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Data acquisition system for a proton imaging apparatus

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New developments in the proton-therapy field for cancer treatments, leaded Italian physics researchers to realize a proton imaging apparatus consisting of a silicon microstrip tracker, to reconstruct the proton trajectories, and a calorimeter, to measure their residual energy. For clinical requirements, the detectors used and the data acquisition system should be able to sustain 1 MHz proton rate. The tracker read-out, using an ASICs, acquires the signals detector and sends data in parallel to an FPGA. The YAG:Ce calorimeter generates also the global trigger. The data acquisition system and the results obtained with a 60MeV proton beam are presented and discussed

Summary

The proton therapy is a good clinical treatment for cancer as it permits to obtain a dose distribution extremely conform to the target volume. In order to fully exploit the potential of proton dose release, the dose calculation should be performed with high accuracy. This issue requires the knowledge of proton stopping power inside the tissues. Up to now this information is deduced from X-Rays Computed Tomography, but the error related to this procedure is relevant. To overcome this problem, proton imaging can be used as a direct method for stopping power determination. Moreover, the same imaging system can be useful in the patient positioning verification. The aim of the project is to develop a proton imaging system with density and spatial resolution less than 1% and 1 mm respectively. The apparatus that will be presented reconstructs the map of the electron density by tracking the single proton through the traversed tissue and by measuring its residual energy. In order to cross the entire patient thickness, proton energy must be 200-250MeV . The need for tracking the single particle derives from the Coulomb multiple scattering of protons inside the matter. In order to acquire an image in a fraction of a second, following clinical requirements, the system should be able to sustain 1MHz proton beam. Our apparatus includes a tracker with eight x-y planes based on position sensitive microstrip detectors to determine particle entry and exit point and direction. Downstream the tracker, a calorimeter is used for residual energy measurement. Each tracker plane consists of two module with sensors positioned at 90° to each other. The tracker module includes a front-end board and a digital board. The microstrip silicon detector, positioned in the front-end board, is coupled with eight ASICs each serving 32 front-end channels. The integrated circuit, developed by the collaboration, via a charge sensitive amplifier, a shaper and a comparator, converts the fast current signal from the microstrip crossed by the particle, in a digital pulse of 300-800ns. The duration of the pulse depends on the amount of energy released by the proton and on the threshold value used. So, for fixed threshold value, by the Time Over Threshold (TOT) technique it is possible also to measure the charge released into the silicon detector. The outputs signals are sent in parallel to an FPGA located on the digital board which performs zero suppression and moves data to a buffer memory. An Ethernet commercial module is use both for data transfer to the central acquisition PC and to control the tracker module DAQ parameters. Results about a single plane test performed at Laboratori Nazionali del Sud (LNS) with 60MeV proton beam will be presented. The calorimeter consists of four YAG:Ce scintillating crystals, coupled with commercial photodiodes. The read-out system acquires the information about the residual energy of the particle and generates the trigger signal and the system global event number. Thanks to the fast scintillating light decay constant the YAG:Ce crystal is able to sustain 1MHz proton rate. This apparatus was tested with 60MeV and 200MeV proton beams at LNS and Loma Linda University Medical Center (LLMC) respectively. Data analysis shows that this crystal meets high and spatially-uniform efficiency and energy resolution requirements.

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