Pulse shape analysis for short-lived decay of superheavy elements

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In heavy or superheavy element research, it is important to know the α decay energies and half-lives of the nuclei to confirm that objective nuclei have been formed. The α decay half-lives of these nuclei are very short (0.1-1 μs) for heavier Z according to some theoretical calculations. However in the traditional system, the combination of a shaping amplifier and PH-ADC cannot separate sequential events within 1 μs. To measure the α decay properties of such short-lived nuclei, a digital data acquisition system with flash-ADC was implemented in the GARIS-II[1)] read-out system. In the new system, waveforms from a preamplifier are directly registered with flash-ADC SIS3301 to avoid the summing phenomena caused by pileup in the shaping amplifier. Figure 1 shows the PH-ADC read-out and flash-ADC read-out systems. The DAQ systems for the PH-ADC and flash-ADC are operated independently. Separately obtained data are synchronized by the LUPO time-stamp module.

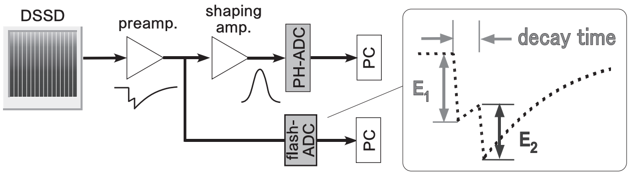

Fig. 1. The setup of PH-ADC and flash-ADC read-out systems.

In a recent study, a pulse shape analysis (PSA) algorithm for the waveforms from the GARIS-II read-out system was developed[2)]. PSA was tested using off-line tests. ^{241}Am α was implanted in a Si PIN photodiode (Hamamatsu S3204) and the signal was preamplified by the Clear Pulse 579. The sampling rate was 100 MHz. Some pileup events occurred when the α source was set close to the detector. Figure 2(a) shows an example of a pileup pulse. In order to distinguish pileup events from single events, the weighted mean in time over threshold (MTOT) method for the differentiated waveforms was developed and applied. MTOT is defined as:

$$\mathrm{MTOT} = \frac{\sum_{t=0}^{t_m} t w_t}{\sum_{t=0}^{t_m} w_t} - T, \quad w_t = \begin{cases} 1 & (v_t \le v_{th}) \\ 0 & (v_t > v_{th}) \end{cases}, \quad (1)$$

where t is the time, t_m is the sampling period (800 clock), v_t is the voltage, v_{th} is the voltage threshold, and T is the minimum t when $w_t = 1$. Figure 2(b) shows a histogram of the MTOT. The peak that corresponds to single events is seen around 17 clock (= 170 ns). The larger MTOT events from this peak correspond to pileup ones. For example the MTOT for the waveform in Fig.2(a) is calculated as $(\sum_{t=83}^{116} t + \sum_{t=273}^{305} t)/(\sum_{t=83}^{116} + \sum_{t=273}^{305}) - 83 = 109.8$ (> 17). Therefore, this event is treated as a pileup one.

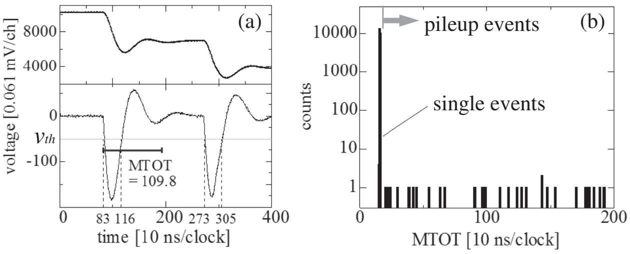

Fig. 2. (a) An example of a pileup pulse (upper panel) and its differential (lower panel). (b) MTOT histogram when ^{241}Am α was implanted in the PIN diode.

In the second stage, template fitting for each pulse was performed[3)]. The template was made by averaging 10000 ^{241}Am α waveforms for each channel. The fitting function is given as:

$$f(t) = A[0] \cdot template(t - A[1]) + baseline, \quad (2)$$

where the free parameters ($A[i]$; $i = 0, 1$) represent the pulse height and time offset. The baseline is an average of the data from $t = 0$ to the start of the pulse. For a single pulse, an energy resolution of 25 keV (FWHM) for 5486 keV α was obtained, while a resolution of 20 keV was obtained using the original PH-ADC system. In addition the shortest time interval between sequential events identified by PSA was 349 ns (Fig. 3). The energies of the first and second pulses were 5494 keV and 5444 keV, respectively. Further development of PSA is now underway.

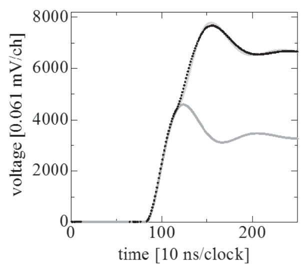

Fig. 3. Pileup pulse (dotted line) and fitting of this event (solid line). From this fitting, the time interval between two events was determined to be 349 ns.

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References

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