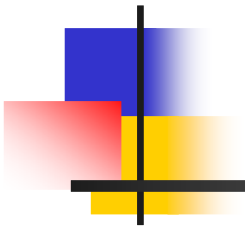
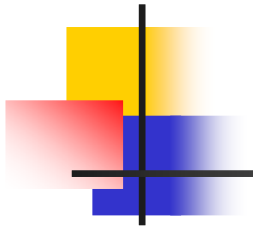


Other Geant4 Processes

Geant4 Users' Tutorial at CERN

25-27 May 2005

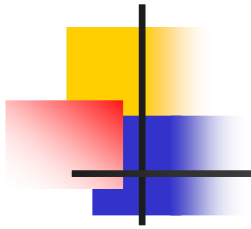
Dennis Wright (SLAC)



Outline

- The Decay Process

- Radioactive Decay
- Optical Photons

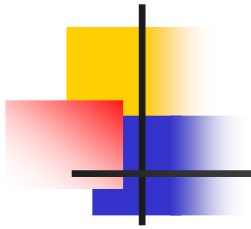


The Decay Process

- Derived from G4VRestDiscreteProcess
  - decay can happen in-flight or at rest
- Should be applied to all unstable, long-lived particles
- Different from other physical processes:
  - mean free path for most processes: $\lambda = N\rho\sigma / A$
  - for decay in-flight: $\lambda = \gamma\beta c\tau$
- Same decay process for all eligible particles
  - decay process retrieves BR and decay modes from decay table stored in each particle type

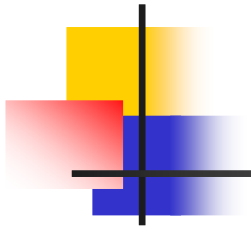
Available Decay Modes

- Phase space:
  - 2-body e.g. $\pi^0 \rightarrow \gamma\gamma$, $\Lambda \rightarrow p\,\pi^-$
  - 3-body e.g. $K^0_L \rightarrow \pi^0\,\pi^+\,\pi^-$
  - many body
- Dalitz: $P^0 \rightarrow \gamma\, l^+\, l^-$
- Muon decay
  - V – A, no radiative corrections, mono-energetic neutrinos
- Leptonic tau decay
  - like muon decay
- Semi-leptonic K decay: $K \rightarrow \pi\, l\, \nu$



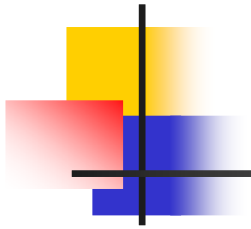
Pre-assigned Decays

- Geant4 provides decay modes for long-lived particles
  - user can re-define decay channels if necessary
- But decay modes for short-lived (e.g. heavy flavor) particles not provided by Geant4
  - user must "pre-assign" to particle:
    - proper lifetime
    - decay modes
    - decay products
  - decay process can invoke decay handler from the generator
    - must use G4VExtDecayer interface
- Take care that pre-assigned decays from generators do not overlap with those defined by Geant4
  - K^0_S , τ



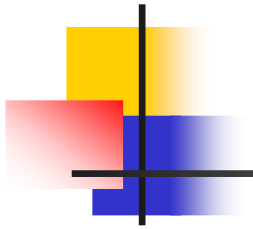
Specialized Decay Processes

- G4DecayWithSpin
  - produces Michel positron spectrum with 1st order radiative corrections
  - initial muon spin is required
  - propagates spin in magnetic field (precession) over remainder of muon lifetime
- G4UnknownDecay
  - only for "unknown" particles (Higgs, SUSY, etc.)
  - discrete process – only in-flight decays allowed
  - pre-assigned decay channels must be supplied by user or generator



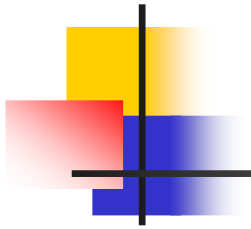
Radioactive Decay

- Simulates α, β^+, β^- emission and electron capture
  - derives from G4VRestDiscreteProcess: decay in-flight or at rest
  - must be assigned to G4GenericIon
- Model is data-driven, empirical
  - uses Evaluated Nuclear Structure Data File to look up:
    - nuclear half-lives
    - level structures for parent or daughter nuclei
    - decay branching ratios
    - energy of the decay process
- If daughter nucleus is an excited isomer, G4PhotonEvaporation de-excitation model is used



