Lifetime measurement in Gd isotopes around N = 90

S. Basak[1, 2,*], D. Kumar[1, 2], A. Pal[1, 2], D. Banerjee[3], S. S. Alam[4], and T. Bhattacharjee[1, 2]

[1]*Variable Energy Cyclotron Centre, Kolkata – 700 064, INDIA*
[2]*Homi Bhabha National Institute, Mumbai – 400 094, INDIA*
[3]*RCD-BARC, Variable Energy Cyclotron Centre, Kolkata – 700 064, INDIA*
[4]*Government Degree College, Chapra, West Bengal – 741 123, INDIA*
* email: shefali.b@vecc.gov.in

Introduction

In recent years, study of quantum shape phase transitions (QPT) and shape coexistence in finite many body quantum systems, such as nuclei, have become of great interest [1]. In the rare-earth region around N = 90, nuclei can undergo rather rapid shape changes as a function of nucleon number. The N = 90 nuclei in Sm-Gd region are well known for the observation of quantum shape phase transition from spherical to well deformed rotor as well as coexistence of different shapes with very close lying minima. Empirical signatures for shape changes in a sequence of even-even nuclei are, e.g., a change in the ratio $R_{4/2} = E(4_1^+)/E(2_1^+)$ or a sudden rise in the E2 transition strength $B(E2; 2_1^+ \rightarrow 0^+_{gs})$ [2,3].

Another signature for a QPT is the E0-transition strength $\rho^2(E0)$. The coexistence of deformed shapes are manifested with the presence of multiple low lying 0^+ levels with one of the key signatures being the high E0 decay rates. In this context, the experimental identification of the low lying 0^+ levels and the measurement of their lifetimes is very important.

Among the Gd and Sm nuclei, quantum shape phase transition has been proposed with observation of high E0 decay from the 0_2^+ level in N = 88 ^{152}Gd. In our recent measurement, similar signature in the 0_3^+ level of N = 88 ^{150}Sm have been observed as the decay of level shows high E0 strengths [4]. Other than the Sm nuclei, the E0 strength is not known for the 0_3^+ levels in any other nuclei in this mass region. Specifically, the 0_3^+ level has already been observed in N = 90 Gd and the associated structure has been conjectured as the pairing isomer. However, there is no experimental data available on the lifetime measurement in this nucleus. In the present work, the level lifetime measurement of 0_3^+ in ^{154}Gd (N=90) and other spin states such as 2_1^+, 4_1^+ in ^{152,154}Gd has been aimed using γ–γ fast timing technique.

Experiment

The low lying excited states of ^{154}Gd were populated through two different reactions - one through the β – decay of ground state of ^{154}Tb ($T_{1/2}$ ~ 21.5 hr.) produced using ^{154}Gd(p,n)^{154}Tb reaction with 12 MeV proton beam delivered from K-130 cyclotron at VECC, Kolkata. Proton induced reaction has been performed for the cleaner population of 0_3^+ in ^{154}Gd (N=90) by restricting the population of high spin isomers in ^{154}Tb. The high spin states in ^{152,154}Gd has been populated through the β – decay of higher lying isomers in Tb isotopes produced through neutron evaporation reaction using 40 MeV α beam from K-130 cyclotron on ^{nat}Eu target. The decaying gamma rays from excited states have been detected with VENTURE array [5], which consists of eight fast scintillator $CeBr_3$ detectors, coupled to two Compton supressed Clover HPGe detectors, as shown in Fig. 1. Clover HPGe detectors has been used for cleaner identification of γ-transitions. The pulse processing has been done with NIM electronics and VME data acquisition with high resolution Mesytec ADCs.

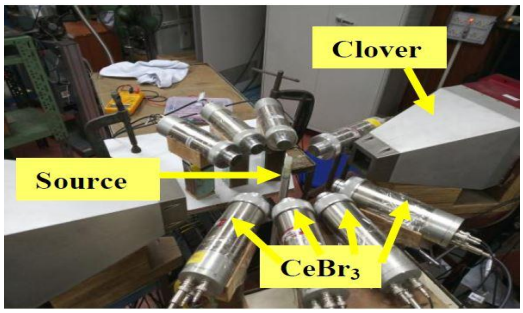

Fig. 1: Experimental setup with VENTURE array and two Compton suppressed Clover HPGe detector.

Analysis and Results

With a TAC range of 50 ns, measurements of level lifetimes in pico-second range has been carried out using generalized centroid difference (GCD) analysis whereas for longer lifetimes in ns range has been obtained by slope fitting of $CeBr_3$-$CeBr_3$ TAC.

Total energy spectrum from CeBr3 and Clover data, generated with few list mode runs from ^{nat}Eu(α,3n) data only, are shown below in Figure 1.

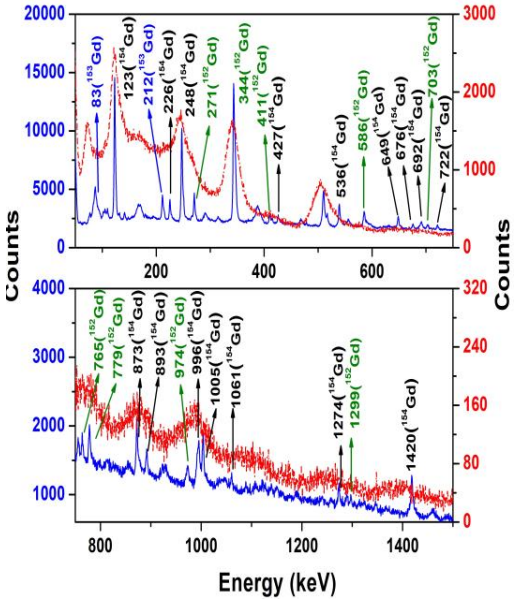

Fig. 2: The total energy spectrum from $CeBr_3$ & Clover detectors.

Level lifetime of 2_1^+ level in ^{154}Gd has been determined using 248 keV – 123 keV cacade. The delayed time distribution of the above cascade has been projected and the lifetime was extracted using slope fitting analysis of $CeBr_3$-$CeBr_3$ TAC. The obtained value of 1.71(32) ns is in very well agreement with literature value of 1.708(7) ns [6]. The gated energy and $CeBr_3$-$CeBr_3$ TAC spectra from this analysis shown below in Figure 3. Lifetime measurement of other levels are in progress.

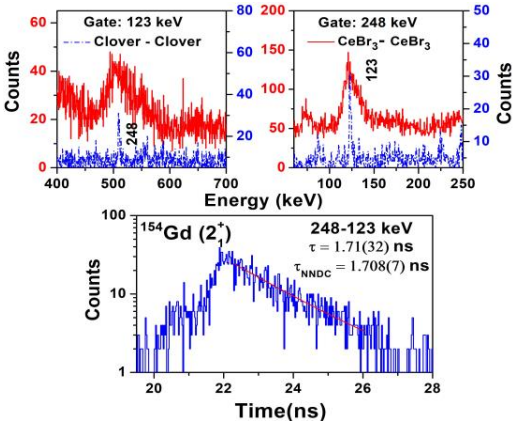

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Fig.3: Gated energy spectrum showing 248 & 123 keV cacade.

Discussion & Summary

In the light of studying exotic quantum phenomena like shape phase transition and shape coexistence in nuclear system, nuclear lifetime of known 0_3^+ in ^{154}Gd has been planned. Several new lifetimes of other higher lying levels in ^{152,154}Gd are also being accessed from the present experiment. The details of new observations will be presented.

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