Study of Yrast spectra, Band structure and Backbending in ^{76}Ge and ^{76}Se within the framework of Projected Shell Model

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Introduction

Recently the technology developments have assisted to set up various $\beta\beta$ decay experiments across the globe to set limits on half life of many $\beta\beta$ decay candidates. The experimental realization of $\beta\beta$ decay processes may help in establishing the properties of neutrinos. Theoretically, various mean field approximaions have been employed to estimate the Nuclear Matrix Elements(NMEs) of $\beta\beta$ decay processes. The accuratly obtained NMEs shell be useful for the extraction of half life of $\beta\beta$ decay and mass of neutrino from the experimental data. The knowledge of nuclear structure is vital for the calculation of NMEs.
The Projected Shell Model scheme has been employed by various theoretical groups[1] to explain nuclear structure properties. In the present paper, we shall be discussing nuclear structure properties such as yrast spectrum, band structure and backbending of ^{76}Ge and ^{76}Se in the PSM[1] framework.

Theoretical Framework

In PSM calculations, the Shell Model truncation is first achieved within the quasiparticle (qp) states with respect to the deformed Nilsson+BCS vacuum $|\phi\rangle$, then rotational symmetry are restored for these states by standard projection techniques to form a spherical basis in the laboratory frame. Finally the shell model Hamiltonian is diagonalized in the basis.
In PSM calculations, we use Hamiltonian of separable forces

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

Where $\hat{H}_0$ is the spherical single particle hamiltonian. The second term is the quadrupole-quadrupole interaction and the last two terms are monopole and quadrupole pairing interactions respectively. The coupling constants for the monopole pairing force G_M is taken as[1]

$$G_M = \left(G_1 \mp G_2 \frac{N-Z}{A}\right)\frac{1}{A}\ (MeV) \quad (2)$$

where -(+) sign for neutron(proton) and G_1 and G_2 are the coupling constants and are adjusted to reproduce the pairing gap in the given mass region. G_1 and G_2 are adjusted to be 20.22 and 13.13. The quadrupole pairing strengh G_Q is assumed to be proportional to G_M with proportionality constant 0.24 for ^{76}Ge and ^{76}Se.

Results and Discussion

A. Yrast Spectra

In Fig. 1, the theoretical yrast spectra obtained by carrying out PSM calculations are compared with the experimental data over entire range of available spin for ^{76}Ge and ^{76}Se. The quadrupole deformation parameter (ϵ_2) used for carrying out the ^{76}Ge and ^{76}Se calculations are 0.220 and 0.256 respectively. The experimental data is taken from[2]. From the results, prsented in Fig.1, we see that the experimental energy levels are in good agreement with the calculated ones.

B. Band Diagram

Fig.2 represents the band diagram for ^{76}Ge. It exhibits band crossing in the spin ranges

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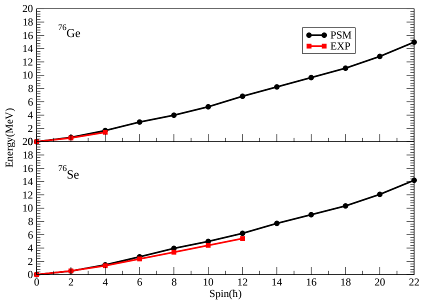

FIG. 1: Comparison of calculated energies of yrast band with experimental data of ^{76}Ge and ^{76}Se

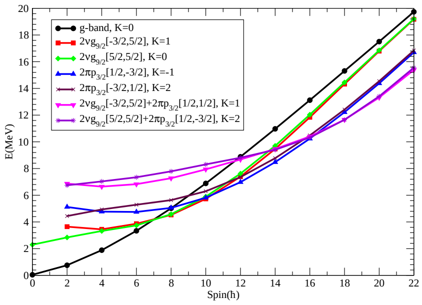

FIG. 2: (color online) Band diagram for ^{76}Ge

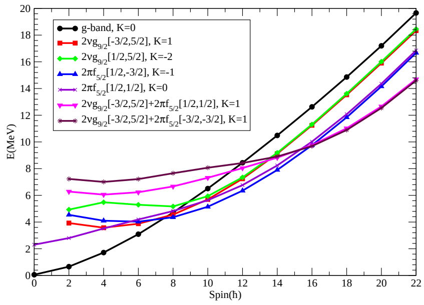

FIG. 3: (color online) Band diagram for ^{76}Se

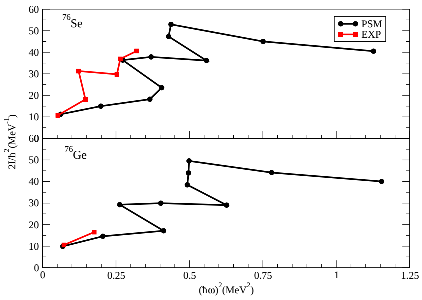

FIG. 4: (color online) Backbending for ^{76}Se and ^{76}Ge

$6\hbar$-$8\hbar$ and $12\hbar$-$14\hbar$. These band crossings are responsible for backbending in the yrast spectrum. The first band crossing is the crossing of four 2-qp band whereas the second band crossing is the crossing of two 4-qp bands with their configuations as shown in figure. Fig.3 represents the band diagram for ^{76}Se. It exhibits band crossing in the spin ranges $8\hbar$-$10\hbar$ and $12\hbar$-$14\hbar$. The first band crossing is the crossing of four 2-qp bands whereas the second band crossing is the crossing of two 4-qp with their respective configurations shown in figure.

C. Backbending phenomena

In Fig.4, the theoretical results of moment of inertia (2I) vs the square of rotational frequency (ω^2) are compared with the experimental results for ^{76}Ge and ^{76}Se. From Fig.4, we observe thet there are two backbendings[3] exhibited by the observed yrast spectrum in ^{76}Se. The first backbending is observed at $8\hbar$ and second at $14\hbar$. These backbendings arises due to crossing of ground band by other bands. Similarly for ^{76}Ge, the two backbendings can be observed at $8\hbar$ and at $14\hbar$.

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