Geant4: A Simulation toolkit

O. Stézowski and M. Pinto

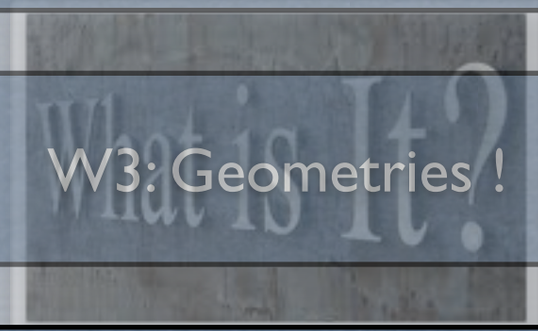
With many thanks to the Geant4 community !!!!

The roadmap of the week

W1: installation / running a G4 application

Why?

W2: Primary generator, GPS, physics list

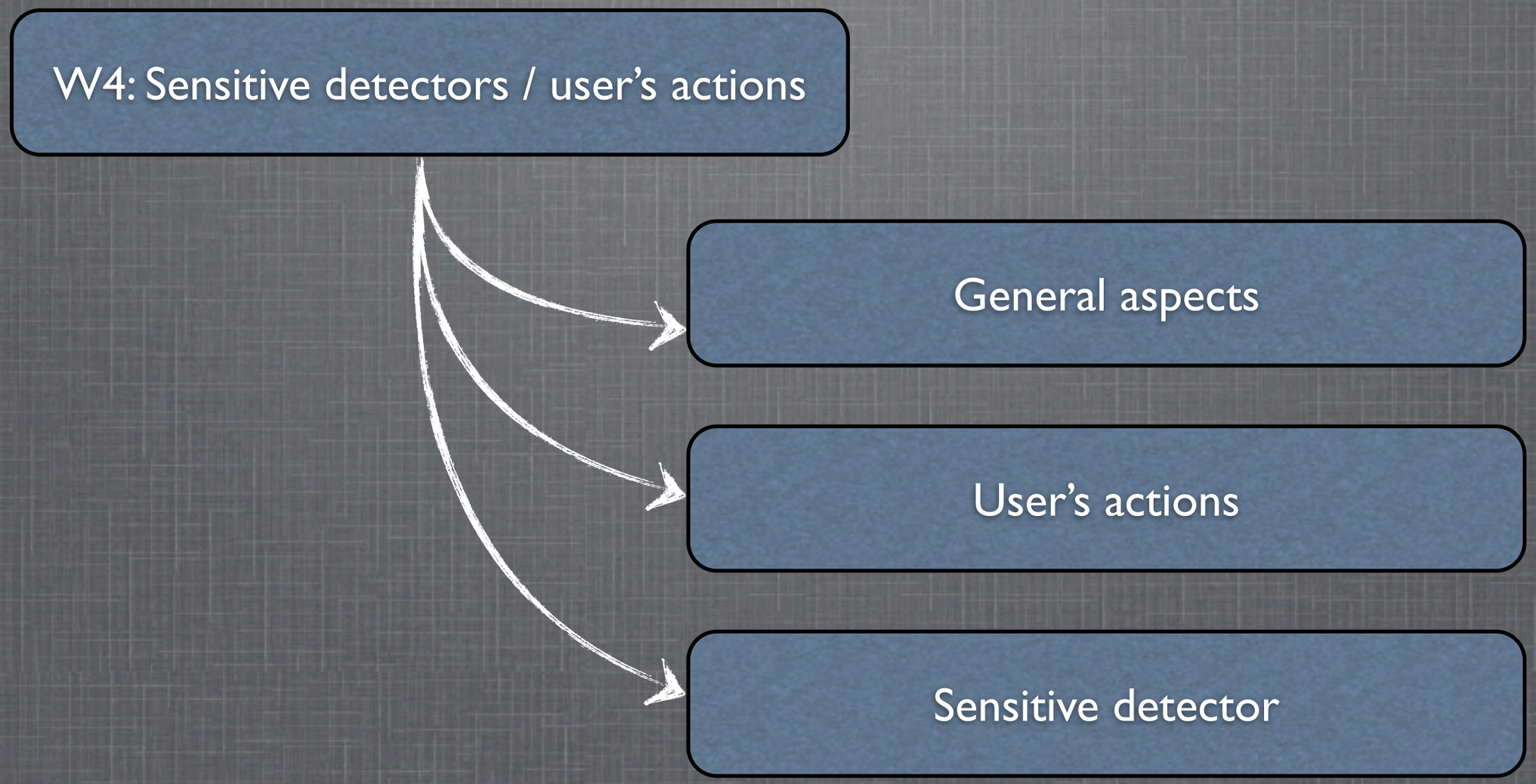


W3: Geometries !

W4: Sensitive detectors / user's actions

w1: 3:00, Monday
w2: 3:00, Tuesday
w3: 4:30, Wednesday
w4: 3:00, Thursday

NOW, HOW does it really work ?


W4: Sensitive detectors / user's actions
General aspects
User's actions
Sensitive detector

To extract information from G4

Given geometry, physics and primary track generation, G4 does proper physics simulation "silently"

➥ You have to add a bit of code **to extract information useful to you**

There are two ways:

❶ Use user hooks (**G4UserTrackingAction, G4UserSteppingAction**, etc.)

☛ You have full access to almost all information

☛ Straight-forward, but do-it-yourself

❷ Use Geant4 scoring functionality

☛ Assign **G4VSensitiveDetector** to a volume i.e. make it a detector !

☛ It is based on **Hits**, a snapshot of the physical interaction of a track or an accumulation of interactions of tracks in the sensitive (or interested) part of your detector.

☛ Hits collection is automatically stored in **G4Event** object, and automatically accumulated if user-defined Run object is used.

