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Does chirality exist in nuclei? The case of ^{102}Rh

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Excited states in ^{102}Rh, populated in the fusion-evaporation reaction ^{94}Zr(^{11}B, 3n)^{102}Rh at a beam energy of 36 MeV, were studied using the INGA spectrometer at IUAC, New Delhi.A new chiral candidate sister band was found. Lifetimes of exited states in ^{102}Rh were measured for the first time by means of the Doppler-shift attenuation technique. A new band was found in the level-scheme of ^{102}Rh.

Key words: chirality, DSAM, INGA, transition strenghts, lifetimes

INTRODUCTION

Chirality is a phenomenon which is often found in nature. Examples for the existence of chirality are present in chemistry, biology, high energy physics etc. An interesting question arose last decade in nuclear physics, does chirality exists in this field? 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 three principal axes can form either a left- or a right- handed system and therefore the system expresses chirality. Since the chiral symmetry is dichotomic, its spontaneous breaking by the axial angular momentum vector leads to a pair of degenerate $\Delta I = 1$ rotational bands, called chiral doublet 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], $A \sim 105$ [4–9], $A \sim 195$ [10] and $A \sim 80$ [11]. In many cases the energy degeneracy of the chiral candidate bands was almost observed but the transition probabilities are different. This is clearly seen in the case of ^{134}Pr [12–14]. According to the work [15] and [16], the nucleus of ^{102}Rh is candidate to express multiple chirality.The main goal of the present work was to check for the existence of chirality in the mass region A $\sim$ 100. In previous works [4–6], an island of chiral candidates has been proposed around ^{104}Rh. Next to the identification of the twin bands, some lifetimes have been reported for the yrast band of ^{104}Rh [6].

EXPERIMENT

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 beam was delivered by the 15-UD Pelletron accelerator at the Inter University Accelerator Center (IUAC) in New Delhi. 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 by the Indian National Gamma Array (INGA), whose 15 Clover detectors are accommodated in a 4π geometry [17]. For the purposes of the Doppler-Shift Attenuation Method (DSAM) analysis the detectors of INGA which lie at approximately the same polar angle with respect to the beam axis were grouped in five rings. Doppler-broadened line shapes were observed for transitions depopulating higher spin levels. The rings where appreciable

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Doppler-shifts are observed are these at angles of 32, 57, 123 and 148 degrees. 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.

DATA ANALYSIS AND RESULTS

The detectors of INGA were grouped into rings positioned with respect to the beam axis. This is needed for DSAM analysis. The rings with appreciable Doppler-shifts are these at angles of 32, 57, 123 and 148 degrees. For the investigation of the level scheme and electromagnetic properties of the transitions in ^{102}Rh we have performed four different types of data analyses. The ordering of the transitions in the level scheme was determined according to γ-ray relative intensities, γ-γ coincidence relationships, and γ-ray energy sums. The multipolarity and the character of the transitions were deduced from the investigation of linear polarization and angular correlations measurements. For this purpose the clover detectors from the ring at 90 degrees were used as a Compton polarimeter [18]. The lifetimes of excited states in ^{102}Rh were derived using the Doppler-shift attenuation methods. The analysis was carried out within the framework of the Differential decay method (DDCM) [19] 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.

In Fig. 1. is shown an example for the line shape analysis of the 669 keV transition and determination of the lifetime of the $I^{\pi} = 11^{-}$ level according to DDCM. Thus, we have succeeded to extend the known level scheme [21] by a new $\Delta I = 1$ band with a negative parity and to determine 8 new lifetimes. The reduced transition probabilities B($\sigma\lambda$) deduced from lifetime data are presented in [22]. The present results come to supercede the preliminary level-scheme published in [23]. To study the bands based on the $\pi g_{9/2} \otimes \nu h_{11/2}$ configuration, we have performed two

