Hosted by the European Science Foundation

http://nupecc.org

NuPECC Long Range Plan 2024 for European Nuclear Physics (LRP 2024)

https://nupecc.org/?display=lrp2024/main

approved June 2024, Lund meeting

Presentation by Teresa Peña

Portuguese Representative at NuPECC

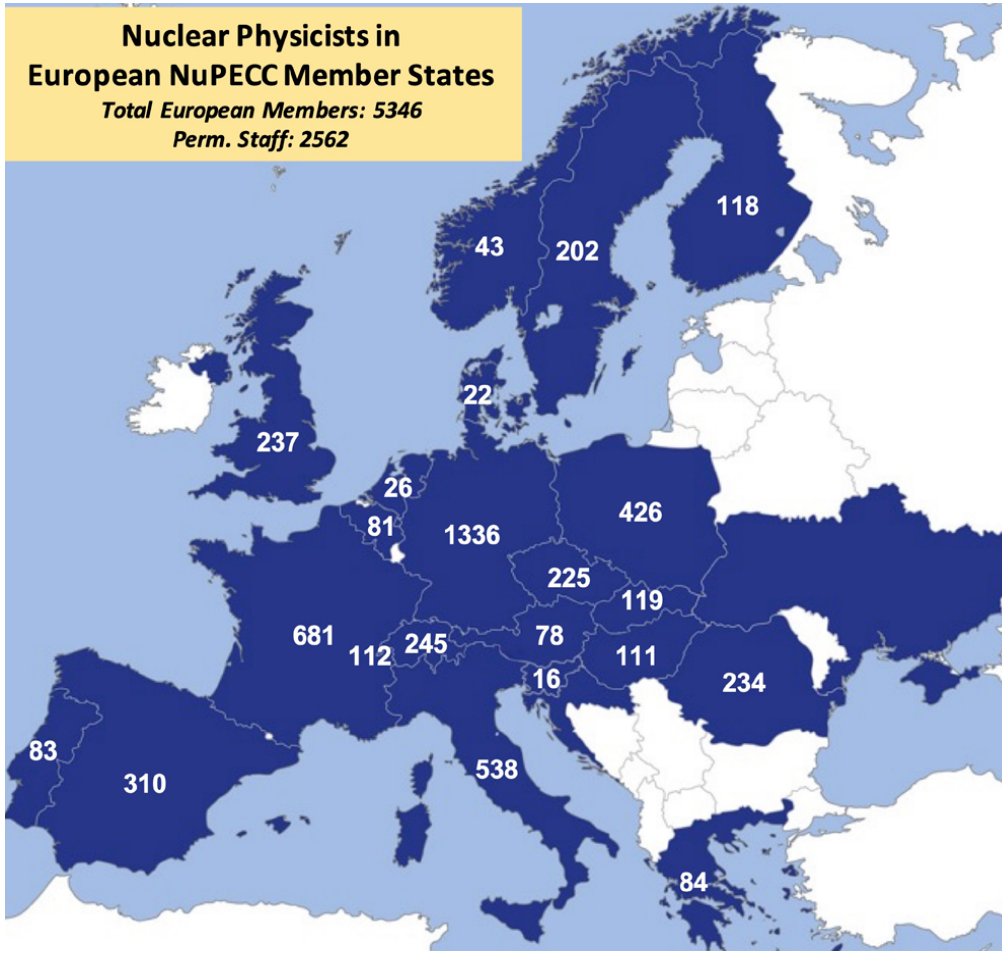
TÉCNICO LISBOA

LIP

2025

NuPECC represents

- the nuclear physics community from 23 countries,
- the European Strategy Forum for Research Infrastructures (ESFRI) of nuclear physics,
- the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*),
- associated members including CERN,
- 10 observers.



European Nuclear Physics Landscape
in numbers of researchers

Numbers on the Long Range Plan 2024 (LRP 2024)

- Steering Committee included the chairs of the Astroparticle Physics European Consortium (**APPEC**) and the European Committee for Future Accelerators (**ECFA**).

- Steering Committee adopted a bottom-up approach with an open call kickoff.

- **159** contributions received.
- Contributions from **400+** individual scientists , collaborations, research infrastructures, and institutions in Europe.

- Steering Committee formed **11** thematic working groups (TWG).
- **29** members of NuPECC in the **11** TWG.
- LRP draft involved **35** members of NuPECC, **250+** TWG conveners and members.

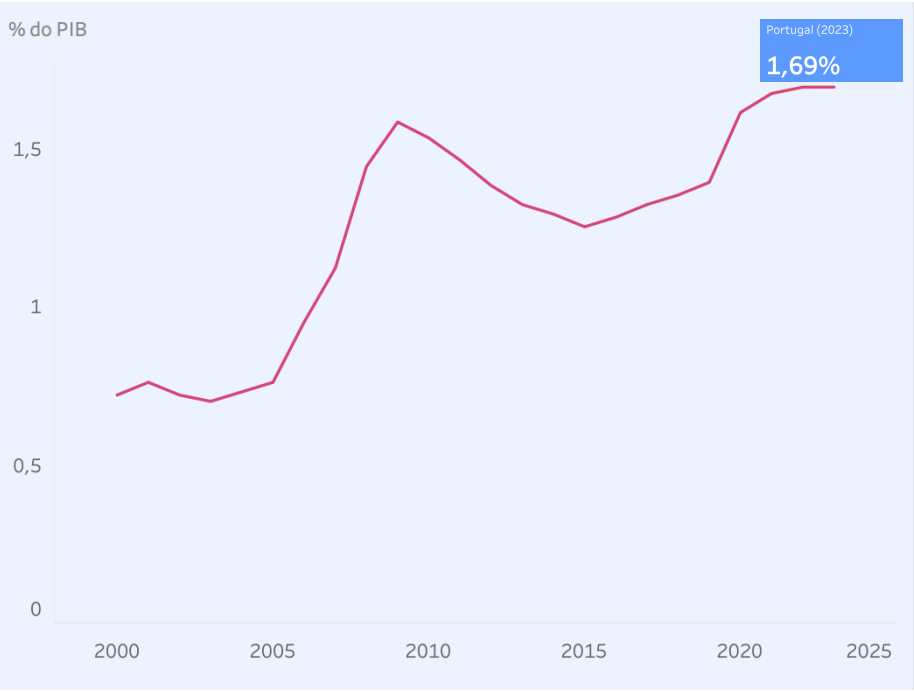
- LRP 2024 has **184** pages.

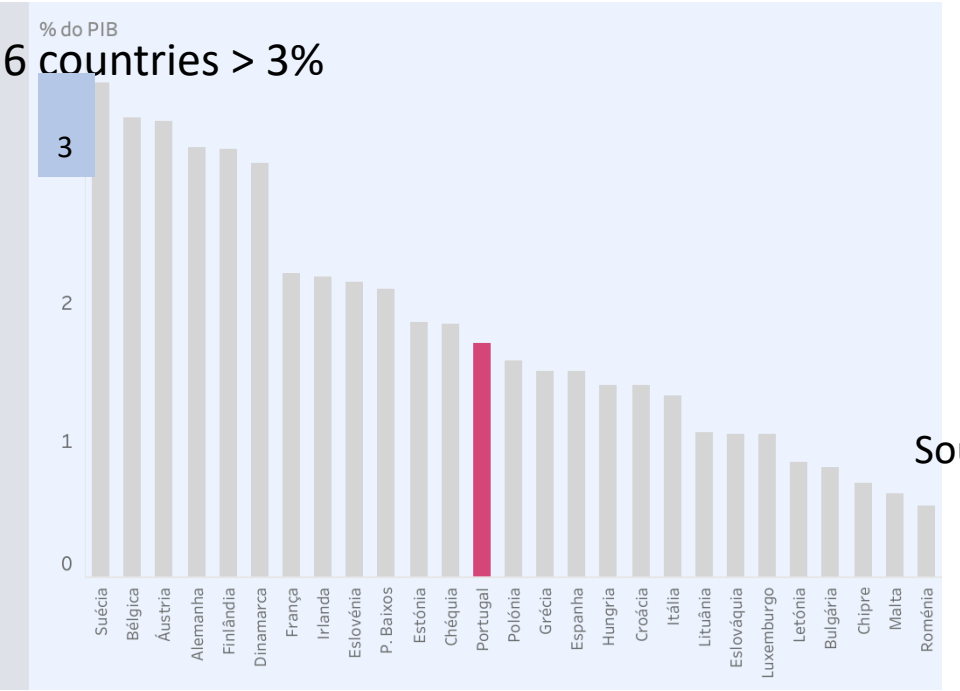
Topics covered by the LRP 2024

- Hadron Physics;
- Properties of Strongly Interacting Matter at Extreme Conditions (Temperature and Baryon Number)
- Nuclear Structure and Reaction Dynamics;
- Nuclear Astrophysics;
- Symmetries and Fundamental Interactions;
- Applications and Societal Benefits;
- Research Infrastructures;
- Open Science and Data;
- Nuclear Science—People and Society
- **Nuclear Physics Tools*—Machine Learning, Artificial Intelligence, and Quantum Computing;**
- **Nuclear Physics Tools*—Detectors and Experimental Techniques.**

