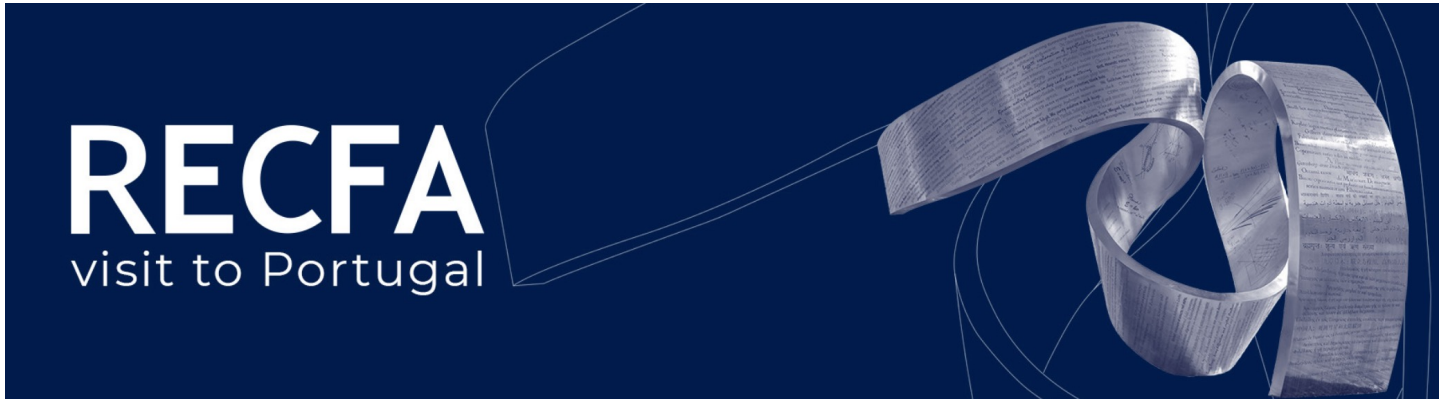

Nuclear Physics in Portugal

Teresa Peña (IST&LIP)

Sept. 2023

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

In **Portugal**, this Research is done across **3** Units

LIP

Line of Research: Structure of Matter

Nuclear Reactions, Instrumentation and Astrophysics (NUC-RIA)

Nuclear Physics and Strong Interaction Group (NPStrong)

CFisUC

Centre for Physics of the University of Coimbra

Ion Beam Laboratory@IST

In **Portugal**, this Research is done across **3** Units

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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]

Applications:

- Semiconductors and Functional Materials
- Cultural Heritage
- Biological Effects of radiation

✓ Expert assistance to IAEA projects

✓ Member of RADIATE

https://www.ionbeamcenters.eu/radiate

✓ Participant in the EUROfusion for Material Irradiation and Material Characterisation for Fusion Technology

In **Portugal**, this Research is done across **3** Units

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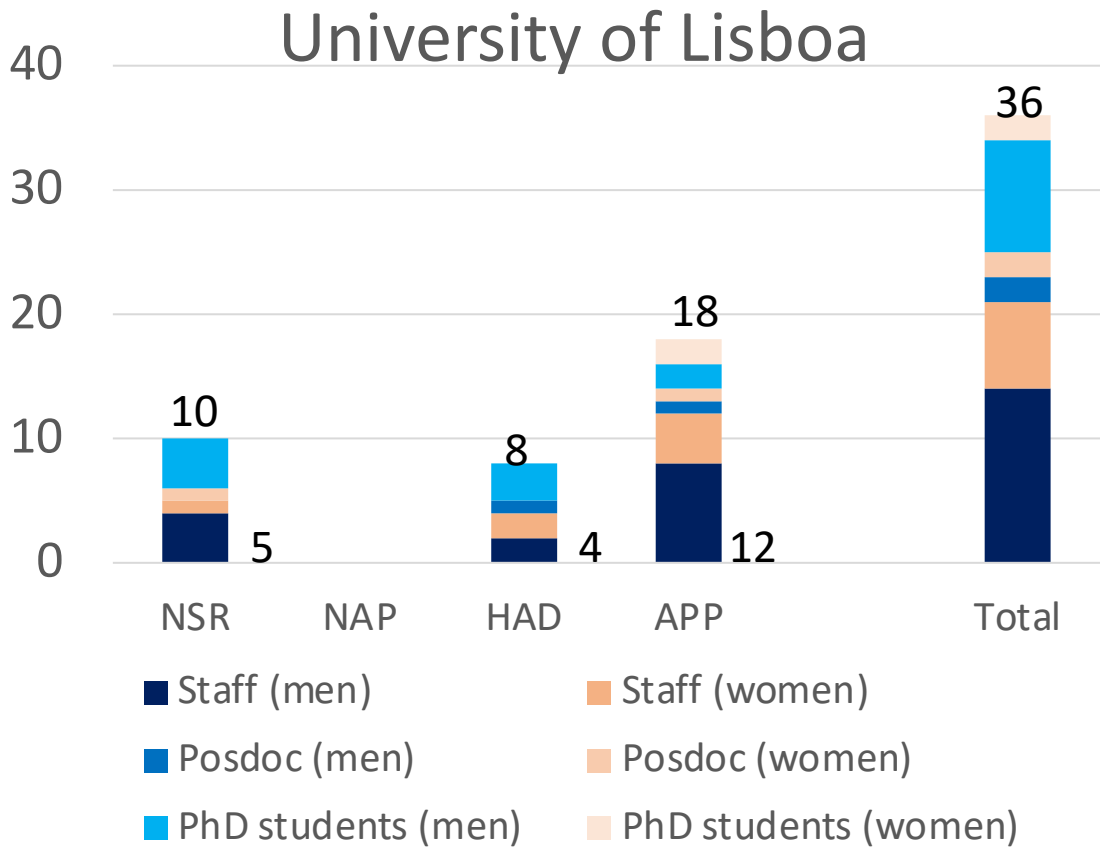
Explored Domains

