Letter of Intent
ALFA: AcceLerator FAcilities for Hadron and Nuclear Physics

HORIZON-INFRA-2025-01-SERV-03: Research infrastructure services advancing frontier knowledge

- *"Area 2: Physical sciences and engineering: hadron physics.*

For Area 2, proposers should fully exploit transversal links to and identify common developments with neighbouring communities within the field of particle and nuclear physics building on the work of recent Horizon projects where applicable."

Marek Lewitowicz, GANIL, France

On behalf of the participating nuclear physics infrastructures

Nantes Town Meeting 1-3 July 2025

Research Objectives

To address contemporary issues and open questions in **Hadron and Nuclear Physics**, we propose

a network of accelerator and other facilities offering physical Transnational Access for provision of services and instrumentation to carry out leading-edge research

- *Hadron and Nuclear Physics communities are naturally linked within the scope of **NuPECC** and the scientific objectives outlined in the **Long Range Plan for Nuclear Physics in Europe**.*
- *The core areas of Hadron Physics (Hadron Spectroscopy, Structure and Interactions) are paralleled in Nuclear Structure and Spectroscopy and Nuclear Reactions.*
- *A wide variety of probes and facilities are employed in parallel to understand the phenomena in question.*

Selected Research Topics

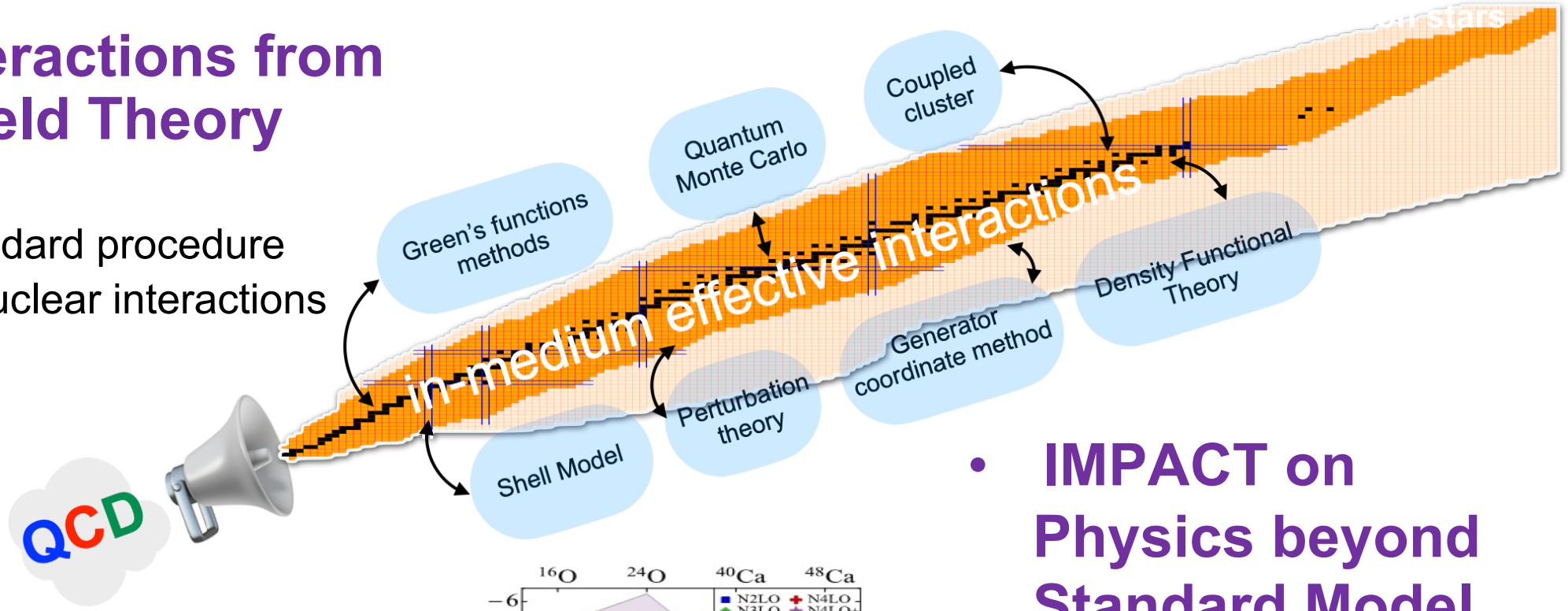
- Nucleon-nucleon, nucleon-hyperon, nucleus-neutrino, three-body interactions
- Equation of State of nuclear matter
- Nuclear charge and matter radii
- Nuclear clustering phenomena
- Nuclear shapes and deformation determined through complementary methods
- Precision experiments in the search for BSM physics

Facilities Network

FAIR/GSI (ESFRI)
GANIL-SPIRAL2 (ESFRI)
ELI-NP / IFIN-HH (ESFRI)
CERN – ISOLDE and n-TOF
INFN – LNL and LNS
IN2P3 – IJCLab infrastructures
JYFL-ACCLAB
NLC Consortium - HIL Warsaw, IFJ/CCB Krakow
Consortium Group – IABA (CNA Seville/CMAM Madrid), ATOMKI Debrecen, IST Lisbon
ECT*

• Nuclear Interactions from Effective Field Theory

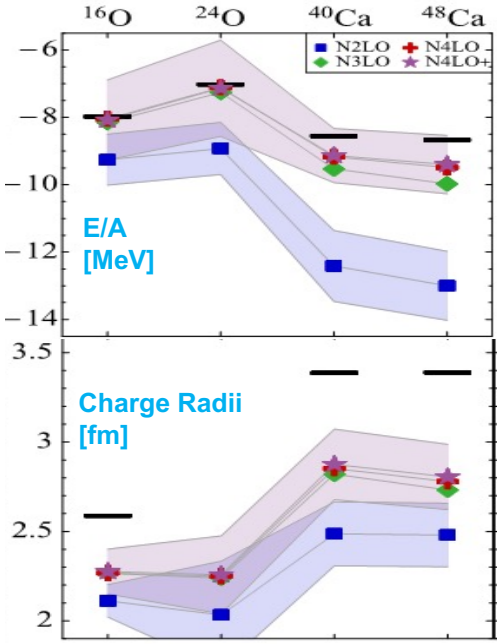
Chiral-EFT is the standard procedure to produce effective nuclear interactions inspired by **QCD**



• Binding Energies, Charge Radii, E/M moments, γ and particle decays, reactions, ...

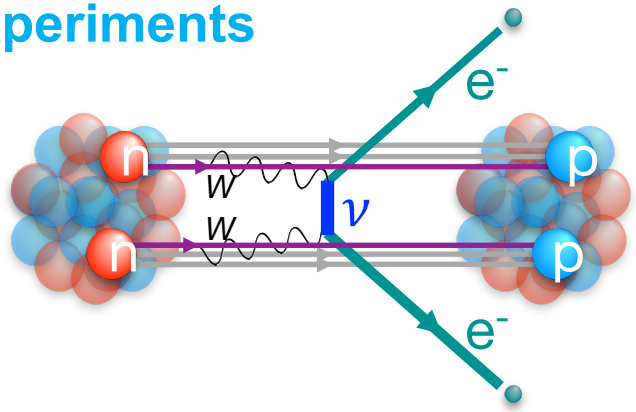
Multi-observable approach

to test most rigorous theory predictions moving into exotic regions of nuclear chart



