Scoring I

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Geant4 Tutorial Course

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- Retrieving information from Geant4
- Command-based scoring
  - Mesh scorer
  - Scorer in real world volume
  - Probe scorer

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Extract useful information

- 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

This talk

- You may also use user hooks (G4UserTrackingAction, G4UserSteppingAction, etc.)
  - You have full access to almost all information
  - Straight-forward, but do-it-yourself

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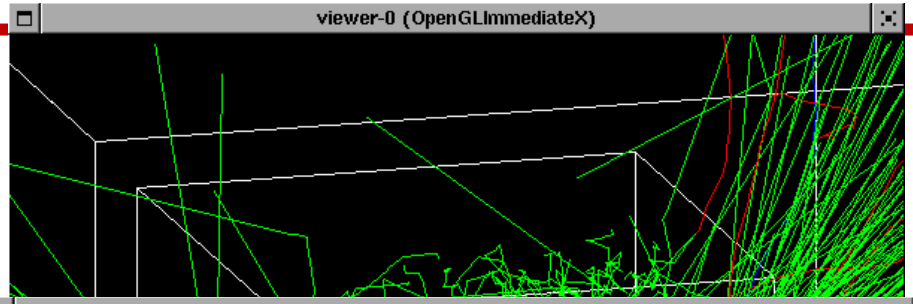
Command-based scoring

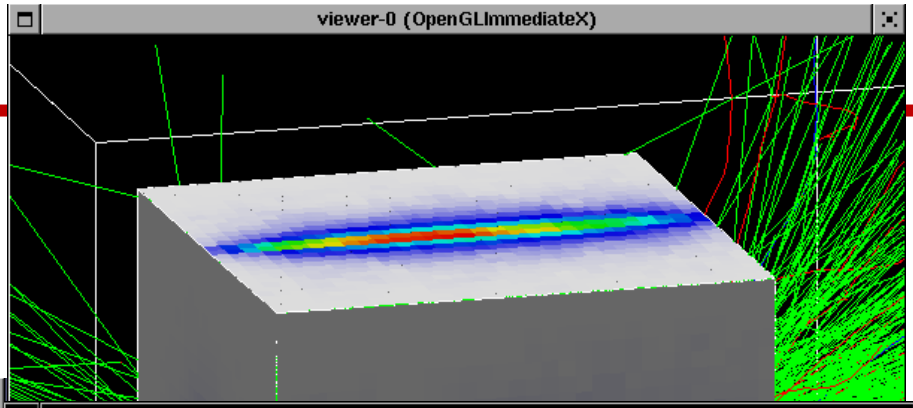
- Command-based scoring functionality offers the various built-in scorers for commonly-used physics quantities such as dose, flux, etc.
  - Due to small performance overhead, it does not come by default.
- To use this functionality, access to the G4ScoringManager pointer after the instantiation of G4(MT)RunManager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