***For the 1st time in a NuPECC LRP**

Evolution&Distribution, by execution sector, of expenditure in R&D (%GDP)





Total expenditure %GDP

Portugal (2023)

1,69%

Source: https://www.pordata.pt/pt

Companies (mostly Applied Science)

Portugal (2023)

1,06%

Portugal (2023)

0,51%

HE institutions

Portugal (2023)

0,08%

State

Portugal (2023)

0,04%

Non-profit

State 0,63

Nuclear Physics Research at LIP and at CfisUC

LIP

Nuclear Reactions, Instrumentation and Astrophysics

(**NUC-RIA**)

Nuclear Physics and Strong Interaction Group

(**NPStrong; pQCD**)

Staff 11 PhD students 11

CFisUC

Centre for Physics of the

University of Coimbra

Staff 12 PhD students 8

Explored Domains

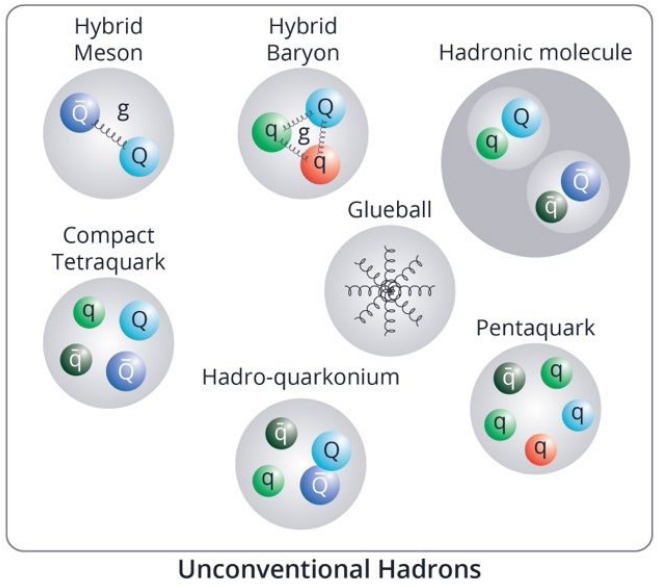
Nuclear Structure and Reactions **NSR**

Nuclear Astrophysics **NAP**

Hadronic Physics **HAD**

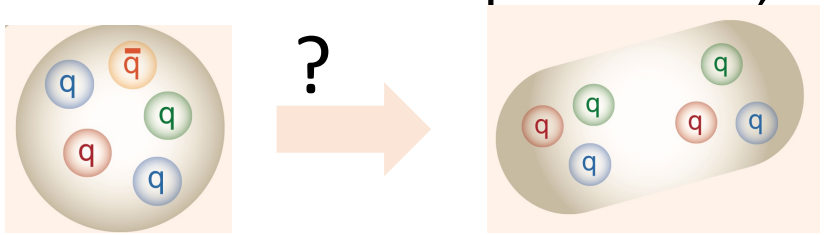
Theory Research

LIP



HAD

Hadron spectroscopy and structure:
Pentaquarks;
Baryon diquark components and clustering;
Deuteron as a six-quark state;



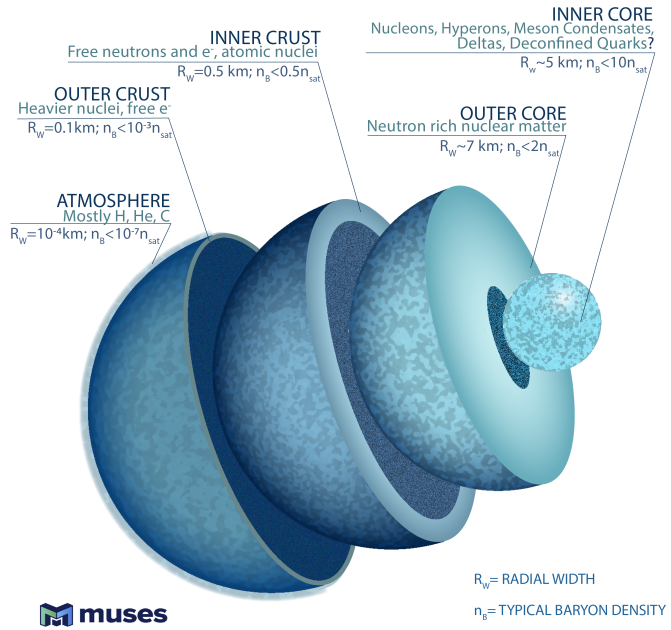
Strangeness and Hyperon form factors.

Theory Research

CFisUC

NAP

Neutron star EOS:



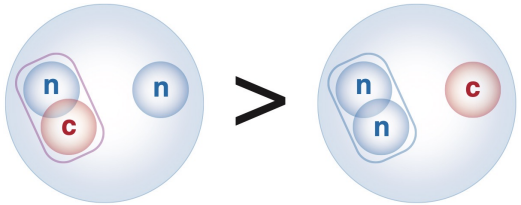
Empirical constraints on symmetry energy.

HAD

Quantum Chromodynamics on the Lattice:
Quark propagator and quark-gluon vertex from lattice QCD at finite temperature.

Challenges

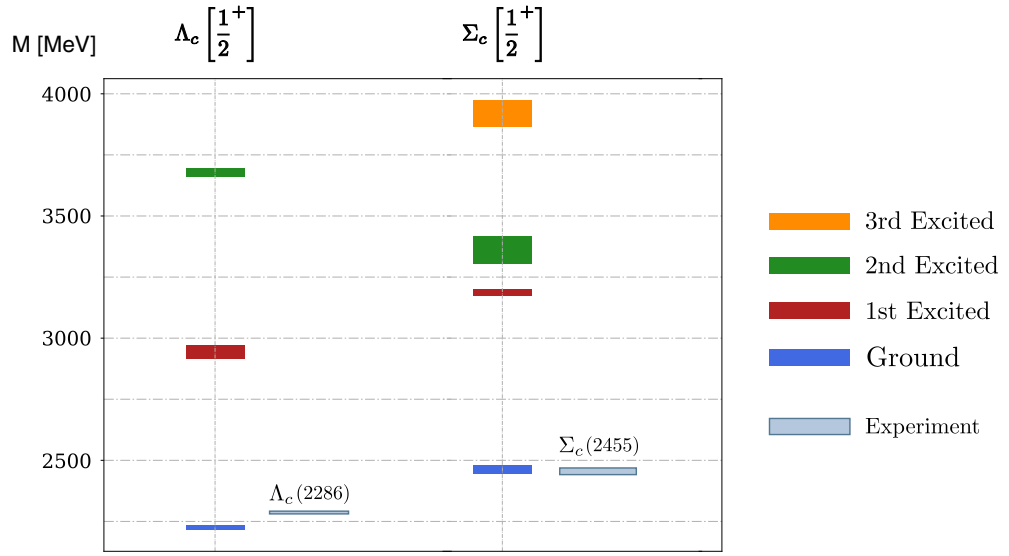
1. Hadron and Nuclear Physics phenomena extend from the tiniest to the largest scales of the universe and determine the attributes of astrophysical objects.
2. Experiment & Theory: Role and signatures of diquarks.
3. Theory: Predictive power and uncertainty control.



~60% ~40%

n is u or d

A. Torcato, A. Arriaga, G. Eichmann, T. Peña
Few Body Syst. 64 (2023) 3, 45



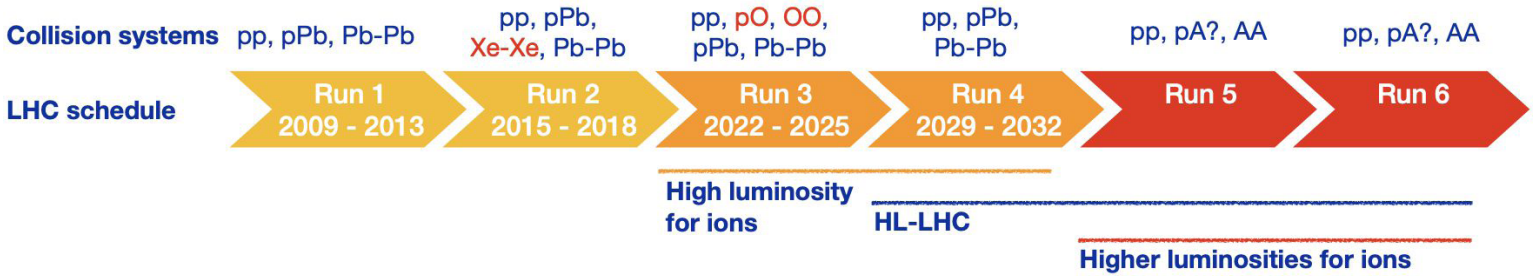
✓ Spectroscopy not enough;
Femtoscopy and structure studies add essential information (e.g cluster correlations or clustering).

✓ Comparison of complementary theoretical approaches (e.g.QCD based vs models).

✓ Merging lattice QCD, nuclear physics, gravitational wave astrophysics, relativistic hydrodynamics, and computer science in front-end development .

