The BEta deLayEd Neutron emission measurements

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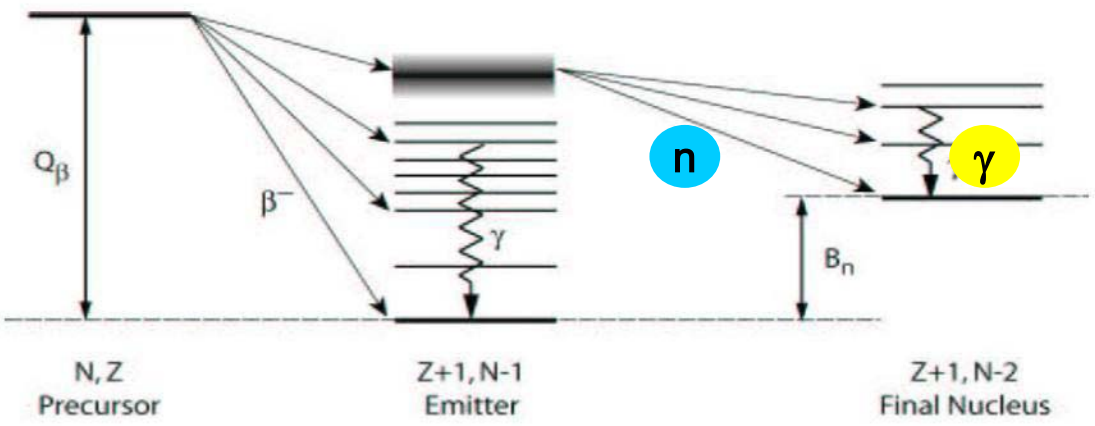
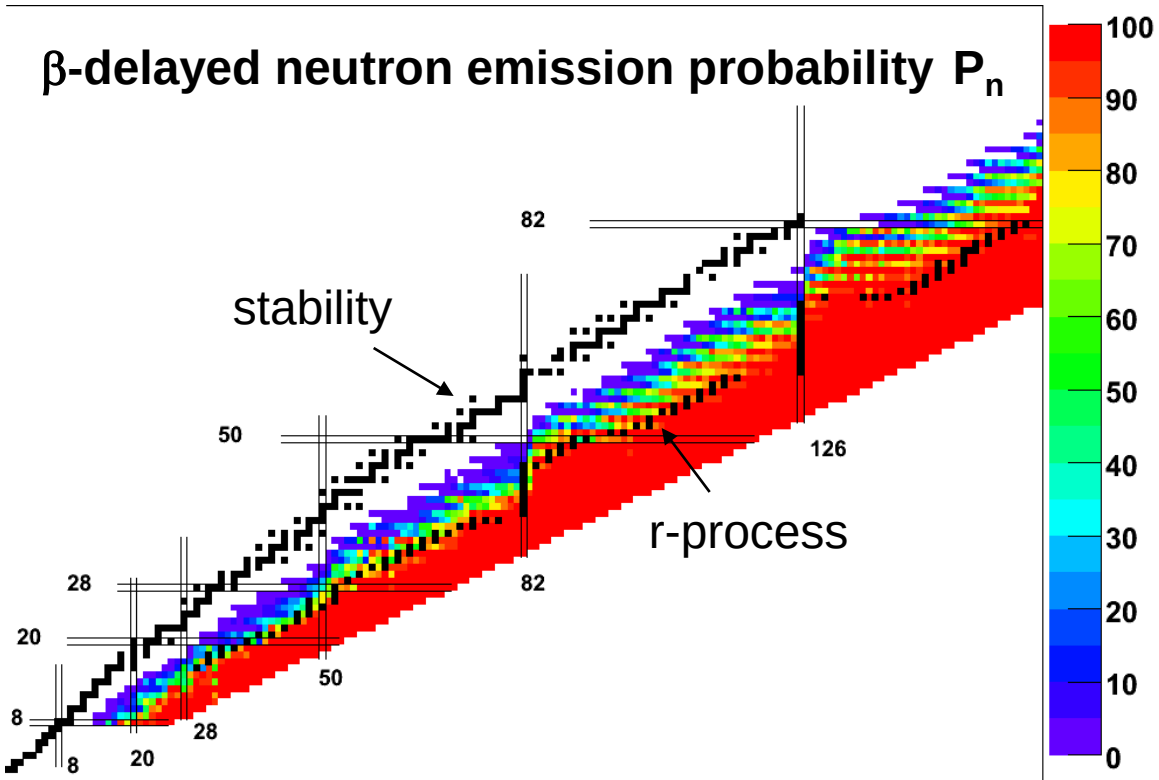
Beta decay of neutron rich nuclei



- For enough neutron rich nuclei S_n lies below Q_β
- If the decay proceeds to states above S_n, neutron emission dominates over γ-ray de-excitation
- Far enough from the stability, **β-delayed neutron emission** becomes the dominant decay process



Nuclear power safety:

Some fission products undergo Beta Delayed Neutron Emission which is essential to control the reaction.

Nuclear Energy Agency (NEA) highlights the importance of experimental measurements and data evaluation of delayed neutron emission in its working group 6 “Delayed neutron data” [WPEC-SG6].

Rapid neutron-capture process of stellar nucleosynthesis:

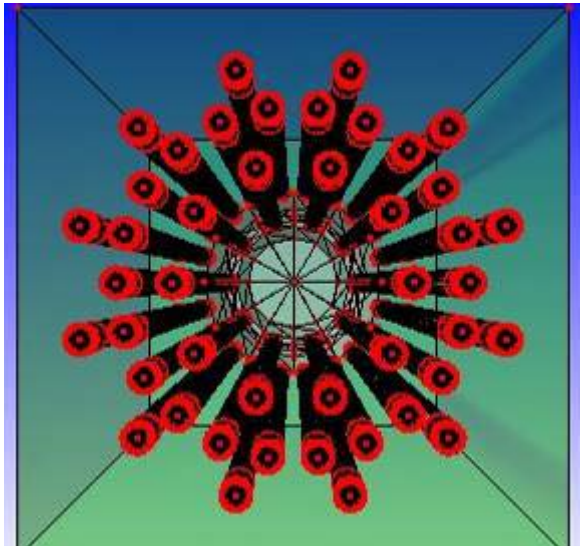
Stellar abundances: delayed neutron emission probability (P_n) of r-process isobaric nuclei define the decay path towards stability during freeze-out, and provide a source of late time neutrons.

Nuclear Structure:

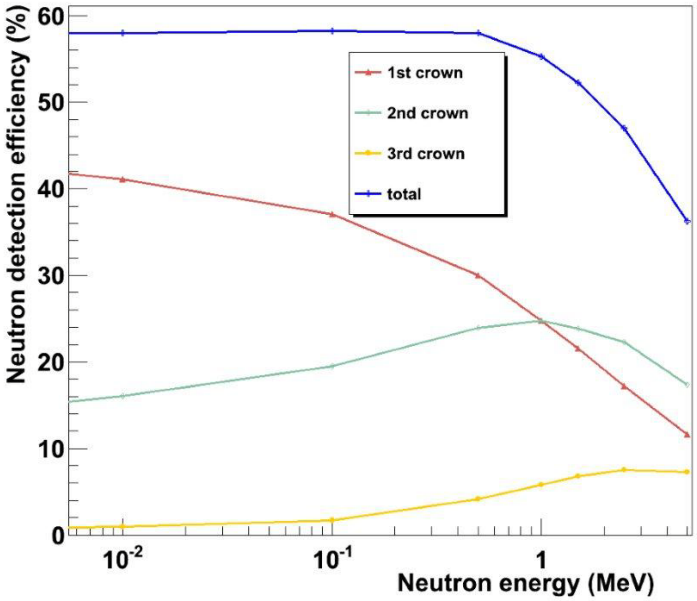
Additionally the measured half-lives ($T_{1/2}$) and β-delayed neutron-emission probabilities (P_n) can be used as first probes of the structure of the β-decay daughter nuclei in this mass region.

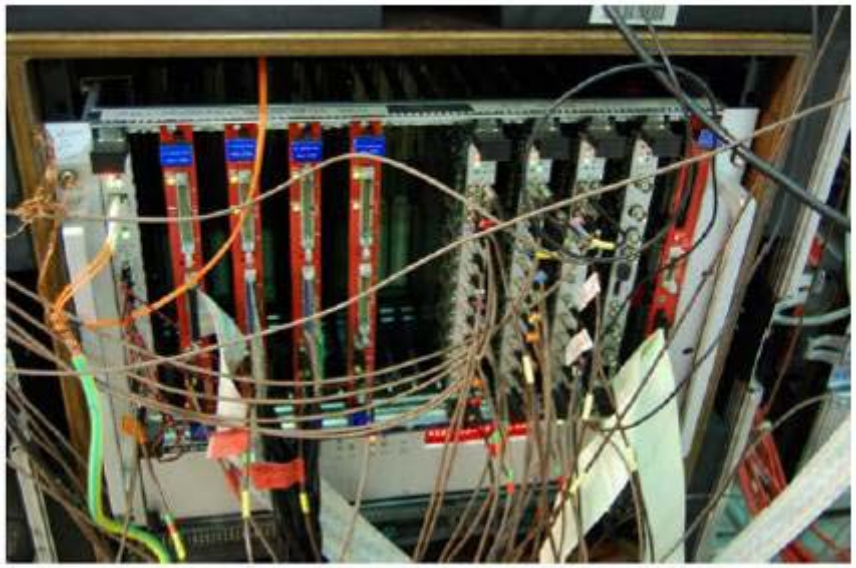
Detector layout

• The neutron detector consists of 44 ^{3}He counters arranged in 3 crowns. A beta detector will measure the beta decay.



