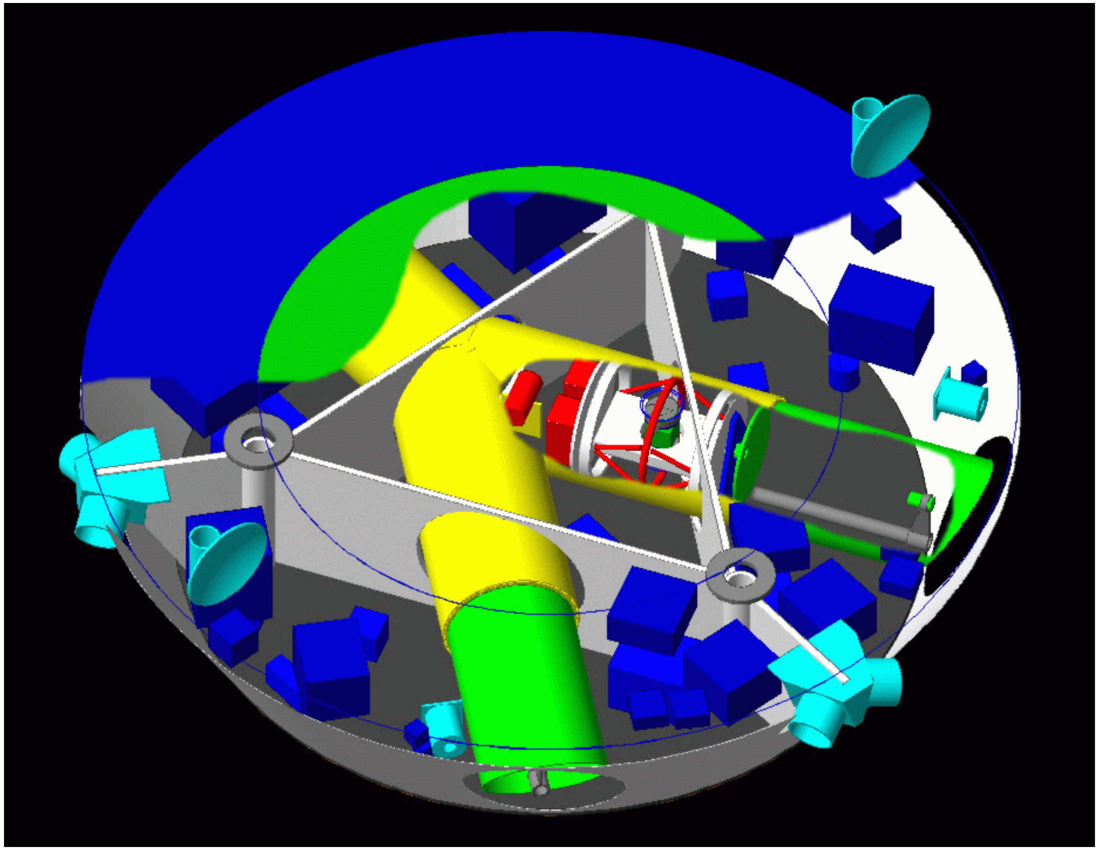
esipap...
European School of Instrumentation in Particle & Astroparticle Physics

E. Chabert
E. Conte

Practical work with G4



Practical work with G4

Skills to acquire

- Building an official Geant4 example
- Using one of the possible GUI (Graphics User Interface)
- Using the user guide & Doxygen documentation of Geant4
- Understanding the structure of a Geant4 program
- Modifying the detector description
- Running the simulation
- Accessing produced data

Outlines

user **developer**

Outlines

Disclaimers

1. Setting your environment

Accessing the Linux virtual machine

The practical sessions will be achieved on a Linux machine for pedagogical motivations. You must connect a virtual machine. First click on the "Start" button, i.e. the button with the Windows logo, located on the bottom left of the screen (see Figure 1).

Figure 1: The Windows Start button

Accessing the Linux virtual machine

According to Figure 2, click on the virtual machine called **"ESIPAP_slc6"**. A password could be necessary and should be supplied by the supervisors.

Figure 2: The screen showing the available virtual machines

Loading G4 environment

- To load the work environment, you can issue the command below at the shell prompt.

```
bash> source /home/esipap/tools/setup.sh
```

- If the system is properly installed, the version of each tool to study should be displayed at the screen like below.

```
----------------------------------------------
ESIPAP environment
----------------------------------------------
- GNU g++ version 4.9.1
- ROOT version 6.06/00
- Geant4 version 10.3.0
----------------------------------------------
```

1. Setting your setup

Checking that G4 environment is properly loaded

- If your setup is properly loaded, you should call the gean4-config program whatever the folder where you are. This program provides some useful information.

- For example, displaying the release version of the Geant 4 program installed on your system:

```
bash> geant4-config --version
```

Are the physics datasets installed?

- Geant4 needs physics datasets which must be downloaded from the official website. As these datasets are heavy, it is possible that all of them are not installed on your system.

- To enumerate the list of the datasets installed on your system, type the following command line.

```
bash> geant4-config --check-datasets
```

What are the GUI installed on your system?