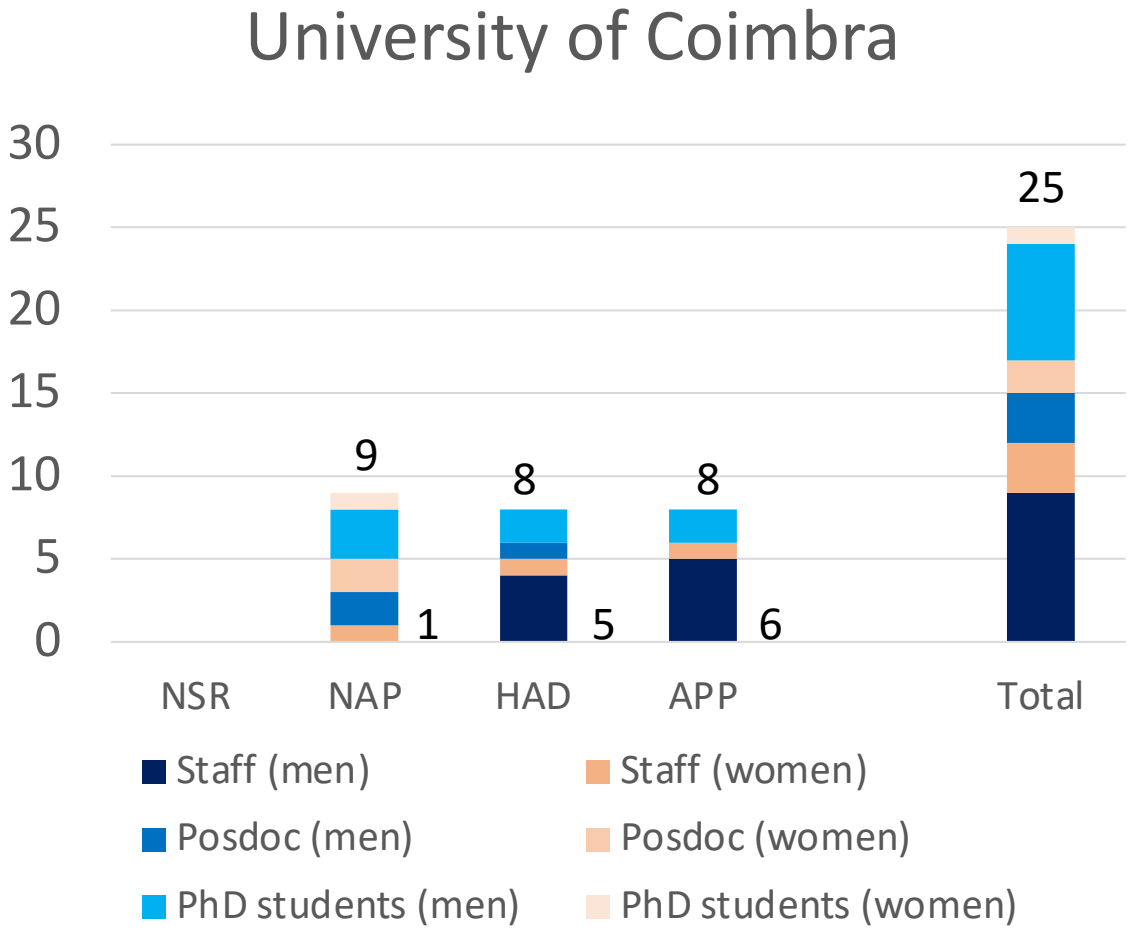
Nuclear Structure and Reactions	**NSR**
Nuclear Astrophysics	**NAP**
Hadronic Physics	**HAD**
Applications	**APP**

(Detectors, Material Science, Biophysics, Decontamination of food and farming products,...)

