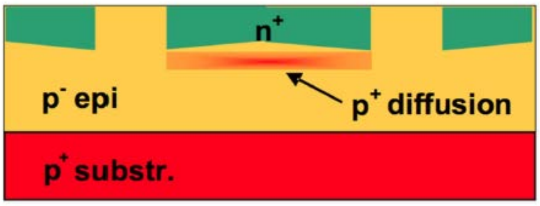
Purpose: Monitoring the prescribed dose in particle therapy with the raster-scan method is equivalent to monitoring the correct delivery of the number of ions and the sequence of beam positions for every energy of the primary beam. The first task is typically carried out by using parallel plate ionization chambers working in transmission mode, where the number of particles is derived from the collected ionization charge with an accuracy in the order of 1%. The use of gas detectors has several drawbacks: they need to be calibrated daily against standard dosimeters and their dependence on beam quality factors need to be fully characterized and controlled with high accuracy. A detector capable of single particle counting is proposed which would overcome all these limitations. Combined with a gas ionization chamber, it will allow determining the average particle stopping power, thus providing an effective method for the online verification of the selected particle energy and range of the beam during the irradiation of the patient.
Materials and methods: Low-Gain Avalanche Detectors (LGADs) are innovative n-in-p silicon sensors with moderate internal charge multiplication occurring in the strong field generated by an additional p+ doping layer implanted at a depth of a few μm in the bulk of the sensor.



The increased signal-to-noise ratio allows designing very thin, few tens of micron, segmented LGADs, called Ultra Fast Silicon Detectors (UFSD) that, due to their large and very fast signal collection time, would be suitable for charged particle counting at high rates in particle therapy applications. We have finished the design of a sensor prototype, with a matrix of 100 pixels which will provide first indications on the particle rate capability and count accuracy. The sensors are expected in early spring 2016.
Results: Different LGAD diodes have been characterized both in laboratory and beam tests, and the results compared both with those obtained with similar diodes without the gain layer and with a program simulating the signal in the sensors. The signal is found to be enhanced in LGADs, while the leakage current and the noise is not affected by the gain. Additional results, as the information on the doping profiles, extracted from the study of CV curves and radiation tolerance studies, are also shown. Possible alternative designs and implementations are also presented and discussed.
Conclusions: Thanks to their excellent counting capabilities, UFSD detectors are a promising technology for future beam monitor devices in hadron-therapy applications. Studies are ongoing to better understand their properties and optimize the design in view of this application.

Keywords: Particle Therapy, Beam Monitoring, Silicon Detectors

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Variance Reduction of Monte Carlo Simulation in Nuclear Medicine
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Purpose: A method, which has had a great impact in many different fields of computational science,is called "Monte Carlo".The range of Monte Carlo application is enormous, from the Nuclear medicine, Radiation therapy, Reactor design, Quantum chromo dynamicsto Traffic flow and econometrics.One of the difficulties associated with Monte Carlo simulations is the amount of computer time required to obtain results with high precision. To shorten the calculation time and also improve the efficiency, there comes the idea to use the variance reduction techniques.
Method: There are many ways in which a user can improve the precision of a Monte Carlo simulation. In this study several of the more widely used variance reduction techniques such as: Splitting/ Russian Roulette, Energy cut off, Time cut off, Weight window, Implicit capture, Forced collision and Exponential transformation are presented. Application of variance reduction and guideline for these techniques in simulation are described.
Results: In Splitting/ Russian roulette technique each region is classified as important and unimportant. If the selected region is unimportant the Russian roulette has been used and in contrary if the important region is selected Splitting is used.
The energy cutoff and time cutoff are similar but more caution is needed in energy cut off because low energy particles can produce high energy particles.
The weight window technique is space energy dependent and can control weight fluctuation by define upper and lower energy bounds. Weight window technique is used to avoid following very low weight particles which causes reasonable computer timer during the simulation.
The main advantage of implicit capture is that a particle always survives a collision. It means when a particle reaches near the tally region would not be absorbed just before a score is made.
The exponential transformation is designed to enhance efficiency for deep penetration problems, but it should be noted that due to the large weight fluctuation that can be produced by this technique, it should be used accompanied by weight controls.
Conclusion: Variance Reduction techniques are used to produce more accurate and precise estimation in Monte Carlo simulations. There is a problem that these techniques may lead to results not being analyzed correctly but it should be noted that experience will lead the users to find the tricks for using these techniques to obtain the more accurate results.

Key words: Variance reduction, Monte Carlo, Simulation

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Simulation of cell survival for proton broad and minibeam radiotherapy with hexagonal and square minibeam alignment
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Purpose: Proton radiotherapy using so-called minibeams of sub-millimeter dimensions allows to additionally enhance the advantages of proton therapy by spatial fractionation. This leads to a lower fraction of cells suffering from direct radiation damage and thus to reduced side effects compared to conventional proton therapy, which has been shown in a human skin and a mouse ear model [1,2]. Tumor control is maintained via homogeneous irradiation of the tumor due to minibeam widening with increasing depth. The minibeam distances need to be maximized for improved tissue sparing while generating a homogeneous tumor dose. Here, the required distances for quadratic vs. hexagonal minibeam arrangement are analyzed (see Figure 1). The resulting dose distributions are simulated in a water phantom with clinically relevant energies leading to different cell survival fractions and side effects.
Figure 1: *Minibeam arrangement on a quadratic lattice (left) and on a hexagonal lattice (right).*