NON-AXIAL QUADRUPOLE AND HEXADECAPOLE DEFORMATIONS IN Cf–Ds NUCLEAR REGION* **

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Large scale calculations in a five-dimensional space of deformation parameters allow us to investigate the influence of quadrupole and hexadecapole non-axialities on the spontaneous fission life time estimates of nuclei. The macroscopic–microscopic method gives the total energy surfaces using the newest Lublin–Strasbourg Drop (LSD) macroscopic energy. The microscopic part is based on the single particle energy spectra of the Woods–Saxon single particle potential with the universal set of parameters in five-dimensional space of deformation parameters for each of about 200 even–even isotopes. Our aim is to obtain the total energy surfaces in the multidimensional space of deformation parameters paying special attention to non-axial quadrupole and hexadecapole parameters $\alpha_{2,2}, \alpha_{4,2}, \alpha_{4,4}$ and to compare them with the total energy surfaces obtained in the axially symmetric space $\alpha_{2,0}, \alpha_{4,0}, \alpha_{6,0}, \alpha_{8,0}, \alpha_{10,0}$ for the region of Cf–Ds and heavier nuclei.

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1. Introduction

Partial experimental tests of the calculated total nuclear energy surfaces can be obtained by comparing the experimental and theoretical masses and multipole moments at the equilibrium deformations of nuclei. Much less direct, global tests are provided through calculated spontaneous fission half

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lives, the latter quantities depending on the integrated barriers and collective mass parameters. Although the life-times are much more difficult to calculate reliably, they play a very important role in the studies of nuclear fission and more generally in examining the nuclear properties at extremely large deformations. The potential energies with the Yukawa–plus-exponential model and Strutinsky microscopic energy for axial shapes was investigated *e.g.* in [1] and [2], non-axial hexadecapole deformations were obtained in [3]. There were also discussed fission barriers and half lives for even–even heavy and superheavy nuclei. The preliminary results for ^{250}Cf isotope with quadrupole and hexadecapole non-axial degrees of freedom were published in [4] and confirmed in [5].

Here we are going to use like in [4] a simplified algorithm allowing for the first glance tests of the calculated total energy surfaces in five-dimensional space of deformation parameters spanned by the non-axial quadrupole and hexadecapole deformations $\{\alpha_{2,0}, \alpha_{22}, \alpha_{4,0}, \alpha_{4,2}, \alpha_{4,4}\}$ and, as an independent test, by the axial even-multipolarity deformations $\{\alpha_{2,0}, \alpha_{4,0}, \alpha_{6,0}, \alpha_{8,0}, \alpha_{10,0}\}$.

In the present context large scale nuclear total energy calculations are understood as simultaneous calculations involving dozens or hundreds nuclei from a given mass range and representing the energy surfaces in multidimensional spaces (here of the dimension equal to 5). The motivation of the calculations of this kind can be multifold. Firstly, by selecting appropriately the new degrees of freedom in excess to the standard ones such as α_{20}, α_{22} and α_{40}, the large scale calculations allow for establishing the new deformation susceptibilities when the nucleus passes from its ground state deformations down to the scission point. The new shape degrees of freedom may influence the equilibrium deformations and the corresponding energies (especially those of the secondary minima) as well as they may lower the potential barriers thus influencing the fission half-lives.

Any realistic large scale calculations are at present strongly limited by the computer capacities and the five- to six-dimensional deformation spaces can be today considered.

2. Calculation method

To calculate the total nuclear energy we use the macroscopic–microscopic method with the macroscopic energy term in the form of LSD approach [6] and the microscopic Strutinsky [7] energy consisting of the shell and pairing energies, obtained using the BCS method with the particle number projection [8]. The single particle energies are calculated using the Woods–Saxon single particle potential with the universal set [9] of parameters. The details of calculation are presented in [4] and in [10].

3. Results

Fission barriers for a few Fm, Rf and No isotopes obtained with axial (full lines) and non-axial (dashed lines) deformation parameters are shown in function of the center-to-center distance r in Fig. 1. The horizontal axis represents the center-to-center distance in $[\mathrm{fm}/(r_0 A^{1/3})]$ units, where $r_0 = 1.225$. In the case of both deformation spaces used, the equilibrium energies are very close to each other; similar applies to the secondary minima. The main differences between axial and non-axial shape parametrisations are the heights of the fission barriers. For each of the studied nuclei, adding non-axial degrees of freedom cuts the fission barriers by about 3 MeV. The axial deformations with multipolarity $\lambda \geq 6$ have rather small values but they change the shapes of the barriers.

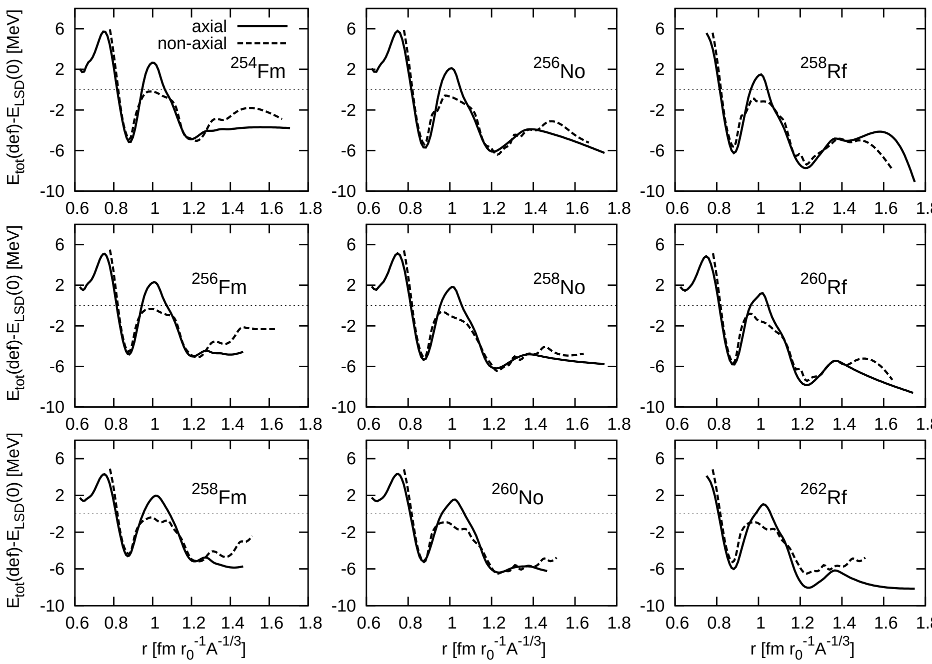

Fig. 1. The total deformation energy defined by the difference $E_{\mathrm{tot}} - E_{\mathrm{LSD}}(0)$, along the fission path found by minimisation of the total energy with respect to $\{\alpha_{2,0}, \alpha_{2,2}, \alpha_{4,0}, \alpha_{4,2}, \alpha_{4,4}\}$ - non-axial case (dashed lines) and $\{\alpha_{2,0}$, $\alpha_{4,0}$, $\alpha_{6,0}$, $\alpha_{8,0}$, $\alpha_{10,0}\}$ axial case (solid lines) for Fm, No and Rf isotopes.

4. Conclusions

The following conclusions can be drawn out from our calculation:

1. The non-axial deformations do not influence the ground state energy of nuclei in the examples illustrated in the paper.
2. The spontaneous fission barriers with non-axial degrees of freedom are about 3 MeV lower than with the axial ones for the studied nuclei.

In the heavier nuclei the non-axial deformations, especially at increasing elongation, influence the total energy landscapes; the systematic analysis of these tendencies will be published elsewhere.

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