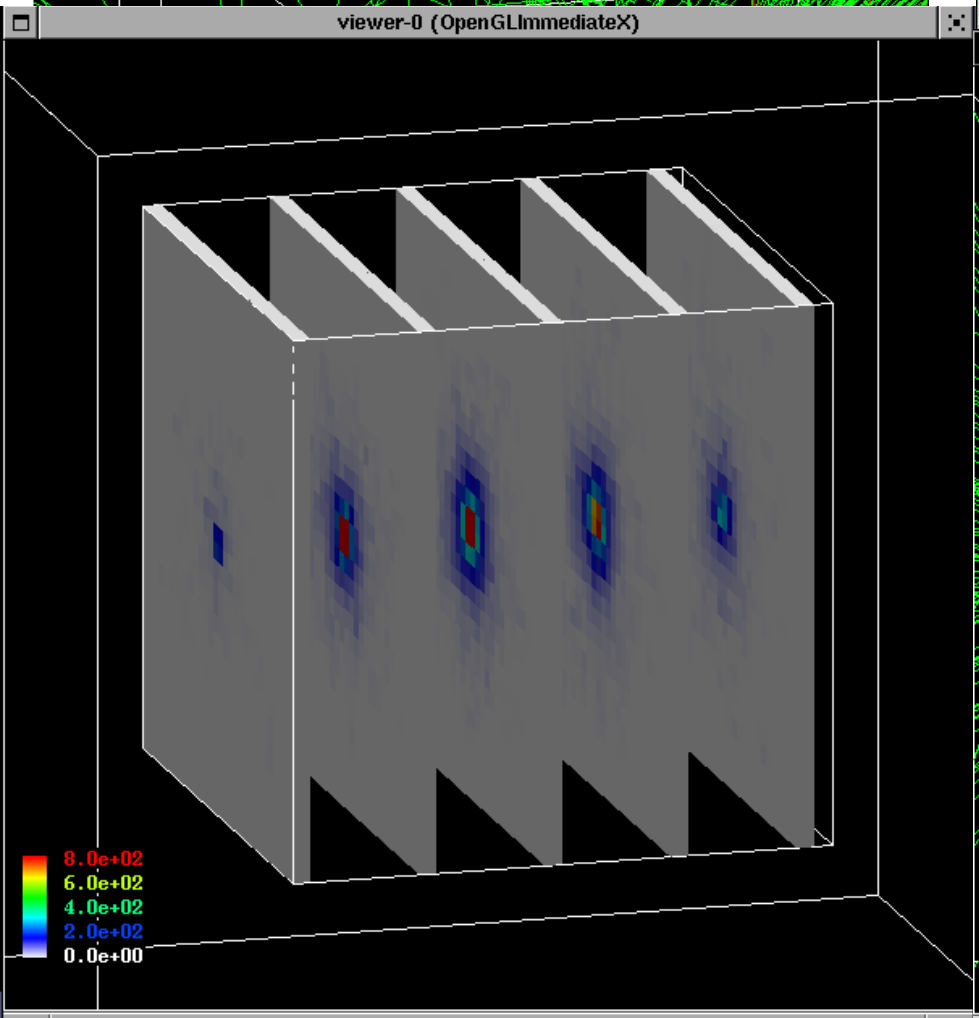
```
#include "G4ScoringManager.hh"
int main()
{
  G4RunManager* runManager = new G4MTRunManager;
  G4ScoringManager* scoringManager =
                              G4ScoringManager::GetScoringManager();
