Introduction to InterSpec

Part 2 of 2

PRESENTED BY

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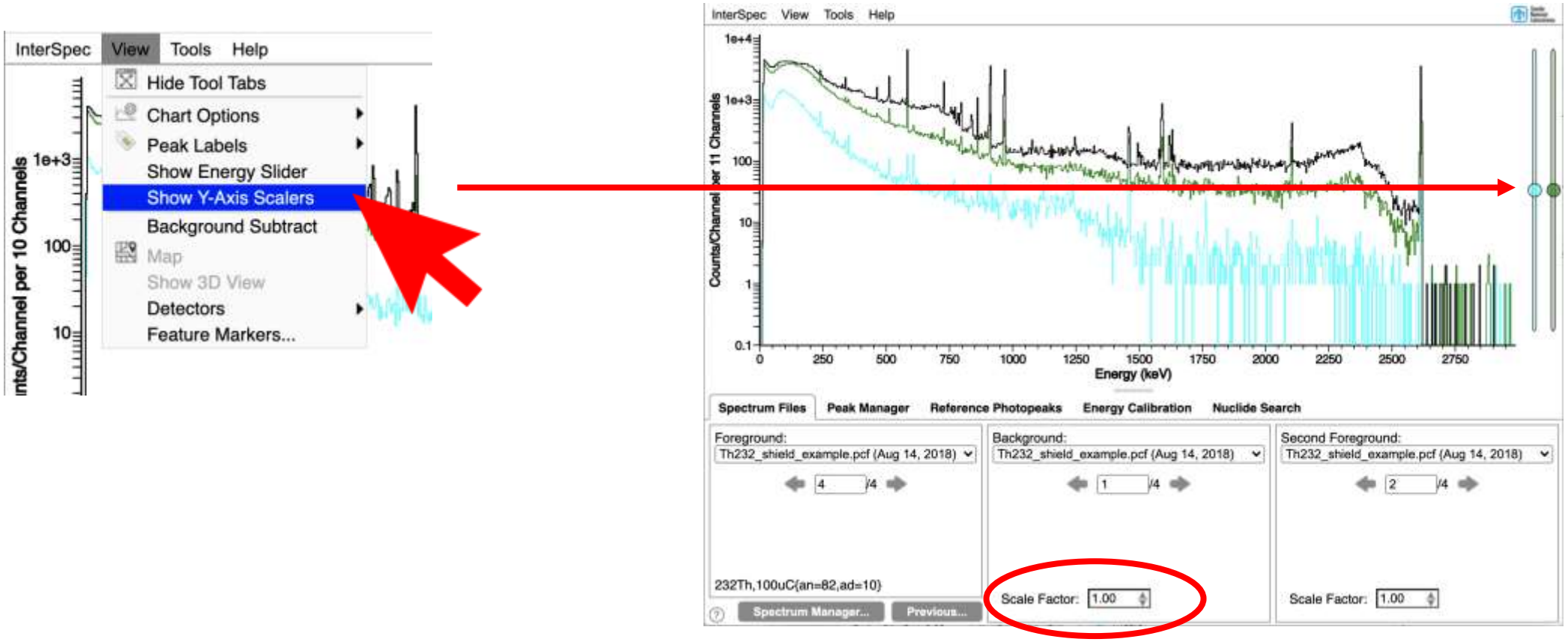
Topics to be covered

Part 1 (previous presentation)
- InterSpec's Capabilities
- A demonstration of using InterSpec for analysis
- Using InterSpec
  - Interacting with spectra, viewing options, spectrum files, saving work, reference photopeak lines, peak-fitting, nuclide search
- Energy calibration
  - Manual adjustment, graphical adjustment, fitting from photo-peaks, multi-file, non-linear deviation pairs
- Fitting activity and shielding
  - Multiple isotopes, shielding types, limitations

Part 2 (this presentation)
- More display options
- Nuclide ID
  - Nuclide Search
  - Reference Photopeak lines
- Other useful tools in InterSpec
  - Dose, gamma flux, nuclide decay, …
- Creating detector response functions

More Display Options

More Display Options – scaling spectrums



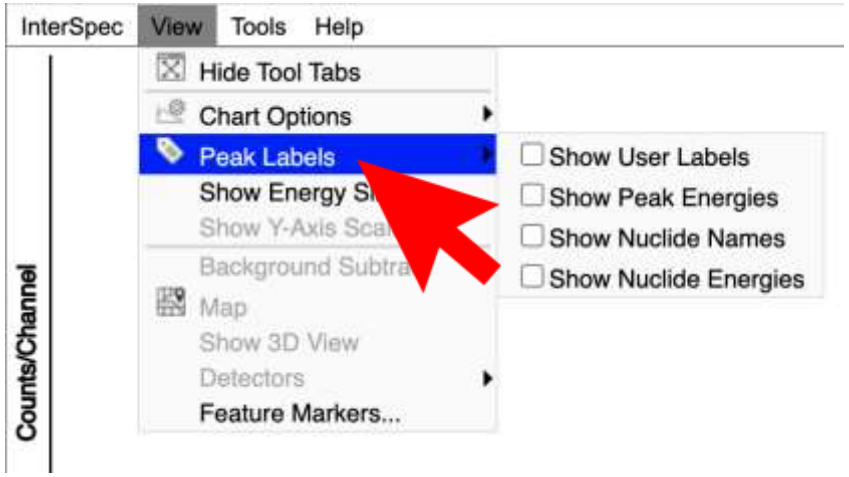
By default, InterSpec will live-time normalize the background and secondary spectrum to the foreground

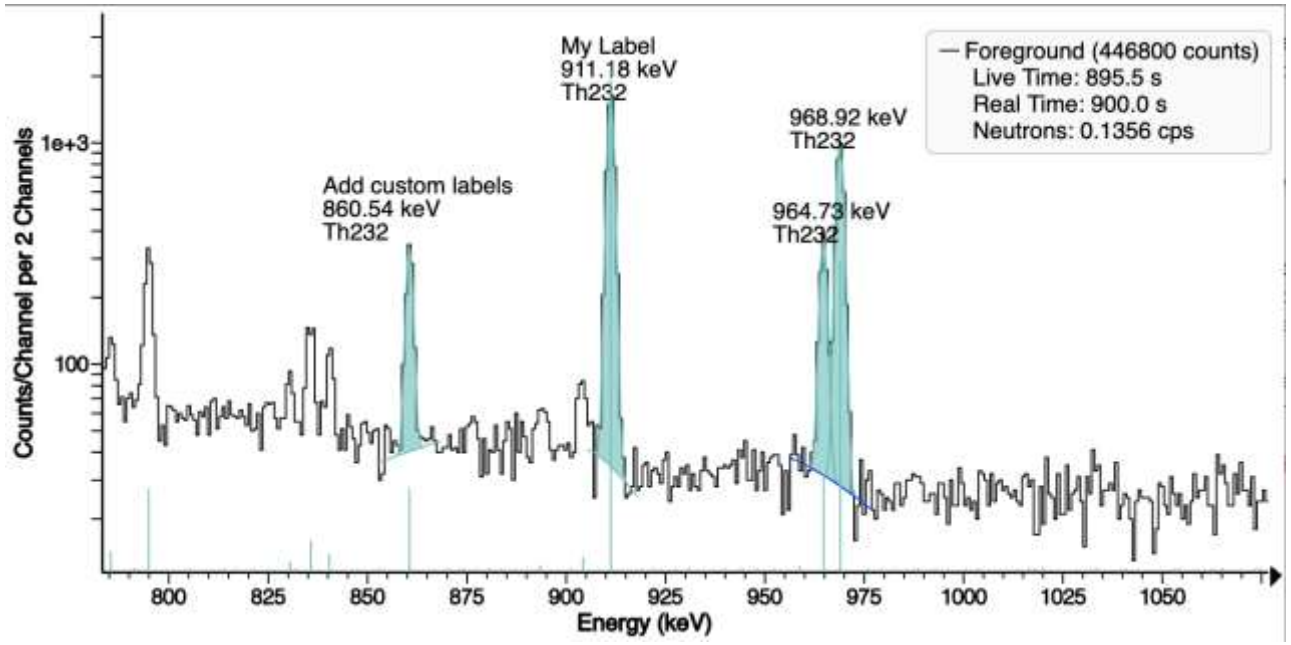
- You can manually enter the scale factor you want on the "Spectrum Files" tab

From the **View** menu you can select **Show Y-Axis Scalers** that let you graphically scale the spectra

- Particularly useful for comparing spectra against reference spectra

More Display Options – peak labels

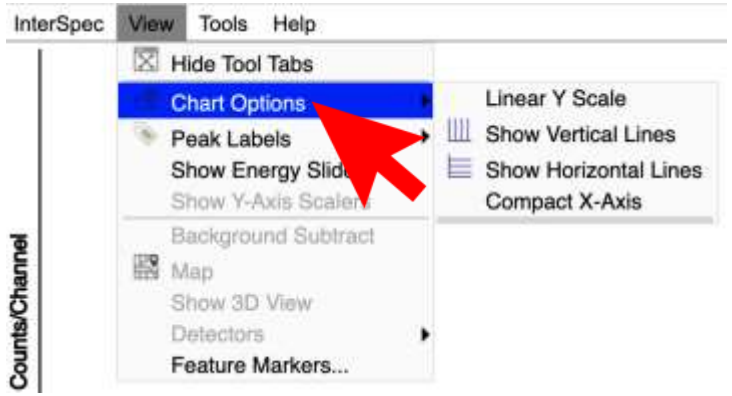


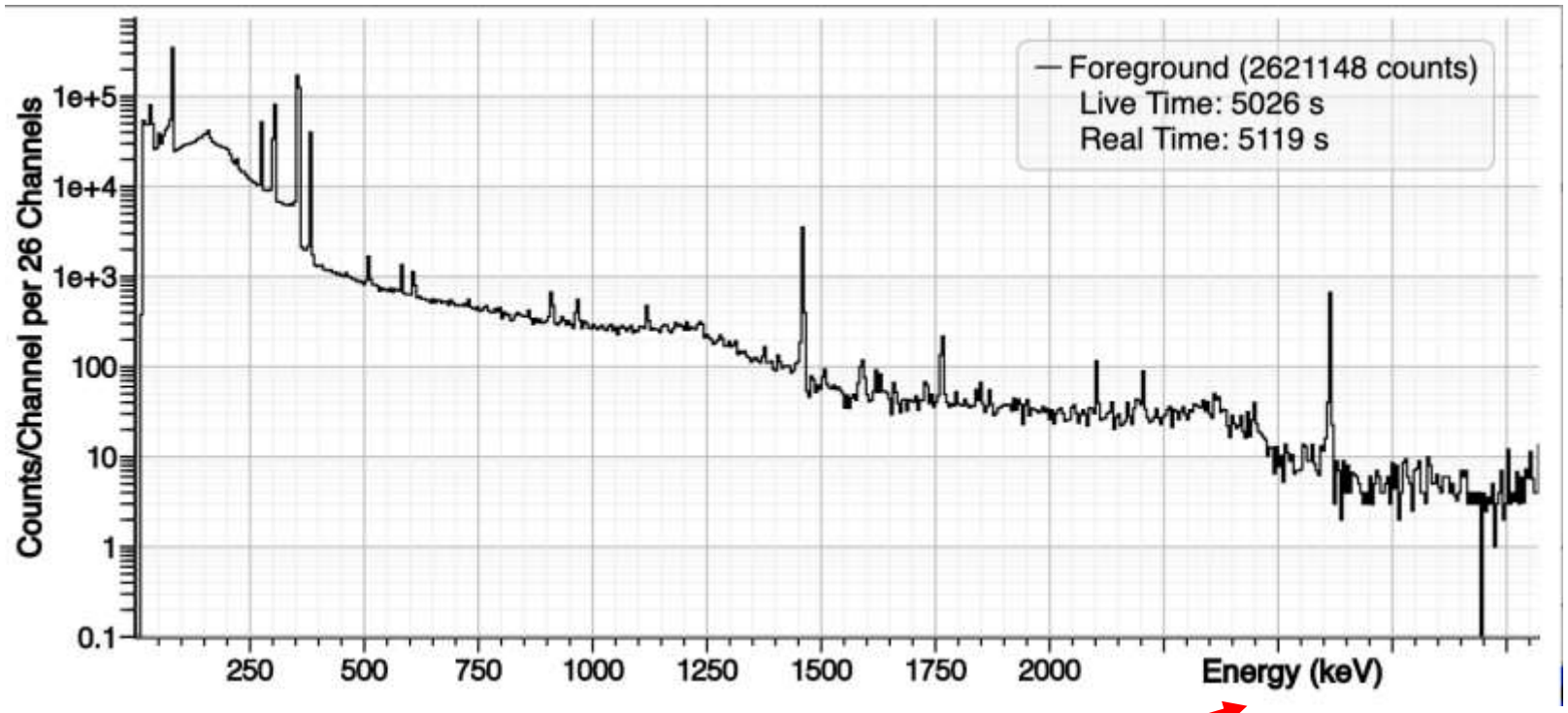


You can choose to show peak energy, nuclide, gamma, and/or a user label for each peak

You can add or edit the user label using the "Peak Manager" tab, or the "Peak Editor"

More Display Options – chart options





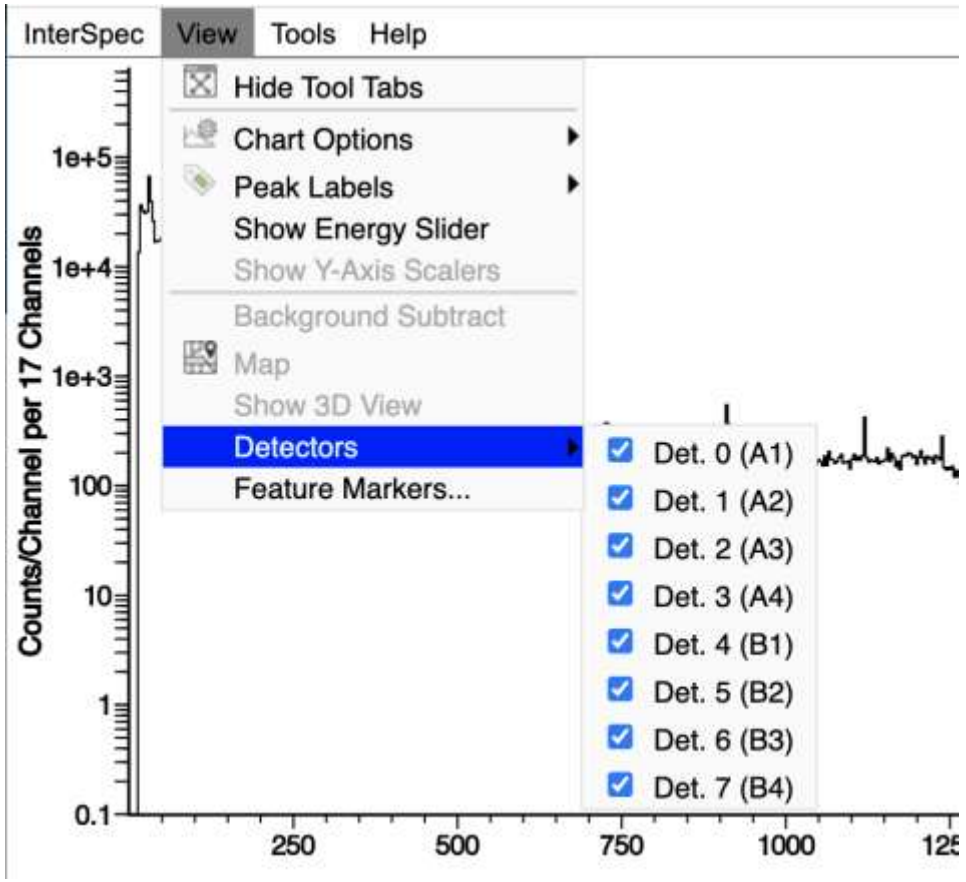
Linear Y Scale: occasionally useful when squinting at tiny peaks or features

Vertical/Horizontal Lines: sometimes useful for reports or HPGe spectra

Compact X-Axis: good for screens with limited real-estate

Hide Tool Tabs: entire screen becomes spectrum; the tabs contents become available in the "Tools" menu

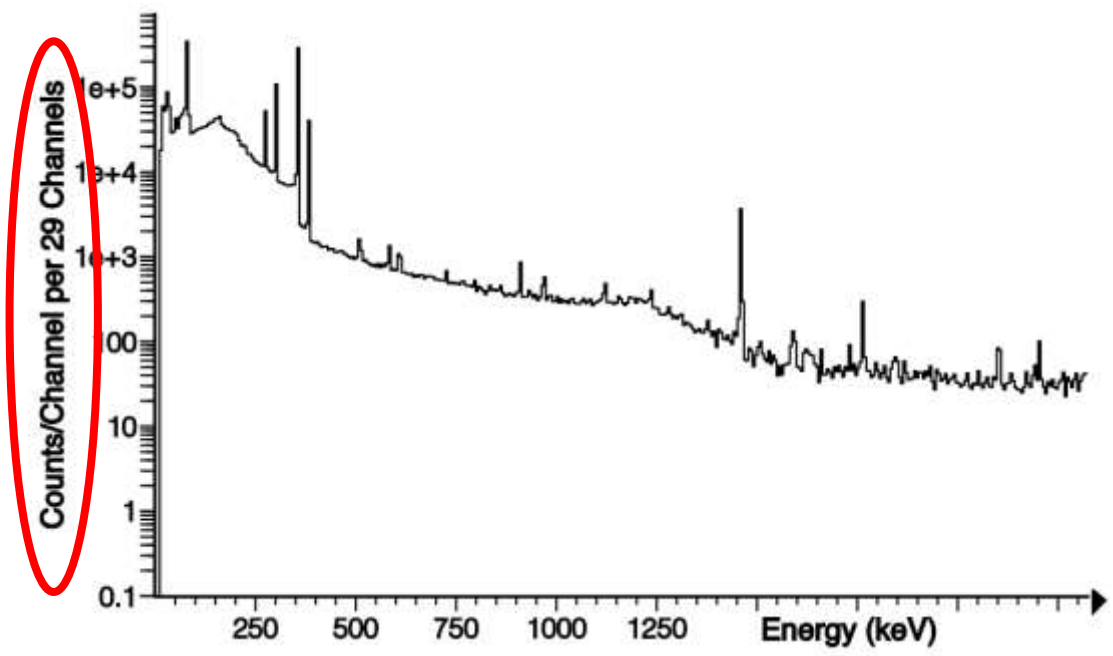
More Display Options – multiple detectors

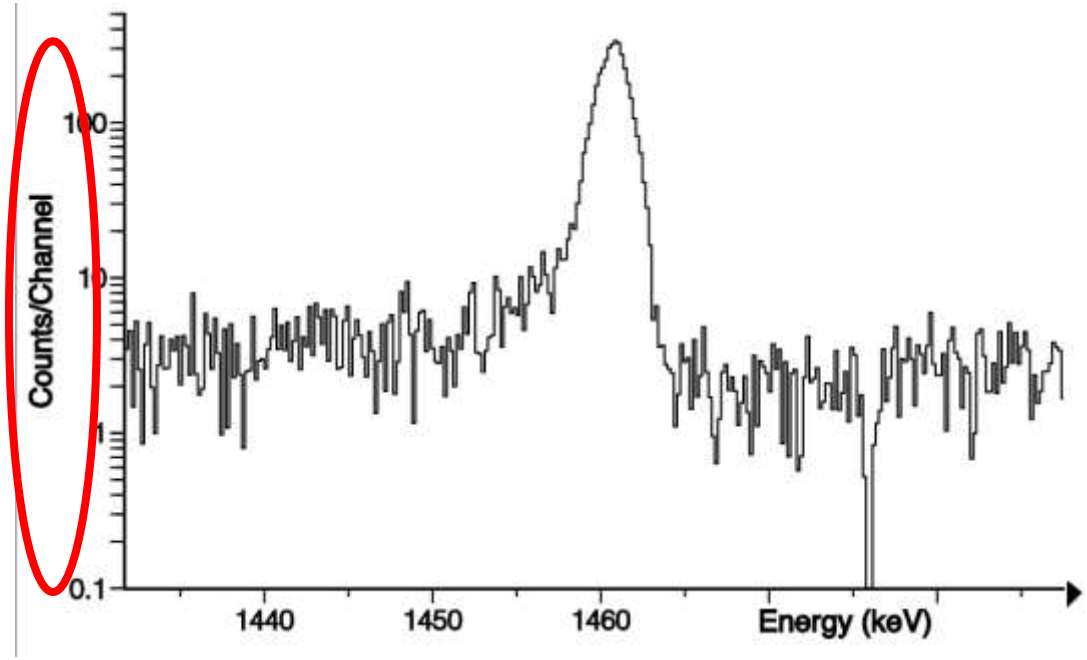


If the spectrum file contained multiple detectors, you can control which ones the data is displayed from

- Can be useful to isolate left/right side of portal monitors, or to energy calibrate sub-set of detectors

A note about the spectrum display:





When there are more spectrum channels than pixels, multiple channels are summed together for display

As you zoom in and out, this is dynamically adjusted

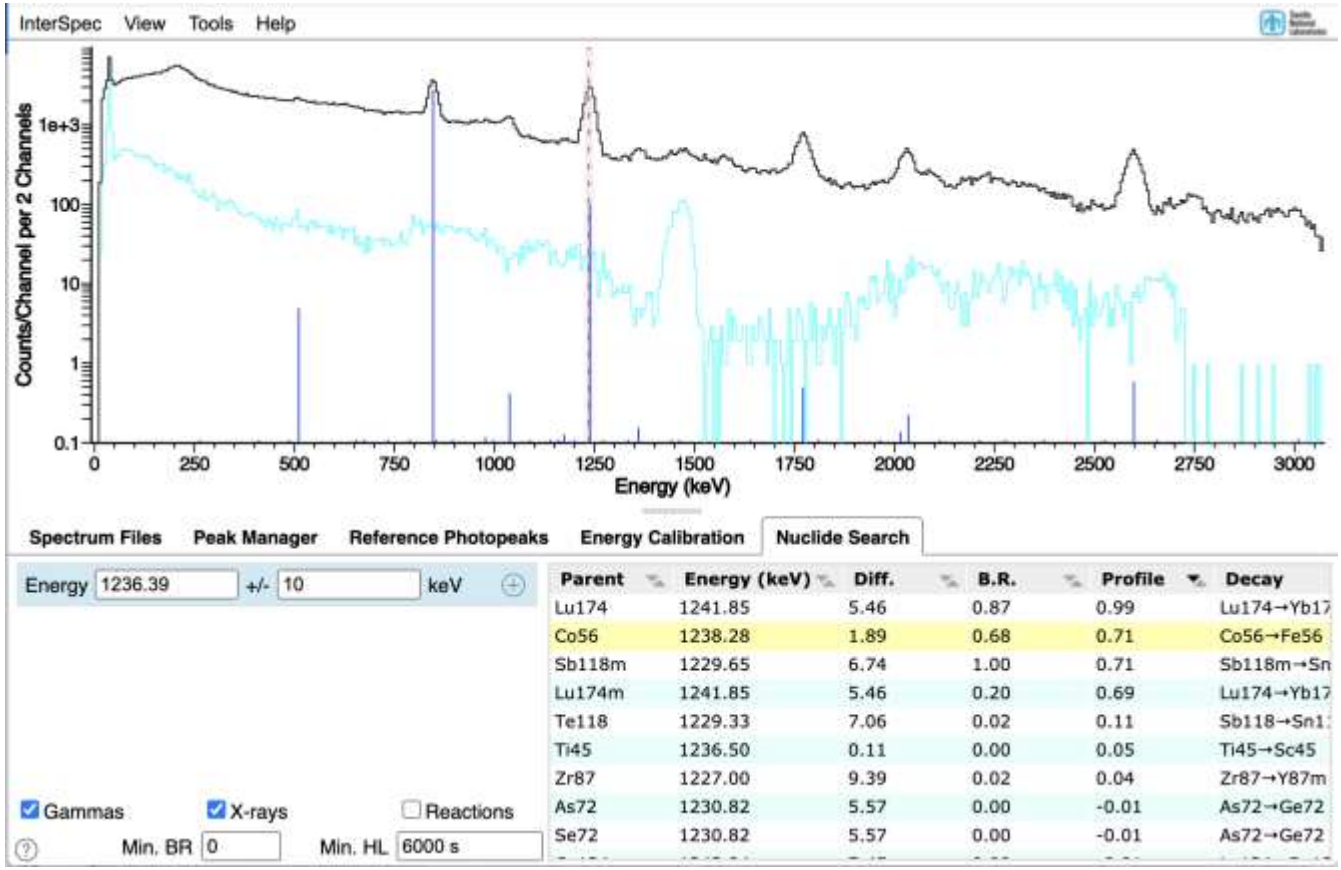
The time-history plot does the same thing (but *currently* doesn't allow zooming in/out)

