Oregon State University

V6 VARSKIN

Uncertainty and Sensitivity in VARSKIN Methodology

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Types of Uncertainty

- Is our interpretation of the exposure scenario correct?
- Are the tools/models used to determine physical phenomena accurate?
- Are other dosimetry models correct? Which one is “best”?
- Are the physical parameters accurate? How might they affect the model?

Uncertainty and Sensitivity

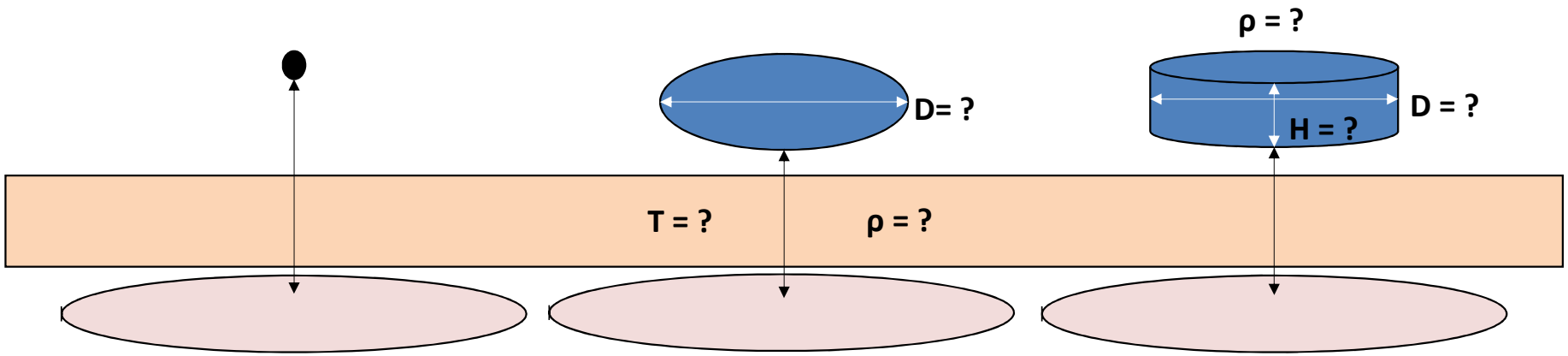
Uncertainty Analysis

How might the variation of the input parameters affect the variation of the output?

Sensitivity Analysis

Which input parameters contribute to the most variation in the output?

Where is the Most Uncertainty?



- What source geometry?
- Characteristics of source geometry?
- Characteristics of cover material?
- What activity and radionuclide concentration?
- How long?

A = ?

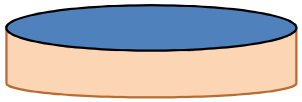
t = ?

Our interpretation of the scenario provides the largest uncertainty

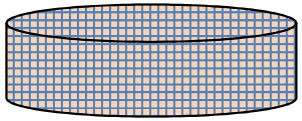
An Example

A lab technician spills a 5 ml solution of rhenium-186 on her lab coat within an area of ~50 square centimeters. She is exposed for ~4.5 hours. The activity is ~379 kBq/ml.

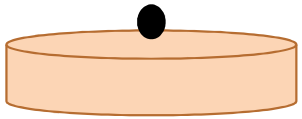
The cloth lab coat has dimensions of $T = .4\ mm$ and $\rho = .9\ g/cm^3$



Did the solution sit on top of the lab coat?



Did the solution soak into the lab coat?

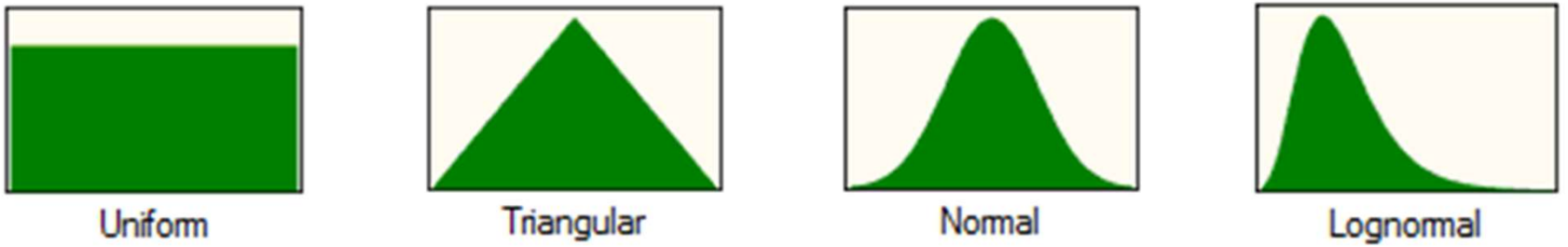


What if we are uncertain of the spill dimensions?

