

Nuclear Physics in Large Environments

Nuclear Physics Group

IPARCOS Scientific Advisory Board: Bi-Annual Review 2026

José Antonio Briz Monago



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Group's Overview

Group Snapshot

- **Group Name & Principal Investigator (PI):** Nuclear Physics Group, PI: J.M. Udías, L. M. Fraile (currently ISOLDE-CERN Physics Group Leader). Web: <https://www.ucm.es/gfn>
- **Current Size:** Total members
 - 5 Staff (J.M. Udías, L.M. Fraile*, J.A. Briz, L. Muñoz, O. Moreno),
 - 2 Postdocs: N. Bernier (Canada), M. Piersa (Poland),
 - 7 PhD students (G. García de Lorenzo , P. González-Tarrío, O. Alonso-Sañudo, M. Caballero, V. Martínez, I. Gutiérrez, J. García-Marcos).
- **Key Personnel Changes:** Three staff left the group:
 - L. M. Fraile in leave since July 2025, currently ISOLDE Physics Group Leader and ISOLDE Collab. Spokesperson.
 - R. González-Jiménez and T. R. Rodríguez now in Seville University.
 - One postdoc (A. Illana) left the group and took a RyC tenure at CSIC.Attracted a MSCA fellow: Monika Piersa and a post-doctoral researcher: Nikita Bernier (HISTARS)

Key Performance Indicators

- **High-Impact Publications:** 88 peer-reviewed papers (37 in Q1 journals / Letters).
- **Funding Secured:**
 - National project: PID2024-160624-NB-I00. FASCINA-2. Sept. 2025- August 2028. 191 k€.
 - HISTARS project (MMR funding): ~1 M€ (529 k€ IPARCOS)
 - GAMMA-MRI (Nuclear applications) → Attracted a MSCA fellow: M. Piersa (Poland)
- **Training:** 2 PhD theses defended since 2024

*on leave due to appointment as ISOLDE (CERN) Physics Group Leader since July 2025

Group's Overview

Top 2-3 Scientific Highlights

- **Highlight 1:** Building and commissioning of HISTARS array at ISOLDE (CERN)
- **Highlight 2:** Leadership of group members in international experimental campaigns:
 - L.M. Fraile, A. Illana, N. Bernier, G. García de Lorenzo and J.A. Briz are PIs of several experiments at ISOLDE-CERN, RIKEN (Japan), ILL (France), U. Jyvaskyla (Finland), CCB (Poland), INFN Legnaro (Italy)
- **Highlight 3:** Enriching knowledge on nuclear structure at ^{132}Sn and ^{78}Ni regions: Publications on “First evidence of a high-spin isomer (18^+) in ^{128}Cd (IS685)” and “Structure of ^{128}Sn selectively populated in the β decay of the ^{128}In ground state”. Others in preparation.

Leadership, Internationalization & Impact

- **Major Roles:**
 - Luis Mario Fraile ISOLDE-CERN Physics Group Leader since July 2025 and Spanish representative in NUPECC committee.
 - Spokespersons of international experiments (L.M. Fraile, A. Illana, N. Bernier, G. Garcia de Lorenzo and J.A. Briz)
 - J.A. Briz is Vice-President of Grupo Especializado de Física Nuclear (GEFN) at Spanish Royal Society of Physics (RSEF)
 - J.A. Briz is member of the scientific committee ASTRANUCAP bilateral research network.
 - T.R. Rodríguez is the PI of the Strategic Network FNUC at national level.
- **Recognitions:**
 - P. González-Tarrío: GEFN-ATI prize to best Master thesis in Experimental Nuclear Physics from GEFN-RSEF. [Link](#). And accésit to G. García de Lorenzo.
 - O. Alonso-Sañudo: prize for best presentation at “Young investigators meeting 2024” CMAM. [Link](#).
 - G. García de Lorenzo: prize to best poster at “ISOLDE Workshop and Users Meeting 2025”, Geneva (Switzerland).
- **Tech Transfer / Outreach:** HELMET PET (see Nuclear applications talk)

The Horizon

- **Next Big Milestone:** Installing and commissioning the HISTARs detector array at ISOLDE (CERN).



Experimental nuclear physics

in line with NUPECC Long Range Plan 2024 for
European Nuclear Physics.



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HISTARS project: A High-Performance Detector for Nuclear Excited-State at HIE-ISOLDE



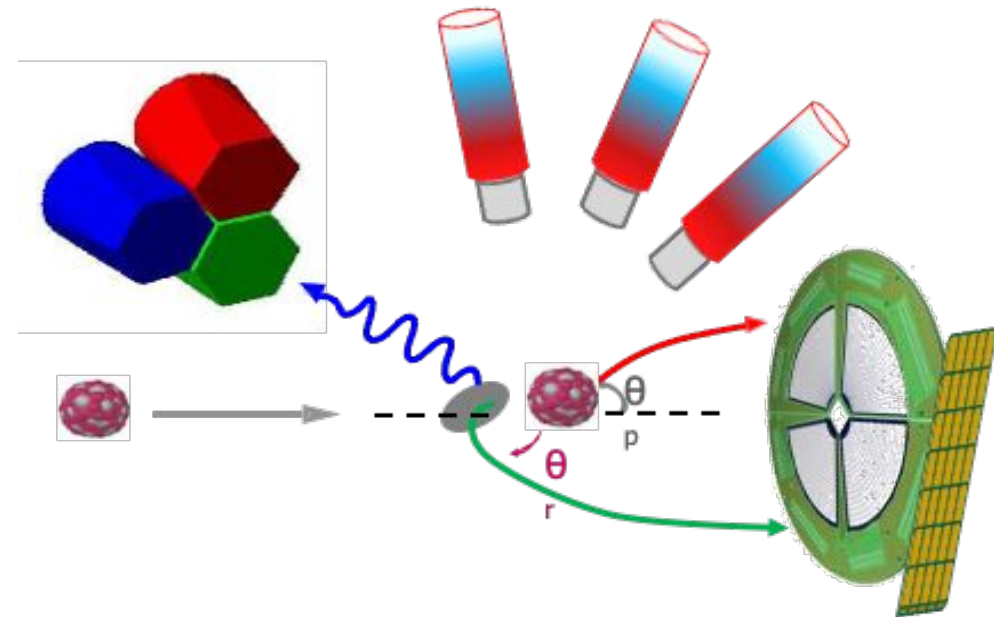
ISOLDE

PIs: L.M. Fraile (UCM) until June 2025, J.M. Udías (UCM) from July 2025, O. Tengblad (IEM-CSIC), E. Nácher (IFIC-CSIC)

~ 1 M€ from Spanish government for “new projects to be developed by Spanish research groups at CERN”

