

Improving the Inverse Cargo Monitoring Treatment

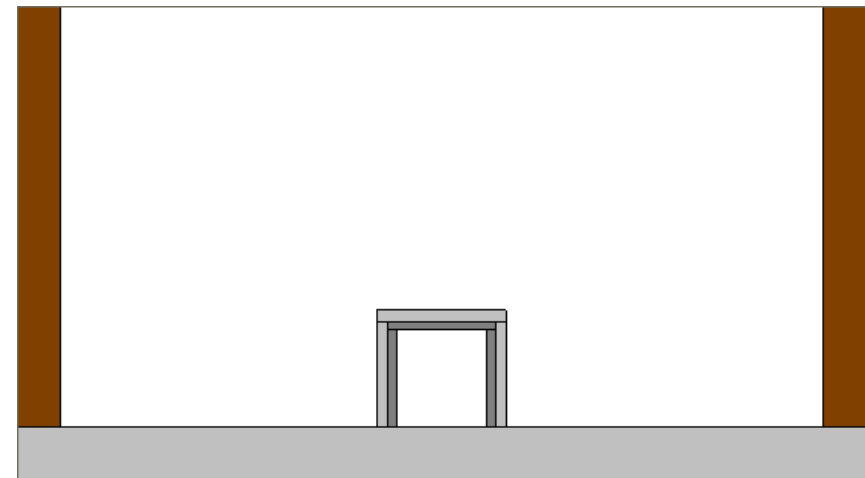
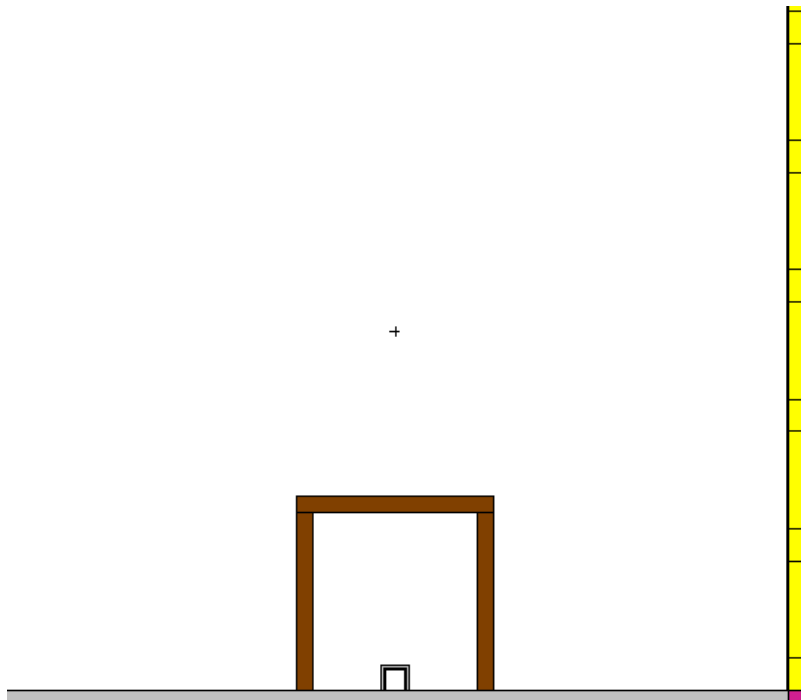
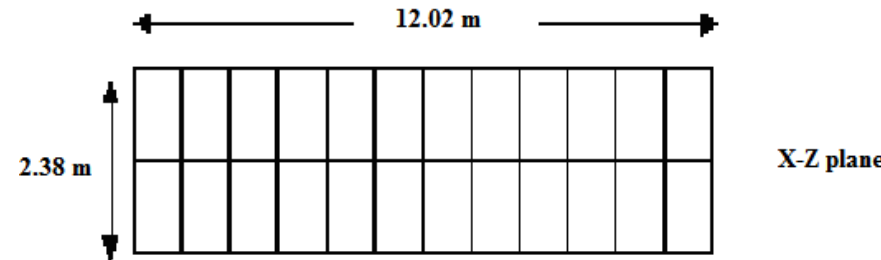
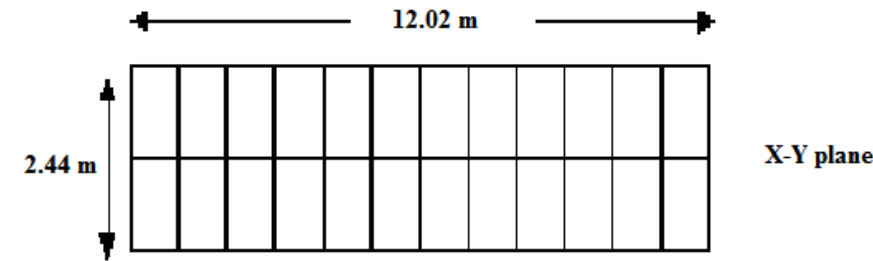


Daniel Speaker
Robin P. Gardner

North Carolina State University

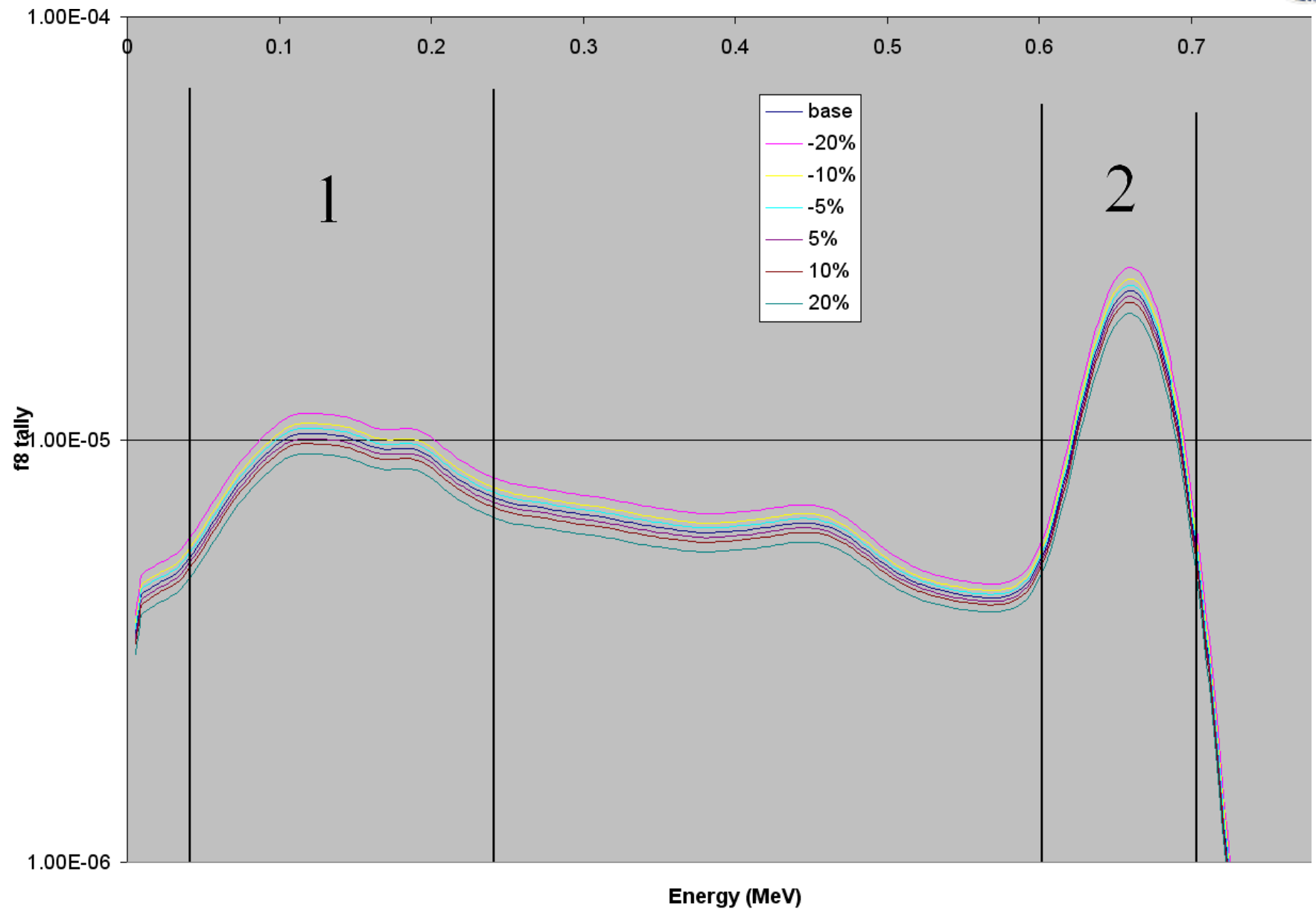
MCNP Setup

- 3 shielding materials
 - Lead
 - Iron
 - Wood--49% Carbon, 6% Hydrogen, 44% Oxogen, 1% Nitrogen





DO analysis



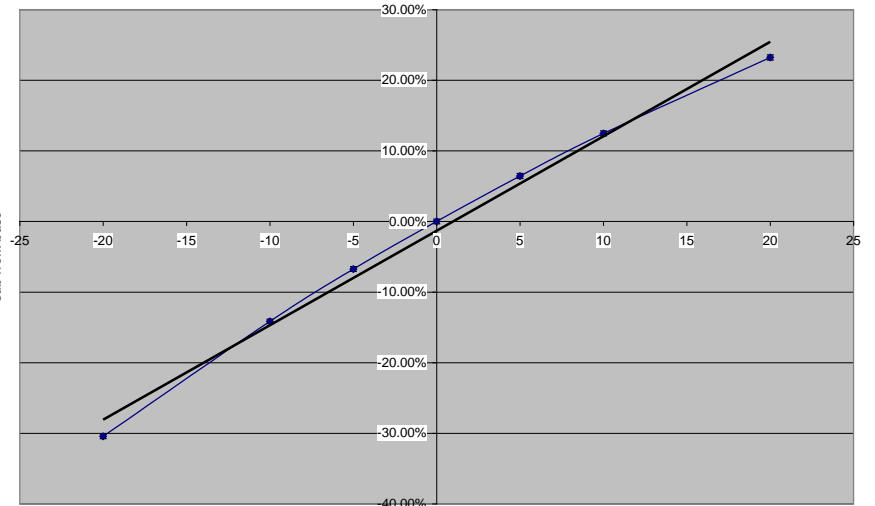
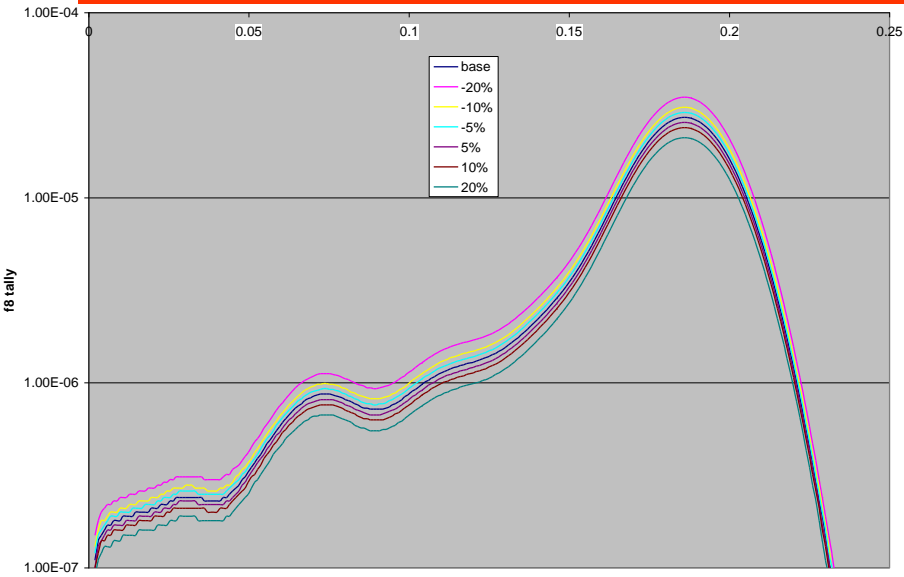


