β-delayed neutron emission probability (P_{xn}) measurements as a candidate for ES

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Super-FRS Experiment Collaboration Meeting

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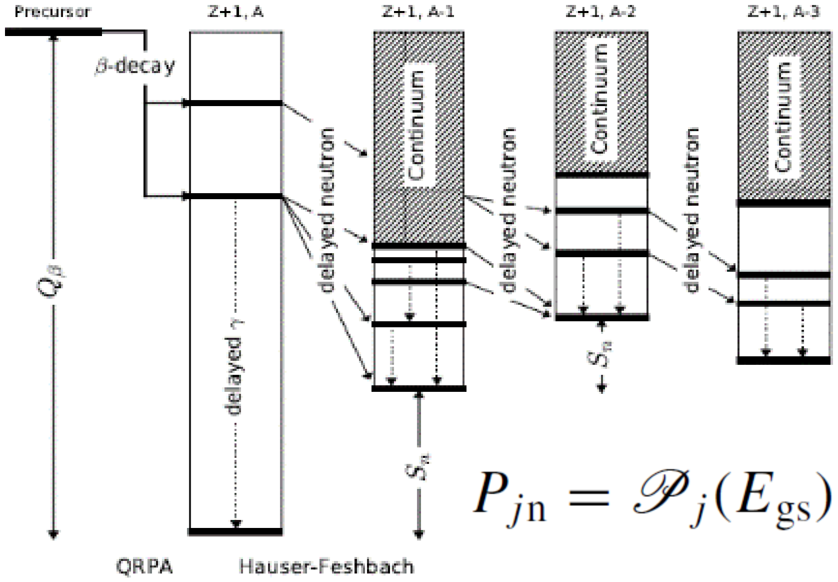
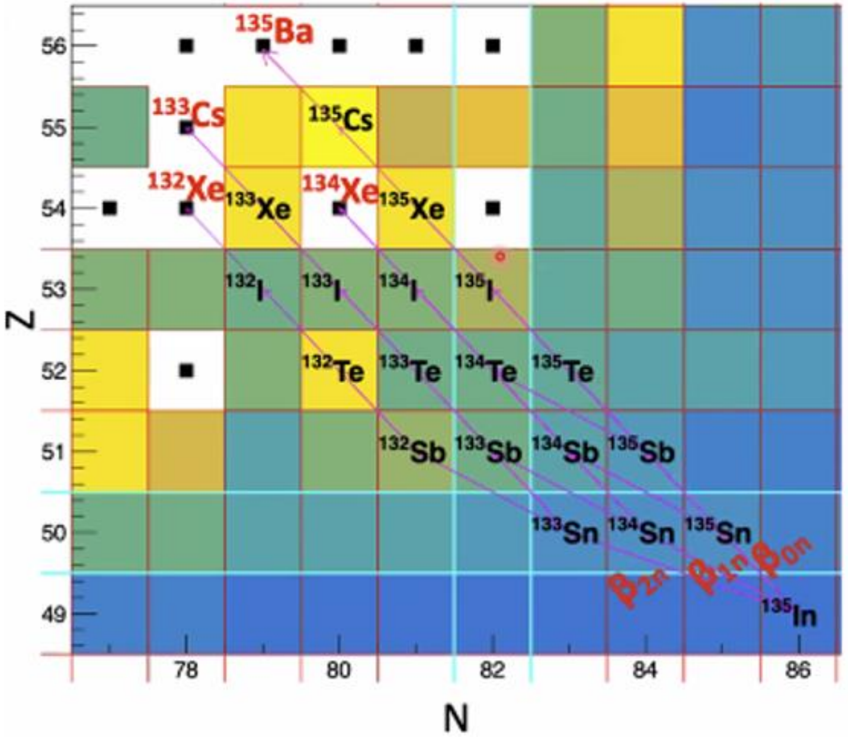
Motivation for P_{xn} measurements

