InterSpec gamma radiation analysis software

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https://github.com/sandialabs/InterSpec

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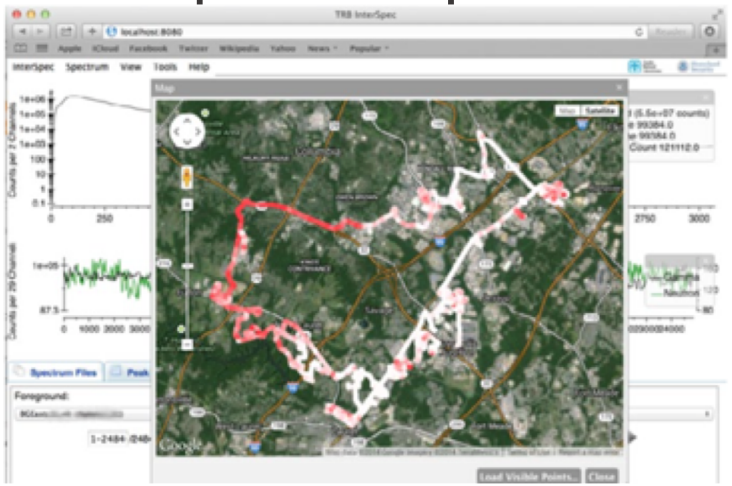
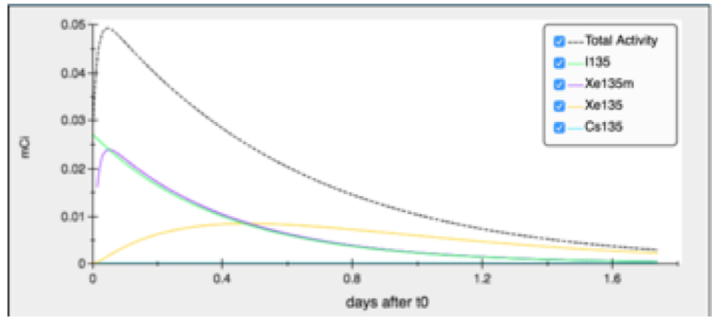
Introduction

- InterSpec helps to interactively perform nuclide identification using gamma data from a wide variety of detectors
  - Uses a peak-based analysis approach with comprehensive nuclide and shielding databases
  - Can be used with identiFINDER, RadSeeker, other NaI, HPGe, LaBr, and more detectors
- Can be used to perform nuclide activity quantification, determine amount and/or type of shielding, nuclide age
  - What information can be extracted depends on nuclides present, shielding amounts, and data quality

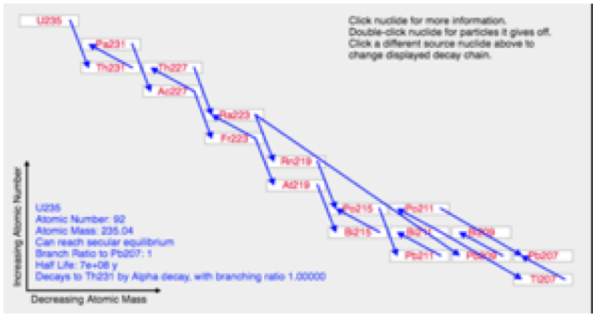
InterSpec also provides many other useful related tools:



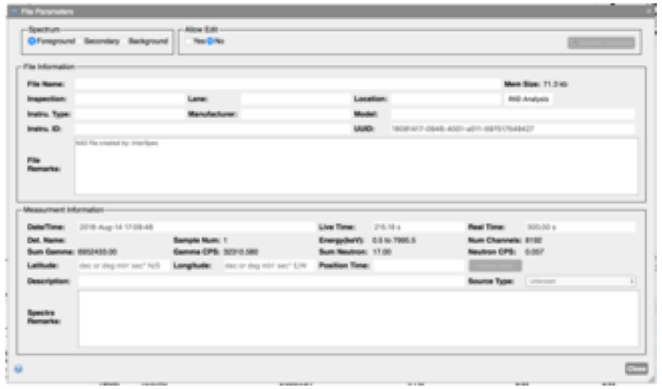
GPS location of measurements



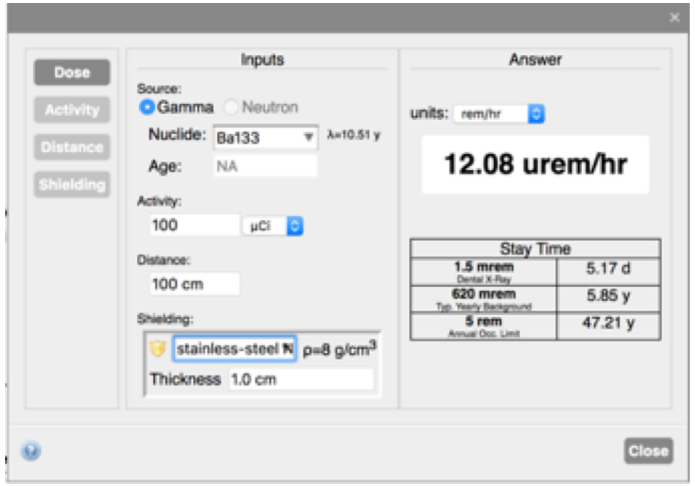
Decay Calculations



Nuclide Reference



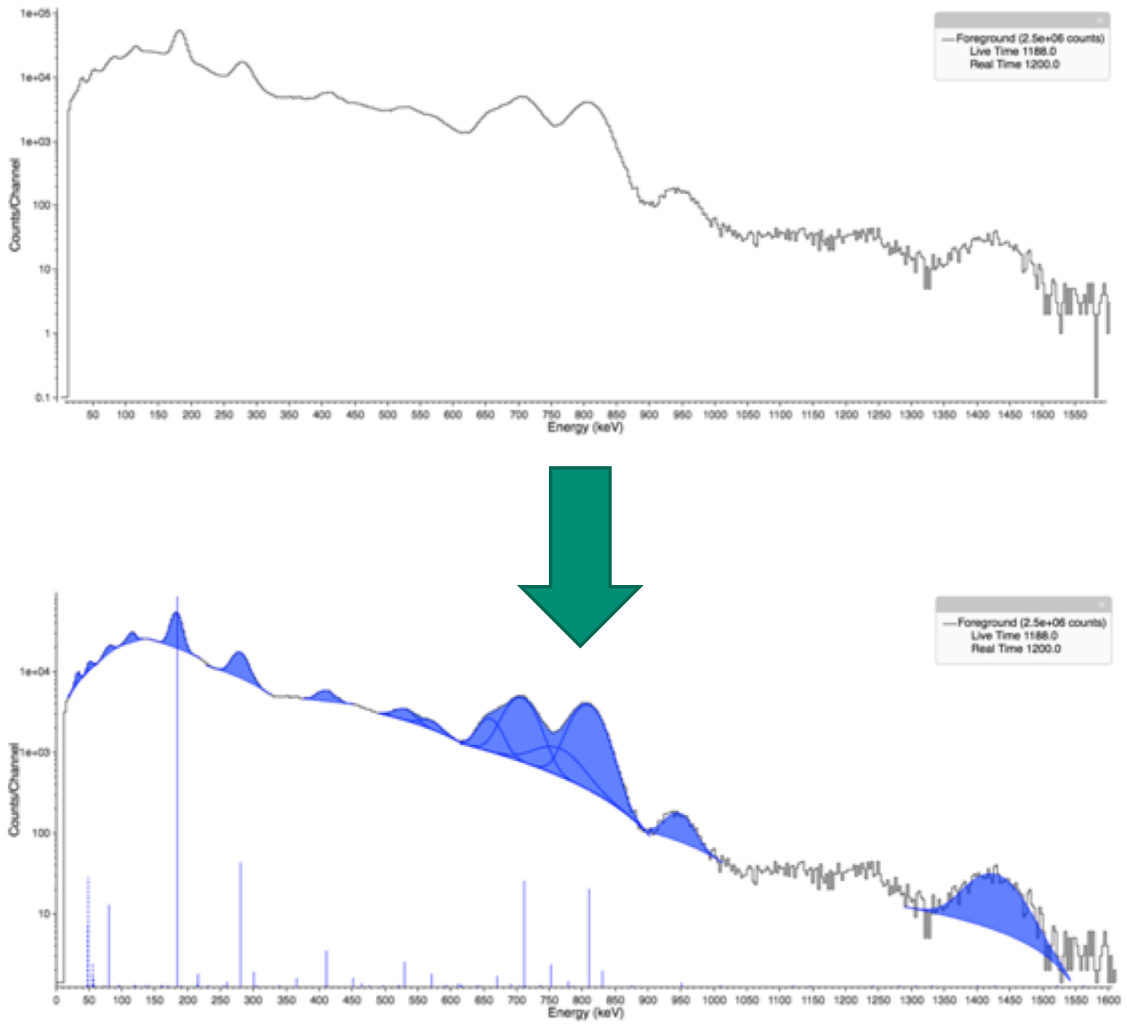
Display/Edit file meta-info
(RIID results, etc.)



