Fission Study and Nuclear Data Measurement at JAEA-ASRC

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16th ASRC Workshop Nuclear Fission and Structure of Exotic Nuclei

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Fission Research Program

JAEA Tandem facility

- Fusion-fission study for heavy-element synthesis
- Multi-nucleon transfer induced fission and surrogate reaction
- New region of mass-asymmetric fission (^{180}Hg and ^{193}Ir)

J-PARC

- Fission and Capture cross section measurements

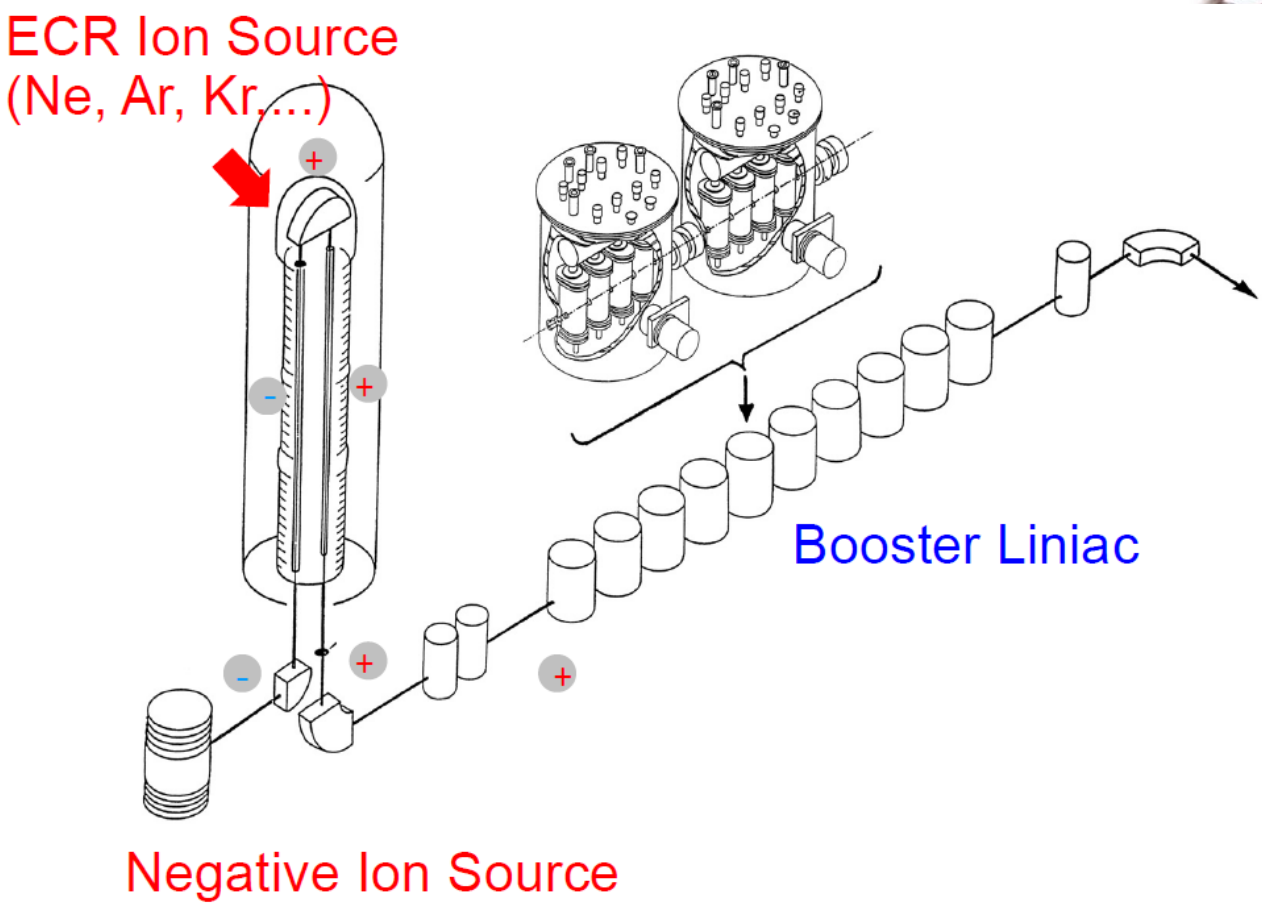
→ *Talk by K. Hirose*

Contribution to Fukushima Issues

- Surveillance detector for criticality of melted fuel at Fukushima power plant.

