

Fission and K-isomer studies @TASCA

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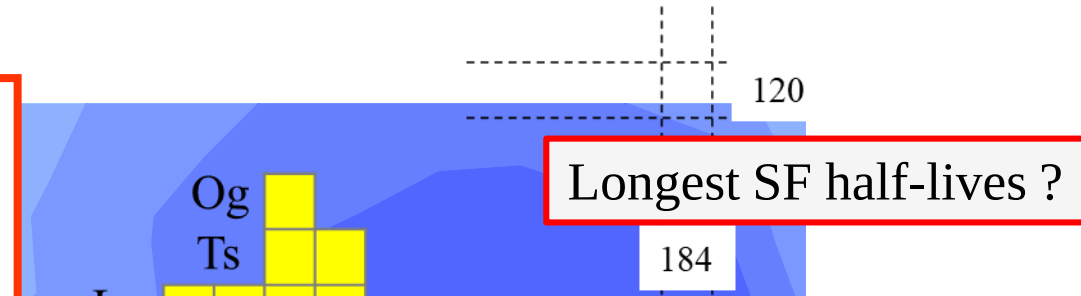
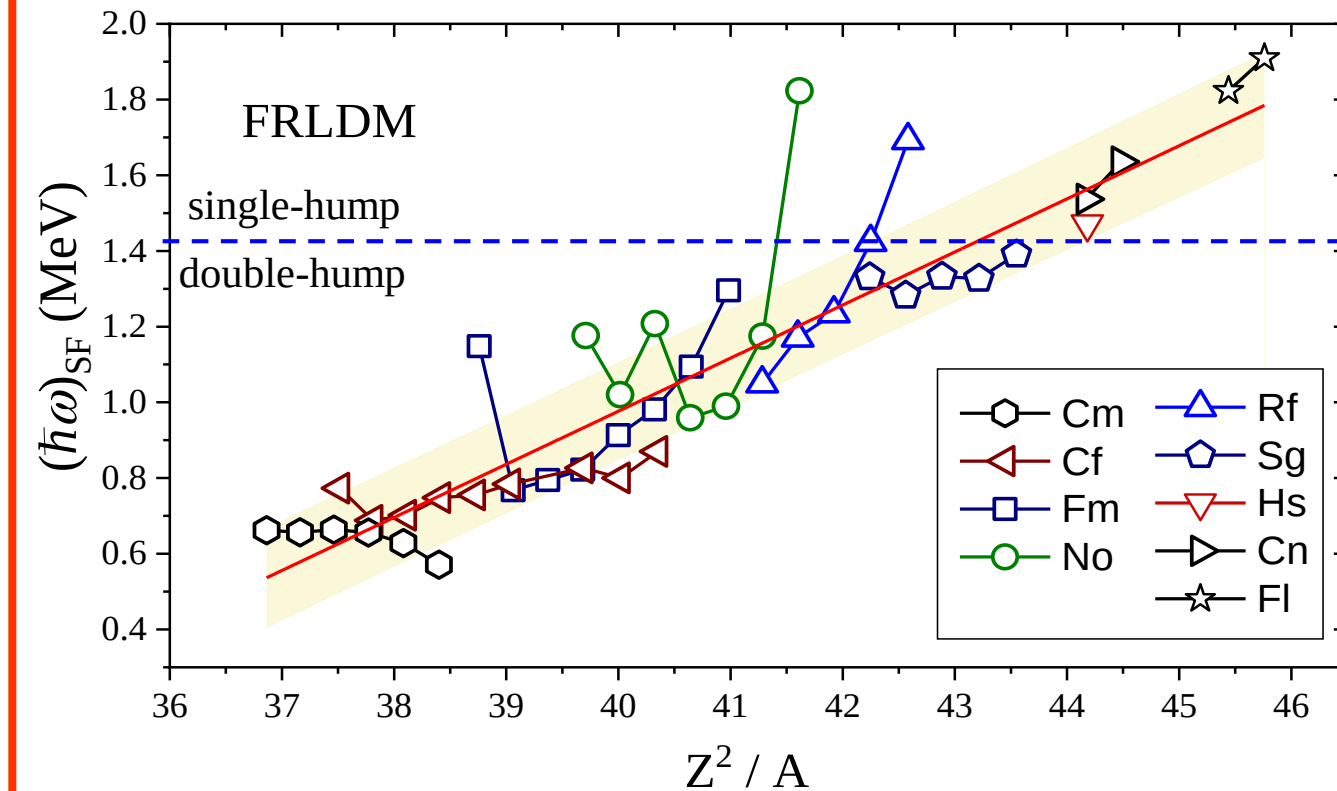
TASCA 25 workshop

Darmstadt, Germany

23-24 April 2025

- Introduction: Fission of superheavy nuclei
 - The ground-state ($K=0$, even-even)
 - The high-K state ($K \neq 0$, even-even)
- Recent experimental results from **TASCA**
 - ^{250}No and ^{252}Rf
- Summary and outlook

J. Khuyagbaatar, Nucl. Phys. A **1002**, 121958 (2020).



Half-life $\sim$ fission-barrier shape $\sim$ path $\sim$ valley

Multi-humped shape

V.M. Strutinsky 1967

S.G. Nilsson et al., Nucl. Phys. A **131**, 1 (1969)

J. Randrup et al., Nucl. Phys. A **217**, 221 (1973)

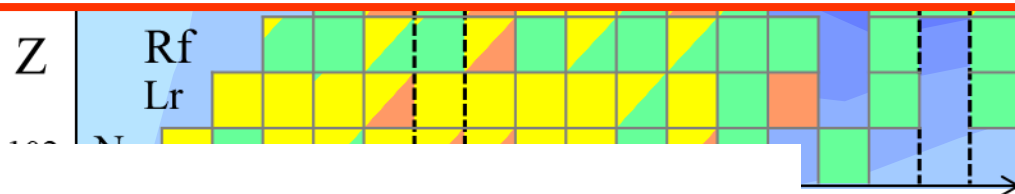
Single-humped shape: ^{256}Rf

Yu.Ts. Oganessian, Lect. Notes. Phys. **33**, 221 (1975).

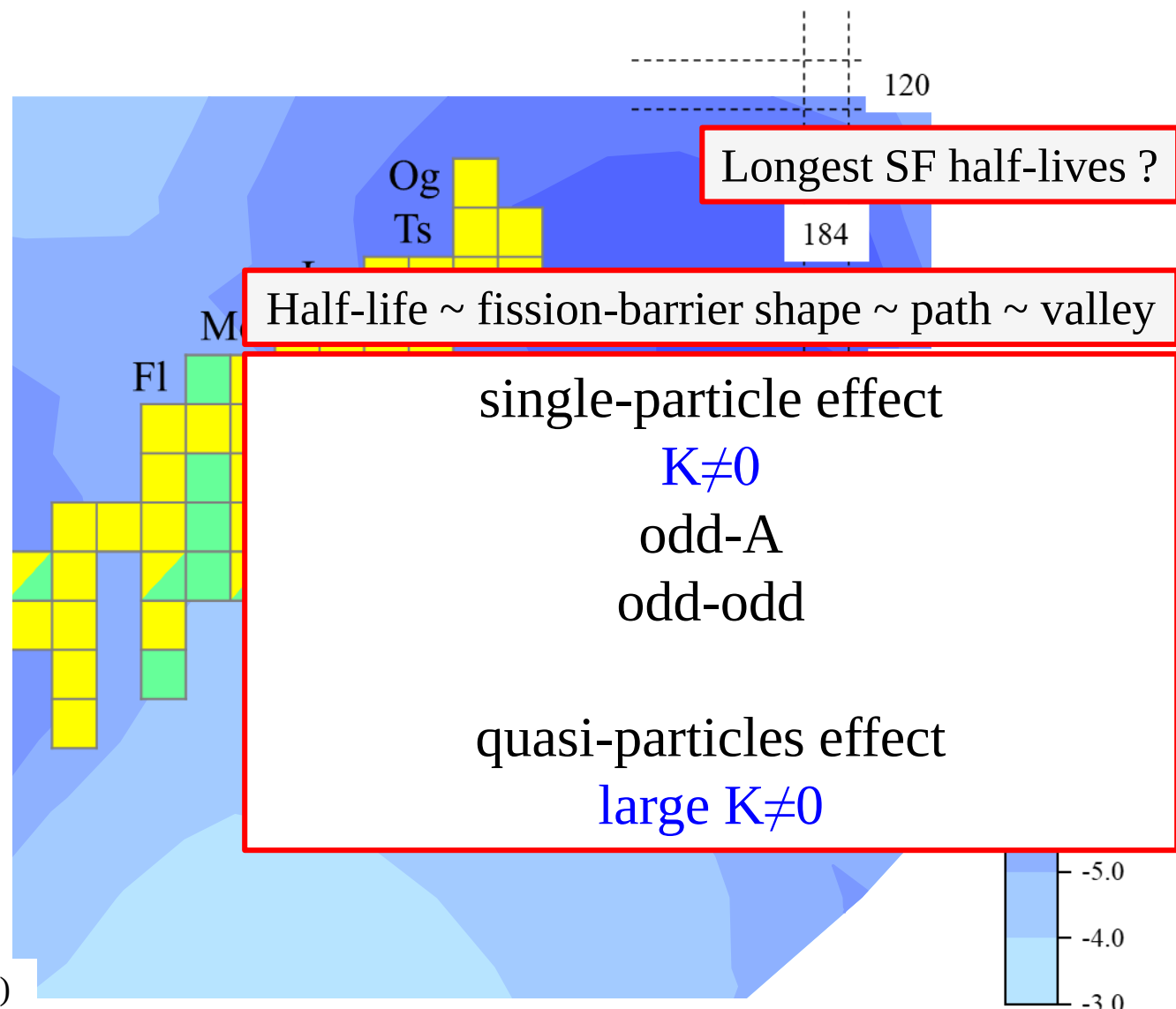
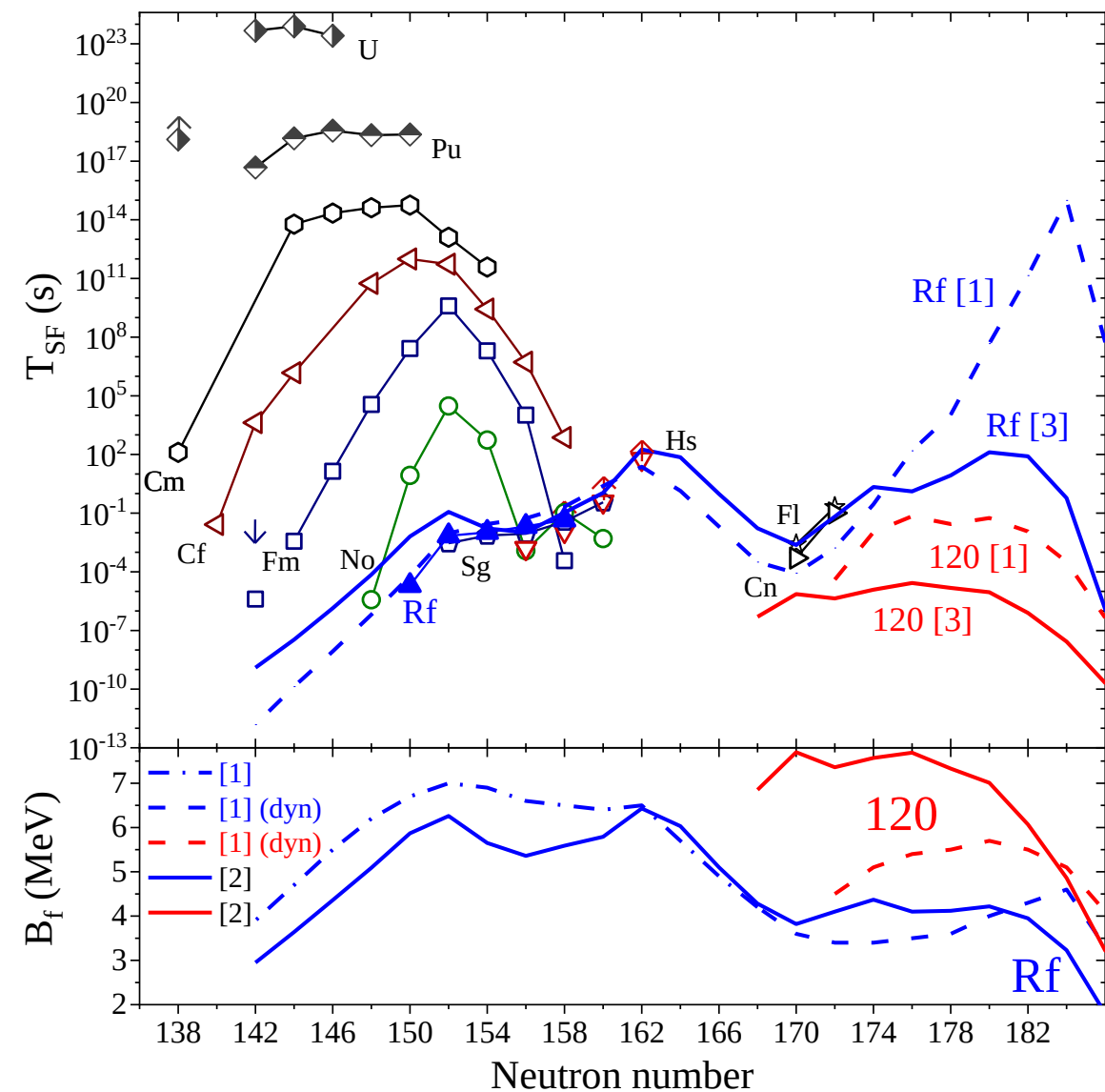
F.P. Heßberger, G. Münzenberg, S. Hofmann et al.,
Z. Phys. A - Atoms and Nuclei **321**, 317-327 (1985)

