Fission Studies using Multi-nucleon Transfer Reactions

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Shapes and Symmetries in Nuclei: from Experiment to Theory (SSNET'18)

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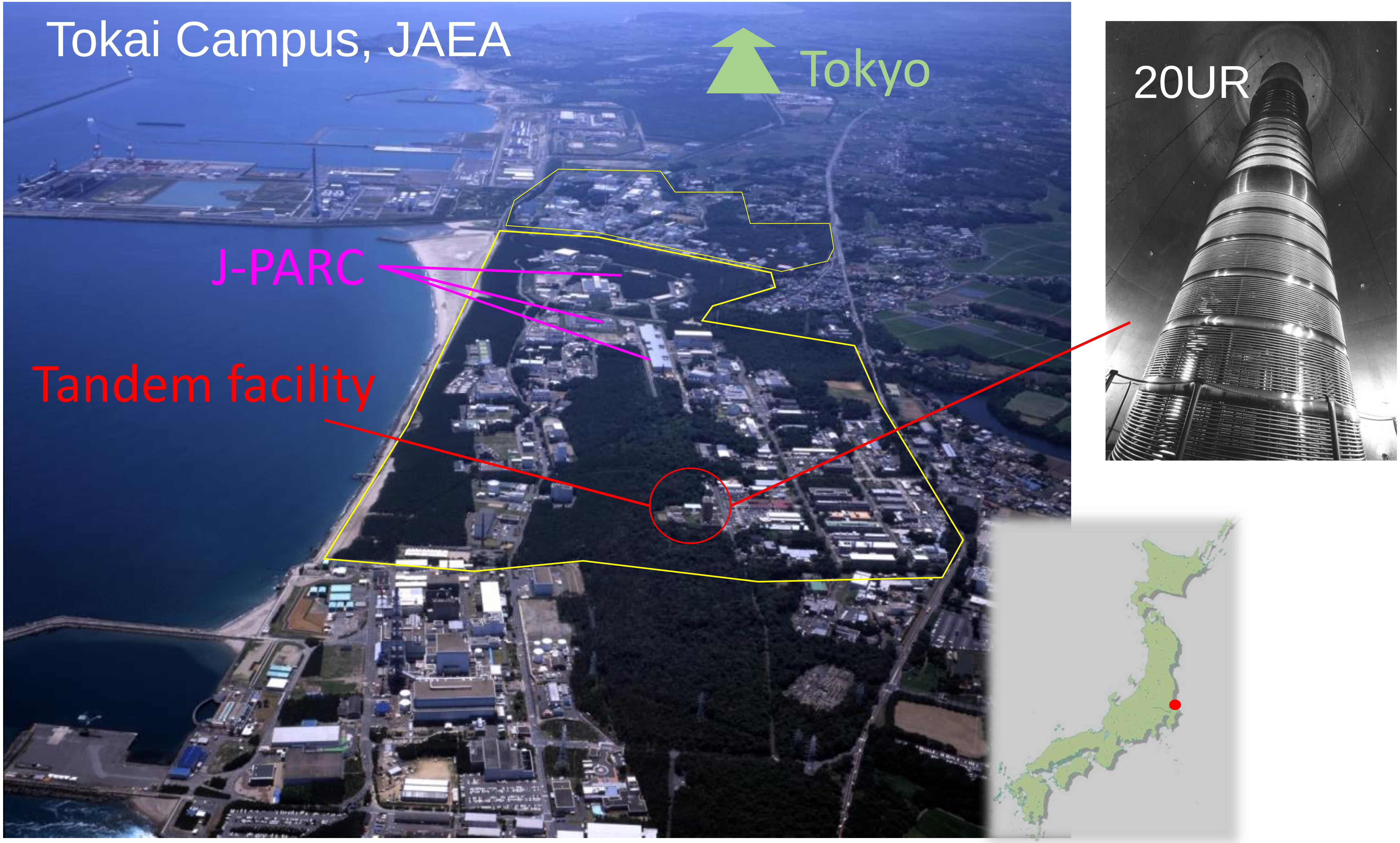
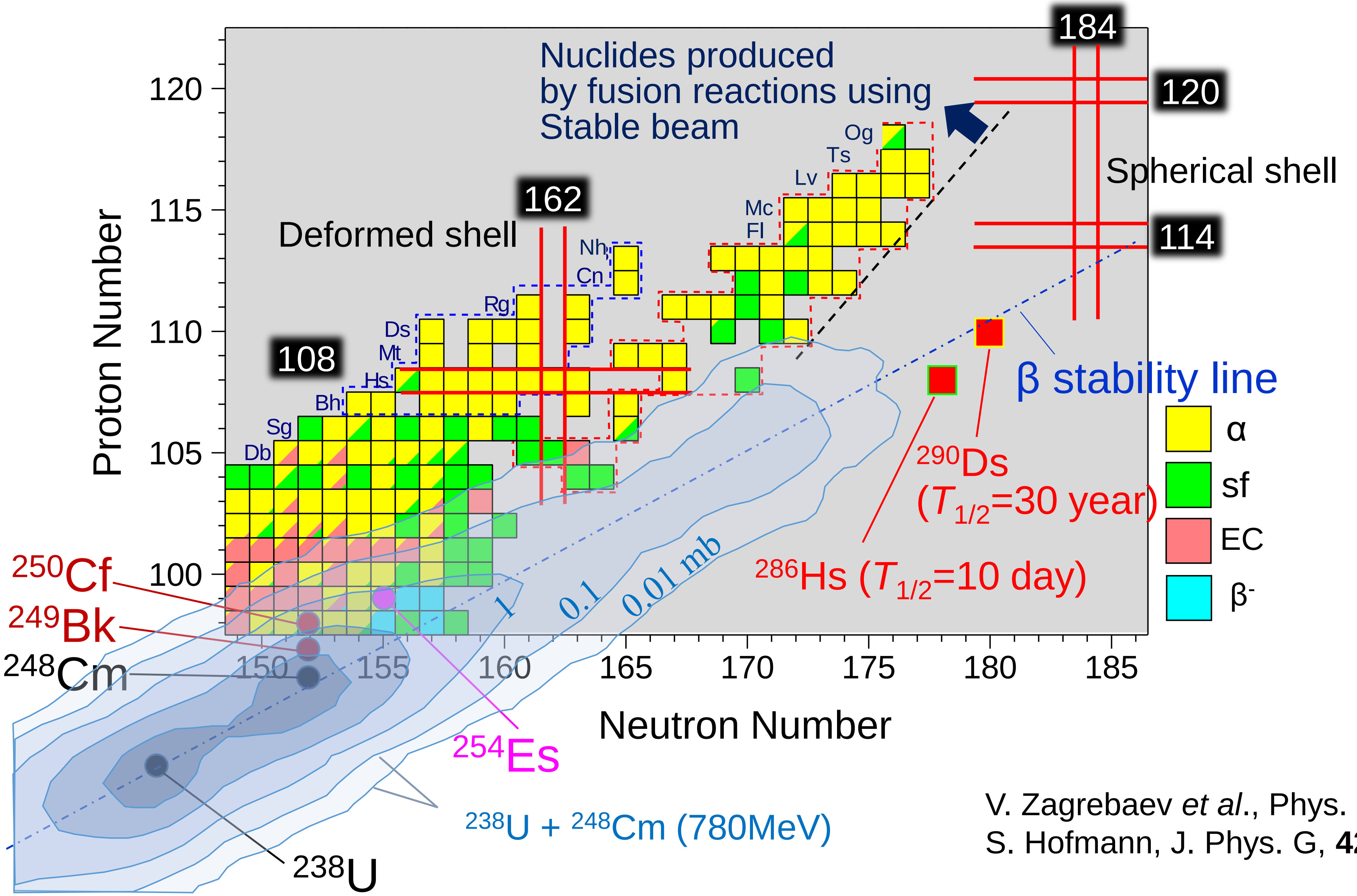

