Nuclear Physics

IPARCOS

IPARCOS

- Theorical Nuclear Physics
- Experimental Nuclear Physics
- Instrumentation
- Applications

gfn UCM
Grupo de Física Nuclear

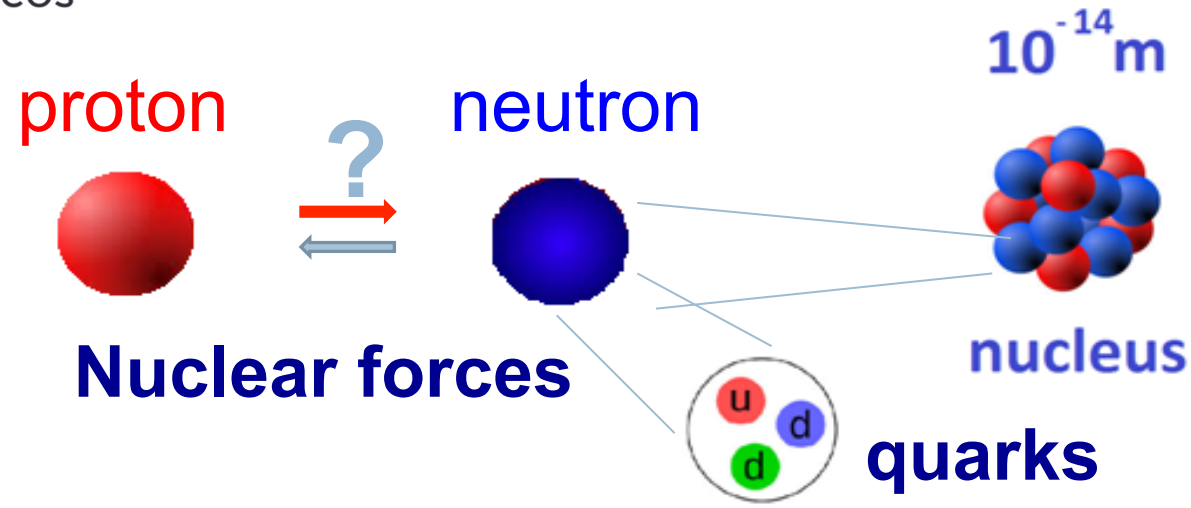
Nuclear Physics Group

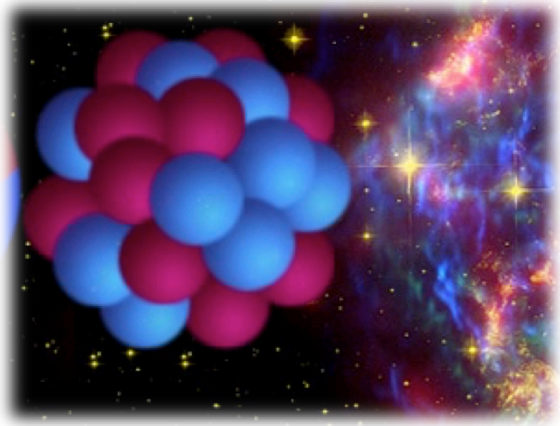
Members:

- 7 Faculty (CU, TU, PCD)
- 6 Young postdocs and researchers
- 9 PhD students

IPARCOS

The study of the atomic nucleus





Some of the key questions in Nuclear Physics research

- How are complex nuclei built from their basic constituents?
  - ➢ get information on the strong interaction (link to QCD)
- What is the structure of nuclear matter?
  - → collective versus individual nucleon behavior
- What is the role of nuclei in the evolution of the universe ?
  - → stellar nucleosynthesis
- Weak interaction and its role in neutrino and dark matter physics
- Is there physics beyond the Standard Model ?
- …

IPARCOS

The nucleus: a many-body system with electromagnetic, strong and weak forces at play

Applied Physics

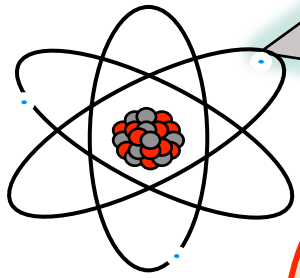
Implanted Radioactive Probes, Tailored Isotopes for Diagnosis and Therapy
Condensed matter physics and Life sciences

Nuclear Physics

Decay Spectroscopy
Nuclear Reactions
Nuclear Structure, Exotic decay modes, Transition Rates, Shapes

Fundamental Physics

Direct Mass Measurements,
Leptons
Weak Interactions
CKM unitarity tests, search for [?]-[?] correlations



Atomic Physics

Laser Spectroscopy and Direct Mass Measurements
Radii, Eletromagnetic Moments, Binding Energies

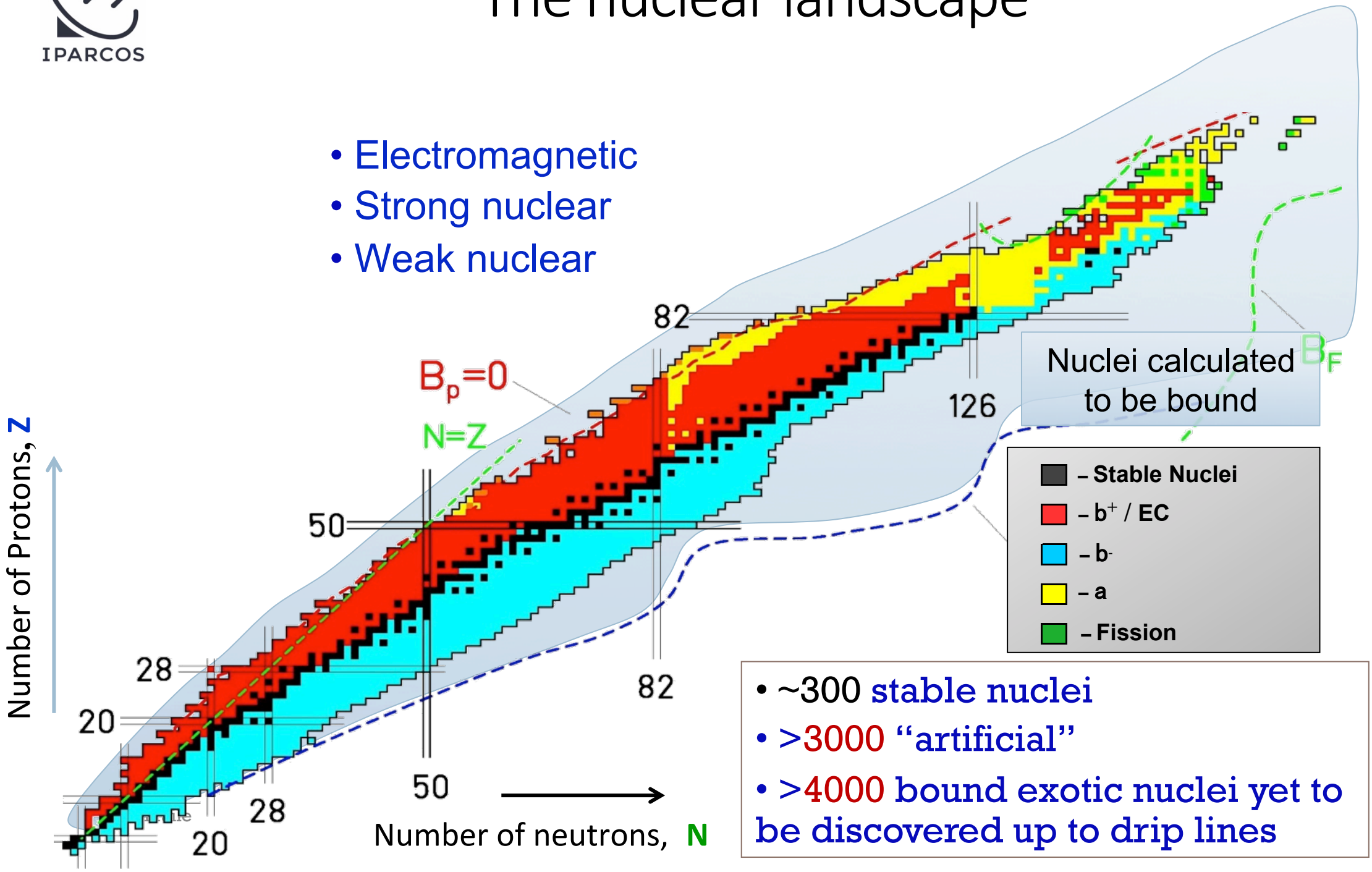
f(N,Z)

Nuclear Astrophysics

Dedicated Nuclear Decay & Reaction Studies
Element Nucleosynthesis, Solar Processes

The nuclear landscape

- Electromagnetic
- Strong nuclear
- Weak nuclear

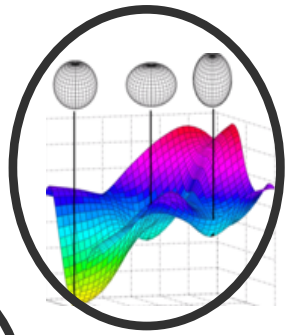


- ~300 stable nuclei
- >3000 "artificial"
- >4000 bound exotic nuclei yet to be discovered up to drip lines

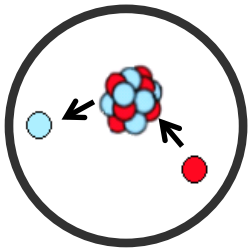
Theoretical nuclear physics

Research topics on the interplay of the **electromagnetic**, the **weak** and the **strong** interactions within the atomic nucleus, with applications to nuclear and particle physics and astrophysics.

