Performance evaluation of time-measurement system using ultra-fast plastic scintillation detectors in BigRIPS

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Unstable nuclei in secondary beams separated through the first stage of the BigRIPS spectrometer at RIBF can be identified in the second stage. The particle identification (PID) deducing the atomic number Z and the mass-to-charge ratio A/Q has been well established using the $B\rho$-TOF-ΔE method.[1)] The relative A/Q resolution of 0.038% (σ) for ^{134}Sn was archived with standard detectors installed in the BigRIPS. Our goal is to improve the TOF resolution of plastic scintillation detectors for the better relative A/Q resolution of RIKEN's standard detectors. For example, $^{137}\mathrm{Sn}^{50+}$ ($A/Q = 2.74$) and $^{134}\mathrm{Sn}^{49+}$ ($A/Q = 2.7347$) must be distinguished with sufficient accuracy. Furthermore, we plan to measure the charge-changing cross sections (CCCS) for neutron-rich Sn isotopes at the 8th focal plane (F8). In this measurement, it is essential to achieve Z separation of fragments immediately after the reaction target within 1–2 meters. To meet this requirement in the Sn region, we need good energy resolution of the ΔE detector as well as good time resolutions of ToF detectors. Although the CVD diamond detector has been developed with good time resolution,[2)] its small size is not suitable for our measurement. In a recent study, the time resolution was improved using fast plastic scintillators and photomultiplier tubes (PMTs).[3)] In this test, we evaluated the performance of a combination of a fast plastic scintillator, fast PMTs, and TAC-ADC (Time-to-Amplitude Converter and Analog-to-Digital Converter) circuits.

The secondary beam including the vicinity of ^{130}Sn was produced by the in-flight fission of ^{238}U at 345 MeV/nucleon on a 3-mm-thick ^{9}Be target. A 2-mm-thick and a 0.8-mm-thick Al degraders were set at F1 and F2, respectively. The $B\rho$ values were set to 7.4588 Tm at D1 and 7.1061 Tm at D2, respectively, corresponding to the beam energy of ^{130}Sn at F3 of 294 MeV/nucleon. Standard plastic scintillation detectors (F3Pla and F7Pla) were placed at F3 and F7. The standard detectors comprised a scintillator (Eljen EJ230) with a size of $100 \times 100 \times 0.2$ mm^3 and two PMTs (Hamamatsu R2083). A new detector (newF7Pla) was placed immediately behind the standard scintillator placed at F7. The new detector comprised a fast scintillator (EJ232) with the same size as that of the standard one and two fast PMTs (R13089). For the data acquisition (DAQ) of time information, a TDC (REPIC RPC-180) with a minimum time width of 25 ps/ch as standard and a TAC-ADC circuits (ORTEC 567 and Mesytec MADC32) with a minimum time width of 5 ps/ch were used.

As shown in Fig. 1, we achieved the relative A/Q resolution of 0.0311% for ^{130}Sn in the new time-measurement system with the F3Pla and newF7Pla. On the other hand, the relative A/Q resolution of 0.0390% for ^{130}Sn was derived using the standard system with the F3Pla and F7Pla, which is nearly consistent with the previous result.[1)] In this analysis, a third-order transfer matrix was used to reconstruct A/Q. The ToF resolution of the new system with the F3Pla and newF7Pla was approximately 48 ps (σ), while that of the standard system was 60 ps. Using three ToF detectors, their intrinsic time resolutions were derived. The intrinsic time resolution of the newF7Pla was 28 ps, while that of the F3Pla was 48 ps.

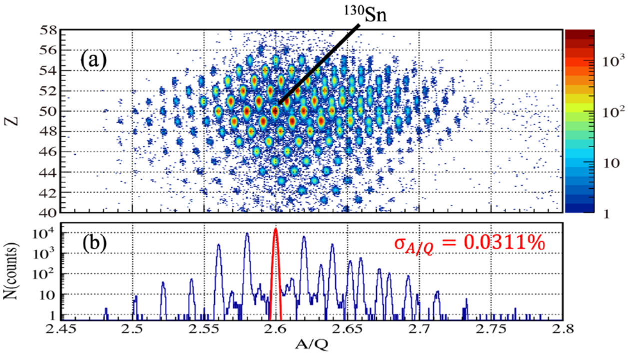

Fig. 1. (a) PID plot with the new system. (b) Projection of the PID plot onto the x-axis for Sn isotopes.

The TAC-ADC system enables measurement with better resolution compared to that of the standard TDC. Moreover, fast plastic scintillators and PMTs can slightly improve the time resolution in the case of TAC-ADC. The ToF resolution with the F7Pla and newF7Pla was 36 ps. A relative ToF resolution of 0.4% can be achieved with this system in the condition of the ToF of approximately 10 ns (*i.e.* flight length of 2 m with $\beta = v/c = 0.6$), which corresponds to the 5-σ separation of Z for Sn isotopes at F8. This high resolution would also contribute to the PID in a high-Z region, where a high A/Q resolution is required to

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separate neighboring different charge states.

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