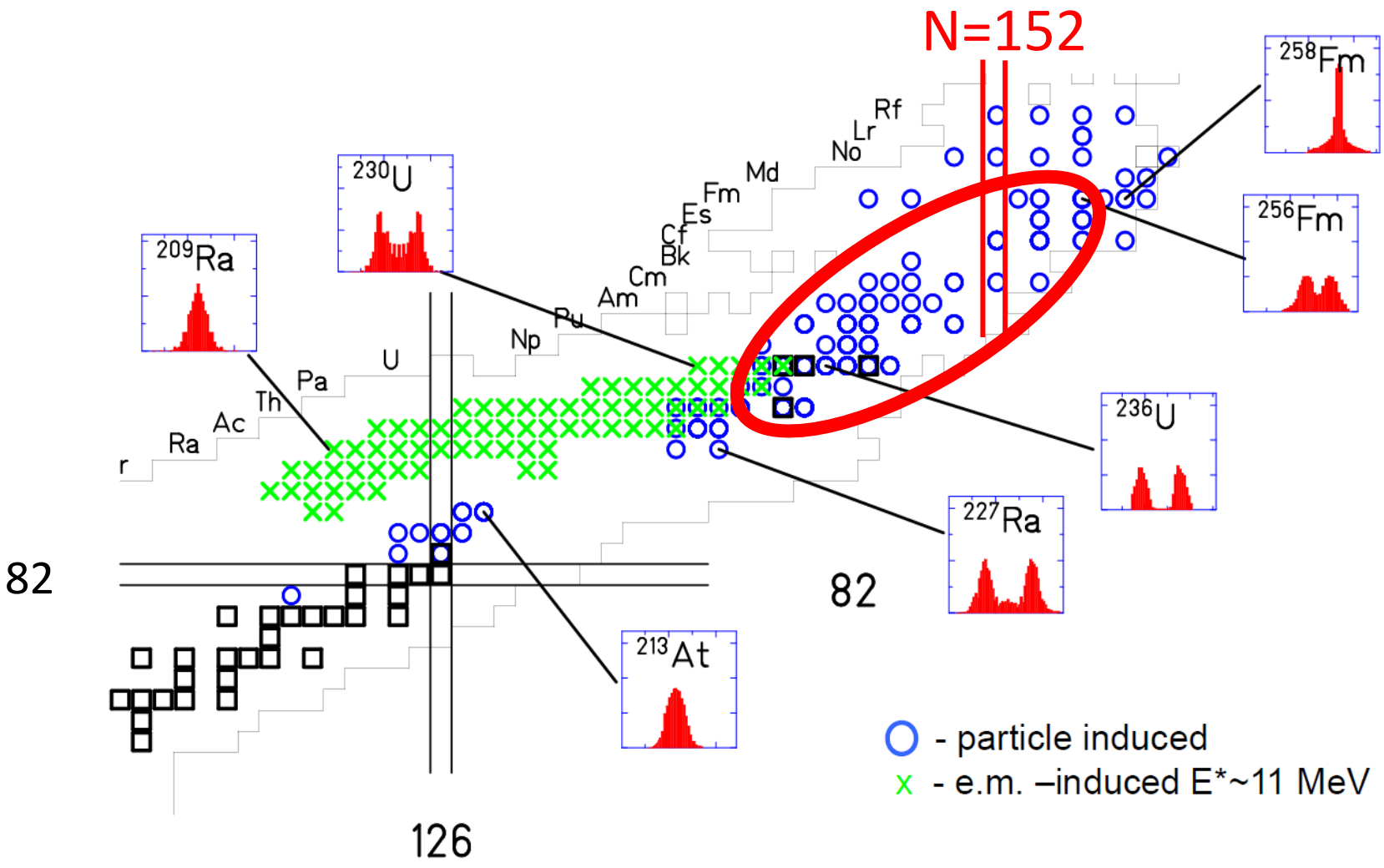
JAEA Tandem facility

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



Multi-nucleon Transfer Induced Fission and surrogate reactions

Fission fragment mass/charge distributions

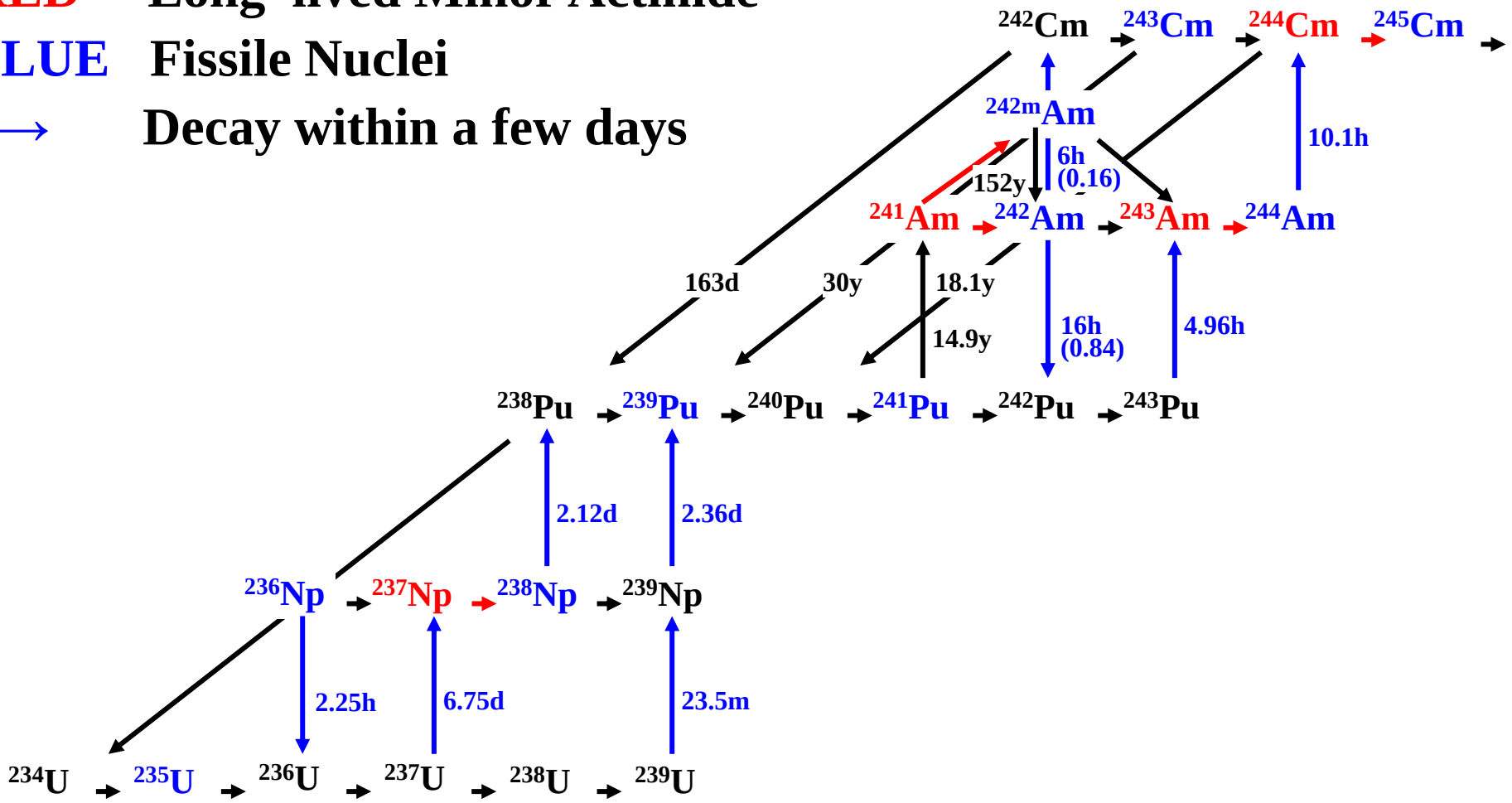


Nuclei Produced in Reactor

RED **Long–lived Minor Actinide**

BLUE **Fissile Nuclei**

→ **Decay within a few days**



Requested Nuclear Data

Fission and capture cross sections σ_{fiss} & σ_{capt}

Prompt Neutron Multiplicity ν

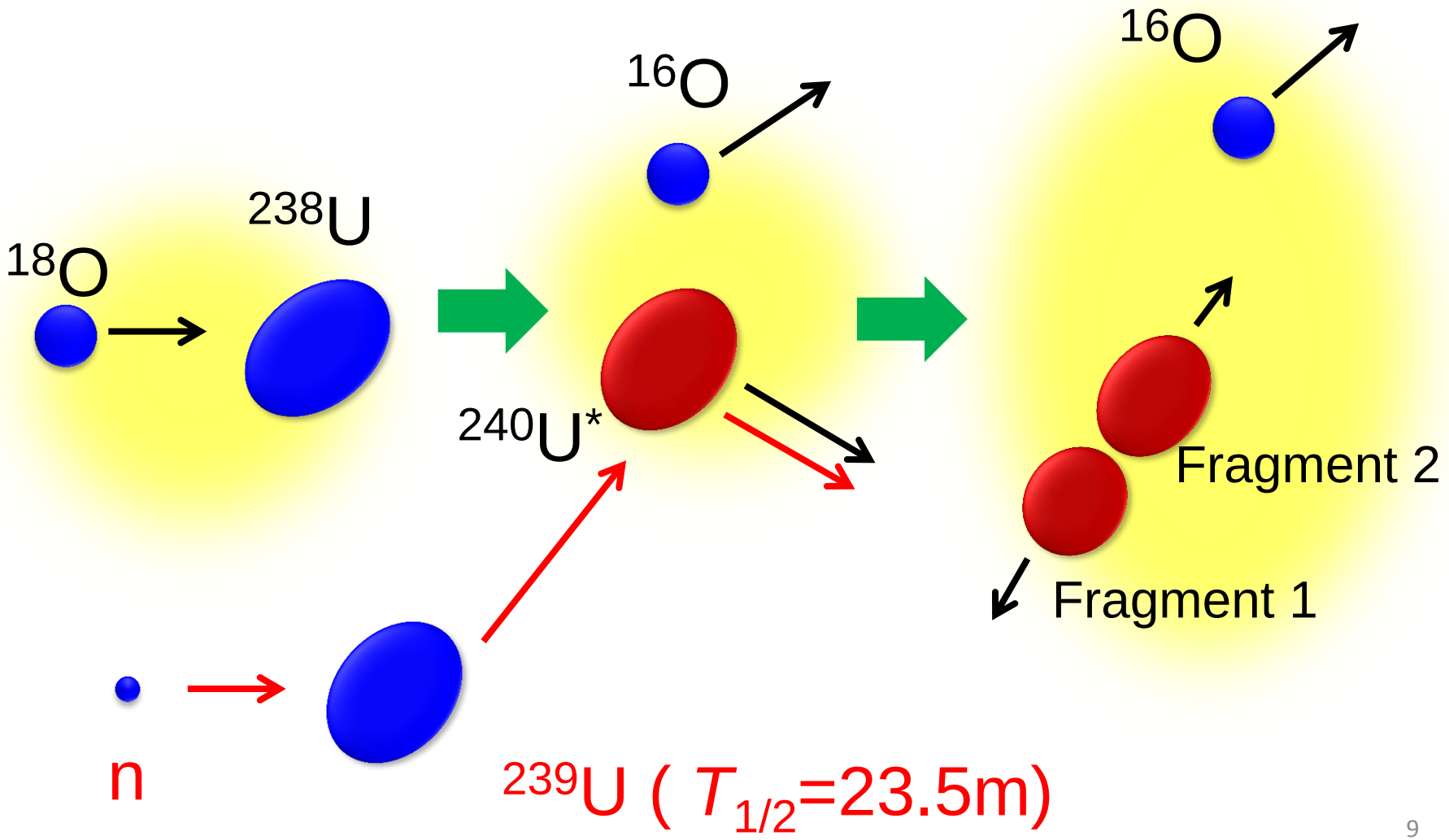
Fission fragment mass distributions $Y(A)$

Prompt neutron spectrum $\chi\,(E_n)$

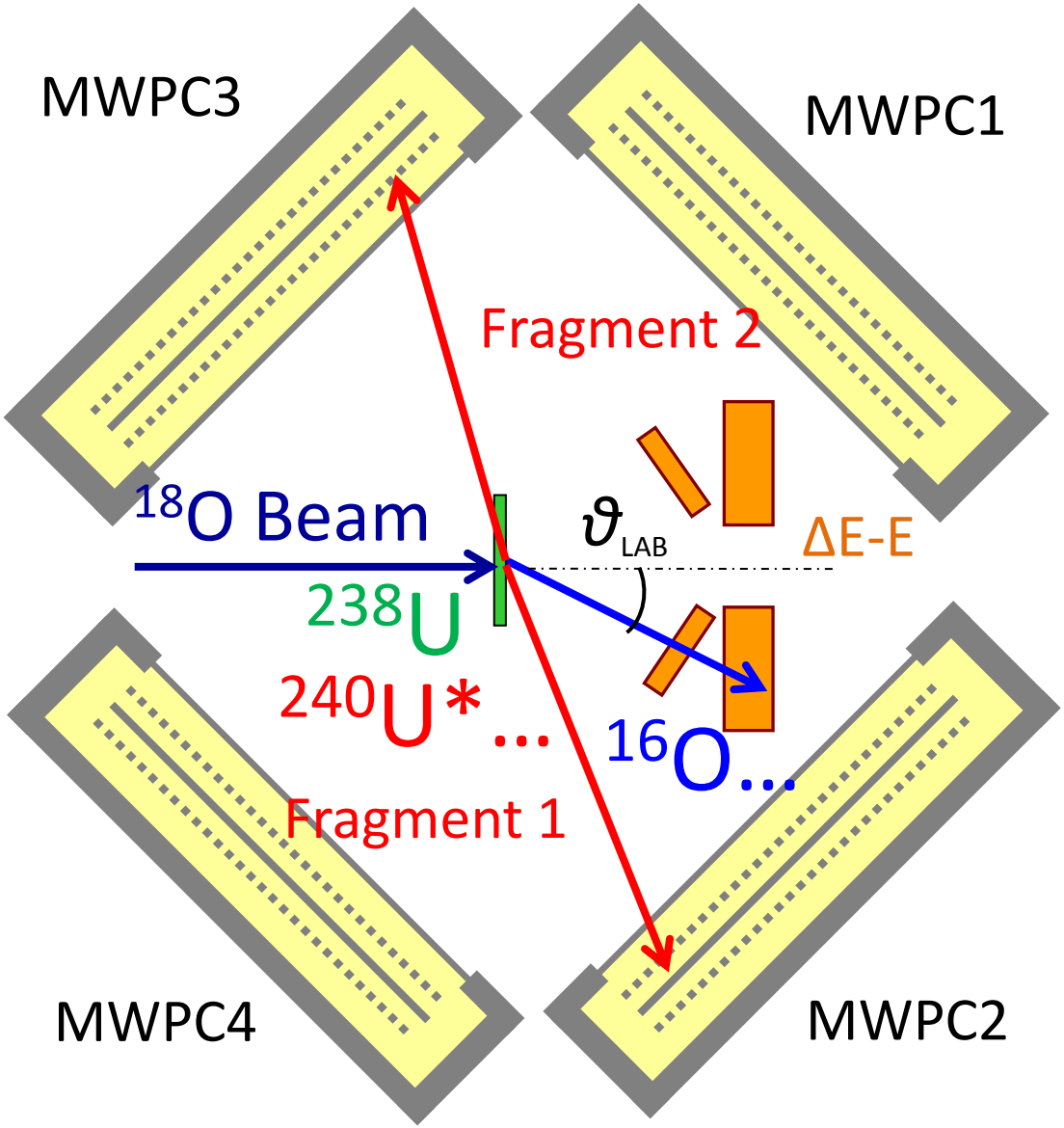
…..

