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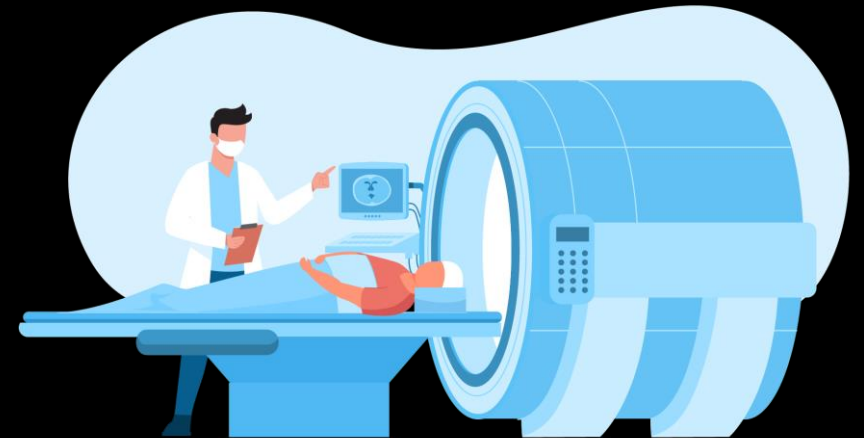
INVESTIGATION OF SUB 1 KEV ELECTRON TRANSPORT IN RADIOTHERAPY

OVERVIEW

- Introduction
- Theoretical background
- Motivations
- Simulation model
- Parameter sensitivity tests
- Explorative runs
- Conclusion & next steps

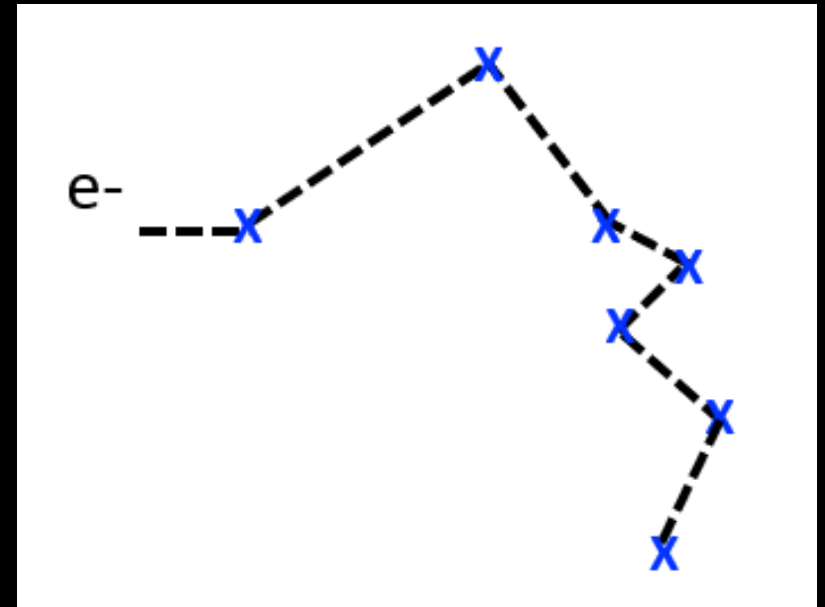
RADIOTHERAPY

- A form of treatment employing ionizing radiation to destroy cancerous or harmful cell groups
- Involves studying the path and energy deposition (or absorbed dose) of beams of ionizing particles
- Monte Carlo simulations are frequently used tools employed to model the stochastic properties of particle transport within various media with varying properties



UNCERTAINTY OF MONTE CARLO

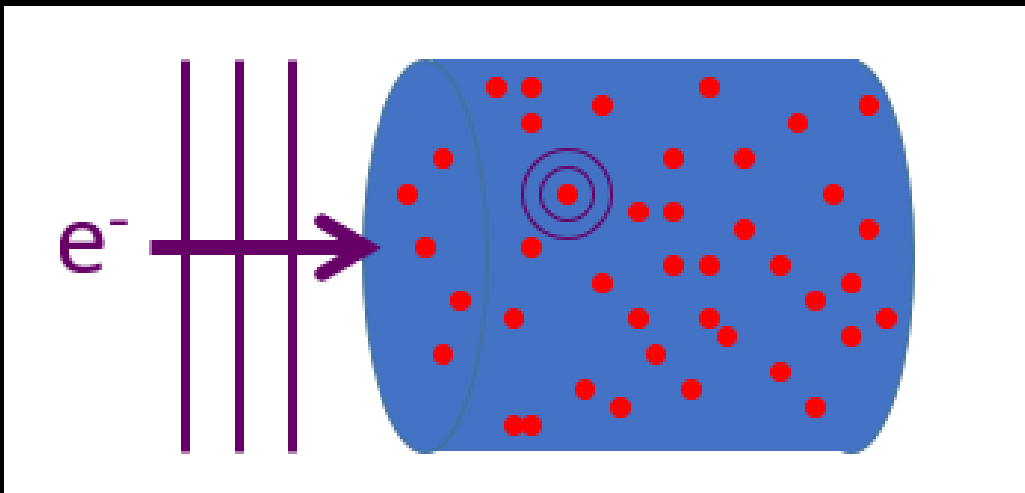
- MC simulations rely on the semi-classical assumption that incident particles are point-like objects undergoing a series of free flights interrupted by discrete interaction points
- Heisenberg uncertainty principle violated by computer precision, which means underestimated uncertainties
- Does not account for electron spread from the De Broglie wavelength, which neglects scattering from multiple sources
- These phenomena become non-negligible below the 1 keV electron energy threshold, which yields an error of 5% or more in the <1 keV region which increases to 17-20% around 100 eV



