EPJ Web of Conferences **66**, 02102 (2014)
DOI: 10.1051/epjconf/ 20146602102

Spectroscopy of the odd-odd chiral candidate nucleus ^{102}Rh

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Abstract. Excited states in ^{102}Rh were populated in the fusion-evaporation reaction ^{94}Zr(^{11}B, 3n)^{102}Rh at a beam energy of 36 MeV, using the INGA spectrometer at IUAC, New Delhi. The angular correlations and the electromagnetic character of some of the γ-ray transitions observed in ^{102}Rh were investigated in detail. A new candidate for a chiral twin band was identified in ^{102}Rh for the first time.

1 Introduction

Chirality is a novel feature of rotating nuclei which is among the most studied phenomena in nuclear physics during last ten years. A spontaneous breaking of the chiral symmetry can take place for configurations where the angular momenta of the valence protons, valence neutrons, and the core are mutually perpendicular [1]. The projections of the angular momentum vector on the axes of the intrinsic system can form a left- or a right-handed system. Since the chiral symmetry is dichotomic, its spontaneous breaking by the angular momentum vector leads to a pair of degenerate $\Delta I = 1$ rotational bands, called chiral twin bands. Pairs of bands, possibly due to the breaking of the chiral symmetry in triaxial nuclei, have been found in mass regions $A\sim130$ [2–4], $A\sim105$ [5–9] and $A\sim195$ [10]. However, in none of these cases the systematic properties [11] of the chiral bands, which originate from the underlying symmetry, were fully confirmed. In many cases, the energy degeneracy of the chiral candidate bands was almost observed but the transition probabilities are different, like in the case of ^{134}Pr [12, 13].

A new phenomenon, the existence of multiple chiral twin bands, i.e. more than one pair of chiral doublet bands in one single nucleus has been predicted for ^{106}Rh and neighboring nuclei. According to the work of Meng et al. [14], the nucleus of ^{102}Rh is one of the candidates to express multiple chirality. The goal of this work is to check for the existence of chirality in ^{102}Rh.

2 Experiment

The experiment was performed at the Inter University Accelerator Center in New Delhi. The beam was provided by the 15-UD Pelletron accelerator. The excited states in ^{102}Rh were populated using the reaction ^{94}Zr(^{11}B, 3n)^{102}Rh at a beam energy of 36 MeV. The target was made of 0.9 mg/cm^2 ^{94}Zr, enriched to 96.5%, evaporated onto a 8 mg/cm^2 gold backing. The recoils were leaving the target with a mean velocity, v of about 0.9% of the velocity of light, c. The Indian National Gamma Array (INGA) registered the de-exciting gamma-rays. It consists of 15 Clover detectors accommodated in a 4π geometry [15]. The detectors of INGA which are positioned at approximately the same polar angle with respect to the beam axis can be grouped in five rings. Doppler-broadened line shapes were observed for transitions depopulating higher spin levels. Efficiency calibration and gain matching of Germanium detectors were performed using ^{152}Eu and ^{133}Ba sources.

3 Data analysis and results

To investigate the level scheme and electromagnetic properties of the transitions of interest in ^{102}Rh, we have performed four different types of data analyses as follows. The level scheme was built by taking into account γ-γ coincidences, relative intensities, and energy sums. The electric or magnetic character and multipolarity of the transitions were derived according to the linear polarization and angular correlations measurements, respectively. The information on the effective level lifetimes, contained in the Doppler-broadened line shapes, was also used to construct the new Band 2 shown on Figure 1.

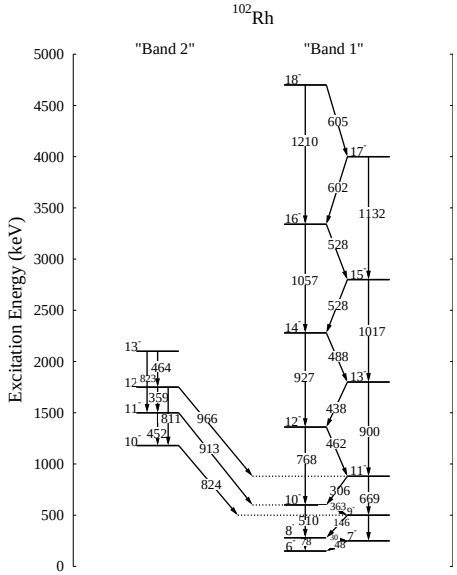

Figure 1. Partial level scheme of ^{102}Rh showing the two chiral candidate bands. Band 2 is established for the first time.

