

Fission study of ^{258}Md populated in the $^4\text{He} + ^{254}\text{Es}$ reaction

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- ❖ JAEA tandem facility
- ❖ Spontaneous fission of $^{256,258}\text{Fm}$
- ❖ Fission from excited states in ^{258}Md

JAEA Tokai Campus



J-PARC

JRR-3

Tandem accelerator
facility



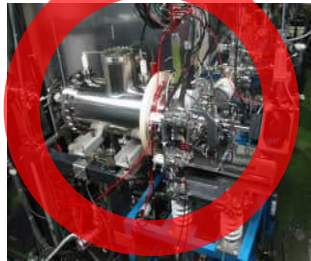
JAEA Tandem Facility

Tandem
(20 MV)



Superconducting
Booster linac

Total 14 Beam Lines



ISOL



Recoil Mass Separator



Fission setup



Ge detector array



Magnetic spectrometer

Actinide target material

Use of actinide material is essential to study fission

The image shows a periodic table of elements. The actinide series (elements 89-103) is highlighted in green. The element Es (Einsteinium, atomic number 99) is circled in red. An orange callout box points to Es with the text $^{254}_{99}\text{Es}$ ($T_{1/2} = 276$ day).

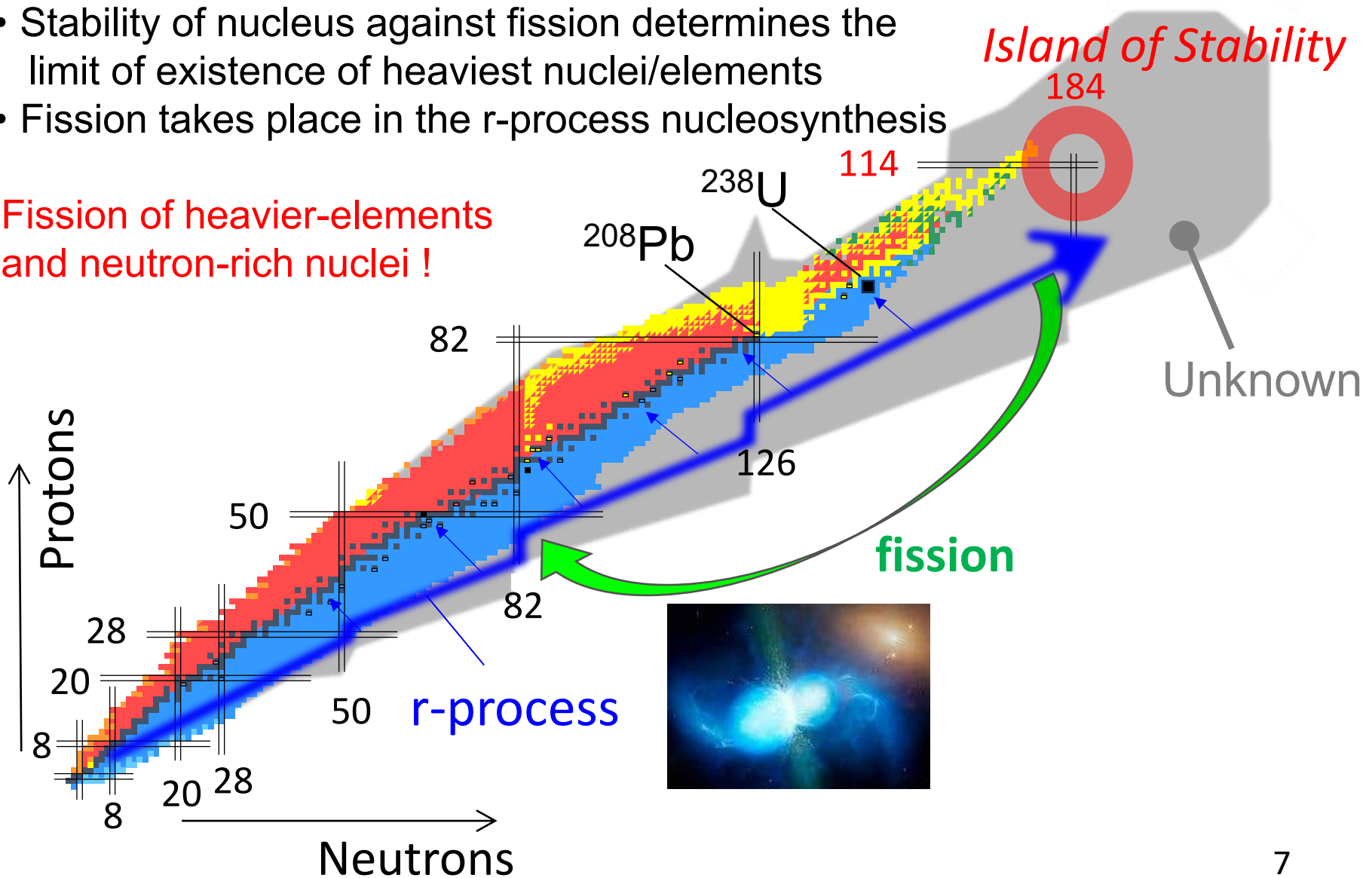
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh					
		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

