

Fission Research Program at JAEA

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Contents

JAEA tandem facility

Fission study for Heavy-element synthesis

- In-beam fission study

Nucleon-transfer induced Fission and Surrogate Reactions

- Fission of neutron-rich nuclei

Fission cross section measurement at the J-PARC

- Campaign for $^{241}\text{Am}(n,f)$

JAEA Tandem-booster facility

Development :

1982 : 20 MV Tandem accelerator in operation

1994 : Super-conducting Booster Liniac

2008 : ECR Ion Source on the terminal

Research Field :

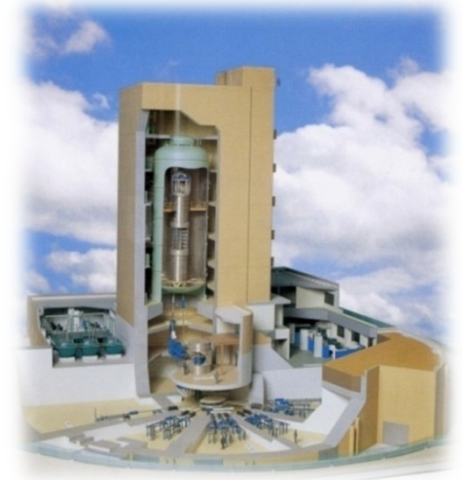
Nuclear Physics

Nuclear Chemistry

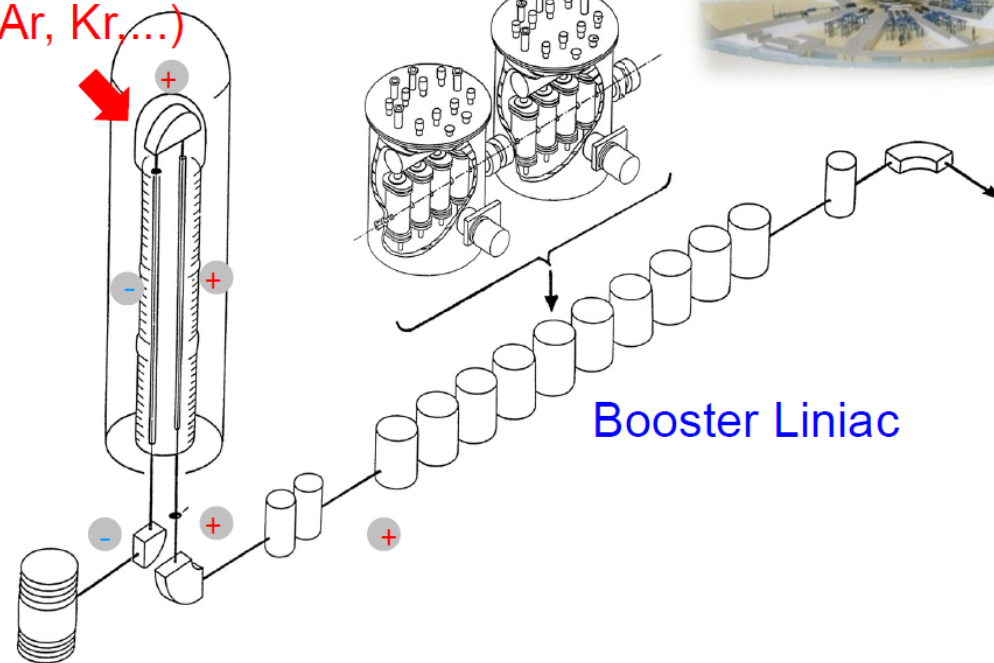
Atomic Physics

Solid state Physics

Medical Applications



ECR Ion Source
(Ne, Ar, Kr,...)



Negative Ion Source

Super-Conducting Booster



Radioactive target materials
Th, U, Np, Pu, Am, Cm
→ *Physics of heavy Element*

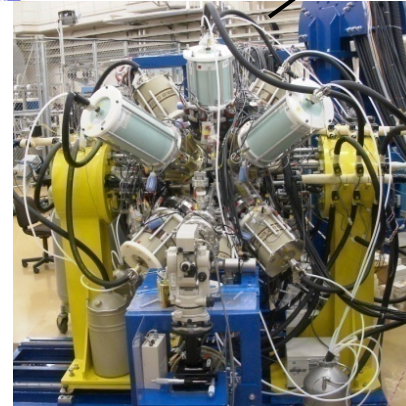
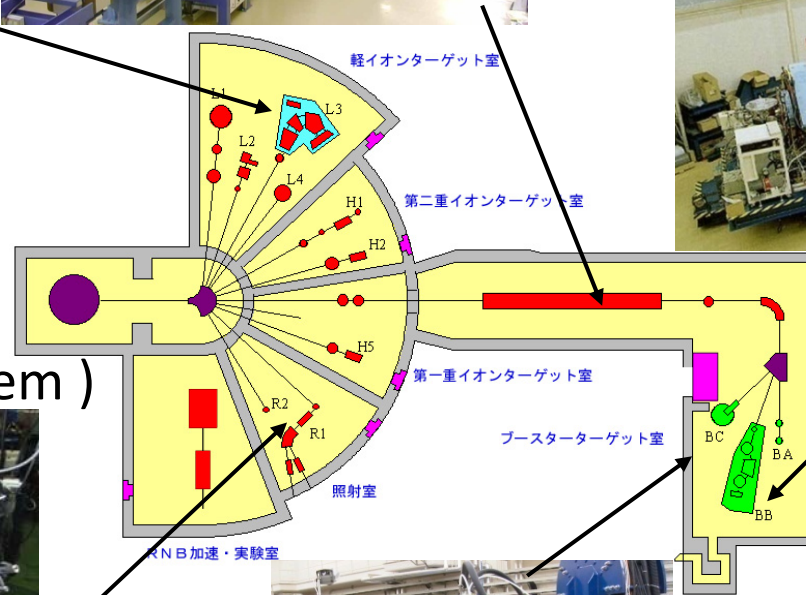
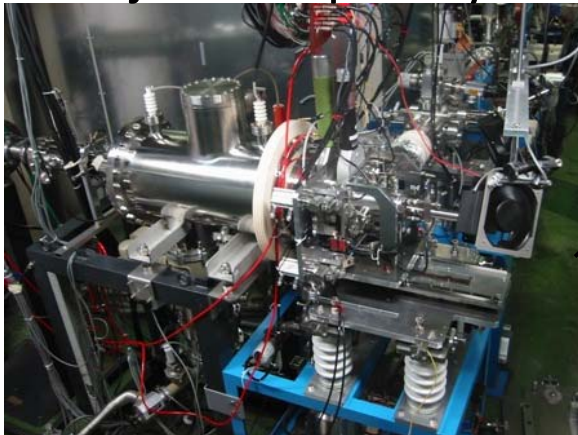
Magnetic Spectrograph



Recoil Mass Separator



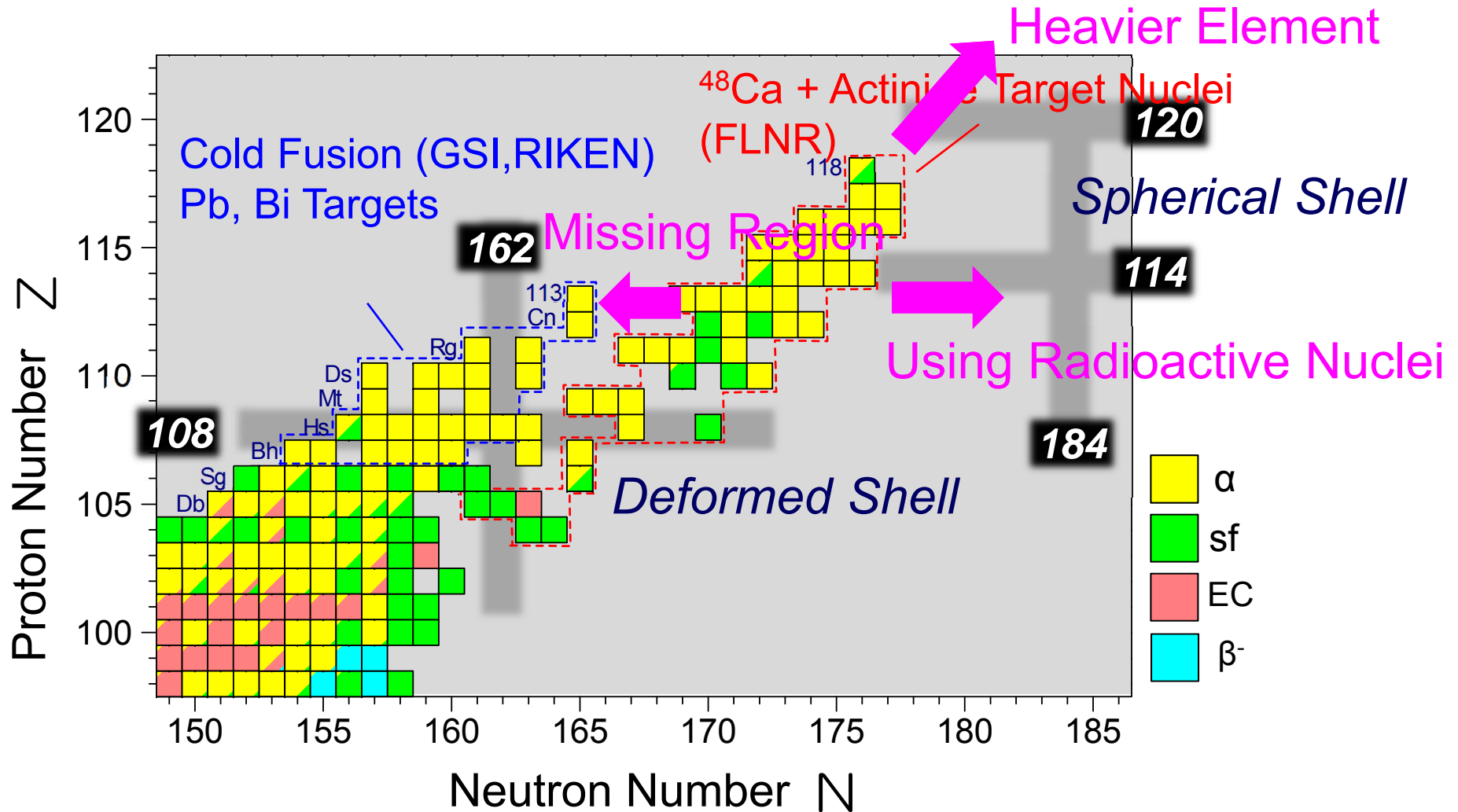
ISOL (Coupled with Gas-jet transport system)



Ge-detector array

Fusion-fission and Quasifission

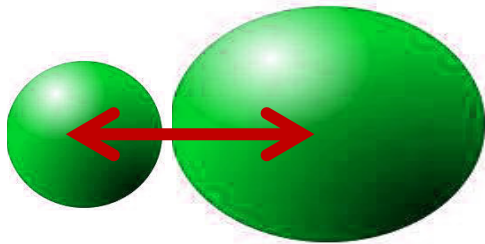
Fission study for heavy-element synthesis



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

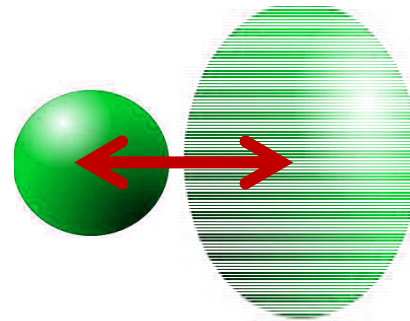
Effects of Nuclear Orientation on Fusion