Counter	2527 LND
Gas	^{3}He
Effective length (mm)	604.8
Effective diameter (mm)	24.38
Gas pressure (torr)	15200
Cathode material	Stainless steel

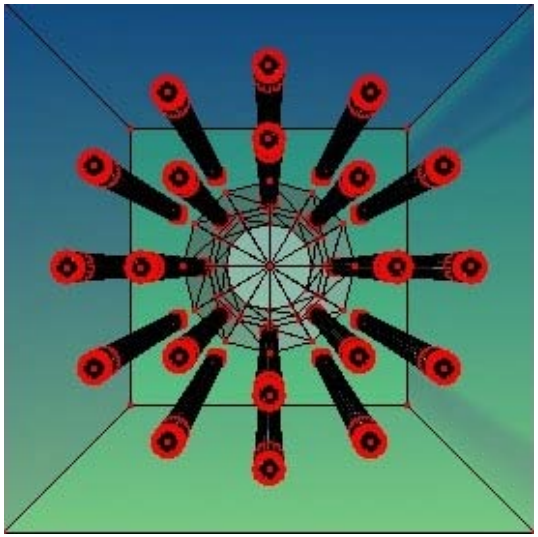




Triggerless DACQ. Full flexibility to modify correlation time neutron emission-detection => clean data
Correlation window 1ms with minimum dead time (~ 2 %)

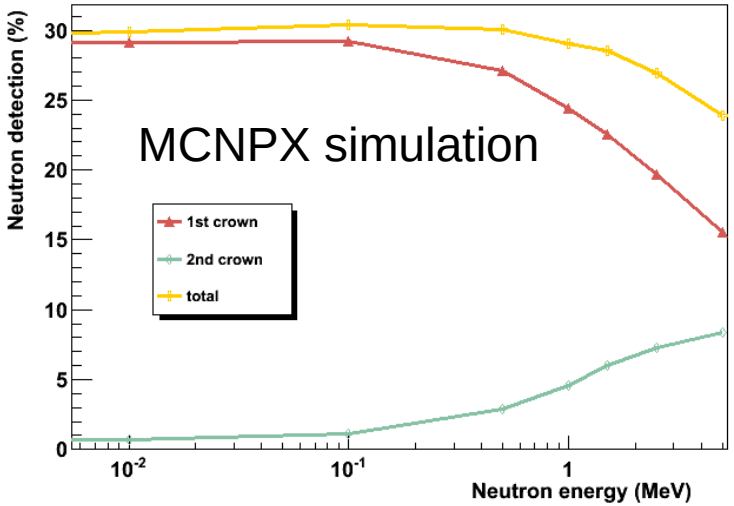
BEta deLayEd Neutron detector prototype

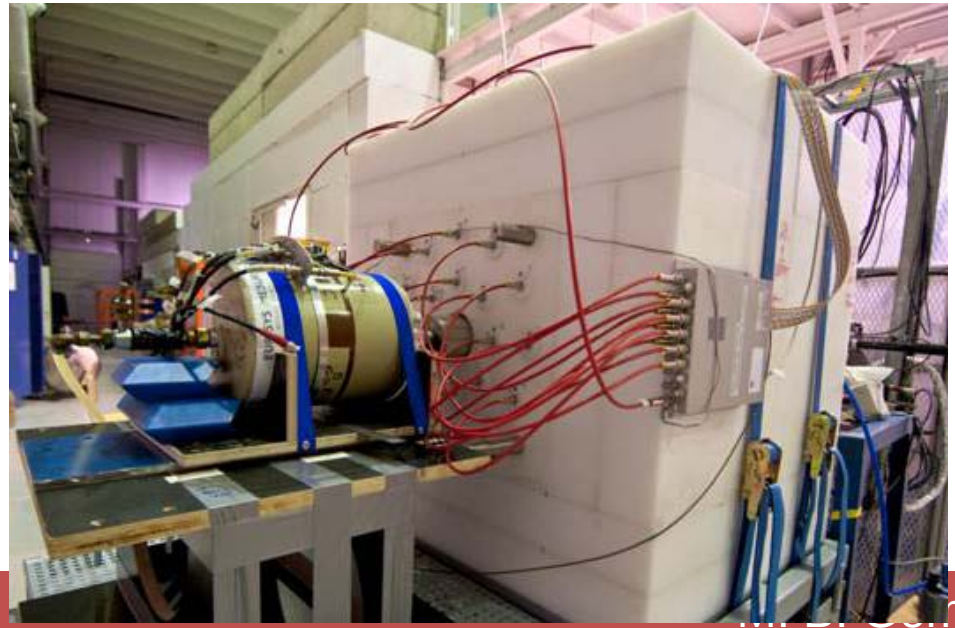
Detector consists of two crowns of (8+12) ^{3}He detectors embedded in a polyethylene matrix with total dimensions 90x90x80 cm^3 and a r=5 cm beam hole

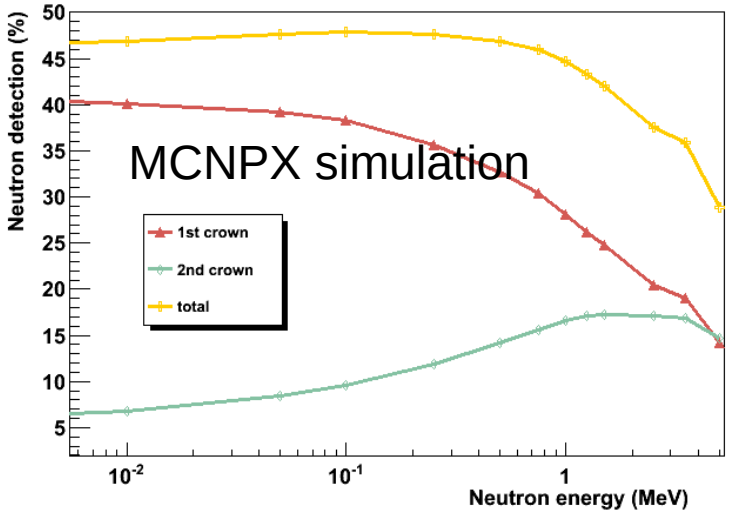


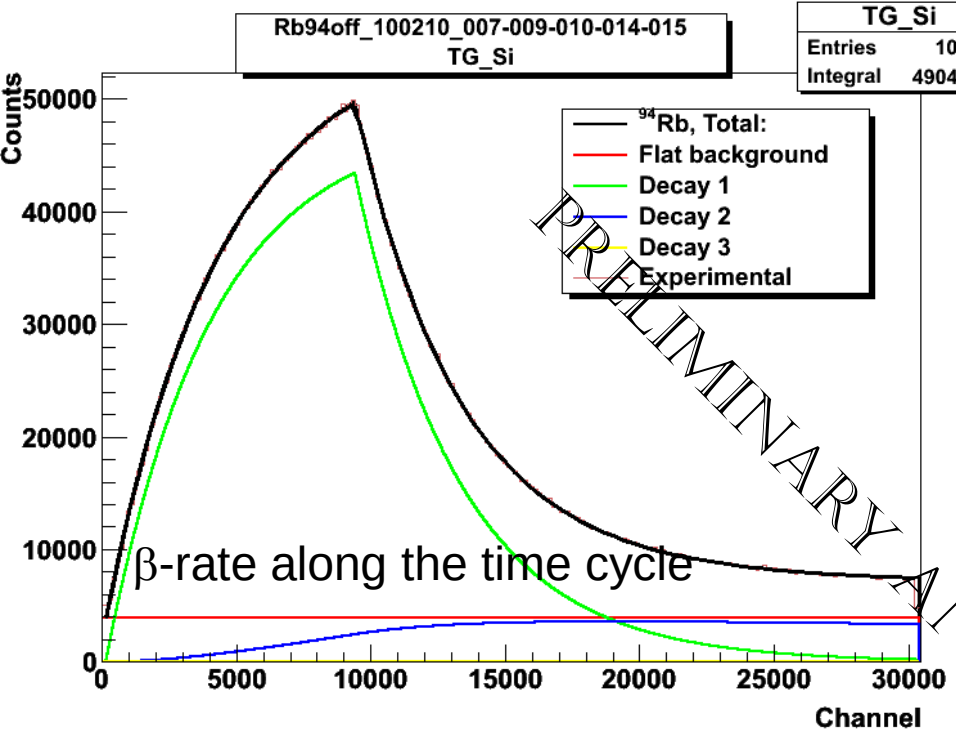
Two different configurations.