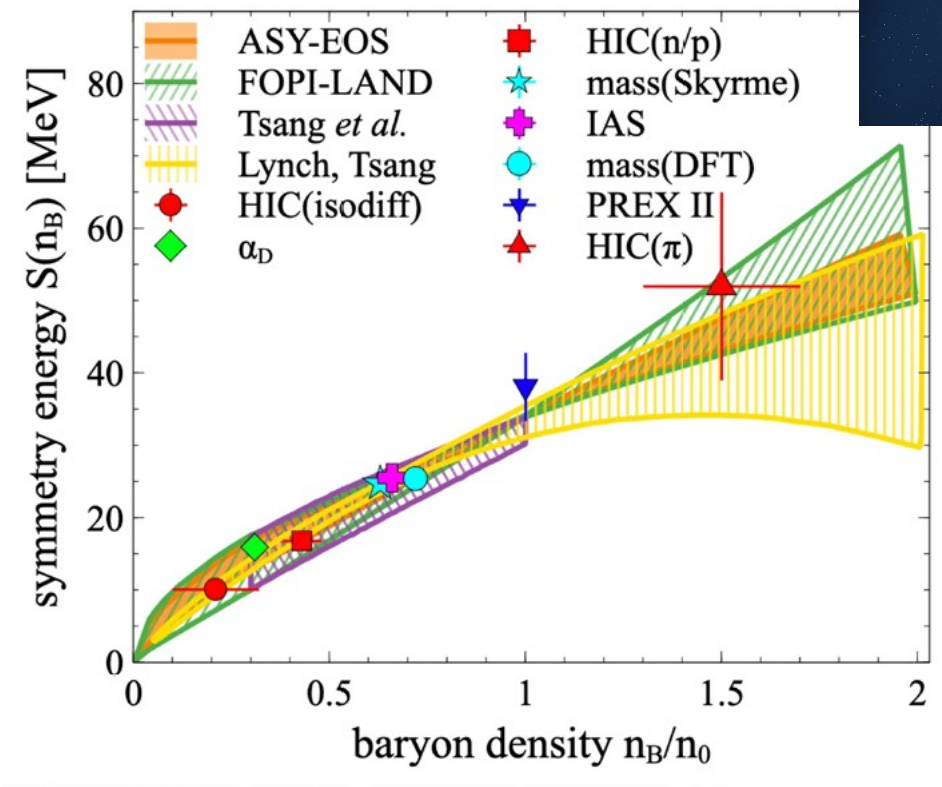
• IMPACT on Physics beyond Standard Model

Precision β decay experiments



Figures from Long Range Plan 2024

- **Equation of state of nuclear matter**



Symmetry energy as a function of the baryonic density extracted from ***heavy ion collisions experiments at low and intermediate energies***

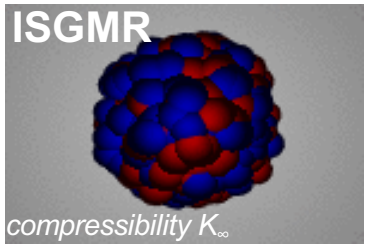
A.Sorensen, et al. Prog. Part. Nucl. Phys. 134(2024)104080

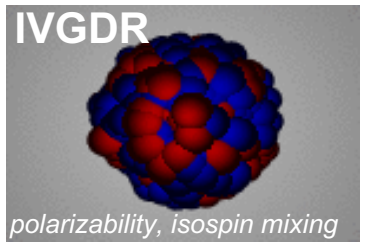
Figure from Long Range Plan2024

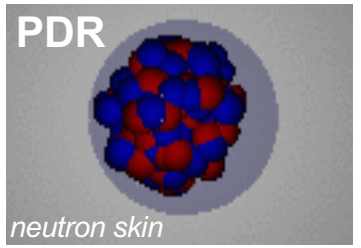
- **Matter radii and compressibility**

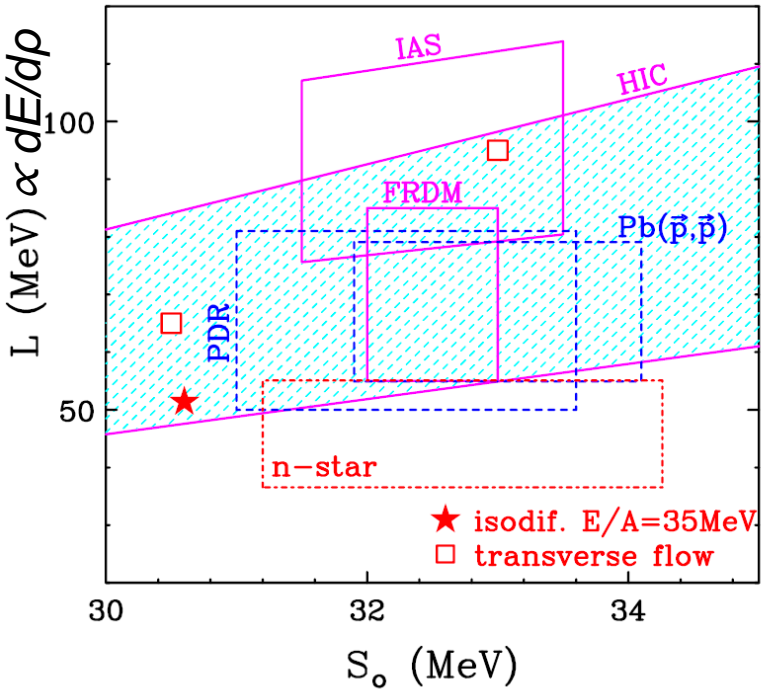
complementary information from Giant and Pygmy resonance studies:

monopole (ISGMR), dipole (IVGDR), pygmy (PDR)









Relevant for

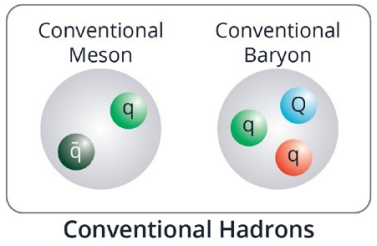
- *neutron skin*
- *neutron stars*
- *r-process nucleosynthesis*

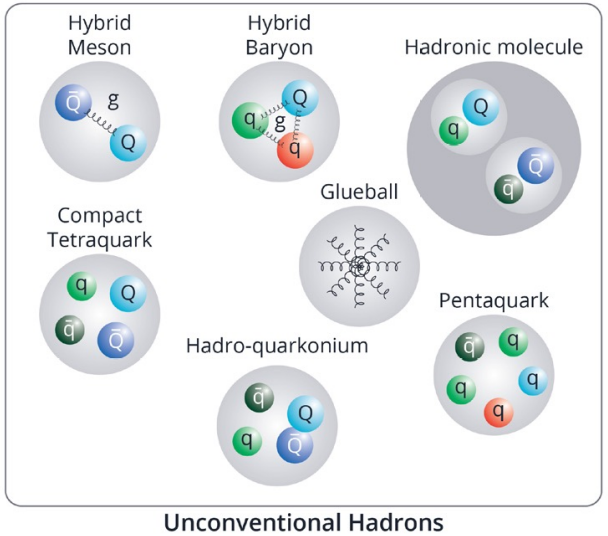
B. Tsang et al., Phys. Rev. C 86(2012)015803

• Few-body Systems and Clustering in Hadrons and Nuclei

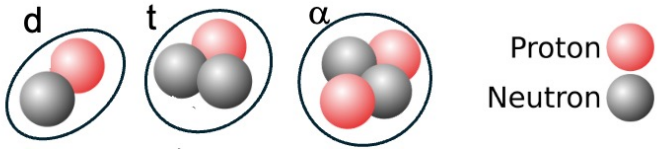
Similar ideas and methods
for the study of the two systems

