European Scientific Institute

European School of Instrumentation in Particle & Astroparticle Physics

Examples

Witold Pokorski, Alberto Ribon
CERN PH/SFT

GEANT4
A SIMULATION TOOLKIT

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Learning and Working with Geant4 Examples

- Most of the people **learn** how to use Geant4 by “playing” with an existing example
  - Choose an example as close as possible to your use-case
  - Look at the code, to see how things are done
  - Read the relevant parts of the “*User's Guide: For Application Developers*” to understand better how things work
  - Modify the example to do what you need
- Beside learning: many **real** detector-simulation **applications** originated from a Geant4 example
  - by adapting the detector description, sensitive detectors, hits, primary source, user actions, and analysis
- Bottom line: examples are very useful!

Geant4 Examples

- ***geant4/examples/***
  - ***basic/*** : oriented to novice users and covering the most typical use-cases of Geant4 applications
  - ***extended/*** : covers many specific use-cases; may require some additional libraries besides of G4
  - ***advanced/*** : real and complete applications for different simulation studies; may require additional third-party products to be built

- There are **README** files in each directory which briefly explain the content of each directory...

Geant4 **Basic** Examples

geant4/examples/basic/ :

- ***B1/***
  Simple geometry with a few solids.
  Scoring total dose in a selected volume; user action classes.
- ***B2/***
  Simplified tracker geometry with global constant magnetic field.
  Scoring within tracker via G4 sensitive detector and hits.
- ***B3/***
  Schematic Positron Emitted Tomography system.
  Radioactive source.
  Scoring within Crystals via G4 scorers.
- ***B4/***
  Simplified calorimeter with layers of two materials.
  Scoring within layers in four ways: (a) via user actions;
  (b) via user data object; (c) via hits & sensitive detectors; (d) via scorer
- ***B5/***
  A double-arm spectrometer with wire chambers, hodoscopes and calorimeters with a local constant magnetic field.
  Scoring used in wire chambers;
  G4 sensitive detector and hits used for hodoscopes and calorimeters.

Geant4 **Extended** Examples

geant4/examples/extended :

- ***analysis/***
- ***biasing/*** : event biasing, scoring and reverse-MC
- ***common/***
- ***electromagnetic/*** : many, different things...
- ***errorpropagation/***
- ***eventgenerator/*** : G4ParticleGun, G4GeneralParticleSource, HepMC, Pythia
- ***exoticphysics/*** : monopoles, phonons, ultra-cold neutrons, channeling, dark matter
- ***field/***
- ***g3tog4/***
- ***geometry/***
- ***hadronic/*** : cross sections, ions, neutron-HP, etc.
- ***medical/***
- ***optical/***
- ***parallel/*** : event-level parallelism
- ***parameterisations/*** : fast simulations
- ***persistency/*** : geometry (GDML) and simulation output (ROOT I/O)
- ***physicslists/*** : usage of Geant4 reference physics lists and physics builders
- ***polarisation/***
- ***radioactivedecay/***
- ***runAndEvent/*** : MC-true, scorers, parallel worlds, regions, readout geometry
- ***visualization/***

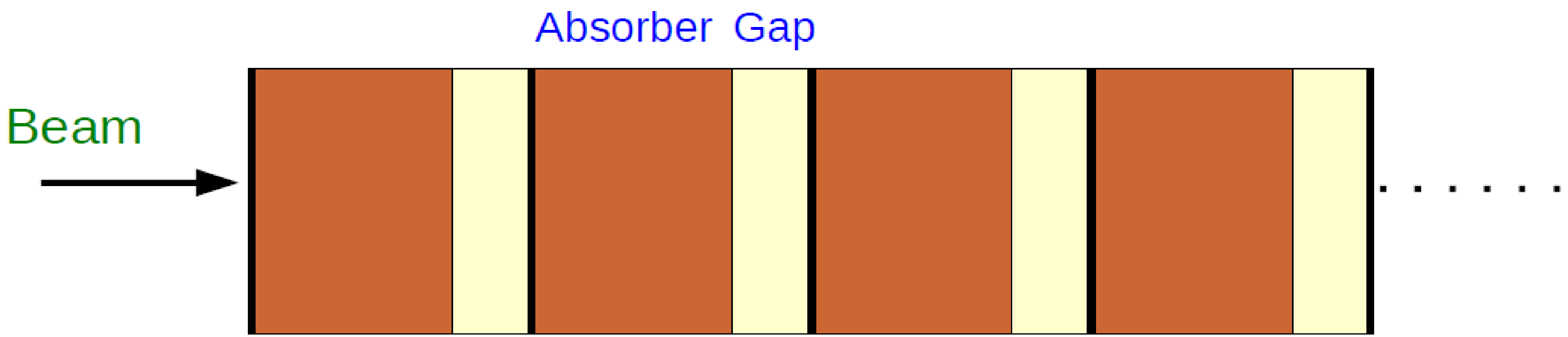
Geant4 **Advanced** Examples

geant4/examples/advanced :

