LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Ciências ULisboa
Faculdade de Ciências da Universidade de Lisboa

Nuclear Astrophysics Landscape in Portugal

D. Galaviz

1st IReNA-IANNA Workshop

South Bend, June 10th 2024

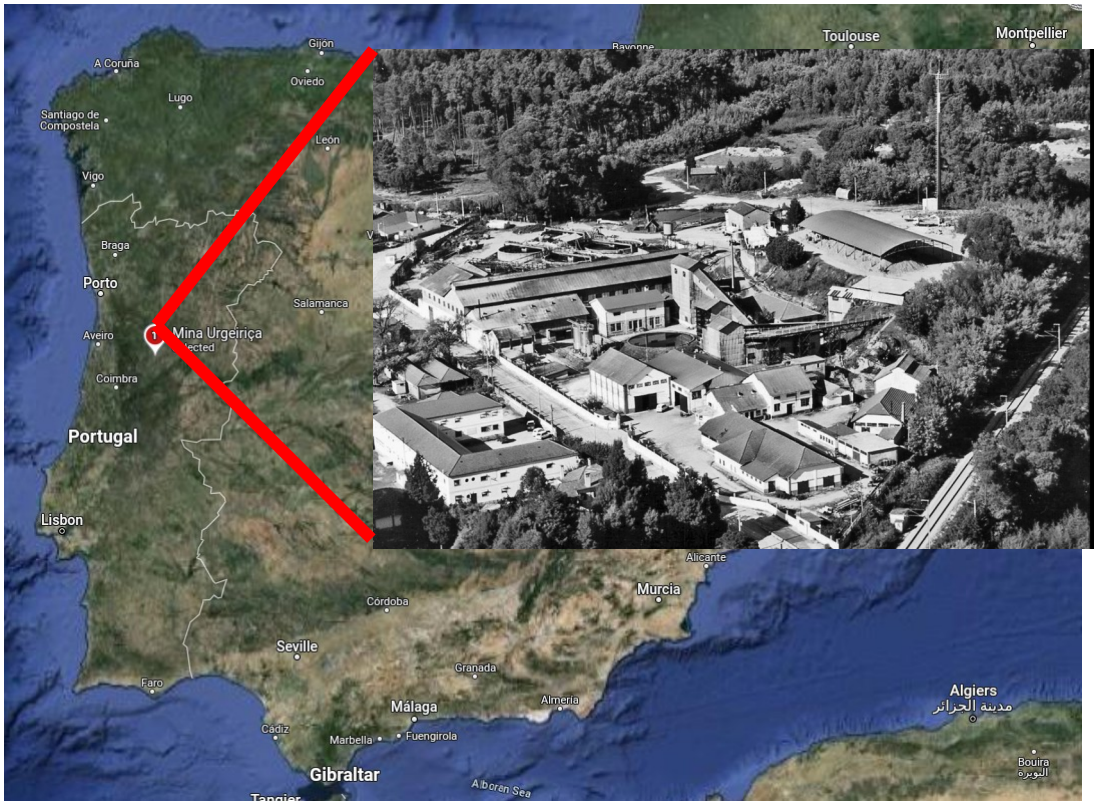
Overview

- A bit of recent **Nuclear (Astro) history** in Portugal
- Portuguese participants/activities in **Nuclear &/or Astrophysics**
- Portuguese facilities for **Nuclear &/or Astrophysics**
- Recent **Low-Energy efforts** for NA in Portugal.
- **Summary**

Some Recent History

Of Portuguese Nuclear Science

Nuclear History in Portugal



The Urgeiriça mines

- Extraction of Radium
  (under M. Curie's supervision)

