New Half-Lives of r-Process Nuclei in the Vicinity of ^{78}Ni

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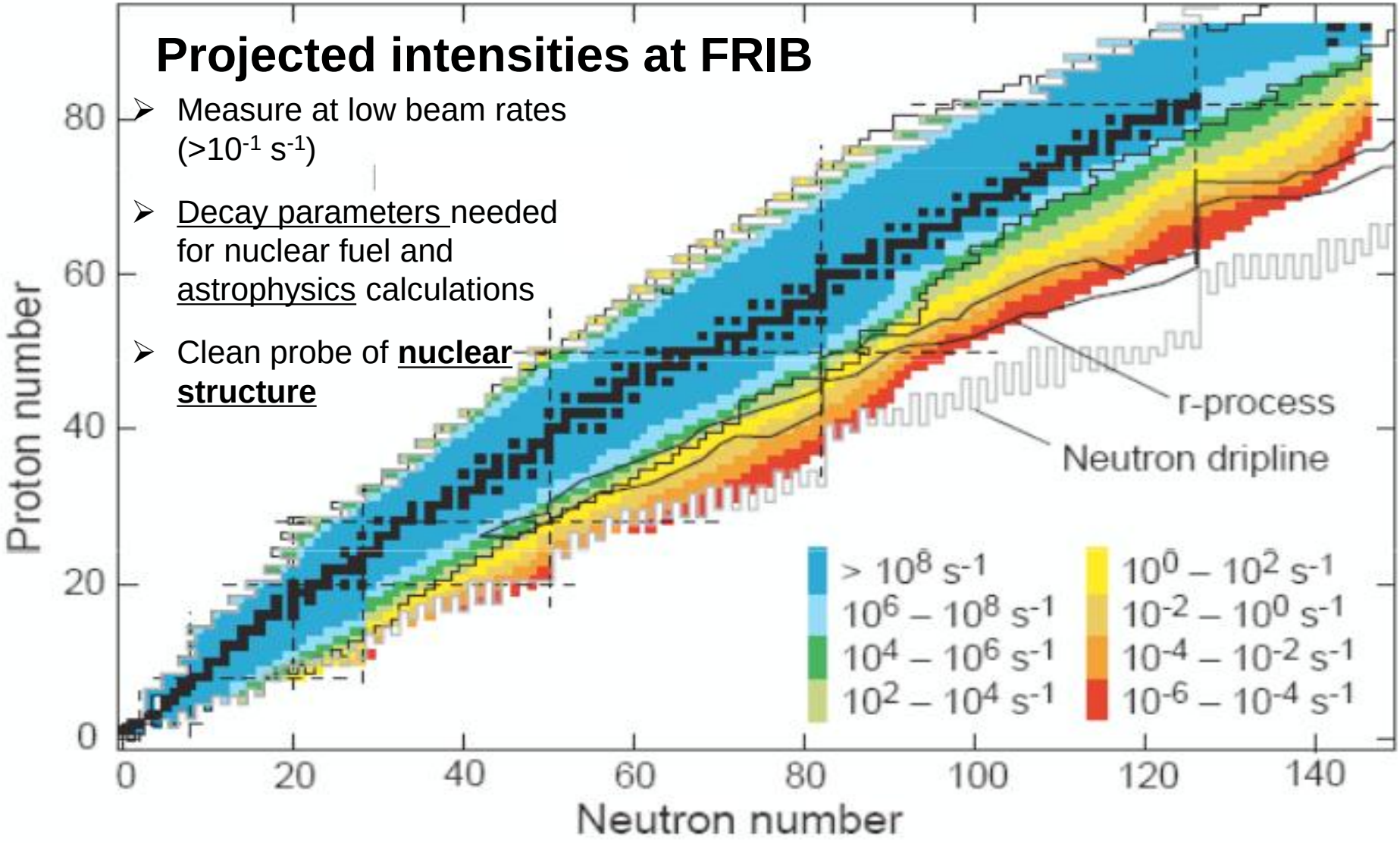
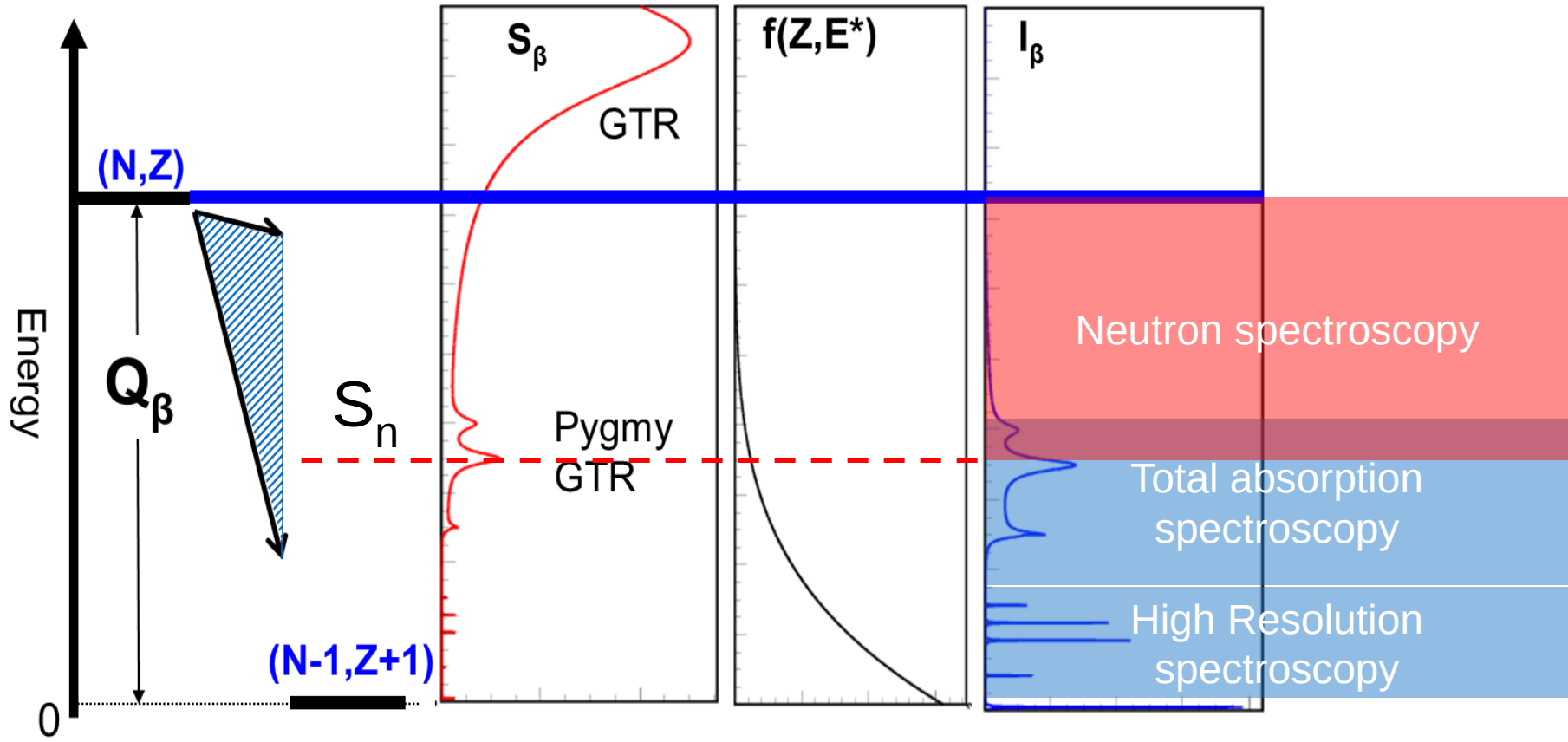
Why beta decay?



