Example of building a detector with Geant4 (practical work)

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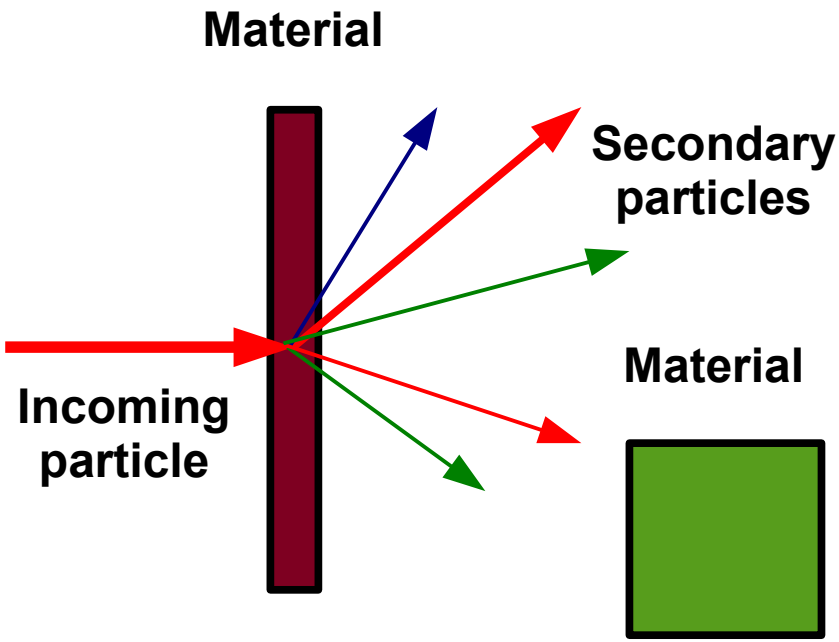


Geant4—a simulation toolkit

Geant4 is a toolkit for simulating the passage of particles through matter. It includes a complete range of functionality including tracking, geometry, physics models and hits. The physics processes offered cover a comprehensive range, including electromagnetic, hadronic and optical processes, a large set of long-livedparticles, materials and elements, over a wide energy range starting, in some cases, from 250eV and extending in others to the TeV energy range. It has been designed and constructed to expose the physics models utilised, to handle complex geometries, and to enable its easy adaptation for optimal use in different sets of applications. The toolkit is the result of a worldwide collaboration of physicists and software engineers. It has been created exploiting software engineering and object-oriented technology and implemented in the C++ programming language. It has been used in applications in particle physics, nuclear physics, accelerator design, space engineering and medical physics.

