PhD opportunities in Nuclear Physics at University of Seville

Raúl González Jiménez, raugj@us.es
University of Seville, Spain

NucPhys Career Orientation Day
November 14, 2025

PhD’s in Spain

Length: 3-5 years (4 on average)
You need: Bachelor Degree + Master Degree

Fellowships

Length: 4 years
Gross salary: ~24.360€/year
Research stays: flights + ~60€/day, ~1-3 months

1. **FPI** (Formación Personal Investigador):
   + Awarded to a research project/group, the research group chooses you.
   + Teaching is optional. Maximum 180 hours / 4 years.
   + When? Contact the group and ask.

2. **FPU** (Formación Profesorado Universitario):
   + Awarded to you (but you apply with a supervisor)
   + Hard to get: Bachelor Degree mark must be >8/10 (just to apply)
   + Teaching is mandatory: minimum 90 hours in the 4 years; maximum 180 hours.
   + When? Usually **December**, don’t miss it this year!!

3. **USeville’s PhD Fellowship,** here
   + If you didn’t get the FPU, but got a good evaluation, you may have a chance here.
   + When? After FPU is resolved (~March-April).

4. **Junta de Andalucía’s PhD Fellowship,** here
   + Last call was in February 2024...
   + Bachelor Degree mark > 7/10 (just to apply)

5. **Other options: contracts linked to research projects, to do specific technical tasks**

PhD Program in **Physical Sciences and Technologies, University of Seville**

https://institucional.us.es/doctoradocytf/en

https://doctorado.us.es/en/studies/phd-programmes/physical-sciences-and-technologies

Summary of research lines in this presentation:

1 Quantum phase transitions, quantum simulations, quantum machine learning, open quantum systems
Pedro Pérez Fernández, pedropf@us.es

2 Development of instrumentation for nuclear reactions measurements and their relevance for Astrophysics
Marcos A. Gonzalez Alvarez, malvarez@us.es, Juan P. Fernández, jpfernandez@us.es

3 Nuclear Reactions
José Antonio Lay, lay@us.es

4 Nuclear Structure Theory
Tomás R. Rodríguez Frutos, trodrig@us.es

5 Modeling neutrino-nucleus interactions
Juan A. Caballero, jac@us.es, Guillermo D. Megias, megias@us.es, RGJ, raugj@us.es

6 Plasma Science and Fusion Technology (PSFT) Laboratory at University of Seville
Eleonora Viezzer, eviezzer@us.es

7 Monte Carlo simulations for hadron therapy and radiobiology
Miguel A. Cortés-Giraldo, miancortes@us.es

Research lines:

Quantum Phase Transitions

Quantum Simulations

Quantum Machine Learning

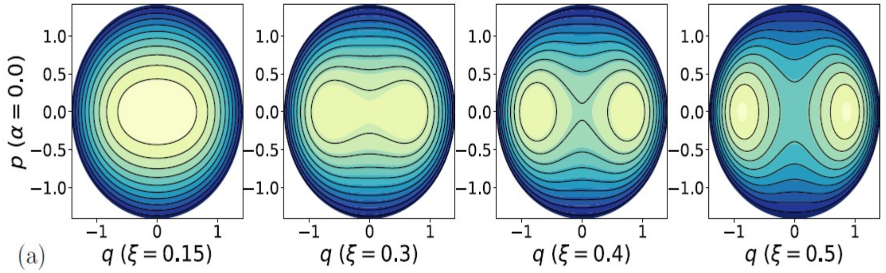
Open Quantum Systems

Contact: Pedro Pérez Fernández, pedropf@us.es

Research group: José Miguel Arias Carrasco, Jesús Casado Pascual, Lucas Lamata, Álvaro Sáiz Castillo y María Laura Olivera Atencio

Quantum Phase Transitions (QPT) and Excited State Quantum Phase Transitions (ESQPT) in Nuclear Physics, Molecular Physics, Condensed Matter, Quantum Optics...

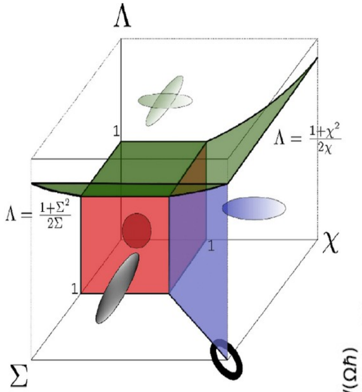
https://doi.org/10.1103/PhysRevE.106.044125



Quantum simulations and Quantum Machine Learning with application to nuclear models:

https://doi.org/10.1103/PhysRevC.106.064322

https://doi.org/10.1002/qute.202300219



Open Quantum systems

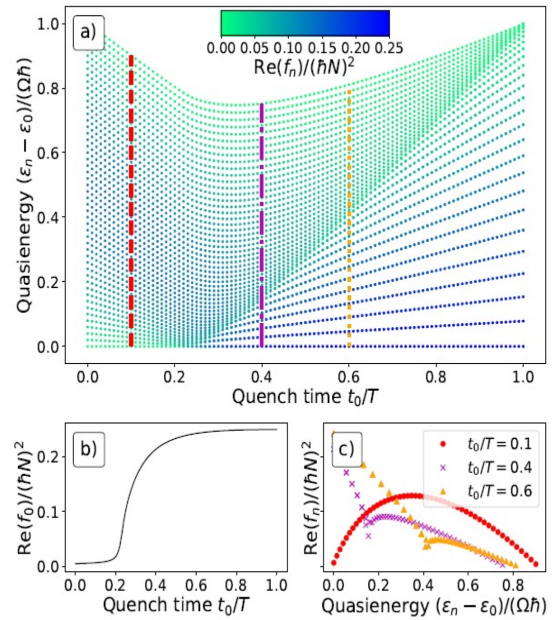
https://doi.org/10.1002/qute.202300247

Effects of noise and dissipation in quantum algorithms

https://doi.org/10.1140/epjs/s11734-025-01760-3

Floquet engineering

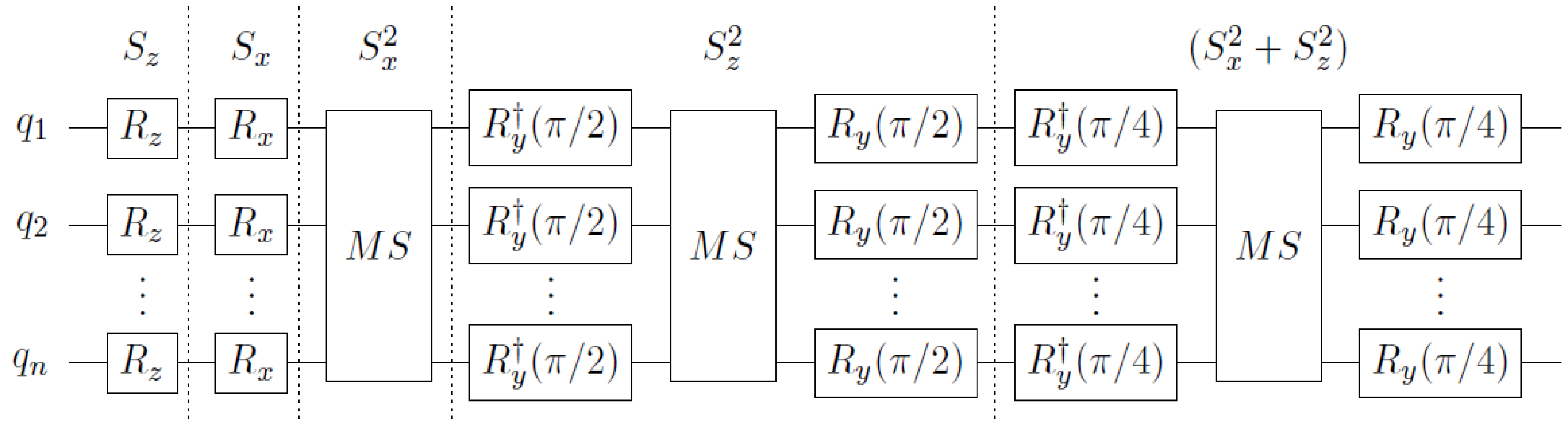
https://doi.org/10.22331/q-2024-06-11-1365



Collaborators:

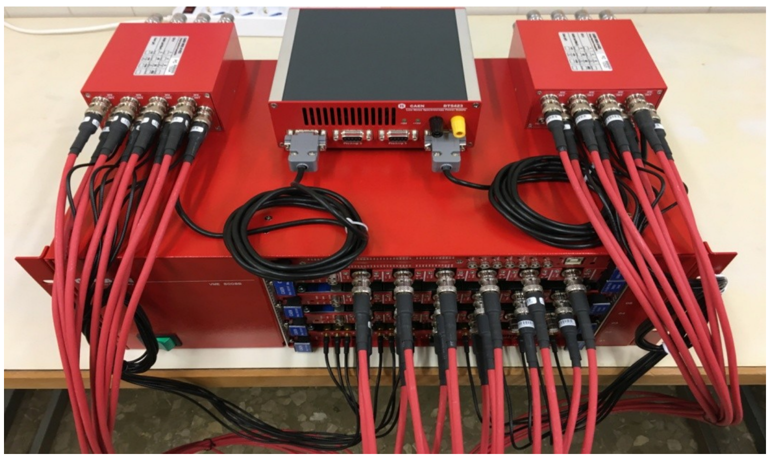
- José Enrique Garcías Ramos (Universidad de Huelva)
- Francisco Pérez Bernal (Universidad de Huelva)
- Armando Relaño (Universidad Complutense de Madrid)
- Arnau Rios (Universidad de Barcelona)
- Denis Lacroix (IPN Orsay)

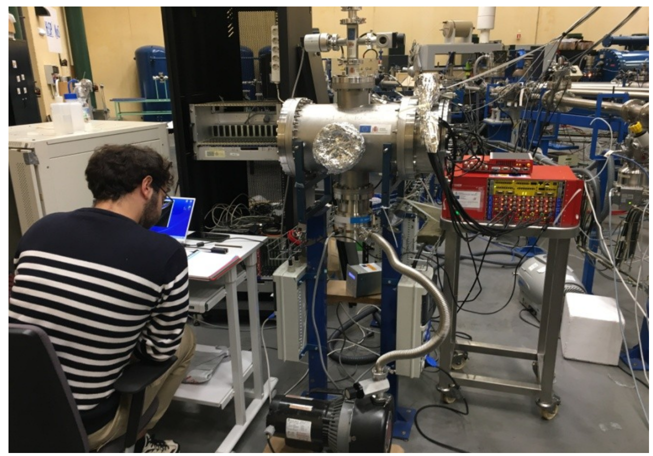
We are planing to ask for a FPI contract soon!!

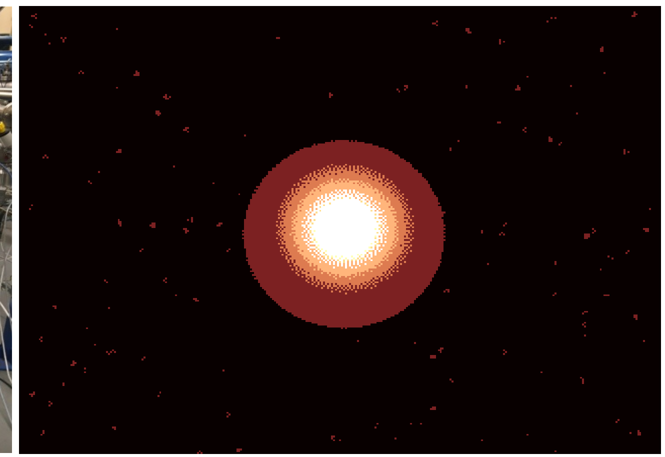


Research line:

Development of instrumentation for nuclear reactions measurements and their relevance for Astrophysics

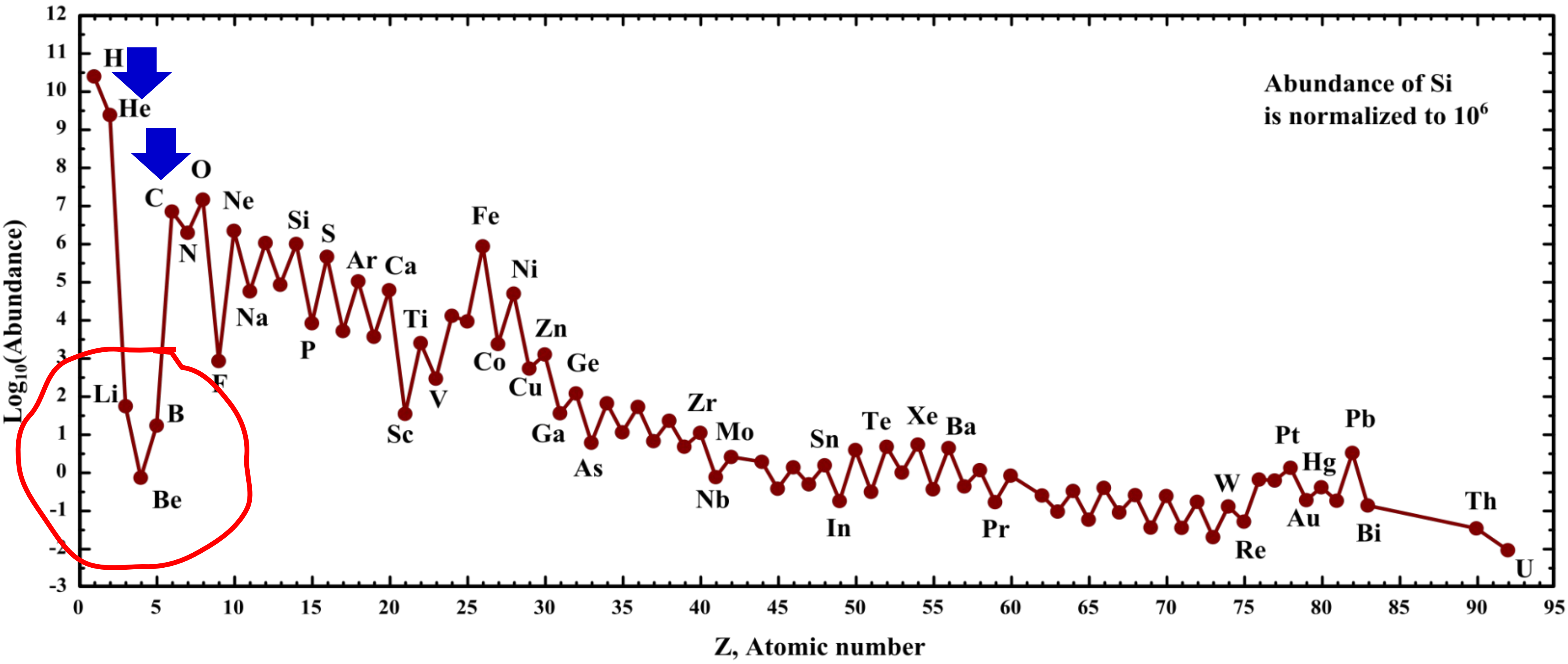






Juan Pablo Fernández García, jpfernandez@us.es
Marcos Aurelio Gonzalez Alvarez, malvarez@us.es

❑ In the **Astrophysics** scenario, the abundances of the nuclei **Li, Be, B** are very low; and the nuclei with mass A=5 and A=8 are not stable.



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- ***IberoAmerican Network of Nuclear Astrophysics (IANNA) – 2022***

  - Andrés Arazi
  - Leandro Gasques
  - Daniel Galaviz
  - **Marcos Alvarez**
  - Elí Aguilera
  - Michael Wiescher

https://jinaweb.org
https://irenaweb.org

- ***International Research Network for Nuclear Astrophysics (IReNA) – 2023***

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IReNA Welcomes New Ibero-American Partner IANNA to Advance Nuclear Astrophysics

Fri, Mar 10, 2023

10 March 2023

For immediate release

EAST LANSING, MI – The International Research Network for Nuclear Astrophysics (IReNA), supported by the National Science Foundation (NSF) and headquartered at Michigan State University (MSU), brings together nuclear physicists, astronomers, and computational scientists to try to answer a long-standing question in science: Where do the elements that make up our world come from?

