# MEDICAL APPLICATIONS AND MICRODOSIMETRY WITH GEANT4

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## 1. INTRODUCTION.

Geant4 [1] Monte Carlo toolkit, an open-source code written in C++, is a very powerful tool for the simulation of the passage of radiation through matter. Although its origin is related to the High-Energy Physics field, Geant4 can be used in a wide range of applications: from space applications to microdosimetry and medical applications.

We present in this contribution an overview of the Geant4 applications developed recently in our group. First, we show the characteristics and results obtained in the medical field, especially related to a system to verify IMRT treatments [2]. Subsequently, we continue with the optimization of the Geant4 code developed by the proton therapy group at the Massachusetts General Hospital (MGH) in order to verify treatments with protons [3-4]. Further, the Geant4 application coded to estimate the energy deposited in all the elements of a AMOSC5 flip-flop is presented [5]. Finally, we present the application developed to study the response of a mini-SeD detector prototype [6], designed for the FAIR project.

## 2. MEDICAL APPLICATIONS.

### A) Simulation of a Micron silicon strip detector to verify IMRT treatments:

A Geant4 application developed for the simulation of the 6-MV-photon mode of a Siemens Primus linac [7], and benchmarked with results obtained with EGSnrc/BEAMnrc code (a standard, well-validated code in radiotherapy), was adapted to study the performance of a single side silicon strip detector (SSSSD) for dosimetric measurements in radiotherapy based on Intensity Modulated Radiation Treatment (IMRT). This work is part of a more complex project which goal is the validation of a novel method for measuring the dose map before treating patients with IMRT. The goal of these simulations is to estimate the sensitivity of this SSSSD in different situations, namely reference radiation field simulations and half-field simulations in order to study the response of the detector to the field penumbra. Further, all these situations were also reproduced experimentally to test the Geant4 calculations.

### B) Optimization of a Geant4 code used for proton therapy:

Geant4 simulations have been frequently used to study the performance of the proton therapy nozzle used at MGH for patient treatments [3]. In proton therapy, Monte Carlo simulations are a powerful tool to verify certain treatments. However, they are usually very expensive in terms of CPU time, which means that Monte Carlo simulations are not a feasible tool in the clinics. In this section we show briefly the most important speed-up techniques that we have developed in collaboration with the proton therapy group leader (Dr. H. Paganetti) [4]. The main results obtained with our techniques, which are useful for another Monte Carlo code which simulates a proton therapy treatment head, are a time reduction of approximately 35% in the most typical case, and a 15% reduction in the worst case, which corresponds to maximum efficiency at the nozzle exit.

## 3. RADIATION EFFECTS IN INTEGRATED CIRCUITS.

Beyond the medical applications, in collaboration with the Electronic Engineering Department at University of Seville, we have developed another Geant4 code to calculate the energy deposited by any kind of ionizing radiation in every element of a complex digital circuit CMOS AMISC5 flip-flop [5]. The goal of these simulations is to perform a microdosimetry study of ionizing radiation effects. Microelectronic devices are sensitive to the passage of ionizing particles due to the parasite charge distributions generated in their components, which can trigger some effects in the electronics leading to unexpected responses that can be analyzed experimentally. This Geant4 simulation calculates the deposited energy track by track, so that an estimation of the collected charge can be done for every sensitive volume of each CMOS transistor. These simulations are also important because a microdosimetry study can only be done with simulations, since there is no possibility of measuring experimentally the actual dose that every system component has absorbed.

## 4. EXPERIMENTAL NUCLEAR PHYSICS.

Finally, the last Geant4 application we present in this contribution is the modeling of a mini-SeD prototype for beam tracking, developed by the Basic Nuclear Physics group at the National Accelerator Center (CNA) for the FAIR project [6]. In this case, the goal of our Geant4 simulations was to improve the promising experimental results by means of optimizing the testing set-up. In particular, the characteristics of the mini-SeD under study were the energy, time and spatial distribution of the electrons passing through cathodes and anode, as well as the energy deposited in the cathode strips of the detector.

## 5. CONCLUSIONS.

We have presented in this contribution several Geant4 simulations developed by our group with application in different research fields, from medical applications to microdosimetry and beam tracking detection. In the medical field, our goal is to use Monte Carlo simulations as a tool to verify treatments for patients as well as optimize the Monte Carlo codes with speed-up techniques applicable for similar treatment heads. In the other cases, we use our Geant4 simulations as a supporting tool to calculate magnitudes not measurable experimentally or to optimize a testing set-up for a detector.

## REFERENCES:


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