  1915 - 1944

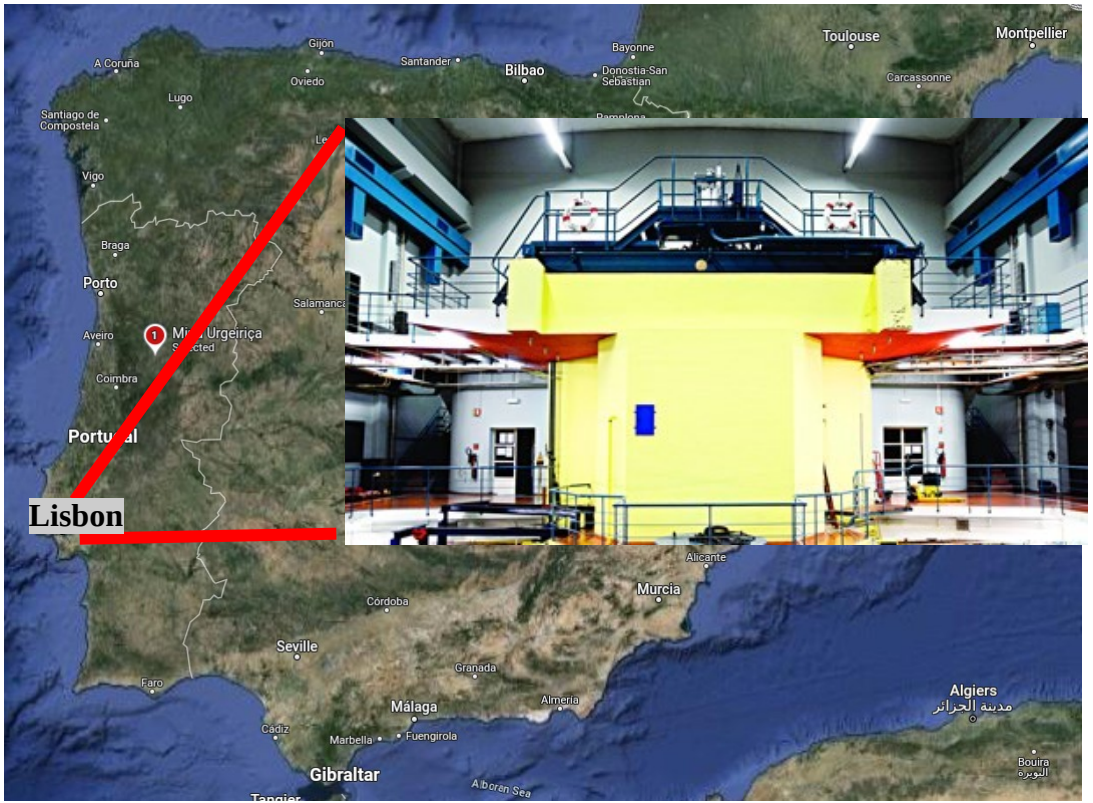
- Extraction of Uranium

  1946 - 1991

- Nuclear Energy Board

  Founded in 1954

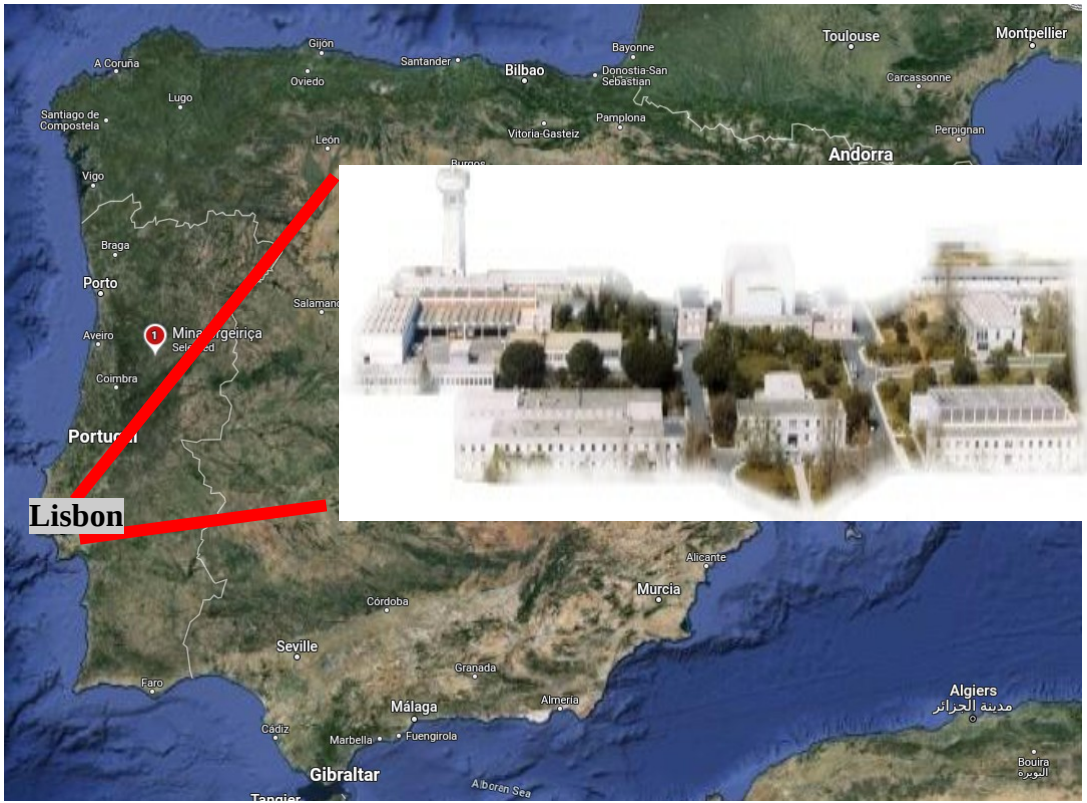
Nuclear History in Portugal



- Construction of the Portuguese Nuclear Reactor

1957

Nuclear History in Portugal



- Construction of the Portuguese Nuclear Reactor

1957

- Laboratory for Nuclear Physcis and Engineering

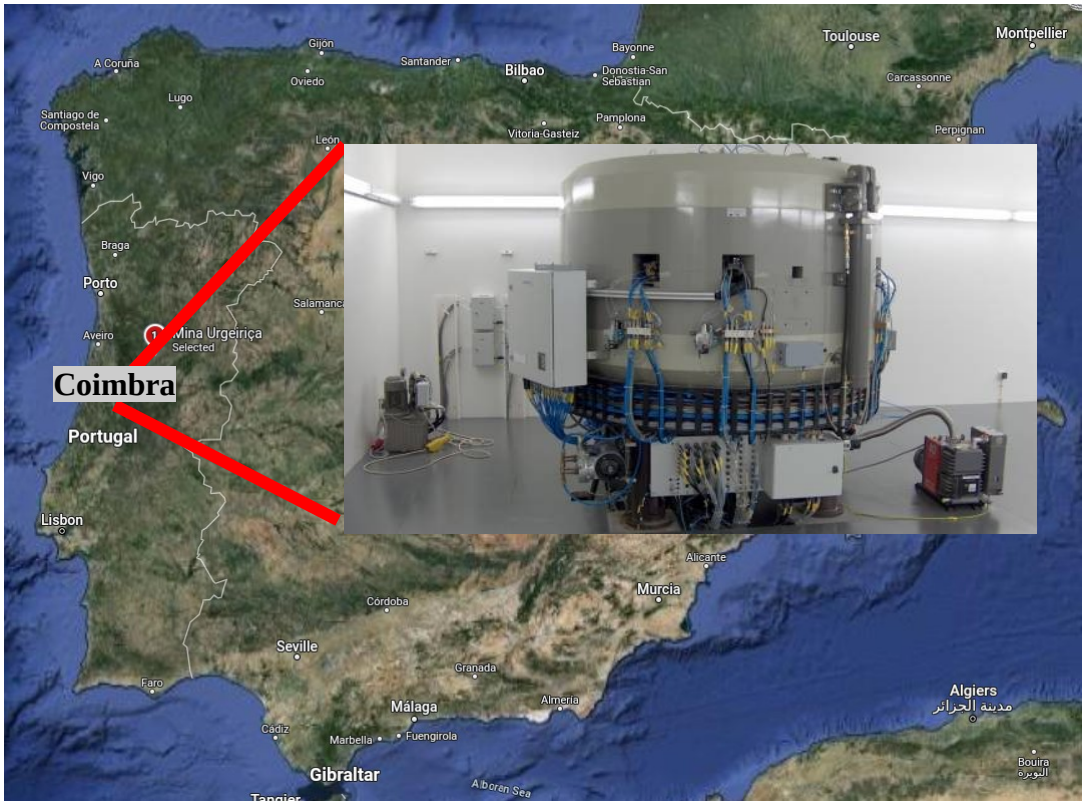
1954

↓

Nuclear Technological Campus (CTN)

2013

Nuclear History in Portugal



- Institute of Nuclear Sciences Applied to Health (ICNAS)

  2010

Nuclear History in Portugal

- Portugal joins CERN

  1986

- **LIP** is founded

Nuclear History in Portugal

- Portugal joins CERN

1986

- **LIP** is founded

2024

- **LIP** has grown to over **200 people** and **3 poles** in Portugal

Portuguese International Partnerships

CYTED
PROGRAMA IBEROAMERICANO DE CIENCIA Y TECNOLOGÍA PARA EL DESARROLLO

esa

CERN

ALBA

EMBL

ESO
European Southern Observatory
www.eso.org

FULBRIGHT Portugal

EMBO
excellence in life sciences

eurocean
The European Centre for Information on Marine Science and Technology

European MARINE BOARD

ECORD
EUROPEAN CONSORTIUM FOR OCEAN RESEARCH DRILLING

Portuguese in the Cosmos

of Nuclear Astrophysics

Portuguese in the Cosmos: LUNA

J. Cruz

- A. Jesus & J. Cruz

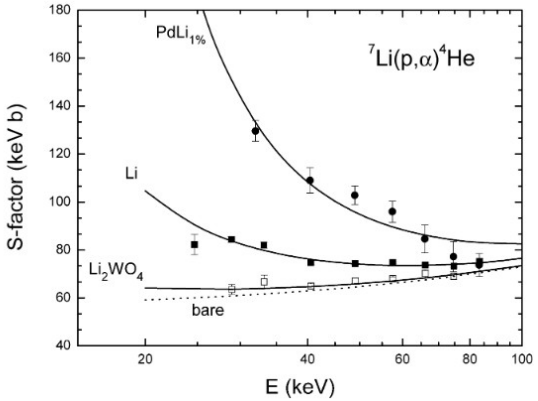
Collaboration with C. Rolfs

Members of the LUNA collaboration

1990s to 2006

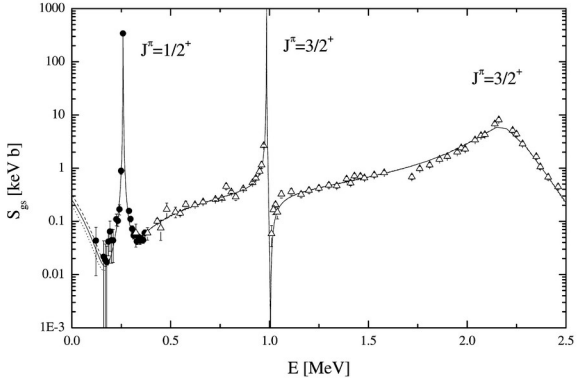
NOVA SCHOOL OF SCIENCE & TECHNOLOGY

Electron screening studies



J. Cruz et al., Phys. Lett. B 624, 181 (2005)

Study of the $^{14}N(p,\gamma)^{15}O$ reaction



A. Formicola et al., Phys. Lett. B 591, 61 (2004)

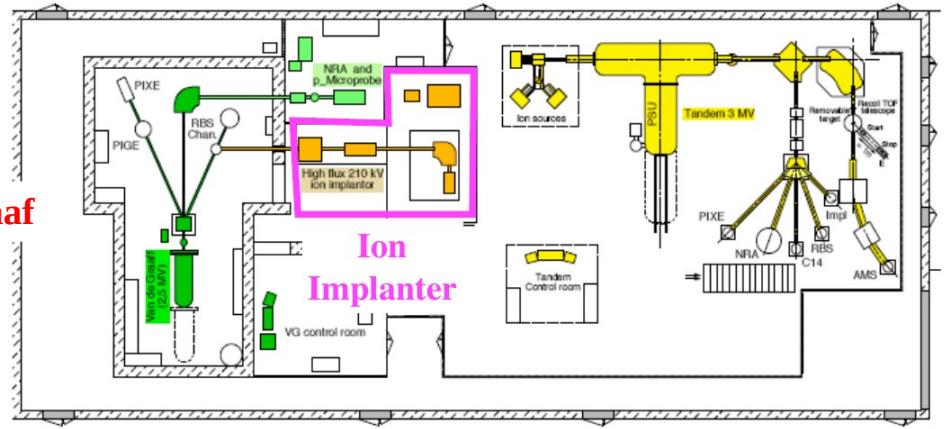
Portuguese in the Cosmos: LUNA

J. Cruz

- Presently: J. Cruz recovered the line of collaboration with **LUNA** for the $^{14}N(p,\gamma)^{15}O$ reaction

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

→ Production and characterization of **^{14}N implanted targets** for $^{14}N(p,\gamma)^{15}O$ measurement at **LUNA**