Highly-sensitive detector setup for **measuring lifetimes of excited states populated in reactions at HIE-ISOLDE**

Key ingredients: Fast scintillators for both charged particles and gamma radiation with fast time response



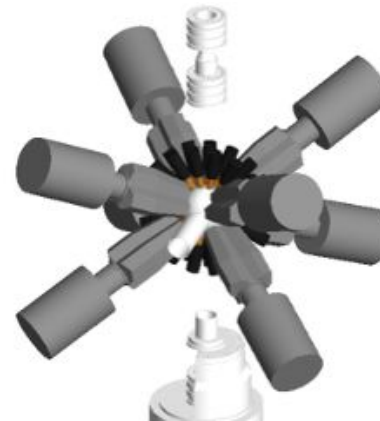
Status of the HISTARS project

Combining:

- an **upgrade of charged-particles detectors** to provide good timing and high-rate capabilities
- addition of a **fast gamma scintillation detector array** at low Doppler-shift angles to measure lifetimes of nuclear excited states

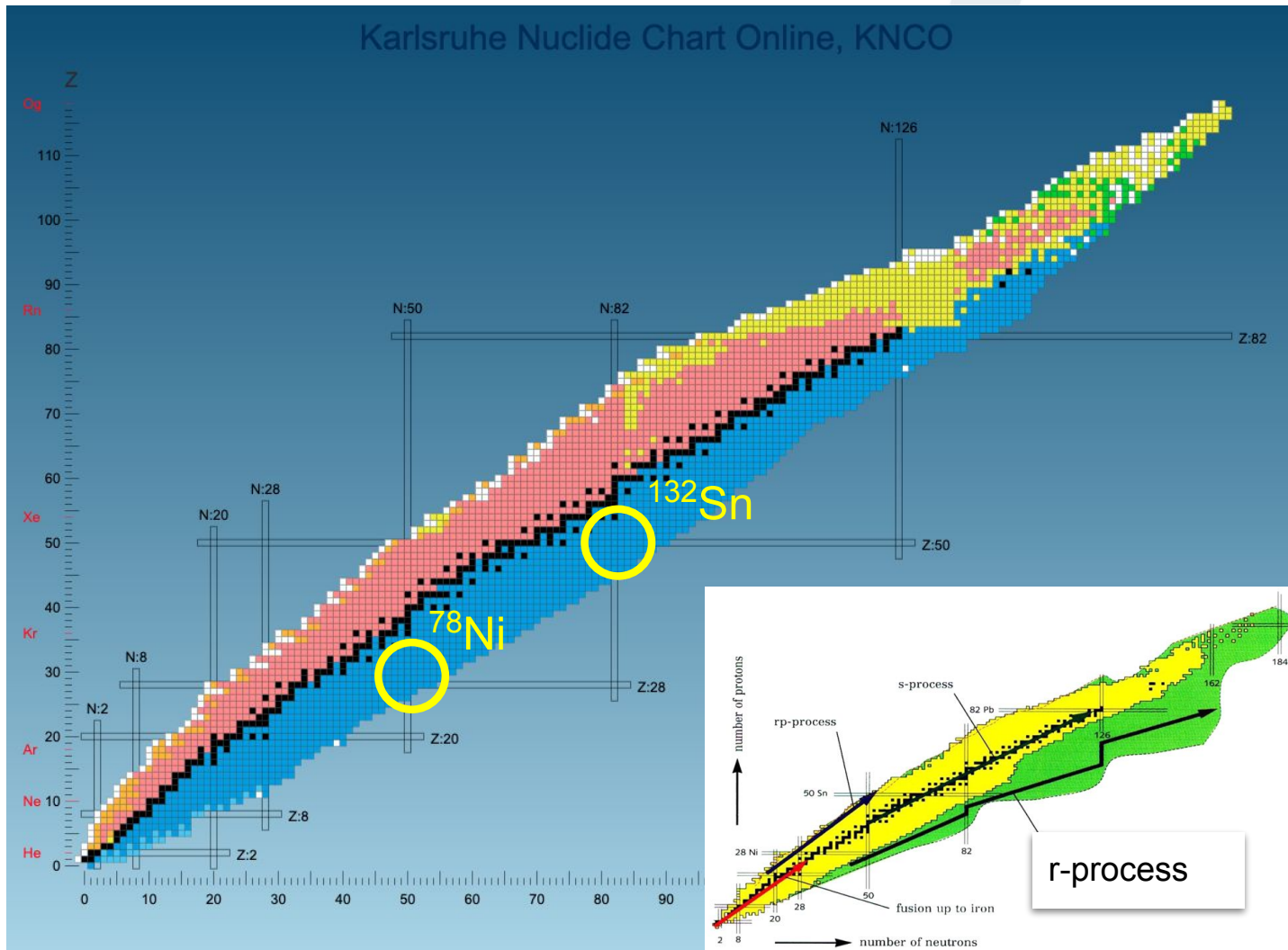
On-going work:

- **Monte Carlo simulations** (Geant4) of several configurations



- **Experimental tests** at CMAM (Madrid) and ISOLDE (CERN) last year and planned for next months.

The nuclear landscape

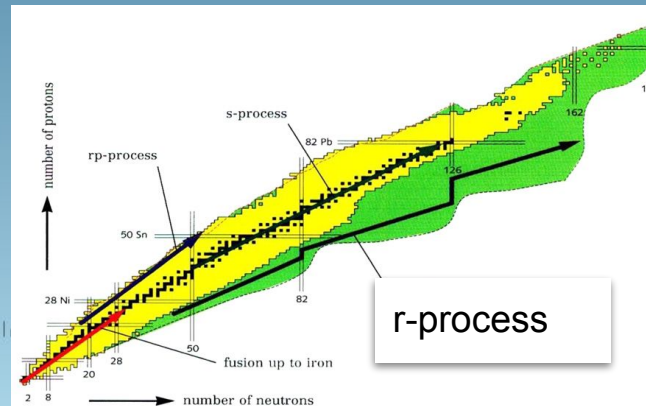


→ Nuclear structure:

- Regions near doubly-magic nuclei to probe properties of **single-particle states**.
- **Evolution of magic numbers** far from stability
- **Shape coexistence and shape mixing phenomena**.
- ^{132}Sn is the heaviest doubly-magic nucleus far from stability
- ...

