

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

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# Contents

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

# JAEA Tokai Campus



J-PARC

JRR-3

Tandem accelerator  
facility



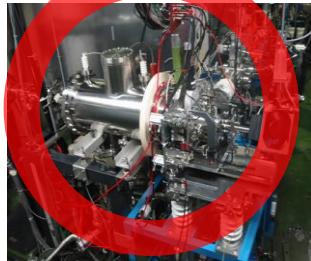
# JAEA Tandem Facility

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 (99) is circled in red. An orange callout box points to Es with the text  $^{254}_{99}\text{Es}$  ( $T_{1/2} = 276$  day).

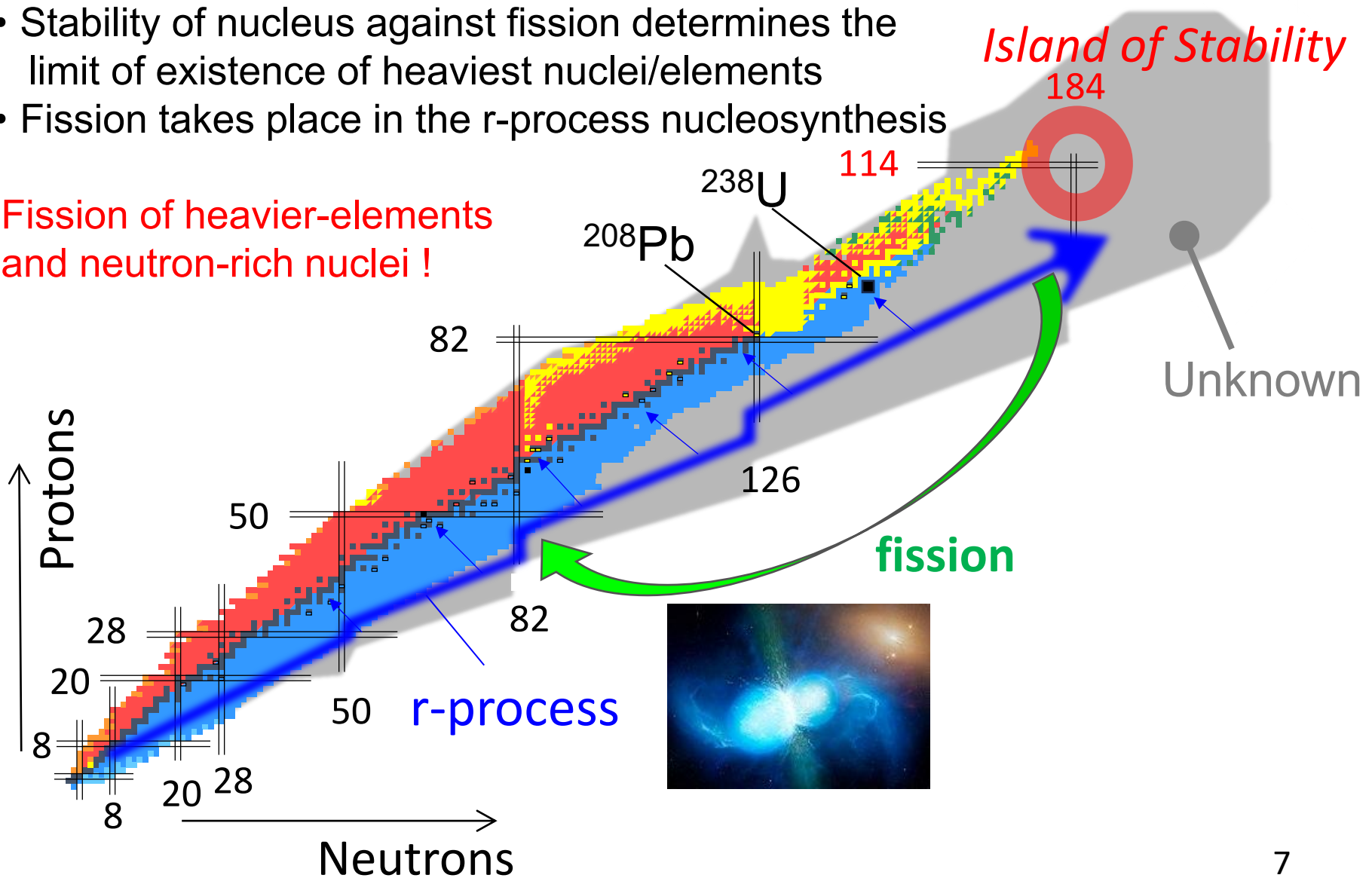
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Tl	Pb
		La系	Ce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

Available at JAEA tandem

# Fission

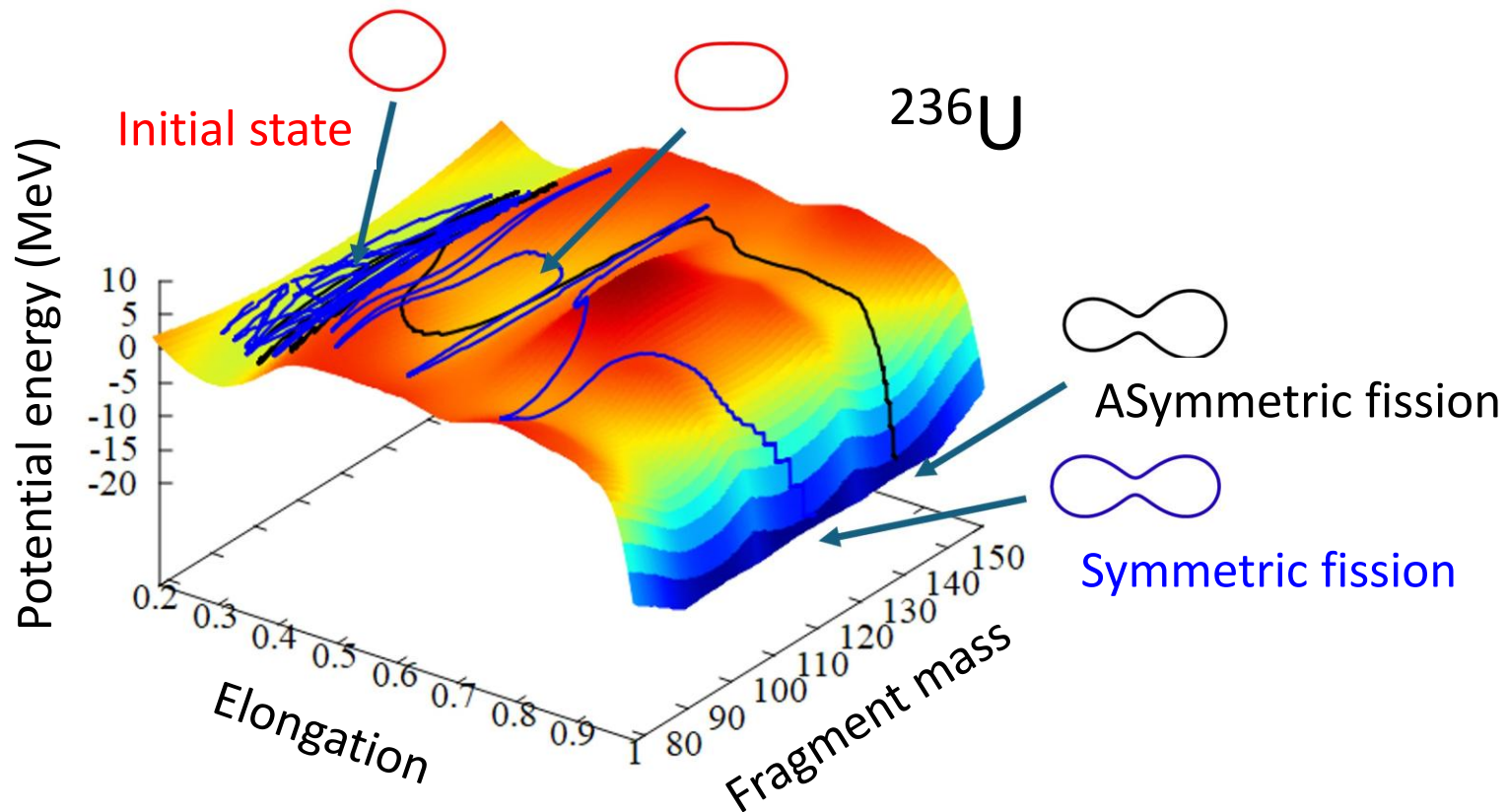
- ❖ Stability of nucleus against fission determines the limit of existence of heaviest nuclei/elements
- ❖ Fission takes place in the r-process nucleosynthesis

