Nuclear structure study at high spin in mass ∼ 100 region

Biswarup Das*
High Energy Nuclear and Particle Physics Division,
Saha Institute of Nuclear Physics, Kolkata-700064, INDIA†

Introduction

Finite fermionic systems are the basic constituents of our world, such as the electron cloud and the atomic nucleus. Among them the atomic nucleus is the most studied finite fermionic system, where the neutron and the proton act as the degrees of freedom when probed in the MeV energy regime.

In the present thesis work, the structure of the mass ∼ 100 region nuclei were studied from their behaviour at high spin. High spin states in nuclei were populated through the fusion evaporation reactions using the heavy ion beams from the pelletron accelerators situated at TIFR, Mumbai and IUAC, Delhi. Nuclear de-excitation process was studied using the γ-spectroscopy methods, where the γ-rays were detected using the Indian National Gamma Array [1] of clover detectors.

Discussion

Study of the Ag isotopes were motivated by the various angular momentum generation mechanisms supported by the single particle configurations in their ground state. In these isotopes, the unpaired proton occupies the hole state in the $g_{9/2}$ orbital, while the neutron fermi levels lie close to the particle states in the $d_{5/2}, g_{7/2}, h_{11/2}$ orbitals. This causes the 'shears mechanism' [2] as a favourable mode of excitation. On the other hand, these oppositely shape driving orbitals might lead to a stable triaxial deformed shape, as a consequence of which the formation of 'chiral partner bands' can take place.

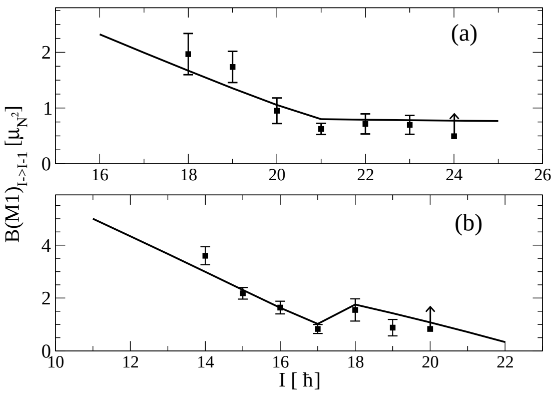

FIG. 1: Measured $M1$ transition rates for (a) the +ve parity and (b) the -ve parity non-yrast bands of ^{106}Ag. Solid line represents the calculated values using the SPAC model.

In the present work, the level-scheme of ^{106}Ag was extended by establishing the $-ve$ and the $+ve$ parity non-yrast bands. The high spin transition rates were calculated for both the bands using the measured lifetimes from DSAM. Both the bands exhibit a falling nature in the $B(M1)$ rates with spin as shown in Fig. 1. Thus, as a first choice, the shears mechanism was considered to generate the high-spin states based on the single particle configurations $\pi g_{9/2}^{-3} \otimes \nu h_{11/2}$ and $\pi g_{9/2}^{-1} \otimes \nu[(d_{5/2}/g_{7/2})h_{11/2}^2]$ for the $-ve$ and the $+ve$ parity bands, respectively. In these non-yrast bands, the principal axis rotation was found to co-exist with the shears mechanism to generate the high spin states. In addition, the shears structure in this nucleus led to interesting observations. The shears mechanism in the $-ve$ parity band was found to arise from a $\pi g_{9/2}^{-3} \otimes \nu h_{11/2}$ configuration and this three proton hole structure was observed for the first time in the Ag isotopes [4]. A shears band-crossing was also found in this band,

*Electronic address: `bd.physics@gmail.com`
†Presently at Deptartment of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai - 400005, INDIA.