IReNA is an international network of networks dedicated to nuclear astrophysics research

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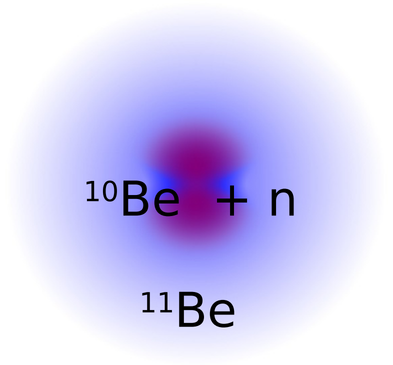
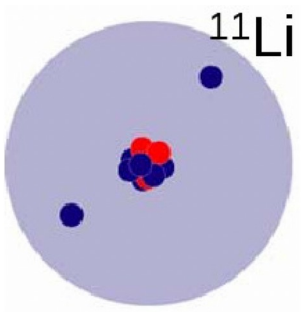
- **FA1: <u>Nuclear Reaction Rates</u>** ← **Seville's team**
- **FA2: Stellar Abundances**
- **FA3: Dense Matter in Supernovae and Neutron Star Mergers**
- **FA4: r-process Experiments**
- **FA5: Computer Models**
- **FA6: Nuclear Data for Astrophysics**
- **FA7: Weak Interactions**
- **FA8: Professional Development and Broadening Participation**

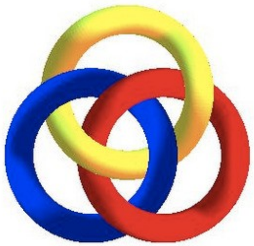
Nuclear Reactions Theory Group @ Seville

Advances in low energy nuclear reactions:





- Halo nuclei -> role of deformation of the core, pairing
  - + P. Punta et al. PRC111 (2025) 064614
  - + A.M. Moro and J. A. Lay, PRL109 (2012) 232502
- Borromean and 3-body nuclei -> 2p or 2n halo, 2p emitters
  - + J. P. Fernández-García, M. Cubero, M. Rodríguez-Gallardo et al. PRL110 (2013) 142701
  - + J. Casal PRC97 (2018) 034613



- 2n-transfer -> GPV, shape phase transitions
  - + F. Barranco, G. Potel, and E. Vigezzi PRL134 (2025) 062501
  - + J. A. Lay et al. PLB838 (2023) 137719
- Quenching of Spectroscopic Factors from Knock-out, Quasi-free
  - + M. Gómez-Ramos, J. Gómez-Camacho, and A. M. Moro PLB847 (2023) 138284
  - + M. Gómez-Ramos PRC109 (2024) 064622

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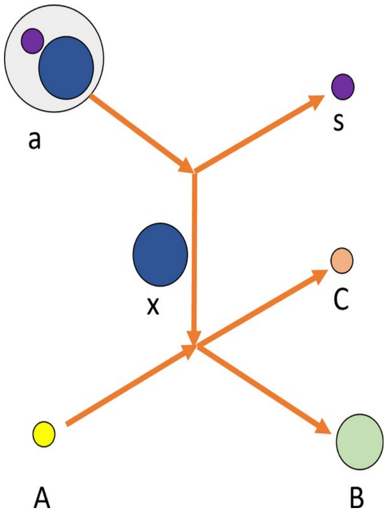
Nuclear Reactions Theory Group @ Seville

- Reactions of astrophysical interest -> 3b radiative capture
  - J. Casal, M. Rodríguez-Gallardo, J. M. Arias, and J. Gómez-Camacho [PRC93 (2016) 041602(R)]
  - J. Casal et al. [PRC94 (2016) 054622]

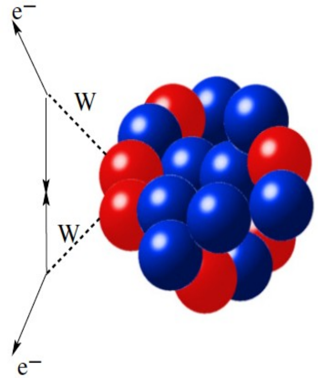


- Strong collaboration with experimental groups:
  - Surrogate reactions

    + J. Lei, A. M. Moro [PRL122 (2019) 042503]
  - NUMEN charge exchange reactions and $0\nu2\beta$ decay

    + F. Cappuzzello et. al [PPNP128 (2023) 103999]

NUMEN



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Nuclear Reactions Theory Group @ Seville

- Some contacts:

  J. A. Lay (lay@us.es) A. M. Moro (moro@us.es)

  M. Rodríguez-Gallardo (mrodri@us.es) M. Gómez-Ramos (mgomez40@us.es)

- Collaborations with:

  L. Fortunato (UniPD) M. Colonna and S. Burrello (UniCT) G. Colò and E. Vigezzi (UniMIB) Experimental groups from IEM-CSIC, USC, GANIL, UniPD, UniCT,…

- More info/presentations:

  CPAN Days 2022   M. Gómez-Ramos@DREB24

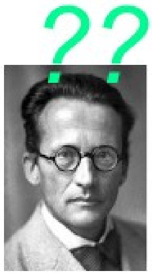
  La Rábida International School on Nuclear Physics

  Euroschool on exotic beams

Nuclear Structure Theory

The nuclear many-body problem is… a **challenging** problem!

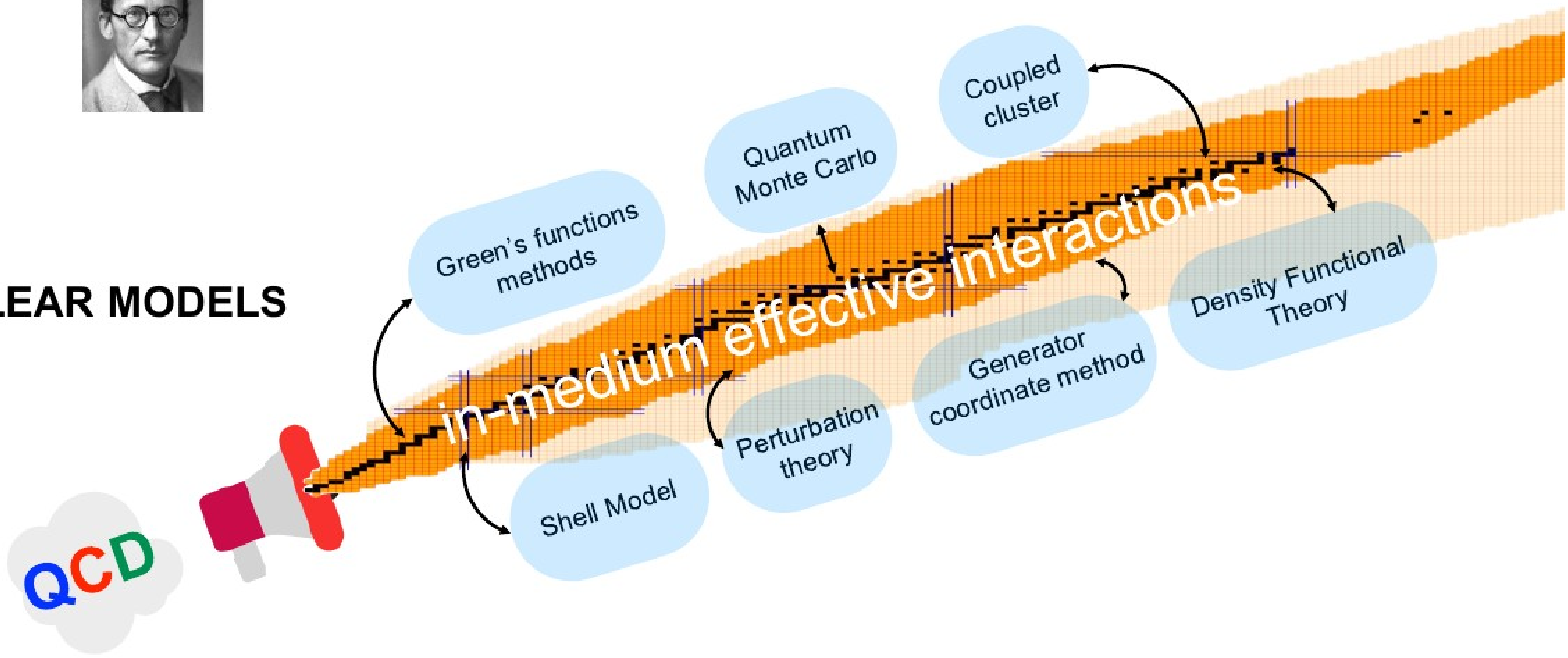
$$\hat{H}|\Psi_n\rangle = E_n|\Psi_n\rangle$$