Fission of heavier-elements and neutron-rich nuclei !

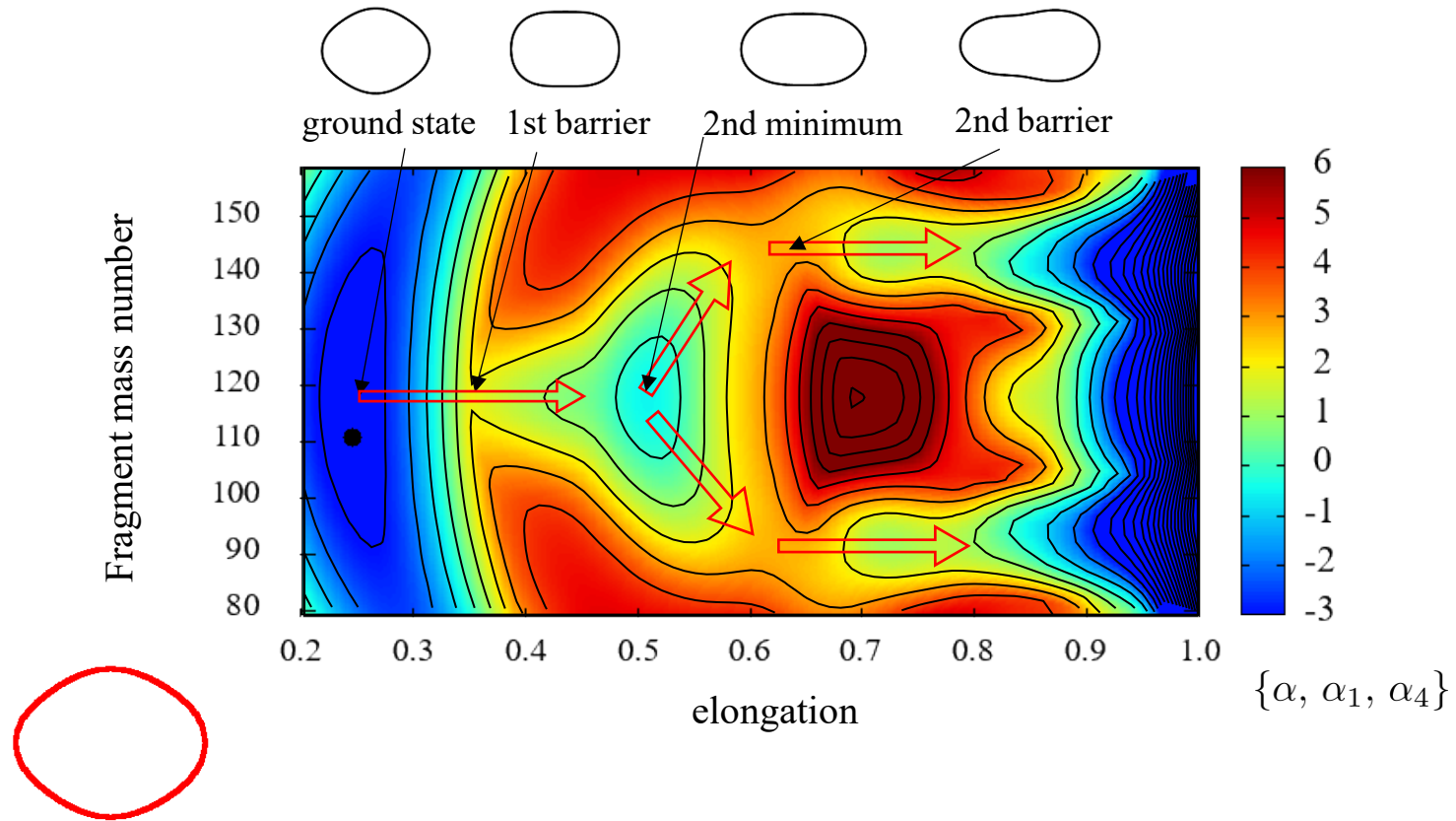


# Nuclear fission

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

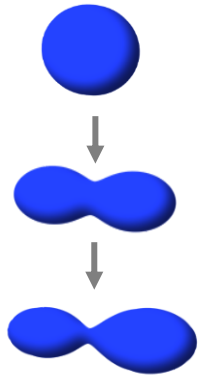
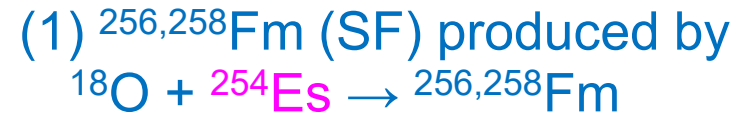
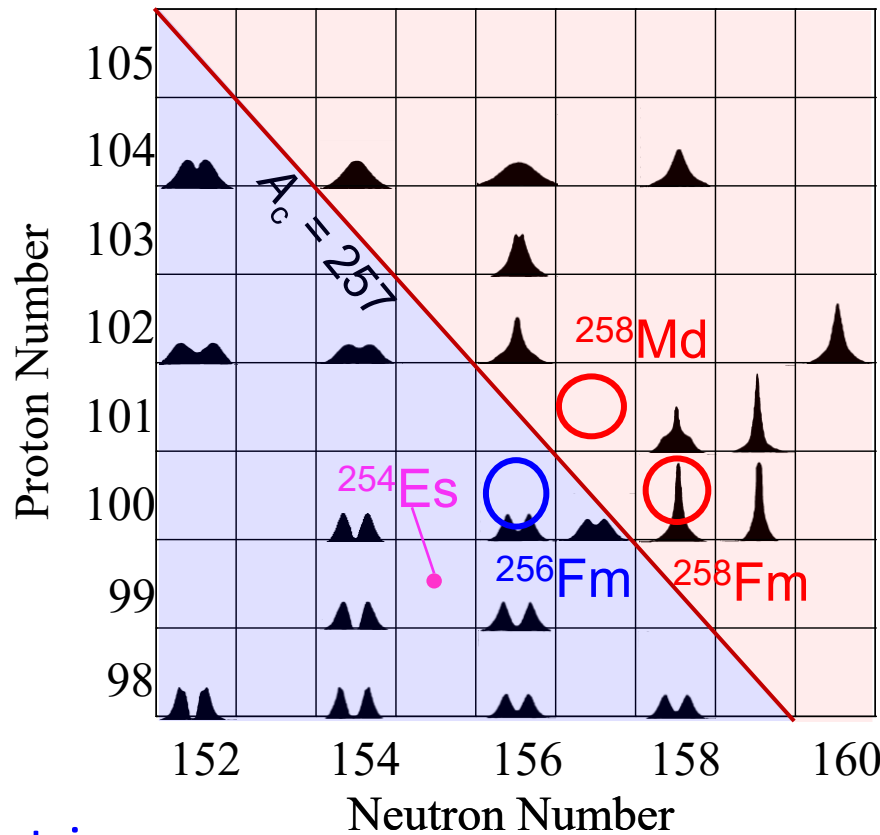