Tokai Campus, JAEA
Tokyo
J-PARC
Tandem facility
20UR

Contents

- ☑ Multi-nucleon transfer (MNT) reactions and the island of stability
- ☑ Fission setup for multi-nucleon transfer induced fissions
- ☑ Experimental results and discussions
- ☑ Summary

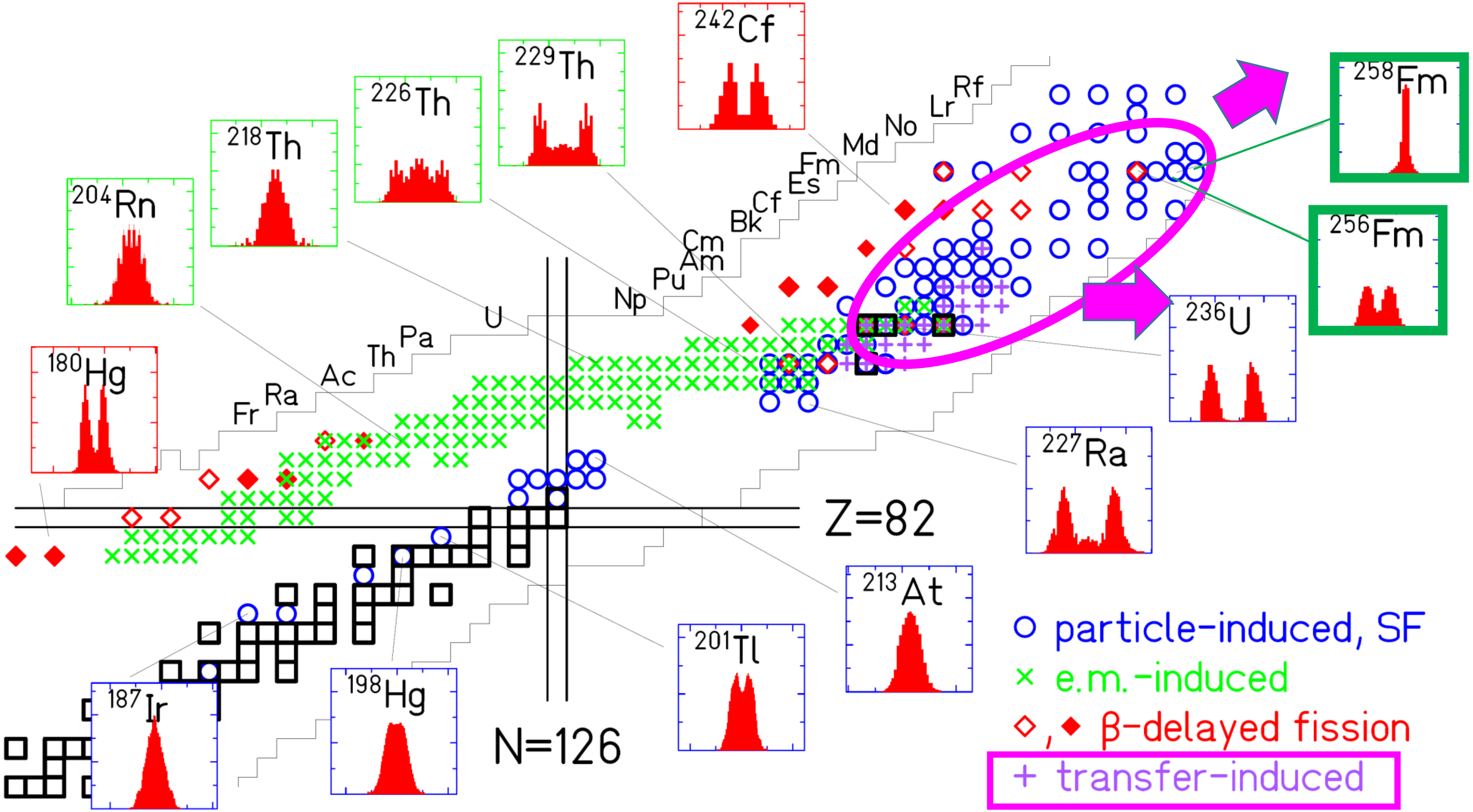
Super-heavy Elements : Spherical shells and Long-lived nuclides



Multi-nucleon transfer reaction is a potential method to reach the “Island of stability”