Lead Perturbation

Subtract from base 1

$$y = 0.0134x - 0.0132$$

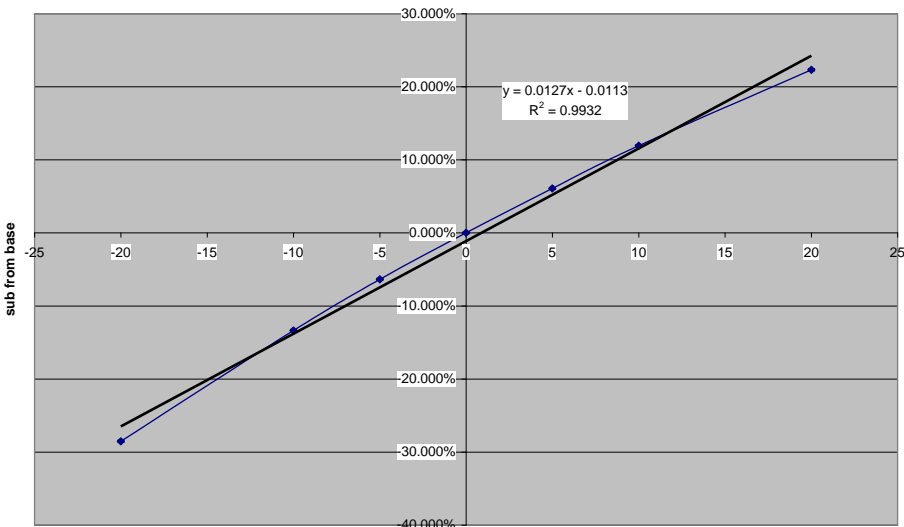
$$R^2 = 0.9919$$



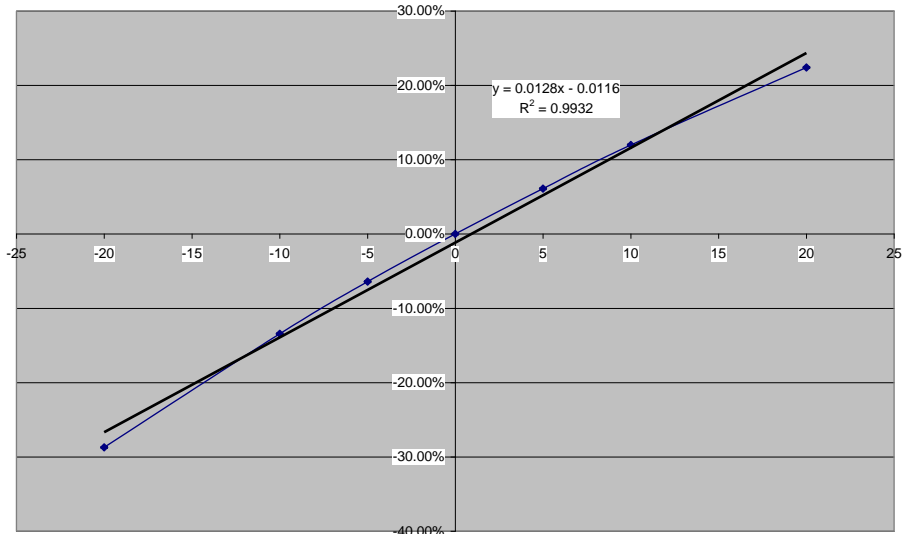
Perturbation on Density

Energy (MeV)
Subtract from base 2

Subtract from base tot

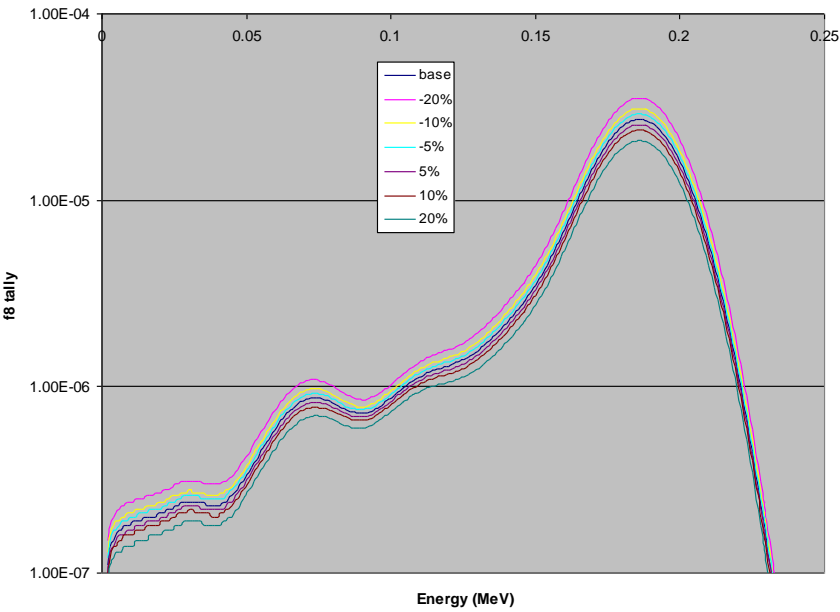


Perturbation on Density

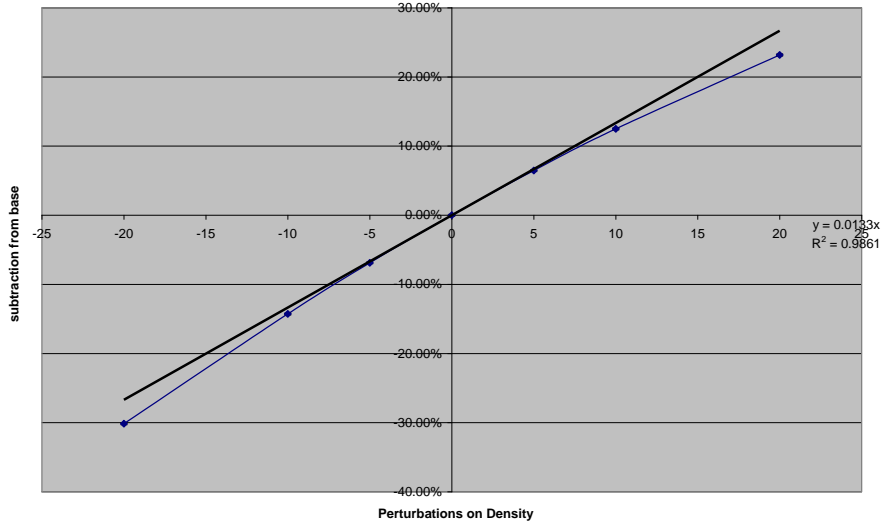


Perturbations on Density

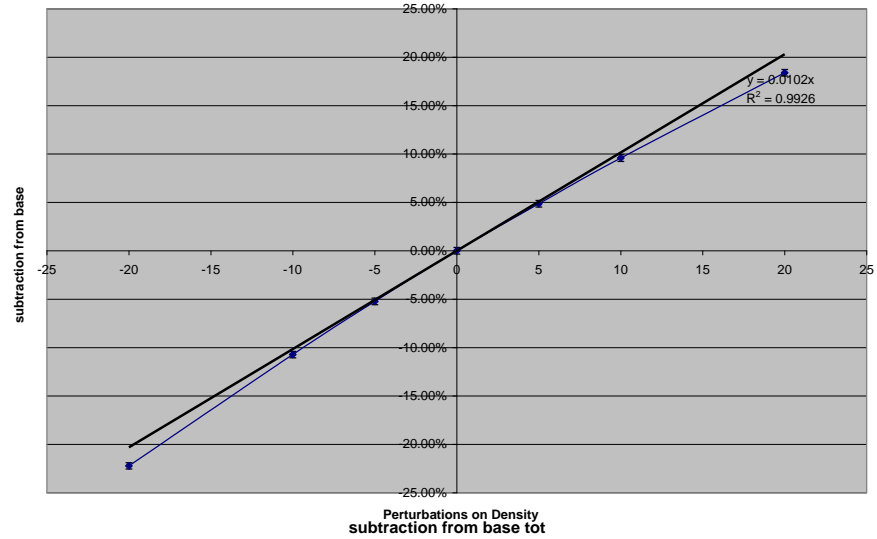
Lead-Wood



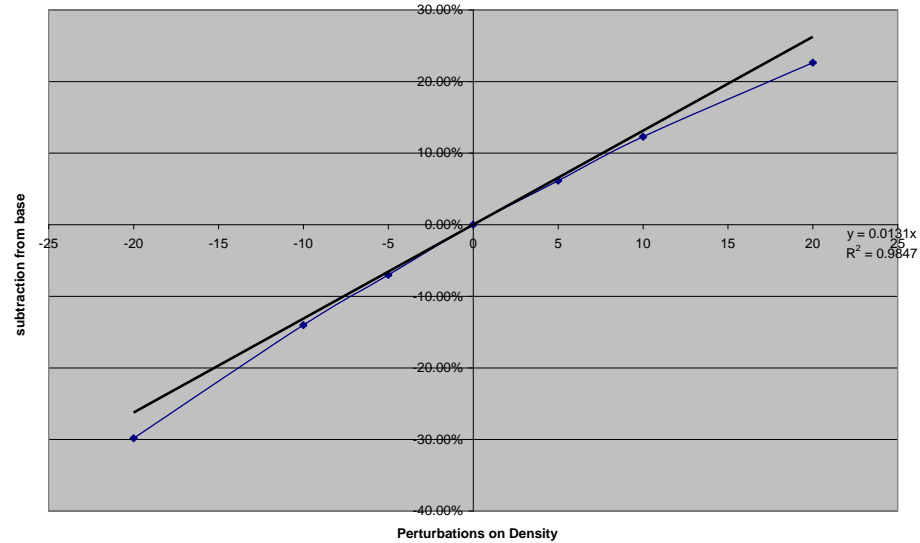