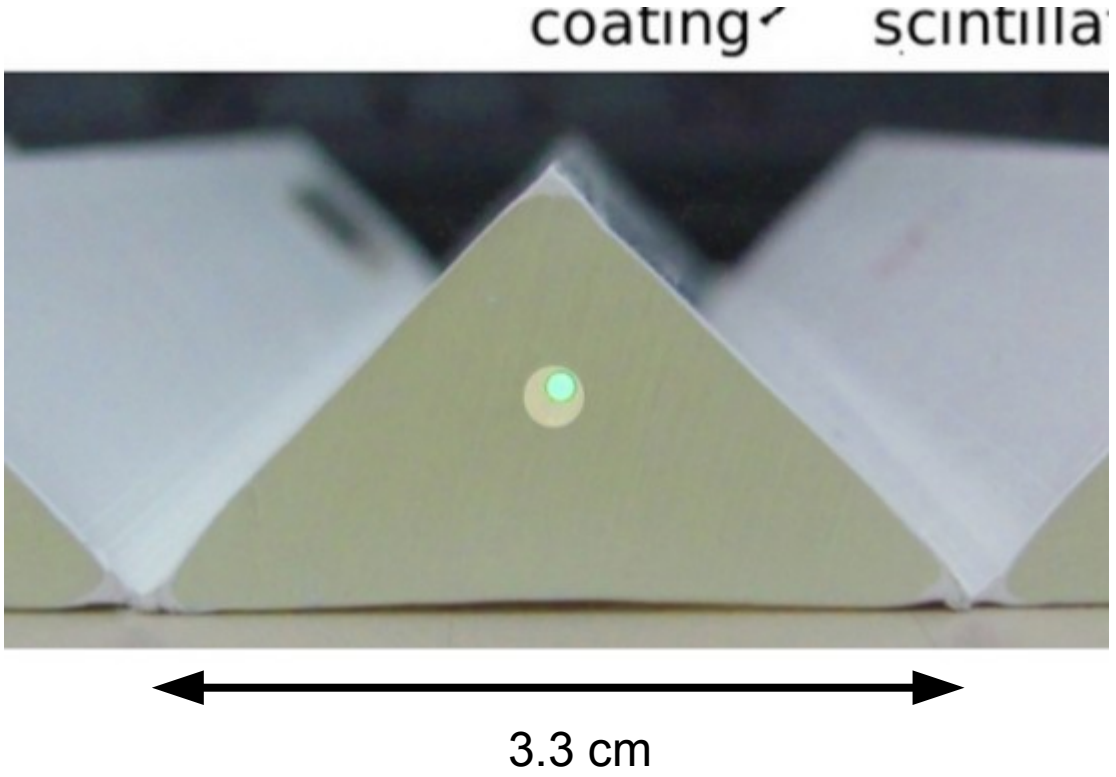
Nuclear Instruments and Methods in Physics Research A 506 (2003) 250–303

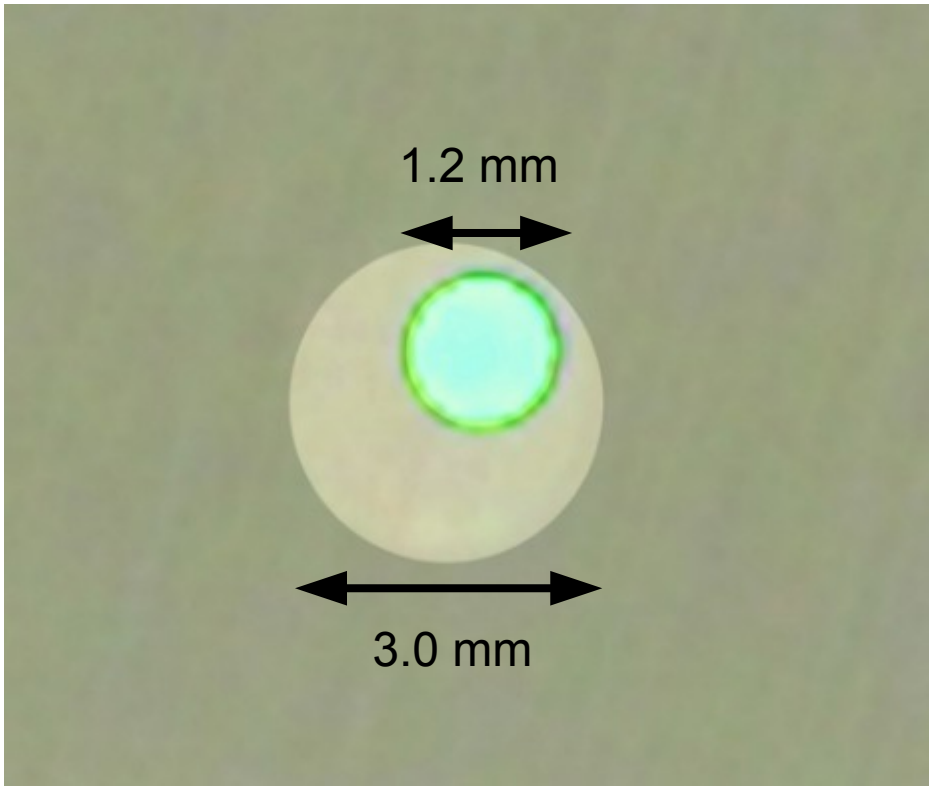
Geant4

- Geant4 is a toolkit for simulating the passage of particles through matter.
- It includes a complete range of functionality:
  - Tracking
  - Geometry
  - Physics models
  - Hits
- The physics processes includes:
  - Electromagnetic
  - Hadronic
  - Optical
- Very wide energy range
  - Minimum : 250eV
  - Maximum : ~ TeV
- Written in C++