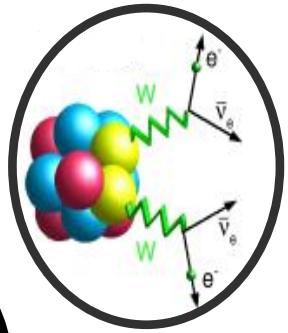
Beta stability and deformation



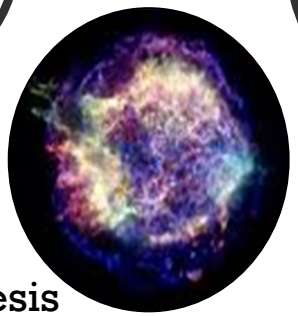
Nuclear reactions



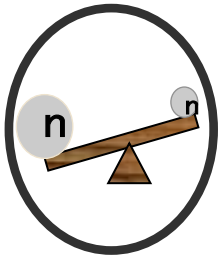
Double beta decay

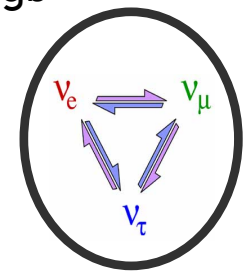


Stellar nucleosynthesis



Neutrino masses and mixings



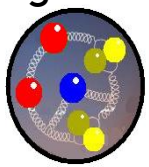


Dark matter detection and production (sterile neutrinos, WIMPs)

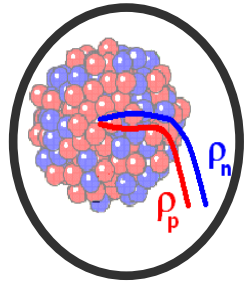
Weak interaction parameters

G_F q_W
$c_{V,A}$

Strangeness



Nuclear densities and form factors

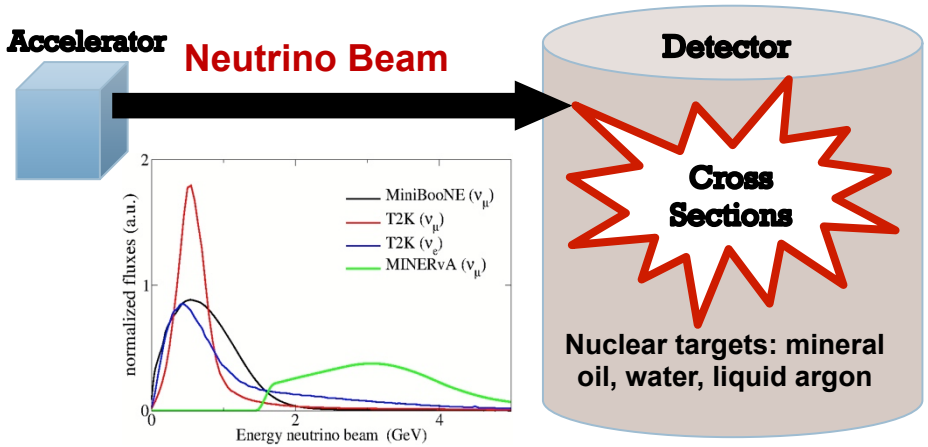


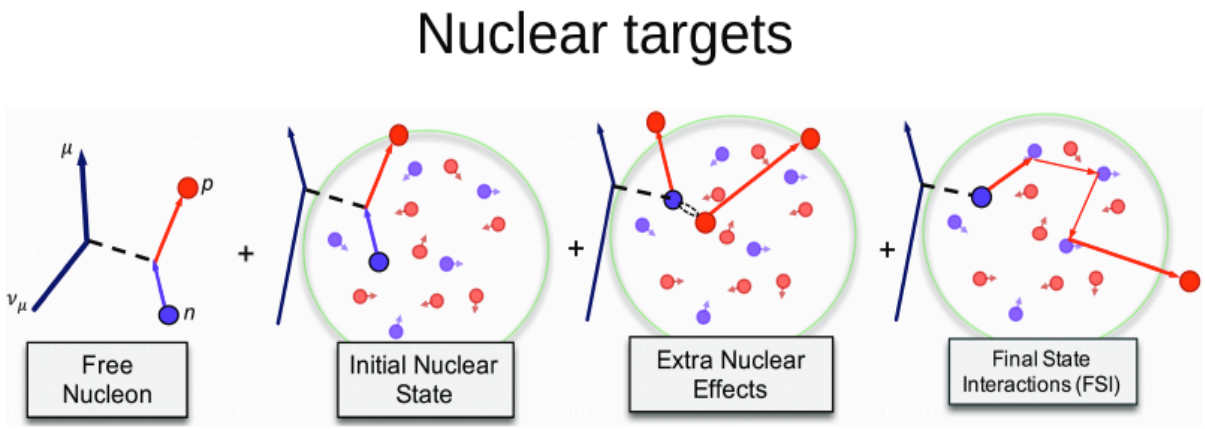
Structure of neutron stars

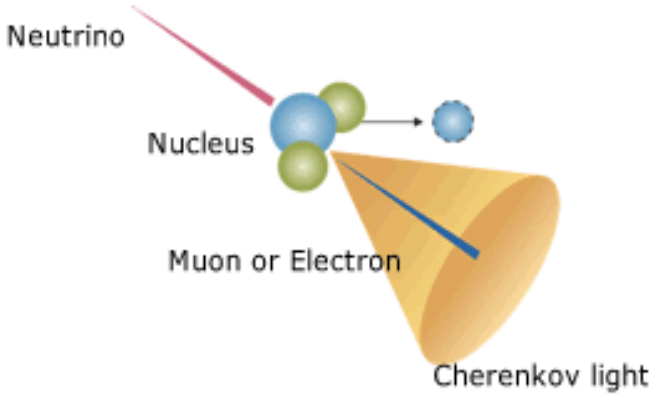
Elvira Moya, Óscar Moreno, José Manuel Udías, Raúl González Jiménez *et al.*

Theoretical nuclear physics

- Electron scattering off nuclei.
- Parity violation in polarized electron scattering off nuclei: nuclear structure effects and fundamental physics connections.
- Modeling of neutrino-nucleus interactions





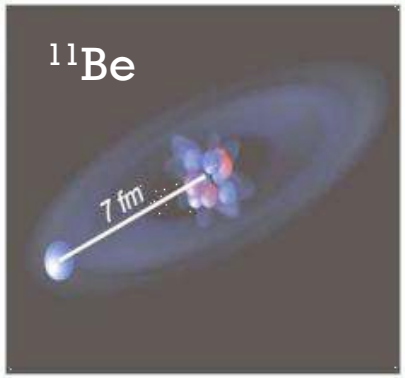


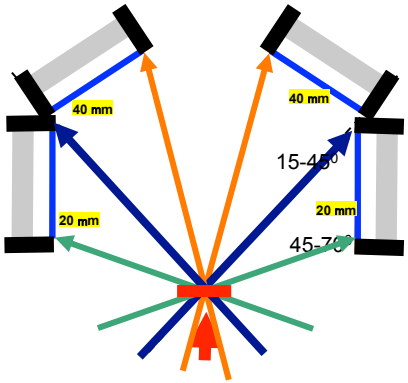
- neutrino detectors are made of complex nuclei…
- nuclear effects in n-nucleus interactions are essential to reduce systematic errors
- monochromatic neutrino beams are not available

Theoretical nuclear physics

Three-body break up of light nuclei

Core excitation plays an important role in the description of structure and reactions of halo nuclei.



