Multi-nucleon Transfer Reactions for Fission Study

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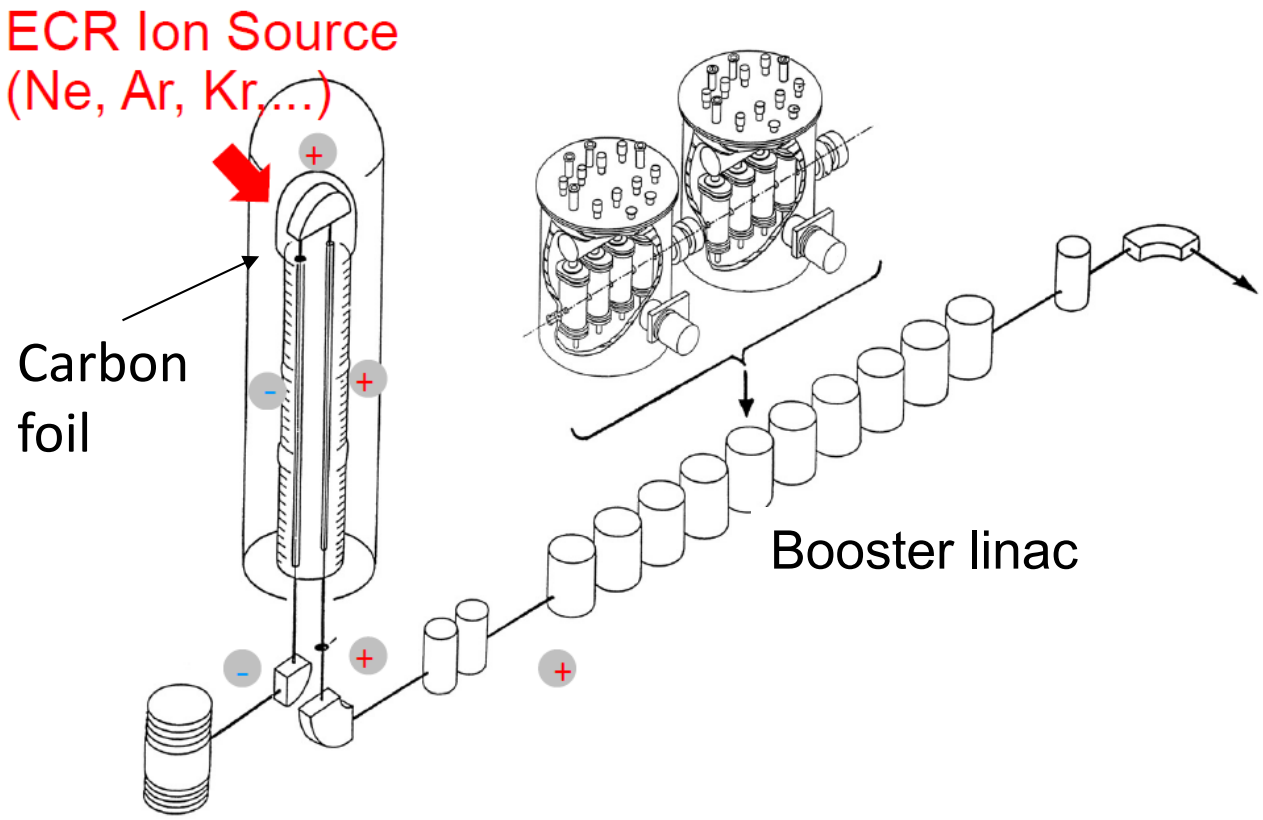
Tokai Campus, JAEA
Tokyo
J-PARC
Tandem facility