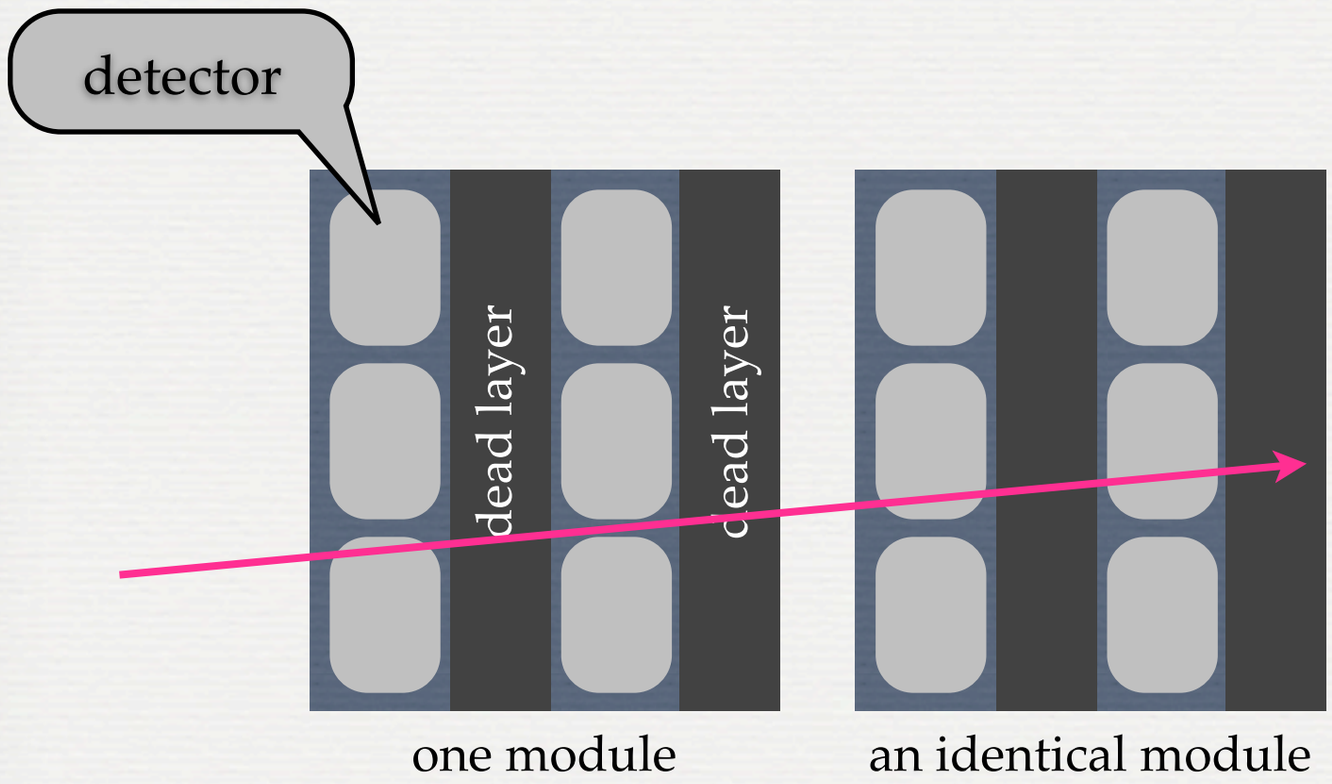
☛ Use user hooks (**G4UserEventAction**, **G4UserRunAction**) to get event / run summary

+ **G4Digi**, **G4DigitizerModule** ... the electronic chain could be emulated !

Mapping in Geant4: touchable

As any real detector, a mapping is required to know where things happen

➥ Done using the **copy#** which is set at the **G4VPhysicalVolume** level




```
aphysiBox = new G4PVPlacement(
                    0,
                   G4ThreeVector(X_C, Y_C, Z_C),
                    alogicBox,
                    "PBlueCube",
                    logicWorld,
                    false,
                    0); // THIS IS the copy number !
```

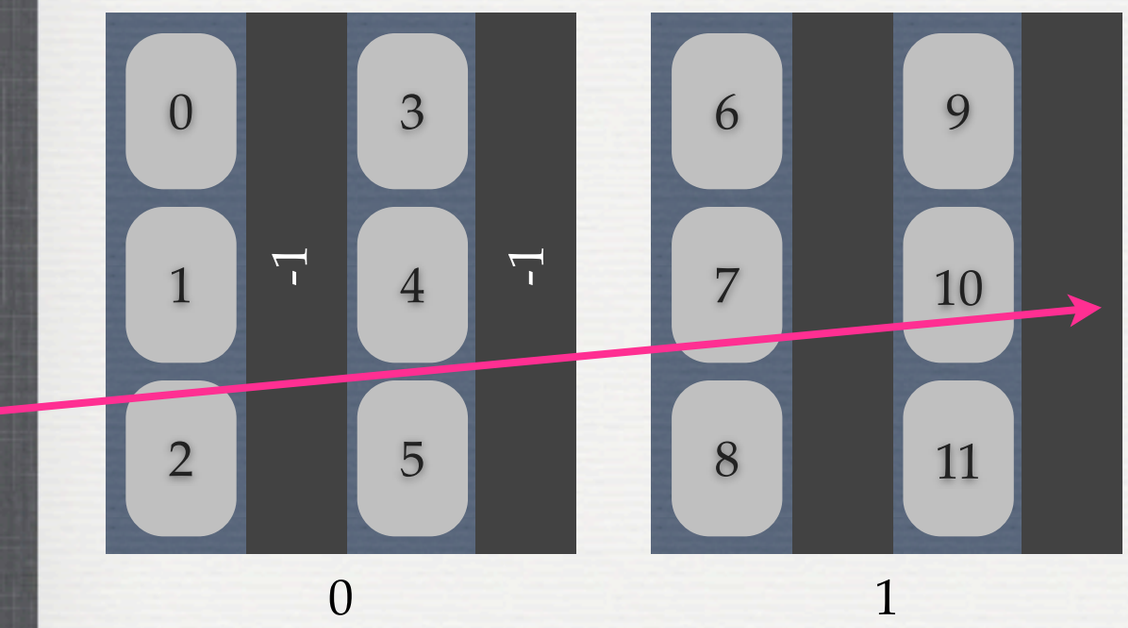
The **copy#** is configurable by the user [collaboration policy]

