Triaxial projected shell model study of $^{178-186}$W nuclei

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The triaxiality, as the broken axial symmetry, in atomic nuclei have been quite convincing both experimentally and theoretically. However, the problem how a triaxially deformed nucleus rotates has been an active topic in nuclear structure studies. A nucleus with the elongated shape rotates favorably around the shortest intrinsic principle axis, and the yrast states can be well described by the theoretical models in which a fixed rotational axis is assumed and the rotation is introduced independently from the mean field to provide the states with angular momentum. A nucleus with triaxial deformation rotates in a much more complex way that the rotational axis is not fixed at all and could be changed dramatically with increasing spin, so the theoretical description of such states becomes a great challenge. By treating the rotation and the mean field in a unique uniformity, the triaxial projected shell model (TPSM) provides a reasonable explanations of self-consistency between the rotation and the mean field, and thus provides a powerful tool to explore the insight into the triaxial rotation in fully quantum mechanically. Thus the TPSM study of high-angular-momentum phenomena has provided a deep understanding of the motion of nucleons in a rotating mean field.

Recently, The multi-quasiparticle TPSM approach has been employed to investigate the high-spin band structures in Er-isotopes and in the mass $\sim$ 130 region [1, 2]. It has been demonstrated in these studies that $\gamma-$bands are built on each intrinsic configuration of the mean-field potential and generalizes the well known surface γ-vibration in deformed nuclei built on the ground-state configuration. In the mass $\sim$ 130 region, the TPSM model has provided an alternative explanation of a long-standing puzzle of two-aligned bands with identical intrinsic configuration observed in some nuclei. It has been shown that the two observed aligned states in ^{134}Ce, having identical neutron configuration, are the normal two-quasiparticle neutron aligned band and the $\gamma-$band built on this configuration. More recently, TPSM has been used to investigate the interplay between the vibrational and the quasiparticle excitation modes in $^{166-172}$Er [3]. It has been established that low-lying K = 3 bands observed in these nuclei are, in fact, built on triaxially deformed two-quasiparticle states. This band is observed to interact with the γ-vibrational band and becomes favored at high angular momentum for some Er nuclei. Therefore, these recent developments in TPSM approach have greatly enhanced the model predictability and may provide new insights into the observed bands with unknown structures. As a matter of fact, by using this approach, the interpretation of complicated band structures has reached a quantitative level.

However, there has been a considerable experimental evidences of high-K bands emerging around the yrast line. As there is experimental evidence that as the Fermi surface moves into the upper half of the intruder subshell, the states with high-K start emerging around the yrast line and these bands start competing with the low-K bands. This has been observed in W, Re, and Os nuclei [5]. Since the present version of the TPSM for even-even nuclei is composed of projected 0-qp state (or qp-vacuum), two-proton, two neutron, and 4-qp configurations. To achieve an uniform fine description of the high K bands

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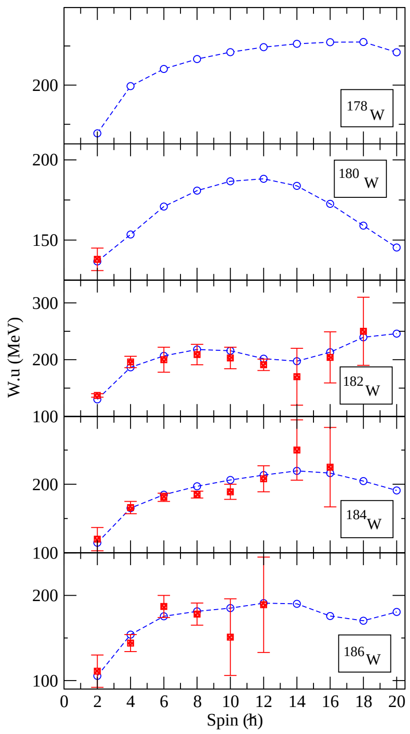

FIG. 1: (Color online) Comparison of experimental and the calculated band energies for ^{109}Tc.

and their interaction with the yrast line, the TPSM model basis needs to be extended up to the 8qp-configuration of 4 neutron+4 proton, which is in pipeline and is our future investigation. Further, in the present abstract we have studied the transition probabilities for $^{178-186}$W nuclei which has been the major spotlight of the present work. As the electromagnetic transition probabilities contain important information on the intrinsic structures of a quantum many-body system. For instance, the intrinsic deformation is directly related to the quadrupole transition strength.

As in the earlier TPSM calculations, we use the pairing plus quadrupole-quadrupole Hamiltonian [1, 2]. Once the Hamiltonian is diagonalized in the TPSM basis, the eigenfunctions are used to calculate the electric quadrupole transition probabilities

$$B(E2) = \frac{1}{2I_i + 1} \left| \left\langle \Psi^{K_f}_{I_f} || \hat{Q}_2 || \Psi^{K_i}_{I_i} \right\rangle \right|^2 .$$

The explicit expression for the reduced matrix element in the projected basis can be found in [4]. In the calculation, we have used the standard effective charges of 1.5e for protons and 0.5e for neutrons.

TPSM calculations have performed for $^{178-186}$W nuclei with deformation parameter ϵ and ϵ'. 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 minimum 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. TPSM calculations have been performed to evaluated the B(E2) transition probabilities along the yrast line that has been shown in Fig. 1. It has been noted that the TPSM approach provides an accurate description of the measured B(E2). In particular, we have shown that both axial deformation and non-axial deformation contribute to the observed behavior of B(E2) in the low-spin regime. In the high-spin region, it has been substantiated that the drop in the transitions (^{180}W) is due to the rotational alignment of neutrons.

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