- **r-process nucleosynthesis[1]**
  - Detours in β-decay chains
  - More neutrons during freeze-out
- **Nuclear physics models[2]**
  - Calculations of n-γ competition
  - Optical models for neutron transmission in the nucleus
  - Nuclear energy level schemes
- **Nuclear reactor operation[3]**
  - Next generation reactors
  - New fuel types
  - Accelerator Driven Systems
- **Worldwide βxn programs[3]**
  - Mostly using n, β, γ detectors
  - Usually, no direct recoil identification



$$P_{jn} = \mathscr{P}_j(E_{gs})$$



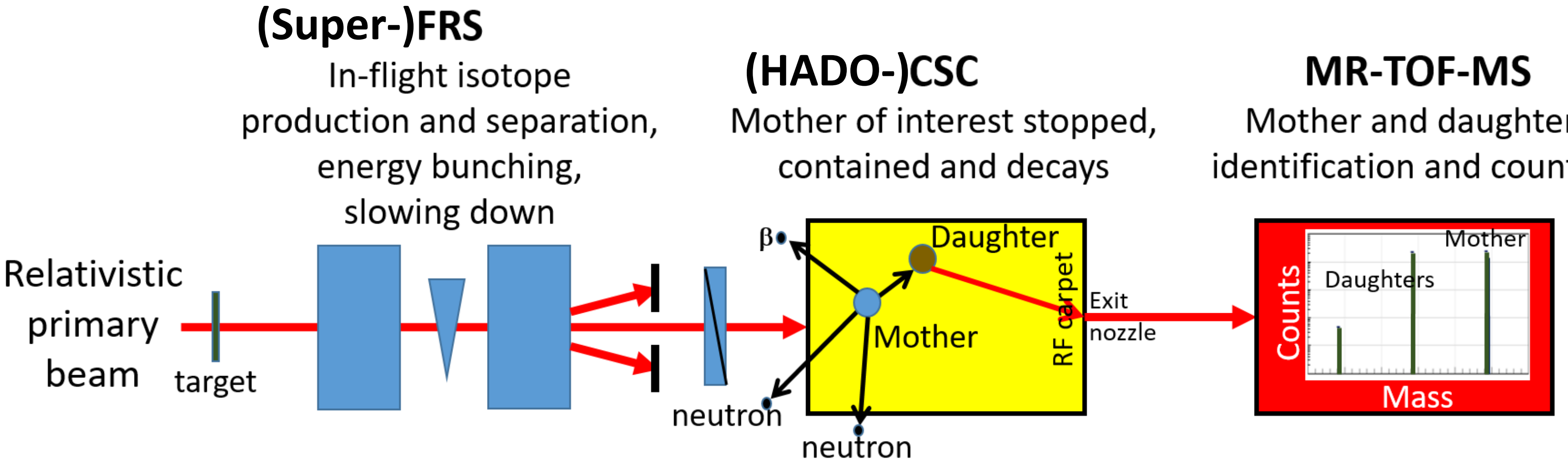
[1] R. Surman et al., JPS Conf. Proc. , 010010 (2015)

[2] M. R. Mumpower et al., Physical Review C 94, 064317 (2016)

[3] P. Dimitriou et al., Development of a Reference Database for Beta-Delayed Neutron Emission, Nuclear Data Sheets 173, 144 (2021)

P_{xn} measurement at an Ion Catcher

- A novel method for measuring **β-delayed single- and multi-neutron emission probabilities** (**P_{xn}**), simultaneously with **mass**, **$Q_{\beta xn}$**, **S_{xn}** and **$T_{1/2}$**