  …
```

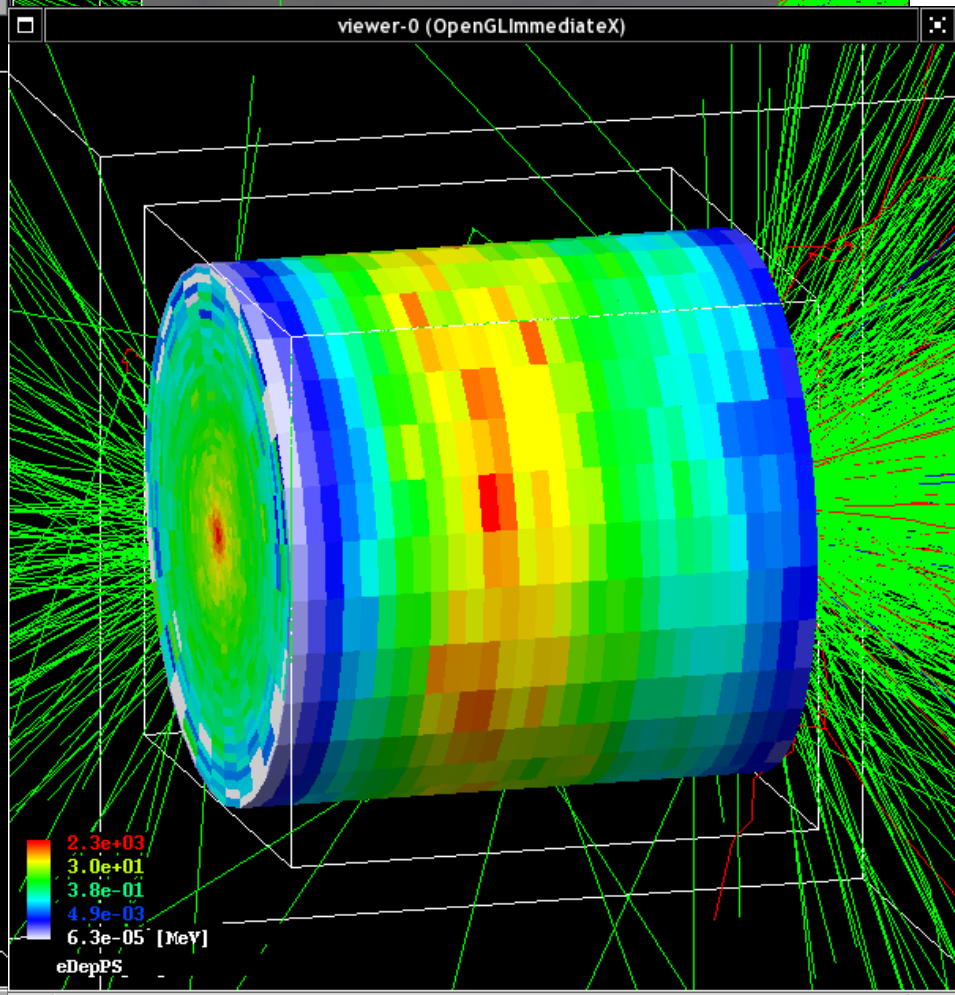
- All of the UI commands of this functionality are in /score/ directory.
- /examples/extended/runAndEvent/RE03 and /examples/advanced/gorad are good examples

