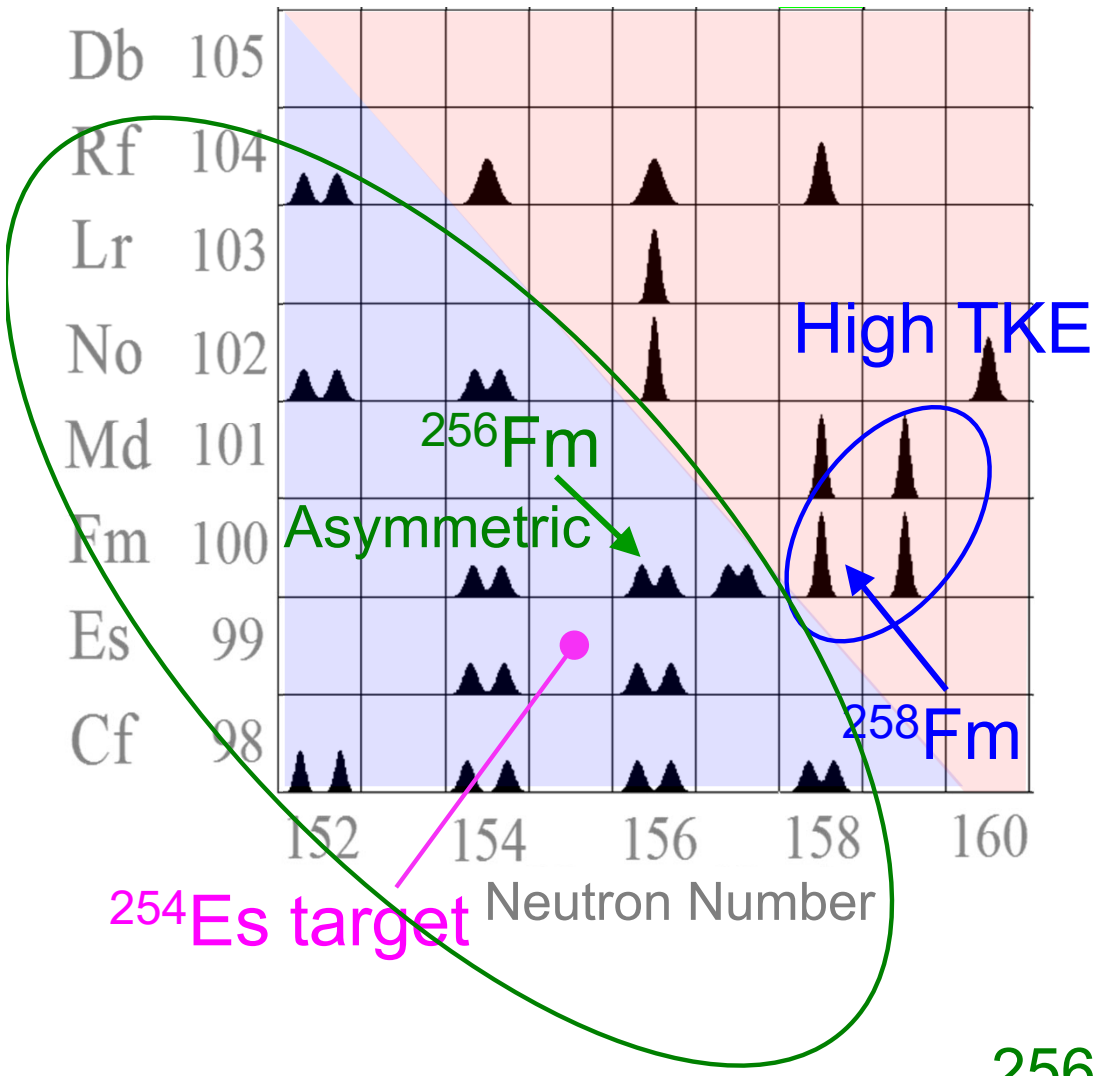
理研RIBFミニワークショップ「理論と実験で拓く中性子過剰核の核分裂」
2023年2月16-17日（理研）

中性子過剰Fm領域核の自発核分裂測定

浅井雅人 （原子力機構先端基礎研究センター）

Fission studies in neutron-rich Fm region

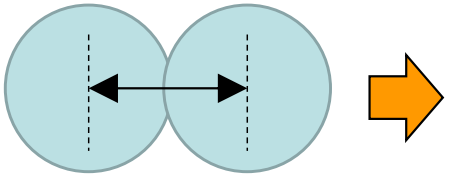
Fission-fragment mass distribution



M.R. Lane et al., PRC 53 (1996) 2893.

High TKE symmetric

$^{258}Fm = {}^{129}Sn + {}^{129}Sn$

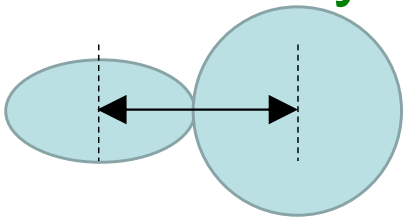


High TKE

Spherical + Spherical

Low TKE Asymmetric

^{256}Fm

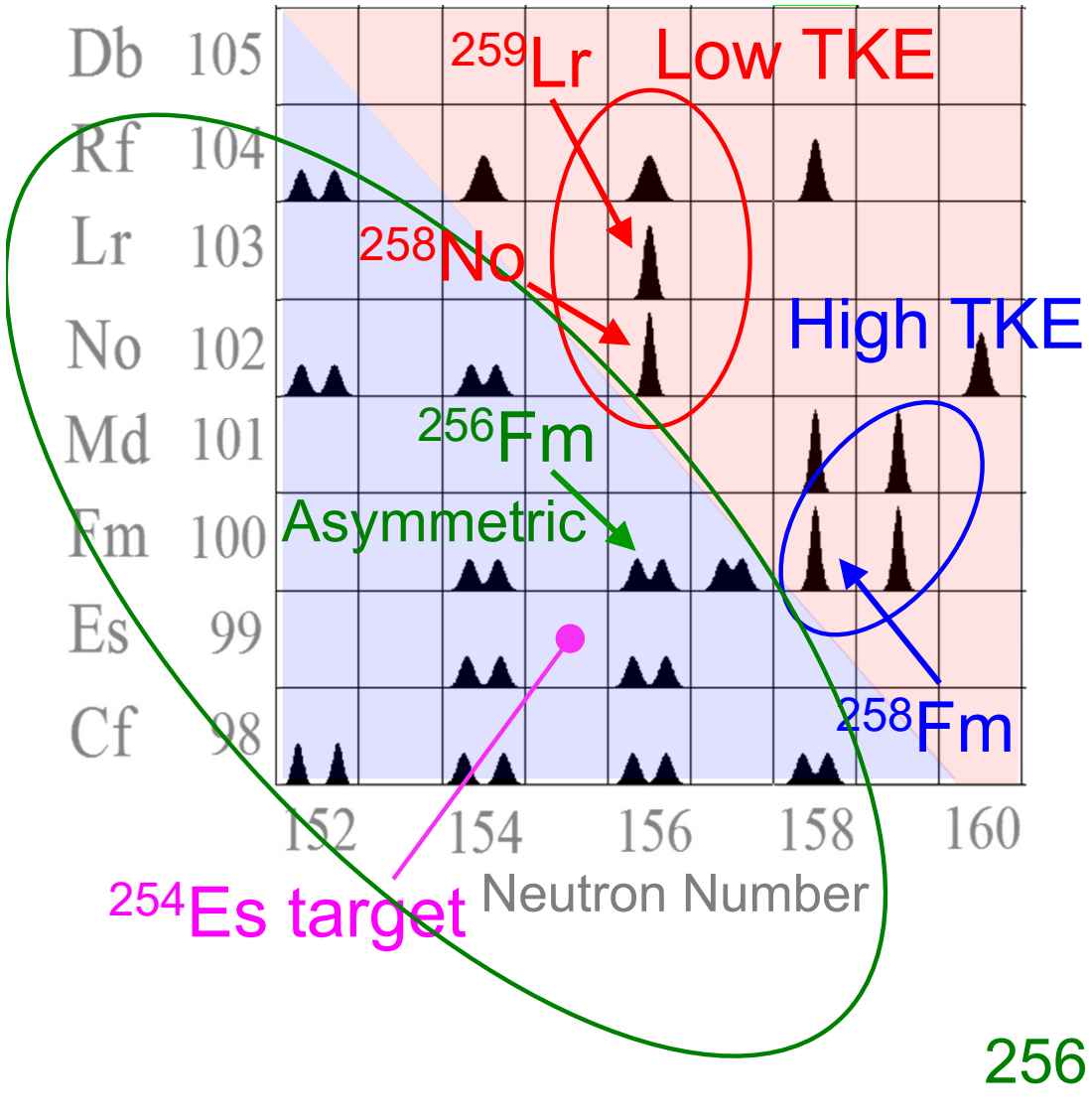


Low TKE

Deformed + Spherical

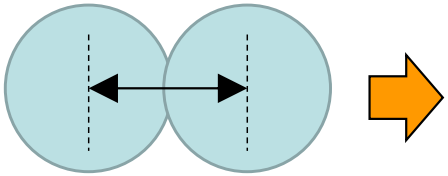
Fission studies in neutron-rich Fm region

