Fission research at JAEA and opportunity with J-PARC for fission and nuclear data

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A. Andreyev, D. Jenkins

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, B. Sulignano, Ch.E. Düllmann, M.Schädel

S. Chiba

S. Antalic, S. Saro

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A. Yakushev, A. Gorshkov, R. Graeger, A. Türler

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Y. Watanabe

Y. Aritomo

S. Yan

N. Tamura, S. Goto

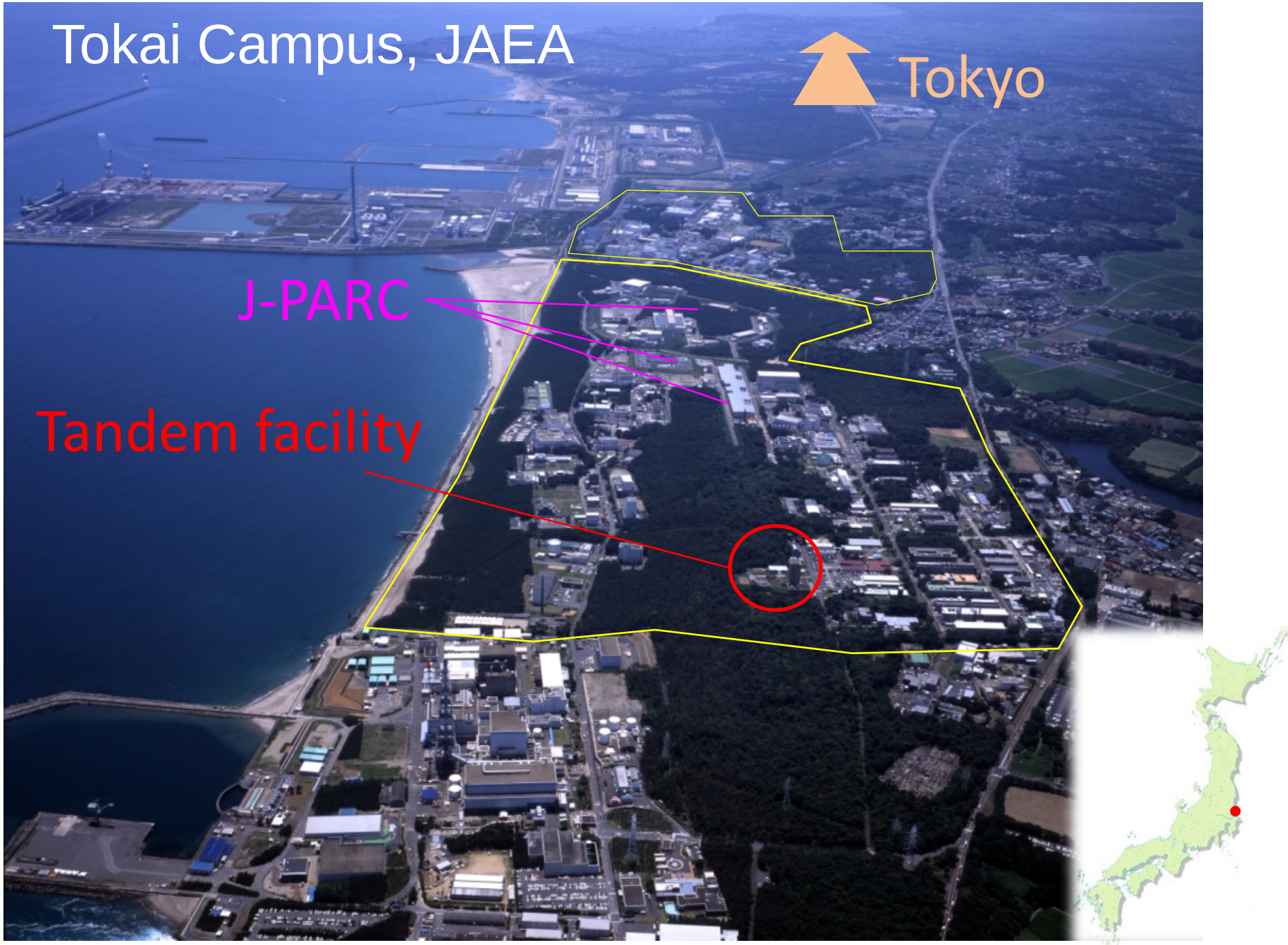
Fission Research Program at JAEA

@ JAEA Tandem facility

- Fission study for heavy-element synthesis
- Fission of new region of chart of nuclei
- Multi-nucleon transfer induced fission