Staff 21
Postdoc 4
PhD students 11

Staff 12
Postdoc 5
PhD students 8





Let us focus now on

LIP

Line of Research: Structure of Matter

Nuclear Reactions, Instrumentation and Astrophysics (NUC-RIA)

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Explored Domains

Nuclear Structure and Reactions	**NSR**
Nuclear Astrophysics	**NAP**
Hadronic Physics	**HAD**

How do they relate to International Accelerator Facilities?

We are living an era where new theoretical methods based on QCD principles are making an old dream come true:

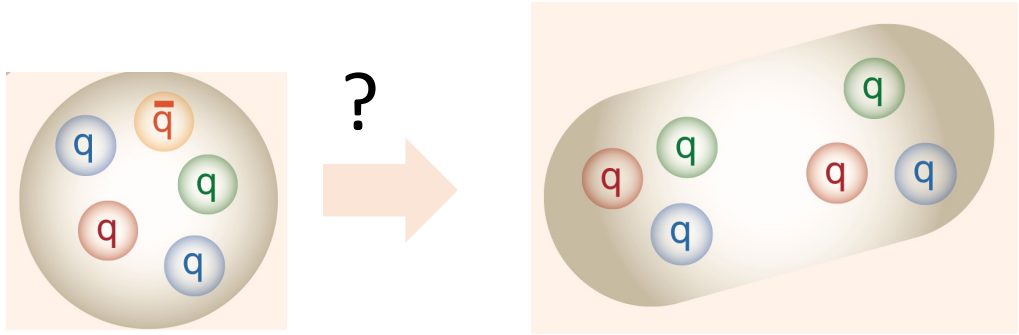
Hadrons, nucleons and nuclear interaction can be
considered together in a unified manner
as different manifestations of the structure formation of QCD.

We are living an era where new theoretical methods based on QCD principles are making an old dream come true:

Hadrons, nucleons and nuclear interaction can be considered together in a unified manner as different manifestations of the structure formation of QCD.

