Mass measurements of neutron-rich Ni isotopes in Rare RI Ring

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Nuclear mass measurements are important to investigate nuclear structure and pathway of nucleosynthesis. Neutron separation energies (S_n and S_2n), which can be deduced from the nuclear masses, are very sensitive to the nuclear shell structure. In nucleosynthesis, S_n is a key parameter to determine the pathway of the r-process. Ni isotopes have a magic number for the protons ($Z = 28$) and three doubly magic isotopes ($N = 20$, 28, 50). Ni isotopes close to ^{78}Ni are assumed to lie on the r-process path. Thus, the mass measurements for neutron-rich Ni isotopes are anticipated. Until now, in neutron-rich Ni isotopes, masses up to ^{73}Ni have been evaluated in Atomic Mass Evaluation.[1)] The mass of ^{74}Ni has been reported in Ref. 2). However, the error bar is quite large (approximately 1 MeV). Thus, in this experiment, we performed the mass measurements for neutron-rich Ni isotopes (^{74,76}Ni) in Rare RI Ring (R3).

The experimental setup in this measurement is essentially the same as that in the previous experiment at R3.[3)] We improved beam optics after installing the OEDO system.[4)] The primary beam of ^{238}U accelerated in SRC up to 345 MeV/nucleon was impinged on a Be target. Secondary beams including ^{74,76}Ni isotopes were produced through in-flight reaction. We adjusted the thickness of the degraders located at F1 and F2 in BigRIPS such that the beam energies of ^{74,76}Ni became approximately 160 MeV/nucleon, which is the suitable energy for individual ion injection.[5)]

Particle identification in BigRIPS was done by TOF between F2 and F3, which were measured by two plastic scintillators, and ΔE at F3, that was measured by an ionization chamber (IC). In this experimental setting, a typical count rate for ^{76}Ni in F3 was approximately 0.16 cps for the full primary beam intensity (approximately 60 particles nA). The plastic scintillator at F3 also provided trigger signals for the kicker magnets in R3. To maintain the trigger rate of the kicker magnets within 100 Hz, we applied TOF-ΔE gates to the trigger signals, as described in Ref. 6). A typical particle identification spectrum at F3 (for the case of ^{74}Ni) is shown in Fig. 1. In this experiment, momentum dispersive focus was applied at F5 in BigRIPS. We placed two PPACs there to measure the momentum of the beams ($B\rho$). At S0, *i.e.*, at the entrance of SHARAQ, we located a TOF counter, which is a similar to the one used inside R3.[7)] This TOF counter provided a start signal to the TOF in R3.

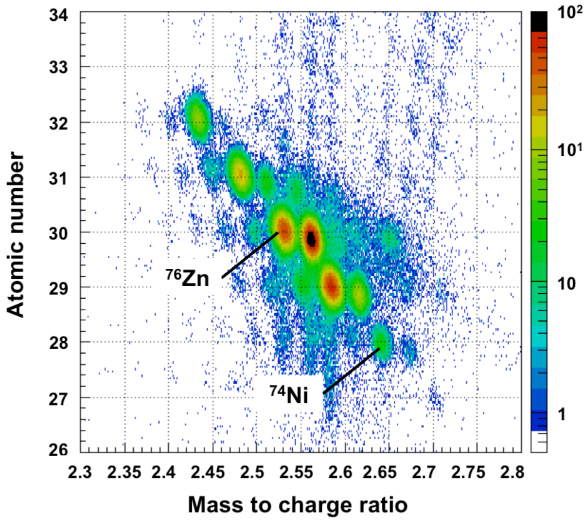

Fig. 1. A typical particle identification spectrum as measured at F3 for ^{74}Ni mass measurement.

We also measured the TOFs of each particle between F3 and S0, which were converted to the β of their beams. The particle injected into R3 was extracted after approximately 700 μs using the same kicker magnets. After the extraction, the particle was collided with a plastic scintillator, which provided a stop signal for the TOF in R3 and IC. Finally, it was stopped in an NaI scintillator. In the measurement of ^{74}Ni (^{76}Ni), the isochronous optics of R3 were tuned using ^{76}Zn (^{78}Zn) such that the width of TOF in R3 was the narrowest for this nucleus, thereby resulting in a width of approximately 3 ps. Furthermore, we carefully tuned the septum magnets and magnets at the injection line of R3 to increase the transmission efficiencies of ^{74,76}Ni from F3 to R3. The achieved values for ^{74}Ni and ^{76}Ni were approximately 0.5% and 2.8%, respectively. In this experiment, we accumulated the events for ^{74}Ni (^{76}Ni) for approximately 5 h (10 h). To deduce the masses, the TOF in R3 should be corrected by the corresponding β or $B\rho$. The analysis of data is still ongoing.

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