β-decay and β-delayed neutron emission measurements at GSI for r-process nucleosynthesis

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La Rábida - Huelva

Contents

- Astrophysics and Nuclear Physics motivation
- Experiment: Setup and detectors
- Beta delayed neutron detector (BELEN)
- Analysis - Ongoing work

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- **Astrophysics and Nuclear Physics motivation**
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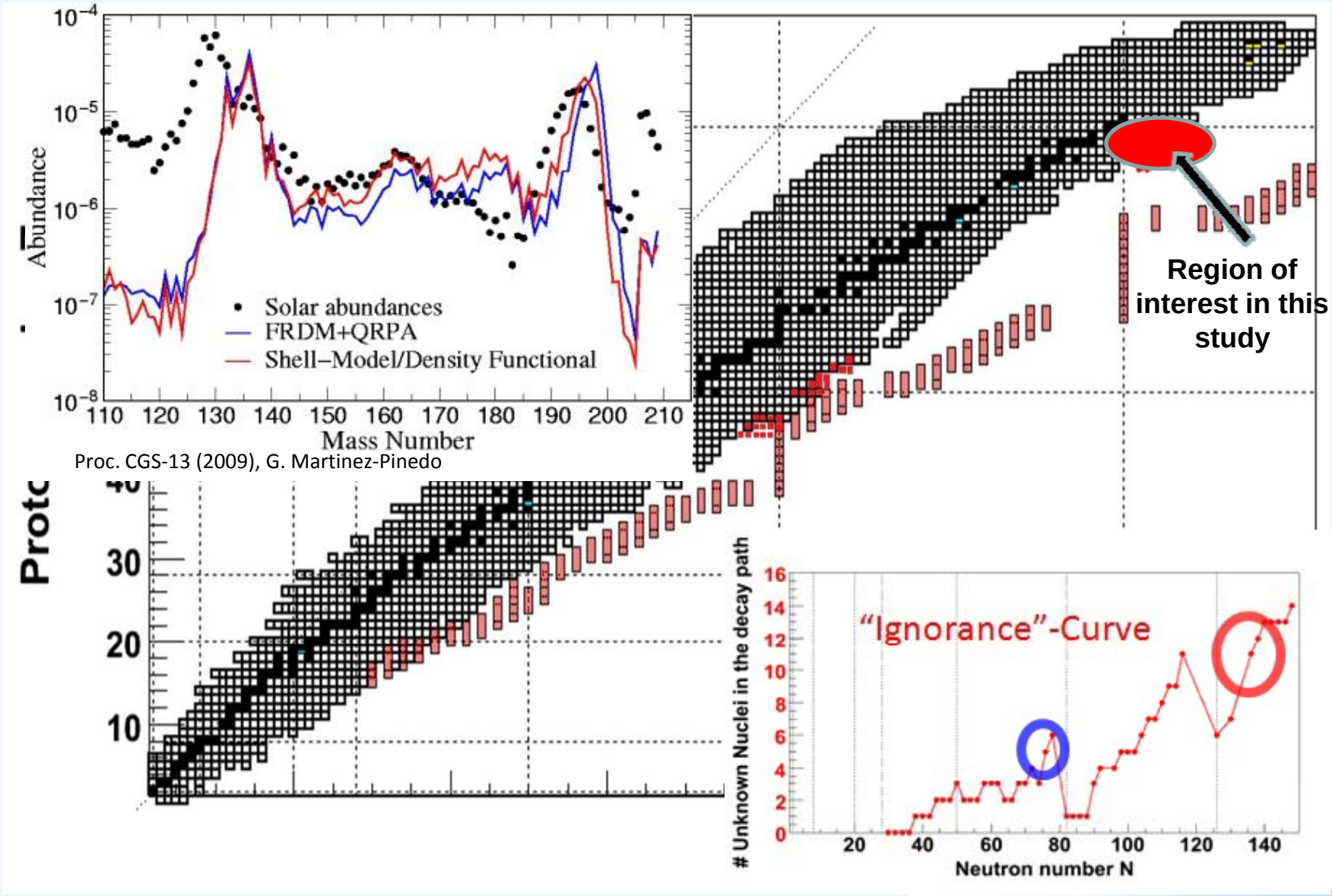
R-process & region of interest



