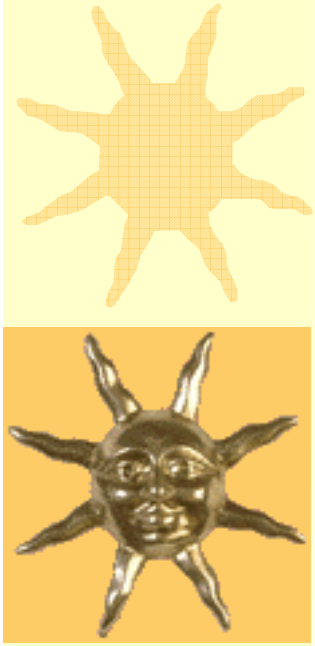

Geant4 Electromagnetic Physics

Introduction

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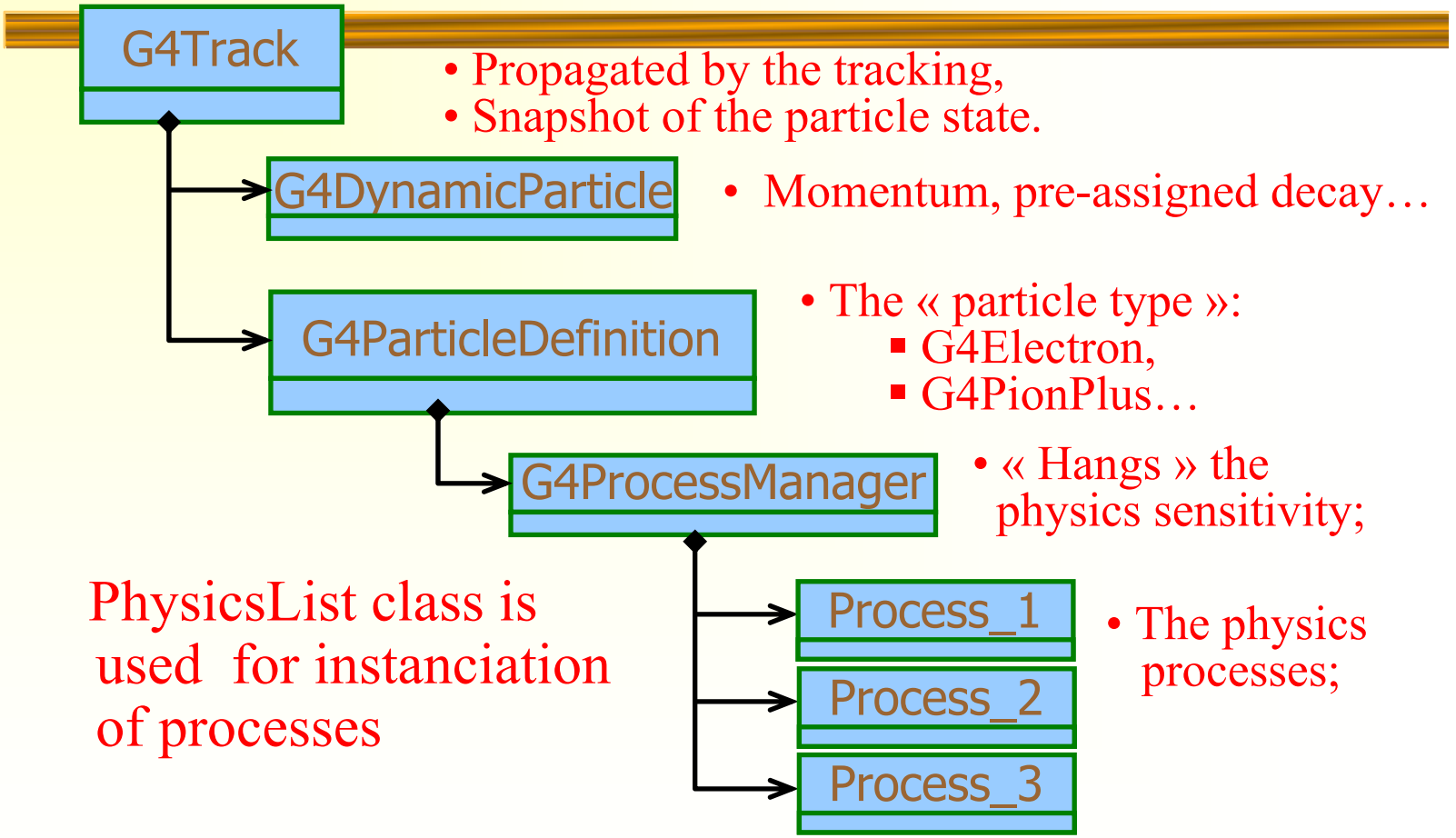
- Process interface
- Physics categories
- Electromagnetic physics
- PhysicsList and Cuts