Fission-fragment mass distribution



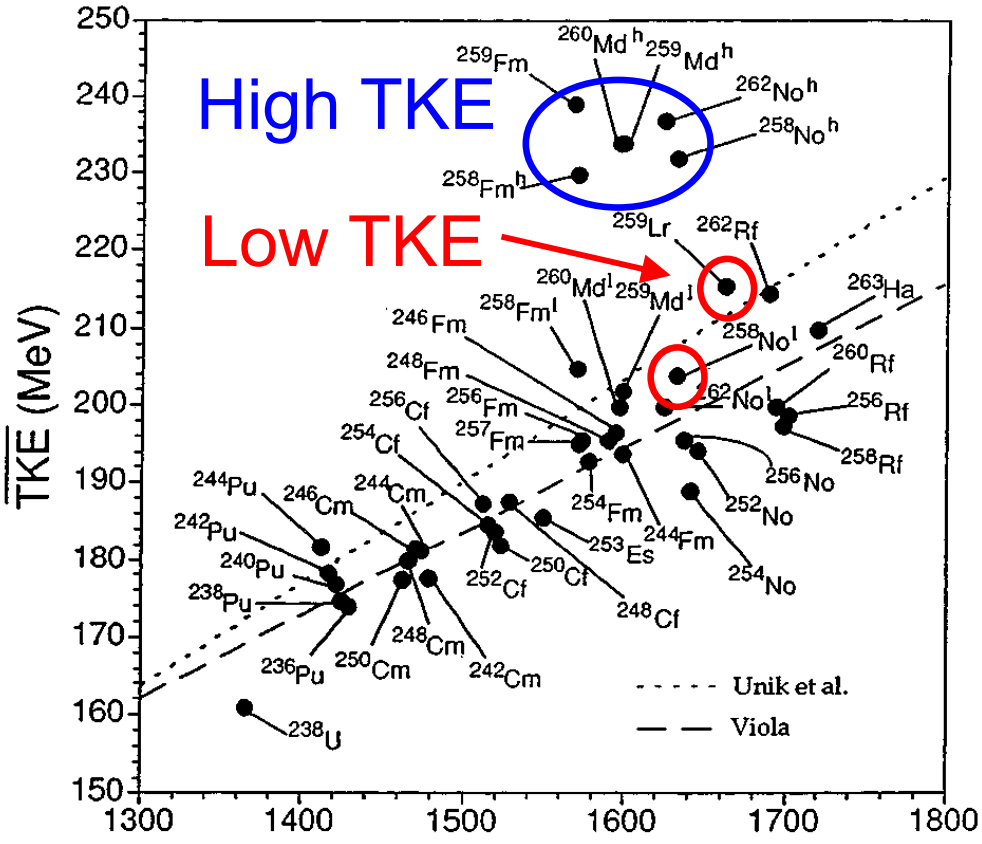
High TKE symmetric

$^{258}Fm = {}^{129}Sn + {}^{129}Sn$



High TKE

Spherical + Spherical

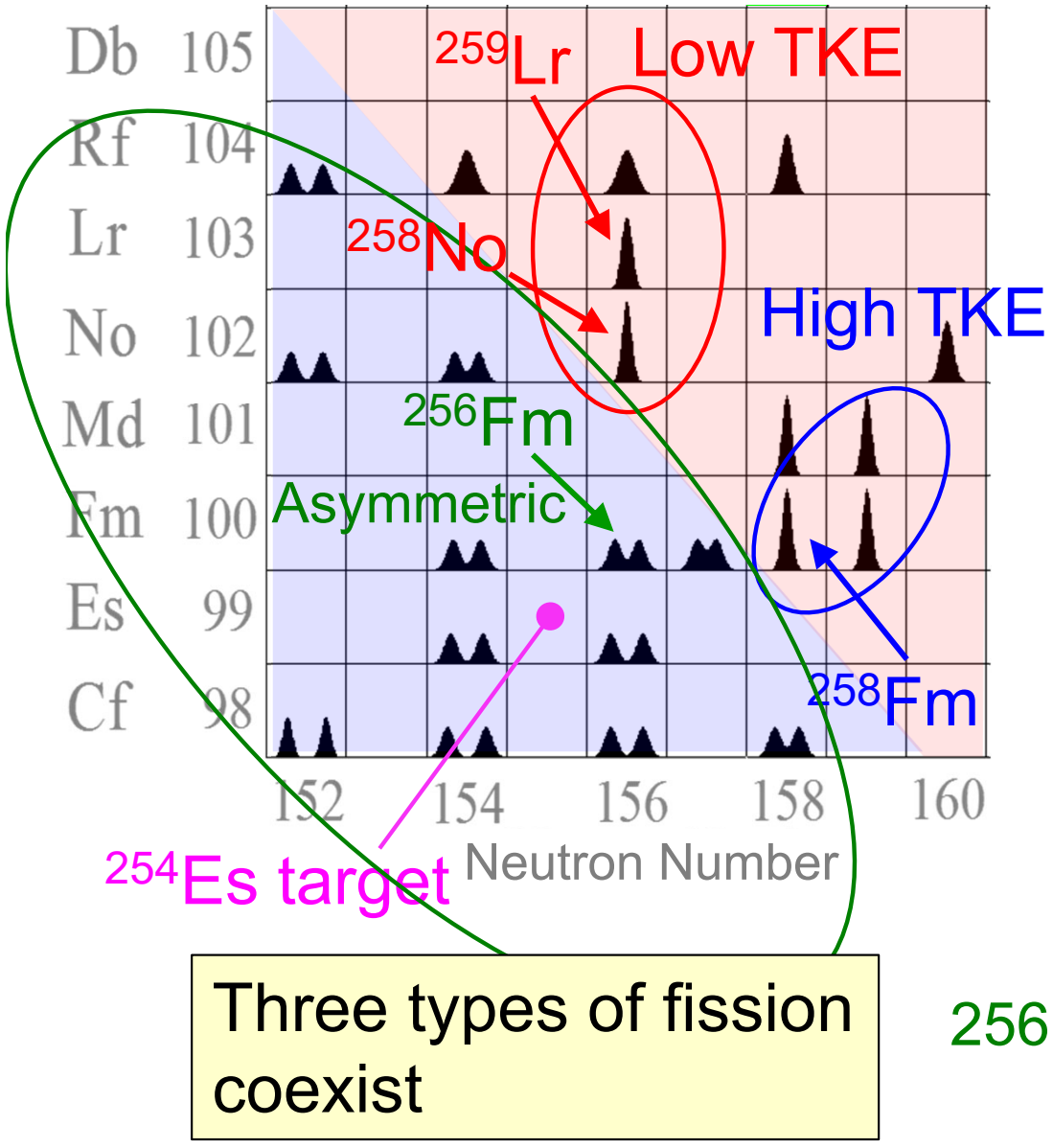


256F

M.R. Lane et al., PRC 53 (1996) 2893.

Fission studies in neutron-rich Fm region

Fission-fragment mass distribution

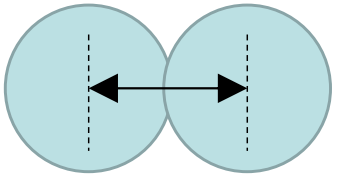


Three types of fission coexist

M.R. Lane et al., PRC 53 (1996) 2893.

High TKE symmetric

$^{258}Fm = {}^{129}Sn + {}^{129}Sn$

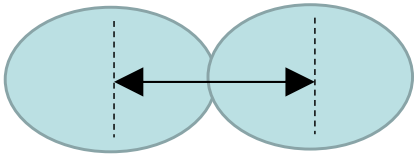


High TKE

Spherical + Spherical

Low TKE symmetric

$^{258}No = {}^{129}Sb + {}^{129}Sb$

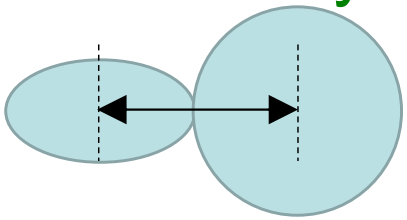


Low TKE

Deformed + Deformed

Low TKE Asymmetric

^{256}Fm

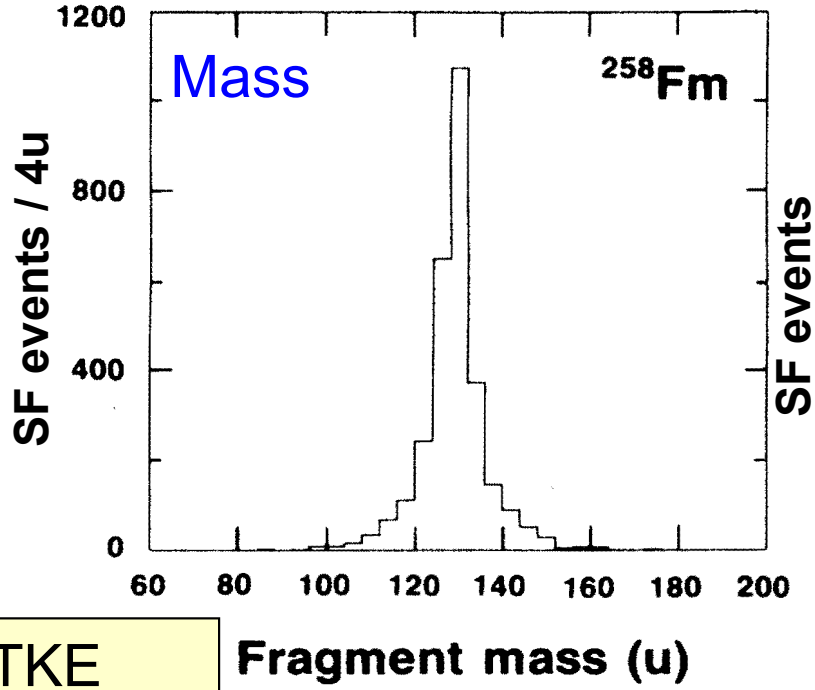


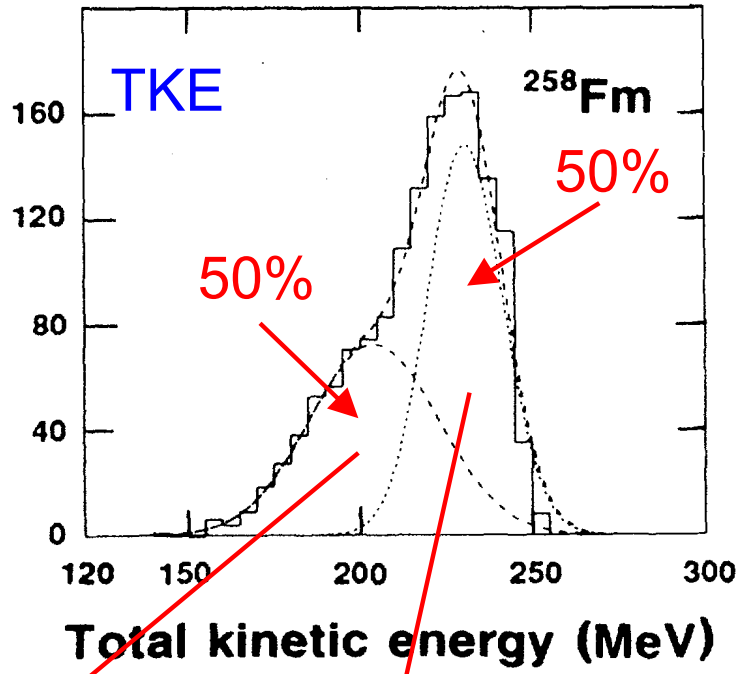
Low TKE

Deformed + Spherical

Previous fission experiment for ^{258}Fm ($T_{1/2}$ = 370 μs)

Hulet et al. PRC40, 770 (1989)



