In-beam Fission Study at JAEA

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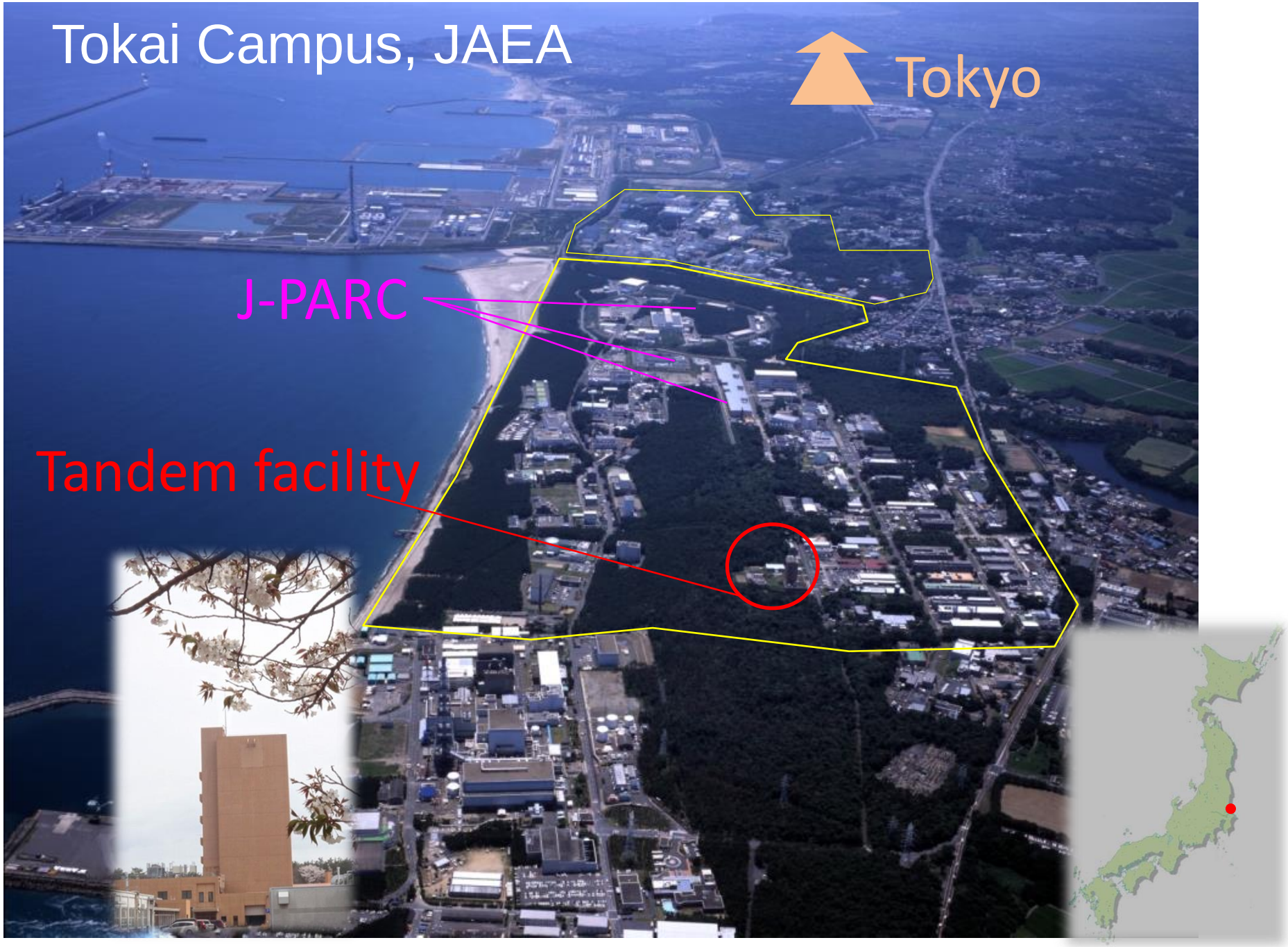
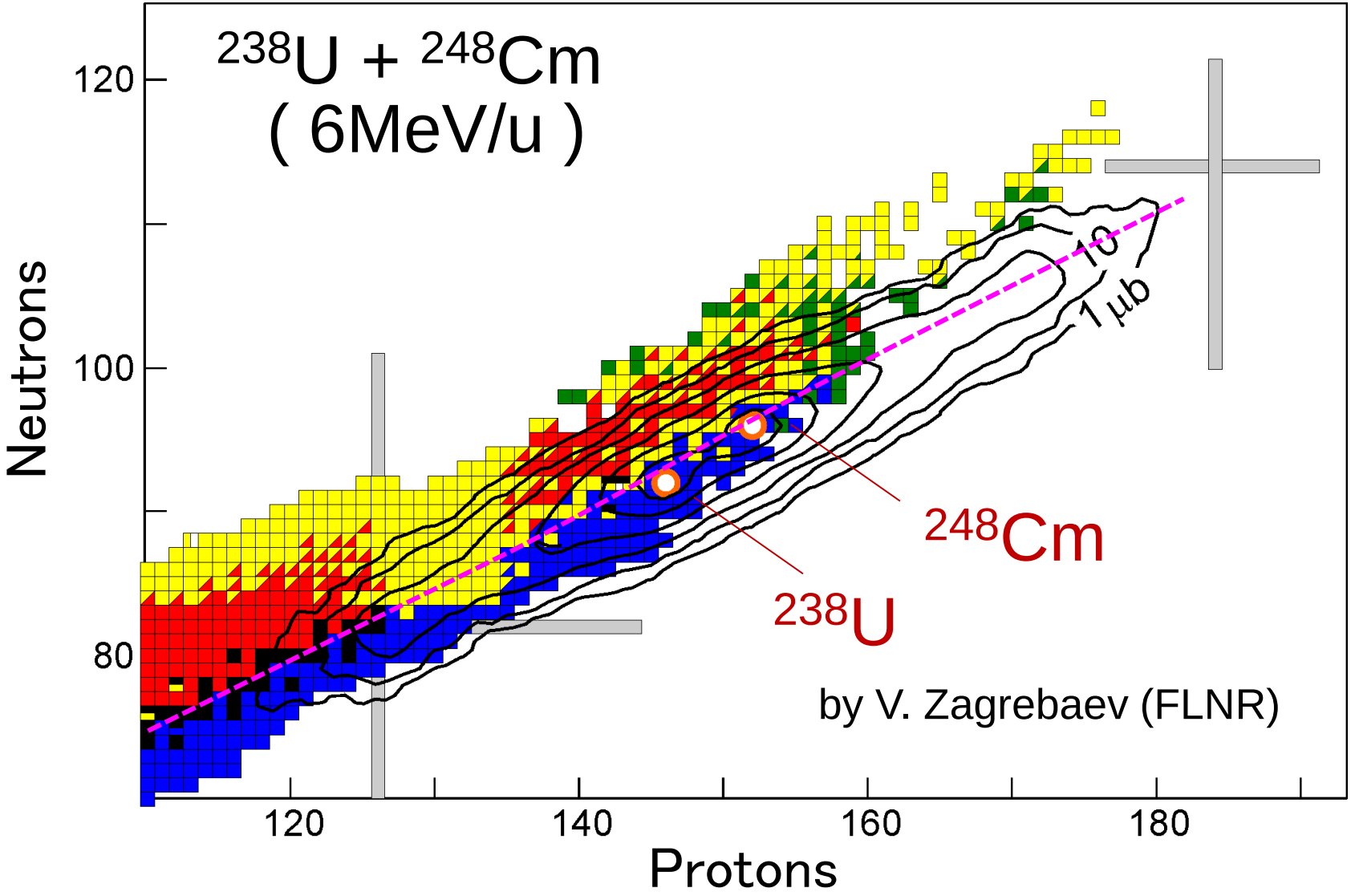

