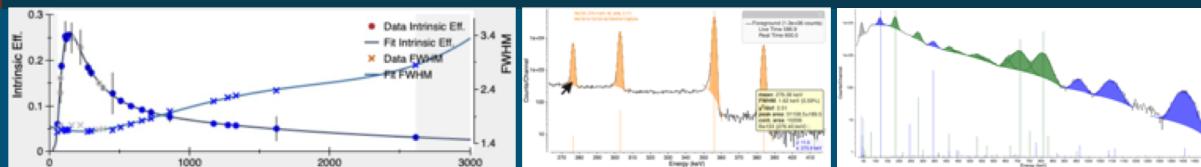
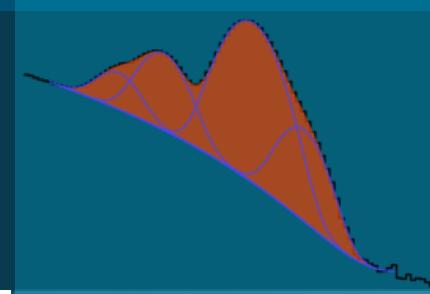


Detector Characterization in InterSpec



P R E S E N T E D B Y

Will Johnson 20190617

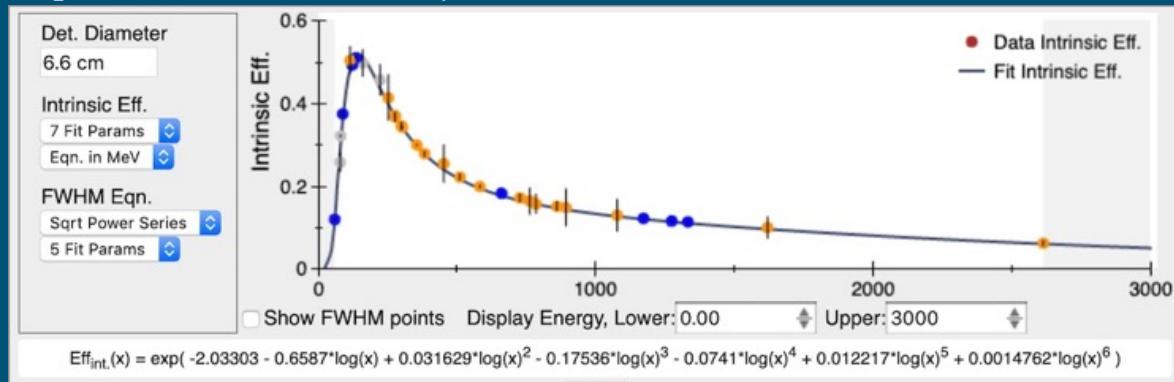


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Motivation/Overview



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.

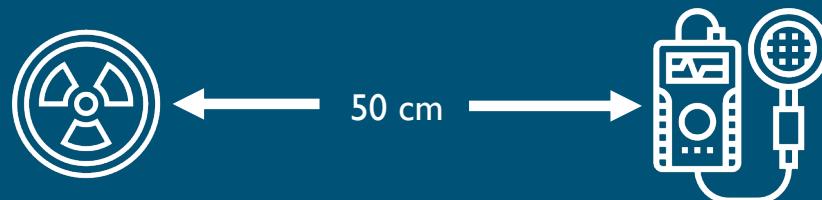
The known calibration data is used to fit the *Intrinsic Efficiency* equation. I.e., the equation that describes the efficiency of a gamma incident on the detector face to contribute to the full-energy photopeak for that gamma energy.

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.g., Cs-137, Na-22), a background is also needed.

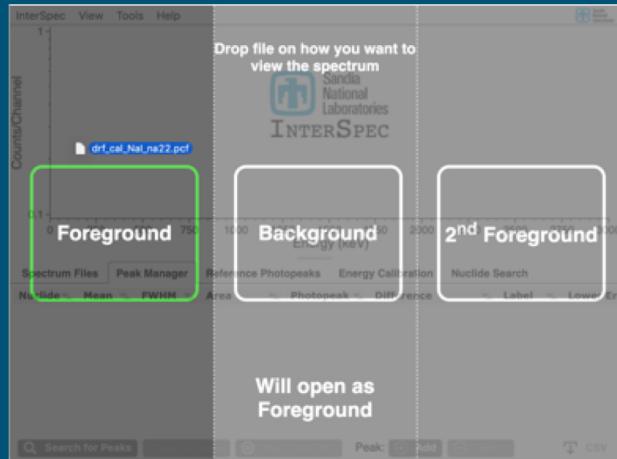
Test-source photo-peaks should have substantial statistics. I.e., a clearly visible, high statistics peak.

