Prelab 3: Radiation Simulations

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1.

For this lab the field of interest is radiation therapy physics, specifically simulation of running cancer treatments using virtual phantoms. To understand the concepts used I will outline what radiation therapy is, the types of beams (lepton and hadron). Radiation Therapy is a medical treatment plan that uses high energy ionized electromagnetic radiation (gamma rays, X-rays, hadron beams, etc.) to target cancerous tumors by releasing energy deposits on the tumor with the goal of destroying it without damaging healthy organs. For treatment plans most of the time the beams that are used are gamma rays or x-rays but there has been a shift to transition to hadron beams like protons. Both radiation beams are governed by the Bethe-Bloch equation (Equation 1) which described the physical principles of stopping power of how much energy can be released based on particles going through cross-sections of matter. This governing equation is what makes hadron beams superior to proton. For treatment plans a phantom is made to model a tissue of the cancer area, density, and orientation. The Bethe-Bloch equation makes the proton be in favor as treatment beam because since it's heavier than photon and electron it'll move slower and can be easier to plan out when to release the energy because stopping power can be modeled to release energy as specific orientation deep within the tumor. This is modeled by Bragg-Peak curves which measure deposit per depth. For Photon beams deposits it is harder to model when to release and not very abrupt which means that as you go deeper to where the tumor needs to be targeted it can release energy deposits onto healthy organs causing toxicity side effects [1].[Count: 276]

$$\frac{-dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}[\ln(\frac{2m_ec^2\beta^2\gamma^2T_{max}}{I^2}) - \beta^2 - \frac{\delta(\beta\gamma)}{2}] \tag{1}$$

2.

The figure between the radiation beam and phantom has a few observation that I can tell. The wave orientation is moving straight down with most of the dosage being released at center of the phantom. There are also some tracking lines that are bent so they can be result of weak scattering or effects of a weak electromagnetic field based from the phantom (Figure 1).

Geant-4 simulation

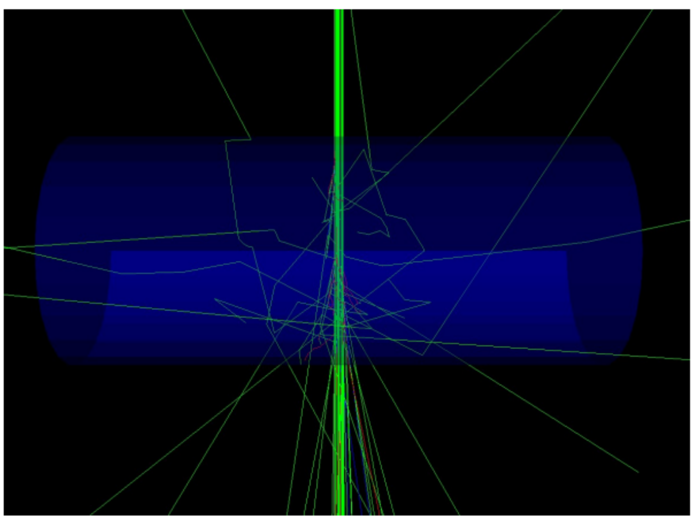

Figure 1: Geant-4 simulation that uses the water phantom and 1 Mev gamma ray beam to simulate a specific radiation treatment.

3.

- $E_\gamma = 200\,\mathrm{keV}$

- attenuated = 10%
- Assume full gamma absorption deposited in phantom.

$$D = \frac{E_d}{m} \quad \left(\frac{J}{kg}\right)$$

$$m = 1\,\text{kg of tissue}$$

$$E_d = D \cdot m = (50\,\text{Gy})(1\,\text{kg})$$

$$E_d = 50\,\text{J}$$

$$N \to \text{be the number of incident photons.}$$

$$0.1 \cdot N \cdot E_\gamma = E_d$$

$$N = \frac{E_d}{0.1 \cdot E_\gamma}$$

$$N = \frac{(50\,\text{J}) \cdot (6.242 \times 10^{18}\,\text{eV/J}) \cdot (2000\,\text{keV/eV})}{0.1 \cdot (200\,\text{keV})}$$

$$N \approx 1.561 \times 10^{21}\,\text{photons}$$

Works Cited

[1] Dr. Paul King. *Physics 6751: Nuclear Lab Manual*. Version 24.5. Athens, Ohio, 2024.