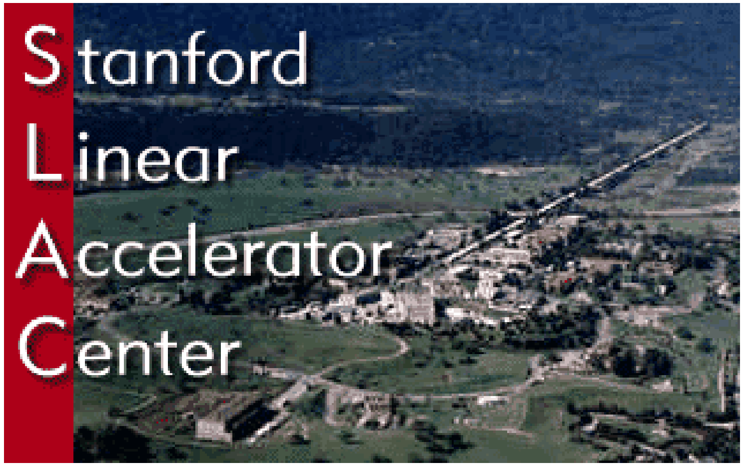

Advanced features in Geant4 kernel

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Geant4 Tutorial Course @ DESY

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- Event biasing
- Parameterization (fast simulation) and ghost volume
- Cuts per region
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- Parallelization and integration in a distributed computing environment

Event biasing in Geant4

- Event biasing (variance reduction) technique is one of the most important requirements, which Geant4 collaboration is aware of.
- This feature could be utilized in many application fields, for example,
  – Radiation shielding
  – Dosimetry
- Since Geant4 is a toolkit and also all source code is open, the user can do whatever he/she wants.
  – CMS, ESA, Alice, and some other experiments have already had their own implementations of event biasing options.
- It’s much better and convenient for the user if Geant4 itself provides most commonly used event biasing techniques.

Event biasing techniques

- Primary event biasing
  - Biasing primary events and/or primary particles in terms of type of event, momentum distribution, etc.
- Leading particle biasing
  - Taking only the most energetic (or most important) secondary
- Physics based biasing
  - Biasing secondary production in terms of particle type, momentum distribution, cross-section, etc.
- Geometry based biasing
  - Importance weighting for volume/region
  - Duplication or sudden death of tracks
- Forced interaction
  - Force a particular interaction, e.g. within a volume

