First direct mass measurements of mendelevium and einsteinium with an MRTOF mass spectrograph

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Precision mass measurements of trans-uranium nuclei, which provide a direct measure of the nuclear binding energy, are invaluable for nuclear structure study in heavy nuclear systems and have the potential for unique identification of atomic nuclides. Thus far, masses of only 6 nuclei of nobelium and lawrencium were directly measured with the Penning trap mass spectrometer[1,2]. Recently, we implemented a multi-reflection time-of-flight mass spectrograph (MRTOF) located after a cryogenic helium gas cell coupled with the gas-filled recoil ion separator GARIS-II[3] and performed direct mass measurements of mendelevium and einsteinium isotopes for the first time.

We produced fusion-evaporation residues (ER) of ^{254}No/$^{249-251}$Md via ^{208}Pb/^{nat}Tl(^{48}Ca, xn) reactions and ^{252}Md/^{246}Es via ^{238}U/^{232}Th(^{19}F, 5n) reactions. The ER were transported into the gas cell through GARIS-II and converted to low-energy radioactive ion (RI) beams. All isotopes were extracted as doubly charged atomic ions from the cold gas cell at 130-150 K. The extracted ions were transferred to the MRTOF, which can analyze the ions with a mass resolving power of $R_m \sim 140,000$. The MRTOF measurements were performed with a concomitant referencing method[4], wherein RI measurements and reference measurements were made sequentially in each cycle of 15 ms. The reference ions of $^{133}Cs^+$ provided from a thermal ion source were used for both time-of-flight drift compensation and mass reference. Drift-compensated spectra were fitted by an exponentially modified Gaussian function[5] (Fig. 1). Using times-of-flight for RI and reference ions, we determined the masses using a single-reference analysis method[6] and computed mass excesses and mass deviations from AME2012[7] (Fig. 2). All masses are in good agreement with AME2012 within uncertainty even for extrapolated masses. By this work, the masses of ^{246}Es and ^{249,250,252}Md were directly determined for the first time, and the uncertainties of ^{246}Es and ^{250}Md were reduced by 60%. Combining the direct masses of ^{249,250}Md with α decay Q-values of decay parents, we could determine masses of 7 heavier nuclei, up to meitnerium, for the first time.

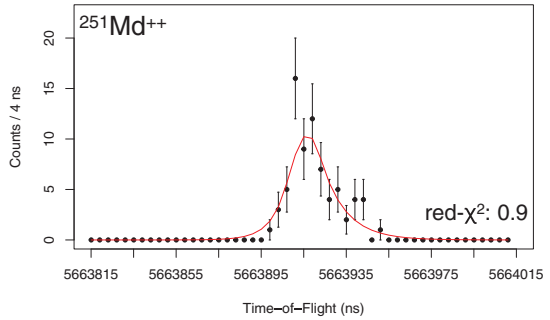

Fig. 1. Time-of-flight spectrum of $^{251}Md^{++}$ and exponentially modified Gaussian fit

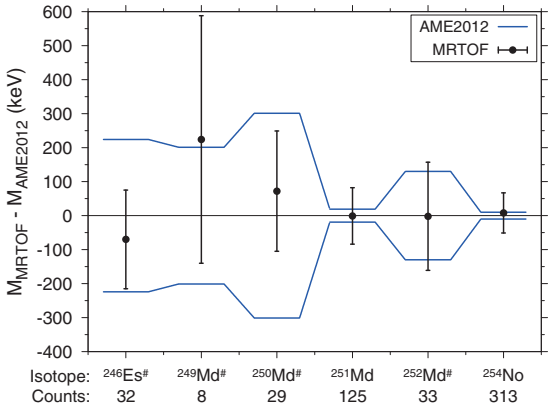

Fig. 2. Preliminary evaluation of mass deviations from the AME2012. The solid lines mark the uncertainty of the AME2012 values and # on element symbols indicate extrapolated values.

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