# Langevin Calculation

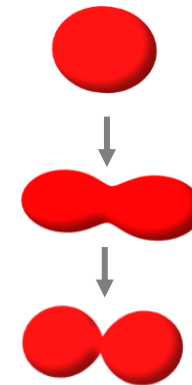


# Fission of heavy-element and neutron-rich region

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



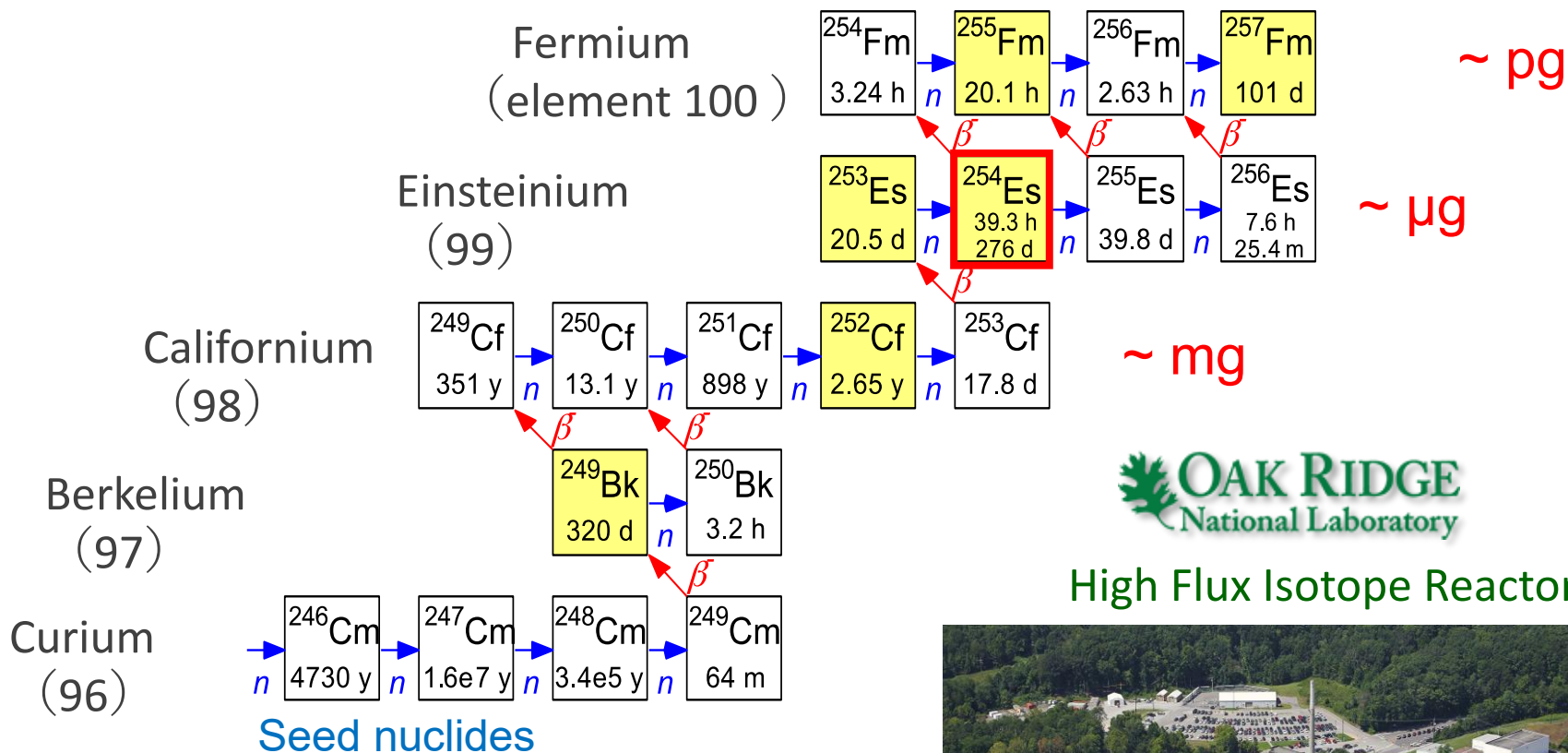
ASymmetric



Symmetric

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

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



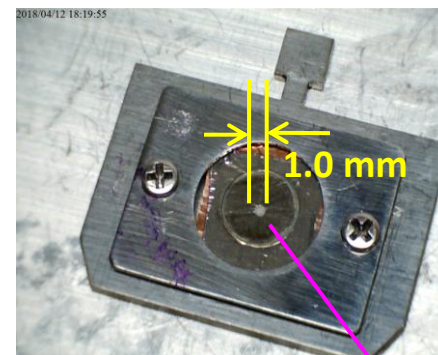
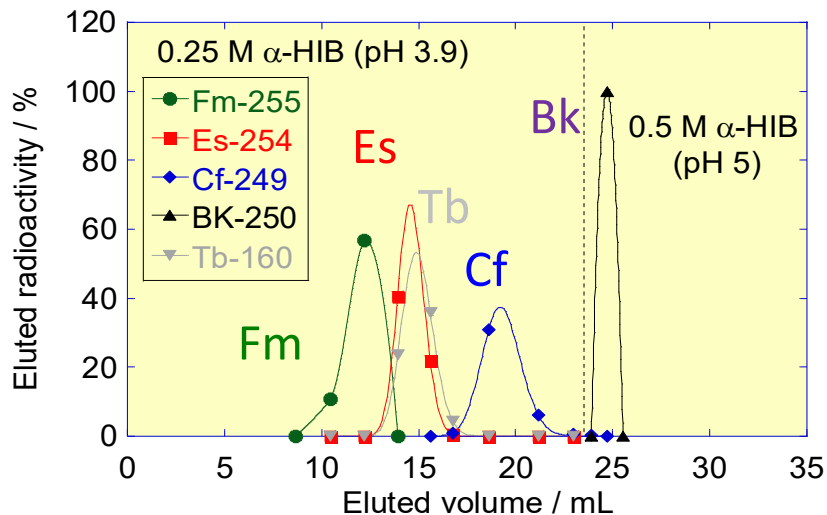
High Flux Isotope Reactor



