

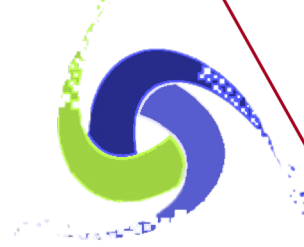
**GEANT4**  
A SIMULATION TOOLKIT

Version 10.5

# Scoring I

Makoto Asai (SLAC)  
Geant4 Tutorial Course

- Introduction to sensitivity
- Command-based scoring
- Add a new scorer/filter



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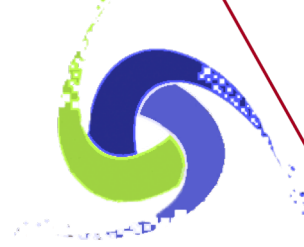
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## Retrieving information from Geant4

- Given geometry, physics and primary track generation, Geant4 does proper physics simulation “silently”.
  - You have to do something to **extract information useful to you.**
- There are three ways:
  - Built-in scoring commands
    - Most commonly-used physics quantities are available.
  - Use scorers in the tracking volume
    - Create scores for each event
    - Create own Run class to accumulate scores
  - Assign **G4VSensitiveDetector** to a volume to generate “hit”.
    - Use user hooks (G4UserEventAction, G4UserRunAction) to get event / run summary
- You may also use user hooks (G4UserTrackingAction, G4UserSteppingAction, etc.)
  - You have full access to almost all information
  - Straight-forward, but do-it-yourself