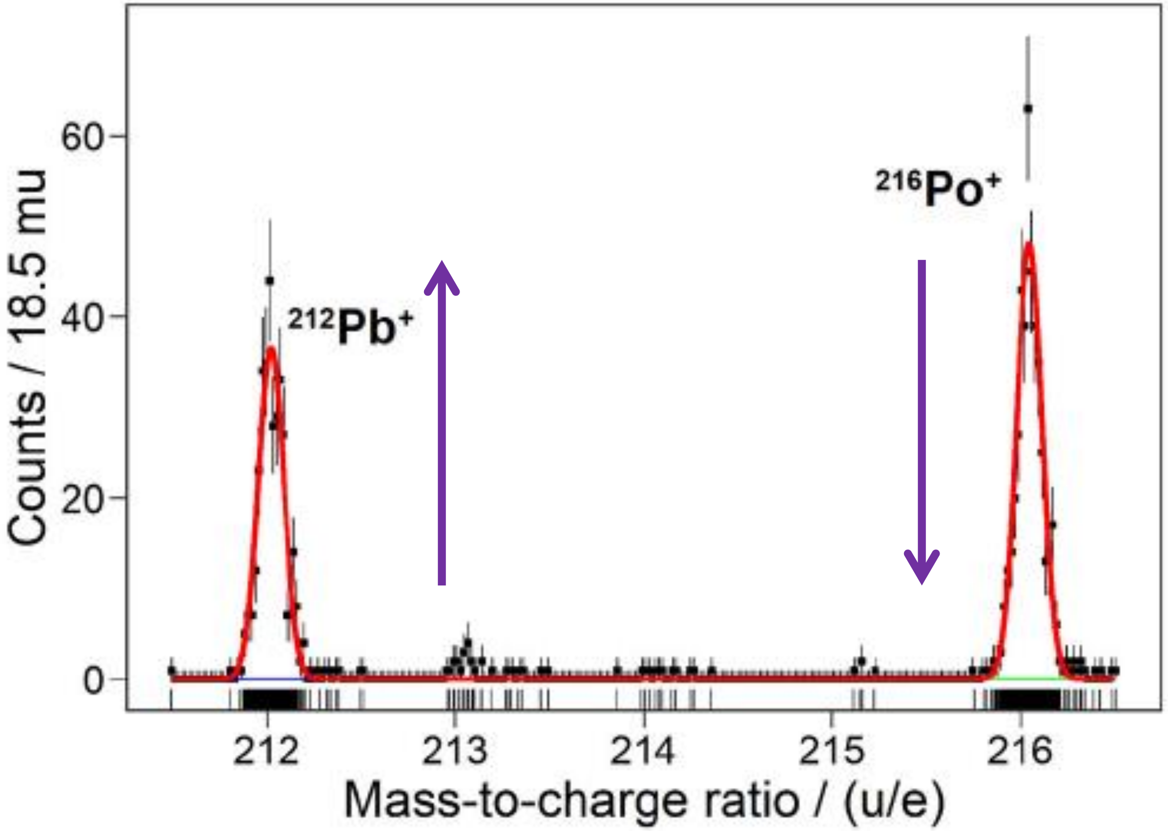
- P_{xn} is determined by the ratios between the daughters: $$P_{xn} = \frac{D_i(t_s)}{\sum D_i(t_s)}$$
- Method is **complementary** to worldwide programs
- Especially suited for **multi-neutron** emission probabilities

'Straight forward' analysis
Isotopes of same element
Hardly any corrections needed

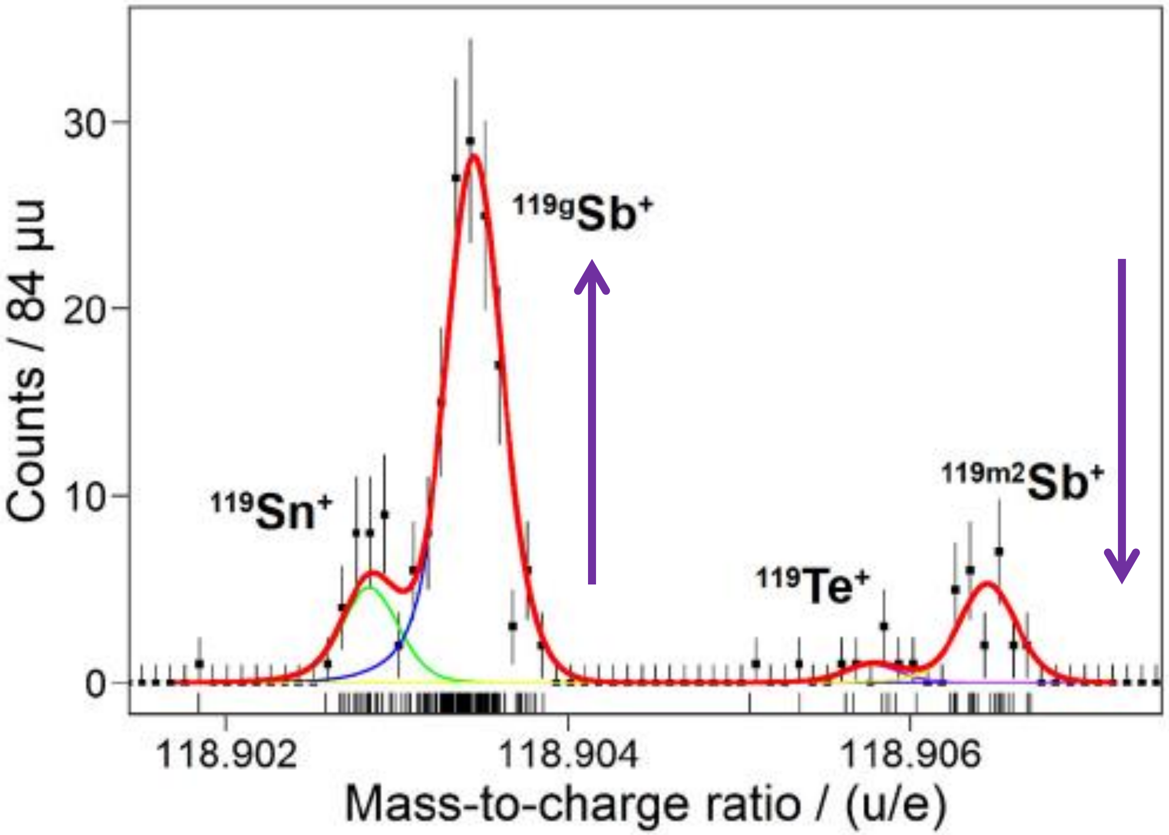
I. Miskun et al., A novel method for the measurement of half-lives and decay branching ratios of exotic nuclei, Eur. Phys. J. A (2019) 55: 148