Tokai Campus, JAEA
Tokyo
J-PARC
Tandem facility

In-beam Fission/Reaction Studies

(1) Fusion-fission and quasifission

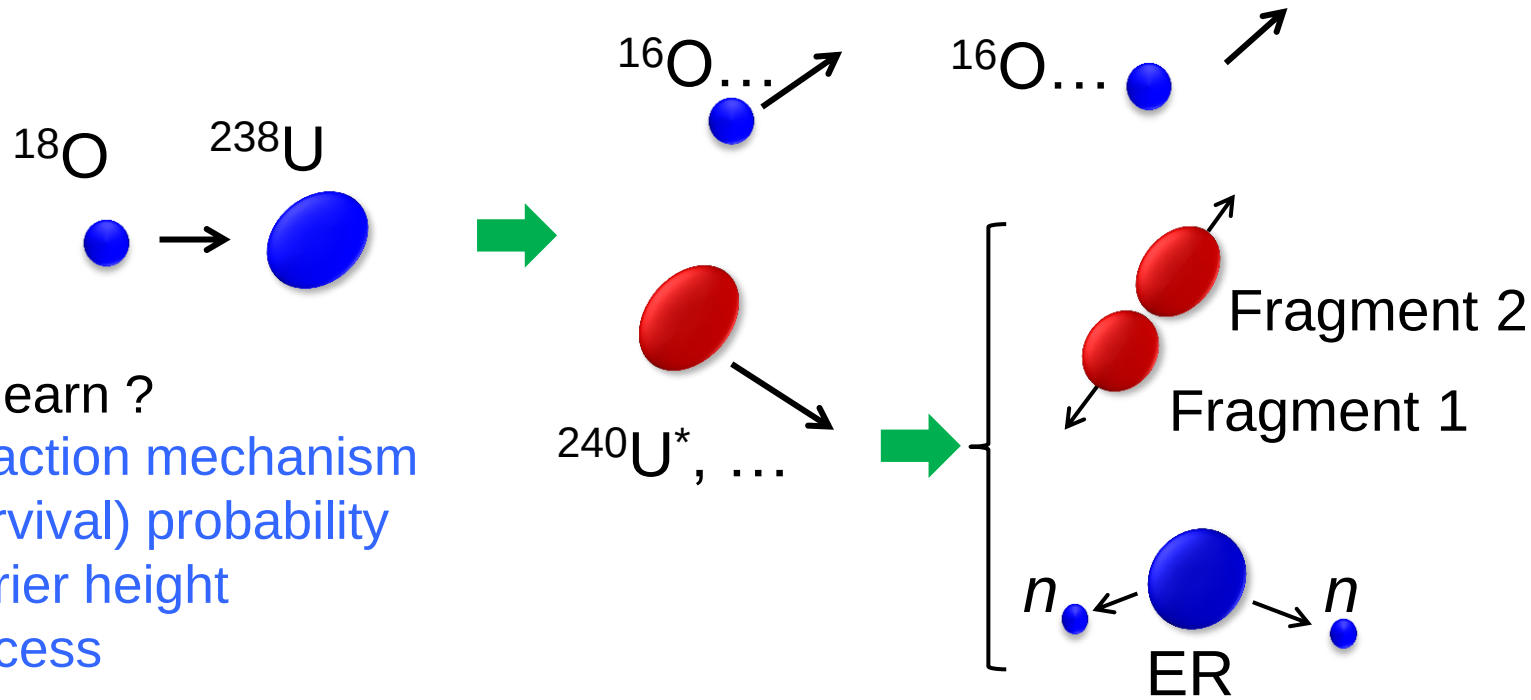
(2) Multi-nucleon transfer induced fission

Access to Neutron-rich SHN



Multi-nucleon Transfer Reaction

- Producing many nuclei including neutron rich isotopes
- Populating large-range excitation energies



What we will learn ?

