Development of a high-bandwidth waveform processing system using RFSoC

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We are developing a real-time digital waveform processing unit using a GHz-band flash-type analog-to-digital converter (FADC) to establish a next-generation data acquisition system at RIBF. Each particle needs to be identified in experiments using radioactive ion (RI) beams. Thus, detectors are installed along the beam line, and signals are acquired on an event-by-event basis. However, conventional CAMAC/VME ADC/TDC modules become a measurement bottleneck because of their slow processing rate with an increase in the amount of beams. For germanium detectors, real-time digital waveform analysis is applied using 100-MHz FADCs instead of conventional ADC/TDC modules.[1)] However, the sampling rate of 100 MHz is insufficient for signals with high-frequency components such as those from plastic scintillators used as beam-line detectors. We started to develop a new system named as CALDERA using the Xilinx RFSoC ZCU111 evaluation kit[2)] that has 8 channels of 4-GHz FADC since last year to apply waveform processing to a beam-line detector.[3)]

First, we examined the performance of this device. We measured the resolution of CALDERA, and we compared it with those of the conventional CAEN V792 QDC[4)] and V775 TDC.[5)] The energy resolution was evaluated by measuring γ rays at 662 keV using a $LaBr_3$(Ce) scintillator, and the timing resolution was obtained from two NIM logic signals with a constant time difference.

The results of the CALDERA measurements are shown in Fig. 1. The energy and timing resolutions of CALDERA are 4.3% in FWHM and 15 ps in σ, respectively; those of QDC/TDC are 4.3% and $\sigma = 27$ ps, respectively. CALDERA achieves the same or better performance than that of the conventional QDC/TDC.

Next, this system was commissioned at the RIBF experiment (NP1712-RIBF141R1).[6)] We acquired the waveforms of the plastic scintillators installed at F5 and F7 in the ^{9}Li beam, and the charge and time information were obtained through waveform analysis. The particle identification plot is shown in Fig. 2. CALDERA can be used to acquire both charge and time information.

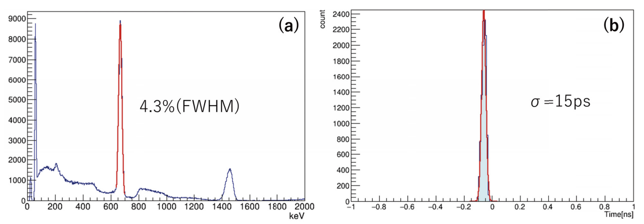

Fig. 1. Energy and timing resolutions with CALDERA. (a) ^{137}Cs energy spectrum using $LaBr_3$(Ce) scintillator. (b) Time difference obtained from two NIM logic signals.

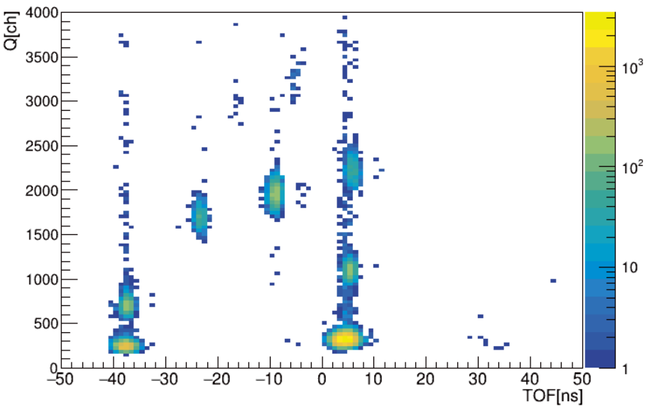

Fig. 2. Particle identification of ^{9}Li beam with CALDERA.

Further, we studied the algorithm to implement waveform processing in the FPGA. The timing information is determined by the centroid of the waveform as

$$G = \frac{\Sigma x_i y_i}{\Sigma y_i}. \tag{1}$$

This equation can be written as a recurrence formula

$$\begin{cases} q_n = q_{n-1} + v_n \\ g_n = g_{n-1} + q_n \end{cases}, \tag{2}$$

where v_n, q_n, and g_n represent the value of the n-th signal, denominator, and numerator, respectively.

The implementation of this waveform processing is now in progress.

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References

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