High rate capability of gas ionization chamber with flash ADC

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At world-leading RI beam facilities such as RIBF, the region of the nuclear chart containing nuclei to be studied simultaneously, or the yield of every nuclear species is often restricted by the high rate capabilities of beam detectors. Herein, we examined the high rate capability of gas ionization chambers (ICs)[1–4]. We recorded the waveforms of preamplifier output signals using a flash analog-to-digital converter (FADC) and corrected for the so-called pile-up effect in the offline analysis, as previously done in a pioneering work[4]. We also shortened the time needed to release amplified charge for recovering the ground level from 10 μs, a commonly used duration, to 1 μs, thereby reducing the probability of pile-up events.

A test has been performed at the Heavy Ion Medical Accelerator in Chiba (HIMAC) during other experimental programs as a parasite setup. Primary beams of Ne and Xe at 180 and 200 AMeV, respectively, were incident on our setup, after passing through other experimental setups. As a result, the beam energy was degraded and well spread at the location of our setup. An IC with an effective length of 440 mm composed of 12 cathode and 11 anode planes, each with an area of 60 mm ϕ and placed at 2-cm intervals, was filled with P10 gas at a pressure of 720 Torr and used in our setup. A positive bias of 400 V was applied to the anode planes to yield a typical drift time of 360-400 ns for 2-cm drift length. Five signals, each from two neighboring planes, plus one signal from the last plane were preamplified with Mesytec MPR-16L, which has a time constant of 1 μs. After the amplified signals were split into two, one part was sent to a CAEN V1740 digitizer with a 62.5-MHz sampling period, and the waveform was recorded. In parallel, using the other part of the split signals, the preamplified charge was digitized with peak-sensing ADCs (Mesytec MADC32) through a shaping amplifier (Mesytec MSCF-16) with a shaping time of 0.5 μs (σ).

The left window of Fig. 1 shows the correlation between the amplitudes of energy loss in the IC obtained using the above two readout methods for the data of Xe beam at 50 kilo particles per spill (kppp) with a duration time of $\sim$1 s for each spill. In addition to well-correlated events, there are events in which the amplitude calculated using the conventional method deviates from the systematics. In such events, the pulse of interest lies on top of the tail of the preceding pulse, producing an unwanted rise of the amplitude of the MADC value, as exemplified in the right figure. Such effects can be removed by decomposing neighboring pulses through the fitting of the waveforms, as shown with the red curve in the figure.

In that example, there are about 10 beam particles in a time window of 188 μs. After time averaging, this can be considered as a beam rate of about 50 kHz in cyclotron facilities such as RIBF but without a RF-periodic time structure. In the Xe beam, the rate defined thus varies from a few tens of kilohertz to about 200 kHz within each spill. The probability of pile up as a function of the beam rate is under analysis. The analysis of the energy resolution requires the correction of the beam energy dependence of the energy loss, which is ongoing.

In summary, we performed an experiment to test a signal-readout method based on FADCs coupled with a preamplifier having a short time constant and showed that the method is feasible for beam rates up to a few hundreds of kilohertz at least, while the method based on the shaping amplifier exhibits a pile-up effect from about several tens of kilohertz. Further analysis is ongoing.

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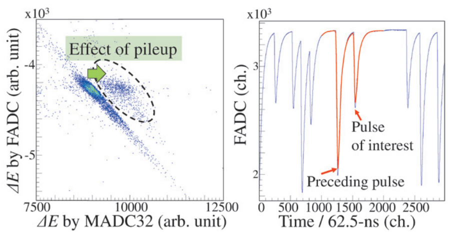

Fig. 1. Two dimensional correlation (left) between the amplitudes of the energy loss obtained from the FADC (vertical axis) and MADC32 (horizontal axis), and a typical waveform for the events enclosed with the dashed curve in the left window (right). See the text for details.

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