3 main driving forces

LHCb, Belle, BES III discoveries of Exotic Hadrons call for interpretation



New computing power/algorithms are game-changing

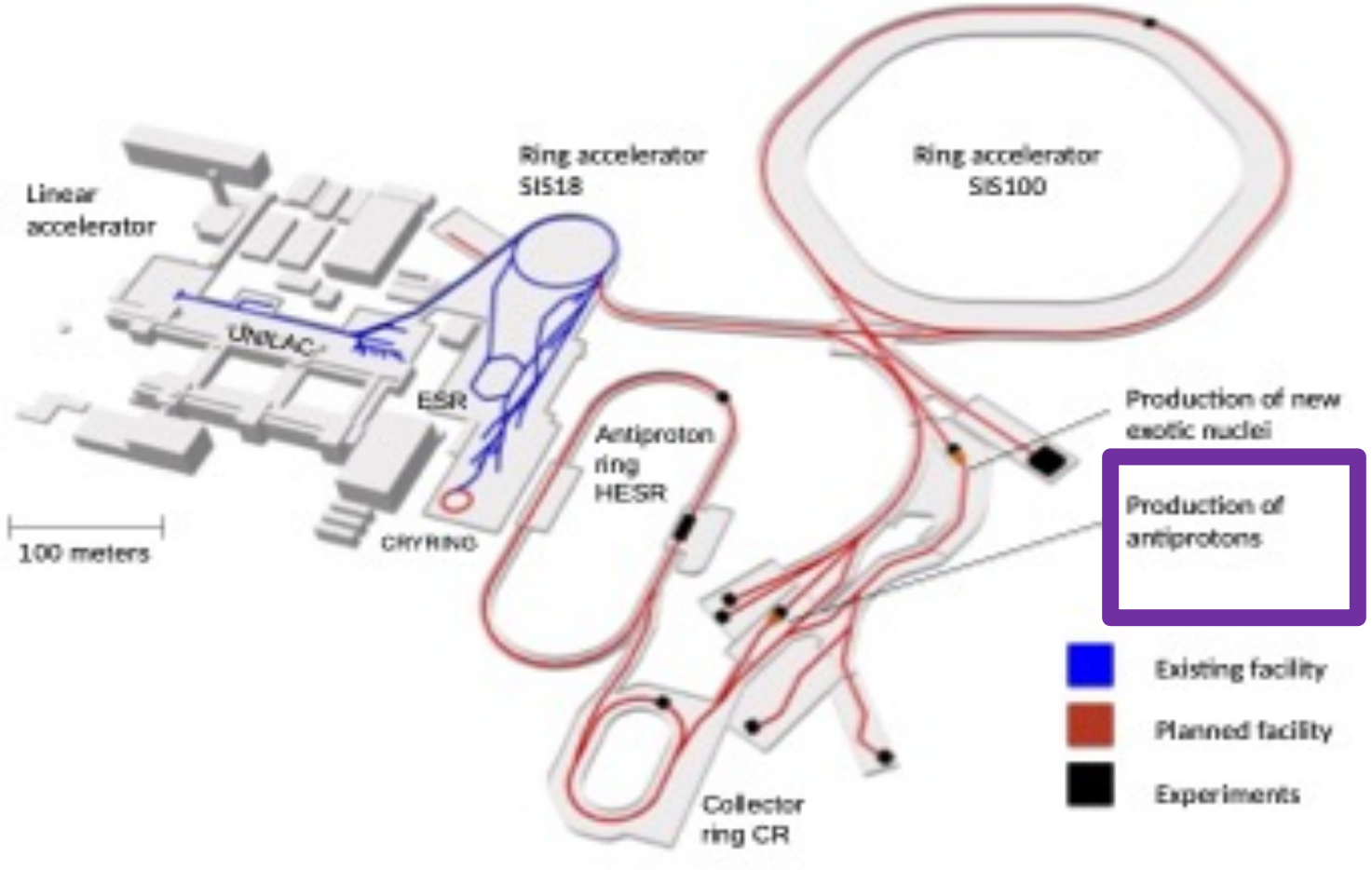
FAIR Accelerator complex and program inspires the dream

FAIR-GSI research focuses on the structure + evolution of matter on both the microscopic and the cosmic scale.

It is the **Universe in the Laboratory**.