Actinide nucleus has deformed shape



Polar collision

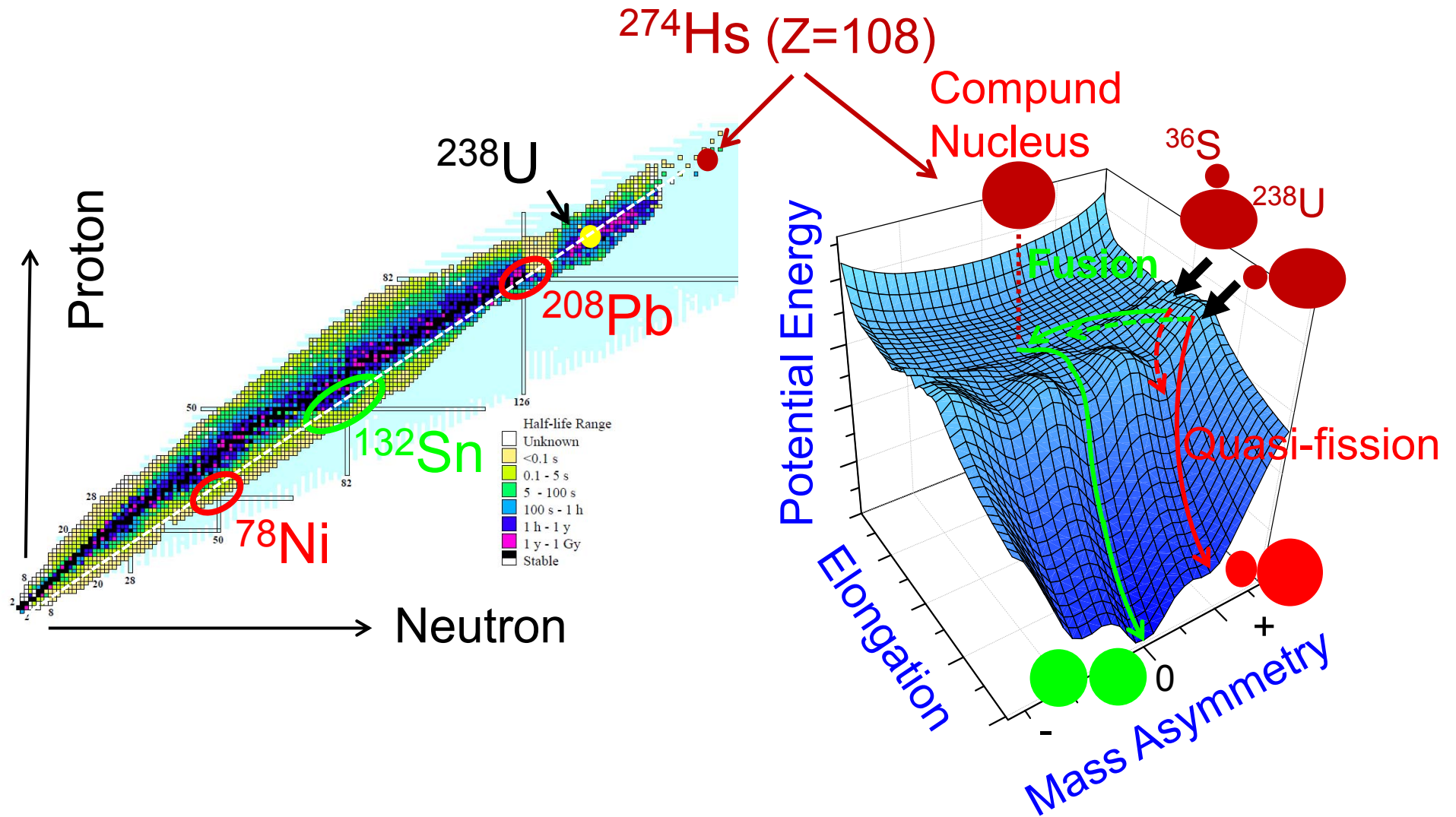
- Low Coulomb Barrier
- Distant configuration



Equatorial collision

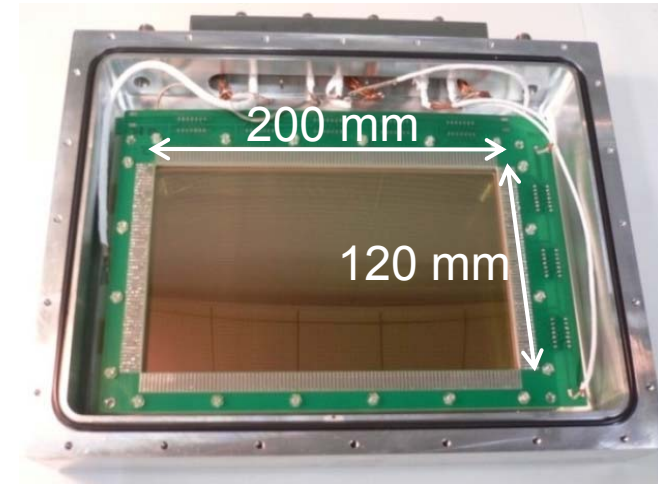
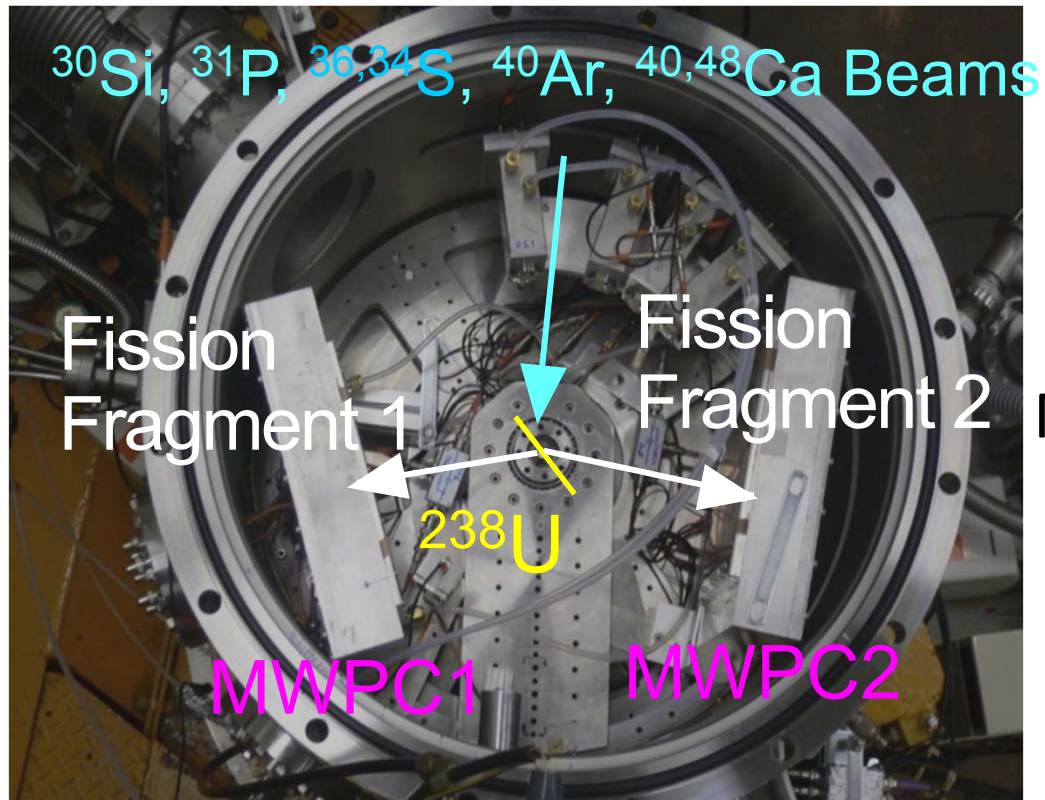
- High Coulomb Barrier
- Compact configuration

