DIRECT PERTURBATION CALCULATION FOR TSUNAMI SENSITIVITY COEFFICIENT VALIDATION

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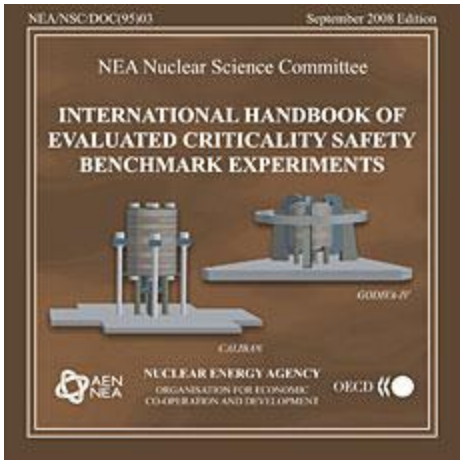
Good Morning

- Introduction
- Background
  - Validation/Similarity/Bias
  - TSUNAMI and DP Calculation
- HST-001, Case 001
- 3-point DP
- Multi-point DP
- Results
- Conclusion



Introduction/Background

- TSUANAMI-3D
  - Tools for Sensitivity and Uncertainty Analysis Methodology Implementation in Three Dimensions.
  - Computes Forward and Adjoint keff and neutron flux moments to determine the sensitivity of keff to the nuclear data
- Validation/Similarity/Bias
  - Direct Perturbation Calculations
    - Ensure that system is correctly represented.
  - Forward and Adjoint multiplication Difference
    - Less than 0.5%

HEU-SOL-THERM-001, Case 001

- Metal Tank
  - Uranyl Nitrate – Critical Height
- 10 Cases, 2 Different Tanks
  - Case 001 Stainless Steel Tank
- Stainless Steel – 7.927 g/cm^3
- Uranyl Nitrate 93.172 ± 0.060 wt. %

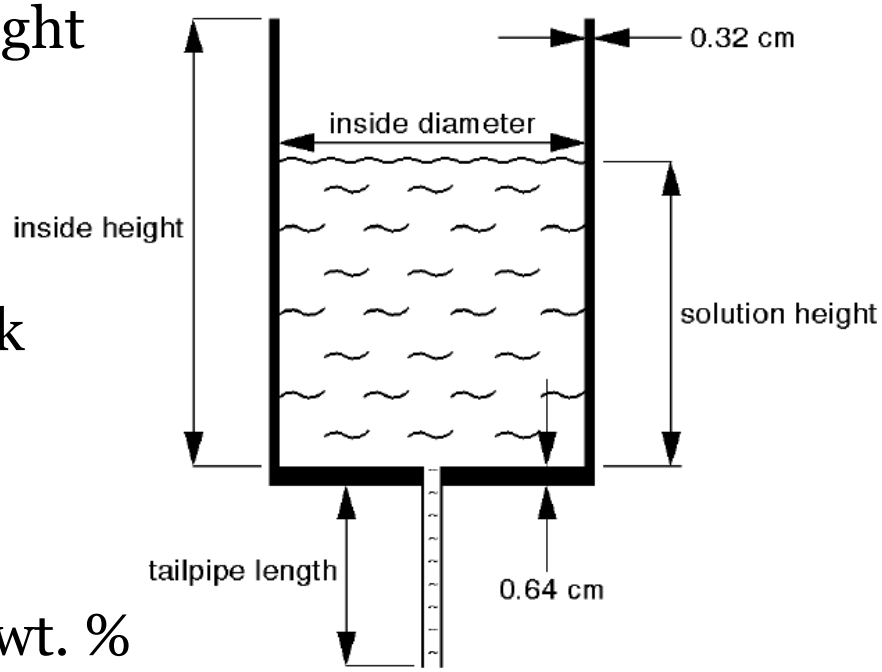
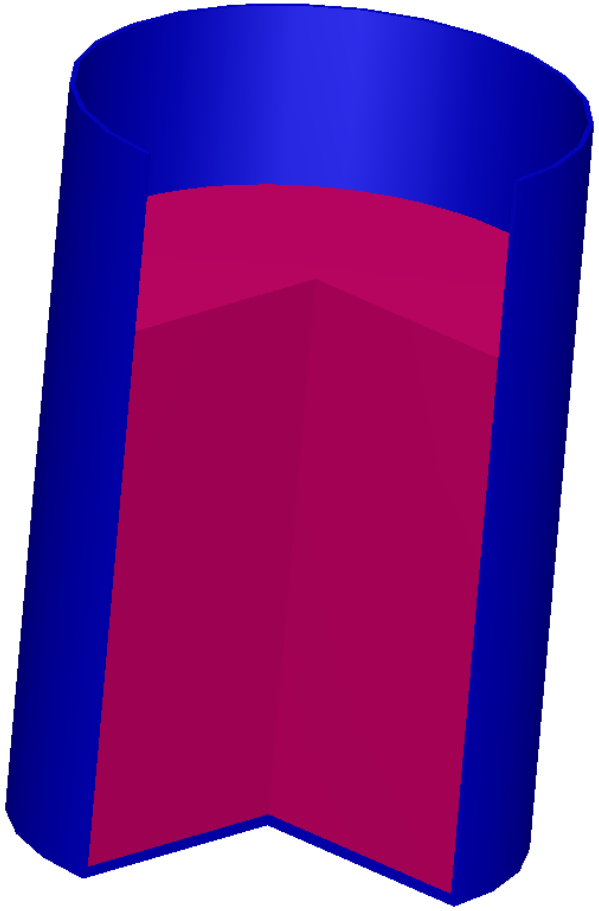


Figure 1. Experimental Configuration.