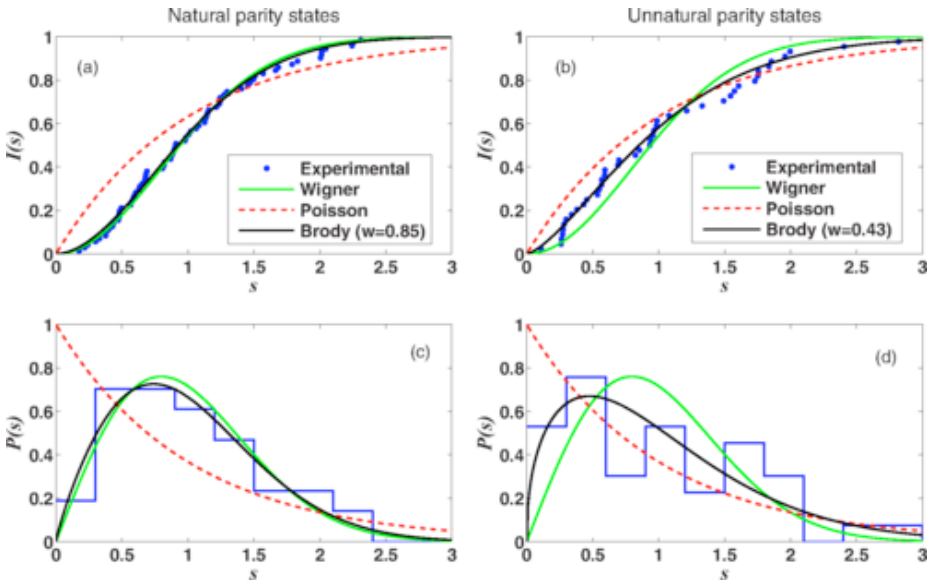


- Looselyl bound projectile in weak coupling limit
- THO+XCDCC method
- Three-body breakup observables derived and fragment distributions compared to experimental results.

R. de Diego *et al.*

Quantum chaos

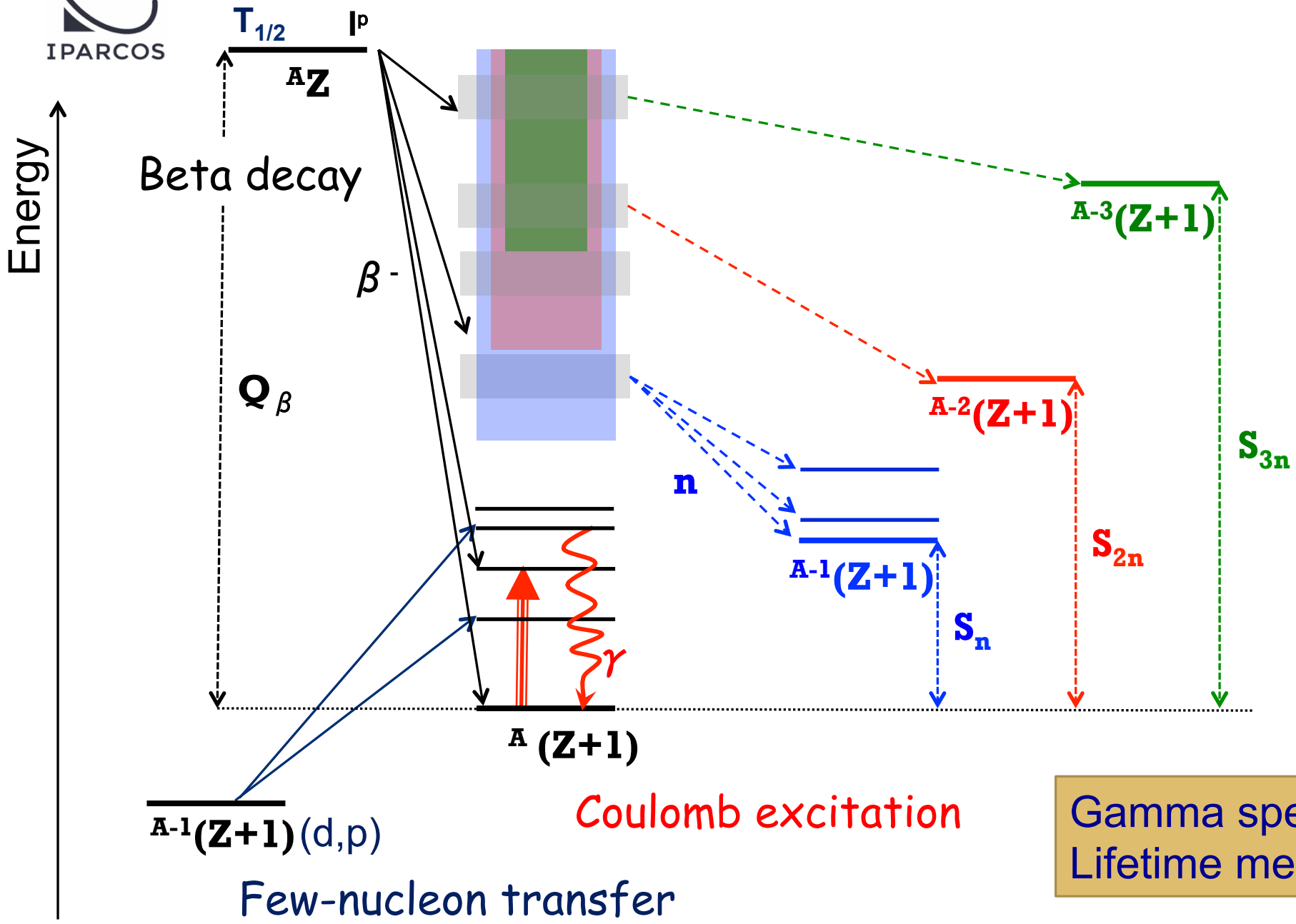
Study of spectral fluctuations by Random Matrix Theory in theoretical and experimental (nuclei, hadron resonances) systems.



Chaos in the bound states of ^{208}Pb, Phys. Rev. C 95, 014317 (2017)

