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# Ground State Deformations of Nuclei with 50<Z,N<82

*Dedicated to Professor*
*Dr hab. Mieczysław Subotowicz*
*on occasion of His 65th Birthday*

## 1 Theory

The shapes of the even-even neutron deficient rare-earth nuclei are investigated in the frame of the generator coordinate method (GCM) [1]. The calculation was performed in the two-dimensional collective variables space $(\varepsilon, \varepsilon_4)$ of quadrupole and hexadecapole deformation parameters. The model bases on the hamiltonian consisting of the Nilsson single-particle potential [2] with the pairing residual interaction and the long-range two-body correlations taken in the local approximation [3].

The potential energy $V_{GCM}$ in the generator coordinate method consists of the two terms: the traditional macroscopic-microscopic energy $V_{Strut}$ and the zero-point correction energy $E_0$:

$$V_{GCM} = V_{Strut} - E_0. \tag{1}$$

$V_{Strut}$ is obtained by the Strutinsky [4] shell correction method and consists of the macroscopic part $E_{LD}$ - calculated in the liquid drop model with the parameters from Ref. [5] and the shell correction $\Delta E_{SHELL}$:

$$V_{Strut} = E_{LD} + \Delta E_{SHELL}. \tag{2}$$

The single-particle levels and wave functions were obtained with the Nilsson average potential with the universal set of parameters for the mass number $A = 126$ as proposed by Seo in Ref. [2]. The pairing correlations were included using the BCS functions projected on a good particle number [6]. The strength of pairing forces was taken from Ref. [7].

## 2 Results

We minimize the potential energy surface $V_{GCM}(\varepsilon, \varepsilon_4)$ of all $50 < Z, N < 82$ nuclei for the prolate ($\varepsilon > 0$) and oblate ($\varepsilon < 0$) deformation separately to get the information about the possible equilibrium shapes. It was already shown in Ref. [8] that the ground state energy of the most of investigated nuclei has two minima, one for the prolate and the second for the oblate shape of nucleus. In Fig. 1 one can see the potential energy surface of $^{126}Ba$ with the two wells $(\varepsilon, \varepsilon_4) = (-0.24, 0.01)$ and $(\varepsilon, \varepsilon_4) = (0.26, 0.05)$.

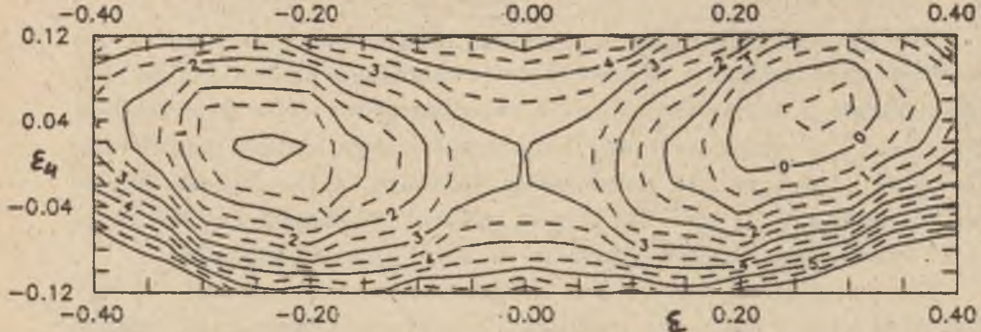


Figure 1: The GCM potential energy surface of $^{126}Ba$ on the $(\varepsilon, \varepsilon_4)$ plane. The distance between layers is equal 1 MeV.

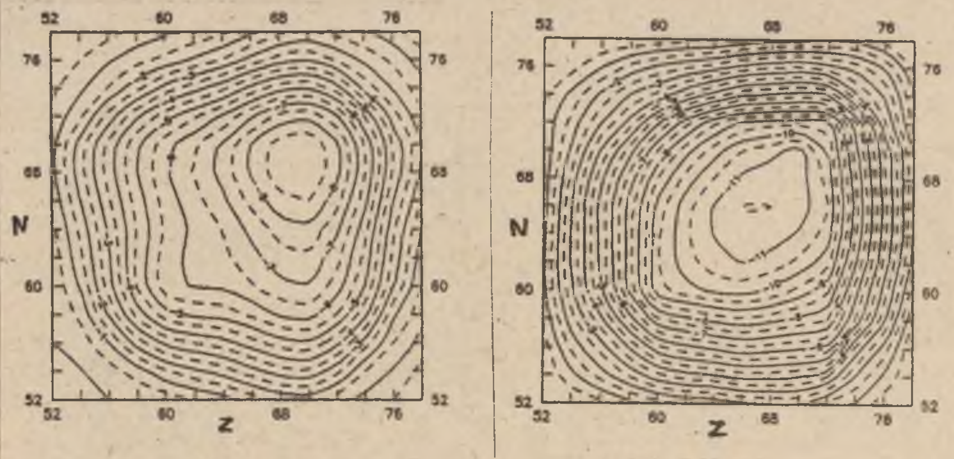


Figure 2: The deformation energies for the oblate (l.h.s.) and prolate (r.h.s.) form of nuclei.