Detector we will simulate

Plastic scintillator + wavelength shifting fiber + SiPM





Step 0 : setup the simulation

1) cd TESHEP2019;
and unpack jre-6u26-linux-x64.bin : > ./jre-6u26-linux-x64.bin
New directory will appear : jre1.6.0_26 (this directory contains an old Java)

2) Edit the setup.sh file : put your path to the root and other directories.

3) source setup.sh

4) make build dir : > mkdir ex02-build

5) prepare for compilation :> cmakegeant41004 ../ex02

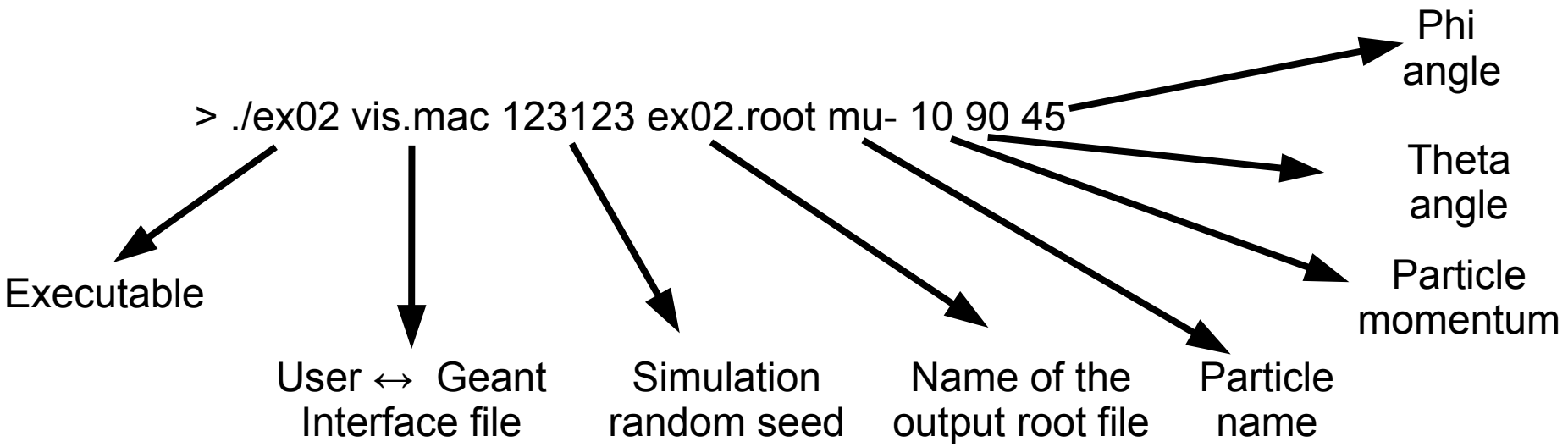
6) compile :> make -j

7) Verify the executable : ./ex02

ERROR of the input parameters !!!
- [0] - vis.mac or run.mac or *.mac
- [1] - seed
- [2] - output root file name
- [3] - name of the particle (e+, e-, mu+, mu-, pi+, pi-, kaon+, kaon-, proton, gamma)
- [4] - particle momentum (GeV/c)
- [5] - particle theta (deg)
- [6] - particle phi (deg)

