
GATE Versus Geant4 Developer's point of view

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Outline

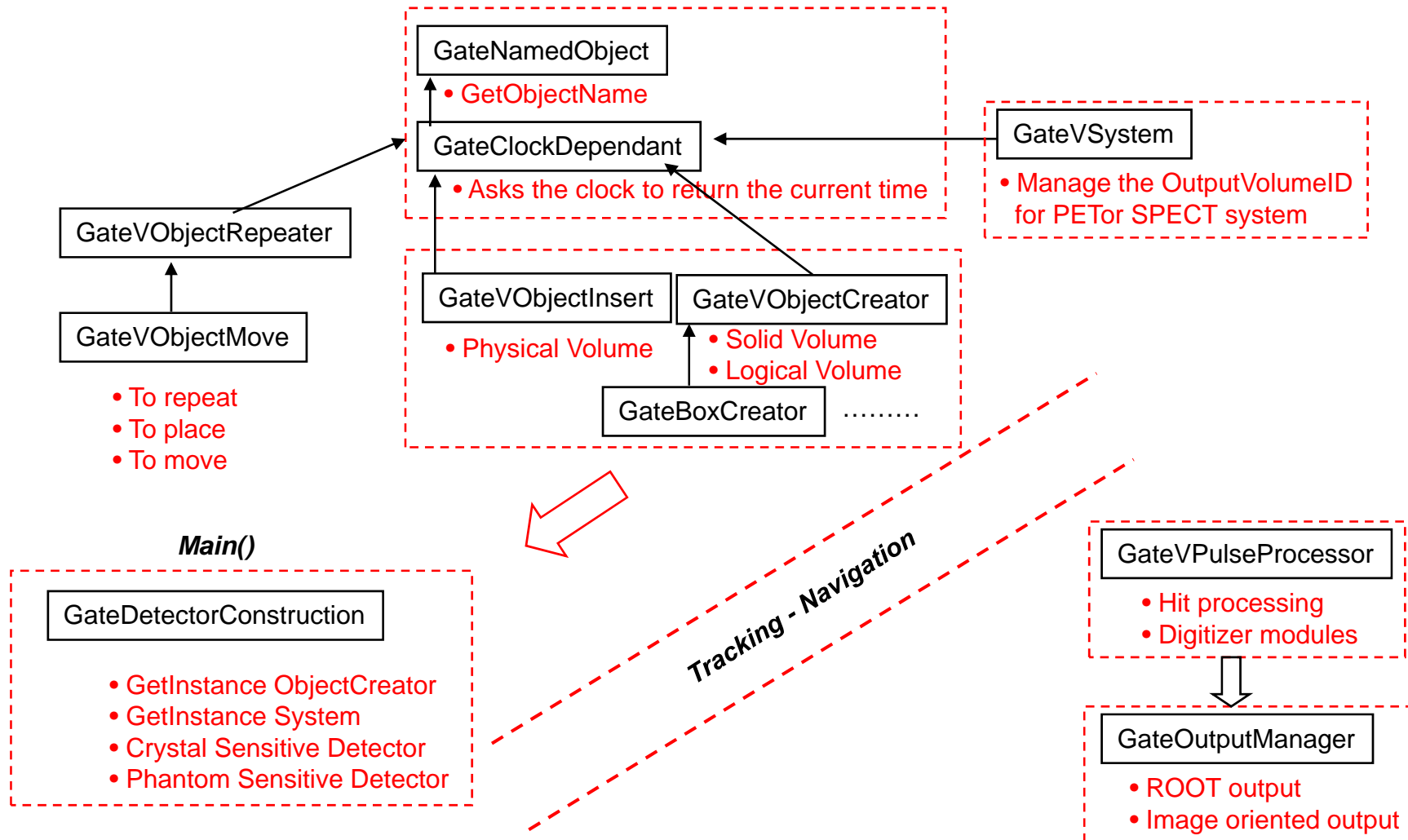
- Context
- Class Management : Overview
- Volume & Geometry
- Materials
- Physics list & Cuts
- Primary Generator
- Navigation & Tracking
- Digitizer
- Output
- Simulation Management

Introduction

- GATE : Geant4 Application for Emission Tomography (SPECT and PET)
- Geant4-based tool to model SPECT and PET scans (positron and photon transport, 70 keV - 600 keV range), including the tracer distribution in the patient, patient movements, scintillation detector components and detector electronics. Recent extension to dosimetry calculations
- Developments started in 2001, 1st public release in May 2004
- 2 releases per year
- 1200 users to date, 5-8 labs actively developing the code
- Position wrt other ET dedicated-software : most flexible BUT far too slow

Class Management : Overview

Object description



Class Management : Overview

Main() – Mandatory Classes

GateRunManager

GateDetectorConstruction

GatePhysicsList

GatePrimaryGenerator

Init the Clock

```
GateClock::GetInstance()->SetTime(0);
```

Start the DAQ

```
GateApplicationMgr* applMgr = GateApplicationMgr::GetInstance();
```