subtraction from base 2



subtraction from base 1

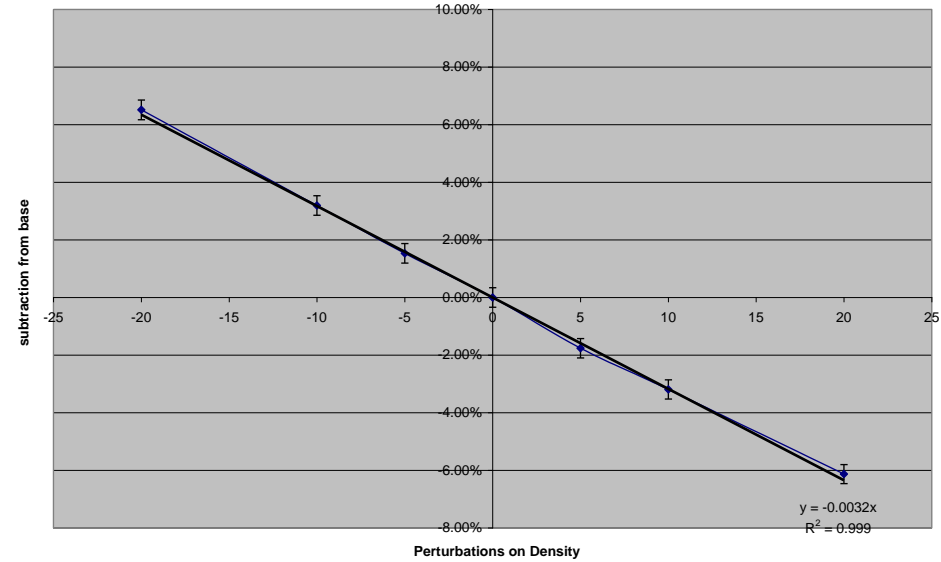
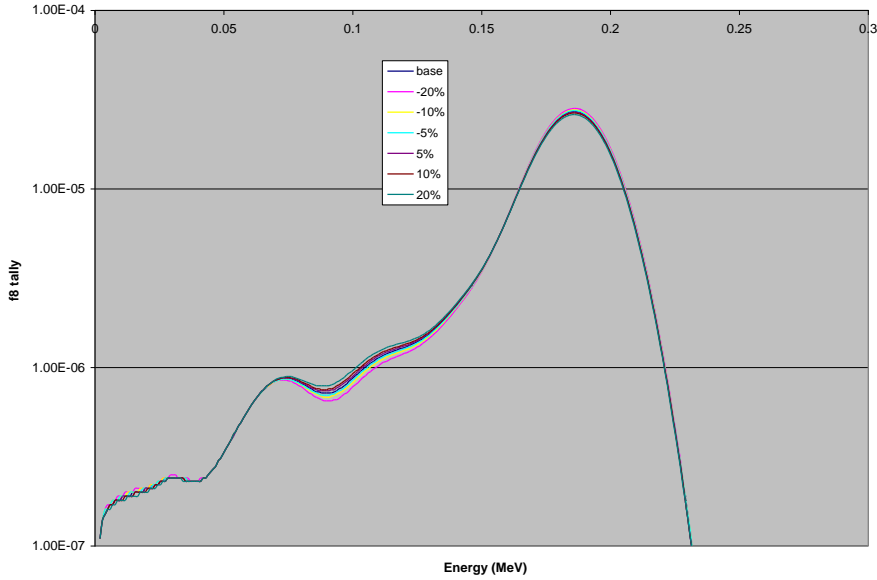


subtraction from base tot

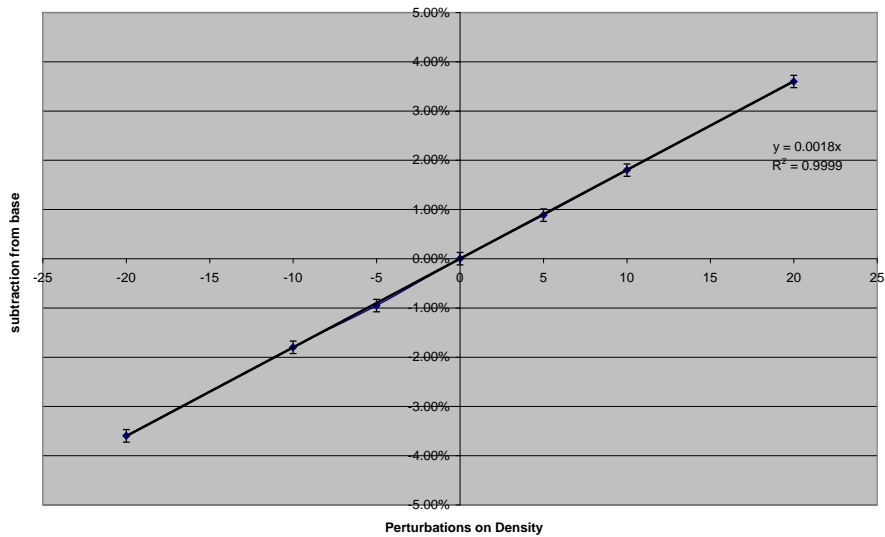


All

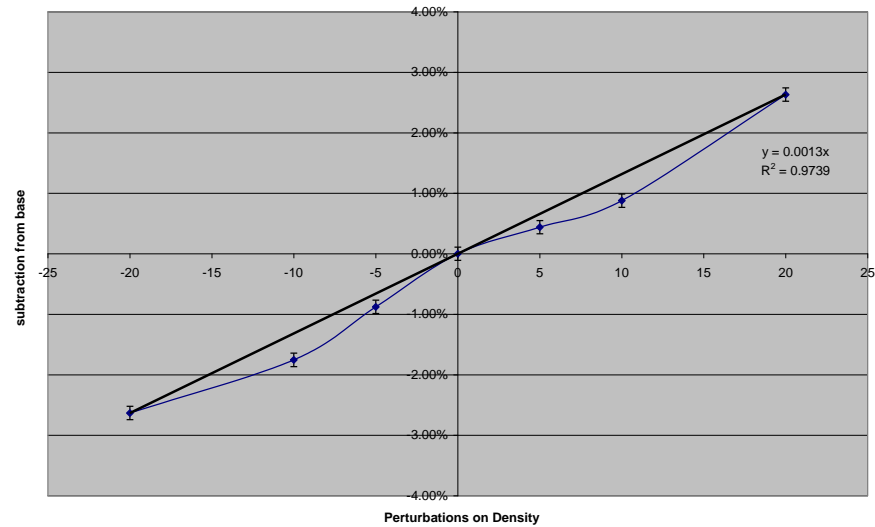
subtraction from base 1



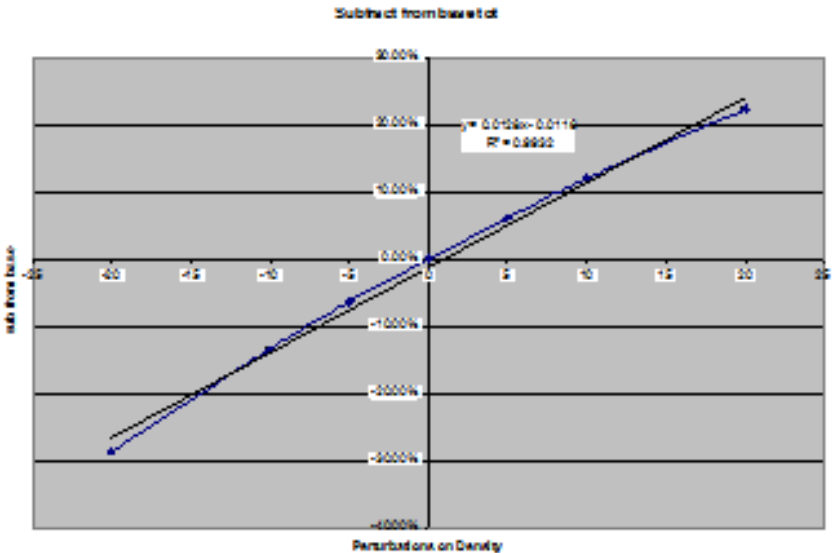
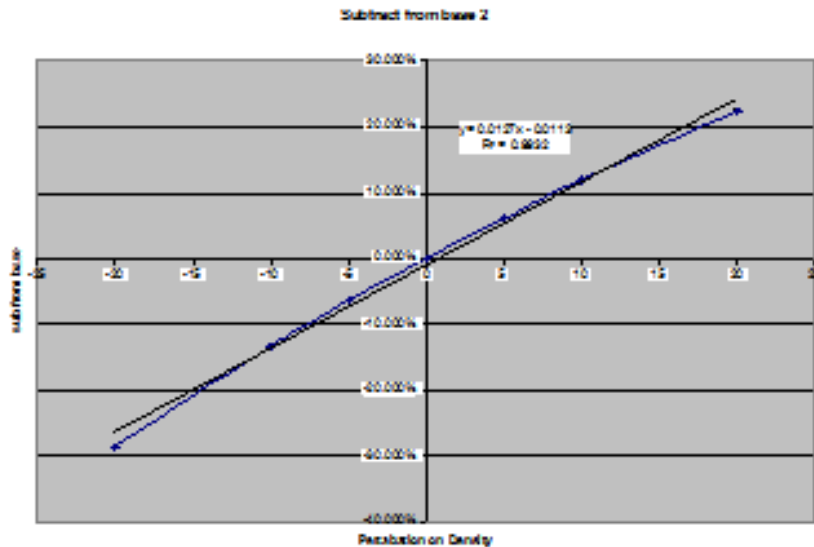
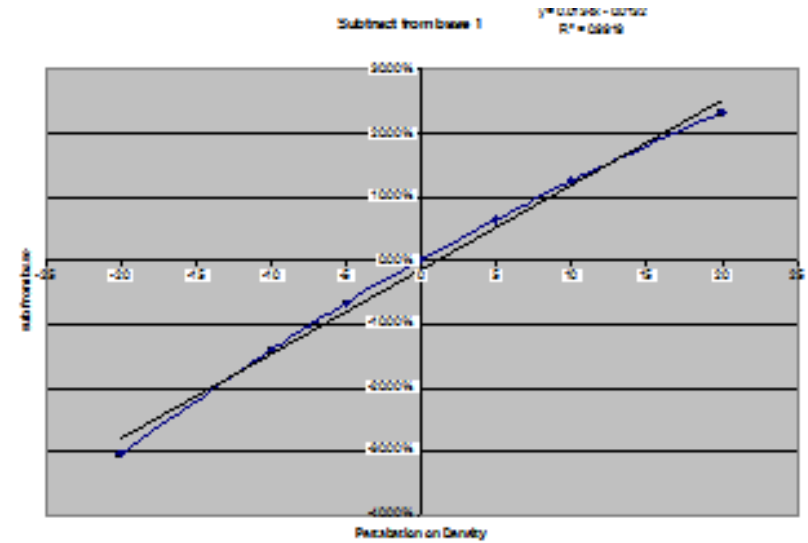
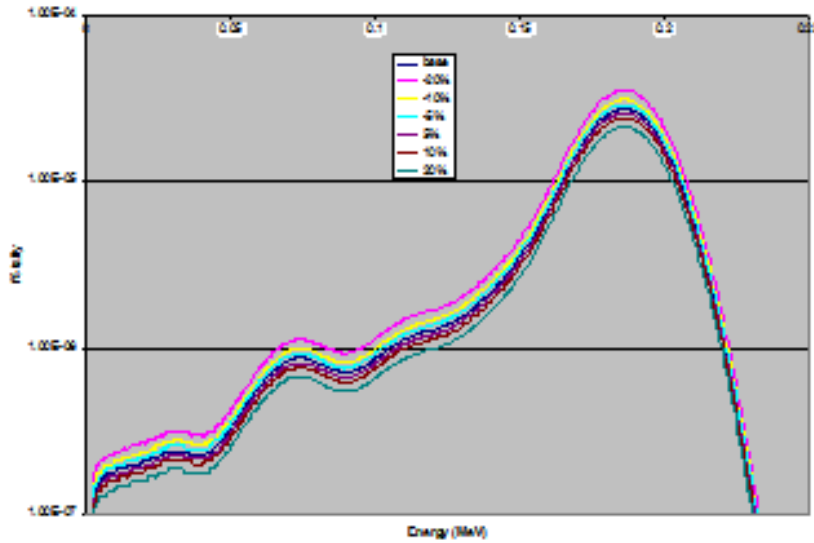
subtraction from base 2