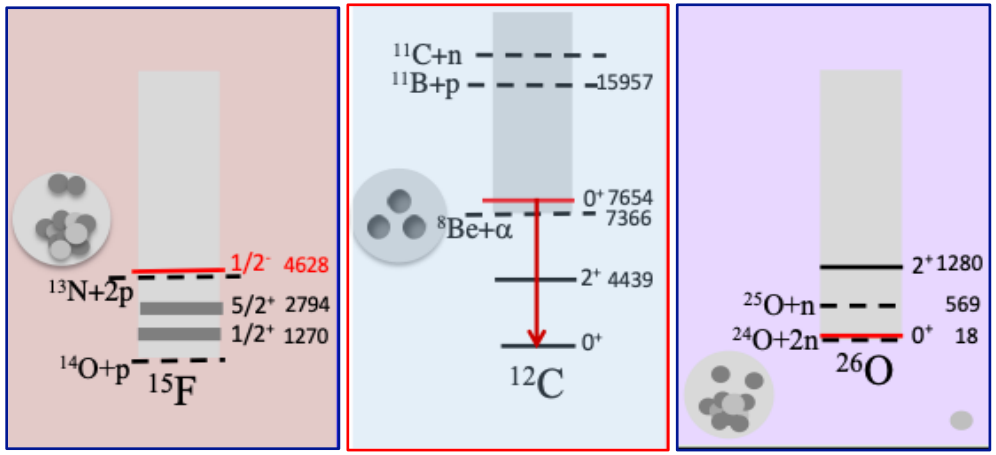
in Hadrons:
quark clusters





in Nuclei:
n, p, d, t, α, ... clusters



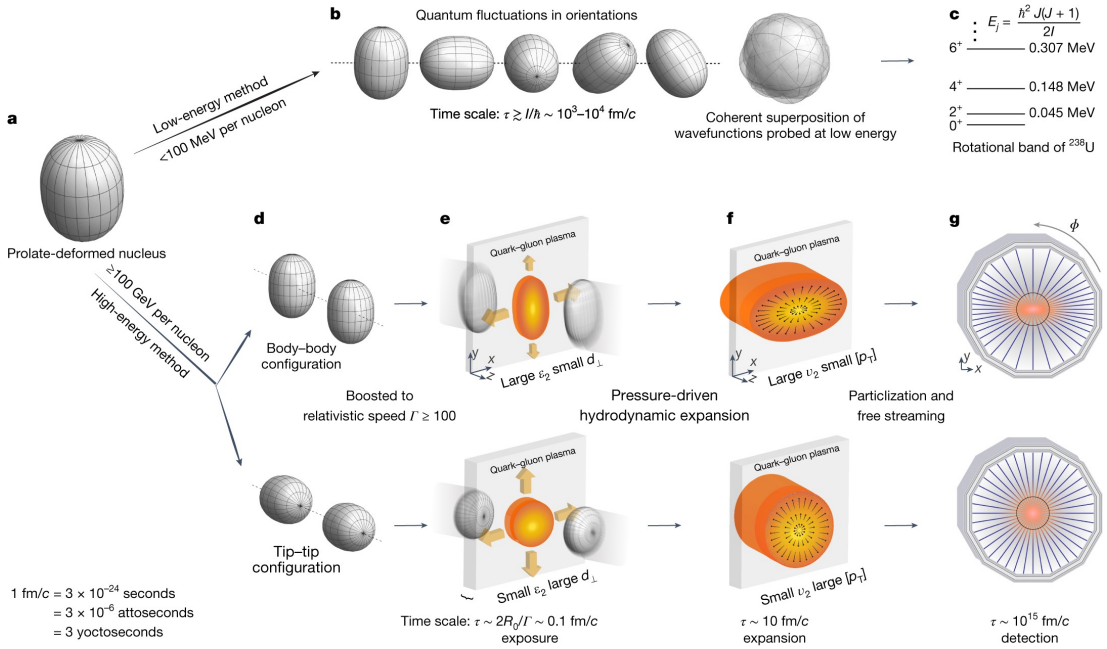


Figures from Long Range Plan 2024

• Nuclear Shapes and Deformation

Different shapes emerge because of the nuclear interactions; evolution along isotopic chains; strong benchmark for theory; complementary methods

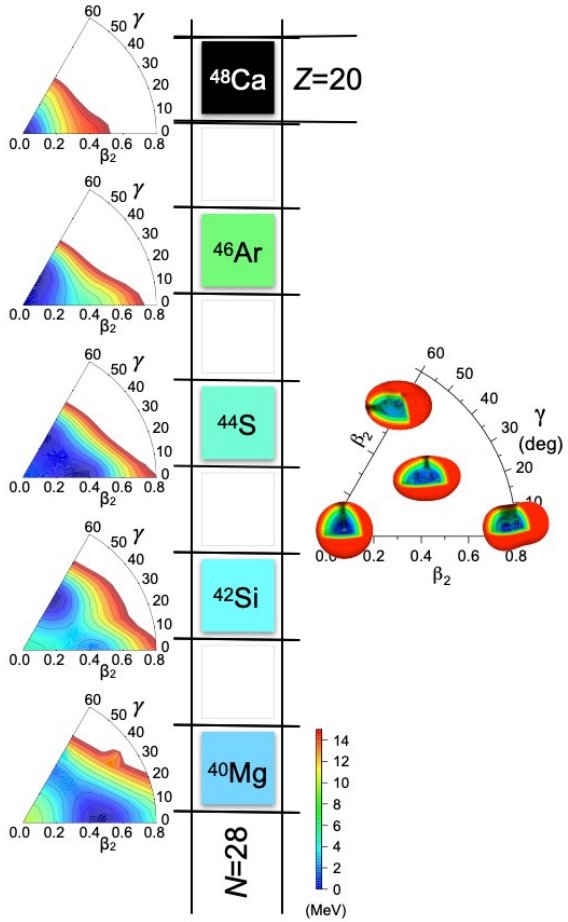
Relativistic HI can probe shapes of nuclei



STAR Collaboration *Nature* **volume 635**, pages 67–72 (2024)

PRL112, 112501 (2014); PRL124, 202301 (2022); PRL128, 082301 (2022)…

Nuclear shapes studied via nuclear spectroscopy



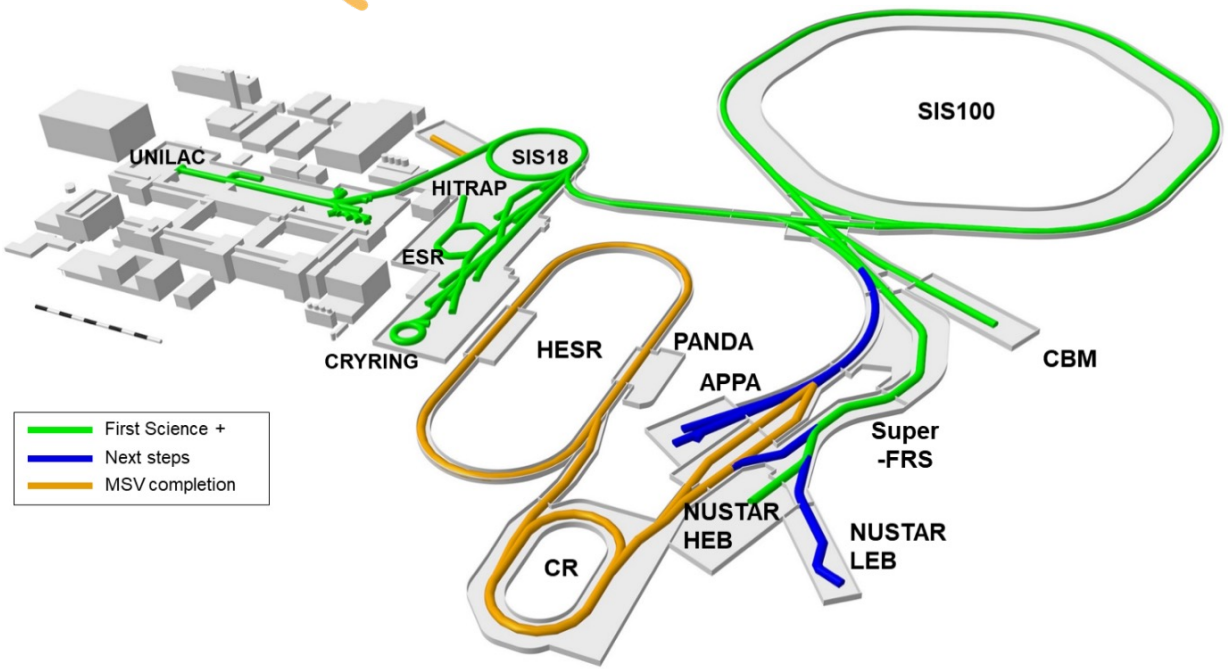
Figures from Long Range Plan 2024

GSI/FAIR – Darmstadt, Germany (ESFRI)