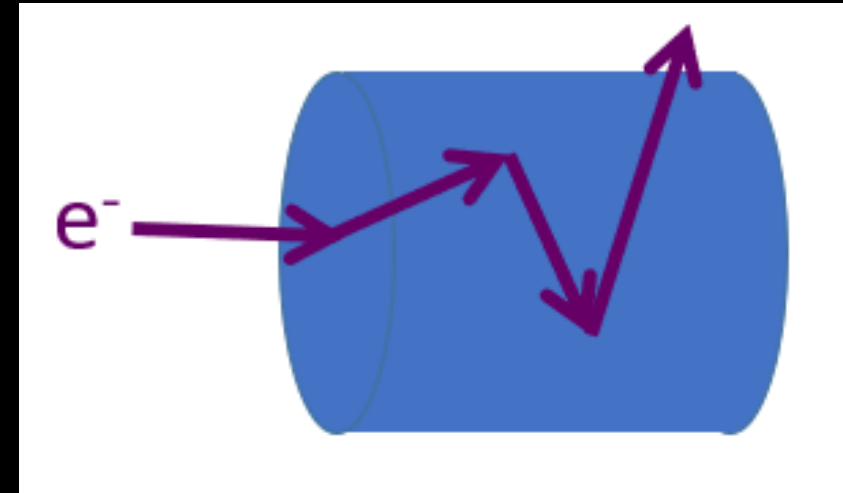
free-flight segments (- - - -)
discrete interaction sites (X)

SIMPLIFIED MODEL

- **Quantum simulation:** Electrons represented by plane waves incident on a cylindrical water droplet containing N point scatterers (water molecules)



- **Monte Carlo simulation:** Point like particle travelling through homogeneous cylindrical volume of water with interaction probabilities determined by quantum cross sections



Minimum separation between 2 point scatterers $d_{\min}=0.001\text{ nm}$
 Average separation between 2 point scatterers $d_{\text{avg}}=0.311\text{ nm}$
 Number of point scatterers $N=1000$

CALCULATIONS

- Partial cross section: probability of a particle being scattered into polar angle $\theta_{(i)}$

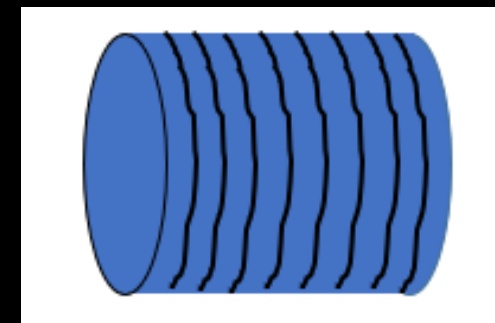
$$PCS_{(i)} = \frac{\# \text{ of particles escaping into polar angle interval } \theta_i}{\# \text{ of incident particles per unit area}}$$

- Scattering event density: number of scattering events per unit volume in layer l

$$SED_{(l)} = \frac{\# \text{ of scattering events in layer } l}{(\# \text{ of incident particles}) \cdot (\text{volume of layer } l)}$$

- Relative error: quantity summarizing the convergence of the QM and MC simulations

