Nuclear fission properties of fermium isotopes calculated by dynamical model

- Origin of sharp transition of mass asymmetry in fermium isotopes -

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   1-1. Change of FFMDs pattern in the region of Fm
   1-2. Bimodal-fission mode in the region of Fm

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   2-2. Definition of neck parameter ε value

3. Results & Discussion
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4. Summary & Perspective

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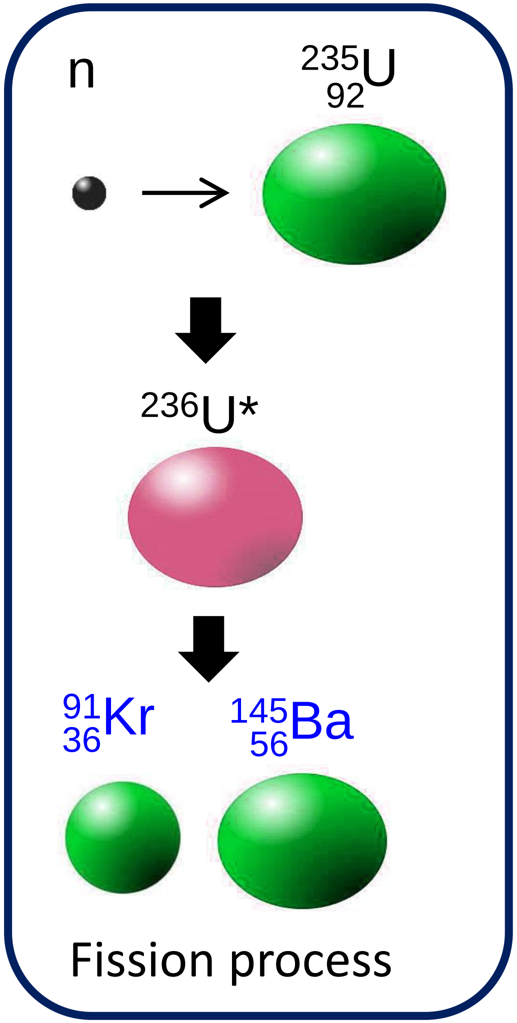
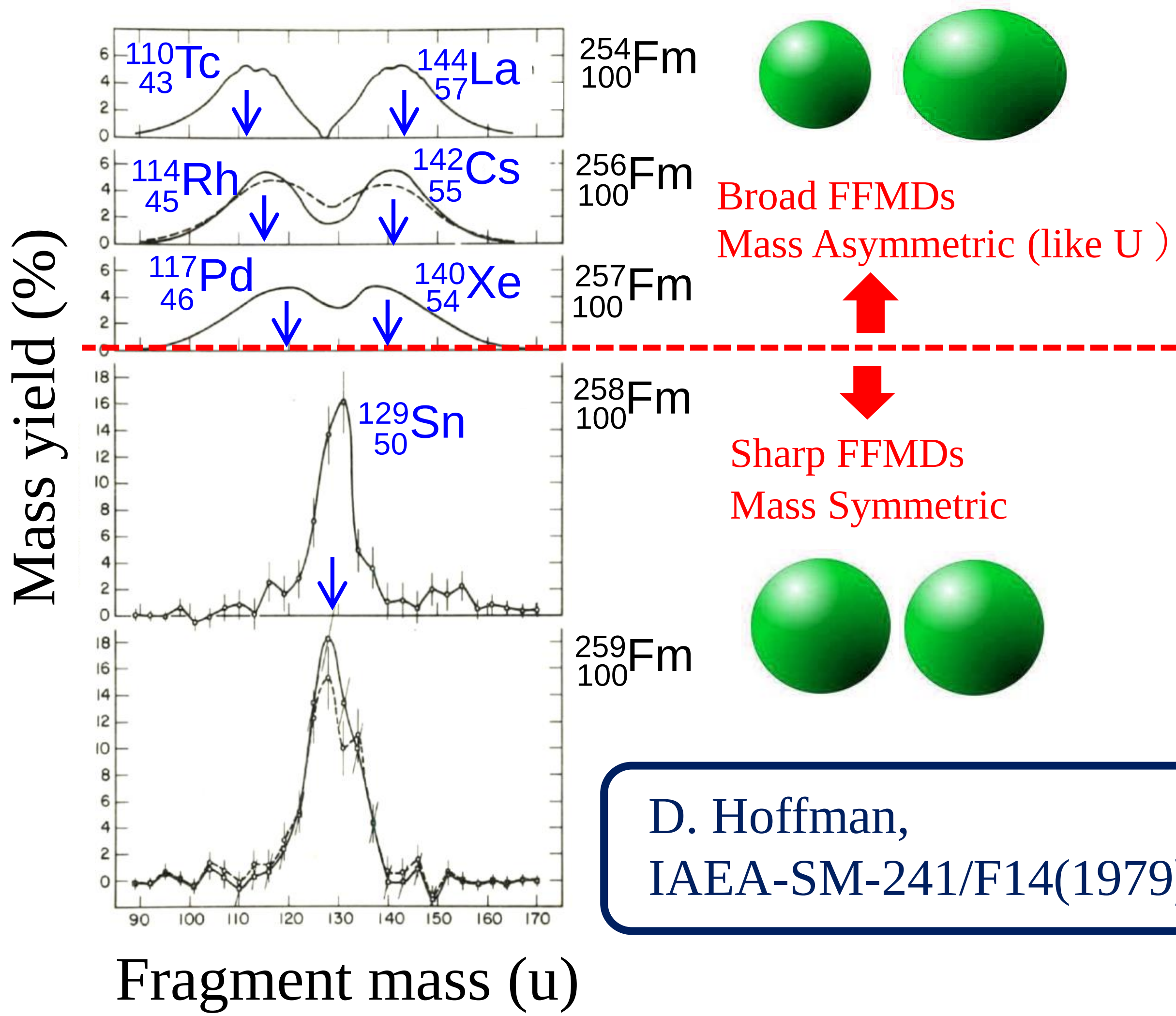
The sharp transition is observed from the asymmetric fission of ^{257}Fm to symmetric fission of ^{258}Fm - Experiment results -





