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ON THE PROPERIES OF SUPER-HEAVY EVEN–EVEN NUCLEI AROUND ^{294}Og[*]

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The potential-energy surfaces of even–even super-heavy nuclei are evaluated within the LSD macroscopic–microscopic approach with a Yukawa-folded mean-field potential using the Fourier shape parametrization. The calculations are performed in a four-dimensional deformation space, defined by quadrupole, octupole, hexadecapole and nonaxiality degrees of freedom. It is shown that the both pear-like and nonaxial deformation modes are important when evaluating fission barrier heights.

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1. Introduction

As it was shown in Refs. [1, 2], already a 4-dimensional deformation space given by the Fourier parameters defining elongation (q_2), left–right asymmetry (octupole q_3), neck- (hexadecapole q_4) and nonaxiality (η) degrees of freedom, ensures a quite reasonable description of the very rich variety of nuclear shapes which appear around the ground state and all along the nuclear path to fission. The potential energy surfaces (PES) of super-heavy nuclei show a very rich structure, with not only equilibrium points (ground states), but often also several local minima (shape isomers) and saddle points, as well as symmetric or/and asymmetric paths to fission. These structures are well-visible in 2D cross sections of our 4D deformation space, which will be presented below.

The aim of this contribution is to discuss the competition between nonaxial and pear-like degrees of freedom around the saddle-point configuration. We are going to show that only taking simultaneously into account both these types of deformations allows for a proper estimate of fission barrier heights.

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2. Results of the calculation

The main ingredients of our model are the macroscopic–microscopic approximation [3] using the Lublin–Strasbourg Drop (LSD) [4] for the macroscopic part, and the Strutinsky shell-correction method [5] with a Yukawa-folded single-particle potential [6], and the BCS formalism with a monopole pairing force and an approximate particle number projection [7] for the microscopic corrections. The large variety of nuclear deformations is finally described by the Fourier shape parametrization [2].

Our calculations are preformed for 234 even–even super-heavy isotopes from ^{250}Rf to ^{324}126. All parameters of the calculation are standard (see Ref. [2] for details) and none is adjusted to the considered region of nuclei. We are going to show in the following the PES for ^{294}Og and eight neighbouring even–even isotopes. A more extensive analysis of this whole region will be presented in a forthcoming publication. The potential energy surface of each nucleus is evaluated on a 4D deformation-parameter grid consisting of 43 200 points. Different 2D cross sections of such potential-energy surfaces are analysed in order to study the role of various degrees of freedom. Some examples of the 2D surfaces of the macroscopic–microscopic potential energy $E_{\rm tot}({\rm def})$, relative to the LSD energy $E_{\rm LSD}^{\rm sph}$ of the corresponding spherical nucleus, are presented in the following.

In Fig. 1, the PES are shown on the (q_2, η) plane for even–even isotopes of Lv, Og and $Z = 120$. For each point in that plane, the potential energy is minimised with respect to q_4, but keeping the shape reflection symmetric ($q_3 = 0$). All these nuclei turn out to be indeed spherical or weakly deformed in the ground state. The effect of a finite nonaxiality η starts to play a significant role only at larger elongations, *i.e.* around the first saddle ($q_2 \approx 0.3$), the second minimum ($q_2 \approx 0.5$) and the outer saddle ($q_2 \approx 0.7$) of the investigated nuclei, leading to a reduction of the first and even of the second barrier. It came for us a surprise that nonaxial shapes may appear at elongations beyond the first saddle. This is probably related to the new definition of nonaxial deformations which is different (and more general) than the frequently used γ deformation (as shown in Ref. [2]). The situation changes significantly when the potential energy is, in addition, minimized with respect to q_3 as demonstrated on the PES presented in Fig. 2, showing that the role of the nonaxial degree of freedom then becomes weaker. No significant decrease of the fission barriers due to the η deformation is now observed. This indicates that there is a strong competition between nonaxial and left–right asymmetric modes in ^{294}Og and neighbouring nuclei.

