# Scoring - 1

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Geant4 IN2P3 and ED PHENIICS Tutorial,
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# Outline

- Extracting useful information
- Sensitive detectors, hits and hits collections
- Other scoring classes

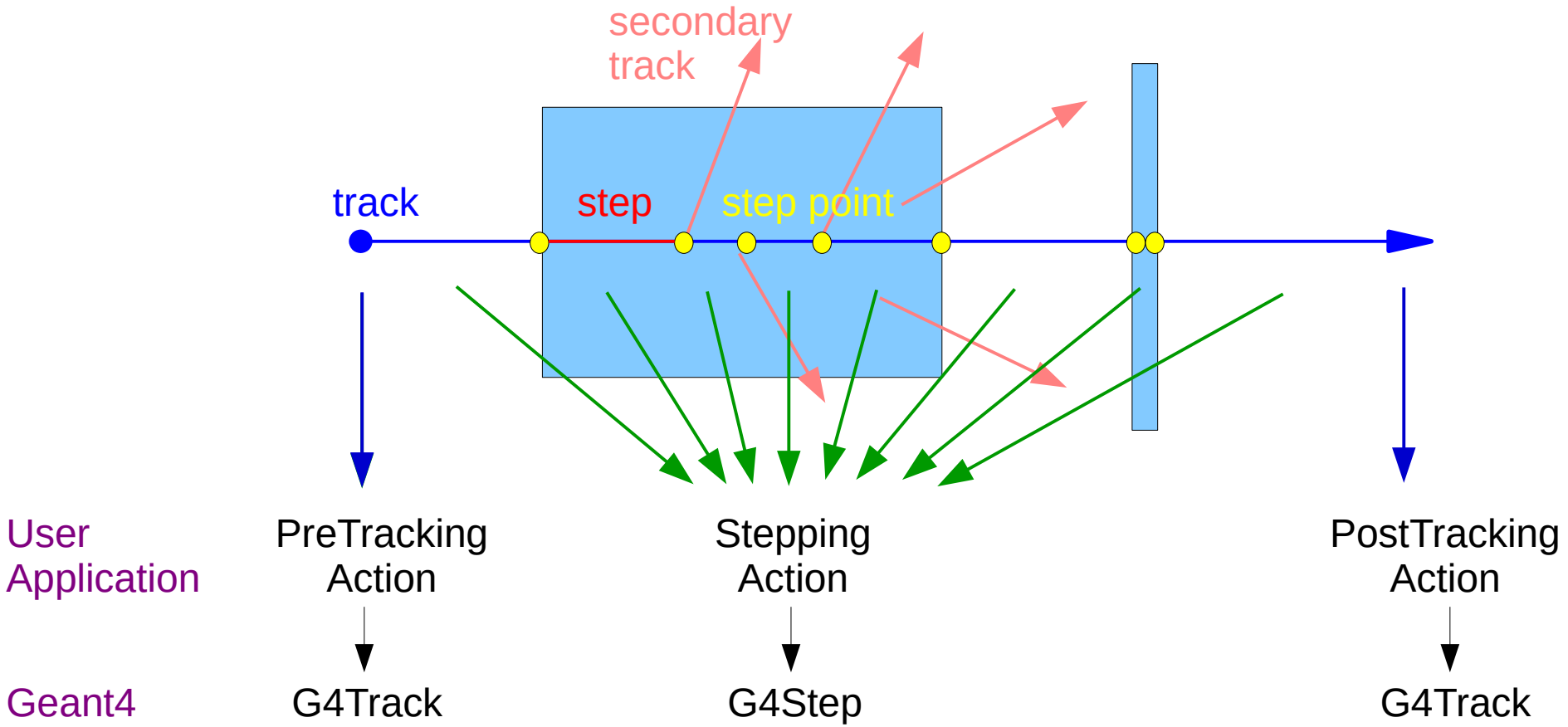
# Extracting Useful Information

- 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.
- The user action classes, if provided, are called by Geant4 kernel during all phases of tracking and have access to “theirs” Geant4 objects:
  - G4Run, G4Event, G4Track, G4Step

