^{84}Zr at High Spins

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Introduction

Nuclei with Z≈40 and N≈45 lie in a transitional region between the deformed nuclei and spherical nuclei. There exist collective bands in these nuclei, also their structure have single-particle features, such as some isotopes of nuclei Sr, Zr and Mo etc. Among these nuclei, the systematics of γ -vibrational states, and structure of ^{84}Zr have been studied using in-beam γ-ray spectroscopy by Doring et al. [1] and three discrete transitions were observed between the yrast superdeformed band and states of normal deformation in ^{84}Zr by Chiara et al. [2]. Further, multiple superdeformed bands in ^{83,84}Zr have been studied in a backed-target experiment, using the Gammasphere and the Microball 4π detector arrays [3]. Recently, Zheng et al. [4] have investigate the shape evolutions of A $\sim$ 80 nuclei and found triaxial deformations in ^{84}Zr using Total-Routhian-Surface calculations.

Encouraged by the above studies on Zr isotopes near A = 80 region, we would like to investigate high spin properties and shape of ^{84}Zr using cranked Hartree-Fock-Bogoliubov (CHFB) theory employing a pairing + quadrupole + hexadecapole model interaction [5–7] which has already implemented on Kr isotopes for successful description of high spin structures [5–7].

Theoretical Formulation and Model

We employ a quadrupole-plus-hexadecapole-plus-pairing model interaction hamiltonian,

$$H = H_0 - \frac{1}{2}\sum_{\lambda=2,4}\chi_\lambda \sum_{\mu}\hat{Q}_{\lambda\mu}(-1)^{\mu}\hat{Q}_{\lambda-\mu} - \frac{1}{4}\sum_{\tau=p,n} G_\tau \hat{P}_\tau^\dagger \hat{P}_\tau \ , \quad (1)$$

where, H_0 stands for the one-body spherical part, χ_λ term represents the quadrupole and hexadecapole parts with λ = 2, 4 and the G_τ term represents the proton and neutron monopole pairing interaction. Explicitly we have

$$\hat{Q}_{\lambda\mu} = (\frac{r^2}{b^2})Y_{\lambda\mu}(\theta,\phi)\,, \quad (2)$$

$$\hat{P}_\tau^\dagger = \sum_{\alpha_\tau,\bar{\alpha_\tau}} c^\dagger_{\alpha_\tau} c^\dagger_{\bar{\alpha_\tau}}\,. \quad (3)$$

In the above $c^\dagger$ are the creation operators with $\alpha \equiv (n_\alpha l_\alpha j_\alpha m_\alpha)$ as the spherical basis states quantum numbers with $\bar{\alpha}$ denoting the conjugate time-reversed orbital. The standard mean field CHFB equations are solved self-consistently for the quadrupole, hexadecapole and pairing gap parameters. For more details of calculations readers can refer to Ref [5, 6].

Results and Discussions

We investigate the energies of the yrast levels with comparison to the experimental values which are plotted in the lower panel of Fig. 1. The parabolic shape is quite well reproduced as can be seen by figure. However, calculated numbers are found lower as compared to the experimental values toward higher angular momentum. In order to demonstrate the change in structure as a function of angular momentum, we display a plot of moment of inertia I vs. rotational frequency ω in the upper panel of Fig.1, (J = Iω). It is clear from

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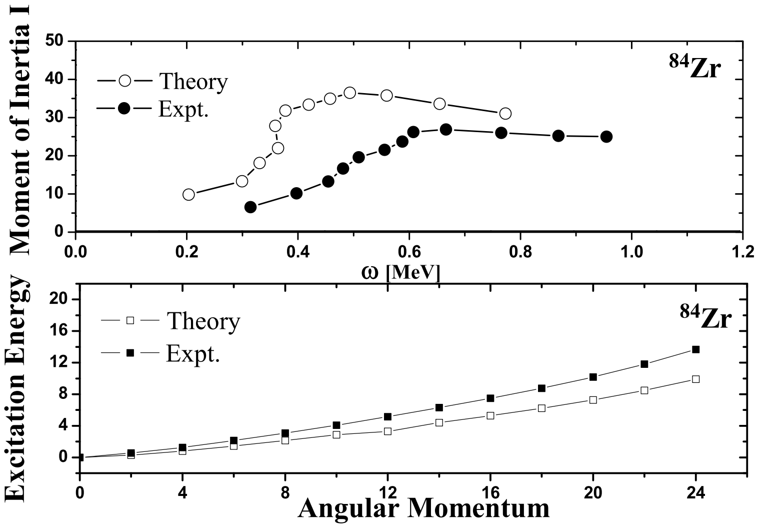

FIG. 1: Lower panel: Calculated energies (hollow square) of the yrast states of ^{84}Zr compared with the experimental values (solid square). Upper panel: Variation of calculated moment of inertia (hollow circle) as a function of rotational frequency in ^{84}Zr is shown along with experimental values (solid circle).

the upper panel of Fig.1 that calculated results exhibit upbends at frequency $\omega = 0.35$ MeV like a sharp discontinuity at this point. In the experimental curve this backbanding is not observed. The experimental curve however, shows small sudden jumps at 0.5 MeV and at 0.6 MeV. It is worth to note here that for the nucleus ^{84}Zr, triaxial and prolate deformations coexist in our calculations at high spins which is similar result as that of ref∼[4]. As can be seen from Fig. 1, the moments of inertia of the triaxial rotational band agree with the experimental results in shapes however, not in the values . The upbending at the rotational frequency is due to the alignments of a pair of quasiprotons and quasineutrons.

At high spins in both experimental and theoretical curve, a down slope appears indicating the decreasing deformation which is also in accordance with our theoretical calculations for high spins. Our calculations show that quadrupole deformations parameter β has its value 0.29 for J = 0 i.e. for ground state. For larger spins this value of β increases and reaches upto its maximum 0.32 for J = 10, and for high spin i.e. J > 10, the value of β decreased and has its value 0.24 for J = 24, which is in accordance of upper panel of Fig.1 and with the experimental data.

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