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Fast timing characteristics and lifetime measurement using $1.5'' \times 1.5''$ CeBr₃ detectors coupled with PMT Hamamatsu R13089-100

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Measurement of lifetime of nuclear excited states and determination of electromagnetic transition strengths from that provides direct insight into nuclear structure. The measurement of lifetime in $\gamma - \gamma$ electronic coincidence method depends on the time resolution and energy resolution of the detector system. The ideal γ -ray spectroscopy requires a combination of excellent energy and time resolution along with the good photo-peak efficiency. With the availability of new generation scintillator detectors with reasonably good energy resolution, the precise measurement of lifetime in sub nanosecond ranges have been possible.

At Variable Energy Cyclotron Centre (VECC), Kolkata, $1.5'' \times 1.5''$ CeBr₃ detectors coupled with a new Photo-Multiplier tube Hamamatsu R13089-100 has been characterized [1]. The typical energy and time resolution obtained with $1.5'' \times 1.5''$ CeBr₃ detectors are 4.1% (at 662 keV of ¹³⁷Cs source) and 199(2) ps (for 1173-1332 keV cascade of ⁶⁰Co source). The systematic variation of the time-resolution for different PMT bias voltages and external CFD delays has also been studied. It has been observed that the time resolution improves with shorter CFD delays and higher PMT bias voltages.

With the knowledge of the basic characteristics of two detector set-up, time-walk response for this set-up was determined using Mirror Symmetric Centroid Difference (MSCD) method [2]. In order to calibrate the Prompt Response Function (PRF) of the experimental set-up for the energy range of interest, Prompt Response Difference (PRD) calibration curve [3] has been determined for two $1.5'' \times 1.5''$ CeBr₃ detectors with ¹⁵²Eu source. As this detector+PMT assembly was found to be linear upto PMT Bias voltage of -1400 V, hence the PRD calibration was first carried out at this bias voltage with 5 ns CFD external delay. Then the variation of the PRD curve has been studied at different PMT bias voltages and CFD external delays.

Nuclei near ²⁰⁸Pb region are expected to have spherical structure at lower spin and collective structure at higher spin and excitation energies. For even-even Po (Z=84) isotopes in this region, the variation of R_{4/2} ratio approaches towards vibrational limit as neutron holes increase whereas, E2 transition strength increase from ²¹⁰Po to ²⁰⁶Po [4]. The low-lying states of neighbouring odd-A nuclei in this region are mainly described by the coupling of one neutron hole with the nearest even-even core. The lifetime measurement of low-lying states of Po isotopes will be of great importance to understand how the collectivity arises for the lower and the higher spin states. In this regard, the lifetime of 11/2⁻ state of ²⁰⁹Po, has been measured with two $1.5'' \times 1.5''$ CeBr₃ detectors in MSCD method. The ²⁰⁹Po was populated via electron capture decay of ²⁰⁹At, which was produced using the reaction ²⁰⁹Bi(α ,4n)²⁰⁹At with 52 MeV α beam from K-130 cyclotron at VECC, Kolkata. The lifetime of 11/2⁻ state at 1521.85 keV of ²⁰⁹Po has been obtained as 98(6) ps using 239-195 keV cascade [5], which is found to be in good agreement with a recently reported value [6].

References :

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