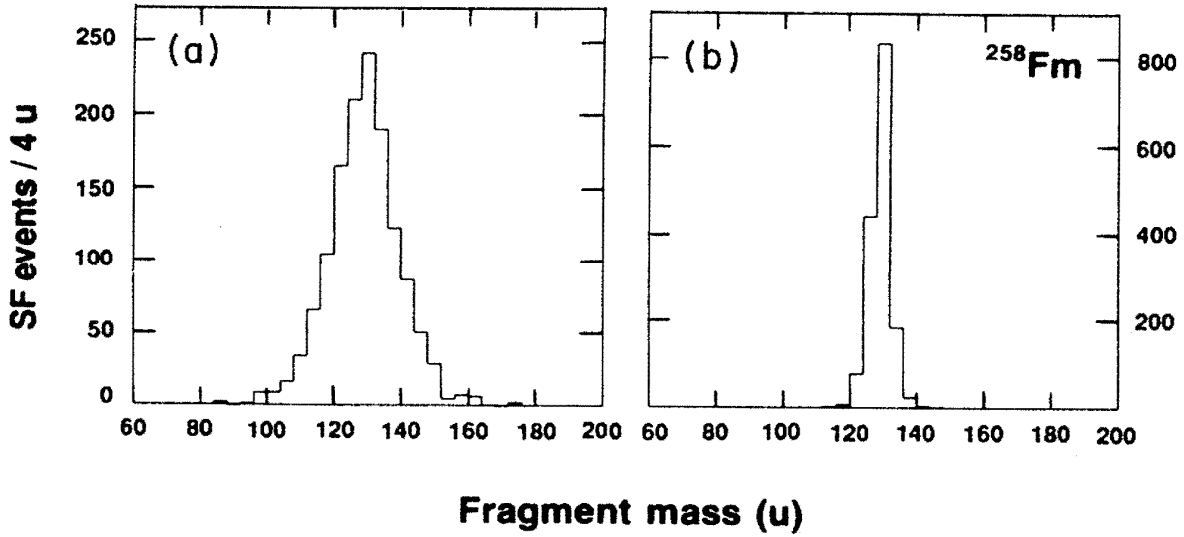


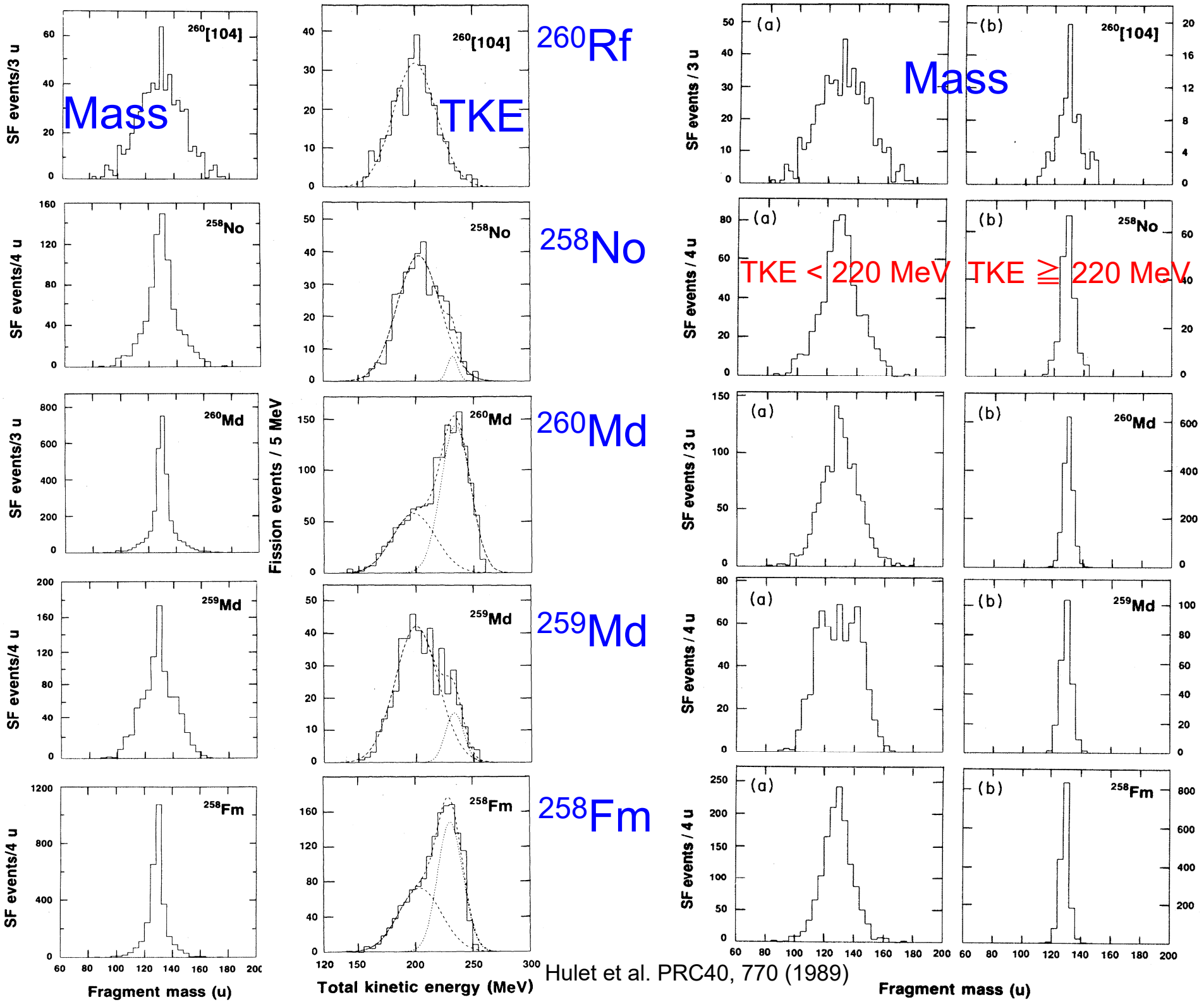
High-TKE and low-TKE symmetric fissions coexist.
— Bimodal Fission —

- Asymmetric fission also coexist?
- Need more detailed Mass-TKE distribution data !

TKE < 220 MeV

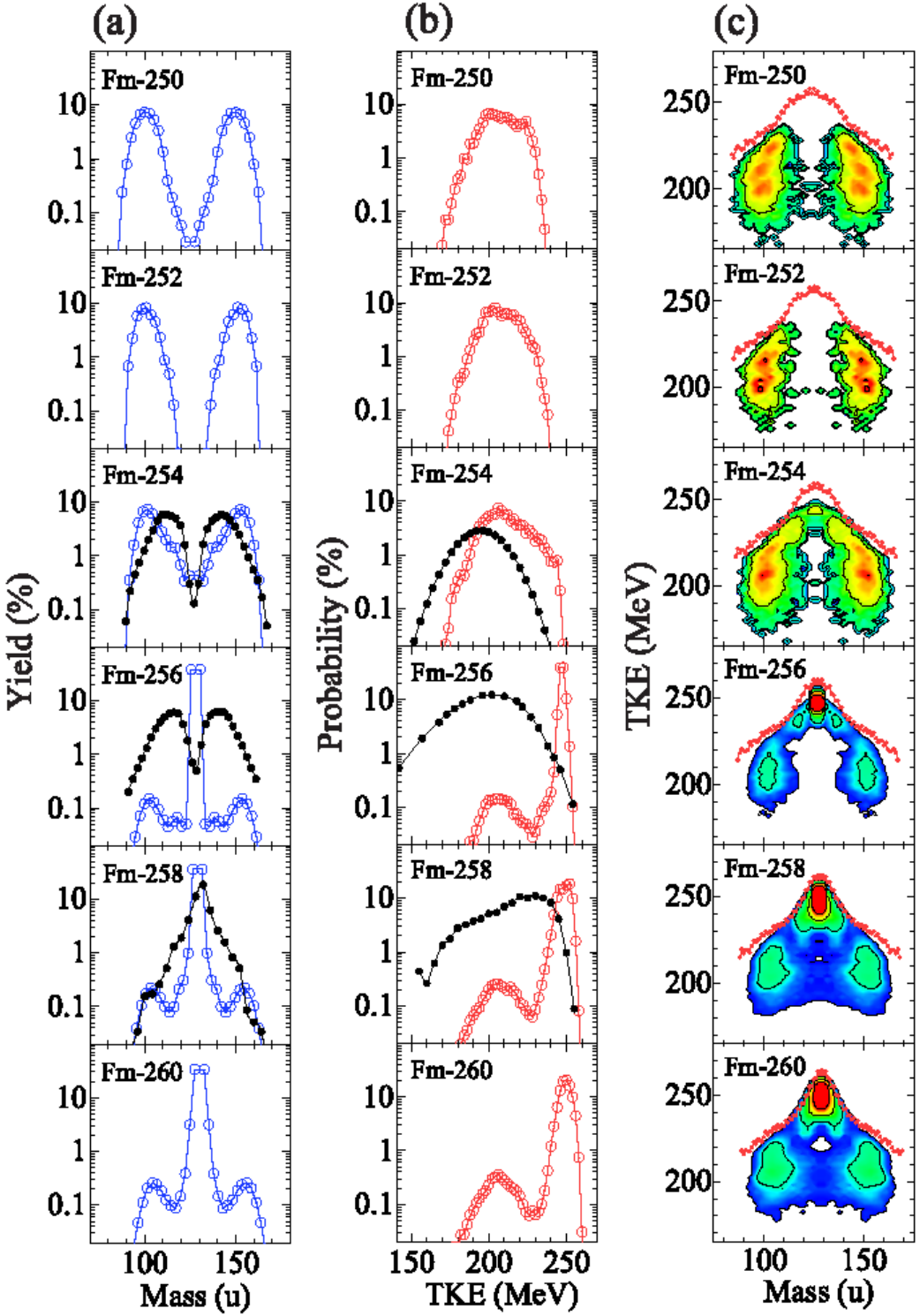
TKE ≧ 220 MeV





Hulet et al. PRC40, 770 (1989)

Theoretical calculation -- Miyamoto et al., PRC 99, 051601(R) (2019).