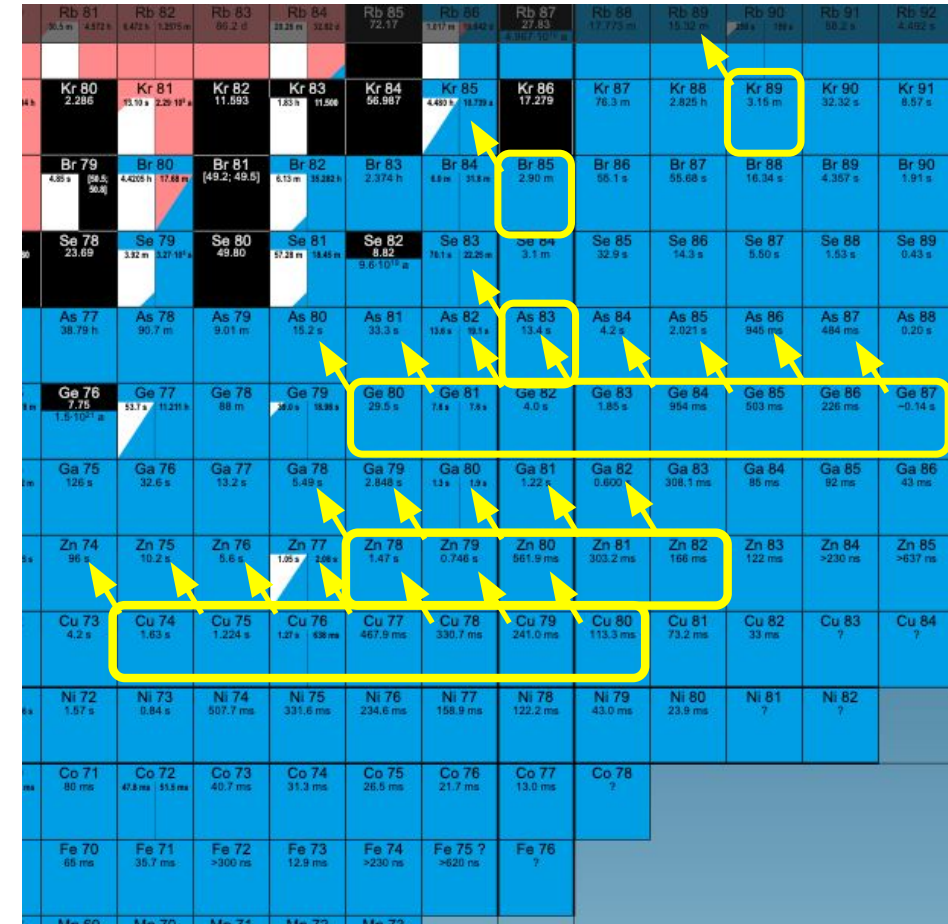
→ Nuclear astrophysics

Regions of ^{78}Zn and ^{132}Sn are traversed by nucleosynthesis processes (mainly r-process) of production of heavy isotopes in stellar scenarios.



Nuclear structure in the vicinity of ^{78}Ni

1. **IS771-** (ISOLDE, Geneva) $^{80-87}\text{Ge}$ decays at IDS.
PIs: J. Benito, **L.M. Fraile**, **A. Illana**
2. L-forbidden decays ^{85}Br at Lohengrin (ILL, Grenoble).
PIs: **L.M. Fraile**, **G. García de Lorenzo**
3. Beta decay of ^{89}Kr at Lohengrin (ILL, Grenoble).
PI: **N. Bernier** Run in June 2026
4. **IS684-** $^{78-82}\text{Zn}$ via Total Absorption Spectroscopy (ISOLDE, Geneva).
PI: **L.M. Fraile** and A.I. Morales
5. ^{76}Cu beta decay at IGISOL (U. Jyväskylä, Finland).
PIs: **A. Illana**, B. Olaizola, M. Stryczyk. Run: end 2026.
6. **IS622-** (ISOLDE, Geneva) “Cu decay into neutron-rich Zn isotopes: shell structure near ^{78}Ni .”
PIs: B. Olaizola, **A. Illana**



L-forbidden transitions

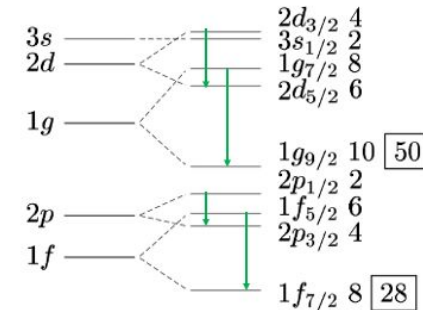
-Exploration on L-forbidden M1 transitions in Odd-A N=50 nuclei.

- For pure single-particle states, ordinary M1 transitions require $\Delta l=0$

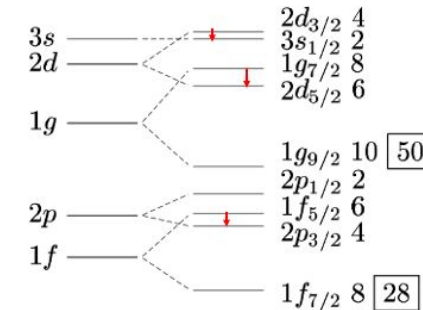
-Lifetimes of the first excited states of the ^{85}Br and ^{87}Rb for the first time via β^- decay at Lohengrin (**ILL, Grenoble**) and ^{83}As via β^- decay at IDS (**ISOLDE-CERN**).

- Fast-timing technique (up to $\sim\text{ps}$) for which our group is internationally recognised.

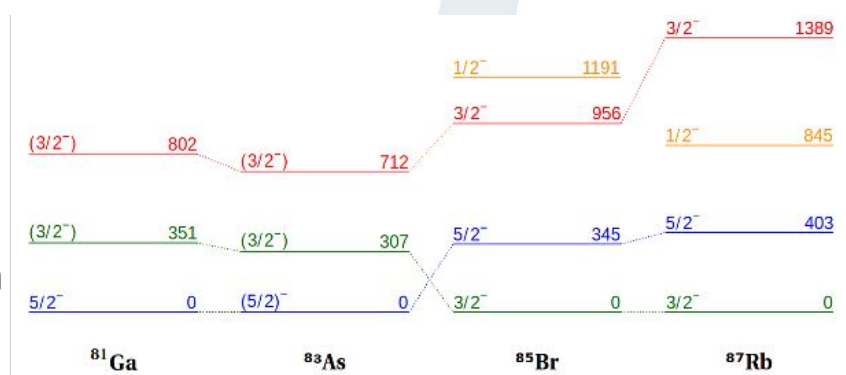
Allowed M1 transitions ($\Delta l=0$)



L-forbidden M1 transitions ($\Delta l=2$)



