جامعة الملك فهد للبترول والمعادن
King Fahd University of Petroleum & Minerals

Monte Carlo Simulation of Radiation Transport

PHYS499 Seminar

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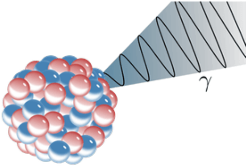
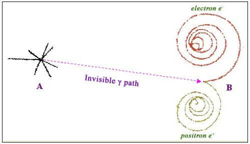
Outline

Introduction

Radiation Transport of Gamma Rays

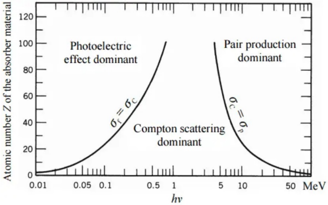


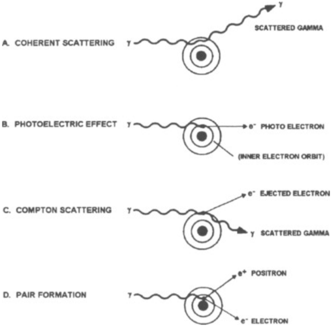


- High-energy photons emitted by radioactive nuclei.
- γ-ray transport refers to the process by which γ-rays propagate through a medium and interact with the atoms and molecules in the medium.
- Radiation transport models are used in various fields, such as nuclear physics, astrophysics, and medical imaging.

Gamma Ray Interactions

- γ-rays interacts with matter via several mechanisms:
  - Photoelectric effect
  - Compton scattering
  - Pair production
- The probability of each type of interaction depends on the energy of the gamma ray and the composition of the material.





Monte Carlo Simulation

Definition

Monte Carlo is a computational technique that involves the usage of random numbers to simulate complex processes.

Main random ingredients:

- Distance to next interaction s
- Scattering angles $\theta \& \phi$

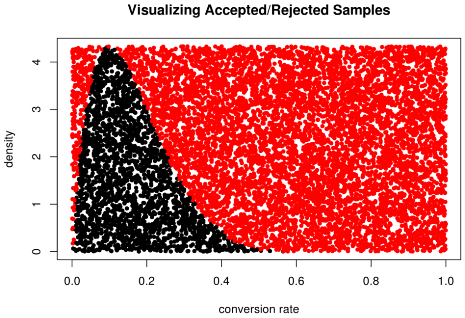
$$s\ follows:\ p(s)ds = \frac{1}{\lambda} 2e^{-s/\lambda} ds$$

$$\theta\ follows:\ p(\theta)d\theta = \frac{d\sigma_{KN}}{d\Omega} 2\pi \sin\theta d\theta$$

Acceptance / Rejection Method

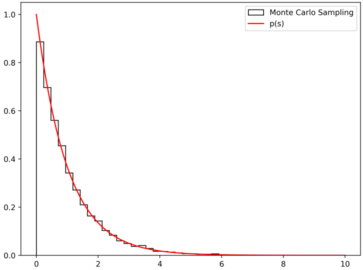
We propose a distribution, $U(x)$, to find the distribution $p(x)$.

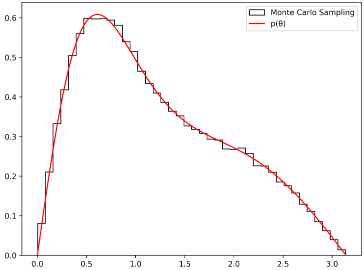
1. Sample x_i, y_i according to $U(x)$.
2. Check $y_i \leq p(x_i)$.
3. If $y_i \leq p(x_i)$ = True $\Longrightarrow$ Accept, otherwise reject and go to 1.