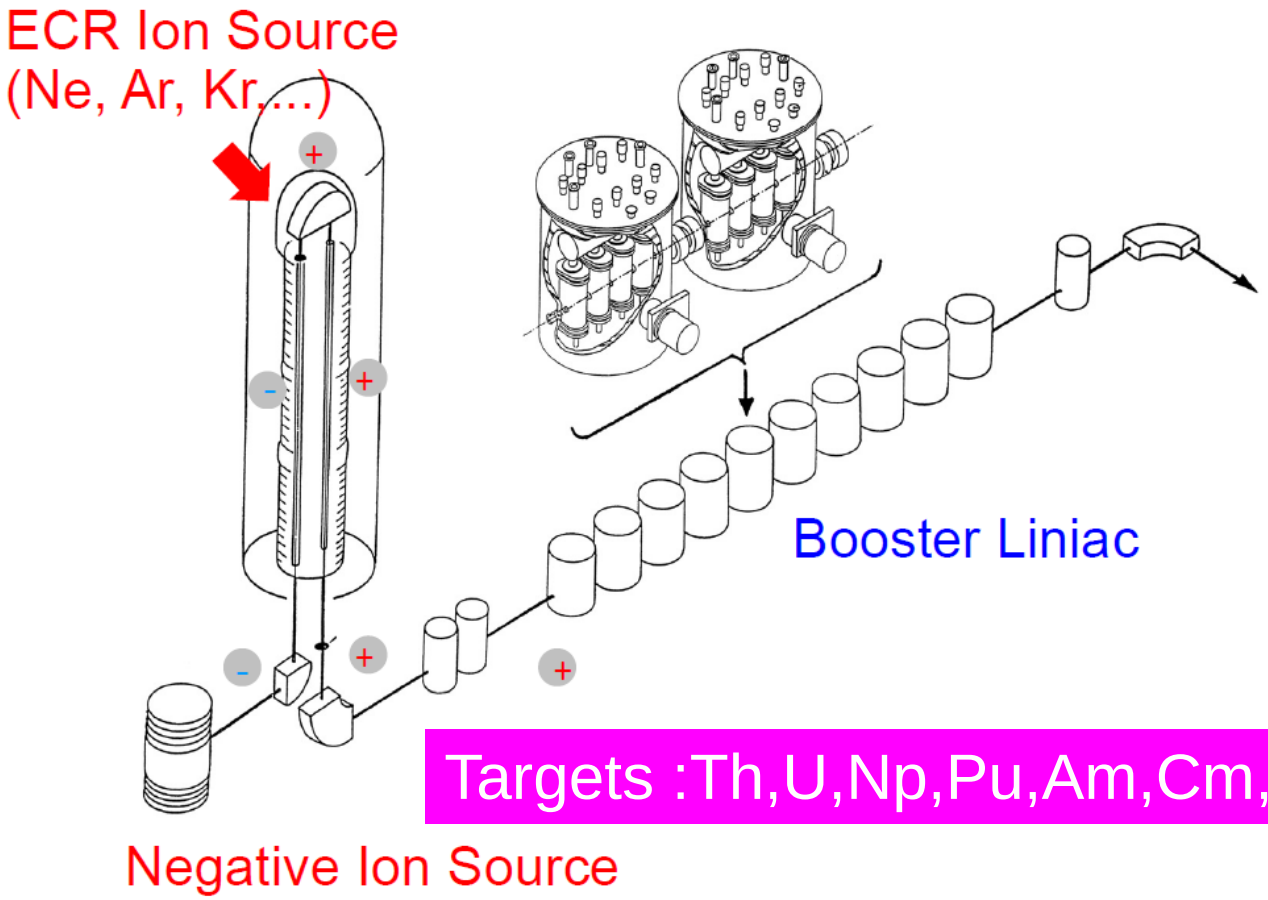
@ J-PARC

- n –TOF fission measurement and future


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

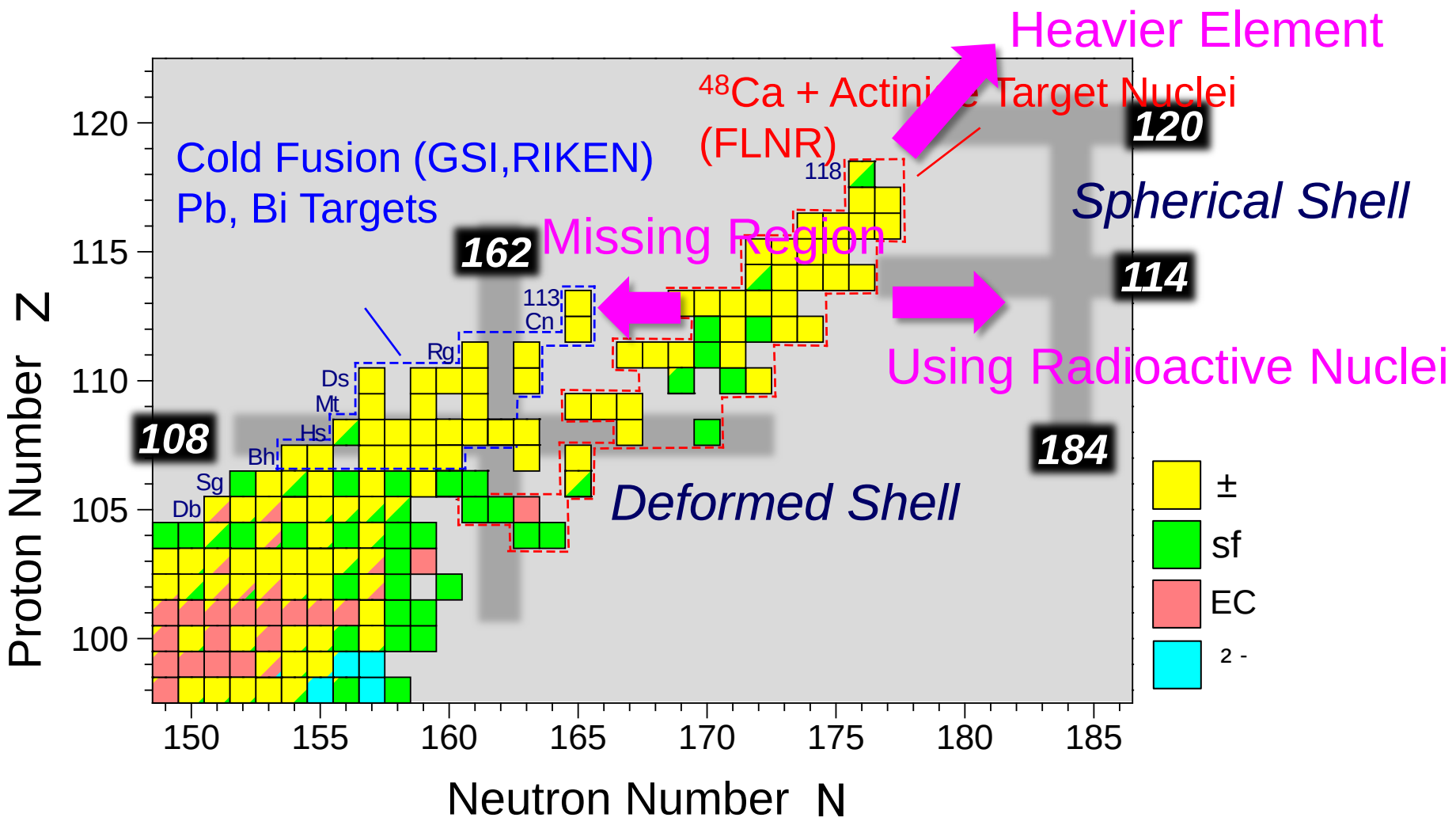


Targets :Th,U,Np,Pu,Am,Cm,Cf

Fission Study for Heavy Element Synthesis

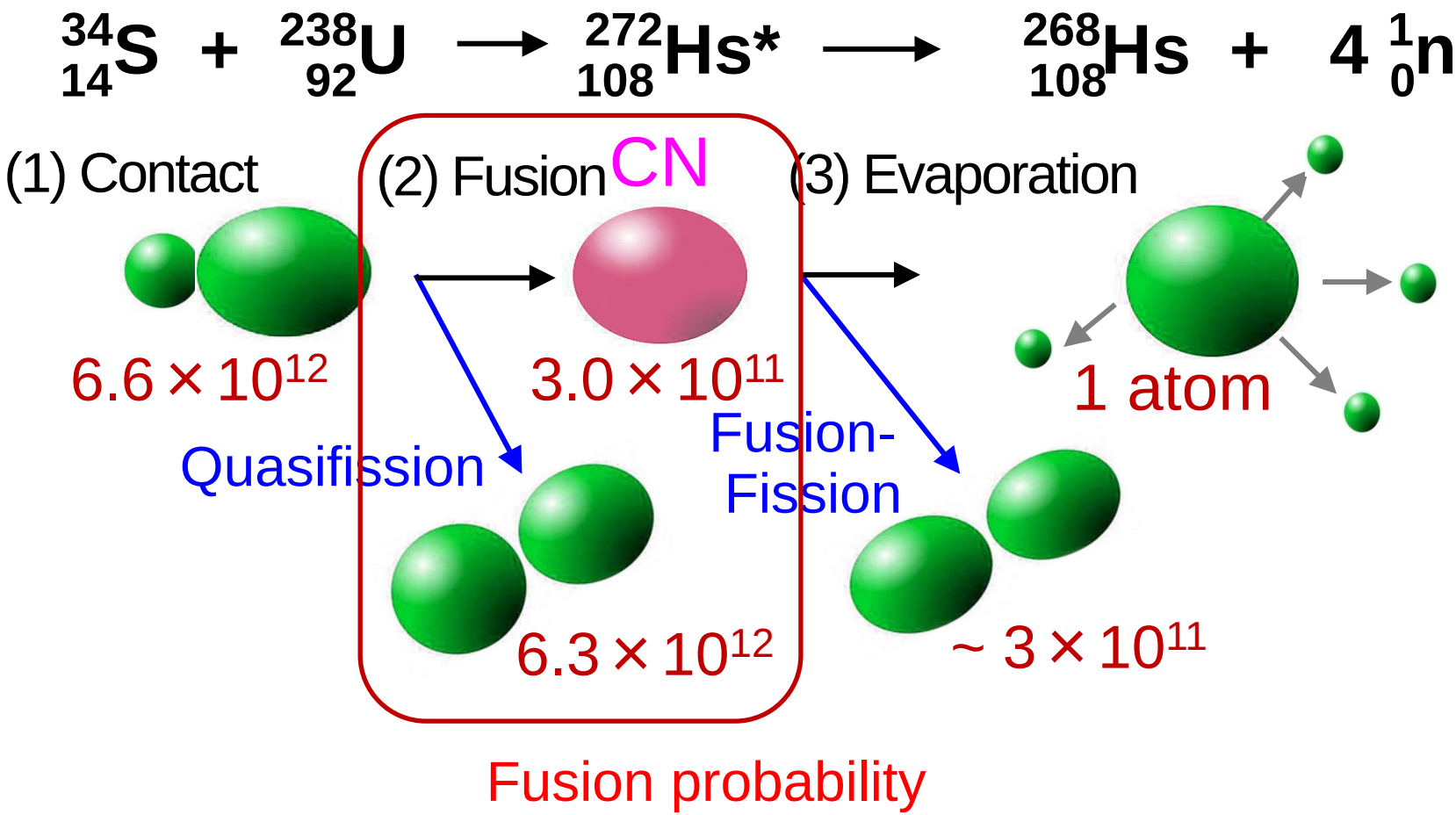
How to determine fusion probability

Super-heavy Nuclei

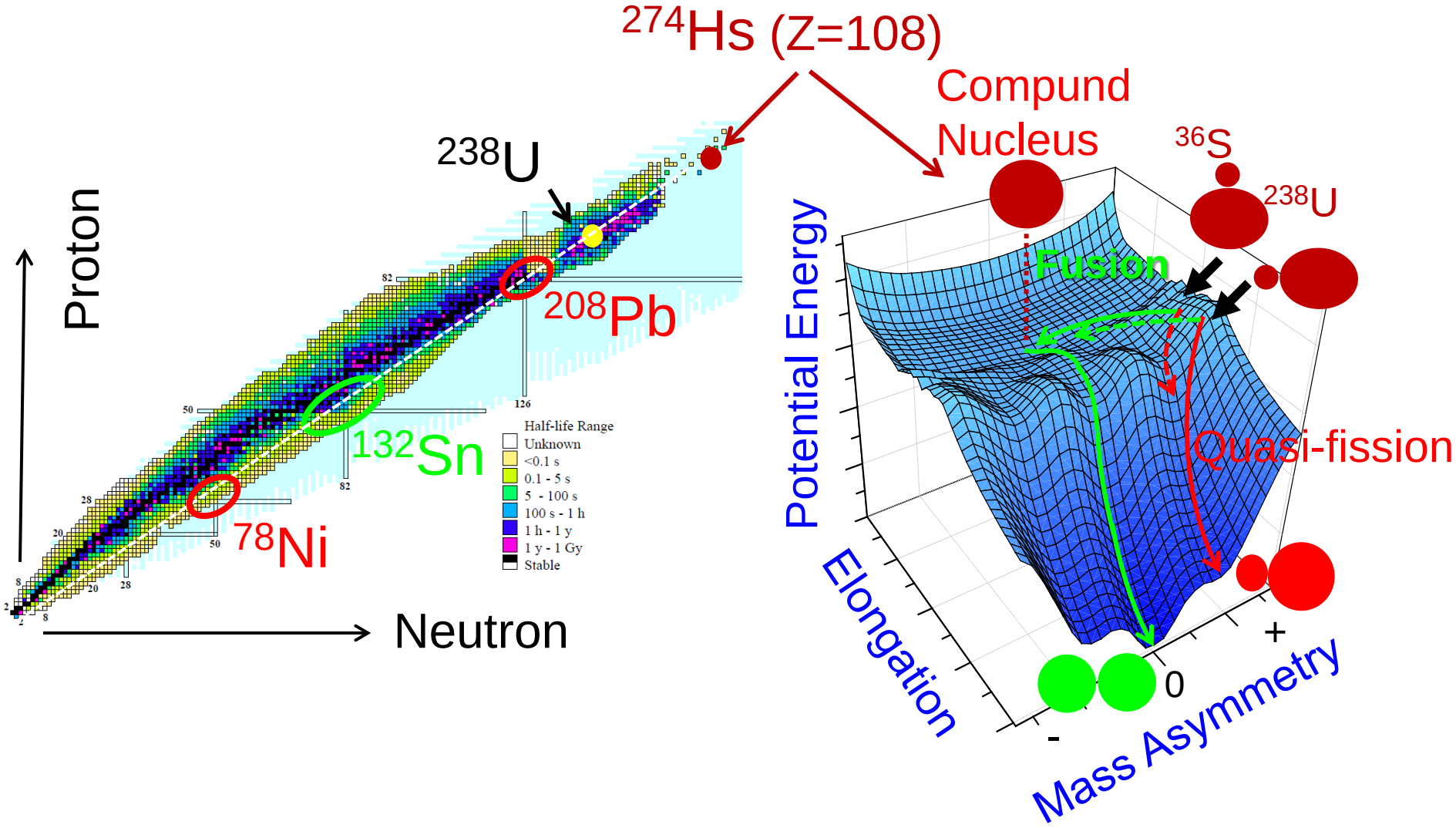


Understanding for fusion using actinide target nuclei are important to explore SHN