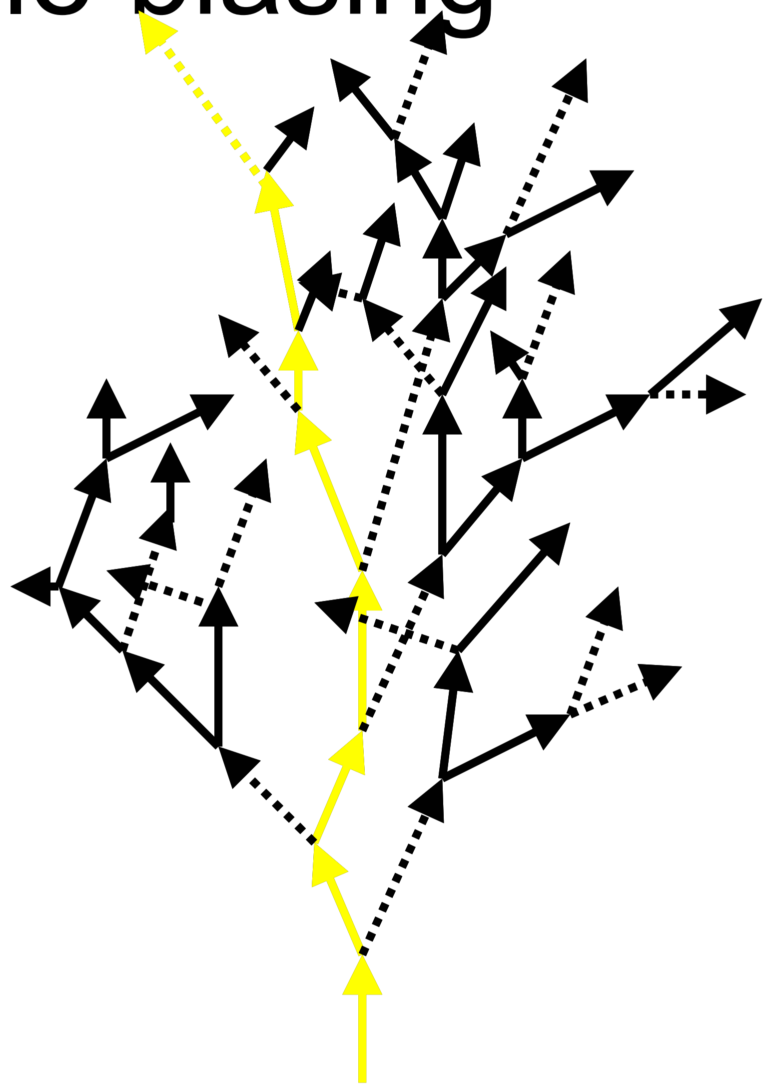
→ Weight on Track / Event

Current features in Geant4

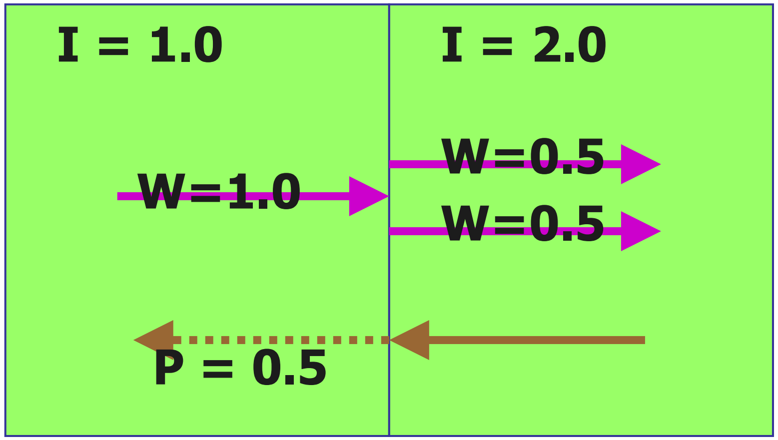
- Partial MARS migration
  - n, p, pi, K (< 5 GeV)
  - Since Geant4 0.0
- General particle source module
  - Primary particle biasing
  - Since Geant4 3.0
- Radioactive decay module
  - Physics process biasing in terms of decay products and momentum distribution
  - Since Geant4 3.0
- Cross-section biasing (partial) for hadronic physics
  - Since Geant4 3.0
- Leading particle biasing
  - Since Geant4 4.0
- Geometry based biasing
  - Weight associating with real volume or artificial volume
  - Since Geant4 5.0

