Hits and Digits

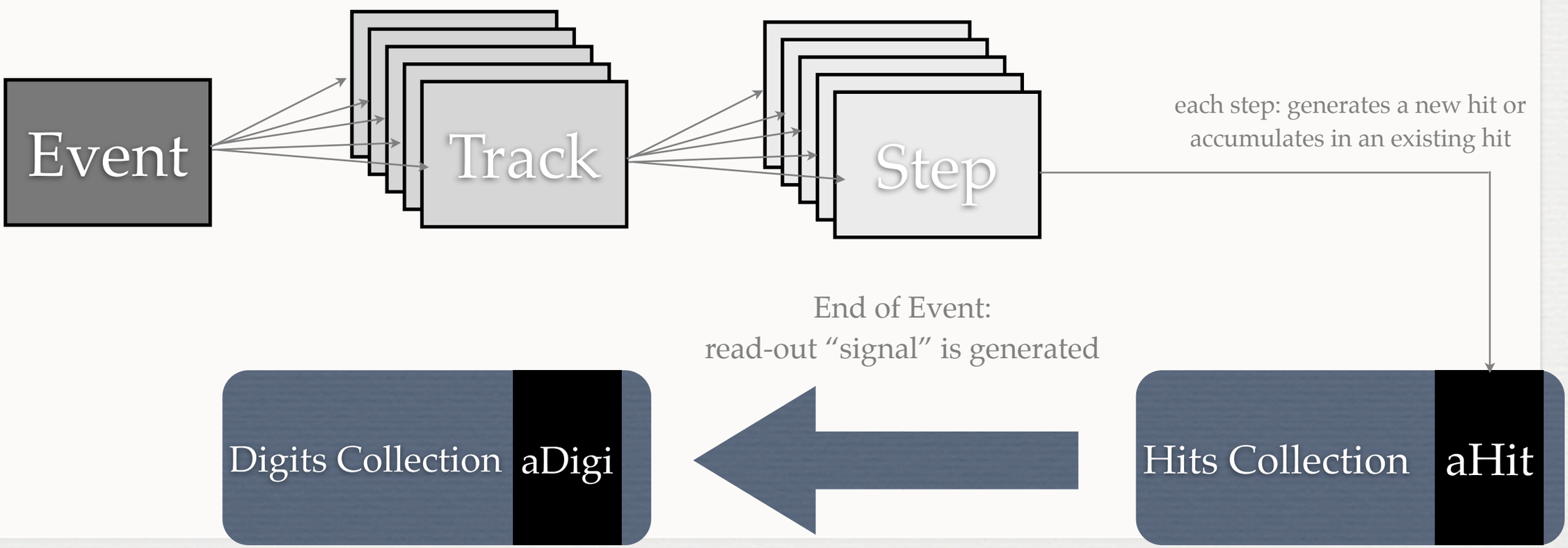
Collecting Information

- User Action allow to interact with the simulation of the physics and collect information for analysis
- Hits simplify the job in collecting information for active parts of the detector
- Hits are created only for the pieces of the detector that are defined sensitive: SensitiveDetector. Example: in a tracker the SD is the active part of the Si wafer, the electronics circuits do not participate in collecting charge, they are not SD thus do not generate hits

Hits Vs Digits

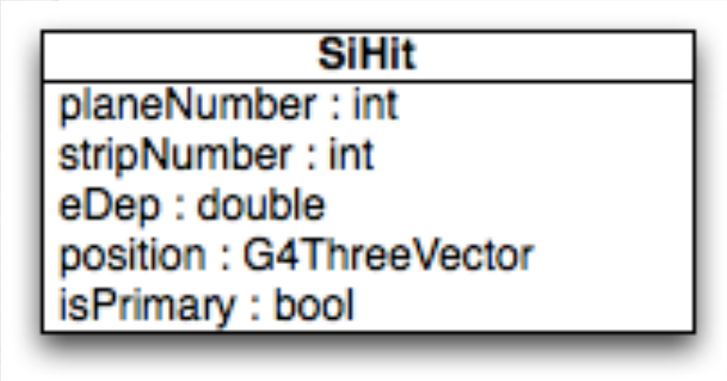
- Hits are a "snapshot" of the physical interaction of a track (step) or an accumulation of interactions of tracks in the sensitive region of the detector, thus hits represent the "true" energy deposited in the detector

- Digits are instead intended to be used to simulate the process of reading-out of the signal: for example "true" energy is transformed into collected charge, electronic noise can be applied together with all instrumental effects



Implementing Your Hit Class

- Hit is a user-defined class derived from G4VHit
- You can store any type of information by implementing your concrete Hit class. For example: position of the step, energy deposition of the step
- See SiHit class: http://www-zeuthen.desy.de/ILC/geant4/g4course2010/task2/classSiHit.html
  - Accumulates energy of all steps in each strip
  - Contains also information about absolute position of the energy deposit



- Hits must be stored in a collection of hits instantiated from G4THitsCollection template class
- G4 provides optimized allocators for memory management

Sensitive Detector

- Each logical volume can have an associated SD: a user-defined class derived from G4VSensitiveDetector
- See SensitiveDetector class: http://www-zeuthen.desy.de/ILC/geant4/g4course2010/task2/classSensitiveDetector.html
- SDs must have a unique name, however the same SD can be shared between different logical volumes. In our exercise, the same SD is shared between all Si planes
- SD is created and associated to Si planes of the detector in DetectorConstruction class in Construct method. See: http://www-zeuthen.desy.de/ILC/geant4/g4course2010/task2/classDetectorConstruction.html

The SD Interface - 1

- Constructor:

```
00028 SensitiveDetector::SensitiveDetector(G4String SDname)
00029   : G4VSensitiveDetector(SDname)
00030 {
00031
00032   // 'collectionName' is a protected data member of base class
G4VSensitiveDetector.
00033   // Here we declare the name of the collection we will be using.
00034   collectionName.insert("SiHitCollection");
00035
00036   // Note that we may add as many collection names we would wish: ie
00037   // a sensitive detector can have many collections.
00038 }
```