Note: **G4PVDivision, ...** deal internally with **copy #**,

➥ to see whether or not it fits the user's requirements

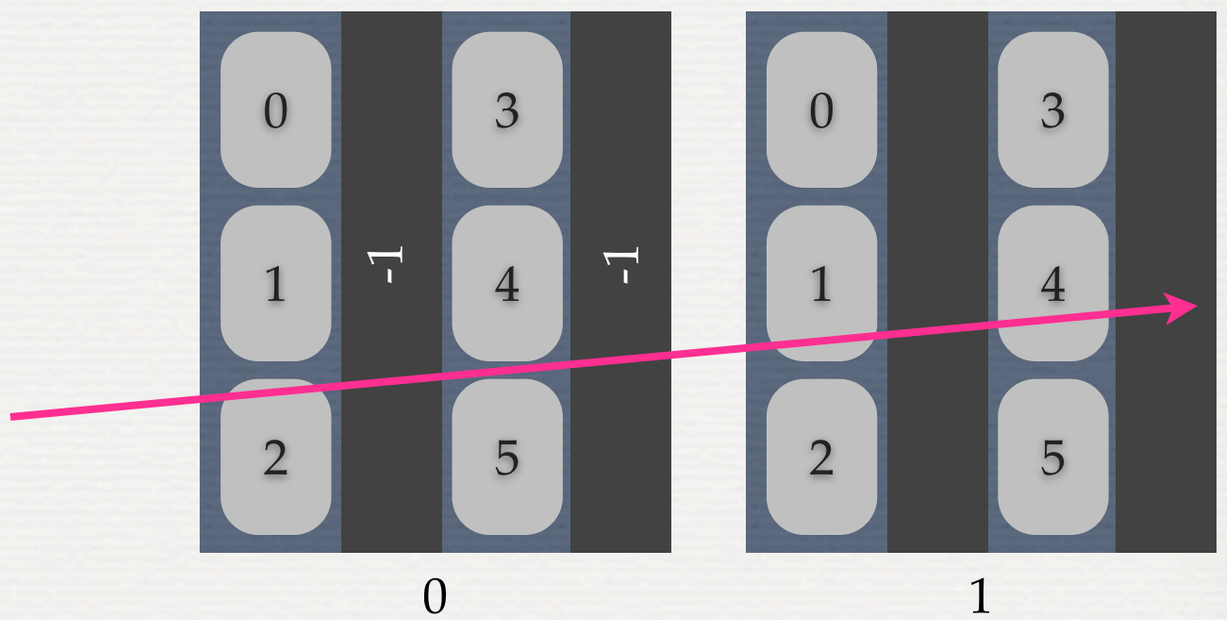
Mapping in Geant4: touchable

There are many different possibilities



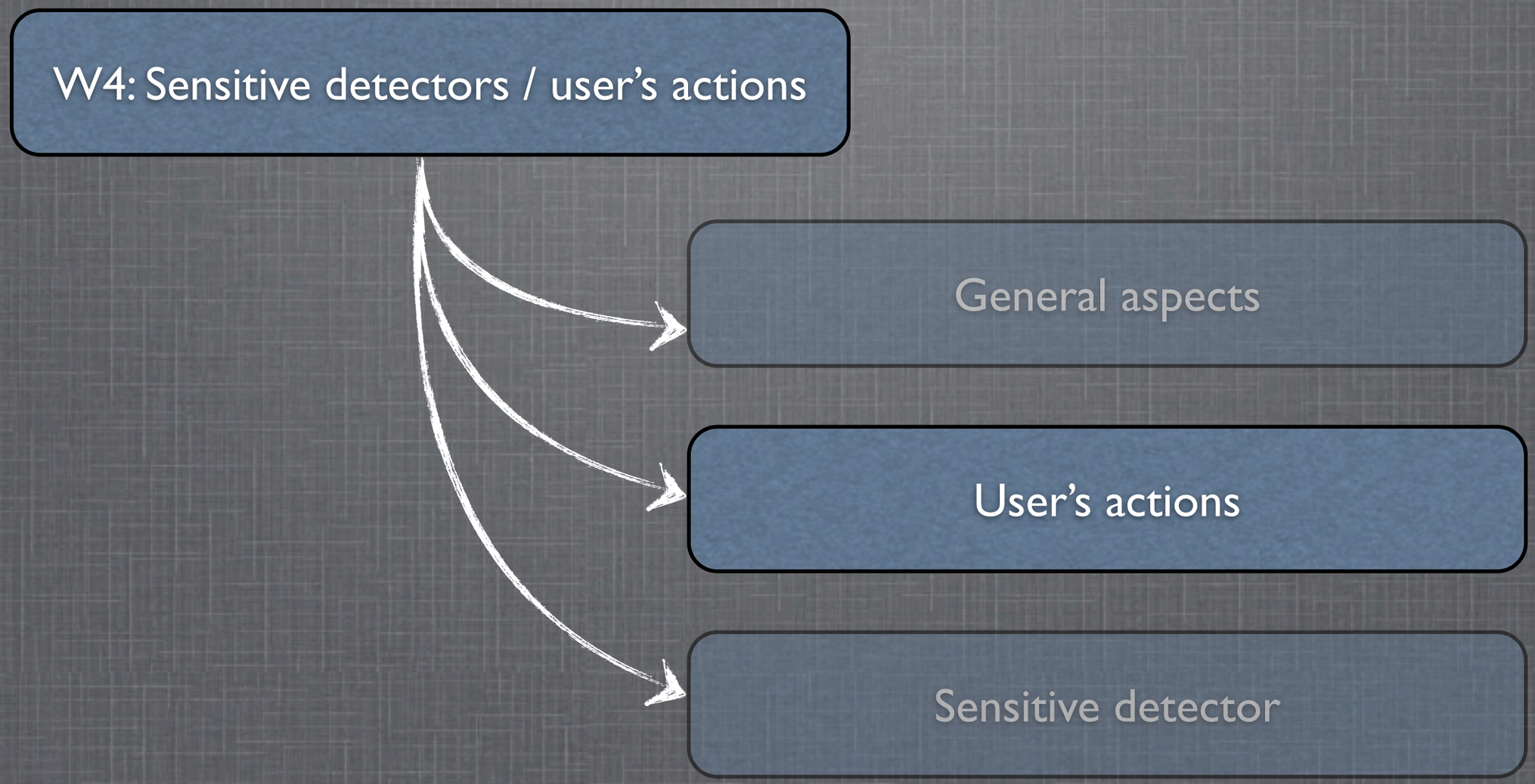
The particle goes through 2 ☛ 7 ☛ 10

a unique copy#
per detectors



The particle goes through 0:2 ☛ 1:1 ☛ 1:4

One has to deal with
sequences of numbers.
For that G4 provides
G4TouchableHistory