# Purification of Es at JAEA Tandem facility

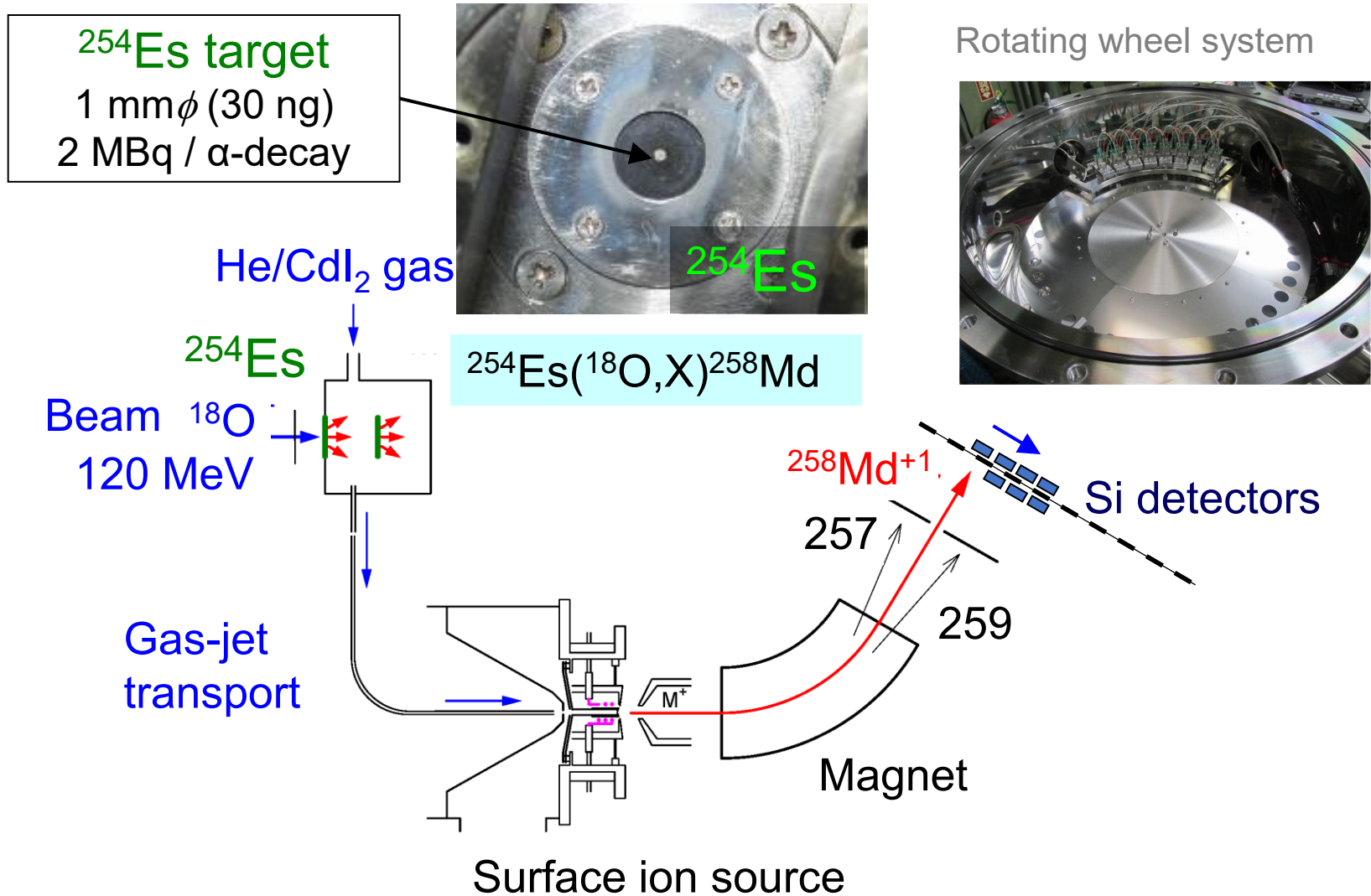
Available  $^{254}\text{Es}$  material was only  $\sim 0.1\mu\text{g}$

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



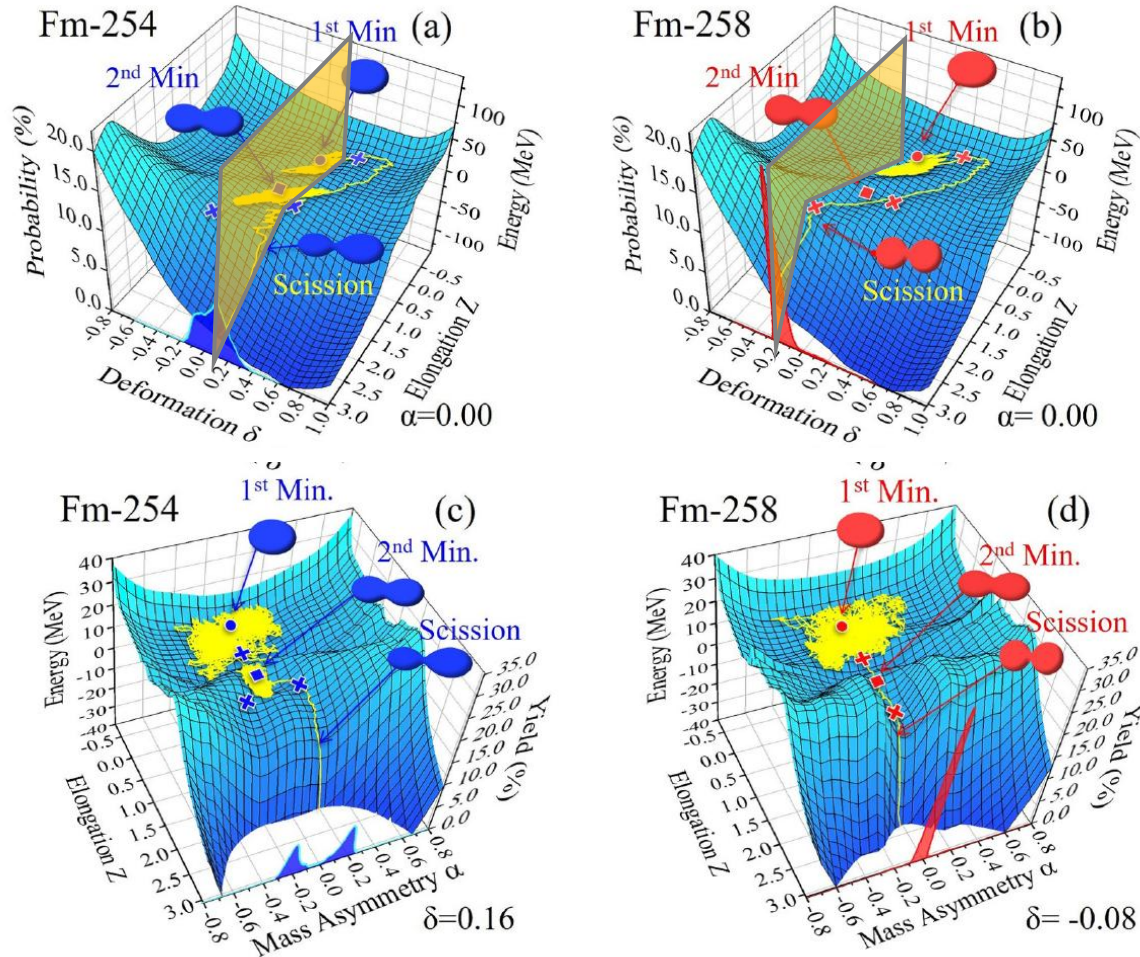
Electro-deposition of  $^{254}\text{Es}$  material on  $0.1\mu\text{m}$  thick Ni-backing layer.  $10\text{ ng}$  ( $\sim 0.7\text{ MBq}$   $\alpha$ -decay)