- **Hadron physics :**

opportunities at HL-LHCb@CERN
are a pillar of a world-leading hadron
physics research programme;



but spectroscopy is not enough; it has to be complemented
by femtoscopy and struture studies (BESIII, BELLE, FAIR, AMBER@CERN).

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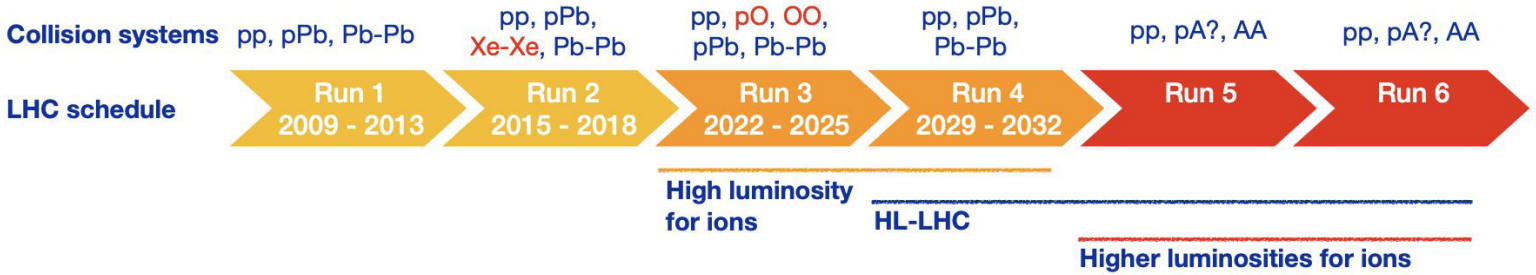

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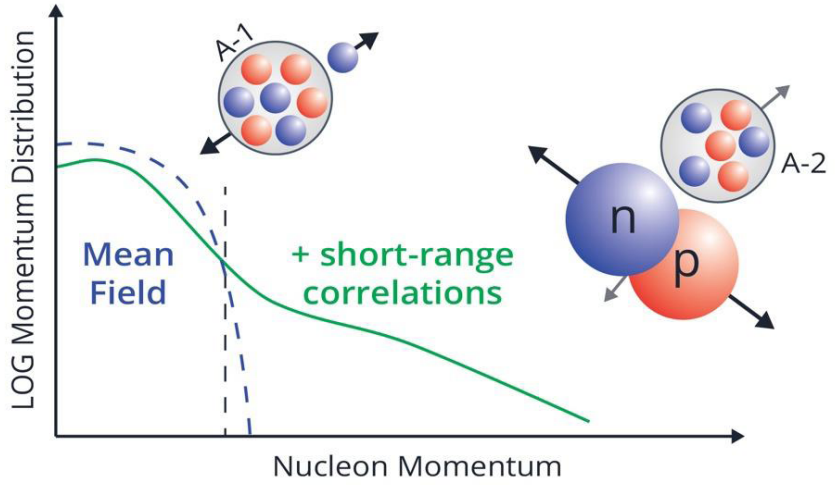
- **Nuclear Physics**: in the 80's revolutionized by discovery of exotic nuclei at ISOLDE@CERN; today there is complementary between Radioactive Beam facilities;

R3B@FAIR probes relativistic **regime of extreme n to p ratios as in neutron stars;** HIE-ISOLDE@CERN probes temperature regime as in supernovae;



both are needed to study exotic nuclei production in different stellar environments.

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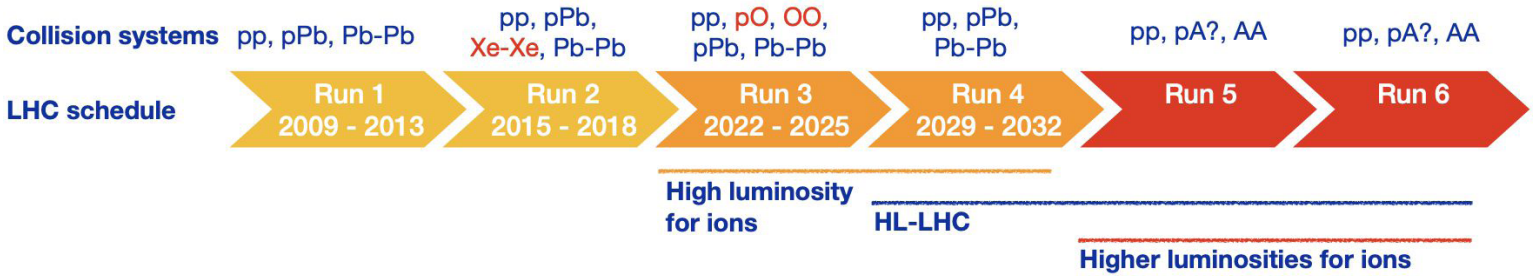

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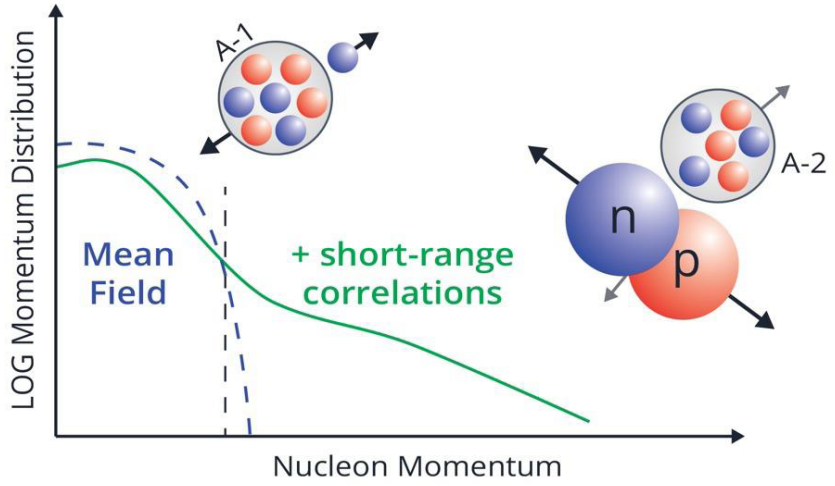
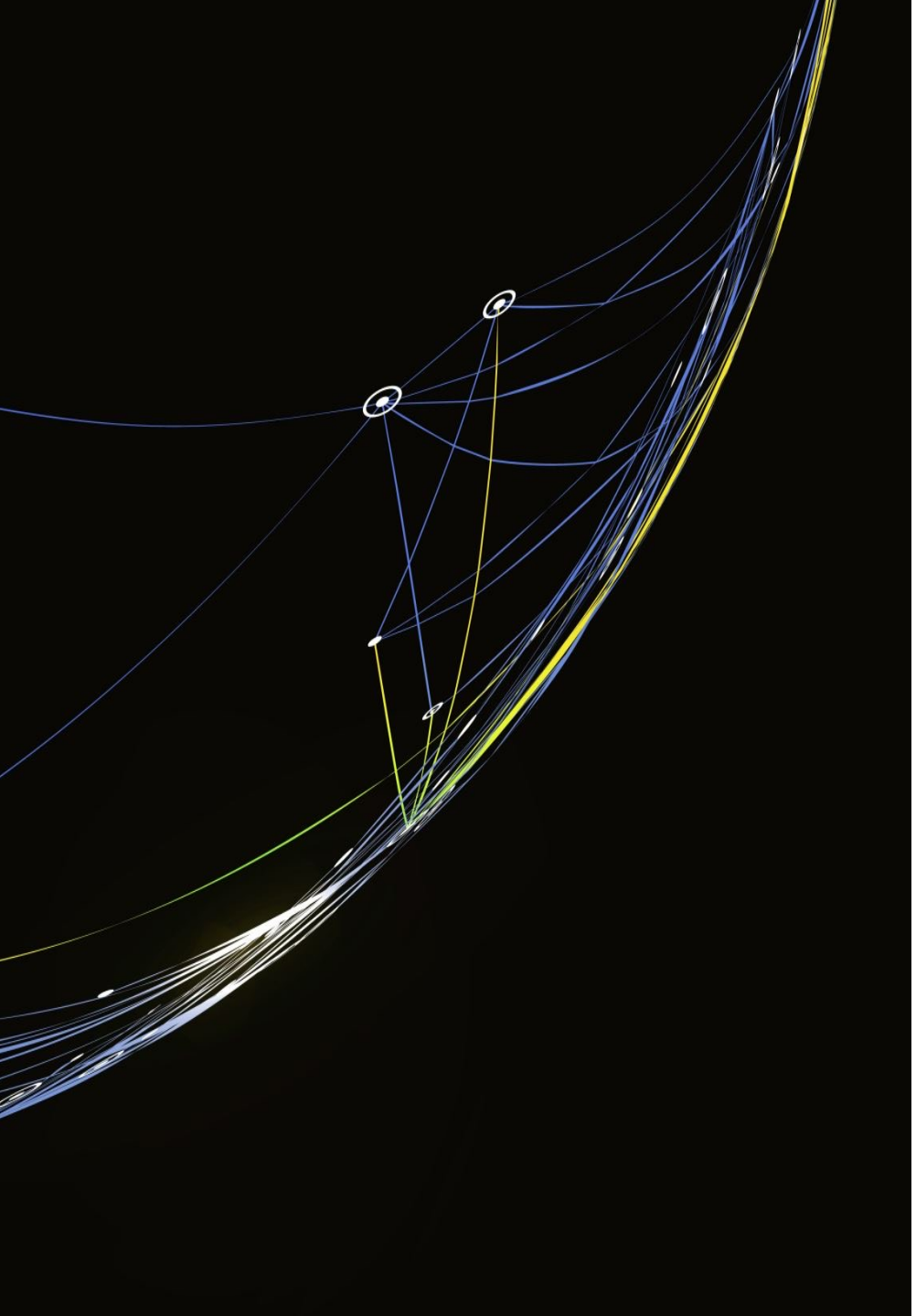


both are needed to study exotic nuclei production in different stellar environments.

