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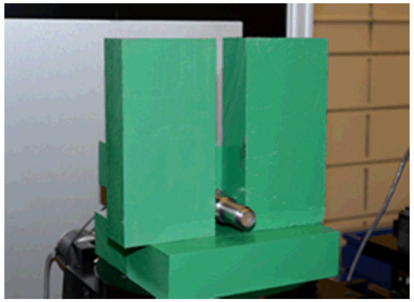

Material Identification with Multichannel Radiographs

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Sandia National Laboratories – Software Systems R&D

QNDE – Review of Progress in Quantitative Nondestructive Evaluation

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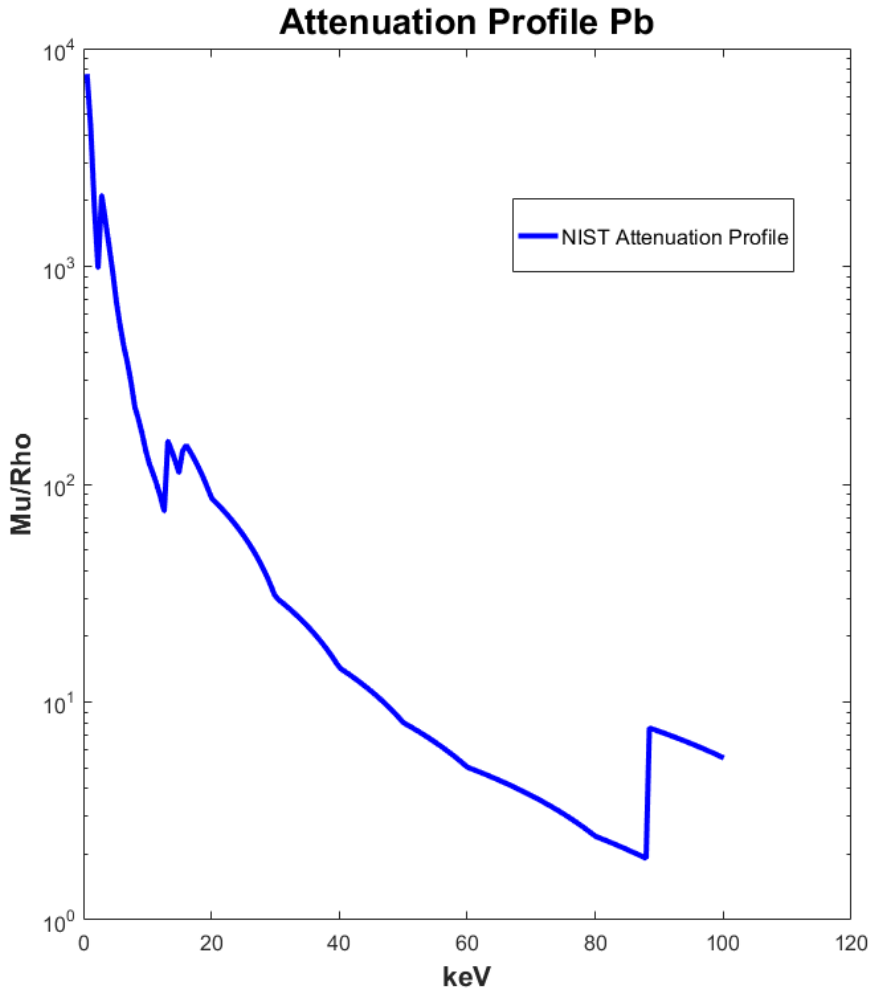
Introduction

- The identification of specific materials by extracting linear attenuation coefficients with a Bremsstrahlung x-ray source is a challenging problem.
- Previous work has evaluated the feasibility of extracting attenuation profile of various materials through simulation and optimization.
- This work determined multichannel radiographs delivered the best approximations, however noise was ignored.
- This work aims to validate the previous work by applying spectral images to the previous optimization methods.
- A few notable applications of this work include National Security, quality assurance, and medicine.



Goals and Approaches

- Goals
  - Identify a material of interest by extracting its mass attenuation profile and comparing it to the NIST attenuation profile.
  - Collect Images
    - Initial – spectral image without material between source and detector
    - Attenuated – spectral image with material between source and detector
  - Evaluate the effects of noise compared to simulation study
- Approach
  - Optimization - Nelder-Mead Method
    - A simplex method for finding the local minimum.
    - Legendre Polynomials used as the basis for this optimization
  - Direct Calculation
    - Calculate mass attenuation profile using Beer’s law.

Experimental Design

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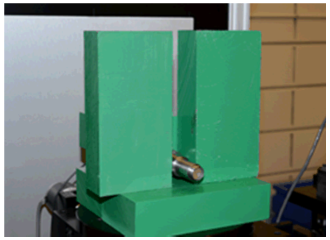
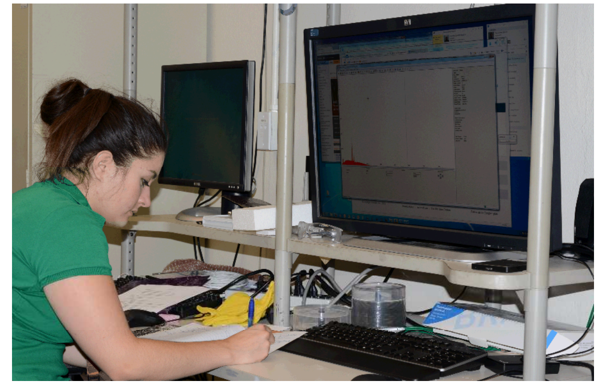
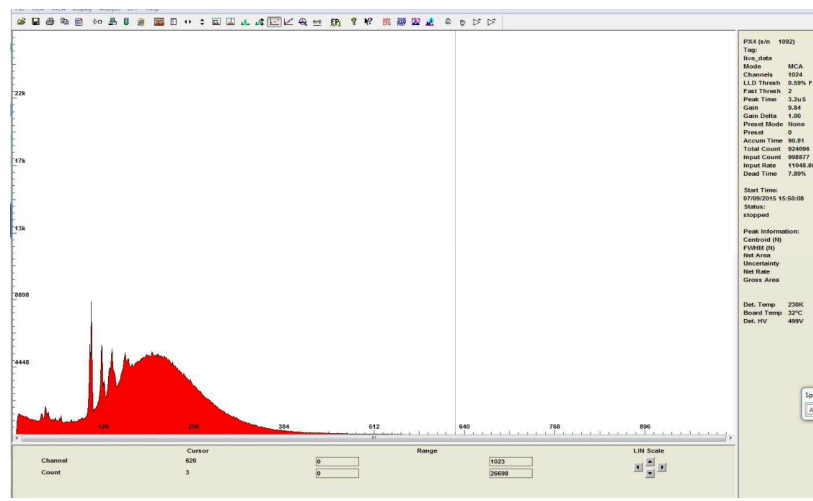
- Detector
  - Amptek XR-100CdTe X-ray and Gamma Ray Detector - CdeTe single pixel energy discriminating
  - Tungsten Collimator – 3 cm long with a 500μm aperture
- Source
  - Comet 450 keV
  - Tungsten Target
- Geometry
  - Detector to source distance 189 cm
  - Object to Detector distance 174 cm
- Materials
  - Flat sheets (thickness in cm) **– lead (0.0762), tin (0.0762), copper (0.203)**, titanium (0.378), zinc(0.145), and plastic (0.686).