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).

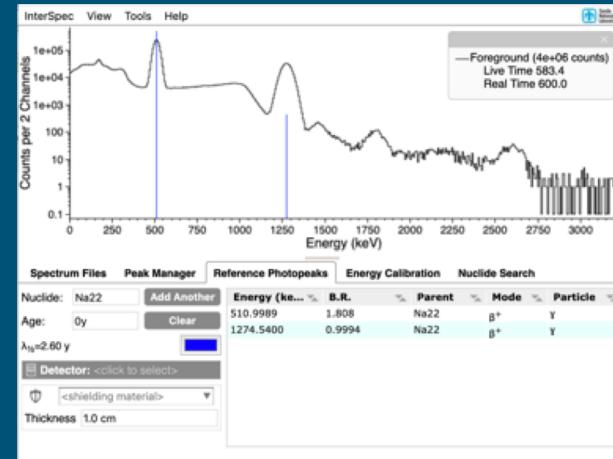
How to create a DRF:



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.

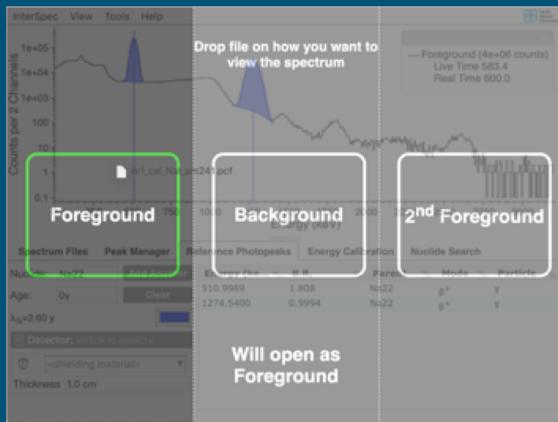


Fit peaks by double-clicking in their area on the chart. Since reference lines are showing, the test-source nuclide will be associated with the peak. You can also use the Peak Manager, or Peak Editor to associate nuclides with peaks

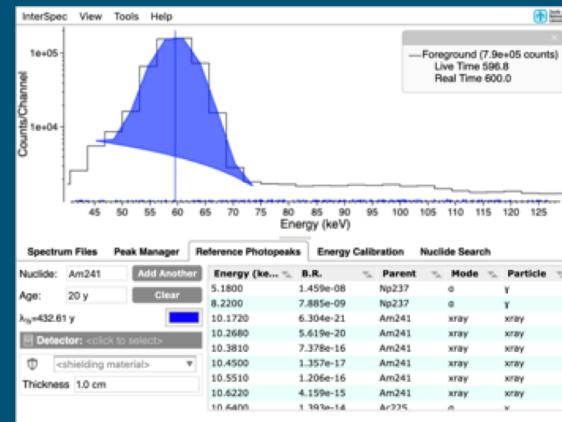
How to create a DRF:



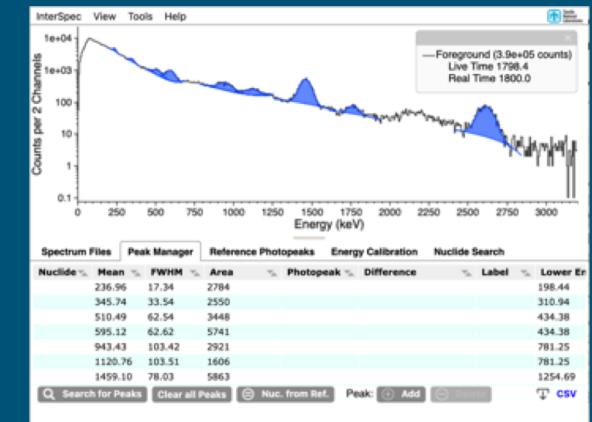
Step 2 (continued):



