Integrator method for resistive dual-axis duo lateral position sensitive silicon detectors

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The Dual-Axis Duo-Lateral (DADL) detectors of the Forward Array Using Silicon Techbology (FAUST) are position sensitive silicon detectors that measure the position of incident particles through resistive charge splitting [1]. Vertical position information is obtained by measuring the charge collected on the contacts F1 (bottom) and F2 (top) while horizontal position information is obtained by measuring the charge collected on contacts B1 (left) and B2 (right) as shown in Fig. 1(a). Prior work has shown that conventional pulse processing methods yield position and energy non-linearities [2,3]. To this end, the summed trigger analysis method was developed to significantly reduce these distortions by measuring the charge for all contacts in a region of the pulse absent of distortion effects and over the same time interval as outlined in Fig 1(b) [4]. While this method provides excellent position and energy resolution, the requirement of writing out waveforms can be prohibitive due to immense data storage and event rate saturation. An upcoming experiment that will measure the 7-α breakup of ^{28}Si requires data collection rates unobtainable using this method. This work presents a new method that approximates the summed trigger analysis method using the eight integrators of the Struck SIS3316 waveform digitizer.

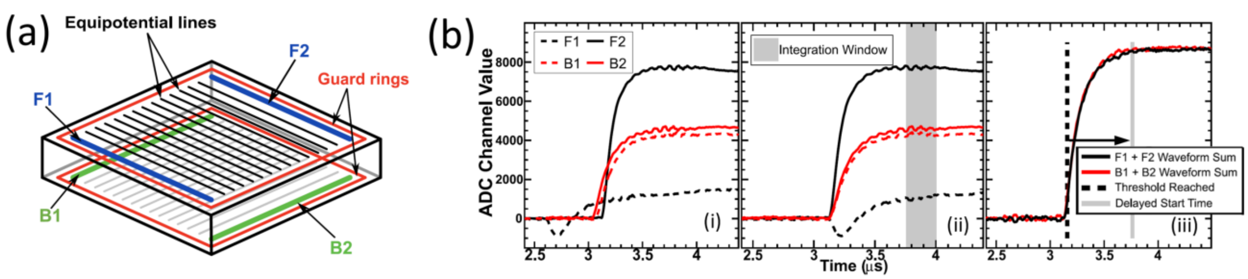

Fig. 1. (a) Schematic of a DADL detector. Charge is collected on the contacts F1 and F2 on the front face and B1 and B2 on the back face. The equipotential conductive lines help facilitate charge movement and the guard rings help to prevent charge bleeding. (b) Summed trigger analysis method. (i): Waveforms from the four contacts for a single event aligned based on their trigger time. (ii): Waveforms have been shifted in time based on the 3316 digitizer time stamp relative to F2. (iii): Sum of time shifted front (black) and back (red) waveforms. The time that the summed waveform reaches threshold (dashed line) is delayed by 0.6 μs (gray line) and is used as the integration start time in panel (ii). Reproduced from Ref [4].

The eight integrators of the 3316 have a start time that can be set relative to the internal trigger of each channel. One integrator is used to calculate the baseline of the waveform. In the summed trigger analysis method, the integration start time is found by applying a 0.6 μs delay to the time that the sum waveform for a given face (i.e., F1 + F2) reaches a threshold above noise. In Fig. 2(a), the F1 and F2 waveforms result from a particle incident near the top or bottom edge of the detector. The two waveforms are displayed based on when they trigger, where F1 triggers just as it deviates from baseline while the F2 trigger occurs roughly 0.5 μs past its deviation from baseline. For any given position, the waveform that triggers earliest in time will have less of the bimodal feature of F2 that causes late triggering. This gives a trigger time for F1 that will approximate well the summed waveform threshold time due to its sharp rise and qualitatively same shape as the summed waveform. Therefore, an integrator that starts 0.6 μs after the internal trigger is used for the waveform that has the earlier trigger time, in this case F1. However, due to the later triggering of smaller, distorted pulses such as F2, this delayed integrator will begin integration later than it would using the summed trigger analysis method. To accommodate, the remaining integrators can be set to begin integration in 72 ns intervals before the first delayed integrator shown by the blue lines in Fig. 2(a). By comparing the trigger time between the two waveforms, the ideal integrator can be chosen for the smaller waveform.