Three steps for heavy-element synthesis

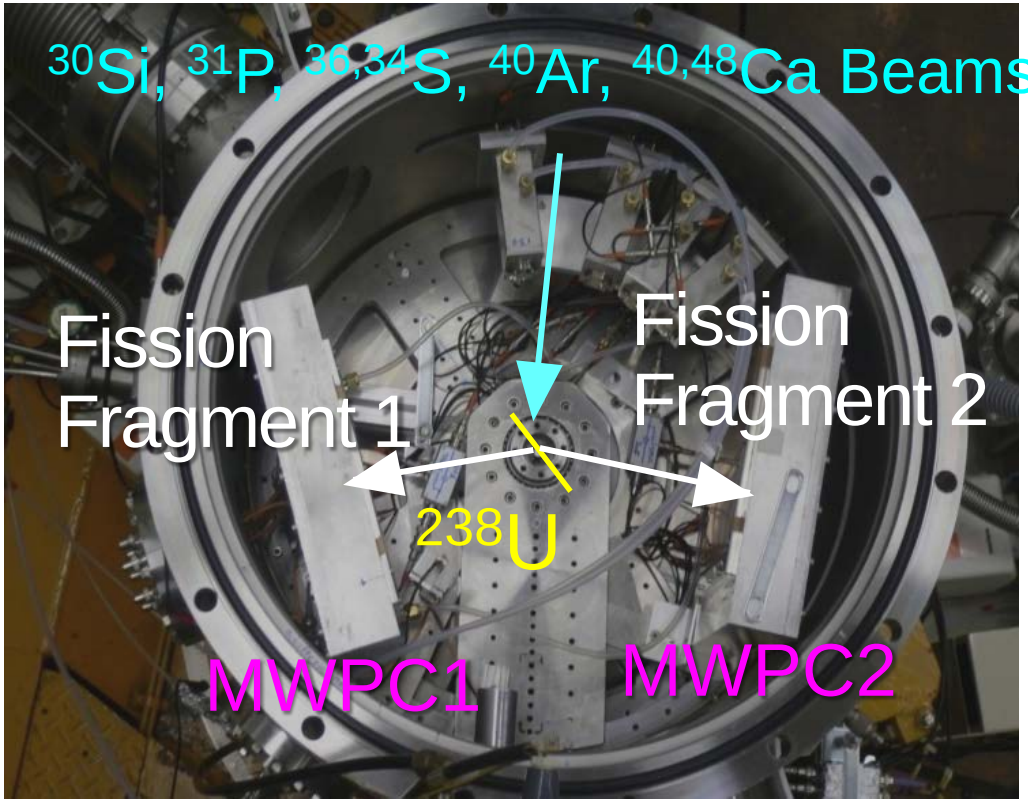


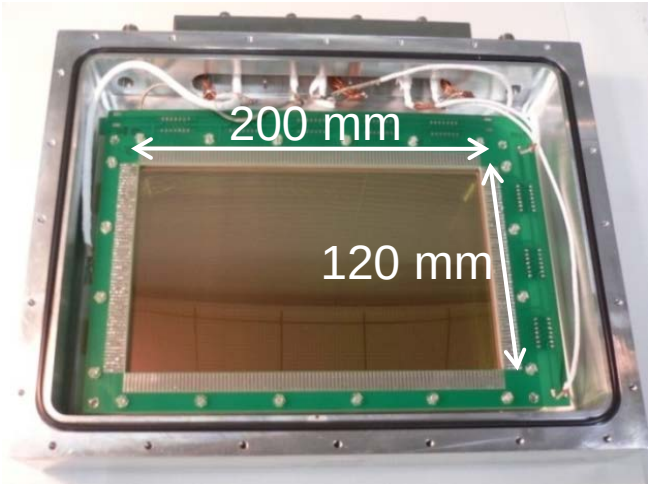
Fusion-fission and Quasi-fission



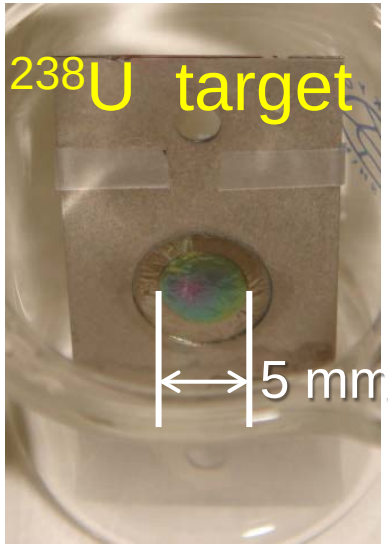
Potential by Y. Aritomo

In-Beam Fission Measurement



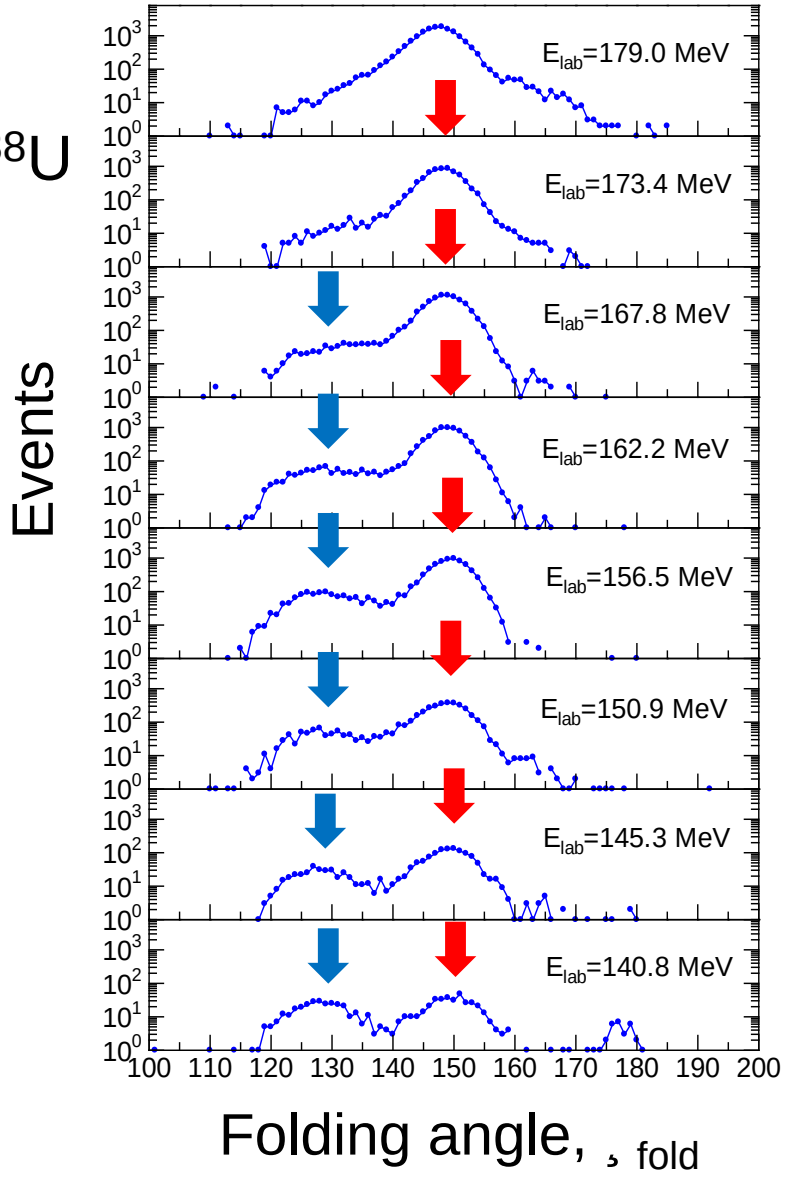


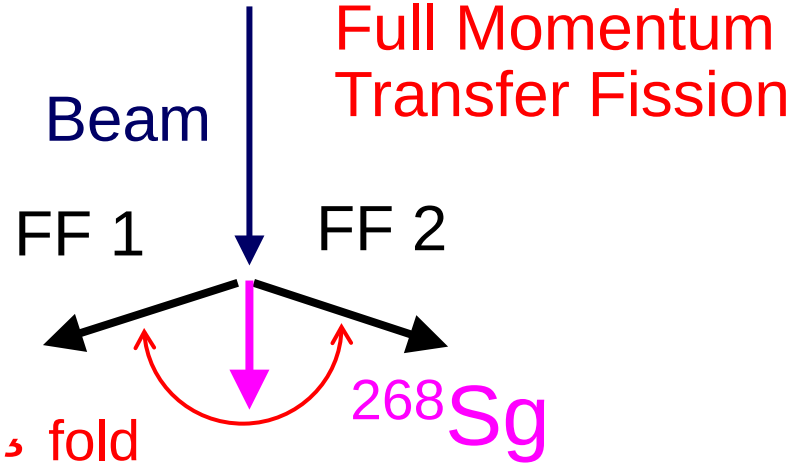
Multi-Wire Proportional Counter

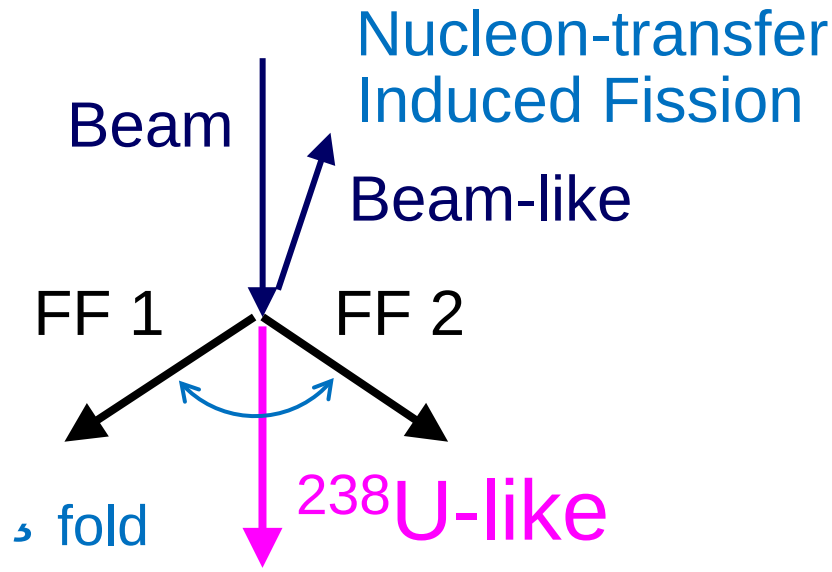


Folding Angle Distribution

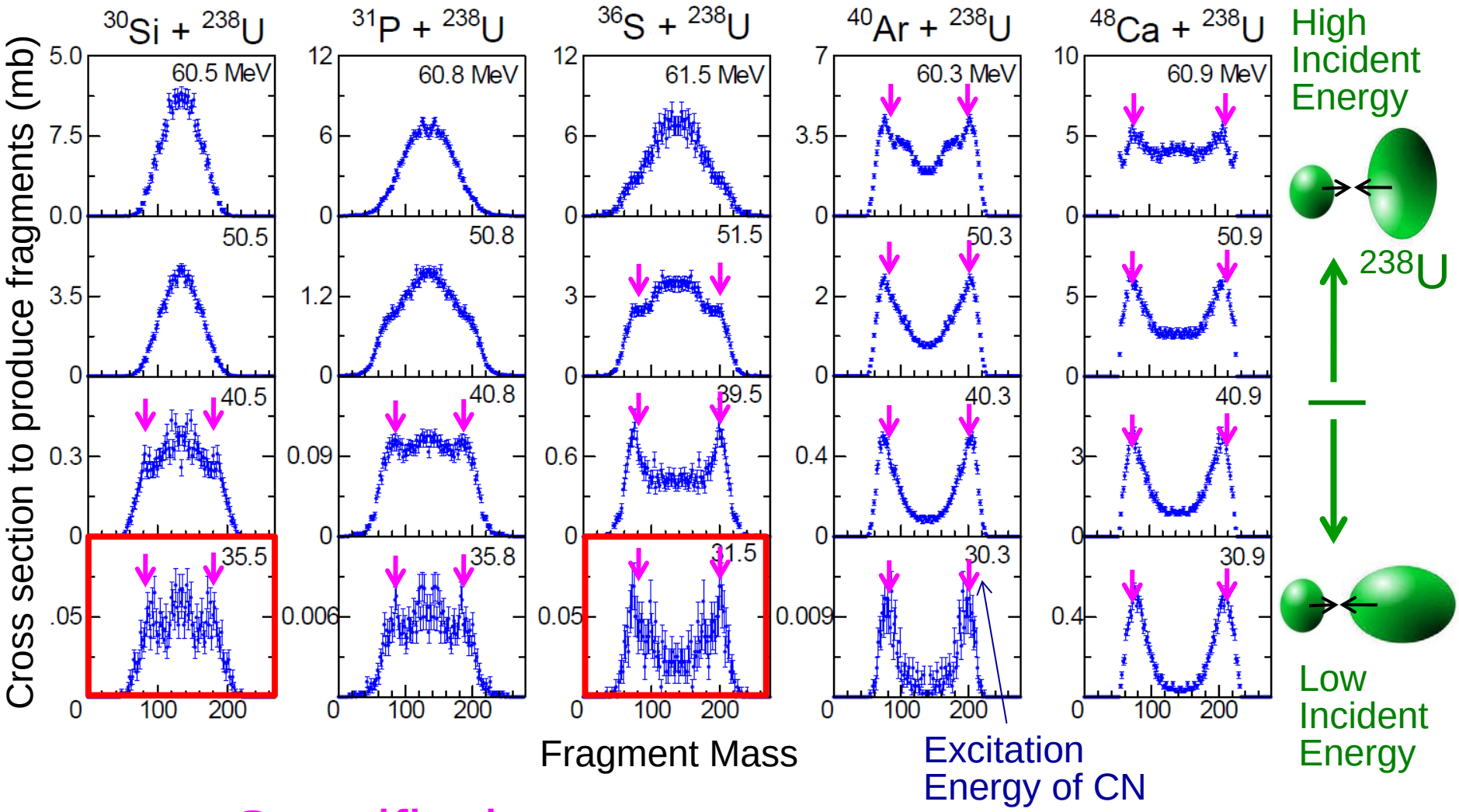
$^{30}Si + ^{238}U$







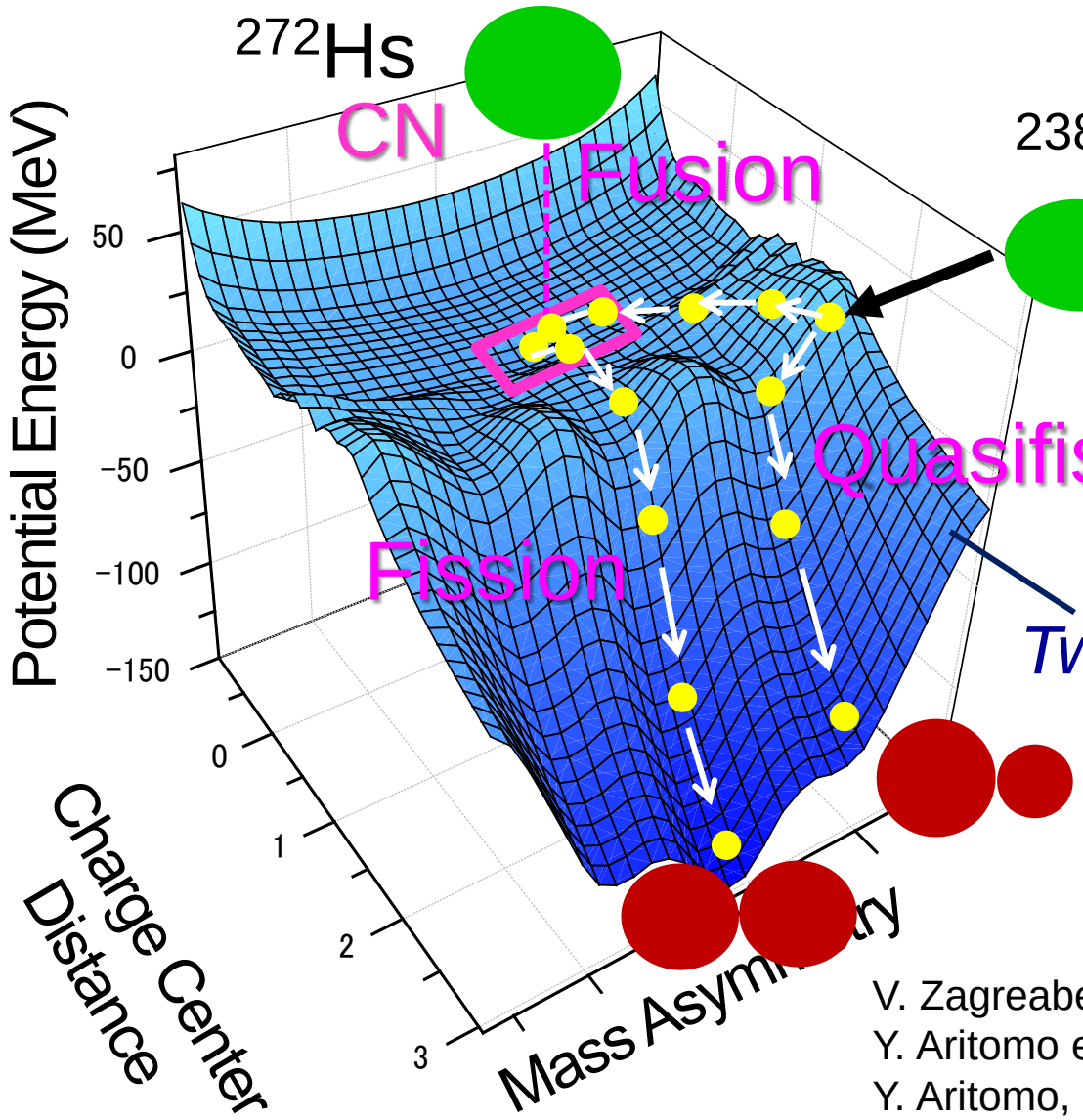
