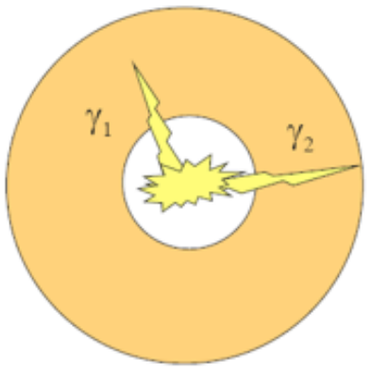
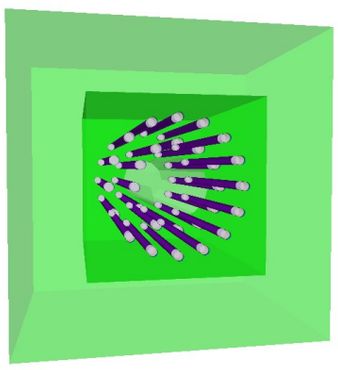
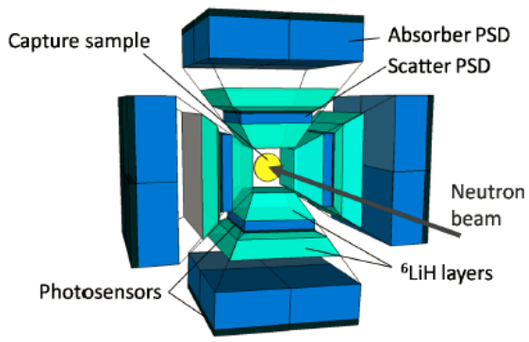
Gamma and Neutron Spectroscopy Group

Presented by A. Algora







IFIC INSTITUT DE FÍSICA CORPUSCULAR

CSIC

VNIVERSITAT DE VALÈNCIA

EXCELENCIA SEVERO OCHOA

Gamma and neutron spectroscopy group

Gamma and neutron spectroscopy group

Members of the group :
Dr. Berta Rubio (Prof.)
Dr. Jose Luis Taín (Inv. Cient)
Dr. Alejandro Algora (Cient. Tit.)
Dr. Cesar Domingo (Cient. Tit.)
Dr. Sonja Orrigo (Postdoc)
Dr. Anabel Morales (Postdoc)
Dr. Luis Caballero (Postdoc)
Ion Ladarescu (Ing. Cont.)
Jorge Agramunt (Ing. Cont.)
Ana Montaner (Est. doc.)
Victor Guadilla (Est. doc.)
Alvaro Tolosa (Est. doc.)
Pablo Gramaje (Est. doc.)

Other colaborators:
Prof. William Gelletly (Prof.)
Dr. Enrique Nácher (Cient.Tit.)
Ebhelixes Valencia (Est. doc.)
Dr. Dolores Jordan (Postdoc)
Dr. Ariel Tarifeño (Postdoc)
Dr. Ela Ganiouglu (Prof.)

Main funding in the 2016-2017 period:

FPA: FPA2014-52823-C2-1-P
PI: Alejandro Algora

ERC-grant: 681740 (started 2016) !!!
PI: Cesar Domingo

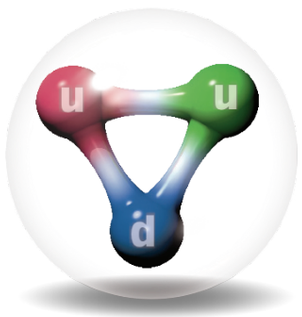
R+D Collaboration Project IFIC-ENRESA
PI: Cesar Domingo, Berta Rubio

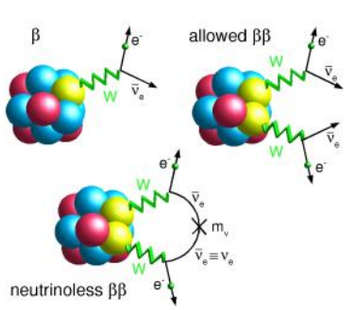
Colaborations (most relevant):
GSI (Alemania), RCNP(Japon), RIKEN (Japon), GANIL (Francia), Univ. Surrey (UK), Univ. Jyväskylä (Finlandia), Subatech (Francia), MTA ATOMKI (Hungría), CIEMAT (España), UPC (España), etc.

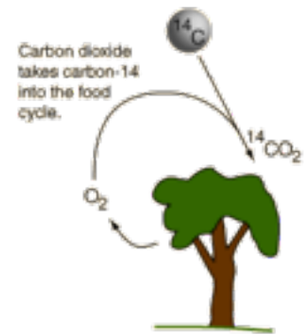
Keywords: nucler structure, beta decay, total absorption, neutron spectroscopy, gamma spectroscopy, nuclear astrophysics, n-capture reactions, n_TOF, reactor applications.

The big picture: why NP is still interesting

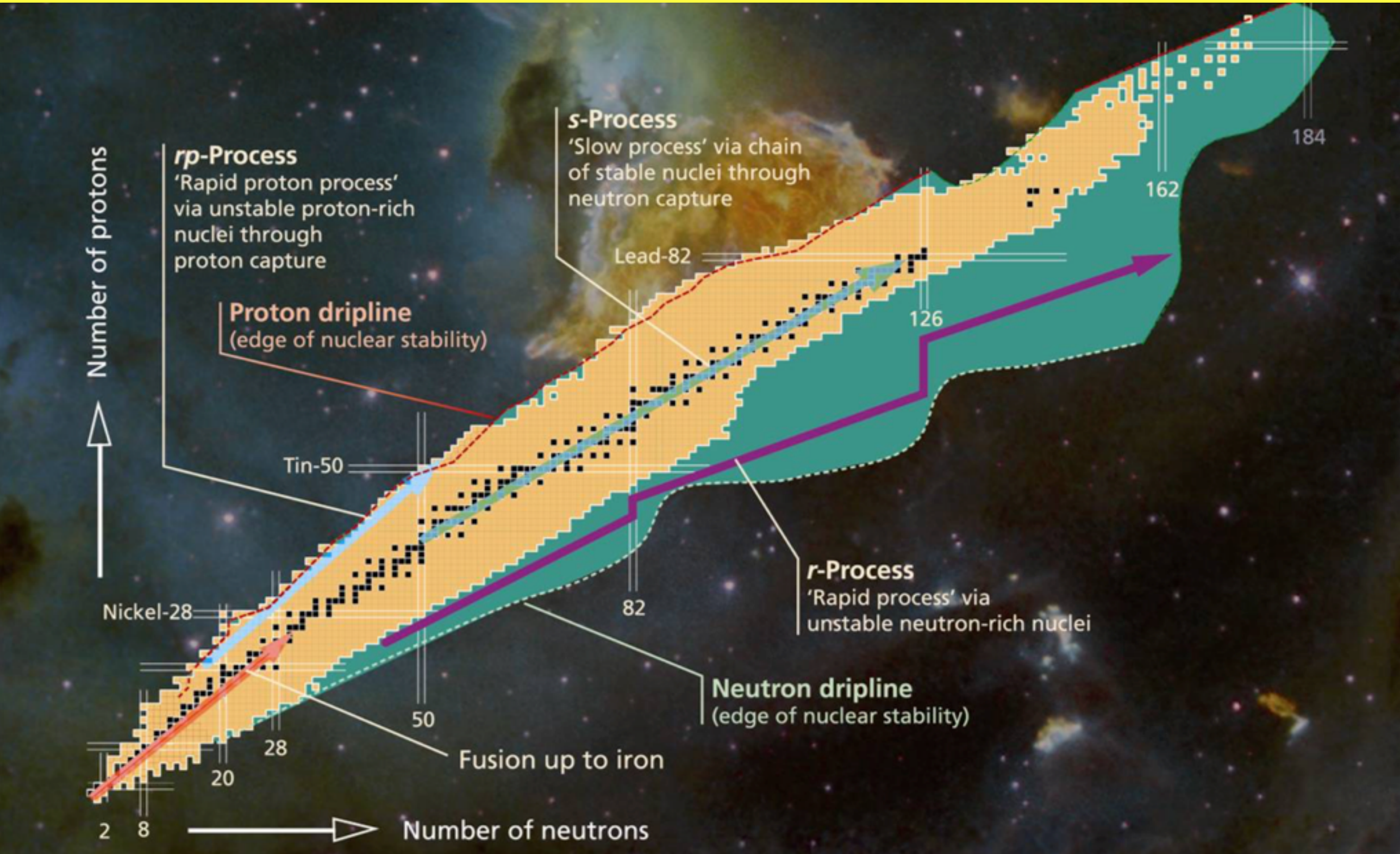
- Quantum system of variable number of particles (1≤A≤300)
- Playground of the strong, electromagnetic and weak interaction
- The states of these quantum systems can be excited more or less flexibly (by means reactions and beta decay, constrained by nature laws)
- Test ground of many-body approaches
- Explain many things related also to the macroscopic World (nuclear astrophysics, the internal heat of our planet, etc.)
- Multiple applications in our lives (nuclear energy, medical diagnostics, cancer therapy, non-proliferation control, monitor climate change, material analysis, etc.).







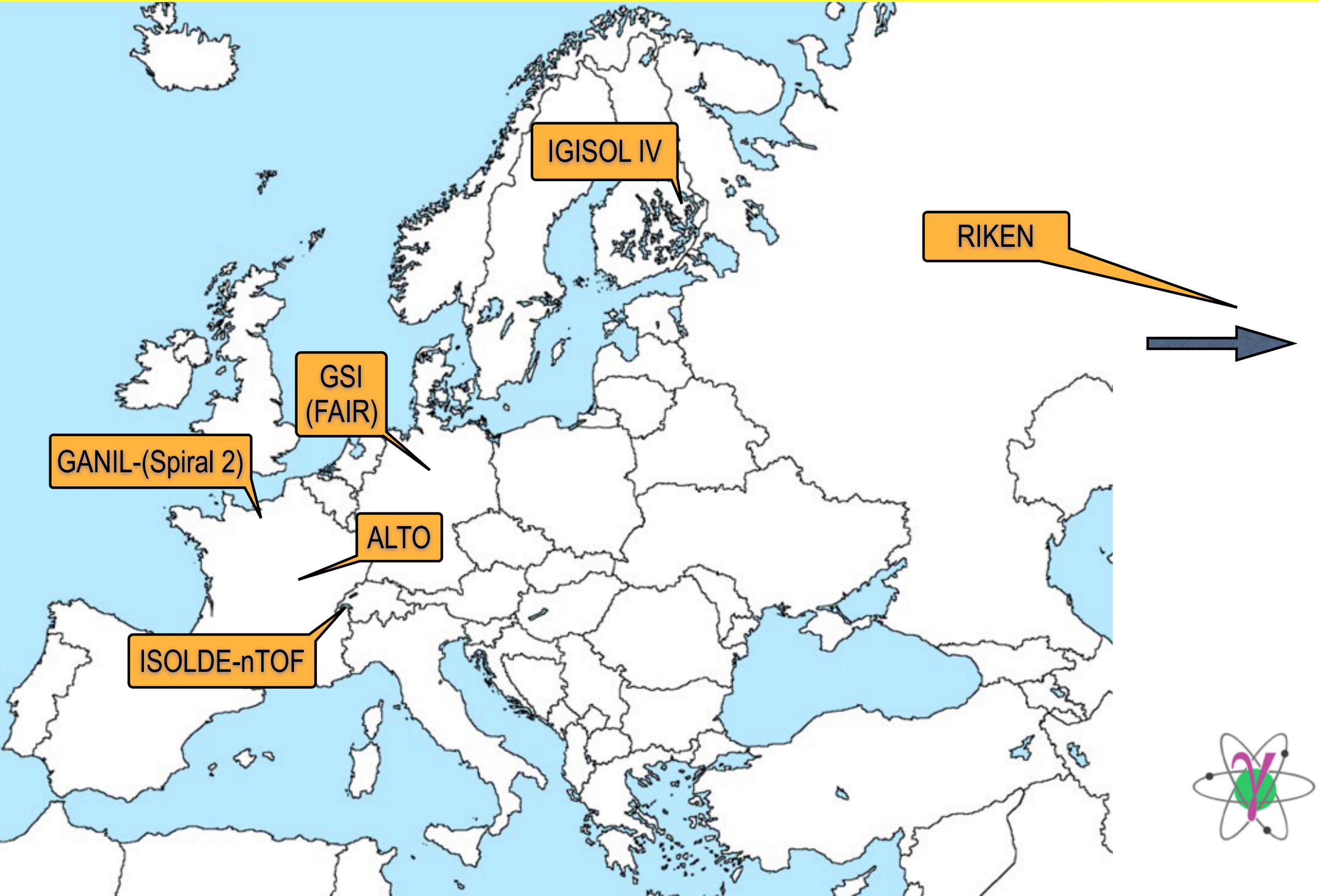
The big picture



Main research lines (tasks, FPA project)

- Nuclear structure studies
  - a) Study of the beta decay of ^{100}Tc
  - b) Beta decay studies in the ^{132}Sn region
  - c) Studies of p-rich nuclei above the fp shell
  - d) Shape effects in the Hg isotopes
- Nuclear astrophysics:
  - e) Beta decay studies of the N=Z rp process waiting points
  - f) Experimental study of the stellar neutron density via the 147Pm(n,gamma) reaction.
  - g) Neutron capture at the s-process branching points 171Tm and 204Tl.
  - h) Discovery and measurement of new beta delayed neutron emitters close to the r-process path around A=80 and A=130
- Applications
  - i) Measurements of the beta decay of nuclei of relevance for the prediction of the antineutrino spectra for reactors and for the estimation of the decay heat.
  - j) Measurement of Pn values with improved accuracy for key isotopes at the low and high mass fission mass groups
- Development of methods of analysis and instrumentation
  - k) Development of a new and complementary instrumentation.
  - l) Characterization of the neutron background field at n_TOF EAR2

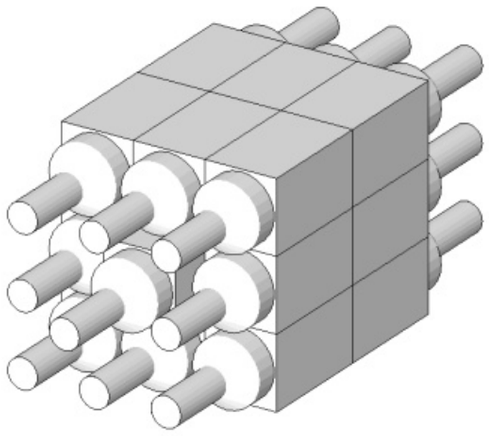
The large scale facilities we use



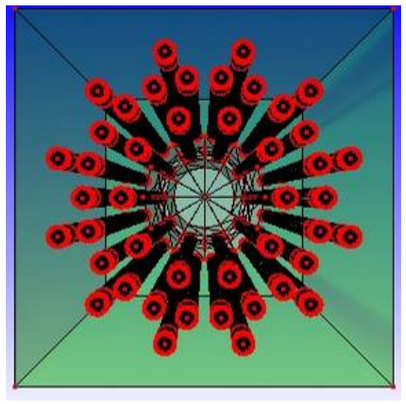
The quintessential installation: FAIR

Development of instrumentation for DESPEC
DTAS, BELEN, MONSTER, etc.

