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## INNOVATIVE THIN SILICON DETECTORS AS MONITOR OF THERAPEUTIC PROTON BEAMS

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### Purpose

Beam monitoring in particle therapy can be critical in some applications that, due to intensity and time structure, are a challenge for instrumentation. Silicon detectors might overcome the limits of ionization chambers (response dependence on beam energy, slow collection time, reduced sensitivity). Based on internal charge multiplication, Low-Gain Avalanche Detectors (LGAD) provide high signal-to-noise ratio and fast collection time in a small thickness (1 ns in 50µm), allowing direct single particle counting at high rates. LGADs optimized for excellent time resolutions (Ultra Fast Silicon Detectors, UFSD) can also measure beam energy using time-of-flight techniques.

### Material and Methods

Particle fluxes and time resolutions have been measured using two UFSD pads (1.2 x 1.2 mm<sup>2</sup> surface x 50 µm thickness) at the CNAO proton beam (intensity=10<sup>9</sup> p/s, FWHM=1 cm). Based on the results, dedicated UFSDs for beam monitoring are being designed and produced, together with custom microelectronics readout. Different doping possibilities will be investigated to extend the radiation resistance of the sensors.

### Results

The sensor signals show well separated contributions from single particles, with low pileup probability up to almost 10<sup>9</sup> p/(cm<sup>2</sup>s). Number of particles, beam flux and crossing time are determined via offline analysis of collected waveforms. The obtained time resolution is 40 ps for single crossing; this allows precise beam energy measurement during treatment using the timing difference between two sensors separated by approximately 1 m. The counts obtained with two aligned detectors are well correlated and beam structure is resolved at the nanosecond level.

### Conclusions

UFSD detectors are suitable to monitor therapeutic proton beams by directly counting the number of particles. This information will improve the indirect measurement provided nowadays by ionization chambers.