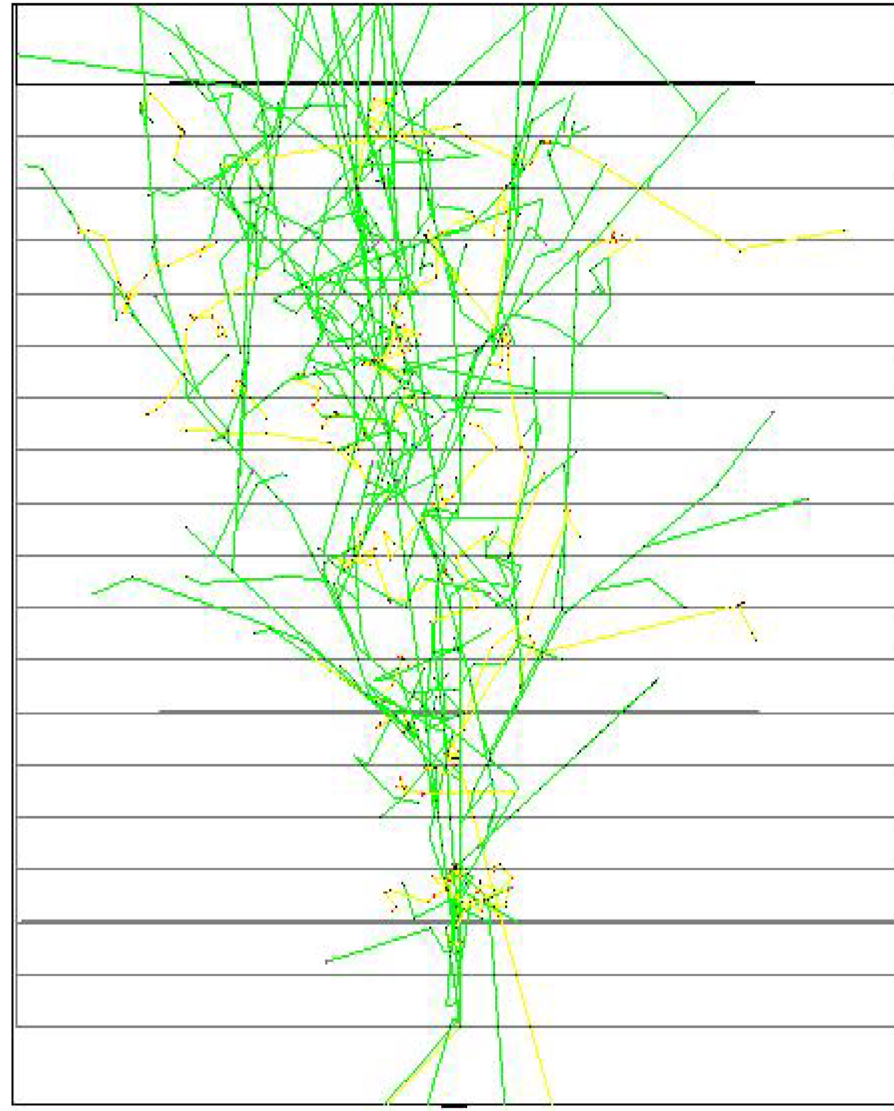
Leading particle biasing

- Simulating a full shower is an expensive calculation.
- Instead of generating a full shower, trace only the most energetic secondary.
  - Other secondary particles are immediately killed before being stacked.
  - Convenient way to roughly estimate, e.g. the thickness of a shield.
  - Of course, physical quantities such as energy are not conserved for each event.



Geometrical importance biasing





- Define importance for each geometrical region
- Duplicate a track with half (or relative) weight if it goes toward more important region.
- Russian-roulette in another direction.
- Scoring particle flux with weights
  – At the surface of volumes

Plans of event biasing in Geant4

- Full interface to MARS
  - For fully biased mode
- Cross-section biasing for physics processes
- General geometrical weight field
  - In continuous process for geometrical, angular, energy biasing and weight window.
- Another biasing options are under study.
- Other scoring options rather than surface flux counting which is currently supported are under study.

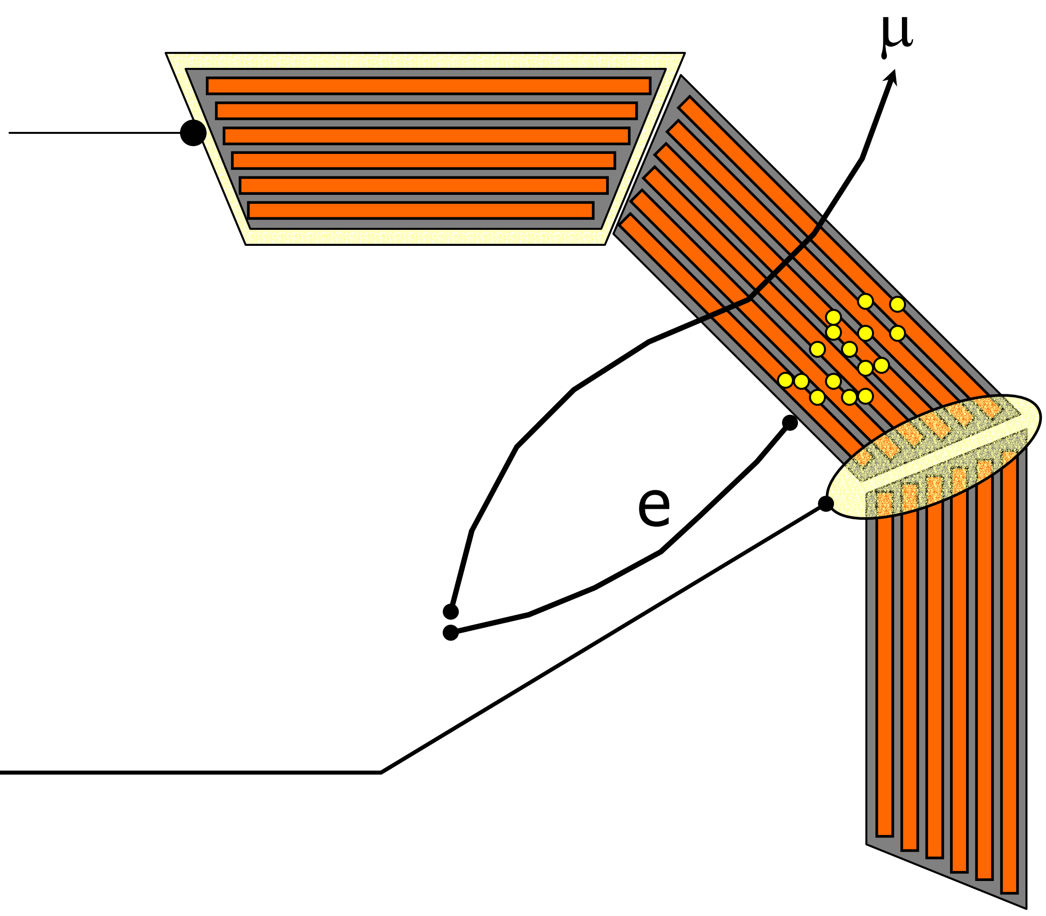
→User's contribution is welcome.