Seems to be the least-misleading way to display the data in discernable way

Nuclide ID

general features

Nuclide ID

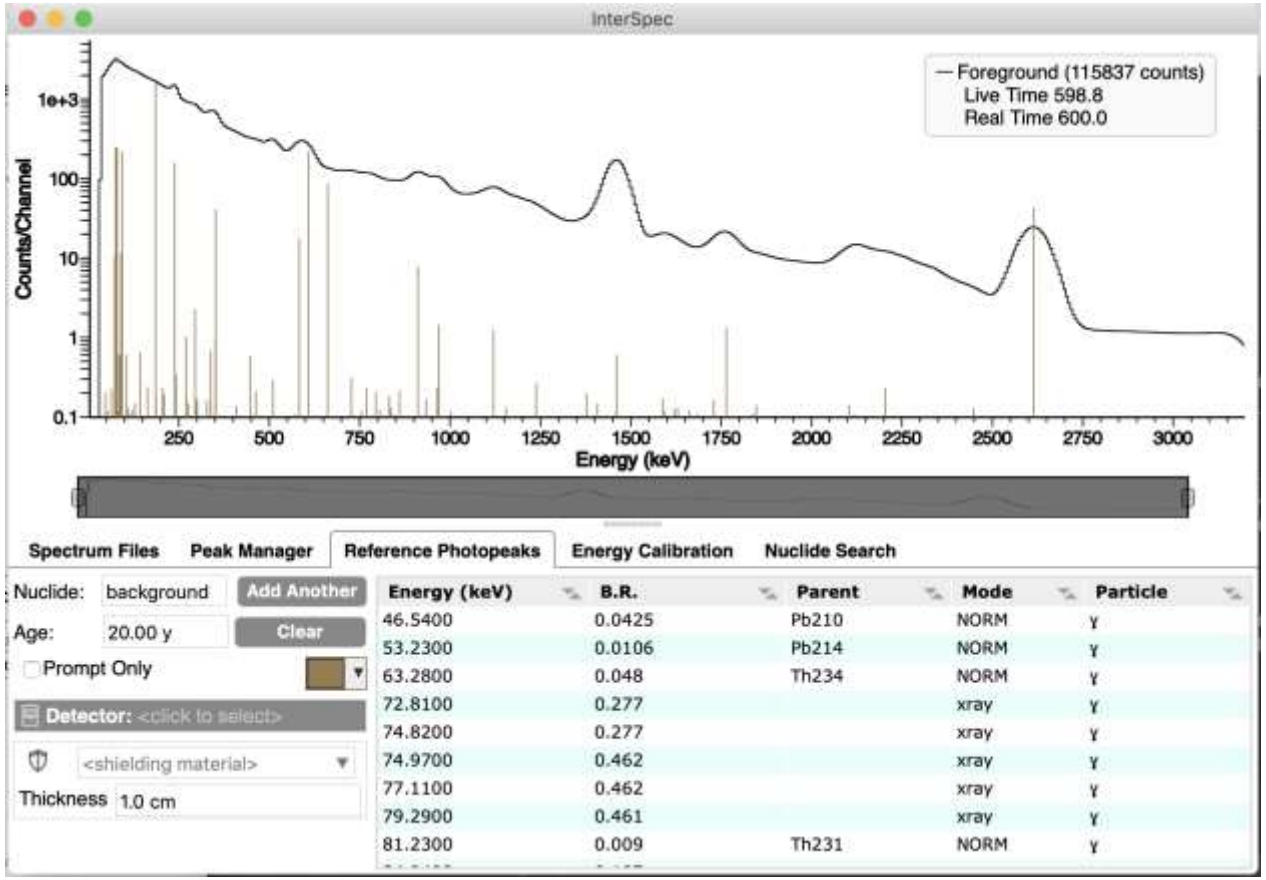


The two primary tools to help you with nuclide ID in InterSpec are "Nuclide Search" and "Reference Photopeaks"

- InterSpec does not perform nuclide ID, but assists you, the competent analyst, with the ID

Before performing a nuclide ID, check your energy calibration

First, check your energy calibration

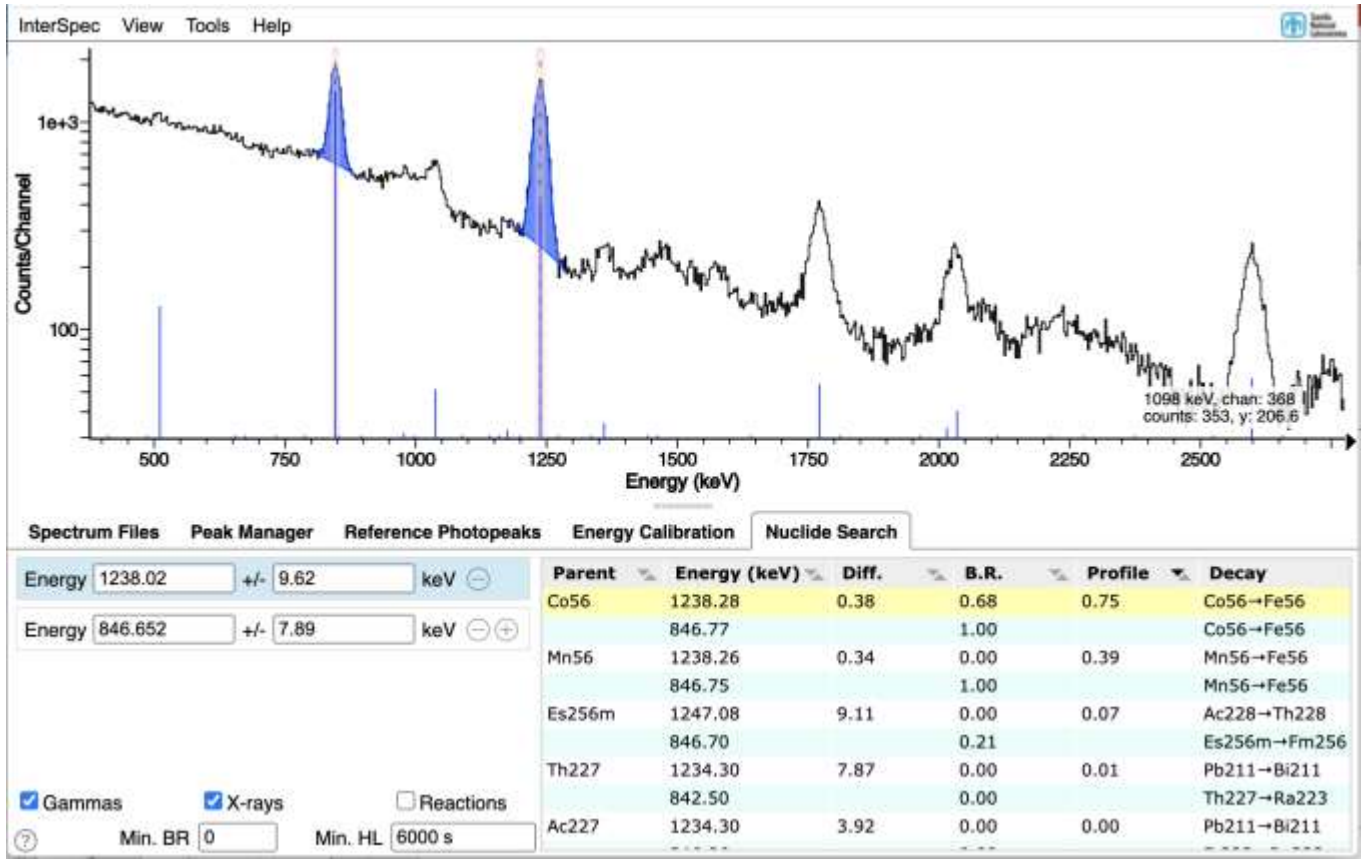


A recent spectrum of a known test source is best, but looking for background peaks in the primary spectrum or provided background may be good enough

You can provide "background" as a nuclide in the reference photo-peak tool to see most common background lines.

- Intensities will of course vary with geographical location, but taller lines are generally more likely to be seen

Nuclide Search

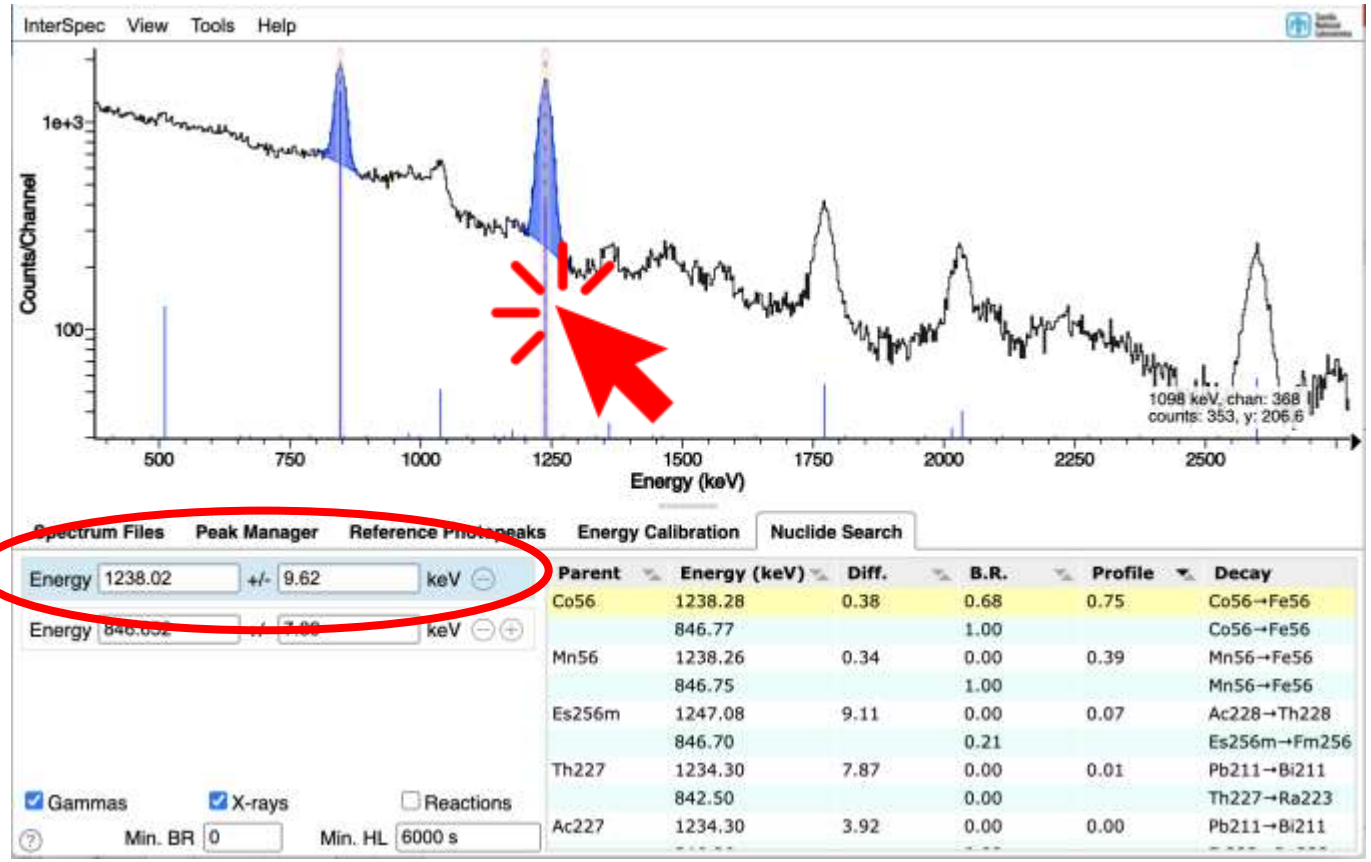


The "Nuclide Search" tool provides you a list of nuclides and reactions that have gammas, or optionally x-rays, within specified energy windows.

- You can have any number of energy windows; results will have a gamma or x-ray in each window
- More windows narrows choices, but also increases probability peaks are from separate nuclides

Clicking on a row in the results table will show reference lines for that nuclide – you then perform an inter-ocular assessment if that is the correct nuclide for your spectrum

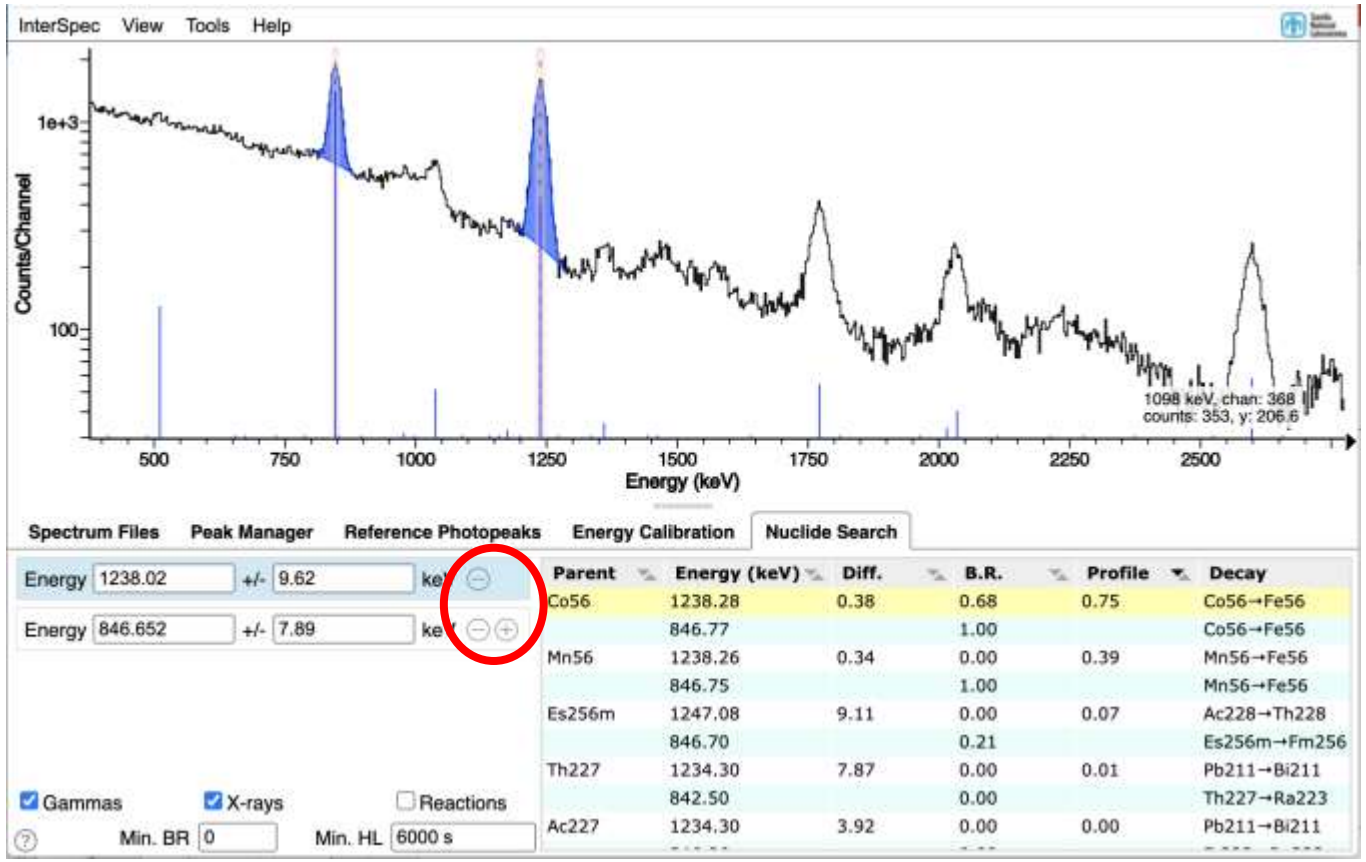
Nuclide Search (cont.)



Clicking on the spectrum while the "Nuclide Search" tab is showing will put the energy you clicked on into the entry form; you can then click somewhere else, and it will fill in the next energy entry.

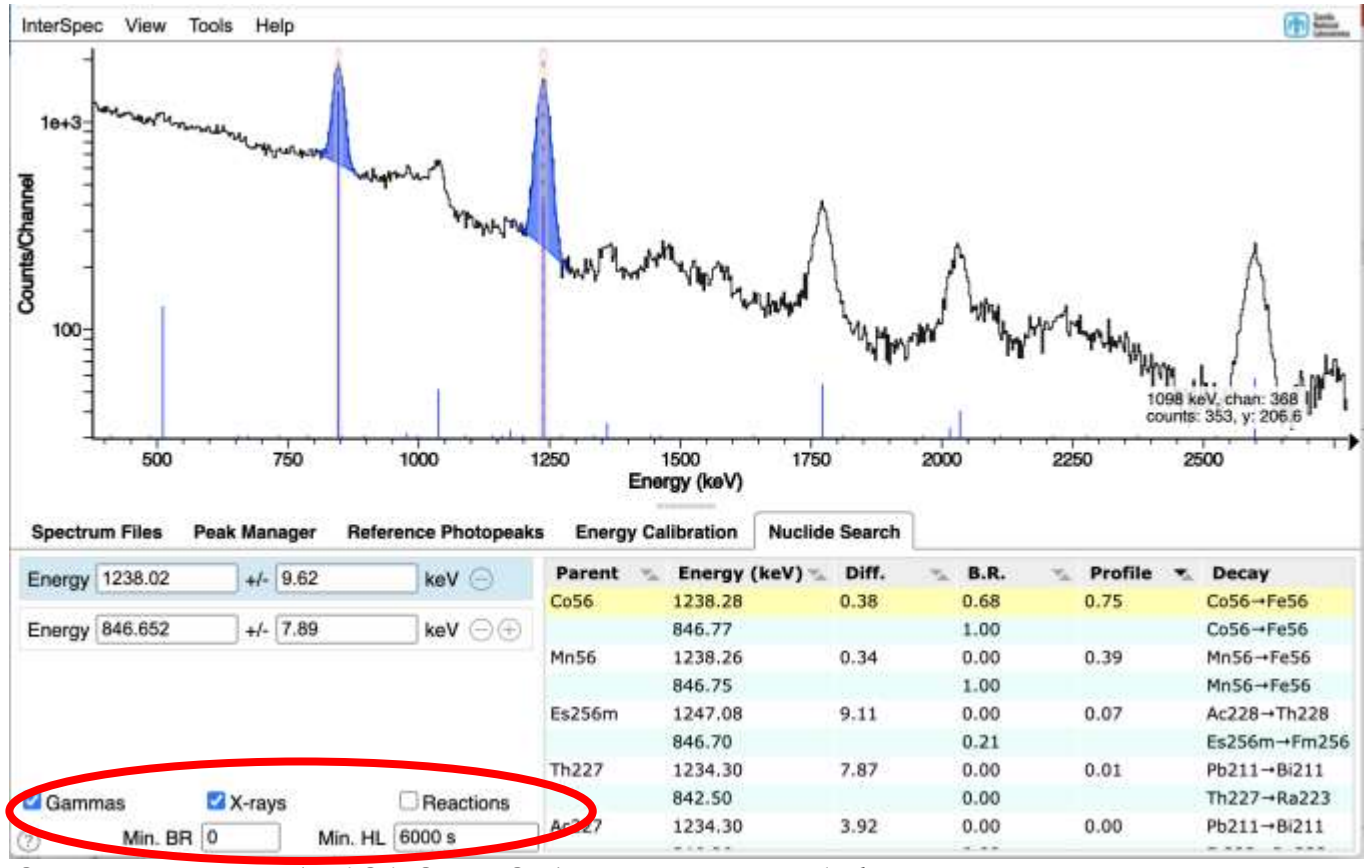
- If you click near a peak (within 1.15*FWHM), the window-width will be filled out as well; for HPGe will be 1 FWHM of the peak, and lower resolution detectors will be 0.35*FWHM.

Nuclide Search (cont.)



You can add or remove energy windows using the "+" and "-" buttons

Nuclide Search (cont.)



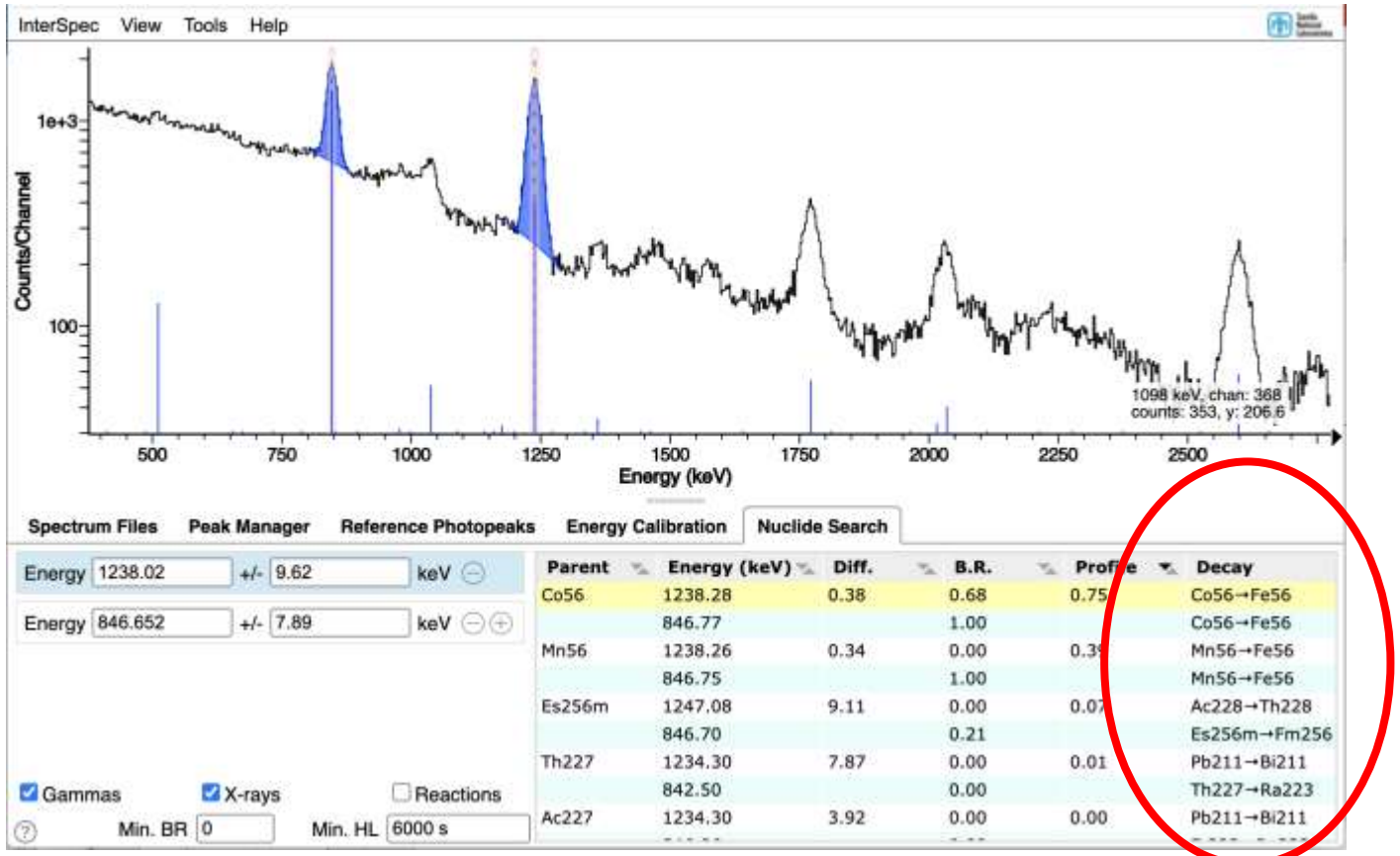
You can also specify a minimum half-life (of the parent nuclide)

- useful to eliminate the many very shortly lived nuclides; default is 100 minutes

You can also specify the minimum branching-ratio gammas must have to be considered for matching in the energy windows

