GEANT4 – A SIMULATION TOOLKIT

Francisco García (HIP)

Aug. 13th – 18th, 2012

@ Savonlinna Summer School

OUTLINE

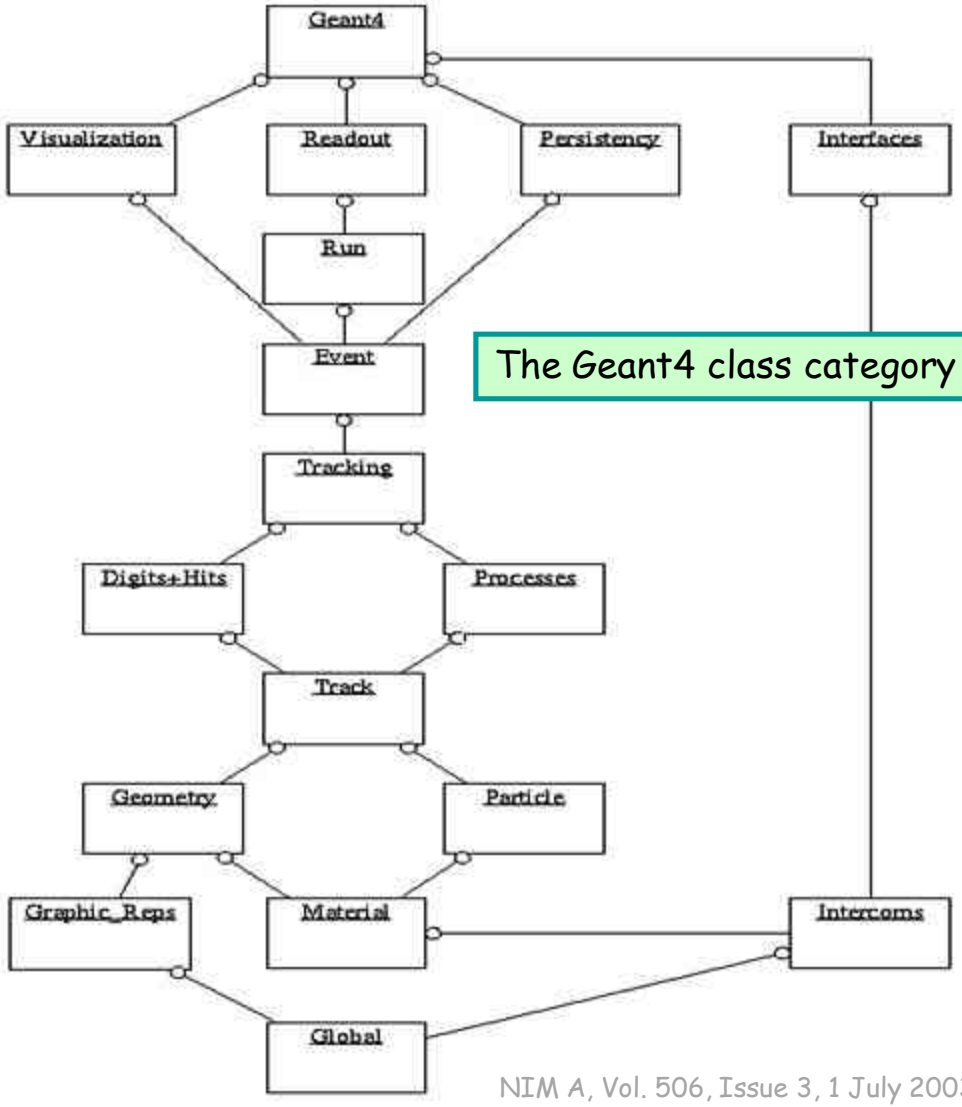
- GEANT4 INTRODUCTION
- ABOUT C++
- GEANT4 MODEL STRUCTURE
- DEFINITION OF A MODEL
- MAIN COMPONENTS
- START A SIMULATION WITH /run/beamOn 1

GEANT4 INTRODUCTION

GEANT4 Geant4 is a free software package composed of tools which can be used to accurately simulate the passage of particles through matter.

