^{107}Cd: Unique co-existence of several exciting features

Deepika Choudhury[1],* R.Palit[1], P. Singh[1], J. Sethi[1], S. Saha[1], S. Biswas[1], H.C. Jain[1], V. Nanal[1], R.G. Pillay[1], R. Dhonti[1], S.K. Jadav[1], B.S. Naidu[1], S.C. Pancholi[2], R.P. Singh[2], Rojeeta[3], Sukhjeet Singh[4], L. Chaturvedi[5], L.S. Danu[6], S. Mukhopadhyay[6], D.C. Biswas[6], S. Tandel[7], B. Maheshwari[8], and A.K. Jain[8]
[1]*Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai-400085, India*
[2]*Inter University Accelerator Center, New Delhi-110067, India*
[3]*University of Delhi, Delhi-110007, India*
[4]*Maharishi Markandeshwar University, Mullana, Ambala-133207, India*
[5]*Guru Ghasidas University, Bilaspur-495009, India*
[6]*Bhabha Atomic Research Centre, Mumbai-400085, India*
[7]*UM-DAE Centre for Excellence in Basic Sciences, Mumbai-400098, India and*
[8]*Indian Institute of Technology, Roorkee-247667, India*

Introduction

The odd-A ^{107}Cd, situated in a transitional region between spherical and deformed nuclei, has proven to be a fertile case for the observation of several exciting nuclear phenomena arising due to particle alignment and nuclear rotation competing each other. A number of experiments to study the low spin states of ^{107}Cd were carried out in 1970s and 1980s. An earlier work on the high spin states was carried out by Jerrestam *et al.* [1] in 1992. In 2013, ^{107}Cd was discovered by us to have multiple AMR bands based on same particle configuration with slightly different neutron alignments [2]. We also got a glimpse of an unusual pair of partner bands based on a special kind of symmetry breaking [3] due to time-odd mean field, which needed further confirmation. With the Indian National Gamma Array (INGA) and digital data acquisition (DDAQ) [4], we aimed at further developing the level scheme of ^{107}Cd to high spins so as to unfold the various exciting features in more detail and also unobserved till date. We report in this paper the co-existence of magnetic rotation (MR) bands along with the AMR bands; a 5qp band being crossed by another 5qp band, arising due to an interplay between particle alignment and core rotation.

*Electronic address: deepika.chry@gmail.com

Experimental details

High spin states of ^{107}Cd were populated using the ^{94}Zr(^{16}O,5n) reaction at a beam energy of 90 MeV provided by the TIFR-BARC Pelletron facility at TIFR, Mumbai. An isotopically enriched self supporting ^{94}Zr target of thickness 0.99 mg/cm^2 was used. The emitted γ-rays were detected by using the INGA set-up. Two and higher fold coincidence events were collected in list mode format using the DDAQ system based on Pixie-16 modules developed by XIA LLC [4]. One more experiment was also performed using with ^{94}Zr target of thickness 0.9 mg/cm^2 on ^{197}Au backing of thickness 10 mg/cm^2 and beam energy of 72 MeV. The coincidence events, after calibration, gain matching and proper doppler correction, were sorted into $E_\gamma - E_\gamma$ symmetric and angle-dependent asymmetric matrices along with $E_\gamma - E_\gamma - E_\gamma$ cube. The RADWARE [5] and LINESHAPE [6] analysis programs were used for further data analysis. The spins and parities of the excited states were assigned on the basis of the DCO ratio and linear polarization measurement of the de-exciting γ-ray transitions. The transition probability, $B(M1)$, values of few high spin excited states of ^{107}Cd were also obtained by measuring the lifetimes of the states using doppler shift attenuation method (DSAM).

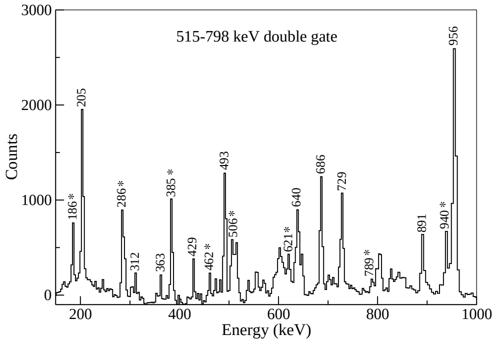

FIG. 1: Double gated spectrum with gates on the 515 and 798 keV transitions.

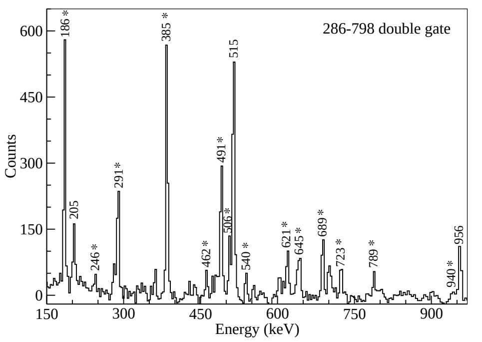

FIG. 2: Double gated spectrum with gates on the 286 and 798 keV transitions.

Results and discussion

The present work modifies the negative parity part of the earlier known level scheme [1] with the addition of 29 new transitions and rearrangement of 12 transitions. A negative parity $M1$ band structure (upto spin $49/2^-$) has been established feeding the low spin states via several different paths. The band structure and the various paths connecting it to the low spin states, together comprise of 33 transitions placed in the level scheme on the basis of their coincidence relations, relative intensities and multipolarities. Figs. 1 and 2 show most of the transitions under discussion (peaks marked with asterisks). The extracted lifetimes of the states in the M1 band show a decrease in the $B(M1)$ values with increase in spin from $33/2^-$ to $39/2^-$. The tilted axis cranking (TAC) calculations have been performed to explain the observed properties of the M1 band structure, the results of which have been found to be in good agreement with the experimental observations. The semi-classical particle-plus-rotor model calculations have also been performed which also successfully explains the empirical findings. The experimental observations together with the theoretical calculations indicate that the newly observed M1 band structure is developed due to shears mechanism based on 5qp configuration. The high-Ω $g_{9/2}^{-2}$ proton angular momentum vector and the resultant of the 3 low-Ω $h_{11/2}$ and $g_{7/2}$ neutron angular momentum vectors, nearly perpendicular to each other, form the band head spin (14^-). The high spin states arise due to the gradual closing of the n-p vectors up to spin $39/2^-$. At this excitation energy, the n-p blades reopen due to all three neutrons particles now occupying only the $h_{11/2}$ orbitals. The band structure further extends to high spin states due to the closing of these blades along with contribution from core rotation. Hence, we find that ^{107}Cd is a unique example of co-existence of MR and AMR bands. Further, it also exhibits a pair of negative parity degenerate, same spin parity bands which can only be explained by a time-odd symmetry breaking of the mean-field.

Acknowledgments

We thank the entire INGA collaboration and the Pelletron-LINAC staff at TIFR. Financial support from D.S.T., D.A.E. (Govt. of India) is also gratefully acknowledged.

References

[1] Dan Jerrestam *et al.*, Nucl. Phys. **A545**, 835 (1992).
[2] Deepika Choudhury *et al.*, Phys. Rev. C **87**, 034304 (2013).
[3] Deepika Choudhury *et al.*, DAE Symp. on Nucl. Phys., **57**, A38 (2012).
[4] R. Palit *et al.*, Nucl. Instrum. and Meth. in Phys. Research A **680**, 90 (2012).
[5] D.C. Radford, NIM A **361**, 297 (1995).
[6] J.C. Wells *et al.*, ORNL Phys. Division, Report No. ORNL-6689, Sept 30, (1991).