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In a search for a chiral symmetry in ^{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 phenomenon which is often found in nature. Examples of systems demonstrating chirality are present in chemistry, biology, high energy physics etc. 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 ΔI = 1 rotational bands, called chiral twin bands. Pairs of bands, presumably due to the breaking of the chiral symmetry in triaxial nuclei, have been recently found in the mass regions $A \sim 130$ [2, 3], $A \sim 105$ [4, 5, 6, 7], $A \sim 195$ [8] and $A \sim 80$ [9]. However, only in few cases (^{126}Cs [10], ^{128}Cs [11]), the systematic properties [12] of the chiral bands, which originate from the underlying symmetry, were confirmed including the transition from chiral vibrations to static chirality in ^{135}Nd [3]. Thus, the yrast and side bands should be nearly degenerate. 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 [13, 14]. The main goal of the present work was to check for the existence of chirality in the mass region A $\sim$ 100. According to the works [15] and [16], 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 the mass region A $\sim$ 100.

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2. Experiment

Excited states in ^{102}Rh were populated through the reaction ^{94}Zr(^{11}B,3n)^{102}Rh. The beam of ^{11}B with an energy of 36 MeV was provided by the 15-UD Pelletron accelerator at the Inter University Accelerator Centre (IUAC) in New Delhi, India. The target consisted 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 de-exciting gamma rays were registered with the Indian National Gamma Array (INGA), whose 15 Clover detectors were accommodated in 4π geometry [17]. Gain matching and efficiency calibration of the Ge detectors were performed using ^{152}Eu and ^{133}Ba radioactive sources before sorting the data in matrices and cubes.

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 ordering of transitions in the level scheme was determined according to the γ-ray relative intensities, γ-γ coincidence relationships, and γ-ray energy sums. The character and multipolarity of the transitions was deduced from the investigation of linear polarization and angular correlations measurements, respectively. 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. We have determined the spins, the levels and the multipolarity of the corresponding transitions using angular correlation analysis of data taken with the INGA spectrometer with the computer code CORLEONE [19]. In figure 1 the negative lines correspond to transitions of predominantly magnetic character while the positive lines correspond to transitions of predominantly electric character. The negative character of the lines 304, 306 and 363 in the spectrum, proves that the corresponding transitions are of predominantly magnetic character.

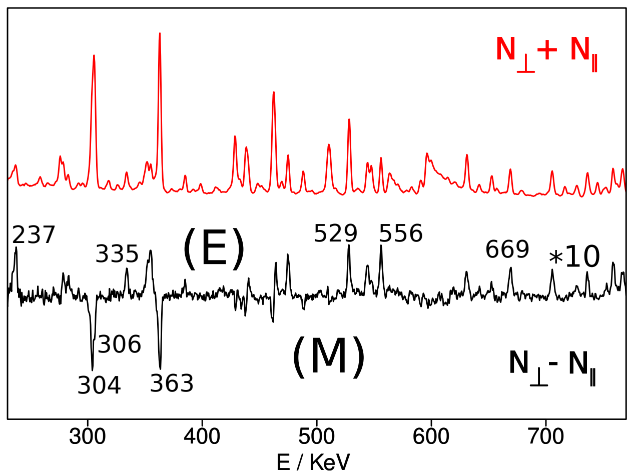

Figure 1. Coincidence spectra registered by the perpendicular and parallel arms of the compton polarimeter. Transitions with energies of 304, 306 and 363 keV have predominantly magnetic character.

The lifetimes were derived using the Doppler-shift attenuation methods. The analysis was carried out according to the procedure outlined in [20], where details about the Monte-Carlo simulation of the slowing down process, determination of stopping powers and fitting of line shapes can be found.

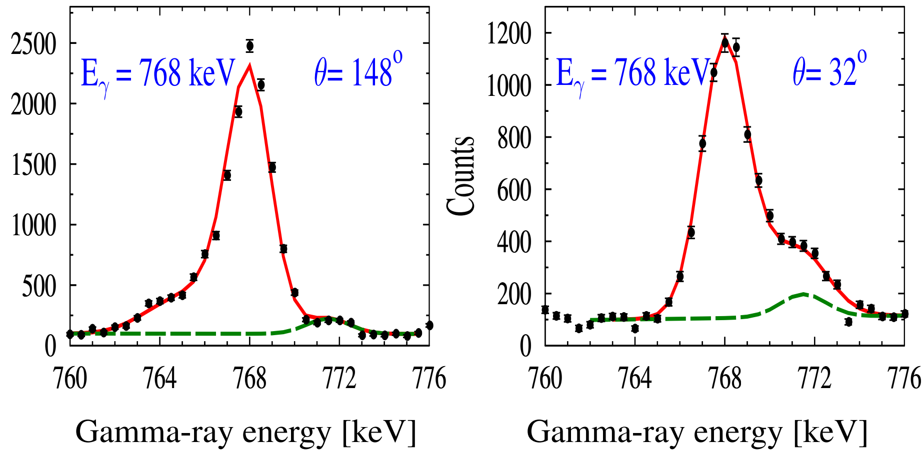

Figure 2. Fitted line-shape of transitions observed at 32° and 148°.

