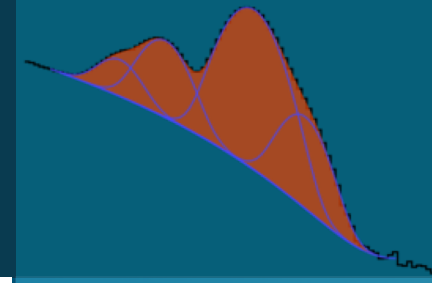
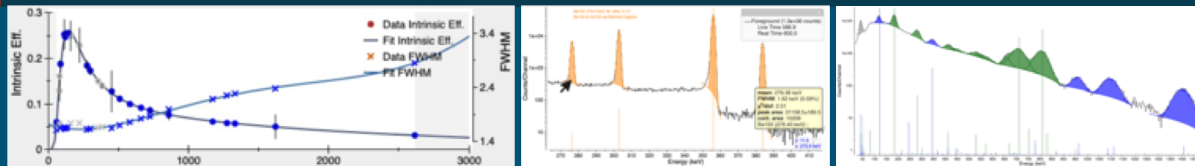


Detector Characterization in InterSpec



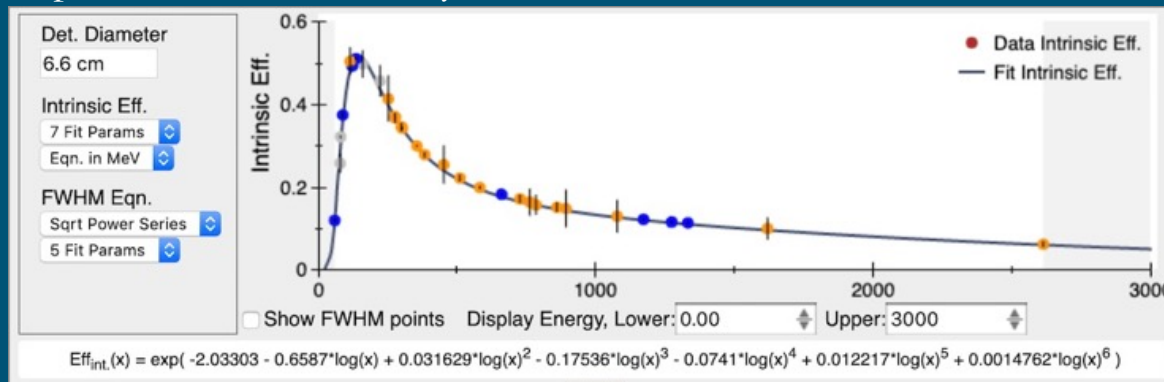
PRESENTED BY

Will Johnson 20190617

Motivation/Overview



To determine an unknown source's activity, or unknown shielding, or nuclide age you usually need to know the photo-peak detection efficiency of the detector.



To determine the detector response function (DRF), you will need some calibration data of known sources with photo-peaks that span the energy range you might later be interested in.

- Common choices of sources include Am-241, Cd-109, Co-57, Ba-133, Y-88, Cs-137, Co-60, Na-22, and Th-228, or Th-232, or U-232. However, InterSpec should accommodate using nearly any test-sources.

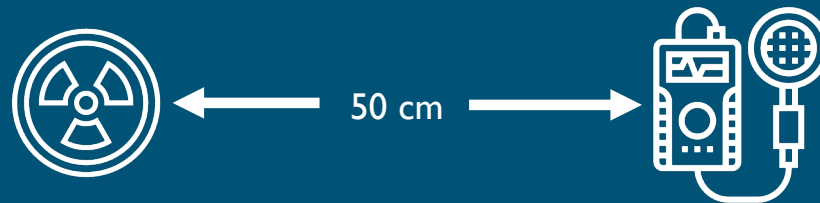
The known calibration data is used to fit the *Intrinsic Efficiency* equation. I.e., the equation that describes the efficiency of a gamma incident on the detector face to contribute to the full-energy photopeak for that gamma energy.

Characterization usually only has to be done once for a detector, and is usually valid for other detectors of the same model

How to create a DRF:



Step 1: take or acquire spectra of known sources, at known distances



Most portable or lab systems can use sources in the 10's of μCi range at 25 to 100 cm, for 5 to 30 minute dwells.

