



Lab # 2: Monte-Carlo detector simulation

The purpose of this exercise is to familiarize the student with Monte Carlo (MC) simulations in order to study detector response to radiation and to understand some basic concepts using GEANT4 as an example. Geant4 is a last generation code which uses general C++ libraries which the user can freely adopt to run a specific simulation. This makes Geant4 very versatile and flexible compared to general-purpose MC codes, yet it also makes it more difficult to use. The libraries include various EM and hadronic physics packages, powerful tools to define detector geometry, and allows one to have complete information on the trajectory of the particles.

Bibliography

- 1.-Alex Bielajew, Fundamentals of the Monte Carlo method for neutral and charged particle transport: <http://www-personal.engin.umich.edu/~bielajew/MCBook/book.pdf>
- 2.- Geant4 : <http://geant4.cern.ch/>
- 3.-Linux: <http://www.debianhelp.co.uk/commands.htm>
- 4.-Gnuplot: <http://www.gnuplot.info/>
- 5.-Fortran: http://www-teaching.physics.ox.ac.uk/unix+prog/hargrove/tutorial_77/

Materials

The following materials are available to the student:

- 1.-Linux computer
- 2.-Working directory /g4work/DEA/practica4_grupon#/ which contains a simple Geant4 simulation program called Planar1.cc in addition to related subroutines which are located in subdirectory /src/ and /include/. Subdirectory /data/ contains program outputs as well as analysis programs
- 3.-Macros used to run the program and with environment variables (vis.mac, energystore.mac, env.sh...)
- 4.-Attached paper which specifies the measurements, geometry, and materials which each group must use for the exercise.
- 5.-Fortran programs to analyze the data.
- 6.-Gnuplot to graph the data.



Procedure

- 1.-The first step is for the student to connect from their computer to the work computer which has Geant4 installed. To do this the teacher will give the student the IP address of the work computer as well as a username and password. Once connected to the work computer, the student should go to the /g4work/DEA directory and copy the / practica4/ folder to one called /lab2_grupon#_/ (**scp -r practica4 lab2_grupon#**). This will be the working directory for the exercise. The student will also receive a separate worksheet which defines the different characteristics to be used throughout the exercise.
- 2.-Configure the boundary conditions in Geant4 found in the file env.sh **source env.sh**
- 3.-Familiarize yourself with the program structure and the relevant subroutines. Identify: the description of geometry, the event generator, the particles and processes involved, and the information on the particle trajectory, event, and simulation
- 4.-Compile Planar1.cc: **make**; first run **make clean** to make sure there are no existing files which can cause a compilation error.
- 5.-Run the program: **\$G4BIN/Linux-g++/Planar1**. In order to execute the orders of point 4 and five automatically, a script has been created. To execute it type: **./compile.script**
- 6.-View the defined geometry in the attached file by running the visualization macro: **/control/execute vis.mac**. Change the colors (in PlanarDetectorConstruction.cc file) and orientation of the view (in vis.mac file). Don't forget to compile when you change ".cc files"
- 7.-For the different particles and energies included in the attached sheet, run the macro: **energystore.mac**. *The output of the Geant4 simulations is automatically stored in a file called runOutput.dat. With this macro, the names of these files will change (make sure to name them appropriately) and will be saved in the /data/ subdirectory. What spectra do you expect to obtain?*
- 8.-Change the dimensions of the geometry as indicated in the attached sheet and view it. Using this geometry, run the macro with the energies and particles from (7). Make sure to change the filenames which are to be saved in order to analyze them later.
- 9.-Change the parameters as explained in the attached, and rerun the previously mentioned macro for the same energies and particles defined in (7). Make sure to change the filenames which are to be saved in order to analyze them later.
- 10.-Using the initial geometry and materials, include the geometry indicated by the professor in the attached sheet, and run the macro again using the specified energies and particles. Do you expect to see a change in the histograms?
- 11.-Run the fortran file dea.f with each of the output files from Geant4. This program gives an output named by the user while executing the program. Using the output files from dea.f, view the energy histograms from each step using gnuplot or any other program.



Report

To evaluate the overall completion of the laboratory exercise the student should hand-in a lab report. This report should explain the procedure followed during the exercise as well as include the following:

- a) **An image of the cylindrical geometry** used in steps six and seven with the dimensions specified in the attached sheet. The color and orientation of the view is chosen by the student and could not be the default values.
- b) **Spectrum** obtained from the simulations in step seven. Run four simulations: two different particles each with two different energies. The energy and particles are defined in the attached sheet for each group. Comment on the spectra, using the Geant4 output files if necessary. Do you find it something special in the positrons spectra?
- c) **An image of the cylindrical geometry with new dimenstions** outlined in step eight, using the values defined in the attached sheet. **Show and analyze the obtained spectra**, comparing it with the spectra from the previous geomery parameters. These will again be four simulations: using the same energies and particles in (7).
- d) **Spectrum** obtained from the simulations in step nine with the new detector composition and the cylinder dimensions from the attached sheet. Run four simulations using the energy and particles defined in the attached sheet (7). Comment on the differences in this and the previous spectra.
- e) **Spectrum** obtained from the simulations in step ten in which in addition to the initial cylindrical geometry you are to include a new geometry (**show also the image of this geometry in the report**) defined in the attached sheet (as well as the energy and particles). View the spectrum obtained in which the energy was deposited only in the initial cylinder and comment on which effects, if any, have been introduced by including the new geometry.
- f) The student will comment on the following:
 - a) The photopeak efficiency of the LaBr_3 (scintillating material) is greater than the real efficiency. Why do you think this is?
 - b) Taking into account the previous question: What would be the next step in our code if we want to obtain photopeaks with a more realistic efficiency?



ANEXO: Lab #4: MONTECARLO DETECTOR SIMULATION

GRUP N#: _____

Students: _____

Section 6 y 7:

Particle: e- e+ γ

Energy: 663 keV 1173 keV 1274 keV 1332 keV 1460 keV

Cylinder: Radius 1 cm
LaBr3 Thickness 3cm

Section number 8 :

Radio 1.5 cm
Thickness 5 cm

Radius 2 cm
Thickness 4 cm

Radius 2 cm
Thickness 5 cm

Section number 9 :

Thickness 3cm
Radius 1 cm
Material: LYSO

Thickness 3cm
Radius 1 cm
Material LaCl3(:Ce)

Thickness 3cm
Radius 1 cm
Material CsI

Section number 10:

Cilindro: LaBr₃
Cover of 0.5 cm
Ge
e+ 1460 keV

Cylinder: LaBr₃
Cover of 1cm
Al
e+ 663 KeV

Cylinder: LaBr₃
Cover de 0.5 cm
Al
e- 1332 keV

Composiciones de los diferentes materiales:

LYSO: d= 7.10 g/cm³ [Lu]=71.45% [Y]= 4.03 % [Si]= 6.37% [O]=18.15%

LaCl3(:Ce) : d= 3.85g/cm³ [La]=53.804% [Cl]= 45.196% [Ce]= 5%

CsI: d= 4.51 g/cm³ Cs:I= [1:1]

Al: d= 2.7 0g/cm³

Ge: d= 5.32 g/cm³

IMPORTANT NOTE: Each run sends 100000 events