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Monte Carlo simulation on heterogeneous organs

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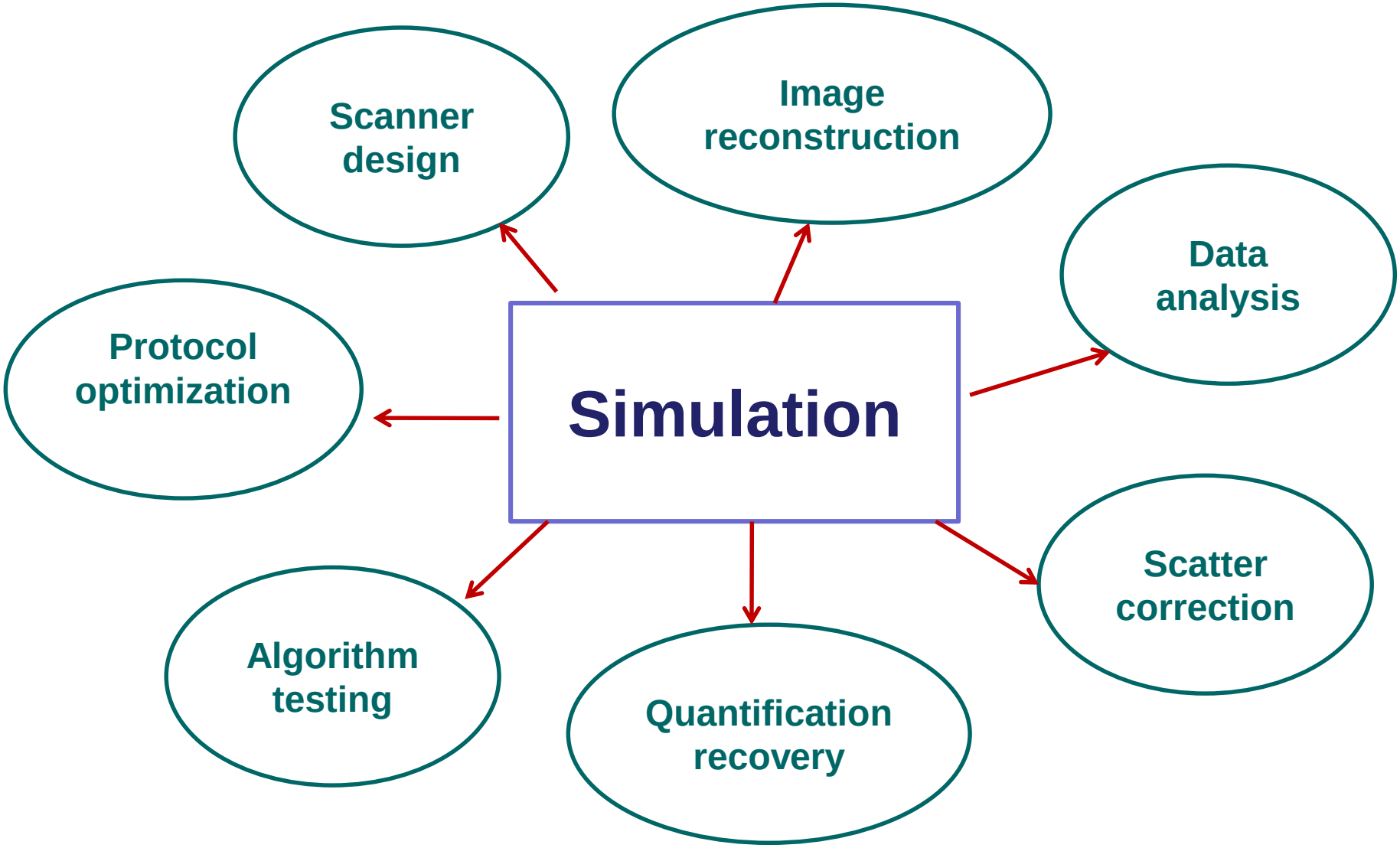
Plan

- Definition
- Geant4 simulation
- Exampleson G4 and Gate
- Results
- Conclusion

Why simulation in medical field?



Geant4

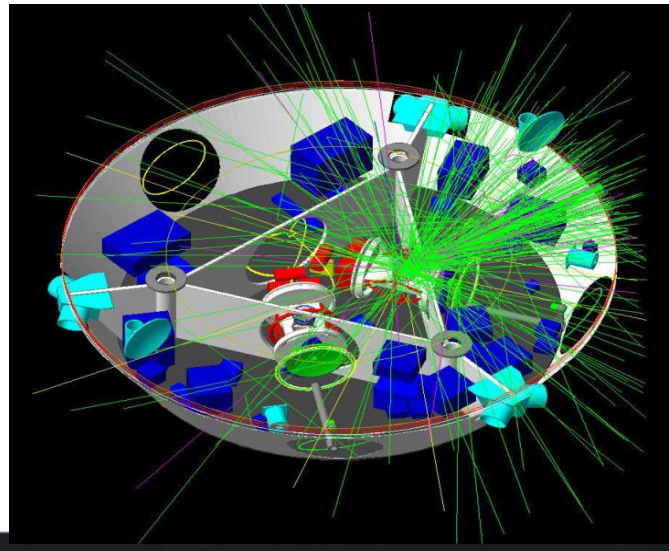
Monte Carlo

"A Monte Carlo technique is any technique making use of random numbers to solve a problem"

[F.James '80]