W4: Sensitive detectors / user's actions
General aspects
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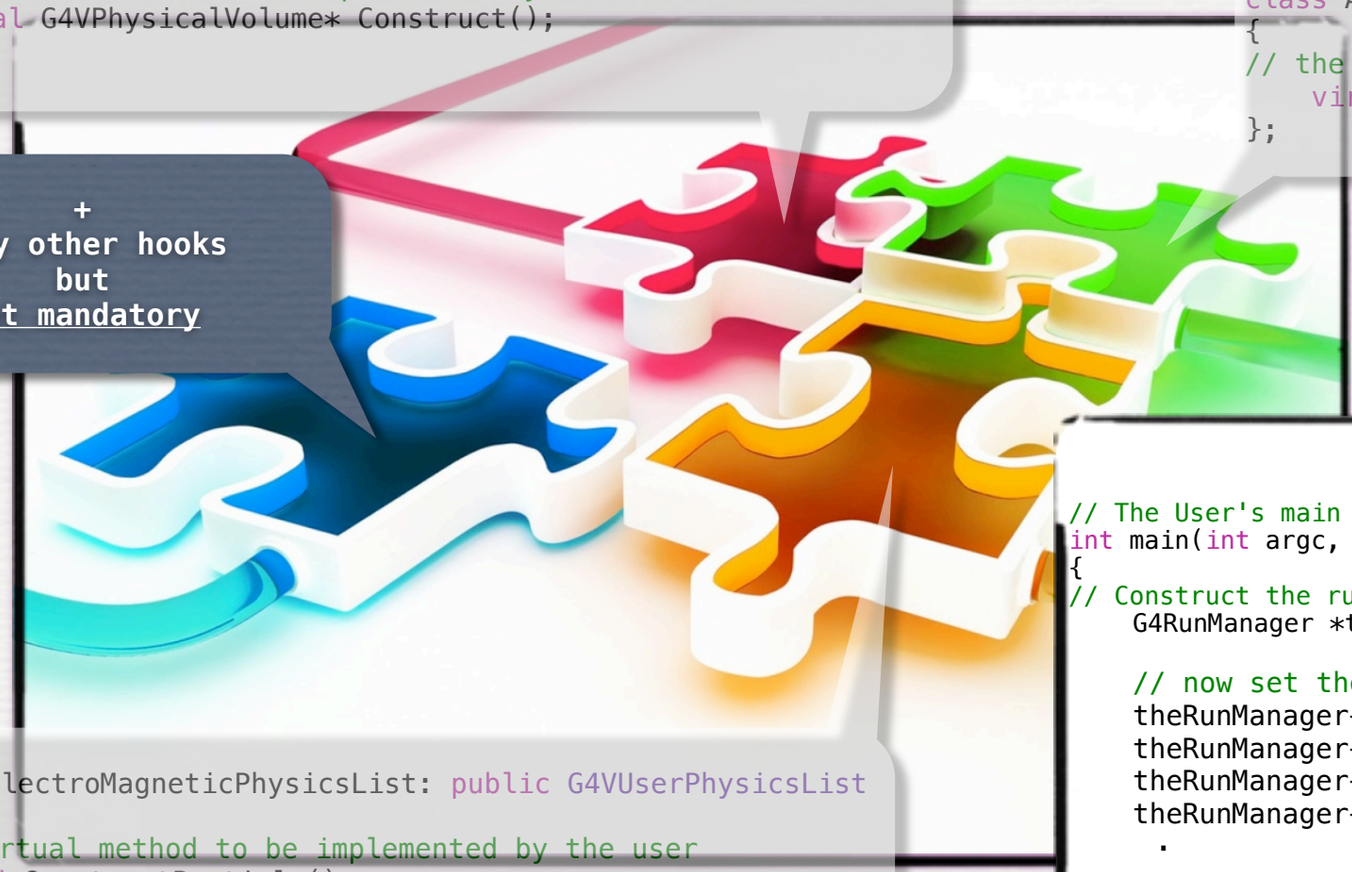
The user's application

Building an application requires to put together 3 mandatory bricks*

the detector construction - the description of the physics - the primary generator

```
class ARedSphereConstruction : public G4VUserDetectorConstruction
{
// the virtual method to be implemented by the user
    virtual G4VPhysicalVolume* Construct();
};
```

```
class AGammaGun : public G4VUserPrimaryGeneratorAction
{
// the virtual method to be implemented by the user
    virtual void GeneratePrimaries(G4Event* anEvent);
};
```



+
many other hooks
but
not mandatory

```
class AnElectroMagneticPhysicsList: public G4VUserPhysicsList
{
// the virtual method to be implemented by the user
     void ConstructParticle();
// the virtual method to be implemented by the user
     void ConstructProcess();
// the virtual method to be implemented by the user
     void SetCuts();
};
```

```
// The User's main program to control / run simulations
int main(int argc, char** argv)
{
// Construct the run manager, necessary for G4 kernel to control everything
    G4RunManager *theRunManager = new G4RunManager();

    // now set the others user actions
    theRunManager->SetUserAction( new MyRunAction() );
    theRunManager->SetUserAction( new MyEventAction() );
    theRunManager->SetUserAction( new MyTrackingAction() );
    theRunManager->SetUserAction( new MySteppingAction() );
      .
      .
    return 0;
}
```

User's hooks to extract information

G4UserXXXAction should be defined by the user
Where are they called, what is provided by Geant4 ...

Where are they called in the G4 loop ?

Start run # 1 :
  Start event # i
    Start track # j
      Start step # k

      Stop step # k
    Stop track # j
  Stop event # i
Stop run # 1

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Start track # j

Start step # k

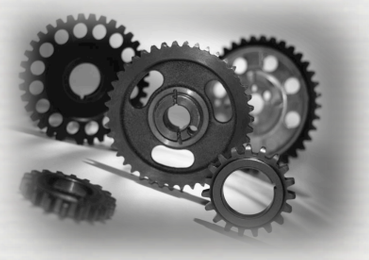
Stop step # k

Stop track # j

Stop event # i

Stop run # 1

```
class MyRunAction : public G4UserRunAction
{
public:
    virtual void BeginOfRunAction(const G4Run *therun);
    virtual void EndOfRunAction(const G4Run *therun);
};
```



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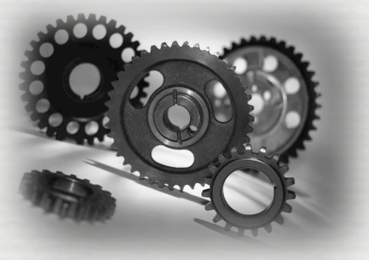

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};
```

```
class MyTrackingAction : public G4UserTrackingAction
{
public:
    virtual void PreUserTrackingAction(G4Track *track);
    virtual void PostUserTrackingAction(G4Track *track);
};
```

User's hooks to extract information

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```

```
class MyTrackingAction : public G4UserTrackingAction
{
public:
    virtual void PreUserTrackingAction(G4Track *track);
    virtual void PostUserTrackingAction(G4Track *track);
};
```