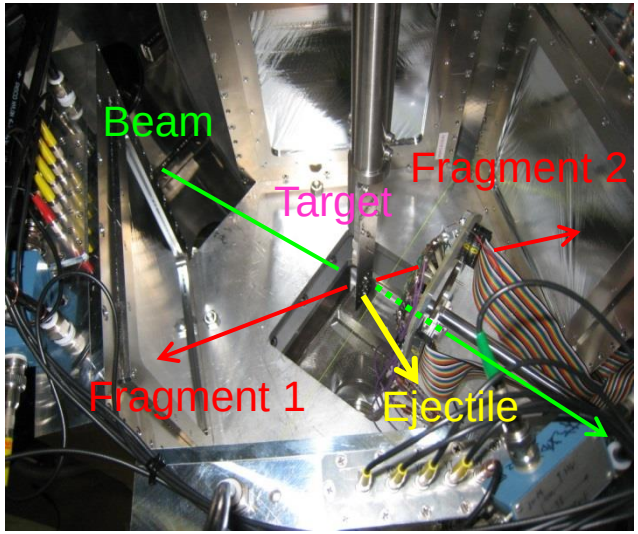
- Transfer reaction mechanism
- Fission (survival) probability
- Fission barrier height
- Fission process
- …

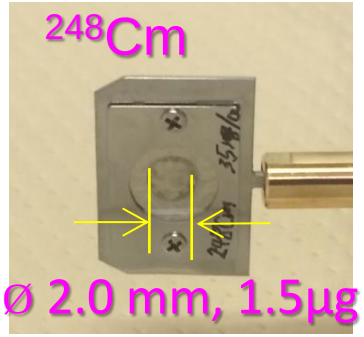
Starting a campaign from ^{18}O + ^{232}Th, ^{238}U, ^{248}Cm, ^{237}Np, ^{249}Cf

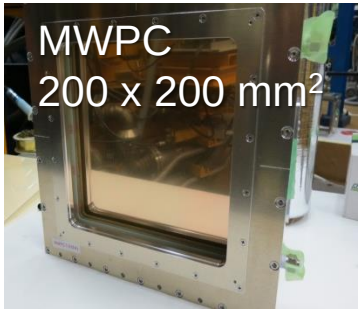
Future ^{22}Ne, ^{26}Mg, … beams

New beam line for reaction and fission study using radioactive materials (Np, Am, Cm, Cf, …)