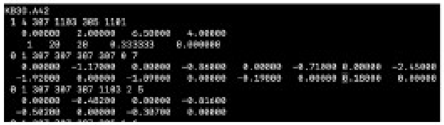
- The nuclear interaction is problematic

- The quantum *A*-body system is problematic

NUCLEAR MODELS



Nuclear Structure Theory



$$v(1,2) = v_c(1,2) + v_{\mathrm{LS}}(1,2) + v_{\mathrm{DD}}(1,2) + v_{\mathrm{Coul}}(1,2)$$

$$v_c(1,2) = \sum_{i=1,2} e^{-\frac{|\vec{r}_1-\vec{r}_2|^2}{\mu_i^2}} (W_i + B_i P_\sigma - H_i P_\tau - M_i P_\sigma P_\tau).$$

$$v_{\mathrm{LS}}(1,2) = i W_{\mathrm{LS}} (\overleftarrow{\nabla}_{12} \delta(\vec{r}_1 - \vec{r}_2) \wedge \vec{\nabla}_{12})(\vec{\sigma}_1 + \vec{\sigma}_2)$$

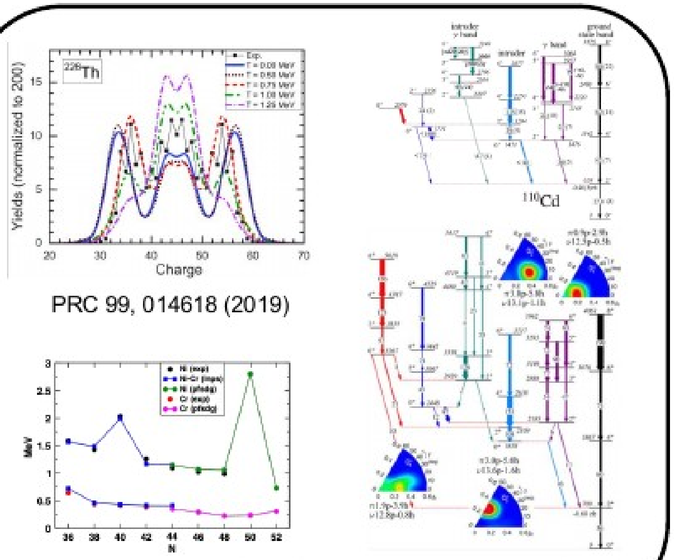
$$v_{\mathrm{DD}}(1,2) = t_3 (1 + P_\sigma x_0) \delta(\vec{r}_1 - \vec{r}_2) \rho^\alpha((\vec{r}_1 + \vec{r}_2)/2)$$

Nuclear interactions

$$\hat{H}|\Psi_n\rangle = E_n|\Psi_n\rangle$$

$$\delta\left[E\left(\rho\right)\right] = 0$$

Many-body methods



PRC 99, 014618 (2019)

PRL 117, 272501 (2016)

PRL 123, 142502 (2019)

Results

- Description of degradation/appearance of magic numbers
- Nuclear shape evolution, coexistence and/or mixing
- Fission properties
- Astrophysical applications (nuclear equation of state, decay half-lives, masses, etc.)
- Fundamental symmetries (neutrinoless double-beta decay, dark matter)

Nuclear Structure Theory

Contact: Tomás R. Rodríguez,
trodrig@us.es

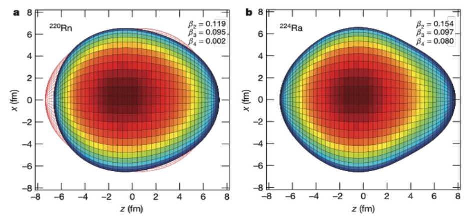


Figure 4 | Graphical representation of the shapes of ^{220}Rn and ^{224}Ra. **a**, ^{220}Rn; **b**, ^{224}Ra. Panel **a** depicts vibrational motion about symmetry between the surface shown and the red outline, whereas **b** depicts static deformation in the intrinsic frame. Theoretical values of β_4 are taken from ref. 10. The colour scale, blue to red, represents the y-values of the surface. The nuclear shape does not change under rotation about the z axis.

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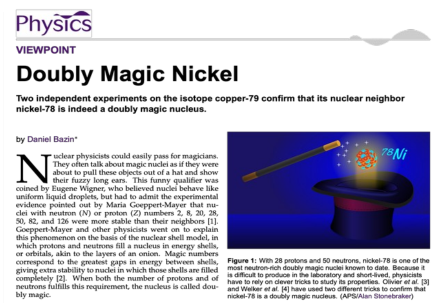


Physics

VIEWPOINT

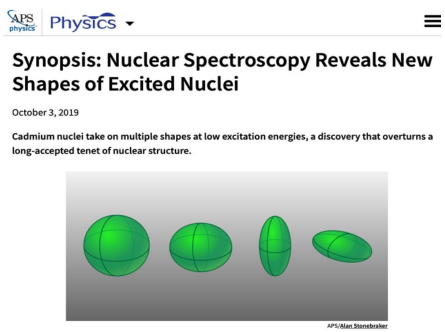
Doubly Magic Nickel

Two independent experiments on the isotope copper-79 confirm that its nuclear neighbor nickel-78 is indeed a doubly magic nucleus.

by Daniel Bazin*

Nuclear physicists could easily pass for magicians. They often talk about magic nuclei as if they were about to pull these objects out of a hat and show their fuzzy long ears. This funny qualifier was coined by Eugene Wigner, who believed nuclei behave like uniform liquid droplets, but had to admit the experimental evidence pointed out by Maria Goeppert-Mayer that nuclei with neutron (N) or proton (Z) numbers 2, 8, 20, 28, 50, 82, and 126 were more stable than their neighbors [1]. Goeppert-Mayer and other physicists went on to explain this phenomenon on the basis of the nuclear shell model, in which protons and neutrons fill a nucleus in energy shells, or orbitals, akin to the layers of an onion. Magic numbers correspond to the greatest gaps in energy between shells, giving extra stability to nuclei in which those shells are filled completely [2]. When both the number of protons and of neutrons fulfills this requirement, the nucleus is called doubly magic.

Figure 1: With 28 protons and 50 neutrons, nickel-78 is one of the most neutron-rich doubly magic nuclei known to date. Because it is difficult to produce in the laboratory and short-lived, physicists have to rely on clever tricks to study its properties. Olivier *et al.* [3] and Welker *et al.* [4] have used two different tricks to confirm that nickel-78 is a doubly magic nucleus. (APS/Alan Stonebraker)



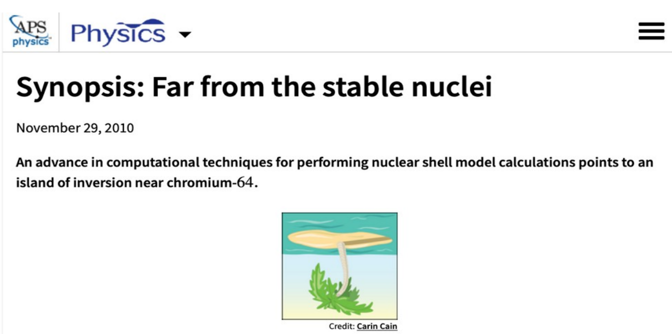
APS physics | Physics

Synopsis: Nuclear Spectroscopy Reveals New Shapes of Excited Nuclei

October 3, 2019

Cadmium nuclei take on multiple shapes at low excitation energies, a discovery that overturns a long-accepted tenet of nuclear structure.

APS/Alan Stonebraker



APS physics | Physics

Synopsis: Far from the stable nuclei

November 29, 2010

An advance in computational techniques for performing nuclear shell model calculations points to an island of inversion near chromium-64.

