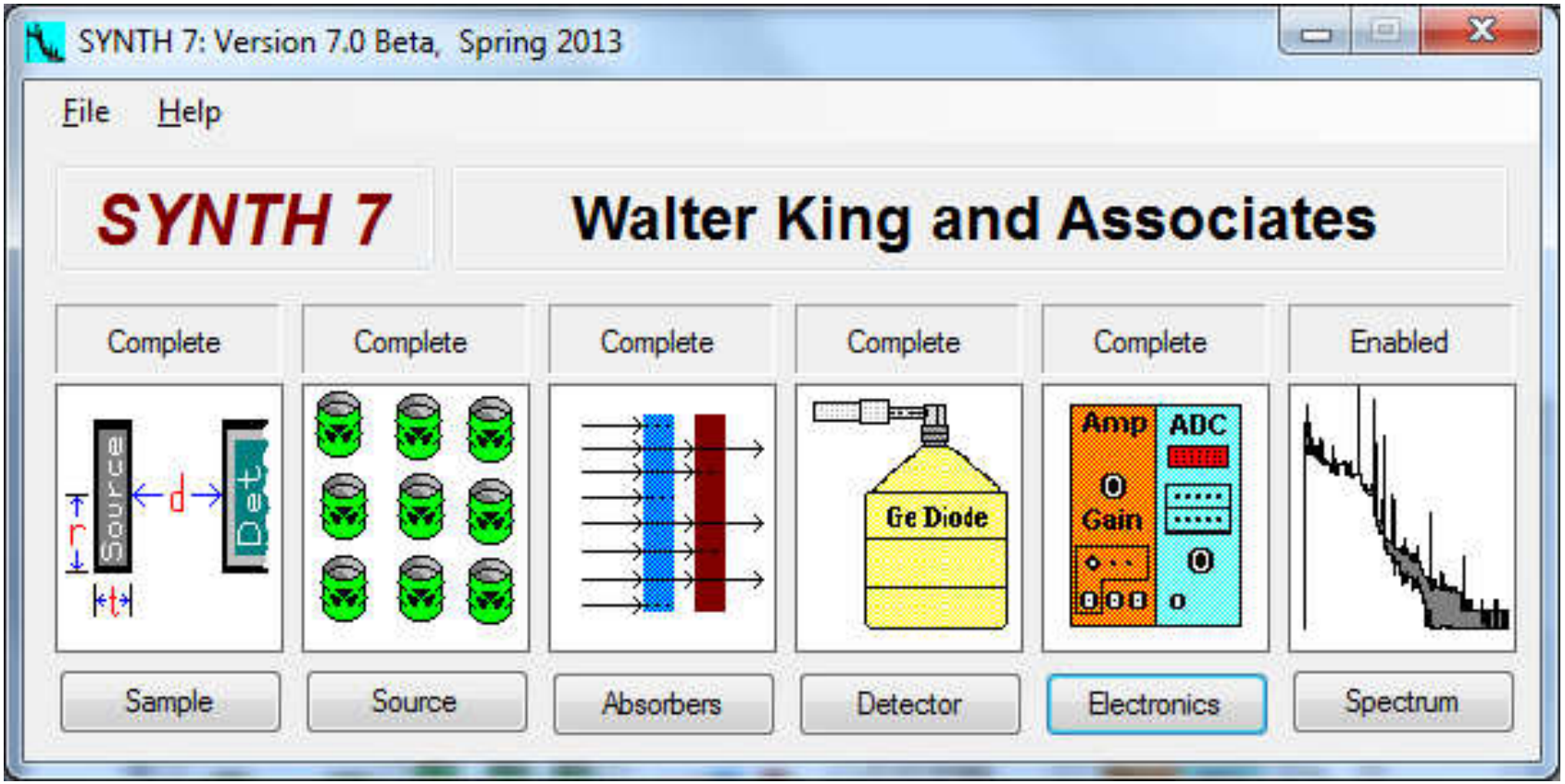
SYNTH 7

A Gamma-Ray Spectrum Generator



Overview

What ***SYNTH 7*** is and does

- A Gamma-Ray Spectroscopy Interface to a very simple deterministic physics engine designed to quickly model gamma-ray measurements

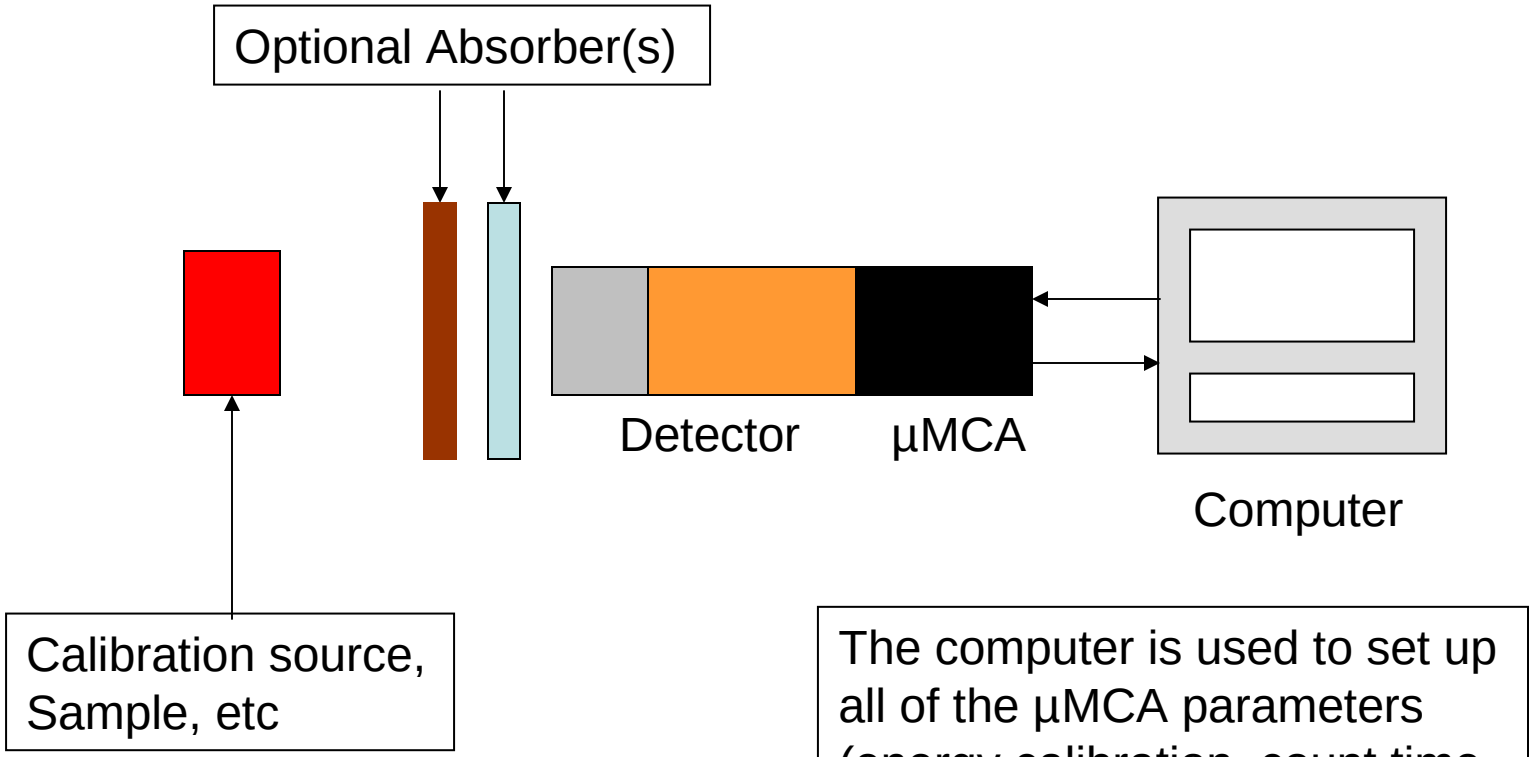
- Uses simplified models and physics (e.g. “transport” is $e^{-\mu x}$, no scattering, no buildup, etc) Because the emphasis is on spectroscopy, the focus is on peak energies, intensities, and shapes. Details of the continuum are secondary

