Revisiting the Lockwood Albedo Measurements for Validation of the Integrated Tiger Series Electron-Photon Transport Code

Authors: Rowdy Davis(PhD Candidate in Nuclear Engineering), Dr. Christopher Perfetti (University of New Mexico), Dept of Nuclear Engineering, Dr. Aaron Olson (Sandia, 01341)

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Introduction and Motivation

Definitions:

- CAU: Combined Aleatoric Uncertainty
- St. Dev: Standard Deviations
- Rel. Err: Relative Error
- UQ: Uncertainty quantification
- XS: Cross sections

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Introduction and Motivation

ITS: Integrated Tiger Series

- A Monte Carlo Transport Code for Electrons and Photons
- Works well for 1D transport
- Contains Validation Suite
- 7 Problems in Suite

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Introduction and Motivation

ITS: Integrated Tiger Series
- A Monte Carlo Transport Code for Electrons and Photons
- Works well for 1D transport
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- 7 Problems in Suite

Goal:
- Ensure most accurate validation suite possible
- Provide relevant uncertainty quantification
- Provide a robust test suite

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Approach

Decision Making

- Picked Lockwood Electron Albedo to meet goal
- First step in overall process
- Simple to work with

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Lockwood Albedo
- Simple, 1D geometry

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Lockwood Albedo
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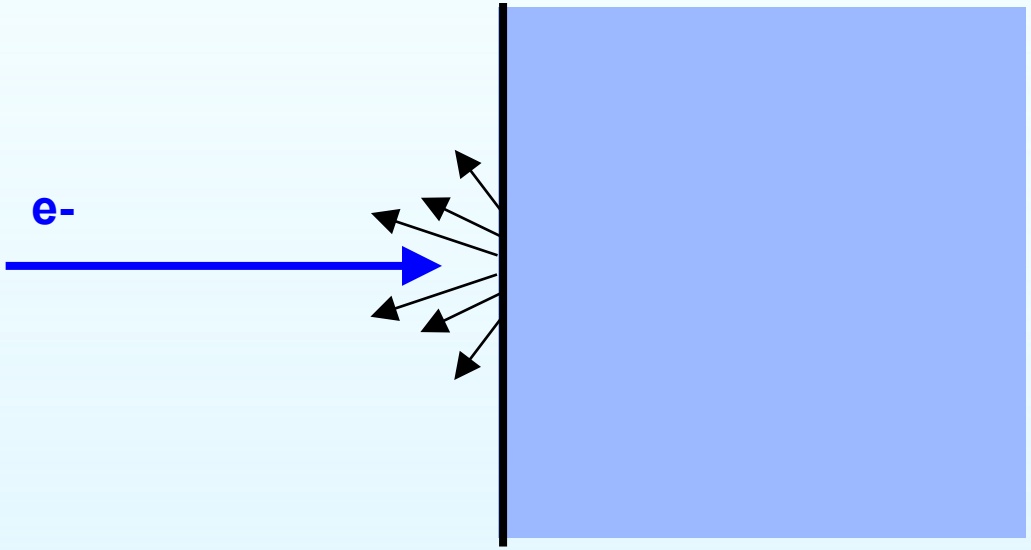
- Blue beam hits black line



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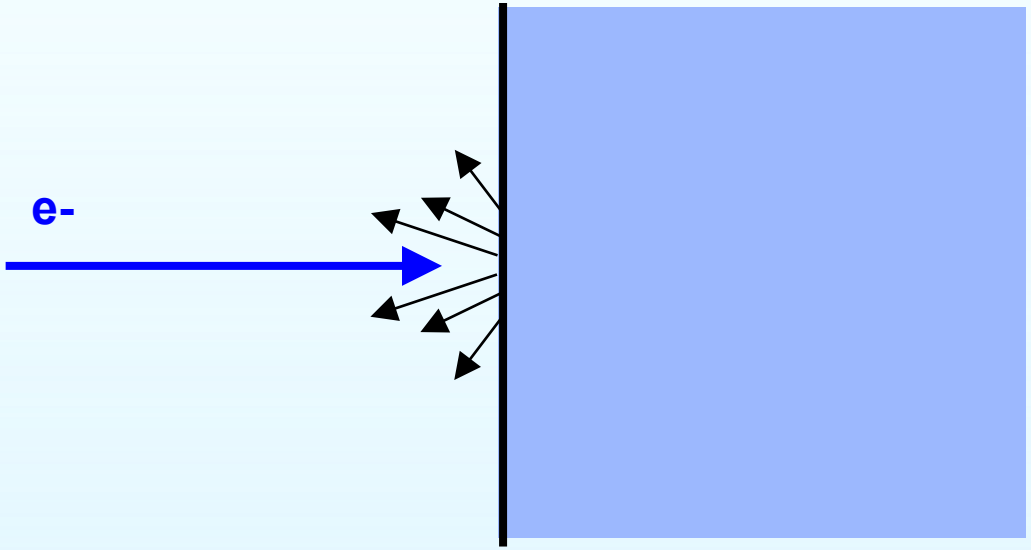

