Event biasing and Variance Reduction - Geometrical

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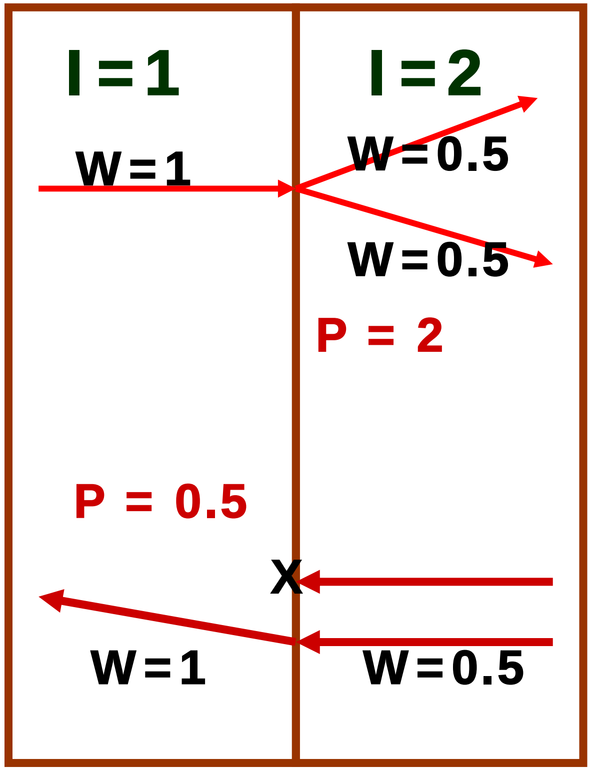
Geometric Biasing

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 assigned to the cell.
- In general, a track is either split or plays Russian roulette at the geometrical boundary depending on the importance value assigned to the cell.

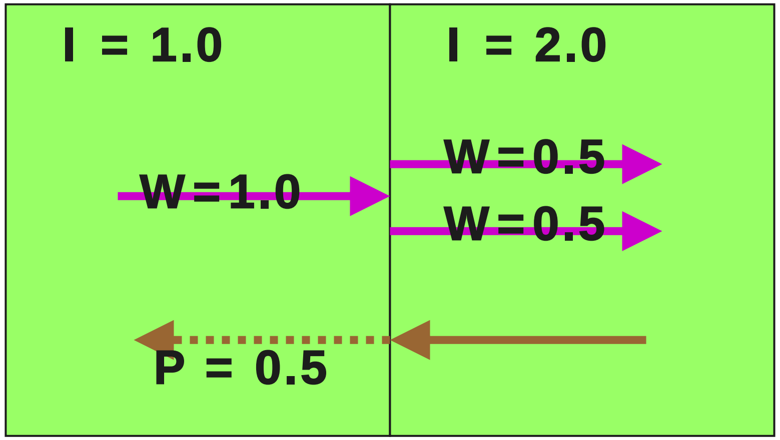


- Survival probability (P) is defined by the ratio of importance value.
  $P = I_{post} / I_{pre}$
- The track weight is changed to W/P.