**This talk**



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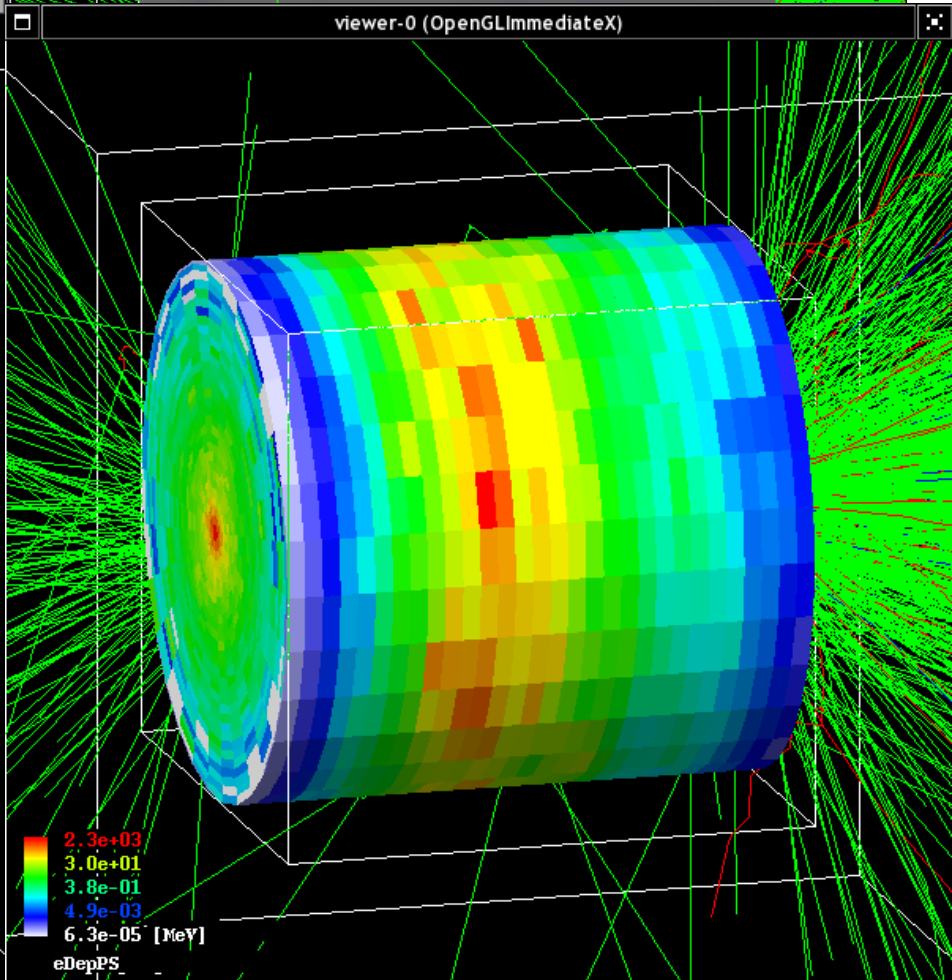