Scenario	Dose (Gy)
Disk	.0923
Cylinder	.169
Point	.461

Crystal Ball

- Monte Carlo Excel add-in allowing for multi-parameter uncertainty and sensitivity analysis.
- Define assumptions for uncertain variables in model by assigning probability distributions, based on what is known of those variables:



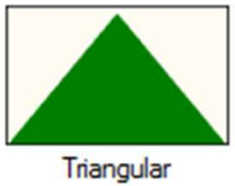
Photon Methodology

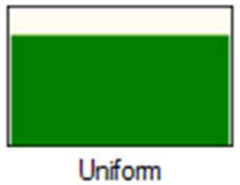
$$D\left[\frac{Gy}{nt}\right] = \frac{k}{4\pi} * \sum_{j=1}^{N} \frac{w_j}{d_j^2} * \sum_i \left[y_i * E_i * \left(\frac{\mu_{en}}{\rho}\right)_i * \left(f_{cpe}\right)_{i,j} * \left(F_{oa}\right)_{i,j} * e_i^{-\mu_i * d_j} \right]$$

Bounding between large errors

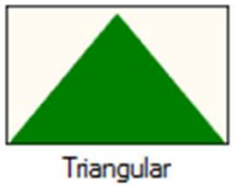
Small variations in textbook values

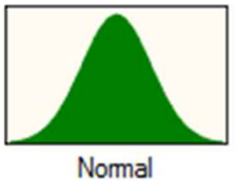
$\frac{\mu_{en}}{\rho}$ μ_i →





F_{oa} f_{cpe} →



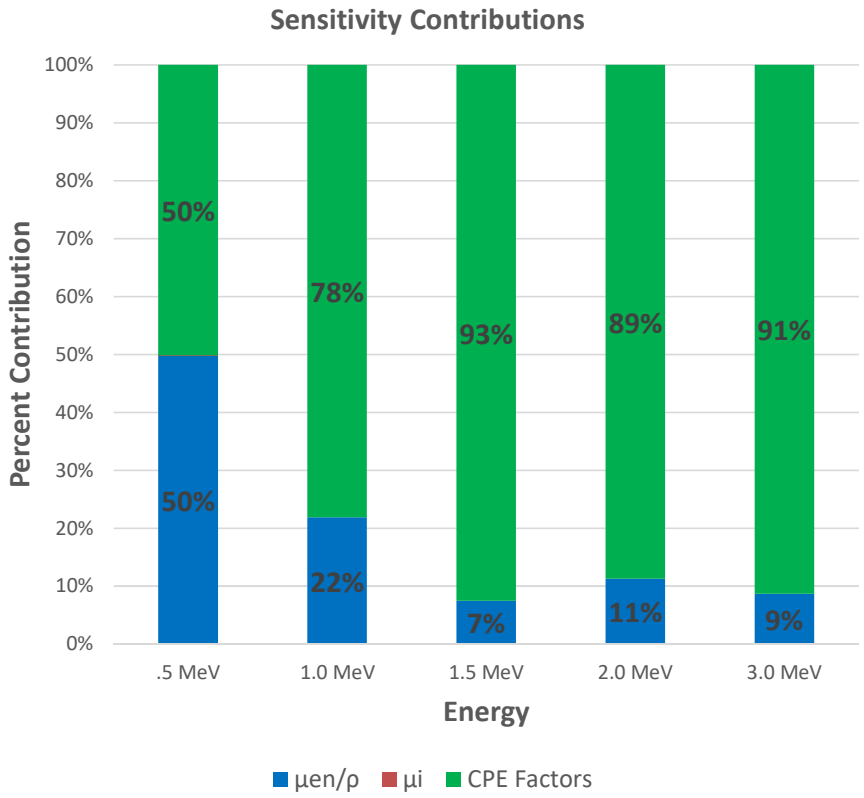


$$f_{cpe}(d_j) = \frac{1}{a + b\ln(d_j) + \frac{c}{\sqrt{d_j}}}$$

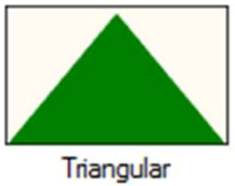
Bounding with associated Monte Carlo error