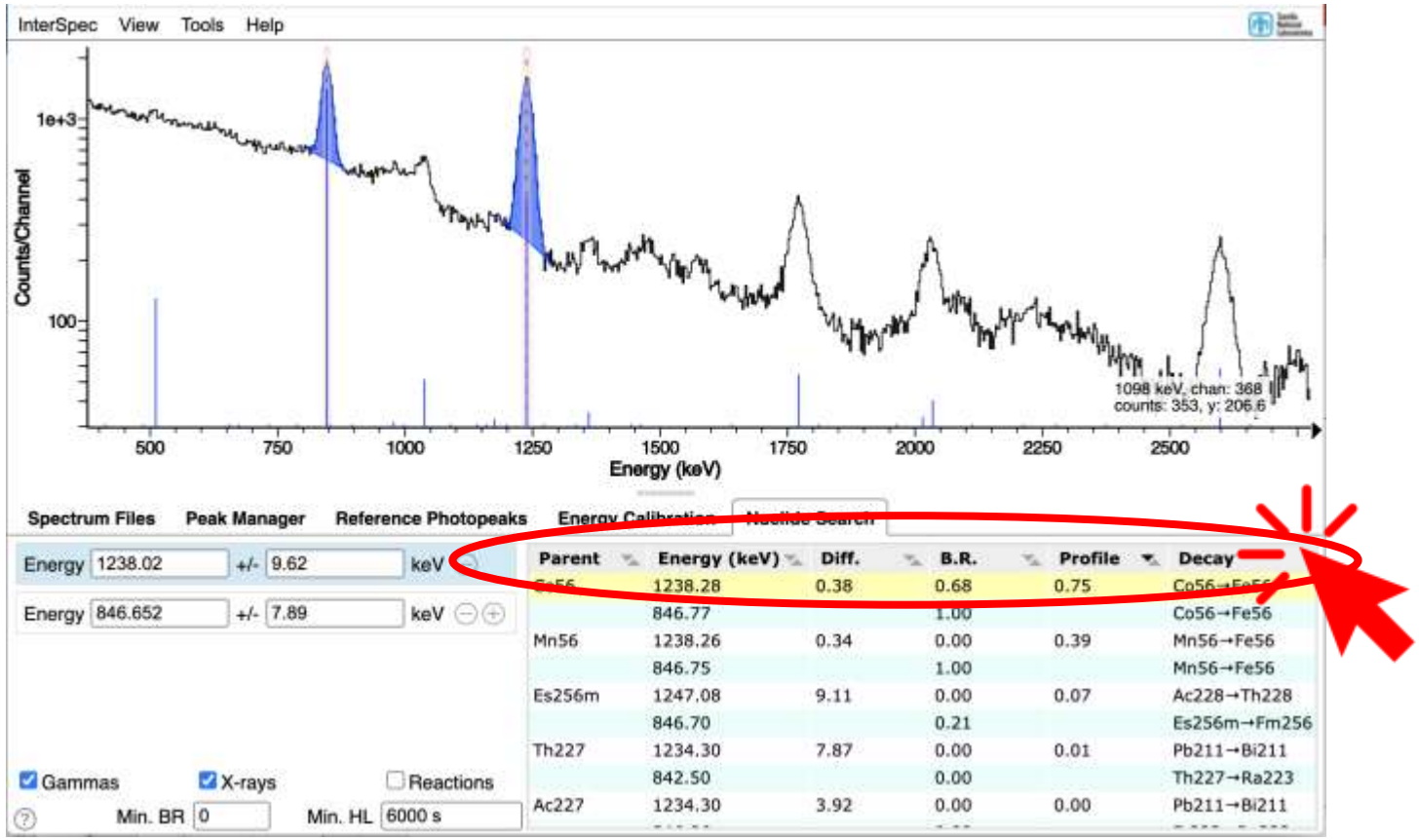
- Useful to eliminate nuclides that have a ton of low-intensity gammas
- This actually filters based on the fraction of gammas at each energy, at each stage of decay, so some lower-BR gammas may still get included

Nuclide Search (cont.)



- The energy matching is performed after decaying each nuclide, so that all prodigy are also considered in doing the match; the last column on the right show you which decay in the chain the gamma comes from
- All >4000 nuclides, and ~110,000 gammas are considered for the search
- x-rays above ~10 keV are considered for all elements
- About 200 alpha,n, n,alpha, alpha-proton, n-capture, and inelastic n-scatter reactions are considered

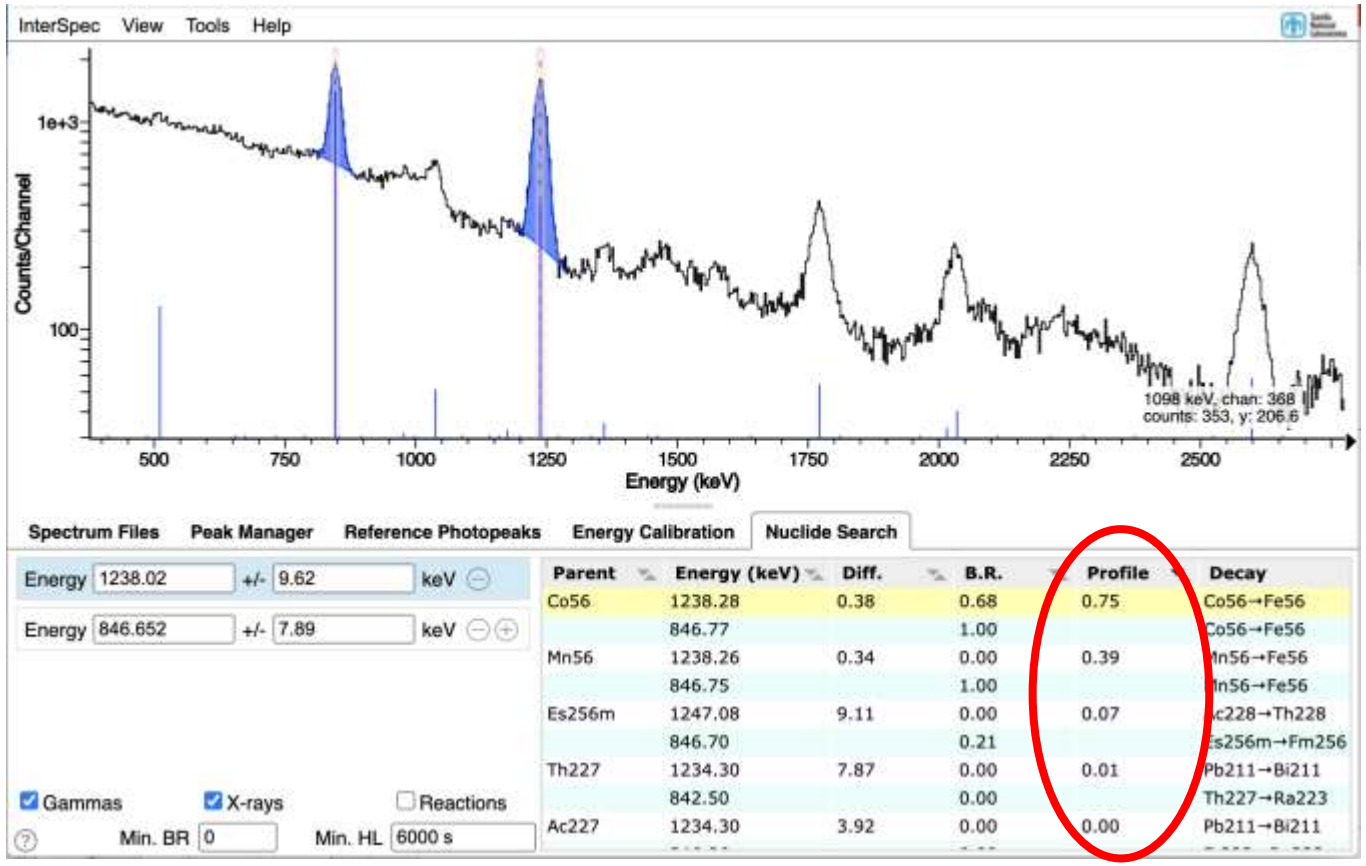
Nuclide Search (cont.)



You can sort results by any column by clicking on the table header

- The "Diff." column is the sum difference between the search energies, and the matching gamma
- The "B.R." column is, after decay, the relative intensity of the gamma, to the largest intensity gamma of the decay
  - A heuristic is used to select the age to decay nuclides to based on if it can reach secular equilibrium, half-life, and descendants half-life
- The "Profile" column is default, and almost always provides best result

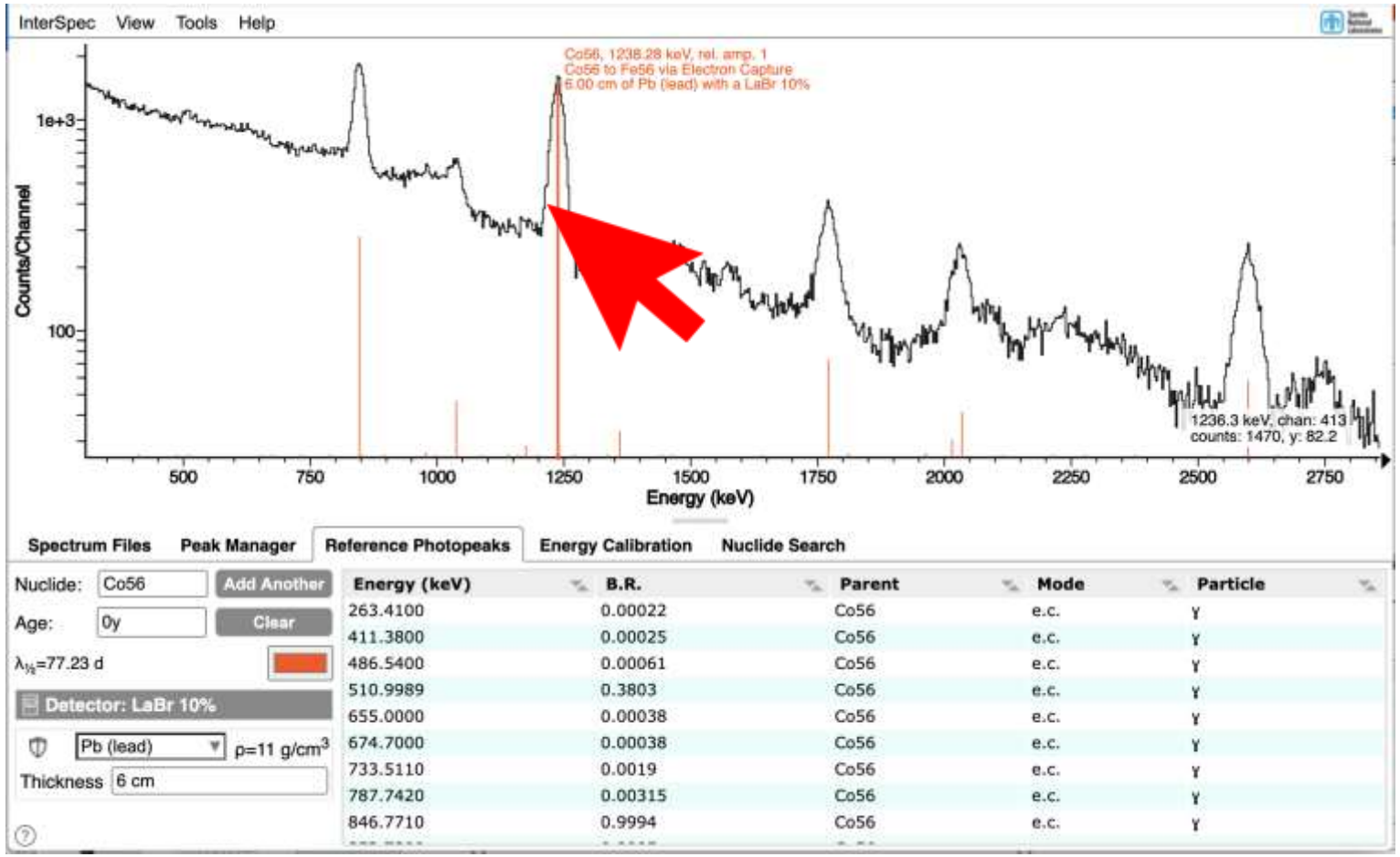
Nuclide Search (cont.)



The "Profile" column is a heuristic that ranges between -1 and 1 to give you a relative idea of match quality

- Use this value relative to other search results – it doesn't have an absolute meaning
- This value takes into account all peaks in the spectrum (the ones you've fit, plus ones returned from an auto-search), a few possible shielding and aging scenarios, relative amplitudes of peaks, and gamma-lines that should-have created a peak but were no peak is observed
- Normally much better than ordering by "Diff." or "B.R."

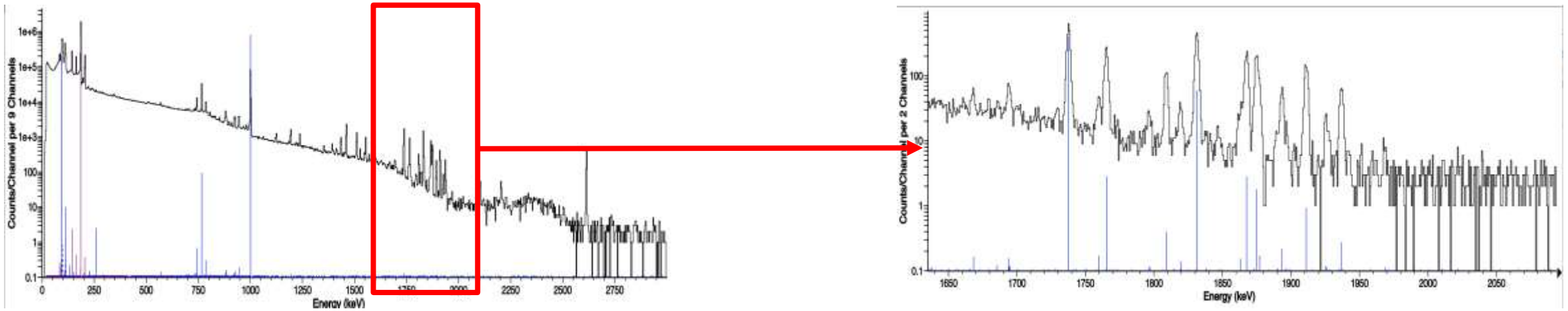
Reference Photopeaks



The "Reference Photopeaks" tab might be the most useful tool in InterSpec

- Gives you access to all >4000 nuclides, all x-rays, and ~200 reactions
- You can age nuclides, add shielding, DRF, and when appropriate just prompt products
- The reference lines on the spectrum provide additional information when you mouse-over them

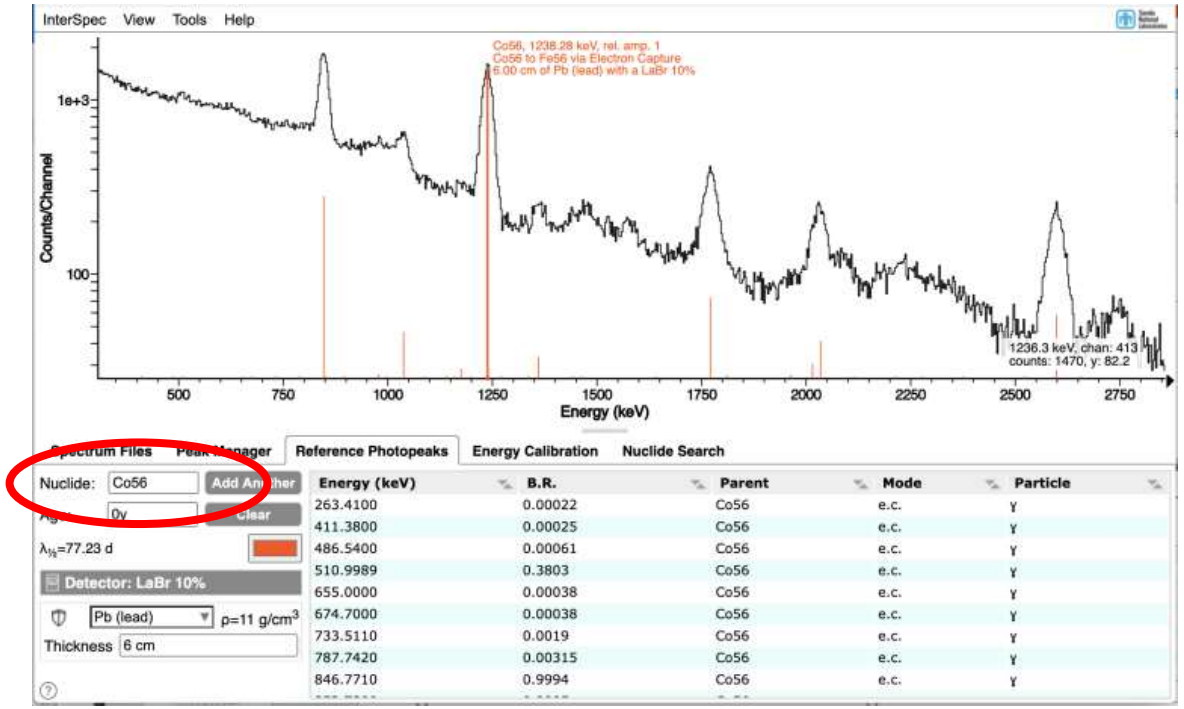
Reference Photopeaks (cont.)



The height of the lines on the spectrum indicate relative intensity of gammas/x-rays

- The heights are scaled so the highest intensity gamma line in currently displayed energy range has a height of 1, and all other lines are scaled linearly relative to this
  - Even if the spectrum y-axis is log, reference lines are linear – this best matches what is seen in the data-spectrum, given the continuum counts
- Shielding and DRF (if entered) are taken into account in the chart-line amplitudes, but not on table values

Reference Photopeaks (cont.)



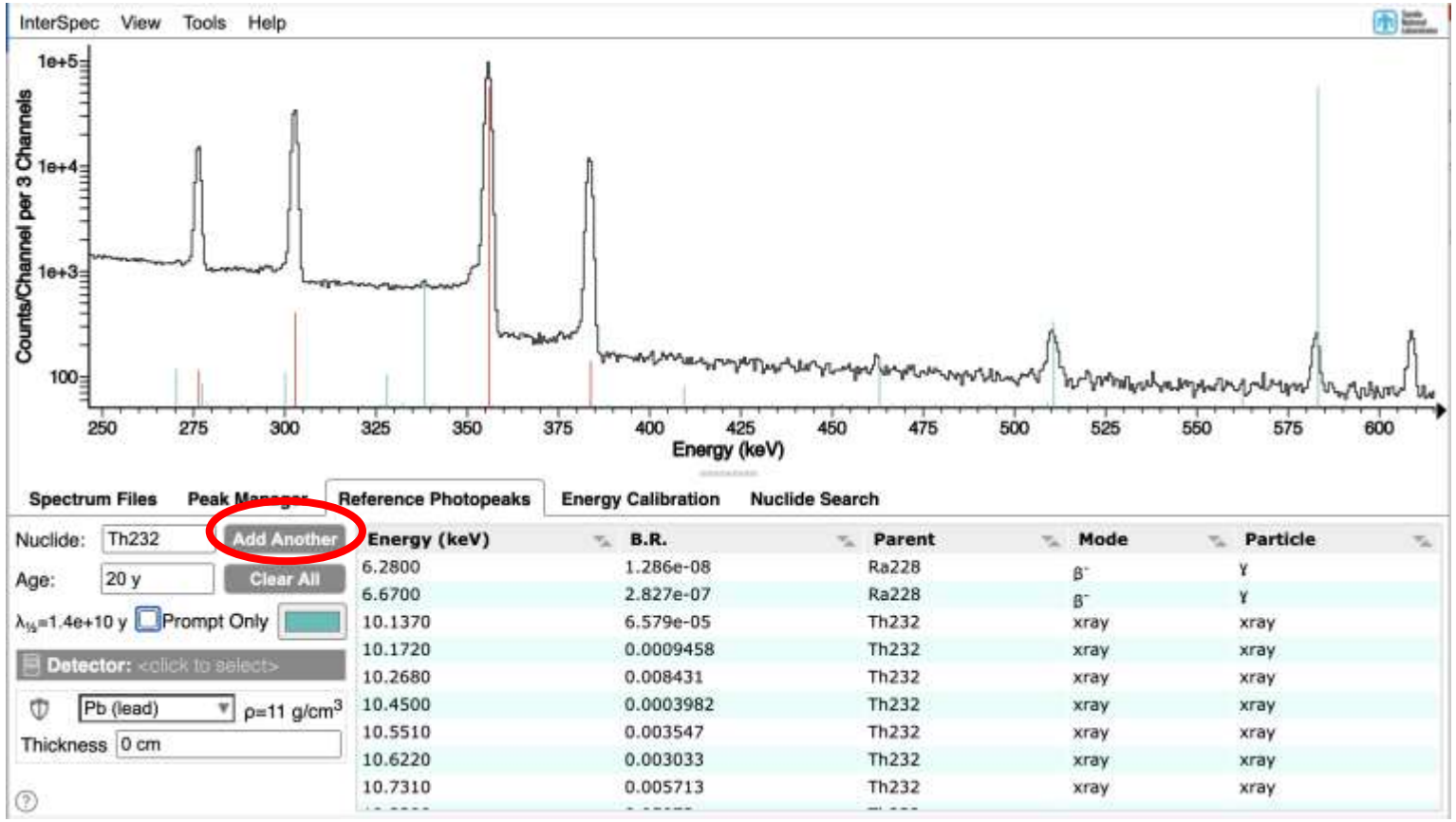
You can enter "nuclides" in fairly flexible, e.g., all the following are valid:

- Co56, Co-56, 56Co, 56 Co, 56-Co, cobalt 56, 56 Cobalt.
- Ho166m, Ho-166 meta, 166m Ho, 166m-Ho, holmium 166m
- Once you finish entering, will be converted to format like "Co56"

Reactions are entered like: "H(n,g)", "Ge(n,n)", etc

You can also enter "Background", or an element name/symbol for its florescence x-rays

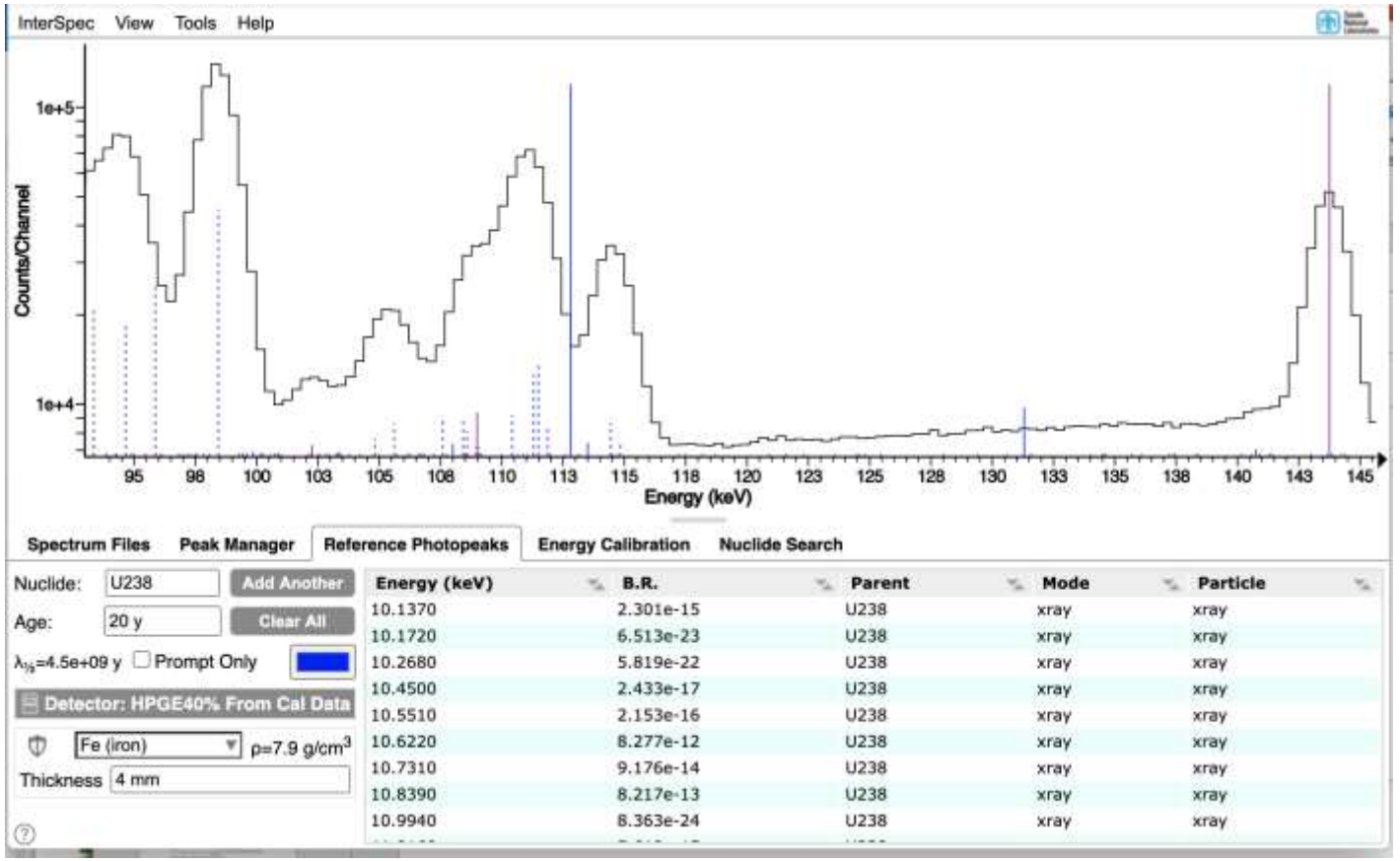
Reference Photopeaks (cont.)