Fission Fragment Mass Distributions



Quasifission

K. Nishio et al., Phys. Rev. C, **77**, 064607 (2008).
K. Nishio et al., Phys. Rev. C, **82**, 044604 (2010).

Dynamical calculation of nuclear shape
– Fluctuation dissipation model –



Langevin Equation

^{238}U

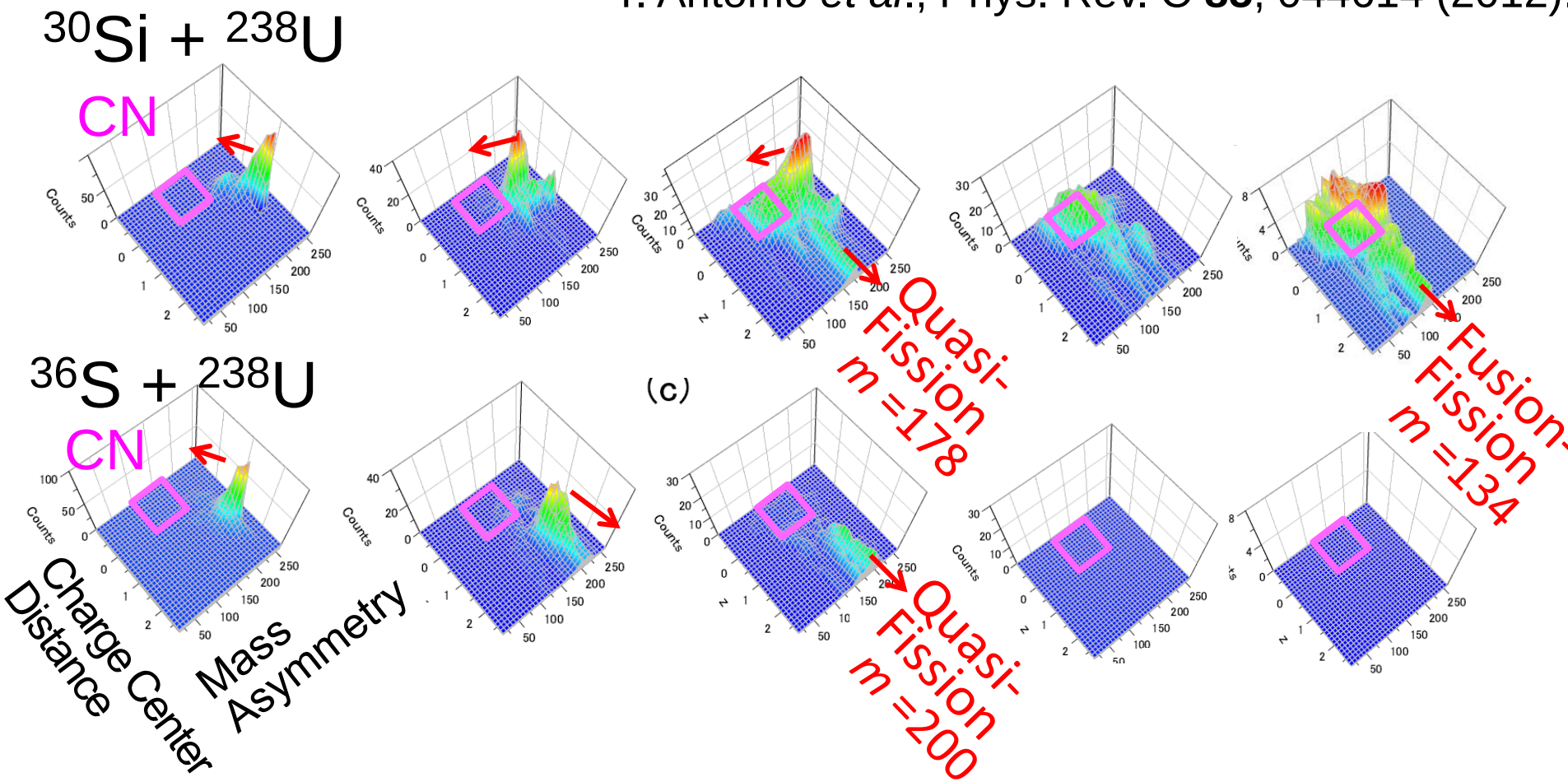
^{34}S

Two center shell model
(3 dimension)

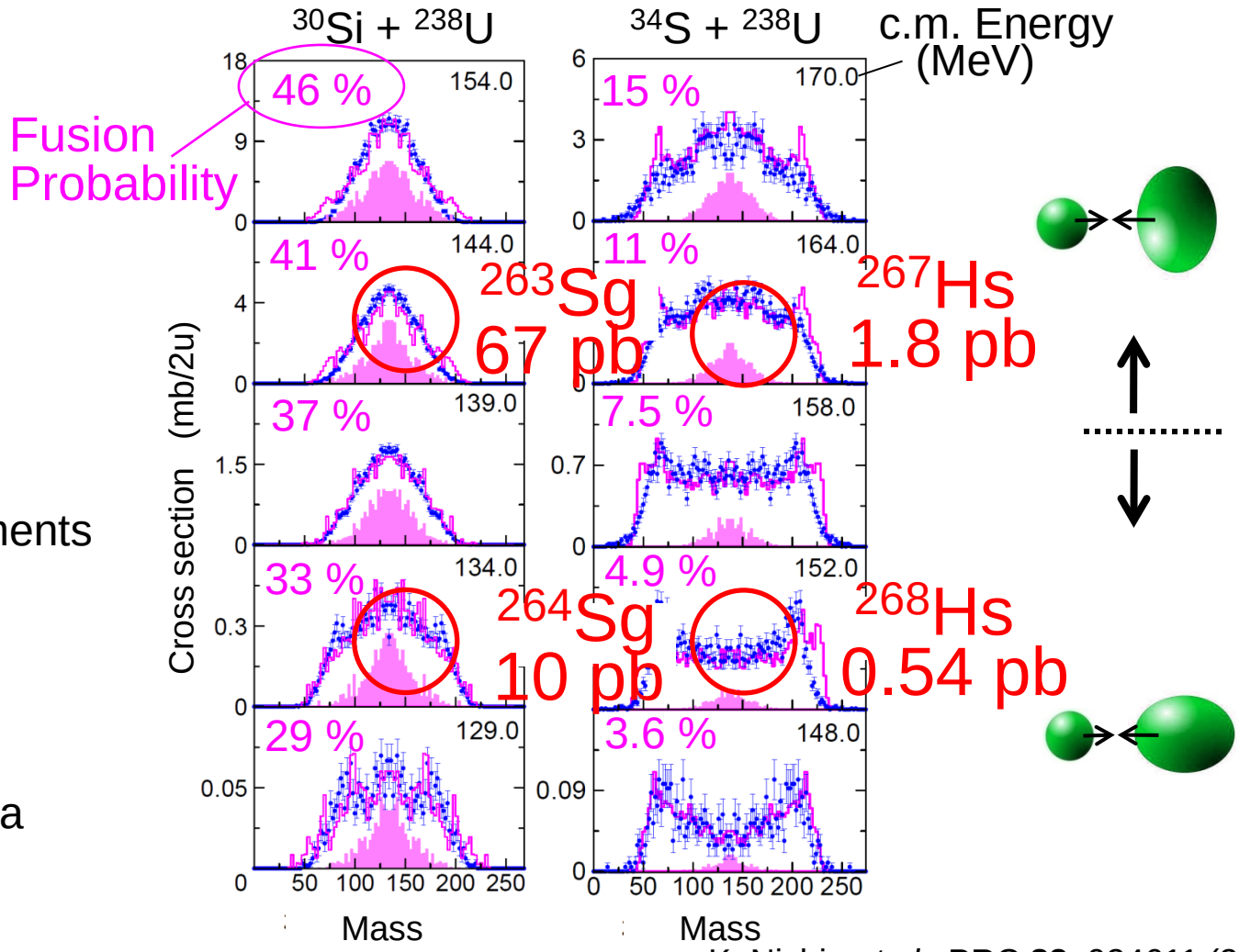
V. Zagreabev, J. Phys. G, **31,** 825 (2005).
Y. Aritomo et al., Nucl.Phys. **A753**, 152 (2005).
Y. Aritomo, Phys.Rev.C, **80**, 064604 (2009).

