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A New Strategy for Range Verification in Proton Therapy: the Coaxial Approach

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Eight years ago, the milestone of first-in-human range verification of a proton therapy treatment using prompt gamma-rays was achieved using a collimated gamma-ray camera. Despite being developed by a major proton accelerator vendor, the widespread clinical application and commercial availability of this device is not yet in sight. It remains unsure whether its size and weight will allow their integration on every treatment room worldwide.
To address this shortcoming, a new method without collimation was recently proposed: the monitoring of prompt gamma-rays with a single detector, coaxial to the proton beam, behind the treated area. This orientation exploits the solid angle effect, as the number of gamma-rays reaching the detector will increase in case of an overshoot, or decrease in case of an undershoot.
By solely counting the number of detections per proton, one would be able to identify range deviations with respect to the treatment plan. With this compact and affordable method, the integration in the treatment room would be facilitated compared to the state-of-the-art collimated gamma-ray cameras.
Nonetheless, this novel orientation entails unexplored challenges, namely high count rates and large neutron background in forward direction.
We report on initial developments of a demonstrator system specifically tailored to cope with up to 10 million counts per second. It comprises a cerium bromide scintillator coupled to a photomultiplier tube and a fast digitizer. First experimental tests show the ability of acquiring continuous waveforms at 2.5 GSPS without any dead time during a time span typical of a clinical treatment field, which in turn allows for a sophisticated decomposition of pile-up events. Dedicated photomultiplier supply electronics able to sustain high count rate variations have been designed with the help of behavioral circuit simulations and are being tested with controlled light sources. In parallel, detailed Monte Carlo simulations of the detector and photomultiplier tube are under development. During the next year, we plan to conduct first tests at a bremsstrahlung beam and at a clinical proton beam to obtain the first experiment proof-of-principle of coaxial detection for proton therapy range verification.

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