To display lines for multiple isotopes, click "Add Another" and enter a new nuclide in

- Each nuclide can have a different shielding, age, etc. Changing these fields only changes the current nuclide, if you want to alter a previously entered set of reference lines, just type that name into the "Nuclide" field
- Line height scaling for currently visible energy range happens on a per-nuclide level
- If you fit a peak while showing multiple nuclides, usually the best one is chosen to associate with a peak

Reference Photopeaks (cont.)



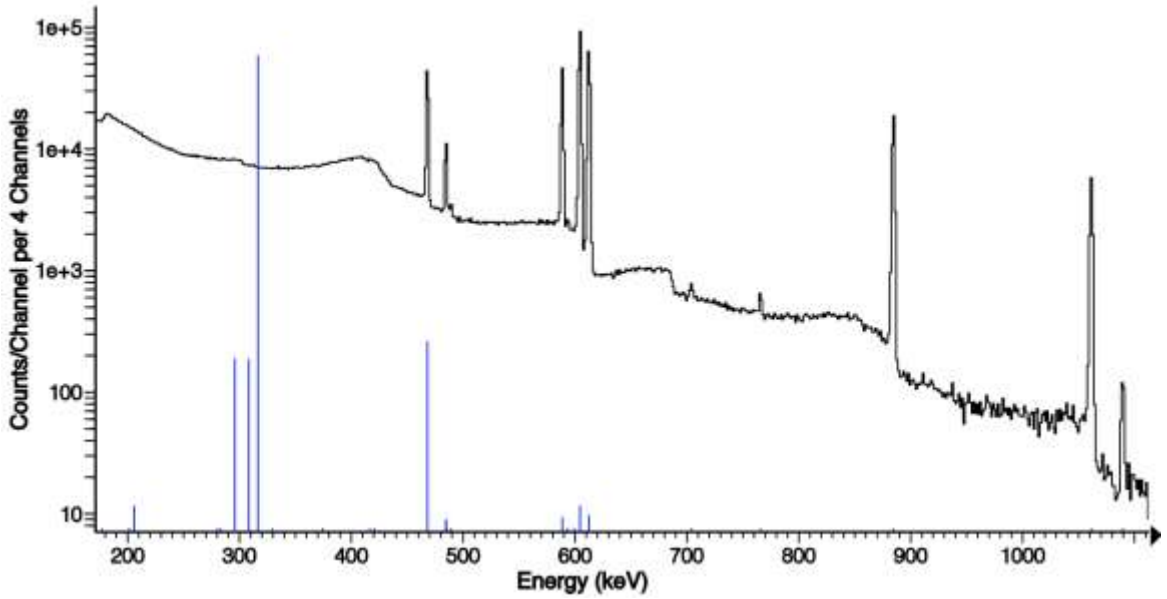
Reference lines for nuclides will also include x-rays that are emitted during decays

- x-ray intensities are computed during decay calculations so their intensities are comparable to the gammas
  - But be aware of geometry or florescence effects

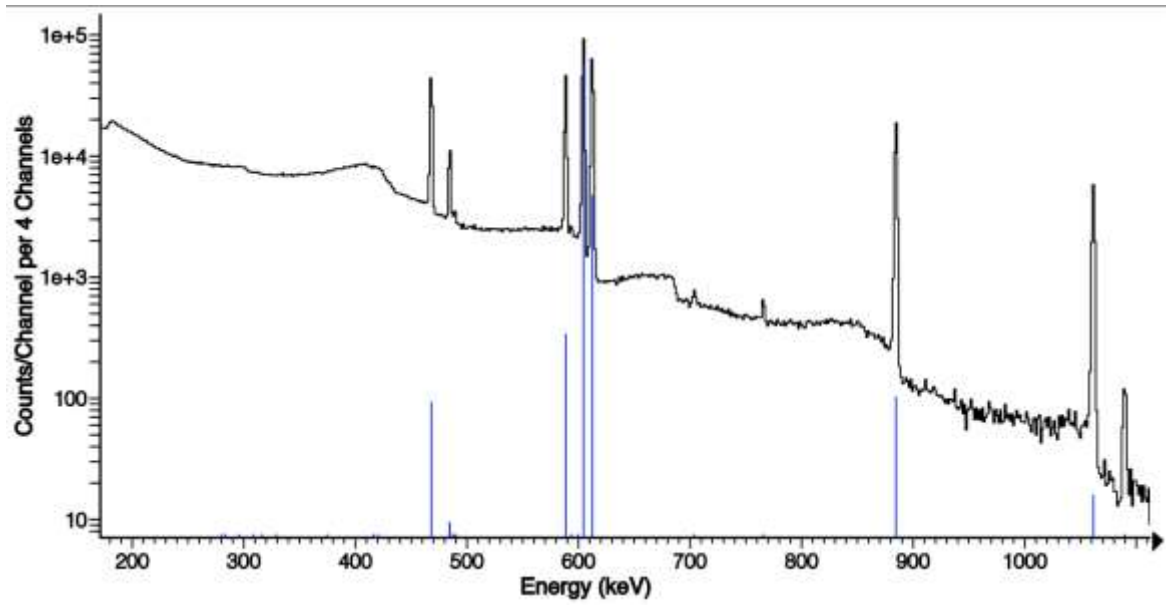
X-rays are shown as dotted lines on the spectrum

If you just enter a element, its florescence x-rays are shown

Reference Photopeaks (cont.)



Ir-192 reference lines with no shielding

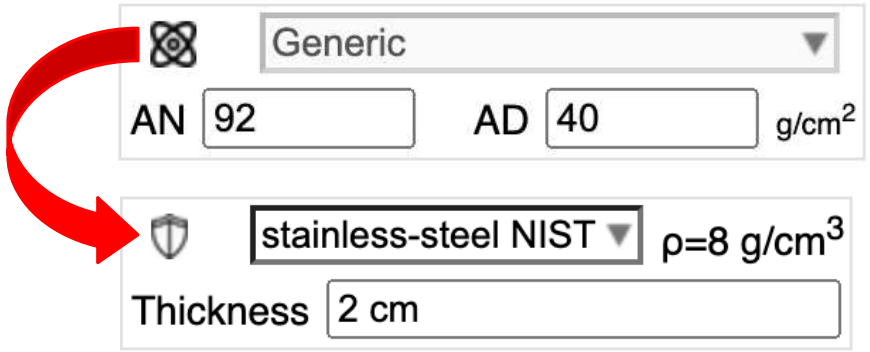


Ir-192 reference lines with heavy shielding

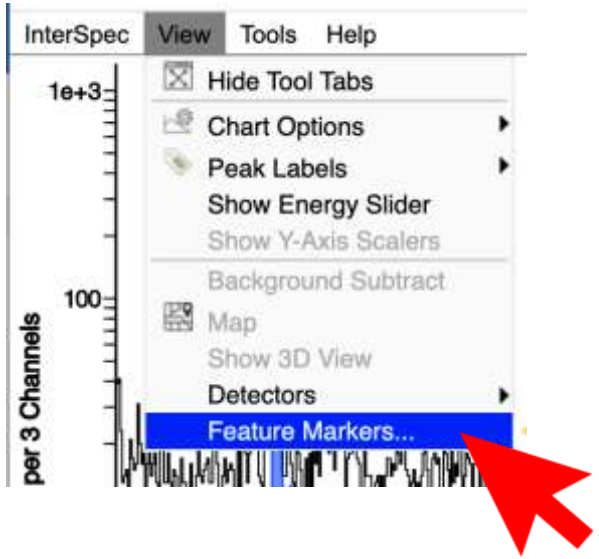
Adding shielding can be useful to:

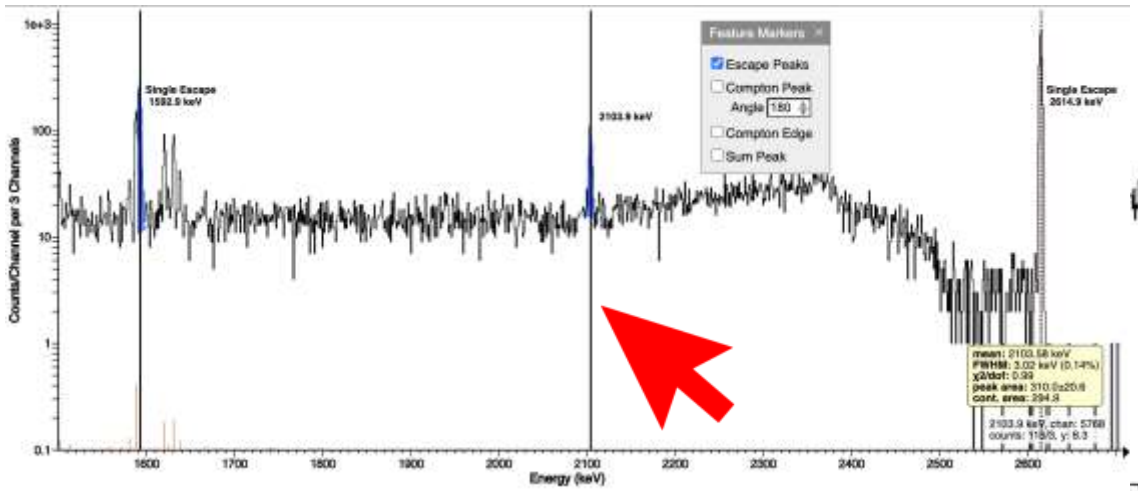
- Knock down high-intensity low-energy lines that are easily shielded
- Account for large amounts of shielding

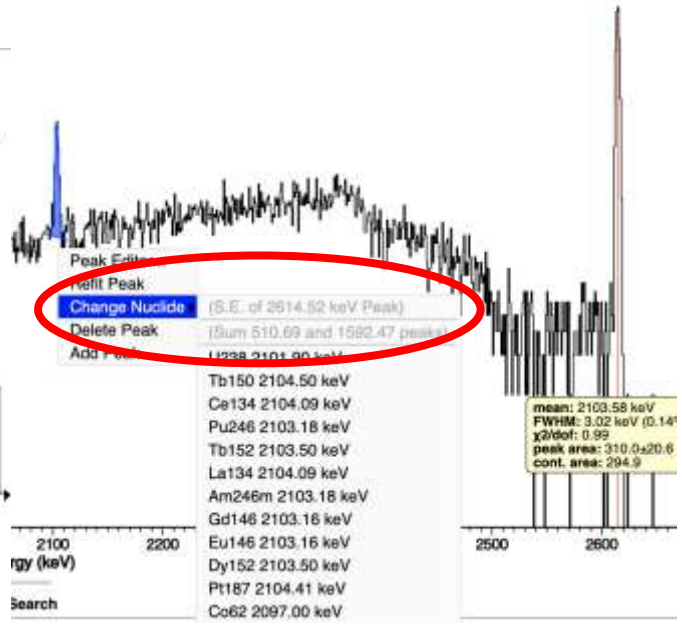
Clicking on the atom/shield symbol converts between generic and specific material



Other useful tools in InterSpec – Feature Markers







Not all peaks and features in a spectrum are caused by full-energy absorption of a gamma/x-ray

- Escape peaks fall 511 keV and 1022 keV bellow the full energy peak
- Sum peaks at double the actual energy
- Compton peaks or Compton edges can be confused for peaks, or scatter angle can be important to figure out

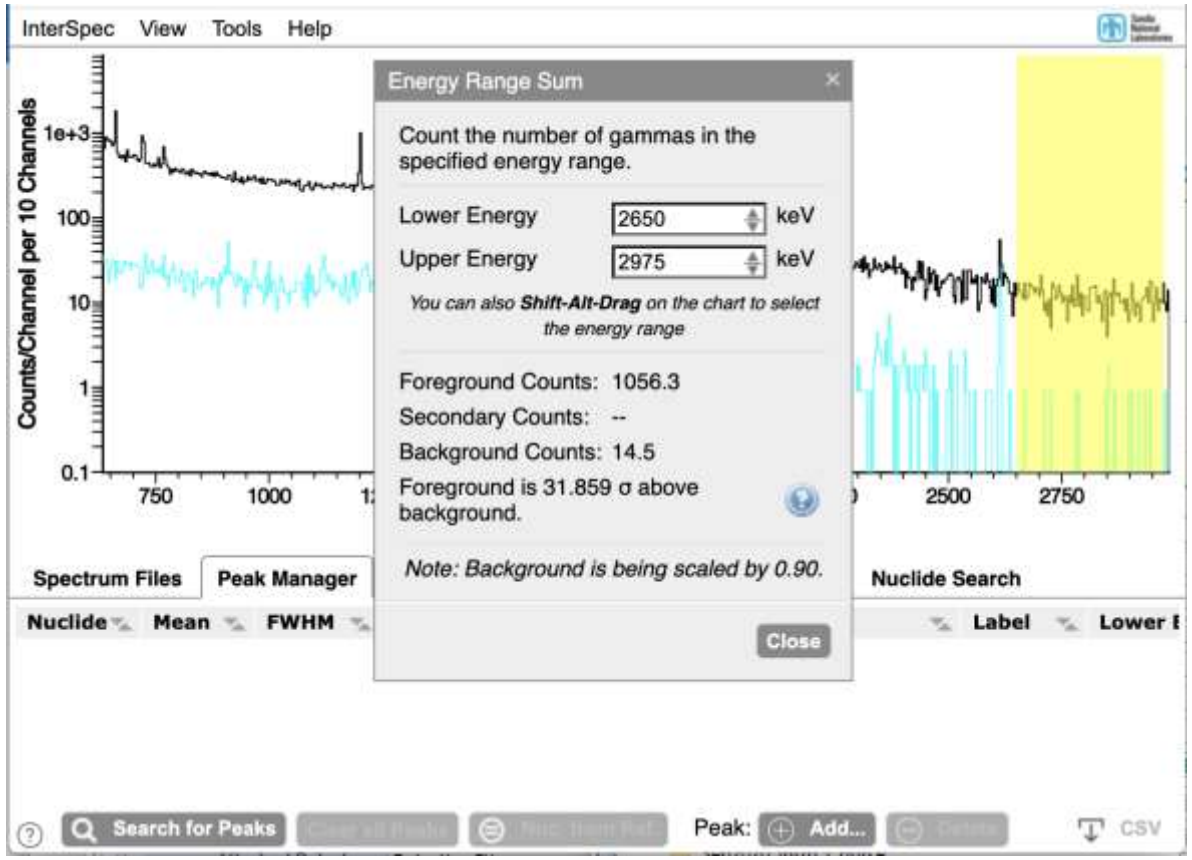
As you move the mouse on the spectrum, lines will be drawn on left and right to show where the source peak and feature peak would be for the current mouse position

You can also try right-clicking on a peak and InterSpec will let you know about sum and escape peak possibilities

- Uses both the peaks you've fit, as well as the automated peak search results, so it works pretty well

If there are some peaks left in the spectrum that you cant identify, this tool is worth a try, especially for HPGe

Other useful tools in InterSpec – Energy Range Sum

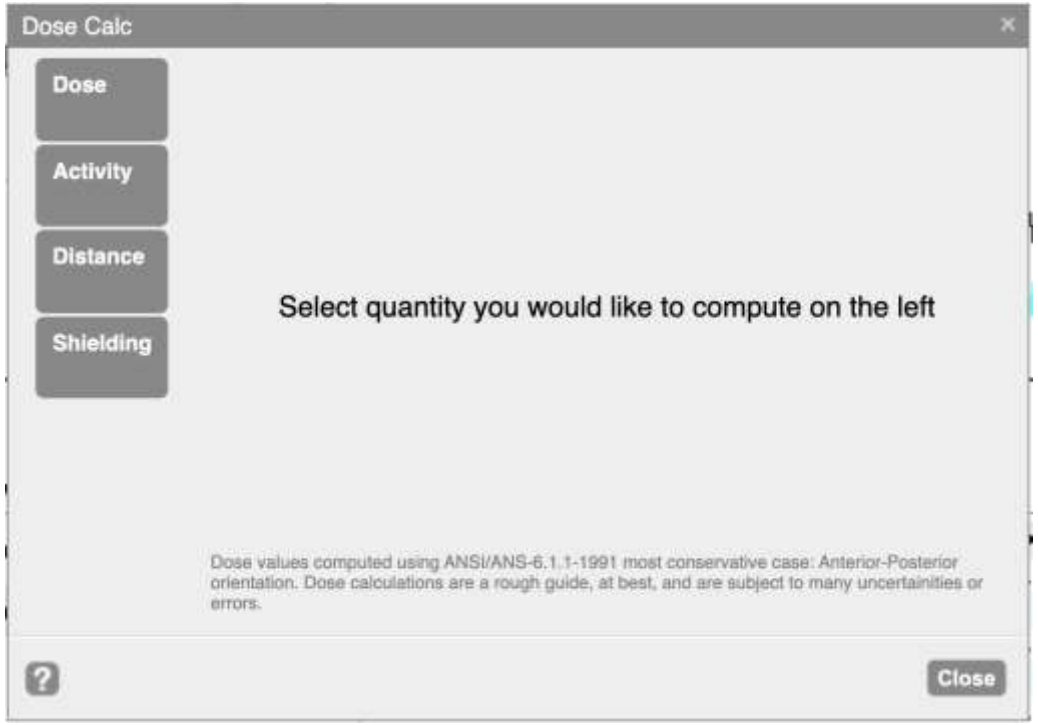


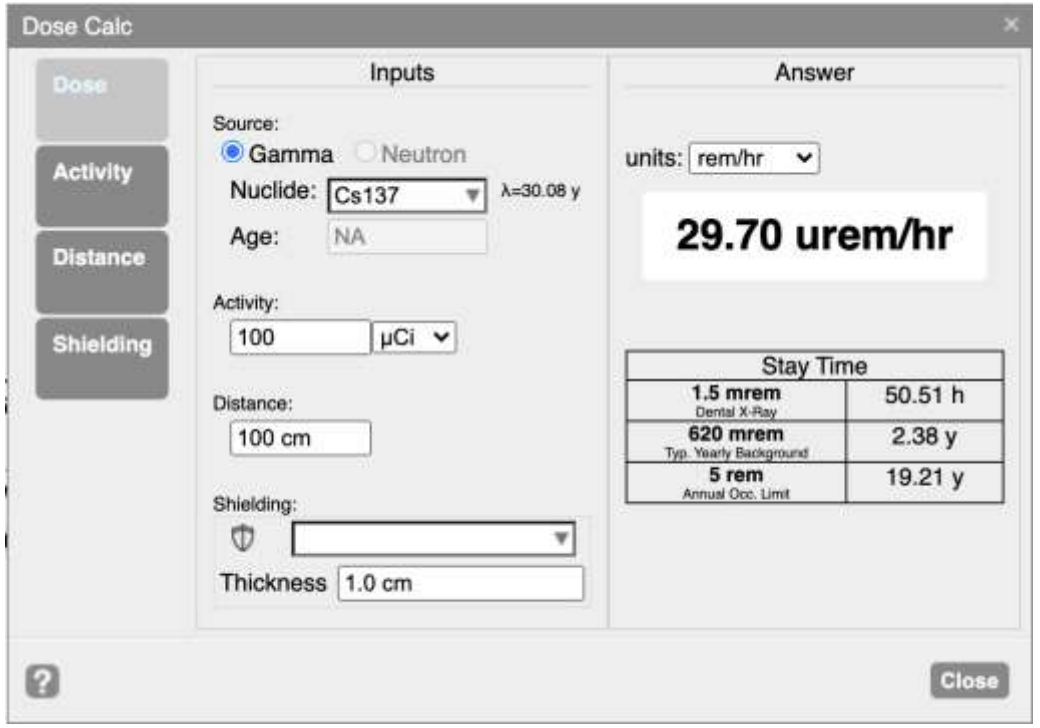
Presence of neutrons can be indicated by an elevated continuum, especially above 2614 keV; the "Energy Range Sum" tool provides a comparison of foreground to background and secondary spectra

You can access it either from the "**Tools**" menu, or by **Option+Shift+Drag** on the spectrum

- Option+Shift+Drag will update in real-time as you move the mouse, and then bring the dialog up once you release the mouse

Other useful tools in InterSpec – Dose Calc





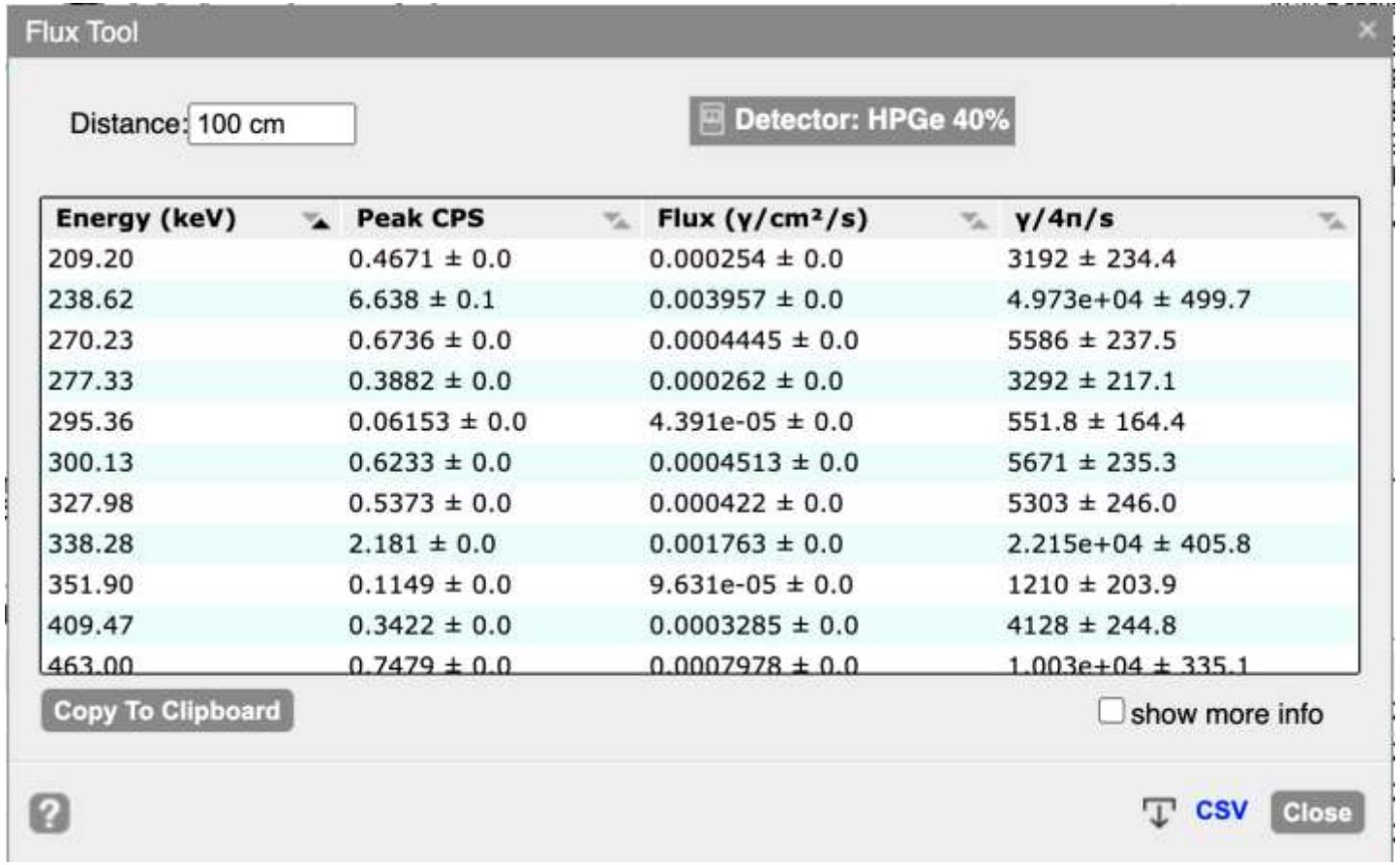
This tool lets you compute expected dose for a given source and shielding combination, or if you have measured dose, you can calculate activity, distance, or shielding, assuming you know the other quantities