Start the DAQ : management of time and movement

GateApplicationMgr

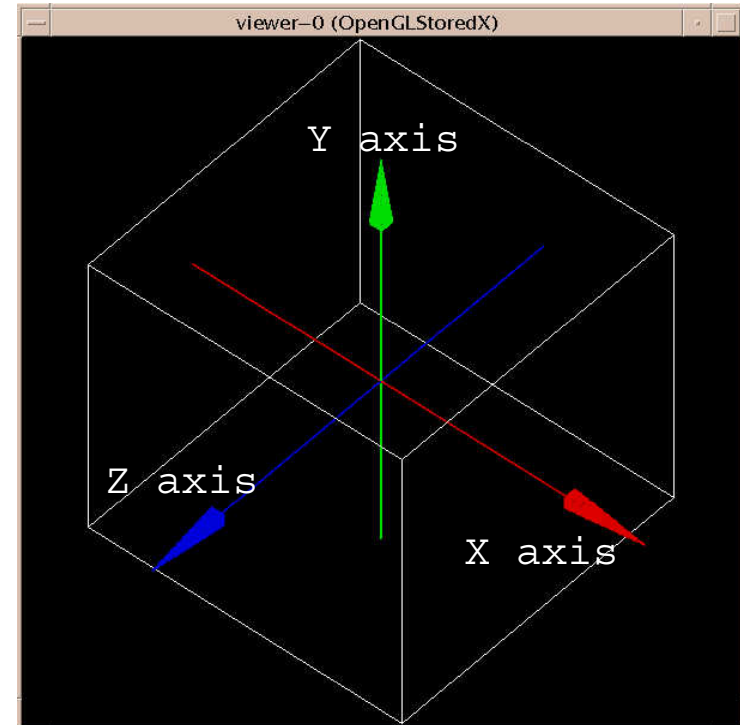
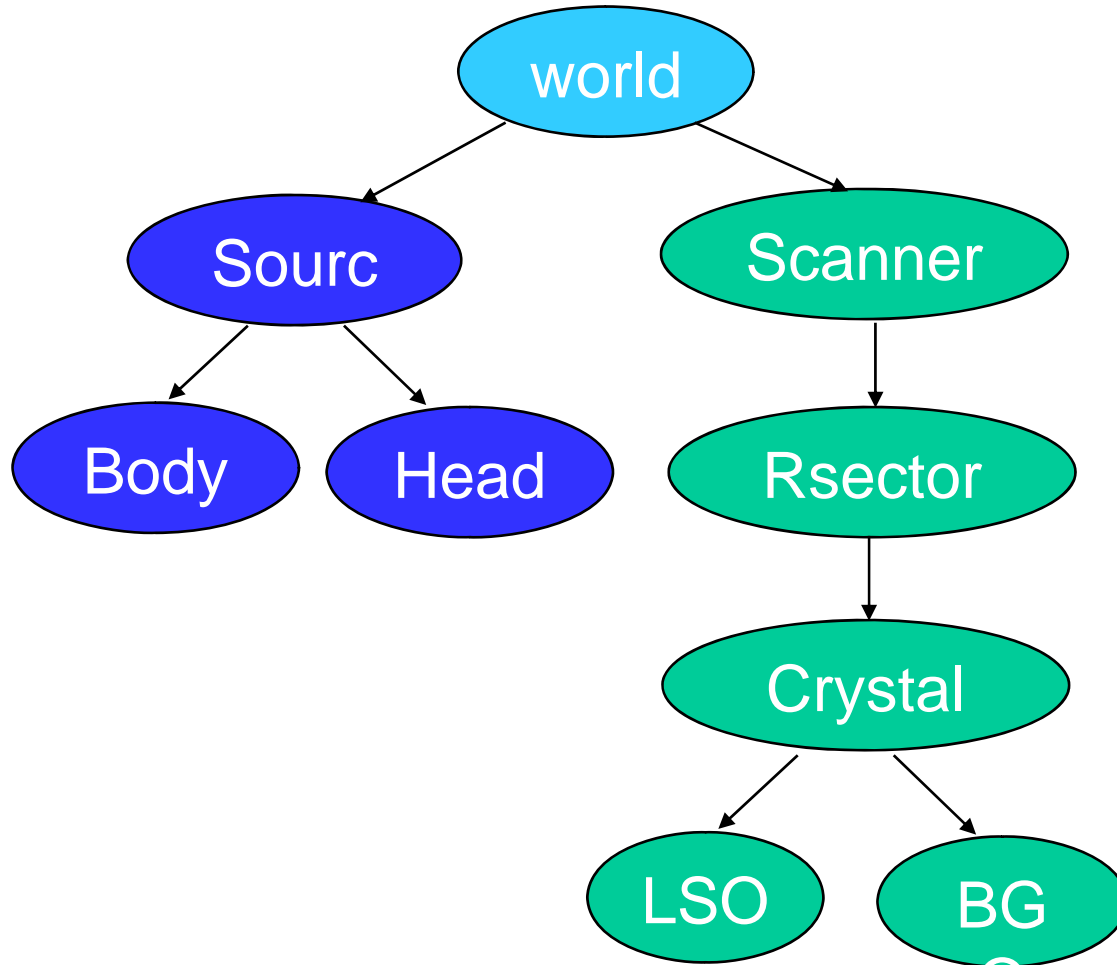
:: StartDAQ()

```
GateClock* theClock = GateClock::GetInstance();  
m_time = m_timeStart; //Init time start  
theClock -> SetTime(m_time);  
GateOutputMgr::GetInstance() -> RecordBeginOfAcquisition();  
While (m_time < m_timeStop) { // m_timeStop = end of acquisition  
GateRunManager::GetRunManager() -> BeamOn(INT_MAX);  
m_time += m_timeSlice;  
theClock -> SetTime(m_time);  
}  
GateOutputMgr::GetInstance() -> RecordEndOfAcquisition();
```

Volume & Geometry

The World is the only volume initially present in GATE

All volumes are daughters or granddaughters of the world : the World volume is essential



Volume & Geometry

To build a volume :

1. Give the new volume a name

```
/gate/world/daughters/name vol_name
```

2. Assign a shape to the new volume

```
/gate/world/daughters/insert box
```

```
//create the volume vol_name
```

The user can create a cylinder, a sphere, an ellipse, a hexagon, a box.....