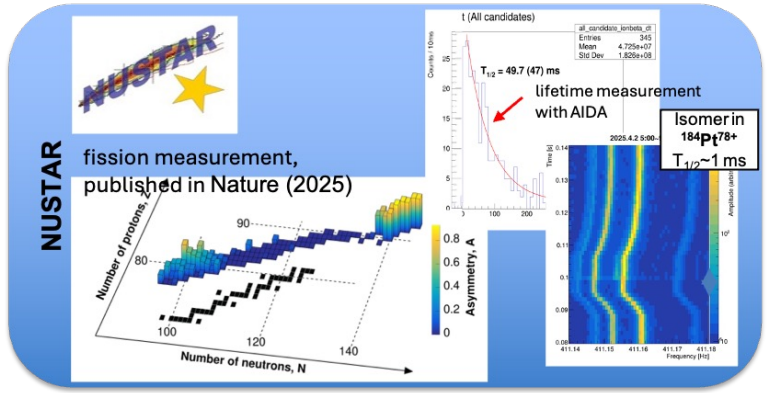
ESFRI

https://www.gsi.de/en/researchaccelerators/fair
https://fair-center.eu

- UNILAC, SIS18, SIS100
- Available beams: p to U, up to GeV/u
- SHIP/TASCA/R3B/FRS/Super-FRS/CRYING/ESR/HADES/CBM/…



- Nuclear Masses and Charge and Matter Radii
- Equation of State of Nuclear Matter
- Nuclear Shapes and Deformation
- Nuclear Astrophysics
- Nuclear Clustering Phenomena
- Nucleon-Nucleon, Nucleon-Hyperon Interactions



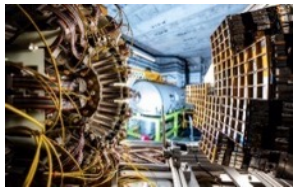
LoI TA2GSI/FAIR submitted for TA

GANIL- SPIRAL2 – Caen, France (ESFRI)

ESFRI

- The cyclotron deliver stable, high intensity beams from 12C to 238U 4-3 months/year from 4 MeV/A to 100 MeV/A
- The SPIRAL2 LINAC delivers mA proton, deuton, alpha beams
- SPIRAL1 delivers both post-accelerated and low energy RIB
- RIB at ~30-70 MeV/A at the LISE fragment separator

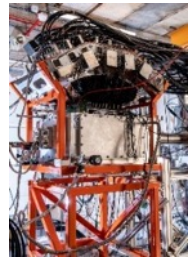
- Incoming program of heavy ions program at the SPIRAL2 linac with S3 and DESIR

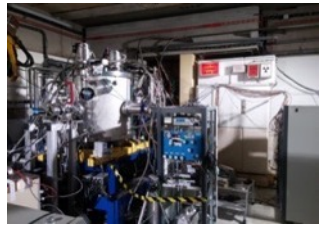


INDRA + FAZIA

- Equation of State of nuclear matter
- Nuclear charge and matter radii
- Nuclear clustering phenomena
- Nuclear shapes and deformation determined through complementary methods
- Precision experiments in the search for BSM physics

ACTAR TPC





MUGAST

EXOGAM

VAMOS

https://www.ganil-spiral2.eu

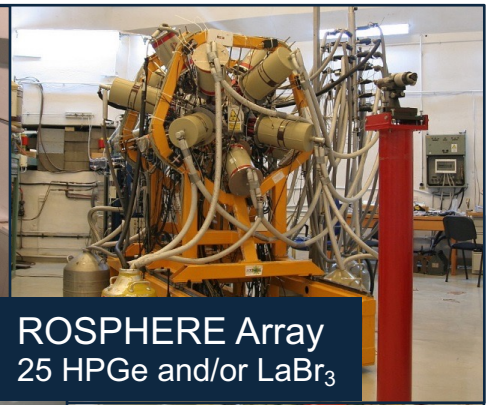
IFIN-HH

Magurele, Romania ELI-NP (ESFRI)