Beta decay of neutron rich nuclei

$$\frac{1}{T_{1/2}} = \sum_{E_i \geq 0}^{E_i \leq Q_\beta} S_\beta(E_i) \times f(Z, Q_\beta - E_i)$$

$$S_\beta(E_i) = \langle \psi_f | \hat{O}_\beta | \psi_{mother} \rangle$$

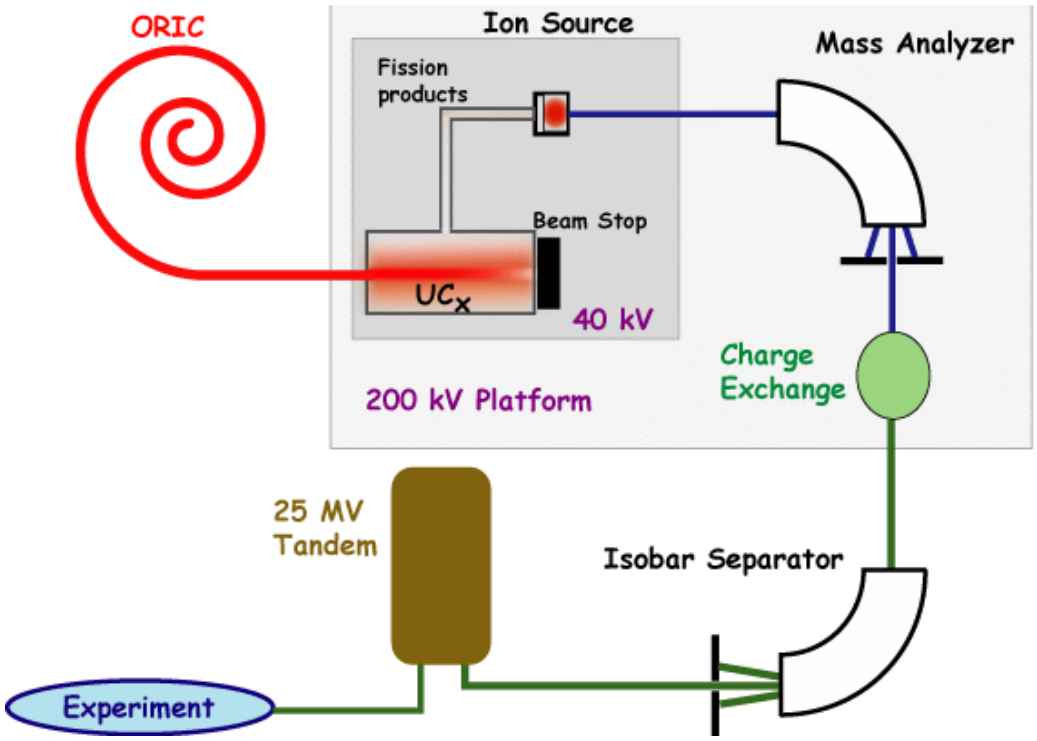


Studies of neutron-rich nuclei at HRIBF
Production and separation of neutron rich isotopes

"ISOL" technique - intense beam of light ions and thick targets. Effective utilization of the beam and the target material.

but … ion "so(u)rce(ry)"

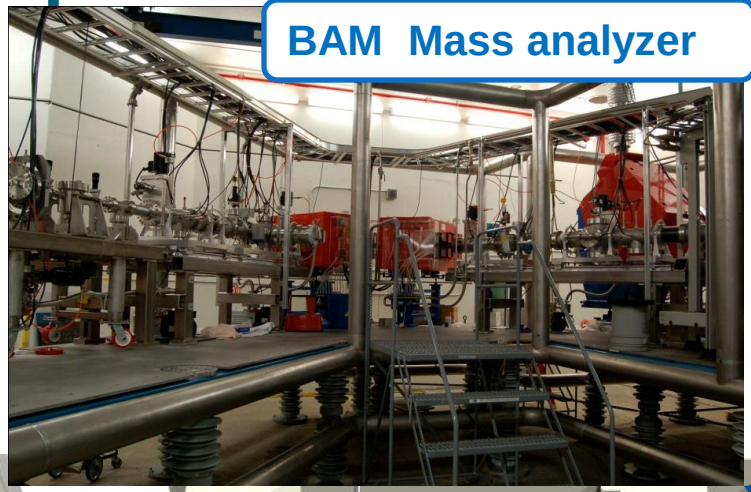
Unique HRIBF capability *ISOBAR SEPARATOR !* enables selective studies of ions with given A and Z. Much easier to operate than e.g. laser ion source !