extended/runAndEvent/RE03









Three types of command-based scorers

1) Scoring mesh
   - Define 3-D mesh (box or cylinder)
   - The mesh may overlap with real-world volumes
   - Assign arbitrary number of primitive scorers to mesh cell
2) Assigning scorers to a real-world logical volume
   - Declare a real-world logical volume as a detector
   - Assign arbitrary number of primitive scorers to the detector
   - If the volume is placed more than once, assigned scorers individually score for each physical volume
3) Scoring probe
   - A probe is a small cube that is located at arbitrary position. It may overlap with real-world volumes.
   - Assign arbitrary number of primitive scorers to the probe
   - If probe is placed more than once, assigned scorers individually score for each probe.

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. It may overlap with any volumes in the real-world volumes.
  - Must be fully contained inside the world volume.

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>

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/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+

Same primitive scorers with different filters may be defined.

/score/close ← 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>

- Available only for box or cylindrical mesh.

- 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>

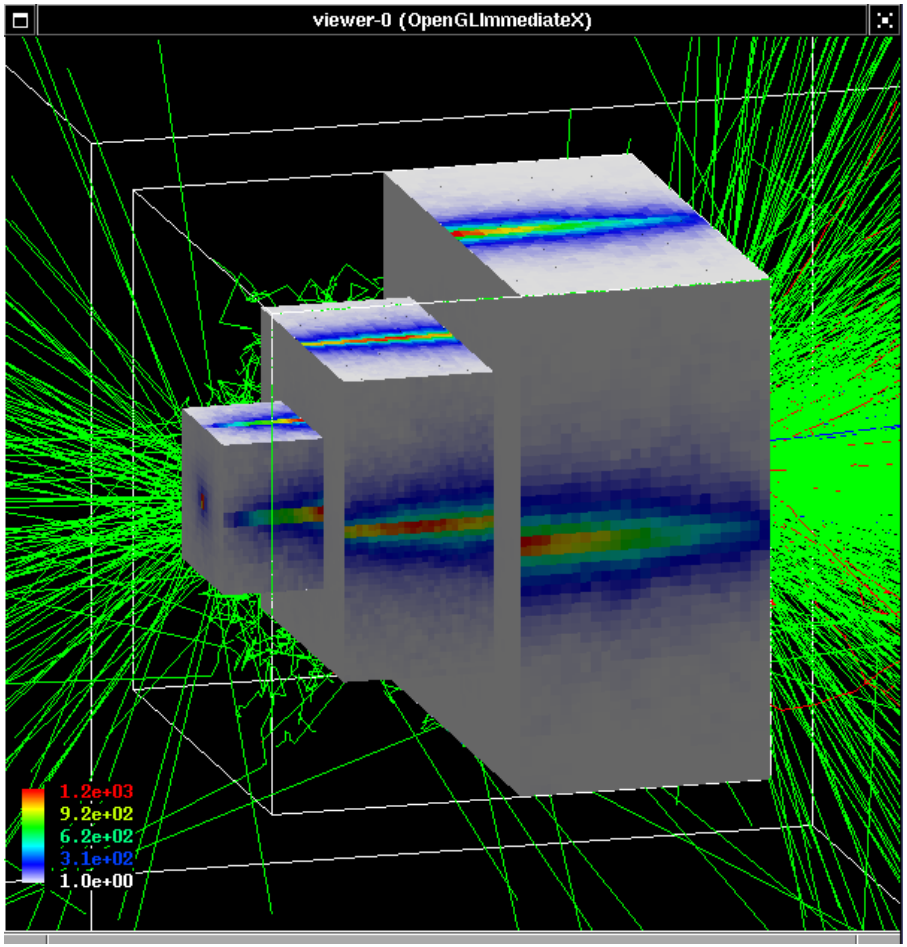
- All scores

  /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 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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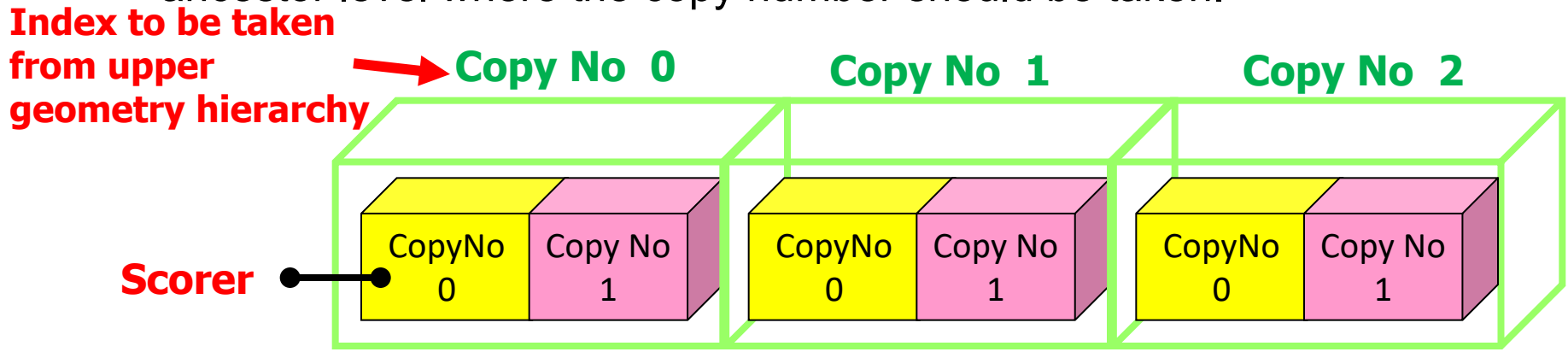
Define scorer to a tracking volume

- Define a scorer to a logical volume.

