

# Geant4 Hands-on Exercises

**Workshop on Use of Monte Carlo  
Technique for Design and Analysis  
of Radiation Detectors**

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# Introductory Remarks

- ▶ This short tutorial supposed to be an introduction to the Geant4 toolkit
- ▶ Today only Linux
- ▶ More detailed tutorial materials are available in Geant4 web: <http://cern.ch/geant4>
- ▶ Complete documentation is also available in the web

# Installation

- ▶ Geant4 toolkit requires installation procedure
- ▶ The only mandatory external library CLHEP
- ▶ Today you will use Geant4 already installed in the server `polaris.fis.uc.pt`

# Geant4 Environment

▶ Login

▶ Define G4 environment:

```
. /opt/g4tutorial/setup.sh
```

```
pwd
```

```
env | grep G4
```

▶ You see in the screen the list of G4 environment variables

▶ Copy first example to your directory

```
cp -r /opt/g4tutorial/temp/TestEm3 .
```

# User Classes

cd TestEm3

less TestEm3.cc

## ▶ main()

- The toolkit does not provide *main()*.
- There are more 70 examples

## ▶ Initialization classes

- **Detector Construction**
- **Physics List**

## ▶ Action classes

- Invoked during an event loop
  - ▶ **Primary Generator Action**
  - ▶ Run Action
  - ▶ Event Action
  - ▶ Stacking Action
  - ▶ Tracking Action
  - ▶ Stepping Action

- ▶ You can define VisManager, (G)UI session, optional user action classes, and/or your persistency manager in your *main()*.

Note : classes written in **yellow** are mandatory.

# Compile, link and run

```
cd TestEm3
```

► It is an example of G4; to see its components:

```
ls src
```

► To see the main():

```
less TestEm3.cc
```

► To run in batch mode:

```
gmake
```

```
TestEm3 TestEm3.in >& result.out
```

```
less result.out
```

# Exercise 1: Proton stopping

- ▶ Start interactive session:

TestEm3

```
/control/execute tutor.mac
```

```
/gun/particle proton
```

```
/gun/energy 1 GeV
```

```
/run/beamOn
```

```
/gun/energy 200 MeV
```

```
/run/beamOn
```

```
/run/beamOn 10
```

- ▶ **Question:** estimate energy below which protons stopped

# Exercise 2: Muon physics

```
/gun/particle mu+
```

```
/gun/energy 1 GeV
```

```
/run/beamOn 10
```

```
/gun/energy 10 GeV
```

```
/run/beamOn 10
```

```
/gun/energy 100 GeV
```

```
/run/beamOn 10
```

```
/gun/energy 100 MeV
```

