Spectral Unfolding Process Using Processed Pinhole Images

0900 – August 12, 2009

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Objective

- To better characterize and quantify the Saturn spectrum via scintillator images and simulated impulse responses for tungsten and copper filters.

Experimental Setup

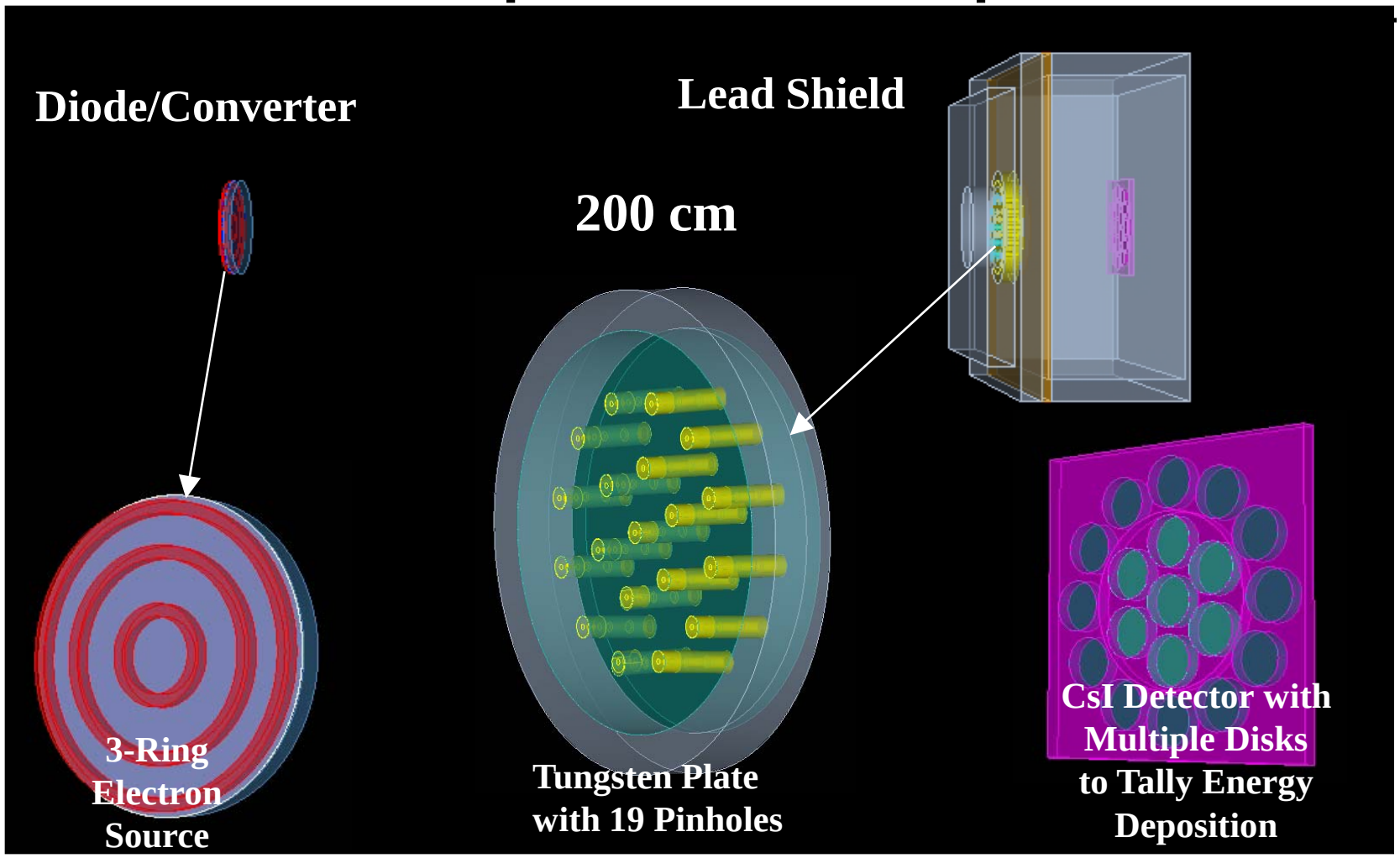

*Image Courtesy of Wesley Fan

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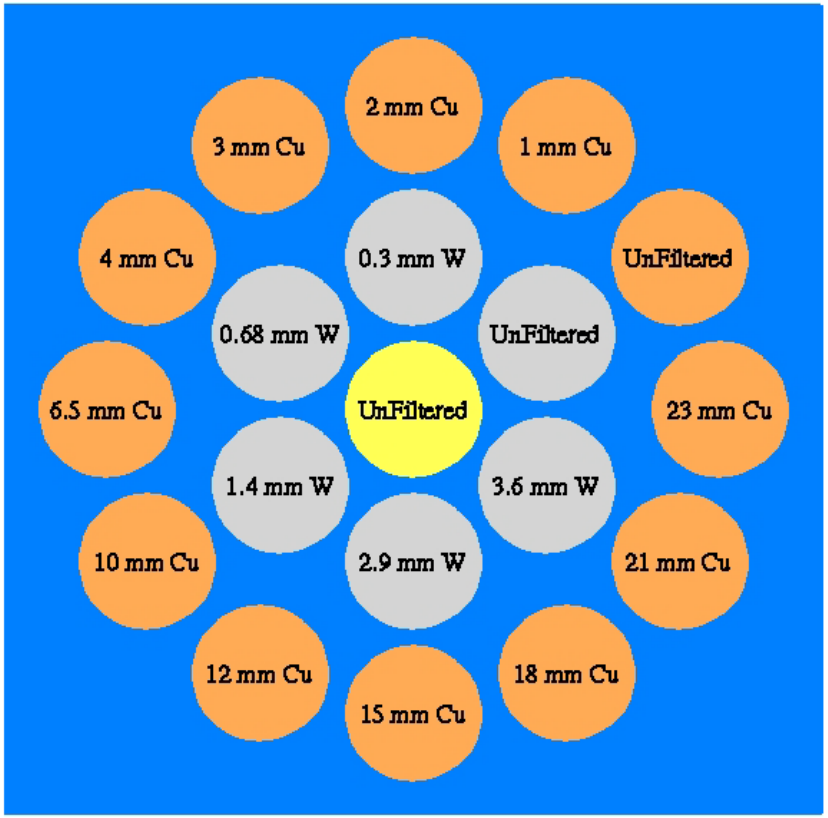
Experimental Setup