Probe of the barrier-shape of SHN ($\hbar\omega$)

F. P. Heßberger et al., J. Less. Com. Met. **122**, 445 (1986).



B_f from P. Möller, et al., Phys. Rev. C **79** 064304 (2009)



- [1] R. Smolańczuk, J. Skalski and A. Sobczewski, Phys. Rev.C **52** 1871 (1995)
 [2] P. Möller, et al., Phys. Rev. C **79** 064304 (2009)
 [3] J. Khuyagbaatar, Nucl. Phys. A **1002**, 121958 (2020).

K-isomeric states with half-lives longer than the ground states

^{270}Ds (≈ 20 times longer)

S. Hofmann et al., Eur. Phys. J. A **10**, 5 (2001).

^{250}No (≈ 10 times longer)

A.V. Belozarov et al., Eur. Phys. J. A **16**, 447 (2003).

D. Peterson et al., Phys. Rev. C **74**, 014316 (2006).

A. Svirikhin et al., Phys. Part. Nucl. Lett. **14**, 571 (2017).

M. Tezekbayeva et al., Eur. J. Phys. Func. Mat. **3**, 300 (2019).

J. Kallunkathariyil et al., Phys. Rev. C **101**, 011301 (2020).

^{254}Rf (≈ 10 times longer)

H. M. David et al., Phys. Rev. Lett. **115**, 132502 (2015).

K-isomeric state: Inverted fission-stability

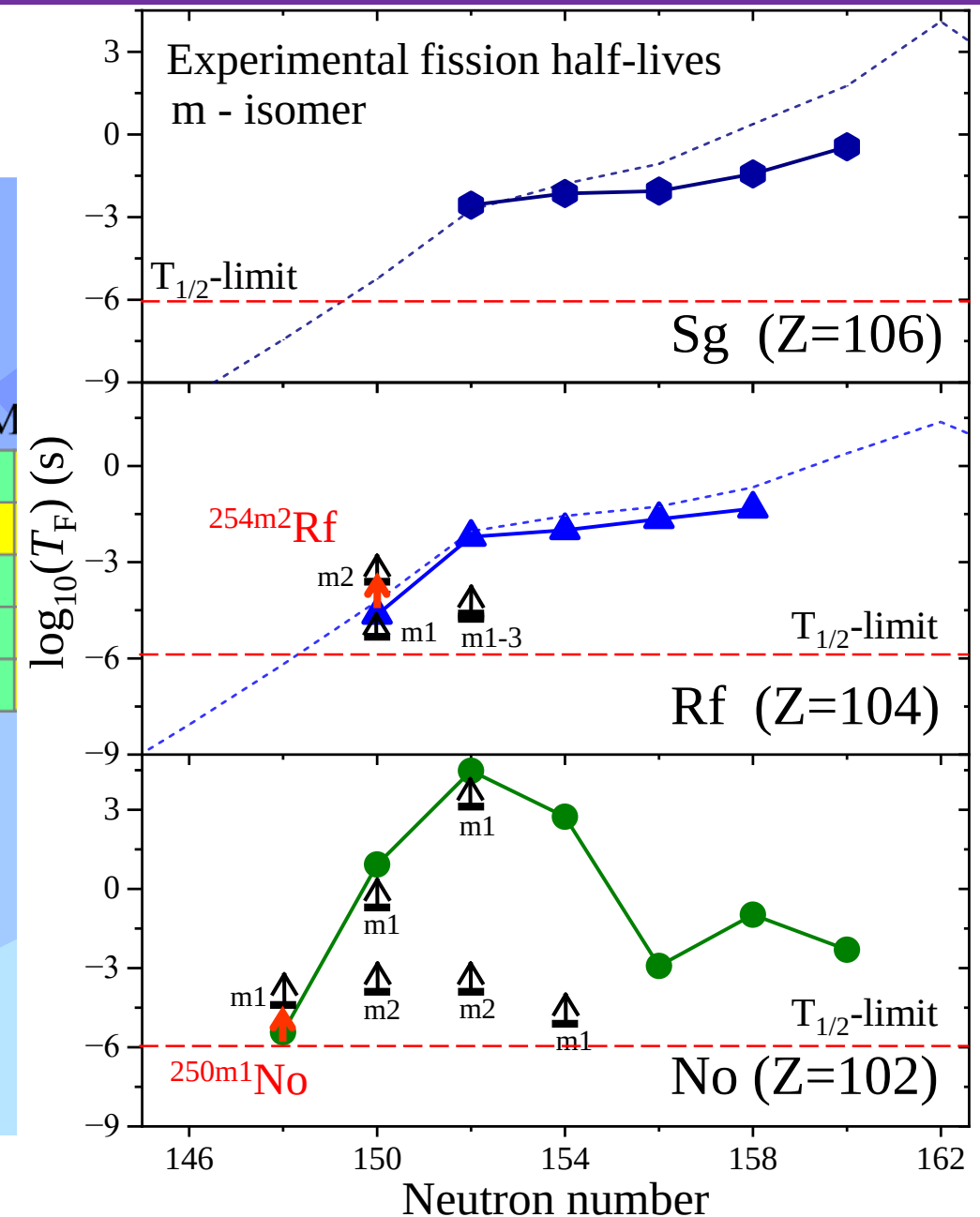
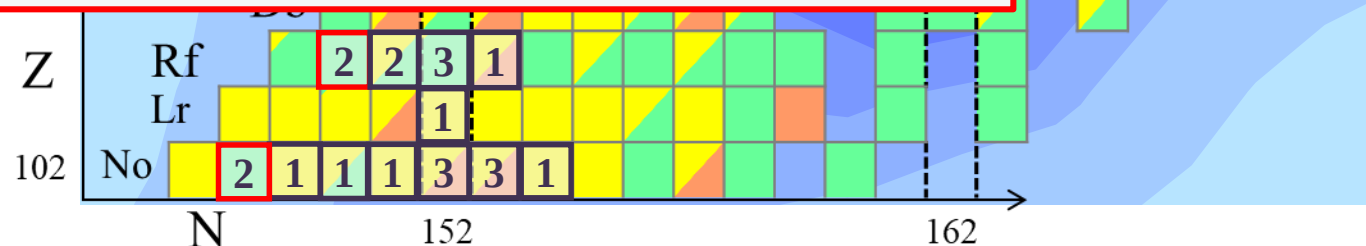
A. Baran and Z. Lojewski, Nucl. Phys. A **475**, 327 (1987).

