

Geant 4

*IEEE Nuclear Science Symposium and Medical Imaging Conference
Short Course*

Simulation Techniques Using Geant4

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<http://www.ge.infn.it/geant4/events/nss2008/geant4course.html>

This course exploits training material developed by several Geant4
Collaboration members: thanks to all of them!

Event biasing

Basic concepts of simulation with Geant4 a s
a general purpose Monte Carlo toolkit

Event biasing

- What is analogue simulation ?
 - Sample using natural probability distribution, $N(x)$
 - Predicts mean with correct fluctuations
 - Can be inefficient for certain applications
- What is non-analogue/event biased simulation ?
 - Cheat - apply artificial biasing probability distribution, $B(x)$ in place of natural one, $N(x)$
 - $B(x)$ enhances production of whatever it is that is interesting
 - To get meaningful results, must apply a weight correction
 - Predicts same analogue mean with smaller variance
 - Increases efficiency of the Monte Carlo
 - Does not predict correct fluctuations
 - Should be used with care

Event biasing

- Geant4 provides built-in general use biasing techniques
- The effect consists in producing a small number of secondaries, which are artificially recognized as a huge number of particles by their statistical weights → reduce CPU time
- Event biasing can be used, for instance, for the transportation of particles through a thick shielding
- An utility class **G4WrapperProcess** support user-defined biasing

Event biasing techniques

- **Production cuts / threshold**

- This is a biasing technique – most popular for many applications: set **high cuts** to reduce secondary production

- **Geometry based biasing**

- Importance **weighting** for volume/region
- Duplication or sudden death of tracks

- **Primary event biasing**

- Biasing **primary events** and/or primary particles in terms of type of event, momentum distribution → generate *only primaries* that can produce *events that are interesting for you*

Event biasing techniques

- **Forced interaction**
 - Force a particular interaction, e.g. within a volume
- **Enhanced process or channel and physics-based biasing**
 - Increasing cross section for a given process (e.g. Bremsstrahlung)
 - Biasing secondary production in terms of particle type, momentum distribution, cross-section, etc.
- **Leading particle biasing**
 - Take into account only the most energetic (or most important) secondary
 - Currently **NOT supported** in Geant4

Variance Reduction

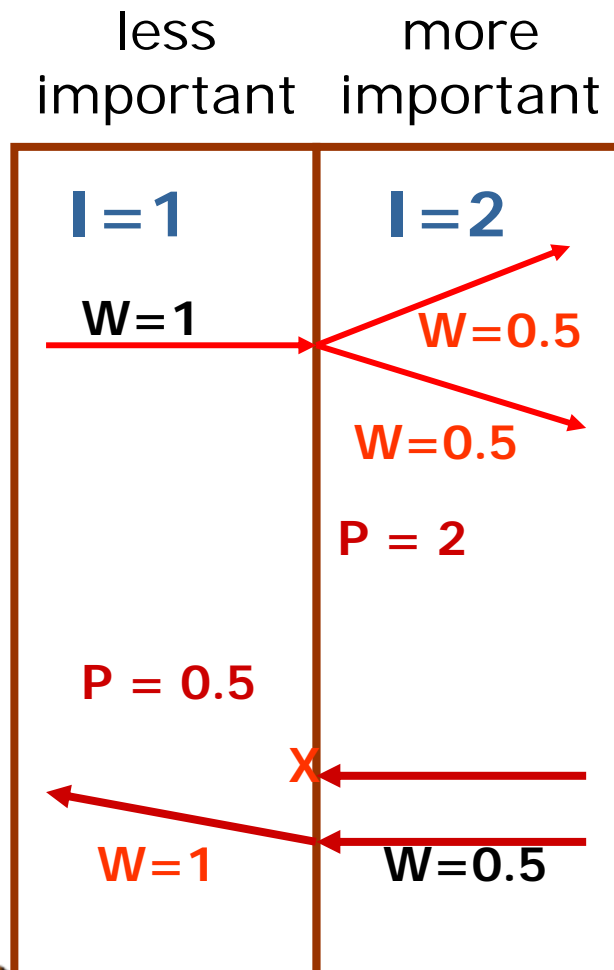
- Use variance reduction techniques to **reduce computing time** taken to calculate a result with a **given variance** (= statistic error)
- Want to **increase efficiency** of the Monte Carlo

