



# Geant4: A Simulation toolkit

O. Stézowski and I. Companis

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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:

① Use user hooks (**G4UserTrackingAction**, **G4UserSteppingAction**, etc.)

- You have full access to almost all information
- Straight-forward, but do-it-yourself

② 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 !

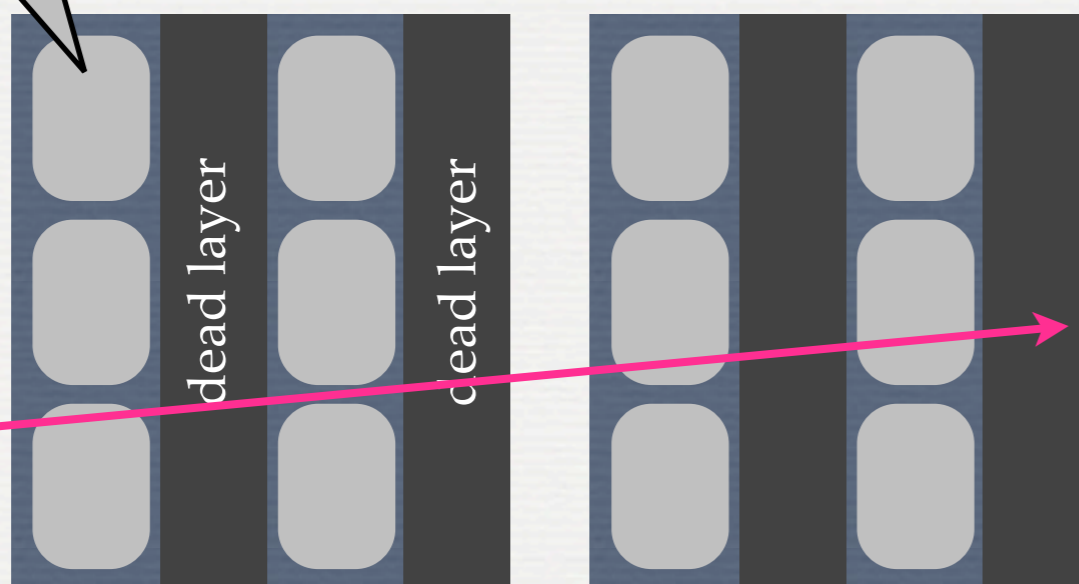


# Mapping in Geant4: touchable

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

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

detector



one module

an identical module

```
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]

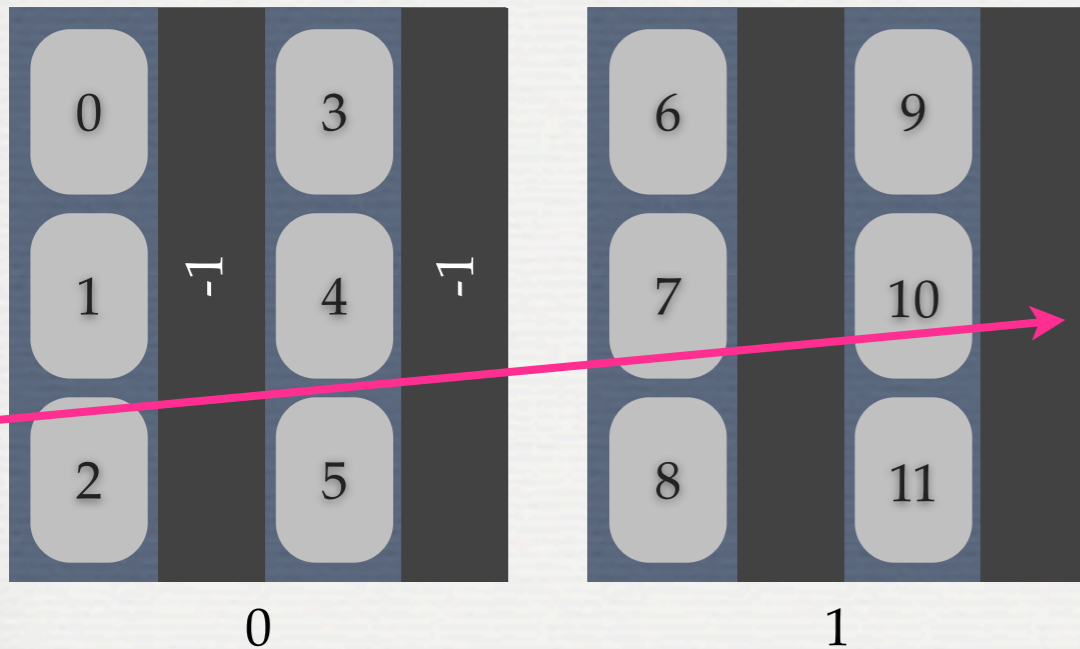
Note: **G4PVDivision, ...** deal internally with **copy #**,

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



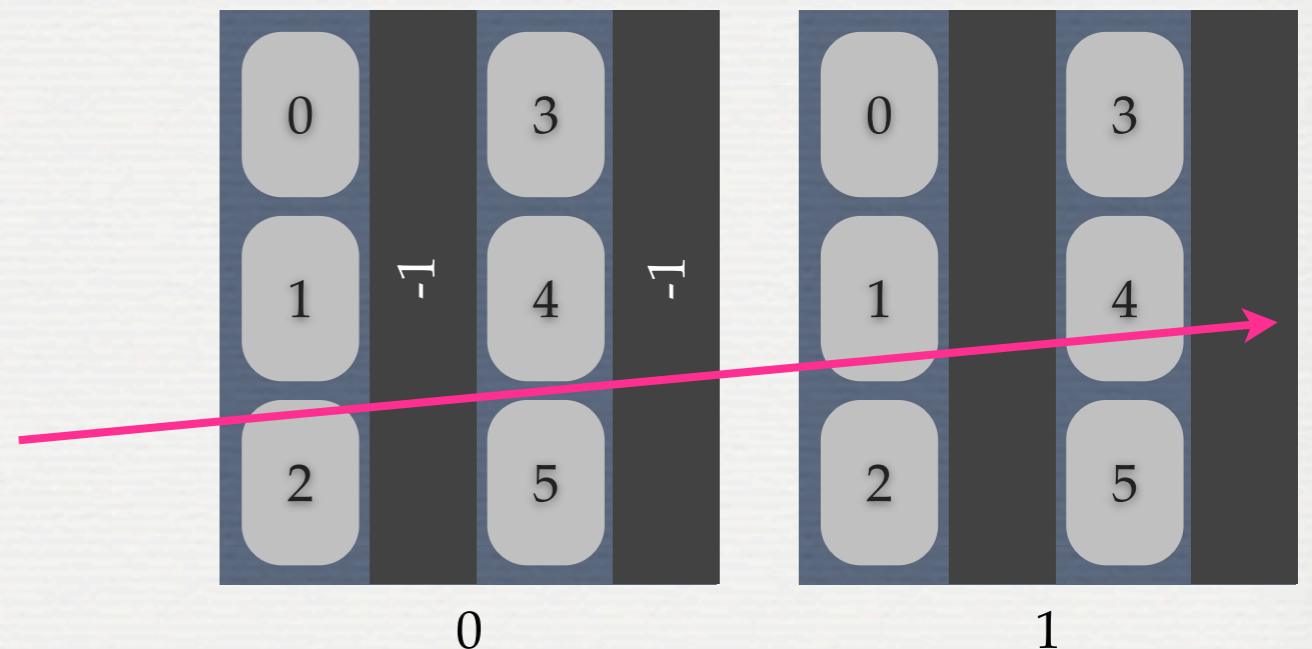
# Mapping in Geant4: touchable

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**

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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();
};
```