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



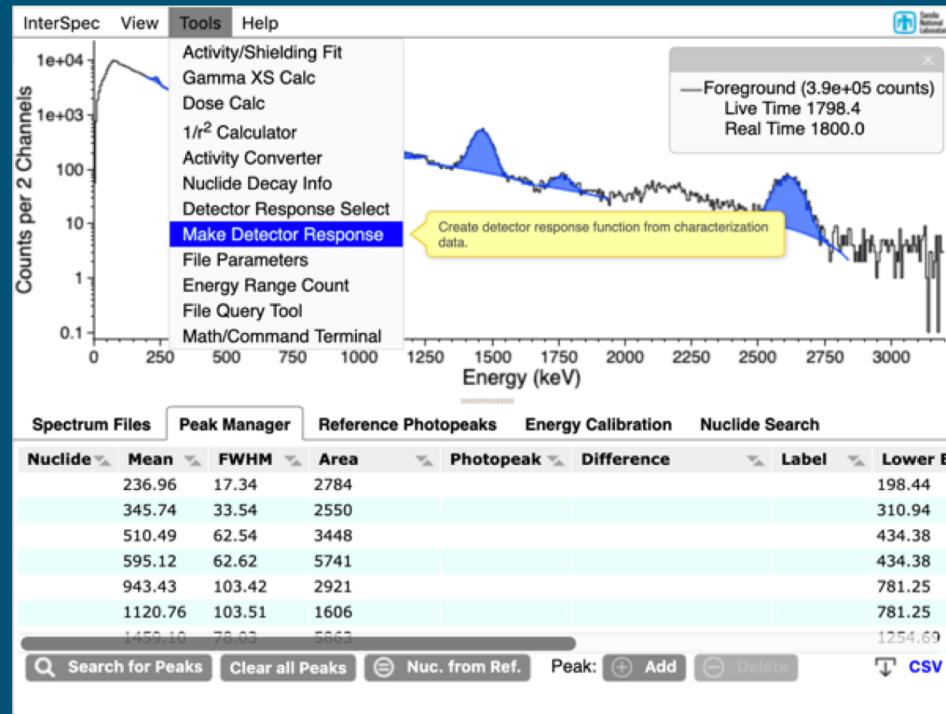
And repeat peak-fitting.
Do this for all test source measurements.



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

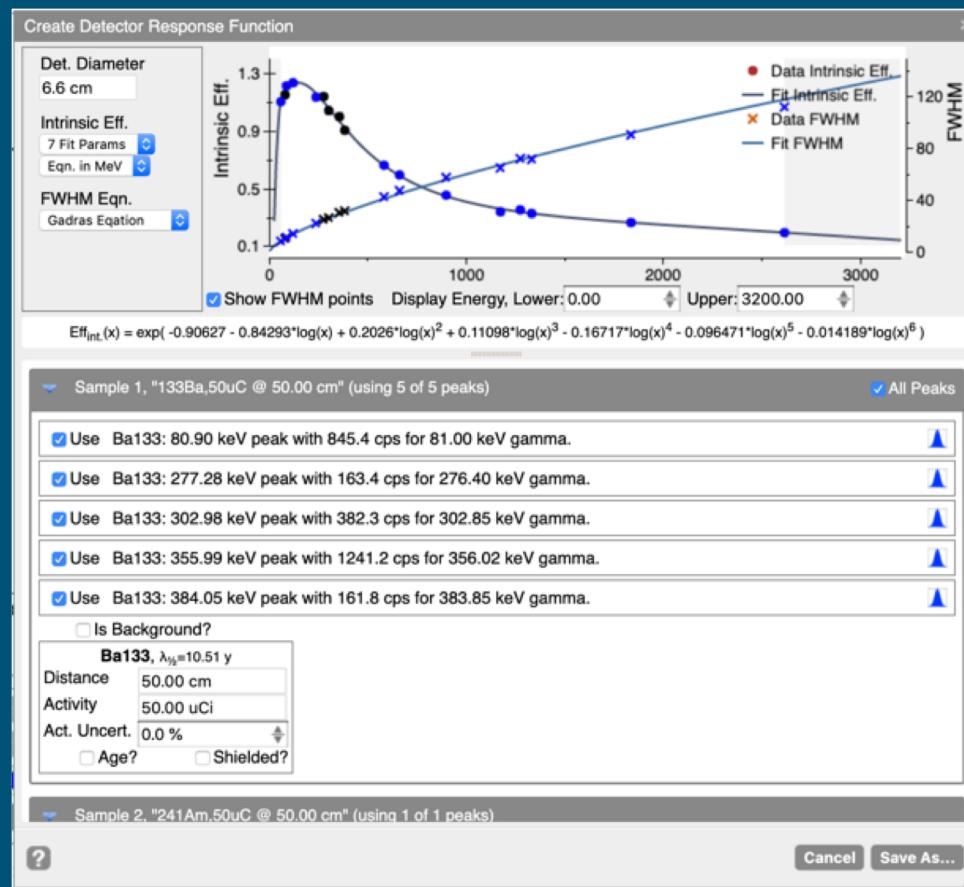
How to create a DRF:

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



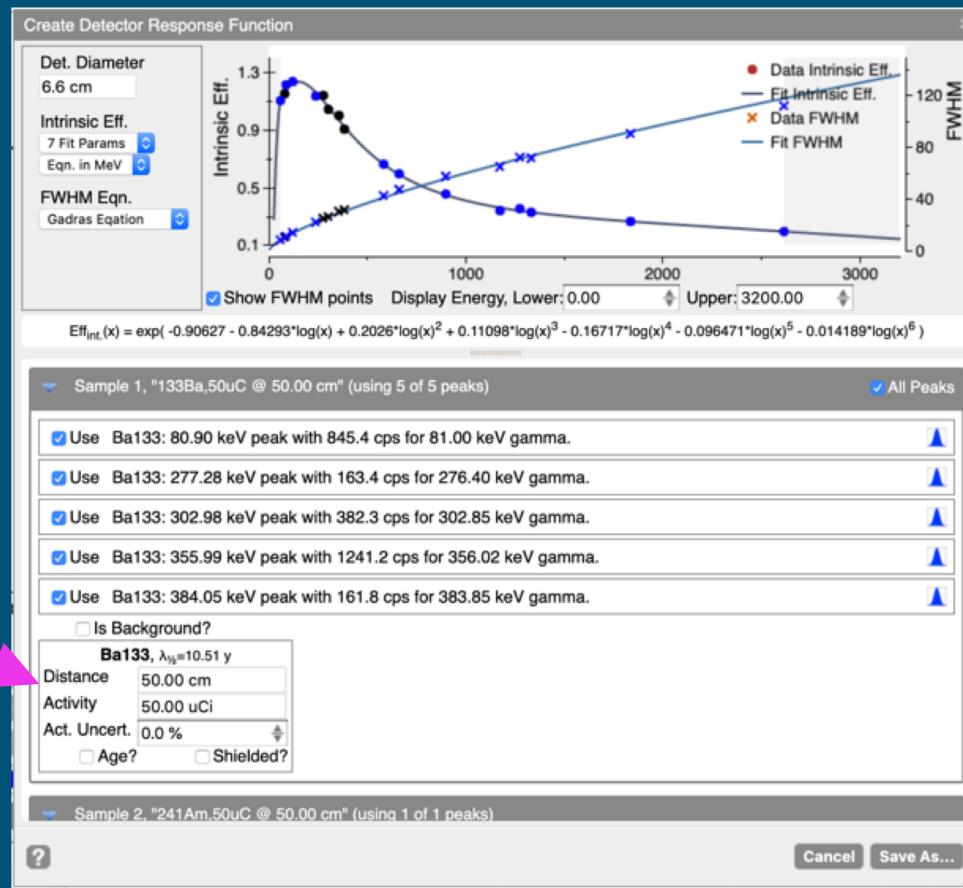
How to create a DRF:

Step 4: Enter detector diameter.



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,25uC+18F,25uC (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"/> Age?
<input type="checkbox"/> Shielded?	<input type="checkbox"/> Shielded?

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.

drf_cal_Cs137.pcf: 137Cs,50uC @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	
<input checked="" type="checkbox"/> Age?	<input type="checkbox"/> Shielded?

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

If the sources 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,50uC @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 %	
<input type="button" value="Fe (iron)"/>	$\rho=7.9$ g/cm ³
Thickness 1.0 cm	
<input type="checkbox"/> Age?	<input checked="" type="checkbox"/> Shielded?