Langevin calculation

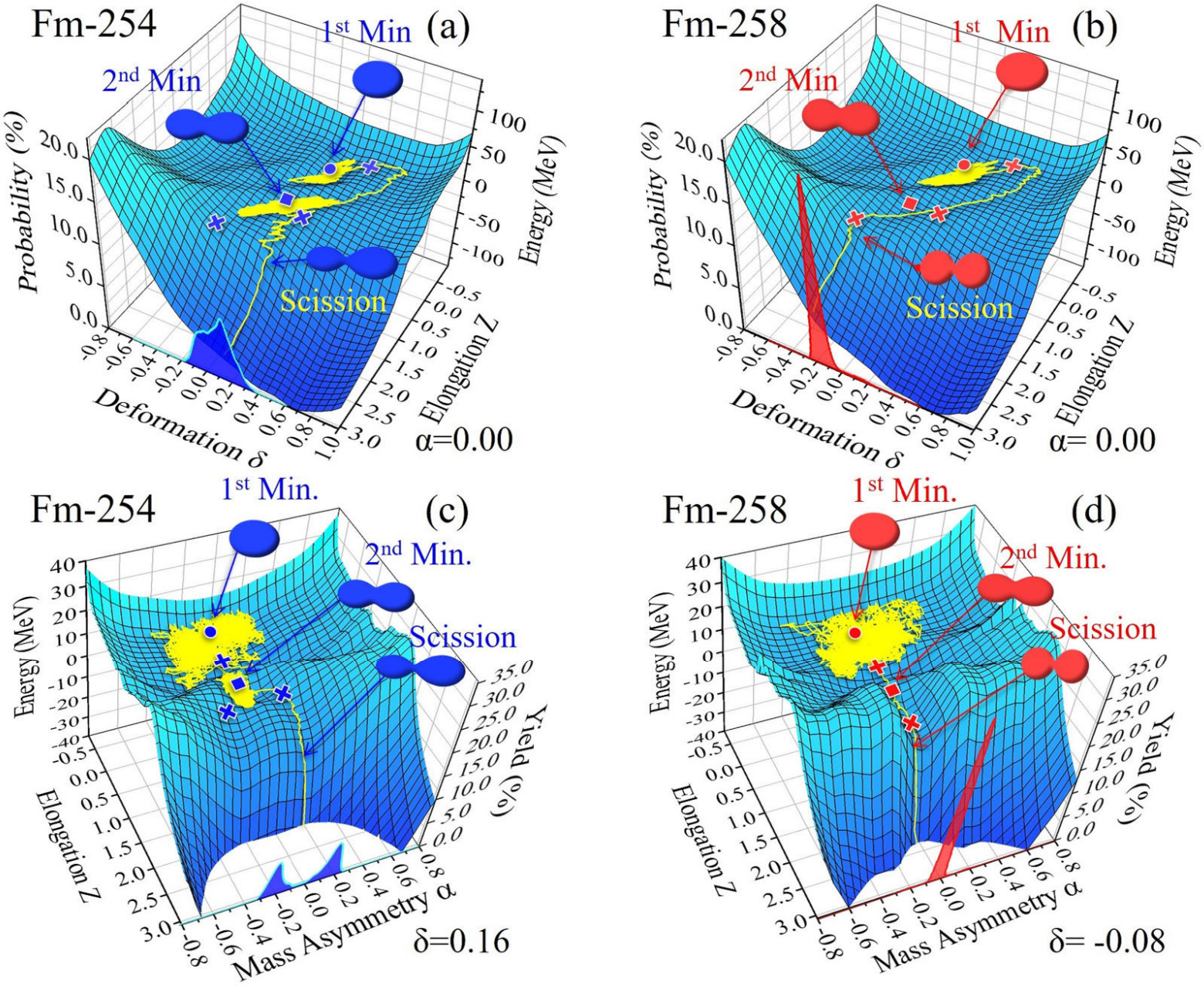
Asymmetric

^{254}Fm

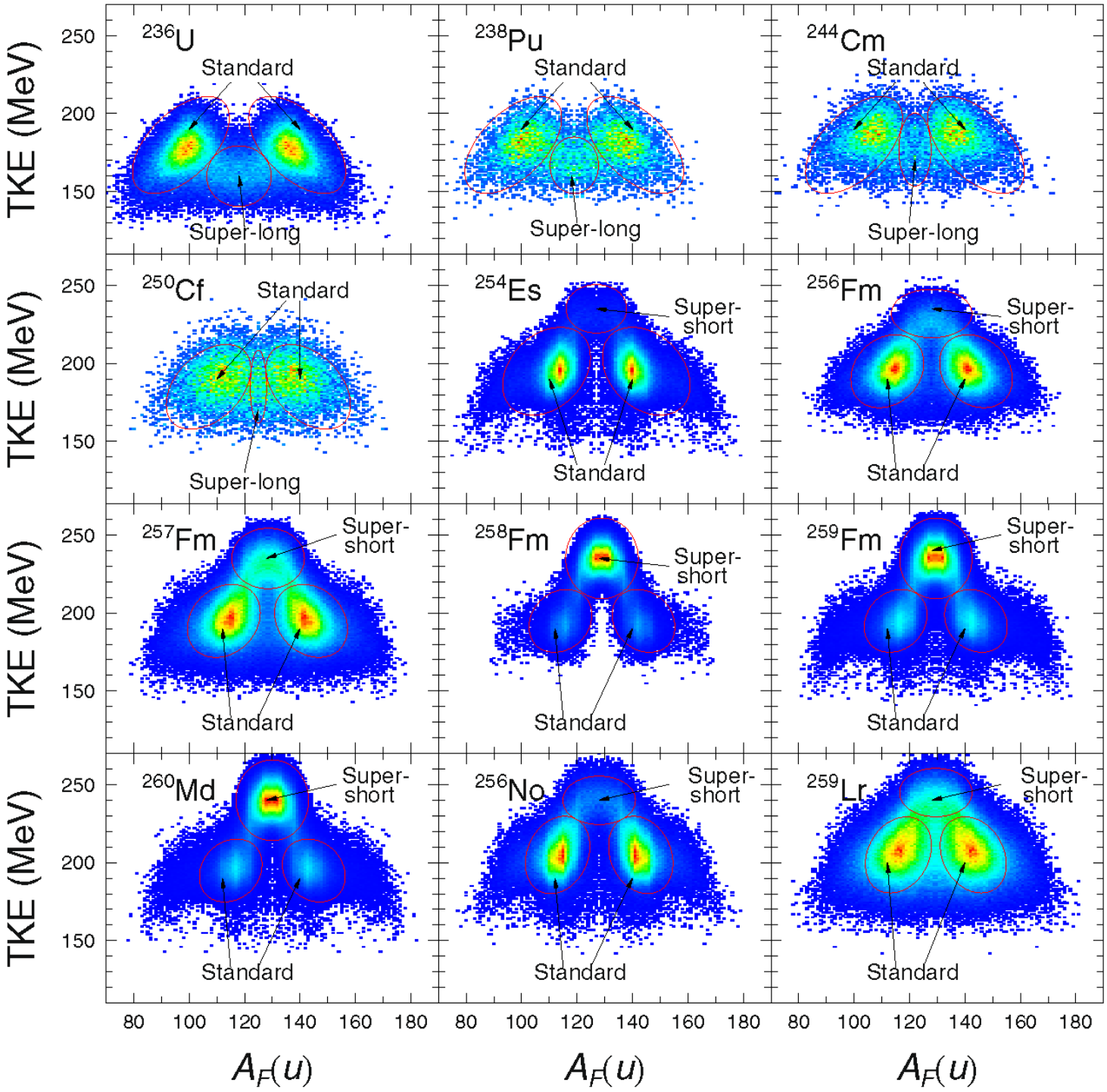
^{256}Fm

High-TKE symmetric
+ Asymmetric

Theoretical calculation -- Miyamoto et al., PRC 99, 051601(R) (2019).



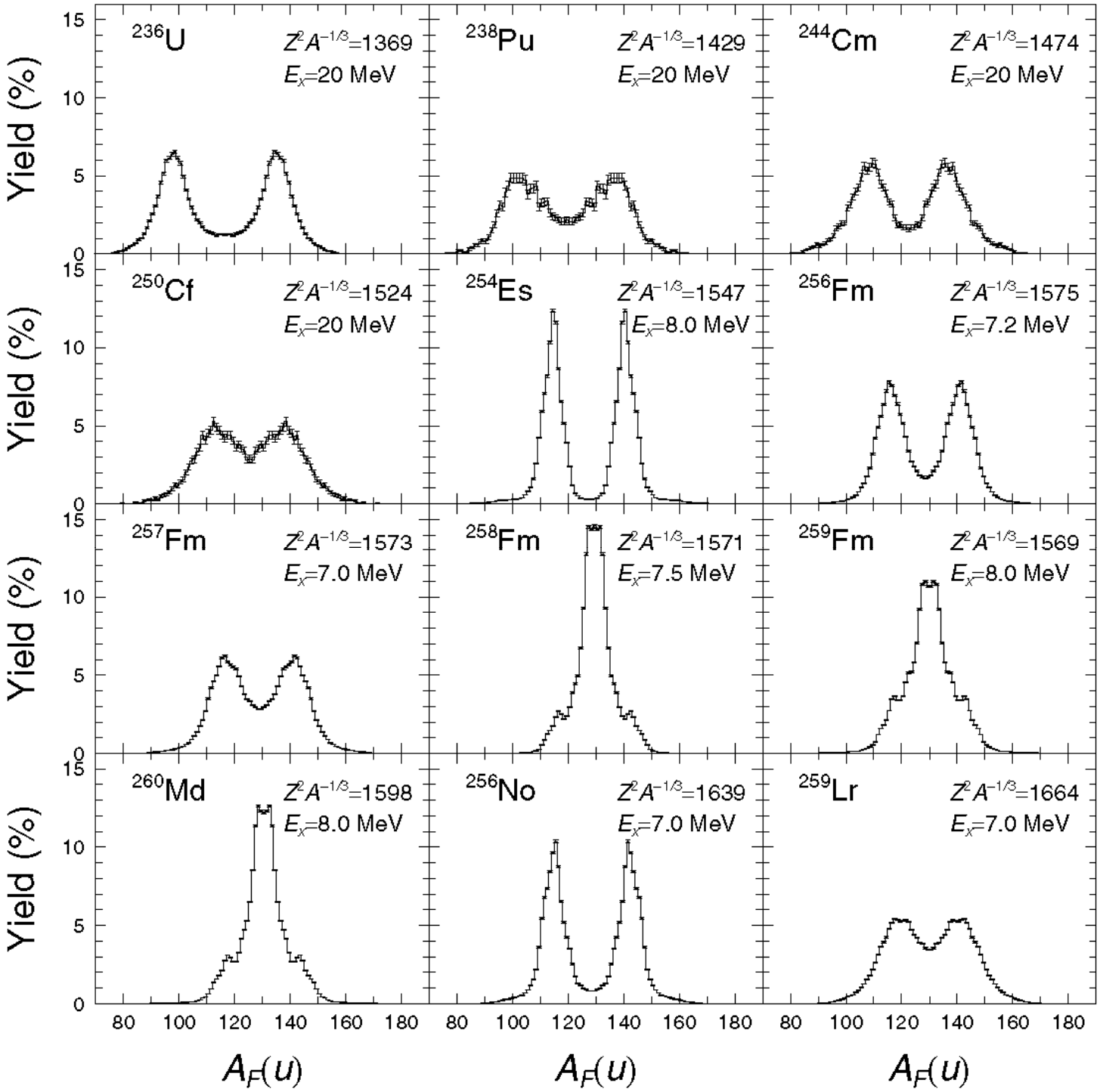
Theoretical calculation -- Usang et al., Sci. Rep. 9, 1525 (2019).



4D Langevin calc.

High-TKE symmetric
+ Asymmetric

Theoretical calculation -- Usang et al., Sci. Rep. 9, 1525 (2019).

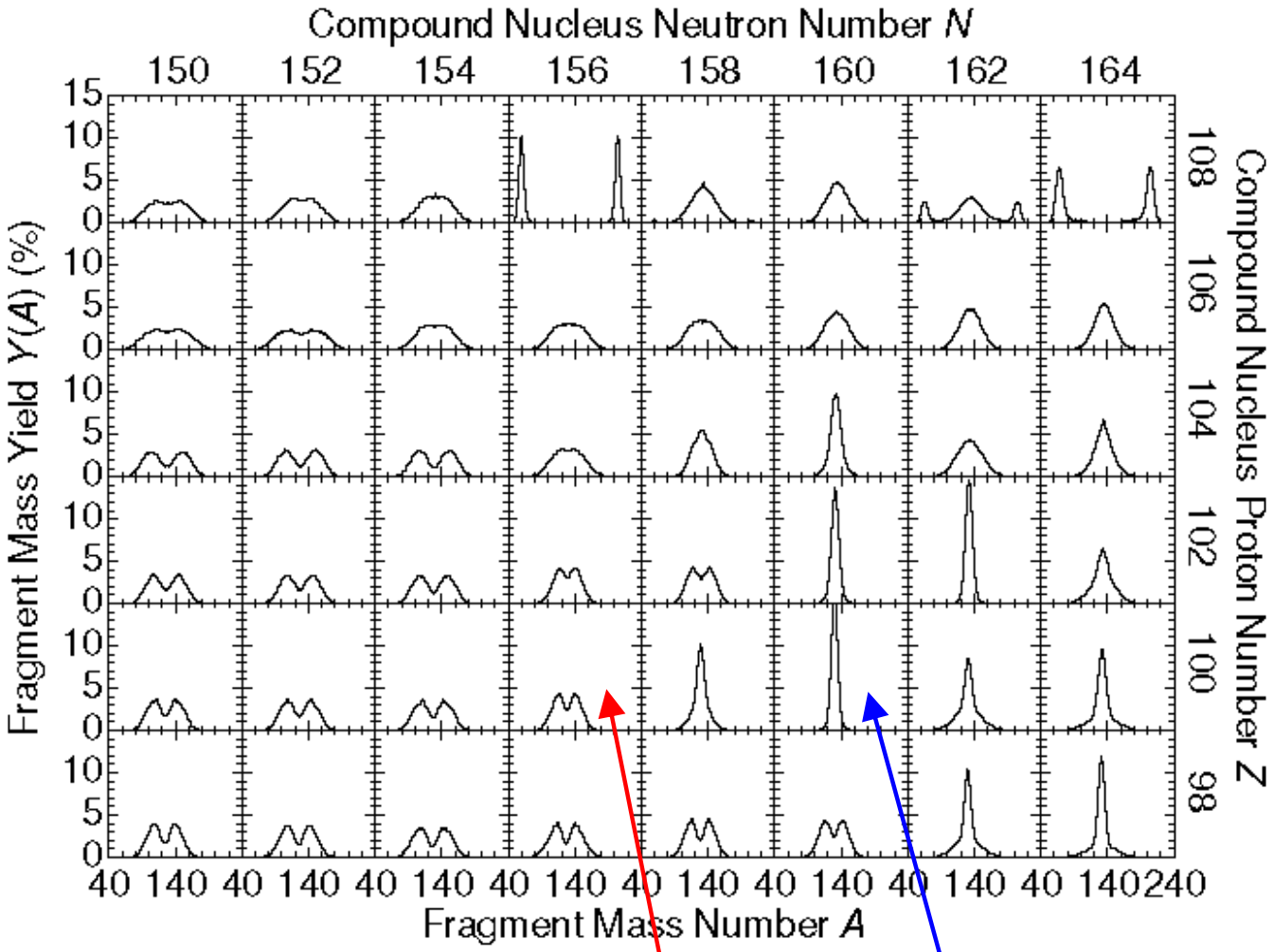


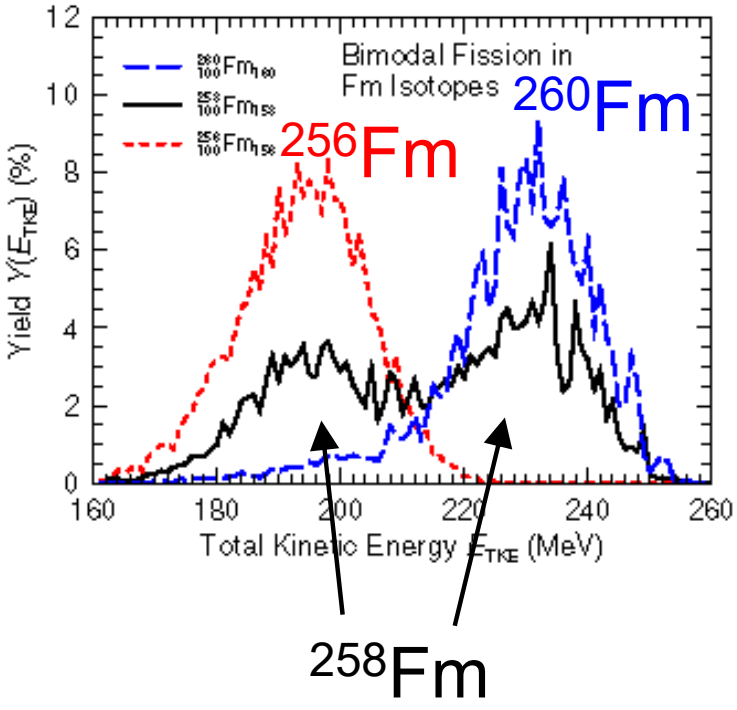
4D Langevin calc.

