Scoring I

Makoto Asai (SLAC)

Geant4 Tutorial Course

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- Retrieving information from Geant4
- Command-based scoring
- Add a new scorer/filter to command-based scoring
- Define scorers in the tracking volume
- Accumulate scores for a run

Retrieving information from Geant4

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 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

This talk

  - 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

Command-based scoring

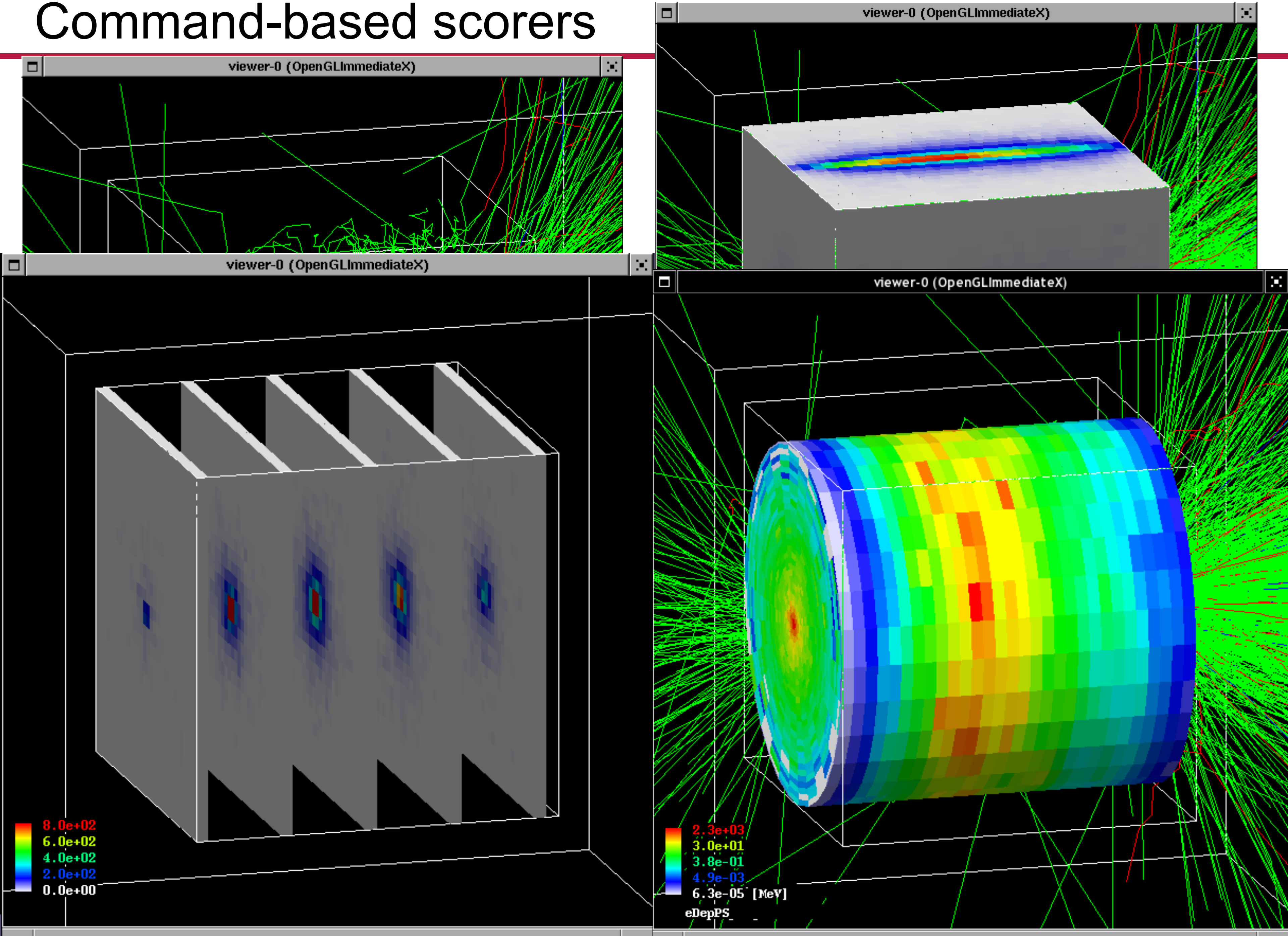
Command-based scoring

- 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 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 are in /score/ directory.
- /examples/extended/runAndEvent/RE03

Command-based scorers


viewer-0 (OpenGLImmediateX)
viewer-0 (OpenGLImmediateX)
viewer-0 (OpenGLImmediateX)
8.0e+02
6.0e+02
4.0e+02
2.0e+02
0.0e+00
viewer-0 (OpenGLImmediateX)
2.3e+03
3.0e+01
3.8e-01
4.9e-03
6.3e-05 [MeV]
eDepPS

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. 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 to the real material geometry.

