Shape coexistence in ^{72}Se within framework of cranked Nilsson Strutinsky model

Nidhi Goel[1]* and Somnath Nag[1]
[1]*Dept. of Physics, Indian Institute of Technology (BHU), Varanasi (U.P.), India*

Introduction

Atomic nuclei near the mid-shell regime exhibit many unique characteristics like shape coexistence, evolution of shapes, octupole correlations, time-reversal chirality and thus provide a platform within quantum many-body framework to understand the spontaneous symmetry breaking phenomena [1]. The competition between spherical configuration and deformed shapes lead to the phenomenon of shape coexistence which is quite prominent in high mass region $A \sim 180$ [2]. In the mass region, A $\sim$ 70, ^{72}Se was the first nucleus where such shape coexistence was reported for the first time [3]. At the same time it was suggested that low lying members of $K^{\pi} = 0^{+}$ deformed rotational band may coexist with vibrational states associated with the spherical ground state. In addition, lower spin states are oblate but soft to vibration, which gradually settles down to a prolate deformed shape at high spins. With the above motivations, A. Mukherjee *etal.* recently reported shape coexistence and octupole phenomenon in ^{72}Se [4]. Present work focuses on the discussion of coexistence various possible nuclear shapes in high-spin rotational regime (Band A in the published paper) in framework of cranked Nilsson-Strutinsky (CNS) model.

Model Calculations

In pairing independent cranked Nilsson Strutinsky calculations, coefficient of $\mathbf{l} \cdot \mathbf{s}$ and $\mathbf{l^2}$ in the nuclear potential were derived for $A = 80$ region [5]. Observed energies have been calculated with respect to a standard rotating drop energy. Lublin-Strasbourg drop (LSD) [6] with diffused surface. An absolute energy scale based on mass excess has also been applied so that different nuclei can be compared. The calculation minimizes the energy with respect to the deformation parameters (ε_2 , ε_4, γ). In the configuration dependent CNS model, the configurations are designated by the number of particles or holes in orbitals labeled by N shell. Each shell is further grouped into high- and low-j shells. The configurations are labeled as per the nomenclature : $[p_1 p_2, n_1 n_2]$, where, p_1 and n_1 are the numbers of protons and neutrons in $p_{3/2}$, $f_{5/2}$ orbitals (which are together designated as pf orbital), respectively, whereas p_2 and n_2 correspond to proton and neutron occupations in $g_{9/2}$ orbitals.

Discussions

Initially, configuration independent energy minimization is performed with respect to the deformation parameters. The probable nuclear shapes are discussed with Fig.1 which shows evolution of stable nuclear shapes as a function of spin. At $I = 15\hbar$, three shapes coexist with $\gamma = 0°$ (prolate), $\sim 20°$ and -30°. Shapes with $\gamma = 0°$ (prolate), $\sim 20°$ are more favorable whereas configuration with -30° is feeble. It is interesting to note that, the minimum at negative γ value disappears immediately as spin increases. On the other hand, shape with $\gamma = 0°$ is quite stable and spans the entire spin range. The minimum with $\gamma \sim 20°$ gradually traverses towards non-collective $\gamma \sim 60°$ and approaches a likely band termination. It is to be remembered that Palit *et al.* reported the coexistence of similar minima in potential energy surface plot using TRS calculations for negative parity bands in ^{72}Se and could correlate the calculated shape tran-

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*Electronic address: `nidhi.goel.rs.phy18@itbhu.ac.in` sition with the observed smooth drop in transitional quadrupole moment Q_t as the spin increased [7]. Finally the shape was stabilized by non-collective oblate shape at high angular frequency. Hence, negative and positive parity bands in ^{72}Se show similar shape characteristics.

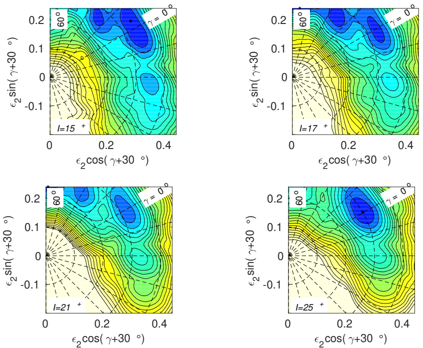

FIG. 1: (Color online) Calculated total energy surface plot for ^{72}Se for a scan run with positive parity and odd spin configurations. The contour line separation is 0.25 MeV.

Different configurations were probed in to explore energetically favorable configurations. The configuration [42, 64] comes out to be the most favorable configuration. At low spin, three minima, viz. a strong minimum at $\gamma \sim$ -45° along with, $\gamma \sim 0°$ and 15° coexist. It is observed that the predominant rotation of nucleus around the longest axis at lower spin states shifts towards rotation about the shortest axis for higher spin states. By comparing the observed energies with the calculated ones it is concluded that, band A can be described by the above two shapes of [42, 64] with a smooth crossing at $I = 16\hbar$. While, band B can be explained by [42, 64] with prolate shape. Thus, the observed crossing is attributed to the nuclear structural transition from rotation around the longest axis to the shortest axis rotation.

For comparing the excitation energy with respect to the rotating liquid drop in band A with [42, 64] we have used γ-energies from [7] for the states beyond $I = 16\hbar$. They further compared the calculated transitional quadrupole moments with the observed values and thus concluded the the states at $I \leq 6\hbar$ are stabilized by oblate shape whereas higher spin states mostly show prolate deformation.

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