Interaction with the GEANT4 kernel – part 2

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Part I: Sensitive Detectors

Sensitive Detector (SD)

- A logical volume becomes sensitive if it has a pointer to a **sensitive detector** (`G4VSensitiveDetector`)
  - A sensitive detector can be instantiated several times, where the instances are assigned to different logical volumes
    - Note that SD objects must have *unique detector names*
    - A logical volume can **only** have **one SD object attached** (But you can implement your detector to have many functionalities)
- Two possibilities to make use of the SD functionality:
  - Create your own sensitive detector (using class inheritance)
    - Highly **customizable**
  - Use Geant4 built-in tools: Primitive scorers

Adding sensitivity to a logical volume

- Create an instance of a sensitive detector and register it to the SensitiveDetector Manager
- Assign the pointer of your SD to the logical volume of your detector geometry
- Must be done in `ConstructSDandField`() of the user geometry class

```
G4VSensitiveDetector* mySensitive
   = new MySensitiveDetector(SDname="/MyDetector");
```

} create instance

```
G4SDManager* sdMan =G4SDManager::GetSDMpointer();
sdMan->AddNewDetector(mySensitive);
```

} Register to the SD manager

```
SetSensitiveDetector("LVname",mySensitive);
```

} assign to logical volume

Name of the logical volume

Adding sensitivity to a logical volume - variant

- Create an instance of a sensitive detector and register it to the SensitiveDetector Manager
- Assign the pointer of your SD to the logical volume of your detector geometry
- Must be done in `ConstructSDandField`() of the user geometry class

```
G4VSensitiveDetector* mySensitive
   = new MySensitiveDetector(SDname="/MyDetector");
```
} create instance

```
G4SDManager* sdMan =G4SDManager::GetSDMpointer();
sdMan->AddNewDetector(mySensitive);
```
} Register to the SD manager

```
logicVol->SetSensitiveDetector(mySensitive);
```
} assign to logical volume

Pointer of the logical volume

Part II: Native Geant4 scoring

Extract useful information

- Geant4 provides a number of **primitive scorers**, each one accumulating one physics quantity (e.g. total dose) for an event
- This is alternative to the **customized** sensitive detectors (not shown in this course), which can be used with full flexibility to gain complete control
- It is convenient to use primitive scorers instead of user-defined sensitive detectors when:
  - you are not interested in recording each individual step, but accumulating physical quantities for an event or a run
  - you have not too many scorers

G4MultiFunctionalDetector

- `G4MultiFunctionalDetector` is a concrete class derived from `G4VSensitiveDetector`
- It should be **assigned to a logical volume** as a **kind of** (ready-for-the-use) **sensitive detector**
- It takes an arbitrary number of `G4VPrimitiveScorer` classes, to define the scoring quantities that you need
  - Each `G4VPrimitiveScorer` accumulates one physics quantity for each physical volume
  - E.g. `G4PSDoseScorer` (a concrete class of `G4VPrimitiveScorer` provided by Geant4) accumulates dose for each cell
- By using this approach, **no need to implement sensitive detector** and **hit classes**!

G4VPrimitiveScorer

- Primitive scorers (classes derived from **`G4VPrimitiveScorer`**) have to be registered to the **`G4MultiFunctionalDetector`**
  - **`->RegisterPrimitive()`**,
  - **`->RemovePrimitive()`**
- They are designed to **score one kind of quantity** (surface flux, total dose) and to **generate one hit collection** per event
  - automatically named as

`<MultiFunctionalDetectorName>/<PrimitiveScorerName>`

  - hit collections can be retrieved in the EventAction or RunAction (as those generated by sensitive detectors)
  - do not share the same primitive scorer object among multiple G4MultiFunctionalDetector objects (results may mix up!)
    - Create as many instances of the scorer as needed

```
myCellScorer/TotalSurfFlux
myCellScorer/TotalDose
```

For example ...

```
MyDetectorConstruction::ConstructSDandField()
{
   G4MultiFunctionalDetector* myScorer = new
   G4MultiFunctionalDetector("myCellScorer");

    myCellLog->SetSensitiveDetector(myScorer);

    G4VPrimitiveScorer* totalSurfFlux = new
       G4PSFlatSurfaceFlux("TotalSurfFlux");
    myScorer->RegisterPrimitive(totalSurfFlux);
    G4VPrimitiveScorer* totalDose =   new
       G4PSDoseDeposit("TotalDose");
    myScorer->RegisterPrimitive(totalDose);
}
```

instantiate multi-functional detector

attach to volume

create a primitive scorer (surface flux) and register it

create a primitive scorer (total dose) and register it

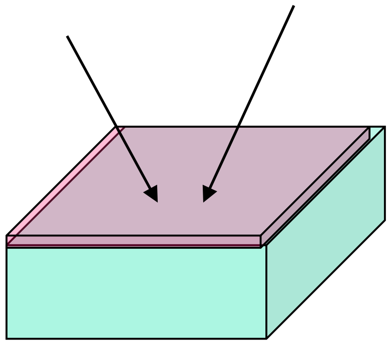
Some primitive scorers that you may find useful