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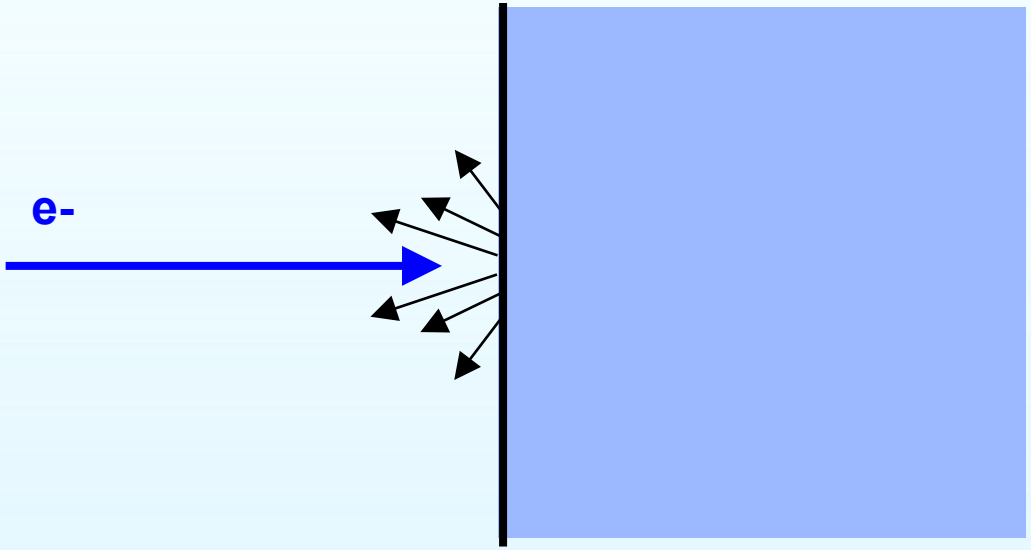

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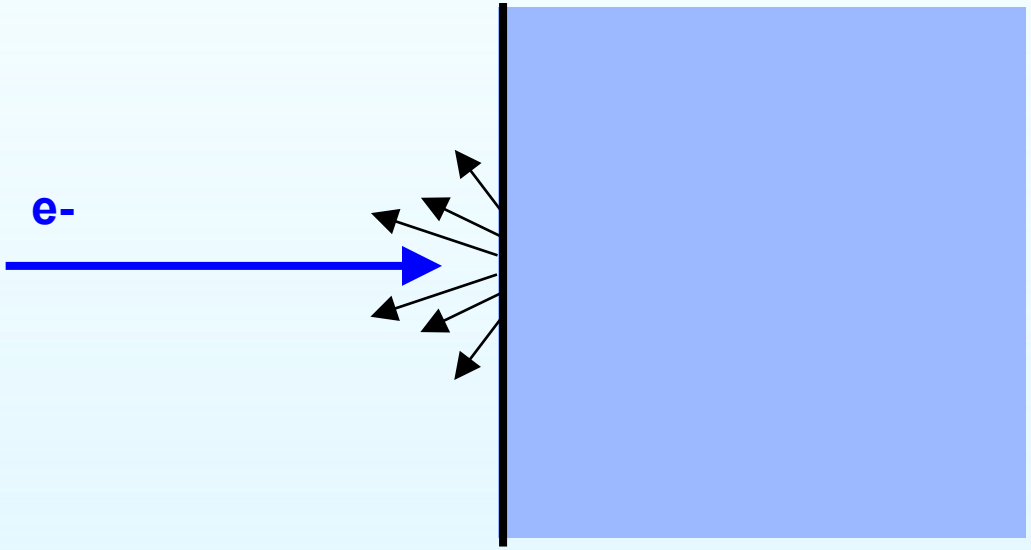

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Approach

Lockwood Albedo

- Over 2000 measurements taken
- Materials: Vary from Be to UO2
- Energy: Vary from ~10 KeV to ~1 MeV
- Angle: Vary from 0 to 83.5 Degrees
- Geometry: 1D

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2 Methods of Uncertainty Quantification

- Error relative to measurement
- Error relative to combined aleatory uncertainty

$$\varepsilon_{TOT} = \sqrt{\sum_{i=1}^{N} \varepsilon_{X_i}^2 \left(\frac{\partial Y}{\partial X_i}\right)^2}$$

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Approach

Cases Looked At

- Be Substep Size
- Thickness (Default v. Problem)
- Electron Trapping
- Cutoff Energy
- Convergence Ratios