Credit: Carin Cain

Collaborators:

Universidad de Sevilla: Gregory Potel

Universidad Autónoma de Madrid: Luis Robledo, Alfredo Poves, Samuel Giuliani

Technishe Universität Darmstadt / GSI-Darmstadt: Gabriel Martínez-Pinedo, Benjamin Bally, …

Universidad de Barcelona: Javier Menéndez

CEA / CNRS: Thomas Duguet, Nathalie Pillet, Frédéric Nowacki, Kamila Sieja

Experimental nuclear physicist: J. Javier Valiente (IFIC), Paul Garrett (Guelph), Wolfgang Korten (CEA), Luis Mario Fraile (UCM), Magdalena Gorska (GSI)…

and many more…

NEUTRINO PHYSICS
much to be done

Researchers@US:

Juan Antonio Caballero jac@us.es
Guillermo D. Megias megias@us.es
Raúl González-Jiménez raugj@us.es

We are part of T2K collaboration: https://t2k-experiment.org/

Collaborations with Turin, Madrid, Paris, Geneve, Fermilab, Seattle, Ghent, Sofia, Granada, Pavia, Valencia, Wroclaw, …

Links for reading:

https://arxiv.org/abs/1706.03621
https://www.nature.com/articles/s41586-020-2177-0
https://doi.org/10.1103/PhysRevLett.123.052501
https://www.nature.com/articles/s41586-025-09599-3
https://www.dunescience.org/

NEUTRINO PHYSICS
much to be done

Multidisciplinary field

Theoretical Hadron, Nuclear and Particle physics

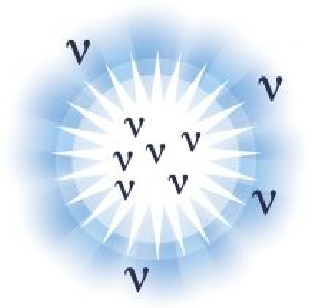
Connection with experiments

Hot topic: publications with high impact, funding

Possibilities all around the world

http://www.dunescience.org/

Aiming for groundbreaking discoveries



Origin of Matter

Could neutrinos be the reason that the universe is made of matter rather than antimatter? By exploring the phenomenon of neutrino oscillations, DUNE seeks to revolutionize our understanding of neutrinos and their role in the universe.

Unification of Forces

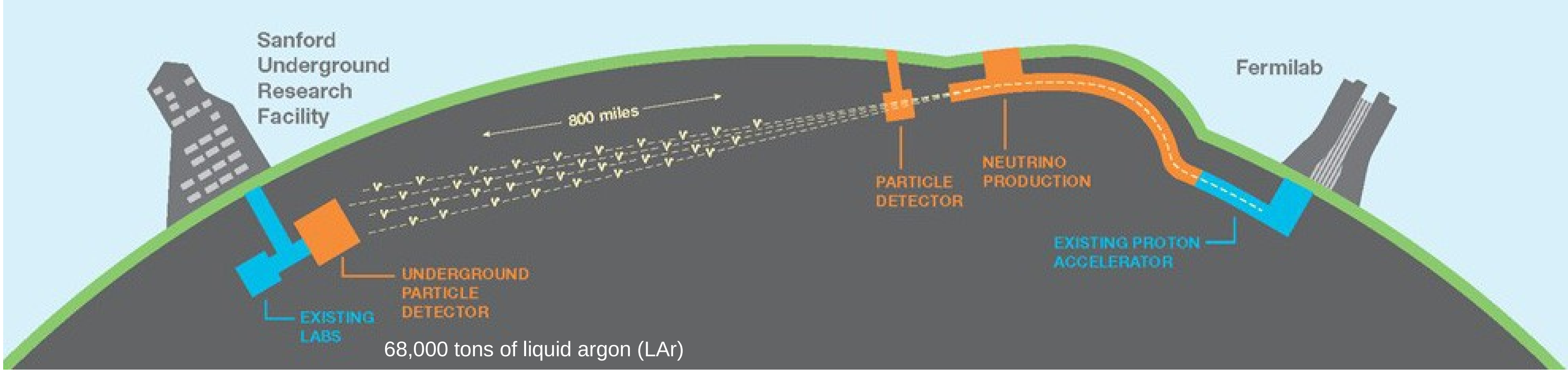
With the world’s largest cryogenic particle detector located deep underground, DUNE can search for signs of proton decay. This could reveal a relation between the stability of matter and the Grand Unification of forces, moving us closer to realizing Einstein’s dream.

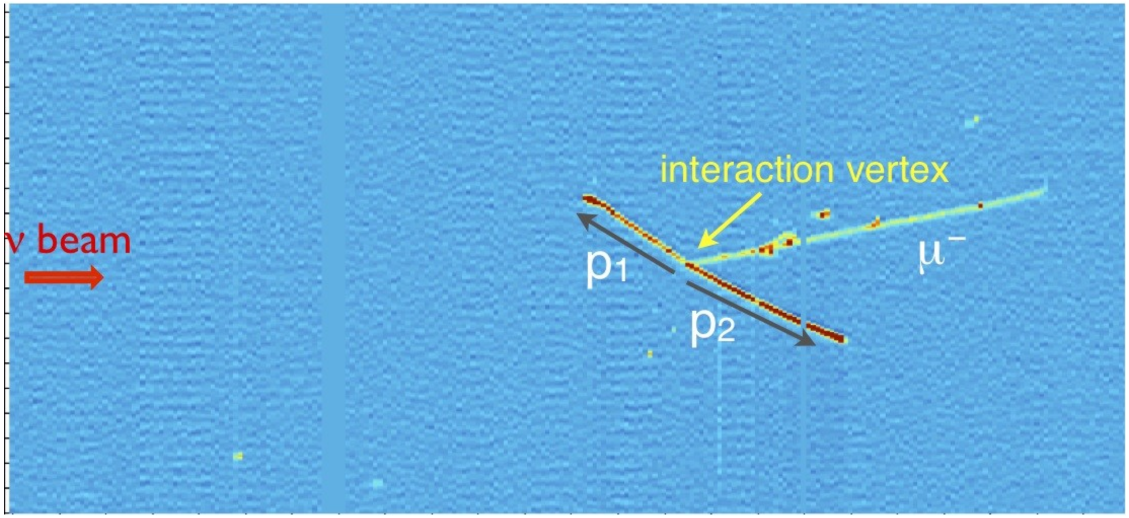
Black Hole Formation

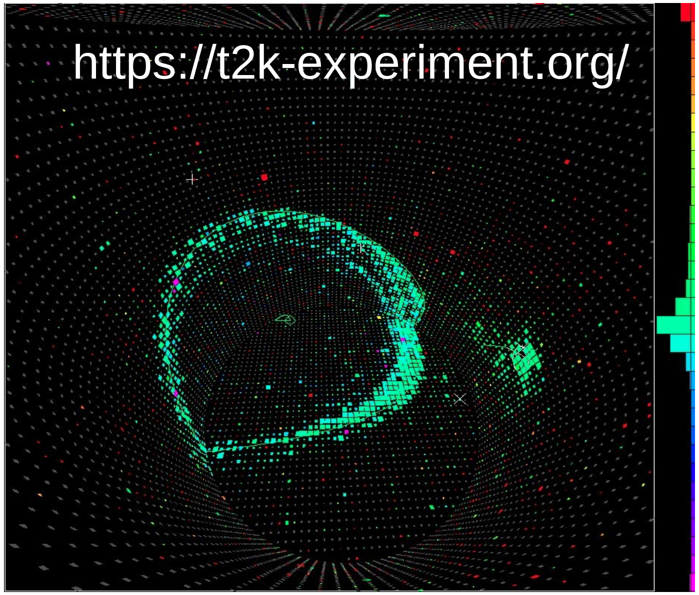
DUNE’s observation of thousands of neutrinos from a core-collapse supernova in the Milky Way would allow us to peer inside a newly-formed neutron star and potentially witness the birth of a black hole.

