Precision Mass Measurements for the Astrophysical r process at Argonne National Laboratory

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The astrophysical r process must take place in a environment of high temperatures and neutron fluxes, to allow for the rapid captures of neutrons that take it far from the valley of stability. The multi-messenger neutron star merger GW170817/AT2017gfo has provided direct evidence of r-process nucleosynthesis, but this does not fully resolve the r-process site. A complete picture will require the comparison of modeled r-process abundances with observed abundances; a recent sensitivity study has shown that key among the data going into these simulations are nuclear masses [1].

The Canadian Penning Trap mass spectrometer (CPT) at Argonne National Laboratory measures such masses using the state-of-the-art phase-imaging ion-cyclotron-resonance technique, which provides an increase in both precision and sensitivity to lowly-produced nuclei over the time-of-flight ion-cyclotron-resonance technique. The CPT is currently located at the CARIBU facility of Argonne's ATLAS accelerator, where it measures masses of interest to the formation of the rare-earth peak in the r-process abundance pattern which are produced from the spontaneous fission of CARIBU's Californium-252 source [2, 3].

The next step in r-process studies for the CPT will be the measurement of masses of interest for the formation of the heaviest $A \sim 195$ r-process abundance peak. Traditional particle-fragmentation, target-fragmentation, or fission production techniques will not efficiently produce these very neutron-rich nuclei around the $N = 126$ shell closure. Multi-nucleon transfer (MNT) reactions between two heavy ions, however, can produce these nuclei effectively[4]. The $N = 126$ factory currently under construction will use MNT reactions to produce such nuclei [5]. Due to the wide angular distribution of these reaction products, a large-volume gas catcher will be used to convert these reaction products into a low-energy continuous beam, and then a mass separating magnet, RFQ cooler-buncher, and MR-TOF will convert the high-emittance continuous beam into a low-emittance bunched beam that can be delivered to the CPT for mass measurements or to other experimental devices. All of these components are currently commissioning, and the facility as a whole is currently under construction and is expected to begin commissioning within the next year.

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