```
class MySteppingAction : public G4UserSteppingAction
{
public:
   virtual void UserSteppingAction(const G4Step *step) ;
};
```

The user's application

TODO List

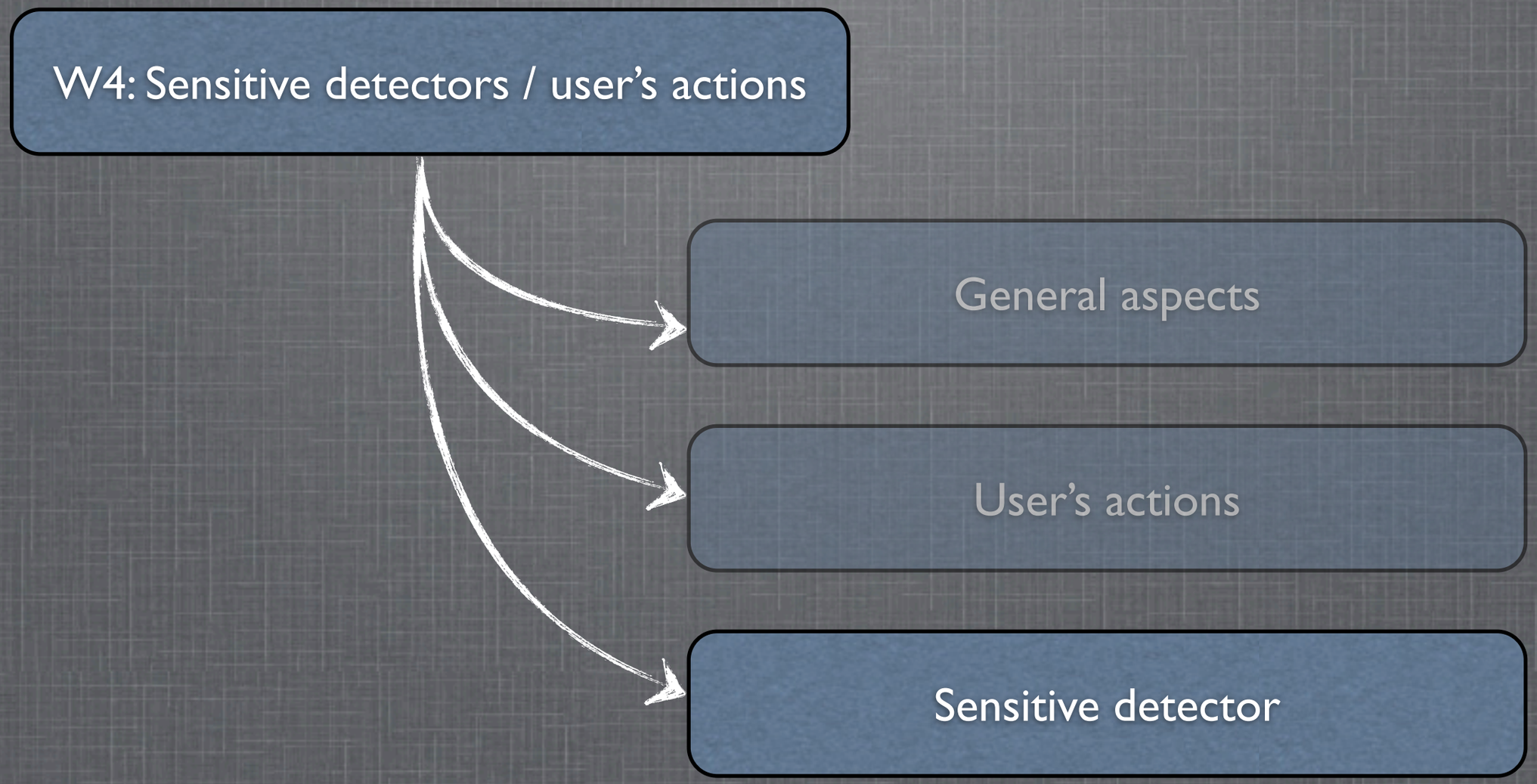
Write your Run, Event, Tracking and Stepping Action. Run adding one by one.

In the RunAction, print out:
- begin - it is starting *[and the world's name]*
- end - the run ID and the number of simulated events

In the EventAction, print out:
- begin - it starts every N (=10) events
- end - it ends + the number of primary vertexes

In the TrackingAction, print out:
- begin - the track ID, the parent ID and what is tracked
- end - the current volume name, total and kinetic energy, velocity

In the SteppingAction, print out:
- the step length if it is the first step in a volume


W4: Sensitive detectors / user's actions
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Sensitive detector - principle

Goal: avoid going into tracking/stepping details for the user

Mechanism:

❶ attach to a volume a sensitivity

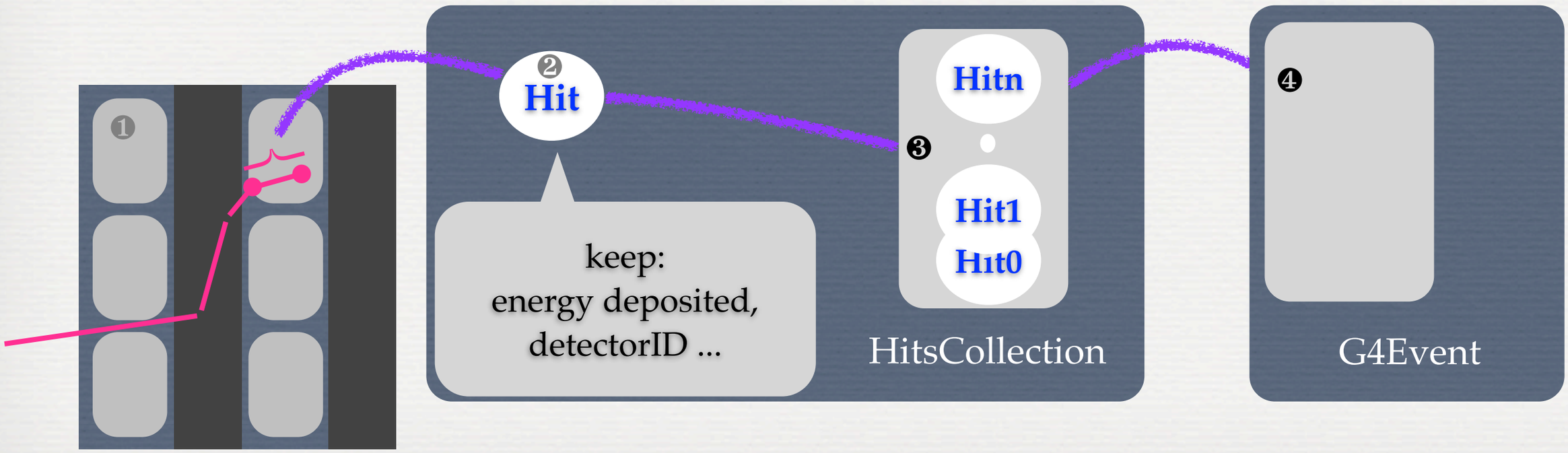
❷ at any step in it keep the required information in a hit

❸ push it on a stack [in a collection]

❹ the list of hits is available in the G4Event

➥ retrieve info at the EndOfEventAction

classes defined by the user



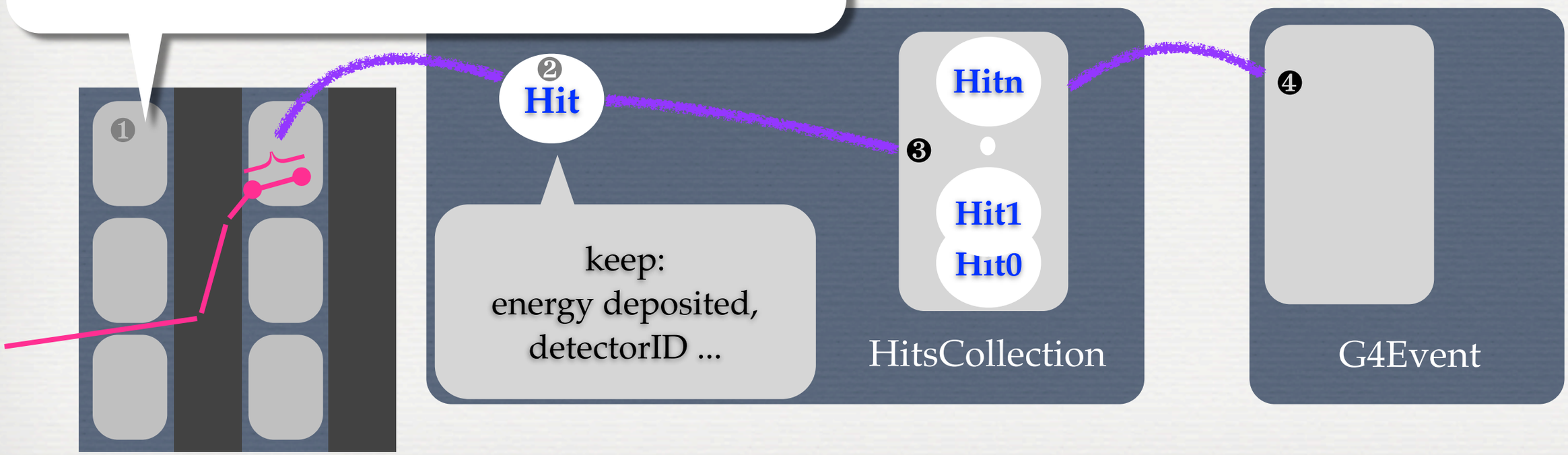
Sensitive detector, implementation

A sensor is added to the SD manager & a logical volume