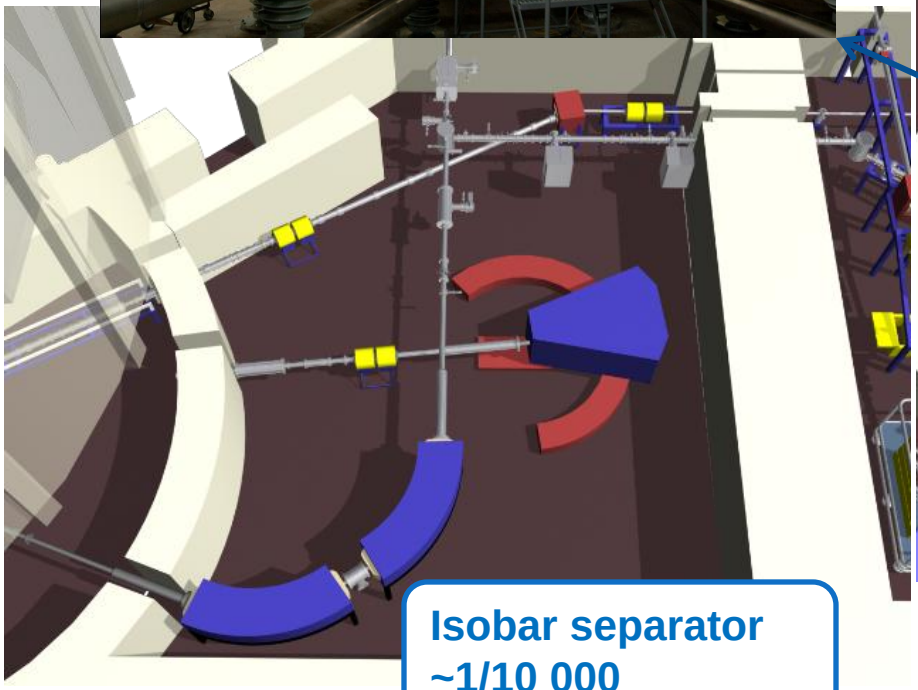


Injector for Radioactive Ion Species IRIS 2

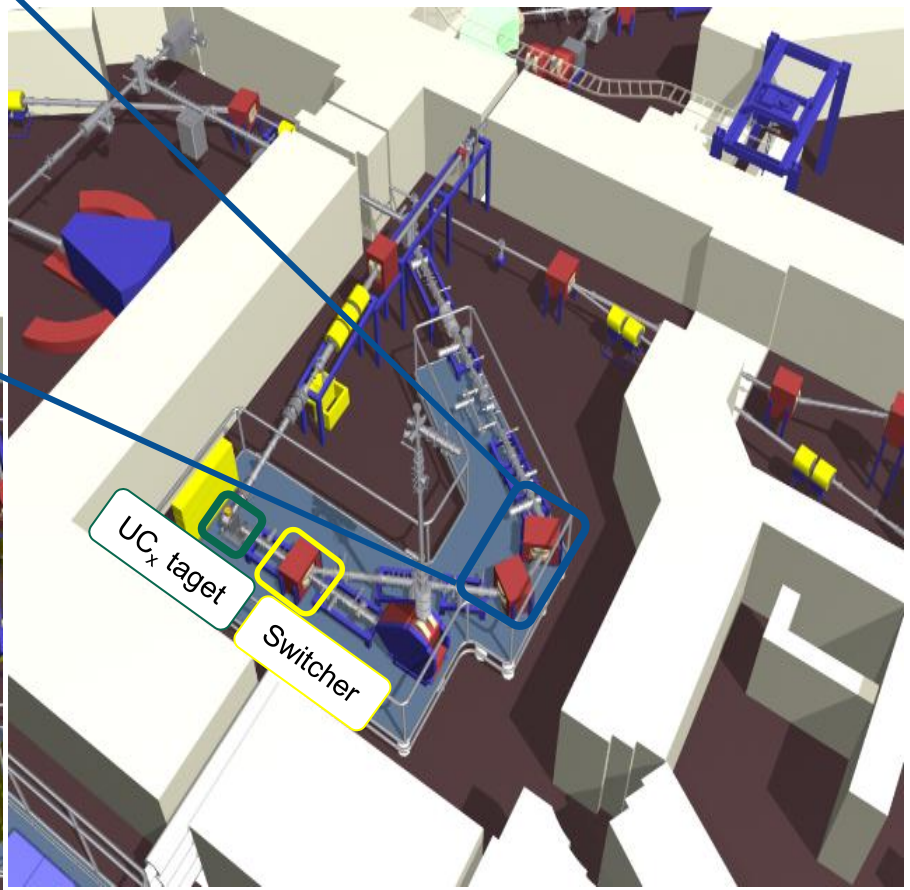
ORIC proton beam
10-15 μA @ ~40MeV

BAM Mass analyzer

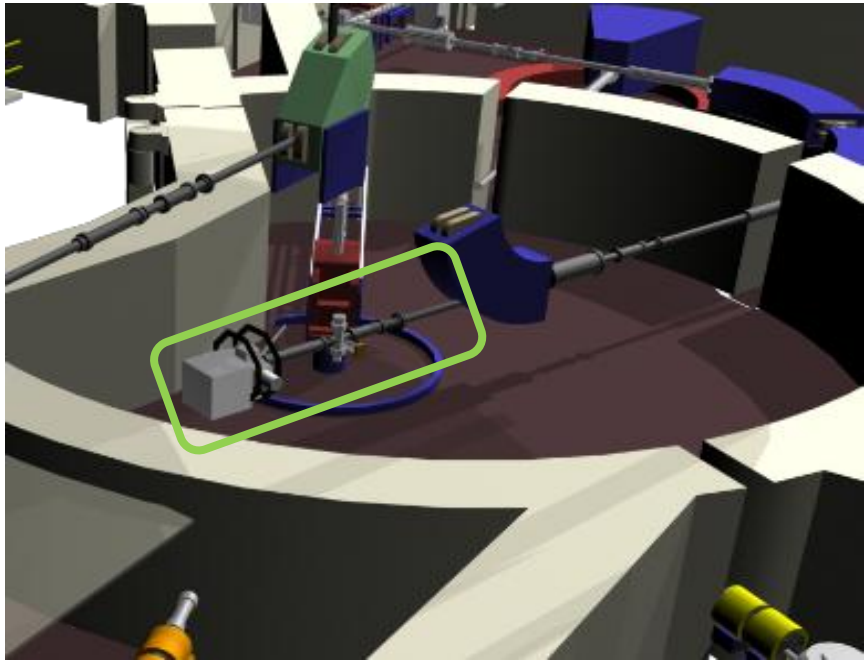


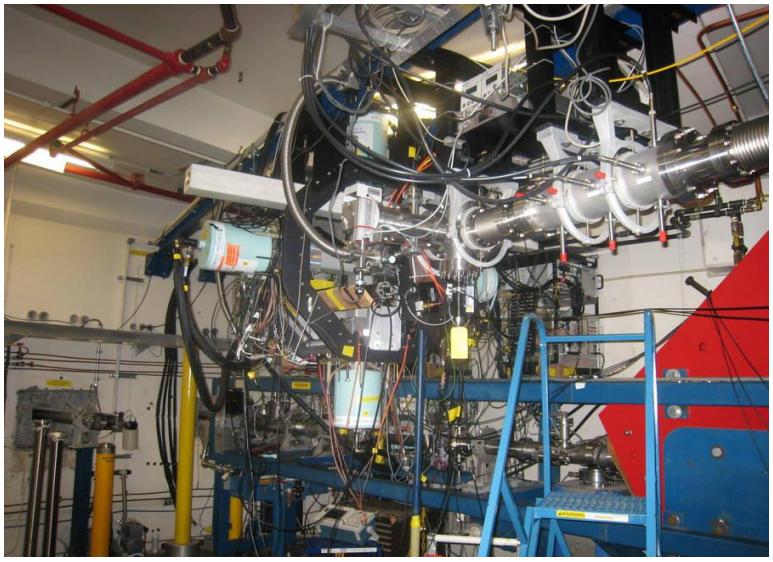


Isobar separator
~1/10 000



High Resolution Spectroscopy:
the Clover Array for Radioactive Decay Studies



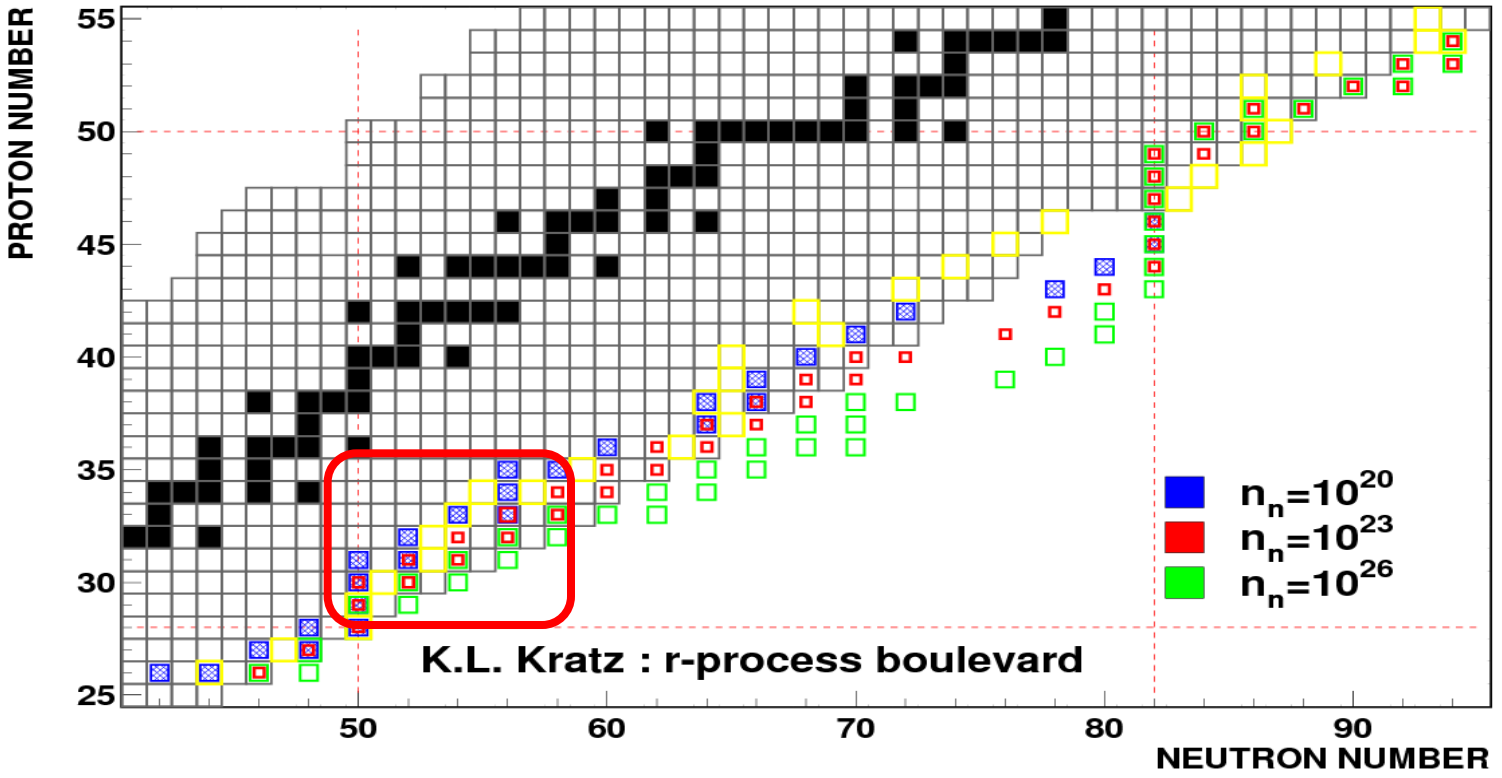


- Radioactive species implanted in moving tape collector
- Gamma-ray detection: 4 HPGe, ε= 6% at 1 MeV
- Beta detection: 2 plastic scintillators, ε=60 %

Half-lives in the vicinity of ^{78}Ni

- Z=28 N=50 shell closures
- Progenitors of r-process nuclei
- <u>Beta decay between different parity subshells:</u>
  - First forbidden transitions play a fundamental role in the half life