All aspects of the simulation process have been included in the toolkit: the geometry of the system, the materials involved, the fundamental particles of interest, the generation of primary events, the tracking of particles through materials and electromagnetic fields, the physics processes governing particle interactions, the response of sensitive detector components, the generation of event data, the storage of events and tracks, the visualization of the detector and particle trajectories, and the capture and analysis of simulation data at different levels of detail and refinement.

Users may construct stand-alone applications or applications built upon another object-oriented framework. In either case the toolkit will support them from the initial problem definition to the production of results and graphics for publication.

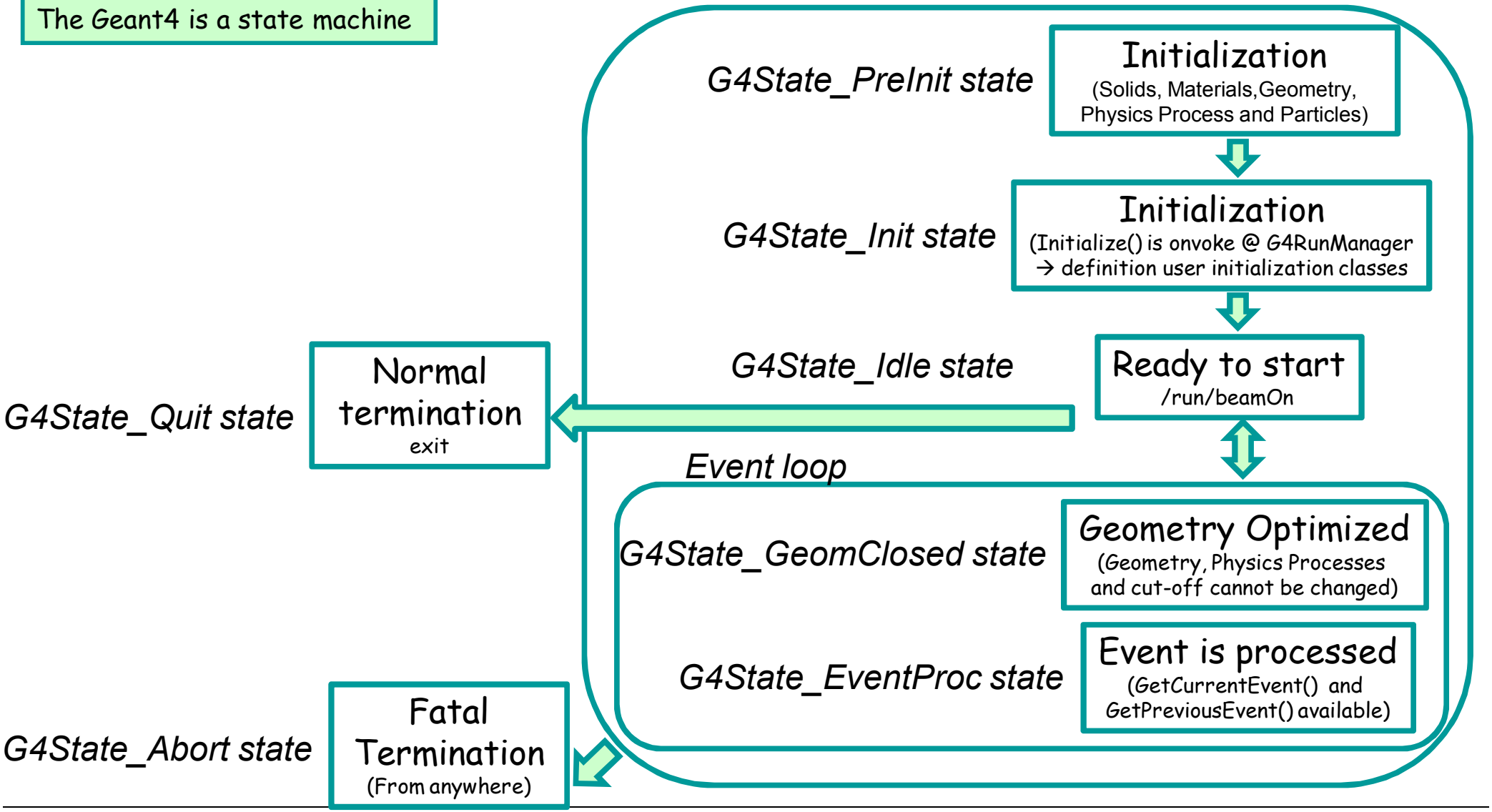


The Geant4 class category diagram

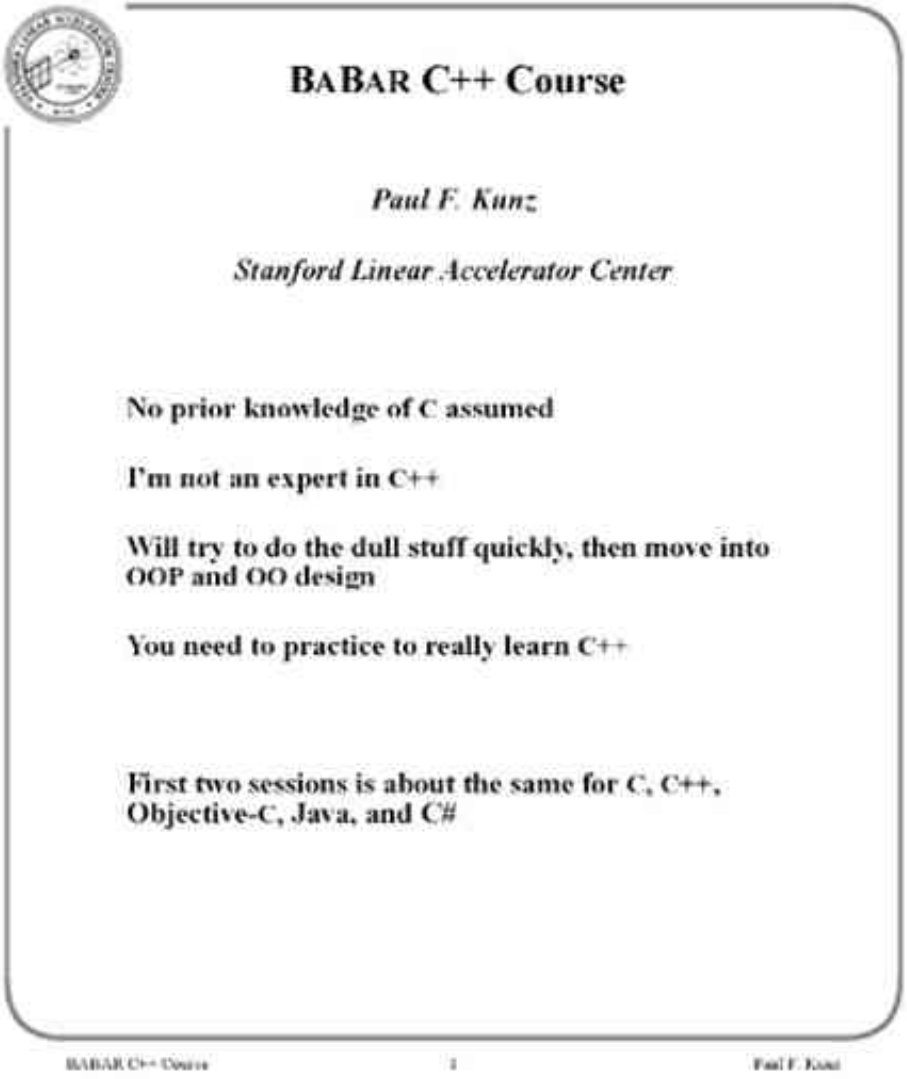
NIM A, Vol. 506, Issue 3, 1 July 2003, pp 250-303

GEANT4 INTRODUCTION (cont.)

