Geant4 9.4

PHYSICS 1

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Outline

- Introduction
  - What is a physics list and why do we need one ?
- The G4VUserPhysicsList class
  - What you need to begin
- Modular physics lists
  - A more sophisticated way to go
- Pre-packaged physics lists

What is a Physics List ?

- A class which collects all the particles, physics processes and production thresholds needed for your application
- It tells the run manager how and when to invoke physics
- It is a very flexible way to build a physics environment
  - user can pick the particles he wants
  - user can pick the physics to assign to each particle
- But, user must have a good understanding of the physics required
  - omission of particles or physics could cause errors or poor simulation

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Introduction

Why Do We Need a Physics List ?

- Physics is physics – shouldn't Geant4 provide, as a default, a complete set of physics that everyone can use ?
- NO
  - there are many different physics models and approximations
    - very much the case for hadronic physics
    - but also the case for electromagnetic physics
  - computation speed is an issue
    - a user may want a less-detailed, but faster approximation
  - no application requires all the physics and particles Geant4 has to offer
    - e.g., most medical applications do not want multi-GeV physics

Why Do We Need a Physics List ?

- For this reason Geant4 takes an atomistic, rather than an integral approach to physics
  - provide many physics components (processes) which are decoupled from one another
  - user selects these components in custom-designed physics lists in much the same way as a detector geometry is built
- Exceptions
  - a few electromagnetic processes must be used together
  - future processes involving interference of electromagnetic and strong interactions may require coupling as well

Physics Processes Provided by Geant4

- EM physics
  - "standard" processes valid from ~ 1 keV to ~ PeV
  - "low-energy" valid from 250 eV to ~ PeV
  - optical photons
- Weak physics
  - decay of subatomic particles
  - radioactive decay of nuclei
- Hadronic physics
  - pure hadronic processes valid from 0 to ~TeV
  - electro- and gamma-nuclear valid from 10 MeV to ~TeV
- Parameterized or "fast simulation" physics

G4VUserPhysicsList

- All physics lists must derive from this class
  - and then be registered with the run manager
- In our example:

```
class BeamTestPhysicsList: public G4VUserPhysicsList
{
  public:
    BeamTestPhysicsList();
    ~BeamTestPhysicsList();
    void ConstructParticle();
    void ConstructProcess();
    void SetCuts();
}
```

- User must implement the methods **`ConstructParticle`** and **`ConstructProcess`**, and optionally **`SetCuts`**

G4VUserPhysicsList

G4VUserPhysicsList: Required Methods

- `ConstructParticle()` : choose the particles you need in your simulation and define all of them here

- `ConstructProcess()`: for each particle, assign all the physics processes important in your simulation
  - What's a process ?
  - a class that defines how a particle should interact with matter (it's where the physics is!)
  - more on this later

- `SetCuts()` : set the range cuts for secondary production
  - What's a range cut ?
  - essentially a low energy limit on particle production
  - more on this later
  - optional

1) ConstructParticle()


```
void BeamTestPhysicsList::ConstructParticle()
{

G4BaryonConstructor* baryonConstructor = new G4BaryonConstructor();
baryonConstructor->ConstructParticle();
delete baryonConstructor;

G4BosonConstructor* bosonConstructor = new G4BosonConstructor();
bosonConstructor->ConstructParticle();
delete bosonConstructor;
....
....
}
```

ConstructParticle() – alternate –


```
void BeamTestPhysicsList::ConstructParticle()
{

G4Electron::ElectronDefinition();
G4Proton::ProtonDefinition();
G4Neutron::NeutronDefinition();
G4Gamma::GammaDefinition();
....
....
}
```

2) ConstructProcess()


```
void BeamTestPhysicsList::ConstructProcess()
{
AddTransportation();
// method provided by G4VUserPhysicsList
// assigned transportation process to all particles
// defined in ConstructParticle()

ConstructEM();
// method may be defined by user (for convenience)
// put electromagnetic physics here

ConstructGeneral();
// method may be defined by user (for convenience)
}
```

ConstructEM()


```
void BeamTestPhysicsList::ConstructEM()
{
theParticleIterator->reset();

while( (*theParticleIterator)() )
{
        G4ParticleDefinition* particle =theParticleIterator->value();
        G4ProcessManager* pmanager =particle->GetProcessManager();
        G4String particleName = particle->GetParticleName();

        if (particleName == "gamma") {
                pmanager->AddDiscreteProcess(new G4GammaConversion());
...
}
.....
```