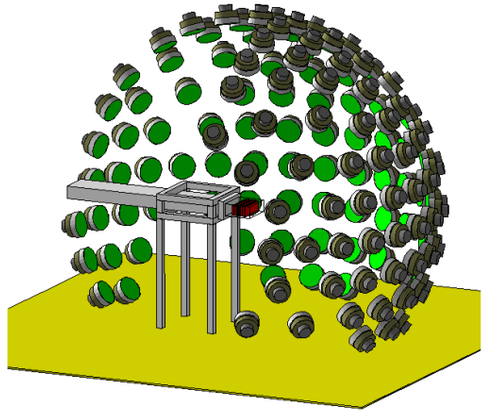
DTAS
(gamma calorimeter
for beta decay studies)

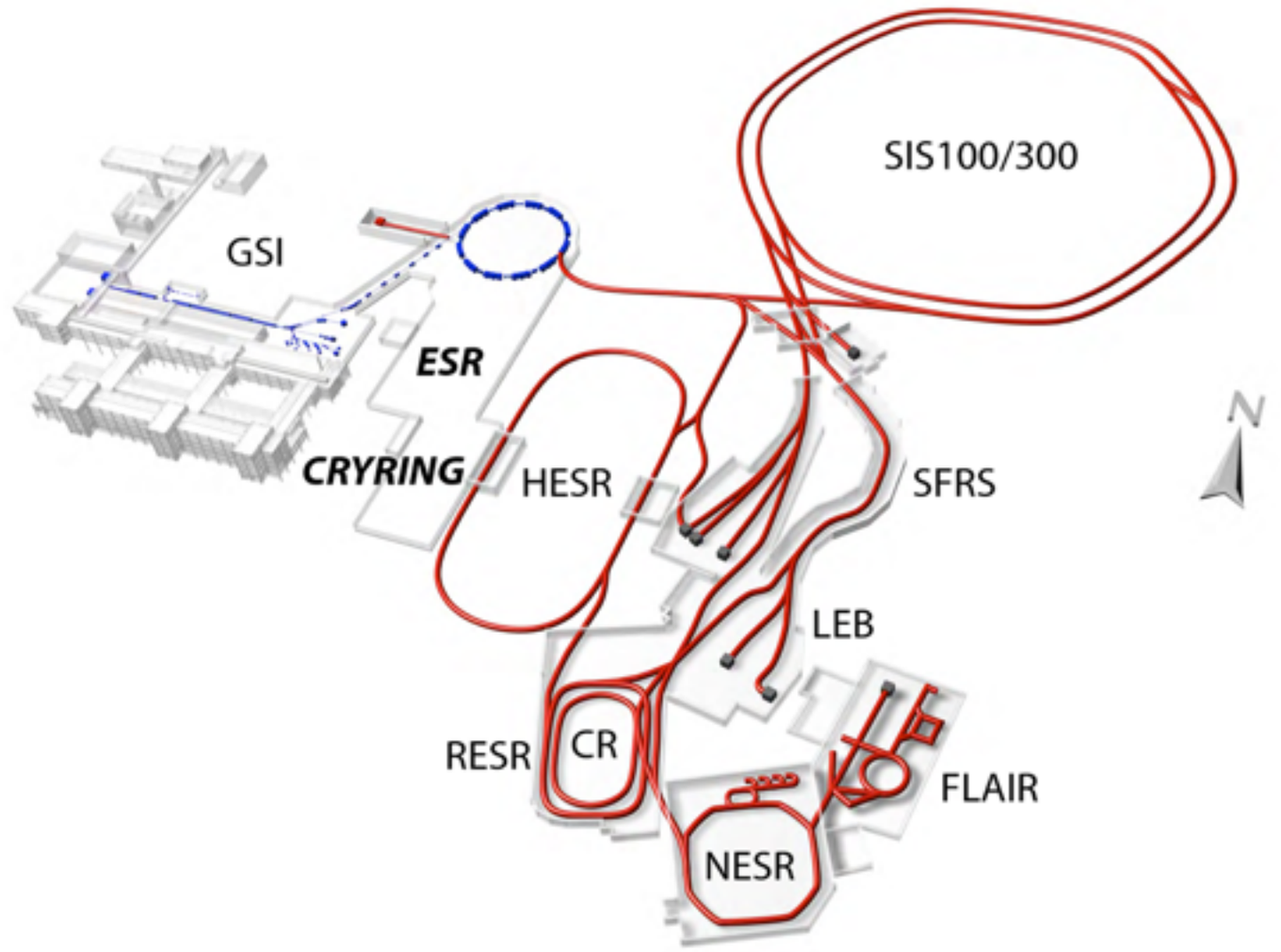


BELEN
(beta delayed)
neutron counter)

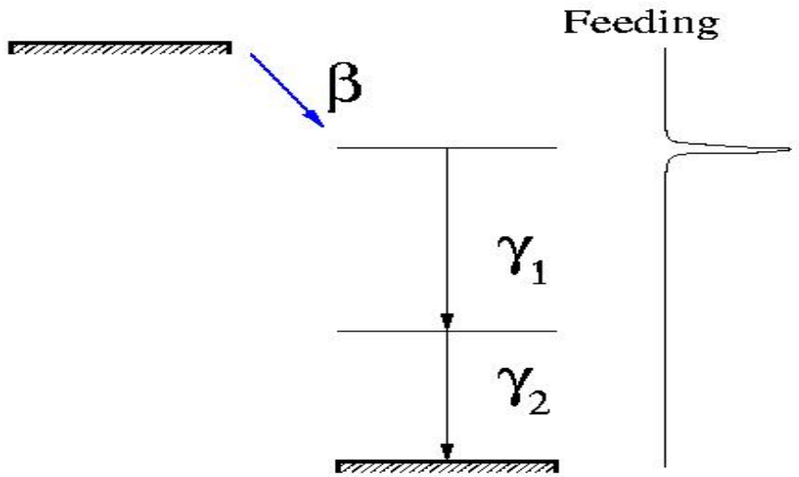


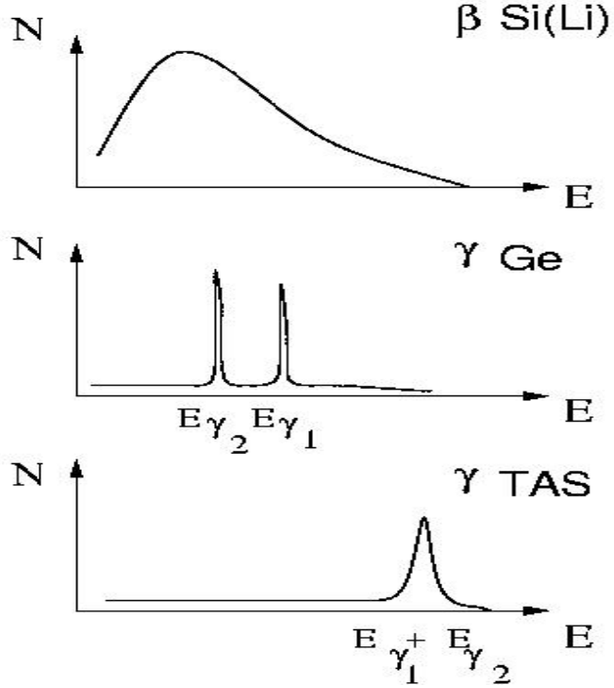
MONSTER
(beta delayed neutron
tof spectrometer)

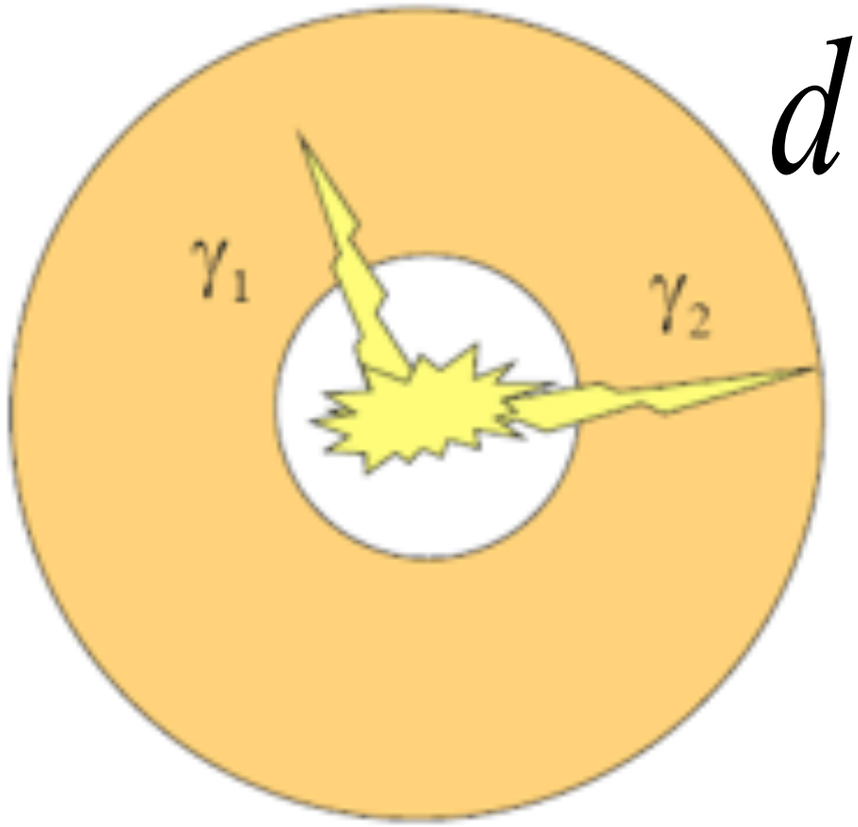




The total absorption technique





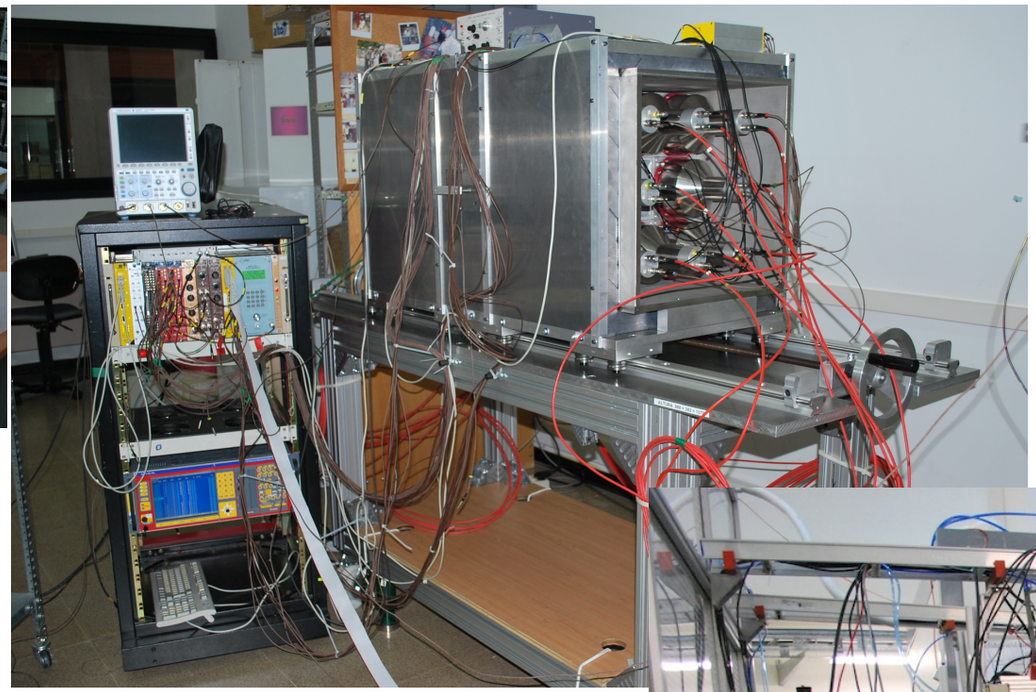


$$d = R(B) \cdot f$$

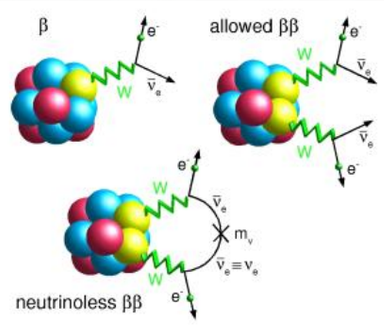
The group has pioneered and revitalized several applications of the technique and it is recognized World leader in the subject