Zr 88 83.4 d	Zr 89 4.81 h	Zr 90 84.1 s	Zr 91 11.22 s	Zr 92 17.13 s	Zr 93 3.64·10 ⁶ a	Zr 94 17.38 h
Y 87 33.27 h	Y 88 106.626 d	Y 89 15.22 s	Y 90 3.28 s	Y 91 8.17 h	Y 92 3.24 h	Y 93 30.26 h
Sr 86 9.86 d	Sr 87 2.221 h	Sr 88 4.258 h	Sr 89 50.562 d	Sr 90 28.91 s	Sr 91 9.65 h	Sr 92 2.604 h
Rb 85 72.1 h	Rb 86 182 m	Rb 87 4.367·10 ⁶ a	Rb 89 33.33 m	Rb 90 58.6 s	Rb 91 58.2 h	
Kr 84 56.987 h	Kr 85 1.081 h	Kr 86 16.28 h	Kr 87 76.9 m	Kr 88 2.825 h	Kr 89 3.13 m	Kr 90 32.52 s
Br 83 2.374 h	Br 84 58 s	Br 85 2.90 m	Br 87 55.88 s	Br 88 16.34 s	Br 89 4.957 s	
Se 82 3.2045 d	Se 83 8.13 s	Se 84 1.21 s	Se 85 32.9 s	Se 86 14.3 s	Se 87 5.70 s	Se 88 1.53 s
As 81 33.3 s	As 82 388 s	As 83 13.6 s	As 85 2.923 s	As 86 845 ns	As 87 484 ns	
Ge 80 29.3 s	Ge 81 78 s	Ge 82 8.4 s	Ge 83 1.83 s	Ge 84 394 ns	Ge 85 503 ns	Ge 86 228 ns
Ga 79 2.848 s	Ga 80 1.31 s	Ga 81 1.22 s	Ga 82 0.605 s	Ga 83 308.3 ns	Ga 84 85 ns	Ga 85 82 ns
Zn 78 1.47 s	Zn 79 3.746 s	Zn 80 561.4 ns	Zn 81 61.2 ns	Zn 82 100 ns	Zn 83 124 ns	Zn 84 >230 ns



L-forbidden M1 transition

ISOLDE TAS experiments



ISOLDE

Total Absorption Spectroscopy (TAS) is a complementary technique to conventional High-Resolution gamma spectroscopy studies to overcome the so-called “*Pandemonium effect*” and get results free from systematic errors.

Our group led four experimental campaigns to study:

$^{78-82}\text{Zn}$ decays: **IS684** (PIs: **L.M. Fraile** & A. I. Morales) - June 2022

Data under analysis: O. Alonso-Sañudo PhD thesis

$^{128-131}\text{In}$ decays: **IS693** (PIs: **L.M. Fraile**, M. Fallot, B. Rubio and A. Korgul)

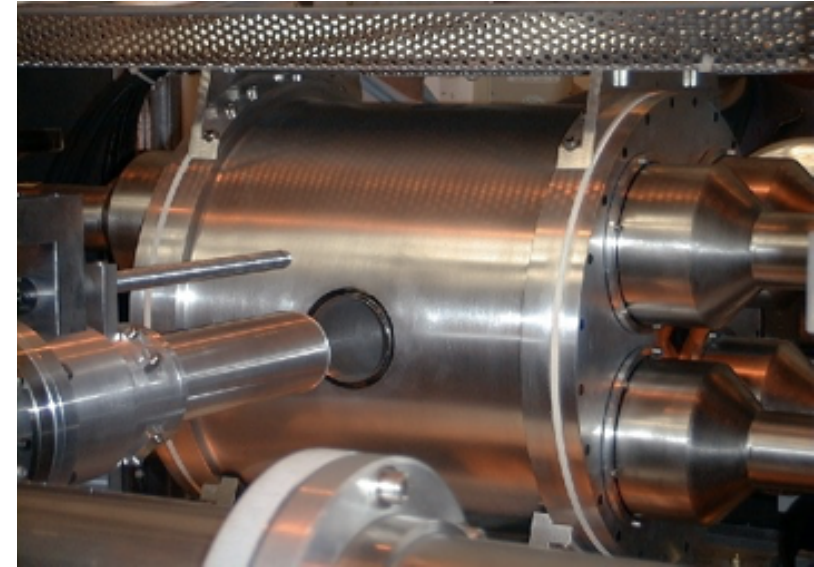
April 2023: Data under analysis.

N=Z region:

$^{64-66}\text{Ge}$, $^{68-70}\text{Se}$: **IS570-IS669** (PIs: E. Nácher, A. Algora, **J.A. Briz**)

- [Isospin mixing in \$^{64}\text{Ga}\$ reexamined via total absorption spectroscopy](#) Phys. Rev. C 112, 064328 (2025) pp. 1-9
- Waiting for some target development to obtain clean Selenium beams

$^{152,155}\text{Tb}$, $^{76,77}\text{Br}$: **IS722** (PIs: E. Nácher, **J.A. Briz**). PhD. thesis A. C. Fonseca (IFIC-CSIC)