The spectra for every gated ring were summed up to increase the statistics. For each level, lifetimes were derived independently at the four rings where appreciable Doppler-shifts are observed. In figure 2 is shown an examples for such analysis and the Doppler-shifts are nicely seen. The gate is set from below of the transition of interest.

To describe the reduced transition probabilities $B(\sigma\lambda)$ and the level scheme in ^{102}Rh we performed two quasiparticles plus triaxial rotor (TQPTR) calculations within the approach given in [21]. Figure 3 illustrates the experimental level scheme of ^{102}Rh compared to TQPTR calculations.

The reduced transition probabilities $B(\sigma\lambda)$ deduced from the lifetime data are presented in Ref.[22]. The comparison between the experimental and calculated B(M1) transition strengths leads to the conclusion that the TQPTR calculations reproduce roughly the data in Band 1 and are consistent with the transition strength in Band 2 at spin 11 $\hbar$. The absence of an appreciable staggering of the data in Band 1 indicates that the expectations for the observation of a static chirality in ^{102}Rh are not realized [22]. If the chirality in ^{102}Rh exists it has mainly a dynamical character.

4. Summary and 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. To construct the level scheme of ^{102}Rh we used γ-γ coincidence data, relative γ-rays intensities and energy sums. For the first time we applied angular correlation analysis and polarization measurements for INGA spectrometer data. The results obtained from angular correlation and linear polarization measurements were essential for the spin and parity assignments. As a result from our analysis 4 new exited states in ^{102}Rh were determined for the first time. In addition 8 new lifetimes have been determined.

5. Acknowledgments

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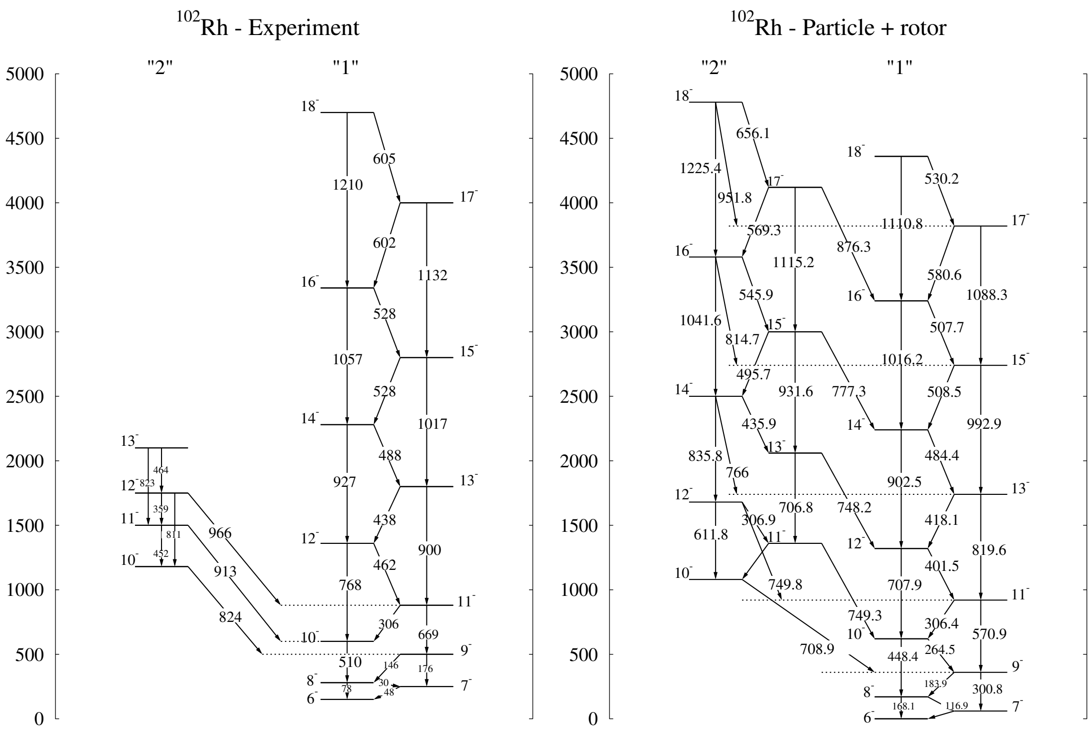

Figure 3. Comparison of the experimental and calculated within the TQPTR level schemes of ^{102}Rh.

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