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HVTrack: A monolithic HV-CMOS detector for hadron therapy

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The hadron therapy is a powerful medical instrumentation for cancer treatment. For the effectiveness of the hadron treatment, it is important to control the energy released by particles for precisely tracking the Bragg peak point. The present contribution refers to the development of a custom detector for proton source characterization. The detector, placed at different distances from the source, has to measure the energy of detected particles and tracking the trajectory of them in order to evaluate possible presence of scattering due to the interaction with the sample.

Summary (500 words)

In a hadron therapy system, the source of particle, typically protons or carbon ion, when interacting with the human body, releases almost all its energy at Bragg peak point, i.e. at specific distance from the surface. Nevertheless, due to the interaction with the material, some particles can scatter, involving neighboring healthy tissues. Therefore, it is very important to monitor this process possibly during the treatment. As alternative, a characterization of the source can be proposed using a human phantom. In the present work, we describe a detector conceived for the characterization of a proton source for hadron therapy.
A couple of sensors, based on a monolithic HV-CMOS approach, are placed inside the water equivalent human phantom at different distances with respect to the source of protons for the Bragg peak estimation. The chip comprises a matrix of 64x64 pixels arranged in 4x4 clusters. Every pixel can be configured to measure the energy, the arrival time or to count detected events. Differently from standard detectors working in continuous mode, this device works synchronous with the source of protons.
Being placed on the focus of the beam, the sensor shows regions with a very poor activity and region where the rate of particles is very high. As a consequence of such a high flux, correlated events detected by the two sensors for trajectory estimation are difficult to identify, while the energy estimation can be affected by pile-up. To allow a best correlation, the detectors are forced to be synchronous, working in gated mode. In this mode all pixels of the array are enabled for a predefined time window Tw and only events detected in Tw are valid for the trajectory reconstruction as well as for energy estimation.
The measurement of the energy is typically implemented using a ToT approach. Nevertheless, due to the high flux, two particles very close in time and hitting the same pixel can induce an energy distortion (pile-up effect) if the second detection happens during the conversion time. In order to avoid this situation, a sample and hold circuit saves the peak of the charge amplifier and convert in a second phase the analog value using a single ramp ADC. Values of energy can be stored in two local memories.
The time information is used to allow a spatio-temporal correlation between the two detectors and extract the particle trajectory. This information is provided by a 9b gray counter shared among the array and running at 1GHz. When the pixel detects an event, the current counter value is sampled into the local memory. To uniformly distribute the value of the counter to the entire array in a scalable way, the detector is divided in 16 clusters. Every cluster has one pixel, the master pixel, not sensitive to particle hit and devoted to the generation of the time reference. The master pixel consists of a ring oscillator with programmable speed followed by a synchronous gray counter while a buffer tree has been implemented in each cluster for counter distribution.

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