- Uses a "full-spectrum" transport method, so does take into account scatter of the shielding, which can contribute significantly to dose
- Provides some comparison dose values to provide context for those of us that don't deal with dose a lot

Do not use this tool for health and safety applications – has not been V&V'd to an appropriate level

- Tool does silently run some sanity checks when started, and you will be clearly notified if they fail on your device for some reason (they shouldn't, but JIC)

Other useful tools in InterSpec – Flux Tool



Energy (keV)	Peak CPS	Flux (γ/cm²/s)	γ/4π/s
209.20	0.4671 ± 0.0	0.000254 ± 0.0	3192 ± 234.4
238.62	6.638 ± 0.1	0.003957 ± 0.0	4.973e+04 ± 499.7
270.23	0.6736 ± 0.0	0.0004445 ± 0.0	5586 ± 237.5
277.33	0.3882 ± 0.0	0.000262 ± 0.0	3292 ± 217.1
295.36	0.06153 ± 0.0	4.391e-05 ± 0.0	551.8 ± 164.4
300.13	0.6233 ± 0.0	0.0004513 ± 0.0	5671 ± 235.3
327.98	0.5373 ± 0.0	0.000422 ± 0.0	5303 ± 246.0
338.28	2.181 ± 0.0	0.001763 ± 0.0	2.215e+04 ± 405.8
351.90	0.1149 ± 0.0	9.631e-05 ± 0.0	1210 ± 203.9
409.47	0.3422 ± 0.0	0.0003285 ± 0.0	4128 ± 244.8
463.00	0.7479 ± 0.0	0.0007978 ± 0.0	1.003e+04 ± 335.1

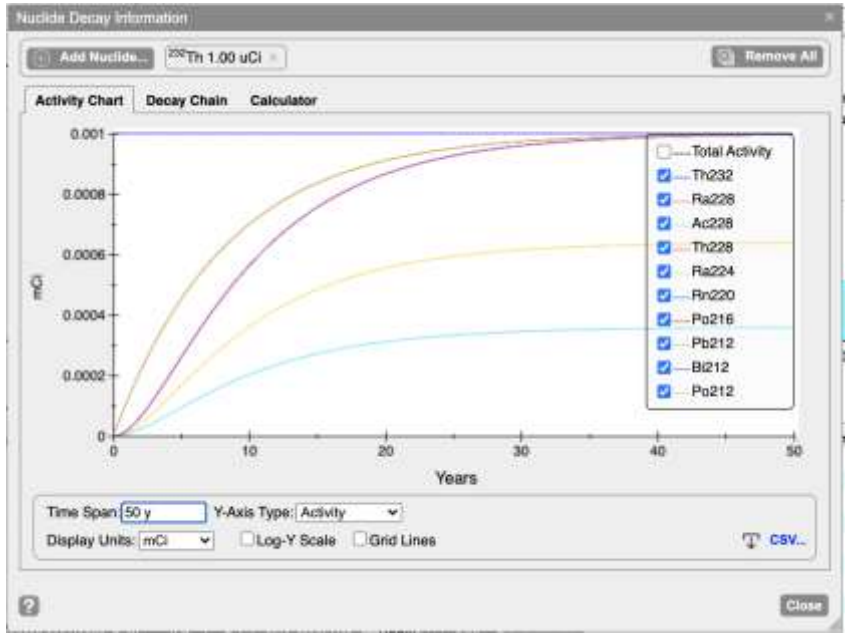
The Flux Tool uses the observed peaks in the spectrum, the DRF, and entered distance to give you the flux of gammas at each energy, both per unit area, and into 4π

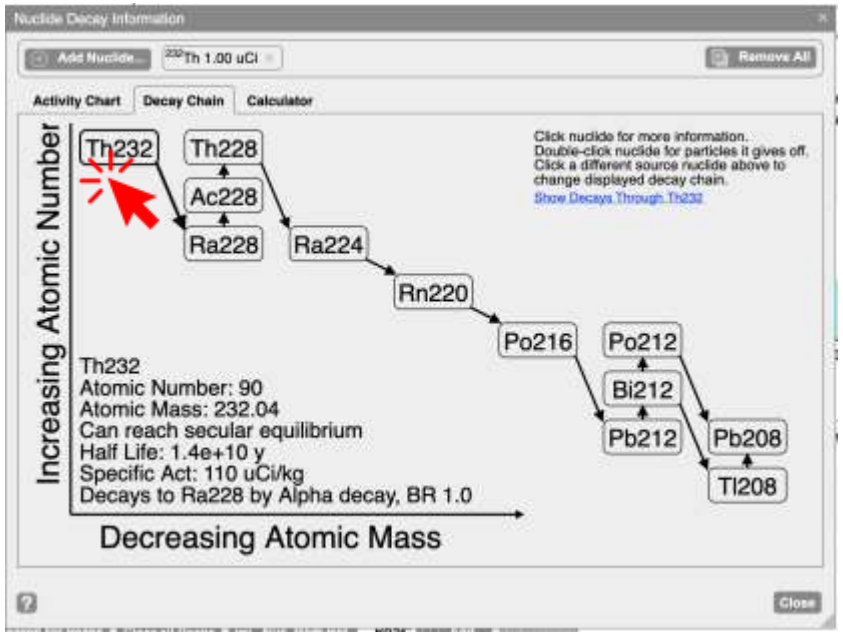
- Uses the peaks you fit in the spectrum
- Uncertainties are statistical from peak-amplitude only

Other useful tools in InterSpec – Nuclide Decay Information

Provide ingrowth and decay rates for a mixture of nuclides over time

- Clicking on the chart gives decay products at that time
- You can export a CSV that includes the information and timing you want to work with in other applications

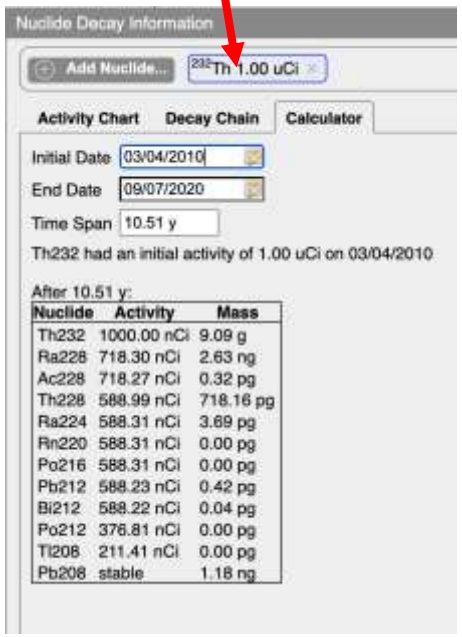




Provide ingrowth and decay rates for a mixture of nuclides over time

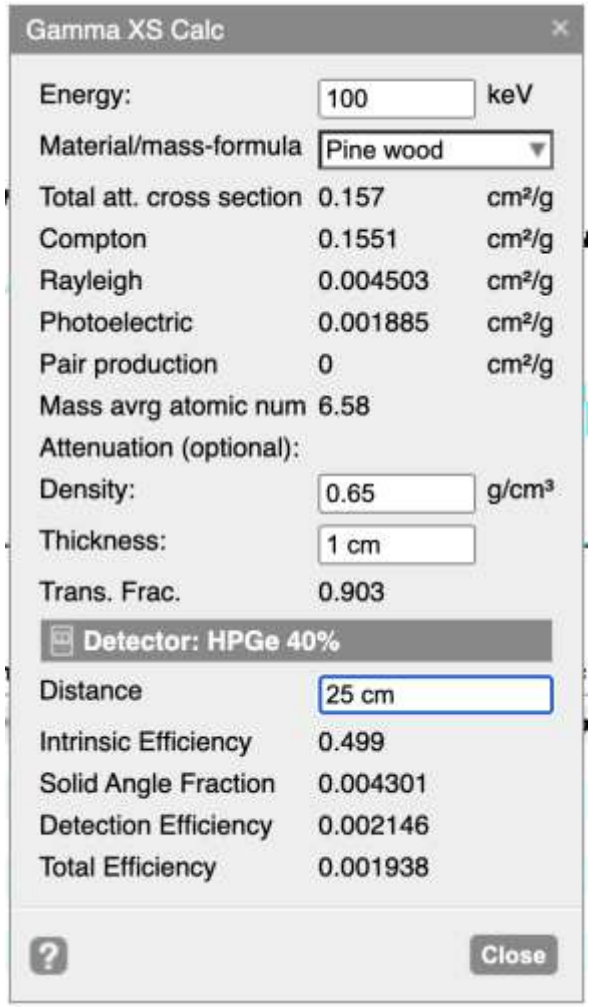
- Clicking on a nuclide in decay chain gives more information about it
- Double-clicking on a nuclide in decay chain provides its decay products
- You can also show all decays through a nuclide (e.g., all possible parent nuclides)

Double click on source text to change nuclide, activity, or initial age



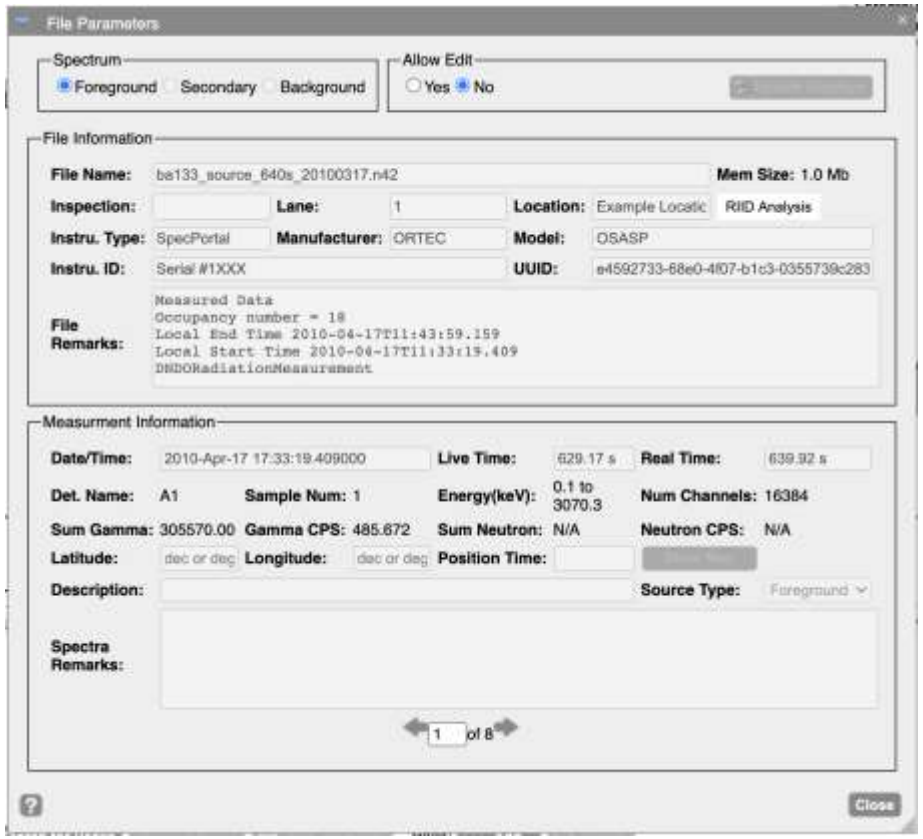
A calculator for ageing sources

Other useful tools in InterSpec – Gamma XS Calc



Quick easy way to check attenuation of a gamma line through shielding, or to take into account distance or DRF

Other useful tools in InterSpec – File Parameters

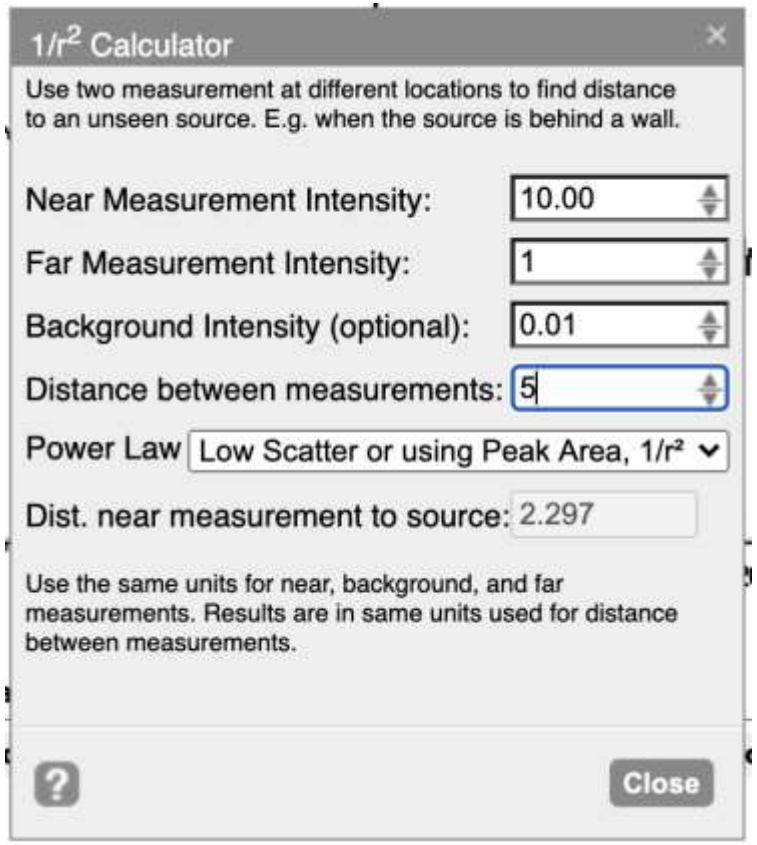


Sometimes spectrum files have useful meta-data: date/time, detector model, RIID results, GPS coordinates, live/real time, etc.

You can edit most of the meta-data to correct input data

- E.x., real time not included in the source data
- E.x., you are going to export the data in N42 format, and want to include GPS coordinates

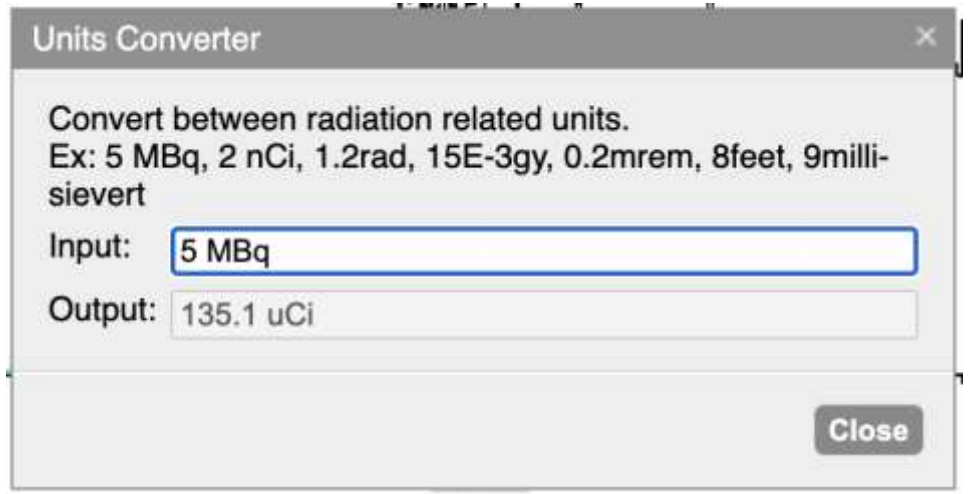
Other useful tools in InterSpec – 1/r2 calculator



For a source behind a wall, or inside a cargo container, and you can take two measurements

- Best to use with a peak count rate of the source, but you can also use with dose-rate provided by detector
- There is a power law for mid-scatter and high-scatter dose measurements as well
- Allows you to optionally enter a background dose or peak rate

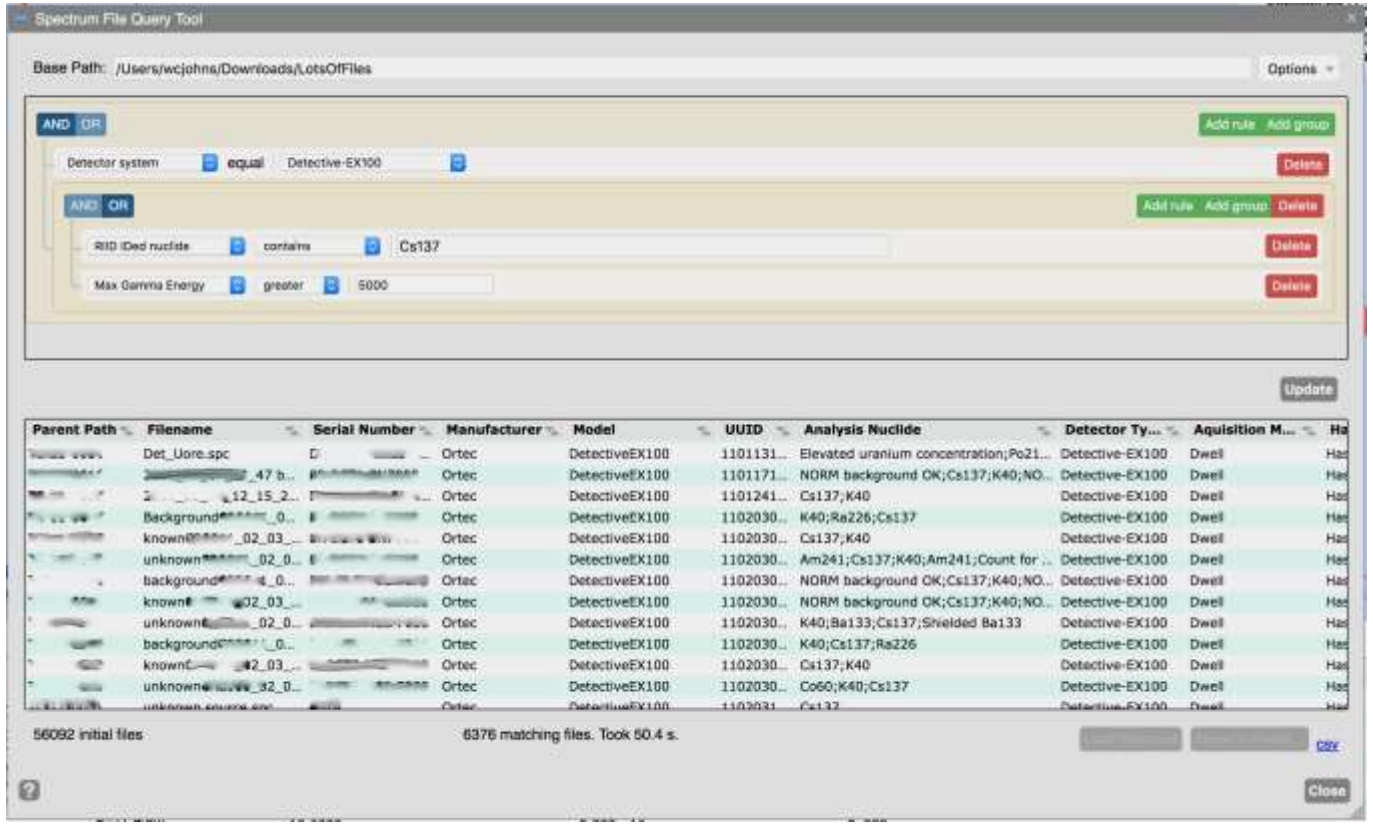
Other useful tools in InterSpec – unit converter



Convert units on activity, dose, or distance

- A lot of general purpose unit converters lack activity or dose, so this sometimes comes in useful

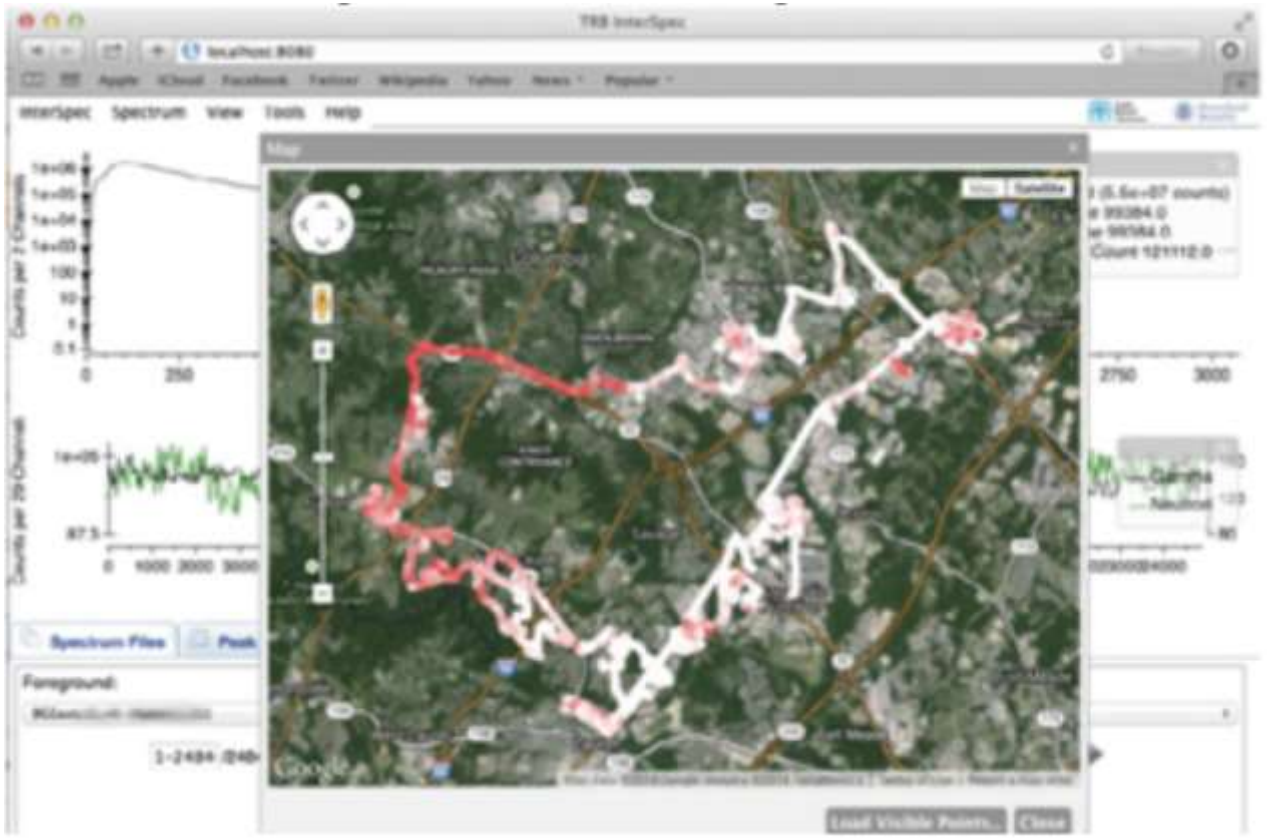
Other useful tools in InterSpec – File Query Tool



Lets you recursively search a directory of spectrum files, filtering on a bunch of quantities

- Detector model, RIID results, GPS coordinates, filename, neutron or gamma CPS, live/real time, …
- Can be extended to search XML manifests that may accompany the spectrum files
- Pretty fast – depending on file sizes, CPU and hard-drive, ~50k files can take 1 minute for first search, and a second or two for subsequent searches
  - See **Options** menu to persist cache between uses of the tool
- Email InterSpec@sandia.gov for further information