Geant4 physics processes

- Physics is described via abstract interface called ***process*** associated with ***particles***
- ***Process*** provides *Interaction Lenths*, *StepLimits*, and *DoIt* methods
- ***Process*** active *AlongStep, PostStep, AtRest*
- Distinction between process and model – one process may includes many models
- Generation of final state is independent from the access and use of cross sections and from tracking

What is tracked in Geant4 ?

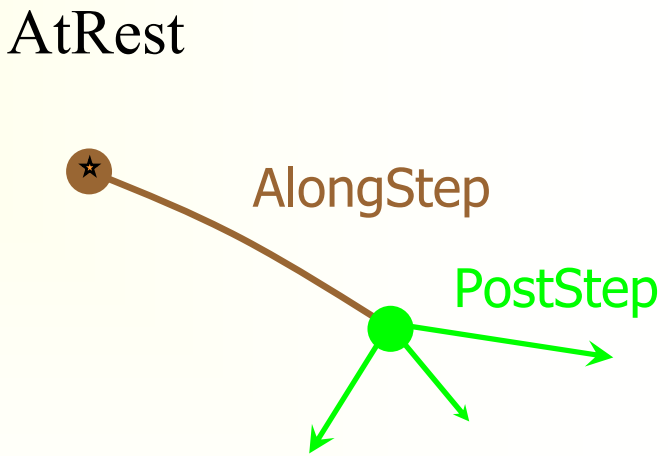


G4VProcess interface

- 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

G4VProcess actions

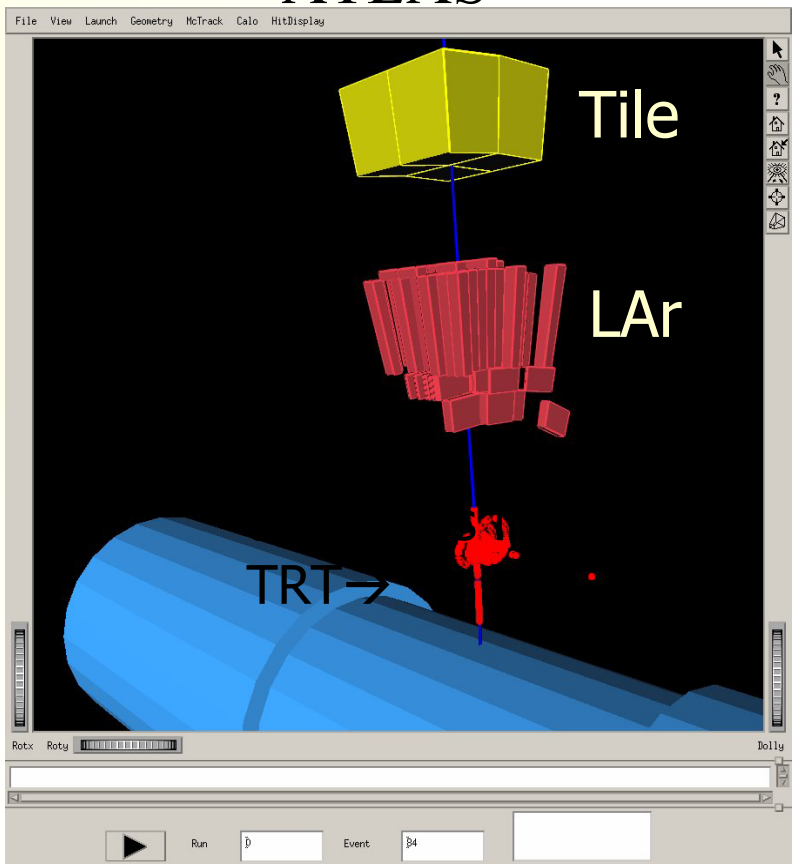
- Abstract class defining the common interface of all processes in GEANT4
- AtRest
  - decay at rest, annihilation at rest, …
- AlongStep
  - continuous energy losses, multiple scattering, …
- PostStep
  - decay in flight, hardron elastic and inelastic, …



