Application study of Scintillation Materials Quenching Effect for Dose-averaged LET measurement in Heavy Ion Therapeutic beam

Chae-Eon Kim[1], Ju Sung Kim[1], Young Kyung Lim[1], Shunuke Inagaki[2,3], Seonghoon Jeong[5], Mutsumi Tashiro[2], Se Byeong Lee[1,*]

[1]Proton Therapy Center, National Cancer Center Korea, Korea
[2]Gunma University Heavy Ion Medical Center, Gunma University, Japan
[3]Gunma University Graduate School of Medicine, Gunma University, Japan
[4]Department of Neurosurgery, College of Medicine, Ilsan Paik Hospital, Inje University, Korea

Corresponding Author Email: sblee@ncc.re.kr

In heavy-ion therapy, dose-averaged linear energy transfer (LETd) is a key parameter that governs biological effectiveness and treatment quality. However, direct measurement of LETd in clinical beam delivery systems remains technically challenging. This study investigates the feasibility of using LET-dependent quenching in a Scintillator–Solar Cell Detector (SSCD) as an indirect method for estimating LETd in carbon ion beams. By analyzing the detector response characteristics under high-LET irradiation, we aim to demonstrate the applicability of scintillator-based detectors.

Measurements were performed at the Gunma University Heavy Ion Medical Center using a passive carbon ion beam delivery system. Three representative beam conditions were used: a 290 MeV/u single Bragg peak, a 290 MeV/u spread-out Bragg peak (SOBP), and a 380 MeV/u SOBP. Physical dose was measured with an Advanced Markus chamber, while scintillation signals were obtained from the SSCD, DRZ-high inorganic scintillator coupled with thin-film solar cells. The detector response was evaluated as a function of depth. The corresponding depth-dose distribution and LETd values were derived from the treatment planning system.

A clear reduction in scintillation signal relative to the physical dose was observed with increasing LETd for all beam conditions, indicating a pronounced LET-dependent quenching effect in the SSCD. The quenching ratio, defined as the ratio of SSCD response to ionization chamber dose, showed a consistent correlation with LETd. Based on this correlation, LETd could be indirectly estimated from measured SSCD and Advanced Markus chamber signal ratio, and results showed agreement with Monte Carlo–derived LETd values. This relationship was independent of beam energy and delivery mode (single Bragg peak versus SOBP), demonstrating robust scintillator response characteristics under carbon ion beams, in the presence of mixed radiation fields from nuclear fragments.

This study demonstrates that LET-dependent scintillation quenching in an SSCD can be effectively exploited to estimate LETd in carbon ion therapy. The observed consistency across different beam qualities highlights the potential of scintillator-based detectors as practical tools for LET-related beam monitoring in medical applications. These results highlight the broader applicability of LET-dependent scintillation response characteristics for beam characterization in particle therapy.

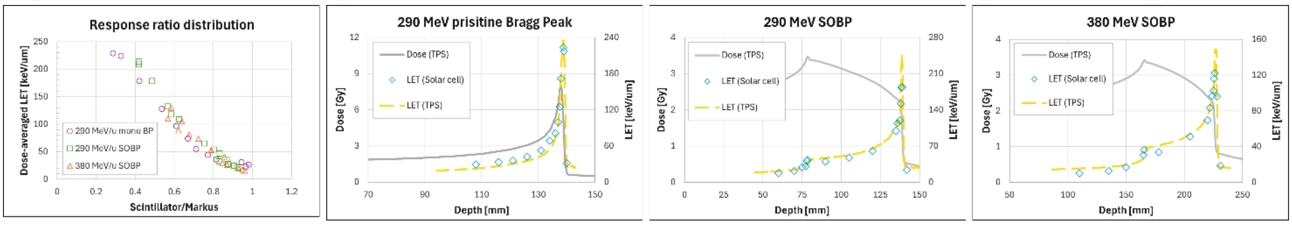

Figure. (from left to right) Response ratio distribution as a function of LETd. LETd estimation result of three representative beams.