Branching-ratio and half-life demonstration @ FRS-IC (1/2)

α decay



Internal Transition

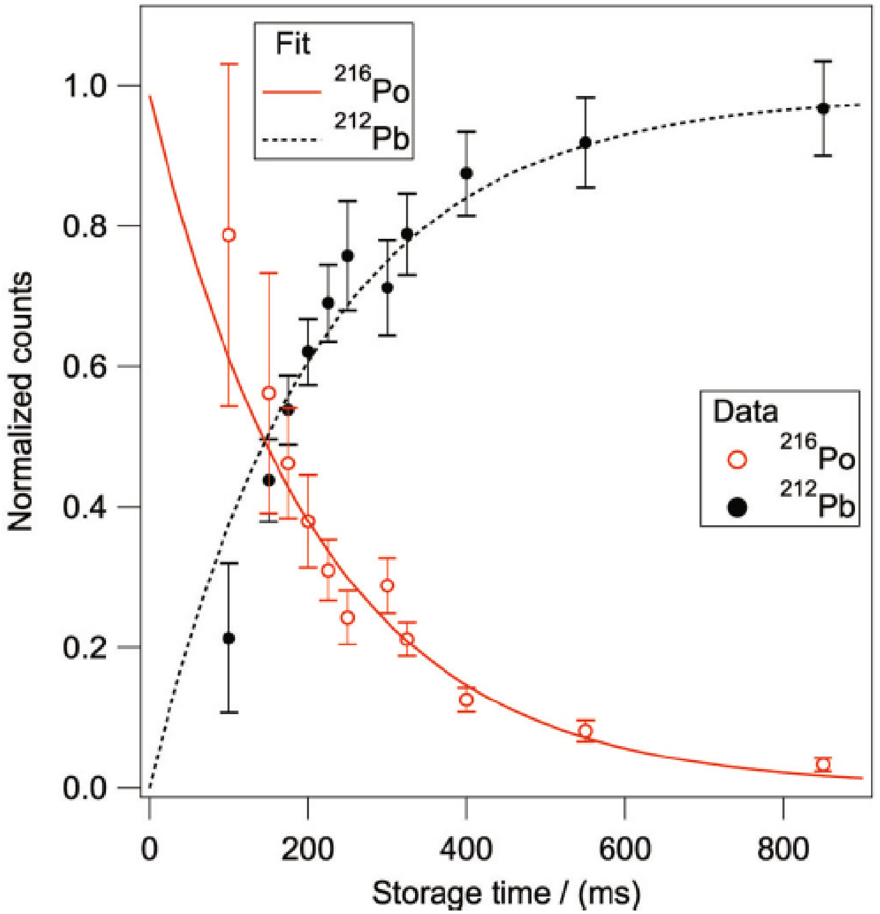


Repeat measurement for several CSC storage times – Extract half-life and branching ratios, reduce beam related background

