Study of potential energy surface of ^{244}Cm nucleus

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Introduction

The Potential Energy Surface (PES) of a nucleus is an essential tool for studying the structural and dynamical properties of atomic nuclei. It provides the idea of shape isomerism, fission barriers, etc. PES defines the total energy of the nucleus in terms of deformation parameters [1]. It can be calculated by phenomenological microscopic-macroscopic methods and evaluated using a specific shape parametrization method. The mic-mac approach is simple and has high flexibility compared with other microscopic scheme such as self consistant model based on the Hartree-Fock approach. In this work, we study the PES of ^{244}Cm nucleus using Finite Range Liquid Drop Model (FRLDM) and Lublin Strasbourg Drop model (LSD) [2][3].

Theoretical Framework

The FRLDM contains the modified version of surface, Coulomb and rotational energies explained in terms of Yukawa-plus-exponential potential energy and deformation depended Wigner energy. The total potential energy in FRLDM with Wigner energy can be defined as,

$$\begin{aligned} V(q)_{FRLDM+W} &= E_S^{(0)}(B_n(q) - B_n^{(0)}) \\ &+ E_c^{(0)}(B_C^{dif}(q) - B_C^{dif(0)}) \\ &+ E_r^{(0)}((L^2 Bj^{dif}(q) \\ &+ K^2 B_K^{dif}(q)) + E_W(q) \end{aligned} \tag{1}$$

The Lublin-Strasbourg version of the nuclear drop energy model relatively modernized LDM and included new terms such as the deformation-dependent curvature energy and congruence energy. The potential energy in the LSD model with congruence energy can be written as,

$$\begin{aligned} V(q)_{LSD+C} &= E_S^{(0)}(B_S(q) - 1) + E_C^{(0)}(B_C(q) - 1) \\ &+ E_r^{(0)}(L^2 Bj(q) + K^2 B_K(q)) \\ &+ E_{curv}^{(0)}(B_{curv}(q) - 1) \\ &+ E_{cong}^{(0)}(B_{cong}(q) - 1)\,. \end{aligned} \tag{2}$$

The shape transitions of the nucleus along the fission pathway are explained using the Funny-Hills parameters such as elongation (c), neck thickness (h), and asymmetry parameter (α). For reason of convenience, the collective coordinates ($q1, q2, q3$) which related to the elongation, neck formation, and mass asymmetry respectively are defined as [3]

$$q1 = c \tag{3}$$

$$q2 = \frac{h + 3/2}{\frac{5}{2c^3} + \frac{1-c}{4} + 3/2} \tag{4}$$

$$q3 = \begin{cases} \alpha/(A_s + B), & B \geq 0 \\ \alpha/A_s, & B < 0\,. \end{cases} \tag{5}$$

Results

Here we study the PES of ^{244}Cm nucleus at the fission limits, where the shell and pairing correction vanishes. The two-dimensional PES of the ^{244}Cm nucleus at a constant angular momentum of $30\hbar$, estimated using the FRLDM and deformation-dependent Wigner energy is shown in Fig. 1. The most probable shape of the nucleus is represented by the red coloured region. The mean path to fission is represented by a dashed line along $q2$ $(0.4-0.9)$, which represents the neck thickness of the nucleus. In ^{244}Cm, it has been

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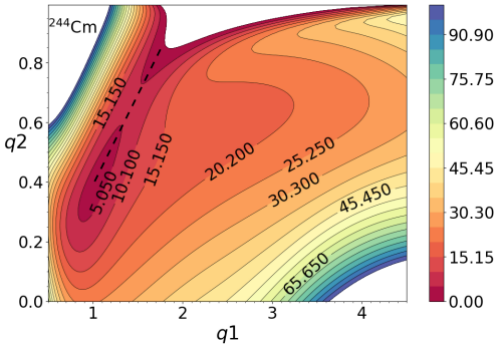

FIG. 1: Two dimensional $(q1, q2)$ potential energy suface of ^{244}Cm compound nucleus at $h = 0$ and $L = 30\hbar$ calculated using FRLDM with shape-dependent Wigner energy.

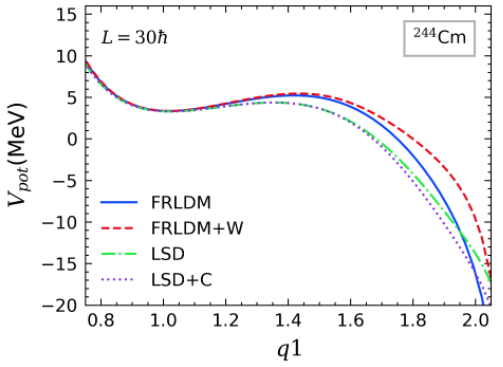

FIG. 2: One-dimensional fission path of ^{244}Cm compound nucleus as a function of $q1$ at $h = 0$ and $\alpha = 0$.

found that PES calculated by FRLDM and LSD are comparable. The one-dimensional fission path in relation to the function of $q1$ in various models including FRLDM, FRLDM with deformation-dependent Wigner energy, LSD and LSD with deformation-dependent congruence energy, are depicted in Fig. 2. The fission barrier height of ^{244}Cm nucleus using FRLDM with Wigner energy is 6.1 MeV, which is comparable with the experimental result of 6.18 MeV [5]. The potential energies derived from various models were inferred to be nearly identical at low deformation. Under the influence of shape-dependent Wigner energy, potential energy varies significantly at high deformation.

In Summary, we have calculated the Potential Energy Surface of ^{244}Cm nucleus using FRLDM and LSD models. By studying the relationship between asymmetric parameter (α) and potential energy, we can understood different fission pathways, the work is under progress.

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