http://www.dunescience.org/

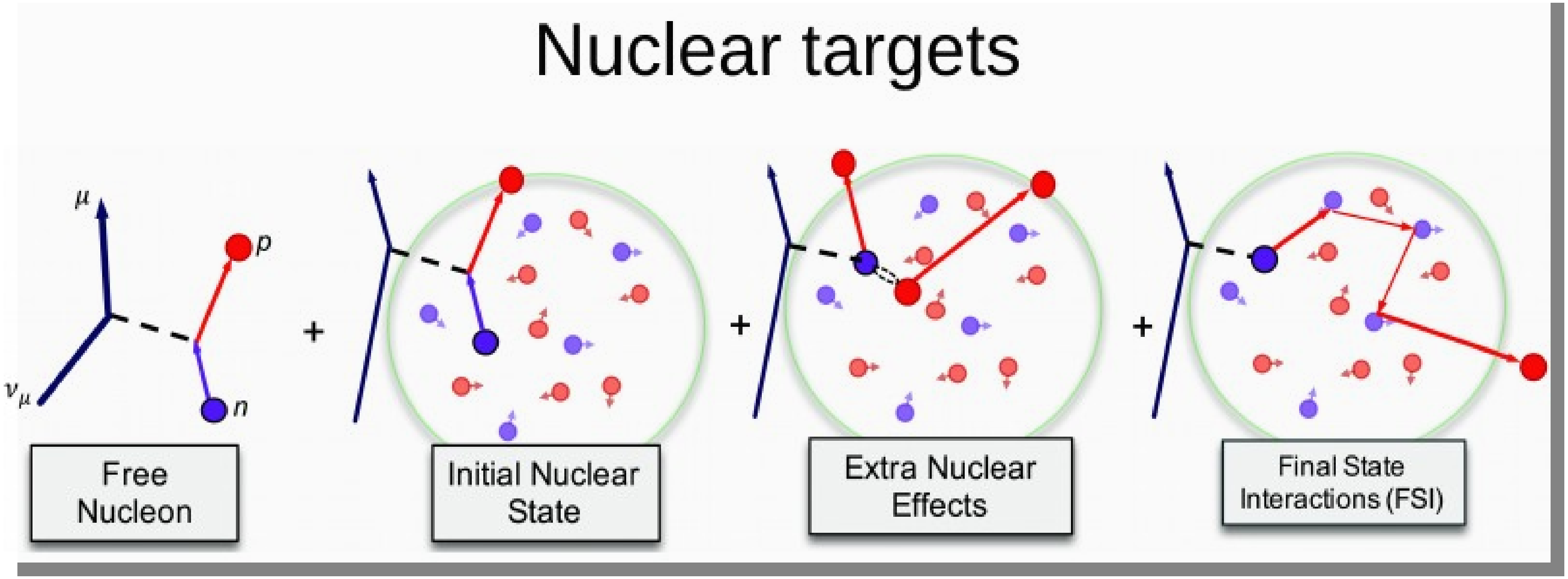
DUNE: Deep Underground Neutrino Experiment







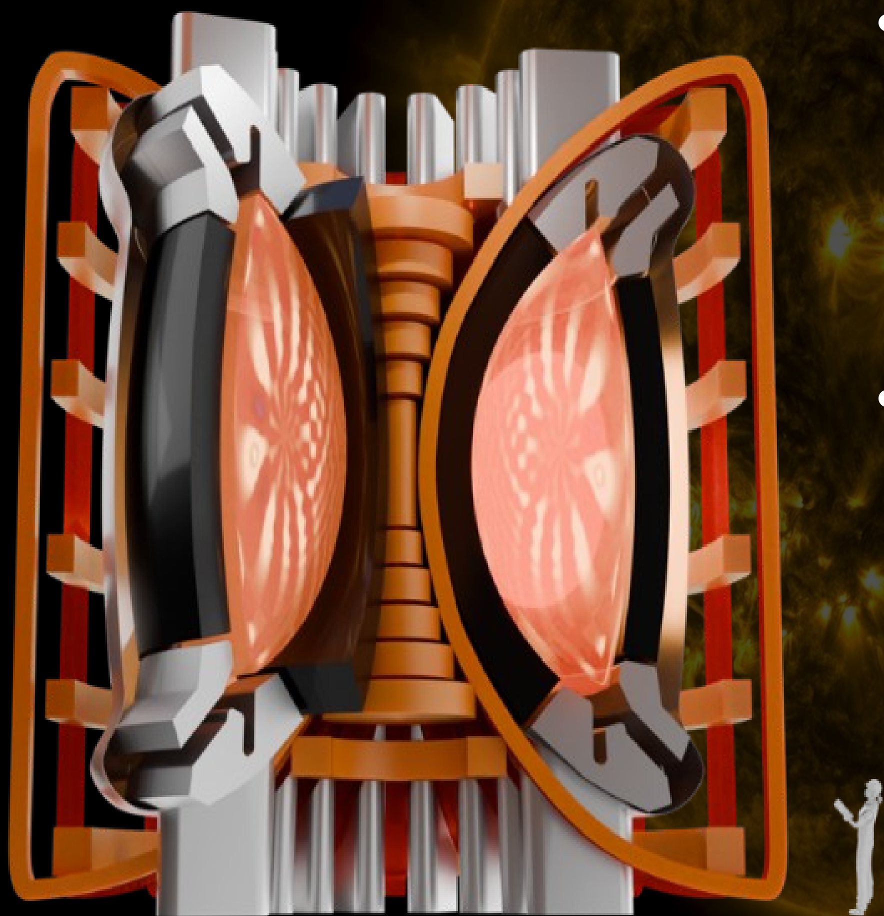
Neutrino detectors are made of complex nuclei



Our work: modeling of neutrino-nucleus interaction

Plasma Science and Fusion Technology (PSFT) Laboratory at University of Seville

Eleonora Viezzer,
eviezzer@us.es



BRIGHT

- **Our mission**

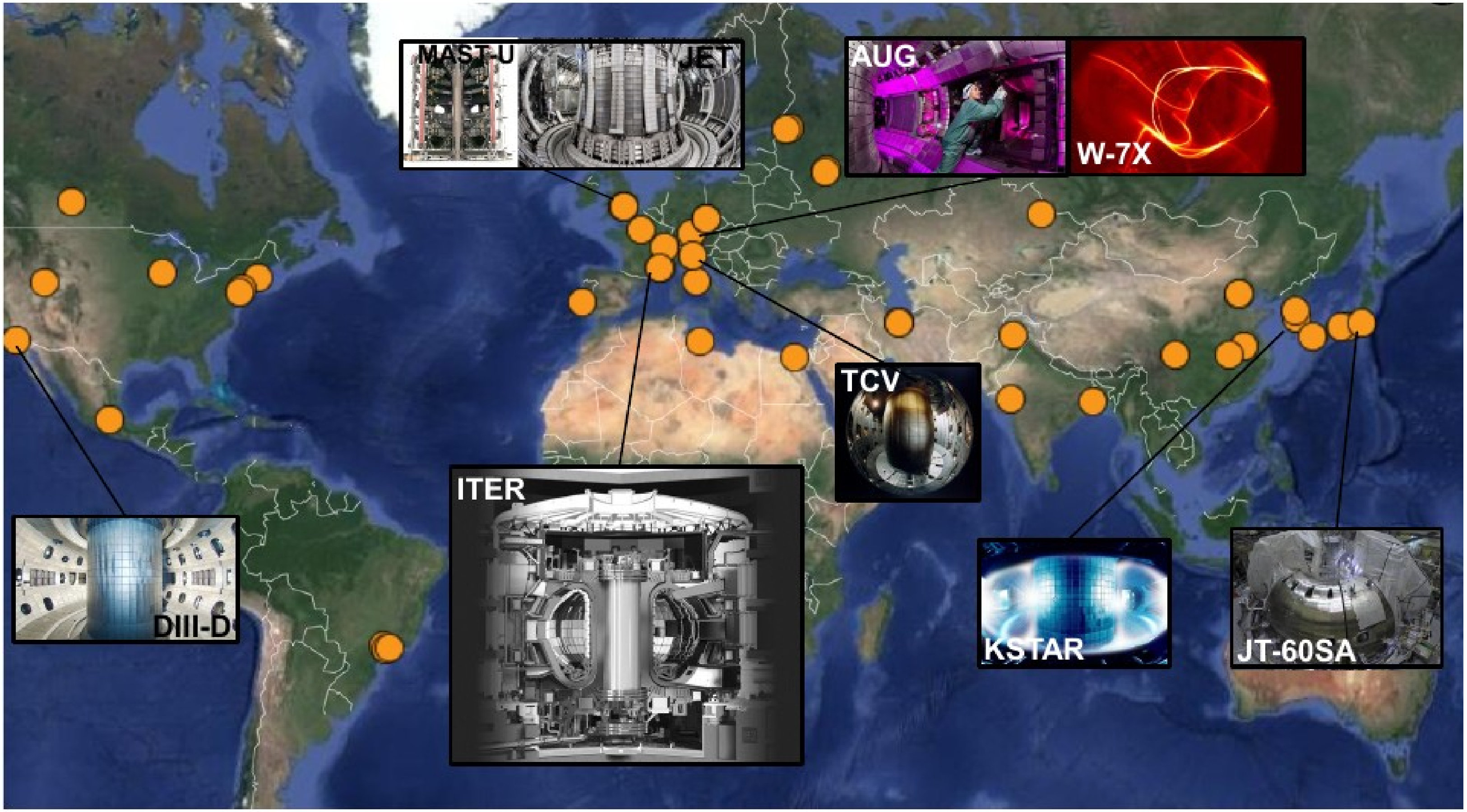
  Making fusion energy a reality for our society