- ***air_shower/***
- ***amsEcal/***
- ***brachytherapy/***
- ***ChargeExchangeMC/***
- ***composite_calorimeter/***
- ***doiPET/***
- ***eRosita/***
- ***gammaknife/***
- ***gammaray_telescope/***
- ***hadrontherapy/***
- ***human_phantom/***
- ***iort_therapy/***
- ***lAr_calorimeter/***
- ***medical_linac/***
- ***microbeam/***
- ***microelectronics/***
- ***nanobeam/***
- ***purging_magnet/***
- ***radioprotection/***
- ***underground_physics/***
- ***xray_fluorescence/***
- ***xray_telescope/***

A closer look to the basic example **B4**

- ***geant4/examples/basic/B4***
  - a simple sampling calorimeter setup
  - 4 variants of scoring:
    - ***B4a/*** : user actions
    - ***B4b/*** : user data object (and user actions)
    - ***B4c/*** : hits and sensitive detectors
    - ***B4d/*** : scorer



- The **calorimeter** is a box made of a number of layers
- A **layer** consists of an **absorber plate** and of a **detection gap**
- The layer is **replicated**

Content of ***geant4/examples/basic/B4/B4a/***

- **CMakeLists.txt** : to build the example using Cmake (recommended)
- **GNUmakefile** : to build the example with the old GNUmake system (deprecated)
- **exampleB4a.cc** : the main program
- **exampleB4.in** : macro file (there are also others: run1.mac, run2.mac, ... *.mac)
- ***include/*** : header files (.hh) of the example:

  B4DetectorConstruction.hh
  B4aActionInitialization.hh
  B4PrimaryGeneratorAction.hh
  B4RunAction.hh
  B4aEventAction.hh
  B4aSteppingAction.hh
  B4Analysis.hh

- ***src/*** : source files (.cc) of the example:

  B4DetectorConstruction.cc
  B4aActionInitialization.cc
  B4PrimaryGeneratorAction.cc
  B4RunAction.cc
  B4aEventAction.cc
  B4aSteppingAction.cc

A look into a G4 macro file: **exampleB4.in**

```
# e+ 300MeV
/gun/particle e+
/gun/energy 300 MeV
/run/beamOn 1
#
# list the existing physics processes
/process/list
#
# switch off MultipleScattering
/process/inactivate msc
/run/beamOn 1
#
# switch on MultipleScattering
/process/activate msc
#
# change detector parameter
/gun/particle gamma
/gun/energy 500 MeV
/run/beamOn 1
```

3 runs, each with a different configuration;

1 event for each run

A look into a G4 main program: **exampleB4a.cc**

```
...
int main( int argc, char** argv ) {
  ...
  // Build the detector
  B4DetectorConstruction* detConstruction = new B4DetectorConstruction();
  runManager->SetUserInitialization( detConstruction );

  // Choose the physics list
  G4VModularPhysicsList* physicsList = new FTFP_BERT;
  runManager->SetUserInitialization( physicsList );

  // Instantiate the user actions
  B4aActionInitialization* actionInitialization
                                = new B4aActionInitialization( detConstruction );
  runManager->SetUserInitialization( actionInitialization );


  …
  // Execute the macro
  UImanager->ApplyCommand( "/control/execute exampleB4.in" )
 …
}
```

B4DetectorConstruction (1)

```
int main( int argc, char** argv ) {
  ...
  // Build the detector
  B4DetectorConstruction* detConstruction = new B4DetectorConstruction();
  runManager->SetUserInitialization( detConstruction );

  // Choose the physics list
  G4VModularPhysicsList* physicsList = new FTFP_BERT;
  runManager->SetUserInitialization( physicsList );
  // Instantiate the primary generator and the user actions
  B4aActionInitialization* actionInitialization
                     = new B4aActionInitialization( detConstruction );
  runManager->SetUserInitialization( actionInitialization );
  // Initialize G4 kernel
  runManager->Initialize()
  ...
}
```

```
G4VPhysicalVolume*
B4DetectorConstruction::Construct() {
  DefineMaterials();
  return DefineVolumes();
}

void B4DetectorConstruction::DefineMaterials() {
  // Lead material defined using NIST Manager
  G4NistManager* nistManager = G4NistManager::Instance();
  nistManager->FindOrBuildMaterial( "G4_Pb" );

  // Liquid argon material
  G4double a;  // mass of a mole
  G4double z;  // number of protons
  G4double density;
  new G4Material( "liquidArgon", z=18., a= 39.95*g/mole, density= 1.390*g/cm3 );

  // Vacuum
  new G4Material( "Galactic", z=1., a=1.01*g/mole,density= universe_mean_density,
                  kStateGas, 2.73*kelvin, 3.e-18*pascal );

  // Print materials
  G4cout << *( G4Material::GetMaterialTable() ) << G4endl;
}
```