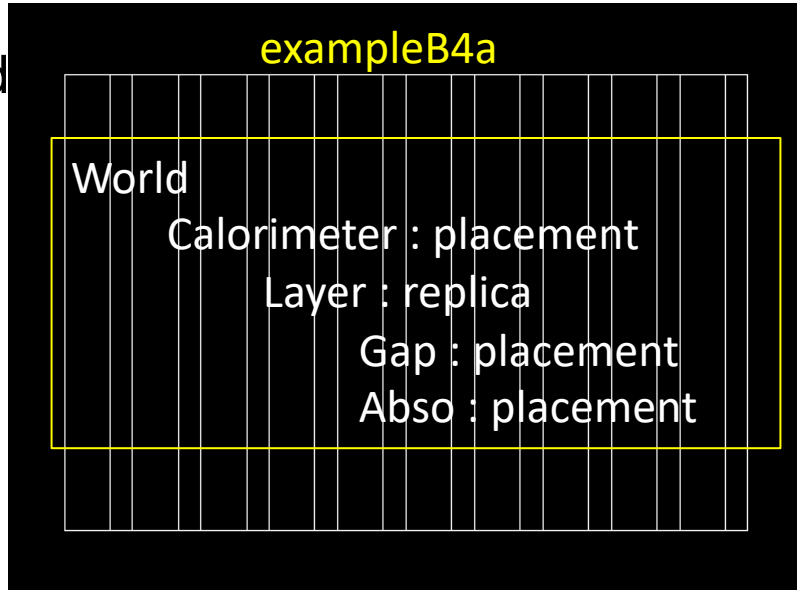
  `/score/create/realWorldLogVol <LV_name> <anc_lvl>`

- One can define arbitrary scoring quantities and filters.
  - Same recipe as scoring mesh.
  - Scores are automatically merged other worker threads and written to a file.
  - Drawing is not yet supported.
- All physical volumes that share the same *<LV_name>* have the same primitive scorers but score separately.
  - Copy number of the physical volume is the index.
  - If the physical volume is placed only once, but its (grand-)mother volume is replicated, use the *<anc_lvl>* parameter to indicate the ancestor level where the copy number should be taken.



Command-based real-world scorer

- Do not use this /score/create/realWorldLogVol command to a mother logical volume.
  - For example of this exampleB4, “Layer” is fully filled with ”Gap” and “Abso” daughter volumes. You won’t see any energy deposition in “Layer” volume.




```
/score/create/realWorldLogVol Gap 1
/score/quantity/energyDeposit eDep MeV
/score/quantity/trackLength sLen mm
/score/filter/charged cFilter
/score/create/realWorldLogVol Abso 1
/score/quantity/energyDeposit eDep MeV
/score/quantity/trackLength sLen mm
/score/filter/charged cFilter
/score/close
```

If this is not set, given “Gap” and “Abso” are placed with copy number 0, energy deposition and track length are accumulated for all layers.

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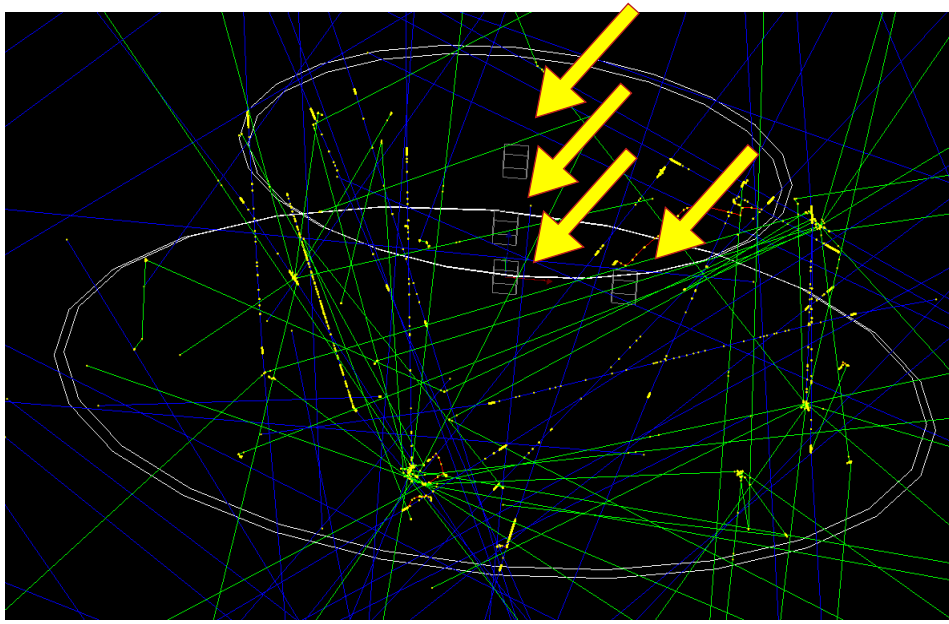
Command-based probe scorer