The deformation energies:

$$\Delta E = V_{GCM}(\varepsilon, \varepsilon_4) - V_{GCM}(0,0) \tag{3}$$

for the oblate (l.h.s.) and prolate (r.h.s) minima of nuclei are shown in Fig. 2 on the $(Z, N)$ plane . Only the nuclei above the diagonal $N = Z$ are experimentally accessible. $\Delta E$ reaches the value of -8.5 MeV for the oblate minima, and -11.5 MeV for the prolate ones.

In Fig. 3 the zero-point correction $E_0$ for the both types of minima is drawn on the $(Z, N)$ plane . The term $E_0$ in eq. 1 enlarges the deformation energies of nuclei and influences slightly the positions of the equilibrium points.

The prolate minimum of $^{126}Ba$ (Fig. 1) was deeper than the oblate one. It is the case for the most nuclei of this region. The difference between the depths of the oblate minimum and the prolate one is plotted in Fig. 4 for all the investigated nuclei. It is seen that only the nuclei with the largest neutron number ($N > 74$) have a chance to be oblate deformed. Nevertheless for the dynamical investigation the positive and the negative quadrupole deformation space is needed. Especially when one would like to obtain the experimental observables like the mean square radius or the quadrupole moments.

The coordinates $(\varepsilon, \varepsilon_4)$ of the oblate and prolate minima of the whole region of nuclei are illustrated on Figs. 5 and 6. The quadrupole deformations ($\varepsilon$) do not exceed 0.38 and are maximal for the largest deformation

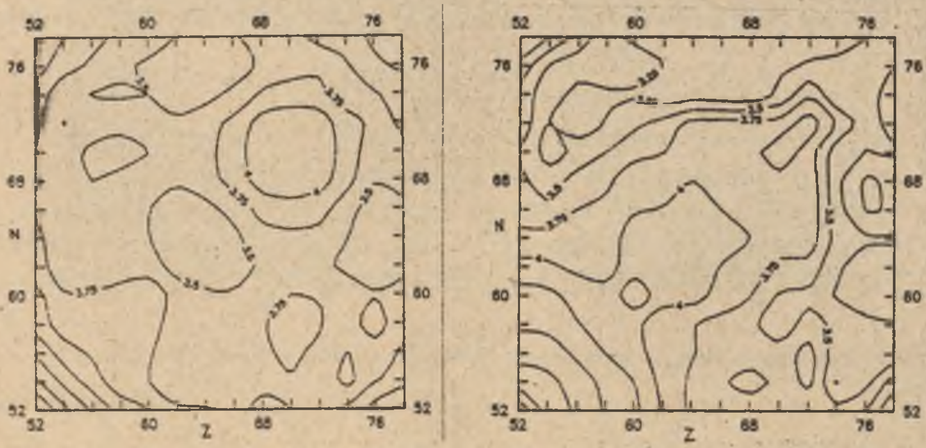


Figure 3: The zero-point correction energy $E_0$ for the oblate (l.h.s.) and prolate (r.h.s.) form of nuclei

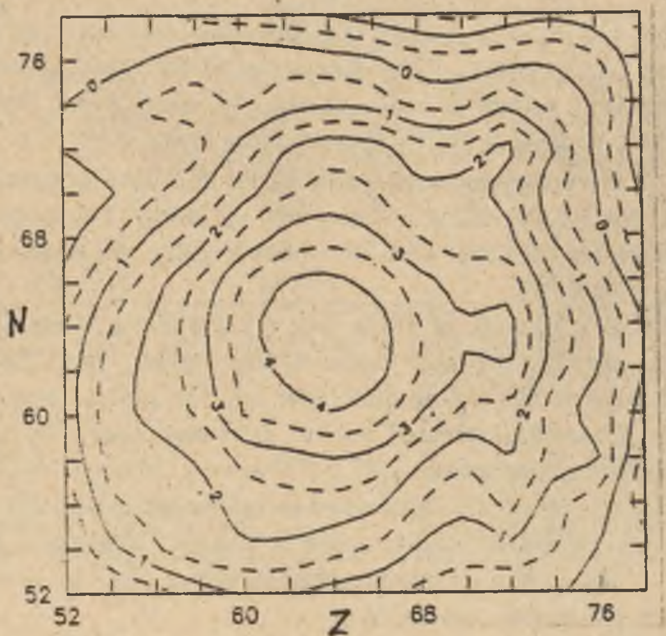


Figure 4: The difference between the depths of the oblate and the prolate minimum (in MeV).