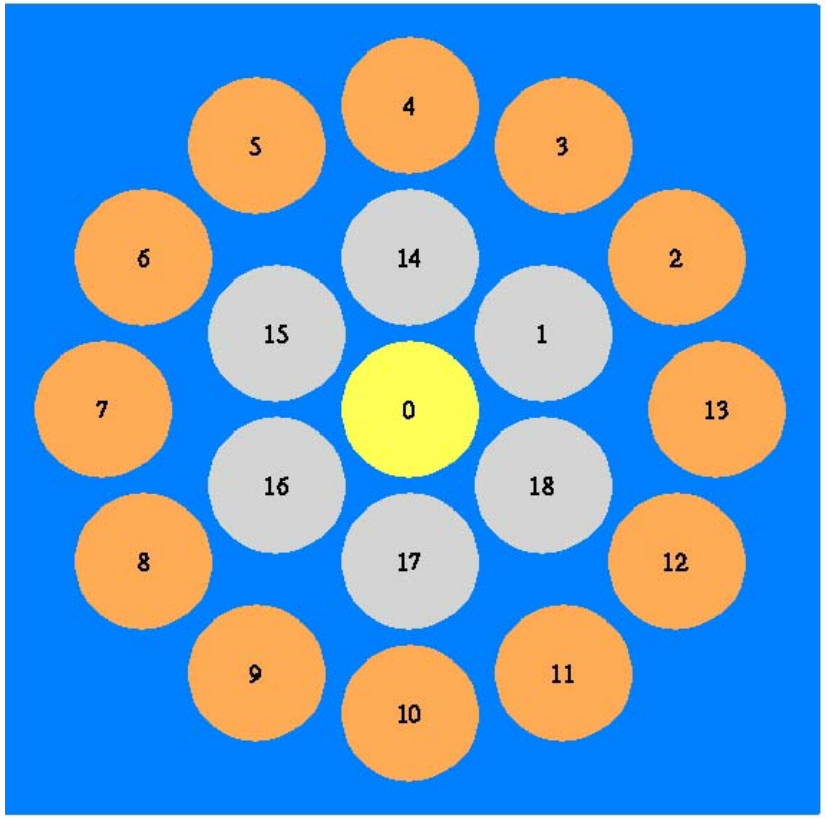


*Image Courtesy of Wesley Fan

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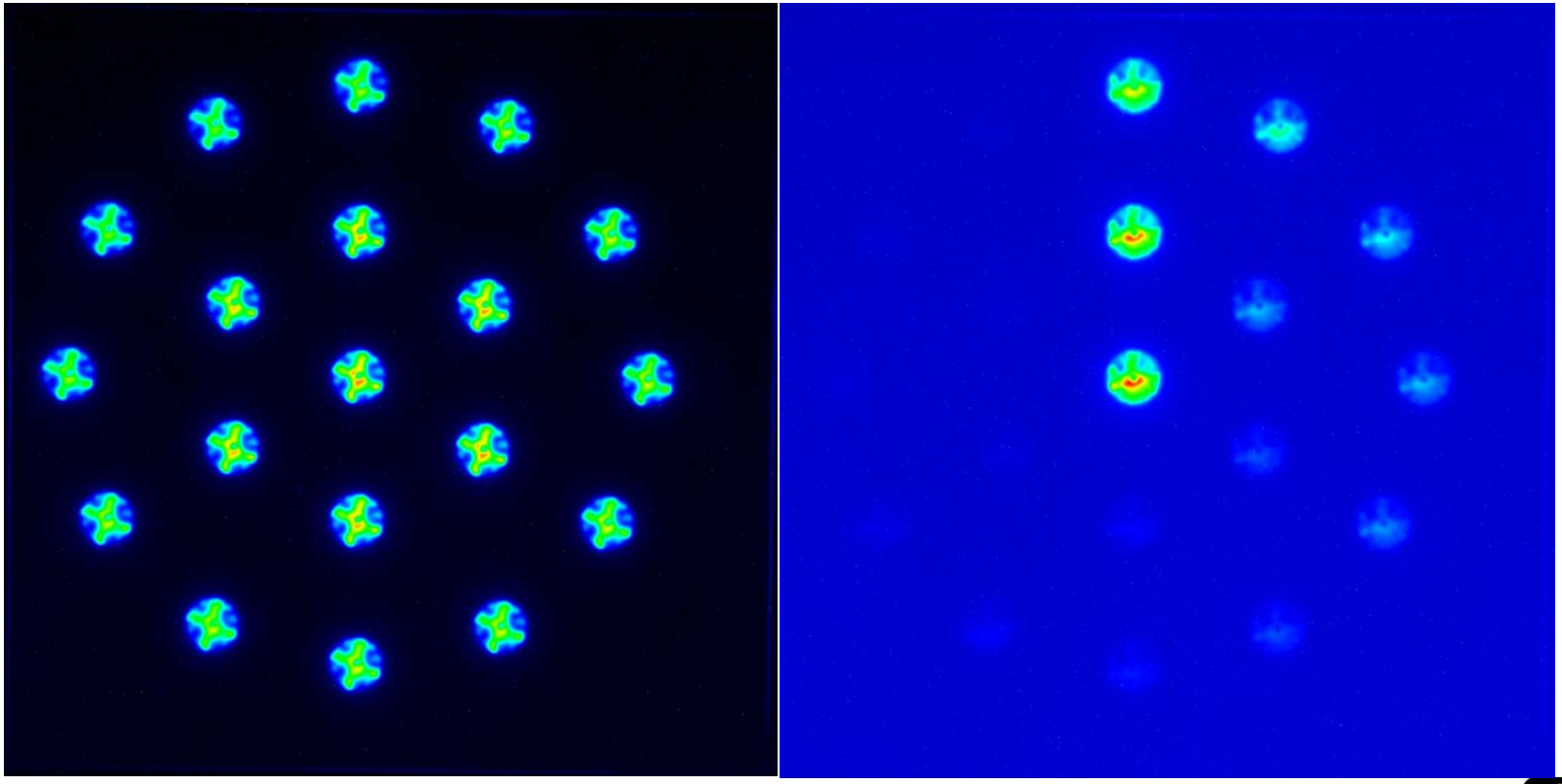
Images

- **Digital scintillator images in gray scale, and RGB.**



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Methodology

- Process Saturn pinhole images to allow image-simulation comparisons
- Build and run simulations of pinhole experiment
- Construct response matrix
- Design stable perturbation algorithm
- Estimate “better” Saturn spectra.

