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Development of a Compton Camera for Online Range Monitoring of Laser-Accelerated Proton Beams via Prompt-Gamma Detection*

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Presently large efforts are conducted in Munich towards the development of proton beams for biomedical applications, generated via the technique of particle acceleration from high-power, short-pulse lasers. While so far mostly offline diagnostics tools are used in this context, we aim at developing a reliable and accurate online range monitoring technique, based on the position-sensitive detection of prompt γ rays emitted from nuclear reactions between the proton beam and the biological sample. For this purpose, we develop a Compton camera, designed to be able to track not only the Compton scattering of the primary photon, but also to detect the secondary Compton electron, thus reducing the Compton cone to an arc and by this increasing the source reconstruction efficiency.
Within a wider context, a detector system consisting of several Compton camera modules could also be used in a versatile hybrid mode for range verification of therapeutic (carbon) ion beams. Prompt γ radiation could be detected during the irradiation, while during the irradiation interrupts delayed photons from short-lived β^+ (or β^+-γ) emitter, produced during the irradiation, could be exploited to allow for a PET- or γ-PET mode of operation.
The design of the Compton camera is based on a $LaBr_3$(Ce) scintillation crystal (50x50x30 mm^3) acting as absorber, preceded by a stack of 6 double-sided silicon strip detectors (DSSSDs) as scatterers. The scintillation material $LaBr_3$ is favourable in view of its unprecedented fast timing properties (achievable time resolution in the range of several 100 ps), while simultaneously exhibiting good energy resolution. In order to achieve optimum position resolution for the absorbed photon, the scintillation crystal is read out by a (256-fold) segmented multi-anode photomultiplier. The Si scatterers (50x50 mm^2) with an active thickness of 300 μm are 128-fold segmented on each side (pitch size 390 μm). Data readout of the scintillator is performed via individual channels of spectroscopy electronics, while the 1536 signal channels of the Si detectors are processed by highly integrated modules based on ASIC chips.
The contribution will review simulation-based design criteria and performance properties for the Compton camera as well as the present status of the commissioning phase of the prototype detector system.

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