Geant4 physics categories

- There are following categories:
  - Decay
  - Electromagnetic
  - Hadronic
  - Optical
  - Transportation
  - Parameterisations

ATLAS



Electromagnetic Physics

- Processes of gamma, electron, and positron interactions with media was traditionally called ***"Electromagnetic Processes" (EM)***
- Hadron interaction with atomic electrons are also EM
- Hadron photo- and electro- production are simulated in framework of G4 hadronic physics

EM packages

- ***Standard*** – basic set of processes for HEP
- ***Muons*** – basic set of muon processes for HEP
- ***Xrays*** – xray and optical proton production
- ***Lowenergy*** – alternative set of processes with low energy extension of gamma, electron, and hadron EM physics
- ***Highenergy*** – EM processes important above 100 GeV
- ***Optical*** – Optical photon interaction
- ***Utils – common classes for other EM packages:***
  - ***Interfaces***
  - ***Energy loss and range table builders***
  - ***Useful utilities***

Standard EM Physics

- The projectile is assumed to have the energy $E_{kin} > 1keV$
- The atomic electrons are quasi-free – their binding energies neglected (except some corrections at low energies)
- The atomic nucleus are fixed – no recoil
- The matter is described as homogeneous, isotropic, amorphous

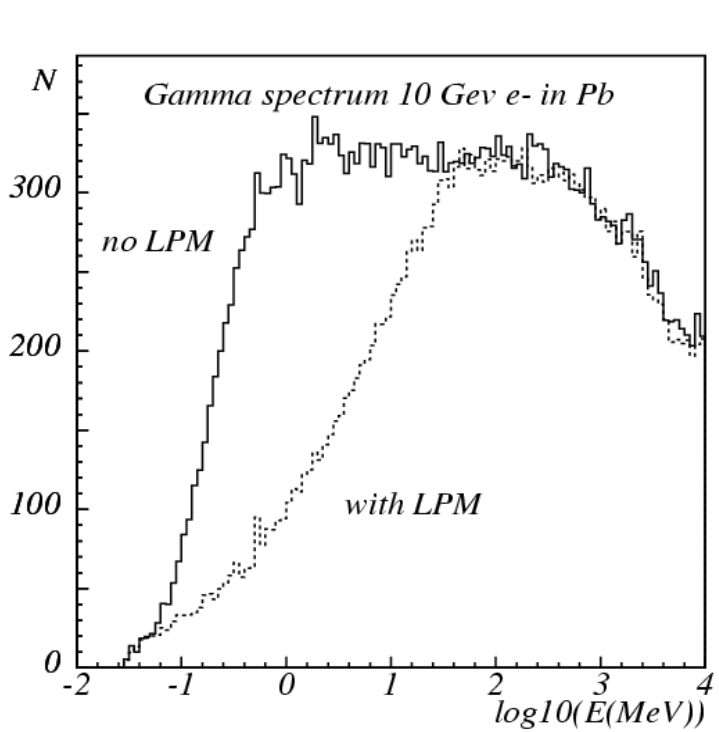
Standard EM Processes

- Gamma
  - Photo-electric effect
  - Compton scattering
  - e^+e^- pair production
  - $\mu^+\mu^-$ pair production
- Electron and positron
  - Ionization
  - Bremsstrahlung
  - Positron annihilation
- Muons
  - Ionization
  - Bremsstrahlung
  - e^+e^- pair production
- Hadrons
  - Ionization
- Ions
  - Ionization
- Multiple scattering