V. Zagrebaev *et al.*, Phys. Rev. C **73**, 031602 (2006).
S. Hofmann, J. Phys. G, **42**, 114001 (2015).

Measured Fission-Fragment Mass/Charge Yields



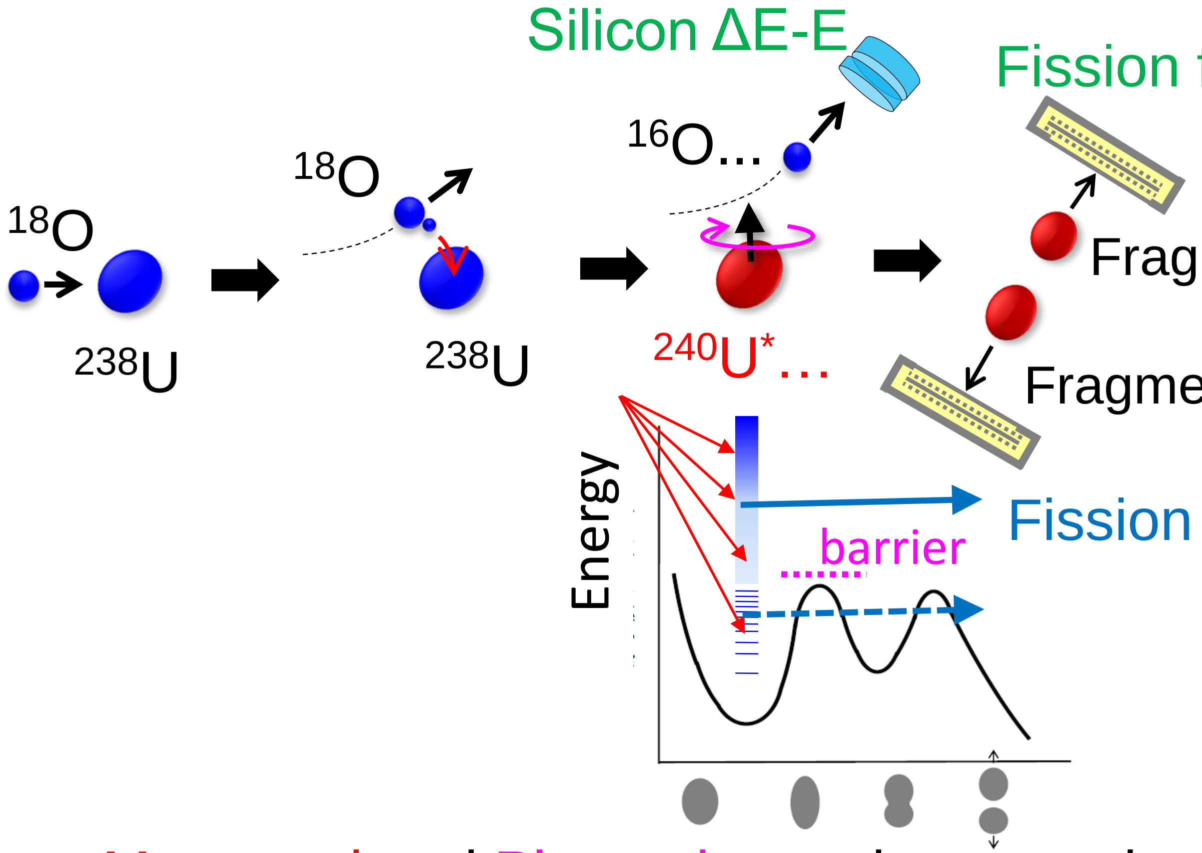
R. Léguillon *et al.*, Phys. Lett. B **761**, 125 (2016)

K. Hirose et al. Phys. Rev. Letters, **119**, 222501 (2017)

A.N. Andreyev, K. Nishio, K.-H. Schmidt, Reports on Progress in Physics, **81**, 016301(2018)

Multi-nucleon transfer reactions and fission

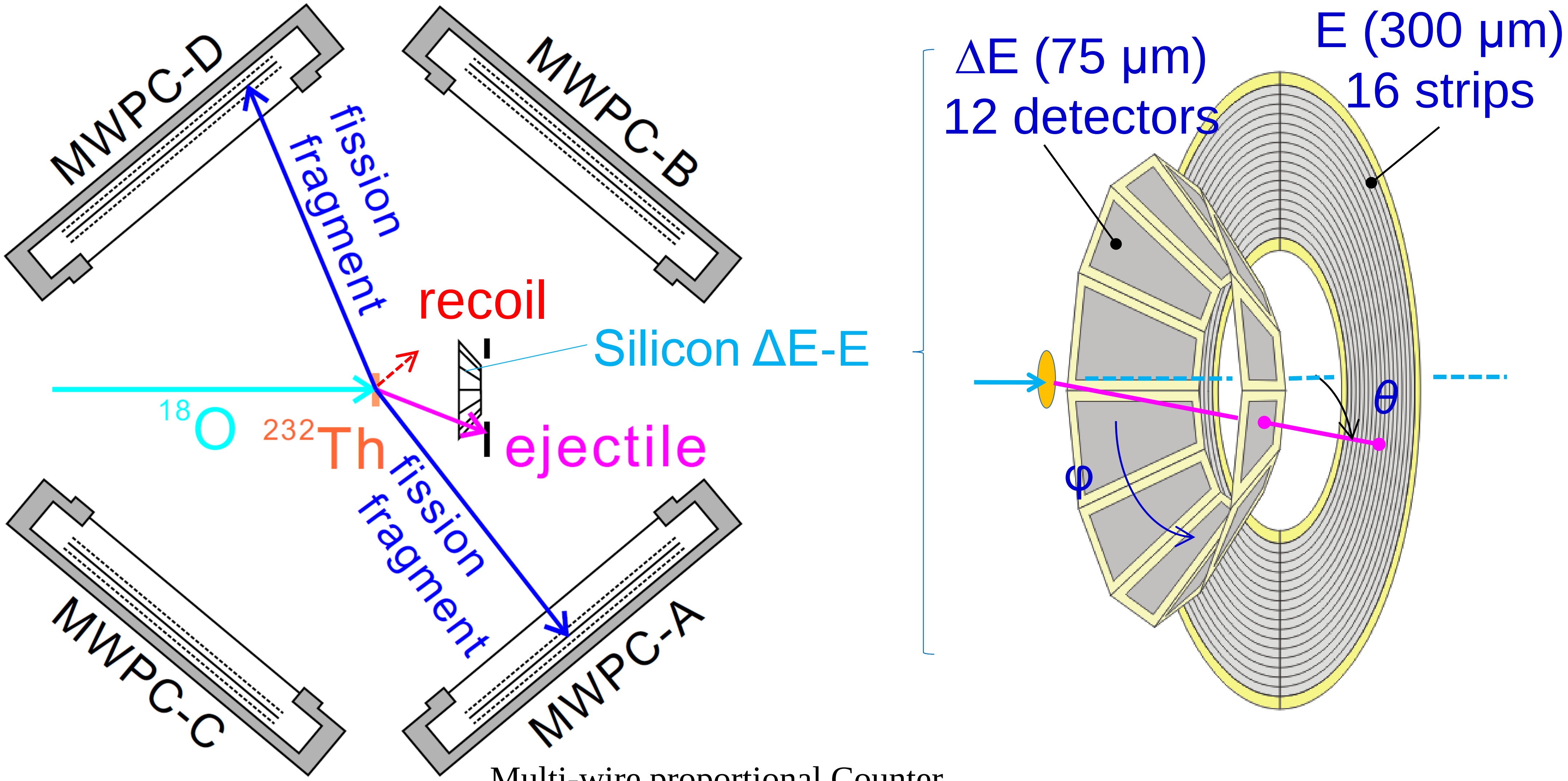
In the multi-nucleon transfer (MNT) reactions:
(1) We can generate many nuclei depending on transfer channels.
(2) Excitation energy of compound nucleus distributes widely.