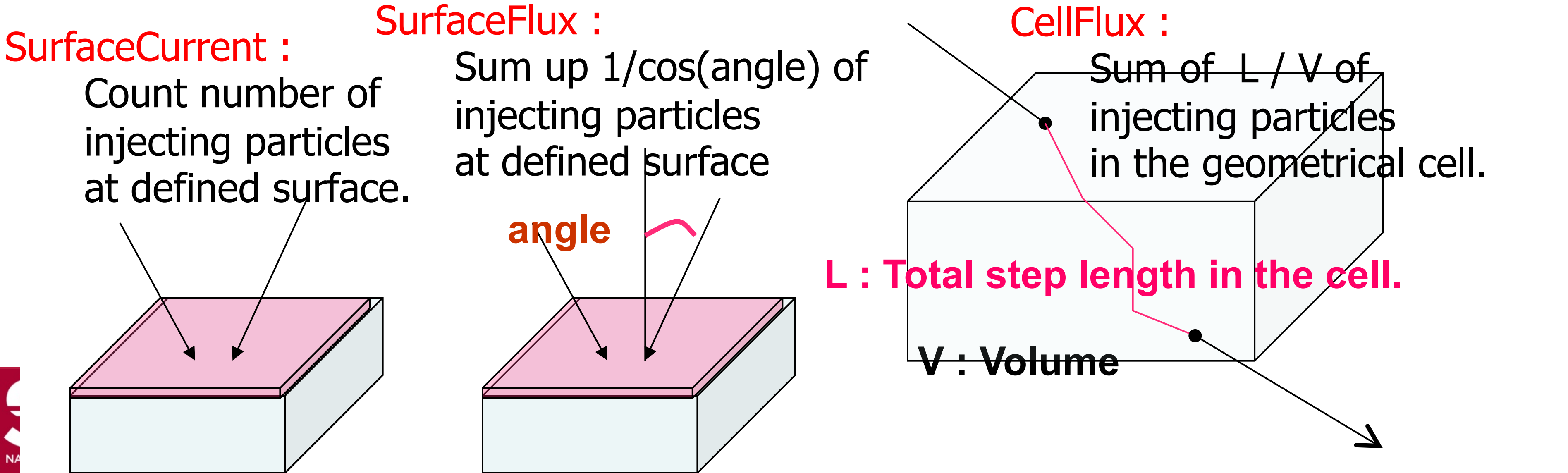
Scoring quantities

- 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/quantitly/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
    - G4PSEnergyDepsit, 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(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

