Triaxiality softness and shape coexistence in Mo and Ru isotopes

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Introduction

A nucleus may take different shapes varying from spherical to quadrupole, octupole and higher order multipole deformations. These shapes are a consequence of the sensitive interplay between collective degrees of freedom and single particle energies . This interplay will lead to phase transition along an isotopic and isotonic chain. Shape evolution for several isotopic chain in the mass region A $\approx$ 100 has been studied through the self-consistent mean-field (SCMF) approximation based on the Gogny-D1M energy density functional(EDF) [1], the potential energy surfaces (PES) using Skyrme HF+BCS [2], and Relativistic Mean Field (RMF) with BCS pairing [3]. In particular, the structural evolution of even-even Ru, Mo, Zr, Sr nuclei, and Ge, Se [1] nuclei have been studied within the SCMF approximation based on the Gogny-D1M energy density functional. This calculation has fully explored the triaxial degrees of freedom and the shape coexistence in these nuclei. The spectroscopic properties have also been done for these nuclei with the help of a fermion-to-boson mapping procedure. This is very important as to clarify to which extent both triaxiality and shape coexistence are reflected in the spectroscopic properties of these nuclei.

In the present analysis, we have done a systematic calculation in the search of triaxial ground state properties and shape coexistence for $^{92-108}$Mo and $^{96-112}$Ru isotopes. The systematic constrained triaxial calculation is done in the self-consistent mean field model-the Relativistic-Hartree-Bogoliubov(RHB) with density-dependent zero and finite range N-N interactions. The model parameter used are the density-dependent DD-ME2 and. Pairing correlations are considered in the separable pairing model. A systematic comparison is made with calculated values and experimental data, Macro-microscopic Finite Range Droplet Model(FRDM) as well as with the self-consistent HFB calculations based on the interaction Gogny-D1S force.

Results and Discussion

Systematic constrained triaxial calculations mapping the quadrupole deformation space defined by β_2 and γ has been performed for $^{92-108}$Mo and $^{96-112}$Ru isotopes, using both DD-ME2 and DD-PC1 parameterizations. For each nuclei two contour plots have been made one each parameterization to investigate the location of a triaxial ground state, and the possibility of shape coexistence. The location of the ground state in the $\beta - \gamma$ deformation space is indicated by the point (β^0, γ^0). Location of the ground state is shown in TABLE I for Ru and Mo isotopes and is extracted from Fig.1. One can relate the smooth transition of the ground state along the isotopic chains with the evolution of several ground state nuclear properties along an isotopic chain. For that we study the evolution of binding energy (BE), proton radii (R_p) and neutron radii (R_n), two neutron separation energies (S_{2n}) and root mean square charge radii (R_c) with $\delta\langle r_c^2\rangle^{50,N} = \langle r_c^2\rangle^N - \langle r_c^2\rangle^{50}$, for both Ru and Mo isotopic chain [4].

Conclusion

We have used the Relativistic-Hartree-Bogoliubov (RHB) formalism with separable pairing to perform a systematic calculation along two isotopic chains, Ru and Mo, for the search of triaxial ground state and shape co-

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TABLE I: Location of the ground state indicated by (β^0, γ^0) for Ru and Mo isotopes using DD-ME2 and DD-PC1 parameterizations.

Nucleus	DD-ME2	DD-PC1
^{104}Ru	(0.25,22^o),(0.4,0^o)	(0.27,22^o)
^{96}Mo	(0.23,25^o), (0.20,0^o)	(0.22,22^o)
^{98}Mo	(0.25,10^o)	(0.22,32^o), (0.23,10^o)
^{100}Mo	(0.25,20^o),(0.22,60^o)	(0.25,20^o)
^{102}Mo	(0.33,20^o), (0.40,0^o)	(0.33,20^o)
^{104}Mo	(0.37,17^o),(0.22,55^o)	(0.38,17^o),(0.23,55^o)
^{106}Mo	(0.39,17^o),(0.22,55^o)	(0.36,17^o),(0.23,55^o)
^{108}Mo	(0.37,20^o),(0.24,55^o)	(0.37,20^o),(0.24,55^o)

existence. The results of our investigation can be summarized as follows.

Shape coexistence doesn't show up in any of the Ru isotopes except in ^{104}Ru using DD-ME2 parameterization. But triaxiality softness is clear in all of these isotopes. Shape coexistence and triaxiality softness manifest themselves in a clear manner in Mo isotopes. At the beginning of each isotopic chain, the ground state has a near prolate shape, but as the number of neutrons increases the shape smoothly move into triaxiality and then into the near oblate shape toward the end of the chain. The results we obtained is independent of the choice of model and parameter set as it agrees with the results obtained in [3]. A comparison of our results with those in Refs. [1, 5, 6] shows very good agreement with the majority of the calculations. The results of the calculations for the ground state bulk properties are in good agreement with the available experimental data and FRDM. It also reflects the smooth transition of the ground state and the softness in the γ-direction.

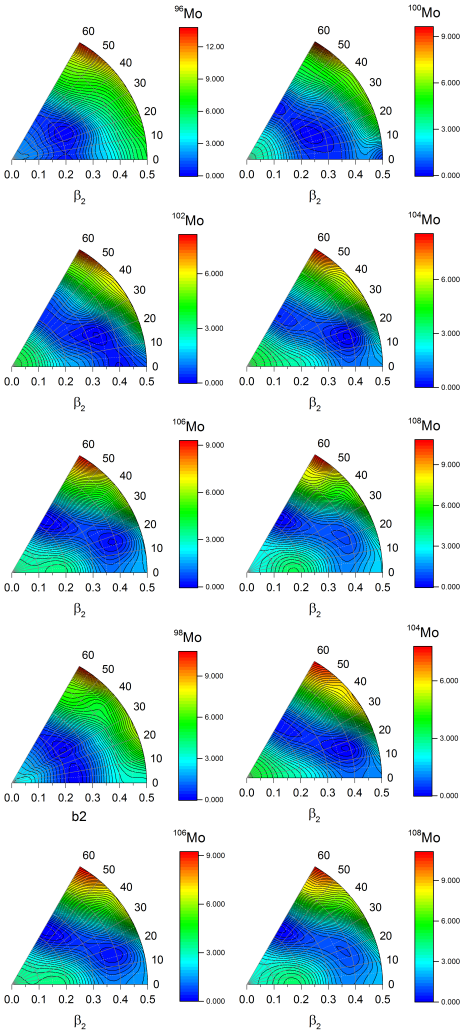

FIG. 1: (Color online) Potential energy surfaces of the Mo isotopes in the (β, γ) plane, obtained from a triaxial RHB calculations with the DD-ME2 parameter set. The color scale shown at the right has the unit of MeV, and scaled such that the ground state has a zero MeV energy.

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