## Geant4 and User Application

# Event Processing

*User classes are called during event processing and can collect the information about tracked particles from Geant4 objects*



# Example

- Using G4Event information in Event action to print event number at the beginning of event

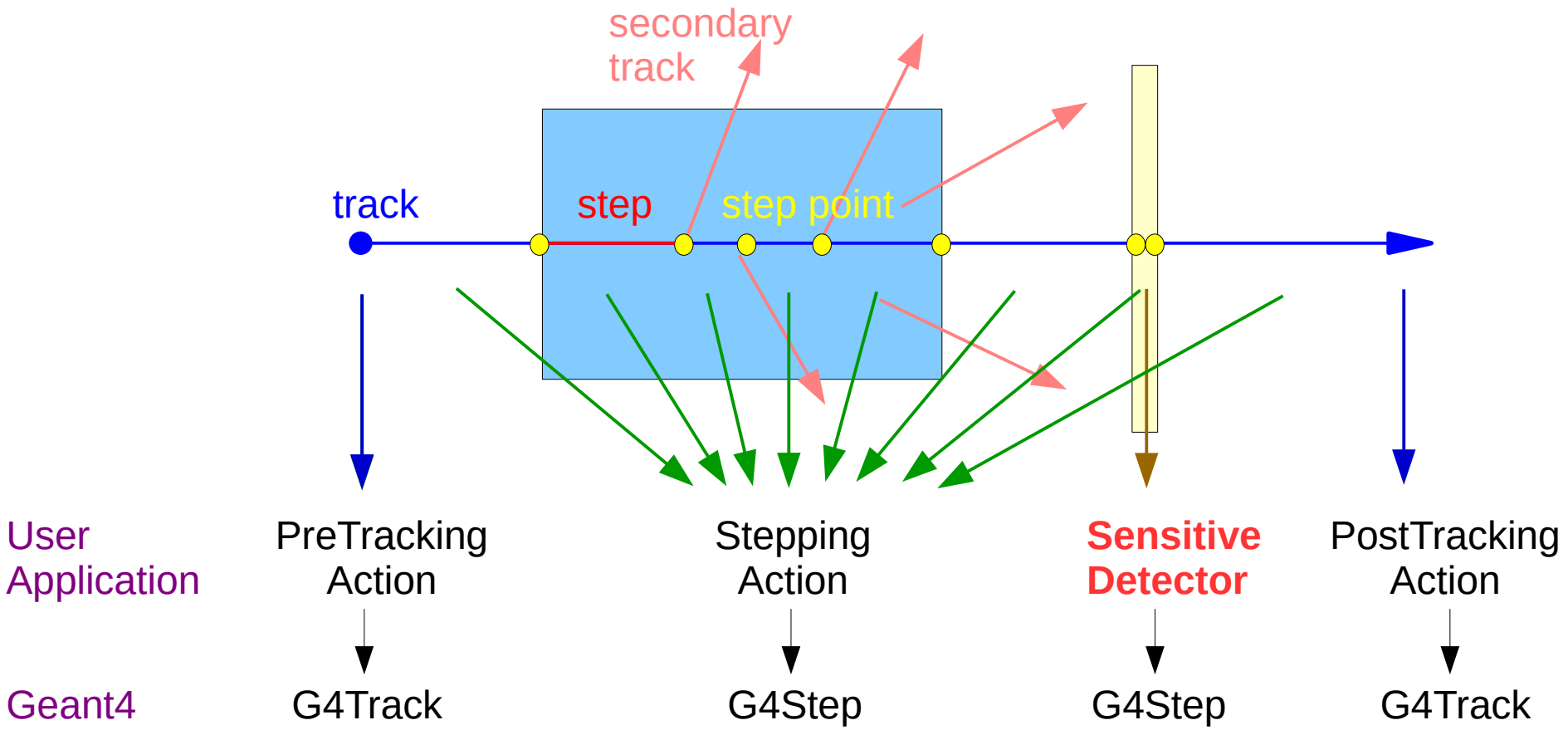
EventAction.cc

```
#include "EventAction.hh"
#include "G4Event.hh"

EventAction::BeginOfEventAction(const G4Event* event)
{
  // Get current event number
  G4int eventID = event->GetEventID();

  // Print this info on the screen
  G4cout << “Starting event: “ << eventID << G4endl;
}
```