- **Our objectives**

  Gaining a better understanding of energetic particle and plasma edge physics by means of cutting-edge diagnostics and state-of-the-art numerical tools

The PSFT Group is World Leader in Some Key Fusion Areas

Activities carried out under the umbrella of international (ERC, EUROfusion and ITER) and national (Ministerio de Ciencia e Innovación, Junta de Andalucía) research programs



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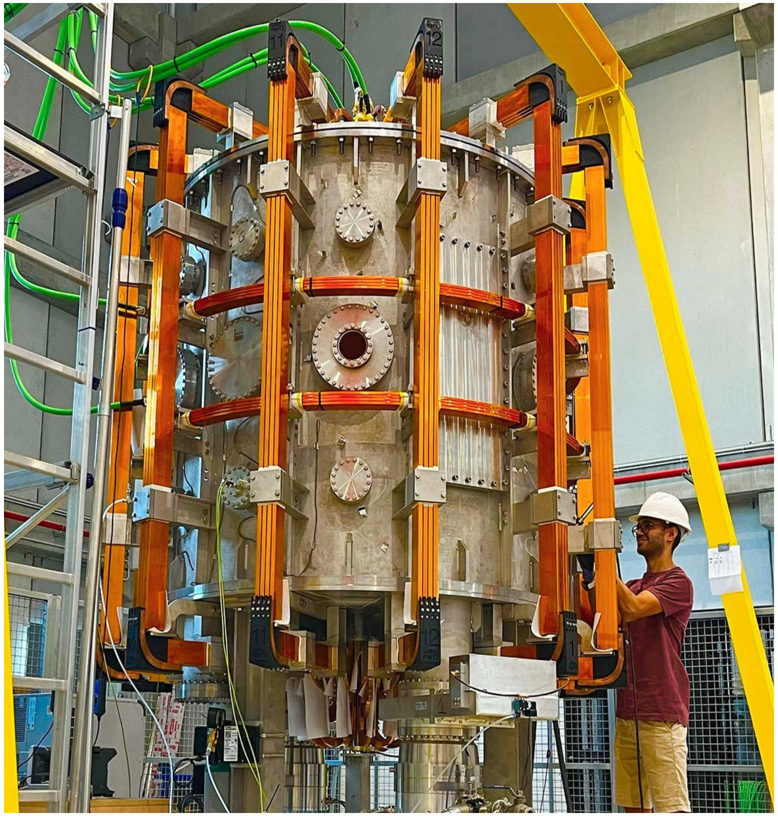
SMART – Small Aspect Ratio Tokamak of the University of Seville

- SMART: new spherical device currently being commissioned at University of Seville

  Attractive, fast and **economic path** to fusion reactors with high power densities



- **SMART's missions include:**
  - Explore high confinement regimes in spherical tokamaks with flexible shaping
  - Develop novel diagnostic and plasma control techniques
  - Develop alternative exhaust techniques
  - Training next generation of fusion physicists and engineers

eviezzer@us.es

First micro-wave heated tokamak plasma achieved

eviezzer@us.es

Projects carried out in PSFT Group

- **Fusion2Grid strategy and SMART tokamak**
- **ERC Starting, Consolidator and Advanced Grants**
- **EUROfusion activities**
  - **Experiments & modelling at AUG, MAST-U, TCV, JET, WEST, DTT**
  - **Enabling Research project for SMART**
- **Design of ITER Fast-Ion Loss Detector - FILD (ITER contract)**
- **Design and Construction of JT60SA FILD (F4E + EUROfusion contract)**
- **W7-X FILD + Coherence Imaging Spectroscopy**
- **HTSMART – HTS magnets for SMART (CDTI - Transmisiones (Public-Private Partnership)**

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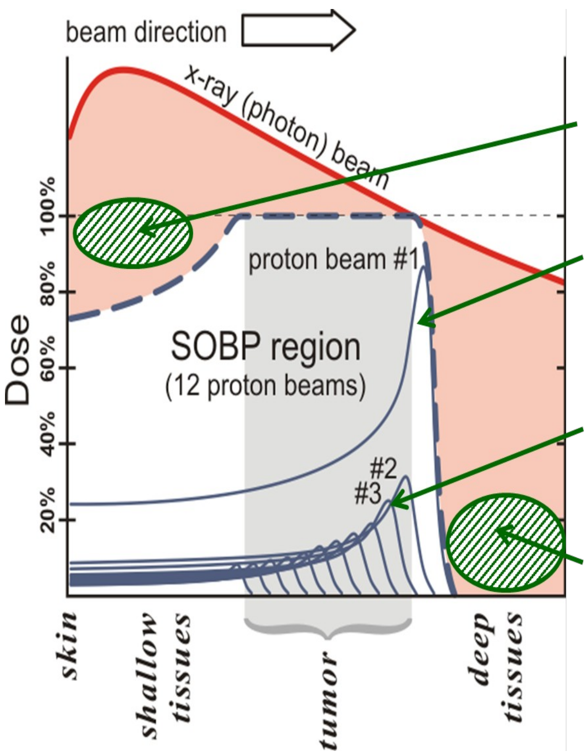
Monte Carlo simulations for hadron therapy and radiobiology

Physical and biological benefits of hadron therapy vs conventional radiotherapy

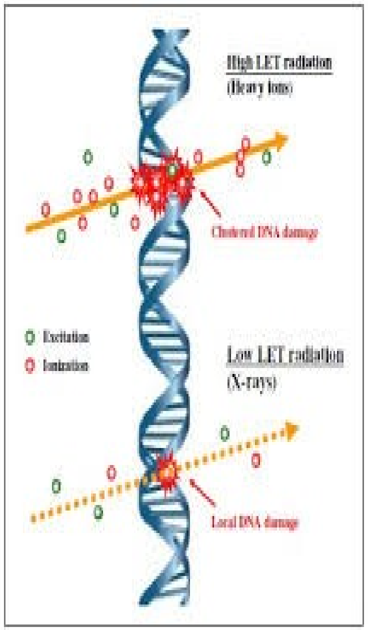


Lower dose delivered a
entrance.

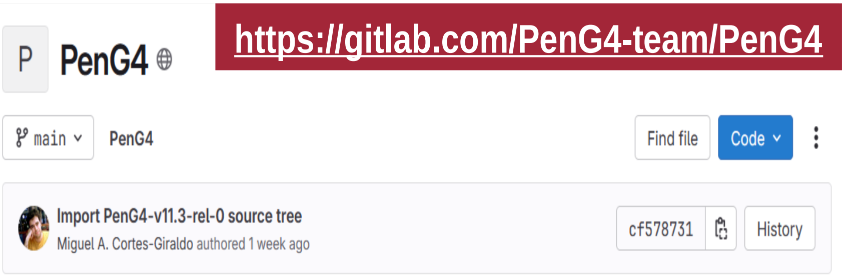
Maximum dose is delivered at the **Bragg peak region**.

The depth of the Bragg peak depends on the beam energy.

Absence of "exit dos
Especially important if a critical organ is present.