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

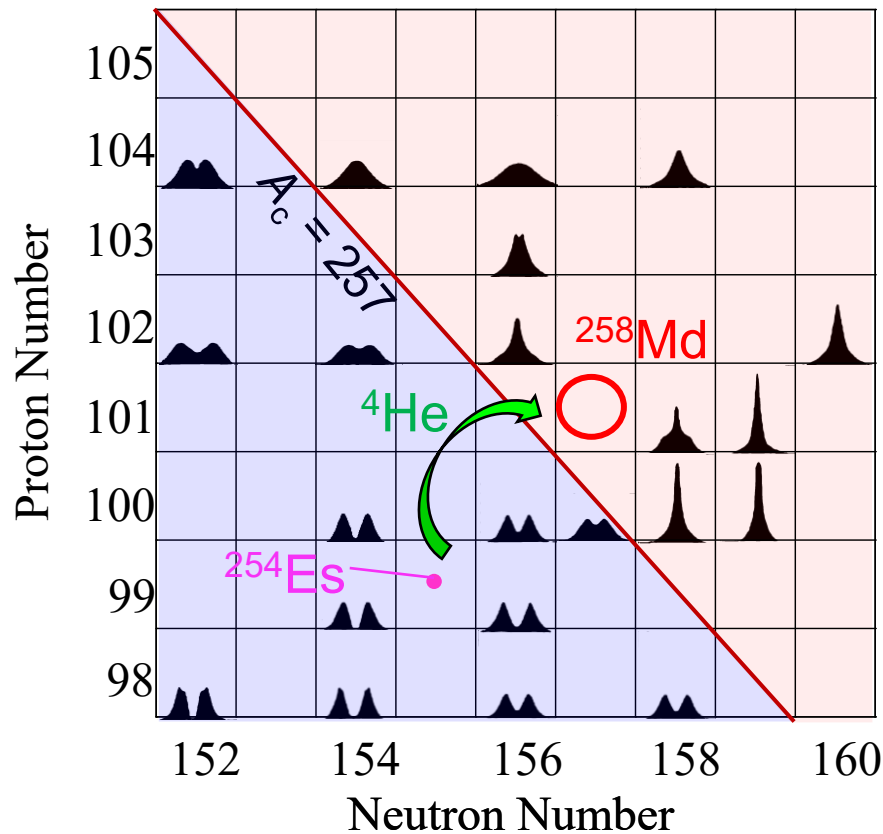


# Langevin Calculation for Fm-isotopes using two-center shell model

Three nuclear-shape parameters, Charge-center distance ( $z$ ), mass-asymmetry ( $\alpha$ ), deformation ( $\delta$ ).

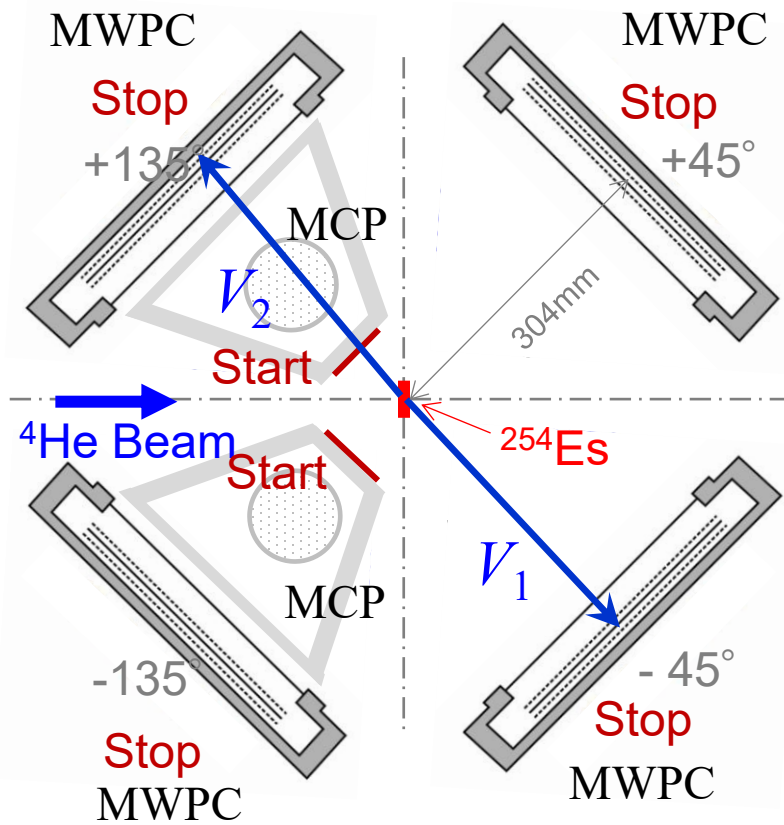


# Fission of $^{258}\text{Md}$ from excited states

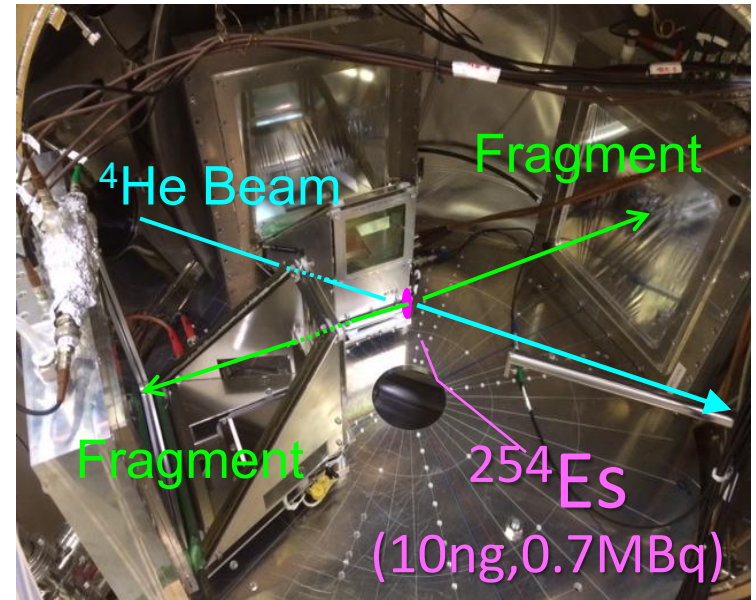


M.R. Lane et al., Phys. Rev. C **53** (1996) 2893.