B4DetectorConstruction (2)

```
G4VPhysicalVolume* B4DetectorConstruction::DefineVolumes() {
  ...
  // --- World ---
  G4VSolid* worldS  = new G4Box( "World",          // its name
                        worldSizeXY/2, worldSizeXY/2, worldSizeZ/2 ); // its size
  G4LogicalVolume* worldLV = new G4LogicalVolume( worldS,           // its solid
                                                  defaultMaterial,  // its material
                                                  "World" );        // its name
  G4VPhysicalVolume* worldPV = new G4PVPlacement( 0,                // no rotation
                                                  G4ThreeVector(),  // at (0,0,0)
                                                  worldLV,     // its logical volume
                                                  "World",     // its name
                                                  0,           // its mother  volume
                                                  false,       // no boolean operation
                                                  0,           // copy number
                                                  fCheckOverlaps );

 //  --- Calorimeter ---
 G4VSolid* calorimeterS = new G4Box( "Calorimeter", calorSizeXY/2, calorSizeXY/2,
                                     calorThickness/2 );
 G4LogicalVolume* calorLV = new G4LogicalVolume(  calorimeterS, defaultMaterial,
                                     "Calorimeter" );
 new G4PVPlacement( 0, G4ThreeVector(), calorLV, "Calorimeter", worldLV, false, 0,
                    fcheckOverlaps );
```

CONTINUE...

B4DetectorConstruction (3)

```
// --- Layer ---
G4VSolid* layerS  = new G4Box( "Layer", calorSizeXY/2, calorSizeXY/2,
                               layerThickness/2 );
G4LogicalVolume* layerLV = new G4LogicalVolume( layerS, defaultMaterial, "Layer" );
new G4PVReplica( "Layer",           // its name
                 layerLV,           // its logical volume
                 calorLV,           // its mother
                 kZAxis,            // axis of replication
                 nofLayers,         // number of replica
                 layerThickness );  // witdth of replica
 // --- Absorber ---
G4VSolid* absorberS = new G4Box( "Abso", calorSizeXY/2, calorSizeXY/2,
                                 absoThickness/2 );
G4LogicalVolume* absorberLV = new G4LogicalVolume( absorberS, absorberMaterial,
                                                   "Abso" );
fAbsorberPV = new G4PVPlacement( 0, G4ThreeVector( 0., 0., -gapThickness/2 ),
                                 absorberLV, "Abso", layerLV, false, 0,
                                 fCheckOverlaps );
 // --- Gap ---
G4VSolid* gapS = new G4Box( "Gap", calorSizeXY/2, calorSizeXY/2, gapThickness/2 );
G4LogicalVolume* gapLV = new G4LogicalVolume( gapS, gapMaterial, "Gap" );
fGapPV = new G4PVPlacement( 0, G4ThreeVector( 0., 0., absoThickness/2 ), gapLV, "Gap",
                            layerLV, false, 0, fCheckOverlaps );
...
return worldPV;
}
```

B4aActionInitialization

```
int main( int argc, char** argv ) {
  ...
  // Build the detector
  B4DetectorConstruction* detConstruction = new
B4DetectorConstruction();
  runManager->SetUserInitialization( detConstruction );
  // Choose the physics list
  G4VModularPhysicsList* physicsList = new FTFP_BERT;
  runManager->SetUserInitialization( physicsList );

  // Instantiate the primary generator and the user actions
  B4aActionInitialization* actionInitialization
                     = new B4aActionInitialization(detConstruction);
  runManager->SetUserInitialization( actionInitialization );

  // Initialize G4 kernel
  runManager->Initialize()
  ...
}
```

```
void B4aActionInitialization::Build() const {

   SetUserAction( new B4PrimaryGeneratorAction );

   SetUserAction( new B4RunAction );

   B4aEventAction* eventAction = new B4aEventAction;
   SetUserAction( eventAction );

   SetUserAction( new B4aSteppingAction( fDetConstruction, eventAction ) );

}
```

In this example, 2 user actions are not used:
- Tracking action
- Stacking action