Standard EM Physics

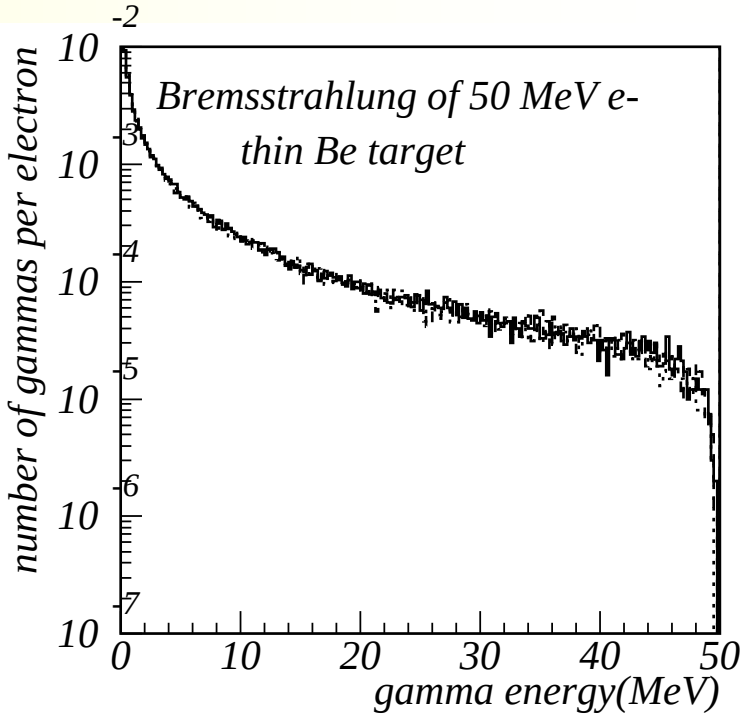
- Standard G4 physics was based on G3 knowledge/experience
- Review of G3 models have been done
- More precise theories were used if possible/ necessary
- Extension to highest energies in progress

Landau-Pomeranchuk-Migdal Effect for bremsstrahlung



Energy Cuts for EM Physics

- Energy spectrum of δ-electrons ~ $1/T^2$
- Energy spectrum of Bremsstahlung ~ $1/\omega$
- Huge number of low energy e- and gammas cannot be tracked efficiently by any Monte Carlo
- Cuts should be used



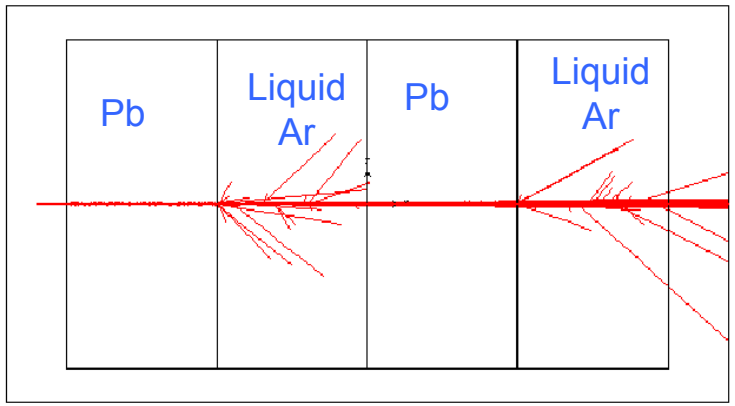
Geant4 cuts

- For a typical process G4Ionisation production threshold T_c subdivides continues and discrete part of energy loss:
- Energy loss $\frac{dE}{dx} = n \int_0^{Tc} t \frac{d\sigma(t)}{dt} dt$
- δ-electron production $\sigma = \int_{Tc}^{T\max} \frac{d\sigma}{dt} dt$
- By default energy is deposited at the step
- Energy loss can be used optionally for generation of δ-electrons under the threshold (subcutoff) and for fluorescence and Auger–electrons emission

