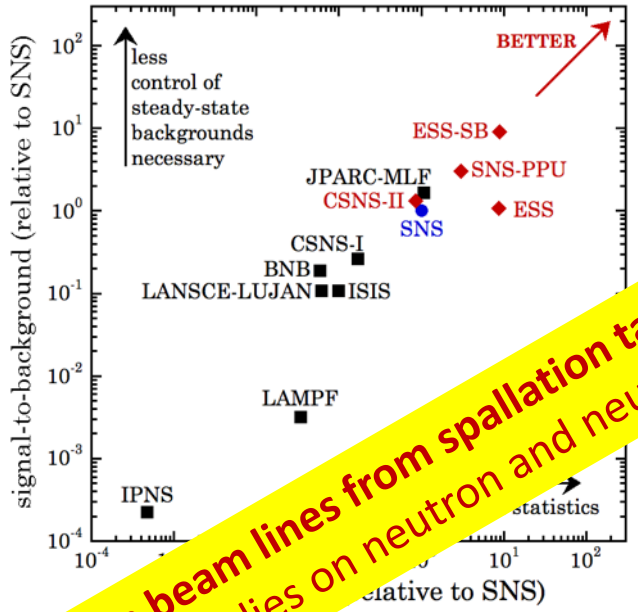
ISOL@MYRRHA





ISOL facility at ADS proton accelerator: Isotope production and long experiments

ESS



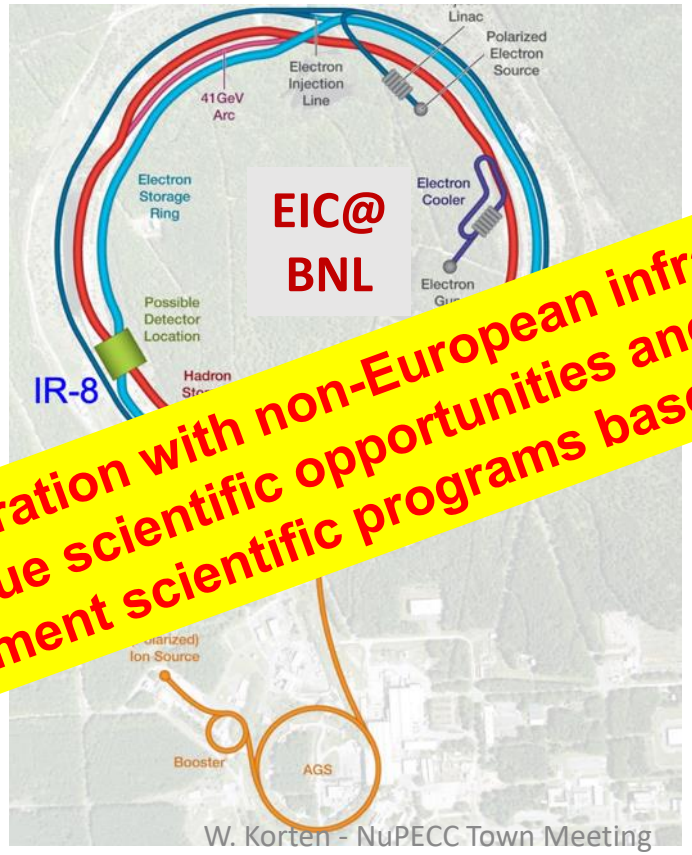
Cold neutron beam lines from spallation target Fundamental studies on neutron and neutrinos

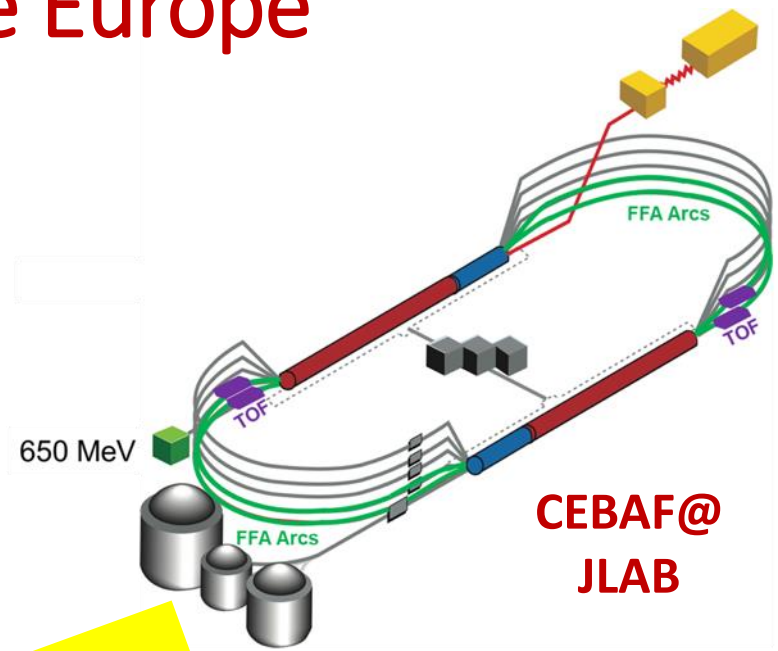
See the supplementary slides for details