F. R. Xu et al., Phys. Rev. Lett. **92**, 252501 (2004).

G. G. Adamian et al., Phys. Rev. C **81**, 024320 (2010).

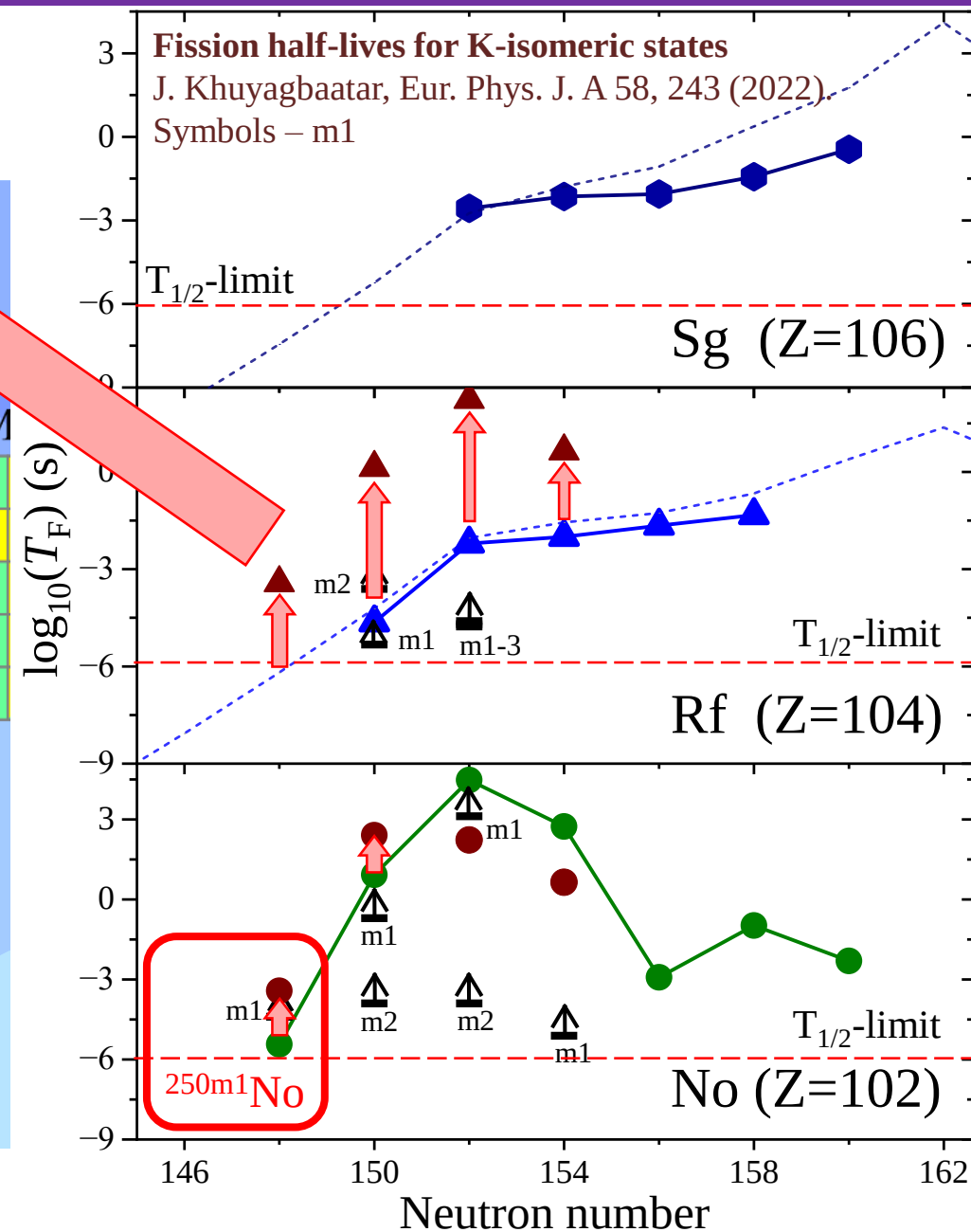
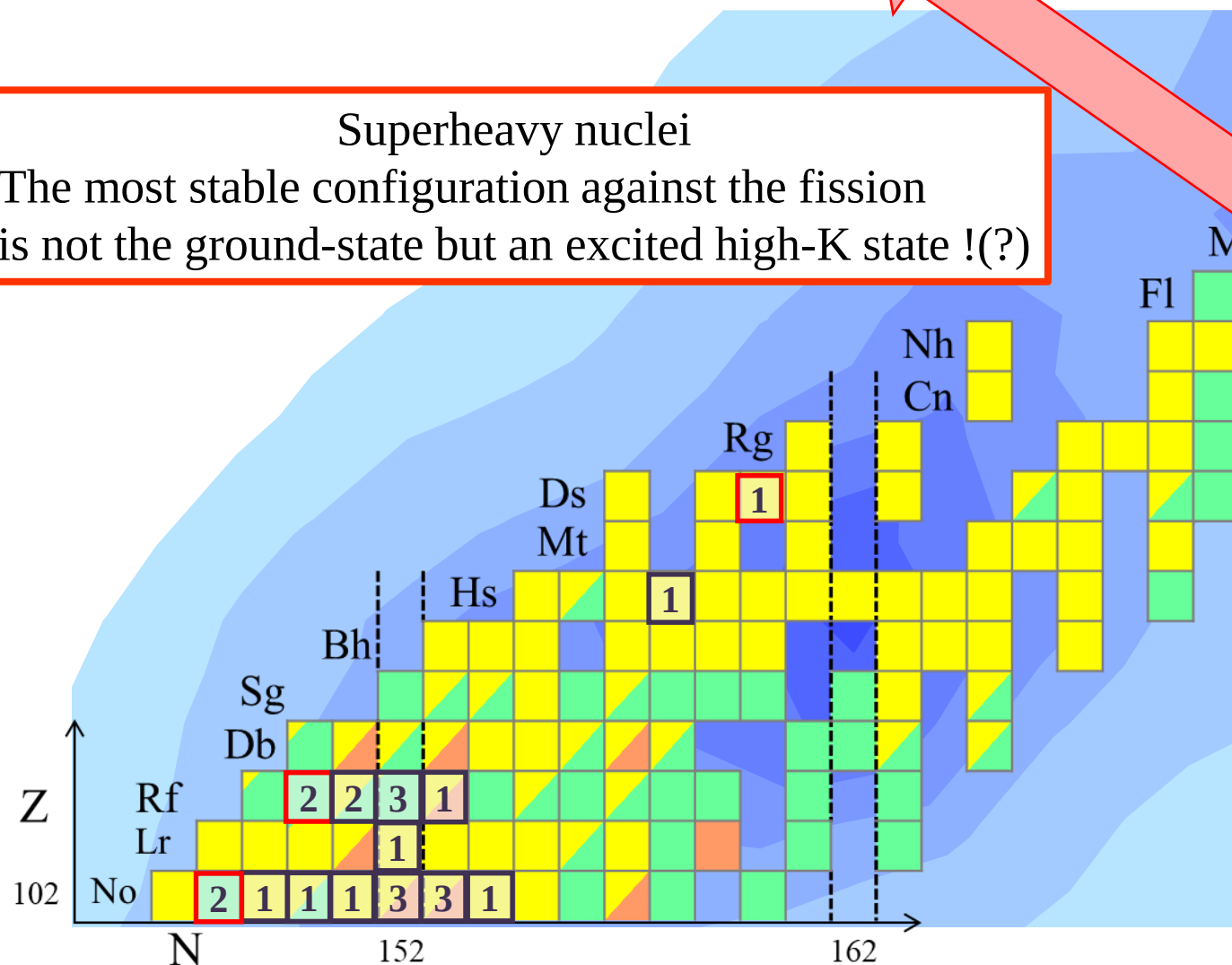
H. L. Liu et al., Phys. Rev. C **89**, 044304 (2014).

J. Khuyagbaatar, Eur. Phys. J. A **58**, 243 (2022).



SHN: Narrow/ single-humped fission barrier

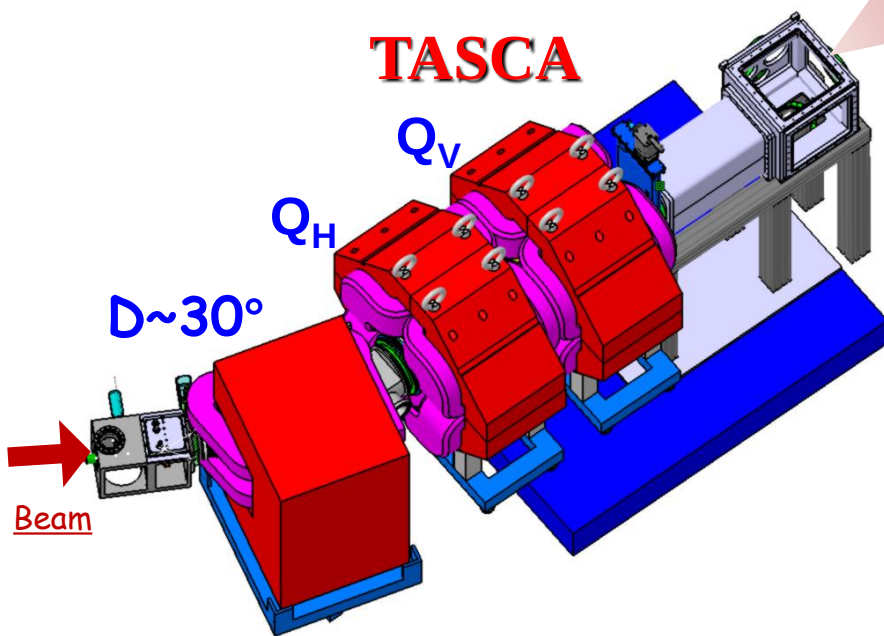
Superheavy nuclei
The most stable configuration against the fission is not the ground-state but an excited high-K state !(?)