Lucrecia TAS spectrometer at ISOLDE-CERN



IDS experiments at ^{78}Ni region

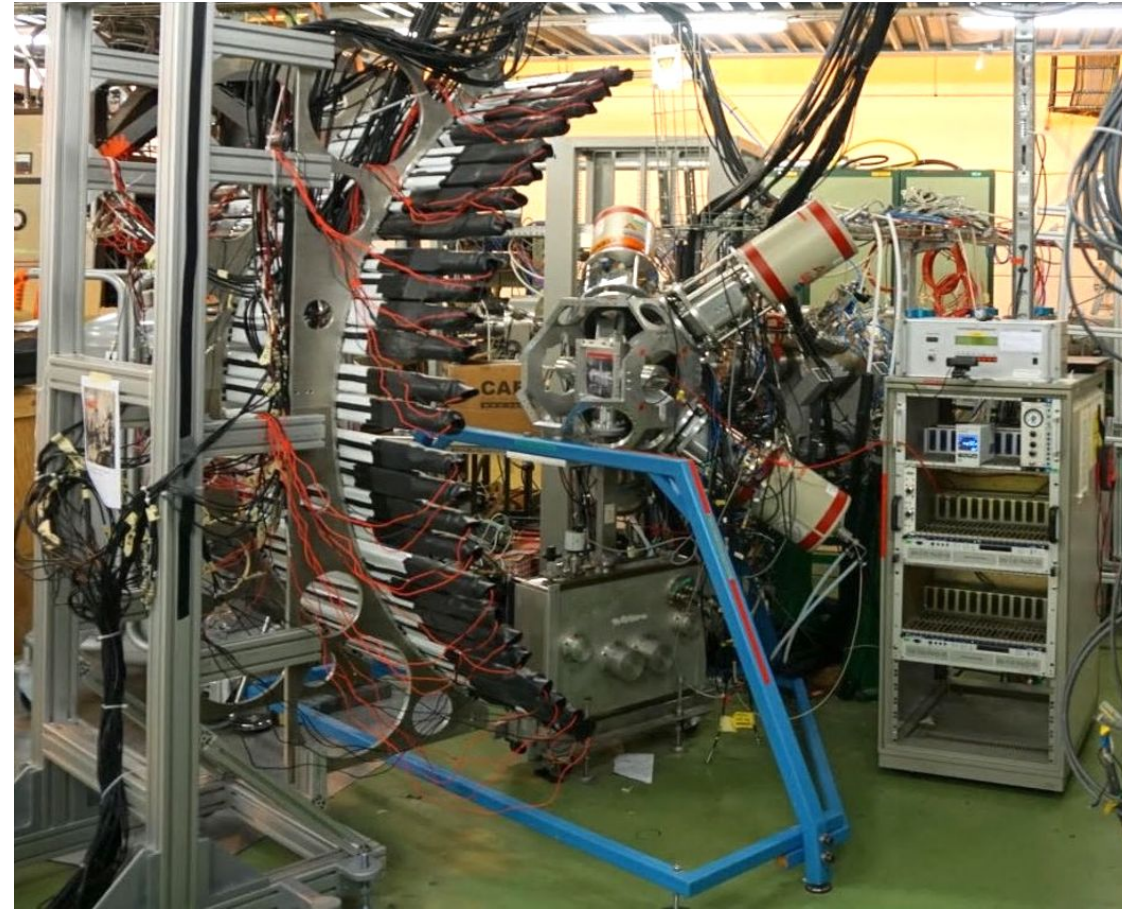


ISOLDE

IS771 - $^{82-87}\text{Ge}$ beta decay. Pls: **L.M. Fraile**, **A. Illana**, J. Benito. PhD. thesis of **P. González-Tarrío** (UCM)

IS622 - "Cu decay into neutron-rich Zn isotopes: shell structure near ^{78}Ni ." Pls: B. Olaizola and **A. Illana**.

- PhD. thesis of J. Sánchez-Prieto at UCM. Supervisors: B. Olaizola and **J.A. Briz**
- PhD. thesis of D. Palacios at USC. Supervisors: B. Olaizola and Y. Ayyad.
- 6 Master theses in the last 2-3 years: Carlos (ongoing), David, Oñoro, Miguel, Gabriel and Pablo.



Studies in the ^{132}Sn region



- IS685** - ISOLDE-CERN - “Beta-decay spectroscopy of neutron-rich Cd isotopes”. Pls: **L.M. Fraile**, and A. Korgul.
- PhD. thesis of **M. Llanos-Expósito** (UCM, Jan 2026)
 - **M. Llanos-Expósito** et al. “Structure of ^{128}Sn selectively populated in the beta decay of the ^{128}In gs” Phys. Rev. C **111**, 064310 (2025)
 - other 2-3 papers submitted or in preparation.

- IS693** - ISOLDE- CERN - $^{128-131}\text{In}$ decays. Pls: **L.M. Fraile**, M. Fallot, B. Rubio and A. Korgul.
April 2023: Data under analysis

Historically the group was key part of the collaboration in several studies in the region:

2024:

First β -Delayed Two-Neutron Spectroscopy of the r-Process Nucleus ^{134}In and Observation of the $i_{13/2}$ Single-Particle Neutron State in ^{133}Sn . Phys. Rev. Lett. 135, 15, 152501

Detailed structure of ^{131}Sn populated in the β decay of isomerically purified in 131 states Phys. Rev. C, Vol. 110, 1

2023:

Evidence of nonstatistical neutron emission following β decay near doubly magic Sn 132 Phys. Rev. C, Vol. 108, 2

In 133: A Rosetta Stone for Decays of r -Process Nuclei Phys. Rev. Lett. 131, 2

β -delayed neutron spectroscopy of in 133 Phys. Rev. C 108, 1

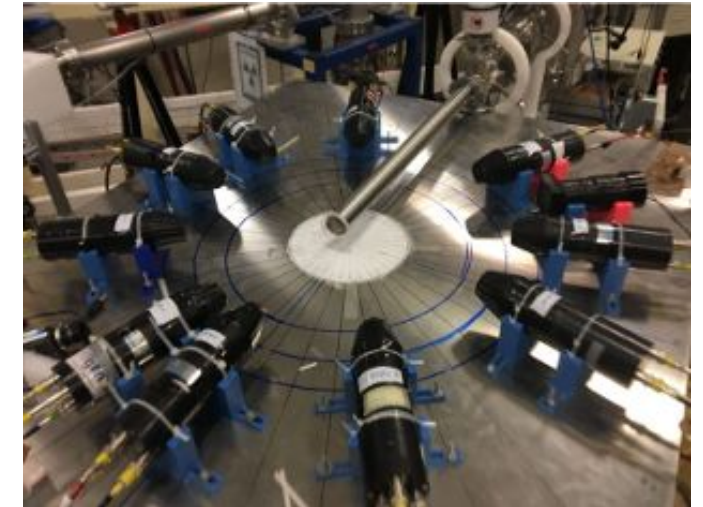
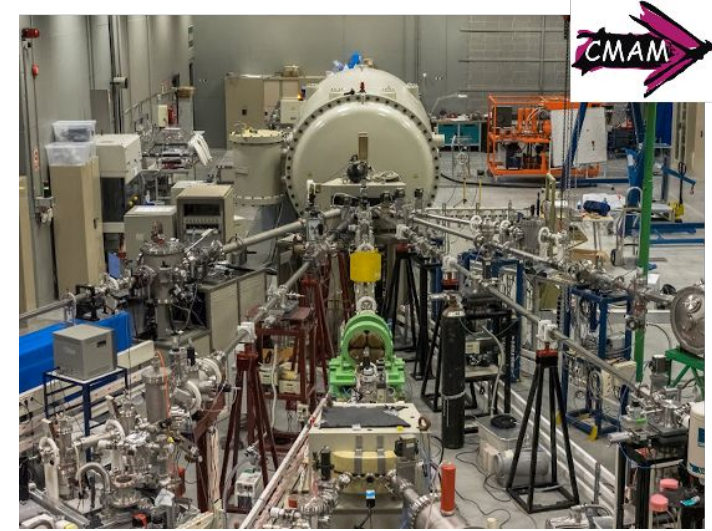
2020:

Detailed spectroscopy of doubly magic Sn 132 Phys. Rev. C, 102, 1



Research at National accelerators

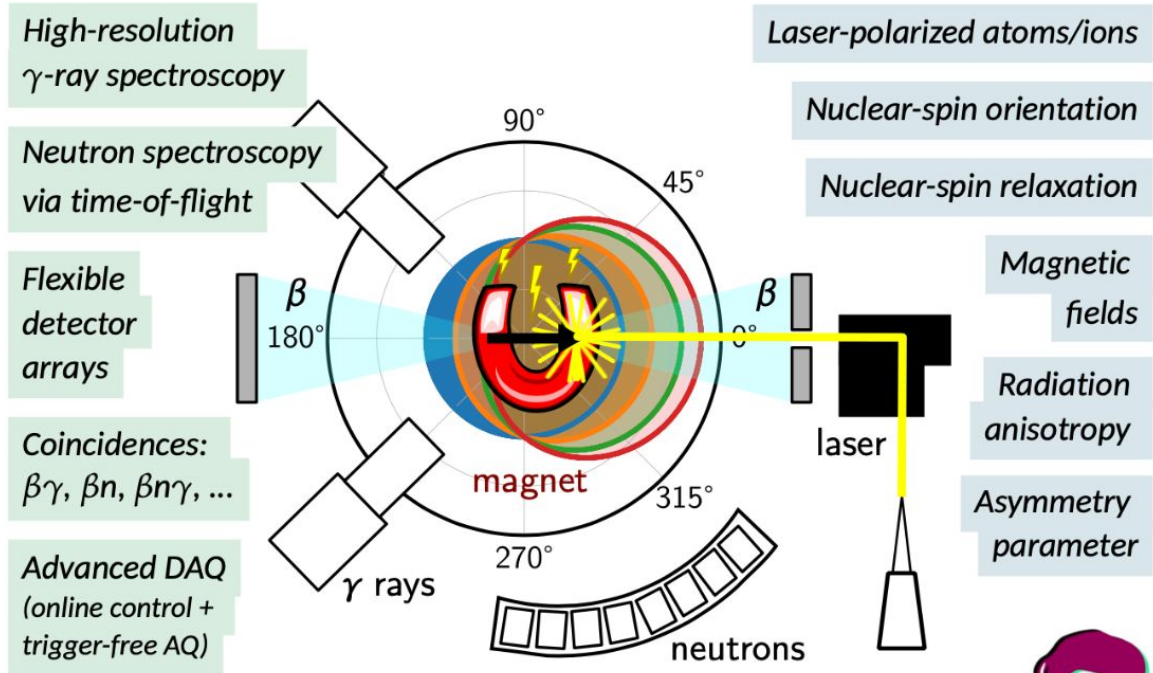
- **MANY collaboration** at CMAM (Madrid), CNA (Seville):
 - Study of $^{27}\text{Al}(\alpha,n)$ reaction using GARY array: [Radiation Physics and Chemistry 244 \(2026\) 113815](#). **O. Alonso-Sañudo, L. M. Fraile, J.A. Briz, A. Illana** et al.
 - “Design and commissioning of the miniBELEN neutron counter for the study of (α,n) reactions”, N. Mont-Geli, **L.M. Fraile**, ..., **O. Alonso-Sañudo**, ..., **J.A. Briz**, ..., **A. Illana** et al. Eur. Phys. J. Plus (2026) 141:381 [link](#)
- Isomers in ^{94}Mo populated via (α,n) : PI: **A. Illana**
- Studies of reactions of interest for Nuclear Fusion at CMAM:
 - $^{10}\text{B}(\alpha,n)^{13}\text{N}$, $^{14}\text{N}(\alpha,n)^{18}\text{F}$. PI: **L.M. Fraile**. Hina Ali Master Thesis (2024).
 - $^9(\alpha,n)$ reactions on Zr isotopes. PI: **L.M. Fraile**.



MSCA fellow (M. Piersa) currently at UTK (USA)

RADESO: Next-Generation Radiation Detectors in Experiments with Spin-Oriented Exotic Nuclei

- Anisotropy of radiation from spin-oriented nuclei offers an underutilized observable that is sensitive to nuclear spin-parity
- Beta-decay spectroscopy with laser-polarized radioactive beams at CERN-ISOLDE
- Cross-disciplinary experimental approach



• Host:  UNIVERSIDAD COMPLUTENSE MADRID
07/2025 - 06/2028

• Partner:  THE UNIVERSITY OF TENNESSEE KNOXVILLE
07/2025 - 06/2027

• Facility:  ISOLDE
(where the main experimental activities)

Three project phases/goals:

Funded by the European Union



- Deliver results from the ISOLDE's 1st decay spectroscopy on laser-polarized beams
- Plan setup upgrades and • design the next experiment with spin-oriented exotic nuclei

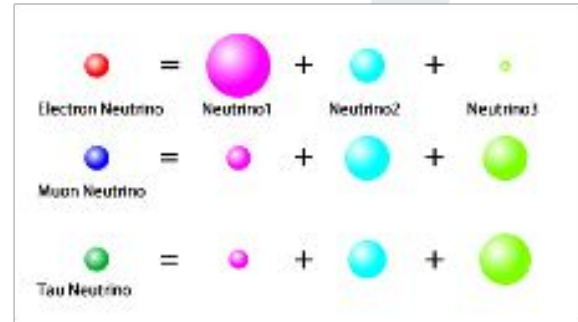
M. Piersa-Siłkowska, M. Madurga, M. Kowalska et al., *Tech. rep. CERN-INTC-2023-026*, Geneva (2023).

Theoretical nuclear physics

in line with NUPECC Long Range Plan 2024 for European Nuclear Physics.



Neutrino oscillations experiments



when they propagate the **flavor oscillates with a probability:**

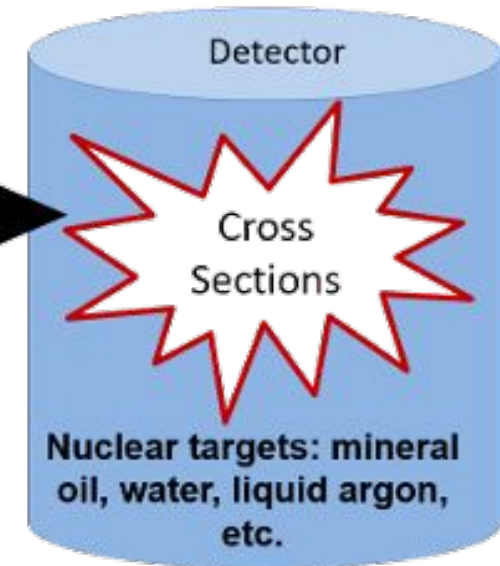
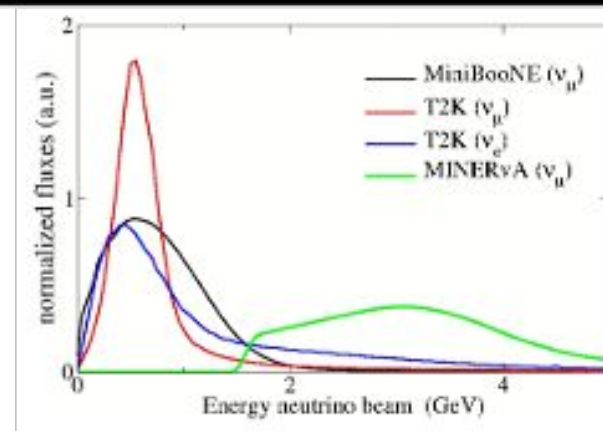
$$P_{\alpha\beta} = \delta_{\alpha\beta} - 4 \sum_{i>j} \text{Re}(U_{\alpha i}^* U_{\beta i} U_{\alpha j} U_{\beta j}^*) \sin^2 \left(\frac{\Delta m_{ij}^2 L}{4E} \right) + 2 \sum_{i>j} \text{Im}(U_{\alpha i}^* U_{\beta i} U_{\alpha j} U_{\beta j}^*) \sin^2 \left(\frac{\Delta m_{ij}^2 L}{2E} \right)$$



