Study of Resolution and Linearity in $LaBr_3$: Ce scintillator through digital-pulse processing

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Introduction

Advent of digital pulse processing has led to a paradigm shift in pulse processing techniques by replacing analog electronics processing chain with equivalent algorithms acting on pulse profiles digitized at high sampling rates.

In this paper, we have carried out offline digital pulse processing of Cerium-doped Lanthanum bromide scintillator ($LaBr_3$: Ce) detector pulses, acquired using CAEN V1742 VME digitizer module. Algorithms have been written to approximate the functioning of peak sensing analog-to-digital convertor (ADC) and charge-to-digital convertor (QDC). Energy dependence of resolution and energy linearity of $LaBr_3$: Ce scintillator detector has been studied by utilizing aforesaid algorithms.

Experiment details

The measurements were carried out using a $LaBr_3$: Ce crystal of 3” (diameter) × 6” (length) dimension. The crystal was coupled to a photomultiplier tube (Hamamatsu R11973).

The front end electronics comprises of CAEN V1742 digitizer [1] (32 channels, 5/2.5/1 GHz sampling, 12 bit resolution, 110 µS dead time), based on domino ring sampler (DRS-4) [2], housed in a VME64 crate. Optical fiber cable link between computer and digitizer helps sustain the high data transfer rate.

Experimental setup is described in Fig.1. Radioactive ^{22}Na, ^{137}Cs and ^{60}Co were used as sources for the detector. Voltage across PMT was kept at -800 V. Anode signal from PMT was fed to a fast amplifier. One branch of output from fast amplifier was fed to a constant fraction discriminator (CFD) module to generate a logic pulse for triggering the module.

Trigger to V1742 digitizer is given through a low latency trigger input (TR 0/1) because individual channels are incapable of self-triggering.V1742 digitizer provides two such low latency trigger input, each common to 16 channels and capable of accepting NIM/TTL inputs.

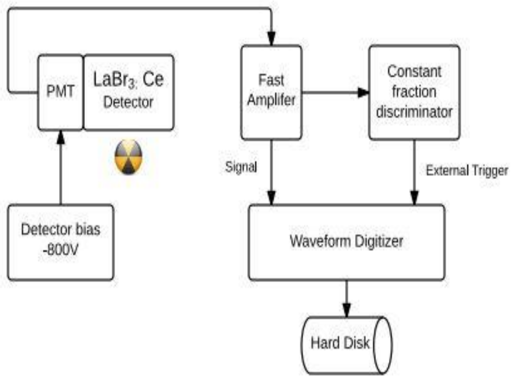

Fig. 1: Block diagram representing the experimental setup

Another branch from fast amplifier was fed as input to digitizer, after delaying the signal for a suitable time period, for waveform digitization. Signal from fast amplifier is delayed as there is a time lag (~35ns) between the trigger arrival on TR 0/1 and the issuing of the acquisition trigger that causes the board to save the waveform on V1742 digitizer.

Digital pulse processing algorithms

Input to digitizer was digitized at 1 and 5 Gs/s (Giga-samples/second) rate with a 12 bit amplitude resolution. Raw waveform acquired from digitizer is saved on disk and subjected to offline analysis. Thirty out of 1024 samples, at the end of each digitized pulse, are discarded to get rid of a fixed pattern noise, introduced by DRS4 chip, before subjecting the recorded pulse to analysis.

The pruned signal rides over some baseline fluctuation. Baseline of the signal is calculated by taking the mean of a fixed number of sampling points before the start of the signal. This baseline is taken as a reference with respect to which various parameters viz. amplitude etc. of the waveform are recorded.

Moving average filter is, thereafter, applied to get rid of high frequency noise present in the signal. It prevents the trigger logic to generate false triggers on spikes (fast fluctuation of signals). The treatment of signal after application of moving average filter depends on the module type being replicated.

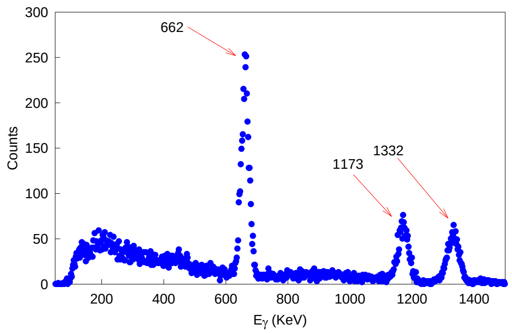

Fig. 2: Histogram measured with $LaBr_3$: Ce scintillator with a cocktail source of ^{60}Co and ^{137}Cs

For algorithm approximating the QDC functioning, signal value in the region of interest are summed (to approximate the area) and recorded for each pulse.

For the algorithm written to mimic ADC functioning, peak of the signal is recorded in the region of interest. Histogram for recorded peak height (proportional to the energy deposited by γ -rays in the scintillator) and converted to energy calibrated spectrum is plotted. (Fig.2)

Results

Energy linearity has been checked by applying the QDC algorithm to raw data sampled at 5 Gs/s and 1 Gs/s. (Fig.3) The reduced $\chi 2$ was found to be equal to 0.3 for data sampled at 5 Gs/s(blue dashed line) and 2.8 for data sampled at 1 Gs/s(red solid line). Linearity between energy and channel number of the peak position corresponding to specific energy is, thus, exhibited at 800V.

The resolution at each Eγ is fitted by the curve: FWHM(%) = $a/\sqrt{E\gamma}$ (keV) + b. (Fig.4) The reduced $\chi 2$ was found equal to 0.9 for data sampled at 5 Gs/s(blue dashed line) and 0.7 for data sampled at 1 Gs/s(red solid line) by applying the QDC algorithm.

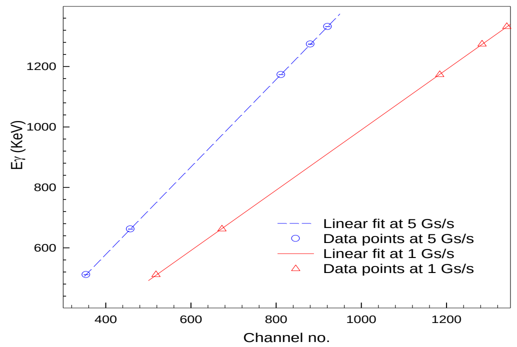

Fig.3: Linearity plot of the LaBr3: Ce scintillator. Channel corresponding to the peak is plotted against Eγ.

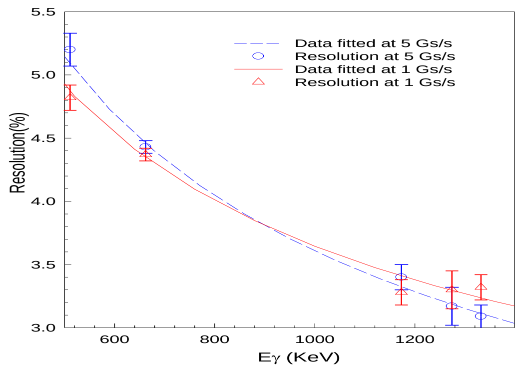

Fig. 4: Energy resolution measured with the use of different sources (^{22}Na, ^{60}Co, and ^{137}Cs) compared to the expected $1/\sqrt{E\gamma}$ behavior.

Conclusion

Digital algorithms for mirroring the functionality of ADC and QDC have been developed. Resolution and linearity characteristics have been studied for $LaBr_3$: Ce by applying aforesaid algorithms on raw data obtained from waveform digitizers from CAEN. Efforts are underway to improve the algorithms further.

References

[1] http://www.caen.it/
[2] http://www.psi.ch/drs/