- Organizes the problem into five logical steps

- Because the process is deterministic (hard coded algorithms), as opposed to stochastic (Monte Carlo methods), the spectrum is generated in minutes and is independent of “count time”

- Produces a spectrum that can be viewed and saved in a number of different spectral data formats

An Over Simplified Gamma-Ray Measurement



Five Easy Pieces

(With apologies to Richard Feynman)

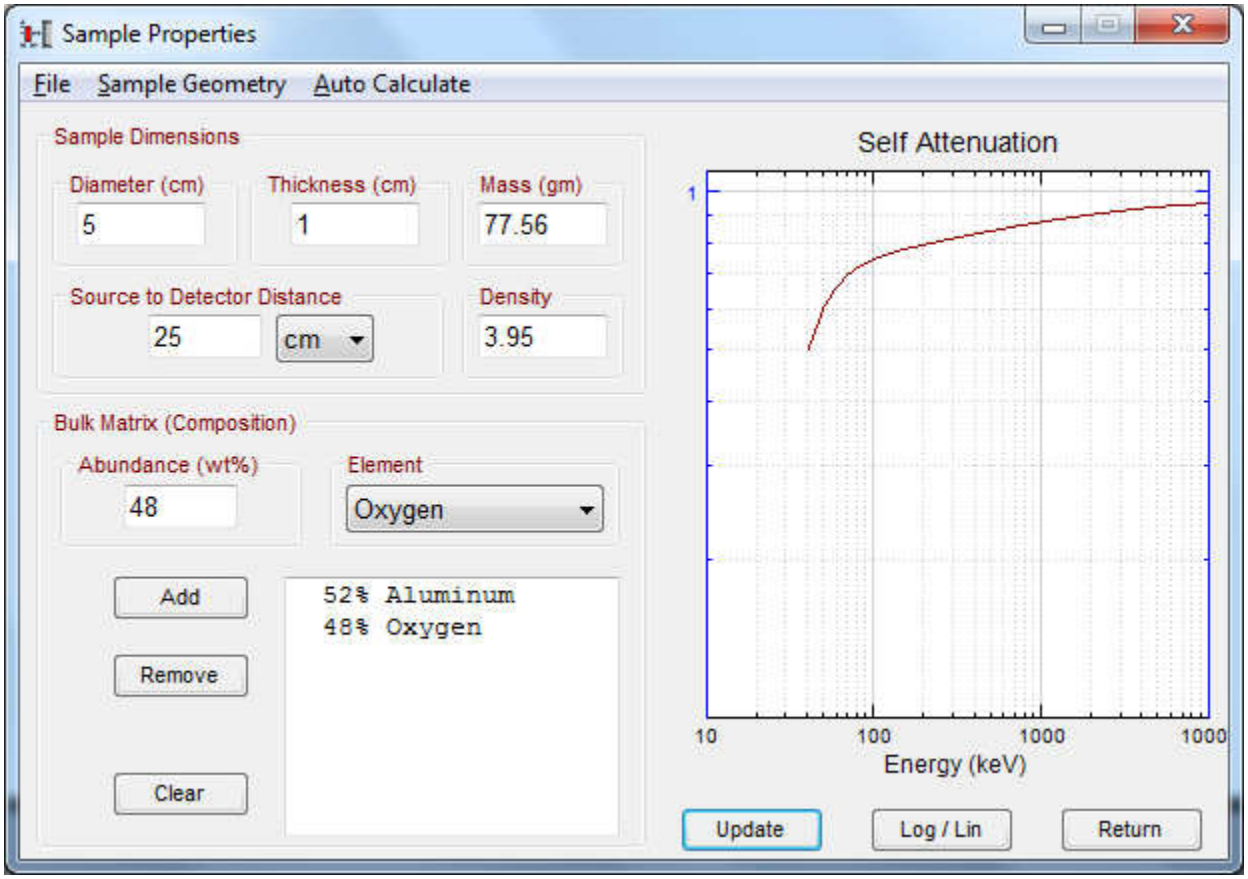
- Sample Geometry and Bulk Composition
- Source Term (^{241}Am, ^{137}Cs, ^{60}Co, etc)
- Absorbers (composition, thickness)
- Detector (type, size, resolution, etc)
- Counting Parameters (energy calibration, etc)

- => Generated Gamma-Ray Spectrum

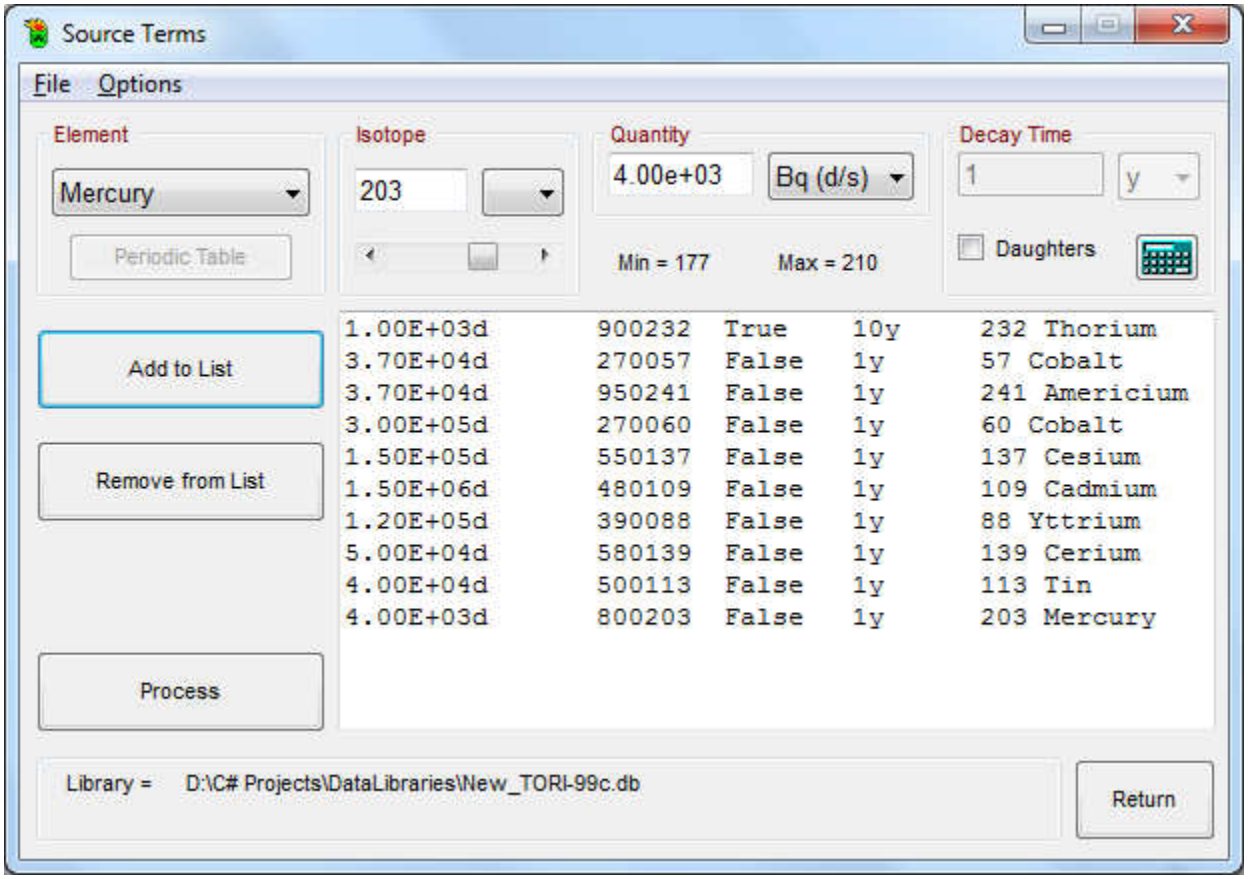
Sample Properties

- Point
  - Location (Distance from detector face)
- Disk
  - Location (Distance from detector face)
  - Composition
    - Mass
    - Size
    - Density