Available at JAEA tandem

Fission

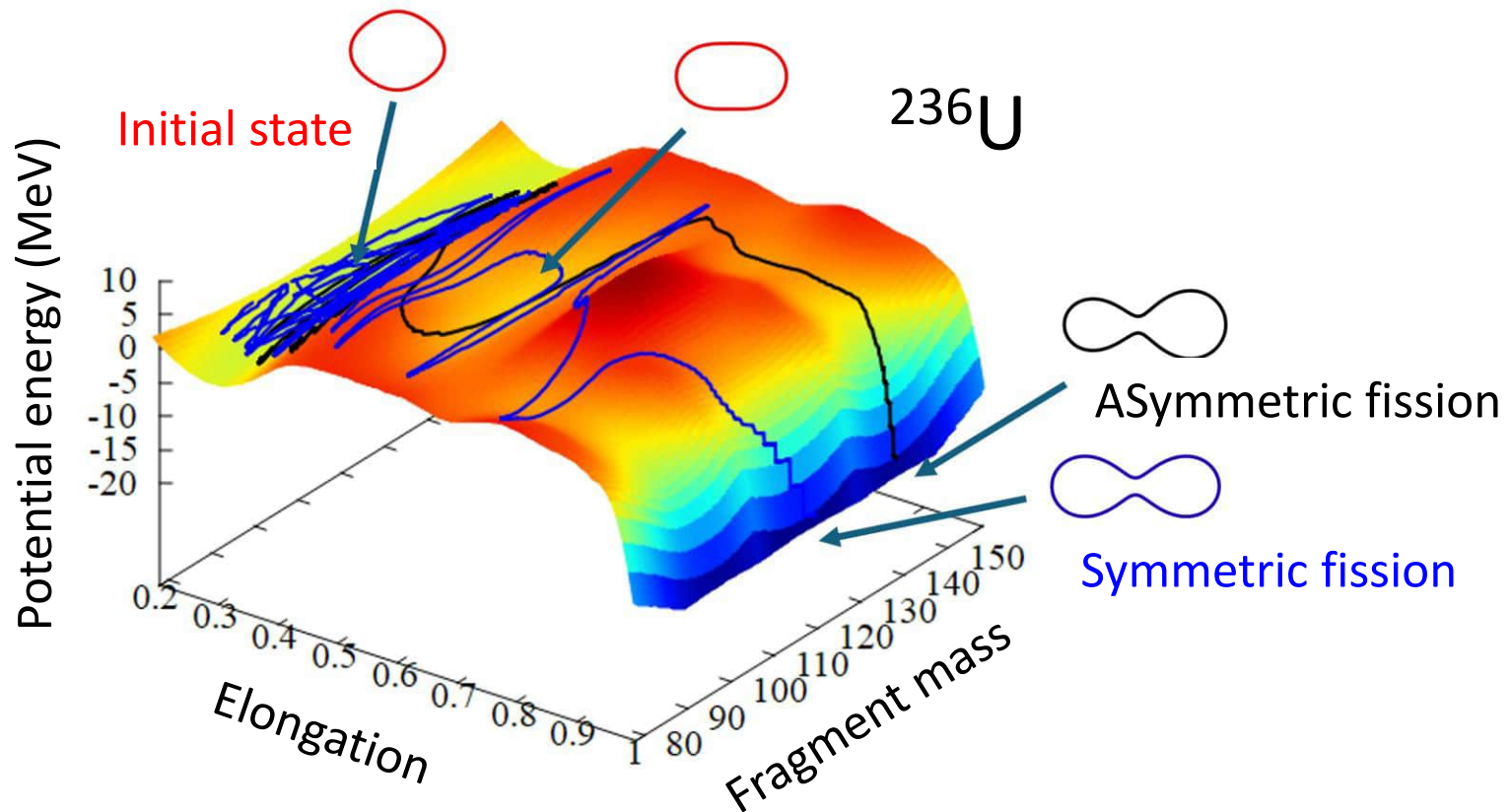
- ❖ Stability of nucleus against fission determines the limit of existence of heaviest nuclei/elements
- ❖ Fission takes place in the r-process nucleosynthesis

Fission of heavier-elements and neutron-rich nuclei !



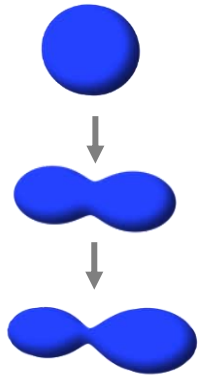
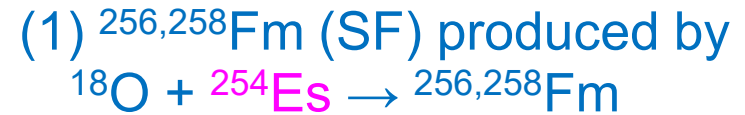
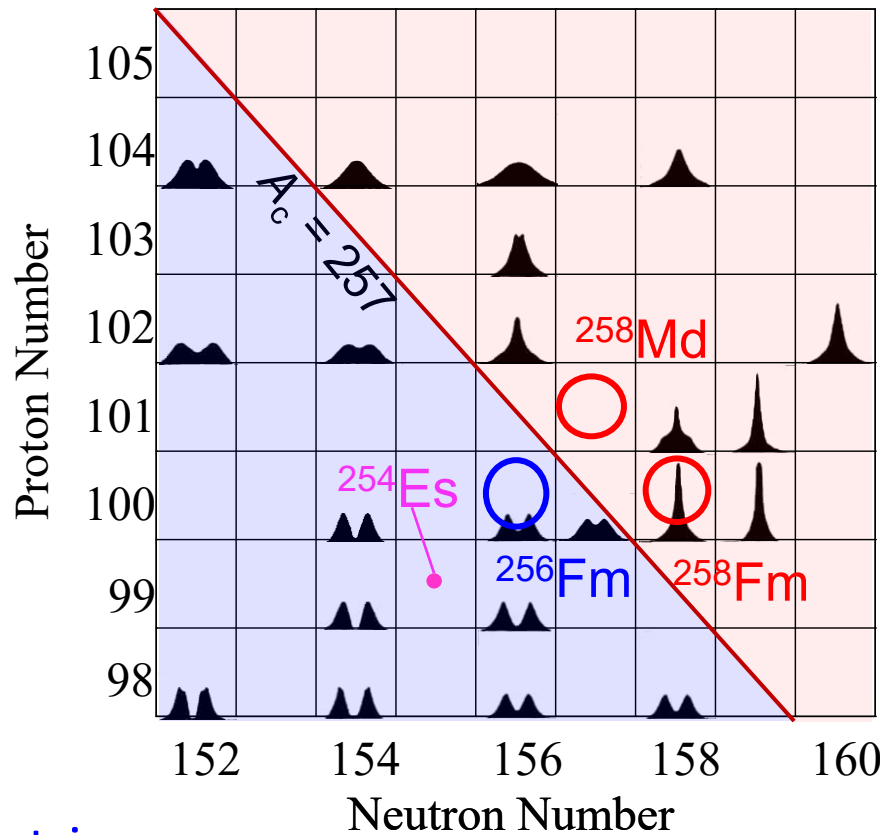
Nuclear fission

- (1) Nucleus moves on the potential energy landscape, which is largely influenced by shell structure.
- (2) Dynamical behavior of nucleus (Langevin).

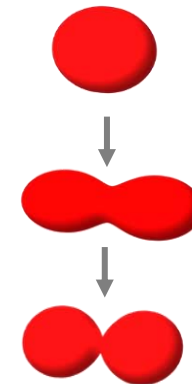


Fission of heavy-element and neutron-rich region

Spontaneous fission properties of neutron-rich heavy-element nuclei changes dramatically in the heavy-element and neutron-rich region.



