Rotational alignments of the $j_{15/2}$ neutrons in the $5/2^+[622]_\nu$ rotational bands

Anshul Dadwal* and Xiao-Tao He†

Department of Nuclear Science and Technology,
College of Materials Science and Technology,
Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China.

Introduction

One of the most surprising issue in the heavy systems under rotational stress is the neutron alignment. For Pu isotope, it well know that the alignment of protons occupying the $i_{13/2}$ is responsible [1]. It was expected that for the $j_{15/2}$ orbital, the results would be similarly dramatic and clear. However, no traces of the neutron alignment was found. Theoretically, "standard" cranking calculations shows clear evidences of the neutron alignment. The cranked relativistic Hartree-Bogoliubov theory suggests that both neutrons and protons contribute to the alignment at the same frequency [2]. In the case of ^{235}Np, experimental evidence supports neutron alignment based on the $5/2^+[642]$ Nilsson orbital of $\pi i_{13/2}$ parentage, while theoretical studies suggest proton alignment based on the $5/2^-[523]$ Nilsson orbital of the $\pi h_{9/2}$ subshell [3]. Thus, the alignment effect is primarily attributed to protons in high-j orbitals, and experimental evidence for neutron participation in alignment is sparse or inconclusive.

The particle number conserving method

In the particle-number conserving (PNC) treatment of cranked shell model (PNC-CSM), particle number is conserved and the Pauli blocking effect is treated consistently. The cranked shell model Hamiltonian with pairing is

$$H_{\rm CSM} = H_{\rm SP} - \omega J_x + H_p = H_0 + H_p$$

where $H_0 = \sum_i h_{\rm nilsson} - \omega j_{x_i}$. The term H_p has monopole and quadrupole pairing correlations $H_p = H_p(0) + H_p(2)$ The $H_{\rm CSM}$ is diagonalized in a sufficiently large cranked many-particle configuration (CMPC) space to obtain the yrast and low-lying eigenstates. The eigenstate of $H_{\rm CSM}$ is expressed as:

$$|\psi\rangle = \sum_i C_i |i\rangle$$

here $|i\rangle$ denotes an occupation of particles in the cranked Nilsson orbitals and C_i denotes the corresponding probability amplitude.

Results and Discussion

In this study, we have analyzed the excited bands based on the $\nu 5/2^+[622]$ configuration in the odd-N 151 isotones, ^{247}Cm and ^{249}Cf, using the particle number conserving cranked shell model (PNC-CSM). While the PNC-CSM has previously been successfully applied to the ground state bands of these N=151 isotones, experimental data for the excited bands was not available at that time [4]. The experimental data used in this study is sourced from Refs. [5, 6].

In figure 1, we present the calculated kinematic ($\Im^{(1)}$) and dynamic ($\Im^{(2)}$) moments of inertia for the excited N=151 isotones ^{247}Cm and ^{249}Cf, comparing these results with experimental data. The contributions of both neutrons and protons to the kinematic moment of inertia are also illustrated for all the nuclei. The figure demonstrates that the experimental moments of inertia are accurately reproduced for the $\nu 5/2^+[622]$ bands in N=151 isotones. It is noteworthy that the same set of parameters used in this study also successfully reproduces the kinematic moment of inertia of

*Electronic address: dadwal.anshul@gmail.com
†Electronic address: hext@nuaa.edu.cn

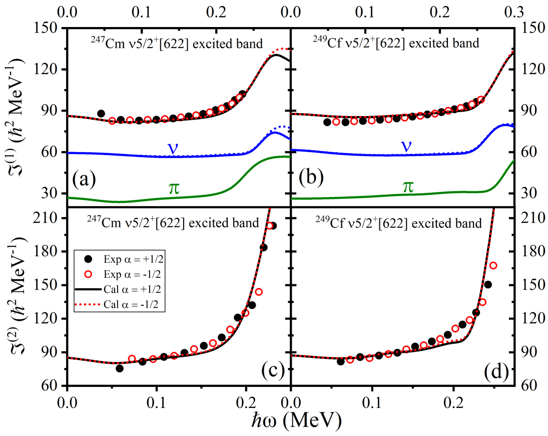

FIG. 1: The experimental and calculated kinematic ($\Im^{(1)}$) and dynamic ($\Im^{(2)}$) moment of inertia for the excited bands in ^{247}Cm and ^{249}Cf The proton (π) and neutron (ν) contributions to the kinematic moment of inertia is also shown in olive and blue lines, respectively.

the ground state band $\nu 9/2^{-}[734]$ (not shown in figure 1). This strongly supports our choice of parameters for studying these N=151 nuclei. In Ref. [4], calculations of the ground state bands for N=151 isotones using PNC-CSM revealed that protons in orbitals originating from $\pi i_{13/2}$ are responsible for the upbending mechanism, while orbitals originating from $\nu j_{15/2}$ are blocked throughout the rotational frequency. For the excited bands, however, this is not the case, as both protons and neutrons contribute to the upbending (see protons and neutrons contribution in figure 1).

Conclusion

In summary, the excited rotational bands based on $\nu 5/2^{+}[622]$ configurations in $N = 151$ isotones, ^{247}Cm and ^{249}Cf, have been investigated within the framework of the particle number conserving cranked shell model. For neutrons, the upbending is mainly due to the $1j_{15/2}$ and $2h_{11/2}$ ($N = 7$) intruder orbitals, with the latter contributing more prominently. This study marks the first instance of $\nu j_{15/2}$ alignment in the $A \sim 250$ mass region.

References

[1] I. Wiedenhöver, R. V. F. Janssens, G. Hackman, I. Ahmad, J. P. Greene, H. Amro, P. K. Bhattacharyya, M. P. Carpenter, P. Chowdhury, J. Cizewski, et al., Phys. Rev. Lett. **83**, 2143 (1999), URL https://link.aps.org/doi/10.1103/PhysRevLett.83.2143.

[2] A. V. Afanasjev and O. Abdurazakov, Phys. Rev. C **88**, 014320 (2013), URL https://link.aps.org/doi/10.1103/PhysRevC.88.014320.

[3] A. M. Hurst, C. Y. Wu, M. A. Stoyer, D. Cline, A. B. Hayes, S. Zhu, M. P. Carpenter, K. A. Saleem, I. Ahmad, J. A. Becker, et al., Phys. Rev. C **81**, 014312 (2010), URL https://link.aps.org/doi/10.1103/PhysRevC.81.014312.

[4] Z.-H. Zhang, J.-Y. Zeng, E.-G. Zhao, and S.-G. Zhou, Phys. Rev. C **83**, 011304 (2011), URL https://link.aps.org/doi/10.1103/PhysRevC.83.011304.

[5] *National Nuclear Data Center* , https://www.nndc.bnl.gov/ensdf/.

[6] S. Hota, P. Chowdhury, T. Khoo, M. Carpenter, R. Janssens, Y. Qiu, I. Ahmad, J. Greene, S. Tandel, D. Seweryniak, et al., Physics Letters B **739**, 13 (2014), ISSN 0370-2693, URL https://www.sciencedirect.com/science/article/pii/S0370269314007448.