Lifetime Measurements in $^{102}$Rh: a Test for Existence of Chirality in Mass Region A $\sim$ 100


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INTRODUCTION AND MOTIVATION

The present contribution to the LNL Annual report is a part of a common program performed by the Laboratori Nazionali di Legnaro, the Institute for Nuclear Research and Nuclear Energy, Sofia and the Inter-university Accelerator Centre (IUAC), New Delhi, which aims to investigate the chiral symmetry in nuclei. Our successful experiments in the mass region A $\sim$ 130 have shown that the chiral symmetry has a dynamic character and the weak dynamic chirality is present most probably due to shape fluctuations [1, 2]. As a next step of our program we have performed an experiment at the IUAC, New Delhi in order to check for existence of the chiral symmetry in mass region A $\sim$ 100 and more precisely in the chiral candidate $^{102}$Rh.

A spontaneous breaking of chiral symmetry can take place for configurations where the angular momenta of the valence protons, valence neutrons and the core are mutually perpendicular [3]. This can occur, for example, when the proton and neutron Fermi levels are located in the lower part of valence proton high-$j$ (particle-like) and in the upper part of valence neutron high-$j$ (hole-like) sub-shells, and the core is essentially triaxial. Under such conditions the angular momenta of the valence particles are aligned along the short and long axes of the triaxial core, while the angular momentum of the rotational core is aligned along the intermediate axis [4]. The non zero components of the total angular momentum on all the three axes can form either a left-handed or a right-handed set and therefore, according to Kelvin’s definition, the system manifests chirality [5]. Since chirality is a dichotomic symmetry, its spontaneous breaking leads to doublets of closely lying rotational bands of the same parity.

Pairs of bands possibly due to the breaking of the chiral symmetry have been found in the mass A $\sim$ 130 region where the proton Fermi surface is positioned in the lower part and the neutron surface in the higher part of the $h_{11/2}$ sub-shell. The studies [1, 2] suggest that the existence of the two crossing $\Delta I = 1$ bands with the same parity in $^{134}$Pr should be attributed to a weak fluctuation dominated chirality combined with an intrinsic symmetry yet to be revealed. In order to confirm or reject the hypothesis of nuclear chirality, next to establish the existence of almost degenerate rotational bands, it is necessary to measure also other observables and compare them to the model predictions. Critical experimental observables for the understanding of nuclear structure and for checking the reliability of theoretical models are the electromagnetic transition probabilities.

The goal of our experiment performed in June 2009 was to test the existence of dynamic chirality in the mass A$\sim$100 region.

It has been shown that nuclei around $^{104}$Rh form an island of nuclei candidates to express chirality [6–8]. Next to almost degenerate chiral candidate bands it is shown that they have B(M1)/B(E2) ratios which are characterized by a staggering with increasing spin.

Recent theoretical studies of the chiral phenomenon within the framework of the adiabatic and configuration-fixed constrained triaxial Relativistic Mean Field (RMF) approaches have been performed in order to investigate the triaxial shape coexistence and possible chiral doublet bands [9]. A new phenomenon, the existence of multiple chiral doublets, i. e. more than one pair of chiral doublets bands in one single nucleus is predicted for $^{106}$Rh and in neighboring nuclei. The nucleus $^{102}$Rh according to the work of Meng et al. [9] is one of the candidates to present such a phenomenon.

EXPERIMENT AND DATA ANALYSIS

Excited states in $^{102}$Rh were populated using the 3n exit channel, of the reaction $^{11}$B + $^{90}$Zr. The beam of $^{11}$B, with an energy of 36 MeV, was delivered by the 15-UD Pelletron accelerator of the Inter University Accelerator Centre (IUAC), Delhi. The target consisted of 0.9 mg/cm$^2$ $^{94}$Zr onto 8 mg/cm$^2$ $^{197}$Au backing. The de-exciting gamma rays were registered with the Indian National Gamma Array (INGA), which 15 Clover detectors were accommodated in 4 $\pi$ geometry [10]. Gain matching and efficiency calibration of the Ge detectors were performed using $^{152}$Eu and $^{133}$Ba radioactive sources. In four days experiment we succeeded to collect data with an excellent statistics in order to investigate the level-scheme of $^{102}$Rh as well as to perform polarization measurements and to measure lifetimes in the sub-picosecond region. The quality of the data is illustrated in Fig. 1. The Doppler-shifts corresponding to the forward and backward rings are nicely seen.
In order to determine a lifetime in a Doppler-Shift Attenuation Method measurement we need to know exactly the velocity histories of recoiling nuclei when they are slowing down in the target and stopper, until the moment they stop. For the Monte Carlo simulation of the slowing-down histories of the recoils we use a procedure described in [11]. According to the calculations performed, the mean velocity of the recoils was about 0.9 % of the velocity of light.

The first result from the investigation of the level-scheme of $^{102}$Ru is the identification of a $\Delta I = 1$ candidate twin chiral band. As it is expected this band has a negative parity. Both, transitions in the band as well as linking transitions to the first chiral candidate band are clearly seen.

Presently the data are under analysis.

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