Normal distribution with Monte Carlo error

Photon Simulations – Less Likely

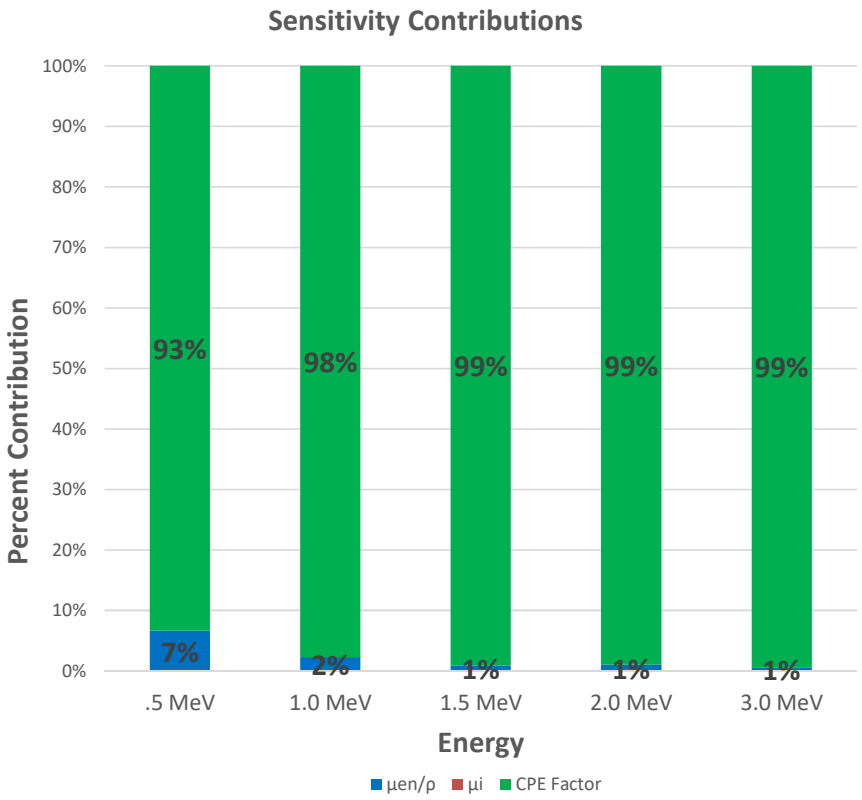


Off-axis factor excluded due to dependence on skin depth, a factor assumed to be constant



