Geant4 release 9.6+P02

SCORING

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Contents

- What is scoring
- Three types of scoring
  - User hooks
  - Sensitive detectors
  - Command-based scoring

Extract useful information

- Given geometry, physics and primary track generation, Geant4 does proper physics simulation "silently"
  - You have to add a bit of code to extract information useful to you

- There are several ways
  - Use user hooks (G4UserTrackingAction, G4UserSteppingAction, etc.)
    - You have full access to almost all information
    - Straight-forward, but do-it-yourself
  - Use sensitive detectors : assign G4VSensitiveDetector to a volume and optionally generate "hits"
    - Use user hooks (G4UserEventAction, G4UserRunAction) to get event / run summary
  - Built-in scoring commands
    - Most commonly-used physics quantities are available.
  - (other less common alternatives)

1) USER HOOKS

User hooks

- "Do it yourself" approach
- In Geant4, you have full access to almost all information
  - G4UserSteppingAction
  - G4UserTrackingAction
  - G4UserEventAction
  - G4UserRunAction
- Well adapted to small applications & Geant4 examples
- In large applications, where many data from many volumes need to be recorded, too heavy
  - Crowded SteppingAction
  - Need to subdivise problem, which Sensitive Detectors already do for you

Principle

- In your SteppingAction, check that particle is in volume A and do what you want
- Usually, your containers and histograms will be attributes of Track, Event or Run
  - therefore you will have to instanciate TrackingAction and/or EventAction and/or RunAction
  - pass their pointer to SteppingAction
- This approach is illustrated in
  - examples/novice N03, N06,
  - extended/electromagnetic, optical, and many others ...

Geometrical information - 1

- A G4Step object consists of two points

```
G4StepPoint* point1 = step->GetPreStepPoint();
G4StepPoint* point2 = step->GetPostStepPoint();
```

- To get their positions in the global coordinate system

```
G4ThreeVector pos1 = point1->GetPosition();
G4ThreeVector pos2 = point2->GetPosition();
```

- Hereafter we call 'current volume' the volume where the step has just gone through

Geometrical information is available from **preStepPoint !**

Geometrical information - 2

- G4VTouchable and its derivates keep these geometrical information

```
G4TouchableHandle touch1 = point1->GetTouchableHandle();
```

- To get the current volume

```
G4VPhysicalVolume* volume = touch1->GetVolume();
```

- To get its name

```
G4String name = volume->GetName();
```

- To get copy number

```
G4int copyNumber = touch1->GetCopyNumber();
```

- To get logical volume

```
G4LogicalVolume* lVolume = volume->GetLogicalVolume();
```

Geometrical information - 3

- To get material the following statements are equivalent

```
G4Material* material = point1->GetMaterial();
G4Material* material = lVolume->GetMaterial();
```

- To get region

```
G4Region* region = lVolume->GetRegion();
```

- To get mother volume

```
G4VPhysicalVolume* mother = touch1->GetVolume(depth=1);
```

grandMother: depth=2 ...etc...

- To get copy number of mother

```
G4int copyNumber = touch1->GetCopyNumber(depth=1);
```

grandMother: depth=2 ...etc...

Geometrical information - 4

- To check that particle has just entered in the current volume, ie. is at the first step in the volume; the preStepPoint is at boundary

```
if (point1->GetStepStatus() == fGeomBoundary)
```

- To check that particle is leaving the current volume, ie. is at the last step in the volume; the postStepPoint is at boundary

```
if (point2->GetStepStatus() == fGeomBoundary)
```

- In the above situation, get touchable of the next volume:

```
G4TouchableHandle touch2 = point2->GetTouchableHandle();
```

- From `touch2`, all information on the next volume as above.

