Japan Atomic Energy Agency – Advanced Science Research Center

Research Group for Reactions involving Heavy Nuclei

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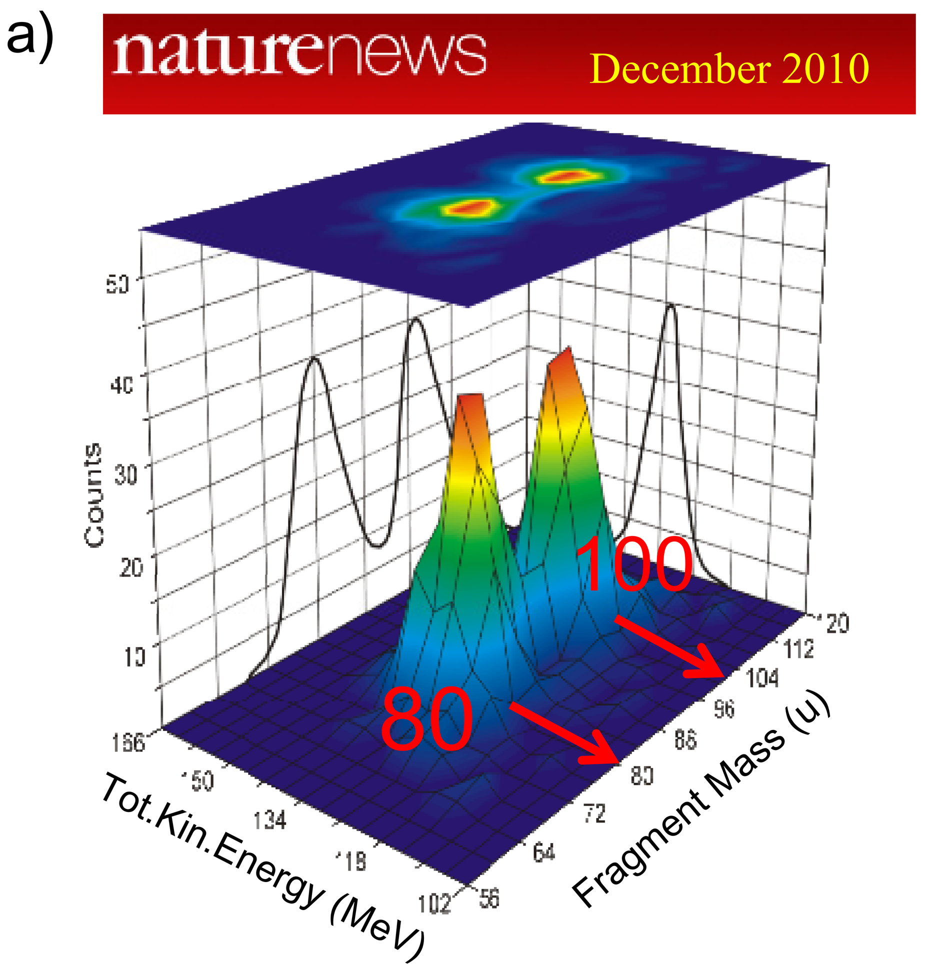
Research Activity Summary for Fiscal Years 2010-2014

