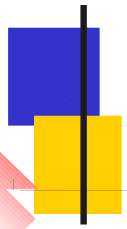
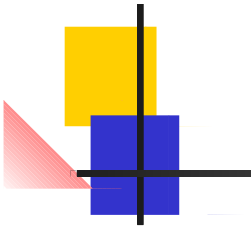


Physics II : Overview and Processes

SLAC Geant4 Tutorial

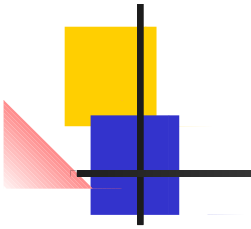
8 March 2006

Dennis Wright



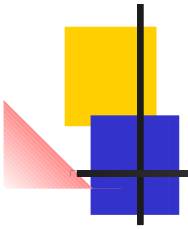
Outline

- Physics Overview
  - the physics Geant4 has to offer
- Processes
  - how they work
  - example processes



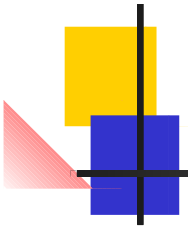
Geant4 Physics

- Geant4 provides a wide variety of physics components for use in simulation
- Physics components are coded as processes
  - a process is a class which tells a particle how to interact
  - user may write his own processes (derived from Geant4 process)
- Processes are grouped into
  - electromagnetic, hadronic, and decay categories



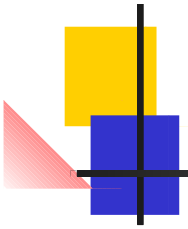
Geant4 Physics: Electromagnetic

- standard – complete set of processes covering charged particles and gammas
  - energy range 1 keV to ~PeV
- low energy – specialized routines for e+, e-, gamma, charged hadrons
  - more atomic shell structure details
  - some processes valid down to 250 eV or below
  - others not valid above a few GeV
- optical photon – only for long wavelength photons (x-rays, UV, visible)
  - processes for reflection/refraction, absorption, wavelength shifting, Rayleigh scattering



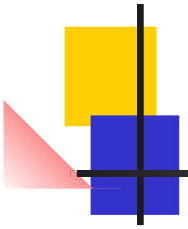
Geant4 Physics: Hadronic

- Pure hadronic (0 - ~100 TeV)
  - elastic
  - inelastic
  - capture
  - fission
- radioactive decay
  - at-rest and in-flight
- photo-nuclear (~10 MeV - ~Tev)
- lepto-nuclear (~10 MeV - ~Tev)
  - e+, e- nuclear reactions
  - muon-nuclear reactions



Geant4 Physics: Decay and Parameterized

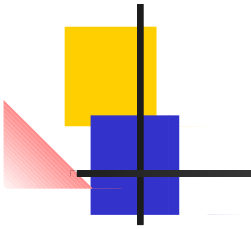
- Decay processes include
  - weak decay (leptonic decays, semi-leptonic decays, radioactive decay of nuclei)
  - electromagnetic decay (π^0, Σ^0, etc. decay)
  - strong decays not included here (they are part of hadronic models)
- Parameterized processes
  - electromagnetic showers propagated according to parameters averaged over many events
  - faster than detailed shower simulation



Physics Processes (1)

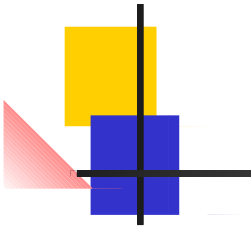
- All the work of particle decays and interactions is done by processes
  - transportation is also handled by a process

- A process does two things:
  - decides when and where an interaction will occur
    - method: GetPhysicalInteractionLength()
    - this requires a cross section, decay lifetime
    - for the transportation process, the distance to the nearest object along the track is required
  - generates the final state of the interaction (changes momentum, generates secondaries, etc.)
    - method: DoIt()
    - this requires a model of the physics



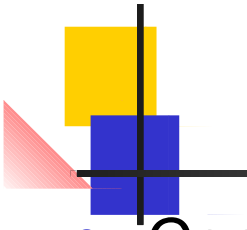
Physics Processes (2)

- There are three flavors of processes:
  - well-located in space -> PostStep
  - distributed in space -> AlongStep
  - well-located in time -> AtRest
- A process may be a combination of all three of the above
  - in that case six methods must be implemented (GetPhysicalInteractionLength() and DoIt() for each action)
- “Shortcut” processes are defined which invoke only one
  - Discrete process (has only PostStep physics)
  - Continuous process (has only AlongStep physics)
  - AtRest process (has only AtRest physics)