3. Define the size of the new volume

```
/gate/vol_name/geometry/setXLength 20. cm  
/gate/vol_name/geometry/setYLength 40. cm  
/gate/vol_name/geometry/setZLength 40. cm
```

4. Place the new volume in the user's geometry

```
/gate/vol_name/placement/setTranslation 10. 0. 0. cm
```

5. Assign a material to the new volume

```
/gate/vol_name/setMaterial Air
```

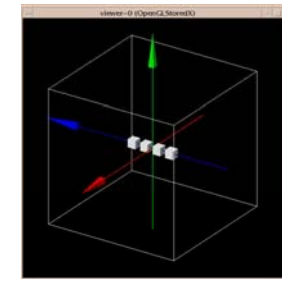
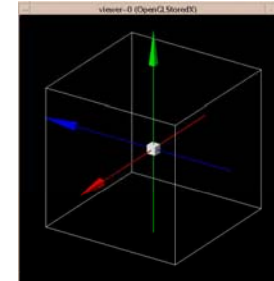
The list of the available materials is in the GateMaterials.db file

Volume & Geometry

Special classes to repeat Volumes

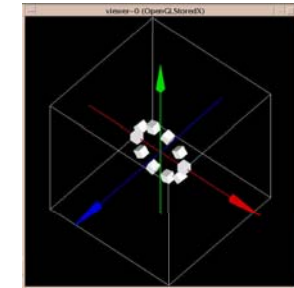
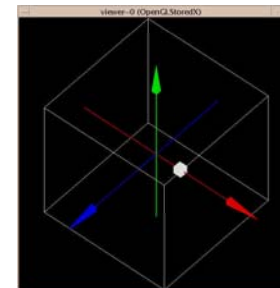
Linear repeater

```
/gate/vol_name/repeaters/insert linear  
/gate/vol_name/linear/setRepeatNumber 4  
/gate/vol_name/linear/setRepeatVector 0. 0. 5. mm
```



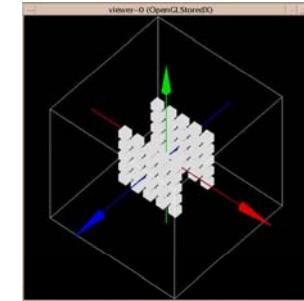
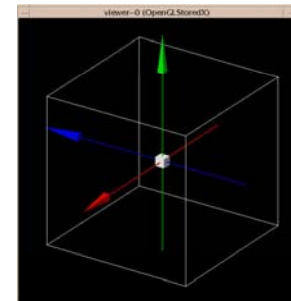
Ring repeater

```
/gate/vol_name/repeaters/insert ring  
/gate/vol_name/ring/setNumber 10  
/gate/vol_name/ring/setPoint1 0. 0. 1. mm  
/gate/vol_name/ring/setPoint2 0. 0. 0. mm
```



Cubic array repeater

```
/gate/vol_name/repeaters/insert cubicArray  
/gate/vol_name/cubicArray/setRepeatNumberX 5  
/gate/vol_name/cubicArray/setRepeatNumberY 5  
/gate/vol_name/cubicArray/setRepeatNumberZ 2  
/gate/vol_name/cubicArray/setRepeatVector 5. 5. 15. cm
```



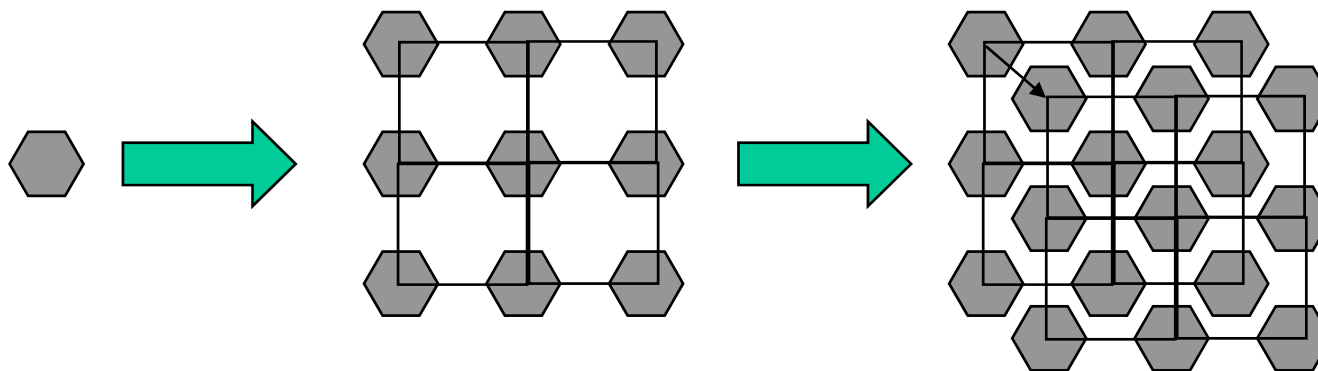
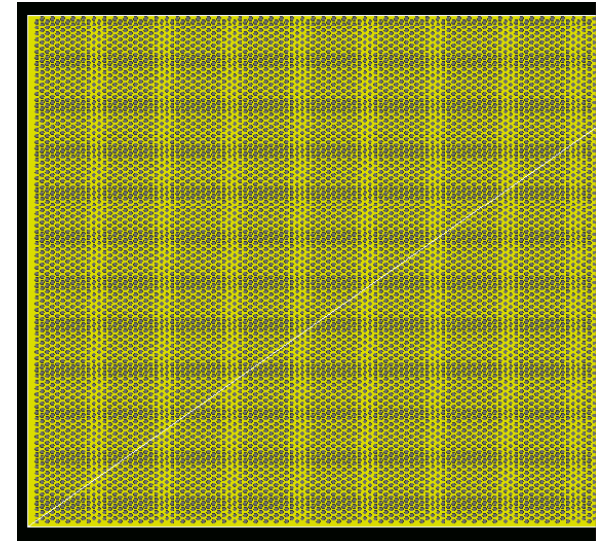
Volume & Geometry