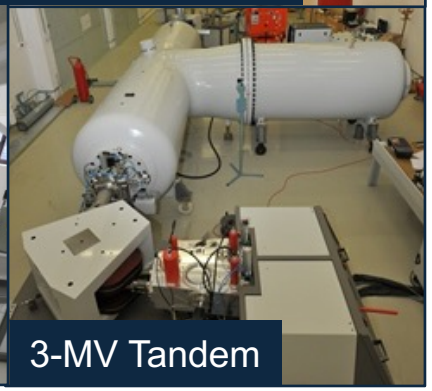
Emergent Facility

ESFRI


9-MV Tandem

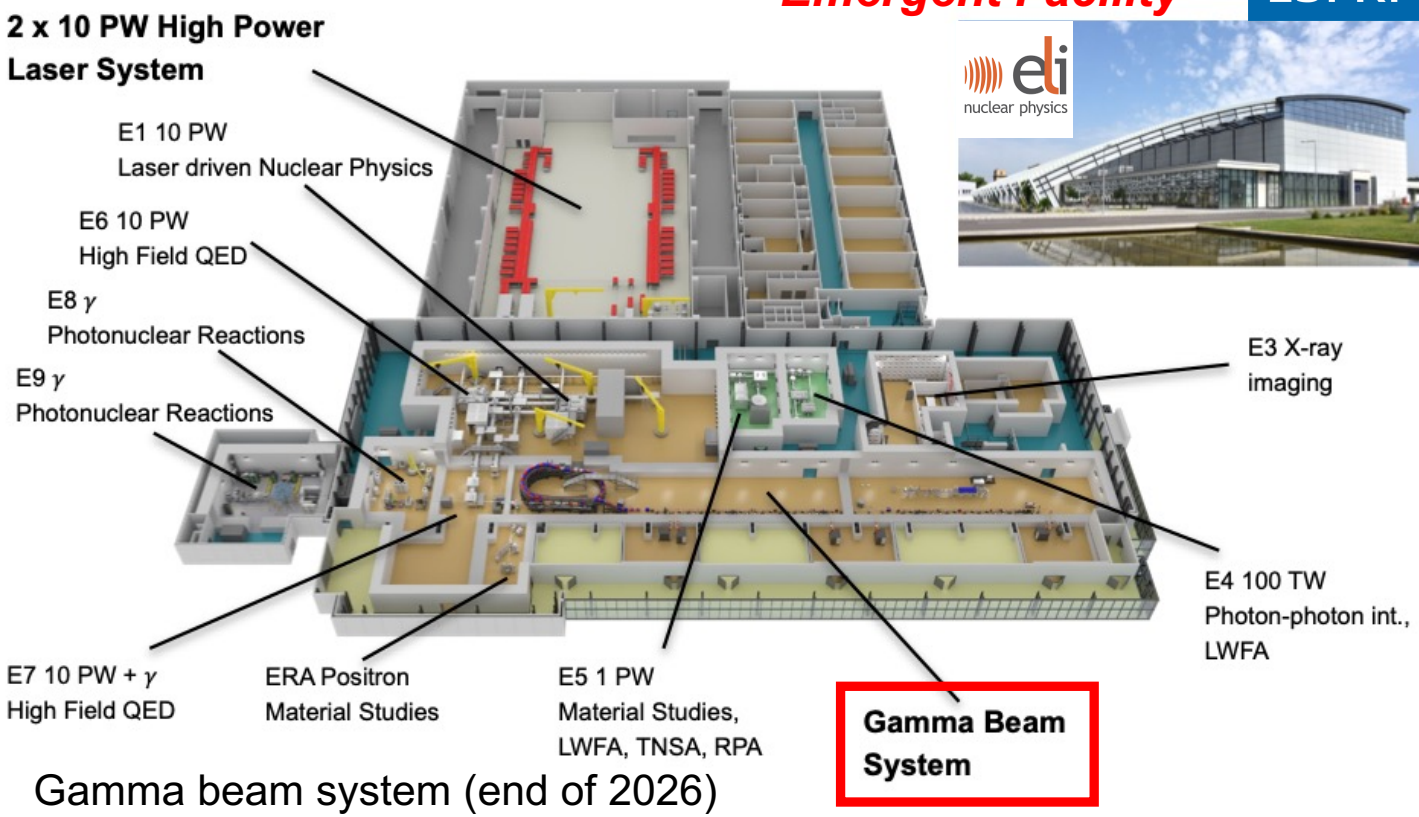

ROSPHERE Array
25 HPGe and/or $LaBr_3$


1-MV Tandem


3-MV Tandem

- 3 Tandem accelerators available: 9 MV, 3 MV, 1 MV
- Available beams: Stable ions from p to Au.
  Two pulsing systems (millisecond/nanosecond).
- Nuclear Shapes and Deformation
- Nuclear clustering phenomena
- Giant/Pygmy resonances, EOS
- Nuclear Astrophysics

https://tandem.nipne.ro



Gamma beam system (end of 2026)

Emax = 19.5 MeV, Rel. bwd < 0.5%,

SPD > 5000 ph/s/eV

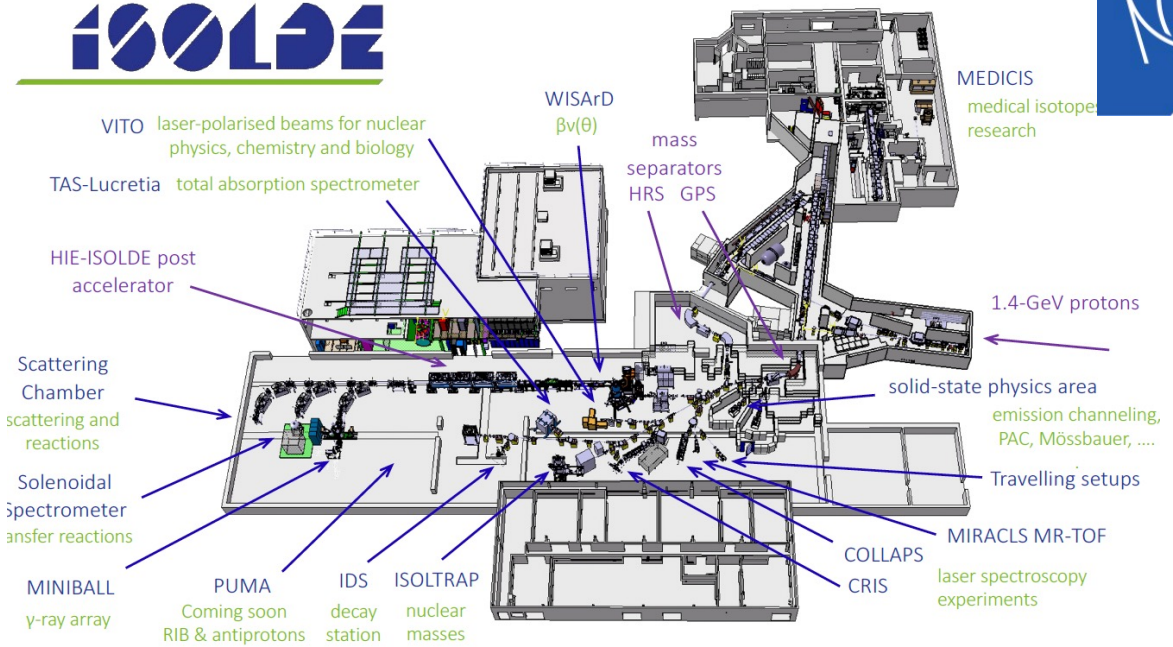
- Photonuclear reactions:
  - Giant/Pygmy resonances, EOS
  - Nuclear astrophysics
  - Application to medicine

https://www.eli-np.ro


ELIADE Array

ISOLDE

https://isolde.cern



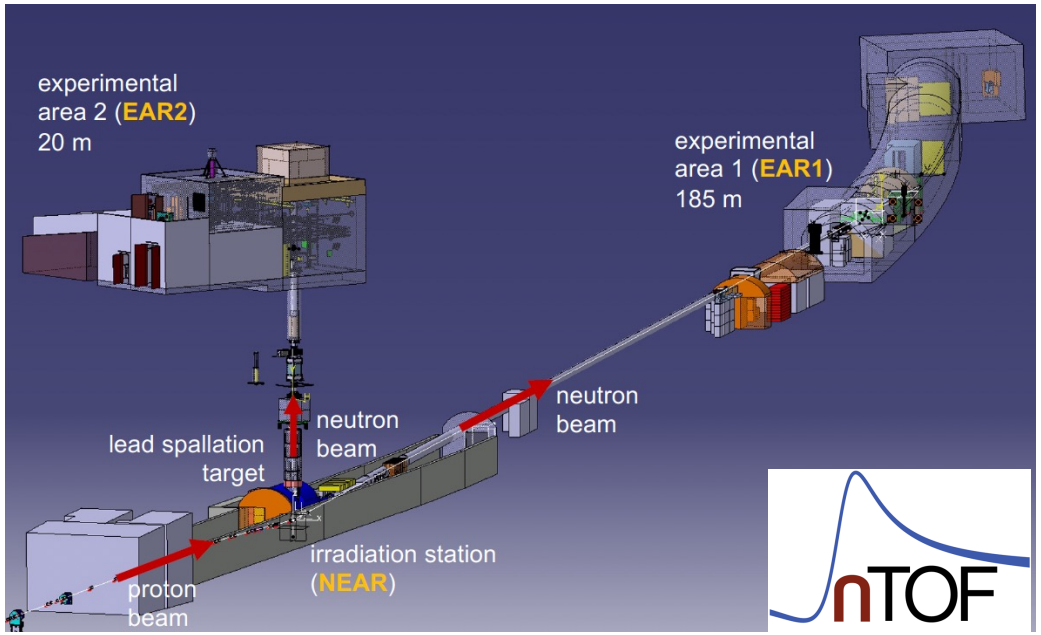
- ISOL Facility for Radioactive Ion Beams from spallation (1.4 GeV p on thick targets)
- Available beams: > 1300 isotopes and > 75 elements (He to Pu) energies up to 11 MeV/u


MINIBALL

- Charge Radii
- Nuclear Masses
- Nuclear clustering, Shapes and Deformation
- Nuclear Astrophysics
- BSM searches
- Medical Application

n-TOF

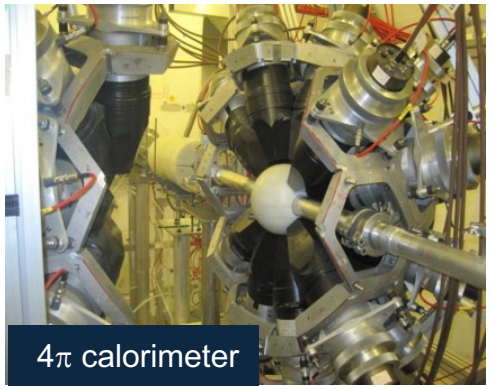
https://home.cern/science/experiments/n_tof