Dose calculation
(or dose to activity, etc. calculation)

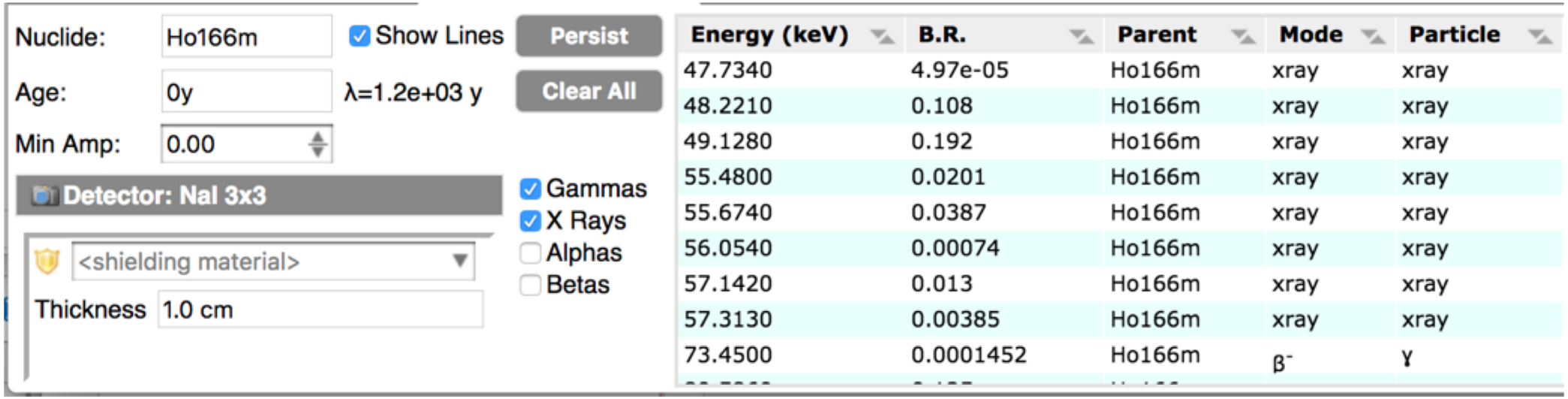
Supports iOS/Android/Windows/macOS/Linux

InterSpec Analysis Overview



Analyzing data in InterSpec primarily happens by fitting for “photo-peaks” in gamma spectrum

InterSpec Analysis Overview (cont)



Energy (keV)	B.R.	Parent	Mode	Particle
47.7340	4.97e-05	Ho166m	xray	xray
48.2210	0.108	Ho166m	xray	xray
49.1280	0.192	Ho166m	xray	xray
55.4800	0.0201	Ho166m	xray	xray
55.6740	0.0387	Ho166m	xray	xray
56.0540	0.00074	Ho166m	xray	xray
57.1420	0.013	Ho166m	xray	xray
57.3130	0.00385	Ho166m	xray	xray
73.4500	0.0001452	Ho166m	β^-	γ

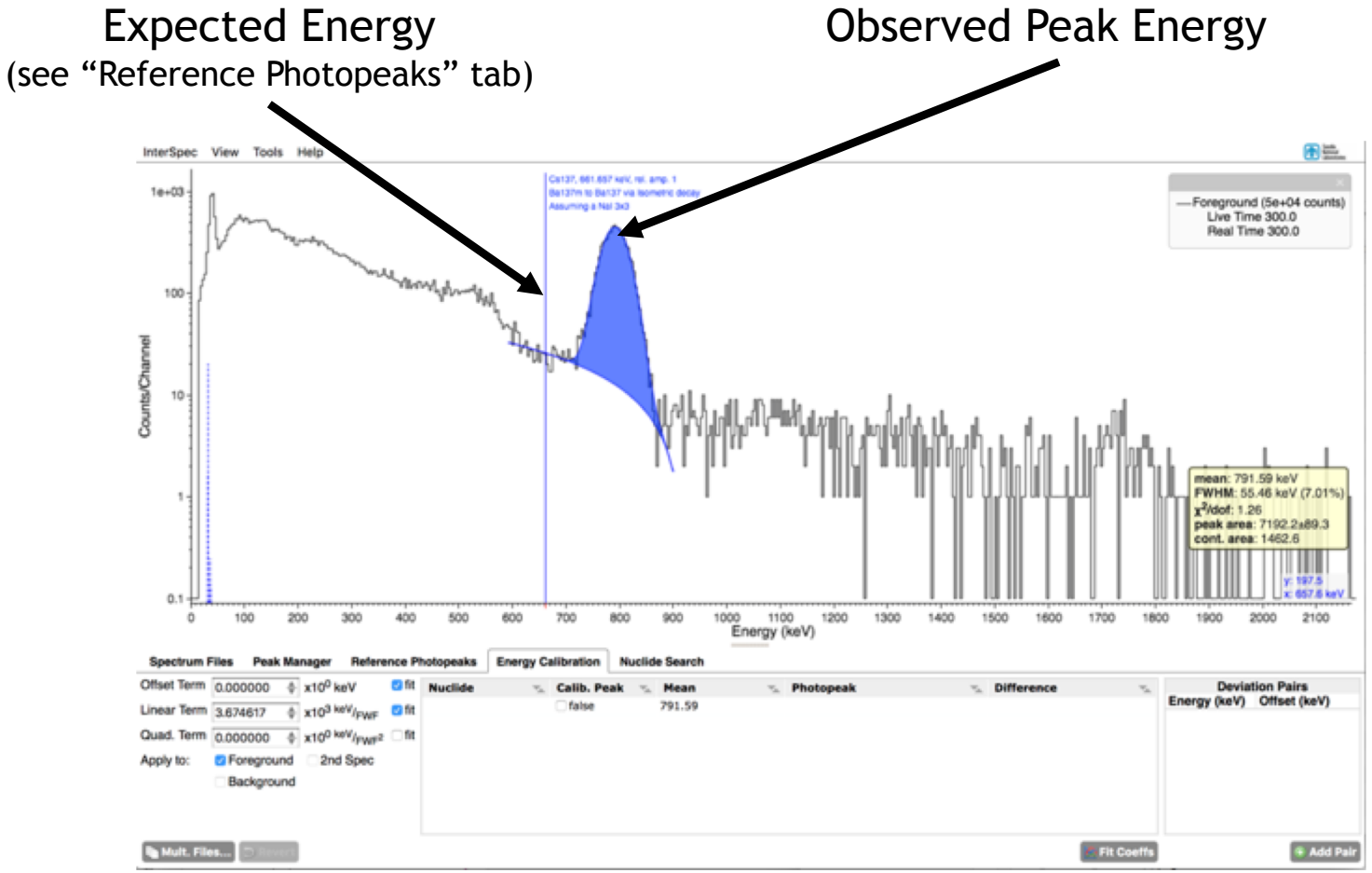
Since the expected yields of gammas at a given energy is known, as well as the efficiency of detection for a given detector at each energy is known – InterSpec can use this information to back-out: source strength, shielding amount, possibly shielding type, possibly nuclide age, and more information

Overview of using InterSpec to analyze spectra

To use InterSpec to analyze spectra, you will generally perform the following steps:

- Make sure the spectrum has a good energy-calibration. This usually done using a background, or a known source, taken at around the same time as the spectrum of interest
- Identify the source nuclides (or x-rays, or nuclear reactions) that cause each of the peaks in the spectrum
- Fit for the nuclides activities, maybe ages, and shielding amount and types

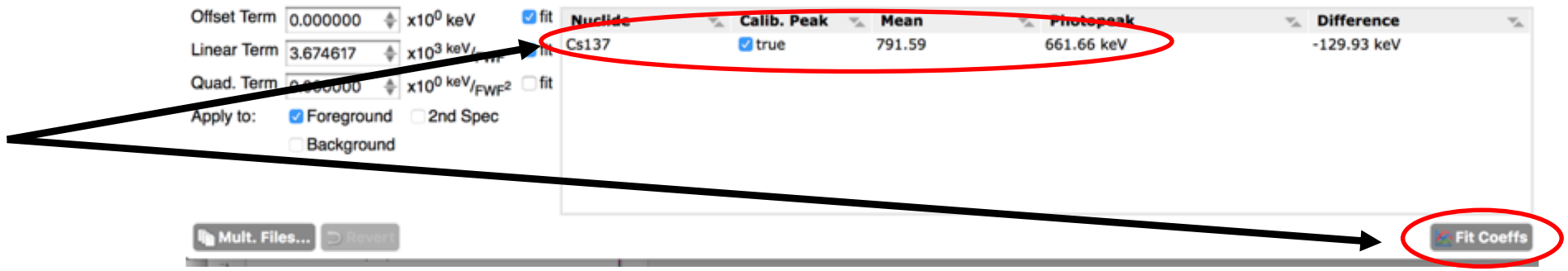
Energy Calibration Check: Spectrum of a known Cs137 source



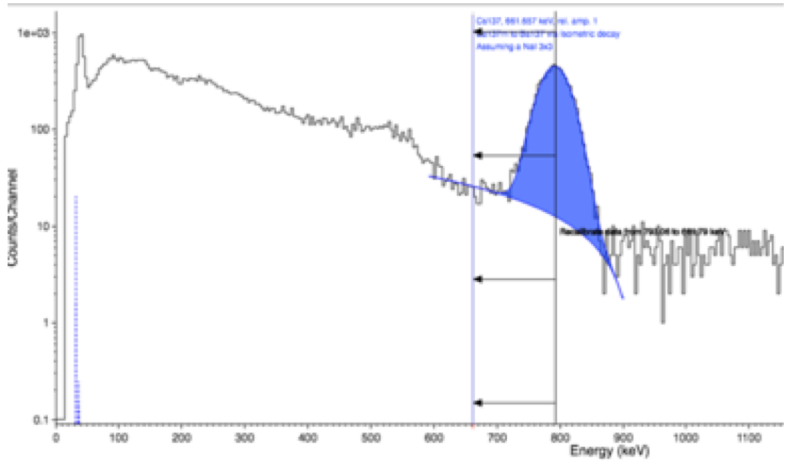
Usually, you check that one or a few peaks, that you know what energy they should be, are actually at those energies.