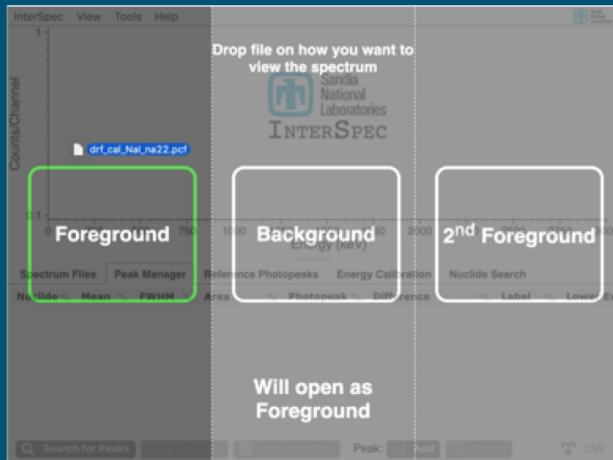
If any of the sources have photo-peaks that overlap with background peaks, or the detectors seed-source (e.x., Cs-137, Na-22), a background is also needed.

Test-source photo-peaks should have substantial statistics. I.e., a clearly visible, high statistics peak.

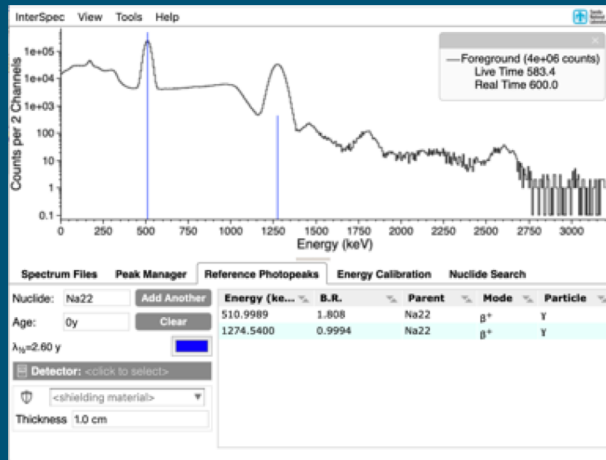
You will also need to know the detectors face surface area; InterSpec assumes a circular diameter, but if other geometry you can just convert to the equivalent surface area (ex, a 7cm by 7cm rectangular face is equivalent to a circle with diameter 3.95 cm).

4 How to create a DRF:

Step 2: Fit photo-peaks of test-sources



Open spectrum files by dragging them from the Explorer/Finder onto InterSpec. Or you can use “Open File...” from within InterSpec



Display reference photo-peaks for your test-source.

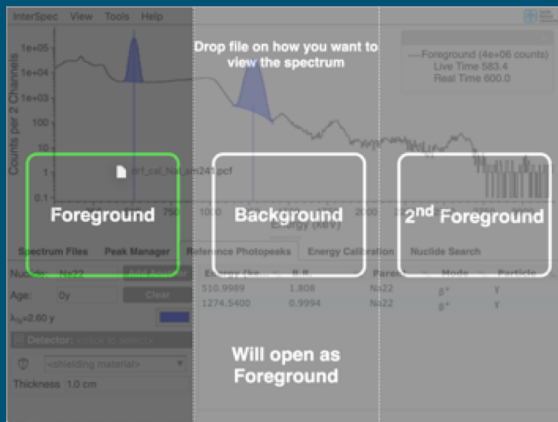


Fit peaks by double-clicking in their area on the chart. Since reference lines are showing, the test-source nuclide will be associated with the peak. You can also use the Peak Manager, or Peak Editor to associate nuclides with peaks

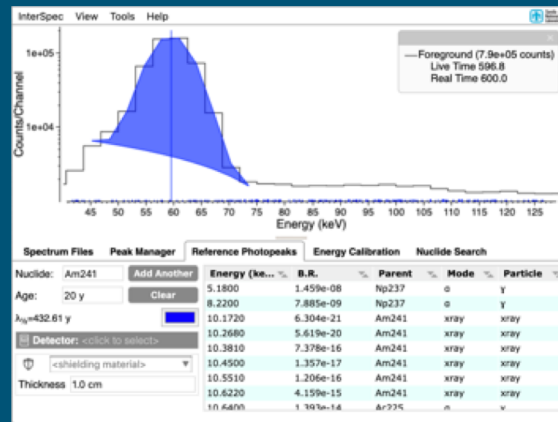
5 How to create a DRF:



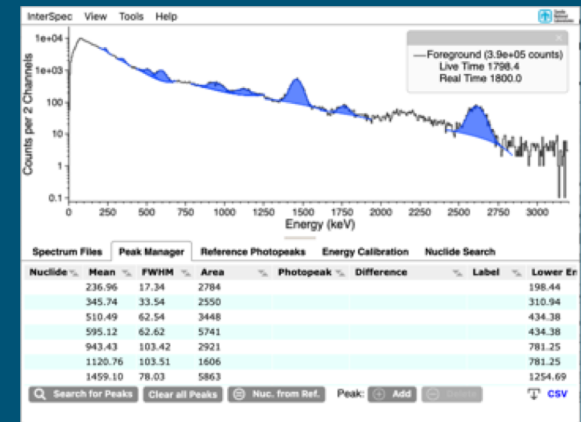
Step 2 (continued):



Open the next test-source spectrum in the same instance of InterSpec.



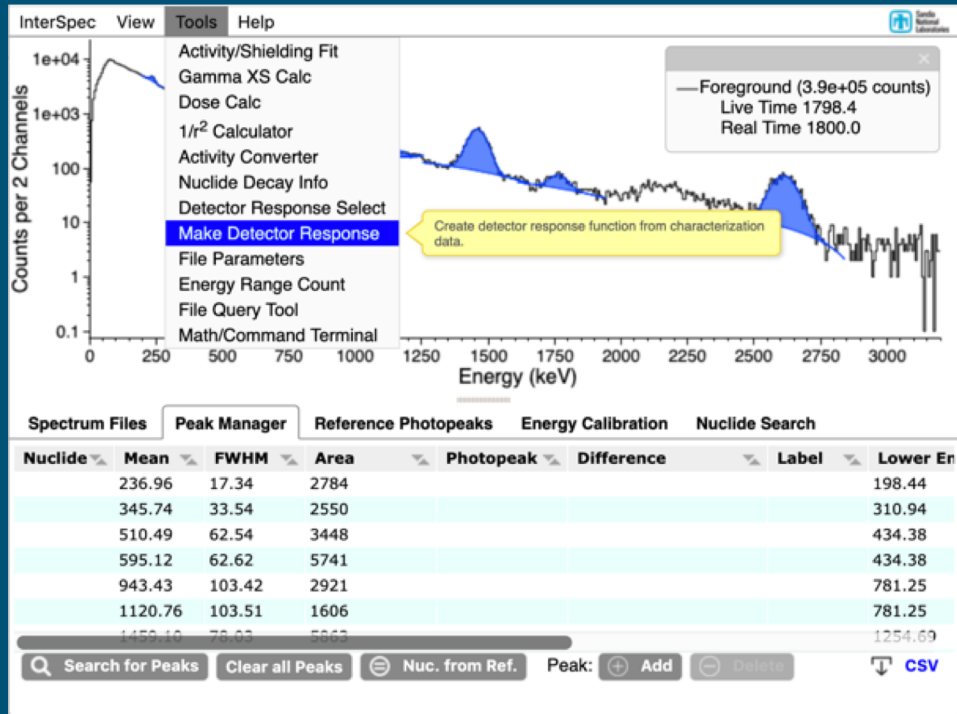
And repeat peak-fitting. Do this for all test source measurements.



For the background there is no need to associate nuclides with the peaks

6 How to create a DRF:

Step 3: Open the “Make Detector Response” tool.



How to create a DRF:



Step 4: Enter detector diameter.

Create Detector Response Function

Det. Diameter
6.6 cm

Intrinsic Eff.
7 Fit Params

Eqn. in MeV

FWHM Eqn.
Gadras Equation

Show FWHM points Display Energy, Lower: 0.00 Upper: 3200.00

$$Eff_{int}(x) = \exp(-0.90627 - 0.84293 \cdot \log(x) + 0.2026 \cdot \log(x)^2 + 0.11098 \cdot \log(x)^3 - 0.16717 \cdot \log(x)^4 - 0.096471 \cdot \log(x)^5 - 0.014189 \cdot \log(x)^6)$$

Sample 1, "133Ba,50uCi @ 50.00 cm" (using 5 of 5 peaks) All Peaks

- Use Ba133: 80.90 keV peak with 845.4 cps for 81.00 keV gamma.
- Use Ba133: 277.28 keV peak with 163.4 cps for 276.40 keV gamma.
- Use Ba133: 302.98 keV peak with 382.3 cps for 302.85 keV gamma.
- Use Ba133: 355.99 keV peak with 1241.2 cps for 356.02 keV gamma.
- Use Ba133: 384.05 keV peak with 161.8 cps for 383.85 keV gamma.