Other useful tools in InterSpec – GPS map

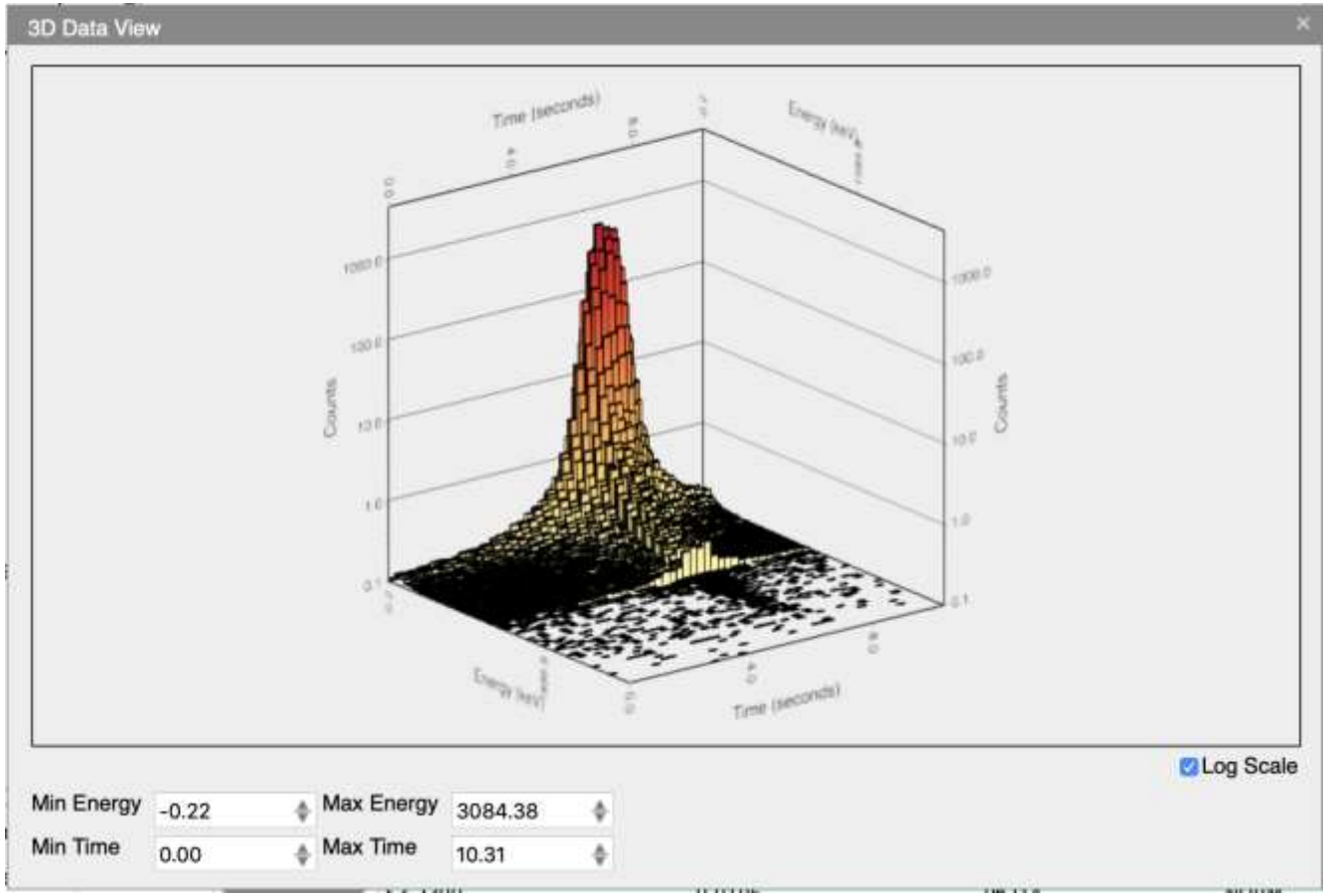


If spectrum file contains GPS coordinates, you can view them on a map

When you zoom in on a subset of measurement locations, you can sum all the visible points to a spectrum

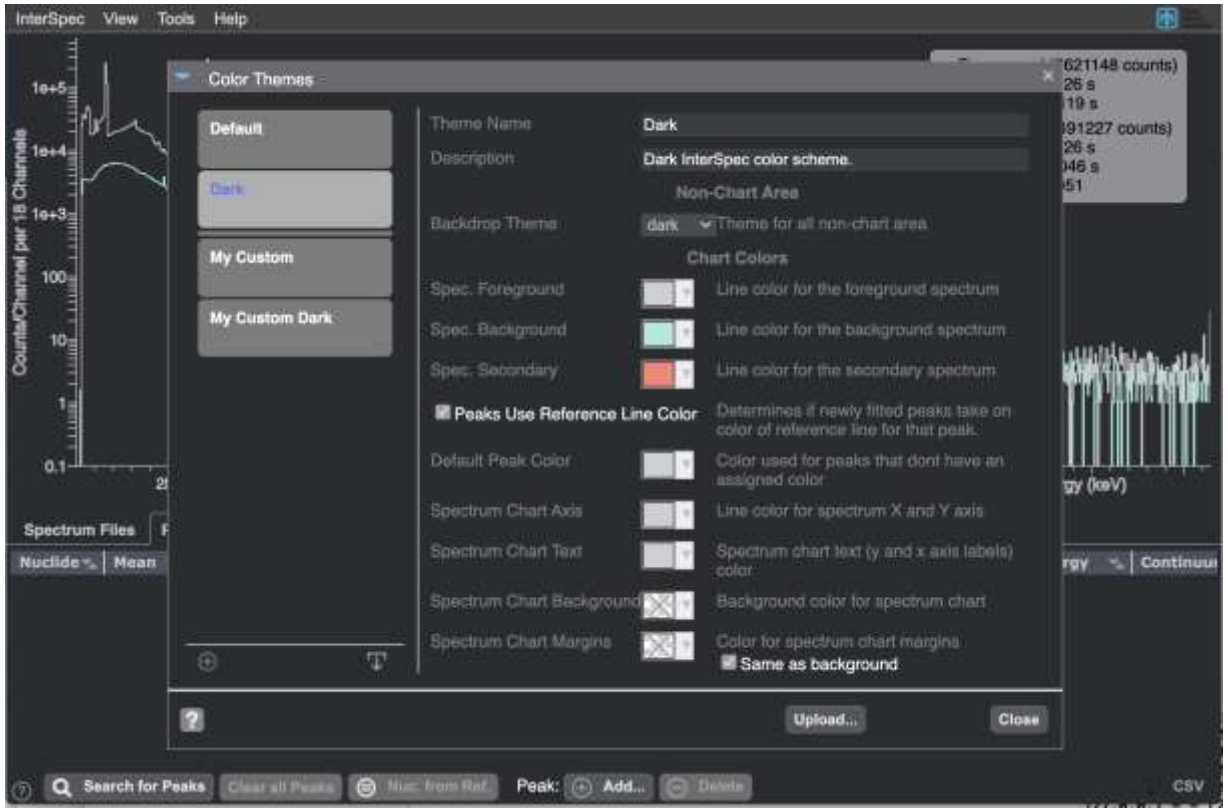
Not enabled on all platforms

Other useful tools in InterSpec – 3D plot for time data



Probably most useful for presentations – usually not that insightful

Other useful tools in InterSpec – color theme



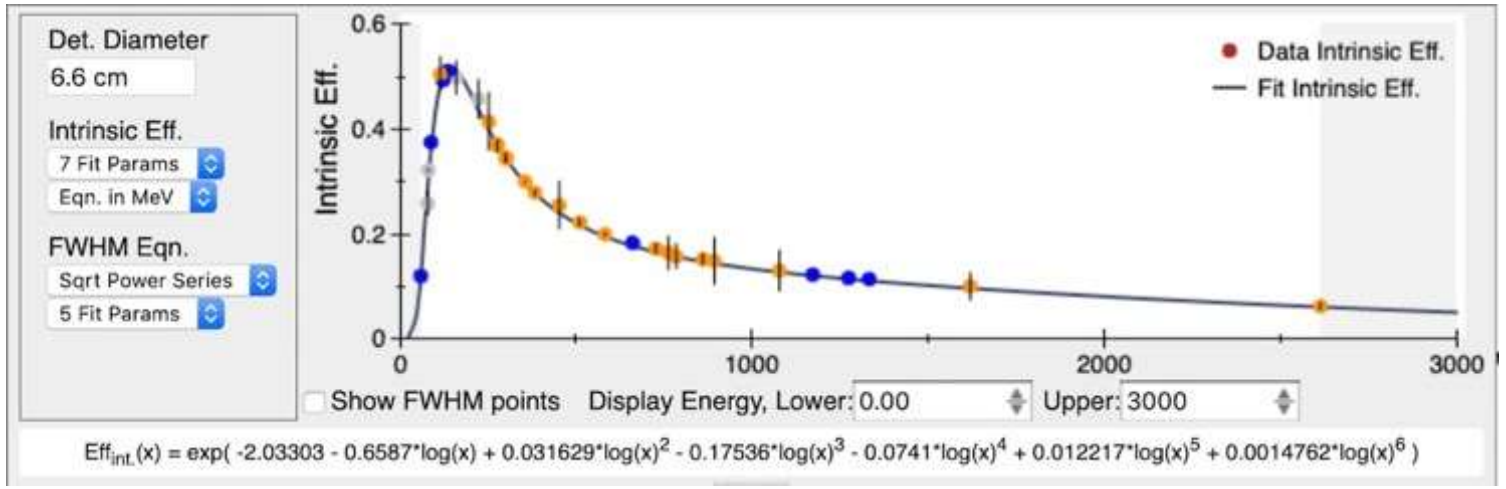
You can customize the colors of almost everything, including the order of colors used for reference lines, or you can assign nuclides to always be a certain color.

- You save themes to InterSpecs internal database, or you can export/import them from files for sharing across devices
- On macOS and iOS if you leave it on "Default", will respect the OS dark/light theme

Creating detector response functions

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.

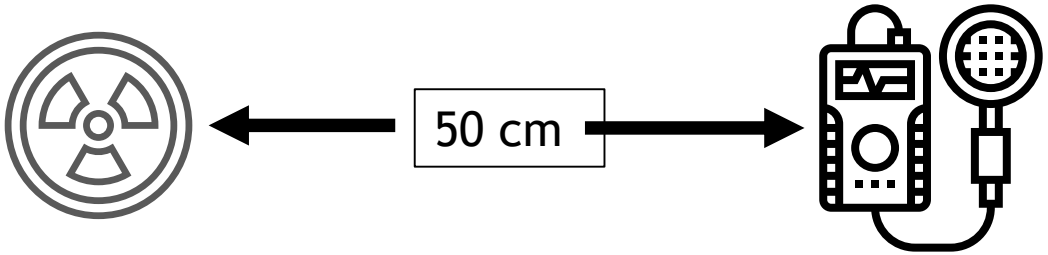
- Common choices of sources include Am-241, Cd-109, Co-57, Ba-133, Y-88, Cs-137, Co-60, Na-22, and Th-228, or Th-232, or U-232. However, InterSpec should accommodate using nearly any test-sources.

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.

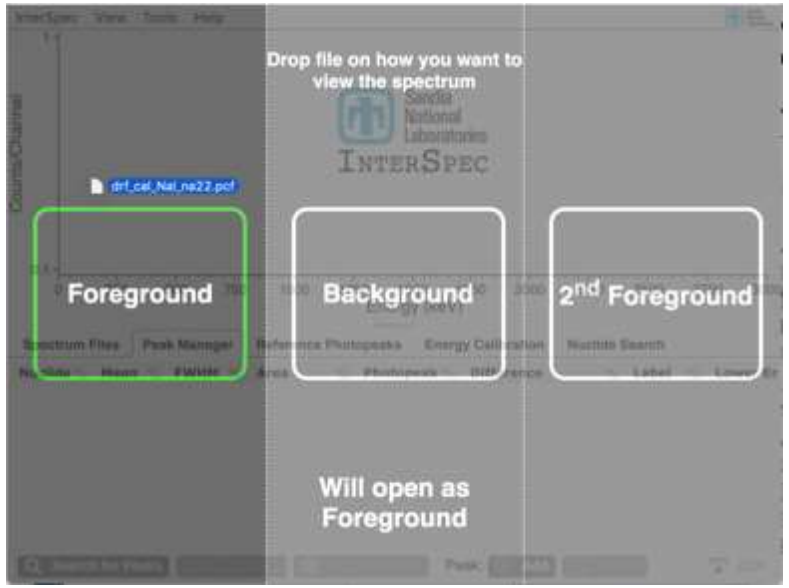
If any of the sources have photo-peaks that overlap with background peaks, or the detectors seed-source (e.x., Cs-137, Na-22), a background is also needed.

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

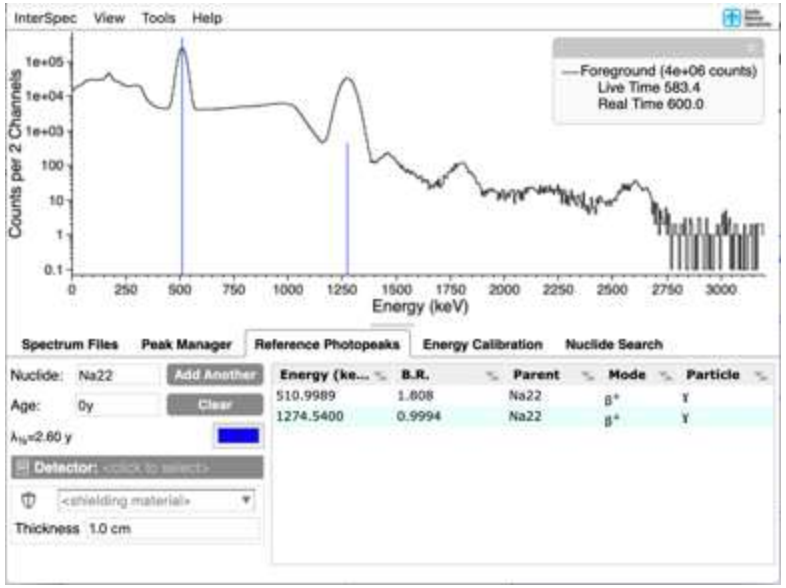
You will also need to know the detectors face surface area; InterSpec assumes a circular diameter, but if other geometry you can just convert to the equivalent surface area (ex, a 7cm by 7cm rectangular face is equivalent to a circle with diameter 3.95 cm).

How to create a DRF:

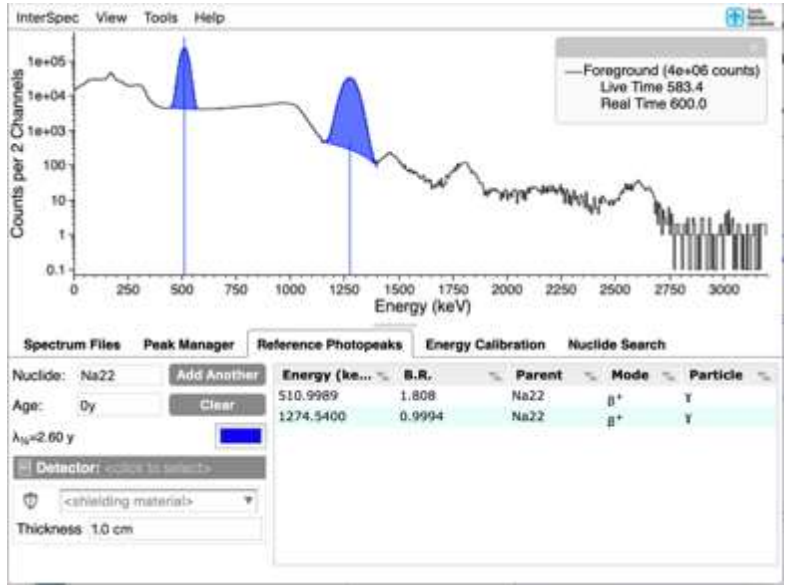
Step 2: Fit photo-peaks of test-sources



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



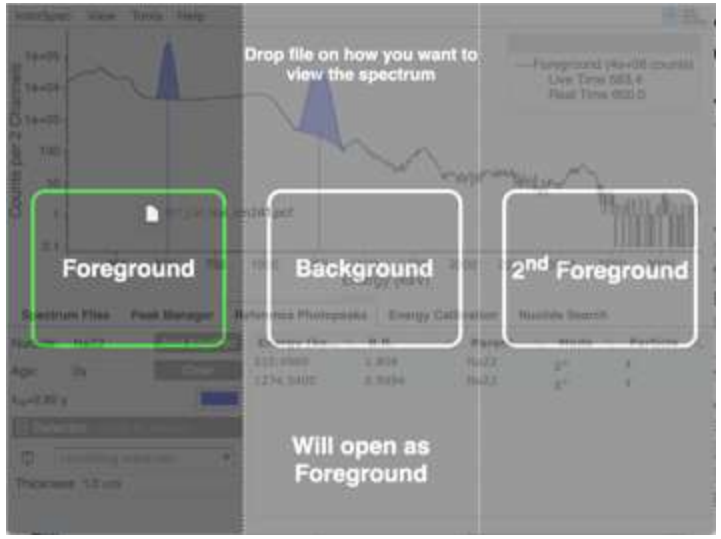
Display reference photo-peaks for your test-source.



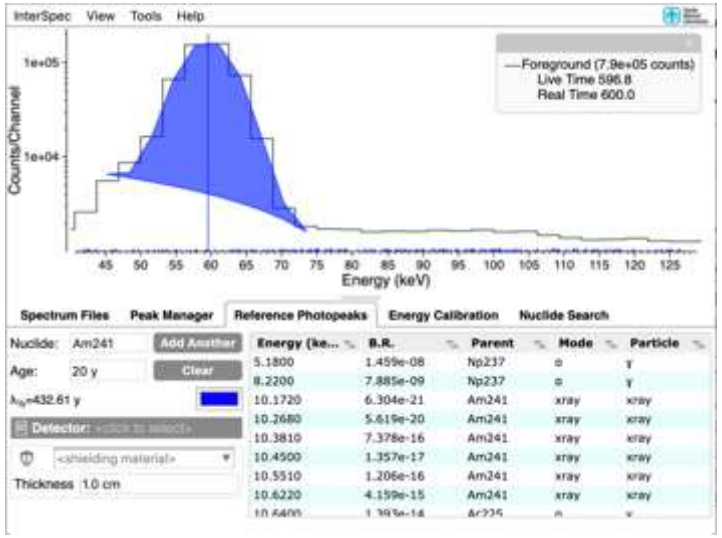
Fit peaks by double-clicking in their area on the chart. Since reference lines are showing, the test-source nuclide will be associated with the peak. You can also use the Peak Manager, or Peak Editor to associate nuclides with peaks

How to create a DRF:

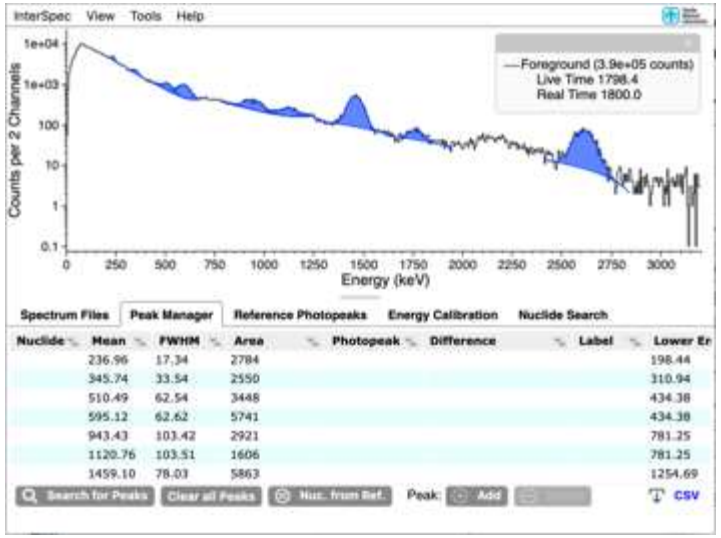
Step 2 (continued):



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



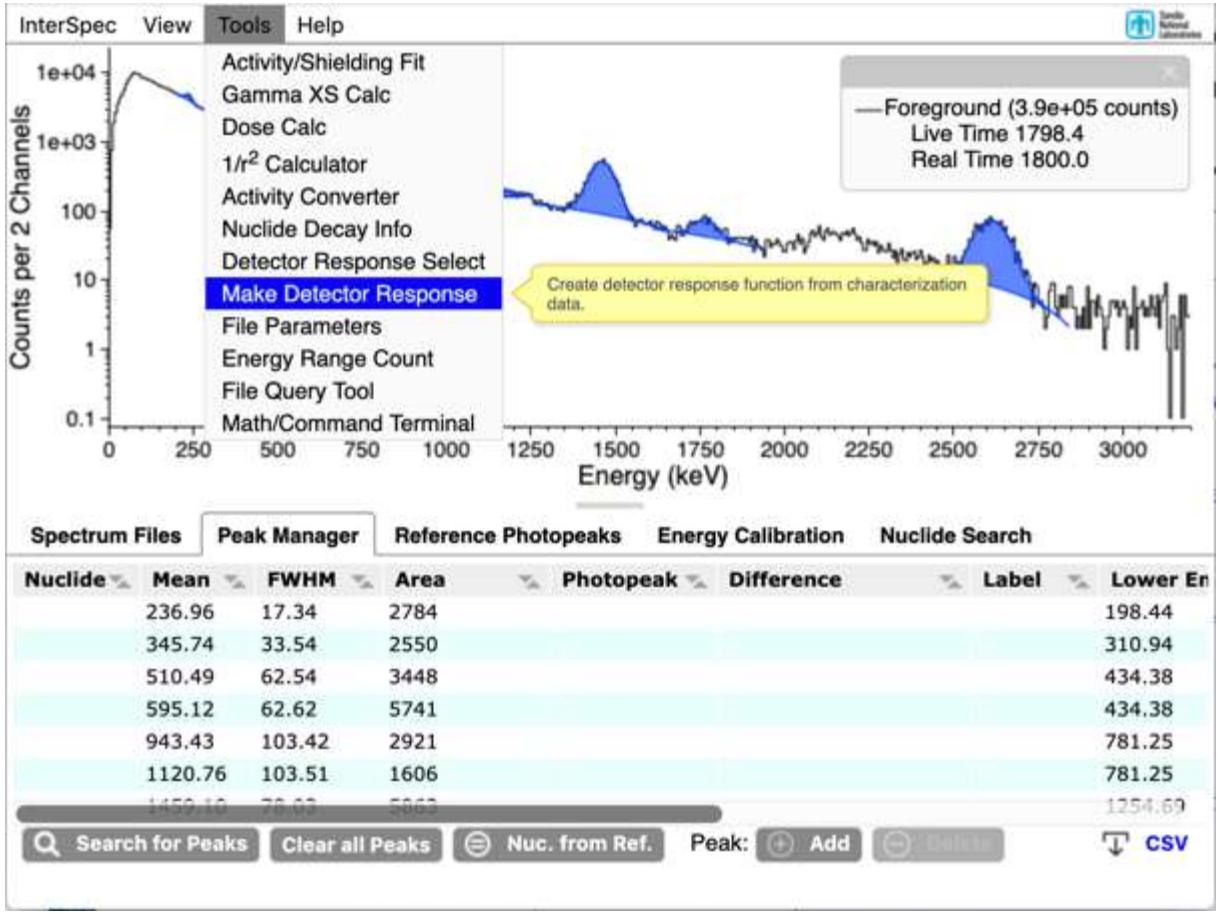
And repeat peak-fitting.
Do this for all test source measurements.



