Alignment through shape-coexistence in ^{124}Cs

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Introduction

The $A \sim 125$ region is classified as transitional mass region, characterized by shape transition from prolate to oblate via intermediate triaxial shape due to opposite shape driving characteristics of protons occupying lower half of $h_{11/2}$ orbital and neutrons from upper part of the intruder orbital respectively. At high spin, alignment of all valence particles beyond the corresponding closed-shell core drives the rotational bands with prolate shape to terminate at non-collective oblate shape [1, 2]. Cranked shell model calculations for $^{119-131}$Cs predicted that due to the alignment of $\nu h_{11/2}$ orbitals the triaxiality parameter spans a region from collective oblate γ = -60° in heavier isotope to prolate shape γ = 0° in lighter ones [3] via intermediate values. The triaxial deformed odd-odd nuclei can also express chirality [4–6]. However, the phenomenon is suggested to be persistent within a spin range of $9\hbar \leqslant I \leqslant 18\hbar$ [6]. Motivated by the earlier results of [4, 7], cranked Nilsson Strutinsky model calculations were performed to provide a thorough insight in to the coexistence of shapes in ^{124}Cs.

Model calculations

In the calculations, parameters derived for A = 110 region have been applied [9]. Observed energies have been calculated with respect to a standard rotating drop energy preferably Lublin-Strasbourg drop (LSD) with diffused surface. An absolute energy scale [8] based on mass excess has also been applied so that different nuclei can be compared. The calculation minimizes the energy with respect to the deformation parameters $(\varepsilon_2, \varepsilon_4, \gamma)$. Configurations are labelled relative to a core with $Z = 50$ and $N = 70$ as $[p_1p_2, n_1n_2]$, where p_1 and p_2 are the number of protons in orbitals $g_{7/2}d_{5/2}$ and $h_{11/2}$ respectively, whereas n_1 is the number of neutron holes in N = 4 shell and n_2 the number of neutrons in $h_{11/2}$. Sometimes, a subscript + or - is added to specify signature of the occupied orbitals, $\alpha = +1/2$ or $\alpha = -1/2$.

Results and Discussion

The potential surface energy plots for the positive-parity states from $I = 6^+$ to 30^+ in ^{124}Cs (Fig. 1) reveal that these states are formed within three stable minima. For low-spin states up to $I \sim 24^+$, a stable collective-oblate minimum is observed with γ = -60°, $\varepsilon_2 \sim 0.2$ that migrates towards γ = -40° gradually before finally disappearing beyond $I = 30\hbar$. This minimum corresponds to configuration $\pi h_{11/2} \otimes \nu h^5_{11/2}$ or [41, 65]. Interestingly, it was found that after $I = 25\hbar$, this same configuration stabilizes with prolate shape at $\varepsilon_2 \sim 0.2$, while below $I = 25\hbar$, the prolate shape is attributed to contribution from $\nu h^6_{11/2}$. In addition, a second prolate minimum involving proton excitations across the $Z = 50$ core is also evident with higher axial deformation value of $\varepsilon_2 \sim 0.3$. Finally, at spin $I \sim 30\hbar$, the minima move towards $\gamma = 60°$, that signifies termination of corresponding band at a non-collective oblate shape.

The experimental excitation energies of bands published in [4] (labeling of the bands as given in [4] is used) were compared with that of [41, 65] configuration in Fig. 2. Owing to nice agreement, the positive parity bands 1 and 2 should be assigned to configuration [41, 65], which is at par with previous publication [7]. Gizon *et al.* [7] observed alignment

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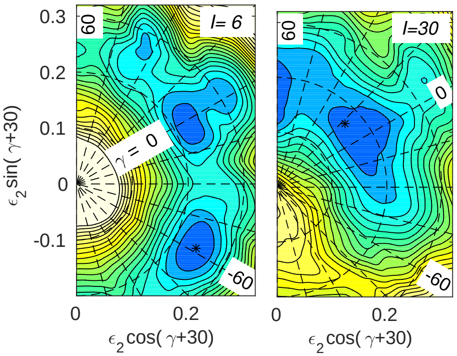