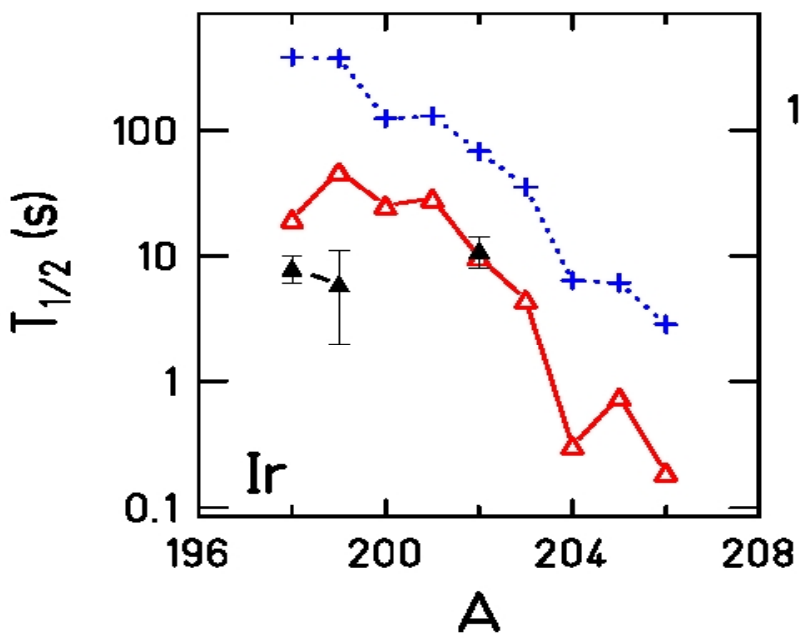
Proc. CGS-13 (2009), G. Martinez-Pinedo

Motivation

Goal: to measure for first time **half life** and **β-delayed neutron emission probability (P_n)** for exotic nuclei near the third *r-process* peak.

✓ N=126 is one of the regions most difficult to reproduce with *r-process* model calculations.

✓ Scarce experimental information available for β-decay half-lives, masses and β-delayed neutrons.



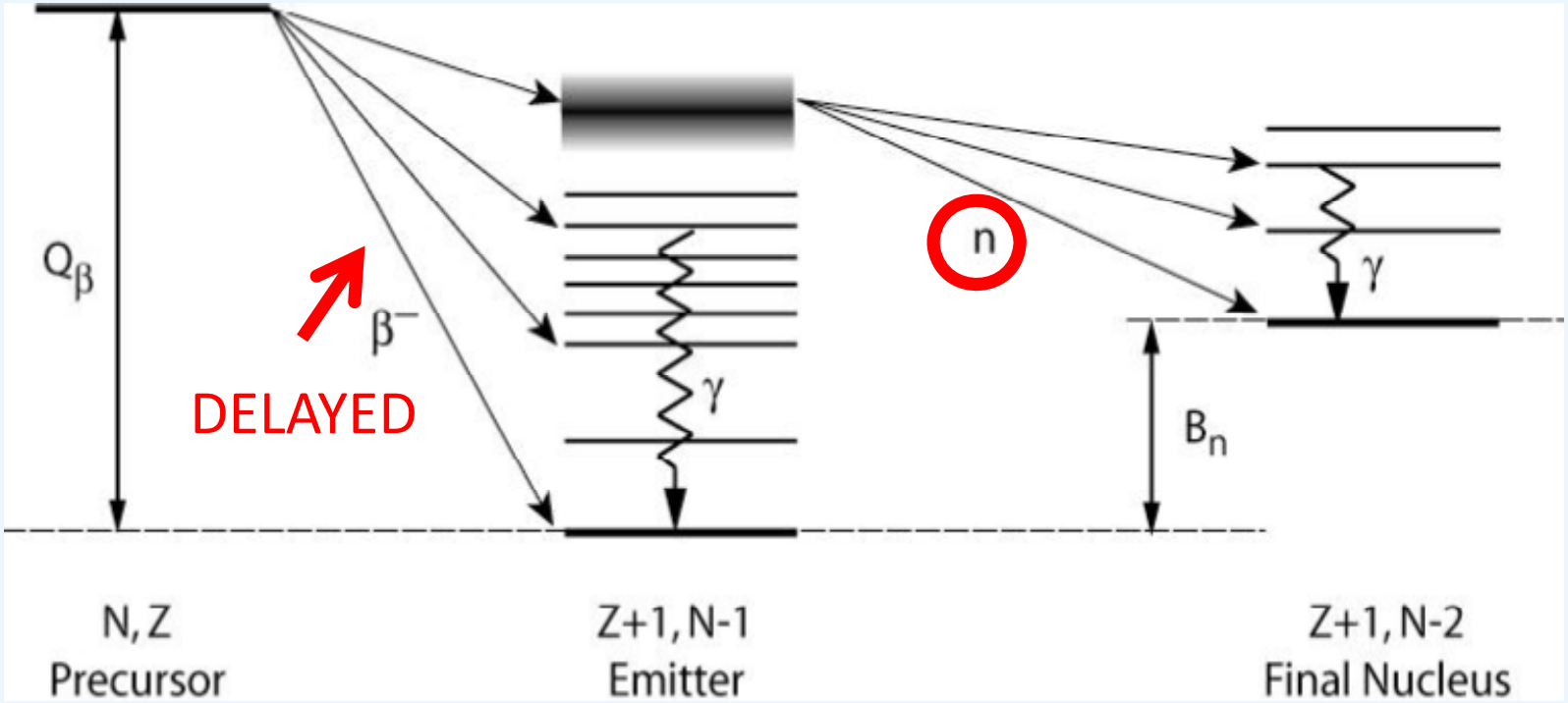
✓ Theoretical models have discrepancies of one order of magnitude for masses of Ir. Furthermore the trend of the unique experimental measurement seems to be in the opposite direction.