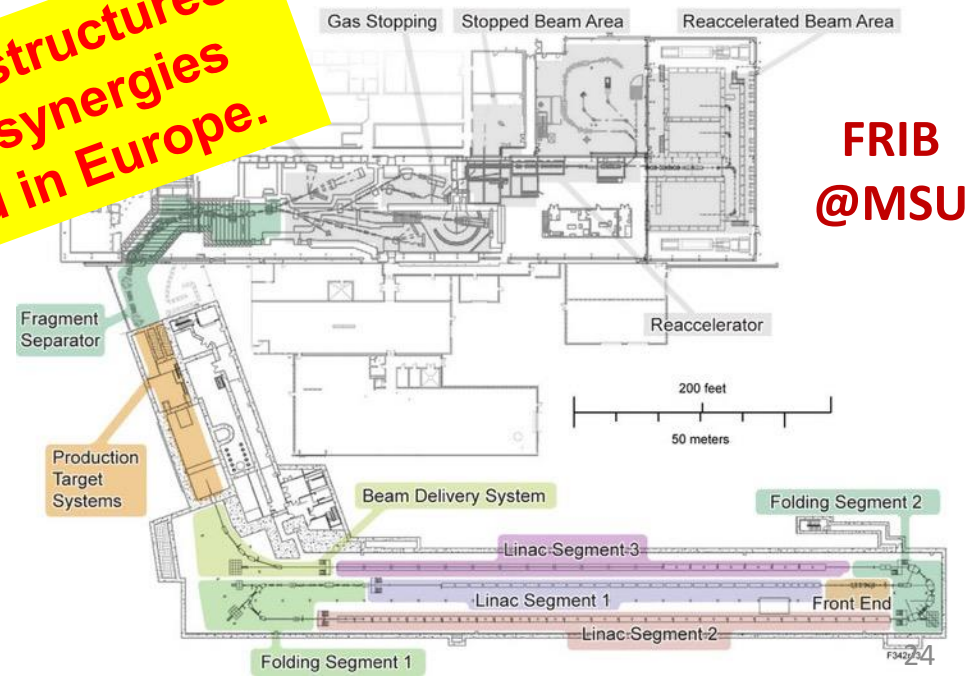
Research Infrastructures outside Europe

Criteria for inclusion

- Complementarity with facilities in Europe or additional capabilities
- Strong interest and contributions to experiments from European research groups (or contribution to LRP call)
- CEBAF@JLAB, EIC@BNL, FRIB@MSU, ISAC@TRIUMF, RIBF@RIKEN





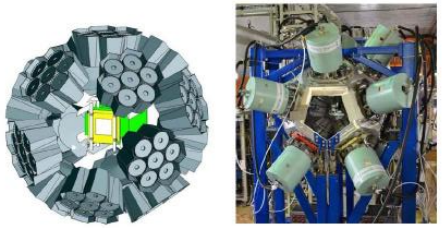


Foster collaboration with non-European infrastructures to seize unique scientific opportunities and synergies that complement scientific programs based in Europe.

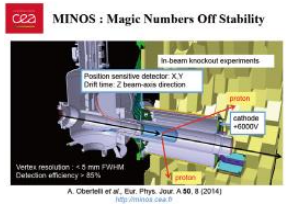
RIBF at RIKEN

Large-Size International Collaborations

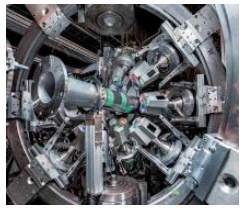
EURICA (2011-2016):
EUroball-RIKEN Cluster Array



SEASTAR (2014-2017):
thick liq. H2 +TPC+NaI
for in-beam gamma spectroscopy

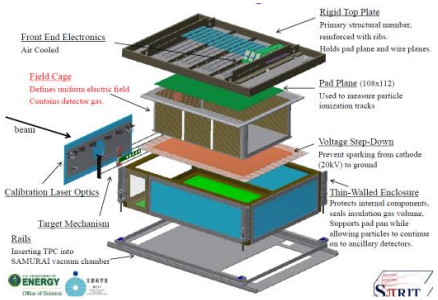


HiCARI (2019-2020):
Tracking Ge detectors
for in-beam gamma spectroscopy

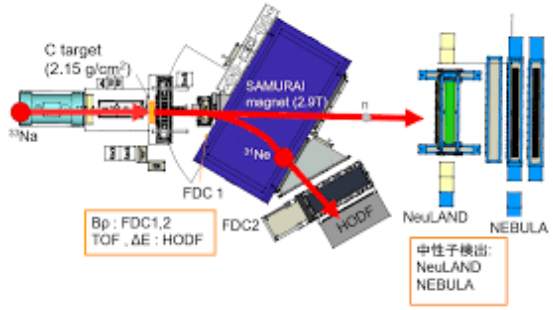


BRIKEN(2017-2021):
He-3 detector array for beta-delayed neutron

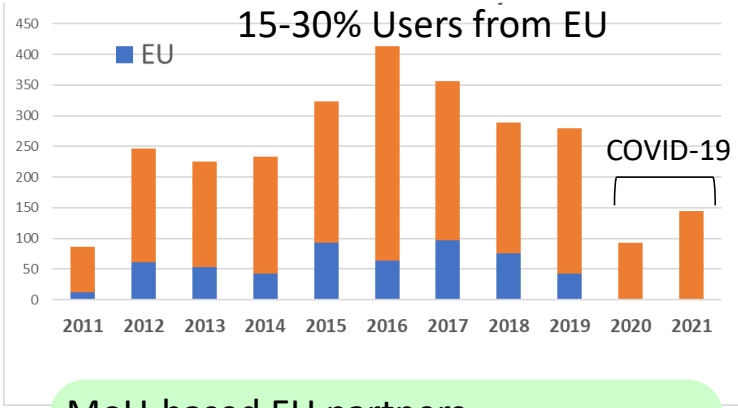
SpiRIT TPC (2015-):
heavy-ion collision program for EOS



SAMURAI (2012-):
neutron detectors + CsI+…
for neutron correlation



The number of users at the new facility



MoU-based EU partners

- ENSAR2 -> EURO-Labs ECT*
- ATOMKI
- CNRS CEA Normandy Univ
- PSI
- GSI/FAIR TU Darmstadt
- U Oslo
- ENEA
- U Jyvaskyla
- IFJ PAN
- U Bucharest