GEANT4
A SIMULATION TOOLKIT

Physics List: in a nutshell

Mihaly Novak (CERN, EP-SFT)

Getting Started with Geant4 at CERN, Geneva (Switzerland)

- What is a Physics List?
- The Geant4 Physics List interface
- Modular and reference Physics Lists

WHAT IS A PHYSICS LIST?

- **Physics List** is an object that **is responsible to:**
  - **specify** all the **particles** that will be used in the simulation application
  - together with the list of **physics processes** assigned to them
- One out of the 3 **mandatory** objects that the user needs to provide to the `G4RunManager` in case of all Geant4 applications
- Provides a very **flexible** way to set up the **physics environment**
  - the user can chose, specify the particles that they want to be used
  - the user can chose the physics to assign to each particle
- **BUT**, the user must have a good understanding of the physics required to describe properly the given problem:
  - omission of relevant particles and/or physics interactions could lead to poor modelling results !!!

- **Why** do we need **Physics List:**
  - physics is physics - Shouldn't Geant4 provide, as default, a complete set of physics that everyone can use?
  - there are many **different approximations** and models to describe the same interaction: **computation time**
  - there is no any simulation application that would require all the particles, all their possible interactions that Geant4 can provide (also **alternative theories** to describe a given interaction)
- For this reason, Geant4 provides an **atomistic**, rather than an integral approach to physics::
  - provides many independent (for the most part) physics components i.e. physics **processes**
  - users select these components in their custom-designed physics lists

Physics List

THE GEANT4 PHYSICS LIST INTERFACE

- **`G4VUserPhysicsList`** is the Geant4 physics list interface:
  - user must implement the 2 pure virtual methods: **`ConstructParticle`** and **`ConstructProcess`**
  - user can implement the **`SetCuts`** method (optional)

```
4   class YourPhysicsList: public G4VUserPhysicsList {
5     public:
6       // CTR
7       YourPhysicsList();
8       // DTR
9       virtual ~YourPhysicsList();
10
11      // pure virtual => needs to be implemented
12      virtual void ConstructParticle();
13      // pure virtual => needs to be implemented
14      virtual void ConstructProcess();
15
16      // virtual method
17      virtual void SetCuts();
18      ...
19      ...
20  };
```

- `ConstructParticle`: is the interface method to define the particles to be used in the simulation:
  - constructing them either individually

```
23  void YourPhysicsList::ConstructParticle() {
24      G4Electron::Definition();
25      G4Gamma::Definition();
26      G4Proton::Definition();
27      G4Neutron::Definition();
28      // other particle definitions
29      …
30      …
31  }
```

  - or by using helpers

```
35  void YourPhysicsList::ConstructParticle() {
36      // construct baryons
37      G4BaryonConstructor baryonConstructor;
38      baryonConstructor.ConstructParticle();
39      // construct bosons
40      G4BosonConstructor bosonConstructor;
41      bosonConstructor.ConstructParticle();
42      // more particle definitions
43      …
44      …
45  }
```

- `ConstructProcess`: is the interface method to define the list of **physics processes** to be used in the simulation **for** a given **particle**:
  - **process**: an object that defines the way in which a given particle interacts with matter through a given type of interaction (e.g. *electron ionisation process*)

```
48  void YourPhysicsList::ConstructProcess() {
49      // method (provided by the G4VUserPhysicsList base class)
50      // that assigns transportation process to all particles
51      // defined in ConstructParticle()
52      AddTransportation();
53      // helper method might be defined by the user (for convenience)
54      // to add electromagnetic physics processes
55      ConstructEM();
56      // helper method might be defined by the user
57      // to add all other physics processes
58      ConstructGeneral();
59  }
```

The Geant4 Physics List interface

```
62  void YourPhysicsList::ConstructEM() {
63    // get the physics list helper
64    // it will be used to assign processes to particles
65    G4PhysicsListHelper* ph = G4PhysicsListHelper::GetPhysicsListHelper();
66    auto particleIterator   = GetParticleIterator();
67    particleIterator->reset();
68    // iterate over the list of particles constructed in ConstructParticle()
69    while( (*particleIterator)() ) {
70      // get the current particle definition
71      G4ParticleDefinition* particleDef  = particleIterator->value();
72      // if the current particle is the appropriate one => add EM processes
73      if ( particleDef == G4Gamma::Definition() ) {
74        // add physics processes to gamma particle here
75        ph->RegisterProcess(new G4GammaConversion(),  particleDef);
76        ...
77        ...
78      } else if ( particleDef == G4Electron::Definition() ) {
79        // add physics processes to electron here
80        ph->RegisterProcess(new G4eBremsstrahlung(), particleDef);
81        ...
82        ...
83      } else if (...) {
84        // do the same for all other particles like e+, mu+, mu-, etc.
85        ...
86      }
87    }
88  }
```

The Geant4 Physics List interface

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62  void YourPhysicsList::ConstructEM() {
63    // get the physics list helper
64    // it will be used to assign processes to particles
65    G4PhysicsListHelper* ph = G4PhysicsListHelper::GetPhysicsListHelper();
66    auto particleIterator   = GetParticleIterator();
67    particleIterator->reset();
68    // iterate over the list of particles constructed in ConstructParticle()
69    while( (*particleIterator)() ) {
70      // get the current particle definition
```

Too complicated for us!

```
76        ...
77        ...
78      } else if ( particleDef == G4Electron::Definition() ) {
79        // add physics processes to electron here
80        ph->RegisterProcess(new G4eBremsstrahlung(), particleDef);
81        ...
82        ...
83      } else if (...) {
84        // do the same for all other particles like e+, mu+, mu-, etc.
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87    }
88  }
```

Physics List

MODULAR AND REFERENCE PHYSICS LISTS

- **Modular physics list:**
  - significantly easier way to obtain/compose a physics list?
  - allows to use “physics modules”: a given physics module handles a well defined **category of physics** (e.g. EM, hadronic physics, decay, etc.)
  - transportation is automatically added to all constructed particles
- **Reference physics list:**
  - even easier way to obtain a complete physics list
  - these are “ready-to-use”, complete physics lists provided by the toolkit and constructed by expert developers
  - each pre-packaged physics list includes different combinations of EM and hadronic physics
  - note, these are physics lists used by some larger user groups like ATLAS, CMS, etc
  - given as it is: the user is responsible for validating them
  - see more details can be found in the **Guide for Physics Lists**

- **Example:** to use the **`QGSP_BIC_HP`** physics list with **`EMZ`** EM option

```
212   // IM YOUR MAIN APPLICATION
213   //
214     // create your run manager
215   #ifdef G4MULTITHREADED
216     G4MTRunManager* runManager = new G4MTRunManager;
217     // number of threads can be defined via macro command
218     runManager->SetNumberOfThreads(4);
219   #else
220     G4RunManager* runManager = new G4RunManager;
221   #endif
222     //
223     // create a physics list factory object that knows
224     // everything about the available reference physics lists
225     // and can replace their default EM option
226     G4PhysListFactory physListFactory;
227     // obtain the QGSP_BIC_HP_EMZ reference physics lists
228     // which is the QGSP_BIC_HP refrence list with opt4 EM
229     const G4String plName = "QGSP_BIC_HP_EMZ";
230     G4VModularPhysicsList* pList = physListFactory.GetReferencePhysList(plName);
231     // (check that pList is not nullptr, that I skipp now)
232     // register your physics list in the run manager
233     runManager->SetUserInitialization(pList);
234     // register further mandatory objects i.e. Detector and Primary-generator
235     ...
```

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```

This is what we will do!

```
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223     // create a physics list factory object that knows
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