Triaxial Projected Shall Model study of low excitation of the second 0^+ state in ^{72}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}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 $^{68-76}$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 investigate the high-spin properties of ^{72}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-

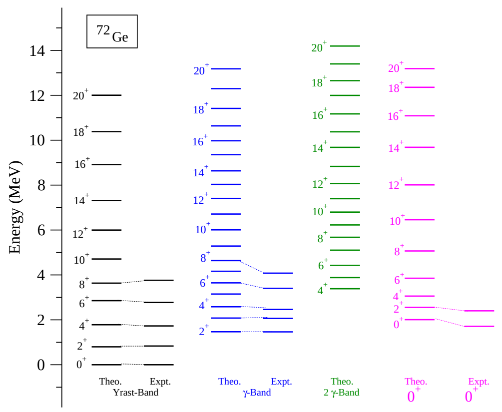

FIG. 1: Comparison of the TPSM energies after configuration mixing with the available experimental data for ^{72}Ge nucleus. Data are taken from [9].

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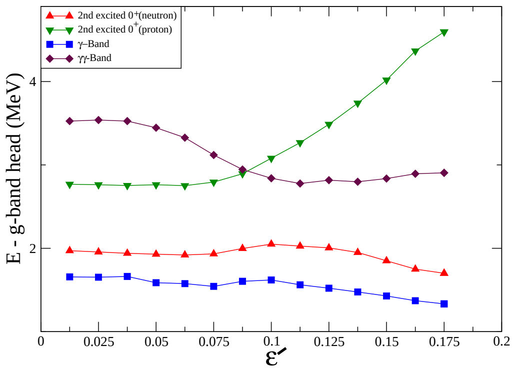

FIG. 2: Behavior of the projected energies of various configurations as a function of triaxial deformations for ^{72}Ge nucleus.

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}Ge-nucleus. It has been demonstrated that the admissible K-values for the triaxial vacuum state are $K = 0, 2, 4, \ldots$ and the projection from these possible values give rise to the ground-state band with $K = 0$, γ-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}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 γ-bands. However, these bands become yrast at higher angular-momenta as these aligned configurations demand less rotational energy to generate 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}Ge, the spin-dependence of the transition energies with respect to g-band are plotted in Fig. 2 for varying values of ϵ'. For higher values of ϵ', 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 ϵ'. This demonstrates that there is strong mixing between excited 0^+ and the γ-band.

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

References

[1] M. Hasegawa et al Nuclear Physics A **789**, 46 (2007).
[2] E. Padilla-Rodal, et al., Phys. Rev. Lett. **94**, 122501 (2005).
[3] E. Caurier, F. Nowacki, A. Poves, Eur. Phys. J. A **15**, 145 (2002.
[4] M. N. Vergnes, et al., Phys. Lett. B **72**, 447 (1978).
[5] R. Lecomte, et al., Phys. Rev. C **25**, 2812 (1982).
[6] P. D. Duval, D. Goutte, M. Vergnes, Phys. Lett. B **124**, 297 (1983).
[7] E. Caurier, F. Nowacki, A. Poves, Eur. Phys. J. A **15**,145 (2002).
[8] J.A. Sheikh and K. Hara, Phys. Rev. Lett. **82**, 3968 (1999).
[9] A. D. Ayangeakaa, et al., Phys. Lett. B **754**, 254 (2016).