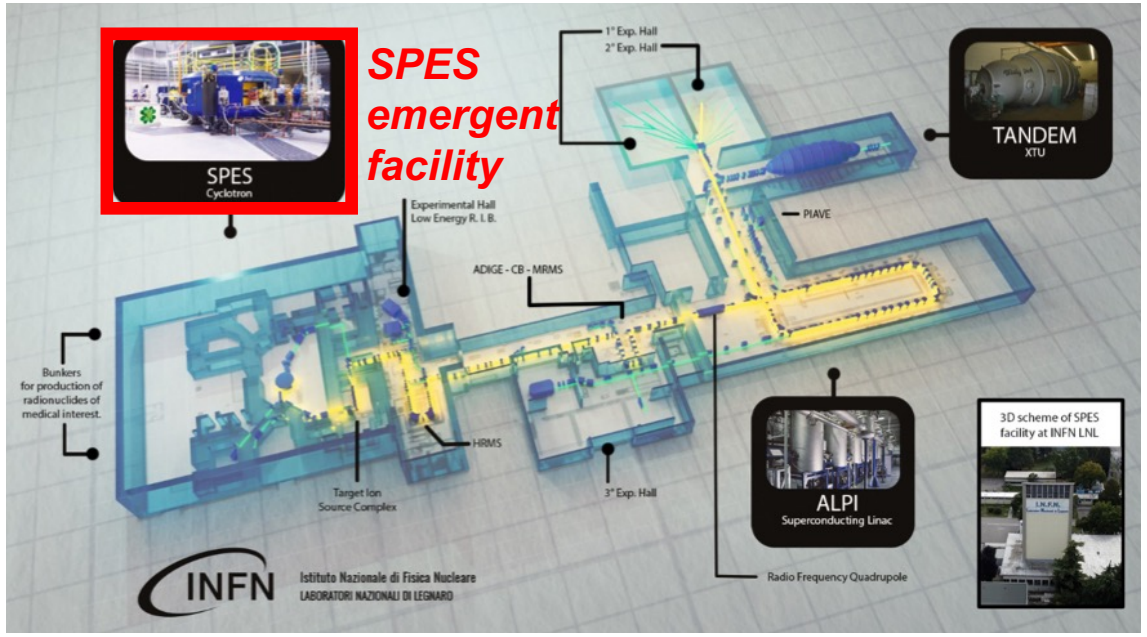
Pulsed neutron source coupled to a 200 m flight path

Neutron energy: from few meV to several GeV

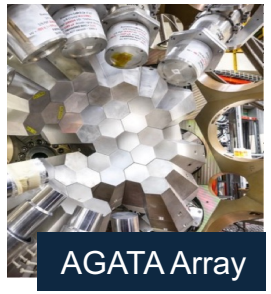
- neutron-induced reactions:
  - Nuclear Astrophysics
  - Medical Application
  - Nuclear Data


4π calorimeter

LNL–Legnaro



- 15 MV TANDEM + ALPI SC LINAC (SC injector with ECR source)
- 2 MV (AN2000) and 6 MV (CN) Van-der-Graaf
  Available beams: Stable ions from p to U
- **SPES ISOL Facility** - Cyclotron: 70 MeV p beam, 750 μA
  Available beams (from 2025): neutron-rich radioactive ion beams

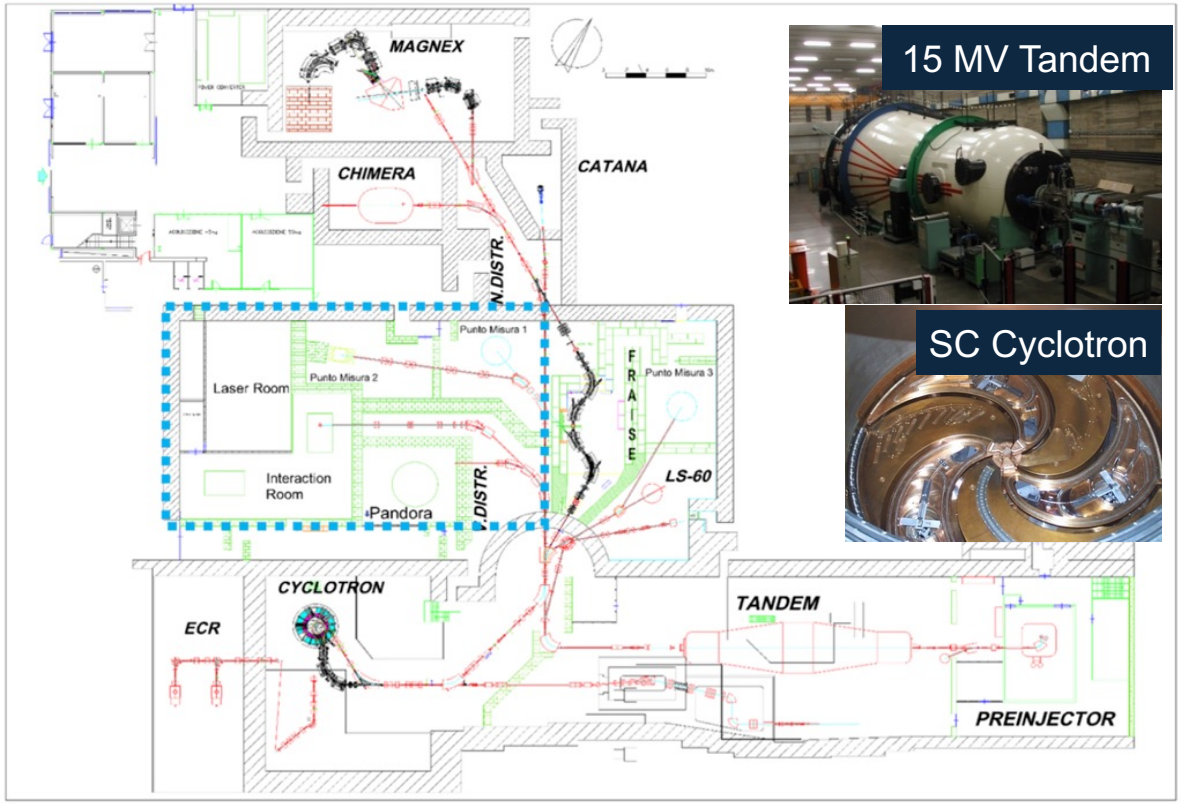


- Nuclear Shapes and Deformation
- Nuclear clustering phenomena
- Giant/Pygmy resonances, EOS
- Nuclear Astrophysics
- BSM physics

https://www.lnl.infn.it

Italy

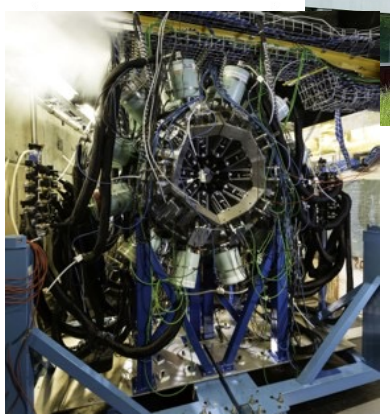
LNS–Catania

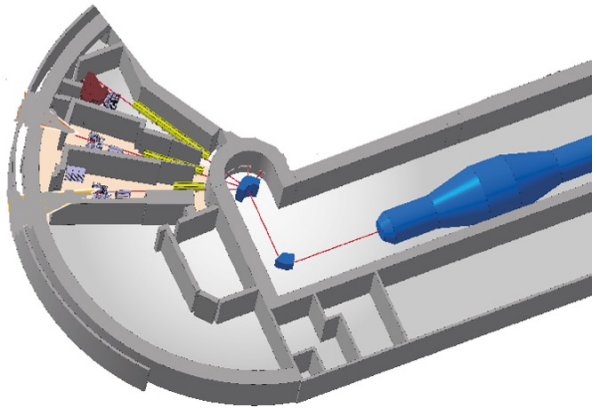


- 15 MV TANDEM
- K800 SC Cyclotron
  Available beams: Stable ions from H to Pb, up to 80 MeV/u
- Nuclear clustering phenomena
- Giant/Pygmy resonances, EOS
- Nuclear Astrophysics
- BSM physics

https://www.lns.infn.it

ALTO IJCLab – Orsay, France





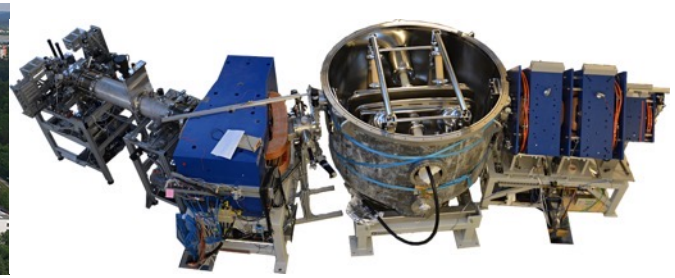
https://alto.ijclab.in2p3.fr/en/overview/