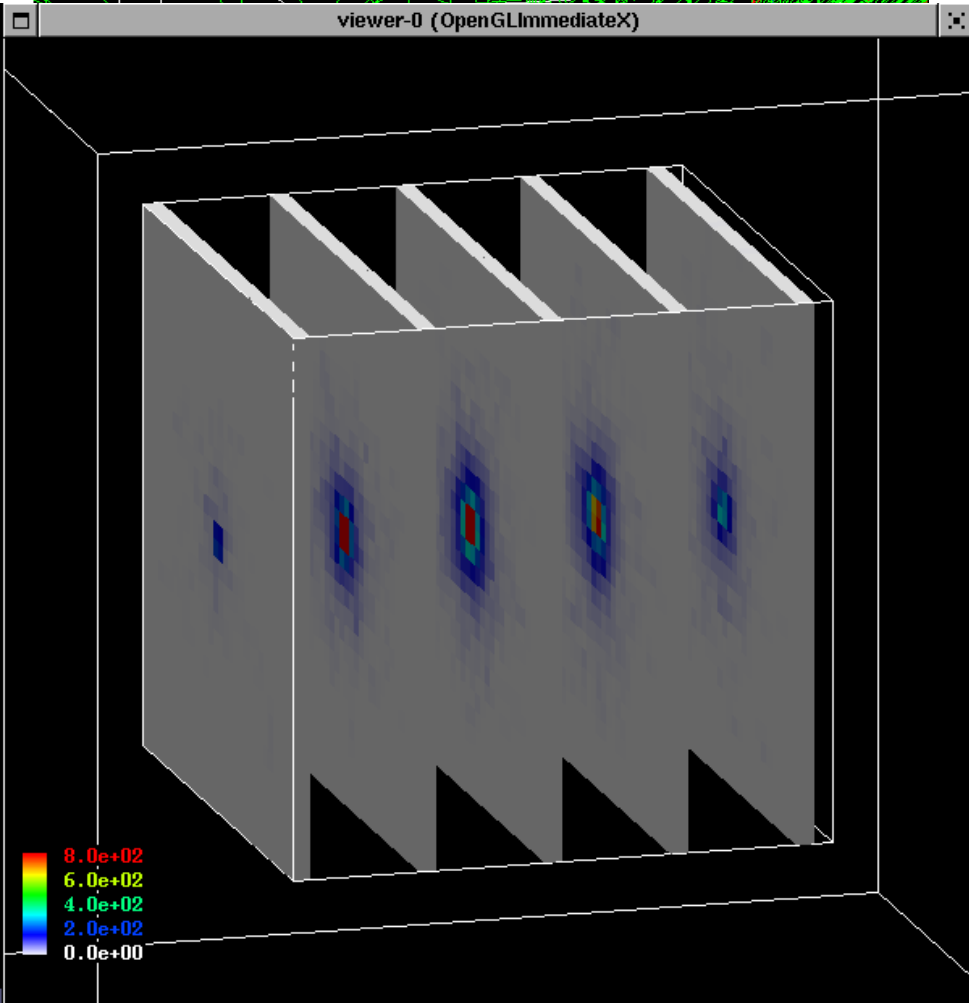
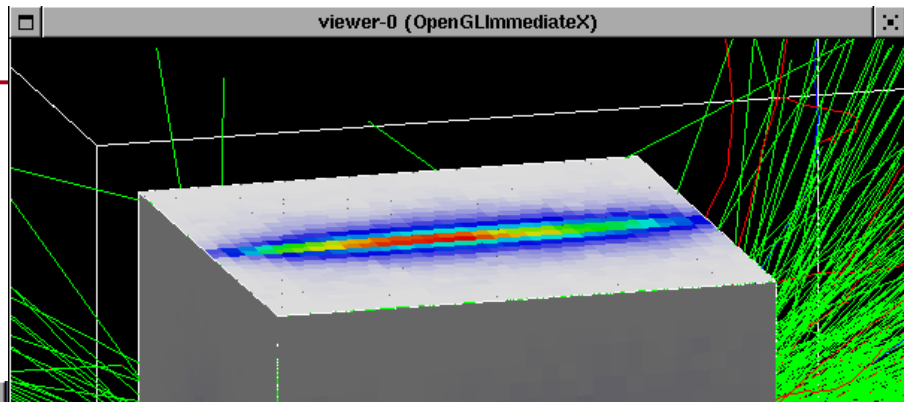
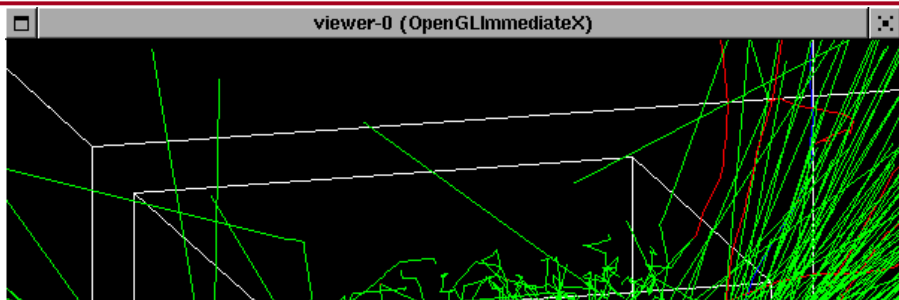
Command-based scoring

