Study of nuclear structure near the Z = 82 and N = 82 shell closures

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The nuclei near the Z = 82 and the N = 82 shell closures in A ~ 190 and A ~ 130 mass regions, respectively, are crucial laboratories to observe interesting nuclear structure phenomena and to test a variety of nuclear models. The proximity of the spherical shell closures and competing shape (prolate and oblate) driving effects of the high-j orbitals ($\pi h_{9/2}$, $\pi i_{13/2}$ & $\nu i_{13/2}$ for Thallium and Bismuth nuclei in A ~ 190 region and $\pi h_{11/2}$ & $\nu h_{11/2}$ in A ~ 130 mass region for the Cesium nucleus), near the proton and neutron Fermi levels, induce shape co-existence and triaxiality in the nuclei in these regions. Therefore, apart from normal deformed band structures, the magnetic rotational (MR) band and chiral doublet bands are expected in these nuclei.

In the present thesis work, high spin level structures of ^{195}Bi, ^{198}Bi, ^{197}Tl and ^{194}Tl nuclei belonging to the A~190 region (near Z = 82) and of ^{134}Cs nucleus belonging to the A~130 region (near N = 82), have been investigated using the technique of high resolution γ-ray spectroscopy. Most of the data in this thesis work were taken using different configurations of Indian National Gamma Array (INGA) at the different accelerator centres in India i.e VECC, Kolkata; TIFR, Mumbai and at IUAC, New Delhi using heavy ion beams. ^{197}Tl were studied by α induced reaction, using the modest in-house facility of γ detectors at VECC, Kolkata.

In the Bismuth nuclei (Z = 83) a variety of structures are identified from spherical to superdeformed shapes as one goes down in neutron number from N = 126 shell closure to midshell. The odd proton nucleus ^{195}Bi, with neutron number N = 112, is an interesting transitional nucleus whose two immediate odd-A neighbors on either side have different shapes at low excitation energies. Spherical shape dominates in ^{197}Bi and deformed bands (built on $\pi h_{9/2}$ and $\pi i_{13/2}$ levels) observed for ^{193}Bi. However, as the high spin states in ^{195}Bi were not well studied and no rotational band has been reported so far in ^{197}Bi, the neutron number corresponding to the onset of deformation in Bi nuclei was not known. In the present thesis work, a rotational band built on a $13/2^+$ band head has been identified in ^{195}Bi [1] at low excitation which clearly indicate the onset of deformation takes place at neutron number N = 112 in Bi isotopes. It is also suggested that N = 112 is the border of sphericity in Bi isotopes. In other words, it also indicates that the effect of N = 126 shell closure to reinforce the spherical shape in nuclei lessens for neutron number N ≤ 112.

In A = 190 region, valence protons occupy high-j and high-Ω orbital ($\pi h_{9/2}$) and valence neutrons occupy high-j, low-Ω orbital ($\nu i_{13/2}$) for oblate deformation. This is an ideal situation for magnetic rotation to occur. Such bands were found in several Pb and Bi isotopes. In many cases, particularly in Bi isotopes, the excitation energies and definite spin-parities (J^π) could not be assigned for such bands. So, the configurations could not be established. In this thesis work, a detailed study of the high-spin spectroscopy of odd-odd nucleus ^{198}Bi has been done with an aim to investigate the magnetic rotational bands in this nucleus. In the present work, these MR bands (B1, B2 and B3) have been connected to the lower-lying states for the first time. The excitation energy of these bands could be established as these are now connected with the known excited states in this nucleus. Moreover, the configuration of these bands could be proposed as definite J^π assignments were made, in this work, for the states in these three bands. The bands B1 and B2 were discussed in the frame work of a semiclassical approach and the band B3 does not seem to satisfy the criteria of a MR band.