- Multi-nucleon transfer reaction and fission
- Fusion-fission & quasifission

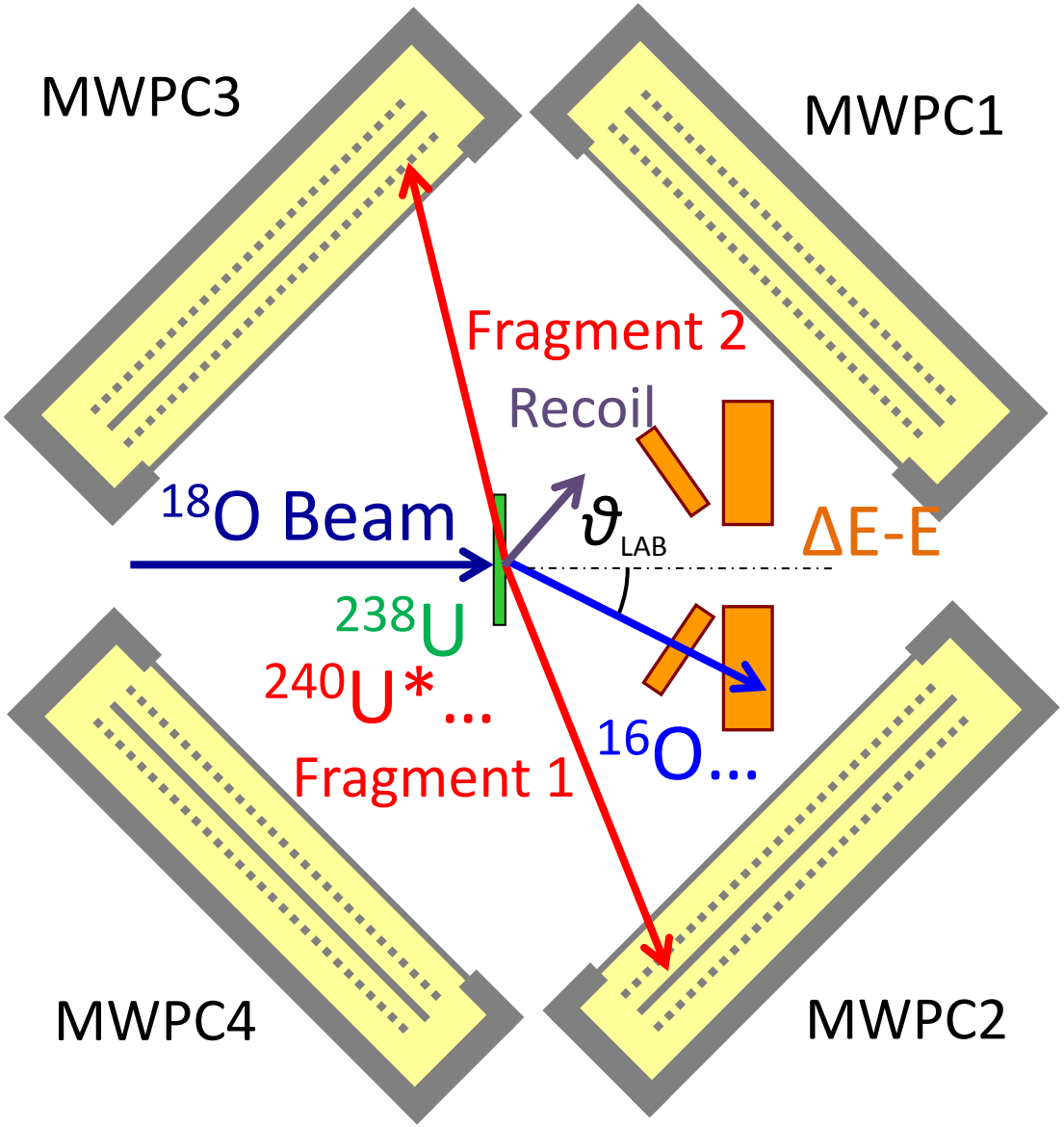


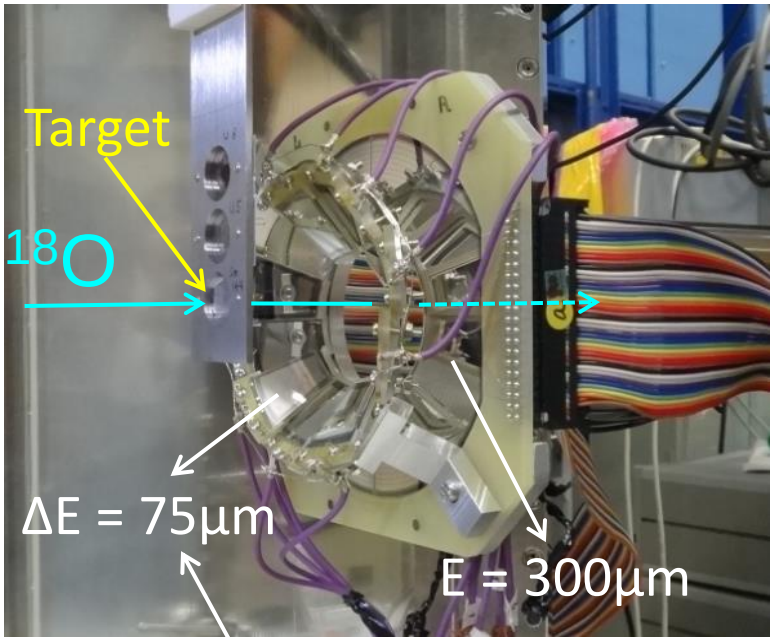


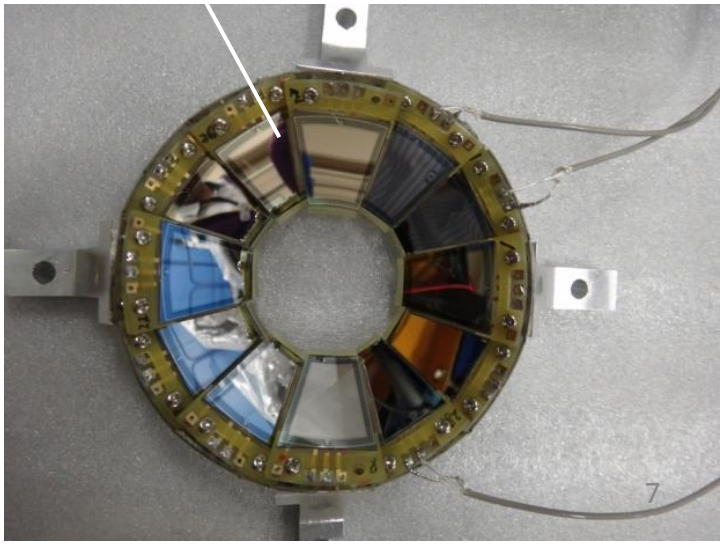


- Identification of Transfer Channels
- Fission Fragments Mass & Angular Distribution
- Neutrons from Fragments and reaction process
- …