Geometric Biasing

The purpose of **geometry-based event biasing** is to save computing time by sampling less often the particle histories entering “less important” geometry regions, and **more often in more “important” regions**

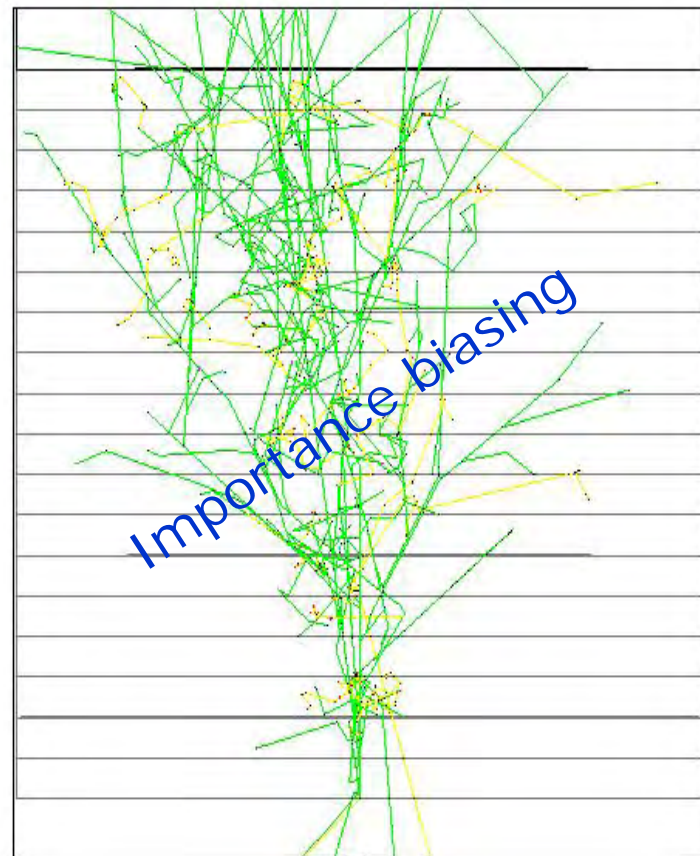
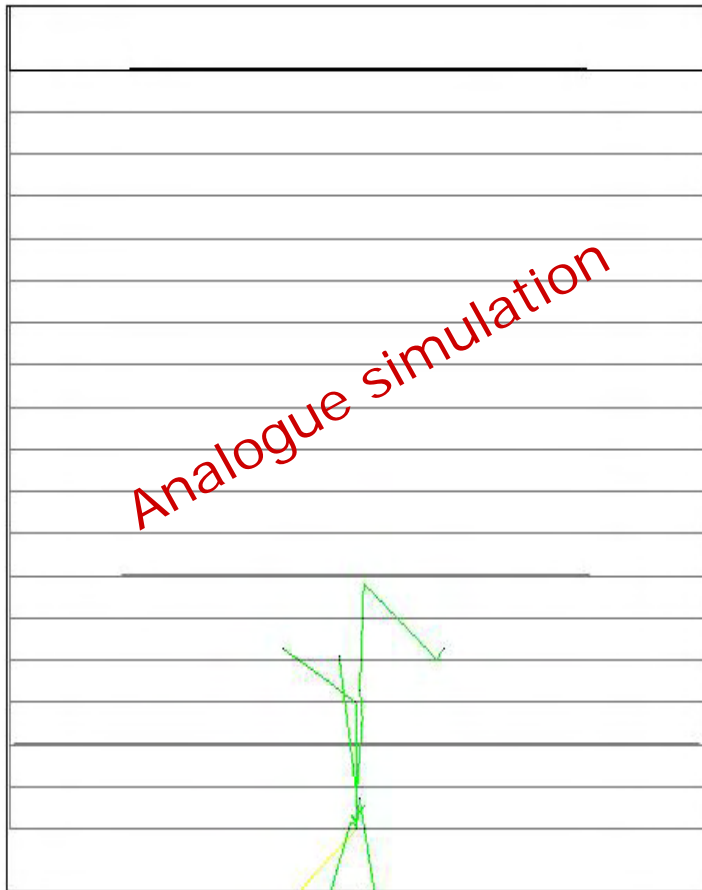
- * Importance sampling technique
- * Weight window technique