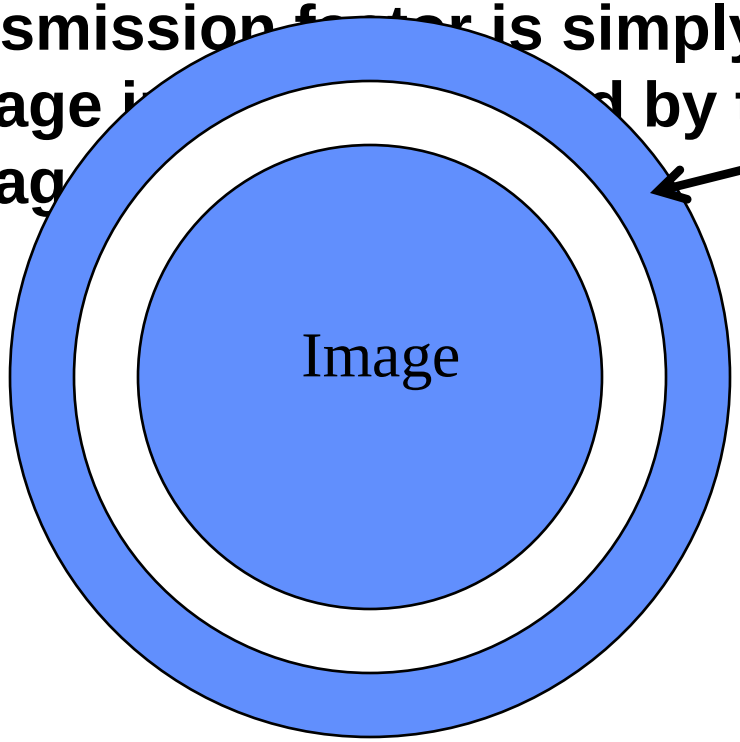
Image Processing

- Methodology for processing of digital scintillator images was established by Robert Hohlfelder using LabView.
- Three main steps:
  - Image Alignment
  - Transmission Factor
  - Background Noise

$$Intensity = \frac{(Intensity - Background\ Noise)}{Transmission\ Factor}$$

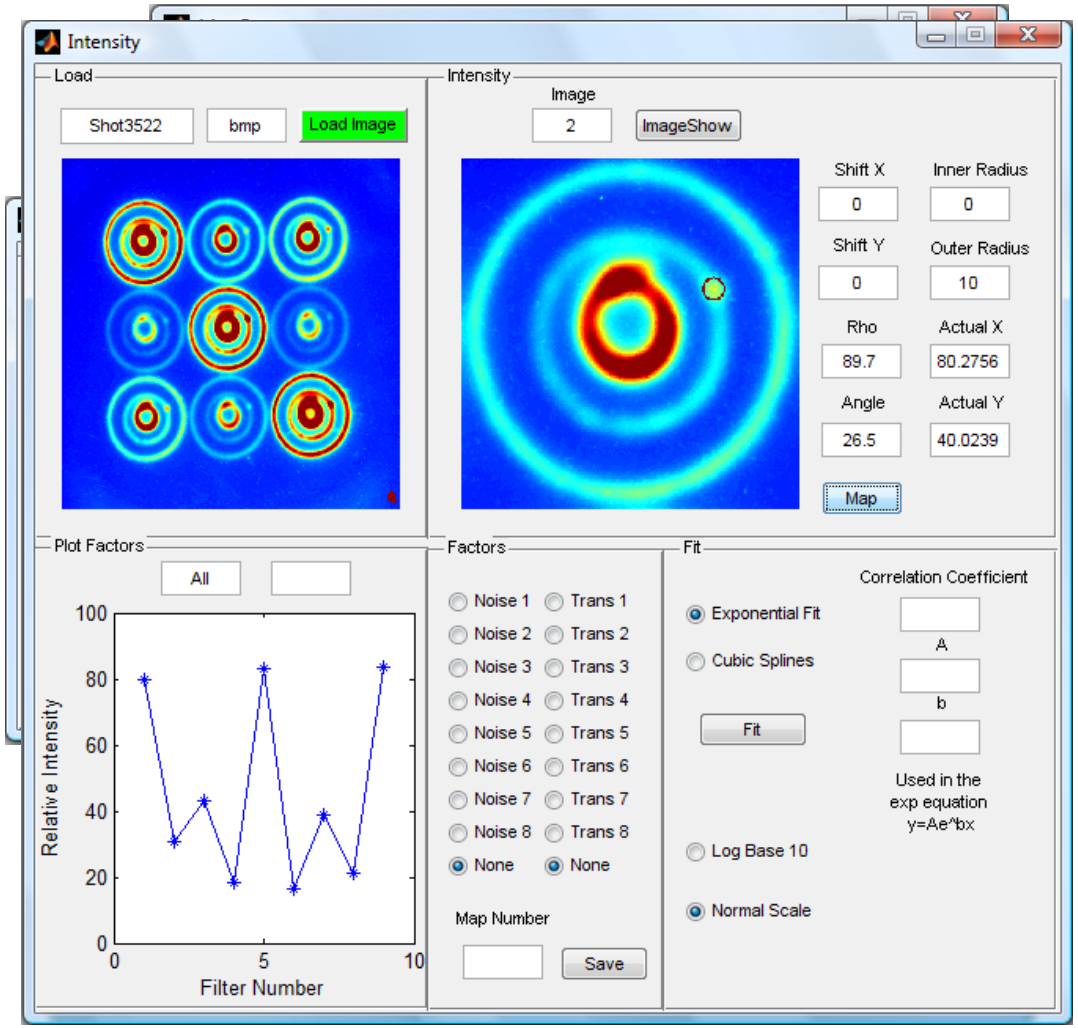
Image

- **How to quantify background noise and transmission factor?**
- **Transmission factor is simply each image's average i d by the brightest image's averag**