▲ DF3 + QRPA
(I.Borzov, et al. 2003)
+ FRDM + QRPA
(P.Moeller, et al. 2003)

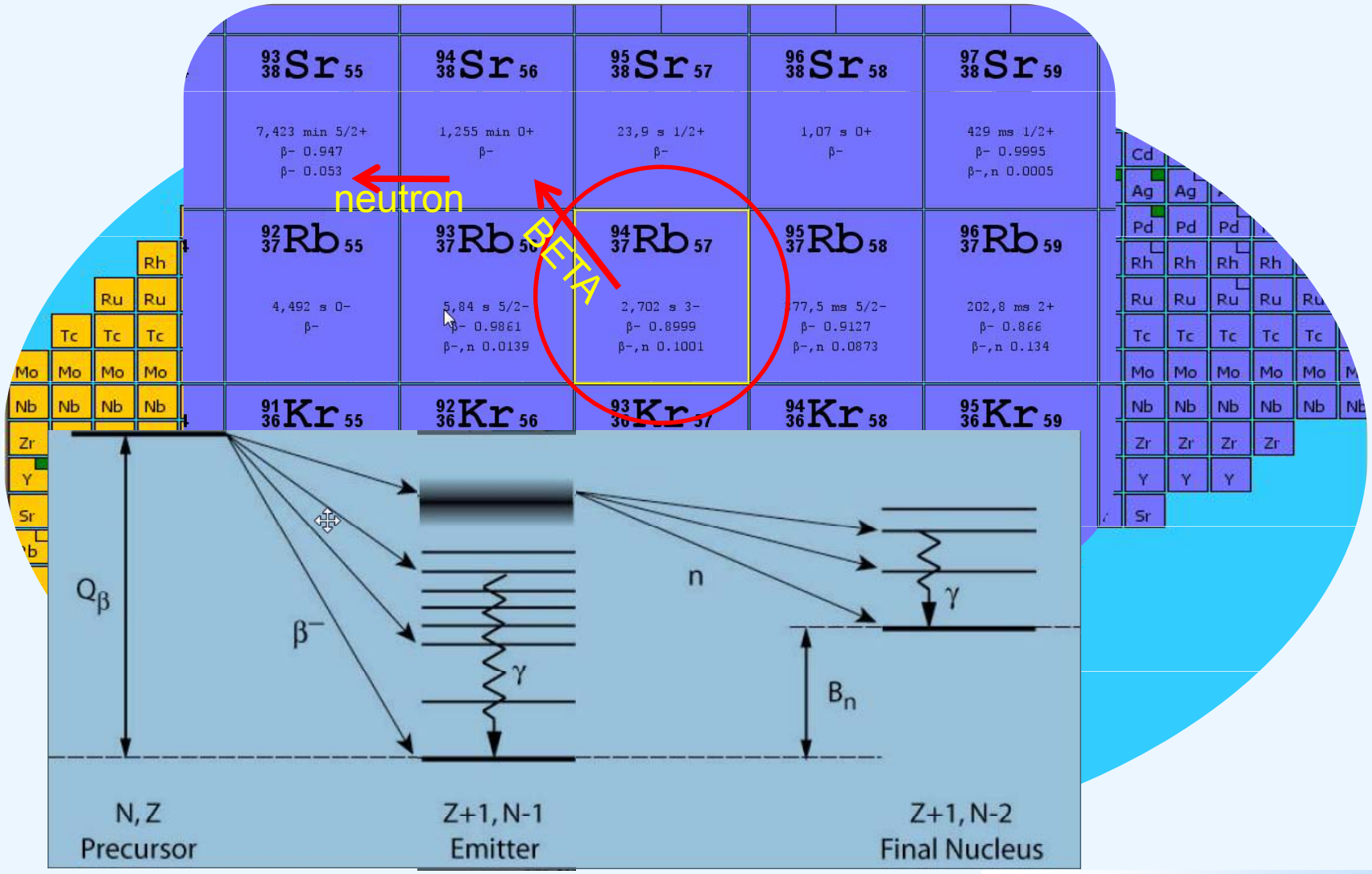
▲ **Exp. T. Kurtukian et al.**
Phys. Lett. B (Submitted)