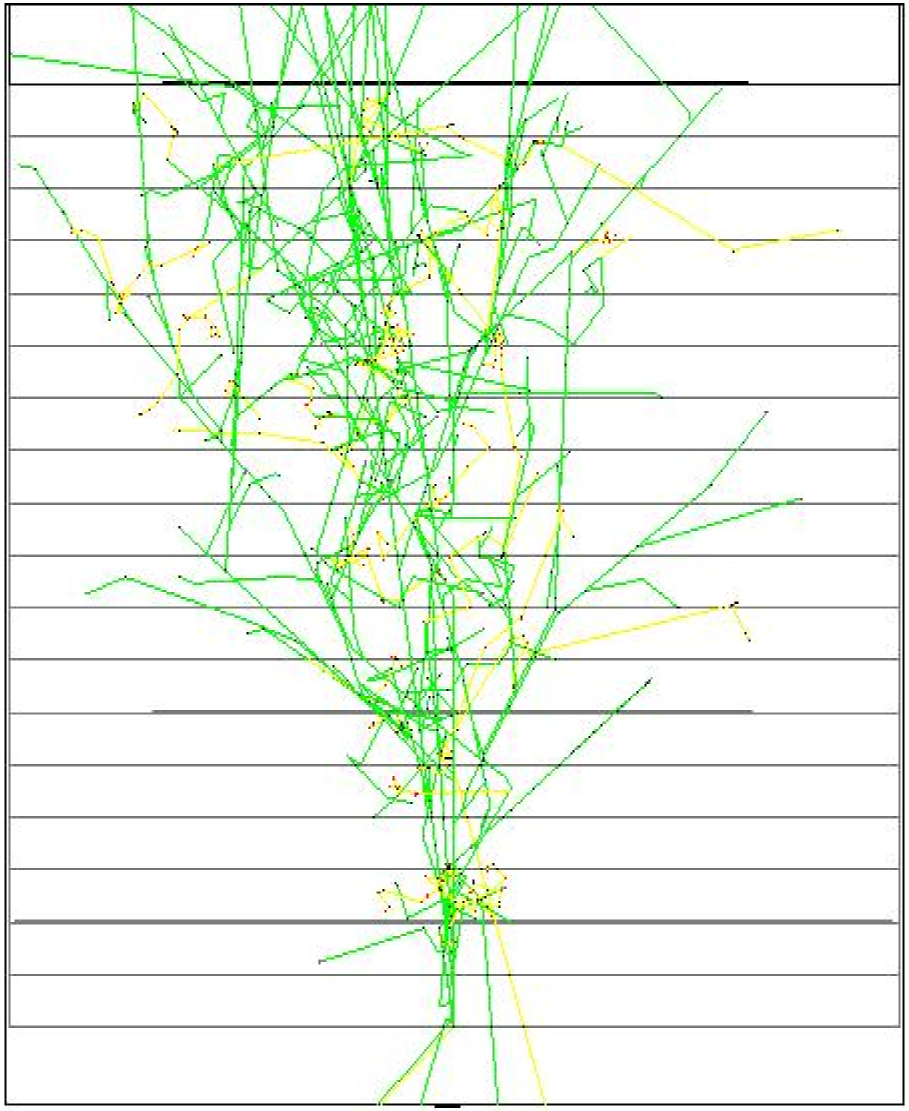
- Splitting a track (P > 1)
  - E.g. creating two particles with half the ‘weight’ if it moves into volume with double importance value.

- Russian-roulette (P < 1) in opposite direction
  - E.g. Kill particles according to the survival probability (1 - P).

