**Test runs the multi-nucleon transfer reaction detector array for synthesis of heavy elements**

A. Wakhle, K. Hagel, A.B.Mcintosh, M. Barbui, J. Gauthier, A. Jedele, A. Rodriguez Manso, J.B. Natowitz, R. Wada, S.Wuenschel, A. Zarrella, and S.J. Yennello

An IC-Si and YAP active catcher array was constructed in 2016 [1] to study multi-nucleon transfer reactions forming heavy elements. The array consists of 40 YAP scintillating detectors coupled to Hamamatsu PMTs via Lucite light guides at forward angles, and 8 IC-Si detectors at backward angles (see Fig. 1). In August 2016, experimental data were taken using this array: a beam of $^{238}$U at 7.5 MeV/nucleon was incident on a $^{232}$Th target. Digital signal processing was achieved using the Struck SIS3316 250MHz Flash ADC modules, and worked very well in conjunction with the YAP based active catcher array.

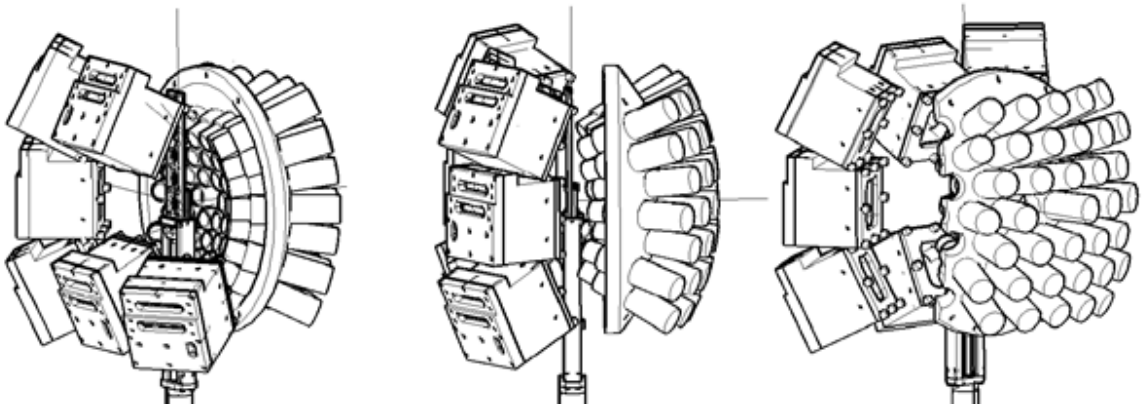

**FIG. 1**. Schematic of IC-Si and YAP detector array.

The results of this experiment have been recently accepted for publication [2], and this first 'physics' measurement has shown tantalizing glimpses into the synthesis of elements with Z as high as 116. Differential cross sections are also presented in [2]. Clear identification of alpha chains was not possible due to the difficulty of analysis, and the relatively uncharted and violent reaction landscape of $^{238}$U+$^{232}$Th.

We are preparing for a series of test runs with the motivation to benchmark the detector against a previously measured reaction ($^{22}$Ne+$^{232}$Th), and a second reaction ($^{208}$Pb+$^{208}$Pb) populating residues with known alpha decay energies and half-lives. Details of the two proposed reactions follow:

**$^{22}$Ne + $^{232}$Th**

A $^{232}$Th target will be bombarded with a $^{22}$Ne beam at 143 MeV (6.5 MeV/nucleon) to measure the production cross sections of $^{227}$Th, $^{226}$Ac, $^{225}$Ac and $^{224}$Ac. These nuclides are long-lived and will be implanted in the forward angle YAP Active Catcher, to determine their activities/cross sections by simple alpha counting in a backward angle Si+IC array. The cross sections will be compared to the measurement

of Kumpf and Donets [3].

**$^{208}$Pb + $^{208}$Pb**

A $^{208}$Pb target will be bombarded with a $^{208}$Pb beam at 1456 MeV (7 MeV/nucleon) to measure the production cross sections of nuclei with 82<Z<92 and 208<A<228. These nuclides decay primarily by alpha emission with alpha energies between 7MeV and 10MeV, and half-lives ranging from ~1s down to a few 100ns. The ability (and efficiency) of the detector array to identify alpha chains will be benchmarked against known alpha chains in this region of the nuclear chart, and to establish parent-daughter relationships.

We expect these measurements will streamline the analysis procedure for future campaigns, and help identify alpha chains in decays of nuclides with Z>110. The measurements will be performed under identical trigger logic and detector setup to the previous experiment (see annual report from 2017 [4]). All detector signals will be processed using the Struck SIS3316 250MHz Flash ADC modules.

[1] S. Wuenschel *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2015-2016), p. II-21.
[2] S. Wuenschel *et al.*, arXiv:1802.03091 (2018).
[3] H. Kumpf and E.D. Donets, Soviet Phys. JETP **17**, 3 (1963).
[4] S. Wuenschel *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2016-2017), p. II-15.