How does the sampling rate affect the digital timing response of fast scintilltors ?

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Time of flight resolution study is performed for fast scintillator detectors using digital oscilloscope HDO4000A from LeCroy. Signals were acquired from a pair of detectors situated at a flight distance of 133 cm from the source. This measurement involves $LaBr_3$, BaF_2, and BC501A scintillation detectors. While constructing a digital constant fraction signal and performing the optimization at various rates, the saturated resolution of $LaBr_3$-BC501A, BaF_2-BC501A, and $LaBr_3$-BaF_2 pairs are found to be ; $\approx$ 1 ns, $\approx$ 1 ns and $\approx$ 500 ps respectively.

Introduction

Timing detectors plays a vital role in understanding the nuclear reaction dynamics as well as structure physics. For instance, timing signals from multiwire proportional counters are used to explore the fission mass distribution, signals from fast scintillator can be used to study the lifetime of a nuclear state. In order to get the minimum spread in the measure physical quantity, digital pulse processing (DPP) can be pursued. DPP advantages includes ; minimum signal distortion, retains original signal information, can be encoded with incident particle and event characteristics, large density of channels can be handled with faster processing algorithm leading to minimum system dead time. For instance, sample train of digitized pulse can be processed to decode the arrival time, energy, as well as type of the incident particle falling on the detector surface. Using DPP one can achieve for example, energy resolution of $< 2\%$, and timing dispersion of 350 ps using $LaBr_3$ detector [1]. Further, using recursive filtering algorithm, neutron-γ figure of merit as 2.1 can be achieved for a BC501A scintillator [2]. Present analysis results are in continuation of our previous investigation on digital time of flight measurement of fast scintillators [4]. We have extended our study to explore the effect of sampling rate on time of flight (TOF) broadening.

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Signal time marker calculation

Signals were collected from the detector pairs ; (BaF_2-$LaBr_3$), (BaF_2-BC501A), and ($LaBr_3$-BC501A) and digitized using HDO4000A oscilloscope from LeCroy [3]. Waveforms were stored at the rates of 2.5 giga samples per second (GSPS), 1.25 GSPS, and 500 mega samples per second (MSPS) [4]. Sample train collected from the oscilloscope were processed by the digital equivalent of constant fraction discriminator method, given as :

$$DCF[i] = F * (Sig[i] - BSL) - (Sig[i + \Delta] - BSL)$$

$DCF[i] : Digital\ constant\ fraction\ signal$

$Sig[i] : Signal\ sample\ train$

$BSL : Average\ baseline\ value$

$F : Fraction\ applied$

$\Delta : Delay\ introduced$

Here, $DCF[i]$ provides a bipolar pulse with discrete points connecting the two polarities, acting as a transition region. In general, the zero crossing position may not coincide to the sample time stamp, thus we performed a cubic spline interpolation which preserves the phase

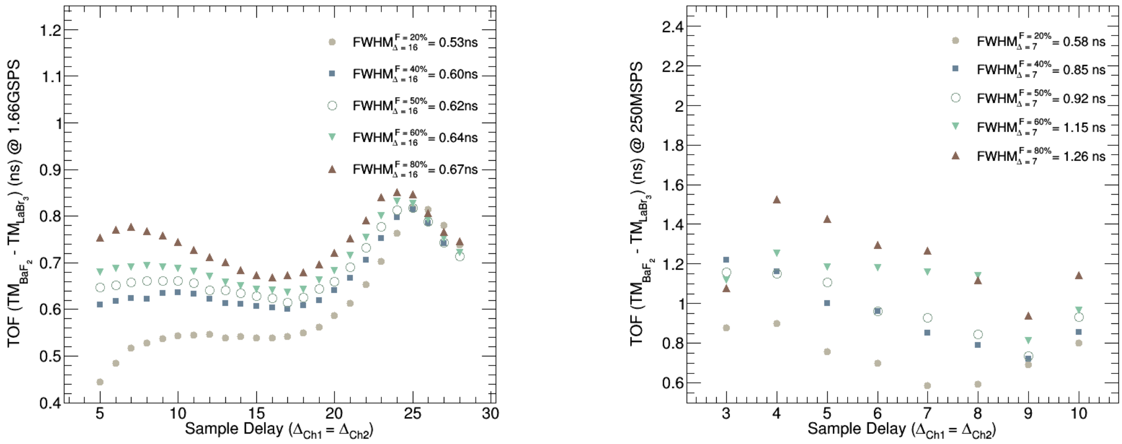

FIG. 1: Left : TOF optimization graph for BaF_2-$LaBr_3$ pair at 1.66 GSPS rate, pulses are generated from 2.5 GSPS data. Right : For the same pair optimization curves are depicted at 250 MSPS rate, pulses are generated from 500 MSPS data.

information of the sampling points [5]. To get the accurate time marker (zero-crossing) position a standard Bisection method is used.

TOF resolution at different sampling rates

To explore the effect of sampling rate on TOF broadening, we have used 2.5 GSPS and 500 MSPS data for each of the mentioned detector pair. Since the sampling resolution is 0.4 ns (for 2.5 GSPS) and 2 ns (for 500 MSPS), thus all the possible sampling resolution can be achieved by altering the sample points. For instance, by removing the even (or odd) number of sample points in the sampling train of 500 MSPS data, higher resolution of 4 ns can be achieved. While adopting similar procedure, we have generated the data at 250 MSPS, 333 MSPS, 625 MSPS, 833 MSPS, 1.25 GSPS, and 1.66 GSPS rates.

Results and Discussion

Optimization results obtained at 1.66 GSPS and 250 MSPS rates for a BaF_2-$LaBr_3$ pair is displayed in fig. 1. Minimum TOF broadening of 530 ps and 580 ps is obtained at the rates 1.66 GSPS and 250 MSPS respectively. Higher value at 250 MSPS is attributed to increased in systematic error in the time marker calculation. We have conducted a systematic study about the variation in the resolution for all the pairs at different rates and found that it becomes constant after 500 MSPS rate. Here, one can raise the following question : why the resolution is not dropping down even at the higher sampling rates ?. To search answer in a deeper sense, we are presently pursuing pulse modeling of all the mentioned detector pairs. Analysis and results of the study would be presented during the symposium.

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