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

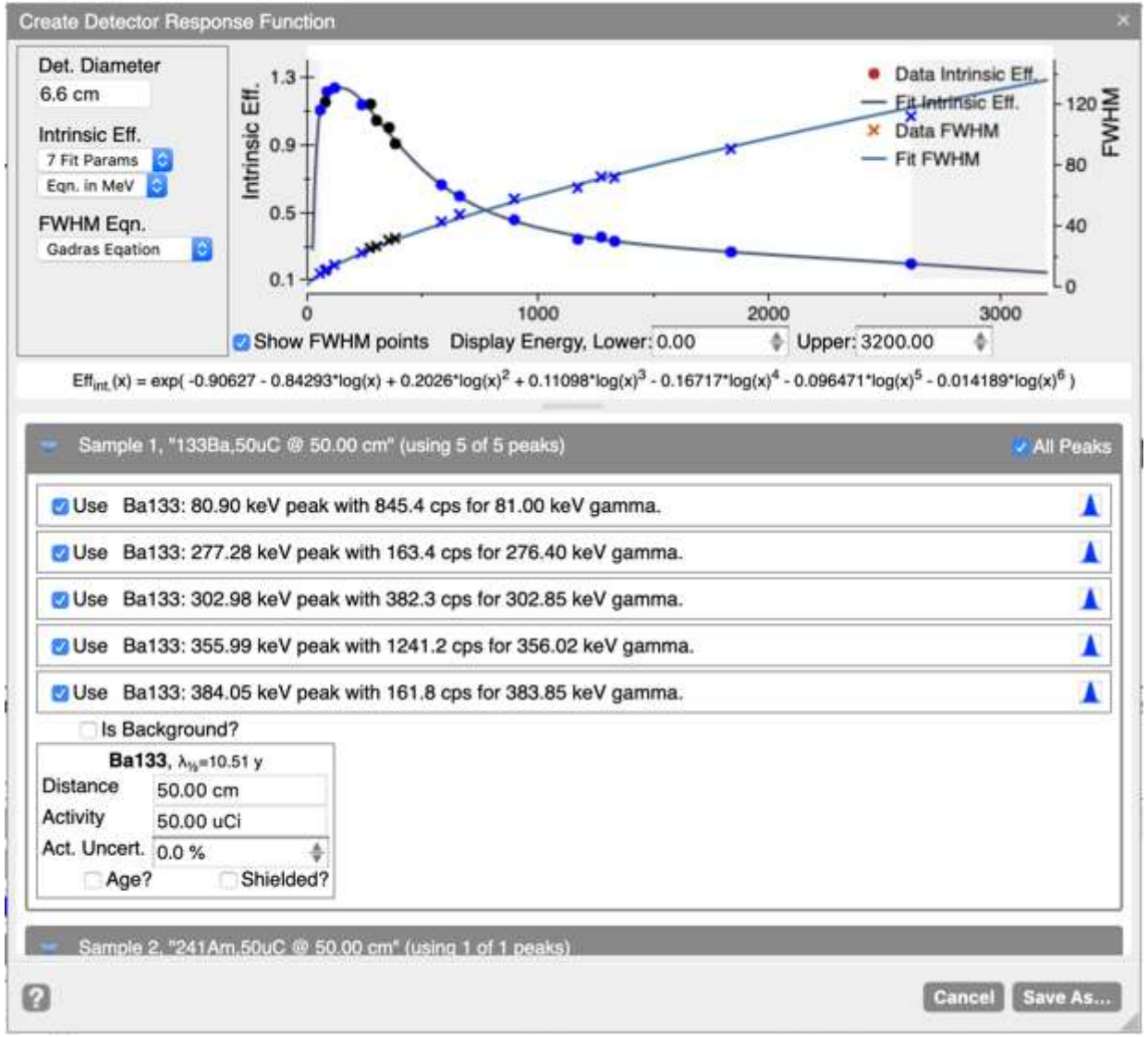
How to create a DRF:

Step 3: Open the "Make Detector Response" tool.



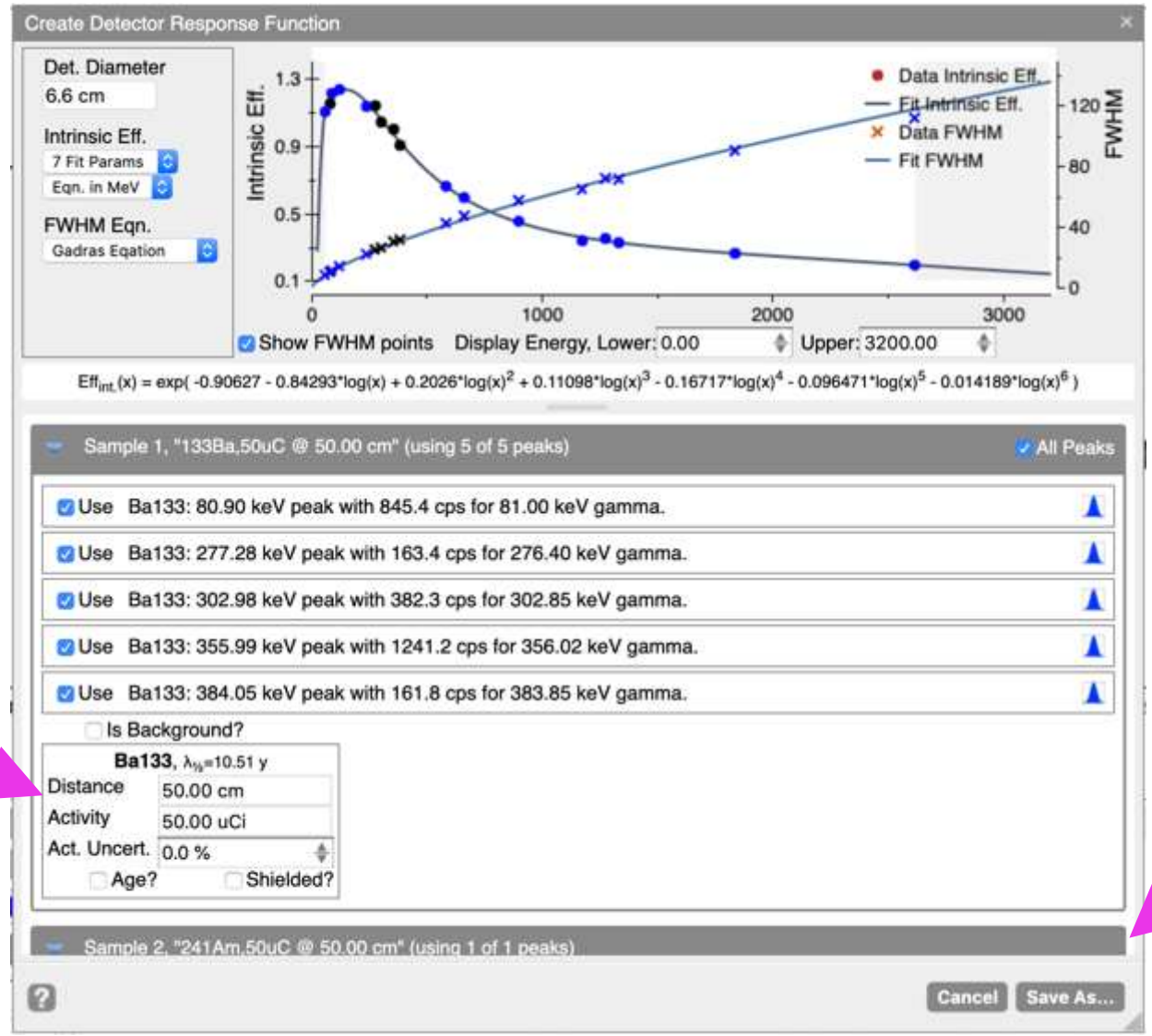
How to create a DRF:

Step 4: Enter detector diameter.



How to create a DRF:

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

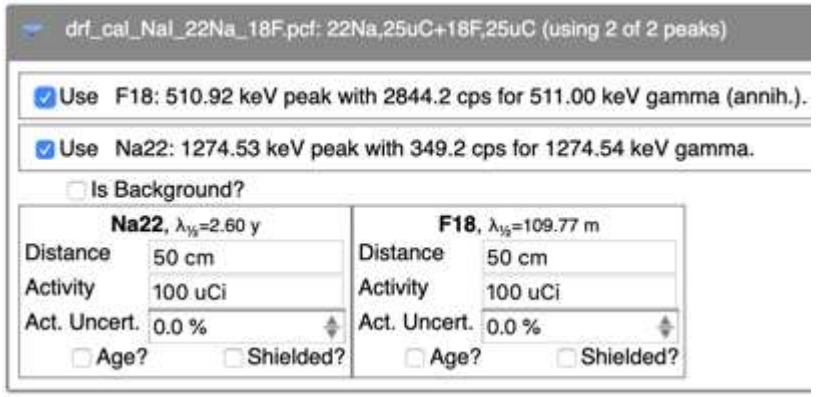


When you select a peak, an area will appear for you to enter source information

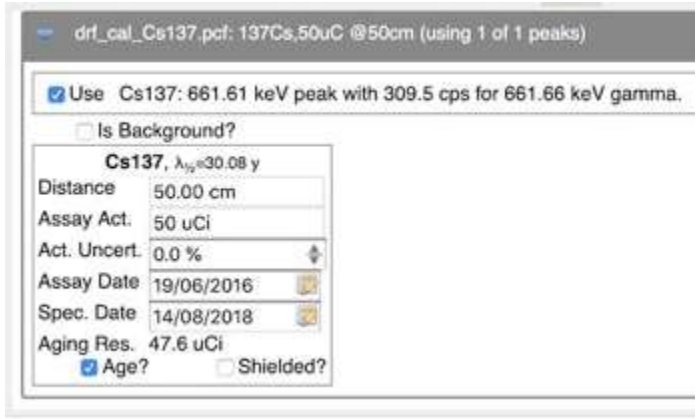
You can choose peaks from all of the spectrum files you've used in your current session by scrolling down.

How to create a DRF:

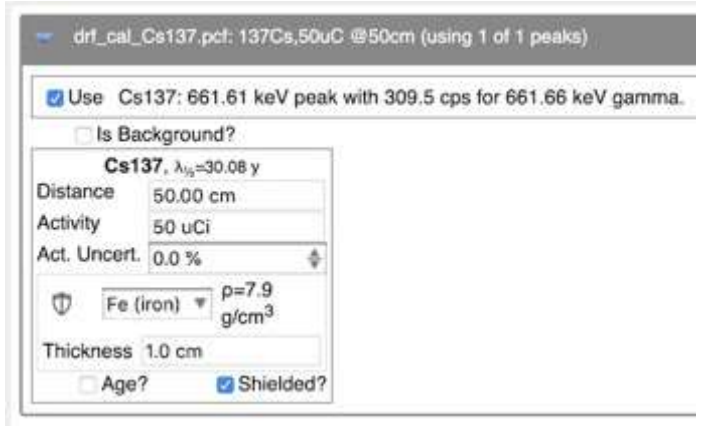
Step 5 (continued): Entering source information



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



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.

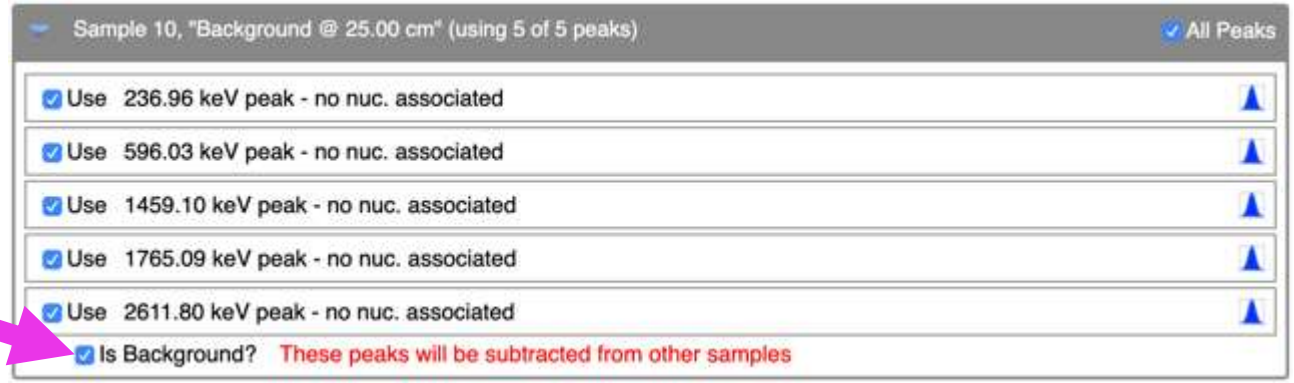


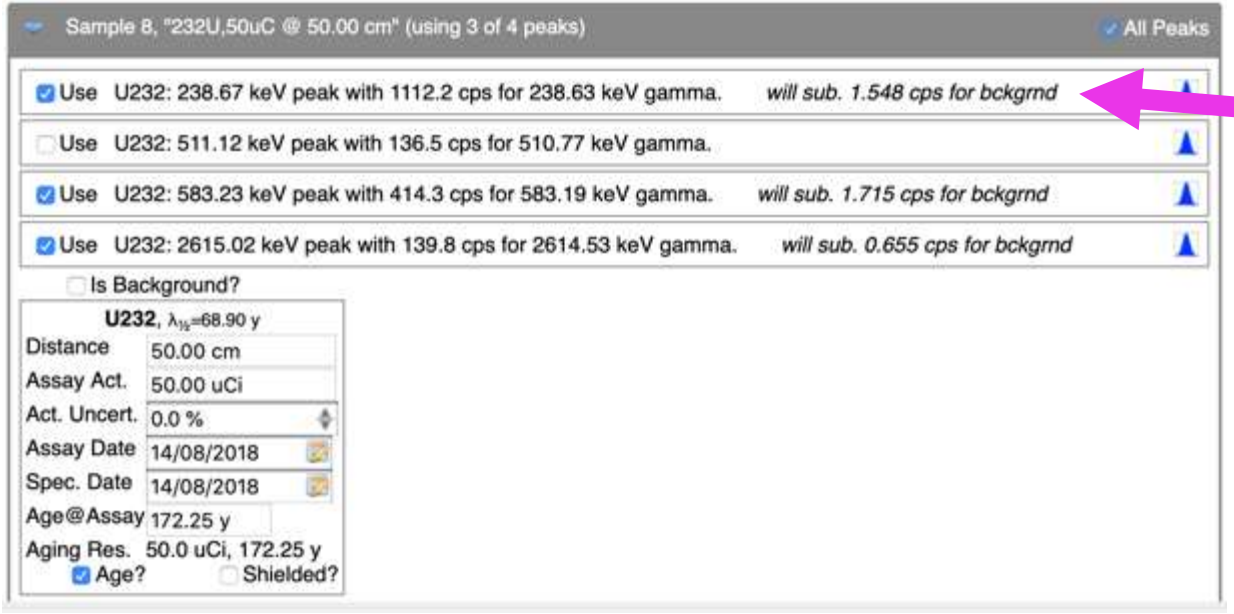
You can also opt to correct for shielding around the source. However, shielding should be avoided or minimized for characterization measurements

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



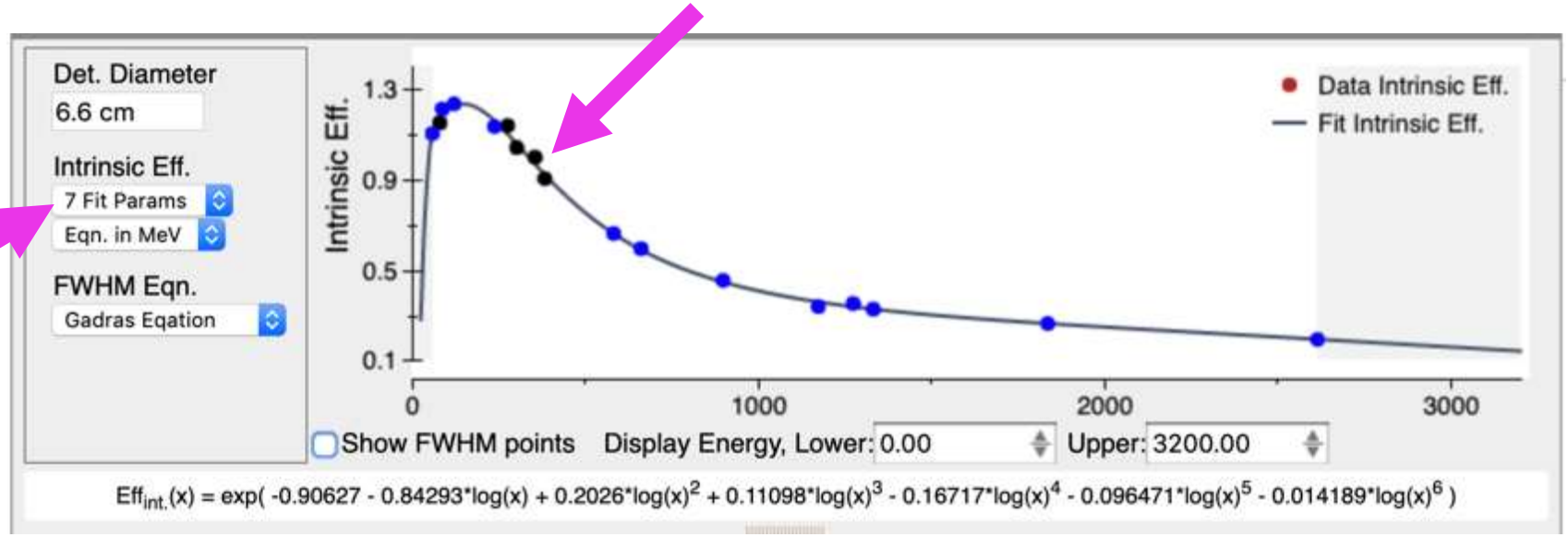


When background subtraction occurs from test-sources, it will be indicated next to the normal text

How to create a DRF:

Step 6: Refine

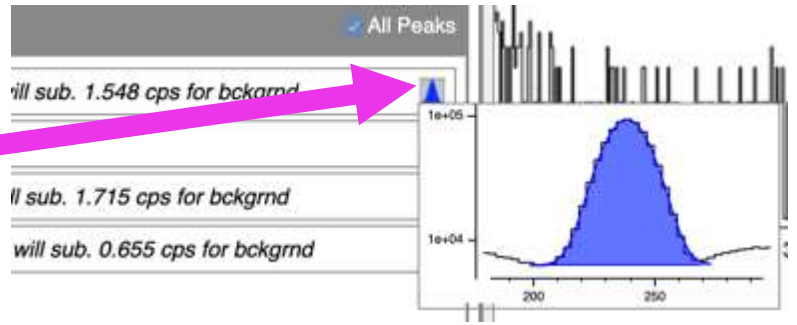
Your points should look continuous – you shouldn't have any significantly off of the fit line; if you do, check that source's activity, distance, or that the correct gamma energy is associated with that peak



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

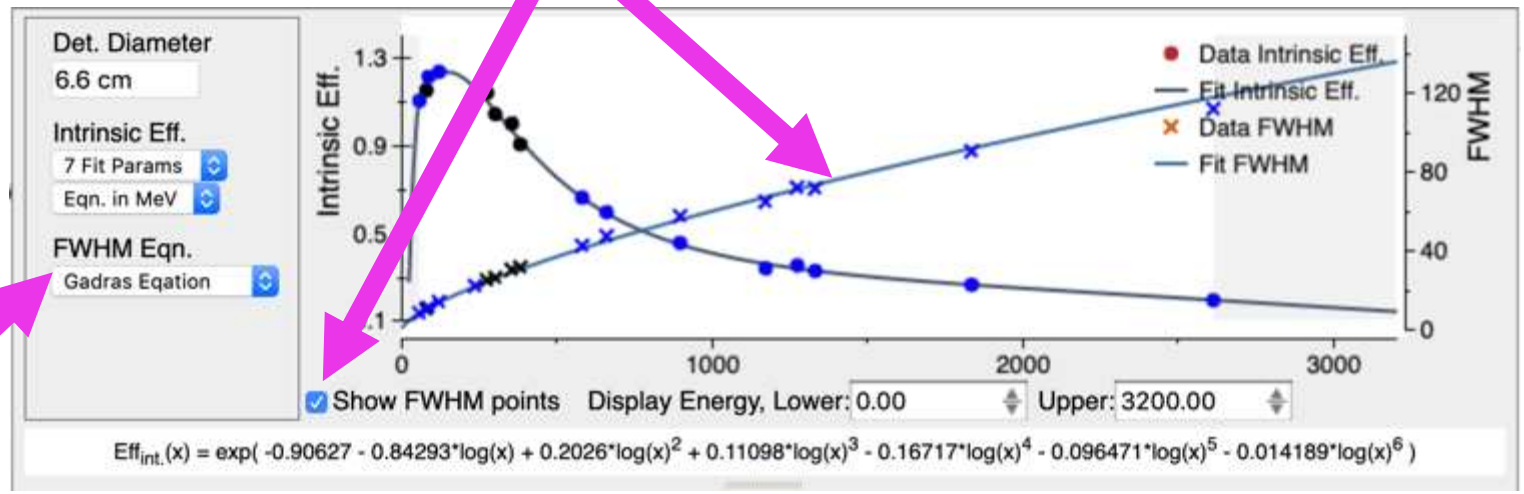
Clicking/tapping on the peak icon to the right on each row will let you preview the peak fit as a sanity check the fit is good



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.