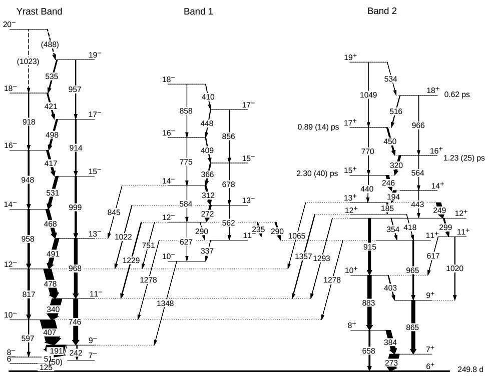

FIG. 2: Partial level scheme of ^{110}Ag.

after a pair of neutrons are aligned in the $(d_{5/2}/g_{7/2})$ orbitals at a spin of $I = 17\hbar$. On the other hand, no band-crossing was observed in the $+ve$ parity band, as the AB-crossing is blocked. Thus, to generate the high spin states in this band after the shears mechanism was exhausted, the nucleus exhibit a non-collective rotation. As a result, the falling trend of the transition rate becomes nearly constant beyond the spin of $I = 21\hbar$. Thus, a clear termination of the shears mechanism was observed for the first time in the $+ve$ parity non-yrast band of ^{106}Ag [5].

In a separate experiment, the high spin states of ^{110}Ag were populated using the ^{96}Zr(^{18}O, p3n) reaction. A detailed level scheme was established using the 2-fold and the 3-fold coincidence data, where two non-yrast bands (Band 1 and 2 of Fig. 2) along with their decay paths were established for the first time. The yrast band sequence is built on the single particle configuration $\pi g_{9/2}^{-1} \otimes \nu h_{11/2}^{1}$ up to $I = 16\hbar$ and $\pi g_{9/2}^{-1} \otimes \nu h_{11/2}^{3}$ after that [6]. A similar configuration of $\pi g_{9/2}^{-1} \otimes \nu h_{11/2}^{3}$ is also responsible for the Band 1. The near degenerate energy levels establishes band 1 as the partner of the yrast band. A similar trend of the estimated $B(M1)/B(E2)$ values for the partner bands can be a indication that the partner bands arise by breaking the chiral symmetry of the nucleus in the lab frame. On the other hand, the measured transition rates for the Band 2 shows that the shears mechanism competes with the core rotation to generate the high spin states in this band. This competition has been described theoretically by the SPAC model based on the single particle configuration of $\pi g_{9/2}^{-1} \otimes \nu[(d_{5/2}/g_{7/2}) h_{11/2}^{2}]$ [7].

At last, a systematic study was done to explain the origin of the so called 'staircase bands' in the odd-A Ag isotopes, namely ^{105,107,109}Ag. In these isotopes, the yrast cascades beyond $I = 11.5\hbar$ are developed on the single particle configuration $\pi g_{9/2}^{-1} \otimes \nu h_{11/2}^{2}$, where a falling trend in the transition rates with increasing spin has been observed. However, a deviation from the shears mechanism can be seen in the $E(I) - E(I-1)$ vs. I plot, which forms a staircase like structure. The energy staggering behaviour could be explained if a signature dependent term, arising from the $\Omega = 1/2$ mixing of the triaxial nucleus, is included in the standard SPAC hamiltonian. Within this framework, the energy behaviour and the $B(M1)$ rates could be explained for the staircase bands [8].

References

[1] S. Muralithar *et al.*, Nucl. Inst. Meth. Phys. Res., Sect. A **622**, 281 (2010); R. Palit *et al.*, Nucl. Inst. Meth. Phys. Res., Sect. A **680**, 90 (2012).

[2] R. M. Clark and A. O. Macchiavelli., Annu. Rev. Nucl. Part. Sci. **50**, 1 (2000).

[3] N. Rather *et al.*, Phys. Rev. Lett. **112**, 202503 (2014).

[4] B. Das *et al.*, Phys. Rev. C **93**, 064322 (2016).

[5] B. Das *et al.*, Phys. Rev. C **95**, 051301(R) (2017).

[6] S. Roy *et al.*, Phys. Lett. B **710**, 587 (2012).

[7] B. Das *et al.*, Phys. Rev. C **98**, 014326 (2018).

[8] B. Das *et al.*, Proceedings of the DAE-BRNS Symp. on Nucl. Phys. **60**, 82 (2015).