TRIAXIAL DEFORMATION OF MEDIUM HEAVY NUCLEI IN THE RELATIVISTIC MEAN FIELD THEORY

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Many experiments and theoretical calculations with non-relativistic and relativistic frameworks indicate that in proton-rich Xe region, nuclei may have triaxial shapes in their groundstates. We study systematically the triaxial deformation of even-even nuclei in this region with the relativistic mean field(RMF) theory.

We briefly describe the framework of the RMF theory and the procedure of the calculation. All details can be found in [1, 2]. In the RMF theory the system of a nucleus is described by fields of mesons and nucleons under mean field approximation. We start with the effective Lagrangian, which is relativistically covariant, composed of meson and nucleon fields. We adopt the Lagrangian with the non-linear σ and ω terms as

$$\begin{aligned}
\mathcal{L}_{RMF} &= \overline{\psi}_i \left[i\gamma^\mu \partial_\mu - M \right] \psi_i \\
&+ \frac{1}{2}\partial^\mu \sigma \partial_\mu \sigma - \frac{1}{2}m_\sigma^2 - \frac{1}{3}g_2\sigma^3 - \frac{1}{4}g_3\sigma^4 - g_\sigma \overline{\psi}_i \psi_i \sigma \\
&- \frac{1}{4}U^{\mu\nu}U_{\mu\nu} + \frac{1}{2}m_\omega^2 + \frac{1}{4}c_3\left(\omega^\mu\omega_\mu\right)^2 - g_\omega \overline{\psi}_i \gamma^\mu \psi_i \omega_\mu \\
&- \frac{1}{4}G^{a\mu\nu}G^a_{\mu\nu} + \frac{1}{2}m_\rho^2 \rho^{a\mu}\rho^a_\mu - g_\rho \overline{\psi}_i \gamma^\mu \tau^a \psi_i \rho^a_\mu \\
&- \frac{1}{4}F^{\mu\nu}F_{\mu\nu} - e\overline{\psi}_i \gamma^\mu \frac{1}{2}\left(1-\tau^3\right)\psi_i A_\mu ,
\end{aligned}$$

where the notation follows the standard one. This Lagrangian contains the meson masses, the meson-nucleon coupling constants and the meson self-coupling constants as free parameters. We adopt the parameter set TMA[3], which has mass dependence so as to reproduce nuclear properties quantitatively from the light mass region to the superheavy region[4]. By Euler-Lagrange equation we obtain a set of the Dirac equations for nucleons and the Klein-Gordon equations for mesons. These equations are solved self-consistently by expanding the fields of mesons and nucleons in terms of the eigenfunctions of a triaxially deformed harmonic oscillator potential [1, 2]. We perform the constrained calculations on the quadrupole moments of nucleon distribution to get of the energy surface due to the deformation[2, 5]. We take the basis up to N = 12 major shells of harmonic oscillator wave functions for nucleons and N = 10 for mesons.

We have made the RMF calculation with the triaxial deformation of about 40 nuclei covering Z = 50 - 58 and N = 64 - 72 (All calculations were performed on the Fujitsu VPP500 supercomputer of the Computation Center in RIKEN). We have found that this region is rich in triaxial deformation. We can see the tendency that in this region the shape of nuclei changes from oblate to prolate through triaxial and/or γ-soft as neutron number

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increases. Figure1 shows the energy surface, which are calculated by the constrained method, of isotones with N = 68 in the deformation parameter space, β and γ. In this figure, the horizontal axis ($\gamma = 0°$) denotes prolate shape and the tilted axis ($\gamma = 60°$) denotes oblate shape. The region among these axes denotes triaxially deformed shape. The larger value of β indicates the stronger deformation. From Fig.1 we can observe that the shape of nuclei changes from oblate(Z = 50) to triaxial shape(Z = 54, 56) through γ-soft(Z = 52) and from the triaxial shape to prolate(Z = 62) again through γ-soft(Z = 58). Almost same transition can be observed along the isotones with N = 70. We note that the calculation with the pairing correlations is extremely time consuming and for our systematic study of many nuclei we do not include the pairing correlation, although it may play an important role for the nuclear deformation[5]. However, for some cases we perform the calculation with BCS-type treatment of pairing correlation. In this case we find that the position of the minimum moves slightly to spherical shape. The global feature is, however, unchanged. We need further investigations of its effect, which is now in progress.

