Commissioning of Rare RI Ring using exotic nuclei

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

The Rare RI Ring[1)] is an isochronous storage ring constructed to measure the masses of short-lived rare nuclei using the time-of-flight (TOF) measurement method. We conducted two commissioning experiments[2–4)] in 2015. In the first commissioning experiment, we verified the operation of each component, while in the second commissioning experiment, we made the first attempt of mass measurement using stable nuclei. This year, we have performed commissioning using exotic nuclei with well-known masses to confirm the feasibility and principle of mass determination using the following equation:

$$\frac{m_1}{q} = \frac{m_0}{q}\frac{T_1}{T_0}\sqrt{\frac{1-\beta_1^2}{1-(\frac{T_1}{T_0}\beta_1)^2}}, \quad (1)$$

where $m_{0,1}/q$ denote the mass-to-charge ratio of the reference particle and particle of interest, respectively; $T_{0,1}$ are revolution times of these particles; and β_1 is the velocity of the particle of interest. Because the isochronous condition is adjusted for the reference particle, isochronism is not fulfilled for particles of interest by the velocity measured upstream.

Exotic nuclei around ^{78}Ge were produced from the relativistic in-flight fission of a primary beam of ^{238}U at an energy of 345 MeV/nucleon on a ^{9}Be target with a thickness of 10 mm. We identified these nuclei before the F3 achromatic focus of BigRIPS. Figure 1 shows a particle identification plot. The energy loss (ΔE) was obtained using an ionization chamber located at F3, and TOF was measured between F2 and F3. Using Bρ and the measured TOF between F3 and the S0 achromatic focus of SHARAQ, the β_1 values for particles were deduced. We injected these nuclei to the ring using the individual injection method with the fast kicker system.[5)] The isochronous magnetic field in the ring was adjusted for the reference particle ^{78}Ge with a precision of 5 ppm for a momentum spread of ± 0.3%.[6)] We confirmed the storage of several particles by using a circulation detector[7)] and a δ-ray detector.[8)] These particles circulated in the ring for about 1850 turns, which corresponds to about 0.7 ms. Exotic nuclei ^{79}As, $^{77-79}$Ge, ^{76,77}Ga, ^{75,76}Zn, and ^{75}Cu were successfully extracted from the ring as indicated by the red dot in Fig. 1. $T_{0,1}$ for each nuclei are deduced from the TOF between S0 and the ring exit ELC. Figure 2 shows the TOF spectra with peak assignments. Mass accuracies are preliminary obtained for ^{79}As, ^{77}Ga, ^{76}Zn, and ^{75}Cu as 7.2×10^{-6}, 1.1×10^{-5}, 1.5×10^{-5}, and 2.1×10^{-5}, respectively. The successful individual injection, storage, extraction, and TOF measurement in the ring for exotic nuclei make the mass measurement of more neutron-rich nuclei feasible in the near future.

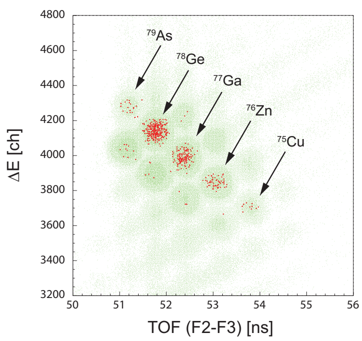

Fig. 1. Particle identification plot. Green dots indicate all events at F3, and red dots indicate extracted events.

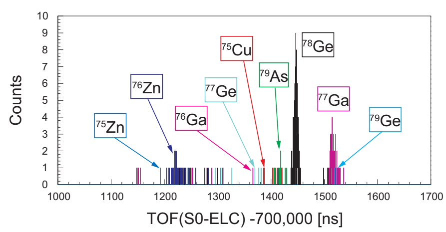

Fig. 2. TOF spectra between S0 and ELC.

*1 RIKEN Nishina Center
*2 Department of Physics, Saitama University
*3 Institute of Physics, University of Tsukuba
*4 Center for Nuclear Study, University of Tokyo
*5 Department of Physics, University of Surrey
*6 GSI Helmholtzzentrum für Schwerionenforschung

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