Experimental Procedure

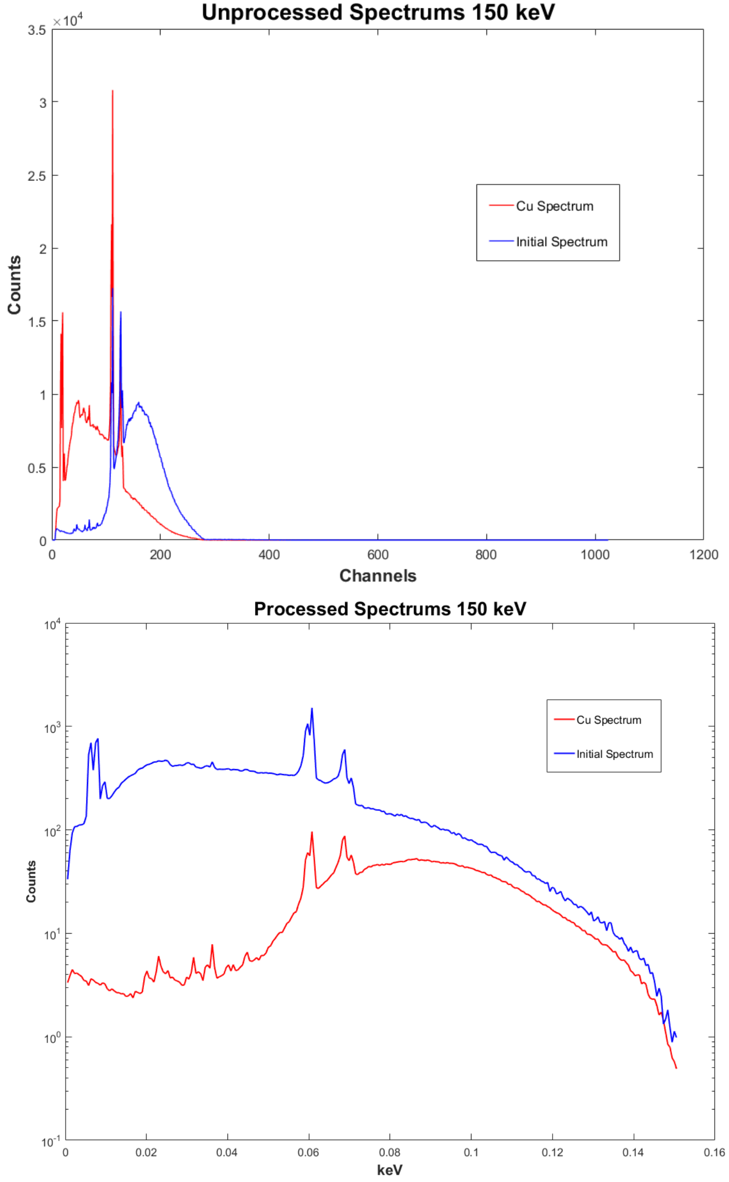
- Detector Alignment
  - Laser and 2D stage
  - Adjust detector until maximum flux of photons to detector achieved
- Data Collection
  - ADMCA Software - the main display and acquisition software
  - 90 second exposure
  - Saved with current, thickness and material information.