$$RE_{(X)} = \frac{\sum_m |X_{(m)}^{QM} - X_{(m)}^{MC}|}{\sum_m X_{(m)}^{QM}}$$

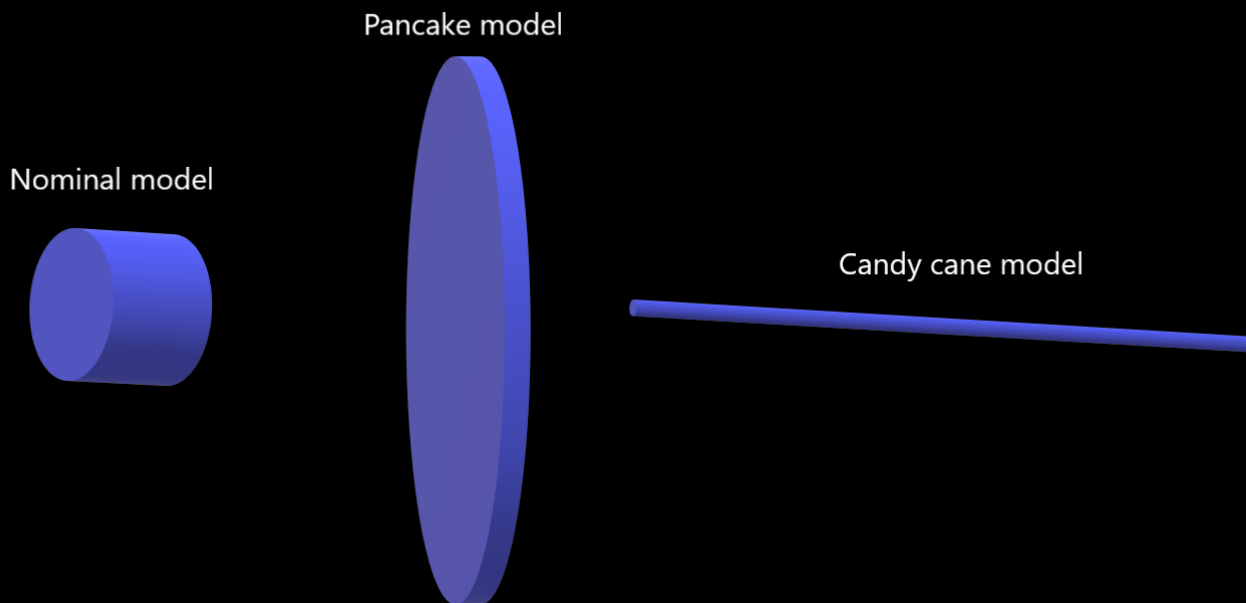


Cylindrical volume
divided into L layers

WORK PERFORMED

- Previously: demonstrated that quantum effects could not be neglected
- Currently: studying how convergence may be influenced by cylinder dimensions through 2 new configurations, the candy cane & pancake models

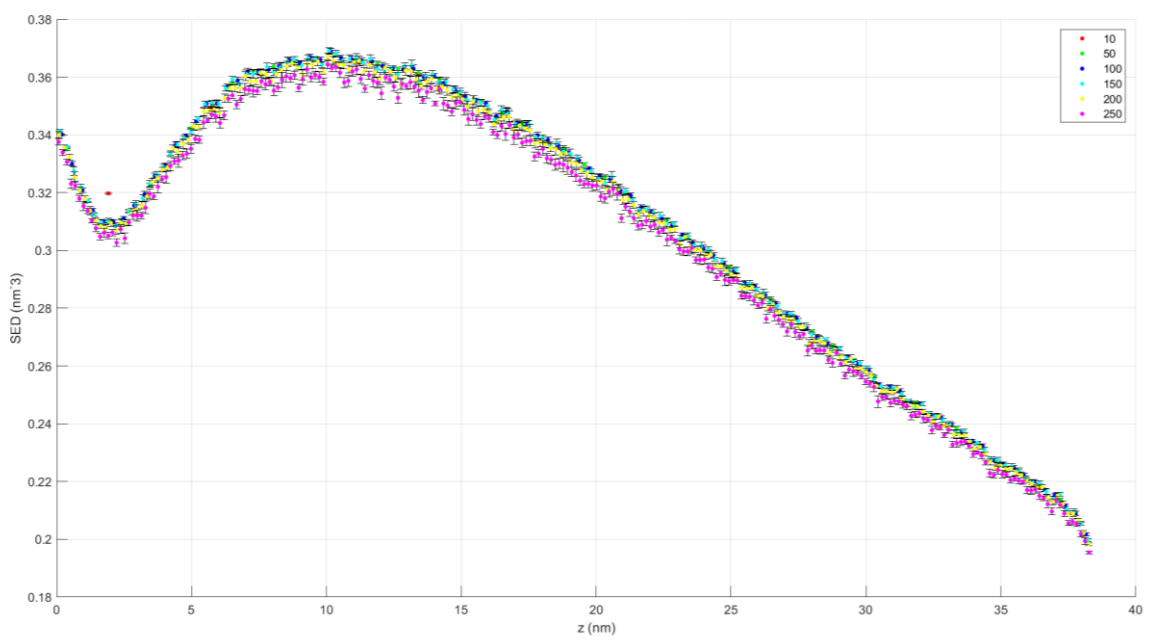
1. Nominal: radius=2.124nm & length=2.124nm
2. Pancake: radius=0.5nm & length=38.35nm
3. Candy cane: radius=10nm & length=0.0959nm