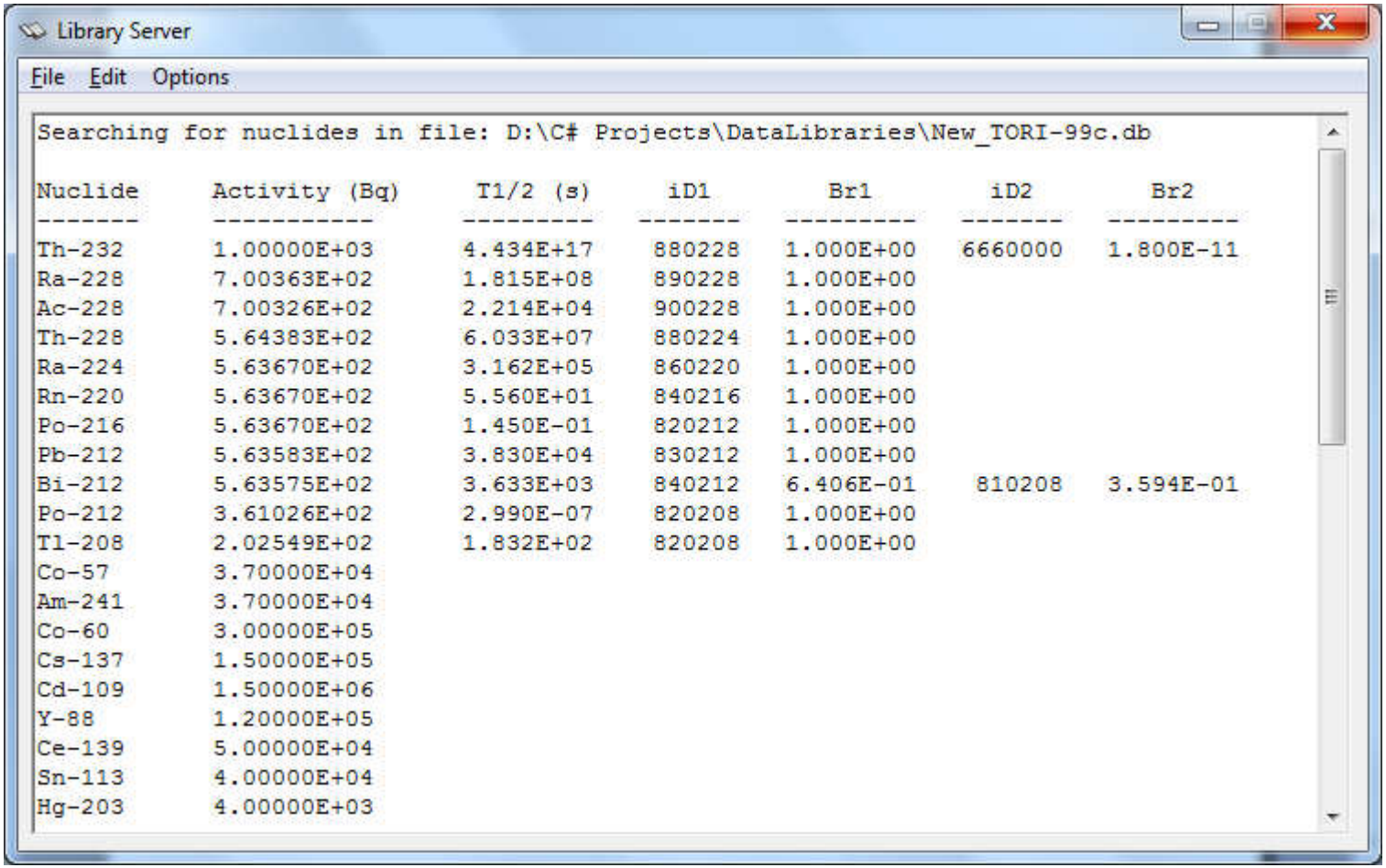
Sample Geometry and Composition



Source Term


Source Terms
File Options
Element
Mercury
Periodic Table
Isotope
203
Quantity
4.00e+03
Bq (d/s)
Min = 177
Max = 210
Decay Time
1
y
Daughters
Add to List
Remove from List
Process
1.00E+03d 900232 True 10y 232 Thorium
3.70E+04d 270057 False 1y 57 Cobalt
3.70E+04d 950241 False 1y 241 Americium
3.00E+05d 270060 False 1y 60 Cobalt
1.50E+05d 550137 False 1y 137 Cesium
1.50E+06d 480109 False 1y 109 Cadmium
1.20E+05d 390088 False 1y 88 Yttrium
5.00E+04d 580139 False 1y 139 Cerium
4.00E+04d 500113 False 1y 113 Tin
4.00E+03d 800203 False 1y 203 Mercury
Library = D:\C# Projects\DataLibraries\New_TORI-99c.db
Return

Library Server



Nuclide	Activity (Bq)	T1/2 (s)	iD1	Br1	iD2	Br2
Th-232	1.00000E+03	4.434E+17	880228	1.000E+00	6660000	1.800E-11
Ra-228	7.00363E+02	1.815E+08	890228	1.000E+00		
Ac-228	7.00326E+02	2.214E+04	900228	1.000E+00		
Th-228	5.64383E+02	6.033E+07	880224	1.000E+00		
Ra-224	5.63670E+02	3.162E+05	860220	1.000E+00		
Rn-220	5.63670E+02	5.560E+01	840216	1.000E+00		
Po-216	5.63670E+02	1.450E-01	820212	1.000E+00		
Pb-212	5.63583E+02	3.830E+04	830212	1.000E+00		
Bi-212	5.63575E+02	3.633E+03	840212	6.406E-01	810208	3.594E-01
Po-212	3.61026E+02	2.990E-07	820208	1.000E+00		
Tl-208	2.02549E+02	1.832E+02	820208	1.000E+00		
Co-57	3.70000E+04					
Am-241	3.70000E+04					
Co-60	3.00000E+05					
Cs-137	1.50000E+05					
Cd-109	1.50000E+06					
Y-88	1.20000E+05					
Ce-139	5.00000E+04					
Sn-113	4.00000E+04					
Hg-203	4.00000E+03					

