Fission fragments mass distributions of nuclei populated by the multinucleon transfer channels of the $^{18}O+^{232}Th$ reaction

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Nuclear fission process is usually described as an evolution of a nuclear shape on a potential-energy surface resulting from the interplay of macroscopic (collective) and microscopic (single particle) degrees of freedom in a nucleus. In particular, the mass division in fission is directly influenced by nuclear shell effects. Then fission-fragment mass distribution (FFMDs) and their sensitivity to the excitation energy and isospin provide a deep insight into the mechanism of the process of fission.

The scope of the present work is to explore the potential of the multi-nucleon transfer (MNT) reactions to measure FFMDs and their excitation energy dependence for the neutron-rich actinides including nuclides which cannot be accessed by particle-capture and/or heavy-ion fusion reactions. Advantage of this method is that fission of many compound nuclides can be studied in a single experiment. A key development for this method is a silicon ΔE-E detector to separate ejectiles to identify transfer channels and determine the excitation energy of compound nuclei. Fission fragments were detected in coincidence using multi-wire proportional counters. We studied the reaction ^{18}O + ^{232}Th using the ^{18}O beam from the JAEA tandem accelerator.

Figure 1 shows the FFMDs of $^{231\text{-}234}Th^*$, $^{232\text{-}236}Pa^*$, and $^{234\text{-}238}U^*$, for excitation energies with an interval of 10 MeV [1]. The experimental FFMDs for all nuclides studied have predominantly asymmetric shape in the lowest excitation energy, while the symmetric component grows with increasing excitation energy. The data for $^{231,234}Th^*$, $^{234,235,236}Pa^*$ were obtained for the first time, which exhibits a larger advantage of the MNT reactions for fission studies. It is found that the measured spectra reveal larger peak-to-valley ratio in the FFMDs for nuclei with large isospin values, as seen for the most neutron rich isotopes of the same element, considered at the same excitation energy, for instance at the E*=20-40MeV. This might be explained by the growing influence of the magic ^{132}Sn nucleus on the mass division toward neutron-rich nuclei.

The general behaviour of the FFMDs at low excitation energies is explained by the calculation based on the fluctuation-dissipation fission model [2] shown by the red curves in Fig.1. The measured FFMDs however show the double-humped shape more clearly at the highest excitation energy. By a further analysis, it is found that the asymmetric FFMDs observed at higher energies are due to the effects of multi-chance fission; contribution of the fissions of several lower-excited lighter nuclei produced after neutron evaporation (or emission).

From this study, the MNT reaction was found to be a powerful tool to explore fission observables in a wide nuclide region up to the high excitation energy of 60 MeV. In higher excitation energies, an interesting observation was reported that the number of the prompt-fission neutrons only from the heavy fragment increases when the excitation energy of a fissioning nucleus increases [3]. Now we are planning to measure the prompt-fission neutrons as well as FFMDs by combining neutron detector array with the present setup.

References

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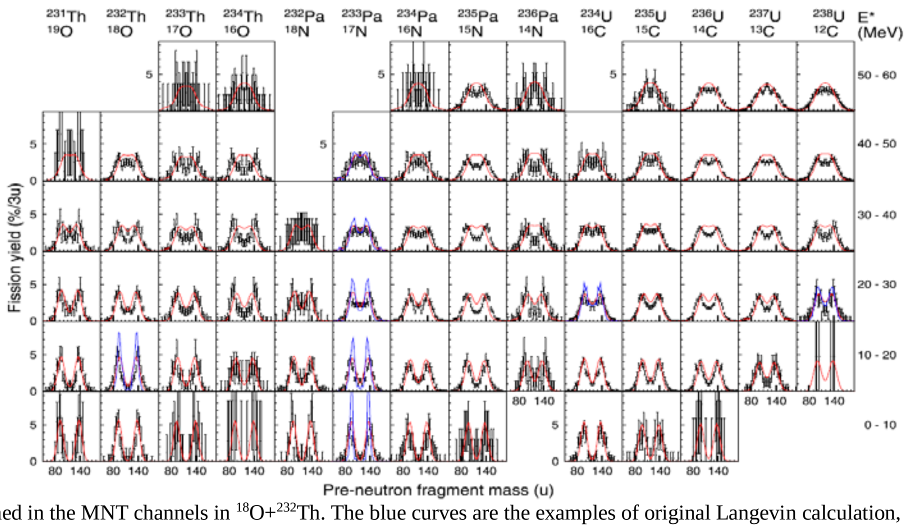

Fig.1 FFMDs obtained in the MNT channels in $^{18}O+^{232}Th$. The blue curves are the examples of original Langevin calculation, which are broadened with the mass resolution (red curves) to make a comparison to the measured spectra [2].