Fission Barriers of Actinides Using Fourier-over-Spheroid Parametrization within the Macroscopic-Microscopic Model

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Nuclear fission remains one of the most complex phenomena in nuclear physics, with the evolution from ground state to scission involving the navigation of intricate potential energy surfaces characterized by multiple barriers and competing fission modes. Accurate determination of fission barrier heights is crucial for predicting fission cross sections, particularly relevant for superheavy element synthesis and nuclear energy applications. This work presents a systematic investigation of fission barriers in actinide nuclei through an innovative dual-parametrization approach, which bridges the Fourier-over-Spheroid (FoS) [1] and beta deformation frameworks within the Warsaw macroscopic-microscopic model [2].

The FoS parametrization offers significant computational advantages by describing nuclear shapes from ground state to scission with minimal collective coordinates: elongation (c), asymmetry (a_3), and neck parameter (a_4). This approach captures the essential physics of nuclear deformation while dramatically reducing the dimensionality of the calculation space compared to the traditional spherical harmonics expansions. In our methodology, nuclear shapes are first generated using the FoS parametrization on a discrete grid, then converted to spherical harmonics representation through numerical fitting of up to 20 beta deformation parameters. This dual approach enables an accurate description of highly deformed configurations while maintaining compatibility with the established Warsaw macroscopic-microscopic framework for energy calculations.

We present comprehensive results for selected actinides, including: ^{230}Th, ^{236}U, ^{240}Pu, ^{246}Cm, and ^{250}Cf. The potential energy surfaces are computed on four-dimensional grids with the ground states and secondary minima identified through gradient-based local minimization. Critical saddle points are located using a water immersion technique. This systematic approach yields first and second fission barrier heights that show good agreement with available experimental data and previous theoretical calculations.

Our results demonstrate that the FoS parametrization provides an efficient and accurate framework for describing the full range of nuclear shapes, from compact ground states to highly elongated configurations beyond the second fission barrier. The successful reproduction of experimental barrier heights validates this computationally efficient approach, suggesting its utility for systematic studies of fission properties across extended regions of the nuclear chart. This work contributes to the broader understanding of nuclear fission dynamics and provides essential input for modeling fission cross sections.

[1] K. Pomorski *et al.*, PRC **107**, 054616 (2023).
[2] P. Jachimowicz *et al.*, At. Data Nucl. Data Tables **138**, 101393 (2021).