Effect of the clover geometry on the LINESHAPE analysis

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Introduction

In nuclear structure physics, the absolute transition rates play a crutial role to understand behavior of the nucleons in a nucleus and requires the erudition about lifetimes of the states. As the rate of the decay of an excited nuclear state is proportional to the square of the matrix element of the transition operator between the initial and final state wavefunction, measured lifetimes provide a very sensitive fingerprint of the relevant nuclear models.

In recent time, the Doppler shift attenuation method (DSAM) has been used to determine the short (sub picosecond) lifetimes of the excited nuclear states. The measured Doppler shift [$\Delta E_\gamma = E_\gamma - E^0_\gamma = E^0_\gamma\ \beta\ \cos\theta$] depends directly on the angle between the γ-ray emission and recoil direction and on the recoil velocity at the moment of emission. The extensive investigations on the DSAM technique have been performed using single Ge detectors placed in different array, like EUROGRAM, EUROBALL and GAMMASPHERE. The recent development of the clover detectors has adds a new era to the γ ray detection technique in terms of detection efficiency. A clover detector made up of four individual Ge crystals may be different in terms of the γ detection efficiency and addback factor. These parameters should be taken care of when one measure the level lifetime in the DSAM procedure using clover detectors. The present investigation aimed to determine the effect of these parameters on the lifetimes obtained from the DSAM analysis.

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Experimental details

For the purpose of measuring the level lifetime an experiment has been performed at Tata Institute of Fundamental Research (TIFR), Mumbai using the Pelletron Linac Facility. Several nuclei, ^{141,142}Sm and ^{142,143}Eu are dominant in cross section, have been populated using the ^{31}P beam (E_{lab} = 148 MeV) which was incident on 2.4 mg/cm^2 of ^{116}Cd (99% enriched) target on a 14.5 mg/cm^2 thick Pb backing. The de-exciting γ-rays were detected by the Indian National Gamma Array (INGA) array [1] which consisted of nineteen Compton suppressed clover detectors in six different angles. About 4×10^9 two and higher fold γ-γ coincidence events have been recorded with the digital data acquisition system based on Pixie-16 modules from XIA LLC [1, 2].

Results and discussion

Doppler-broadened line shapes have been observed for the different transitions of the several bandlike structures in the residual nuclei ^{142}Sm and ^{142,143}Eu. The level lifetimes of the states have been measured using the LINESHAPE code [3]. The process of lineshape fitting has been described in detail in Ref. [4]. To gather knowledge of how the four independent crystal of a clover detector affect the acquired level lifetimes, two different procedures have been followed. Firstly, the line shapes have been calculated for the full clover geometry. The detector geometry for the composite clover detector has been incorporated in the calculation assuming the response is identical to a single piece of detector with dimension same that of the clover detector placed at the same distance. In second procedure, the line shapes have been analyzed for a single crystal of a particular clover detector in the array. In this analysis, we have constructed the asymmetric E_γ-E_γ matrices in which events registered in all detectors are recorded on one axis and coincident events in a particular crystal at an angle θ are placed on the other axis.

Lifetimes for the states of the dipole and quadrupole bands in ^{142}Sm and ^{142,143}Eu have been extracted from the lineshape analysis using full clover geometry and have been compared with the values obtained from the single crystal data. Typical line shape fits for the transition of the dipole band DB I in ^{143}Eu for the full clover and single crystal data are shown in Fig. 1. The evaluated level lifetimes are tabulated in Table I.

It has been observed that the values of the

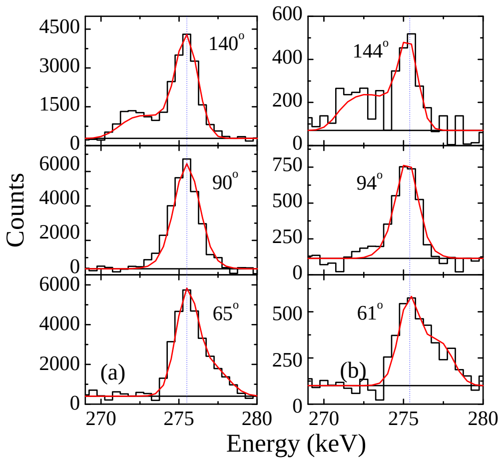

FIG. 1: Representative spectra along with the calculated line shapes for 275.5 keV transition of the dipole band DB I in ^{143}Eu obtained from (a) the full clover (b) a single Ge crystal data.

TABLE I: Level lifetimes obtained from the full clover and single crystal detector data for the dipole bands DB I in ^{143}Eu.

I_i^π	$E_\gamma(keV)$	τ(ps)[full clo.]	τ(ps)[single crys.]
$37/2^+$	188.2	$1.10^{+0.20}_{-0.17}$	$1.27^{+0.40}_{-0.32}$
$39/2^+$	275.5	$1.23^{+0.15}_{-0.12}$	$1.33^{+0.38}_{-0.29}$
$41/2^+$	361.3	$0.99^{+0.14}_{-0.10}$	$1.17^{+0.31}_{-0.28}$
$43/2^+$	459.6	1.22$\downarrow$	1.58$\downarrow$

life times of the states obtained from the full clover geometry are within the uncertainty limits of that obtained from analysis of the single crystal data. The small variation in the absolute values of the life times may be due the averaging effect of the four crystals of a clover. This averaging includes the variation of the angles of the crystals in a clover, variation in relative efficiencies due to different sizes of the crystals and the effect of anisotropy in the angular correlation of the γ-transitions. Hence, it can be propose that the construction of the clover detectors with the four individual Ge crystals does not affect the measured level lifetimes dramatically. This affirms the widely used lifetime results of the DSAM analysis obtaine from the full clover data.

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