Lifetime measurement of yrast 2^- state in ^{154}Gd

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Introduction

The presence of negative parity levels and strong E1 transitions indicate the presence of reflection asymmetric shape of the nuclear surface. The nuclei around $Z = 64$ and $N = 90$ are appropriate candidates for observing reflection asymmetric octupole shapes due to the presence of unique parity orbitals for both protons and neutrons that differ by $\Delta J = 3$ compared to the normal parity orbitals. Although the quadrupole deformation is driven by the neutron excitations, the proton particle play important roles in the generation of both static and dynamic octupole shapes in these nuclei. Several octupole sequences are observed in deformed Sm and Gd isotopes which are designated with different K configurations generated from the fragmentation of the octupole state in their spherical counterparts.

The $K^\pi = 1^-$ octupole-vibrational band of ^{154}Gd displays surprisingly different energy sequence of rotational levels, viz., I = 2,1,4,3 instead of conventional I = 1,2,3,4. This is explained by Meyer [1] to be arising due to strong Corriolis (rotation - vibration) coupling to the $K^\pi = 0^-$ otupole sequence. However, it is not clear whether the inversion of levels has any contribution from the pseudo-rotor-particle coupling (p-RPC) Coriolis-type force between the $([411] \uparrow (3/2)^+[523] \uparrow (7/2)^-)2^-$ and $([411] \uparrow (3/2)^+[532] \uparrow (5/2)^-)1^-$ two proton quasiparticle states that significantly contribute to the wavefunctions of the odd parity levels. Therefore, measurement of absolute B(E1) transition rates are of extreme importance to understand the inversion of states of $K^\pi = 1^-$ octupole sequence in ^{154}Gd.

The lifetime measurement for the lowest 2^- level of the $K^\pi = 1^-$ octupole sequence has been carried out and reported in the present work that provides the information on the B(E1) rates for the decay transitions from the 2^-_1 level.

Experimental Details

The low lying excited states of ^{154}Gd were populated through the decays of the three isomers of ^{154}Tb ($I^\pi = 3^-$, 9.4h; $I^\pi = 7^-$, 22.7h; $I^\pi = 0$, 21.5h) that were produced using two nuclear reactions, viz., ^{154}Gd(p,n)^{154}Tb and ^{nat}Eu(α, 4n)^{154}Tb. The former reaction, performed with enriched (67 %) ^{154}Gd provides cleaner γ spectrum and has been used in the present work aiming at the lifetime measurement of the 2^-_1 state. The proton and α beams of energies 12 MeV and 40 MeV, respectively, were delivered by K 130 cyclotron at VECC, Kolkata. The decaying gamma rays from excited states were detected using the VENTURE array [2], which features eight fast $CeBr_3$ scintillator detectors paired with two Compton-suppressed Clover HPGe detectors. Pulse processing was performed using NIM electronics and VME data acquisition with LAMPS [3] software.

Analysis, Results & Discussions

The known lifetimes of the low-lying excited states of ^{154}Gd was utilized to verify the experimental data analysis. Details on lifetime measurement technique using VENTURE array employing Generalized centroid difference(GCD) method can be found in

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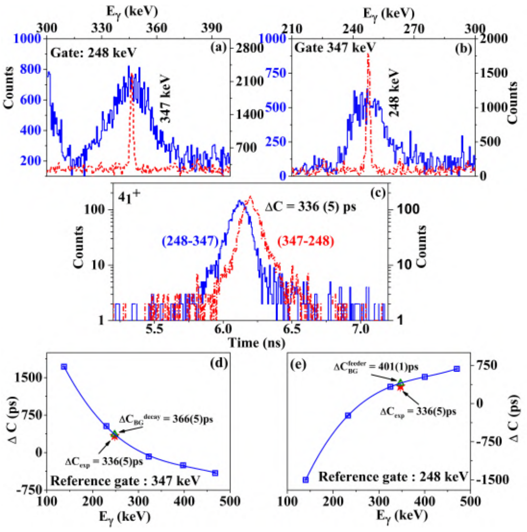

FIG. 1: Lifetime analysis for 4_1^+ level with 347 - 248 keV cascade resulting 65(5)ps.

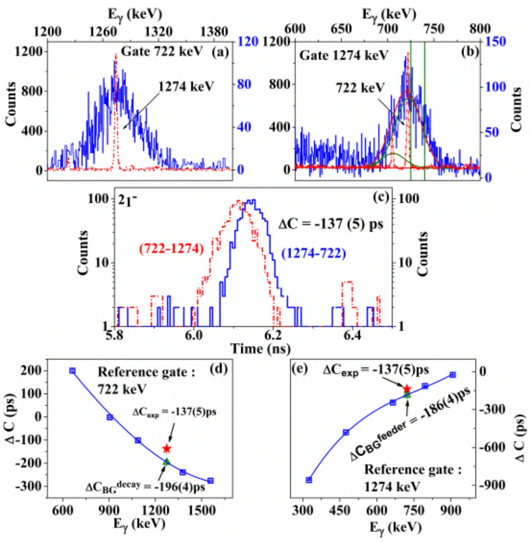

FIG. 2: Lifetime analysis for 2_1^- level with 722-1274 keV cascade resulting 45(5)ps.

Ref. [4]. The lifetime analysis for the 4_1^+ (known) and 2_1^- levels are shown in Fig. 1 and Fig. 2, respectively. In these figures, the $CeBr_3$ energy-gated projections of $CeBr_3$ (blue,solid) and Clover (red, dash-dot-dot) detectors are shown in panel (a) for decay and in panel (b) for feeder γ rays corresponding to a cascade. The delayed (red, dash-dot-dot) and anti delayed (blue, solid) time difference spectra are also shown in panel (c). Background correction analysis are displayed in panel (d) and (e). The true centroid differences (ΔC) due to photopeak-photopeak coincidences were obtained through determination of (1) the experimental centroid differences (including photopeak and Compton background) (ΔC_{expt}) and (2) the centroids corresponding to photopeak-Compton and Compton-Compton coincidences (ΔC_{bkg}). Lifetimes (τ) were measured using the relation of $\Delta C - PRD = 2\tau$. PRD represents the prompt response distribution of the setup.

Isotope	N=88	N=90	N=92
Gd	-	2.5 $\times 10^{-6}$	$< 3.2 \times 10^{-5}$
Sm	-	2.6 $\times 10^{-4}$	-

TABLE I: B(E1) Values in W.u. for $2_1^- \rightarrow 2_1^+$ decays in Gd and Sm

The B(E1) rates have been determined for the $2_1^- \rightarrow 2_1^+$ decay and compared with the neighboring nuclei in TABLE I. It is observed that the E1 decays are more enhanced in neighboring N = 90 Sm compared to that in N = 90, 92 Gd indicating much lower octupole collectivity in these nuclei. This indicates that the role of particle core coupling can be a dominating factor for the inversion of energy levels in the $K^\pi = 1^-$ band in ^{154}Gd.

References

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