Isochronous mass spectrometry at the RIKEN Rare-RI Ring facility†

D. Nagae,[*1,*2] S. Omika,[*1,*3] Y. Abe,[*1] Y. Yamaguchi,[*1] F. Suzaki,[*1] K. Wakayama,[*3] N. Tadano,[*3] R. Igosawa,[*3] K. Inomata,[*3] H. Arakawa,[*3] K. Nishimuro,[*3] T. Fujii,[*3] T. Mitsui,[*3] T. Yamaguchi,[*3,*4] T. Suzuki,[*3] S. Suzuki,[*4] T. Moriguchi,[*4] M. Amano,[*4] D. Kamioka,[*4] A. Ozawa,[*4] S. Naimi,[*1] Z. Ge,[*1,*3] Y. Yanagisawa,[*1] H. Suzuki,[*1] H. Baba,[*1] S. Michimasa,[*5] S. Ota,[*5] G. Lorusso,[*6] Yu.A. Litvinov,[*7] M. Wakasugi,[*1] T. Uesaka,[*1] and Y. Yano[*1]

A mass measurement at the Rare-RI Ring[1)] has been demonstrated using exotic nuclei with well-known masses, such as ^{79}As, ^{78}Ge, ^{77}Ga, ^{76}Zn, and ^{75}Cu. In this demonstration, the mass of ^{75}Cu was deduced relative to the mass and revolution time of the reference nucleus ^{78}Ge. An isochronous ion optics (isochronism) of the ring was tuned to the reference nucleus. Thus the isochronism cannot be established for other nuclei. For the masses of nuclei with non-isochronism to be evaluated, a correction of their revolution time by a velocity or a magnetic rigidity is essential. Mass can be derived as follows:

$$\frac{m_1}{q_1} = \frac{m_0}{q_0}\frac{T_1}{T_0}\sqrt{\frac{1-\beta_1^2}{1-\left\{\left(\frac{T_1}{T_0}\right)\beta_1\right\}^2}}$$

$$= \frac{m_0}{q_0}\frac{T_1}{T_0}\sqrt{1+\frac{1-\left(\frac{T_0}{T_1}\right)^2}{\left(\frac{(m_0/q_0)c}{B\rho_1}\right)^2}},$$

where $m_{0,1}/q_{0,1}$ denotes the mass-to-charge ratios of the reference particle and particles of interest, respectively; $T_{0,1}$ represents the revolution time for the reference particle and particles of interest, respectively; β_1 and $B\rho_1$ are the velocities in units of light speed c and magnetic rigidity for the particles of interest, respectively. The velocity in the ring cannot be measured directly. The time-of-flights (TOFs) from F3 at BigRIPS to S0 at SHARAQ were used to deduce the velocity for each particle. In the previous analysis,[2,3)] the velocity upstream of the ring was used as the velocity in the ring. However, owing to the momentum-dependent flight path lengths and energy losses in the position detectors at F6, the upstream velocity was not determined accurately and was not matched to the velocity in the ring. In the current analysis, the upstream velocity was matched to the velocity in the ring by adding a correction to the upstream velocity. The magnetic rigidity $B\rho$ was determined using position information at a dispersive focal plane F6 with sufficient accuracy.

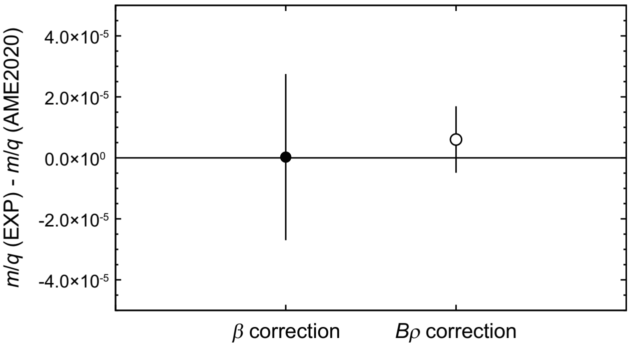

Fig. 1. Difference in the experimental ^{75}Cu m/q values for two correction methods and the literature value.

The m_1/q_1 values of ^{75}Cu were determined to be $m_1/q_1(\beta) = 2.583644(27)$ u/q and $m_1/q_1(B\rho) = 2.583650(11)$ u/q by employing the β and $B\rho$ correction methods, respectively. Figure 1 presents a comparison of the experimental m_1/q_1 values of ^{75}Cu with the literature m/q value m_1/q_1(AME2020) $= 2.58364357(3)$ u/q.[4)] The uncertainty in the mass derived using the velocity correction is larger than that derived using the magnetic rigidity because of the difficulty of measuring velocity upstream of the ring precisely.

We established two analytical methods for the mass determination employing either the β or $B\rho$ correction in this study. The obtained mass accuracies and uncertainties were on the order of 10^{-6} u/q and 10^{-5} u/q, respectively, for both β and $B\rho$ correction methods. Nonetheless, the obtained mass of ^{75}Cu agrees satisfactory with the literature value. The Rare-RI Ring facility has proved to be an effective tool for mass measurements of rare RI.

References

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*1 RIKEN Nishina Center
*2 Laboratory for Zero-Carbon Energy, Tokyo Institute of Technology
*3 Department of Physics, Saitama University
*4 Institute of Physics, University of Tsukuba
*5 Center for Nuclear Study, University of Tokyo
*6 Department of Physics, University of Surrey
*7 GSI Helmholtzzentrum für Schwerionenforschung GmbH

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