Event biasing

J. Apostolakis

Event biasing in Geant4

- Event biasing (variance reduction) techniques are a vital requirement for many applications
- These feature could be utilized by many application fields such as
  - Shielding
  - Radiation environment assessment
  - Dosimetry
- Since Geant4 is a toolkit and also all source code is open, the user can do whatever he/she wants.
  - Capable users in experiments/institutions created their own implementations of event biasing.
- Yet it is more convenient for user if Geant4 itself provides most commonly used event biasing techniques.

Event biasing techniques

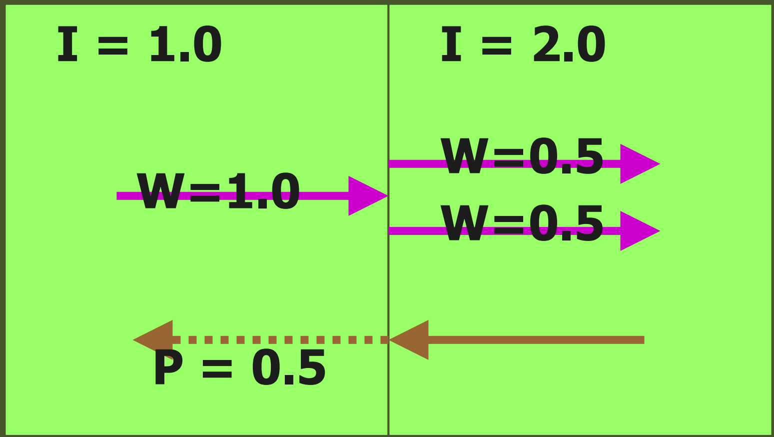
- Production cuts / threshold
  - This is a biasing technique – most popular for many applications
- Geometry based biasing
  - Importance weighting for volume/region
  - Duplication or sudden death of tracks
- Leading particle biasing
  - Taking only the most energetic (or most important) secondary
- Primary event biasing
  - Biasing primary events and/or primary particles in terms of type of event, momentum distribution, etc.
- Forced interaction
  - Force a particular interaction, e.g. within a volume
- Enhanced process or channel
  - Increasing cross section for a process
- Physics based biasing
  - Biasing secondary production in terms of particle type, momentum distribution, cross-section, etc.

    → 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
- Geometry based biasing
  - Weight associating with real volume or artificial volume
    - Since Geant4 4.2
- Weight cutoff and weight window
  - Since Geant4 5.2
- Cross-section biasing and leading particle biasing for hadronic processes
  - Since Geant4 7.0

Geometrical importance biasing



- Define importance for each geometrical region
- Splitting a track,
  - Eg creating two particles with half the 'weight' if it moves into volume with double importance value.
- Russian-roulette in opposite direction.
- Scoring particle flux with weights
  - At the surface of volumes

Using importance biasing

- Decide whether to bias in "mass" geometry, or in a dedicated 'parallel' geometry ("importance geometry").
- Assign an importance value to all volumes in this geometry
  - The importance is a number (double)
- Register the processes for importance biasing (and scoring, optionally) to each particle type (eg neutron, gamma, proton, …)
  - Examples show easy ways to do this.
- Caveats
  - World of importance geometry must 'overlap' exactly with mass world
  - Biasing and scoring of charged particles in a field is not yet supported when using an "importance geometry".
- More details
  - Users can choose their importance sampling algorithm,
    - Or accept the default one ('equal weight').
    - For customisation & further information see "Geant4 User's Guide for Application Developers", Section 3.7

Biasing example B01

- Examples demonstrating the use of importance biasing and scoring can be found in examples/extended/biasing
- B01
  - Shows the importance sampling and scoring in the mass (tracking) geometry
    - Option to show weight window
  - Geometry is 80 cm high concrete cylinder divided into 18 slabs
    - Importance values assigned to 18 concrete slabs in the detector construction - for simplicity.
  - The G4Scorer is used for the scoring
    - Top level class uses the frame work provided for scoring.

Example biasing B02

- Show how to use
  - importance sampling in a parallel geometry and
  - a customized scoring making use of the scoring framework.
- A simple mass geometry consists of a 180 cm high concrete cylinder
- A parallel geometry is created to hold importance values for slabs of width 10cm and for scoring.
  - Note: The parallel world volume must overlap the mass world volume
  - The radii of the slabs is larger than the radius of the concrete cylinder in the mass geometry.
  - The importance value is assigned to each 'G4GeometryCell'
    - To do this, pairs of G4GeometryCell and importance values are stored in the importance store.
- The scoring uses the G4CellSCorer and one customized scorer for the last slab.

