Triaxial shape and its manifestations in nuclei in A ~ 180 – 190 region

G. Mukherjee[1*]
[1]*Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata - 700064, INDIA*
** email: gopal@vecc.gov.in*

The structure of nuclei with proton number (Z) just below the Z = 82 shell closure and in mass region A ~ 180 – 190 has been experimentally investigated by gamma ray spectroscopy method using Indian National Gamma Array spectrometer. The triaxial shapes have been identified in some of the isotopes of Os (Z = 76), Au (Z = 79) and Tl (Z = 81) nuclei through different manifestations in their level schemes, e.g. the chiral doublet bands, gamma bands and wobbling excitations. These were well reproduced by theoretical calculations. Some new aspects of these exotic excitations have been discussed.

1. Introduction

The atomic nucleus is a wonderful many-body quantum mechanical system, which can be used as a laboratory to test several quantum mechanical symmetries. Nuclei can occur in different shapes and sizes, e.g spherical, deformed prolate or oblate, superdeformed, etc. These shapes are primarily the result of the shell effects in nuclei. Different nucleonic orbitals have different shape driving effects. The nuclear shapes are manifested in their level schemes. The nuclei with proton and neutron numbers close to the spherical magic numbers (shell closures) are generally spherical in shape. As the nucleon number moves away from the shell closures, deformed structures are developed. Apart from the axially symmetric deformations, it has been found that the nuclei can also have non-axial or triaxial deformations. As the variation of nuclear shape is believed to be the result of the nuclear shell effects, therefore, the systematic study of the nuclear shapes as a function of nucleon number and excitation energy are important to understand the effect of different orbitals in determining the shape of a nucleus. The odd proton or the odd neutron in an odd-A nucleus occupies different single-particle orbitals and so it is important to investigate the odd-A nuclei to study the shape driving effect of these orbitals.

The level scheme of a nucleus carries the fingerprint of its structure. A deformed nucleus is characterized by a rotational band structure, the level energy (E) and spin (angular momentum, I) of which obey the parabolic rule:

$$E = A*I*(I+1),$$

Where, A is the moment of inertia parameter.

In case of triaxial nuclei, three of the most common manifestations in the level schemes are: (i) occurrence of chiral doublet bands, (ii) occurrence of gamma bands and (iii) occurrence of wobbling bands.

The nuclei with proton number Z below the Z = 82 magic number in the mass region A ~ 180 – 190 are very interesting from the structural point of view. The shape of these nuclei depend on the competition between the effect of the spherical shell closures at Z = 82 and the shape driving effect of the high-j proton intruder single-particle orbitals of $h_{9/2}$ and $i_{13/2}$. The neutron Fermi level also plays important role in this. Because of the influence of the spherical shell closures of both proton and neutrons, the heavier Tl (Z = 81) and Au (Z = 79) isotopes are spherical in nature. However, as the neutron number decreases towards mid shell, the nuclei starts to develop deformed shapes, as the deformation driving effects of the proton orbitals starts to play significant role. For example, the deformation driving effect of the proton $i_{13/2}$ orbital becomes so important to generate rotational band based on this configuration in ^{195}Bi nucleus suggesting onset of deformation in Bi isotopes at neutron number N = 112 [1]. The heavier Bi isotopes are near spherical, where as the lighter ones are deformed. On the other hand, the deformation driving effect of the intruder proton $h_{9/2}$ orbital in Tl isotopes have been observed even at N = 120 in ^{201}Tl [2] with the observation of a band structure which was interpreted with the calculated minimum in the potential energy surfaces at oblate deformation. The triaxial shapes in Tl isotopes have been reported for neutron deficient isotopes in A ~ 190 region [3, 4]. On the other hand, the even-even isotopes of Os (Z = 76) and Pt (Z = 78) in A ~ 180 region, are known to be of triaxial shape [5,6]. Therefore, it is interesting to investigate the effect of an odd proton or an odd neutron in different single particle orbitals on these even-even triaxial cores.

In this talk, I shall focus on our experimental study of triaxial shapes in ^{195}Tl, ^{187}Os and ^{183}Au nuclei [7, 8, 9] in which the aforementioned three manifestations are observed in their level schemes.

2. Experiments and Analysis

The excited states in the nuclei of interest were populated by using the following fusion evaporation reactions: (i) ^{185,187}Re(^{13}C,xn)^{195}Tl at 75 MeV of beam energy. The beam was delivered from the Pelletron-Linac facility at TIFR, Mumbai and the INGA spectrometer with 15 Compton Suppressed (CS) clover HPGe detectors is used to detect the de-excited prompt gamma rays; (ii) ^{4}He(^{186}W,3n)^{187}Os. The 36-MeV α beam was delivered from the K-130 cyclotron at VECC, Kolkata and INGA at VECC with 7 CS clovers and 1 LEPS HPGe detector were used to detect prompt gamma rays; (iii) ^{169}Tm(^{20}Ne, 6n)^{183}Au at the beam energy of 146 MeV, delivered from the K-130 cyclotron at VECC. In this experiment, there were 8 CS clovers and 2 LEPS detectors were used in the INGA spectrometer at VECC to detect the prompt gamma rays.

In all these experiments, digital data acquisition system comprised of pixie-16 modules of XIA were used [10, 11, 12]. The events were recorded when the condition of two or more fold clover events were detected.

The analysis procedure involves the generation of different gamma-gamma matrices and gamma-gamma-gamma cubes from which the coincidence relations were determined by putting appropriate gates on a single gamma (in a matrix) or on double gammas (in the cube). The spin and parities of the levels were assigned from the multipolrity (λ) and type (E/M) of the de-excited gamma rays. These quantities were obtained from the angular correlation (DCO) and polarization (and polarization asymmetry) measurements of the gamma rays. The details of the analysis procedure specific for the nuclei are given in the refs. [7, 8. 9].

3. Results and discussion

The level schemes of the three nuclei ^{195}Tl, ^{187}Os and ^{183}Au have been considerably extended in our work with the placement of several new gamma transitions in the level schemes of the respective nuclei. The new results, specific to the triaxiality in these three nuclei are discussed below:

3.1: ^{195}Tl

In the previous work [13] on this nucleus, a rotational band based on proton $h_{9/2}$ orbital was identified and it was interpreted as an oblate deformed structure. A 3-quasiparticle (qp) band was also identified in that work. In our work, the 1-qp $h_{9/2}$ band has been extended beyond band crossing. The configuration of the 3-qp band (band 1 in Fig.1) has been assigned as $\pi h_{9/2} \otimes \nu i_{13/2}^{-2}$. This assignment is based on the large gain in the measured aligned angular momentum (i_x ~ 9ħ) of this band. This band has been extended up to 39/2 ħ.

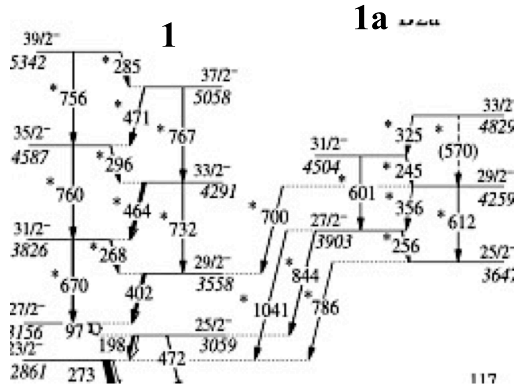

Fig. 1: Doublet bands 1 and 1a in ^{195}Tl. The newly observed γ-lines are marked by *

A partner band (band 1a in Fig. 1) is also identified in our work, the excitation energy of