L. Muñoz, J.M. Gómez *et al.*

Experimental nuclear physics

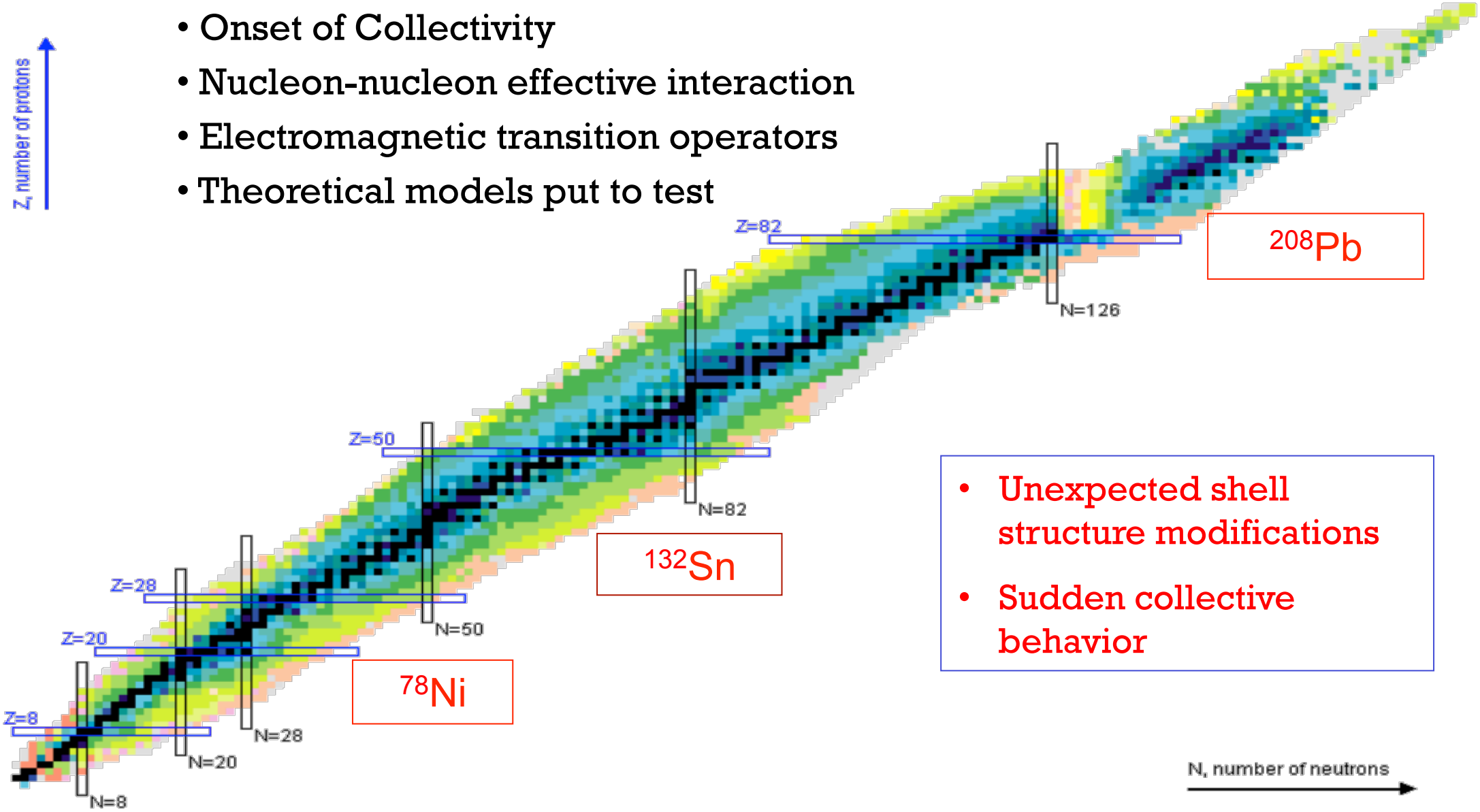


Gamma spectroscopy
Lifetime measurements

Nuclear structure around double closures

IPARCOS

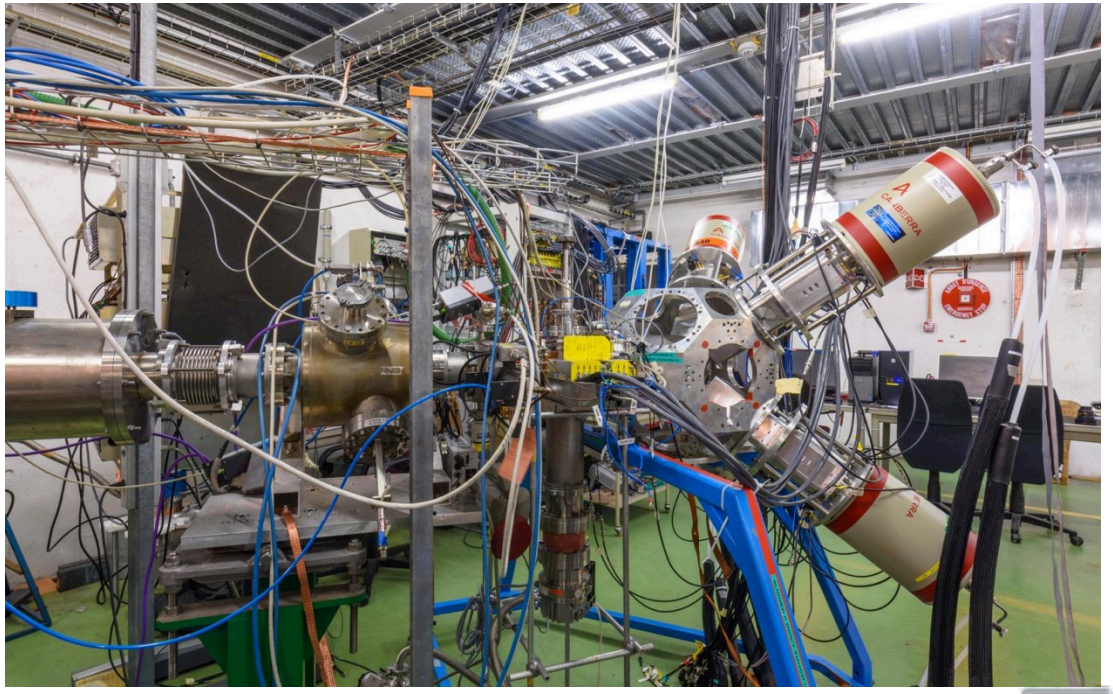
- Single-particle states
- Onset of Collectivity
- Nucleon-nucleon effective interaction
- Electromagnetic transition operators
- Theoretical models put to test