Setup for multi-nucleon transfer induced fission

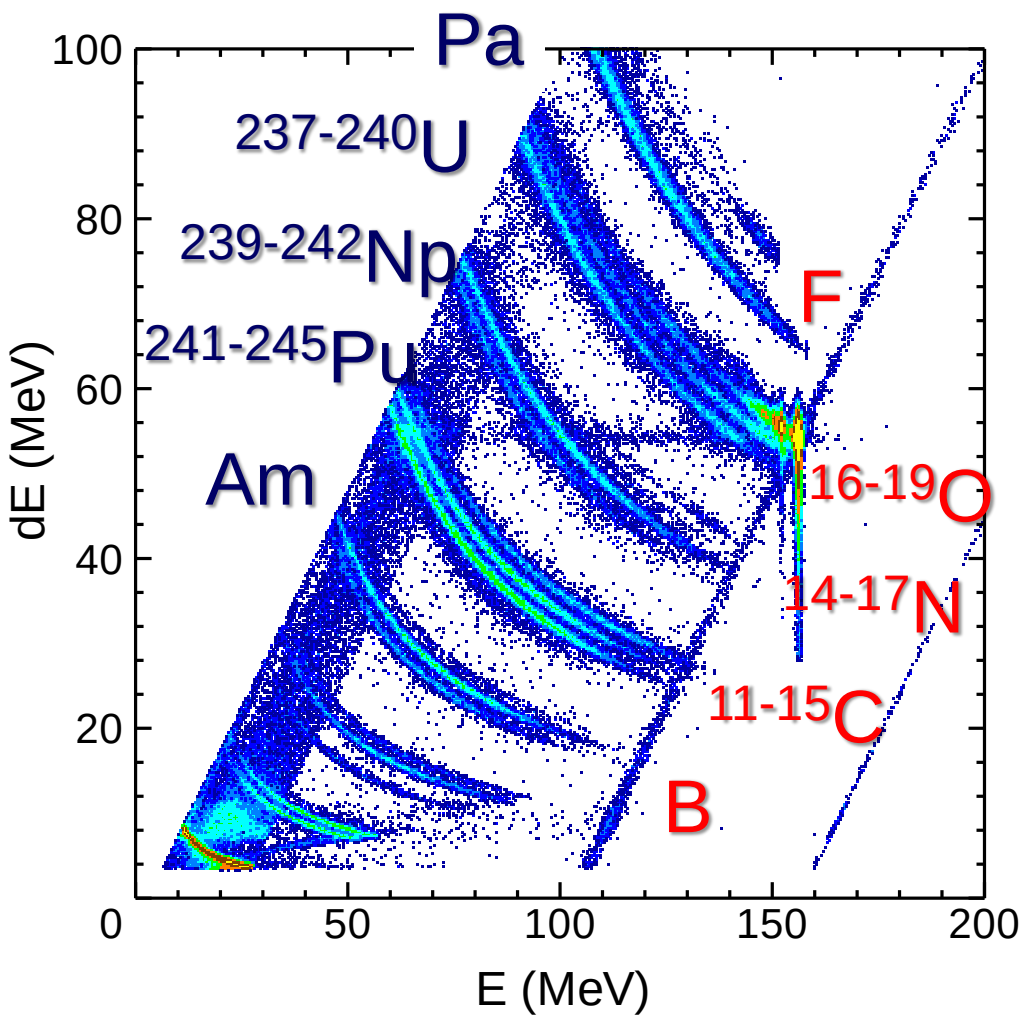






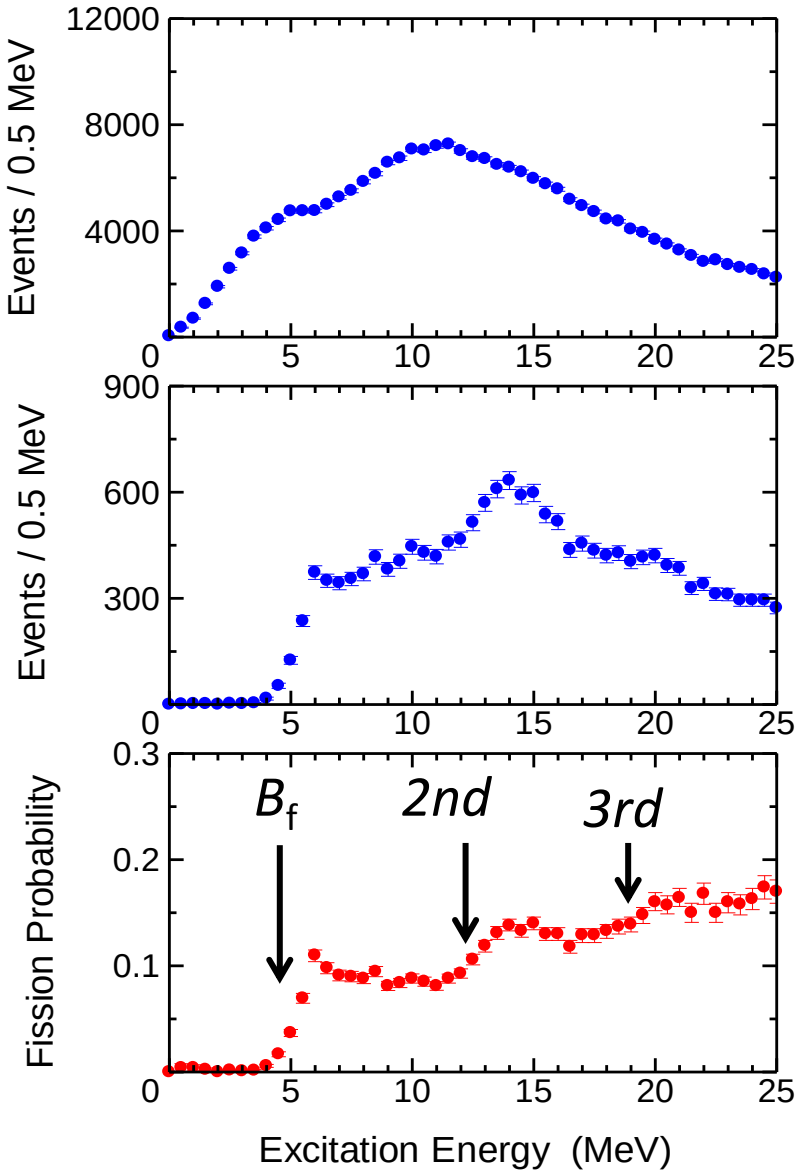
Particle Identification

$^{18}O + ^{238}U$ (E_{beam}=157.5 MeV)



