Development of a total-kinetic-energy counter for high-rate experiments at ZeroDegree spectrometer

R. Taniuchi,[*1,*2] H. Wang,[*2] N. Aoi,[*3] H. Baba,[*2] S. Koyama,[*1,*2] M. Kurokawa,[*2] M. Matsushita,[*4] S. Momiyama,[*1,*2] M. Niikura,[*1] Y. Shiga,[*2,*5] and S. Takeuchi[*2]

A total-kinetic-energy (TKE) counter for particle identification at the ZeroDegree (ZD) spectrometer was tested in 2014. The detector is aimed at the discrimination of not fully stripped ions for the mass region $A \gtrsim 100$. For example in the case of ^{136}Sn (RIBF31), the mass-to-charge ratios (A/Q) of $^{133}Sn^{49+}$ and $^{136}Sn^{50+}$ are similar and the resolution of A/Q obtained by the TOF$-$B$\rho-\Delta$E method is not sufficient to separate them. In order to separate the fully stripped ions from the neighboring charge-state contaminants, the TKE counter is required to have the mass resolution of 1% (FWHM).

Considering the beams with high counting rate (~100 kcps), the counter should have a short decay time and radiation resistance. For this purpose, a ø3″ $LaBr_3$(Ce) scintillator[a)] with a 0.5-mm^t aluminum housing is prepared[b)]. It is mounted downstream of the F11 multiple sampling ionization chamber (MUSIC). In previous studies[1–3)], the feasibility of charge-state identification using this scintillator was tested. The mass resolution was not as good as 1% (FWHM). Simultaneously, a quenching phenomenon was observed [3)], namely, the light yield per energy deposition of the incident beam decreased as a function of Z. To obtain higher resolution, the degree of the quenching phenomenon should be known for the optimization of the amplification factor of the light readout.

In 2014, two types of light readouts were tested. For the first case (tested in the experiments RIBF31R1 and DA14-01-01), five PIN-photodiodes (S3204-08, HPK) were aligned on the downstream surface of the scintillator[4)]. For the second setting (tested in the experiments RIBF61, RIBF51R1 and RIBF56R1), the readout consisting of a ø3″ PMT (R6091HA, HPK) and a tapered-type divider (E5859, HPK) were coupled with the scintillator. In this report, the result of the second setting is discussed.

During three experiments, the amplitudes of the signal of the PMT were measured using an oscilloscope with several high-voltage (HV) settings. The ZD spectrometer were set for ^{132}Sn (20.8 GeV), ^{70}Ni (15.2 GeV), and ^{22}O (5.21 GeV)[c)], for the respective experiments. Figure 1 shows the signal amplitudes as a function of applied HV for different isotopes. For reference, data of γ-ray calibration before and after the experiment with ^{22}Na, ^{60}Co and ^{137}Cs sources are also plotted. They are normalized by the energy of the γ-ray, namely, the amplitudes per 1 MeV.

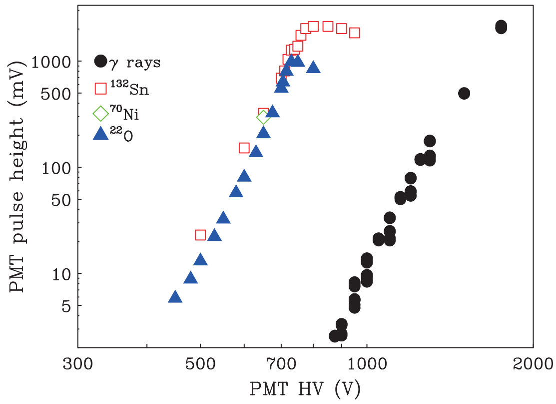

Fig. 1. Amplitude of the PMT output with several HVs for each ZD spectrometer settings.

Table 1. Signal amplitudes per unit energy.

Particle	Amplitude (mV/GeV)	Quenching factor[d)]
γ/δ-ray	124	1
^{22}O	40	0.32
^{70}Ni	19	0.16
^{132}Sn	15	0.13

For the ^{132}Sn and ^{22}O settings, owing to the frequent implantation rate (~40-100 kcps) and high light yield, the PMT output was saturated with overcurrent of the divider circuit when the HV value was above 700 V. On the other hand, the slopes below 700 V are similar to the one of γ-ray. This ensures that the PMT has linearity even for the lower operation voltage.

By extrapolating the γ-ray results to the lower-voltage region, the light yield of the scintillator is compared with heavy ions. The values in the center column of Table 1 are the signal amplitudes per the kinetic energies when the HV is set at 650 V. The quenching phenomena of the light yield are observed obviously.

According to this result, optimum gain of the PMT can be discussed. A new divider circuit designed from this result will be tested in 2015.

References

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*1 Department of Physics, the University of Tokyo
*2 RIKEN Nishina Center
*3 Research Center for Nuclear Physics, University of Osaka
*4 Center for Nuclear Study, the University of Tokyo
*5 Department of Physics, Rikkyo University

a) Saint-Gobain BrilLanCe™ 380
b) $LaBr_3$(Ce) is known to have a light decay time around 16 ns.
c) The kinetic energies of heavy ions are deduced from the $B\rho$ values of the last dipole of ZD spectrometer.
d) the ratio of the signal amplitudes per energies of heavy ions to that of γ-ray.