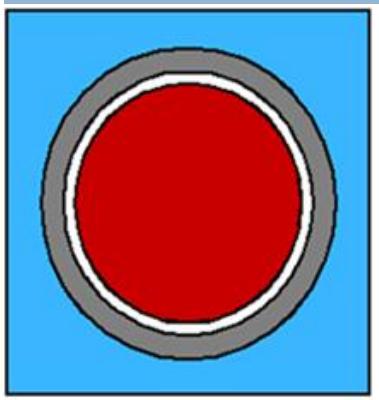
Parameters

read parameter
 gen=10000
 npg=10000
 nsk=150
 htm=yes
 sig=0.0005
 tfm=no
 mfx=yes
 msh=2.792
 ask=150
 asg=0.001
end parameter

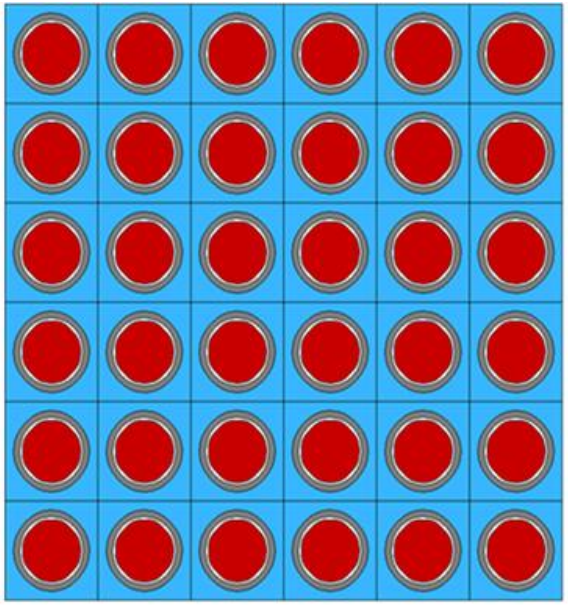
*agn and apg are left as defaults (3X forward)



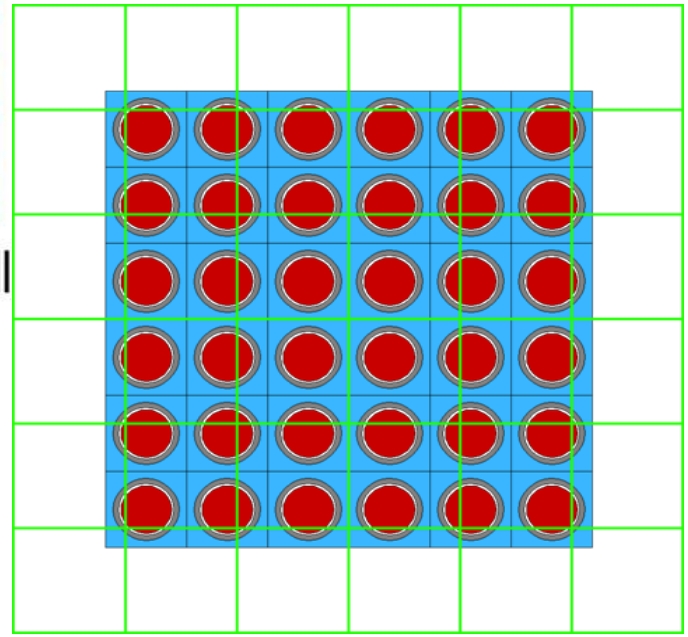
Mesh



4 flux regions
fuel, gap, clad, mod

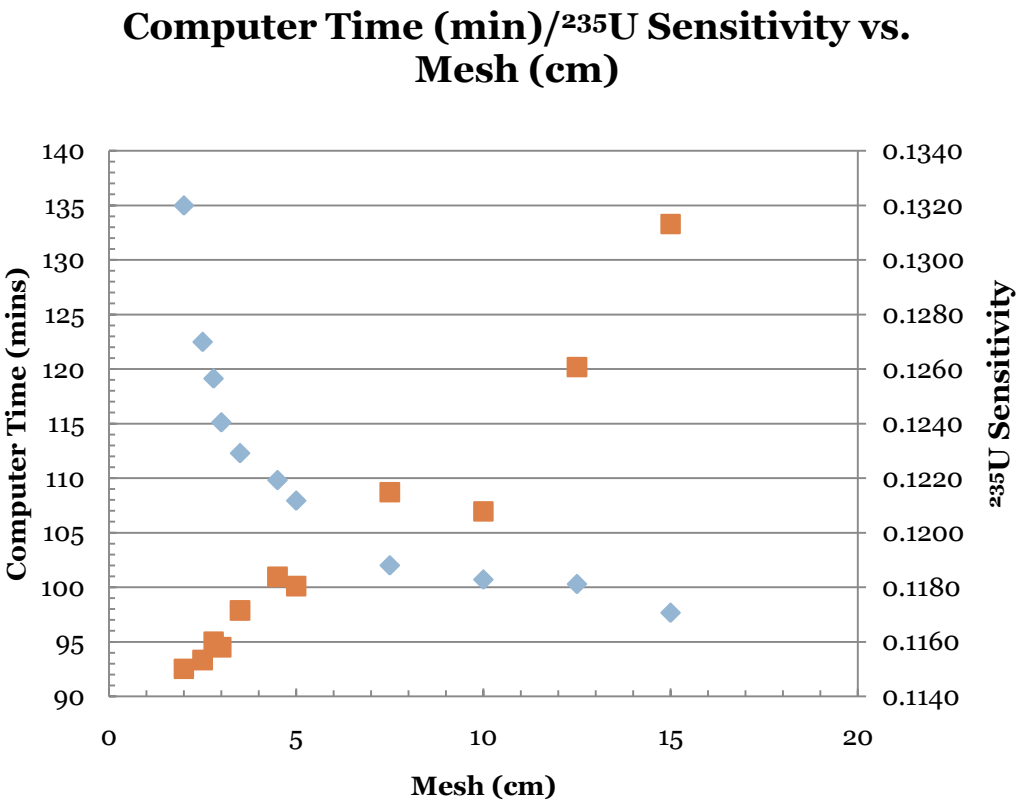


6 × 6 Array of 4-region cell
for 144 regions



Computer Time vs. Mesh Size

Mesh Size	Computing Time	U-235 Sensitivity
2.0	134.98	1.1502E-01 +\- 1.0322E-04
2.5	122.48	1.1534E-01 +\- 8.1209E-05
2.792	119.13	1.1601E-01 +\- 7.2617E-05
3.0	115.11	1.1581E-01 +\- 6.7822E-05
3.5	112.29	1.1716E-01 +\- 5.9039E-05
4.5	109.82	1.1839E-01 +\- 4.8837E-05
5.0	107.94	1.1805E-01 +\- 4.5759E-05
7.5	102.01	1.2149E-01 +\- 3.8684E-05
10.0	100.71	1.2079E-01 +\- 3.6194E-05
12.5	100.3	1.2608E-01 +\- 3.5595E-05
15.0	97.67	1.3132E-01 +\- 3.5588E-05