- Geant4 requires one graphical package for visualization.
  There are several possible packages:

  - **OpenGL (OGL)**
  - **Qt**
  - **OpenInventor**
  - **RayTracer**
  - **ASCIITree**
  - **Wt**
  - **HepRep**
  - **DAWN**
  - **VRML**
  - **gMocren**

1. Setting your setup

What are the GUI installed on your system?

- In this tutorial, we use the OpenGL (or « OGL » in G4 language) package.

- Check with geant4-config that this package is installed.

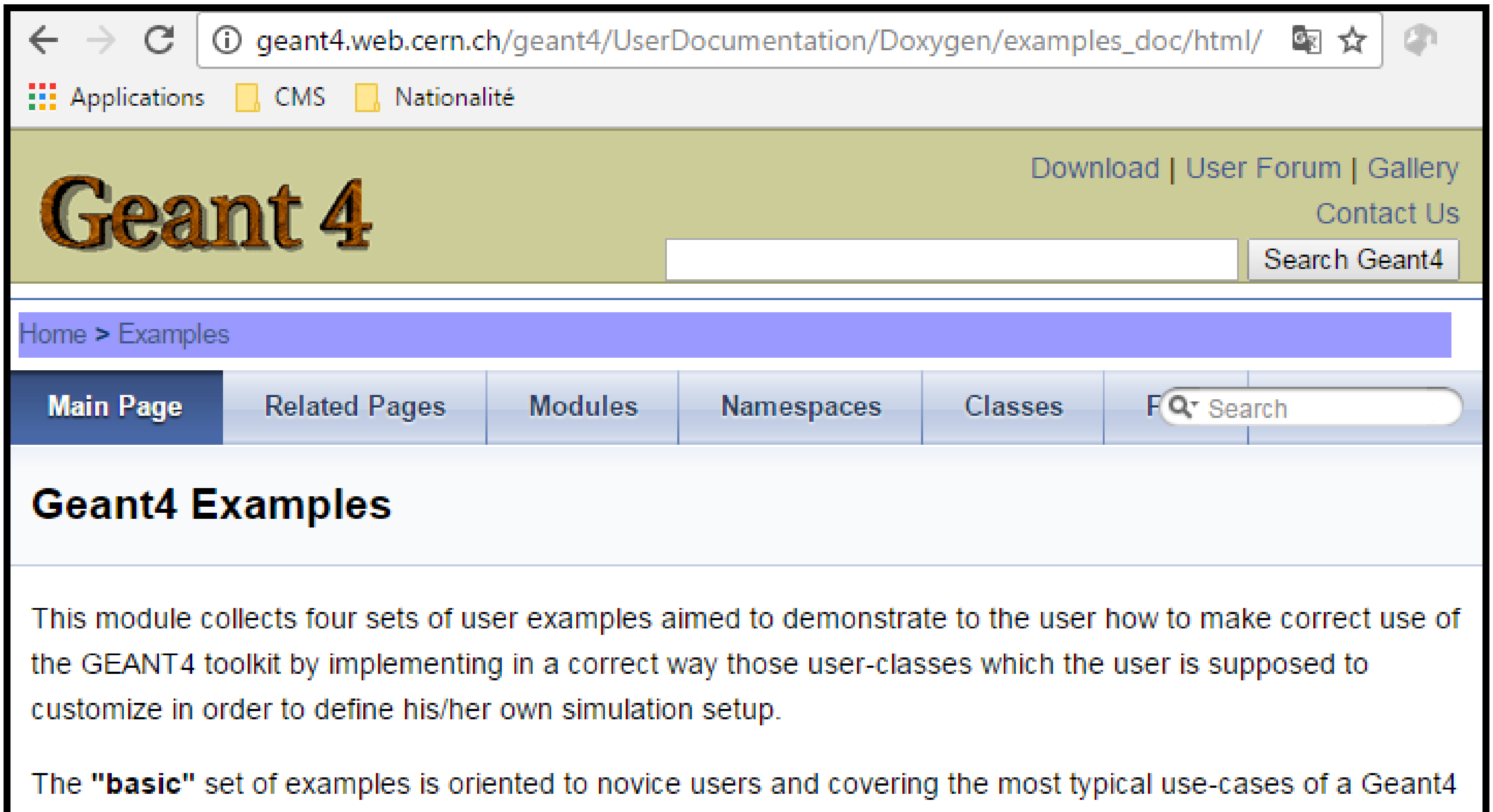
```
bash> geant4-config --has-feature opengl-x11
```

