Interaction with the Geant4 kernel – part 3

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The ingredients of user SD

- A powerful and flexible way of extracting information from the physics simulation is to **define your own SD**
- Derive **your own concrete classes** from the base classes and customize them according to your needs

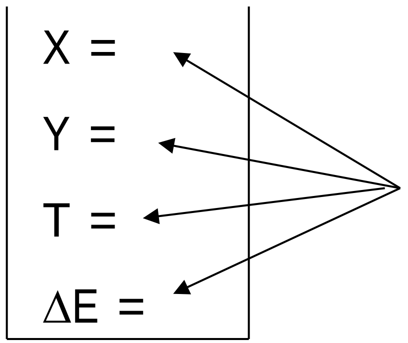
	Concrete class	**Base class**
Sensitive Detector	MySensitiveDetector	G4VSensitiveDetector
Hit	MyHit	G4VHit
		Template class
Hits collection		G4THitsCollection<MyHit*>

Hit class - 1

- Hit is a user-defined class which derives from the base class **G4VHit**. Two virtual methods
  - **Draw()**
  - **Print()**
- You can store various types of information by implementing your own concrete Hit class
- Typically, one may want to record information like
  - Position, time and ΔE of a step
  - Momentum, energy, position, volume, particle type of a given track
  - Etc.

Hit class - 2

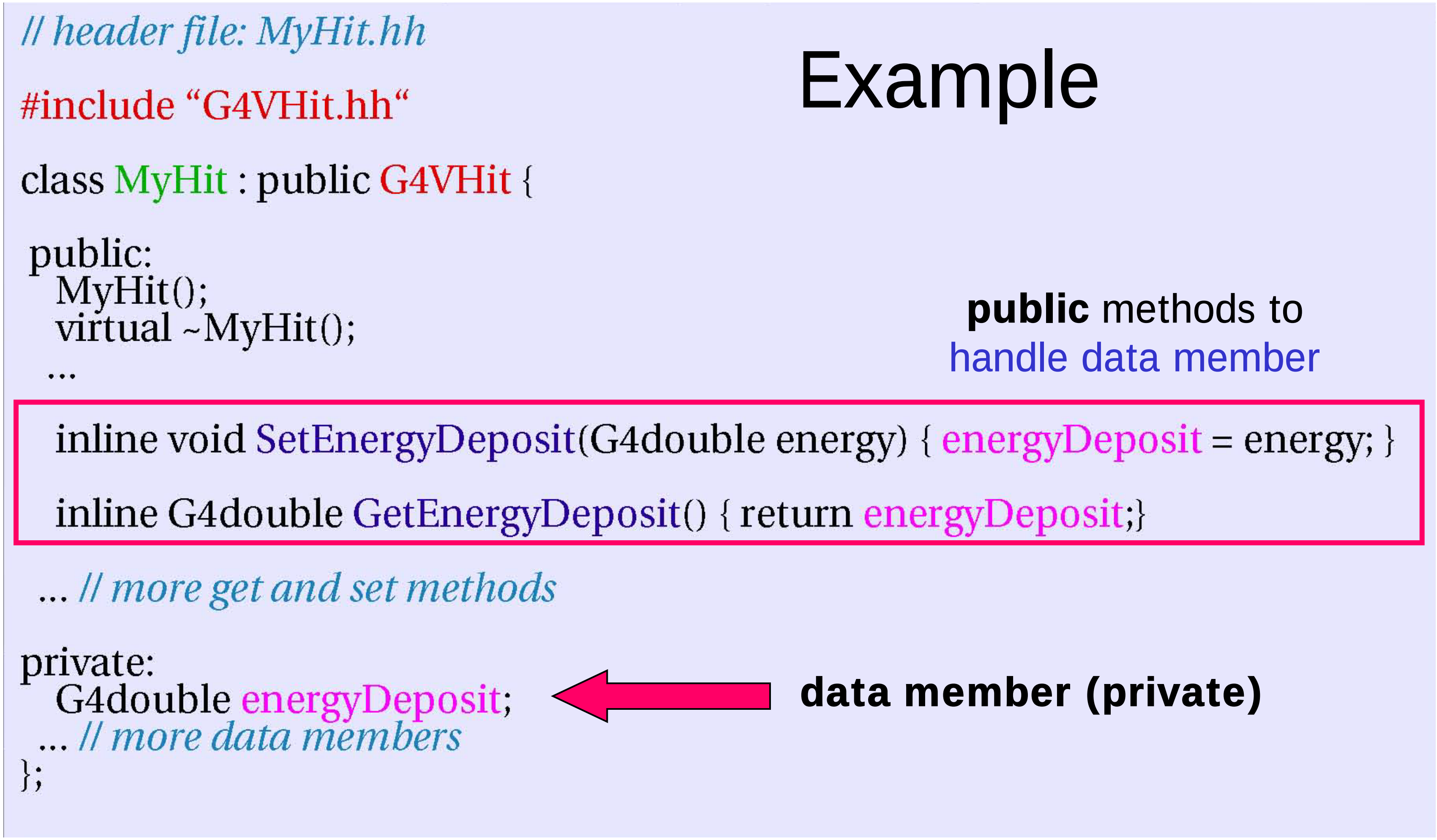
A "Hit" is like a "container", a **empty box** which will store the information retrieved step by step