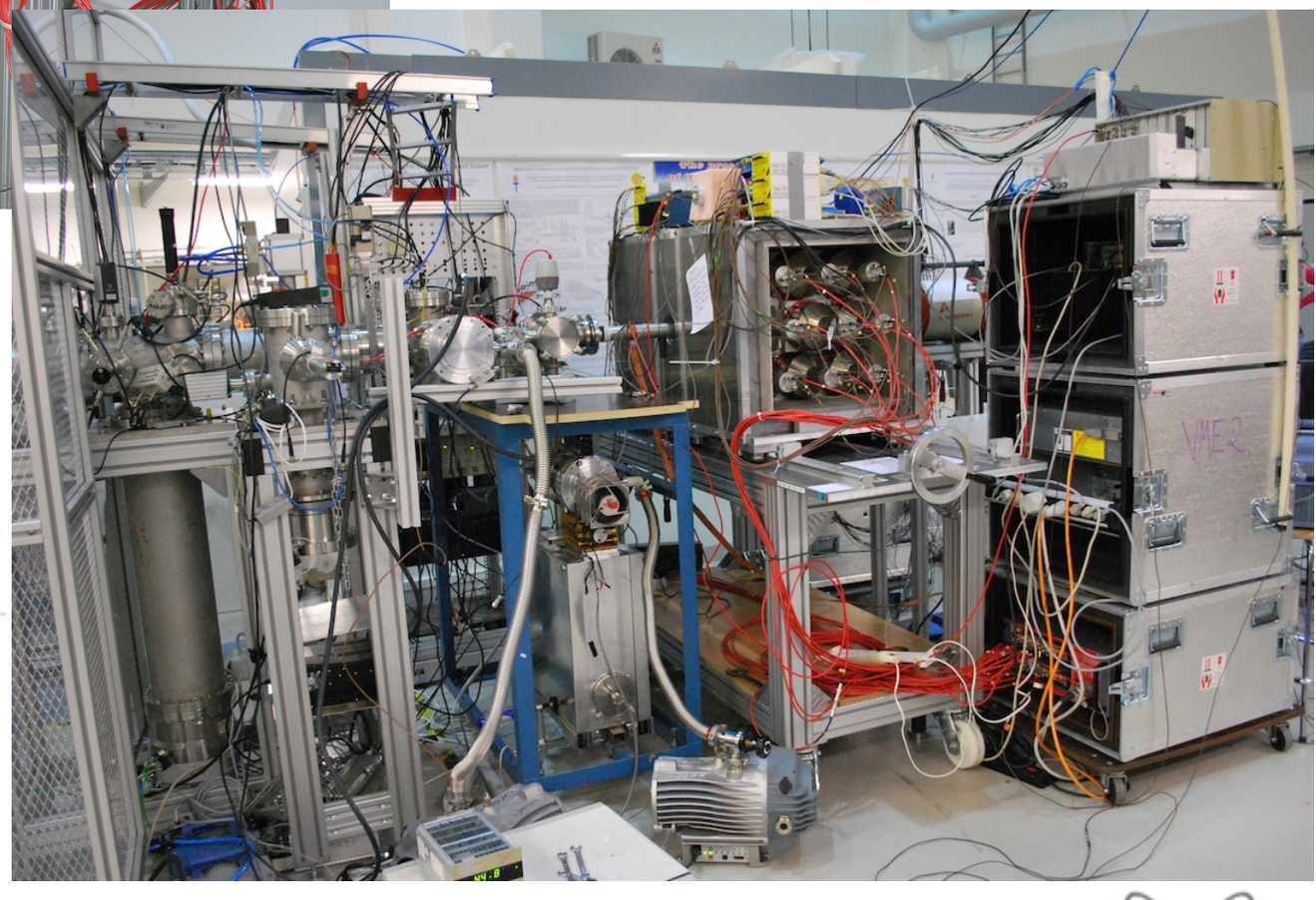
Example: DTAS detector for FAIR

CPAN article: https://www.i-cpan.es/es/content/nuevo-detector-para-medir-la-desintegraci%C3%B3n-beta

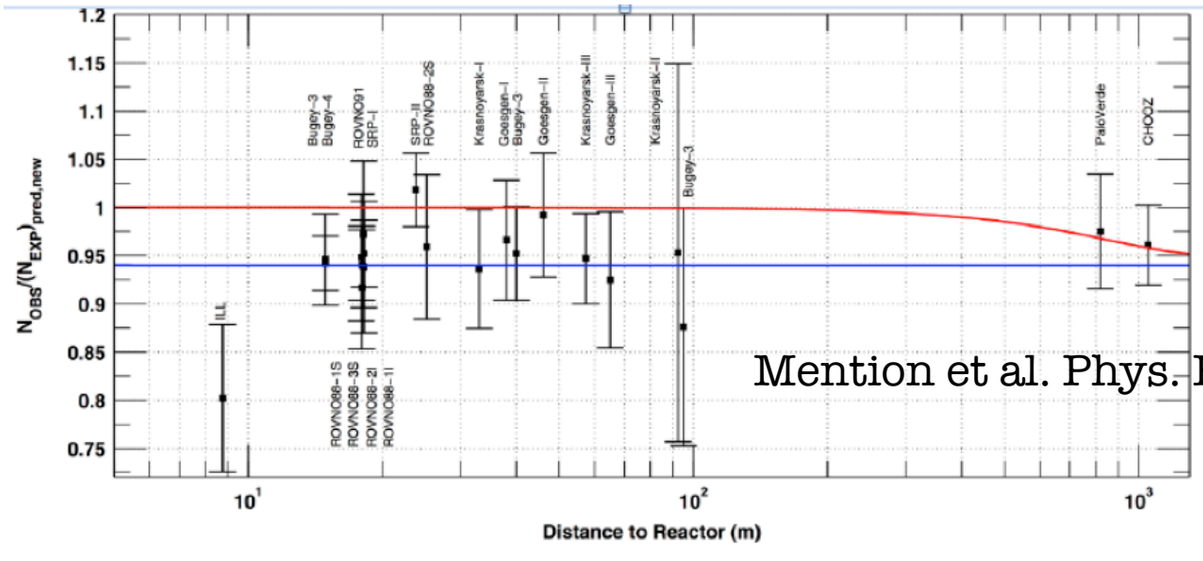


DTAS spokesperson: J.L Tain
TDR aproved: Nov. 2012
Construction grants.:
FPA 2008-06419-C02-01 (IP: Tain)
FPA 2011-24553 (IP: Algora)
AIC-A-2011-0696 (IP: Algora)
Finished: Dic. 2013
First exp.: Feb. 2014, IGISOL IV





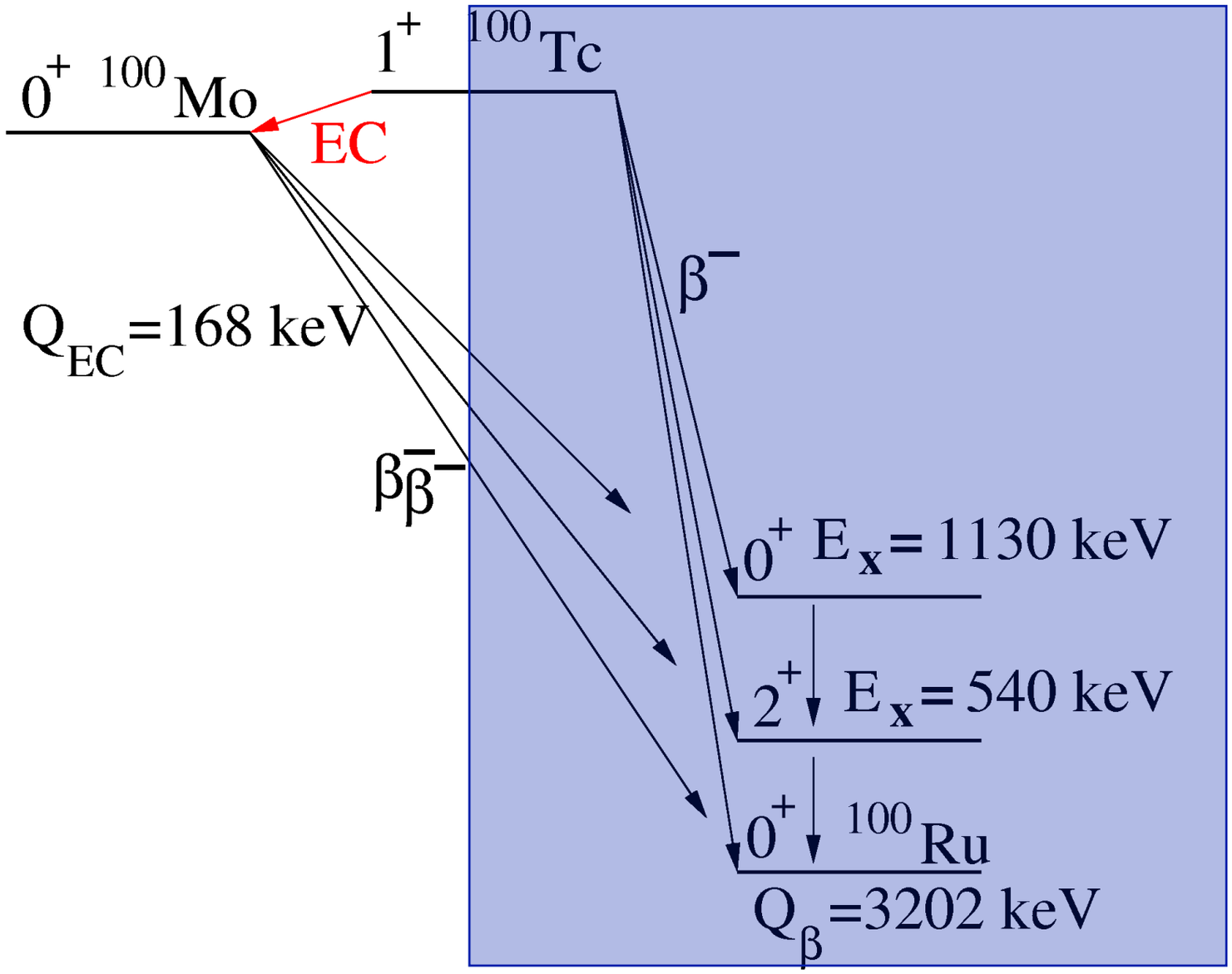
IGISOL IV, February 2014
Experiment I154: TAS and double beta decay
(Spokespersons: A. Algora, J.L Tain)
Experiment I153: TAS and reactor antineutrinos
(Spokespersons: M. Fallot, J.L Tain, A. Algora)

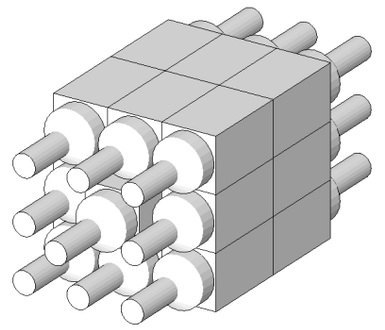


Mention et al. Phys. Rev. D83 073006

DTAS detector (pres. and short term future)

Study of the beta decay of 100Tc (trap assisted measurement)





Idea: improve the knowledge of simple beta decays that can contribute to a better theoretical description of the double beta decay systems.

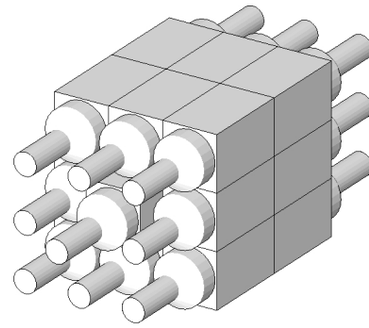
Future: possible presentation of new measurements related to this topic.