I. Miskun et al., A novel method for the measurement of half-lives and decay branching ratios of exotic nuclei, Eur. Phys. J. A (2019) 55: 148

Branching-ratio and half-life demonstration @ FRS-IC (2/2)

α decay



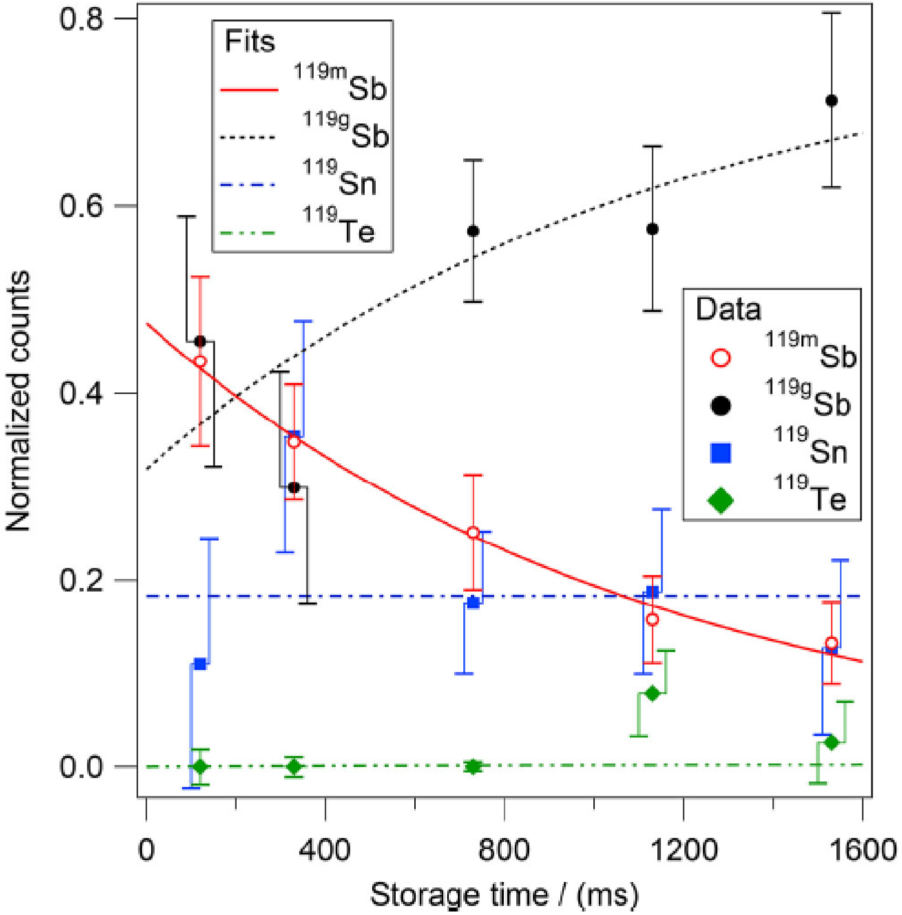
Overall fits results

^{216}Po half-life [ms]	
FRS-IC	145 ± 11
Literature	145 ± 2

^{119m}Sb half-life [ms]	
FRS-IC	784 ± 203
Literature	850 ± 90

^{119m}Sb branching ratios	
IT (^{119g}Sb)	0.99 ± 0.51
β^+ (^{119}Sn)	0.00 ± 0.45
β^- (^{119}Te)	0.01 ± 0.08