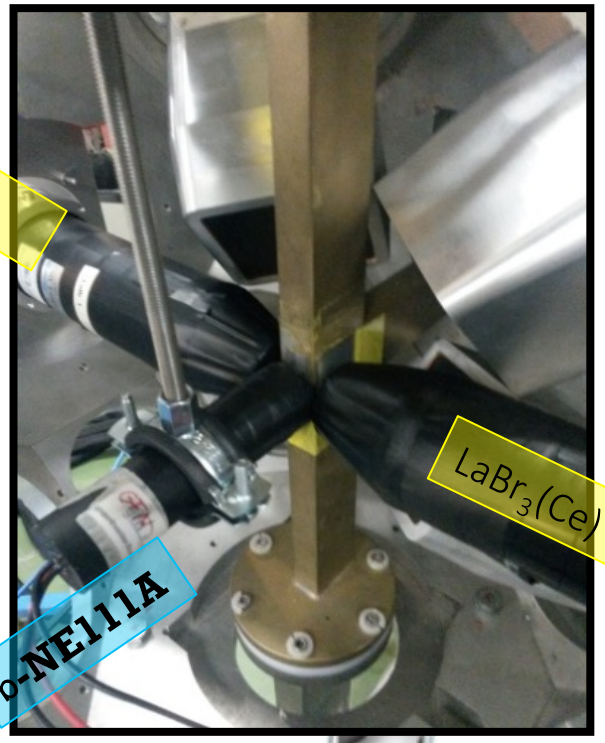


- Unexpected shell structure modifications
- Sudden collective behavior

Decay experiments at CERN-ISOLDE

IPARCOS



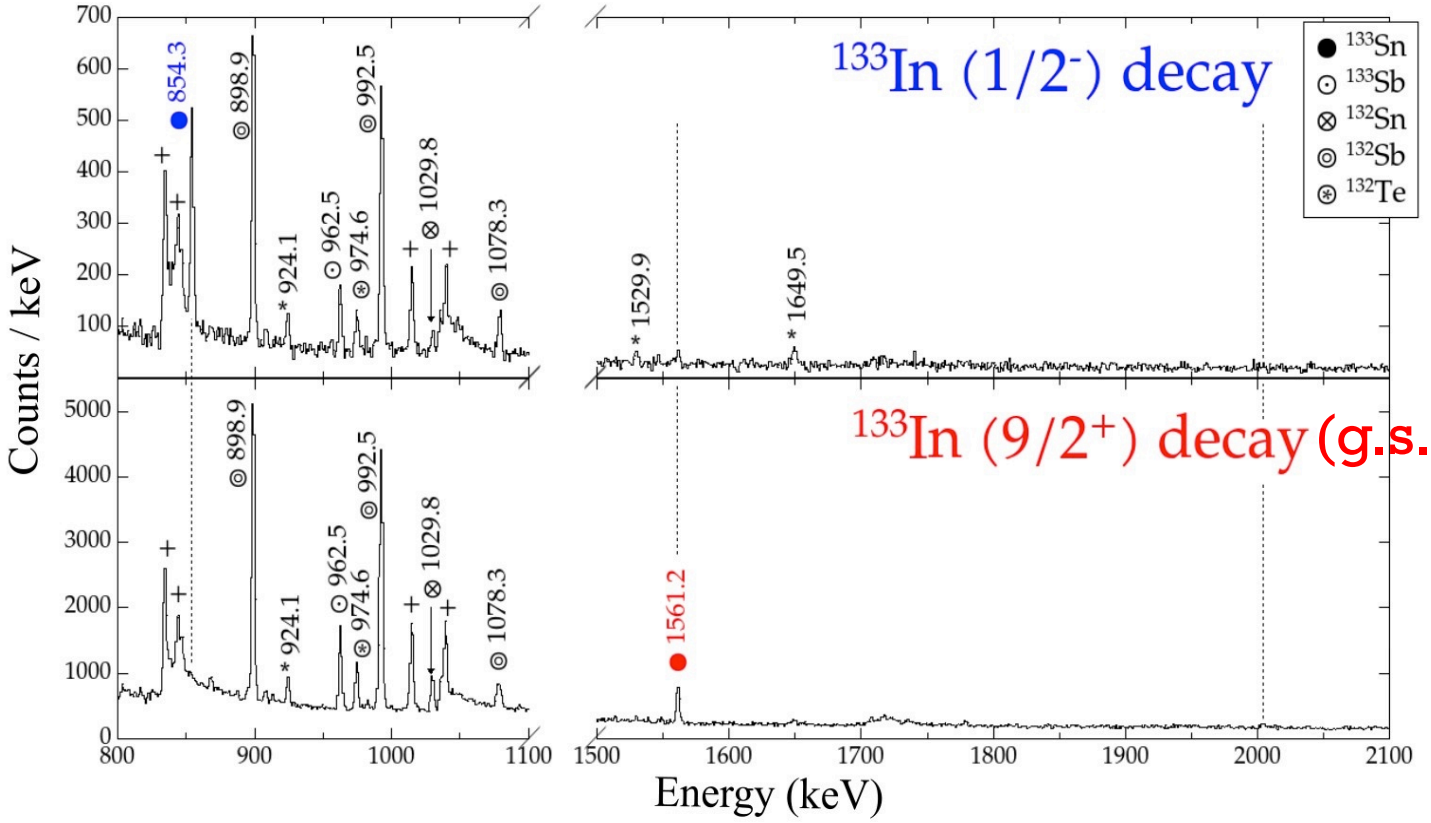


Spectroscopy of ^{133}Sn: single-particle states

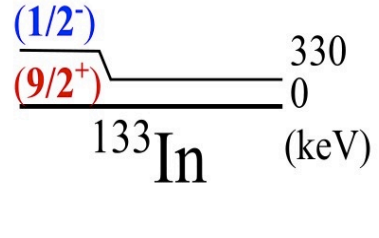
IPARCOS

Gamma spectroscopy
Fast timing (level lifetimes)

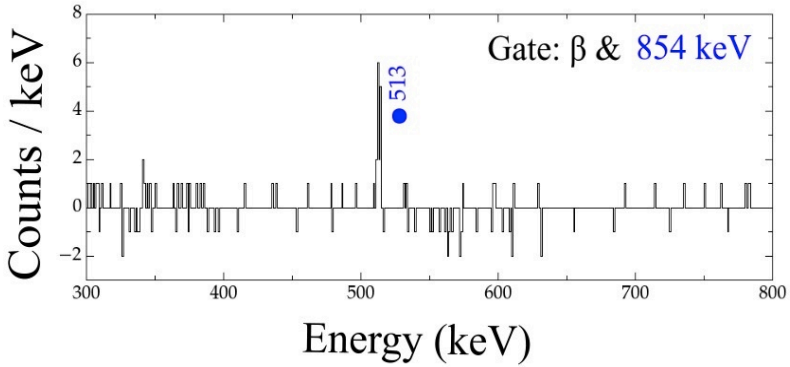
Competition of gamma and neutron decay
Gamma emission above S_n OBSERVED



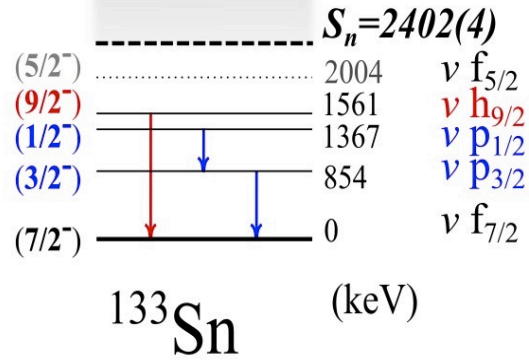
$T_{1/2}$ = 180(15) ms
$T_{1/2}$ = 165(3) ms



+ lifetime limit



513-keV line reported by K. L. Jones et al., Nature 465, 454 (2010)



M. Piersa, J. Benito, L.M. Fraile et al.

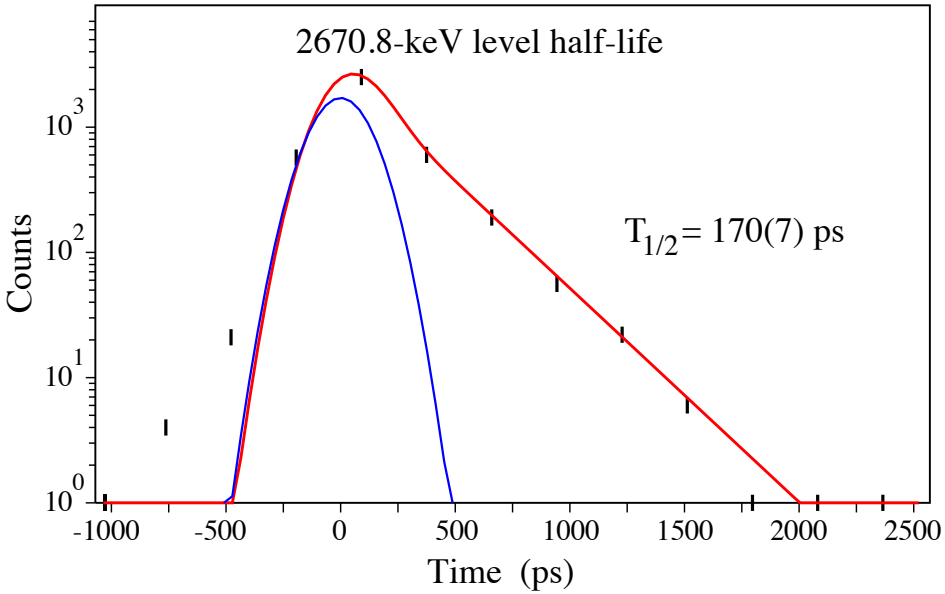
Co-existing shapes in nuclei: ^{66}Ni

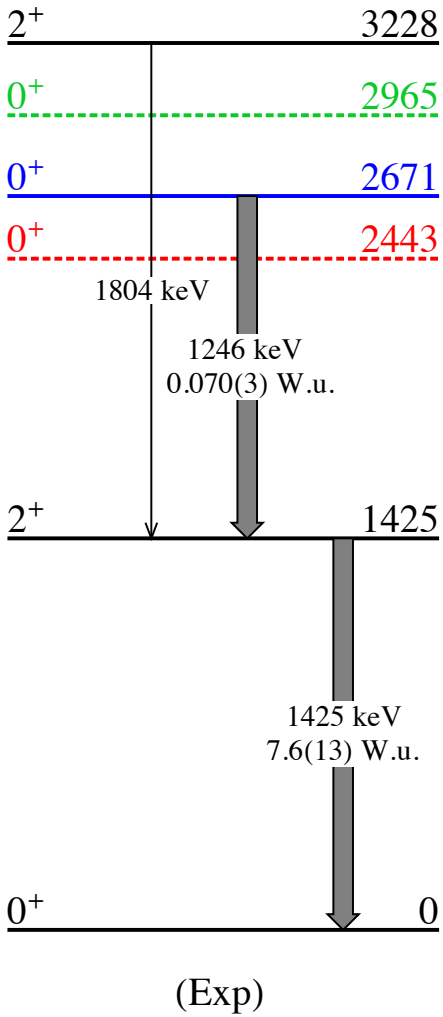
IPARCOS

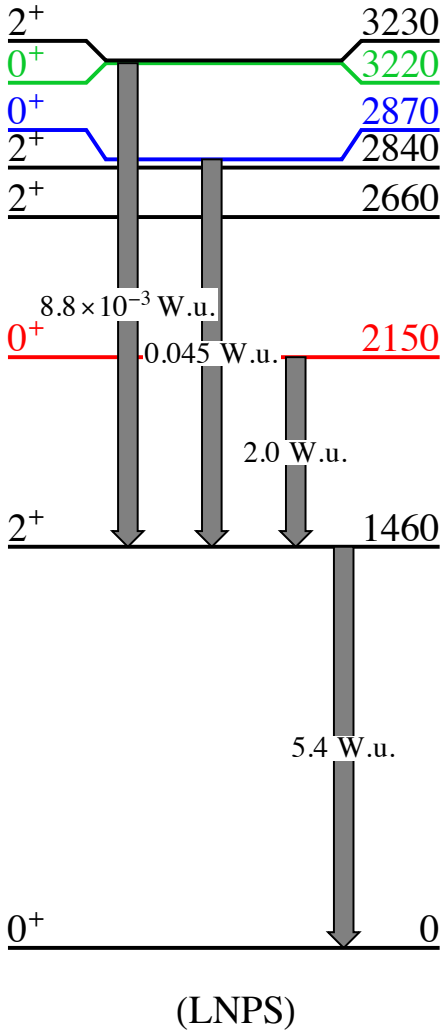
Prolate

Spherical!