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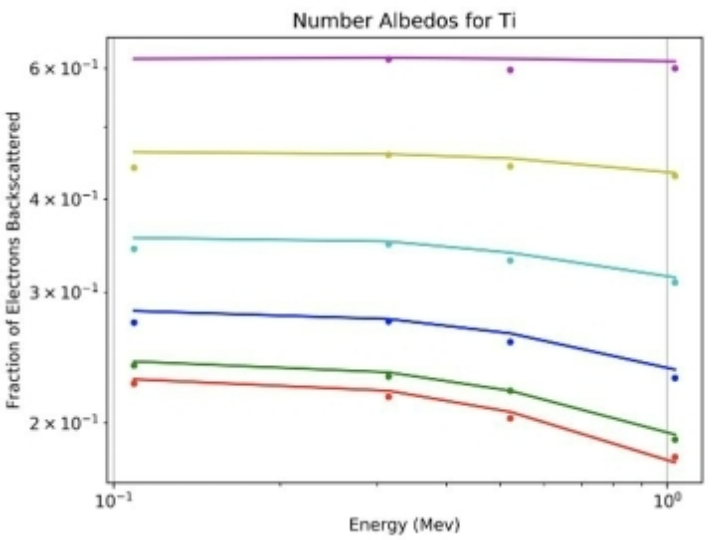
Current Status and Results (if any)

Created Albedo plots

- Energy v. Electrons backscattered
- Qualitative method of viewing accuracy
- One for each material/case runs



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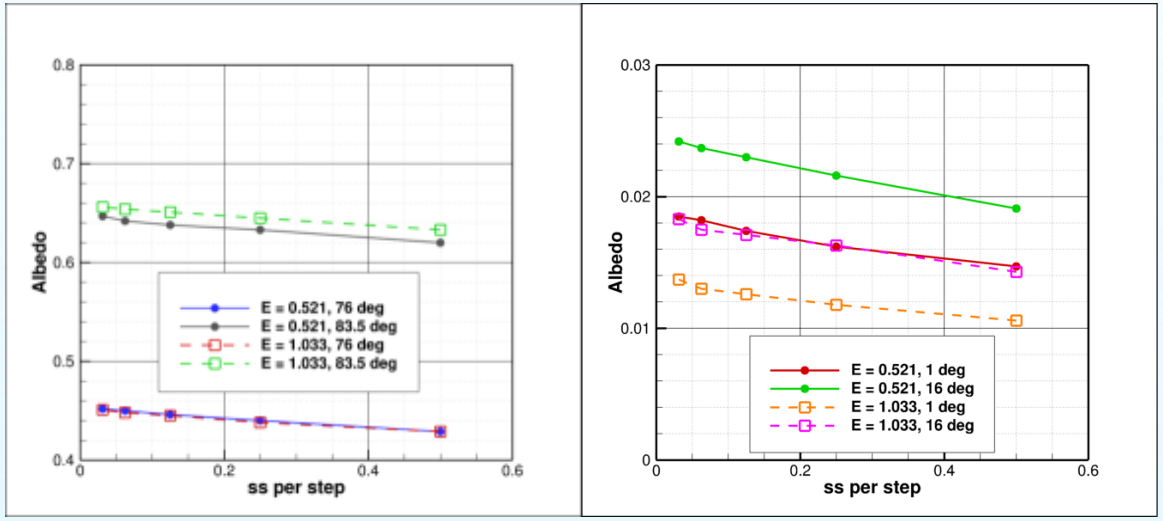
Current Status and Results (if any)

Be Substep Size Change

- "ss" = Substep
- 30% change in Albedo ~1 MeV
- 5% change at 83.5 degrees
- Z value increase = Albedo change decrease
- Substep going to 0 leads to convergence
- Using converged values removes bias in substep size