TransActinide Separator and Chemistry Apparatus

Beam: in pulse mode 5 ms-long and 50Hz
Penning and ECR ions sources + UNILAC
 $^1\text{H} - ^{238}\text{U}$ with energies 11 MeV/u

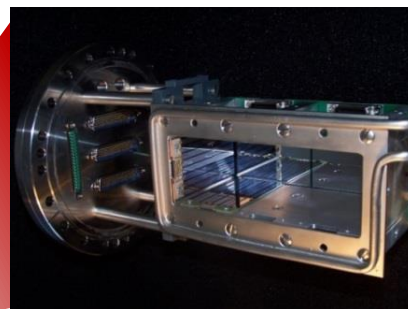
TASCA



Separation by $B\rho = mv / \langle q \rangle$

J. Khuyagbaatar *et al.*, NIM A **689**, 40 (2012)

J. Khuyagbaatar *et al.*, PRA **88**, 042703 (2013)



Focal plane detector

Physics

Detection system

MWPC

Stop: 2 DSSD 72*48 mm²

Box: 8 DSSD and Veto: 2 SSD

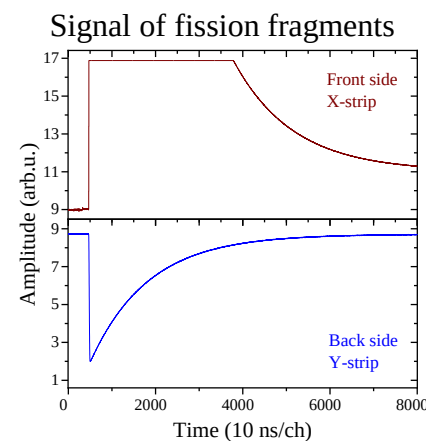
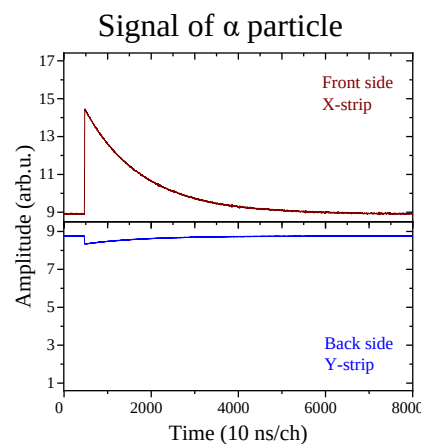
Gamma: BEGe detectors

DAQ system



Febex
Mbs
go4

Experiment Electronics Department, GSI



J. Khuyagbaatar *et al.*,

Element Ts (Z=117)

Phys. Rev. C **99**, 054306 (2019).

Phys. Rev. Lett. **112**, 172501 (2014).

Search for elements 119 and 120

Phys. Rev. C **102**, 064602 (2020).

N=126 shell and discovery of ^{221}U

Phys. Rev. Lett. **115**, 242502 (2015).

EC-delayed fission

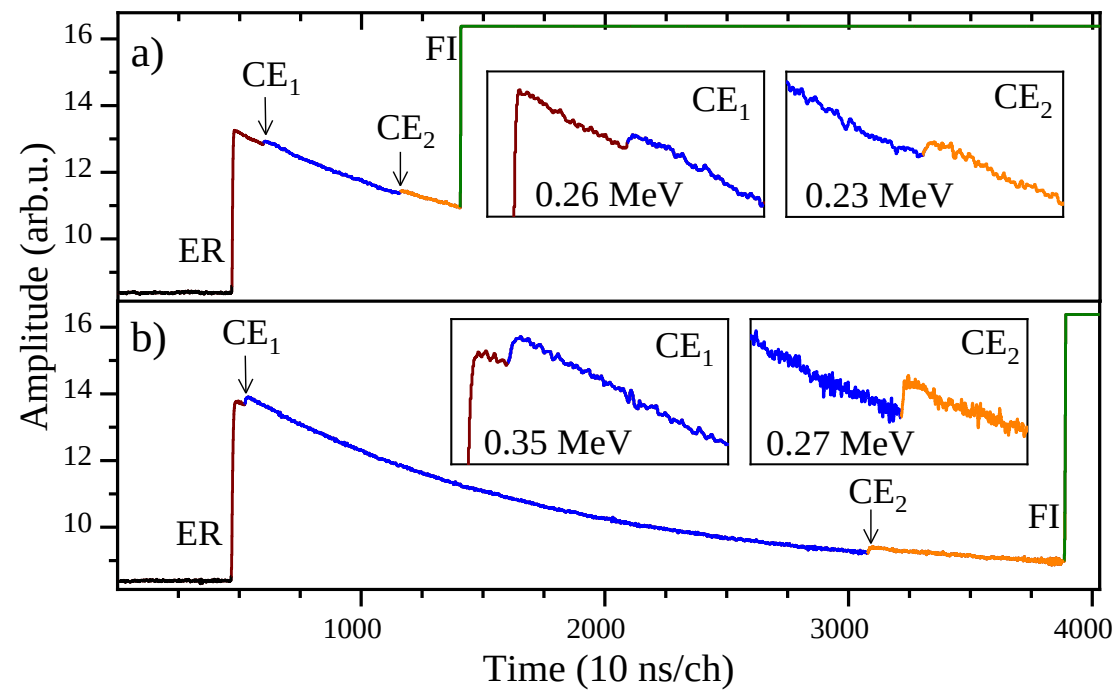
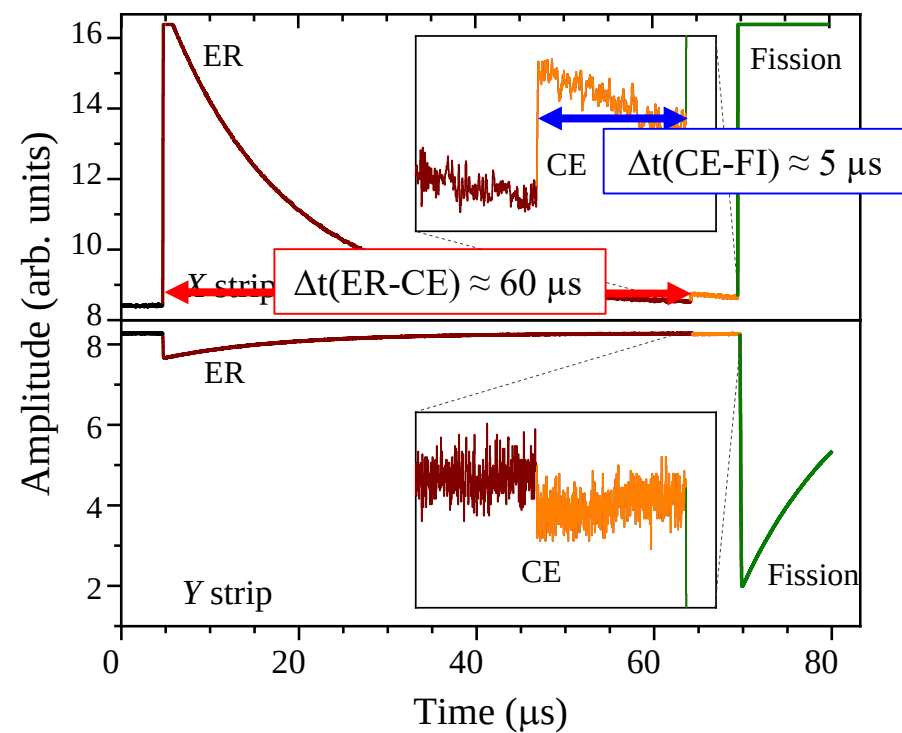
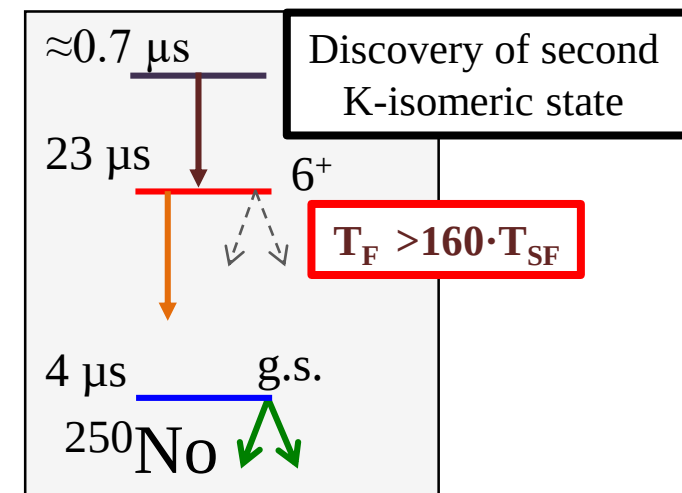
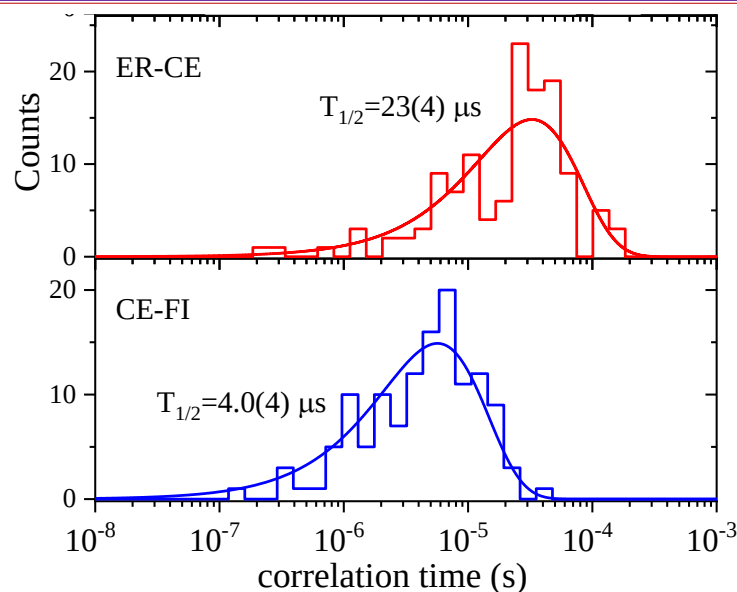
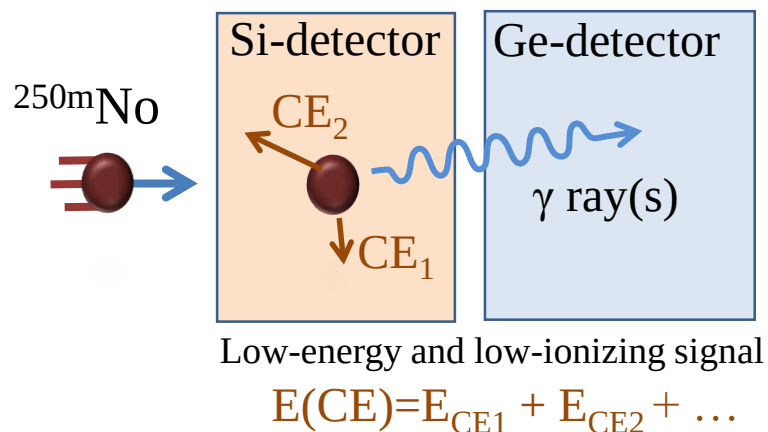
Phys. Rev. Lett. **125** 142504 (2020).

Phys. Rev. C **109**, 034311 (2024).