- **Short Range Correlations:** bridge Hadron Physics&Nuclear Physics;

Radioactive beam facilities connect nuclear and hadron physics since they also measure short-range correlations enabling us to link QCD and low energy nuclear physics;

customised instrumentation and beam time availability should be guaranteed for HIE-ISOLDE.



Inlight of

- the impact of the recent discoveries by LHCb, of new QCD bound states that escape the conventional standard quark model explanation,
- the established know-how, leadership and volume of the Hadron and Nuclear Physicscommunity in Portugal,
- the possibilities of the HL-LHC,
- the guidelines and science cases of the NuPECC Long Range Plan 2024 for European Nuclear Physics,

we propose a consistent and predictable funding for the activities Hadron Physics, by FCT for

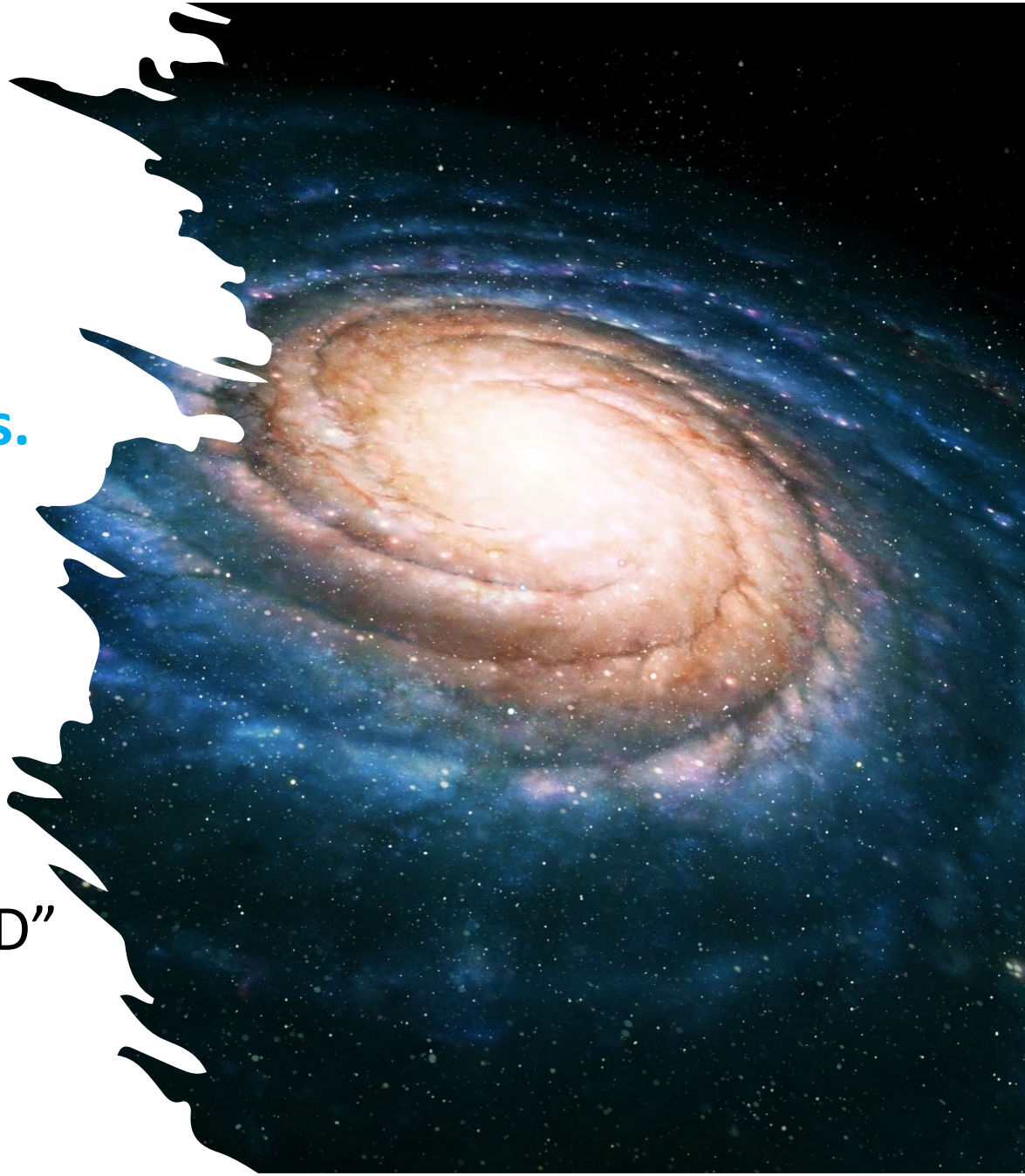
- sustainable theoretical projects,
- international partnerships and collaborations with CERN and other facilities for structure studies going beyond spectroscopical data analysis,
- a PhD grant program, interfacing Nuclear and Particle Physics,
- renewal and capture of talent.

Takeaway:

QCD is paramount in the connection of
Particle, Astro, Hadron and Nuclear Physics.

It has the double role of
source and **sink** of knowledge:

“Research **streams flow into and out** of QCD”



END

Portugal's Nuclear Physics research

Three main institutions: LIP, CFisUC, and CTN.

LIP and CFisUC: theoretical and experimental research in nuclear reactions, astrophysics, hadron spectroscopy and structure, lattice QCD.

CTN: Nuclear Physics applications for society (health sector, new materials, energy technology, environment).

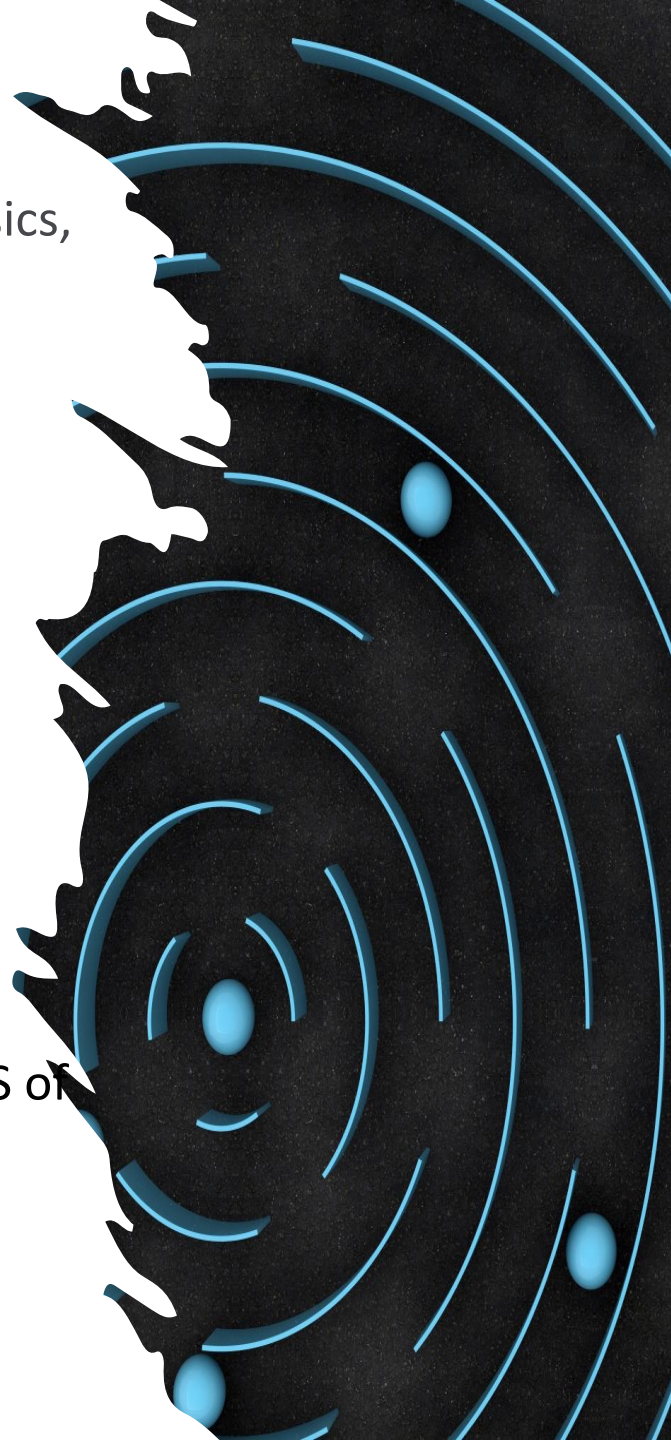
Portugal has a record of participation in experimental collaborations, including theory support.