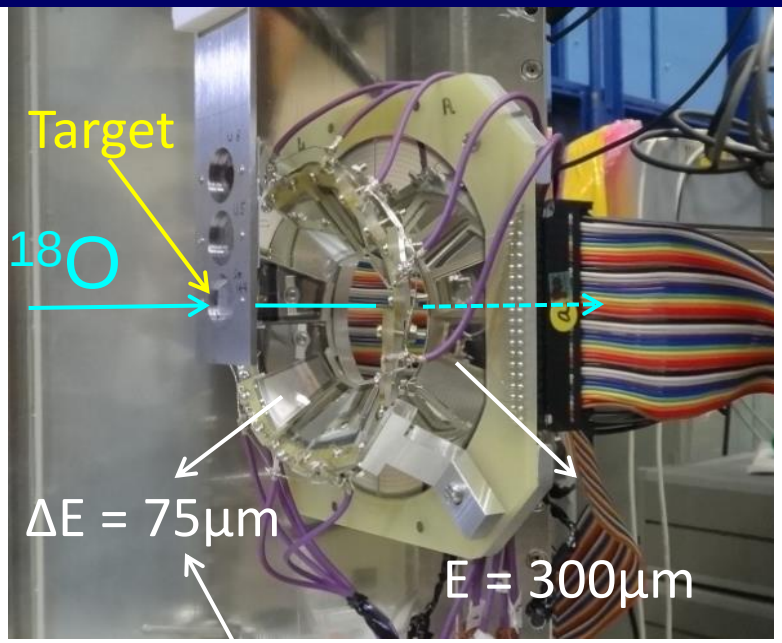
as a function of incident neutron energy

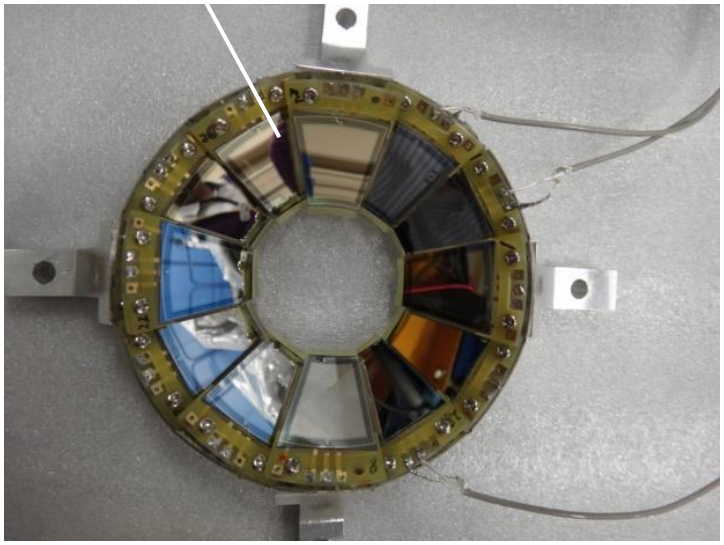
Surrogate Reaction



Experimental Setup

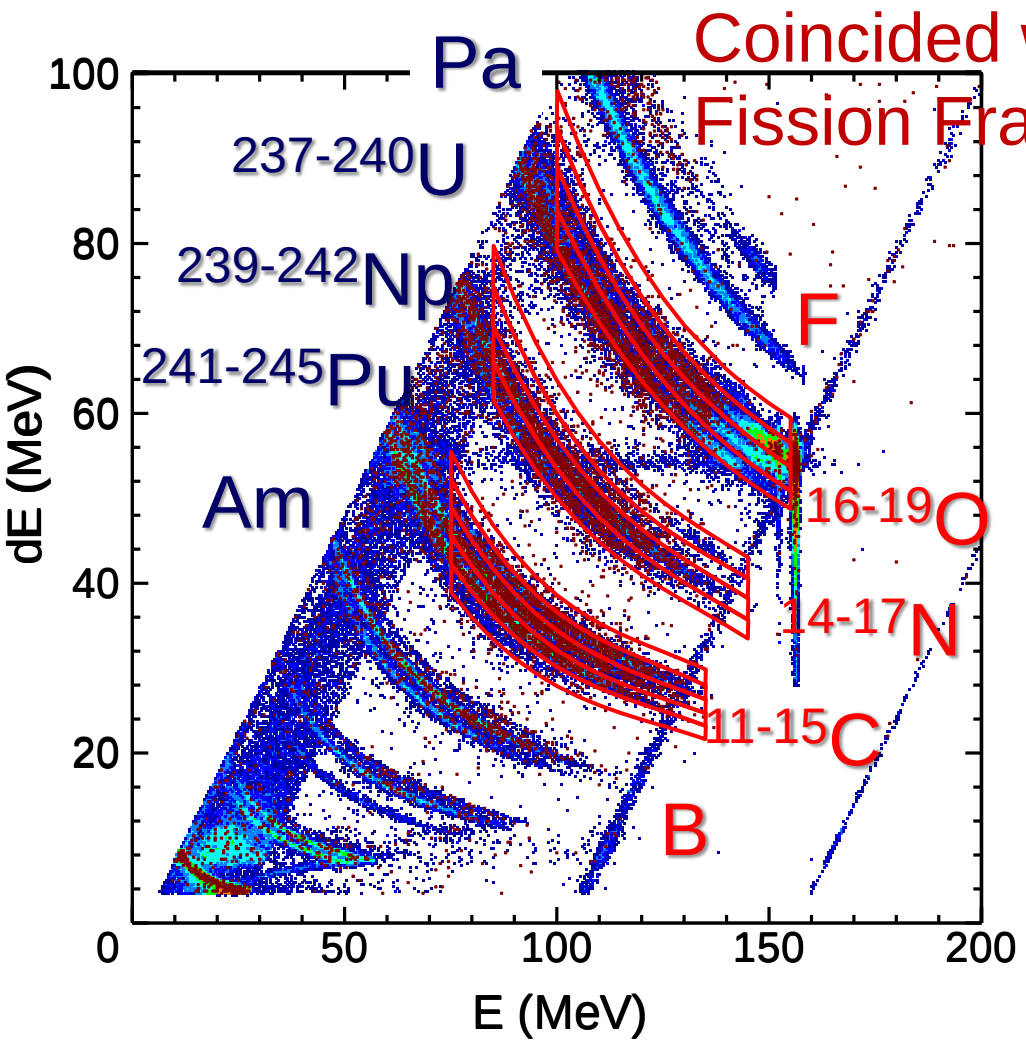






Particle Identification

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



$^{240,239,238,237}U^{*}$

n + ^{239}U (23.5 min)
n + ^{237}U (6.8 day)

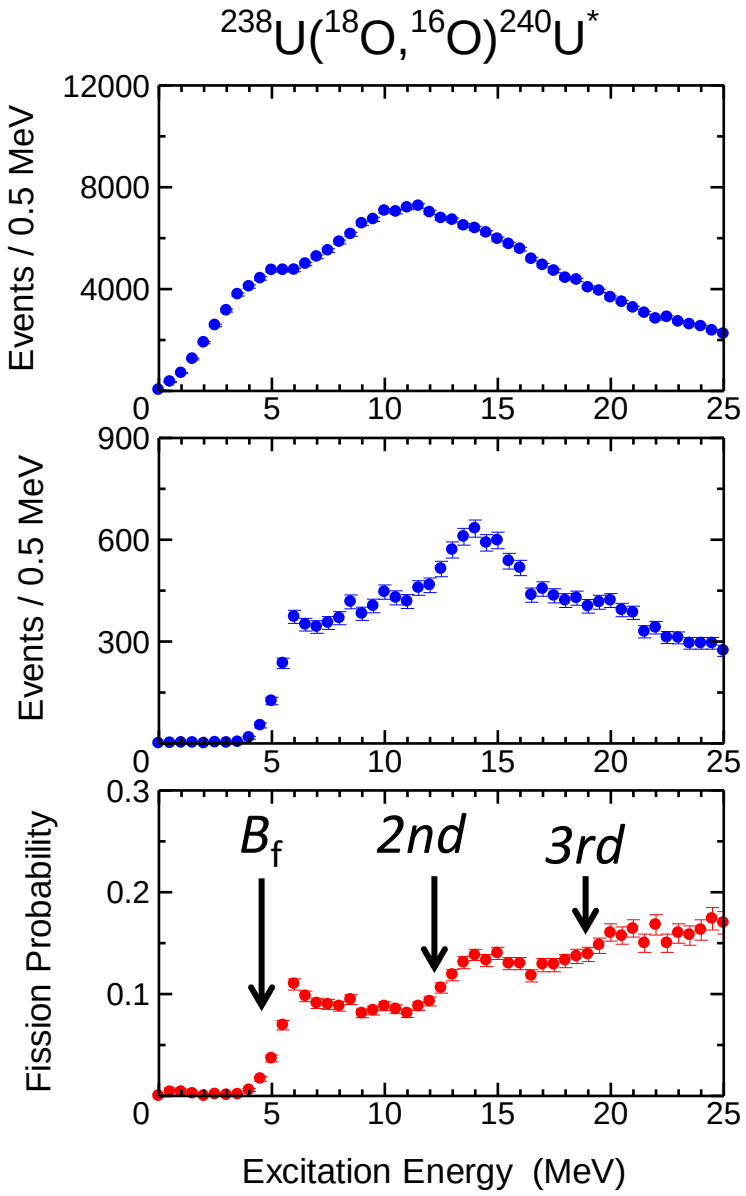
$^{242,241,240,239}Np^{*}$

n + ^{241}Np (13.9 min)
n + ^{240}Np (65 min)
n + ^{239}Np (2.4 day)
n + ^{238}Np (2.1 day)

$^{245,244,243,242,241}Pu^{*}$

n + ^{243}Pu (4.9 hr)
n + ^{241}Pu (14 yr)