Internal Transition



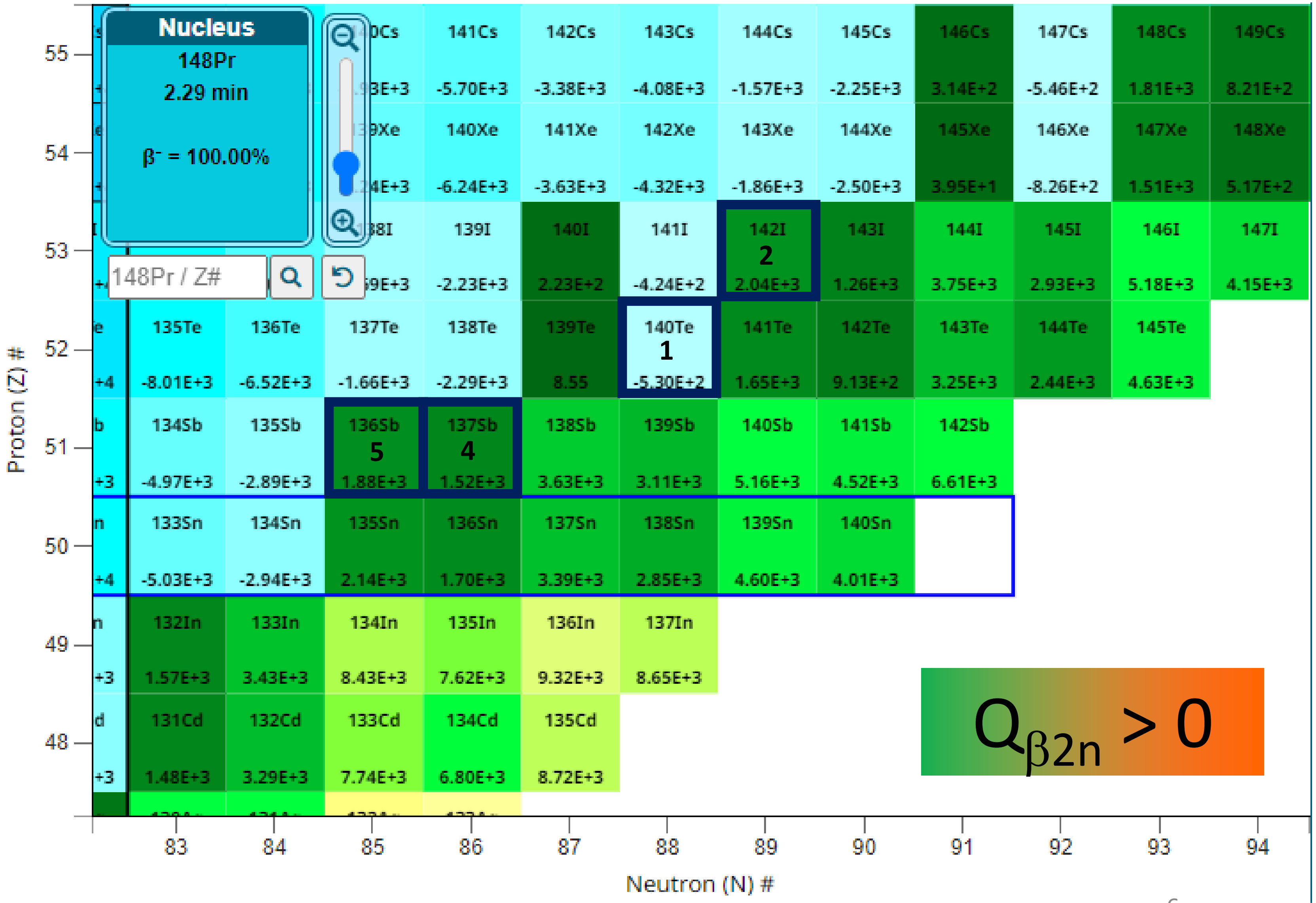
I. Miskun et al., A novel method for the measurement of half-lives and decay branching ratios of exotic nuclei, Eur. Phys. J. A (2019) 55: 148

Proposed P_{2n} measurements at FRS-IC (2020)

S528 Proposed P_{2n} measurements

^{A}X
P_{2n}/hour
$Q_{\beta 2n}$ [keV]

12 P_{1n} and **4 P_{2n} in 18 shifts**



Proposed P_{2n} measurements at Super-FRS-IC (ES, 2026)