+  
many other hooks  
but  
not mandatory

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

```
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 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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class MyEventAction : public G4UserEventAction
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    virtual void BeginOfEventAction(const G4Event *event);
    virtual void EndOfEventAction(const G4Event *event);
};
```

```
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

General aspects

User's actions

Sensitive detector

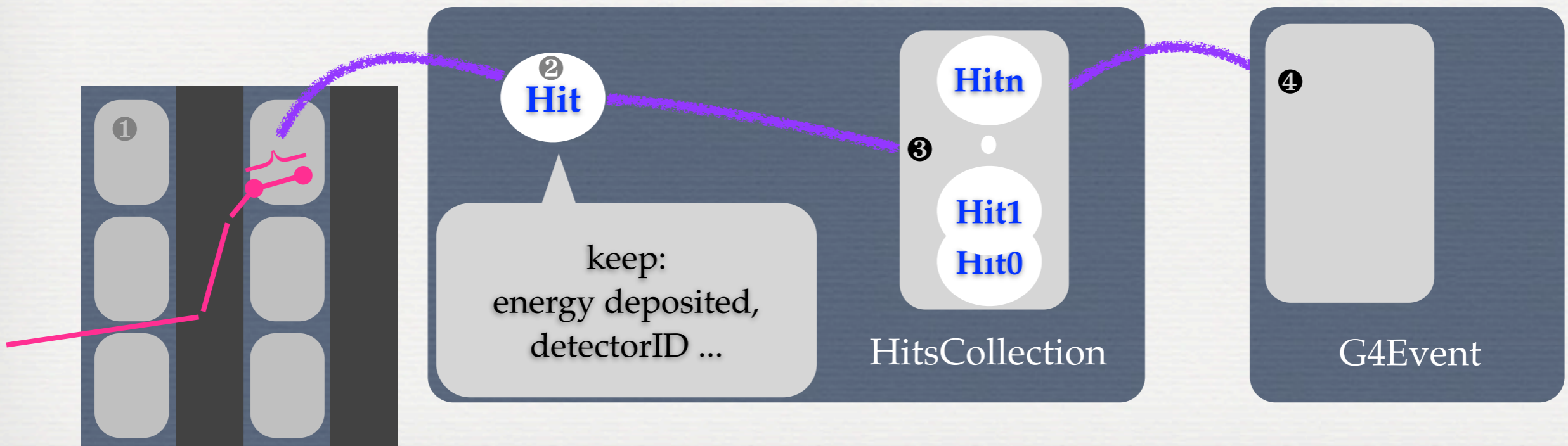


# Sensitive detector - principle

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

Mechanism:

- ① attach to a volume a sensitivity classes defined by the user
  - ② at any step in it keep the required information in a hit
  - ③ push it on a stack [in a collection]
  - ④ the list of hits is available in the G4Event
- ➔ retrieve info at the EndOfEventAction







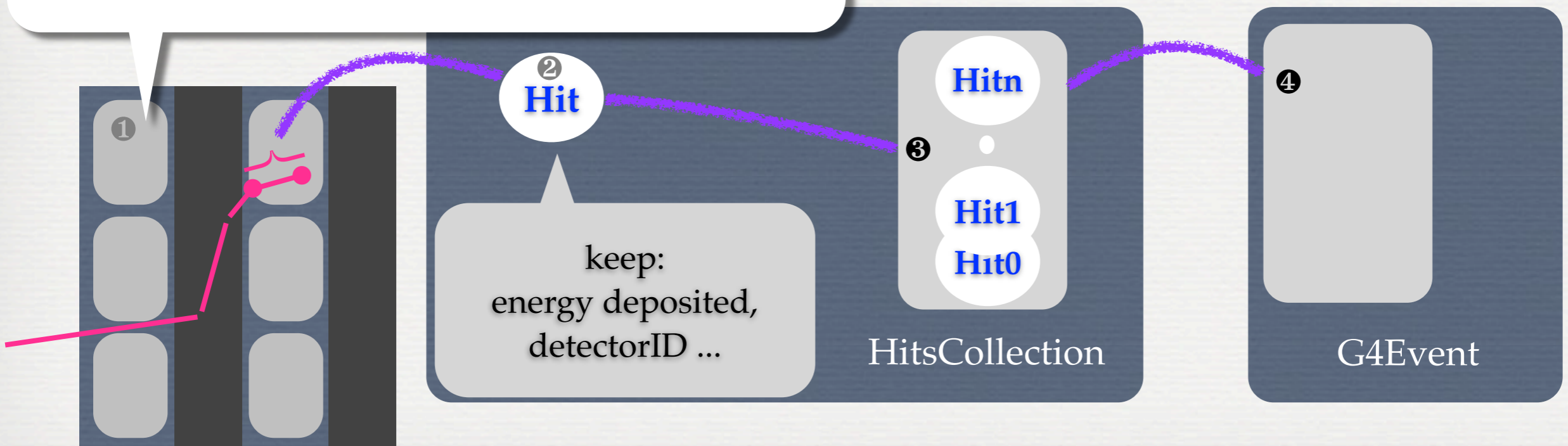
# Sensitive detector, implementation

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( ... )
```