ConstructGeneral()


```
void BeamTestPhysicsList::ConstructGeneral()
{
// Add decay process
G4Decay* theDecayProcess = new G4Decay();

theParticleIterator->reset();
while( (*theParticleIterator)() )
  {
        G4ParticleDefinition* particle = theParticleIterator->value();
        G4ProcessManager* pmanager = particle->GetProcessManager();
        if (theDecayProcess->IsApplicable(*particle) )
        {
                pmanager->AddProcess(theDecayProcess);
                pmanager->SetProcessOrdering(theDecayProcess,idxPostStep);
                pmanager->SetProcessOrdering(theDecayProcess,idxAtRest);
        }
  }
}
```

3) SetCuts() – optional –


```
void BeamTestPhysicsList::SetCuts()
{
        defaultCutValue = 1.0*mm;
        SetCutValue(defaultCutValue, "gamma");
        SetCutValue(defaultCutValue, "e-");
        SetCutValue(defaultCutValue, "e+");
        //
        // These are all the production cut values you need to set
        // not required for any other particle
}
```

Modular Physics list

G4VModularPhysicsList

- The physics list in our example is relatively simple

- A realistic physics list is likely to have many more physics processes
  - such a list can become quite long, complicated and hard to maintain
  - try a modular physics list instead

- Features of G4VModularPhysicsList
  - derived from G4VUserPhysicsList
  - `AddTransportation()` automatically called for all registered particles
  - Allows you to define "physics modules": EM physics, hadronic physics, optical physics, etc.

A Simple G4VModularPhysicsList

- Constructor:

```
MyModPhysList::MyModPhysList(): G4VModularPhysicsList()
{
defaultCutValue = 1.0*mm;

RegisterPhysics( new ProtonPhysics() );
// all physics processes having to do with protons

RegisterPhysics( new ElectronPhysics() );
// all physics processes having to do with electrons

RegisterPhysics( new DecayPhysics() );
// physics of unstable particles
}
```

- Set Cuts:

```
void MyModPhysList::SetCuts()
{ SetCutsWithDefault() ; }
```

Usage of Physics Constructors

- Allows you to group particle and process construction according to physics domains

```
class ProtonPhysics : public G4VPhysicsConstructor
{
  public:
        ProtonPhysics(const G4String& name = "proton");
        virtual ~ProtonPhysics();

        virtual void ConstructParticle();
        // easy - only one particle to build in this case

        virtual void ConstructProcess();
        // put here all the processes a proton can have
}
```

- We will see Physics Constructor examples soon

Pre-packaged Physics lists

Pre-packaged Physics Lists (1)

- Our example deals mainly with electromagnetic physics
- A complete and realistic EM physics list can be found in novice example N03
  - good starting point
  - add to it according to your needs
- Adding hadronic physics is more involved
  - for any one hadronic process, user may choose from several hadronic models
  - choosing the right models for your application requires care
  - to make things easier, pre-packaged physics lists (also called « reference » physics lists) are now provided according to some reference use cases

Pre-packaged Physics Lists (2)