(1) Fission probability and Fission barrier height.
(2) Fission fragment mass distributions.
(3) Fission fragment angular distributions.
(4) Prompt neutrons accompanied by fission.

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

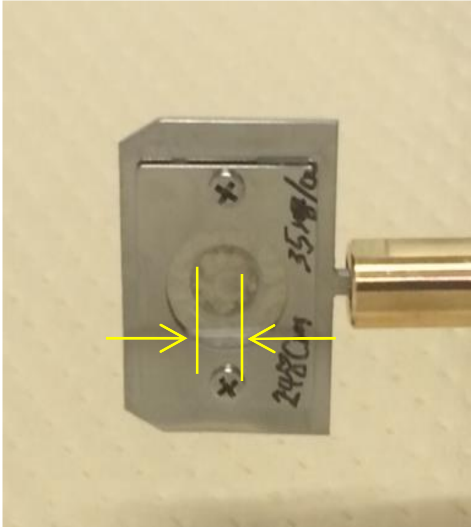
Experimental Setup



Multi-wire proportional Counter

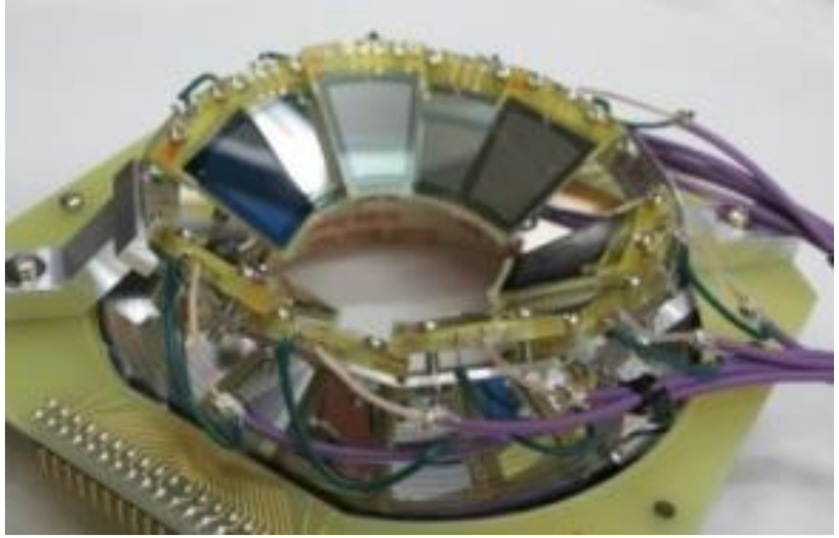
Targets and Detectors

Target (^{248}Cm)



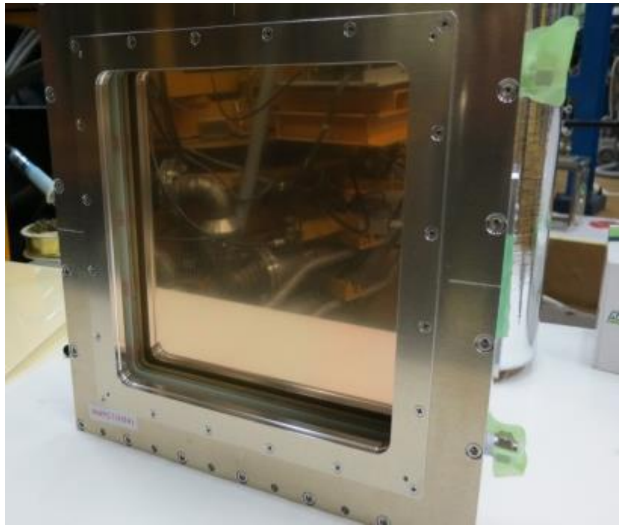
~ 30 - 60 μg/cm^2
~ ø2.0 mm

Silicon ΔE-E detector



ΔE = 75 μm
Thickness fluctuation < 1 μm.