My Simulation

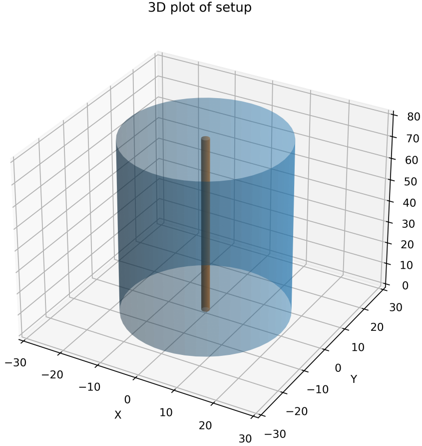
$p(s)$ & $p(\theta)$





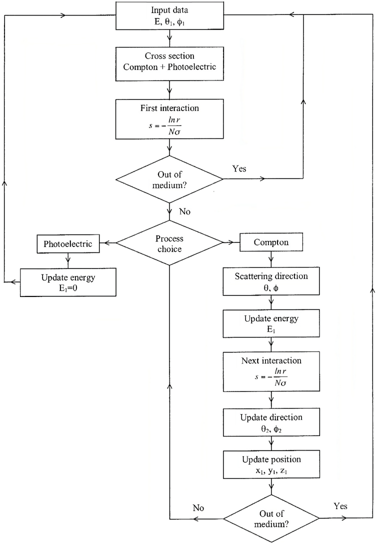
My Monte Carlo Accept / Reject method results

The Setup



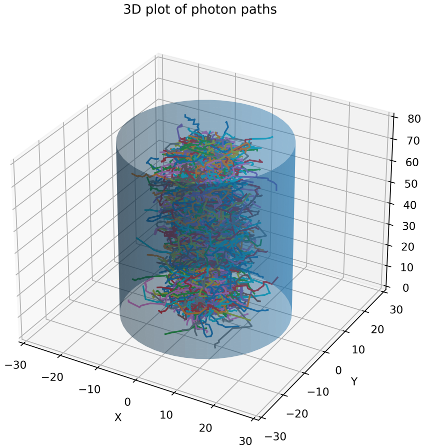
$$E = 1.00\ MeV; \quad N = 2000$$

Flowchart

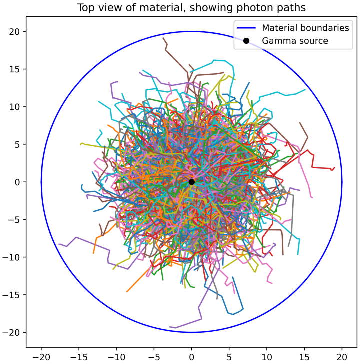

Input data
E, θ1, φ1
Cross section
Compton + Photoelectric
First interaction
s = -ln r / Nσ
Out of medium?
Yes
No
Process choice
Photoelectric
Update energy
E1=0
Compton
Scattering direction
θ, φ
Update energy
E1
Next interaction
s = -ln r / Nσ
Update direction
θ2, φ2
Update position
x1, y1, z1
No
Out of medium?
Yes

