Alternative reaction paths to heavy elements

K. Hagel, M. Barbui, S. Wuenschel, K. Schmidt, G. Giuliani , H. Zheng, N. Blando, Z. Majka, A.Wieloch, Z. Sosin, S. Kowalski and J. B. Natowitz

The search for alternative reaction paths for heavy and super-heavy element production requires a careful experimental investigation. Mechanisms other than fusion, e.g., multi-nucleon transfer or very asymmetric fission of even heavier transient systems, could have favorable cross sections for production of new isotopes. In earlier work on this problem we used the BigSol Superconducting Time of Flight Spectrometer at Texas A&M to perform several surveys of projectile target combination and bombarding energy for collisions of two very heavy nuclei (A=197 to 238) in an effort to identify good candidate reactions for heavy and superheavy element production. This experiment indicated the possibility to produce heavy elements of Z above 100 however the experiment was discontinued when the spectrometer developed a He leak which made it not possible to sustain the necessary magnetic field. Although the spectrometer is now repaired it has been relocated for use in the TAMU exotic beam accelerator upgrade and is no longer directly accessible for the required beams from the K500 cyclotron. Given this, we proposed a new direction of investigation of these alternative reactions. It is based upon the implantation of heavy reaction products in a catcher foil and the detection of alpha particle decays characteristic of these heavy nuclei. Many super heavy elements are expected to decay by alpha particle emission. Results of calculations of alpha particle Q values predicted for various heavy elements are shown in Fig.1 (M. Bender, NN2012).

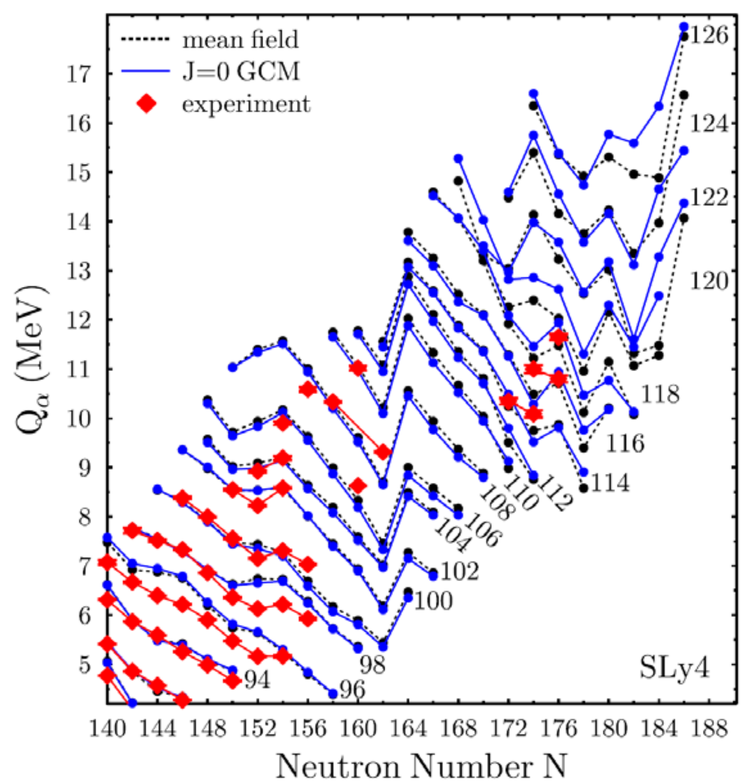

FIG. 1. Alpha Q-values for a range of heavy elements.

With increasing charge the alpha-particle Q-value increases (Momentum conservation in the decay leads to alpha particle kinetic energies which are ~2% less than the Q values.) and the expected half -lives decrease. The heaviest elements are characterized by unusually high alpha particle energies which distinguish them (in general) from the lighter elements. To aid in development of a new system to search for high energy alpha emission, we carried out test experiments in which heavy reaction products emitted in the angular range from 3° to 45° were implanted in a downstream catcher foil. Decays of the implanted nuclei were detected using ΔE and E silicon detectors placed in the backward position.The first test was in 2011. We have now constructed new detectors and done a more sophisticated test The latest test setup is depicted in Fig.2. The catcher was a polypropylene layer of thickness 7.5 μm placed at 4 cm from the target. Six newly constructed IC Si telescopes incorporating seven-strip silicon detectors surrounded the target and faced the downstream catcher foil. The 7.5 MeV/nucleon ^{197}Au beam was delivered by the K500 superconducting cyclotron and pulsed at different intervals in order to be able to identify species of different half-life (i.e. 100 ms beam-on, 100 ms beam-off; 10 ms beam-on, 10 ms beam-off etc.