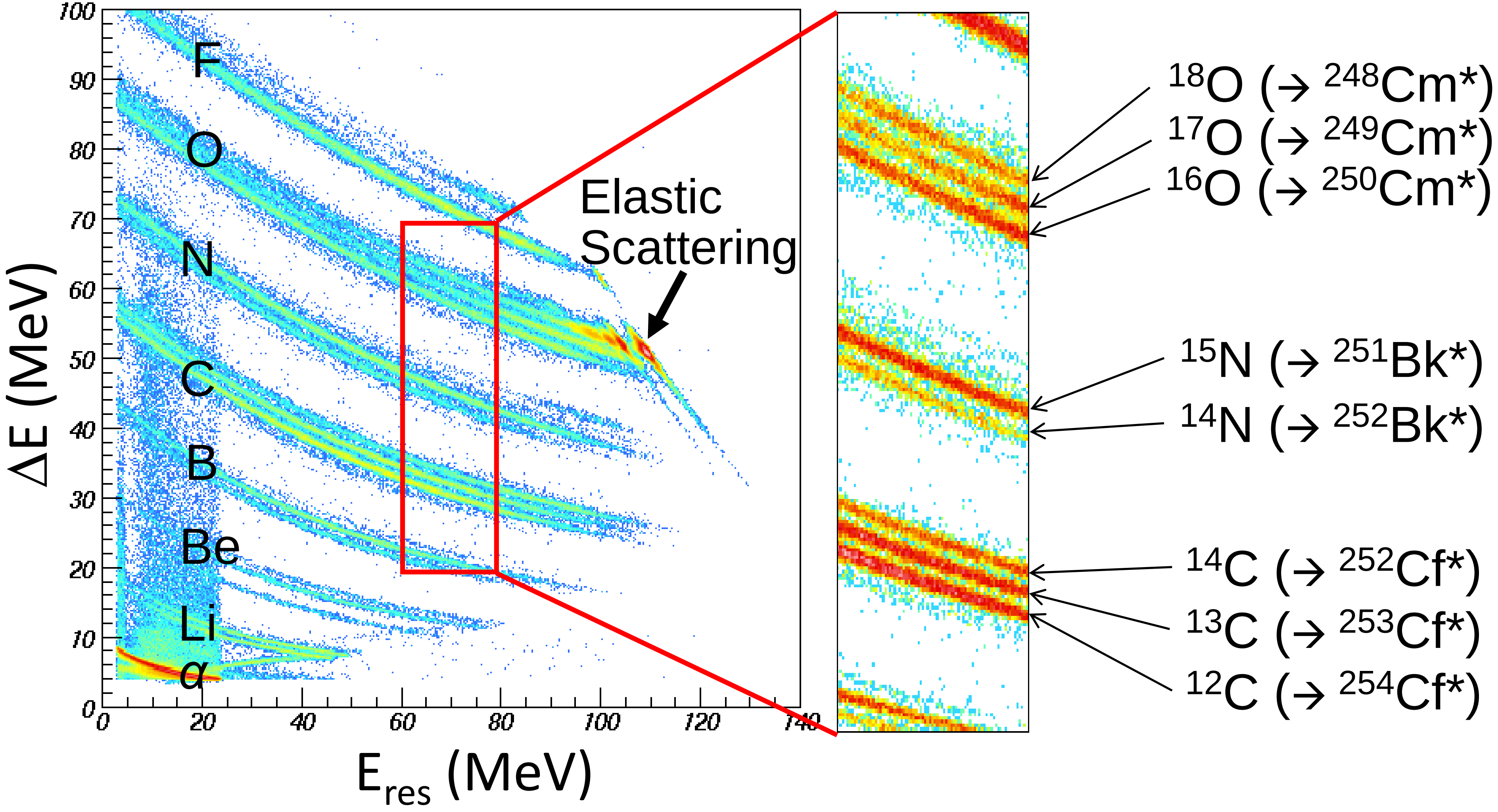
MWPC



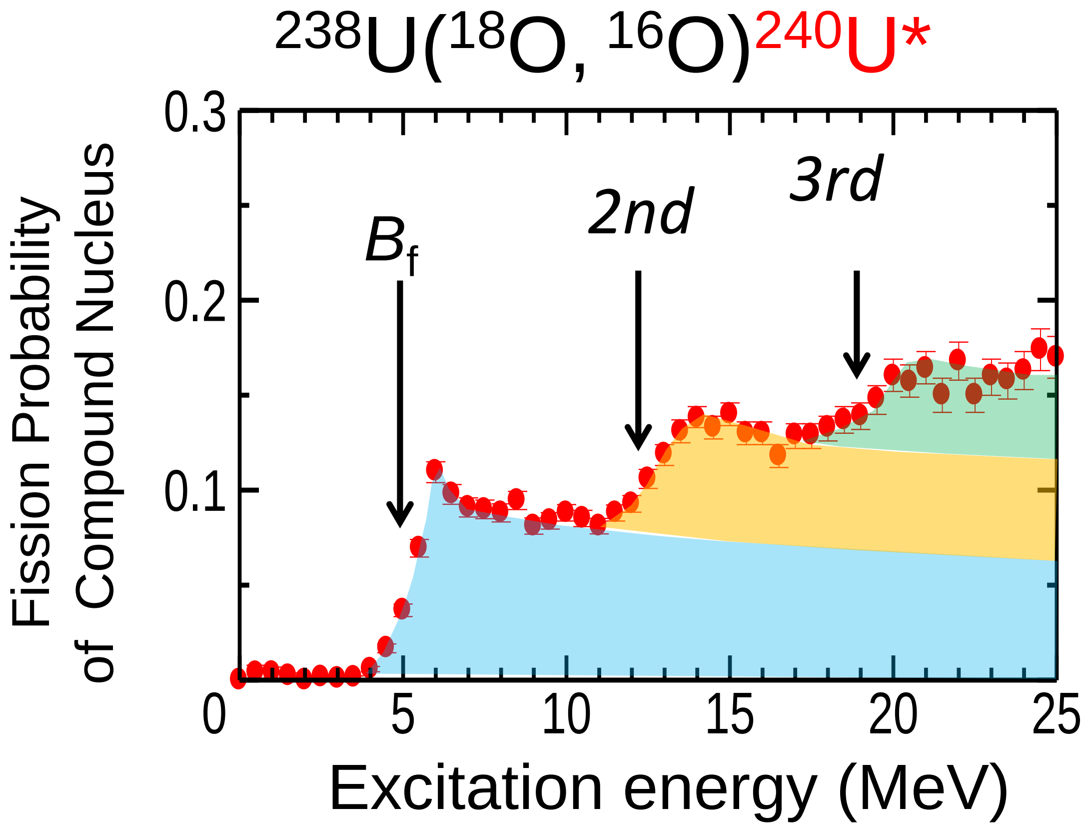
Position Sensitive
200 x 200 mm^2

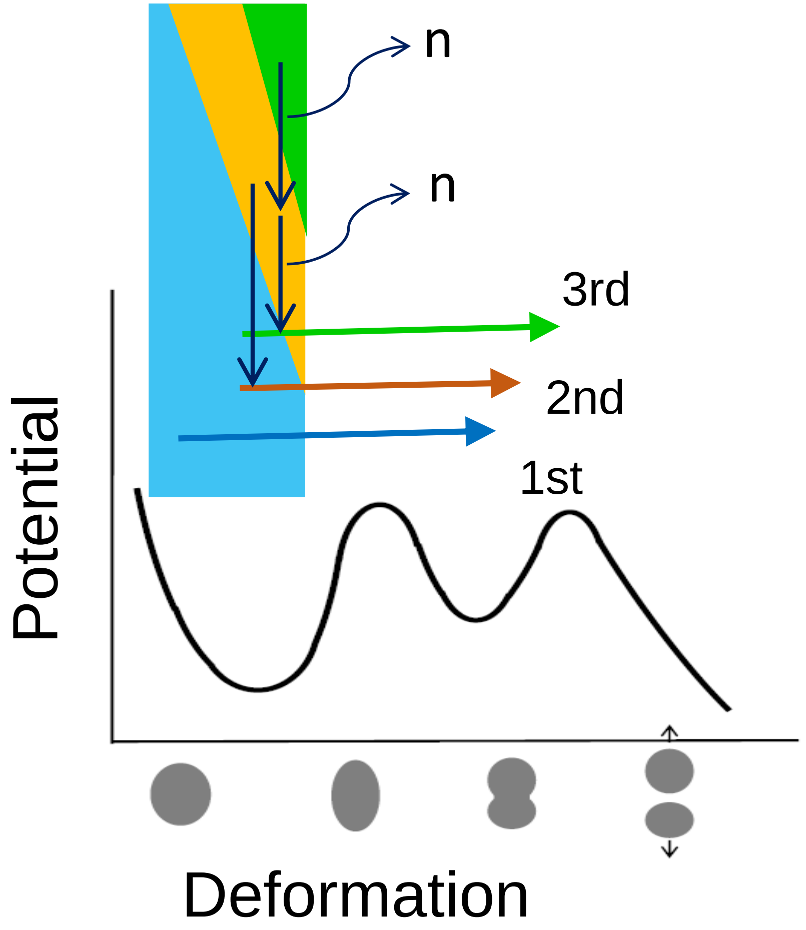
Particle Identification using ΔE–E Telescope