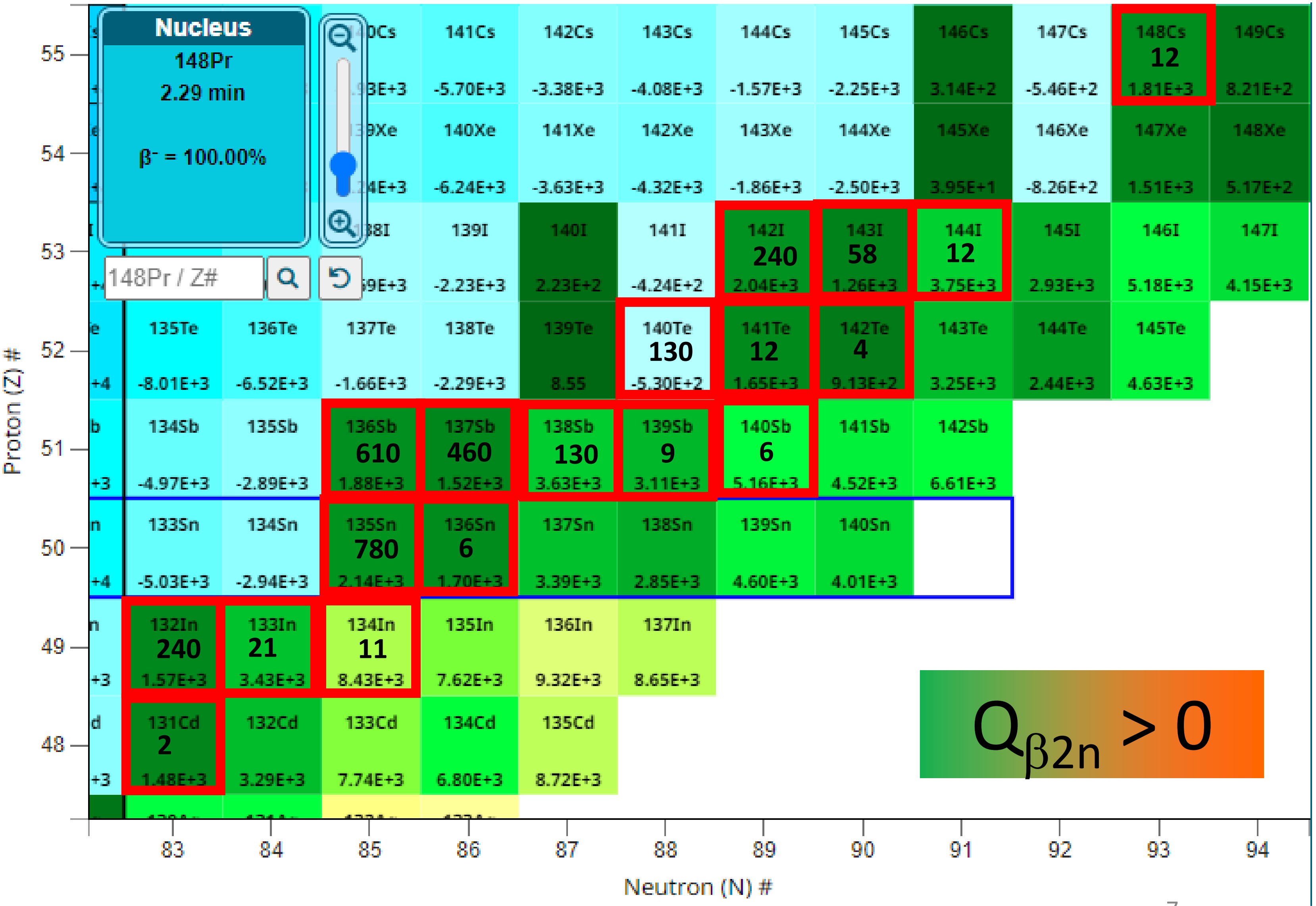
Measured fission products improvement

Parameter	Factor
^{238}U @ production target	~3
Super-FRS transmission	~8
Super-FRS Ion Catcher	~5
Total	**~120**

