First in-beam tests on simultaneous PET and Compton imaging aimed at quasi-real-time range verification in hadron therapy

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Hadron Therapy (HT) with protons has advantages with respect to conventional radiotherapy because of the maximization of the dose at the Bragg peak. As a drawback, and because of different systematic uncertainty sources, a quasi-real time monitoring for the proton range verification is required to reduce safety margins and thus enhance its potential benefits. In this respect, a promising technique is prompt gamma-ray (PG) monitoring, which requires detection systems with large detection efficiency, high time resolution, compactness, fast response, low sensitivity to neutron-induced backgrounds and powerful image reconstruction capabilities. To a large extent, these criteria are fulfilled by the i-TED detection system. i-TED is an advanced array of Compton cameras originally designed for neutron-capture time-of-flight experiments. In this contribution we will demonstrate the suitability of i-TED also for PG monitoring in ion-range monitoring during HT. Furthermore, aiming at improved signal-to-noise Compton images in the high-energy gamma-ray range characteristic of HT, a novel Machine Learning (ML) methodology has been developed and applied for identification of full-energy events during the irradiations. Together with the use of GPUs, a quasi-real time PG monitoring can be achieved using i-TED.

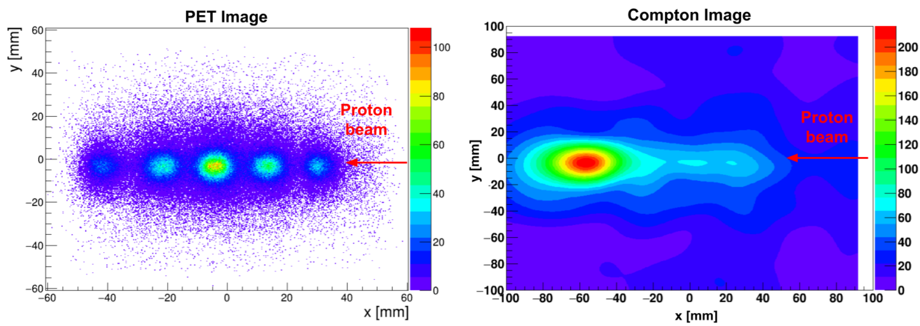

Figure 1. Raw experimental images along the proton beam axis. Left: PET image of five 180 um thick Nylon layers obtained with two i-TED modules. Right: Experimental Compton image during the proton irradiation, reflecting mostly the position of a 2 mm thick graphite sample placed beyond the stack of Nylon layers.

At this conference we will present the first results from an experiment performed at the cyclotron of the CNA facility, Spain, where 18 MeV protons impinged on a 5-layers stack of thin Nylon foils separated by 1.6 cm and followed by a 2 mm thick graphite layer. The latter assembly was surrounded by two i-TED modules. The latter could be therefore simultaneously operated as a positron-emission tomography (PET) system for in-beam image reconstruction from 511 keV positron annihilation gamma-rays (Fig.1-Left). Also, using the high-energy prompt gamma-rays the i-TED modules were simultaneously used as a high-efficiency and large field-of-view Compton imager (Fig.1-Right). Finally, a short outlook will be presented on forthcoming plans with i-TED for simultaneous PET and Compton imaging at a HT facility under realistic clinical conditions.

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