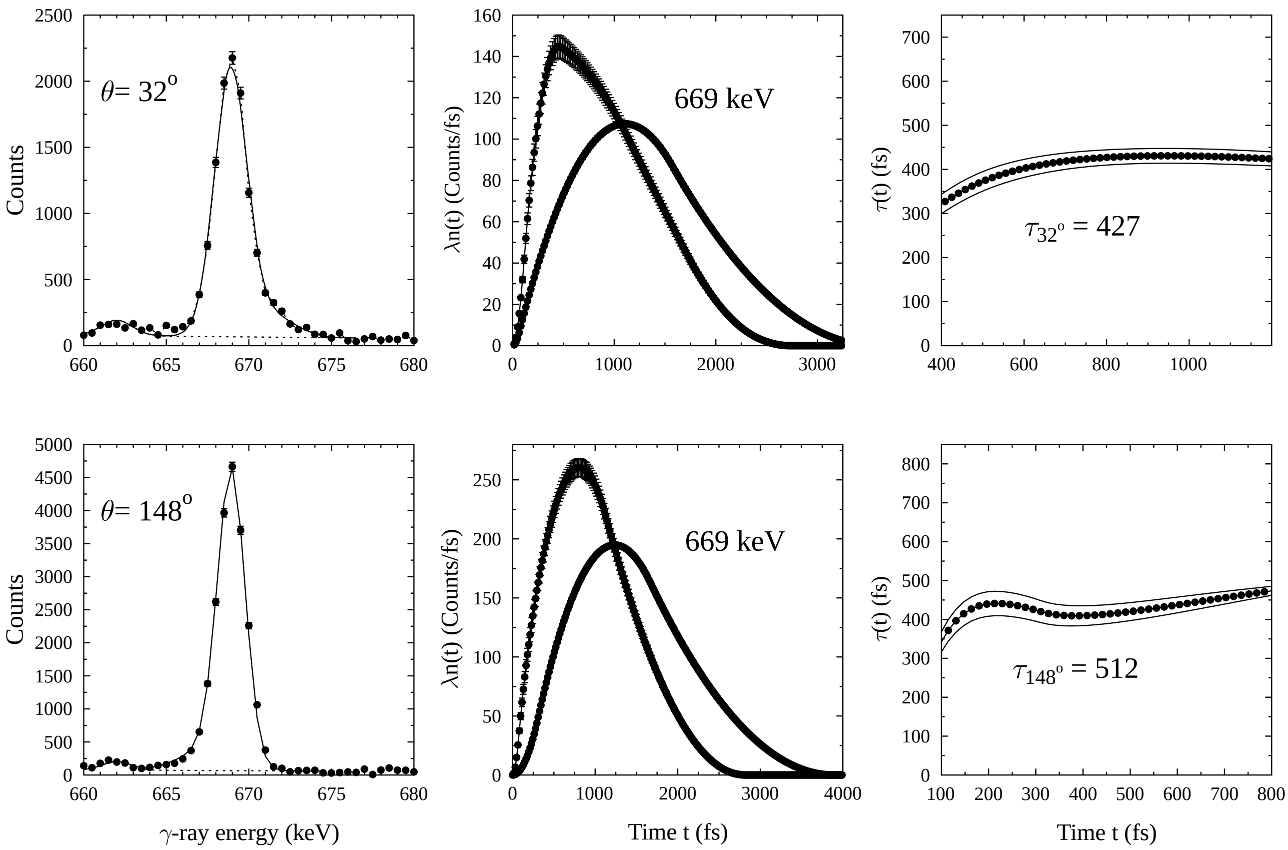

Fig. 1. Line shape analysis of the 669 keV transition in the first chiral-candidate band and determination of the lifetime of the I$^{\pi}$=11^{-} level according to DDCM.