Sampled annular region gives average noise/area

MATLAB Graphic User Interface



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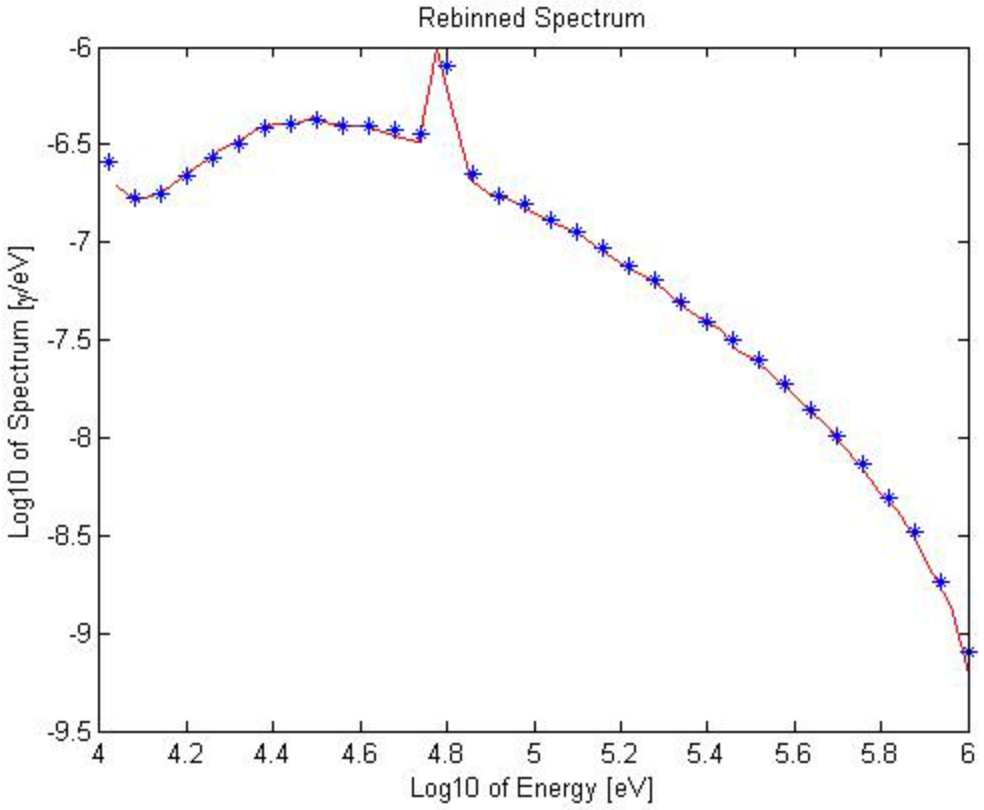
Preliminary Simulation Work

- Before simulations could proceed, simulation parameters need to be determined
  - Beam size (1cm radii vs. 1mm radii)
  - ITS vs. ADEPT
- ITS (Integrated Tiger Series) is a 1, 2, or 3-D Monte Carlo electron/photon code
- ADEPT is a 1-D radiation transport code
- How to rebin spectra into different energy bins?

Rebinning Algorithm

- Suppose one wanted to go from one set of energy bins {B} to another set {B*} while keeping the spectrum as close to possible?
- Kolmogorov-Smirnov Test
  - Evaluates distance between discrete distributions
  - Used to evaluate distances between binned photon distributions
- Interpolate values from the cumulative photon distribution via natural cubic splines.

Rebinning Effects



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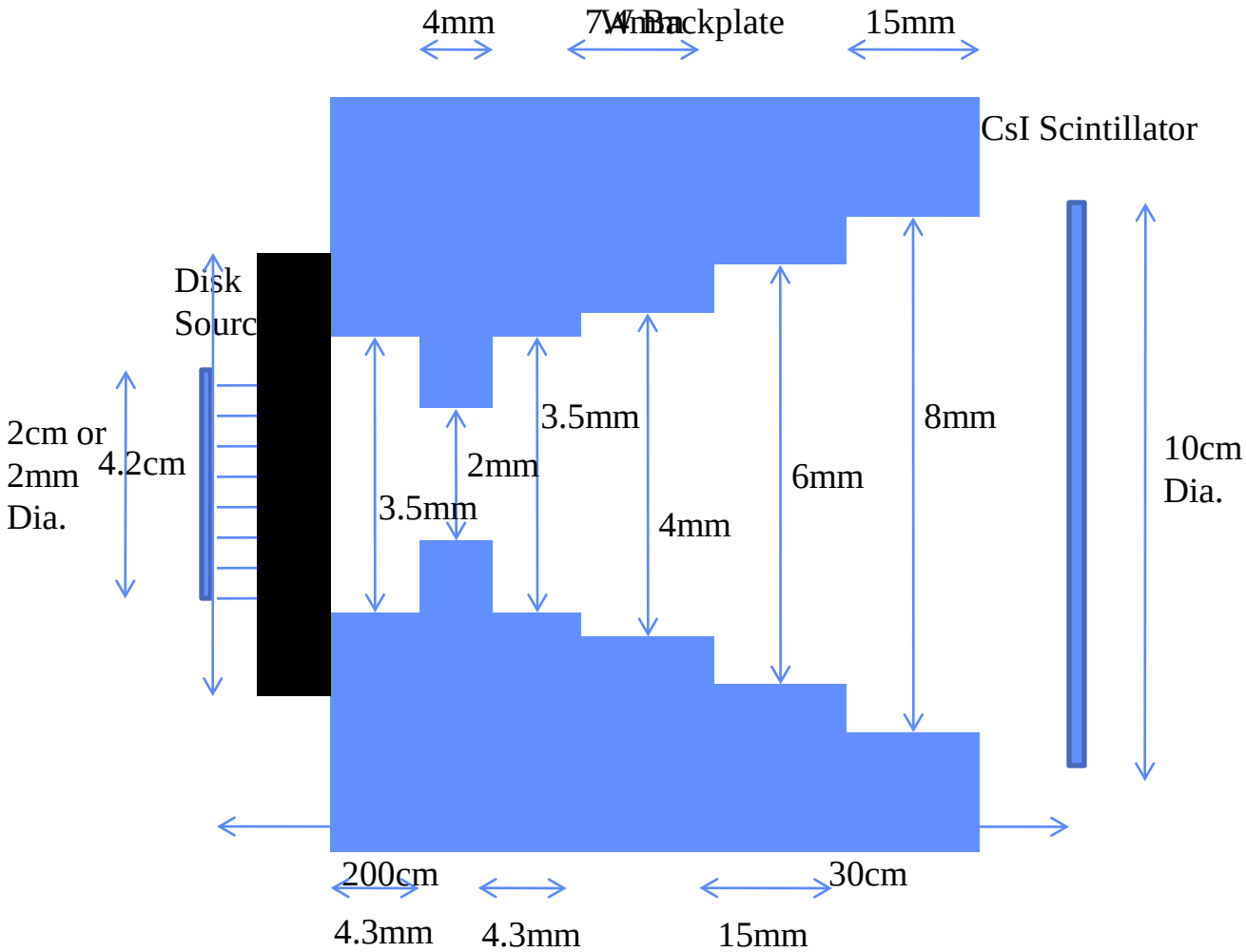
Response Matrix