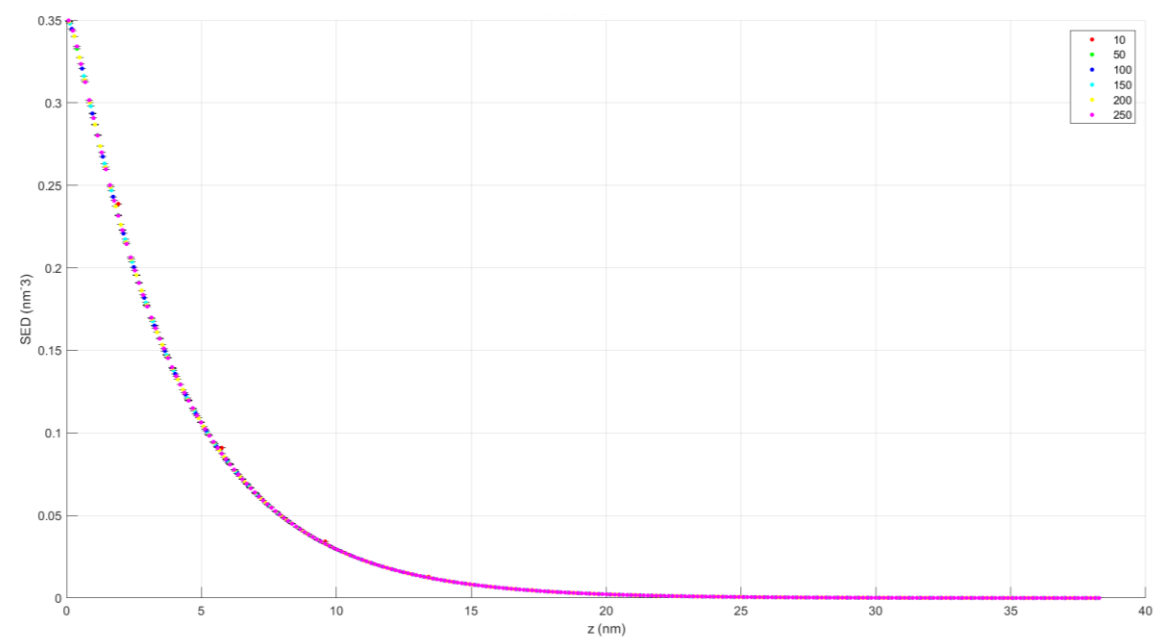
NLAYER SENSITIVITY TEST

- Consisted of:
 - 2 sets of parameters for each cylinder size, one with purely elastic scattering and one including inelastic scattering (6 simulations total)
 - λ fixed at 0.311nm
 - Each of the 6 simulations were run for 6 nlayer values:
10, 50, 100, 150, 200 and 250
- Resulted in PCS vs angular bin and SED vs layer plots, where the 6 corresponding layer plots were displayed on the same figure for comparison