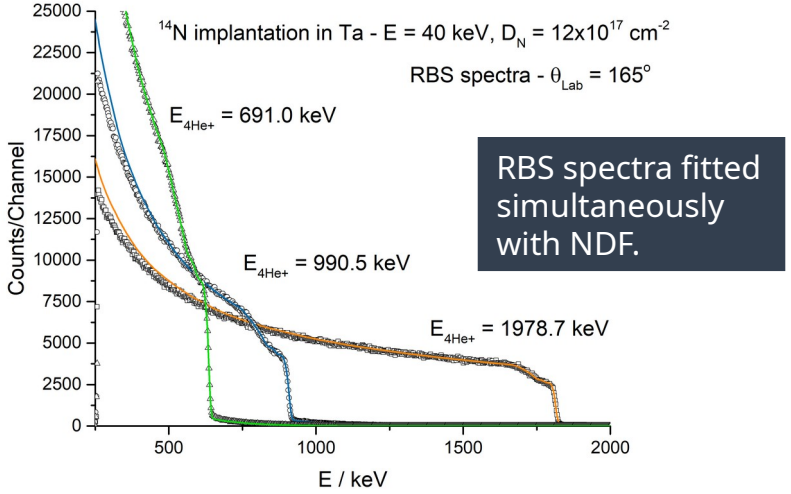


Portuguese in the Cosmos: LUNA

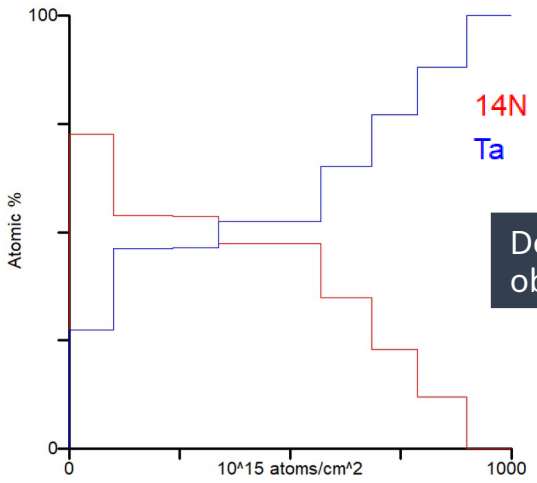
J. Cruz

^{14}N implantations in Ta - E = 40 keV

- RBS analysis @ 2.5 MV Van de Graaff accelerator (CTN-IST)
  - $^{4}He^{+}$ beam and 3 energies: 691.0 keV, 990.5 keV and 1978.7 keV



RBS spectra fitted simultaneously with NDF.

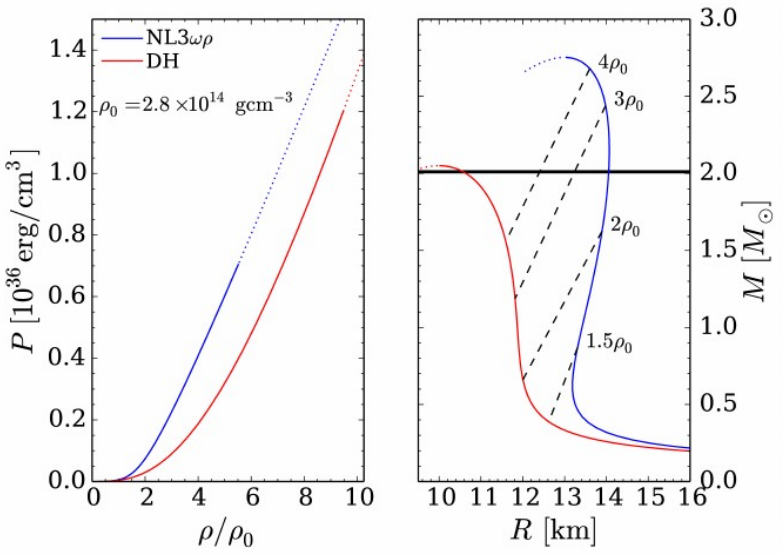


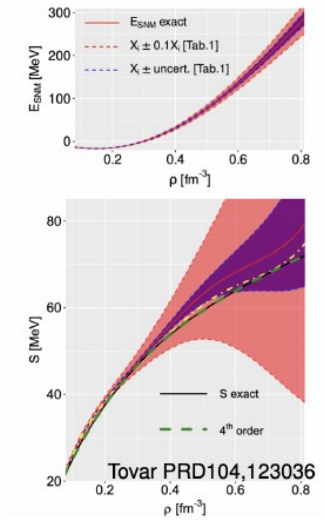
Depth profiles obtained by RBS

Portuguese in the Cosmos: Neutron Stars

C. Providência

- Neutrons stars provide a laboratory for testing
  - nuclear physics: high density, highly asymmetric matter
  - QCD: deconfinement, quark matter, superconducting phases
- mass-radius → equation of state → composition?

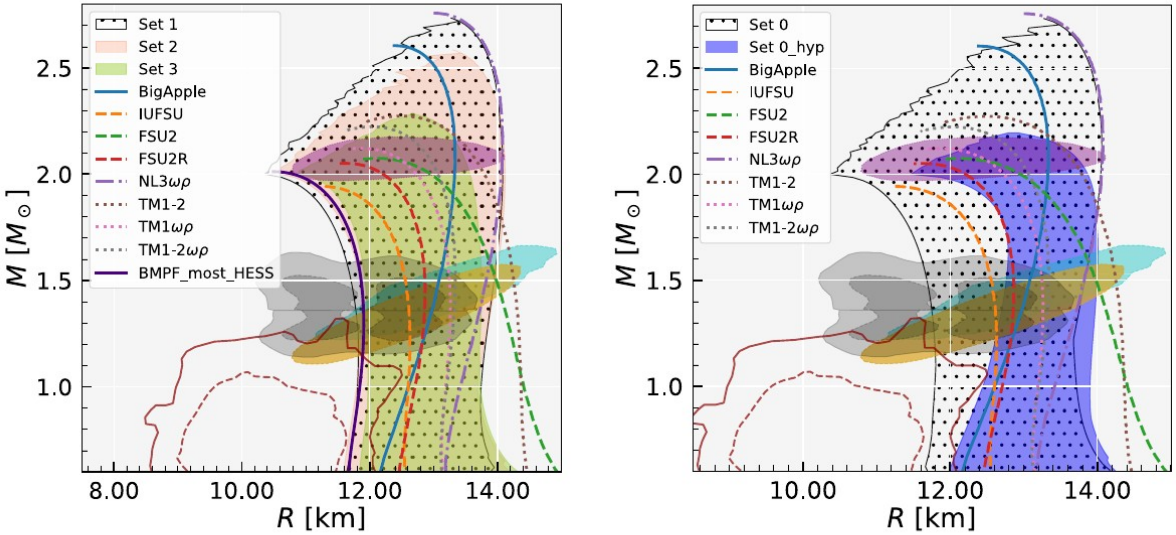




Portuguese in the Cosmos: Neutron Stars

C. Providência

NS properties: full posterior NL



- Observations: GW170817, NICER J0740 and J0030, HESS
- RMF models: NL3$\omega\rho$,FSU2, FSU2R, IUFSU, BigApple, TM1-2($\omega\rho$)
- Bayesian study Left: Set 1 ($\xi < 0.004$), 2, 3 ($\xi > 0.015$)
- Bayesian study Right: Set 0 with and without hyperons

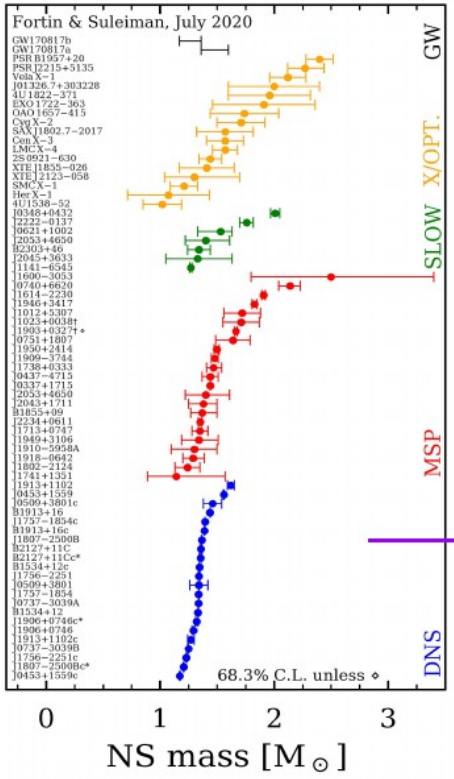
Portuguese in the Cosmos: Neutron Stars

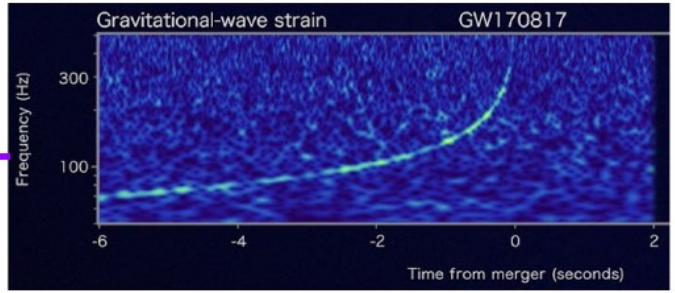
C. Providência

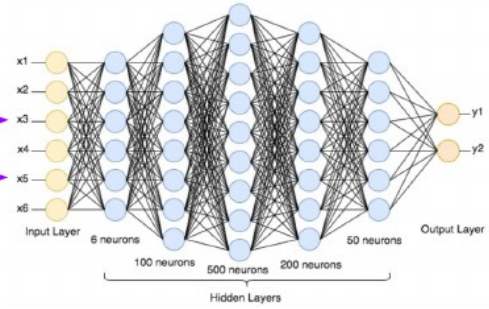
Neutron Star Physics and Machine Learning