```
// Now add a blue cube to the world
 asolidBox = new G4Box("BlueCube",Side/2.,Side/2.,Side/2.);
 alogicBox =
    new G4LogicalVolume(asolidBox, CubeMaterial, "LBlueCube", 0, 0, 0);

 // the cube is blue
 visatt = new G4VisAttributes( G4Colour(0.0, 0.0, 1.0) );
 visatt->SetVisibility(true);
 alogicBox->SetVisAttributes( visatt );
 // and is a sensitive detector of type MySD
 MySD *sd = new MySD(SDname="/MySD");
 G4SDManager* SDman = G4SDManager::GetSDMpointer();
 SDman->AddNewDetector(sd);
 alogicBox->SetSensitiveDetector(sd);


aphysiBox = new G4PVPlacement( ... )
```



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aphysiBox = new G4PVPlacement( ... )
```

```
#include "G4VSensitiveDetector.hh"
#include "MySingleHit.hh"

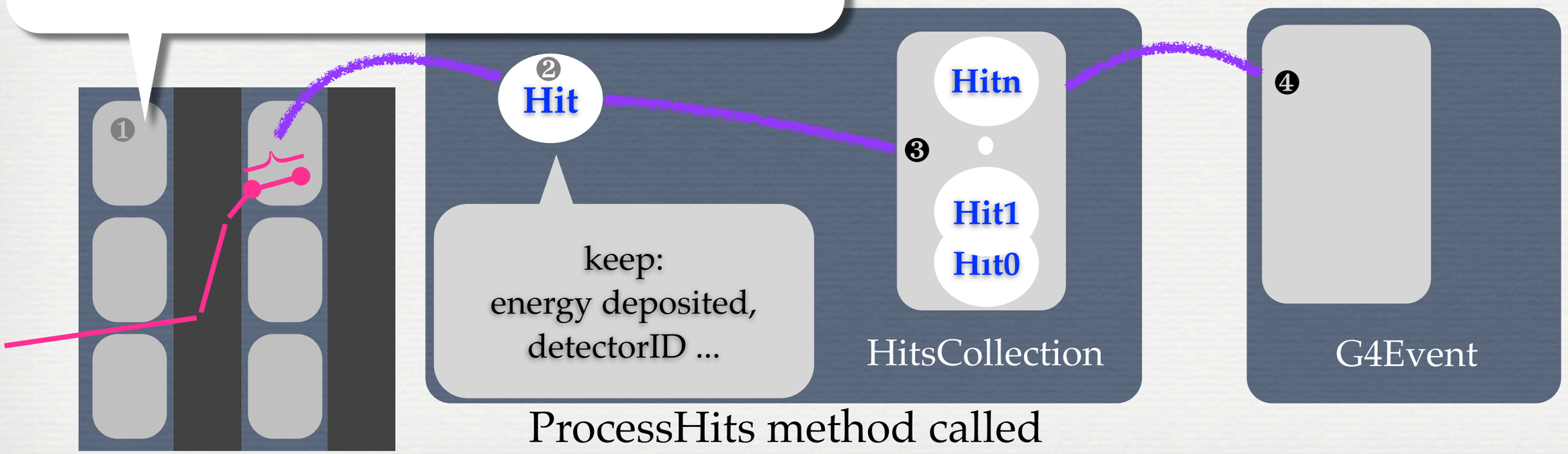
class G4Step;
class G4HCofThisEvent;
class G4TouchableHistory;

class MySD : public G4VSensitiveDetector
{
      MySD(G4String name = "/MySD");

      void Initialize(G4HCofThisEvent *HCE);
      G4bool ProcessHits(G4Step *aStep, G4TouchableHistory *hist);
      void EndOfEvent(G4HCofThisEvent *HCE);

private:
      MyHitsCollection *myCollection;
};
```

