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First demonstration of real-time gamma imaging by using a handheld Compton camera for particle therapy

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Real-time gamma imaging during particle therapy is expected to improve the accuracy of the therapy. A Compton camera is a promising detector for online monitoring during the particle therapy because it is capable of conducting measurements across a wide energy range, measuring not only the annihilation gamma rays (511 keV) but also a part of the prompt gamma rays. In this study, we demonstrated the imaging of gamma rays generated by the nuclear interactions during proton irradiation by using a handheld Compton camera $(14\ \mathrm{cm} \times 15\ \mathrm{cm} \times 16\ \mathrm{cm},\ 2.5\ \mathrm{kg})$ based on scintillation detectors. The angular resolution of this Compton camera is $\sim 8^{\circ}(\mathrm{FWHM})$ for a $^{137}\mathrm{Cs}$ source.

We used the cyclotron at the National Institute of Radiological Sciences (NIRS) in Japan, which can generate a 70 MeV proton pencil beam. We measured the energy spectra of the gamma rays using a $\mathrm{LaBr_3}$(Ce) scintillator and photomultiplier tube (PMT) and performed image reconstruction using the handheld Compton camera when using the proton beam to irradiate the water, $\mathrm{Ca(OH)_2}$, and PMMA phantom.
In the energy spectrum of the PMMA phantom, we found the obvious peak at not only 511 keV but also 718 keV, a part of the prompt gamma rays that derived from $^{10}\mathrm{C}$. Therefore, we evaluated the peak positions of the projection of the reconstructed images using both of them. This evaluation showed that the peak positions are 23 $\pm$ 1.8 mm and 30 $\pm$ 8.1 mm, respectively, while the Bragg peak position calculated by simulation is 33mm. We cannot arrive at a clear conclusion that prompt gamma rays trace the Bragg peak well from these results, because of the uncertainty by the spatial resolution of the Compton camera.

We can acquire online gamma imaging of both of the energy ranges during proton irradiation in a short time. We are going to develop a high-resolution Compton camera in the near future.

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