

Introduction to GEANT4



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What is GEANT4 ?

GEANT4 is *a toolkit for the simulation of the passage of particles through matter.*

- Often used in physics (nuclear, high-energy, accelerator, and medical) as well as space science
- **Toolkit:** Using GEANT4, users need to build a simulation program.
- Developed from GEANT3 (fortran). GEANT4 is written in C++ (Object-Oriented programming)
- Developed and maintained by **GEANT4 Collaboration** (<http://www.cern.ch/geant4>)

What does GEANT stand for?

Two answers posted to the GEANT4 forum:

- **GE**neration **ANd** **T**racking (End of 1970's, at the beginning of GEANT1)
- **GE**ometry **ANd** **T**racking (Nowadays)

Why is simulation needed anyway?

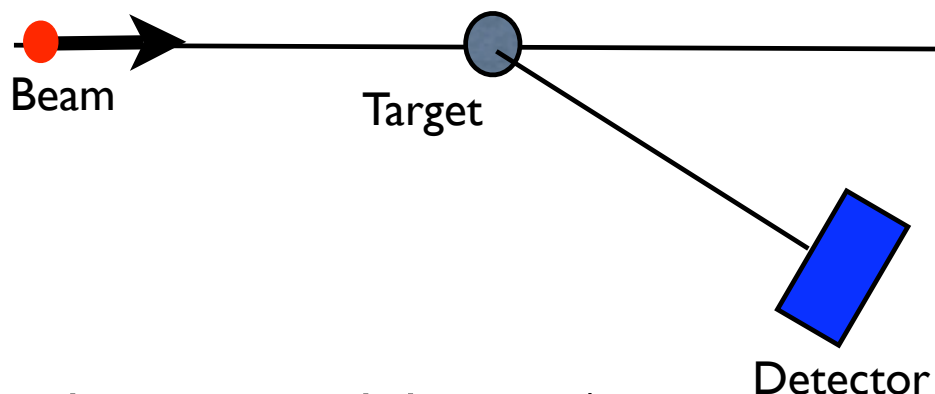
In nuclear/high-energy physics, **Monte-Carlo simulation** is often needed to do the followings:

- To determine the experimental setup
 - optimize the detector/shielding locations to obtain decent results in experiment
 - study the expected background and radiation level
- Compare the simulated results with experiment to make sure there is no error in analysis (or simulation code).
- Correct the experimental results by comparing them with simulated results with inputs from theory

What are needed in simulation?

To simulate a nuclear physics **experiment**, information on the followings is needed.

- Beam
- Target
- Detectors
- E&M Fields
- Physics interactions (in the target and detector) and cross sections
- and so on...



What are needed in GEANT4?

Below is a minimum list of things **users** need to do in GEANT4 programming

- Define Materials and Geometries (target, detector...)
Add E&M fields [optional]
- Define particles and physics interactions
- Decide how a primary event should be generated
- and so on...

What are needed in GEANT4?

Below is a minimum list of things **users** need to do in GEANT4 programming

G4UserDetectorConstruction class

- Define Materials and Geometries (target, detector...)
Add E&M fields [optional]

- Define particles and physics interactions

G4UserPhysicsList class

- Decide how a primary event should be generated

- and so on...

G4UserPrimaryGeneratorAction class

Then, what does GEANT4 do for you?

- A particle is transported through matter for every step until the particle
 - goes out of the world volume
 - loses its kinetic energy to zero
 - it disappears by an interaction or decay
- Users can access the transportation process to get the simulated results ==> **USER Action**
 - at the beginning and end of transportation
 - at the end of each transportation step
 - when the particle enters the sensitive volume of the detector

GEANT4 related resources

- **GEANT4 Home page:** <http://cern.ch/geant4>
- Overview of C++ for GEANT4 users:
<http://geant4.in2p3.fr/2007/prog/prog.htm>
- software reference manual and GEANT4 cross reference are available to understand Geant4 classes
- GEANT4 Tutorial classes held almost every year by SLAC GEANT4 team [Many lecture slides available online]

GEANT4 credits

- Two main reference papers for Geant4 have been published:
 - Nuclear Instruments and Methods in Physics Research A 506 (2003) 250-303
 - IEEE Transactions on Nuclear Science 53 No. 1 (2006) 270-278.
- Geant4 software license is given at <http://cern.ch/geant4/license> .
- Many course slides for this TUNL geant4 tutorial are courtesy of SLAC GEANT4 team (<http://geant4.slac.stanford.edu/>)