Fusion-fission and Quasi-fission

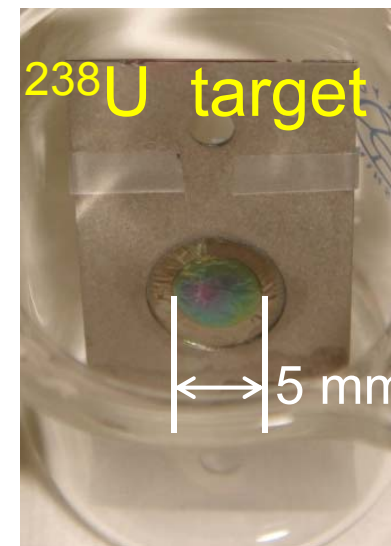


Potential by Y. Aritomo

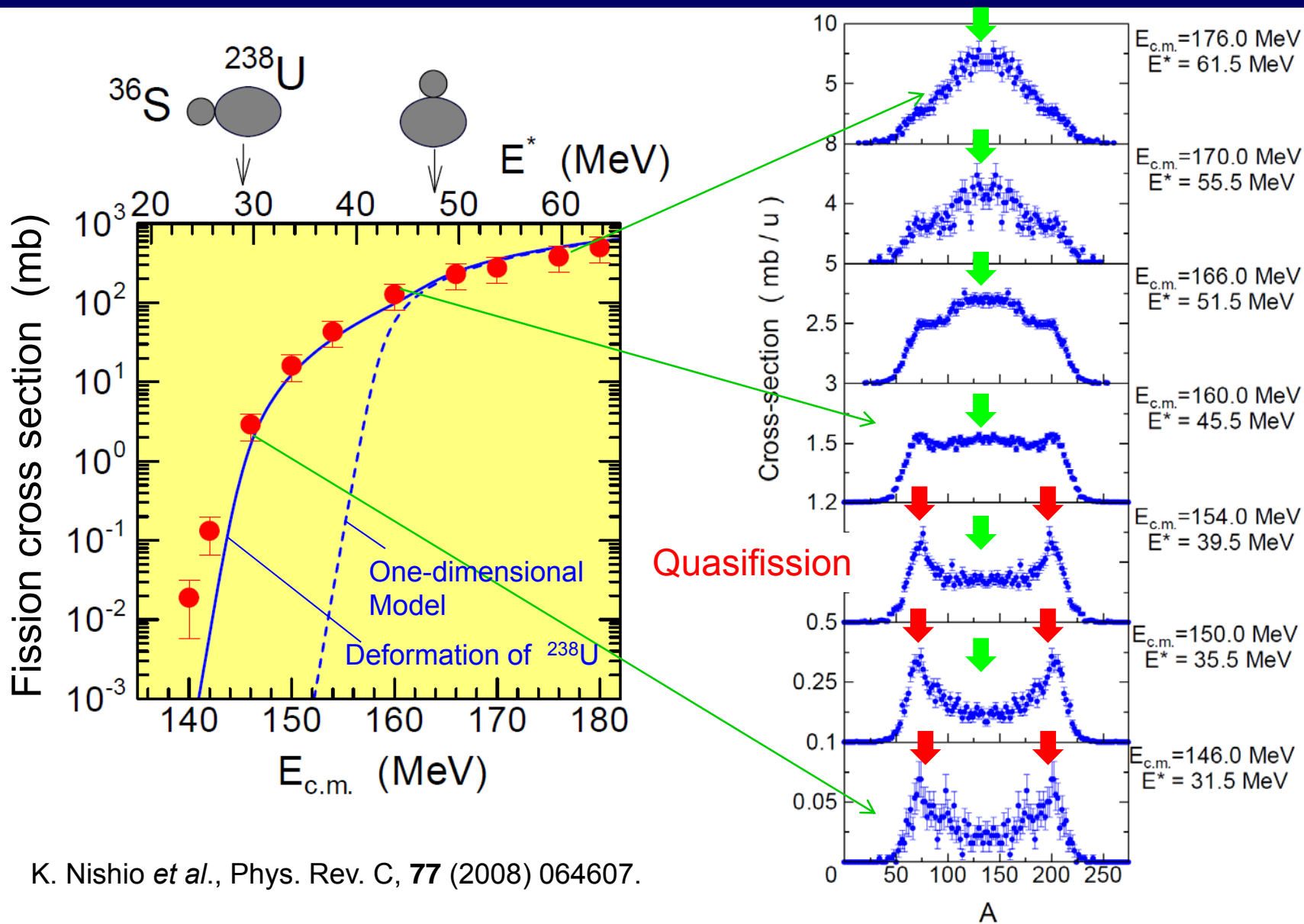
In-Beam Fission Measurement



Multi-Wire Proportional Counter

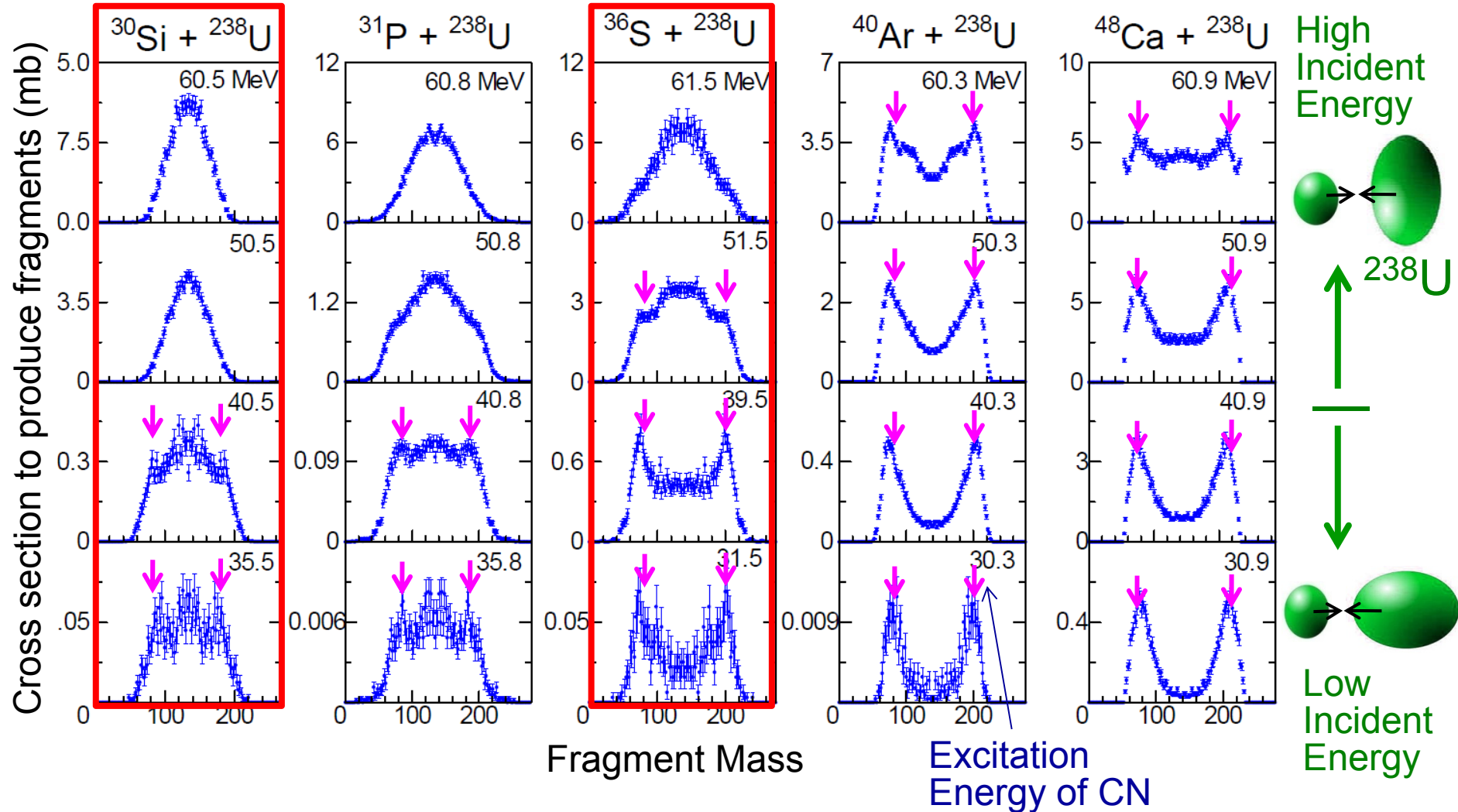


Orientation effects on fragment mass distributions in $^{36}\text{S} + ^{238}\text{U}$



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

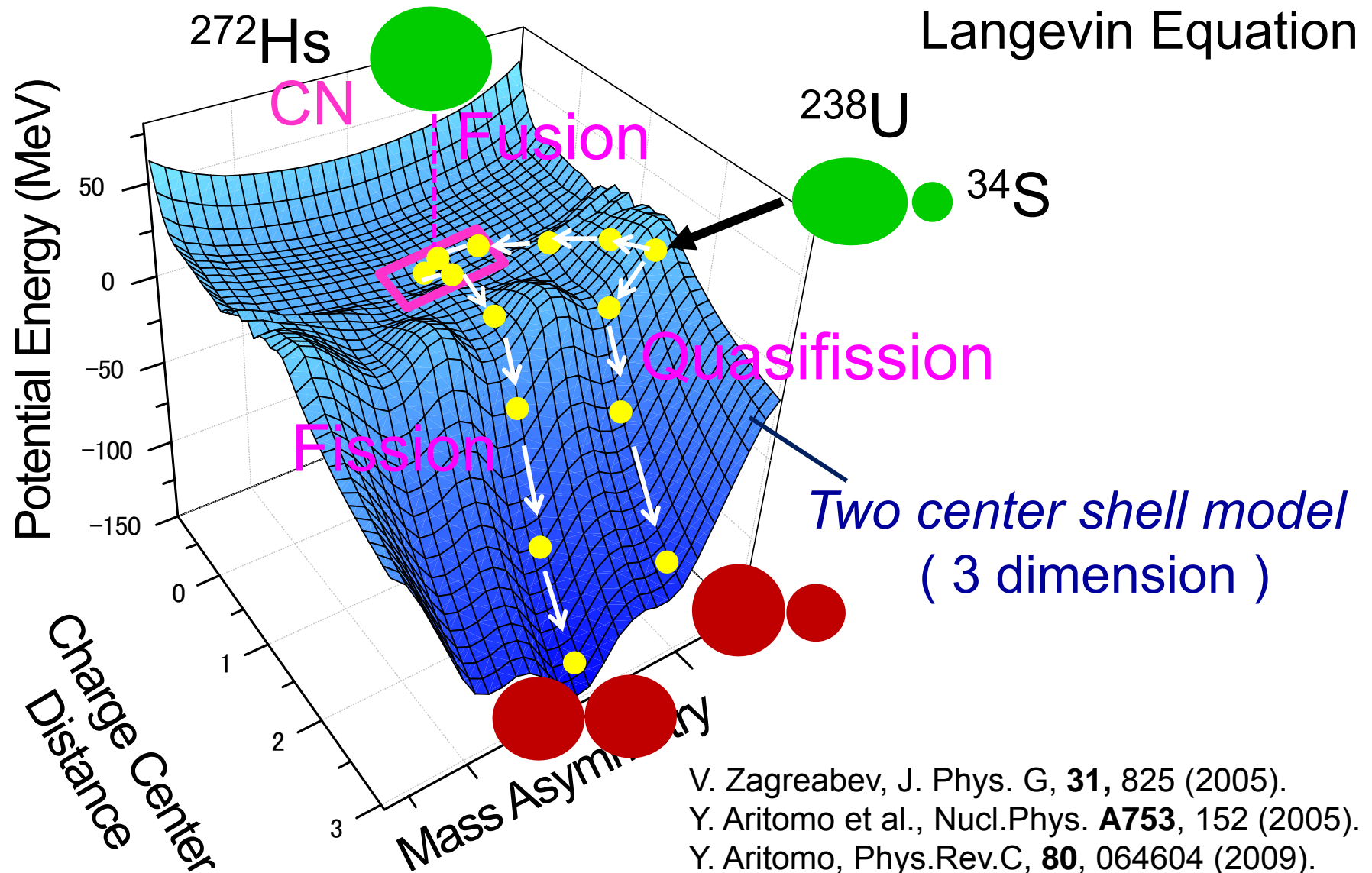
Fission Fragment Mass Distributions



Quasifission

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

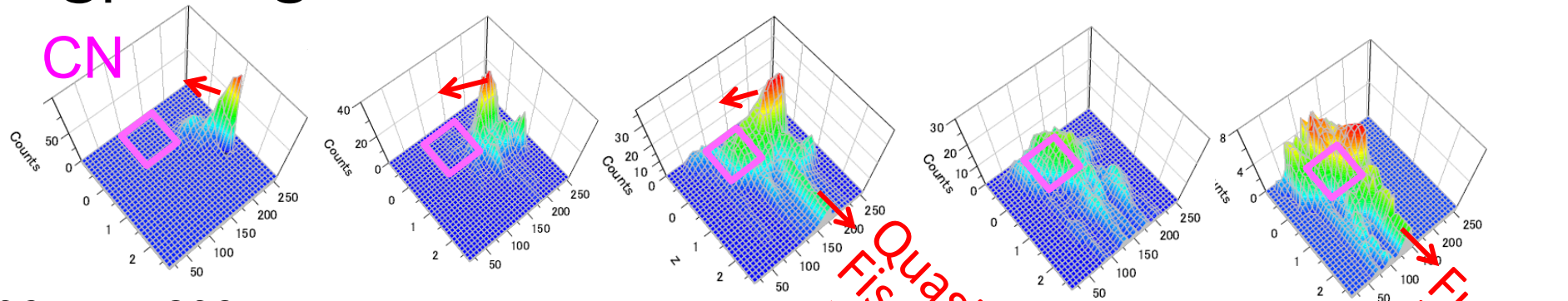
Dynamical calculation of nuclear shape – Fluctuation dissipation model –



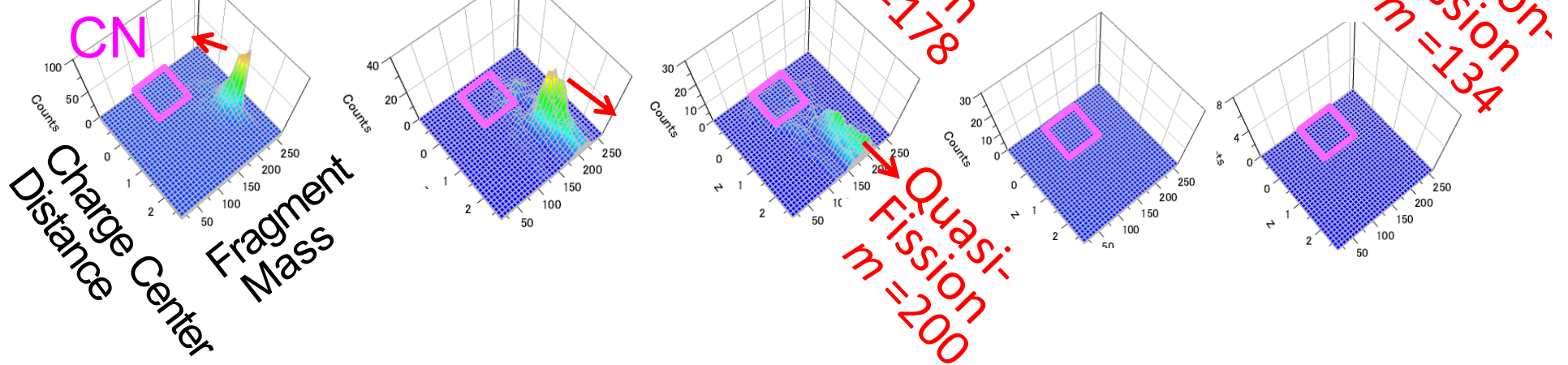
Shape evolution

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

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



$^{36}\text{S} + ^{238}\text{U}$



(c)