Physics

- To get the process which has limited the current step

```
G4VProcess* aProcess = point2->GetProcessDefinedStep();
```

- Current particle name

```
step->GetTrack()->GetDynamicParticle()->GetDefinition()->GetParticleName()
```

- Physics quantities are available from step (G4Step) or track (G4Track)

- To get energy deposition, step length, displacement and time of flight spent by this step

```
G4double eDeposit      = step->GetTotalEnergyDeposit();
G4double sLength       = step->GetStepLength();
G4ThreeVector displace = step->GetDeltaPosition();
G4double tof           = step->GetDeltaTime();
```

- To get momentum, kinetic energy and global time (time since the beginning of the event) of the track after the completion of the current step

```
G4Track* track          = step->GetTrack();
G4ThreeVector momentum = track->GetMomentum();
G4double kinEnergy     = track->GetKineticEnergy();
G4double globalTime    = track->GetGlobalTime();
```

- Additional remark: to transform position from the global coordinate system to the local system of current volume, use preStepPoint transformation

```
G4ThreeVector localPosi = touch1->GetHistory()->GetTopTransform().TransformPoint(position);
```

And more…

- Similarly in TrackingAction one can access track information

```
void MyTrackingAction::PostUserTrackingAction(const G4Track* track)
{
 G4double tracklen = track->GetTrackLength();
 G4double charge   = track->GetDefinition()->GetPDGCharge();
…
```

- See more in
  - $G4INSTALL/include/Geant4/G4Step.hh
  - $G4INSTALL/include/Geant4/G4Track.hh
  - …

- You can retrieve easily quantities at each step and cumulate them over events or run using user accessors/ recorders added to your EventAction and RunAction classes

```
G4double dose = aStep->GetTotalEnergyDeposit()/MassTarget;
Run->AddDose(dose);
```

2) SENSITIVE DETECTORS

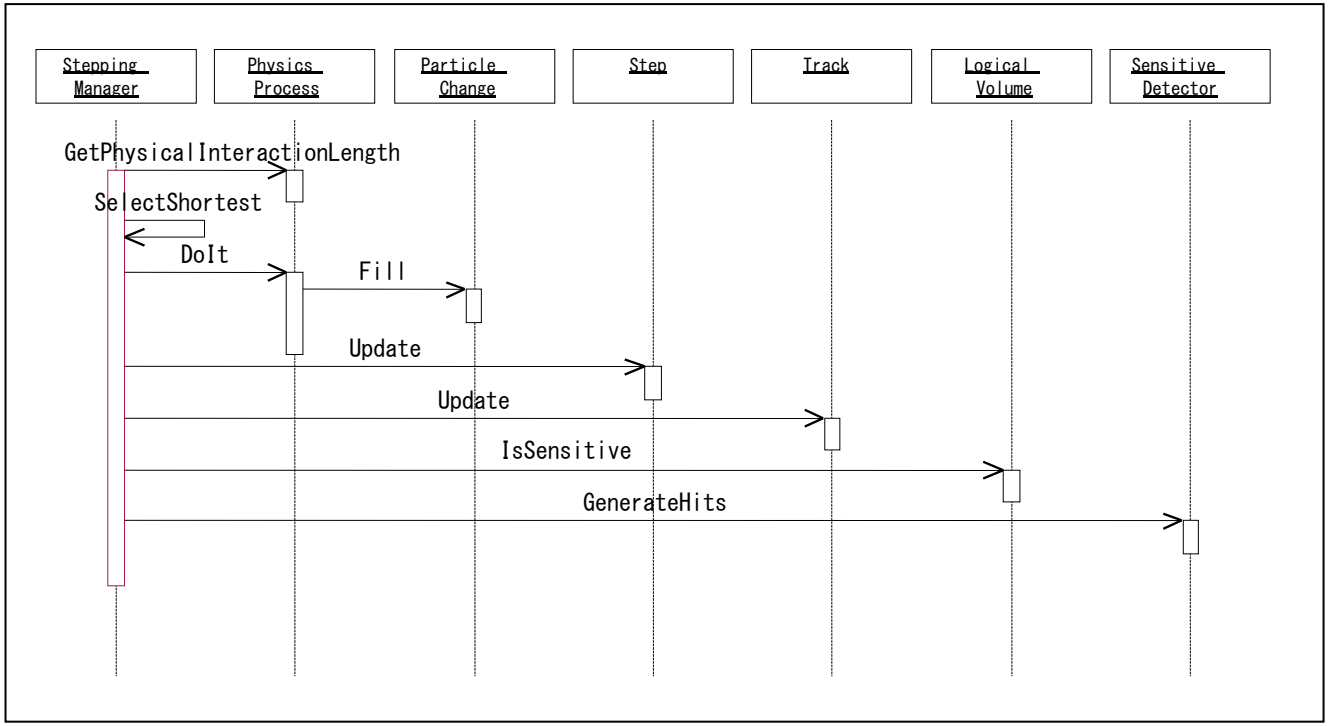
A sensitive detector ?