CFisUC

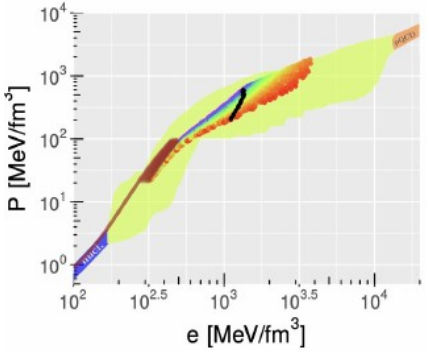
Astrophysics and Cosmology







Inference model



Nuclear matter EOS

C. Providência

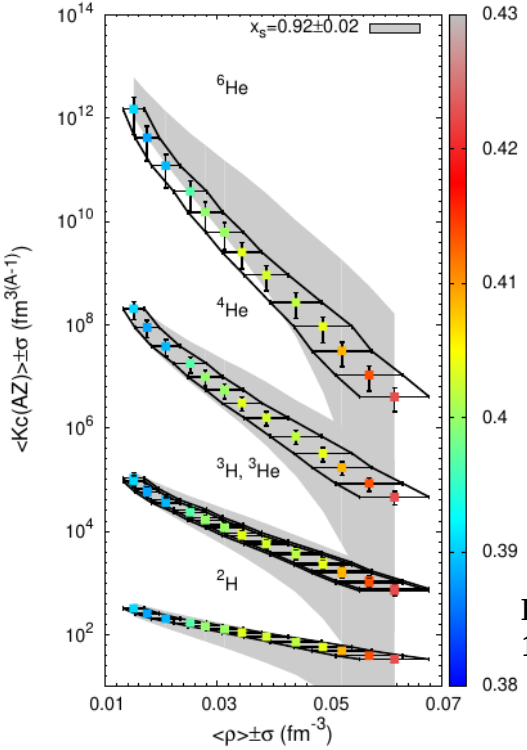
Portuguese in the Cosmos: Neutron Stars

Equilibrium constants: model versus experiment

System ^{136}Xe+^{124}Sn (INDRA - GANIL), Bougault *et al* JPG 47 (2020) 025103

Chemical equilibrium constants :

- $K_c[i] = \rho_i / (\rho_p^{Z_i} \rho_n^{N_i})$
- chemical equilibrium constants for homogeneous matter with five light clusters
- calculated at the average value of (T, $\rho_{\rm exp}$, $y_{pg,\rm exp}$)
- cluster-meson scalar coupling constants $g_{s_i} = x_{s_i} A_i g_s$, with $x_{s_i} = 0.92 \pm 0.02$
- global proton fraction: color code

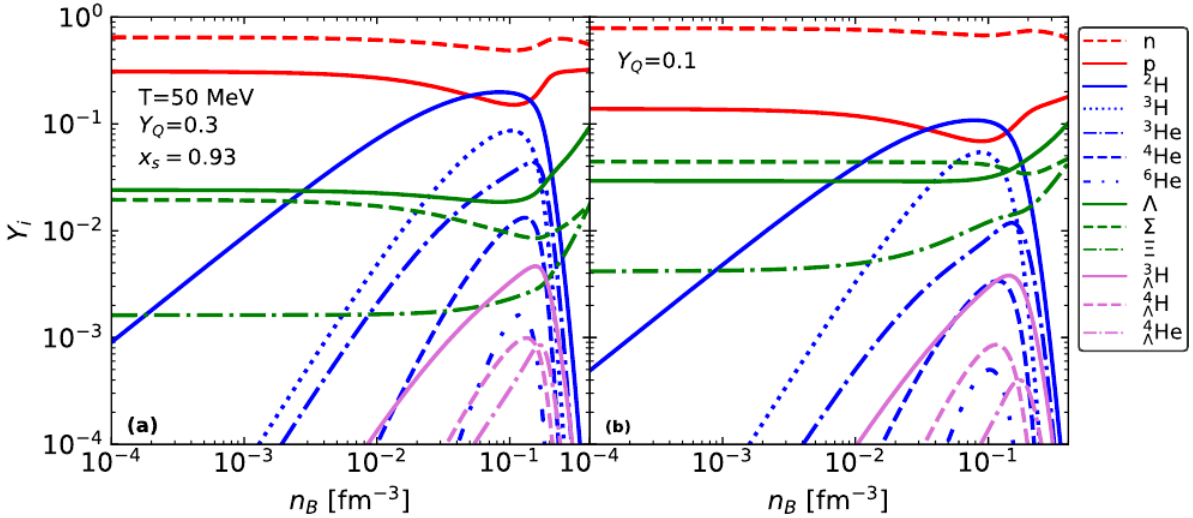


H. Pais et al., Phys. Rev. Lett. 125, 012701 (2020)

Portuguese in the Cosmos: Neutron Stars

Light hyperclusters: how abundant in warm low density matter?

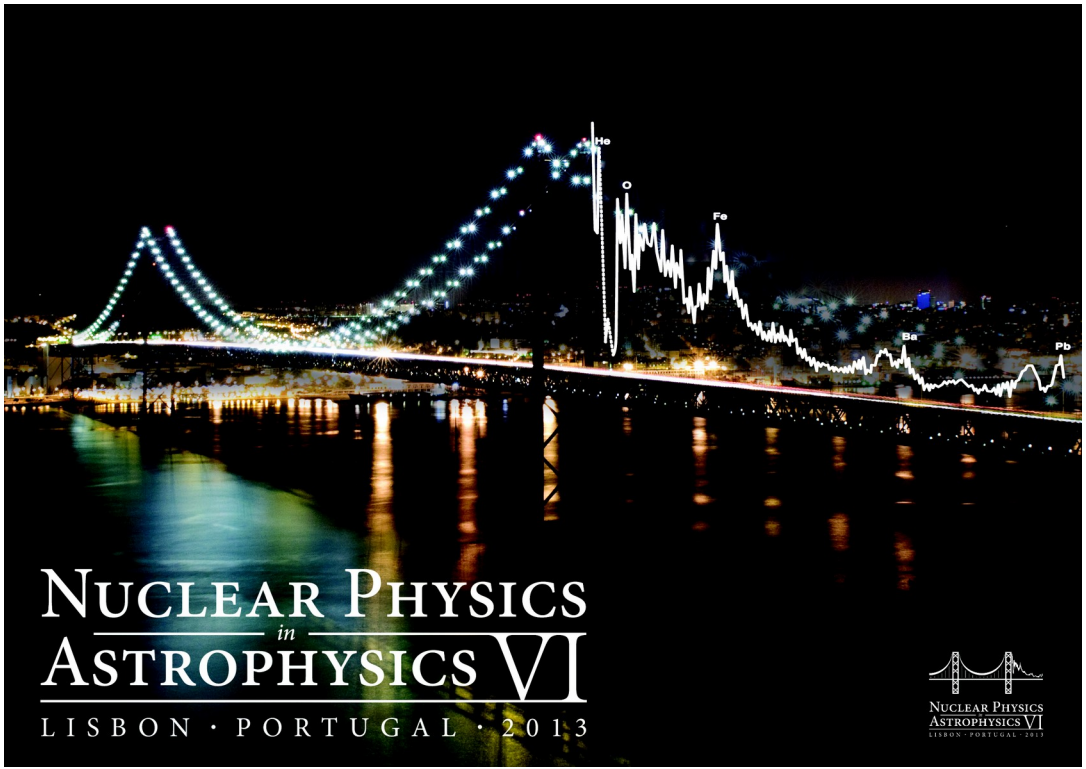
C. Providência



- Mass fractions of the unbound protons and neutrons Λ, Σ and Ξ, light clusters and light hypernuclei
- Hypernuclei may be more abundant than α-particles or other heavier clusters, for small Y_Q

Portuguese in the Cosmos: Nuclear Reactions

D. Galaviz



19th - 24th May, 2013

Topics

- Big Bang Nucleosynthesis
- Stellar Nucleosynthes and Evolution
- The s- and r-process
- Explosive Nucleosynthesis (p, np, rp-process)
- Astrophysics of Compact Stars & SN
- Nucl. Astroph. with RIBs

Portuguese in the Cosmos: Nuclear Reactions

D. Galaviz

Ciências ULisboa

enαpγ CFN Experimental Nuclear AstroPhysics Group

Daniel Galaviz

Ángel Miguel Sánchez Benítez

Pablo Cabanelas

Ana Henriques

Pamela Teubig

Paulo Velho

David Ferreira

Sara Perestrelo

Frederico Arez

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Portuguese in the Cosmos: Nuclear Reactions

Nuclear Reactions, Instrumentation and Astrophysics (NUC-RIA)