Quantum simulation SED for Candy cane model

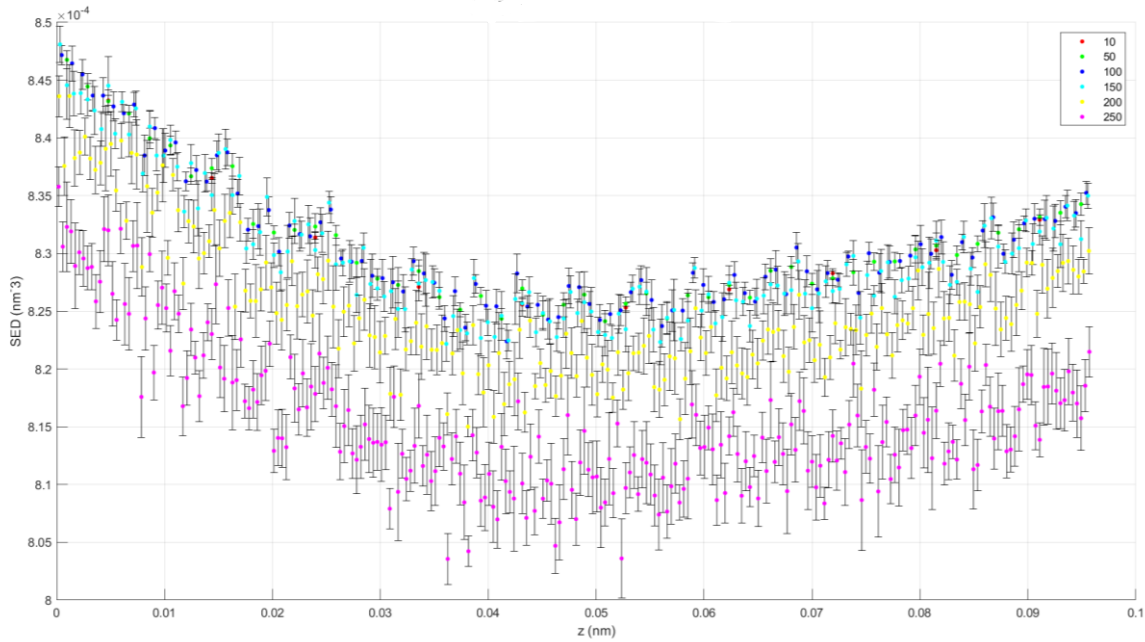


Track simulation SED for Candy cane model

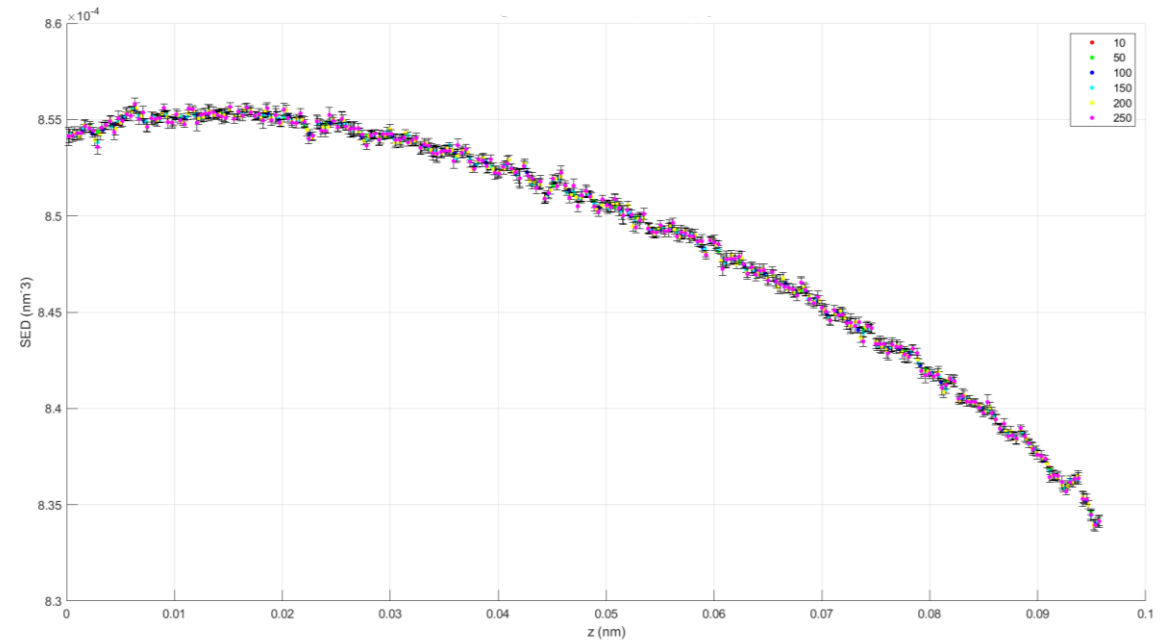


CANDY CANE MODEL