D. Hoffman,
IAEA-SM-241/F14(1979)

Spontaneous fission in the mass region of Fm and bimodal-fission - ^{260}Md fission fragment -

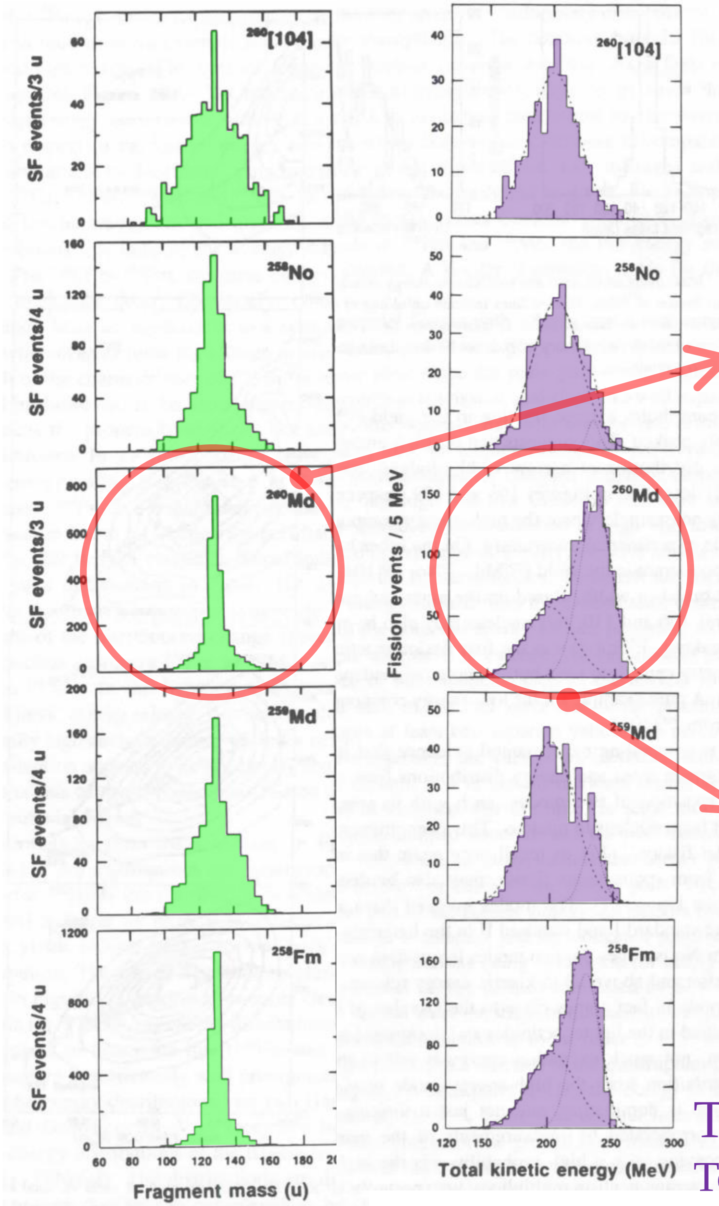
$^{260}_{104}$Rf

$^{258}_{102}$No

$^{260}_{101}$Md

$^{259}_{101}$Md

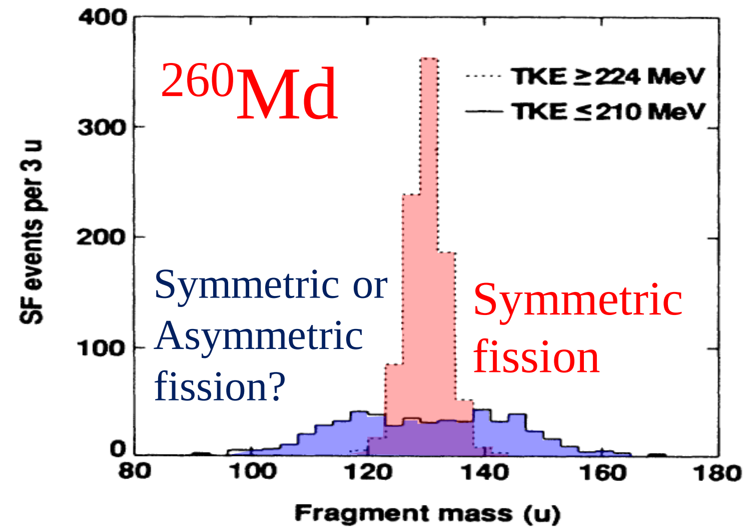
$^{258}_{100}$Fm

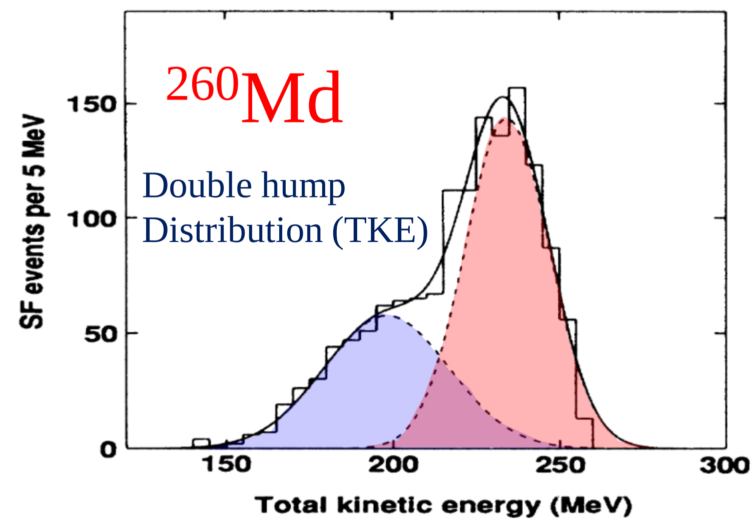


Fission Fragment Mass Distribution (FFMDs)

