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

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In continuation of our investigations of super heavy element synthesis, we have enhanced our experimental apparatus. In the previous version[1], heavy reaction residues were collected on a passive foil. Alpha particles emitted by the residues were then collected in 8 IC-Si modules located upstream of the target. The passive catcher foil has been replaced by an active catcher: a collection of 63 BC-418 fast plastic scintillator coupled to photomultiplier tubes via light guides (Fig. 1). This design enhancement provides position information for correlation with the alphas detected in the backward direction and may lead to the ability to follow alpha decay chains. In addition, a mounting system was constructed that provides increased control and reproducibility in IC-Si module positioning. Finally, the IC was shortened to increase the fraction of the active catcher to which each IC-Si is sensitive.

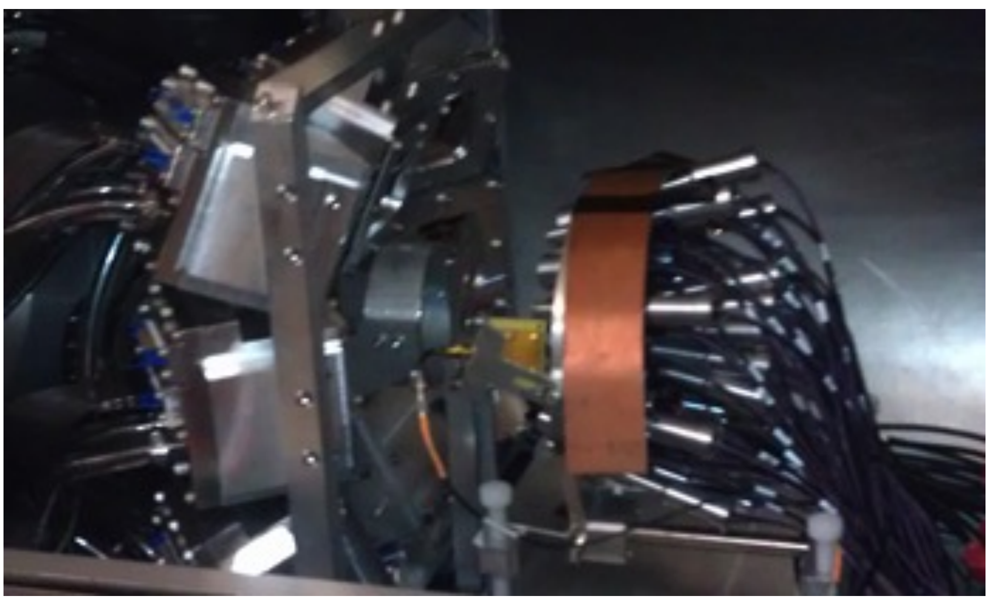

FIG. 1. Experimental setup. Beam enters from the left. Active catcher array is on right hand side.

The fast plastic PMT output was collected using Caen V1742 flash ADCs configured to provide 1 microsecond of waveform in 1 nanosecond buckets (Fig. 2). The waveforms provide the capacity to observe residue implantation, implantation then decay, and fast decay chains. We discovered that gammas emitted during beam/target interaction provide consistent and distinctive peaks in the waveforms. This provides a check of the RF beam time location and a sensitive probe for the presence of beam during nominally beam-off periods.