Shape evolution (polar collision)

Y. Aritomo *et al*., Phys. Rev. C **85**, 044614 (2012).

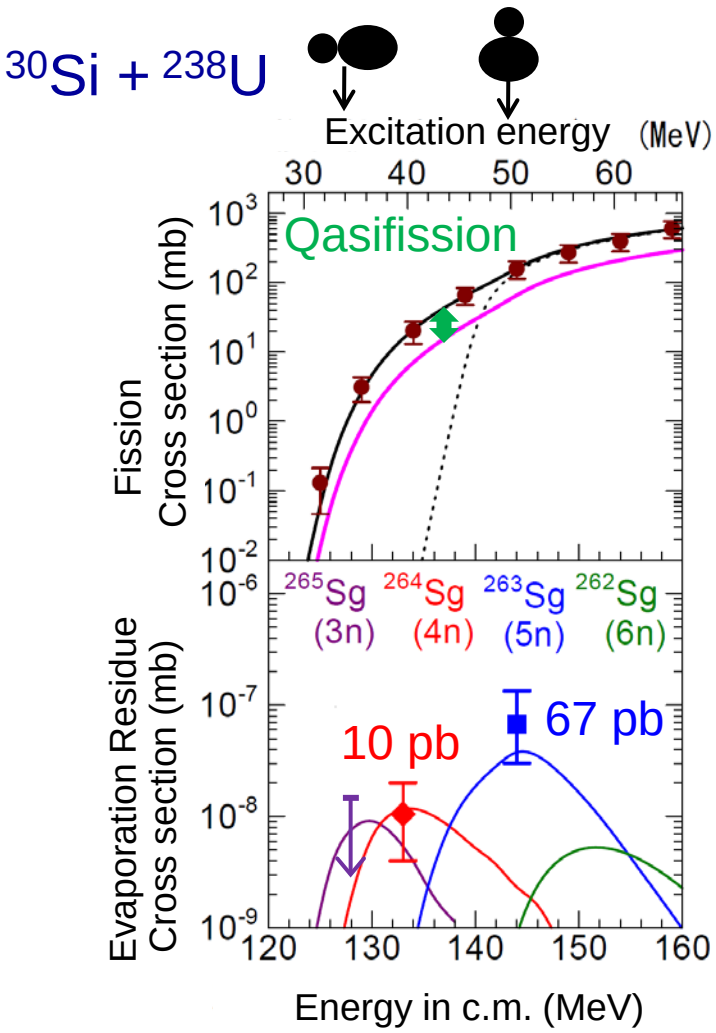


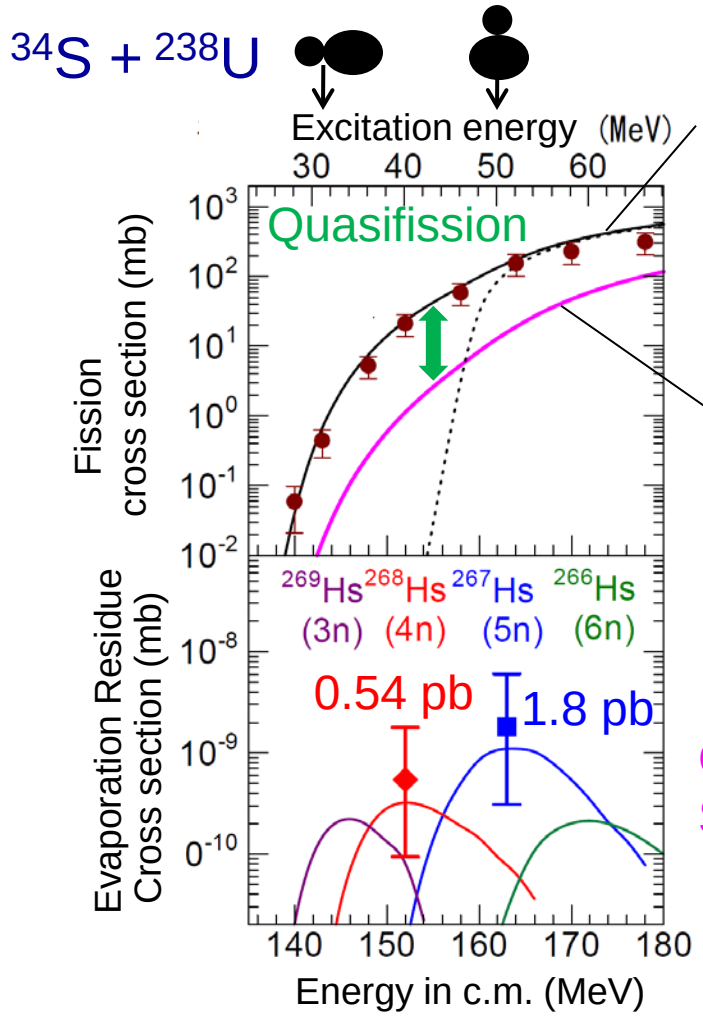
Fusion probability



K. Nishio *et al.*, PRC **82**, 024611 (2010).
K. Nishio *et al.*, PRC **82**, 044604 (2010).

Fusion and ER cross sections





Capture Cross Section

× Fusion Probability

Fusion Cross Section

× Survival Probability (Statistical Model)

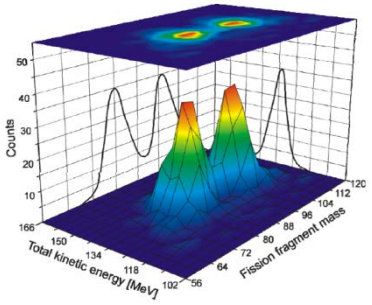
Cross sections for SHN

K. Nishio *et al*., PRC **82**, 024611 (2010).
K. Nishio *et al*., PRC **82**, 044604 (2010).

Fission of New Region of Chart of Nuclei

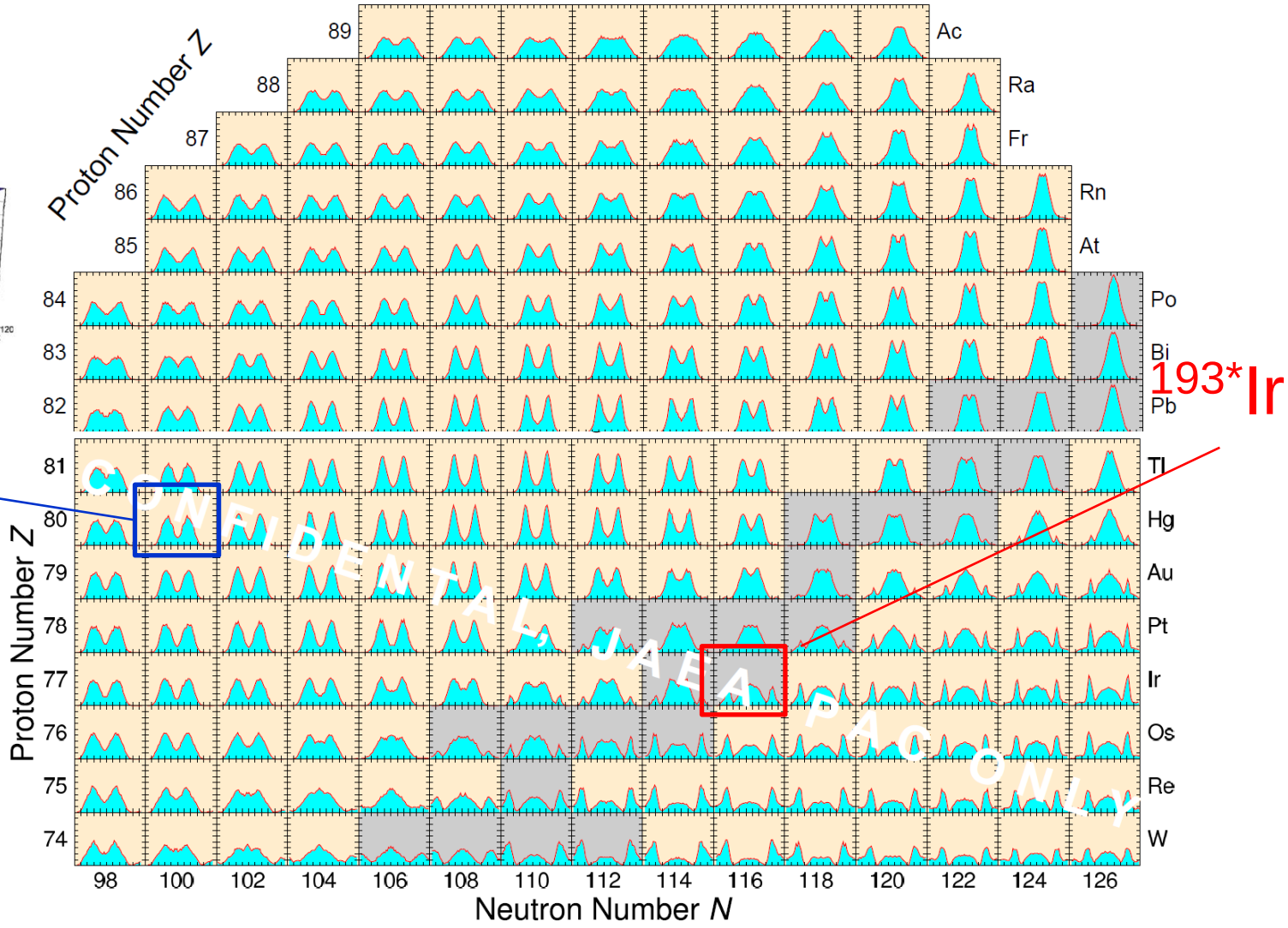
Appearance of a new shell in fission

Predicted Fission Fragment Mass Distributions



^{180}Hg

^{193*}Ir

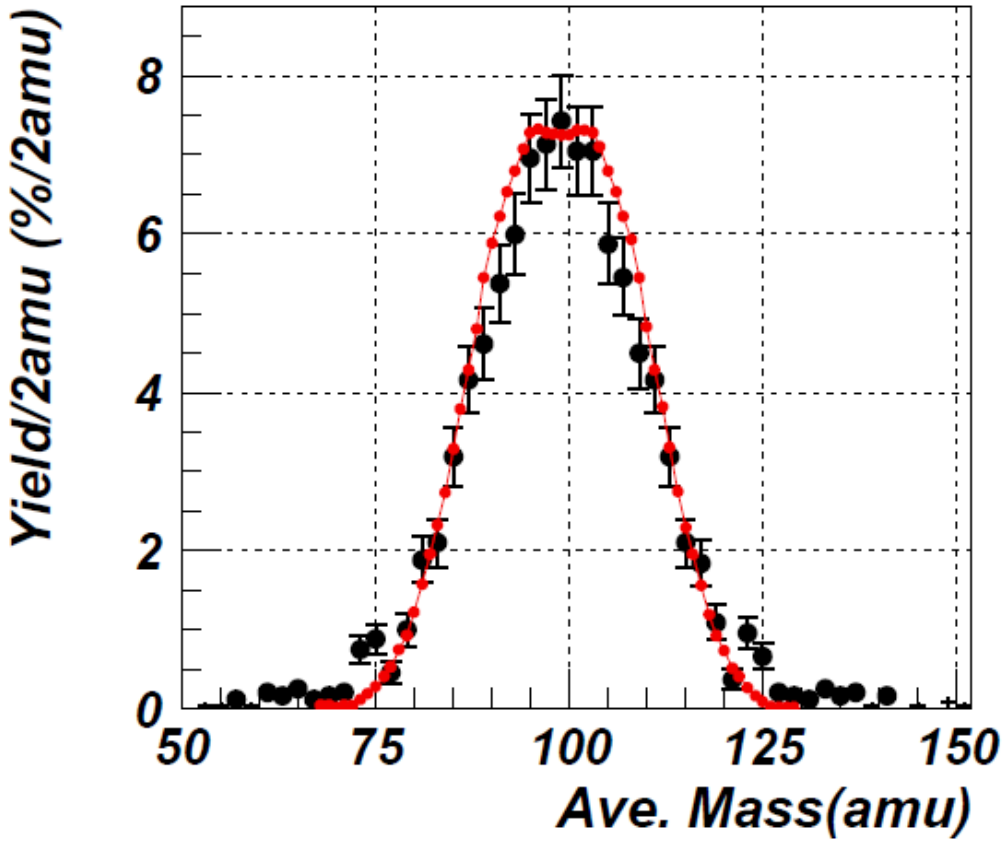


Calculated by P. Moller (LANL) and J. Randrup (LBNL)
Perspectives in Nuclear Fission, (Tokai 2012)

