Production of super heavy elements using multinucleon transfer reactions

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A problem of significant interest in nuclear science has been the production and chemical characterization of super-heavy elements (SHEs) [1]. The most commonly used (and thus far successful) technique for SHE synthesis is to fuse a light projectile with a heavy target (such as a Ca projectile on a Cf or Cm target) [1-4]. Fusion reactions lead to the formation of a highly excited compound nucleus (CN). De-excitation of this CN can result in fission or the production of heavy isotopes. Additionally, fusion reactions typically produce nuclei that are neutron deficient relative to the line of beta stability, thus producing SHEs that are more likely to undergo β^+ decay. With these limitations in mind, multinucleon transfer has been examined as an alternative reaction mechanism for SHE production, especially to synthesize longer-lived, neutron rich isotopes [5-8].

We would like to continue the investigation on multinucleon transfer to see if it is a viable mechanism for SHE synthesis. Reactions using ^{22}Ne on ^{232}Th, ^{197}Au on ^{208}Pb, and ^{208}Pb on ^{208}Pb have been conducted by Aditya Wakhle using an Yttrium Aluminum Perovskite (YAP) active catcher (AC) detector array and ionization chamber-Si detectors in the same setup used in Ref. [8]. With this detector setup, the purpose is to measure the energies of alphas and establish alpha decay chains for the identification of decaying heavy isotopes. To aid with isotope identification, we can extract decay curves from the alphas identified in both the YAP ACs (Fig. 1) and the IC-Sis (Fig. 2).

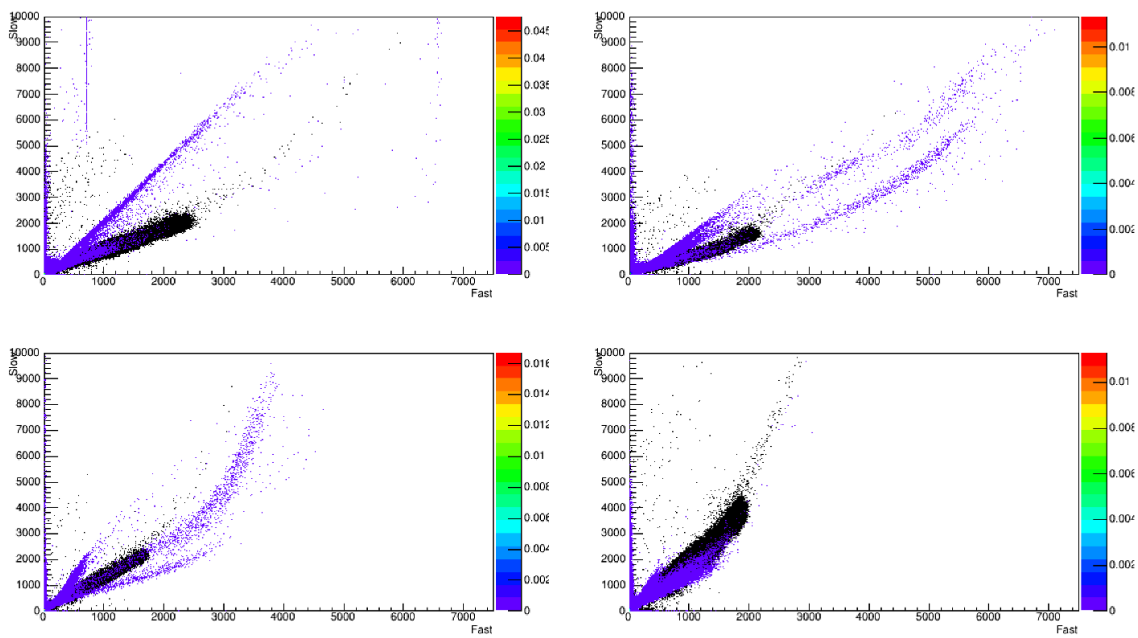

FIG. 1. Pulse shape discrimination plots for the YAP AC array. Shown are representative plots for each of the 4 rings (from top-left to bottom-right: ACs 1, 13, 30, and 39). The data shown was taken from the Au + Pb run. Here, the data collected from beam is plotted over the data from the calibration source. Note that the slow is plotted as a function of the fast.