The Hit **concrete class** (derived by **`G4VHit`**) must be written by the user: the user must decide **which variables** and/or information the hit should store and **when** store them

The Hit objects are **created** and **filled** by the **`SensitiveDetector`** class (invoked at each step in detectors defined as sensitive). **Stored** in the "**HitCollection**", attached to the **`G4Event`**: can be retrieved at the end of the event

Hit class - 3



```
// header file: MyHit.hh

#include “G4VHit.hh“

class MyHit : public G4VHit {

 public:
   MyHit();
   virtual ~MyHit();
  ...

   inline void SetEnergyDeposit(G4double energy) { energyDeposit = energy; }

   inline G4double GetEnergyDeposit() { return energyDeposit;}

  ... // more get and set methods

private:
   G4double energyDeposit;
  ... // more data members
};
```

Example

public methods to
handle data member

data member (private)

Geant4 Hits

Since in the simulation one may have different sensitive detectors in the same setup (e.g. a calorimeter and a Si detector), it is possible to define **many Hit classes** (all derived by **`G4VHit`**) storing different information

X =

Y =

T =

ΔE =

Class Hit1 :
public G4VHit

Z =

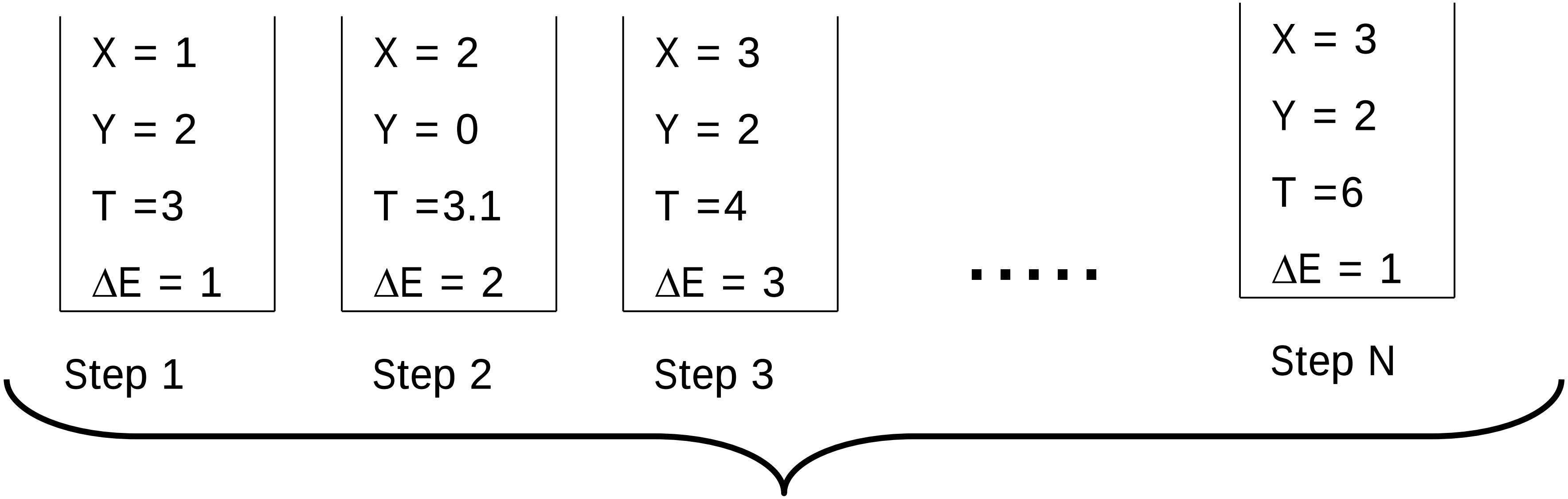
Pos =

Dir =

Class Hit2 :
public G4VHit

Hits Collection - 1

At each step in a detector defined as sensitive, the method **`ProcessHit()`** of the user SensitiveDetector class is invoked: it must **create**, **fill** and **store** the Hit objects