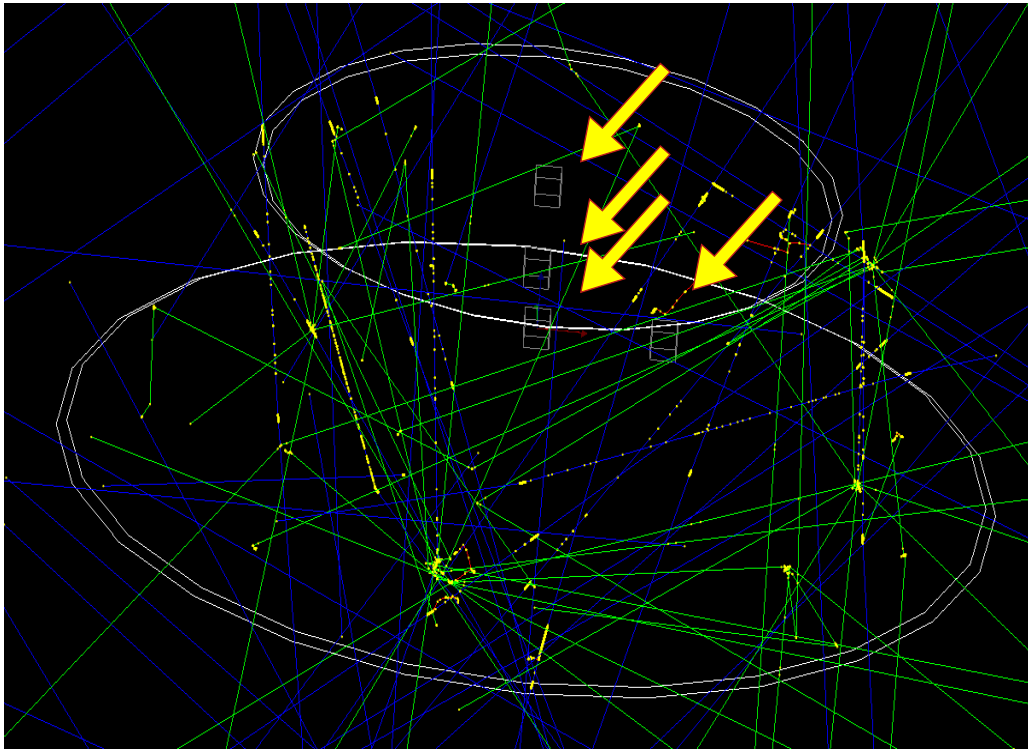
- User may locate scoring “probes” at arbitrary locations. A “probe” is a virtual cube, to which any Geant4 primitive scorers could be assigned.
- Given these probes are located in an artificial “parallel world”, probes may overlap to the volumes defined in the mass geometry.
- If probes are located more than once, all probes have the same scorers but score individually.



- In addition, the user may optionally set a material to the probe. Once a material is set to the probe, it overwrites the material(s) defined in the mass geometry when a track enters the probe cube.
  - Because of this overwriting, physics quantities that depend on material or density, e.g. energy deposition or dose, would be measured accordingly to the specified material
- Once a probe is defined, user can associate arbitrary number of primitive scorers and filters like the conventional scoring mesh.
- All probes have the same scorers but score individually.

Scoring probe

```
/score/create/probe Probes 5. cm
/score/probe/material G4_WATER
/score/probe/locate 0. 0. 0. cm
/score/probe/locate 25. 0. 0. cm
/score/probe/locate 0. 25. 0. cm
/score/probe/locate 0. 0. 25. cm
/score/quantity/energyDeposit eDep MeV
/score/quantity/doseDeposit dose mGy
/score/quantity/volumeFlux volFlx
/score/quantity/volumeFlux protonFlux
/score/filter/particle protonFilter proton
/score/close
```



Note: To visualize the probes defined in a parallel world, the following command is required.

```
/vis/drawVolume worlds
```