- Each entry represents the dose response on a filter to an impulse of energy equal to a particular energy bin.
- Impulse responses can be used to completely define a system's behavior.
  - Convolve input spectra with impulse response
- Use ITS to generate pulses of one energy bin width and measure the dose deposition per filter (~digital approximation of impulse function).
- Need span(impulse functions)>=domain(input)

ITS ACCEPT Geometry



*Images are not to scale

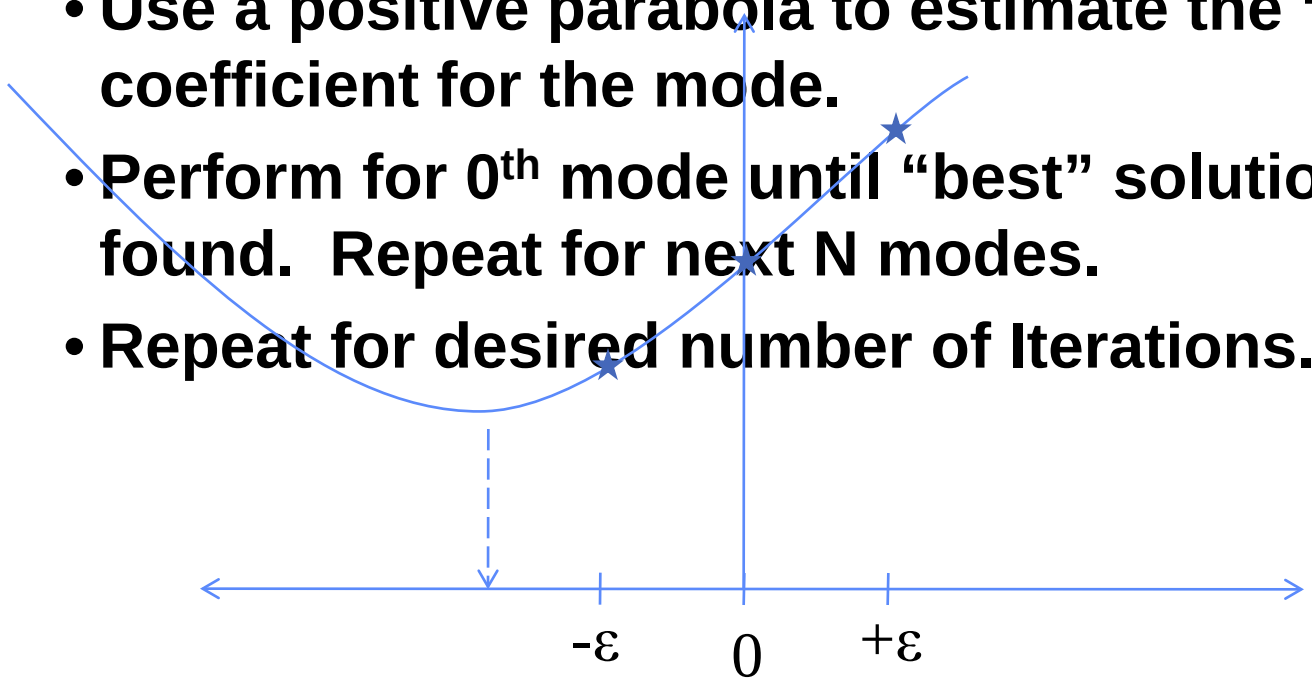
Perturbation Algorithm

- **Minimize distance between test function and fitted function.**
  - **Iteratively add layers of 0th, 1st, and 2nd Fourier modes to the test function. (neural network)**
  - **Any set of orthogonal basis functions such as Chebyschev polynomials or wavelets can be used.**

- **How do you calculate the best coefficients of the modes to use? (training the neural network)**

Perturbation Algorithm

- Evaluate the response to the addition and subtraction of a small magnitude mode.
- Use a positive parabola to estimate the “best” coefficient for the mode.
- Perform for 0th mode until “best” solution is found. Repeat for next N modes.
- Repeat for desired number of Iterations.