General Information

Input Data

Results

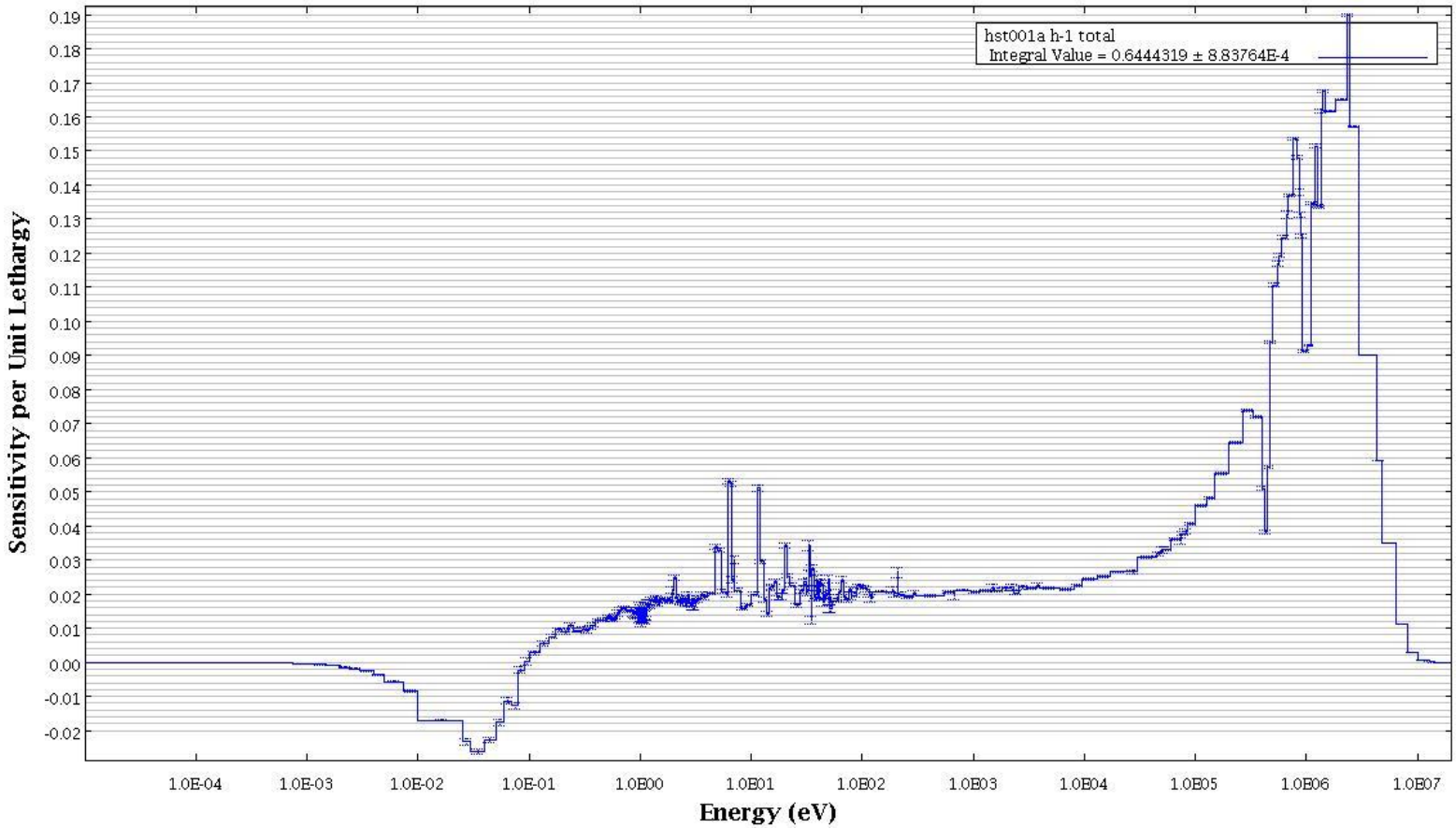
- Energy, Region and Mixture Integrated Sensitivity Coefficients for this Problem
- Energy and Region Integrated Sensitivity Coefficients for this Problem
- Total Sensitivity Coefficients by Nuclide
- Sensitivity Data Plot
- Problem Characterization
- Uncertainty Information

SAMS - Energy, Region and Mixture Integrated Sensitivity Coefficients for this Problem hst001a

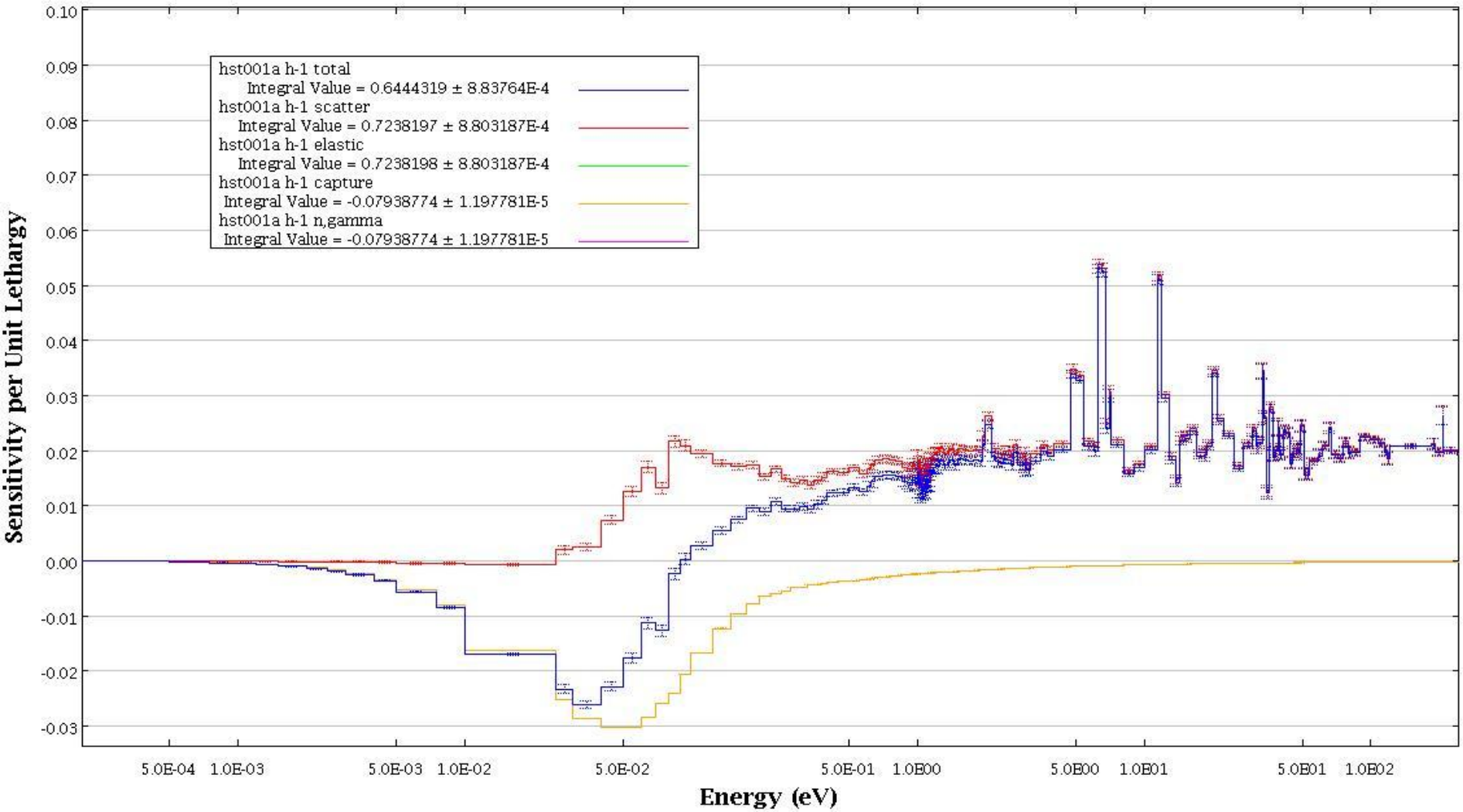
Sensitivity Coefficients for each Nuclide and Reaction