TKE

Total Kinetic Energy

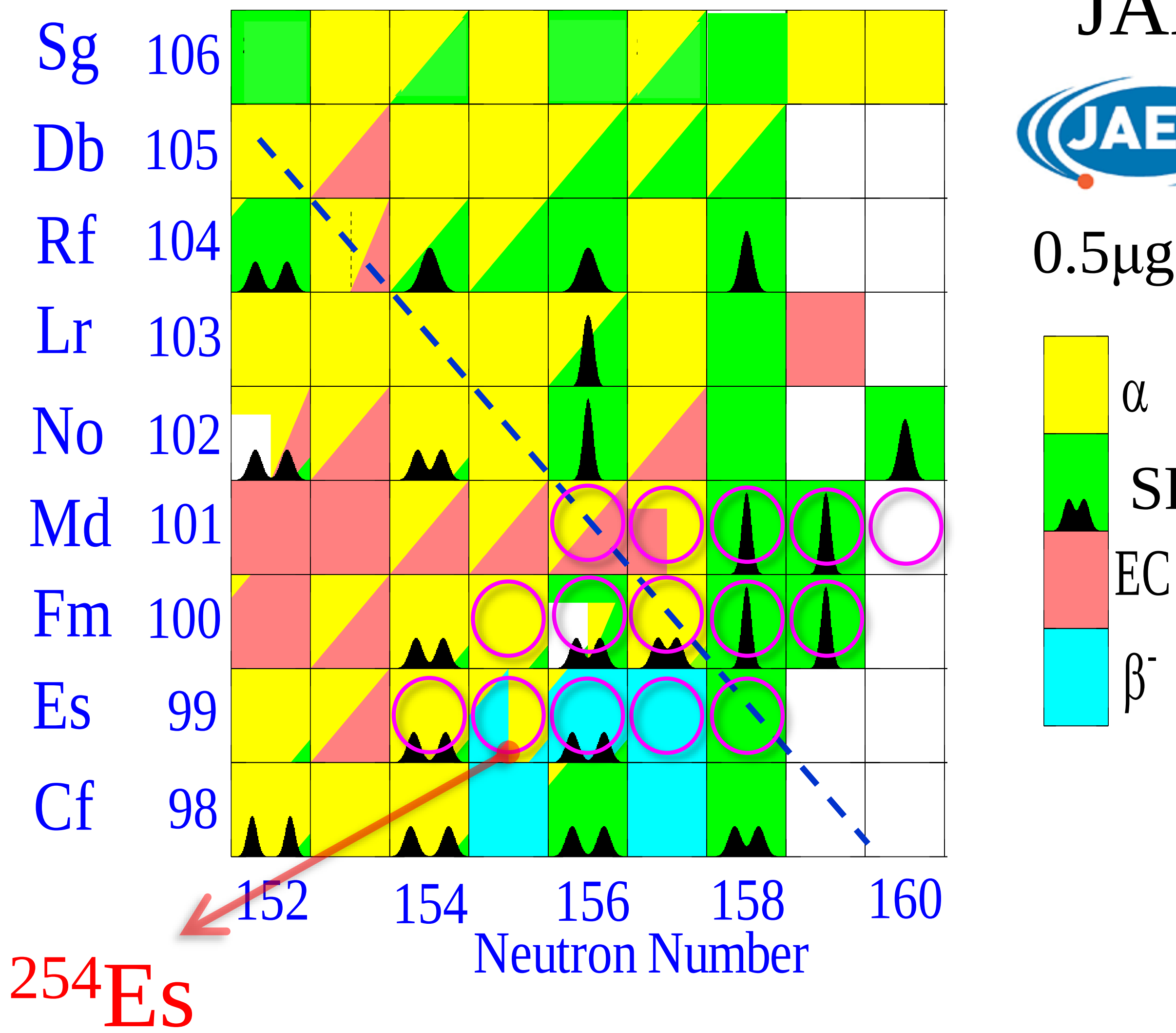




J.F. Wild et al., Phys. Rev. C, **41**, 649 (1990)

Change of FFMDs pattern In the region of Fm

Fission mode appearing in neutron rich Fm Isotope



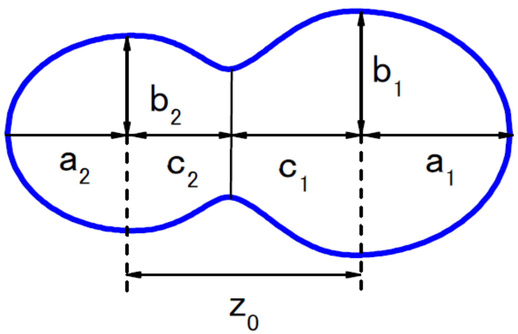
JAEA - ORNL

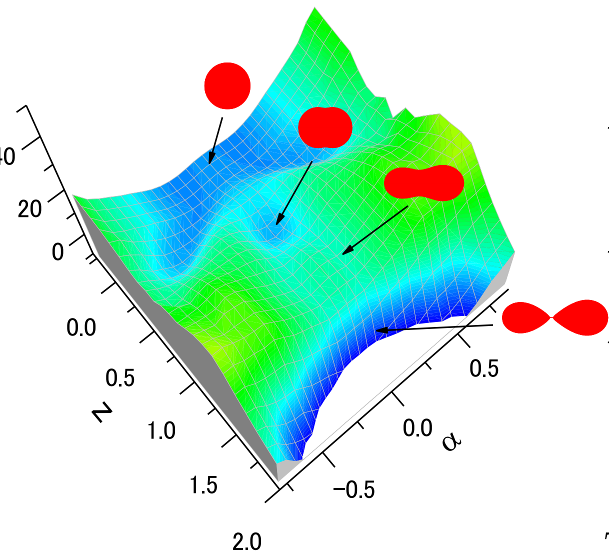
0.5μg, ^{254}Es ($T_{1/2}$=276 day)