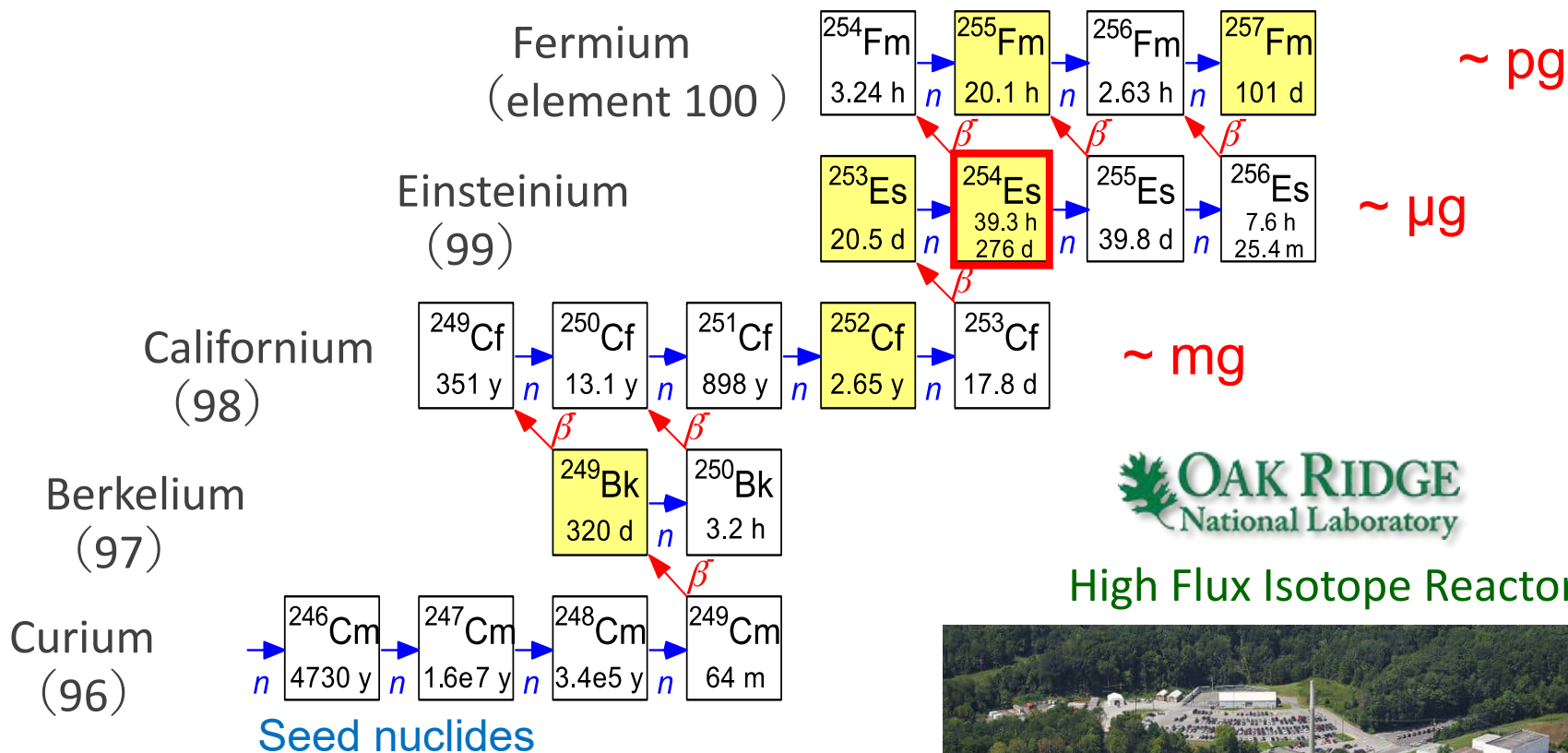
ASymmetric



Symmetric

M.R. Lane et al., Phys. Rev. C **53** (1996) 2893.

Production Scheme of ^{254}Es ($T_{1/2} = 276$ day)



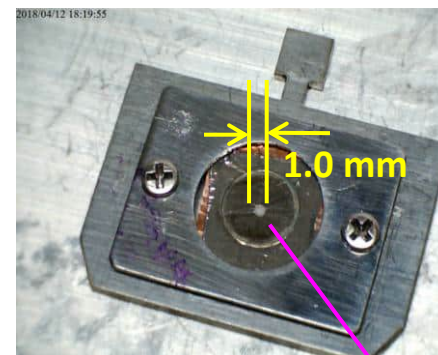
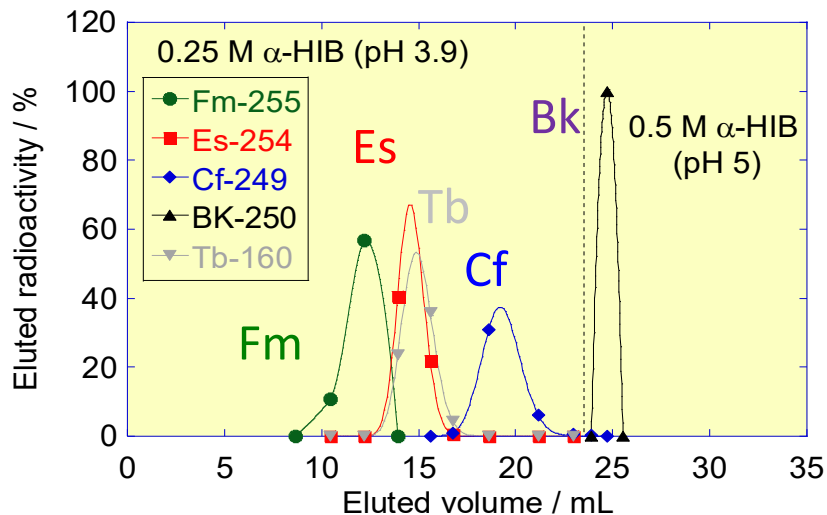
High Flux Isotope Reactor