Geant4

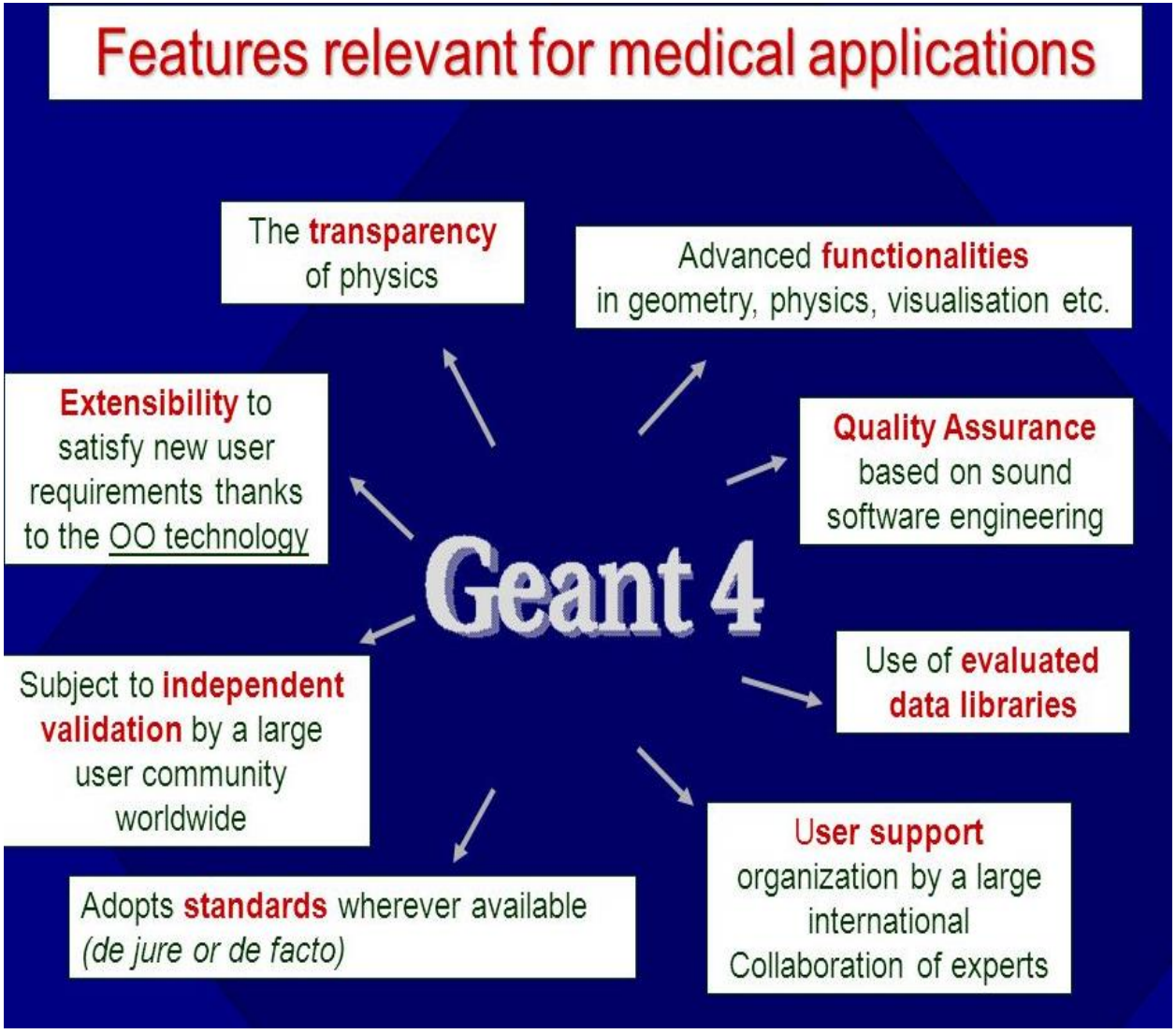
- **Toolkit** created by CERN to simulate the passage of particles through matter.
- Designed to make the physics used **transparent** within the toolkit, handle a wide range of geometries,.
- An enable and easy adaptation of different physics to fit the application.
- Its areas of applications span diverse fields.
- Is open to **extension** and **evolution**
  - With attention to user Requirements
  - Facilitated by the OO approach
- User Support **granted** by the Geant4 Collaboration.



Geant4 Applications

- **Hadronic Physics:** String Models, Intranuclear Cascade Models, precompound, Fermi-Breakup, Fission/Evaporation, Radioactive Decays
- **HEP**: BaBar, CMS, LHC. First use of Geant4 for an actual Physics Experiment**.**
- **Space Applications**: Planetary Scale Simulation of Soil Level, Spaceship Sim for Radioprotection, etc.
- **Medical:** Radiationtherapy**,** Brachytherapy Devices, Radioprotection, Nuclear Imaging, etc.
- **Biology** :DNA **,** Applied to Silicon for Single Upset Events.