Original Plan 4 Pillars

NUSTAR
CBM
PANDA
APPA

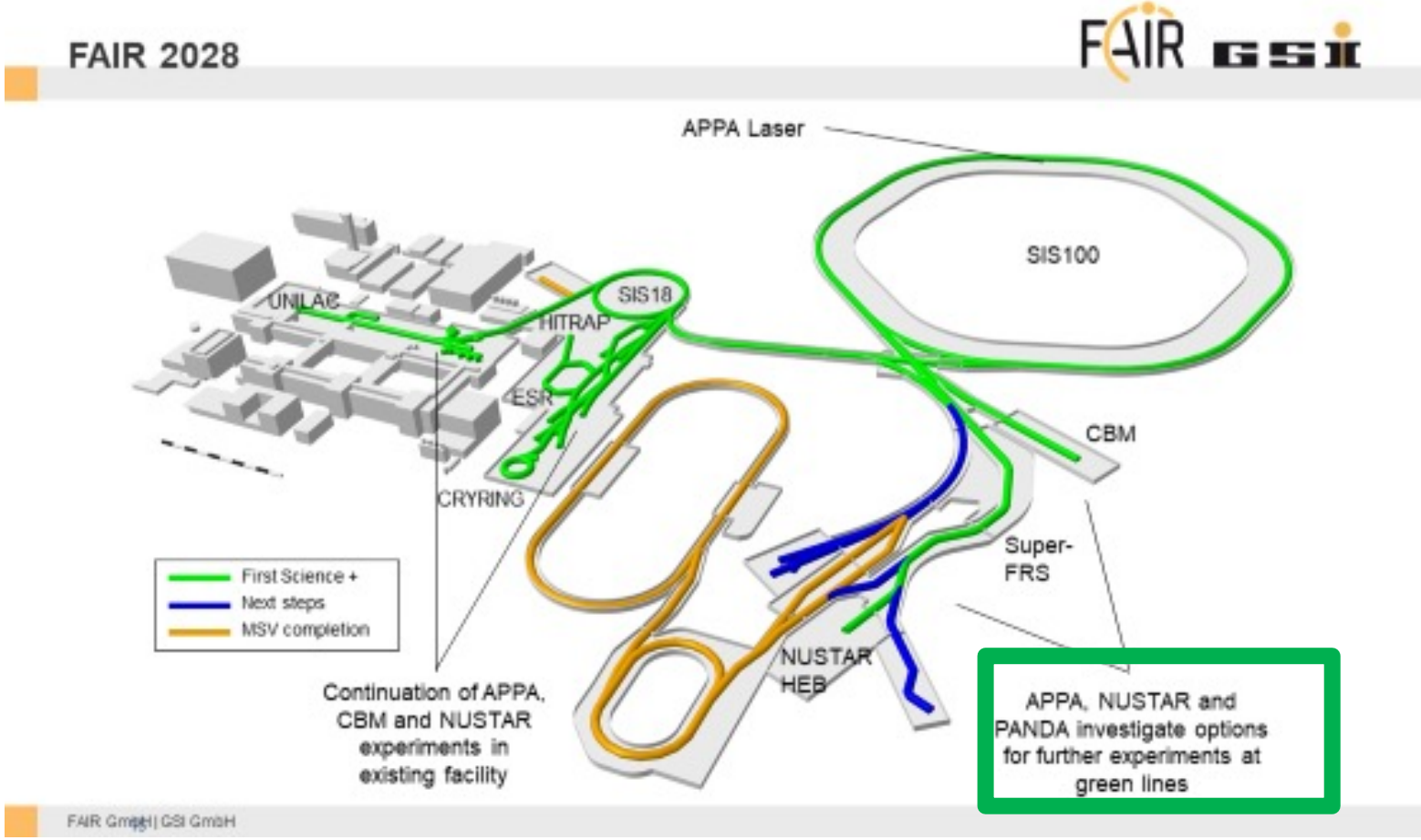


Adaptation to new conditions created by the war and suspension of the Russian federation from the collaboration is under way:

PANDA Pillar activities “diverted” to the CBM proton beam cave

Current Adaptation

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



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

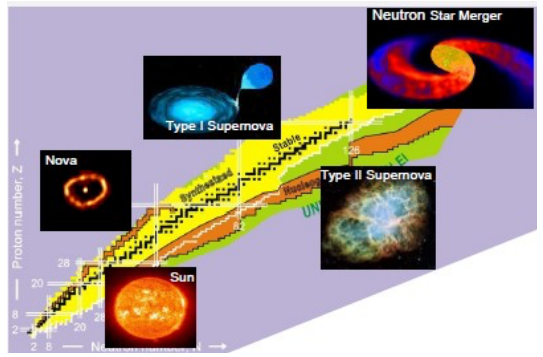
Nuclear Reactions ISOLDE @ CERN

★ IS698 Experiment

Complementary to low energy radioactive beams

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

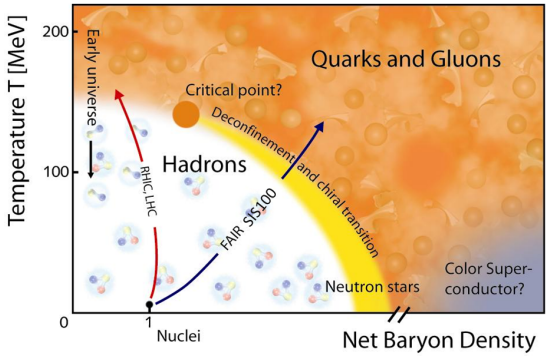
short-range correlations (p,ppn) (p,ppp) reactions with 16C beams



✓ **NAP:** **CBM FAIR-GSI**

Complementary to LHC

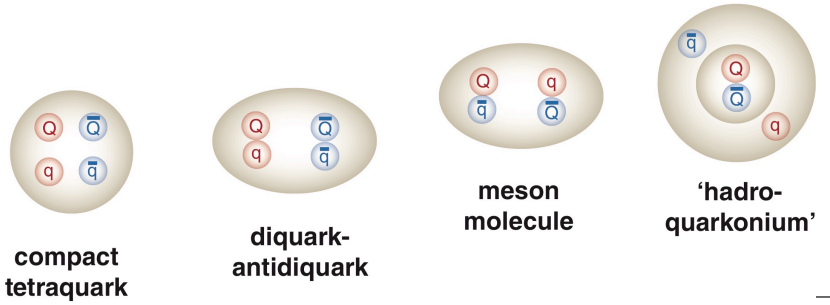
Probes QCD Phase diagram in the region of high baryon densities; EOS neutron stars



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

Interaction rates 3 orders of magnitude higher than in other heavy-ion experiments