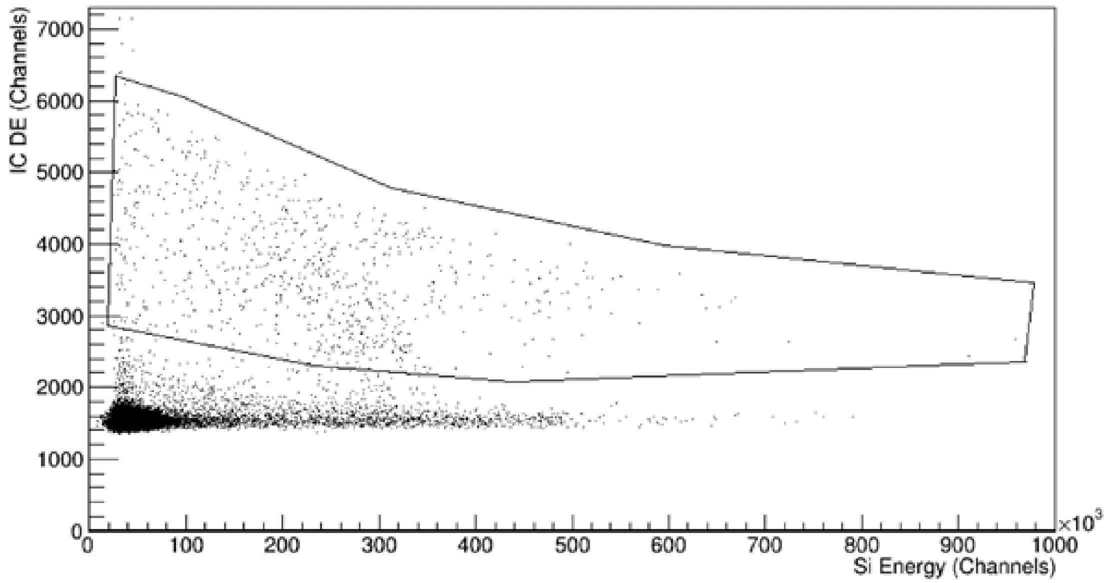

FIG. 2. An example of an DE_E plot for one of the IC-Sis. Here, the IC DE is plotted as a function of the Si energy. In the figure, a gate is drawn around the alpha branch. Below this branch are protons. The Au+Pb run data was used for this plot.

To begin the data analysis, the gain-matching and energy calibrations of the YAP ACs were examined. The gain-matching for the YAP ACs were updated. The detectors had been calibrated and gain-matched in earlier runs, but it was necessary to check if any drifting had occurred or if there were any issues with the calibration curve. As a result of the non-linearity of the energy calibration for the YAP scintillators, some higher energy (>12 MeV) particles were not accurately displayed in the PSDs.

Particle identification for the alphas was done by examining the pulse-shape discrimination plots (PSDs) of the YAP ACs and the ΔE-E plots for IC-Si plots. In order to identify the α particles in PSD plots, an a α particles band from a ^{228}Th calibration source was overlaid on the PSDs collected from beam (Fig. 1). In Fig. 2, the α particles are shown within the gate. Below this branch, lighter charged particles, such as protons, are present.

The next short-term goal of this project is to extract decay curves. To do this, we will examine data collected using a beam pulser and offline counting. In the pulsed beam mode, the beam was turned on and off throughout the run, with 30 ms beam-on and 30 ms beam off. From the pulser, we can measure the half-lives of short-lived heavy isotopes within a 30 ms beam-off window. This has already been examined for the IC-Si plots. Preliminary analysis for this was done by looking at different time windows (e.g. 0 to 2.5 ms, 0 to 5 ms, 0 to 15 ms, and 0 to 30 ms) during the beam-off period at certain energy ranges. Further refinements to this procedure are currently being examined. We will next perform this procedure on the AC detector array. For longer lived nuclei, offline counting after beam will need to be examined. From this, we can use the energies of the emitted alphas and the half-lives to identify the heavy isotopes.

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