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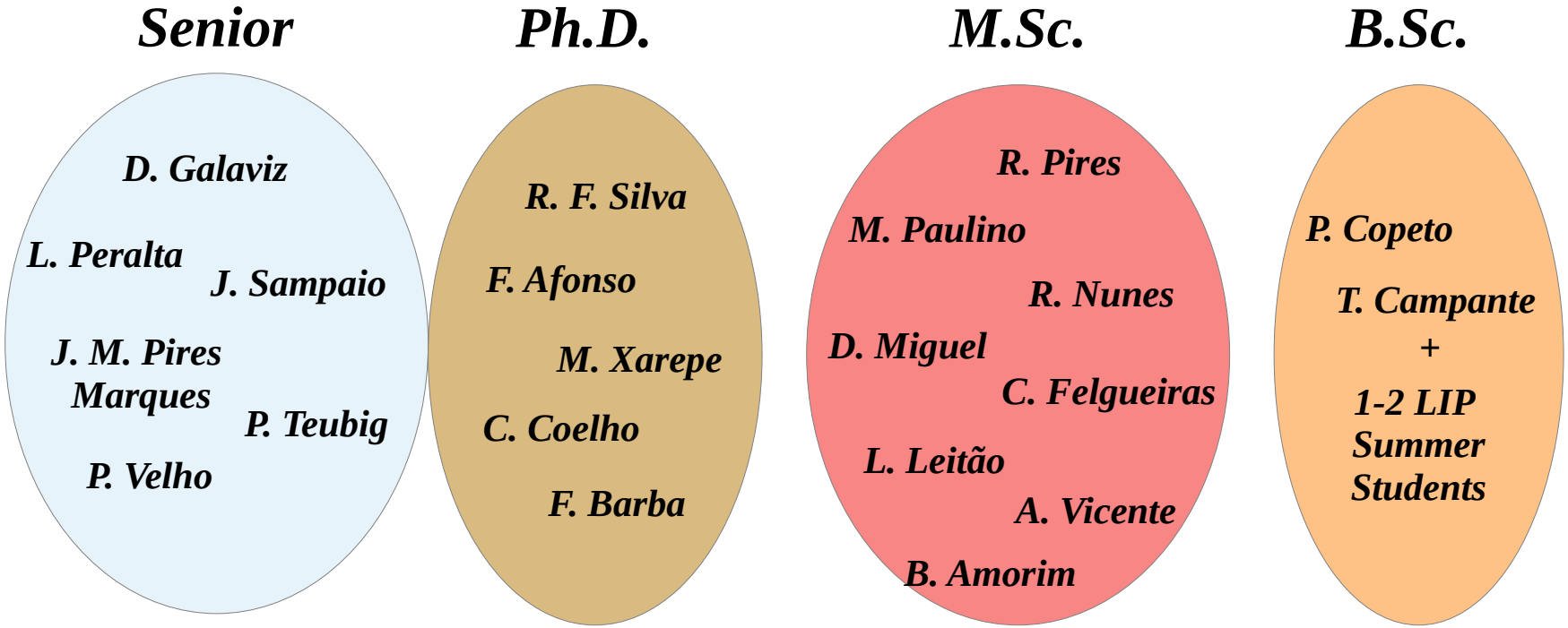

Portuguese in the Cosmos: Nuclear Reactions

Nuclear Reactions, Instrumentation and Astrophysics (NUC-RIA)

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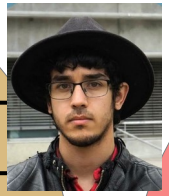
Senior	*Ph.D.*	*M.Sc.*	*B.Sc.*
D. Galaviz	*R. F. Silva*	*R. Pires*	*P. Copeto*
L. Peralta	*F. Afonso*	*M. Paulino*	*T. Campante*
J. Sampaio	*M. Xarepe*	*R. Nunes*	+
J. M. Pires Marques	*C. Coelho*	*D. Miguel*	*1-2 LIP Summer Students*
P. Teubig	*F. Barba*	*C. Felgueiras*	
P. Velho		*L. Leitão*	
		A. Vicente	
		B. Amorim	



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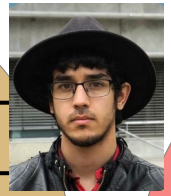
D. Galaviz	*R. F. Silva* 	*R. Pires*	*P. Copeto*
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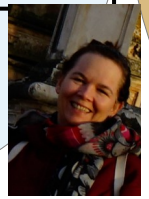
P. Teubig 	*F. Barba*	*C. Felgueiras*	
P. Velho		*L. Leitão*	
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		B. Amorim	

Portuguese in the Cosmos: Nuclear Reactions

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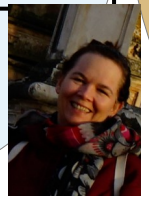
J. M. Pires

Marques

P. Teubig



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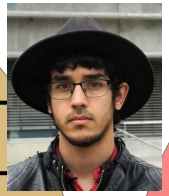
Ph.D.



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1-2 LIP Summer Students

Portuguese in the Cosmos: Nuclear Reactions

Nuclear Reactions, Instrumentation and Astrophysics (NUC-RIA)

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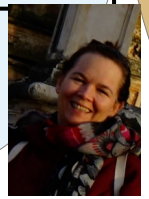

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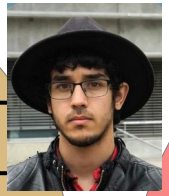

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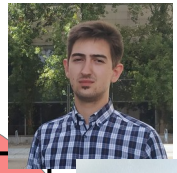
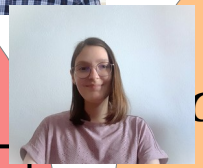
M.Sc.



R. Pires



M. Paulino

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D. Miguel

C. Felgueiras

L. Leitão

A. Vicente

B. Amorim

B.Sc.

Copeto

T. Campante

+

1-2 LIP Summer Students

Portuguese in the Cosmos: Networks and Collaborations

- COST Actions: Compstar, NewCompstar, PHAROS, ChETEC
- Collaborations: MUSES, SKA, CompOSE, R^3B/FAIR, IANNA/IReNA
- Infra-structure Projects: EURONS, ENSAR, ENSAR2, EURO-LABS

Facilities

In Portugal for Nuclear Astrophysics

Infrastructures

Lisbon (Portugal)

Infrastructures

Ultra High-Vacuum Thermal Evaporator

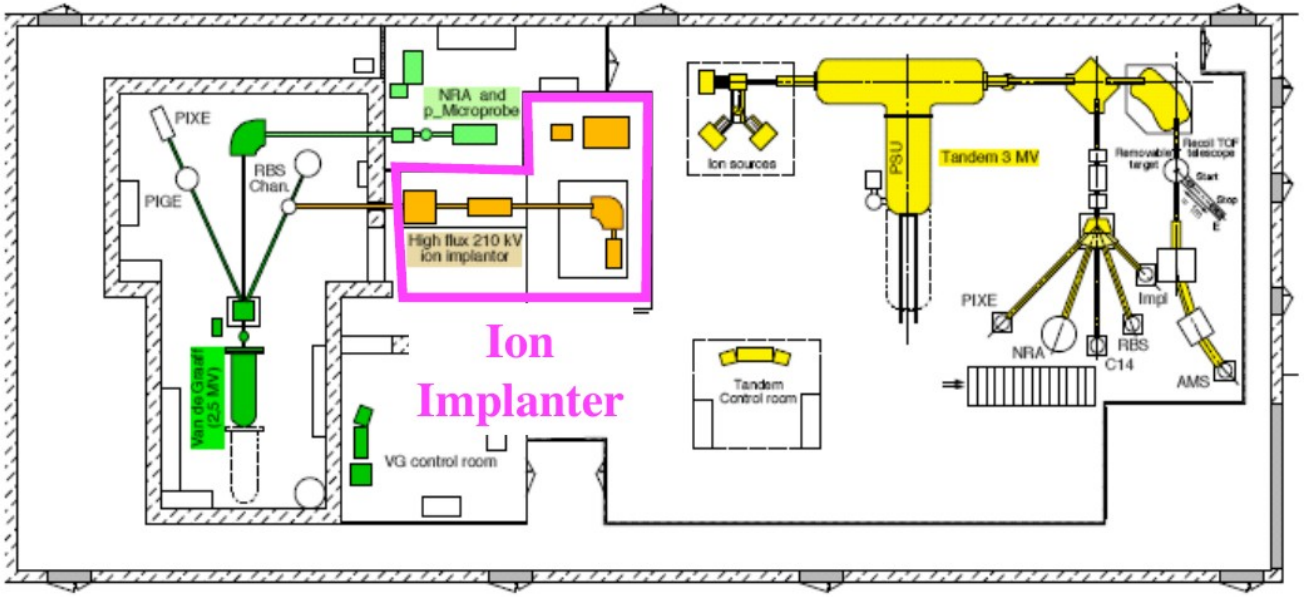
Tomorrow's talk
by
P. Teubig

Infrastructures

Lisbon (Portugal)