The Geant4 is a state machine



ABOUT C++



BABAR C++ Course

Paul F. Kunz

Stanford Linear Accelerator Center

No prior knowledge of C assumed

I'm not an expert in C++

Will try to do the dull stuff quickly, then move into OOP and OO design

You need to practice to really learn C++

First two sessions is about the same for C, C++, Objective-C, Java, and C#

BABAR C++ Course 1 Paul F. Kunz

Generate a file .txt

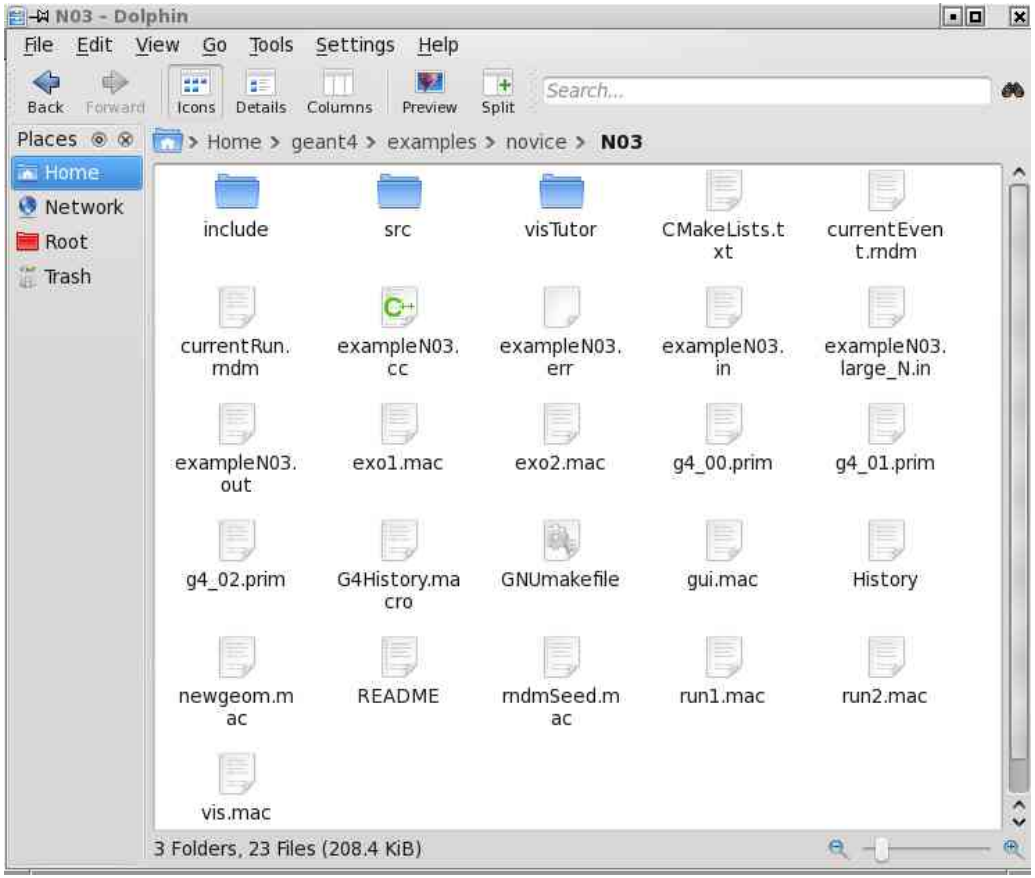
Filename: SealedGEMEventAction.cc

```
.
.
#include "fstream.h"     or #include <fstream>
.
.
void SealedGEMEventAction::EndOfEventAction(const G4Event* evt)
{
.
.
  G4int evtNb = evt->GetEventID();
  n_hit = DrfHC->entries();
  if (n_hit > 0){
    for(G4int i=0;i<n_hit;i++){
       depEnerg1 += (*DrfHC)[i]->GetDepositEnergy();
    }
  }
  ofstream out1;
  out1.open("EnergyDepositeDriftHits.dat",fstream::app);
  out1 <<  evt << "          " << depEnerg1/keV << G4endl;
  out1.close();
.
.
}
```

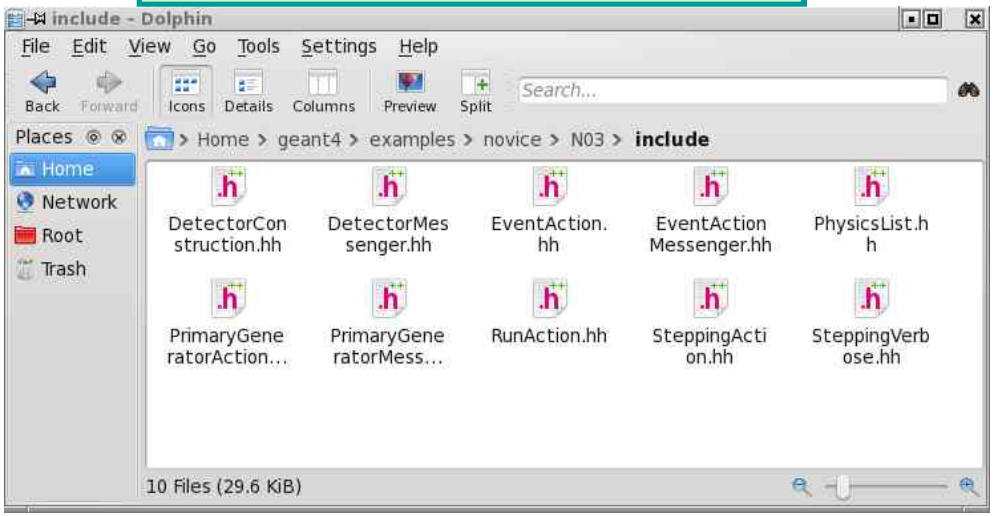
http://esmane.physics.lsa.umich.edu/wlap-cwis/SPT--BrowseResources.php?ParentId=215