In Fig. 3, the PES, now minimised with respect to q_4, are presented for ^{294}Og and its neighbouring even–even nuclei on the (q_2, q_3) plane. Here, only axially symmetric shapes ($\eta = 0$) are considered. Apart from a broad symmetric path to fission, another valley corresponding to very asymmetric

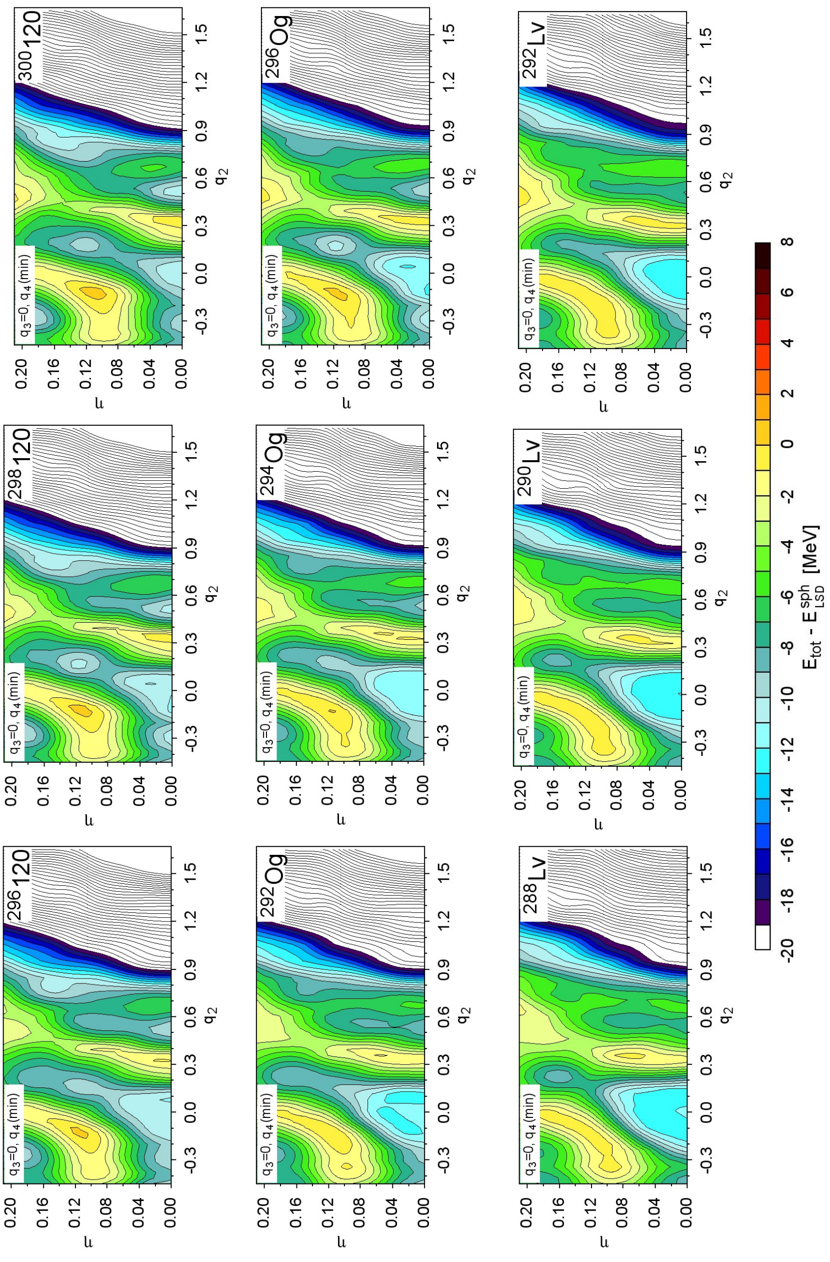

Fig. 1. Potential energy surfaces of ^{294}Og and neighbouring even–even nuclei minimized with respect to q_4 but keeping $q_3 = 0$ on the (q_2, η) plane.