Infrastructures

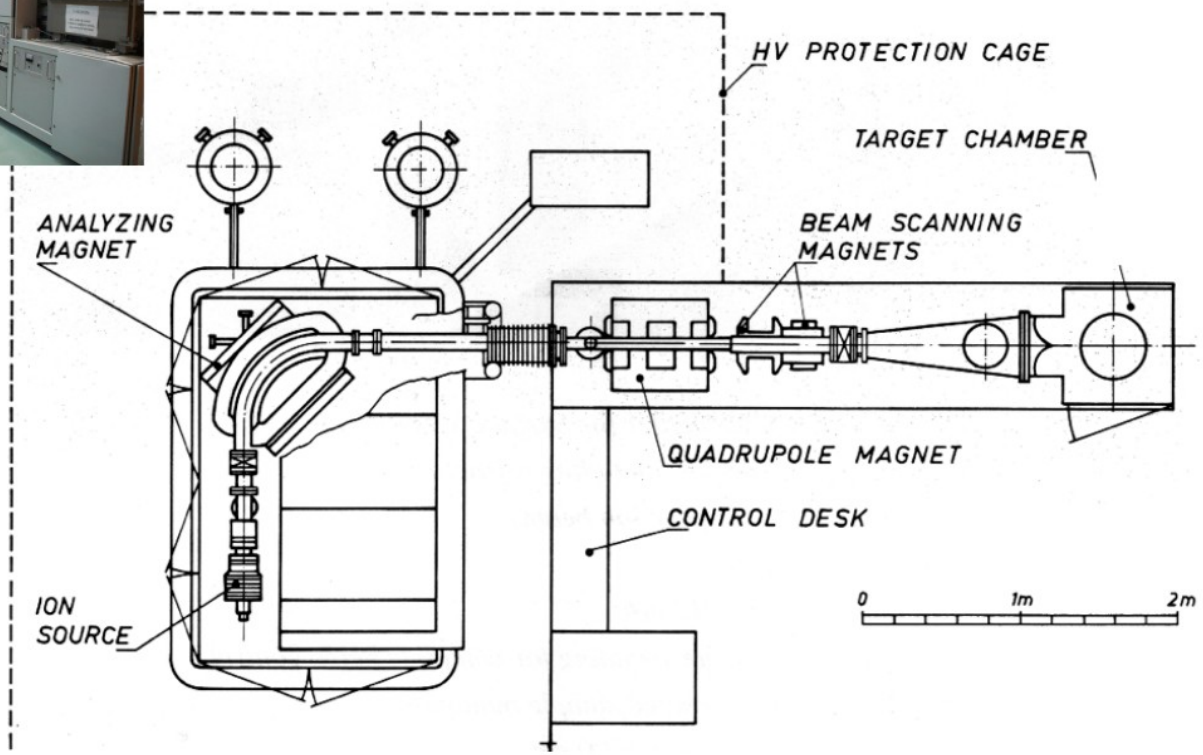
http://www.ctn.pt



Infrastructures

210 kV Ion Implanter

Infrastructures



Infrastructures

210 kV Ion Implanter

Already implanted ions

Beam current (µA)

< 10	10-50	50-100	100-500	> 500

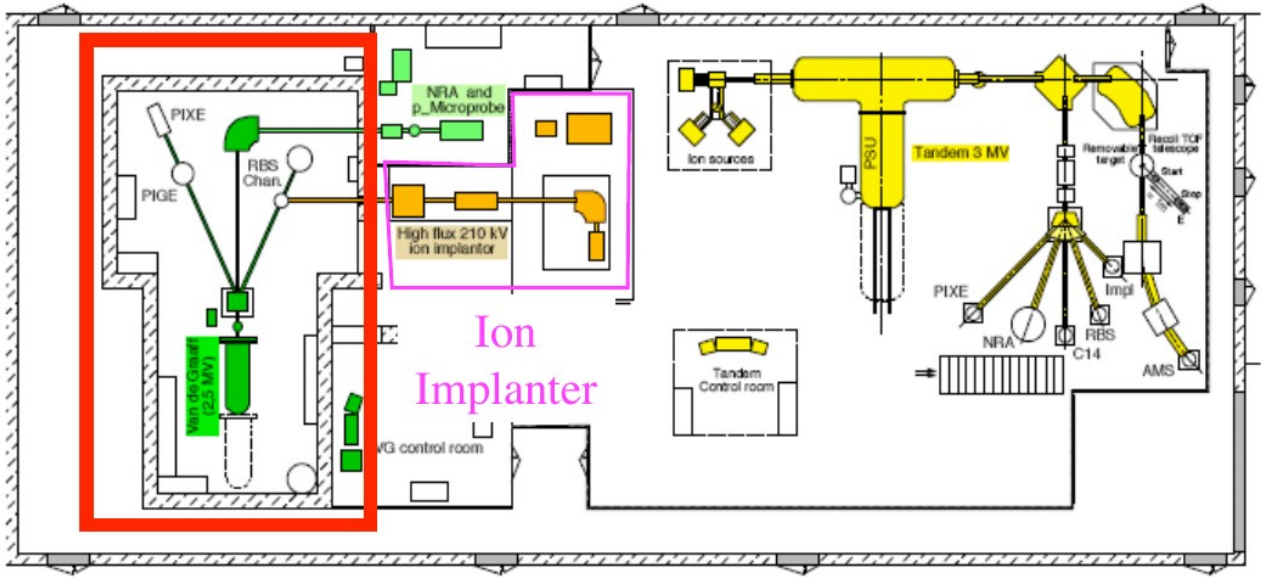
H																He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

