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Mass measurements with the Canadian Penning Trap mass spectrometer to study the astrophysical r process

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About half of the elements in the universe heavier than iron (^{56}Fe) are believed to be produced via the r process (rapid neutron capture process), which is thought to occur during explosive astrophysical events. Due to the short-lived nature of these nuclides and the unique conditions necessary for the occurrence of the r process, our knowledge of this topic is limited. Observations from the recent gravitational wave event (GW170817) and its electromagnetic counterpart at LIGO and VIRGO have reported evidences of neutron star mergers being possible r-process sites. But exactly where the r process occurs in the merging neutron star environment, and whether merging neutron stars can alone account for all the r-process elements are still open questions. Building theoretical models and making reasonable predictions about this r process rely on the availability of mass and other nuclear data for nuclides near the expected r-process path, which is currently available in limited capacity, due to the challenges in producing the rare isotope beams (RIB) necessary for such experiments.
With the recent development of a number of advanced RIB facilities, the situation has improved. One such facility is the CAlifornium Rare Isotope Breeder Upgrade (CARIBU), at the Argonne National Laboratory (ANL), which uses the spontaneous fission of a ^{252}Cf source to produce beams of neutron-rich isotopes. The fission fragments are collected, thermalized and extracted as an ion beam, which undergoes multiple stages of purification before being sent to the Canadian Penning Trap (CPT) mass spectrometer. An upgrade to the CPT detection system allowed for the implementation of the novel detection technique, Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR), which permits us to make fast and precise mass measurements of the exotic neutron-rich isotopes nearer to the r-process path.
Recently, the masses of a number of rare-earth, neutron-rich nuclides have been measured, which are consistent with the masses needed to reproduce the solar abundance pattern in the rare-earth region for a hot, neutron star merger wind scenario, as determined by reverse engineered Markov Chain Monte Carlo simulations.

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