Probes QCD spectrum and exotic hadrons

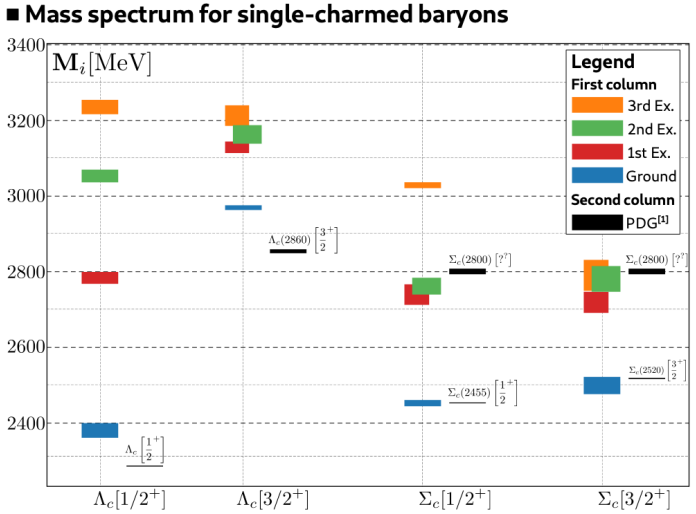


Compact versus molecular near threshold line shapes

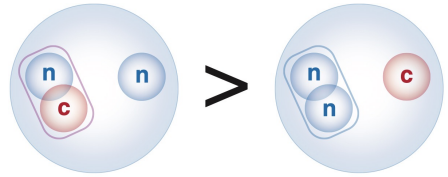
Capacity
publications/YEAR

NSR ~ 10
NAP ~ 20
HAD ~ 15
APP ~ 30

Capacity
Theory predictive power



n is u or d



~60% ~40%

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

$\Gamma(pe^+e^-)/\Gamma_{total}$ Γ_5/Γ

VALUE (units 10^{-5})	*DOCUMENT ID*
4.19±0.34±0.62	[1] ADAMCZEW... 17

[1] The systematic uncertainty includes the model dependence.

The obtained Δ Dalitz branching ratio at the pole position is equal to 4.19×10^{-5} when extrapolated with the help of the Ramalho-Peña model [27], which is taken as the reference, since it describes the data better. The branching ratio

HADES Collaboration, Phys.Rev. C95 0652205 (2017)

Strengths:

- ✓ Unique expertise in functional methods in nonperturbative QCD
  hadron properties, multiquark systems
- ✓ Use of complementary toolkits (Exp.&Theo.)
- ✓ Intl. recognition & collaborations (Exp.&Theo.)

Threats:

- ✓ Lack of funding (but ERC-A proposal)
- ✓ Lack of permanent positions and generational renewal

Internationalization

Recent Highlights CFisUC

NAP

Group is member of MUSES collaboration supported by NSF.

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

HAD

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

Recent Highlights LIP

HAD

TP associate member of HFHF
(Helmholtz Forschungsakademie Hesse fur Fair.)

Student awarded the McCartor ILCAC Fellowship
(JLab area Universities Research Association)

One paper was editor's selection

In 1 year, 7 Invited talks

Presence in OC or IAC of Recent/Future International Meetings

- Baryons 2022, Seville
- ECT* Doctoral Training Program 2022 ECT*, Trento
- NSTAR2024, U of York (UK)

A unified theoretical description of hadrons and nuclei is now feasible.