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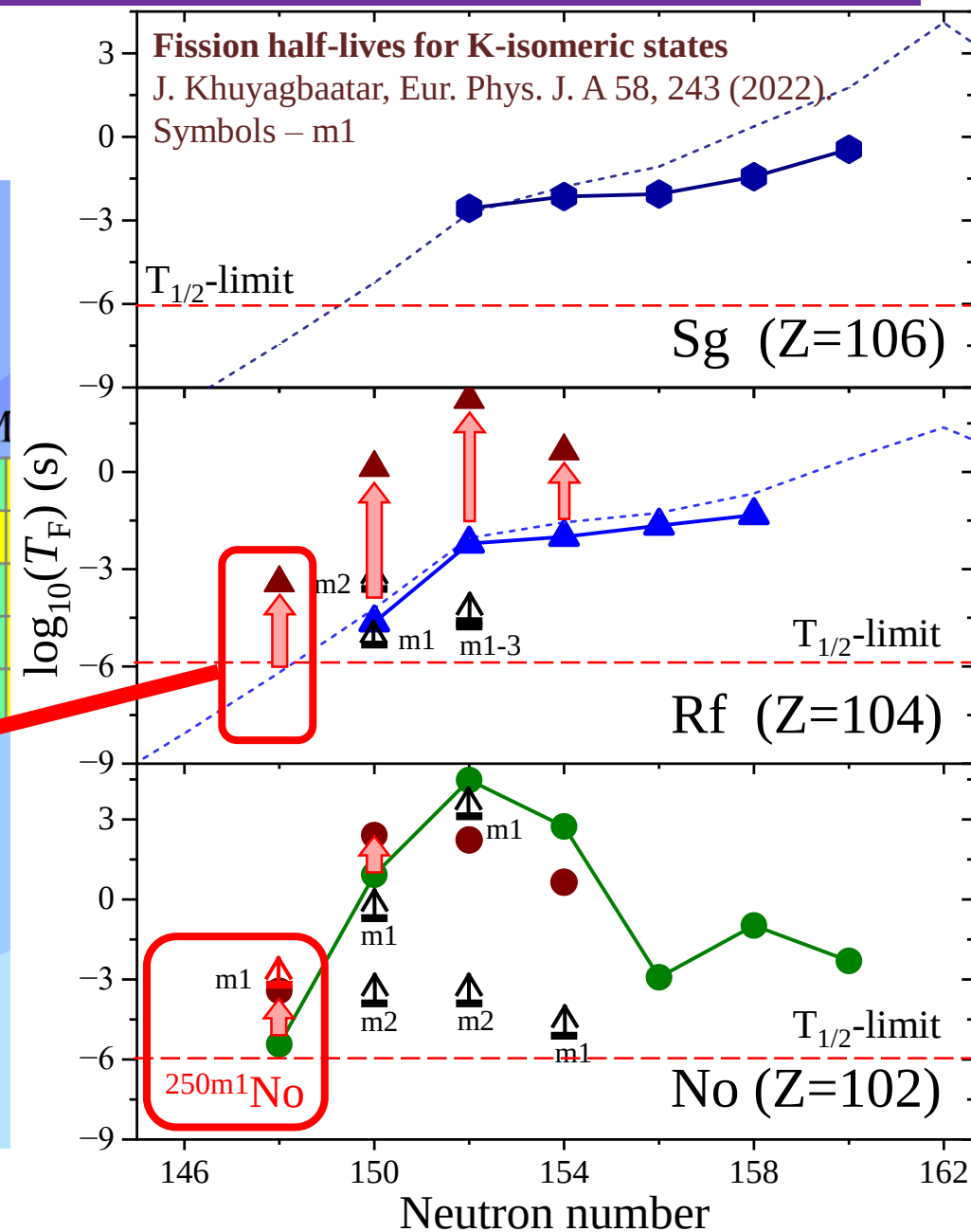
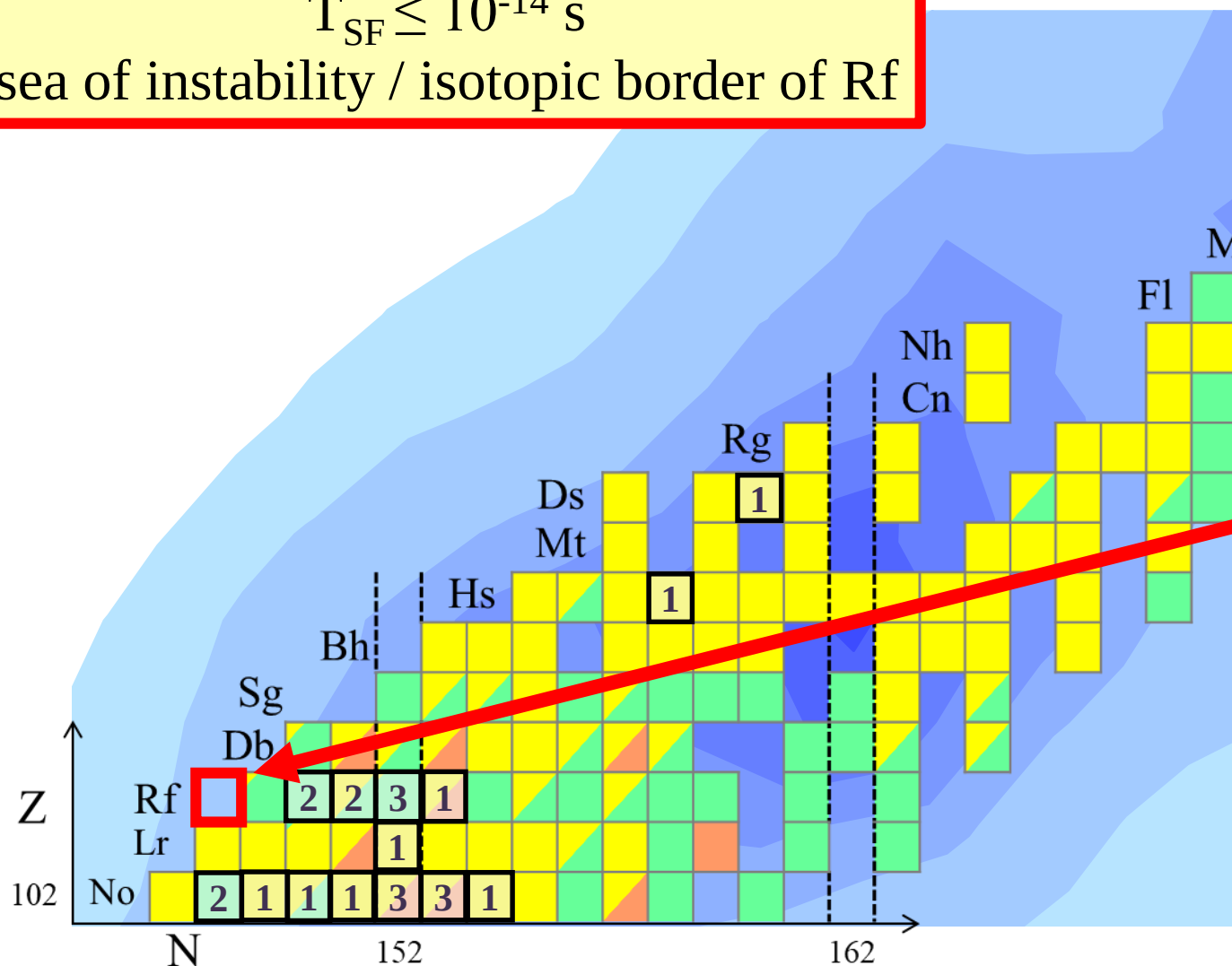
J. Khuyagbaatar et al., Phys. Rev. C 106, 024309 (2022)



