Development of β-TOF detector for decay-correlated mass measurement of β-decaying nuclides

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A novel "α-TOF" detector,[1)] has been recently developed and installed on a multi-reflection time-of-flight mass spectrograph (MRTOF-MS). This detector can measure ion implantation to deduce the time-of-flight (TOF), along with subsequent α-decay and spontaneous fission (SF) events from the implanted ions. We recently succeeded in the direct mass measurement of superheavy nuclides, ^{257,258}Db,[2,3)] wherein the count rate of ^{257}Db was as low as two events per day.[2)] Furthermore, we have initiated a new field of nuclear spectroscopy using decay-correlated mass measurements.[4)] The potential of this technique was initially demonstrated using decay properties to discriminate between the two states of ^{207}Ra, followed by mass analyses of each state; the two states could not be independently resolved by the MRTOF.

While the α-TOF detector is limited to α-decay and SF nuclides, it would be valuable to expand its performance to encompass β-decays. Here, we report the development of a new "β-TOF" detector, an extension of the α-TOF detector, that enables the decay-correlated mass spectroscopy of $\alpha/\beta/$SF decaying nuclides.

The β-TOF detector uses double-layered SSDs with a thickness of 500 μm (Hamamatsu S-14605) to provide a ΔE-ΔE telescope for β-decay. In the first layer of the SSD, α-decay and SF are detected in the same manner as those in α-TOF. The basic characteristics—time resolution, α-particle energy resolution, implantation, and α-decay detection efficiency—of the β-TOF detector are the same as those of α-TOF. Owing to the solid angle coverage of the two SSDs, the telescope is geometrically limited to a detection efficiency of 33% for β-rays.

Online commissioning for the β-TOF detector was performed via MRTOF,[5)] located at the end of the ZeroDegree spectrometer beamline.[6)] The so-called ZD-MRTOF was coupled to a cryogenic helium gas cell that thermalized the relativistic beam delivered by BigRIPS. In the first online test of this new detector, we succeeded in measuring the correlation between the TOF of the neutron-rich ^{81}Ga isotope and subsequent β-decay. Figure 1 shows the histogram of TOF singles and decay-correlated TOF events. Accordingly, the detection efficiency for β-rays was found to be 27(7)%, which in good agreement with the geometric estimation. The half-life of ^{81}Ga was successfully extracted from the time between individual implantations and subsequent decay events. Figure 2 shows the decay time distribution with the expected decay curve. The half-life of ^{81}Ga was determined to be 1.44(31) s, which is in agreement with the value in literature, *i.e.*, 1.217(5) s.[7)]

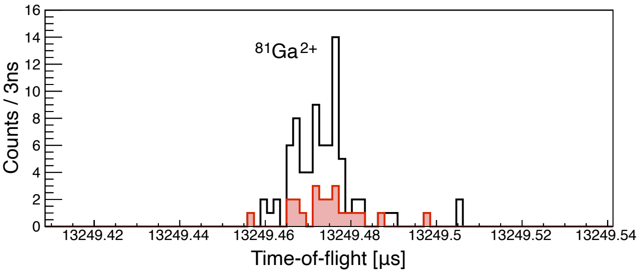

Fig. 1. TOF spectrum of ^{81}Ga^{2+}. The TOF singles spectra are drawn in black, while β-decay correlated events are shaded in red.

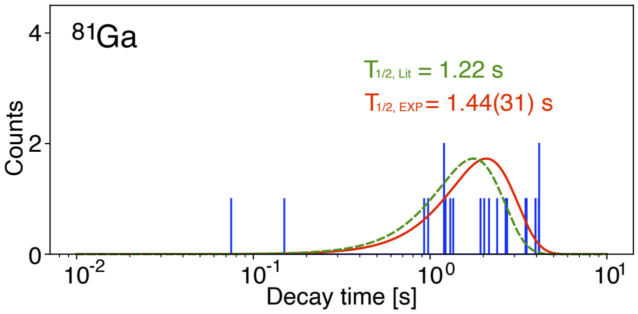

Fig. 2. Measured decay time distribution of ^{81}Ga. The red solid line and green dashed curve indicate the distribution curve drawn with the experimental and literature ($T_{1/2}$ = 1.22 s) values, respectively.

References

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