to be implemented by the user



ProcessHits method called

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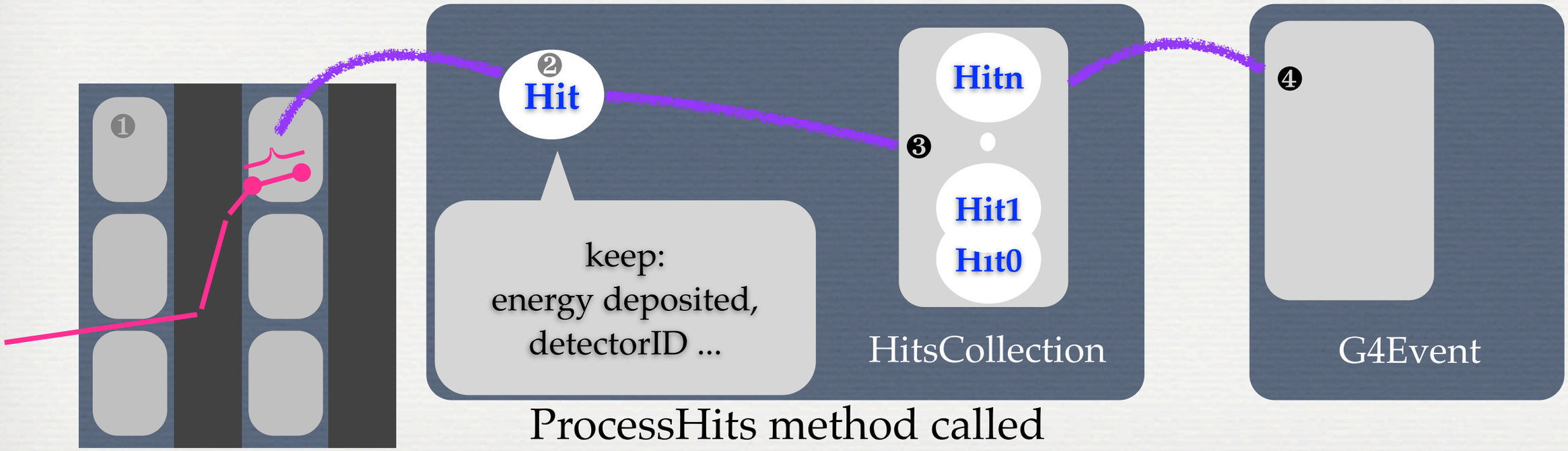

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      G4bool ProcessHits(G4Step *aStep, G4TouchableHistory *hist);
      void EndOfEvent(G4HCofThisEvent *HCE);

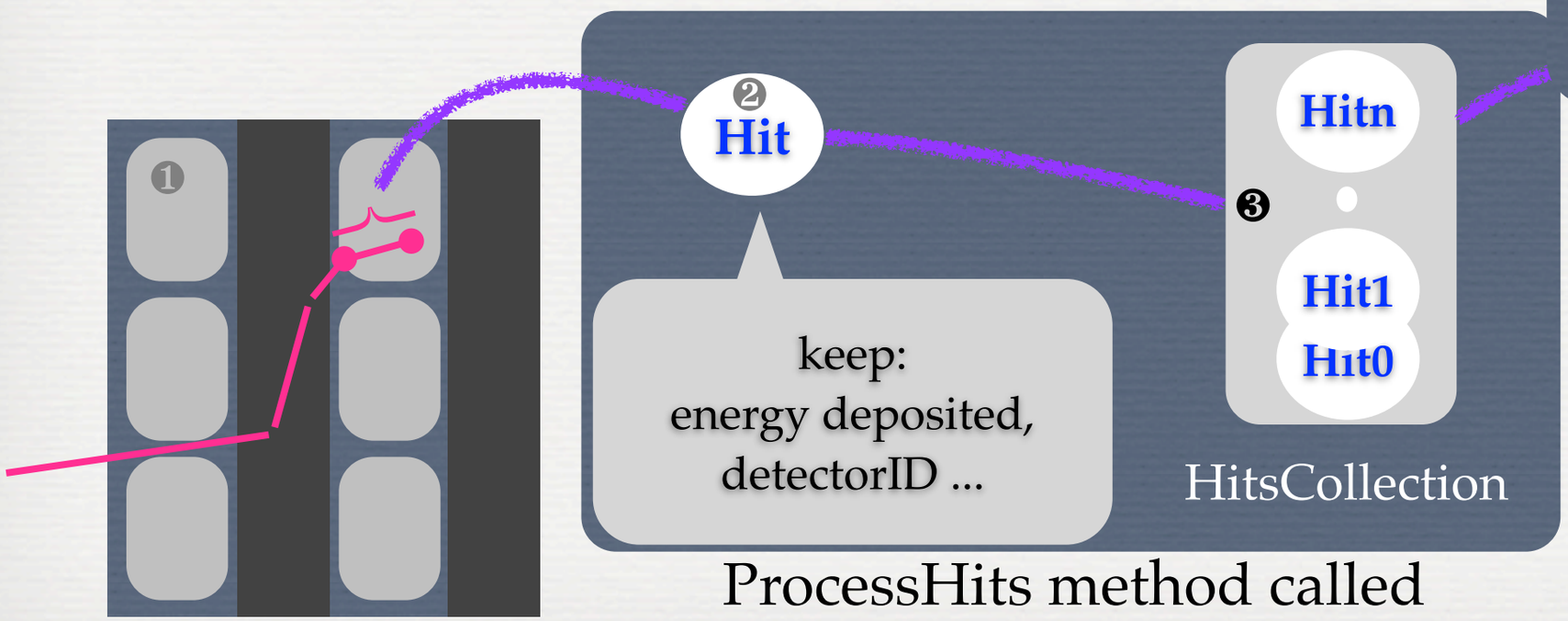
private:
      MyHitsCollection *myCollection;
};
```