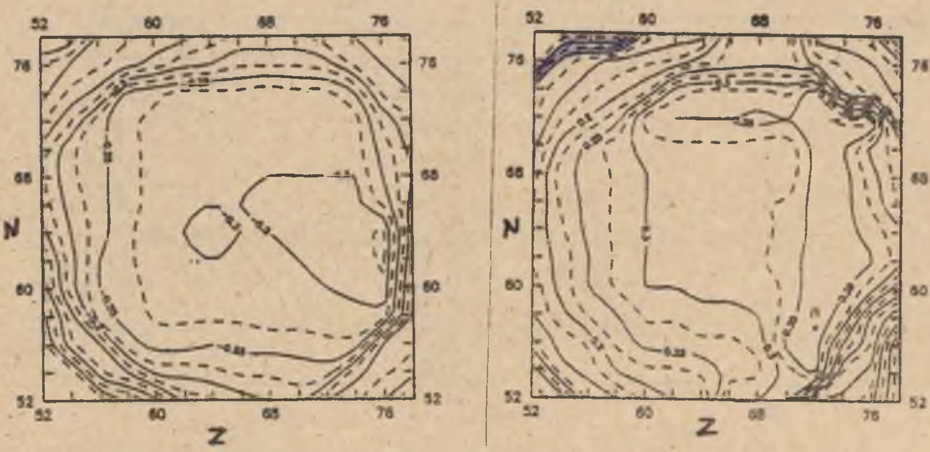


Figure 5: The quadrupole equilibrium deformations for the oblate ($\varepsilon < 0$) (l.h.s.) and prolate ($\varepsilon > 0$) (r.h.s.) forms of nucleus.

energies. The ground state hexadecapole deformations (Fig. 6) vary from $\varepsilon_4 = -0.05$ (for the oblate shapes) to $\varepsilon_4 = 0.10$ (for the prolate ones).

## 3 Conclusions

The following conclusions may be drawn from the results of the present calculations.

1. Nuclei in the $50 < Z, N < 82$ region seem to be as well deformed as the rare-earth nuclei.

2. The GCM zero-point correction to the Strutinsky energy increases the absolute value of deformation energies.

3. Contrary to the result of the paper [8] the most of the nuclei are prolate.

4. Only the nuclei with $N > 74$ have the comparable depths of the both prolate and oblate minima.

We have presented here only the static results. The dynamical calculation with the whole collective hamiltonian are in progress now. The inclusion of the nonaxial deformation is also necessary to get the proper dynamical picture of the collective motion of nuclei in this region. We are planing such a calculation.

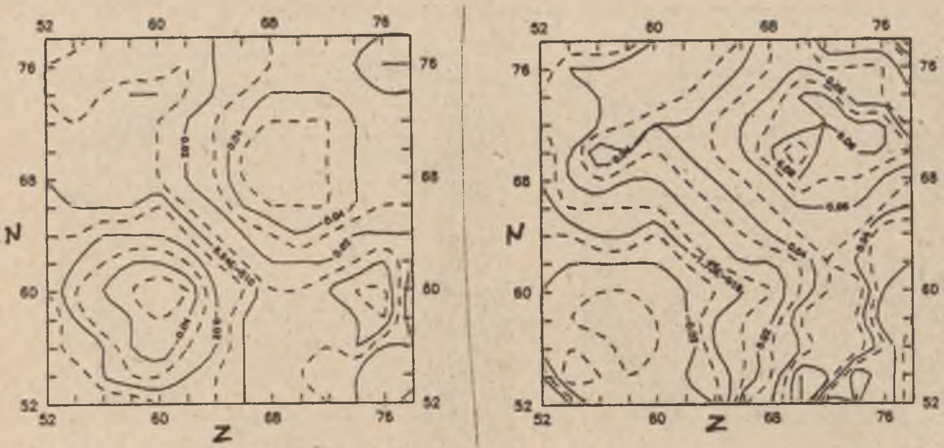


Figure 6: The hexadecapole deformations $\varepsilon_4$ for the oblate ($\varepsilon < 0$) (l.h.s.) and prolate ($\varepsilon > 0$) forms of nucleus.

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