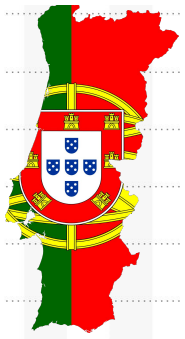
Challenges for the future:

Nuclear Physics phenomena extends to the largest of scales and determine the attributes of astrophysical objects.

Theoretical methods are ready for a unified description of hadrons and nuclei and EoS of nuclear matter.

Different Experimental Programs/Facilities provide complementary needed data;
Funding is very limited, keeping talent in Portugal is difficult.
International collaborations may mitigate these two problems.





- Area is 92256 m^2
- Population is 10 467 366
- GDP is 250 thousand million euros
- Public expenditure in R&D is 0.63% of GDP

Inlight of

- the impact of the recent discoveries by LHCb, of new QCD bound states that escape the conventional standard quark model explanation,
- the established know-how, leadership and volume of the Hadron Physics expert community in Portugal,
- the possibilities of the HL-LHC,
- the guidelines and science cases of the NuPECC Long Range Plan 2024 for European Nuclear Physics,

We propose a consistent and predictable funding for the activities in the scientific domain of Hadron Physics, by the Portuguese Fundação para a Ciência e Tecnologia (FCT) to support

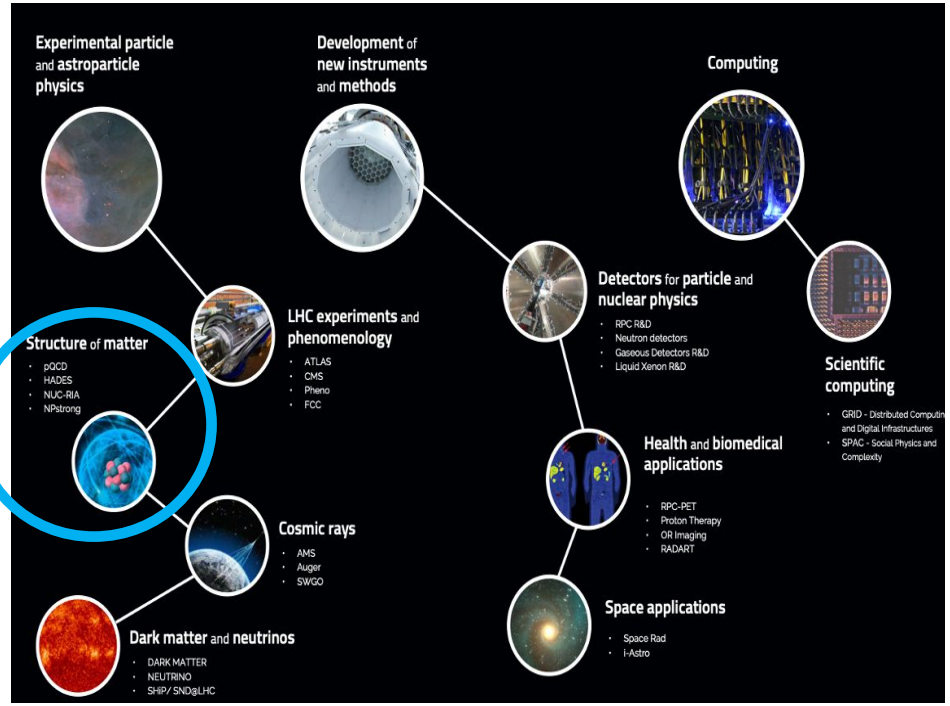
- sustainable theoretical projects,
- international collaborations with CERN and also with complementary facilities allowing structure studies going beyond spectroscopical data analysis
- PhD grants, interfacing Nuclear and Particle Physics.
- renewal and capture of talent.

In **Portugal**, Nuclear Physics Research runs mainly across across **3** Units:

LIP

Laboratory of Instrumentation and Experimental Particle Physics

https://www.lip.pt



CFisUC

Centre for Physics of the University of Coimbra

CTN

Campus Tecnológico e Nuclear IST

Nuclear Applications

30

Staff

10

PhD Students

✓ **NSR:** **NUSTAR; FAIR-GSI phase-0 R³B collaboration,**

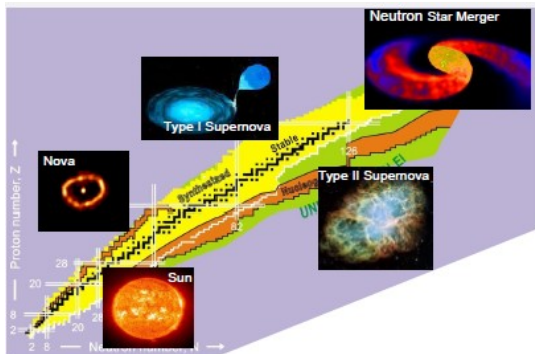
Nuclear Reactions ISOLDE @ CERN

★ IS698 Experiment

Complementary to low energy radioactive beams

Probes regime of extreme n to p ratios as in neutron stars;

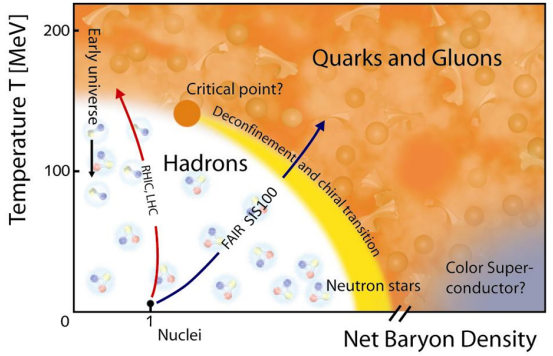
short-range correlations (p,ppn) (p,ppp) reactions with 16C beams



✓ **NAP:** **CBM FAIR-GSI**

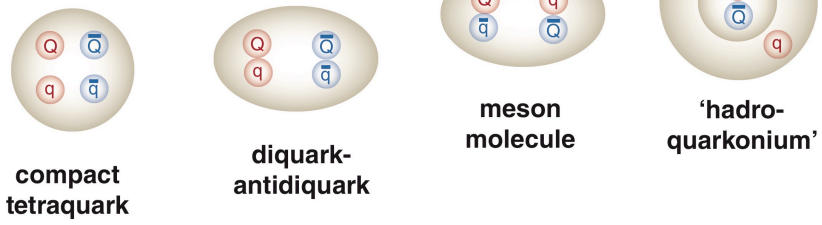
Complementary to LHC

Probes QCD phase diagram in the region of high baryon densities; EOS neutron stars

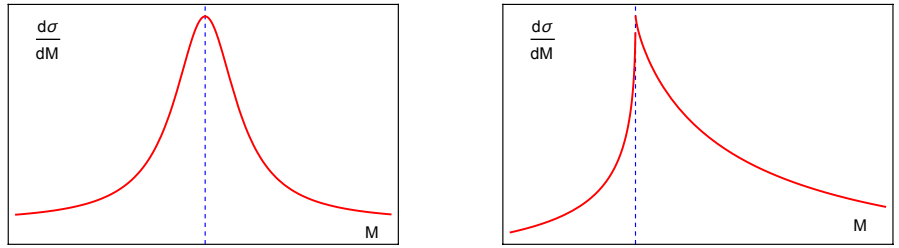


✓ **HAD:** **PANDA pillar (reconfigured);**

Interaction rates are orders of magnitude higher than in other heavy-ion experiments



Probes QCD spectrum and exotic hadrons; strangeness sector



Compact versus molecular near threshold line shapes

CTN

Centro Tecnológico e Nuclear

Applied Nuclear Physics in Portugal

CTN

Campus **T**ecnológico e **N**uclear**, IST, ULisboa**

Hosts the infrastructure **LA** (two small **A**ccelerators)