Geant4 Details

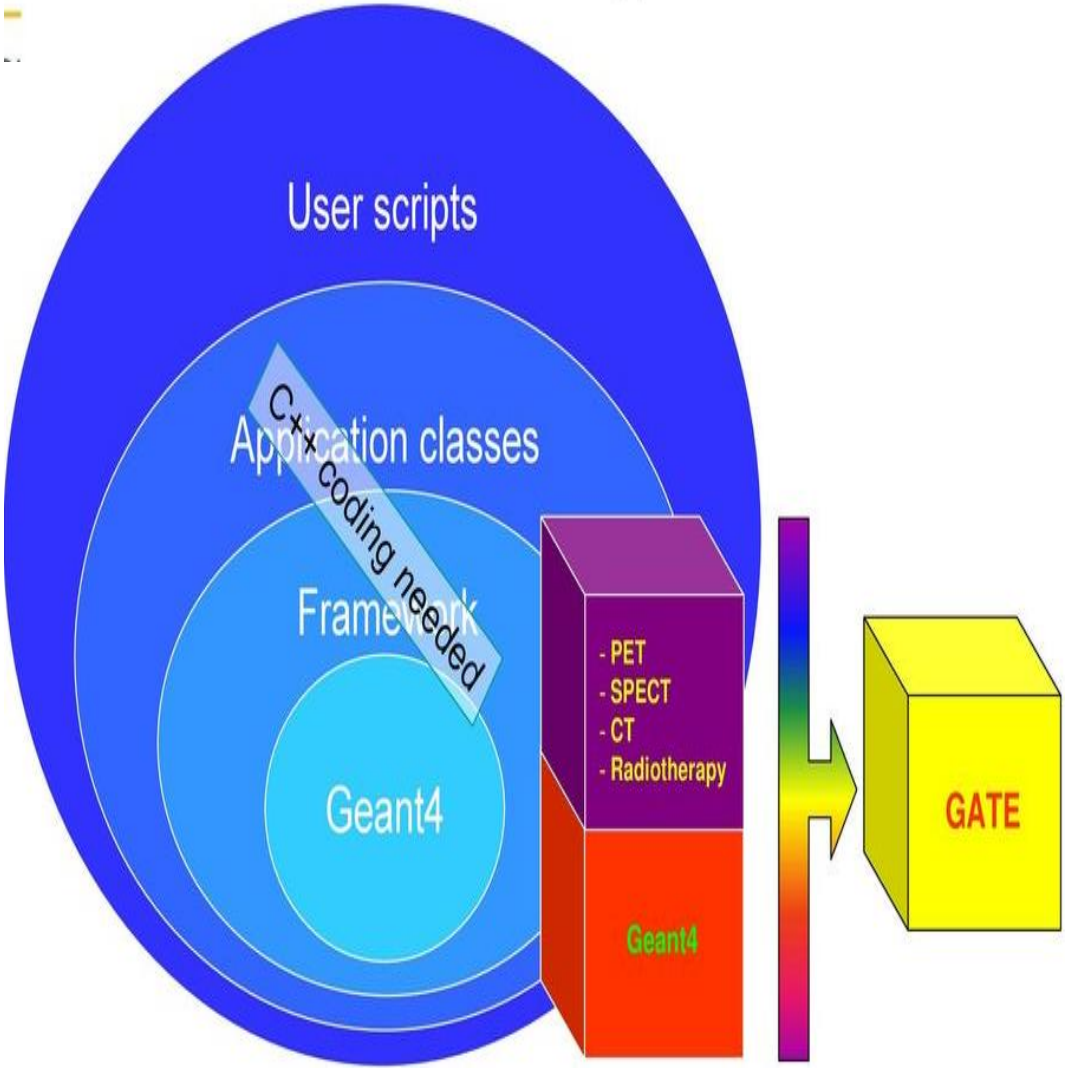


- An all particle code
- Able to handle complex Geometry
- Able to handle motion
- Able to handle fields
- With a modern programming language (C++)
- Open and free

Gate/ Geant4

- **G**eant4 **A**pplication for **T**omographic **E**mission
- Open source software developed by the international Open Gate collaboration and dedicated to numerical simulations in medical imaging and radiotherapy.
- It currently supports simulations of Emission Technology (Positron Emission Tomography- **PET** and Single Photon Emission Computed Tomography – **SPECT** Computed Tomography - **CT** and radiotherapy experiments and others.

Gate Structure

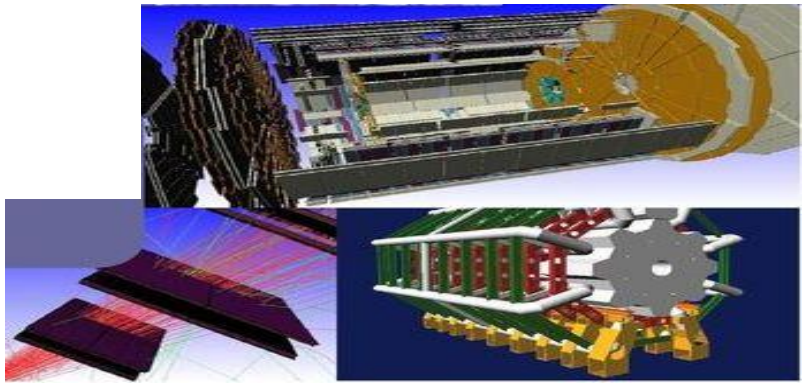


- **Ease of use, interactivity**
  - Use of scripting
  - Interface to image reconstruction
- **Modelling of time**
  - In kinetic, movement, dead time…
- **Modular design**
  - New extension easlly added
- **Shared development**
  - *OpenGate collaboration*
  - Long team support

Summray

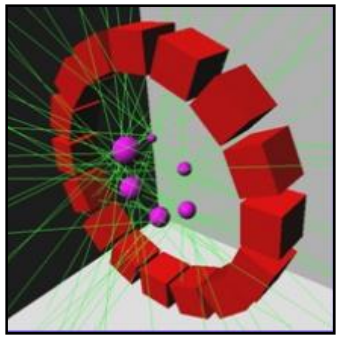
Geant4

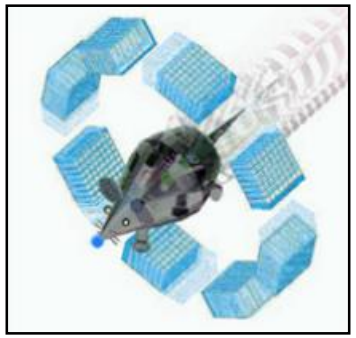
- ☺ Wide range of physics
- ☺ Wide community of developers and users
- ☺ Documentation, maintenance and support
- ☹ Complexity
- ☹ Speed