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  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
```

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

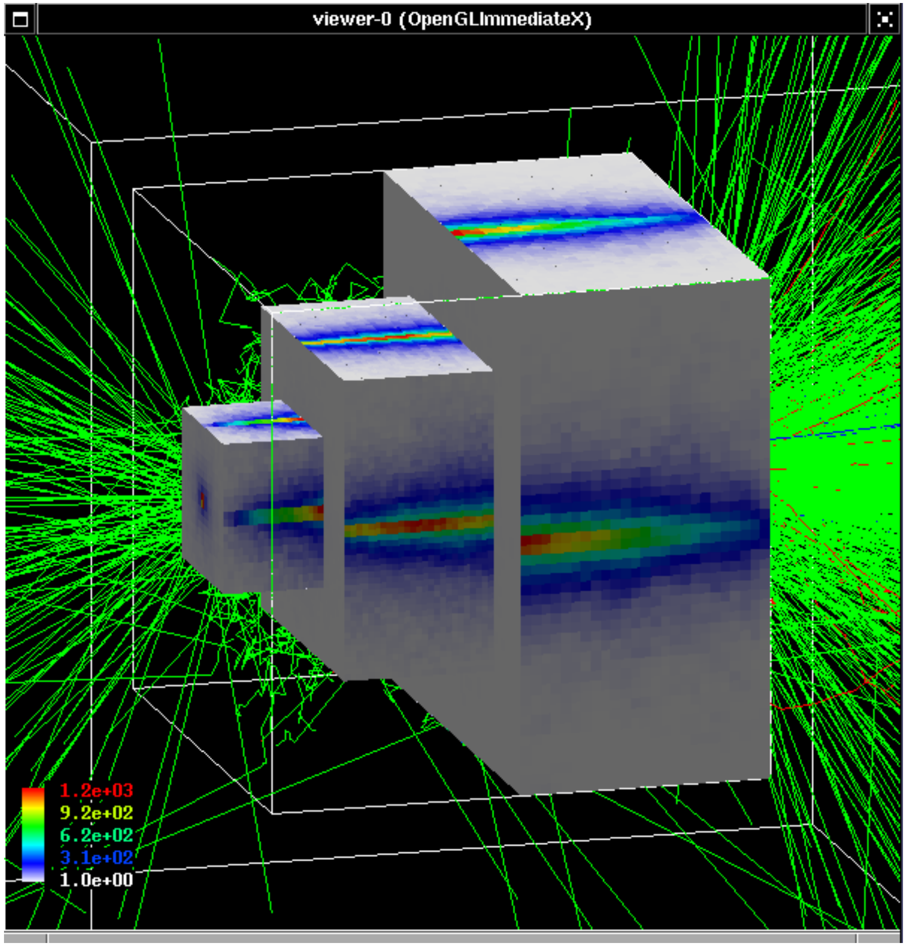
  /score/dumpQuantityToFile <mesh_name> <scorer_name> <file_name>
- All scores

  /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 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



Add a new scorer/filter to command-based scorers

Scorer base class

- 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.

Filter class

- 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.

Define scorers to the tracking volume

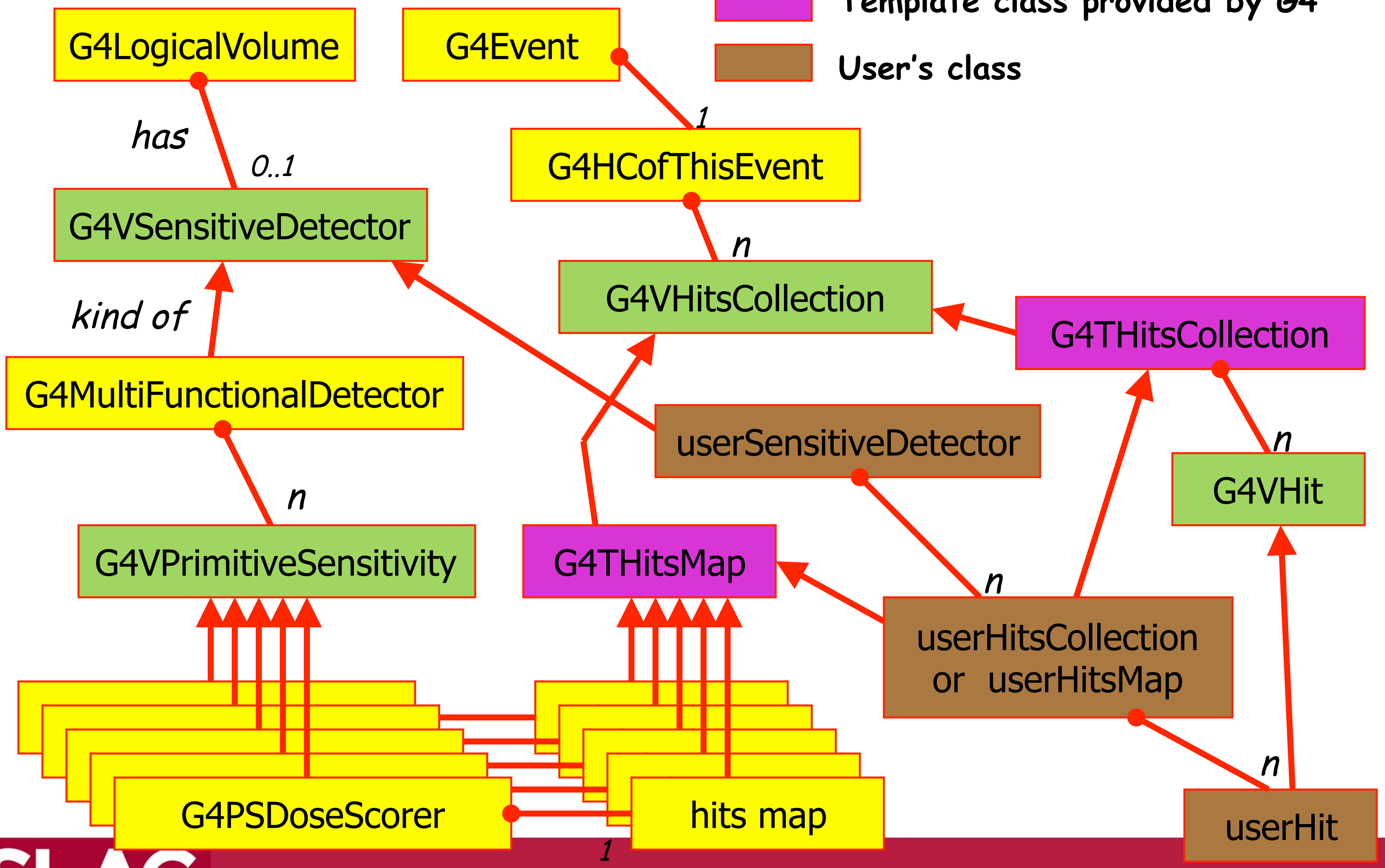
Class diagram

🟨 Concrete class provided by G4

🟩 Abstract base class provided by G4

🟪 Template class provided by G4

🟫 User's class



example