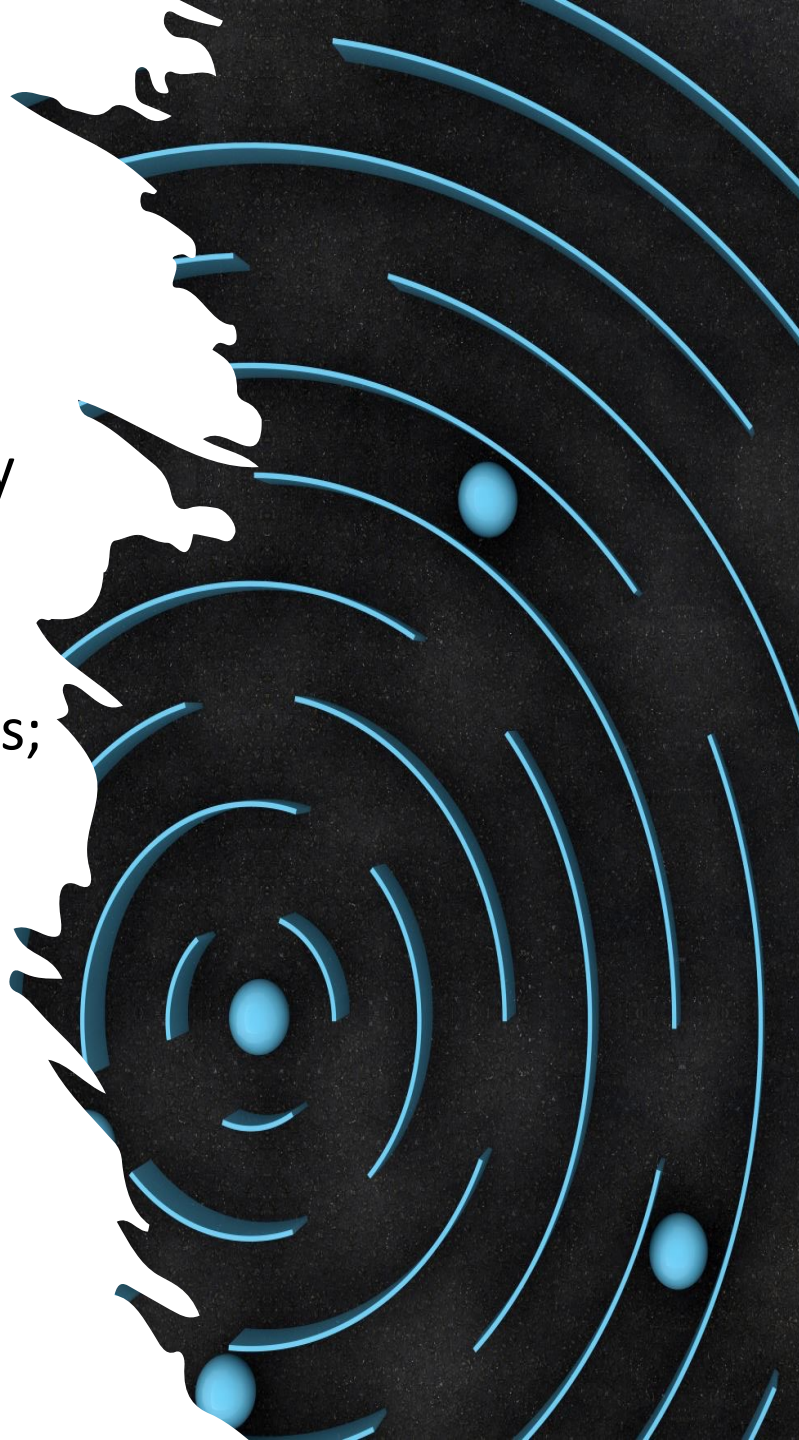
Different Experimental Programs/Facilities supply complementary data; FAIR/GSI pillars and LHCb are prime examples.

International collaboration in large facilities leverages investments;

