Investigation of the use of multi-nucleon transfer reactions between very heavy nuclei for heavy element synthesis

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Previous tests with a plastic scintillator array demonstrated that the use of a time filtering device to search for alpha decay following reactions between 7.5 MeV/nucleon ^{197}Au and ^{238}U with ^{232}Th was feasible even in the harsh environment encountered in such experiments.

While fast plastics provide the optimum in time resolution, the quenching of the light-output inherent In solid scintillators meant that, within the scintillator itself, discrimination between high energy alpha particles and spontaneous-fission fragments could be difficult. Since the active catcher has a much higher inherent efficiency than the ionization chamber array we decided to explore the use of scintillator materials offering pulse shape discrimination possibilities.

A second active catcher array was constructed using YAP scintillating detectors coupled to Hamamatsu PMTs via Lucite light guides. The YAP scintillators, obtained from Proteus, were chosen because of the fast rise time and light decay properties (t1=~14ns, t2=~140ns) that provide access to pulse shape discrimination based particle identification. An example of the typical separation achievable is provided in Fig. 1 with labeled gated regions.

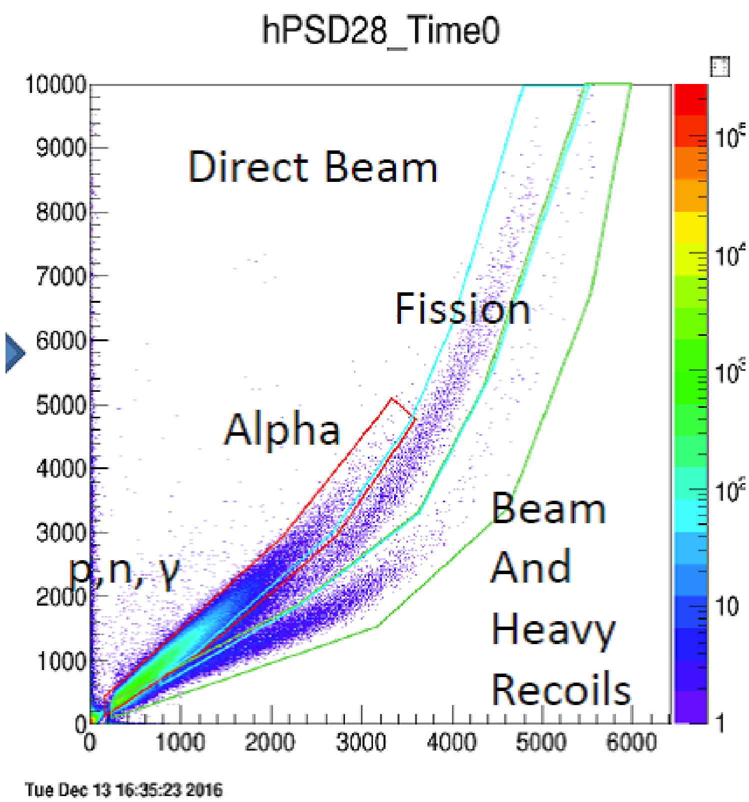

FIG. 1. Pulse shape discrimination of YAP active catcher ,7.5 MeV/nucleon ^{197}Au +^{232}Th direct beam.

It is important to note that the PSD (fast vs slow light output) shown in Figure 1 is sufficient to separate alpha decays from fission fragments, degraded beam and heavy residues.

The time decay constants inherent in YAP scintillators are notably slower than the fast plastic utilized previously. Thus, the dedicated, custom-made electronics and trigger scheme employed for the plastic scintillator array could not be easily adapted to these detectors. For this reason we turned top commercially available electronics for the YAP array. An experimental set-up triggering and signal acquisition scheme based upon the Struck SIS3316 250MHz Flash ADC modules was developed. These modules provide flexible digital triggering mechanisms. The trigger scheme utilized in the experiment was based on three operational considerations.

1. The experiment was carried out in a pulsed beam mode with variable beam on/beam off times.
2. The backward angle silicon detector modules generated triggers at a relatively low rate and very high quality.
3. While the SIS3316 modules could trigger in a mode very similar to the first-generation analog electronics. Such operation required vetoing ~40% of the time due to the convolution of 4ns FADC bins with the broader YAP decay times (relative to the plastic).

To avoid the problems associated with the last point, we decided to allow the forward angle YAP detectors to trigger acquisition only during the beam off periods.

The triggering scheme was divided into two primary modes, beam on and beam off. During the beam on periods, only the silicon detectors triggered the acquisition. The active catcher array was read in slave mode and a 2us waveform stored for each active catcher module. The synchronization between Si and YAP was set so that a coincident exit peak in an active catcher module would appear at ~800ns into the 2us waveform. During the beam off periods, the active catcher detectors were permitted to trigger the acquisition. Two microsecond waveforms were stored only for modules that triggered during the event. Because the trigger was generated entirely digitally, the beam on/off trigger mode was swapped using beam on/off bits provided to the acquisition system.

A third overarching trigger was also built into the logic. This intermittent trigger was applied to the silicon detectors. The threshold for this trigger was set to 8-8.5 MeV energy in the silicon detectors. For events generating the second, high energy trigger signal, the beam was pulsed off for 20 seconds and the acquisition set into the beam off trigger mode. Additionally, the stored waveforms were modified to be 160us long.

In August 2016, Experimental data were taken using the YAP active catcher array coupled to the backward angle IC-Si detector modules. Beams of ^{197}Au and ^{238}U of 7.5 meV/nucleon were incident on ^{232}Th targets. The digital triggering worked very well in conjunction with the now YAP based active catcher array.

The data are currently under analysis.