0 – 5

5 – 10

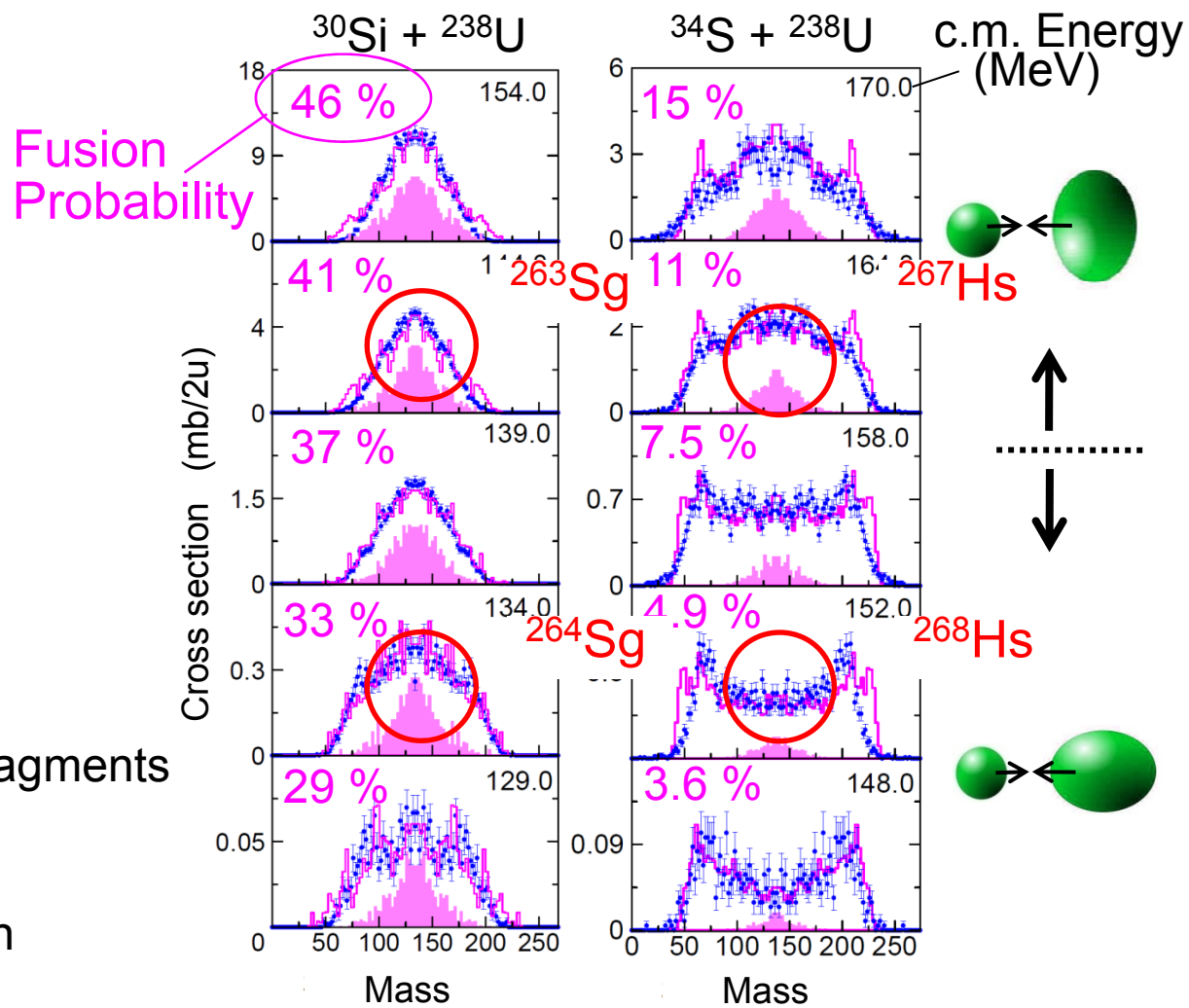
10 – 30

30 – 50

> 50

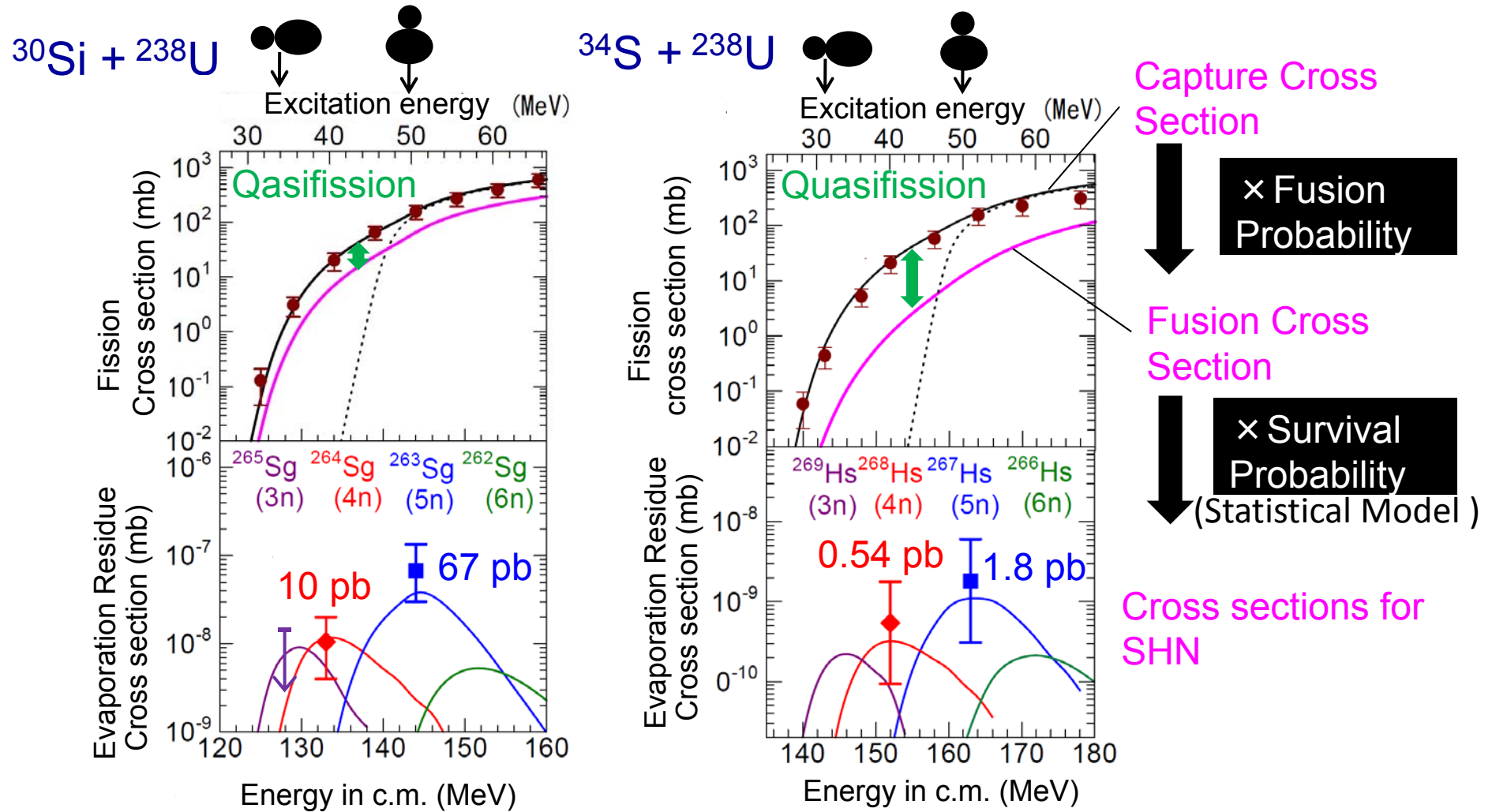
Time ($\times 10^{-21}$ s)

Fusion probability



- { Histogram
- } All Fission Fragments
- { Filled Area
- } Fusion-Fission
- { • Experimental Data
- }

Fusion and ER cross sections

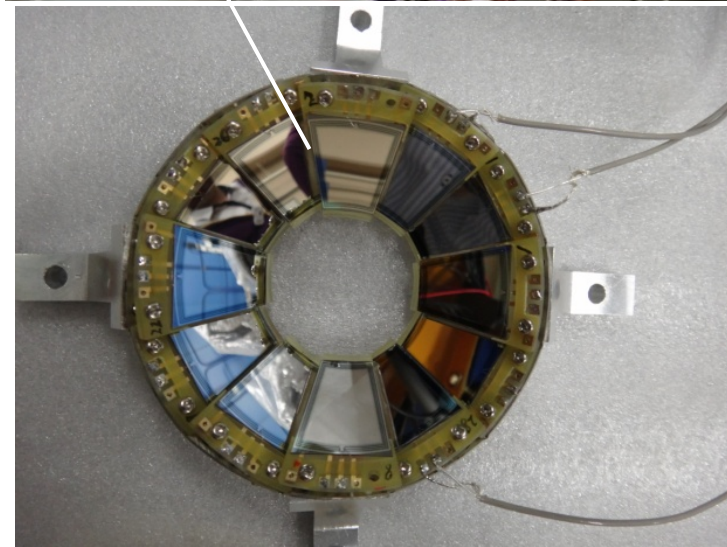
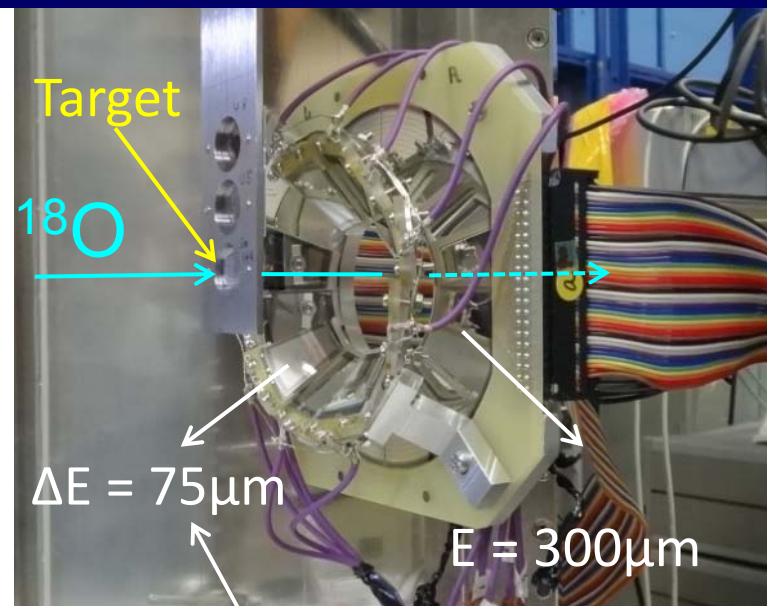
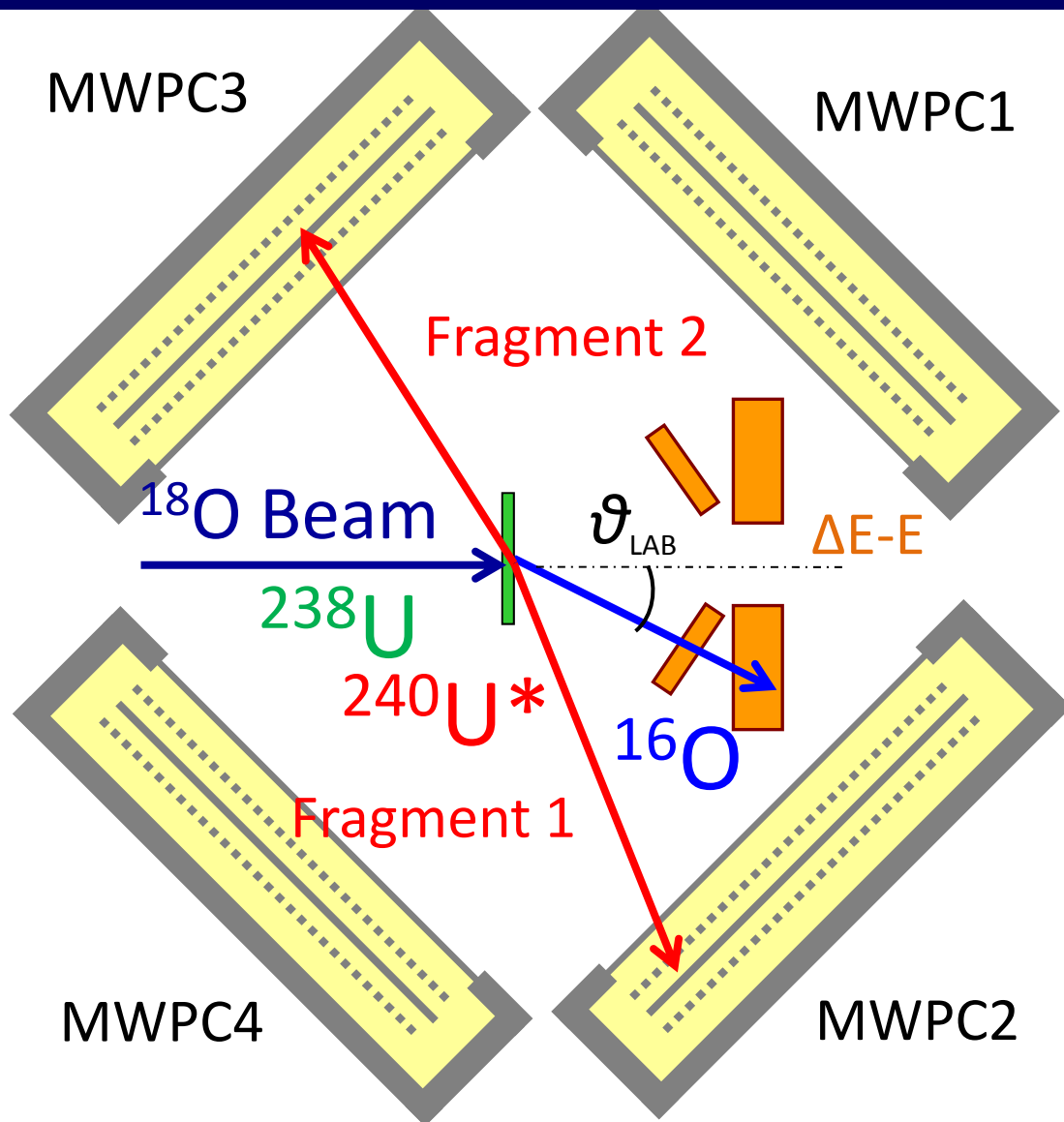