Upper and lower bounds of $\pm 5\%$ for each parameter

Photon Simulations – More Likely

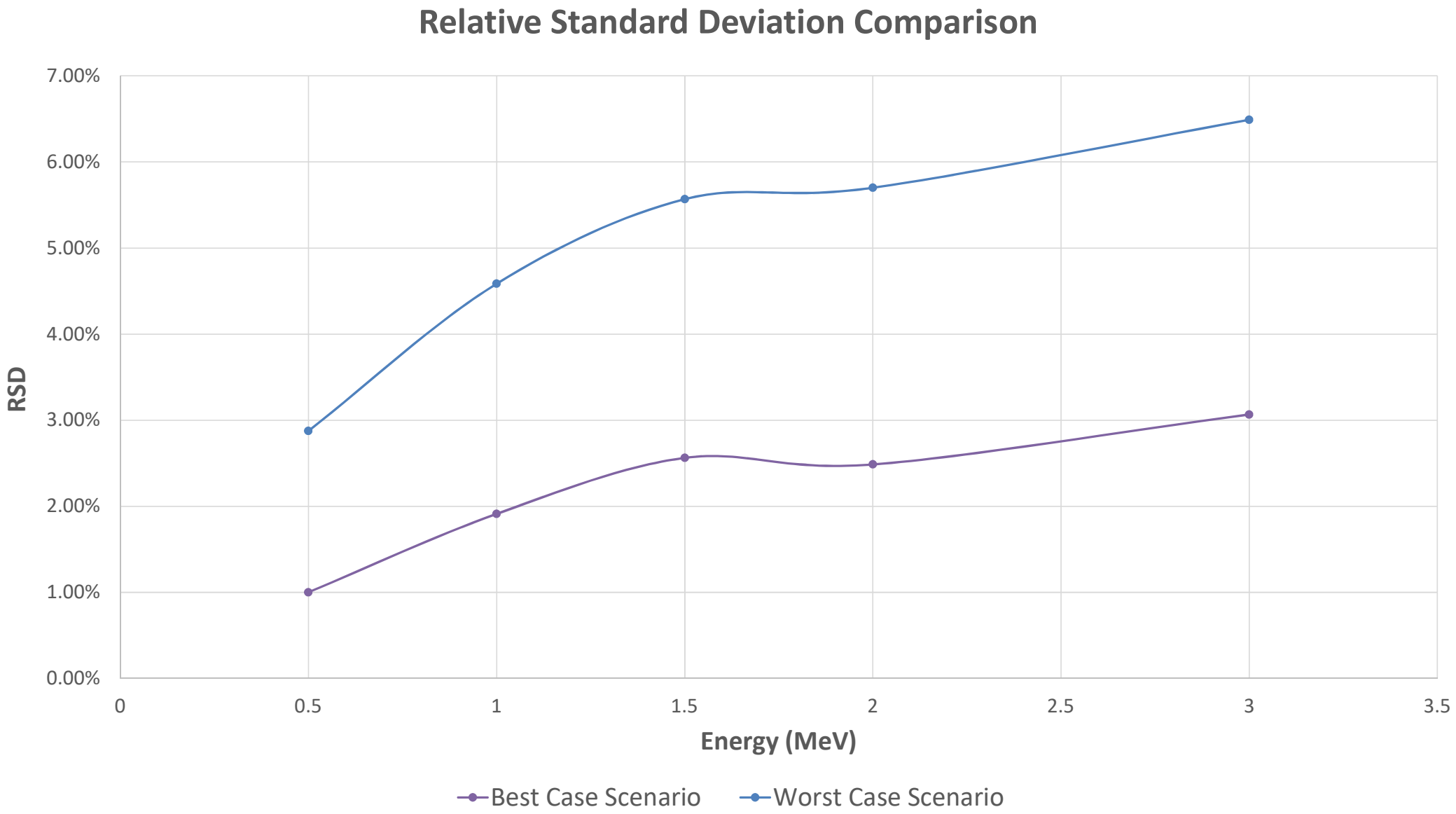


$\frac{\mu_{en}}{\rho}$ μ_i

Bound about ICRU 44 values

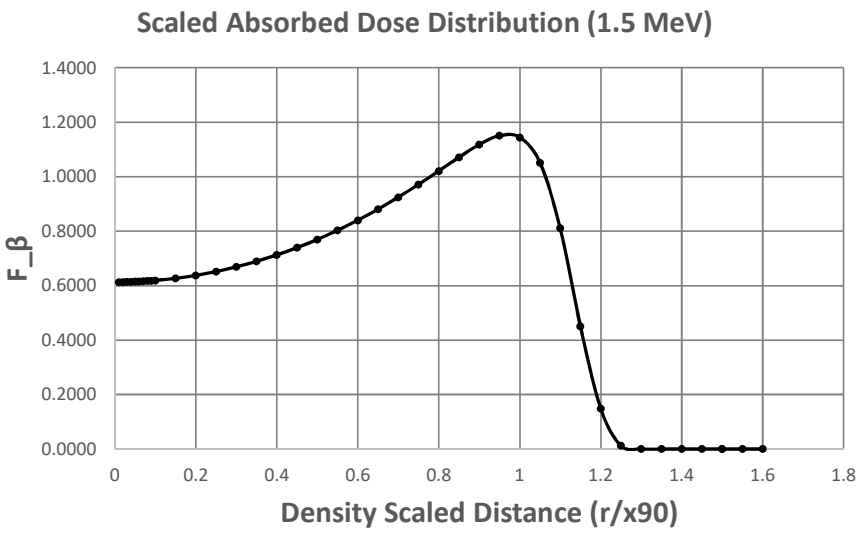
Standard deviation of 1% for each factor of CPE.