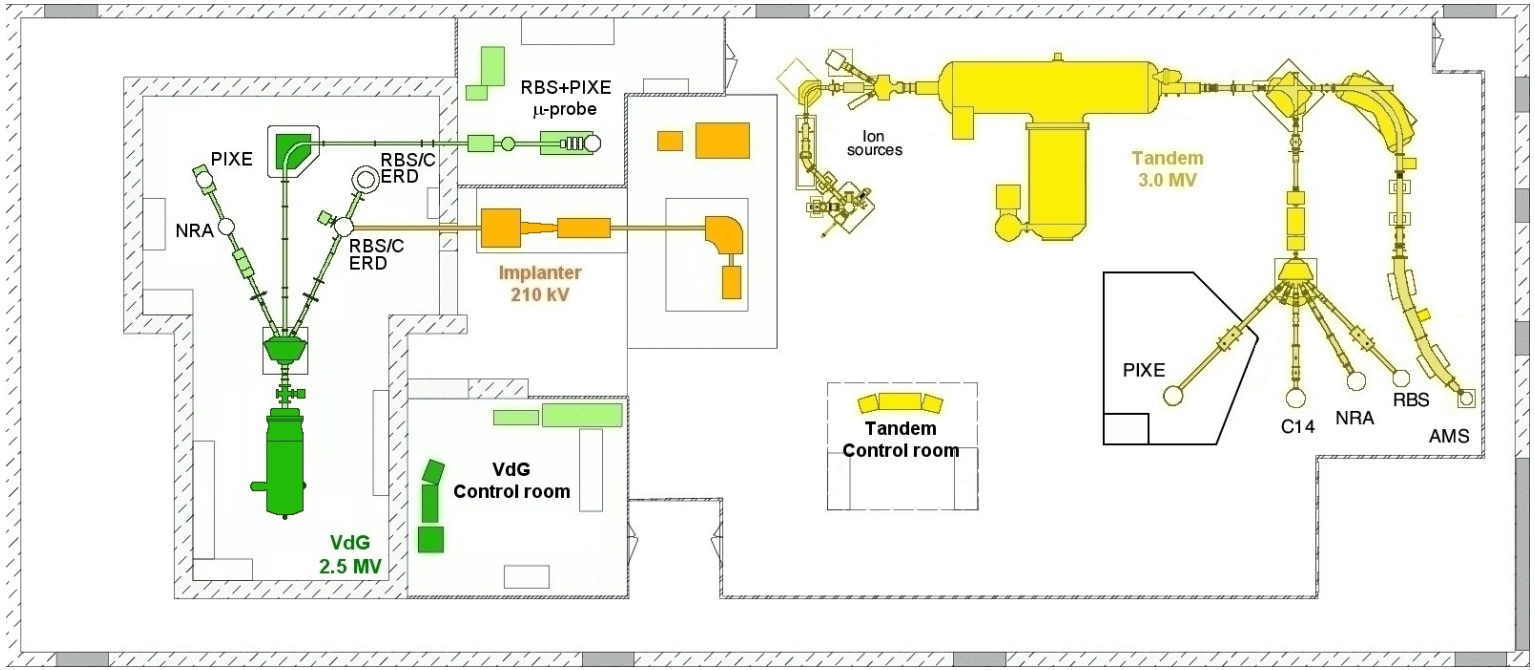
two electrostatic accelerators

an **ion implanter**, an **ion microprobe**, a **micro-AMS system**

a high-resolution high-energy (**HRHE**) particle-induced X-ray emission (**PIXE**) setup

30
Staff

10
PhD Students



Eur. Phys. J. Plus (2021) 136:684
https://doi.org/10.1140/epjp/s13360-021-01629-z

THE EUROPEAN PHYSICAL JOURNAL PLUS

Regular Article

Check for updates

An insider view of the Portuguese ion beam laboratory

E. Alves[1,a], K. Lorenz[1,2,b], N. Catarino[1], M. Peres[1], M. Dias[1], R. Mateus[1], L. C. Alves[3], V. Corregidor[3,c], N. P. Barradas[3], M. Fonseca[4], J. Cruz[4], A. Jesus[4]

LA@CTN

Provides expert assistance to IAEA projects.
Develops applications of nuclear engineering and analytical techniques in 4 areas:

Materials Characterization and Innovation:

Semiconductors, sensors, electronics and opto-electronics, new energy sources.
Participation in the EUROfusion project *Application of Ion Beam Techniques for Materials Irradiation and Characterisation relevant to Fusion Technology.*

Environment:

Geo/bio-environmental and cultural heritage studies.
Decontamination of food and farming products.

Health:

Dosimetry and radiobiology.

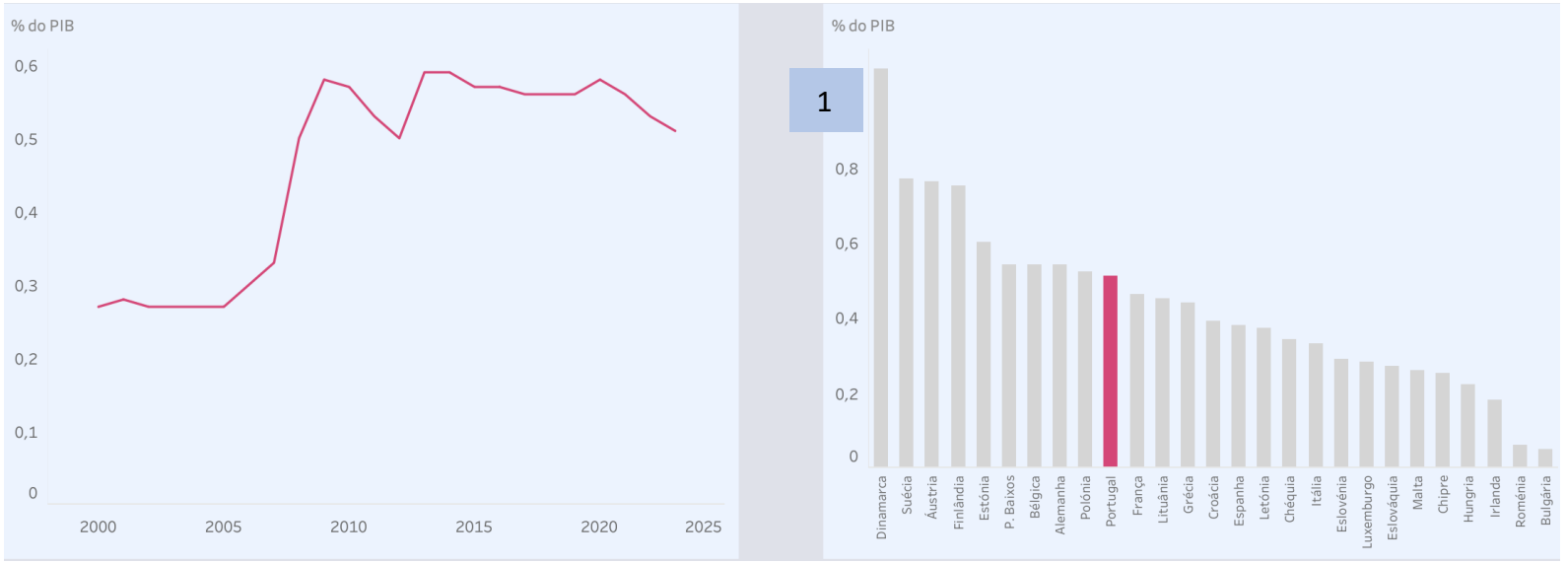
Radiation Protection Safety:

Environmental radioactivity and radio-ecology. Radioactive waste management.
Metrology of ionizing radiations. Preparedness for radiological & nuclear accidents.

CTN

Networks, Collaborations

- PIANOFORTE (the European Partnership for Radiation Protection Research)
- Projects, such as EURADOS, MEDICIS, EURAMET, in collaborations with CERN
- European Radioecology Alliance, a Research Platform
- ISOLDE-CERN

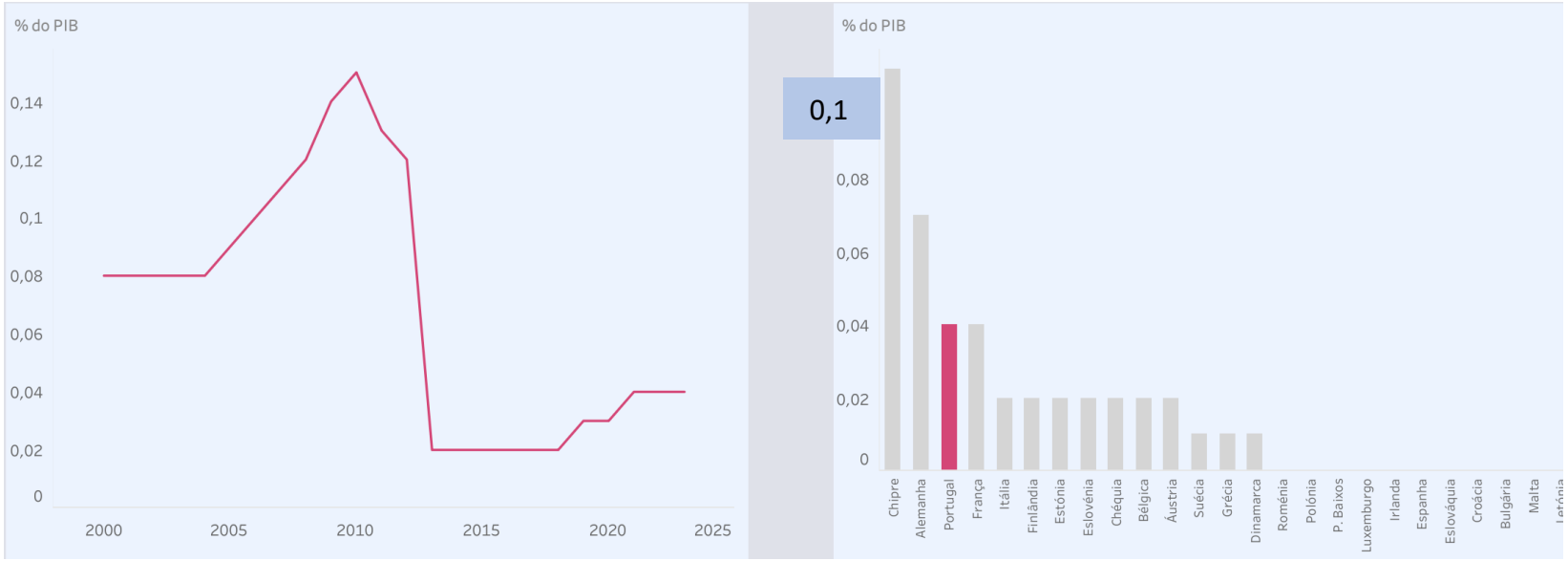


HE institutions %GDP

Portugal (2023)