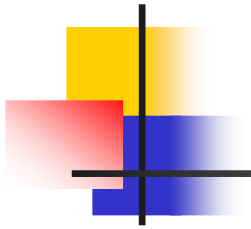
Radioactive Decay Biasing Methods

- Sampling time bias
  - decays can be biased to occur more often at certain times
  - useful if your detector cannot observe all times
- Equal branching ratio bias
  - for a given decay mode, branching ratios to daughter nuclei can be sampled with equal probability
    - enhances small branching ratios
- User can multiply the number of parent nuclei in order to increase sampling of the decay products
  - each parent has correspondingly smaller statistical weight



Optical Photons (1)

- Technically, should belong to electromagnetic category, but:
  - optical photon wavelength is >> atomic spacing
  - treated as waves -> no smooth transition between optical and gamma particle classes
- Optical photons are produced by the following Geant4 processes:
  - G4Cerenkov
  - G4Scintillation
  - G4TransitionRadiation
- Warning: these processes generate optical photons without energy conservation

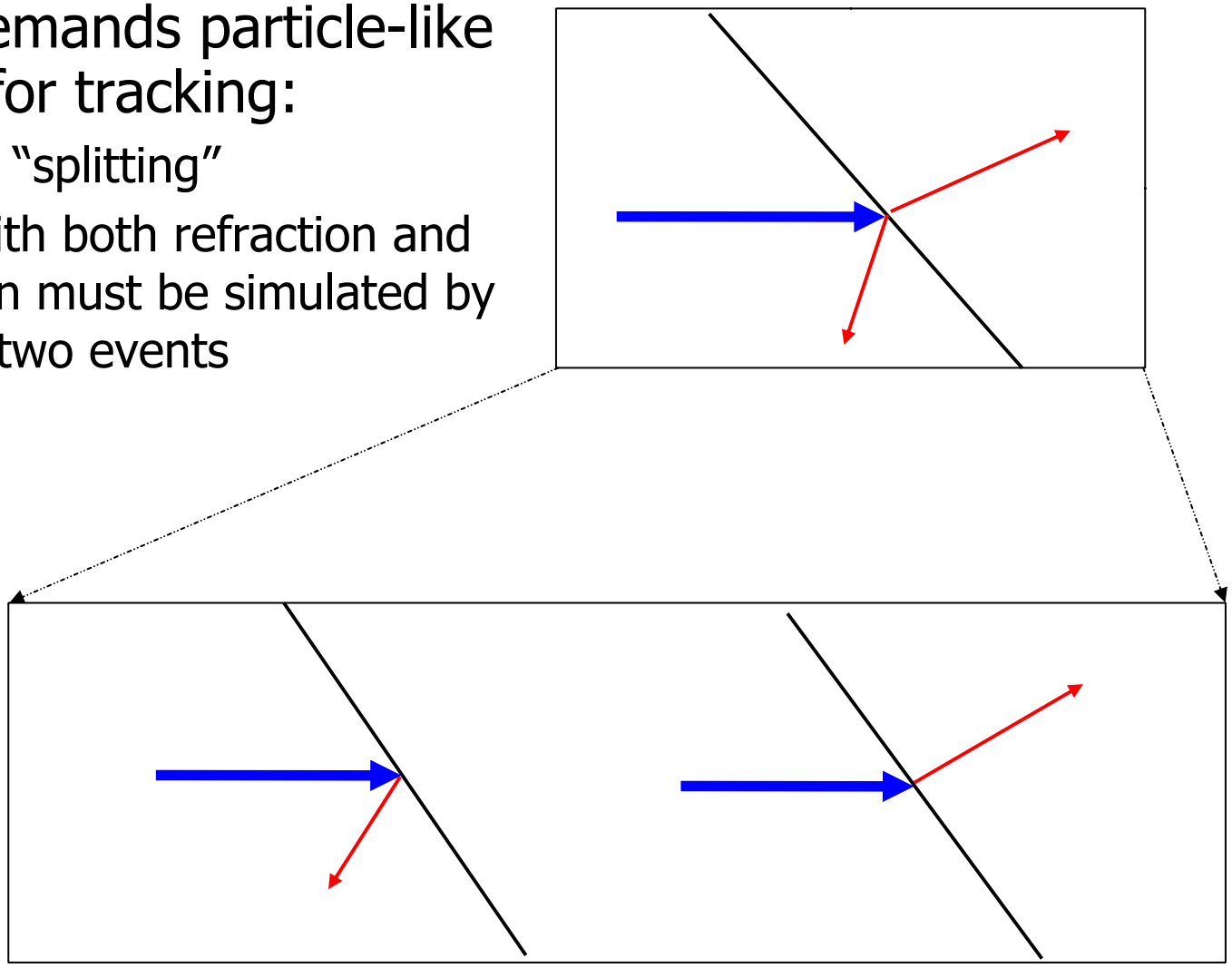


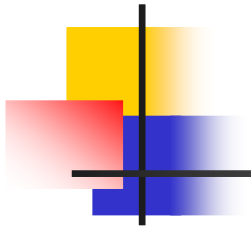
Optical Photons (2)

- ***Optical photons undergo:***
  - ***Rayleigh scattering***
  - ***refraction and reflection at medium boundaries***
  - ***bulk absorption***
  - ***wavelength shifting***
- ***Geant4 keeps track of polarization***
  - ***but not overall phase -> no interference***
- ***Optical properties can be specified in G4Material***
  - ***reflectivity, transmission efficiency, dielectric constants, surface properties***