X = 1
Y = 2
T =3
ΔE = 1

Step 1

X = 2
Y = 0
T =3.1
ΔE = 2

Step 2

X = 3
Y = 2
T =4
ΔE = 3

Step 3

……

X = 3
Y = 2
T =6
ΔE = 1

Step N

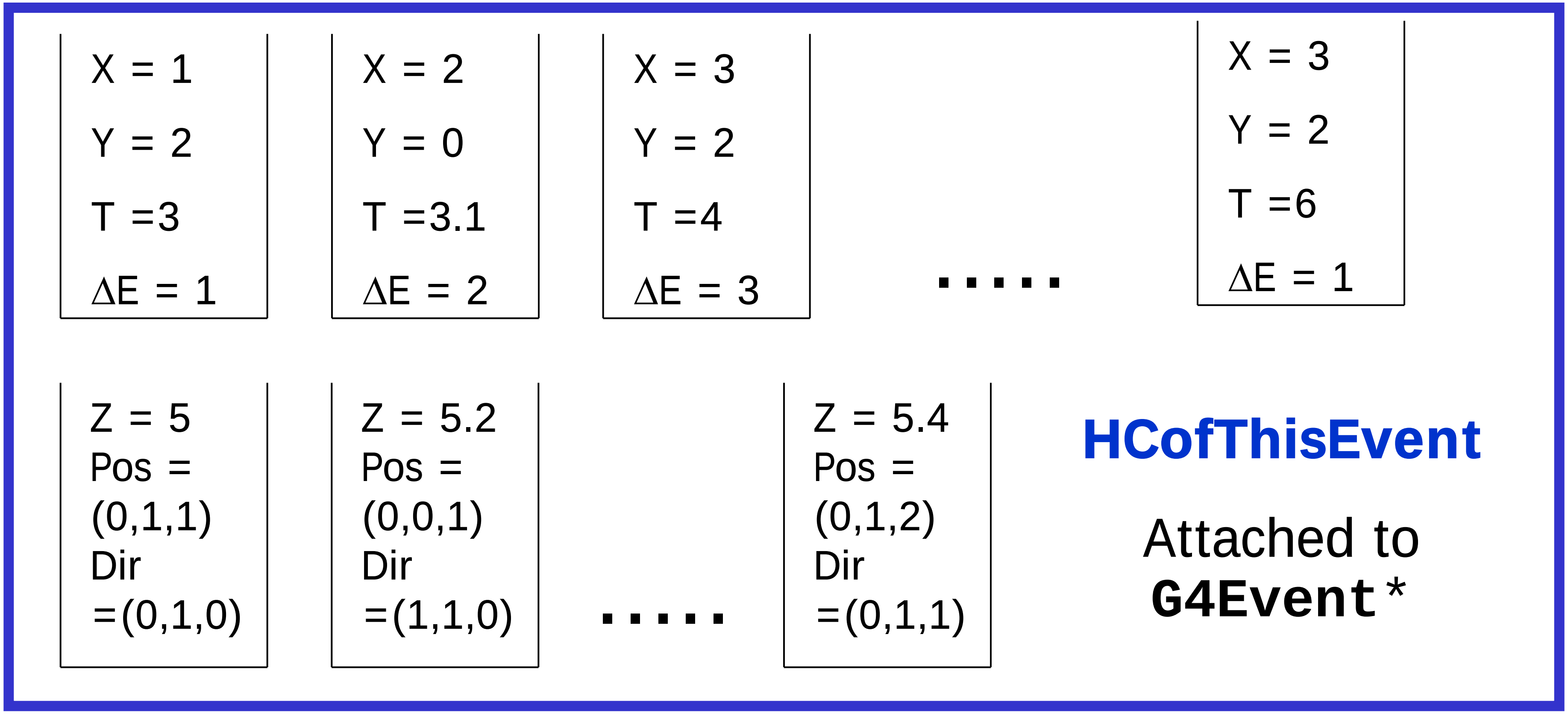
Hits collection (= vector<Hit>)

Hits Collection - 2

- Once created in the sensitive detectors, objects of the concrete hit class **must be stored** in a **dedicated collection**
  - Template class **`G4THitsCollection<MyHit>`**, which is actually a vector of **`MyHit*`**
- The hits collections can be accesses in different phases of tracking
  - At the end of each event, through the **`G4Event`** (*a-posteriori event analysis*)
  - During event processing, through the Sensitive Detector Manager **`G4SDManager`** (*event filtering*)

The HCofThisEvent

Remember that you may have **many kinds of Hits**
(and Hits Collections)



X = 1
Y = 2
T =3
ΔE = 1

X = 2
Y = 0
T =3.1
ΔE = 2

X = 3
Y = 2
T =4
ΔE = 3

. . . . .

X = 3
Y = 2
T =6
ΔE = 1

Z = 5
Pos = (0,1,1)
Dir =(0,1,0)

Z = 5.2
Pos = (0,0,1)
Dir =(1,1,0)

. . . . .