- In the constructor, define the name of the hits collection handled by this SD
- In case your sensitive detector generates more than one kind of hits, define all collection names

The Hits Collection

- Hits are accumulated in the hits collection
- Each collection has a unique name (a string): multiple collections can be retrieved by name
- However searching a string can be time consuming: a unique ID (integer) is also (automatically) associated to each collection
  - Ask G4 which ID corresponds to your name and use ID to get the collection

The SD Interface - 2

- Initialize() method is invoked at beginning of each event
- You can get here the unique ID associated to your collection
- Instantiate the hits collection and attach it to G4HCofThisEvent passed as argument

```
void SensitiveDetector::Initialize(G4HCofThisEvent* HCE)

00087 {
00088   // -- G4cout << "Initialize method of SD `" << GetName() << "' called." << G4endl;
00089
00090   // ------------------------------
00091   // -- Creation of the collection
00092   // ------------------------------
00093   // -- collectionName[0]  as declared in constructor
00094   hitCollection = new SiHitCollection(GetName(), collectionName[0]);
00095
00096   // ------------------------------------------------------------------------
00097   // -- and attachment of this collection to the "Hits Collection of this Event":
00098   // ------------------------------------------------------------------------
00099   // -- To insert the collection, we need to get an index for it. This index
00100   // -- is unique to the collection. It is provided by the GetCollectionID(...)
00101   // -- method (which calls what is needed in the kernel to get this index).
00102   static G4int HCID = -1;
00103   if (HCID<0) HCID = GetCollectionID(0); // <<-- this is to get an ID for collectionName[0]
00104   HCE->AddHitsCollection(HCID, hitCollection);
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The SD Interface - 3

- For each G4Step occurring in the (logical) volume to which this SD is attached the ProcessHits method is invoked

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00044 {
00045   // step is garanteed to be in Strip volume : no need to check for volume
00046
00047   G4TouchableHandle touchable = step->GetPreStepPoint()->GetTouchableHandle();
00048   // energy deposit in this step
00049   G4double edep = step->GetTotalEnergyDeposit();
00050
00055   // get step points in world coordinate system
00056   G4ThreeVector point1 = step->GetPreStepPoint()->GetPosition();
00057   G4ThreeVector point2 = step->GetPostStepPoint()->GetPosition();
00058
00059   // randomize point of energy deposition
00060   G4ThreeVector pointE = point1 + G4UniformRand()*(point2 - point1);
00061
00062
00069   G4int stripCopyNo = touchable->GetReplicaNumber();
00070   G4int planeCopyNo = touchable->GetReplicaNumber(1);
00071
00072   SiHit* hit = new SiHit(stripCopyNo,planeCopyNo,isPrimary);
00073   hitCollection->insert(hit); // size of collection is returned by insert(..)
00074
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00076   hit->AddEdep(edep);
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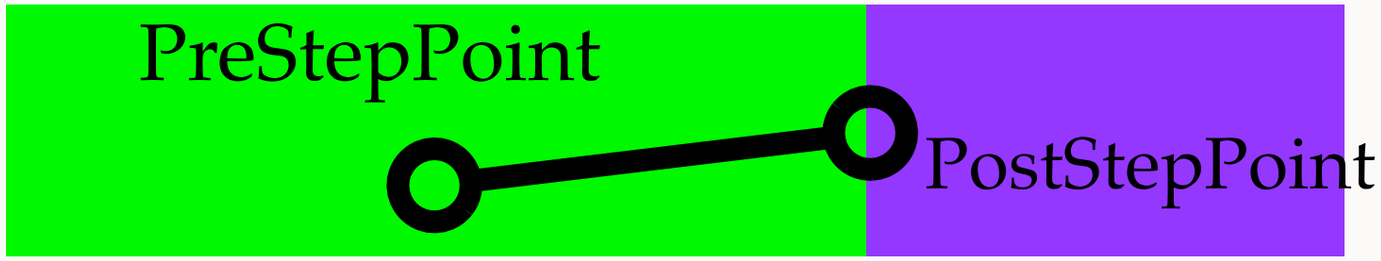
Reminder

Step

- Step has two points and “delta” information of a particle (energy loss along the step, time-of-flight, etc)
- Each point knows the volume (and material) associated to it
- A step is always limited by geometry boundaries (i.e. never spans across boundaries)
  - If the step is limited by a boundary, the post-step point stands on the boundary and it logically belongs to the next volume
  - Get the volume information from the PreStepPoint



Touchable: Locate A Hit

- It would be too complex to locate which strip the step belongs to from its position (G4ThreeVector). Each G4Step knows which volume it is in.
- Example: the detector you have built in Task1.1 is made of 3 identical planes of Si, each one made of 48 identical strips
- Strips have been created as "replica"
  - In memory there is only one volume object "strip". Its position is parametrized by its replica number
  - We also need the number of the "mother volume" containing the strip: the plane number
- Touchables can retrieve these number

Remember: PostStep belongs to NEXT volume, use PreStepPoint!