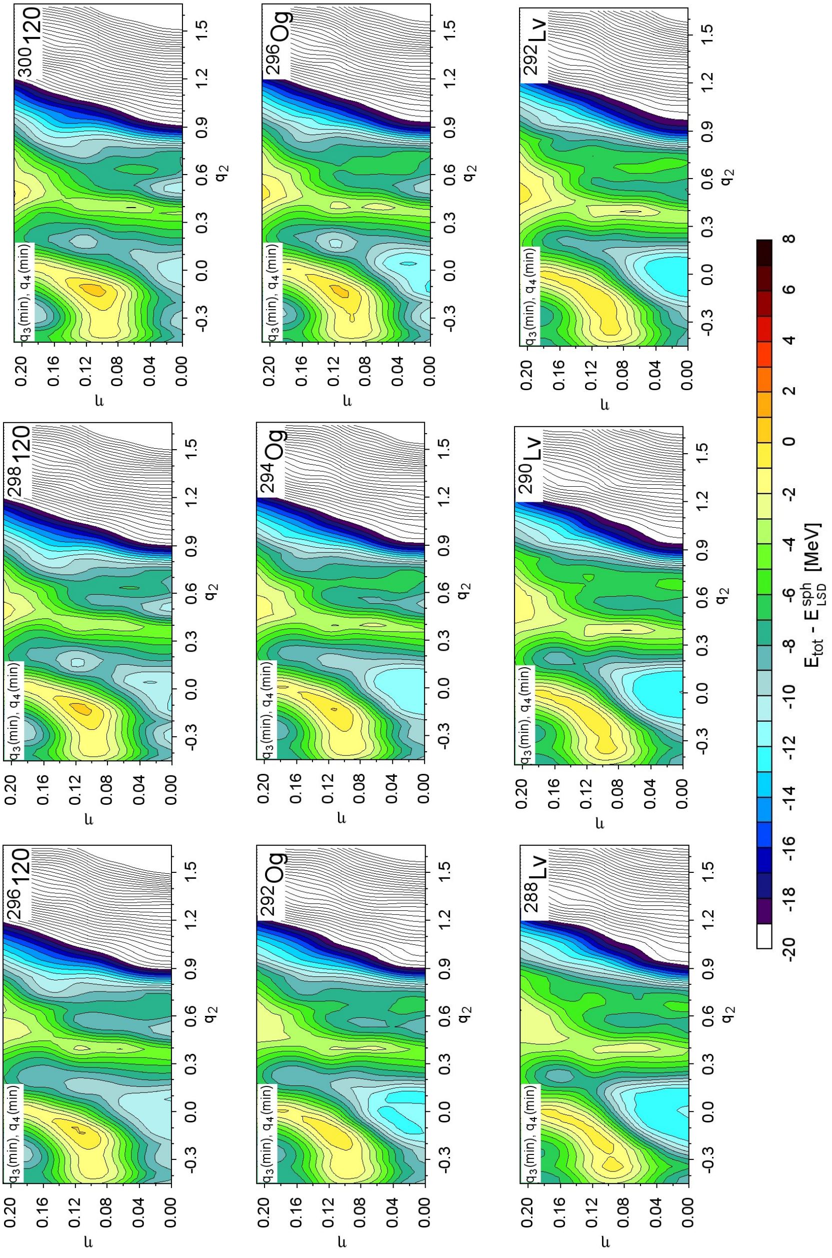

Fig. 2. The same as in Fig. 1 but minimized in addition with respect to q_3.

