Determination of half-life of ^{89}Rh by measuring in-flight decay

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The in-flight decay of ^{89}Rh was measured to deduce its half-life using two-fold particle-identification (PID) sections, the second stage of the BigRIPS separator and the ZeroDegree spectrometer. Moreover, its production cross section was deduced.

Inconsistent results were observed for the half-life of ^{89}Rh. One was $\gtrsim$1.5 μs estimated from Ref. 1). In this experiment at the LISE spectrometer in GANIL, ^{89}Rh was produced using a ^{112}Sn + ^{nat}Ni reaction and its yield was consistent with the yield systematics of the neighboring RIs. Thus, its half-life was considered to be comparable to or longer than the time of flight (TOF) in the spectrometer ($\sim$1.5 μs). The other was <120 ns, invesitgated at RIBF, RIKEN.[2)] Using a ^{124}Xe + Be reaction, no events of ^{89}Rh were obtained at F11, the final focal plane of the ZeroDegree spectrometer. The production yield at the F0 target was estimated from the yield systematics, and in-flight decay during the flight from F0 to F11 was assumed. Subsequently, the upper limit of the half-life was deduced to be 120 ns. Thus, direct measurement of the decay was required to determine the half-life.

We measured the in-flight decay of ^{89}Rh at RIBF. The proton-rich RI beams including ^{89}Rh were produced from a 120-particle nA 345-MeV/nucleon ^{124}Xe beam impinged on a 4-mm Be target. The fully-stripped ^{89}Rh was identified[3)] in the second stage of the BigRIPS. With a 4.9 hours primary-beam dose, 17 events were obtained as shown in Fig. 1. They were re-identified in the following sepctrometer, ZeroDegree, whether they maintained ^{89}Rh until F11 or decayed to ^{88}Ru by proton emissions. The PID method in the ZeroDegree spectrometer was basically the same with the one in the second stage. In the PID, the mass-to-charge ratios (A/q) could not be deduced for the events that $^{89}_{45}$Rh decayed to $^{88}_{44}$Ru, because their magnetic-rigidity values changed before and after the decays. In contrast, the atomic number Z at F11 was properly deduced to be 44, because the velocity almost unchanged by the decay. Figure 2 shows the Z spectra of the all events and the ^{89}Rh events at F7. Among 17 events of ^{89}Rh at F7, eight events were located around Z = 44, suggesting their decays to ^{88}Ru. The remaining nine events were ^{89}Rh until F11. From the numbers of ^{89}Rh nuclei at F7 and F11 and the γ-corrected TOF of 258 ns, its half-life was determined to be 281 ± 101 ns (preliminary).

The production cross section of ^{89}Rh was deduced from its half-life, γ-corrected TOF from F0 to F7, the observed events at F7, and the transmission in the BigRIPS. It was $(3.81^{+2.46}_{-0.80}) \times 10^{-10}$ mb (preliminary), and was $\sim$1/20 of expected cross section from the systematics of the other isotopes with $N = Z - 1$. This small cross section might cause the inconsistent short half-life estimated in the Ref. 2).

More elaborate analysis is now in progress.

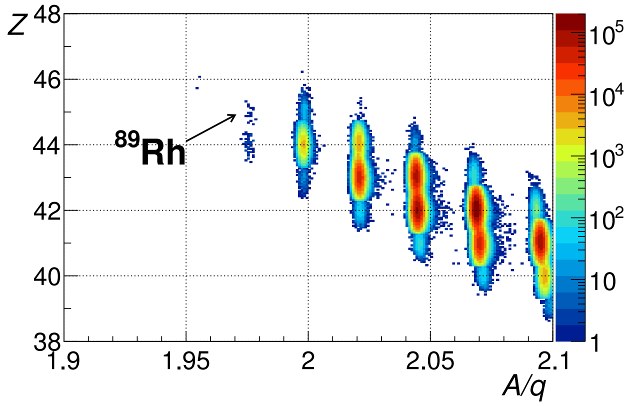

Fig. 1. (Preliminary) Z versus A/q PID plots in the second stage of the BigRIPS for ^{89}Rh produced by the reaction of ^{124}Xe + Be (4 mm) at 345 MeV/nucleon. Seventeen events of ^{89}Rh were obtained.

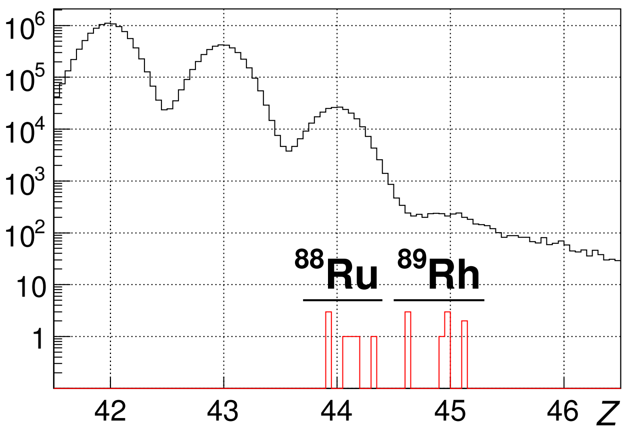

Fig. 2. (Preliminary) Z spectra in the ZeroDegree spectrometer for all events (black) and ^{89}Rh events at F7 (red). Till F11, eight nuclei of ^{89}Rh decayed to ^{88}Ru.

References

1) K. Rykaczewski *et al.*, Phys. Rev. C **52**, R2310 (1995).
2) I. Čeliković *et al.*, Phys. Rev. Lett. **116**, 162501 (2016).
3) N. Fukuda *et al.*, Nucl. Instrum. Methods Phys. Res. B **317**, 323 (2013).

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