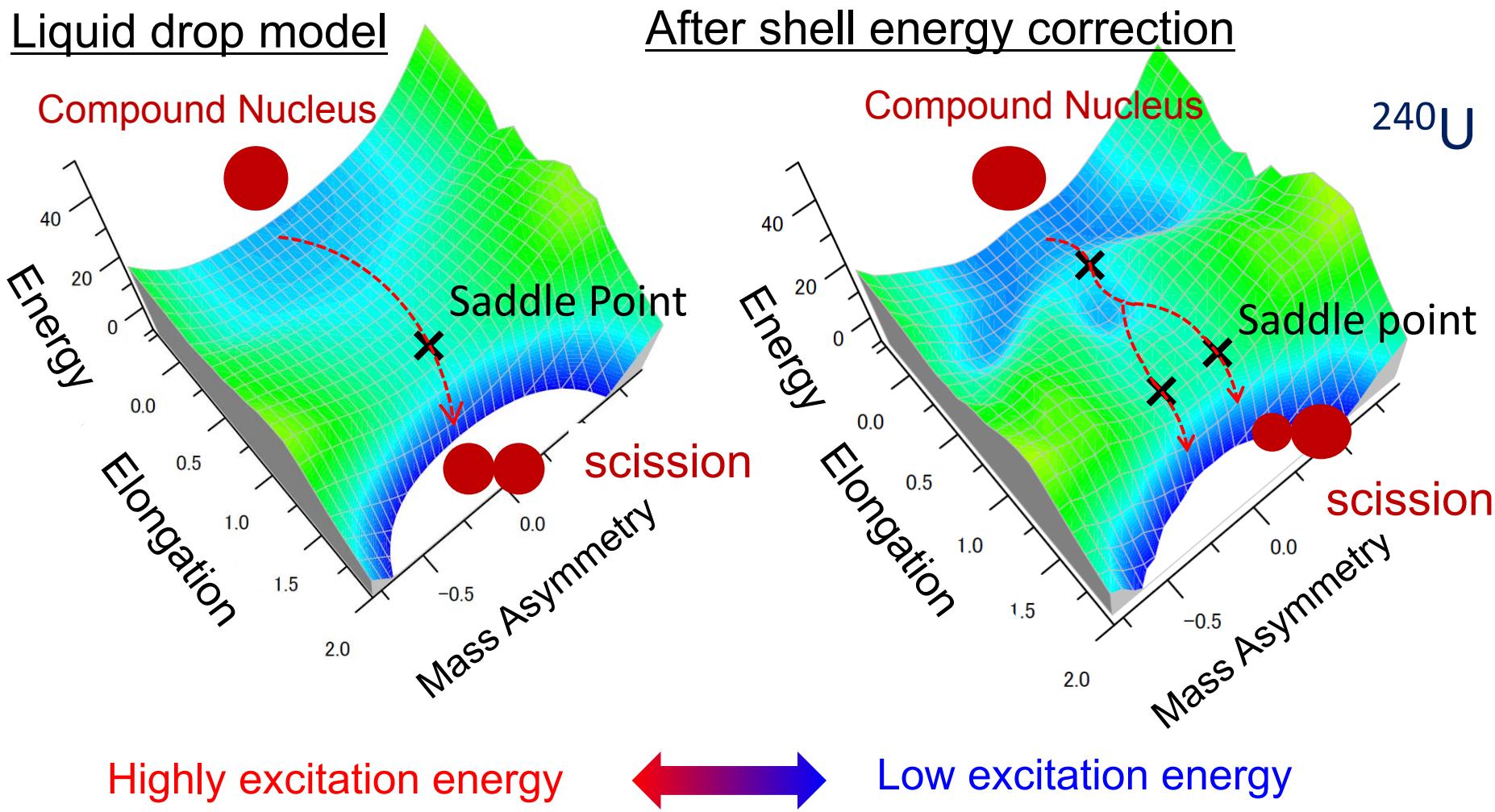
JAEA Tandem facility

20 MV Tandem accelerator (20UR)
Super-conducting Booster Liniac
ECR Ion Source on the terminal



Negative Ion Source

Potential Energy and Fission

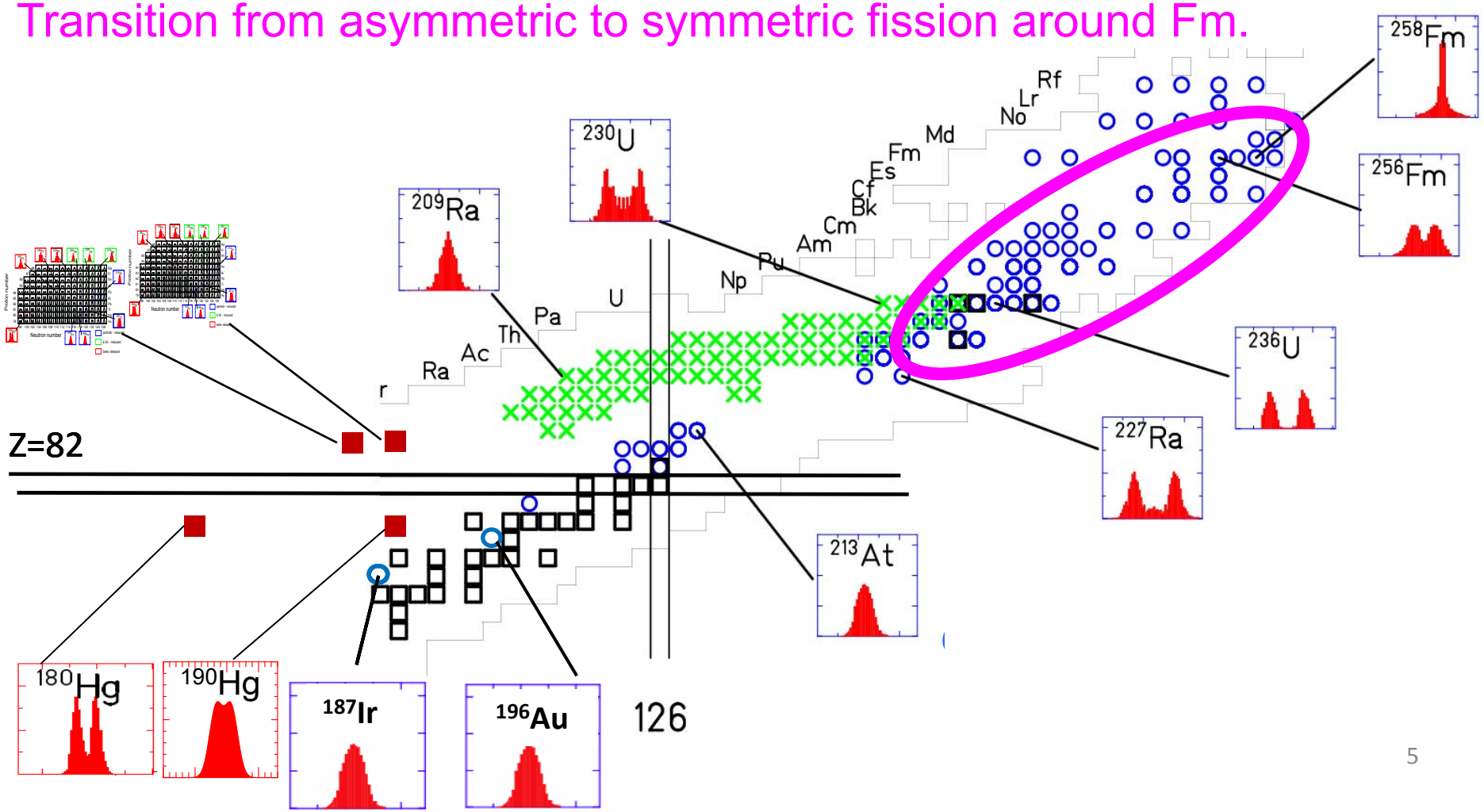


Highly excitation energy ⟷ Low excitation energy

Measured Fragment Mass/Charge Yield

Fission of n-rich actinide nuclei

Transition from asymmetric to symmetric fission around Fm.