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

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

- Use 236.96 keV peak - no nuc. associated
- Use 596.03 keV peak - no nuc. associated
- Use 1459.10 keV peak - no nuc. associated
- Use 1765.09 keV peak - no nuc. associated
- Use 2611.80 keV peak - no nuc. associated

Is Background? These peaks will be subtracted from other samples

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

- Use U232: 238.67 keV peak with 1112.2 cps for 238.63 keV gamma. will sub. 1.548 cps for bckgrnd
- Use U232: 511.12 keV peak with 136.5 cps for 510.77 keV gamma.
- Use U232: 583.23 keV peak with 414.3 cps for 583.19 keV gamma. will sub. 1.715 cps for bckgrnd
- Use U232: 2615.02 keV peak with 139.8 cps for 2614.53 keV gamma. will sub. 0.655 cps for bckgrnd

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
<input checked="" type="checkbox"/> Age? <input type="checkbox"/> Shielded?	

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

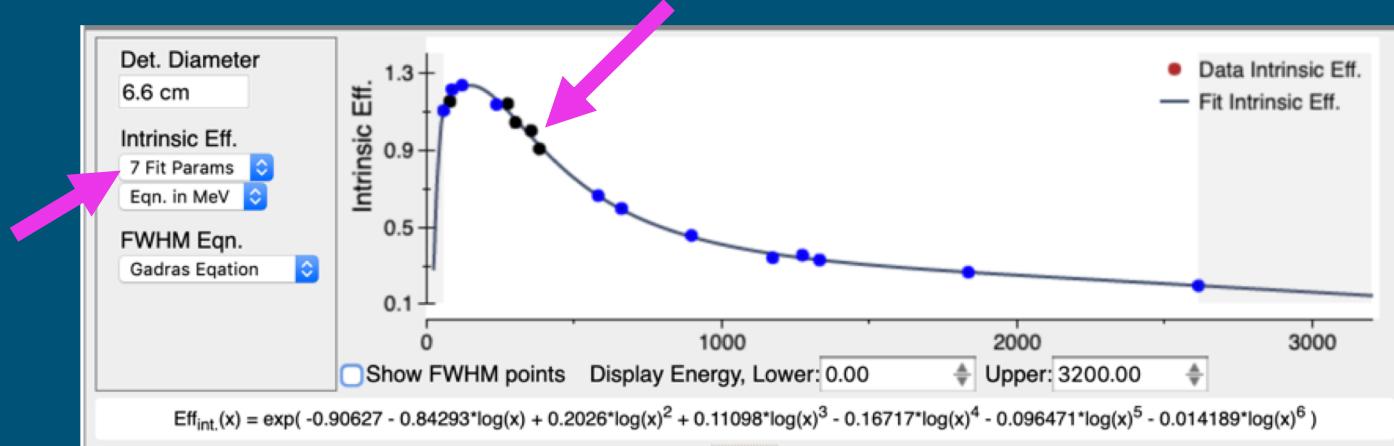
How to create a DRF:

Step 6: Refine

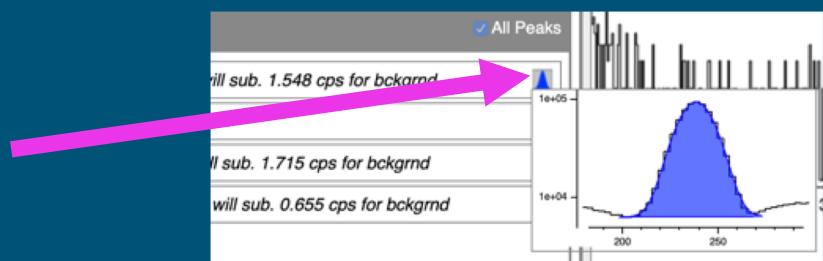
You can choose the number of parameters to fit. You can fit the equation in energy units of MeV, or keV

