Triaxial shapes in nuclei of mass ∼ 130: A perspective through lifetime measurements

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Introduction

In the nuclear landscape, atomic nuclei are characterized by diverse shapes. The nuclear force, which is responsible for binding nucleons in the nucleus, is not well understood yet and more experimental inputs are required for a better understanding.

This thesis work is focused on the structure of nuclei near mass 130 region. The nuclei in this region tend to have triaxial nuclear shape due to the presence of oblate driving $\nu h_{11/2}$ and prolate driving $\pi h_{11/2}$ orbitals near the Fermi surface, which leads to the various interesting nuclear phenomena. In the present work, we have studied different nuclear properties through the measurement of lifetimes using the technique of Doppler shift attenuation method (DSAM). The reduced transition probability (B(E2)) is a sensitive observable for providing a stringent test to various theoretical models. The single-quasi particle rotor model (PRM) is employed to interpret the experimental results.

Experiments and analysis

An experiment was performed to populate the high spin states of ^{128}La using the Pelletron accelerator facility at Inter-University Accelerator Centre (IUAC), New Delhi. The ^{19}F beam was bombarded on to 4.85 mg/cm^2 thick and isotopically enriched ^{114}Cd target. The nuclei of interest, ^{128}La was formed by the 5n channel. The De-exciting γ-rays were detected by Indian National Gamma Array (INGA) setup consists of HPGe clover detectors. Further, the ^{129}Cs, ^{127}I nuclei were studied using the previous data sets. The lineshape analysis was performed using the following three asymmetric $E_\gamma - E_\gamma$ matrices: (i) Forward vs. all (ii) Backward vs. all (iii) 90° vs. all.

Results and discussion

^{129}Cs [1]: In the positive parity band B3, all the observed transitions (459.4, 631.0, 768.6, 860.2, 820.7 and 707.2 keV) exhibited lineshapes. Further, In the negative parity band B6, the transitions 448.4, 604.2, 768.2, 840.0, 878.8, 917.7, 957.7 and 1011.8 keV exhibited lineshapes. Furthermore, we have also observed lineshapes for three M1 transitions - 341 keV in band B5, 327.6 and 363.8 keV in band B1. The Doppler Shift Attenuation Method (DSAM) analysis was performed using the code of J. C. Wells. The example of lineshape fit is shown in Fig. 1

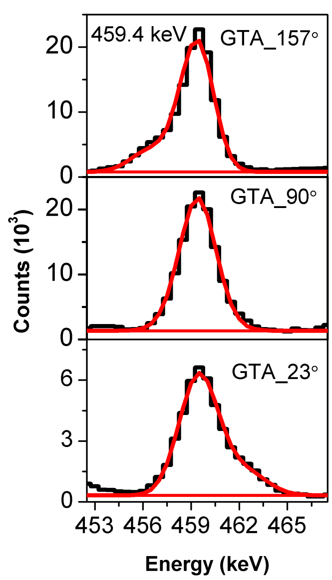

FIG. 1: Typical lineshape fitting of 459.4 keV transtion in ^{129}Cs [1].

We examined our PRM results for the reduced transition probabilities (B(E2)) along with the signature splitting behavior mentioned above, to finally

*Electronic address: umakant@phy.iitb.ac.in establish the deformation parameter values for both the bands B6 and B3. In other words, for both B6 and B3 bands, we found the deformation parameter values ϵ=0.14 and $|\gamma|$=18° and ϵ=0.15 and $|\gamma|$=18° by simultaneously matching the experimental and theoretical results for the signature splitting and B(E2) values.

^{127}I [2]: The aim was to deduce the level lifetimes of the different bands in ^{127}I using DSAM - to study the phenomenon of signature inversion using measured lifetime values. In this work, five transitions (982.1, 431.2, 651.5, 658.7, and 490.3 keV) of negative parity band and five transitions (877, 610.0, 763.3, 659.0, and 744.9 keV) of two different positive parity bands exhibited Doppler lineshapes. The lifetimes were measured and B(E2) values were extracted. The B(E2) value for the state $19/2^+$, where the signature inversion takes place is dropped sharply. In PRM, we achieved a good match in signature splitting and their inversion (ΔE) with ϵ_2 = 0.23 and $|\gamma|$ = 28° at low spins, and with an increased value of $|\gamma|$ = 37° and constant ϵ_2 above the inversion, in which excitation energy was matched at inversion point. In the negative parity band, the state $23/2^-$ at which backbending occurs, has a significantly larger B(E2) value than the other spin states, further the B(E2) value after backbending has been dropped sharply.

To understand the backbending phenomenon, the Total Routhian Surface (TRS) calculations were carried out. In the positive parity band, we found the lowest possible quasi-neutron Nilsson state $\pi g_{7/2} \otimes \left(\nu h_{11/2}\right)^2$[5 5 11/2 -9/2] with the first backbend at 0.43 MeV which is in good agreement with the experimentally observed value of 0.44 MeV.

^{128}La: An experiment to populate the high spin states of ^{128}La was performed at IUAC, New Delhi in October 2020. The initial data analysis only has been performed.

Different gates were set on intense transitions decaying from low spin states in yrast band [3]. The transitions up to spin state 19^+ were observed. Two M1 transitions (299 and 335 keV) in the yrast band exhibited lineshapes. The preliminary lineshape analysis has been performed for these two transitions. The measured lifetime values for the states 14^+ and 13^+ are <1.04* *ps* and 3.40* *ps* respectively, here ‘ < ’ represents the lifetime value is not corrected for feeding and * indicates the lifetime values are tentative.

^{123,125}I [4]: The signature inversion in positive parity yrast bands of ^{123,125}I occurred at spin state $13/2^+$ and $15/2^+$ respectively. In our calculation using PRM, we varied the triaxial parameter, γ to get the best possible match in the ΔE value and observed it at γ= 35° and γ= 41° below and above inversion for ^{123}I, γ= 33° and γ= 45° below and above inversion for ^{125}I. The significant change in the value of γ below and above inversion indicates the change in shape at the inversion point from near triaxial to non-collective oblate.

^{125,127,129,131}Cs [5]: The systematic study of different band structures, signature splitting and reduced transitions probabilities in negative and positive parity states have been theoretically studied. Further, the calculated values have been compared with the available experimental values, to validate the model calculations.

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