Is Background?

Ba133, $\lambda_{1/2}=10.51$ y

Distance 50.00 cm

Activity 50.00 uCi

Act. Uncert. 0.0 %

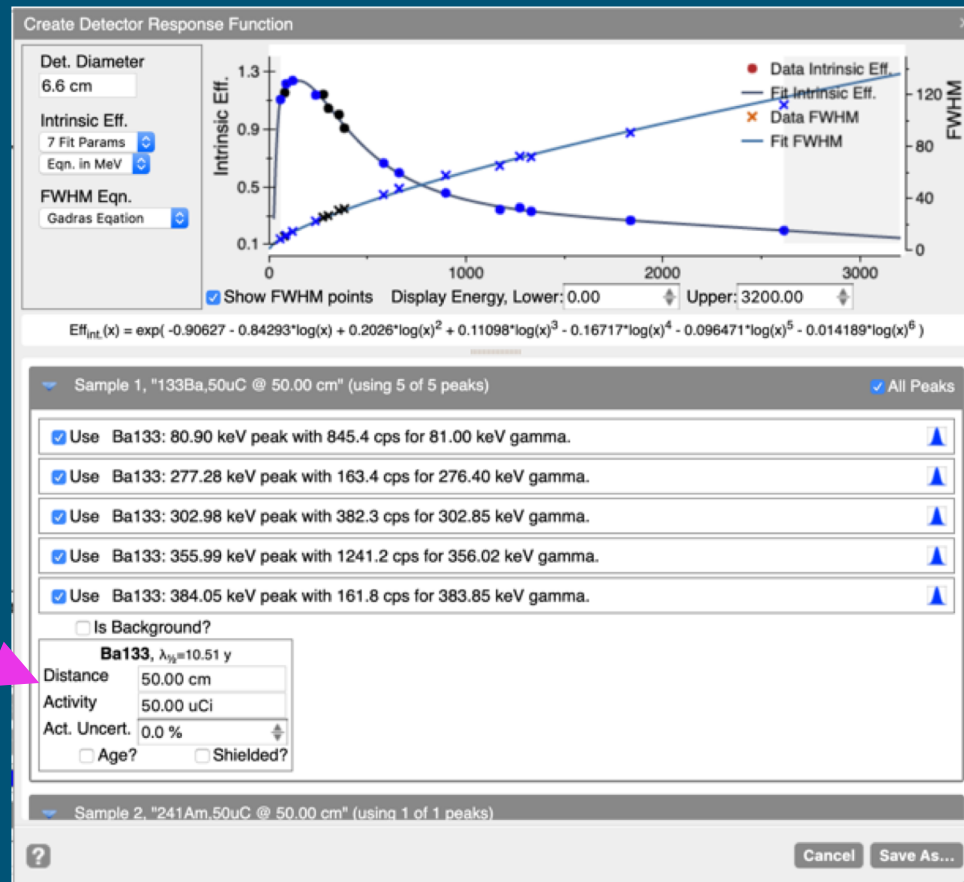
Age? Shielded?

Sample 2, "241Am,50uCi @ 50.00 cm" (using 1 of 1 peaks)

Cancel Save As...

How to create a DRF:

Step 5: Select Peaks to use, and enter source information



When you select a peak, an area will appear for you to enter source information

You can choose peaks from all of the spectrum files you've used in your current session by scrolling down.

9 How to create a DRF:

Step 5 (continued): Entering source information

drf_cal_NaI_22Na_18F.pcf: 22Na,25uCi+18F,25uCi (using 2 of 2 peaks)

Use F18: 510.92 keV peak with 2844.2 cps for 511.00 keV gamma (annih.).

Use Na22: 1274.53 keV peak with 349.2 cps for 1274.54 keV gamma.

Is Background?

Na22, $\lambda_{1/2}=2.60$ y		F18, $\lambda_{1/2}=109.77$ m	
Distance	50 cm	Distance	50 cm
Activity	100 uCi	Activity	100 uCi
Act. Uncert.	0.0 %	Act. Uncert.	0.0 %
<input type="checkbox"/> Age?	<input type="checkbox"/> Shielded?	<input type="checkbox"/> Age?	<input type="checkbox"/> Shielded?

drf_cal_Cs137.pcf: 137Cs,50uCi @50cm (using 1 of 1 peaks)

Use Cs137: 661.61 keV peak with 309.5 cps for 661.66 keV gamma.