Nuclide	Reaction		Explicit		Std. Dev.		Implicit		Std. Dev.		Sensitivity		Std. Dev.	% Std. Dev.
^{1}H	total		6.4490E-01	±	8.8376E-04		-4.7300E-04	±	3.3688E-07		6.4443E-01	±	8.8376E-04	0.14%
^{1}H	scatter		7.2429E-01	±	8.8032E-04		-4.7290E-04	±	3.3658E-07		7.2382E-01	±	8.8032E-04	0.12%
^{1}H	elastic		7.2429E-01	±	8.8032E-04		-4.7290E-04	±	3.3658E-07		7.2382E-01	±	8.8032E-04	0.12%
^{1}H	capture		-7.9388E-02	±	1.1978E-05		-1.0510E-07	±	4.9210E-10		-7.9388E-02	±	1.1978E-05	0.02%
^{1}H	n,gamma		-7.9388E-02	±	1.1978E-05		-1.0510E-07	±	4.9210E-10		-7.9388E-02	±	1.1978E-05	0.02%
C	total		4.2975E-05	±	7.3540E-08		1.1560E-07	±	6.0327E-10		4.3091E-05	±	7.3543E-08	0.17%
C	scatter		4.2977E-05	±	7.3535E-08		1.1560E-07	±	6.0326E-10		4.3093E-05	±	7.3538E-08	0.17%
C	elastic		4.2874E-05	±	7.3501E-08		1.1560E-07	±	6.0326E-10		4.2990E-05	±	7.3504E-08	0.17%
C	n,n'		1.0262E-07	±	8.2490E-10		6.8772E-14	±	9.4198E-16		1.0262E-07	±	8.2490E-10	0.80%
C	capture		-1.7371E-09	±	0.0000E+00		1.6879E-13	±	1.5198E-15		-1.7370E-09	±	1.5198E-15	0.00%
C	n,gamma		-1.1993E-09	±	0.0000E+00		1.6546E-13	±	1.5165E-15		-1.1991E-09	±	1.5165E-15	0.00%
C	n,p		-3.3109E-14	±	0.0000E+00		8.1397E-20	±	4.6823E-20		-3.3109E-14	±	4.6823E-20	0.00%
C	n,d		-2.5616E-14	±	0.0000E+00		1.8873E-19	±	1.2874E-19		-2.5616E-14	±	1.2874E-19	0.00%
C	n,alpha		-5.3782E-10	±	0.0000E+00		3.3338E-15	±	1.0090E-16		-5.3782E-10	±	1.0090E-16	0.00%
^{14}N	total		-3.1164E-03	±	4.7526E-06		-1.2775E-06	±	2.5347E-09		-3.1177E-03	±	4.7526E-06	0.15%
^{14}N	scatter		4.0990E-03	±	4.4174E-06		-1.4281E-06	±	2.4941E-09		4.0976E-03	±	4.4174E-06	0.11%
^{14}N	elastic		4.0619E-03	±	4.4170E-06		-1.4415E-06	±	2.4934E-09		4.0605E-03	±	4.4170E-06	0.11%
^{14}N	n,n'		3.7105E-05	±	1.6095E-08		1.3413E-08	±	8.2617E-12		3.7118E-05	±	1.6095E-08	0.04%
^{14}N	n,2n		2.0519E-08	±	2.5620E-11		6.0319E-13	±	1.9302E-15		2.0520E-08	±	2.5620E-11	0.12%
^{14}N	capture		-7.2155E-03	±	1.0156E-06		1.5060E-07	±	1.1119E-10		-7.2153E-03	±	1.0156E-06	0.01%

