Geant4: Electromagnetic Physics 4

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- Process interface for developers
- Conception of interaction lengths
- Interaction with G4 kernel
- Examples

G4VProcess interface overview

- All processes inherit from base class G4VProcess
- Standard interface: a process provides *Interaction Lenths*, *StepLimits*, and *DoIt* methods
- Processes active *AlongStep, PostStep, AtRest*

- There are 7 types of processes with predefined interfaces:
  - ContinuousProcess
  - ContinuouesDiscreteProcess
  - DiscreteProcess
  - RestContinuouesDiscrete Process
  - RestContinuouesProcess
  - RestDiscreteProcess
  - RestProcess

G4VProcess interface

- G4VProcess defines 6 pure virtual methods:
  - AtRestGetPhysicalInteractionLength(….)
  - AtRestDoIt(…)
  - AlongStepGetPhysicalInteractionLength(…)
  - AlongStepDoIt(…)
  - PostStepGetPhysicalInteractionLength(…)
  - PostStepDoIt(…)
- There are also other virtual methods:
  - IsApplicable(const G4ParticleDefinition&)
  - BuildPhysicsTable(const G4ParticleDefinition&)
  - ….
- G4VProcess defined in source/processes/management

Number of interaction length

- G4VProcess and derived classes implement a scheme based on the « number of interaction length » to define the time/space point of the interaction and to choose the process of interaction
  - assumed for the processes dealing with the exponential law
- At the beginning of the tracking the process is given a sampled value « number of interaction lenght » N_{int}
- At the beginning of each step
  - The (concrete) process evaluates the current « mean free path » l_{free}, given the current material;
  - The « true path length » the process allows to the particle before the interaction occurs is then: $N_{int} \times l_{free}$;
  - This value is returned by GetPhysicalInteractionLength;

Number of interaction length

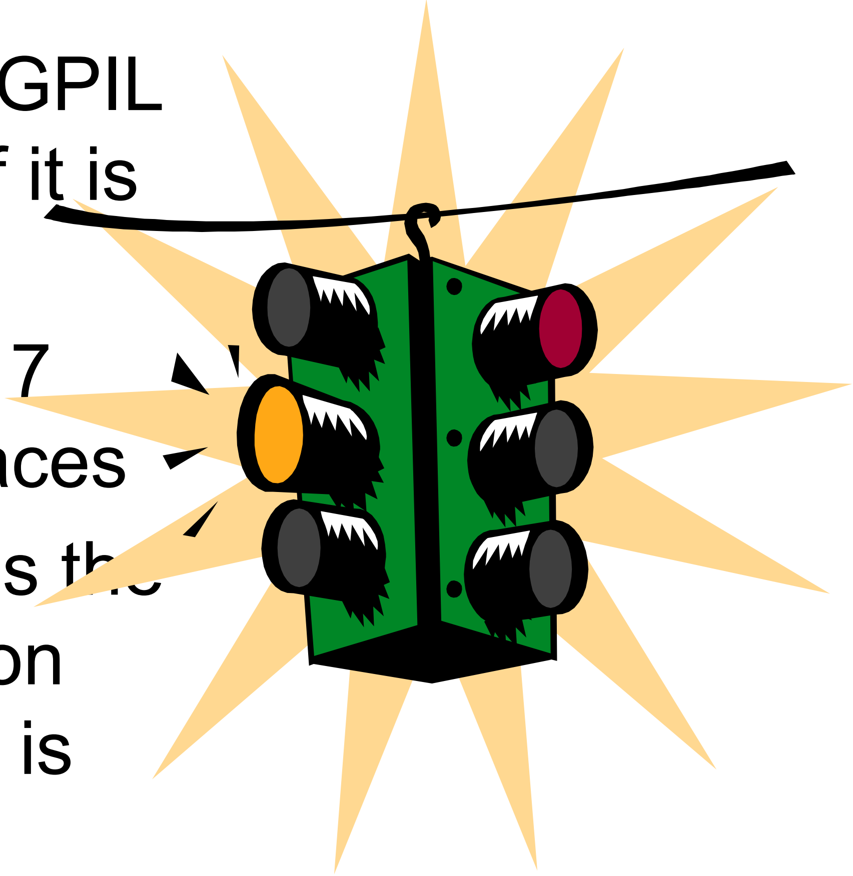
- Then the step occurs with the actual step length L_{step} value;
- At the beginning of the new step:
  - If the process has limited the previous step (ie its interaction occured), it gets a new N_{int} value;
  - Otherwise, the process converts back L_{step} into a number of « consumed » interaction length, which is substracted to its N_{int} amount;
- Please review for example G4VDiscreteProcess;
  - Note that all related methods are virtual, allowing to redefine them, if needed.