K. Nishio *et al.*, PRC **82**, 044604 (2010).

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

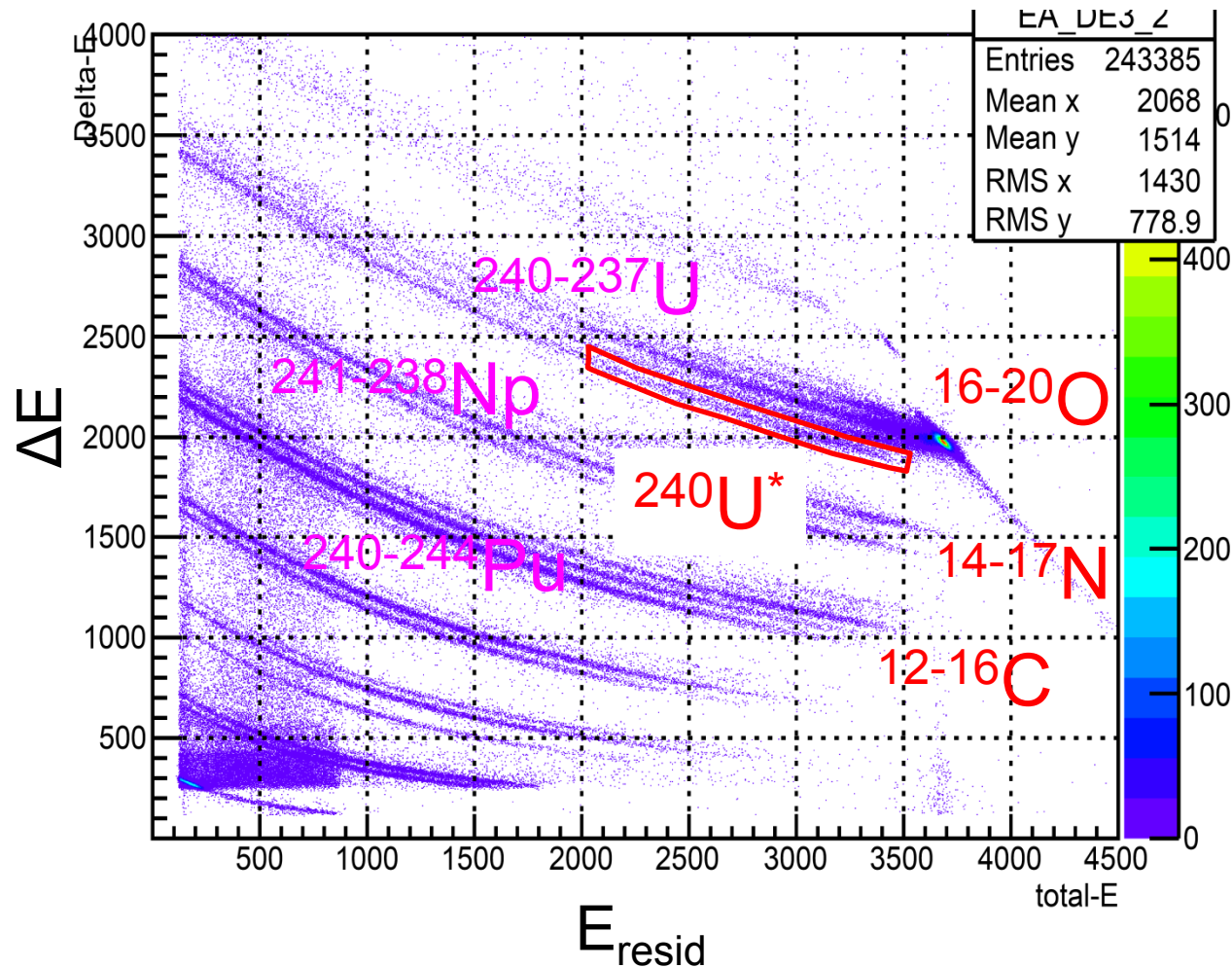
Nucleon-transfer Induced Fission and Surrogate Reactions

Experimental Setup



Particle Identification and Surrogate Reaction

$^{18}\text{O} + ^{238}\text{U}$



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

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

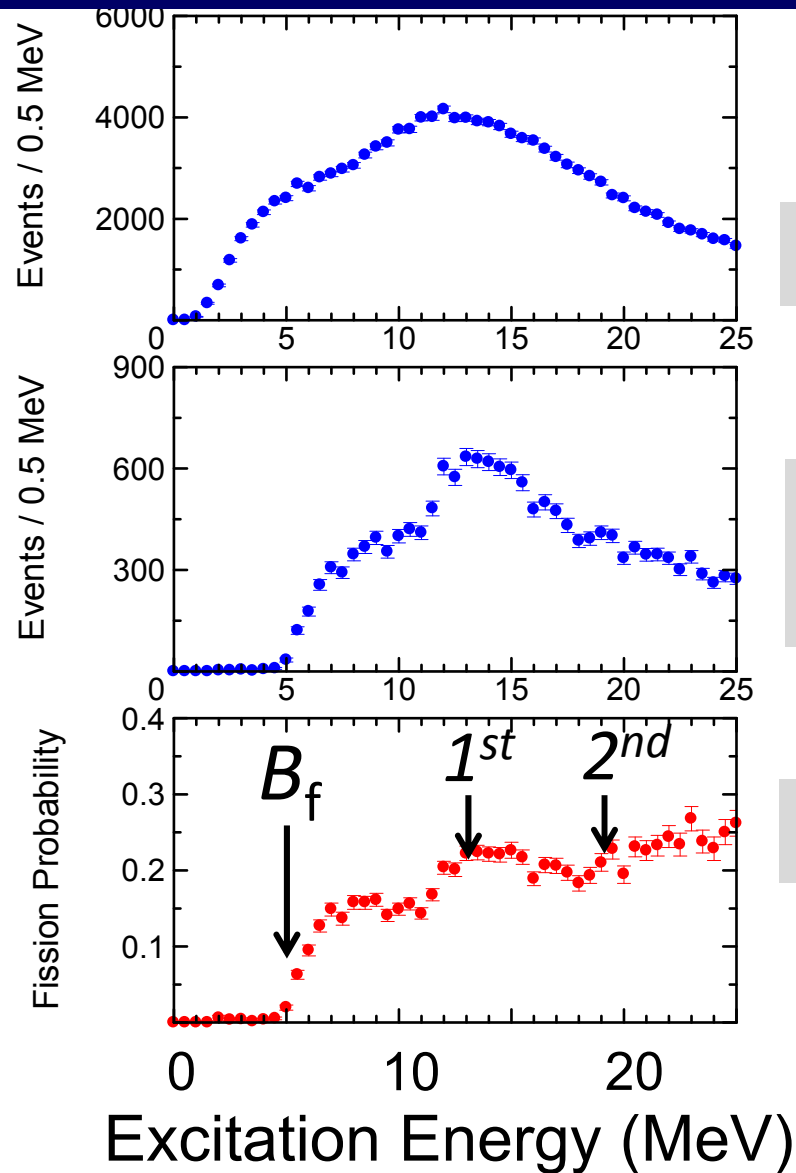
$^{242,241,240,239}\text{Np}^*$

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

$^{244,243,242,241,240}\text{Pu}^*$

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

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



Excitation Energy (MeV)

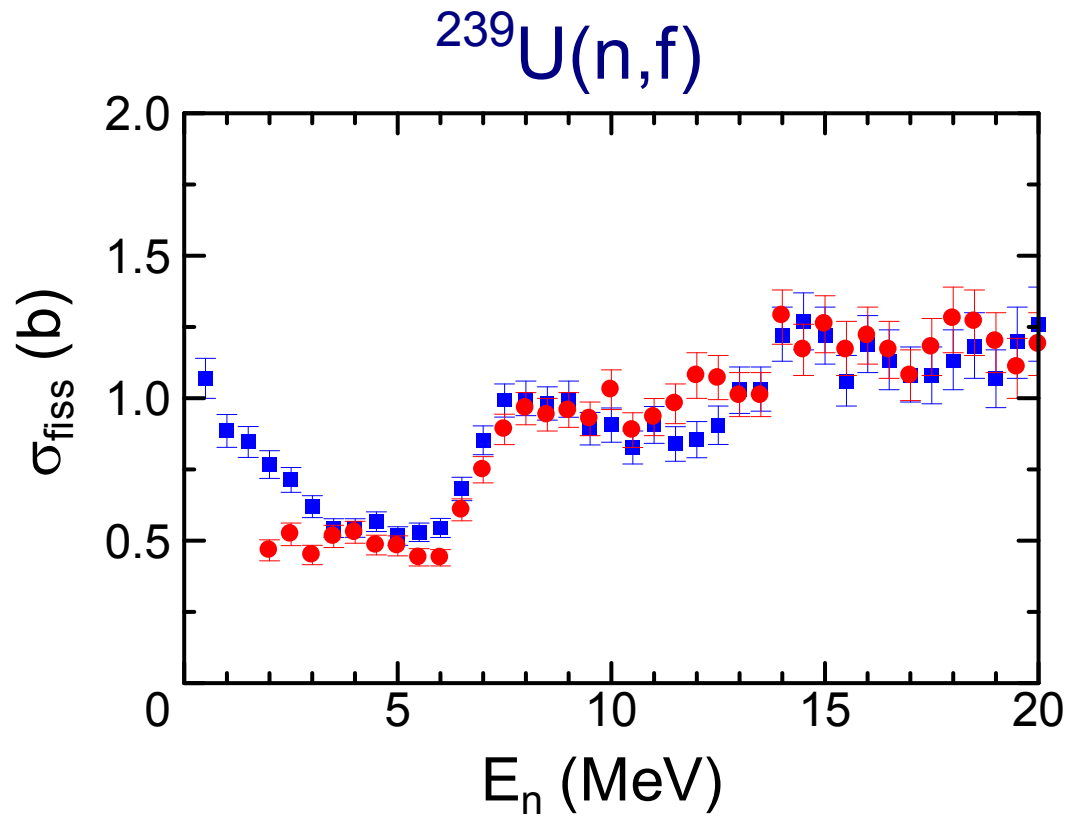
(A) Spectrum for ^{16}O

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

(C) Fission Probability

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

Fission cross sections in surrogate reaction

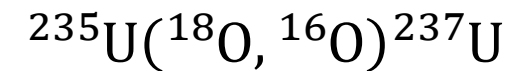
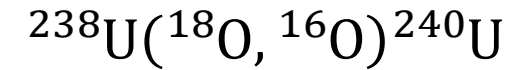