Gamma-Ray Data Libraries

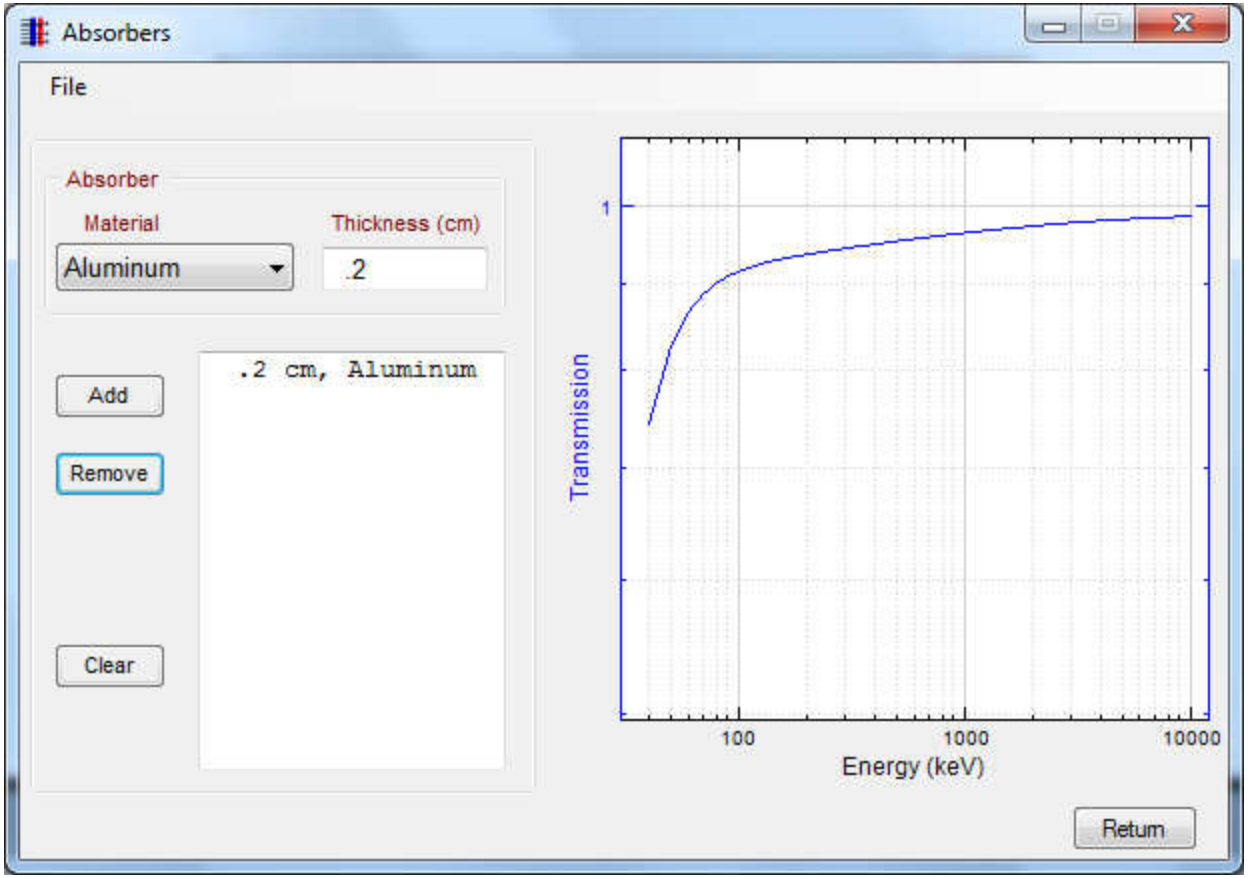
- Enhanced TORI-99 (based on the LBL Table of Radioactive Isotopes compilation revised to 1999)
- PCNuDat (based on the NNDC compilation revised to 2004)
- User Supplied (It’s an open format that can implemented as a Microsoft Access or SQLite database

Absorber Geometry

- Disk
  - Composition
  - Thickness

I said the model was simple!

Absorbers


Absorbers
File
Absorber
Material
Thickness (cm)
Aluminum
.2
Add
Remove
Clear
.2 cm, Aluminum
Transmission
1
100
1000
10000
Energy (keV)
Return

Detectors

- Built-in High Purity Ge (Coaxial and Planar)
- Loadable Detector definitions (pseudo XML)
  NaI, CZT, BGO, CsI, LaX_3, PVT, Other
- Detector definitions can be generated with MCNP, and / or from experimental data

<Efficiency @ 25cm>
40, 4.53E-03
50, 4.78E-03
60, 5.01E-03
70, 5.12E-03
80, 5.22E-03
90, 5.28E-03
100, 5.30E-03
120, 5.30E-03
150, 5.24E-03
200, 5.02E-03
300, 4.32E-03
400, 3.61E-03
500, 3.06E-03
600, 2.61E-03
800, 2.05E-03
1000, 1.70E-03
1500, 1.22E-03
2000, 9.50E-04
3000, 6.71E-04
4000, 5.12E-04
5000, 4.20E-04
6000, 3.49E-04
8000, 2.63E-04
10000, 2.09E-04
</Efficiency @ 25cm>

<Peak-to-Total>
-5.129502308
2.381025409
-0.325915678
0.010552866
</Peak-to-Total>

<Single-Escape-Peak>
-7.2
9.14
-3.965
0.634
</Single-Escape-Peak>

<Double-Escape-Peak>
-7.88
8.78
-3.78
0.6
</Double-Escape-Peak>

<FWHM>
8.478
0.0
7.0
0.65
</FWHM>

<diameter_cm>
7.62
</diameter_cm>

<length_cm>
7.62
</length_cm>

<relative_efficiency>
100
</relative_efficiency>

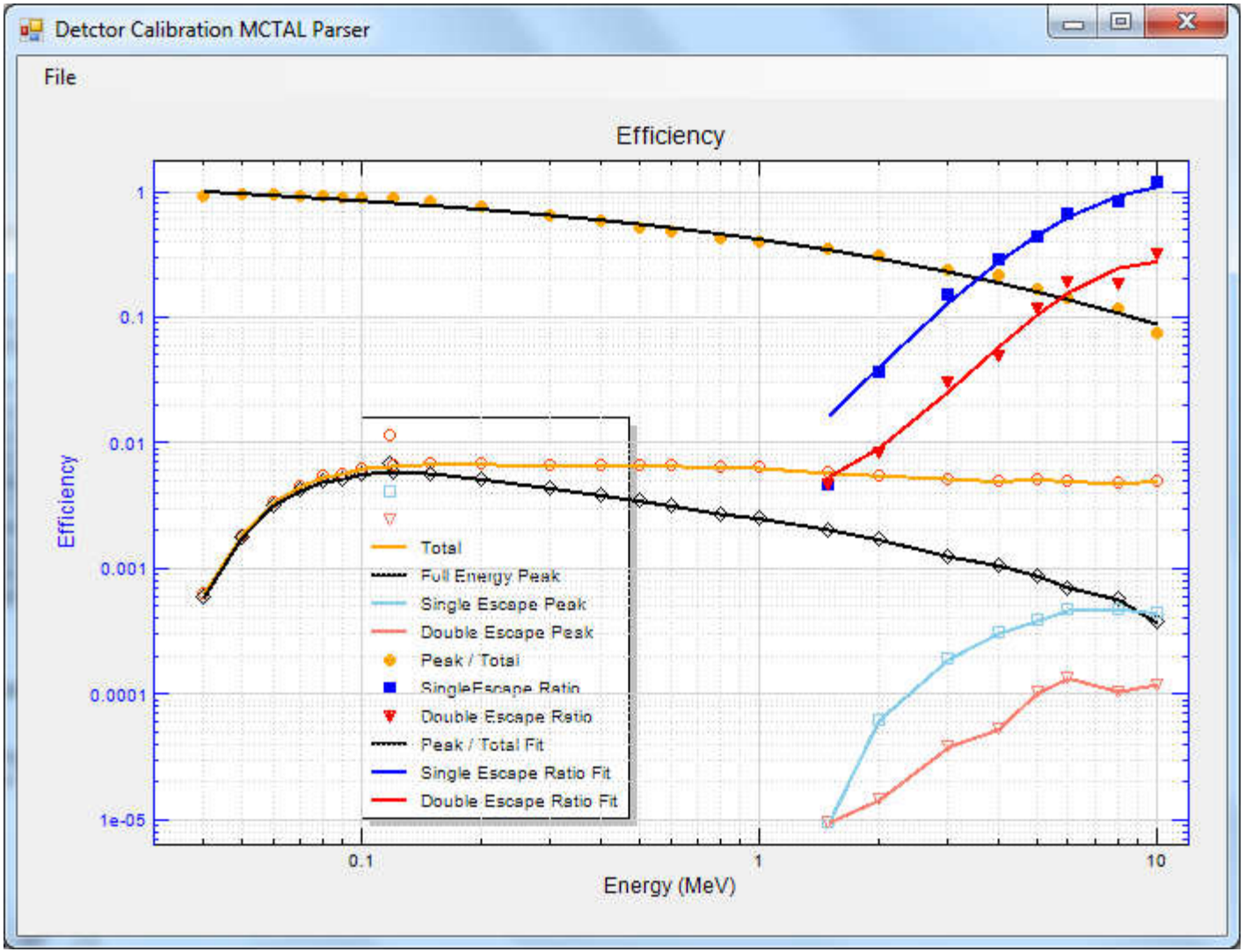
Detector Definition Equations

- Peak / Total = $\mathrm{Exp}(A_o + A_1 \mathrm{Ln}(E/1000) + A_2 \mathrm{Ln}(E/1000)^2 + A_3 \mathrm{Ln}(E/1000)^3)$