# Sensitive detector, implementation

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G4SDManager* SDman = G4SDManager::GetSDMpointer();
SDman->AddNewDetector(sd);
alogicBox->SetSensitiveDetector(sd);

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

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

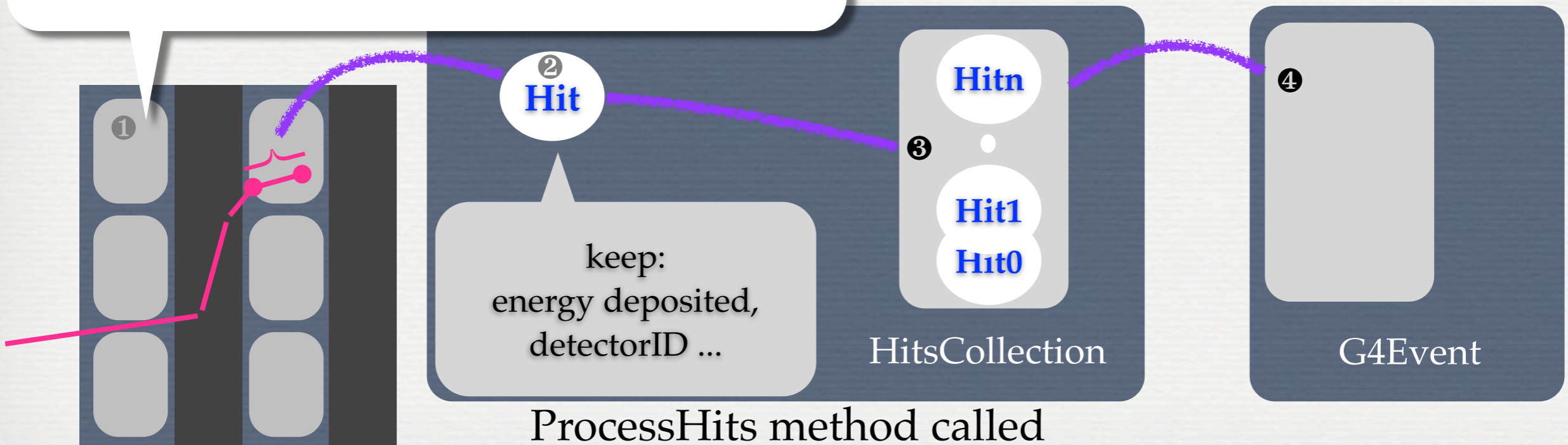
class G4Step;
class G4HCofThisEvent;
class G4TouchableHistory;

