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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Nuclear fission is the most important physical phenomenon underlying nuclear technology. Due to its complexity, the mechanisms of nuclear fission are still to be debated, and many theoretical and experimental works are actively performed worldwide. Among various properties of nuclear fission, the fission barrier height is the most important quantity, and fission probability is thoroughly governed by it. The fission barrier height and probability can be determined via both experimental and theoretical methods. However, the potentiality and the precision of these both methods need to be checked and improved. Traditionally, fission barriers have been deduced from experiments with reactions induced by neutrons, protons, or other light charged particles. However, these experiments cannot deduce fission barriers and fission probabilities of short live nuclei due to the difficulties of target preparation, e.g., radioactive nature. For such cases, multinucleon transfer (MNT) reactions is an alternative measure to populate fissioning compound nuclei far reach by the traditional methods. However, in turn, the reaction mechanism of MNT reactions is very complicated, and it is not obvious at all that compound nuclei populated by the MNT reactions exhibit similar fission behavior to that of the traditional method or not. For example, if too high angular momenta are introduced by the MNT reactions which are not the case for light-particle induced fission, the transition state of the fissioning system my go through will be different to each other, which makes fission barrier significantly different from each other. Therefore, the validity of the MNT reaction to deduce fission properties which we wish for nuclear engineering must be verified. The fission barrier heights are overestimated by the quadrupole-deformation constrained Hartree-Fock + BCS theory using the Skyrme forces, namely SkM* and SLy4. Although the reason of the overestimation has been well understood from Strutinsky calculations that the restriction of the nuclear shapes to axial symmetry in our calculations leads to too high barriers, we cast out on another factor “the nuclear medium effect”.

For these purposes, experiments employing ^{18}O beam on ^{237}Np was carried out at the

JAEA tandem accelerator facility. We deduced fission barriers of ^{239}Np and ^{239,240}Pu and compared their values with conventionally determined values. In the experiments, the ^{18}O beam (162.0 MeV, ~ 0.5 pnA) were accelerated to bombard the ^{237}Np target (76.3 μg/cm^2 thick) electrodeposited on a natural nickel backing (300 μg/cm^2 in thickness). The detection system was composed of four multi-wire proportional counters (MWPCs and of a segmented silicon ΔE-E telescope. The MWPC detectors serve for the detection of fission events, whereas the ΔE-E telescope delivers specific energy loss and total kinetic energy of the ejectiles. A combination of the ΔE and E signals allows for an unambiguous identification of the ejectile to be made, as well as for the excitation energy, E*, of the exit channel to be determined. The fission barrier and maximum fission probabilities were obtained by the probability distribution spectra. Fitted to the probability spectra by the Hill-Wheeler's barrier penetration expression, fission barrier heights were inferred from the fission probabilities of ^{239}Np and ^{239,240}Pu nuclei produced in the 2n and pn/p2n transfer channels, respectively. The deduced values of fission barriers agree well with the literature data, thus demonstrating the potential of the MNT reactions for obtaining fission-barrier data for nuclei not accessible for fission studies via neutron- or light charged particle-induced reactions. However, the fission probabilities disagree with the literature data due to the different transferred angular momentum during the collisions.

This nuclear medium effect is represented by the density-dependent force term of the energy density functional including three- and more-body forces. The optimal strength of the density-dependent force was deduced by adjusting the fractional power of the density-dependent force in Skyrme interaction. We see that the newly proposed modified Skyrme parameter sets have a better description of nuclear fission property. According to a systematic calculation for Thorium, Protactinium, Uranium, Neptunium, Plutonium, Americium, and Curium isotopes, the many-body force is shown to have a significantly large impact on the description of heavy nuclei.

In conclusion, the fission barrier height can be accessed by both experimental techniques and theoretical predictions. The experiment using ^{18}O beam on ^{237}Np target suggests that the MNT reactions can yield the correct fission barrier height, proving that MNT reactions can be a good alternative to deduce fission barrier heights of nuclei not accessible by traditional experiments. However, we also found it was difficult to reproduce fission probabilities obtained with traditional methods. It gives an insight that MNT reactions may bring a large angular momentum to the compound nucleus. Furthermore, we proposed a new Skyrme-type effective nuclear force which can explain the fission barrier height of the actinide region much better than the previously proposed parameter sets.