
**FLUKA Beginners' Online Training**

# Answers to questionnaire on Electromagnetic interactions and thresholds

# Question 1

Let a 10-MeV $e^-$ beam impinge on a region filled with water. Suppose you need to score energy deposition with a `USRBIN` with bins of volume 50x50x50 $\mu$m$^3$. Considering that the ranges of 1-MeV and 10-keV electrons in water are $\sim$1 mm and $\sim$1 $\mu$m respectively, which of the following values would you pick as electron transport and production threshold?

A. 10 MeV.

B. 1 MeV.

C. **10 keV.**

D. It does not matter.

Picking 10-MeV thresholds for a 10-MeV $e^-$ beam would imply that they would deposit their energy almost immediately upon entering a material, whereas they can actually manage to travel beyond 1 mm (more than 20 bins in the proposed scoring grid). This would distort the energy deposition picture significantly.

Likewise, putting 1-MeV thresholds *i.e.* killing electron tracks below 1 MeV is also premature in the proposed scoring grid: such electrons could travel up to a further 1 mm (20 bins in the proposed scoring grid). Thus, depositing their energy on the spot would distort the picture too much.

Instead, 10-keV thresholds are meaningful in this situation, since 10 keV can travel up to 1 $\mu$m (much shorter than the bin size).

## Question 2

Delta-ray-production and transport-threshold values...

A. ...are not written in the output files.

B. ...are written in the .err file.:

C. ...are written in the .log file.

D. **...are written in the .out file.**

You can indeed examine the transport and delta-ray-production thresholds in the output file. See slides 32, 33, and 34 of the corresponding lecture for turn-by-turn instructions.

# Question 3

Spikes and steps in energy-deposition spectra in thin slabs...

A. ...are not artefacts: they are physical

B. ...can always be removed by correctly setting transport thresholds

C. ...can always be removed by correctly setting delta-ray production thresholds

D. **...can be removed by requesting single scattering near geometry boundaries as well as in conditions where the Molière theory does not apply, and by limiting the maximum step size.**

You are invited to examine slide 47 in the lecture backup material. The situation considered there is a 1 $\mu$m$^3$ detector volume immersed in a 10 $\mu$m$^3$ Si volume irradiated by a 100-MeV proton beam.

Examining the histogram of deposited energies, spikes appear. Among the problems there is the fact that particle steps are too short for the Molière theory to apply. These spikes vanish as soon as ones requests to switch to single scattering by issuing a `MULSOPT` card and by further restricting the maximum step size.

In general, steps and spikes artifacts can be smoothened out by shortening the particle step sizes with the help of the `FLUKAFIX`, `EMFFIX`, and `STEPSIZE` commands.

# Question 4

When performing particle tracking in the condensed history approximation:

A. delta-rays are explicitly generated when the energy transfer is small.

B. **small ionisation losses are taken into account in terms of their cumulative effect along the particle step.**

C. elastic scattering events are individually sampled.

D. the Molière theory is applicable in case of thin layers as well as transport in low density gas.

The first proposed answer is false: delta-rays are generated explicitly if the energy transfer from the transported charged projectile is large (more quantitatively: when it exceeds the delta-ray production threshold).

Instead, the second suggested reply is correct: as shown in the lecture, small ionization losses are frequent, in fact too frequent to sample individually. Thus, their aggregate effect is taken into account via an energy loss along a charged-particle step.

The third reply is incorrect: elastic scattering events on the screened Coulomb potential of target atoms are too frequent and too many to sample explicitly. Their aggregate deflection is accounted for by means of a multiple-scattering angular distribution (the Molière distribution in FLUKA).

The fourth reply is incorrect: the Molière theory requires a minimum step length (typically 10–20 elastic mean free paths) to apply.

# Question 5

Select the correct sentences:

A. Delta-ray production thresholds can be set by regions.

B. **For electrons, positrons and photons, transport thresholds are set by regions with the `EMFCUT` card.**

C. The `PART-THR` card sets the transport threshold for all particles.

D. **If the transport of electrons, positrons, and photons is off, their energy is deposited on the spot.**

The first reply is incorrect: delta-ray production thresholds are set by material.

The second reply is correct. For charged hadrons, ions, and muons, instead, the transport threshold is set with the `PART-THR` card and the delta-ray production threshold is set with the `DELTARAY` card.

The third reply is false: the `PART-THR` card sets the transport threshold for charged hadrons, ions, and muons.

The fourth answer is true: when `EMF` is off, any energy that would otherwise be carried away by the $e^{\pm}$ and $\gamma$ and eventually deposited by electrons elsewhere is instead deposited on the spot in the first encountered material.