- SE / Peak = $\mathrm{Exp}(A_o + A_1 \mathrm{Ln}(E/1000) + A_2 \mathrm{Ln}(E/1000)^2 + A_3 \mathrm{Ln}(E/1000)^3)$

- DE / Peak = $\mathrm{Exp}(A_o + A_1 \mathrm{Ln}(E/1000) + A_2 \mathrm{Ln}(E/1000)^2 + A_3 \mathrm{Ln}(E/1000)^3)$

Detector Definition Sample

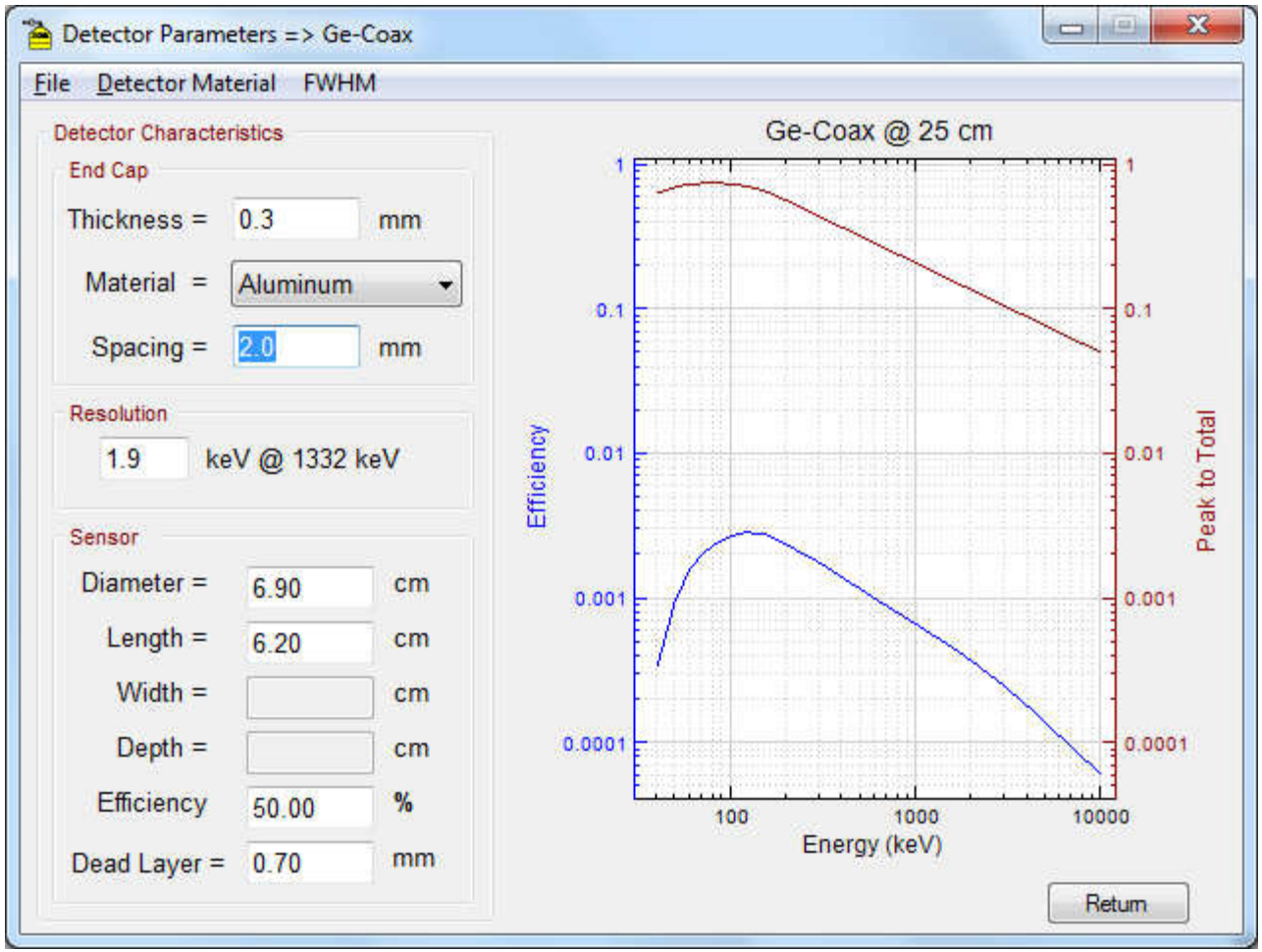


Detectors

- A number of adjustable parameters in addition to the crystal dimensions and resolution

- Standard EndCap materials
  - Beryllium
  - Carbon Fiber
  - Magnesium
  - Aluminum
  - Stainless Steel
  - Copper