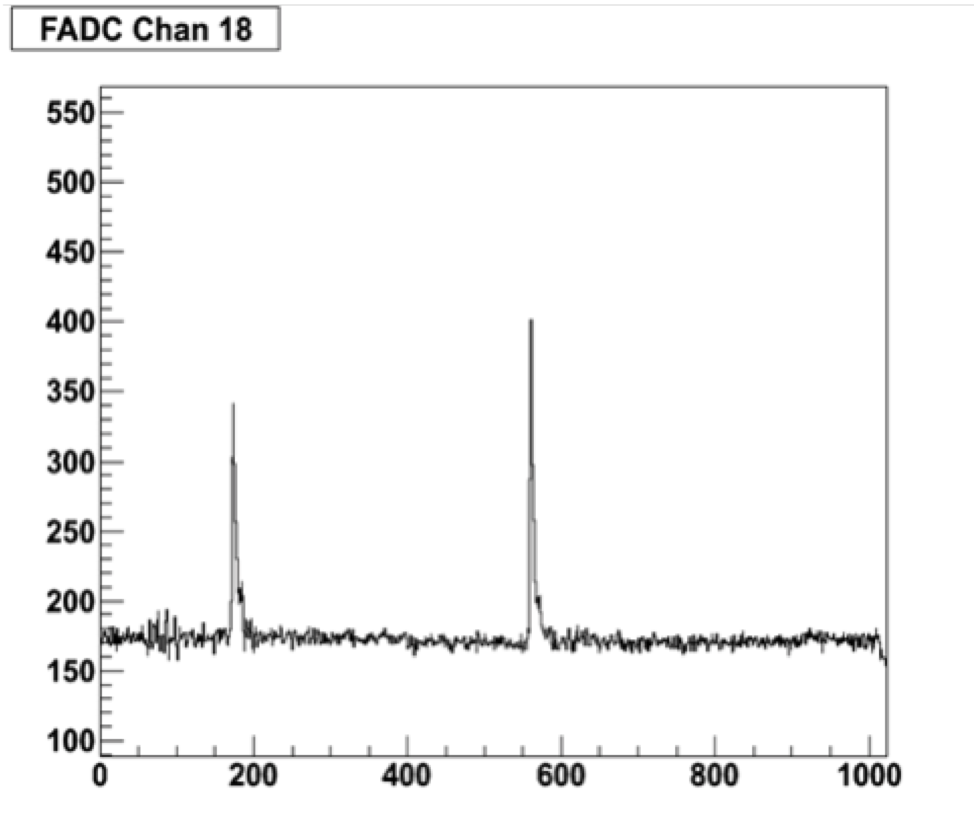

FIG. 2. Active catcher waveform.

The experimental array was used to collect data for nearly two weeks. However, the timing correlation between the IC-Si and the fast plastic was not calibrated to sufficient precision. This caused ambiguity in correlation between signals in the fast plastic and alphas detected in the upstream IC-Si modules. We believe that the correlation can be recovered in future experiments by a very careful time calibration.

Several improvements are being investigated for the next experiment. The fast plastic is unable to independently differentiate alpha particles from fission fragments and residue implantation and has exhibited poor energy resolution in our implementation. We are investigating two options for replacing the current fast plastic. YAP scintillators would retain the fast timing characteristics and allow for pulse shape discrimination based separation of the alphas from heavier fragments [2] because of its two component light output (Fig. 3). Another alternative to the current fast plastic would be the use of scintillating fibers. Scintillating fibers have a fast rise time and would eliminate the need for the light guides that are negatively affecting the fast plastic energy resolution. In addition, active bases will eliminate concerns about overheating in vacuum and increase the gain stability of the PMTs over time.

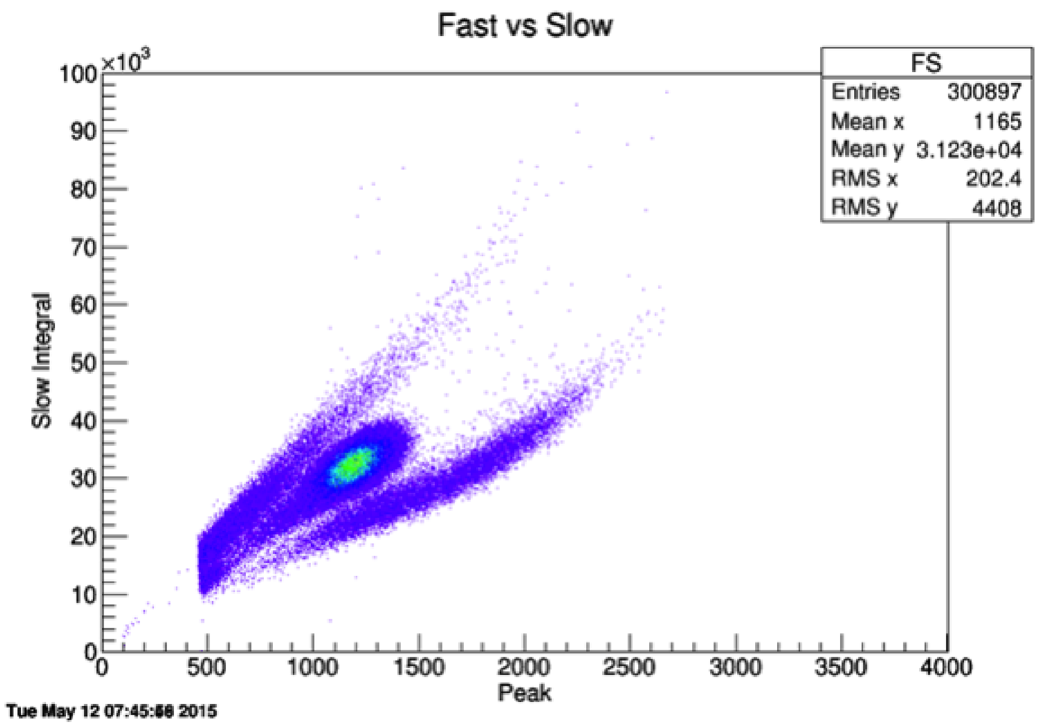

FIG. 3. Test of YAP scintillator with 252Cf. Alphas constitute the peak in the center. The lower band is fission fragments.

[1] S. Wuenschel *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2013-2014), p. II-14.

[2] M. Barbui, Ph. D. Thesis, Università degli studi di Padova, 2005.