Fast simulation - Generalities

- Fast Simulation, also called as shower parameterization, is a shortcut to the "ordinary" tracking.
- Fast Simulation allows you to take over the tracking and implement your own "fast" physics and detector response.
- The classical use case of fast simulation is the shower parameterization where the typical several thousand steps per GeV computed by the tracking are replaced by a few ten of energy deposits per GeV.
- Parameterizations are generally experiment dependent. Geant4 provides a convenient framework.

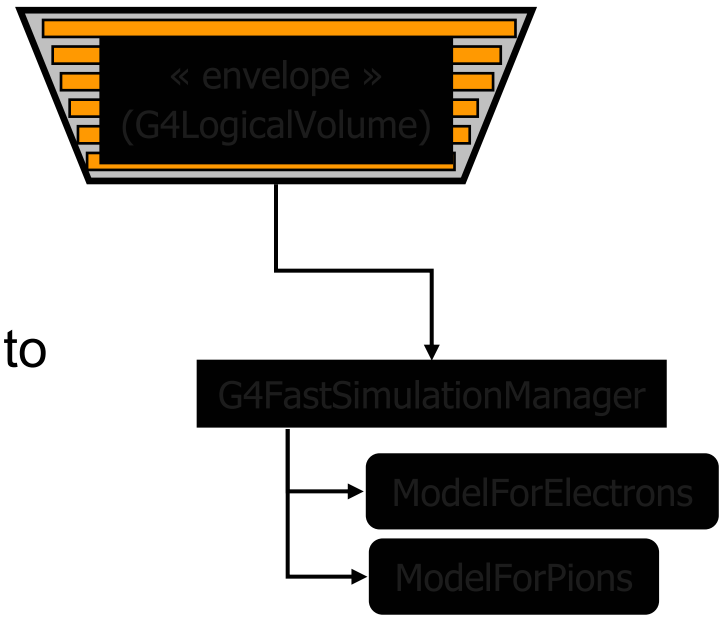
Parameterization features

- Parameterizations take place in an *envelope.* This is typically a mother volume of a sub-system or of a major module of such a sub-system.
- Parameterizations are often dependent to particle type and/or may be applied only to some types of particles.
- They are often not applied in complicated regions.