(1/2) Fission and Surrogate Reaction Studies

New Type and Region of Asymmetric Fission

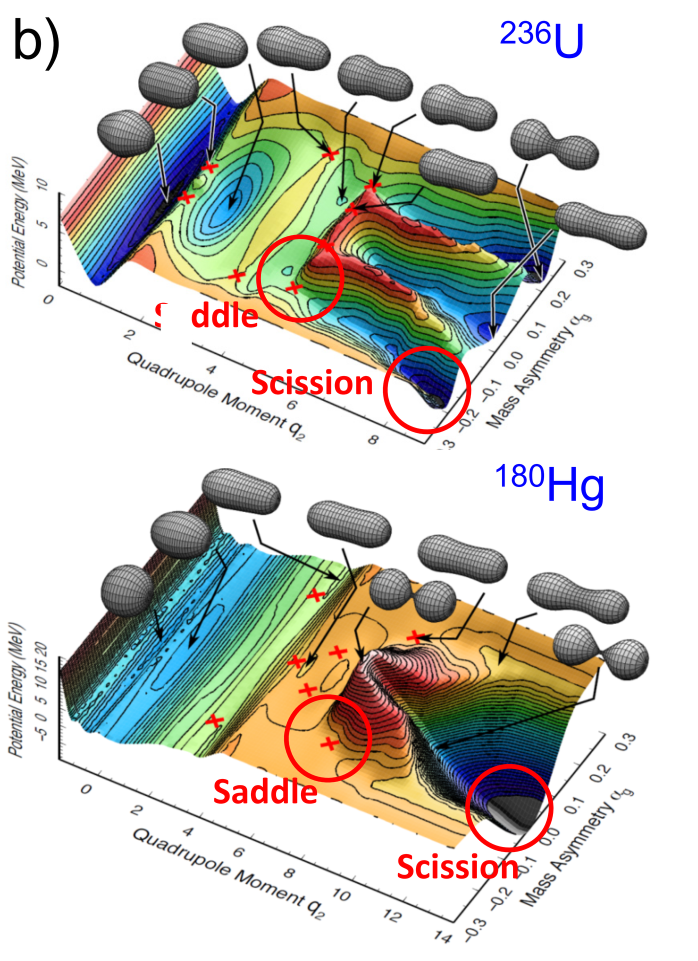
It is a well known fact that actinides fission asymmetrically, while lower mass nuclei usually symmetrically. **Our group pioneered the discovery of a new region of asymmetric fission**, located near proton-rich Pb isotopes. Fission of ^{180}Hg was measured by populating its excited states by **the β^+/EC decay of parent ^{180}Tl** [a], carried out at ISOLDE, CERN. Instead of splitting into two ^{90}Zr isotopes, **^{180}Hg fissions with an asymmetric distribution**. Potential energy landscapes were calculated to explain this unexpected finding [b]. **An extended experimental campaign** at ISOLDE and the JAEA Tandem permitted the study of the fissioning properties of several isotopes, shown in [c], such as ^{194,196}Po, ^{202}Rn and ^{190}Hg. The region highlighted in purple is where β^+/EC delayed fission can be observed.

a)