Fission Barrier

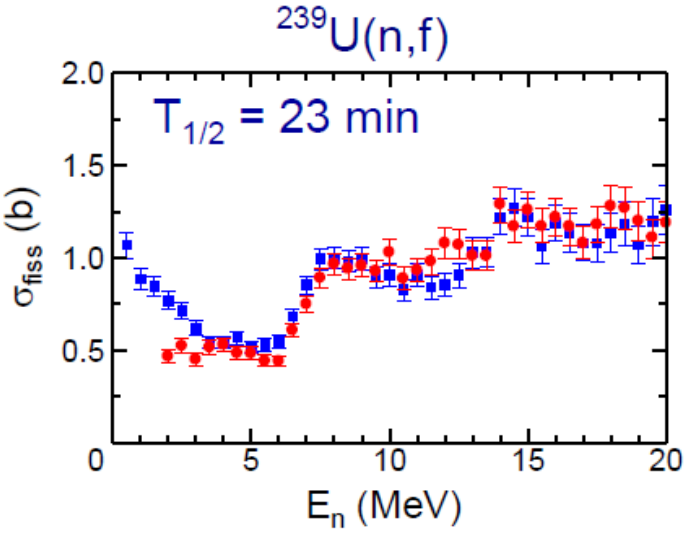


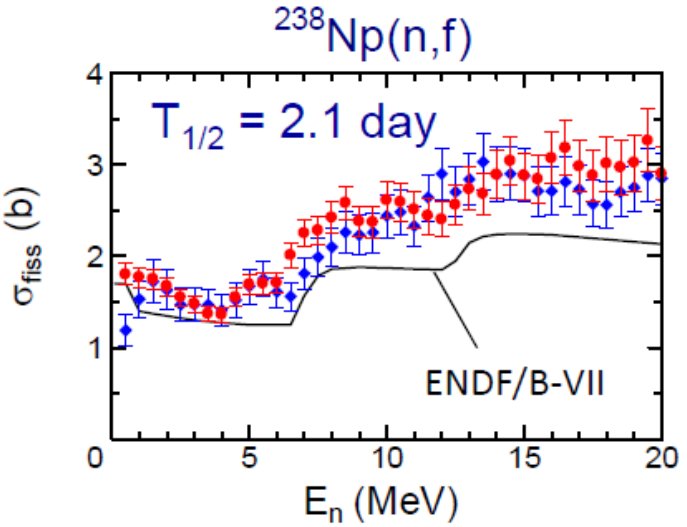
(A) Spectrum for ^{16}O

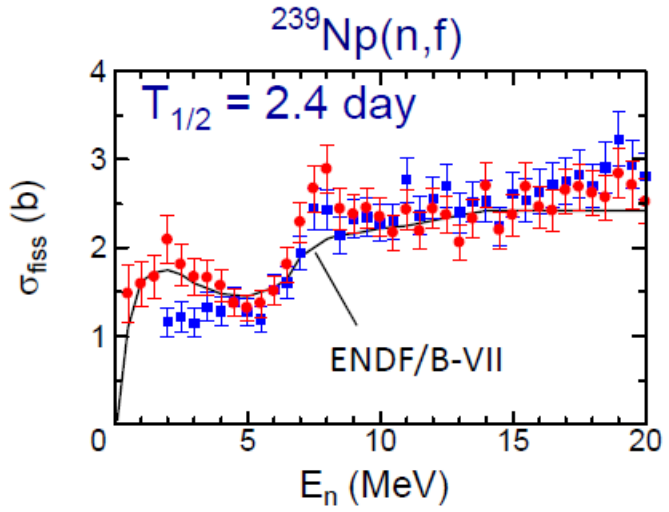
(B) Coincidence between ^{16}O and fission fragments

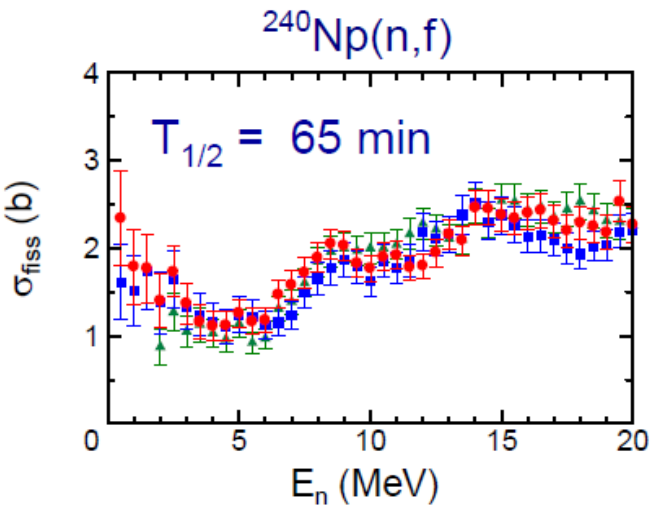
$$\frac{(B)}{(A)} \frac{1}{\text{Efficiency}}$$

