Improved mass measurement of ^{257}Db by decay-correlated mass spectroscopy

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We present an improved direct measurement of the atomic mass of the superheavy nuclide ^{257}Db. Atoms of ^{257}Db ($Z = 105$) were produced online at the RIKEN Nishina Center for Accelerator-Based Science using the fusion-evaporation reaction ^{208}Pb(^{51}V, $2n$)^{257}Db. The gas-filled recoil ion separator GARIS-II was used to suppress both the unreacted primary beam and some transfer products, prior to delivering the energetic beam of ^{257}Db ions to a helium gas-filled ion stopping cell wherein they were thermalized. Thermalized ^{257}Db^{2+} ions were then transferred to a multi-reflection time-of-flight mass spectrograph (MRTOF) for mass analysis. An alpha particle detector embedded in the ion time-of-flight detector allowed disambiguation of the rare ^{257}Db^{2+} time-of-flight detection events from background by means of correlation with characteristic α-decays. The extreme sensitivity of this technique,[1)] allowed a precision atomic mass determination from 22 decay-correlated events.

In our previous measurement of this nuclide,[2)] metallic Pb targets were utilized, limiting the permissible primary beam intensity to below 500 particle nA. In this measurement we tested PbS targets produced via sputtering. The targets were capable of withstanding 2 particle μA primary beam without degradation in their performance. This allowed for twice as many events in half as much time as the previous measurement, while the MRTOF's mass resolving power was significantly improved. Additionally, the implementation of a pulsed deflector,[3)] inside the MRTOF allowed selective rejection of transfer products such as ^{211}Po which had previously produced some spurious decay correlations.

Using the same correlation method as previously employed,[2)] a mass was determined for the detected ion in each decay-correlated event. A histogram of the masses is shown in Fig. 1. A Gaussian fit to the histogram data, shown in violet, indicates that a mass resolving power of $m/\Delta m = 800\,000$ was achieved; the flight time was $t \approx 17$ ms. The shape of the distribution indicates that either only a single state was present or the isomeric excitation energy is below 300 keV. The centroid of the histogram indicates a mass excess of 100 408(75) keV/c^2 for the possible mixed ensemble of states. Regardless, however, the measured mass is not in agreement with the Atomic Mass Evaluation.[4)]

Within the new set of data, only 8 decay-correlated events were determined to have had observed α-decays from ^{257}Db—the others having observed decays of ^{253}Lr or ^{249}Md. A further followup effort to gather more data and better determine the state ordering via decay-correlated mass analysis is planned for FY2022.

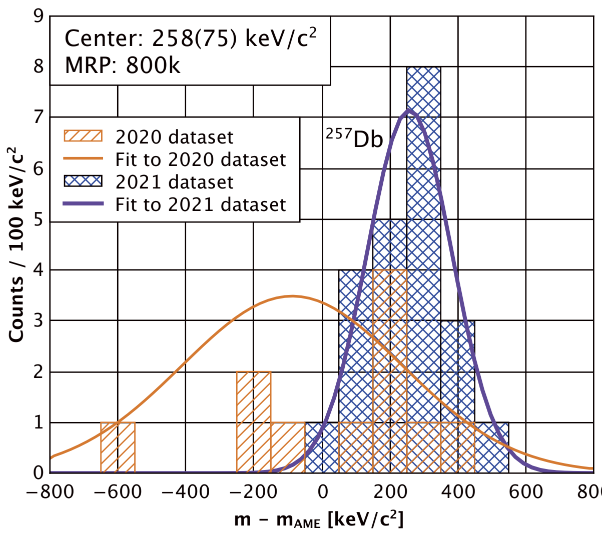

Fig. 1. Histograms of evaluated atomic masses for ions detected with subsequent α-decays consistent with ^{257}Db, ^{253}Lr, or ^{249}Md. If present, isomeric state must have excitation below 300 keV. In the legend, "MRP" refers to mass resolving power.

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