E(5) critical point symmetry in ^{48}Ti and ^{52}Ti

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Introduction

In nuclear structure, critical point symmetries have attracted a lot of attention. These symmetries describe the nuclei at the points of shape phase transitions between the dynamical symmetries U(5), SU(3) and O(6), geometrically corresponding to spherical vibration, axially deformed rotation and γ-unstable rotation, respectively. The E(5) critical point symmetry corresponds to a second order shape phase transition from spherical vibrator U(5) to γ-unstable rotor O(6)[1]. In the present work, we have applied the Relativistic-Hartree-Bogoliubov (RHB) model with density dependent finite range interaction (DD-ME2) along with Triaxial Projected Shell Model (TPSM) to study the E(5) critical point symmetry in ^{48,52}Ti. The numerical calculations for Potential Energy Surfaces (PES) are performed for the triaxial shape with the quadratic constraint method. Relativistic form of density functional theory has successfully been used to investigate many nuclear structural and astrophysical properties[2, 3]. More details about the method can be found in Ref.[4].

Results and Discussion

In Fig.1, we have plotted the triaxial potential energy surfaces (PES) for ^{48}Ti and ^{52}Ti nuclei. A continuous γ-soft minima is noticed in these nuclei which is extending from prolate to oblate side of PES that makes the search for E(5) critical symmetry in these nuclei signifcant.

The potential contains only β degree of freedom in case of E(5) critical point symmetry and independent of γ. It become important to investigate the dependency of potential on γ. In Fig.2, we have shown the variation of energy as a function of triaxial parameter γ for fixed values of quadrupole deformation parameter β_2 for ^{48}Ti and ^{52}Ti. The potential becomes stiff for $|\beta_2| > 0.15$. The energy curves of ^{48}Ti and ^{52}Ti are plotted as a function of triaxial parameter γ for four different values of axial deformation, $\beta_2 = 0.05$, 0.10, 0.15, and 0.20. The energy difference ΔE $(=|E_{\gamma=0^\circ} - E_{\gamma=60^\circ}|)$ is indicating a weak dependence on γ with ΔE is much less than unity for $0.05 \leq \beta_2 \leq 0.20$. Further, the rotational properties of these nuclei are obtained by using the triaxial projected shell model (TPSM).

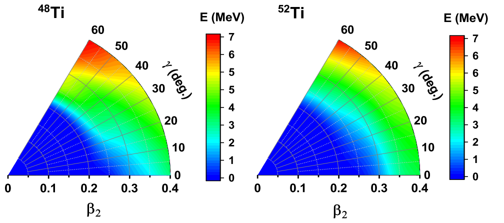

FIG. 1: The PES for ^{48,52}Ti in $(\beta_2 - \gamma)$ plane. The energies are normalized with respect to the binding energy of the absolute minima.

In the TPSM approach, the shell model Hamiltonian is diagonalized in deformed basis which are constructed by solving the triaxial Nilsson potential with quadrupole deformation parameters ϵ and ϵ' (generally related to deformation parameters β_2 and γ). Fig.3

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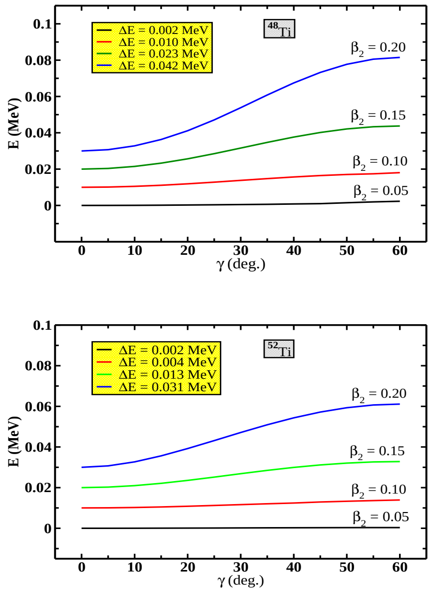

FIG. 2: Binding energy curves of the nuclei ^{48}Ti and ^{52}Ti, as functions of the deformation parameter γ for fixed values of (β_2).

displays the yrast band and non-yrast γ-band of ^{48}Ti and ^{52}Ti, calculated from TPSM approach. The ratios calculated excitation energies and transition probability are shown in Table 1 along with the predictions of E(5) symmetry for comparison. In Table 1, the characteristic ratios $R_{4/2} = E(4_1^+)/E(2_1^+)$, $R_{6/2} = E(6_1^+)/E(2_1^+)$, $R_{0/2} = E(0_2^+)/E(0_1^+)$ and $R_{2/2} = E(2_2^+)/E(2_1^+)$ are shown ^{48}Ti and ^{52}Ti. In addition to these energy ratios, we have also analyzed the $B(E2; 4_1^+ \rightarrow 2_1^+)/B(E2; 2_1^+ \rightarrow 0_1^+)$ ratio. The calculated data for ^{48,52}Ti are found to be in good agreement with the E(5) predictions.

The γ independent behavior of potential, the excitation energy ratios and $B(E2)$ ratios suggest the nuclei ^{48}Ti and ^{52}Ti to have signatures of E(5) critical point symmetry. Overall analysis indicate that these nuclei can be good example for quantum shape phase transition from spherical to γ-soft shape.

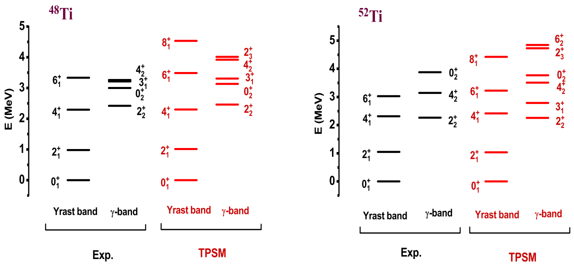

FIG. 3: Comparison of the experimental and calculated excitation energies of yrast and non-yrast states of ^{48}Ti and ^{52}Ti. The experimental data are taken from [5].

TABLE I: The ratios of calculated excitation energies of ^{48}Ti and ^{52}Ti. The comparison is done with the predictions of E(5) symmetry.

	TPSM				
Nuclei	$R_{4/2}$	$R_{6/2}$	$R_{0/2}$	$R_{2/2}$	$\frac{B(E2;4_1\rightarrow 2_1)}{B(E2;2_1\rightarrow 0_1)}$
^{48}Ti	2.26	3.44	3.13	2.42	1.72
^{52}Ti	2.33	3.31	3.46	2.27	1.64
E(5)	2.20	3.59	3.03	2.20	1.56

References

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