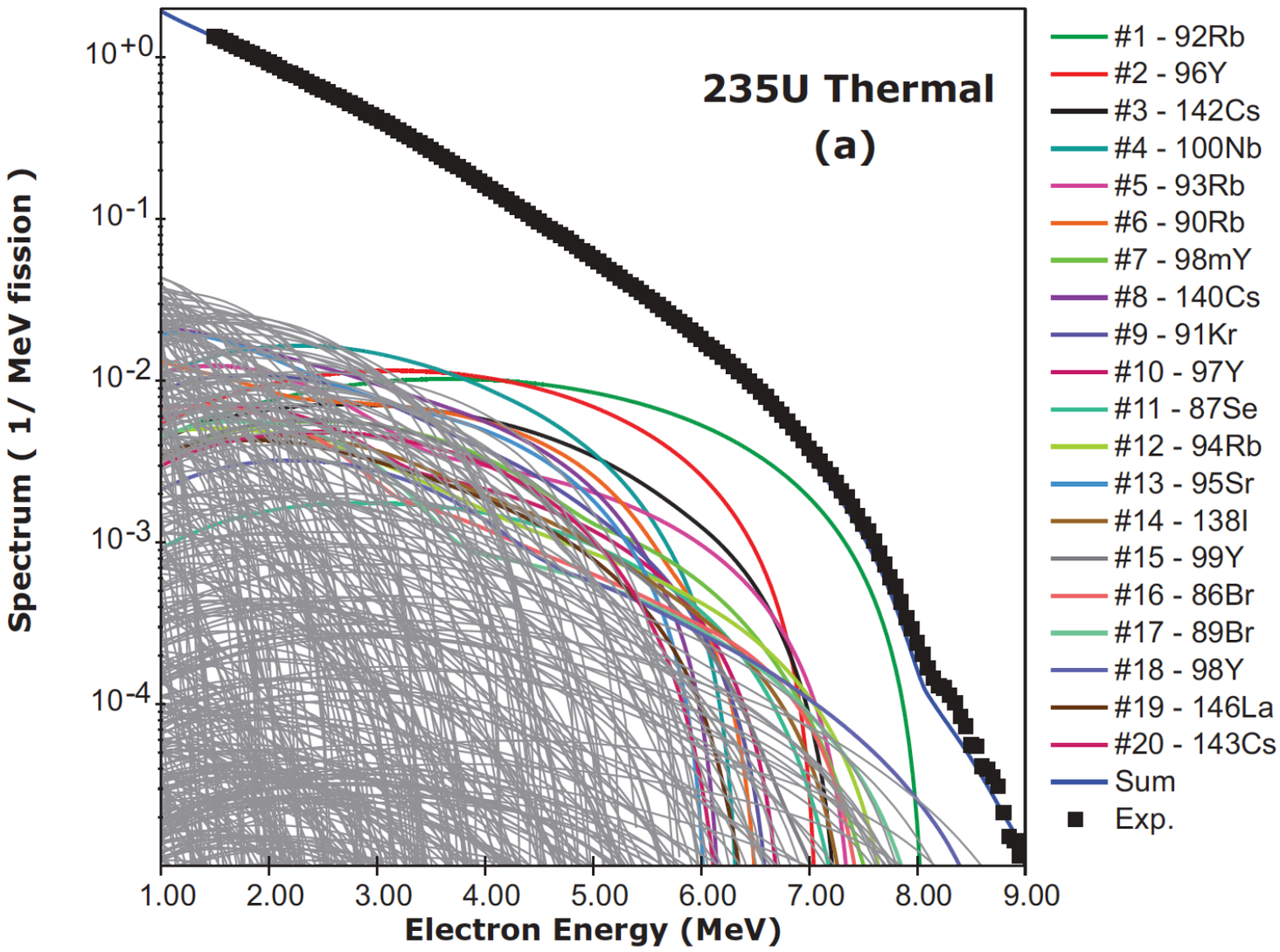
Thesis work: Victor Guadilla, FPU student

DTAS detector (pres. and short term future)

Study of the beta decay of some Rb, Sr, Y, Nb, I and Cs isotopes using the TAS technique

Goal: Obtain beta decay data relevant for the prediction of the neutrino spectrum from reactors. This could help to understand the "reactor anomaly" and the mysterious "bump". It has also impact for possible non-proliferation applications.



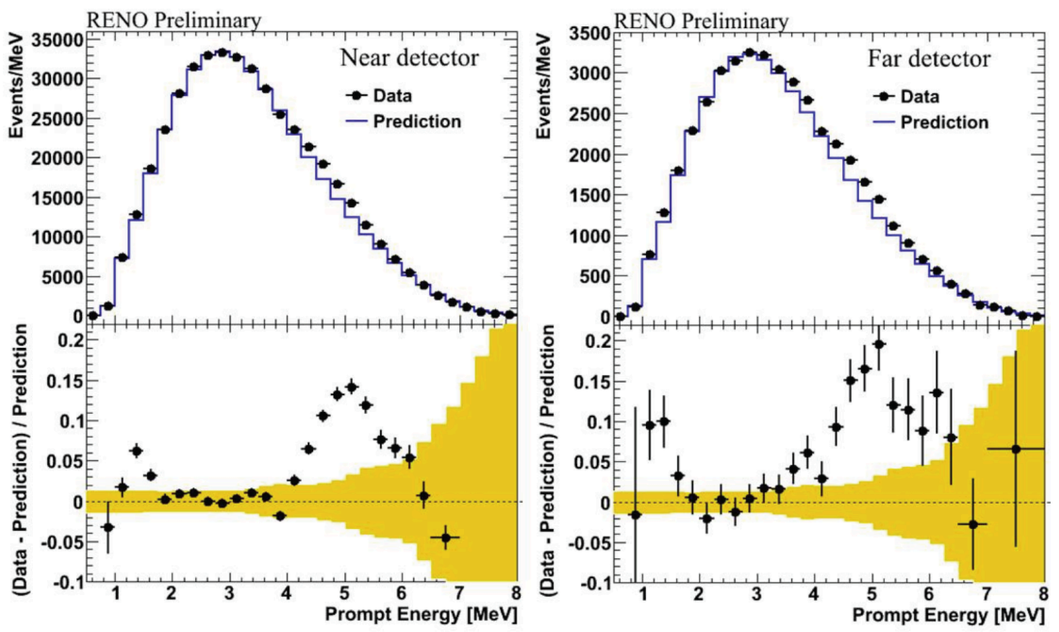


Thesis work: Victor Guadilla, FPU student

Main players

- Large cum. fission yields
- Large decay Q_{beta}
- Large beta feeding to gs

The mysterious "bump"



RENO results, arXiv:1504.08268
also seen in DAYA BAY

DTAS detector (future, prep. for FAIR)

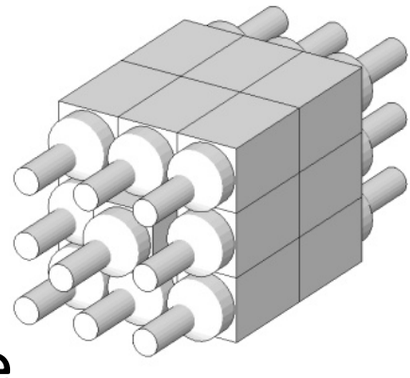
GSI-FRS (2018):

Motivation: Study of the beta strength crossing N= 126 magic number and the 3rd abundance peak in the r process

Status: to be presented in the PAC,

Spokespersons: Morales, Tain, et al.

Relevance: measure with the best available technique the beta strength to further test nuclear models (astrophysical interest)



RIKEN (2018-2019):

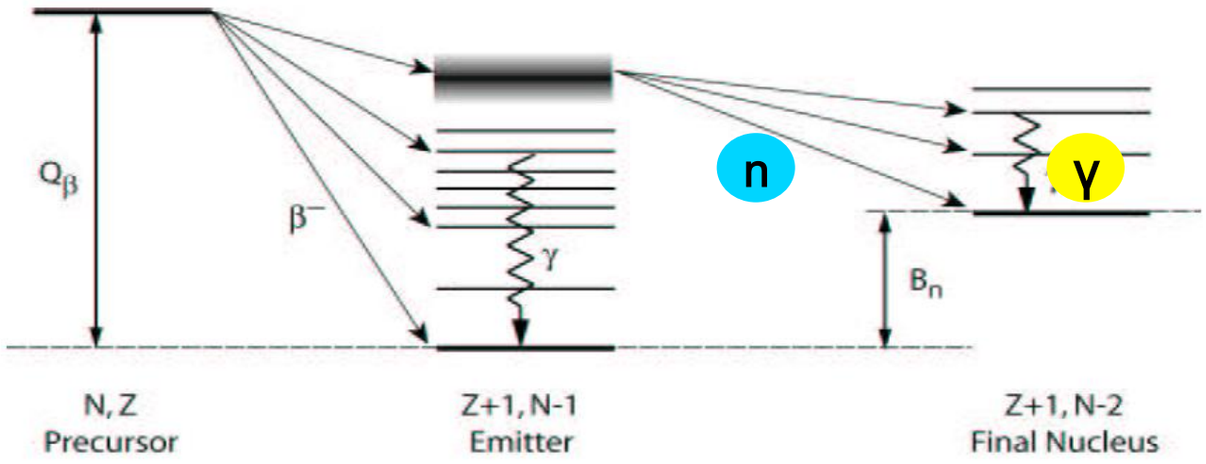
Motivation: Study of the beta decay of the100Sn

Status: approved experiment (10.0 days, grade A)

Spokespersons: Algora, Rubio (NP1612-RIBF147)

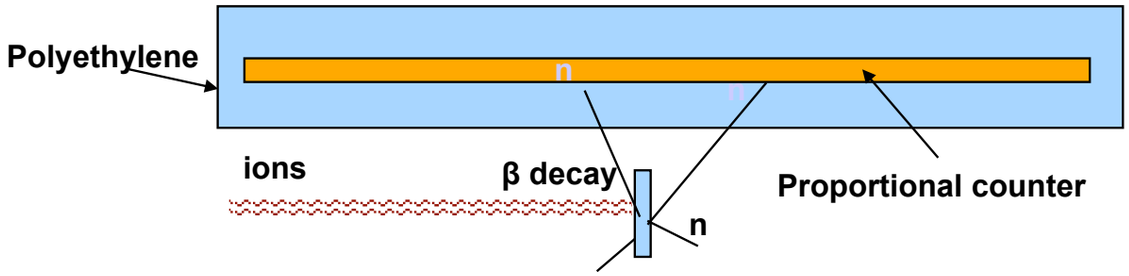
Relevance: define better the energy of the 1+ state populated in 100In, and its possible fragmentation, which will allow a more precise calculation of its logft value of this very relevant decay (super-allowed GT transition)

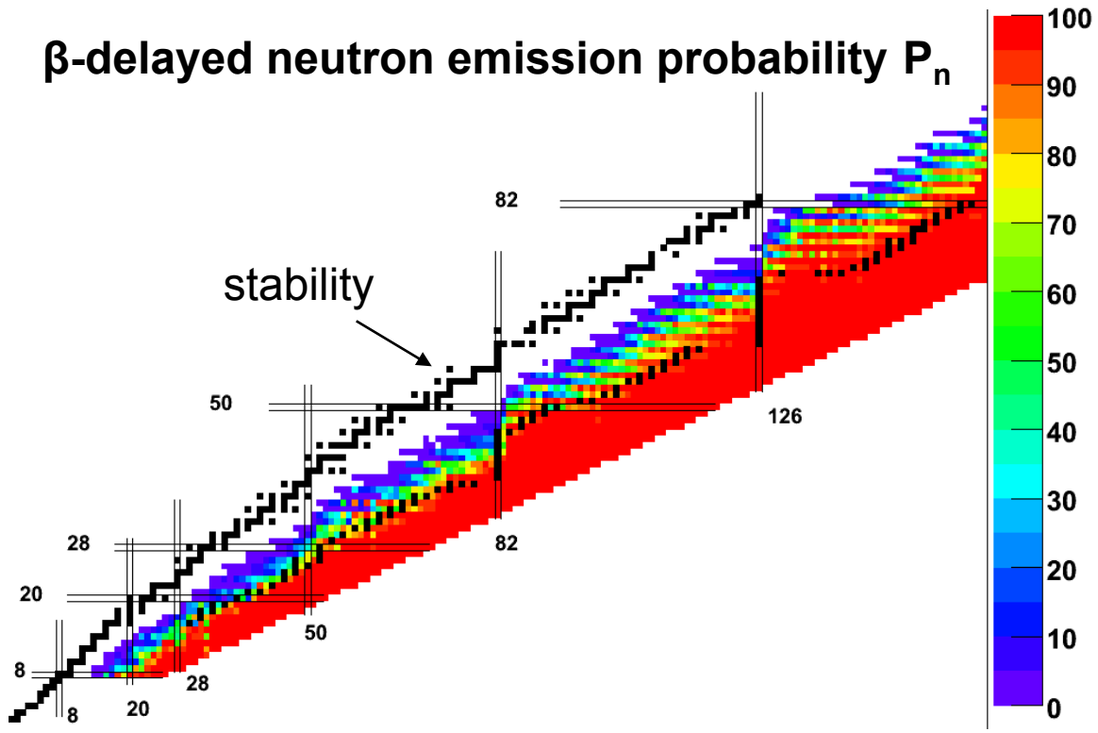
Measurements of beta delayed neutrons

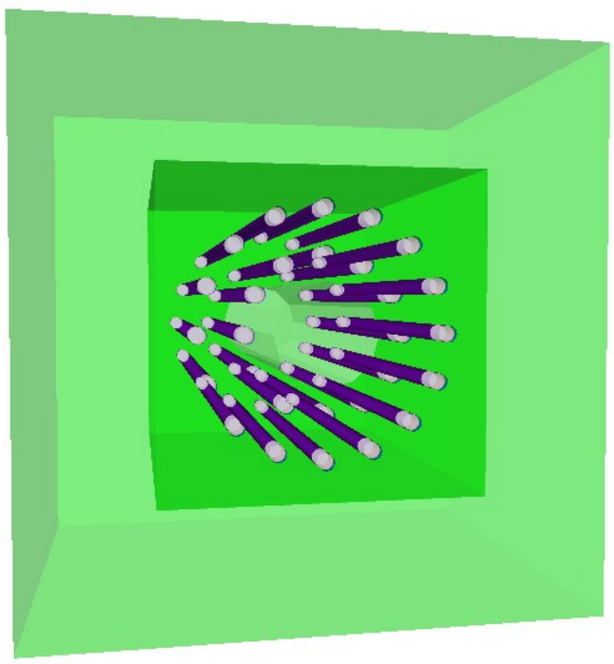


$$P_N = \frac{N_n}{N_\beta}$$

$n + {}^3He \rightarrow {}^3H + {}^1H + 765\ keV$







BELEN (present and short term future)

IFIC contribution
DACQ development: J. Agramunt

JYFL

1st Experiment: ^{85}Ge, ^{85,86}As,^{91}Rb
Spokesperson: Algora, Cano, Gomez, Jokinen
2nd Experiment: ^{98,98m,99}Y, ^{135}Sb,^{137,138}Te, ^{138,139,140}I
Spokesperson: Tain, Gomez
3rd Experiment: ^{136}Sb (β2N)
Spokesperson: Dillman