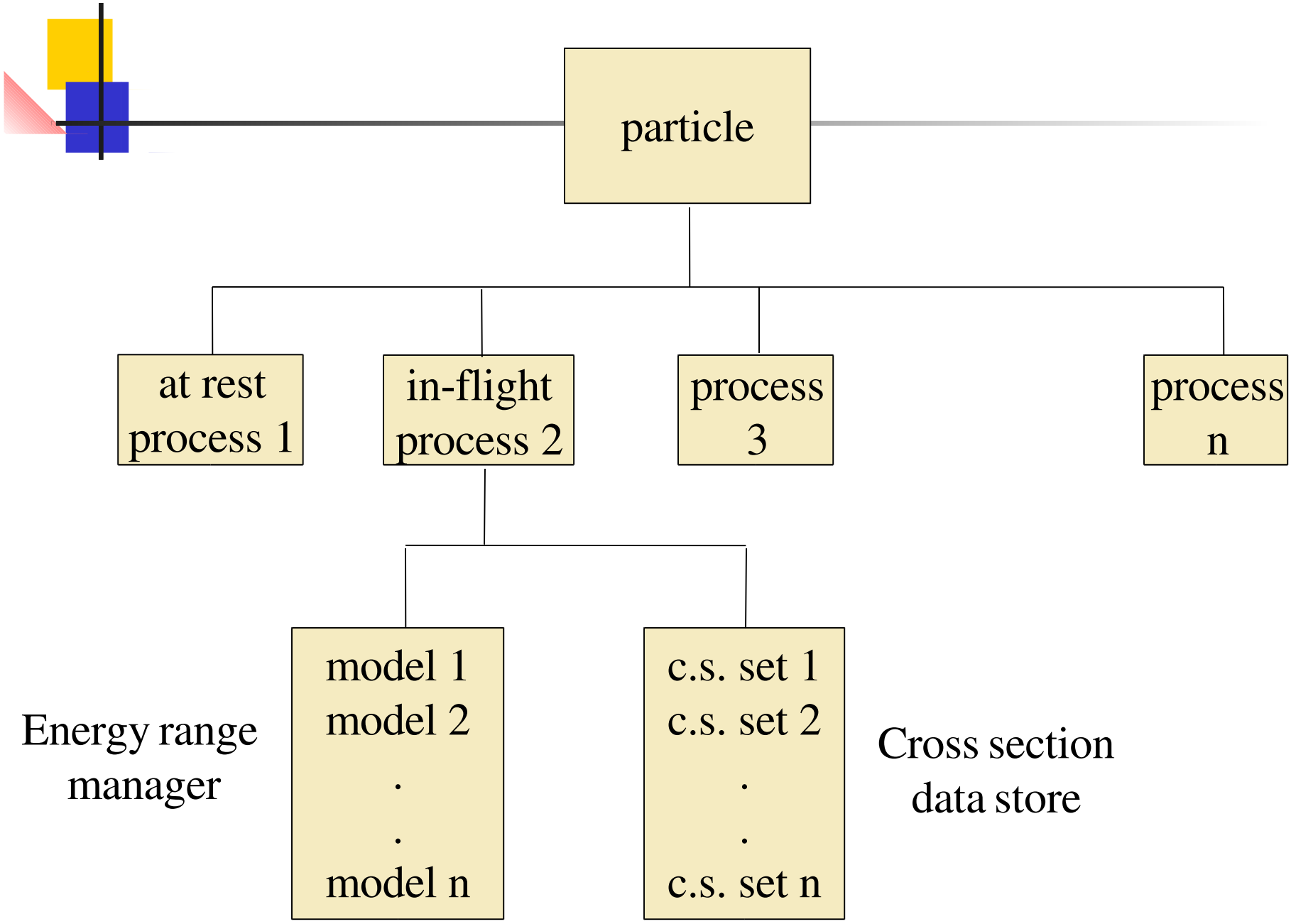
Example Processes (1)

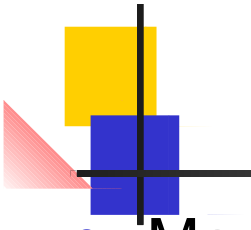
- Discrete process: Compton Scattering
  - step determined by cross section, interaction at end of step
    - PostStepGPIL()
    - PostStepDoIt()
- Continuous process: Cerenkov effect
  - photons created along step, # roughly proportional to step length
    - AlongStepGPIL()
    - AlongStepDoIt()
- At rest process: positron annihilation at rest
  - no displacement, time is the relevant variable
    - AtRestGPIL()
    - AtRestDoIt()
- These are examples of so-called “pure” processes



Example Processes (2)

- Continuous + discrete: ionization
  - energy loss is continuous
  - Moller/Bhabha scattering and knock-on electrons are discrete
- Continuous + discrete: bremsstrahlung
  - energy loss due to soft photons is continuous
  - hard photon emission is discrete
- In both cases, the production threshold separates the continuous and discrete parts of the process
  - more on this later
- Multiple scattering is also continuous + discrete


particle
at rest process 1
in-flight process 2
process 3
process n
model 1
model 2
.
.
model n
c.s. set 1
c.s. set 2
.
.
c.s. set n
Energy range manager
Cross section data store



Handling Multiple Processes

- Many processes (and therefore many interactions) can be assigned to the same particle