$^{239}\text{U} : T_{1/2} (^{239}\text{U}) = 23.5\text{m}$

ENDF/B-VII

$\sigma^{236}\text{U}(n,f)$

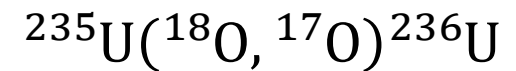
$$\frac{B_f(^{240}\text{U}^*)}{B_f(^{237}\text{U}^*)}$$

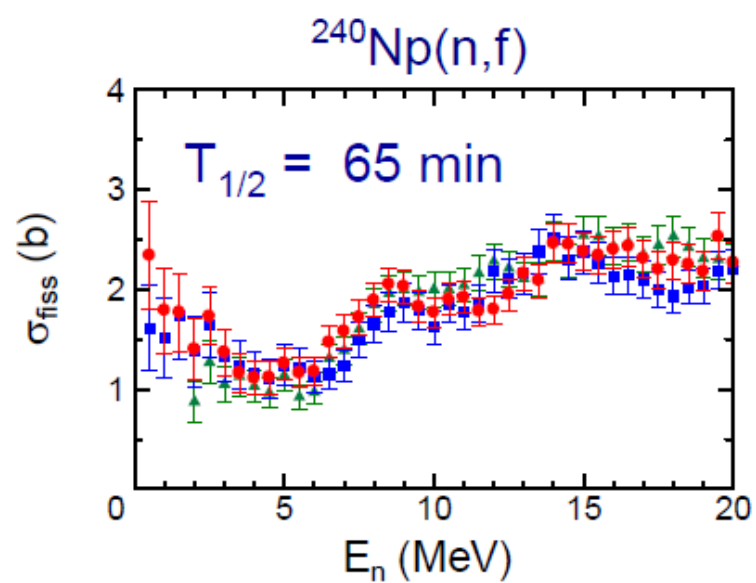
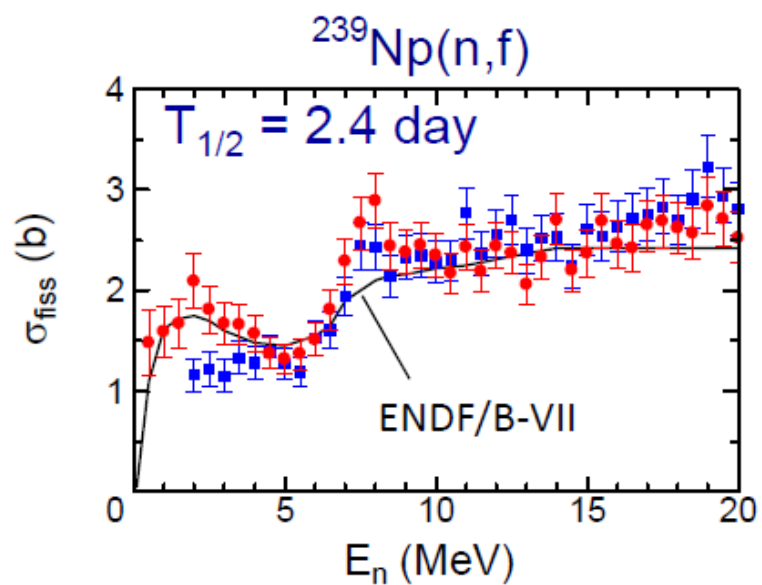
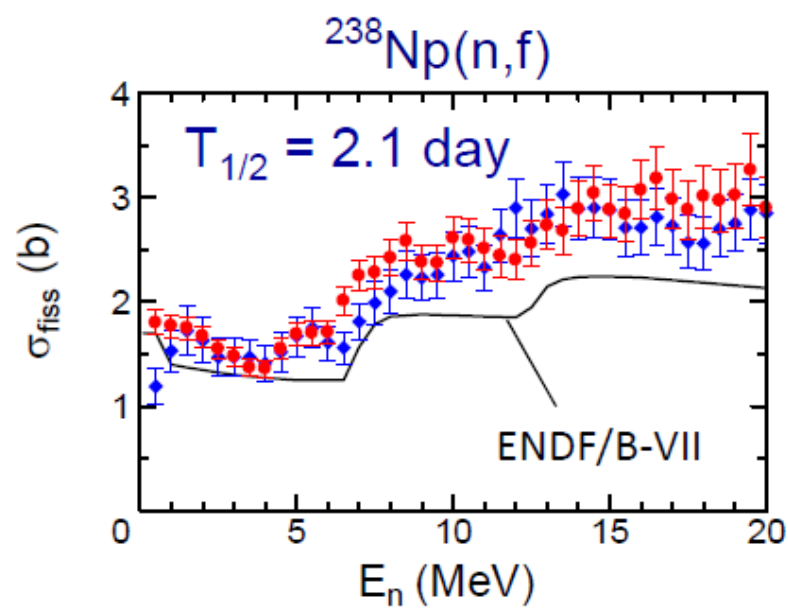
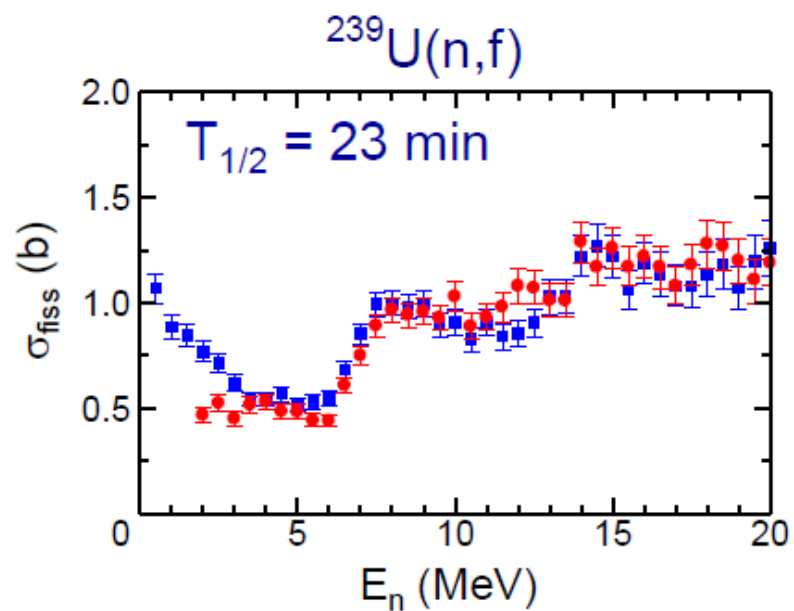


ENDF/B-VII

$\sigma^{235}\text{U}(n,f)$

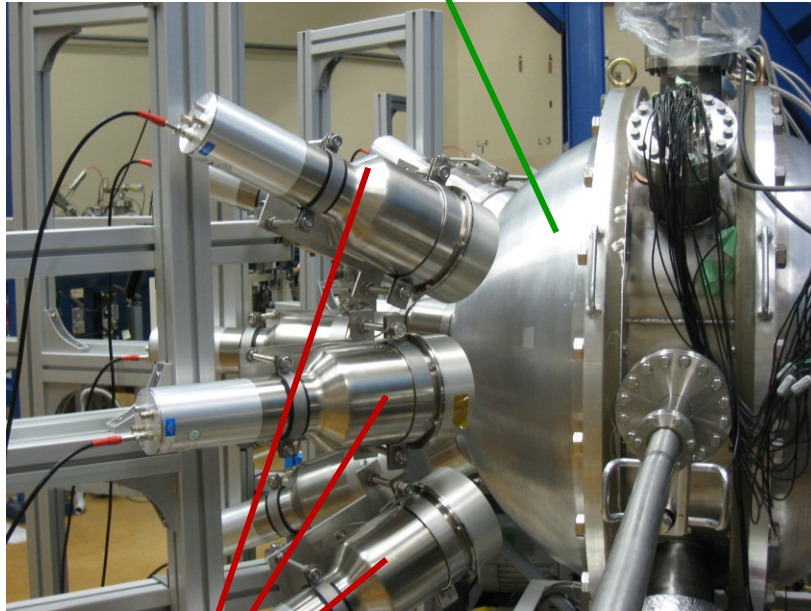
$$\frac{B_f(^{237}\text{U}^*)}{B_f(^{236}\text{U}^*)}$$





