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A novel technology for particle beam monitoring based on thin silicon sensors

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Purpose: An innovative detector based on thin silicon UFSD detectors was developed and characterized by the medical physics group of the University and INFN-Torinofor single ion discrimination and ion counting in a therapeutic particle beam.

Materials and Methods: Thin silicon sensors were developed, characterized and used in a prototype detector aiming at discriminating and counting single protons or carbon ions of therapeutic beams at a maximum fluence rate of 108 p/(cm2*s) with a systematicuncertainty of less than 1%. The sensor is segmented into 146 strips with a sensitive area of 2.7×2.7 cm2 to cover the beam cross-section of about 1 cm FWHM at the isocenter.

The detector is read out by six custom ASICs housed on a dedicated frontend board connected to 3 FPGAs (Xilinx Kintex7). A LabVIEW program is used to display online the counting rate of each strip and to store the data for offline analysis. An extensive characterization was performed first in the laboratory with a pulse generator and then with proton and carbon ion beams at the Italian National Center of Oncological Hadrontherapy (CNAO).

Results: Data were collected and analyzed at different beam energies at CNAO for carbon ions and protons. The beam profile was studied by measuring the number of measured particlesas a function of the strip number and fitting the corresponding distribution with a Gaussian.The beam FWHM measured for different energies is compared with nominalvalues at the isocenter.Moreover, the counting efficiencywas determined by comparing the total number of counts with the delivered number of protons for different beamfluences and energies. Finally, the uniformity over 20 identical spillswas studied and was found to be better than 1% independently of the beam energy.

Conclusions: The tests performed proves the feasibility of directly measuring the particle rate during treatments.Further studies towards using this technology for beam monitoring in clinical practice require improving the radiation resistance, using finer segmentation and increasing the detector-sensitive area.

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