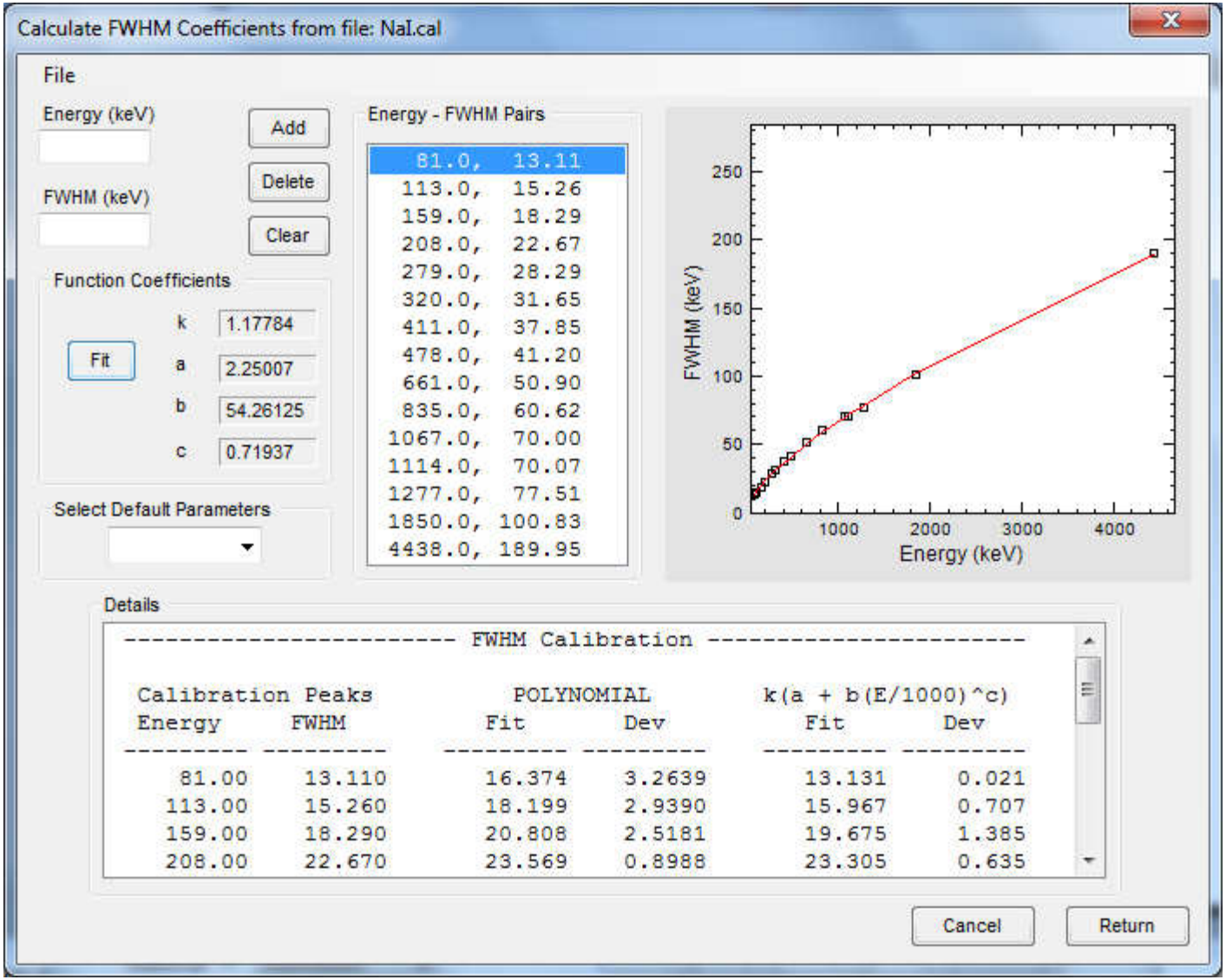
Detector Parameters



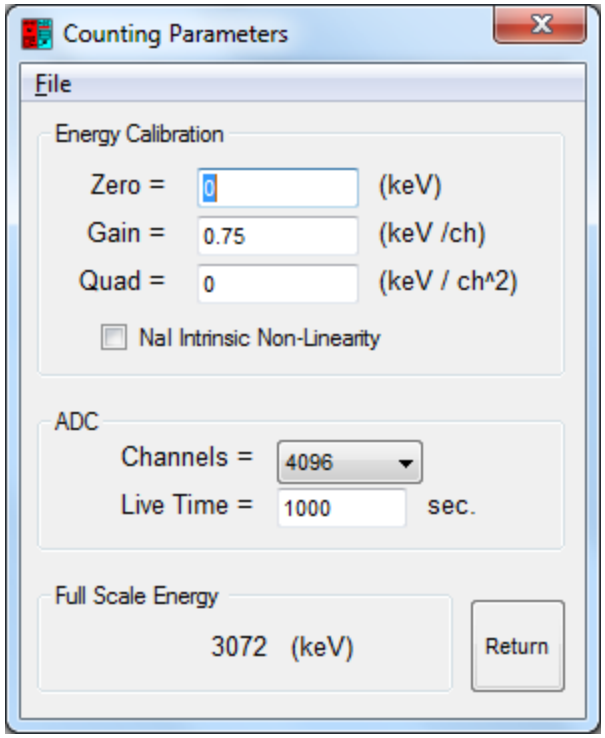
Tool to make life a bit easier

- FWHM coefficient calculator to fit the
  Full Width at Half Maximum function
  $$FWHM = k(a + b(E / 1000)^c)$$
  to experimental data