Level	Exp. E(MeV)	Calc. E(MeV)	$\pi f_{7/2}$	$\nu g_{9/2}$	$\nu d_{5/2}$	β_s	γ_s
0^+_1	0	0	6.6	1.0	0.1	0.20	39°
0^+_2	2.443	2.15	6.0	2.0	0.2	0.25	36°
0^+_3	2.671	2.87	6.7	0.5	0.1	0.17	36°
0^+_4	2.965	3.22	5.1	3.1	0.7	0.39	12°







B. Olaizola, L.M. Fraile, H. Mach, A. Poves, et al., Phys. Rev. C 95, 061303(R) (2017)

$B(E2;0^+_3 \rightarrow 2^+_1) = 1.11(5)\ e^2fm^4 = 0.070(3)$ W.u.

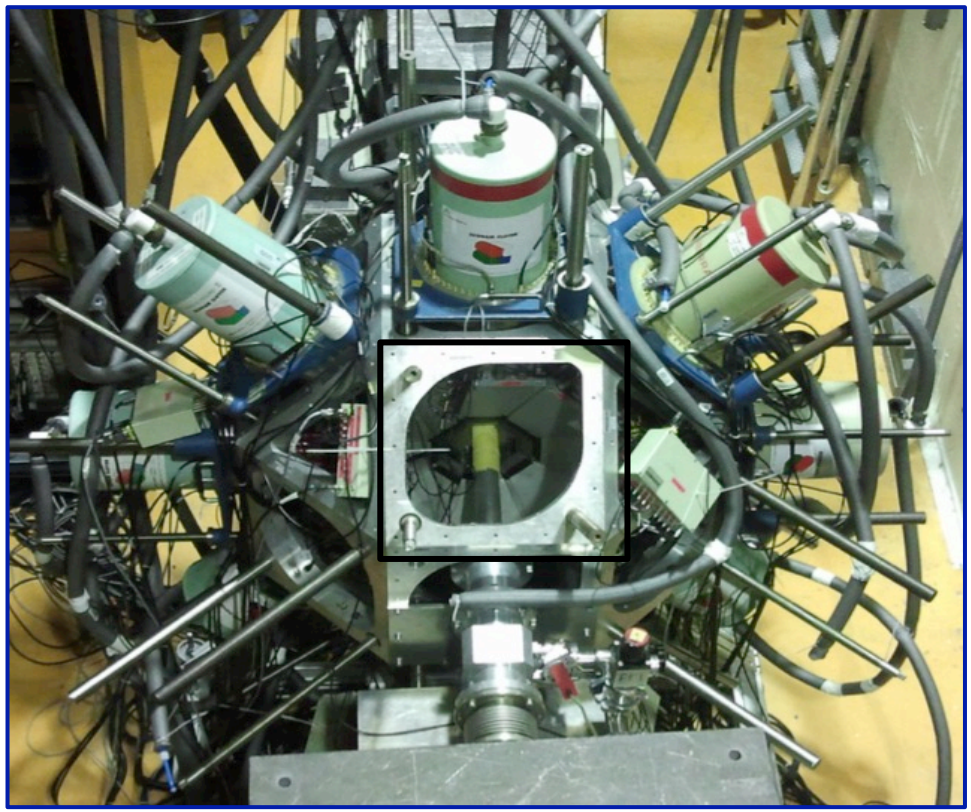
^{68}Fe: 39(3) e^2fm^4 [Crider et al.]

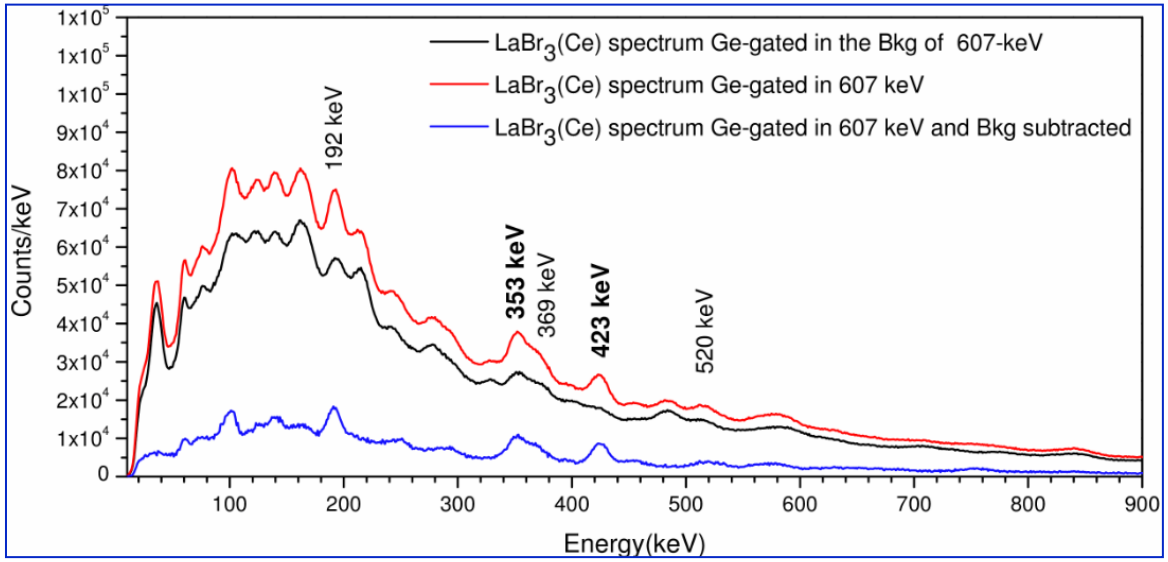
Lifetime measurements of fision products at ILL

IPARCOS

On the ^{136}Te "anomaly"

- Nuclear Spectroscopy of Prompt Fission Fragments
- Targets of ^{235}U and ^{241}Pu
- Cold collimated neutron beam of ?=1.2 cm

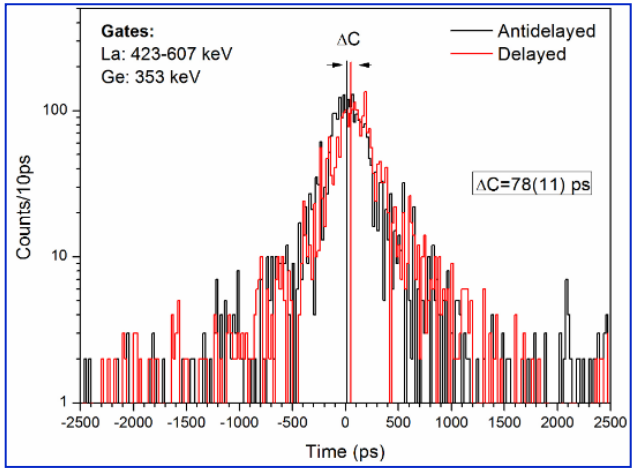




✓Direct lifetime measurement, t_{2+}= 35(10) ps

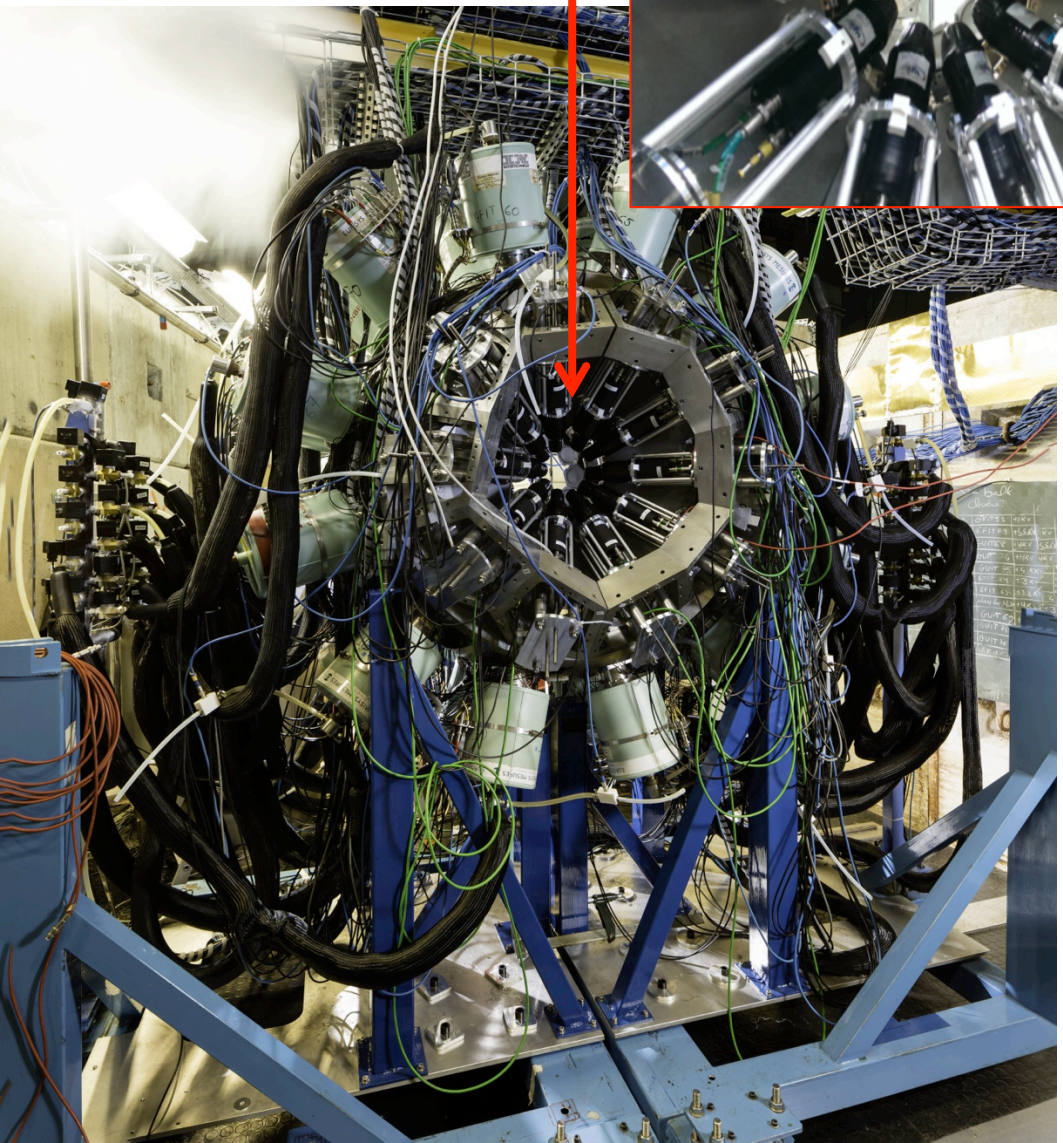
✓ Measured lifetime for the 4^+ state t_{4+}= 85(15) ps

