The search for super heavy elements using alternative mechanisms

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We reported in [1] the motivation and calibration for a search for super heavy elements using alternative reaction mechanisms. With the calibration complete, we have substantially refined the analysis reported in [1] to minimize the probability of identifying accidental events as super heavy element candidates.

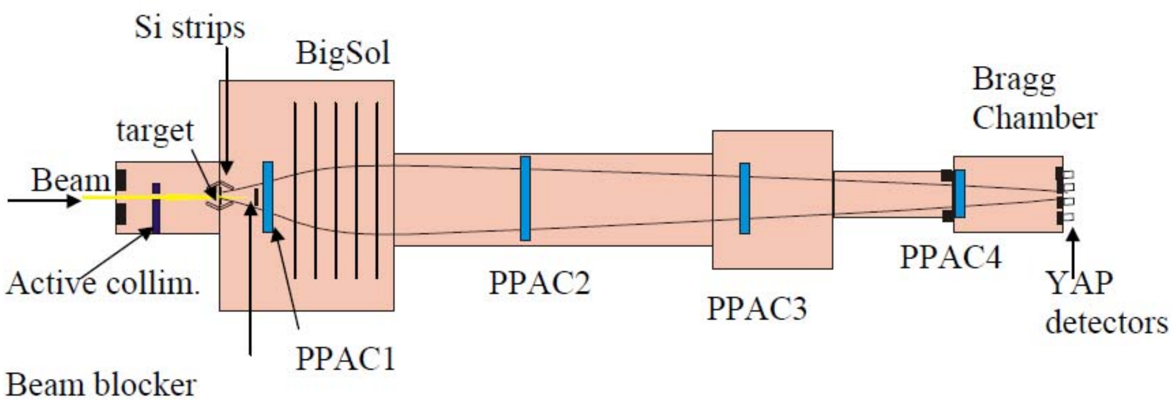

FIG. 1. Experimental setup.

Fig 1. shows the experimental setup. 7.5 MeV/u Au ions were incident on a Th target depicted on the left side of the figure. A 16 segment annular Parallel Plate Counter (labeled PPAC1) with a 2.5 cm hole in the center was positioned 25 cm downstream from the target. Three parallel plate counters were positioned at 3.3m (labeled PPAC2), 5.1m (labeled PPAC3) and 6.15m (labeled PPAC4) from the target. A 40cm gas ionization chamber(IC) was placed just past PPAC4. During the data taking part of the experiment a beam blocker depicted just in front of PPAC1 was inserted in order to block the beam and allow for reaction products emitted at angles larger than 6 deg to be detected in the IC downstream after passing through the BigSol magnet.

The experimental setup provided a number of redundant time measurements. These time measurements consisted of independent measurements of the time difference between PPAC3 and PPAC4, between PPAC2 and PPAC3, between PPAC2 and PPAC4 and between PPAC1 and PPAC4. All time measurements were required to be consistent in order for an event to be considered. We also implemented a pileup rejection scheme in which the time between two events in PPAC4 was measured and if the time between two event in PPAC4 was less than 8μs, the event was rejected.

The IC provided a measurement of the energy loss through eight 4.65 cm anodes. The energy loss in each anode of the IC was measured both in the traditional method of using a peak sensing ADC after signal shaping as well as measuring the trace of the raw signal using a flash ADC. The inclusion of the flash ADC for the purpose of analyzing the signal shape proved invaluable in rejecting spurious events.

After the calibration was completed, events were first filtered by requiring that the above mentioned time measurements were consistent, and that the pileup measurement indicated no pileup. Then products that were heavier than the beamlike particles were selected using the energy vs time measurement as shown in [1]. This narrowed the selection down to a few hundred events. The traces of the signals of each anode measured by the flash ADC from these events were then visually inspected and events were selected that showed no double peaks or any other abnormalities.