Implanted targets on **thick** (Ta) and **thin** (C) substrates

Infrastructures

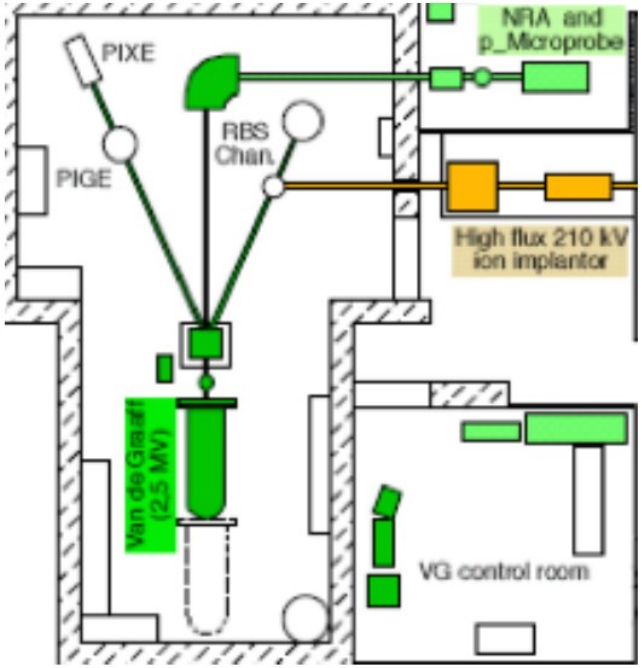
http://www.ctn.pt

Van de Graaf



Infrastructures

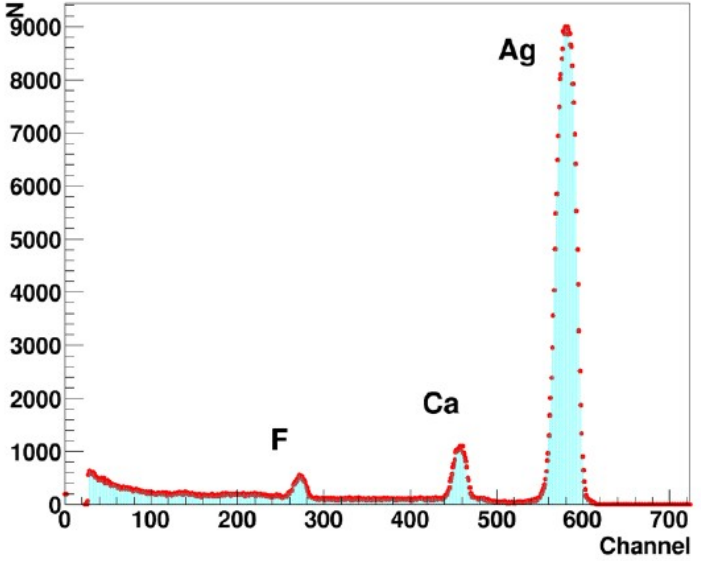
2.5 MV Van de Graaf



Infrastructures

2.5 MV Van de Graaf

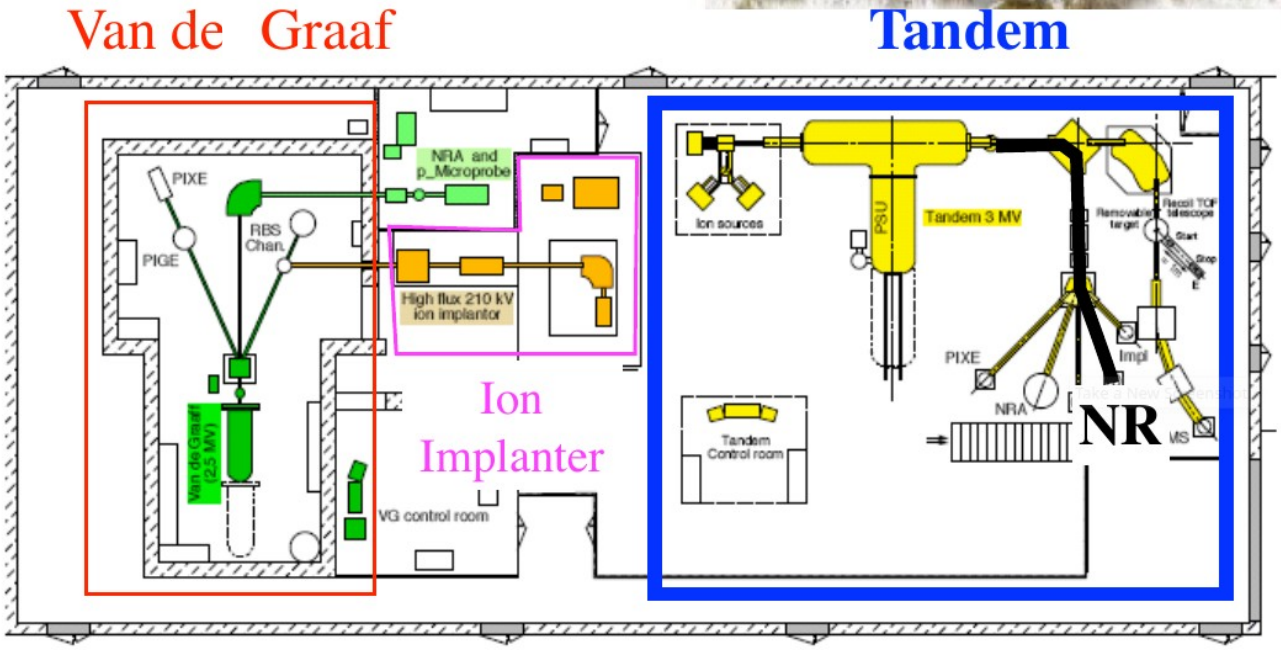
Rutherford Back Scattering line



Local **characterisation** of **evaporated/implanted** targets

Infrastructures

http://www.ctn.pt



Infrastructures

General Ionex Cockroft-Walton 3 MV Tandetron

1 HPGe detector

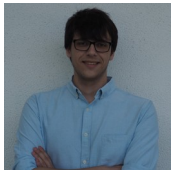
2 PIPS detectors

NaI, BaF_2 scintillators

Low-Energy approaches

for Nuclear Astrophysics

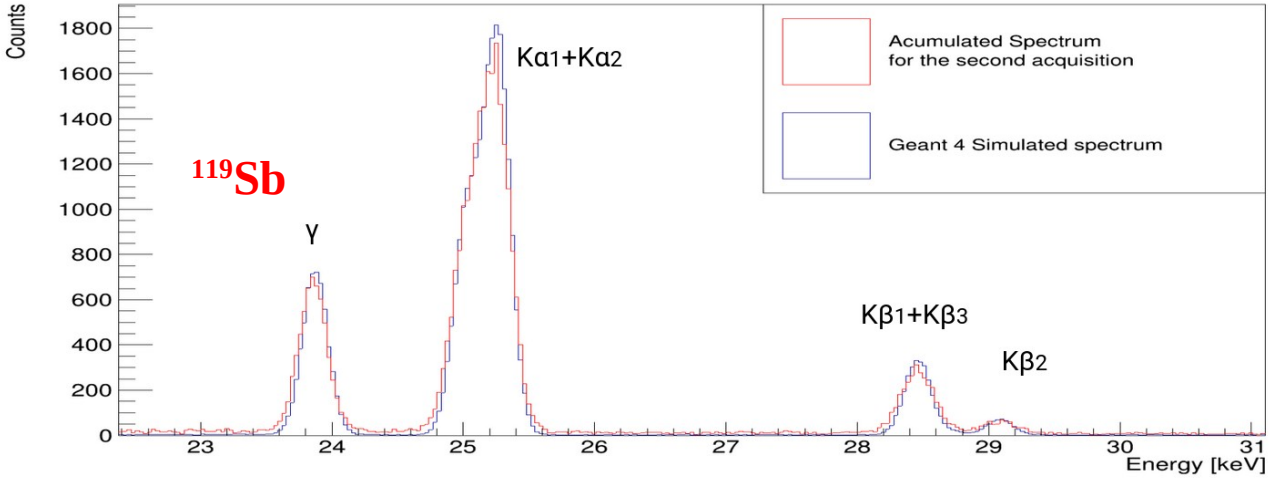
Activation studies with X-ray detection



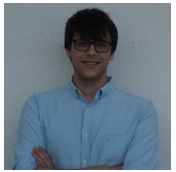
M. Xarepe

R. Pires

- **Phase 1**: Sn-nat activation

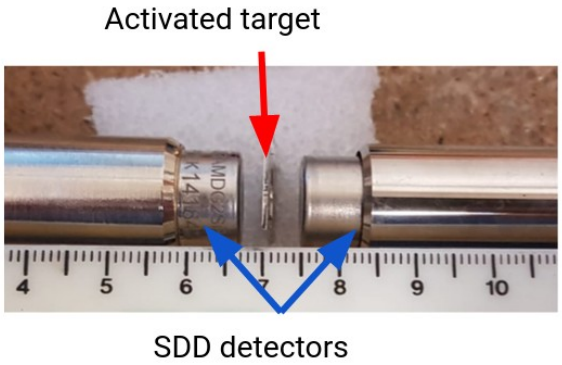


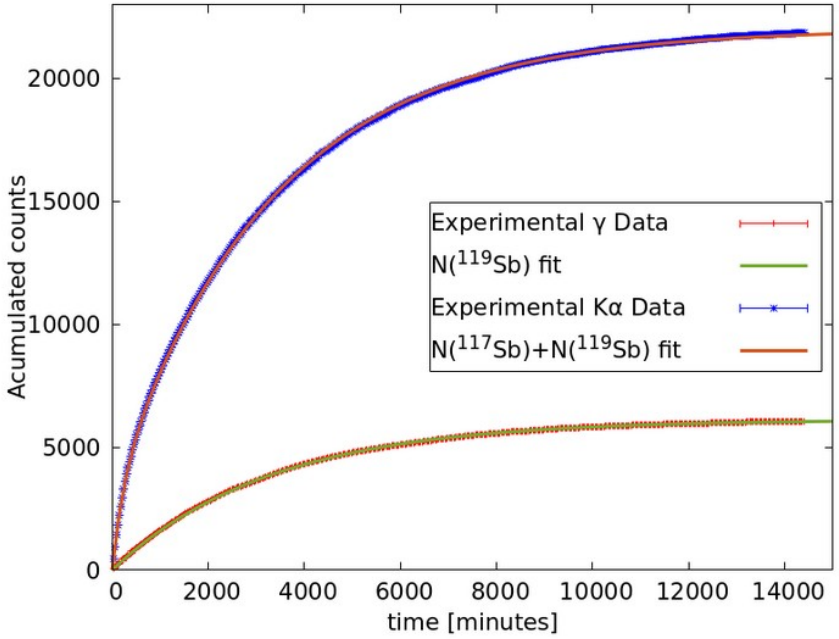
Activation studies with X-ray detection



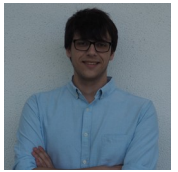
M. Xarepe R. Pires

- **Phase 1**: Sn-nat activation





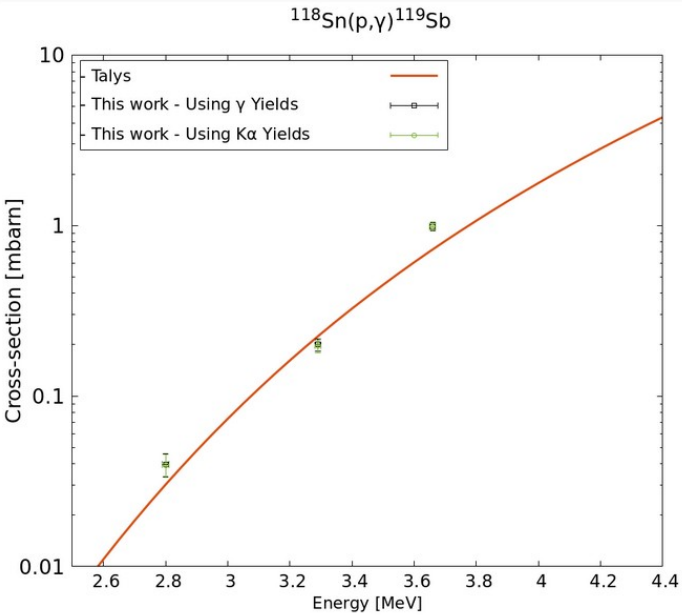
Activation studies with X-ray detection

