Development of a Framework for Analysis of Trace Data

R. Raut[1],* S. S. Ghugre[1], R. Palit[2], G. Mukherjee[3], S. Bhattacharyya[3], R. P. Singh[4], S. Muralithar[4], and H. Tan[5]
[1]*UGC-DAE CSR, Kolkata Centre, Kolkata 700098, INDIA*
[2]*Tata Institute of Fundamental Research, Mumbai 400005, INDIA*
[3]*Variable Energy Cyclotron Centre, Kolkata 700064, INDIA*
[4]*Inter University Accelerator Centre, New Delhi 110067, INDIA and*
[5]*XIA LLC, California 94544, USA*

Introduction

The use of digitizers in nuclear physics experiments has facilitated higher throughput, owing to faster processing in the digital domain, and consequently much higher event rates vis-a-vis the conventional (analog) hardware. The higher event rates, that can be acquired through application of digital pulse processing, has led to increased flexibility in the experimental conditions. It is now common to acquire data with an event trigger of lesser stringency in the hardware and identify the events of interest during data reduction/analysis by subjecting them to varying (trigger) conditions, set in the software. The use of digital hardware for gamma-ray spectroscopy is now being extensively practiced in the country. Digital data acquisition systems have been used to sustain two different campaigns of the Indian National Gamma Array (INGA), at TIFR (2009-2013) [1] and at VECC (2017-2021) [2]. The digital signal processing is based on implementation of fast recursive algorithms in the digitizer firmware. As far as those for spectroscopic applications are concerned, major strides have been accomplished in the associated developments, since the pioneering works by Jordanov and Knoll [3, 4]. The use of digitizers make it possible to acquire trace of the detector pulses in the data, subject these to different processing algorithms offline and conclude on the optimum values of the associated parameters and/or develop new algorithms in the process. This work is about the development of a framework for the purpose and is envisaged to eventually contribute in the pulse shape analysis pursuits, for applications such as gamma-ray tracking.

*Electronic address: `rraut@alpha.iuc.res.in`

Measurements, Algorithms and Analysis

The acquisition hardware used for the purpose was the digital data acquisition system of UGC-DAE CSR, Kolkata Centre. The principal component of the same is PIXIE-16 digitizers, manufactured by XIA LLC (USA), and equipped with 250 MHz 12-bit ADC. Accordingly, the detector preamplifier pulse, input to the digitizer, is sampled at an interval of 4 ns. The upper panel Fig. 1 depicts a typical digitized trace of a pulse of a HPGe detector and for a duration of 4 μs. The trace data can be read-in by a code, as per the format characteristic to the system. In the present work the coding has been carried out in the ROOT [5] framework. The data format, for each detection, is four 32-bit words of an event header followed by two trace points, in ADC units, that are each of 12-bits and are packed into one 32-bit word for the entire length of the trace being recorded. The latter is specified in bits 31:16 of the last 32-bit word of the event header and is the number of trace points for record. The value corresponding to 4 ns of sampling interval and length of 4 μs of the pulse is 1000.

The algorithm for extracting Fast Filter (FF) from the digitized pulse is expressed as,

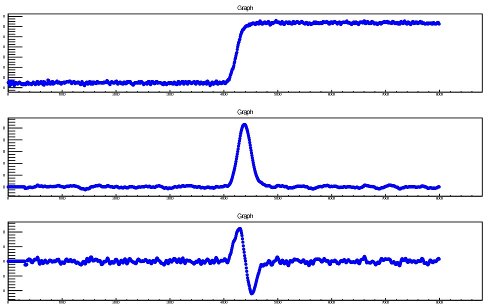

FIG. 1: The upper panel represents digitized pulse of a HPGe clover detector, plotted up to 4μs. The middle panel represents the output of the fast trapezoidal filter applied on the pulse. The bottom panel represents the output of the CFD algorithm applied on the fast filter output.

$$FF[i] = \sum_{j=i-(FL-1)}^{i} Trace[j] - \sum_{j=i-(2*FL+FG-1)}^{i-(FL+FG)} Trace[j] \quad (1)$$

where FL and FG are the Fast Length and the Fast Gap respectively and are the parameters associated with the FF. The latter is used to mark the arrival of a detection event and check for the coincidence multiplicity. The time stamp of the detection in the output data stream is latched to the point at which the leading edge of the FF crosses the preset threshold (in ADC units). The middle panel of Fig. 1 represents the FF output corresponding to the aforementioned algorithm applied on the digitized pulse. The FL and FG were chosen to be $\sim$ 100 ns for the purpose. The CFD value corresponding to a detection is calculated from

$$CFD[i+D] = FF[i+D] * (1 - w/8) - FF[i] \quad (2)$$

with D and w being the delay and the scale parameter associated with the CFD. One set of values for these may be D = 64 ns and w = 2. The lower panel of Fig. 1 illustrates the corresponding CFD response of the FF. The specific CFD value in the data record is one that corresponds to the Zero Crossing Point (ZCP) and complies with the criterion CFD[i] $\geq$ 0 and CFD[i+1] $<$ 0. The value is calculated from

$$CFD = \frac{CFDout1}{CFDout1 + |CFDout2|} * 16384 \quad (3)$$

where CFDout1 is CFD value before ZCP and CFDout2 is the one after it. As a part of the coding undertaken in the present endeavours, it has been possible to calculate the CFD value from the trace data and compare the same with the actual value in the data stream. The overlap between the two is around $\sim$ 95% for the 25000 traces that have been analyzed. The correspondence between the actual and the calculated values of the CFD indicate the possibility of probing the impact of different processing algorithms and parameters through their application on the trace data in the current coding framework.

Outlook

It is envisaged that the analysis of the trace data would be extended to those acquired with the segmented HPGe clover detectors. Difference in the pulse shapes, for the same (energy) deposition in different segments, will facilitate the position information associated with the detection. The methodology can eventually be extended to understanding of the gamma-ray tracking algorithms.

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