ECS Transactions

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To cite this article: Kaushik Katre *et al* 2022 *ECS Trans.* **107** 12577

ECS Transactions, 107 (1) 12577-12584 (2022)
10.1149/10701.12577ecst ©The Electrochemical Society

High spin study of ^{104}Ag nucleus

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High spin states in ^{104}Ag were populated via heavy-ion (^{32}S) induced fusion evaporation reaction at a beam energy of 110 MeV. The de-exciting γ-rays were detected by 18 Compton suppressed HPGe clover detectors, placed in different (θ, φ) angles. Spin of several excited states were assigned firmly from the present angular correlation measurement.

Introduction

Existence of different dynamical symmetries like wobbling, chirality, magnetic and anti-magnetic rotations in the nuclei near A ≈ 100 region have attracted a lot of attention in recent times (1-16). In these nuclei, the proton Fermi surface lies near $g_{9/2}$ orbital and the neutron Fermi surface and $d_{5/2}$, $g_{7/2}$, $h_{11/2}$ orbitals are close to neutron Fermi surface. Interplay between these shape-driving orbitals play a crucial role to generate a variety of band structures associated with the aforementioned phenomena. The odd-odd Ag isotopes with three proton-holes below the Z = 50 shell closure and a few neutron-particle above the N = 50 shell closure exhibit a small quadrupole deformation typically. Consequently, a series of magnetic rotational bands were reported systematically in odd-odd Ag nuclei at higher spin regime (18). At lower spin, the collective rotational bands are mainly associated with 1p-1h two-quasi particle configurations (17). A structure based on a three proton-hole configuration was also reported in ^{106}Ag (12). However, in spite of their proximity to the double shell closure, the Ag nuclei in this mass region also exhibit strongly deformed bands.

Structure of the ^{104}Ag nuclei was studied via both light and heavy ion induced reactions (17-22). From the latest spectroscopic investigation on this nucleus, Z. G. Wang and co-workers reported two positive parity rotational bands based on $\pi g^{-1}_{9/2} \otimes \nu d_{5/2}$ and $\pi g^{-1}_{9/2} \otimes \nu g_{7/2}$ configurations (17). However, the spin and parity of several excited states of these band were assigned tentatively. Thus, in this work an attempt has been made to assign the spin of these states unambiguously from angle dependent spectroscopic measurements.

Experimental Details

High spin states in ^{104}Ag nucleus were populated by using the ^{76}Ge (^{32}S, p2nγ)^{104}Ag fusion evaporation reaction at a beam energy of 110 MeV. Energetic beam of ^{32}S was delivered from the TIFR-BARC 14UD Pelletron, located at Tata Institute of Fundamental Research (TIFR), Mumbai. The target consisted of isotopically enriched ^{76}Ge with a thickness of 500 μg/cm^2, evaporated on a 26 mg/cm^2 gold backing. A thin layer (11 μg/cm^2) of aluminum was placed in between the target and backing to prevent the migration of target material into the stopper. The de-exciting gamma rays emitted from the residual nuclei were detected by utilizing the Indian National Gamma Array (INGA) at the TIFR, Mumbai (24). The INGA spectrometer was consisted of 18 Compton suppressed clover detectors at the time of the experiment. The clover detectors were placed at six different angles (θ) viz.: θ = 40° (φ = 0°, 120°, 240°), θ = 65° (φ = 90°, 330°), θ = 90° (φ = 60°, 120°, 180°, 240°, 300°), θ = 115° (φ = 90°, 210°, 330°), θ = 140° (φ = 0°, 120°, 240°), and θ = 157° (φ = 60°, 180°, 300°) with respect to the beam direction.

Data Analysis

The data were sorted in γ-γ symmetric and asymmetric matrices and analyzed by using the RADWARE program XMESC and SLICE respectively (25). The symmetric matrix was used to the checked the published level scheme and to place new gamma in the level scheme. The asymmetric matrix was used to find the direction correlation ratio of oriented states (23) and defined as,

$$R_{DCO} = \frac{I_\gamma\,(\text{Observed at }140°,\text{Gate on }90°)}{I_\gamma\,(\text{Observed at }90°,\text{Gate on }140°)} \qquad [1]$$

In the asymmetric matrices, the γ-transitions recorded by detectors placed at θ_1 =140° correspond to the x-axis and the γ-transitions recorded by detectors placed at θ_2 = 90° correspond to the y-axis. In order to obtain the gamma transitions intensities, the gate was set on the x-axis and projected on the y-axis. In the same way, the gate was set on the y-axis and projected on the x-axis. If R_{DCO} is equal to one then the multipolarities of the unknown transition is same as the gated transition and if the multipolarities is different from the gated transition then R_{DCO} is not equal to zero. The energy and efficiency calibration were done by using the standard ^{152}Eu and ^{133}Ba radioactive source placed at the target position.