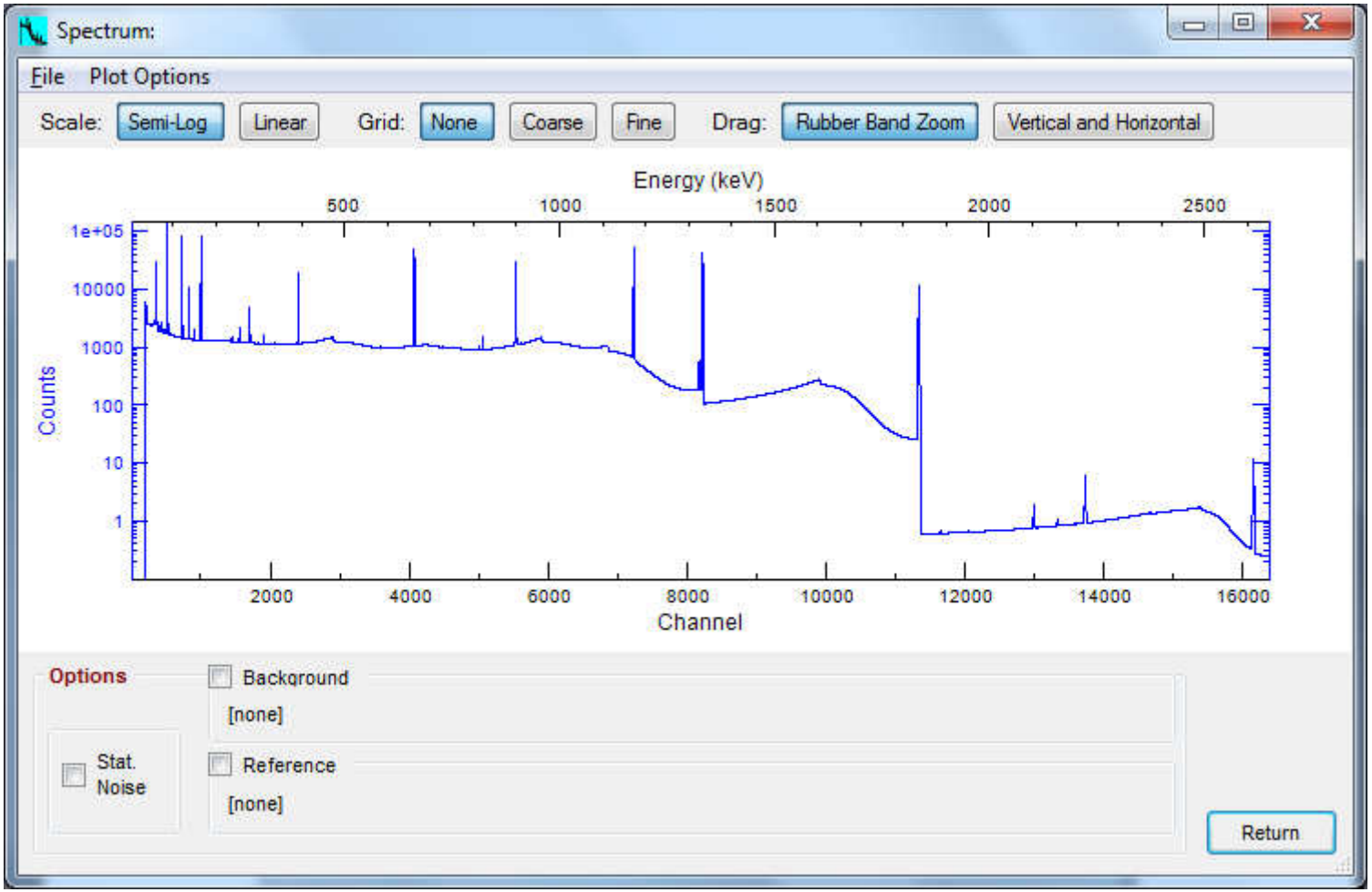
FWHM Coefficient Calculator



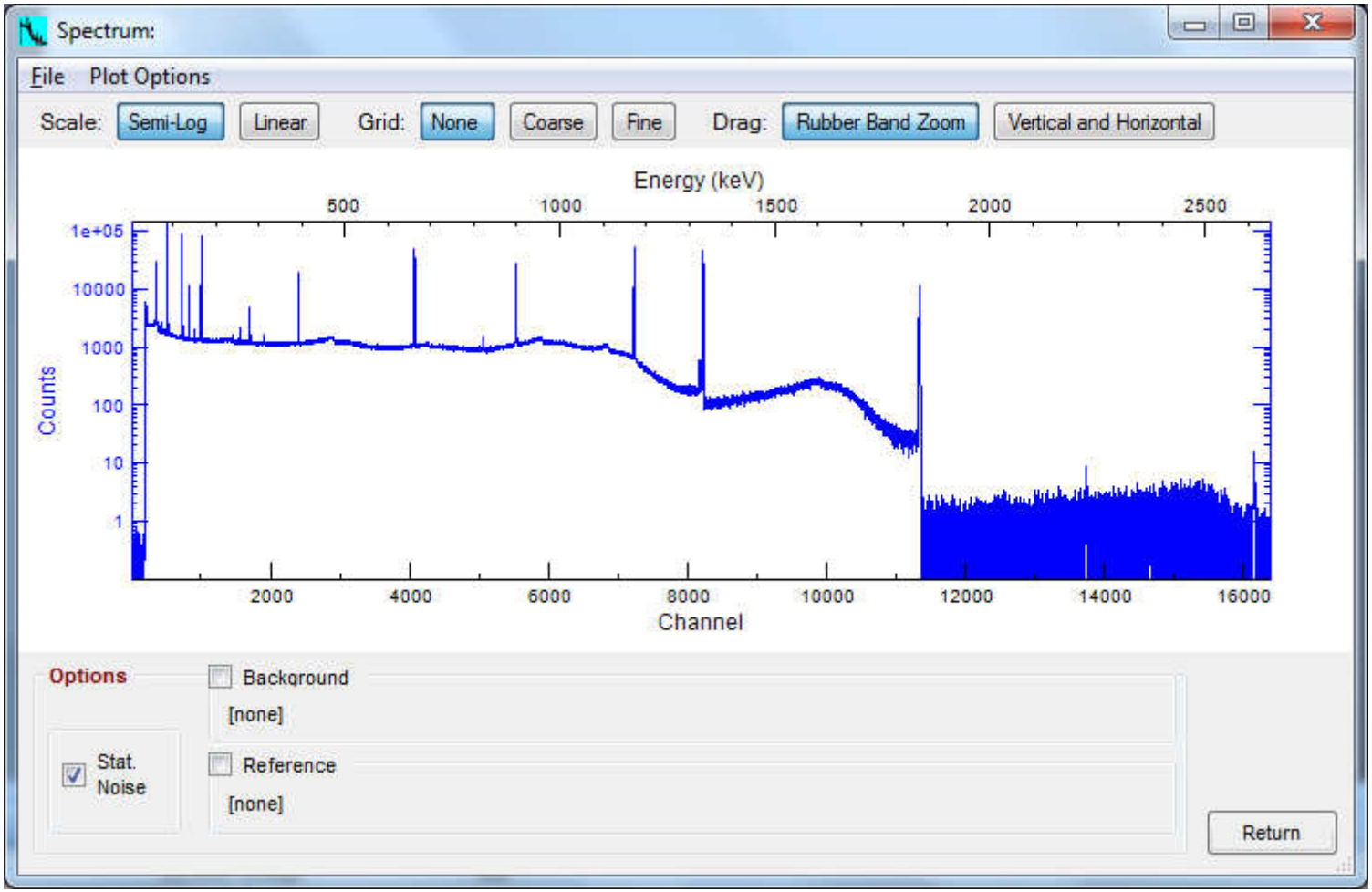
Counting Parameters



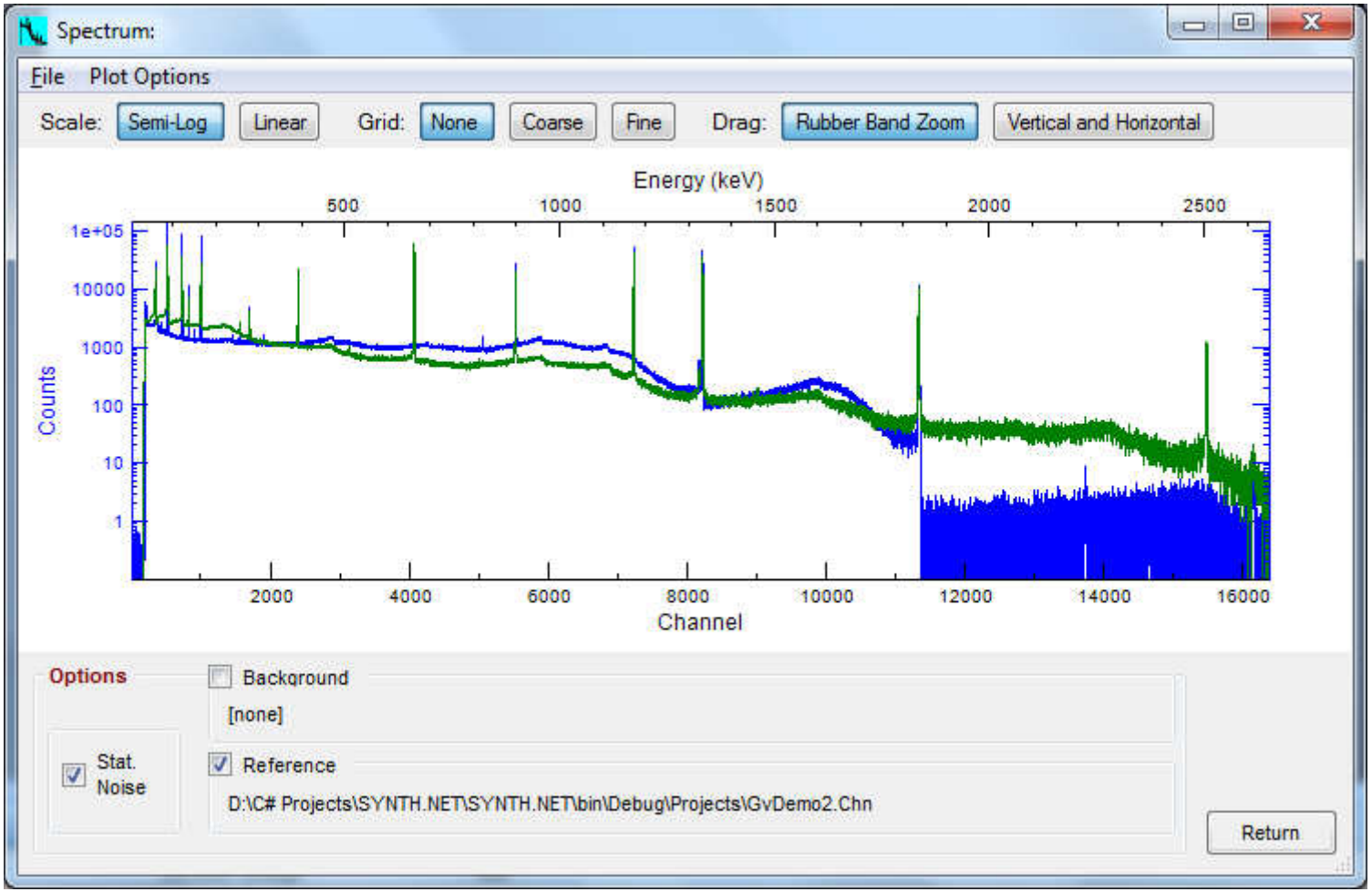
View the Generated Spectrum



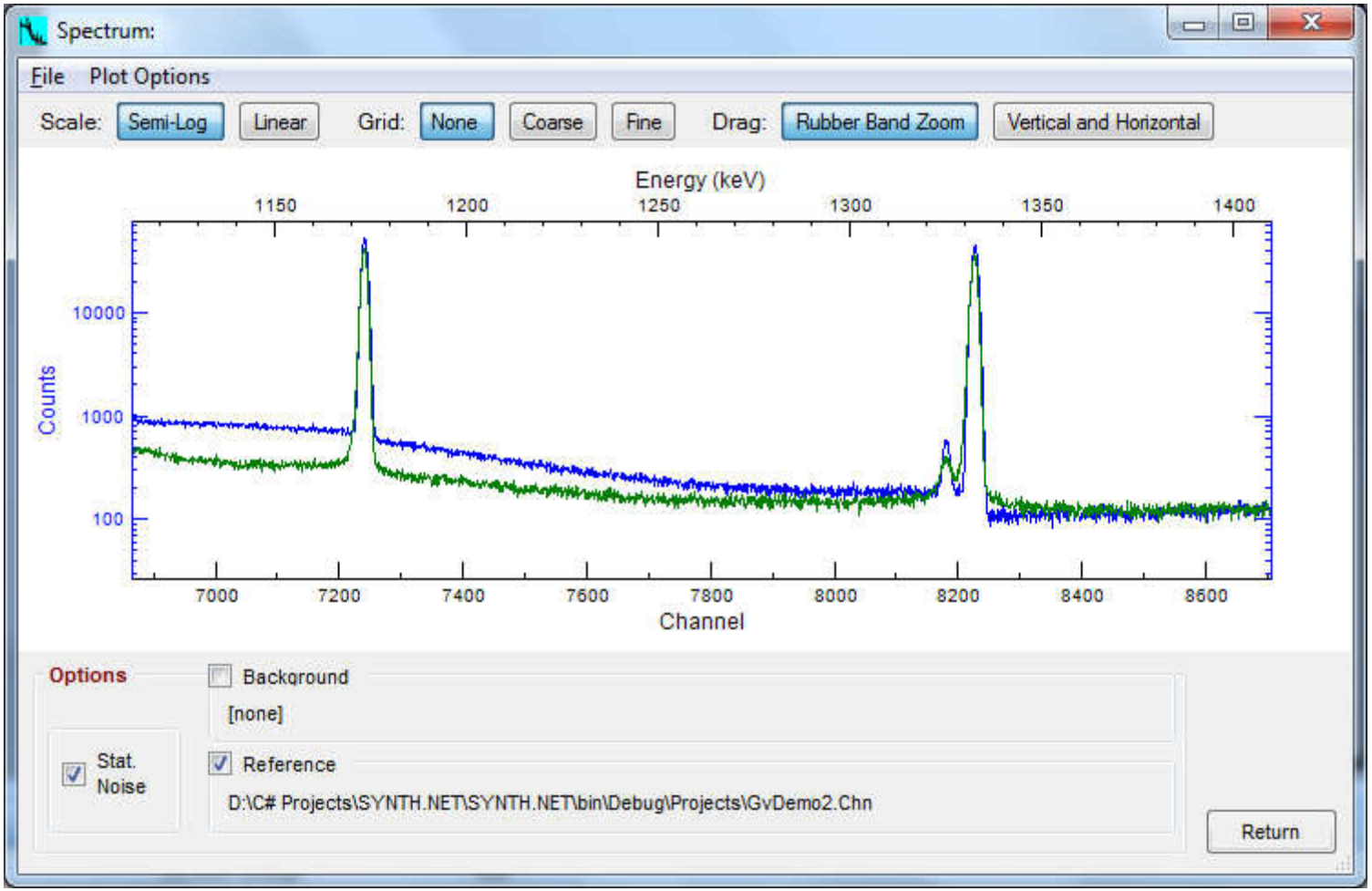
Add Statistical Noise to the Generated Spectrum



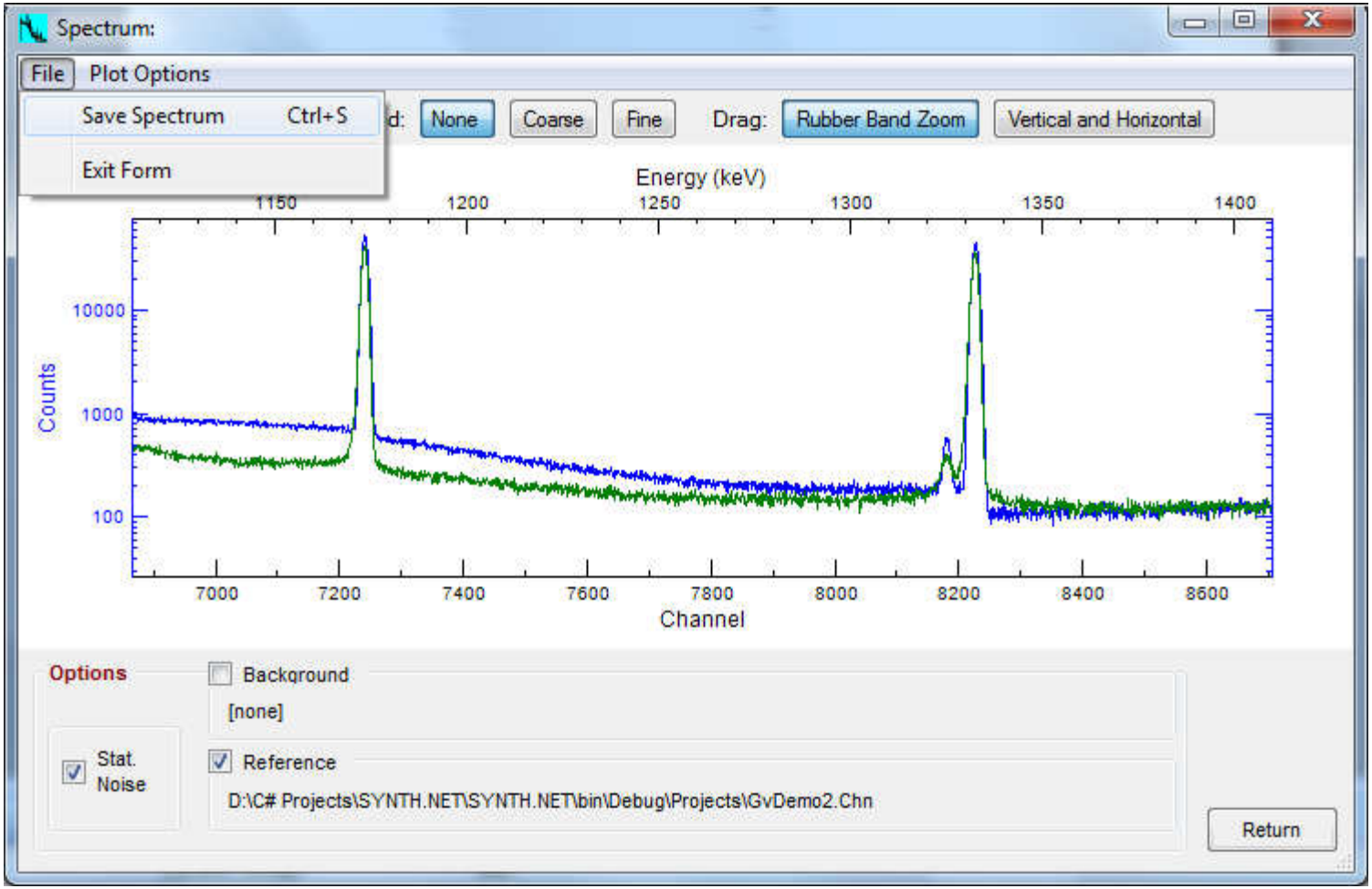
Compare the Generated Spectrum to a Measured Spectrum



Compare the Generated Spectrum to a Measured Spectrum



Save the Generated Spectrum to a File



Break / Questions

Practical

- Source
  - Point, Volume
- Source Term
  - No decay, Decay
- Absorbers
- Detectors
  - Ge, NaI, …
- Electronics
- Spectrum Options…