Purification of Es at JAEA Tandem facility

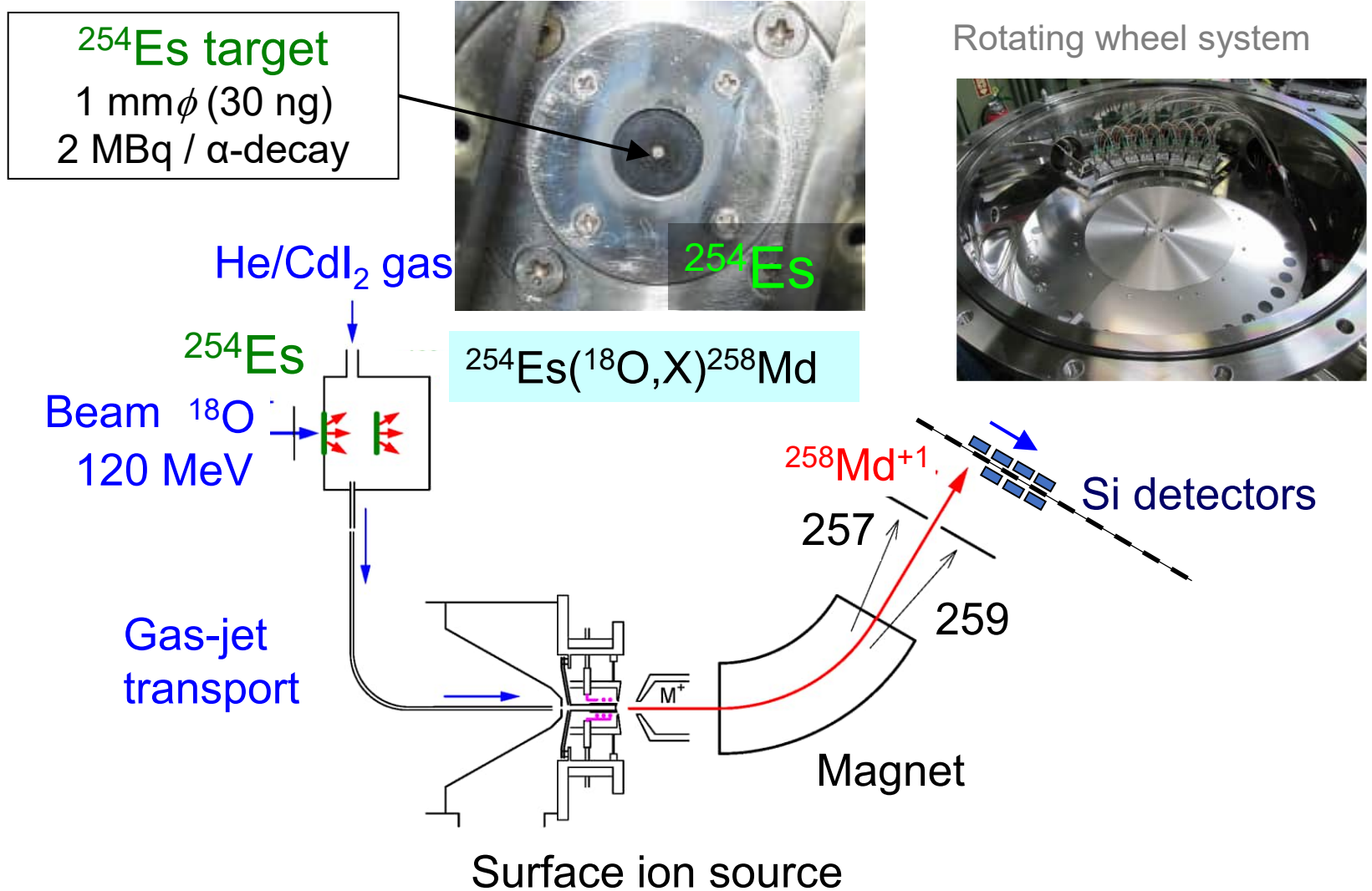
Available ^{254}Es material was only $\sim 0.1\mu\text{g}$

Before making target, we made chemical separation of the sample to remove the other actinide-element isotopes.



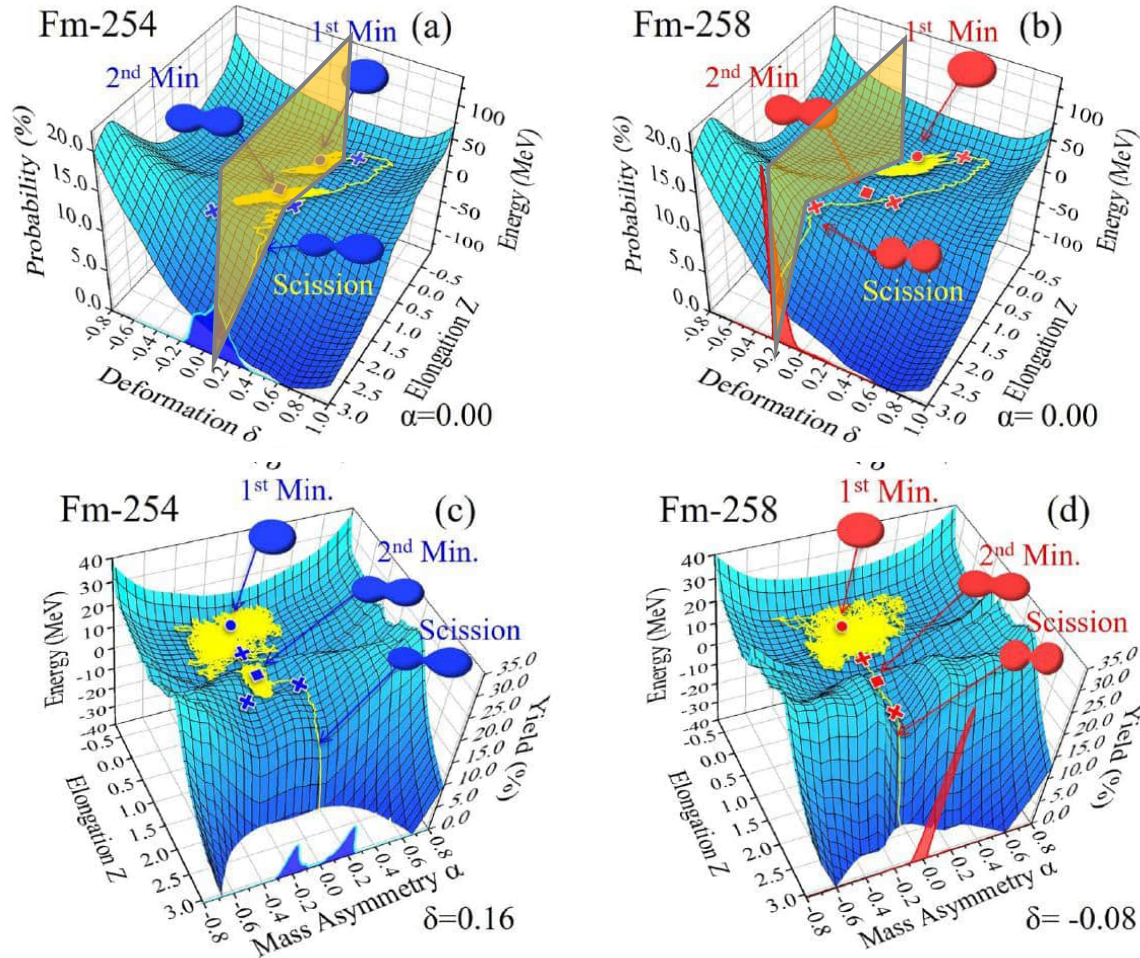
Electro-deposition of ^{254}Es material on $0.1\mu\text{m}$ thick Ni-backing layer. 10 ng ($\sim 0.7\text{ MBq}$ α -decay)

