Cerenkov luminescence imaging for the range verification of radioactive beam

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Heavy ion therapy is a promising cancer therapy technique which can deliver the optimal dose to a tumor while minimizing the unnecessary dose to normal tissues. Recently, the potential of radioactive beam therapy has been investigated with a combination of the OpenPET system to improve the accuracy of *in vivo* beam range verification. The aim of this study is to estimate the radioactive beam depth in a water phantom by a principle of Cerenkov luminescence imaging (CLI) for beam quality control. In this work, GATEv6.2 Monte Carlo simulation was carried out. A water phantom ($10 \times 10 \times 60$ mm^3) was irradiated by heavy ion beams of carbon-12, carbon-11, and oxygen-15. The Cerenkov luminescence light emitted from the water phantom was detected by an optical system which consists of a lens (f= 7.5 mm), pinhole aperture (D= 3.2 mm), and a CCD (10×10 mm^2) as shown in Fig. 1. When a C-12 beam was irradiated, the Cerenkov luminescence image showed no correlation with the dose distribution as shown in Fig. 2. However, in the case of radioactive beams such as C-11, and O-15, the Cerenkov luminescence images showed a good correlation with the dose distribution (peak difference = 0.2 mm) as shown in Fig. 3 and 4. In conclusion, the CLI has the potential to be used for the radioactive beam range verification. In the future, experimental measurements will be performed in HIMAC to validate the GATE simulation results.

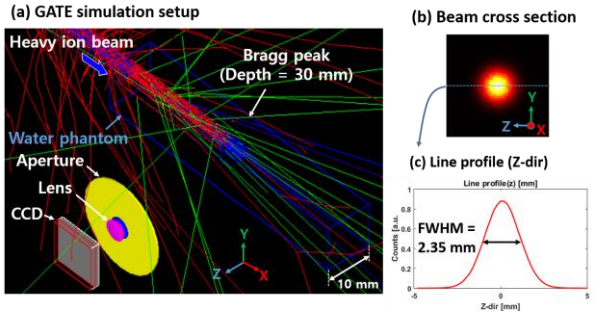

Fig. 1. (a) GATE simulation of carbon-12 beam, (b) cross section of the dose distribution, and (c) line profile of dose distribution in the Z-direction.

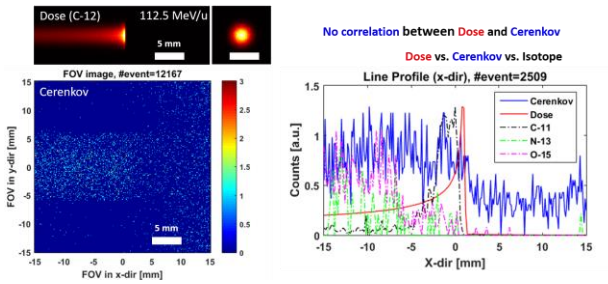

Fig. 2. Carbon-12 beam: (a) dose distribution, (b) Cerenkov luminescence image of the CCD, and (c) line profiles of the dose, Cerenkov, and isotope stop position.

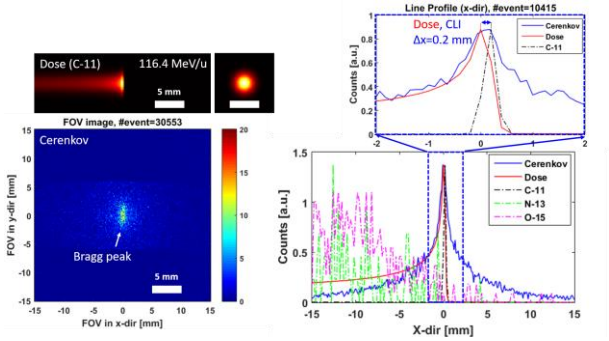

Fig. 3. Carbon-11 beam: (a) dose distribution, (b) Cerenkov luminescence image of the CCD, and (c) line profiles of the dose, Cerenkov, and isotopes stop position.

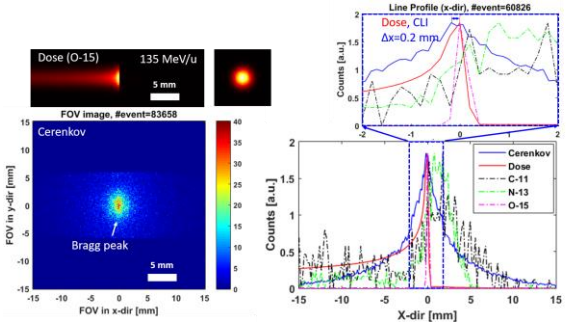

Fig. 4. Oxygen-15 beam: (a) dose distribution, (b) Cerenkov luminescence image of the CCD, and (c) line profiles of the dose, Cerenkov, and isotope stop position.