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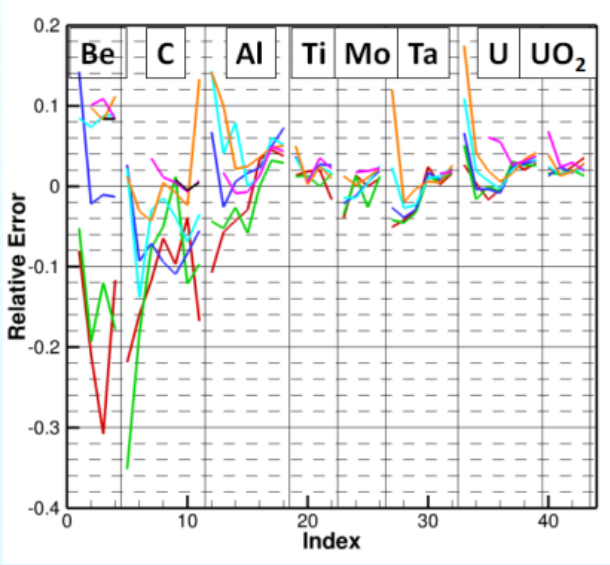
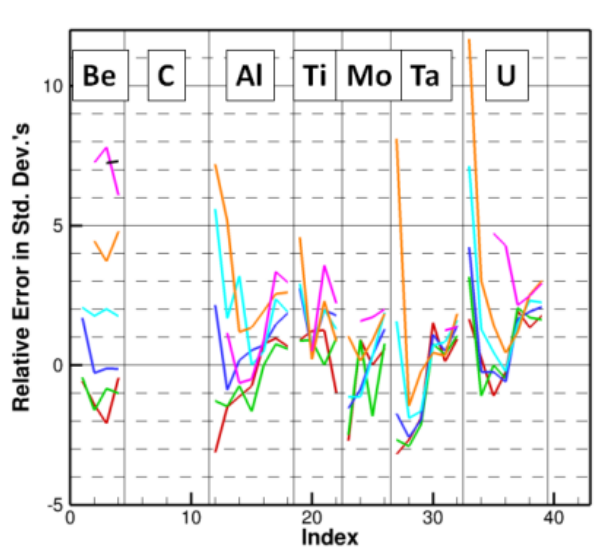
Current Status and Results (if any)

Relative Error

- Be/C have Large Vertical Spreads
- Associated measurement Error for Be = 26%
- Err. At 1.033 MeV, normal incidence
- No error information for UO2/C
- Al, Ta, U have same orange spike
- Suggests not statistical flukes



Err Rel. to measurement



Err. w.r.t combined St. Dev

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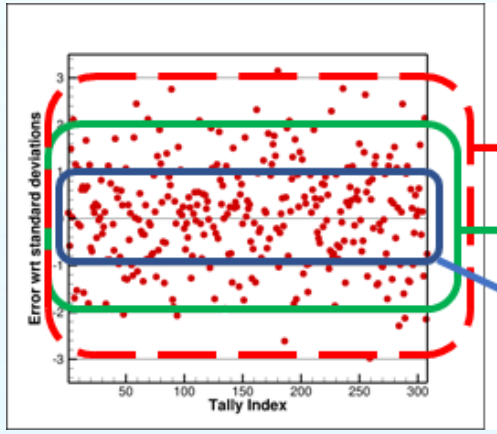
Current Status and Results (if any)

Ratios of St. Devs

- Blue = -1 to 1 St. Dev
- Green = -2 to 2 St. Dev
- Red = -3 to 3 St. Dev
- Converge to 1/sqrt(N=10)
- Theory matches with Actual
- Properly yields a normal distribution



800 K vs 8 M	THEORY	80 K vs 8 M
99.6	99.7	99.7
96.4	95.45	93.5
67.2	68.3	64.6

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Current Status and Results (if any)

No significant contribution to change in Error:

- Change in default thickness

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Current Status and Results (if any)

No significant contribution to change in Error:

- Change in default thickness
- Electron Trapping
  - Makes runs faster

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Current Status and Results (if any)

No significant contribution to change in Error:

- Change in default thickness
- Electron Trapping
  - Makes runs faster
- Default energy cutoff

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Overall Error Analysis:

- 90% of comparisons w/in 5% Rel. Err.

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No significant contribution to change in Error:

- Change in default thickness
- Electron Trapping
- Default energy cutoff

Overall Error Analysis:

- 90% of comparisons w/in 5% Rel. Err.
- 75% of measurements w/in 2 St. Devs CAU

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Current Status and Results (if any)

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- Change in default thickness
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Overall Error Analysis:

- 90% of comparisons w/in 5% Rel. Err.
- 75% of measurements w/in 2 St. Devs CAU
- Suggests some systematic bias in results

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Current Status and Results (if any)

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Overall Error Analysis:

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- 75% of measurements w/in 2 St. Devs CAU
- Suggests some systematic bias in results
- Bias either in simulation, measurement, UQ

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Impact of Work

- Quantified certain types of error

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Impact of Work

- Quantified certain types of error
- Identified potential bias in system

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Impact of Work

- Quantified certain types of error
- Identified potential bias in system
- Created a strong test foundation for future work

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Impact of Work

- Quantified certain types of error
- Identified potential bias in system
- Created a strong test foundation for future work
- Method exists for quantitative UQ

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Challenges and Risks / Next Steps and Future Work

- Investigate discrepancy at low energies

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Challenges and Risks / Next Steps and Future Work

- Investigate discrepancy at low energies
- Investigate more robust moment calculations

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Challenges and Risks / Next Steps and Future Work

- Investigate discrepancy at low energies
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- Convergence study on more than Be

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- Study error in direction setting

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- Expand tests and quantify those uncertainties

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- Explore XS sensitivity calculations

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