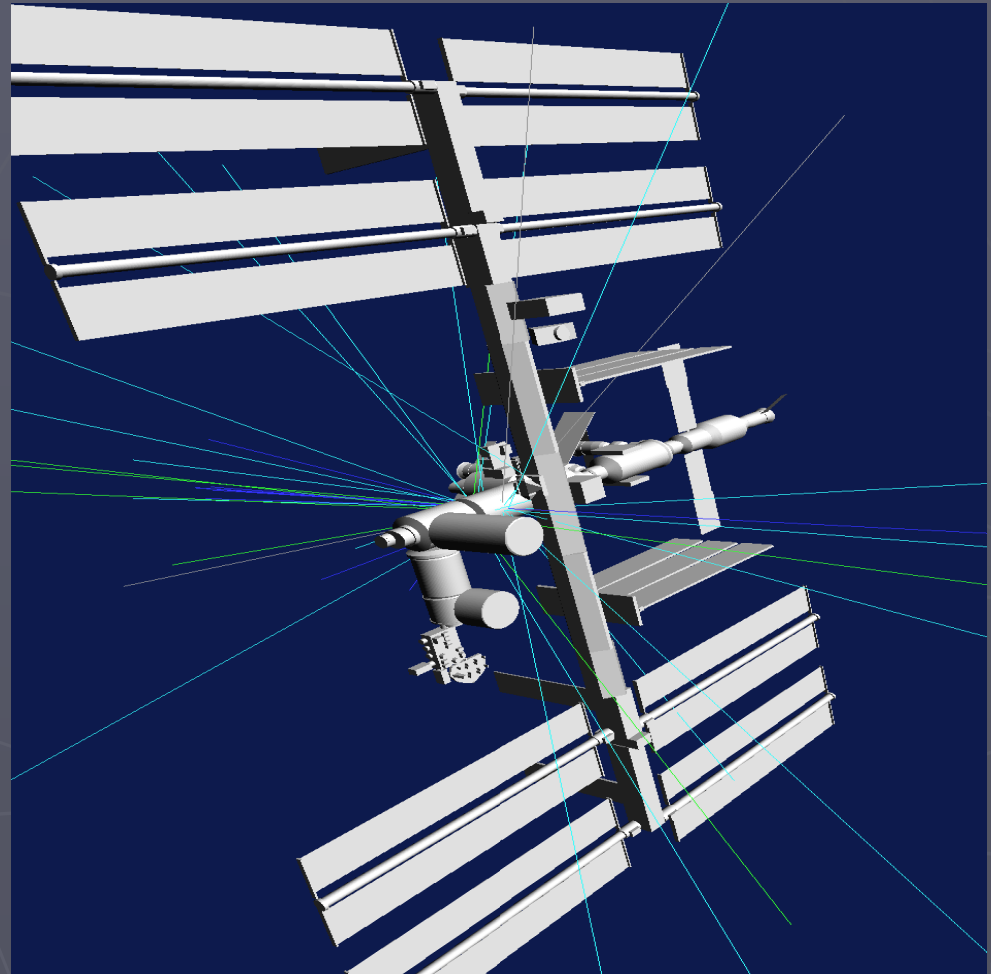
```
/run/beamOn 10
```

► **Question:** explain the last plot

`/tracking/verbose 1` can help

# Terminology (G4 jargons)

- ▶ Run, event, track, step, step point
- ▶ Geometry volumes:
  - Solid, Logical, Physical
- ▶ Media:
  - Material, element, isotope
- ▶ Particle:
  - Particle Definition – static parameters
  - Dynamic Particle – dynamic parameters
- ▶ Track  $\leftrightarrow$  trajectory, step  $\leftrightarrow$  2 trajectory points:
  - PreStepPoint, PostStepPoint
- ▶ Process = Physics
  - At rest, along step, post step
- ▶ Cut -> production threshold!
- ▶ Sensitive detector, hit, hits collection



# Exercise 3: EM shower

- ▶ TestEm3 was created for simulation of sampling calorimeters – there are number of macro files for different configurations and there is a standard output of calorimeter response

```
/gun/particle e-
```

```
/gun/energy 1 GeV
```

```
/run/beamOn 1
```

```
/run/beamOn 10
```

```
/gun/particle gamma
```

```
/run/beamOn 1
```

```
/run/beamOn 10
```

- ▶ **Question:** estimate energy below which electron shower will not be developed

# Exercise 4: Production Thresholds

Is /testem/phys

- ▶ Unix command ls and also tab can be used to see available Geant4 UI commands

```
/testem/phys/setCuts 0.1 mm
```

```
/gun/particle e-
```

```
/gun/energy 0.5 GeV
```

```
/run/beamOn 10
```

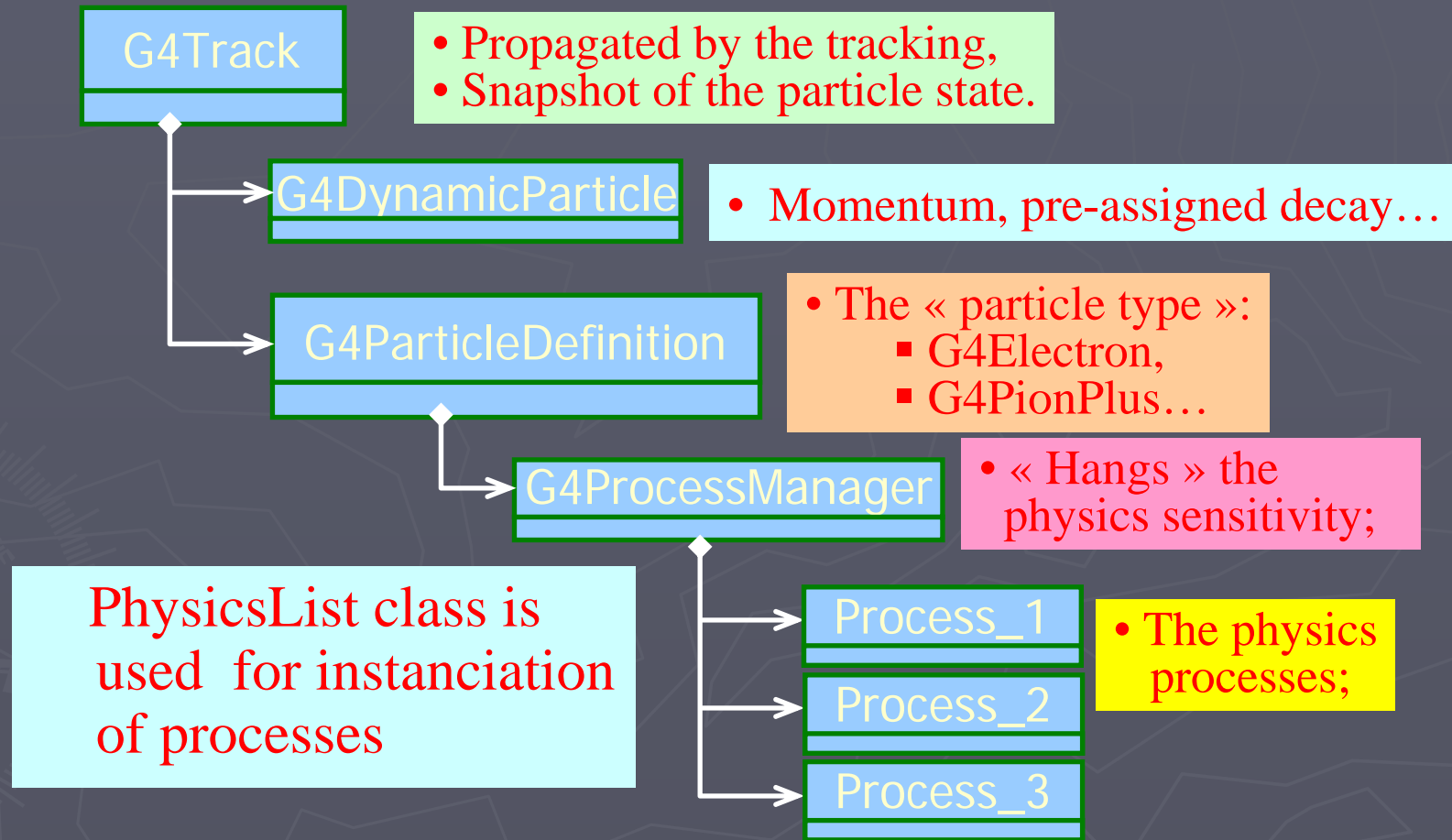
- ▶ Physics tables have been recalculated

```
/testem/phys/setCuts 1 cm
```

```
/run/beamOn 10
```