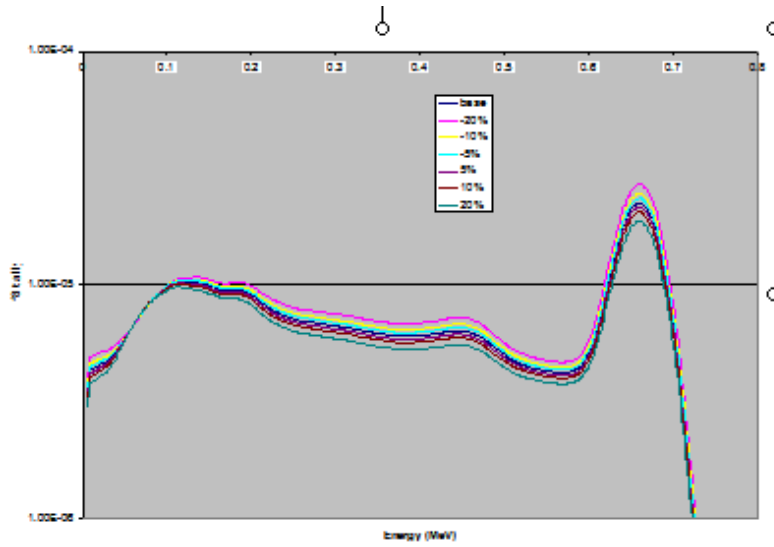
subtraction from base tot



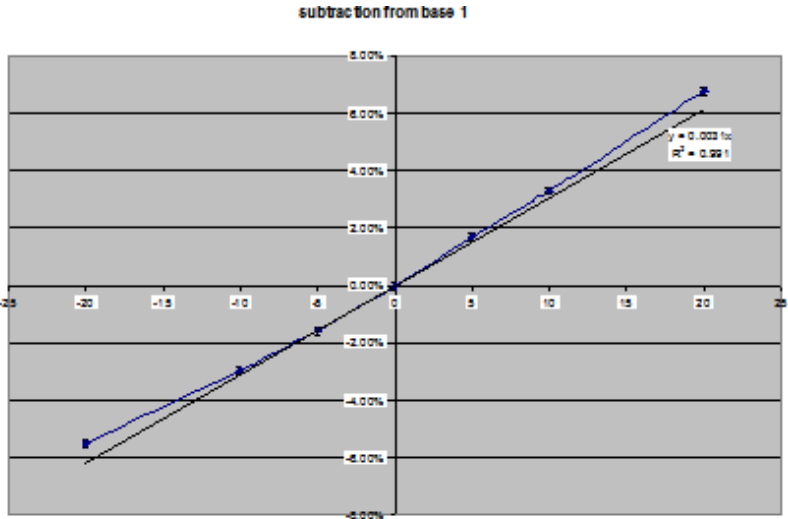
Lead Perturbation



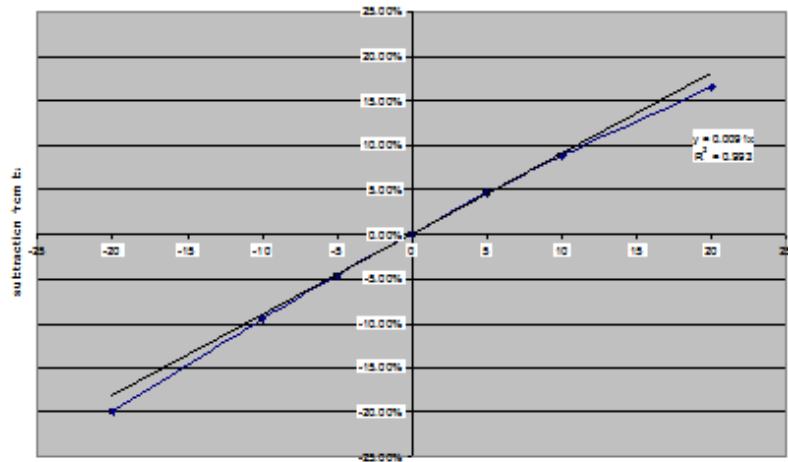
Lead-Wood



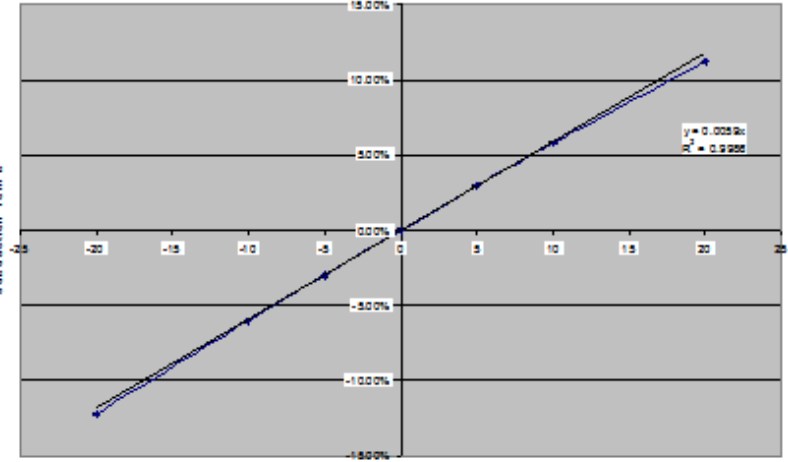
subtraction from base 2



subtraction from base 1a

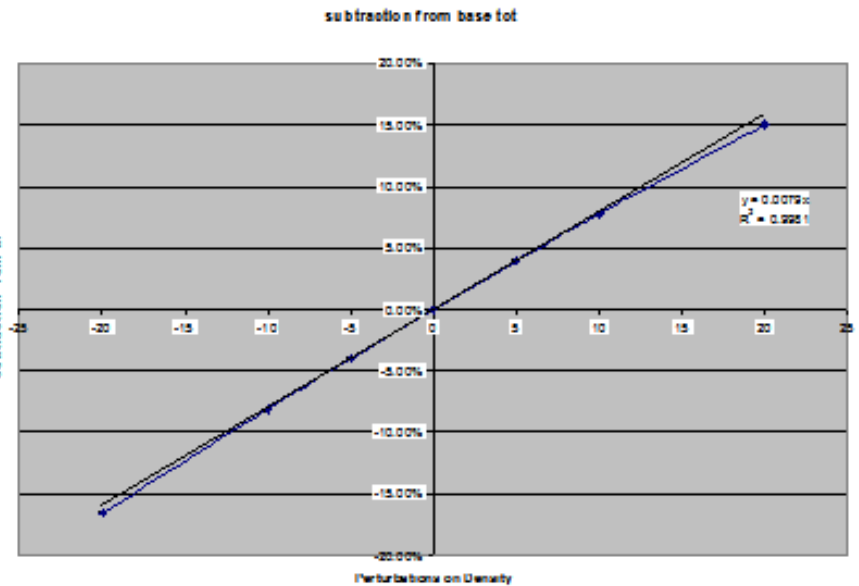
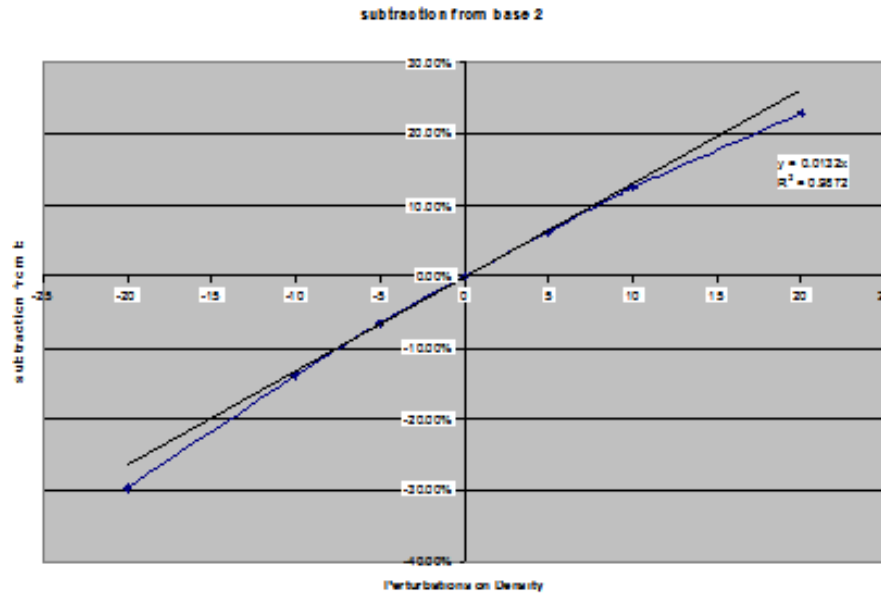
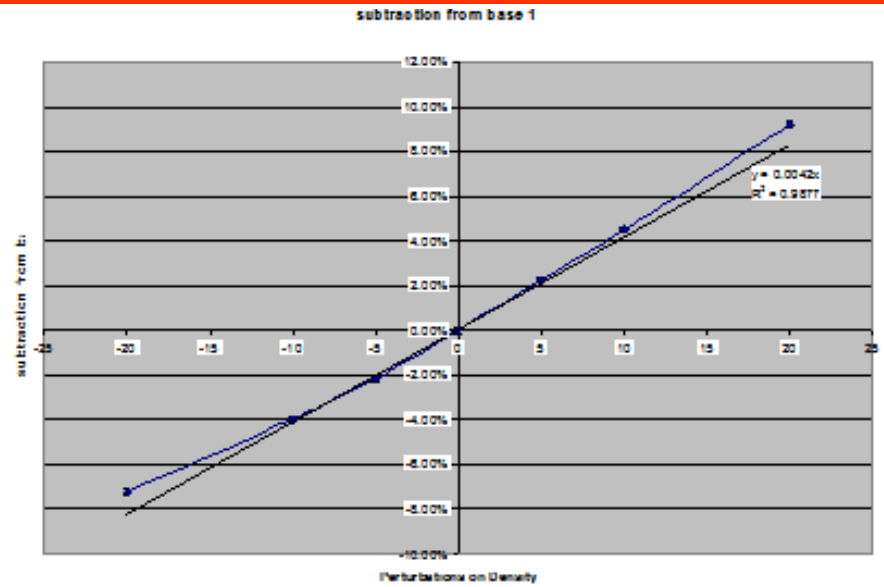
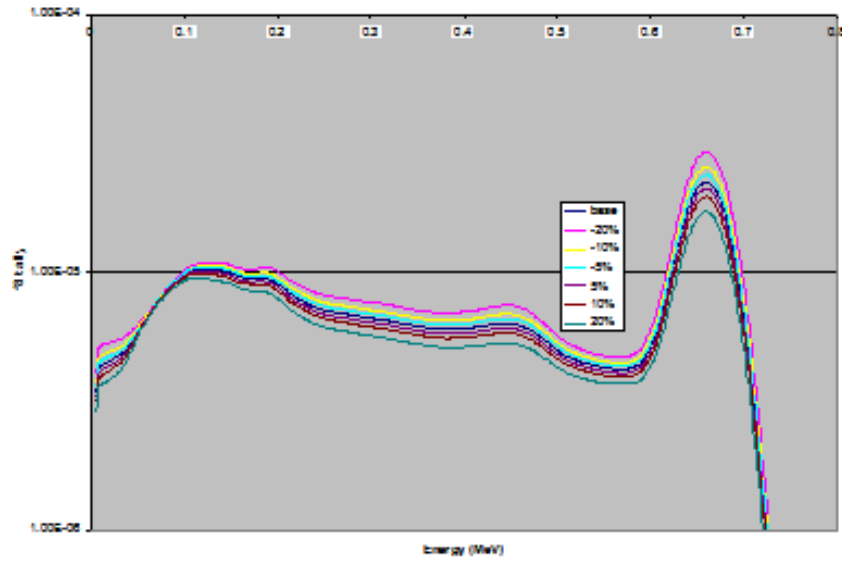