Special classes to repeat Volumes : SPECT collimator example

```
/gate/world/daughters/name holeg1
/gate/world/daughters/insert hexagone
/gate/holeg1/geometry/setHeight 2.7 cm
/gate/holeg1/geometry/setRadius .122 cm

/gate/holeg1/repeaters/insert cubicArray
/gate/holeg1/cubicArray/setRepeatNumberX 69
/gate/holeg1/cubicArray/setRepeatNumberY 84
/gate/holeg1/cubicArray/setRepeatNumberZ 1
/gate/holeg1/cubicArray/setRepeatVector 0.774 0.447 0. cm

/gate/holeg1/repeaters/insert linear
/gate/holeg1/linear/setRepeatNumber 2
/gate/holeg1/linear/setRepeatVector 0.387 0.2235 0. cm
```



Volume & Geometry

Special classes to place and set up volume movements

Translation

```
/gate/vol_name/placement/setTranslation 10. 0. 0. cm
```

Rotation

```
/gate/vol_name/placement/setRotationAxis 0 1 0  
/gate/vol_name/placement/setRotationAngle 90 deg
```

Move with time

★ Rotation

```
/gate/vol_name/moves/insert rotation  
/gate/vol_name/rotation/setSpeed 1 deg/s
```

★ Translation

```
/gate/SPECThead/moves/insert translation  
/gate/SPECThead/translation/setSpeed 0 0 1 cm/s
```

★ Orbiting

```
/gate/SPECThead/moves/insert orbiting  
/gate/SPECThead/orbiting/setSpeed 1. deg/s  
/gate/SPECThead/orbiting/setPoint1 0 0 0  
/gate/SPECThead/orbiting/setPoint2 0 0 1
```

Materials

```
/gate/vol_name/setMaterial Air
```

The material used must be in the Gate material database

File GateMaterials.db

As follows : This file can be edited to add new materials

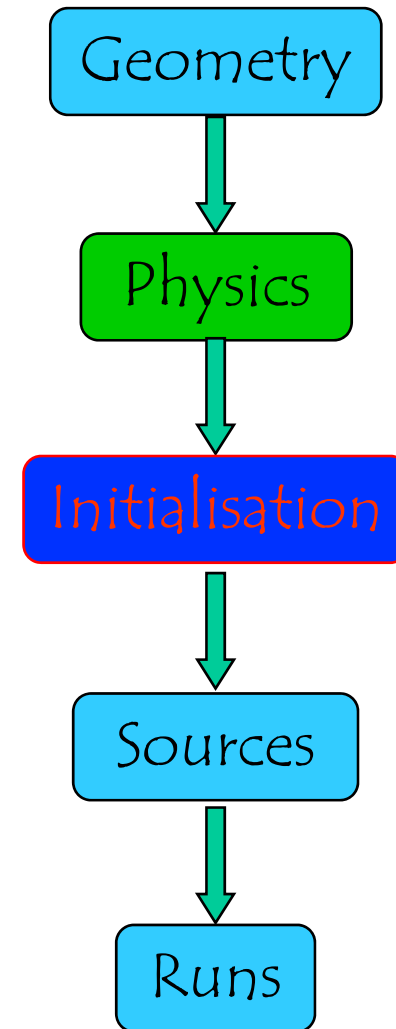
```
[Elements]
Hydrogen:  S= H   ; Z=  1   ; A=  1.01  g/mole
Carbon:    S= C   ; Z=  6   ; A= 12.01  g/mole

[Materials]
Aluminium: d=1.350 g/cm3 ; n=1 ; state=solid
           +el: name=auto ; n=1
NaI: d=3.67 g/cm3; n=2; state=solid
     +el: name=Sodium ; n=1
     +el: name=Iodine ; n=1

CsITl: d=4.51 g/cm3; n=3; state=solid
      +el: name=Cesium ; f=0.511
      +el: name=Iodine ; f=0.488
      +el: name=Thallium ; f=7.86e-04
```

Physics List & Cuts

- **GATE includes a physics list**
 - Particles of interest
 - Interactions for photons, electrons/positrons...
 - Radioactive decay
 - Cuts
- **Scripted selections**
 - Process selection for X/gamma interactions
 - Cuts
 - **Must be done before initialization**



