

Geant 4

A Short Course on Geant4 Simulation Toolkit

Introduction

<http://cern.ch/geant4>

The role of simulation

- Simulation plays a fundamental role in various domains and phases of an experimental physics project
 - design of the experimental set-up
 - evaluation and definition of the potential physics output of the project
 - evaluation of potential risks to the project
 - assessment of the performance of the experiment
 - development, test and optimisation of reconstruction and physics analysis software
 - contribution to the calculation and validation of physics results
- The scope of these lectures (and of Geant4) encompasses the **simulation of the passage of particles through matter**
 - there are other kinds of simulation components, such as *physics event generators*, *electronics response* generation, etc.
 - often the simulation of a complex experiment consists of several of these components interfaced to one another

Detector Simulation - General

- General characteristics of a detector simulation system
 - You specify the geometry of a particle detector
 - Then the software system automatically transports the particle you shoot into the detector by simulating the particle interactions in matter based on the Monte Carlo method
- The heart of the simulation: the Monte Carlo method
 - A method to search for solutions to a mathematical problem using a statistical sampling with random numbers

Basic requirements for a simulation system

- Modeling the experimental set-up
- Tracking particles through matter
- Interaction of particles with matter
- Modeling the detector response
- Run and event control
- Accessory utilities (*random number generators, PDG particle information etc.*)
- Interface to event generators
- Visualisation of the set-up, tracks and hits
- User interface
- Persistency

The zoo

EGS4, EGS5, EGSnrc

Geant3, Geant4

MARS

MCNP, MCNPX, A3MCNP, MCNP-DSP, MCNP4B

MVP, MVP-BURN

Penelope

Peregrine

Tripoli-3, Tripoli-3 A, Tripoli-4

...and I probably forgot some more

DPM

EA-MC

FLUKA

GEM

HERMES

LAHET

MCBEND

MCU

MF3D

NMTC

MONK

MORSE

RTS&T-2000

SCALE

TRAX

VMC++

Monte Carlo codes presented at the MC200 Conference, Lisbon, October 2000

What Can Geant4 Do for You?

- Transports a particle step-by-step by taking into account the interactions with materials and external electromagnetic fields until the particle
 - loses its kinetic energy to zero,
 - disappears by an interaction,
 - comes to the end of the simulation volume
 - Provides a way for the user to access the transportation process and grab the simulation results
 - at the beginning and end of transportation,
 - at the end of each stepping in transportation,
 - at the time when the particle is going into the sensitive volume of the detector
 - etc.
- ➡ ***These are called “User Actions”***

What Do You Have to Do for Geant4?

- Three essential information you must provide:
 - Geometrical information of the detector
 - Choice of physics processes
 - Kinematical information of particles going into the detector
- Auxiliary matter you could prepare:
 - Magnetic and electric field
 - Actions you want to take when you access the particle transportation
 - Actions you want to take when a particle goes into a sensitive volume of the detector
 - etc.

Tools for Input Preparation

Geant4 provides standard tools to help you to prepare input information

- Multiple choices to describe the detector geometry
 - Combining basic geometry elements (box, cylinder, trapezoid, etc)
 - Representation by surface planes
 - Representation by boolean operation, etc.
- Standard way to define materials in the detector
 - A large collection of examples to define various materials
- A set of wide variety of particles
 - Standard elementary particles (electron, muon, proton,....)
 - Unstable particles (resonances, quarks, ...)
 - Ions
 - Exotic particles (geantino, charged geantino)

Choice of Physics Processes

Geant4 provides a wide variety of physics models of particle interactions with matter you can select

■ Category of physics processes

- Standard electromagnetic processes
- Low energy electromagnetic processes
- Hadronic processes

■ How to use physics processes

- A rich samples of ***Physics List*** provided with example applications
- Recommended ***Physics List*** (educated guess) for hadronic physics

Minimum Software Knowledge to Use Geant4

- C++
 - Geant4 is implemented in C++, therefore a basic knowledge of C++ is mandatory
 - C++ is a complex language, but you are not required to be a C++ expert to use Geant4
- Object Oriented Technology
 - basic concepts
 - in-depth knowledge needed only for the development of complex applications
- Unix/Linux
 - Unix/Linux is a standard working environment for Geant4, therefore a minimum knowledge/experience is required
 - How to use basic Unix command
 - How to compile a C++ code
 - Windows
 - You can use Visual C++
 - Though still you need some knowledge of Unix (cygwin) for installation

Tools for Your Simulation

■ User interface

- **Interactive mode with terminal or GUI**
- **Batch mode**

■ Visualisation

- **Trajectory of a particle and its all secondaries**
- **Detector geometry**

■ Debugging

- **Controllable verbose outputs from the kernel during transportation**
- **Errors in the geometry definition, etc.**

■ Data analysis