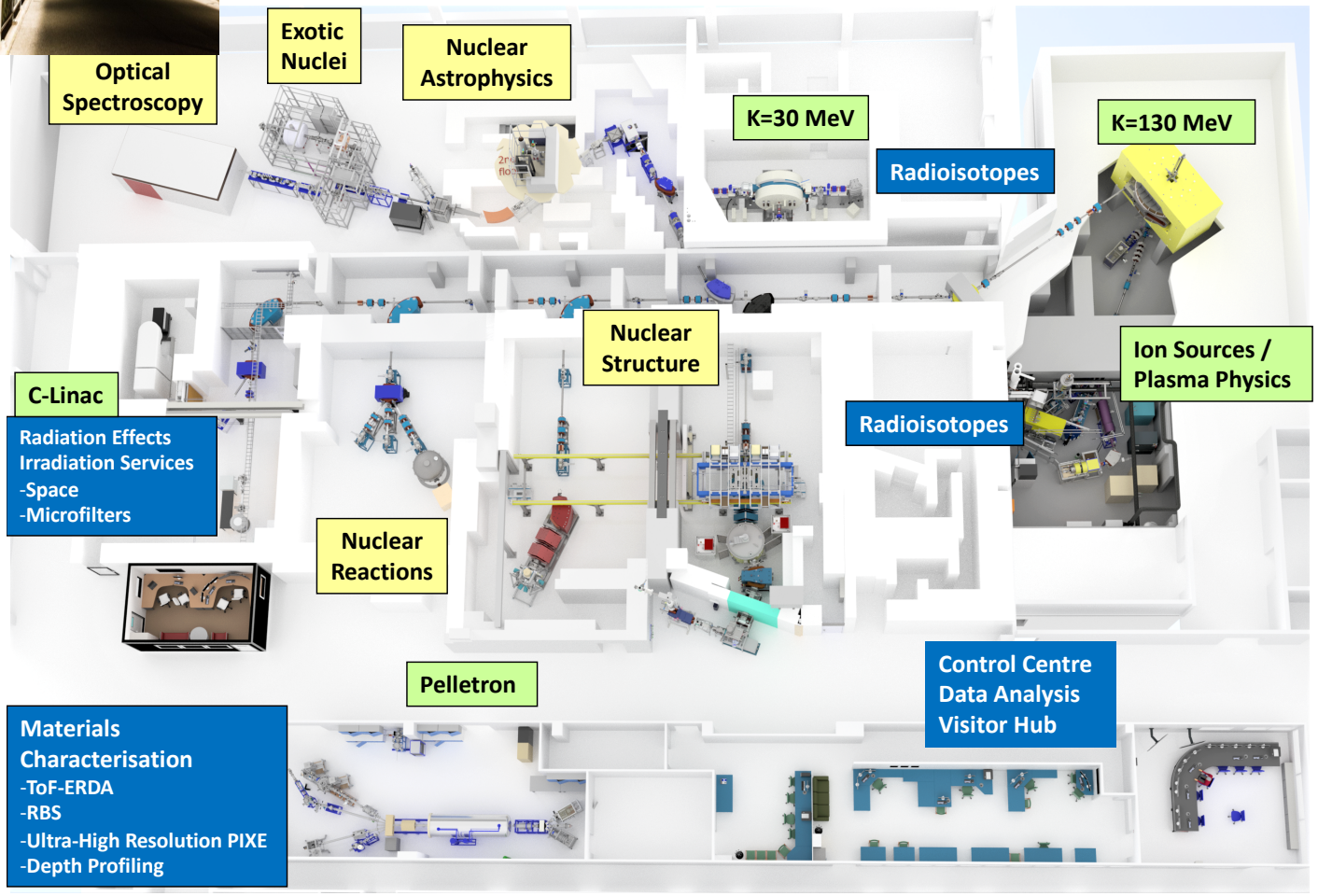
- Tandem Accelerator
- Available beams: H,^{3}He,^{4}He, ..., ^{14}C, ... up to ^{127}I
- Low-energy radioactive ion beams from photofission
- Neutron beams from LICORNE

- Nuclear Shapes and Deformation
- Nuclear Astrophysics
- Nuclear Clustering Phenomena
- Nucleon-Nucleon Interactions

Hadron Physics research at IJCLabs

JYFL-ACCLAB – Jyväskylä, Finland





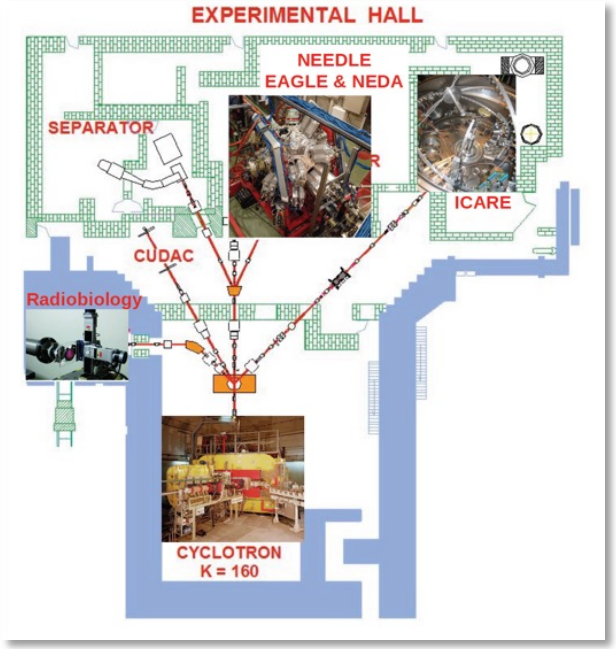
https://www.jyu.fi/accelerator

- K130 and K30 cyclotrons, 1.7MV Pelletron
- Available beams: Stable ions from p to Au, energies up to 22 MeV/u (Kr), heavy ions up to 500pnA, protons typically 10-20 μA
- Low-energy radioactive ion beams from IGISOL facility

- Nuclear Shapes and Deformation
- Charge Radii
- BSM searches
- Nuclear Masses
- Nuclear Astrophysics

JYU also hosts *Centre of Excellence in Quark Matter* and Nuclear Theory group

NLC-SLCJ – Univ. of Warsaw, Poland

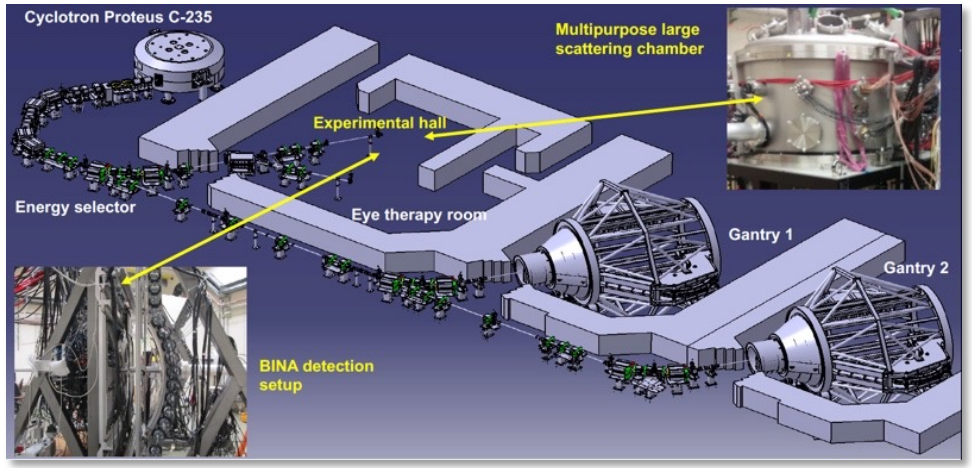


https://www.slcj.uw.edu.pl/en/home-page-3/

U-200P cyclotron (K=160) runs about 3000 hrs/year
Stable-ion beams from α to Ar, energies up to 10 MeV/u , typical beam intensity 1 pnA