LAYER TEST PLOTS

Quantum simulation SED for pancake model



Track simulation SED for pancake model

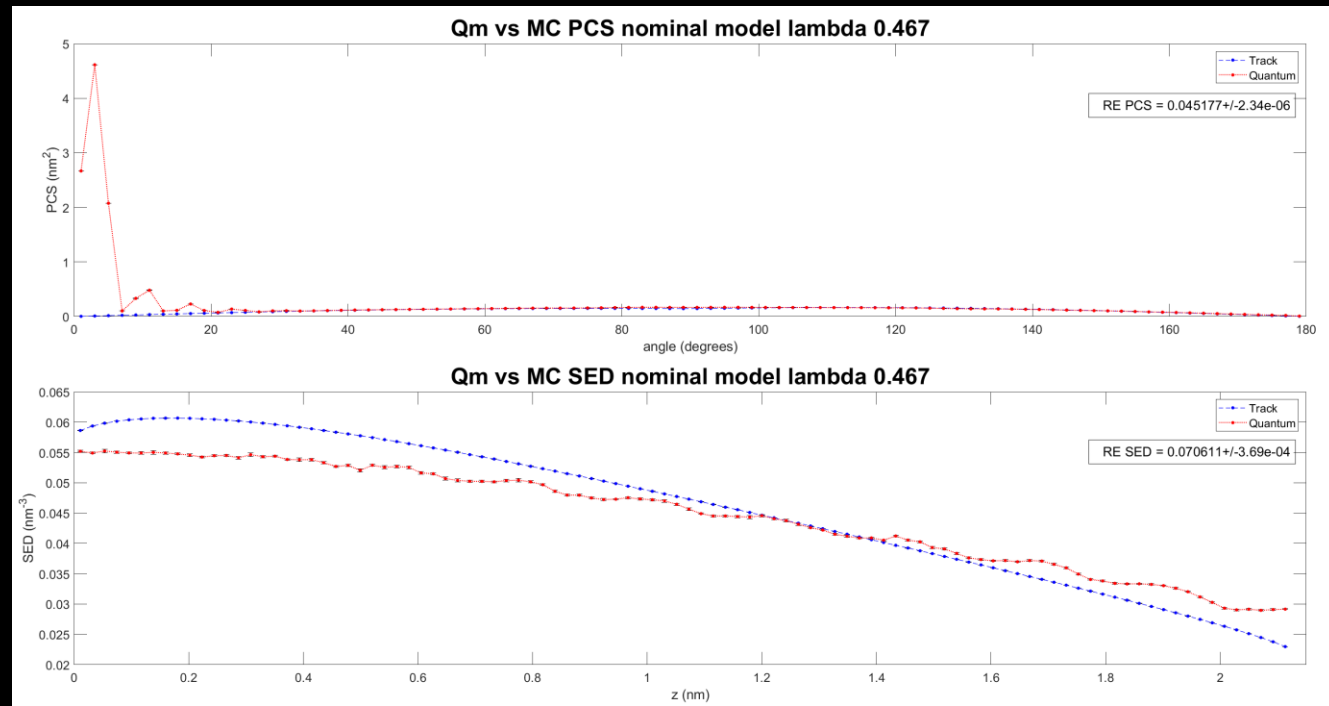
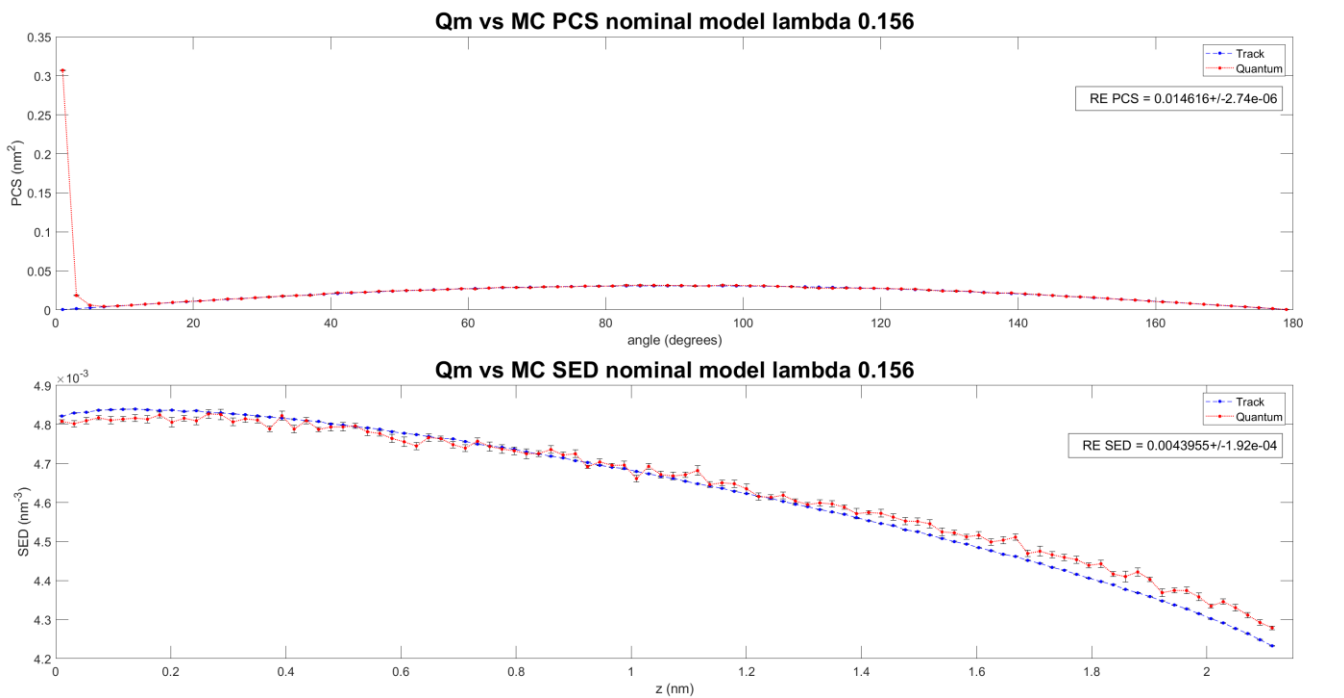