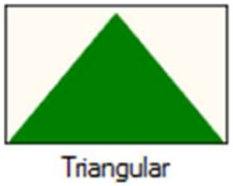
$$f_{cpe}(d_j) = \frac{1}{a + bln(d_j) + \frac{c}{\sqrt{d_j}}}$$


Relative Standard Deviation Comparison
7.00%
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
RSD
0
0.5
1
1.5
2
2.5
3
3.5
Energy (MeV)
Best Case Scenario
Worst Case Scenario

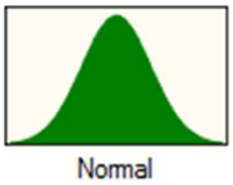
Electron Methodology

$$D = \sum_{j=1}^{N} \left[\frac{k * W_j * BSCF * A * y * E * F_{\beta_j}}{4\pi r^2 * \rho * x_{90}} \right]$$



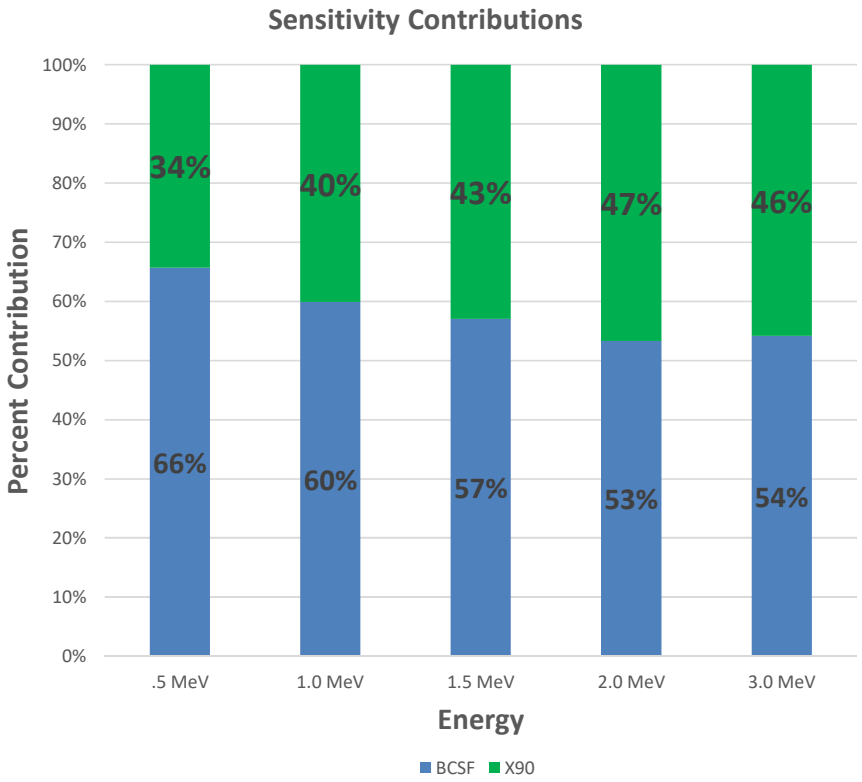


Between $\pm 5\%$



Assuming standard deviation of 1%

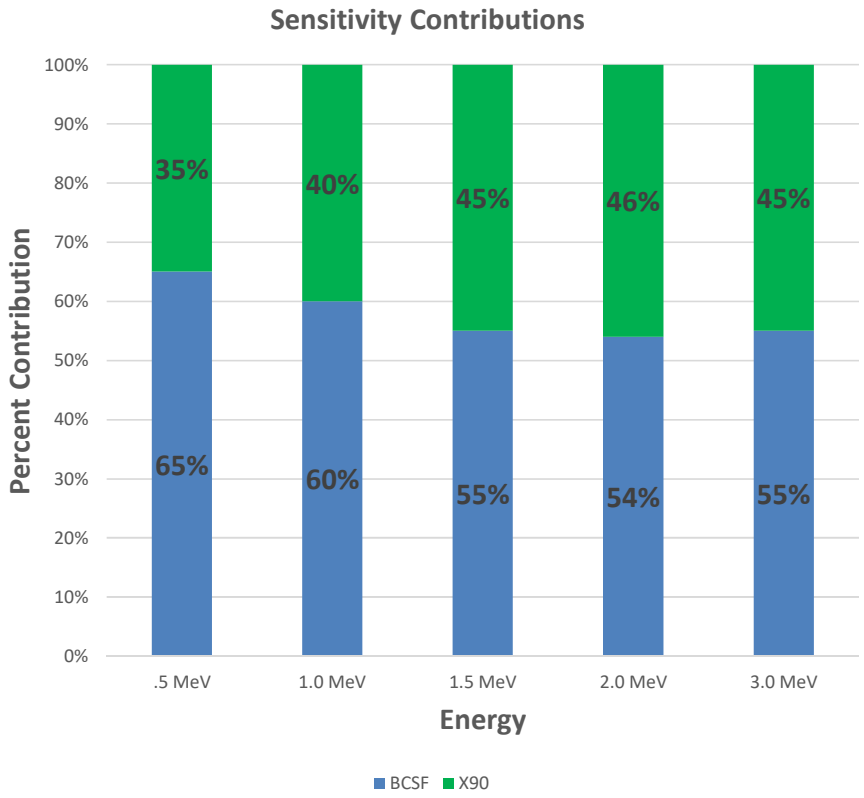
Electron Simulations – Less Likely



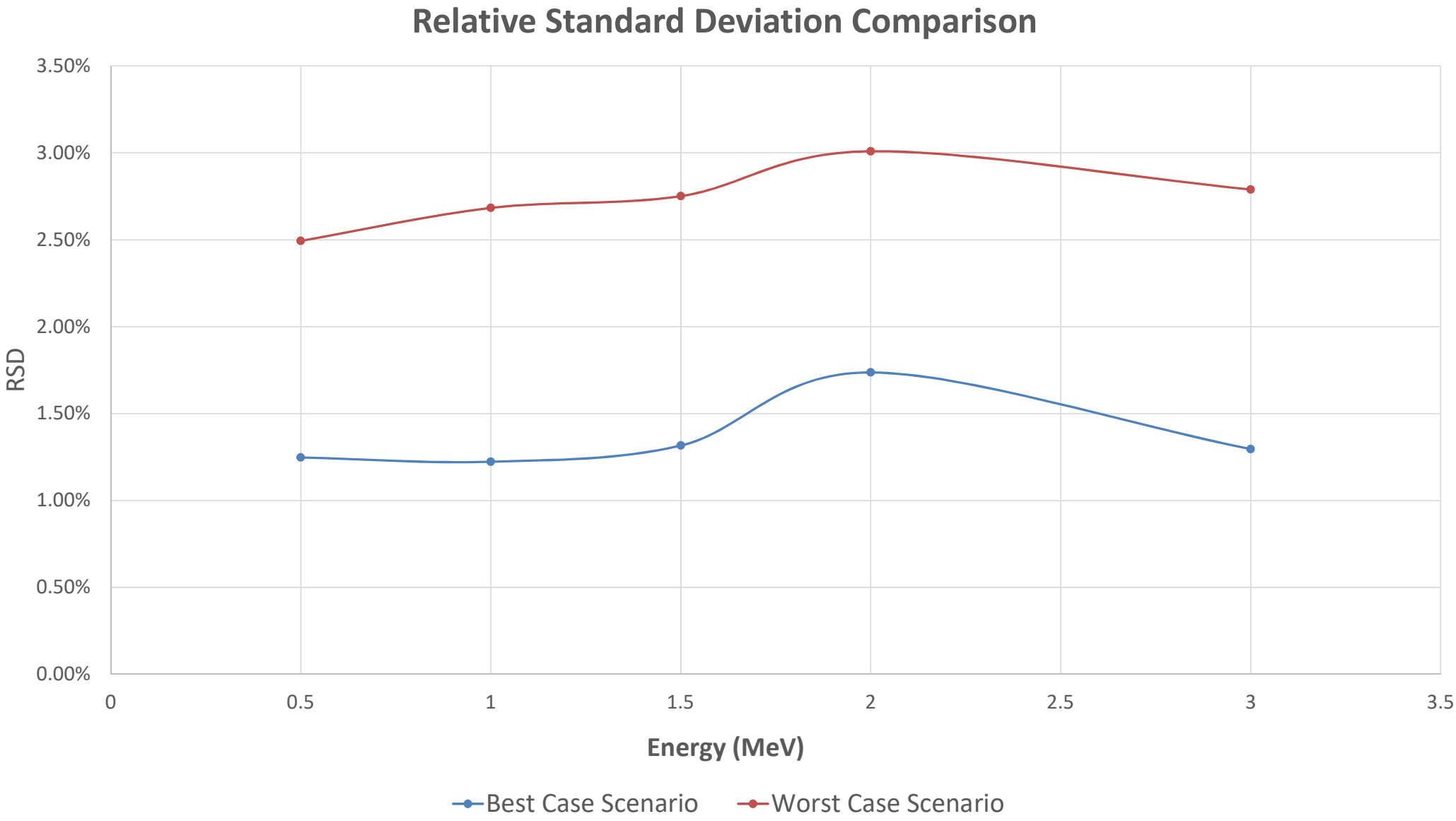
Uncertainty in X_{90} drives uncertainty in Scaled Absorbed Dose Distribution

Between $\pm 5\%$

Electron Simulations – More Likely



Small standard deviation of 1% assigned to both X_{90} and the backscatter factor.