Neutron-deficient Rf isotopes

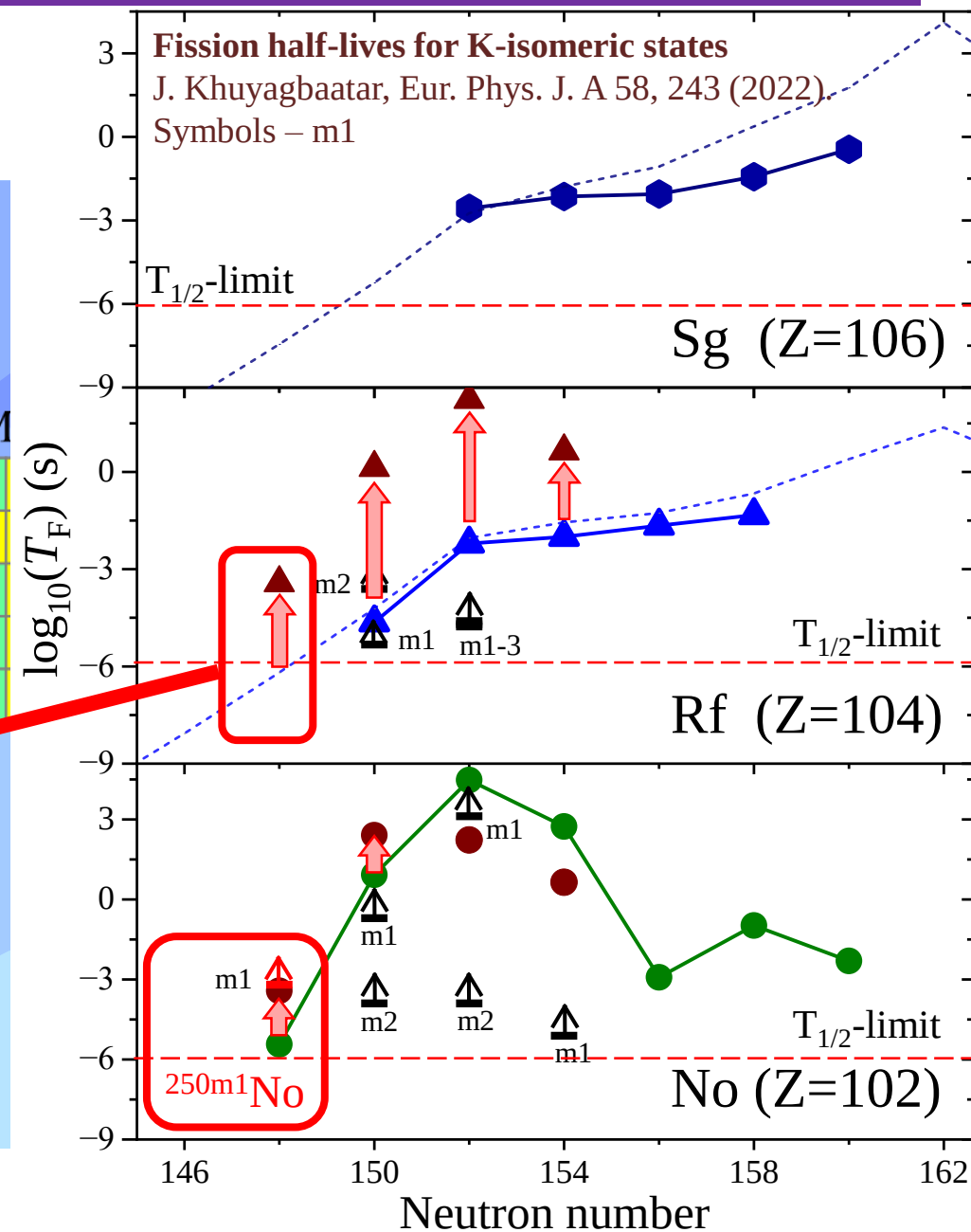
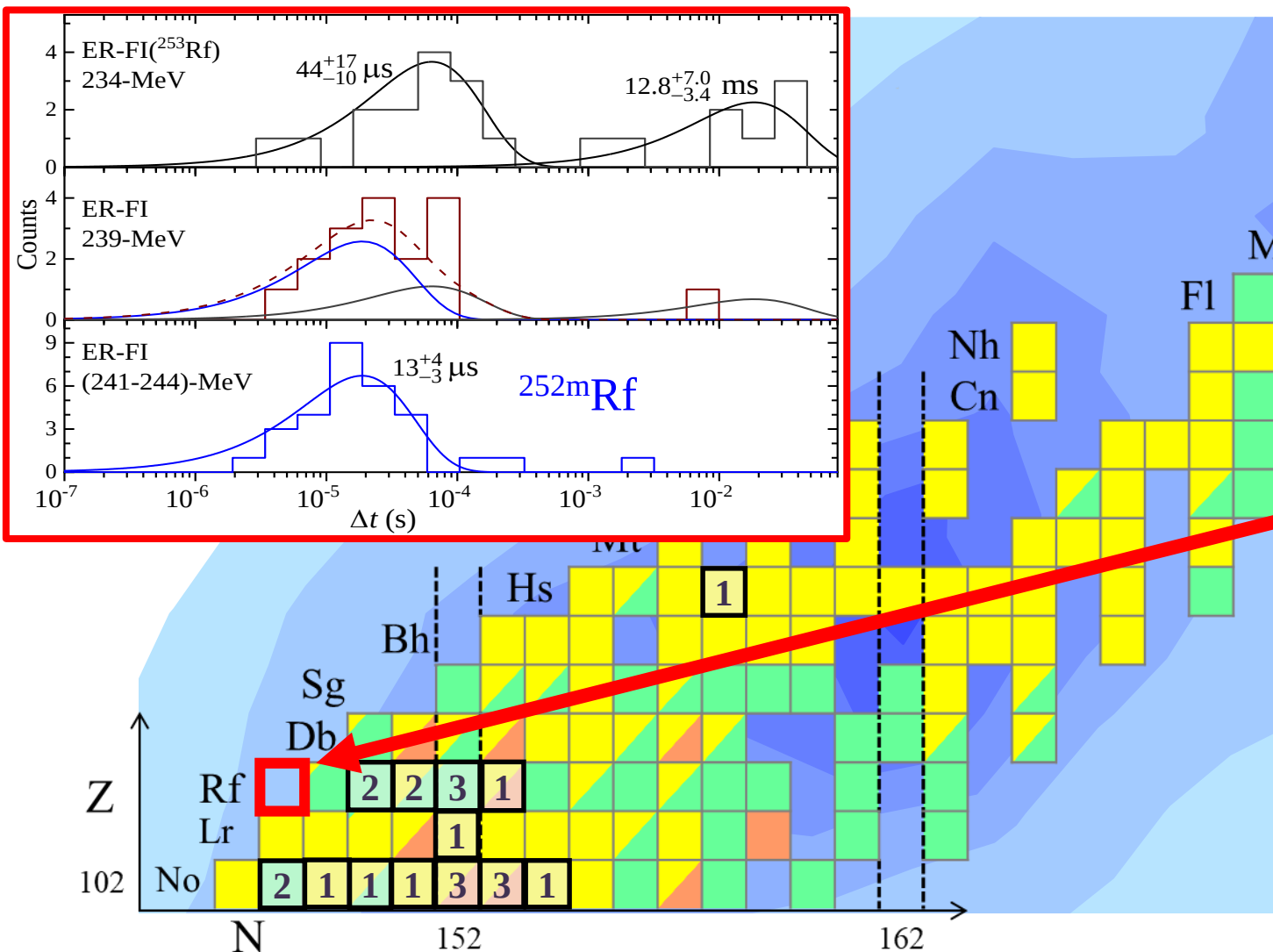
$$T_{\text{SF}} \leq 10^{-14} \text{ s}$$

sea of instability / isotopic border of Rf

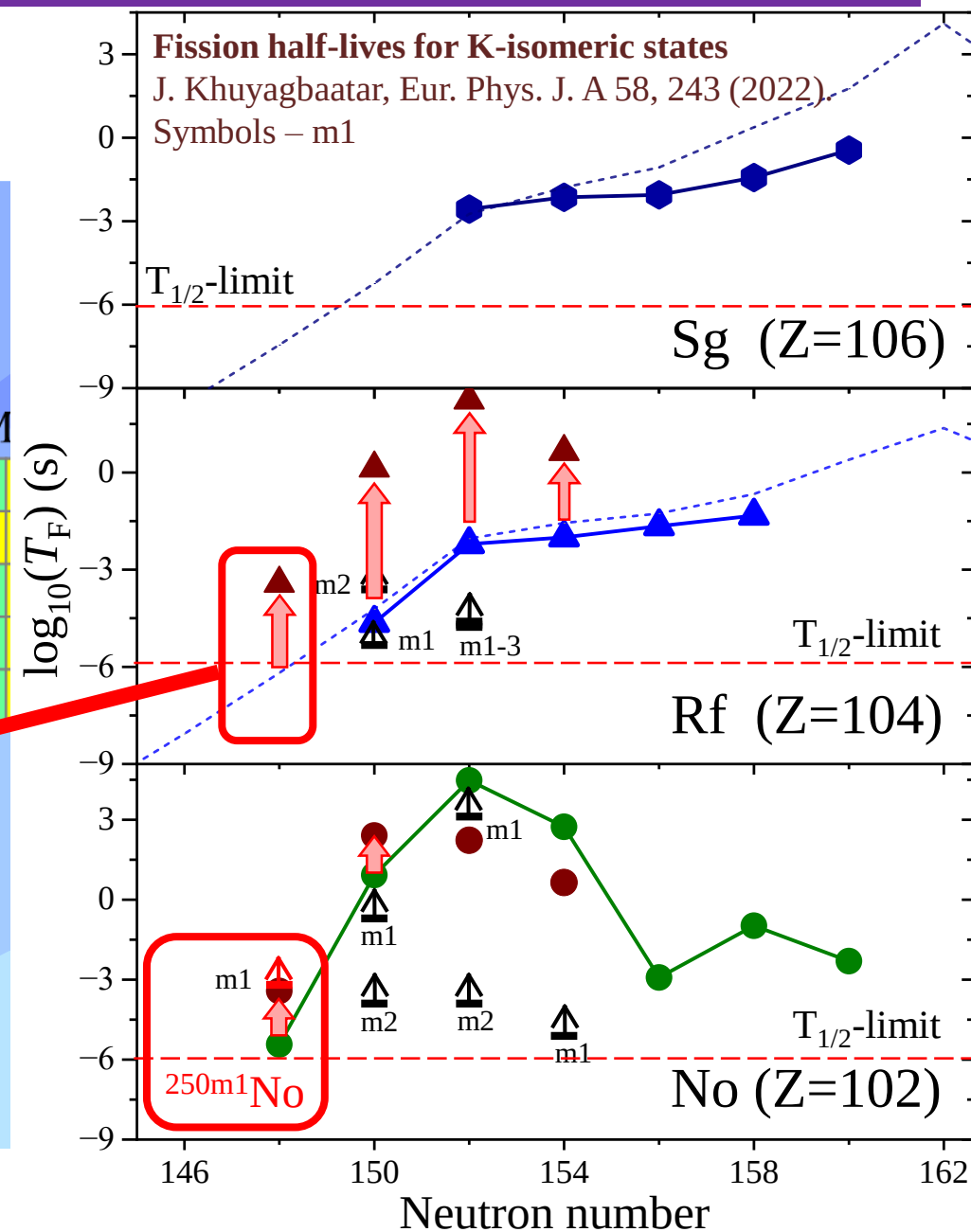
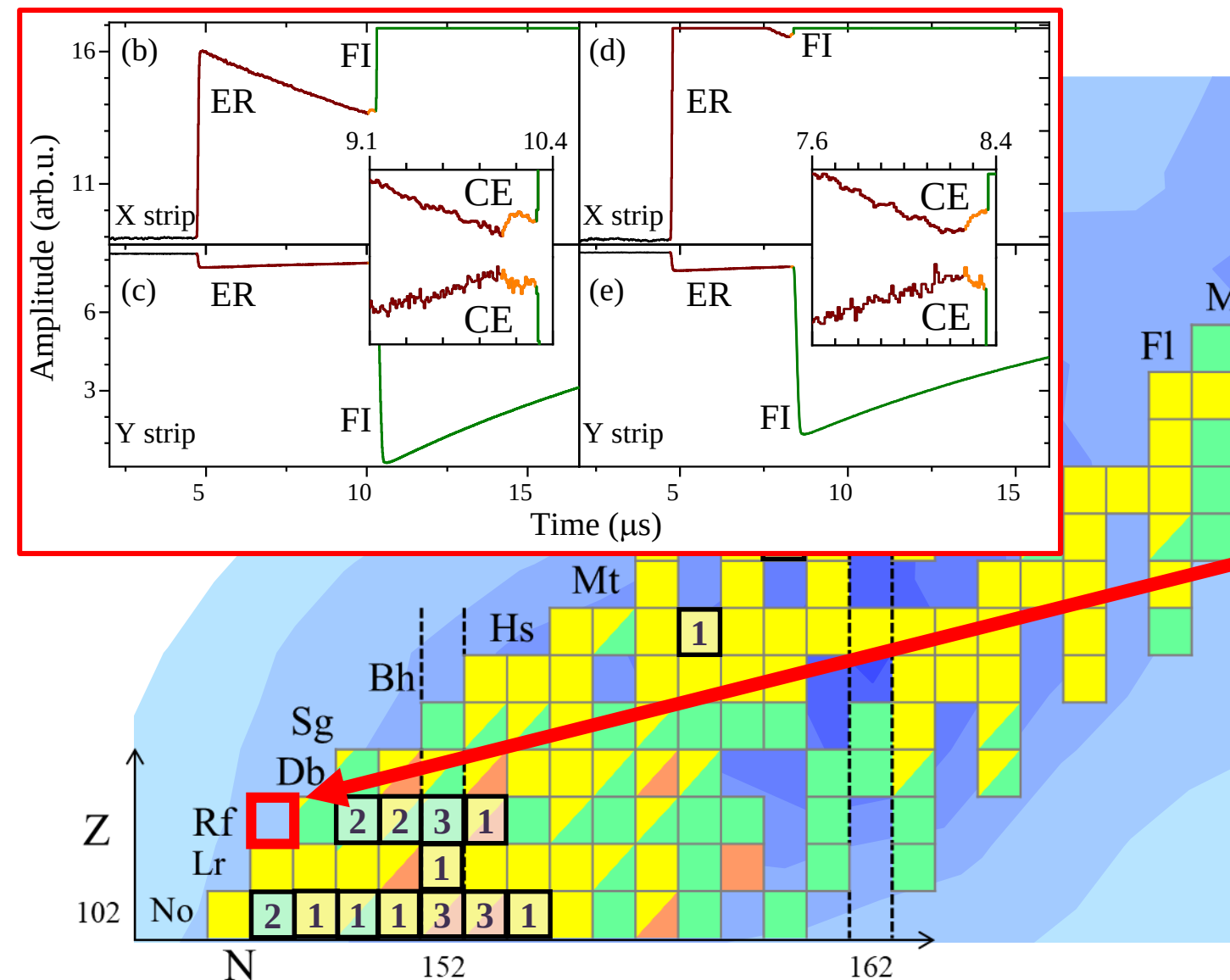