Fission Cross sections with surrogate ratio method

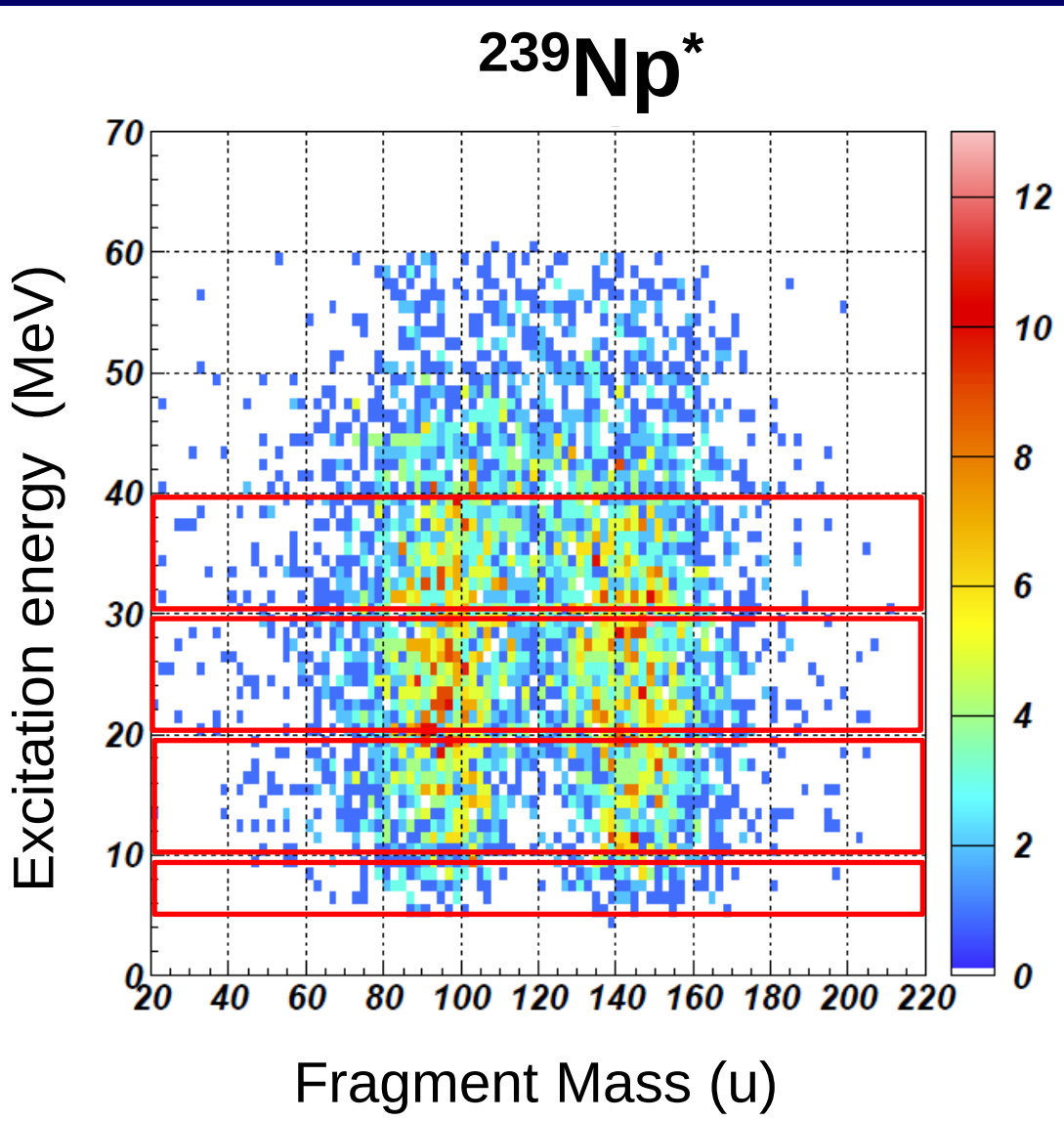


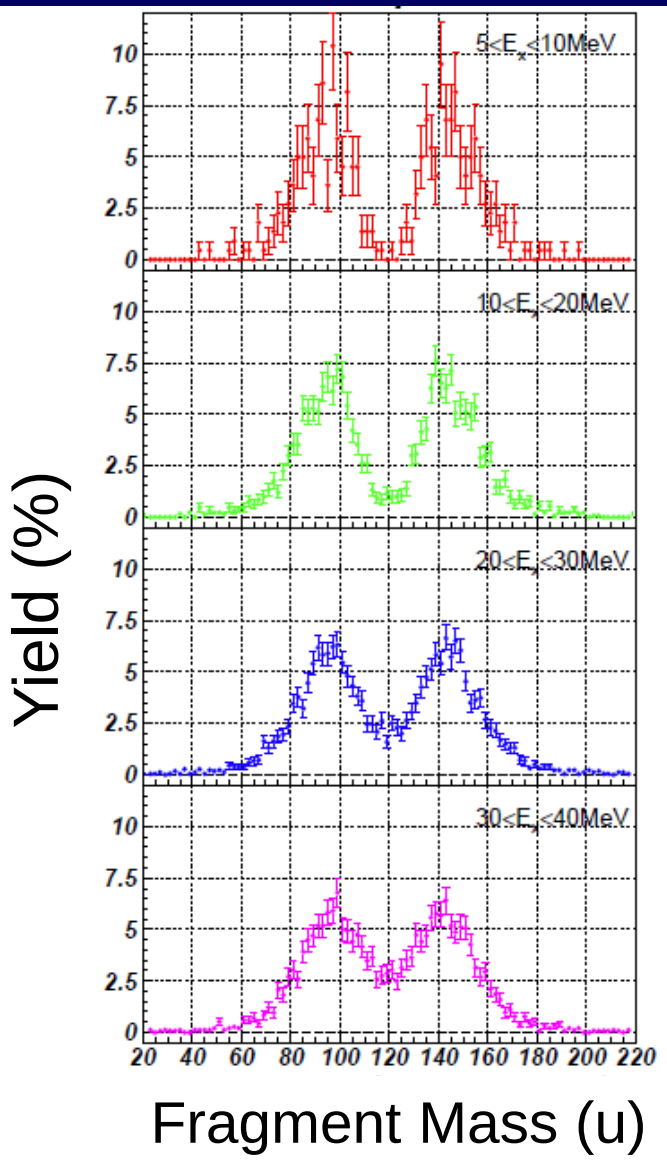


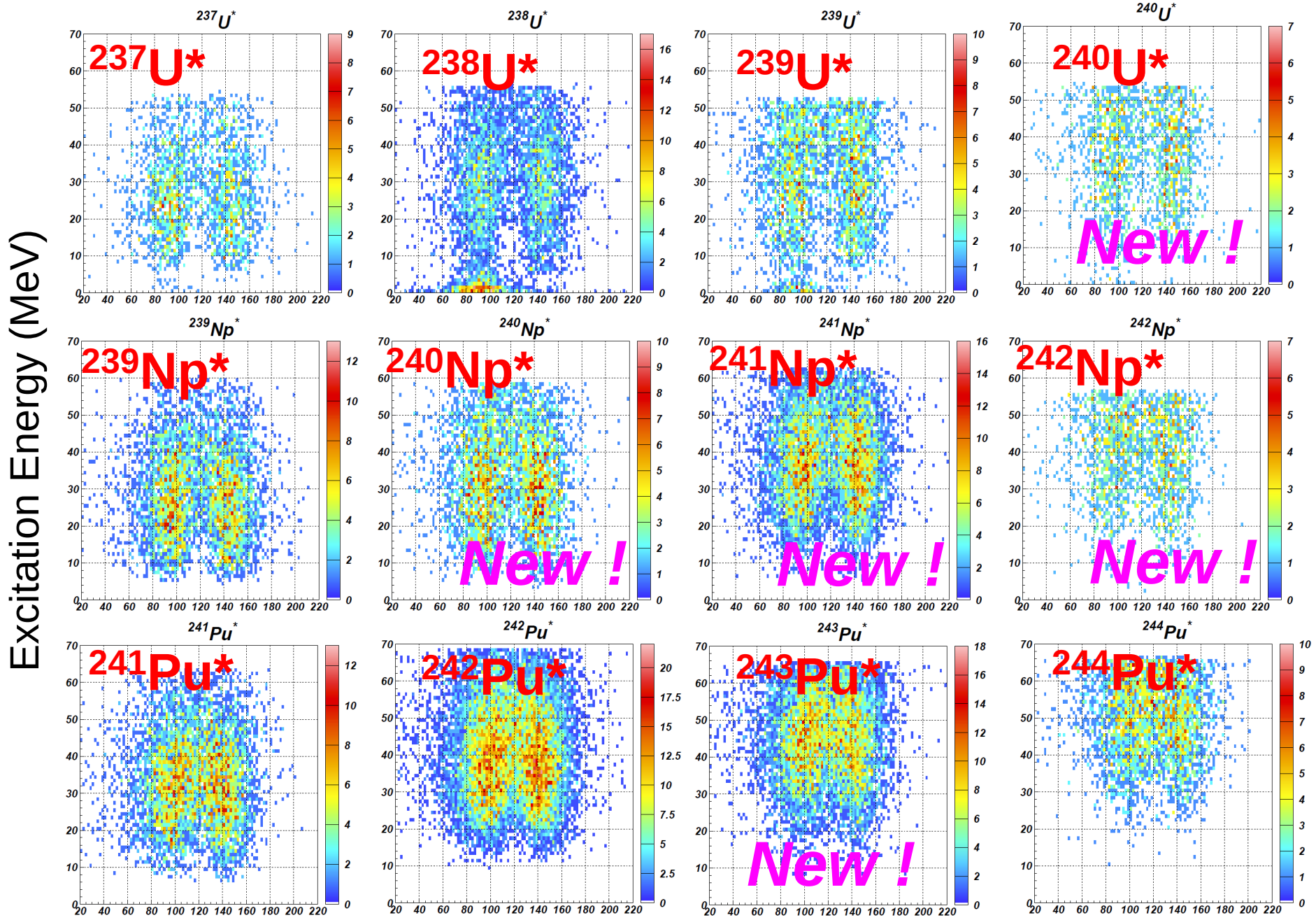




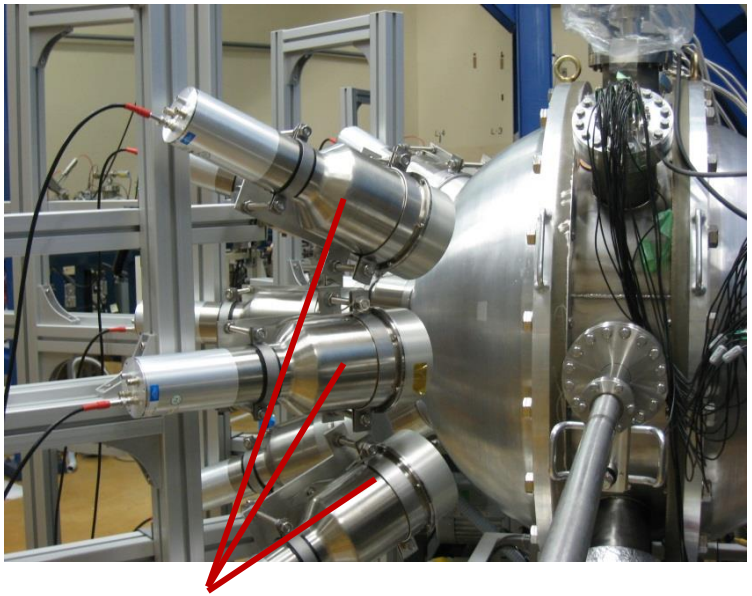
Fission fragment mass distribution



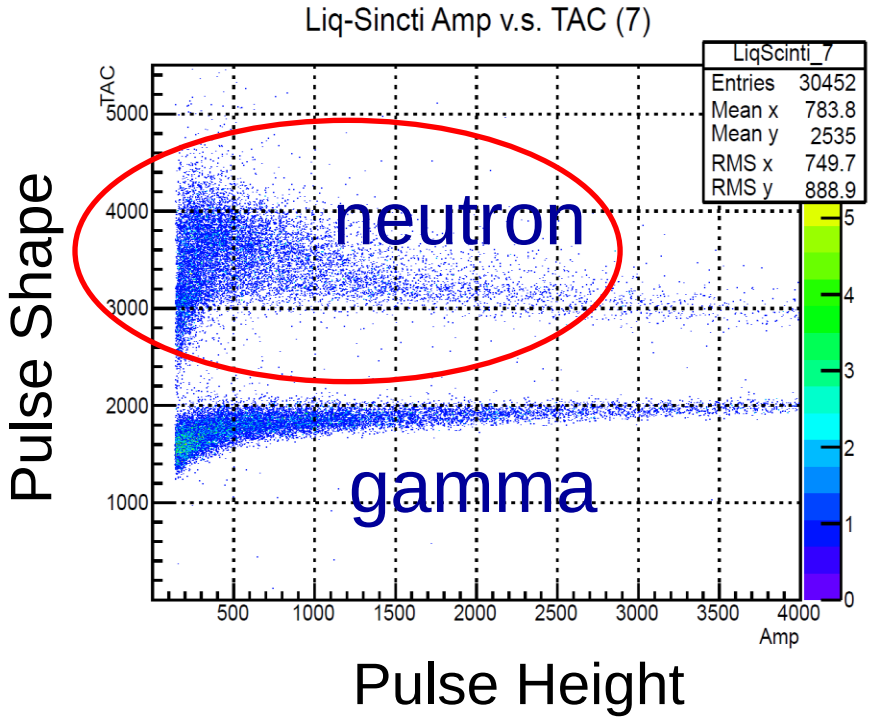



Excitation Energy (MeV)
Fragment Mass (u)
237U*
238U*
239U*
240U*
New !
239Np*
240Np*
New !
241Np*
New !
242Np*
New !
241Pu*
242Pu*
243Pu*
New !
244Pu*