Multi-Nucleon Transfer reactions in ^{18}O + ^{254}Es

Presentation contents

Two center shell model





$$z = \frac{z_0}{BR}$$

$$q(z, \delta, \alpha)$$

$$B = \frac{3+\delta}{3-2\delta}$$

q : Two Center parametrization

R : Radius of the spherical compound nucleus

$$\delta = \frac{3(a-b)}{2a+b}$$

$$\alpha = \frac{A_1 - A_2}{A_{CN}}$$

z : Two Cent. Dist.
δ : Nuclear Deformation
α : Mass Asymmetry
ε : Neck Parameter

$\delta_1 = \delta_2$
$\varepsilon =$ const.

$$V(q,\ell,T) = V_{DM}(q) + \frac{\hbar^2 \ell(\ell+1)}{2I(q)} + V_{SH}(q,T)$$

$$V_{DM}(q) = E_S(q) + E_C(q)$$

$$V_{SH}(q,T) = E^0_{shell}(q)\Phi(T)$$

$$\Phi(T) = \exp\left\{-\frac{aT^2}{E_d}\right\}$$

T : nuclear temperature $\quad E_d = 20\,\mathrm{MeV}$

$E^* = aT^2 \quad a$: level density parameter

Toke and Swiatecki

E_S : Generalized surface energy (finite range effect)
E_C : Coulomb repulsion for diffused surface
E^0_{shell} : Shell correction energy at $T=0$

I : Moment of inertia for rigid body

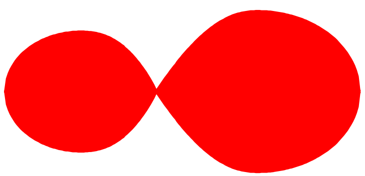
$\Phi(T)$: Temperature dependent factor

Definition of ε parameter

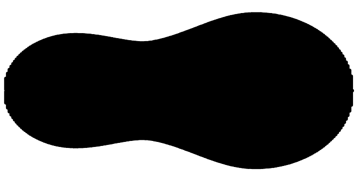
Neck parameter ε: ratio of smoothed potential height to the original one where two harmonic oscillator potential cross each other

