Study of negative parity band structures in ^{167}Lu

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Introduction

The neutron-deficient isotopes of Lutetium (Lu) lie in the rare-earth region of the nuclear chart. The nuclear structure of these isotopes have received the much attention experimentally as well as theoretically [1–3]. Most of these isotopes have prolate shape in their ground states. The complete high spin spectroscopy of ^{167}Lu is presented by Roux et al. [3]. They have investigated the high spin states of ^{167}Lu by using the Gammasphere spectrometer array at Lawrence Berkeley National Laboratory. Now, eighteen energy bands are known experimentally in ^{167}Lu. Out of these eighteen energy bands ten bands are of positive parity and eight bands are of negative parity. All the bands are assigned configurations by performing Cranked shell model calculations. Recently, Rohilla et al. [4] carried out life time measurement experiment for one of the negative parity bands of ^{167}Lu by using the recoil distance Doppler shift method. They obtained the reduced transition probabilities [B(E2)] and transition quadrupole moments (Q_t) of the low lying excited states and compared the results with the cranked Hartree-Fock-Bogoliubov model total Routhian surface (TRS) calculations. The experimental data on B(E2), Q_t and TRS calculations support the prolate stable deformation for $[541]1/2^-(\pi h_{9/2})$ negative parity band of ^{167}Lu. The interpretation of huge experimental data available on the energy bands of ^{167}Lu is a challenge for existing theoretical models. Therefore, in the present work, an attempt is made to investigate the negative parity bands of ^{167}Lu by using projected shell model (PSM) approach.

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The Model

The projected shell model was developed by Hara and Sun [5] to interpret the high spin data of nuclei and it is quite successful in explaining the quantitative features of the experimental data available from the latest experimental techniques. The quadrupole quadrupole plus monopole pairing plus quadrupole pairing forces are taken into account in the Hamiltonian of this model. The three oscillator shells (N) are taken both for neutrons and protons and in the present study, N =4,5,6(3,4,5) for neutrons (protons) are taken for active nucleons. The quasiparticle configurations are chosen as one proton and three (one proton+two neutrons). From the Nilsson diagram, generated for protons, one finds that the negative parity proton orbitals around the fermi surface in ^{167}Lu are $[514]9/2^-(\pi h_{11/2})$, $[541]1/2^-(\pi h_{9/2})$, $[505]11/2^-(\pi h_{11/2})$, $[523]7/2^-(\pi h_{11/2})$. The one quasiparticle negative parity bands in ^{167}Lu are formed from these orbitals. The quadrupole and hexadecapole deformation parameters taken are the same as predicted by Moller et al. [6]. The monopole and quadrupole pairings are adjusted to obtain the correct pairing gaps, band head spins, band head energies and band crossings in the yrast bands.

Results and Discussion

The ground state negative parity band of ^{167}Lu in ref. [3] is band number 15, which is assigned configuration $[514]9/2^-(\pi h_{11/2})$. This is the yrast negative parity band amongst negative parity bands. The energy levels of this band are obtained by PSM calculations. It is known that kinetic moment of inertia ($J^{(1)}$) and rotational frequencies (ω) show accurately the band crossings and signature splittings in nuclei. Therefore, $J^{(1)}$ versus ω

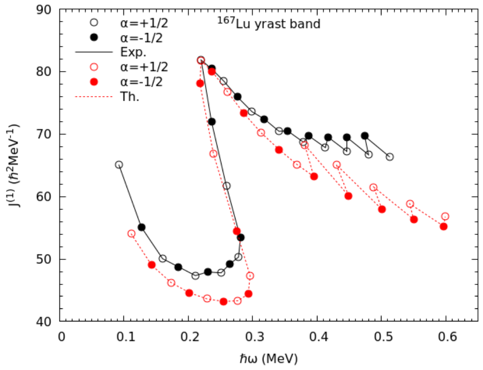

FIG. 1: Comparison of experimental and calculated moment of inertia ($J^{(1)}$) versus rotational frequency (ω) of yrast negative parity band in ^{167}Lu

are plotted in Fig.1. From this figure, it is seen that the experimental data shows backbending at positive and negative signatures of yrast band at $\hbar\omega$=0.278 and 0.281 around spins 29/2 and 31/2, respectively. This band also shows signature splitting above spins 49/2. The calculated results reproduce the phenomenon of backbending at the same spins at $\hbar\omega$ = 0.296 and 0.275 and signature splitting above spins 51/2. The backbending phenomenon is predicted to arise due to the crossing of [514]9/2$^-$(πh$_{11/2}$) band by three quasiparticle (3-qp) bands consisting of 3/2 and 5/2 components of $\nu i_{13/2}$ orbital, leading to the alignment of a pair of neutrons in $\nu(i_{13/2})^2$ orbital. Further, around spin 51/2, these bands are crossed by 3-qp band which is composed of 1-qp proton [541]1/2$^-$(πh$_{9/2}$) band. This 1-qp band has low K=1/2 component of $h_{9/2}$ orbital which may lead to signature splitting and shows staggering at higher spins.

Similarly, the excited negative parity band of ^{167}Lu in ref. [3] is band number 13, which is assigned configuration [541]1/2$^-$(πh$_{9/2}$). The $J^{(1)}$ versus ω for this band are plotted in Fig. 2. From this figure, it is seen that the experimental signature splitting is reproduced qualitatively by the present calculations. The signature splitting is observed in this band due to the K=1/2 component of $h_{9/2}$ orbital. The ex-

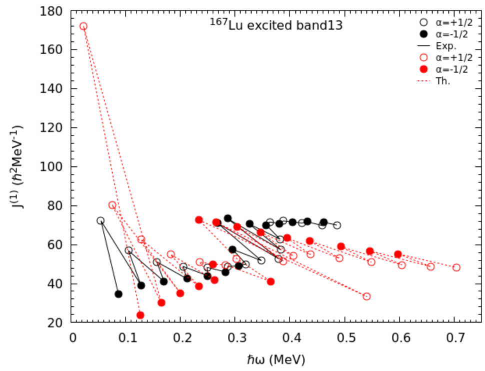

FIG. 2: Comparison of experimental and calculated $J^{(1)}$ versus ω of excited negative parity band in ^{167}Lu

perimental plot of $J^{(1)}$ versus ω, displayed in Fig. 2 of this band shows irregularities around spins 49/2 and 31/2, for positive and negative signatures at $\hbar\omega$=0.384 and 0.306, respectively. The calculated results predict the band crossings around spins 41/2 and 27/2 at $\hbar\omega$ =0.388 and 0.260 in positive and negative signatures, respectively. Around these spins the 1-qp bands are crossed by 3-qp bands arising from $i_{13/2}$ neutron orbital. The present calculations reproduce the experimental data on two prolate deformed negative parity bands of ^{167}Lu nicely and would be extended to study the positive parity and more number of excited negative parity bands of this nucleus.

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