Is Background?

Cs137, $\lambda_{1/2}=30.08$ y

Distance 50.00 cm

Assay Act. 50 uCi

Act. Uncert. 0.0 %

Assay Date 19/06/2016

Spec. Date 14/08/2018

Aging Res. 47.6 uCi

Age? Shielded?

Selecting the “Age?” checkbox will allow you to age the source to calculate the activity at measurement time.

If the source's spectrum changes significantly with age, you will also be prompted for age at the original assay date so the correct branching ratios can be calculated for the time of measurement.

drf_cal_Cs137.pcf: 137Cs,50uCi @50cm (using 1 of 1 peaks)

Use Cs137: 661.61 keV peak with 309.5 cps for 661.66 keV gamma.

Is Background?

Cs137, $\lambda_{1/2}=30.08$ y

Distance 50.00 cm

Activity 50 uCi

Act. Uncert. 0.0 %

Fe (iron) $\rho=7.9$ g/cm³

Thickness 1.0 cm

Age? Shielded?

You can also opt to correct for shielding around the source. However, shielding should be avoided or minimized for characterization measurements.

You can have multiple sources for a single spectrum (especially for high-resolution detectors). Interferences between sources will be accounted for.

Distances also must be entered for each source.



How to create a DRF:



Step 5 (continued): Background

When you select to use a spectrum as background, all peaks in that spectrum that you choose to use will be considered background

Sample 10, "Background @ 25.00 cm" (using 5 of 5 peaks) ✓ All Peaks

<input checked="" type="checkbox"/> Use	236.96 keV peak - no nuc. associated	
<input checked="" type="checkbox"/> Use	596.03 keV peak - no nuc. associated	
<input checked="" type="checkbox"/> Use	1459.10 keV peak - no nuc. associated	
<input checked="" type="checkbox"/> Use	1765.09 keV peak - no nuc. associated	
<input checked="" type="checkbox"/> Use	2611.80 keV peak - no nuc. associated	
<input checked="" type="checkbox"/> Is Background?	These peaks will be subtracted from other samples	

Sample 8, "232U,50uCi @ 50.00 cm" (using 3 of 4 peaks) ✓ All Peaks

<input checked="" type="checkbox"/> Use	U232: 238.67 keV peak with 1112.2 cps for 238.63 keV gamma.	will sub. 1.548 cps for bckgrnd	
<input type="checkbox"/> Use	U232: 511.12 keV peak with 136.5 cps for 510.77 keV gamma.		
<input checked="" type="checkbox"/> Use	U232: 583.23 keV peak with 414.3 cps for 583.19 keV gamma.	will sub. 1.715 cps for bckgrnd	
<input checked="" type="checkbox"/> Use	U232: 2615.02 keV peak with 139.8 cps for 2614.53 keV gamma.	will sub. 0.655 cps for bckgrnd	
<input type="checkbox"/> Is Background?			

U232, $\lambda_{1/2} = 68.90$ y

Distance: 50.00 cm

Assay Act. 50.00 uCi

Act. Uncert. 0.0 %

Assay Date 14/08/2018

Spec. Date 14/08/2018

Age@Assay 172.25 y

Aging Res. 50.0 uCi, 172.25 y

Age? Shielded?

When background subtraction occurs from test-sources, it will be indicated next to the normal text