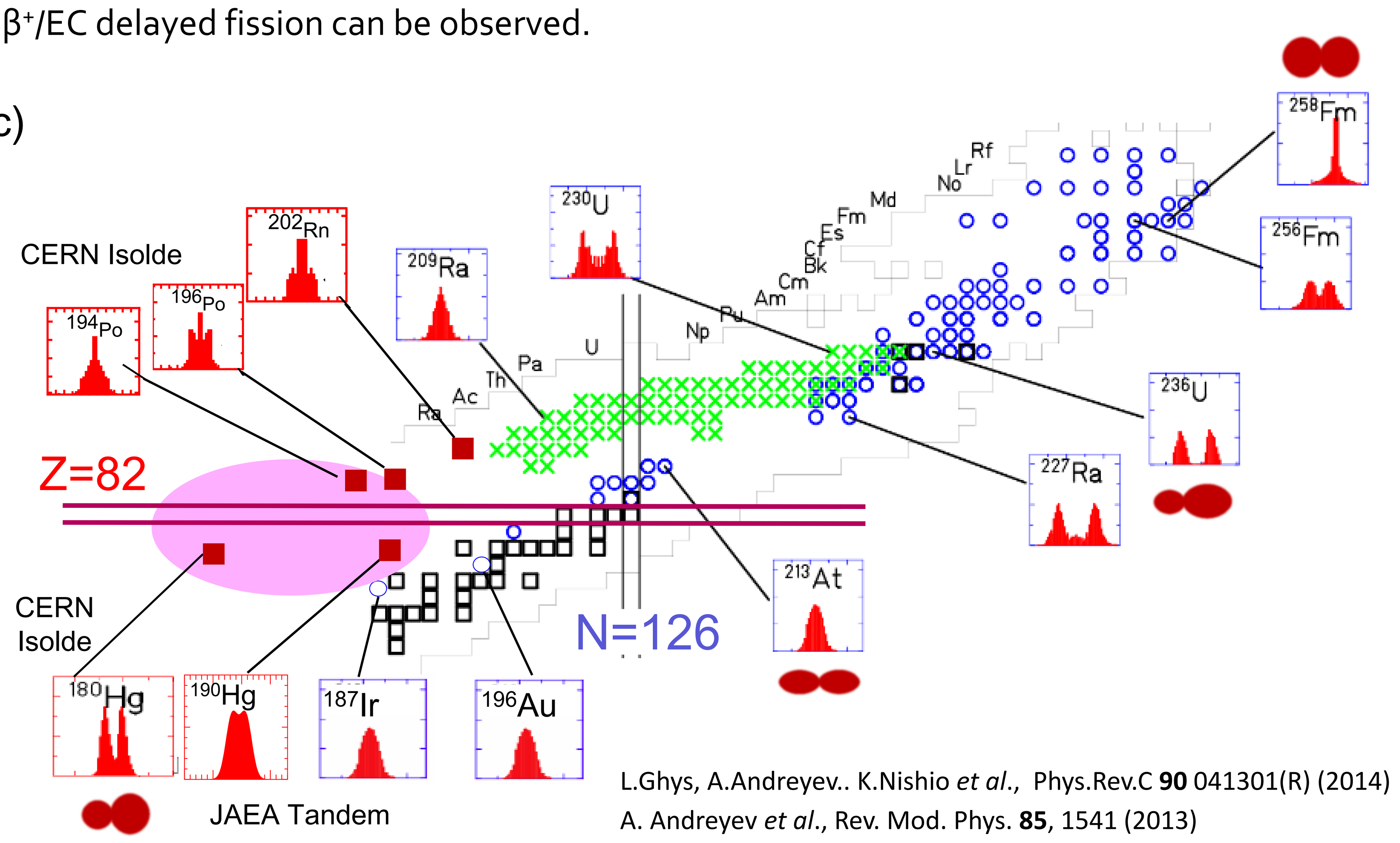
A.Andreyev, .. K.Nishio, P.Möller, A.Iwamoto *et al.*, Phys. Rev. Lett. **105**, 242502 (2010)

b)



T. Ichikawa, A. Iwamoto, P. Möller, A.J. Sierk, Phys. Rev. C **86**, 024610 (2012)

c)