- A sensitive detector can be used to simulate the "read-out" of your detector:
  - It is a way to declare a geometric element "sensitive" to the passage of particles
  - It gives the user a handle to collect quantities from these elements at stepping time
    - For example: energy deposited, position, time information

Sensitive detector

- A G4VSensitiveDetector object can be assigned to G4LogicalVolume

- In case a step takes place in a logical volume that has a G4VSensitiveDetector object, this G4VSensitiveDetector is invoked with the current G4Step object
  - You can implement your own sensitive detector classes, or use scorer classes provided by Geant4



Defining a sensitive detector

- Basic strategy in src/DetectorConstruction.cc


```
G4LogicalVolume* myLogCalor = ……;
G4VSensitiveDetector* pSensitivePart = new MyDetector("/mydet");
G4SDManager* SDMan = G4SDManager::GetSDMpointer();
SDMan->AddNewDetector(pSensitivePart);
myLogCalor->SetSensitiveDetector(pSensetivePart);
```

- Each detector object must have a unique name.
  - Different logical volumes can share one detector object.
  - More than one SD object can be made from the same SD class with different detector name.
  - One logical volume cannot have more than one detector objects. But, one detector object can generate more than one kinds of hits.
    - e.g. a double-sided silicon micro-strip detector can generate hits for each side separately.

Sensitive detector class

- A sensitive detector is a user-defined class that you need to derive from G4VSensitiveDetector

```
#include "G4VSensitiveDetector.hh"

class G4Step;

class MyDetector : public G4VSensitiveDetector
{
  public:
      MyDetector(G4String name);
      virtual ~MyDetector();

      virtual G4bool ProcessHits(G4Step*aStep, G4TouchableHistory*ROhist);

};
```

include

Base class

SD name in constructor

At each step

How to collect information

- At stepping time, Geant4 kernel checks for you that particle is in the sentitive detector
  - If yes, it gives you the control to G4VSensitiveDetector::ProcessHits()

- do what you want in ProcessHits() using hooks
  - See previous section on user hooks to collect information you need from step, track…

3) COMMAND-BASED SCORING

Command-based scoring

- Command-based scoring functionality offers built-in scoring mesh and various scorers for commonly-used physics quantities such as dose, flux, etc.

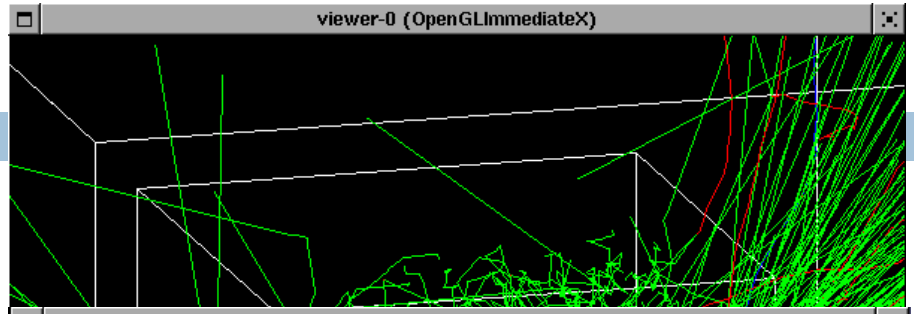
- To use this functionality, access to the G4ScoringManager pointer after the instantiation of G4RunManager in your main()

