# Projected shell model study of antimagnetic rotational band structure in $^{105}$Pd

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## Introduction

The breaking of the spherical symmetry in nuclei results in the appearance of the rotational band structures. The rotational bands are built on deformed states with a substantial quadrupole deformation and exhibit strong electric quadrupole ($E2$) transitions between the rotational states. The collective rotational motion of all the nucleons around an axis perpendicular to the symmetry axis of the deformed density distribution explains the existence of such band structures. Apart from the regular rotational-like bands, a new kind of band structures in nuclei around the shell closures and typically with small deformation has been observed. In contrast to the normal deformed bands, these rotational-like bands are characterized by strong magnetic dipole ($M1$) and very weak $E2$ transitions. These bands were interpreted and characterized as magnetic rotational (MR) bands. There is also a possibility of antimagnetic rotational (AMR) motion in analogy to anti-ferromagnetism in solids. The AMR bands are understood in terms of a twin shears mechanism, wherein the angular momentum is generated by the simultaneous closing of the valence anti-aligned proton and neutron blades towards the angular momentum vector [1]. The anti-alignment of the valence proton blades cancel the perpendicular component of each others magnetic moment leading to the absence of magnetic dipole transitions.

In the present work, projected shell model (PSM) approach calculations have been performed to provide a microscopic understanding of the observed AMR band in $^{105}$Pd [2]. This is the first application of the extended version of PSM approach, where the valence neutrons and protons occupy different shells in contrast to the earlier versions where the basis configurations are constructed from one major oscillator shell only.

## Theoretical Framework

PSM is a microscopic shell model based approach wherein the deformed quasiparticle basis are constructed by solving axially deformed Nilsson potential and BCS equations. In the next stage, using the three-dimensional angular-momentum projection operator, good angular-momentum basis are projected out from the Nilsson + BCS states. This restores the broken rotational symmetry of the system. Finally, the projected states from the quasiparticle configurations close to the Fermi surface are used to diagonalize the shell model Hamiltonian (quadrupole + pairing) given as : :

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

The wavefunctions obtained in the diagonalization of the above mentioned Hamiltonian are then used to calculate the electromagnetic transition probabilities, the details of which can be found in [3].

## Results and Discussion

We have performed the PSM analysis in order to have insight into the nature of band structures observed in $^{105}$Pd. As compared to the phenomenological models, PSM approach is a microscopic tool that allows to investigate the interplay among different excitation modes. In the present study of odd-neutron $^{105}$Pd system, the basis states are comprised of one, three and five

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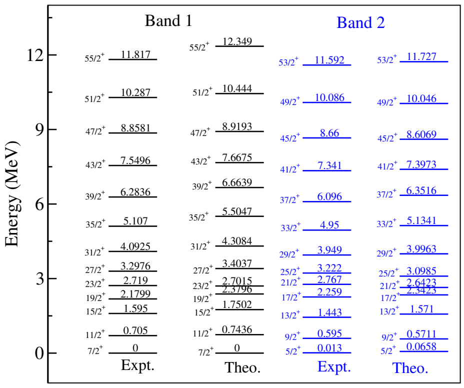

FIG. 1: PSM energies after configuration mixing are plotted along with the available experimental data [2] for the $^{105}$Pd isotope.

quasiparticle excitations. The three quasiparticles are formed from one-neutron coupled to two-proton configurations and one neutron quasiparticle coupled to two neutron quasiparticles. The five quasiparticles are formed from three qasineutrons coupled to two quasiprotons. The basis states have been constructed with the deformation parameter, $\beta = 0.170$ [4]. In the present work we have employed N = 3, 4, 5 (2,3,4) oscillator shells for neutrons (protons). To generate the positive parity, a pair of neutrons and protons is occupying N = 5 and 4 shells respectively. The odd neutron is occupying the N = 4 oscillator shell.

The PSM results after diagonalization are presented and compared with the experimental data in Fig. 1. As is evident from Fig. 1, the agreement between the PSM results and the observed data is satisfactory. The deviation in the calculated energies at high spin is due to the fact that in TPSM approach, the mean field is held fixed for all the spin states and excitation energies. It is known from microscopic studies that mean field can change with spin and excitation energy. In Fig. 1 Band 1 and Band 2 are expected to originate due to AMR and have the same intrinsic structure of three quasi-neutron configuration [2]. In order to probe this, we have analysed the wavefunction decomposition of these bands and the results are plotted in Fig. 2. It is clear from Fig. 2 that the dominant component in both these bands is the three quasi-neutron configuration up to $I = 41/2^+$ and above this spin value, the five-quasiparticle configurations dominate. This is due to the crossing of the five quasiparticle band. To probe the AMR nature of the band structures, $B(E2)$ and $BM(1)$ transitions have been evaluated, and these quantities demonstrate that these bands have AMR character.

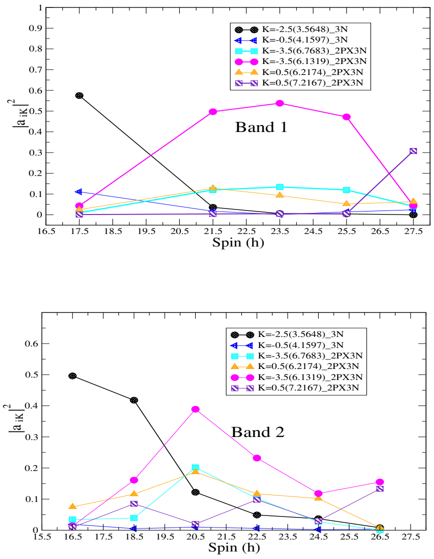

FIG. 2: Probability of various projected $K$ configurations in the wave functions of the band structures after diagonalization are plotted for the $^{105}$Pd nucleus.

In the present work, we have performed a microscopic investigation of anti-magnetic rotational band structures observed in $^{105}$Pd isotope using the PSM approach. This is the first application of the PSM approach to investigate the AMR phenomena observed in $^{105}$Pd.

## References

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