```
MyDetectorConstruction::Construct()
{ …  G4LogicalVolume* myCellLog =  new G4LogicalVolume(…);
     G4VPhysicalVolume* myCellPhys = new G4PVParametrised(…);
     G4MultiFunctionalDetector* myScorer =
        new G4MultiFunctionalDetector(“myCellScorer”);
     G4SDManager::GetSDMpointer()->AddNewDetector(myScorer);
     myCellLog->SetSensitiveDetector(myScorer);
     G4VPrimitiveSensitivity* totalSurfFlux = new
        G4PSFlatSurfaceFlux(“TotalSurfFlux”, fCurrent_In, “percm2”);
     myScorer->Register(totalSurfFlux);
     G4VPrimitiveSensitivity* totalDose = new G4PSDoseDeposit(“TotalDose”);
     myScorer->Register(totalDose);
}
```

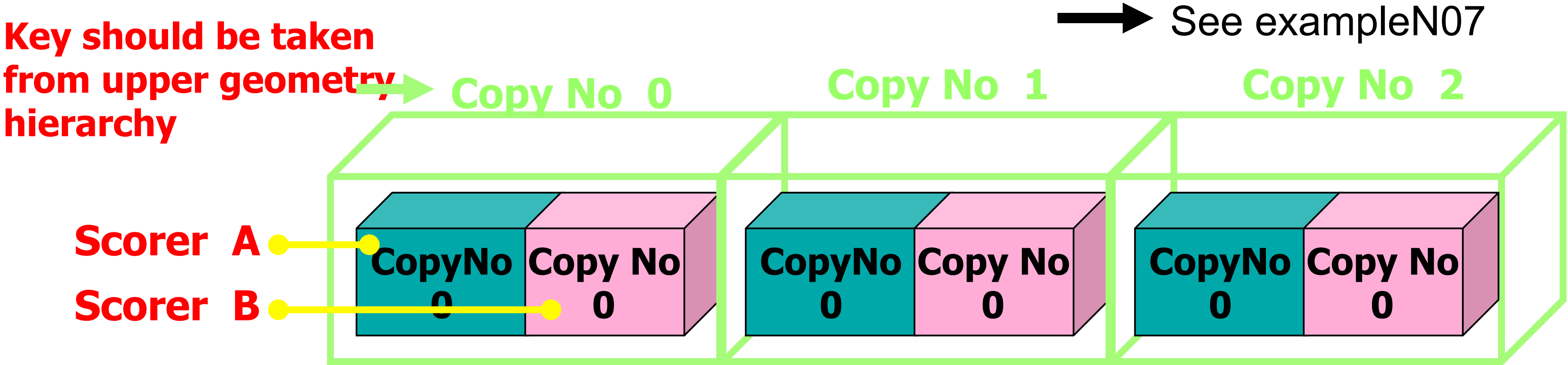
You may register arbitrary number of primitive scorers.

Keys of G4THitsMap

- All provided primitive scorer classes use G4THitsMap<G4double>.
- By default, the copy number is taken from the physical volume to which G4MultiFunctionalDetector is assigned.
  - If the physical volume is placed only once, but its (grand-)mother volume is replicated, use the second argument of the constructor of the primitive scorer to indicate the level where the copy number should be taken.

    e.g. G4PSCellFlux(G4Steing name, G4String& unit, G4int depth=0)

    → See exampleN07



Key should be taken from upper geometry hierarchy

  - If your indexing scheme is more complicated (e.g. utilizing copy numbers of more than one hierarchies), you can override the virtual method GetIndex() provided for all the primitive scorers.

Creating your own scorer

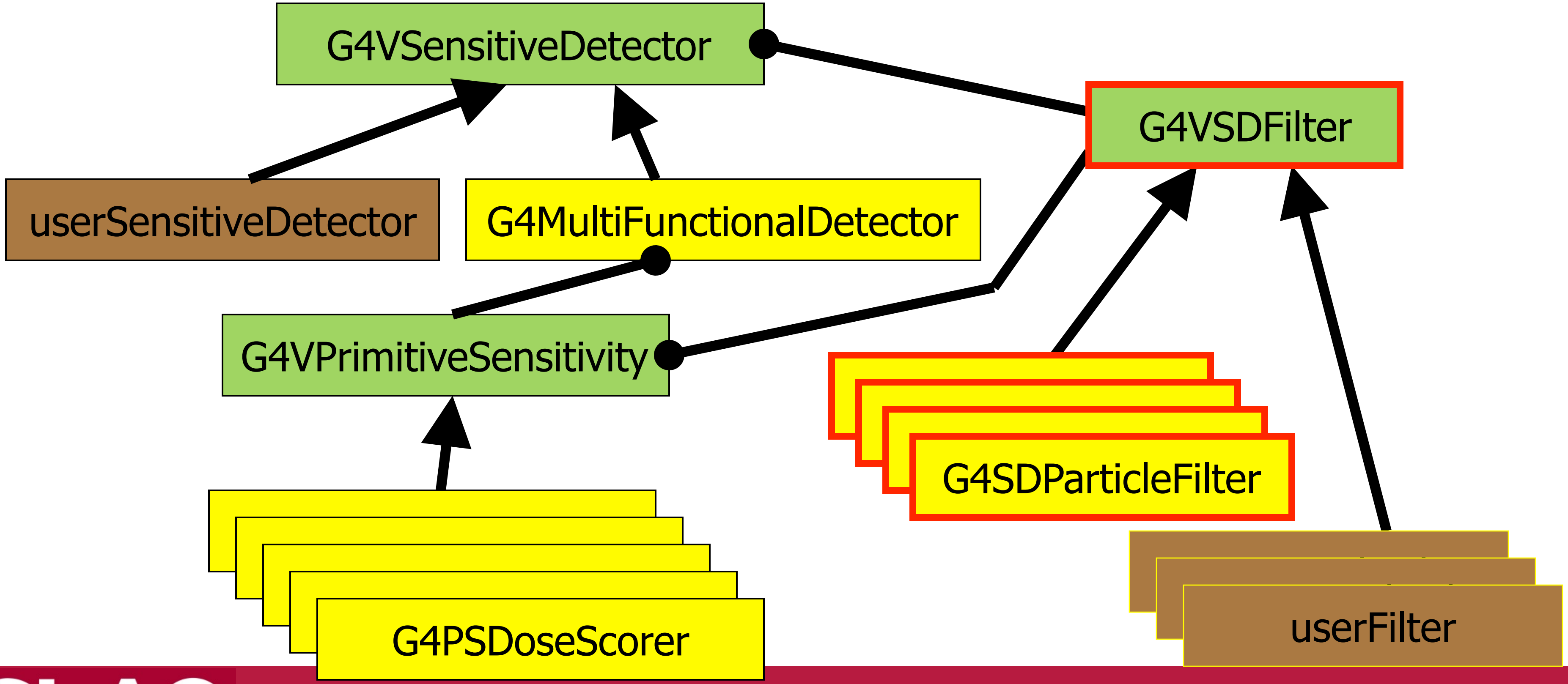
- Though we provide most commonly-used scorers, you may want to create your own.
  - If you believe your requirement is quite common, just let us know, so that we will add a new scorer.
- G4VPrimitiveScorer is the abstract base class.