Energy Calibration Check: fixing calibration up

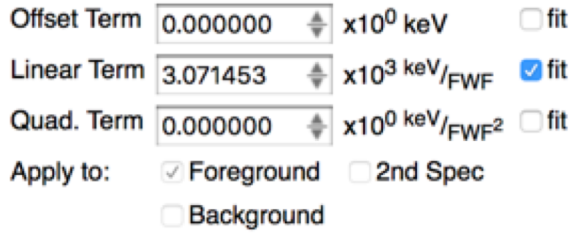
Since we know what energies the peaks should be at, we can have InterSpec fit for the correct energy calibration coefficients



Or you can graphically recalibrate by right-click dragging the peaks to where they are supposed to be



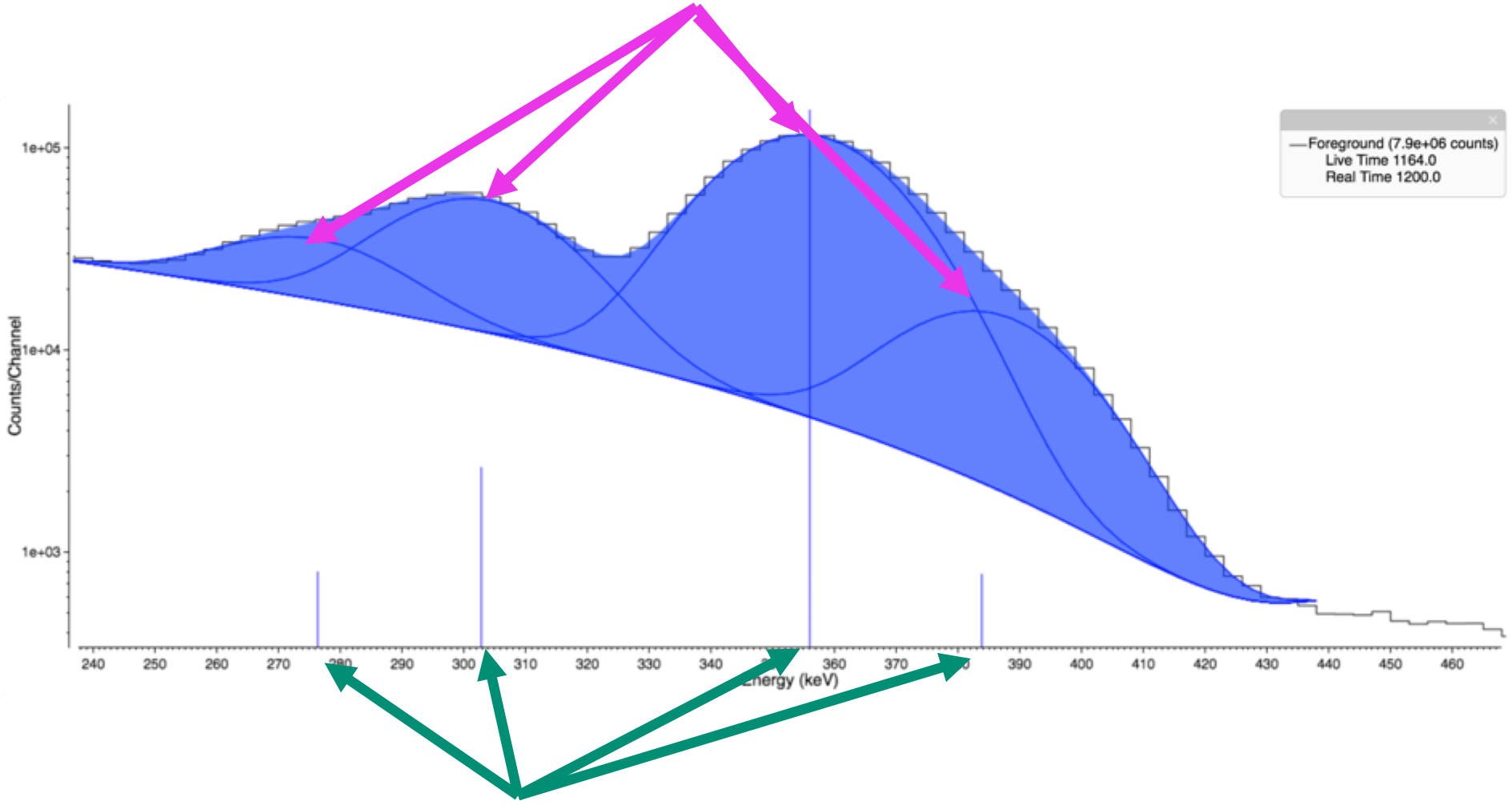
Or you can manually play with the calibration coefficients



Nuclide Identification:

InterSpec uses the photo-peaks in the spectrum to help determine which nuclides are present

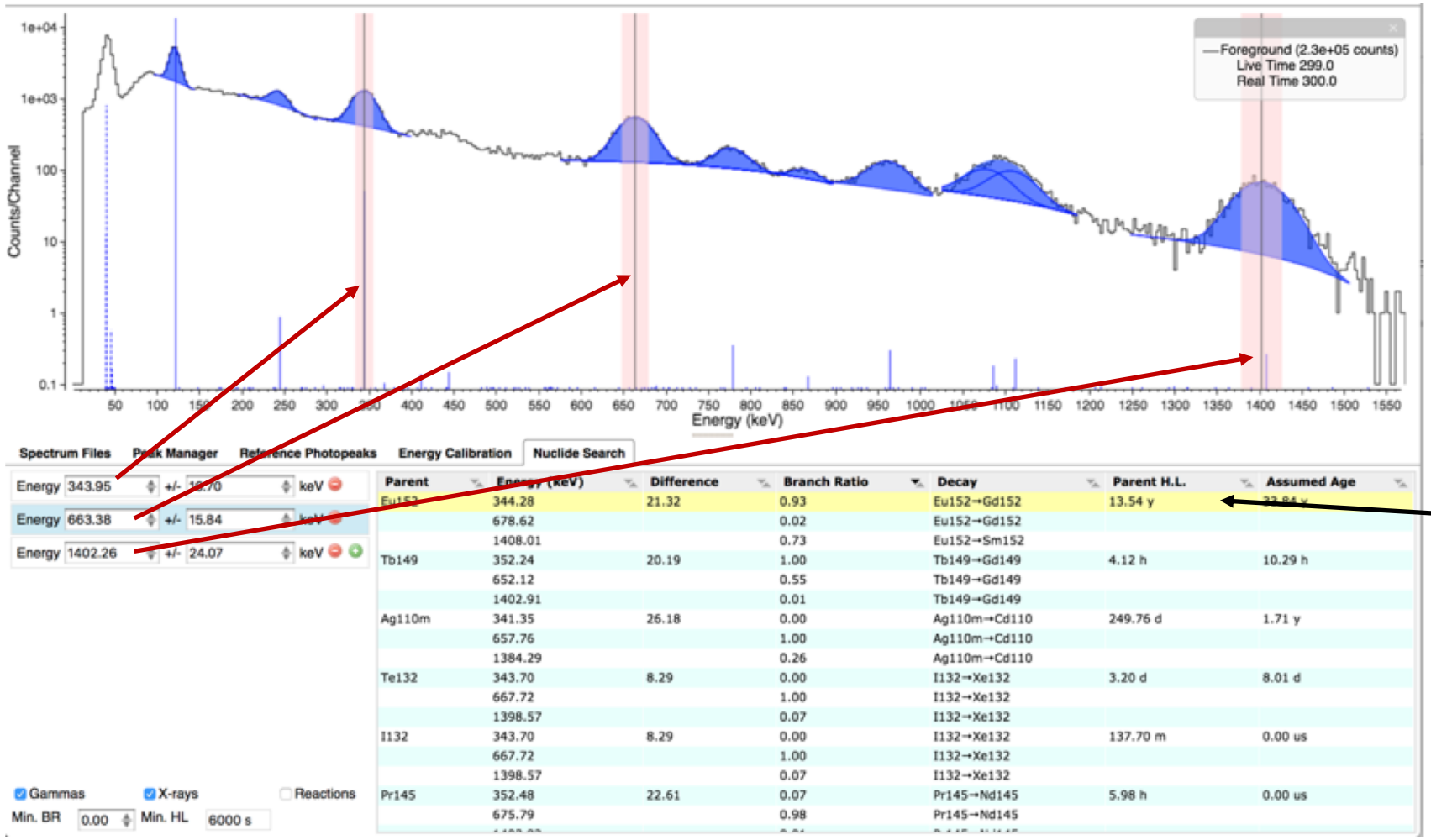
Photopeak's observed in the spectrum



The expected photopeak locations for Ba133

Nuclide Identification (cont):