GEANT4 MODEL STRUCTURE

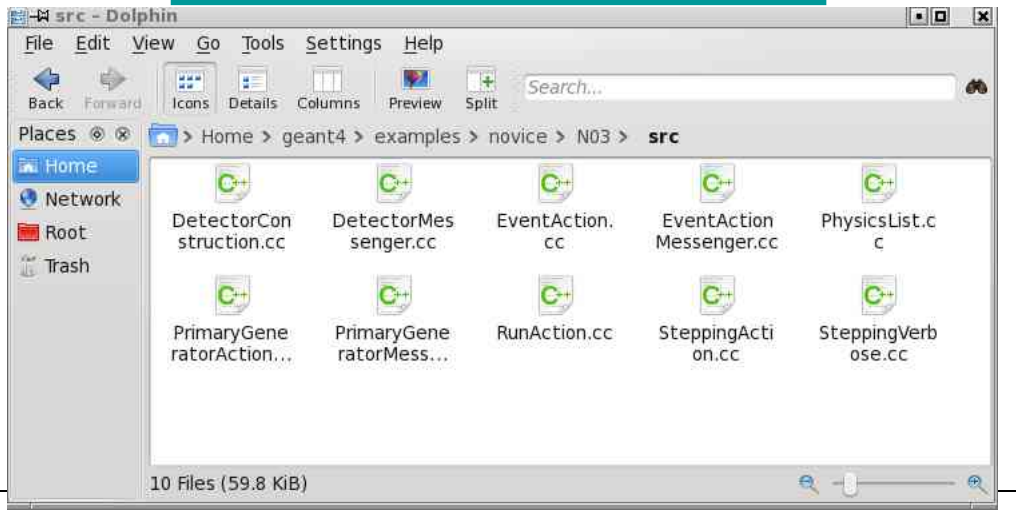
Simulation Model **Main Directory**



Simulation Model **include directory**



Simulation Model **source directory**



DEFINITION OF A MODEL

Simplest example of `main()`

```
#include "G4RunManager.hh"
#include "G4UImanager.hh"

#include "ExG4DetectorConstruction01.hh"
#include "ExG4PhysicsList00.hh"
#include "ExG4PrimaryGeneratorAction01.hh"

int main()
{
  // construct the default run manager
  G4RunManager* runManager = new G4RunManager;

  // set mandatory initialization classes
  runManager->SetUserInitialization(new ExG4DetectorConstruction01);
  runManager->SetUserInitialization(new ExG4PhysicsList00);

  // set mandatory user action class
  runManager->SetUserAction(new ExG4PrimaryGeneratorAction01);

  // initialize G4 kernel
  runManager->Initialize();

  // get the pointer to the UI manager and set verbosities
  G4UImanager* UI = G4UImanager::GetUIpointer();
  UI->ApplyCommand("/run/verbose 1");
  UI->ApplyCommand("/event/verbose 1");
  UI->ApplyCommand("/tracking/verbose 1");

  // start a run
  int numberOfEvent = 3;
  runManager->BeamOn(numberOfEvent);

  // job termination
  delete runManager;
  return 0;
}
```

G4RunManager

The first thing main() must do is create an instance of the G4RunManager class. This is the only manager class in the Geant4 kernel which should be explicitly constructed in the user's main(). It controls the flow of the program and manages the event loop(s) within a run. When G4RunManager is created, the other major manager classes are also created.