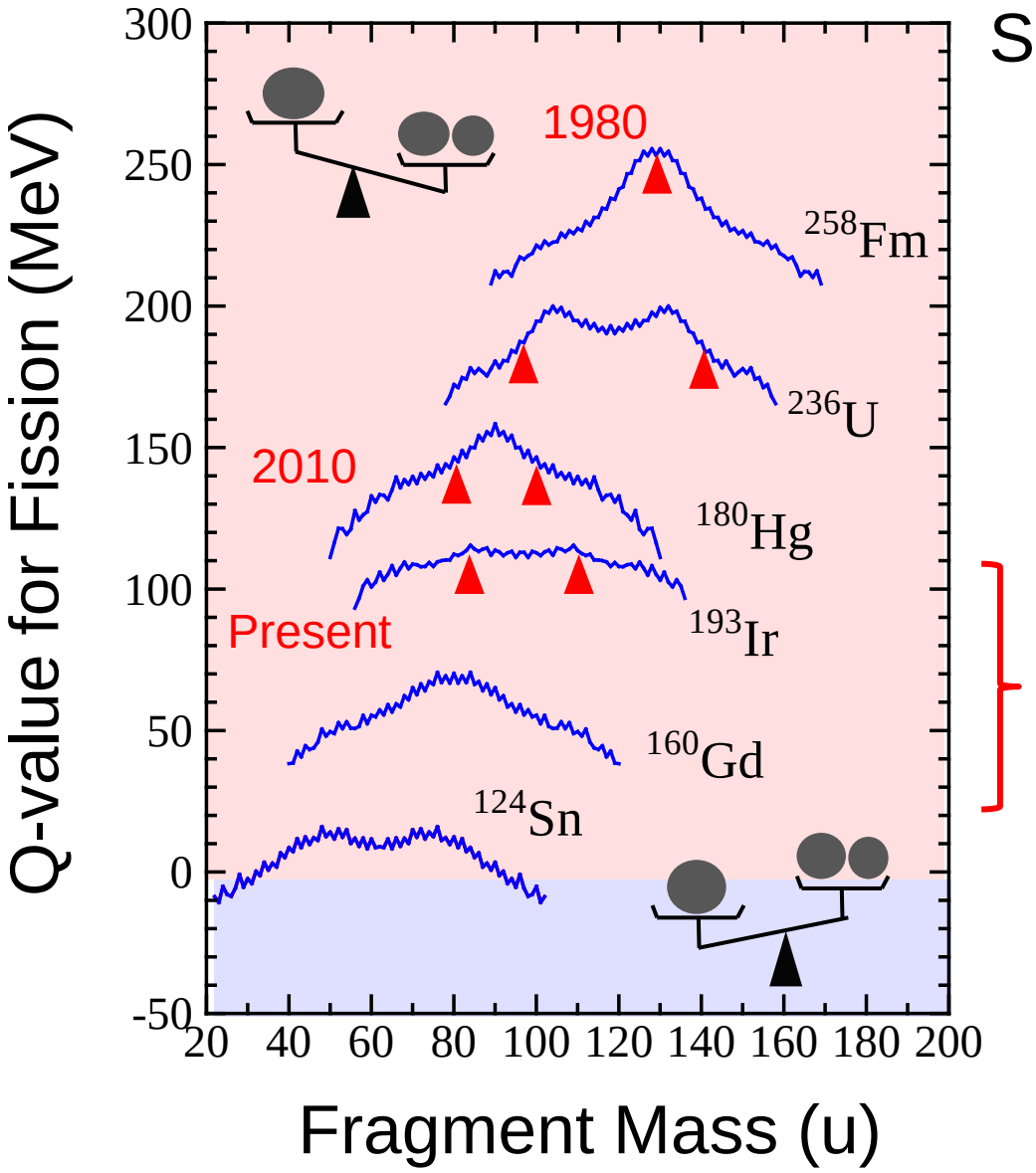
p + ^{197}Au → ^{198}Hg*

Present (E_p=31.1MeV)

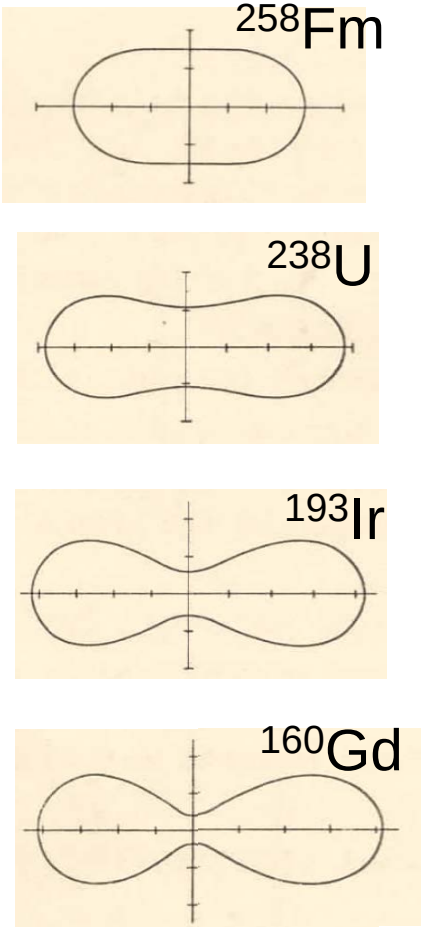
Itkis (E_p=30.0MeV)



Fission Q-value



Saddle Point Shape

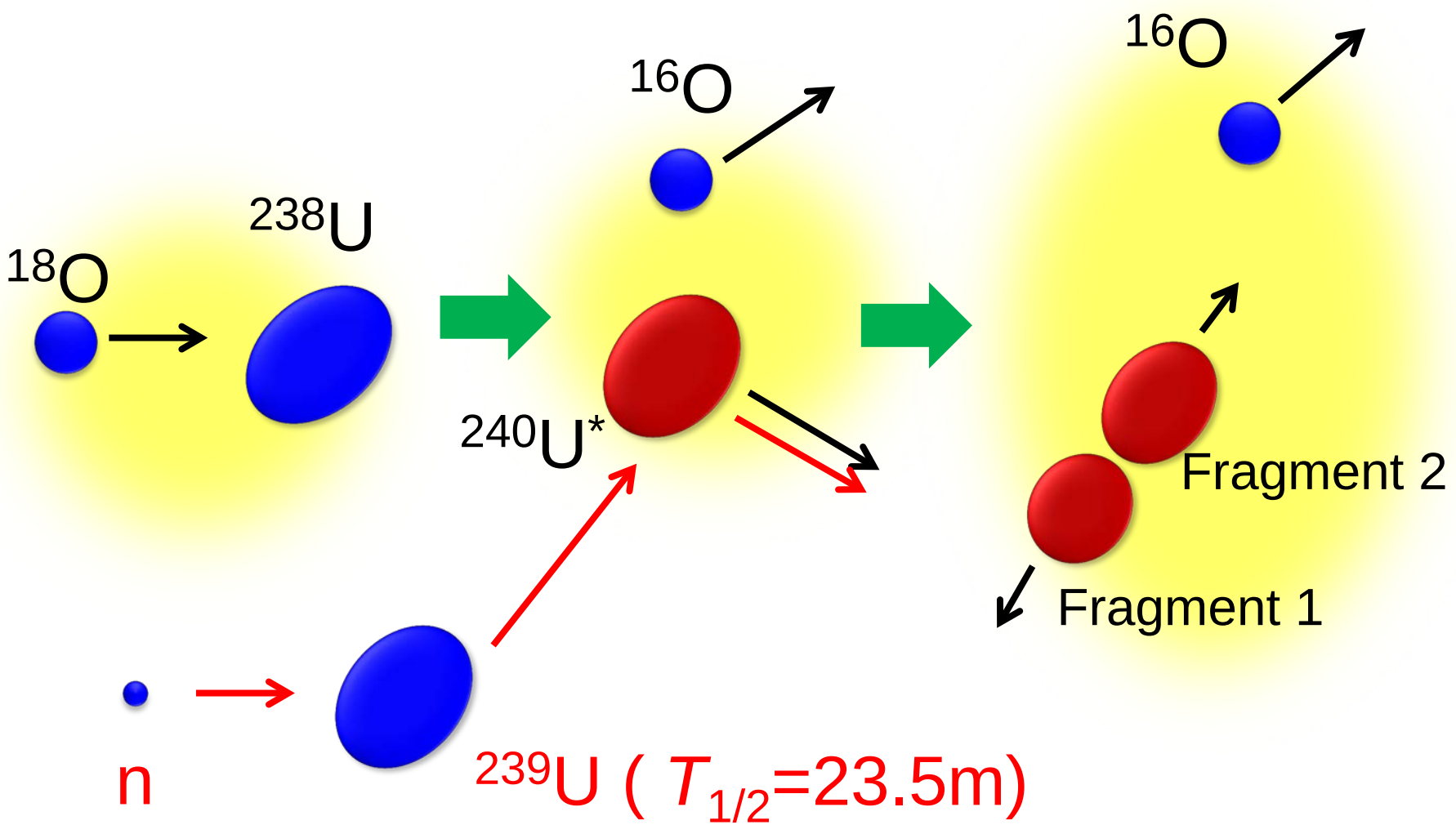


Multi-nucleon transfer Induced Fission (Surrogate Reaction)