Data Post Processing

- Calibration
- Dead Time
- Pulse Pile Up
- Current

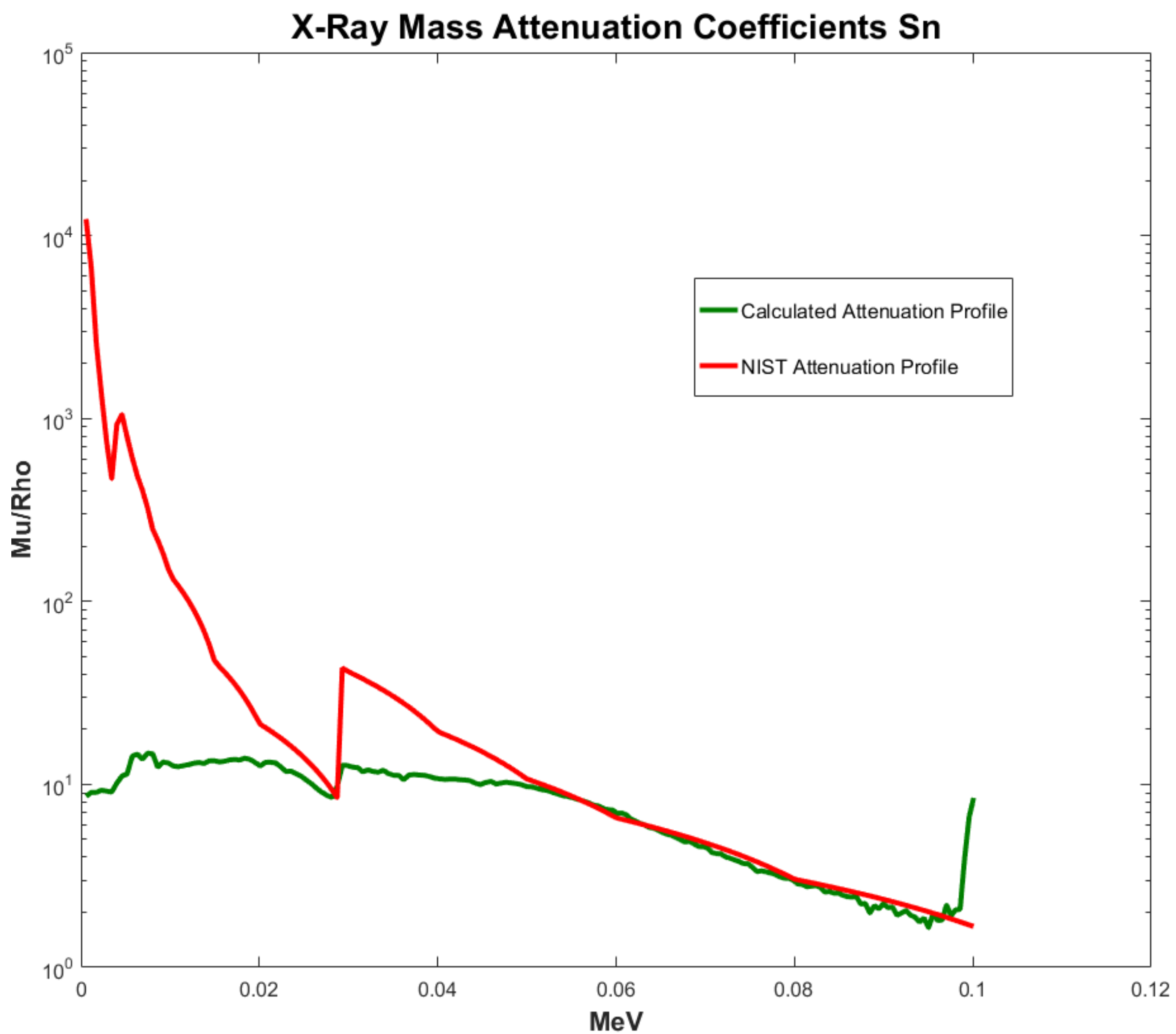


Direct Calculation

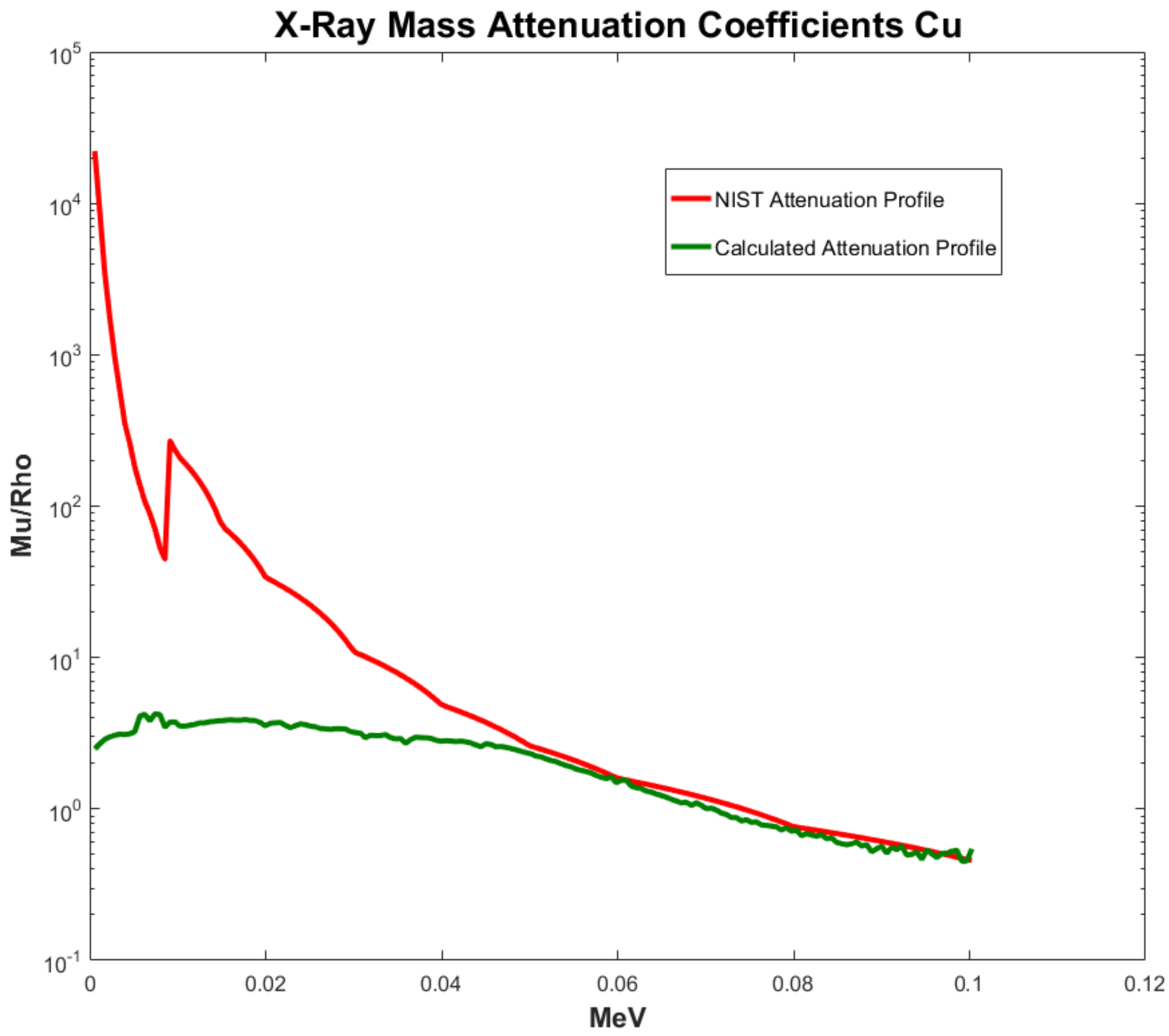
- Known information
  - Experimental Geometry
  - Material density and thickness
- Beer's Law
  - μ - linear attenuation coefficient
  - l - thickness
  - ρ - density
  - I_{in} - initial spectrum
  - I_{out} - attenuated spectrum

$$\frac{\mu}{\rho} = -\frac{1}{l} \cdot \frac{1}{\rho} \cdot ln(\frac{I_{in}}{I_{out}})$$