Prompt Fission Neutron Multiplicity in Fission

Fission Vacuum Chamber



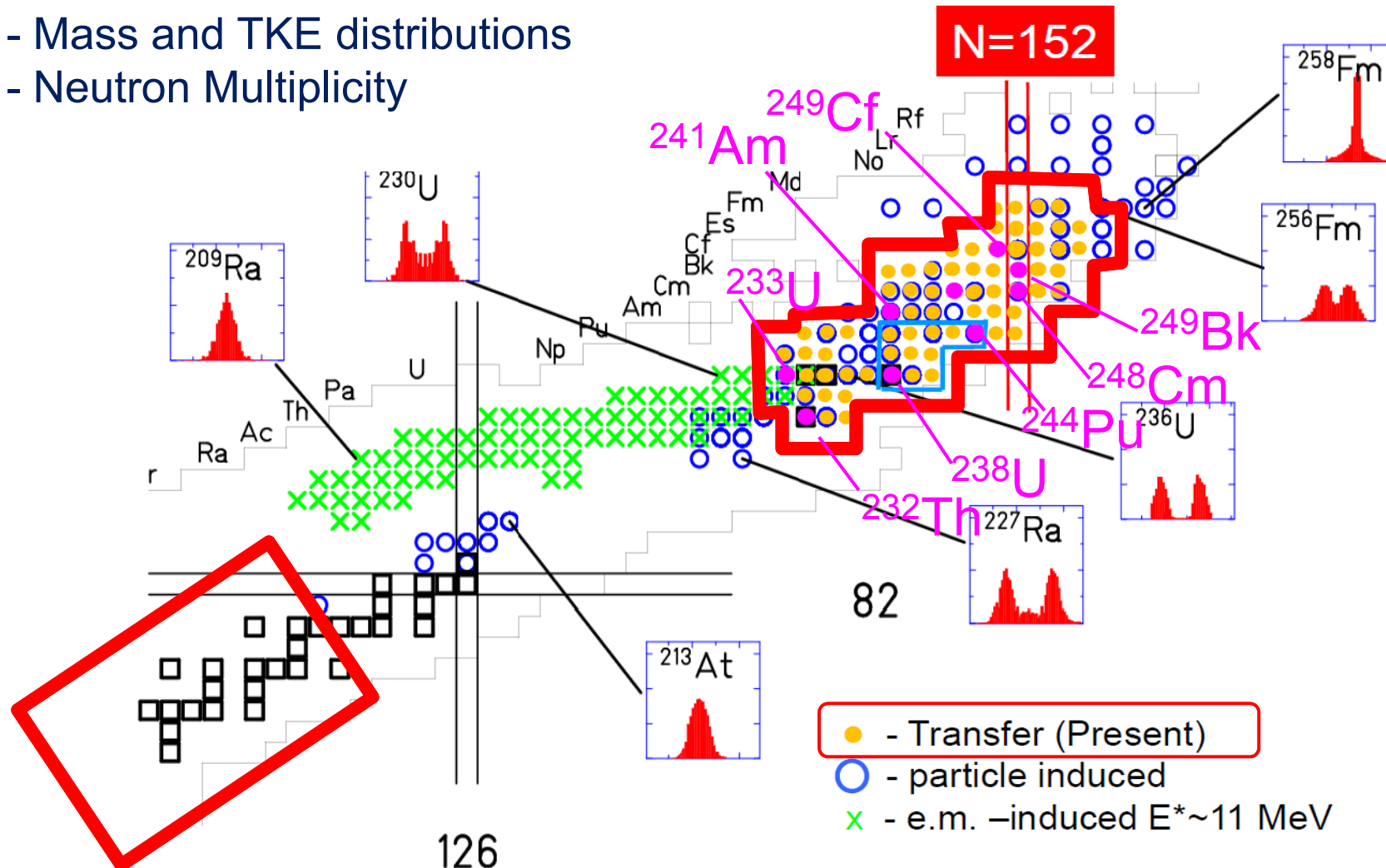
Neutron Detectors

12 Liquid Scintillators
($\varnothing = 127$ mm, $t = 50$ mm)

Fission fragment mass/charge distributions

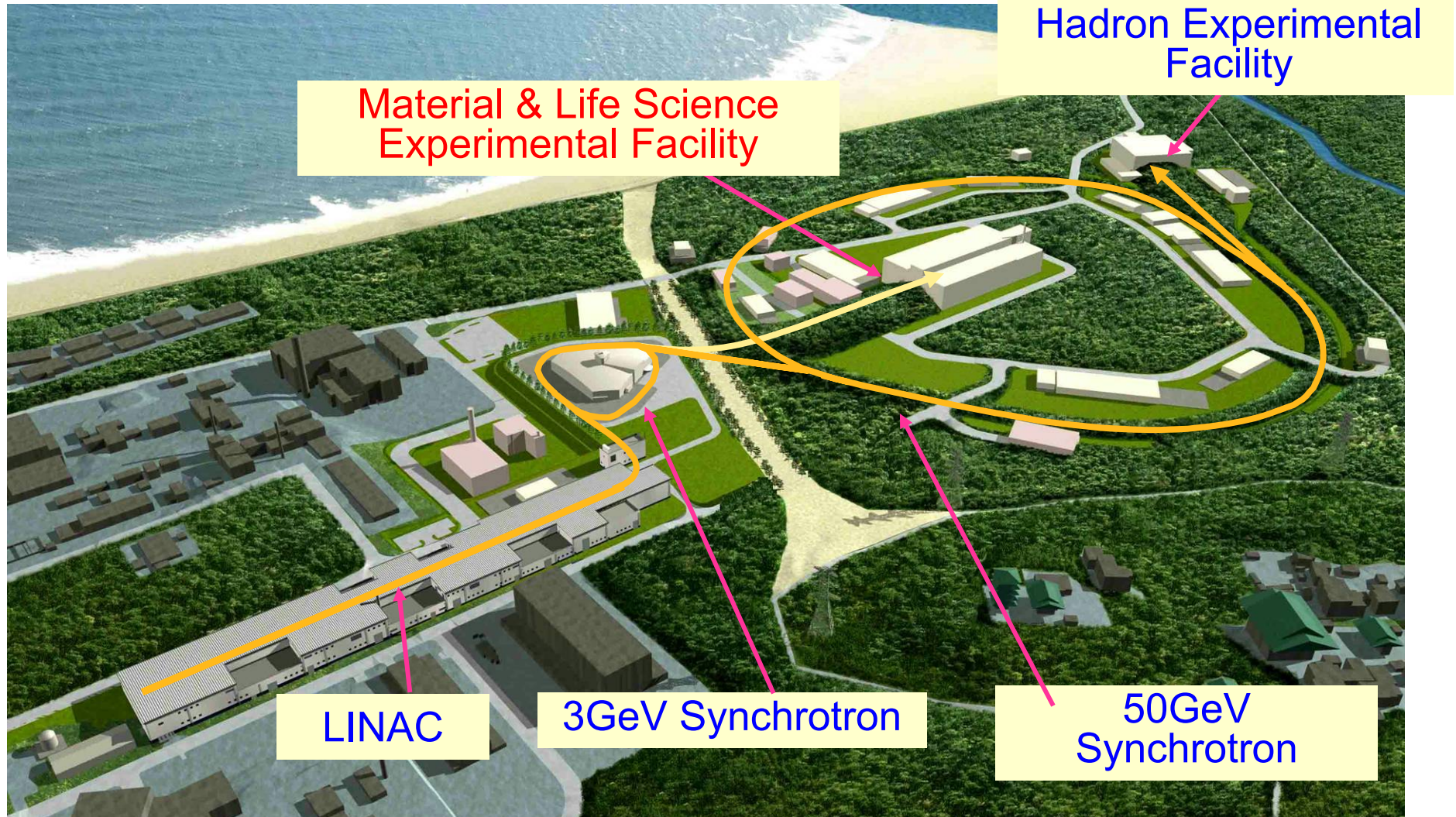
New Data for 38 Nuclei

- Mass and TKE distributions
- Neutron Multiplicity

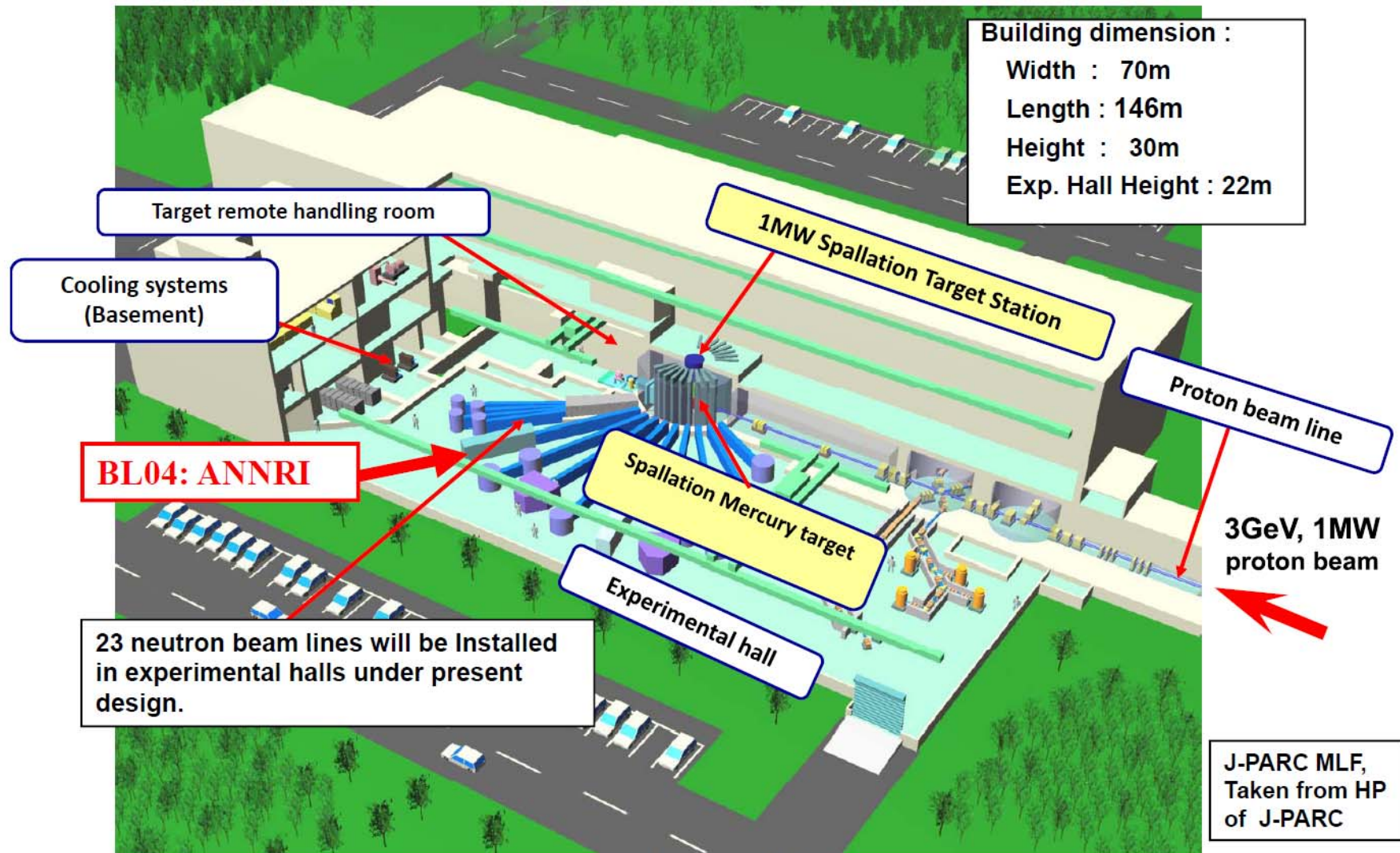


Neutron-induced Fission

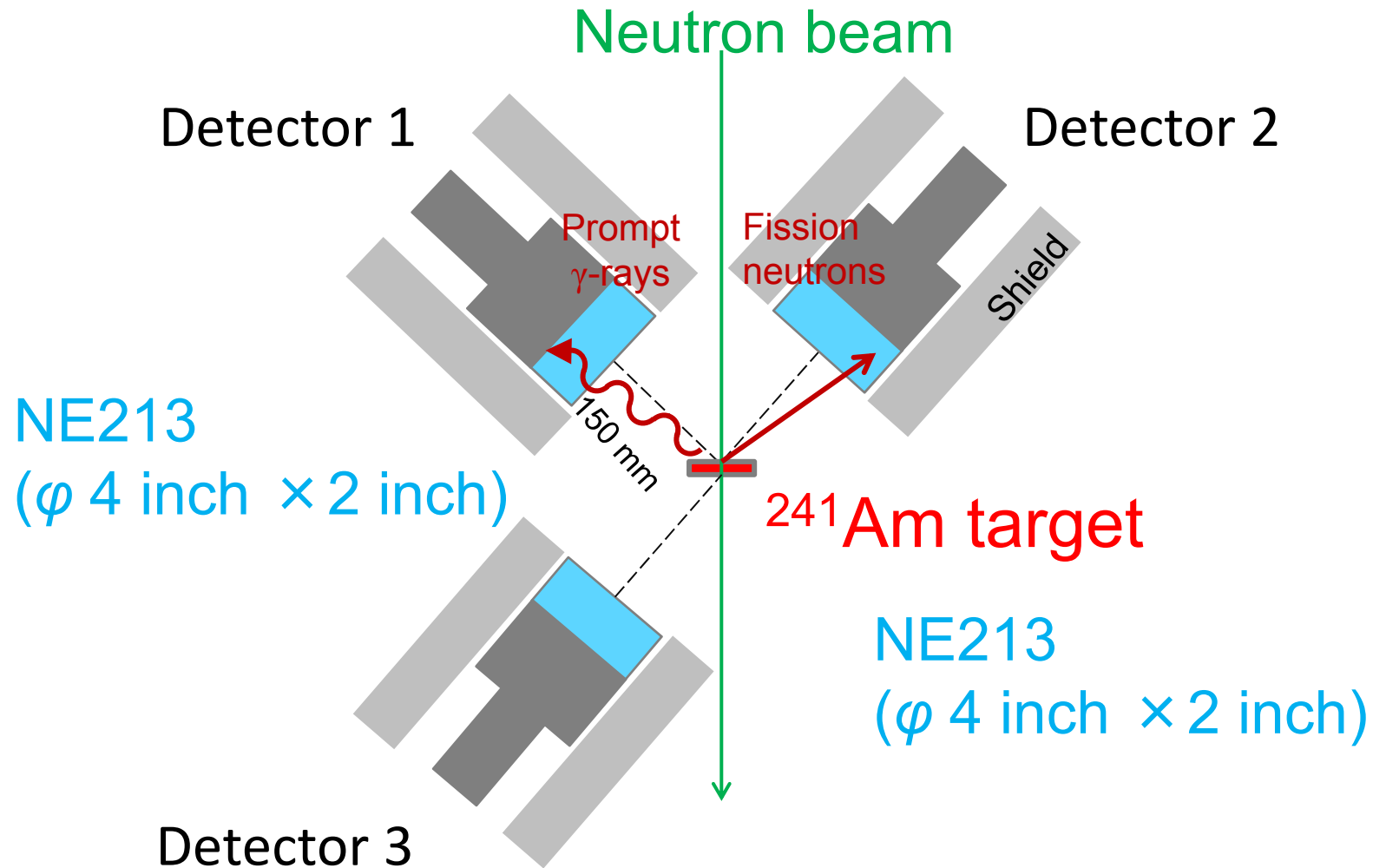
J-PARC



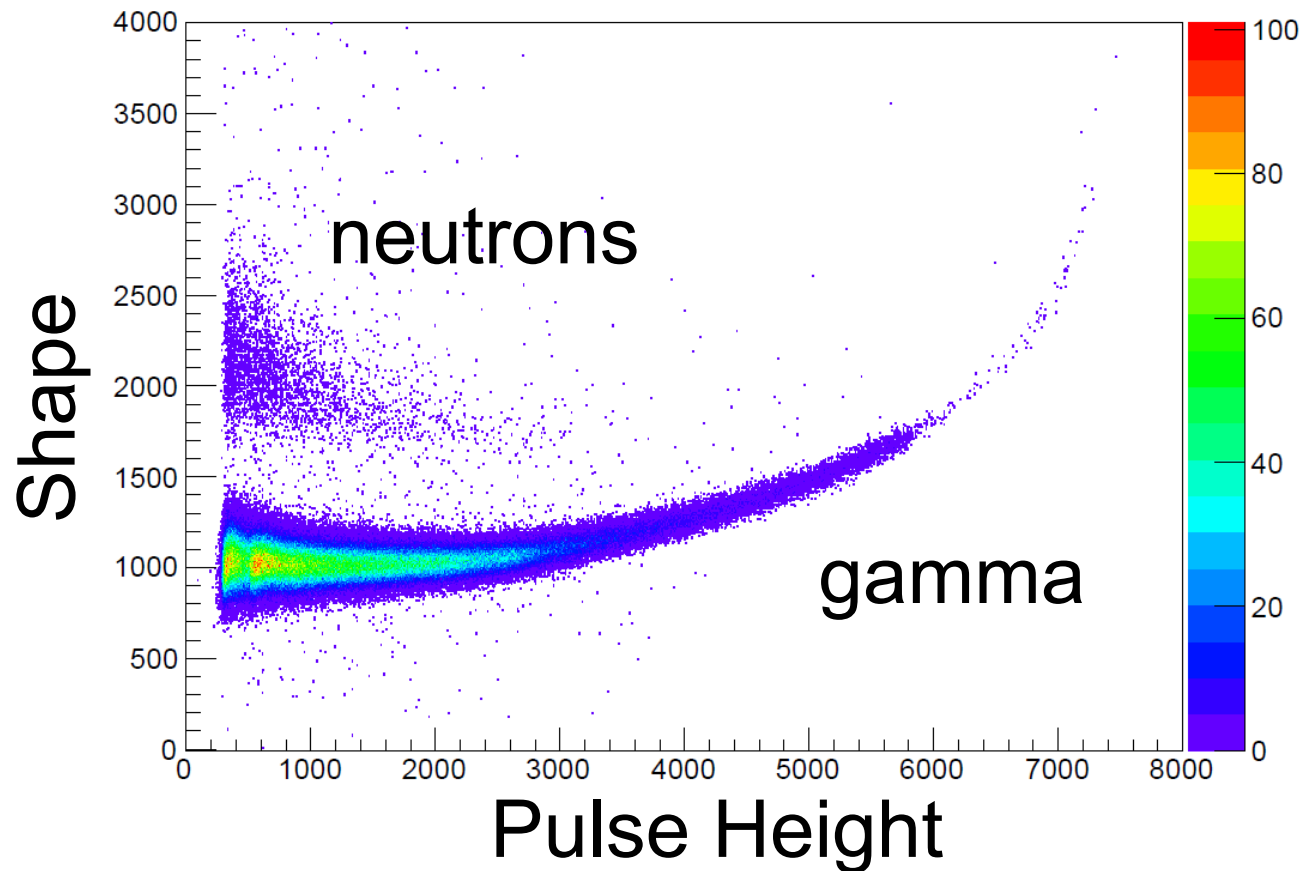