"Speeding-up the classical r-process"
P.Moeller et al. Phys. Rev. C 67, 055802 (2003)

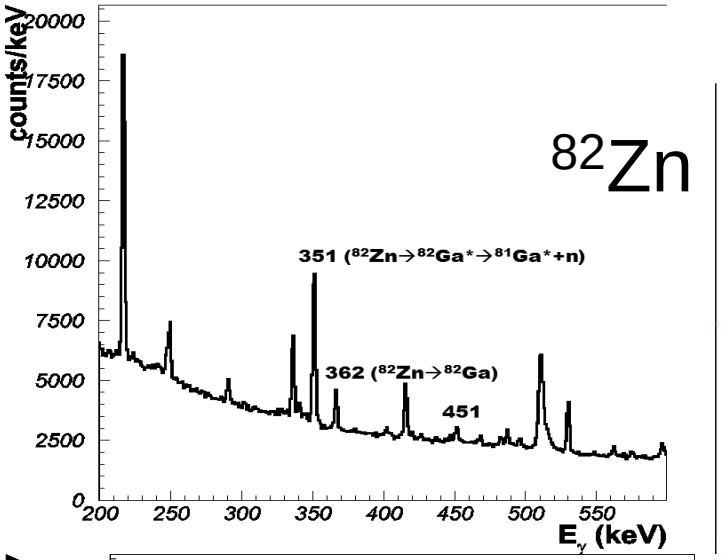


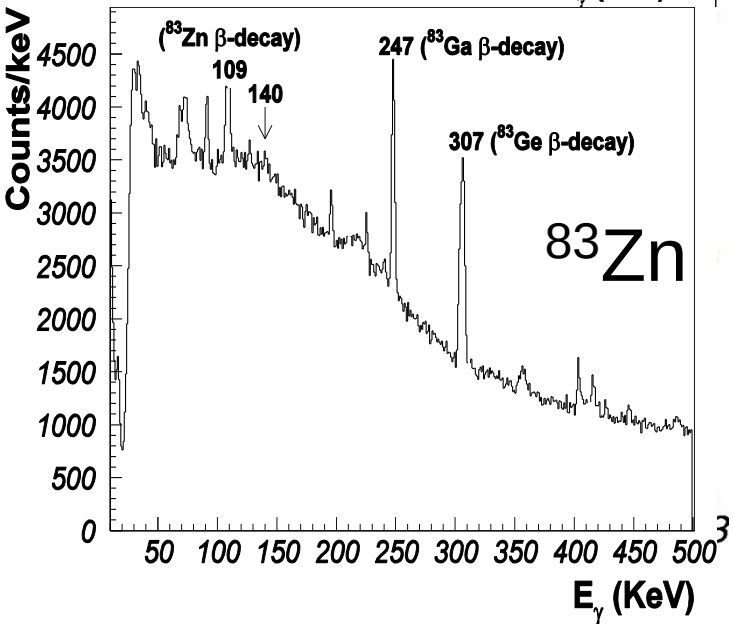
Frontier Nuclear Physics: 4 new half-lives measured at LeRIBSS

81Ge	82Ge	83Ge	84Ge	85Ge	**86Ge** 219 (40) ms
80Ga	81Ga	82Ga	83Ga	84Ga	**85Ga** 93(7) ms
79Zn	80Zn	81Zn	**82Zn** 228(10) ms	**83Zn** 117(20) ms	
78Cu	**79Cu**				
77Ni	78Ni				

M.M. et al., PRL, in press. (2012)