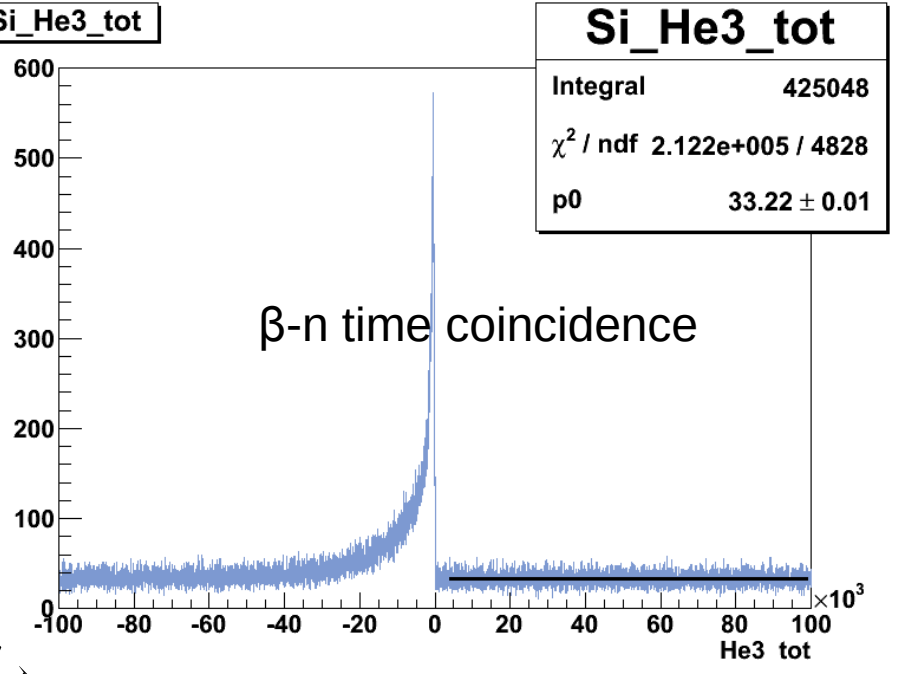
Both used successfully at JYFLTRAP for measurement of fission products











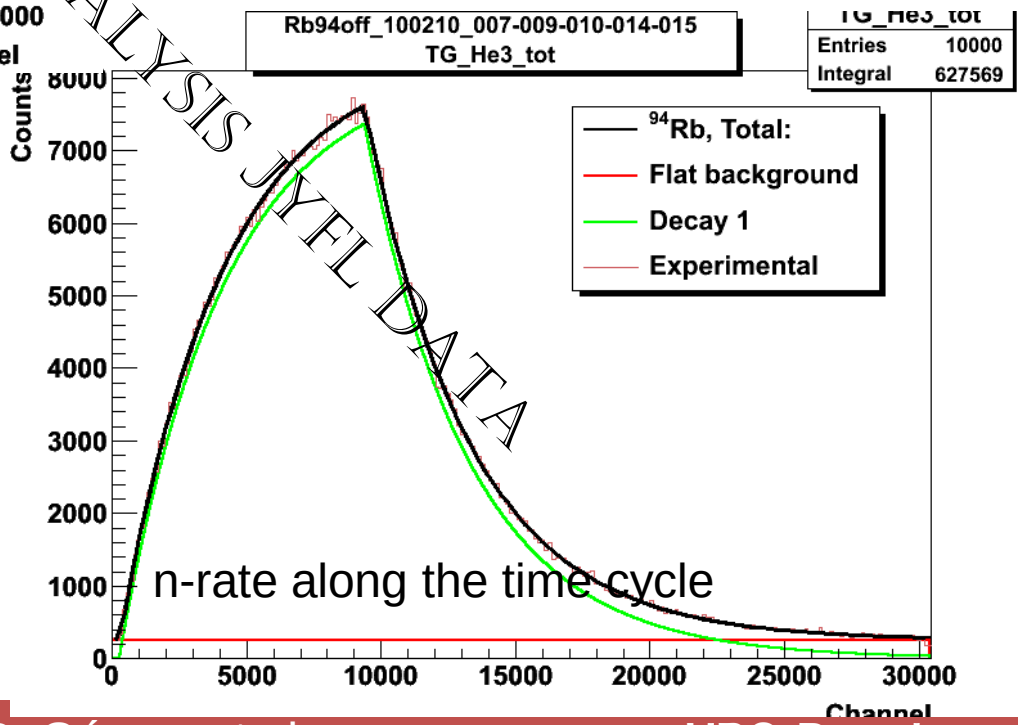
PRELIMINARY ANALYSIS JYFL DATA

Experiment at JYFLTRAP with fission products

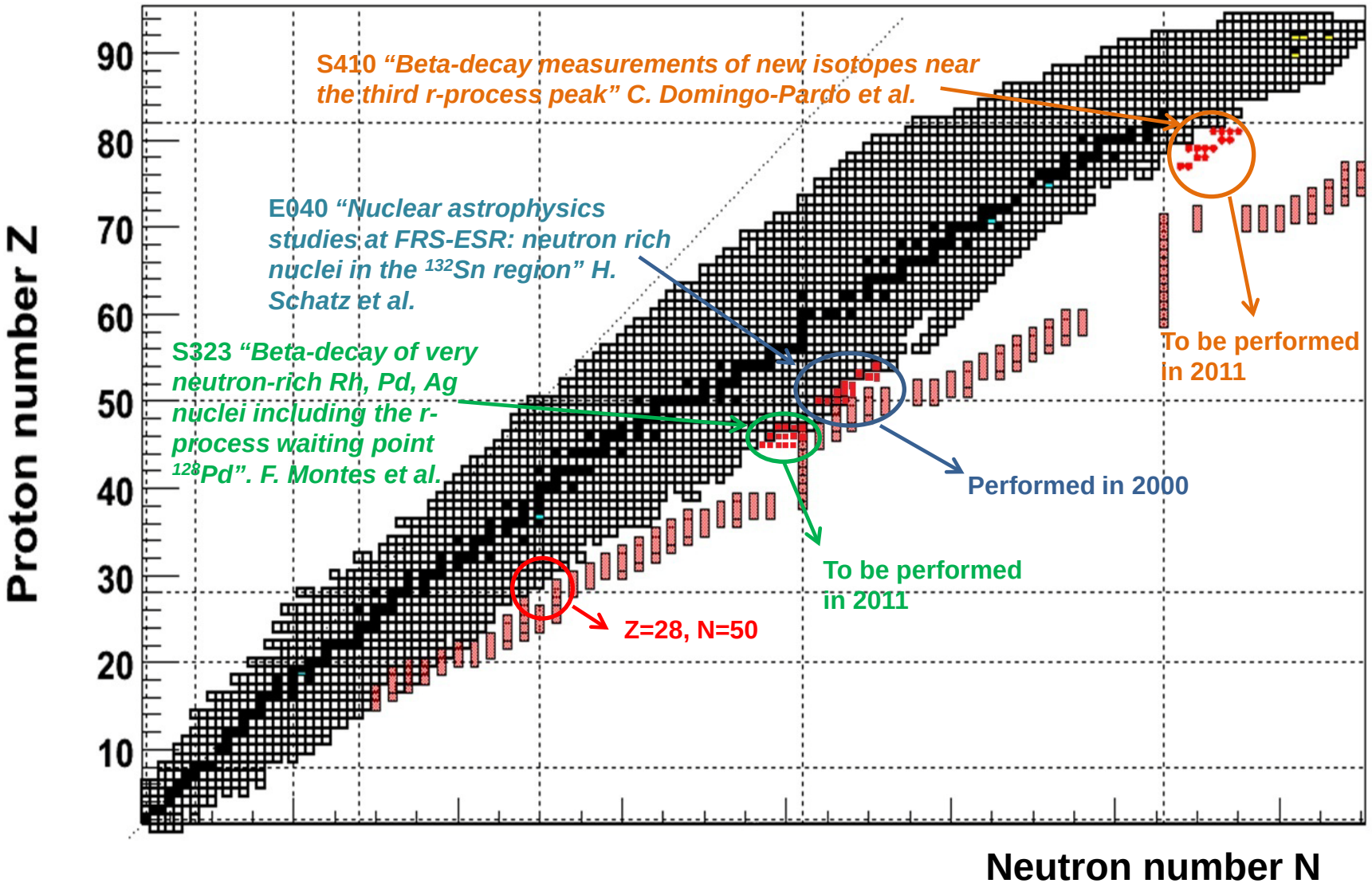
Ions were implanted on a tape for $3T_{1/2}$ and left decay for $7T_{1/2}$ before moving it away from the Si detector.