GSI

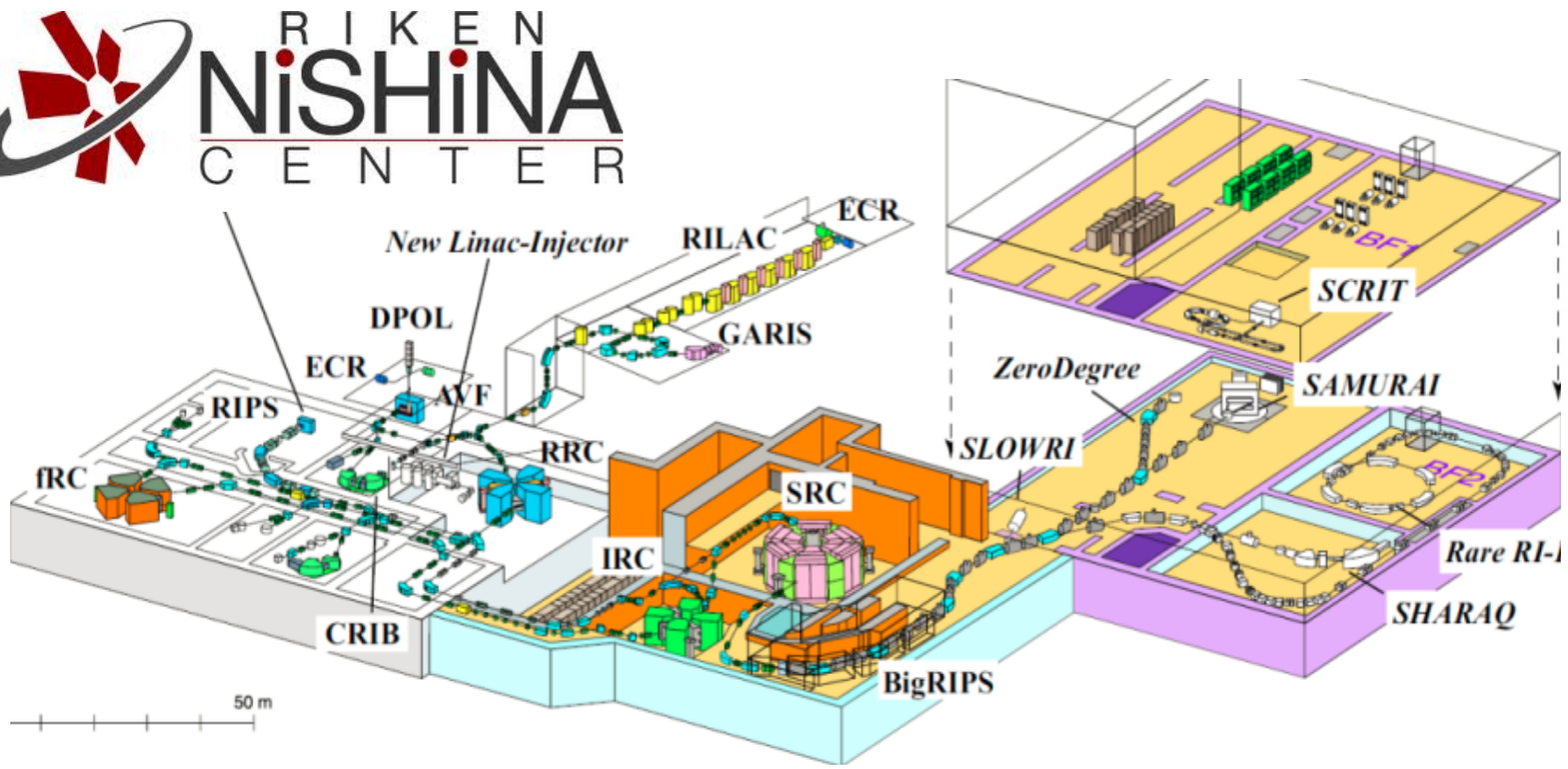
1st Experiment: $^{123\text{-}127}$Pd, $^{124\text{-}129}$Ag
Spokesperson: Montes
2nd Experiment: $^{204\text{-}206}$Au, $^{208\text{-}211}$Hg, $^{211\text{-}216}$Tl, $^{215\text{-}218}$Pb, ^{219,220}Bi
Spokespersons: Domingo, Gomez, Dillman
Some results:
J. Agramunt et al., NDS120(2014)74
J.Agramunt et al., NIMA807(2016)69
R.Caballero, C. Domingo, et al., PRL117(2016) 012501
Thesis work: R. Caballero, J. Agramunt

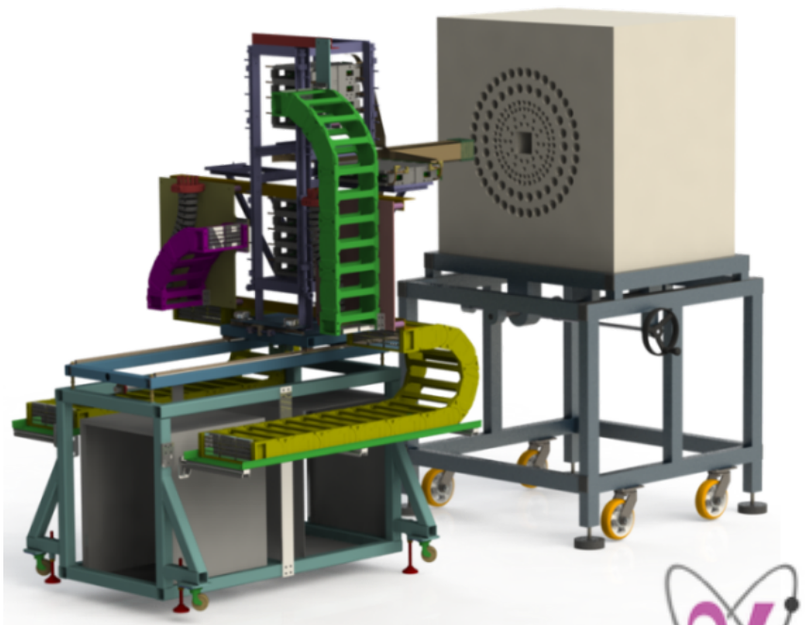
BELEN to BRIKEN (present and short term)

Collaboration of more than 20 institutions and more that 50 members

The group has a leading role in the international collaboration

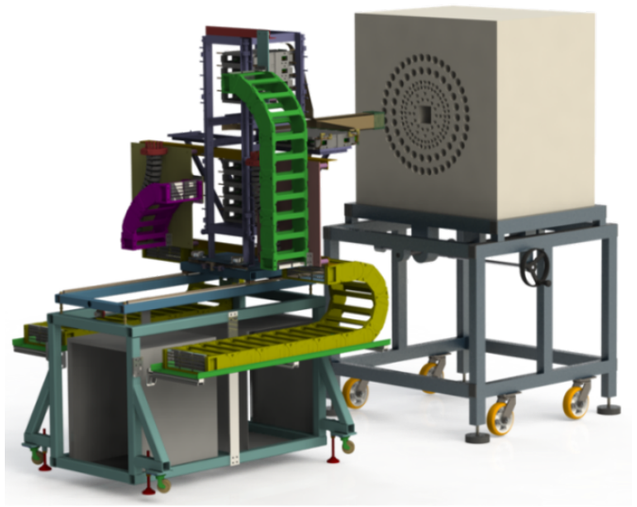
- Collaboration coordinator: C. Domingo
- Development of the acquisition system and the analysis techniques (J. Agramunt, + A. Tolosa (PhD student))
- Members of the group act as spokesperson of approved proposals (Tain, Algora, Morales, etc).





BRIKEN (from conce(p)t to reality)

Tested at IFIC (2015-2016)
July 2016, mounting the setup at RIKEN
November- December 2016 commissioning at RIKEN
2017 first experiments (next slide)



BRIKEN (short term future, this year)

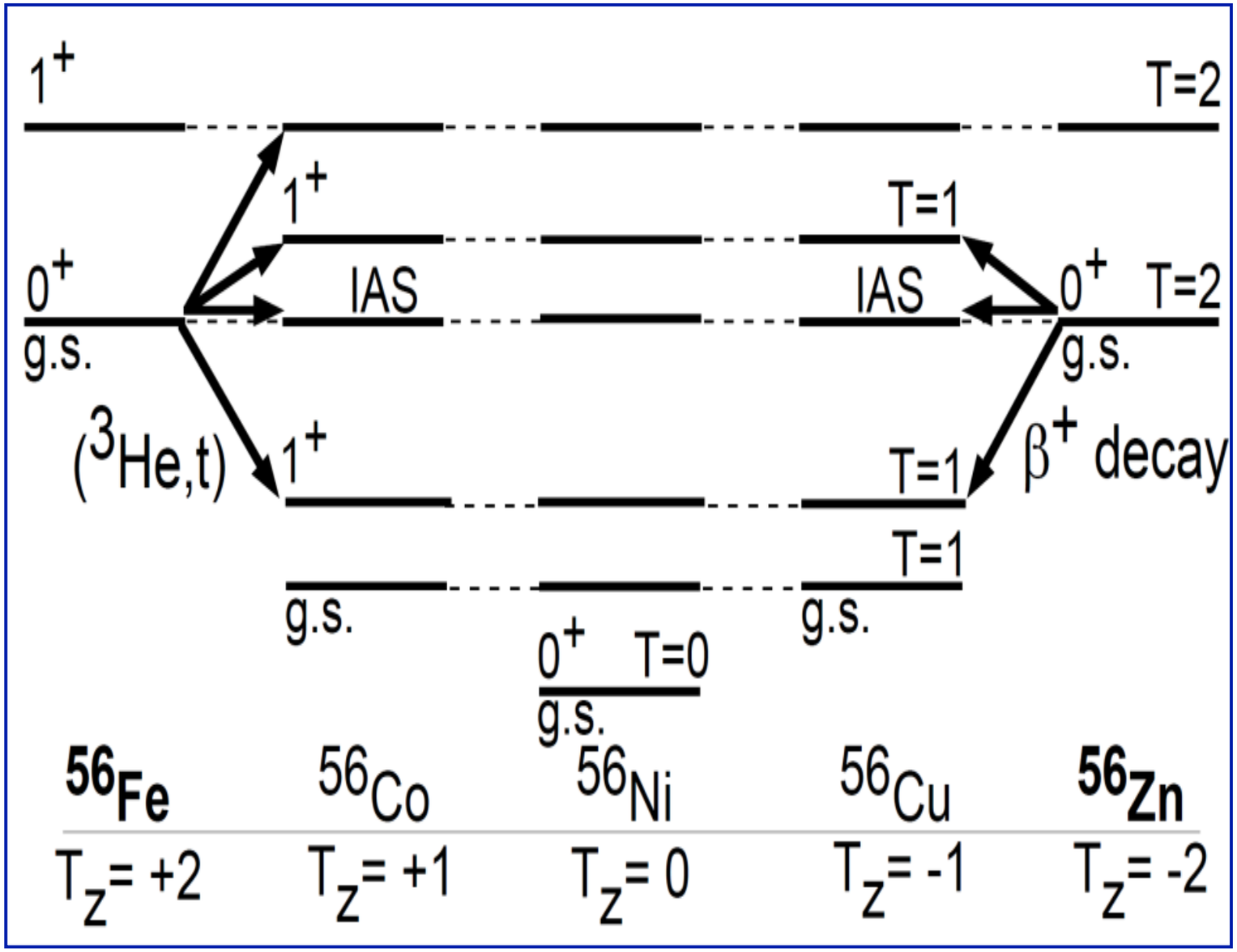
Experiments to be performed at RIKEN (2017-2018)

- **NP1406-RIBF128**: Measurement of bn relevant for A=130 r-process abundant peak (Spokespersons: Lorusso, Estrade, Montes)
- **NP1412-RIBF127R:** Measurement of bn properties around doubly magic ^{78}Ni (Spokespersons: Rykaczewski, Dillmann, Grywacz,Tain)
- **NP1512-RIBF139:** Decay properties of r-process nuclei in deformed region arouns A=100-130 (Spokespersons: Nishimura, Algora)
- **NP1612-RIBF148:** Masses, half-lives and beta delayed neutron emission probabilities relevant to understand the formation of the rare earth r process peak (Spokespersons: Kiss, Morales, Tarifeño, Estrade)

