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Searching for saddle points on fission energy surfaces using Cassini parameters/Cassini パラメータを用いた核分裂エネルギー曲面でのサドルポイントの探索

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The mass and total kinetic energy (TKE) distribution of fission fragments brings essential information on fission dynamics. The fission dynamics have been investigated theoretically with the multi-dimensional Langevin approach, in particular, for actinide nuclei [1]. In this approach, the deformation potential plays a key role in determining the fragment distribution. In order to understand the results of multi-dimensional Langevin calculations, a specific analysis of the structure of the deformation potential is essential. In general, double-humped barrier structures are known for actinide nuclei, but triple-humped barriers are predicted for some nuclides. Identification of the positions and heights of saddle points corresponding to second and third barriers in the multi-dimensional potential space will explain the mass-TKE distributions obtained by Langevin calculations and contribute to the understanding of the origin of various fission modes.

In this study, to investigate the structure of the energy surface in a multi-dimensional deformation space, we focus on the positions and heights of minima and saddle points. The deformation space is described by the Cassini parameter, which is composed of an overall elongation α and deformation parameters α_n, and can flexibly describe various nuclear shapes. We used $\alpha, \alpha_1, \alpha_3, \alpha_4, \alpha_6$ and investigated the structure of the energy surface in a 5-dimensional deformation space. The deformation potential was calculated by adding the microscopic shell correction energy to the macroscopic droplet energy. The saddle points are searched for using the water immersion method. In a multi-dimensional space, there may be many saddle points, and the dam method is used to find them [2]. The 5-dimensional energy surface described by the Cassini parameter is complex, with many saddle points. This is the first attempt to analyze their distribution and height.

In this presentation, the results for Fm isotopes will be presented, since it is known that the mass distribution changes from asymmetric to symmetric between $A = 256$ and 258 in Fm. In ^{256}Fm, an asymmetric third saddle point arises which induces asymmetric splitting. In contrast, in ^{258}Fm, we obtain the symmetric splitting at the third saddle point. It was found that the third saddle point is higher than the second saddle point at ^{256}Fm, whereas the second saddle point is higher than the third saddle point at ^{258}Fm. The changes in the barrier structure in response to the neutron number are thought to lead to changes in the mass distribution.

References

[1] K. Okada, T. Wada, and N. Carjan, "Four-dimensional Langevin approach to fission with Cassini shape parameterization", EPJ Web of Conferences 284, 04018 (2023).

[2] P. Möller, A.J. Sierk, T. Ichikawa, A. Iwamoto, R. Bengtsson, H. Uhrenholt, and S. Åberg, "Heavy-element fission barriers", Phys. Rev. C 79, 064304 (2009).

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