Fast Timing measurement in neutron rich ^{131,132}I

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Introduction

The neutron rich odd-A and odd-odd iodine nuclei have extra proton (neutron) particles (holes) compared to the ^{132}Sn shell closure. Experimental investigation of these nuclei thus provides the opportunity for studying the single particle energy levels as well as the effective interactions around Z=50 and N=82 which are difficult to access through conventional techniques. The odd-odd nuclei are of particular importance for studying the p-n residual interaction associated with the available single particle orbits. The systematics of the measured quadrupole moments of the $5/2^+$ and $7/2^+$ states of odd-A iodine nuclei shows an anomalous behavior when compared with the shell model calculations [1]. This has been explained with the configuration mixing associated with a modification of n-p interaction. The recent experimental and theoretical investigations carried out in this direction [2–5] also indicate the importance of the lifetime measurements in these nuclei. Such measurements in ^{131,132}I nuclei was attempted [6] using Mirror Symmetric Centroid Difference(MSCD) [7, 8] technique, giving rise to the limits on the level lifetimes. In the present work, the lifetime measurements have been carried out by using the Generalized Centroid Difference(GCD) technique [9, 10] for several states of ^{131,132}I nuclei, produced from decay of the radio-chemically separated fission products.

Experiment

In this ultra-fast timing experiment, the ^{131m,132}Te nuclei was produced using ^{nat}U(α,f) reaction with 40 MeV α-beam from the K=130 cyclotron at VECC. Two $LaBr_3$(Ce) detectors, kept at an angle of 180° w.r.t each other, have been used for the detection of γ-rays obtained from the source prepared by chemical separation of the Te nuclei from the other fission products. The coincidence timing spectra were obtained by using conventional electronics and a time calibration of 6 *ps/channel*. The lifetimes have been measured using the GCD technique which has been described below:

The MSCD and GCD methods are the newly proposed and improved timing techniques which are being used since the availability of $LaBr_3$(Ce) scintillator detectors. In MSCD technique, the timing asymmetry in the branch timing characteristic is cancelled by defining the centroid difference(ΔC) between the start and the stop detector for a particular γ-ray cascade. In this case,

$$\begin{aligned}|\Delta C(\Delta E_\gamma)| &= |PRD(\Delta E_\gamma)| + 2\tau : \Delta E_\gamma > 0\\ &= |PRD(\Delta E_\gamma)| - 2\tau : \Delta E_\gamma < 0\end{aligned}$$

where $\Delta E_\gamma = E_{feeder} - E_{decay}$, the difference between the two coincidence γ-ray energies. The PRD(prompt response difference) curve, thus, can be generated by plotting ΔC as a function of ΔE and for a level lifetime τ this curve should be shifted by two times τ. At ΔE_γ=0, PRD(ΔE_γ)=0 and so the lifetime can be determined by direct determination of $\tau=\frac{1}{2}\Delta C$,ΔC being the shift of the centroid associated with the level lifetime. The extended technique arrived from the same principle gives rise to the GCD method, where the centroid differences are calibrated as a function of the incident photopeaks instead of their energy difference. As the time response of Compton background is also a function of energy, so peak-to-background ratio (π) has to be considered to determine the true centroid difference (ΔC_{true}) where,

$$\Delta C_{true} = \Delta C + \frac{\Delta C - \Delta C_{compton}}{\pi}$$

A precise calibration of the PRD is possible due to the mirror symmetry of PRD which provides additional data points and finally gives the value of PRD for any energy

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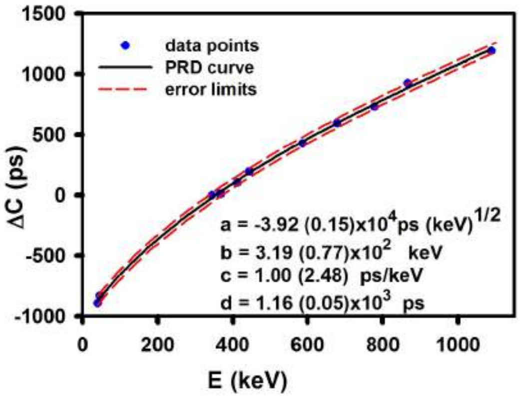

FIG. 1: The PRD curve obtained from the reference energy gates of 344 keV and 244 keV.

combination by the equation: $PRD(E_{feeder} - E_{decay}) = PRD(E_{feeder}) - PRD(E_{decay})$.

In the present work, the PRD curve has been generated by utilizing the known level lifetimes of the 344 keV level of ^{152}Gd and 365 keV level of ^{152}Sm. This was performed with a ^{152}Eu source by detecting the photopeaks of 344 and 244 keV in the start(stop) detector and other photopeaks in coincidence with the stop(start) detector. The difference of the centroids was obtained by interchanging the start and stop energy gates of the corresponding combination of the coincidence photopeaks. The PRD curve has been generated by plotting the centroid differences against the photopeak energy of the feeding γ-ray and after correcting them for the associated level lifetimes and differences in energy dependent time walk. In fig. 1, the PRD curve has been shown which has been generated by using the literature value of 46.7 ps lifetime for 344 keV level of ^{152}Gd and that of 83.3 ps for the 244 keV level of ^{152}Sm. The PRD curve was fitted by the equation given by:

$$\Delta C = \frac{a}{\sqrt{b + E_\gamma}} + cE_\gamma + d,$$

where a, b, c and d are the fit parameters, as shown in figure. The lifetimes have been obtained for the 1646 keV and 1899 keV states of ^{131}I and 162 keV state of ^{132}I after obtaining the centroid shifts of the associated cascades as shown in fig. 2.

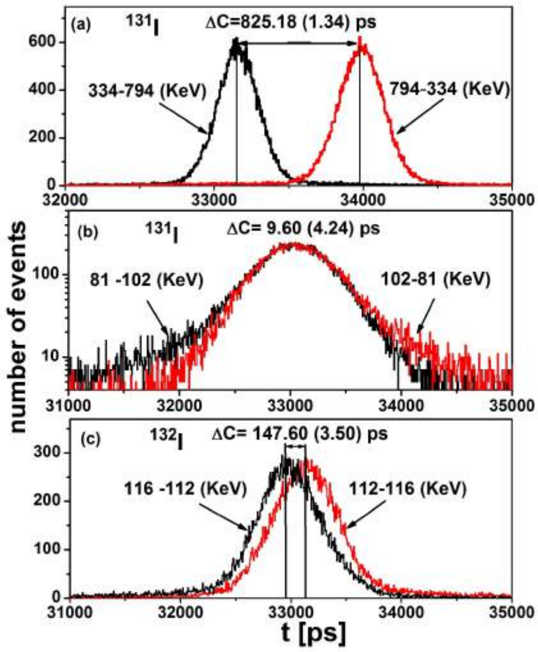

FIG. 2: The Centroid difference spectrum a) for (344-794) cascade and b) for (81-102) cascade of ^{131}I c) for (116-112) cascade of ^{132}I

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