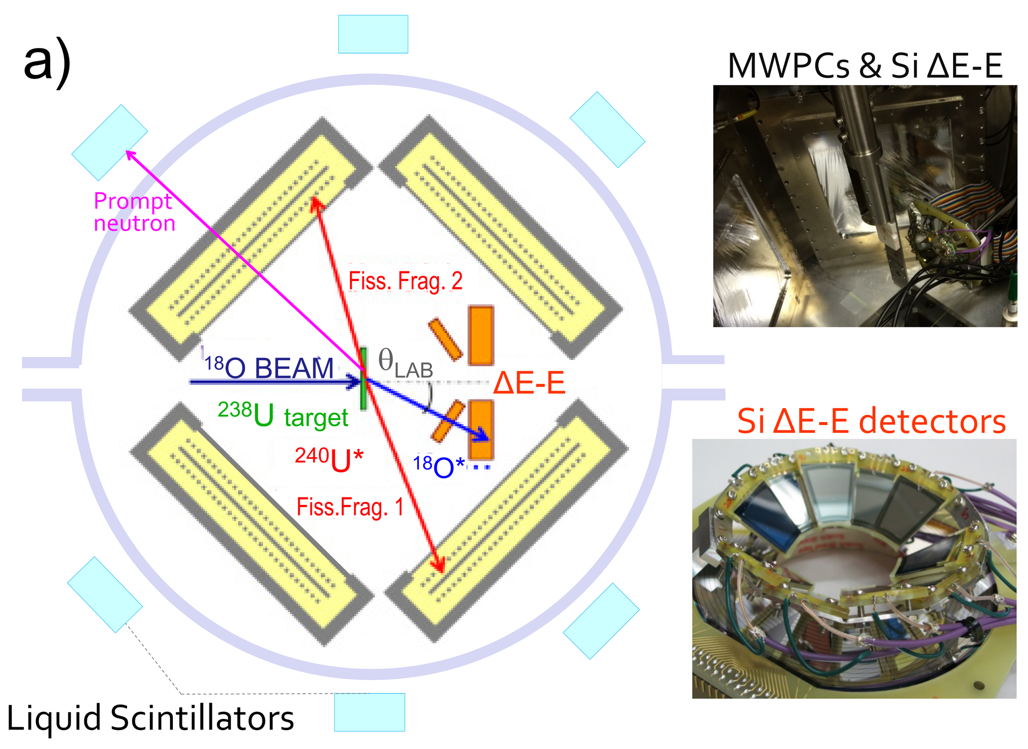


L.Ghys, A.Andreyev.. K.Nishio *et al.*, Phys.Rev.C **90** 041301(R) (2014)
A. Andreyev *et al.*, Rev. Mod. Phys. **85**, 1541 (2013)
K.Nishio, A.Andreyev, I.Nishinaka, H.Makii *et al.*, to be submitted.

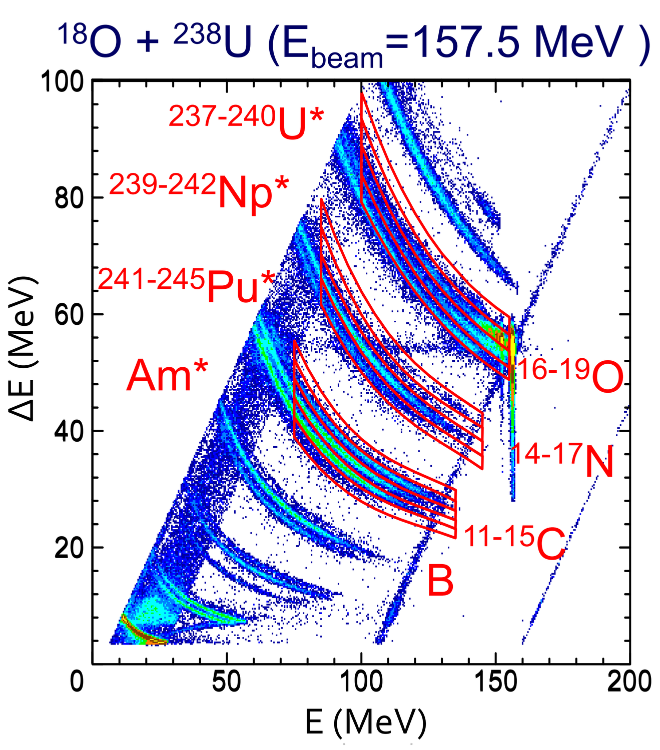
Fission of Neutron-Rich Nuclei populated by Multi-Nucleon Transfer Reactions

In order to study the **fission of neutron-rich nuclei** which cannot be accessed by usual particle-capture reactions, we developed a experimental setup to measure **multi-nucleon-transfer-induced fission**. The species and excitation energies of the fissioning isotopes produced were deduced from **the detection of the corresponding light ejectile in our ΔE-E Si detector setup**, [a] and [b]. Fission fragments were detected using MWPCs. In the study of the ^{18}O + ^{238}U reaction, the mass distributions of more than 12 isotopes, and excitation energy ranges up to 50 MeV, could be studied simultaneously [c]. Neutrons accompanied by fission were also measured with liquid scintillators. These data, which includes short-lived minor-actinides (MA), can be used as a **surrogate method to study neutron-induced fission**, providing nuclear data important for future Accelerator Driven Systems (ADS) and innovative fast reactors. This work is also supported by MEXT funding.