```
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();
       …
};
```

- GetIndex() has already been introduced. Other four methods written in red will be discussed at "Scoring 2" talk.

G4VSDFilter

- G4VSDFilter can be attached to G4VSensitiveDetector and/or G4VPrimitiveSensitivity to define which kinds of tracks are to be scored.
  - E.g., surface flux of protons can be scored by G4PSFlatSurfaceFlux with a filter that accepts protons only.



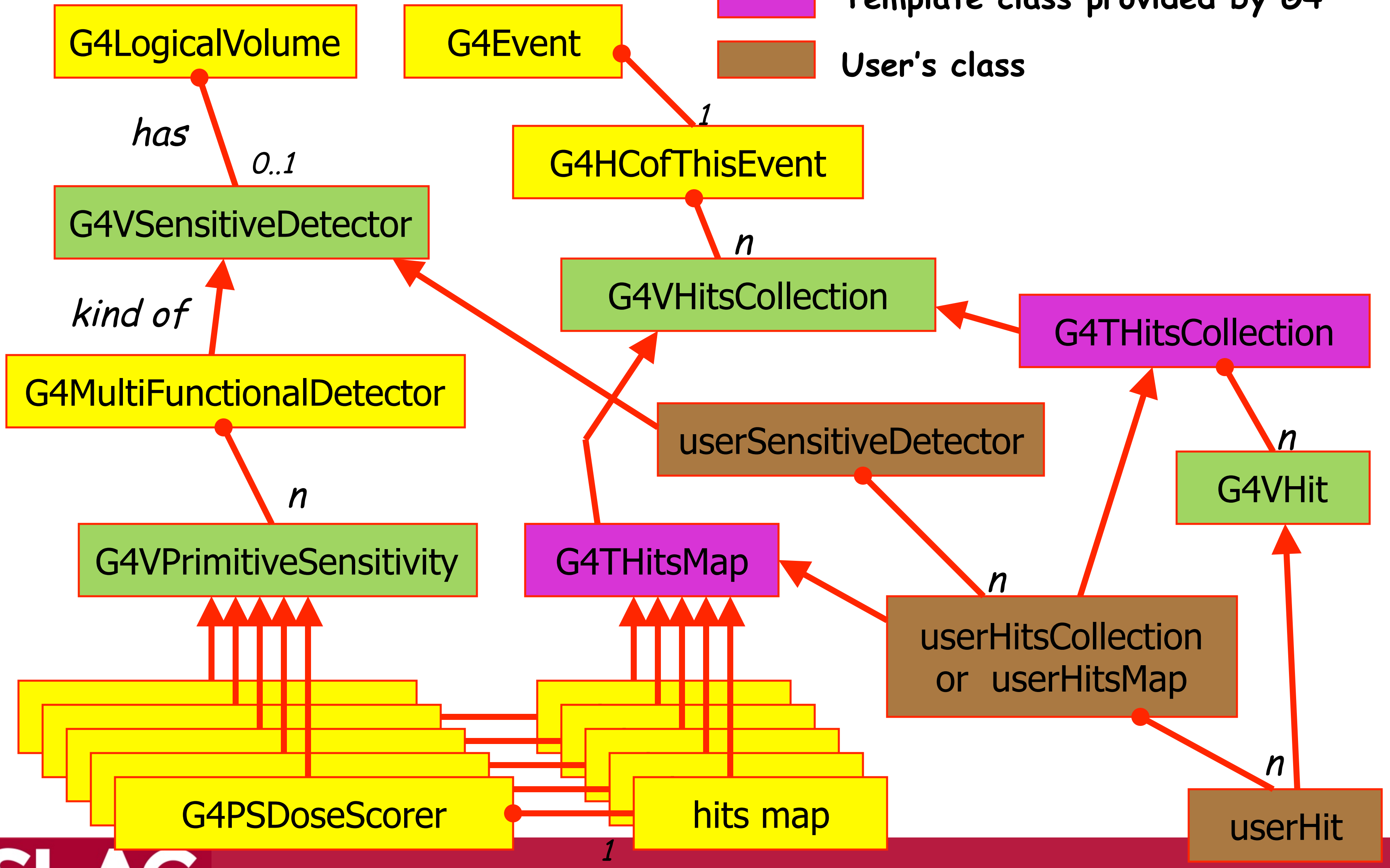
example…