Results

The partial level scheme of ^{104}Ag nucleus, as shown in Figure 1, has been constructed using the relative intensities, coincidence relation and R_{DCO} measurement. The present work confirms the previously reported work (17-18) and the part of level scheme modified is discussed below. The γγ-coincidence spectra with γ-rays belongs to ^{104}Ag nucleus with 907 keV gate is shown in Figure 2.

In the previous work, the 1465 keV (→13^+) γ-transition deexciting 4521 keV level was tentatively placed in the level scheme due to week intensity. Present work confirms the 1465 keV gamma in the level scheme and these can be nicely seen in the 907 keV transition gate as shown in Figure 2. In addition, one more γ transition with energy 576 keV (13^+→12^+) was observed in the 640 keV gate.

The spin of many levels has been confirmed from the present R_{DCO} measurement. The DCO values have been extracted from the asymmetric matrices using different gates and has been tabulated in Table 1. Variation of the DCO ratio for dipole transitions as a function of multipole mixing ratio (δ) is shown in Figure 3. These curves are found sensitive to the multi polarity of the gating transition, particularly for higher magnitudes of δ. Figure 4 shows the intensity of the γ-rays with different multi polarity at θ = 90° and θ = 140°.

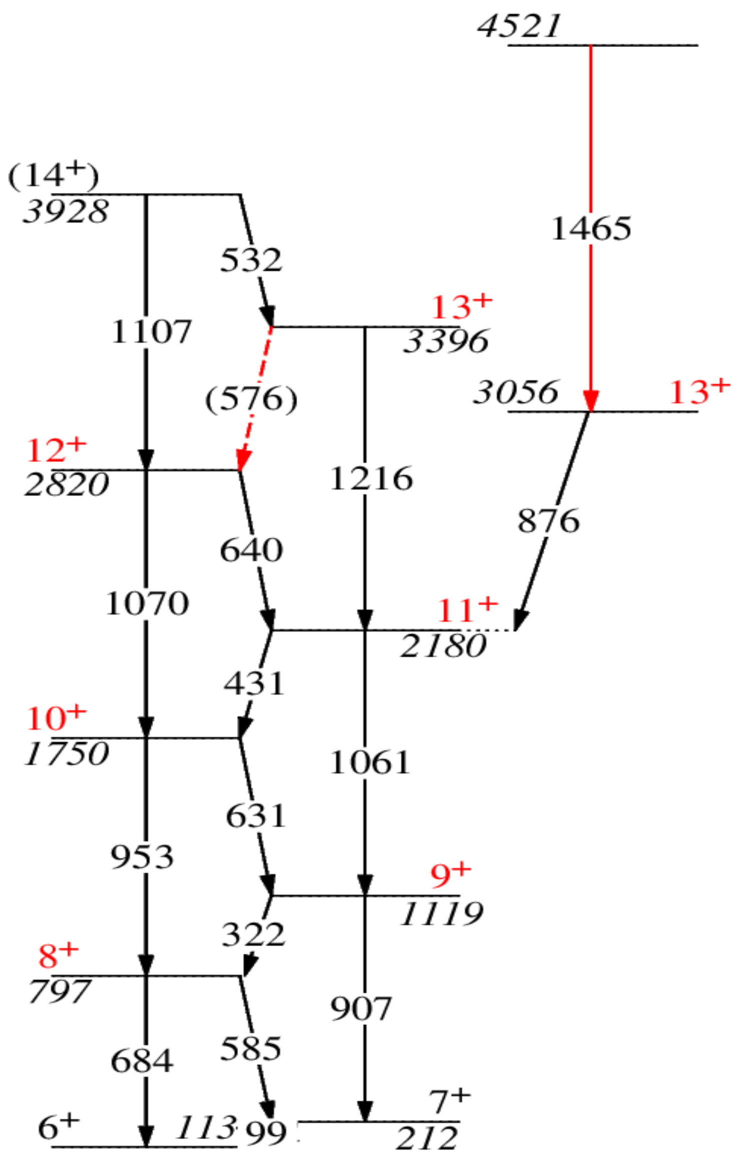

Figure 1: Partial level scheme of the ^{104}Ag nucleus, developed in the present work. Newly added experimental information's are shown in red color.

