Measurement of total kinetic energy using $LaBr_3(Ce)$ crystal in ZeroDegree spectrometer for two-step experiment

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A $LaBr_3(Ce)$ crystal was used as the total-kinetic-energy (TKE) counter for particle identification (PID) in the ZeroDegree spectrometer in the two-step experiment.[1] In this experiment, events of partially-stripped radioactive isotopes (RI) were not negligible, because the mass numbers, A, of RIs produced at the target at the entrance of ZeroDegree were over 100 and their kinetic energies were 200 MeV/nucleon. For the PID, the atomic number, Z, and the mass-to-charge ratio, A/Q, were deduced based on a TOF-$B\rho$-ΔE method. However, the A/Q resolution in ZeroDegree with Medium-Resolution-Achromatic mode[2] was 0.061% in RMS and inadequate to separate fully-stripped RIs from the partially-stripped ones. Thus, the value of A was deduced from the velocity (β) and TKE of each RI and was used for the separation.

The $LaBr_3(Ce)$ crystal[3,4] was mounted at the end of ZeroDegree. It is cylindrical in shape with 3-inch diameter and length, covered with a 0.5-mm thick Al housing. Nine PIN-photodiodes were attached to the back of the crystal through a light-guide made of Lucite. Five diodes with effective areas of 18 mm^2 (S3204-08; Hamamatsu Photonics K.K.) were arranged in the shape of a cross and other four diodes of 10 mm^2 (S3590-18; Hamamatsu) were placed at the four corners. The signal from each diode was amplified by a pre-amplifier (MSI-8; mesytec GmbH & Co. KG) whose dynamic range was set to be 1 GeV in Si energy-loss equivalent and a shaping amplifier (MSCF-16; mesytec) whose shaping time was set to be 2 μs.

The energy of the crystal was calibrated by comparing the light output and calculated energy-loss of RIs using an energy-loss code ATIMA.[5] Owing to the quenching effect, the light output was not proportional to the energy loss. In this experiment, $\frac{E^2}{Z}$ (E; energy loss in the crystal) was found to be proportional to the light output, as shown in Fig. 1. In previous studies by Kobayashi[4] and Taniuchi *et al.*,[6] $\frac{E^2}{Z^2}$ and $\frac{E}{\sqrt{Z}}$ respectively, were proposed as the proportional variables. It is unclear why the quenching effects are different in these three cases. It may be caused by the width of the Z range, which was 41–50 in our case, 28–52 in Ref. 4), and 8–50 in Ref. 6).

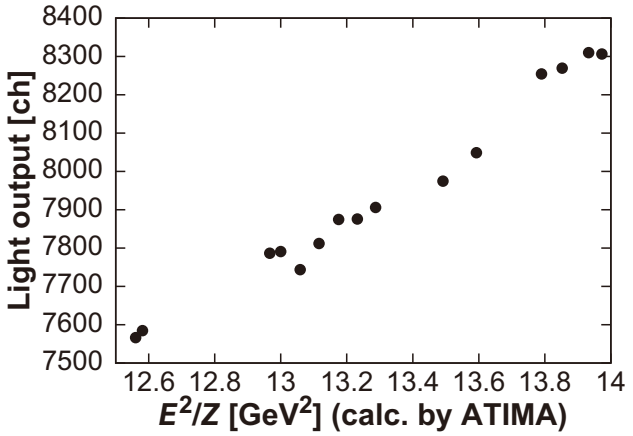

Fig. 1. Relation between light output from $LaBr_3(Ce)$ crystal and calculated $\frac{E^2}{Z}$ by ATIMA.[5]

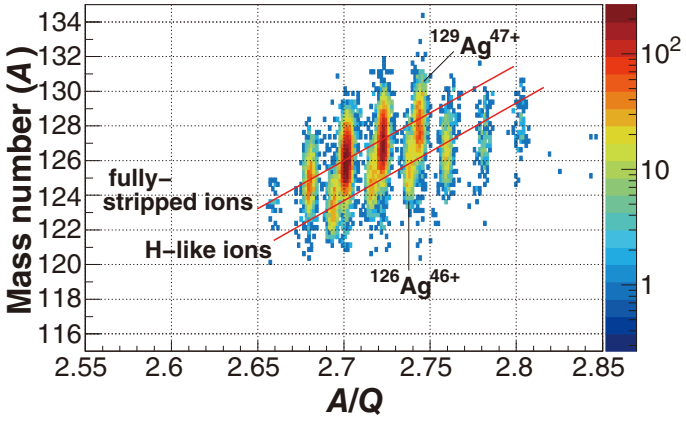

Fig. 2. Separation of Ag isotopes in A versus A/Q. 4.6σ separation was achieved between $^{129}Ag^{47+}$ and $^{126}Ag^{46+}$.

The distribution of A in the two-step experiment was 0.95 in RMS around $^{129}Ag^{47+}$. Thus, the resolution of A was 0.8% and 3σ separation was achieved between the fully-stripped $^{129}Ag^{47+}$ and H-like $^{126}Ag^{46+}$ in mass. In A/Q axis, 3.5σ separation was obtained between these two isotopes. Thus, 4.6σ separation was achieved using both A/Q and A separations. Figure 2 shows the separation of Ag isotopes in the two-step experiment in A versus A/Q plot. The fully-stripped RIs are well separated from the H-like RIs. The charge number, Q, was deduced from A/Q and A. 2.5σ separation was achieved in the Q separation.

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References

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