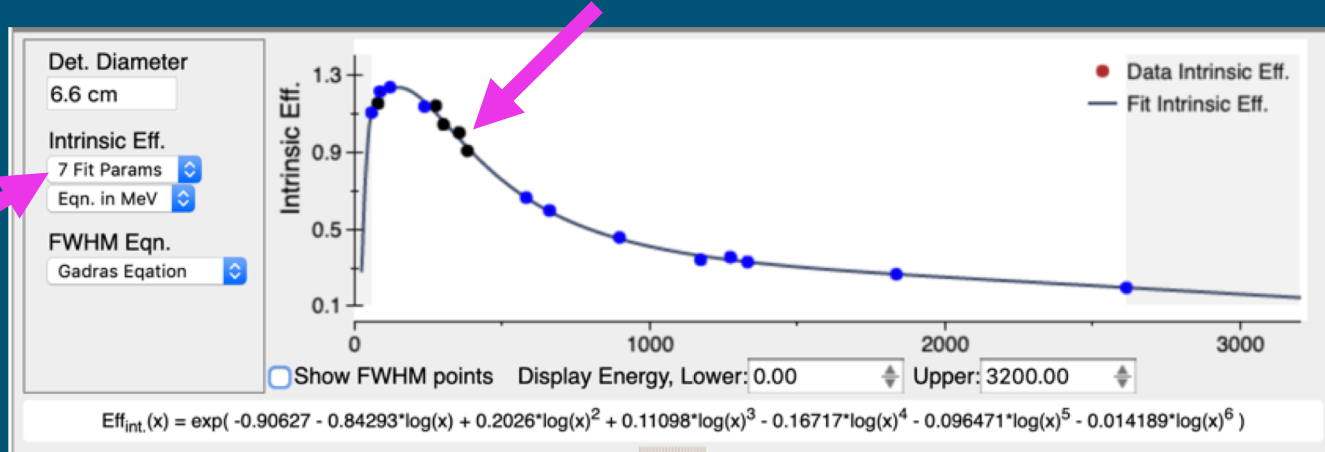
How to create a DRF:

Step 6: Refine

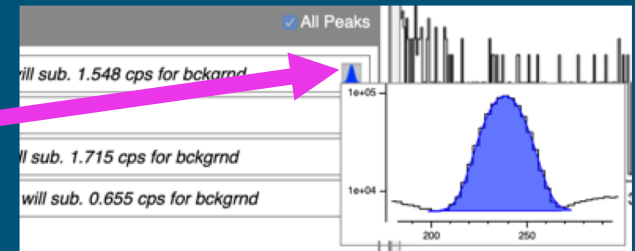
Your points should look continuous – you shouldn't have any significantly off of the fit line; if you do, check that source's activity, distance, or that the correct gamma energy is associated with that peak

You can choose the number of parameters to fit. You can fit the equation in energy units of MeV, or keV

The fit equation is continuously updated whenever you select/deselect peaks, or change source info, or other options



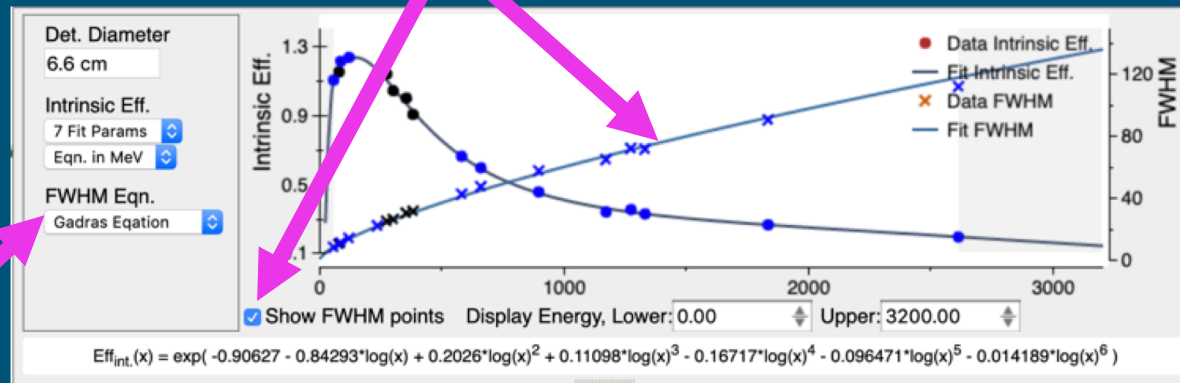
Clicking/tapping on the peak icon to the right on each row will let you preview the peak fit as a sanity check the fit is good



How to create a DRF:

Step 6: Refine (cont)

The peak resolution (Full Width Half Maximum, FWHM) as a function of energy is also fit for.



$$FWHM(\text{energy}) = \sqrt{A_0 + A_1 \cdot \text{energy} + A_2 \cdot \text{energy}^2 + A_3 \cdot \text{energy}^3 + \dots} \quad [\text{energy in MeV}]$$

```
def getFWHM( energy ):
//P6--> resolution @ E=0 (energy in keV)
//P7--> % FWHM @ 661 keV
//P8--> resolution power
if energy >= 661 or P6=0
    return 6.61xP7x(energy/661)P8
if P6 < 0.0
    var p = pg1.0/log(1.0-P6)
    return 6.61xP7x(energy/661)P
if P6 > 6.61xP7
    return P6;
var p = sqrt((6.61xP7)2-P62)/6.61;
return sqrt(P62+(6.61x(energy/661)P8)2)
```

You can choose to fit FWHM to either a power series equation, or the GADRAS-DRF resolution function.