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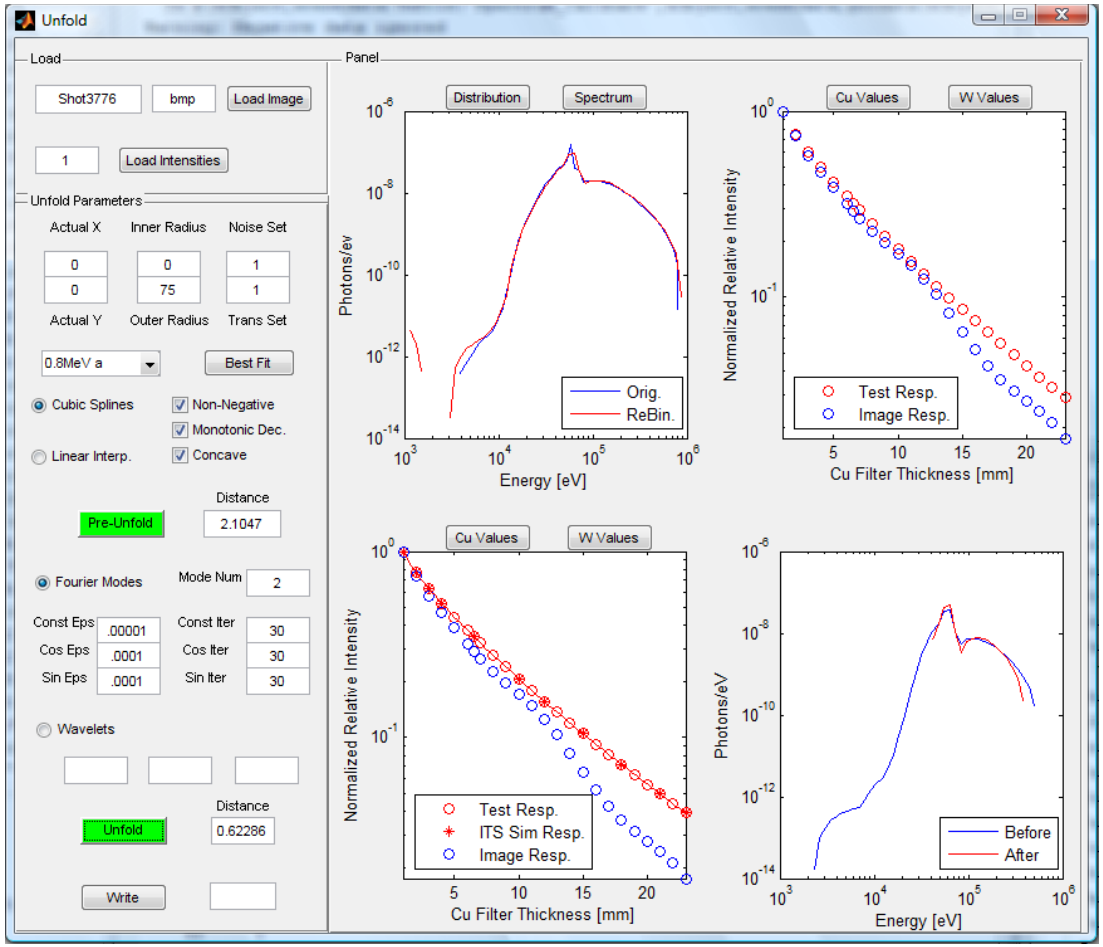
MATLAB Graphic User Interface



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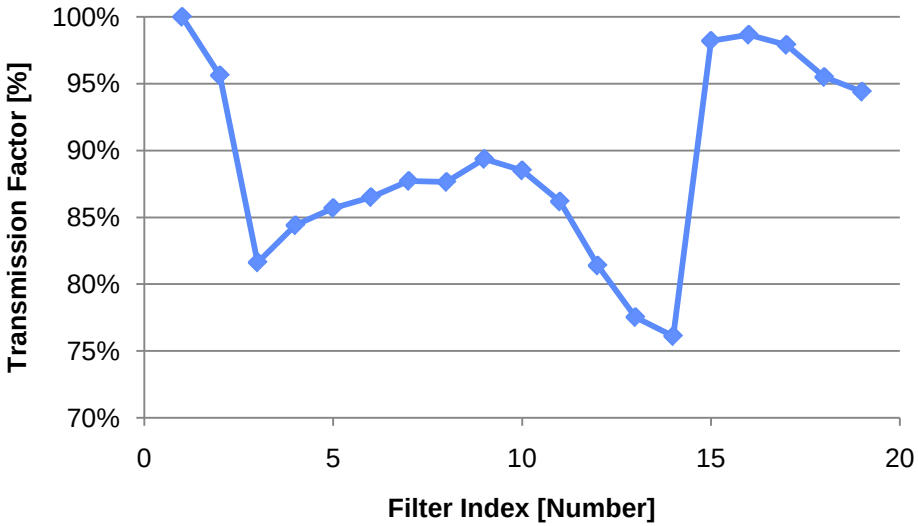
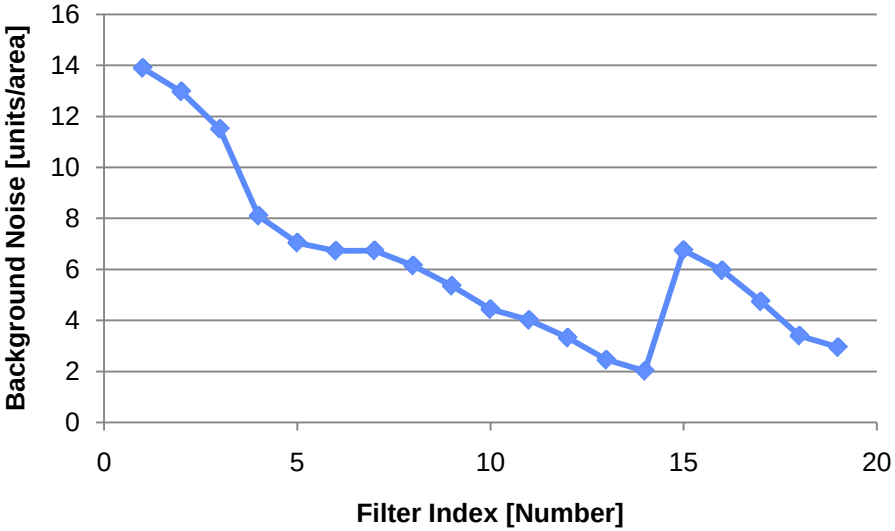
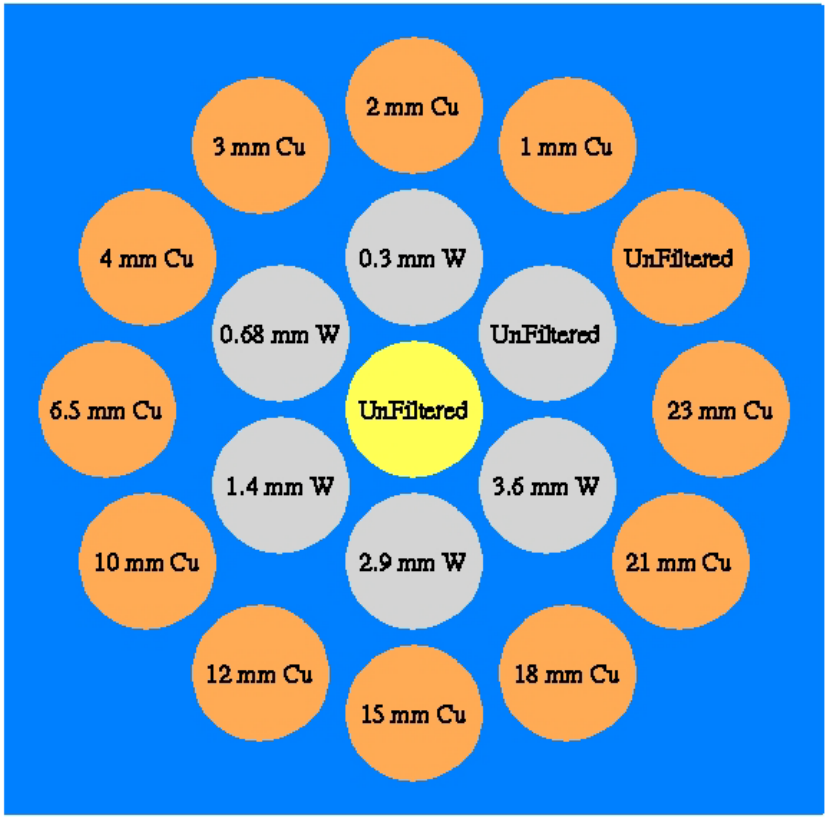
Results