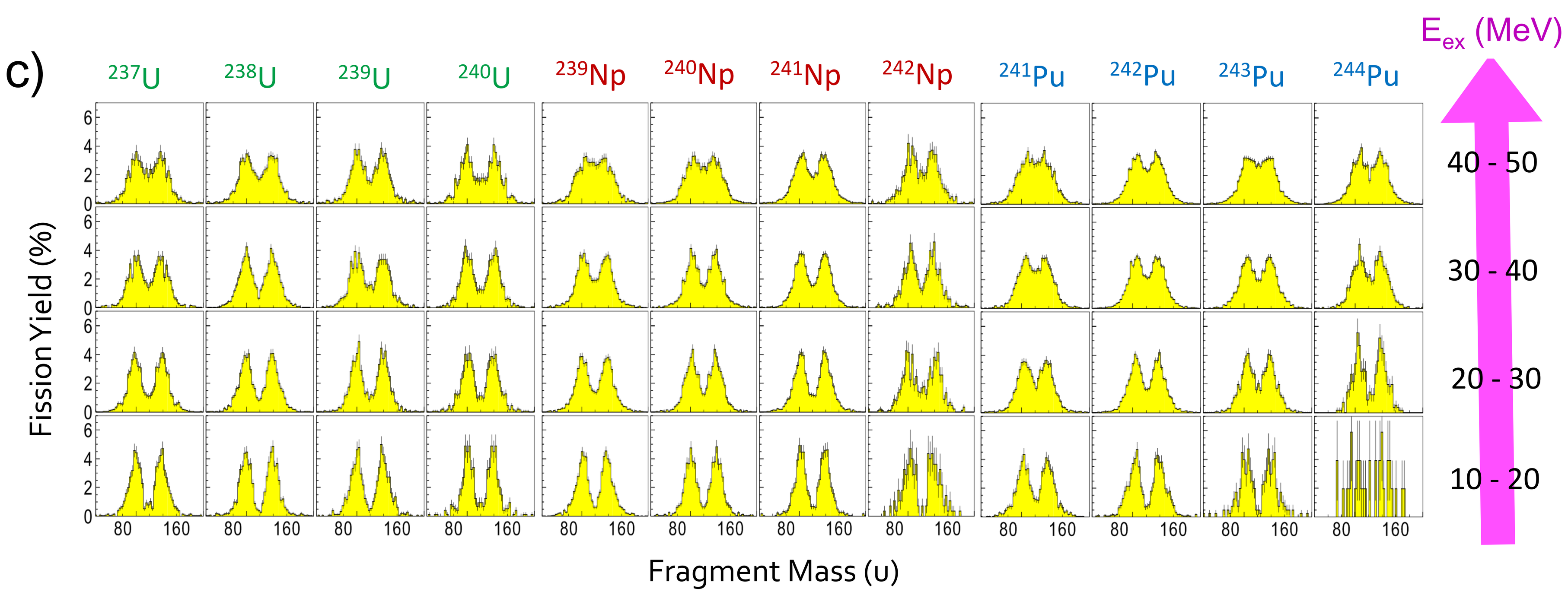
a)



b)