Effect of production thresholds

Geant 4

500 MeV incident proton



Range threshold: 1.5 mm

455 keV electron energy in liquid Ar

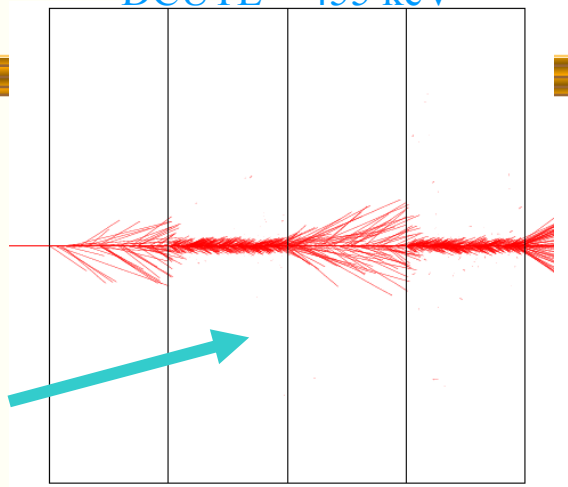
2 MeV electron energy in Pb

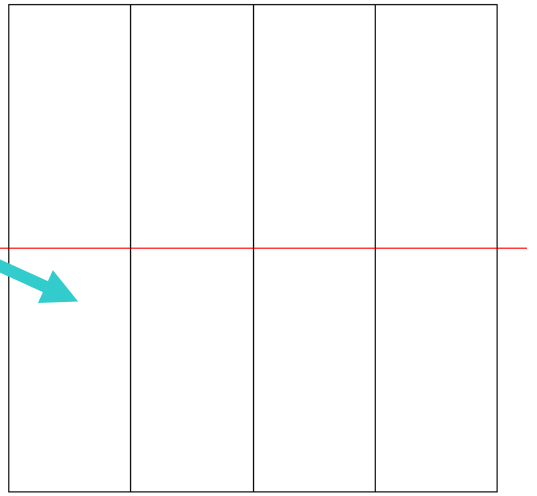
one must set the cut for delta-rays (DCUTE) either to the Liquid Argon value, thus producing many small unnecessary δ-rays in Pb,

or to the Pb value, thus killing the δ-rays production everywhere

In Geant3

DCUTE = 455 keV





DCUTE = 2 MeV

Remarks about Geant4 cuts

- The use of production threshold is mandatory only for Standard ionization and bremsstahlung
- Other processes can use or ignore G4 cuts
- Alternative mechanism is UserLimits, which can be defined in a given G4LogicalVolume:
  - Maximum step size
  - Maximum track length
  - Maximum track time
  - Minimun kinetic energy
  - Minimum range

PhysicsList

- It is one of the « mandatory user classes »;
  - Defined in source/run
- Defines the three pure virtual methods:
  - ConstructParticle()
  - ConstructProcesse()
  - SetCuts()
- Concrete PhysicsList needs to inherit from G4VUserPhysicsList or G4VModularPhysicsList
- For interactivity G4UserPhysicsListMessenger can be used to handle PhysicsList parameters

Example: Gamma processes

- Discrete processes - only PostStep actions;
  - Use function AddDiscreteProcess;
  - **pmanager** is the G4ProcessManager of the gamma;
  - Assume the transportation has been set by AddTransportation;
- Code sample:

```
// Construct processes for gamma:
pmanager->AddDiscreteProcess(new G4GammaConversion());
pmanager->AddDiscreteProcess(new G4ComptonScattering());
pmanager->AddDiscreteProcess(new G4PhotoElectricEffect());
```

Some Remarks

- Standard package of EM interactions was created for HEP applications
- It is well adequate for instrumental studies, space and medical applications
- Examples of different usage of the Standard package:
  - $G4INSTALL/examples/novice
  - $G4INSTALL/examples/extended/electromagnetic