InterSpec does not perform automatic nuclide identification, but provides tools to help you determine them



Clicking on a trial nuclide shows the photopeak reference lines for that nuclide – this allows determining which nuclide most closely matches observed data

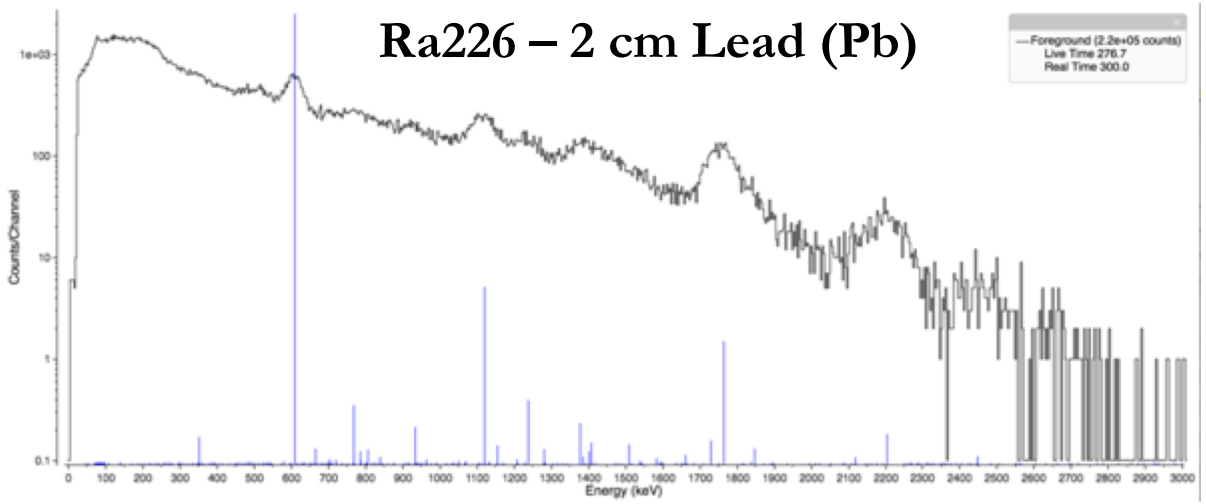
Here we are searching for nuclides that have the three photopeaks highlighted

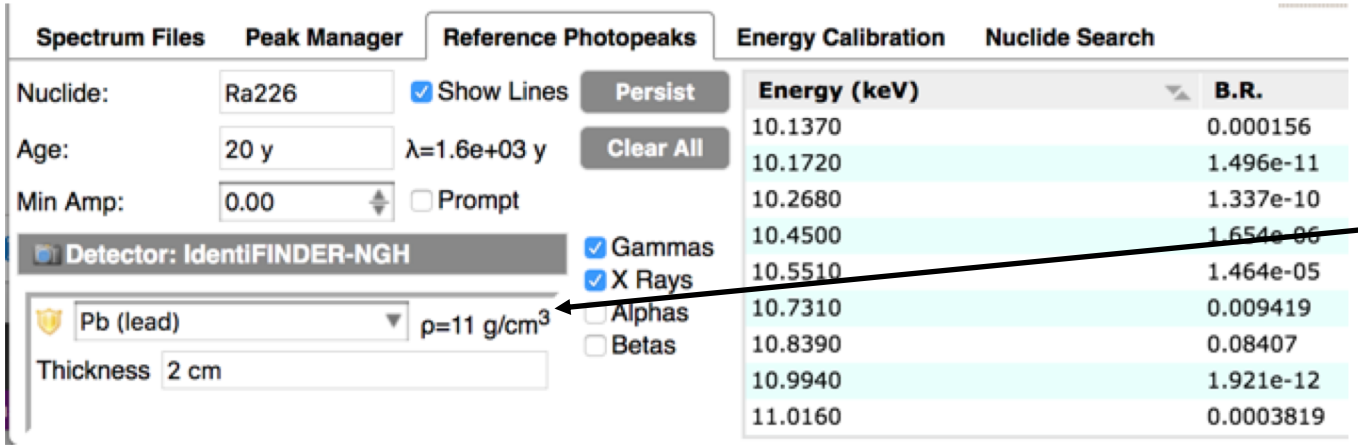
Nuclide Identification (cont):

Shielding or nuclide age can alter what photopeak are observed in the data – InterSpec can help with this

Ra226 – no shielding

Ra226 – 2 cm Lead (Pb)





Entering shielding amount, nuclide age, or detector response changes amplitude of reference photopeaks

(calculating shielding/age from data to be shown later in presentation)

Nuclide and Shielding Quantification:

- InterSpec uses the amplitude of peaks, in combination with the known emission rate of gamma radiation, a known distance, and the detector response function (efficiency of detecting gamma at a given energy) to calculate source strength
- If an unknown amount of shielding is present: the amount of shielding, and possibly its effective atomic number, may be able to be calculated from the data
  - The probability of gammas interacting with the shielding is energy and atomic number dependent; InterSpec will use the relative amplitudes of peaks at different energies in the spectrum to calculate how much and what type of shielding there is

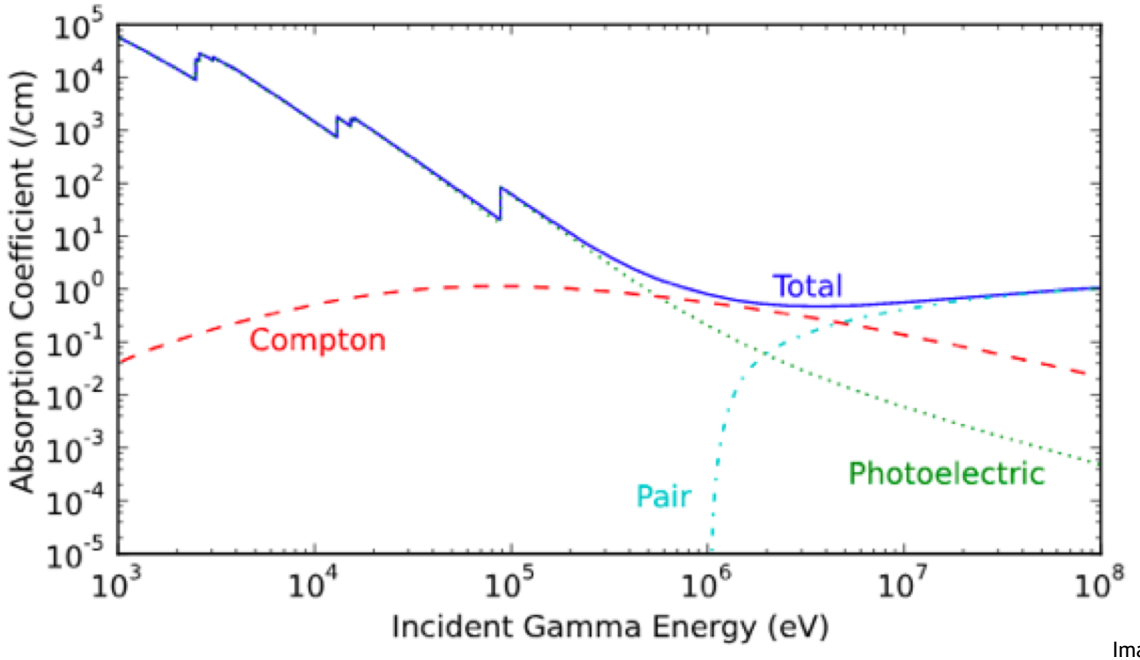
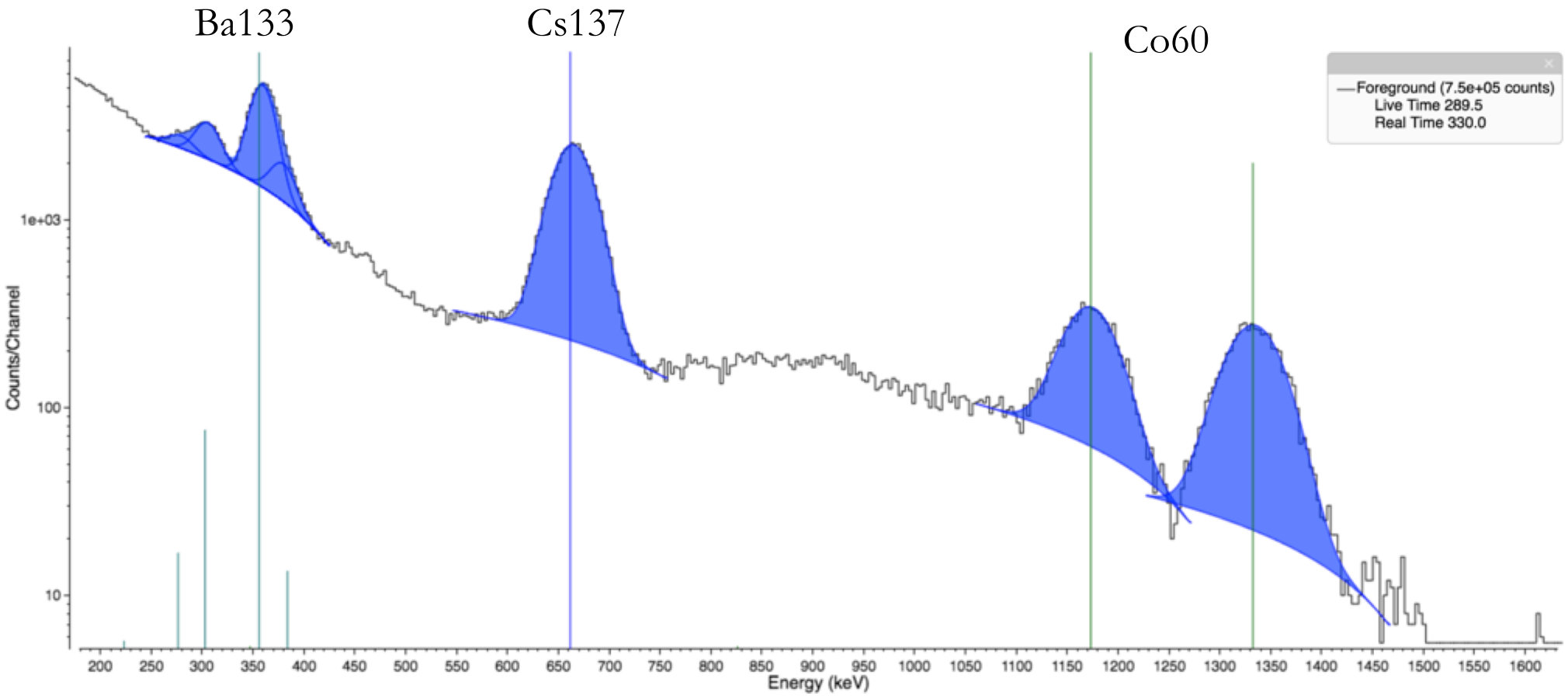