MORE THAN 28 DAYS OF BEAM TIME IN THE WORLD LEADING RADIOACTIVE BEAM FACILITY RIKEN

Exploring the limits of nuclear existence

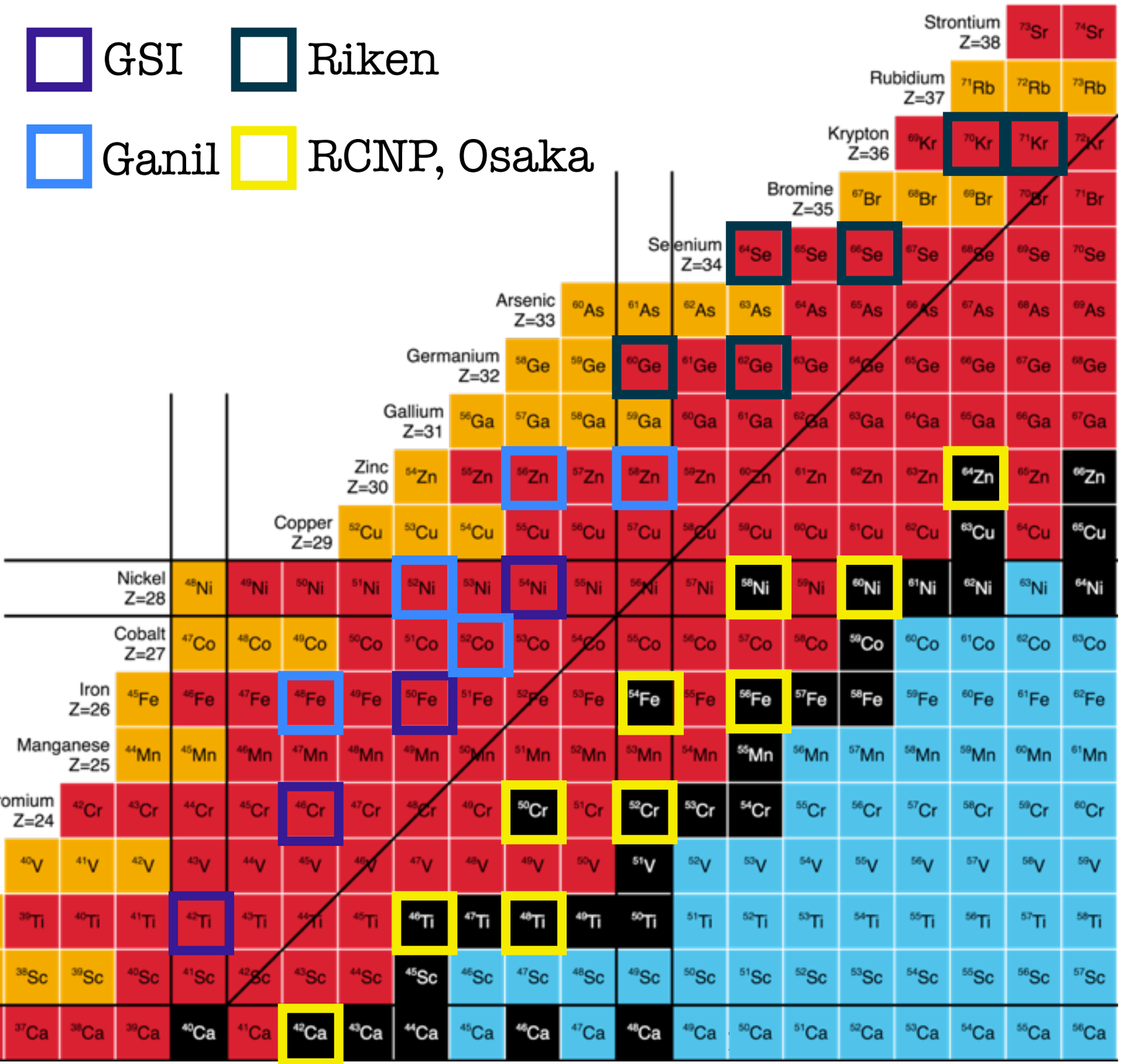
- Study of proton rich nuclei in the fp shell and above
- Main goal: study of the complementary character of the beta decay and charge exchange reactions (isospin-symmetry, mirror transitions should have the same intensity)



Exploring the limits of nuclear existence

GSI Riken

Ganil RCNP, Osaka



Main results: Isospin symmetry studies (charge exchange vs beta decay), study of nuclei properties in the vicinity of the drip lines, new forms of radioactivity, test of the CVC hypothesis.

Many experiments at different facilities
Spokesperson: B. Rubio
Analysis: S. Orrigo, A. Montaner, L. Kucuk
Thesis work:
A. Montaner, L. Kucuk

Shape effects, pn pairing, CVC hyp (70,71Kr, 70Br)
Spokespersons: Algora, Rubio, et al
Analysis: A. Morales

Some statistics from last years (since 2012)

Año	Artículos	Conf/charlas
2012	30 (3PRL)	31
2013	22 (2PRL)	28
2014	24 (5PRL)	18
2015	18 (4PRL)	44
2016	>20 (2PRL)	>14
TOTAL	>114 (16 PRL)	>135

MAIN RECENT PROJECTS

FPA2011-24553, period 2012-2014
Total budget: 644 930 € (direct cost 533 000 €)
AIC-A-2011-0696, período 2012-2014
Total budget: 225 900 €
FPA2014-52823-C2-P-1, period 2015-2017
Total budget: 423 500 € (direct cost 350 000 €)
IFIC-ENRESA Collaboration project
Total budget: 572495 €
ERC Consolidator Grant 681740
Total budget: 1.9 M€

In addition some colaboration projects and European projects like I-COOP (Chile) ENSAR2 SATNurSe, CHANDA, etc.

Some representative results

High-sensitivit**Y** **M**easurements of key stellar **N**ucleo-**S**ynthesis reactions

ERC CoG, Started in June, 2016

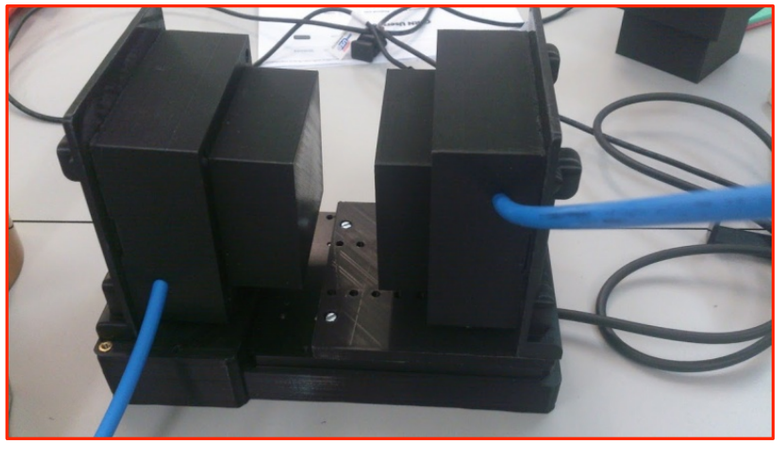
PhD Student, P. Gramage

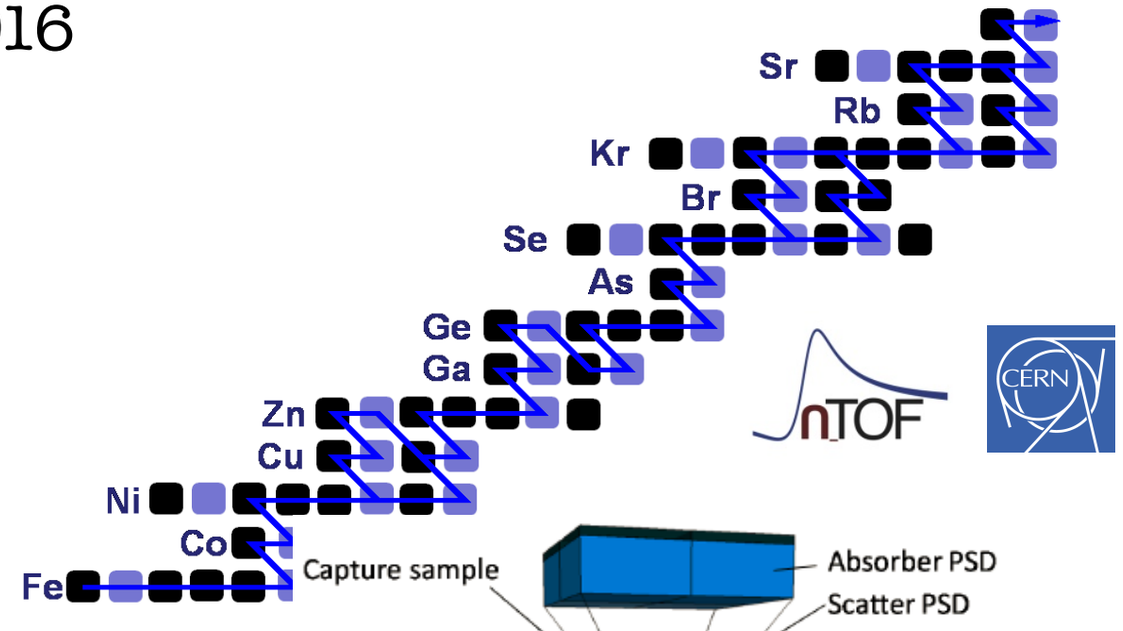
Engineer, I. Ladarescu

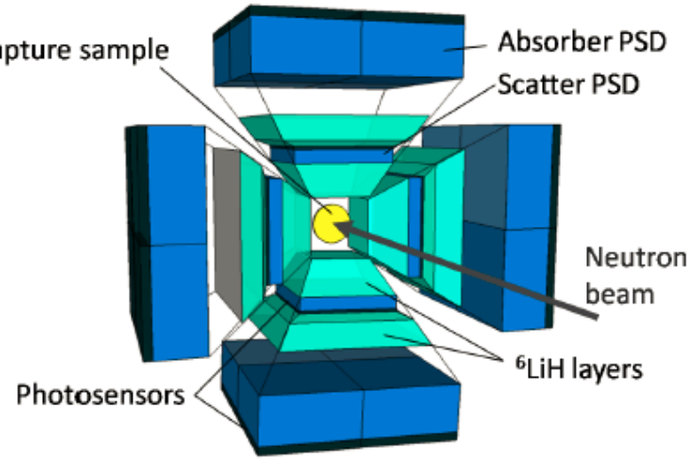
Postdoc, L. Caballero

PI, C. Domingo

1st i-TED module prototype







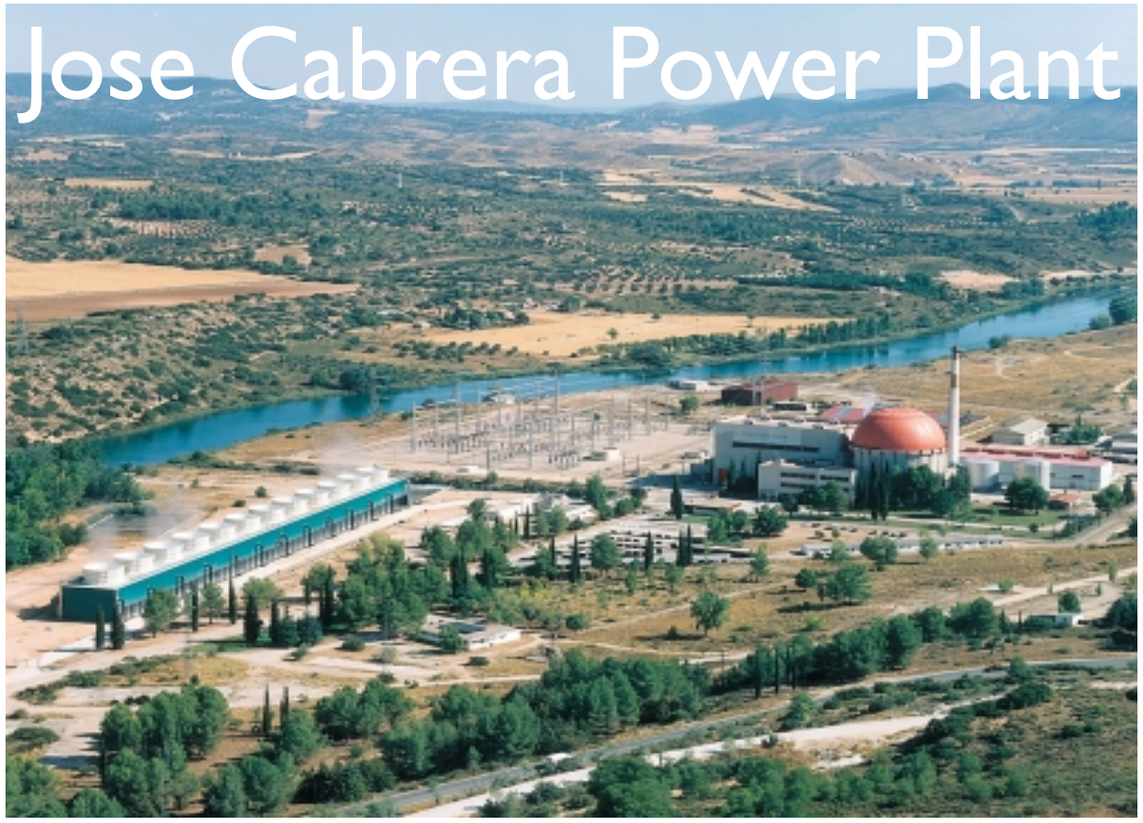
CPAN article: https://www.i-cpan.es/es/content/el-erc-financia-un-proyecto-espa%C3%B1ol-para-recrear-la-formaci%C3%B3n-de-elementos-pesados

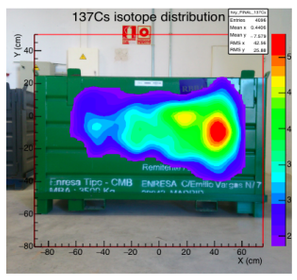
Some representative results

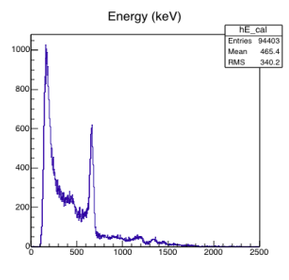
R+D Collaboration Project IFIC-ENRESA

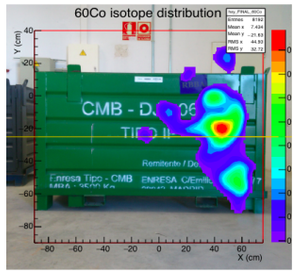
Objective: To develop a portable gamma-ray spectrometer to monitor de activity of γ-ray emitting isotopes on walls and contaminated rooms.