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

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



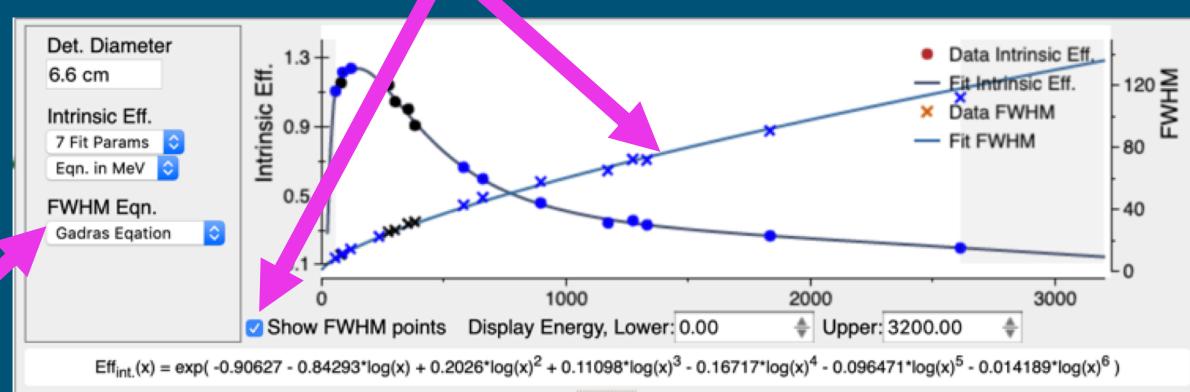
Clicking/tapping on the peak icon to the right on each row will let you preview the peak fit as a sanity check the fit is good



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.



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

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

```
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 = P61.0/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+(6.61xp(x(energy/661)P8)2))
```

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

How to create a DRF:

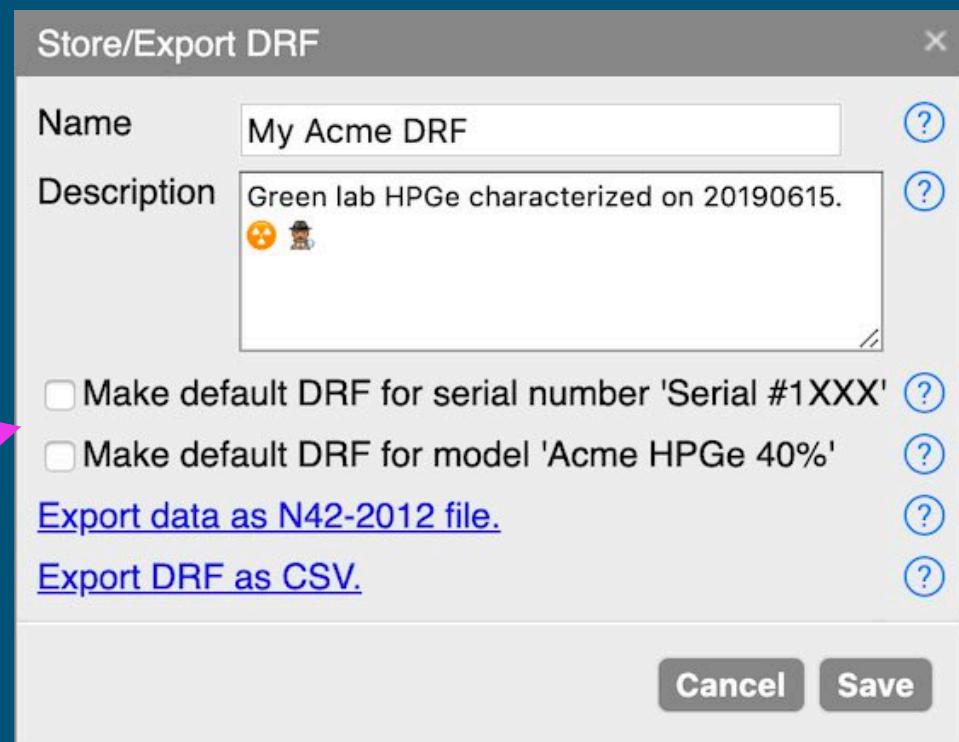
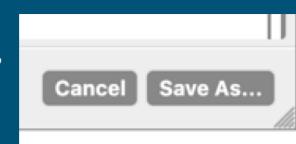
Step 7: Save