High-TKE symmetric
+ Asymmetric

Theoretical calculation -- Albertsson et al., EPJA 56, 46 (2020).

Brownian shape motion





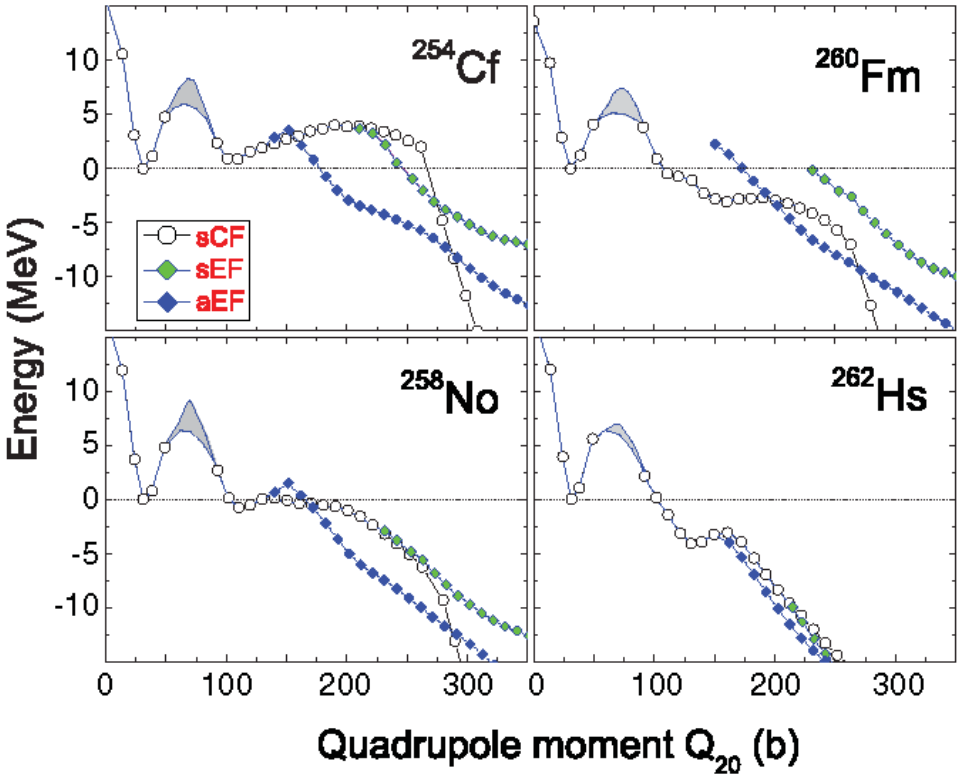
^{256}Fm
Asymmetric

^{260}Fm
High-TKE symmetric

^{258}Fm
High-TKE symmetric
+ Asymmetric?

Calculations with Density Functional Theory (DFT)

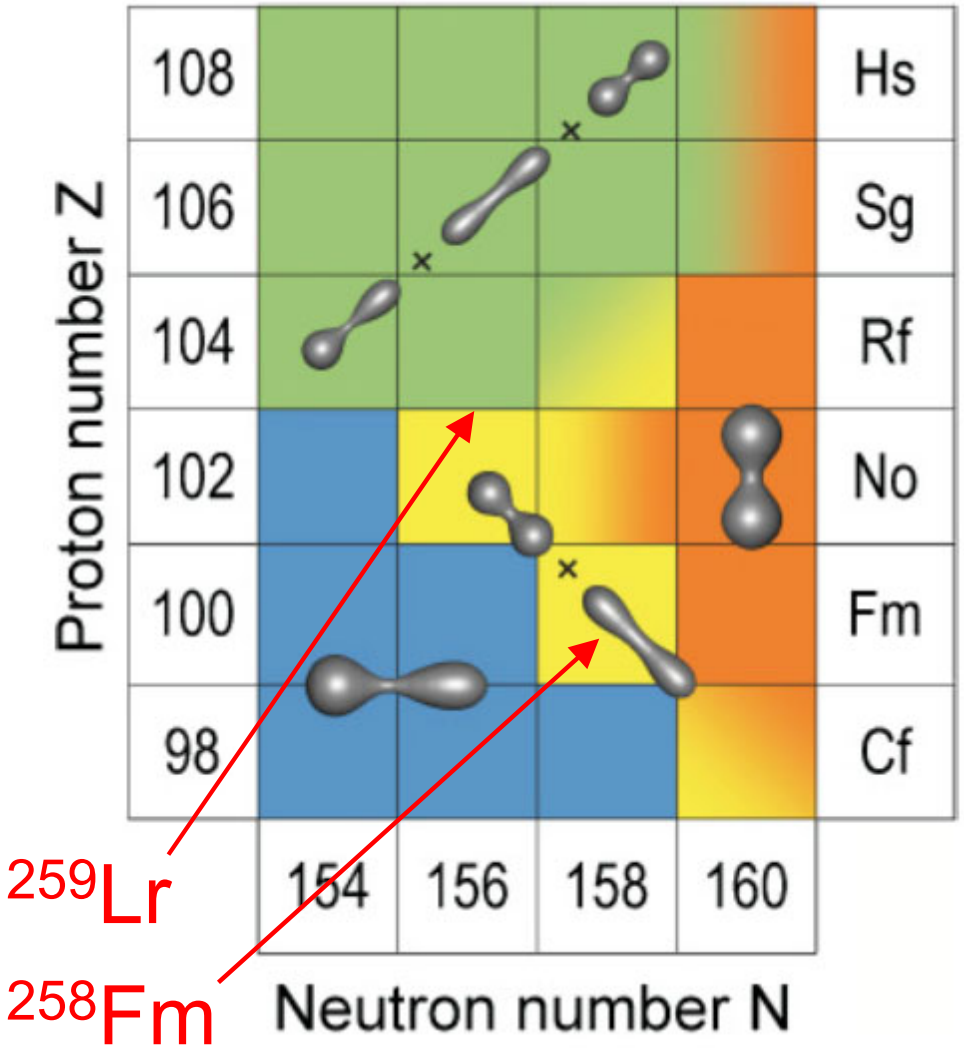
A. Staszczak et al., PRC 80 (2009) 014309.



○ Symmetric Compact

◆ Symmetric Elongated

◆ Asymmetric Elongated

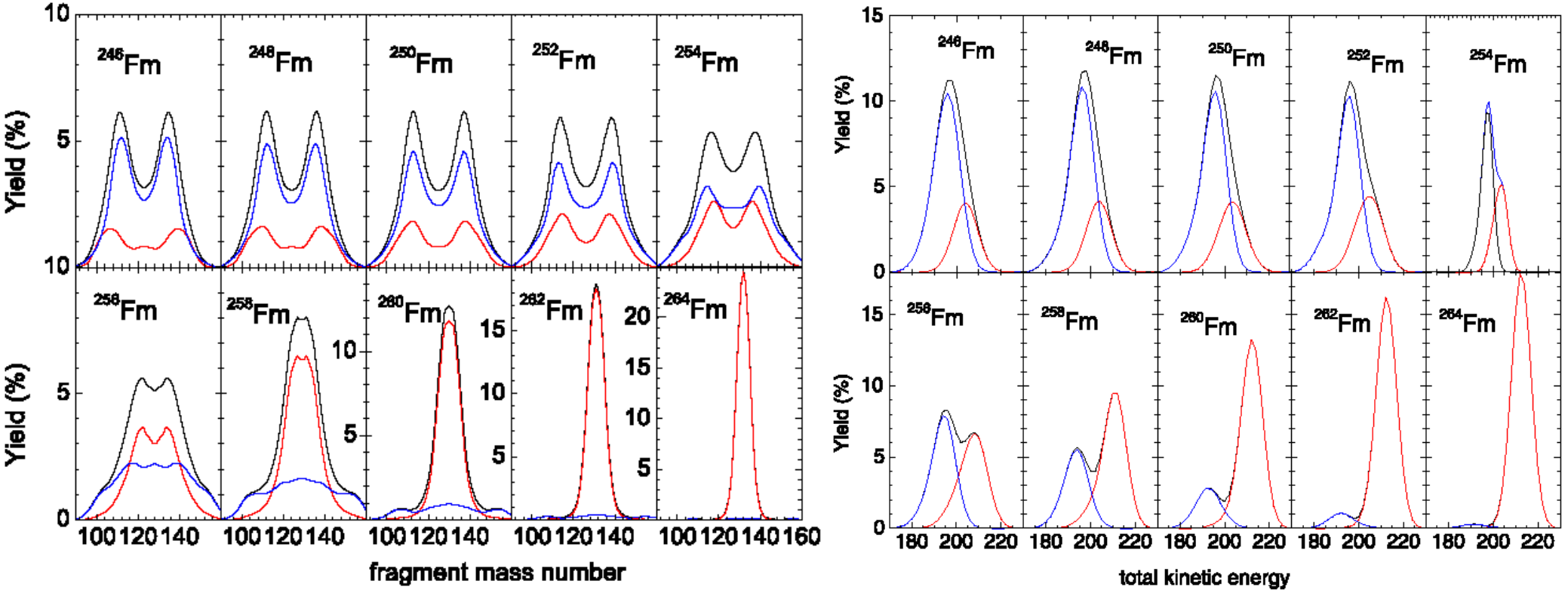


Theoretical calculation – Carjan et al., NPA 942, 97 (2015).

