Progress on campaign surveying deep inelastic multi-nucleon transfer for creation of super- and hyper-heavy elements

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In recent years, we have investigated the deep-inelastic transfer method for creating new super- and possibly hyper-heavy nuclei. As of our last report [1], we were in the process of constructing an improved ionization chamber based design for detection of alpha particles emitted from the reaction products. An approximate schematic of the detection set up is provided in Fig. 1.

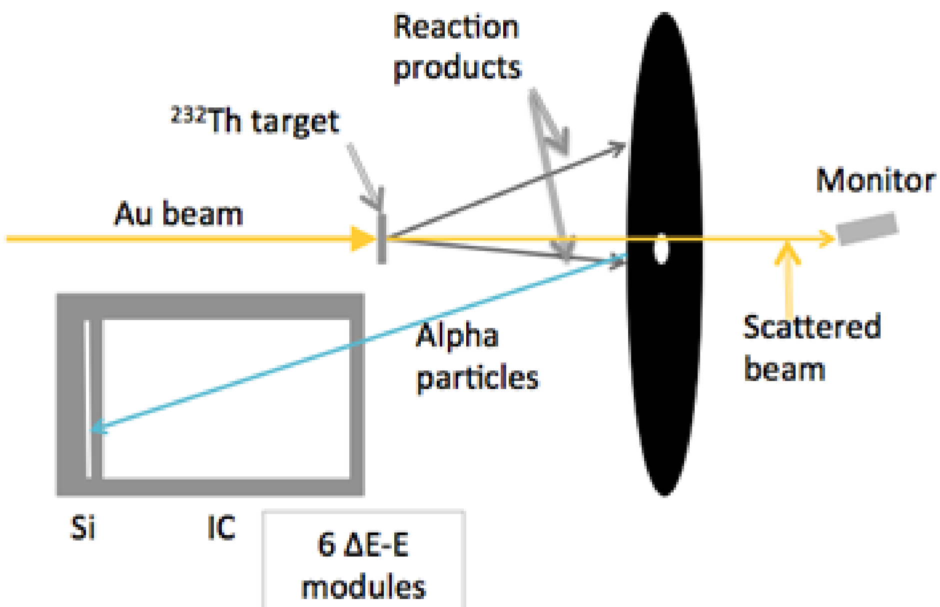

FIG. 1. Schematic arrangement of detectors versus target, catcher foil, and monitor for experiments.

The ionization chambers were constructed as described in [1], with the following modifications: PPACs were not included, and the 16 strip detectors were omitted.

Three experiments were carried out in the last year utilizing these ionization chambers to observe 7.5MeV/A ^{197}Au+^{232}Th reactions. During the first experiment, a variety of beam pulsing times were surveyed. These beam on/off scenarios provided alpha energy dependent growth and decay curves. Example curves are provided in Fig. 2 for the 100ms on/off beam pulsing. It is clear from these data, that as the alpha energy increases the particles observed are emitted from nuclei with increasingly short half-lives.

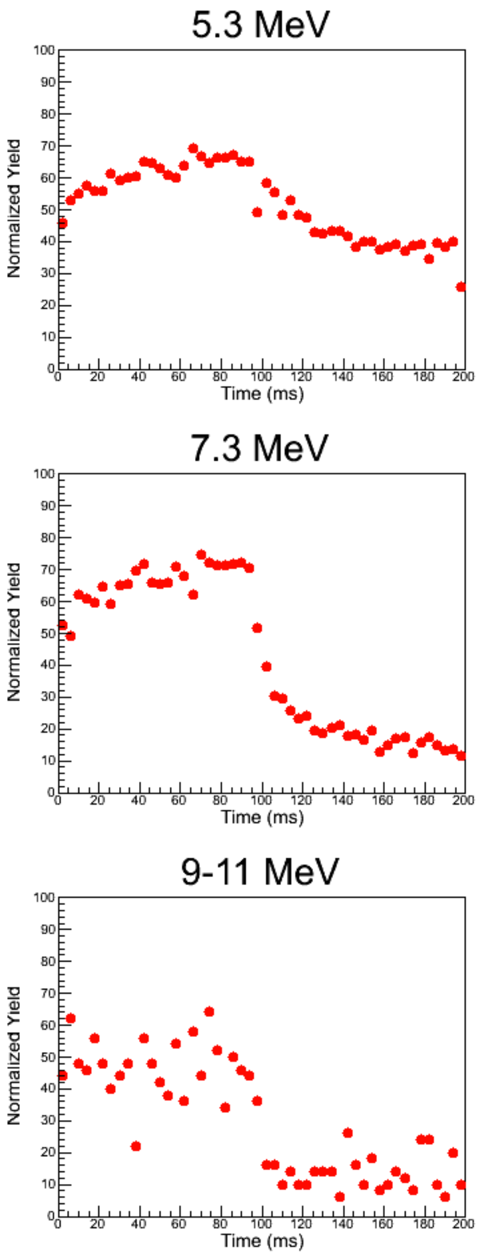

FIG. 2. Yield versus time curves divided into energy windows. Data was obtained with 100ms on/off beam pulsing.