Decay fits to Bateman equations.

$$\varepsilon_n = \frac{1}{P_n}\frac{N_{\beta n}}{N_\beta}$$

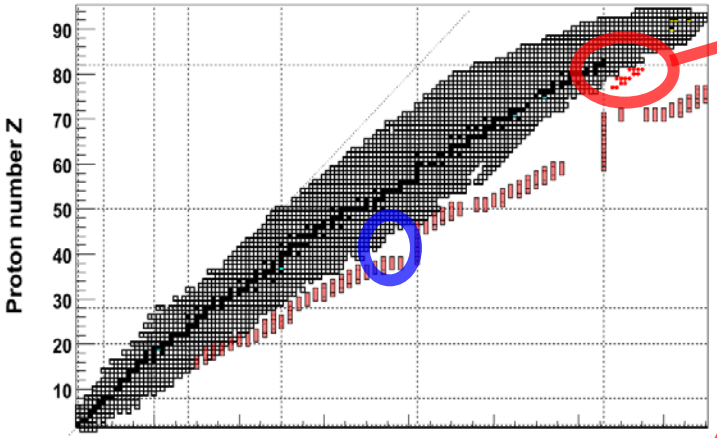


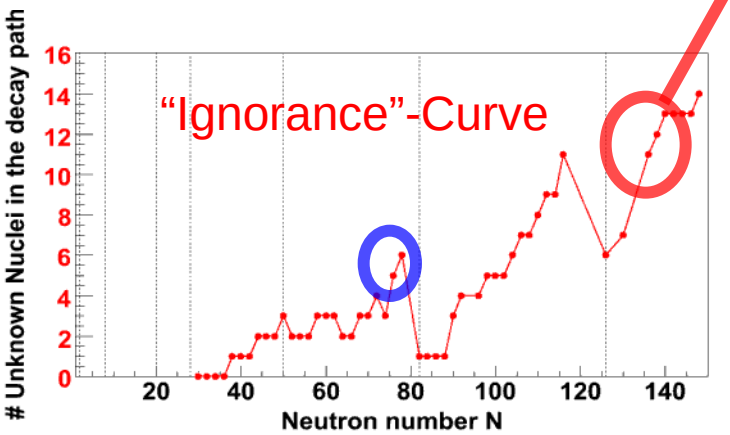
Pn measurements at GSI



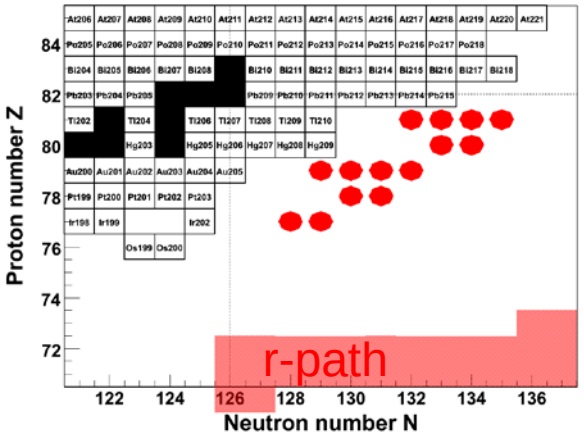
Scientific Motivation

- Explosive nucleosynthesis and the r-process around the third abundance peak

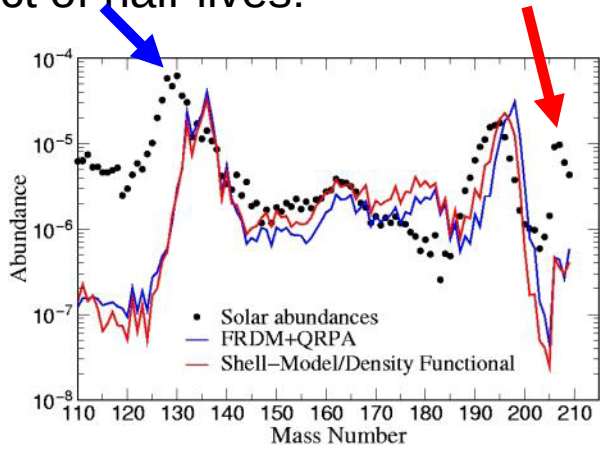




Focus of present proposals:



Effect of half-lives:

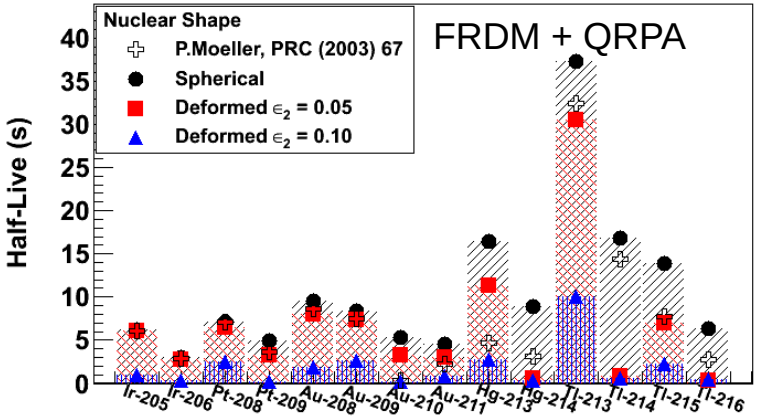


The Astr. Jour., 579 (2002), H. Schatz et al.

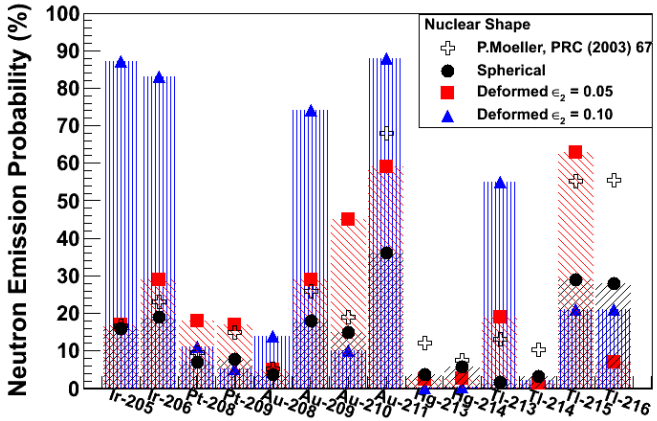
Proc. CGS-13 (2009), G. Martinez-Pinedo

Scientific Motivation

- Difficult to calculate/predict half-live and Pn-values of the nuclei in this region:



K.-L. Kratz, (private communication)



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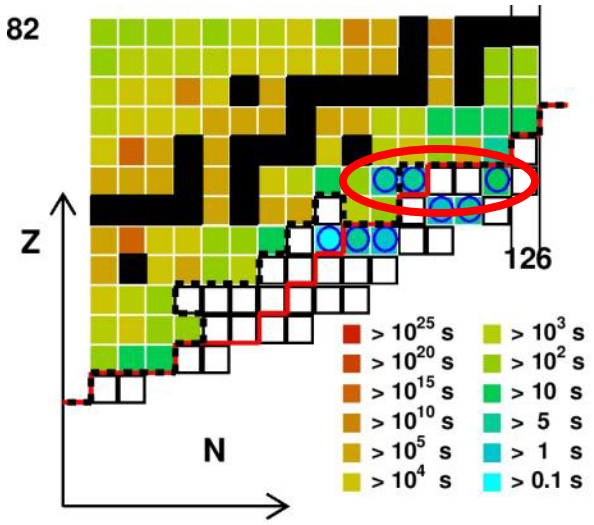
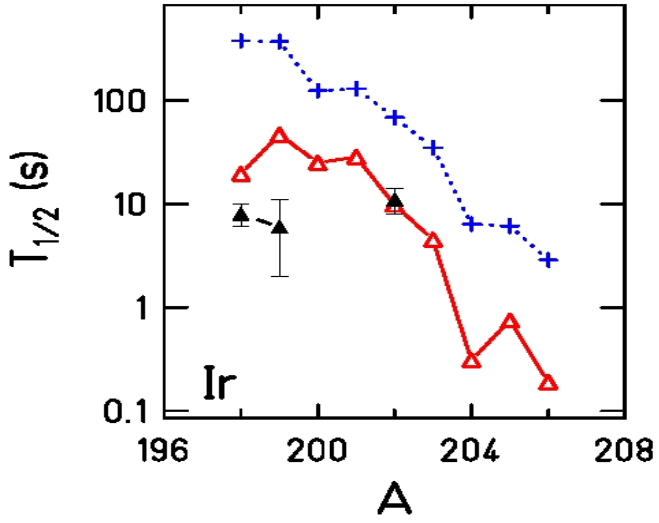




DF3 + QRPA
(I.Borzov, et al. 2003)

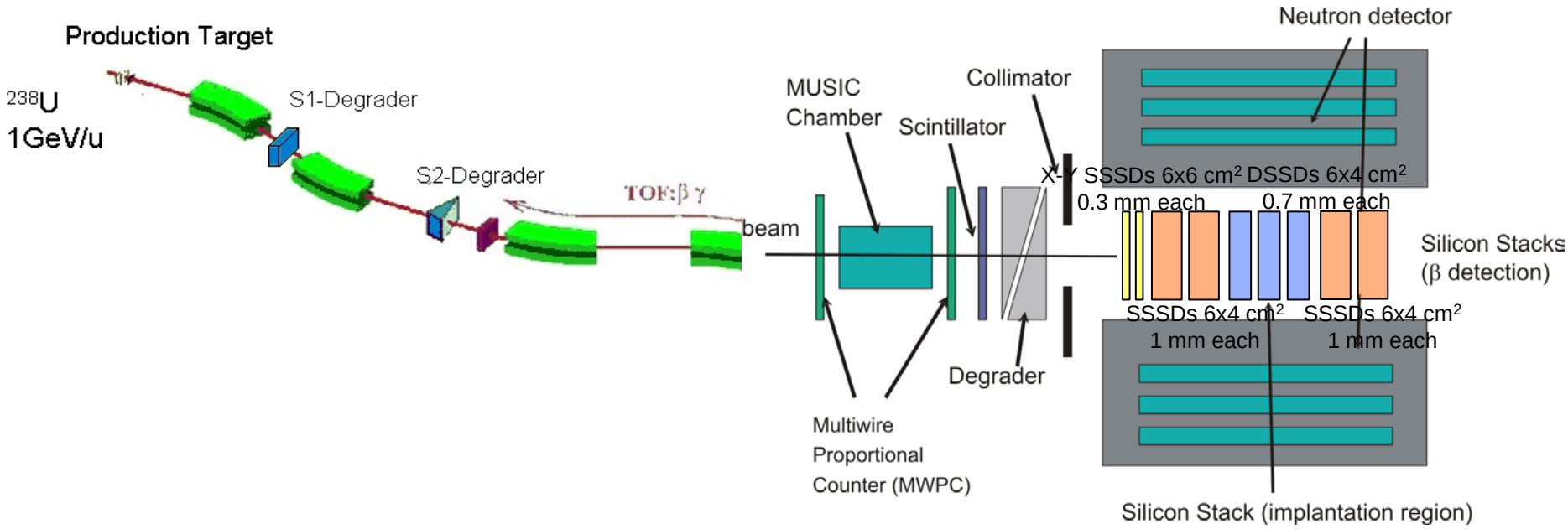
FRDM + QRPA
(P.Moeller, et al. 2003)

Exp. T. Kurtukian et al.