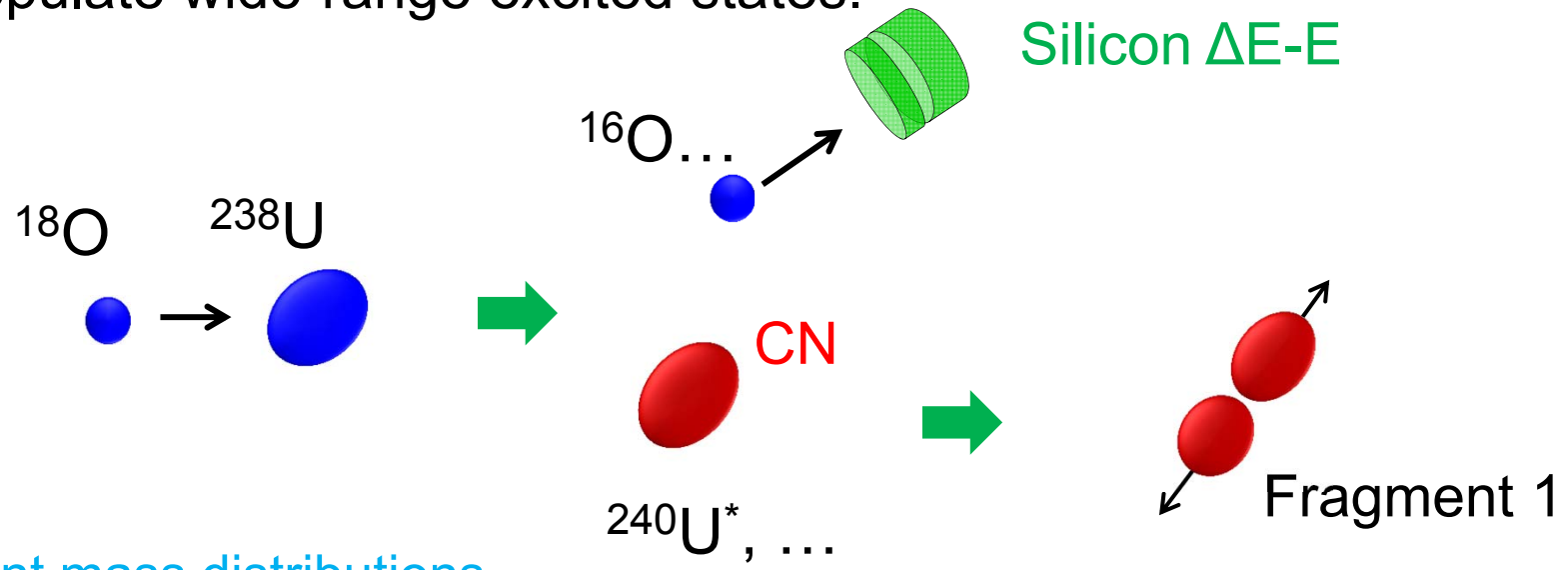


Multi-nucleon Transfer Reaction and Fission

Multi-nucleon transfer reaction

can produce many compound nuclei including neutron rich isotopes.

can populate wide-range excited states.



