Status of the GEANT4 Advanced Examples for medical physics applications

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Introduction

Geant4 is a Monte Carlo code widely used in medical physics applications, ranging from radiotherapy and imaging to radiation protection. To support users, the *Geant4 Advanced Examples* include applications of the toolkit in a set of realistic application scenarios: *brachytherapy*, *gammaknife*, *hadrontherapy*, *human_phantom*, *iort_therapy*, *medical_linac*, *microbeam*, *nanobeam*, *purging_magnet*, *radioprotection*. In this work, recent additions and improvements included in Geant4 10.5 are presented.

The Geant4 Advanced Examples: recent improvements and additions

The *brachytherapy* example demonstrates the modelling of radioactive sources used in interstitial, endocavitary and superficial brachytherapy. The example has been recently improved by including two new ^{192}Ir brachytherapy sources and a new ^{125}I source. The Flexisource (Nucletron, Elekta) [1] source is commonly used for high dose rate brachytherapy treatments. The TG186 source [2] is a generic, reference ^{192}Ir source, created to provide developers of dose engines with a method of validating new dose calculation techniques. The Oncura 6711 ^{125}I source [1] has been added as well. An additional recent improvement is the option to compare simulation results with reference data in terms of dose rate distribution.

The *hadrontherapy* example was specifically developed for dosimetric and radiobiological studies with protons and heavy ions beams. It allows the simulation of three passive ion INFN beamlines: CATANA (INFN-LNS, Catania); the Zero-degree multidisciplinary facility (INFN-LNS, Catania); and the Multidisciplinary beam line (INFN-TIFPA, Trento). Recently, the primary event generator was optimized with the capability of generating primary particles from a phase space file. A recent development is the calculation of biological-related quantities such as averaged LET-dose and LET-track [3, 4], Relative Biological Effectiveness (RBE) [5], survival fraction and biological dose.

The *iort-therapy* example simulates intraoperative radiotherapy (IORT) devices used in clinical environment to treat breast cancer. This Geant4 example allows the dose distributions to be calculated in different clinical scenarios and can be used to perform radiation protection studies. Such applications can be very useful, especially during the acceptance of a new IORT accelerator, periodic quality assurance procedures or treatment plan verification. One of the most interesting recent improvements to the *iort-therapy* example was the possibility to simulate an innovative model of IORT devices, i.e. NOVAC11.

The *microbeam* and *nanobeam* examples describe transport beamlines for radiobiological studies, used for single-cell irradiation experiments and high-resolution irradiation of samples. The *microbeam* example implements a cellular phantom obtained from confocal microscopy, and includes scoring of energy deposition [6]. The *nanobeam* example allows to the user to extract beam optics parameters (e.g. aberration coefficients) and includes several alternative models of quadrupole magnetic field [7].

The *medical_linac* example performs the dosimetry of a typical medical linear accelerator for Intensity Modulated Radiation Therapy (IMRT), such as the Varian Clinac 2100 accelerator. Nowadays, dose calculation algorithms based on the Monte Carlo method are generally regarded as the most accurate tools for radiotherapy and an independent Monte Carlo simulation can be used to validate commercial treatment planning systems for radiotherapeutic treatments. This example demonstrates the use of Geant4 in oncological radiotherapy by simulating a linear accelerator for radiotherapy in a flexible way and providing an evaluation of the resulting dose distributions.

The *radioprotection* example shows how to perform experimental microdosimetry, by means of diamond microdosimeters, developed at the Centre for Medical Radiation Physics, University of Wollongong, Australia [8]. This example evaluates the microdosimeters for radiation protection of astronauts, however it can be easily adapted for hadrontherapy Quality Assurance.

The *doiPET* example, released for the first time in Geant4 10.5, simulates a depth-of-interaction enabled positron emission tomography (PET) scanner. This Geant4 example emerged from a collaboration of ANSTO, the University of Wollongong and NIRS (Chiba, Japan) in the context of the OpenPET project without the open gap [9]. The scanner model consists of 4 rings, each with 40 detector modules. The detector modules feature a four layer GSO scintillator block, with each layer consisting of a 16x16 array of crystals. Each scintillator block is coupled to a single PMT.

References

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