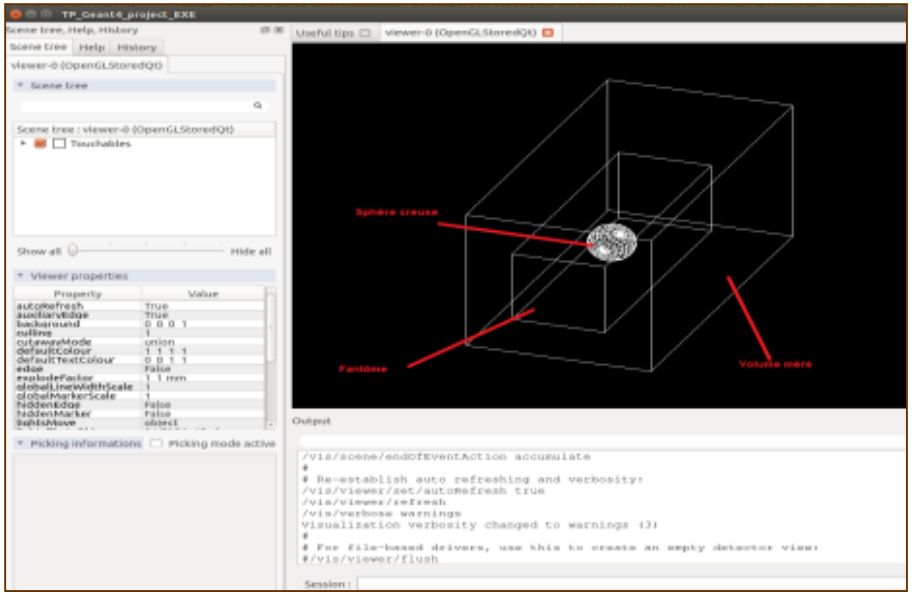
Gate

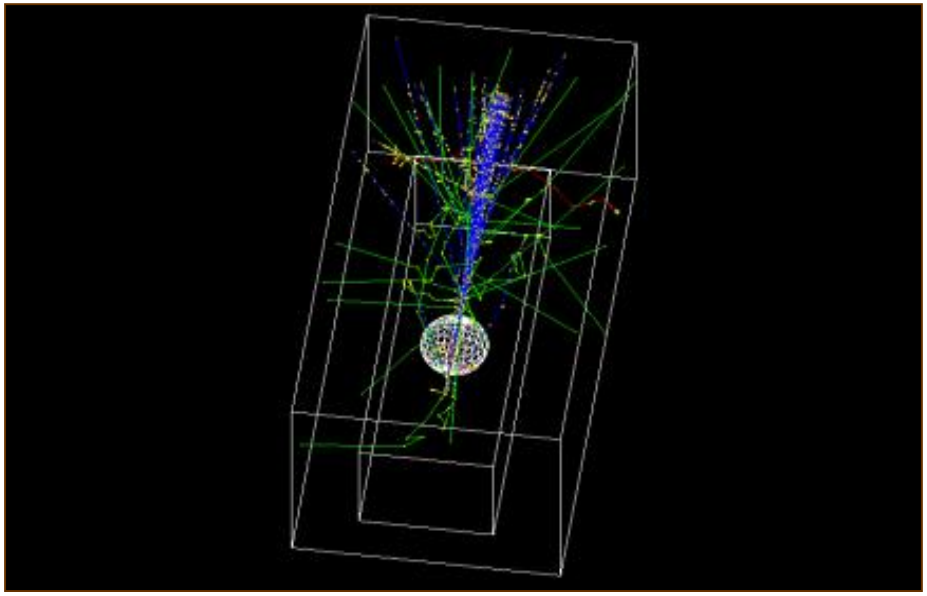
- ☺ Optimized for nuclear medical imaging application (geometry, physics…)
- ☺ Ease of use and fast development
- ☹ Maintenance, upgrade





(G4) Spherical Phantom



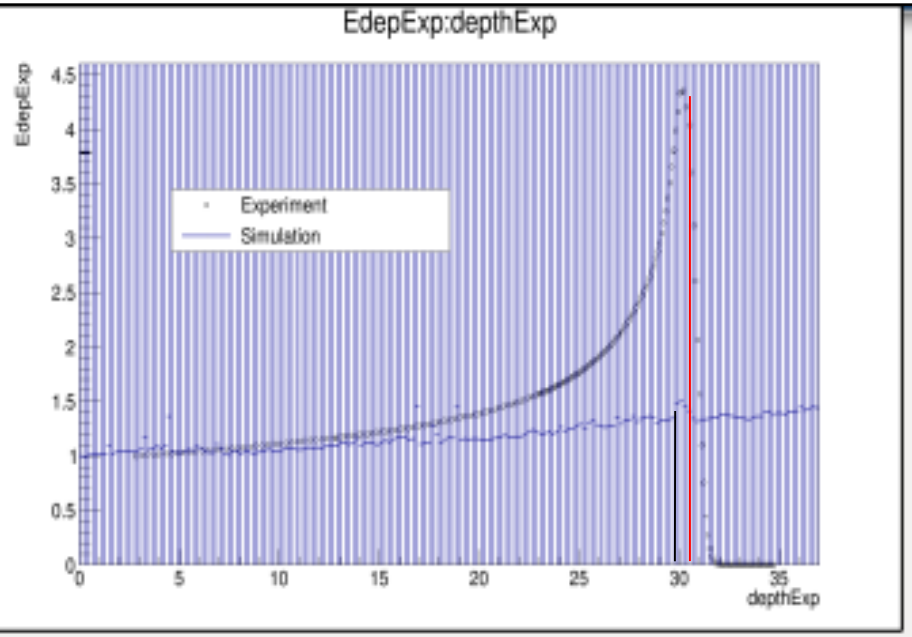


- Box (air) (10, 10, 30) cm
- Sphere (water) 1g/cm3
- Umpty inside (air)

Heterogeneity

With Carbon/Proton 270 MeV energy, 1000 events

Results



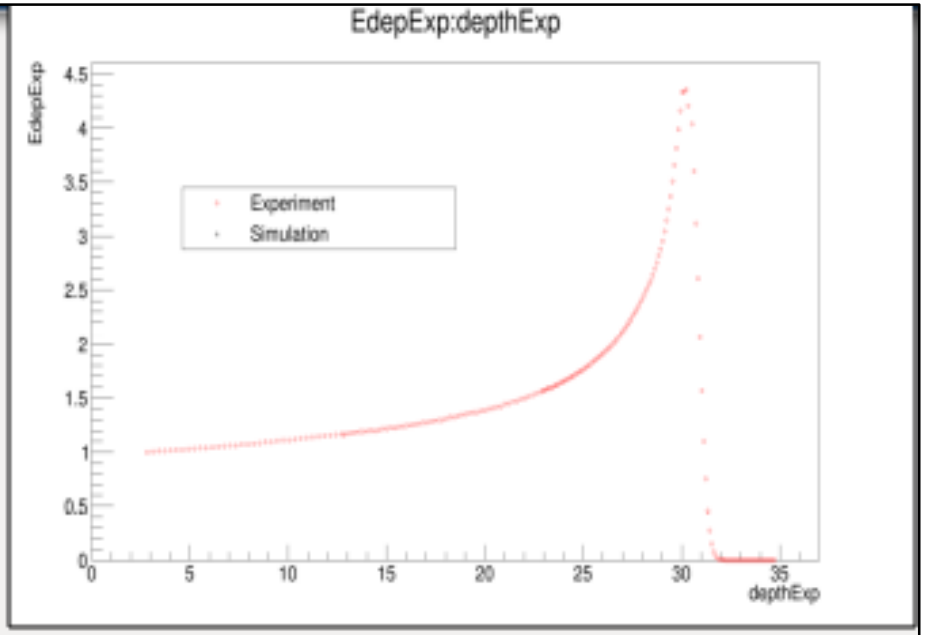


Fig3. Simulated and experimental depth dose profiles of a 62 MeV Carbon beam in water