Shot3776

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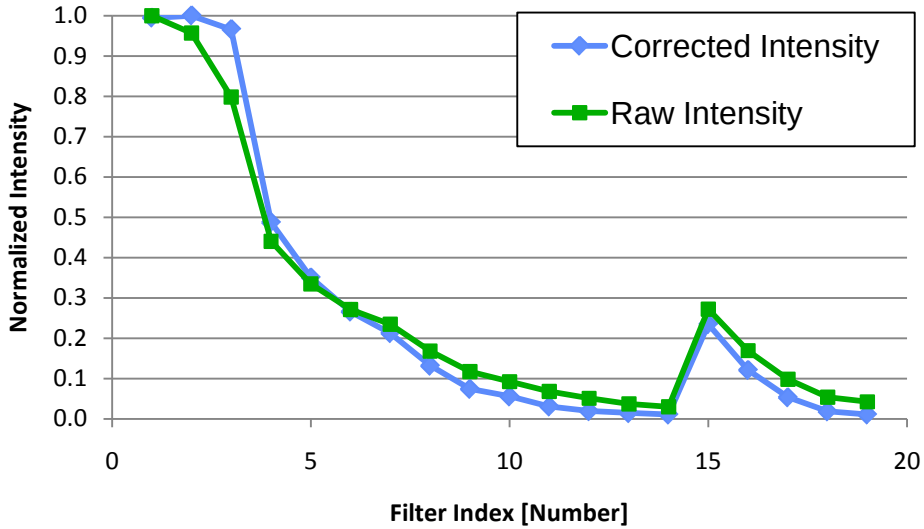
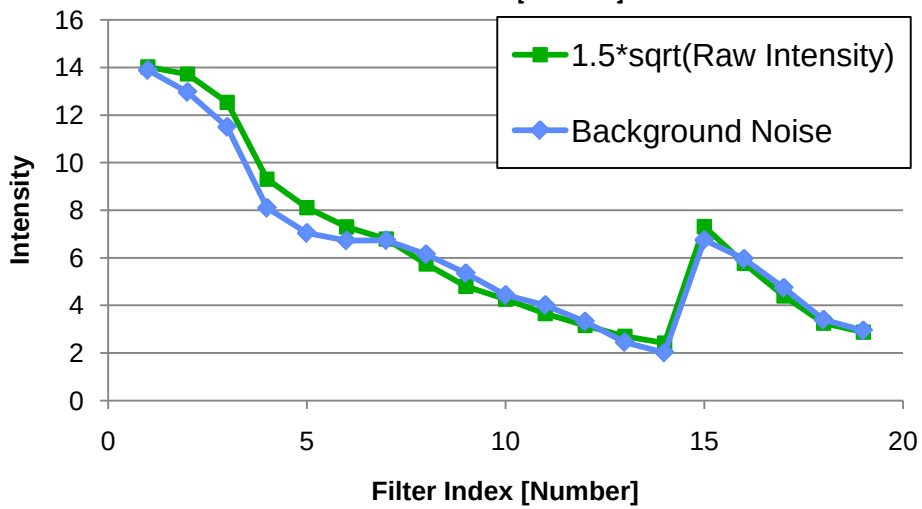
Results

- **Analysis of intensities leads to estimation of background noise.**
- **B.N. estimation useful for Shots 3522 and 3523 where image proximity is problem.**