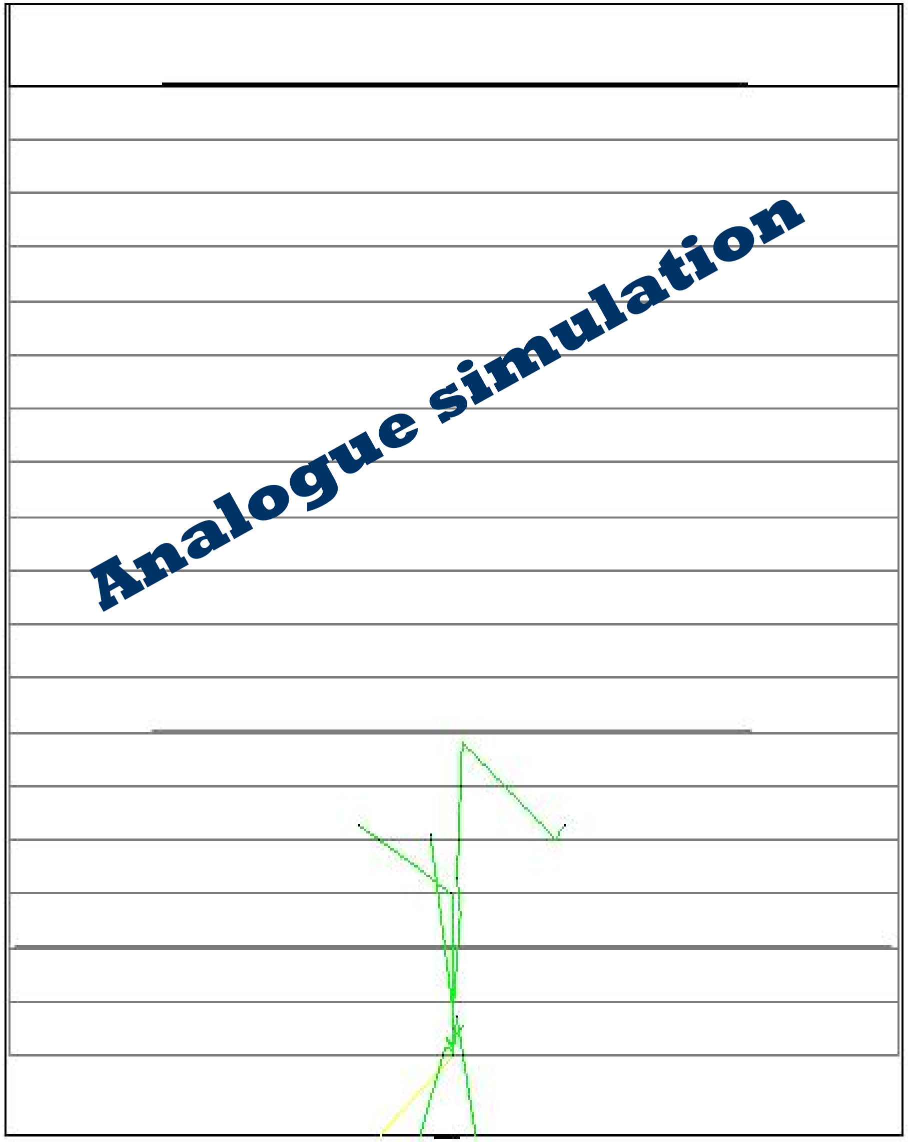
Geometrical importance biasing

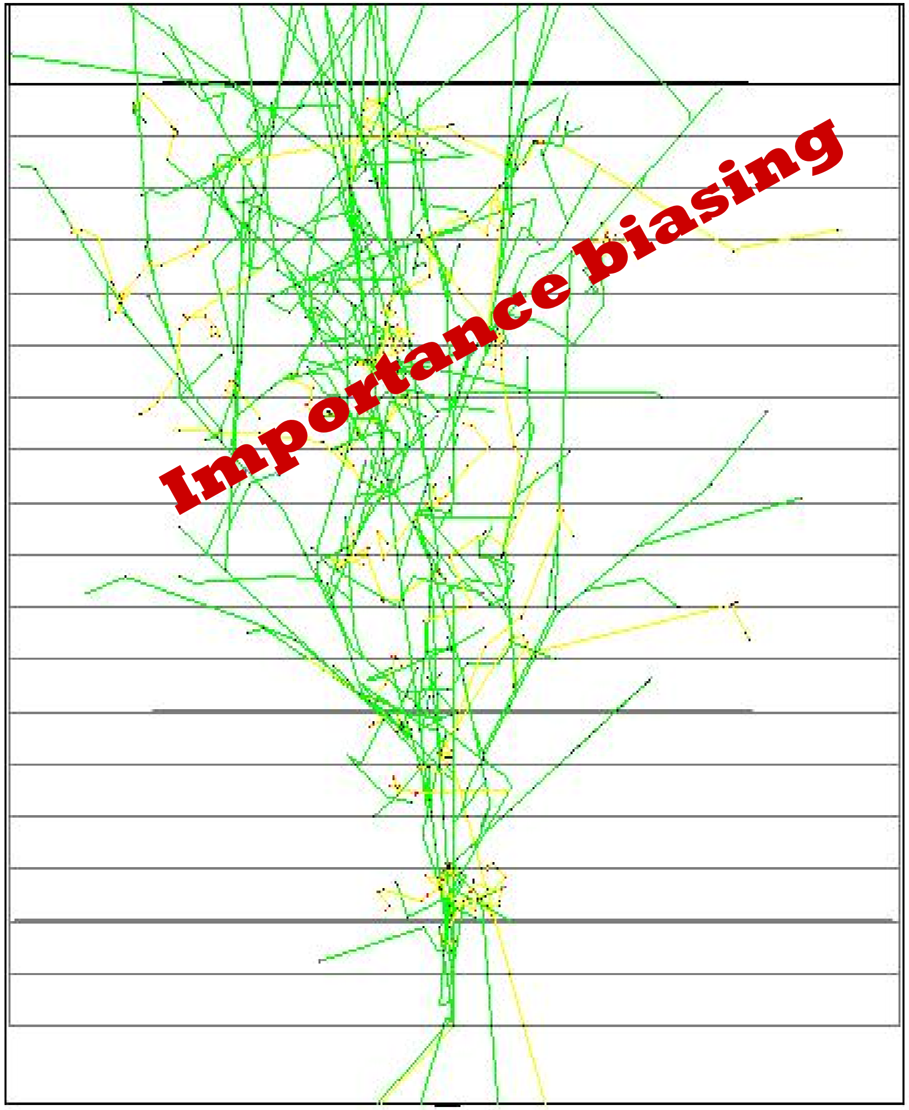


- Define importance for each geometrical region
- Duplicate a track with half *(or relative)* weight if it goes toward more important region
- Russian-roulette in opposite direction
- Scoring particle flux with weights
  - at the surface of volumes