β-delayed neutron emission

Neutron emission after β^- decay scheme



Example of β⁻delayed neutron emission



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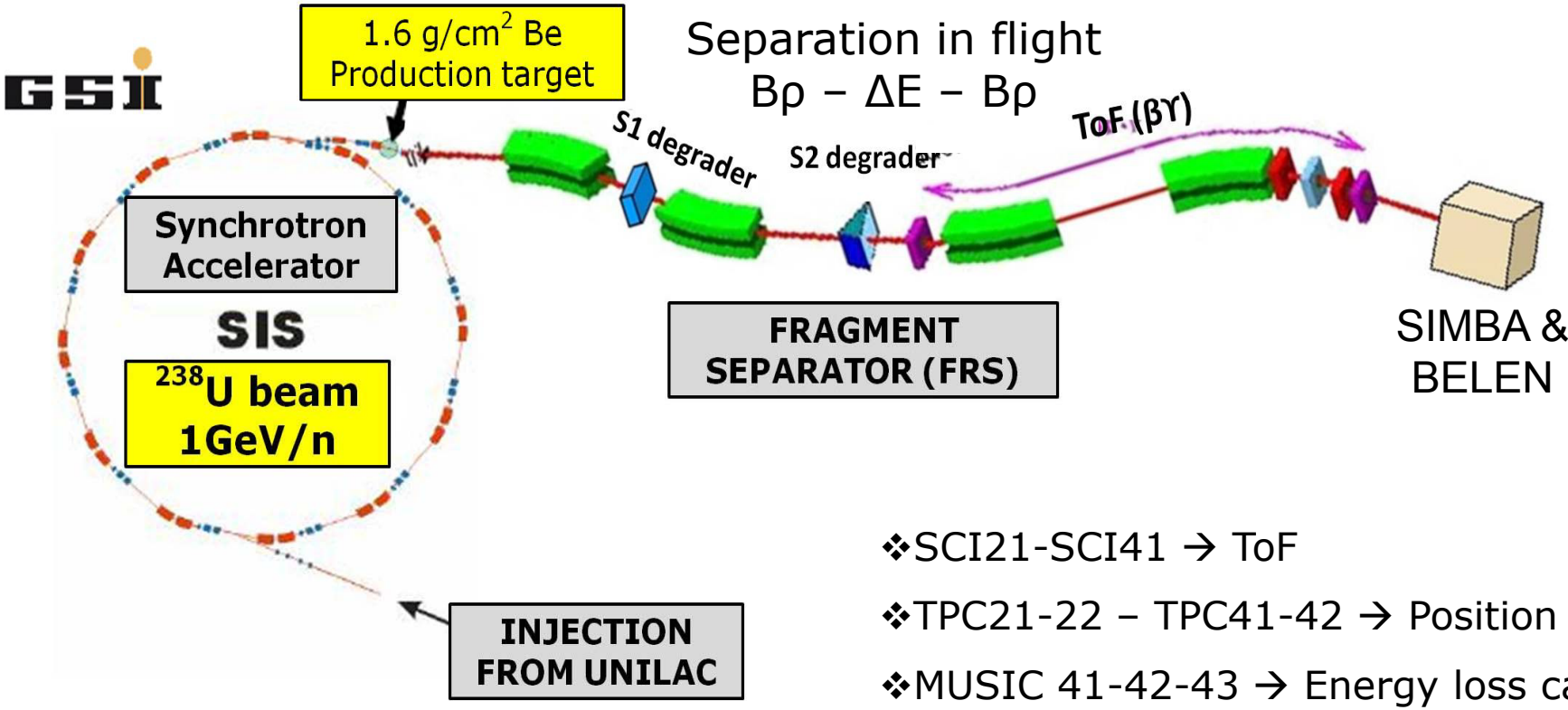
GSI facility. Fragment separator spectrometer (FRS) and Beam characteristics.

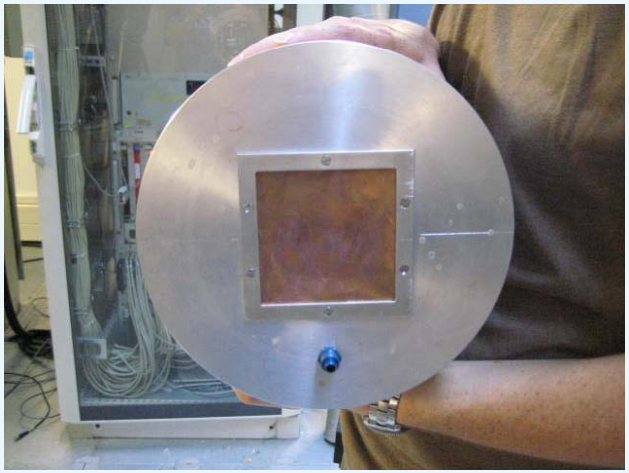


- SCI21-SCI41 → ToF
- TPC21-22 – TPC41-42 → Position calib.
- MUSIC 41-42-43 → Energy loss calib.

$$B\rho = \frac{m}{q} * v = \frac{A}{Q} * \left(\frac{L}{Tof}\right) \rightarrow \frac{A}{Q} = B\rho * \left(\frac{L}{Tof}\right) \qquad Z \; \alpha \; E_{Loss}$$

Implantation detector: SIMBA (Silicon Implantation Detector and Beta Absorber)

SIMBA detector

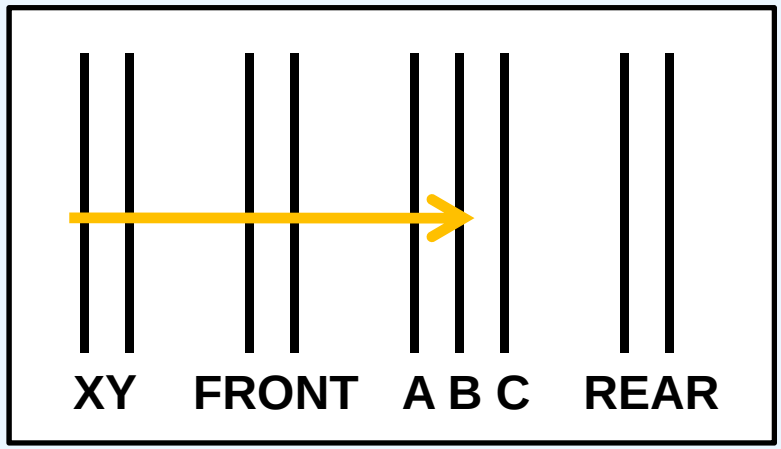


Front view

Multilayer silicon detector

Allows to measure both ion implants and β-decays.

Decay events can be correlated in time with the detection of neutrons.