```
MyDetectorConstruction::Construct()
{ …  G4LogicalVolume* myCellLog =  new G4LogicalVolume(…);
     G4VPhysicalVolume* myCellPhys = new G4PVParametrised(…);
     G4MultiFunctionalDetector* myScorer = new G4MultiFunctionalDetector(“myCellScorer”);
     G4SDManager::GetSDMpointer()->AddNewDetector(myScorer);
     myCellLog->SetSensitiveDetector(myScorer);
     G4VPrimitiveSensitivity* totalSurfFlux = new G4PSFlatSurfaceFlux(“TotalSurfFlux”);
     myScorer->Register(totalSurfFlux);
     G4VPrimitiveSensitivity* protonSufFlux = new G4PSFlatSurfaceFlux(“ProtonSurfFlux”);
     G4VSDFilter* protonFilter = new G4SDParticleFilter(“protonFilter”);
     protonFilter->Add(“proton”);
     protonSurfFlux->SetFilter(protonFilter);
     myScorer->Register(protonSurfFlux);
}
```

Accumulate scores for a run

Class diagram

- 🟨 Concrete class provided by G4
- 🟩 Abstract base class provided by G4
- 🟪 Template class provided by G4
- 🟫 User's class



G4LogicalVolume

G4Event

has

0..1

1

G4HCofThisEvent

G4VSensitiveDetector

n

G4VHitsCollection

kind of

G4THitsCollection

G4MultiFunctionalDetector

userSensitiveDetector

n

n

G4VHit

G4VPrimitiveSensitivity

G4THitsMap

n

userHitsCollection or userHitsMap

n

G4PSDoseScorer

hits map

1

userHit

Score == G4THitsMap<G4double>

- At the end of successful event, G4Event has a vector of G4THitsMap as the scores.
- Create your own Run class derived from G4Run, and implement RecordEvent(const G4Event*) virtual method. Here you can get all output of the event so that you can accumulate the sum of an event to a variable for entire run.
  - RecordEvent(const G4Event*) is automatically invoked by *G4RunManager*.
  - Your run class object should be instantiated in GenerateRun() method of your *UserRunAction*.

Customized run class