Step 1: Run en example with one muon and empty volume

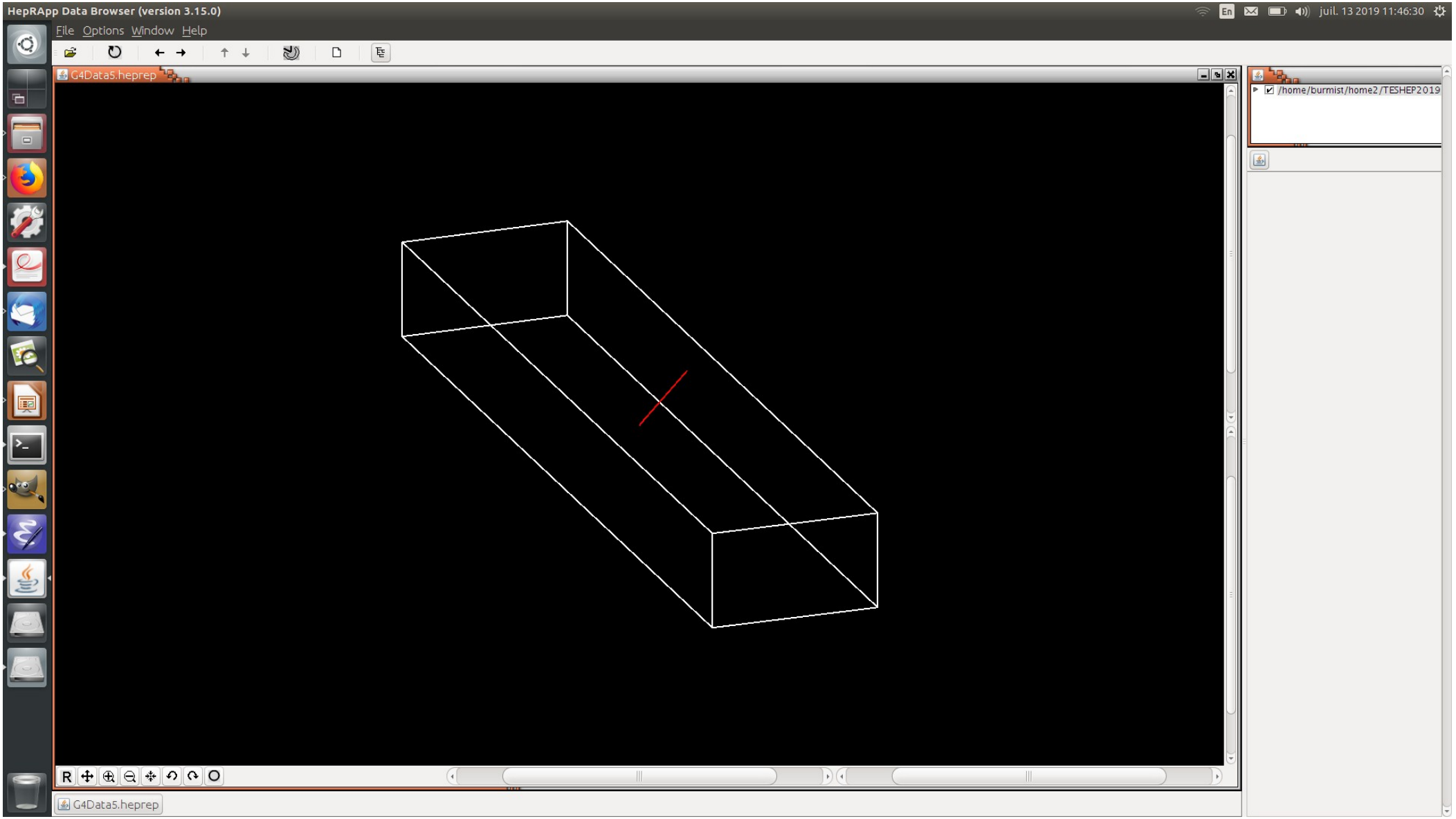
1) run an example



2) Visualize an example

> wired3_15_0 G4Data0.heprep

Visualization :