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



Fission Probability and Fission Barrier Height



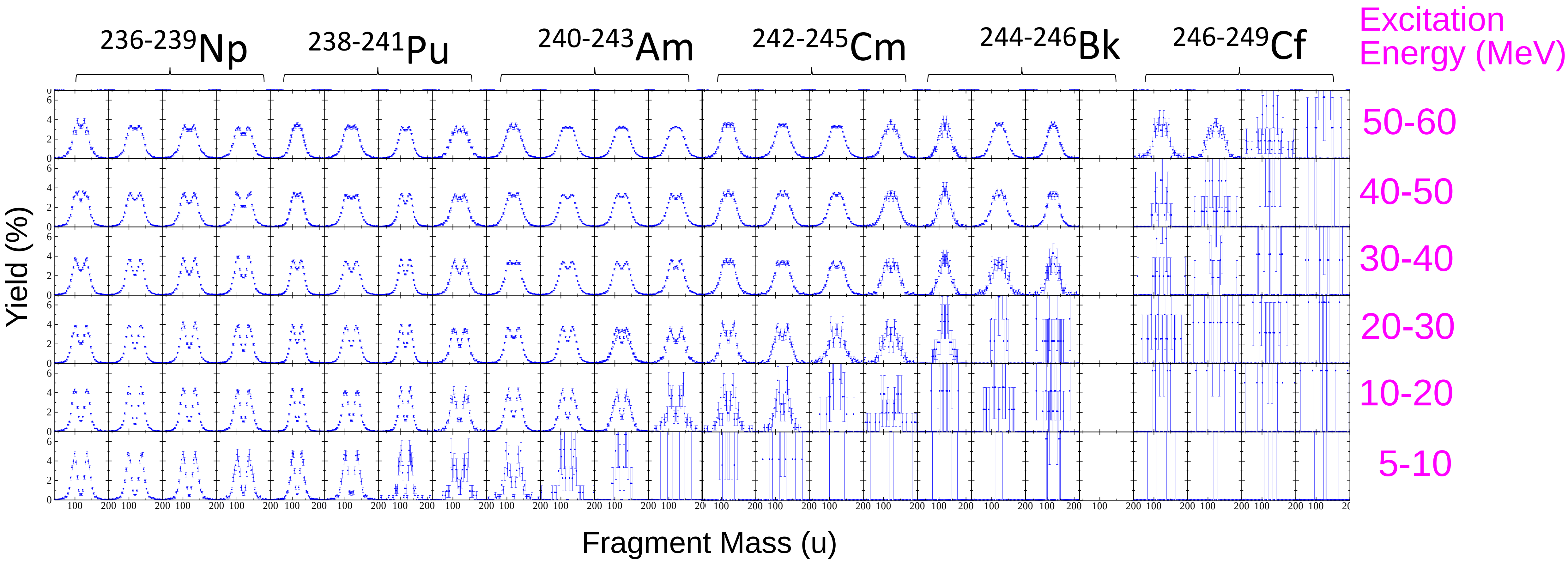


B_f^{exp} = 5.5 MeV

B_f^{cal} = 6.38 MeV (P. Möller)

Fission after neutron evaporation is called “Multi-chance fissions”

Fission Fragment Mass Distributions (FFMDs) obtained in $^{18}O + ^{237}Np$



Fission data for 23 nuclides are obtained in one setup/experiment.