Importance biasing



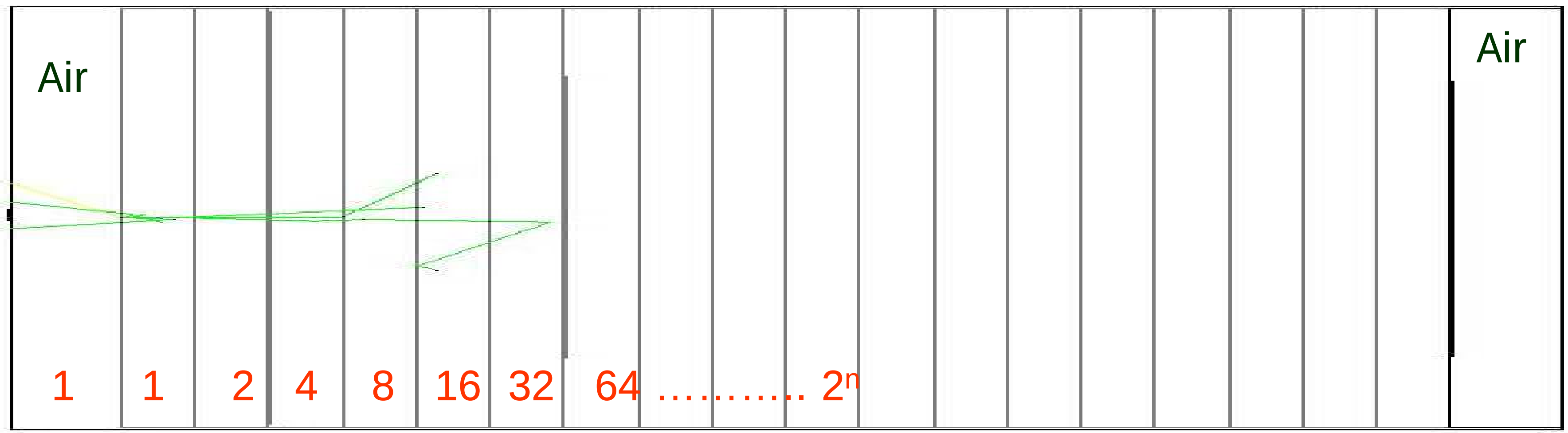


10 MeV neutron in thick concrete cylinder

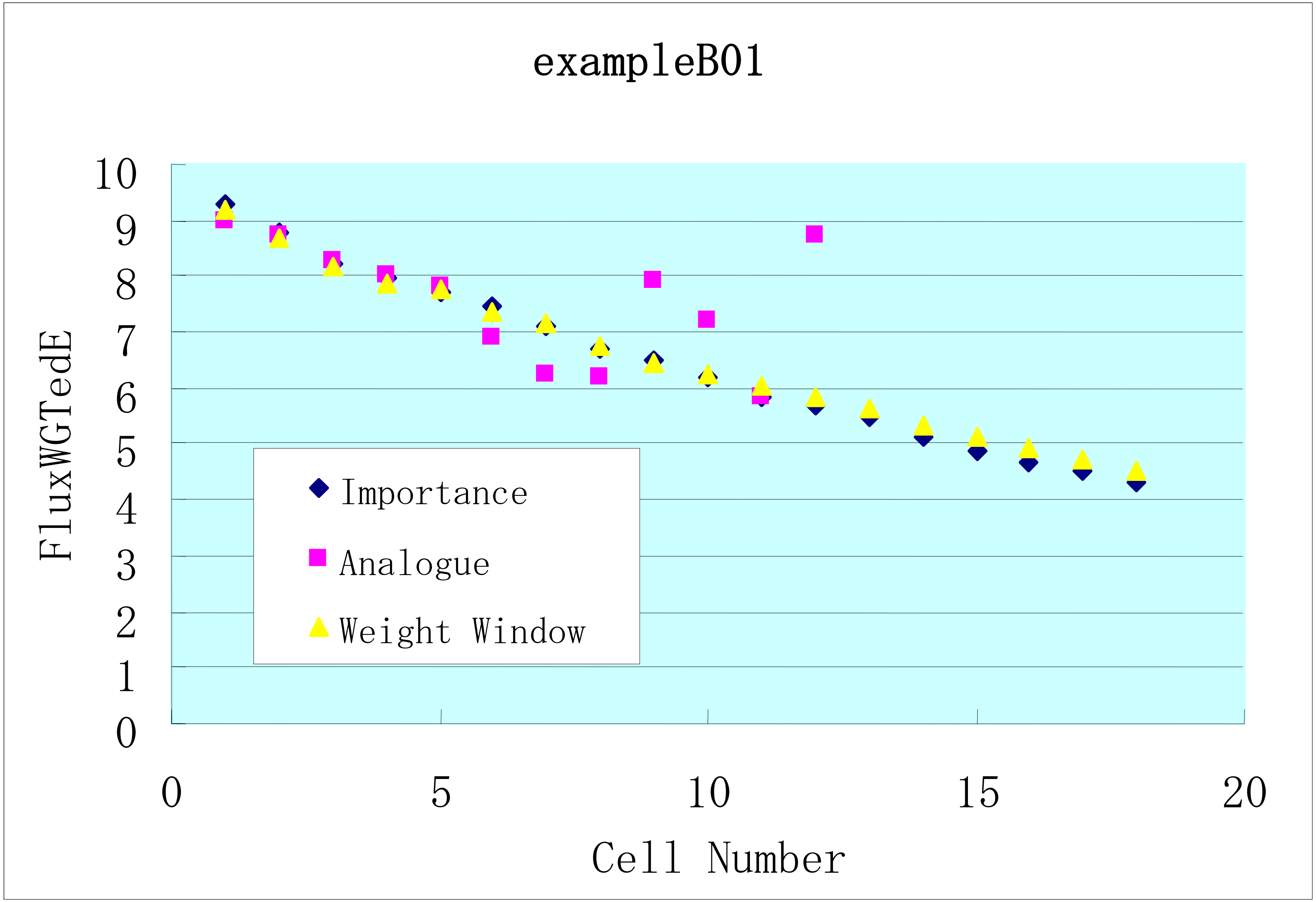
Examples/extended/biasing

Biasing example B01

- Shows the importance sampling **in the mass (tracking) geometry**
- Option to show weight window
- 10 MeV neutron shielding by cylindrical thick concrete material
- Geometry
  - 80 cm high concrete cylinder divided into 18 slabs
  - Importance values assigned to 18 concrete slabs in the DetectorConstruction for simplicity.
  - The G4Scorer is used for the checking result
    - Top level class uses the framework provided for scoring.



Flux multiplied by Kinetic energy of particle



Example B02

- B02 example for showing
  - importance sampling **in a parallel geometry**
  - a customized scoring making use of the scoring framework.
  - Mass geometry consists of a 180 cm high simple bulk 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'
      - Pairs of G4GeometryCell and importance values are stored in the importance store, G4IStore.
  - The scoring uses the G4CellSCorer and one customized scorer for the last slab.
  - 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 "b02.hbook" is created.

Example B03

- Uses Geant4 importance sampling and scoring through python.
- It creates a simple histogram via AIDA and PI.
- 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.
- Uses different python implementation to G4Py – now redundant?