In conclusion, we have made the RMF calculation with the triaxial deformation in proton-rich Xe region. We find that this region is rich in triaxial deformation. We also find smooth transition from oblate shape to prolate shape through triaxial shape and/or γ-soft for isotones with N = 68, 70 as Z increases.

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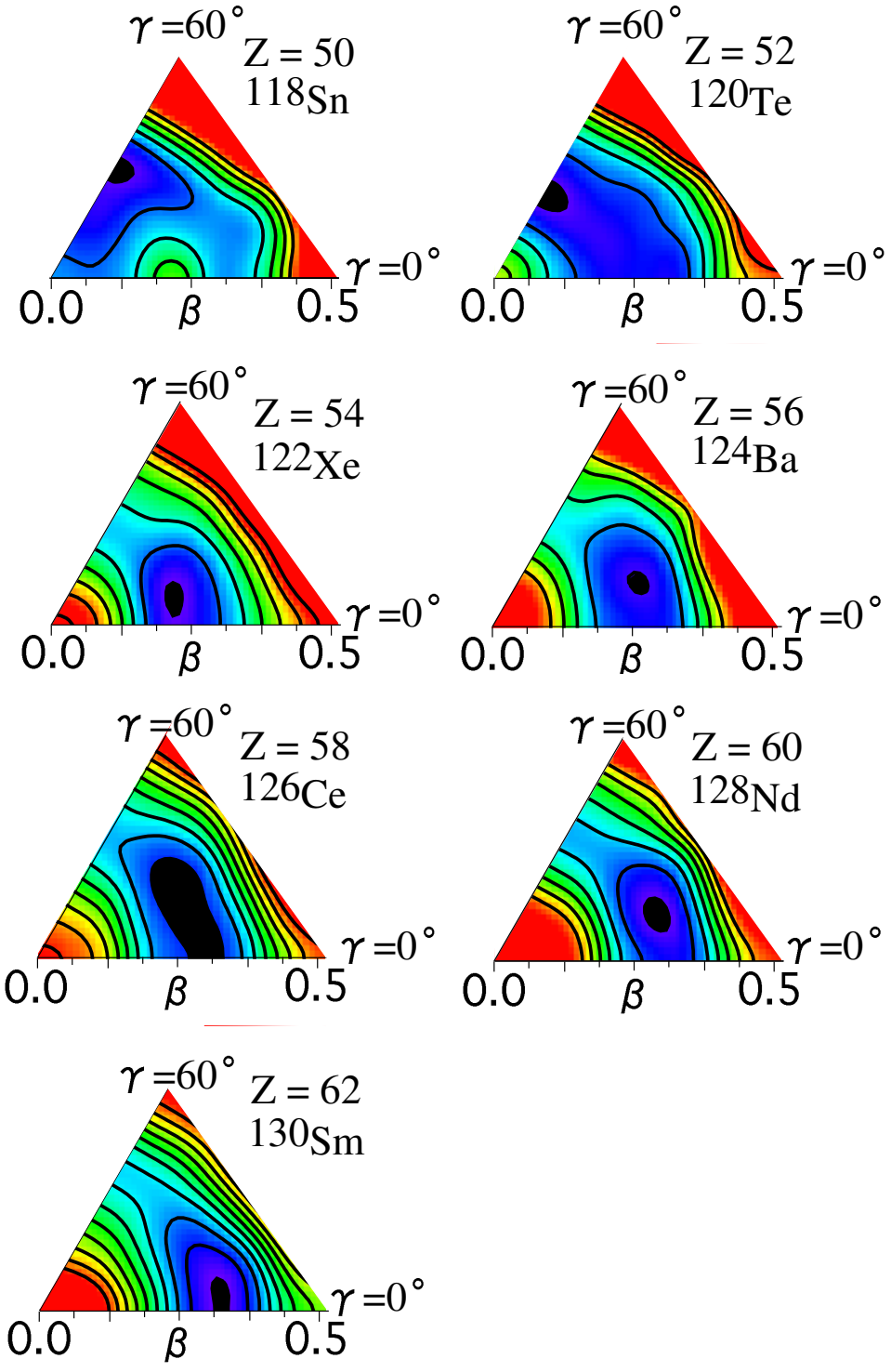

Figure 1: The energy surfaces of the isotones with N = 68 in the $\beta - \gamma$ plane. The position of the absolute minimum for each nucleus is denoted by the black area. The energy difference between the contours is about 0.01 MeV per nucleon.