FIG. 1: Total energy surfaces with the constraint, $\pi = +$, $\alpha = 0$. The contour line separation is 0.25 MeV.

gain of around $6\hbar$ (complete alignment was not observed) in band 1 at 0.55 MeV rotation frequency and suggested a contribution from alignment of second pair of neutrons in $h_{11/2}$ similar to previous assignments in other neighboring nuclei. Using CSM calculation they predicted $\beta_2 \approx 0.24$ and 0.18 prolate shape before and after the alignment respectively. Later PRM calculations by Wang *et al.* [6] claimed that γ should be 22° up to $I \sim 18\hbar$, i.e. below alignment. Moreover, K. Selvakumar *et al.* [4] observed that band 1 is chiral up to $I \sim 18\hbar$ and triaxiality stabilizes chiral configuration. Thus configuration [41, 65] with triaxial shape is assigned to band 1 for states below alignment which is overtaken by prolate shape at $\gamma \sim 0°$, $\beta \sim 0.2$ above alignment (ref. to Fig. 1 and 2). Interestingly, recent work on ^{124}Cs [11] reports about observation of complete alignment gain of $8\hbar$ in band 1 which is beyond the scope of contribution from alignment of either neutrons or protons in mid-Fermi region. Rather the gain is due to the shape change from triaxial to prolate where particles in several orbitals contribute. It should be noted, however, that protons are easily aligned at prolate γ compared to the triaxial one. Therefore, the spin contribution from the protons play a major role at the alignment.

Details on negative parity bands will be discussed during the conference.

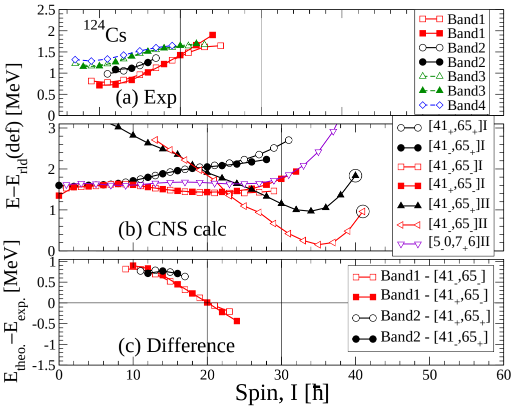

FIG. 2: (a) Excitation energies relative to a rotating-liquid drop energy of the positive and negative parity bands in ^{124}Cs. (b) Calculated excitation energies with respect to the same reference as in (a) for configurations [41, 65] (triaxial and prolate minima are designated as I and II respectively.). (c) Comparison between experimental and calculated results.

References

[1] A. K. Singh *et al.*, Phys. Rev. C **70**, 034315 (2004).

[2] A. Al-Khatib *et al.*, Phys. Rev. C **74**, 014305 (2006).

[3] J. R. Hughes *et al.*, Phys. Rev. C **44**, 6 (1991).

[4] K. Selvakumar *et al.*, Phys. Rev. C **92**, 064307 (2015) and references therein.

[5] U. Yong-Nam *et al.*, J. Phys. G 31, B1 (2005).

[6] S. Y. Wnag *et al.*, Phys. Rev. C **82**, 027303 (2010).

[7] A. Gizon *et al.*, Nucl. Phys. **A694** 63-102 (2001) and references therein.

[8] B. G. Carlsson and I. Ragnrasson, Phys. Rev. C **74**, 011302 (2006).

[9] A. V. Afansjev, D. B. Fossan, G. J. Lane, and I. Ragnars, Phys. Rep. 322, 1 (1999), and references therein.

[10] T. Bengtsson and I. Ragnarsson, Nucl. Phys. A436, 14 (1985) and references therein.

[11] Unpublished.