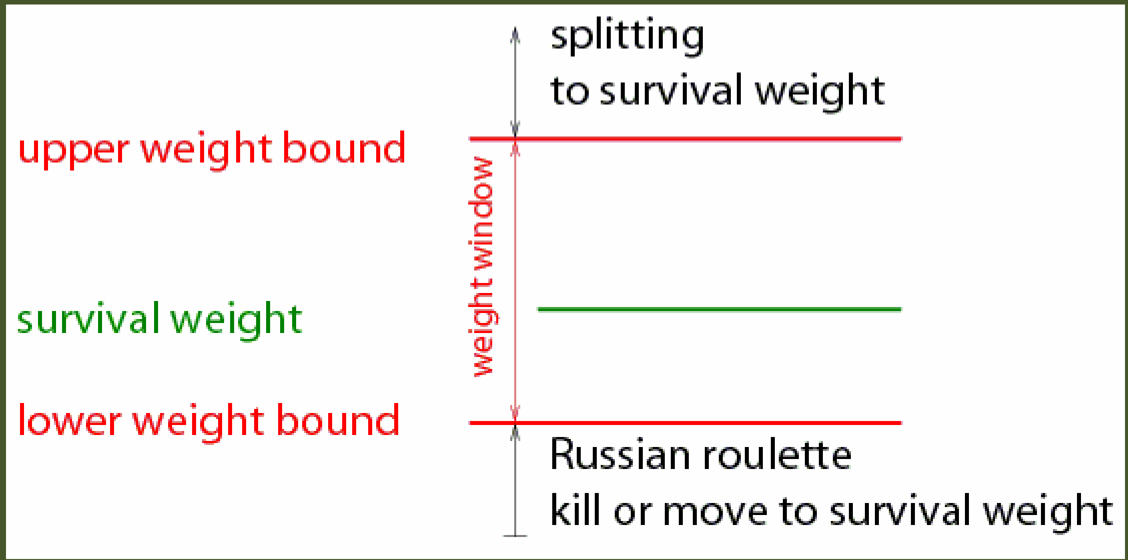
Example B03

- Uses Geant4 importance sampling and scoring through python.
- It creates a simple histogram.
- It demonstrates how to use a customized scorer and importance sampling in combination with a scripting language, python.
- Geant4 code is executed from a python session.
  - Note: the swig package is used to create python shadow classes and to generate the code necessary to use the Geant4 libraries from a python session.
- It can be built and run using the PI implementation of AIDA
  - For this see http://cern.ch/PI.
- At the end a histogram called "trackentering.hbook" is create.

The Weight Window Technique

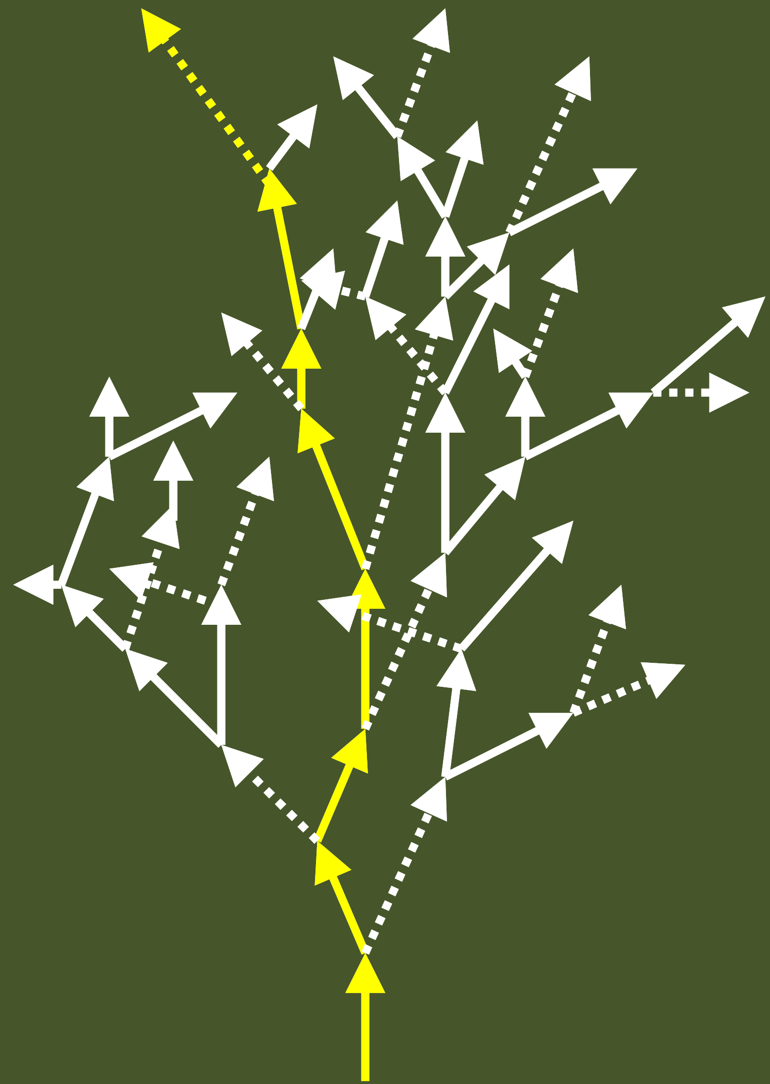
- The weight window technique is a weight-based algorithm – generally used together with other techniques as an alternative to importance sampling:
  - It applies splitting and Russian roulette depending on space (cells) and energy
  - user defines weight windows in contrast to defining importance values as in importance sampling
- It checks the value of the particle weight
  - Comparing it to a 'window' of weights defined for the current energy-space cell.
  - Doing splitting or roulette in case if it is outside, resulting in 0 or more particles 'inside' the window.
- apply in combination with other techniques such as cross-section biasing, leading particle and implicit capture, or combinations of these.

- A weight window may be specified for every cell and for several energy regions: *space-energy cell* .



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.



Scoring

- Scoring is provided by a framework and is done according to particle type.
  - It is possible to score particles of different types into the same scorer. The framework may also be easily used for customized scoring.
- Scoring may be applied to a mass or a parallel geometry. It is done with an object generically called a scorer using a sampler.
  - The scorer receives the information about every step taken by a particle of chosen type. This information consists a G4Step and a G4GeometryCellStep (created for scoring and importance sampling).
    - G4GeometryCellStep provides information about the previous and current "cell" of the particle track.
- A "scorer" class derives from the interface G4VScorer. Users may create customized "scorers" or use the standard scoring.

Plans of event biasing in Geant4

- Extending “importance” geometries for use with charged particles in field.
- More general leading-particle biasing are under consideration.
- Further scoring options.

→User’s contribution is welcome.