## Geant4 and User Application

# Event Processing (2)

*A special user class, **sensitive detector**, can be attached to (a) selected volume(s) and then called during event processing*



# Sensitive Detectors

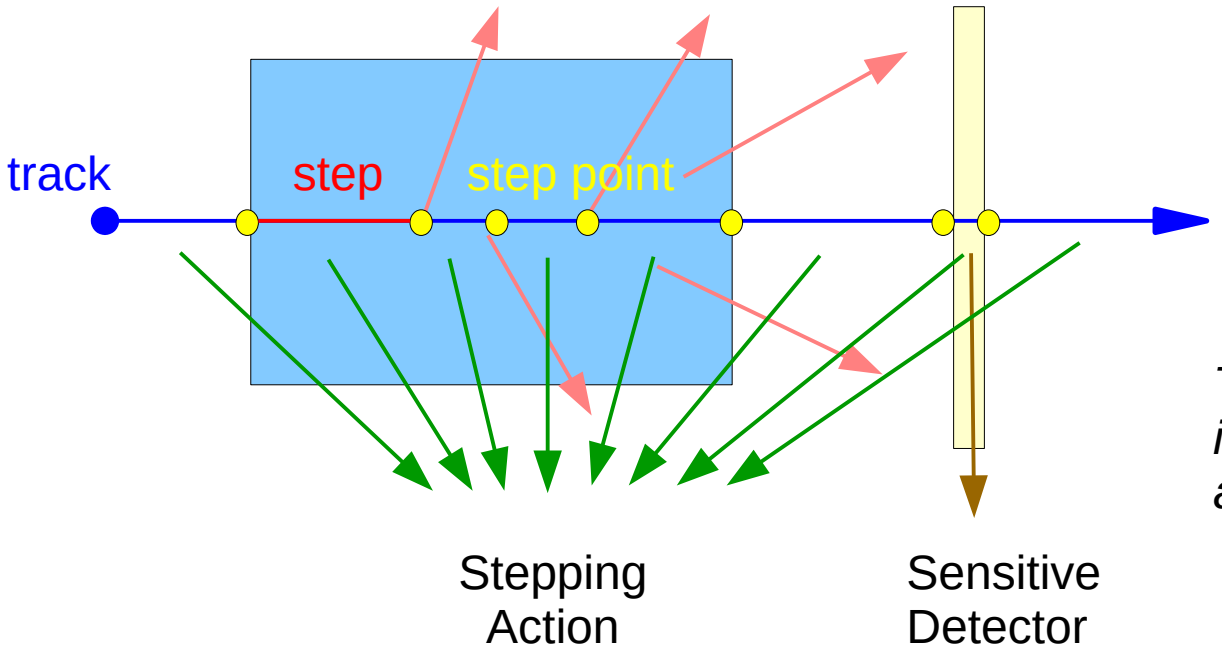
# Extracting Useful Information (2)

- During stepping, two user classes can be called
  - User stepping action – called in each step
  - User sensitive detector – called only when a track passes a "sensitive" volume
  - Both have access to G4Step
    - Example of code where we use G4Step to access the track position

```
// Get G4Step object
G4Step* step = ...

// Get the position of the step start (pre-step point)
G4StepPoint* preStepPoint = step->GetPreStepPoint();
G4ThreeVector position = preStepPoint->GetPosition();

// Print this info on the screen
G4cout << "This step position: " << position  << G4endl;
```

# Sensitive Detector

- A sensitive detector is assigned to a logical volume
- The sensitive detectors are invoked when a step takes place in the logical volume that they are assigned to