$^{50}\text{Ti} + ^{204}\text{Pb} \rightarrow ^{252}\text{Rf} + 2\text{n}$ @ **TASCA**

ER-Fission correlation

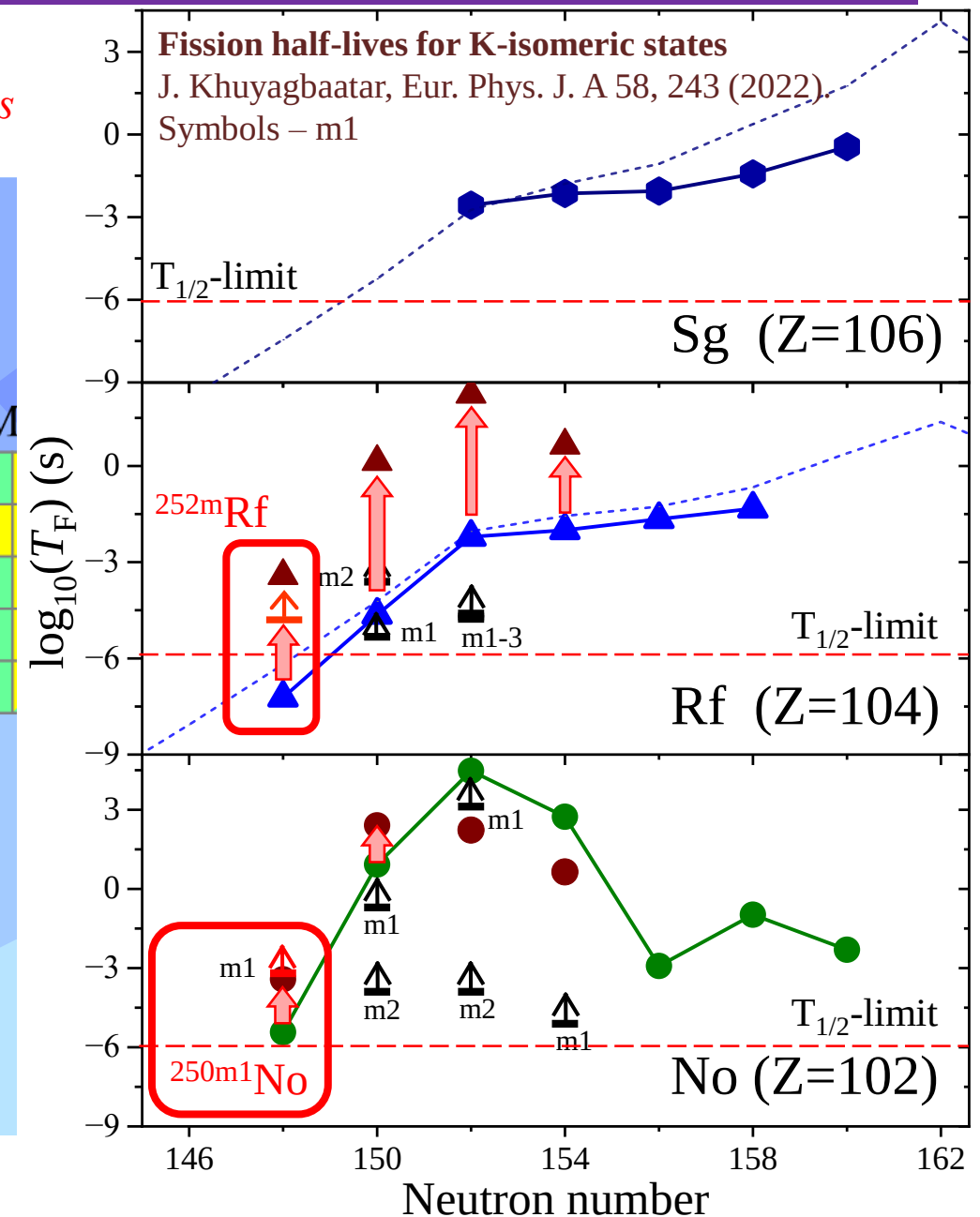
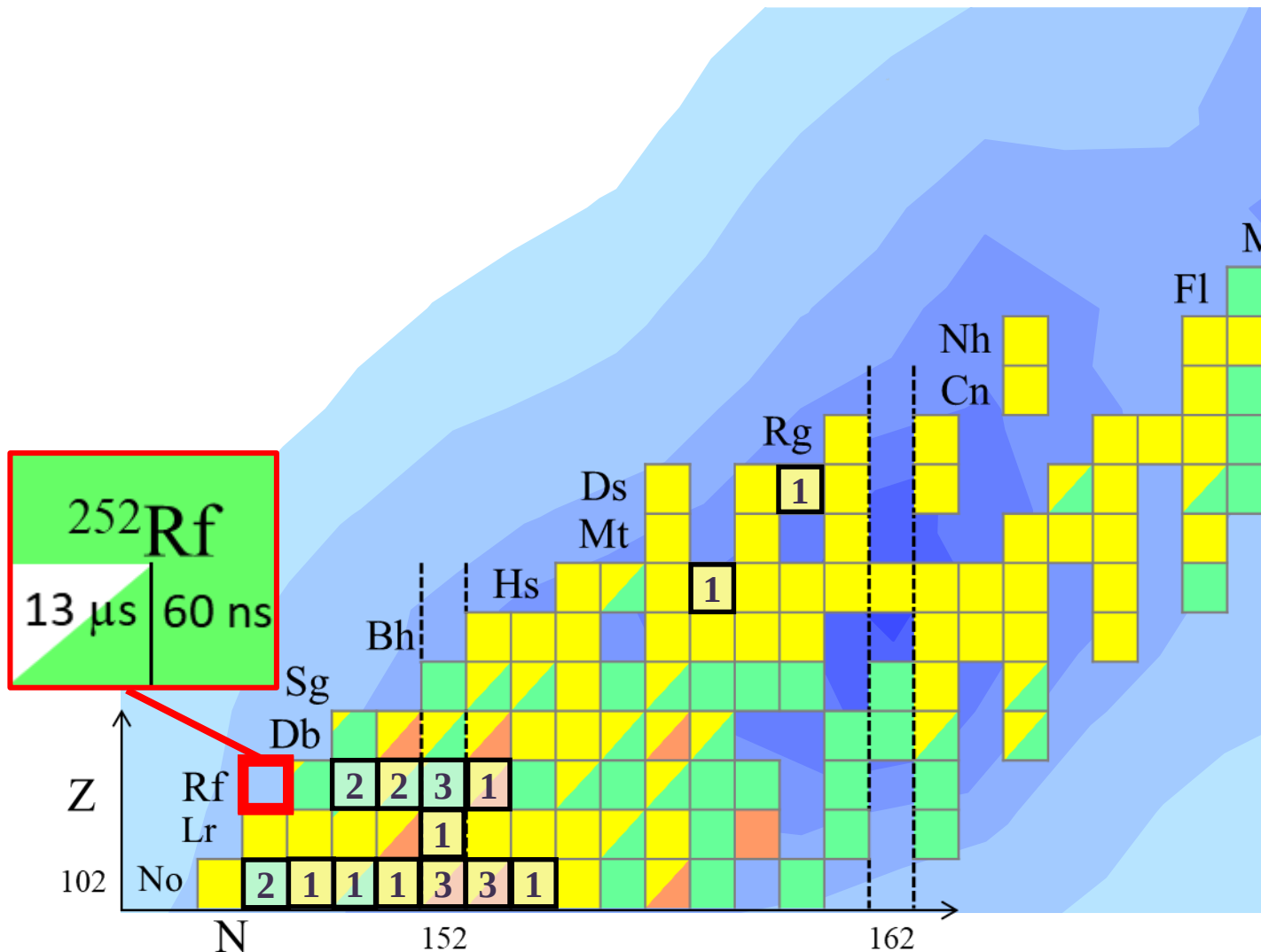


$^{50}\text{Ti} + ^{204}\text{Pb} \rightarrow ^{252}\text{Rf} + 2\text{n}$ @ **TASCA** Three **ER-CE-FI** events