Fission Barrier and Fission Probability

$^{18}O + ^{238}U \rightarrow$
$^{16}O + ^{240}U^*$

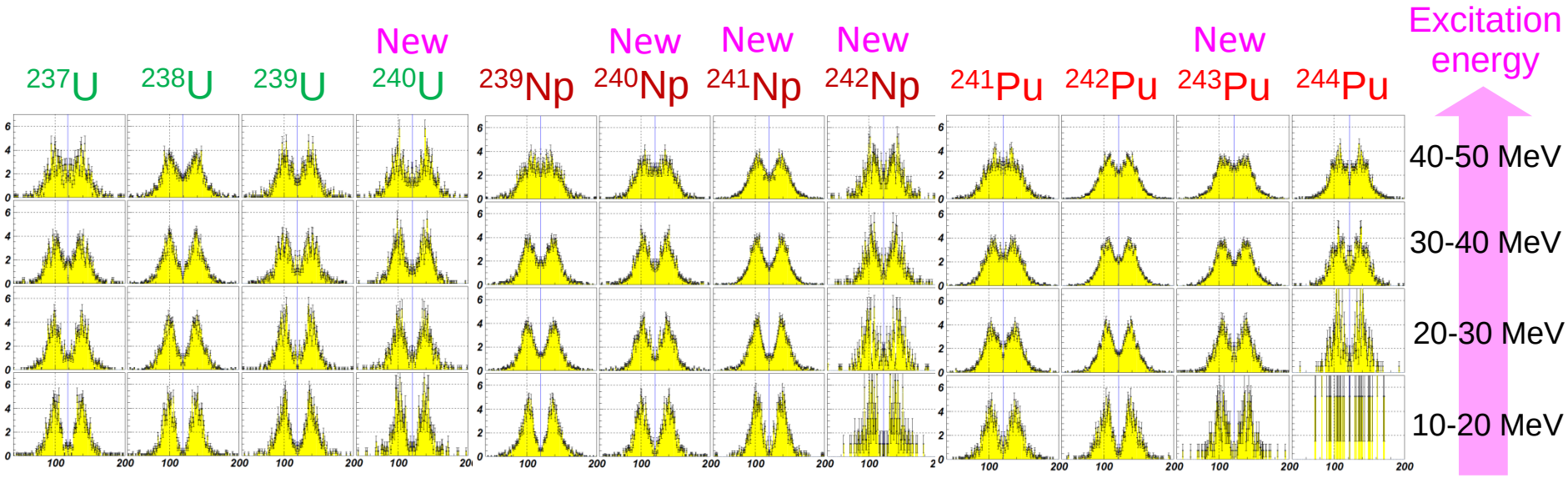


^{16}O Events

^{16}O coincided with fragments

Fission Fragment Mass Distribution

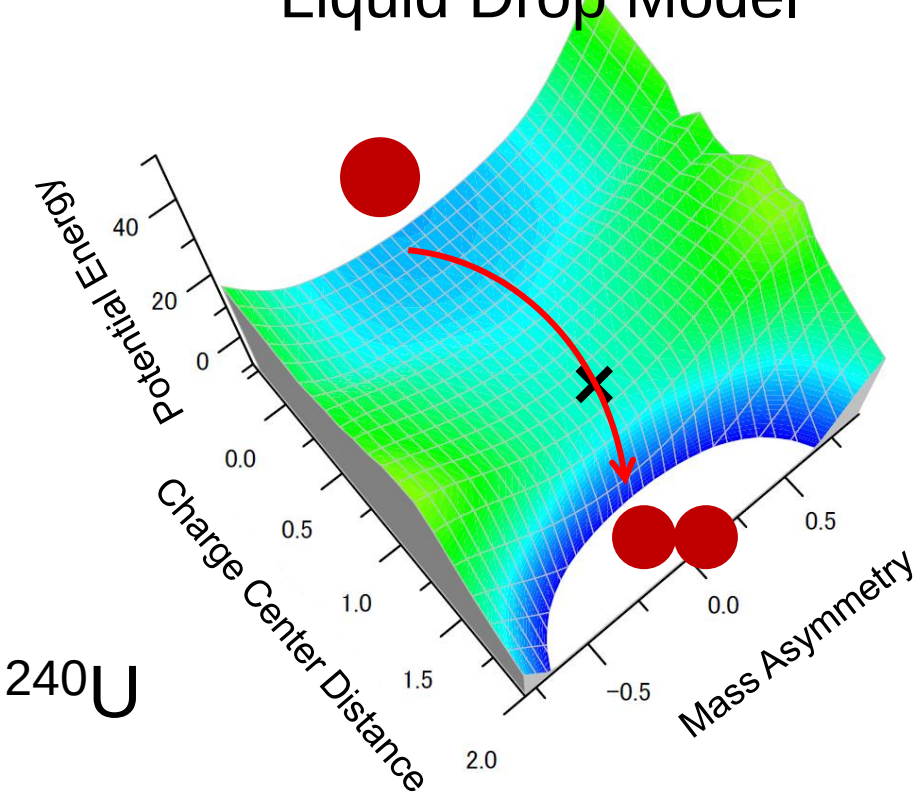
Data from $^{18}O + ^{238}U$ (E_{beam} = 157.5 MeV)



Fragment Mass (u)