PANCAKE MODEL
LAYER TEST PLOTS

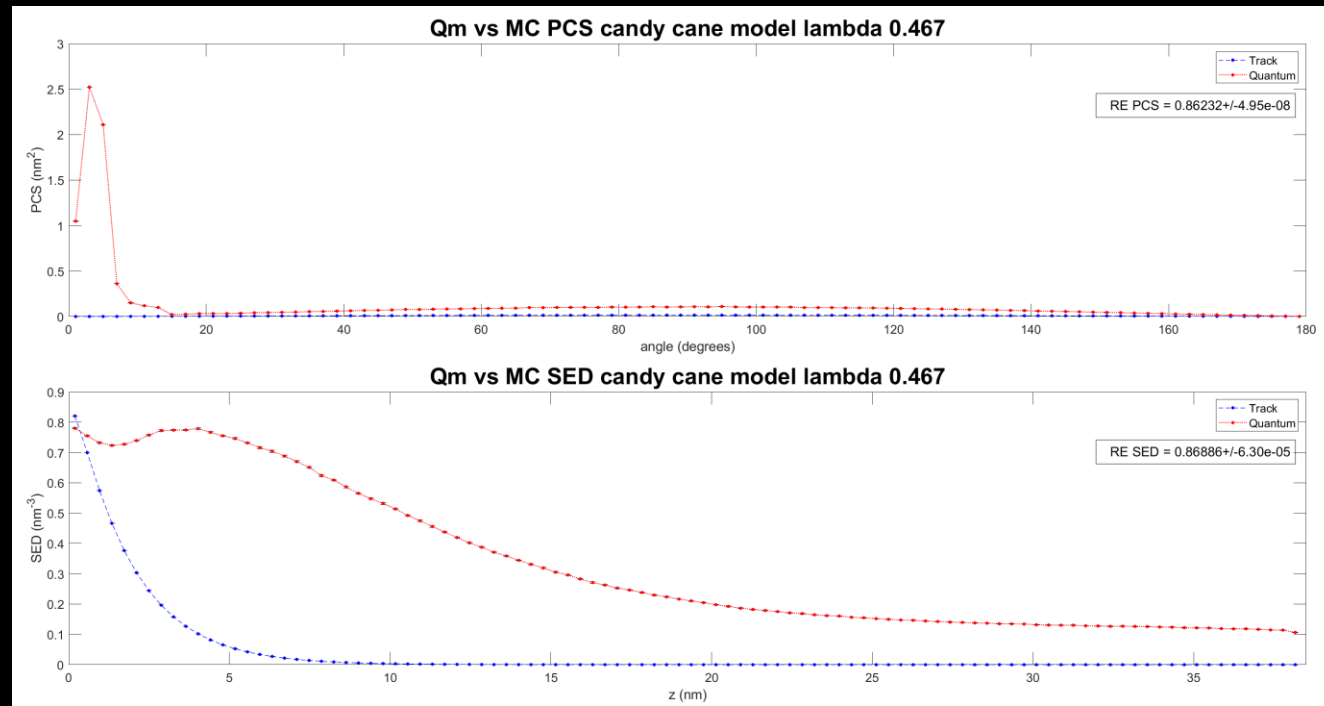
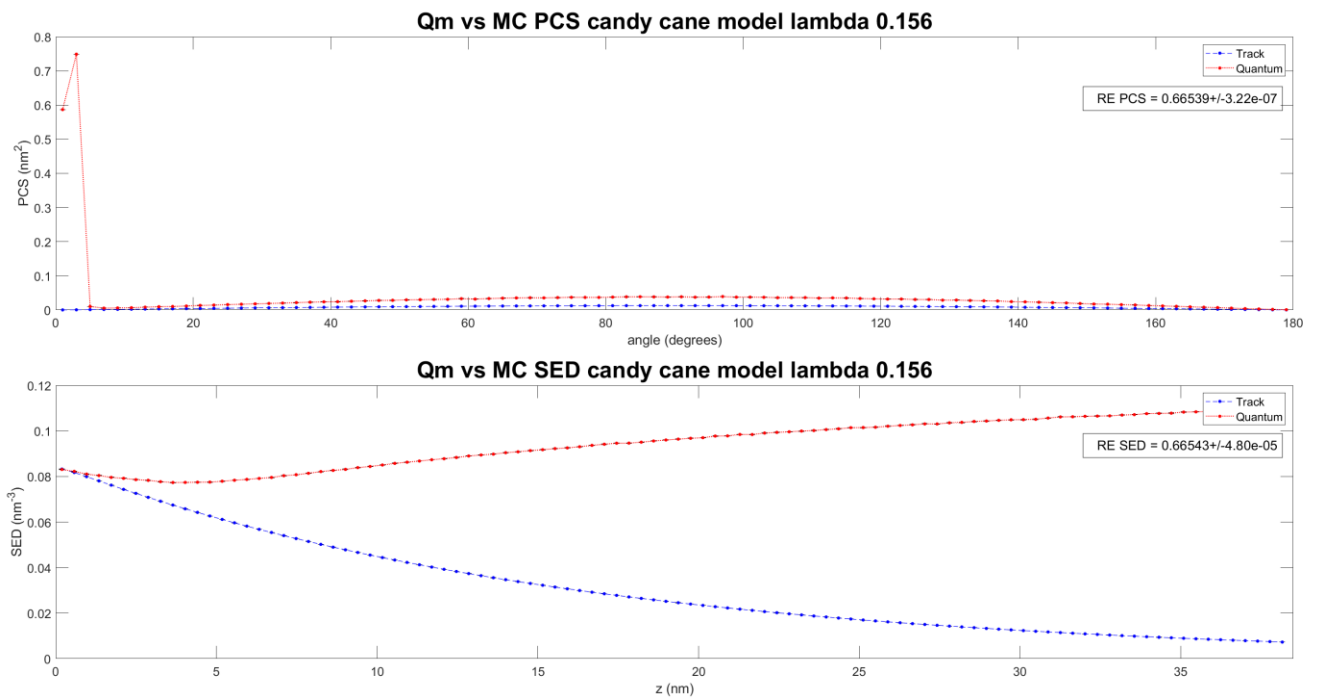
MULTI-WAVELENGTH SIMULATIONS

- Consisted of:
 - 2 sets of parameters for each cylinder size, one with purely elastic scattering and one including inelastic scattering (6 simulations total)
 - nlayer fixed at 100 following sensitivity test
 - Each of the 6 simulations were run for 5 wavelength values:
0.156nm, 0.233nm, 0.311nm, 0.389m, 0.467nm
 - Note that only the purely elastic data has been analyzed
- Resulted in PCS vs angular bin and SED vs layer plots, where the quantum and track versions were displayed on the same figure for comparison