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

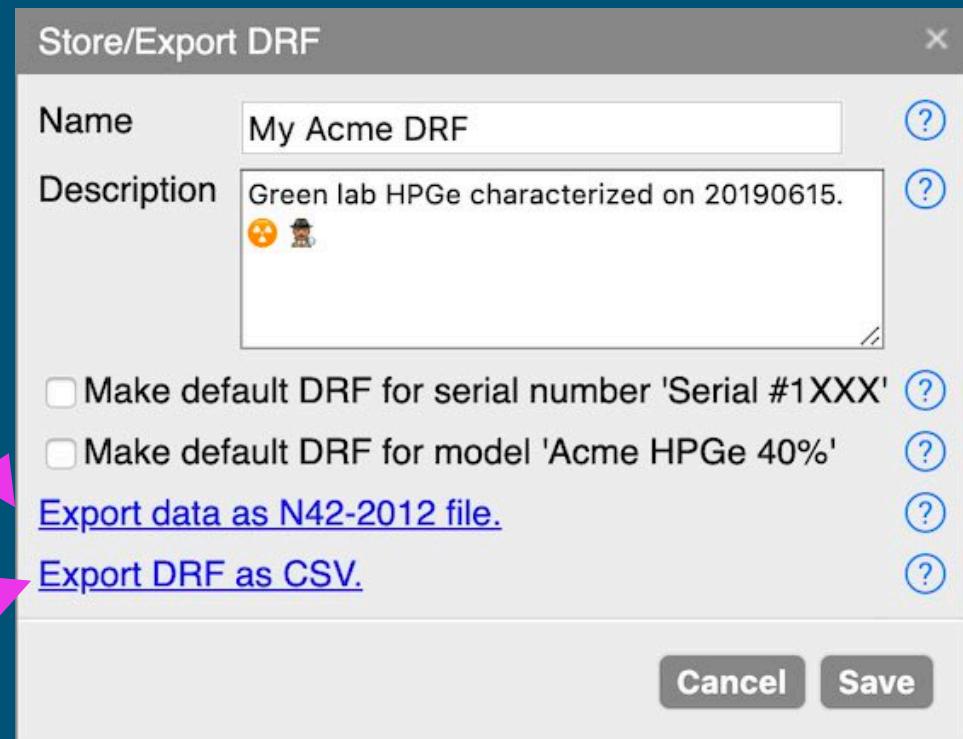


How to create a DRF:

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.

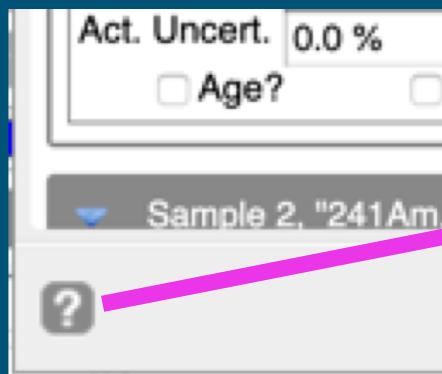
Exporting the DRF as a CSV is a nice way to use the DRF with other applications. It also includes the efficiency data points, the equation as an absolute efficiency, as well as some further information



More Info



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



InterSpec Help

Search

- Getting Started
 - Display Options
 - Interacting with the Spectra
 - Zoom In
 - Zoom Out
 - Changing Energy Range
 - Fit Peak(s)
 - Delete Peak(s)
- Tools
 - Reference Gamma Lines
 - Energy Calibration
 - Detector Select
 - Create Detector Response
 - Activity Shielding Fit
 - Gamma XS Calc
 - Peak Editor
 - 1/r² Calc
 - Nuclide Decay Info
 - Colors/Theme
 - File Parameters
 - Energy Range Count
 - Dose Calculations
 - Spectrum File Query Tool
 - Nuclide Search By Energy
 - Math/Command terminal
 - Math Commands/Funct

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 Eff.: 2.0% in series
Eg. in MeV
FWHM Egn.: Sort Power Series
Sort Parameters

Int. Eff. vs. Energy (keV)

Legend: Data Intrinsic Eff. (red circles), Fit Intrinsic Eff. (blue line), Data FWHM (orange squares), Fit FWHM (green line).

Eff_{int}(E) = exp(-2.48813 - 0.66705 log(E) - 0.0372797 log(E)² - 0.17533 log(E)³ - 0.0490209 log(E)⁴ + 0.0348844 log(E)⁵ + 0.0033139 log(E)⁶)

Show FWHM points | Display Energy, Lower: 0.00 | Upper: 3000.00 | All Peaks

dr_cal_U232.pdf: 232U.59eC @90cm (using 10 of 12 peaks)

Use U232: 115.10 keV peak with 6.2 cps for 115.18 keV gamma.
Use U232: 238.59 keV peak with 369.7 cps for 240.99 keV gamma, will sub. 0.529 cps for background.
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.

Tutorials and usage hints

Close