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Low-lying bands with different quadrupole deformation in ^{155}Dy

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Abstract. To investigate the interplay between collective and single particle degrees of freedom in odd nuclei, Recoil distance Doppler-shift and Doppler-shift attenuation lifetime measurements were carried out for levels in ^{155}Dy in coincidence detection of gamma-rays. 26 lifetimes were determined using the Differential decay curve method. Particle plus triaxial rotor model (PTRM) calculations were performed to compare the experimental level scheme and transition strengths with theoretical ones in order to get information on the quadrupole deformation (ϵ,γ) of the bands. As a result, different quadrupole deformations for the one-quasineutron bands at low and medium spins are deduced.

1 Introduction

The nucleus ^{155}Dy is positioned in the mass region A∼150 [1], which is characterized by a rapid shape transition. The main goal of the present work was to measure electromagnetic transition strengths, at low, intermediate and high spins in the different bands observed. Information on the collectivity in ^{155}Dy was available before the present study only at high spins [2]. To achieve our goal, we performed lifetime measurements using the Recoil distance Doppler-shift (RDDS) and Doppler-shift attenuation method (DSAM). The second aim of the study was to perform PTRM calculations of the level scheme and transition strengths. On the basis of the comparison between experiment and theory, conclusions are made about the nuclear structure and the collectivity of ^{155}Dy.

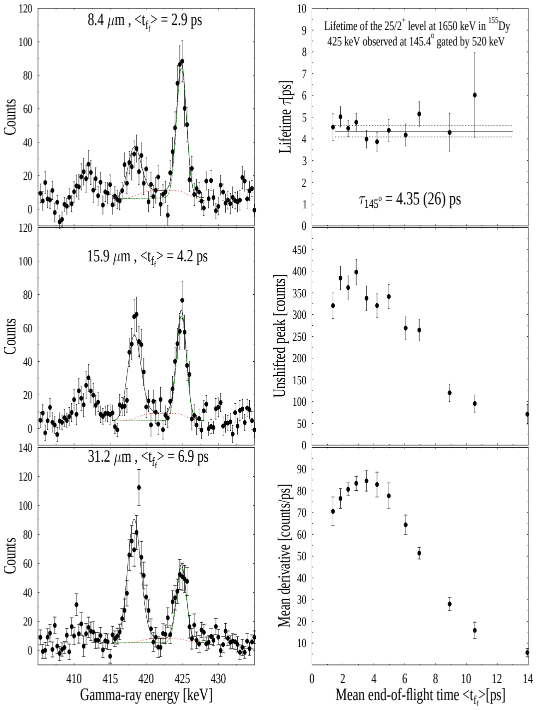

Figure 1. Example of a lifetime determination of the $25/2^+$ level in Band 4 using gated spectra measured with the detectors positioned at 145,4°.The detector rings and the distances are indicated.

2 Experiments

Two experiments were carried out to measure electromagnetic transition strengths and lifetimes at the Laboratori Nazionali di Legnaro with the multidetector array GASP using the reaction ^{124}Sn(^{36}S, 5n). The beam was provided by the XTU Tandem. For the RDDS experiment, the exited states in ^{155}Dy were populated at a beam energy of 155 MeV. The target and stopper foil were mounted in the Cologne coincidence plunger, described in details in [3]. By moving the target, the target-to-stopper distance was modified. The target was made of 0,9 mg/cm^2 Tin, enriched to 97,7 % in ^{124}Sn and evaporated onto a 1,8 mg/cm2 Ta foil serving as a backing. To stop the recoils, which were leaving the target with a mean velocity v of 1,87(2)% of the velocity of light, c, a 12,0 mg/cm^2 Au foil was used. For the analysis of the RDDS spectra, gates from above were set on the shifted component of a transition feeding directly the level of interest. In the DSAM experiment, the excited states of interest in ^{155}Dy were populated using a beam energy of 145 MeV. The target consisted of a 0,9 mg/cm^2 Sn foil enriched to 95,3 % in ^{125}Sn. It was evaporated onto a 13,4 mg/cm^2 Ta foil serving as a backing to stop the recoils which were leaving the target with a mean velocity of about 1,86% of the velocity of light, c. To obtain the line shapes to be analyzed, gates were set from below, on fully stopped peaks depopulating levels in the band of interest. Energy, FWHM and efficiency calibrations were made with a ^{125}Eu source and after shift-corrections and gain matching the data were sorted in γ-γ coincidence matrices.