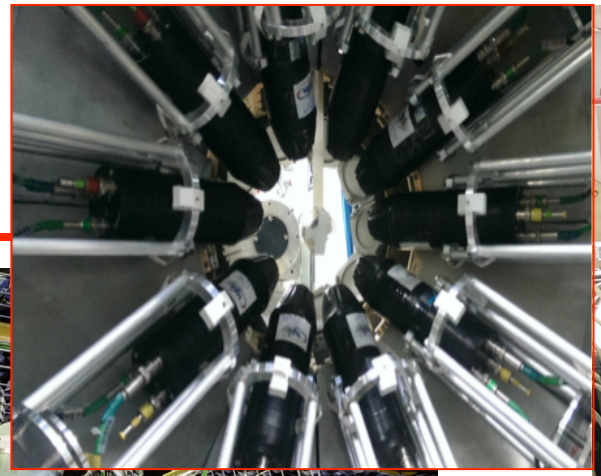
✓ First time measured lifetimes of the 6^+ and 8^+ states, t_{6+}, t_{8+}

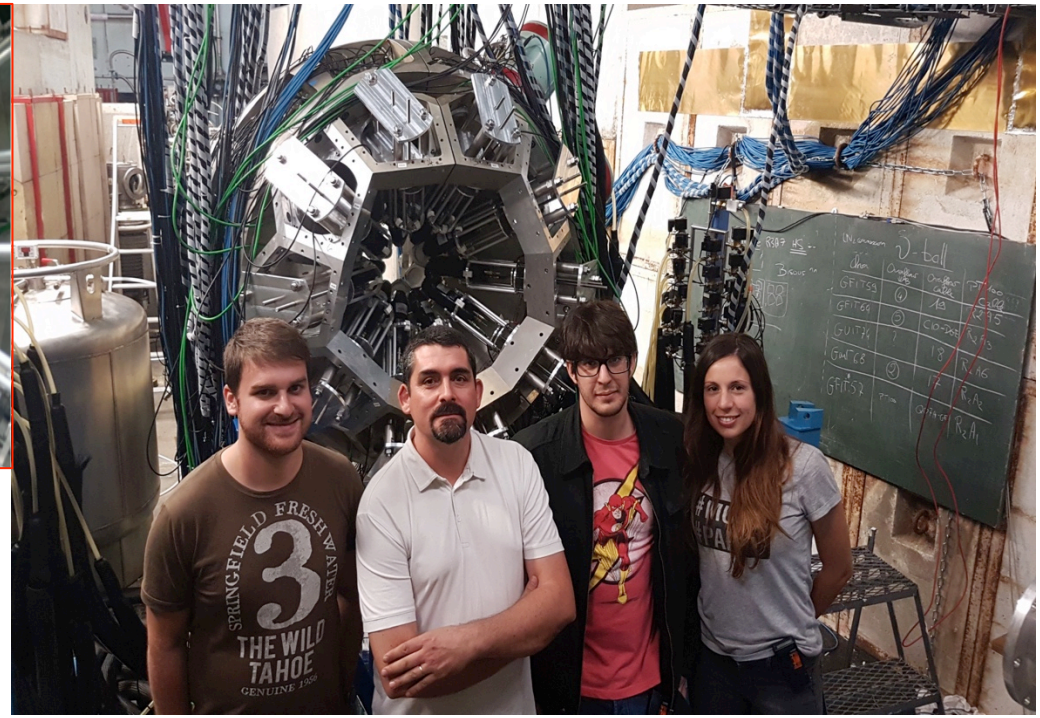


V. Vedia, L.M. Fraile et al.

Measurement campaign at ALTO



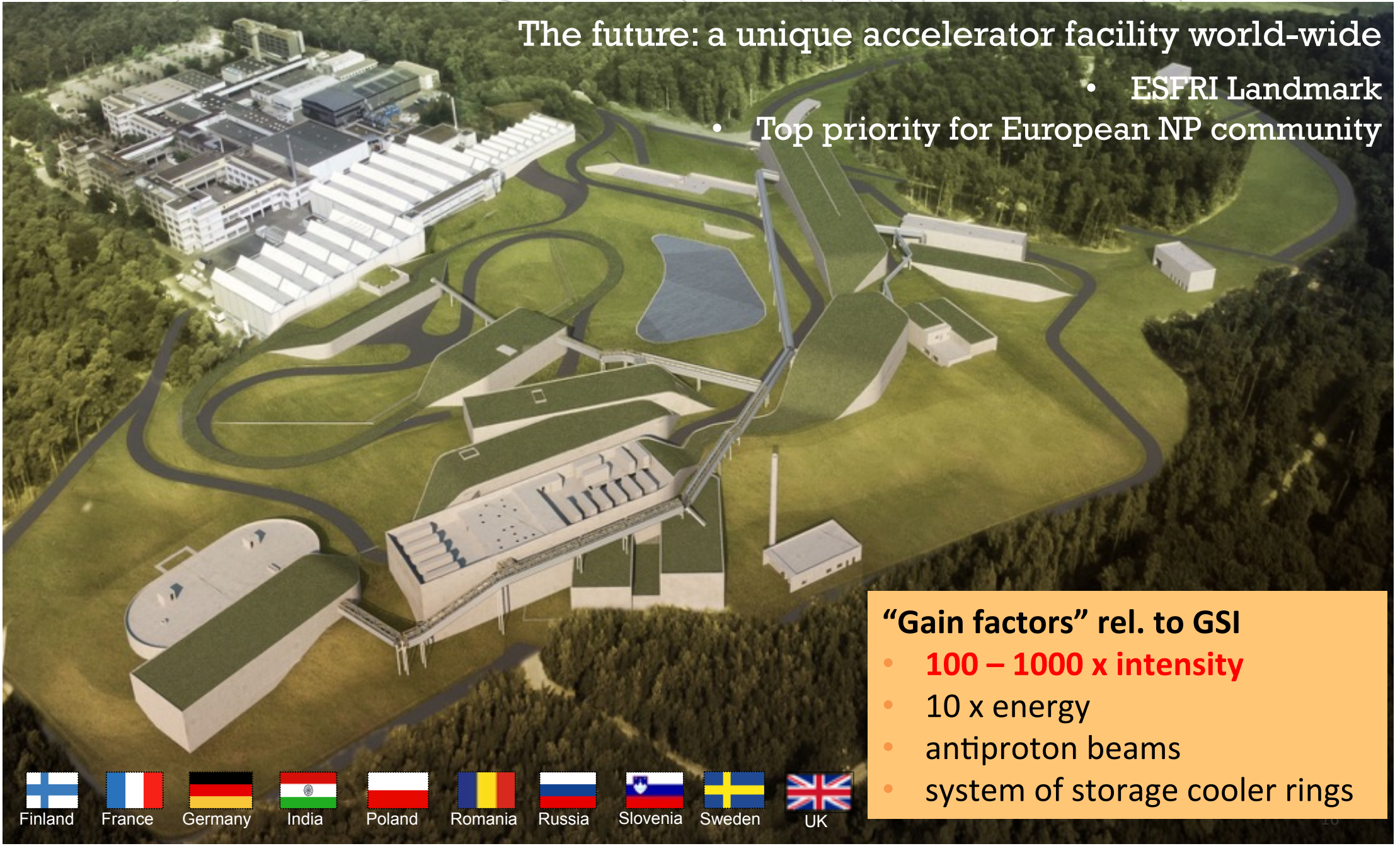




- Accepted proposal to measure ^{138}Te, ^{132,133}Sn, ^{134}Sn, ^{135}Sb
- Accepted proposal to measure $^{81-85}$Ge
- Measurement campaign in 2018 with strong contribution from the group

L.M. Fraile, V. Vedia, J. Benito, J.L. Herraiz, V. Sánchez-Tembleque, J.M. Udías et al.