The Nilsson orbitals $\pi[505]9/2^-$ and $\pi[606]13/2^+$ are the intruder proton orbitals for the Thallium (Z = 81) nuclei. They are originated from the $\pi h_{9/2}$ and $\pi i_{13/2}$ levels, respectively, situated below the Z = 82 shell closure. In odd-A Tl isotopes, rotational band based on the intruder $\pi i_{13/2}$ orbital have been observed in lighter odd-mass Tl nuclei but this state has not yet been identified above ^{193}Tl. So, it is interesting to study the intruder $\pi i_{13/2}$ orbital above ^{193}Tl. The intruder levels are, often, non-yrast and can be better accessed by α-induced fusion evaporation reactions. In the present thesis work, the γ-ray spectroscopy of ^{197}Tl has been studied using α beam in order to investigate the proton $i_{13/2}$ intruder state along with the multi-quasiparticle states in this nucleus. In ^{197}Tl, the intruder $\pi i_{13/2}$ state could be established for the first time [2], through polarization and DCO measurements. We have assigned negative parity for the band B2 and a new configuration has been proposed for this band.

The study of band structure based on $\pi h_{9/2} \otimes \nu i_{13/2}$ configuration in odd-odd Tl isotopes is another point of interest. Indication of collective rotational bands based on this configuration have been reported in a few doubly-odd Tl isotopes in this mass region. But in most cases there are ambiguities on level energies, spins and parities except in ^{190}Tl and ^{198}Tl. However, the band based on the above configuration in these two nuclei have been interpreted differently in these two nuclei. In ^{198}Tl, this band was interpreted as due to chiral symmetry breaking and a triaxial shape has been proposed while the similar band in ^{190}Tl was interpreted assuming oblate deformation. Therefore, it was important to know the band structure in the intermediate isotopes. In the present work, the band based on the above configuration in ^{194}Tl [3] show similar behaviour as those in ^{190,198}Tl. It has been shown that the signature splitting and the moment of inertia for this band is very similar in all these three isotopes. The TRS calculations also suggest oblate deformation for all the three isotopes with similar deformation. Moreover, a MR band has also been observed in ^{194}Tl in this work, based on a six quasiparticle configuration.

It may be pointed out that it is for the first time that a MR band has been observed for an odd-proton nucleus below Z = 82 in the Pb-Hg region.

In order to extend the present work for the nuclei near N = 82 shell closure, detailed investigation of the high spin states in ^{134}Cs has been carried out. The lighter, neutron deficient Cesium isotopes are known to be deformed and the band structure based on the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration in the odd-odd Cs isotopes (up to ^{132}Cs), are reported as, arises due to chiral symmetry breaking with a stable triaxial deformation. As the neutron number increases towards N = 82 shell closure, it is an open question whether the shape driving effects of the neutrons are strong enough to stabilize the triaxial shape, so that the similar band structure (chiral doublet bands) persists for the heavier odd-odd Cs isotopes. ^{132}Cs (N = 77) is the heaviest isotope of Cs for which the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration has been identified with chiral doublet bands built on it. The $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration has not yet been identified in ^{134}Cs which is the next heavier odd-odd Cs isotope. Therefore, to address the issue of persistence of chirality for the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration in the heavier isotopes of Cs, the high spin states in ^{134}Cs near N = 82 magic gap have been studied and the nature of the band built on this configuration has been investigated in detail in the present thesis work. Four band structures have been observed in this odd-odd nucleus and the configurations have also been proposed for these bands. The $\pi h_{11/2} \otimes \nu h_{11/2}$ band has been identified and characterized for the first time in ^{134}Cs (N=79) [4]. This particular band in ^{134}Cs looks very different than the same band in lighter Cs isotopes. This band has the characteristic of a MR band in sharp contrast to the bands built on the same configuration observed in the lighter odd-odd isotopes of Cs which were interpreted as chiral bands. The Tilted Axis Cranking (TAC) calculations and TRS calculations also support the observed change in the band structure. This result signifies the onset of sphericity in Cs (Z = 55) isotopes at neutron number N = 79. The details of the experiments, analysis and theoretical calculations will be discussed in the conference.

References

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