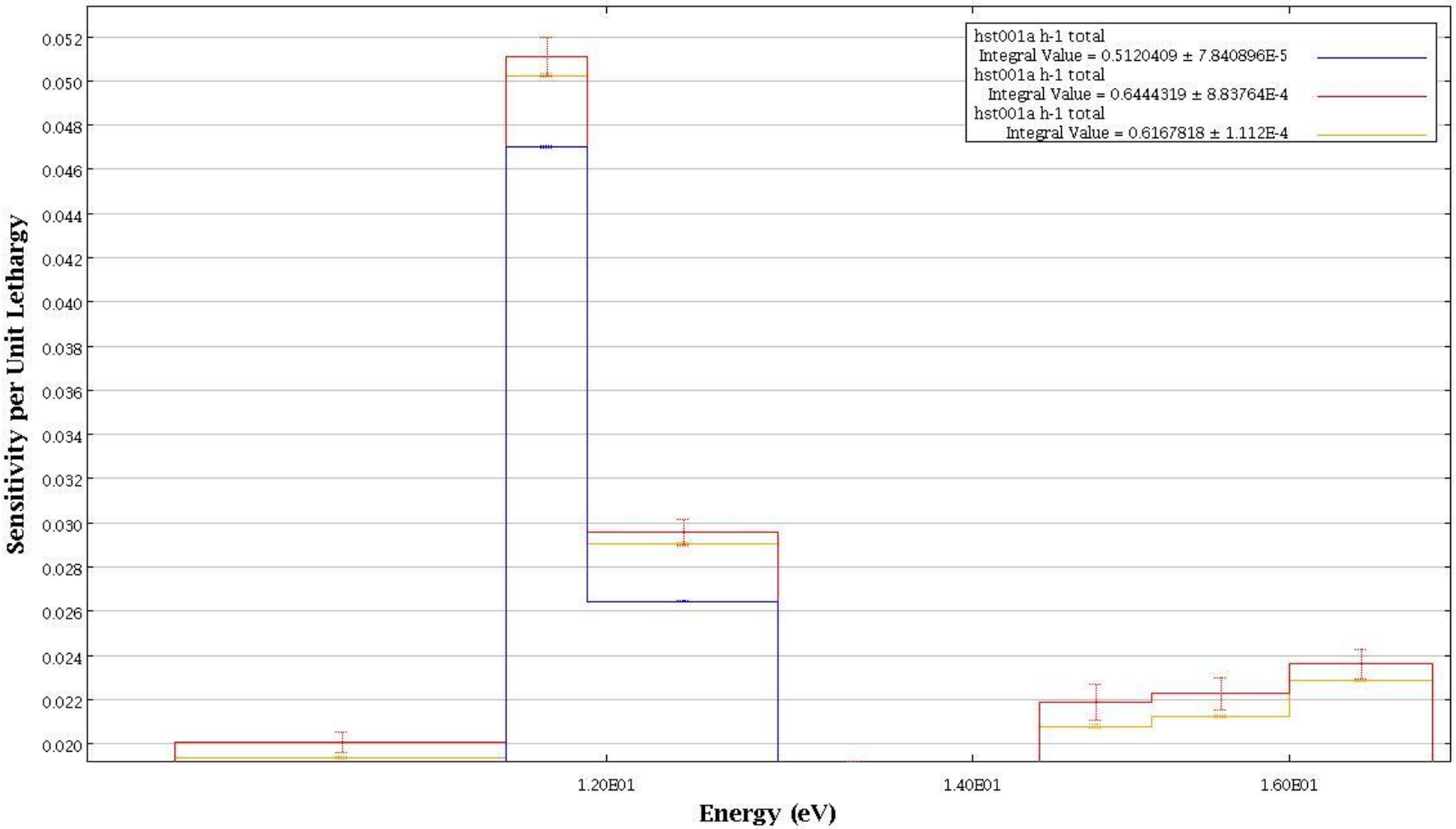
H-1 Total


hst001a h-1 total
Integral Value = 0.6444319 ± 8.83764E-4
Sensitivity per Unit Lethargy
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E00
1.0E01
1.0E02
1.0E03
1.0E04
1.0E05
1.0E06
1.0E07
Energy (eV)