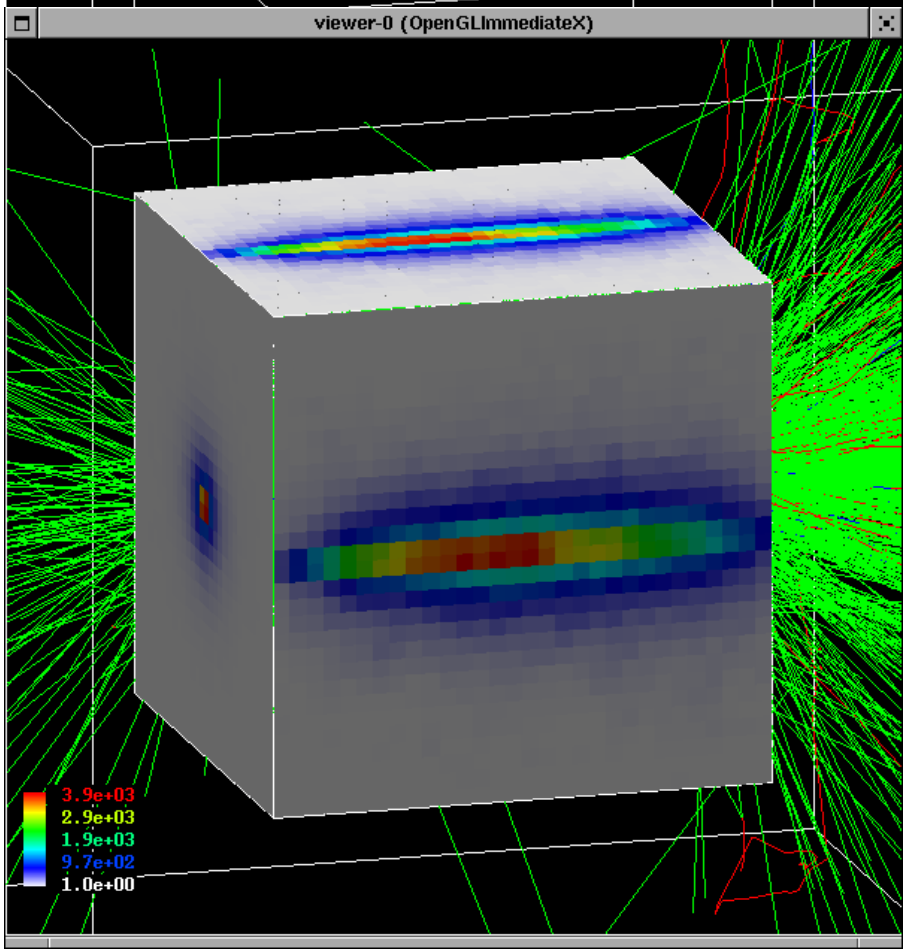
```
#include "G4ScoringManager.hh"
int main()
{
  G4RunManager* runManager = new G4RunManager;
  G4ScoringManager* scoringManager = G4ScoringManager::GetScoringManager();
   …
```