*The sensitive detector will be invoked all in the steps inside a sensitive volume*

# Sensitive Detector Class

- A sensitive detector is defined in a user class, MySD, derived from G4VSensitiveDetector base class
  - It defines the following user functions which are invoked by Geant4 kernel during event processing:
    - At **begin of event**: Initialize()
    - In **a step** (if in the associated volume): ProcessHits(..)
    - At **end of event**: EndOfEvent(..)
- Note that User stepping action defines only a function invoked when processing a step

# Sensitive Detector Class
# Header

MySD.hh

```
#include "G4VSensitiveDetector.hh"
...
class MySD : public G4VSensitiveDetector {
public:
  MySD(const G4String& name);
  virtual ~MySD();

  virtual void   Initialize(G4HCofThisEvent* hce);
  virtual G4bool ProcessHits(G4Step* step,
                             G4TouchableHistory* ROhistory);
  virtual void   EndOfEvent(G4HCofThisEvent* hce);
};
```

*The user functions called by Geant4 kernel*

# Defining a Sensitive Detector

- Sensitive detector objects are constructed and assigned to logical volumes in a **user detector construction** class in ConstructSDandField() function
- Creating SD object:

DetectorConstruction.cc

```
// create a sensitive detector object
G4VSensitiveDetector* mySD = new MySD("MySD");
// register this sensitive detector in SDManager
G4SDManager::GetSDMpointer()->AddNewDetector(mySD);
```

- Each sensitive detector object must have a unique name.
- More than one sensitive detector instances (objects) of the same type (class) can be defined with different names
- The created SD object must be registered to `G4SDManager`

# Assigning a Sensitive Detector to a Logical Volume

- Explicit setting to G4LogicalVolume
  - Using the SetSensitiveDetector function is defined in the G4LogicalVolume class

DetectorConstruction.cc

```
// defined previously
G4LogicalVolume* myLogicalVolume = ...;
G4VSensitiveDetector* mySD = ...;

// assign this sensitive detector to a logical volume
myLogicalVolume->SetSensitiveDetector(mySD);
```

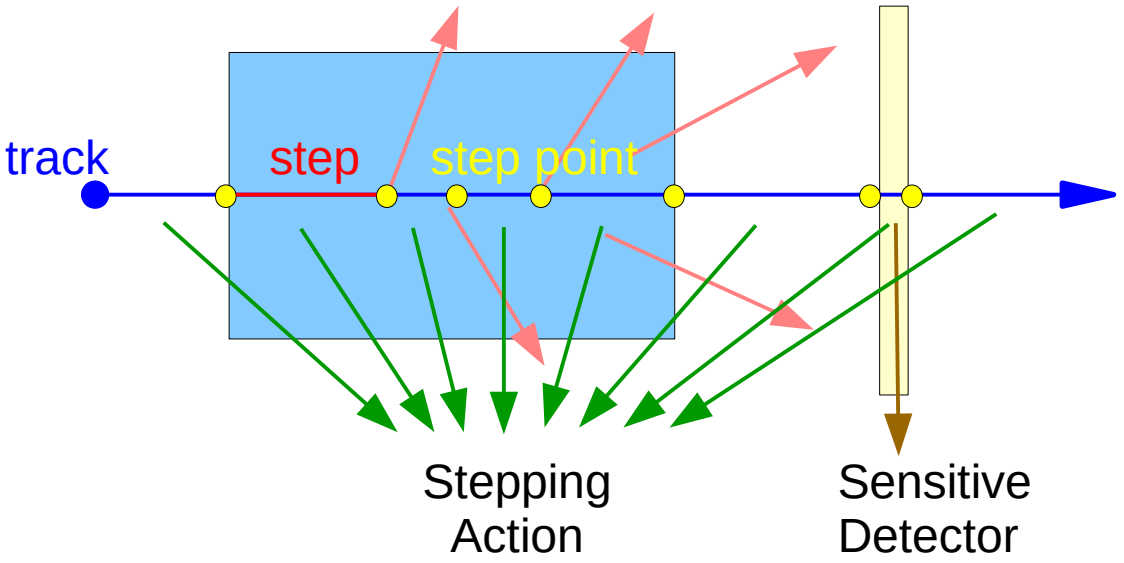
- Via the volume name
  - Using the SetSensitiveDetector function is defined in the G4VUserDetectorConstruction base class

```
// defined previously
G4VSensitiveDetector* mySD = ...
SetSensitiveDetector("MyLVName", mySD);
```