- Concrete Primitive Scorers (→ Application Developers Guide 4.4.5)
  - Track length
    - G4PSTrackLength, G4PSPassageTrackLength
  - Deposited energy
    - G4PSEnergyDepsit, G4PSDoseDeposit
  - Current/Flux
    - G4PSFlatSurfaceCurrent, G4PSSphereSurfaceCurrent,G4PSPassageCurrent, G4PSFlatSurfaceFlux, G4PSCellFlux, G4PSPassageCellFlux
  - Others
    - G4PSMinKinEAtGeneration, G4PSNofSecondary, G4PSNofStep, G4PSCellCharge

A closer look at some scorers

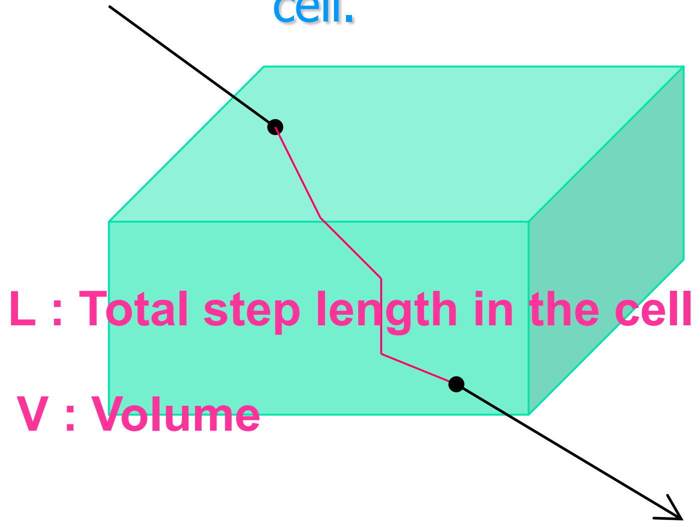
SurfaceCurrent :

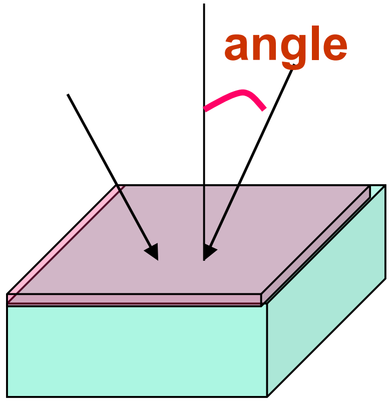
Count number of injecting particles at defined surface.



CellFlux :

Sum of L / V of injecting particles in the geometrical cell.





SurfaceFlux :

Sum up 1/cos(angle) of injecting particles at defined surface

V : Volume

G4VSDFilter

- A **`G4VSDFilter`** can be attached to **`G4VPrimitiveScorer`** to define **which kind of tracks** have to be scored (e.g. one wants to know surface flux of protons only)
  - **`G4SDChargeFilter`** (accepts only charged particles)
  - **`G4SDNeutralFilter`** (accepts only neutral particles)
  - **`G4SDKineticEnergyFilter`** (accepts tracks in a defined range of kinetic energy)
  - **`G4SDParticleFilter`** (accepts tracks of a given particle type)
  - **`G4VSDFilter`** (base class to create user-customized filters)

For example ...

```
MyDetectorConstruction::ConstructSDandField()
{
   G4VPrimitiveScorer* protonSurfFlux
   = new G4PSFlatSurfaceFlux("pSurfFlux");
    G4VSDFilter* protonFilter = new
      G4SDParticleFilter("protonFilter");
    protonFilter->Add("proton");

    protonSurfFlux->SetFilter(protonFilter);

    myScorer->RegisterPrimitive(protonSurfFlux);
}
```

create a primitive scorer (surface flux), as before

create a particle filter and add protons to it

register the filter to the primitive scorer

register the scorer to the multifunc detector (as shown before)

How to retrieve information - part 1

- At the end of the day, one wants to retrieve the information from the scorers
  - True also for the customized hits collection
- Each scorer creates a hit collection, which is attached to the **`G4Event`** object
  - Can be retrieved and read at the end of the event, using an integer ID
  - Hits collections mapped as **`G4THitsMap<G4double>*`** so can loop on the individual entries
  - Operator **`+=`** provided which automatically sums up all hits (no need to loop manually)

How to retrieve information - part 2

copyNb (key)

Quantity to be scored by the scorer (e.g. energy)

HCofThisEvent

	Scorer 1	Scorer 2
Event#1	(0, 5.32)	(0, 1.43) (2, 7.41)
Event#2	(1, 1.12)	(0, 1.11)
Event#3	*empty*	*empty*
…	…	…
Event#N	(0,7.12) (1,1.15)	(0, 2.0)