Measurement of Spontaneous Fission of $^{256,258}\text{Fm}$ at JAEA - ISOL

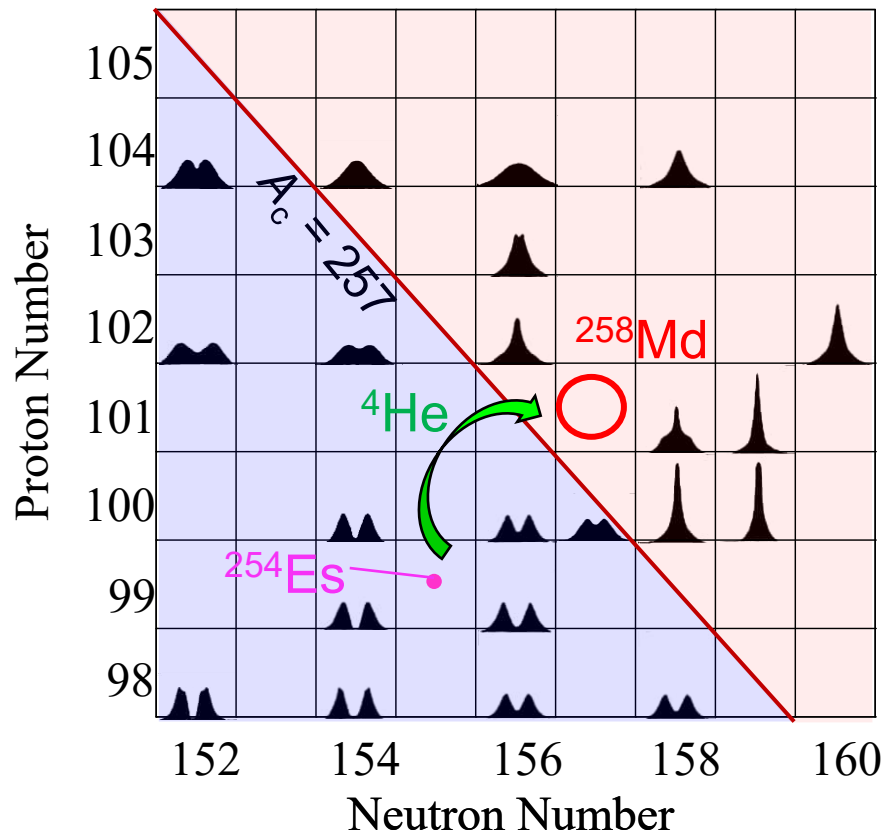


Langevin Calculation for Fm-isotopes using two-center shell model

Three nuclear-shape parameters, Charge-center distance (z), mass-asymmetry (α), deformation (δ).

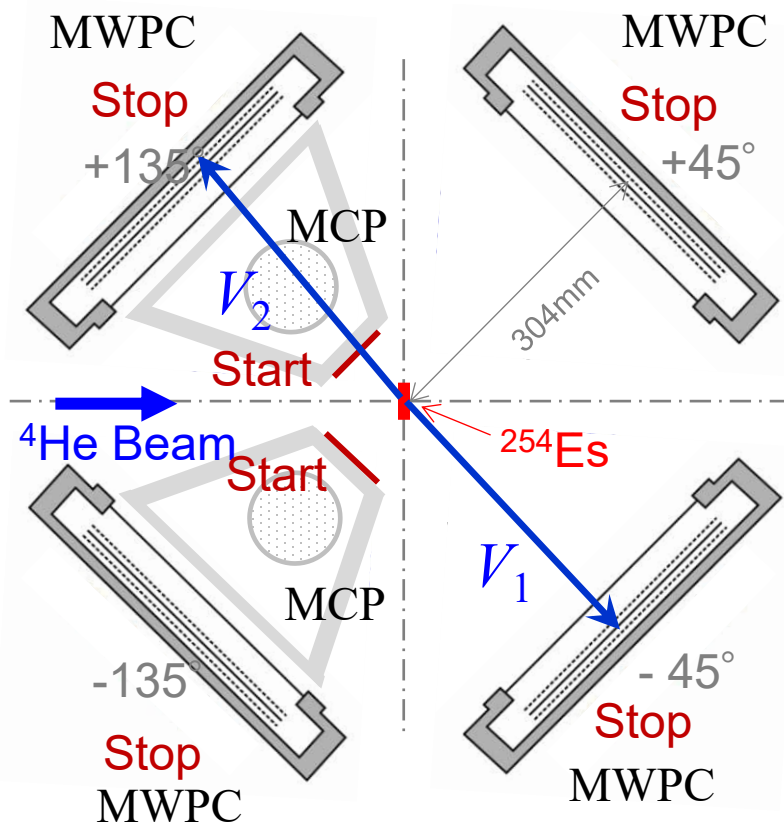


Fission of ^{258}Md from excited states

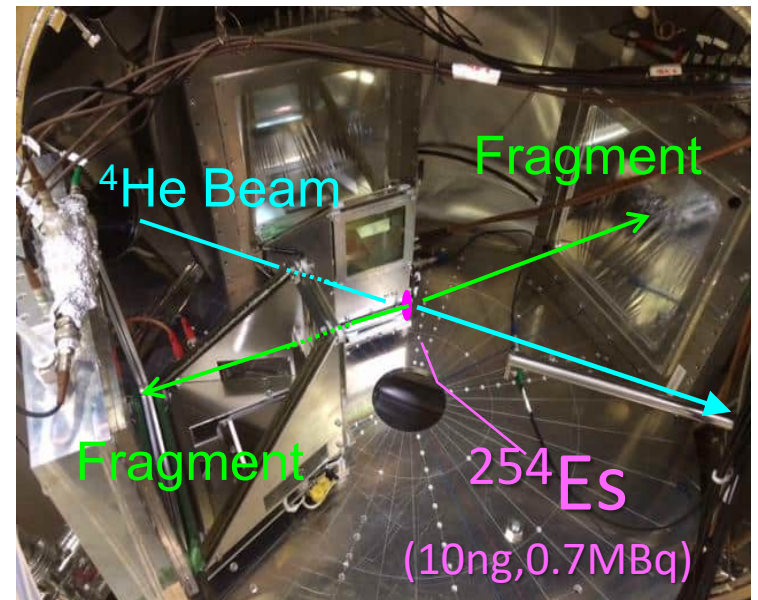


M.R. Lane et al., Phys. Rev. C **53** (1996) 2893.