Step 2: Geometry - src/DetectorConstruction.cc

2) Construct a simple BOX

1.1) Solid → shape

```
G4Box(const G4String& pName, G4double pX, G4double pY, G4double pZ);
```

1.2) logical → material

```
G4LogicalVolume::G4LogicalVolume( G4VSolid* pSolid,
                                  G4Material* pMaterial,
                            const G4String& name,
                                  G4FieldManager* pFieldMgr,
                                  G4VSensitiveDetector* pSDetector,
                                  G4UserLimits* pULimits,
                                  G4bool optimise )
```

1.3) placement

```
G4PVPlacement(G4RotationMatrix *pRot,
        const G4ThreeVector &tlate,
              G4LogicalVolume *pCurrentLogical,
        const G4String& pName,
              G4LogicalVolume *pMotherLogical,
              G4bool pMany,
              G4int  pCopyNo,
              G4bool pSurfChk=false);
```

Step 3: add scintillation process src/PhysicsList.cc

```
"G4Scintillation.hh"

new G4Scintillation("Scintillation");

G4ProcessManager* pmanager =    particle->GetProcessManager();

pmanager->AddProcess(theScintillationProcess);
```

Step 4 : “drill” a hole for the fiber

The solids of the box already have :

```
G4VSolid* solidScintillatorBox = new G4Box();
```

1) Create the solid G4Tubs

```
G4Tubs( const G4String& pName,
        G4double pRMin,
        G4double pRMax,
        G4double pDz,
        G4double pSPhi,
        G4double pDPhi );
```

2) Create the solid by subtracting from the solid Box the solid G4Tubs

```
G4SubtractionSolid*
solidScintillatorHoleBox = G4SubtractionSolid( const G4String& pName,
                                               G4VSolid* pSolidA ,
                                               G4VSolid* pSolidB ,
                                               const G4Transform3D& transform ) ;
```

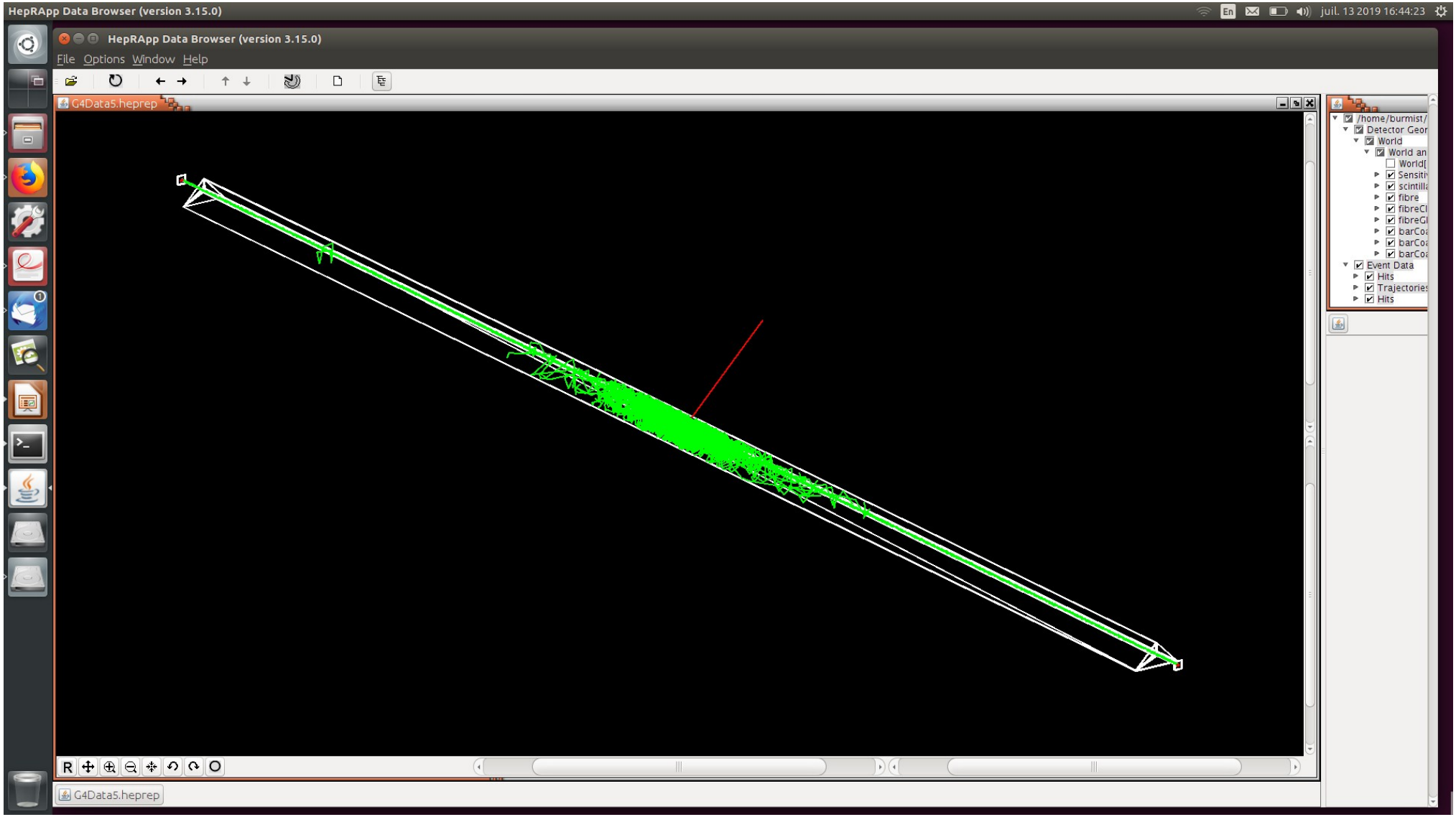
3) Create logical volume with new solid

```
G4LogicalVolume* logicScintillatorHoleBox = new G4LogicalVolume( solidScintillatorHoleBox,
polystyrene_scint, "logicScintillatorHoleBox");
```

