E(5) critical symmetry

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Transitional nuclei have proven difficult to describe with conventional nuclear structure models; however, a possible interpretation is to depict such nuclei as undergoing a phase transition. Iachello [1] proposed that a critical point may exist in such a transition, similar to that exhibited by matter undergoing a phase transition. The E(5) symmetry corresponds to a system undergoing a second-order phase transition. In nuclei, this symmetry may be used to describe the critical point of the transition from a spherical vibrator to a $\gamma-$soft rotor. ^{134}Ba [2], ^{108}Pd [3], ^{132,134}Xe [4] are known to show such symmetry.
In order to understand the E(5) critical symmetry, the Relativistic−Hartree−Bogoliubov (RHB) with density dependent finite range interaction (DD-ME2) along with Triaxial Projected Shell Model(TPSM) has been used.

As in E(5) critical symmetry, the potential is said to be independent of γ degrees of freedom i.e., the potential contains only the β degrees of freedom U(β). The dependency on the triaxial parameter (γ) is an important investigation for such cases. In order to check the properties of $\gamma-$dependence for E(5) symmetry in these nuclei, we have plotted in Fig. 1, the energy curves as a function of $\gamma-$variable for fixed values of β_2 . The results are obtained by constrianing the system in a particular deformation (both β and γ) domain. Here ΔE is the energy difference between the minimum and maximum energy from $\gamma = 0°$ to $\gamma = 60°$ for fixed β_2 . We can see that, ^{132,134}Xe are showing a weak dependence on γ for $0.05 \leq |\beta_2| \leq 0.2$. ^{108}Pd

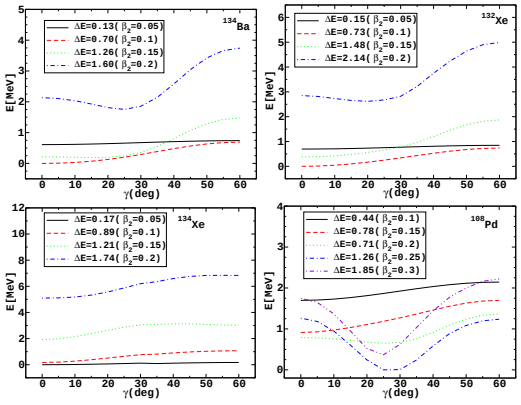

FIG. 1: Binding energy curves of the nuclei ^{134}Ba, ^{132,134}Xe, and ^{108}Pd as functions of the deformation parameter γ, for fixed values of axial deformation (β_2).

show weaker $\gamma-$dependence for $0.05 \leq |\beta_2| \leq 0.3$. Similarly, the negligible dependence on the $\gamma-$variable is found in ^{134}Ba. Therefore, we can say that,^{108}Pd, ^{132,134}Xe, and ^{134}Ba could be suitable candidates to look for E(5) critical-point symmetry predicted by RHB are in accordance with the earlier predictions.

Further study, designed to explore the rotational properties of these systems, is obtained by using the triaxial projected shell model (TPSM) approach.

The basic strategy of the TPSM approach is similar to the spherical shell model model (SSM) with the only difference that deformed basis are employed for diagonalizing the shell model Hamiltonian rather than the spherical one. The deformed basis are constructed by solving the triaxial Nilsson potential with optimum quadrupole deformation parameters of ϵ and ϵ'. In principle, the deformed basis can

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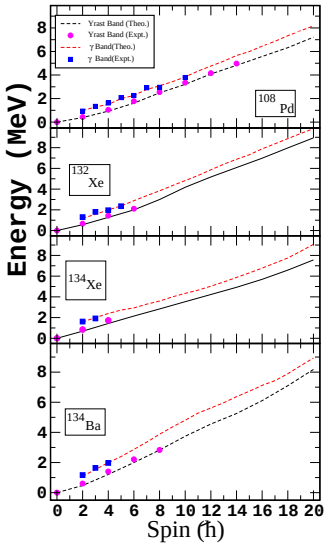

FIG. 2: Comparison of experimental and the calculated band energies for ^{102,108}Pd, ^{132,134}Xe, and ^{134}Ba isotopes.

be constructed with arbitrary deformation parameters, however, the basis are constructed with expected or known deformation parameters (so called optimum) for a given system under consideration. These deformations have been earlier calculated for selected nuclei ^{108}Pd, ^{132,134}Xe, and ^{134}Ba using the microscopic RHB approach. In the present TPSM study, we have slightly modified these deformations and is justified as the two models are quite different in nature. It is worth to mention here that these deformation values lead to an accurate Fermi surface and it is possible to choose a minimal subset of the basis states around the Fermi surface for a realistic description of a given system. The Nilsson basis states are then transformed to the quasiparticle space using the simple Bardeen-Cooper-Schriefer (BCS) ansatz for treating the pairing interaction. As the deformed basis are defined in the intrinsic frame of reference and don't have well defined angular-momentum, in the second stage these basis are projected onto states with well defined angular-momentum using the angular-momentum projection technique. In the third and the final stage of the TPSM analysis, the projected basis are employed to diagonalize the shell model Hamiltonian. It is worth to mention here that the model Hamiltonian consists of pairing and quadrupole-quadrupole interaction terms.

The projected energies after diagonalization shown in Fig. 2, indicates that yrast bands for all studied isotopes have two slopes, corresponding to crossings of bands with two distinct configurations. The change in slope occurs at spin I = 8 or 10. This feature has been well described by the calculation, for the ^{108}Pd where high-spin data exist. Furthermore, we observe that for the rest of nu- clei, i.e., ^{132,134}Xe, and ^{134}Ba, the current ground-band data are available only before the predicted onset of the band-crossing at I = 10. The first and second excited bands at low-spins are predominantly composed of the collective γ-band structures, but the high-spin states of these bands have considerable mixing with the 2-qp states. The present calculation further predicts some irregularities in the staggering of γ-bands due to band mixing (e.g. staggering appears in a certain spin range but diminishes at high spins) [5]. We hope that our results can serve as a guidance for future experiments to identify γ-bands in this mass region.

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