

Improvements to the heavy elements program aimed toward reaching lower cross-sections at the Texas A&M University Cyclotron Institute

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With the discovery of elements up to $Z = 118$, heavy elements scientists have reached the current limit of the chart of the nuclides. Future discovery will require reaching cross-sections on the level of tens of femtobarns or below [1], requiring either an extremely lengthy beam time, or an advancement in technology that allows us to reach these incredibly small cross-sections in a reasonable timeframe. Also, projectiles heavier than the doubly-magic ^{48}Ca need to be developed due to the lack of sufficient target material of elements beyond Cf.

In the Heavy Elements group, we are interested in studying lighter system with higher cross-sections and then drawing analogies to the superheavy systems. The study of projectiles ranging from $Z = 20-24$ reacting with lanthanide targets provides a suitable system of reactions to measure excitation functions within a seven day period. However, as the atomic number of the projectile increases, the cross-section decreases to the point where the reaction of ^{54}Cr with ^{162}Dy is on the level of microbarns and below our current sensitivity limits. One factor that limits sensitivity is the need to pulse the beam. Beam pulsing greatly reduces background, but also cuts sensitivity by a factor of four. To allow the study of smaller cross-sections, improvements are being made to the detection capabilities of the Heavy Elements group that will eliminate the need for beam pulsing. Additionally, improvements are being made to the cyclotron ion source that will increase beam intensities.

MCP:

The microchannel plate (MCP) detector is a widely used type of radiation detector that consists of a series of channels that serve as continuous electron multipliers [2]. As shown in Fig. 1, when a

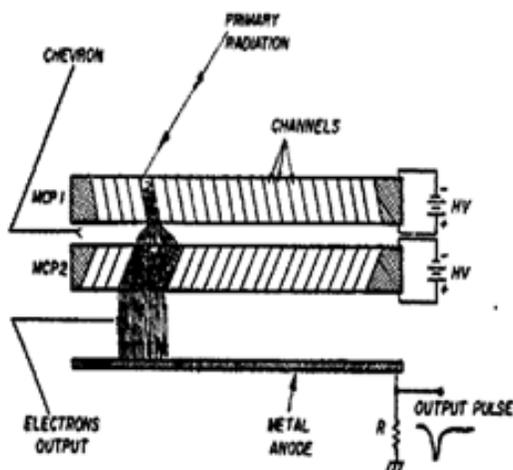


FIG. 1. Electron path and amplification through an MCP detector [2].

quantum of radiation impacts the active area of the detector, it creates a few electrons that are accelerated by a large voltage applied across the plate. Each electron collides with the walls of a channel, creating a cascade with an electron multiplication factor of 10^3 to 10^4 . In a standard detector configuration, two plates are stacked together in a chevron configuration. The two plates have a combined multiplication of 10^6 to 10^7 . After exiting the channels, the electrons are accelerated toward an anode, usually metal or a resistive material. The anode collects the electrons and creates a charge pulse.

An MCP detector was installed in the detector chamber in MARS below and parallel to the beam axis as shown in Fig. 2. The MCP detector was biased to +1800 V on the anode, and +1425 V across the plates. Ions that traverse MARS and reach the detector chamber pass through a $0.6 \mu\text{m}$ Al foil and an

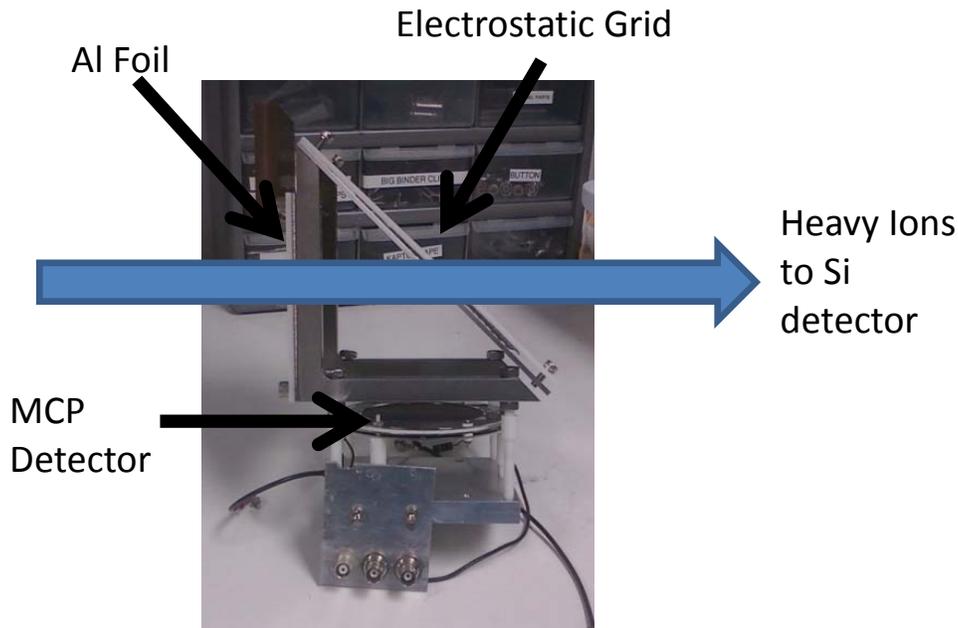


FIG. 2. Picture of the MCP detector assembly. Heavy ions (Scattered beam, scattered target, evaporation residues) pass through the Al foil. The foil ejects a few electrons, which are steered downward by the electrostatic grid.