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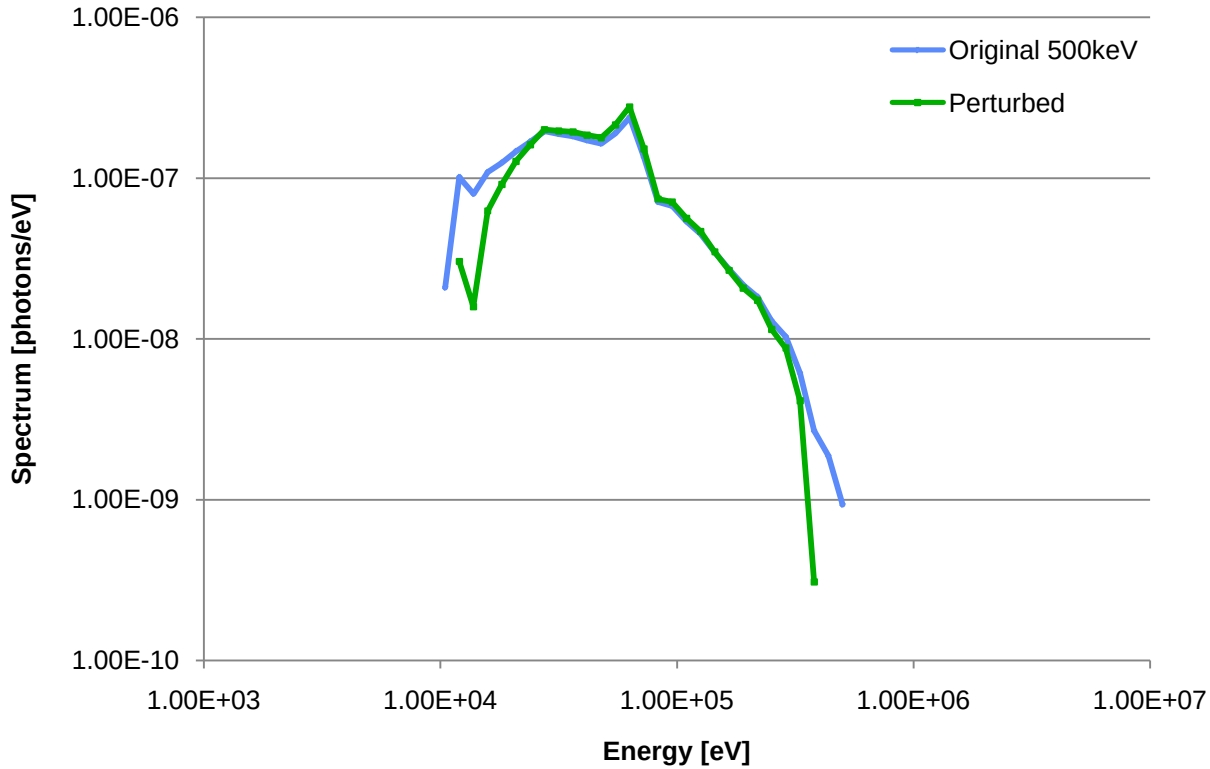
Results

- **500keV spectrum fitted to Shot3776 intensity data.**



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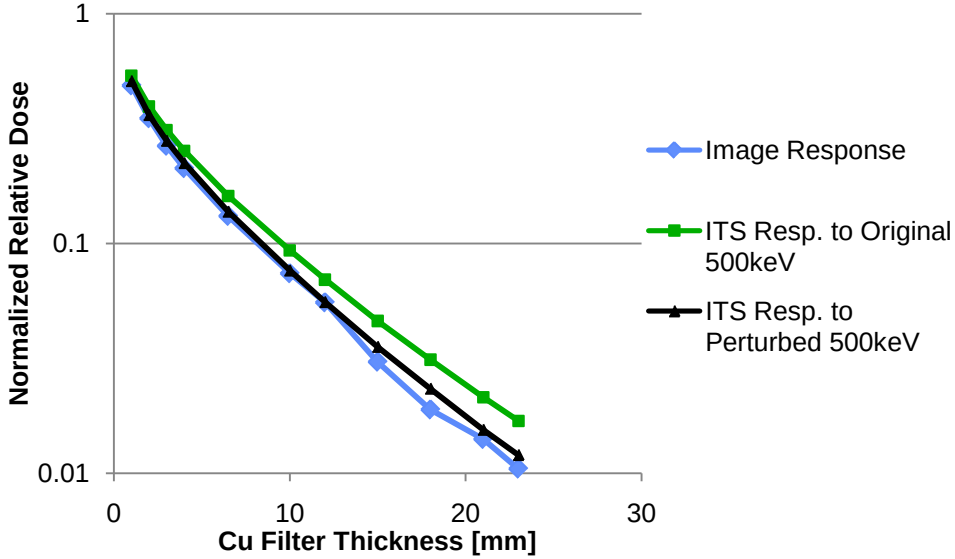
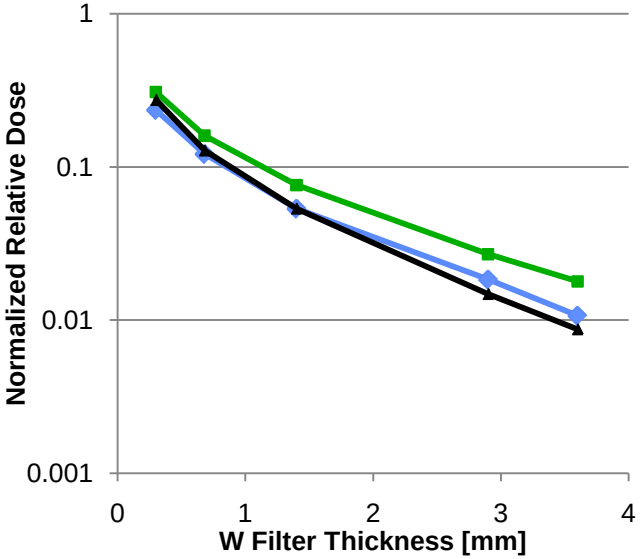
Results

- **Original and perturbed 500keV spectrum response on Cu and W filters.**





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Conclusions

- ITS is better suited for the response matrix calculations than ADEPT due to its more complex physics capabilities.
- Image processing can be done equally well in LabVIEW and MATLAB.
- A stable perturbation algorithm is possible, so long as there are proper constraints.
- Correct interpretation of background noise and transmission factors are necessary.

Acknowledgements

- I would like to acknowledge the following people for their help over the last two and a half months.
  - Vic Harper-Slaboszewicz
  - Trish St.John
  - Tom Laub
  - Robert Hohlfelder and Wesley Fan

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