Relative Standard Deviation Comparison
3.50%
3.00%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
RSD
0
0.5
1
1.5
2
2.5
3
3.5
Energy (MeV)
Best Case Scenario
Worst Case Scenario

Photon Model Comparison

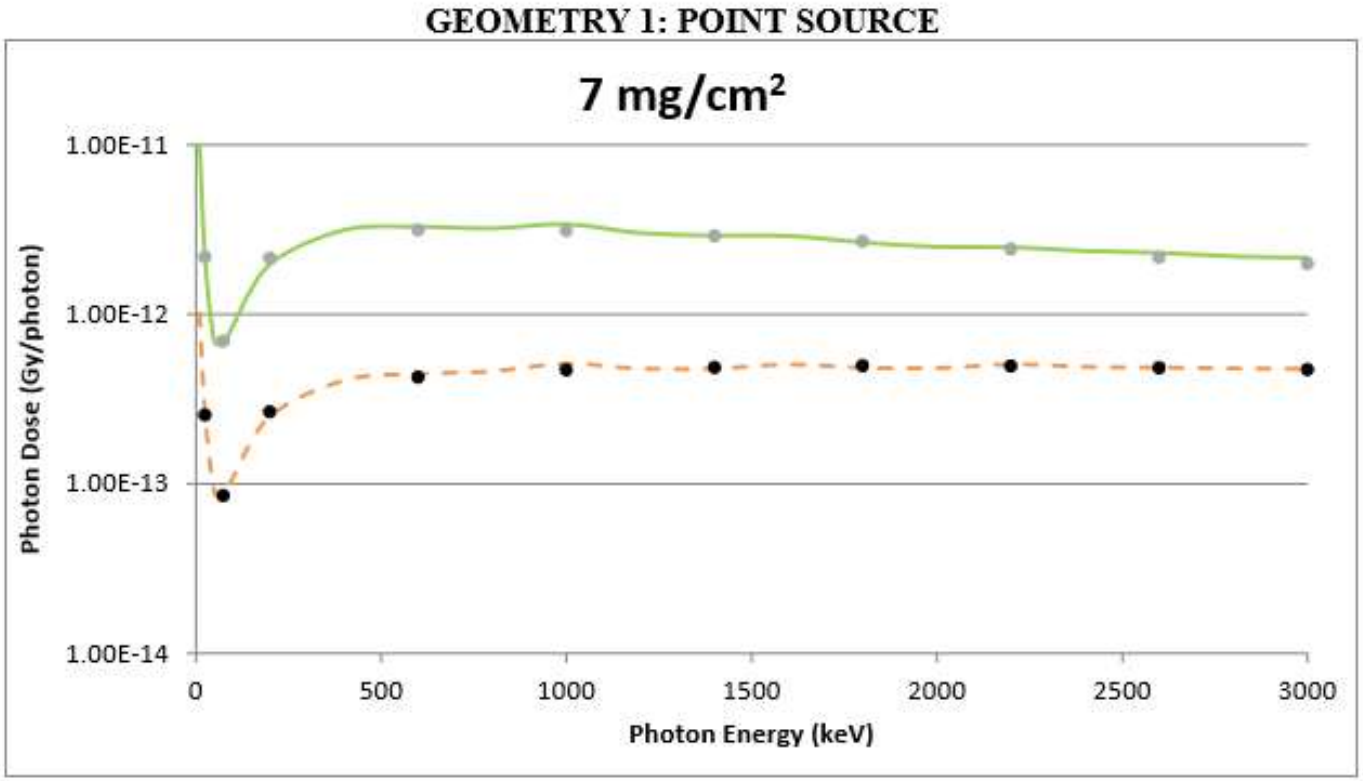
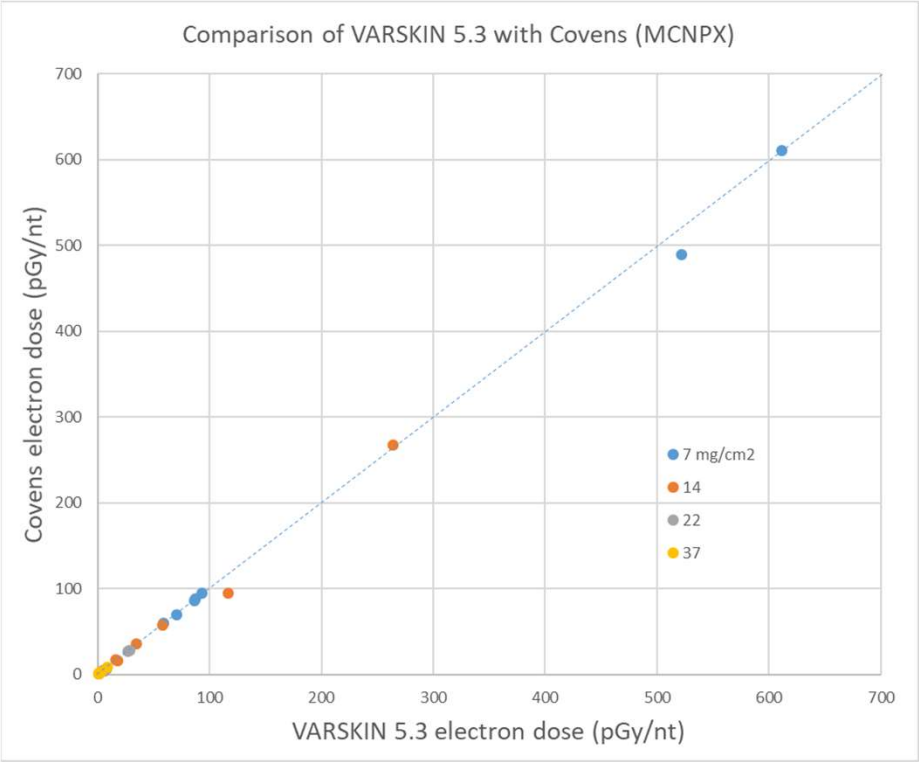
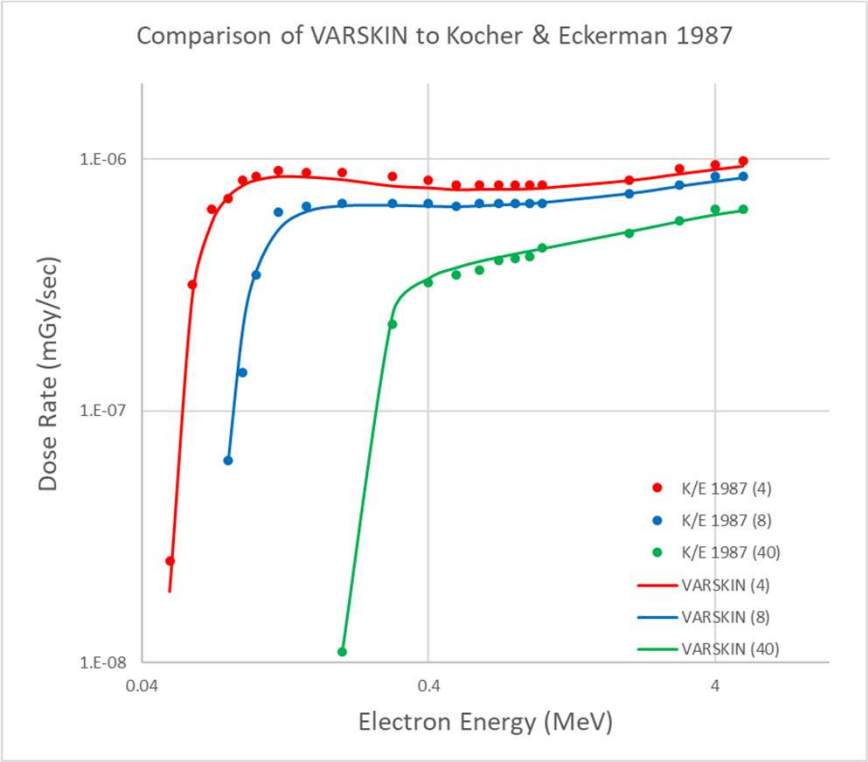


Figure B.1.1. A point source geometry comparison of VARSKIN 5 (circles) and MCNP5 (lines) predicted dose per initial photon as a function of photon energy in tissue at a density thickness of 7 mg/cm^2 and a tissue volume cylinder of area 1 cm^2 (solid line) and 10 cm^2 (dashed line), with a thickness of 20 μm

Electron Model Comparisons



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