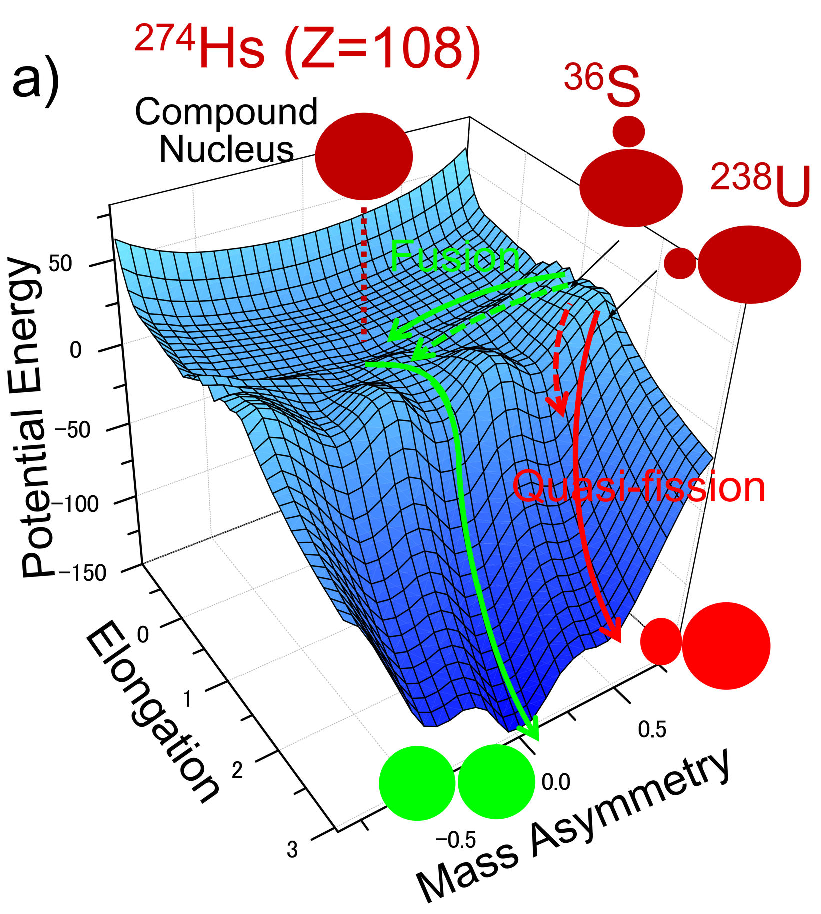
c)



K. Nishio, K. Hirose, R. Léguillon, H. Makii, I. Nishinaka, R. Orlandi, R. Tatsuzawa *et al.*, Physics Procedia, in print.

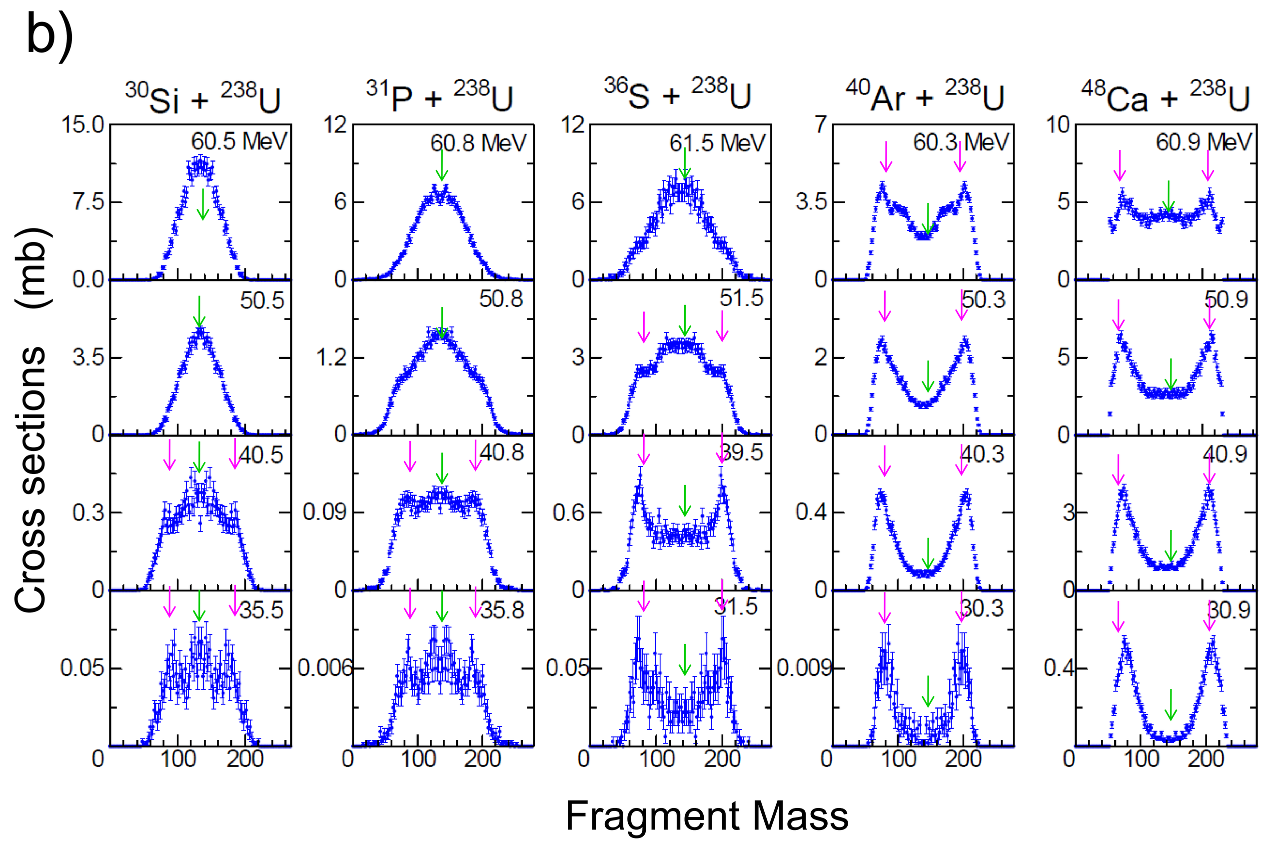
Reaction Mechanism for Heavy-Element-Synthesis