```
00047   G4TouchableHandle touchable = step->GetPreStepPoint()->GetTouchableHandle();
00069   G4int stripCopyNo = touchable->GetReplicaNumber();
00070   G4int planeCopyNo = touchable->GetReplicaNumber(1);
```

Go up by one in hierarchy: the plane

Touchable: Locate A

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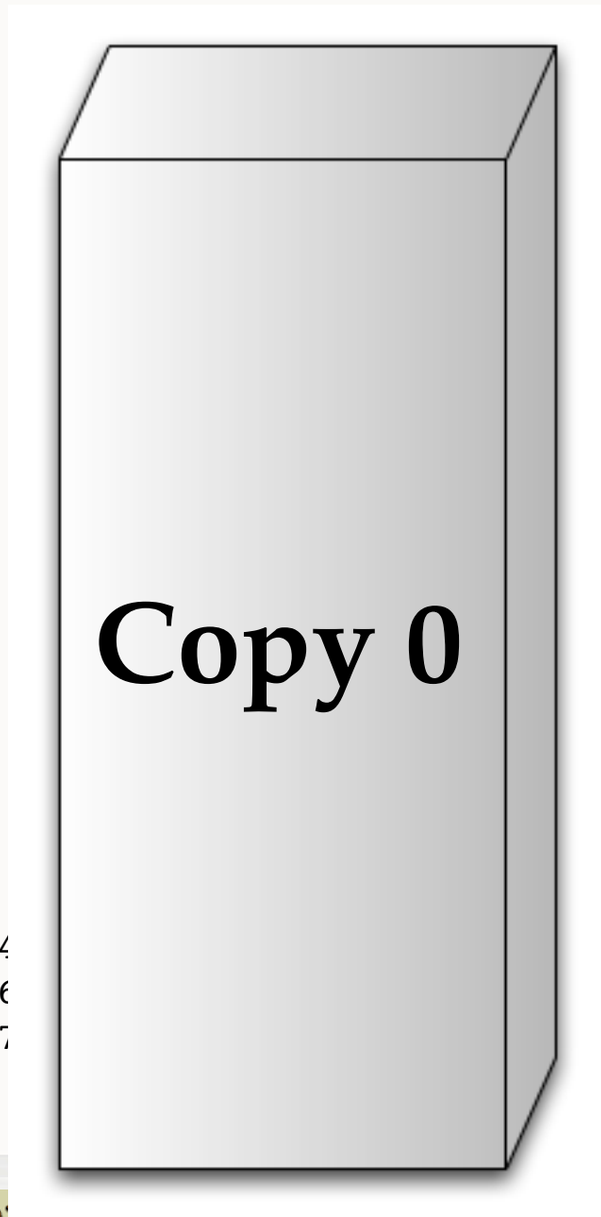

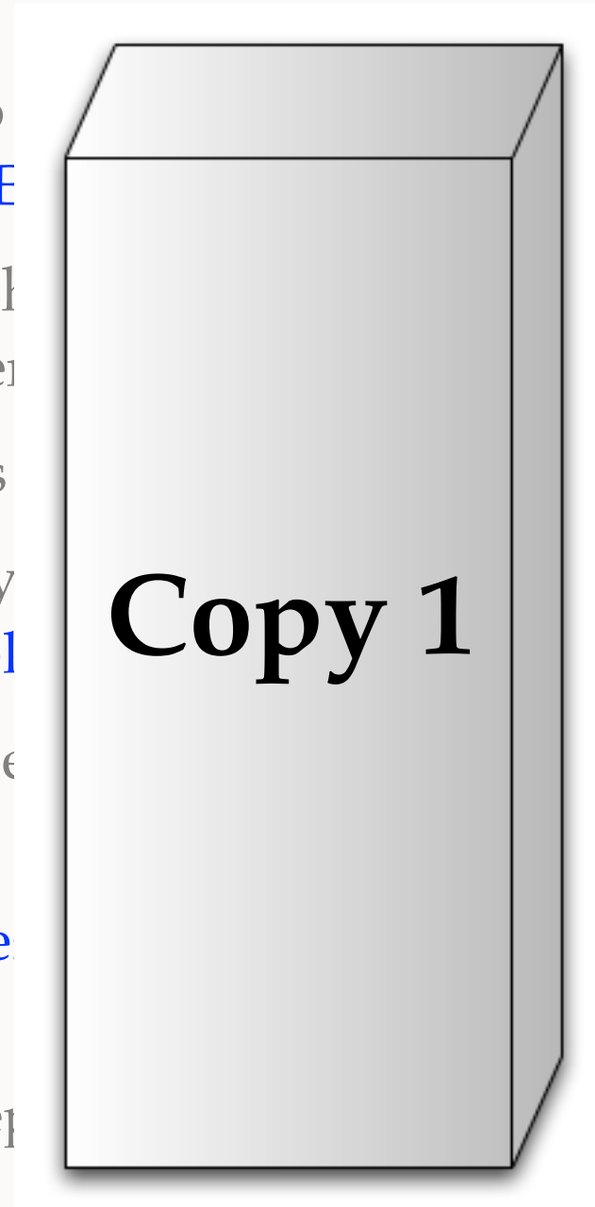

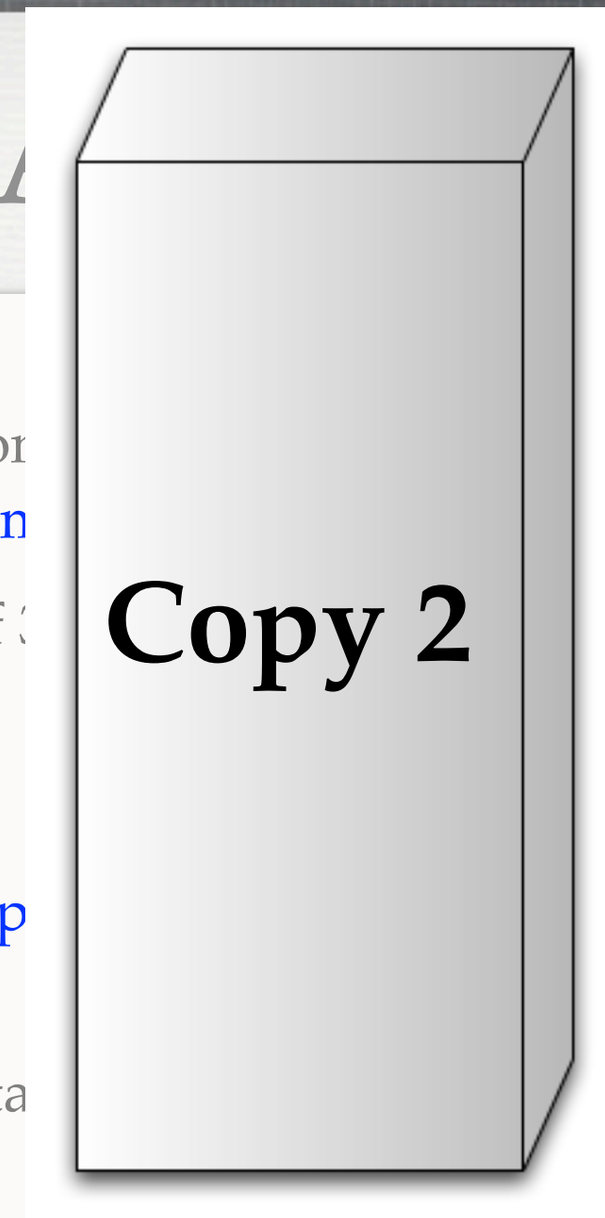

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```
