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Physical and Biological investigations using Geant4 Monte Carlo simulation of the beam delivery line components in particle therapy.

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Background: The importance of Monte Carlo (MC) simulations in the field of advanced radiation therapy increases with the necessity to investigate the effect of detectors, monitoring systems and ripple filters at the design phase. In this work we present our investigations using MC simulations of the effects of each of the elements in a beam delivery line of a particle therapy facility.
Methods and Materials: A full beam delivery line of the national center of oncologic hadrontherapy (CNAO) is simulated with the Monte Carlo package Geant4 to get the actual distribution of particles and fragments and the corresponding energies, in the treated volume. The evaluation of biological effects was studied using a code based on the Local Effect Model (LEM). The monitoring system on the beam delivery line was fully simulated, as well as the ripple filters and range shifters. The computational effort was performed using the distributed INFN Grid computing resources.
Measurements were done within the facilities of INFN Laboratori Nazionali del Sud to compare physical data of the lateral distribution of the beam and the Bragg peak curve (energy loss in depth curve) to MC simulations. The measurements were performed to test the design of the ripple filters to be used at CNAO. We calculated also the corresponding biological effect to evaluate the biological equivalent dose.
Results: A good agreement between simulations and experimental measurements for protons was obtained. The test for the design of new filters was successfully realized.
Given this good agreement we are confident about other improvements of the nozzle based on the simulation results. We modeled the effect of both ripple filters and monitoring system defining the corresponding transfer functions optimized the design of the monitoring system and especially for the design and test of ripple filters improving some of their features. We provided as well a tool to estimate both the physical and the biological equivalent dose distribution with the definition of corresponding transfer functions.
Conclusion: MC simulations using Geant4 helped for the design of the monitoring system and especially for the design and test of a new ripple filters to be installed at CNAO, improving some their features. We provided as well a tool to deduce both the physical and biological equivalent distribution determining their corresponding transfer functions.
Physical dose simulated data was largely verified. We are expecting the verification of the biological equivalent dose from future biological measurements using ripple filters.

Are you a Memeber of the Geant4 Collaboration (yes/no)

no

Keymords

MC simulations, ripple filters, beam delivery line, particle therapy

Summary

The importance of Monte Carlo (MC) simulations in the field of advanced radiation therapy increases with the necessity to investigate the effect of detectors, monitoring systems and ripple filters at the design phase. In this work we present our investigations using MC simulations of the effects of each of the elements in a beam delivery line of a particle therapy facility.

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