+

Improved S-FRS separation reduces background by order(s) of magnitude

High-mass peak
~18 P_{2n} in ~15 shifts



Proposed P_{2n} measurements for ES

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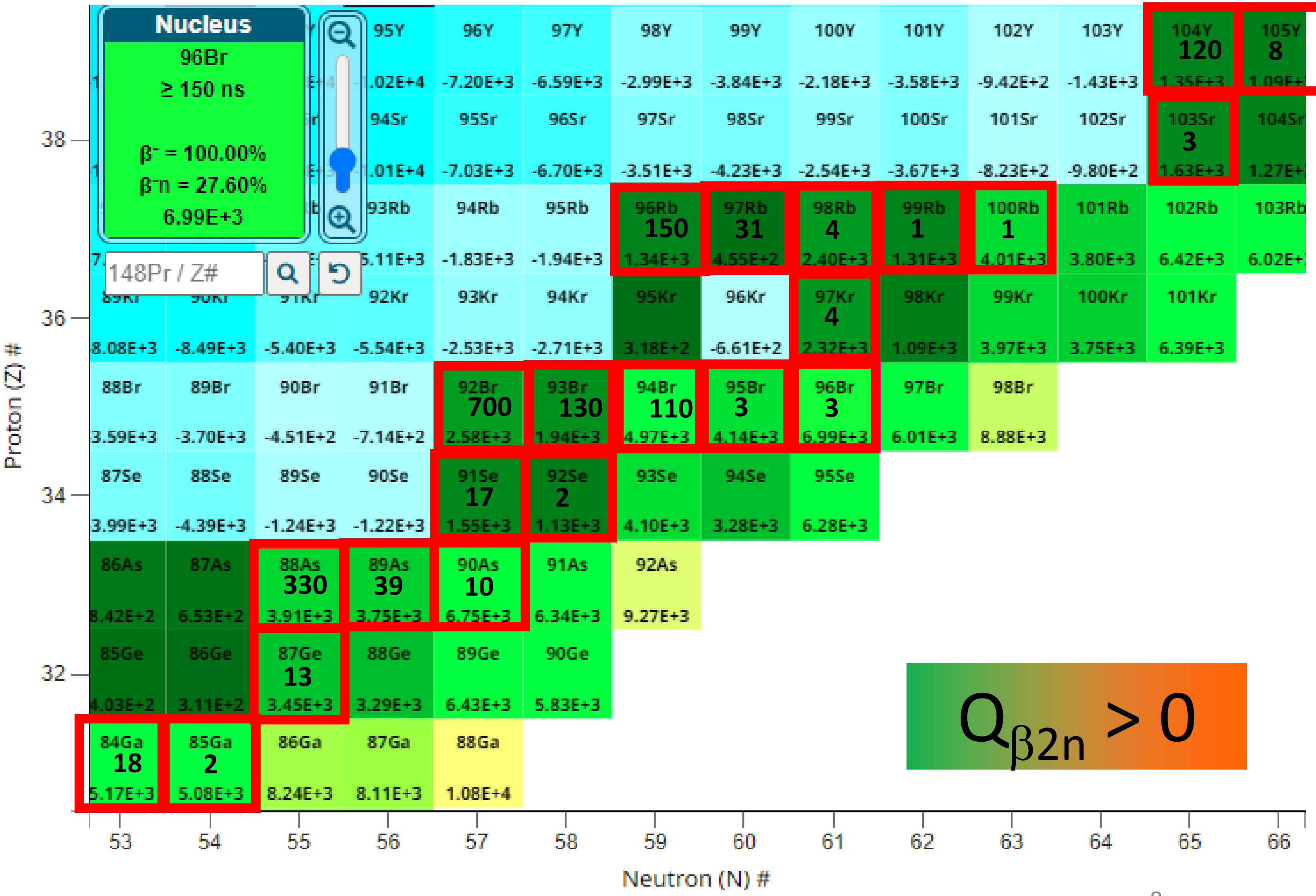

Proposed P_{2n} measurements for ES

Summary and Conclusions

- During Early Science we will be able to measure ~30-35 P_{2n} values
  - New measurements
  - Replace upper limits
  - Re-check cases where other methods reported $P_{2n}= 0$ for $Q_{\beta 2n} > 0$
  - Improve uncertainties
- Data analysis is ‘straight forward’ - for many cases, ‘almost final’ results will be available online
- Try to demonstrate first P_{1n} results during n-skin experiment in 2025
- Good example of utilizing the enhanced transmission and separation of Super FRS, even with similar primary beam intensity

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FRS Ion Catcher Collaboration

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