Image Credit: Joshua Hykes [CC BY-SA 3.0] https://commons.wikimedia.org/wiki/File:Pb-gamma-xs.svg

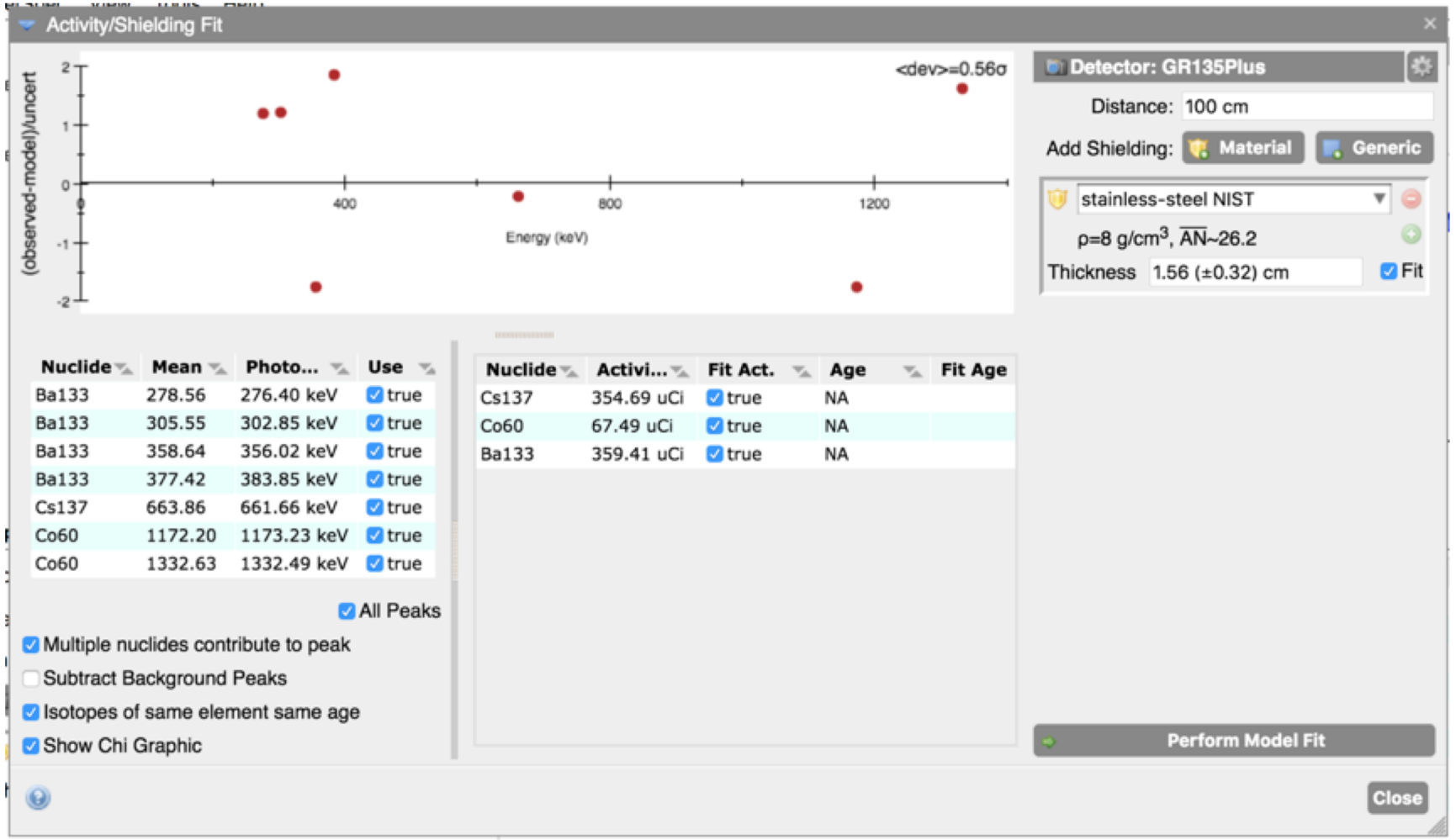
Nuclide Quantification:

InterSpec allows calculating activities of multiple nuclides



If multiple nuclides contribute to a peak, InterSpec will account for this

Nuclide Quantification: Fitting for values



The "Activity/Shielding Fit" tool uses the peaks you fit for to then fit for source strength/age and shielding

Using InterSpec

InterSpec requirements:

- InterSpec works on all major platforms
  - Using on iPhone/iPad and Android works surprisingly well!
- Open-source: https://github.com/sandialabs/InterSpec
  - You can make any changes you want to it, and/or compile it from source
- Does not require installing on Windows – just unzip the package and run the EXE
  - On the google play app store, and we are (slowly) working on adding to Apple app stores – currently distributed for iOS ad-hoc
- InterSpec accepts data from nearly all commercially available RIID detectors and detection systems
- InterSpec comes with a few generic detector response functions, but ones for specific model detectors will have to be given you separately

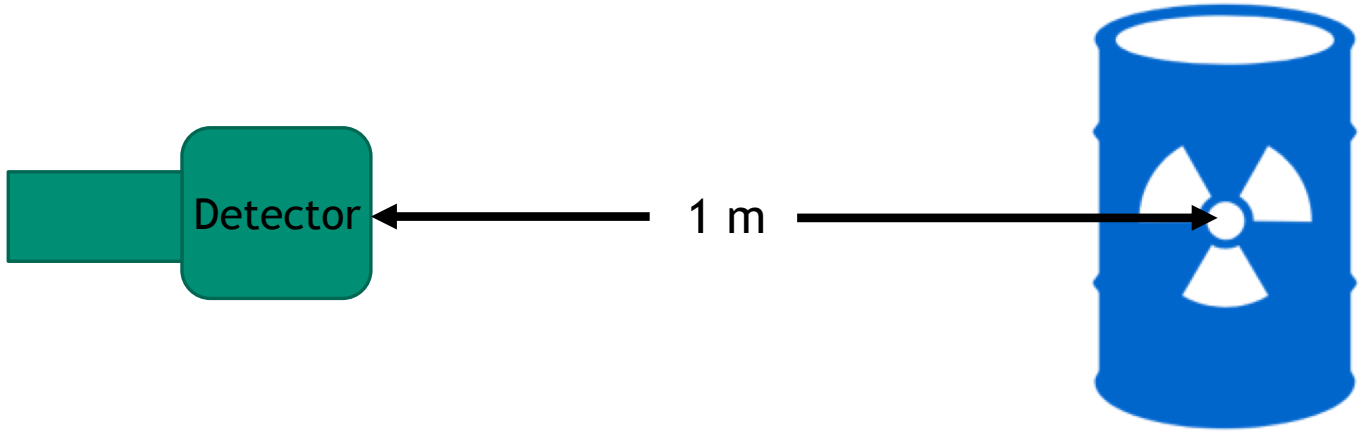
Using InterSpec

We will now perform a few example analysis – the next 23 slides is are meant for later reference