3 DSSD (implantation area, 60x40 segm.): 60x40 mm^2 (0.7mm thick)

PhD thesis C. Hinke, TUM (2010)

Diploma thesis K. Steiger, TUM (2009)

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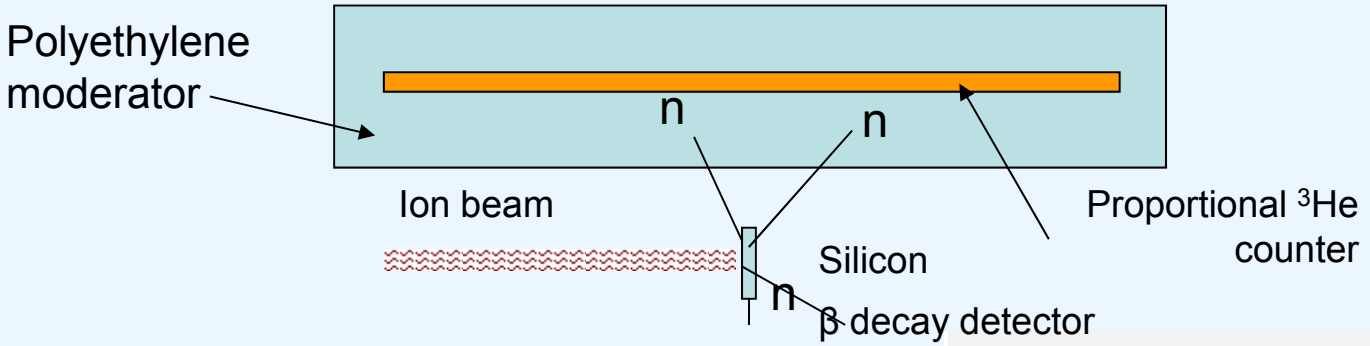
Beta Delayed Neutron detector - **BELEN**

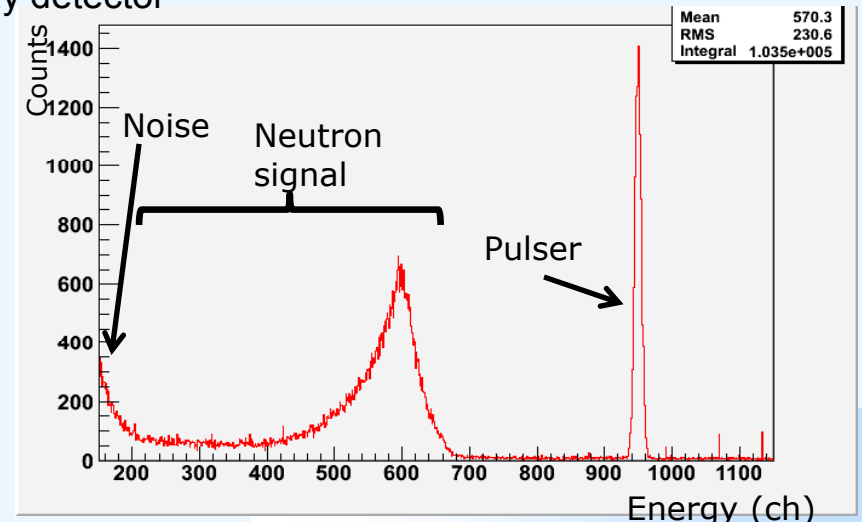
Developed at the technical university UPC-Barcelona

✓ The detection of the neutron is based on the detection of products of the reaction of the neutron with 3He counters :

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



- ✓ Polyethylene matrix moderator
- ✓ Approx 700 kg weight
- ✓ Dimensions: 80cmx80cmx60cm



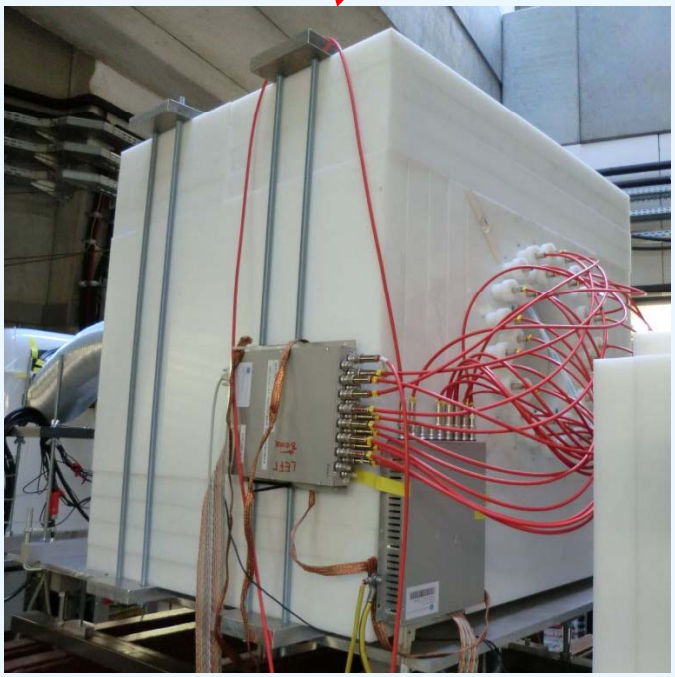
Beta Delayed Neutron detector - **BELEN**

