Compilation and run of a Geant4 Advanced example

Corso Nazionale sull’utilizzo del toolkit di simulazione Geant4
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The Geant4 example categories

- Novice examples
  - Basic application

- Extended examples (Demonstration of Geant4 specific usage)
  - Electromagnetic
  - Analysis
  - Biasing
  - visualisation
  - ........

- Advanced examples (Simulation of real experimental set-up)
  - Brachytherapy
  - Gammaray_telescope
  - Medical_linac

- Hadrontherapy
What is Hadrontherapy?

- Is an advanced example contained in the Geant4 distribution
- It shows how to simulate typical transport beam lines for proton/ion therapy
- Different geometrical and physics options can be chosen
Geometrical set-up of hadrontherapy

The source point
Energy, particle, spot size, etc

Region simulating a water phantom

(HadrontherapyPrimaryGeneratorAction.cc)

(HadrontherapyDetectorConstruction.cc)
The detector to collect the energy deposited.

The energy deposited in each slice is stored.
Compilation and run of Hadrontherapy

- cd $G4INSTALL/examples/advanced/hadrontherapy
- gmake

Use the command ‘ll’ to see all the files and folders contained in the principal directory

- Hadrontherapy.cc: the main file
- /src: source file container
- /include: header file container
- /macro: a set of already prepared macro files
- /experimentalData: some experimental set
- /RootScripts: ROOT scripts to perform a fast check of your results
Compilation and run of Hadrontherapy

Firstly run Hadrontherapy without call explicitly a macro file

A default macro file is loaded accorded to the main file specifications:

// If the environment variable for the TCSH terminal is active, it is used and the defaultMacro.mac file is executed
#if defined(G4UI_USE_TCSH)
    session = new G4UITerminal(new G4UITcsh);
    UI->ApplyCommand("/control/execute defaultMacro.mac");
#endif
Compilation and run of Hadrontherapy

Let’s give a look into the default.mac macro file

```
# Set of the physic models

/physic/addPhysics standard_opt3     # Electromagnetic model
/physic/addPhysics elastic          # Hadronic elastic model
/physic/addPhysics binary           # Hadronic inelastic model
/physic/addPhysics radioactive_decay # Radioactive decay

# Initialisation procedure

/run/initialize

# Set the primary particle type

/gun/particle proton
/beam/energy/meanEnergy 63 MeV
/beam/energy/sigmaEnergy 400 keV
/beam/position/Xposition -2600 mm
```
Compilation and run of Hadrontherapy

The visualisation commands

```
# Visualisation

/vis/scene/create
/vis/open OGLIQt # only if QT library are installed
/vis/open OGLIX
/vis/viewer/flush
/vis/viewer/set/viewpointThetaPhi 30 140 deg
/vis/viewer/zoom 1
/vis/viewer/pan -10 0 cm
/tracking/storeTrajectory 1
#/vis/scene/endOfEventAction accumulate
/vis/scene/endOfEventAction accumulate -1
/vis/viewer/update
```

```
# Display the event number
during the run
/event/printEventNumber 10
```

```
# Start of the run
/run/beamOn 1000
```

We can modify the number of events
(10 K events are at minimum necessary for an acceptable proton dose distribution but we’ll try with 1 K)
Compilation and run of Hadrontherapy

Now we are ready to run the application:

```bash
$G4WORKDIR/bin/$G4SYSTEM/Hadrontherapy
```

At the end two files are generated containing information on the dose deposited inside the water box:

- A .root file
- An ASCII file

Give a look inside them.
Interaction with the application using the macro commands

- Many operations can be done externally without the need to recompile the code: Geant4 native messengers and Users messengers

  - We can change the geometry
  - We can run time-dependent simulations
  - We can change the physics models
  - All the command can be integrated in one macro file (.mac extension)
Change of the entire geometry

The iaea.mac file simulate the configuration of typical nuclear physics experiment

- A target whose material and thickness can be changed
- A detector plane where to registered the secondary particles produced in the interaction
- Here I used a water target and a 12C ion beam of 400 AMeV

The program run with the following command:

```
$G4WORKDIR/bin/$G4SYSTEM/Hadrontherapy macro/iaea.mac
```
The iaea.mac geometry
Time dependent simulations

- We change the position of one of the transport beam line after a given number of events.
- This element is an energy modulator: a wheel of different thicknesses that intercepts the proton beam.
- The macro used is `modulator.mac`
  
  `G4WORKDIR/bin/$G4SYSTEM/Hadrontherapy macro/modulator.mac`
Change some transportation parameter

- Production cut of secondary particles
- Max step
- We can change again the defaultMacro.mac where cuts and steps are defined
- Bigger cut and step values will affect (decreasing) the simulation times but also the quality and precision of results
- We van try with 1 km of cut

```bash
/physic/setCuts 1 mm
/Step/waterPhantomStepMax 1 mm
```
Recursive change of beam parameters: the position

Let try to change the position of the beam origin during the same simulation (but in different runs)

The defaultMacro.mac can be change in such a way:

```
/beam/position/Xposition -2700 mm
#########################
# Display the event number
# during the run
#
/event/printEventNumber 10
#########################
# Start of the run
#
/run/beamOn 10
/beam/position/Xposition -2000 mm
/run/beamOn 10
/beam/position/Xposition -1000 mm
/run/beamOn 10
```
Recursive change of beam parameters: the energy

Let now change energy of the primary beam

```
/beam/position/Xposition -2700 mm

# Display the event number
# during the run
#
/event/printEventNumber 10

# Start of the run
#
/run/beamOn 10
/beam/energy/meanEnergy 100 MeV
/run/beamOn 10

/beam/energy/meanEnergy 300 MeV
/run/beamOn 10
```
Change of physics models

- Also physics models can be changed via macro commands
- But in Hadrontherapy a default assure the activation of the electromagnetic processes
- Let came back to the defaultMacro.mac

```
# Set of the physic models
#
/physic/addPhysics standard_opt3 # Electromagnetic model
/physic/addPhysics elastic # Hadronic elastic model
/physic/addPhysics binary # Hadronic inelastic model
/physic/addPhysics radioactive_decay # Radioactive decay
```

- If we wish to activate only the inelastic processes?
- I must change the code (HadrontherapyPhysicsList.cc file)

```c
// electromagnetic physics list
//
//emPhysicsList->ConstructProcess();
//em_config.AddModels();
```