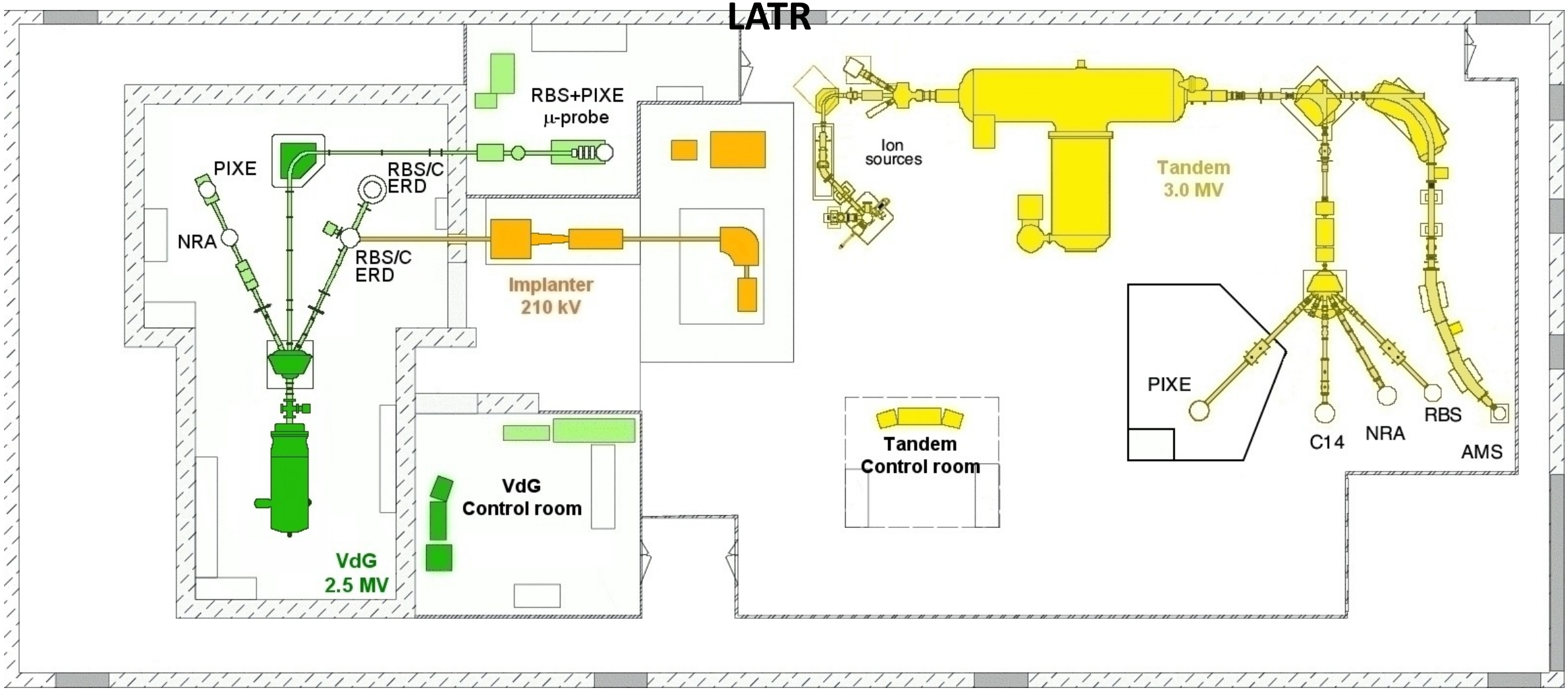
Portugal has competency and knowledge for experimental and theory support.

In other talks:

Nuclear Physics benefits society by providing innovation in medicine, material research, energy technology, climate research,…

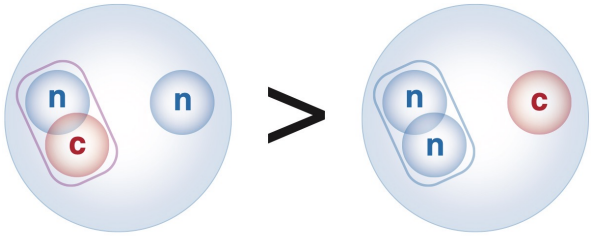


LATR


RBS+PIXE
μ-probe
PIXE
RBS/C
ERD
NRA
RBS/C
ERD
Implanter
210 kV
Ion
sources
Tandem
3.0 MV
PIXE
C14
NRA
RBS
AMS
Tandem
Control room
VdG
Control room
VdG
2.5 MV

Research LIP

HAD



~60% ~40%

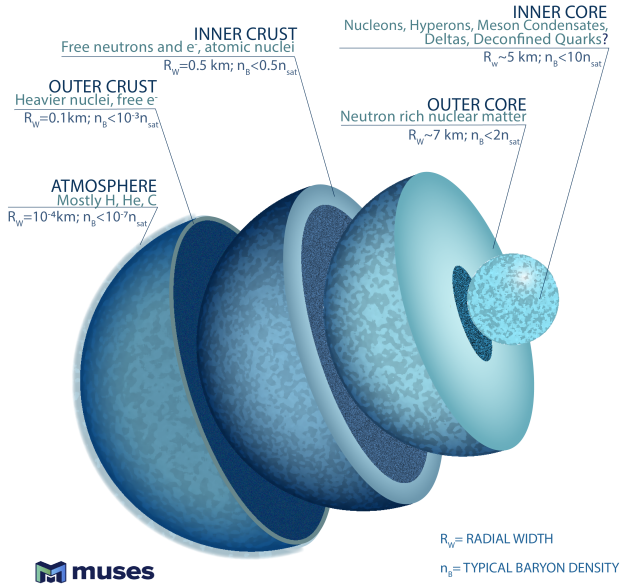
Hadron spectroscopy and Structure:
Pentaquarks;
Baryon Diquark Components and Clusterization;
Hadrons on the light front;
Deuteron as a six-quark state
(connection to short range correlations@R3B)

Strangeness:
Hyperon form factors
(connection to GSI/HADES Collaboration)

Research CFisUC

NAP

Neutron star EOS:
Strangeness;
Tetraneutron;
Delta degrees of freedom;
Empirical constraints on symmetry energy versus baryon density
(connection to CBM)



HAD

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