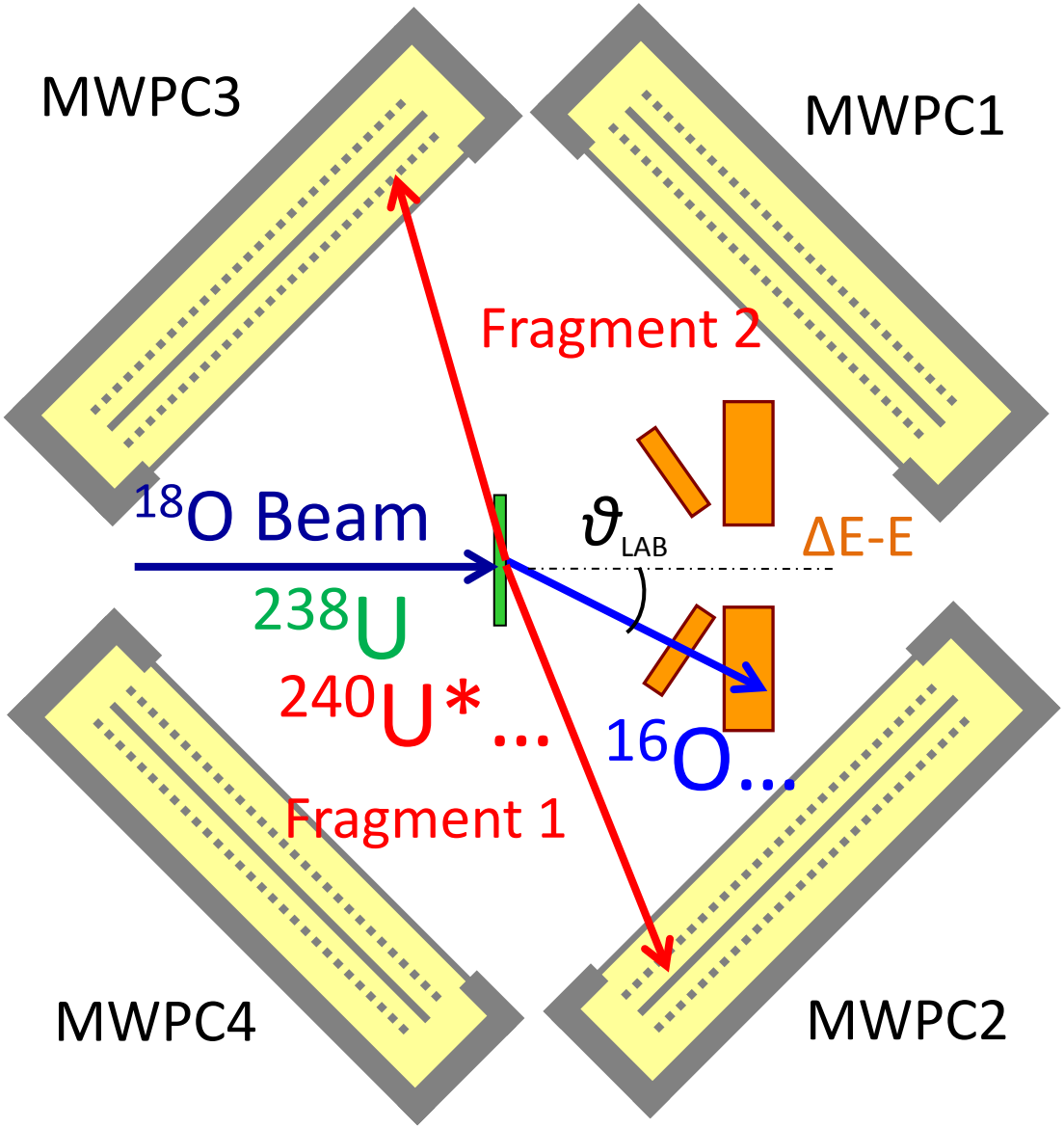
Fission of neutron-rich nuclei

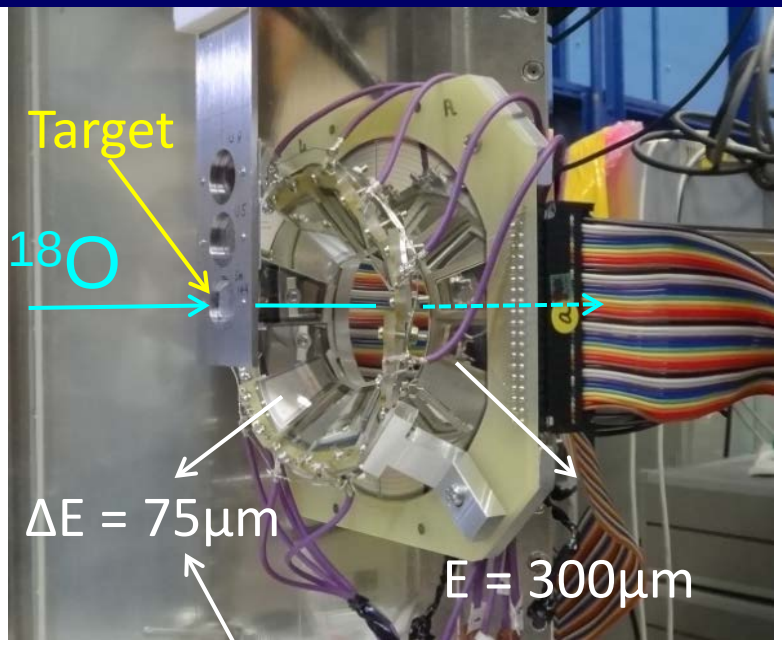
Nuclear data ($\tilde{A}$, $Y(m)$, ½)

