MCNEG Workshop 2016 - Part 2

Modelling of shielding and enclosures using variance reduction

The aim of this practical is to introduce the use of Monte Carlo modelling for two typical shielding scenarios, a thick shield and a maze corner. Use will be made of FLUKA functionality for implementing variance reduction schemes.

Getting started

Type in 'flair' at the console. The graphical interface for FLUKA, called Flair, will appear

Click on the Input tab and 'New' to start a new input file. A basic input file will be displayed. Note the several essential aspects to setting up a Monte Carlo problem, the radiation beam description, the geometry and material assignments.

Click on

BEAM:
Switch from momentum to energy description of the beam. Choose an photon of energy, *E*, of 5 MeV. Recall that FLUKA uses the units GeV and cm. Choose a Flat angular distribution that produces a beam of diameter of 20 cm at 1 m. The opening angle is specified in mrads. [Hint: an isotropic source is 2pi*1000 = 6283 mrad]

BEAMPOS:
This will default to the photon travelling from the origin in the Z direction.

RCC:
The geometry defines a cylindrical COPPER target. Change the thickness and diameter of the target to 40 cm and move it to a position 1 m from the origin. Check the geometry viewer and insure you understand what you are seeing.

ASSIGNMA:
Change the assigned material of the target to WATER and the assigned material for the Void to AIR. We will look at the products of the interaction of photons in the water phantom and display the distribution of these products in the surrounding air. [As you are allowing interactions in the void region it is sensible to reduce the radius of SPH void to 10 cm]

Add scoring components USRBIN with an X-Y-Z arrangement for photon and electron fluence, selecting a unique BIN for each output file. Define a cube that encompasses the source and target and extends to include 1 m of air on all sides. The overall cube should be 3x3x3 m^3 in dimension. Choose 30 voxels in each of these directions.

Save the input file and click Run and Start button to start the calculation. The calculation is performed in 5 batches and should take about a minute. Click on the data sub-tab and

Scan (for newly created files) and Process (to form one single set of 3D data). Click on the Plot tab and add USRBIN plots for photons and electron fluence and energy. Load each of the bnn (binary format) files and reflect on the distributions generated in each case.

Examine one of the *.out files, which contains a lot of information about the batch, much of which is not relevant to the particular calculation you have performed. Look for the energy deposited in the Void, the Target and the three spherical test masses, the number of histories used and the time taken towards the end of the file.

Extract the energy deposited in the water from all 5 *.out files. Calculate the mean and standard deviation of the dose in the phantom per incident photon. [Hint you will need to determine the volume of the phantom.]

Calculate the figure of merit for dose in the target:

$$\text{f.o.m.} = 1 / (\text{ CPU time} * \text{standard\_deviation}^2)$$

Creating a primary barrier

Create a new parallelepiped RPP volume of thickness 1 m, width and height 2 m and position it at 2 m from the origin. Add 'Concrete' as new material. Add a new REGION and ASSIGNMA, accordingly.

Move the phantom to a position 4 m from the origin and move the USRBIN grids to cover Z = 200 to Z = 500 cm.

Run the simulation again, observe the fluence distributions. Calculate the mean and standard deviation of the dose and the figure of merit. What has happened to photon fluence and what can you say about the quality of the calculation?

How long a simulation would be required to get a result that has a comparable to the previous case? What is wrong with using Monte Carlo in this way?

[Hint: In shielding problems we aim the reduce the number of photons reaching our regions of concern, however this reduces the probability of photons interacting with the phantom and effects the quality of the calculation.]

Variance reduction methods

Monte Carlo calculations can be very time consuming. One way of speeding up calculations is to use leading particle biasing. This ensures that the most time is spent on particles that have the most energy. Add leading particle biasing by selecting an EMF-BIAS biasing card. Choose LPBEMF to apply to Compton, pair-production and photoelectric effect. Use the figure-of-merit to determine if there is an improvement in the quality of the calculation.

Note: The leading particle biasing technique is useful for primary barriers, where the particles of interest are forward directed, but will not be useful for shielding problems where scattering is an important process.

A more general alternative is to create an importance map which is used to steer photons in a direction of interest.

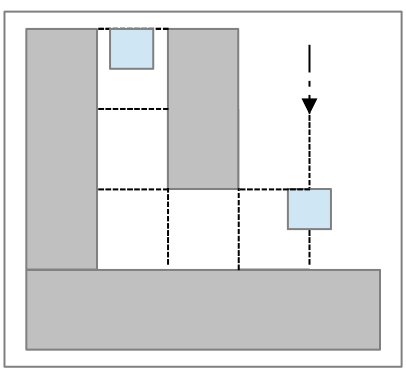
Split the wall into ten, 10 cm thick, sections. Use the Cloning operation to make this easier. Add BIASING components and increase the importance of regions for photons penetrating deeper into the shield. [Hint: For every tenth-value layer (TVL) the importance needs to be increased by a factor of 10].

Again use the figure-of-merit to determine if the approach offers an improvement. What would be the optimal importance map?

Maze design

Extend the wall in one direction so that it extends 4 m off-axis. Add two new wall sections at 90 degrees that extend the outer wall at a distance of 3 m off-axis back to a level 1 m behind the source, as well as a 1 m thick wall between the source and outer wall. Add a 1 m thick roof and floor.

Return the phantom to its original position at 1 m from the source and clone it to add a phantom outside the maze. Extend the USRBIN grid to cover the maze and rerun, examining the dose and quality of the statistics in the second phantom.



The photon fluence should be greatly reduced at the entrance but non-negligible and is general important to calculate this component accurately. Devise an importance map to examine photons that travel through the maze. [Hint: It will be useful to partition the void into regions of increasing importance].