2. Building an example

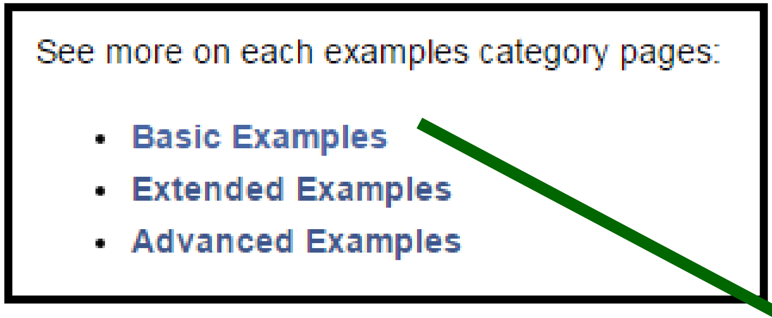
Practical work with G4

2. Building an example

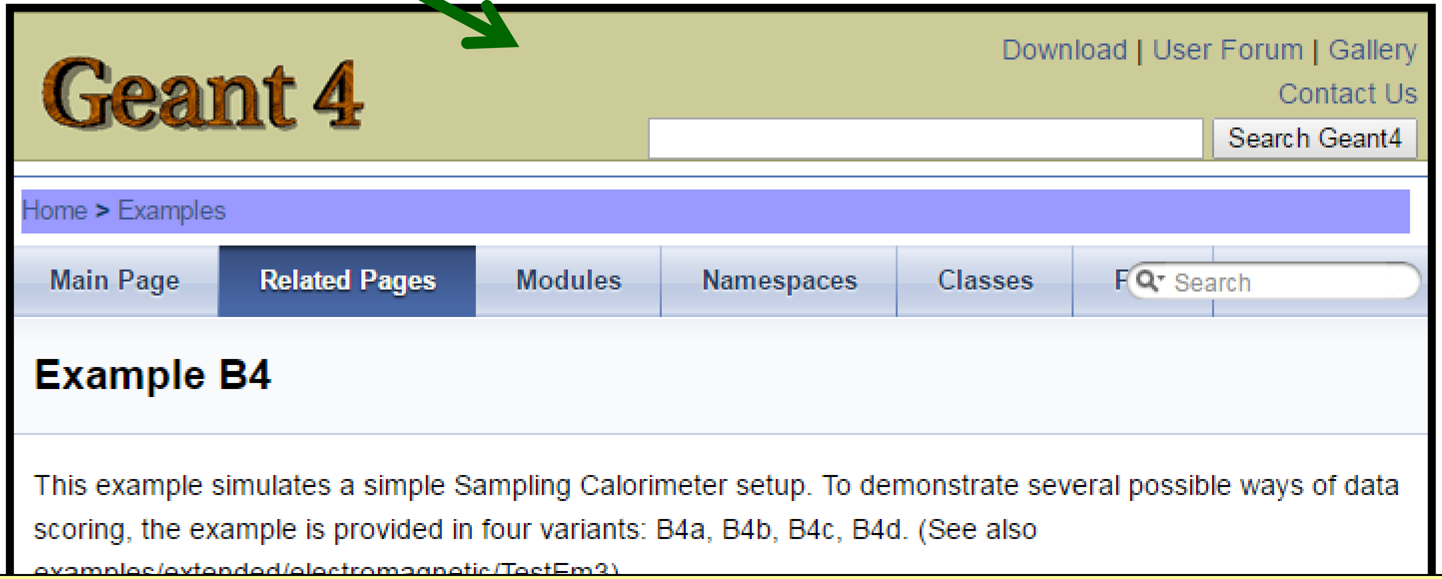
Choosing an example



Choosing an example



- 3 categories of examples
- Selecting **« Basic Examples » →B4**



Choosing an example


Geant 4

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Example B4

This example simulates a simple Sampling Calorimeter setup. To demonstrate several possible ways of data scoring, the example is provided in four variants: B4a, B4b, B4c, B4d. (See also examples/extended/electromagnetic/TestEm3)

GEOMETRY DEFINITION

The geometry is constructed in **B4DetectorConstruction** class (see also **B4c** , **B4d** variants). The calorimeter is a box made of a given number of layers. A layer consists of an absorber plate and of a detection gap. The layer is replicated.

Four parameters define the geometry of the calorimeter :

- the thickness of an absorber plate

- There are 4 variants of the B4 example: B4a, B4b, B4c & B4d.
- **Focusing only on B4a.**

Practical work with G4

2. Building an example

Choosing an example

To do

- What kind of apparatus does the B4a example describe?
- Which physis datasets are required? Are they installed on your system?

Copying a G4 example

- Finding where are stored the Geant4 example.
  On the ESIPAP computers, you have to issue the following command:

```
bash> ls /home/esipap/tools/geant4.10.03/share/Geant4-10.3.0/examples
```

- Copying the folder related to the B4a example into your home folder:

```
bash> cp -rv /home/esipap/tools/geant4.10.03/share/Geant4-  \
      10.3.0/examples/basic/B4/B4a ./
```

2. Building an example

Building with cMake

- Creating, in your home folder, a folder devoted to the building of the example. In this tutorial, this folder will be called « B4a_build »:

```
bash> make B4a_build
bash> cd B4a_build
```

- Launching the CMake program for generating automatically a Makefile:

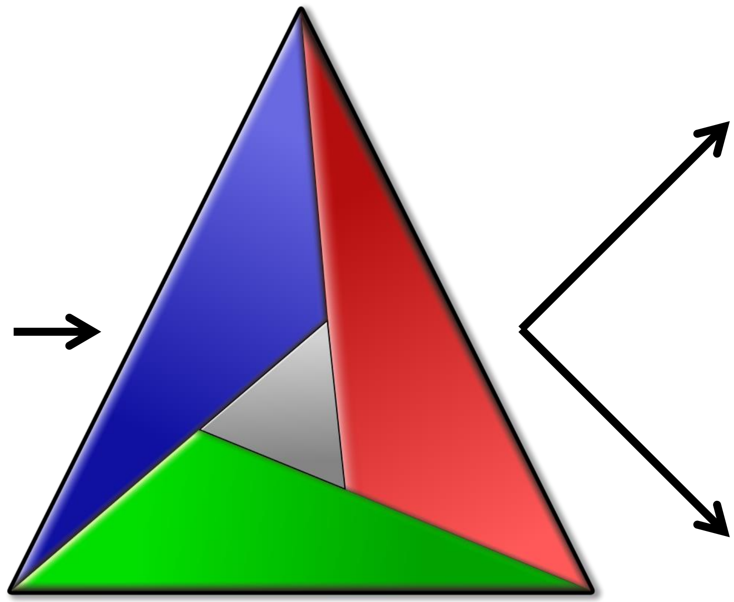
```
bash> cmake ../B4a
```

- Building the example with GNU Make:

```
bash> make
```

What is cMake?

CMakeLists.txt



Makefile

for **GNU Make**

*.sln

Visual Studio

for **Visual Studio**

CMake

3. Running the example

3. Running the example

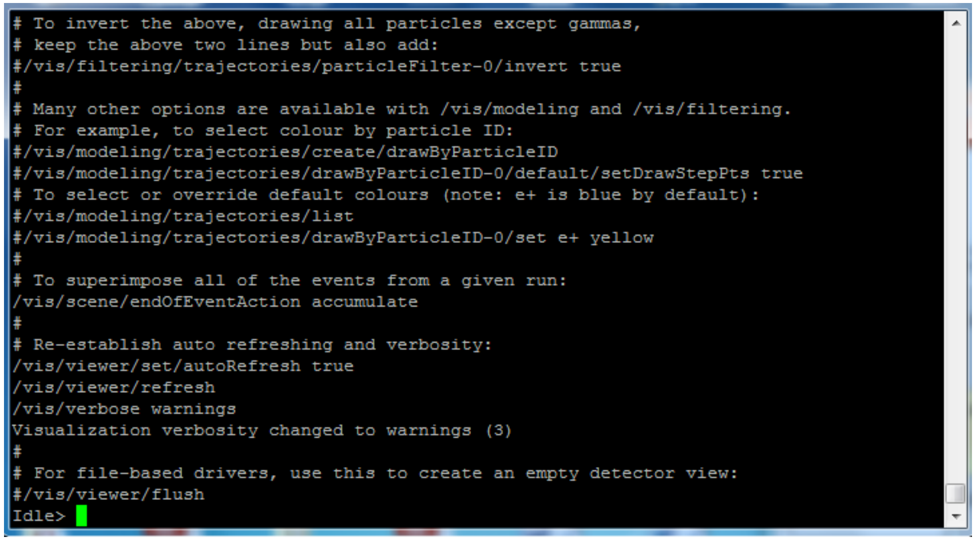
Executing the example

- In the B4a_build folder, if the building is successful, you must find the executable file « exampleB4 ».

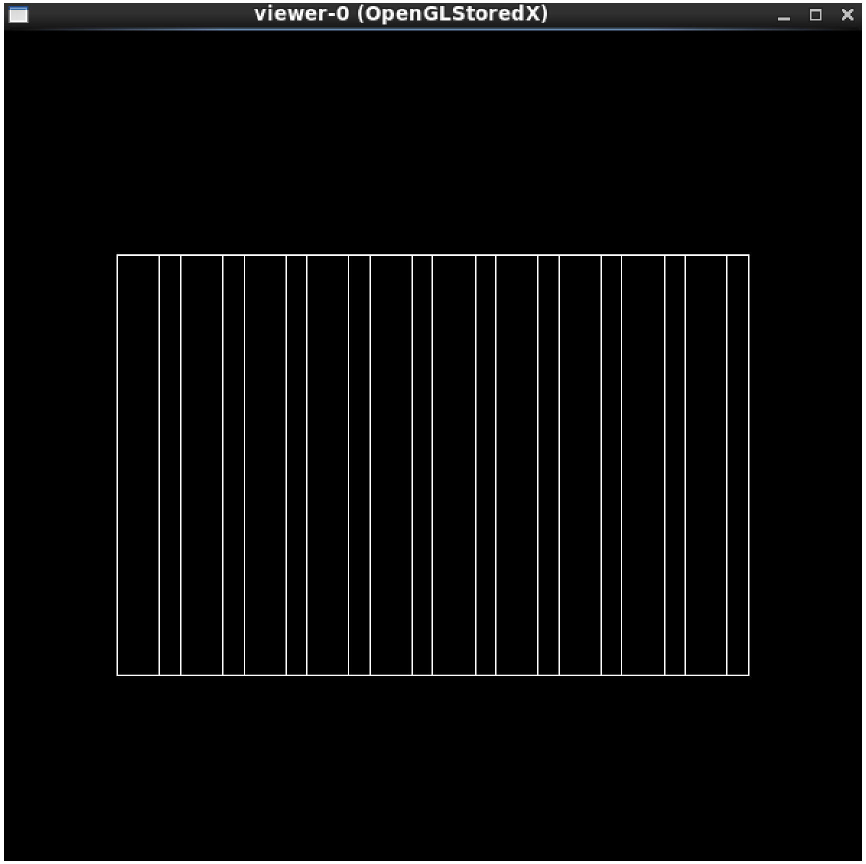
- Issue the command line to execute the program.

```
bash> ./exampleB4
```