Perturbations on Density



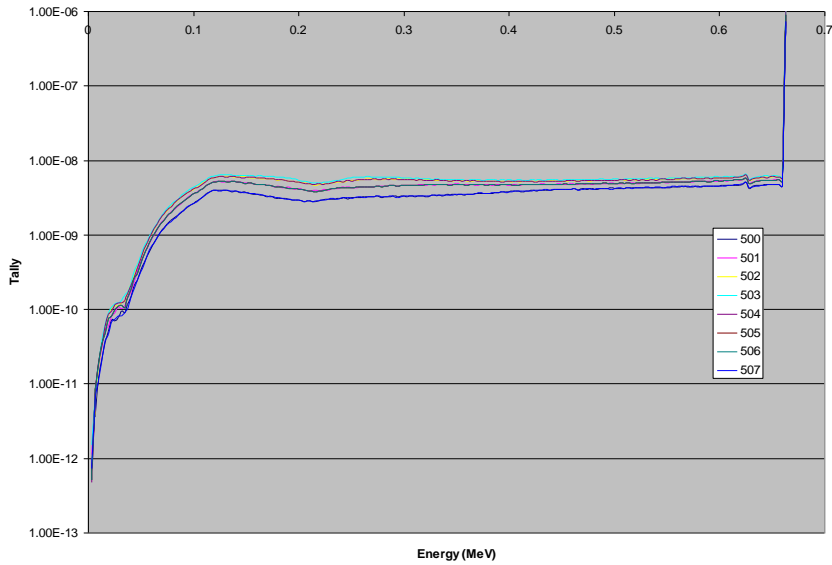
Perturbations on Density

All

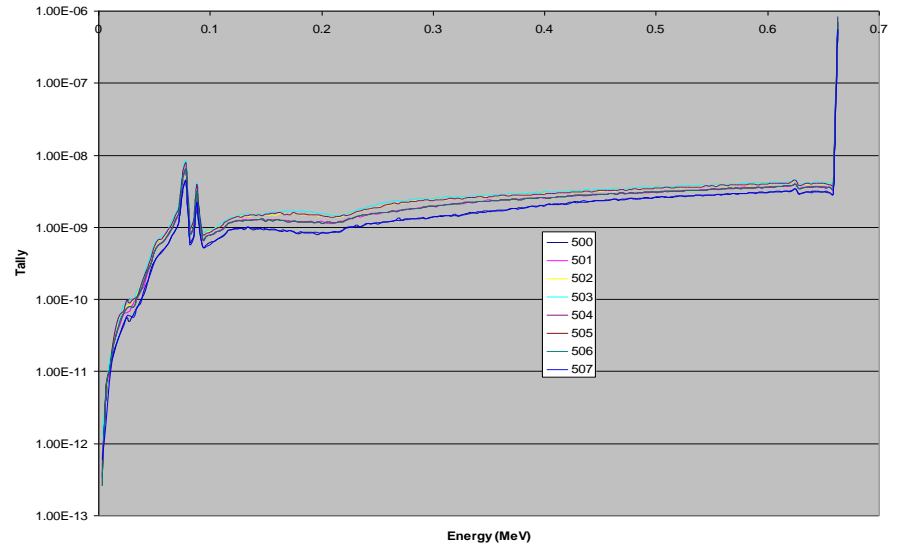


Taking out materials

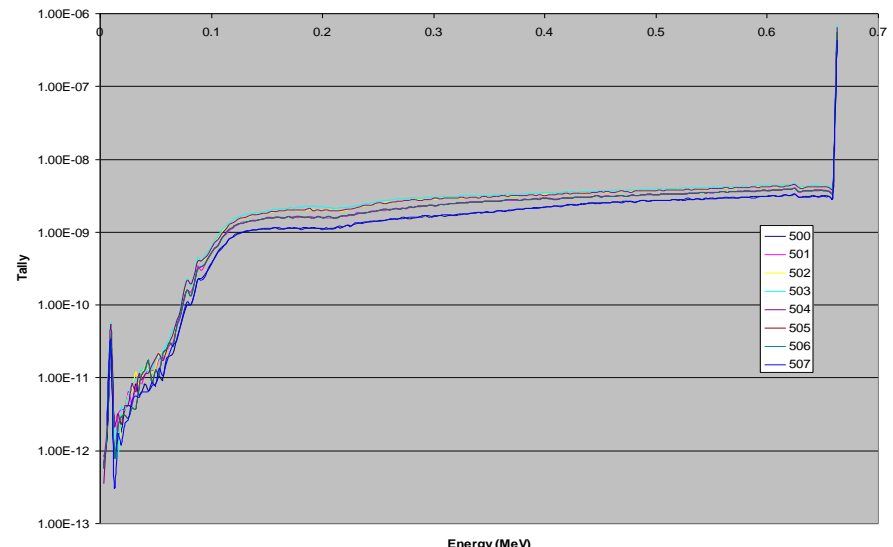
No Lead



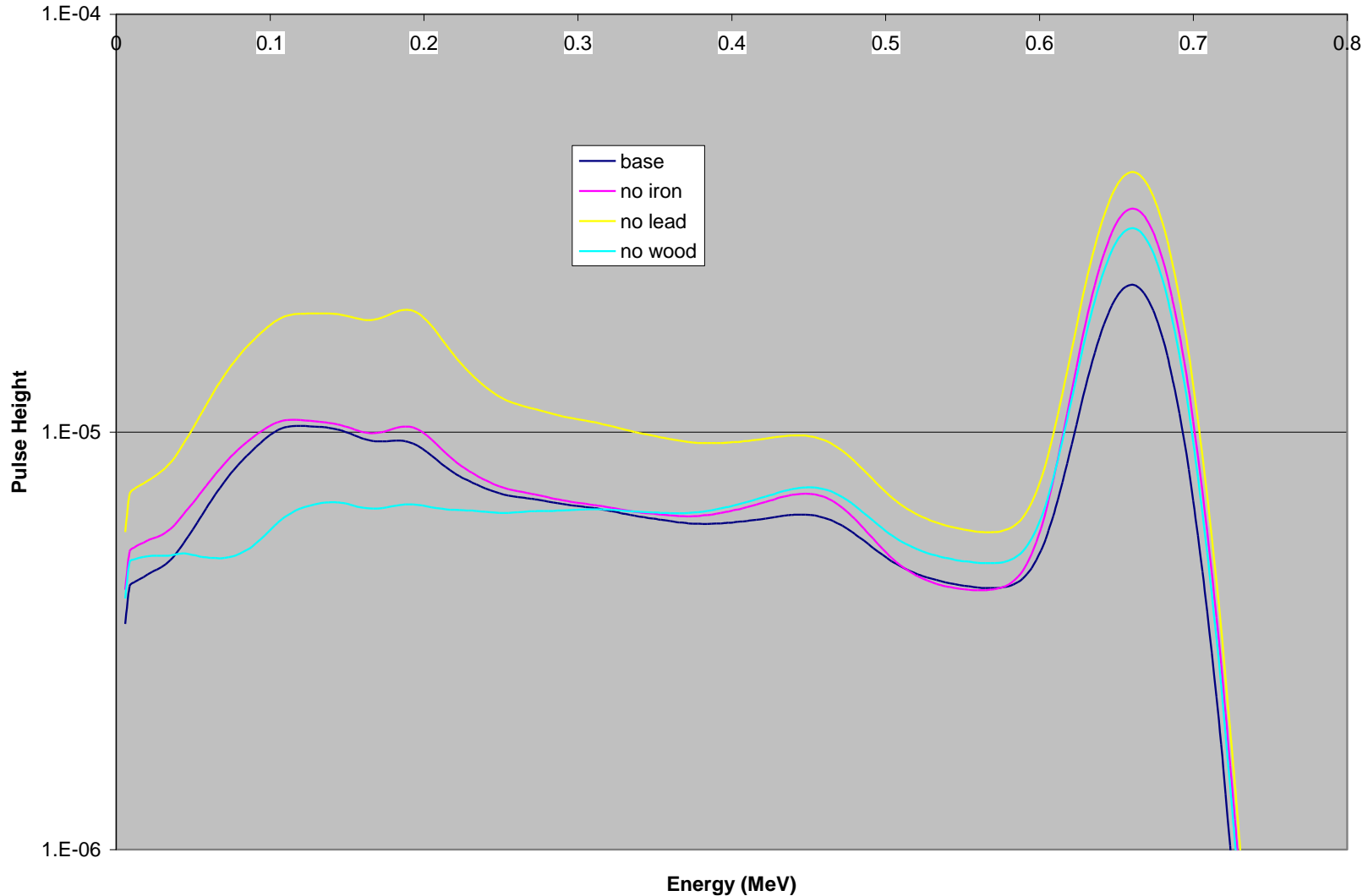
No Iron



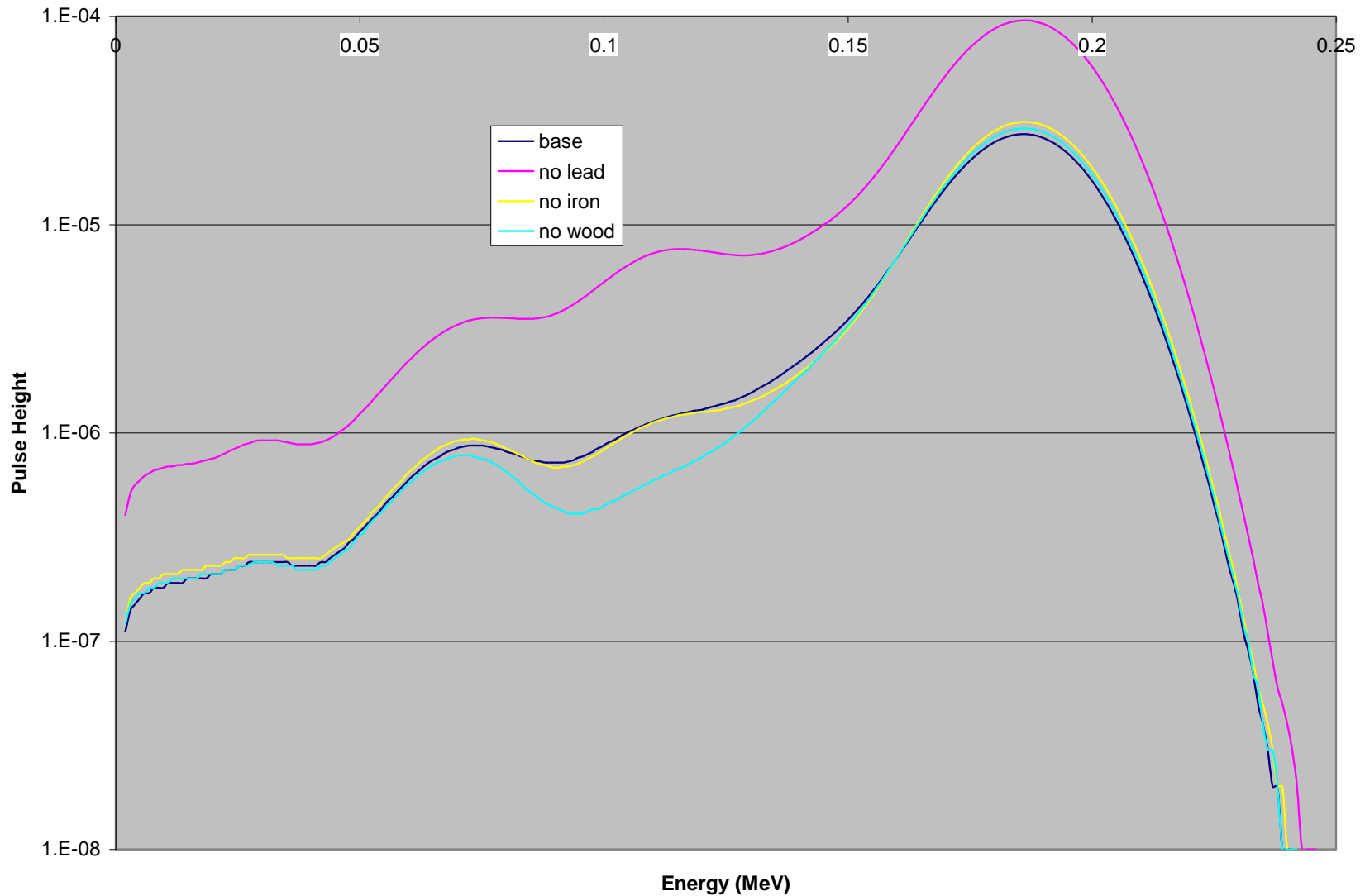
No Wood



Taking out Materials -- Cesium



Taking out Materials -- Uranium

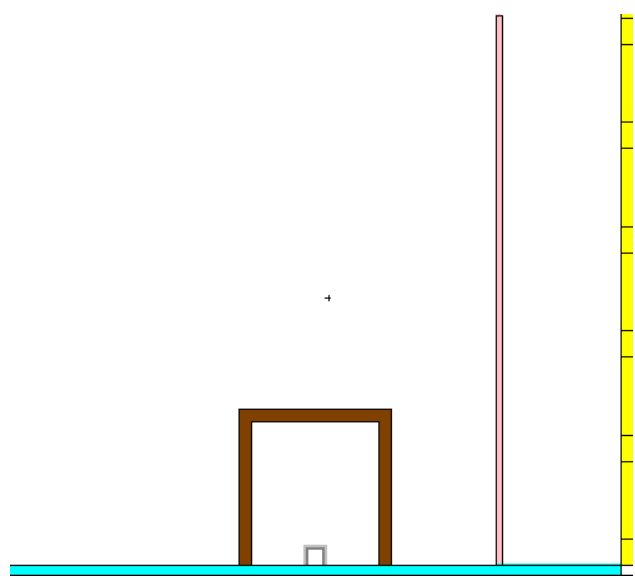


Case Studies

Case Studies



- ❑ Typical Fertilizer -> NPK mix 15:2:5
- ❑ Rice->25% Carbon, 50% Hydrogen, 25% Hydrogen
- ❑ Electronics-> 100% Silicon



Fertilizer	Chemical composition	S content (%) ^a
S Fertilizers		
Elemental S	S	99.6
Agric-S	S	90.0
Gypsum	CaSO ₄ · 2H ₂ O	18.6
Commercial gypsum	CaSO ₄ · 2H ₂ O + impurities	13–14
Pyrites	FeS ₂	53.5
N Fertilizers		
Ammonium sulfate	(NH ₄) ₂ SO ₄	23.7
Urea sulfur		10