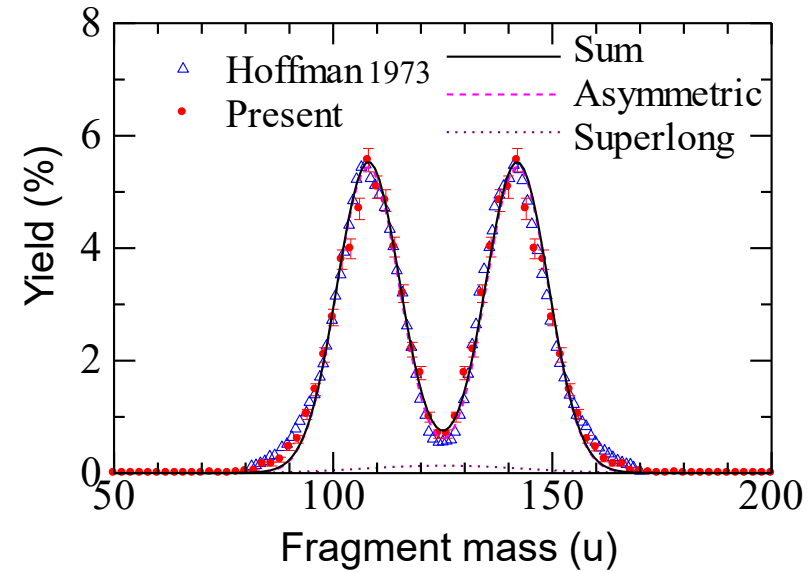
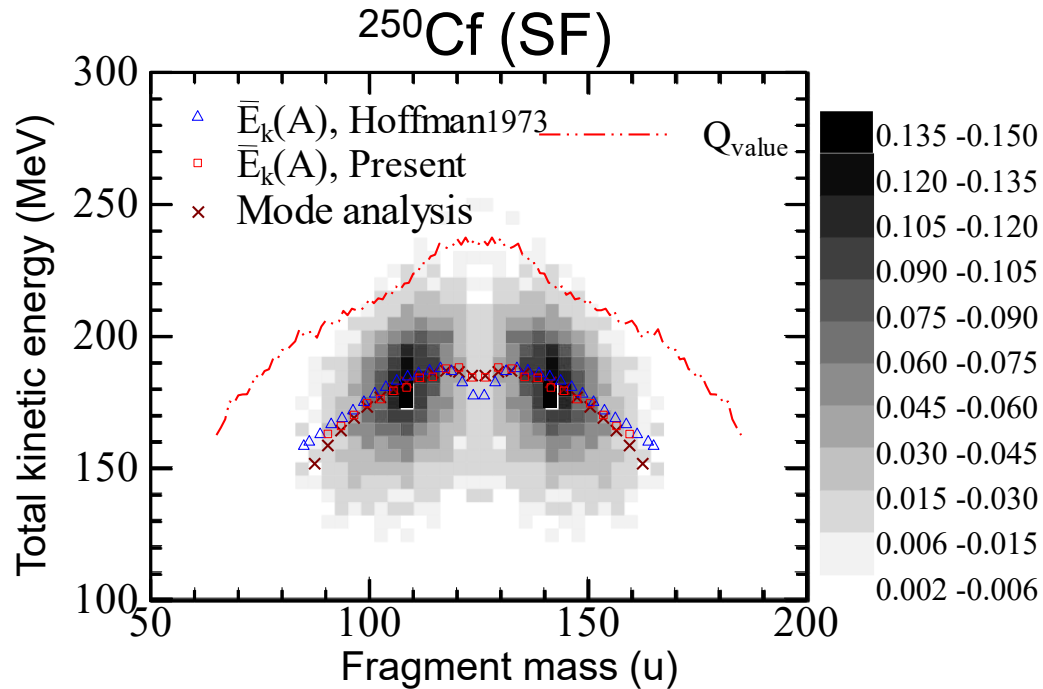
In-beam prompt fission measurement for $^{258}\text{Md}^*$ $_{101}$