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

```
def getFWHM( energy ):
    //P6---> resolution @ E=0 (energy in keV)
    //P7---> % FWHM @ 661 keV
    //P8---> resolution power
    if energy ≥ 661 or P6=0
        return 6.61×P7×(energy/661)^P8
    if P6 < 0.0
        var p = P8^1.0/log(1.0-P6)
        return 6.61×P7×(energy/661)^p

    if P6 > 6.61×P7
        return P6;

    var p = sqrt((6.61×P7)^2-P6^2)/6.61;
    return sqrt(P6^2+(6.61×p×(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.

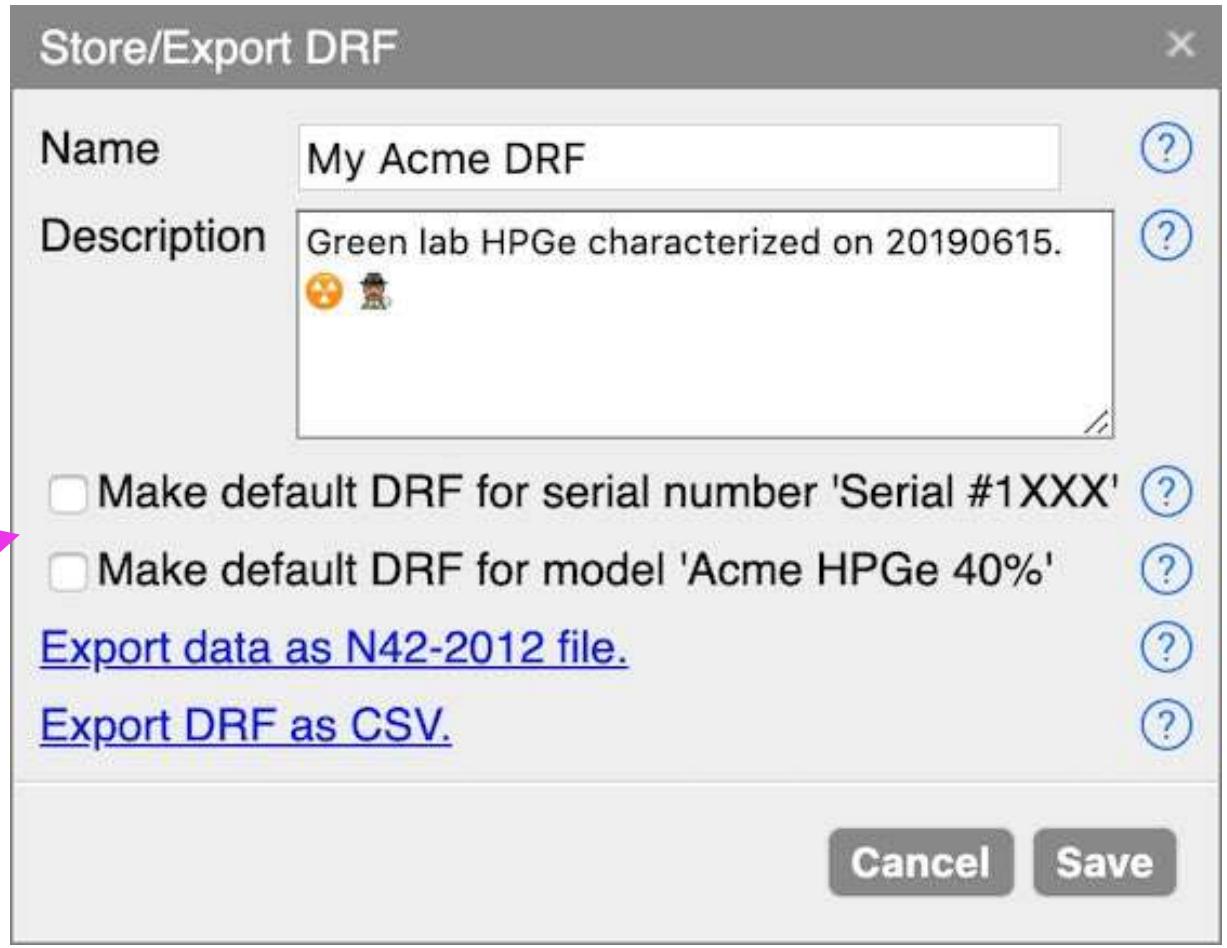
How to create a DRF:

Step 7: Save

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

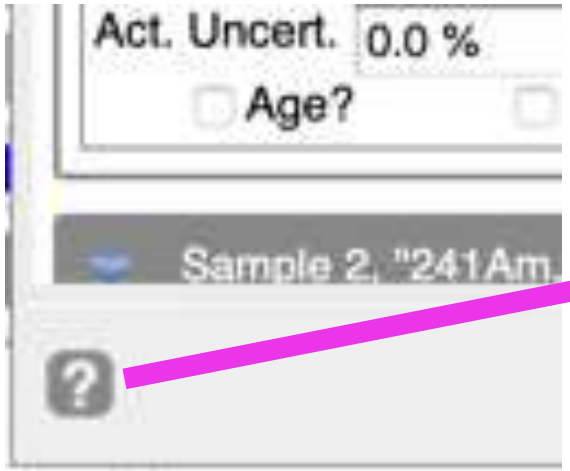
Enter a useful name and description. Symbols such as slashes, backslashes, quotes, commas, semicolons, and question marks are not allowed in the name.

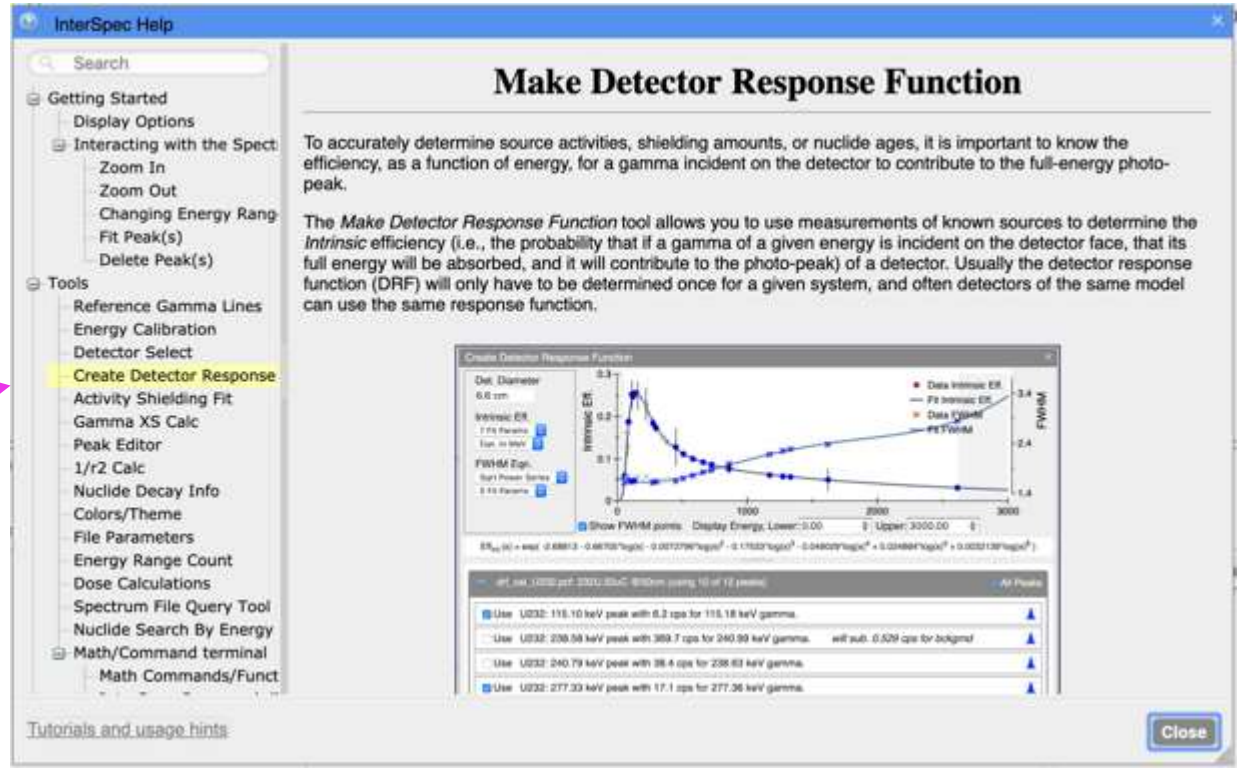
You can also choose to have InterSpec load this DRF automatically when you load spectra from either this specific detector, or this model of detector.
You can also load this DRF from the “Previous” tab of the “Detector Response Select” tool.



How to create a DRF: More Info

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



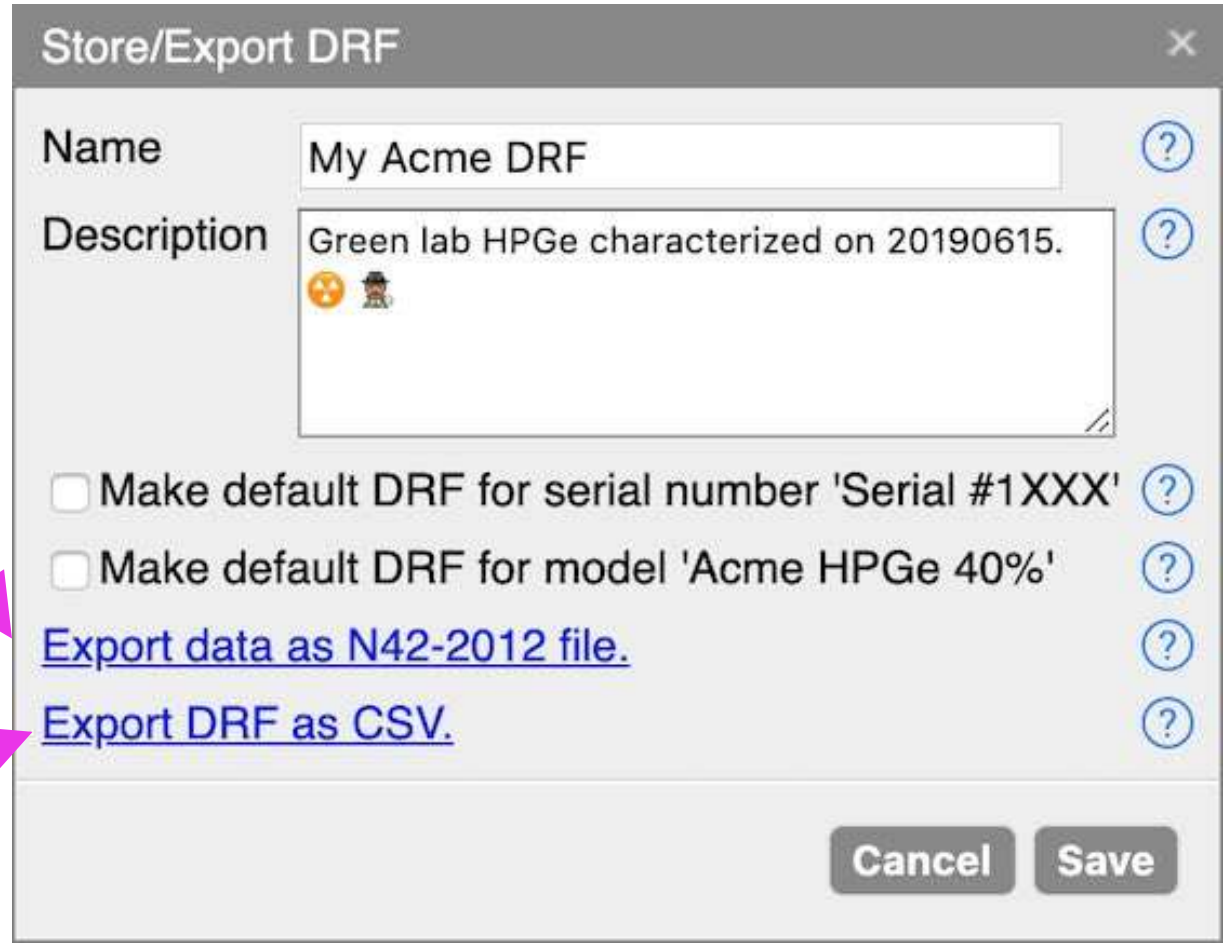


How to create a DRF:

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

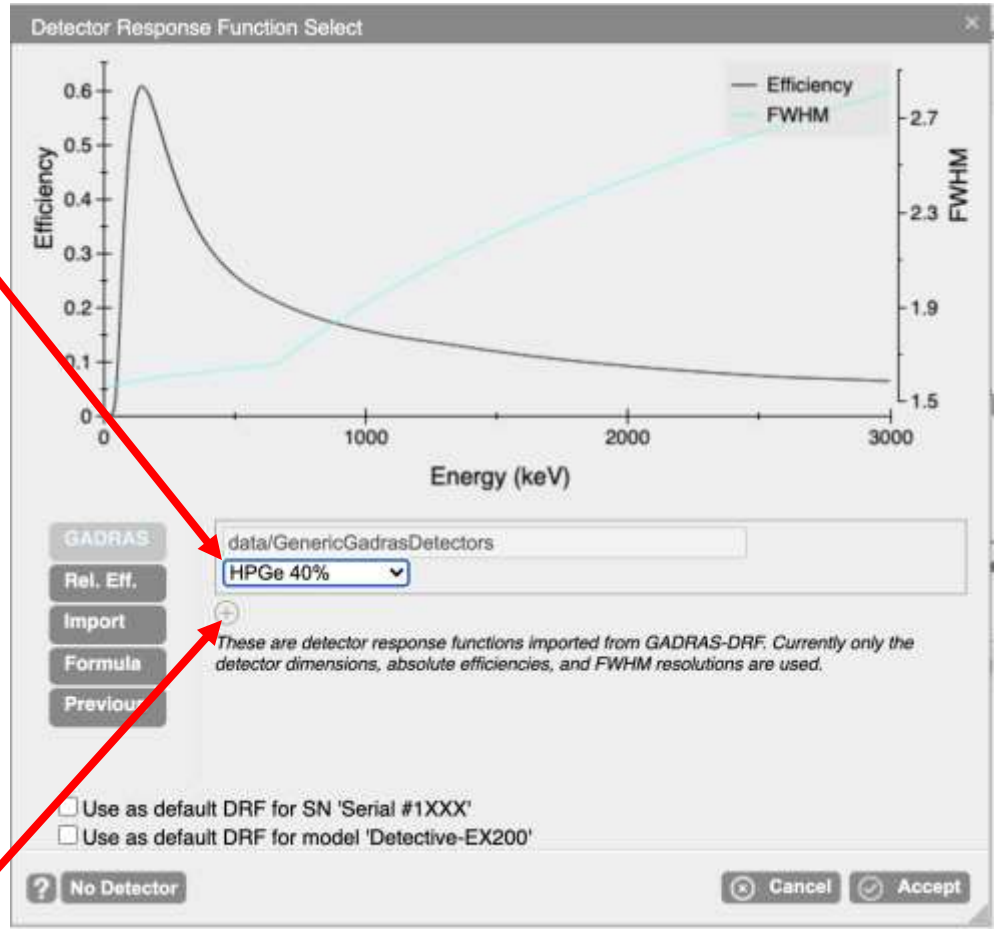


Selecting An existing DRF for use

To load a DRF, click on a detector widget anywhere available

Selecting An existing DRF for use (cont.)

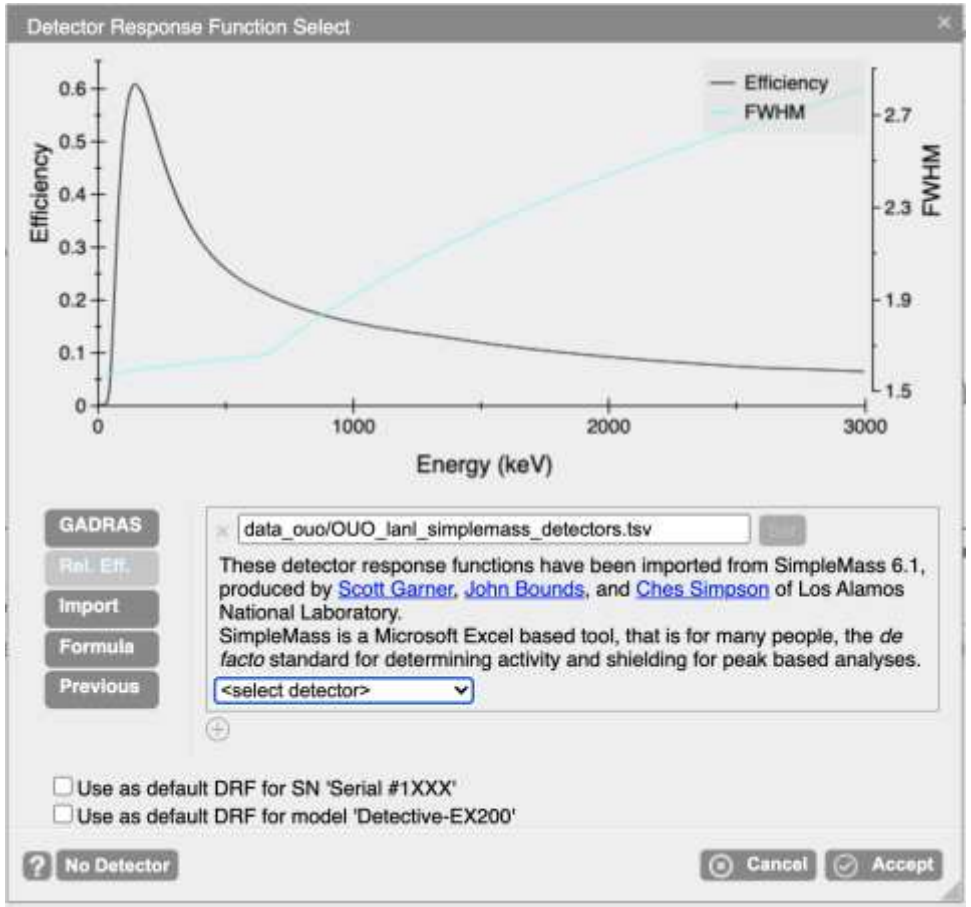
InterSpec comes with a number of generic GADRAS DRFs



If you have GADRAS installed, or some DRFs from it, you can point InterSpec to the detector directory, and then all the DRFs you have used in GADRAS will become available in InterSpec.

- You need to have at least opened the DRF in GADRAS so Efficiency.csv will have been created by GADRAS

Selecting An existing DRF for use (cont.)

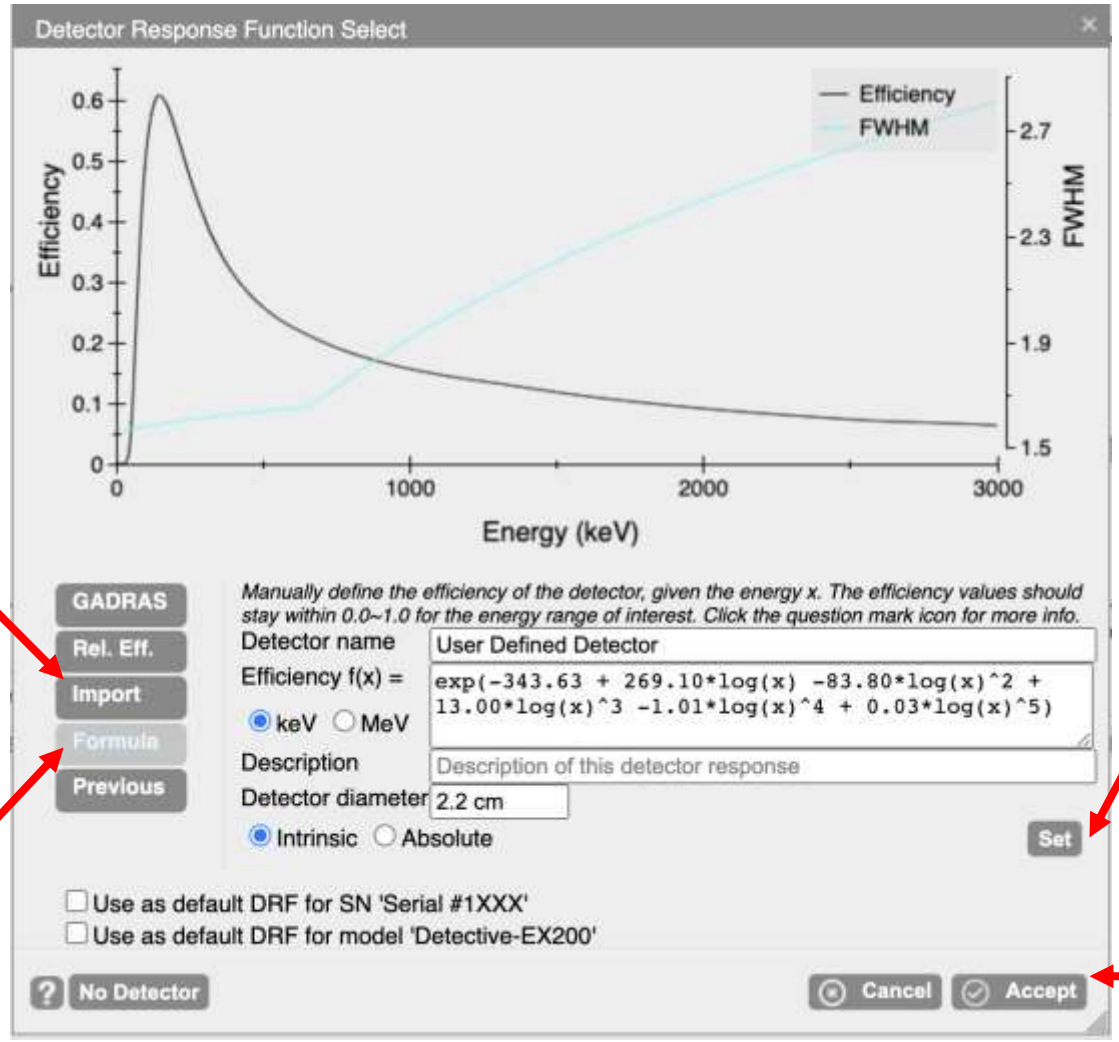


You can also use DRFs defined by relative efficiency from a CSV format

- You can also use DRFs from LANL SimpleMass – just copy-paste the DRF section from SimpleMass into a TSV/CSV

Selecting An existing DRF for use (cont.)

Import single DRF from CSV/TSV, or GADRAS



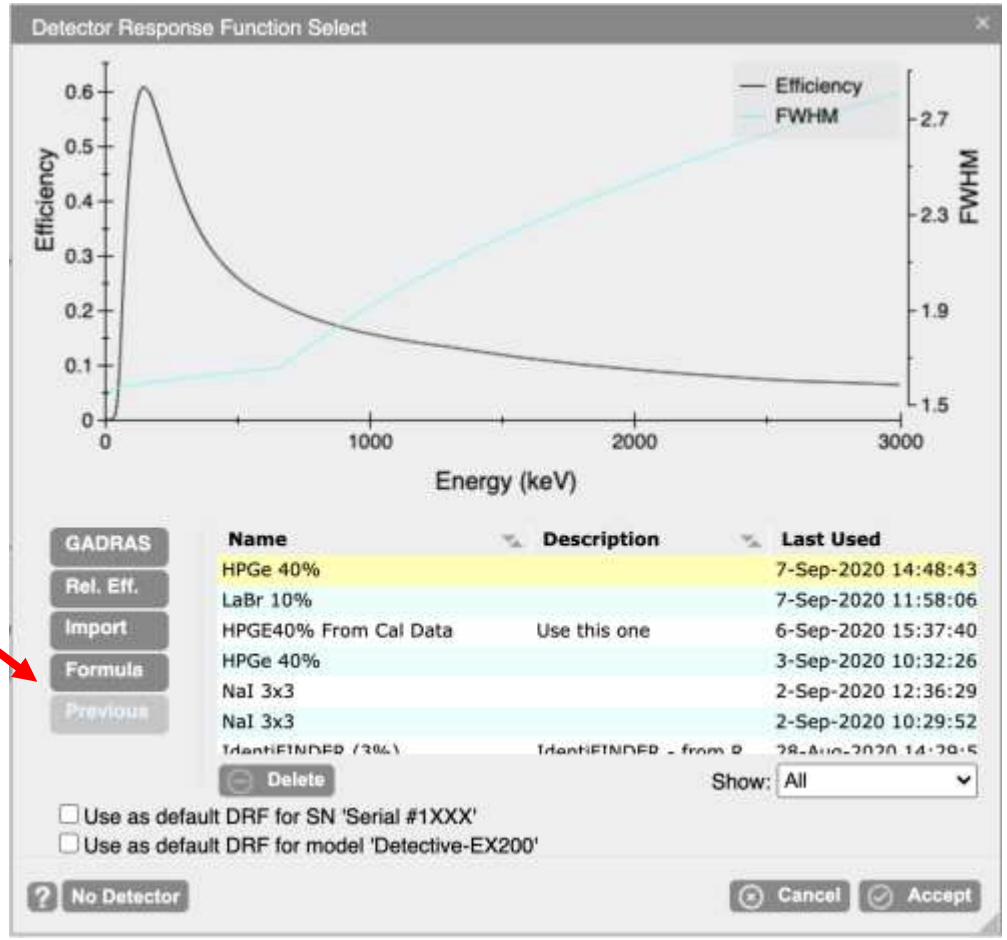
Click "Set" after entering formula and other information

Once you "Accept" this DRF will be saved to InterSpecs internal database, and available under the "Previous" section

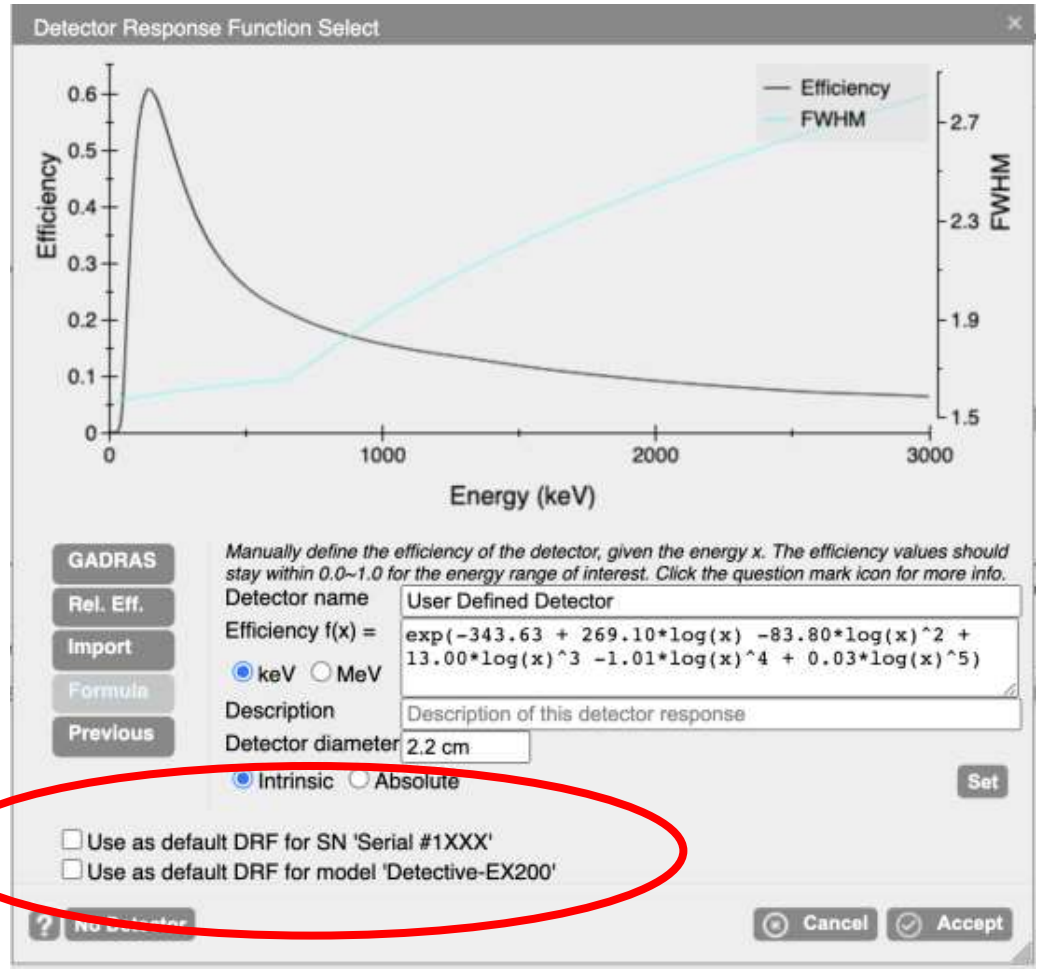
Its also common to have intrinsic or absolute efficiency of a detector given as a function of energy – you can enter that under the "Formula" section

Selecting An existing DRF for use (cont.)

DRFs you've previously used, or saved into InterSpecs internal database are also available



Selecting An existing DRF for use (cont.)



You can also set it so whenever you load data from a given detector model, or a specific detector, then the DRF you are about to select will automatically be loaded

- Convenient if you work with the same detector models regularly