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

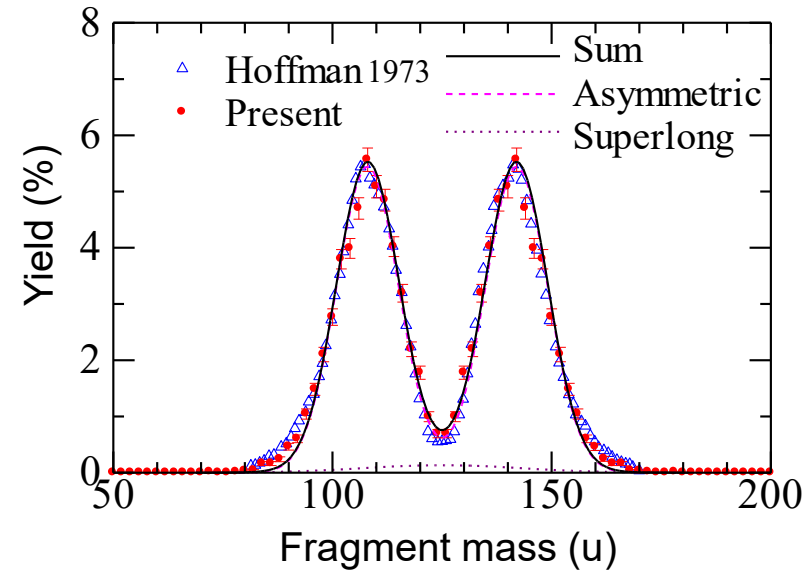
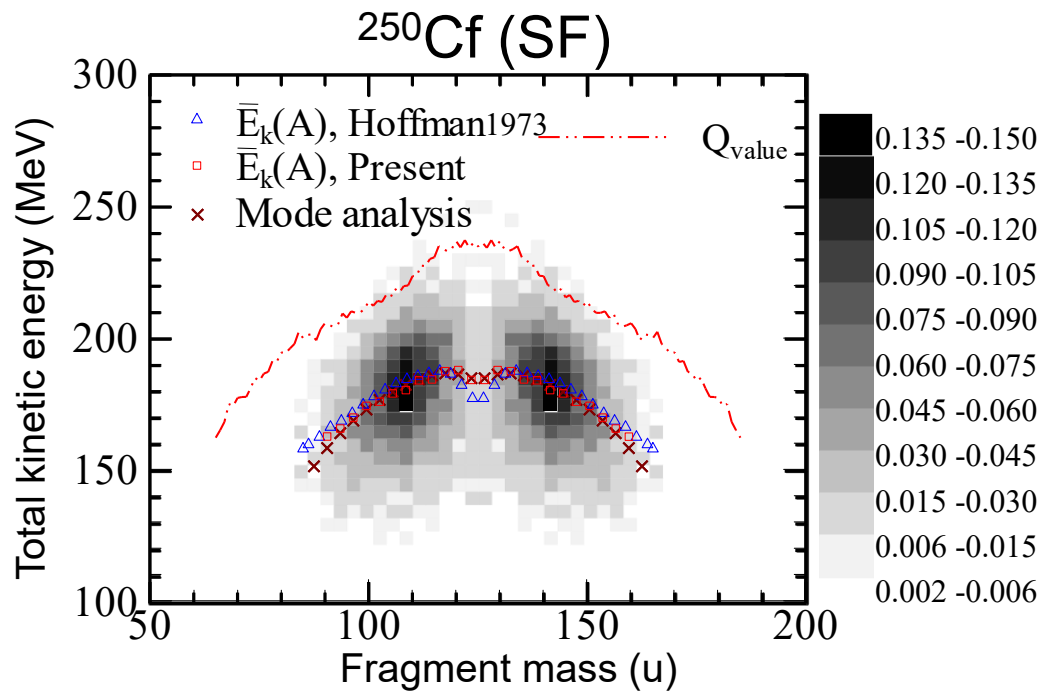


Velocities of both fragments are measured

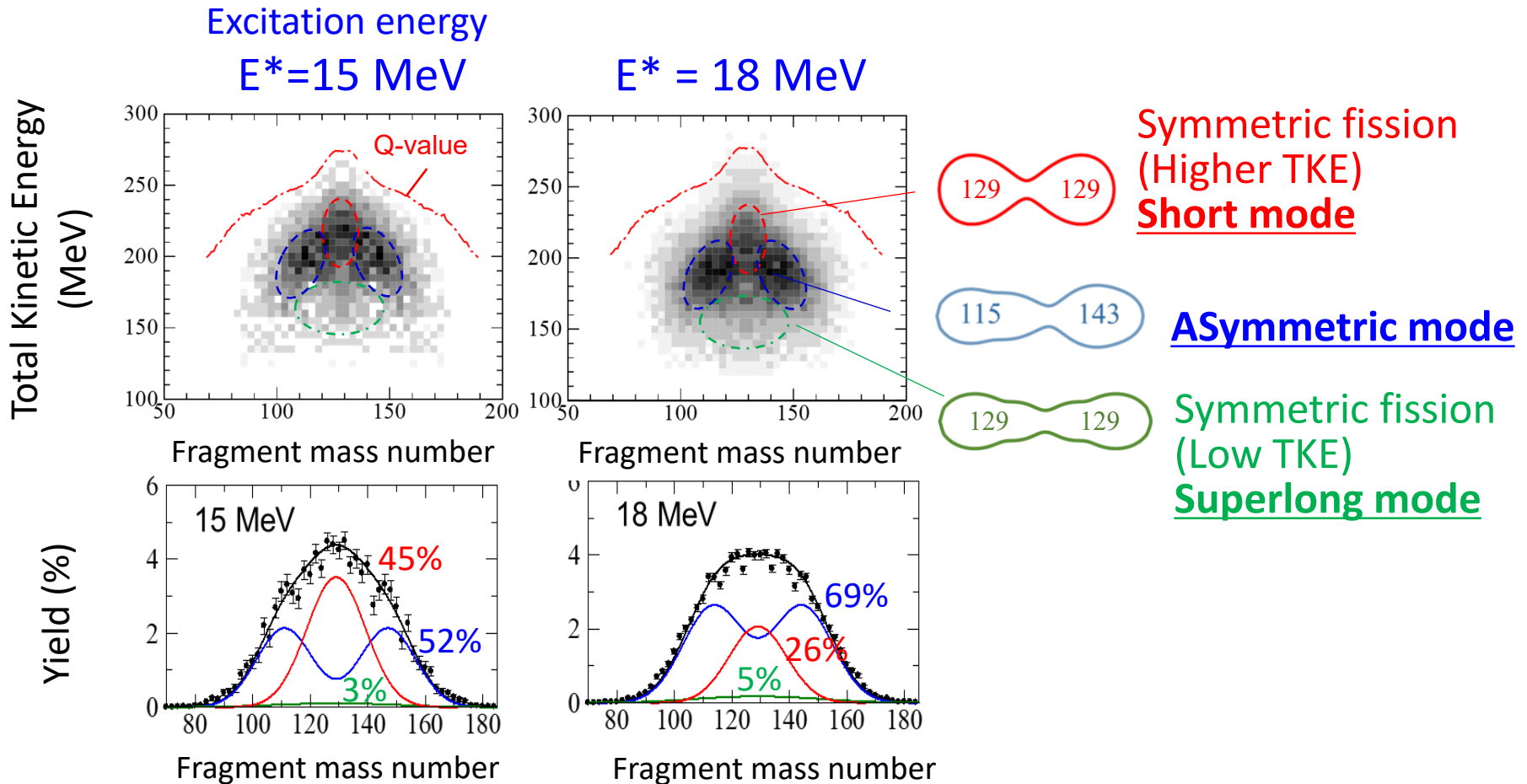


# Spontaneous fission of $^{250}\text{Cf}$

Calibration of the detection system was given using  $^{250}\text{Cf}(\text{SF})$