Velocities of both fragments are measured

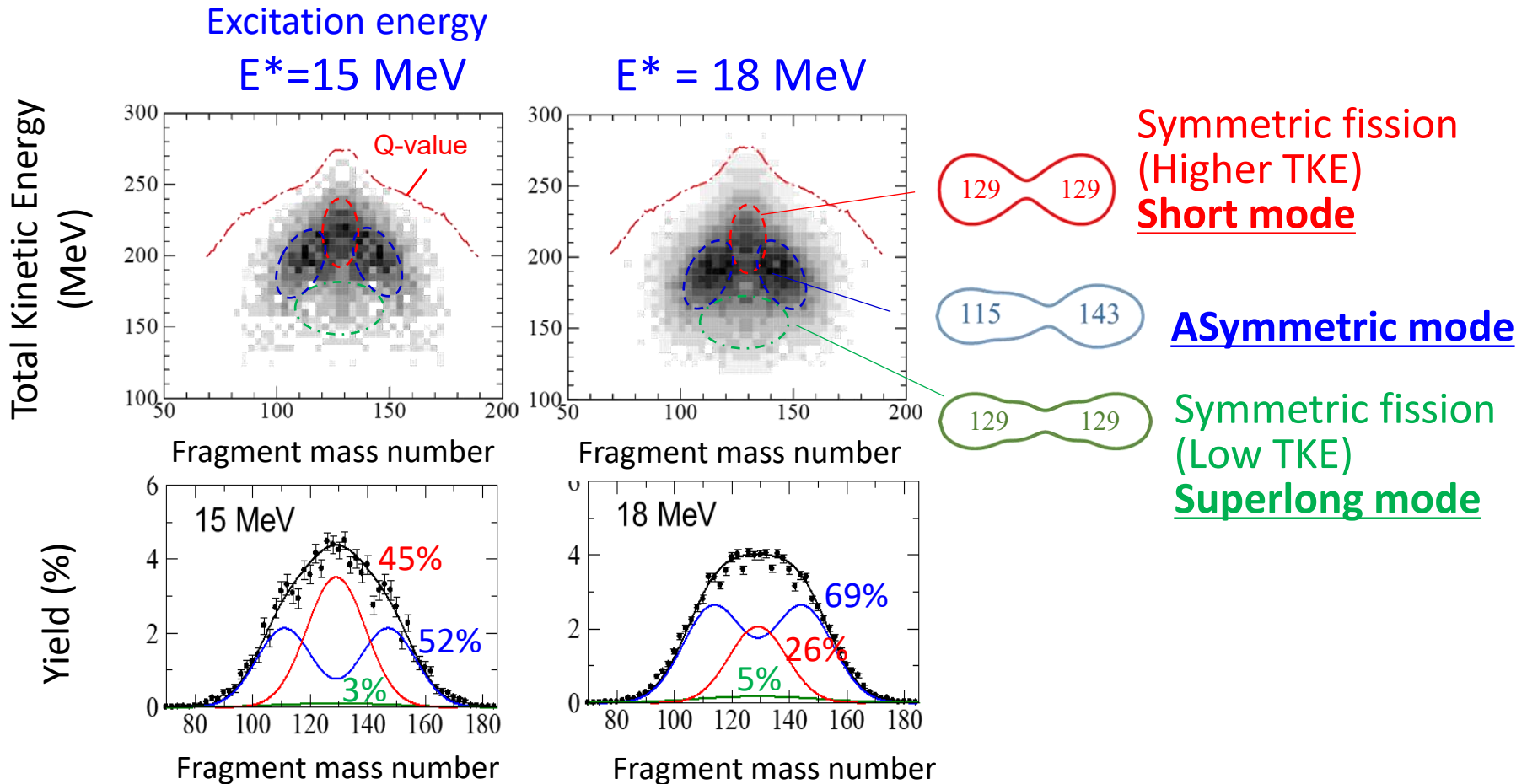


Spontaneous fission of ^{250}Cf



Obtained in the same setup

Fission of $^{258}_{101}\text{Md}$ from excited states

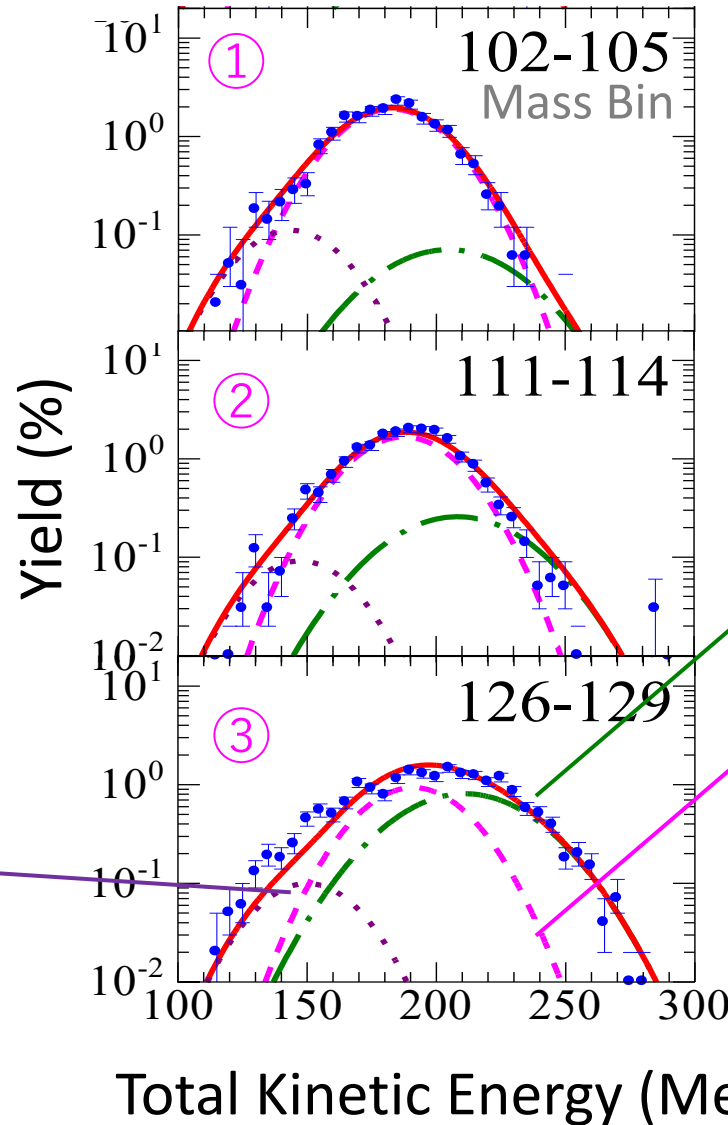
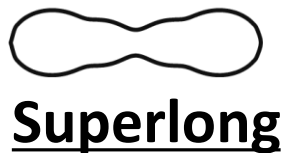
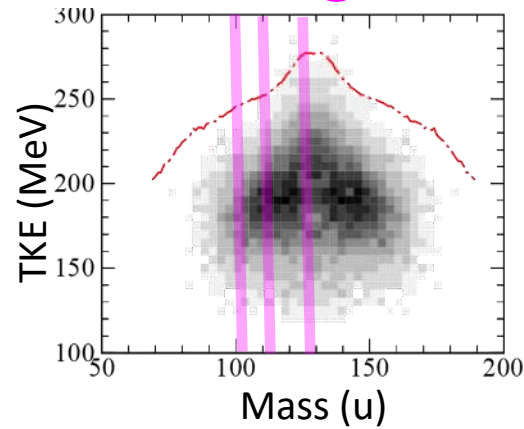


- (1) Symmetric and asymmetric fission modes competes.
- (2) Yields of asymmetric fission mode enhances with excitation energy.