InterSpec doesn't really use the FWHM information, so this information isn't emphasized in the user interface.

How to create a DRF:

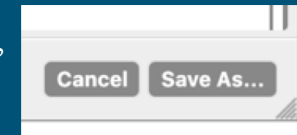
Step 7: Save

Enter a useful name and description. Symbols such as slashes, backslashes, quotes, commas, semicolons, and question marks are not allowed in the name.

You can also choose to have InterSpec load this DRF automatically when you load spectra from either this specific detector, or this model of detector.

You can also load this DRF from the “Previous” tab of the “Detector Response Select” tool.

To store the DRF into InterSpecs internal database, or export it, click the “Save As...” button

A screenshot of the "Store/Export DRF" dialog box. The dialog has a title bar with a close button (X). It contains the following fields and options:

- Name:** A text input field containing "My Acme DRF".
- Description:** A text area containing "Green lab HPGe characterized on 20190615." with a radiation warning icon.
- Make default DRF for serial number 'Serial #1XXX'**
- Make default DRF for model 'Acme HPGe 40%'**
- [Export data as N42-2012 file.](#)
- [Export DRF as CSV.](#)

At the bottom right are "Cancel" and "Save" buttons. A pink arrow points from the text "or this model of detector." to the second checkbox option.

How to create a DRF:

Step 7: Save (cont)

Clicking/tapping on the export data option will create and save a single N42 file with all the data used to create the DRF.

The N42 file can be opened in other applications, but if opened in InterSpec, all of your fit peaks, source information, and the actual DRF will be included as well.

Exporting the DRF as a CSV is a nice way to use the DRF with other applications. It also includes the efficiency data points, the equation as an absolute efficiency, as well as some further information

Store/Export DRF

Name: My Acme DRF

Description: Green lab HPGe characterized on 20190615.

Make default DRF for serial number 'Serial #1XXX'

Make default DRF for model 'Acme HPGe 40%'

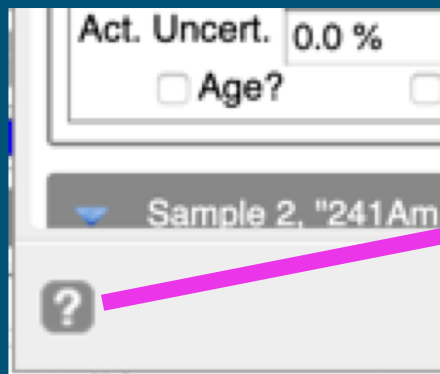
[Export data as N42-2012 file.](#)

[Export DRF as CSV.](#)

Cancel Save



For further information, click on the help icon in the lower-left of the tool.



InterSpec Help

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Tutorials and usage hints

Make Detector Response Function

To accurately determine source activities, shielding amounts, or nuclide ages, it is important to know the efficiency, as a function of energy, for a gamma incident on the detector to contribute to the full-energy photo-peak.

The *Make Detector Response Function* tool allows you to use measurements of known sources to determine the *Intrinsic* efficiency (i.e., the probability that if a gamma of a given energy is incident on the detector face, that its full energy will be absorbed, and it will contribute to the photo-peak) of a detector. Usually the detector response function (DRF) will only have to be determined once for a given system, and often detectors of the same model can use the same response function.

Create Detector Response Function

Det. Diameter: 6.0 cm
 Intrinsic ER: 7 Fit Params
 FWHM Eqn: Sort Power Series: 1 Fit Params

$E_{\text{FWHM}}(E) = \exp(-0.48813 - 0.06705 \log(E) - 0.007279 \log(E)^2 - 0.11532 \log(E)^3 - 0.046029 \log(E)^4 + 0.024881 \log(E)^5 + 0.0032139 \log(E)^6)$

Use U232: 115.10 keV peak with 6.2 cps for 115.18 keV gamma.
 Use U232: 208.58 keV peak with 369.7 cps for 240.89 keV gamma. will sub. 0.529 cps for bgnd
 Use U232: 240.79 keV peak with 38.4 cps for 238.63 keV gamma.
 Use U232: 277.33 keV peak with 17.1 cps for 277.36 keV gamma.

Close