Lifetime measurement in n-rich ^{133}I

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Introduction

The measurement of level lifetimes offers a direct window into the internal structure of excited nuclear states. In particular, conducting such measurements in nuclei neighboring ^{132}Sn holds profound significance for gaining insights into the two-body effective interactions and the evolution of collectivity around the double shell closure Z = 50 and N = 82 [1,2]. Particularly, Iodine (I) nuclei, characterized by Z = 53, possess an excess of three protons and a few additional neutron particles compared to the doubly shell-closed ^{132}Sn [Z = 50, N = 82] nucleus and they occupy an intriguing intermediate position between the vibrational Tellurium (Te) and deformed Xenon (Xe) nuclei. Therefore, measurement of level lifetime of these nuclei provides crucial insights into the underlying structure of these excited nuclear states [3-5]. However, the lifetime data in these nuclei around Z=50 and N=82 are very scanty mainly, because of difficulty of accessing them experimentally [6]. Therefore, a program has been initiated at VECC aimed at systematically exploring the low-lying level structure of neutron-rich nuclei in this region, by following the decay spectroscopy of radio-chemically separated fission fragments [7-10].

The present work reports the measurement of level lifetime, through the employment of the γ-γ fast timing technique, for the low lying excited level $11/2^+_1$ in ^{133}I, populated as a result of the decay of radio-chemically isolated Te fission fragments. The generalized centroid difference (GCD) method [11], which has the capability to measure lifetime down to just a few picoseconds (ps), has been used to analyze the experimental γ -γ time difference distribution obtained with the VENTURE array [7].

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Experimental Details

Alpha induced fission of Uranium (^{nat}U) followed by radio-chemical separation was utilized for the production of n-rich Te nuclei. The subsequent decay of these nuclei generates isotopes ranging from $^{131-134}$I and $^{131-134}$Xe. The yield of those daughter and grand-daughter nuclei mainly depends on both the irradiation time and the half-life values of the parent nuclei ^{131m}Te (τ ~ 33 h), ^{132}Te (τ ~ 3 d), ^{133}Te (τ ~ 54 min), and ^{134}Te (τ ~ 42 min). The energies of decaying γ–rays out coming from all these nuclei are very closely spaced and therefore, are very difficult to study. Hence, in order to obtain a more distinct energy spectrum, with a higher production yield of ^{133}I nucleus, multiple targets were irradiated for a shorter duration, typically around ~2 hours. This irradiation was accomplished using the stacked foil method, by bombarding ^{nat}U using a 40-MeV α beam generated by the K-130 cyclotron at VECC, Kolkata. The ^{nat}U targets were prepared using the electrodeposition technique on 25 μm-thick ^{nat}Al backing foils. The details of preparation of targets, electronic setup and experimental methods can be found in Ref. [8].

The VENTURE array [7], consisting of eight 1"x1" $CeBr_3$ detectors, coupled with an array of six clover HPGe detectors known as VENUS array [12] was used for collecting the data. To generate time differences between two detectors in the VENTURE array, the common start fast timing technique has been employed. To ensure accuracy and reliability in the measurements, the energy spectra obtained from VENUS and VENTURE have been compared, which aided in the selection of precise energy gates for projecting time distributions using the $CeBr_3$ detectors within the VENTURE array. To conduct lifetime measurements through the GCD method, a prompt response difference (PRD) curve, which depicts the immediate time characteristics of the array, is generated and can be found in ref. [7].

Results

Lifetime has been measured of the intermediate state $11/2^+_1$ in ^{133}I using 648-913 keV cascade with the GCD method. Fig. 1 illustrates the gated energy spectrums recorded using the VENTURE array compared with that of the VENUS array. These comparisons are important to identify the regions of the energy gates to minimize the contribution from the contaminated neighboring peaks.

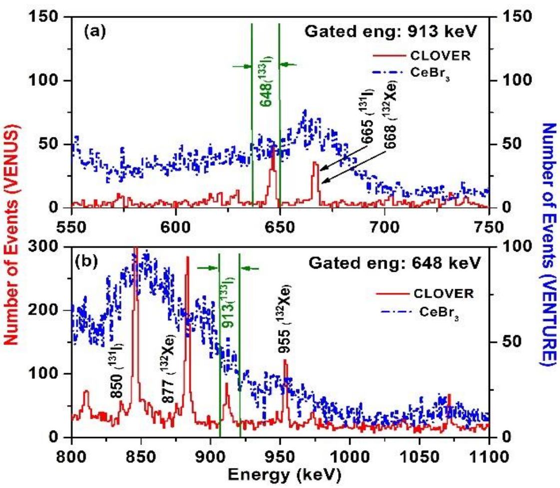

Fig.1: The gated spectrum obtained with the VENTURE array (blue dotted line) has been compared to that obtained with VENUS array (red solid line). The region of VENTURE gates used for generation of time distribution of the 648-913 keV cascade of ^{133}I is shown with solid lines. Different scales have been used for VENUS and VENTURE and are indicated with different colours.

The energy gates associated with 648-913 keV cascade have been used to generate delayed and anti-delayed time distribution spectra (Fig. 2) obtained with VENTURE data. The measured centroid difference of the time distribution spectra is about -122 (7) ps. After incorporating the PRD value [-129(13) ps] obtained from the PRD curve [7], the measured lifetime of this level is about $\leq$ 8 ps (upper limit of lifetime of $11/2^+_1$ level which is equivalent to the lowest estimated error in this method). To provide further insights into the experimental findings, shell model calculations using the NUSHELLX code [13] have been initiated to interpret the experimental data and the results will be presented.

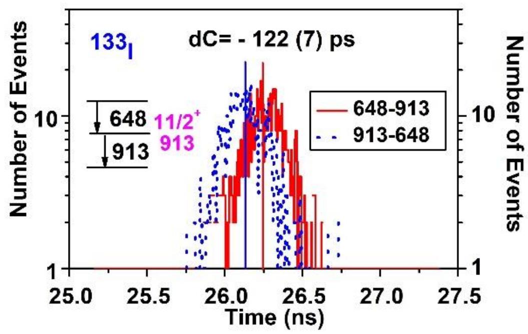

Fig.2: Delayed and anti-delayed time distributions spectra of 648-913 keV cascade of ^{133}I obtained with VENTURE data, used for lifetime measurement using GCD technique. The delayed and anti-delayed time distributions are shown with red (solid) and blue (dotted) lins respectively.

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