Ammonium phosphate sulfate	(NH ₄) ₂ SO ₄ + NH ₄ H ₂ PO ₄ + (NH ₄) ₂ HPO ₄	15.5
P Fertilizers		
Ordinary superphosphate (OSP)	Ca(H ₂ PO ₄) ₂ + CaSO ₄ · 2H ₂ O	13.9
Concentrated superphosphate (CSP)	Ca(H ₂ PO ₄) ₂	1.5
Ammoniated OSP		12
Ammoniated CSP		1.4
K Fertilizers		
Potassium sulfate	K ₂ SO ₄	17.6
Potassium magnesium sulfate	K ₂ SO ₄ · 2 MgSO ₄	22.0
Others		
Copper sulfate	CuSO ₄ · 5H ₂ O	12.8
Zinc sulfate	ZnSO ₄ · H ₂ O	17.8
Manganese sulfate	MnSO ₄ · 4H ₂ O	14.5
Magnesium sulfate (Epsom salt)	MgSO ₄ · 7H ₂ O	13.0
Ammonium thiosulfate	(NH ₄) ₂ S ₂ O ₃	43.3

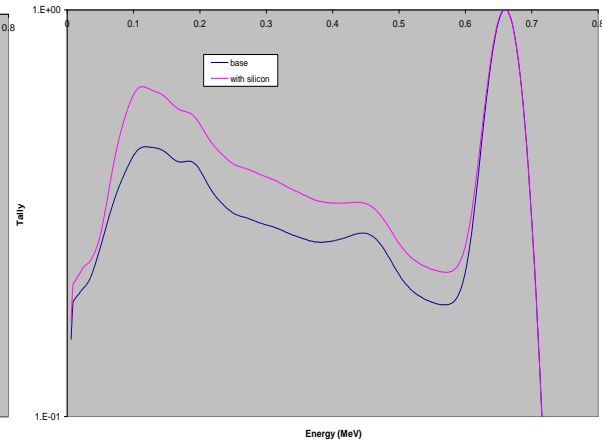
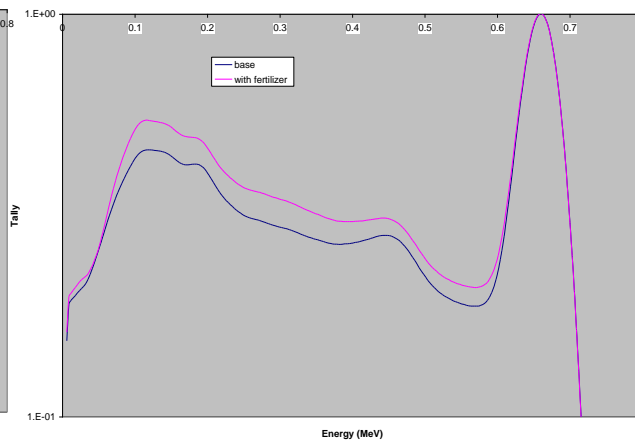
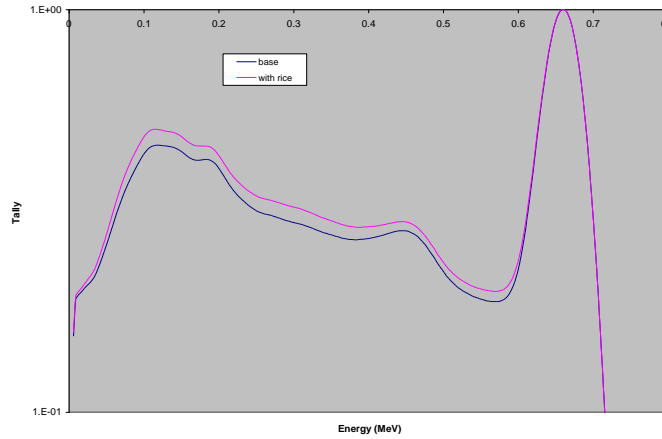
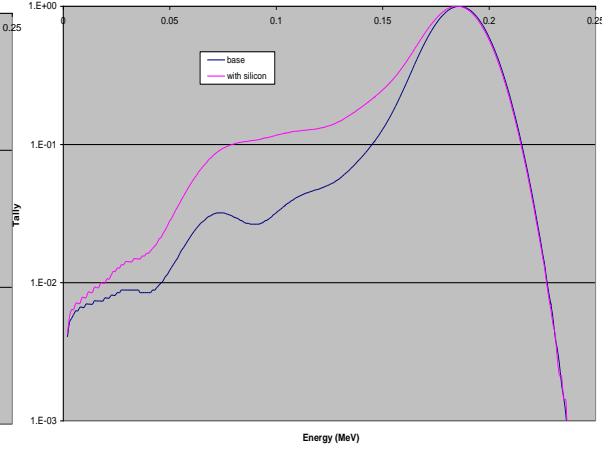
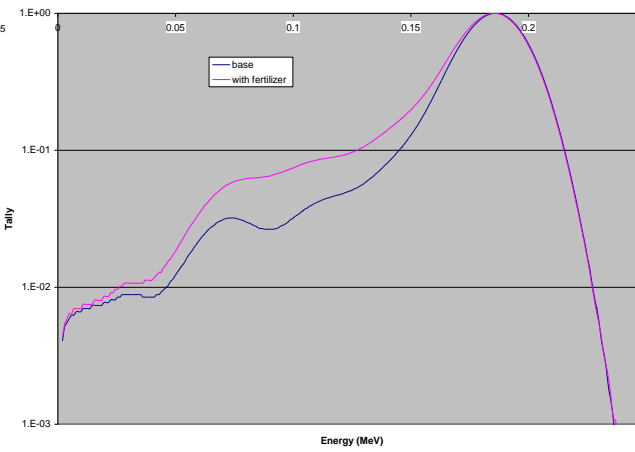
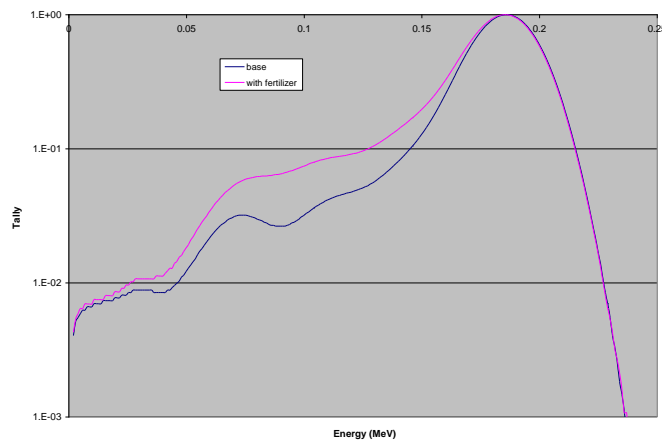
^a Commercial grades generally contain somewhat lesser values.