Cassinian ovals

Mass

TKE

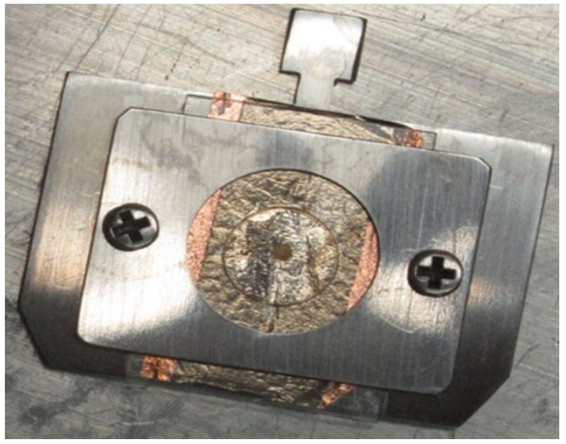


Compact + Elongated

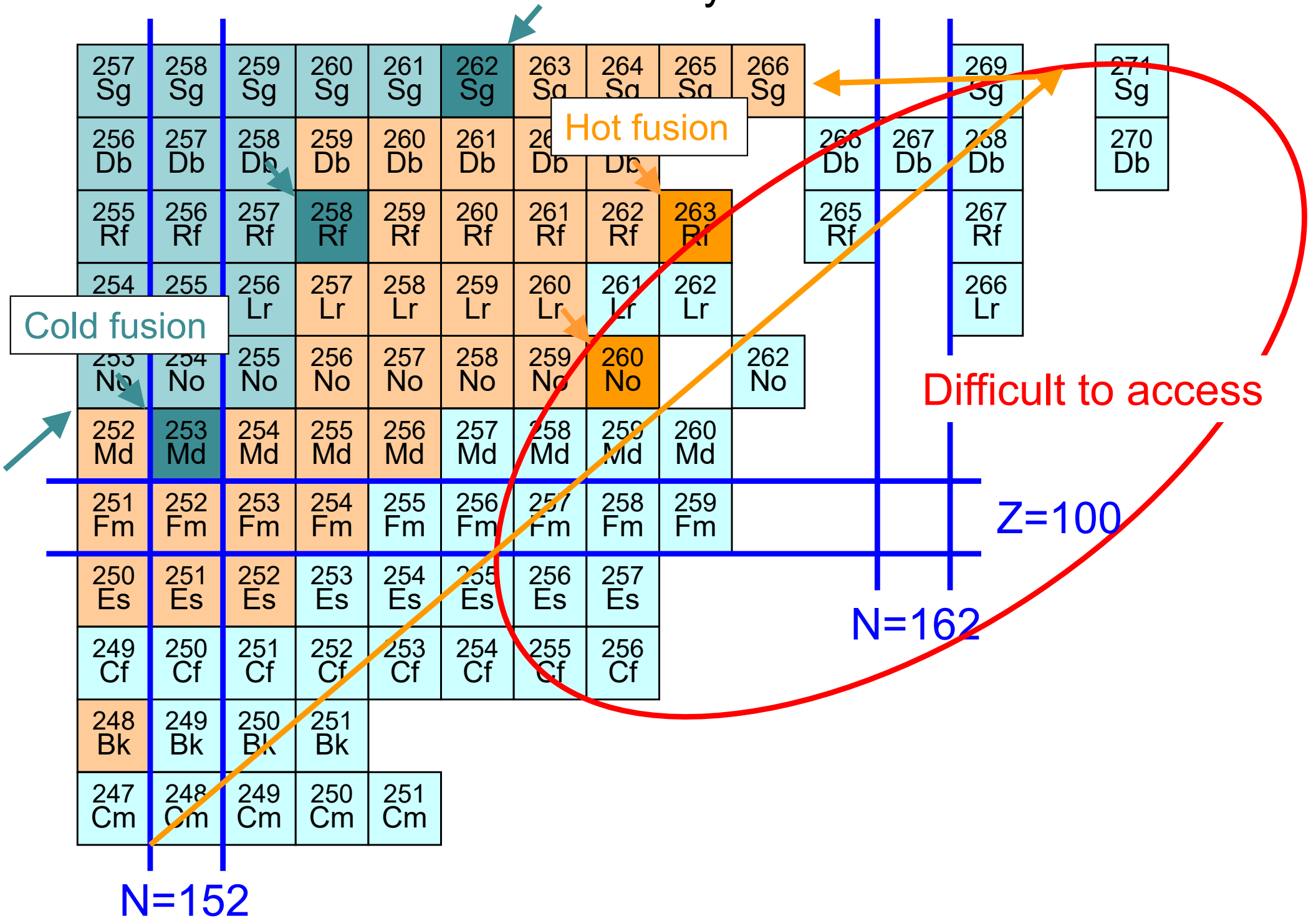
Spontaneous fission measurements for neutron-rich heavy actinide nuclei using ^{254}Es target at JAEA tandem accelerator

^{254}Es target

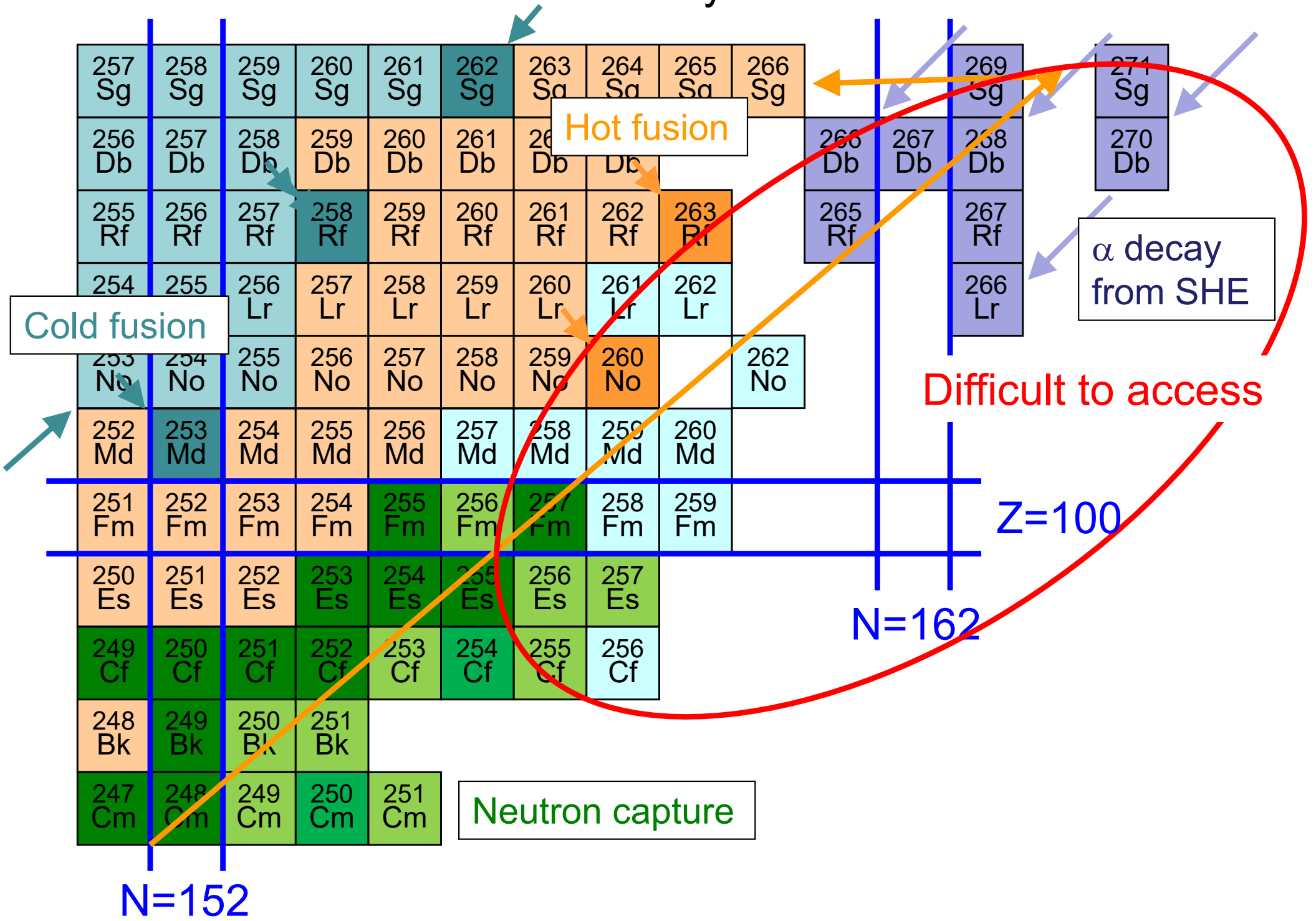
^{254}Es target



Production of neutron-rich heavy- and trans-actinide nuclei



Production of neutron-rich heavy- and trans-actinide nuclei



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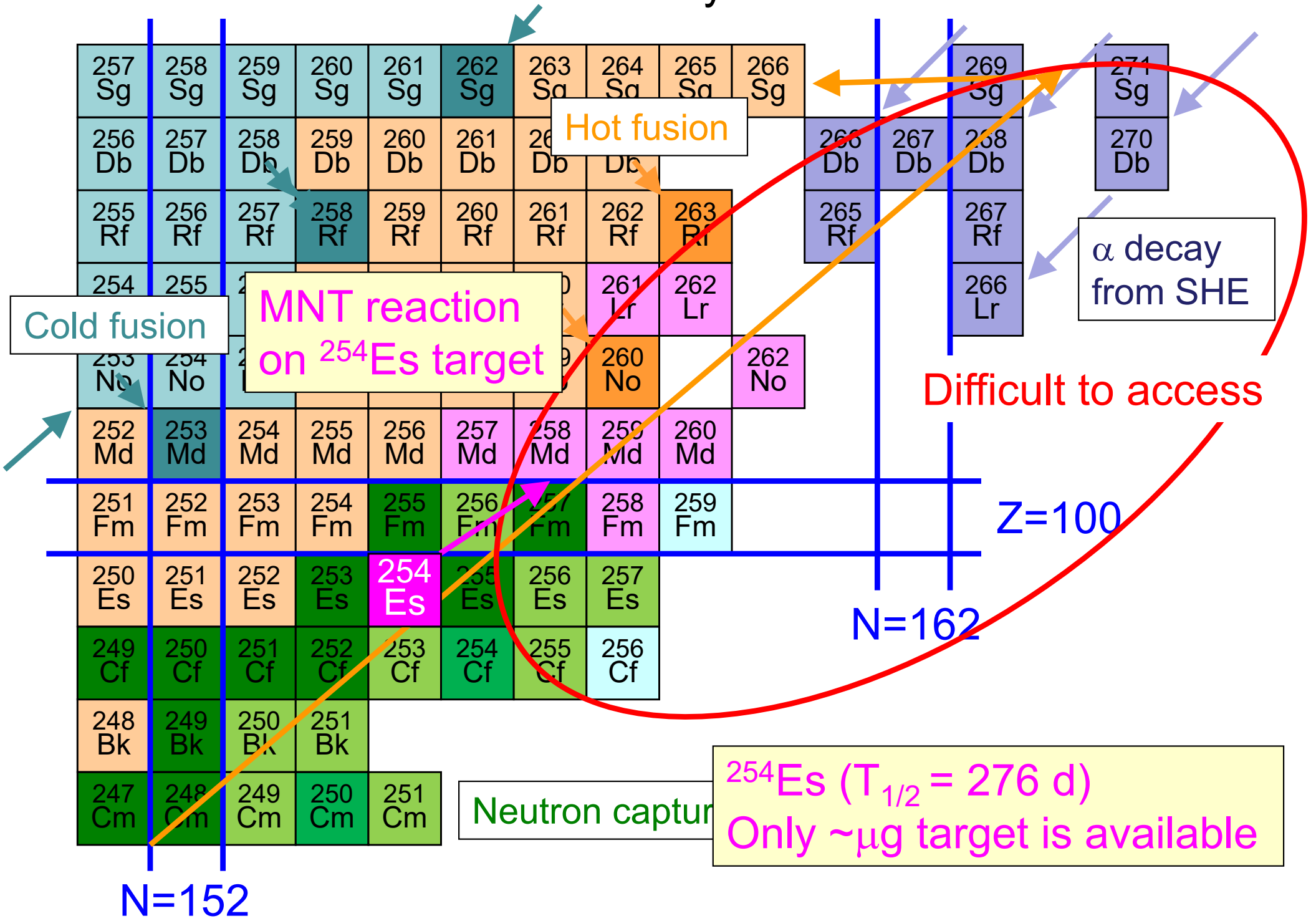