Monte Carlo codes



https://gitlab.com/PenG4-team/PenG4

Current team @ Universidad de Sevilla

- Prof. Miguel A. Cortés-Giraldo (miancortes@us.es)
- Prof. José M. Quesada (quesada@us.es)
- Prof. M. Isabel Gallardo (gallardo@us.es) (*retired*)
- Damián Domínguez-Muñoz (adominguez18@us.es)
- Daniel Suárez-García (dsgarcia@us.es)
- Miguel Galocha-Oliva (mgalocha@us.es)

Selected recent papers

- Arce et al., *Med Phys* 52 (2025)
- Papadopoulos et al., *Radiat Environ Biophys* 64 (2025)
- M.A. Cortés-Giraldo et al. (2024) [doi:10.1201/9781003023920-4]
- D. Suárez-García et al., *Radiother Oncol* 185 (2023)
- A.D. Domínguez-Muñoz et al., *Radiat Phys Chem* 199 (2022)
- M. Asai et al., *Front Phys* 9 (2021)
- A. Baratto-Roldán et al., *Front Phys* 9 (2021)

Microdosimetry and radiobiology in hadron therapy

M. Galocha-Oliva, PhD Project
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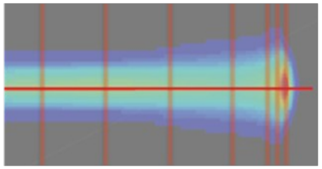
1. Ion radiation therapy:

Dose-depth profiles maximize dose in cancerous tissue (**Bragg peak**), but there is **no consensus quantifying** its **biological effect.**

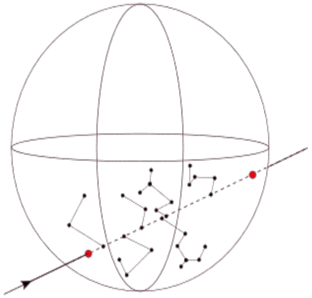


2. Relative biological efectiveness (RBE):

- **RBE** of ions is **not constant – it** depends on energy, ion type, depth, and tissue type.
- **RBE** can **be modeled** by **energy deposition patterns** at **cellular scale.**

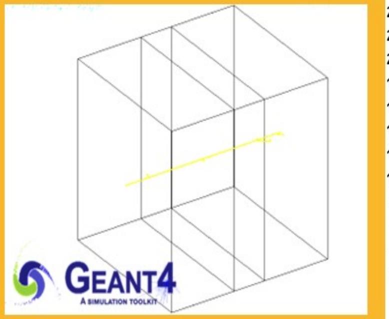
3. Microdosimetry:

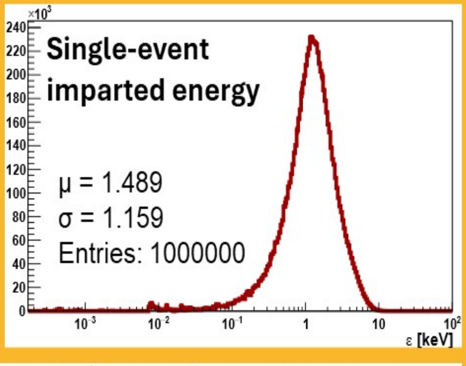
- Studies the stochastic nature of **energy deposited** by particle tracks in randomly-placed **microscopic volumes** called **sites**.



4. Our work

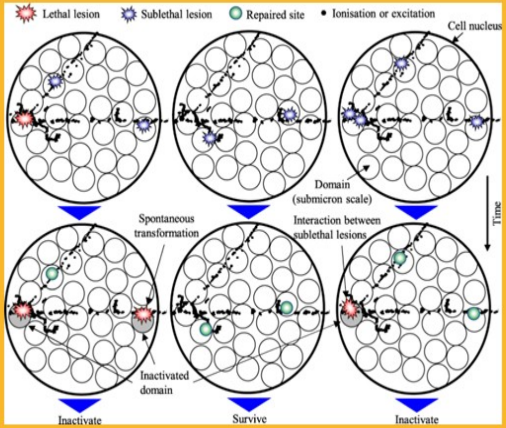
- Development and validation of **Monte Carlo codes** using **Geant4-DNA** to simulate microscale processes. **Obtention of microdosimetric stochastic quantities** (lineal energy, specific energy…).





- **Assessment** of proton and ion **RBE** through **models** based on **microdosimetric** quantities

T. Sato et al.
EJNMMI Physics (2021)



Monte Carlo simulations for radiopharmaceutical therapy

D. Suárez-García, PhD Project
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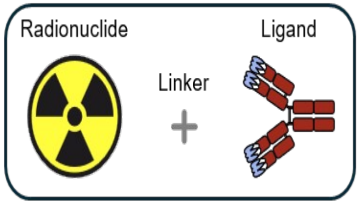
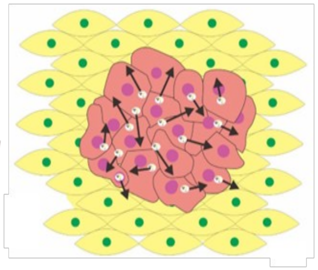
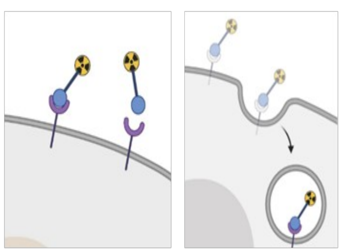
Radiopharmaceutical therapy (RPT) uses **radiolabeled ligands** that bind selectively to **molecular targets overexpressed in tumor cells** or their microenvironment

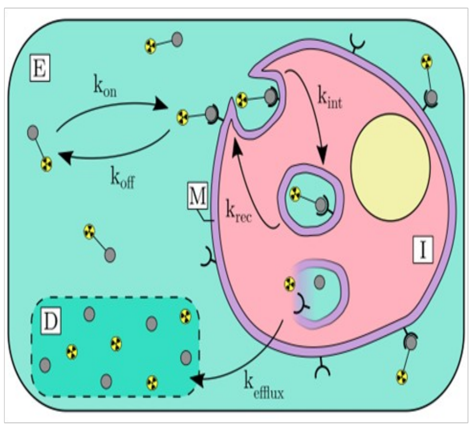




Binding kinetics

Binding kinetics describe the ligand-receptors **interaction** and the **intracellular trafficking** of the complex



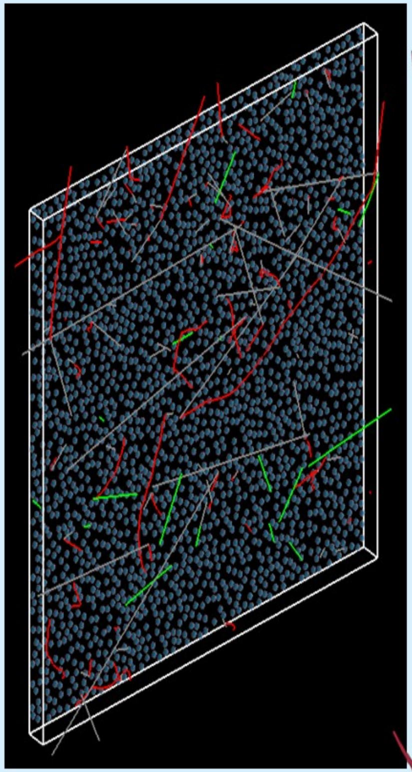


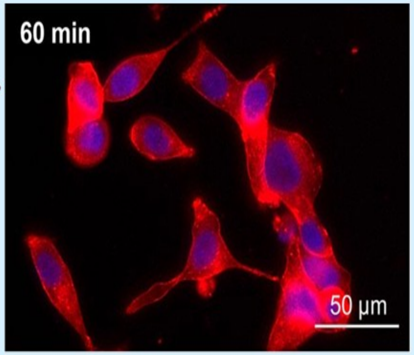
And... why is binding kinetics important?

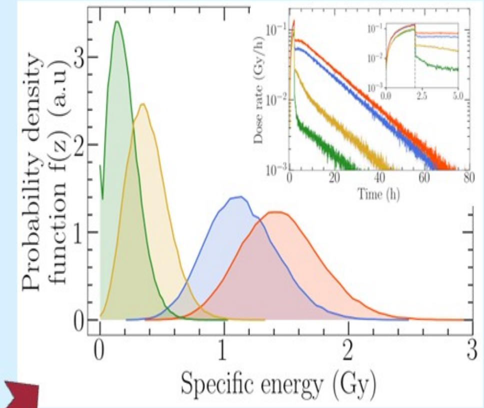
Because **binding kinetics** define **dose deposition patterns**, which in turn determine the **biological response**

So... what do we do here?

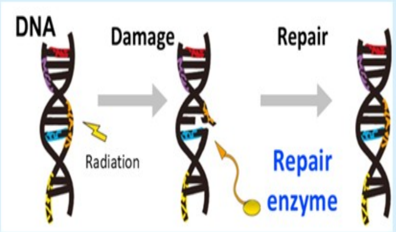
We developed **TOPAS-RPT** as a C++ extension of OpenTOPAS, a wrapper of Geant4, to **model in vitro RPT experiments and binding kinetics**







We obtain the **temporal and spatial dose distribution** and study its relationship with **the biological response**



Thanks!