Case studies

Rice

Fertilizer

Electronics

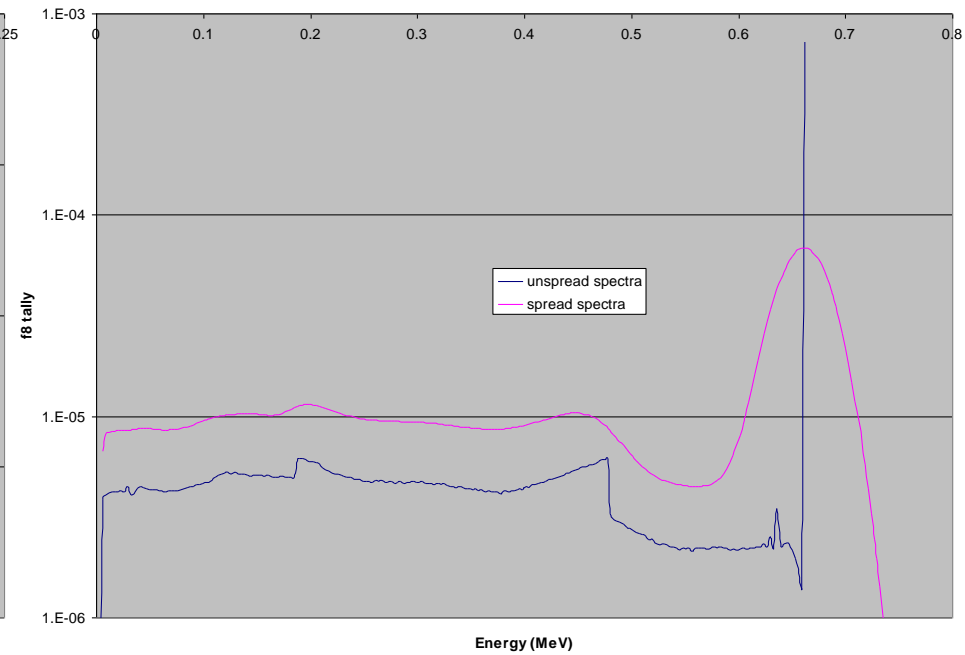
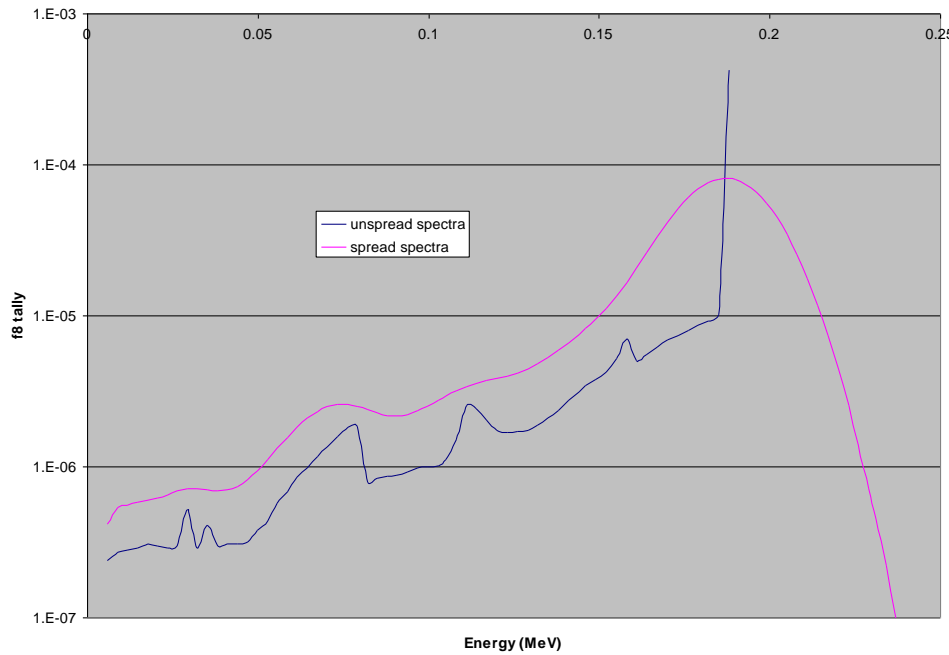


Differential Operator File Setup

MCNP runs

- ❑ Reference spectra for the thickness of lead, iron, and wood are 0.1, 0.1442, and 0.71 cm respectively for both energies
- ❑ Unknown spectra that has 0.108, 0.146, and 0.68 cm shielding of lead, iron and wood respectively for both energies
- ❑ +/- 5% density for lead, iron and wood for both energies at reference file thickness