Z = 5.4
Pos = (0,1,2)
Dir =(0,1,1)

HCofThisEvent

Attached to **`G4Event*`**

Hits Collections of an event

- A **G4Event** object has a **G4HCofThisEvent** object at the end of the event processing (if it was successful)
  - The pointer to the **G4HCofThisEvent** object can be retrieved using the **G4Event::GetHCofThisEvent()** method
- The **G4HCofThisEvent** stores all hits collections creted within the event
  - Hits collections are accessible and can be processes e.g. in the **EndOfEventAction()** method of the User Event Action class
  - Transient: information **cleaned up** at each new event

SD and Hits

- Using information from particle steps, a sensitive detector either
  - constructs, fills and stores one (or more) **hit object**
  - accumulates values to existing hits
- Hits objects can be filled with information in the **`ProcessHits()`** method of the SD concrete user class → next slides
  - This method has pointers to the current **`G4Step`** and to the **`G4TouchableHistory`** of the Parallel World (if defined)

Sensitive Detector (SD)

- A specific feature to Geant4 is that a user can provide his/her own implementation of the detector and **its response** → customized
- To create a sensitive detector, **derive** your own concrete class from the **`G4VSensitiveDetector`** abstract base class
  - The principal purpose of the sensitive detector is to create hit objects
  - Overload the following methods (see also next slide):
    - **`Initialize()`**
    - **`ProcessHits()`** (Invoked for each step if step starts in logical volume having the SD attached)
    - **`EndOfEvent()`**

Sensitive Detector

```
class  G4VSensitiveDetector {
 public:
   ...
     virtual void Initialize(G4HCofThisEvent*);
     virtual void EndOfEvent(G4HCofThisEvent*);
 protected:
     virtual G4bool ProcessHits(G4Step* ,
                                 G4TouchableHistory*) = 0;
  ...
};
```

abstract base class

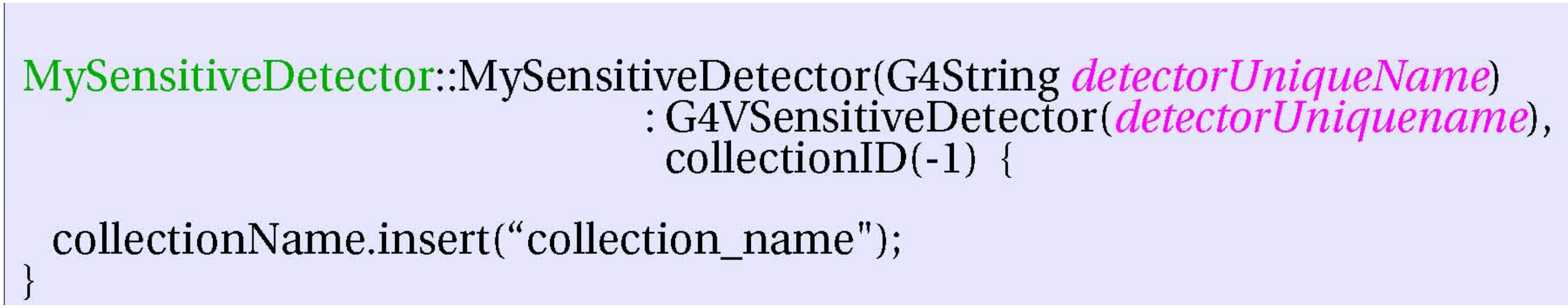
pure virtual method

```
// header file: MySensitiveDetector.hh
#include “G4VSensitiveDetector.hh“
...
class MySensitiveDetector : public G4VSensitiveDetector {

 public:
    MySensitiveDetector(G4String name);
    virtual ~MySensitiveDetector();

    virtual void Initialize(G4HCofThisEvent*HCE);
    virtual G4bool ProcessHits(G4Step* step,
                               G4TouchableHistory* ROhist);
    virtual void EndOfEvent(G4HCofThisEvent*HCE);

 private:
    MyHitsCollection * hitsCollection;
    G4int collectionID;
};
```