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





# Sensitive detector, implementation

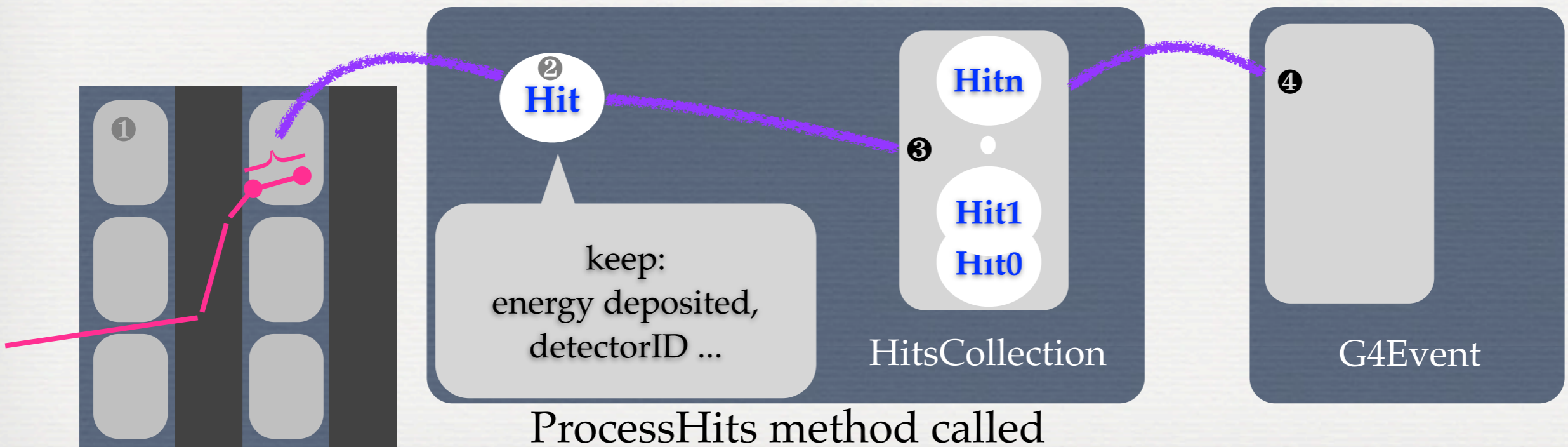
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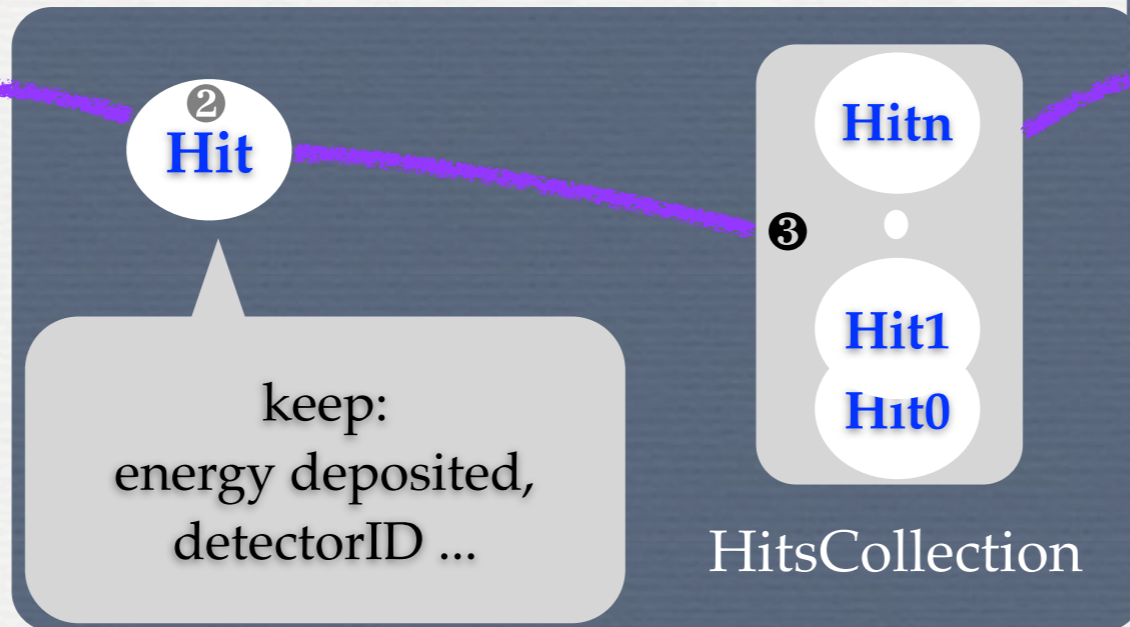
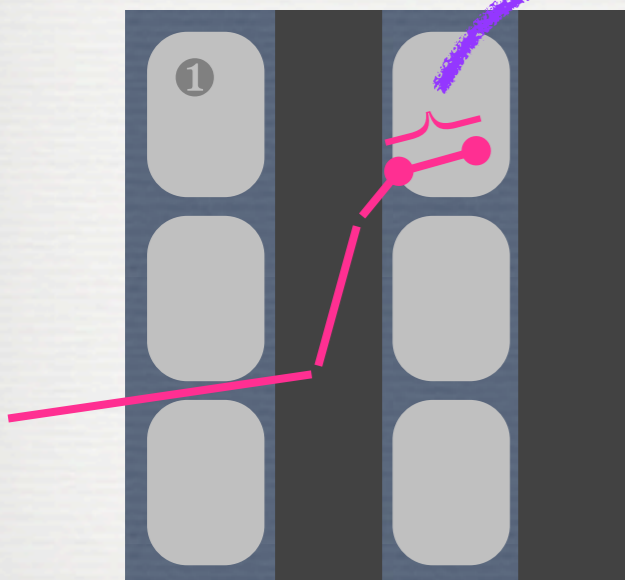
private:
    MyHitsCollection *myCollection;
};
```

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

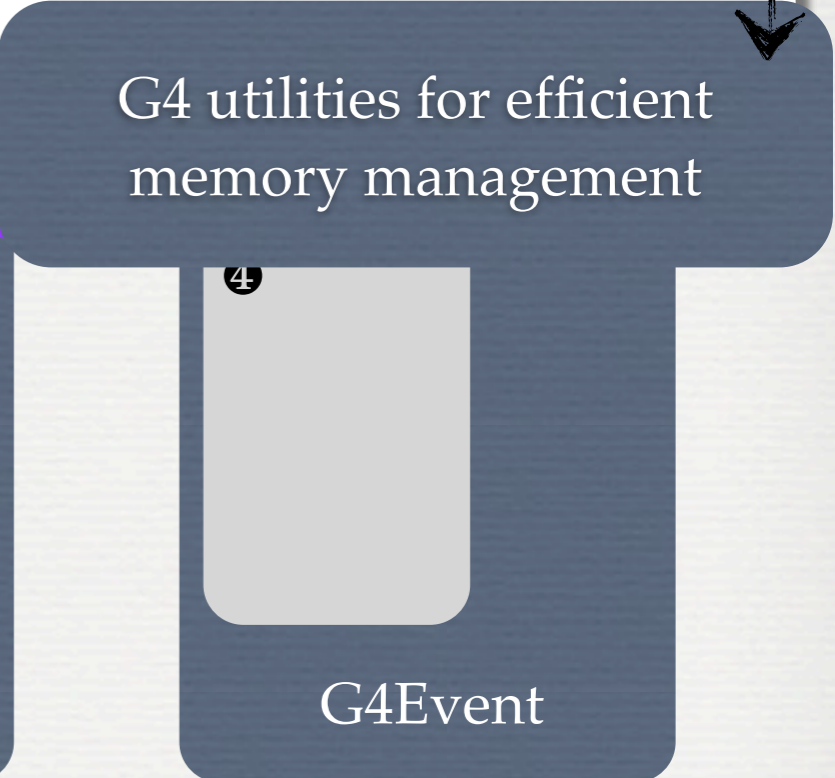
    inline void *operator new(size_t);
    inline void operator delete(void *aHit);

    ...
};

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);
}
```