$$\varepsilon = \frac{E}{E_o}$$

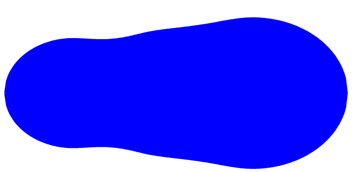
ε = 1.00

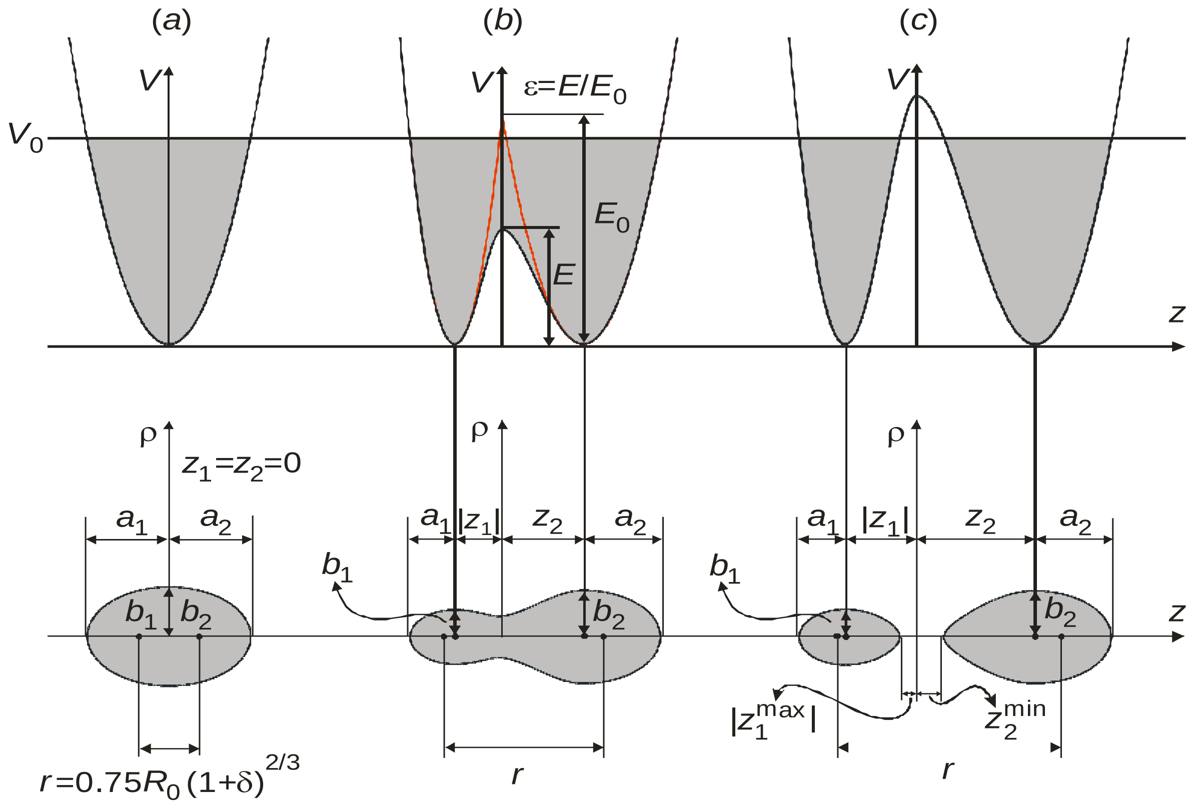


ε= 0.35



ε = 0.0





Example of the nuclear shapes in two-center parametrization and The corresponding potentials V(Z) shown for δ1=δ2=0.5. The mass Asymmetry α=0.0 for (a) and α=0.625 for (b) and (c)

Langevin equation

$$\frac{dq_i}{dt} = \left(m^{-1}\right)_{ij} p_j$$

Friction dissipation | Random force fluctuation

$$\frac{dp_i}{dt} = -\frac{\partial V}{\partial q_i} - \frac{1}{2}\frac{\partial}{\partial q_i}\left(m^{-1}\right)_{jk} p_j p_k - \gamma_{ij}\left(m^{-1}\right)_{jk} p_k + g_{ij} R_j(t)$$

$\langle R_i(t)\rangle = 0,\ \langle R_i(t_1) R_j(t_2)\rangle = 2\delta_{ij}\delta(t_1 - t_2)$: white noise (Markovian process)

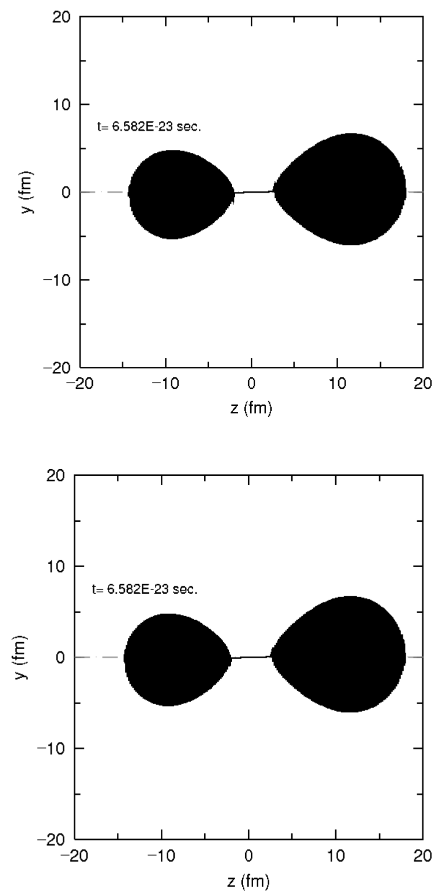
$$\sum_k g_{ik} g_{jk} = T\gamma_{ij}$$

$$E_{\mathrm{int}} = E^* - \frac{1}{2}\left(m^{-1}\right)_{ij} p_i p_j - V(q)$$

E_{int} : intrinsic energy

E^* : excitation energy

q_i : deformation coordinate
two-center parametrization
(Maruhn and Greiner, Z. Phys. 251(1972) 431)
p_i : momentum
m_{ij} : Hydrodynamical mass
γ_{ij}: Wall and Window (one-body) dissipation



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Summary & Perspective

1. The correlation between ε value and PES
→ To analyze the effect of Neck parameter

2. Trapping time distribution
→ Clarification of the mechanism of fission

3. TKE vs. Deformation distribution
→ To investigate of the energy dependence

4. Excitation energy dependence
→ To investigate Sym. & Asy. fission mode

5. JAEA - MNT reactions in $^{18}O + ^{254}Es$ –
→ To cooperate as Kindai theoretical group.

Thank you for your attention.