# Hits and Hits Collections

# A Hit

- Hit is a snapshot of the physical interaction of a track or an accumulation of interactions of tracks in the sensitive region of your detector
- Depending on your application you may be interested in various types information:
  - position and time of the step, momentum and energy of the track, energy deposition of the step, geometrical information, …



# User Hit Class

MyHit.hh

- You can store various types information by implementing your own concrete Hit class.
  - In this example we store the energy deposition of the step

```
class MyHit
{
public:
  MyHit();
  // set/get methods; eg.
  void     SetEdep (G4double edep);
  G4double GetEdep() const;
private:
  // some data members; eg.
  G4double fEdep;  // energy deposit
};
```

- Typically for each information to be stored in a hit we add:

| Data member | G4type fData; | G4double fEdep; |
|---|---|---|
| Set function | void SetData(G4type data); | void SetEdep(G4double edep): |
| Get function | G4type GetData() const; | G4double GetEdep() const; |

# Create a Hit

- A hit can be created e.g. when a step takes place in a sensitive logical volume, in a user sensitive detector function ProcessHits(..)

MySD.cc

```
// Create a hit object
MyHit* newHit = new MyHit();

// Get some properties from G4Step and set them to the hit
// newHit->SetXYZ();
G4double edep = step->GetTotalEnergyDeposit();
newHit->SetEdep(edep);}
```

# Hits Collections

- Many hits can be created during one event
- Hit objects must be stored in a dedicated collection
- Geant4 provides a dedicated class, G4THitsCollection, which allows to associate the hits collections with G4Event object and can be then accessed
  - through G4Event at the end of event, to be used for analyzing an event
  - through G4SDManager during processing an event, to be used for event filtering.
- When using Geant4 hits collections, the user hit class must derive from G4VHit base class
- Users may also define their own hits collections, eg.
  - Using STL library: std::vector<MyHit>
  - Using their application framework, eg. in the context of ROOT, it can be a ROOT collection (TObjArray, TClonesArray)

# User Geant4 Hit Class

- Hits collection of a concrete hit class is defined as a specialization of the G4THitsCollection template class
  - Note the analogy of G4THitsCollection<MyHit> with std::vector<MyHit>
  - To avoid long names we define a name shortcut using **typedef**

MyHit.hh

```
#include "G4VHit.hh"
class MyHit : public G4VHit
{
  // the class definition as before
  // utility functions (called by Geant4)
  virtual void Draw();
  virtual void Print();
};
#include "G4THitsCollection.hh"
typedef G4THitsCollection<MyHit> MyHitsCollection;
```

*When using Geant4 hits collections, the user hit class must derive from G4VHit*

*Geant4 hits collection for MyHit objects*

# G4Allocator

- Creation / deletion of an object is a heavy operation.
  - It may cause a performance concern, in particular for objects that are frequently instantiated / deleted like hits.
- Geant4 provides the G4Allocator class which provides functions for efficient memory allocation and de-allocation
  - It allocates a chunk of memory space for objects of a certain class.
- The same pattern can be used in all user classes, its is sufficient just to put the relevant user class name

# G4Allocator (2)

MyHit.hh

```
#include "G4Allocator.hh"
class MyHit : public G4VHit {
    // ...
    inline void* operator new(size_t);
    inline void  operator delete(void* hit);
    // ...
};
extern G4Allocator<MyHit>* MyHitAllocator;
inline void* MyHit::operator new(size_t) {
  return (void*)MyHitAllocator->MallocSingle();
}
inline void MyHit::operator delete(void* hit) {
  MyHitAllocator->FreeSingle((MyHit*)hit);
}
```