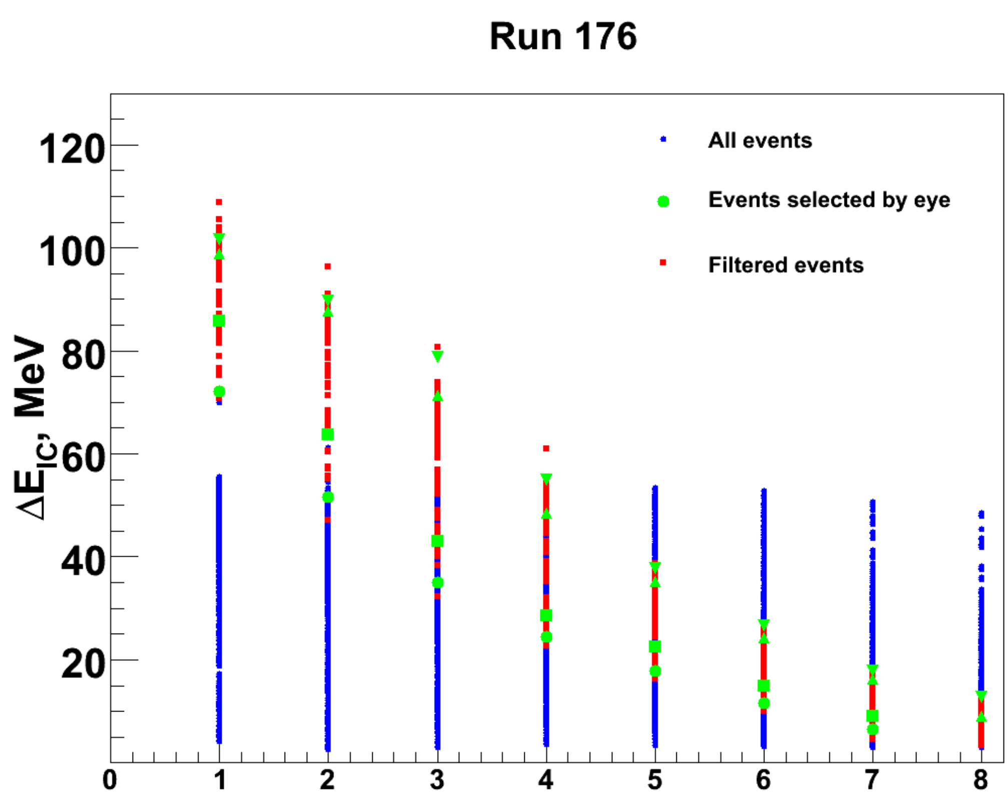

FIG. 2. IC Track profile for different classes of events.

The green symbols in Fig. 2 show the trace of these selected events as they traverse the anodes of the IC. The blue symbols in the top panel of Fig. 2 show the traces of the rest of the event sample. We note that the selected events show a different energy loss profile through the IC. They start out with a significantly higher than normal energy deposit in the first anode (75-100 MeV as opposed to about 40 MeV for normal events) and they lose energy at a much larger rate. This behavior could be consistent with heavy products.

Inspired by the significant difference of these selected events from normal events, we decided to investigate whether an interesting set of events could be obtained by simply filtering on the energy loss profile of heavy fragment candidates. We therefore selected events of a similar profile in delta E as that of the events that were found by eye in the first pass. In the first pass, no other requirements were placed on those vents. The red symbols in Fig. 2 show the events selected using this filtering technique. We note that the events selected follow the same trend as the visually selected events. After these events were selected, we examined the events to see how consistent they were with the different redundant measurements performed in this experiment.

The top panel of Fig. 3 shows the pileup rejection TAC for the complete sample of events for one run. The events at the far right in channel 2000 are events in which a second product did not fire PPAC4 for at least 8 μs after the event of interest. It is seen that this comprises the vast majority of the events when considering the entire event sample. In contrast, we observe in the lower panel that when gating on our selected IC profile filtered events that only two events in that run are left over in channel 2000 (events that show no pileup).