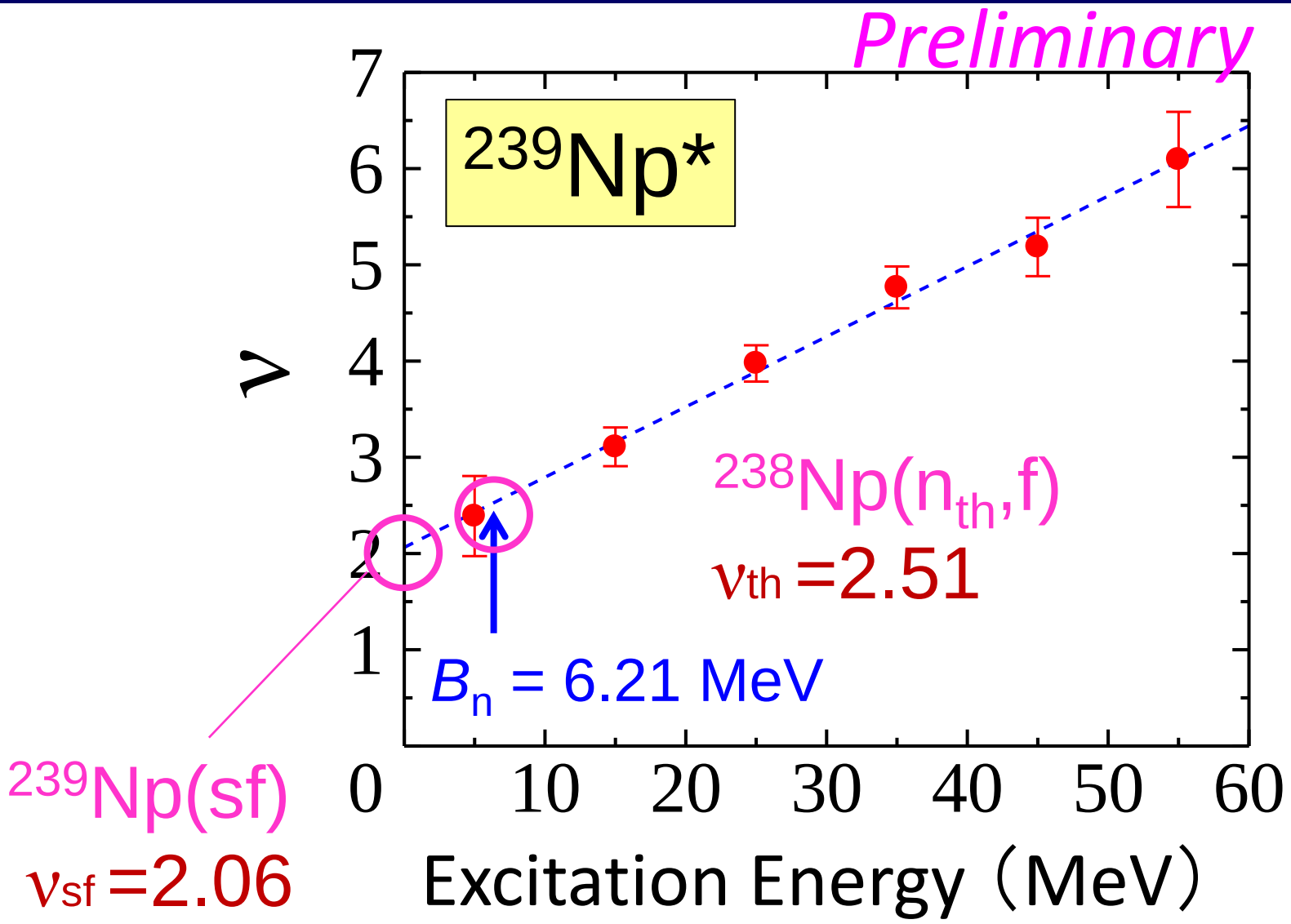
Prompt Neutron Multiplicity in Fission



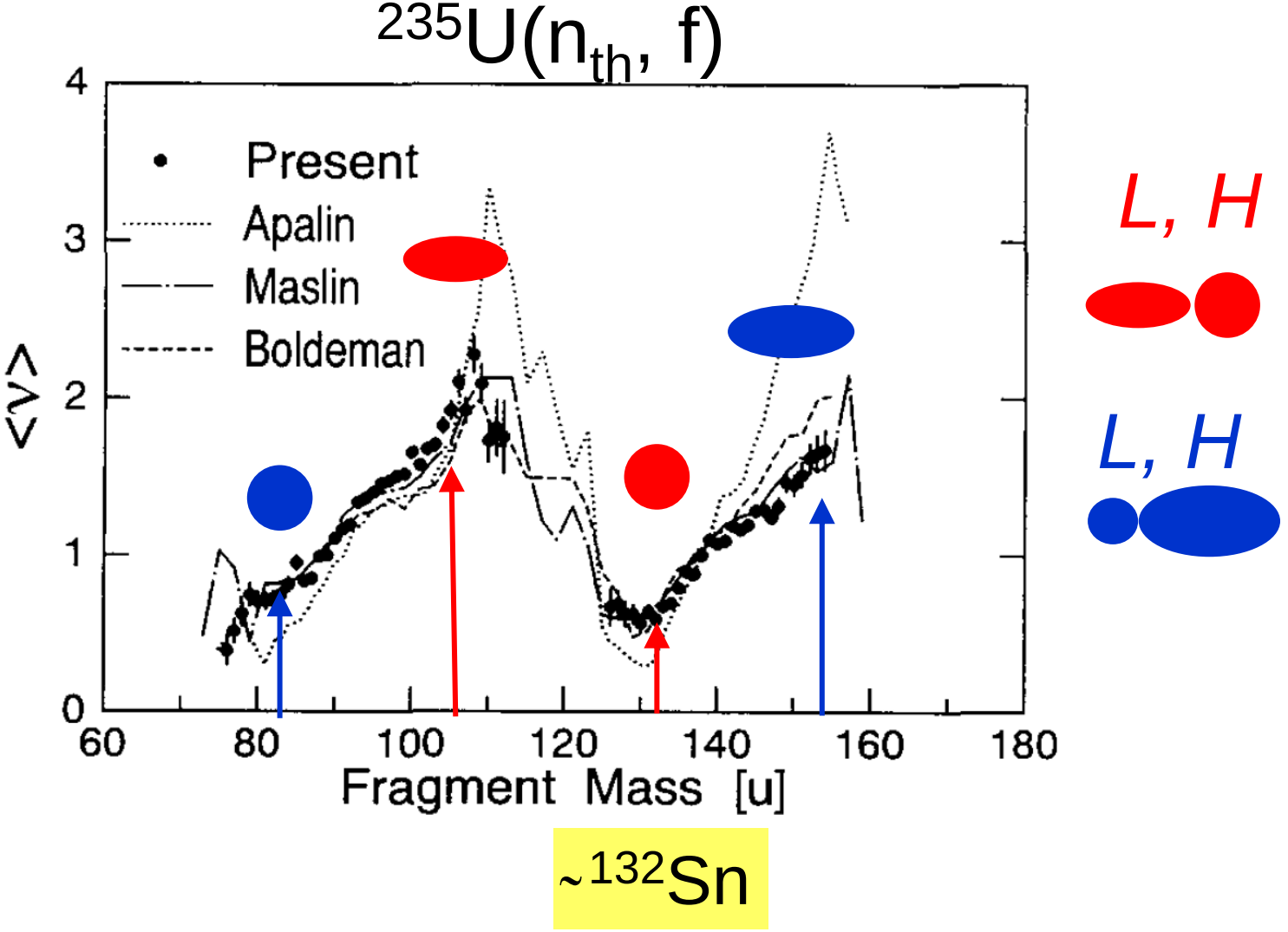
Neutron Detectors
(Liquid Scintillator)



Prompt neutron multiplicity for fission of ^{239}Np*



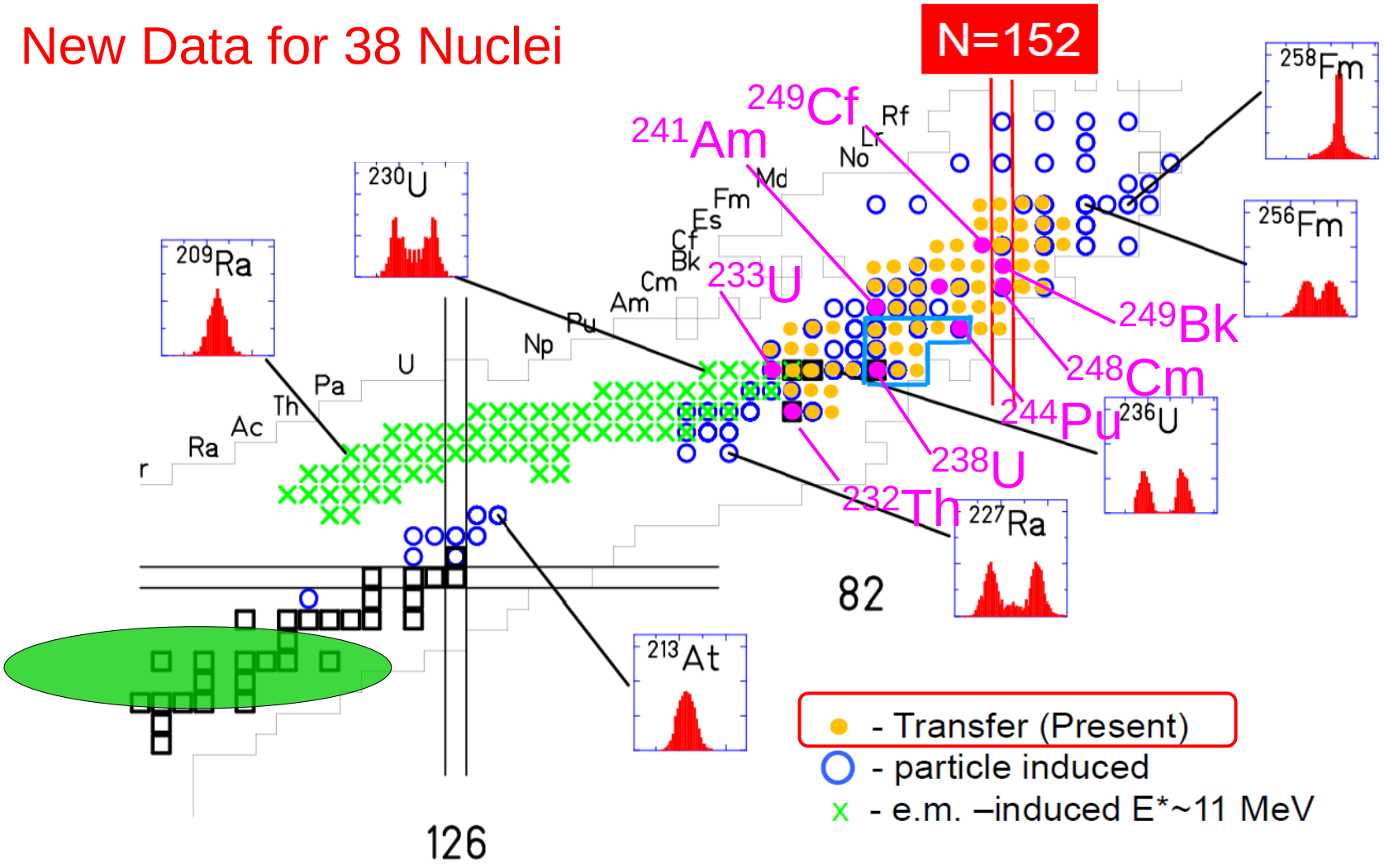
Neutron multiplicity from Individual Fragments