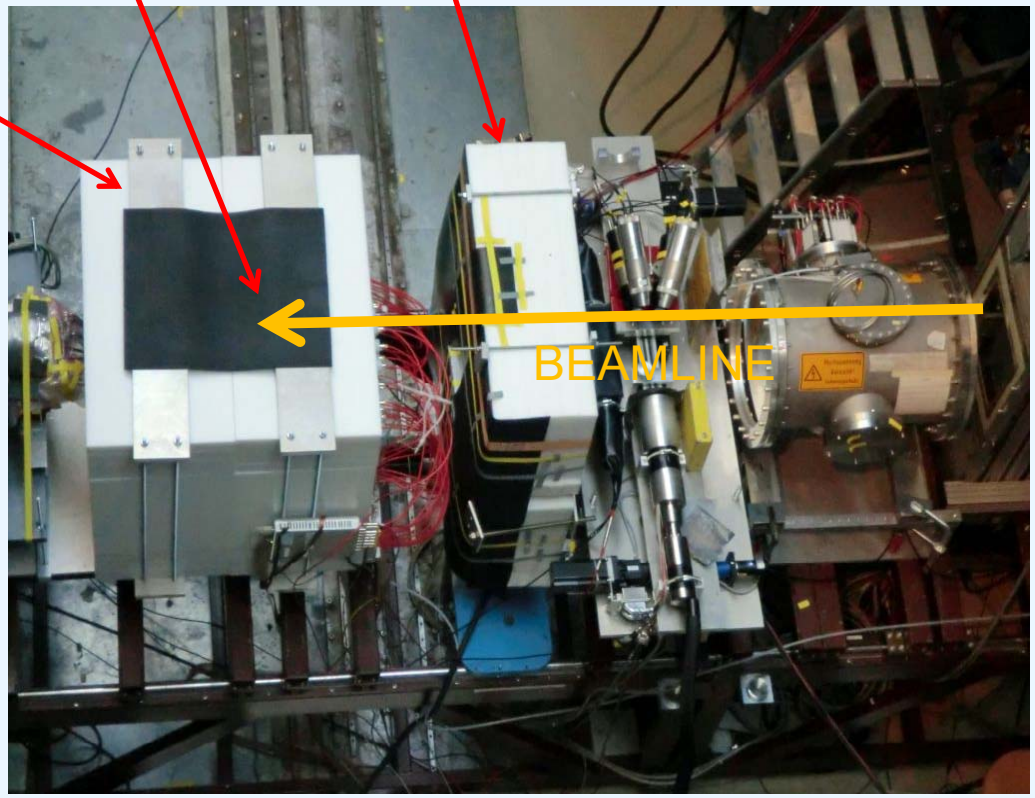
BELEN-30 neutron detector

(efficiency 40%)

Neutron shielding

SIMBA inside the matrix





Digital Data Acquisition System (DDAS)

Triggerless digital data acquisition system:

✓Struck digitizer modules (SIS3302): provide time-stamps very versatile for time correlations

✓Negligible dead-time when compared to analog systems

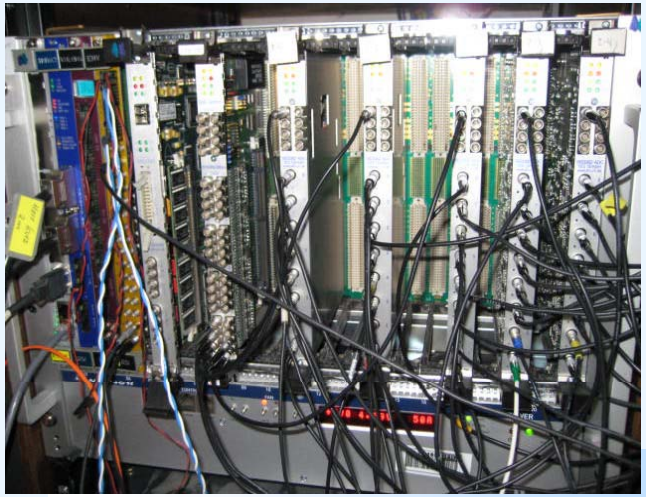
✓Increase the efficiency by about 8% (from 27 to 35%)

✓Flexibility for large time correlation (fundamental to obtain correlations with all neutron and to change the gates offline)

✓Allows to correct some experimental effects, e.g. To reduce neutron background from uncorrelated neutrons

✓Developed at IFIC (València-Spain)

