Introduction of storage-ring experiments at RIBF

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The RI Beam Factory (RIBF) in RIKEN Nishina center is a synergetic-use facility where the world's most intense high-energy exotic nuclear beams are supplied to users worldwide mostly for nuclear physics experiments. We have introduced storage-ring-experiment capability at the RIBF in this decade by constructing both an electron storage ring and a heavy-ion storage ring. The electron storage ring facility will be used for the world's first electron scattering experiments from unstable nuclei, and the heavy-ion storage ring is used for precision mass measurements, especially for extremely exotic nuclei located on the r-process path. Both have been defined as core experimental instrumentations at RIBF.

The Self-confining RI ion target (SCRIT), which was developed for electron scattering off unstable nuclei, is a novel internal target forming technique in an electron storage ring. The construction of the SCRIT electron scattering facility[1)] was started in 2009 and almost completed in 2015. As shown in Fig. 1, it consists of an electron accelerator, RTM; an electron storage ring, SR2; an ISOL-type RI beam generator, ERIS;[2)] and a high-resolution spectrometer, WiSES, for analyzing scattered electrons. The momentum transfer distribution of elastically scattered electrons from the ^{132}Xe isotope extracted from ERIS was observed with three electron beam energies, as shown in Fig. 1, and we successfully determined the proton distribution for the first time.[3)] The luminosity reached $2 \times 10^{27}/(\mathrm{cm}^2\mathrm{s})$ with 10^8 injected target ions at an electron beam current of 200 mA – 250 mA. We evaluated the performance of the SCRIT system and demonstrated the feasibility of electron scattering off unstable nuclei. The first experiments for unstable nuclei are now under preparation.

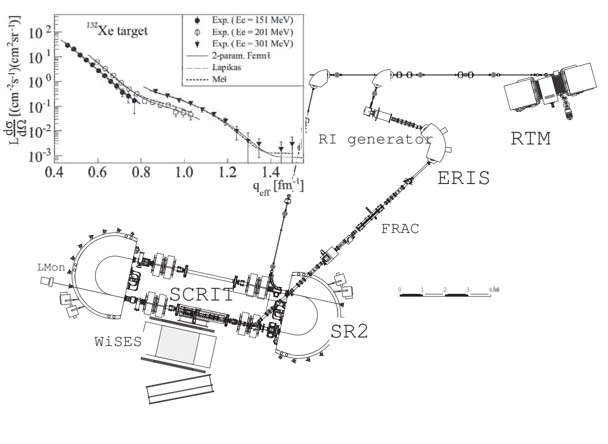

Fig. 1. Schematic view of the SCRIT electron scattering facility and the recently observed momentum transfer distribution of elastically scattered electrons from ^{132}Xe.

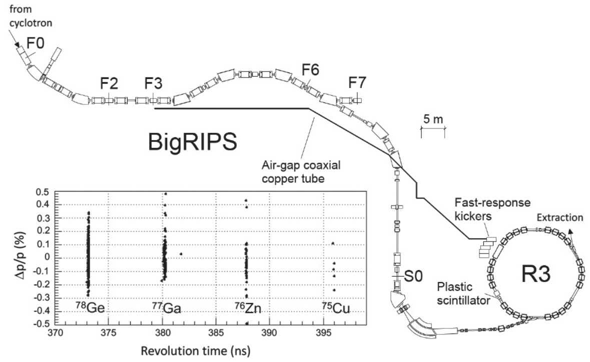

Fig. 2. Schematic view of R3 connected to BigRIPS and typical data of revolution times measured for exotic nuclei.

The heavy-ion storage ring named R3 (Rare-RI Ring)[4)] connected to BigRIPS, as shown in Fig. 2, was constructed in 2012–2014. Masses of nuclei are determined by measuring the revolution times for less than 1-ms accumulation under the isochronous condition. The magnetic structure yielding a high-precision isochronism ($\sim$ 1 ppm) is formed solely by only bending magnets equipped by trim coils. This provides not only large acceptances of $\Delta p/p \sim \pm 0.5$ % in momentum space and $\sim 150\pi$ mm mrad in transverse emittance, but also a high-precision mass-determination capability with an accuracy of the order of 1 ppm even with poor statistics. The isotope-selectable self-triggered injection (ISSI) method, which combines particle identification in the transport line and a newly developed ultrafast response kicker, was adopted in the R3 system, and it enables efficient mass measurement for rarely produced exotic nuclei. Since the injection kicker magnet is activated by a trigger signal produced by the isotope of interest at the F3 focal point, the isotope is identified with certainty and accumulated in R3 one by one. As shown in Fig. 2, revolution times for exotic nuclei measured in the commissioning are independent of their momentum spread as expected, and the mass values relative to that of the reference isotope ^{78}Ge were precisely determined. Mass measurements for $^{74-78}$Ni are now under preparation.

References
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