K. Nishio et al., Nucl. Phys. A632 (1998) 540.

Fission fragment mass/charge distributions

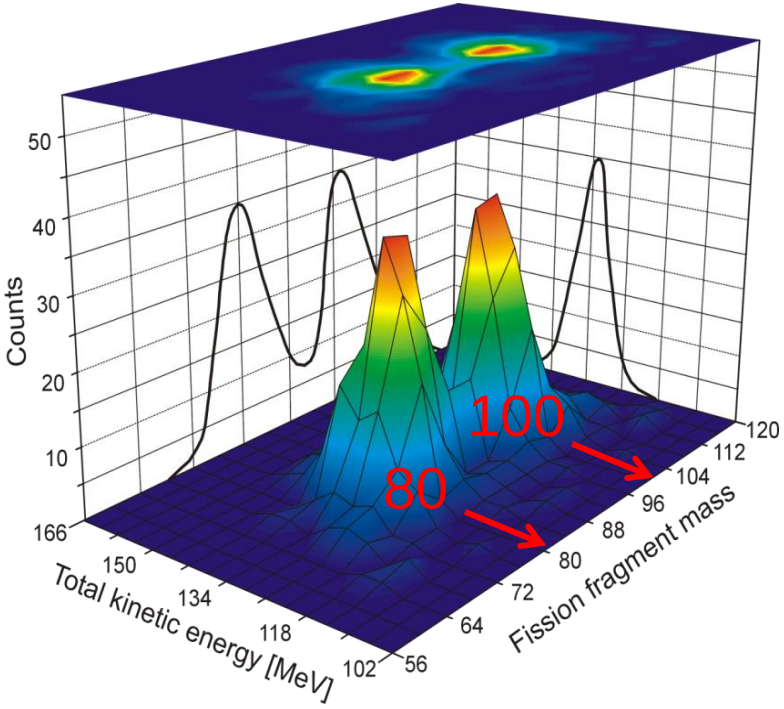
New Data for 38 Nuclei



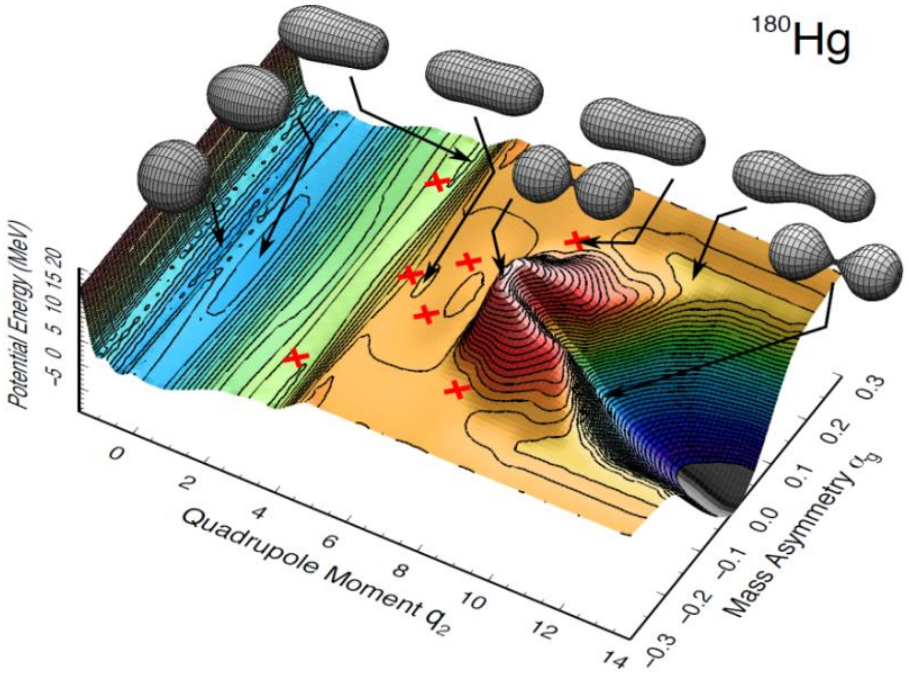
New region of mass asymmetric fission

New Region for Mass Asymmetric Fission

^{180}Hg



A.Andreyev *et al.*,
Phys. Rev. Lett.105, 252502 (2010).

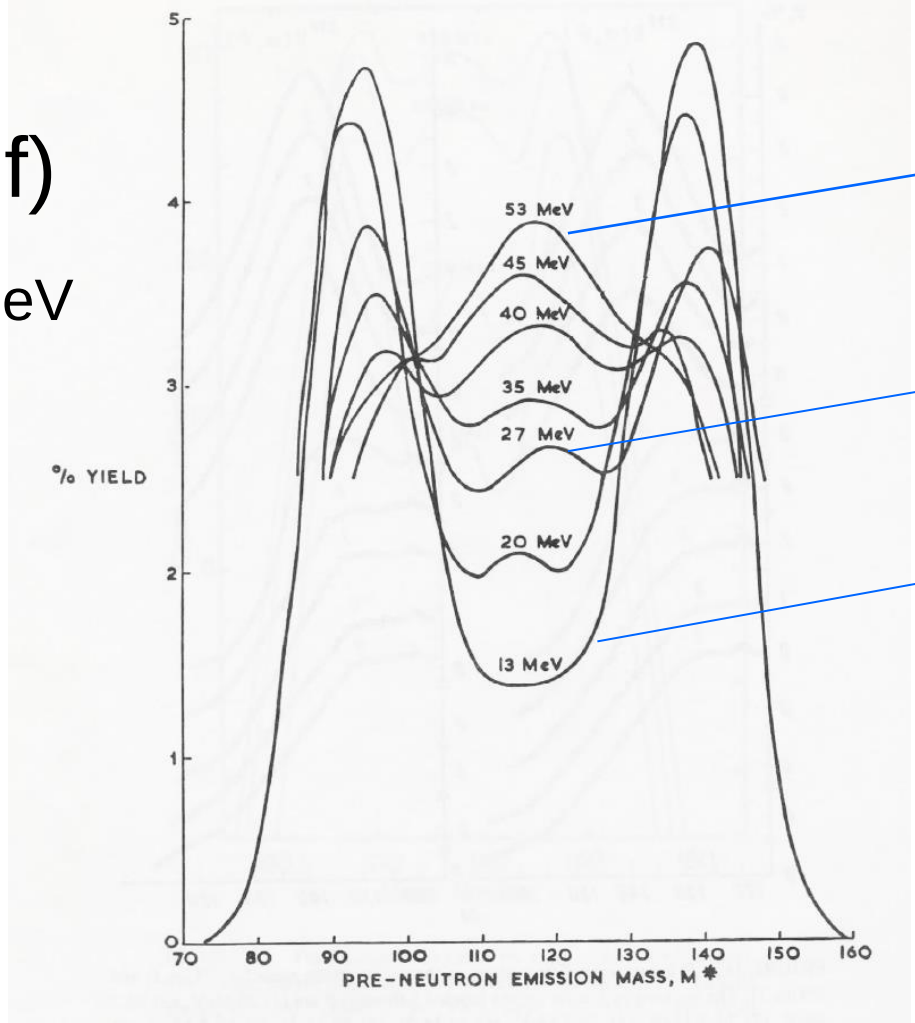


T. Ichikawa *et al.*,
Phys. Rev.C.**86**, 024610 (2012).

Fission modes

^{232}Th(*p*,f)

Q = 5.24 MeV



E_p = 53 MeV
(E^* = 58MeV)