Example: G4VDiscreteProcess

```
inline G4double
   G4VDiscreteProcess::PostStepGetPhysicalInteractionLength(
                              const G4Track&    track,
                               G4double             previousStepSize,
                               G4ForceCondition*   condition) {
 if ( (previousStepSize <=0.0) || (theNumberOfInteractionLengthLeft<=0.0))
    {
       // beginning of tracking (or just after DoIt of this process)
       ResetNumberOfInteractionLengthLeft()
 } else {
       //subtract NumberOfInteractionLengthLeft
       SubtractNumberOfInteractionLengthLeft(previousStepSize);
       if(theNumberOfInteractionLengthLeft<perMillion)
         theNumberOfInteractionLengthLeft=0.;
 }
  //get mean free path
_currentInteractionLength = GetMeanFreePath(track, previousStepSize,
    condition)
 G4double value =
    theNumberOfInteractionLengthLeft*currentInteractionLengt; return
    value;
```

Some advices

- Do not overwrite GPIL virtual functions if it is possible!
- Try to use one of 7 predefined interfaces
- In these interfaces the accurate control on interaction length is provided for you



Interfaces to be used

- protected:
- // For all processes
- virtual G4double GetMeanFreePath(
  const G4Track& track,
  G4double previousStepSize,
  G4ForceCondition* condition)
  = 0;
- // For continuous processes
- virtual G4double GetContinuousStepLimit(
  const G4Track& track,
  G4double previousStepSize,
  G4double currentMinimumStep,
  G4ForceCondition* condition)
  = 0;

When process is active?

- All Continuous processes are invocated at each step of the particle
- If Discrete or Rest process limits the step then it is invocated
- To help to activate Rest or Discrete process at each step one should use G4ForceCondition

G4ForceConditions

- GetPhysicalInteractionLength methods involve G4ForceCondition & G4GPILSelection;
- These are two enumerations:
  - They define signals, that processes send to the stepping, to require the treatment they wish from the stepping;
  - Involve ± « delicate » aspects;
  - Defined in source/track;

G4ForceConditions

- G4ForceCondition (AtRest and PostStep) defines requests for treatment of the DoIt methods.
- It can take the values:
  - **NotForced**: Usual case ☺ : the DoIt method is invoked if the related GetPhysicalInteractionLength has limited the step
  - **Forced**: The related DoIt is applied is particle is not killed
  - **Conditionally**: The PostStepDoIt is applied if the AlongStep has limited the step
  - **ExclusivelyForced**: Only the PostStepDoIt of the process is applied: all other AlongStep and PostStep are ignored
  - **StronglyForced**: The related DoIt is applied in any

G4GPILSelection

- More delicate…
- G4GPILSelection (AlongStep) defines requests for the treatment of the GetPhysicalInteractionLength methods.
- It can takes the values:
  - **CandidateForSelection**: ***usual case*** ☺ : the process will be « declared » to have limited the step if it returns the smallest length;
  - **NotCandidateForSelection**: the process will not be « declared » to have limited the step, even if it returns the smallest lenght;
- In practice, only the multiple-scattering makes use of the « NotCandidateForSelection » signal up to now

Examples of processes

- G4hIonisation – notForced ContinuousDiscrete
- G4Decay – notForced RestDiscrete
- G4Cherenkov – Continuous
- G4Scintillation – Forced RestDiscrete
- G4MuonMinusCaptureAtRest – Rest
- G4ProtonInelasticProcess – notForced Discrete

DoIt signature

-
  ```
  virtual G4VParticleChange* AtRestDoIt(
                       const G4Track& track,
                       const G4Step&  step
                                    ) = 0;
  ```

-
  ```
  virtual G4VParticleChange* AlongStepDoIt(
                       const G4Track& track,
                       const G4Step&  step
                                    ) = 0;
  ```

-
  ```
  virtual G4VParticleChange* PostStepDoIt(
                       const G4Track& track,
                       const G4Step&   step
                                   ) = 0;
  ```