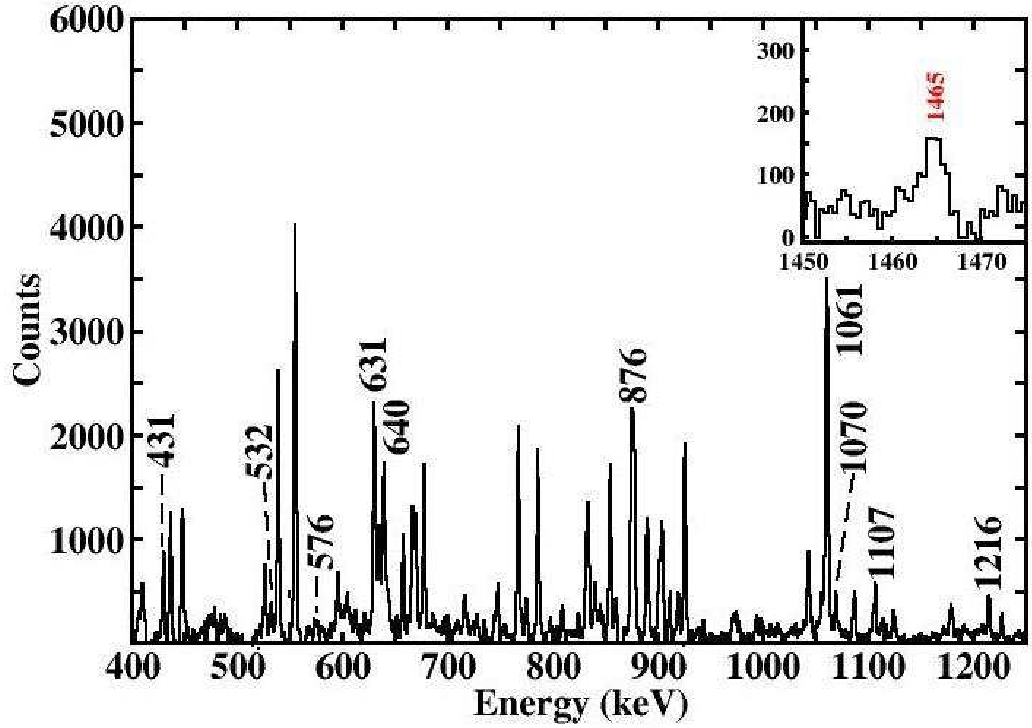

Figure 2: Spectrum of the γ-rays observed in coincidence with the 907 keV γ-ray.