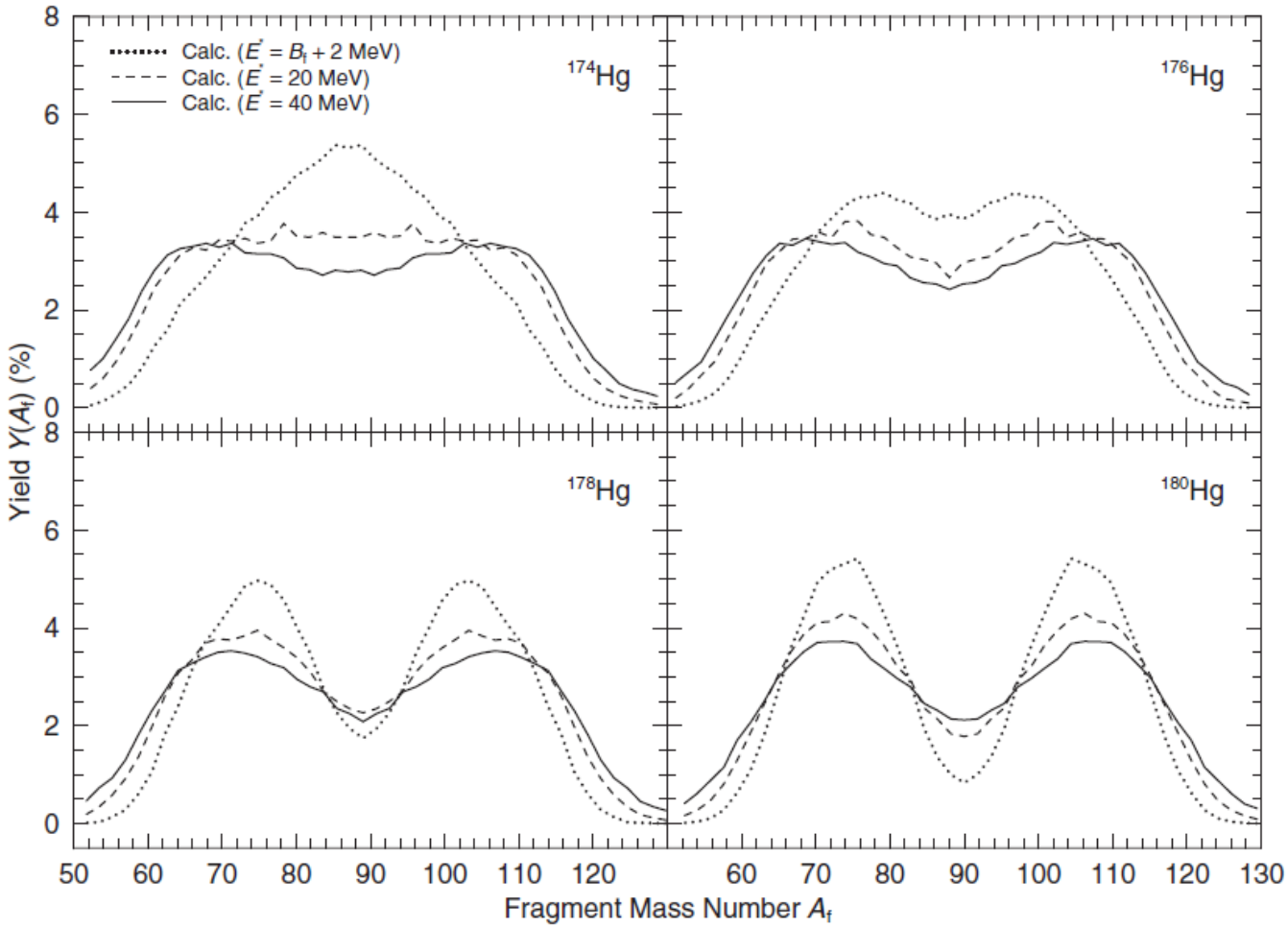
E_p = 27 MeV
(E^*= 32 MeV)

E_p = 13MeV
(E^*=18 MeV)

Two fission modes

I.F. Croall *et al*., Nucl. Phys. A 125, 402 (1969)

Calculated Excitation Energy Dependence



P. Moller, J. Rnadrup, A. Sirk, Phys.Rev.C, 85 (2012) 024306.

^{180}Hg and ^{190}Hg

^{36}Ar + ^{144}Sm = ^{180}Hg*

^{36}Ar + ^{154}Sm = ^{190}Hg*

E^* = 65.5 MeV

47.8 MeV

39.8 MeV

33.4 MeV

E^* = 70.5 MeV

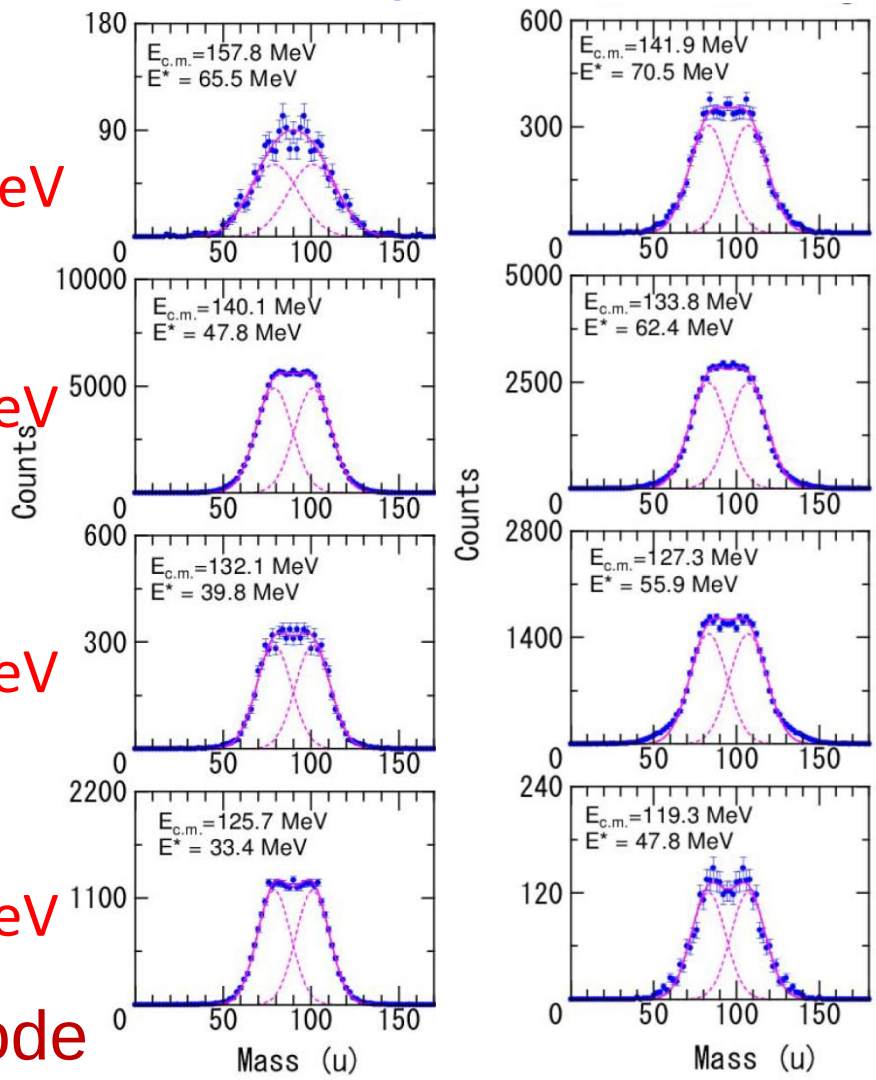
62.4 MeV

55.9 MeV

47.8 MeV

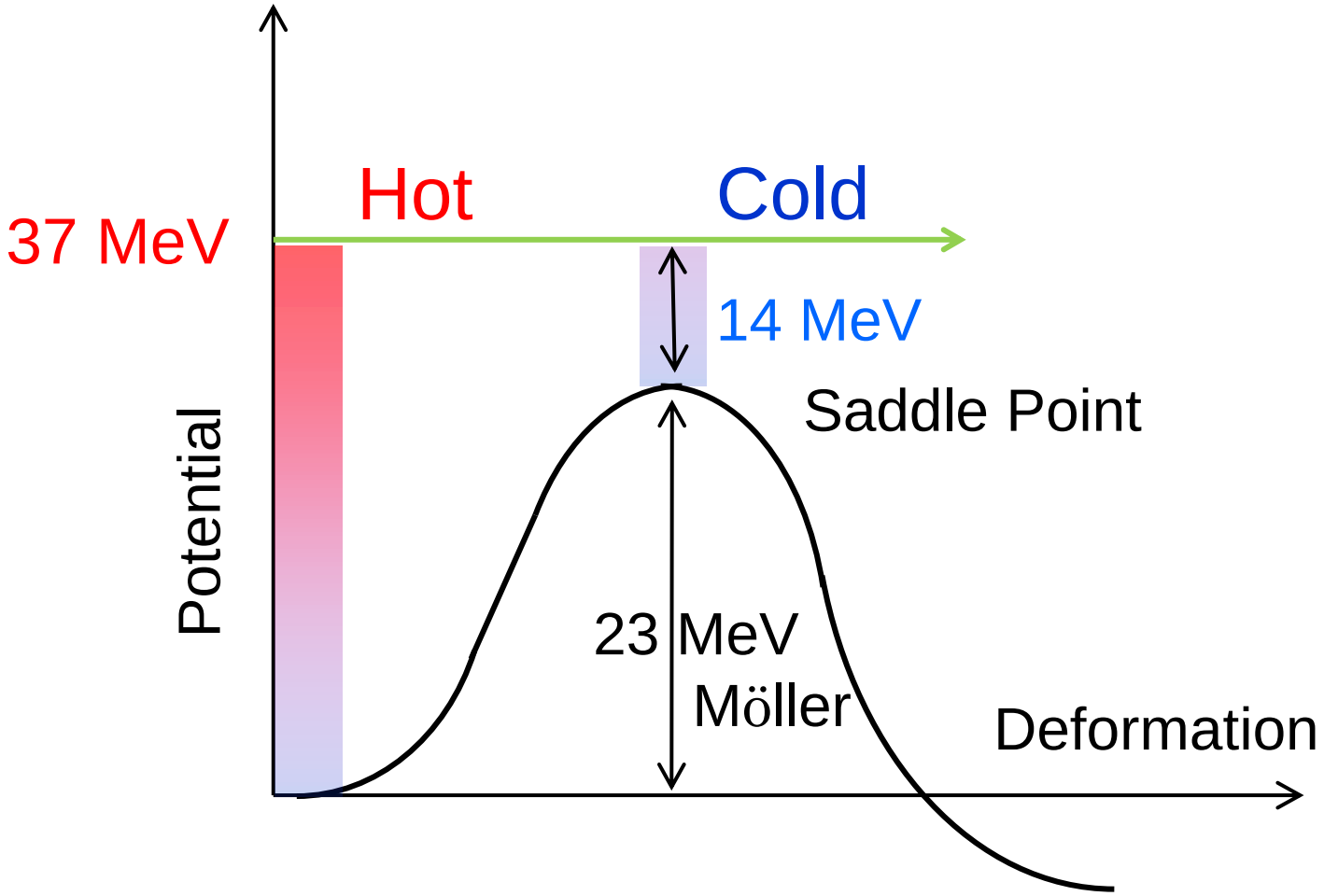
$\frac{A_L}{A_H} = \frac{79}{101}$

$\frac{A_L}{A_H} = \frac{83}{107}$



One fission mode

Fission Potential



Summary

- Transfer reaction using normal kinematics offers a study for fission of neutron-rich actinide nuclei up to fermium.

B_f , σ_f , $Y(A, E^*)$, $\nu(A, E^*)$

- ^{180}Hg has a single fission mode.

- Asymmetric fission in ^{193}Ir.

Thank you.