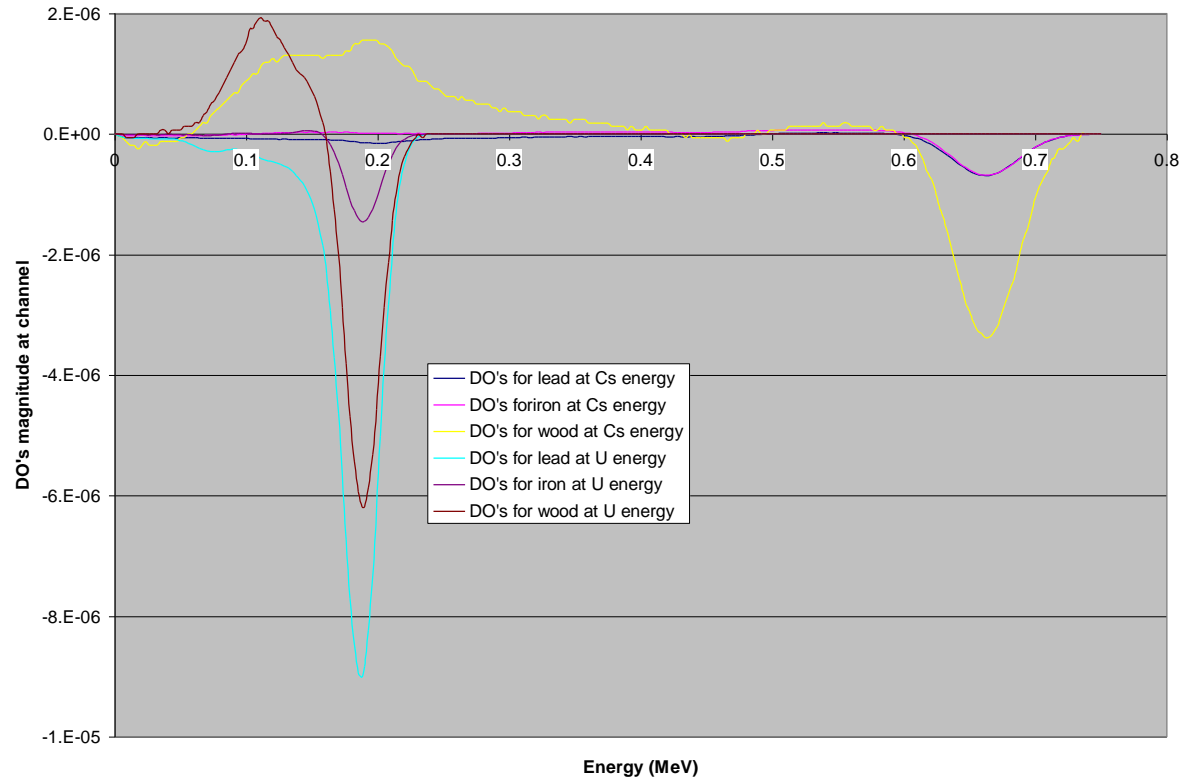
Spreading Spectra



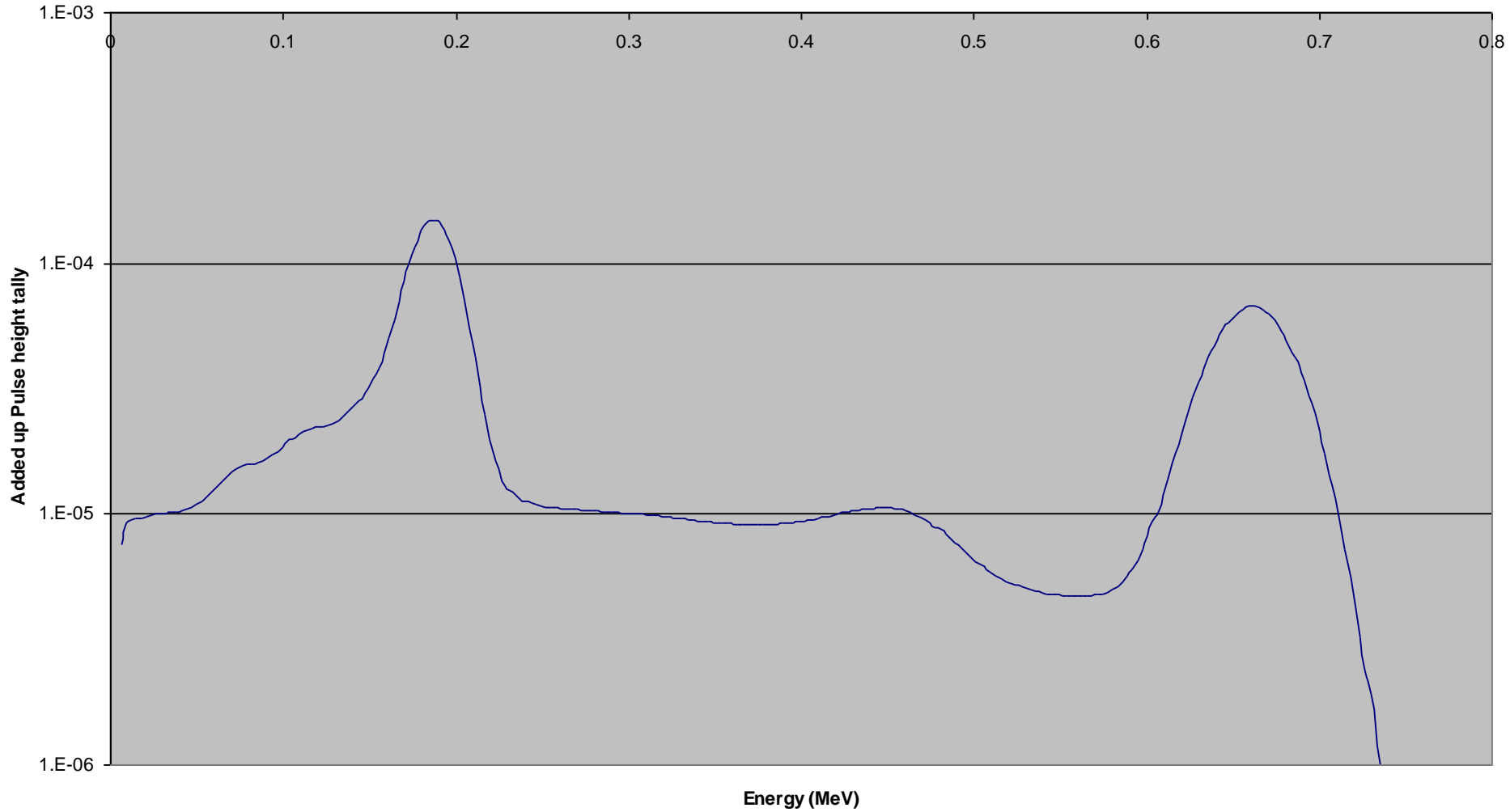
DO Derivation

$$D.O._{ref-5\%} = \frac{R_{ref} - R_{-5\%}}{\rho_{ref} - \rho_{-5\%}}$$

$$D.O._{ref-5\%} = \frac{R_{ref} - R_{-5\%}}{\rho_{ref} - \rho_{-5\%}}$$



Unknown Spectra



Setup Verification File

chan #	Uknown added	ref lib Cs	ref lib U	DO for Pb	DO for Fe	Cs			U	
						DO for Wd	DO for Pb	DO for Fe	DO for Wd	DO for Fe
1	0.00E+00	0	0	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	7.53E-06	6.7E-06	4.2E-07	-4.85E-08	-1.91E-08	-6.25E-08	-4.85E-08	-6.35E-09	0.00E+00	0.00E+00
3	9.27E-06	8.22E-06	5.4E-07	-5.73E-08	-2.54E-08	-1.25E-07	-6.17E-08	-6.35E-09	-6.25E-08	-6.25E-08
4	9.48E-06	8.37E-06	5.6E-07	-5.73E-08	-2.54E-08	-1.87E-07	-6.17E-08	-6.35E-09	-6.25E-08	-6.25E-08
5	9.58E-06	8.43E-06	5.8E-07	-5.73E-08	-2.54E-08	-1.87E-07	-6.61E-08	-6.35E-09	-6.25E-08	-6.25E-08
6	9.67E-06	8.46E-06	6E-07	-6.17E-08	-2.54E-08	-2.50E-07	-7.05E-08	-6.35E-09	0.00E+00	0.00E+00
7	9.77E-06	8.5E-06	6.2E-07	-5.73E-08	-1.91E-08	-1.87E-07	-7.05E-08	-6.35E-09	0.00E+00	0.00E+00
8	9.87E-06	8.52E-06	6.5E-07	-5.73E-08	-2.54E-08	-1.25E-07	-7.05E-08	-6.35E-09	0.00E+00	0.00E+00
9	9.98E-06	8.54E-06	6.9E-07	-6.17E-08	-3.18E-08	-1.87E-07	-7.93E-08	-1.27E-08	0.00E+00	0.00E+00
10	1.01E-05	8.54E-06	7.2E-07	-6.61E-08	-2.54E-08	-1.87E-07	-7.93E-08	-6.35E-09	0.00E+00	0.00E+00
11	1.01E-05	8.55E-06	7.2E-07	-6.61E-08	-3.18E-08	-1.87E-07	-7.93E-08	-1.27E-08	0.00E+00	0.00E+00
12	1.01E-05	8.59E-06	7.1E-07	-6.17E-08	-3.18E-08	-1.25E-07	-7.93E-08	-6.35E-09	6.25E-08	6.25E-08
13	1.02E-05	8.65E-06	6.9E-07	-6.17E-08	-3.18E-08	-1.25E-07	-7.93E-08	-6.35E-09	6.25E-08	6.25E-08
14	1.03E-05	8.71E-06	7E-07	-6.61E-08	-3.18E-08	-1.25E-07	-7.93E-08	0.00E+00	0.00E+00	0.00E+00
15	1.04E-05	8.73E-06	7.4E-07	-6.61E-08	-3.18E-08	-1.25E-07	-8.37E-08	-6.35E-09	6.25E-08	6.25E-08
16	1.06E-05	8.72E-06	8.2E-07	-6.61E-08	-2.54E-08	-1.25E-07	-9.25E-08	-6.35E-09	6.25E-08	6.25E-08
17	1.09E-05	8.69E-06	9.4E-07	-6.17E-08	-2.54E-08	-6.25E-08	-1.10E-07	-6.35E-09	6.25E-08	6.25E-08
18	1.13E-05	8.65E-06	1.11E-06	-6.17E-08	-2.54E-08	-6.25E-08	-1.28E-07	-1.27E-08	1.25E-07	1.25E-07
19	1.17E-05	8.62E-06	1.33E-06	-6.17E-08	-3.18E-08	0.00E+00	-1.50E-07	-6.35E-09	1.25E-07	1.25E-07
20	1.23E-05	8.59E-06	1.57E-06	-6.17E-08	-3.18E-08	7.94E-23	-1.76E-07	-1.27E-08	1.25E-07	1.25E-07
21	1.29E-05	8.58E-06	1.83E-06	-6.17E-08	-2.54E-08	6.25E-08	-2.03E-07	-1.91E-08	1.88E-07	1.88E-07
22	1.35E-05	8.57E-06	2.1E-06	-6.61E-08	-3.18E-08	1.25E-07	-2.38E-07	-1.91E-08	1.88E-07	1.88E-07
23	1.41E-05	8.58E-06	2.32E-06	-6.61E-08	-2.54E-08	1.88E-07	-2.64E-07	-2.54E-08	3.13E-07	3.13E-07
24	1.47E-05	8.6E-06	2.5E-06	-6.61E-08	-1.91E-08	1.87E-07	-2.82E-07	-3.18E-08	3.75E-07	3.75E-07
25	1.52E-05	8.63E-06	2.59E-06	-6.61E-08	-1.91E-08	3.12E-07	-2.91E-07	-2.54E-08	5.00E-07	5.00E-07
26	1.55E-05	8.68E-06	2.6E-06	-7.05E-08	-1.91E-08	3.75E-07	-2.95E-07	-1.91E-08	5.63E-07	5.63E-07
27	1.58E-05	8.74E-06	2.52E-06	-7.05E-08	-1.27E-08	4.38E-07	-2.91E-07	-1.27E-08	6.88E-07	6.88E-07
28	1.59E-05	8.81E-06	2.41E-06	-7.05E-08	-1.27E-08	5.00E-07	-2.78E-07	-6.35E-09	8.13E-07	8.13E-07
29	1.61E-05	8.89E-06	2.28E-06	-7.05E-08	-1.27E-08	5.63E-07	-2.60E-07	0.00E+00	9.38E-07	9.38E-07
30	1.64E-05	8.99E-06	2.19E-06	-7.05E-08	-6.35E-09	6.25E-07	-2.56E-07	6.35E-09	1.06E-06	1.06E-06
31	1.67E-05	9.1E-06	2.17E-06	-7.05E-08	-1.27E-08	6.88E-07	-2.51E-07	1.27E-08	1.19E-06	1.19E-06
32	1.72E-05	9.22E-06	2.22E-06	-7.05E-08	-6.35E-09	6.87E-07	-2.60E-07	1.27E-08	1.31E-06	1.31E-06
33	1.79E-05	9.35E-06	2.34E-06	-7.05E-08	-6.35E-09	8.12E-07	-2.73E-07	1.27E-08	1.38E-06	1.38E-06
34	1.86E-05	9.48E-06	2.52E-06	-7.49E-08	-6.35E-09	8.75E-07	-3.00E-07	1.27E-08	1.50E-06	1.50E-06
35	1.95E-05	9.63E-06	2.78E-06	-7.93E-08	0	9.38E-07	-3.30E-07	1.27E-08	1.75E-06	1.75E-06
36	2.00E-05	9.72E-06	2.94E-06	-7.93E-08	0	1.00E-06	-3.52E-07	6.35E-09	1.75E-06	1.75E-06
37	2.08E-05	9.82E-06	3.18E-06	-7.93E-08	6.35E-09	1.00E-06	-3.79E-07	6.35E-09	1.88E-06	1.88E-06
38	2.13E-05	9.91E-06	3.39E-06	-8.37E-08	6.35E-09	1.13E-06	-4.05E-07	6.35E-09	1.94E-06	1.94E-06



Dr Gardner's Stuff here