To determine spins of excited states, we performed for the first time an angular correlations analysis of data taken with the INGA spectrometer with the computer code CORLEONE [16]. In this way,

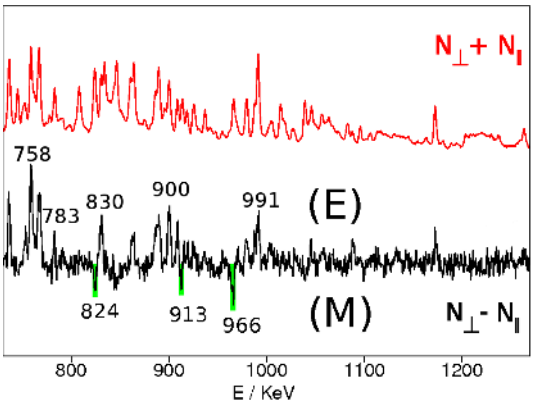

Figure 2. Sum (on the upper part) and difference (on the lower part) of the coincidence spectra registered by the perpendicular and parallel arms of the Compton polarimeter. It is clearly seen that ^{102}Rh transitions with energies of 824, 913 and 966 keV have predominantly magnetic character.

the spins of the levels and the multipolarity of the corresponding transitions were determined. The angular correlation function is given by the expression:

$$W(\theta_1, \theta_2, \phi) = \sum_{\lambda_1,\lambda,\lambda_2} B_{\lambda_1}(I_1) A_{\lambda}^{\lambda_1,\lambda_2}(\gamma_1) A_{\lambda_2}(\gamma_2) H_{\lambda_1,\lambda,\lambda_2}(\theta_1, \theta_2, \phi) \quad (1)$$

The term $B_{\lambda_1}(I_1)$ describes the orientation of the upper nuclear state, the term $A_{\lambda}^{\lambda_1,\lambda_2}(\gamma_1)$ the orientation of the intermediate state due to emission of γ_1, and $A_{\lambda_2}(\gamma_2)$ the emission of γ_2. $H_{\lambda_1,\lambda,\lambda_2}(\theta_1, \theta_2, \phi)$ presents the angular function. Detailed information about the angular correlation function can be found in [17]. Complementary details about the angular correlations analysis can be found in the work [18].

To study the electric or magnetic character of the transitions, we performed a linear polarization measurement. For this purpose, the clover detectors positioned close to 90° were used as a composite Compton polarimeter [18]. The efficiency with which the Compton scattering events were registered was determined with the ^{152}Eu and ^{133}Ba sources that emit γ-rays of natural polarization isotropically. The coincidence signals from the respective arms of the polarimeter, perpendicular and parallel to the reaction plane, were summed up to improve the statistics. The sum and difference of the coincidence spectra in the energy interval of 750 to 1300 keV is shown in Figure 2. The difference spectrum in Figure 2 reflects the linear polarization of the transitions observed. The negative peaks correspond to transitions of predominantly magnetic character while the positive peaks correspond to transitions of predominantly electric character. For example, the negative peaks that appear around 913 and 966 keV in Figure 2 are due to M1/E2 transitions in ^{102}Rh [19]. The positive sign of the lines 830, 900, 991 in the linear polarization spectrum, Figure 2, proves that the corresponding transitions are of predominantly electric (E2/M1) character. The present work confirms all the transitions reported from J. Gizon et al. in work [19] and in addition identify a new sister chiral candidate band, called Band 2.

The results obtained from angular correlations and linear polarization measurements were essential for the spin and parity assignments of the new Band 2 in ^{102}Rh.

The newly determined Band 2 in ^{102}Rh is presented in Figure 1. It decays by strong transitions of predominantly M1 character to the known states of Band 1. The lifetimes determined for the excited states of twin chiral candidate bands will be published in a forthcoming paper [20].

4 Conclusions

For the investigation to the level-scheme of ^{102}Rh we have performed an experiment at the IUAC in New Delhi using the INGA spectrometer. The level scheme of ^{102}Rh has been constructed from the γ-γ coincidence data and relative γ-rays intensities and energy sums. The powerful techniques of angular correlations and linear polarization measurements were applied for the INGA spectrometer data. For the first time four new excited states were identified in Band 2, candidate for a chiral partner of Band 1. The two bands are not degenerated in the energy range explored and conclusions about the type of chiral symmetry involved, if existing, could be done on the basis of the study of the transition probabilities in the two bands. The determination of lifetimes is in progress.

5 Acknowledgments

This research has been supported by Bulgarian Science Fund under contract DFNI-E 01/2 and by a NUPNET - NEDENSAA project funded by the Bulgarian Ministry of Education and Science. Thanks to the Pelletron Staff of IUAC, New Delhi for their perfect work for our experiment.

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