User concrete SD class

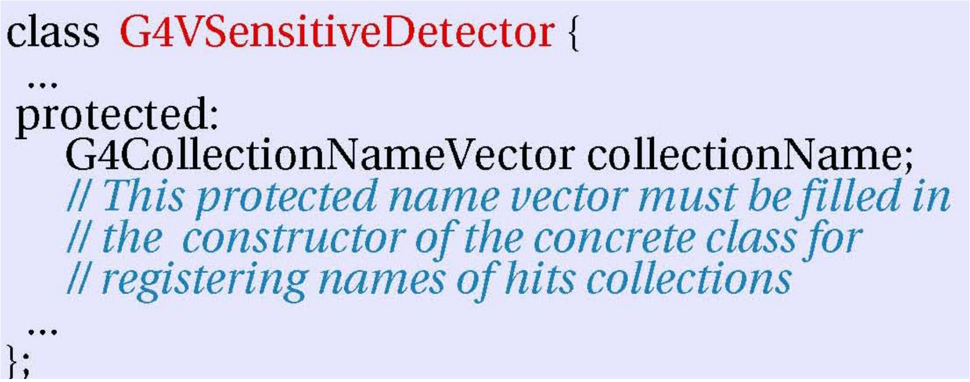
SD implementation: constructor

- Specify a hits collection (by its unique name) for each type of hits considered in the sensitive detector:
  - Insert the name(s) in the collectionName vector



```
MySensitiveDetector::MySensitiveDetector(G4String detectorUniqueName)
                                       : G4VSensitiveDetector(detectorUniquename),
                                         collectionID(-1)  {

  collectionName.insert(“collection_name");
}
```

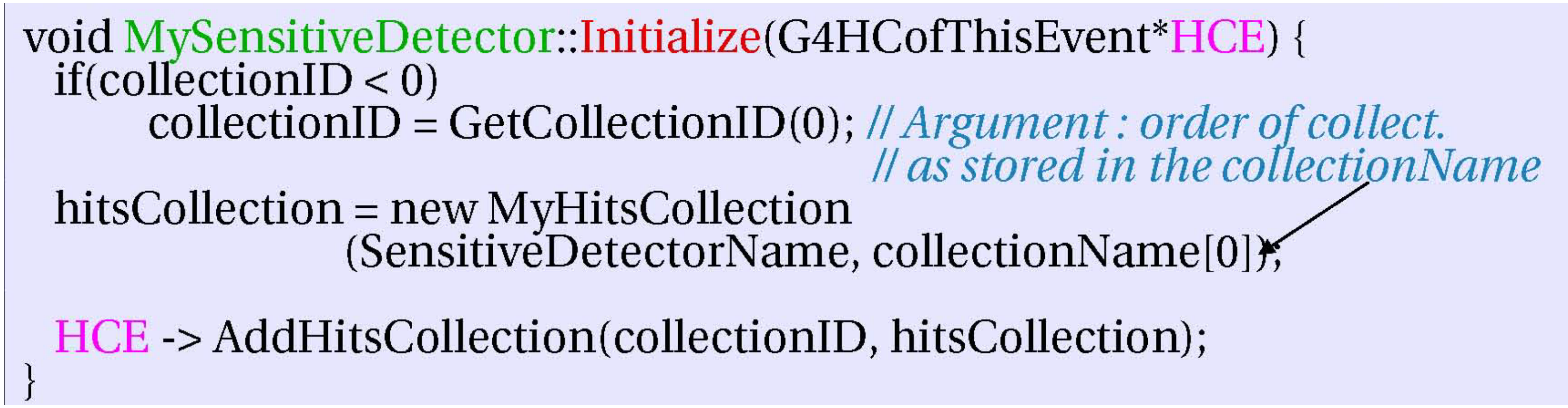
Base class



```
class  G4VSensitiveDetector {
  ...
 protected:
     G4CollectionNameVector collectionName;
     // This protected name vector must be filled in
     // the  constructor of the concrete class for
     // registering names of hits collections
  ...
};
```

SD implementation: Initialize()