Executing the example



```
# To invert the above, drawing all particles except gammas,
# keep the above two lines but also add:
#/vis/filtering/trajectories/particleFilter-0/invert true
#
# Many other options are available with /vis/modeling and /vis/filtering.
# For example, to select colour by particle ID:
#/vis/modeling/trajectories/create/drawByParticleID
#/vis/modeling/trajectories/drawByParticleID-0/default/setDrawStepPts true
# To select or override default colours (note: e+ is blue by default):
#/vis/modeling/trajectories/list
#/vis/modeling/trajectories/drawByParticleID-0/set e+ yellow
#
# To superimpose all of the events from a given run:
/vis/scene/endOfEventAction accumulate
#
# Re-establish auto refreshing and verbosity:
/vis/viewer/set/autoRefresh true
/vis/viewer/refresh
/vis/verbose warnings
Visualization verbosity changed to warnings (3)
#
# For file-based drivers, use this to create an empty detector view:
#/vis/viewer/flush
Idle>
```



2 windows are opened!!!

Using the prompt

In the text console, you can type some commands.
2 main commands to know:

- **Exit the program**

```
Idle> exit
```

- **Listing the possible commands and see their syntax**

```
Idle> help
```

Using numbers for selecting an item

Using the prompt

- All the commands follow the scheme: **/xxx/yyy/zzz/… arg1 arg2**
  Example: list of the units used

```
Idle> /units/list
```

- Tab completion can be useful. Type only the 2 characters of your commands and push the Tab touch.

- Comments can be written. Just put a # character before.
  Example:

```
Idle> # I believe I can fly!
```

Using the prompt

- It is also possible to access to the value of parameters.
  Just put a ? character before the command.
  Example:

```
Idle> ?/gun/particle
```

Visualization commands

List of useful commands related to the visualization of the detector

```
# zoom
Idle> /vis/viewer/zoom 2      # zoom x 2
Idle> /vis/viewer/zoom 0.5    # zoom / 2

# translation in the plane
Idle> /vis/viewer/pan 1 1 cm      # with direction (1,1)
Idle> /vis/viewer/pan -1 -1 cm    # with direction (-1,-1)

# visualization of the solid
Idle> /vis/viewer/set/style surface    # plain solid
Idle> /vis/viewer/set/style wireframe  # wired solid
```

Visualization commands

Sometimes the graphical windows must be refreshed by the command:

```
Idle> /vis/viewer/flush
```

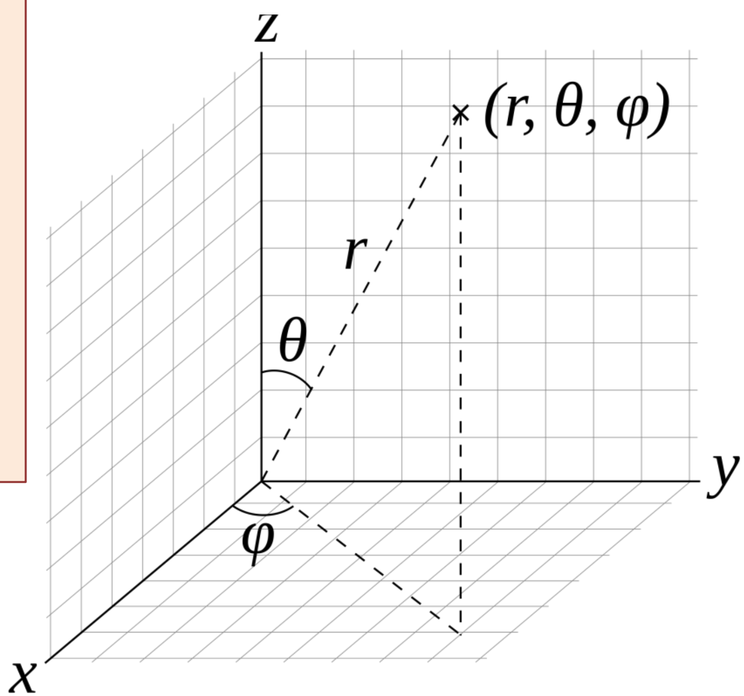
Adding axis

```
Idle> /vis/scene/add/axes 0 0 0 1 cm # Frame centered in (0,0,0)
                                      # axis length = 1cm
```

Visualization commands

Rotation

```
# xy frame
Idle> /vis/viewer/set/viewpointThetaPhi 0. 0.

# yz frame
Idle> /vis/viewer/set/viewpointThetaPhi 90. 180.

# xz frame
Idle> /vis/viewer/set/viewpointThetaPhi 90. 90.
```



Visualization commands

Rotation

```
# xy frame
Idle> vis/viewer/set/viewpointVector 1 0 0

# yz frame
Idle> vis/viewer/set/viewpointVector 0 1 0

# xz frame
Idle> vis/viewer/set/viewpointVector 0 0 1
```

Magnetic field

A global and uniform magnetic field can be activated in this example.