- Command-based scoring functionality offers the built-in scoring mesh and various scorers for commonly-used physics quantities such as dose, flux, etc.
  - Due to small performance overhead, it does not come by default.
- To use this functionality, access to the G4ScoringManager pointer after the instantiation of G4(MT)RunManager in your *main()*.

```
#include "G4ScoringManager.hh"
int main()
{
    G4RunManager* runManager = new G4MTRunManager;
    G4ScoringManager* scoringManager =
        G4ScoringManager::GetScoringManager();
    ...
}
```

- All of the UI commands of this functionality are in /score/ directory.
- /examples/extended/runAndEvent/RE03

# Command-based scorers



# Define a scoring mesh



- To define a scoring mesh, the user has to specify the followings.
  1. **Shape and name** of the 3D scoring mesh.
    - Currently, box and cylinder are available.
  2. Size of the scoring mesh.
    - Mesh size must be specified as "**half width**" similar to the arguments of G4Box / G4Tubs.
  3. **Number of bins** for each axes.
    - Note that too many bins causes immense memory consumption.
  4. Specify 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
/score/mesh/translate/xyz 0. 0. 100. cm
```

- The mesh geometry can be completely independent to the real material geometry.



# Scoring quantities

- A mesh may have arbitrary number of scorers. Each scorer scores one physics quantity.
  - 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.

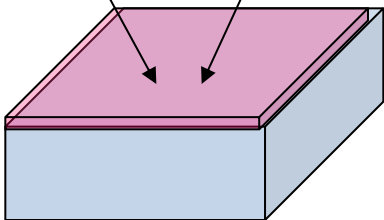
**/score/quantity/xxxxx <scorer\_name> <unit>**

# List of provided primitive scorers

- Concrete Primitive Scorers ( See Application Developers Guide 4.4.6 )
  - Track length
    - G4PSTrackLength, G4PSPassageTrackLength
  - Deposited energy
    - G4PSEnergyDeposit, G4PSDoseDeposit, G4PSChargeDeposit
  - Current/Flux
    - G4PSFlatSurfaceCurrent, G4PSSphereSurfaceCurrent, G4PSPassageCurrent, G4PSFlatSurfaceFlux, G4PSCellFlux, G4PSPassageCellFlux
  - Others
    - G4PSMinKinEAtGeneration, G4PSNofSecondary, G4PSNofStep

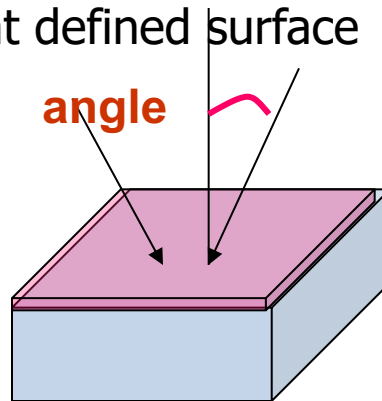
## SurfaceCurrent :

Count number of injecting particles at defined surface.



## SurfaceFlux :

Sum up  $1/\cos(\text{angle})$  of injecting particles at defined surface

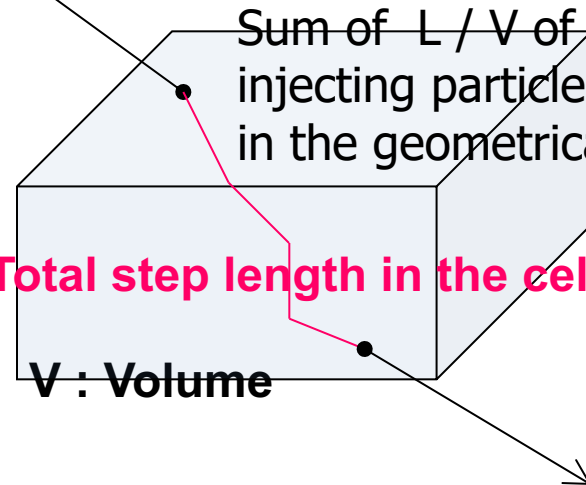


## CellFlux :

Sum of  $L / V$  of injecting particles in the geometrical cell.

**L : Total step length in the cell.**

**V : Volume**



- 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/filter/ParticleWithKineticEnergy  
<fname> <eLow> <eHigh> <unit> <p1> ... <pn>`

`/score/quantity/energyDeposit eDep MeV`

`/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`



**Close the mesh when defining scorers is done.**

**Same primitive scorers  
with different filters  
may be defined.**

- 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.

- 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.

- One of most frequently asked questions is “How to get energy spectrum?”.
- Create arbitrary number of flux scorers of same kind combined with particle and kinetic energy filters.