85% transparent electrostatic grid before reaching the focal plane silicon detector. The foil and grid are each biased to -200 V. As the ions pass through the foil, several electrons are knocked off the Al and accelerated toward the MCP by the field created by the foil, grid, and the detector. The silicon signal is used as the ‘Start’ signal for a Time-to-Amplitude Converter (TAC). The MCP detector signal is delayed and used as the ‘Stop’ signal. The TAC records the time difference between the two pulses and digitizes the signal as a voltage pulse. This creates a unique signal for all ions that implant in the silicon detector and can be used to separate out radioactive decays from these implantation events, significantly reducing background as shown in Fig. 3. Thus, using the MCP detector allows us to eliminate the need to pulse the beam, giving a factor of two increase in beam dose, and a factor of two increase in the collection time where alpha decays of the evaporation residue (EvR) can be observed. Analysis of the data suggests that the efficiency of the MCP detector for EvRs is at least 99%.

Series of Si energy spectra with unpulsed beam and gating on MCP

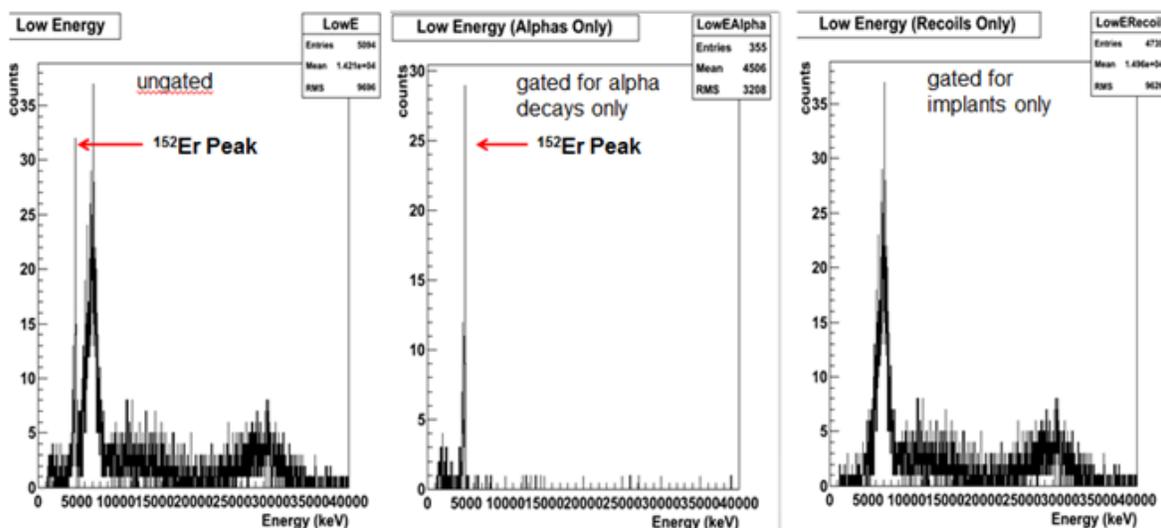


FIG. 3. Representative energy spectra for the products of the $^{40}\text{Ar} + ^{118}\text{Sn}$ reaction without beam pulsing, but instead using the MCP to gate on the alpha decays. ^{152}Er is the product of interest. *Left:* Ungated spectrum including implants and radioactive decays. *Middle:* Spectrum gated for only radioactive decays in the silicon detector. *Right:* Spectrum gated for only implants in the silicon detector.

Oven and Target Wheel:

The development of a high-temperature oven is in progress and should be completed by the summer of 2012. The design is similar to the oven constructed for use with the Electron Cyclotron Resonance (ECR) source for the 88-inch cyclotron at Lawrence Berkeley National Laboratory [3]. The oven should provide higher beam intensities than currently available techniques such as metal sputtering. The higher intensities will increase our sensitivity to low cross-section exit channels.

With the expected higher beam intensities, we need a target system that can tolerate the larger beam power. To accomplish this, a rotating target wheel has been designed, is under construction and is discussed in a separate contribution to this report. The wheel is based on the design used in the TASCAs separator at GSI, Darmstadt, Germany [4]. The wheel will consist of three, banana-shaped holes that hold the targets and will rotate at a maximum of 1700 rpm.

Conclusions

Due to the incredibly tiny cross-sections for producing superheavy elements, our group's focus is on producing lighter nuclei with higher cross-sections, then drawing meaningful analogies to superheavy nuclei. To reach the required sensitivities for our reactions, a microchannel plate detector was developed and implemented to differentiate implantation events from alpha decays, thus eliminating the need for beam pulsing. The detection efficiency for the implanting ions is at least 99%. Additional improvements

are being made to reach even lower cross-sections. These include a high-temperature oven that will provide higher beam intensities, and a rotating target wheel to tolerate the high power from the beam.

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