- ▶ **Question:** estimate cut in range for which no secondary particles will be produced

# What is tracked in Geant4?



# Exercise 5: UI interface

ls /material

/material/g4/printMaterial Lead

- ▶ Material is defined via its elements and isotopes

/material/nist/listMaterials

- ▶ About 300 predefined materials are available

/particle/list

- ▶ Shows particles defined in current Physics Lists

/process/list

- ▶ Shows particles defined in current Physics Lists

- ▶ **Question:** which processes are defined for pi+? Gamma?

/testem/det/setField 1 tesla

- ▶ Try out different particles at different energies
- ▶ Try out to switch on magnetic using /testem/det subdirectory

# Exercise 6: EM processes

```
Exit
ls
TestEm3
/control/execute exo3q1.mac
▶ Only processes on gamma conversion, ionisation and pair production are active
▶ Only one thick absorber Al; Magnetic field is on.
/run/beamOn 1
/run/beamOn 1
/tracking/verbose 1
/run/beamOn 1
/gun/particle e-
/gun/position 0 0 0
/run/beamOn 1
/run/beamOn 1
/gun/particle e+
/run/beamOn 1
/run/beamOn 1
▶ Question: select energy, which will allow to see e+ annihilation
```

# Exercise 7: Attenuation of photon beam in absorber

```
exit
cd ../
cp -r /opt/g4tutorial/temp/TestEm14 .
cd TestEm14
gmake
TestEm14 TestEm14.in >& res.out
less res.out
```

- ▶ Example demonstrate several ways of computing of gamma attenuation in media
- ▶ **Question:** compute attenuation coefficient in Be, Fe, Pb, water for gamma energy 1 MeV

# Exercise 8: Different Visualization Commands

```
exit  
cd ../  
cp /opt/g4tutorial/temp/TestEm9 .  
cd TestEm9  
gmake  
TestEm9 TestEm9.in >& res.out  
less res.out
```

- ▶ Example demonstrate cuts per region facility for setup, which includes vertex detector and crystal calorimeter

```
TestEm9  
/control/execute vis.mac  
/run/beamOn
```

- ▶ Only charged tracks are shown

```
ls /testem/event
```

- ▶ **Question:** find out a command to switch on neutral tracks

```
ls /vis/viewer/set
```

- ▶ **Question:** find out a command to change viewpoint and display the setup

# Exercise 9: Hadronic Physics

```
exit
cd ../
cp -r /opt/g4tutorial/temp/Hadr01 .
cd Hadr01
gmake
hadr01 hadr01.in >& res.out
less res.out
```

- ▶ Example demonstrate hadronic beam interaction with a target

```
hadr01
```

```
/control/execute vis.mac
```

```
/testhadr/Physics QGSP
```

```
/run/beamOn
```

```
/run/beamOn 10
```

- ▶ **Question:** compare electron and proton showers for different energies and targets
- ▶ Note: to change predefined Physics List you have to exit and start new session