0004 hable = step->GetPreStepPoint()->GetTouchableHandle();
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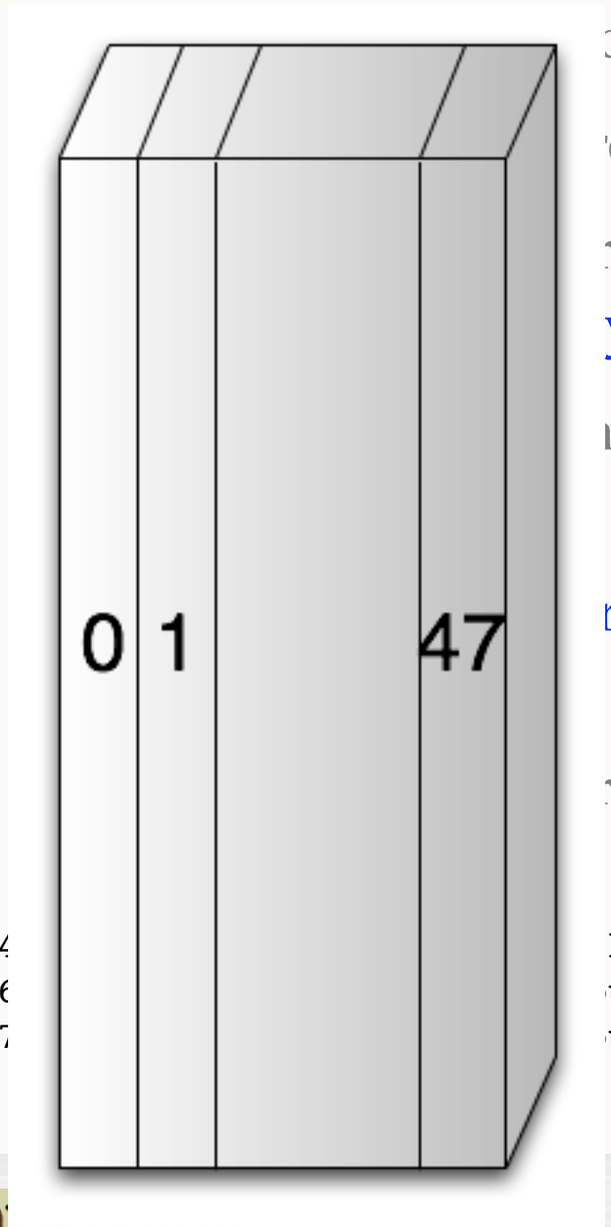

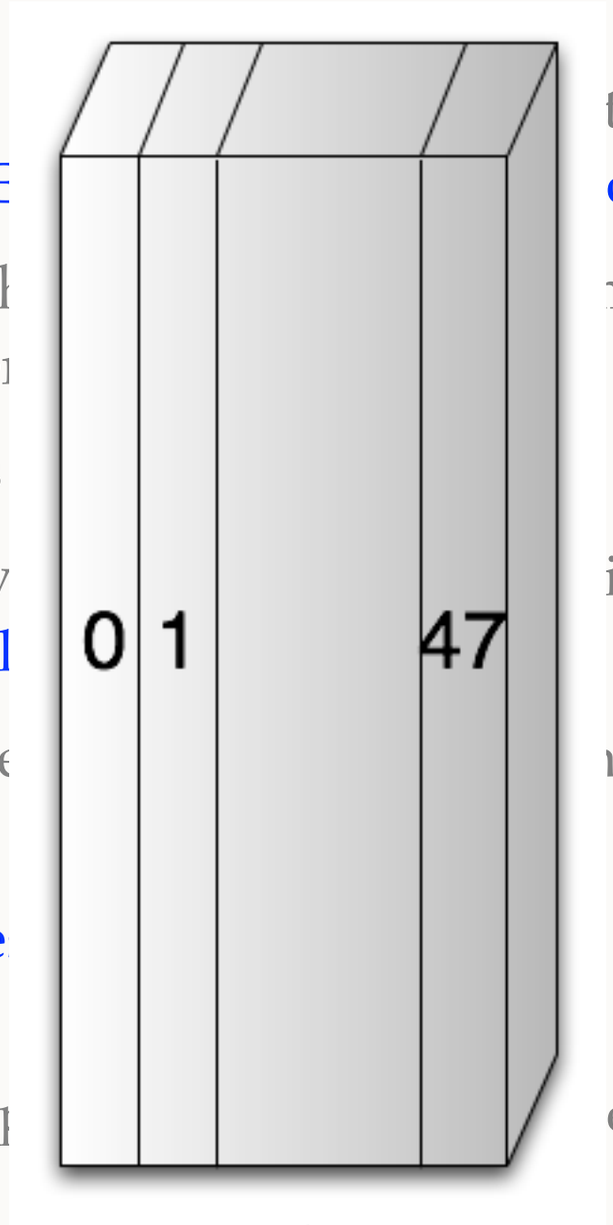

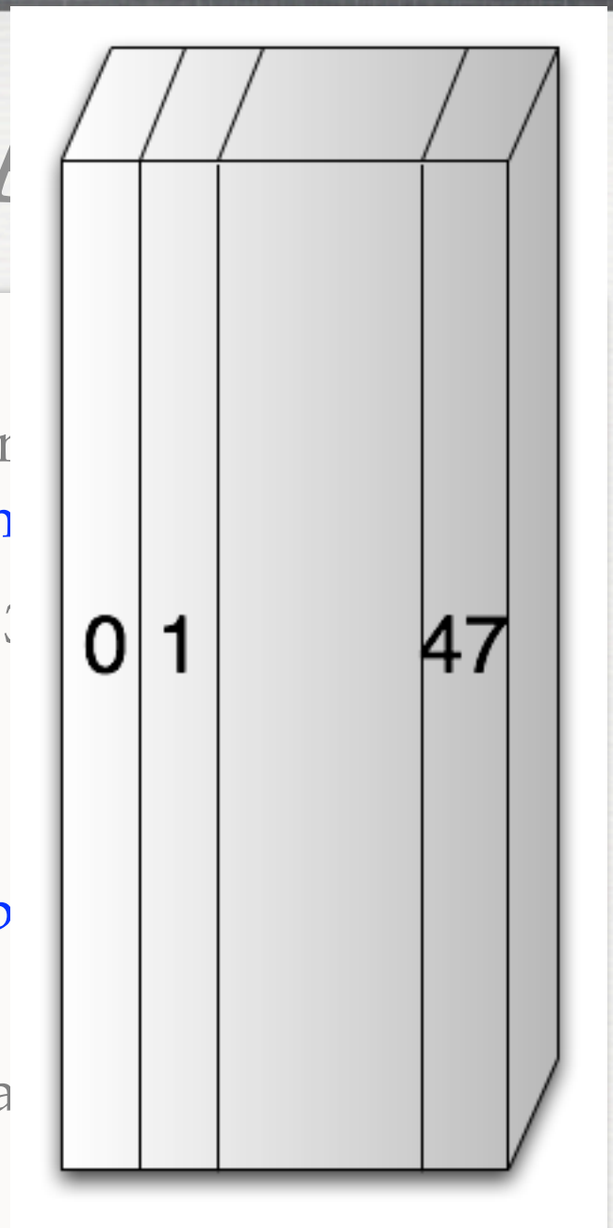

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Go up by one in hierarchy: the plane

Retrieving Hits

- Hits collections can be retrieved by name.
  - First retrieve the collection ID
- Hits are associated to the current G4Event object, it is possible to retrieve the hits collection:

```
void EventAction::EndOfEventAction(const G4Event* anEvent)
00049 {
00044   G4SDManager * SDman = G4SDManager::GetSDMpointer();
00045   G4int hitsCollID = SDman->GetCollectionID(hitsCollName);
00061   //Retrieve digits collection
00065   G4HCofThisEvent* hitsCollections = anEvent->GetHCofThisEvent();
00066   SiHitCollection* hits = 0;
00069   hits = static_cast<SiHitCollection*>( hitsCollections->GetHC
(hitsCollID) );
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Digitization

- At the end of one event the G4HCofThisEvent object contains the hits we have created
- The Digitizer module (electronic read-out simulator) can be used to transform Hits to Digits
- SiDigi class, inherits from G4VDigi. Digits are stored in container, an instance of G4TDigiCollection class: very similar to hits mechanism
- See: http://www-zeuthen.desy.de/ILC/geant4/g4course2010/task2/classSiDigi.html

Digitizer

- Digitizer is identified by name and has to be registered to the DigiManager singleton
- The SiDigitizer class inherits from G4VDigitizerModule base class and implements the Digitize() method
  - Warning: this method has to be called explicitly at the end of the event

```
 EventAction::EventAction()
00026 {
00027         //We build the digitization module
00028         SiDigitizer* digitizer = new SiDigitizer("SiDigitizer");
00029         G4DigiManager * digiManager = G4DigiManager::GetDMpointer();
00030         digiManager->AddNewModule( digitizer );
00031 }
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00051         G4DigiManager * digiManager = G4DigiManager::GetDMpointer();
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Digitizer

- Digitizer creates the digit collection, similarly to hits, these are identified by a collection name

```
00021 SiDigitizer::SiDigitizer(G4String aName) :
00022   G4VDigitizerModule(aName)
00043 {
00044         collectionName.push_back( digiCollectionName );
00047 }
```

- Digits are created and added to the collection:

```
00049 void SiDigitizer::Digitize()
00050 {
00052   SiDigiCollection * digiCollection = new SiDigiCollection("SiDigitizer",digiCollectionName);
00053   //Create a empty collection with one digits for each strip
00055   const G4int numPlanes = 3;  //Number of Si detectors
00056   const G4int numStrips = 48; //Number of strip per plane
00067   for ( G4int plane = 0 ; plane < numPlanes ; ++plane ) {
00068     for ( G4int strip = 0 ; strip < numStrips ; ++strip )
00069       {
00070         SiDigi* newDigi = new SiDigi(plane,strip);
00072         digiCollection->insert(newDigi);
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00074   }
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Retrieving Digits