Ex 1: Results

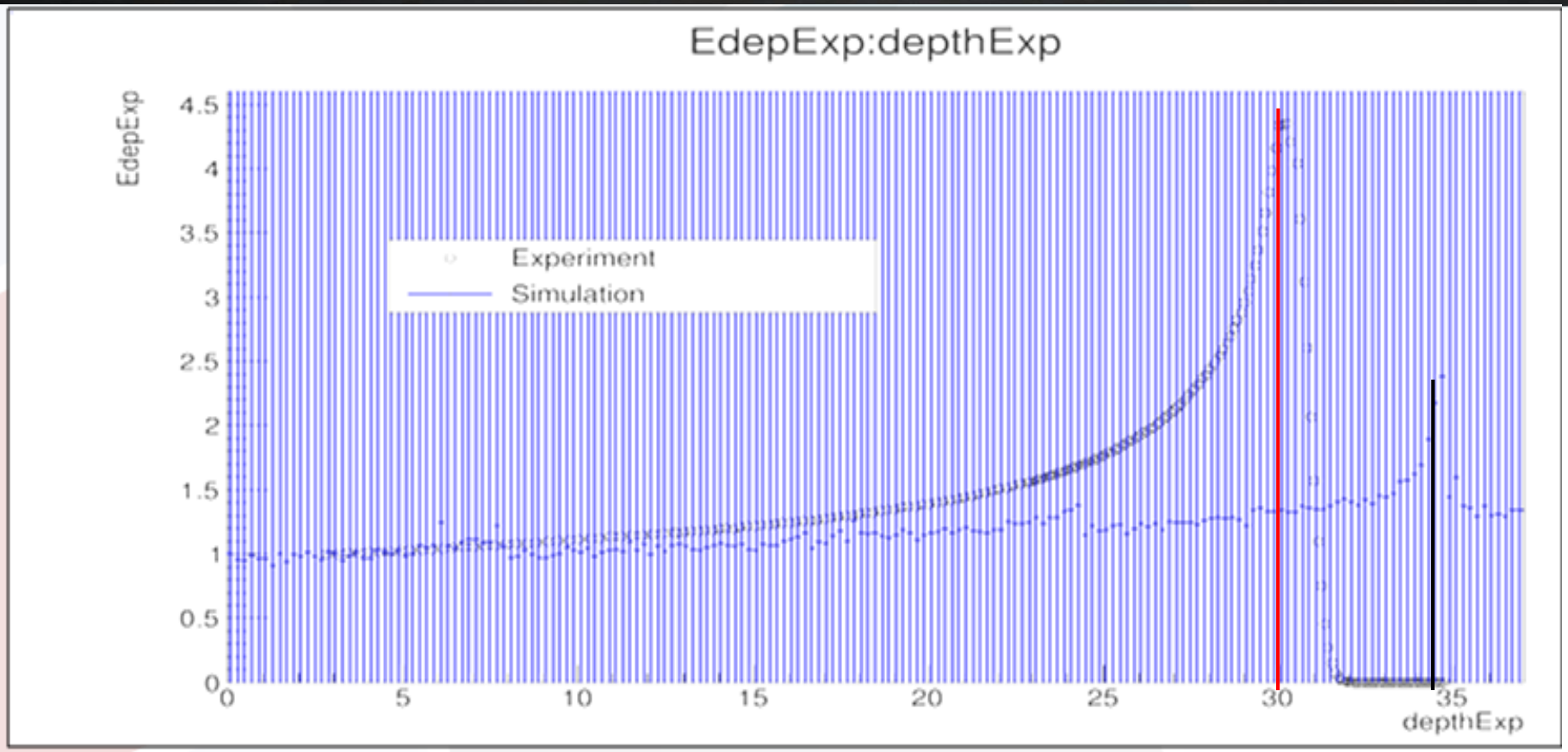
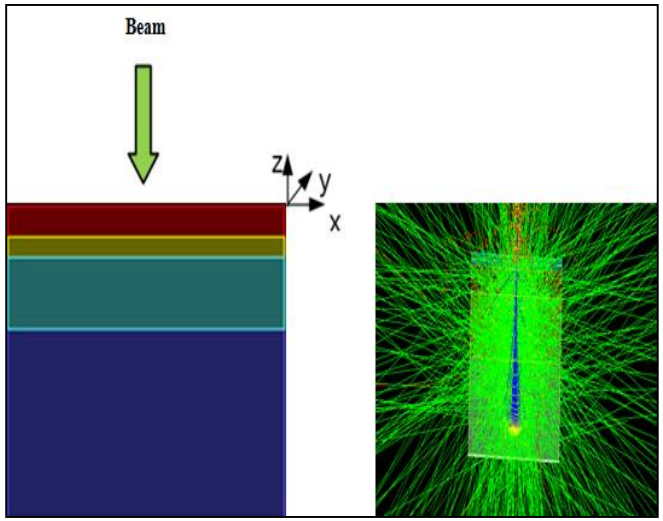


Fig3. Graphic output results of comparison between simulation and experimental data of proton beam 62MeV.

(G4) Heterogeneous phantom



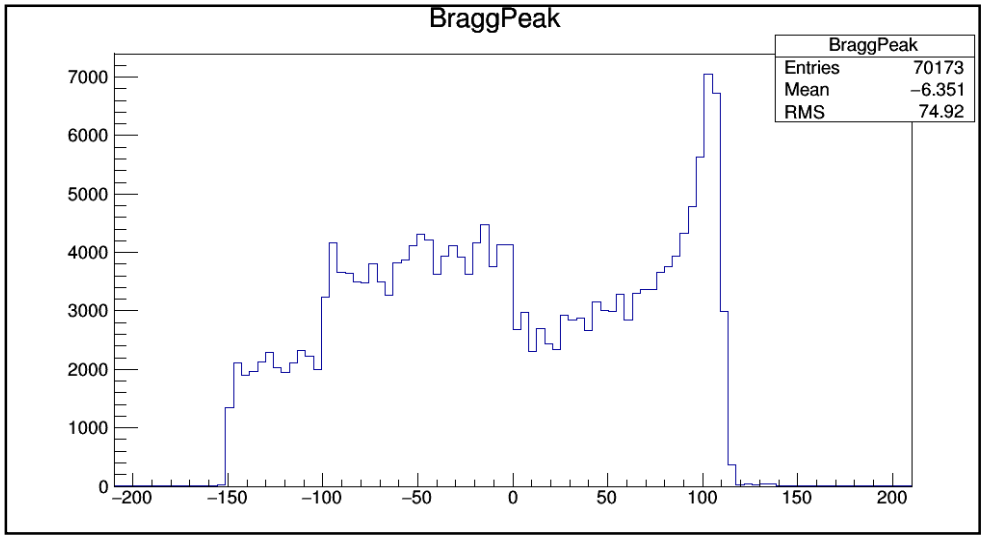
Schematic representation of the heterogeneous configuration used: The different materials are represented by different colors