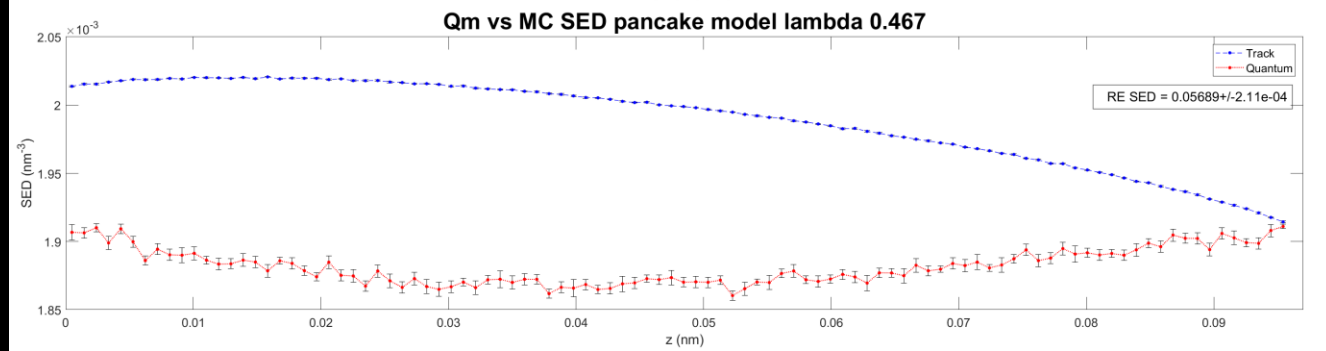
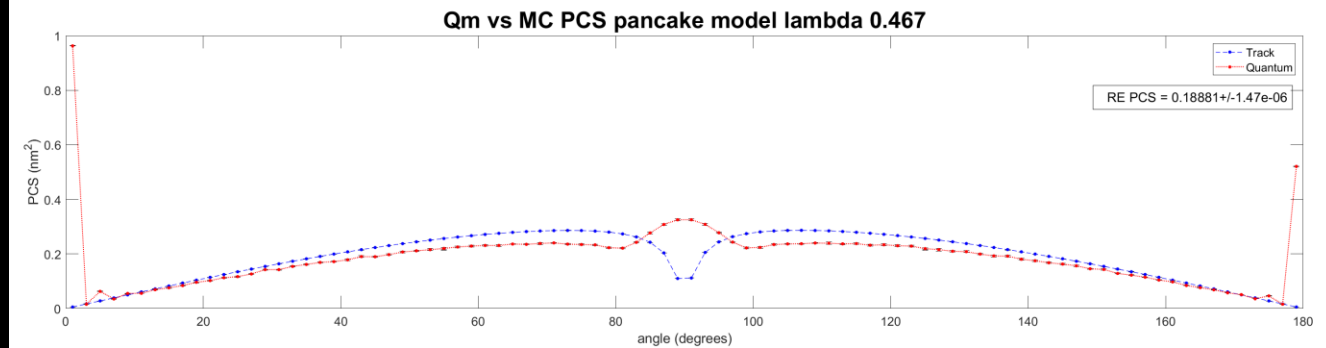
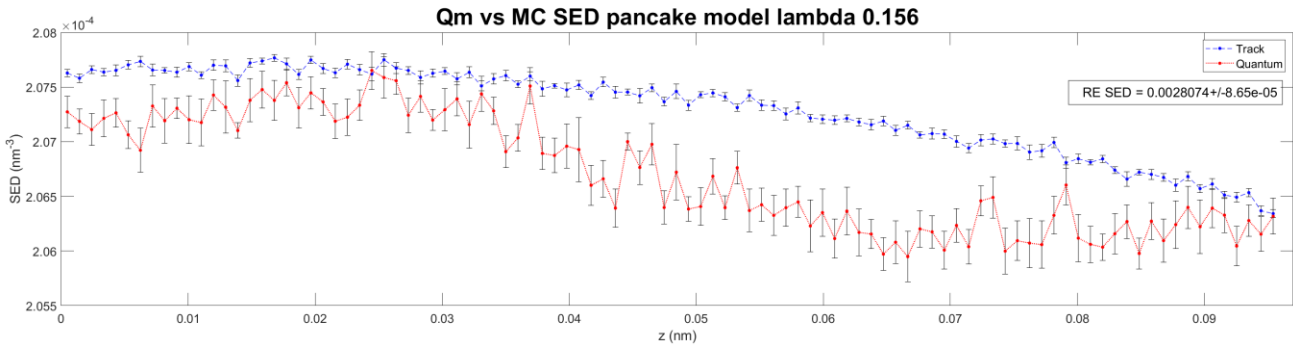
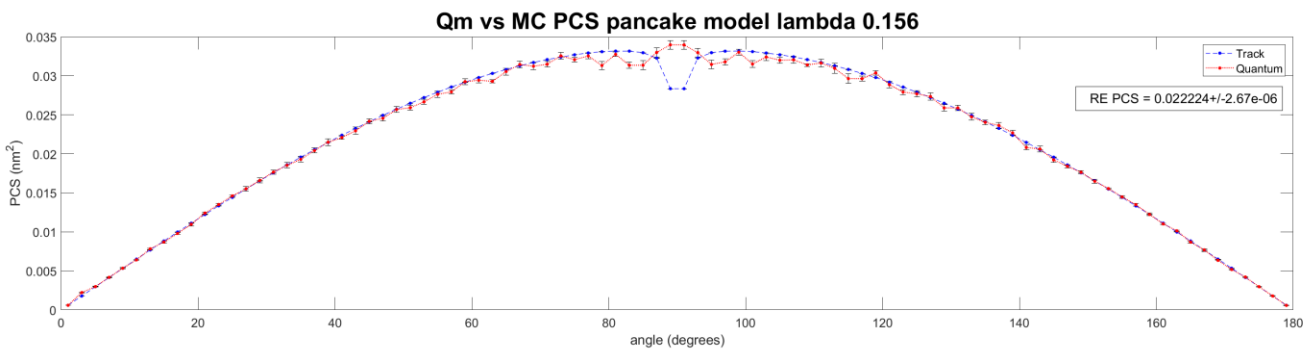
NOMINAL MODEL QM VS MC PLOTS



CANDY CANE MODEL QM VS MC PLOTS



PANCAKE MODEL QM VS MC PLOTS



CONCLUSIONS

- Successfully got simulations running
- Confirmed insensitivity to number of layers
- Gathered and began analyzing data for multiple wavelengths for new models
- Further steps will be continued in honours project

A scenic view of a university campus featuring a river, lush green trees, and modern buildings in the background. The scene is framed by vibrant, flowing abstract shapes in shades of red, orange, yellow, and cyan. The text "THANK YOU" is centered in white, bold, sans-serif font.

THANK YOU