FAIR: Facility for Antiproton and Ion Research



IPARCOS

FAIR/NUSTAR/HISPEC-DESPEC/FATIMA
FAIR-TAC NUSTAR HISPEC-DESPEC FATIMA

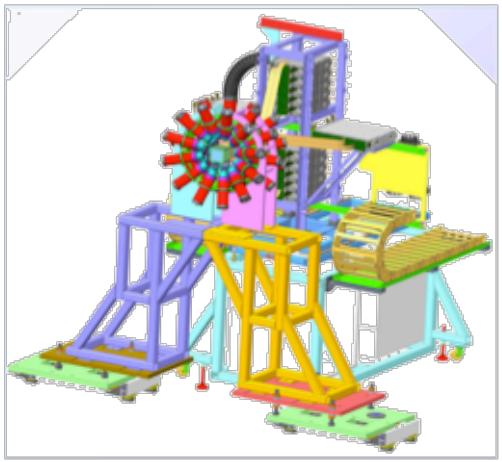
Date: 19 October 2014 - v3

Technical Report for the Design, Construction and Commissioning of FATIMA, the FAst TIMing Array

Abstract

The determination of nuclear lifetimes of excited nuclear states provides a model-independent method of determining nuclear transition rates, which are of great importance to understand nuclear structure. The ultra fast timing method makes use of electronic coincidences between fast scintillator signals for the determination of level lifetimes in the subnanosecond range, using the time difference from the populating and de-exciting radiation from a nuclear level.

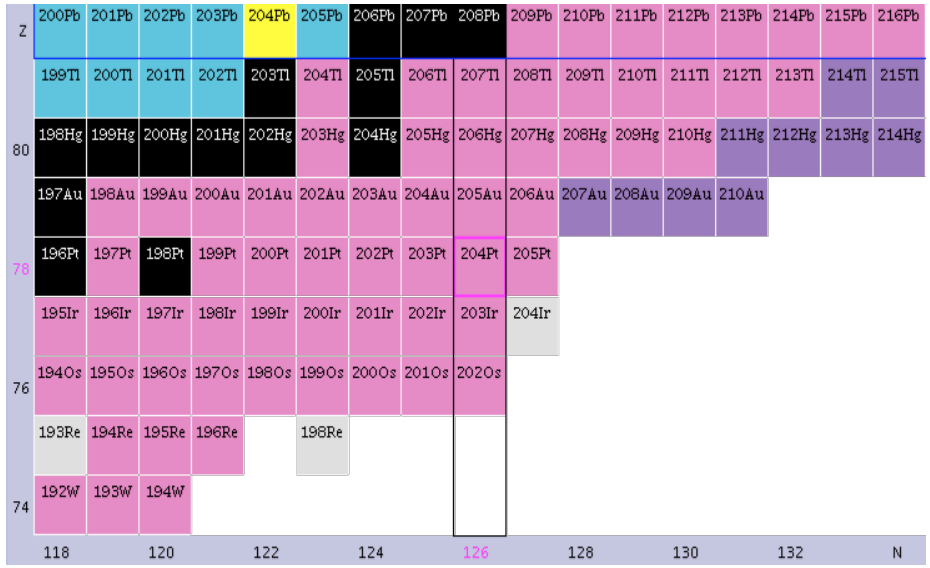
Here we describe the technical design of FATIMA, the FAst TIMing Array designed to measure sub-nanosecond half-lives of excited states in exotic nuclei at the border of stability produced at FAIR, and of special importance for exotic, neutron-rich, nuclei. The system comprises a large number of $LaBr_3(Ce)$ gamma scintillators coupled to fast photomultiplier tubes. It will be placed in the final focus of the SuperFRS and is designed to work in conjunction with AIDA. This report includes the details about the tests of the available technologies, the configuration of the detectors for FAIR and the design and construction of the prototype that has already been used at several facilities.



TDR lead by L.M. Fraile, approved July 2015

FATIMA: FAst TIMing Array

- International FATIMA collaboration co-ordinated by L.M. Fraile
- Several proposals to investigate for the first time the unexplored region around Z=82 and N=126
  - → SPEs not known
  - → Effective interactions
  - → Collectivity vs. single-particle behaviour
- Transition rates not known!
- Influence on r-process



A nuclear astrophysics facility for the LSC

The sources of neutrons in the stars and other reactions of astrophysical interest

Letter of Intent

Canfranc Underground Nuclear Astrophysics

EoI-12-2009-CUNA

October 2012

L.M. Fraile (spokesperson), B. Olaizola, J.M. Udías
*Grupo de Física Nuclear, **Universidad Complutense de Madrid**, Madrid, Spain*

J. José, R. Longland, A. Parikh
GAA, Universitat Politecnica de Catalunya, Barcelona, Spain

M. Hernanz, J. Isern
Institut de Ciencies de l'Espai-CSIC, Bellaterra, Spain

C. Abia, I. Domínguez
Universidad de Granada, Granada, Spain

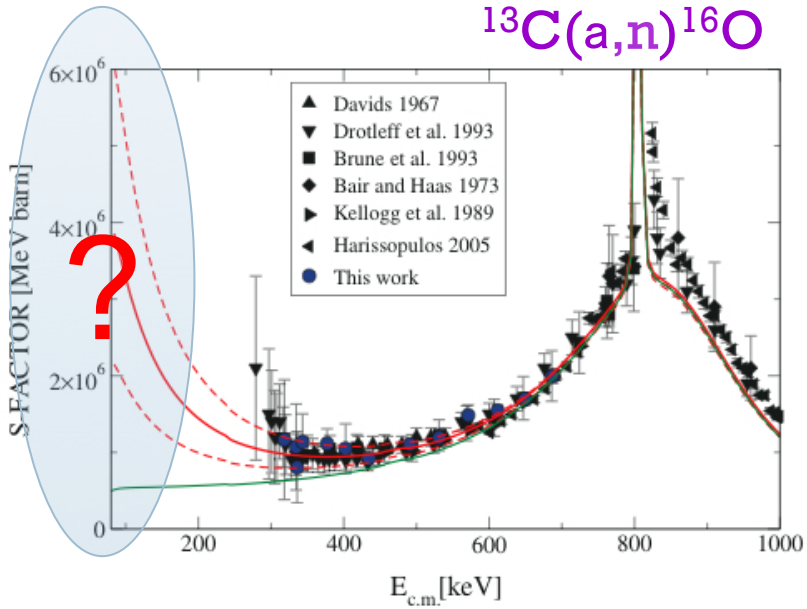
F. Calviño, B. Gómez-Hornillos,
GREENER, Universitat Politecnica de Catalunya, Barcelona, Spain

D. Cano, T. Martínez
Centro de Investigaciones Energéticas y Medioambientales, Madrid, Spain

J. Benlliure, M. Caamaño
Universidad de Santiago de Compostela, Santiago de Compostela, Spain

A. Algora, D. Jordán, J.L. Taín
Instituto de Física Corpuscular, CSIC-Universidad de Valencia, Valencia, Spain

I. Irastorza, G. Luzón
Lab. de Física Nuclear y Astropartículas, Universidad de Zaragoza, Zaragoza, Spain



Source of the required stellar neutron flux for s-process

- $^{13}C(a,n)^{16}O$ (AGB's "pocket")
- $^{22}Ne(a,n)^{25}Mg$ (AGB's He flash and red giants)

Proposal for new facility at Laboratorio Subterráneo de Canfranc