DoIt signature

- All DoIt methods have the same signature:
  - They receive **const** G4Track and G4Step
    - It is not allowed to change directly the track, nor the step
  - They return a G4VParticleChange:
    - This G4VParticleChange returns the changes of the track to the stepping
      - Not the « delta »!
    - It is assumed to create of secondary G4Track
    - Need to be familiar with, to implement a process ☺;

G4VParticleChange

- G4VParticleChange is defined in source/track
- It defines the virtual methods:
  - virtual G4Step* UpdateStepForAtRest(G4Step*);
  - virtual G4Step* UpdateStepForAlongStep(G4Step*);
  - virtual G4Step* UpdateStepForPostStep(G4Step*);
- Which are used to communicate the changes to be applied on the primary;
  - They return the G4Step after having updated it;
- Each concrete G4VParticleChange should modify only the necessary members of the G4Step;
  - Can be relevant if your G4VParticleChange is often used;

G4VParticleChange

- To create secondaries by the process, the following methods have to be used:
  - void SetNumberOfSecondaries(G4int);
    - To declare the maximum number of secondaries which will be created by the process;
  - void AddSecondary(G4Track* aSecondary);
    - Which has to be called for each secondary created;
- G4VParticleChange has a method Initialize(const G4Track&) which is used to initialize the members which will be changed by the process

G4TrackStatus

- G4TrackStatus defines the possible status a track can undertake;
- It is needed when writing a process:

```
fAlive,                         // Continue the tracking
fStopButAlive,                    // Invoke active rest physics processes
  and
                                // and kill the current track afterward
fStopAndKill,                     // Kill the current track

fKillTrackAndSecondaries, // Kill the current track and also
                                // associated secondaries.

fSuspend,                        // Suspend the current track

fPostponeToNextEvent     // Postpones the tracking of thecurrent
                                 // track to the next event.
```

Example with G4GammaConversion (1)

- Example with G4GammaConversion, which uses a particle change defined in the base class G4VDiscreteProcess;

```
G4VParticleChange* G4GammaConversion::PostStepDoIt(
                                              const G4Track& aTrack,
                                                        const G4Step&  aStep)
    {
          aParticleChange.Initialize(aTrack);
          //Does the physics…
          aParticleChange.SetNumberOfSecondaries(2) ;
          //…
          G4double localEnergyDeposit = 0.;

          if (ElectKineEnergy > fminimalEnergy)
          { //…
          // create G4DynamicParticle object for the particle1
          G4DynamicParticle* aParticle1= new G4DynamicParticle(
                G4Electron::Electron(), ElectDirection, ElectKineEnergy);
          aParticleChange.AddSecondary(aParticle1);
         } else { localEnergyDeposit += ElectKineEnergy;}
```

Example with G4GammaConversion (2)

```
  // the e+ is always created (even with Ekine=0) for further annihilation.
  //…
  if (PositKineEnergy < fminimalEnergy)
   { localEnergyDeposit += PositKineEnergy; PositKineEnergy = 0.;}
    //…
  // create G4DynamicParticle object for the particle2
    G4DynamicParticle* aParticle2= new G4DynamicParticle(
                G4Positron::Positron(), PositDirection, PositKineEnergy);
    aParticleChange.AddSecondary(aParticle2);

    aParticleChange.SetLocalEnergyDeposit(localEnergyDeposit);

    //
    // Kill the incident photon
    //
    aParticleChange.SetEnergyChange( 0. );
    aParticleChange.SetStatusChange( fStopAndKill );
    return G4VDiscreteProcess::PostStepDoIt( aTrack, aStep );
}
```

Some remarks

- It is not necessary to know Geant4 kernel in order to implement a new process
- One have to follow the described interfaces
- Having several implementation for given process is normal for Geant4

Conclusion remarks

- The toolkit provides a wide choice of processes, so try to use existing processes
- User can substitute any of existing processes
- It is assumed that Geant4 user is at the same time a developer
- Geant4 team will appreciate an efforts of any user to implement his/her own process or model, if it is correct from physics point of view