T. Kurtukian-Nieto, et al., Phys. Lett. B (Submitted)

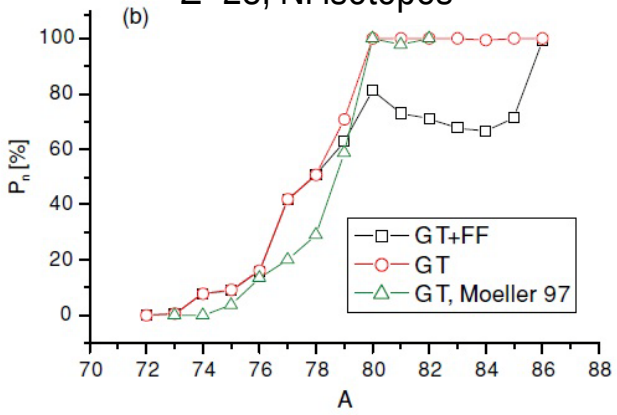
MOTIVATION & SETUP

- The measurements will help to improve/validate theoretical models for determining more accurately the beta-decay properties of the neutron rich nuclei and for the r-process.
- From the point of view of the nuclear structure, these measurements will provide the first insight into the β-strength distribution, and the relevance of FF transitions for the proposed nuclei.

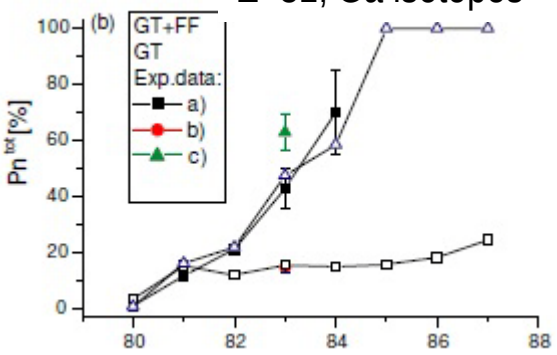


Other areas of interest

Z=28, Ni isotopes

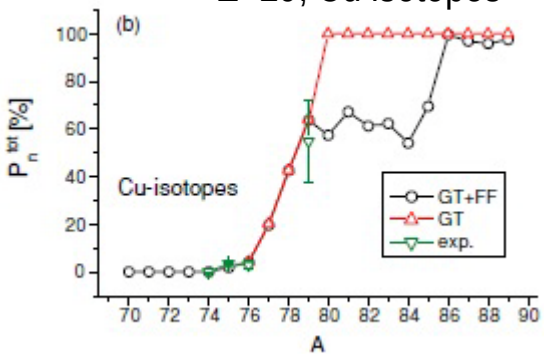


Z=31, Ga isotopes

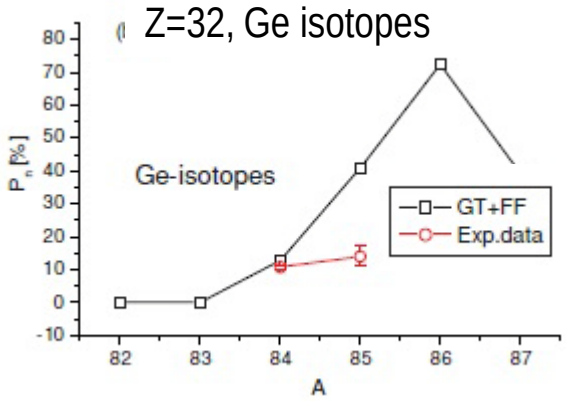


c ^{78}Ni
e and unreliable.
egion.
necked.

Z=29, Cu isotopes

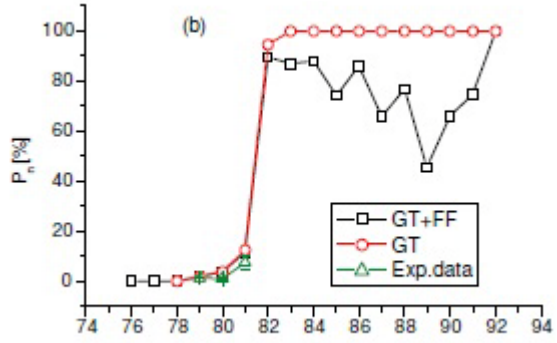


Z=32, Ge isotopes

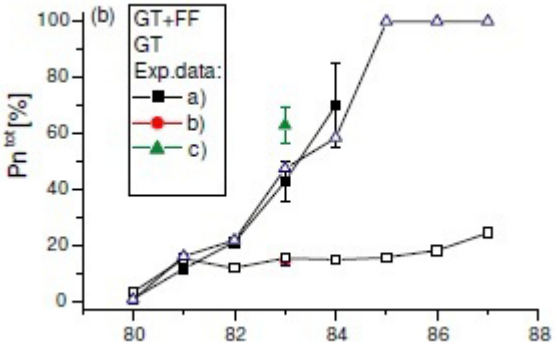


Need of experimental values to validate Gammow Teller + First Fobidden role in beta decay as shell closures are crossed in the r-process region

Z=30, Zn isotopes



Z=33, As isotopes



I. Borzov, PRC 71, 065801, (2005)

✓ Successful measurements of P_n of fission products at JYFLTRAP.

✓ Test time requested for:

- Further background test of the whole BELEN setup at GSI
- Needed to test BELEN detector + Implantation detector (AIDA) + DACQ at GSI

✓ Two proposals approved at FRS-GSI will use the BELEN detector

▪ S323 *"Beta-decay of very neutron-rich Rh, Pd, Ag nuclei including the r-process waiting point ^{128}Pd".* F. Montes et al.

▪ S410 *"Beta-decay measurements of new isotopes near the third r-process peak".* C. Domingo et al.

✓ Interest in the Z=28, N=50 area around doubly magic ^{78}Ni.

SUMMARY

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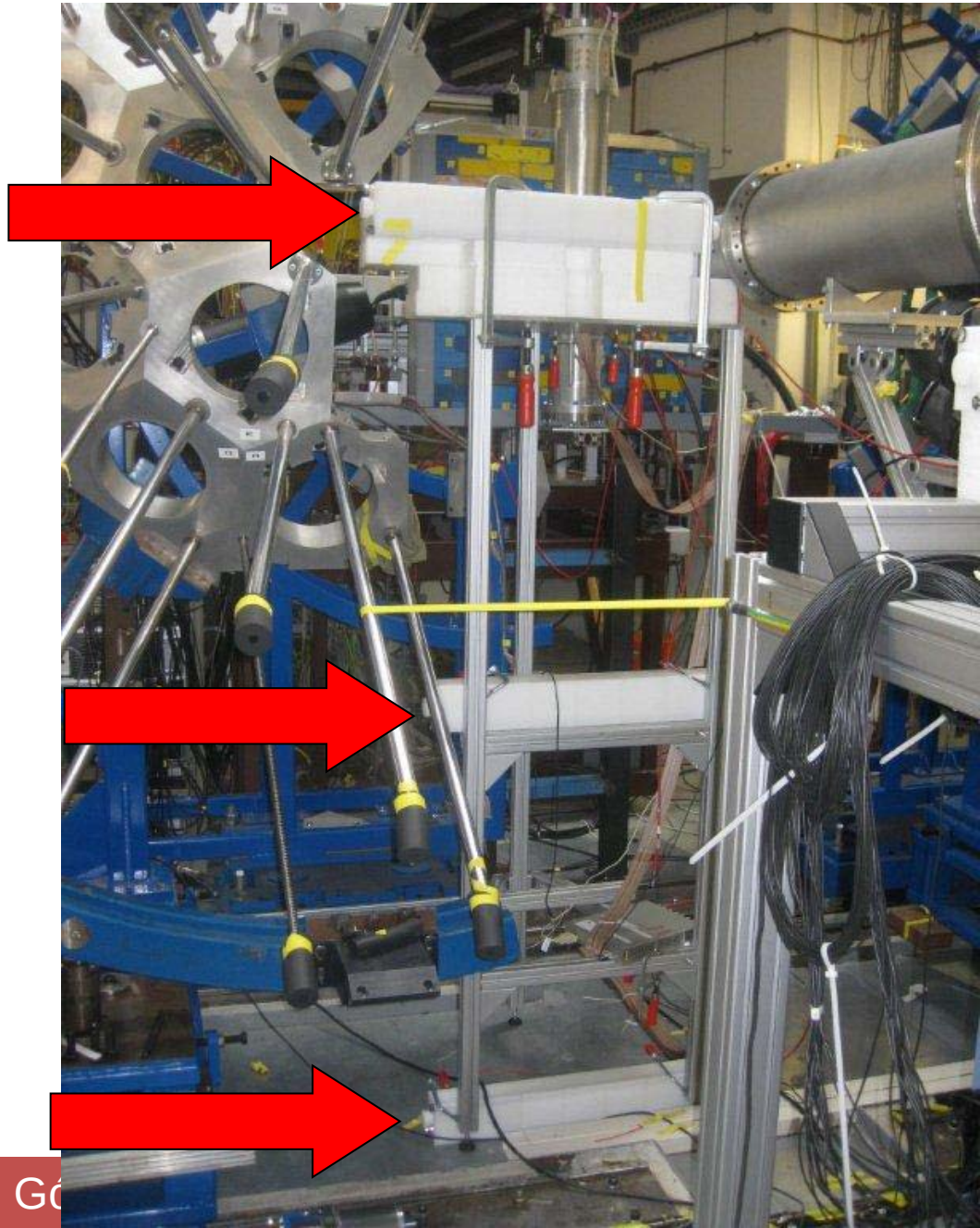
Background test has been performed at GSI