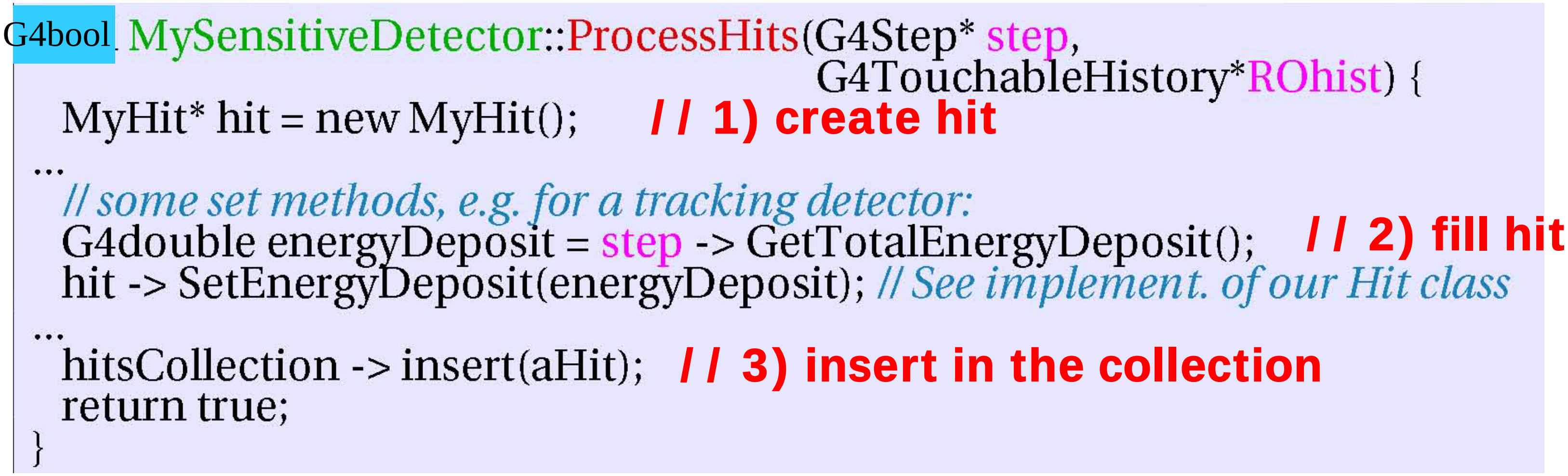
- The **`Initialize()`** method is invoked at the beginning of each event
- Construct all hits collections and insert them in the **`G4HCofThisEvent`** object, which is passed as argument to Initialize()
  - The **`AddHitsCollection()`** method of **`G4HCofThisEvent`** requires the collection ID
- The **unique collection ID** can be obtained with `GetCollectionID`():
  - GetCollectionID() cannot be invoked in the constructor of this SD
  - Hence, we defined a private data member (collectionID), which is set at the first call of the Initialize() function



```
void MySensitiveDetector::Initialize(G4HCofThisEvent*HCE) {
  if(collectionID < 0)
        collectionID = GetCollectionID(0); // Argument : order of collect.
                                           // as stored in the collectionName
  hitsCollection = new MyHitsCollection
                     (SensitiveDetectorName, collectionName[0]);

  HCE -> AddHitsCollection(collectionID, hitsCollection);
}
```

SD implementation: ProcessHits()

- This **`ProcessHits()`** method is invoked for every step in the volume(s) which hold a pointer to this SD (= each volume defined as "**sensitive**")
- The main mandate of this method is to **generate hit(s)** or to accumulate data to existing hit objects, by using information from the current step

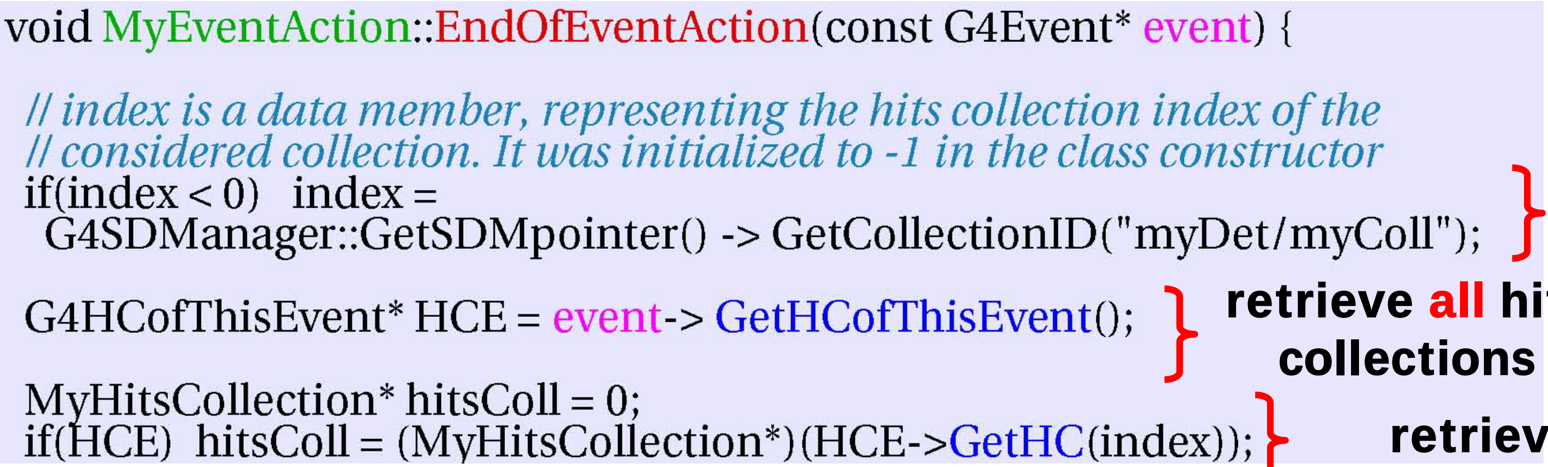


```
G4bool MySensitiveDetector::ProcessHits(G4Step* step,
                                         G4TouchableHistory*ROhist) {
  MyHit* hit = new MyHit();      // 1) create hit
...
  // some set methods, e.g. for a tracking detector:
  G4double energyDeposit = step -> GetTotalEnergyDeposit();    // 2) fill hit
  hit -> SetEnergyDeposit(energyDeposit); // See implement. of our Hit class
...
  hitsCollection -> insert(aHit);  // 3) insert in the collection
  return true;
}
```