MyHit.cc

```
// ...
G4Allocator<MyHit>* MyHitAllocator;
// ..
```

- The pattern (in green) can be cut & pasted in your hit (and other) classes
- Then you need just to replace MyHit with your class name

# Implementing Sensitive Detector

# Sensitive Detector Class
# Constructor

MySD.cc

```
void MySD::MySD(const G4String& name)
  : G4VSensitiveDetector(name)
{}
```

- The class constructor is **called by the user** when creating the sensitive detector object(s) in a detector construction class
  - The sensitive detector name is passed in the base class constructor where it is saved in the SensitiveDetectorName data member

# Define Hits Collection in Initialize

MySD.cc

```
void MySD::Initialize(G4HCofThisEvent* /*hce*/)
{
  // Define a hits collection name
  G4String hcName = SensitiveDetectorName + "HitsCollection";
  // Create a hits collection object
  fHitsCollection =
    new MyHitsCollection(SensitiveDetectorName, hcName);
}
```

- This method is invoked at the beginning of each event
- The **hits collection object** (`fHitsCollection`) is created
  - The G4THitsCollection constructor requires 2 arguments: a sensitive detector name and a hits collection name
  - It can be also attached to the G4HCofThisEvent object given in the argument, it is then available via G4Event object (Not shown in our tutorial)

# Filling A Hits Collection in ProcessHits

MySD.cc

```
void MySD::ProcessHits(G4Step* step,
                       G4TouchableHistory* /*history*/)
{
  // Create a hit
  MyHit* newHit = new MyHit();
  // Set some properties to the hit newHit→SetXYZ();
  // Add the hit in the SD hits collection
  fHitsCollection->insert(newHit);
}
```

- This method is invoked at each step in the associated volume
- The hits are usually inserted in the hits collection when they are created
- Besides ProcessHits(), hits can be also created in Initialize().

# Filling A Hits Collection

- The way how the hits collections are filled depends on a detector type
- *A tracker detector* typically generates a hit for every single step of every single (charged) track
  - Hits are created in MySD::ProcessHits()
  - They typically contain position and time, energy deposition of the step, track ID
- *A calorimeter detector* typically generates a hit for every cell, and accumulates energy deposition in each cell for all steps of all tracks
  - Hits are created in MySD::Initialize() and then updated in MySD::ProcessHits()
  - They typically contain sum of deposited energy, Cell ID

# Iterate over A Hits Collection in EndOfEvent

MySD.cc

```
void MySD::EndOfEvent(G4HCofThisEvent* /*hce*/)
{
  G4int nofHits = fHitsCollection->entries();
  G4cout << nofHits << " hits: " << G4endl;
  for ( G4int i=0; i<nofHits; ++i ) {
    (*fHitsCollection)[i]->Print();
  }
}
```

- This method is invoked at the end of processing an event.
  - It is invoked even if the event is aborted
  - It is invoked before UserEventAction::EndOfEventAction

# Other Scoring Classes

# Other Scoring Classes

- On the top of the sensitive detectors and hits framework, Geant4 provides also classes for scoring ready to be used
  - Users do not need to develop SD and Hits classes
- G4MultiFunctionalDetector can be attached to users logical volume and configured using Geant4 scorer classes to score selected quantities (eg. energy deposit, dose deposit etc.)
  - See e.g. basic example B4d
- Command based scoring
  - Built-in scoring mesh can defined via UI commands and configures with various scorers for commonly-used physics quantities such as dose, flux, etc.
  - See RE03, RE04 extended examples in runAndEvent category
- Discussed in more detail in the last scoring presentation

# Summary

- The Geant4 toolkit provides dedicated classes/tools for user scoring:
  - Sensitive detectors

  and the following (not covered in this session):
  - Geant4 scorers
  - Command-based scoring