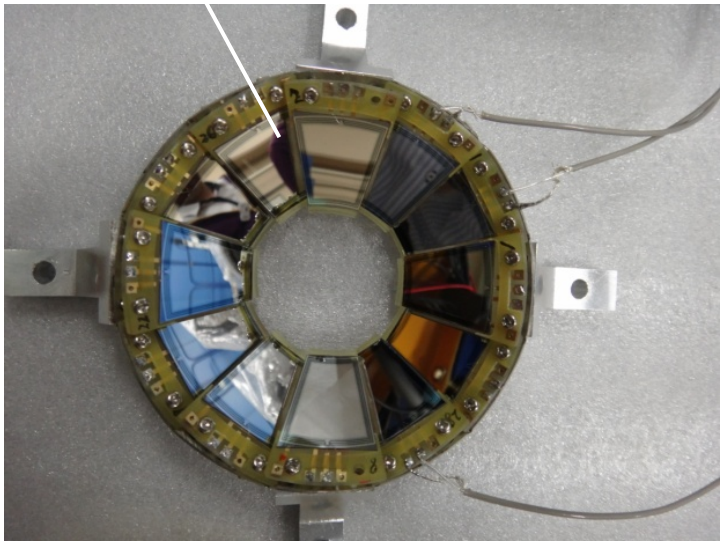
Multi-nucleon Transfer Reaction



Experimental Setup

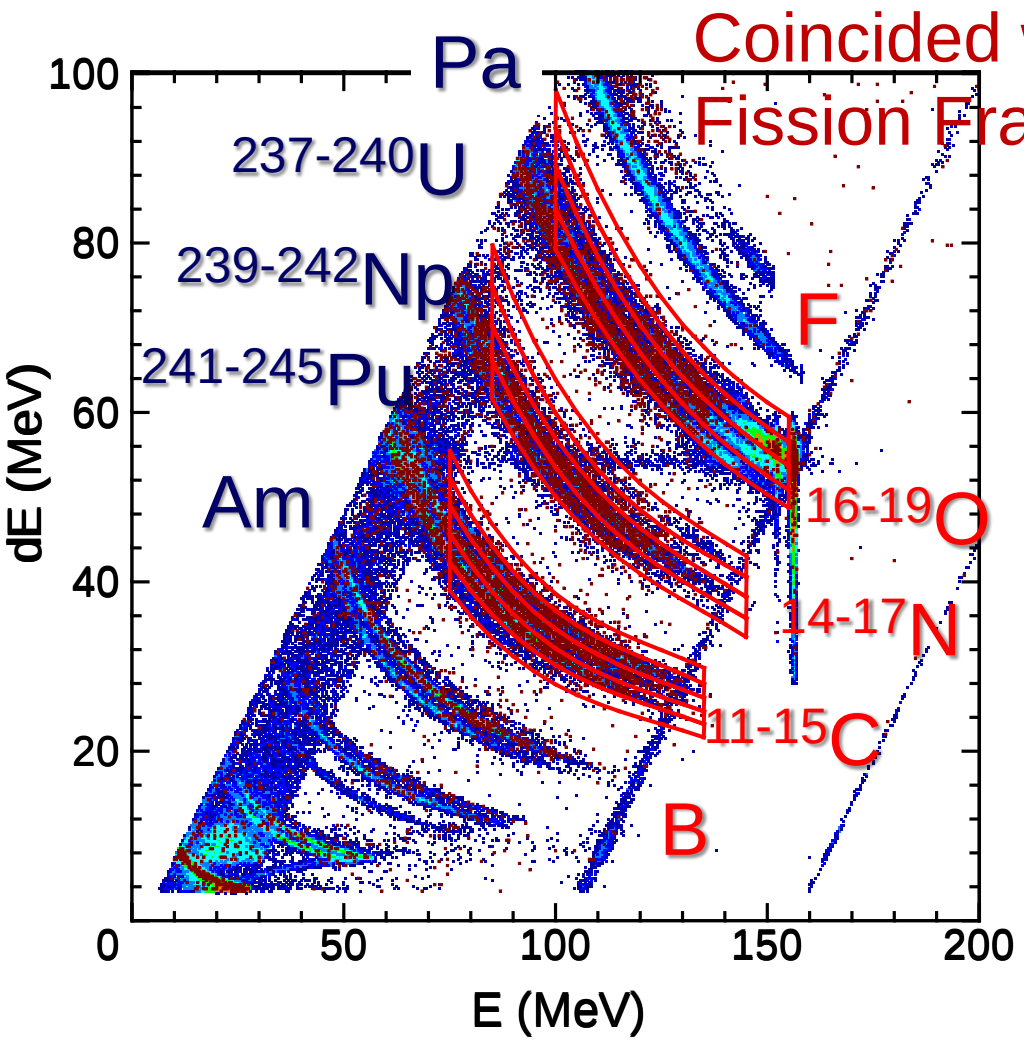






Particle Identification

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



Coincided with Fission Fragment

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

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

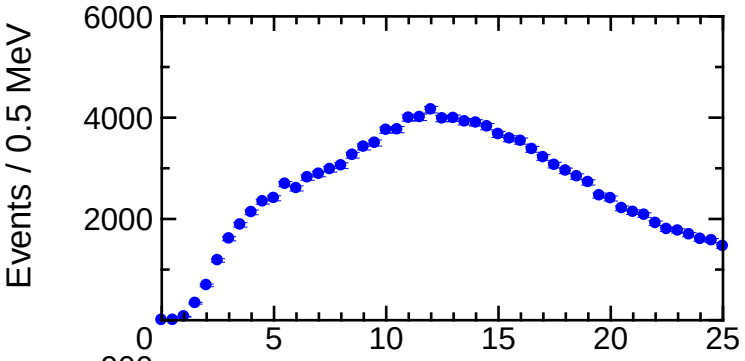
$^{242,241,240,239}Np^{*}$

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

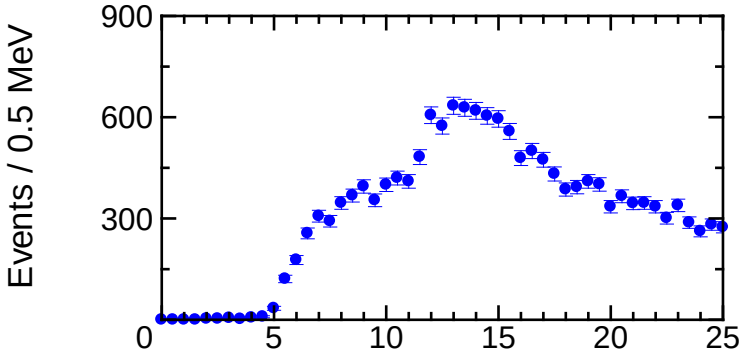
$^{245,244,243,242,241}Pu^{*}$

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

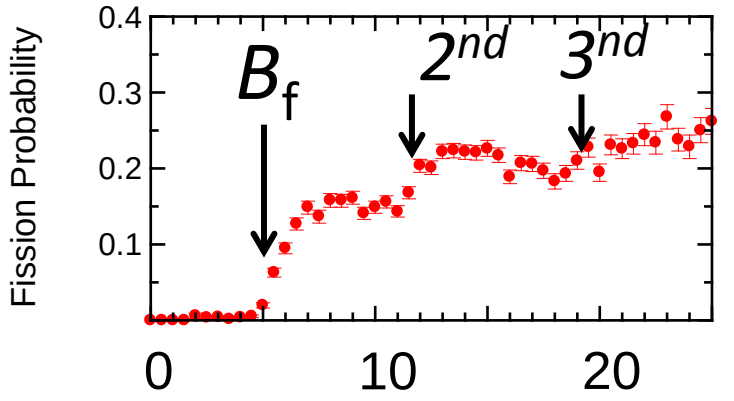
Fission Probability of $^{240}U^{*}$



Spectrum for ^{16}O

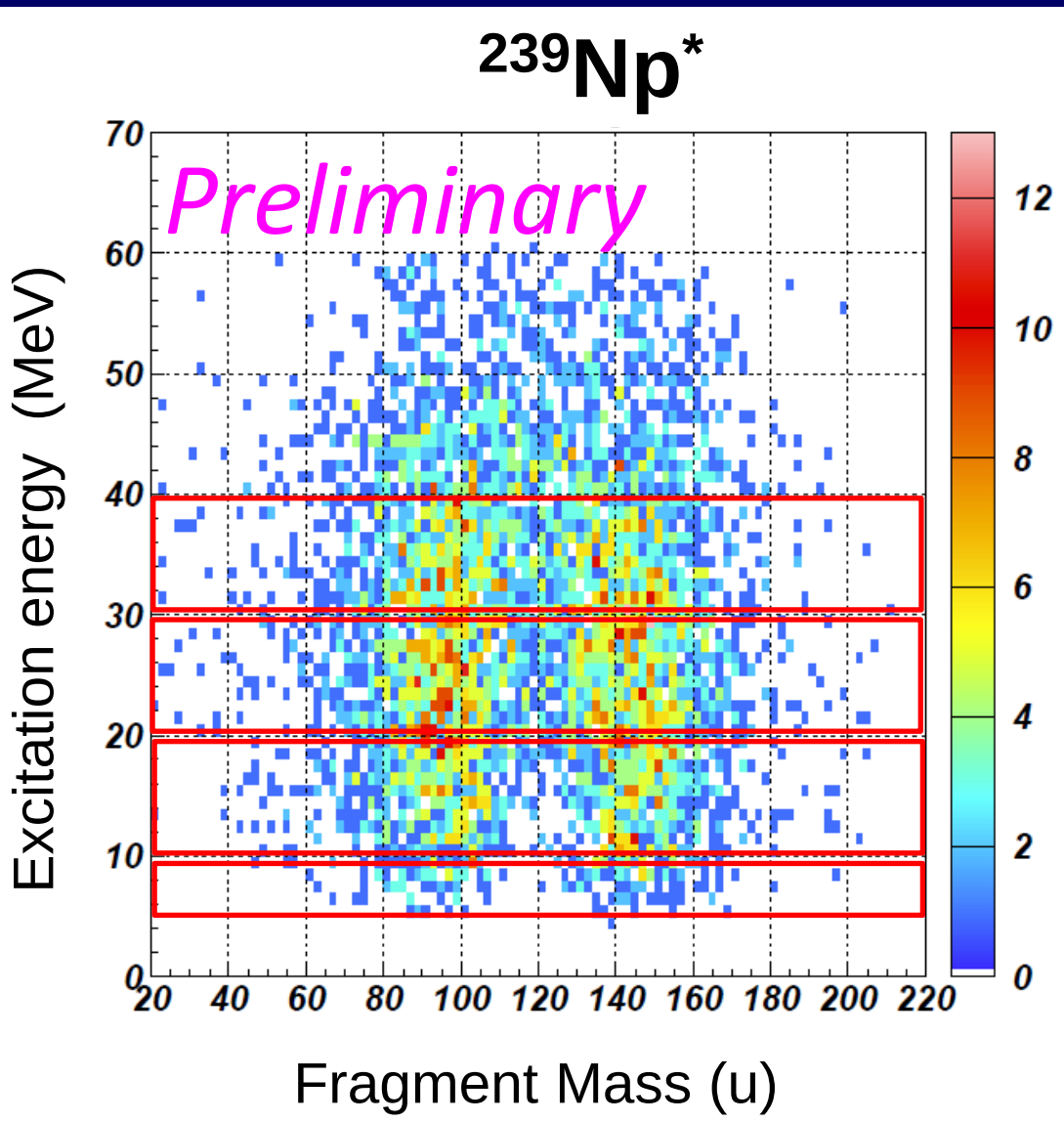


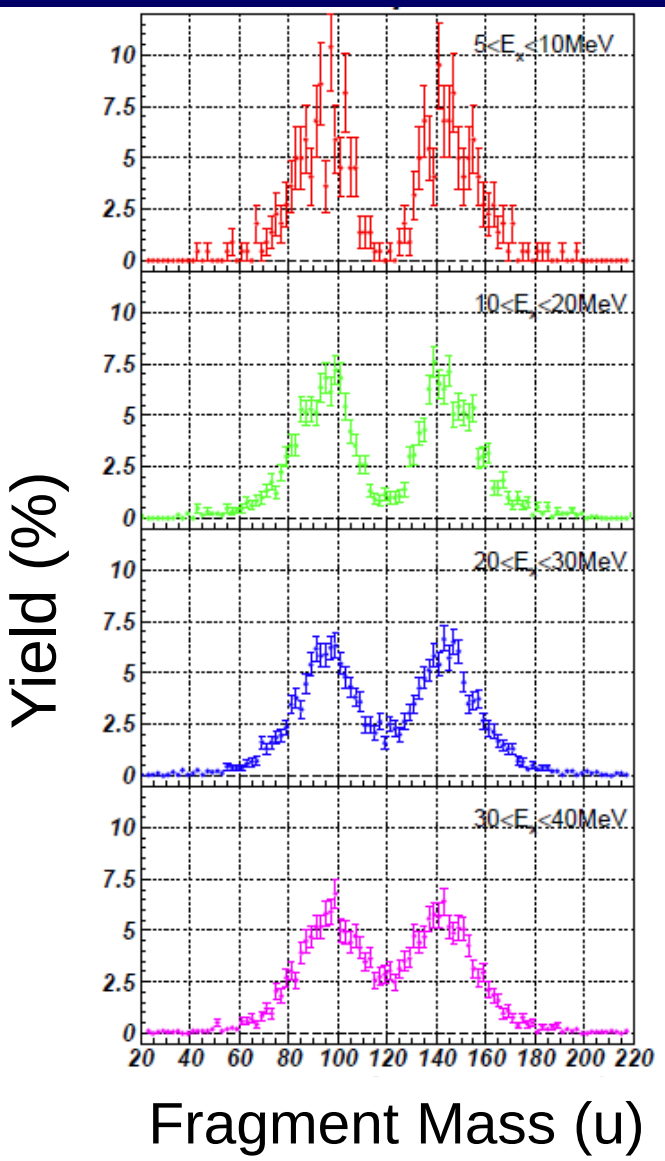
Coincidence between ^{16}O and fission fragments

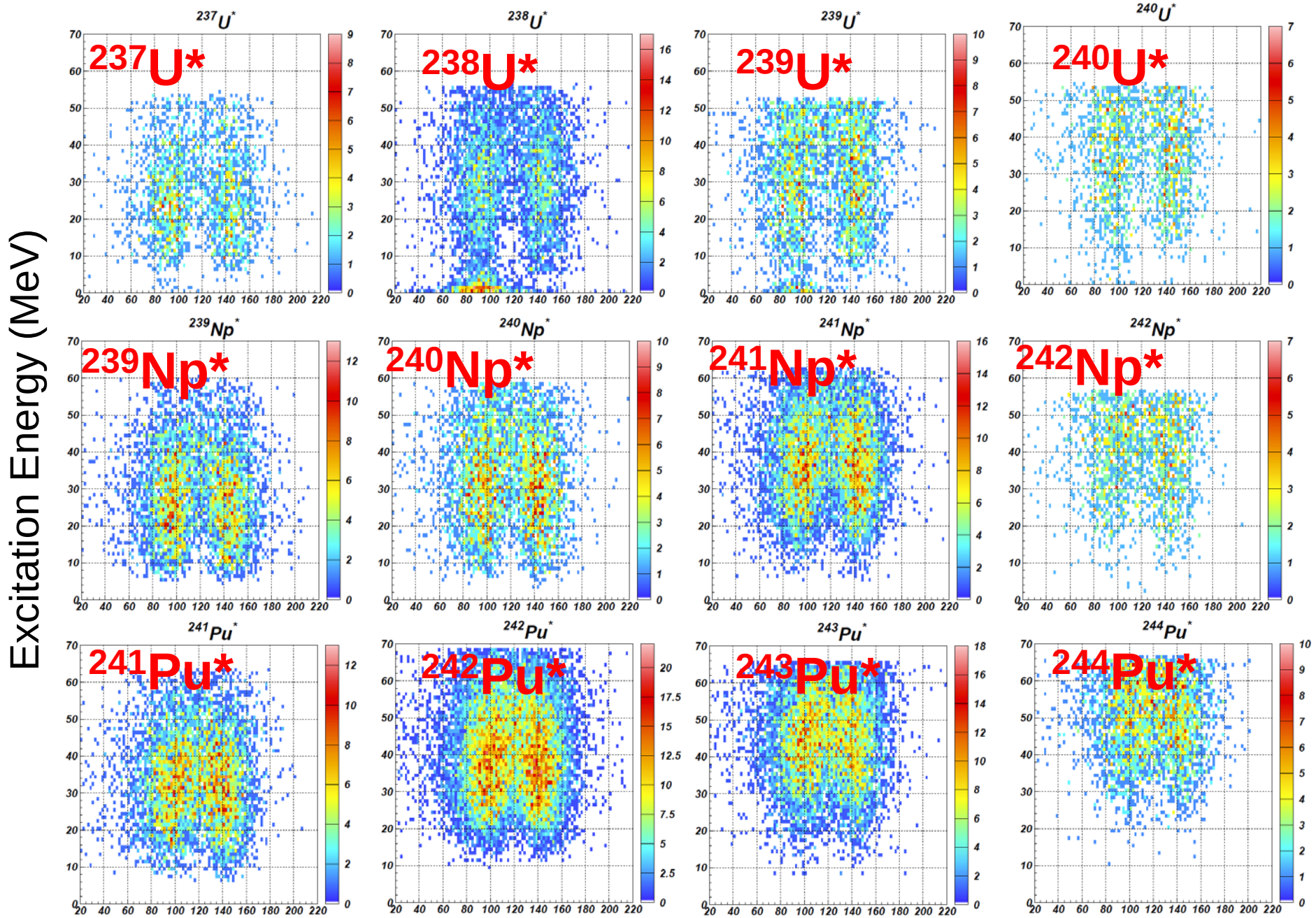


Fission Probability

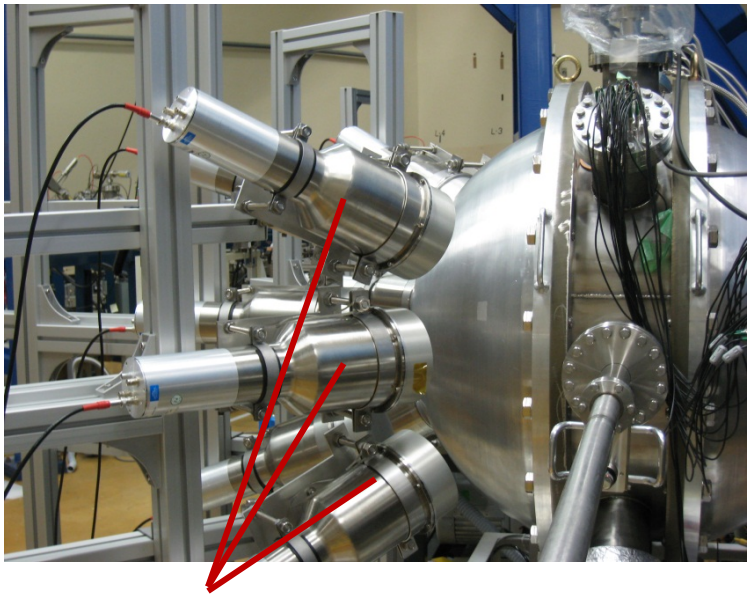
Fission fragment mass distribution



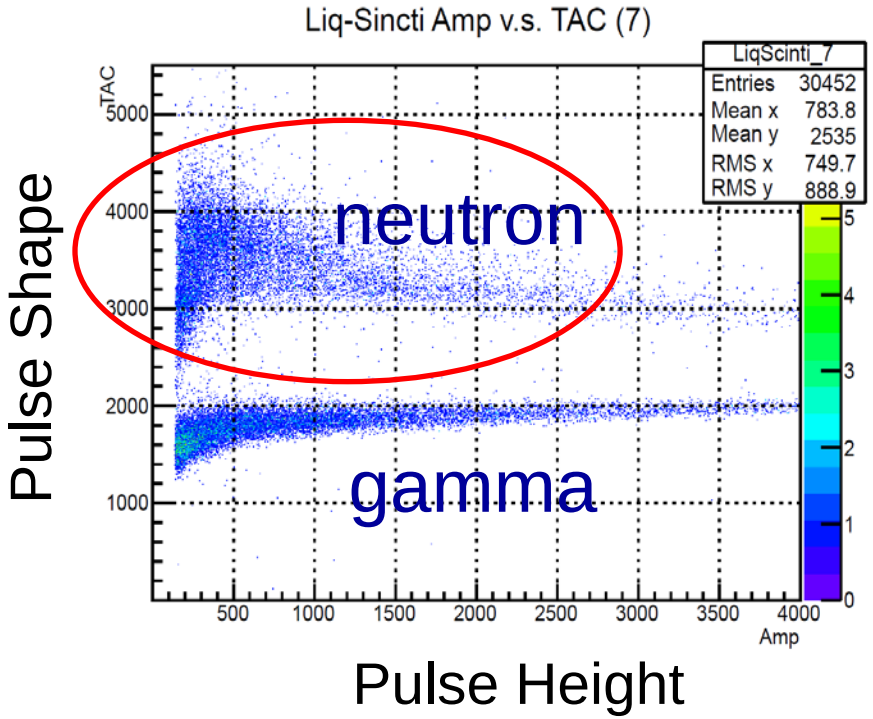



Excitation Energy (MeV)
Fragment Mass (u)
237U*
238U*
239U*
240U*
239Np*
240Np*
241Np*
242Np*
241Pu*
242Pu*
243Pu*
244Pu*

Prompt Neutron Multiplicity in Fission



Neutron Detectors
(Liquid Scintilator)



Summary

- In beam fission experiment can be used to estimate the fusion probability for heavy-element synthesis.
- Using multi-nucleon transfer reactions, nuclear data can be obtained for more than 10 actinide nuclei.

Thank you.