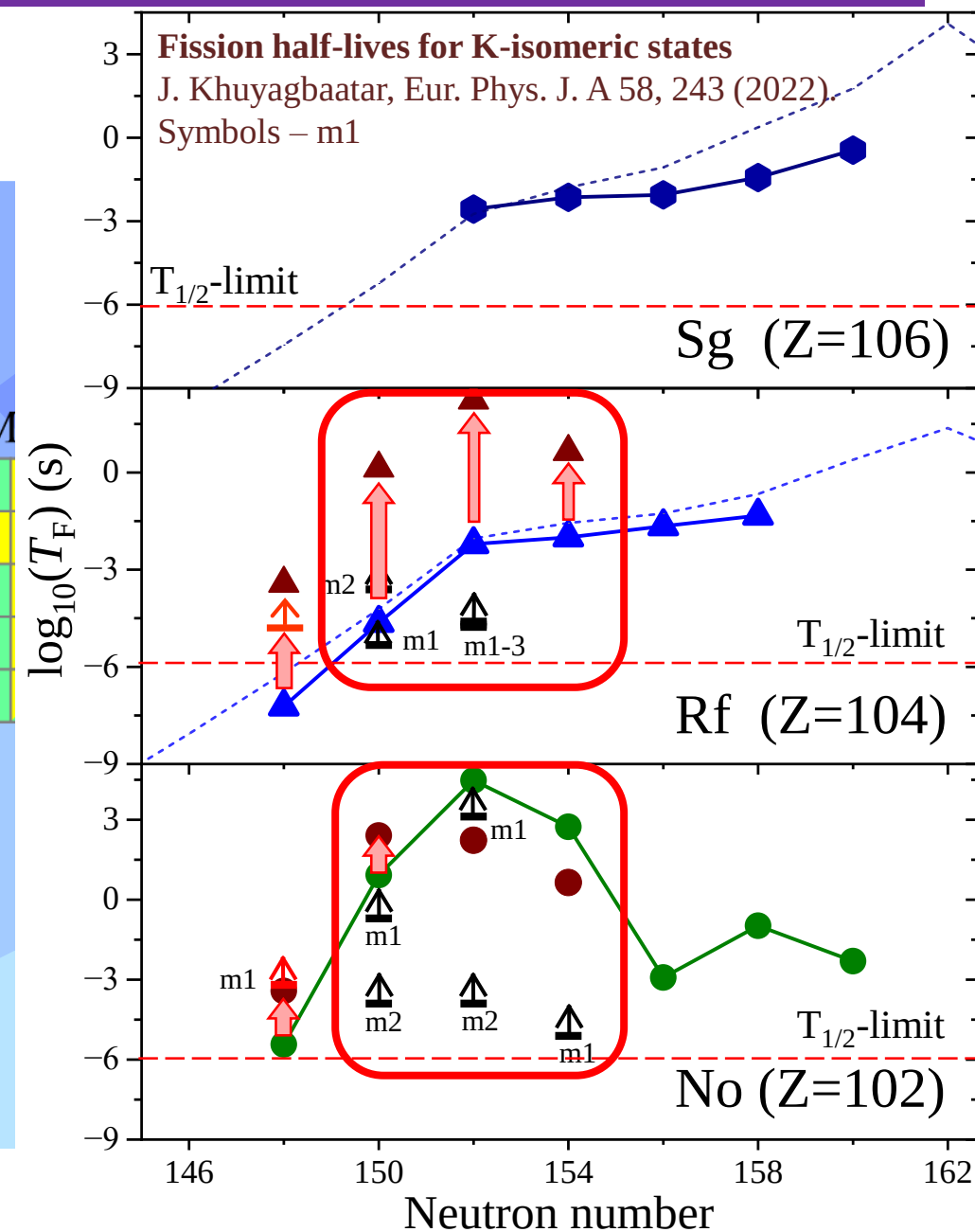
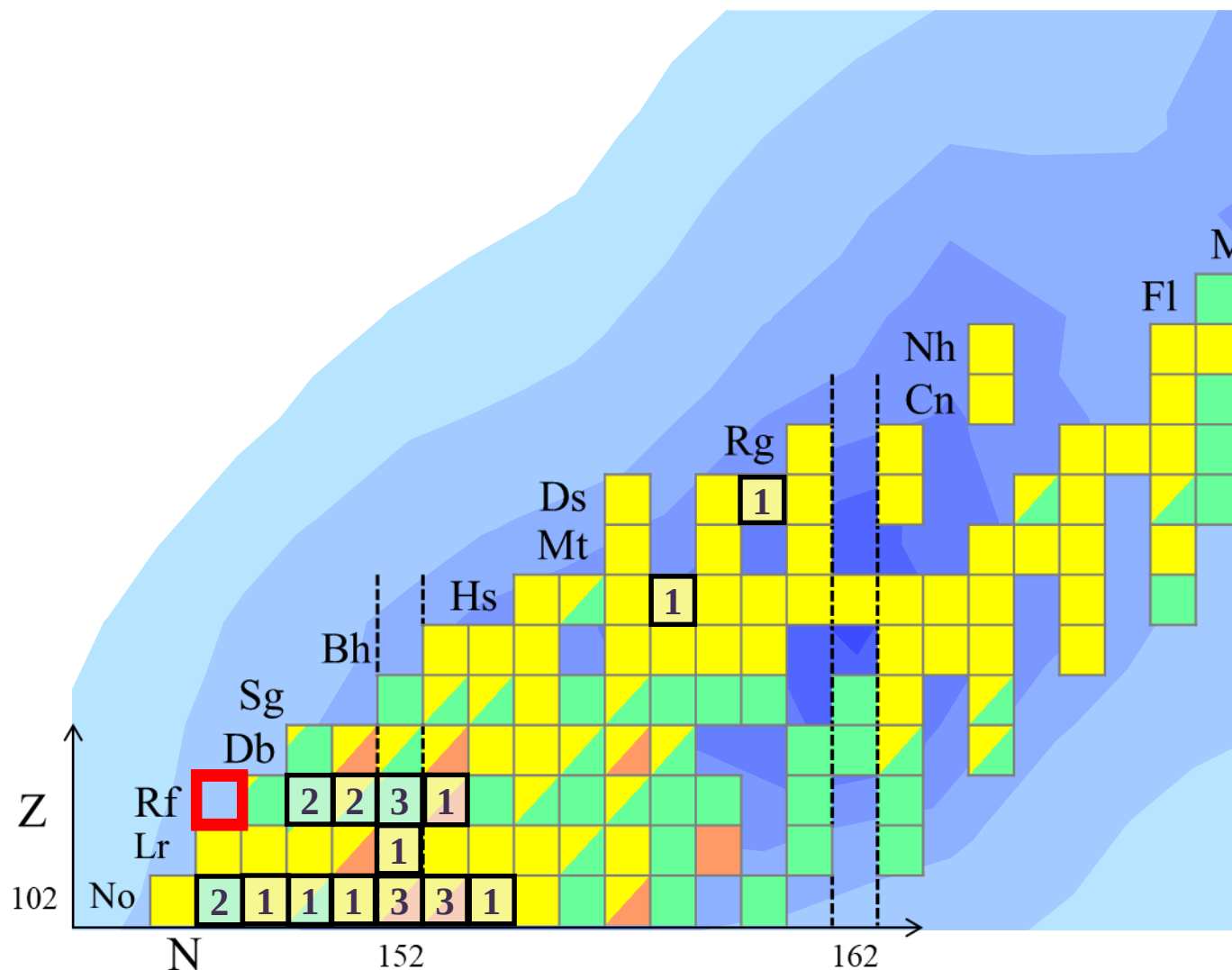


J. Khuyagbaatar, P. Mosat et al., Phys. Rev. Lett. **134**, 022501 (2025)

Editors' Suggestion / Featured in Physics



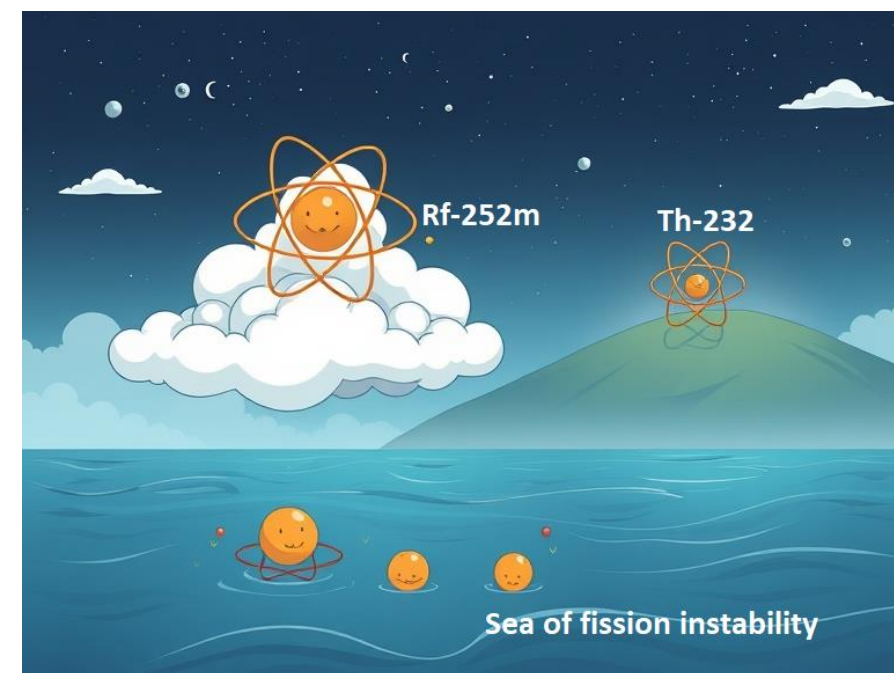
How about the known K-isomers in No and Rf ?



- Intensive program at exploring the properties of SHN @**TASCA** is still ongoing.
- Discovery of second K-isomeric state in ^{250}No
- Discovery of sub- μs SF ^{252}Rf and K-isomer
- Confirmation of K-isomer in ^{251}No
- Confirmations of K-isomers in ^{254}Rf
- Second K-isomeric state in ^{252}No ?
- Triggerless measurements of CE
 - $10^{-8} \text{ s} - 10^{-3} \text{ s}$

Fission landscape of superheavy nuclei

Island of stability + Clouds of stability



Thank you for your attention.



SHE-Chemistry, Target Lab, Experimental Electronics, IT, Ion source, UNILAC, Detector Lab, Radiation safety etc.,