- Digits collection can be retrieved, by name, via the DigiManager singleton

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G4DigiManager * digiManager = G4DigiManager::GetDMpointer();
G4int digiCollID = digiManager->GetDigiCollectionID( digitsCollName );
const SiDigiCollection* digits = static_cast<const SiDigiCollection*>
( digiManager->GetDigiCollection(digiCollID) );
```

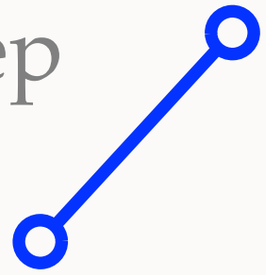
- Remember retrieval is always a two-step process:

  name (string) ⇒ ID (integer) ⇒ collection (pointer)

- Since IDs do not change during a run you can (should) optimize your code: do the first search only once

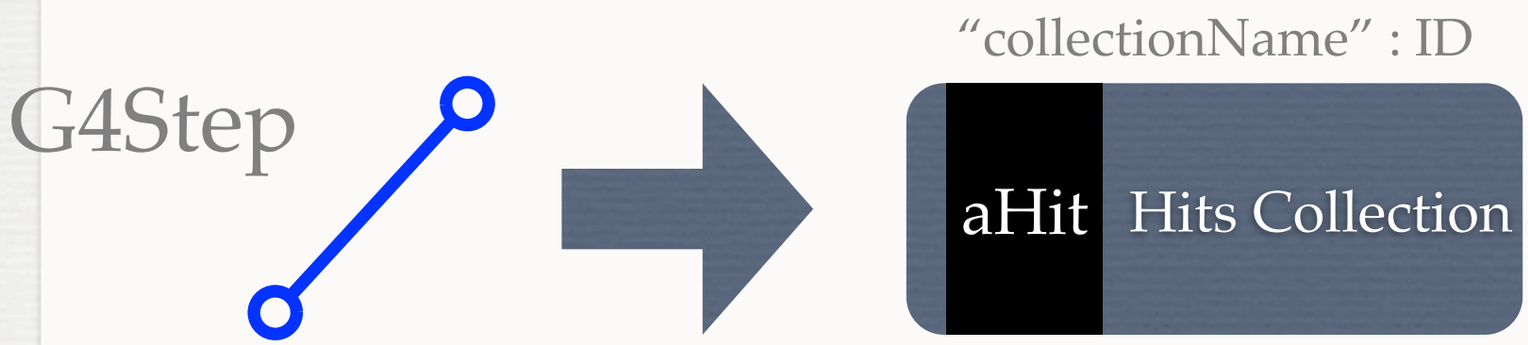
Summary

G4Step



Summary

Summary

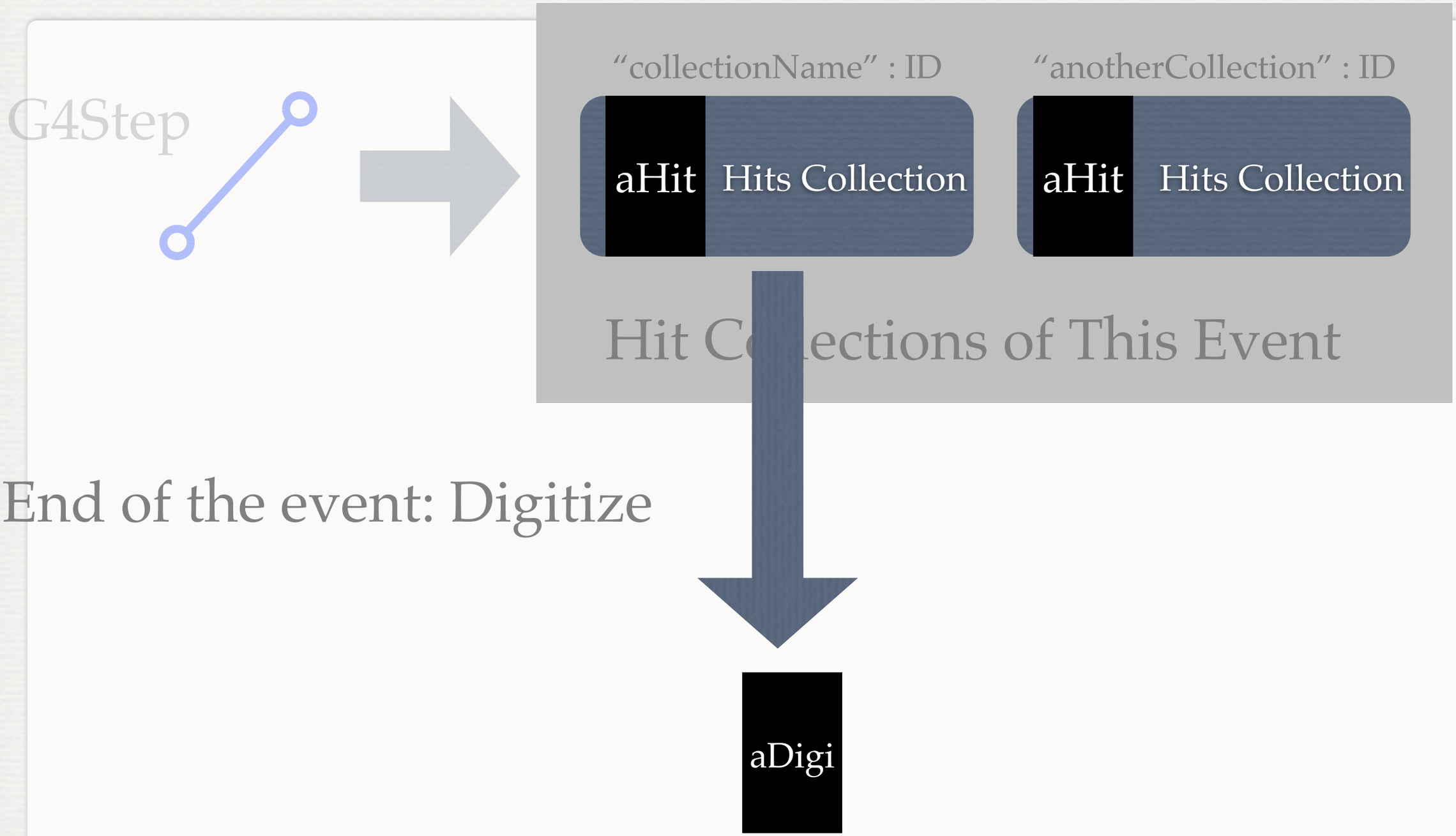


Repeat for each step in the event

Summary

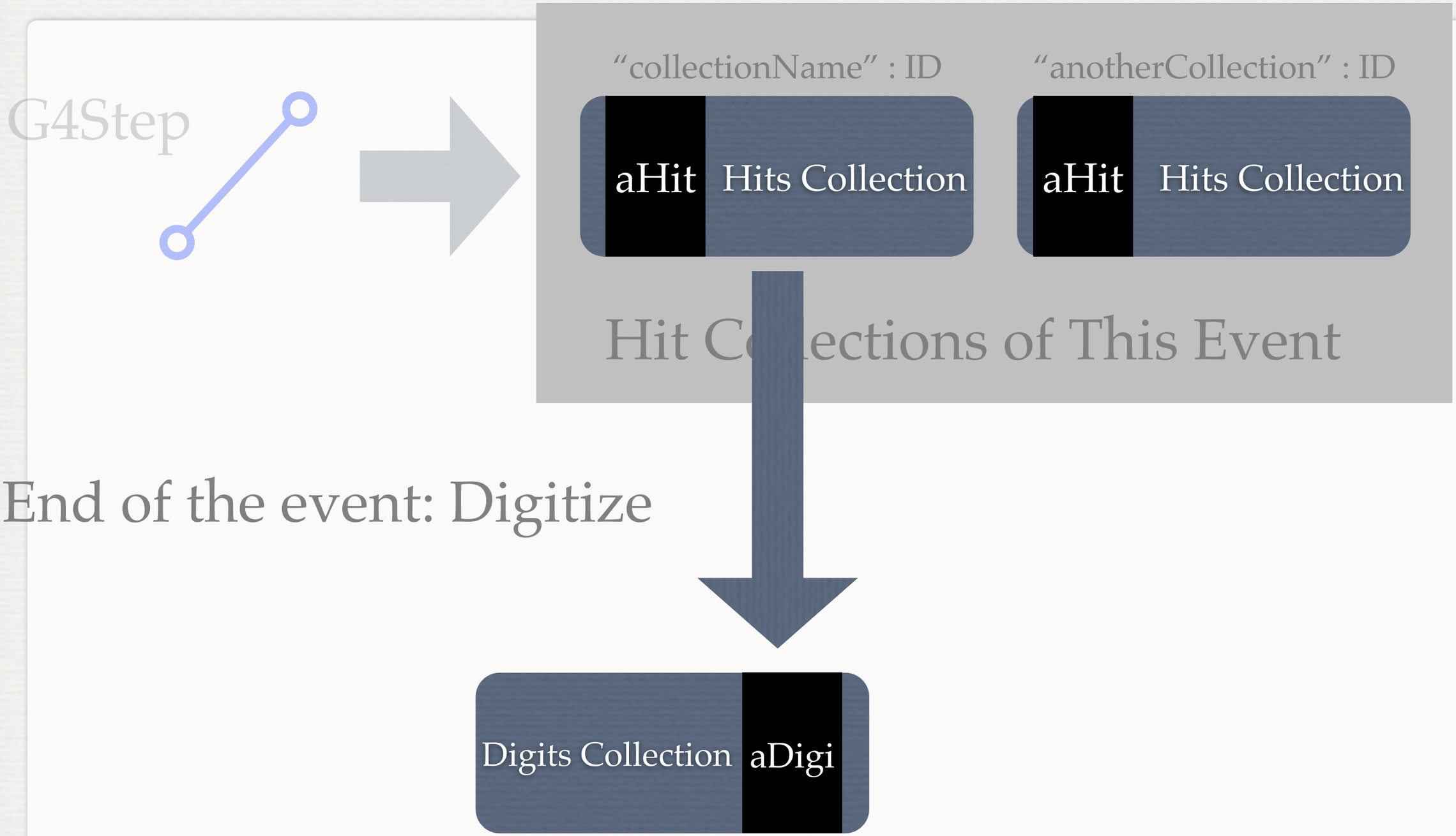
End of the event

Summary

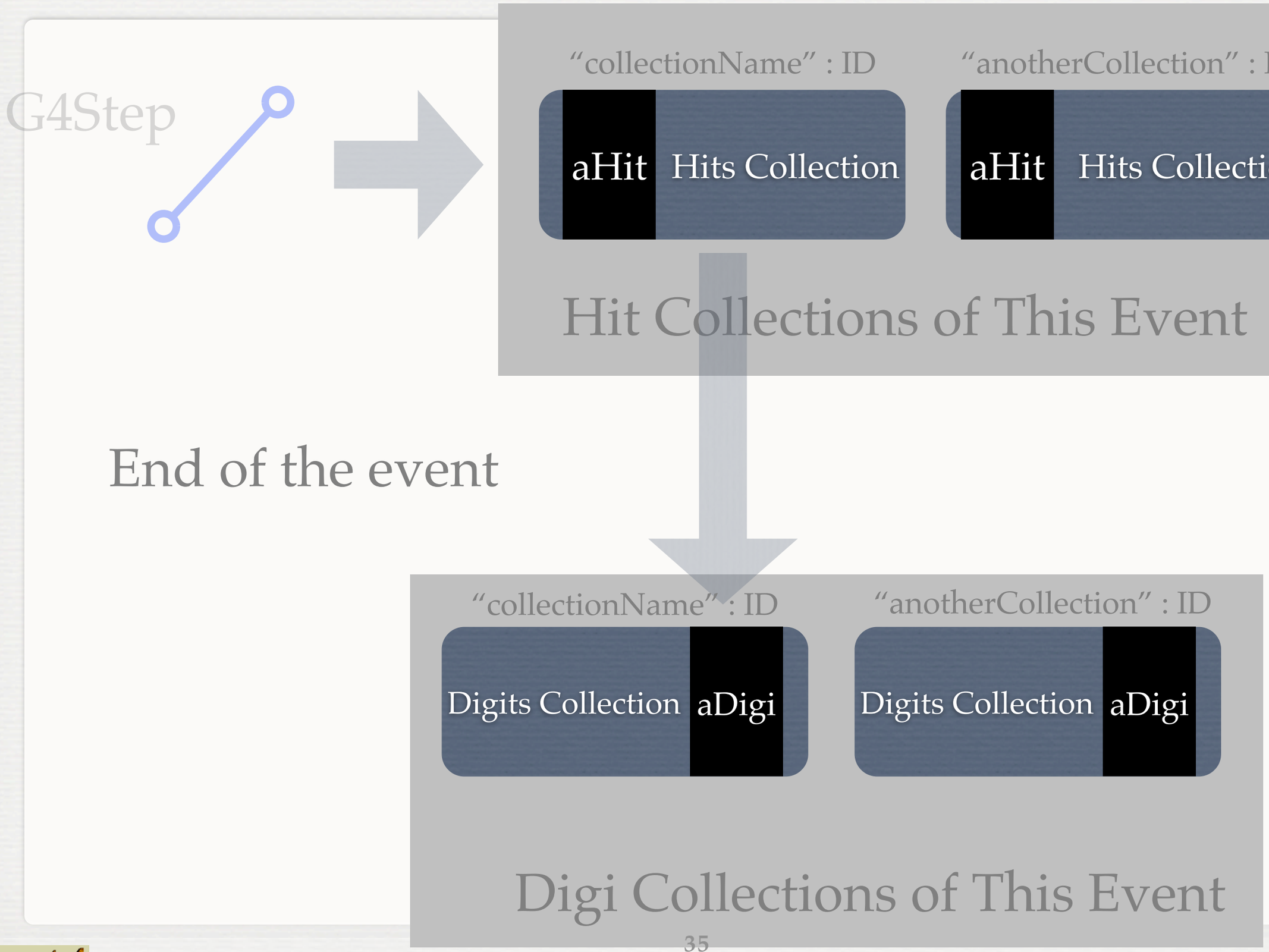


End of the event: Digitize

Summary

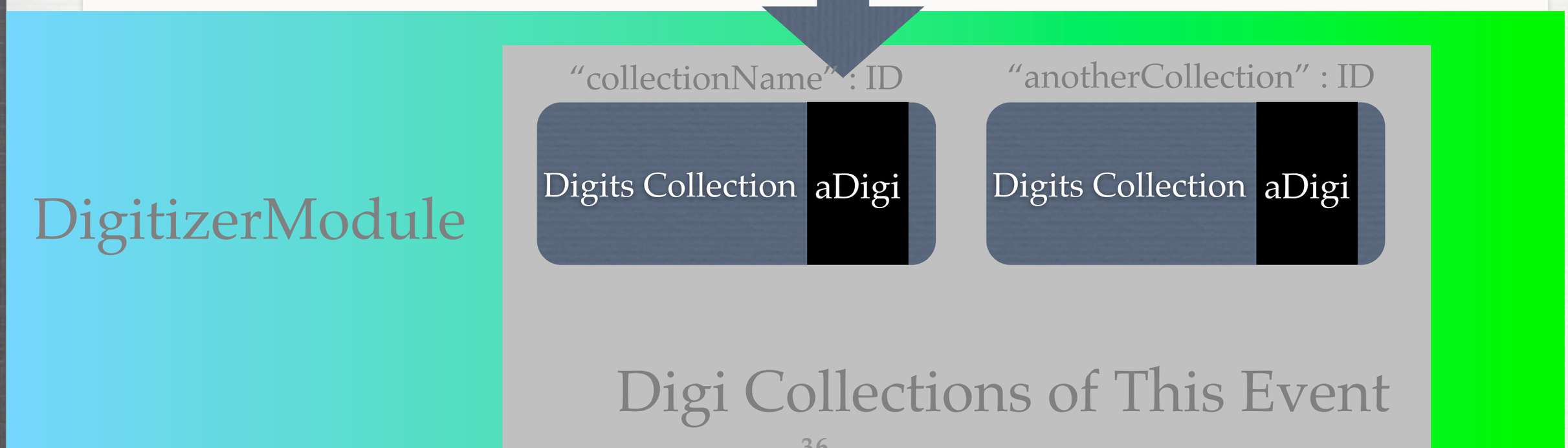

G4Step
"collectionName" : ID
aHit
Hits Collection
"anotherCollection" : ID
aHit
Hits Collection
Hit Collections of This Event
End of the event: Digitize
Digits Collection
aDigi

Summary


G4Step
"collectionName" : ID
aHit
Hits Collection
"anotherCollection" : ID
aHit
Hits Collection
Hit Collections of This Event
End of the event
"collectionName" : ID
Digits Collection
aDigi
"anotherCollection" : ID
Digits Collection
aDigi
Digi Collections of This Event

Summary


G4Step
SensitiveDetector
"collectionName" : ID
aHit
Hits Collection
"anotherCollection" : ID
aHit
Hits Collection
Hit Collections of This Event


DigitizerModule
"collectionName" : ID
Digits Collection
aDigi
"anotherCollection" : ID
Digits Collection
aDigi
Digi Collections of This Event

Exercises For Task 1.2

- http://www.ifh.de/geant4/g4course2010
- Exercise 1.2.2 : Modify the simulation of noise
- Exercise 1.2.3 : Modify code to add time information