# Evolution of Shapes through Collective and Non-Collective Excitations in $^{120}$Te, $^{122}$Te and $^{124}$Xe

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## Introduction

Angular momentum generation in a nucleus can take place either through single-particle contribution or via collective phenomenon. The nuclei in A ∼ 120-125 region lie in a transitional region between spherical Sn isotopes and highly deformed Ce nuclei. The spherical nuclei are characterized by vibrational states at low spin whereas non-collective single-particle contributions dominate at higher spin values. On the other hand, collective excitations prevail in deformed nuclei. The existence of collective and single-particle degrees of freedom within a transitional nucleus provides the motivation to carry out studies on nuclear structural properties up to a large angular momentum and excitation energy.

The present thesis explores the evolution of shape changes in the $^{120}$Te, $^{122}$Te and $^{124}$Xe nuclei with excitation energy and angular momentum using $\gamma$-spectroscopy. The nuclei $^{120}$Te and $^{124}$Xe were populated using heavy-ion fusion reactions $^{80}$Se($^{48}$Ca, $\alpha$4n/4n)$^{120}$Te/$^{124}$Xe with Gammasphere array. The study of $^{122}$Te involved two experiments, one using $^{116}$Cd($^{11}$B, p4n)$^{122}$Te with INGA facility and the other using $^{82}$Se($^{48}$Ca, $\alpha$4n)$^{122}$Te with Gammasphere. The previously known level schemes were extended to considerable higher spins using $\gamma$-ray coincidence measurements. The experimental results were discussed in the theoretical framework of pairing independent cranked Nilsson Strutinsky (CNS) model calculations. The overall findings are summarized below.

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## Non-collective low-spin states

The angular momentum generation within medium-spin region in Te isotopes takes place through alignment of non-zero angular momentum of individual nucleons within the valence space. Non-collective oblate states became energetically favored at maximally aligned or anti-aligned configurations. These states have been observed at $I = 16^+$ and $22^+$, $24^+$, $21^-$, $25^-$ etc. in $^{120,122}$Te, respectively. By comparing observed results with those of CNS model calculation, configuration to the states were assigned as $\pi[(g_{7/2}, d_{5/2})^2] \otimes \nu[((d_{3/2}s_{1/2})^n h_{11/2})^4]$ for positive-parity (where $n$ is 0 and 2 for $^{120}$Te and $^{122}$Te, respectively) and negative parity aligned states involve contribution from odd number of quasiparticles in negative-parity ($h_{11/2}$) orbitals [1–3]. In $^{124}$Xe maximally aligned states were observed at $34^+$ and $35^-$ with configurations $\pi[(g_{7/2}, d_{5/2})^2 h^2_{11/2}] \otimes \nu[d^2_{3/2}, h^4_{11/2}]$ and $\pi[(g_{7/2}, d_{5/2})^2 h^2_{11/2}] \otimes \nu[d_{3/2}, (h_{11/2})^5]$, respectively were observed [4]. Apart from maximally aligned states, occupation of time-reversed orbitals by nucleons produced a few energetically favored anti-aligned states around $I \sim 20\hbar$ in $^{120}$Te and $^{122}$Te.

Several weakly populated high-energy transitions were observed beyond terminating levels [2]. The states could be explained with core-excitation of neutrons from $(g_{7/2}, d_{5/2})$ to either $d_{3/2}, s_{1/2}$ or $h_{11/2}$ orbitals, which may then be coupled to proton configuration with or without $h_{11/2}$ occupancy.

## High-Spin Rotational Bands

Several high-spin rotational bands, extending up to $I \sim 50$ - $60\hbar$, were observed in $^{120,122}$Te and $^{124}$Xe. The bands start around $I \sim 25\hbar$ and an excitation energy of $\sim$ 10 MeV. Though, transitions connecting high-spin bands to the low-spin part of level scheme were not observed. Consequently, tentative spins were chosen in accordance to those of the connected bands in neighboring nuclei ($^{125-126}$Xe [5, 6] and $^{125}$I [7]) and excitation energies were estimated from their relative intensities. $E2$ multipolarity was tentatively assigned to the intra-band transitions owing to smooth variation of the energies of transitions. Moreover, in a few cases, band crossings were observed, which could be addressed through CNS model calculations [8].

The collectivity is replenished through dominant contribution from proton excitations across the $Z = 50$ shell gap (favorably, two proton holes in $g_{9/2}$ orbital compared to single proton excitation). The high-spin bands in $^{120,122}$Te could be explained with the proton-hole excitations coupled to neutron excitations within the $N$ = 50 - 82 shells. Here the number of neutrons is less than or equal to seventy. However in $^{124}$Xe, with $N$ = 70 ($Z$ = 54), similar configurations were theoretically predicated, except for a few bands with configurations involving neutron excitations across the $N$ = 82 core were also observed [8]. Recent calculations [9] for $^{125-126}$Xe showed that bands in $^{125}$Xe with higher deformation involves neutron excitations across the $N = 82$ core compared to less deformed band in $^{126}$Xe where no neutron excitations beyond $N$ = 82 shell closure was suggested. But, further insight is required to draw a conclusion on how the deformation of a nucleus is correlated to the total number of nucleons.

Even though, the CNS model calculations have been very successful in describing high-spin bands in various mass regions, a few discrepancies were reported in $^{124}$Ba [10], $^{125}$I [7], and $^{126}$Xe [5]. For example, the lowest-energy configurations predicted by CNS calculation were not observed experimentally in $^{125}$I [7] and $^{126}$Xe [5]. Similar observations were made in $^{124}$Xe. Thus it remains a puzzle, and requires further exploration.

## Acknowledgments

I acknowledge the support from CSIR, India (09/081(0704)/2009-EMR-I). I acknowledge my supervisor Prof. A. K. Singh, Prof. Herbert Hübel, Prof. G. B. Hagemann, Prof. G. Sletten and Prof. I. Ragnarsson for the constant guidance. I am grateful to the operations staff at TIFR and Gammasphere as well as target lab staffs at TIFR and VECC. I acknowledge the support from INGA collaboration.

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