Changing the magnetic field consists in setting the vector components.
For instance:

```
Idle> /globalField/setValue 0.2 0 0 tesla
```

3. Running the example

Particle Gun

- The ParticleGun tools allows you to generate a single particle with a given momentum which can interact with your detector. Example of commands:

```
Idle> /gun/particle e-          # kind of particle
Idle> /gun/energy 1 GeV         # energy of the incident particle
Idle> /gun/position 0 0 0 cm    # coordinate point (x,y,z) of the origin
Idle> /gun/direction 0 0 1      # momentum direction (px,py,pz)
```

- The particle kind is specified by a label.
  The list of the available labels can be displayed by the command:

```
Idle> /gun/list
```

Practical work with G4

3. Running the example

Launching the simulation

Definition:

- **Event:** 1 particle produced by the ParticleGun interacts with the dectector.
- **Run:** sequence of several events with the same setup properties.

- The simulation can be launched by switching on the beam.
  The following command allows you to create a new run of 10 events.

```
Idle> /run/beamOn 10
```

3. Running the example

Using macros

It is possible to put all the commands you type in a text file and to load them in one time. A such text file is called a "**macro**" and the file extension used for it is "**.mac**".

For example: when you launch the example, a macro called "**init_vis.mac**" is loaded.

3. Running the example

Using macros

init_vis.mac

```
# Macro file for the initialization of example B4 in interactive session
#
# Set some default verbose
#
/control/verbose 2
/control/saveHistory
/run/verbose 2
#
# Change the default number of threads (in multi-threaded mode)
#/run/numberOfThreads 4
#
# Initialize kernel
/run/initialize
#
# Visualization setting
/control/execute vis.mac
```

Using macros

For loading a macro, there are 2 options:

- Running the example and loading the macro from the console.

```
Idle> /control/execute myscript.mac
```

- When you launch the example

```
bash> ./exampleB4a -m myscript.mac
```

do not forget these lines at the beginning of your macro!

```
# Initialize kernel
/run/initialize
```

4. Studying the simulation in Example B4a

Analyzing the simulation 1

- Before launching the simulation, it is advised to set the level of verbosity of the program.

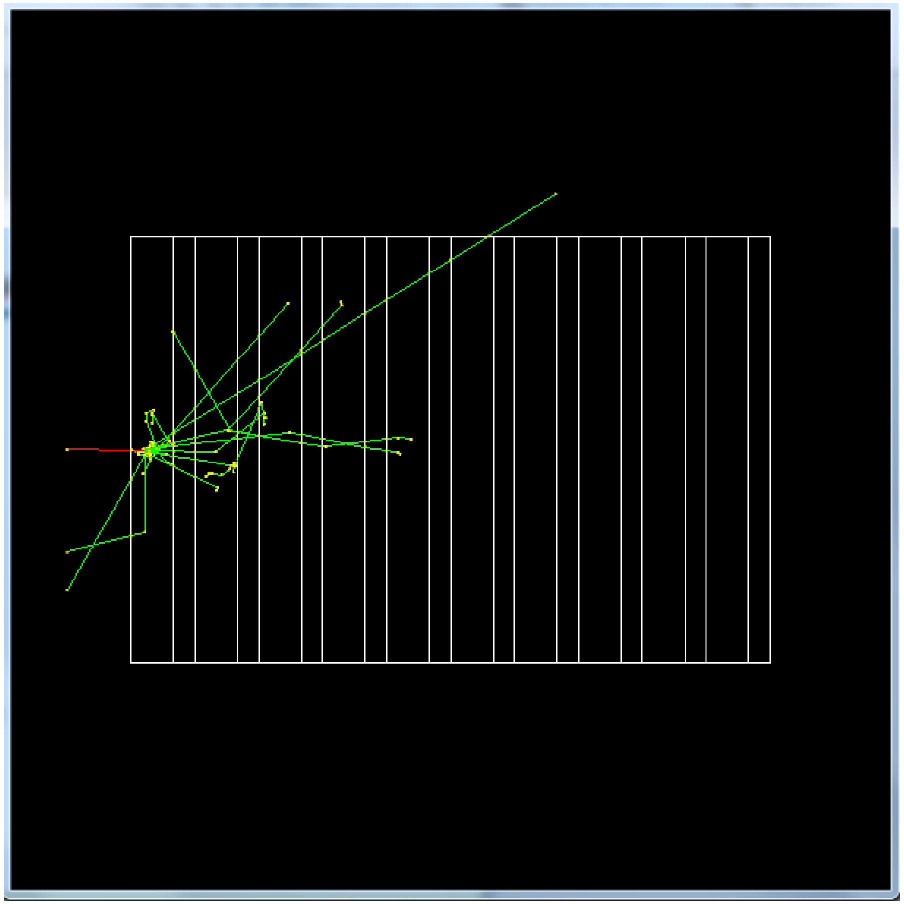
```
Idle> /run/verbose 0
Idle> /event/verbose 0
Idle> /tracking/verbose 0

Idle> /globalField/setValue 0.2 0 0 tesla
Idle> /run/beamOn 10
```