✓ A test has been performed at S4 to study the neutron background with beam.

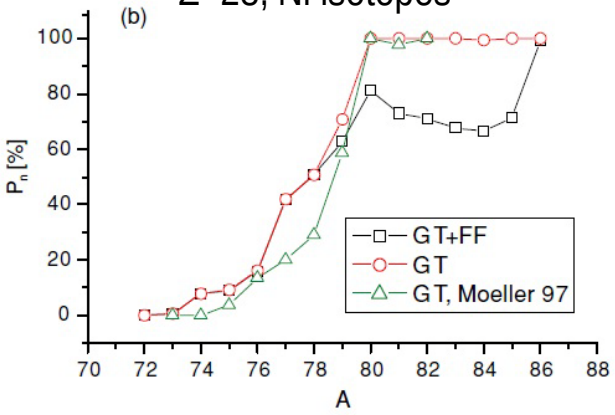
✓ Six counters with individual polyethylene matrix were deployed around S4 to study the neutron background around the experimental hall and in different beam conditions.

✓ Data is currently under analysis.

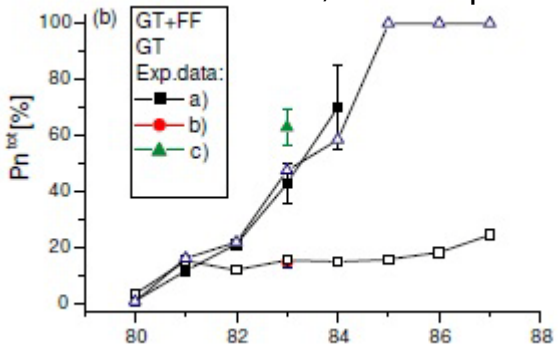


Theoretical Pn predictions

Z=28, Ni isotopes



Z=31, Ga isotopes



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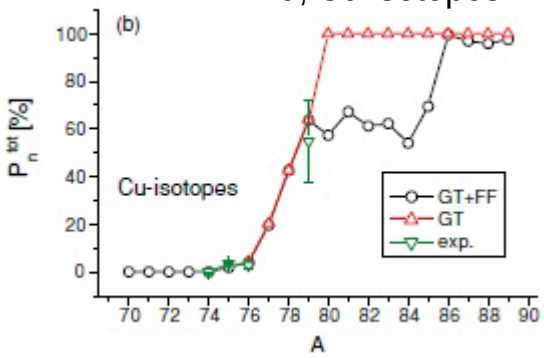

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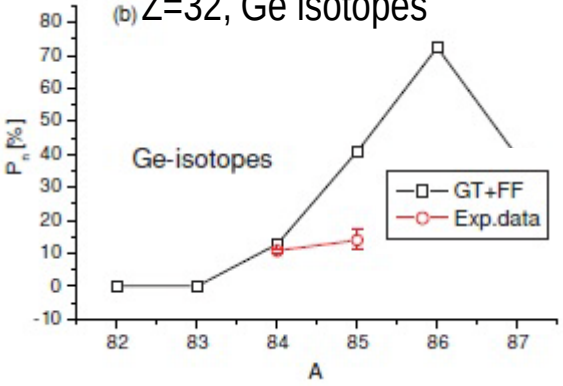
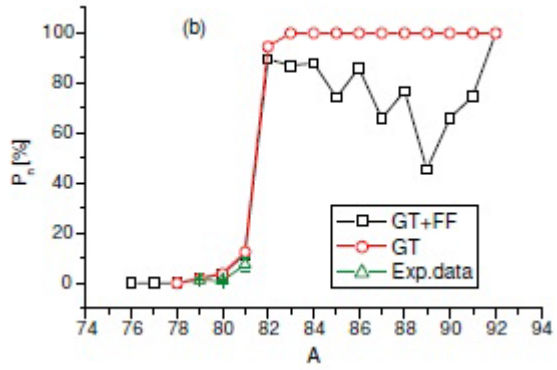
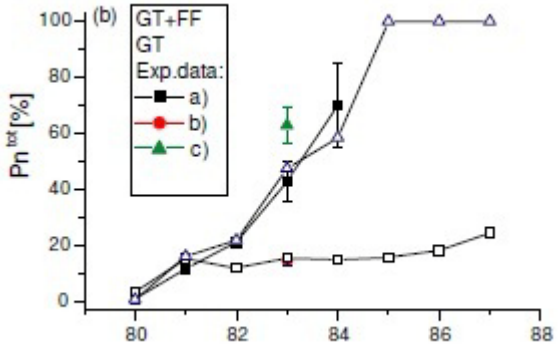


Z=30, Zn isotopes



Z=33, As isotopes

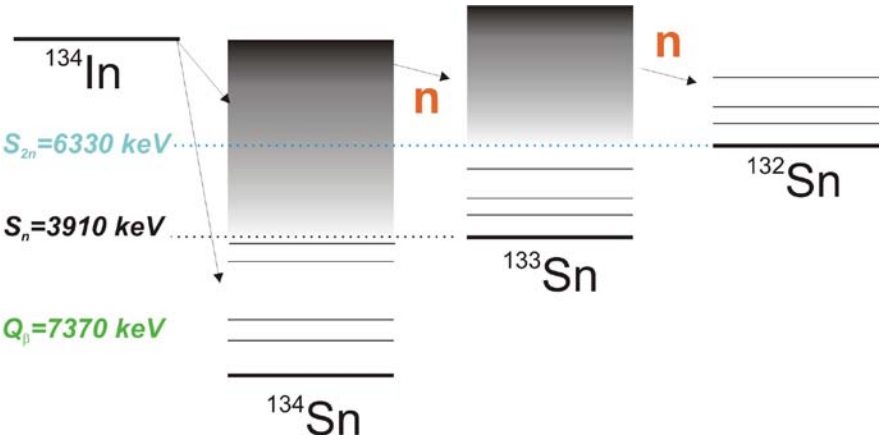


Need of experimental values to validate Gammow Teller + First Fobidden role in beta decay as shell closures are crossed in the r-process region.

I. Borzov, PRC 71, 065801, (2005)

Influence of P(1n) and P(2n)

During „Freeze-out“:
detour of β-decay chains
⇨ *solar r-abundance changes*



QRPA predictions:
β-decay: 0%
P(1n): 0.6 %
P(2n): 99.4%

In 134
138 ms
βn, β2n

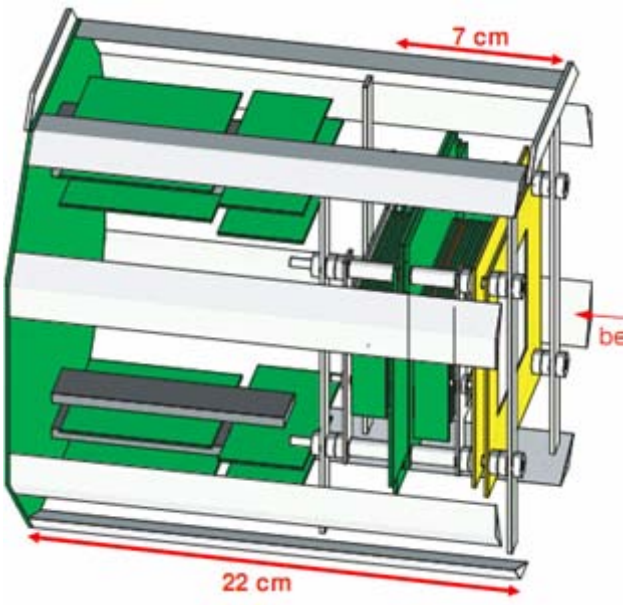
Silicon IMplantation detector and a Absorber