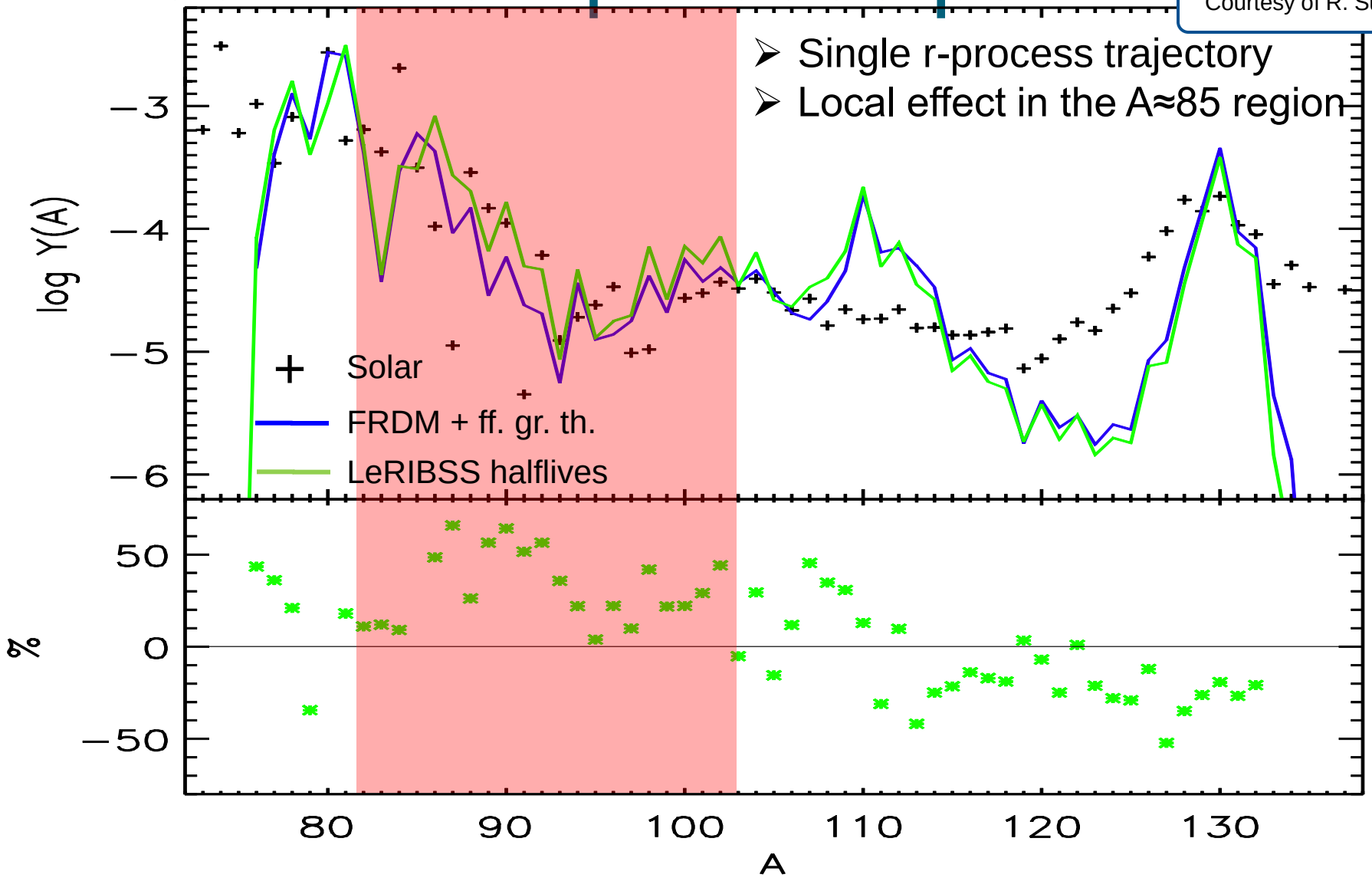
ISOLDE $T_{1/2}(^{82}Zn)$=80(20) ms





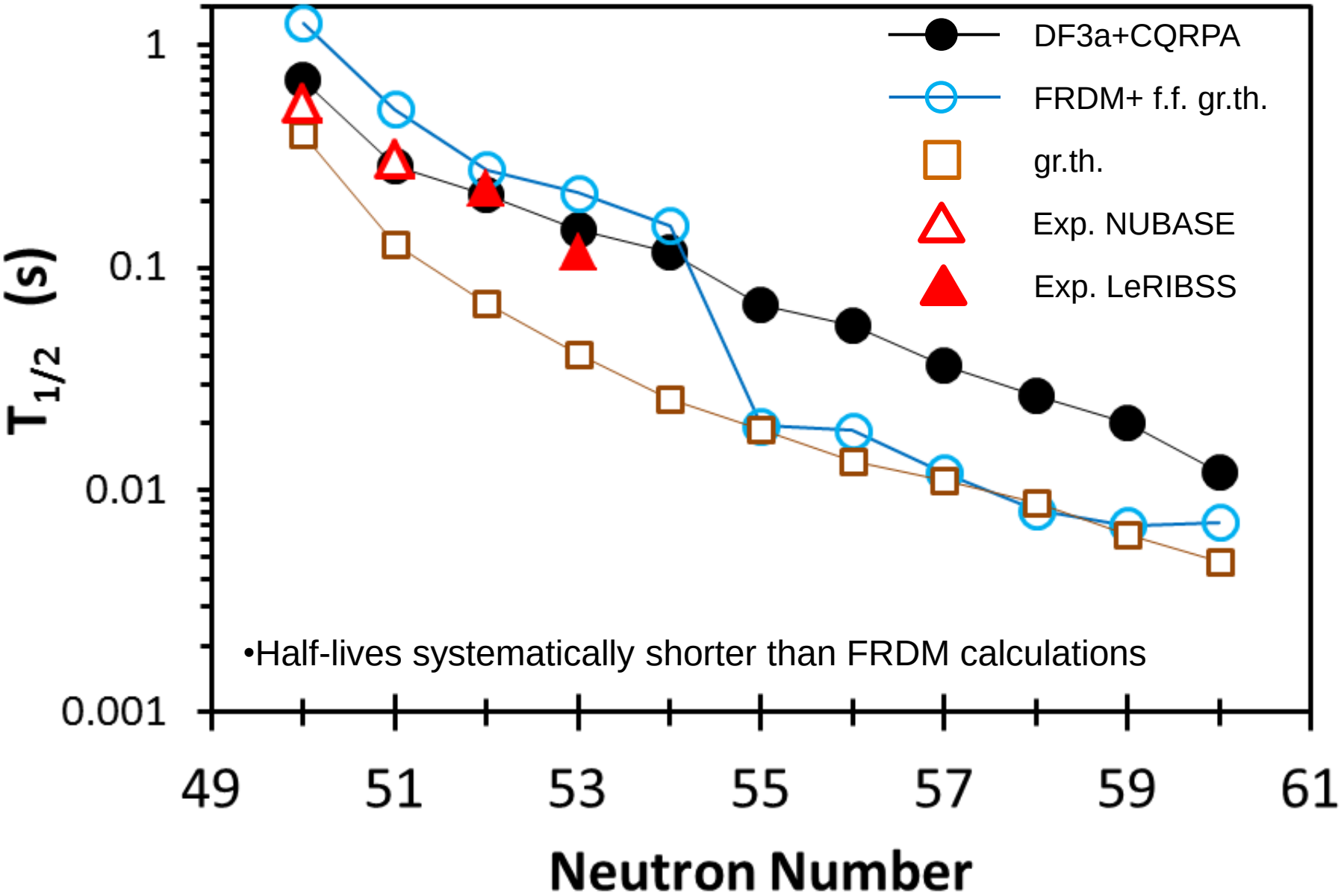
Are the newly measured half-lives in the r-process path?