a)

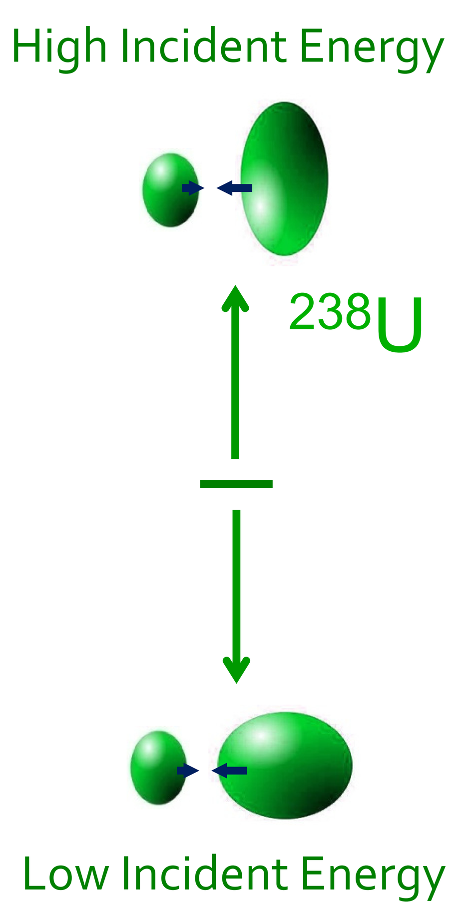


Heavy-ion fusion using actinide nuclei is nowadays a widely-used, key reaction to produce super-heavy elements (SHE) [a].
The reaction mechanism was studied by detecting fission fragments at the JAEA Tandem. Mass distributions were measured for different beams and incident energies [b]. With calculations based on a fluctuation-dissipation model, the competition between fusion and quasifission was determined quantitatively from the measured spectra. We revealed that the **orientation of the deformed target nucleus in the entrance channel affects the fusion probability**, and proposed a method to estimate production cross sections of SHE.

b)



c)



K. Nishio *et al.*, Phys. Rev. C **82**, 024611 (2010); K. Nishio *et al.*, Phys. Rev. C **82**, 044604 (2010); K. Nishio *et al.*, Phys. Rev. C **86**, 034608 (2012)