4) Place it (G4PVPlacement) ….

Run the final full geometry and data analysis

1) Run the example with visualization (vis.mac)
2) Visualize it
3) Run simulation with some statistics (run.mac)
4) enter the analysis directory > cd ana
5) Run the analysis with root > root -l mainAna.C



Step 5 : simulation of the realistic muon directions position distributions : src/PrimaryGeneratorAction.cc

Generate the muons in the different initial positions.

Use :

G4ParticleGun = _particleGun->SetParticlePosition(G4ThreeVector(xInit, yInit, zInit));

Generate the muons in the different direction.

Use :

_particleGun->SetParticleMomentumDirection(dir);

Hint : please use functions of these two classes :

```
#include "TRandom3.h"
#include "TVector3.h"
```

Command reminder

→ cd TESHEP2019	Enter the main directory
→ source setup.bash	Setup working space
→ cd ex02-build/	Working directory of G4 ex.
→ cmakegeant41004 ../ex02	Setup the example
→ make -j	make example
→ ./ex02 vis.mac 123123 ex02.root mu- 10 90 45	Run the example
→ wired3_15_0 G4Data0.heprep	Visualization
→ cd ./ana	Directory for root analysis
→ root -l mainAna.C	Run root analysis

Conclusions. Useful links.

- Homepage:
  http://geant4.cern.ch/

- Main publication:
  Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
  Volume 506, Issue 3, 1 July 2003, Pages 250–303
  Geant4—a simulation toolkit

- Lund Universit, Sweden 7-11 April 2014:
  http://indico.hep.lu.se/conferenceDisplay.py?confId=1378

- LAL-Orsay, France 19-23 May 2014:
  http://groups.lal.in2p3.fr/ED-geant4/2014-19-23-may/program/

- List of Geant4 – related tutorials
  http://geant4.in2p3.fr/spip.php?rubrique6

Backup

Simulation sequence