Lifetime measurement of $(7/2)^+$state in ^{169}Tm with $CeBr_3$ detectors

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Introduction

The study of nuclear structure of odd-A Tm(Z=69) isotopes around A∼170 helps to explore interesting nuclear structural phenomenon around N=98. The ground states of these nuclei are well deformed which leads to the deformed band structures based on the positive and negative parity orbitals. The detailed high spin structure of ^{169}Tm has been already reported in [1]. The low lying states of the ^{169}Tm can be studied from the decay of ^{169}Yb ($T_{1/2}$= 32 days) source, which mainly contains the low energy gamma lines spanning from 40 keV-300 keV, therefore ^{169}Yb source can be used as a calibration standard for lower energy range and it can be produced with reasonable yield without any contaminant activities [2].

The exact measurement of lifetime provides information on the theoretical transition probabilities of the band structures. In the present work, the lifetime of $J^\pi = (7/2)^+$ state at the excitation energy of 139 keV of ^{169}Tm has been measured. This level belongs to the K=1/2 ground-state rotational band for which detailed experimental information is available [3]. The reported lifetime values for this level from earlier measurements vary from 289(24) ps [4] to 321(14) ps [5].The measurement of lifetime in γ-γ electronic coincidence methods directly measures the lifetime of the state. But this method involves the time resolution of the detector systems and reasonable energy resolution to select the decaying and feeding γ rays. With the availability of new generation fast-timing scintillator detectors, like, $LaBr_3$(Ce)or $CeBr_3$, which has very good time resolution and at the same time, good energy resolution(3-4% at 662 keV), the lifetime of the nuclear excited levels in the sub-nanosecond ranges can be measured precisely. The typical time resolution obtained with two 1.5″×1.5″ $CeBr_3$ detectors is 199(2) ps for ^{60}Co source [6]. In the present work, the lifetime of 139 keV level in ^{169}Tm has been measured using slope method with two 1.5″×1.5″$CeBr_3$ scintillator detectors coupled to a new PMT Hamamatsu R13089-100 and the lower energy γ ray spectrum has been studied using a LEPS detector.

Experiment

The lower spin states of ^{169}Tm has been populated via electron capture decay of ^{169}Yb which has been produced in the reaction ^{169}Tm(p,n)^{169}Yb, with 11 MeV beam energy in an average beam current of 1 μA, obtained from K-130 cyclotron at Variable Energy Cyclotron Centre, Kolkata. The produced activity was counted off-beam with two 1.5″×1.5″ $CeBr_3$ scintillator detectors coupled to the PMT Hamamatsu R13089-100 and a LEPS detector. The basic characteristics of this detector and PMT assembly and the time-walk characteristics of this PMT has already been reported [6, 7].

The data was acquired with the trigger condition [($CeBr_3$.AND.$CeBr_3$)].OR.LEPS]. A VME based data acquisition system has been used to acquire the list mode data of all the seven parameters (energy of the 4 individual

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segments of the LEPS and coincidence time and energy of the two $CeBr_3$ detectors) in event-by-event format. The list-mode data was acquired and analysed using LAMPS software package.

Results and discussions

The γ ray spectra of ^{169}Tm as observed by one segment of LEPS detector and one $CeBr_3$ detector has been shown in the upper and lower panels of fig 1 respectively. The observed γ rays are marked for both the spectra. It clearly shows that the energy resolution of the $CeBr_3$ detector is slightly poor compared to that of the LEPS detector. The

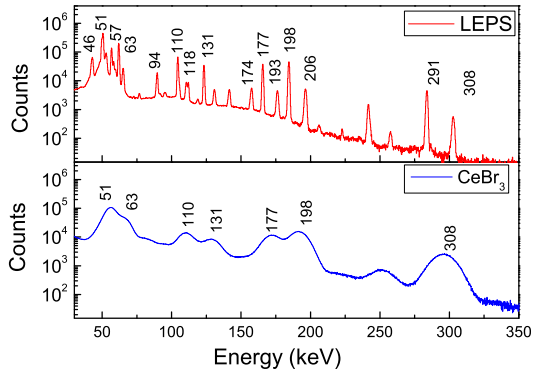

FIG. 1: γ-ray spectrum as observed by one segment of LEPS detector (shown in upper panel) and one $CeBr_3$ (shown in lower panel)

$J^{\pi} = (7/2)^+$ state at the excitation energy of 139 keV in ^{169}Tm is populated by 177 keV and de-populated by 131 keV. As the energy resolution of $CeBr_3$ detector is reasonable, so these two energies can be selected separately from the total energy spectrum(lower panel of fig. 1) to project the total TAC. The time-distribution corresponding to this energy cascade of 177-131 keV has been shown in the fig. 2. It can also be seen from fig. 2, that, a distinct slope is observed in the time spectrum corresponding to the cascade of 177-131 keV. Therefore, slope method has been used for the determination of lifetime of this state. The half-life $T_{1/2}$ of the state has been obtained by fitting the slope with straight line after necessary background correction. Fig. 2 shows

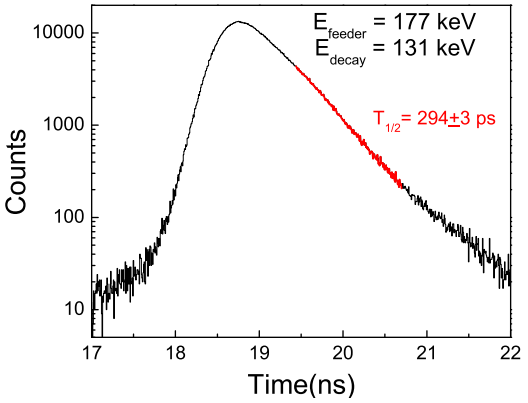

FIG. 2: Time distribution of the 177-131 keV γ ray cascade. The slope of the time distribution is fitted (shown in red colour) and the extracted meanlife is indicated.

the time-distribution along with the straight line fitting of the slope. The half-life of this 139 keV level obtained from our present measurement is $T_{1/2}$ = 294(3) ps. The uncertainty in the measured value of the half-life $T_{1/2}$ is much smaller than the previously reported values. This is due to the better time resolution of the detectors and reasonable energy resolution which is very important for the energy selection of feeding and decaying γ rays.

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