1-D histogram directly filled by a primitive scorer

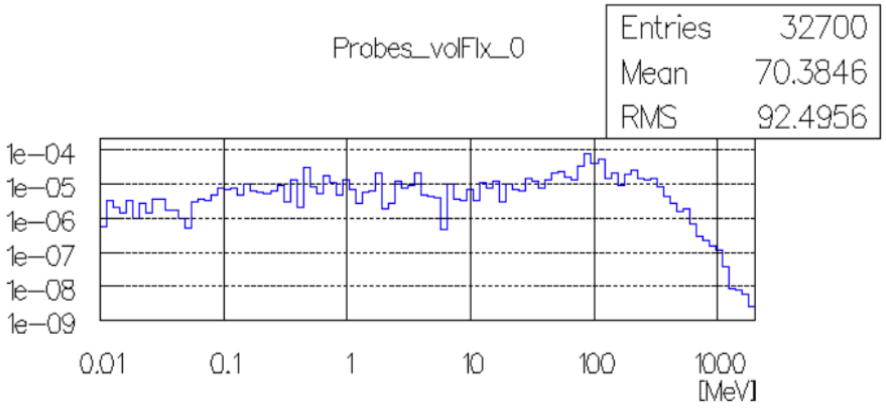
- Through a newly introduced interface class (G4TScoreHistFiller) a primitive scorer can directly fill a 1-D histogram defined by G4Analysis.
  - Track-by-track or step-by-step filling allows command-based histogram such as energy spectrum.
- G4TScoreHistFiller template class must be instantiated in the user's code with his/her choice of analysis data format.

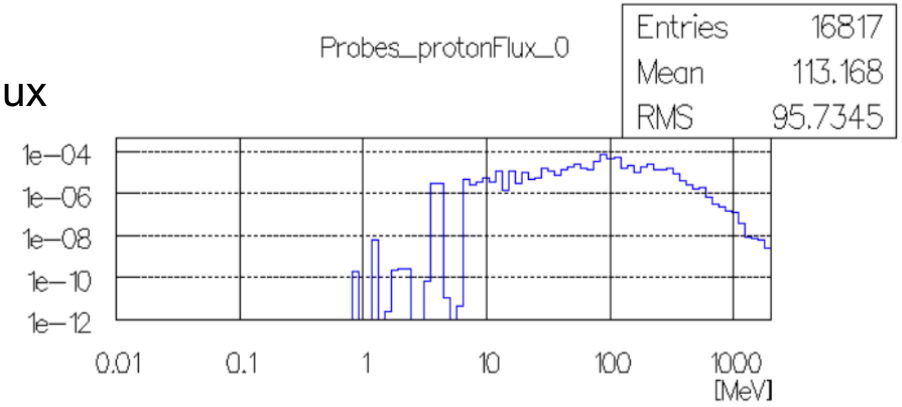
```
#include "G4AnalysisManager.hh"
#include "G4TScoreHistFiller.hh"
auto analysisManager = G4AnalysisManager::Instance();
analysisManager->SetDefaultFileType("root");
auto histFiller = new G4TScoreHistFiller<G4AnalysisManager>;
```

- Primitive scorer must be defined in advance to setting a histogram.
- Histogram must be defined through /analysis/h1/create command in advance to setting it to a primitive scorer.
- This functionality is available only for primitive scorers defined in real-world scorer or probe scorer.
  - Not available for box or cylindrical mesh scorer due to memory consumption concern.

1-D histogram directly filled by a primitive scorer

```
/score/create/probe Probes 5. cm
/score/probe/locate 0. 0. 0. cm
/score/quantity/volumeFlux volFlux
/score/quantity/volumeFlux protonFlux
/score/filter/particle protonFilter proton
/score/close
/analysis/h1/create volFlux Probes_volFlux
                    100 0.01 2000. MeV ! log
/score/fill1D 1 Probes volFlux
/analysis/h1/create protonFlux Probes_protonFlux
                    100 0.01 2000. MeV ! log
/score/fill1D 2 Probes protonFlux
```





N.B. If probe is placed more than once, *fill1D* command should be called to each *copyNo.*

```
/score/fill1D 1 Probes volFlux 0
```