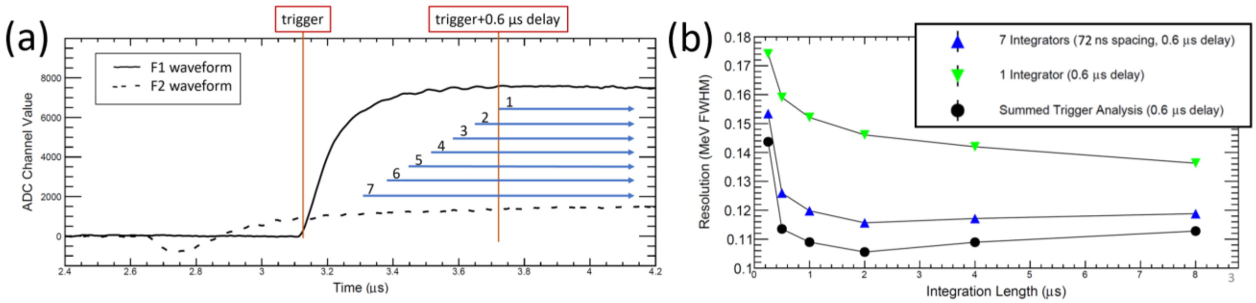

Fig. 2. (a) Integrator method: Waveforms from F1 and F2 for a single event displayed based on their trigger time. The trigger time and first delayed integrator are shown by the red vertical lines. The integration range of the seven integrators are shown as blue arrows. (b) Resolution (MeV FWHM) using a ^{228}Th source comparison between the integrator method, summed trigger analysis method, and a single integrator as a function of the integrator length. Statistical error bars are smaller than the data points.

^{228}Th source data on a DADL detector was used to compare the integrator method to the summed trigger analysis method, and to optimize the integration length for energy resolution as shown in Fig 2(b). A 2 μs integration length gives the best resolution (107 keV for the summed trigger analysis method, 117 keV for the integrator method). To observe the importance of integrating both waveforms over the same interval in time, the resolution obtained from only using one delayed integrator for all waveforms is shown in green. By incorporating additional integrators to compensate for differing pulse shapes and trigger times, the resolution is improved by roughly 50%. Additionally, the use of the integrators over the summed trigger analysis method has been found to have no observable effect on the quality of the position reconstruction. The small sacrifice in energy resolution is levied by the reduction in data storage and increase in data collection rates.

This integrator method was used with the two outermost rings of FAUST (D and E) to measure reaction products from ^{20}Ne on ^{12}C at 17 MeV/u to observe the quality in particle identification prior to full implementation. Isotopic resolution was achieved up through oxygen as seen in Fig. 3. Given the excellent quality in particle identification and retention of good position and energy resolution, this method will be used in an upcoming experiment scheduled that will measure the excitation function for the 7-α breakup of ^{28}Si in the search for high excitation resonance peaks that could possibly be attributed to toroidal nuclei.

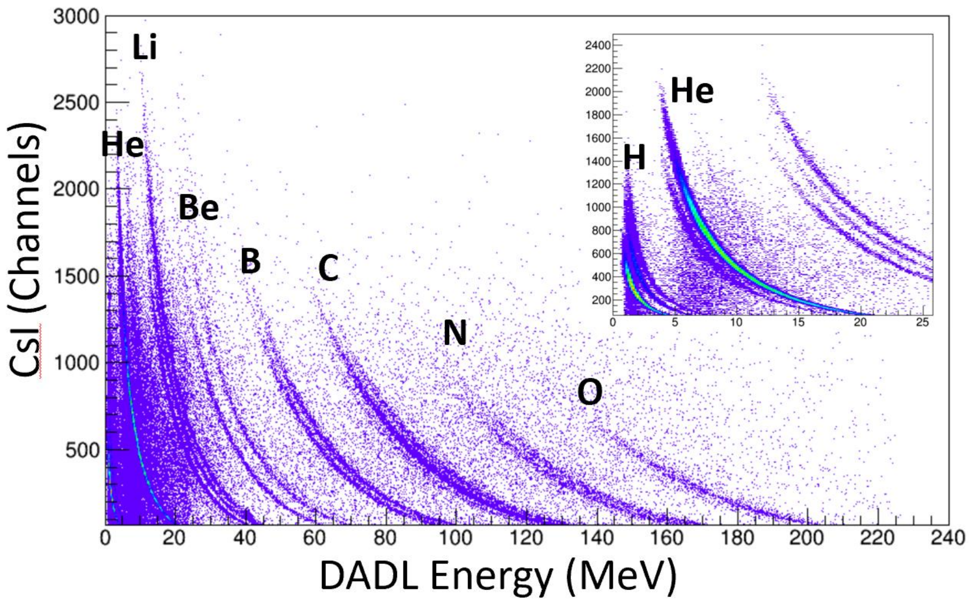

Fig. 3. DADL energy (MeV) as a function of CsI (Channels) for a single detector telescope in ring D of FAUST of reaction products from 17 MeV/u ^{20}Ne on ^{12}C. The inset shows a zoomed in view of H and He isotopes.

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[2] L.A. Heilborn, PhD thesis, Texas A&M University, 2018, http://hdl.handle.net/1969.1/174435.

[3] L.A. McIntosh *et al.*, Nucl. Instrum. Methods Phys. Res. **A985**, 164642, (2021).

[4] M.W. Aslin, A. Hannaman, *et al.,* Nucl. Instrum. Methods Phys. Res. **A985**, 164674 (2021).

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