Triaxial projected shell model study of ^{109}Tc nucleus

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The study of multiphonon band structures is one of the current frontier topics in theoretical physics. An important issue is to understand the collective excitations in low-spin states of neutron-rich nuclei. But to provide reasonable explination of the multiphonon band structures requires the study of higher-spin states which provides the comprehensive understanding of the interaction of multiquasi-particle excitations with γ-vibrational bands. Neutron-rich nuclei in the mass A = 100 region exhibit many interesting structural phenomena. For example, there have been discussions about triaxial deformations and the shape coexistence phenomenon existing in this mass region. With increasing neutron number toward more neutron-rich regions, triaxial deformation and multiphonon γ-vibrational structure develop. Besides the ground state bands, some collective bands such as one-phonon γ-vibrational bands and chiral doublet bands have been observed in neutron rich nuclei in this mass region. For this mass region, the valence nucleons begin to fill the $h_{11/2}$ neutron and the $g_{9/2}$ proton orbital. Experimental $\gamma$and $\gamma\gamma$-vibrational bands have been reported in several nuclei in this mass region as in $^{(103,105,107,109,111)}$Tc [5–7], ^{103}Nb, and in odd-N ^{105}Mo. The reported 2γ-bands in odd-mass nuclei like ^{107}Tc [8], ^{103}Nb and ^{105}Mo are the first identification of such a kind of band structures.

For the comprehensive understanding of these experimentally identified multi-quasiparticle bands with diverse phenomena in structure can serve as an ideal testing ground for various theoretical models. Several theoretical models have been proposed to study γ-bands with varying degrees of success. Like The quasiparticle phonon nuclear model (QPNM), the multiphonon method (MPM), the dynamic deformation model (DDM), algebraic models including the extended version of the interacting boson (sdg-IBM) and pseudosymplectic models have also been employed to study the γ-excitation modes and these predict high collectivity for the double-γ vibration. We would also like to add that a considerable effort has been devoted in understanding the γ-excitation mechanism by using the random phase approximation (RPA) approach. The advantage of the triaxial projected shell (TPSM) model is that it describes the deformed single-particle states microscopically as in QPNM, MPM, and DDM, but its total many-body states are exact eigenstates of the angular momentum operator. Correlations beyond the mean field are introduced by mixing the projected configurations.

Recently, TPSM approach has been developed and it has been shown to provide a coherent and accurate description of yrast-, γ- and $\gamma\gamma$-bands in transitional nuclei [1–3]. More recently, TPSM approach has been generalised to study the γ-vibrational band structures in odd-mass nuclei. It has been demonstrated that TPSM provides an excellent description of the γ-vibrational bands observed in ^{103}Nb [4]. In particular, TPSM study provided a theoretical support for the first observation of $\gamma\gamma$-band in an odd-mass nucleus. For the study of odd-proton system, our model space is spanned by (angular-momentum-projected)

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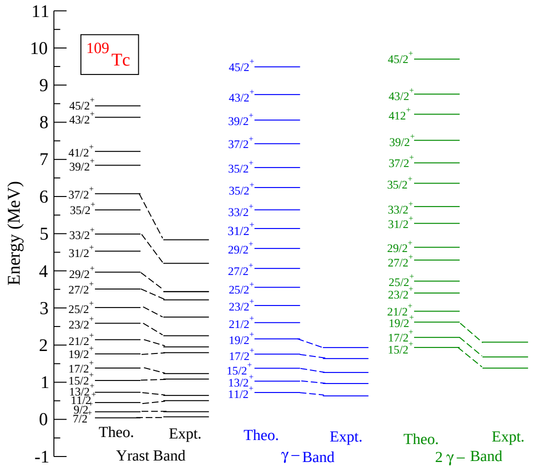

FIG. 1: (Color online) Comparison of experimental and the calculated band energies for ^{109}Tc.

one- and three-qp basis, i.e., $\hat{P}^I_{MK}\ a^\dagger_p \,|\,\Phi >$, $\hat{P}^I_{MK}\ a^\dagger_p a^\dagger_{n1} a^\dagger_{n2}\,|\,\Phi >$ and $|\,\Phi >$ represents the triaxially-deformed qp vacuum state. The qp basis chosen in our model space includes the configurations of two-neutron quasiparticle states built on the one-quasiproton states. The basis, with one- and three-qp configurations included, has proven adequate to describe the high-spin states in odd-mass systems and the rotation alignment process. As in the earlier PSM calculations, we use the pairing plus quadrupole-quadrupole Hamiltonian

$$\hat{H} = \hat{H}_0 - \frac{1}{2}\chi \sum_\mu \hat{Q}^\dagger_\mu \hat{Q}_\mu - G_M \hat{P}^\dagger \hat{P} - G_Q \sum_\mu \hat{P}^\dagger_\mu \hat{P}_\mu ,$$

Here $\hat{H}_0$ is the spherical single-particle Hamiltonian, which contains a proper spin-orbit force. The interaction strengths are taken as follows : The QQ-force strength χ is adjusted such that the physical quadrupole deformation ϵ is obtained as a result of the self-consistent mean-field HFB calculation. In the present calculation, we take $G_1 = 16.22$ and $G_2 = 22.68$, which approximately reproduce the observed odd-even mass difference in the studied mass region. This choice of G_M is appropriate for the single-particle space employed in the model, where three major shells are used for each type of nucleons $(3, 4, 5(2, 3, 4)$ for neutrons (protons)).

TPSM calcualtions have performed for ^{109}Tc nucleus with deformation parameter ϵ = 0.320 and triaxility ϵ = 0.150. The axial parameter ϵ is normally chosen from the measured quadrupole moment of the system, wherever available, or the tabulated values using the phenomenological potential models. The value of ϵ' is, preferably, chosen from the mimimum of the potential energy surface (PES) of the nucleus, or, the value of ϵ' is choosen in such a manner to reproduce the γ-band head energy. To compare theoretical energies with the experimental data, we plot the experimental and theoretical level energies in Fig. 1 for the yrast-, γ- and $\gamma\gamma$-bands. However, there appears to be a problem to reproduce the band head of the $\gamma\gamma$-band for studied nucleus and this problem was already discussed in our earlier investigation for ^{103}Nb [4] It is evident from Fig. 1 that not only the energies of each band but also their relative positions of the bands are correctly reproduced by the current TPSM calculation.

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