A collective plot of all beam on/off events is provided in Fig. 3. Here we must point out difference in relative intensity between beam on/off events as well as the evolution of distribution shape with alpha energy. The evolution of distribution shape has been shown to be dependent upon the choice of beam on/off interval. The ratio of beam on/off events reaches as high as a factor of 80 in the 9-10 MeV region.

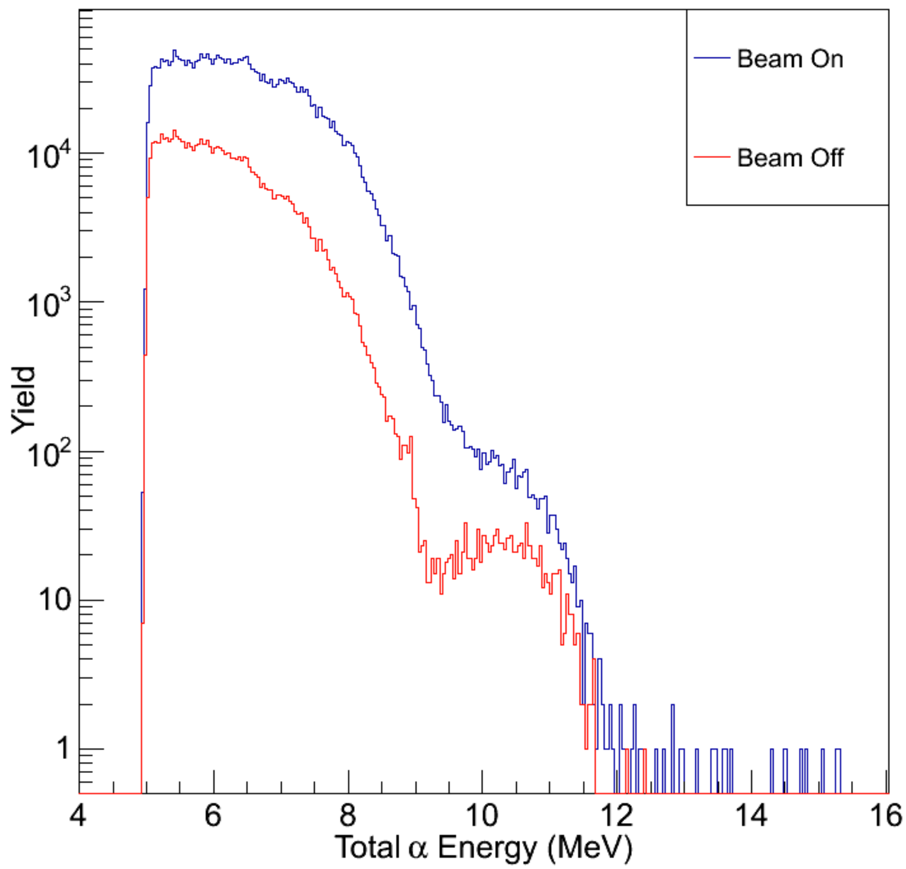

FIG. 3. Yield of detected alpha particles versus total energy lost in the ΔE-E detectors and windows. The top curve (blue) reflects alphas arriving during the beam on period and the lower curve (red) alphas arriving while the beam was turned off.

It must be noted that the 'total' alpha energy, plotted in Fig. 3, does not include any energy lost prior to entering the ionization chamber. Two-body kinematics calculations [2] estimate that interesting super-heavy events may implant as much as 40 μm into the polypropylene catcher foil. This implantation depth was explored during the second experiment of last year. Three thicknesses of catcher foil: 1ply, 2ply, and 4ply (each ~20 μm thick) were tested. After normalizing to total incident beam, the alpha yield distributions indicated that the alpha-emitting reaction products implanted within the first two layers of polypropylene. Calculations utilizing the energy loss code of Barbui *et al.* [3] and SRIM indicate that the observed alpha energies shown in Figure 3 may be 0.5-3 MeV lower than their true values.

The major challenge moving forward will be to correlate detected alphas into decay chains. To do so, we are designing and building an active catcher array to replace the polypropylene foil. This array will consist of ~96 modules of fast plastic read by phototubes. In addition to determining correlations, the active catcher array will provide the capability to identify and/or eliminate ternary alpha emission as a source of high-energy alphas. Prototype modules from the active catcher array were tested during the third heavy element experiment of last year. These modules provided good timing resolution but may not be sufficiently radiation hard. We are investigating including diamond detectors for active catcher angles at which scattered beam is most damaging.

[1] S. Wuenschel *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2012-2013), p. II-15.
[2] http://nrv.jinr.ru/nrv/webnrv/kinematics/two_body.php
[3] M. Barbui *et al.,* Nucl. Insrum. Methods Phys. Res. **B268**, 2377 (2010).