```
#include “G4Run.hh”
#include “G4Event.hh”
#include “G4THitsMap.hh”
Class MyRun : public G4Run
{
  public:
    MyRun();
    virtual ~MyRun();
    virtual void RecordEvent(const G4Event*);
  private:
    G4int nEvent;
    G4int   totalSurfFluxID,   protonSurfFluxID,   totalDoseID;
    G4THitsMap<G4double> totalSurfFlux;
    G4THitsMap<G4double> protonSurfFlux;
    G4THitsMap<G4double> totalDose;
public:
    … access methods …
};
```

Implement how you accumulate event data

Customized run class

```
MyRun::MyRun() : nEvent(0)
{
  G4SDManager* SDM = G4SDManager::GetSDMpointer();
  totalSurfFluxID = SDM->GetCollectionID("myCellScorer/TotalSurfFlux");
  protonSurfFluxID = SDM->GetCollectionID("myCellScorer/ProtonSurfFlux");
  totalDoseID = SDM->GetCollectionID("myCellScorer/TotalDose");
}
```

name of G4MultiFunctionalDetector object

name of G4VPrimitiveSensitivity object

Customized run class

```
void MyRun::RecordEvent(const G4Event* evt)
{
  nEvent++;
  G4HCofThisEvent* HCE = evt->GetHCofThisEvent();
  G4THitsMap<G4double>* eventTotalSurfFlux
            = (G4THitsMap<G4double>*)(HCE->GetHC(totalSurfFluxID));
  G4THitsMap<G4double>* eventProtonSurfFlux
            = (G4THitsMap<G4double>*)(HCE->GetHC(protonSurfFluxID));
  G4THitsMap<G4double>* eventTotalDose
            = (G4THitsMap<G4double>*)(HCE->GetHC(totalDose));
  totalSurfFlux += *eventTotalSurfFlux;
  protonSurfFlux += *eventProtonSurfFlux;
  totalDose += *eventTotalDose;
}
```

No need of loops.
+= operator is provided !

RunAction with customized run

```
G4Run* MyRunAction::GenerateRun()
{ return (new MyRun()); }
void MyRunAction::EndOfRunAction(const G4Run* aRun)
{
  MyRun* theRun = (MyRun*)aRun;
  // … analyze / record / print-out your run summary
  // MyRun object has everything you need …
}
```

- As you have seen, to accumulate event data, you do NOT need
  - Event / tracking / stepping action classes
- All you need are your Run and RunAction classes.

→ Refer to exampleN07