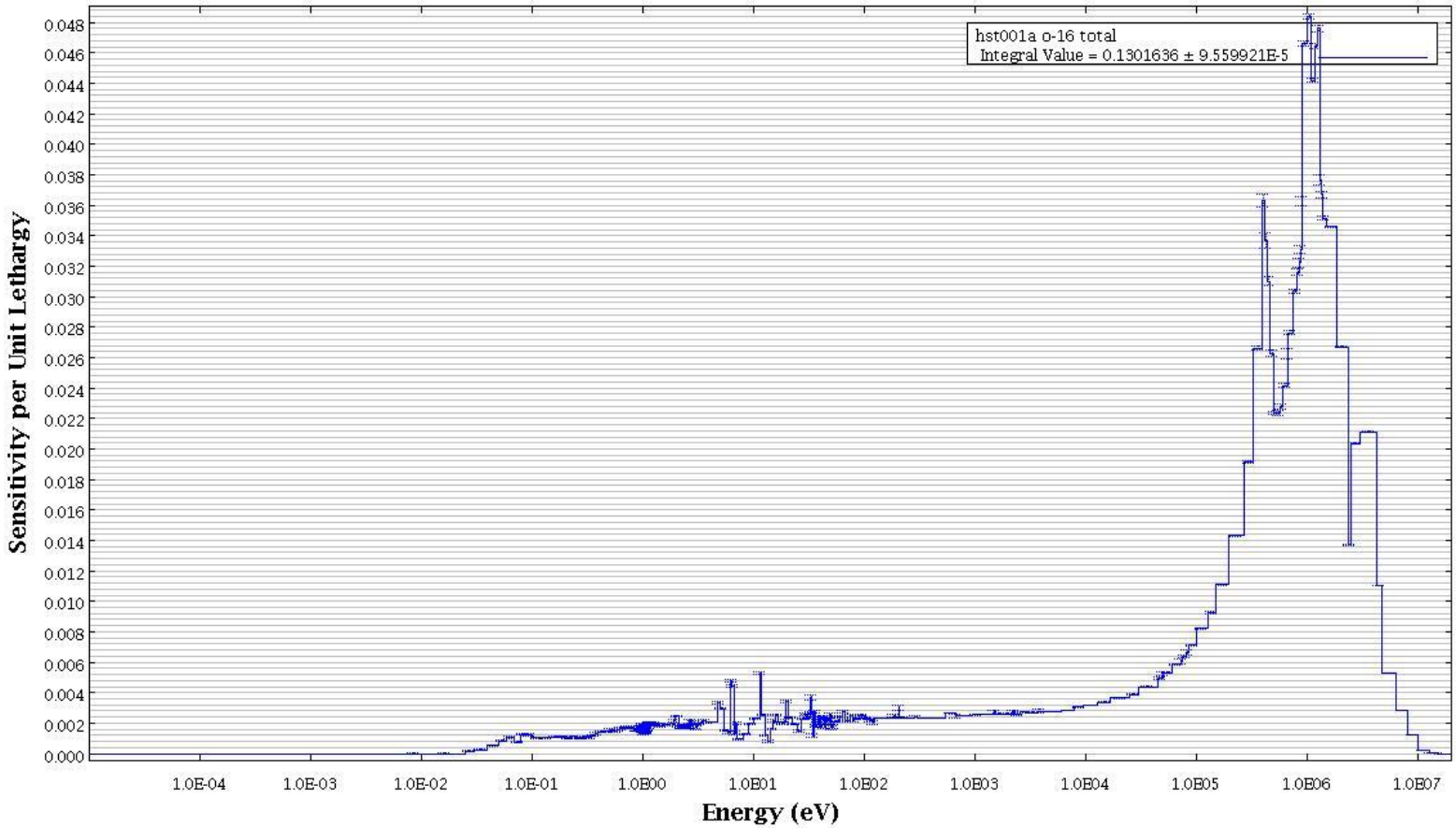
H-1 Total and Reactions



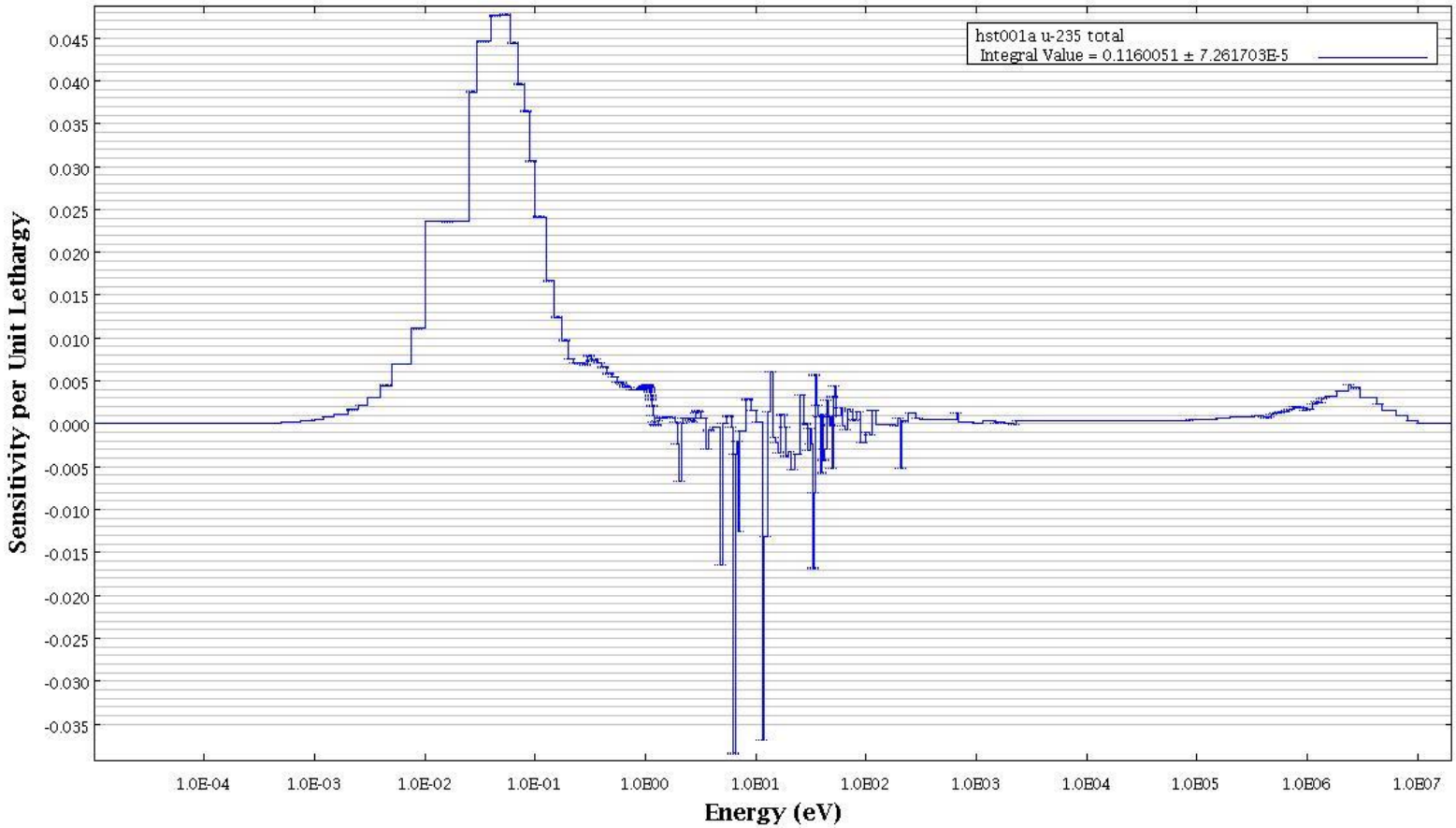
Sensitivity



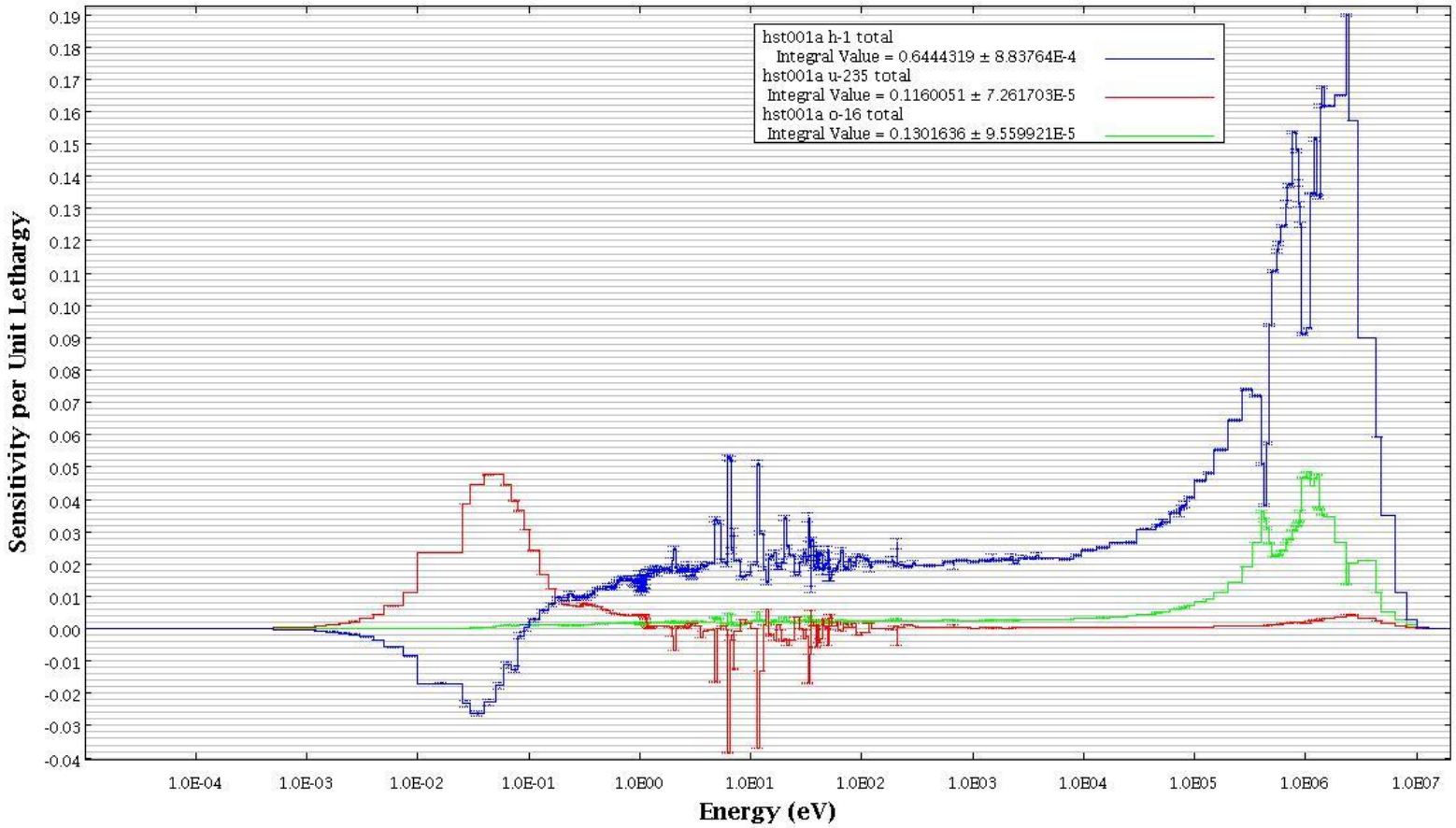
O-16 Total


hst001a o-16 total
Integral Value = 0.1301636 ± 9.559921E-5
Sensitivity per Unit Lethargy
0.048
0.046
0.044
0.042
0.040
0.038
0.036
0.034
0.032
0.030
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E00
1.0E01
1.0E02
1.0E03
1.0E04
1.0E05
1.0E06
1.0E07
Energy (eV)

U-235 Total


hst001a u-235 total
