Charge-state determination for new isotopes near the proton drip-line

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Particle identification (PID) based on the ΔE-TOF-$B\rho$ method, in which atomic number Z and mass-to-charge ratio A/Q are calculated from measured energy loss (ΔE), time of flight (TOF), and magnetic rigidity ($B\rho$), does not work well for isotopes whose A/Z value is close to an integer number, such as 2 or 3. This is because hydrogen-like and fully stripped events are very closely located in a Z versus A/Q PID plot. In these cases, measurement of total kinetic energy (TKE) is additionally needed to identify the charge state. We performed such TKE measurement to calculate the charge state number Q for medium heavy proton-rich isotopes with $A/Z \sim 2$.

The experiment was performed in December 2011 at RIBF using a ^{124}Xe beam at 345 MeV/nucleon. The BigRIPS separator[1)] was used to separate and identify produced isotopes, and was tuned for very proton-rich isotopes with $Z = 30$-45. The PID based on the ΔE-TOF-$B\rho$ method was made at the second stage of the BigRIPS separator.[2)] The TKE measurement was made using a stack of eleven 1-mm-thick silicon detectors, placed downstream of the BigRIPS separator. The energy loss data from the silicon detectors were added to calculate the TKE. We calculated the A value from the TKE and TOF, and the Q value from the A/Q value obtained by the ΔE-TOF-$B\rho$ method.

The relative resolution achieved in the TKE measurement is 0.48% on average. The resulting Q resolution was calculated to be $\sigma = 0.25$ on average, which allows 4.0σ separation for $\Delta Q = 1$ in charge-state identification plot. We observed the dependence of Q resolution on the stopping range in the silicon stack detector. Figure 1 shows the Q resolution as a function of the stopping range of the isotopes, where some deterioration of the Q resolution is observed around a certain value of stopping range. This can be attributed to a thin dead layer on the surface of the silicon detectors. We expect that it is possible to improve the Q resolution by selecting the stropping range according to the $B\rho$ measurement or by using silicon detectors whose dead layer thickness is significantly small.

We can select events of fully stripped isotopes from a Z versus Z-Q plot, where Z-Q gives the number of electrons. Figure 2 shows a Z versus A-$2Q$ PID plot for the fully stripped events (Z-Q = 0). Here, the Z value is obtained from the ΔE-TOF-$B\rho$ method, while A-$2Q$ is calculated using the A and Q values obtained in the present work. Note that for isotopes with $A/Z \sim 2$, the resolution of A-$2Q$ is comparable to the A/Q resolution achieved by the ΔE-TOF-$B\rho$ method, because of the nature of error propagation.

As shown in Fig. 2, the present TKE measurement confirms the identification of four new isotopes, ^{81,82}Mo and ^{85,86}Ru, which we previously observed using the ΔE-TOF-$B\rho$ method.[2)] This also confirms that the new isotopes are fully stripped.

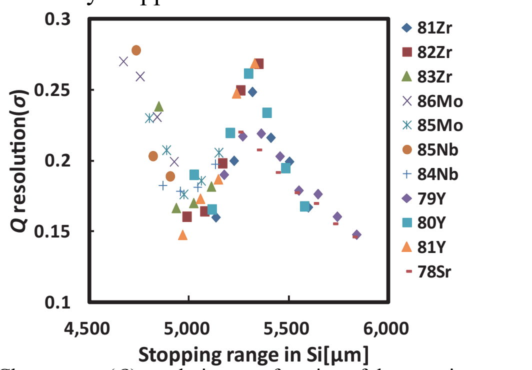

Fig.1 Charge state (Q) resolution as a function of the stopping range

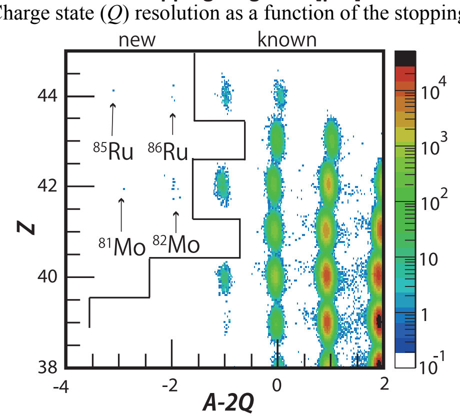

Fig. 2 Z versus A-$2Q$ particle identification plot for projectile fragments produced in the reaction ^{124}Xe+Be at 345 MeV/nucleon.

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