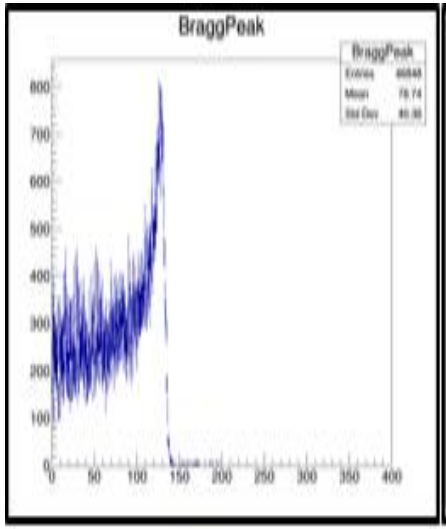
Red: soft tissues

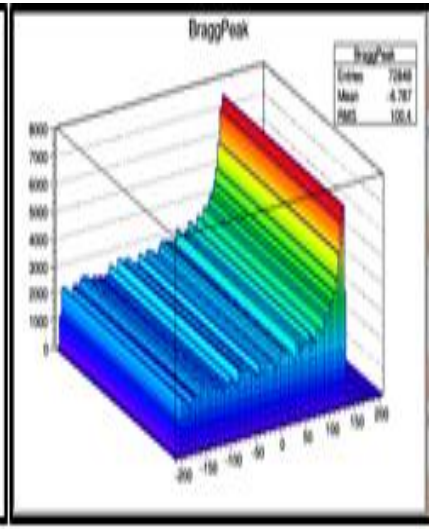
Yellow : cortical bone

Cyan : lung

Bleu : water

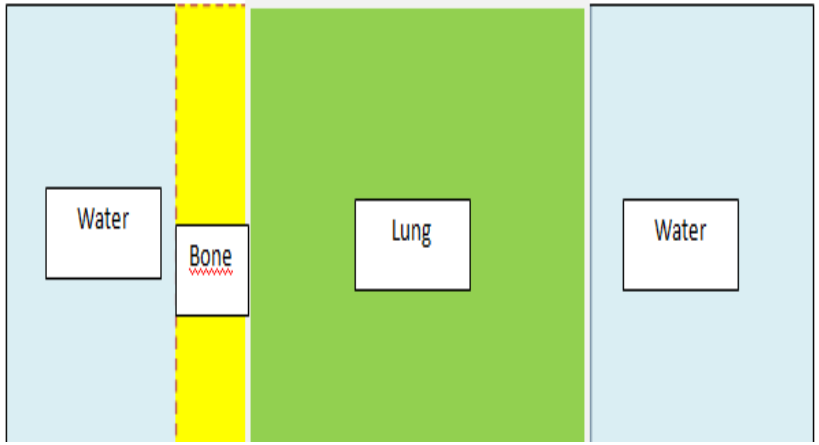


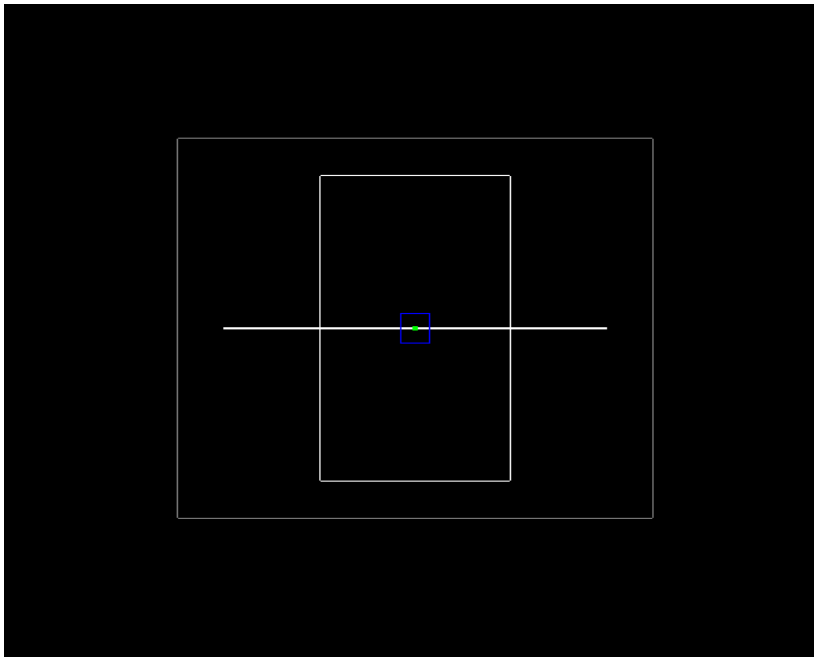




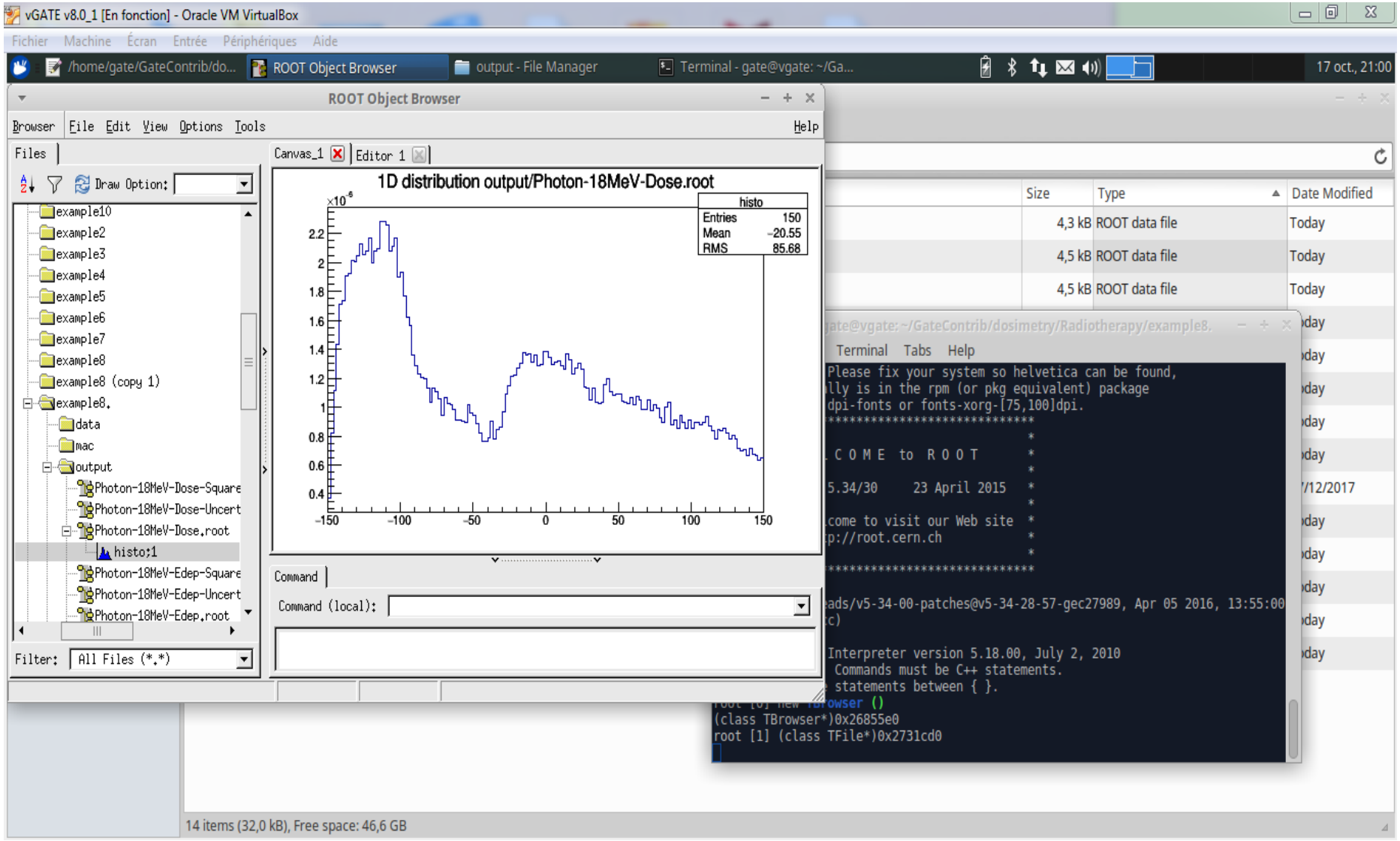
(Gate) Heterogeneous phantom

- We simulate part of human body with Clinac C2100 Varian.
- Beam of X 18MV
- We compare with EGS experimental data.

