Contribution ID: **97** Type: **Talk**

Monitoring of carbon ion therapeutic beams with thin silicon sensors: status and perspectives

Thursday 7 September 2023 12:20 (20 minutes)

Background. Single ion counting in particle therapy may lead to new beam monitoring systems much faster and accurate than those currently used in clinics, thus opening the way to innovative delivery strategies. Thin silicon PIN sensors (60 µm active thickness) segmented in strips, manufactured at FBK with different geometries, were optimized for tracking of clinical carbon ions. The results using the CNAO carbon ion clinical beam will be reported.

Materials and methods. Signals of 8 strips of small size sensors were readout using a custom amplifier board and sampled with a 5 GS/s digitizer. Coincidence signals of two sensors were also acquired. The signal peaks were analyzed in terms of, amplitude, peak duration and time resolution at different sensor bias voltages.

A second system, using a larger area (2.6 × 2.6 cmˆ2) strip sensor covering the entire beam cross section, was tested to evaluate the counting efficiency. The strip signals were read out by a 144-channels front-end board equipped with custom ASICs for signal discrimination, followed by 3 Kintex7 FPGA boards for the counting operations.
All the measurements were performed at different beam energies covering the clinical energy range (115 - 399 MeV/u).

Results:
The peak amplitude distributions show a very good separation between signal and noise, scaling as expected with the beam energy, and the signal duration decreases incrementing the bias voltage up to ˜ 2 ns, reaching a single hit time resolution of ˜ 25 ps. Charge sharing and signal cross talk indicate an overall negligible effect and a counting efficiency of ˜ 90% is achieved.

Conclusions:
Initial tests of silicon sensors with carbon ion beams show very promising results, preparing the groundwork for future devices and applications for particle therapy based on the single ion tracking capability.

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Session Classification: Medical applications

Track Classification: Applications in Life Sciences, Biology & Medicine