Non-axial nuclear shapes in $A \approx 130$ region

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In-beam γ-spectroscopic investigations on the transitional nuclei in the $A \approx 130$ region have been carried out by utilizing the Indian National Gamma Array. Different experimental fingerprints of non-axial nuclear shapes have been found in several Xe and I nuclei. Theoretical calculations based on triaxial models successfully describe the observed experimental findings.

Introduction

Atomic nuclei are considered an ideal laboratory for studying various quantum mechanical processes. Being a many-body quantal system, where, different nucleonic orbitals have different shape driving effects, atomic nuclei can exist in different shapes. Therefore, it is important to understand the effect of deformation on those shape-driving orbitals to infer the structure of the corresponding nucleus.

Specific nuclear shapes exhibit certain experimental fingerprints in nuclear level schemes. The rotational properties of a triaxially deformed nucleus differ significantly from what is expected in an axially symmetric nucleus. For instance, the signature splitting of the negative parity band in ^{125}Xe was found much larger in presence of γ-deformation than what was expected [1]. A few more physical phenomena, such as wobbling motion, chirality and γ-vibration, are also found commonly in triaxial nuclei.

The iodine and xenon isotopes in the $A \approx 130$ region are well known for their non-axial nuclear shape, which mainly arises due to the shape-driving effect of high-j $h_{11/2}$ orbital. In these nuclei, the proton (neutron) Fermi surface lies near the low-Ω (high-Ω) $h_{11/2}$ orbitals. It leads to the emergence of a variety of structural phenomena. In this talk, results obtained from our recent experimental investigations on ^{126,127,131}Xe and ^{127}I will be presented.

Experiments

Experiments were carried out at Inter-University Accelerator Centre (IUAC, New Delhi) and Variable Energy Cyclotron Centre (VECC, Kolkata) to study the structure of the ^{126,127,131}Xe and ^{127}I nuclei. Excited states in these nuclei are populated mostly by lighter-ion-induced fusion-evaporation reactions with good cross-sections. Thus, to study the structures of the high spin states of these nuclei, ^{4}He (delivered by the K-130 cyclotron of VECC), ^{7}Li and ^{9}Be (delivered by the 15 UD pelletron of IUAC) ion beams were used as the projectile. Compton Suppressed clover HPGe detectors of the INGA spectrometer were used to detect the de-exciting γ-rays in all these experiments. Details of the experimental set-up and data analysis are available in Refs. [2, 3, 4].

Triaxiality in $A \approx 130$ region

The shapes of atomic nuclei are manifested in their level schemes. The experimental fingerprints of triaxiality have been reported in several nuclei around the $A = 130$ region. Some novel modes of excitations, associated with the triaxial nuclear shapes, are discussed here.

The γ-vibration

The most common signature of triaxial nuclear shapes is the observation of (quasi)-γ-band. This kind of collective excitation is reported in most of the deformed even-even nuclei. In the case of odd-A nuclei, an odd-quasiparticle is supposed to couple with the γ-vibrational states of the corresponding even-even core to form the (quasi)-γ-band. Such a kind of coupling is observed recently in ^{127}I, where, the $h_{11/2}$ quasiproton gets coupled with the quasi-γ-band of the ^{126}Te core [5]. Also, the electromagnetic properties of the $\Delta I = 0$ transitions, decaying from the (quasi)-γ-band to the ground state band in ^{126}Xe, have been investigated [6].

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Chirality

Observation of chiral doublet bands is considered one of the distinct experimental fingerprints of triaxial nuclear shapes [7]. In this type of excitation mode, the angular momentum vectors of particle-like and hole-like quasi-particles are coupled mutually perpendicular to the angular momentum vector of the triaxial rotor core. In this geometry, two nearly degenerate $\Delta I = 1$ bands with similar electromagnetic properties originate due to the breaking of the time-reversal symmetry of the nuclear wave function. Such kinds of bands were reported mainly in odd-odd Cs and La isotopes in this mass region. In odd-A ^{123}I, two positive parity $\Delta I = 1$ three-quasiparticle bands are proposed to be originated due to the breaking of chiral symmetry [8]. Similar bands are also observed in a recent study on the ^{127}I nucleus [5].

The wobbling mode

The wobbling motion of atomic nuclei draws a lot of attention in the recent past. This kind of nuclear excitation is considered an essential characteristic of the triaxial nuclei. A. Bohr and B. R. Mottelson first proposed this mode, termed *simple wobbling*, for even-even nuclei [9]. However, it was first experimentally identified in an odd-A nucleus: ^{163}Lu [10]. Later, S. Frauendorf and F. Dönau proposed two more forms of wobbling for odd-A nuclei based on the coupling nature of the quasiparticle(s) [11]. The mode is called *transverse* (*longitudinal*) wobbling if the odd-quasiparticle is coupled to an axis perpendicular (parallel) to the axis of maximum moment of inertia (*i.e.*, intermediate axis).

Anomalous signature splitting of the negative parity bands in odd-A Xe isotopes has drawn a lot of attention over the past few decades. The observed large signature splitting in the yrast negative parity band, associated with high-Ω configuration, cannot be explained by a simple core-quasiparticle coupling scheme [12]. A recent study on the structure of the yrast negative parity bands in ^{127}Xe successfully addresses this long-standing issue by proposing an alternative description of these bands in terms of wobbling excitation [13]. The wobbling mode was also reported in odd-N ^{133}Ba [14] and odd-Z ^{133}La [15], ^{135}Pr [16] nuclei in this mass region.

Enhanced signature splitting

Re-interpretation of the unfavoured signature partner (uf-sp) band in terms of wobbling mode raised a serious question on the existence and characteristics of the uf-sp band. The band based on the yrare $I^{\pi} = 13/2^{-}$ state in ^{127}Xe is found to carry the electromagnetic characteristics of an uf-sp band [13]. A similar observation is also reported in neighbouring ^{133}Ba [14]. In the recent work on ^{131}Xe, the heretofore unobserved uf-sp of the $\nu h_{11/2}$ band is identified [17]. The signature splitting in all three cases is found large, in spite of having a high-Ω configuration, mainly due to the presence of γ-deformation.

Summary

The structure of the ^{126,127,131}Xe and ^{127}I nuclei have been studied through in-beam γ-ray spectroscopy. Several experimental signatures of the triaxial nuclear shapes, caused by the shape-driving effects of the intruder $h_{11/2}$ orbital, have been studied. Detailed results of these exotic nuclear excitations will be presented at the symposium from both experimental & theoretical points of view.

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