They run manager is also responsible for managing initialization procedures, including methods in the user initialization classes. Through these the run manager must be given all the information necessary to build and run the simulation, including:

- how the detector should be constructed
- all the particles and all the physics processes to be simulated
- how the primary particle(s) in an event should be produced and any additional requirements of the simulation.

MAIN COMPONENTS

Create a Solid

```
G4double world_hx = 3.0*m;
G4double world_hy = 1.0*m;
G4double world_hz = 1.0*m;

G4Box* worldBox
   = new G4Box("World", world_hx, world_hy, world_hz);
```

Give Attributes

```
G4LogicalVolume* worldLog
   = new G4LogicalVolume(worldBox, Ar, "World");
```

Place in Space

```
G4double pos_x = -1.0*meter;
G4double pos_y =  0.0*meter;
G4double pos_z =  0.0*meter;

G4VPhysicalVolume* trackerPhys
  = new G4PVPlacement(0,                          // no rotation
                      G4ThreeVector(pos_x, pos_y, pos_z),
                                                  // translation position
                      trackerLog,                 // its logical volume
                      "Tracker",                  // its name
                      worldLog,                   // its mother (logical) volume
                      false,                      // no boolean operations
                      0);                         // its copy number
```

Relevant to the Detector Constructor

Create a Tube

```
G4double innerRadius = 0.*cm;
G4double outerRadius = 60.*cm;
G4double hz = 25.*cm;
G4double startAngle = 0.*deg;
G4double spanningAngle = 360.*deg;

G4Tubs* trackerTube
  = new G4Tubs("Tracker",
               innerRadius,
               outerRadius,
               hz,
               startAngle,
               spanningAngle);
```

MAIN COMPONENTS (cont.)

Create a Material e.g. liquid Argon

```
G4double z, a, density;
density = 1.390*g/cm3;
a = 39.95*g/mole;

G4Material* lAr = new G4Material(name="liquidArgon", z=18., a, density);
```

Create a Molecule e.g. H_2O

```
G4double z, a, density;
G4String name, symbol;
G4int ncomponents, natoms;

a = 1.01*g/mole;
G4Element* elH  = new G4Element(name="Hydrogen",symbol="H" , z= 1., a);

a = 16.00*g/mole;
G4Element* elO  = new G4Element(name="Oxygen"  ,symbol="O" , z= 8., a);

density = 1.000*g/cm3;
G4Material* H2O = new G4Material(name="Water",density,ncomponents=2);
H2O->AddElement(elH, natoms=2);
H2O->AddElement(elO, natoms=1);
```

MAIN COMPONENTS (cont.)

Create a Material by Fraction of mass e.g. Air

```
G4double z, a, fractionmass, density;
G4String name, symbol;
G4int ncomponents;

a = 14.01*g/mole;
G4Element* elN  = new G4Element(name="Nitrogen",symbol="N" , z= 7., a);

a = 16.00*g/mole;
G4Element* elO  = new G4Element(name="Oxygen"  ,symbol="O" , z= 8., a);

density = 1.290*mg/cm3;
G4Material* Air = new G4Material(name="Air  ",density,ncomponents=2);
Air->AddElement(elN, fractionmass=70*perCent);
Air->AddElement(elO, fractionmass=30*perCent);
```

Create a Material from the G4 base materials – NIST database

```
G4NistManager* man = G4NistManager::Instance();

G4Material* H2O  = man->FindOrBuildMaterial("G4_WATER");
G4Material* Air  = man->FindOrBuildMaterial("G4_AIR");
```

MAIN COMPONENTS (cont.)

Create a New Material to the G4 base materials

```
G4double density;

density = 1.05*mg/cm3;
G4Material* water1 = new G4Material("Water_1.05",density,"G4_WATER");

density = 1.03*mg/cm3;
G4NistManager* man = G4NistManager::Instance();
G4Material* water2 = man->BuildMaterialWithNewDensity("Water_1.03","G4_WATER",density);
```

MAIN COMPONENTS (cont.)