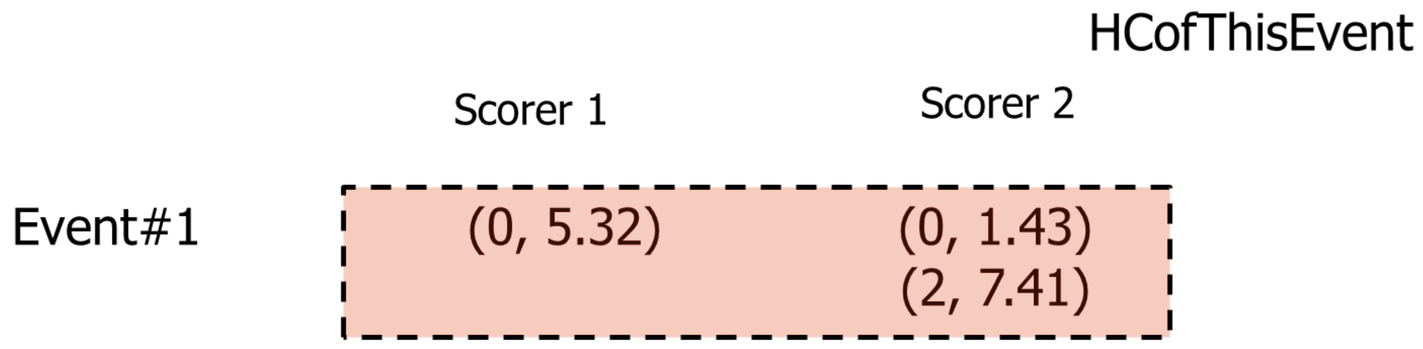
How to retrieve information – recipe

```
//needed only once
G4int collID = G4SDManager::GetSDMpointer()
   ->GetCollectionID("myCellScorer/TotalSurfFlux");
```

Get **ID** for the collection (given the name)

```
G4HCofThisEvent* HCE = event->GetHCofThisEvent();
```

Get **all HC** available in this event



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Get **ID** for the collection (given the name)

```
G4HCofThisEvent* HCE = event->GetHCofThisEvent();
```

Get **all HC** available in this event

```
G4THitsMap<G4double>* evtMap =
    static_cast<G4THitsMap<G4double>*>
    (HCE->GetHC(collID));
```

Get the HC with the **given ID** (need a cast)

HCofThisEvent

	Scorer 1	Scorer 2
Event#1	(0, 5.32)	(0, 1.43) (2, 7.41)

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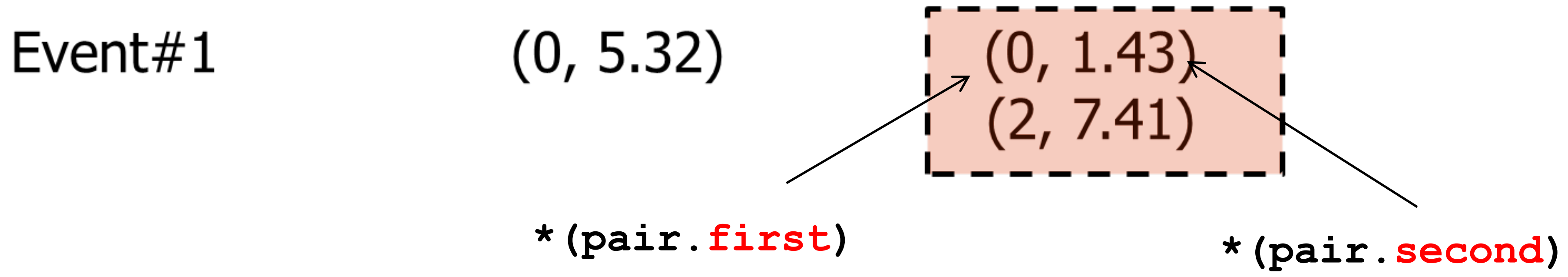
      (HCE->GetHC(collID));
```

Get the HC with the **given ID** (need a cast)

```
for (auto pair : *(evtMap->GetMap())) {
      G4double flux = *(pair.second);
      G4int copyNb  = *(pair.first);
}
```

Loop over the **individual entries** of the HC: the key of the map is the copyNb, the other field is the real content

How to retrieve information – recipe



```
for (auto pair : *(evtMap->GetMap())) {
    G4double flux = *(pair.second);
    G4int copyNb  = *(pair.first);
}
```

Loop1: copyNb = 0, value = 1.43
Loop2: copyNb = 2, value = 7.41

Hands-on session

- Task4
  - Task4c: Native scoring
- Task5 (*Optional*)
  - Very similar to 4c, but on medical physics

- **http://geant4.lngs.infn.it/belgrade2019/task4**
- **http://geant4.lngs.infn.it/belgrade2019/task5**

Backup

How to retrieve information – recipe

```
//needed only once
G4int collID = G4SDManager::GetSDMpointer()
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