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Data Acquisition Board for a Beam-Tagging Hodoscope Used in Hadrontherapy Monitoring

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This paper presents a data acquisition board associated with a beam-tagging hodoscope to be used in hadrontherapy for ion-range monitoring. The board was designed to couple to a 64-channel multi-anode photomultiplier, and to meet the hodosope's requirements: 1-mm spatial resolution and 1-ns temporal tagging resolution, with 100-MHz counting rate capability. It mainly consists of two 32-channel readout ASICs, a signal-processing&control FPGA and a 3-Gbit/s optical transceiver to a μTCA-based data acquisition system. The board was fabricated and its operation was verified by test bench. Beam tests (with hodoscope and acquisition system) have been scheduled and are being prepared.

Summary

There have been suggested methods to implement real-time ion-range monitoring for quality assurance in hadrontherapy. Prompt gamma (PG) detection is a promising technique and several prototypes using various modalities are under developments worldwide. Some systems use time-of-flight (TOF) measurements to discriminate PG from the neutron background (e.g. TOF PG cameras), while others employ Prompt Gamma Timing approach for indirect measurement of ion range. All require precise measurement of arrival time of incident ions detected by a beam-tagging hodoscope. One type of such hodoscopes for this purpose has been developed by CLaRyS collaboration network (consisting of several IN2P3 laboratories). It consists of an array of scintillating fibers in vertical and horizontal directions. The optical fibers are coupled to multi-anode photomultipliers.

We report here the development of a data acquisition (DAQ) board to be associated with a scintillating-fiber-based hodoscope. The board incorporates two 32-channel readout ASICs, a FPGA (StratixII GX EP2SGX30C/D) and an optical transceiver (enhanced small form-factor pluggable transceiver). Each readout ASIC also integrates a time-to-digital converter (TDC) and a multiplexed analog output for monitoring of scintillating fibers ageing. The FPGA performs data processing, transmission and slow control. The transceiver performs electrical-and-optical-signal conversion and bi-directional transmission at 3 Gbit/s rate. Via an optical fiber, the board can be connected to a μTCA-based data acquisition system. The board also include a clock jitter cleaner (LMK04828) to generate several clock signals from an external reference clock. The board supports two types of triggers: a self-trigger for stand-alone tests and an external trigger for coupling with imaging systems like prompt gamma cameras. In order to optimize data throughput, the transceiver uses only basic 8-/10-bit protocol and fully exploits specific control symbols to distinguish different types of frames (control, monitoring, and data).

The board was designed to meet the system requirements: 1-mm spatial resolution, 1-ns timing resolution, and 100-MHz counting rate capability. To ensure time-measuring precision and transmission reliability, phase determination and frequency synchronization techniques were implemented. The board was fabricated and its operation was verified by test benches. Beam tests (with hodoscope and acquisition system) have been scheduled and are being prepared.

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