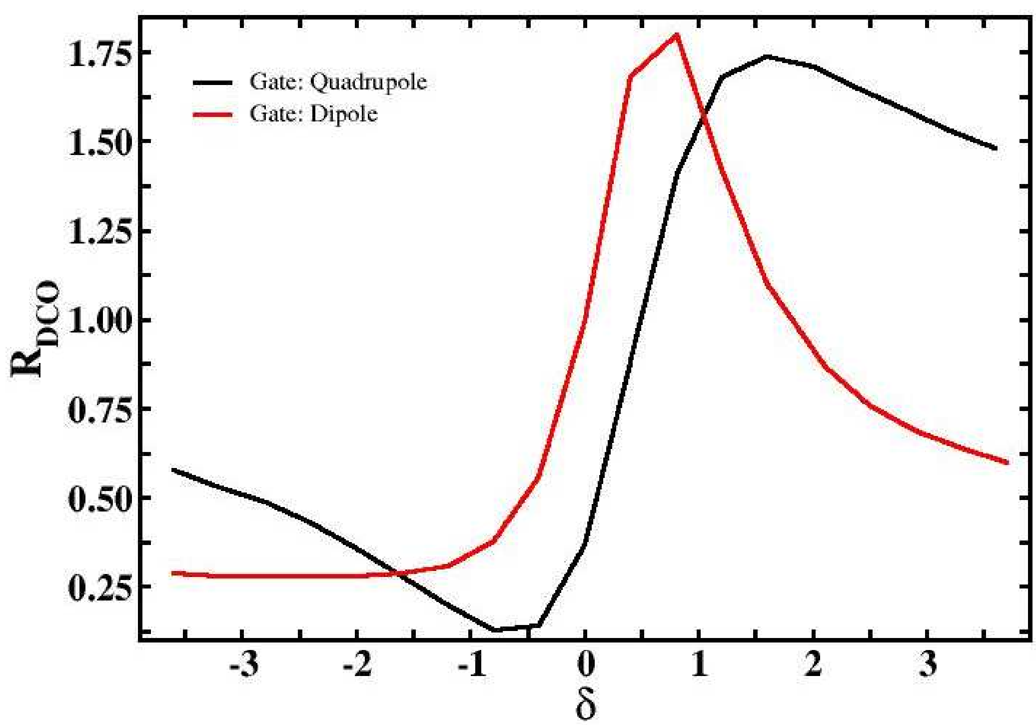

Figure 3: Estimated theoretical DCO ratio of dipole transition for different values of multipole mixing ratio calculated using the software code ANGCORE (26).

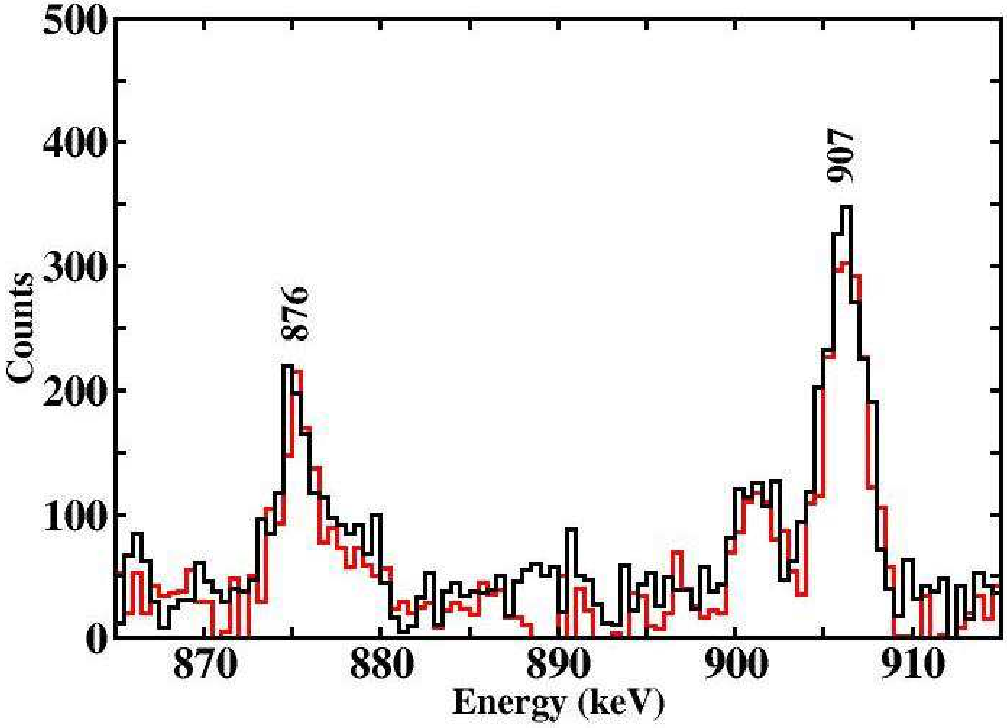

Figure 4: Spectra from DCO matrix with gate on 1061 keV (quadrupole)transition showing 876 and 907 keV transitions.