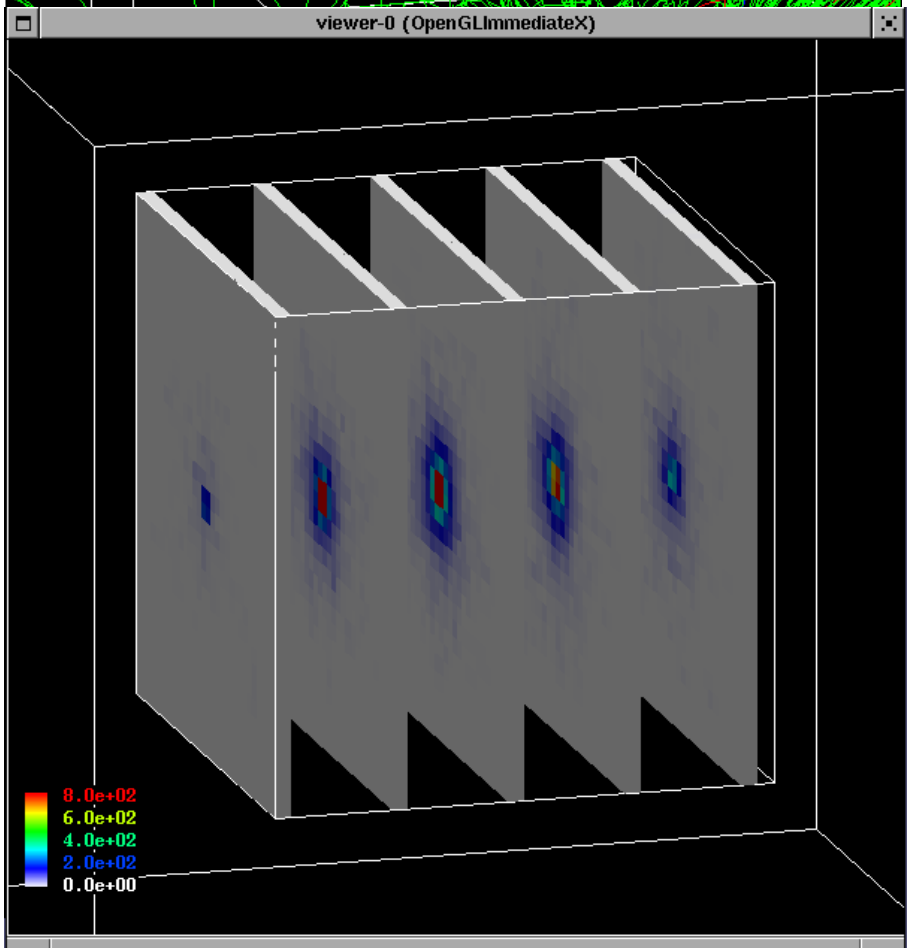
- All of the UI commands of this functionality is in /score/ directory.

- /examples/extended/runAndEvent/RE03

/example/extended/runAndEvent/RE03







Define a scoring mesh

- To define a scoring mesh, the user has to specify the followings
  - Shape and name of the 3D scoring mesh.
    - Box, cylindrical mesh
  - Size of the scoring mesh. Mesh size must be specified as "half width" similar to the arguments of G4Box.
  - Number of bins for each axes. Note that too many bins causes immense memory consumption.
  - Optionally, position and rotation of the mesh. If not specified, the mesh is positioned at the center of the world volume without rotation.

```
# define scoring mesh
/score/create/boxMesh boxMesh_1
/score/mesh/boxSize 100. 100. 100. cm
/score/mesh/nBin 30 30 30
```

- The mesh geometry can be completely independent from the real material geometry

Scoring quantities

- A mesh may have arbitrary number of scorers. Each scorer scores one physics quantity (xxxxx).
  - energyDeposit * Energy deposit scorer.
  - cellCharge * Cell charge scorer.
  - cellFlux * Cell flux scorer.
  - passageCellFlux * Passage cell flux scorer
  - doseDeposit * Dose deposit scorer.
  - nOfStep * Number of step scorer.
  - nOfSecondary * Number of secondary scorer.
  - trackLength * Track length scorer.
  - passageCellCurrent * Passage cell current scorer.
  - passageTrackLength * Passage track length scorer.
  - flatSurfaceCurrent * Flat surface current Scorer.
  - flatSurfaceFlux * Flat surface flux scorer.
  - nOfCollision * Number of collision scorer.
  - population * Population scorer.
  - nOfTrack * Number of track scorer.
  - nOfTerminatedTrack * Number of terminated tracks scorer.

```
/score/quantity/xxxxx <scorer_name>
```

Filter

- Each scorer may take a filter
  - charged * Charged particle filter.
  - neutral * Neutral particle filter.
  - kineticEnergy * Kinetic energy filter.

    `/score/filter/kineticEnergy <fname> <eLow> <eHigh> <unit>`
  - particle * Particle filter.

    `/score/filter/particle <fname> <p1> … <pn>`
  - particleWithKineticEnergy * Particle with kinetic energy filter.

```
/score/quantity/energyDeposit   eDep
/score/quantity/nOfStep   nOfStepGamma
/score/filter/particle   gammaFilter   gamma
/score/quantity/nOfStep   nOfStepEMinus
/score/filter/particle   eMinusFilter   e-
/score/quantity/nOfStep   nOfStepEPlus
/score/filter/particle   ePlusFilter   e+
/score/close
```

Same primitive scorers with different filters may be defined.

