Radiation Therapy

A popular method of treatment:
- Effective against cancer
- Much shorter treatment than chemotherapy
- Eliminate cancerous tissues from the human body, while leaving healthy tissue in tact.

Technological improvements under way:
- More precise and versatile radiation equipment
- More sophisticated software for treatment plans
- Greater understanding of interactions and simulations needed.

Theory

In radiation therapy, the main interactions are:
- Photoelectric effect - low energy
- Pair production - high energy
- Compton Scattering – most common

Compton scattering

- The incoming photon collides with an electron at rest.
- Total energy and momentum are conserved.
- Energy deposited to electron is dependent on scattering angle: $\Delta E = E \cdot e_b (1-\cos \theta)$

Monte Carlo Method

The Monte Carlo method is a computational tool useful for modeling indeterministic situations like Compton scattering.

- Based on the probability of the interaction
- Random generation of trial data

Differential Cross-section

- Describes distribution of probability (dσ) over the solid angle (dΩ).
- Differential cross-section for Compton scattering is Klein-Nishina formula [2]:
  
  $d\sigma = \sigma_{KN} = \frac{2 \pi \alpha^2}{\pi (1 + \cos \theta)^2}$

Methods

To computationally model Compton Scattering, the simulation can be broken down into different sections:

1. Angle Portion
   - Position of event
   - Angle of outgoing photon
   - Probability of event occurring

2. Energy Portion
   - The photon will continue through the material until the photon no longer has enough energy to interact.
   - At each interaction the energy deposited at each spot in the lattice will be recorded.
   - A new photon is generated when there is no longer energy from the previous photon.

3. Full Simulation

Results and Analysis

Figure 1: A diagram of Compton scattering

Figure 2. Flow chart showing the simulation steps.

Figure 3: Generation of 6MeV photons, showing the scattering angles of 30 photons.

Figure 4: Generation of 6MeV photons, showing the scattering angles of 3000 photons.

Figure 5: Two photons scattering through the material, with an initial energy of 6 MeV.

Figure 6: 10 photons scattering through the material, with an initial energy of 10 keV.

Figure 7: 10 photons scattering through the material, with an initial energy of 10 keV.

Conclusion

- Full simulation of Compton Scattering successfully generated.
- Full simulation agreed with expectations:
  - More photons yields a more realistic simulation.
  - Higher initial energy yields higher initial interactions and a higher percentage of the total energy deposited near the surface.
  - Lower cut-off energy yields greater distance irradiated within the material.

References