Physics List & Cuts

- 4 commands available for selecting processes
 - /gate/physics/gamma/selectPhotoelectric
 - /gate/physics/gamma/selectCompton
 - /gate/physics/gamma/selectRayleigh
 - /gate/physics/gamma/selectGammaConversion
- Each command can be used to select a model
 - standard : uses the standard model (not Rayleigh)
 - lowenergy : uses the low-energy model
 - inactive : does not simulate the interaction

```
# The list below is arbitrary
/gate/physics/gamma/selectPhotoElectric lowenergy
/gate/physics/gamma/selectCompton lowenergy
/gate/physics/gamma/selectGammaConversion standard
/gate/physics/gamma/selectRayleigh inactive
```

Physics List & Cuts

- 3 cuts can be used in GATE
 - Range cut for the electrons
 - `/gate/physics/setElectronCut 1000. km`
 - Energy cut for X-rays
 - `/gate/physics/setXRayCut 1. GeV`
 - For low energy processes only
 - Energy cut for low-energy electrons
 - `/gate/physics/setDeltaRayCut 1. GeV`
 - For low energy processes only

Primary Generation

- **GATE includes a mechanism for building sources**

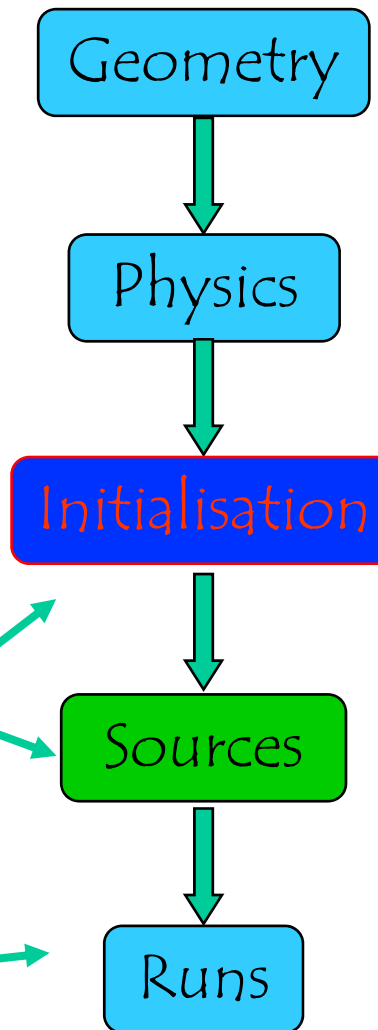
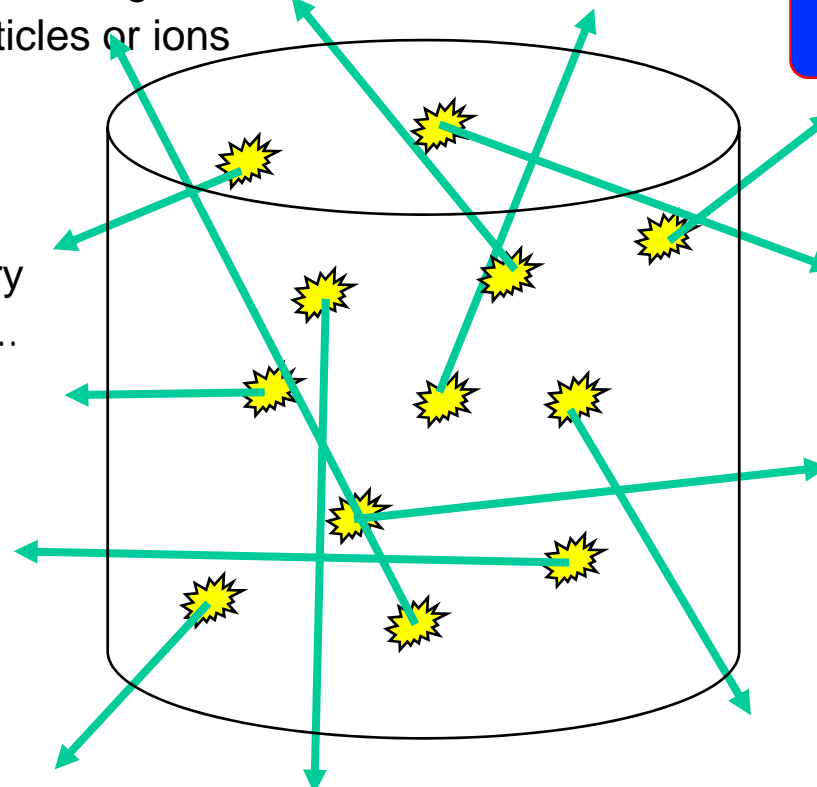
- Source manager
- Multiple sources : **customized GPS from G4**
- Sources are built via scripting
- **Must be done after initialization**

- **General Particle Sources (GPS)**

- Models simple emission geometries
- Can generate particles or ions

- **User must define**

- Total activity
- Emission geometry
- Direction, energy...



Navigator & Tracking

Question : How could we optimize or define the particle navigation to speed up the simulation ?