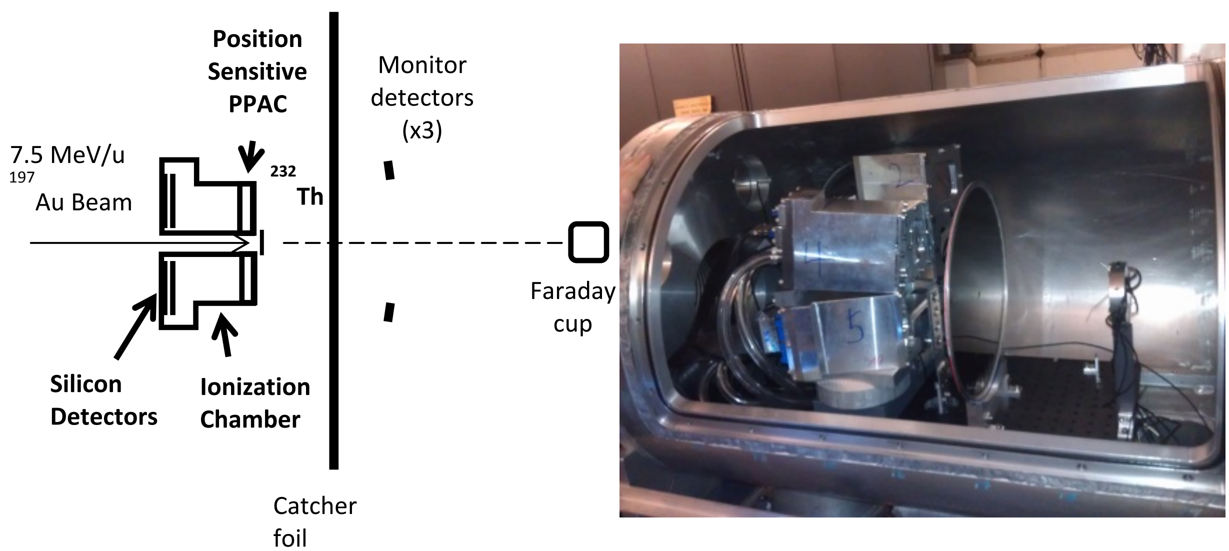

FIG. 2. Schematic (left) and photograph (right) of the test experiment (see text)

In Fig. 3 we present preliminary results for identified alpha particle detection during both beam-on (left side and beam-off (right side) times in reactions of 5-7.5AMeV ^{197}Au + ^{232}Th .. This figure includes alphas from all time sequences sampled. A large number of alpha activities, many with similar energies, were detected. The spectra indicate observation in-beam and out of beam of interesting high alpha-energy activities The analysis is underway. Concurrently, our colleagues in Poland (*Jagiellonian University, Krakow and Silesian University, Katowice)* are constructing a sophisticated active catcher system consisting of a high granularity array of scintillators read by photomultiplier tubes. This will allow us to identify the location of the implanted nucleus. We can then correlate a detected alpha decay with an implantation position and observe multiple decays from the same recoil implantation site.. They have received a grant of $400,000 to construct and instrument this system. A first test of active catcher components was carried out in November 2012. A second test will take place in August 2013. We anticipate a run with an improved configuration in the winter of 2013.

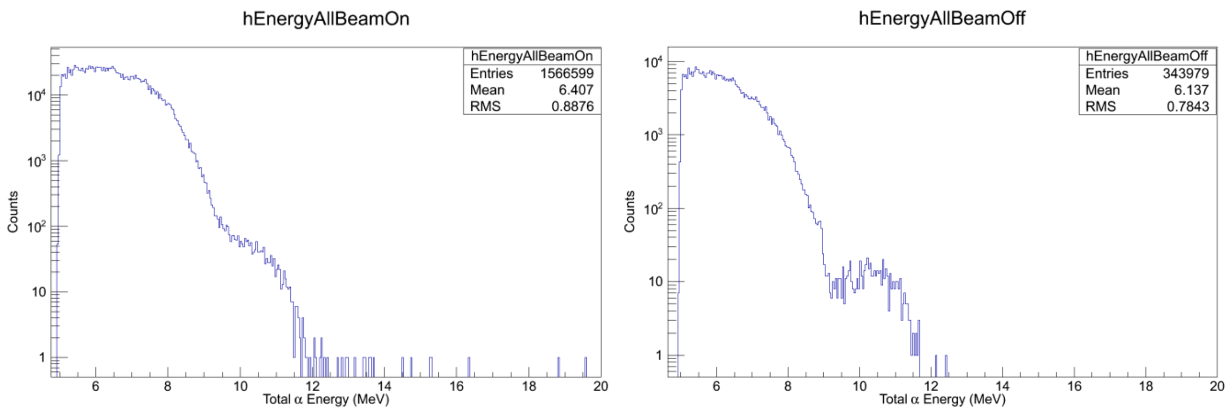

FIG. 3. Observed alpha particle decay energy distributions, beam-on(left) and beam-off (right).