0,51%

Dived in the 2008 crisis,
and with recent trend to decrease



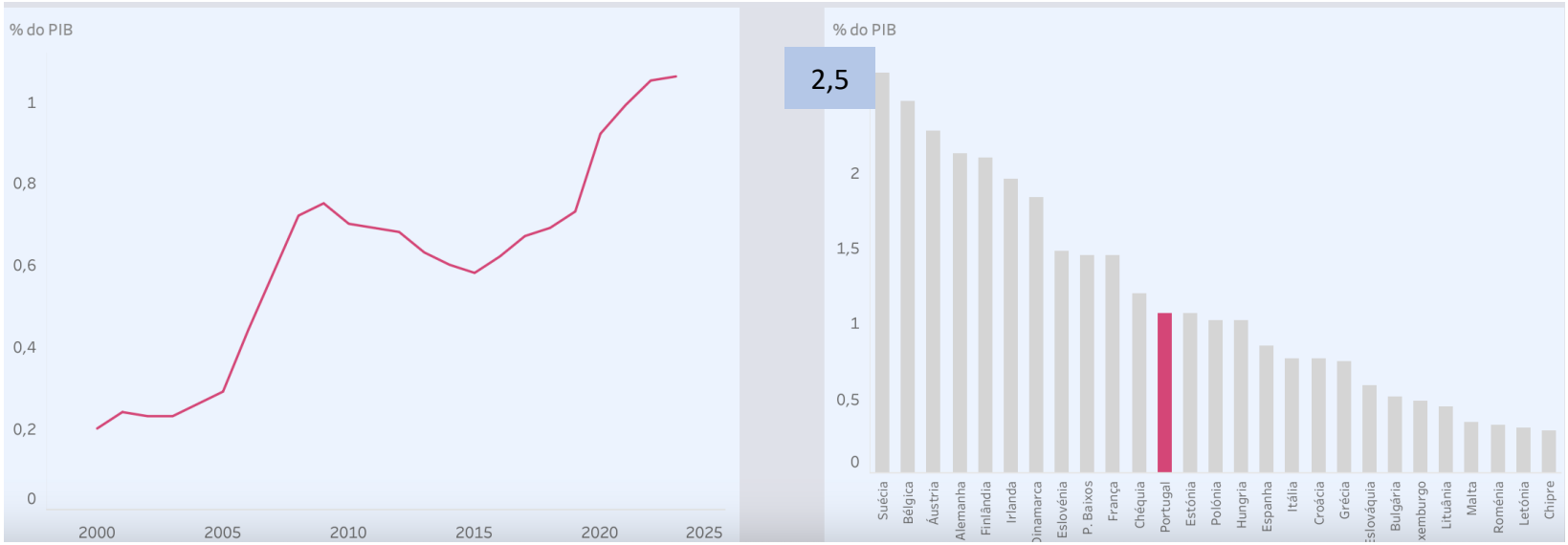
Non-profit institutions %GDP

Portugal (2023)

0,04%

Plunged in the 2008 crisis,
and with recent timid trend to increase

Distribution, by execution sector, of expenditure in R&D (%GDP)

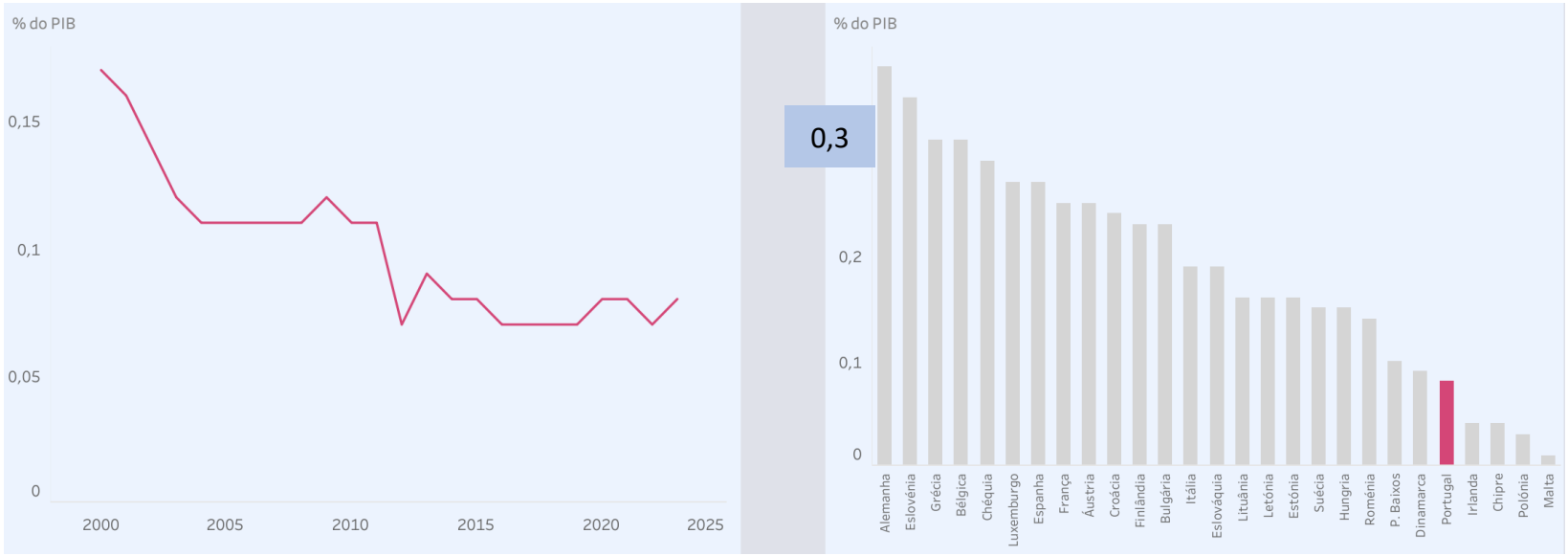


Companies

Portugal (2023)

1,06%

Dived in the 2008 crisis, with steady trend to grow in the last 5 years



State

Portugal (2023)

