Characterization of $LaBr_3(Ce)$ scintillators with 250 MHz Pixie based Digital Data Acquisition System

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Introduction

The knowledge of the lifetimes of excited nuclear states plays a pivotal role in our understanding of the nuclear structure. The lifetime of nuclear excited states varies through orders of magnitude and hence there are several specific methods of measurement, each covering a different range. The electronic method of direct measurement of the time decay spectrum of certain nuclear states, is based on the use of fast scintillator detectors. In recent years, the advent of new $LaBr_3(Ce)$ fast scintillators have revolutionized this method due to their excellent properties concerning both time and energy resolution. These detectors have enabled measurement of lifetimes in the range 50 ps to 10 ns.

Study of nuclear structure and properties using in-beam γ-ray spectroscopy, where thousands of nuclear states are populated, can be much improvised using a triple-gamma coincidence measurement with an array containing both HPGe and $LaBr_3(Ce)$ detectors [1]. Due to their high energy resolution, the Ge detectors can be used to select the desired γ-ray cascade. The fast $LaBr_3(Ce)$ detectors can be used to build the delayed coincidence time spectra for the selected levels. Recently, a PCI-PXI based digital data acquisition (DDAQ) system (Pixie-16) has been successfully implemented for the Indian National Gamma Array (INGA), a spectrometer with the facility to accommodate 24 Compton suppressed clover detectors [2]. It has been proposed to couple the INGA spectrometer with $LaBr_3(Ce)$ detectors for future campaigns.

The readout electronics for the present INGA set up digitizes the detector signal at 100 MHz with 12 bit precision. It provides good energy resolution and is sufficient for decay times in microsecond range. However, in nanosecond regime, their performance is limited as per Nyquist theorem. A digital data acquisition system capable of sampling detector signals at a rate of 250 MHz (referred as P250 in the rest of text) with 12 bit precision has been recently developed by XIA LLC. In the present work, we have characterized the energy and timing properties of $LaBr_3(Ce)$ scintillators using this 250 MHz DDAQ.

Experimental Details and Results

The experimental set up consisted of two 2″x 2″ $LaBr_3(Ce)$ scintillator crystals mounted on XP2020URQ photomultipliers. Each detector was connected to a separate ADC channel in the same module of the digital data acquisition system with 250 MHz sampling rate developed by XIA LLC (P250). The detectors were calibrated using ^{133}Ba, ^{22}Na, and ^{60}Co sources. In order to check the linearity of the energy response of the detector, the γ-ray energy was plotted against ADC channel number, as shown in Fig. 1. The figure clearly shows that a linear response was observed in the energy range of 80−1333 keV.

To determine the timing properties, coincidence measurements were performed using a ^{60}Co source, which is a perfect case of prompt coincidence between the two γ-rays of energy 1.17 and 1.33 MeV. In the offline analysis, the time difference between the two rising edges was measured by applying a constant fraction algorithm to the captured waveforms. As shown in Fig. 2, the timing peak was mea-

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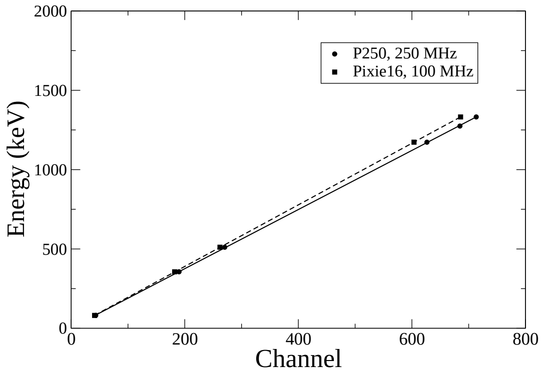

FIG. 1: Linearity plot of the $LaBr_3$(Ce) detectors for Pixie-16 and P250.

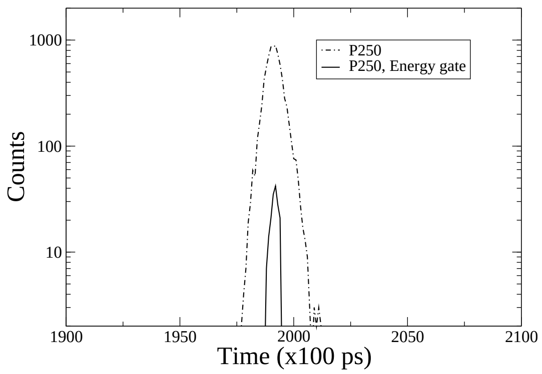

FIG. 2: Histograms of measured time difference ΔT between two coincident ^{60}Co pulses acquired with a pair of $LaBr_3$(Ce) detectors.

sured to have a FWHM of $\sim$800 ps when all the events were included. The peak-to peak coincidence resolving time was observed to have an FWHM of $\sim$400 ps using P250, whereas the same observed using Pixie-16 was $\sim$520 ps, as reported in ref. [3].

A comparison of the performance of the P250 DDAQ with that of the Pixie-16 module clearly demonstrates that a higher digitization rate improves the timing resolution. An array of sixteen fast $LaBr_3$(Ce) scintillation detectors implementing the DDAQ with 250MHz sampling frequency, has been planned to be coupled with the present INGA spectrometer comprising of HPGe clover detectors (with 100 MHz DDAQ). This advancement in the experimental set-up and data acquisition, would lead to a remarkable and qualitative improvement in the study of nuclear structure and properties using the in-beam γ-ray spectroscopy technique.

References

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