Processing hit information - 1

- Retrieve the pointer of a hits collection with the **GetHC()**method of **G4HCofThisEvent** collection using the collection index (a G4int number)
- Index numbers of a hit collection are **unique** and don’t change for a run. The number can be obtained by **G4SDManager::GetCollectionID(“name”);**
- Notes:
  - if the collection(s) are not created, the pointers of the collection(s) are NULL: **check** before trying to access it
  - Need an explicit cast from **G4VHitsCollection** (see code)

Process hit: example



```
void MyEventAction::EndOfEventAction(const G4Event* event) {

 // index is a data member, representing the hits collection index of the
 // considered collection. It was initialized to -1 in the class constructor
 if(index < 0)   index =
   G4SDManager::GetSDMpointer() -> GetCollectionID("myDet/myColl");

 G4HCofThisEvent* HCE = event-> GetHCofThisEvent();

 MyHitsCollection* hitsColl = 0;
 if(HCE)  hitsColl = (MyHitsCollection*)(HCE->GetHC(index));
```

retrieve index

retrieve all hits collections

retrieve hits collection by index

Be sure that this is non-NULL

Processing hit information - 2

- Loop through the entries of a hits collection to **access individual hits**
  - Since the HitsCollection is a vector, you can use the **[] operator** to get the hit object corresponding to a given index
- **Retrieve** the information contained in this hit (e.g. using the Get/Set methods of the concrete user Hit class) and process it
- Store the output in analysis objects

Process hit: example

```
void MyEventAction::EndOfEventAction(const G4Event* event) {

 // index is a data member, representing the hits collection index of the
 // considered collection. It was initialized to -1 in the class constructor
 if(index < 0)   index =
   G4SDManager::GetSDMpointer() -> GetCollectionID("myDet/myColl");

 G4HCofThisEvent* HCE = event-> GetHCofThisEvent();

 MyHitsCollection* hitsColl = 0;
 if(HCE)  hitsColl = (MyHitsCollection*)(HCE->GetHC(index));

 if(hitsColl)  {
   int numberHits = hitsColl->entries();

   for(int i1= 0; i1 < numberHits ; i1++) {
     MyHit* hit = (*hitsColl)[i1];
     // Retrieve information from hit object, e.g.
     G4double energy = hit -> GetEnergyDeposit;
     ... // Further process and store information
   }
 }
}
```