Fragment mass distributions

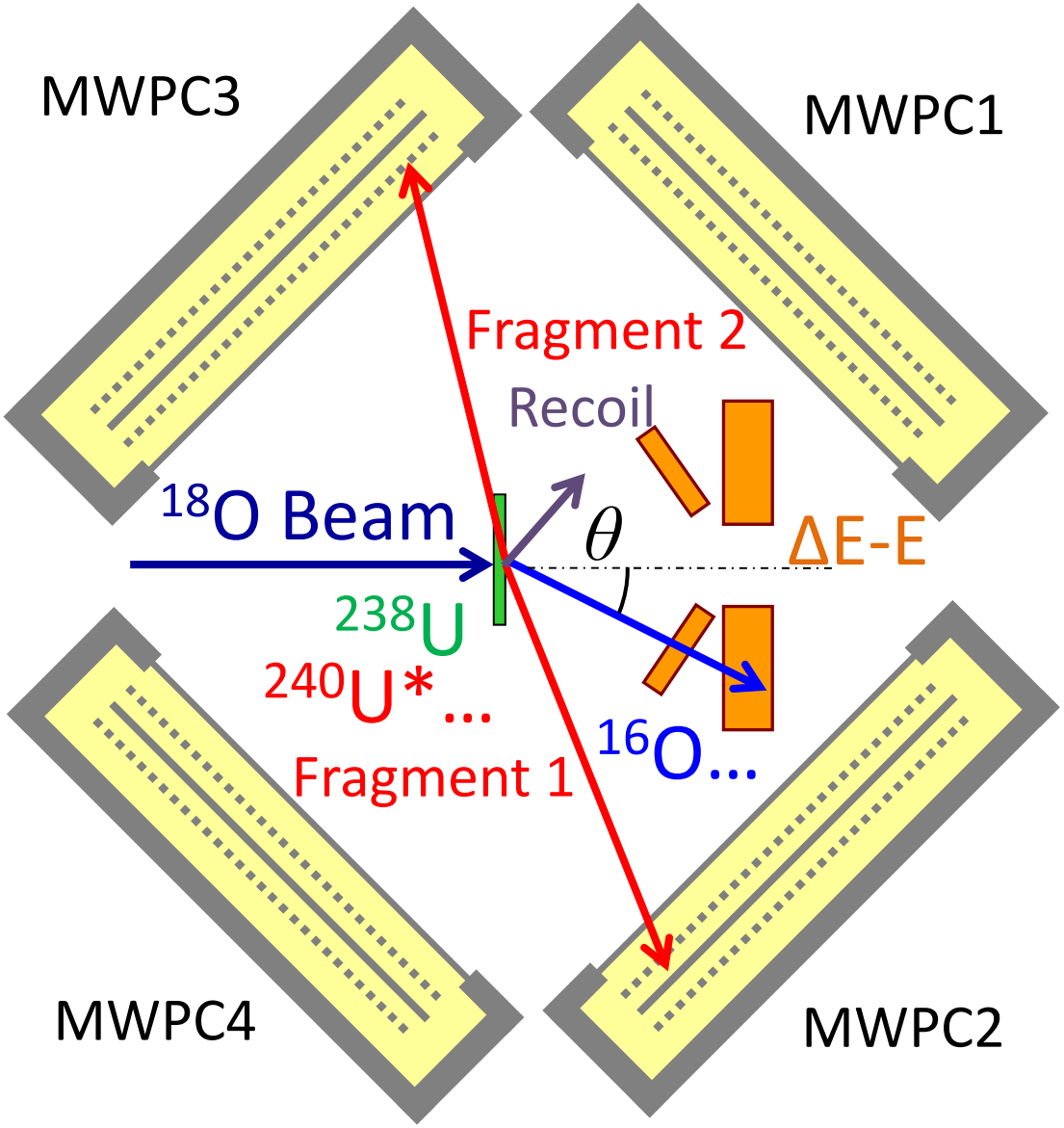
Fission barrier height

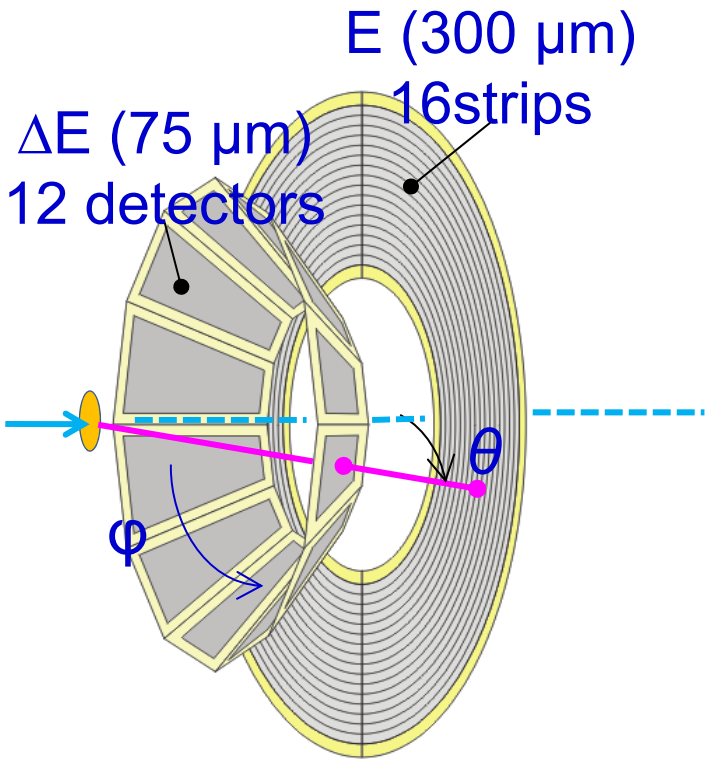
Fission fragment angular distributions

…

Measured and Planned experiments using ^{18}O beam and targets of ^{232}Th, ^{238}U, ^{248}Cm, ^{237}Np, ^{243}Am, ^{231}Pa, ^{249}Cf, ^{254}Es

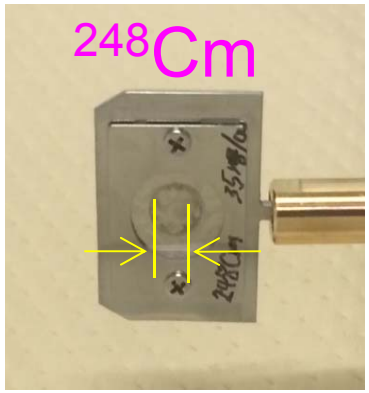
Experimental Setup





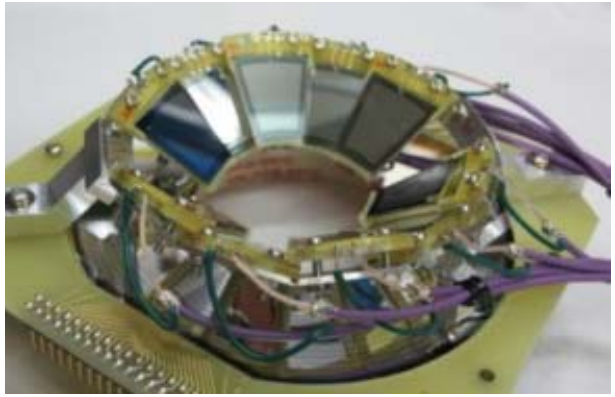
Some Photos

Target

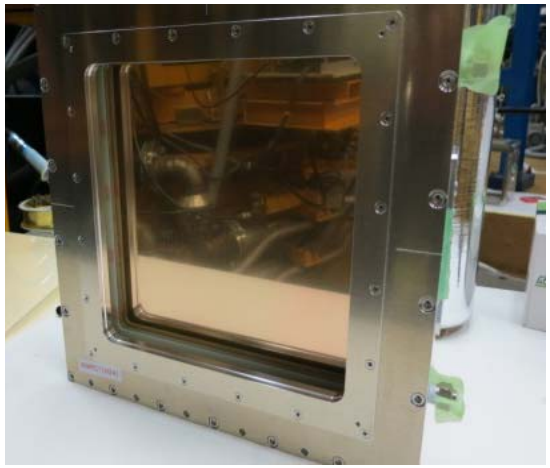


Ø 2.0 mm,
Total = 1.0 µg
(0.1 µg is possible)