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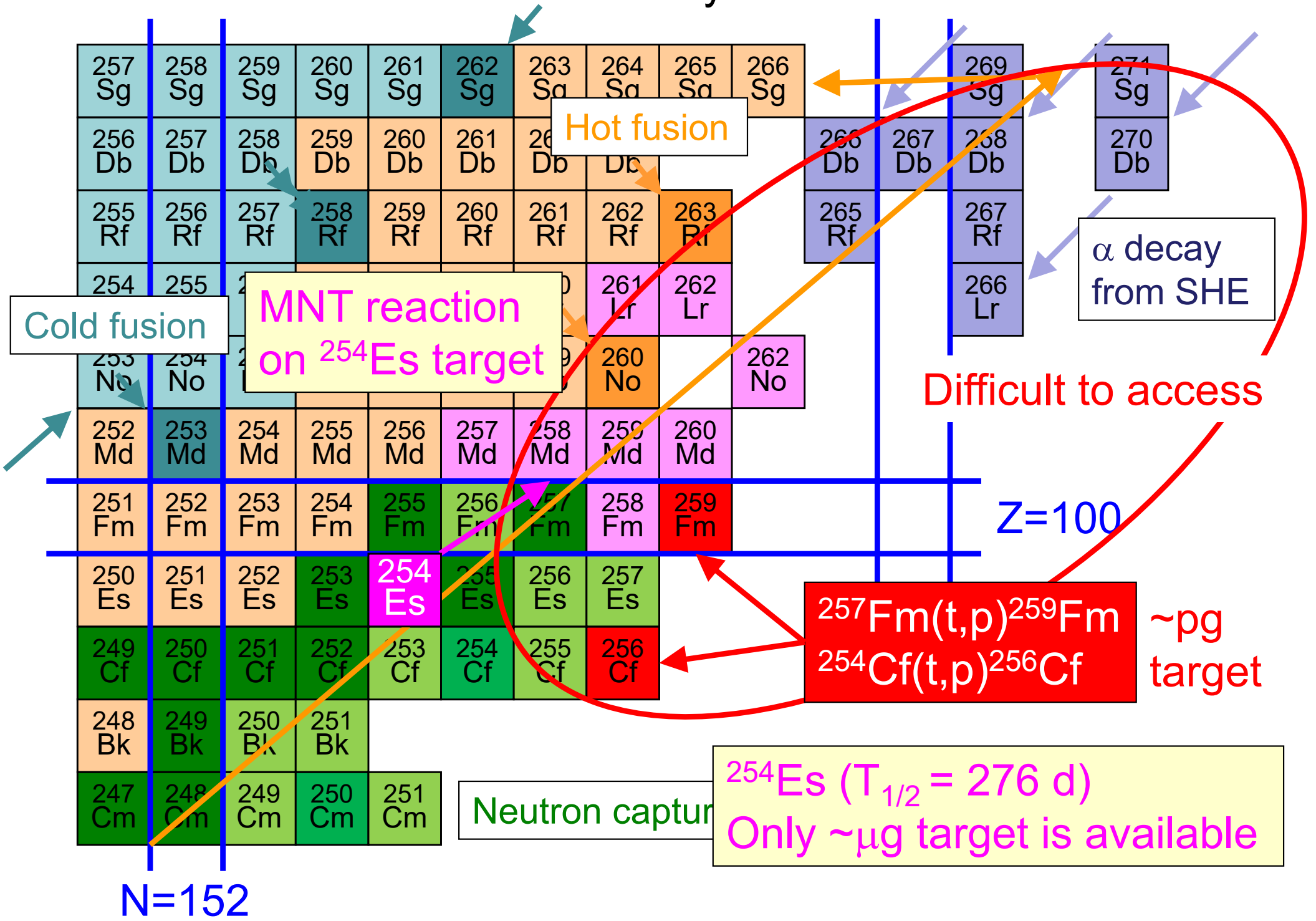
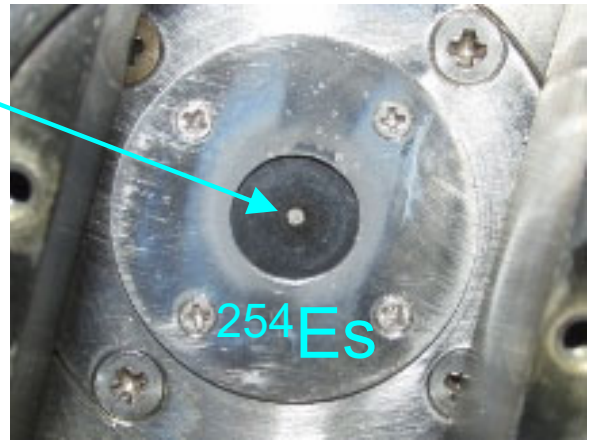
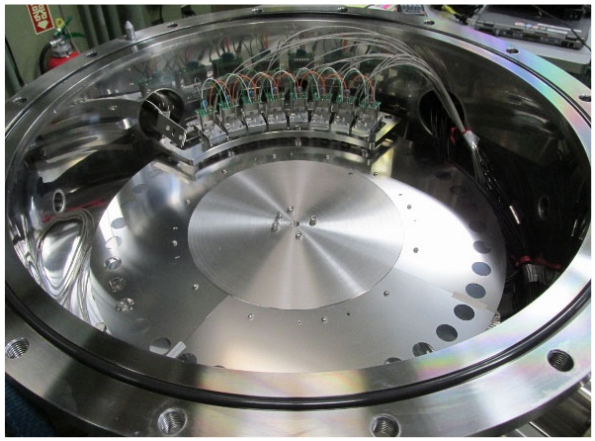


Spontaneous fission measurements using ^{254}Es target

1st Es campaign (2018) at JAEA tandem

^{254}Es target
0.8 mmϕ (30 ng)





Rotating wheel system

^{254}Es(^{18}O,X)^{258m}Md→^{258}Fm

He/CdI_2 gas

Target ^{254}Es

^{197}Au

Beam ^{18}O

120 MeV

Md

Reaction products

^{258m}Md

Si detectors

JAEA Tandem Accelerator

257

259

Surface ion source

Magnet

Gas-jet transport

M^+

Differential pumping

Extractor

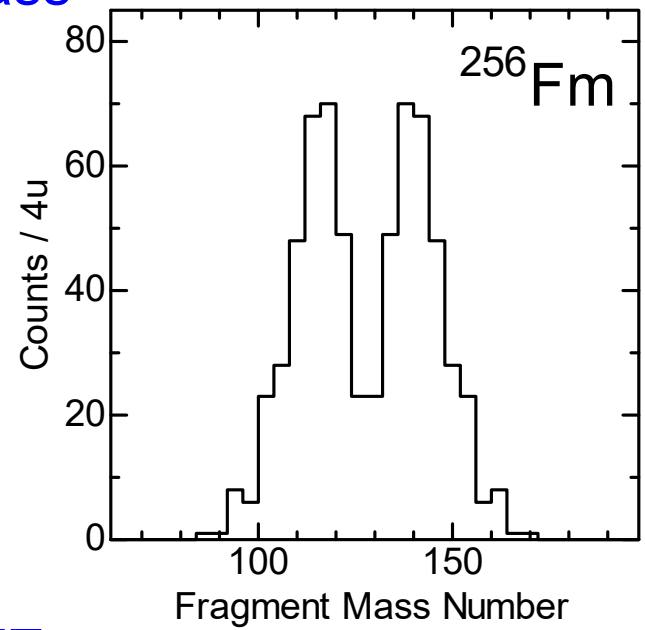
On-line isotope separator (JAEA-ISOL)

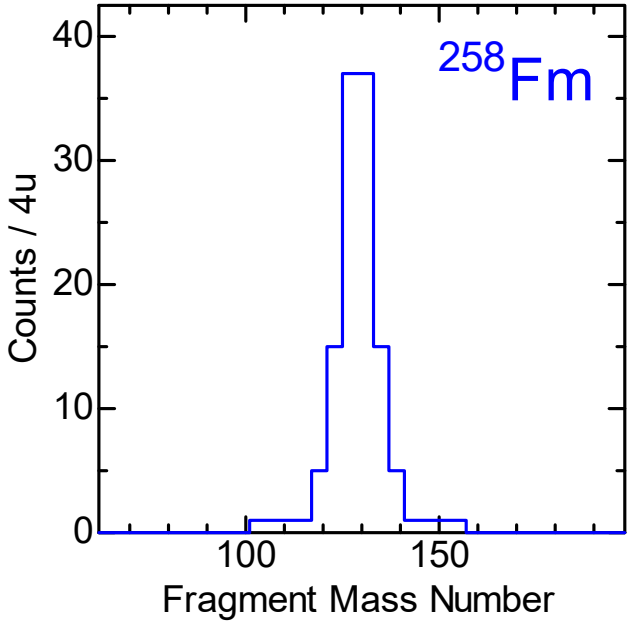
Fragment mass and TKE distributions for SF of ^{256,258}Fm and ^{259}Lr