Benchmark of FFMDs

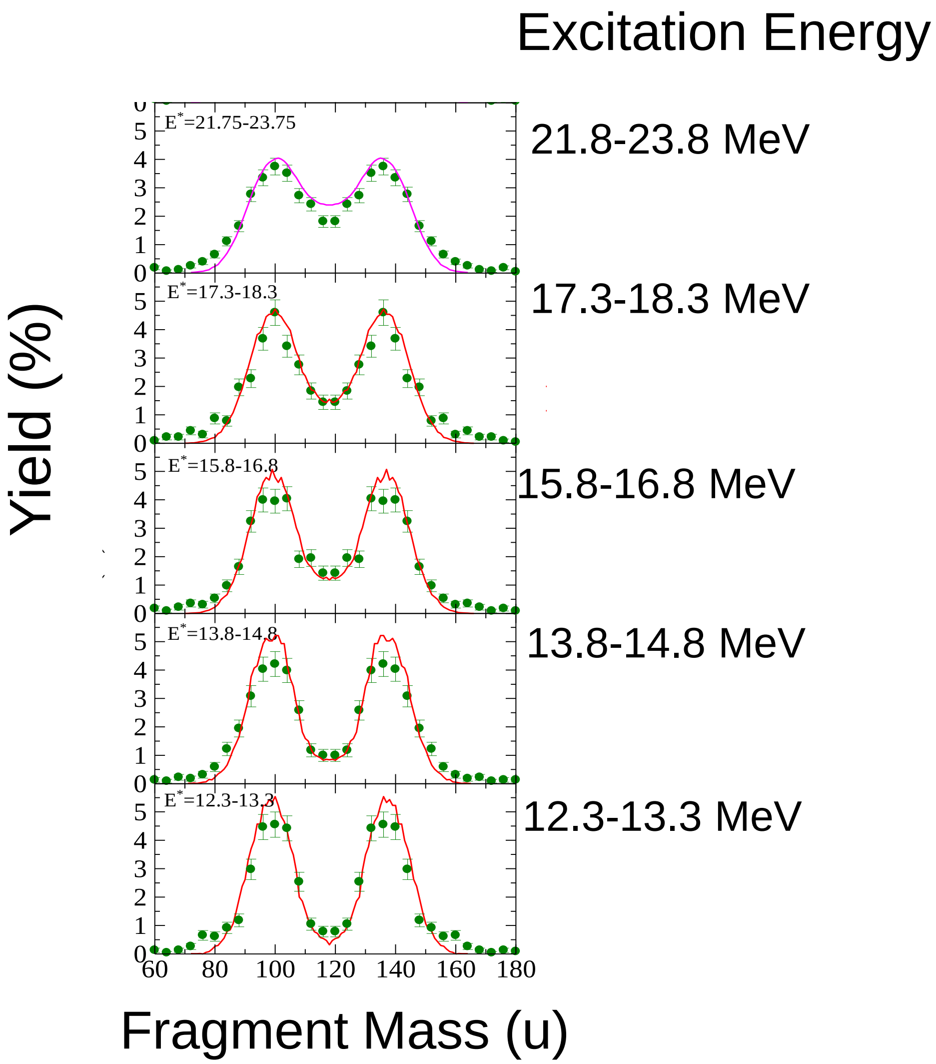
^{237}Np (^{18}O,^{19}O) ^{236}Np*

Present Data

p + ^{235}U = ^{236}Np*

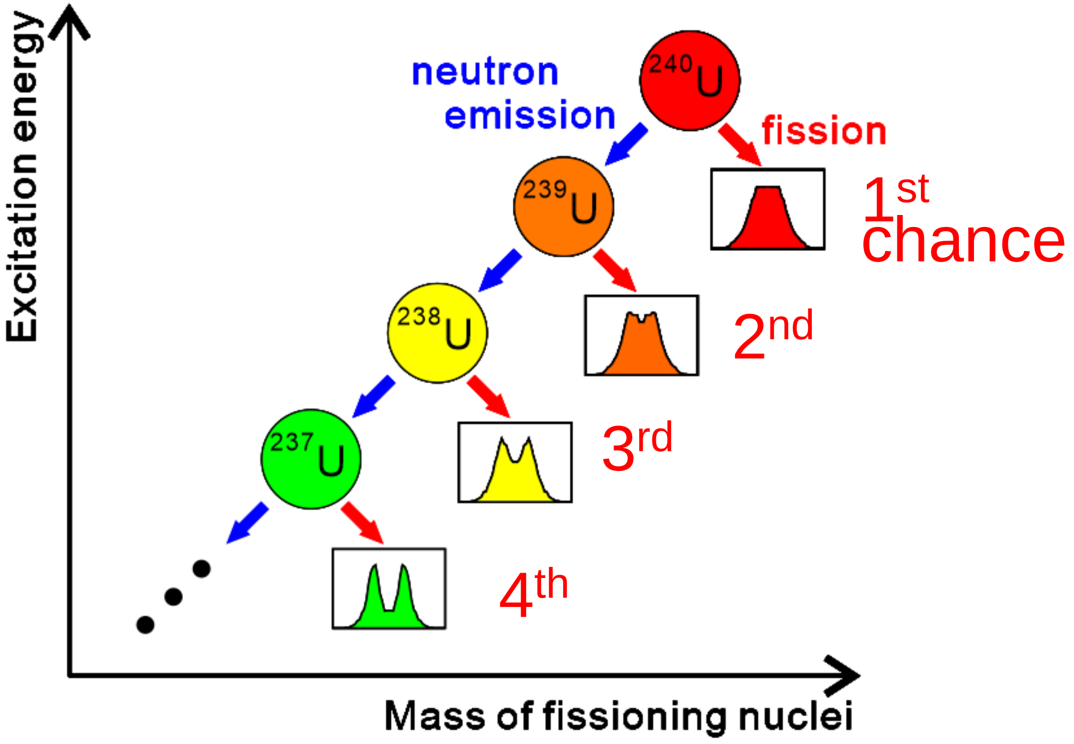
Mulgin (2009)

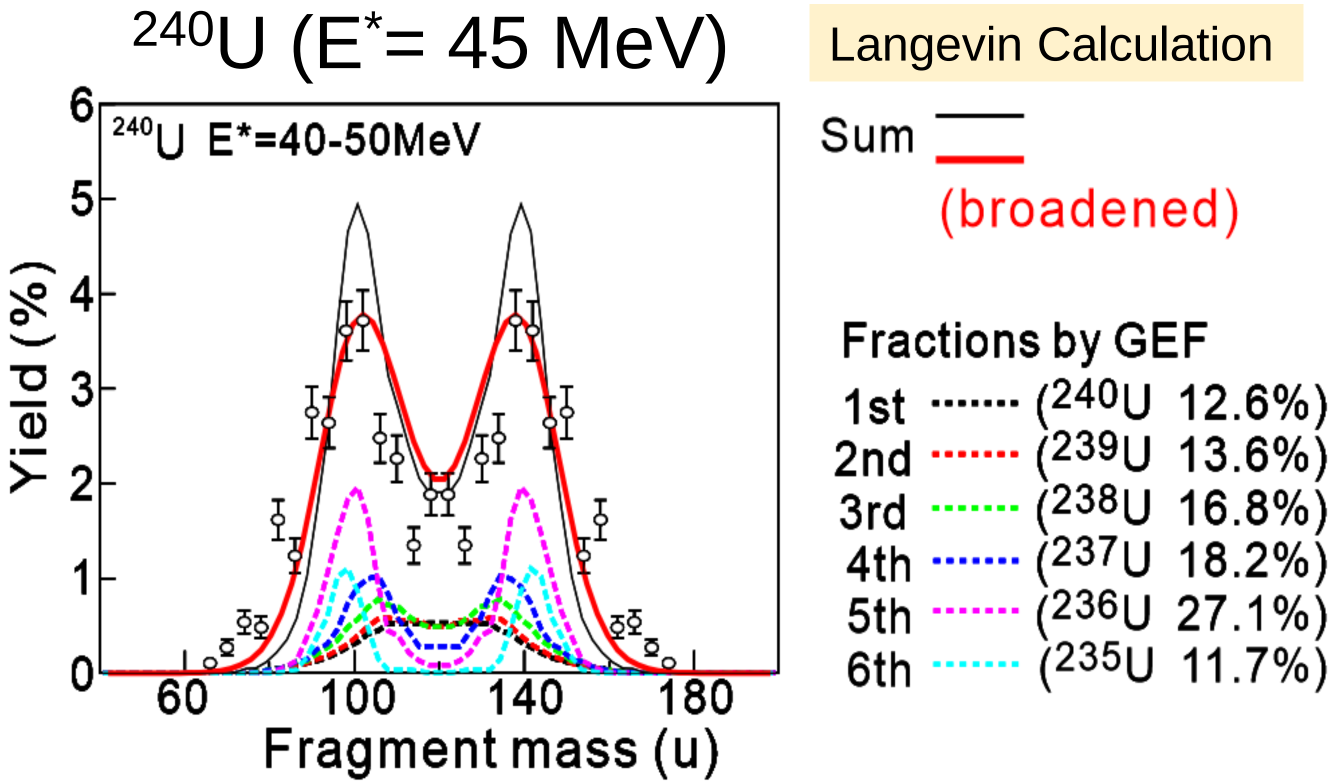
Ferguson (1973)



Good agreement with the literature data is found, confirming the validity of our method.