- ***Photon spectrum properties also defined in G4Material***
  - ***scintillation yield, time structure (fast, slow components)***

Optical Photons (3)

- Geant4 demands particle-like behavior for tracking:
  - thus, no "splitting"
  - event with both refraction and reflection must be simulated by at least two events



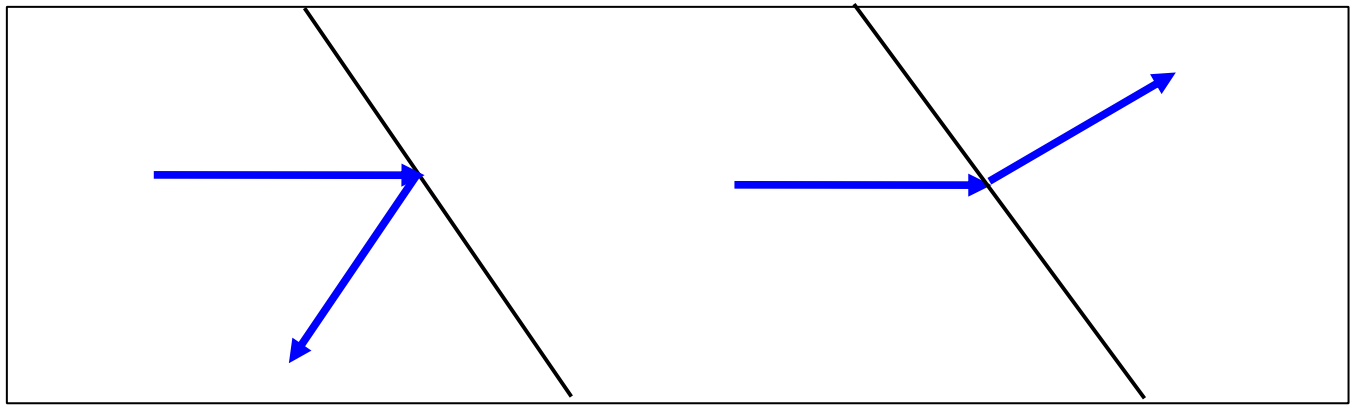


Absorption and Rayleigh Scattering

- ***G4OpAbsorption***
  - uses photon attenuation length from material properties to get mean free path
  - photon is simply killed after a selected path length
- ***G4OpRayleigh***
  - ***elastic scattering including polarization of initial and final photons***
  - ***builds it own private physics table (for mean free path) using G4MaterialTable***
  - ***may only be used for optical photons***

Boundary Interactions

- Handled by G4OpBoundaryProcess
  - refraction
  - reflection
- User must supply surface properties using G4OpticalSurfaceModel
- Boundary properties
  - dielectric-dielectric
  - dielectric-metal
  - dielectric-black material
- Surface properties:
  - polished
  - ground
  - front- or back-painted, ...



Wavelength Shifting

- Handled by G4OpWLS
  - initial photon is killed, one with new wavelength is created
  - builds it own physics table for mean free path
- User must supply:
  - absorption length as function of photon energy
  - emission spectra parameters as function of energy
  - time delay between absorption and re-emission