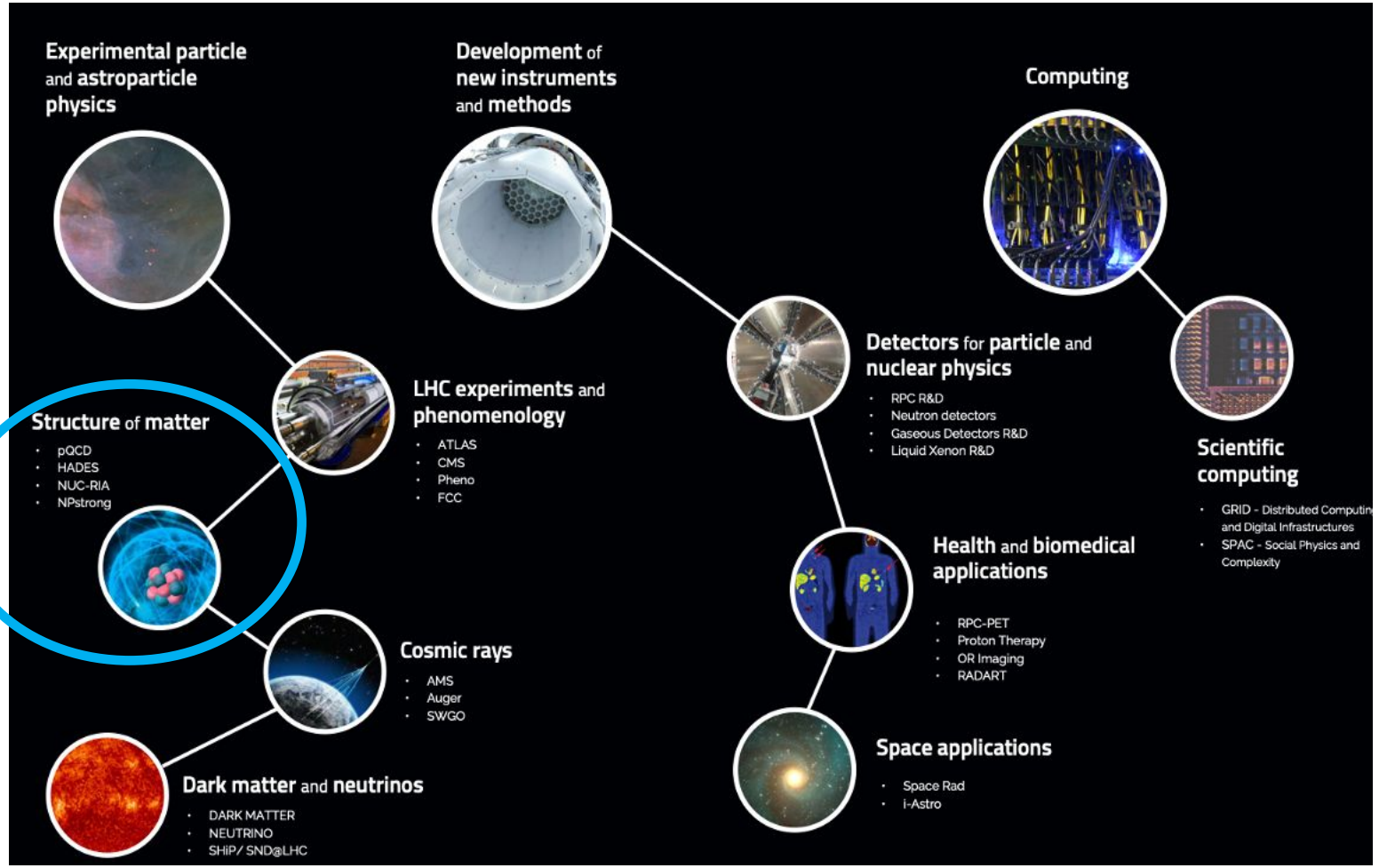
0,08%

Dived in the beginning of the century, with steady trend to flatten in the last decade

Source: https://www.pordata.pt/pt

LIP

Laboratory of Instrumentation and Experimental Particle Physics



.pt

https://www.lip.pt

73

Staff

54

PhD Students

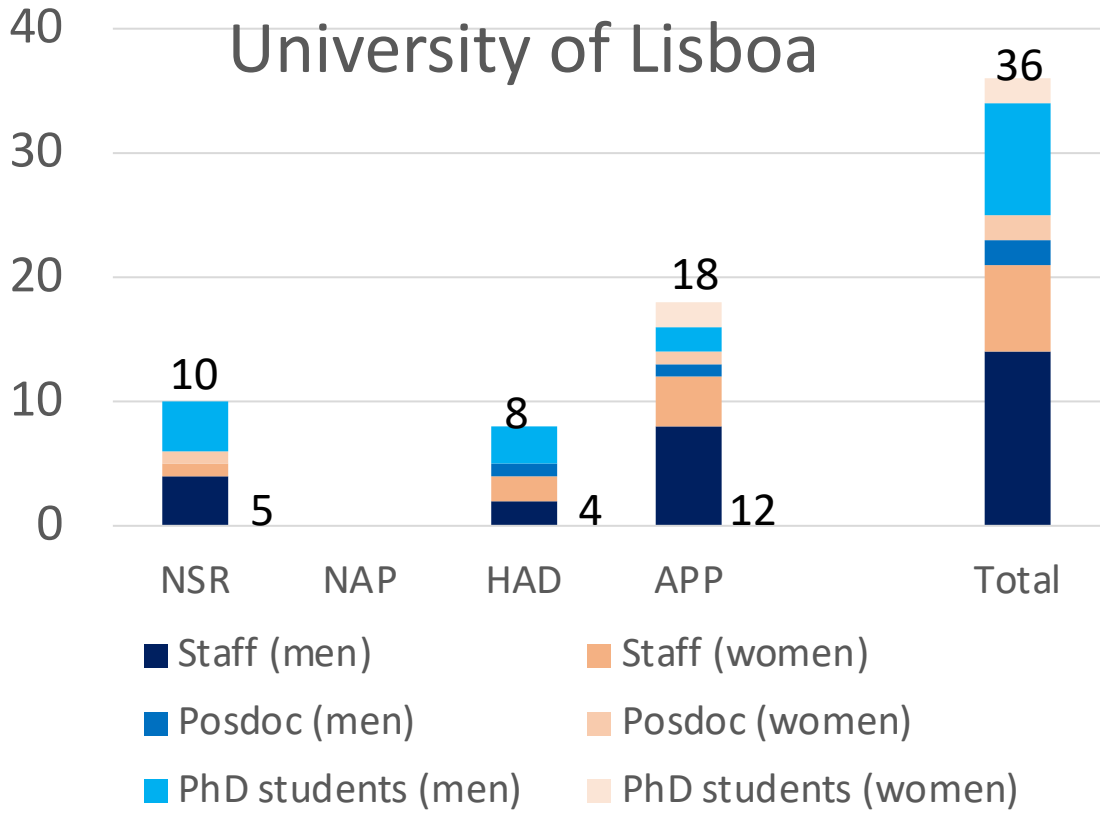
Staff 21

PhD students 11

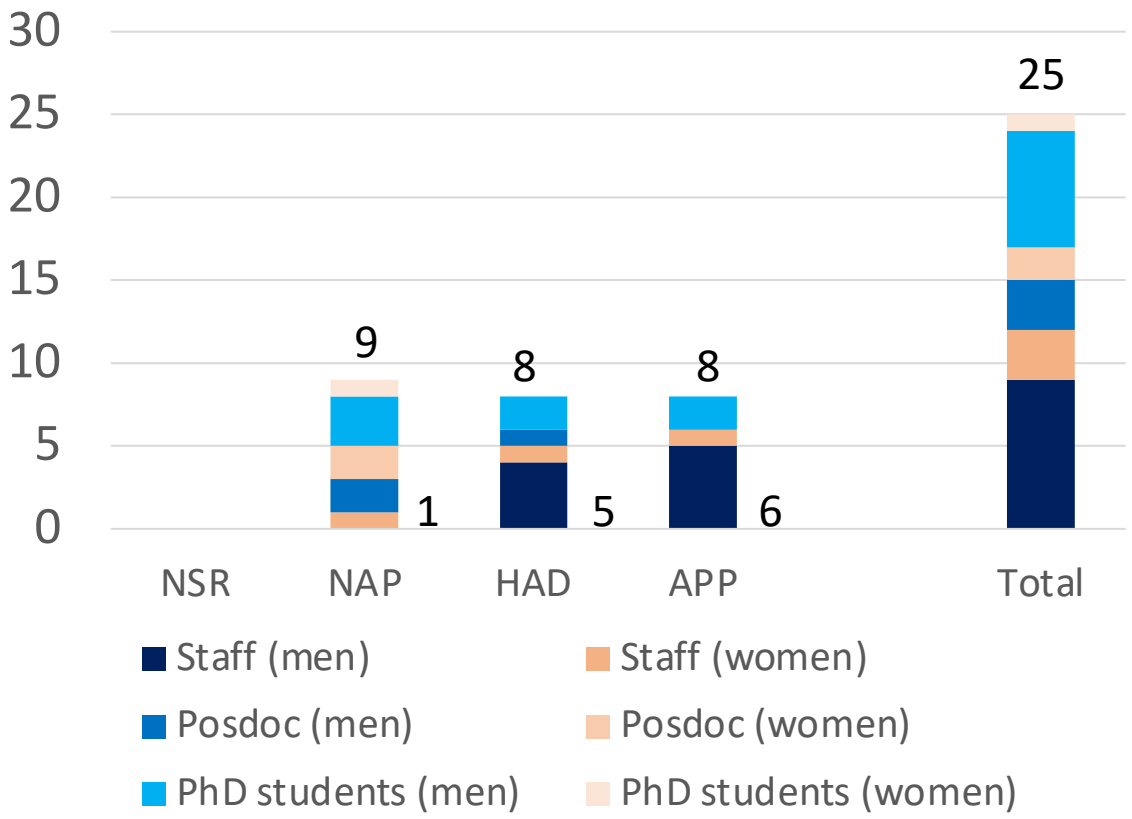
Staff 12

PhD students 8

LIP + part of CTN University of Lisboa



CFisUC University of Coimbra



Highlights of Theoretical Nuclear Physics

NAP

Group is member of **MUSES** collaboration supported by NSF.

Support
from several institutions: DOE, GSI Helmholtz Centre for Heavy-ion Research, São Paulo Research Foundation (FAPESP),
MIT, Princeton, …

HAD

Group Members are Portuguese representatives in PRACE, the Partnership for Advanced Computing in Europe.

Modular Unified Solver of the Equation of State (EoS)
Merges lattice QCD,
nuclear physics, gravitational wave astrophysics, relativistic hydrodynamics, and computer science in programming and front-end development.

Portugal's nuclear physics research happens in three main institutions: LIP, CFisUC, and CTN.

LIP and CFisUC conduct theoretical and experimental research in areas like nuclear reactions, astrophysics, and hadron spectroscopy.

CTN focuses on applied nuclear physics, utilizing accelerators for materials science, environmental studies, and healthcare applications.

Distribution of researchers across these institutions is presented.

Funding limitations and the need for talent retention are highlighted as challenges.

Adaptation of FAIR GSI plans to new conditions was imposed by the war and the suspension of the Russian federation from the collaboration.

Current Adaptation

- ✓ NUSTAR HEB (R^3B) phase-0
- ✓ CBM
  PANDA
- ✓ APPA