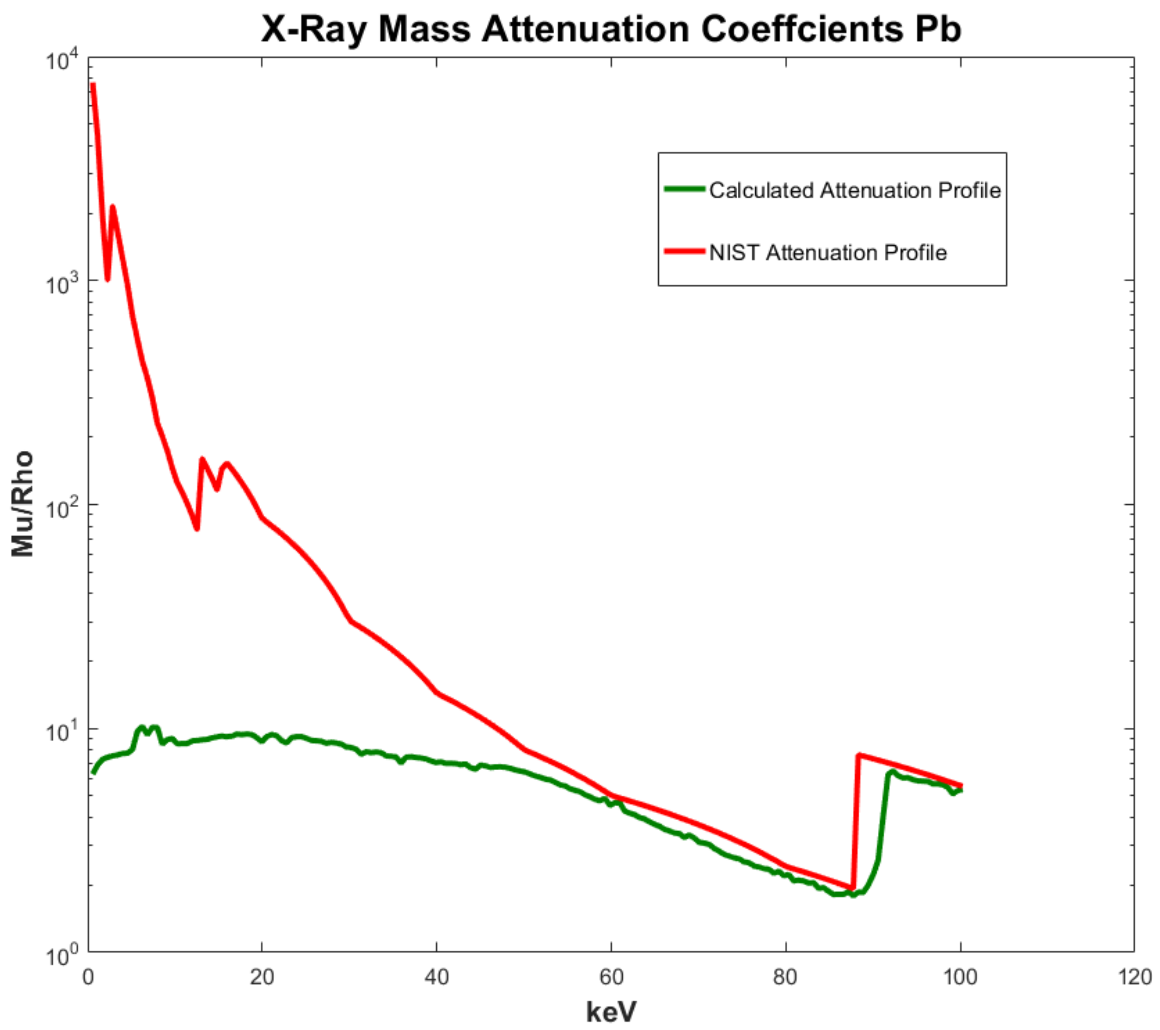
Direct Calculation Sn



Direct Calculation Cu



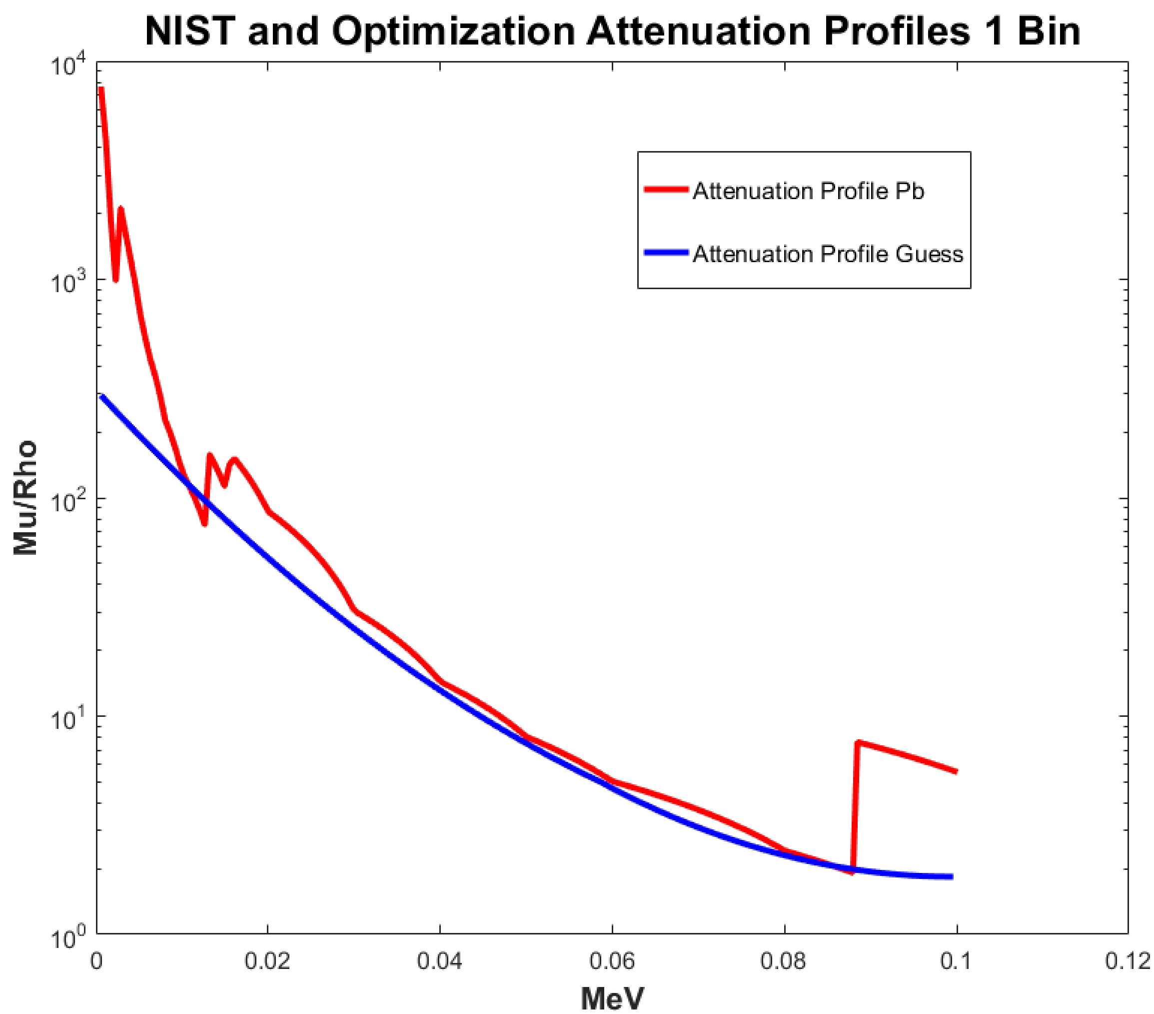
Direct Calculation Pb



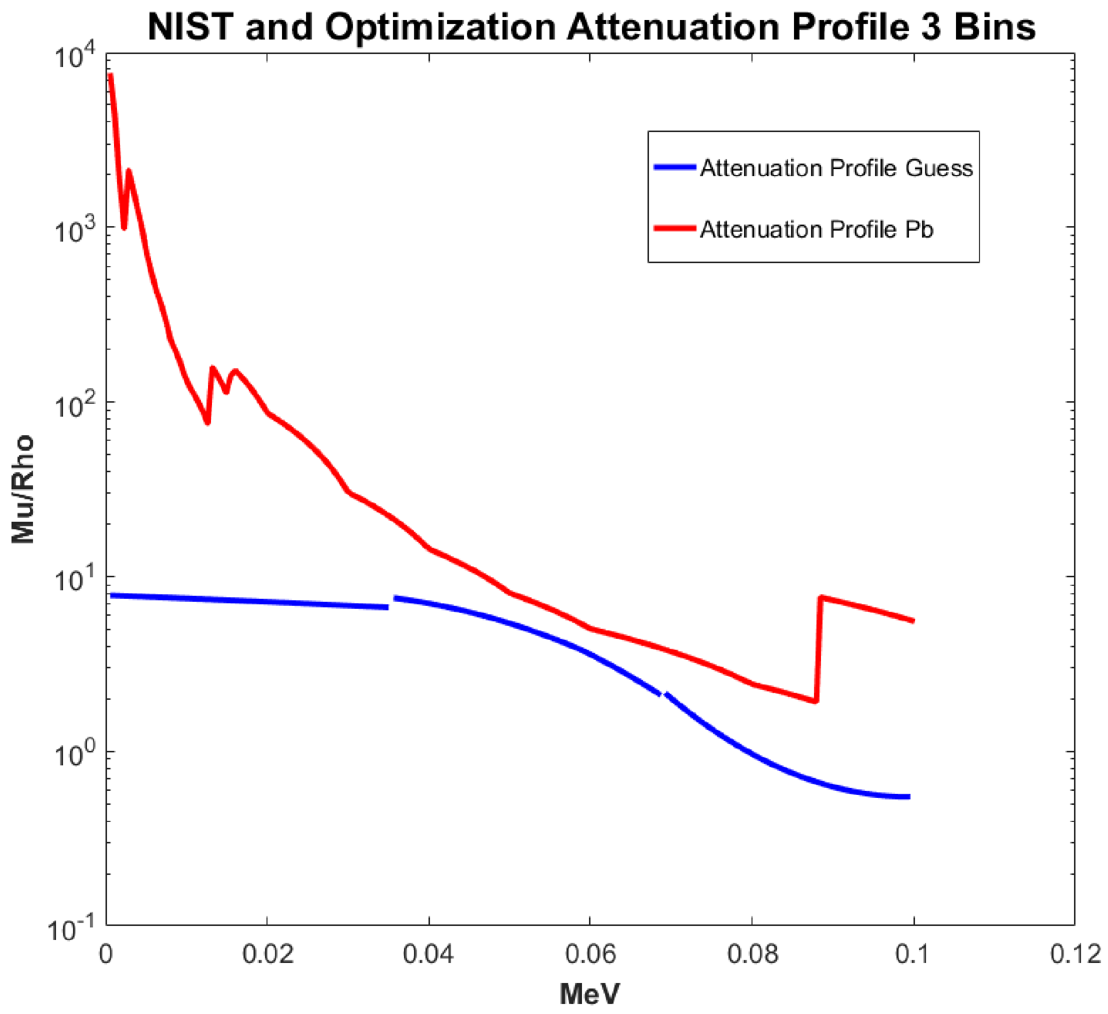
Optimization and Simulation

- Imaging system modeled in MATLAB
- Initial Guess
  - Sum of weighted Legendre Polynomials used to achieve attenuation profile coefficients
- Beer's Law
  - Creates a synthetic image - S_{out}
  - $S_{out} = I_{in} \cdot e^{\mu \cdot l}$
- Synthetic Image vs Real image
- Nelder-Mead Direct search method
  - Chooses different weightings of the Legendre Polynomial until finds the minimum of $\|S_{out} - I_{out}\|$
- Iterative
  - Performed over multiple intervals
    - Single interval best approximation