Courtesy of R. Surman



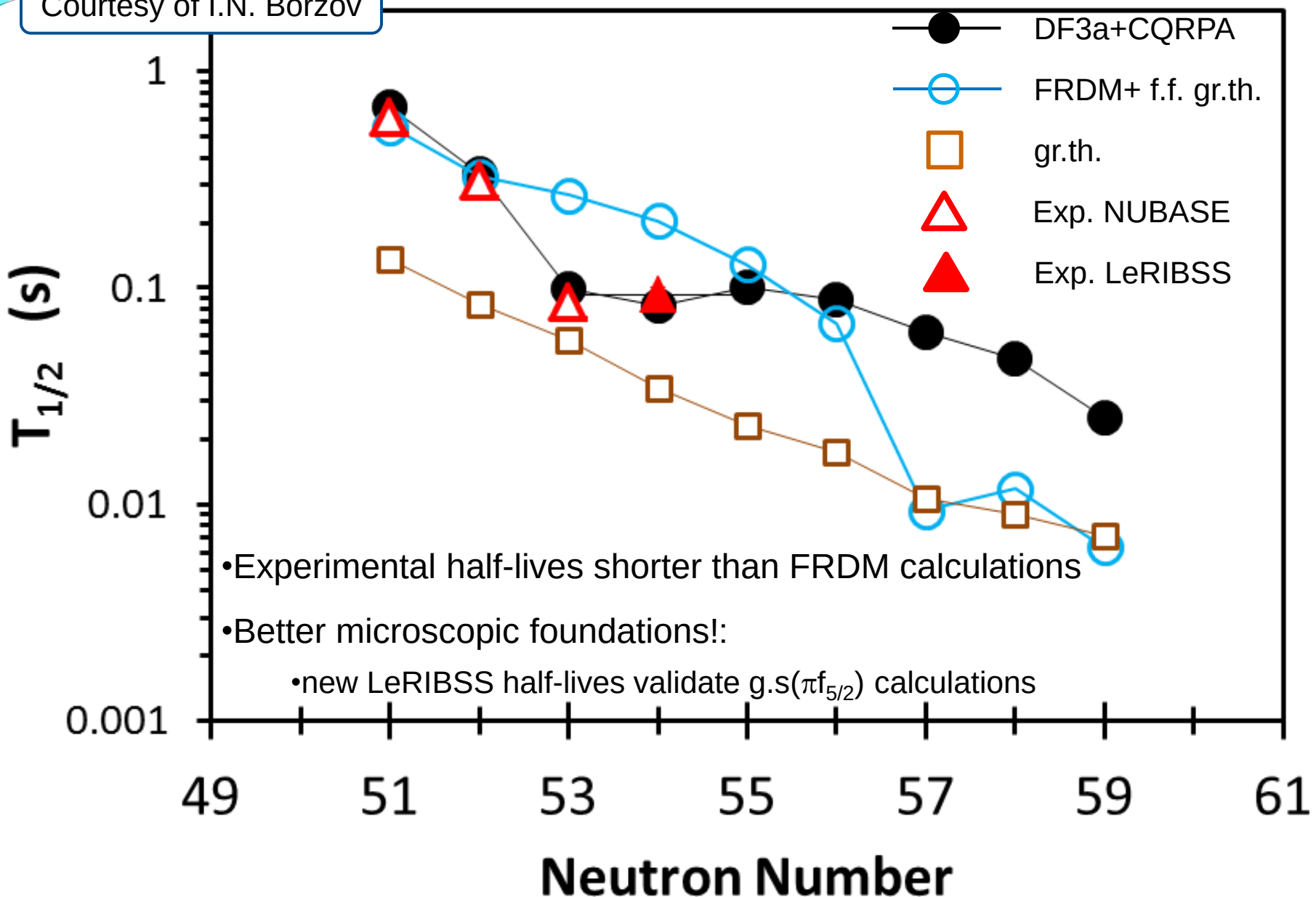
Benchmarking theoretical predictions: Zn half-lives