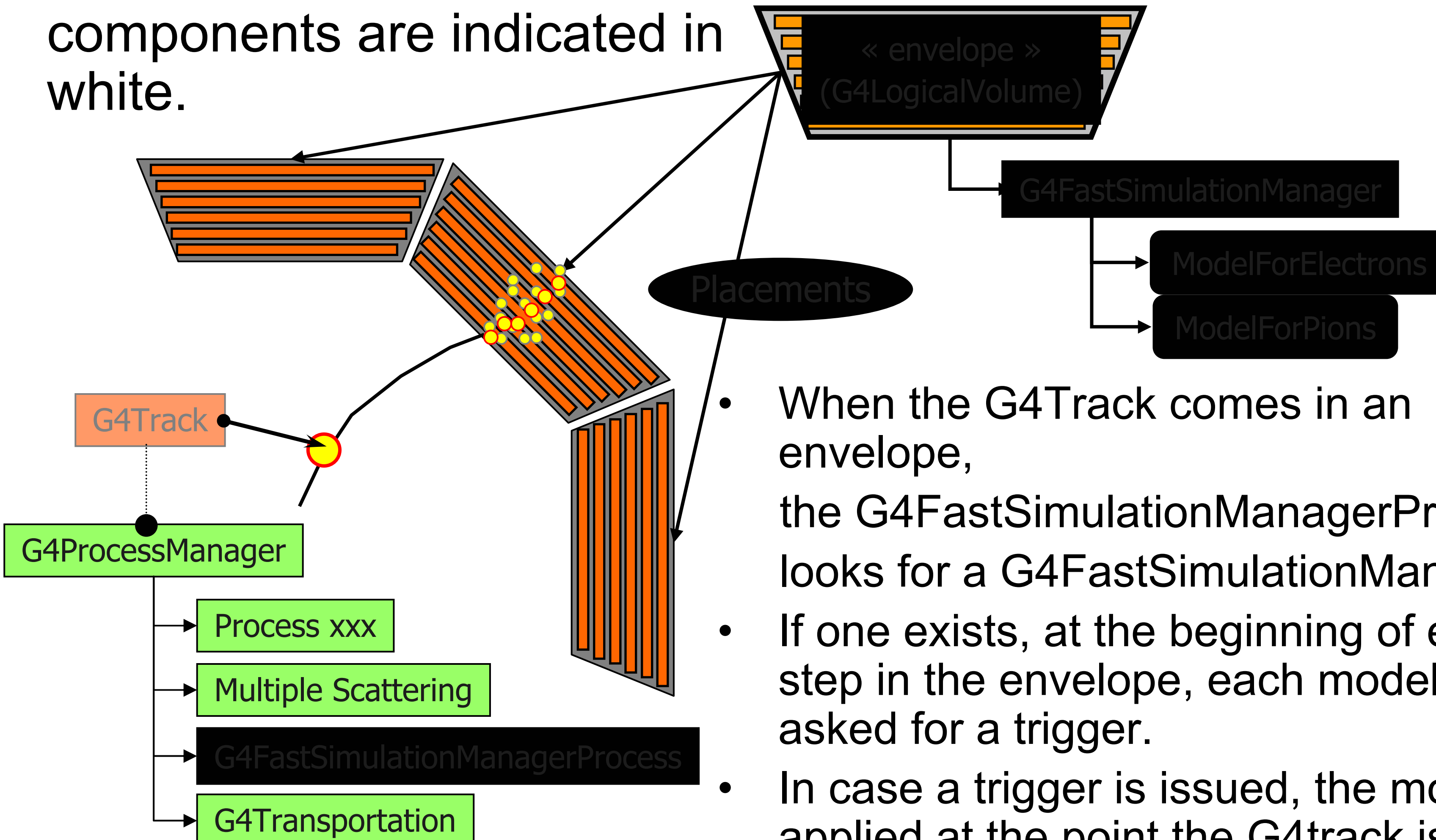
Models and envelope

- Concrete models are bound to the envelope through a G4FastSimulationManager object.
- This allows several models to be bound to one envelope.
- The envelope is simply a G4LogicalVolume which has G4FastSimulationManager.
- All its [grand[…]]daughters will be sensitive to the parameterizations.
- A model may returns back to the "ordinary" tracking the new state of G4Track after parameterization (alive/killed, new position, new momentum, etc.) and eventually adds secondaries (e.g. punch through) created by the parameterization.



Fast Simulation

- The Fast Simulation components are indicated in white.



- When the G4Track comes in an envelope,
  the G4FastSimulationManagerProcess
  looks for a G4FastSimulationManager.
- If one exists, at the beginning of each step in the envelope, each model is asked for a trigger.
- In case a trigger is issued, the model is applied at the point the G4track is.
- Otherwise, the track proceeds with a normal tracking.

G4FastSimulationManagerProcess

- The G4FastSimulationManagerProcess is a process providing the interface between the tracking and the fast simulation.
- It has to be set to the particles to be parameterized:
  - The process ordering must be the following:

    [n-3] ...

    [n-2] Multiple Scattering

    [n-1] G4FastSimulationManagerProcess

    [n] G4Transportation
  - It can be set as a discrete process or it must be set as a continuous & discrete process if using ghost volumes.