Example 1

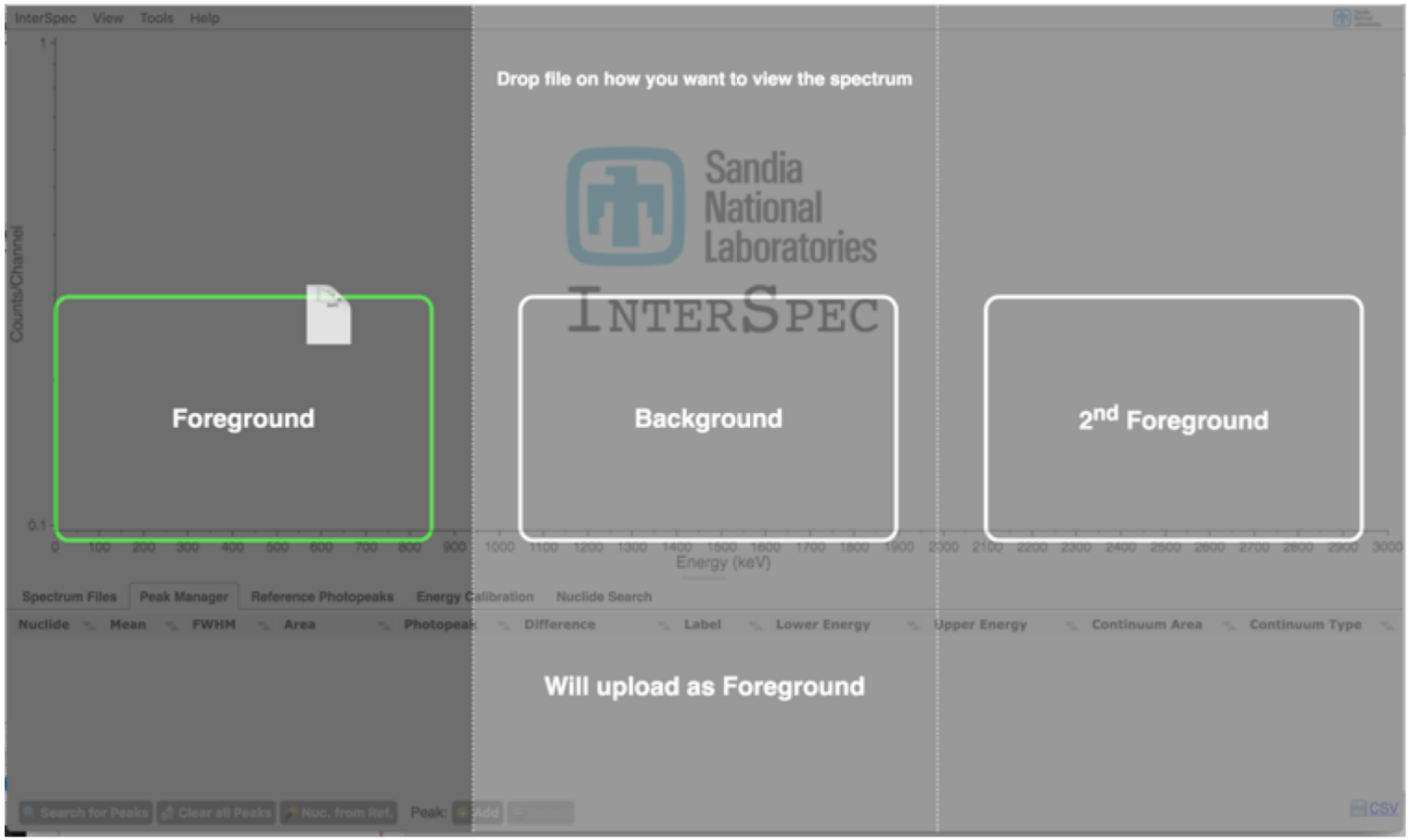
A metal container was located that was giving off increased radiation

- A 5 minute spectrum was taken from 1 m away, along with a 5 minute representative background; both using the same 3x3 NaI detector†
- You would like to determine:
  - What nuclides are present inside the box?
  - The nuclide(s) activity?
  - How much shielding is present?



† 7.62 cm diameter by 7.62 cm long NaI crystal – will produce the conceptually same spectroscopic data as an identiFINDER or RadSeeker

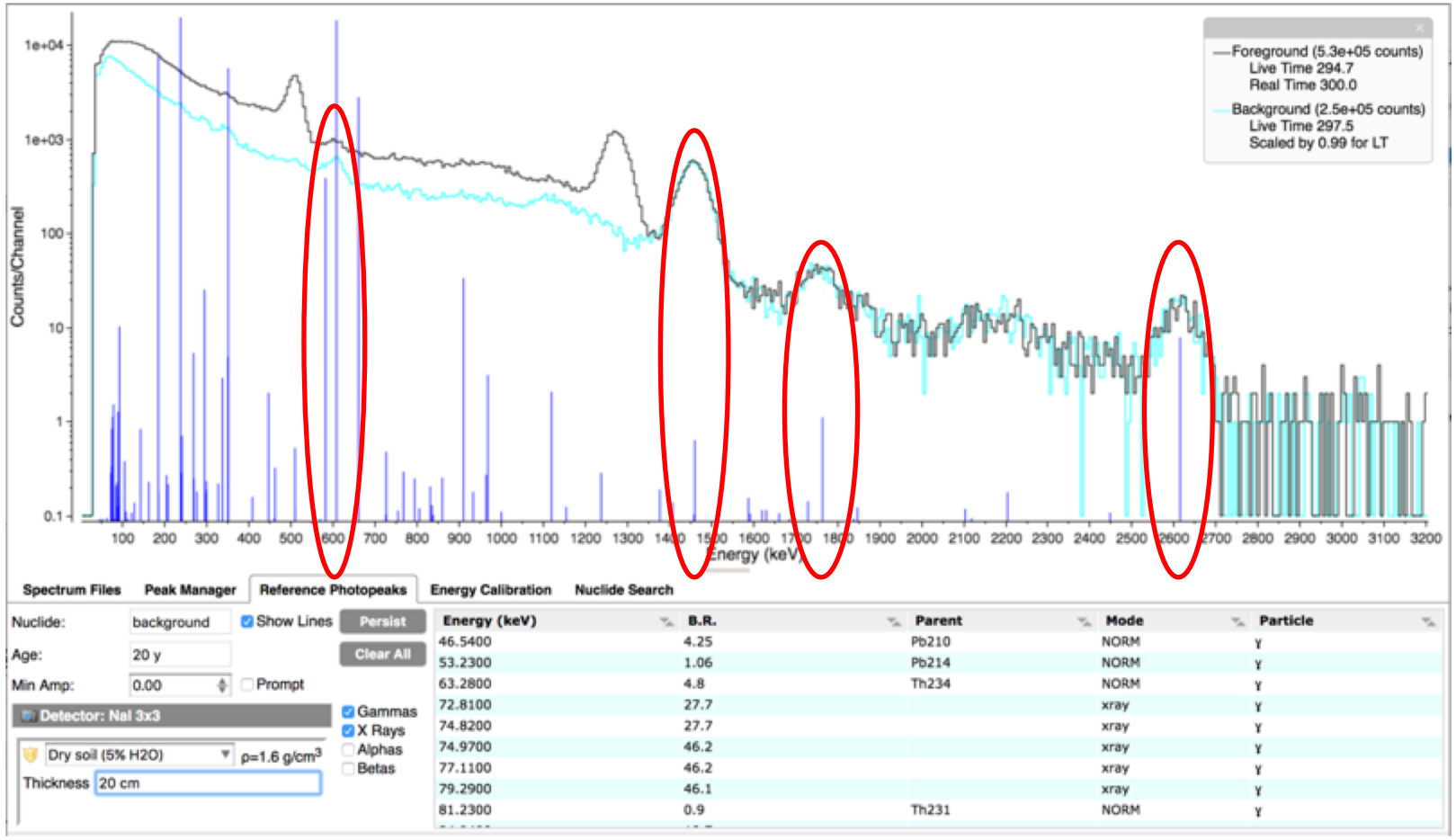
Example 1 (cont):



Easiest way to load spectra is to drag-n-drop from the operating system

- You can display up to three spectra at a time, but peak-fitting is limited to the foreground
- If you have previously worked with the spectra, you may be prompted if you want to pick up where you left off (you can also explicitly save state to InterSpecs database, or “tag” or “branch”)