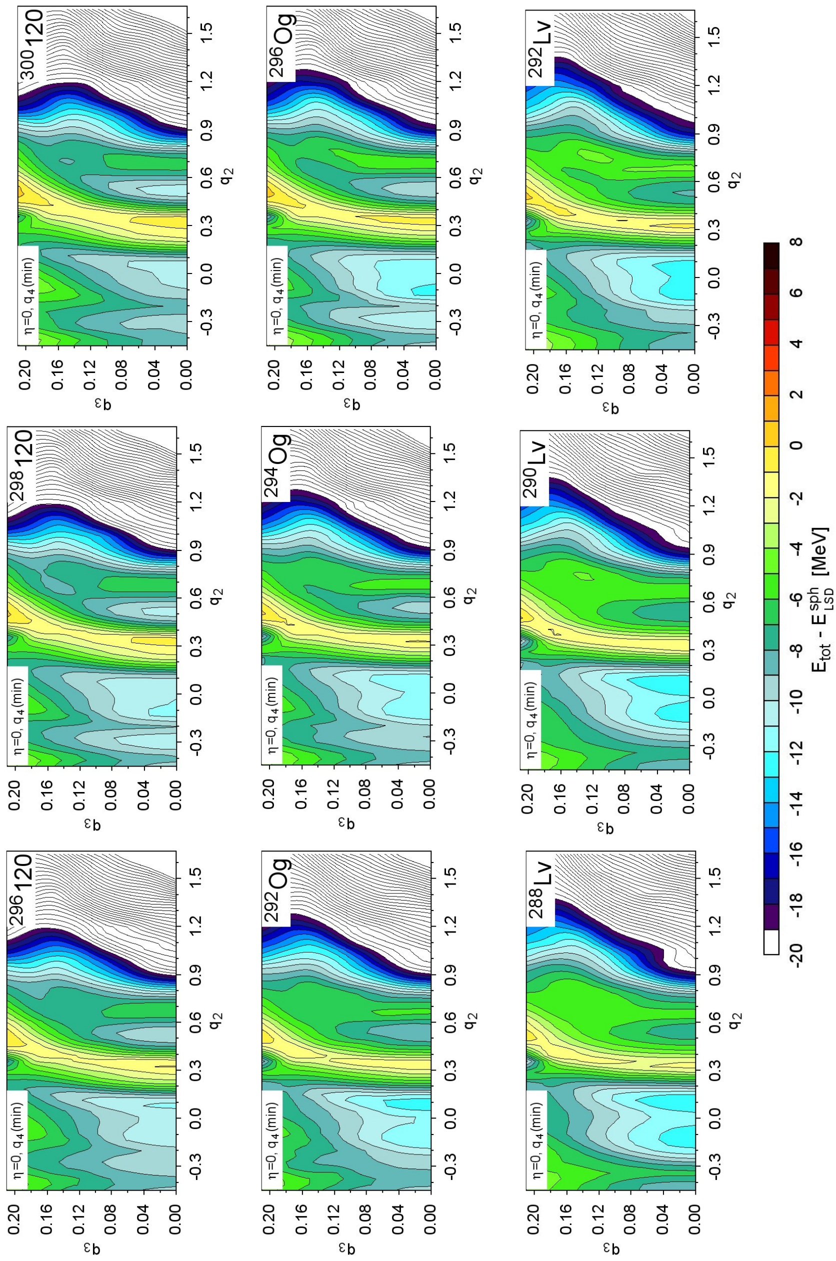

Fig. 3. Potential energy surface of ^{294}Og and neighbouring nuclei minimized with respect to q_4 but keeping $\eta = 0$ on the (q_2, q_3) plane.

fission (cluster emission?) is visible at small elongations $q_2 \approx 0.2$. It is seen that the height of the barrier in this direction is smaller or comparable to the barrier corresponding to a symmetric fission. It is worth noting that this new effect visible in our macroscopic–microscopic calculations has also been observed in Ref. [8] in the HFB calculation with the Gogny force.

3. Conclusions

The following conclusions can be drawn from our investigations:

- The Fourier expansion of nuclear shapes offers a very effective way of describing deformations of fissioning nuclei;
- The macroscopic–microscopic model based on the LSD energy and the Yukawa-folded single-particle potential describes global properties of the heavy and super-heavy nuclei very well;
- Nonaxial and pear-like deformations need to be considered simultaneously when evaluating fission barrier height;
- A new very asymmetric decay mode appears to be present in the PES of the considered super-heavy nuclei around ^{294}Og.

New calculations over a wider range of q_3 deformations with the inclusion of higher rank deformations (q_5 and q_6) are presently on our agenda to study in details the new decay mode suggested by the present investigations.

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