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Experimental results on monitoring proton and carbon ion clinical beams using thin silicon sensors

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The excellent time resolution of LGAD and thin PIN silicon sensors allows for the measurement of the particle flux and profile of clinical beams with single particle sensitivity. The experimental results of a proton and carbon ion counter based on a 2.7 × 2.7 cm2 silicon sensor will be presented. The counter was also integrated with a Time-to-Digital Converter to measure particles'crossing time.

A 60 µm thick PiN diode and a 50 µm thick Low Gain Avalanche Diode were used for detecting carbon ions and protons at CNAO (Pavia), respectively. The sensitive area of both the sensors covers the cross section of a pencil beam and it is segmented in 146 strips with 180 µm pitch. The readout is based on the ESA-ABACUS frontend board, developed to house six 24-channel ASICs able to discriminate particle signal pulses in a wide range of charge (4-150 fC), with a maximum dead time of about 10 ns. The digital pulses produced by the discriminator for each particle are acquired by 3 Kintex7 FPGA boards implementing pulse counters for each channel. Alternatively, the digital pulses of 12 channels can be acquired by the CERN PicoTDC evaluation board providing the time measurements in time bins of 3 ps.

The measurements performed result in beam projections with a FWHM in agreement with beam profiles measured with gafchromic films. The proton counting efficiency shows a dependence on the beam energy because of geometric and pile-up effects, whereas an efficiency above 90 % with lower energy dependence is found for carbon ions. The time measurements with the TDC allowed for the study of the difference of crossing times of consecutive particles in one strip which shows a time structure compatible with the radio-frequency period of the synchrotron.

The results indicate that thin segmented silicon sensors, custom front-end readout with high rate capability and the use of picoTDC allow to perform 4D tracking in particle therapy.

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