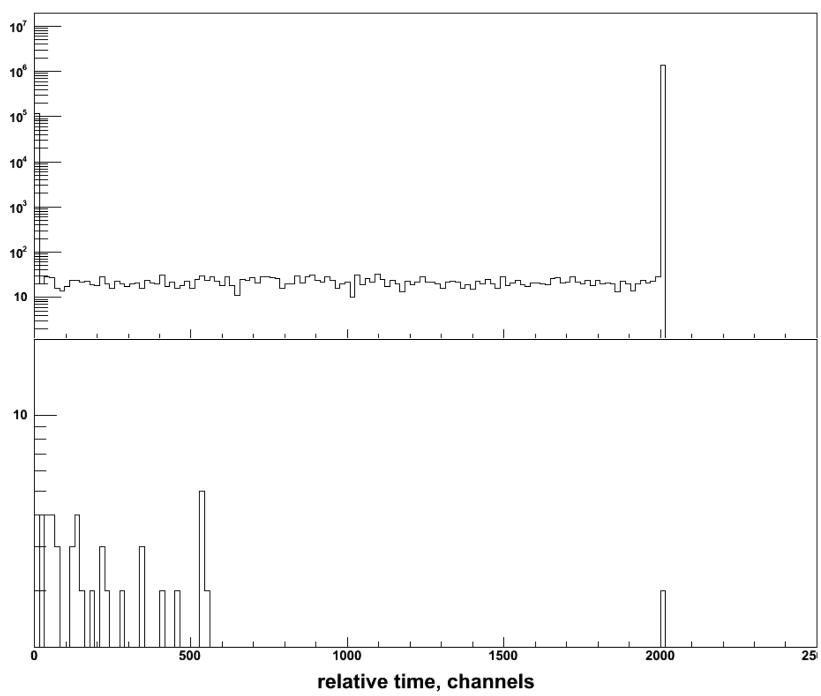

FIG. 3. Top panel: pileup rejection TAC for all events. Bottom panel: pileup rejection TAC for filtered events. An entry in channel 2000 means that there was not another event for 8us after the event of interest.

Fig. 4 shows the E vs t plot for all events (black), for events selected with the IC profile filter (blue) and filtered events requiring no pileup in the pileup rejection TAC (red) for the runs that were analyzed. We note that the filtered events (blue) indicate at face value products heavier than Au. However the majority of those events have entries in the pileup rejection TAC between 0 and 500 indicating that these events result from pileup. The events which indicate no pileup according to the pileup TAC rejection measurement are shown in red and also indicate heavy fragments.