Accelerator

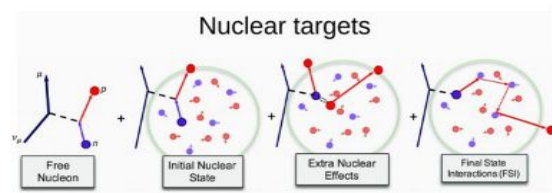


Neutrino Beam



Challenge!!

Neutrino detectors are made of complex nuclei

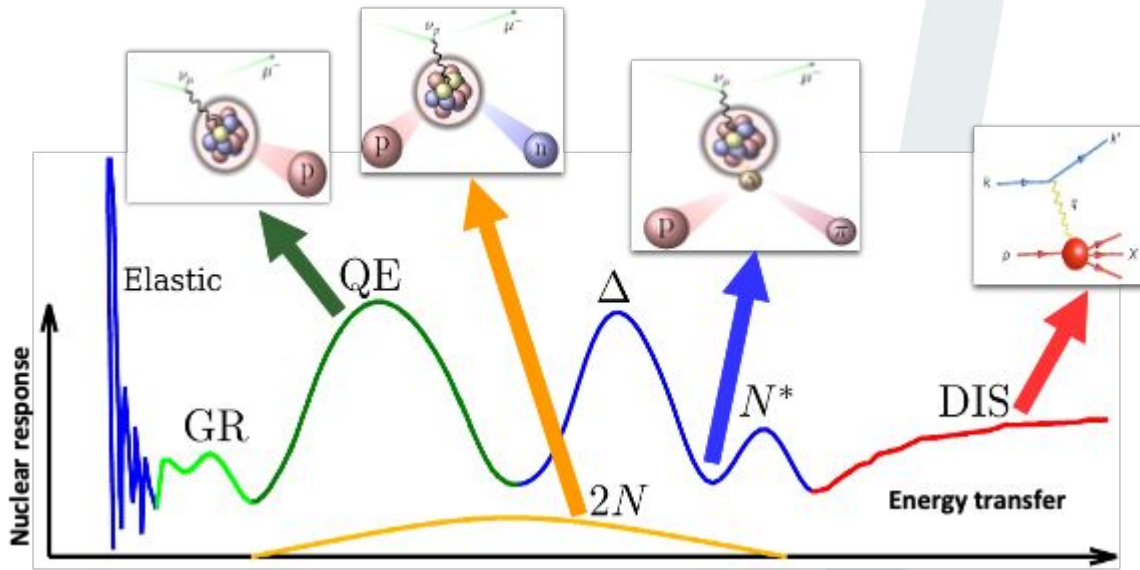


Our work: modeling of neutrino-nucleus interaction



Modelling neutrino-nucleus interaction

- We need theoretical models able to **describe all possible reaction channels**.
- **Main channels:** quasielastic scattering, two-nucleon knockout, resonance production and deep inelastic scattering.



Connection between electron and neutrino scattering allows to **scrutinize theoretical models** by a first comparison to **electron scattering data**.

Implementation of a relativistic distorted wave impulse approximation model into the NEUT event generator

J. McKean^{1,*}, R. González-Jiménez^{2,†}, M. Kabirmezhad^{1,2}, J. M. Udías^{3,4} and Y. Uchida^{1,4}
¹Imperial College London, Department of Physics, London SW7 2BZ, United Kingdom
²Departamento de Física Atómica, Molecular y Nuclear, Universidad de Sevilla, 41080 Sevilla, Spain
³Grupo de Física Nuclear, Departamento de Estructura de la Materia, Física Térmica y Electrónica, Facultad de Ciencias Físicas, Universidad Complutense de Madrid and IPARCOS, CEI Moncloa, Madrid 28040, Spain

(Received 21 February 2025; accepted 24 July 2025; published 26 August 2025)

We describe the implementation of a model for charged-current quasielastic (CCQE) neutrino-nucleus scattering in the NEUT Monte Carlo event generator. This model employs relativistic momentum distributions obtained from mean-field theory and relativistic distorted waves to describe the initial and final nucleon states. Final state interactions, both elastic and inelastic, are modeled by combining distorted waves with NEUT's intranuclear cascade, offering a more accurate representation of the interactions experienced by scattered nucleons. The model and its implementation in NEUT are described in detail and benchmarked against ν_μ - ^{12}C scattering cross section measurements from T2K and MINERvA, as well as ν_μ - ^{40}Ar measurements from MicroBooNE. The results, including transverse kinematic imbalance variables and scattered nucleon kinematics, show improved χ^2 values compared to other CCQE models in NEUT. Furthermore, the model consistently predicts lower cross sections in CCQE-dominated regions, indicating the potential for further refinement, such as incorporating two-body currents or the use of more advanced nucleon axial form factors consistent with lattice QCD calculations.

Other references:

<https://journals.aps.org/prc/pdf/10.1103/PhysRevC.109.024608> (2024)

<https://arxiv.org/abs/2512.01721> (Dec 2025)



Our goal: to incorporate the most realistic theoretical models into neutrino event generators (NEUT (Kamiokande), nuWRO, ...)

Strong collaboration with Seville and Ghent groups, and the experimentalists

Participants:

Óscar Moreno, José Manuel Udías,

Tania Franco-Muñoz (defended PhD in UCM in 2025, now in Ghent Group)

Javier García-Marcos (PhD Student of UCM, Sevilla and Ghent Groups)

Beyond Mean-field calculations on Ge isotopes

T. R. Rodríguez (ancient member of the group, now in Univ. Seville) co-supervising the PhD. thesis of **P. González-Tarrío** on $^{80-87}\text{Ge}$ beta decay studies.