See poster by Jorge Agramunt



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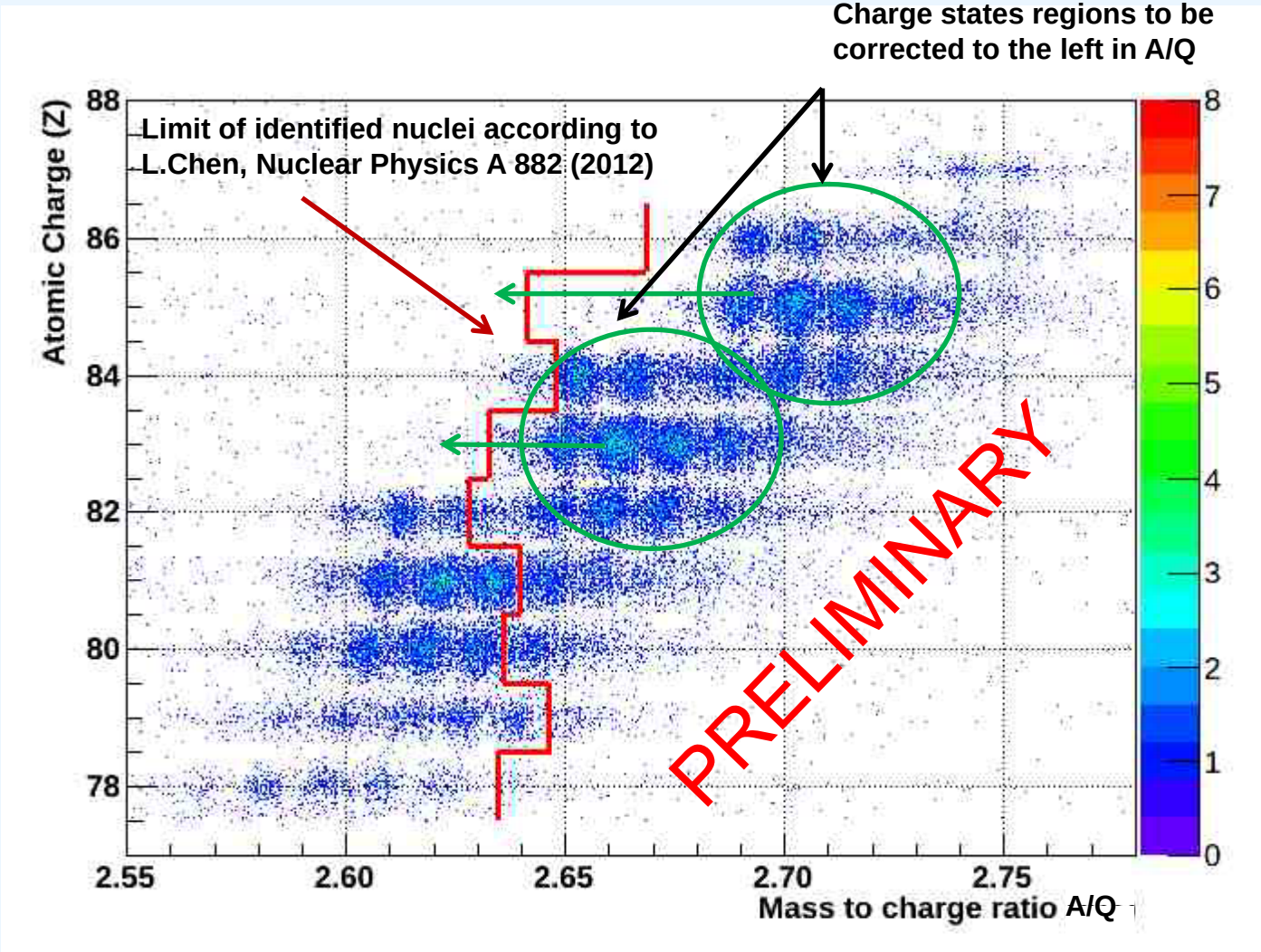
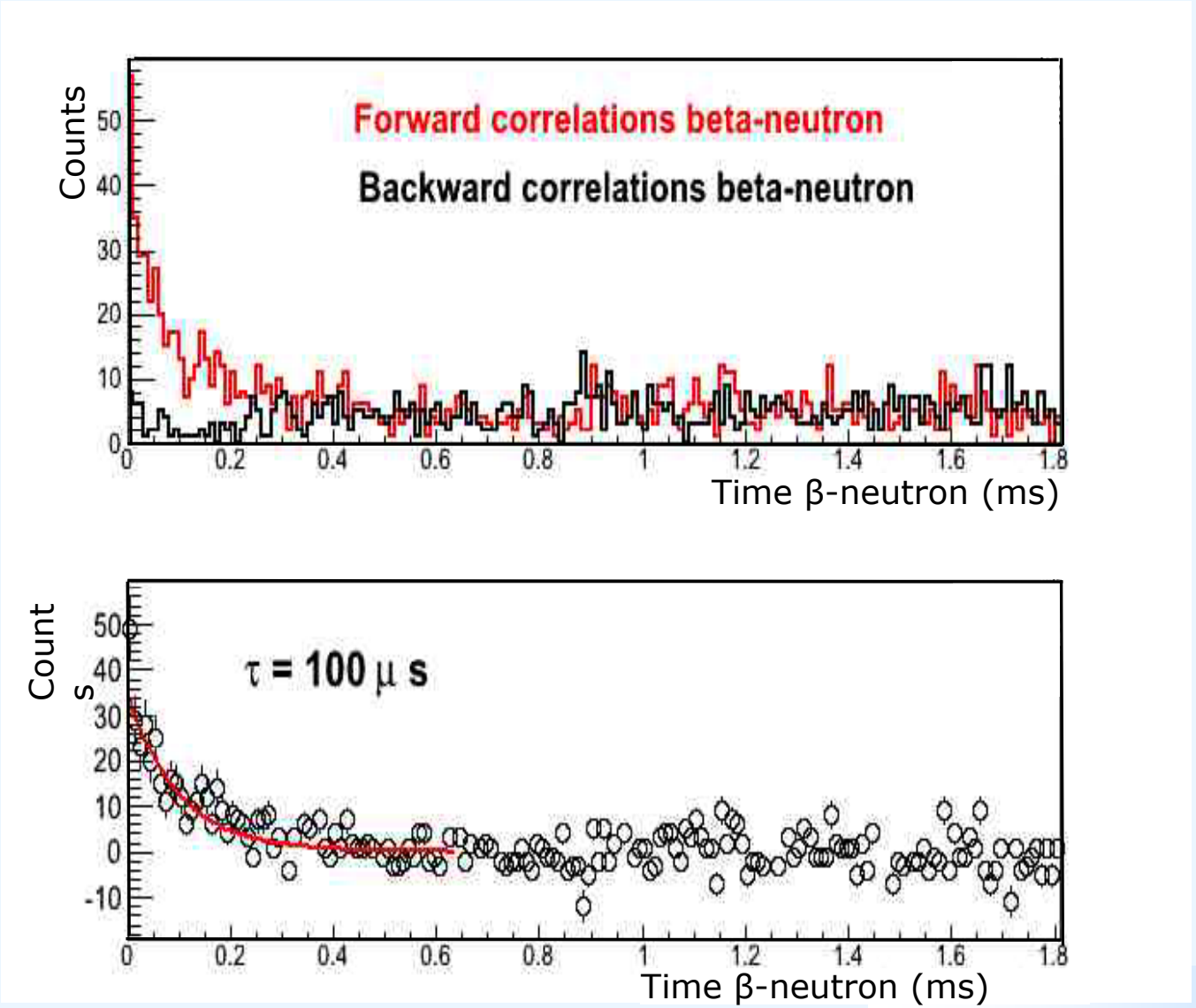
Analysis status: Identification preliminary plot for of ^{211}Hg setting (all statistics)