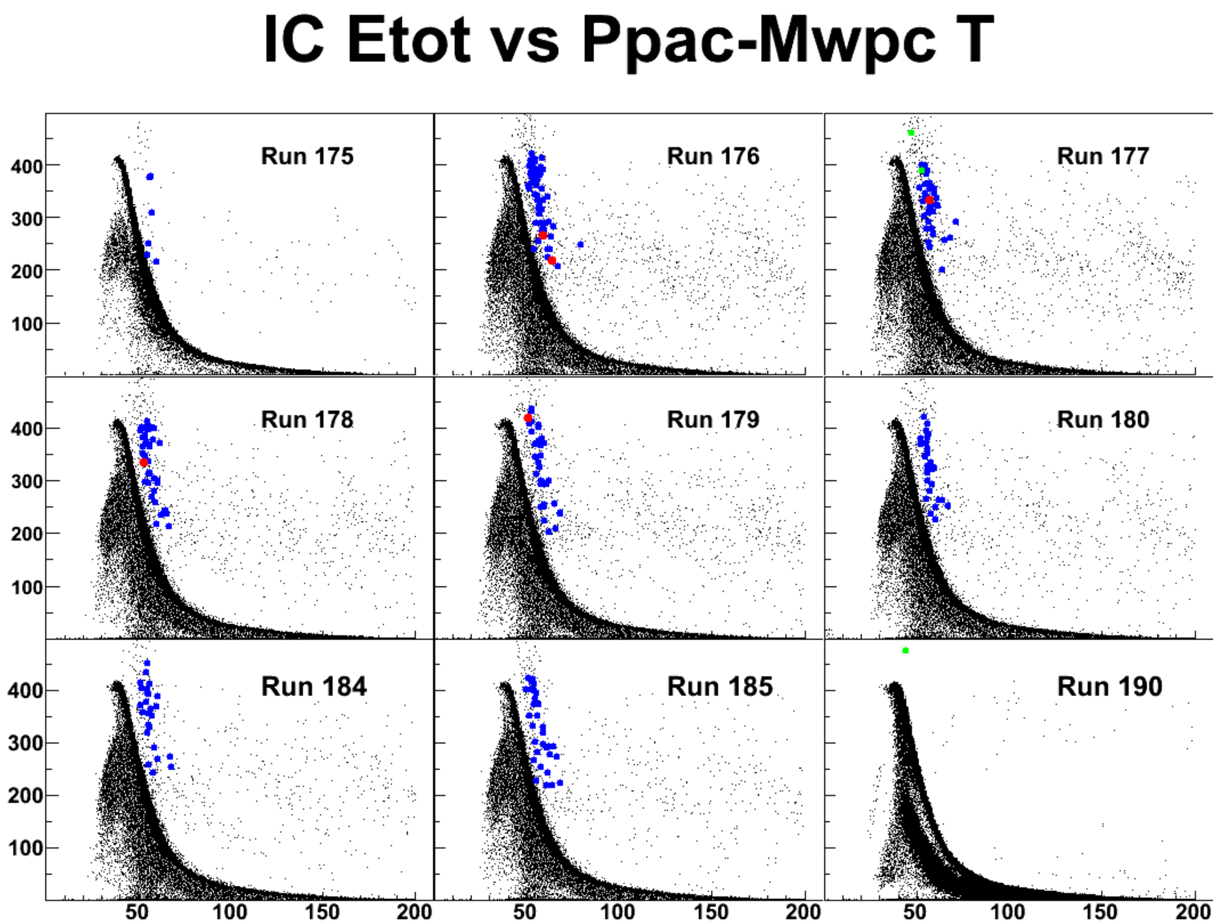

FIG. 4. E vs t for all events (black), IC ΔE profile filtered events (blue) and IC ΔE profile filtered events with no pileup (red).

We have also checked the various redundant timing measurements for the filtered events and found that most events have all time measurements consistent. In particular, those with tagged as pileup free had consistent time measurements.

We now exploit the flash ADC information to check further for consistency of the interesting "pileup free" events (red symbols in Fig. 4). We show in Fig. 5 a plot of the energy loss in the IC as measured from the peak sensing ADC vs the energy loss as measured from an analysis of the flash ADC. The black symbols show all events in the sample. The diagonal line shows where both measurements are equal and is drawn to guide the eye. We note that the majority of events yield the same energy measurement when obtained from the peak sensing ADC or from the flash ADC. There are, however, events away from the diagonal indicating an inconsistency in one or both energy measurements. The blue symbols show the IC ΔE profile filtered events. These events are for seen for the most part to be away from the diagonal line indicating an inconsistency in the measurement of those events. The red symbols show the IC ΔE profile filtered events with the pileup rejection condition added. It is seen that only one of those events shows consistency between the two measurements.

