Beam Hit position dependence of the pulse height of a thin plastic scintillation counter with heavy ion beam

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The most critical concern in the space industry is the malfunction of silicon circuit devices caused by cosmic radiation. To avoid uncontrollable situations, choosing stable silicon circuit devices under high Linear Energy Transfer (LET; dE/dx) environment is necessary. The Nishina Center provides an experimental environment at the E5[1] to evaluate the radiation resistance of devices using heavy ion beams for high-LET conditions.[2]

The detailed setup of the detectors are available in the references.[1,3] The beam is de-focused by scattering with an Au foil and a wobbler to create a flat top distribution with $<10\%$ non uniformity which extends approximately 50 mm in diameter on a tested device.[4] Depending on the experimental requirements, the beam intensity varies from a few hundred Hz to several hundred MHz. We employ ion chambers (ICs) and plastic scintillation counters (PSCs) to complement wide dynamics range of the beam intensity based on their linear correlation. PSCs are suitable for beam intensities below a few tens kHz. However, as the beam profile is enlarged, the position dependence of counting efficiency becomes a significant concern. This study reports the light collection efficiency depending on the beam hit position for thin plastic scintillators with varied thicknesses.

The PSC consists of a plastic scintillator (EJ-214) measuring 70×70 mm attached to a fishtail-shaped light guide, which is optically glued to a 1-inch photomultiplier tube (PMT: Hamamatsu, H7415), as shown in Fig. 1. The scintillator sheet was placed in the central hole of the light guide and secured with a 1.5 mm thick holding frame using optical grease. This structure enabled the frequent replacement of the plastic scintillator when the light yield decreased to half of its original value. To optimize energy deposition in the PSC, the thickness of the scintillator was selected based on the beam species and its the maximum energy: 3 mm for ^{12}C at 135 MeV/nucleon, 500 μm for ^{40}Ar at 95 MeV/nucleon, 100 μm for ^{84}Kr at 70 MeV/nucleon, and 25 μm for ^{136}Xe at 36 MeV/nucleon.

To control the beam hit position, the PSC was mounted on a horizontal (X)-vertical (Y) linear stage, which was moved remotely in 12.5 mm steps on both X and Y directions. The Ar beam of 93 MeV/nucleon was bombarded after 10 mmϕ collimation. The output pulse current from the PMT was integrated using a CAMAC QDC system.

The average integrated charge was normalized by the maximum mesh value for a given PSC and is shown in Fig. 2 as X-Y mesh plots for 3 mm, 500 μm, and 25 μm thicknesses (from left to right). The bottom of the plots corresponds to the PMT side. The 3 mm thick PSC exhibited non-uniformity of $<20\%$, while the other two PSCs showed $<50\%$ signal reduction around the center. This superior signal uniformity is expected, as 3 mm thick scintillator can propagate scintillation lights to the light guide with six times larger geometrical acceptance and with fewer reflections than 500 μm. However, the uniformity was similar between the 500 μm and 25 μm scintillators, despite 20-fold difference in thickness. Additionally, the signal was larger near the PMT side than that near the far side for both the 3 mm and 500 μm scintillators. However, the 25μm thick scintillator showed the opposite trend. The issue may be due to improper optical contact between the light guide and the scintillator, which is to be confirmed. These findings contribute to enhancing the radiation resistance testing capability with heavy ions.

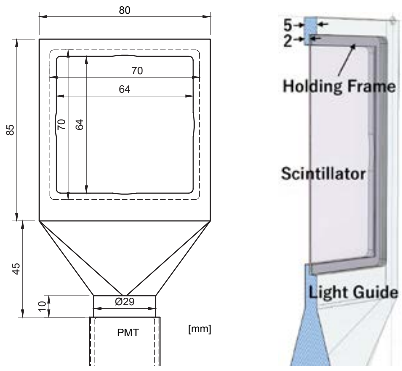

Fig. 1. Design of the light guide for the front view and the cross sectional three dimensional (3D) view.

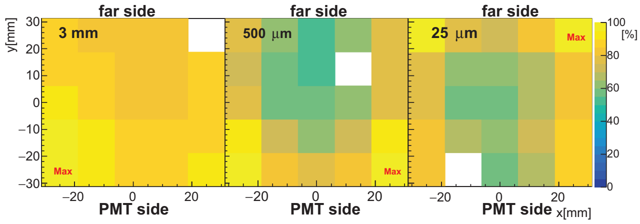

Fig. 2. Position dependence of pulse height normalized by the maximum position shown by "Max." White panels were caused by read-out errors.

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References
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