ProcessHits method called





# Sensitive detector, implementation

```
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*){;}
```

2 3

4

keep:  
energy deposited,  
detectorID ...

Hit1  
Hit0

HitsCollection

G4Event

ProcessHits method called



# Sensitive detector, implementation

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    static int HCID = -1; myCollection = new MyHitsCollection(SensitiveDetectorName, collectionName[0]);
    if ( HCID < 0 )
        HCID = GetCollectionID(0);
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    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*){};
```

2 3

```
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;
        }
    }
}
```

4

keep:  
energy deposited,  
detectorID ...

Hit0

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\***
  - ↳ ...

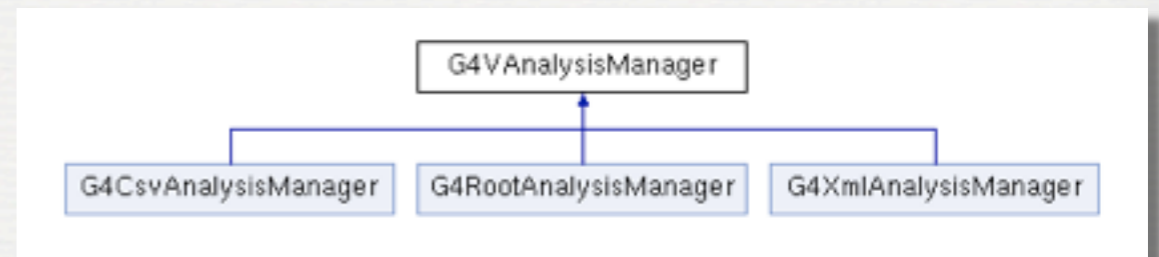
\* XXX being Run, Event, etc ...



# Conclusions of W4

We have seen:

- 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**
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  - ➔ one can play with **G4VUserXXXInformation\***
  - ➔ ...

\* XXX being Run, Event, etc ...