Silicon ΔE-E detector



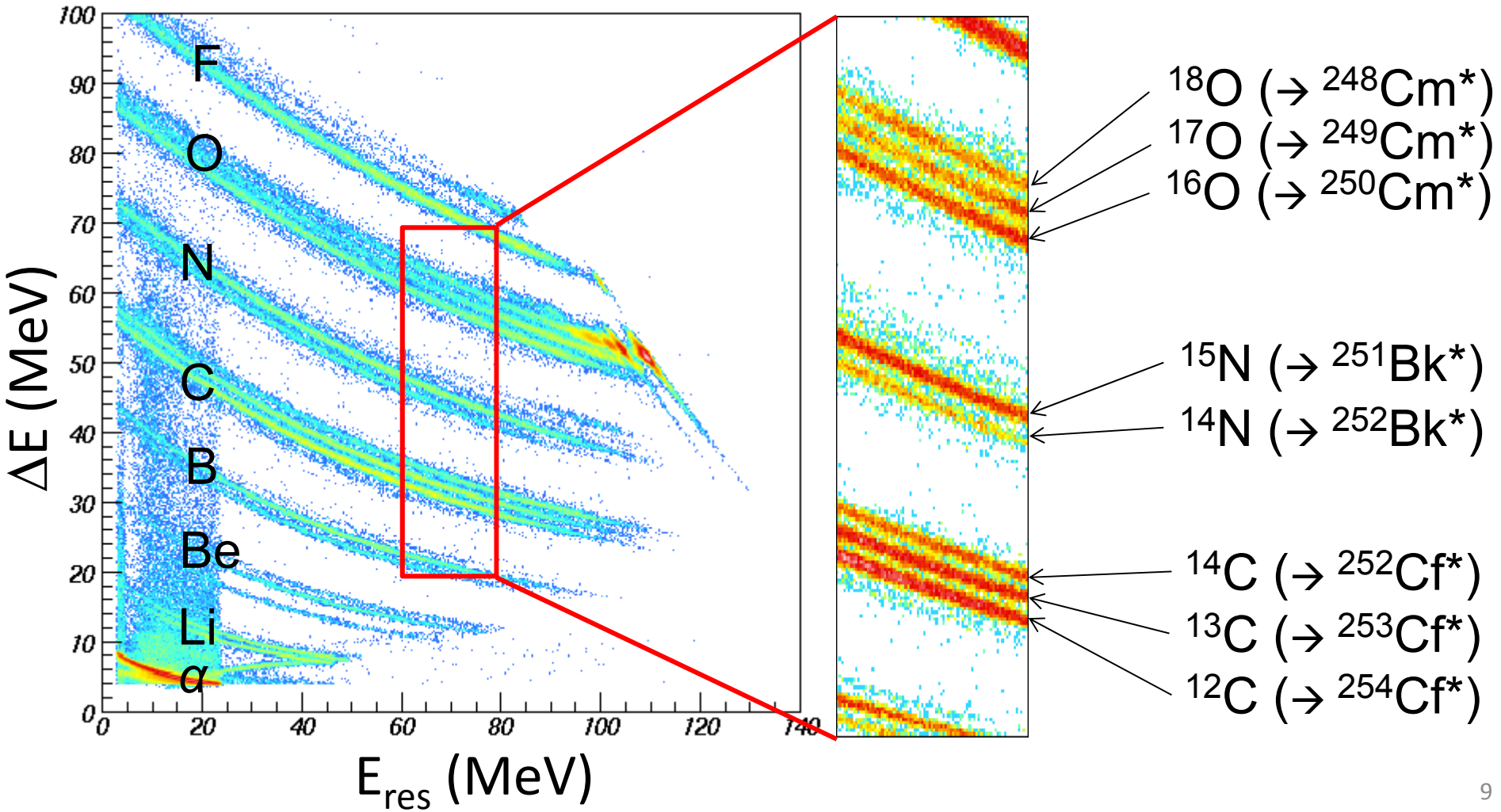
Fission fragment detector



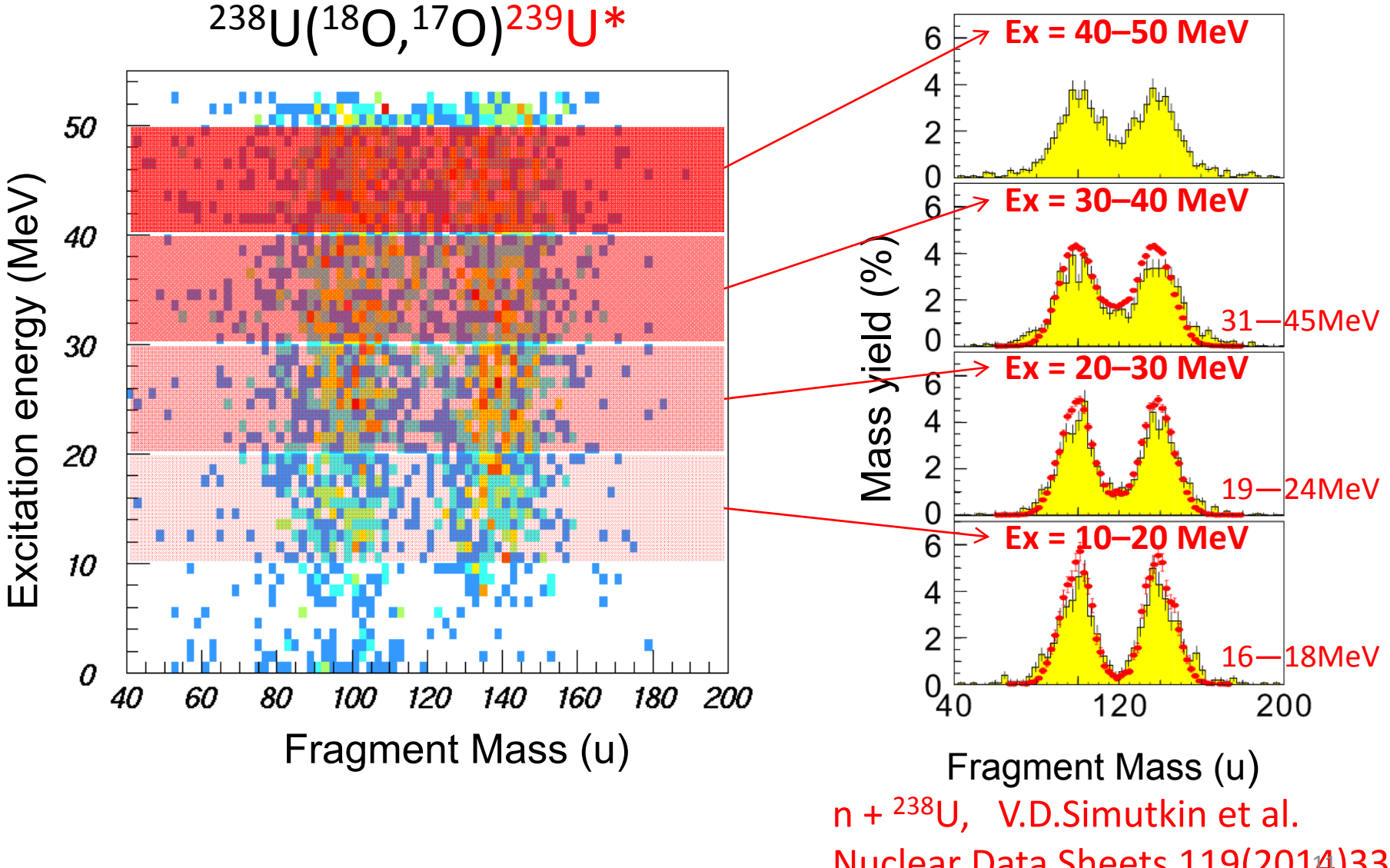
Multi-Wire Proportional Counter (MWPC)
200 x 200 mm^2

ΔE – E Spectrum

$^{18}O + {}^{248}Cm$ (E_{beam}= 162MeV)