Ghost Volume

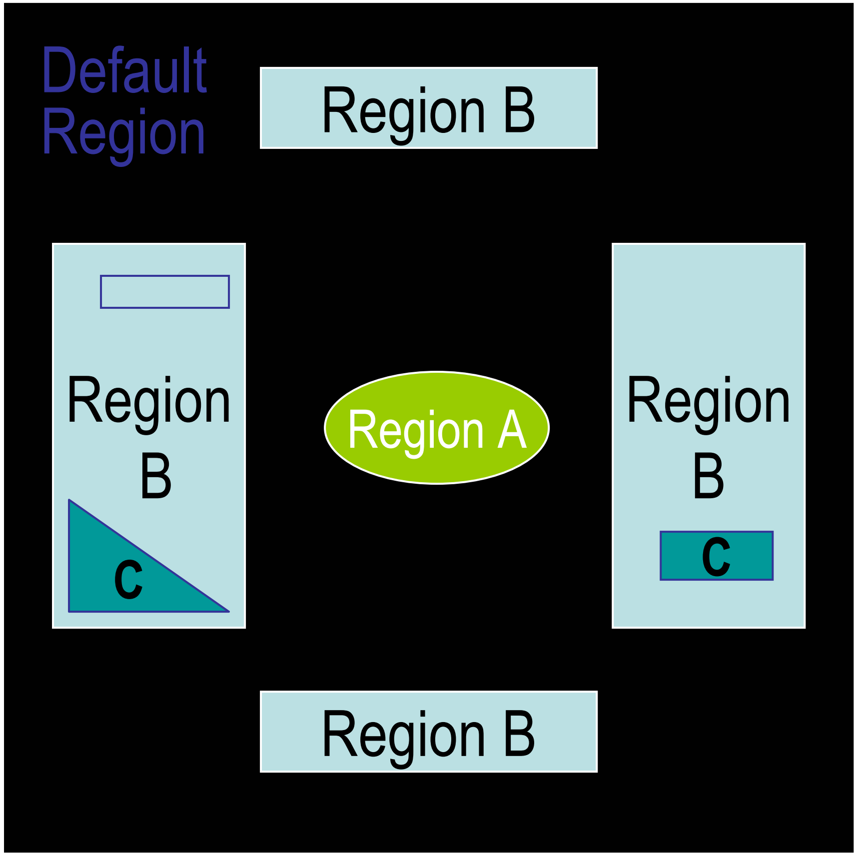
- Ghost volumes allow to define envelopes independent to the volumes of the tracking geometry.
  - For example, this allows to group together electromagnetic and hadronic calorimeters for hadron parameterization or to define envelopes for geometries imported from a CAD system which does not have a hierarchical structure.
- In addition, Ghost volumes can be sensitive to particle type, allowing to define envelops individually to particle types.
- Ghost Volume of a given particle type is placed as a clone of the world volume for tracking.
  - This is done automatically by G4GlobalFastSimulationManager.
- The G4FastSimulationManagerProcess provides the additional navigation inside a ghost geometry. This special navigation is done transparently to the user.

Cuts per Region

- Geant4 has had a unique production threshold ('cut') expressed in length (i.e. minimum range of secondary).
  - For all volumes
  - Possibly different for each particle.
- Yet appropriate length scales can vary greatly between different areas of a large detector
  - E.g. a vertex detector (5 μm) and a muon detector (2.5 cm).
  - Having a unique (low) cut can create a performance penalty.
- Requests from ATLAS, BABAR, CMS, LHCb, …, to allow several cuts
  - Globally or per particle
- New functionality,
  - enabling the tuning of production thresholds at the level of a sub-detector, i.e. region.
  - Cuts are applied only for gamma, electron and positron and only for processes which have infrared divergence.
- 'Full release' in Geant4 5.1 (end April, 2003)
  - Comparable run-time performance

