# Study of $\gamma$-vibrational band structures in $^{105}Nb$ nucleus using triaxial projected shell model approach

W. A. Dar[1],* J. A. Sheikh[1,2], G. H. Bhat[1], R. N. Ali[1], S. Jehangir[3], P. A. Ganie[3], T. A. Mir[4], and P. Javed[1]
[1]Department of Physics, University of Kashmir, Srinagar, 190 006, India
[2]Department of Physics and Astronomy, University of Tennessee, Knoxville, TN 37996, USA
[3]Department of Physics, National Institute of Technology, Srinagar, 190 006, India and
[4]Nuclear Research Laboratory Astrophysical Sciences Division Bhabha Atomic Research Center, Srinagar, 190 006, India

## Introduction

The study of band structures in terms of multiphonon gamma bands is an important topic in nuclear physics. The excitation at low spin region for proton rich nuclei is an important issue, but to understand the interaction of multiquasi particle excitation with gamma vibrational band, it is mandatory to study the high spin states. There are many important phenomena like nuclei with triaxially deformed (triaxial nuclei), shape coexistance are seems to be observed in this mass region. But with the increase in neutron number, the properties like triaxiality and the multiphonon $\gamma$ vibrational bands are developed, as recently observed in neutron rich region i.e in Mo and Ru [1]. The chiral nature of bands and the nature of collective bands (in addition to ground state band) have also been observed in this mass region. The basic configuration for this mass region is $h_{11/2}$ for neutron and $g_{9/2}$ for proton orbitals. There is a lot of experimental data which predicts the $\gamma$- and $\gamma$ $\gamma$- vibrational bands in several nuclei in mass region $A \sim 100$ as in $^{103,105,107,109,111}Tc$ [2–4], $^{103}Nb$, and also in odd-N $^{105}Mo$. The first identifaction of $2\gamma$ bands have been reported in $^{107}Tc$ [5], $^{103}Nb$ [6], $^{105}Mo$ [7] and are the best candidate for the existance such band structures.

Understanding of multiquasi particle bands more elobrately validate the theoritical models. Several theoritical models have been proposed to study the $\gamma$ viberaion properties in various mass regions which gave success to a great extent. 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 $\gamma$-excitation modes and these predict high collectivity for the double $\gamma$- vibration. There was a considerible effort to study the $\gamma$- excitation spectrum by random phase approximation (RPA) approach. The advantage of the triaxial projected shell model (TPSM) is that it describes the deformed single-particle states mircoscopically as in QPNM, MPM, and DDM, but its total many-body states are exact eigenstates of the angular momentum operator.

Recently, TPSM approch has been successful to provide the coherence and accurate description of yrast, $\gamma$- and $2\gamma$- bands in transitional nuclei. In the present work, the TPSM calculations are performed for odd-proton system. For such system, the basis space connsists of one-proton, and one-proton + two-neutron states. The qp basis chosen above is adequate to describe high-spin states up to $I \sim 35/2\hbar$ for odd-mass nuclei considered in this work. In the present analysis we shall, therefore, restrict our discussion to this spin regime. For one-qp state, $\kappa = 1/2$ $(-1/2)$, and the possible values of $K$ are therefore $1/2, 5/2, 9/2, \ldots$ $(3/2, 7/2, 11/2, \ldots)$.

*Electronic address: waheedphy@gmail.com

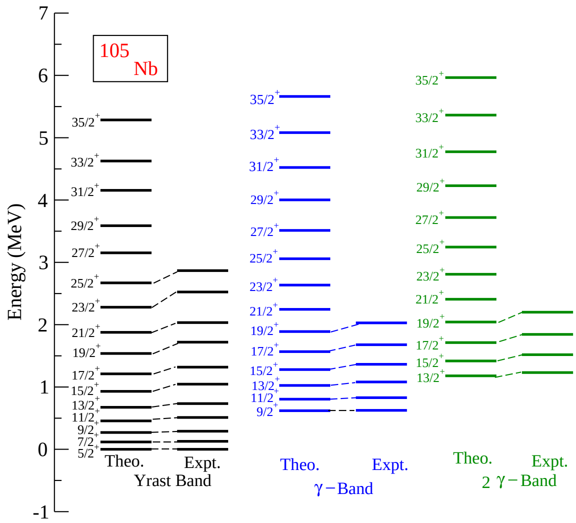


FIG. 1: (Color online) Comparision of experimental and theoritical energies for yrast, $\gamma$ and $2\gamma$ bandsrespectively.

As in the earlier PSM calculations, we use the pairing plus quadrupole-quadrupole Hamiltonian given by.

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

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 $\chi$ is adjusted such that the physical quadrupole deformation $\epsilon$ is obtained as a result of the self-consistent mean-field HFB calculation.
In the present calculation, we take $G_1 = 20.82$ and $G_2 = 13.58$, which approximately reproduce the observed odd-even mass difference in the 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 ($N = 3, 4, 5$ for both neutrons and protons). The quadrupole pairing strength $G_Q$ is assumed to be proportional to $G_M$, and the proportionality constant being fixed as 0.18.

Recently, TPSM approach has been developed and it has been shown to provide a coherent and accurate description of yrast, $\gamma$-, and $2\gamma$-bands in transitional nuclei [8, 9]. TPSM calculations have been performed for odd mass system $^{105}Nb$ with qudrapole deformation parameter $\epsilon = 0.339$ and triaxiality $\epsilon'$ $= 0.150$. The axial parameter is chosen from the measured qudrapole of the system or the available tablated values, while as the triaxiality has been chosen from the minimum potential energy surface (PES) of the neuclus or chosen in such a way so as to reproduce band head of the $\gamma$ band accurately. It is quite evident from the Fig. 1 that TPSM calculations have reproduced the band structures of the $^{105}$Nb quit well. The band heads of $\gamma$ band in our calculation starts from spin $I = 9/2$, while as the band which is build on $\gamma$ band i.e $2\gamma$ starts from $I = 13/2$ which is consistant with experimental investigations. It is quite interesting that the band head of both $\gamma$- and $2\gamma$-bands are quit well reproduced by TPSM calculations.

## References


[1] C. L. Zhang, G. H. Bhat et al., Phys. Rev. C (2015).

[2] A. Bauchet et al., Eur. Phys. J. A 10, 145 (2001).

[3] Y. X. Luo et al., Phys. Rev. C 70, 044310 (2004).

[4] J. K. Hwang et al., Phys. Rev. C 57, 2250 (1998).

[5] G. U. Long et al., Chin. Phys. Lett. **26** 092502 (2009).

[6] J.-G. Wang, et al., Phys. Lett. B 675 420 (2009).

[7] H. B. Ding, et al., Phys. Rev. C 74 054301 (2006).

[8] J. A. Sheikh, G. H. Bhat et al., Phys. Rev. C 77, 034313 (2008).

[9] J. A. Sheikh, G. H. Bhat et al., Nucl. Phys. A 824, 58 (2009).