Exercises - Set 1

Introduction, basic handling of FLAIR and FLUKA

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Notes to exercises:

- Exercises are meant as suggestions, you are welcome to deviate from the suggestions (at own risk, we might not be able to help you if you run into trouble).
- All can be done using the FLAIR user interface, which can be started using the command "flair".
- Flair comes with some plotting capability, but feel free to use any plotting program of your choice.
- Use HADRONTHErapy defaults for all simulations, if not specified otherwise.

1. Your first depth dose curves

a. In flair, start from "NEW-> BASIC" template, and set up a water tank 20x20x20 cm^3 surrounded by air, starting at z = 0 cm, symmetic around the z-axis.
b. Set up beam 120 MeV protons, FWHM = 1.0 cm, 0 mrad divergence, starting at z = -200 cm. Statistics 5000 particles x 5 runs will do fine for now.
c. scoring: use the USRBIN card with 1 mm precision.
    i. Plot 1D dose distribution (Dose versus z) in water tank, make sure all axes have correct units. Score the dose in the entire water tank width (i.e. in 20x20 cm^2 slabs each 1 mm thick)
    ii. Check with a quick calculations using the stopping power of protons (http://dedx.au.dk or android app), whether the dose is what you exepct it to be.
    iii. as i.) but scoring fluence distributions. Check if the number is what you expect.
    iv. and again, scoring energy. Check if the results your expectations.
    v. 2D Dose distribution colour map at X = 0 cm (pixel size 1x1 mm^2 x from -10 to +10 cm)
d. At what position do you find the Bragg-peak? Check it using the webpage http://dedx.au.dk If you see deviations, can you explain the possible reason for deviations?
e. Repeat exercise 1., but with 240 MeV/u carbon-12 ions
f. insert 1x1x1 cm^3 block of ICRP cortical bone halfway into the beam at z = 0 cm.

2. Understanding scoring

a. The classic "*Where did the Bragg peak go*?"-problem.
    i. Use the geometry setup from exercise 1) and apply a proton pencil beam (FWHM = 0 cm) at 230 MeV, and increase size of phantom to z = 40 cm.

ii. as in exercise 1) score again the 1D energy deposition vs depth along the beam, using cylindrical scoring circular r = 5 cm slabs, each 1 mm thick.
iii. Score again energy vs. depth, but r = 0.1 cm. Compare to that calculated previously in ii.
iv. Explain what happened to the Bragg peak? (E.g. check with a 2D map).

b. Another classic: *The divergence problem*. Assume the surrounding air is vacuum, and now consider these three geometries:
   i. A parallel broad r = 5 cm circular beam of protons, divergence = 0 mrad
   ii. And a beam starting at z=-100 cm, but select a divergence (using basic trigonometry rules), so the field is r = 5 cm when it hits the phantom surface
   iii. A beam r = 5 cm, starting at the phantom surface, still with the same divergence as in 2).

   Note that each of the three geometries will have the same spot size (r = 5 cm) at the phantom entrance (z = 0 cm). Now get for each of these geometries,
   1. get a fluence-vs-depth curve,
      a. with a broad beam scoring r = 10.0 cm (encompassing all of the beam) and compare these in one plot
      b. narrow scoring r = 0.2 cm and compare these in a different plot.
   2. Why are the plots different? Explain your observations qualitatively.

3. Lateral penumbras

a. Use the setup from task 1), but use a square beam 5x5 cm², 236 MeV
b. plot the lateral dose profile along the x.-axis at z = 30 cm depth
c. repeat for 465 MeV/u carbon ions, and plot it along with the proton data.
d. repeat for 14 MeV photons (mono-energetic), and plot along with the photon data.
e. BONUS QUESTION for the quick: from what depth have photon beams a better penumbra than protons? [compare with figure 3 in http://rpd.oxfordjournals.org/content/137/1-2/156.full (and find one error in the published figure)].]

4. Particle energy spectra

a. Using the USRTRACK card and the setup from exercise 2 and 238 MeV protons, you can acquire particle energy spectra. Check what the fluence-energy (dPhi/dE vs E) spectrum is
   i. ...at the surface where the beam enters the phantom
   ii. …close to the Bragg peak.

   while choosing an appropriate energy scoring range.