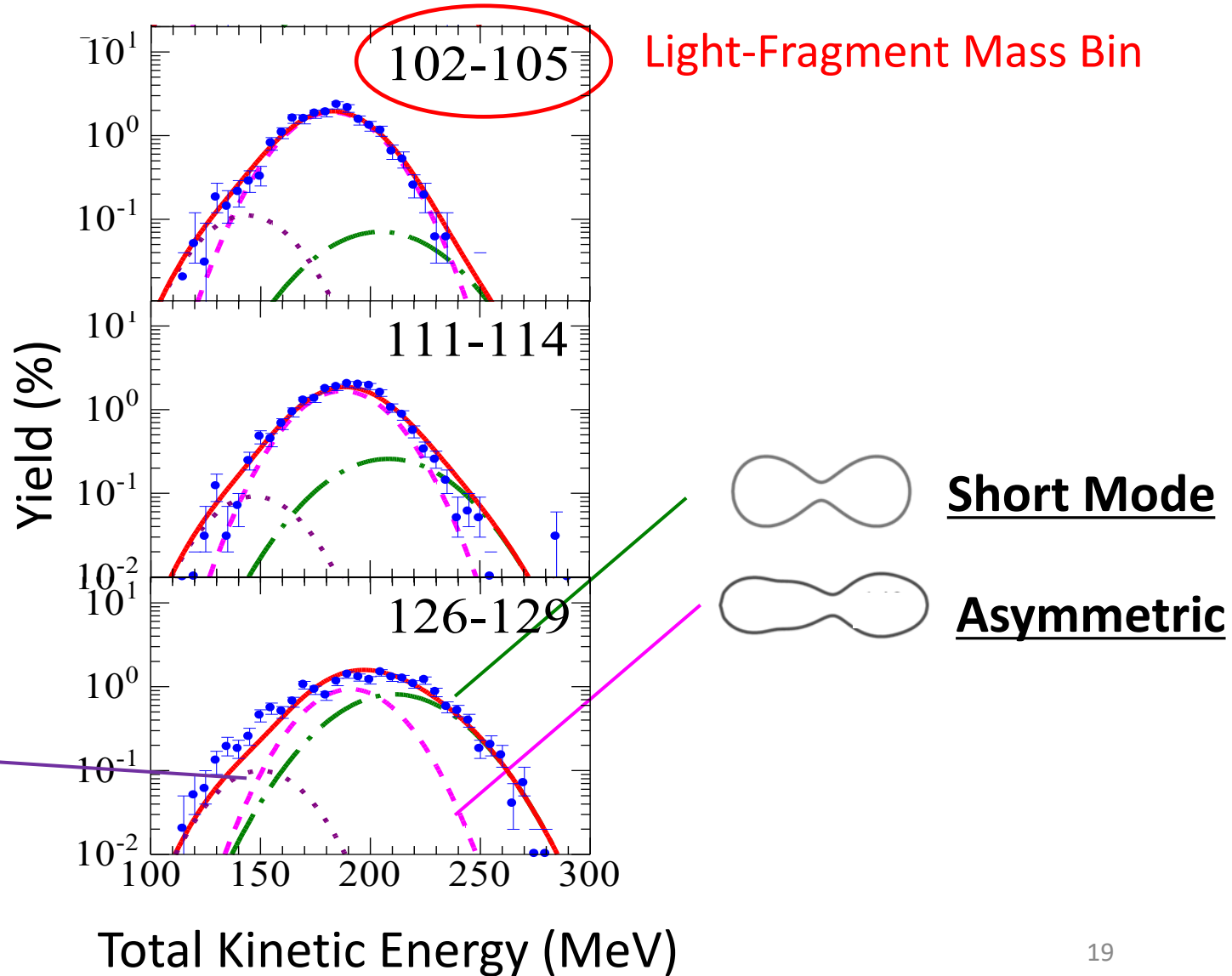
# Fission of $^{258}_{101}\text{Md}$ from excited states



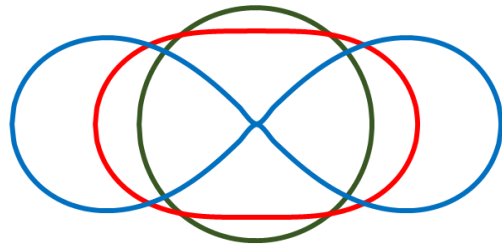
- (1) Symmetric and asymmetric fission modes competes.
- (2) Yields of asymmetric fission mode enhances with excitation energy.

# Three fission modes in $^{258}\text{Md}$

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



# Langevin Calculation with Cassini Ovals shape parameters ( 6 dimensions )



Cassini ovals ( $R = \text{const.}$ )

$\alpha$  : elongation

$\alpha = 0.0$

$\alpha = 0.5$

$\alpha = 1.0$

Pashkevich, Nucl. Phys. A **169** (1971) 275.