Shell correction energy and Fission

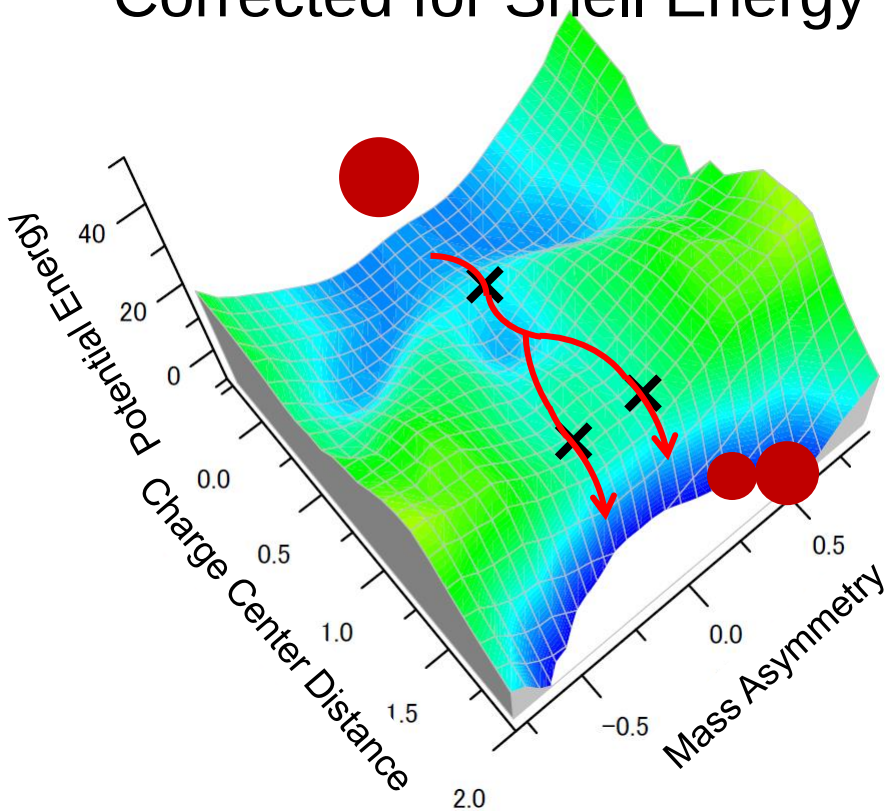
Liquid Drop Model



^{240}U

High Excitation Energy

Corrected for Shell Energy



Low Excitation Energy

$$\Delta E_{Shell}(E^*) = \Delta E^0_{Shell} * exp\left(-E^* / E_D\right)$$

Shell Damping Energy

Langevin Calculation

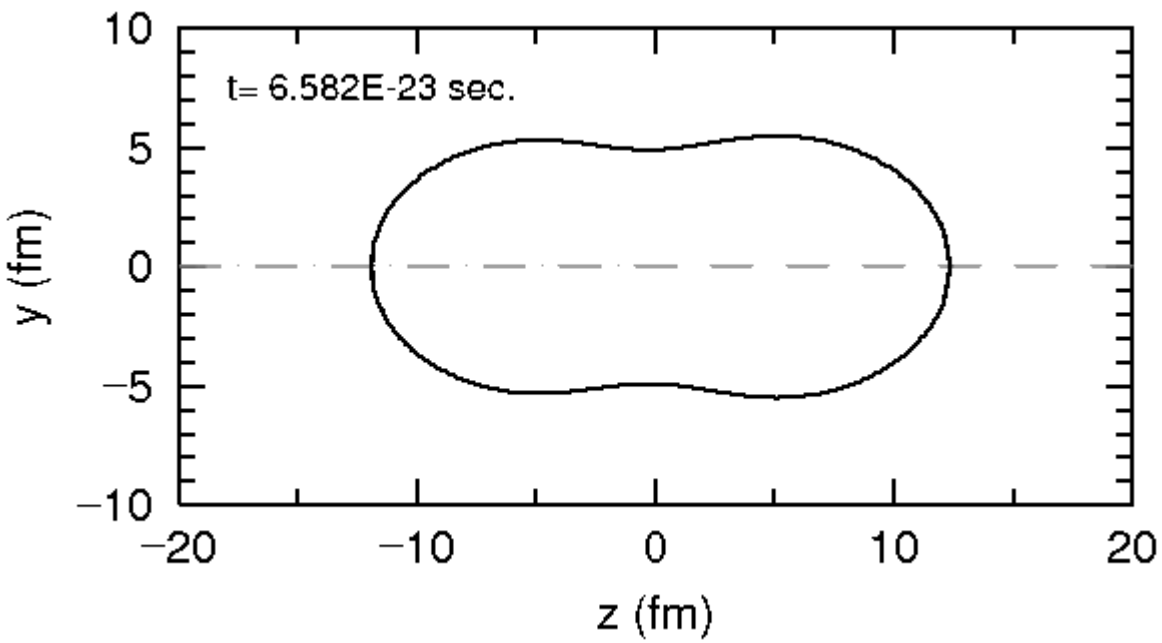
Two center shell-model : (Liquid Drop + Shell Correction)

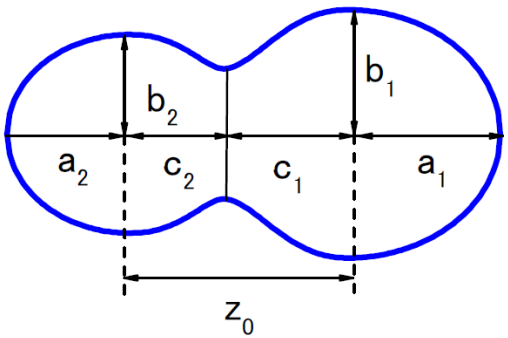
- Charge center distance
- Mass-asymmetry
- Deformation.

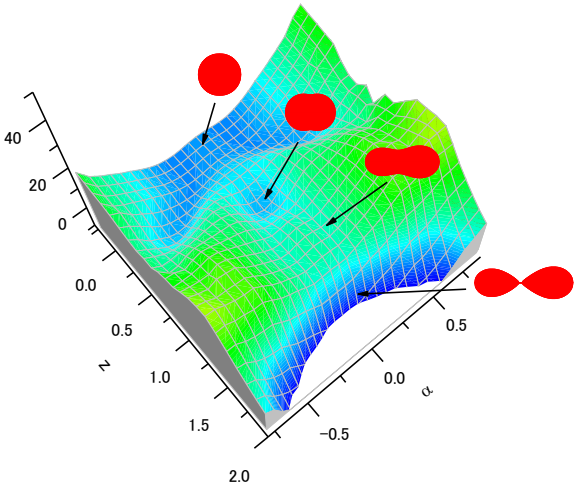
Trajectory (shape evolution) is calculated by solving Langevin equations.