- Nuclear clustering phenomena
- Nuclear shapes and deformation determined through complementary methods
- Detector testing and development for HP and NP using heavy ion beams

NLC-CCB – IFJ PAN – Kraków; Poland



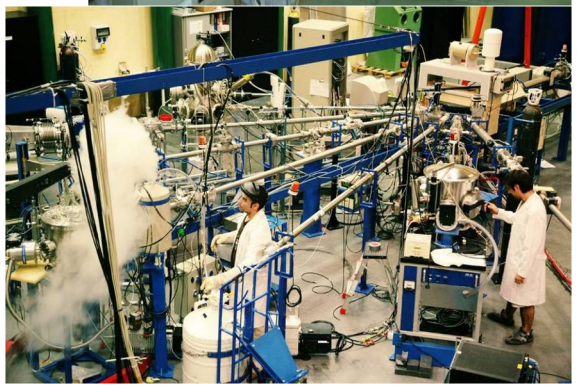
https://experimentsccb.ifj.edu.pl/?lang=en

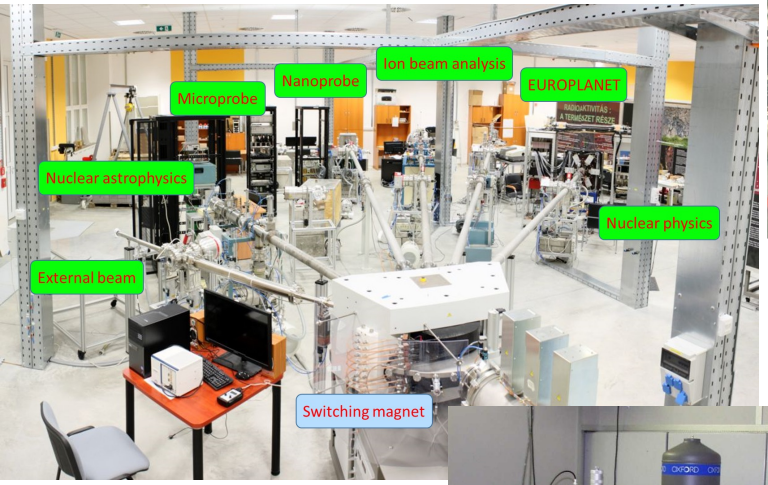
Medical proton therapy facility, proton beam, energies from 70 to 230 MeV, quick energy change (seconds)

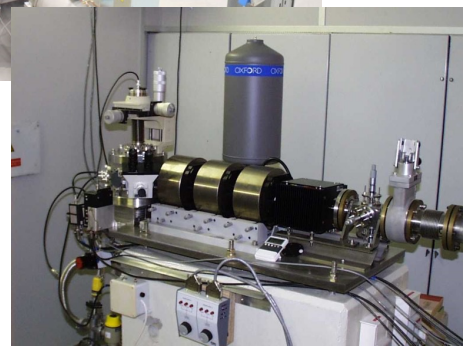
- Neutron skin of nuclei – via study of the Pygmy Dipole Resonances
- Dynamics of few-body systems (three-nucleon force) - short range correlations in nuclei.
- Detector testing and development for HP and NP using a proton beam
- Virtual Access offered: Mean-Field4Exp https://meaneld4exp.ifj.edu.pl/

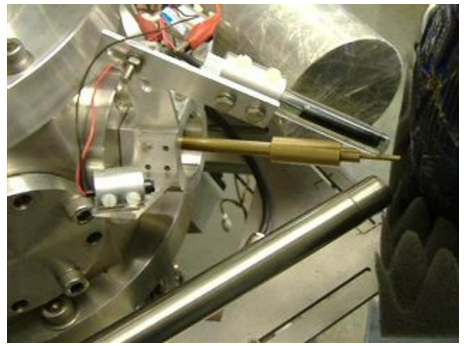
Consortium

https://institucional.us.es/clear/









- Consortium of facilities offering access to lower energy stable beams from cyclotron and tandem accelerators
- Flexible operations and availability of beam at short notice, possibility to carry out development which would not pass PAC procedures at large facilities

- Detector testing and development
- Target testing and development
- Nuclear Astrophysics (e.g. collaboration with Gran Sasso)
- Irradiation and Ion Beam Analysis services
- Virtual Access offered: Reaction4Exp hosted at Univ. de Sevilla https://reaction4exp.us.es

Requested Budget

Access provider short name	Short name of infrastructure	Unit of access	Unit cost (UC) (€)	Min. quantity of access to be provided	Access costs On the basis of UC	Estimated number of users	Travel & subsistence costs	Overhead	Total costs for access	
INFN	LNL- LNS	Beam hour	150	1 500	225 000	150	135 000	33 750	393 750	
GANIL	GANIL-SPIRAL2	Beam hour	150	1 500	225 000	150	135 000	33 750	393 750	
CNRS	IJCLabs	Beam hour	100	700	70 000	35	31 500	7 875	109 375	
GSI/FAIR	GSI	Beam hour	150	1 000	150 000	100	90 000	22 500	262 500	*
CERN	ISOLDE/n-TOF	Beam hour	150	1 000	150 000	100	90 000	22 500	262 500	
JYU	JYFL	Beam hour	150	1 500	225 000	150	135 000	33 750	393 750	
UNIWARSAW	NLC_SLCJ	Beam hour	100	400	40 000	20	18 000	4 500	62 500	
IFJ PAN	NLC_CCB	Beam hour	100	200	20 000	10	9 000	2 250	31 250	
ELI-NP/IFIN-HH	ELI-NP	Beam hour	150	1 500	225 000	150	135 000	33 750	393 750	
CONSORTIUM	CONS	Beam hour	35	600	21 000	30	27 000	6 750	54 750	
FBK	ECT*	Visitor day	100	650	65 000	125	60 000	15 000	140 000	**
TOTAL				9 900	1 416 000	1 020	865 500	216 375	2 497 875	

* *Overlap with GSI/FAIR separate LOI for TA;* ** *ECT* Theory Service for the HP and NP communities*

- Based on experience from previous projects
- At this stage suggested flat rates for Unit Cost and T&S per user (900€), suggested quantity to be provided taking into account LS3 at CERN and known limitations on available beam time at facilities

Conclusion

- As highlighted in the Research Infrastructures chapter of the **NuPECC Long Range Plan 2024**, the Nuclear, Particle and Hadron physics communities benefit *"from a number of selected leading European Research Infrastructures of excellent quality, ranging from test facilities for instrumentation to fully-fledged experimental facilities providing top-quality beam delivery and support…"*
- It is proposed to form **a network of accelerators and other facilities offering physical Transnational Access** for the provision of services and instrumentation to carry out leading-edge research on contemporary issues and open questions in Hadron and Nuclear Physics.
- This LoI is representing a **coordinated "will" of Low-Energy Nuclear Physics community for TA in synergy with the LoIs GATE, ChETEC-INFRA, TA2GSI/FAIR, NUCATOLE,…**
- In line with the expected outcomes and objectives of the call, we propose to investigate the possibilities of providing more streamlined access with revised access models compared to earlier projects. For example, a centralised User Selection Panel could oversee the distribution of T&S costs to the researchers.
- Possibilities allowed within the grant agreement for provision of services, whilst not necessarily being a direct beneficiary of the project are considered (e.g. subcontracting of access).