- Comment what you see

Practical work with G4

4. Studying the simulation in Example B4a

Analyzing the simulation 1



Default color code:

- Track with charge = 0 → green
- Track with charge = -1 → red
- Track with charge = +1 →blue
- Step point = yellow

Analyzing the simulation 1

- If you produce a run of several events, only the last event is showed.
  You have the option to review all the last events with the command:

```
Idle> vis/reviewKeptEvents
```

- There is also a way to superimpose the events on the graphics window.
  Type this command before the generation.

```
Idle> /vis/scene/endOfEventAction accumulate
```

- Graphical visualization requires time resource. There is an option to disable the visualization for big number of events.

```
Idle> /vis/disable
```

Specifities of Example B4a : energy deposit & track length

For each event, the code of Example B4a extracts the energy deposit and the track length in each kind of material. These values are dumped at the screen.

```
Absorber: total energy: 40.667624006703 MeV
          total track length: 3.0357196656771 cm
     Gap: total energy: 848.54860464357 keV
          total track length: 5.0632623359409 mm
```

At the end of the run, Example B4a displays the mean value and the root mean square value of the different distributions.

```
EAbs : mean = 44.680813750829 MeV rms = 4.480475001769 MeV
EGap : mean = 1.0744818487411 MeV rms = 1.7299239878681 MeV
LAbs : mean = 3.2189971903885 cm  rms = 3.2792112794795 mm
LGap : mean = 5.716367983443 mm   rms = 9.3492140235363 mm
```

Practical work with G4

4. Studying the simulation in Example B4a

Specifities of Example B4a : the ROOT file

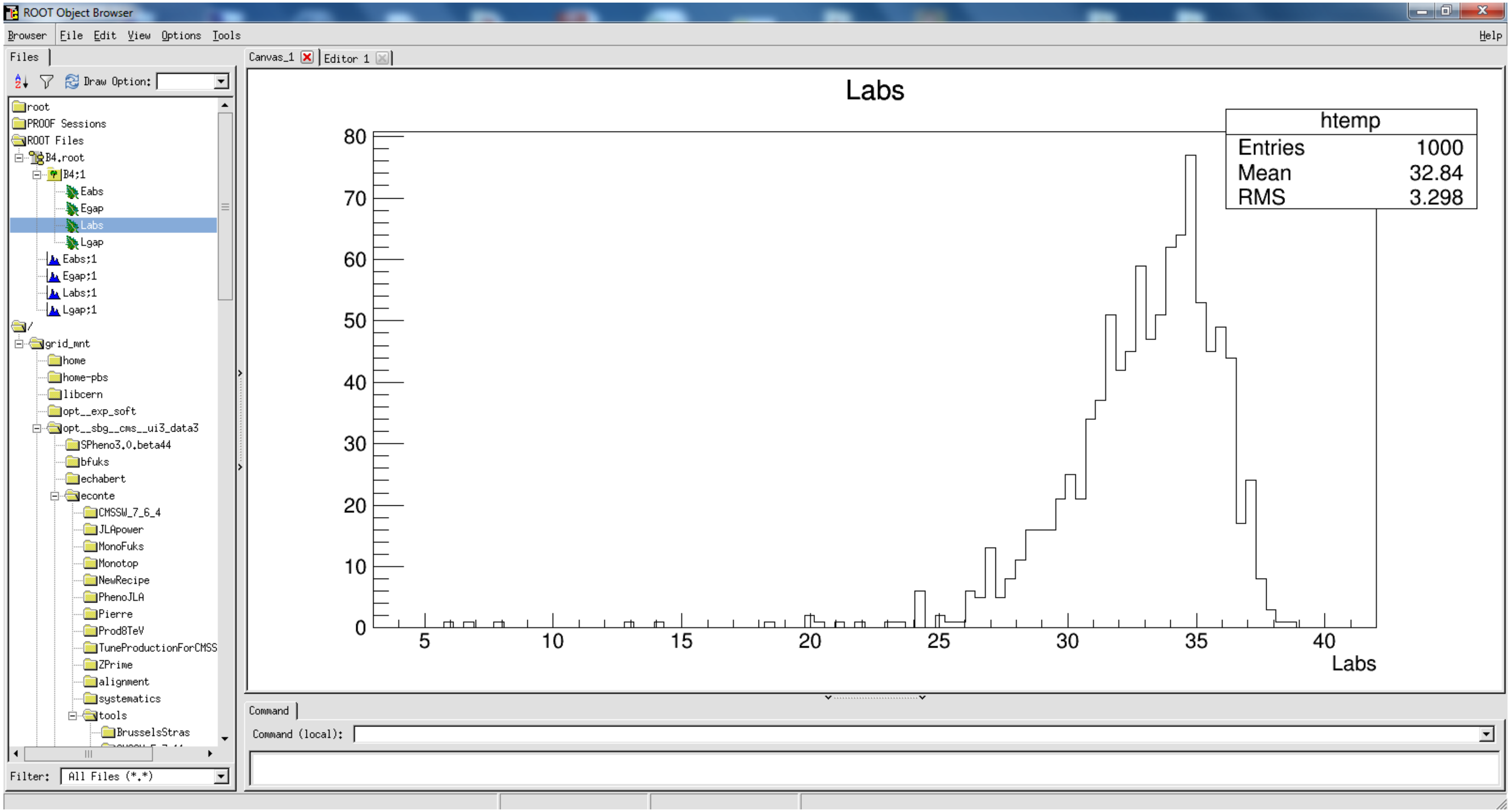
For each event, we monitor the 4 following observables:

- *Energy deposit in the absorber*
- *Track length in the absorber*
- *Energy deposit in the gap*
- *Track length in the gap*

They are stored in a ROOT file called « B4.root ».
To dump the content of this file, you need to use ROOT.

```
bash> root -l B4.root
Root[1] TBrowser d
```

Specifities of Example B4a : the ROOT file



Analyzing the simulation 2

- Before launching the simulation, it is advised to set the level of verbosity of the program.

```
Idle> /run/verbose 0
Idle> /event/verbose 1
Idle> /tracking/verbose 0

Idle> /globalField/setValue 0.2 0 0 tesla
Idle> /run/beamOn 10
```

- Comment what you see

Analyzing the simulation 2

Stopping code? See the file **G4TrackStatus.hh**

- For each event, we have a list of the tracks produced.

```
=====================================
  G4EventManager::ProcessOneEvent()
=====================================
G4PrimaryTransformer::PrimaryVertex (0(mm),0(mm),-90(mm),0(nsec))
1 primaries are passed from G4EventTransformer.
!!!!!!! Now start processing an event !!!!!!!
Track (trackID 1, parentID 0) is processed with stopping code 2
Track (trackID 3, parentID 1) is processed with stopping code 2
Track (trackID 4, parentID 3) is processed with stopping code 2
Track (trackID 2, parentID 1) is processed with stopping code 2
Track (trackID 6, parentID 2) is processed with stopping code 2
Track (trackID 5, parentID 2) is processed with stopping code 2
. . .
```

Analyzing the simulation 3

- Before launching the simulation, it is advised to set the level of verbosity of the program.

```
Idle> /run/verbose 0
Idle> /event/verbose 1
Idle> /tracking/verbose 1

Idle> /globalField/setValue 0.2 0 0 tesla
Idle> /run/beamOn 10
```

- Comment what you see

Practical work with G4

4. Studying the simulation in Example B4a

Analyzing the simulation 3

- More info on each track produced.

```
*******************************************************************************************
* G4Track Information:   Particle = e-,   Track ID = 1,   Parent ID = 0
*******************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0      -90        50        0        0         0       World initStep
    1        0   -0.134      -75        50 5.25e-25       15        15        Abso Transportation
    2    0.025   -0.139    -74.6      2.46    0.646     0.45      15.5        Abso eBrem
    3    0.632   -0.138    -74.2     0.695     1.64     1.44      16.9        Abso eBrem
    4    0.631   -0.105    -74.2         0    0.695    0.468      17.4        Abso eIoni
Track (trackID 1, parentID 0) is processed with stopping code 2
```

Exercise 1

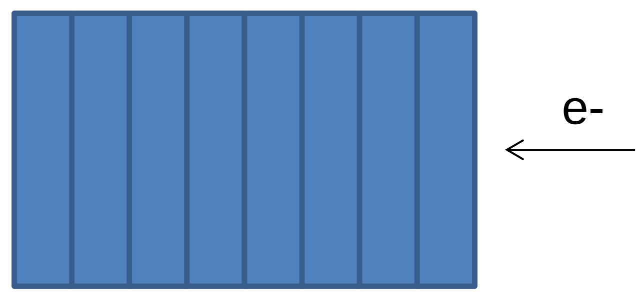
To do

- Compare the results of the simulation for different incident particle:
  - Photon
  - Electron
  - Electronic neutrino
  - Proton

Exercise 2

To do

- Inject the incident particle from behind the detector.



5. Analyzing & editing the main program

6. Analyzing & editing the detector description

Exercise

To do

- Changing the materials of the calorimeter:
  - Absorber : copper
  - Gap : neon
- Reducing by two the thickness of the gap.
- Adding a new layer of absorber+gaz.

6. Analyzing & editing the action description

Practical work with G4

7. Analyzing & editing the action description

Exercise

To do

- Display at the end of each event the energy ratio measured by the absorber.
- Getting energy in each layer of absorber and saving these data in the ROOT file