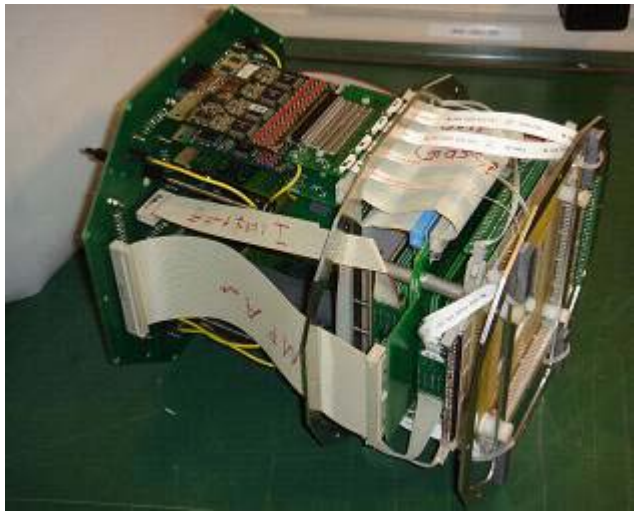
SIMBA

Constructed and developed at

Technische Universität München

Lehrstuhl E12



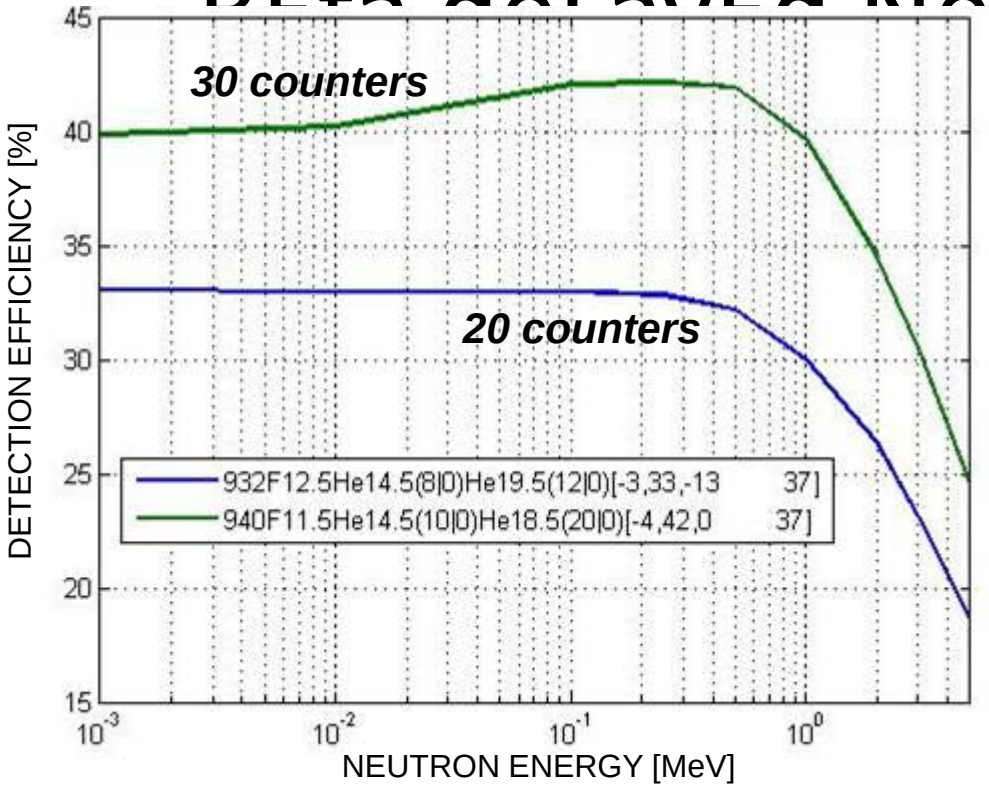


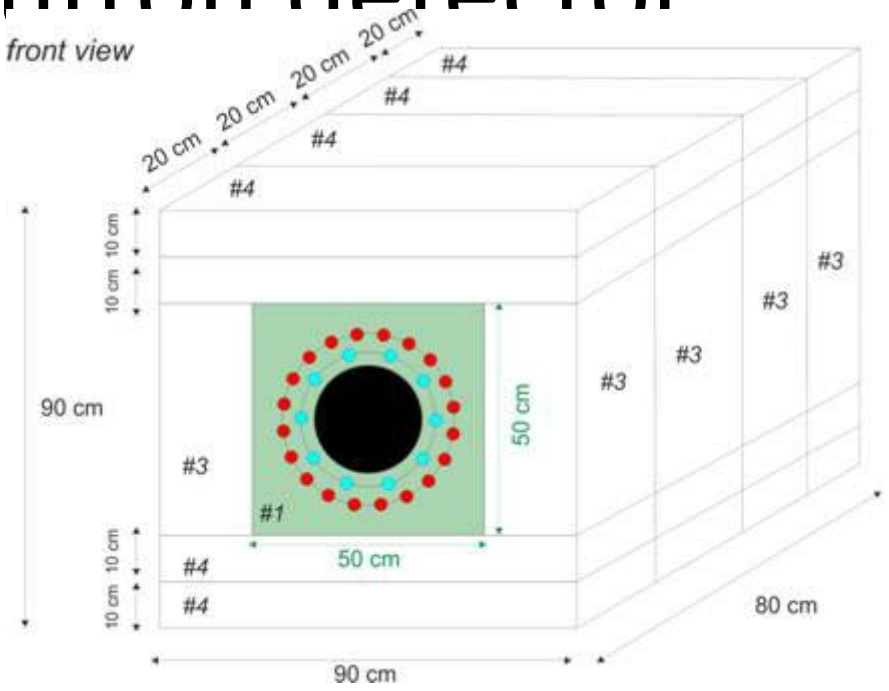
- 1 x and 1 y-detector, 60x60x0.3 mm^3, 60fold segmented each
- 2 SSSSD, 60x40x1 mm^3, 7fold segmented in x
- 3 DSSSD (implantation area), 60x40x0.7 mm^3, 60fold segmented in x-, 40fold in y-direction
- 2 SSSSD, 60x40x1 mm^3, 7fold segmented in x

PhD thesis C. Hinke, TUM (2010)
Diploma thesis K. Steiger, TUM (2009)

Pictures: K. Steiger

BEta delayEd Neutron detector





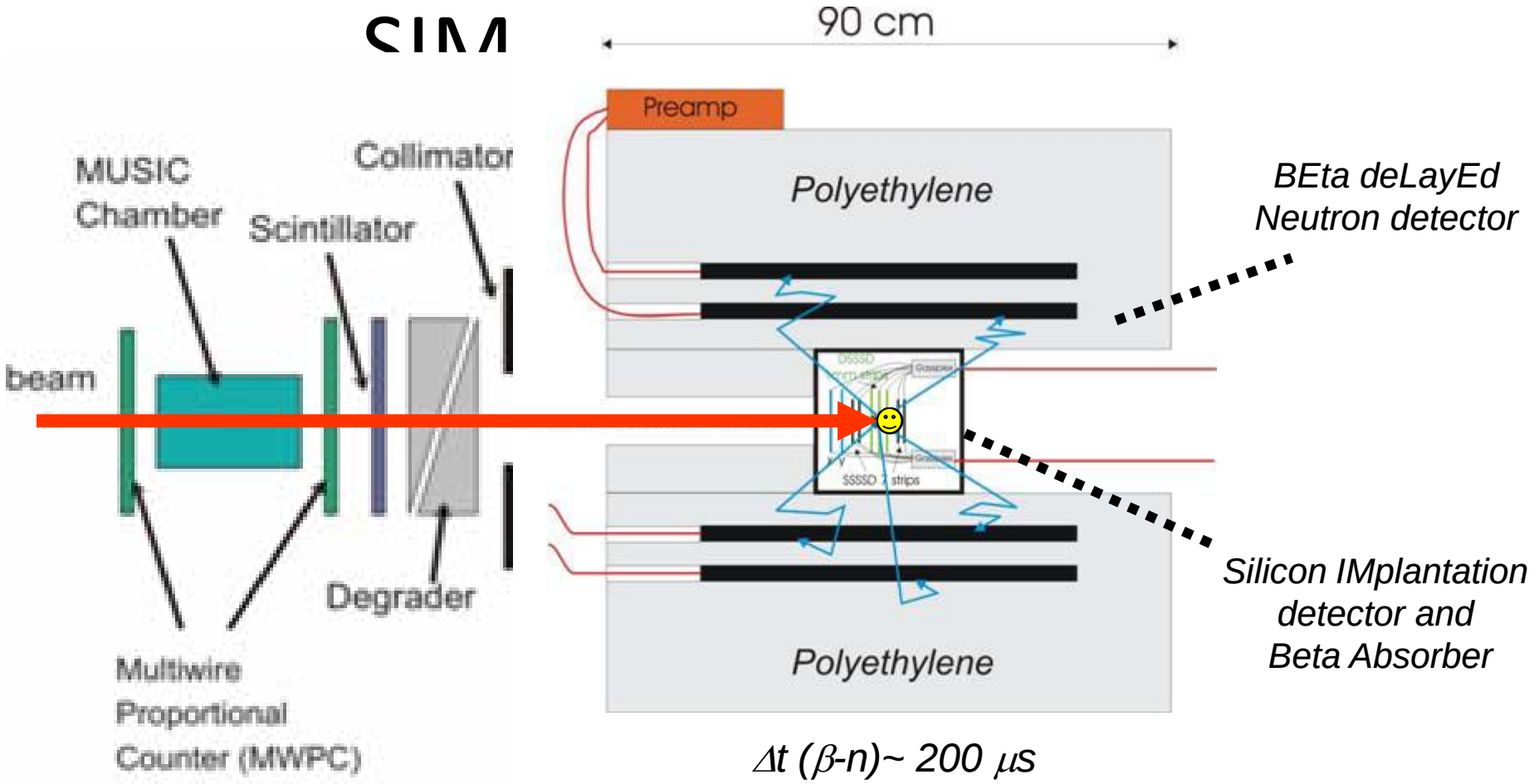
20 ^{3}He counters (20 atm) +
10 ^{3}He counters (10 atm)
Efficiency 40%