```
class MyHit : public G4VHit
{
public:
   G4double eDep;
   G4int detID;

   inline void *operator new(size_t);
   inline void operator delete(void *aHit);
...
};

typedef G4THitsCollection<MyHit> MyHitsCollection;
extern G4Allocator<MyHit> MyHitAllocator;
inline void* MyHit::operator new(size_t)
{
  void *aHit = (void *) MyHitAllocator.MallocSingle(); return aHit;
}
inline void ParisSingleHit::operator delete(void *aHit)
{
  MyHitAllocator.FreeSingle((MyHit*) aHit);
}
```

G4 utilities for efficient memory management



ProcessHits method called

Sensitive detector, implementation

❷ ❸

```
MySD::MySD(G4String name): G4VSensitiveDetector(name)
{
    G4String HCname = "myHitCollection"; collectionName.insert(HCname);
}
void MySD::Initialize(G4HCofThisEvent* HCE)
{
    static int HCID = -1; myCollection = new MyHitsCollection(SensitiveDetectorName,collectionName[0]);
    if ( HCID < 0 )
           HCID = GetCollectionID(0);
    HCE->AddHitsCollection(HCID,myCollection);
}
G4bool ParisTrackerSD::ProcessHits(G4Step* aStep, G4TouchableHistory * /*touch*/)
{
    // nothing to be stored if no energy
    G4double edep = aStep->GetTotalEnergyDeposit();
    if ( edep == 0. ) {
           return false;
    }
    // a new hit is created
    MySingleHit *newHit = new MySingleHit();
    newHit->Edep  = edep;
    newHit->detID
     = aStep->GetTrack()->GetVolume()->GetCopyNo();

    // add this hit to the collection
    myCollection->insert( newHit );

    return true;
}
void MySD::EndOfEvent(G4HCofThisEvent*){;}
```

ProcessHits method called

Sensitive detector, implementation

❷ ❸

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    newHit->Edep  = edep;
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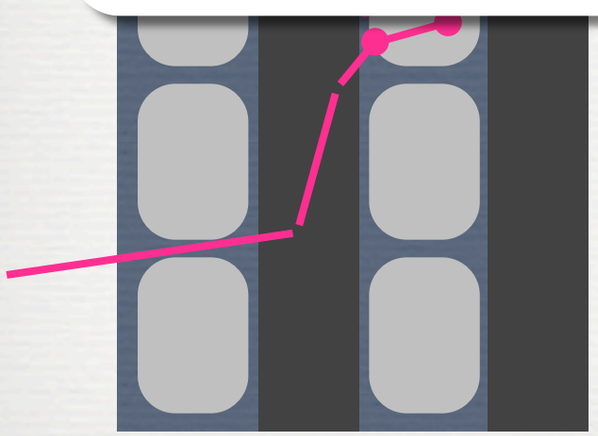
    // add this hit to the collection
    myCollection->insert( newHit );

    return true;
}
void MySD::EndOfEvent(G4HCofThisEvent*){;}
```

```
void MyEventAction::EndOfEventAction(const G4Event *evt)
{
    MyHitsCollection *THC = NULL;

    // to get back my collection
    G4HCofThisEvent * HCE = evt->GetHCofThisEvent();
    if (HCE) {
          THC = (MyHitsCollection *)(HCE->GetHC(0));
    }
    if ( THC ) {
          int n_hit = THC->entries();
          for (int i = 0 ; i < n_hit; i++) {
               MyHit *hit= (*THC)[i];
               G4cout << hit->eDep << " " <<  hit->detID << G4cout;
          }
    }
}
```

❹



keep:
energy deposited,
detectorID ...

HitsCollection

G4Event

ProcessHits method called

Sensitive detectors provided

A general concrete sensitive detector **G4MultiFunctionalDetector*** exists

It is a collection of **G4VPrimitiveScorer**

➥ a **G4VPrimitiveScorer** class accumulates one physics quantity for each physical volume. Ex:

Track length: **G4PSTrackLength**, **G4PSPassageTrackLength**
Deposited energy: **G4PSEnergyDeposit**, **G4PSDoseDeposit**
Current/Flux: **G4PSFlatSurfaceCurrent**, **G4PSSphereSurfaceCurrent**, **G4PSPassageCurrent**
Others: **G4PSMinKinEAtGeneration**, **G4PSNofSecondary**, **G4PSNofStep**

Commands are available:

/score/dumpQuantityToFile - to dump the result in a CSV (column separated values) file

Geant4 also introduces **G4VSDFilter** to filter what kind of tracks is to be considered by sensitivity. Ex, Accepts:

only charged/neutral tracks: **G4SDChargedFilter**, **G4SDNeutralFilter**
tracks within the defined range of kinetic energy: **G4SDKineticEnergyFilter**
tracks of registered particle types: **G4SDParticleFilter**
tracks of registered particle types within defined range of kinetic: **G4SDParticleWithEnergyFilter**

* it inherits from **G4VSensitiveDetector**

The user's application

TODO List

- The files containing the definition of aHit and aTracker are provided see */group/formateurs/stezowski/utilities*

- Integrate them to your application, set the detectors sensitives
- Run, check how the hit collection is filled and how hits are retrieved

Conclusions of W4

We have seen:

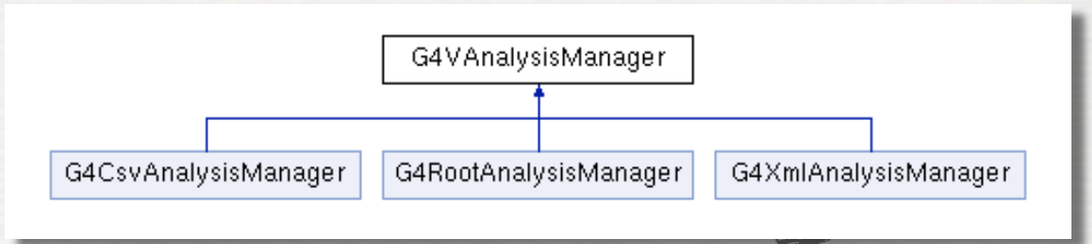
- how to extract information
  - ➥ using user's hooks
  - ➥ using the detector sensitivity

- There are more advanced levels:
  - ➥ notion of analysis manager: **G4VAnalysisManager**
  - ➥ one can implement new **G4VAnalysisManager**
  - ➥ one can implement new **G4VPrimitiveScorer**
  - ➥ one can play with **G4VUserXXXInformation***
  - ➥ ...

* XXX being Run, Event, etc ...

Conclusions of W4

We have seen:



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