Particle Definition

Geant4 provides various types of particles for use in simulations:

- ordinary particles, such as electrons, protons, and gammas
- resonant particles with very short lifetimes, such as vector mesons and delta baryons
- nuclei, such as deuteron, alpha, and heavy ions (including hyper-nuclei)
- quarks, di-quarks, and gluon

Relevant to the Physics List

The `G4ParticleDefinition` Class

`G4ParticleDefinition` has properties which characterize individual particles, such as, name, mass, charge, spin, and so on. Most of these properties are "read-only" and can not be changed directly. `G4ParticlePropertyTable` is used to retrieve (load) particle property of `G4ParticleDefinition` into (from) `G4ParticlePropertyData`.

Definition of an Electron

For example, the class `G4Electron` represents the electron and the member `G4Electron::theInstance` points its only object. The pointer to this object is available through the static methods `G4Electron::ElectronDefinition()`. `G4Electron::Definition()`.

MAIN COMPONENTS (cont.)

Definition of an Ion

```
G4ParticleDefinition* GetIon(  G4int     atomicNumber,
                               G4int     atomicMass,
                               G4double    excitationEnergy);
```

Relevant to the Physics List

Construc a Proton and a Geantino

Construct a proton and a geantino.

```
void MyPhysicsList::ConstructParticle()
{
  G4Proton::ProtonDefinition();
  G4Geantino::GeantinoDefinition();
}
```

Geant4 particle categories

G4BosonConstructor

G4LeptonConstructor

G4MesonConstructor

G4BarionConstructor

G4IonConstructor

G4ShortlivedConstructor.

MAIN COMPONENTS (cont.)

Register Processes for Gammas

Relevant to the Physics List

```
void MyPhysicsList::ConstructProcess()
{
  // Define transportation process
  AddTransportation();
  // electromagnetic processes
  ConstructEM();
}

void MyPhysicsList::ConstructEM()
{
  // Get pointer to G4PhysicsListHelper
  G4PhysicsListHelper* ph = G4PhysicsListHelper::GetPhysicsListHelper();

  //  Get pointer to gamma
  G4ParticleDefinition* particle = G4Gamma::GammaDefinition();

  // Construct and register processes for gamma
  ph->RegisterProcess(new G4PhotoElectricEffect(), particle);
  ph->RegisterProcess(new G4ComptonScattering(), particle);
  ph->RegisterProcess(new G4GammaConversion(), particle);
}
```

Physics Processes

Physics processes describe how particles interact with materials. Geant4 provides seven major categories of processes:

- electromagnetic
- hadronic
- transportation
- decay
- optical
- photolepton_hadron
- parameterisation

MAIN COMPONENTS (cont.)

```
#include "ExG4PrimaryGeneratorAction01.hh"

#include "G4Event.hh"
#include "G4ParticleGun.hh"
#include "G4ParticleTable.hh"
#include "G4ParticleDefinition.hh"

//....oooOOOOOooo........oooOOOOOooo........oooOOOOOooo........oooOOOOOooo......

ExG4PrimaryGeneratorAction01::ExG4PrimaryGeneratorAction01(
                              const G4String& particleName,
                              G4double energy,
                              G4ThreeVector position,
                              G4ThreeVector momentumDirection)
  : G4VUserPrimaryGeneratorAction(),
    fParticleGun(0)
{
  G4int nofParticles = 1;
  fParticleGun  = new G4ParticleGun(nofParticles);

  // default particle kinematic
  G4ParticleTable* particleTable = G4ParticleTable::GetParticleTable();
  G4ParticleDefinition* particle
    = particleTable->FindParticle(particleName);
  fParticleGun->SetParticleDefinition(particle);
  fParticleGun->SetParticleEnergy(energy);
  fParticleGun->SetParticlePosition(position);
  fParticleGun->SetParticleMomentumDirection(momentumDirection);
}

//....oooOOOOOooo........oooOOOOOooo........oooOOOOOooo........oooOOOOOooo......

ExG4PrimaryGeneratorAction01::~ExG4PrimaryGeneratorAction01()
{
  delete fParticleGun;
}

//....oooOOOOOooo........oooOOOOOooo........oooOOOOOooo........oooOOOOOooo......

void ExG4PrimaryGeneratorAction01::GeneratePrimaries(G4Event* anEvent)
{
  // this function is called at the begining of event

  fParticleGun->GeneratePrimaryVertex(anEvent);
}
```

Relevant to the Primary Generation Action

START A SIMULATION WITH /run/beamOn 1