Integral Value = 0.1160051 ± 7.261703E-5
Sensitivity per Unit Lethargy
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E00
1.0E01
1.0E02
1.0E03
1.0E04
1.0E05
1.0E06
1.0E07
Energy (eV)

U-235, H-1 and O-16 Total



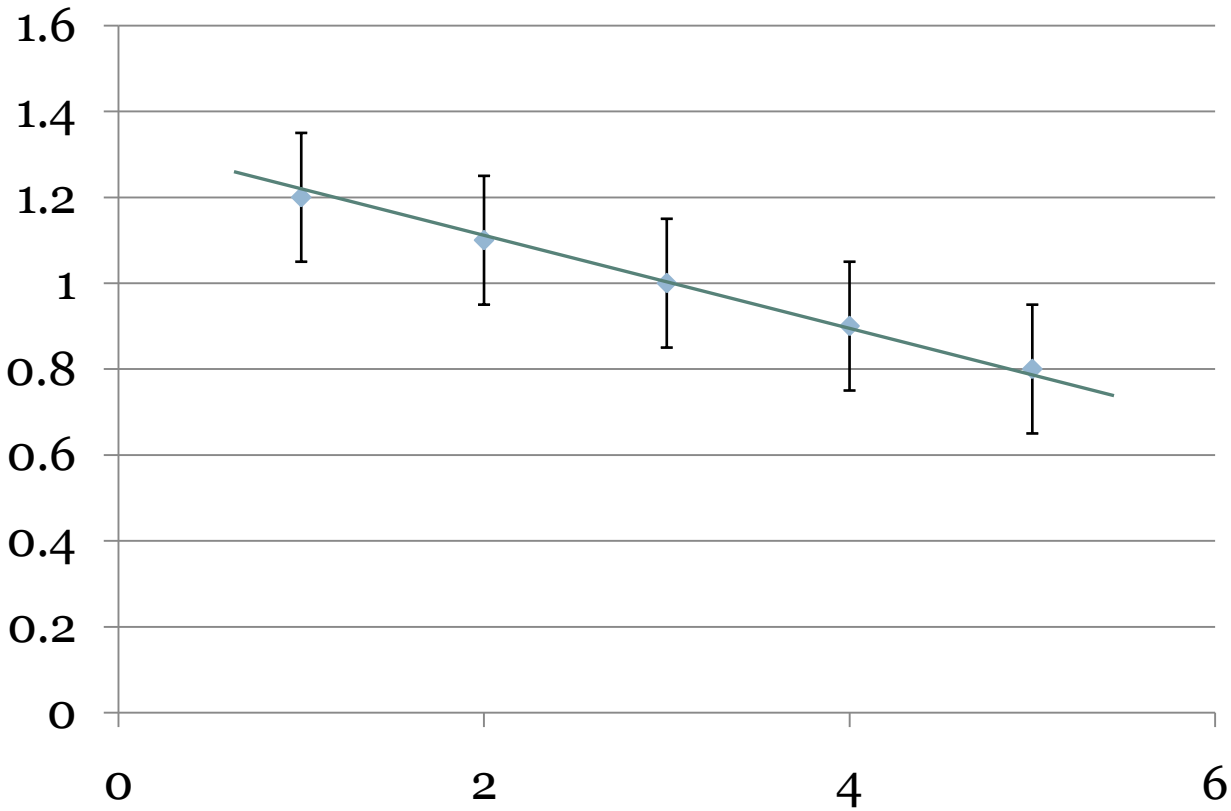
Three-Point DP

- Three or Four Nuclides with Largest Sensitivity
  - Fissile Material and Moderator
    - ^{235}U, O and H for HST-001
- Perturb the Number Densities forward and reverse by a small percentage