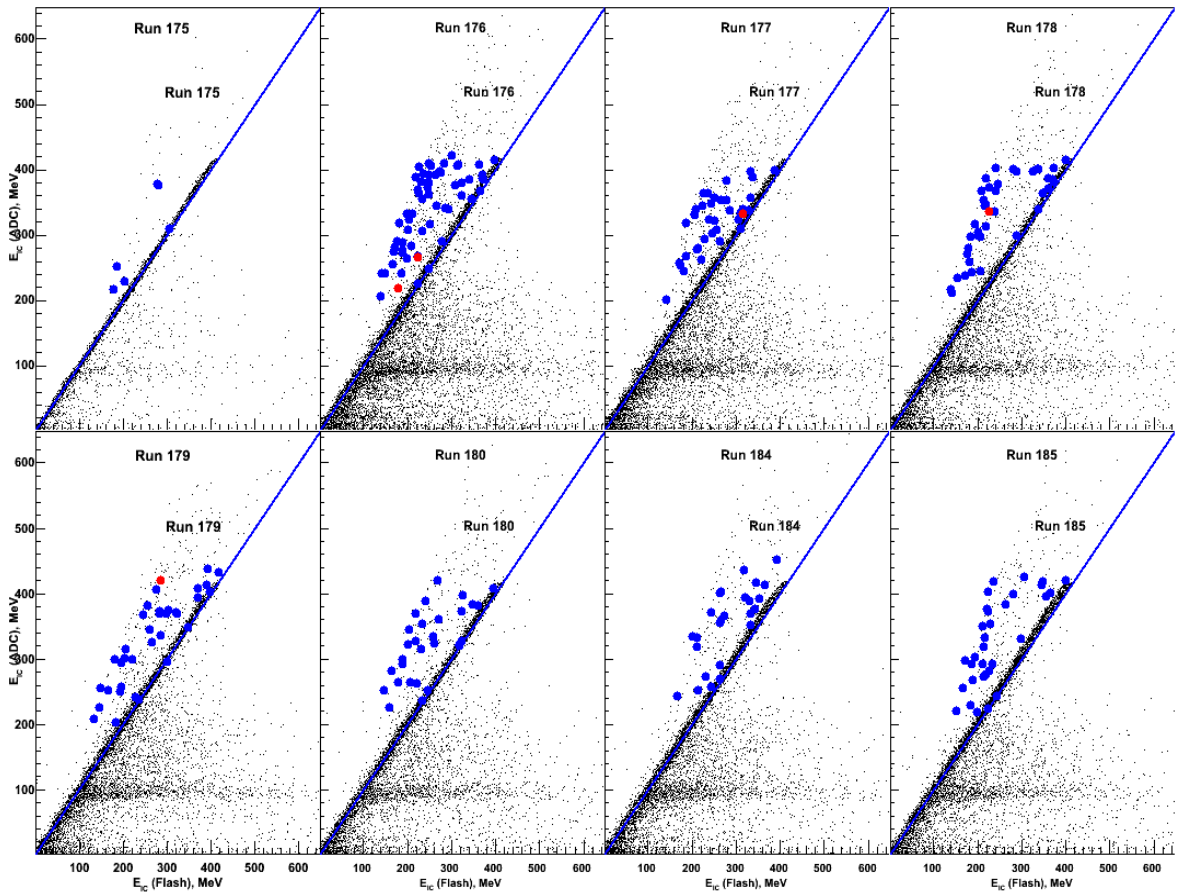

FIG. 5. E derived from Flash ADC plotted against E derived from Peak sensing ADC.

We have investigated the reason for a mismatch in measurements between a peak sensing ADC and the flash ADC. It is possible with a very low probability there could be an event which occurred near the end of an acquisition gate that was integrated by the shaper and was followed by a real event occurring at a very short time after the end of the acquisition of the previous event. This new event could have ended up as a signal added to that accidental event in the shaper and therefore passed to the peak sensing ADC. The events in the flash ADC are not shaped and therefore the previous accidental event would not have been observed in the flash ADC.

More work needs to be done to establish whether the one event that survives all cuts is real. Nevertheless, we used PPAC1 as a monitor and calibrated it using direct beam to obtain an estimate of an upper limit of the cross section of such events. Using that information, we have established that for the amount of data analyzed to date that one event would indicate a cross section between 55-60 nb.

We are planning an experiment designed to increase the statistics to lower the upper limit of our measured cross section. We are also exploring ways to upgrade our pileup rejection techniques. In particular, pulsing the beam such that there would be no beam on target during the readout of an event would eliminate accidental events of the type that we speculate are causing the discrepancy between the peak sensing and flash ADC. We are also considering segmenting the anodes across the IC in an attempt to more easily recognize pileup events.

[1] P. Sahu *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2007-2008), p. II-1.