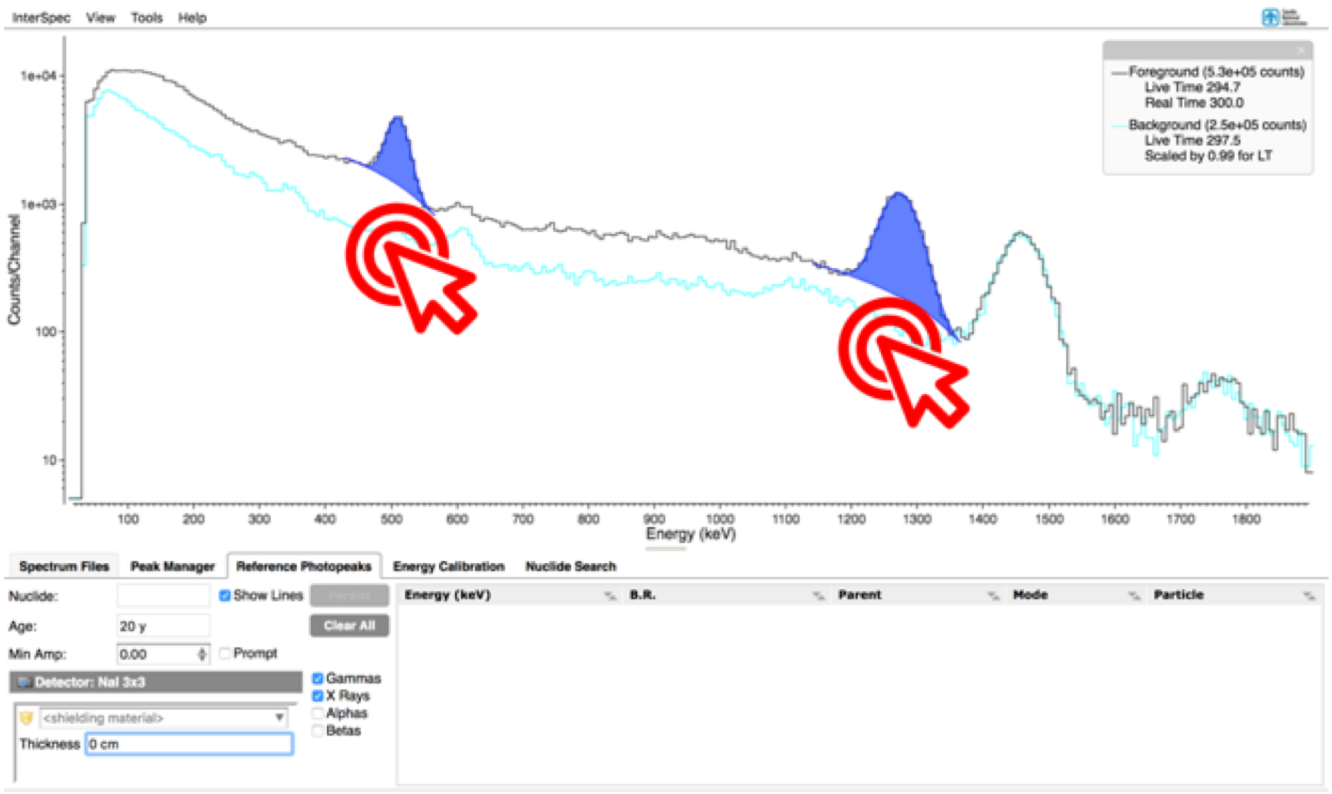
Example 1 (cont):



The background peaks at 1460 keV (K40), 609 keV (Ra226), and 2614 keV (Th232) look to be at the expected energies

- The energy calibration is acceptable, and it looks like we got the correct files off the detector

Example 1 (cont):



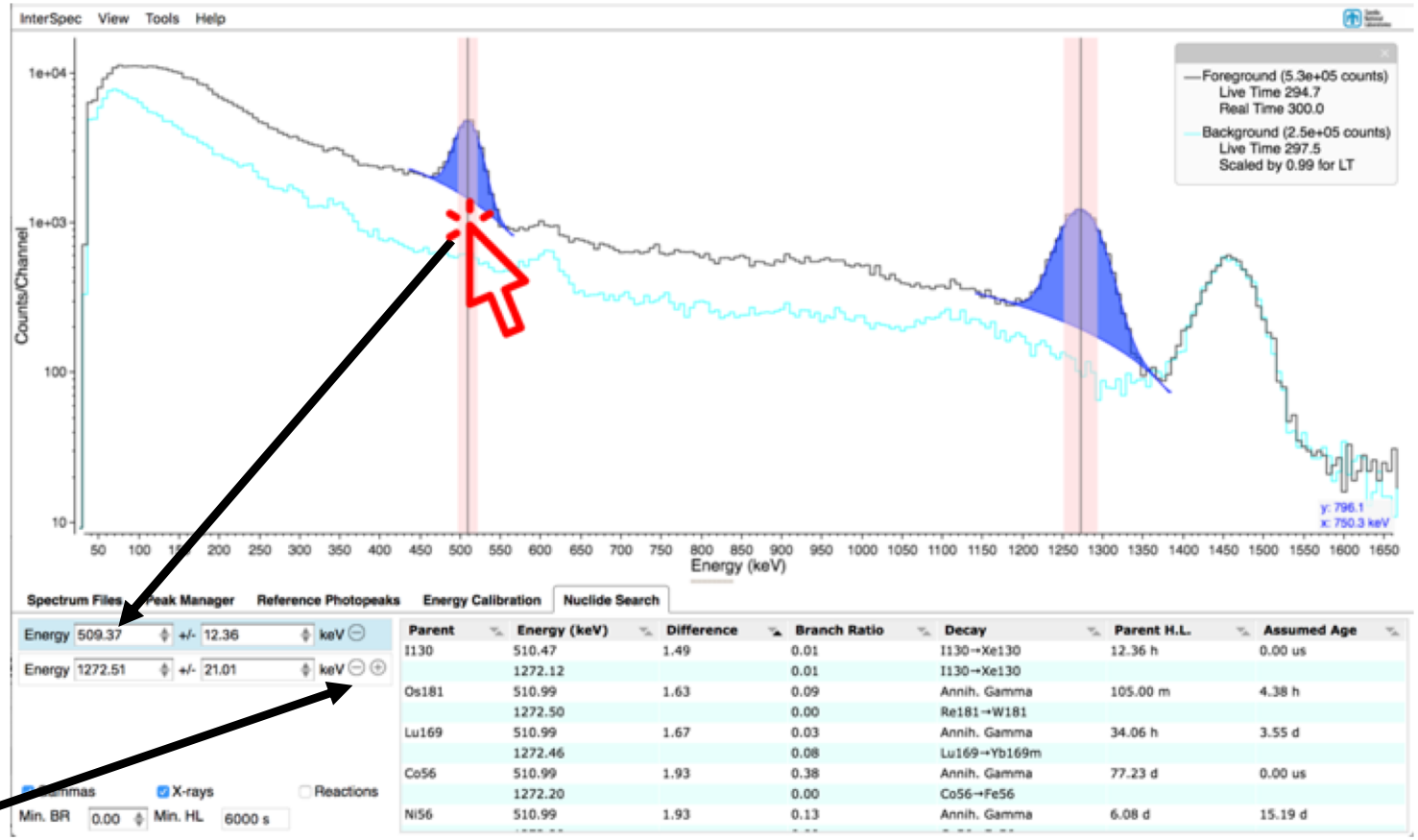
There are two obvious photo-peaks in your item of interest spectrum that are not in the background spectrum.

You can fit peaks by double-clicking near them.

Example 1 (cont):

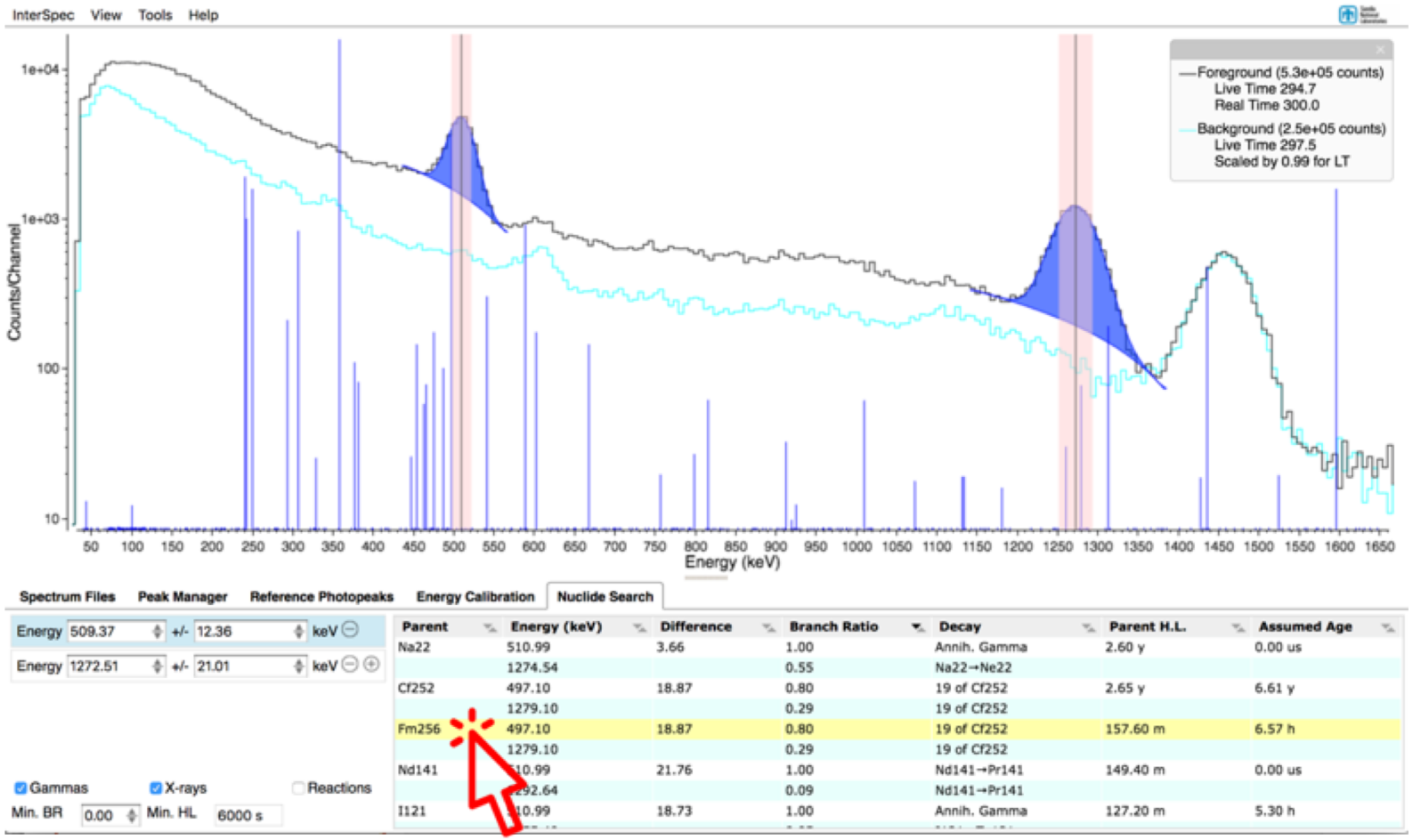
Lets figure out what nuclide causes these photopeaks by using the "Nuclide Search" tab