$$\Delta E_{Shell}(E^*) = \Delta E^0_{Shell} * exp\left(-E^*/_{E_D}\right)$$

E_D = 20 MeV : Shell Damping Energy





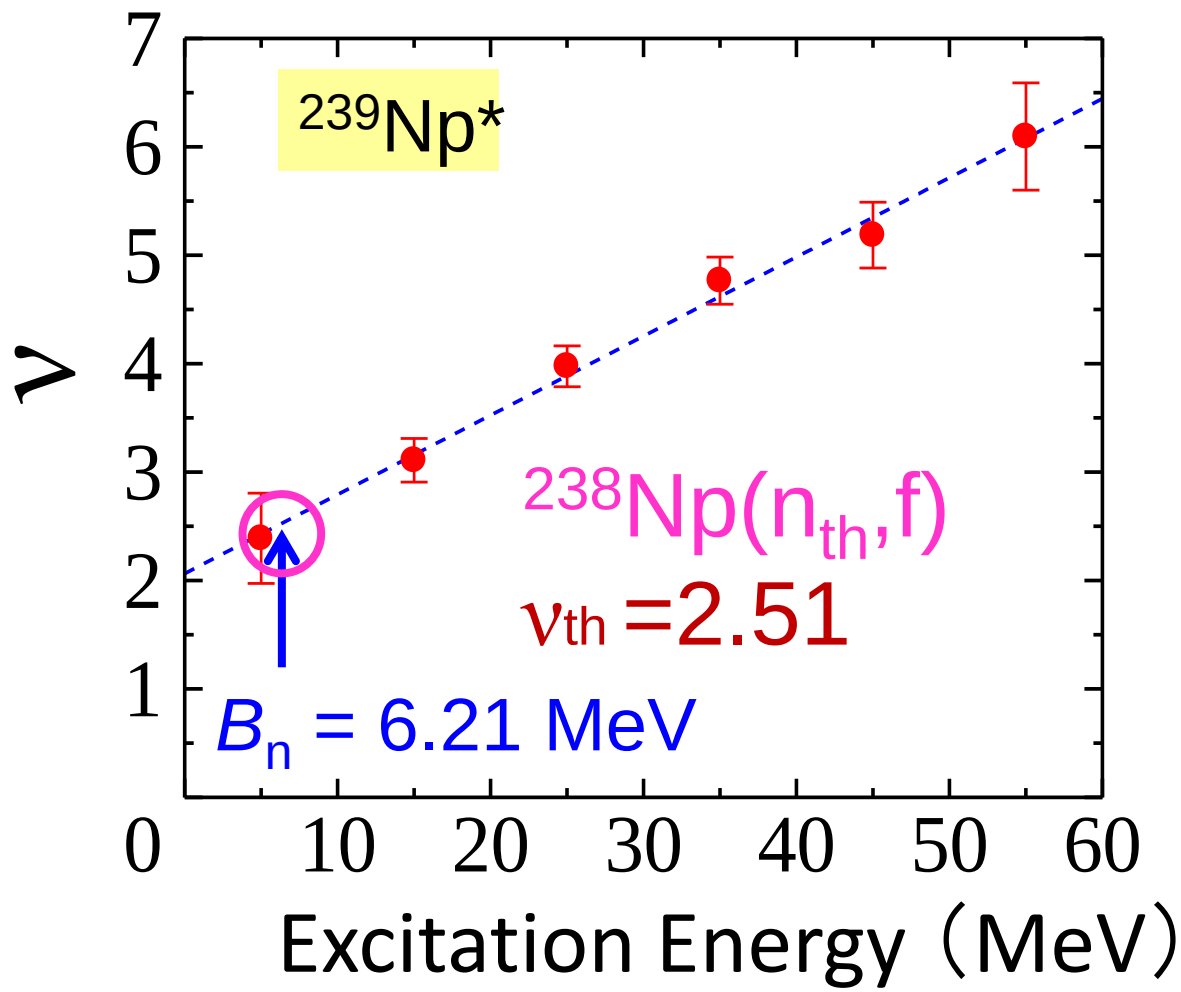


Y. Aritomo and S. Chiba
Phys. Rev. C **88**, 044614 (2013)

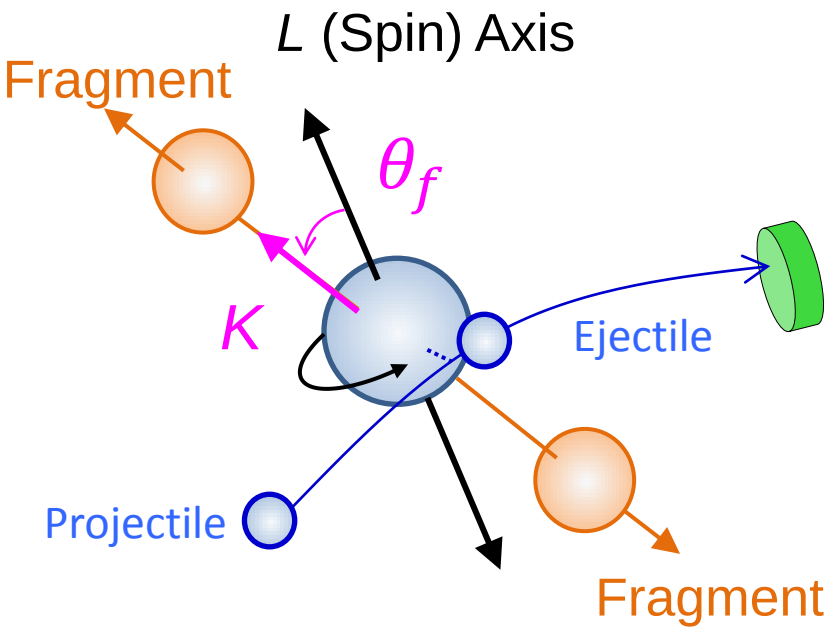
Prompt neutron multiplicity

$^{18}O + ^{238}U \rightarrow ^{17}N + ^{239}Np^*$

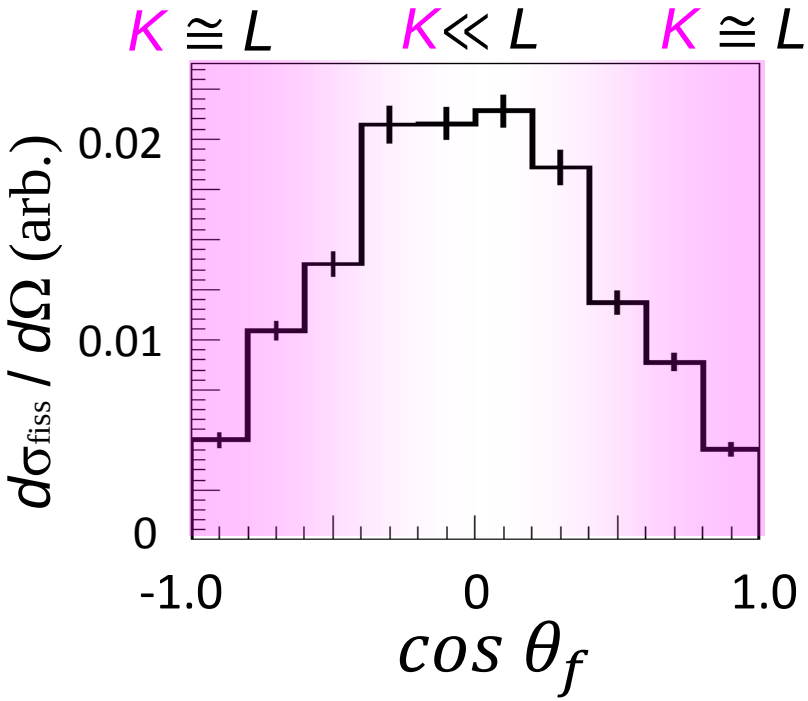
Preliminary



Fission fragment angular distribution



$^{18}O + ^{238}U \rightarrow ^{16}O + ^{240}U^*$



- Fissioning Nuclei (*A*, *Z*)
- Excitation energy *E**
- Spin and its projection to the symmetric axis (*L*, *K*)

Summary

(1) Beam lines for reaction and fission study using RI material

(2) Multi-nucleon transfer reaction and fission

(3) Fragment mass distributions and shell damping energy

(4) Neutron multiplicity in fission

(5) Fragment angular distributions

K. Nishio, K. Hirose, L. Rmomain, J. Smallcombe, R. Orlandi, I. Nishinaka, H. Makii, K. Tsukada, M. Asai, Y. Nagame
A. Andreyev, D. Jenkins
T. Ohtsuki, K. Hagino
S. Chiba, Y. Aritomo
S. Yan
N. Tamura, S. Goto
Y. Watanabe
S. Hofmann, D. Ackermann, F.P. Heßberger, S. Heinz, J. Khuyagbaatar, B. Kindler, V.F. Comas J.A. Heredia, I. Kojouharov, B. Lommel, R. Mann, Ch.E. Düllmann