GEANT4 FINAL PROJECTS

2023-2024

GENERAL GIDELINES

- Reports for the final projects should be more thorough than the ones for the simple simulations we did in class
- You should have:
  - An introduction with some discussion on the topic under study
  - A description of your simulation strategy and the implementation details (may include snapshots of the visualisation, if appropriate)
  - Discussion of the results, including relevant plots, comparison with what was expected
  - Bibliography as appropriate
- You also need to send me the simulation and analysis codes

1 - PROTON THERAPY

- Get the Bragg curve in soft tissue (use a NIST tissue-like material with a density ~1 g/cm^3) for a beam of protons with an mean initial energy of 100 MeV
  - Consider that the energy distribution follows a Gauss curve with a sigma of 2% — use the Box-Muller gaussian generator discussed in Homework #1
- Study the position of the Bragg peak as a function of the initial energy of the proton beam (from 50 to 150 MeV, in steps of 10 MeV)
- Use these results to estimate the mean proton energy required for treatment of a tumour at a depth of 7 cm under the skin
- As your starting point, you can use the alpha particle Bragg peak example

II - GAMMA SPECTROSCOPY

- Create a NaI cylinder (*crystal*), 2 cm high and 4 cm in diameter; place it in the center of the world volume.
- Add an Aluminium holder for the radioactive sources (a flat disk 2 mm thick and with a diameter of 2 cm) and place it 5 cm away from the base of the cylinder defined above (along the cylinder axis)
- Add a lead "castle" around the crystal (a hollow cylinder 2 cm high and 1 cm thick)
- Place different radioactive sources (^{60}Co, ^{137}Cs, ^{22}Na) on top of the Al holder (between the holder and the crystal). You can create a small plastic disk and place the source in its center.
- To simulate light collection and electronics effects, smear the deposited energy in each event using a gaussian distribution (using the Box-Muller approximation from Homework #1) to simulate the energy resolution of the detector (use $\sigma = \sqrt{(E_{dep})}$, with E_{dep} in *keV*)
- Histogram the total energy deposited in each event for each of the radioactive sources. Interpret each of the features observed in the spectra
- As your starting point you can use the *Crystal* example

III - NEUTRON INTERACTIONS

- Estimate the average number of elastic collisions needed to reduce the energy of 2 MeV neutrons to below 0.025 eV (thermal) in different materials (H, He, C, Pb). Note that you need to turn off other neutron processes — see shootNeutrons.mac. Comment the results.

- Shoot a beam of 2 MeV neutrons into blocks of different materials (H_2O, Pb) with a thickness of 10 cm. Plot the energy spectra for the neutrons that get to the other side. Compare (and comment on) the results from using the two materials (note that now you should have all processes active).

- Modify the generator to simulate a Cf-252 neutron source (see Cf252Neutrons.mac). Build a collimator 2 cm away from the source (a 20 cm thick block of material with a 2 cm diameter cylinder of air crossing it from side to side, with the axis at the same height as the source) using the most appropriate material based on the previous results.

- Make a 2D histogram of the spatial distribution (in the plane perpendicular to the air cylinder) of the neutrons on the other side of the collimator. Plot the energy of the neutrons leaving the collimator as a function of the radius in this plane. Comment on the results and compare with those from using what would be the worst material.

IV - RUTHERFORD EXPERIMENT

- Simplified simulation of the Rutherford Experiment:
  - Place a thin gold foil in the center of your laboratory (1 μm thick along Z, 5x5 cm in XY)
  - Use a "perfect" detector: a spherical shell with a radius of 50 cm and 1 mm thickness
- As first step, use a simple beam of 5.5 MeV alpha particles incident on the gold foil (starting 5 cm away from the foil)
- Register the position of the alphas that reach the detector.
  - Plot the positions in 3D and histogram the polar angle.
  - Does the angular distribution follows what you expected? Comment on the results and compare with the Rutherford formula.
- Make your simulation more realistic:
  - Construct a shielding + collimator to place an alpha "source": a cubic Lead box (2 cm side) with a small (1 mm radius) cylindrical hole to act as collimator in the Z direction
  - Shoot your alphas from the center of this box (still 5 cm away from the foil), but now with isotropic direction to simulate the decay of a radioactive source (use the generator you developed in Homework #2)
  - Redo the initial study. Compare and comment the results.