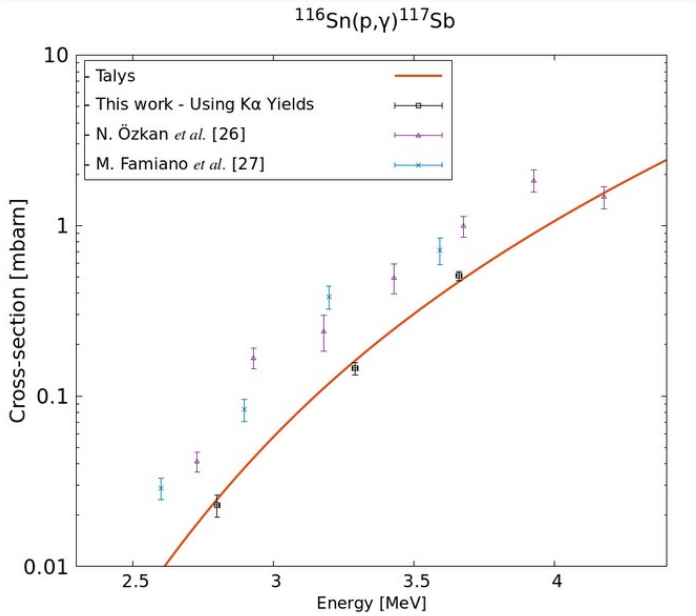


M. Xarepe

R. Pires

- **Phase 1**: Sn-nat activation





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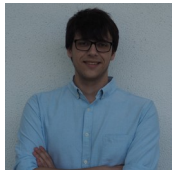
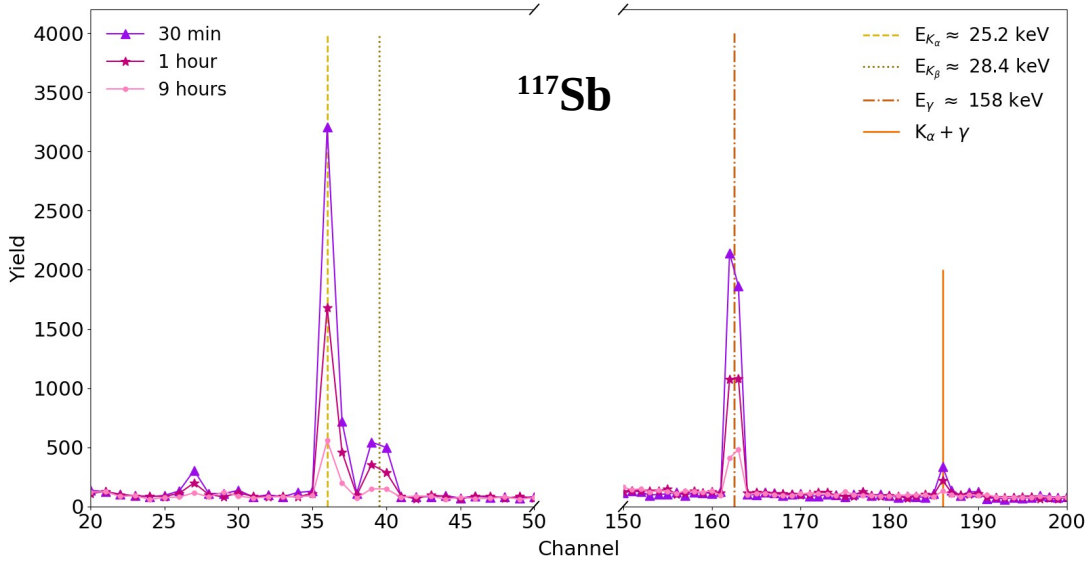
Activation studies with X-ray detection


M. Xarepe


R. Pires

- **Phase 2**: ^{116}Sn activation

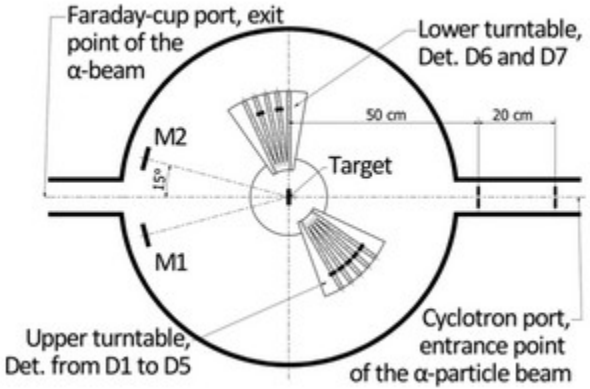

HPGe + SDD detectors



Alpha-scattering studies in ATOMKI

R. Nunes

^{116}Sn(α,α)^{116}Sn and ^{118}Sn(α,α)^{118}Sn

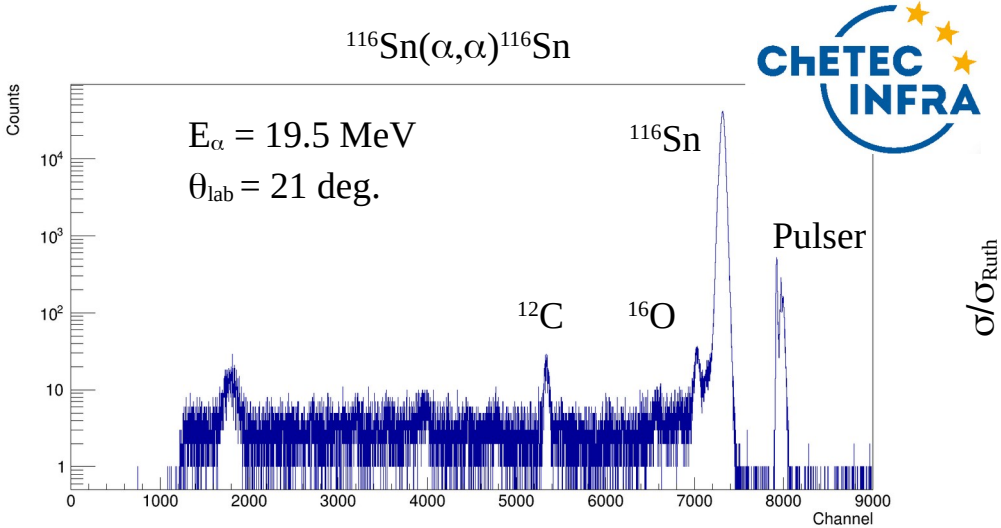


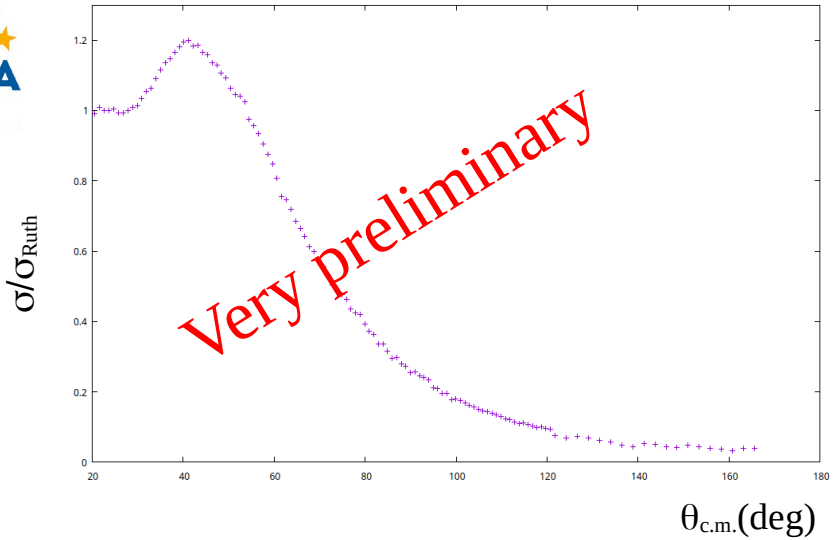
Three complete angular distributions for **each element**
(E_α = 19.5, 17.5 and 16.0 MeV)

Alpha-scattering studies in ATOMKI

R. Nunes

^{116}Sn(α,α)^{116}Sn and **^{118}Sn(α,α)^{118}Sn**





Three complete angular distributions for **each element**
(E_α = 19.5, 17.5 and 16.0 MeV)

Wrapping up…

Summary

- A bit of recent **Nuclear (Astro) history** in Portugal
- Portuguese participants/activities in **Nuclear &/or Astrophysics**
- Portuguese facilities for **Nuclear &/or Astrophysics**
- Recent **Low-Energy efforts** for NA in Portugal.

Obrigado!

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