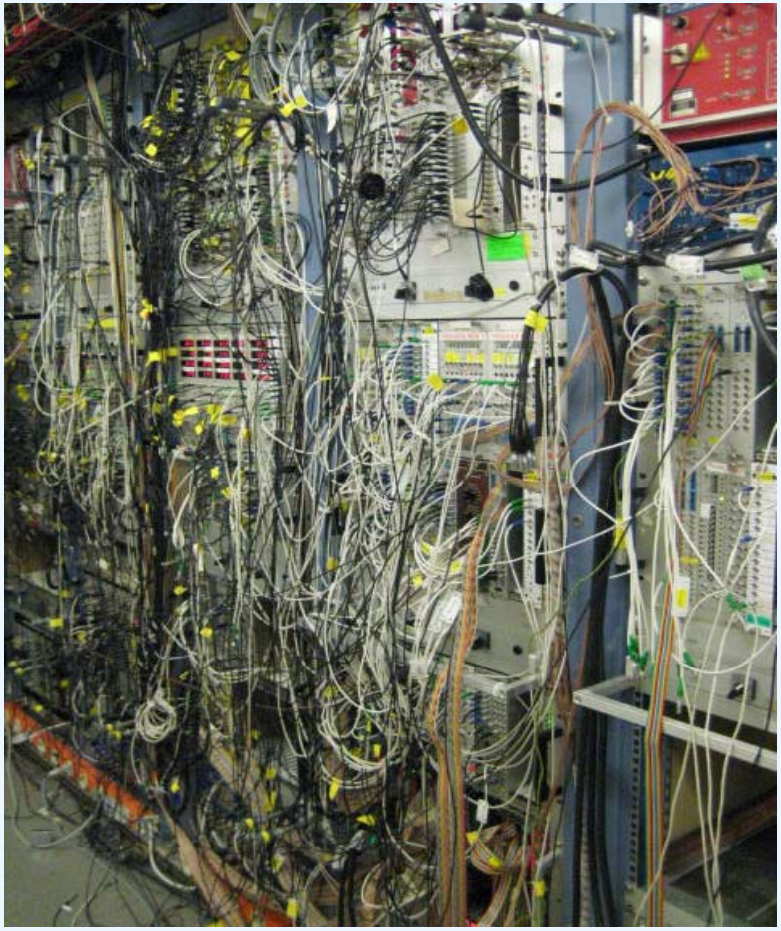
Performance test time correlation between neutron and β-decay for ^{213}Tl



Future analysis work

- Improved ID-Plot via final calibrations of frs detectors
- Determine implantation rates for each identified isotope
- Determine implant-beta correlations and neutron-beta correlations
- Implement an analysis method for deriving half-lifes and for determining beta-delayed neutron emission probabilities.
- In collaboration with theoreticians, study the impact of these results on nuclear models, as well as on r-process nucleosynthesis calculations.

The end!



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CIEMAT (Madrid)

Universidade de Santigo de Compostela (USC)

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CFNUL Universidade de Lisboa (Portugal)

School of Physics & Astronomy, U. Edinburgh (UK)

Department of Physics, University of Liverpool (UK)

STFC, Daresbury Laboratory (UK)

Laboratori Nazionali di Legnaro, INFN (Italy)

Flerov Laboratory, JINR, Dubna (Russia)

CENBG, Université Bordeaux (France)

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