Courtesy of I.N. Borzov



Benchmarking Ga half-lives

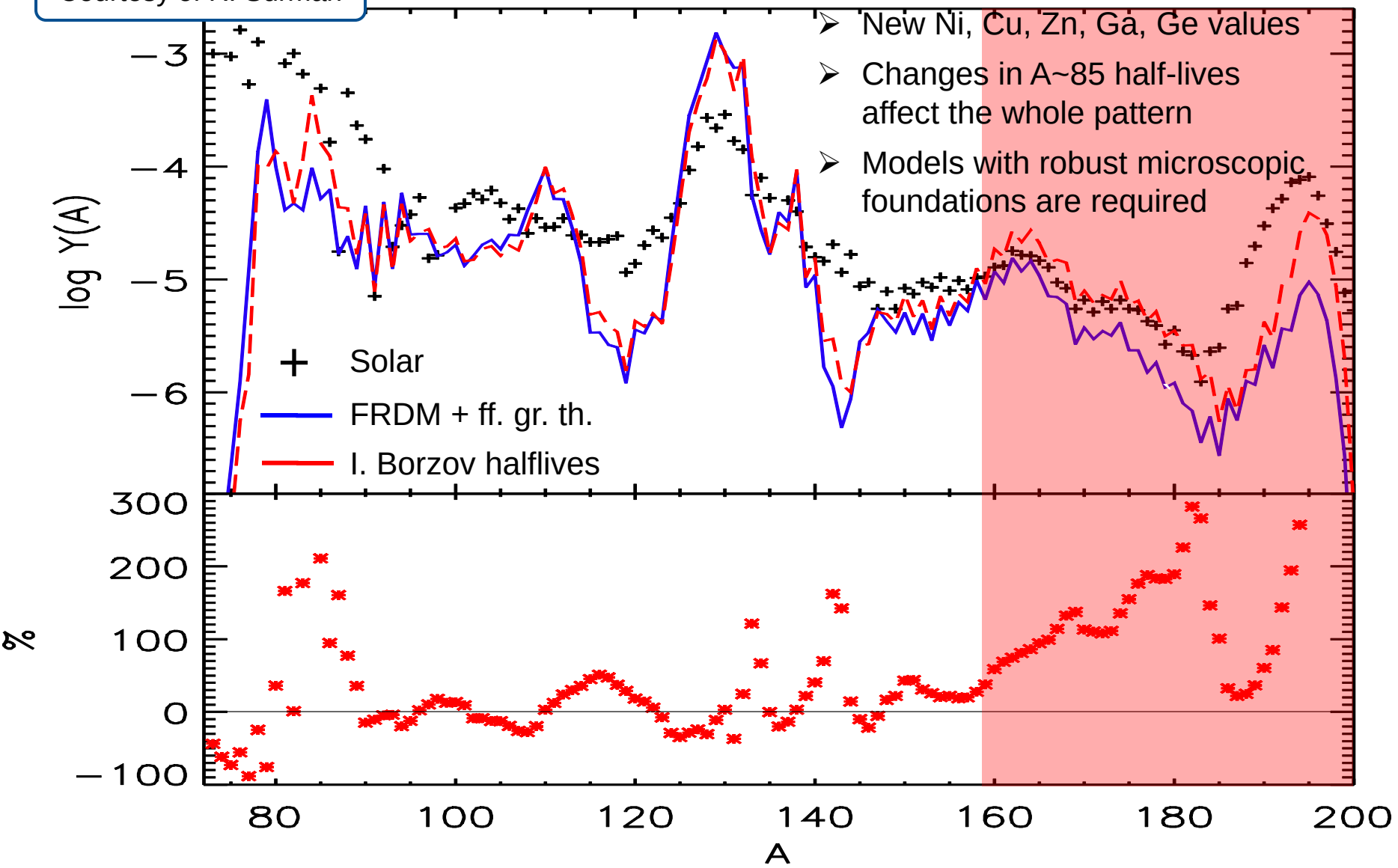
Courtesy of I.N. Borzov



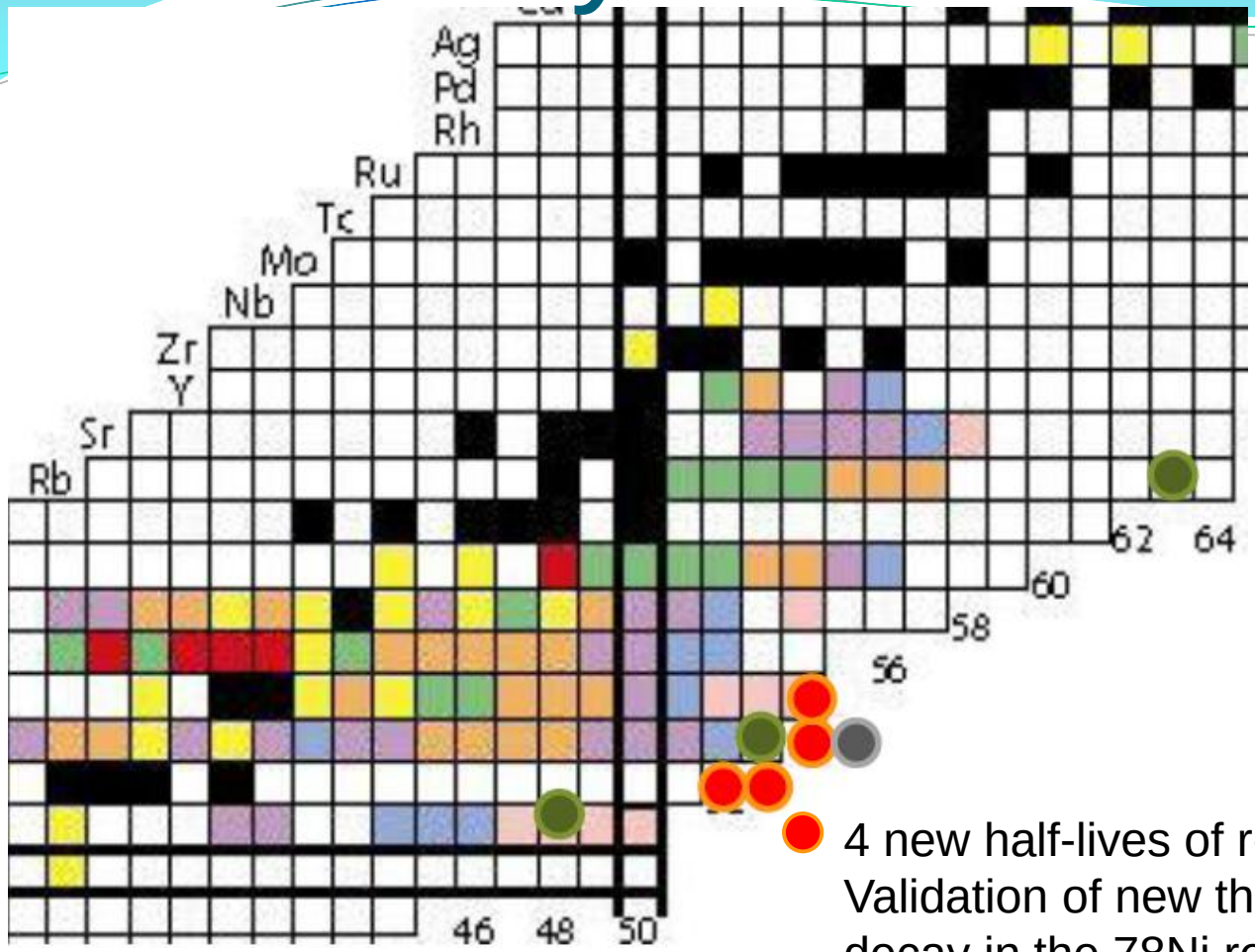
- Experimental half-lives shorter than FRDM calculations
- Better microscopic foundations!:
  - new LeRIBSS half-lives validate g.s($\pi f_{5/2}$) calculations

New calculated half-lives for spherical nuclei affect r-process abundances

Courtesy of R. Surman



Summary



- 4 new half-lives of r-process relevant nuclei. Validation of new theoretical model of beta-decay in the 78Ni region. Profound influence on beta decay rates
- IRIS 2 commission great success! Clean, high intensity high quality data. Laser Ion Source commissioned: Observation of ^{86}Ga

People

- **ORNL support**

  C. Gross, C. Jost, A.J. Mendes II, D. Stracener

- **Decay Spectroscopy group**

  L. Cartegni, R. Grzywacz, A. Kuzniak, D. Miller, S. Padgett, S. Paulauskas, W. Krolas, E. Zganjar, S. Ilyushkin, J. Winger, J.C. Batchelder, S. Liu, M. Wolinska-Cichocka. K. Rykaczewski, K. Miernik, C. Mazzochi, M. Karny, A. Korgul, J.H. Hamilton, N. Brewster, A.V Ramaya, J.K. Hwang

- **VANDLE colaboration**

  C. Matei and I. Spassova ORAU; P.D. O'Malley, M. Howard, B. Manning, E. Merino, and J. Cizewski, Rutgers U.; D. Bardayan, ORNL; C. Brune and T. Massey, Ohio U.; F. Raiola, D. Walter, S. Ilyushkin, and F. Sarazin, Colorado School of Mines; J. Blackmon, Louisiana State U