Close the mesh when defining scorers is done.

Drawing a score

- Projection

  `/score/drawProjection <mesh_name> <scorer_name> <color_map>`

- Slice

  `/score/drawColumn <mesh_name> <scorer_name> <plane> <column> <color_map>`

- Color map
  - By default, linear and log-scale color maps are available.
  - Minimum and maximum values can be defined by `/score/colorMap/setMinMax` command. Otherwise, min and max values are taken from the current score.

Write scores to a file

- Single score

  `/score/dumpQuantityToFile <mesh_name> <scorer_name> <file_name>`

- All scores

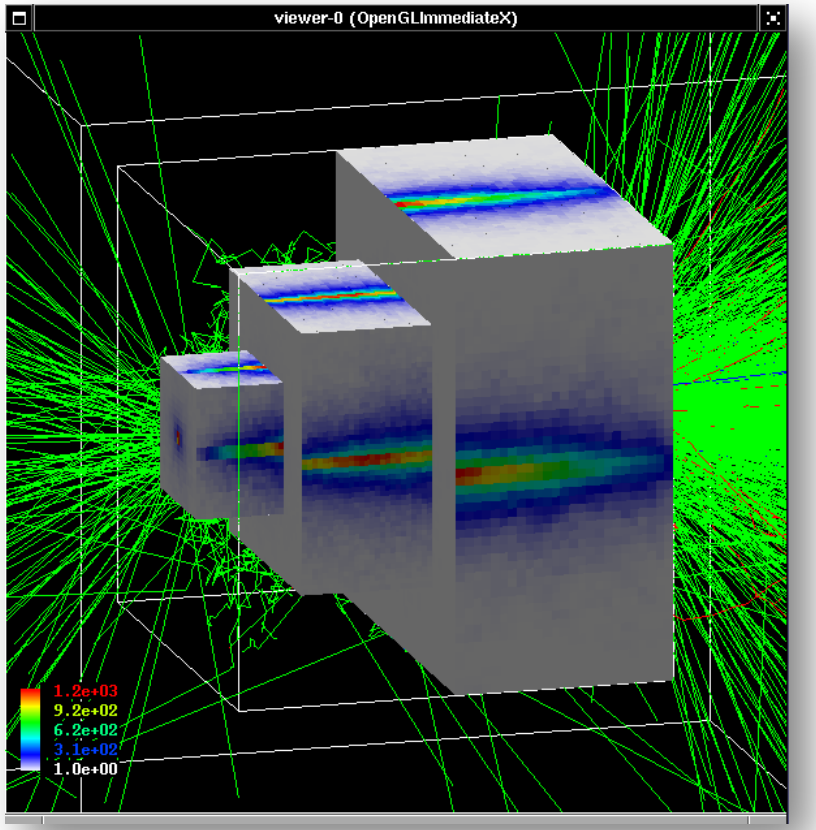
  `/score/dumpAllQuantitiesToFile <mesh_name> <file_name>`

- By default, values are written in CSV.

- By creating a concrete class derived from G4VScoreWriter base class, the user can define his own file format.
  - Example in /examples/extended/runAndEvent/RE03
  - User's score writer class should be registered to G4ScoringManager.

More than one scoring mesh

- You may define more than one scoring mesh.
  - And, you may define arbitrary number of primitive scorers to each scoring mesh.
- Mesh volumes may overlap with other meshes and/or with mass geometry.
- A step is limited on any boundary.
- Please be cautious of too many meshes, too granular meshes and/or too many primitive scorers.
  - Memory consumption
  - Computing speed



Summary

- Geant4 already equipped for scoring

- Several methods
  - Use of user hooks at different stages (step, track, event, run,…)
    - Methods for the retrieval of Physics quantities
  - Sensitive detectors & hit collections
  - Built-in commands for scoring
    - A rich variety of physics quantities