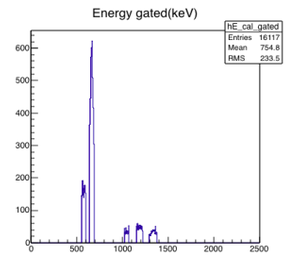
Duration (3 y): 2015-2018
Funding: 250 k€





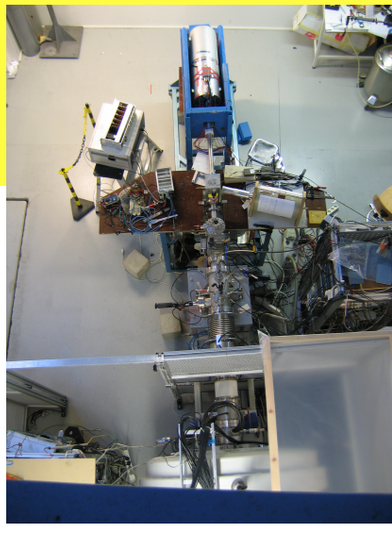






PIs: C. Domingo-Pardo, B. Rubio
L. Caballero Ontanaya, DR FC3 (<Nov.2016)
K. Albiol
A. Corbi
J. Agramunt

Some representative publications



Selected for a Viewpoint in *Physics*

PRL **105,** 202501 (2010) PHYSICAL REVIEW LETTERS week ending 12 NOVEMBER 2010

Reactor Decay Heat in ^{239}Pu: Solving the γ Discrepancy in the 4–3000-s Cooling Period

A. Algora,[1,2,*] D. Jordan,[1] J. L. Taín,[1] B. Rubio,[1] J. Agramunt,[1] A. B. Perez-Cerdan,[1] F. Molina,[1] L. Caballero,[1] E. Nácher,[1] A. Krasznahorkay,[2] M. D. Hunyadi,[2] J. Gulyás,[2] A. Vitéz,[2] M. Csatlós,[2] L. Csige,[2] J. Äystö,[3] H. Penttilä,[3] I. D. Moore,[3] T. Eronen,[3] A. Jokinen,[3] A. Nieminen,[3] J. Hakala,[3] P. Karvonen,[3] A. Kankainen,[3] A. Saastamoinen,[3] J. Rissanen,[3] T. Kessler,[3] C. Weber,[3] J. Ronkainen,[3] S. Rahaman,[3] V. Elomaa,[3] S. Rinta-Antila,[3] U. Hager,[3] T. Sonoda,[3] K. Burkard,[4] W. Hüller,[4] L. Batist,[5] W. Gelletly,[6] A. L. Nichols,[6] T. Yoshida,[7] A. A. Sonzogni,[8] and K. Peräjärvi[9]

CPAN article: https://www.i-cpan.es/es/content/cient%C3%ADficos-espa%C3%B1oles-contribuyen-mejorar-las-predicciones-del-calor-residual-en-reactores

Thesis work: D. Jordan

Publication: A. Algora, D. Jordan, J. L. Tain et al, PRL 105

Exp. spokesperson: Algora, Tain

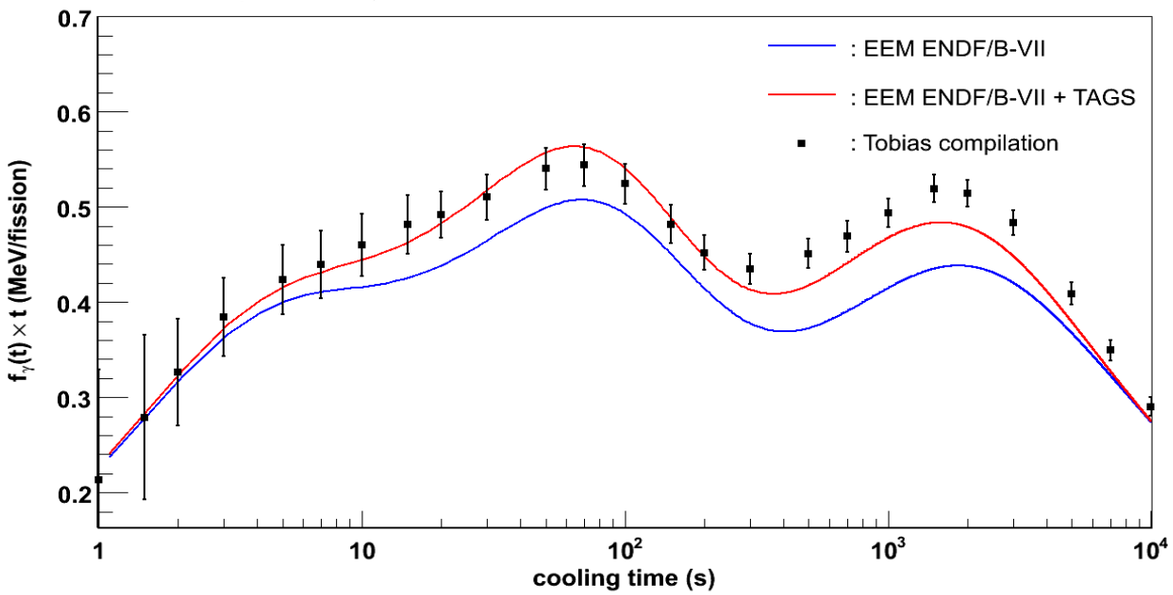
Combination of techniques: IGISOL + JYFLTRAP+ TAS

First trap assisted TAS measurement.

Measurement of 7 important beta decays that contributed to a large improvement of the prediction of the decay heat in reactors. It has also an impact in the prediction of the neutrino spectrum.

Viewpoint article was written about the PRL article, see Physics 3, 94 (2010)

^{239}Pu, γ-component



Some representative results

PRL **112,** 222501 (2014) PHYSICAL REVIEW LETTERS week ending 6 JUNE 2014

Observation of the β-Delayed γ-Proton Decay of ^{56}Zn and its Impact on the Gamow-Teller Strength Evaluation

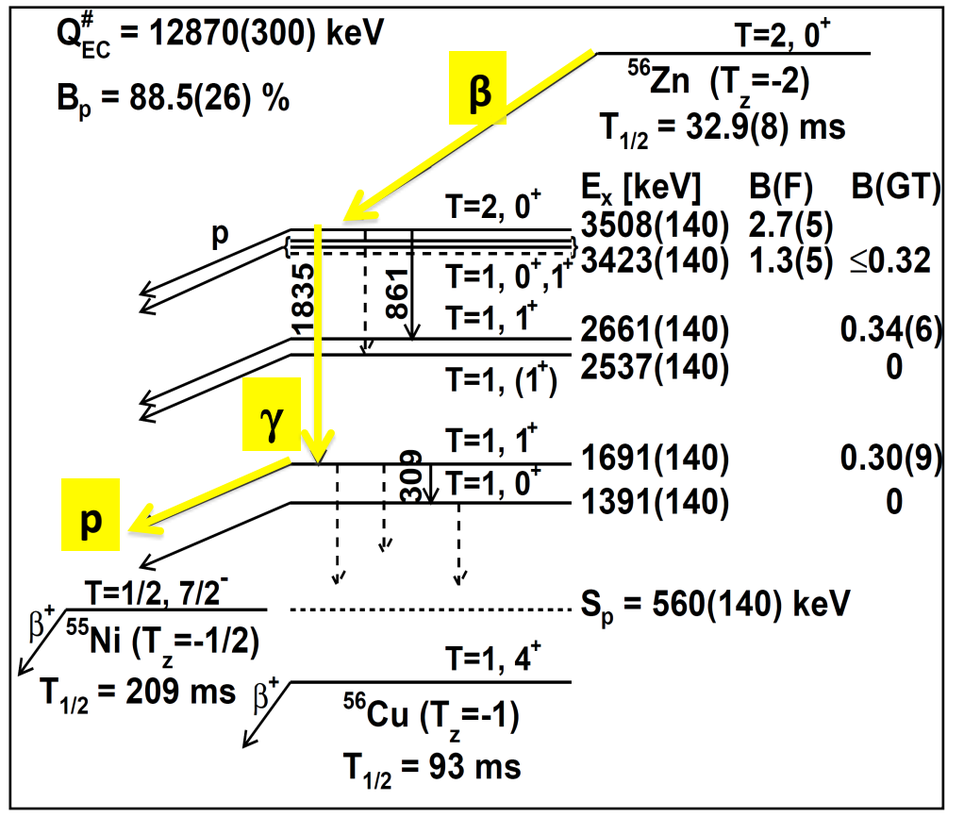
S. E. A. Orrigo,[1,*] B. Rubio,[1] Y. Fujita,[2,3] B. Blank,[4] W. Gelletly,[5] J. Agramunt,[1] A. Algora,[1,6] P. Ascher,[4] B. Bilgier,[7] L. Cáceres,[8] R. B. Cakirli,[7] H. Fujita,[3] E. Ganioğlu,[7] M. Gerbaux,[4] J. Giovinazzo,[4] S. Grévy,[4] O. Kamalou,[8] H. C. Kozer,[7] L. Kucuk,[7] T. Kurtukian-Nieto,[4] F. Molina,[1,9] L. Popescu,[10] A. M. Rogers,[11] G. Susoy,[7] C. Stodel,[8] T. Suzuki,[3] A. Tamii,[3] and J. C. Thomas[8]

CPAN article: https://www.i-cpan.es/es/content/observan-un-nuevo-tipo-de-desintegraci%C3%B3n-en-n%C3%BAcleos-ricos-en-protones

Publication: S. Orrigo, B. Rubio et al. , PRL 112
Exp. spokesperson: B. Rubio

First observation of the exotic beta delayed gamma proton decay in the fp shell and for the second time in the nuclide chart.

This study affects the conventional way of determining the B(F) y B(GT) strengths in studies close to the drip line and demonstrate the need for gamma detection in this kind of studies.



Some representative results

PRL 115, 062502 (2015) PHYSICAL REVIEW LETTERS week ending 7 AUGUST 2015

Enhanced γ-Ray Emission from Neutron Unbound States Populated in β Decay

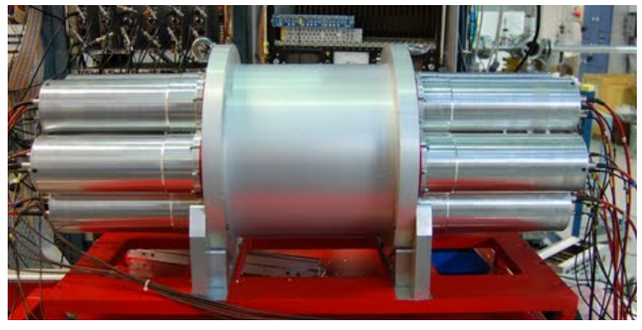
J. L. Tain,[1,*] E. Valencia,[1] A. Algora,[1] J. Agramunt,[1] B. Rubio,[1] S. Rice,[2] W. Gelletly,[2] P. Regan,[2] A.-A. Zakari-Issoufou,[3] M. Fallot,[3] A. Porta,[3] J. Rissanen,[4] T. Eronen,[4] J. Äystö,[5] L. Batist,[6] M. Bowry,[2] V. M. Bui,[3] R. Caballero-Folch,[7] D. Cano-Ott,[8] V.-V. Elomaa,[4] E. Estevez,[1] G. F. Farrelly,[2] A. R. Garcia,[8] B. Gomez-Hornillos,[7] V. Gorlychev,[7] J. Hakala,[4] M. D. Jordan,[1] A. Jokinen,[4] V. S. Kolhinen,[4] F. G. Kondev,[9] T. Martínez,[8] E. Mendoza,[8] I. Moore,[4] H. Penttilä,[4] Zs. Podolyák,[2] M. Reponen,[4] V. Sonnenschein,[4] and A. A. Sonzogni[10]

CPAN article: https://www.i-cpan.es/es/content/miden-en-el-laboratorio-la-velocidad-de-reacciones-nucleares-en-supernovas

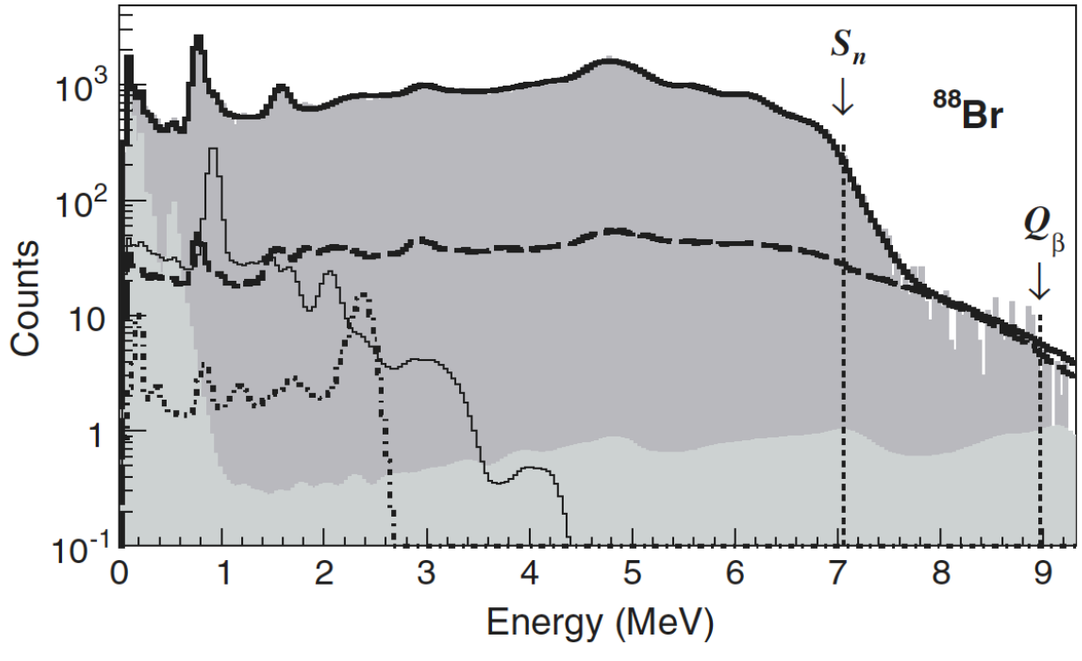
Thesis work: Ebhelixes Valencia

Publication: J. L. Tain et al. PRL 115

Exp. spokesperson: A. Algora, J. L. Tain



Measurement of the gamma de-excitation of states above the neutron separation energy in beta decay using TAS. By measuring the gamma strength around the Sn, it can help to constrain neutron capture cross-sections for exotic nuclei (astrophysical impact and neutrino and decay heat impact)