Three fission modes in ^{258}Md

$E^* = 18 \text{ MeV}$

① ② ③



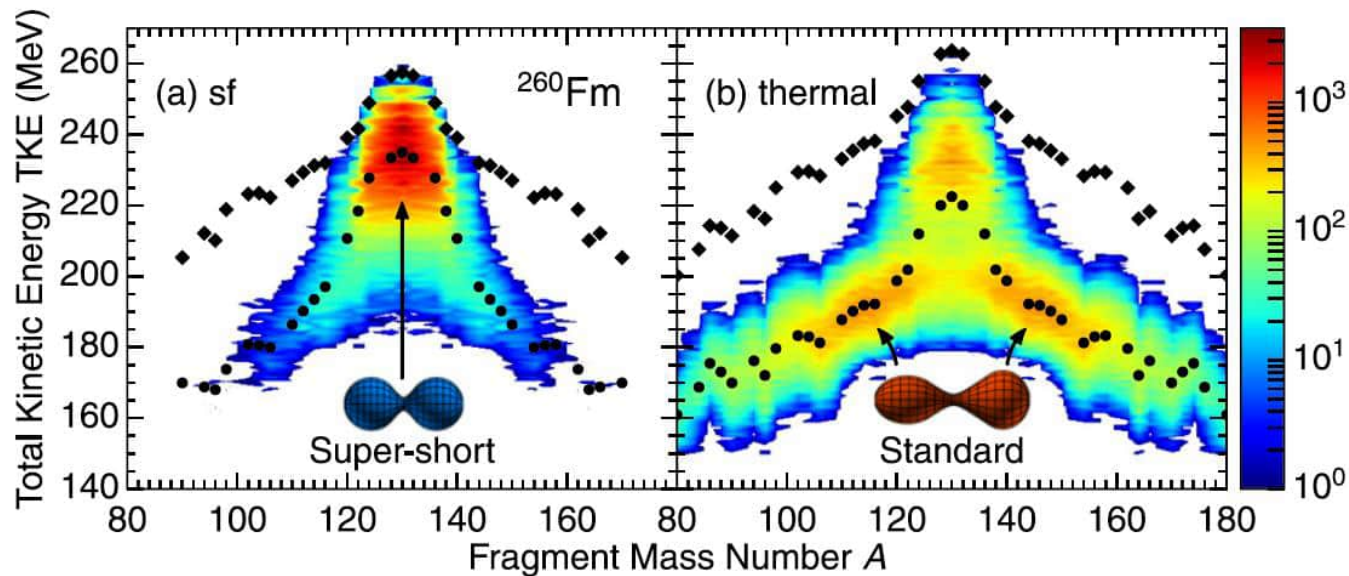
Short Mode



Asymmetric

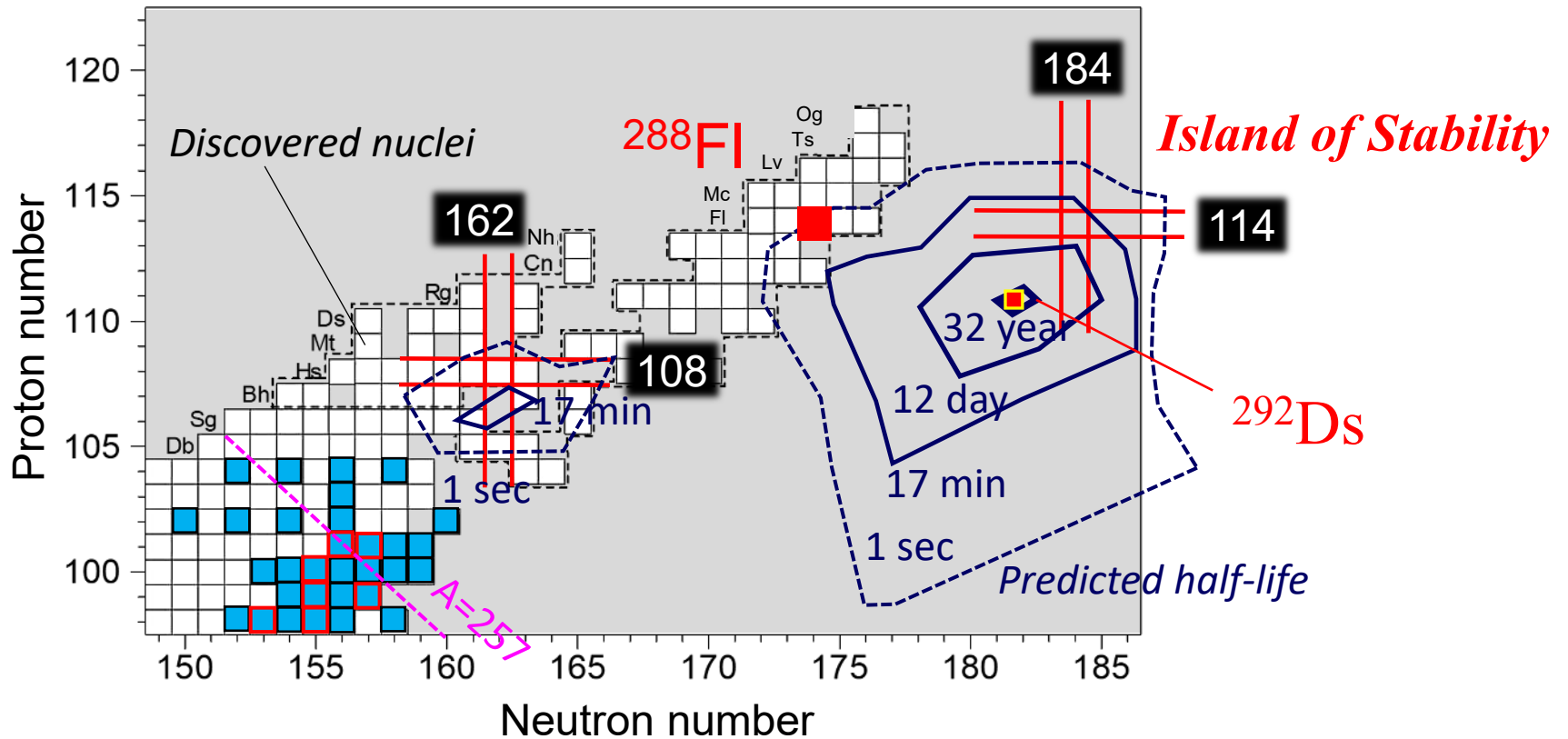
Fission modes and excitation energy in Fm isotopes

5D Nuclear shape + The metropolis method



M. Albertsson et al., Phys. Rev. C **104**, 064616 (2021)

Superheavy elements



Fission properties are measured.

(JAEA Measured/Re-Measured)

Summary

- ♣ We confirmed sharp transition from mass-asymmetric fission of ^{256}Fm to symmetric fission of ^{258}Fm .
- ♣ In the fission of ^{258}Md , *Short mode* (symmetric) and *Asymmetric mode* competes. Structure for Asymmetric mode is easily smeared out with excitation energy.
- ♣ Fission of superheavy-element region would show the fission mode originating from ^{208}Pb -like structure.