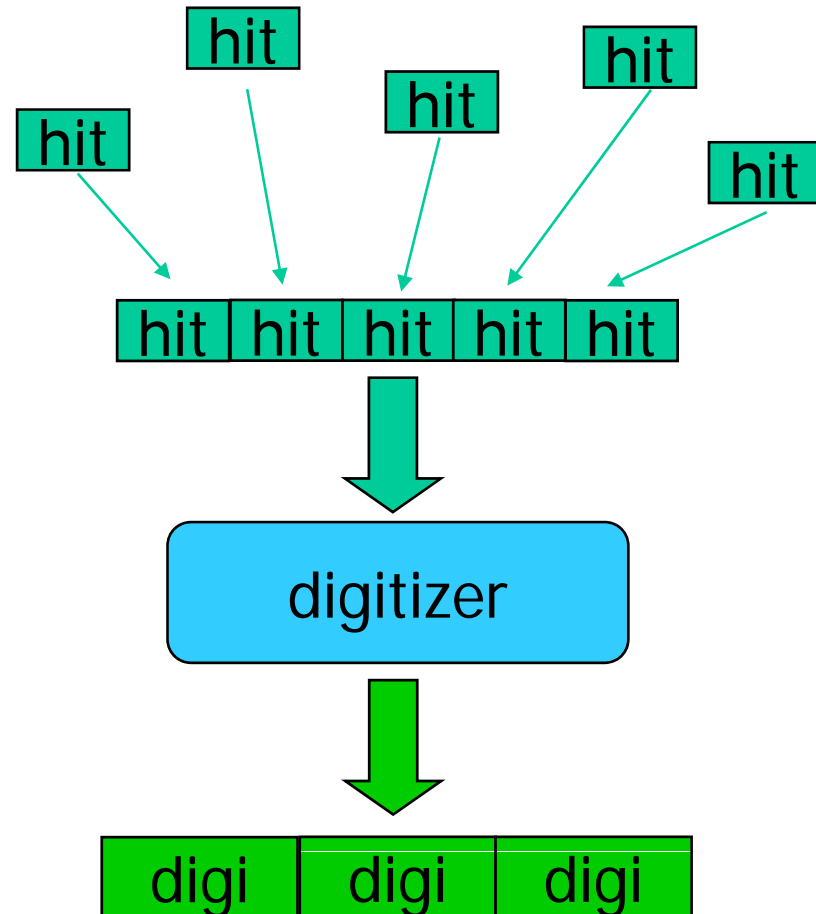
- Tracking in parameterized volumes
- Performance of Geant4 with large voxelized phantoms

Will be discussed in the next talk ...

The Digitizer

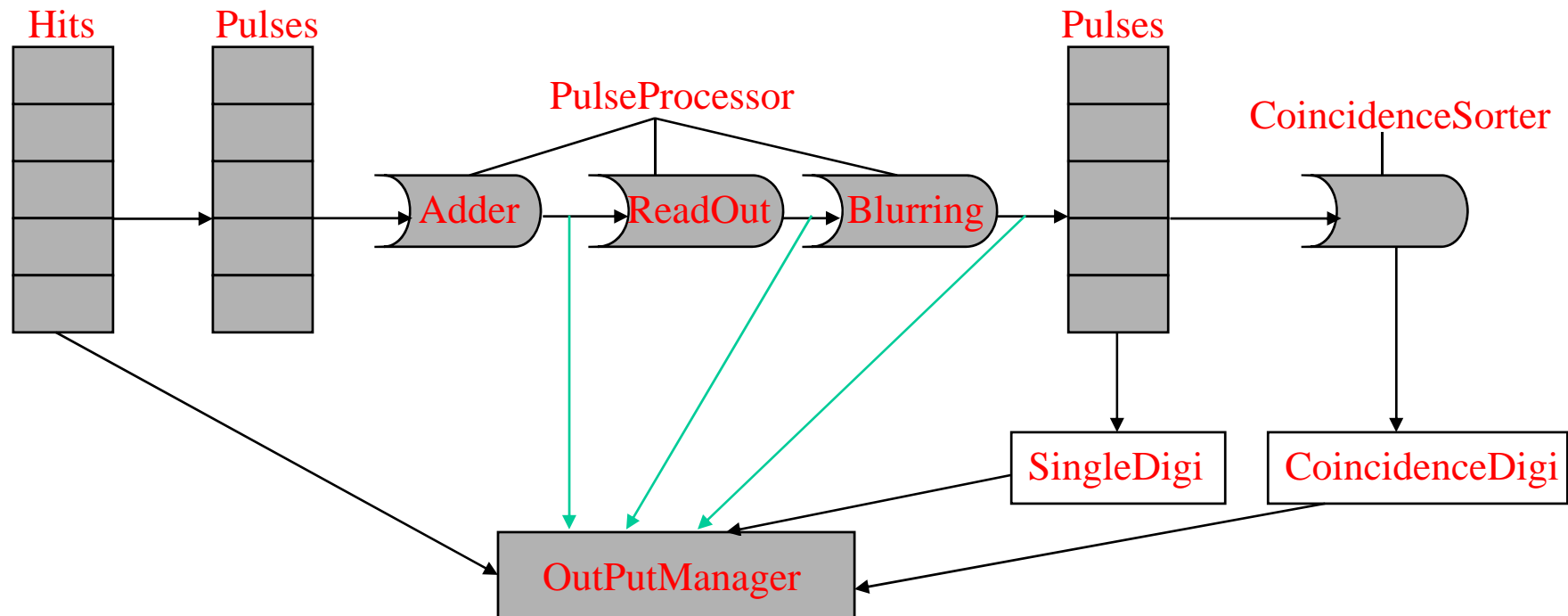
Global definition

- For each event
 - The Crystal-SD creates hits,
 - ... which are grouped into a hit-collection,
 - ... which is processed by the digitizer,
 - ... which returns a digi-collection or pulse-collection