Importance sampling technique



- Importance sampling acts on particles **crossing boundaries** between “importance cells”
- The action taken depends on the **importance value** (I) assigned to the cell
- In general, a track is played either **split** or **Russian roulette** at the geometrical boundary depending on the importance value assigned to the cell

Importance biasing



10 MeV neutron in thick concrete cylinder

Physics biasing

- Built-in **cross section biasing** for PhotoInelastic, ElectronNuclear and PositronNuclear processes

```
G4ElectroNuclearReaction * theeReaction = new G4ElectroNuclearReaction;  
G4ElectronNuclearProcess theElectronNuclearProcess;  
theElectronNuclearProcess.RegisterMe(theeReaction);  
theElectronNuclearProcess.BiasCrossSectionByFactor(100);
```

- Similar tool for **rare EM processes** (e^+e^- annihilation to μ pair or hadrons, γ conversion to $\mu^+\mu^-$)

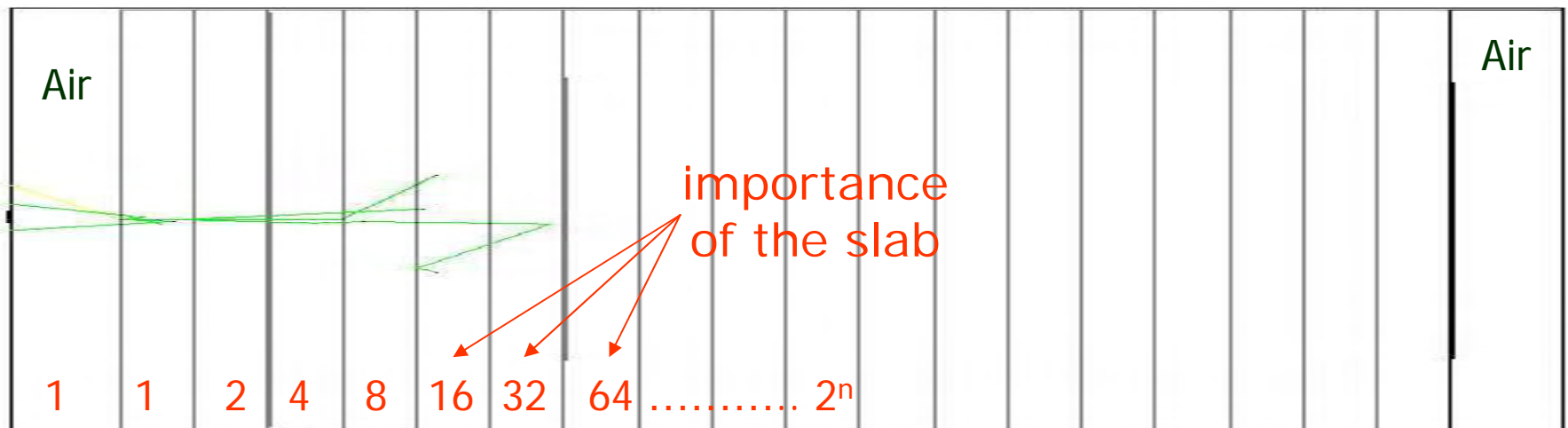
```
G4AnnihiToMuPair* theProcess = new G4AnnihiToMuPair();  
theProcess->SetCrossSecFactor(100);
```

- It is possible to introduce these factors for **all EM processes**, with a definition of customized processes that inherit from the “normal” ones (\rightarrow extended example)
- **Artificially enhance/reduce cross section** of a process (useful for thin layer interactions or thick layer shielding)

General implementation under development

Biasing example B01

- Shows the **importance sampling** in the mass (tracking) geometry
- **10 MeV neutron** shielding by cylindrical thick **concrete**
- 80 cm high concrete cylinder divided into **18 slabs** (importance values assigned in the DetectorConstruction for simplicity)



Results of example B01

