Preliminary test of innovative strip silicon detectors for therapeutic proton beam monitoring

Purpose

Unlike currently used gas ionization chambers, solid state detectors offer large granularity and sensitivity to single incoming particles, therefore being ideally suited to improve the present technology for beam monitoring in particle therapy. However, several drawbacks, such as radiation damage, prevented their use so far on high flux therapeutic beams. Two prototype devices for monitoring particle beams are under development, based on innovative silicon low-gain avalanche detectors optimized for time resolution (Ultra Fast Silicon Detectors - UFSDs). Preliminary results with proton beams are presented.

Methods

UFSDs are low-gain avalanche detectors optimized for time resolution, where sensors as thin as 50 µm provide signals of ~ 1ns time duration with time resolutions of tenths of ps, and large enough signal-to-noise ratio to efficiently discriminate proton signal. One prototype device is being developed to directly count individual protons at high rates, while a second one is under investigation to measure the beam energy with time-of-flight techniques. This requires the design of custom UFSD sensors as well VLSI readout electronics. From simulations' results and first beam tests with UFSD pads, strip detectors were produced, with two geometries (30 mm and 15 mm length) and different doping modalities to improve radiation hardness. In parallel, prototypes of a new readout chip have been submitted to the foundry.

Results

Strips sensors were characterized in the laboratory through laser test and I(V) curve studies, and a test with a therapeutic proton beam, with energy ranging from 62 to 227 MeV, was done. Results were obtained via offline analysis of the collected waveforms for Boron and Gallium doped sensors. Time resolution of 35 ps, signal duration of ns, and good S/N separation were found. A gain degradation of 20% was founded in single pad sensors after 10^{12} protons/cm^2 irradiation. Pile-up effects are under investigation.

Conclusions

Based on the preliminary results, UFSDs are found to be a promising improvement of monitor chamber. The aim of this contribution is to review the advancement of the project and to report on the results of the test of UFSD strip sensors with a therapeutic proton beam.