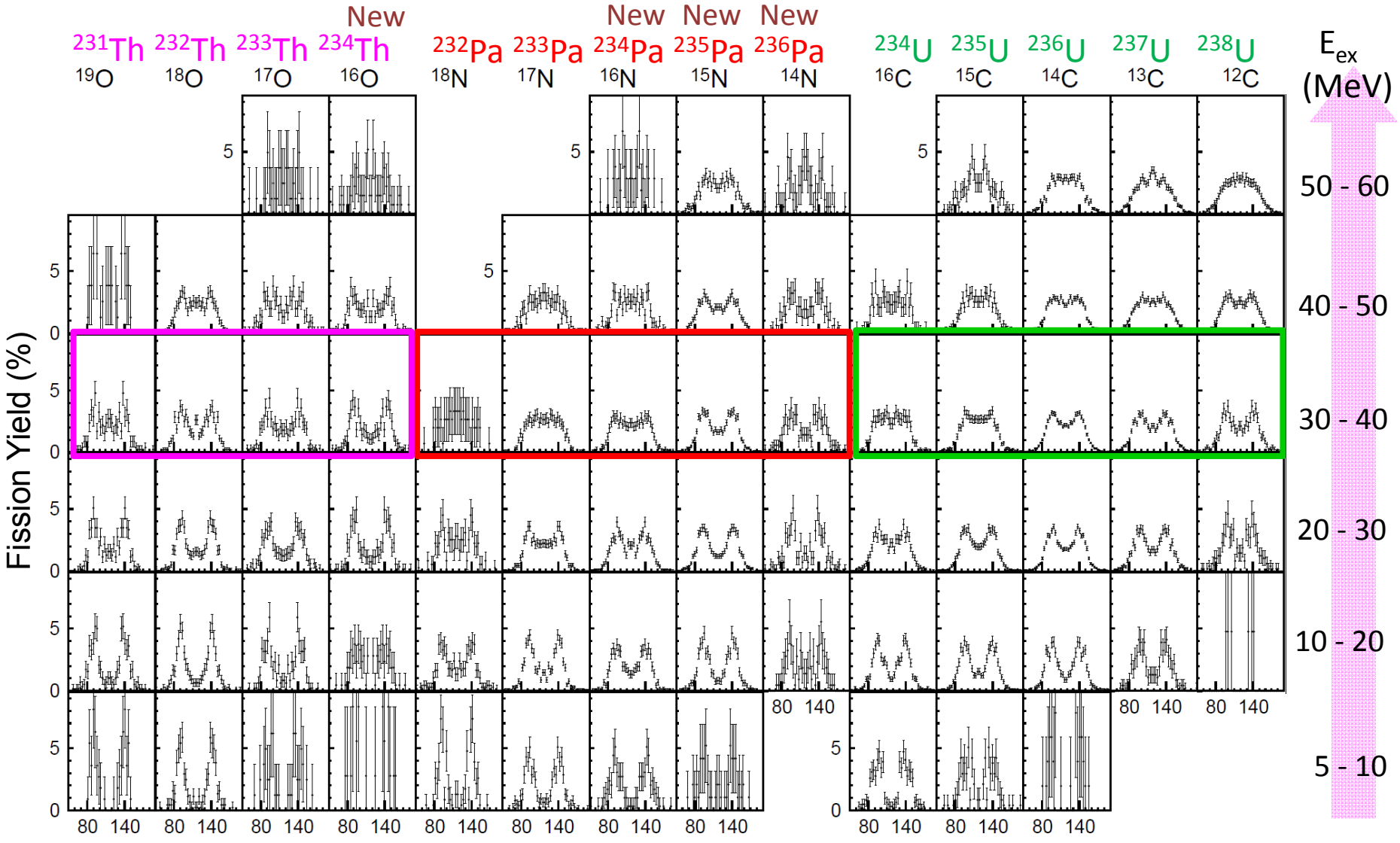


Fission Events on Fragment Mass and Excitation Energy



n + ^{238}U, V.D.Simutkin et al.
Nuclear Data Sheets 119(2014)331

Fission Fragment Mass Distributions from ^{18}O + ^{232}Th

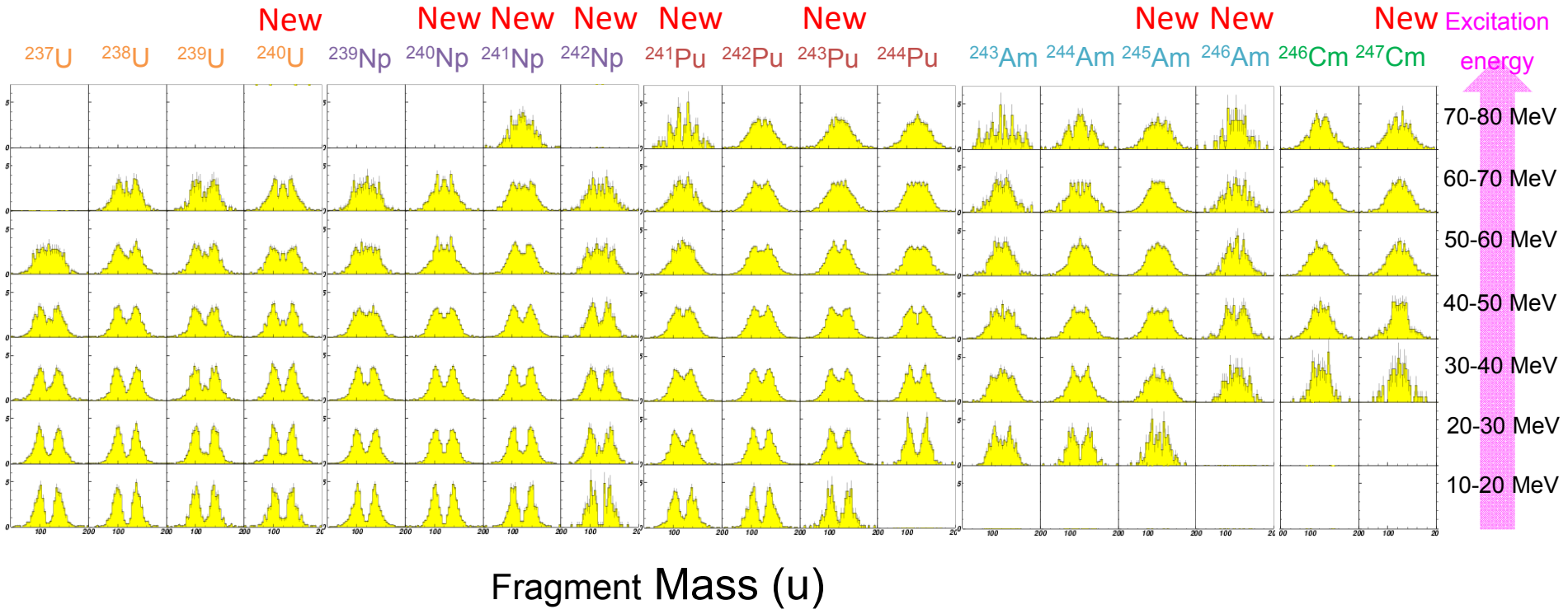


Neutron-rich nuclei show pronounced mass-asymmetric structure, associated with the shells around ^{132}Sn