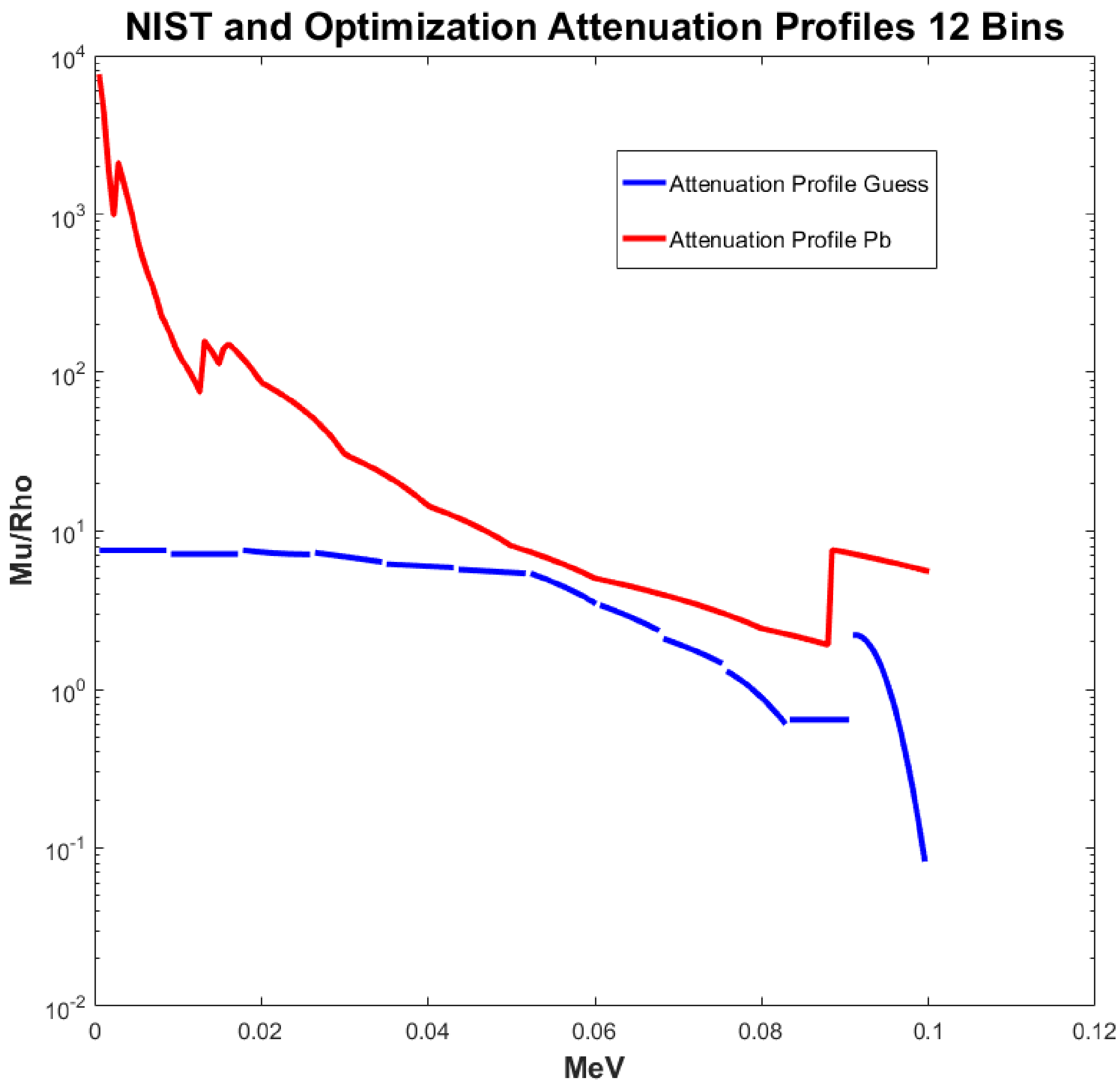
Optimization Pb 1 Bin



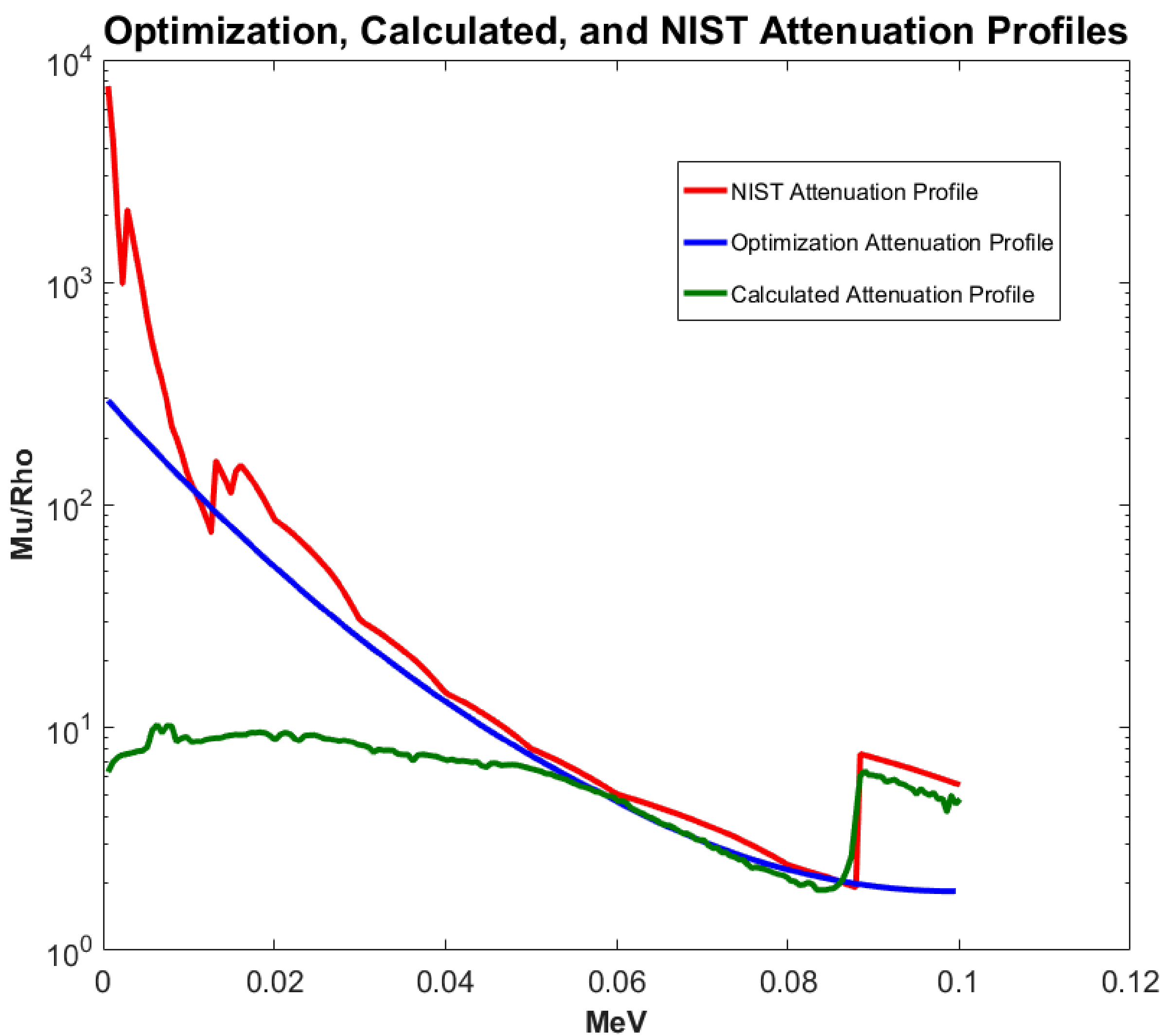
Optimization Pb 3 Bins



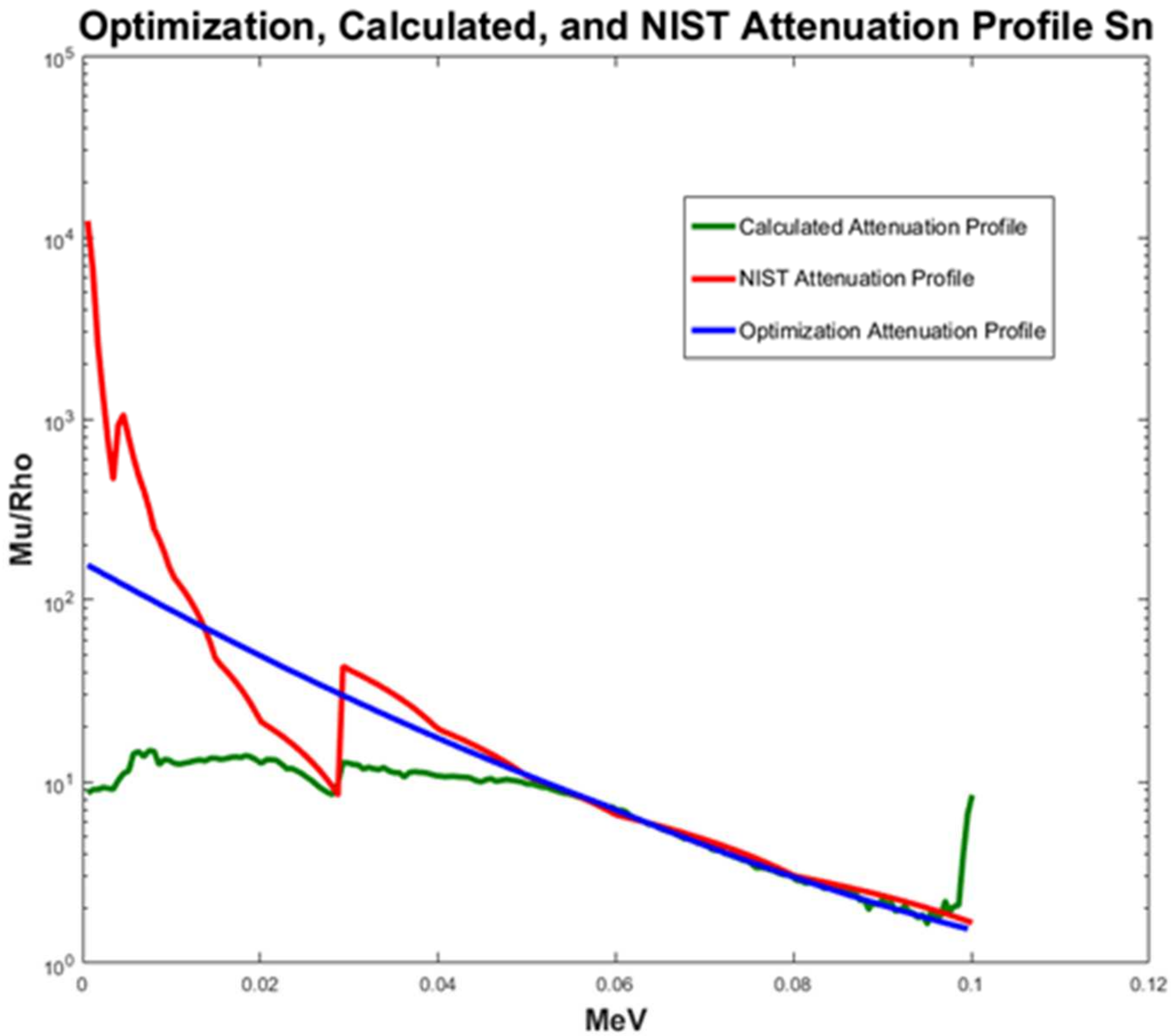
Optimization Pb 12 Bins



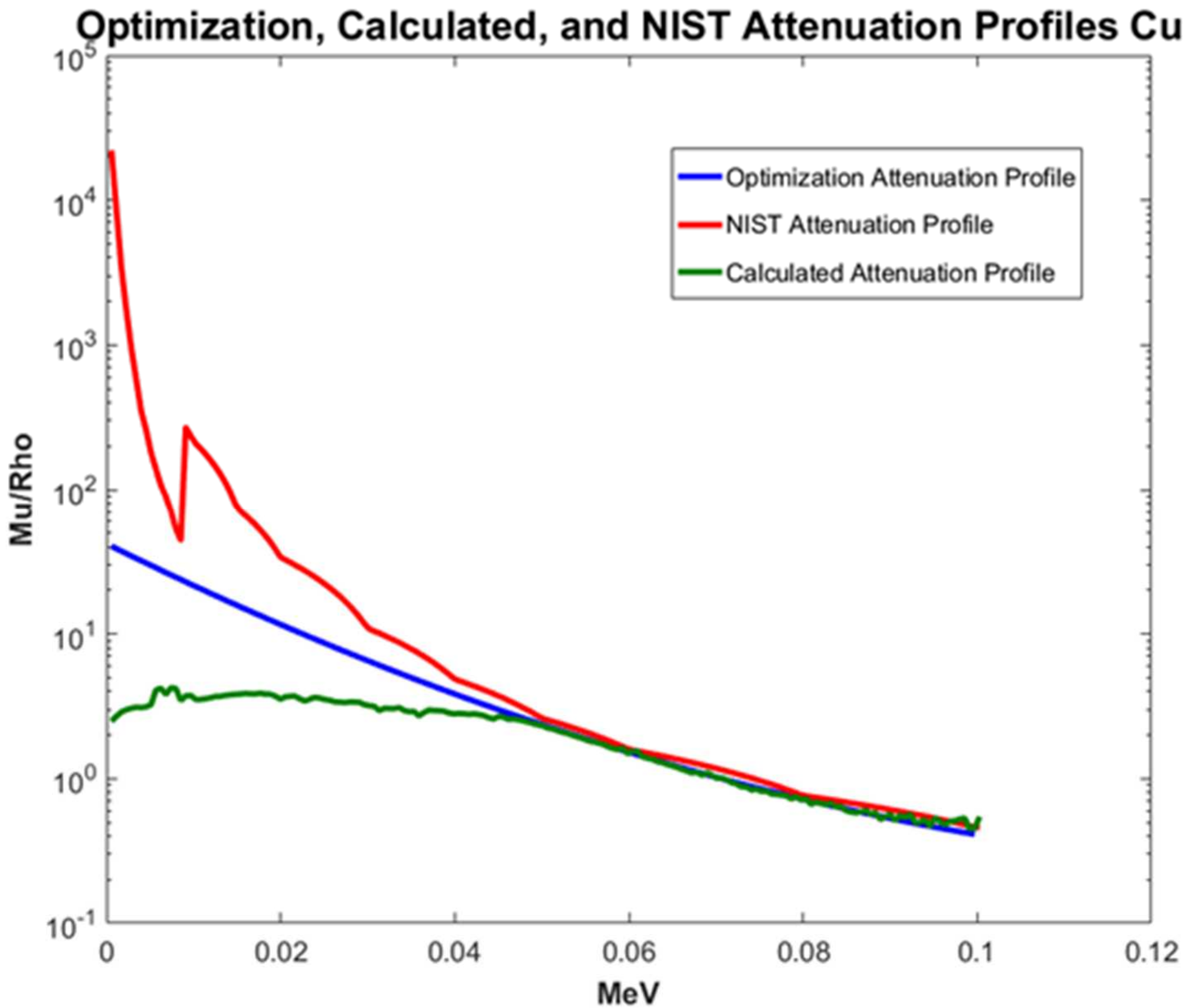
Optimization vs Calculated Pb



Optimization vs Calculated Sn

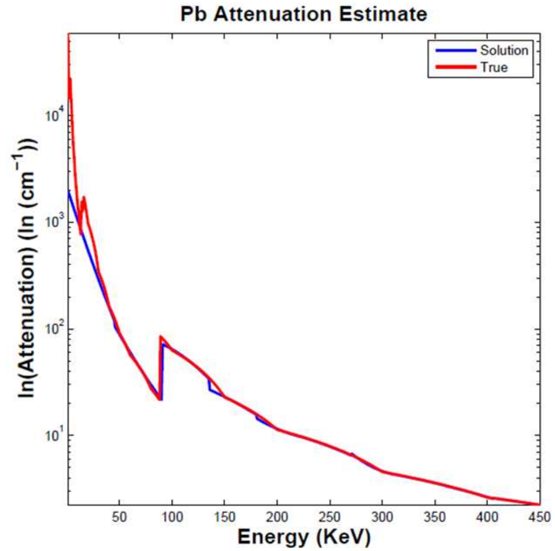


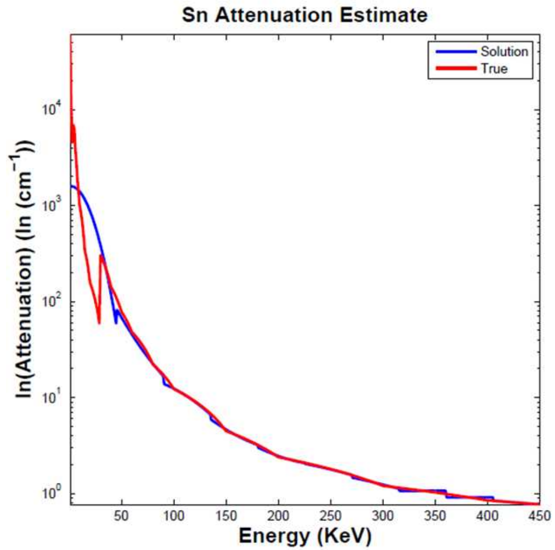
Optimization vs Calculated Cu



Previous Work and Limitations

- Previous Work
  - Noise unaccounted
  - Geometry
  - Interval
- Limitations of Amptek
  - Alignment Issues
  - Energy Threshold
    - Simulated work up to 450keV
    - Amptek 122keV
- Limitations of Optimization
  - Legendre Polynomials





Results and Discussion

- Results
  - Martials with higher Z value resolved K edges best through direct calculation
  - Nelder-Mead provided a better estimate at the beginning of the attenuation profile
  - Showed promise of being able to extract an attenuation profile with multichannel x-rays.
- Discussion
  - Use direct calculation as initial guess
  - Use alternative for Legendre Polynomials

Future Work

- Multix ME100
  - Spectroscopic linear detector - 640 pixels
  - Lower resolution with respect to number of channels - 128 channels
  - Higher energy threshold - 300 keV