„BELEN-30“ (2011)

ca. 1t PE
Value of ^{3}He: 625 k$
(worldwide shortage)

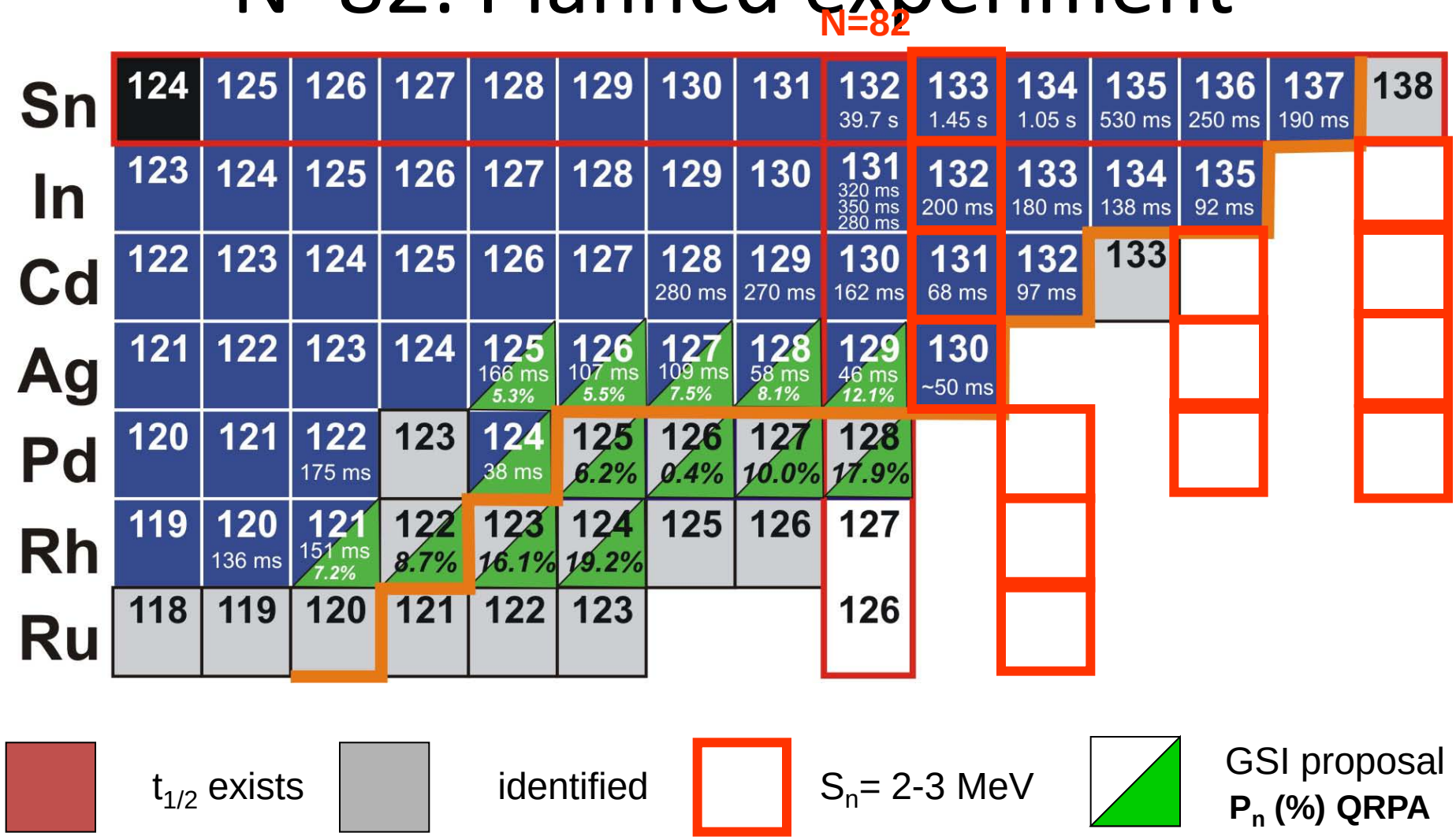
M.B. Gómez Hornillos et al., Proc. Int. Conf. on Nucl. Data for Science and Techn. (2010)

SIM

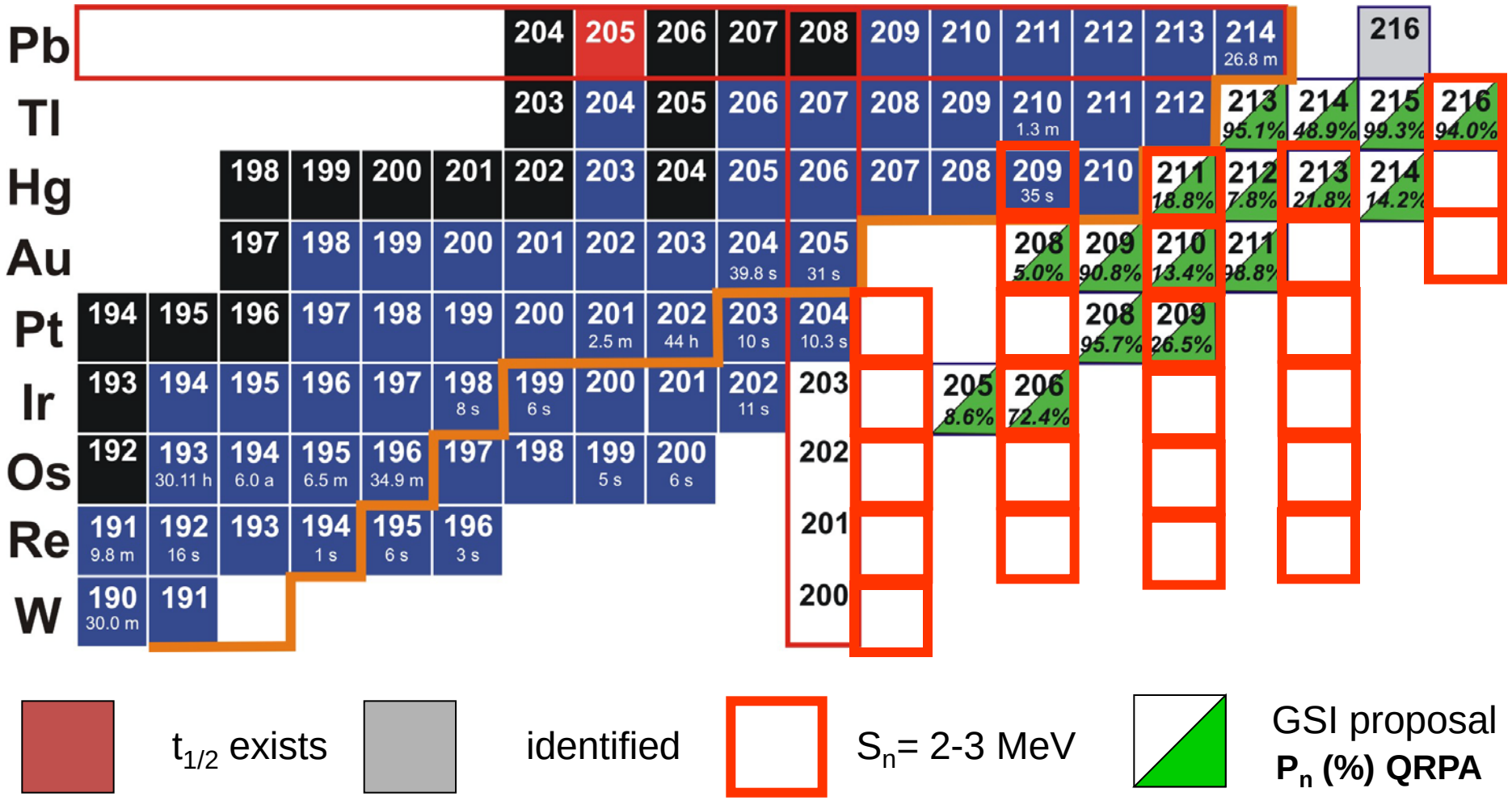


- 2 experiments planned for 2011
- Collaboration with MSU/NSCL, TUM, Barcelona/Valencia/Madrid

N=82: Planned experiment



N=126: Planned experiment



• The neutron emission probability P_n determines the delayed neutron fraction β_{eff} : reactor kinetics. More accurate measurements will improve summation calculations for GenIV reactors with MA containing fuel

Fission Fragment distribution