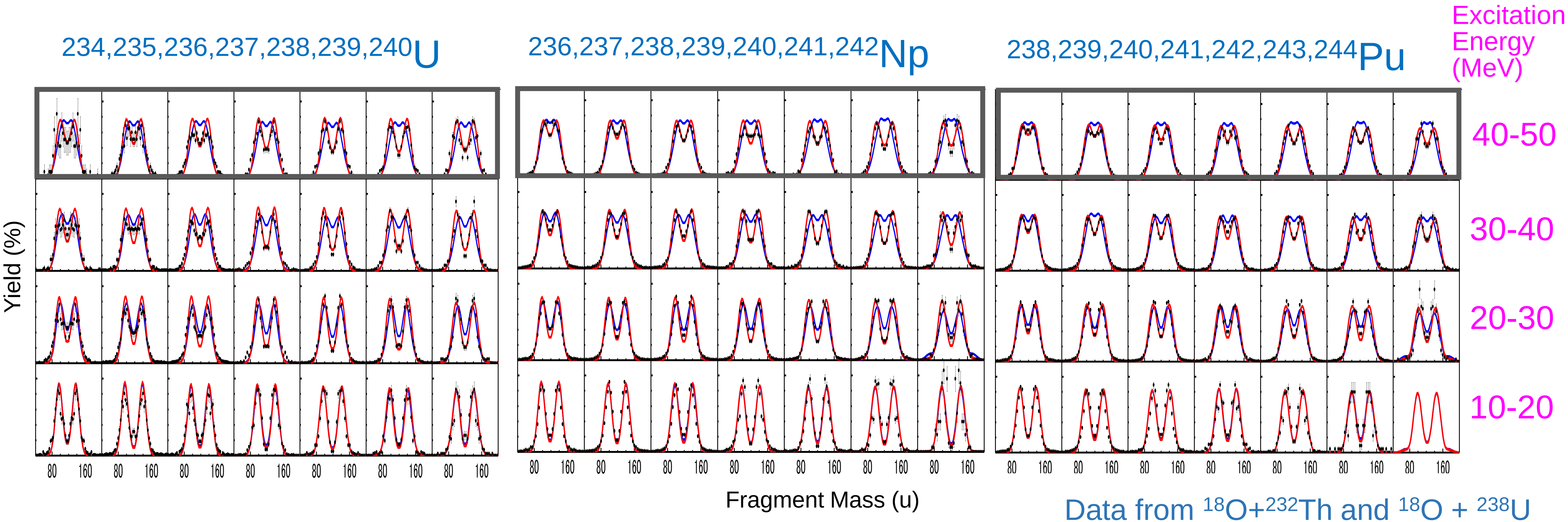
Role of Multi-chance Fission on FFMDs





K. Hirose et al., Phys. Rev. Lett. **119**, 222501 (2017).

Experimental Data in Comparison with Langevin Calculation



Data from $^{18}O + ^{232}Th$ and $^{18}O + ^{238}U$

Without multi-chance fission

With multi-chance fission

Experimental data

Langevin calculation by S. Tanaka, Kindai Univ.
Y. Aritomo and S. Chiba, Phys. Rev. C **88**, 044614 (2013).

Higher-order chance fissions are important for neutron-rich & lighter element isotopes

Summary

- ☑ Multi-nucleon transfer reaction is a powerful too study fissions.
- ☑ Effects of multi-chance fission on fission fragment mass distributions are discussed.
- ☑ We plan to measure the fission barrier data up to mendelevium (Md), the element 101.

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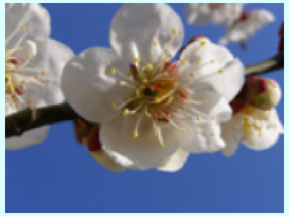
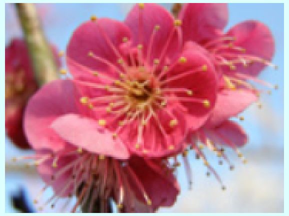
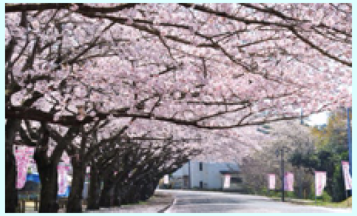
25 – 27 March 2019, Tokai, Japan







ASRC International Workshop Sakura-2019 "Nuclear Fission and Structure of Exotic Nuclei "

Japan Atomic Energy Agency (JAEA), Tokai, Japan
25-27 March 2019

Supported by Advanced Science Research Center (ASRC), JAEA
Organized by the Research Group of Heavy Element Nuclear Science of the ASRC (here)
and Nuclear Physics Group of the University of York (here)

An international workshop : **"Nuclear Fission and Structure of Exotic Nuclei"** will be held on **25-27th March 2019 organized by ASRC of JAEA , Tokai, Japan**. The meeting will mainly be devoted to new experimental and theoretical achievements in fission, super-heavy nuclei, nuclear reaction and structure of exotic nuclei. Especially, our group is driving a dedicated program using the rare target material, einsteinium-254, for which new results and new proposals will be discussed.

This is the 8th meeting in the series of workshops held at ASRC (Tokai). The links to seven earlier workshops can be found below.
2017 "Workshop for Einsteinium Campaign"
2016 "Experimental and Theoretical Advances in Fission and Heavy Nuclei "
2015 "Nuclear Fission and Exotic Nuclei"
2014 "Nuclear Fission and Exotic Nuclei"
2014 "Nuclear Fission and Structure of Exotic Nuclei"
2013 "Nuclear Fission and Decay of Exotic Nuclei"
2012 "Perspectives in Nuclear Fission" .