Research Group for Reactions Involving Heavy Nuclei

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The research objective of our group is to investigate heavy-ion induced reactions such as nucleon-transfer and fusion reactions. One subject is to develop experimental and theoretical methods to determine neutron-induced reaction cross sections with heavy-ion reactions. For nuclei with short half-lives, it is practically impossible to measure the cross sections in experiments using neutron source. The idea of the so-called surrogate reaction method is to populate the same compound nucleus as the neutron-capture reaction by nucleon-transfer reactions using available target nucleus and to measure the decay probabilities for fission and gamma-ray emission to derive fission and capture cross sections. In addition, nuclear fission and nuclear structure of exotic nuclei and reaction mechanism to produce exotic nuclei are in our scope.

Neutron-induced fission cross section of short-lived nucleus ^{239}U determined by surrogate reaction method

Neutron-induced fission cross sections for ^{239}U (half-life 23.5 min) were determined using the surrogate reaction technique. The compound nucleus $^{240}U^*$ was populated by the transfer-reaction ^{238}U(^{18}O,^{16}O)$^{240}U^*$, and the fission probability of $^{240}U^*$ was determined experimentally. The fission cross sections were obtained by refering the know fission cross sections of ^{235}U(n,f) and measuring the fission probability of $^{236}U^*$ populated by the reaction ^{235}U(^{18}O,^{17}O)$^{236}U^*$. The experiment was carried out at the JAEA tandem accelerator facility. A thin uranium target layer was bombarded by oxygen beams with 162 MeV. The transfer channel was identified by detecting the projectile-like nucleus using silicon ΔE-E detectors. Fission events were identifeid by detecting fission fragments with multi-wire proportional counters. The results are shown in Fig. 1.

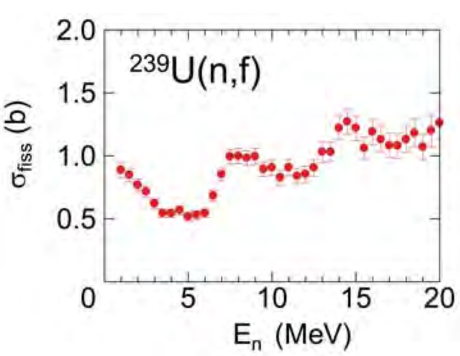

Fig. 1 Neutron-induced fission cross sections (in barn) for ^{239}U(n,f) plotted as a function of neutron energy (preliminary). The step structure associated with the first chance fission is seen at E_n = 7 MeV.

Reaction dynamics in collisions between heavy nuclei in the framework of fluctuation-dissipation model

Exotic nuclei far from stable isotopes are produced by collisions between heavy nuclei. An example is super-heavy nuclei (SHN), which can be produced by fusion-evaporation reactions. Understanding the fusion process is essential to predict the cross section for SHN and to make an experimental strategy. We have developed a model to calculate the evolution of nuclear shape from the initial impact between a projectile nucleus and an actinide target nucleus in the framework of fluctuation-dissipation model [1]. The actinide nucleus is prolately deformed, so that we have effectively taken into account the orientation effects on the reaction. Figure 1 shows the time evolutions of nuclear shape for systems produced by the ^{30}Si + ^{238}U and ^{36}S + ^{238}U reactions. Fusion is defined as the case that the nuclear shape attains the one of ground state of SHN (compound nucleus). The calculation shows the difference between fusion-fission and quasifission in the mass asymmetry of fission fragments and in the time scale for fission. The fusion probability is obtained from the fusion-fission yield relative to the total fission yield. The probability agreed with those determined by the evaporation residue cross sections [2,3]. The same model successfully described the nucleon-transfer induced fission [4].

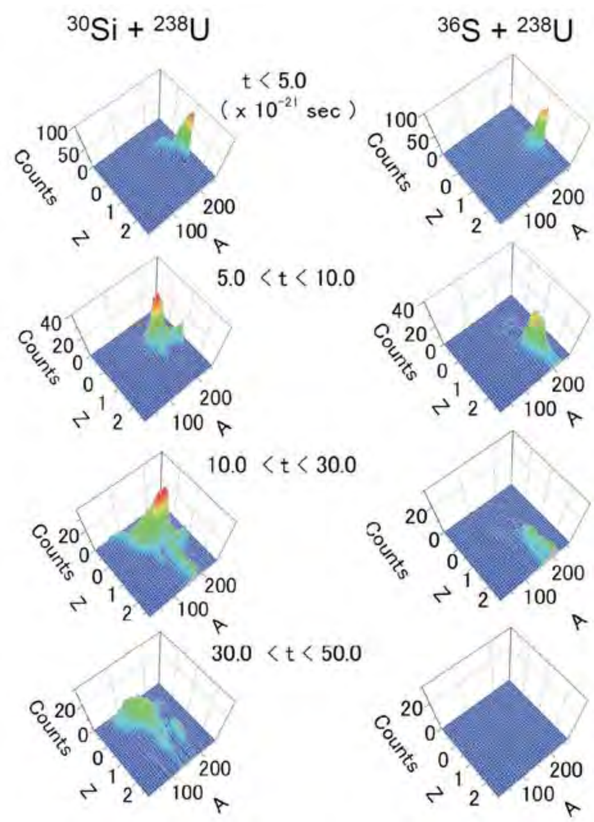

Fig. 2 Time evolutions of the probability distribution on the nuclear shape projected on on the mass asymmetry (mass unit) and charge-center distance for the systems produced in the reactions of ^{30}Si + ^{238}U (left) and ^{36}S + ^{238}U (right). Quasifission finishes at the time less than 30×10^{-21} s, whereas fusion-fission appears later than 30×10^{-21} s.

References

[1] Y. Aritomo *et al.*, Phy. Rev. C **85**, 044614 (2012).
[2] K. Nishio *et al.*, Phys. Rev. C **82**, 024611 (2010).
[3] K. Nishio *et al.*, Phys. Rev. C **82**, 044604 (2010).
[4] Y. Aritomo *et al.*, Phys. Rev. C **84**, 024602 (2011).