Submitted to Phys. Lett. B

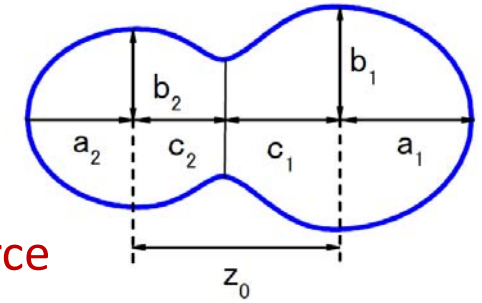
FFMDs of U, Np, Pu, Am, Cm Isotopes

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



3D Langevin Calculation

Nuclear Shape, q_i { Charge-Center Distance, z_0; Mass Asymmetry, α; Deformation, δ

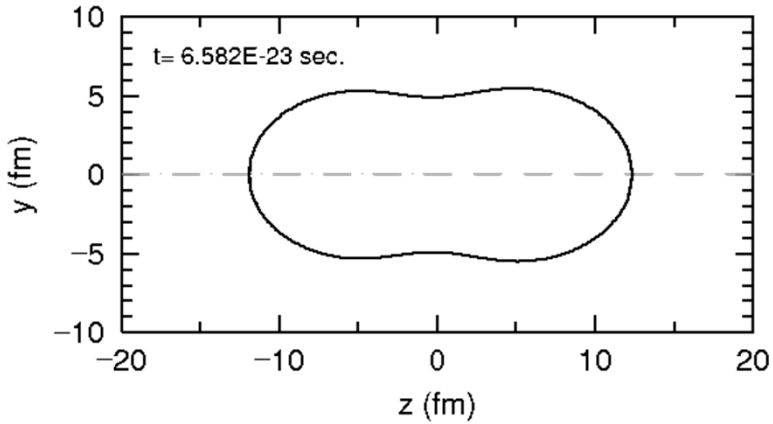


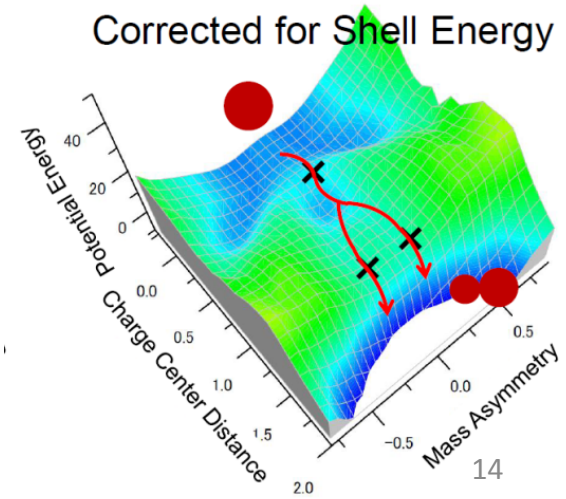
$$\begin{cases} \dfrac{dq_i}{dt} = \left(m^{-1}\right)_{ij} p_j \\ \dfrac{dp_i}{dt} = -\dfrac{\partial V}{\partial q_i} - \dfrac{1}{2}\dfrac{\partial}{\partial q_i}\left(m^{-1}\right)_{jk} p_j p_k - \gamma_{ij}\left(m^{-1}\right)_{jk} p_k + g_{ij} R_j(t) \end{cases}$$

Friction dissipation

Random force fluctuation

$$\Delta E_{Shell}(E^*) = \Delta E^0_{Shell} * exp\left(-E^*/E_D\right), \quad E_D = 20 \text{ MeV}$$