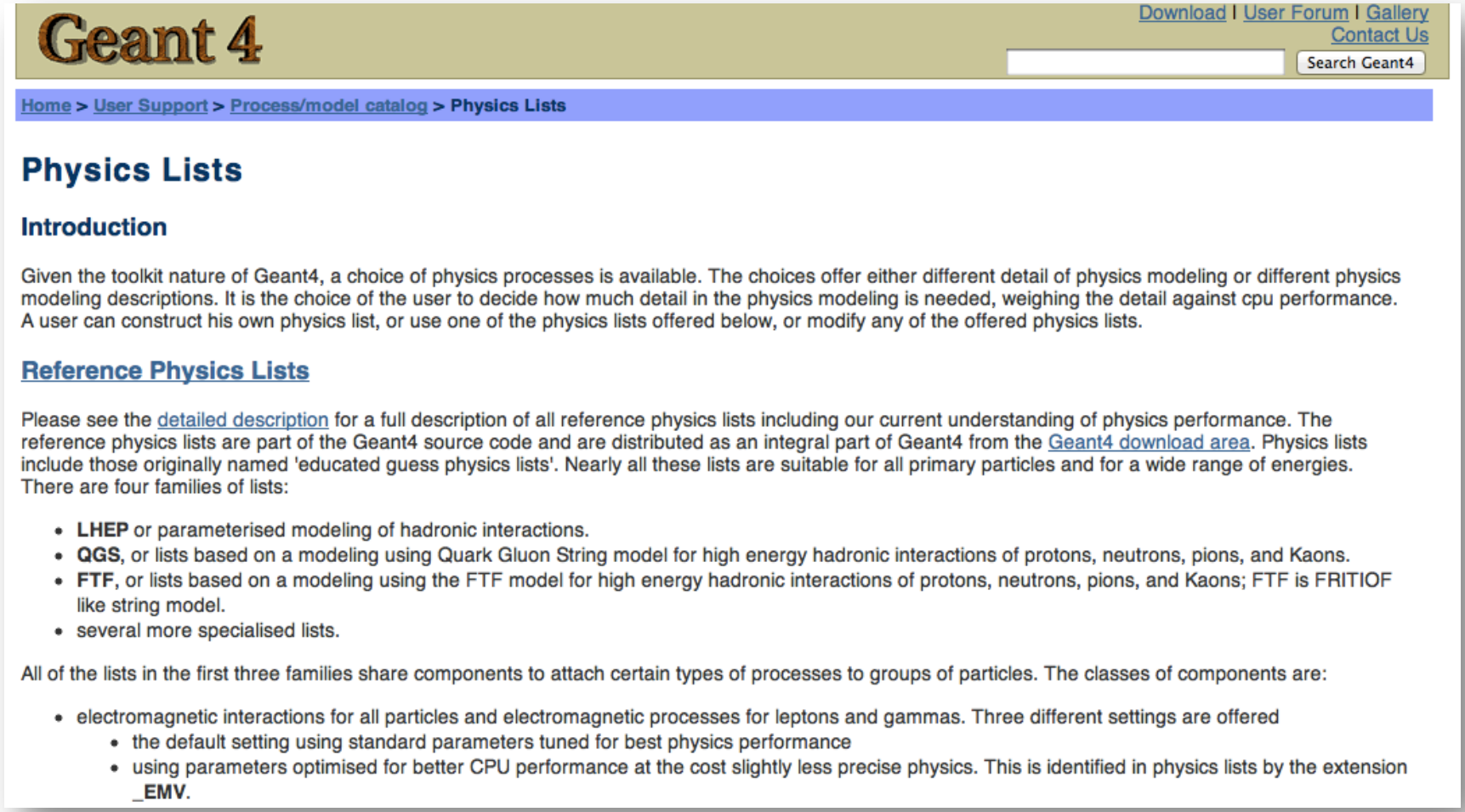
- Each pre-packaged (or reference) physics list includes different choices of EM and hadronic physics, but the EM part derives mainly from the electromagnetic physics of example N03

- These can be found on the Geant4 web page at : http://geant4.cern.ch/support/proc_mod_catalog/physics_lists/physicsLists.shtml

- Caveats
  - these lists are provided as a "best guess" of the physics needed in a given case
  - the user is responsible for validating the physics for his own application and adding (or subtracting) the appropriate physics
  - they are intended as starting points or templates

Physics Lists web page

http://geant4.cern.ch/support/proc_mod_catalog/physics_lists/physicsLists.shtml



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Physics Lists

Introduction

Given the toolkit nature of Geant4, a choice of physics processes is available. The choices offer either different detail of physics modeling or different physics modeling descriptions. It is the choice of the user to decide how much detail in the physics modeling is needed, weighing the detail against cpu performance. A user can construct his own physics list, or use one of the physics lists offered below, or modify any of the offered physics lists.

Reference Physics Lists

Please see the detailed description for a full description of all reference physics lists including our current understanding of physics performance. The reference physics lists are part of the Geant4 source code and are distributed as an integral part of Geant4 from the Geant4 download area. Physics lists include those originally named 'educated guess physics lists'. Nearly all these lists are suitable for all primary particles and for a wide range of energies. There are four families of lists:

- **LHEP** or parameterised modeling of hadronic interactions.
- **QGS**, or lists based on a modeling using Quark Gluon String model for high energy hadronic interactions of protons, neutrons, pions, and Kaons.
- **FTF**, or lists based on a modeling using the FTF model for high energy hadronic interactions of protons, neutrons, pions, and Kaons; FTF is FRITIOF like string model.
- several more specialised lists.

All of the lists in the first three families share components to attach certain types of processes to groups of particles. The classes of components are:

- electromagnetic interactions for all particles and electromagnetic processes for leptons and gammas. Three different settings are offered
  - the default setting using standard parameters tuned for best physics performance
  - using parameters optimised for better CPU performance at the cost slightly less precise physics. This is identified in physics lists by the extension **_EMV**.

Summary

- All the particles, physics processes, and production cuts needed for an application must go into a physics list
- Two kinds of physics list classes are available for users to derive from
  - G4VUserPhysicsList – for relatively simple physics lists
  - G4VModularPhysicsList – for detailed physics lists
- Some pre-packaged physics lists are provided by Geant4 as starting points for users
  - electromagnetic physics lists
  - electromagnetic + hadronic physics lists
- Care is required by user in choosing the right physics to use

Thank you for your attention