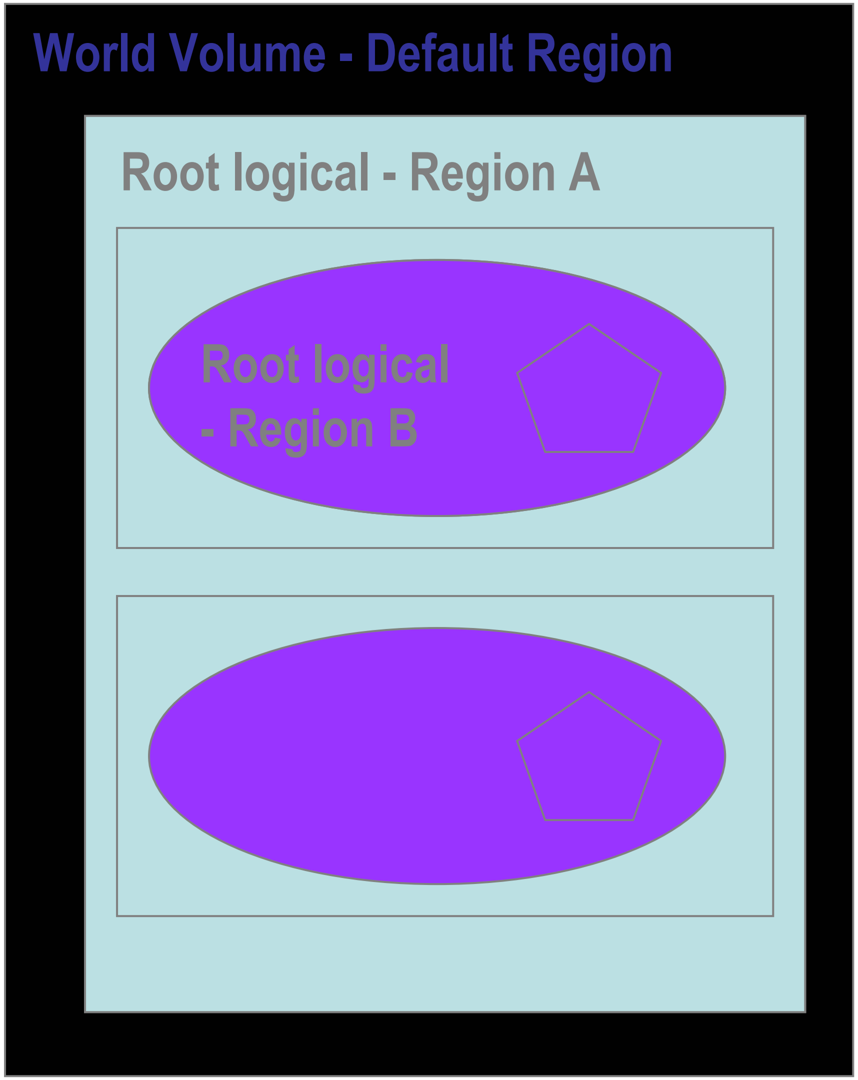
Region

- Introducing the concept of region.
  - Set of geometry volumes, typically of a sub-system;
    - barrel + end-caps of the calorimeter;
    - “Deep” areas of support structures can be a region.
  - Or any group of volumes;
- A set of cuts in range is associated to a region;
  - a different range cut for each particle among gamma, e-, e+ is allowed in a region.



Region and cut

- Each region has its unique set of cuts.
- World volume is recognized as the default region and the default cuts defined in Physics list are used for it.
  - User is not allowed to define a region to the world volume or a cut to the default region.
- A logical volume becomes a root logical volume once it is assigned to a region.
  - All daughter volumes belonging to the root logical volume share the same region (and cut), unless a daughter volume itself becomes to another root.
- Important restriction :
  - No logical volume can be shared by more than one regions, regardless of root volume or not.



Persistency

- Geant4 does not rely on any particular persistency solution.
  - User should provide his/her own solution
    - Exception : Cross-section tables
- Geant4 provides various examples
- Event input
  - G4HEPEvtInterface, G4HepMCInterface
- Geometry
  - XML, GDML, STEP, GGE (Geant4 Geometry Editor), etc.
- Histograms
  - AIDA, ROOT
- Primaries, hits, trajectories, digits
  - G4VPersistencyManager abstract base class
  - Convert Geant4 objects to user persistency objects
    - ASCII file, ROOT, Objectivity/DB, etc.

Parallelization

- By design, Geant4 can be executed in more than one processes/machines in parallel.
- Geant4 itself does not provide any mechanism of parallelization but with some external utilities.
  - "Event parallelism"
    - Master process distributes events to slave processes.
    - Geometry, physics processes, user classes, parameters are sent to slave processes before processing events.
    - Event output and histogram entries are sent back to the master process to be collected.
- Geant4 provides an example based on TOP-C.
  - examples/extended/parallel
  - TOP-C : developed by G.Cooperman (Northeastern U.)