3 Analysis of the data

To analyse the RDDS data, we used a procedure which is an extension of the Differential decay-curve method (DDCM), by taking into account the velocity distribution of the recoils and the finite slowing-down time in the stopper. At every distance x or mean end-of-flight time , the lifetime τ of the level of interest is derived using the following expression [4] :

$$\tau(x) = \frac{(\{B_{SF}, A_U\} + \{B_{SS}, A_U\})}{< d(\{B_{SF}, A_{SF}\} + \{B_{SF}, A_{SS}\} + \{B_{SS}, A_{SS}\})/dt_{f_f} >}$$

where the quantities in braces are the areas of the corresponding contributions to the full gated spectrum. The transition *B* depopulates the feeding level *b* and the transition *A* depopulates the level of interest *a*. The indices *SF*, *SS* and *U* denote emissions during the flight in vacuum, during the slowing down in the stopper and at rest, respectively. For the particular combination of "gating" and "gated" detector rings considered, the lifetime is derived by fitting a horizontal line through the points of this $\tau(x)$-curve within the region of sensitivity where the numerator and denominator in Eq.1 are reliable. The final value is determined by averaging the results obtained using all analyzed two-ring combinations. We note that the additional corrections of the data for relativistic, efficiency and solid angle effects can be neglected in the present analysis. The deorientation effect was shown [5] to not affect the results of the analysis of coincidence RDDS measurements when it is performed in the framework of the DDCM.

The DSAM data were analyzed according to the DDCM procedure outlined in [6, 7]. In particular, this procedure allows for an investigation of the unknown feeding of the level of interest in cases where the line shapes of the depopulating transitions are obtained with gates from below. The Monte-Carlo simulation of the slowing-down process was made by using a modified version of the Winter's code DESASTOP [8–10]. This version follows in three dimensions the evolution of the velocity of the recoils in the stopping media and can use numerical stopping powers.

4 Results

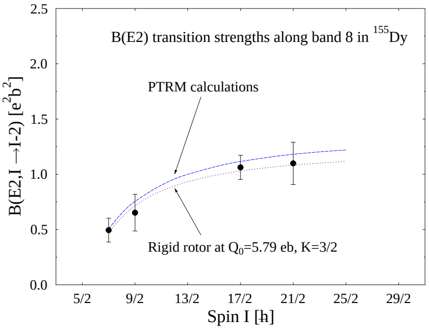

Figure 2. Reduced B(E2) transition strengths in Band 8. Together with the results from the RDDS measurements are presented PTRM and rigid-rotor model calculations. The parameters of the rigid-rotor model are indicated too.

The results from our analysis of the RDDS data are 18 lifetimes determined in 6 different bands, all of them for the first time. An example of lifetime analysis in Band 4 is shown in Fig.1. From the DSAM data, 10 lifetimes have been determined in Band 6 and Band 7 (see band nomenclature in [10]). The PTRM calculations have been performed within the approach and with the codes described in [11, 12]. More details on the results from our work can be found in [13]. The comparison between the experimental and calculated level schemes points to a satisfactory agreement which was obtained for quadrupole deformation ϵ=0.24 and γ=0°. These parameters provide an overall description of the data. However, the experimentally determined B(E2) electromagnetic transition strengths in some of the bands are somewhat larger than the theoretically calculated within the PTRM and smaller in the rest of the bands. This can be seen for example in Fig.2, where the experimental stretched B(E2) values in Band 8 are compared to theory. The calculation within the rigid-rotor model describes better the data than the PTRM calculations. In general, a phenomenological analysis with the rigid rotor model confirms also that the different bands are characterized by a different quadrupole deformation in ^{155}Dy. This fact points to the coexistence of structures with different shapes in this transitional nucleus.

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