```
/score/quantity/flatSurfaceFlux flux0
```

```
/score/filter/particleWithKineticEnergy range0 10. 20. MeV e-
```

```
/score/quantity/flatSurfaceFlux flux1
```

```
/score/filter/particleWithKineticEnergy range1 20. 30. MeV e-
```

```
/score/quantity/flatSurfaceFlux flux2
```

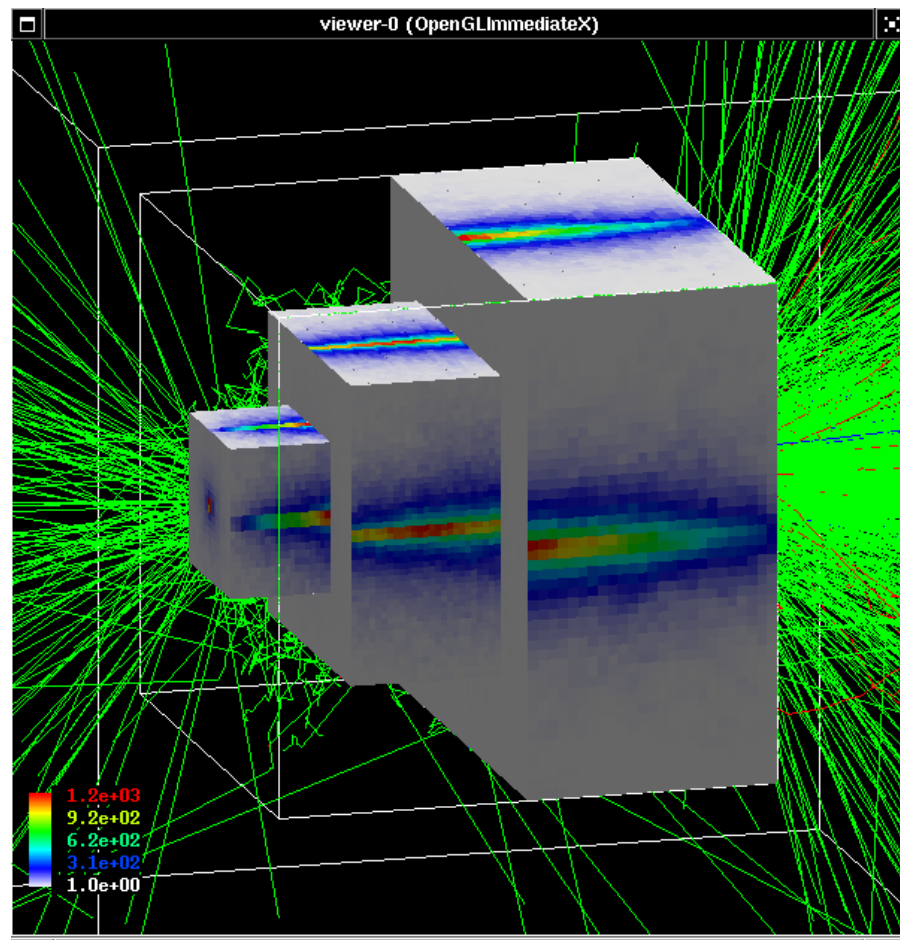
```
/score/filter/particleWithKineticEnergy range2 30. 40. MeV e-
```

```
/score/quantity/flatSurfaceFlux flux3
```

```
/score/filter/particleWithKineticEnergy range3 40. 50. MeV e-
```

# More than one scoring meshes

- 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





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Add a new scorer/filter to command-based scorers



- G4VPrimitiveScorer is the abstract base of all scorer classes.
- To make your own scorer you have to implement at least:
  - Constructor
  - Initialize()
    - Initialize G4THitsMap<G4double> map object
  - ProcessHits()
    - Get the physics quantity you want from G4Step, etc. and fill the map
  - Clear()
  - GetIndex()
    - Convert **three copy numbers** into an index of the map
- G4PSEnergyDeposit3D could be a good example.
- Create your own messenger class to define /score/quantity/<your\_quantity> command.
  - Refer to G4ScorerQuantityMessengerQCmd class.

# Creating your own scorer

- Though we provide most commonly-used scorers, you may want to create your own.
  - If you believe your requirement is quite common, just let us know, so that we will add a new scorer.

- G4VPrimitiveScorer is the abstract base class.

```
class G4VPrimitiveScorer
{
public:
    G4VPrimitiveScorer(G4String name, G4int depth=0);
    virtual ~G4VPrimitiveScorer();
protected:
    virtual G4bool ProcessHits(G4Step*,
                               G4TouchableHistory*) = 0;
    virtual G4int GetIndex(G4Step*);
public:
    virtual void Initialize(G4HCofThisEvent*);
    virtual void EndOfEvent(G4HCofThisEvent*);
    virtual void clear();
    ...
};
```

- Methods written in red will be discussed at “Scoring 2” talk.

- G4VSDFilter
    - Abstract base class which you can use to make your own filter
- ```
class G4VSDFilter
{
    public:
        G4VSDFilter(G4String name);
        virtual ~G4VSDFilter();
    public:
        virtual G4bool Accept(const G4Step*) const = 0;
    ...
}
```
- Create your own messenger class to define /score/filter/<your\_filter> command.
    - Refer to G4ScorerQuantityMessenger class.