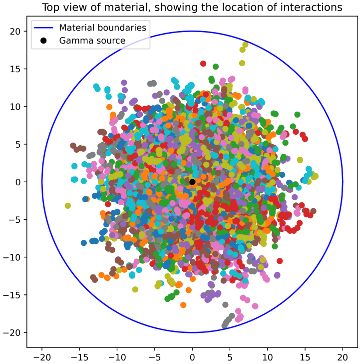
Results

3D Visualization



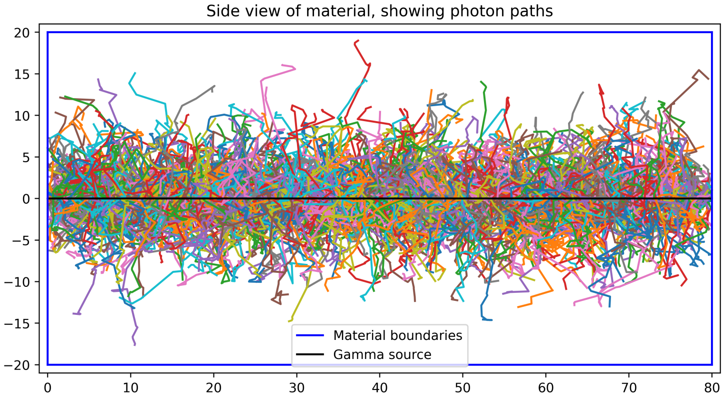
Results





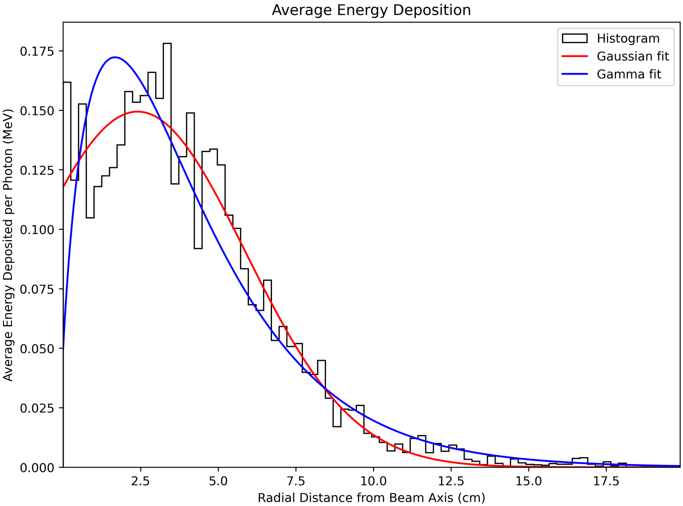
Top view

Results

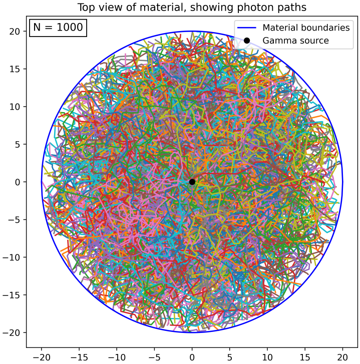


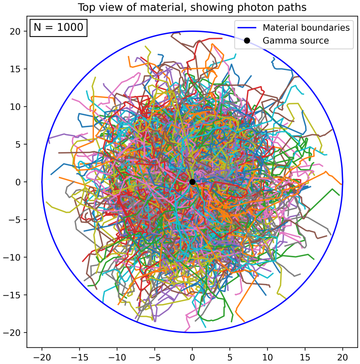
Side view

Results


Average Energy Deposition
Histogram
Gaussian fit
Gamma fit
Average Energy Deposited per Photon (MeV)
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Radial Distance from Beam Axis (cm)

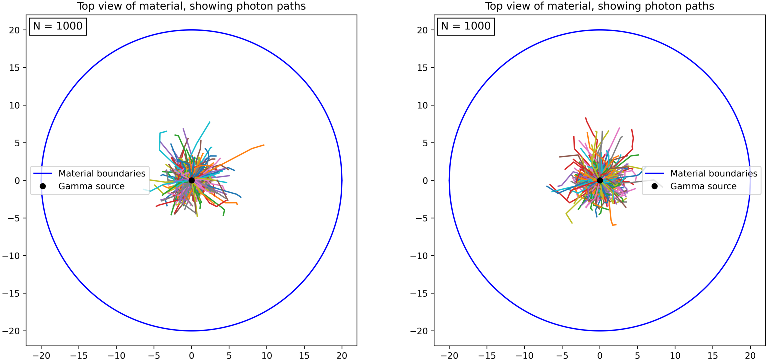
Qualitative Analysis





Hydrogen and Lithium

Qualitative Analysis



Lead and Osmium

Conclusion

- Monte Carlo methods are a powerful and flexible tool for simulating gamma radiation transport.
- They allow for accurate modeling of complex geometries, materials, and sources.
- Monte Carlo simulations can be used to optimize radiation shielding designs and evaluate the performance of radiation detectors.

Thank you!
Questions?