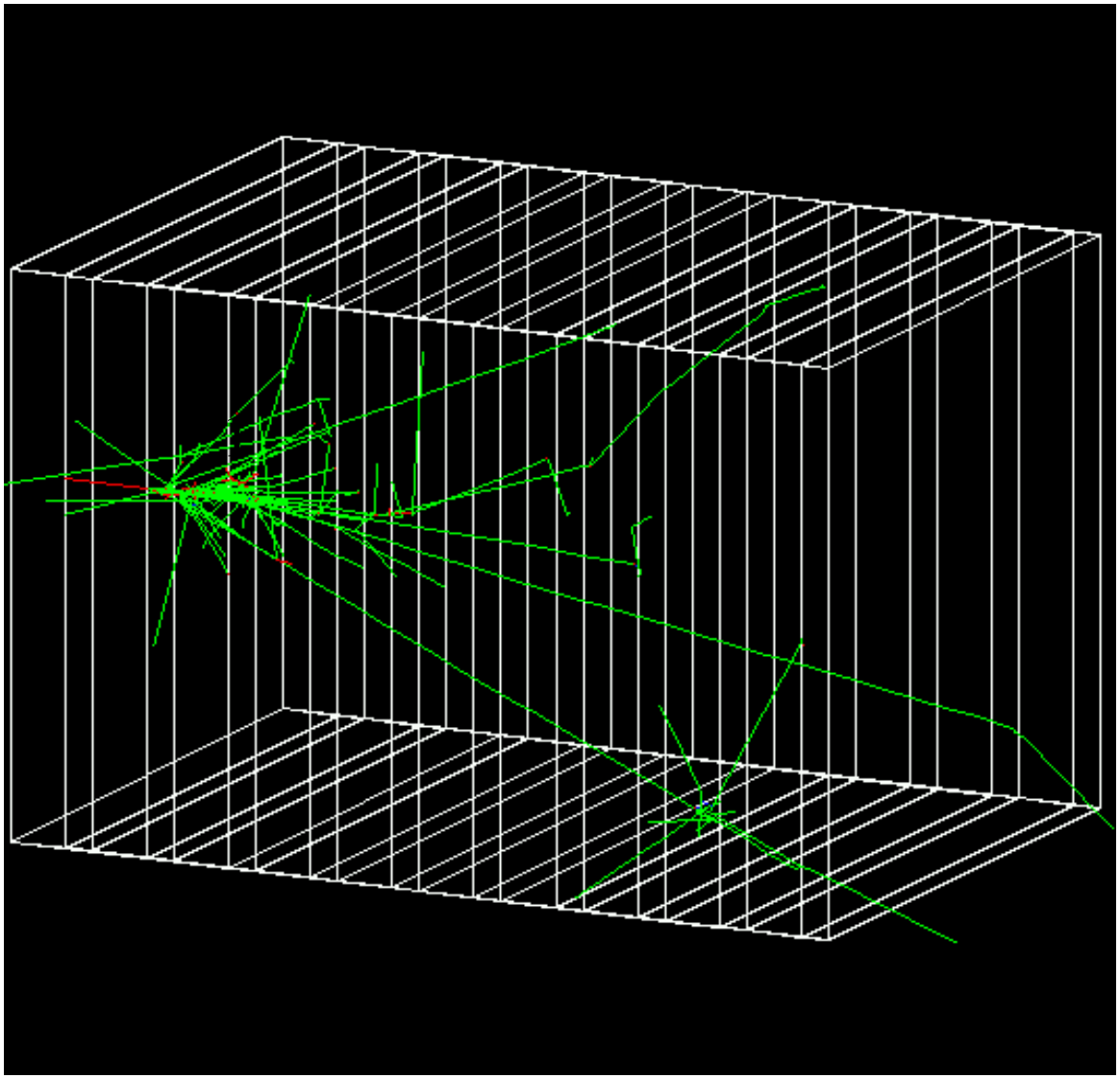
- How does Geant4 decide which interaction happens at any one time?
  - interaction length or decay length is sampled from each process
  - shortest one happens, unless
  - a volume boundary is encountered in less than the sampled length. Then no physics interaction occurs (just simple transport).
  - the processes that were not chosen have their interaction lengths shortened by the distance traveled in the previous step
  - repeat the procedure

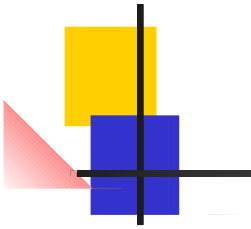
Example Event with Standard EM Processes Turned On

50 MeV e- entering
LAr-Pb calorimeter

Processes used:

- bremsstrahlung
- ionization
- multiple scattering
- positron annihilation
- pair production
- Compton scattering





Summary

- Geant4 supplies many physics processes which cover electromagnetic, hadronic and decay physics
- Processes are organized according to when they are used during the tracking of a particle (discrete, continuous, at-rest, etc.)
- Many processes may be assigned to one particle
  - which one occurs first depends on cross sections, lifetimes, and distances to volume boundaries