B4PrimaryGeneratorAction

```
void B4aActionInitialization::Build() const {
  SetUserAction( new B4PrimaryGeneratorAction );

  SetUserAction( new B4RunAction );

  B4aEventAction* eventAction = new B4aEventAction;
  SetUserAction( eventAction );

  SetUserAction( new B4aSteppingAction( fDetConstruction,
eventAction ) );
}
```

```
B4PrimaryGeneratorAction::B4PrimaryGeneratorAction() ... {
  G4int nofParticles = 1;
  fParticleGun = new G4ParticleGun( nofParticles );
  // default particle kinematic
  G4ParticleDefinition* particleDefinition
           = G4ParticleTable::GetParticleTable()->FindParticle( "e-" );
  fParticleGun->SetParticleDefinition( particleDefinition );
  fParticleGun->SetParticleMomentumDirection( G4ThreeVector(0., 0., 1. ) );
  fParticleGun->SetParticleEnergy( 50.*MeV );
}


void B4PrimaryGeneratorAction::GeneratePrimaries( G4Event* anEvent ) {
  // This function is called at the beginning of event
  ...
 // Set gun position
 fParticleGun->SetParticlePosition( G4ThreeVector( 0., 0., -worldZHalfLength ) );
 fParticleGun->GeneratePrimaryVertex( anEvent );

}
```

B4RunAction

```
void B4aActionInitialization::Build() const {
  SetUserAction( new B4PrimaryGeneratorAction );

  SetUserAction( new B4RunAction );

  B4aEventAction* eventAction = new B4aEventAction;
  SetUserAction( eventAction );

  SetUserAction( new B4aSteppingAction( fDetConstruction,
eventAction ) );
}
```

```
B4RunAction::B4RunAction() ... {
   ...
   G4AnalysisManager* analysisManager = G4AnalysisManager::Instance();
   // Book histograms, ntuple
   analysisManager->CreateH1(...);
   analysisManager->CreateNtuple(...);
   ...
}

void B4RunAction::BeginOfRunAction(...) {
  ...
  G4AnalysisManager* analysisManager = G4AnalysisManager::Instance();
  // Open an output file
  analysisManager->OpenFile( fileName );
}

void B4RunAction::EndOfRunAction(...) {
  // Print something
  ...
 // Save histograms & ntuple
 analysisManager->Write();
 analysisManager->CloseFile();
}
```

B4aEventAction

```
B4aEventAction::B4aEventAction( ) : ... fEnergyAbs(0.) , fEnergyGap( 0. ) ... {}

void B4aEventAction::BeginOfEventAction(...) {
  // initialisation per event
  fEnergyAbs = 0. ;  fEnergyGap = 0.;
  ...
}
```

```
void B4aActionInitialization::Build() const {
  SetUserAction( new B4PrimaryGeneratorAction );

  SetUserAction( new B4RunAction );

  B4aEventAction* eventAction = new B4aEventAction;
  SetUserAction( eventAction );

  SetUserAction( new B4aSteppingAction( fDetConstruction,
eventAction ) );
}
```

```
void B4aEventAction::AddAbs( G4double de, G4double dl ) {
  fEnergyAbs += de;
  ...
}

void B4aEventAction::AddGap( G4double de, G4double dl ) {
 fEnergyGap += de;
 ...
}

void B4aEventAction::EndOfEventAction( const G4Event* event ) {
  // Accumulate statistics: fill histograms and ntuples
  G4AnalysisManager* analysisManager = G4AnalysisManager::Instance();
  analysisManager->FillH1( 1, fEnergyAbs );
  ...
  analysisManager->FillNtupleDColumn( 1, fEnergyAbs );
  ...
  // Print per-event information
  ...
}
```

B4aSteppingAction

```
void B4aActionInitialization::Build() const {
  SetUserAction( new B4PrimaryGeneratorAction );

  SetUserAction( new B4RunAction );

  B4aEventAction* eventAction = new B4aEventAction;
  SetUserAction( eventAction );

  SetUserAction( new B4aSteppingAction( fDetConstruction, eventAction ) );
}
```

```
void B4aSteppingAction::
UserSteppingAction( const G4Step* step ) {
  // Collect energy and track length step by step

  // Get volume of the current step
  G4VPhysicalVolume* volume
    = step->GetPreStepPoint()->GetTouchableHandle()->GetVolume();

  // Get energy deposit
  G4double edep = step->GetTotalEnergyDeposit();

  // Get step length
  G4double stepLength = 0.;
  if ( step->GetTrack()->GetDefinition()->GetPDGCharge() != 0. ) {
    stepLength = step->GetStepLength();
  }

  if ( volume == fDetConstruction->GetAbsorberPV() ) {
    fEventAction->AddAbs( edep, stepLength );
  }
  if ( volume == fDetConstruction->GetGapPV() ) {
    fEventAction->AddGap( edep, stepLength );
  }
}
```