

## Triaxial Projected Shell Model study of low excitation of the second $0^+$ state in $^{72}\text{Ge}$

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The study of nuclear shape changes as a function of particle-number, angular-momentum, and excitation energy has been one of the important research areas in nuclear structure physics. In particular, in the vicinity of the neutron shell closure with  $N \sim 40$ , rapid variations of the nuclear shape have been extensively studied [1]. In the lighter Ge-isotopes, one low-lying excited  $0^+$  state has been observed in even-even  $^{70,72,74}\text{Ge}$  isotopes [2]. The Ni-isotopes also display a broad variety of nuclear shape phenomena [3] where for  $N \sim 50$ , yrast band is dominated by a weakly deformed oblate shape ( $\beta \sim -0.15$ ).

The structure changes in Ge isotopes were discussed in terms of pairing correlation and shape change (or shape coexistence) by using various collective models [4, 5]. The interacting boson model [6] reproduced the observed energy levels for  $^{68-76}\text{Ge}$ . However, a satisfactory microscopic explanation has not been seen. Most of the early studies in the literature limited their discussion on the configuration change within the fp shell. Contributions from the  $g_{9/2}$  orbit were very little mentioned. According to the [7] these early studies are insufficient according to the new knowledge on the  $N = 40$  magicity, which has emphasized that nucleons in the  $g_{9/2}$  orbit play a crucial role in determining the structure of the  $N = 40$  isotones. Thus, as a necessary requirement, a microscopic study for the structure in Ge isotopes should include the  $g_{9/2}$  orbit.

The purpose of the present work is to inves-

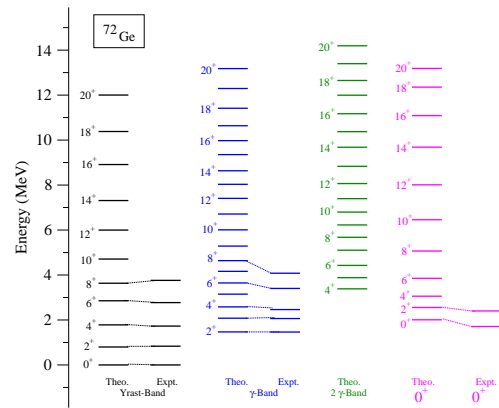


FIG. 1: Comparison of the TPSM energies after configuration mixing with the available experimental data for  $^{72}\text{Ge}$  nucleus. Data are taken from [9].

tigate the high-spin properties of  $^{72}\text{Ge}$  especially the nature of low-lying second excited  $0^+$ -state, using the recently-developed multi-quasiparticle (qp) triaxial projected shell model (TPSM) approach [8]. In TPSM, apart from 0-qp, 2- and 4-qp configurations are explicitly included in the basis space. Therefore, in this model it is possible to investigate the high-spin band-structures, which provides important information on the interplay between collective and single-particle excitations, and thus to probe single-particle structures in the neutron-rich mass region. The angular-

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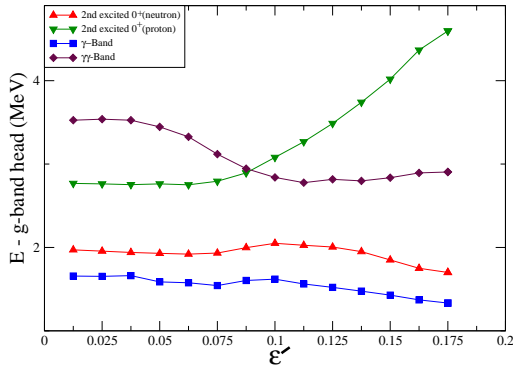


FIG. 2: Behavior of the projected energies of various configurations as a function of triaxial deformations for  $^{72}\text{Ge}$  nucleus.

momentum projected energies after configuration mixing from 0-qp, 2-qp, and 4-qp configurations, calculated with deformation parameters  $\epsilon = 0.230$  and  $\epsilon' = 0.160$ , for the  $^{72}\text{Ge}$ -nucleus. It has been demonstrated that the admissible  $K$ -values for the triaxial vacuum state are  $K = 0, 2, 4, \dots$  and the projection from these possible values give rise to the ground-state band with  $K = 0$ ,  $\gamma$ -band with  $K = 2$ ,  $\gamma\gamma$ -band with  $K = 4$ , and excited  $0^+$  bands. The excited  $0^+$  bands result from the projection of the 2-qp configurations formed from the combination of the normal and time-reversed states with  $\kappa = 0$ . Our calculations indicate that in  $^{72}\text{Ge}$ -nucleus, the lowest excited  $0^+$  band has the neutron 2-qp structure. The excited  $0^+$  band from the proton 2-qp state, not shown in the Fig. 1, lies at a much higher energy and does not interact with the near yrast band spectroscopy. The projected bands from 2-qp configurations with both particles in either normal or time-reversed states having  $\kappa = 1$ , the so-called aligned configurations, are placed at higher excitation energy as compared to the excited  $0^+$  and  $\gamma$ -bands. However, these bands become yrast at higher angular-momenta as these aligned configurations demand less rotational energy to gener-

ate higher angular-momentum states.

In the second stage of the TPSM study, the projected bands, obtained above, are then employed as basis for diagonalization of the shell model Hamiltonian. Fig. 1 depicts the calculated bands after diagonalization and also displays the corresponding available experimental data. It is quite evident from Fig. 1 that agreement between the TPSM results and the experimental data is quite satisfactory.

In order to investigate the importance of the triaxiality on the high-spin properties in  $^{72}\text{Ge}$ , the spin-dependence of the transition energies with respect to g-band are plotted in Fig. 2 for varying values of  $\epsilon'$ . For higher values of  $\epsilon'$ , it is quite evident that the second excited  $0^+$  band with neutron configuration indicate more sudden change in the wave functions as compared to the case of lower values of  $\epsilon'$ . This demonstrates that there is strong mixing between excited  $0^+$  and the  $\gamma$ -band.

In Conclusions it is demonstrated that by performing the exact three-dimensional angular-momentum-projection on multi-quasiparticle configurations, constructed from the triaxially-deformed mean-field, the TPSM provides a consistent description of the yrast band structures,  $\gamma$ -vibrational, and second  $0^+$  band in  $^{72}\text{Ge}$  nucleus.

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