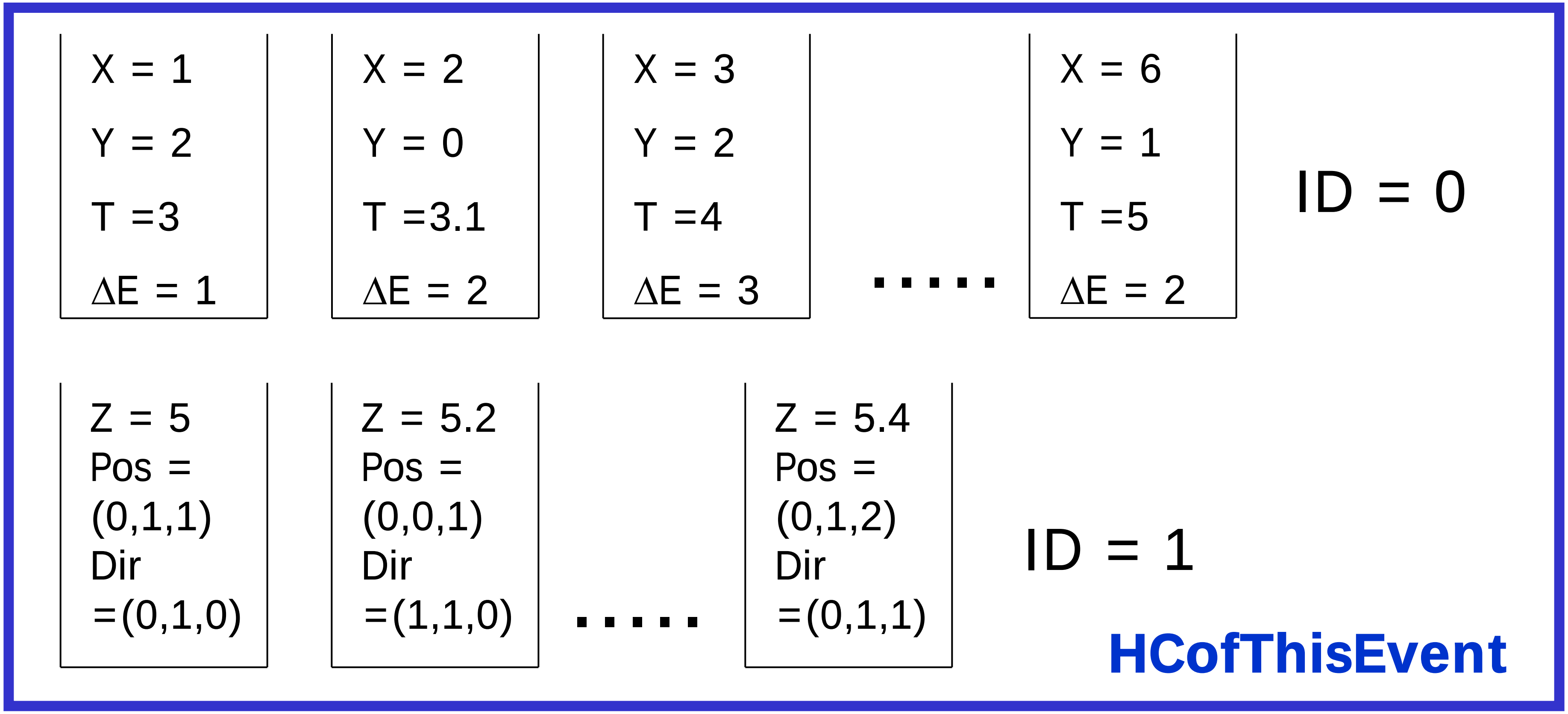
Be sure that this is non-NULL

cast

loop over
individual hits,
retrieve the data

The HCofThisEvent

Remember that you may have **many kinds of Hits**
(and Hits Collections)



X = 1
Y = 2
T =3
ΔE = 1

X = 2
Y = 0
T =3.1
ΔE = 2

X = 3
Y = 2
T =4
ΔE = 3

.....

X = 6
Y = 1
T =5
ΔE = 2

ID = 0

Z = 5
Pos = (0,1,1)
Dir =(0,1,0)

Z = 5.2
Pos = (0,0,1)
Dir =(1,1,0)

.....

Z = 5.4
Pos = (0,1,2)
Dir =(0,1,1)

ID = 1

HCofThisEvent

Recipe and strategy - 1

- Create your detector geometry
  - Solids, logical volumes, physical volumes
- Implement a sensitive detector and assign an instance of it to the **logical volume** of your geometry set-up
  - Then this volume becomes “sensitive”
  - Sensitive detectors are active for each particle steps, if the step starts in this volume

Recipe and strategy - 2

- Create hits objects in your sensitive detector using information from the particle step
  - You need to create the hit class(es) according to **your requirements**
- **Store** hits in hits collections (automatically associated to the **`G4Event`** object)
- Finally, process the information contained in the hit in user action classes (e.g. **`G4UserEventAction`**) to obtain results to be stored in the analysis object

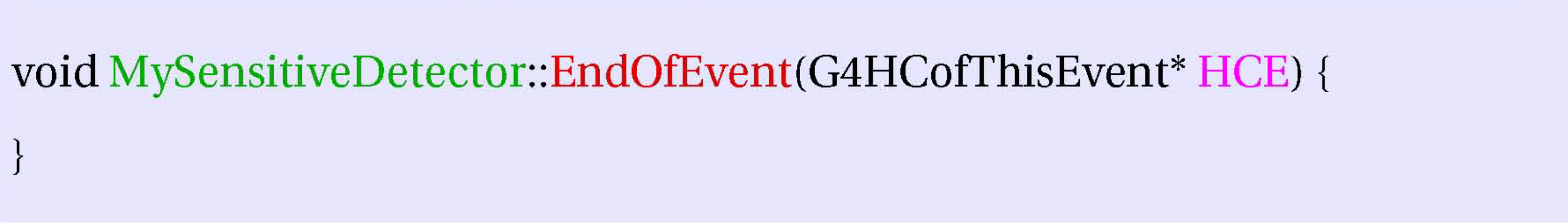
Hands-on session

- Task4
  - Task4d: Custom SD and hits
  - Task4e (optional): try everything in MT mode
- Task5 (bonus summary exercise)

- **`http://202.122.35.46/geant/task4`**
- **`http://202.122.35.46/geant/task5`**

SD implementation: EndOfEvent()

- This `EndOfEvent()` method is invoked at the end of each event.
  - Note is invoked before the EndOfEvent function of the G4UserEventAction class



```
void MySensitiveDetector::EndOfEvent(G4HCofThisEvent* HCE) {
}
```