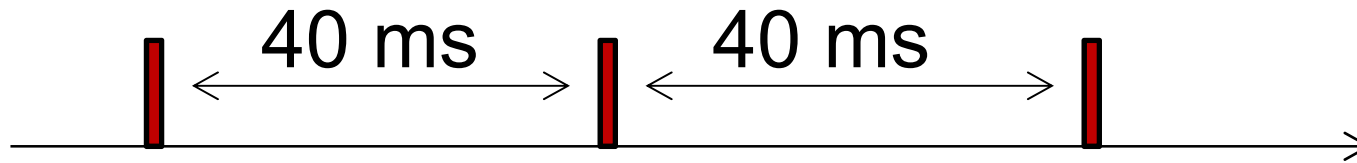
Neutron time-of-flight Measurement at MLF



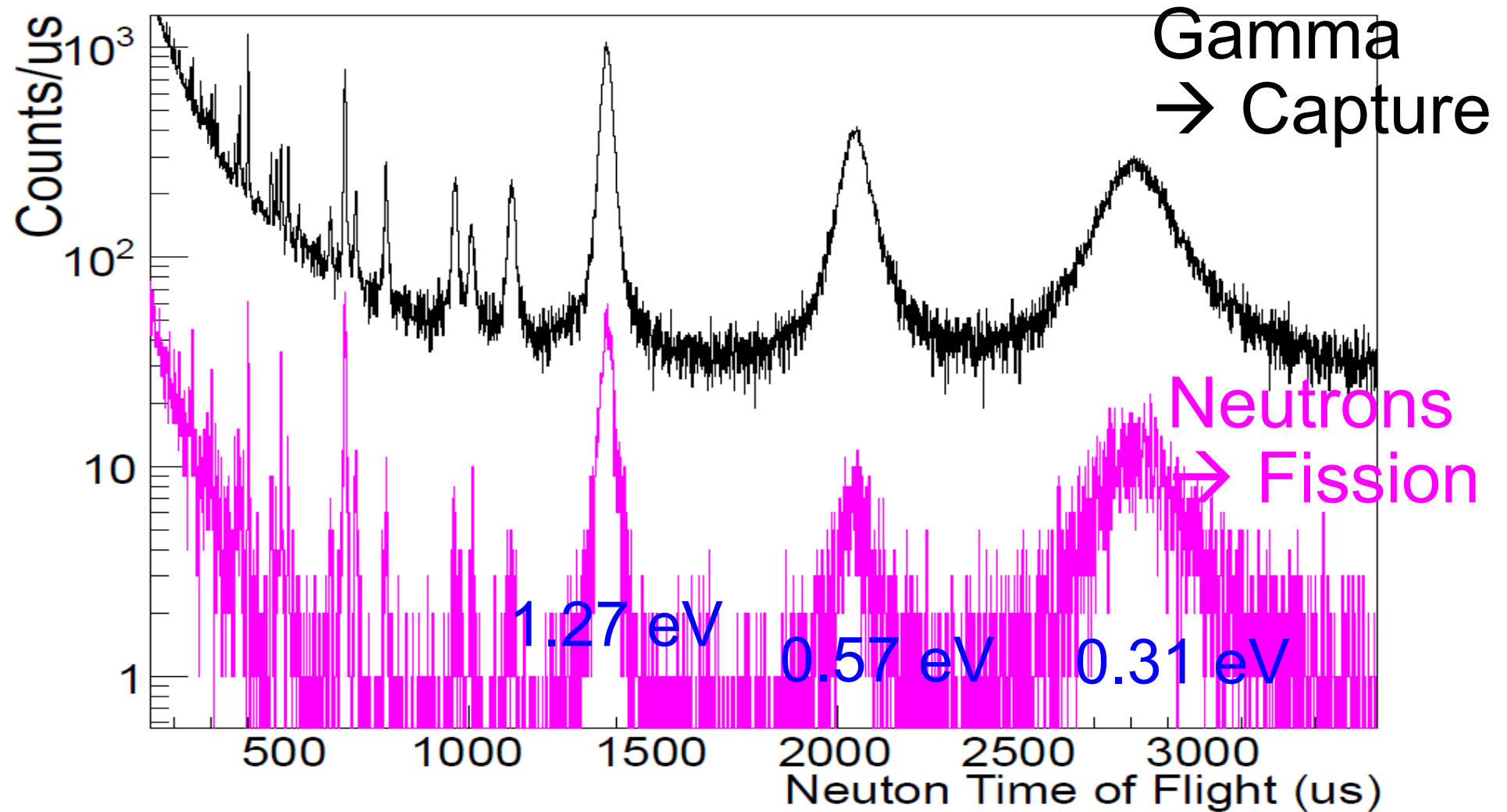
Setup to Measure Fission Cross Section



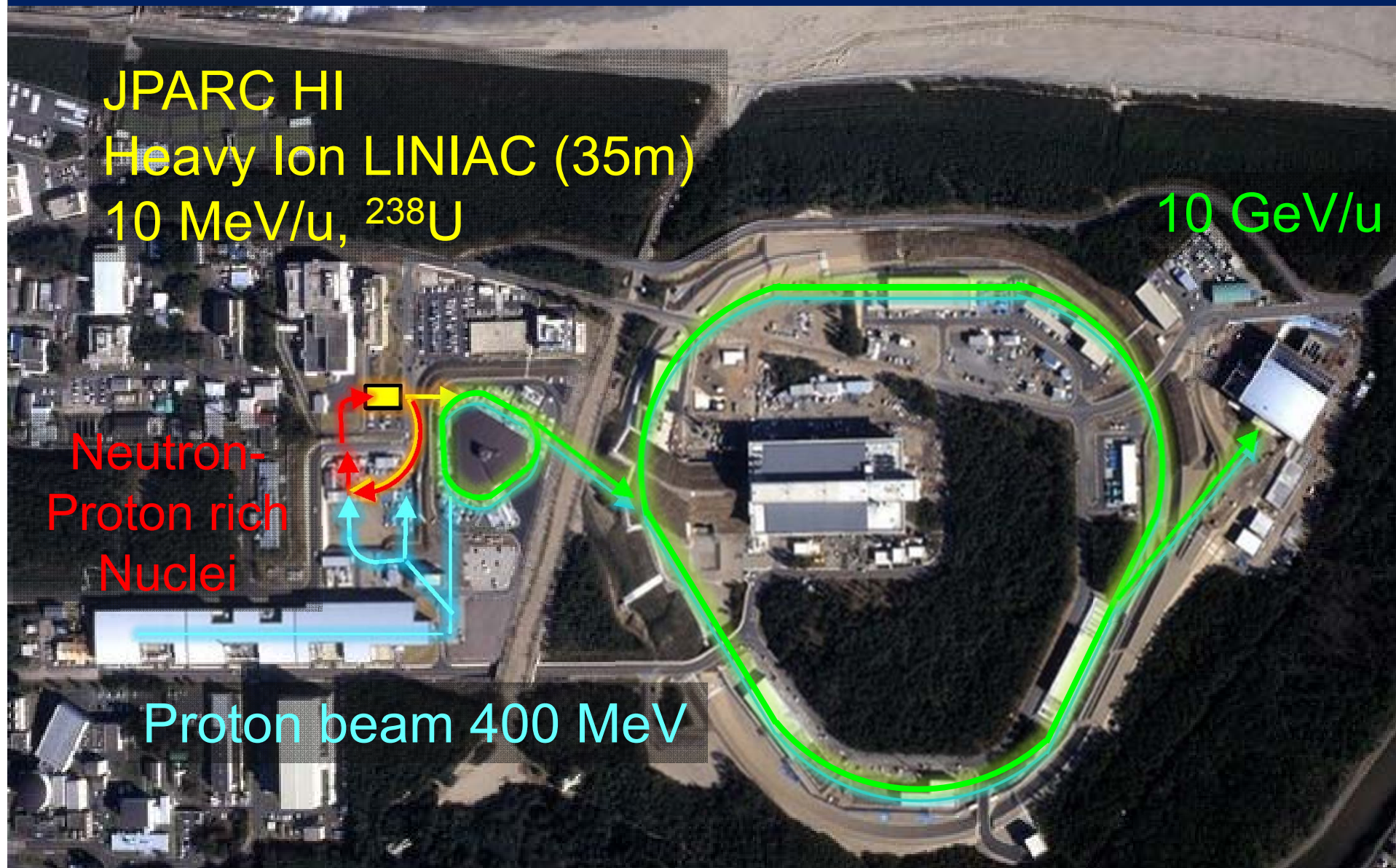
Prompt Neutrons and Capture Gammas



Time-of-Flight Spectrum



Future Idea at J-PARC



Summary

Fission study for Heavy-element synthesis

Nucleon-transfer induced Fission

Fission cross section measurement at the J-PARC

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Thank you.