Implementation of Digital Constant Fraction Discrimination for Fast Scintillators

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Introduction

Investigation of the electromagnetic properties of discrete states of nuclei are extremely crucial in the field of nuclear structure studies. They provide stringent test for the wavefunctions of excited states of nuclei which depends on the details of the model Hamiltonian. The lifetimes of the excited states at low and medium nuclear excitations span over many orders of magnitude and consequently there are specific methods of measurement of lifetime each covering a certain range. The large array for Clover detectors like INGA is being regularly used for measurements of the lifetime of the excited states using Doppler Shift Attenuation Method (DSAM) in the range of 100 fsec to fraction of psec. Use of electronic method using fast-coincidence technique will provide measurement window starting from 20 psec.This method continuously benefited from the occurrence of new scintillators and is currently applicable to lifetimes down to a 20 picoseconds [1]. With the available $LaBr_3$(Ce) based detectors, currently there are broader opportunity for fast timing measurements due to the coupling of $LaBr_3$(Ce) detector array with the clover detectors. In the present work, we will present the implementation of digital constant fraction discrimination for timing measurements of fast timing scintillators using a fast coincidence set-up. The timing resolution between the fast coicidence of two $LaBr_3$(Ce) detectors will be extracted. The scope for further improving the timing response using DDAQ will also be discussed. Adopting the fast scintillators to the 100 MHz multichannel digital data acquisition system for the INGA will bring the capability for performing the lifetime measurements in a new time window range.

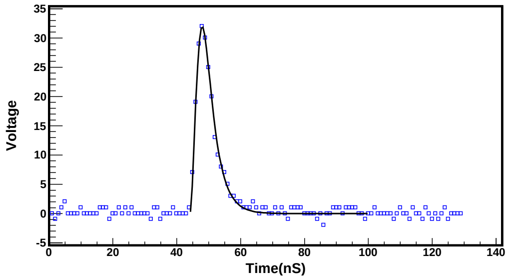

FIG. 1: A digitized trace with sampling interval of 10 nsec of the LaBr3(Ce) detector pulse fitted with a polynomial function is shown.

I. RESULTS

Two $LaBr_3$(Ce) detectors were kept at 50 cm apart. Timing signals of the PMTs were directly given to the two channels of the Pixie-16 modules. The input pulses to the Pixie-16 modules were digitized at 100 MHz sampling rate after amplification and Nyquist filtering [2].

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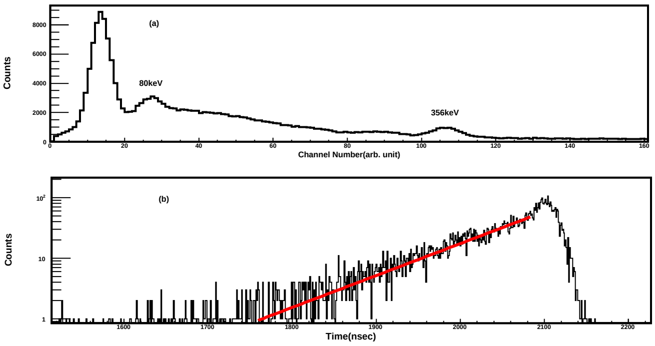

FIG. 2: Energy spectrum obtained from the decay of ^{133}Ba is shown in top panel (a) and decay curve of $5/2^+$ state of ^{133}Cs is shown in the bottom panel (b).

A typical pulse as sampled in the Pixie-16 is shown in Fig 1.

First the fast filter response of the digitized waveform Tr[i] is computed using equation (1):

$$FF(i) = \sum_{j=i-(FL-1)}^{i} Tr[j] - \sum_{j=i-(S-1)}^{i-(FL+FG)} Tr[j] \tag{1}$$

where,

$$S = 2 \times FL + FG$$

The fast length (FL) and fast gap (FG) were kept 100 *nsec* in the present case. Digital CFD for the fast filter of traces were calculated in the offline analysis using equation (2) and the zero-crossing time of the CFD response was extracted. This cross-over time was added to the 48-bit FPGA time to get the time of the event.

$$CFD[i + D] = FF[i + D] - f \times FF[i] \tag{2}$$

The coincidence measurement was carried out with ^{60}Co source and the time spectrum was generated with the condition that measured energy higher than 1000 keV in the off-line data analysis. The time difference spectrum between the two LaBr$_3$(Ce) detectors gave a prompt peak with a *fwhm* of 520(20) *psec*. In the present case, we have used a delay of 10 *nsec* and scaling factor (f) of 0.2. Timing measurement was also performed with a ^{133}Ba source using the same set-up to reproduce the lifetime of the $5/2^+$ level of ^{133}Cs. The energy spectrum for the decay of ^{133}Ba was shown in Fig 2(a) along with the decay curve showing the half-life of 6.2(0.1) *nsec* for the $5/2^+$. The decay curve was generated with gate on 356 and 81 keV transition.

II. SUMMARY

The result presented in this report was performed using XIA 100 MSPS Pixie16 digitizers. Though the pulse is digitized at an interval of 10 nsec, the information of a time transformation smaller than the sampling time is preserved in the pulse shape. Further analysis is in progress to take into account the shape of the pulses for improving the timing information of the radiations. This work demonstrates the successful coupling of the LaBr$_3$(Ce) detectors to the Digital DAQ of INGA and this configuration will be useful for lifetime measurements in nuclear structure studies.

References

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