The Digitizer

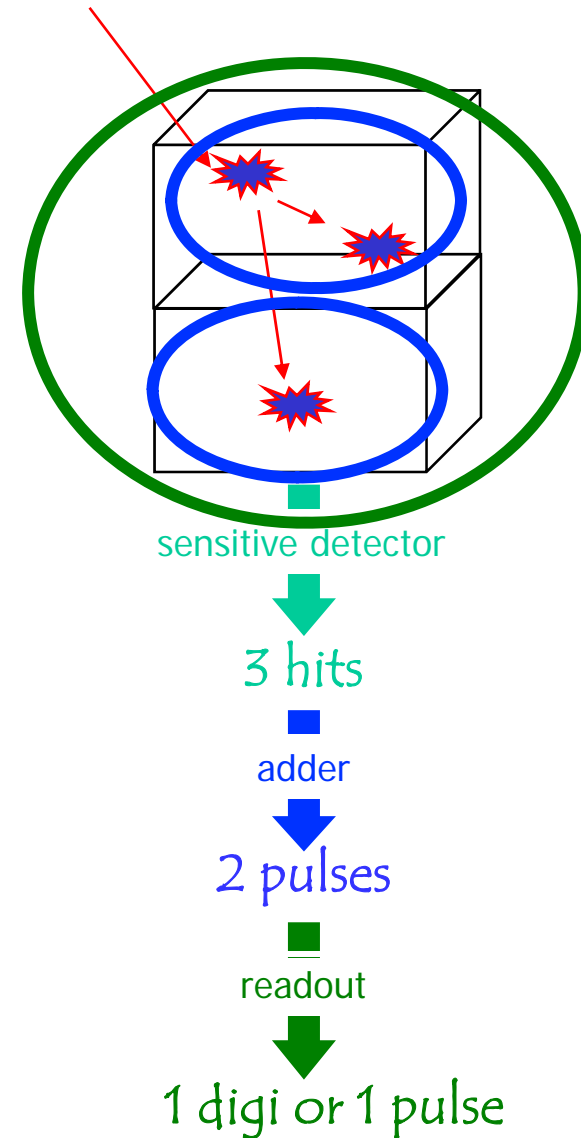
**More than 15 digitizer modules are used to model
the electronic processing of the scanner**



The Digitizer

A example of what we can do using 2 digitizer modules

- **adder**
 - Regroup pulses per volume
 - Energy: total energy in volume
 - Position: energy-weighted centroid
- **readout**
 - Regroup pulses per block
 - Need to specify the block **depth**
 - Energy: total energy in block
 - Position: position of pulse with maximum energy (winner-takes-all)



Output

ROOT output file

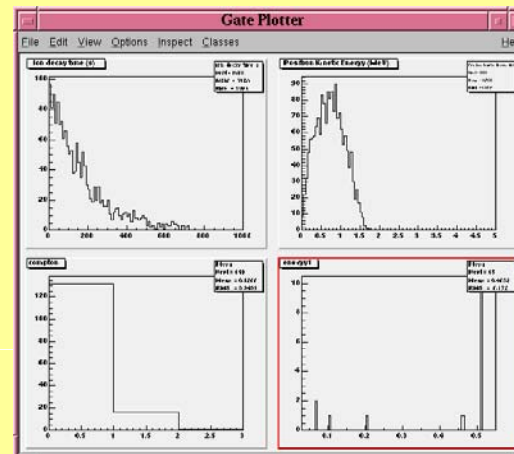
- Data storage
 - ROOT file :[gate.root](#) (default)
 - Binary format
- Separate folders/trees
 - [Hits](#)
 - [Singles](#)
 - [Coincidences](#)
 - ...
- Commands
 - Default: all trees active
 - Command tree: [/gate/output/ROOT/](#)

System-specific outputs

- Principle
 - When new systems are created...
 - ... new output channels are created
 - System-dependent outputs → reconstruction
- Main system-specific outputs
 - [Ecat](#)
 - [Imf1](#)
 - [Interfile](#)