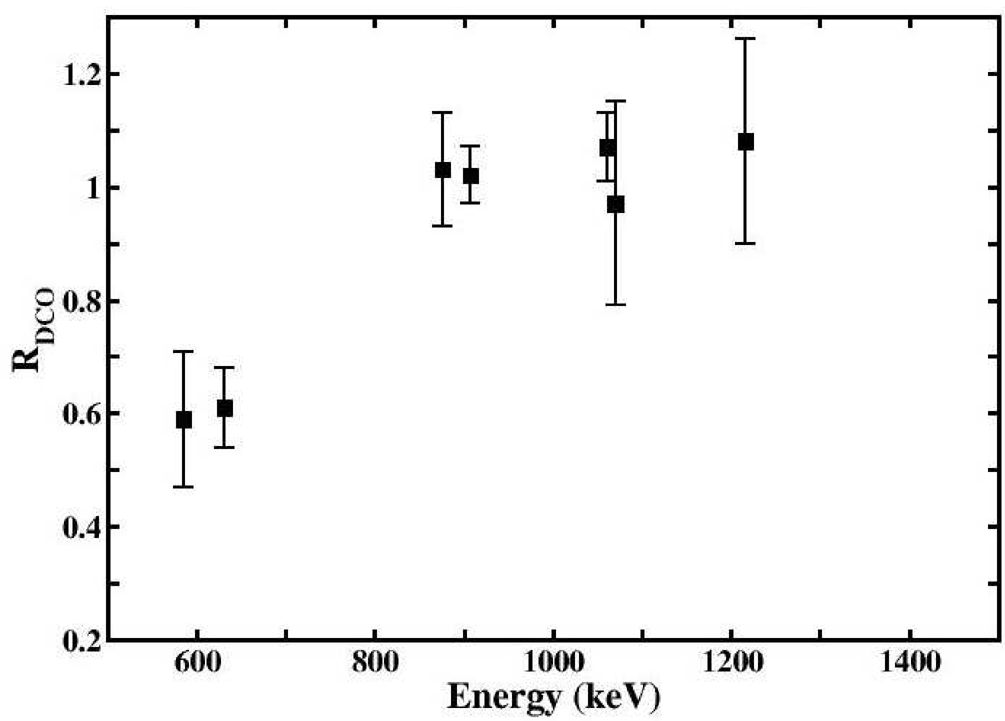

Figure 5: Measured DCO ratio of different γ-rays in ^{104}Ag nucleus.

Table I. Energies (E_γ and E_{level}), DCO ratios (R_{DCO}) and assigned spin-parity for the γ-rays/levels in ^{104}Ag.

E_γ (keV)	E_{level} (keV)	R_{DCO}	E_{gate} (keV)	$J_i^\pi \rightarrow J_f^\pi$
585	797	0.59(12)	1061 (E2)	$8^+ \rightarrow 7^+$
907	1119	1.02(5)	1061 (E2)	$9^+ \rightarrow 7^+$
631	1750	0.61(7)	907 (E2)	$10^+ \rightarrow 9^+$
1061	2180	1.07(6)	907(E2)	$11^+ \rightarrow 9^+$
1070	2820	0.97(18)	907(E2)	$12^+ \rightarrow 10^+$
876	3056	1.03(10)	1061 (E2)	$13^+ \rightarrow 11^+$
1216	3396	1.08(18)	1061 (E2)	$13^+ \rightarrow 11^+$

Summary

The present study is a part of the study of high spin states in ^{104}Ag nucleus. The present work reports the multipolarity determination of transitions in one of the positive parity band based on 212 keV, 7+ state. Placement and spin, parity of many transitions in this band are confirmed. A new transition de-exciting from 3396 keV level to 2820 keV is also added.

Acknowledgments

We would like to acknowledge BARC-TIFR pelletron staff for delivering stable beam of ^{32}S during the experiment. We acknowledge the help of all INGA collaboration. Authors gratefully acknowledge Department of Science and Technology (DST) for INGA project (No.IR/S2/PF-30/2003/I) and CSIR for financial support. We would also like to thanks R. Bhattacharjee, S. S. Bhattacharjee, S. Samanta, S. Das, N. Ghosh, A. K. Sinha, S. Mukhopadhyay, L. Dhanu, B. K. Nayak, D. C. Biswas, A. Y. Deo, S. K. Tandel, N. Kaur, Ashok Kumar, S. Saha, J. Sethi, S. Chattopadhyay for their help during the experiment. This work has been supported in part by the U. S. National Science Foundation (Grants No. PHY-1068192 and No. PHY-2011890).

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