Ingredients of Beyond Mean-field calculations:

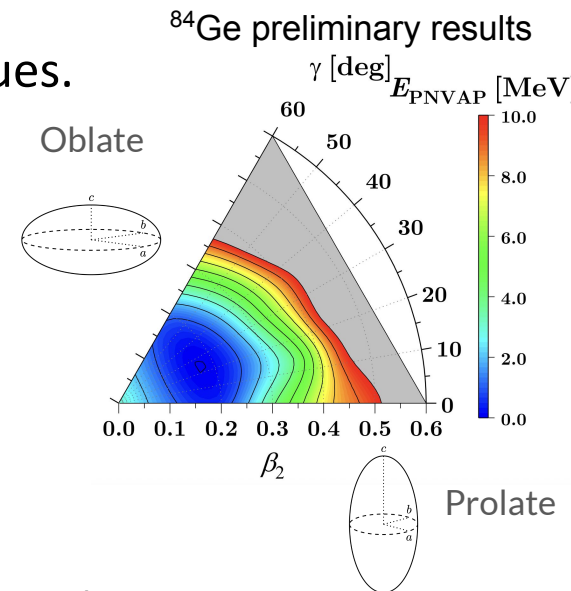
- Hartree-Fock-Bogoliubov (HFB) method (*self-consistent mean field approach*).
- Ritz's variational principle+HFB wavefunctions,
- Broken symmetries (N, Z, J, P,...) added as Lagrange multipliers to preserve mean values.

The Particle Number Variation After Projection (PNVAP) allows to obtain:

→ Nuclear deformations, band structures, level lifetimes and level schemes

^{84}Ge calculations by **P. González-Tarrío**

Experimental results will be compared to theoretical calculations (Shell Model from Antoine and K-shell codes and PNVAP Beyond Mean-Field) in this PhD work.



Summary

Experimental Nuclear Physics:

- Leading the development and construction of a new detection system at ISOLDE-CERN: HISTARS
- Large impact in our research area thanks to leadership in experimental campaigns on several international facilities (ISOLDE, RIKEN, ILL, U. Jyvaskyla, INFN LN Legnaro, ...)
- Research on key regions of the nuclear chart (^{78}Ni and ^{132}Sn)
- Research activity also at National accelerators (CMAM, CNA).
- Attraction of MSCA fellow and a postdoc for HISTARS project.

Theoretical Nuclear Physics:

- Theoretical work on neutrino-nucleus interactions
- Calculations on nuclear properties using state-of-the-art beyond mean field calculations.



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Thanks for your attention

Ideas

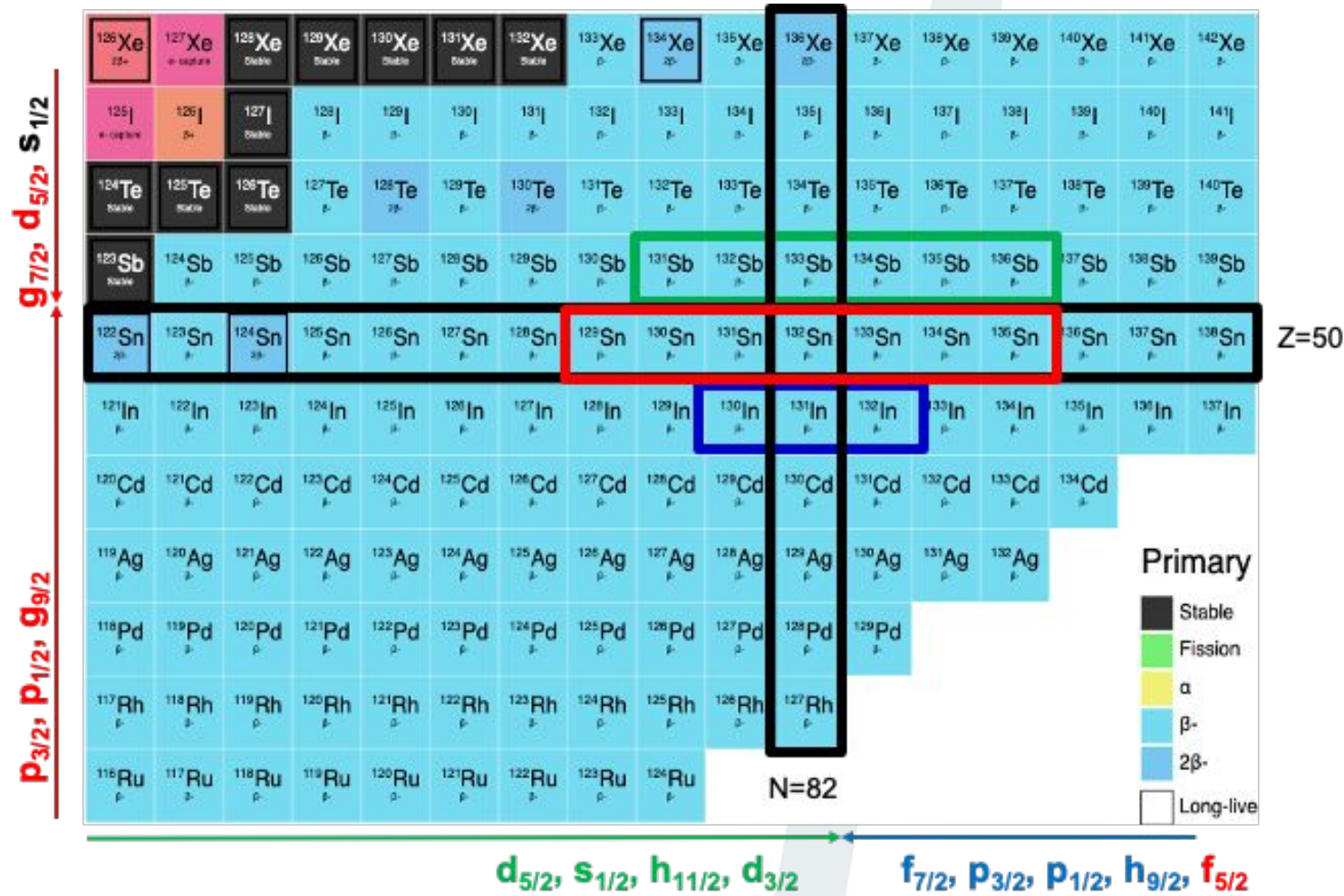
Experimental:

- HISTARs
- ISOLDE
 - IDS: paper Marcos (128Cd, 128Cd isómero?)
 - TAS? papers Kike sobre Selenios
- ILL
- Jyvaskyla?
- RIKEN -> Nature Gabriel
- CMAM - MANY (Odette, Nil papers)

Theory:

- Neutrino physics
- Tomás-Pablo calculations?
-

Interest of ^{132}Sn region



^{132}Sn : heaviest doubly-magic nucleus outside stability

Study of single-particle states

Relevant for stellar nucleosynthesis (r-process)