TIARA - future implementation

- The advanced example of the TIARA experiment offers a nice benchmark for neutron physics – penetration of neutrons through concrete
- Benefits from importance sampling – how many neutrons penetrate through metres of concrete
- It is currently implemented using the “old” python interface
- For ease or use and maintainability this interface will be removed for the coming release(s)

SCORING

examples/extended/runAndEvent/RE02

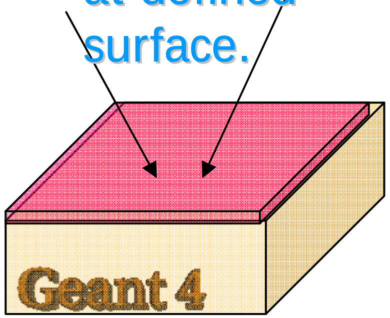
G4VPrimitiveScorer

- `G4VPrimitiveScorer` is an abstract base class representing a class to be registered to **G4MultiFunctionalDetector**.
  - Geant4 provides `concrete primitive scorer` classes such as **dose scoring**, **surface flux counting**, etc.
    - Of course, users can develop his/her own primitive scorer classes.
  - Primitive scorers are designed to *score one kind of quantity* and generates **one hits collection** per event.
    - The name of hits collection is automatically assigned as ***<MultiFunctionalDetector name>/<Primitive Scorer name>.***
      The hits collection is maintained by G4HCofThisEvent object with a unique collection ID number which is assigned by G4SDManager.
      - Each primitive scorer object must be instantiated with *a unique name* among primitive scorers registered in a G4MultiFunctionalDetector object.
      - A primitive scorer object must not be shared by more than one G4MultiFunctionalDetector object. Otherwise, the results are mixed together.

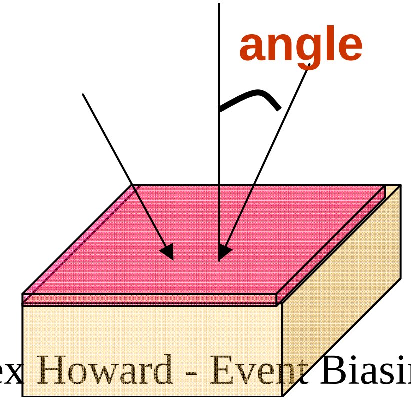
List of concrete primitive scorer

- Concrete Primitive Scorers (See Application Developers Guide 4.4.6)
  - Track length
    - G4PSTrackLength, G4PSPassageTrackLength
  - Deposited energy
    - G4PSEnergyDepsit, G4PSDoseDeposit
  - Current/Flux
    - G4PSFlatSurfaceCurrent, G4PSSphereSurfaceCurrent,G4PSPassageCurrent, G4PSFlatSurfaceFlux, G4PSCellFlux, G4PSPassageCellFlux
  - Others
    - G4PSMinKinEAtGeneration, G4PSNofSecondary, G4PSNofStep

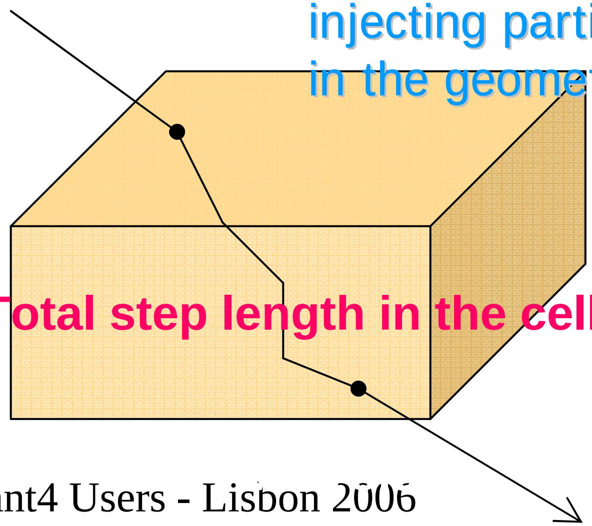
SurfaceCurrent :
Count number of injecting particles at defined surface.



SurfaceFlux :
Sum up 1/cos(angle) of injecting particles at defined surface



CellFlux :
Sum of L / V of injecting particles in the geometrical cell.



Future developments

- Parallel geometry and transportation will be enhanced in the coming releases of Geant4
- The use of fields (electric and magnetic) will be permitted along with the ability to bias charge particles (currently only possible for neutral)
- Multiple scattering and field transportation will be handled correctly and coherently across parallel geometries
- Event biasing and variance reduction will be re-factored and a rigorous software process applied
- Development version should be released in December

Summary

- Geant4 offers the possibility to improve computing performance via fast simulation and biasing
- A number of biasing techniques are available
- Scoring is implemented with a degree of flexibility to reduce hits collection and persistency whilst offering convenience of keeping tallies of common qualities
- Refactoring and implementation of new parallel transportation is ongoing and should be in the December release