Some representative results

PRL 117, 012501 (2016) PHYSICAL REVIEW LETTERS week ending 1 JULY 2016

First Measurement of Several β-Delayed Neutron Emitting Isotopes Beyond $N = 126$

R. Caballero-Folch,[1,2] C. Domingo-Pardo,[3,*] J. Agramunt,[3] A. Algora,[3,4] F. Ameil,[5] A. Arcones,[5] Y. Ayyad,[6] J. Benlliure,[6] I. N. Borzov,[7,8] M. Bowry,[9] F. Calviño,[1] D. Cano-Ott,[10] G. Cortés,[1] T. Davinson,[11] I. Dillmann,[2,5,12] A. Estrade,[5,13] A. Evdokimov,[5,12] T. Faestermann,[14] F. Farinon,[5] D. Galaviz,[15] A. R. García,[10] H. Geissel,[5,12] W. Gelletly,[9] R. Gernhäuser,[14] M. B. Gómez-Hornillos,[1] C. Guerrero,[16,17] M. Heil,[5] C. Hinke,[14] R. Knöbel,[5] I. Kojouharov,[5] J. Kurcewicz,[5] N. Kurz,[5] Yu. A. Litvinov,[5] L. Maier,[14] J. Marganiec,[18] T. Marketin,[19] M. Marta,[5,12] T. Martínez,[10] G. Martínez-Pinedo,[5,20] F. Montes,[21,22] I. Mukha,[5] D. R. Napoli,[23] C. Nociforo,[5] C. Paradela,[6] S. Pietri,[5] Zs. Podolyák,[9] A. Prochazka,[5] S. Rice,[9] A. Riego,[1] B. Rubio,[3] H. Schaffner,[5] Ch. Scheidenberger,[5,12] K. Smith,[5,21,22,24,25] E. Sokol,[26] K. Steiger,[14] B. Sun,[5] J. L. Taín,[3] M. Takechi,[5] D. Testov,[26,27] H. Weick,[5] E. Wilson,[9] J. S. Winfield,[5] R. Wood,[9] P. Woods,[11] and A. Yeremin[26]

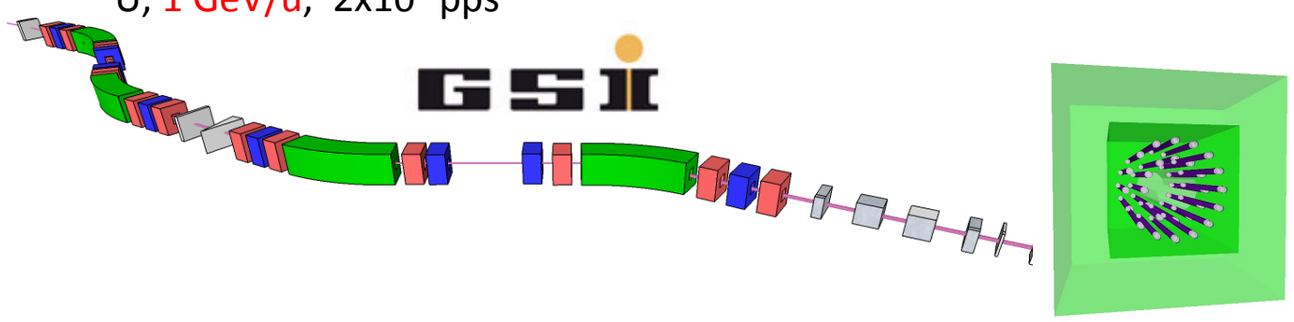
CPAN article: https://www.i-cpan.es/es/content/supernovas-en-el-laboratorio

Thesis work: R. Caballero

Publication: R. Caballero, C. Domingo et al., PRL 117

Exp. spokesperson: C. Domingo, B. Gomez et al.

^{238}U, 1 GeV/u, 2x10^9 pps



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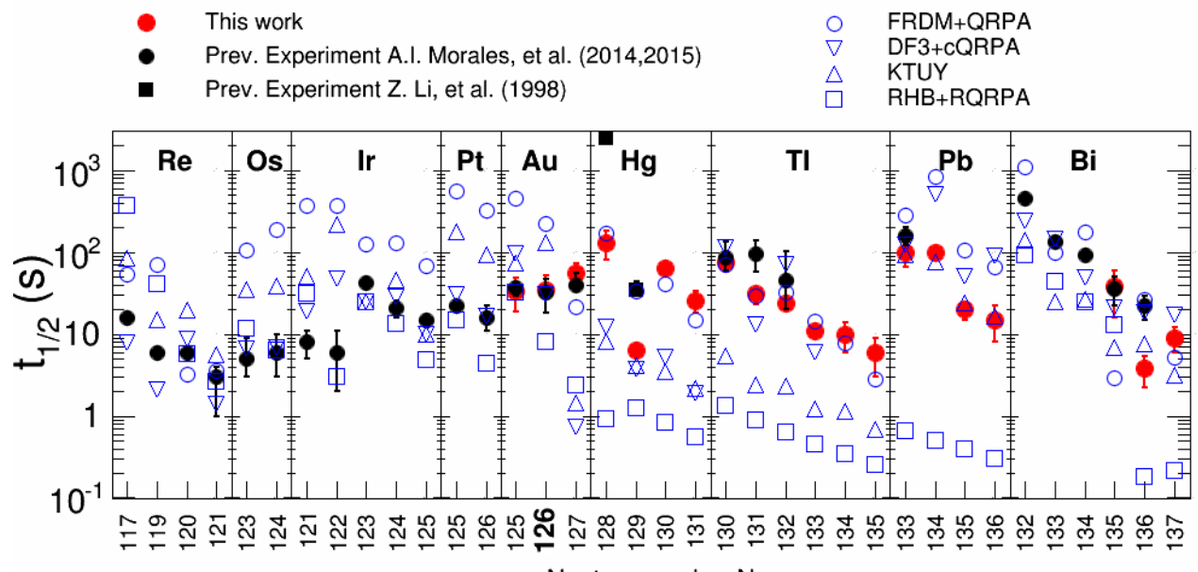
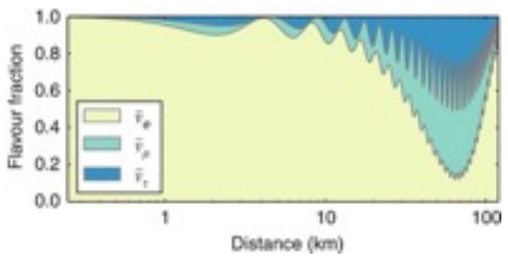
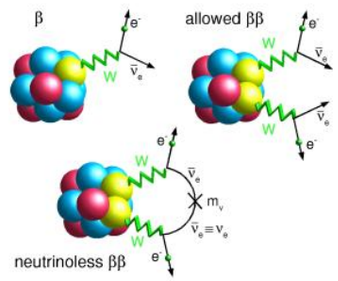
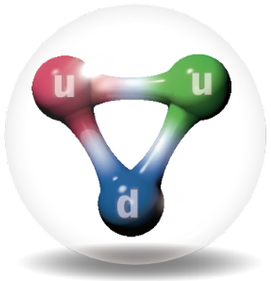


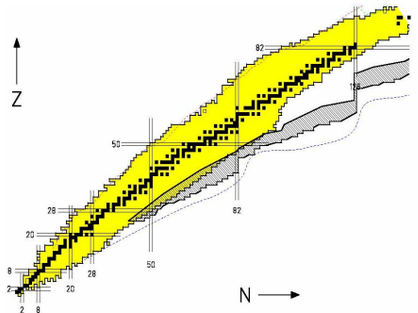
New physics ?

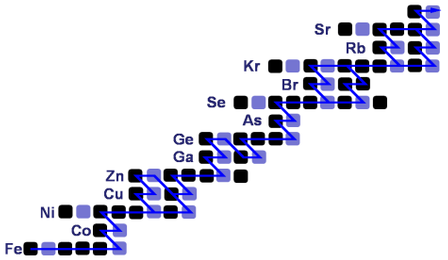
- Study of beta decays that contribute to further test the Conserved Vector Current (CVC) and the unitarity of the Cabibbo-Kobayashi-Maskawa (CKM) matrix (and the determination of the Vud matrix element)
- Study of beta decays that can contribute to a better reconstruction of the reactor neutrino spectrum (reactor anomaly, understanding the mysterious bump in the neutrino spectrum)
- Study of single beta decays that contribute to a better theoretical description of the double beta decay cases
- Study of beta decays relevant for the r process
- Study of neutron capture reactions for a better understanding of the s process (study of branching points at n_TOF)
- ???







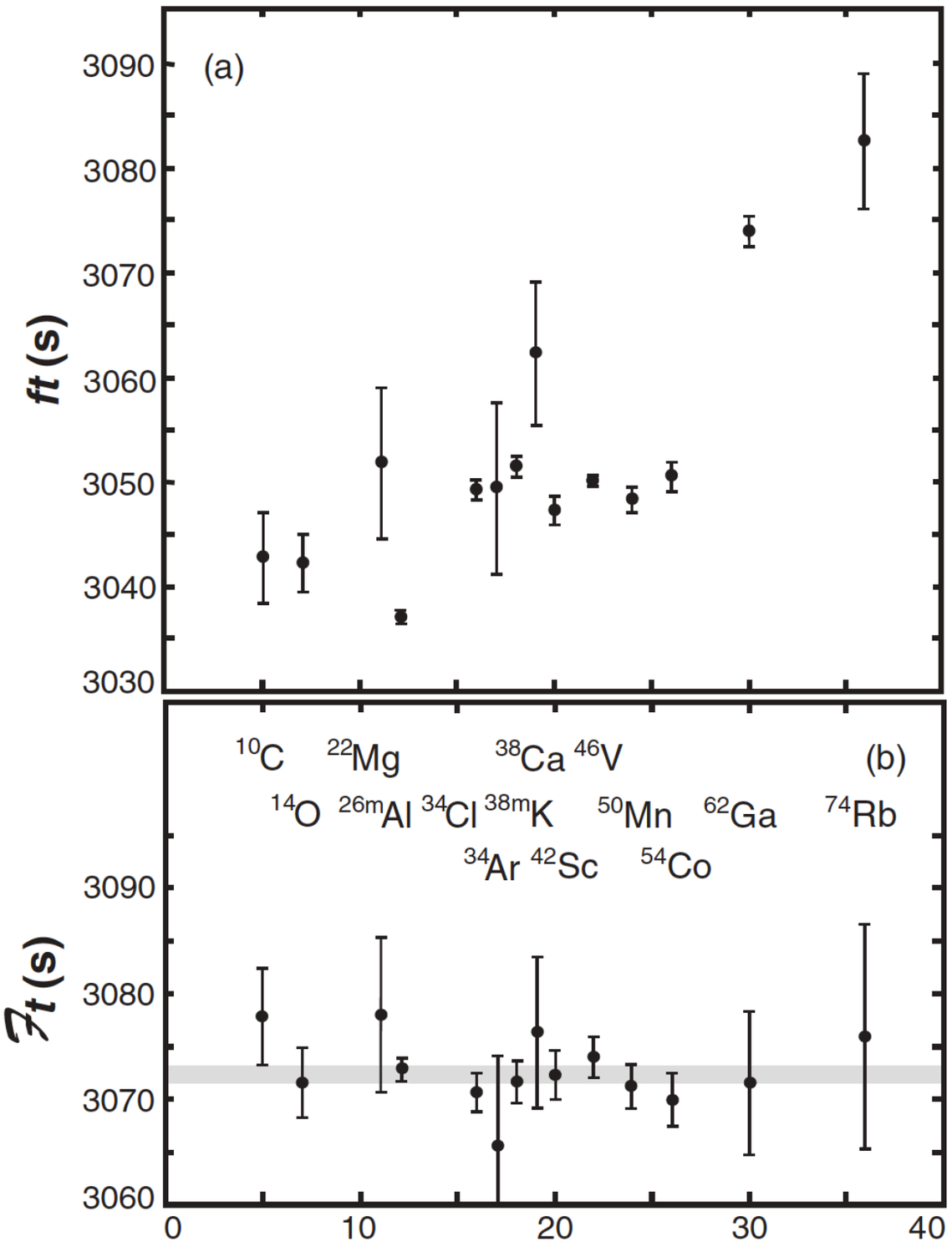




Magical quote (according to the Guardian)

THANK YOU

Beta decay of ^{70}Br



It could be relevant in the framework of 0+->0+ decays. Until now this decay has not been included in the databases used for testing the CVC hypothesis and for the determination of the Vud matrix element of the CKM matrix. Reason, relatively poorly known experimentally.

Experimental needs for the inclusion: better Q-value and half-life determination of the decay, clarification of the isomer 9+ production/contamination, determination of weak GT branches that compite with 0+->0+ decay if possible

$$\mathcal{F}t \equiv ft(1+\delta'_R)(1+\delta_{NS}-\delta_C) = \frac{K}{2G_{\mathrm{V}}^2(1+\Delta_{\mathrm{R}}^{\mathrm{V}})},$$

$$\mathrm{Vud} = 0.97417$$

$$|\mathrm{Vud}|^2 + |\mathrm{Vus}|^2 + |\mathrm{Vub}|^2 = 0.99978$$

Taken from Hardy and Towner, PRC 91 (2015) 025501