$R(x) = 1 + \sum_{n=1}^{\infty} \alpha_n P_n(x)$

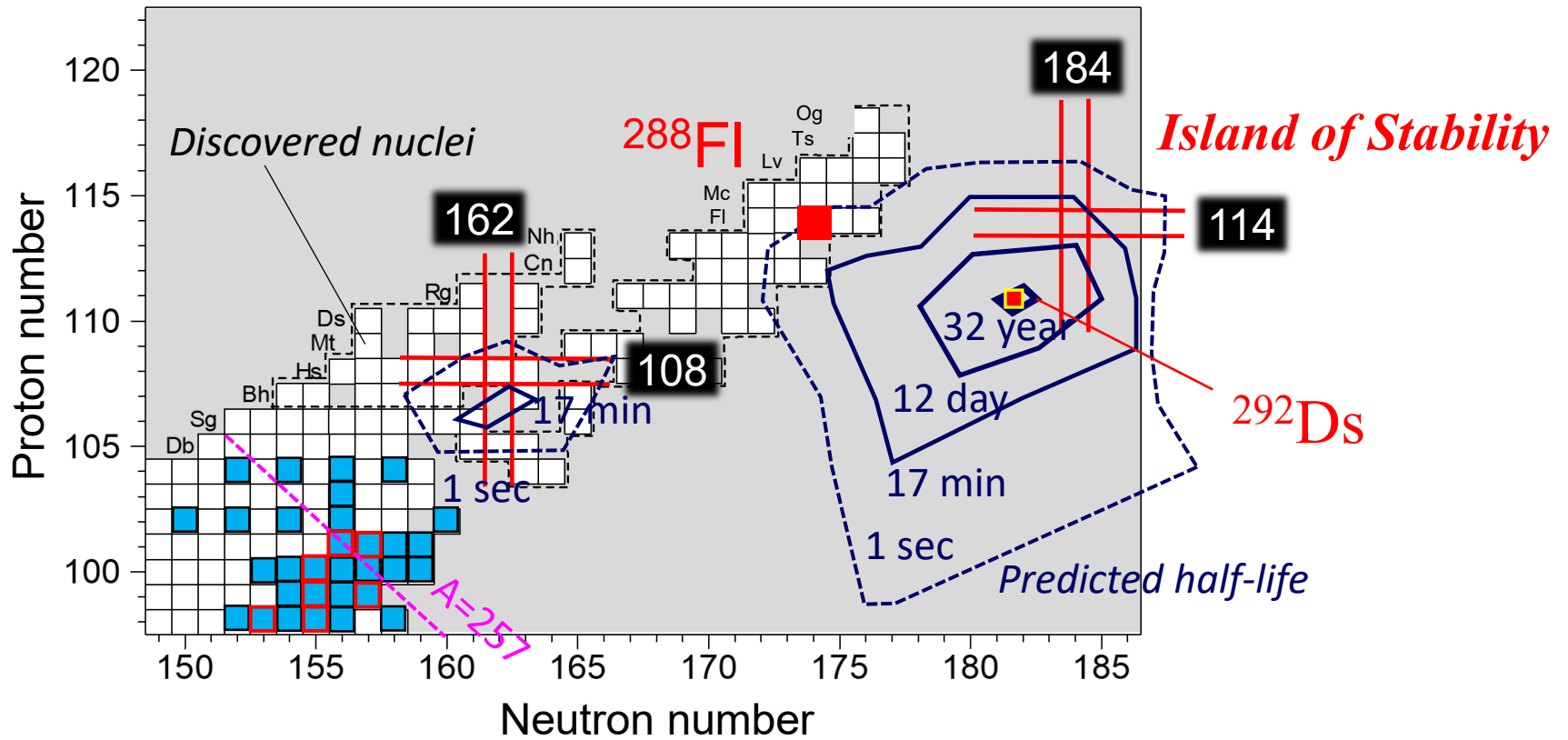
	$\alpha_1$	Mass Asymmetry		$\alpha_1=0.1$		$\alpha_1=-0.1$
odd	$\alpha_3$	Asymmetry of nuclear shape		$\alpha_3=0.1$		$\alpha_3=-0.1$
	$\alpha_5$			$\alpha_5=0.1$		$\alpha_5=-0.1$
	$\alpha_2$			$\alpha_2=1.0$		$\alpha_2=-1.0$
even	$\alpha_4$			$\alpha_4=0.1$		$\alpha_4=-0.1$

Developed by K. Okada

Calculated by JAEA Supercomputer (>8,000 cores)



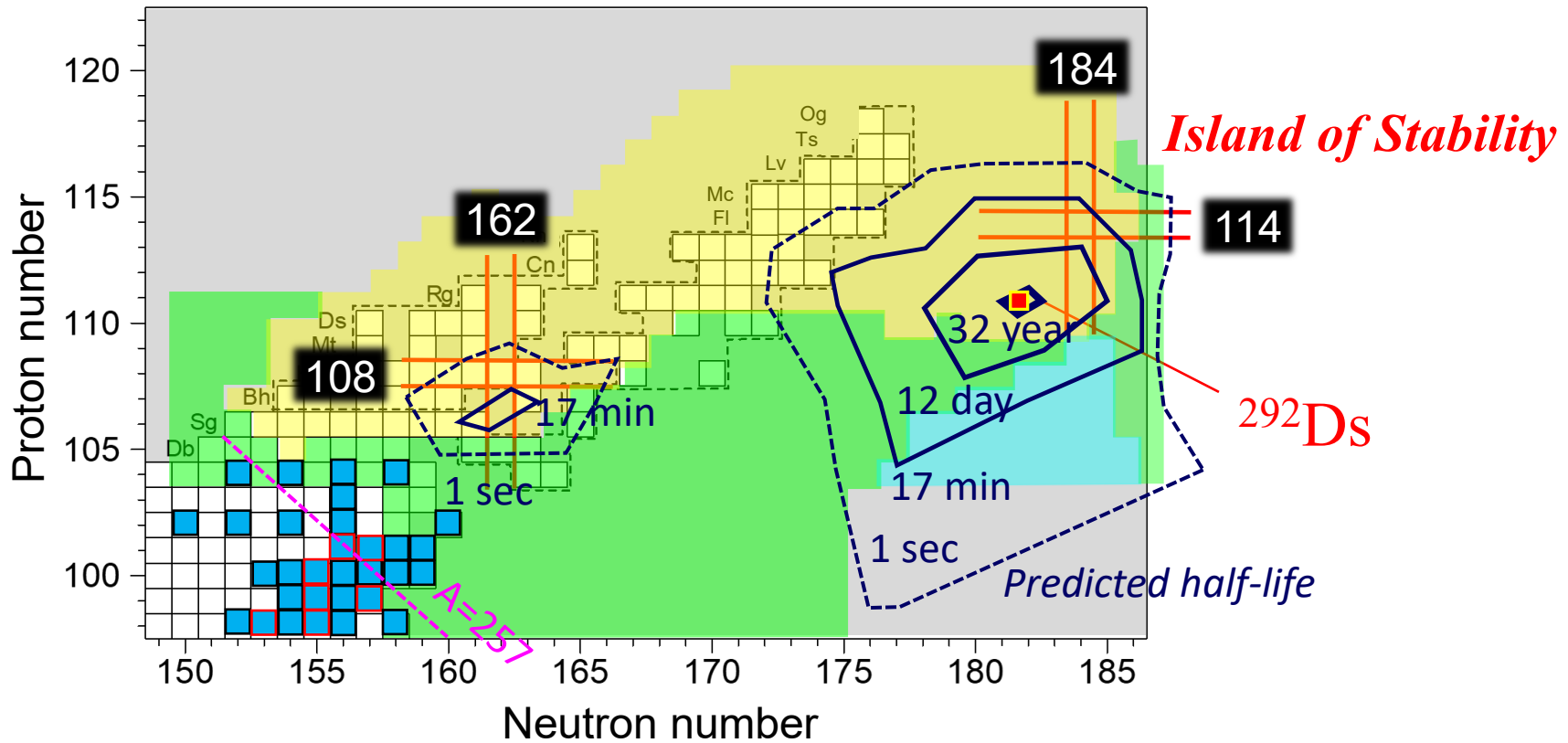
# Superheavy elements



Fission properties are measured.

( JAEA Measured/Re-Measured )

# Decay properties in SHE region



Fission properties  
are measured.



Theory

- Spontaneous fission
- $\alpha$  decay
- $\beta^-$  decay

# Summary

- ♣ We confirmed sharp transition from mass-asymmetric fission of  $^{256}\text{Fm}$  to symmetric fission of  $^{258}\text{Fm}$ .
- ♣ In the fission of  $^{258}\text{Md}$ , *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  $^{208}\text{Pb}$ -like structure.