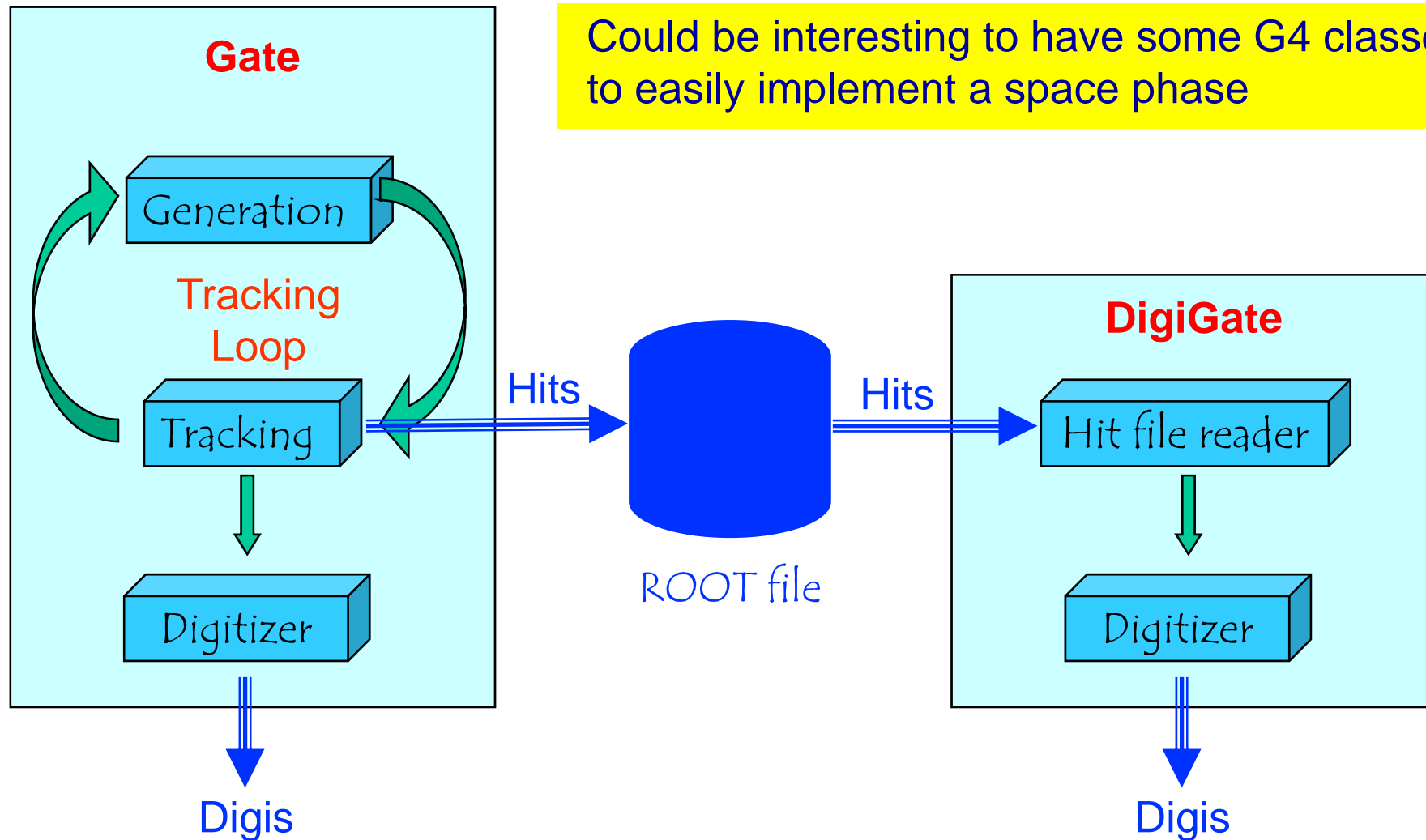
ROOT plotter

- Plotter
 - Real-time display
 - Refreshing after each run
- Commands
 - Default: plotter hidden
 - Command tree: [/gate/output/plotter](#)



Output - DigiGate

Making the processing of hits possible, using different digitizer chains



Simulation Management

- Classical “RecorderBase” structure

- BeginOfAcquisition

- BeginOfRun

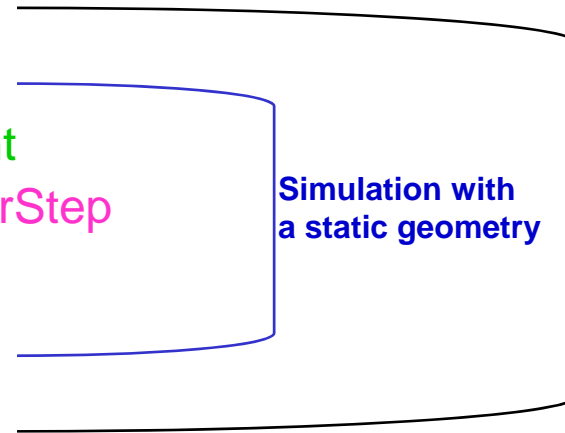
- BeginOfEvent

- » RecorderStep

- EndOfEvent

- EndOfRun

- EndOfAcquisition



To manage dynamic simulation : sequences of static runs

- Command sequence

- Start time: `/gate/application/setTimeStart`
`VALUE UNIT`

- Stop time: `/gate/application/setTimeStop`
`VALUE UNIT`

- Time slice: `/gate/application/setTimeSlice`
`VALUE UNIT`

- Launch: `/gate/application/startDAQ`

Geant4 & Gate - Close interactions

Improving Geant4-based simulations for medical imaging and dosimetry applications

- Tracking and navigation
 - Gold standard : tracking inside a CSG solid (G4Box filled with water)
 - How to improve the voxelised description ?
 - How to improve the navigation inside a voxelized structure ?
 - Could we expect a speed-up factor higher than 15 or 20 ?
- Variance reduction techniques
 - Overview of Geant4 tools
 - Geant4.9.0/source/geometry/biasing
 - G4VCellScorer
 - G4VWeightWindowAlgorithm
 -
 - Contact : Michael Dressel ??
- Physics List
 - Dosimetry for charged particles, validation at low energy
- New volume description
 - Based on CAD description (scanner description)

Geant4 & Gate - Future

Tools to facilitate shared developments

- Geant4 developers at our bi-annual OpenGATE technical meetings
- Mailing list common to GATE and Geant4 developers
- List (emails) of persons technically deeply involved in specific GATE and Geant4 developments who will commit to answer emails ;-)
- Few meetings on specific aspects of developments (VRT, navigation, aso)