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The Microstrip Silicon Detector (MSD) data acquisition system for the FOOT experiment

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The FOOT (FragmentatiOn Of Target) multi-detector experiment aims at improving the accuracy of oncological hadrontherapy for tumor treatment. It studies the nuclear fragmentation due to the interactions of charged particle beams with patient tissues. Among the several FOOT detectors, the silicon Microstrip Detector is part of the charged-ions-tracking magnetic spectrometer. Here we describe the MSD architecture and its data acquisition system whose task is to collect and digitize the detectors output, generating a data packet to be sent to the experiment's central acquisition. This data acquisition system is designed and tested to withstand the high trigger rate and detector's throughput.

Summary (500 words)

Charged Particle Therapy in deep-seated solid tumors permits better effectiveness in cell killing compared to conventional photon radiation due to the depth-dose profile of charged particles. However, there is still room for improvement as there are no precise experimental data to feed into the Treatment Planning Systems (TPS) to compute the delivered dose along the particles path due to the fragments generated by the nuclear interaction that occurs between the charged particles beam and patient tissues. To this purpose, a new experiment FOOT (FragmentatiOn Of Target) has been proposed. It will use the inverse kinematic approach to measure the double differential cross-section of nuclear fragmentation, hence it is composed of different detectors with the aim of being portable among ion beam accelerators and capable of multiple measurements of the kinematic quantities of the charged fragments over a 10° cone around the beam axis. In this work we present the architecture of the Micro Strip Detector (MSD), the last x-y silicon measurement station of the experiment, which is just after the magnetic volum, and has the task of evaluating the Linear Energy Transfer LET (dE/dx) and the nuclear fragments momentum. It consists of 3 layers, each composed of 2 planes of silicon detectors made by Hamamatsu Photonics in which 640 150-um-thick microstrips are oriented orthogonally (one plane of 640 strips for the x axis and another plane for the y axis) to provide space points (x,y,z) along nuclear fragment tracks. The microstrip detectors are hosted in custom printed circuit boards where the output analog signal is preamplified, shaped, sampled and held by several IDE1140, an application specific integrated circuit (ASIC) for the readout of silicon strip radiation detectors. The analog data from each pair of x-y planes are passed to 12-bit high speed, low power ADCs (AD7276) with throughput rates up to 3 MSPS hosted in custom boards (ADC boards). The digitized data from each x and y plane is then collected by a DE10-Nano board, a commercial system-on-chip with a hard processor and an FPGA to complete the final module detector readout chain (one DE10-Nano board for each x- y plane).

The MSD complete subsystem can receive and recognize the signals sent from the central trigger board and instructions sent from the experiment central DAQ system. It contains an adequate number of registers for configuration and monitoring, reads out the data from the detectors when an external trigger occurs, and sends the acquired data to the central DAQ system. For each event, a sequence of headers and footers is added for event recognition as well as for timing information.

The entire path of the data from the raw sensors of the MSD sub-detector system to the central DAQ is an innovative custom data acquisition system relatively small in size and easily portable, which permits over 2 kHz acquisition rate capable of following the characteristics of the beam without generating bottlenecks for the entire experiment and the efficient management of both detectors frontend control and generated data delivery.

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