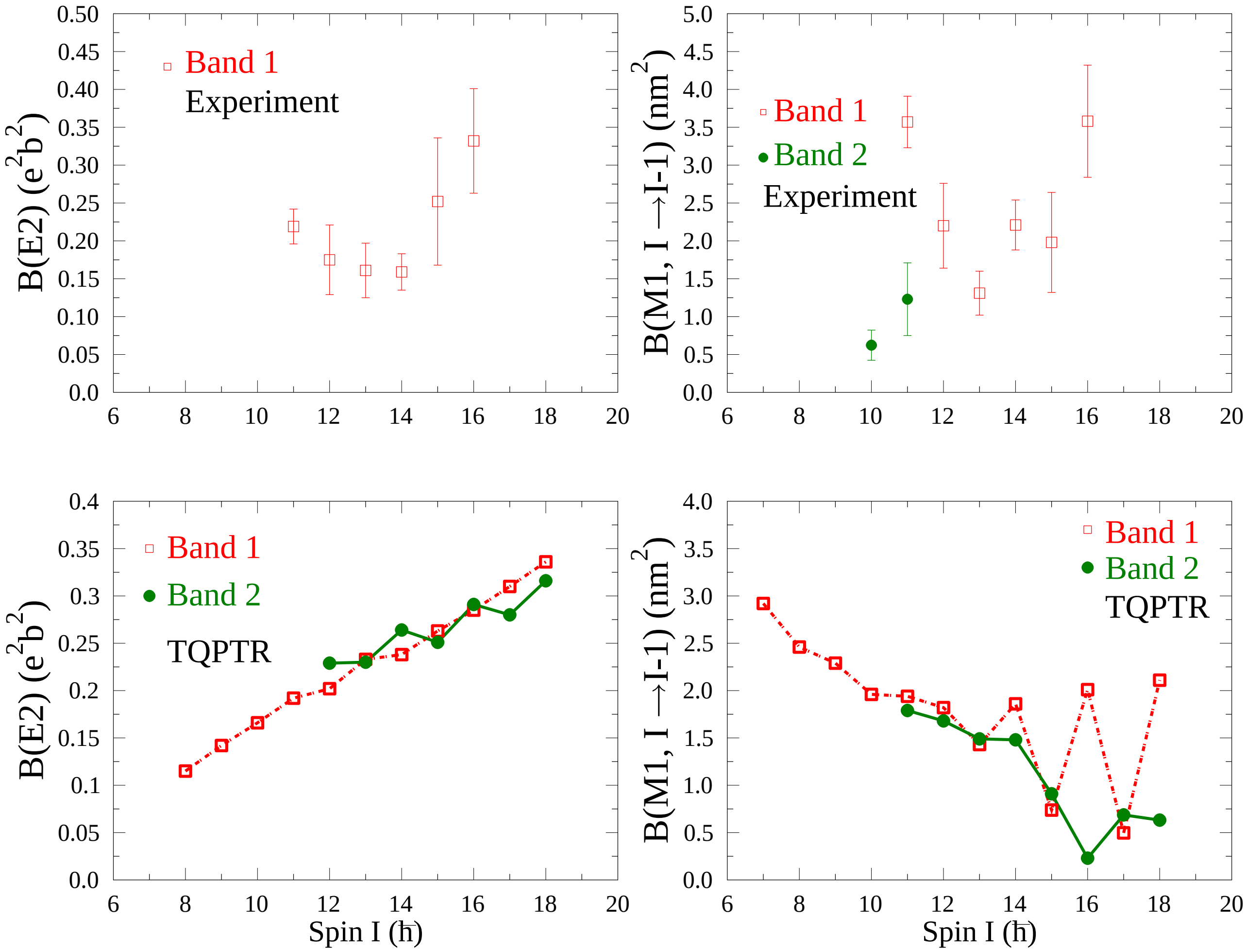

Fig. 2. Experimentally derived and theoretically calculated B(E2) and B(M1) transition strengths in ^{102}Rh. The experimental B(E2) and B(M1) values are presented in the upper panels. The results of TQPTR calculations are displayed in the second row.

quasiparticles + triaxial rotor (TQPTR) calculations in the framework of the model presented in Ref. [24]. The comparison between the experimental and calculated B(M1) transition strenghts leads to the conclusion that this model reproduce roughly the data in Band 1 and is consistent with the transition strenght in Band 2 (see Fig.2.). The TQPTR calculations reveal that the optimum value of the triaxiality parameter γ=20° differs from the value of 30° characterizing chirality.

CONCLUSIONS

In order to investigate the level-scheme and to determine lifetimes of the excited states in the chiral candidate nucleus of ^{102}Rh we have performed an experiment at the Inter University Accelerator Center in New Delhi using the INGA spectrometer. We have succeeded to extend the level-scheme with a new $\Delta I = 1$ band with a negative parity. Our lifetime measurements and the theoretical analysis do not support chirality in ^{102}Rh.

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СЪЩЕСТВУВА ЛИ ХИРАЛНА СИМЕТРИЯ В ЯДРОТО ^{102}Rh?

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(Резюме)

Хиралността е често срещан феномен в природата. Примери за хиралност се срещат в химията, биологията и други. В ядрената физика въпросът за хиралността започва да се разглежда през последните 20 години. Тя е нещо ново за ротационните ядра и е един от най-изучаваните феномени в ядрената физика през последните години. Спонтанното нарушение на хиралната симетрия може да видим там, където ъгловите моменти на валентните протони и неутрони и ядката са перпендикулярни. Проекциите на вектора на ъгловия момент по осите на вътрешната система могат да оформят лява или дясна координатна система. От раздвоеността на хиралната система следва, че спонтанното и нарушаване от вектора на ъгловия момент води до двойка дегенерирани $\Delta I = 1$ ротационни ивици, наречени хирални ивици близнаци. Двойки ивици, вероятно дължащи се на нарушаването на хиралната симетрия в триосево ядро, са намерени в масовите области $A \sim 130$ [1,2], $A \sim 105$ [3-6], $A \sim 195$ [7] и $A \sim 80$ [8]. Въпреки това само в няколко случая (^{126}Cs, ^{128}Cs), свойствата на системата от хирални ивици, които произхождат от основната симетрия, са потвърдени включително преходите от хирални вибрации до статична хиралност в ^{135}Nd. В много от случаите, енергийната изроденост на ивиците, кандидати за хиралност, е била почти изучена, но вероятностите за преход са различни, като в случая на ^{134}Pr [12,13]. Съгласно работите на J. Meng [14,15] ядрото ^{102}Rh е един от кандидатите да покажат хирална структура. По тази причина и поради факта, че в масовата област $A \sim 100$ почти не са правени изследвания за съществуването на хирална симетрия поради, което решихме да го изследваме.

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