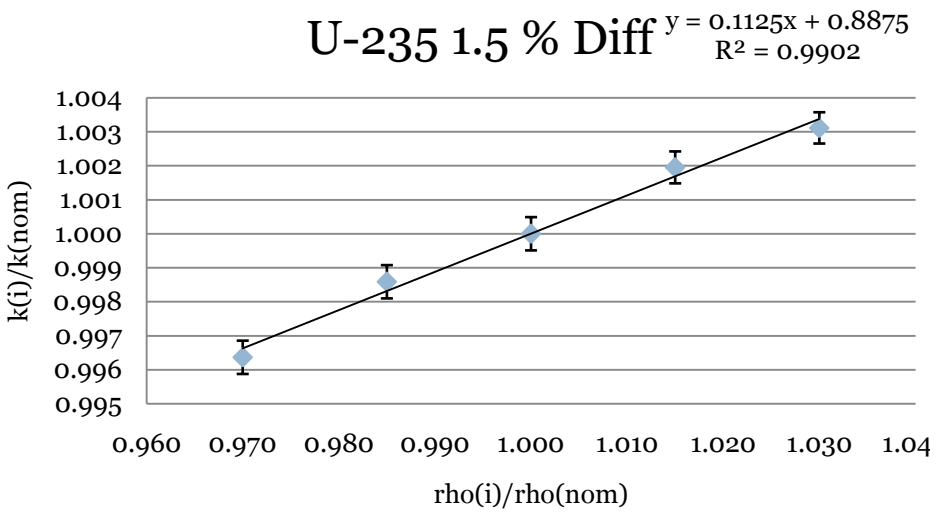
$$S_{k,\alpha} = \frac{\alpha}{k} \times \frac{dk}{d\alpha} = \frac{\alpha}{k} \times \frac{k_{\alpha^+} - k_{\alpha^-}}{\alpha^+ - \alpha^-}$$

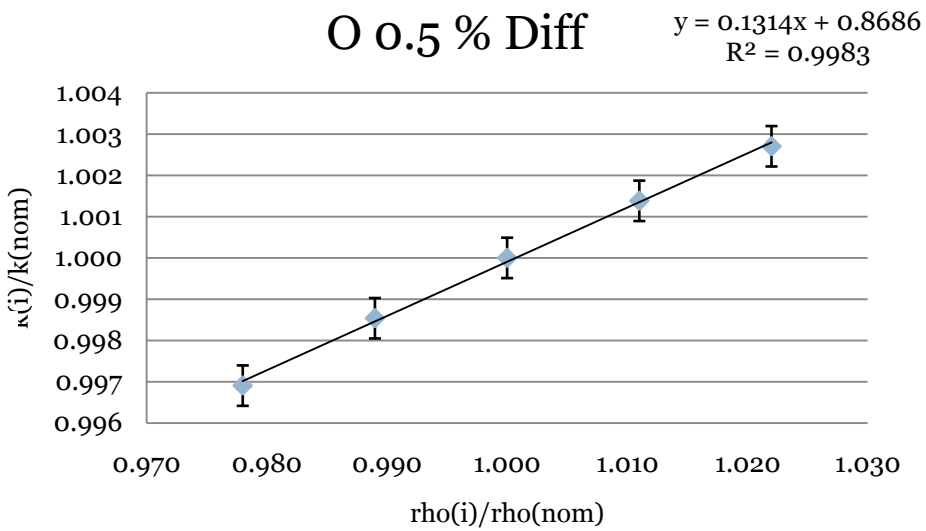
Multipoint DP

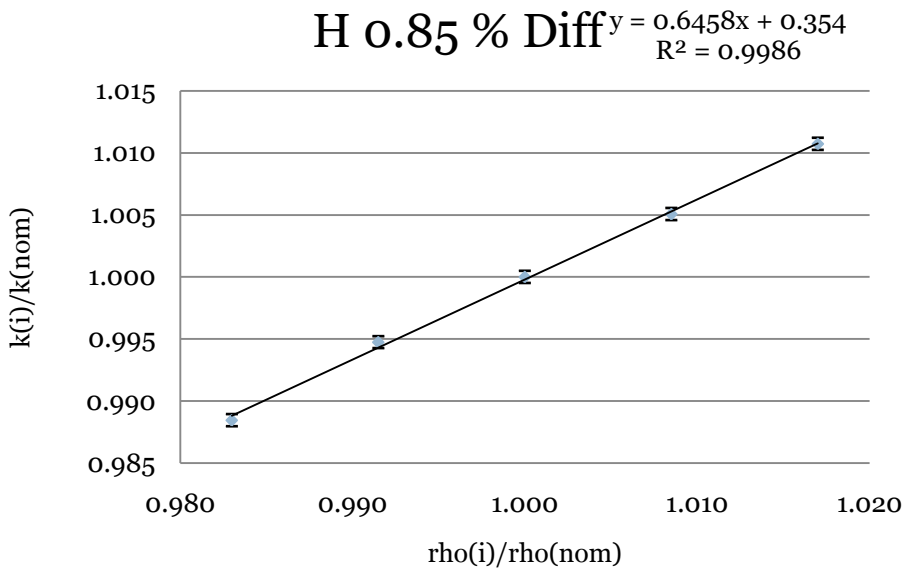
- Resolves non-linearity



Direct Perturbation Results







Results

TSUNAMI-3D Sensitivity Results

Nuclide	Sensitivity	Std. Dev.	% Std. Dev.
U-235	1.16E-01	7.26E-05	0.06
O	1.30E-01	9.56E-05	0.07
H	6.44E-01	8.84E-04	0.14

Three Point Direct Perturbation Calculation

Nuclide	Perturbation Percent	TSUNAMI Sensitivity	DP Sensitivity	Percent Difference
U-235	1.50%	1.16E-01	1.12E-01	3%
O	1.10%	1.30E-01	1.30E-01	1%
H	0.85%	6.44E-01	6.08E-01	6%

Multi-point Direct Perturbation Calculation

Nuclide	DP Sensitivity	Percent Difference
U-235	1.13E-01	3%
O	1.31E-01	1%
H	6.46E-01	0%

Conclusion

- TSUNAMI- Sensitivity and Uncertainty Analysis
- Problem Specific Parameters
- Direct Perturbation Validation
  - 3 Point or Multi-Point
    - Linear
  - Refine Mesh/Generations/Neutrons
- K_{eff} Difference
  - 0.5% Between Forward and Adjoint

Thank You