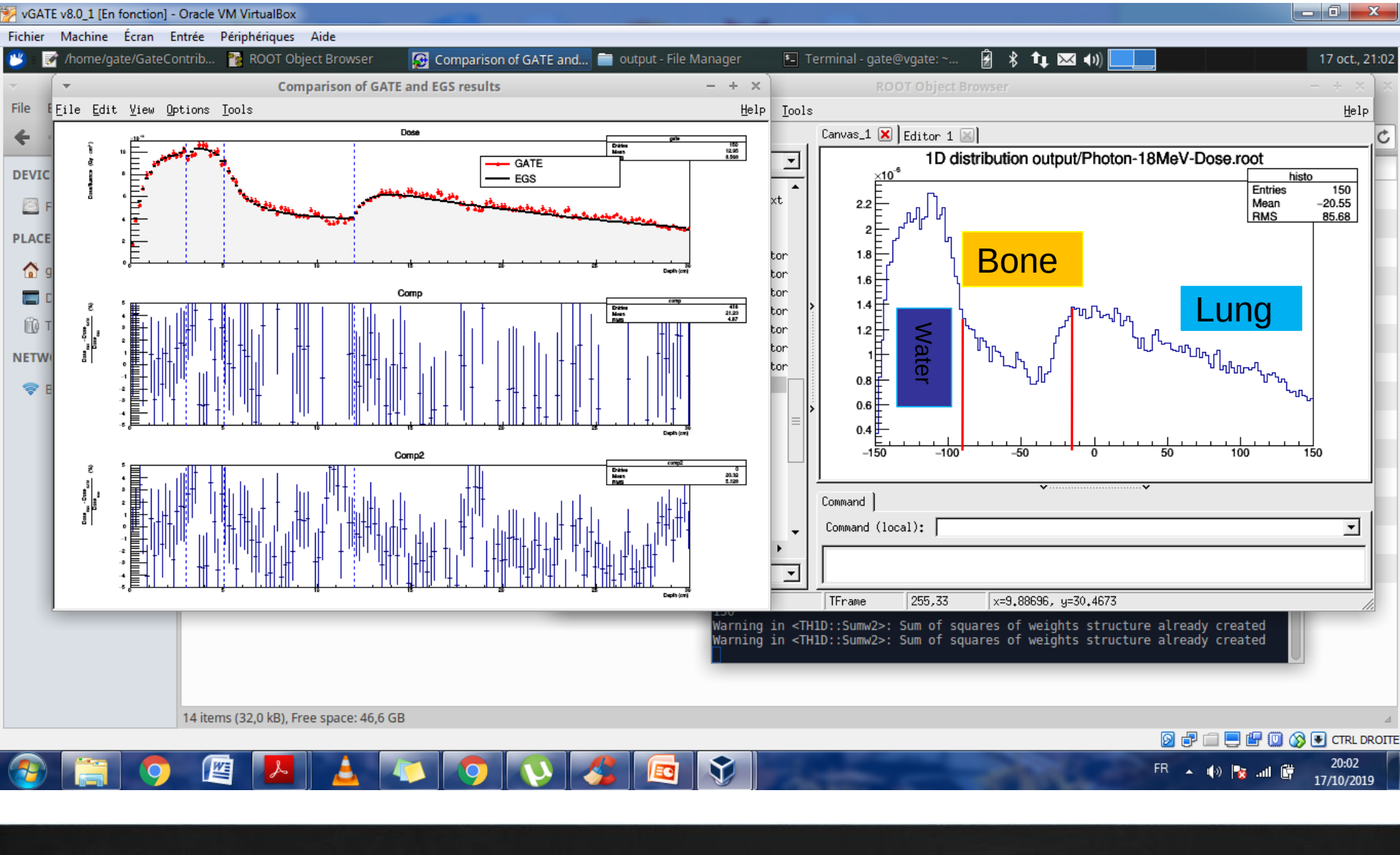




Results


vGATE v8.0_1 [En fonction] - Oracle VM VirtualBox
ROOT Object Browser
1D distribution output/Photon-18MeV-Dose.root
histo
Entries 150
Mean -20.55
RMS 85.68
Photon-18MeV-Dose.root
histo;1
Photon-18MeV-Edep.root
Terminal - gate@vgate: ~/GateContrib/dosimetry/Radiotherapy/example8.
Please fix your system so helvetica can be found,
dpi-fonts or fonts-xorg-[75,100]dpi.
(class TBrowser*)0x26855e0
root [1] (class TFile*)0x2731cd0
14 items (32,0 kB), Free space: 46,6 GB

Results


vGATE v8.0_1 [En fonction] - Oracle VM VirtualBox
Fichier Machine Écran Entrée Périphériques Aide
Comparison of GATE and EGS results
File Edit View Options Tools Help
Dose
GATE
EGS
Comp
Comp2
ROOT Object Browser
Tools Help
Canvas_1
Editor 1
1D distribution output/Photon-18MeV-Dose.root
histo
Entries 150
Mean -20.55