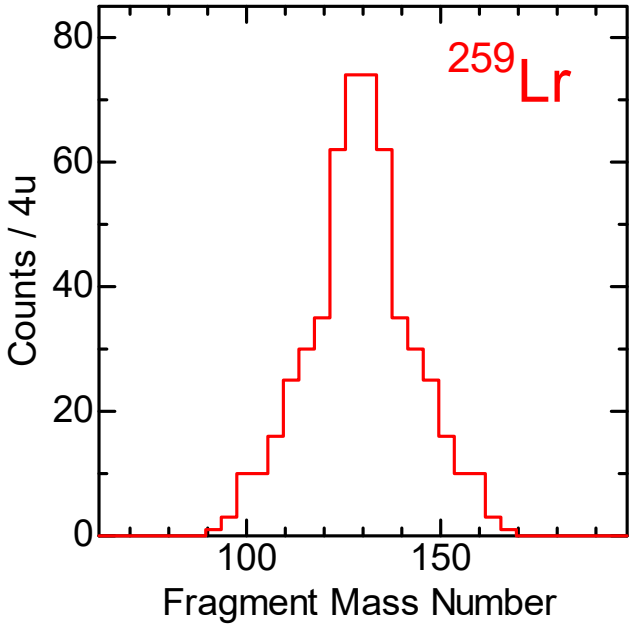
^{254}Es(^{18}O,X)^{256,258}Fm

^{248}Cm(^{15}N,4n)^{259}Lr

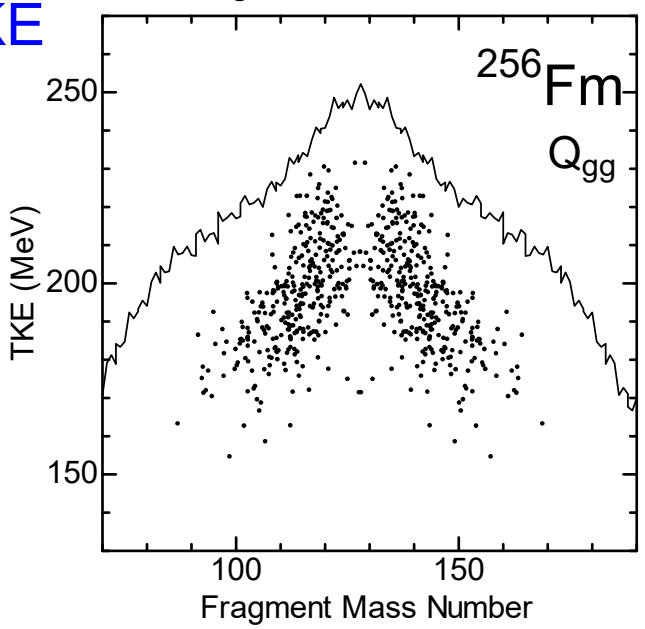
Mass

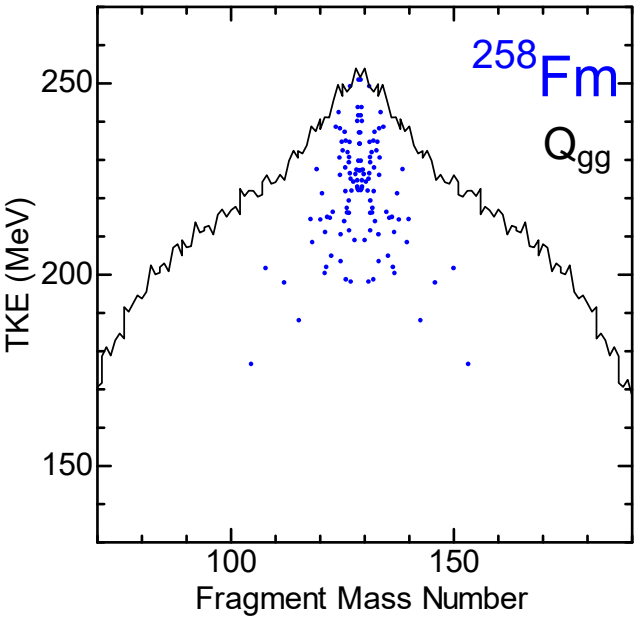


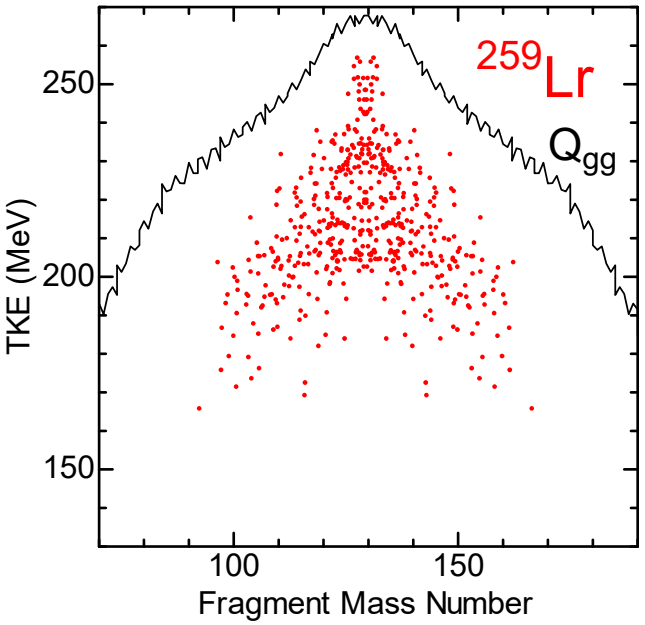




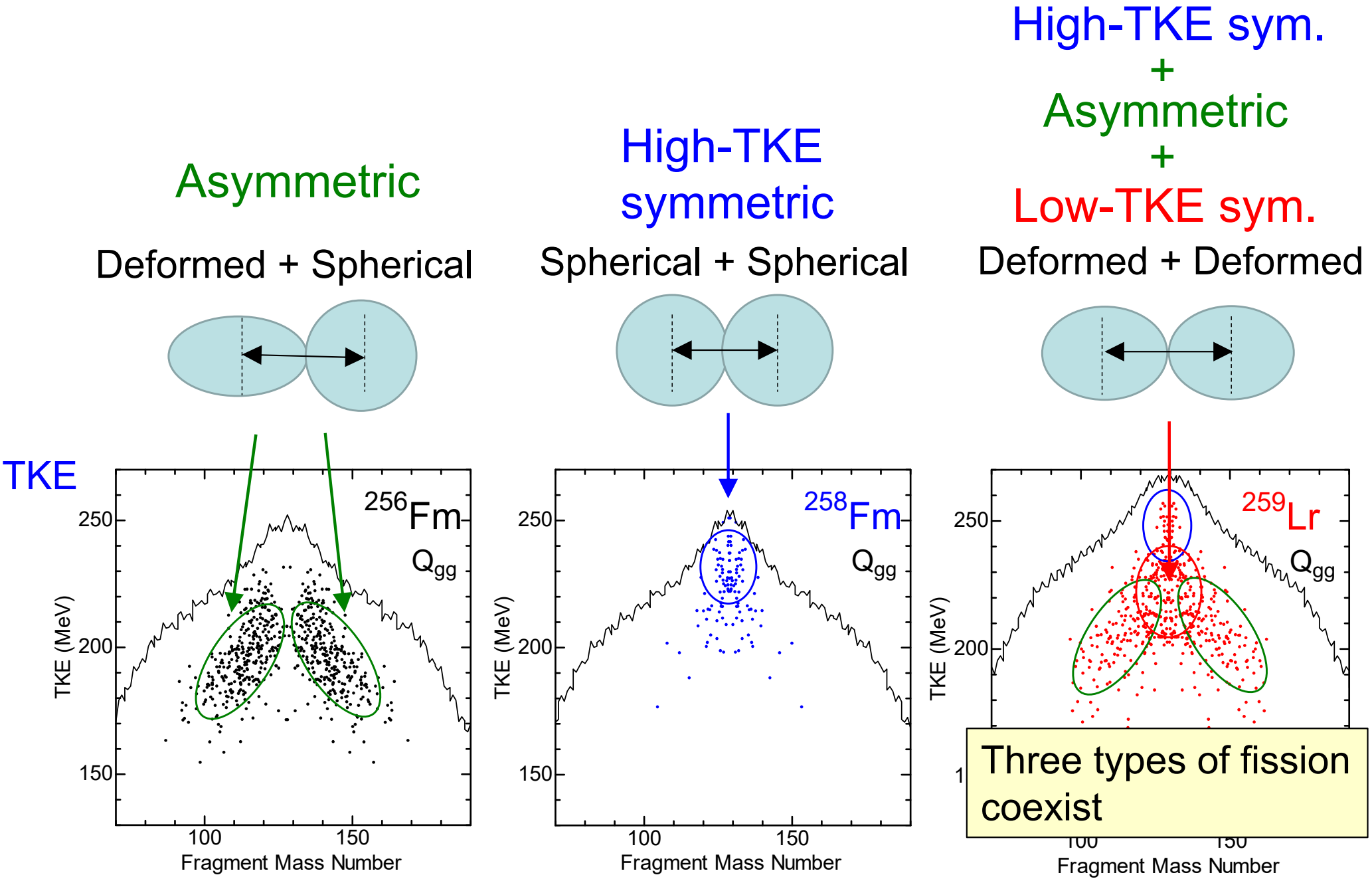
TKE



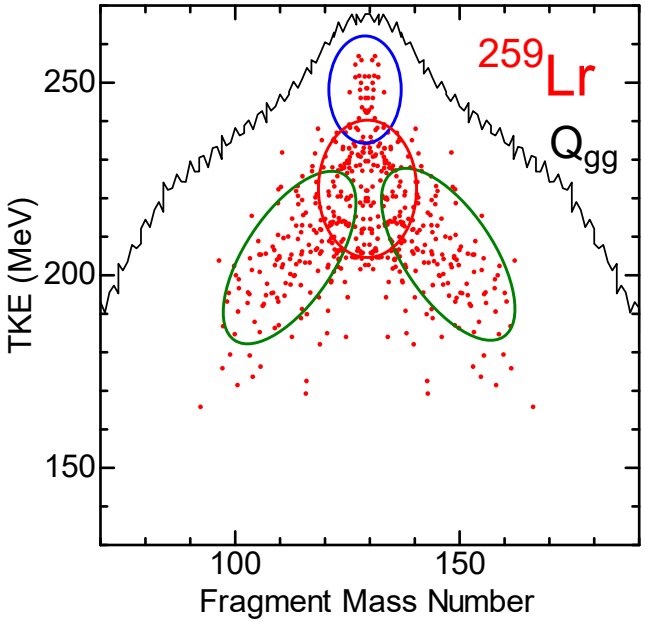


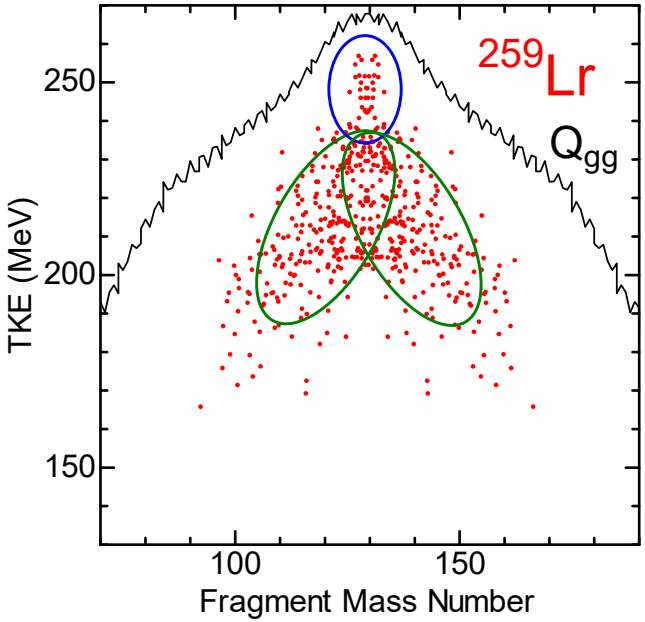


Fragment mass and TKE distributions for SF of ^{256,258}Fm and ^{259}Lr



Origin of Low-TKE Symmetric fission in ^{259}Lr



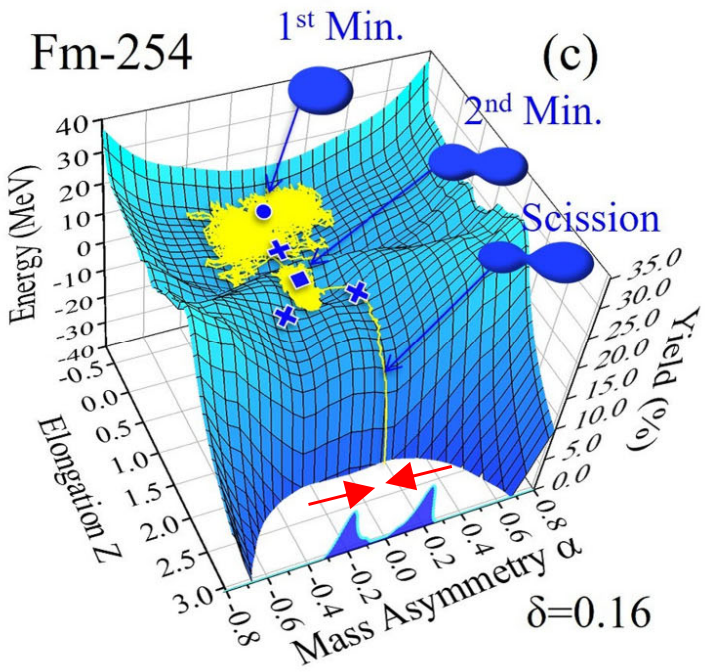


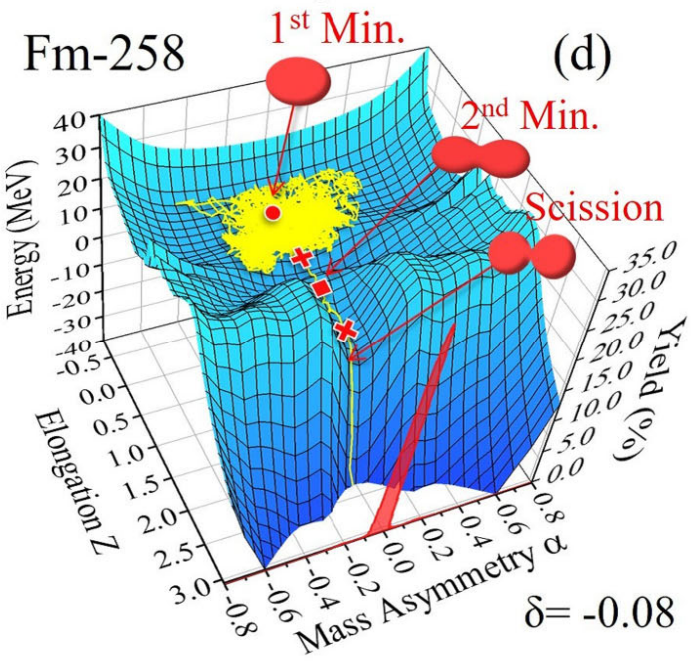
- TKE is higher than Asymmetric-TKE
- It is probably NOT Super-long fission

- How do we explain coexistence of two symmetric fission?
- Existence of two different symmetric saddles? or they are separated after saddle?

- Low-TKE symmetric component is just a merger of Asymmetric components?
- If so, how does mass-TKE distribution look like?

If asymmetric valleys are approaching, how does mass-TKE distribution look like?





Miyamoto et al., PRC 99, 051601(R) (2019).

TKE