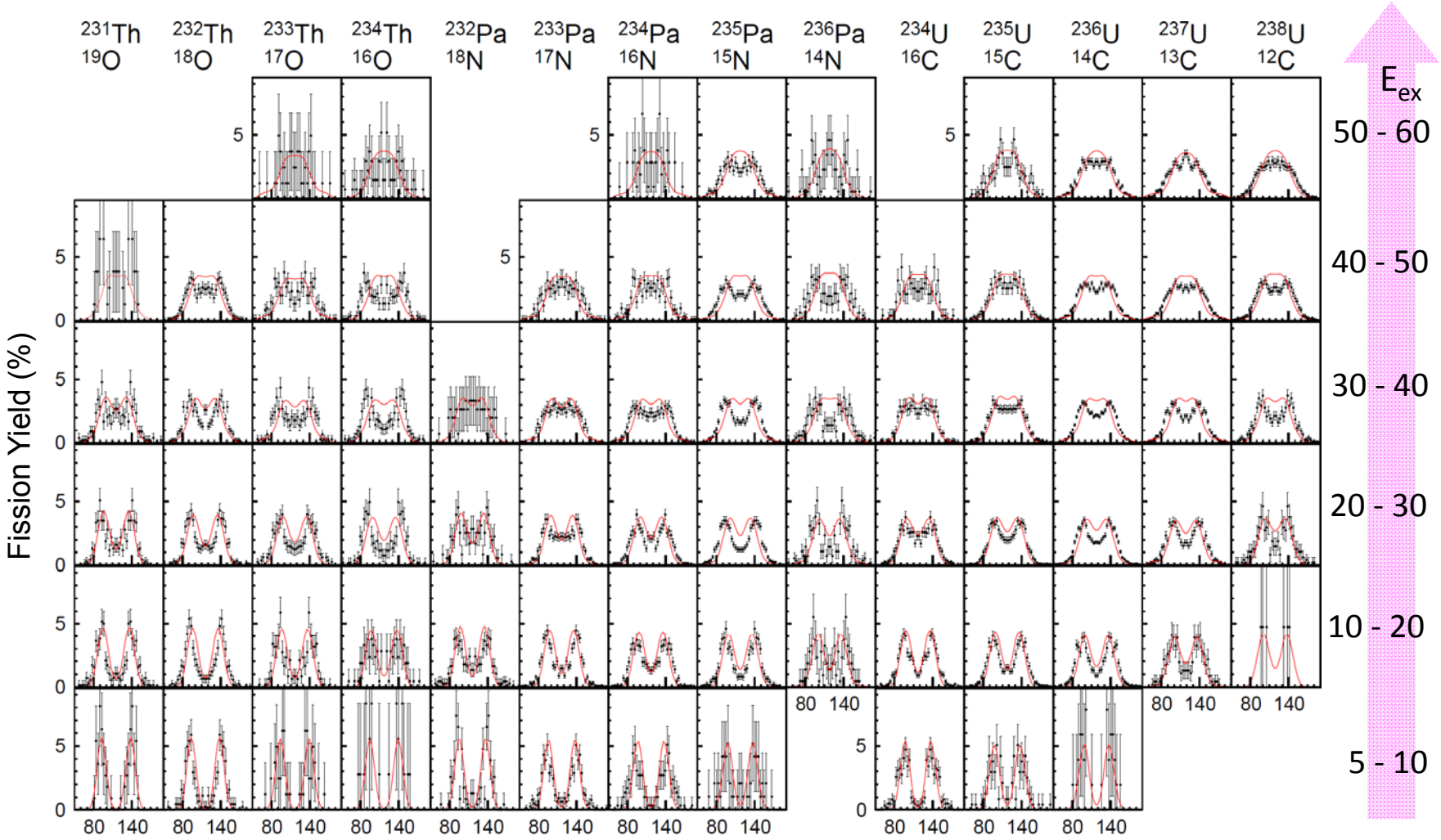
Y. Aritomo and S. Chiba, Phys. Rev. C **88**, 044614 (2013)

Comparison with Langevin Calculation

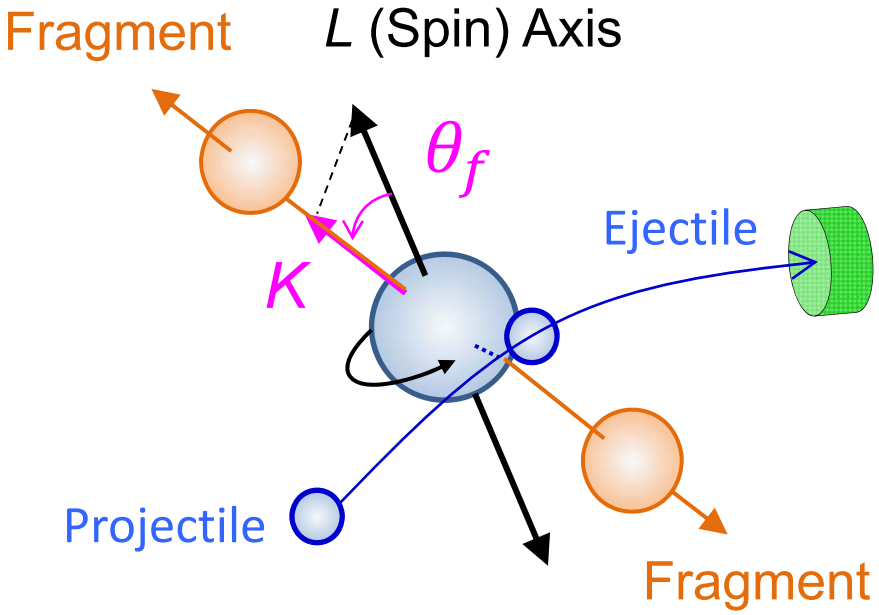
Experimental data from ^{18}O + ^{232}Th at JAEA Tandem

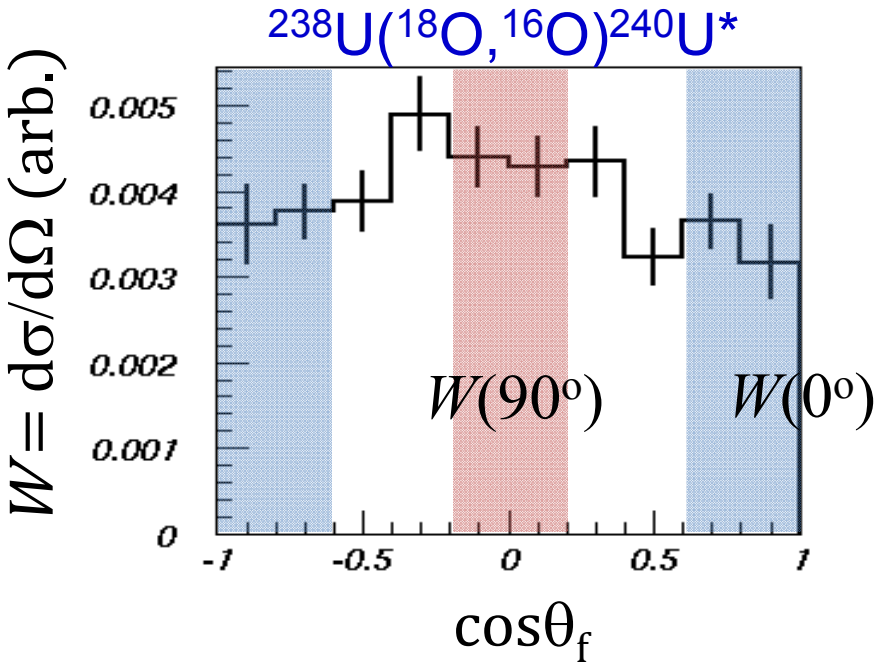
Langevin Calculation

R. Léguillon *et al.*, submitted to Phys. Lett. B



Fission Fragment Angular Distribution





Summary

(1) Multi-nucleon transfer reaction is a useful too study fission of for various nuclei and their excitation energy dependence.

(2) Nice reproduction of the FFMDs was achieved using Langevin calculation.

(3) $\langle J^2 \rangle$ is nearly proportional to the number of transferred nucleons, derived from fragment angular distribution.

Collaborator in Fission Study

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