RMS 85.68
Bone
Lung
Water
Command
Command (local):
TFrame 255,33 x=9.88696, y=30.4673
Warning in <TH1D::Sumw2>: Sum of squares of weights structure already created
Warning in <TH1D::Sumw2>: Sum of squares of weights structure already created
14 items (32,0 kB), Free space: 46,6 GB
CTRL DROITE
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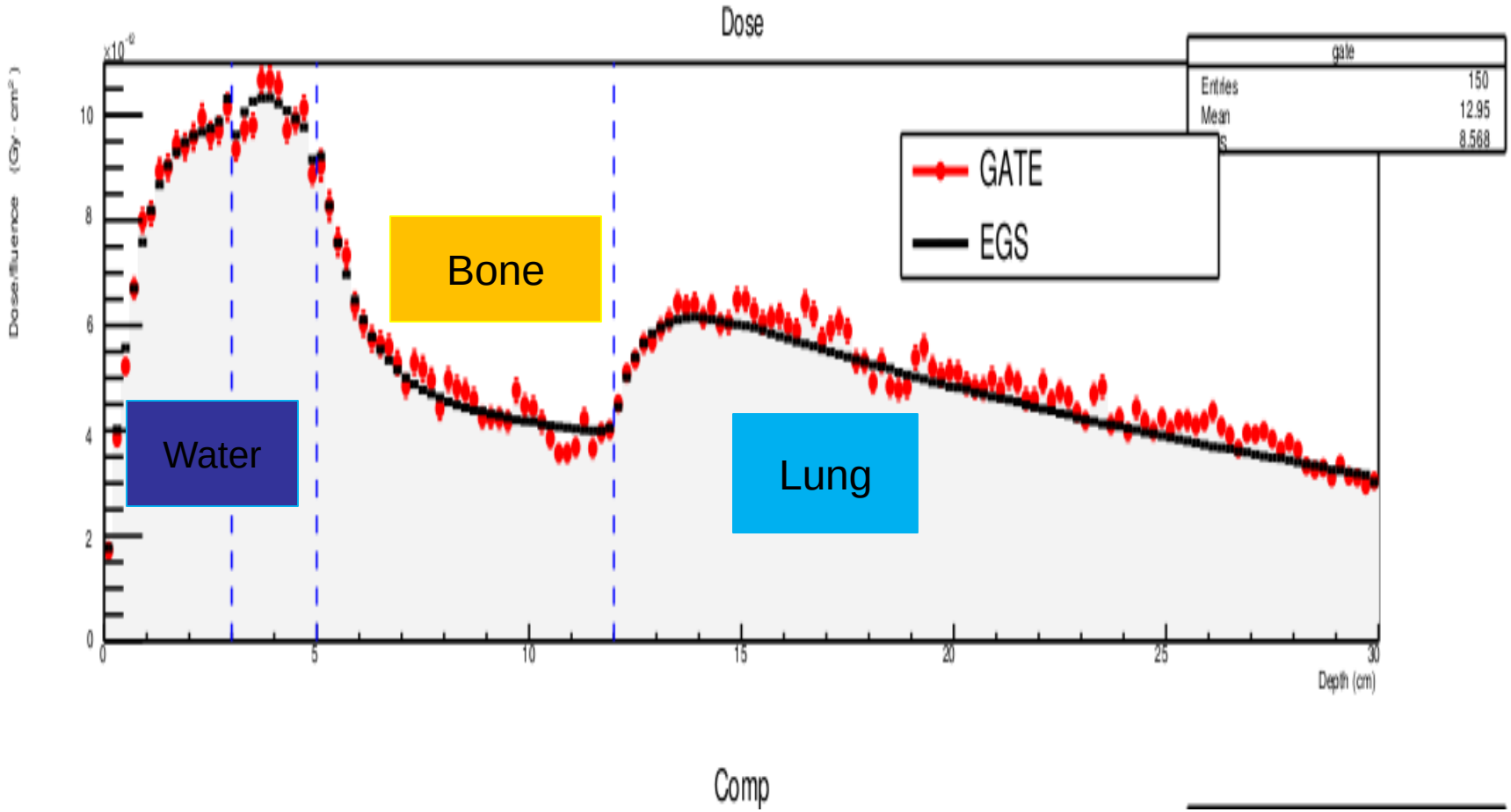
EX4: Results


Dose
Dose/fluence (Gy · cm²)
Depth (cm)
GATE
EGS
gate
Entries 150
Mean 12.95
Water
Bone
Lung
Comp

Conclusion

- Problems which are intrinsically of **probabilistic nature** is the direct simulation, application of MC method appears naturally.
- Until now, MC simulation is **very important** in medical field.
- At this stage in the simulation development, there **are no clear class solutions** to treatment planning for radiationtherapy.

Thank you