When on the "Nuclide Search" tab if you click on a place in the spectrum – that energy is filled in to search on



The number of energies can be changed by using the + and - icons

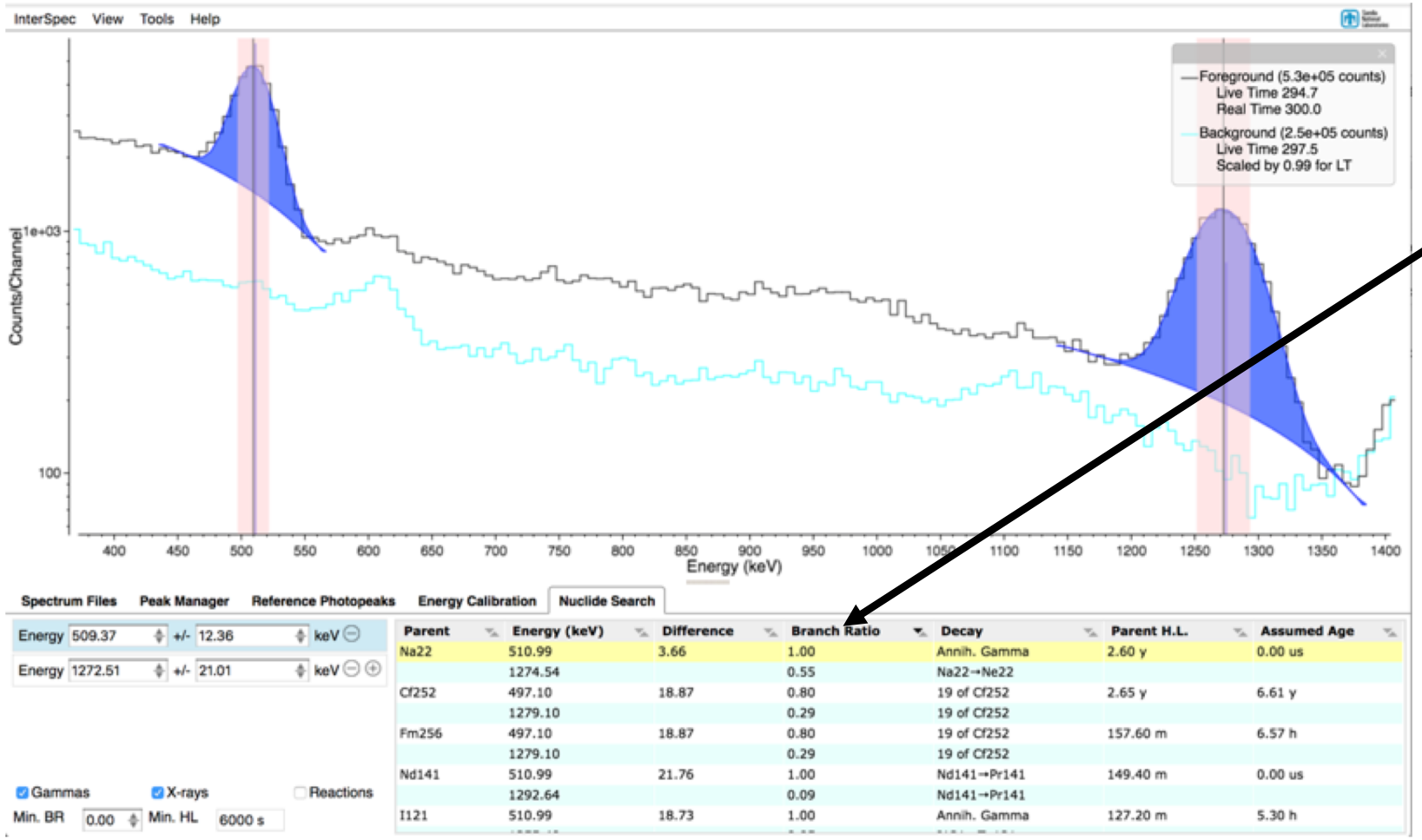
Example 1 (cont):



Clicking on a nuclide will cause the reference photopeak lines for that nuclide to be shown

- Here Fm256 is clearly not right because we would see many other peaks

Example 1 (cont):

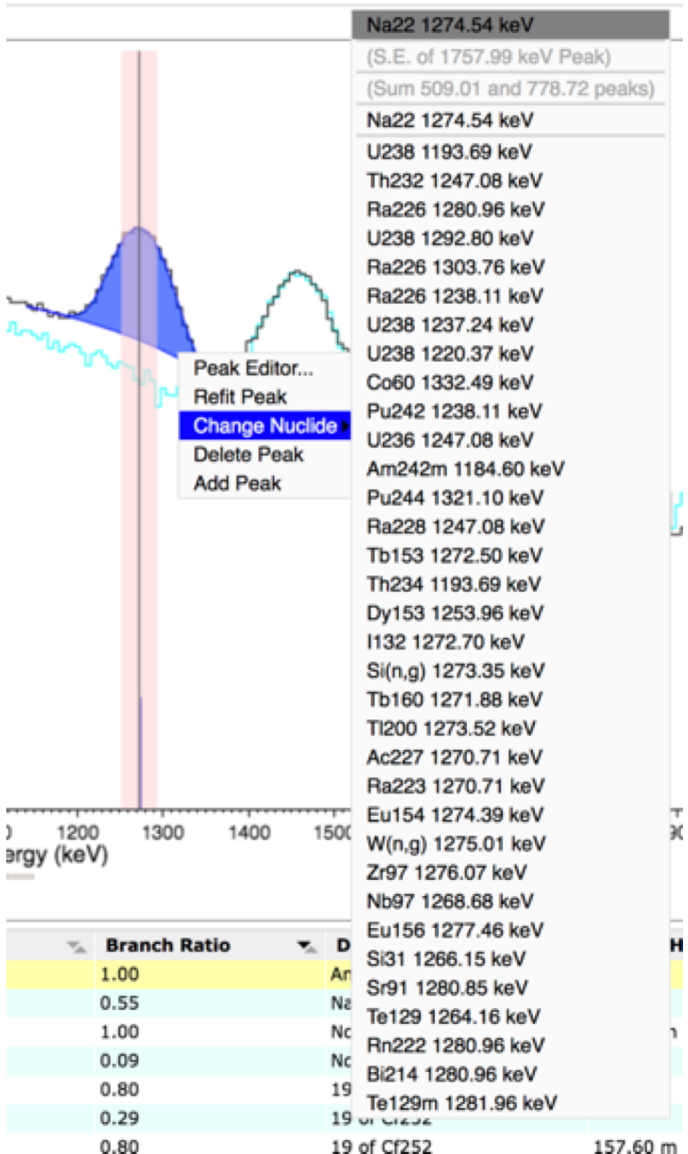


Its usually best to sort this table by the "Branch Ratio" column (default), but other ordering can be changed by clicking on the headers for other columns

It's a little hard to see, but the reference lines for Na22 line up exactly with the observed peaks – and we aren't missing any peaks we would expect for Na22 – so this is our nuclide

Example 1 (cont):

Now we need to assign nuclides to these peaks:

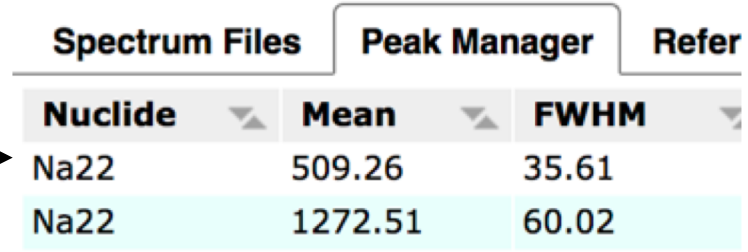


If you right-click on the peak, and go to the "Change Nuclide" menu-item, you can select Na22, or there are a number of other possible isotopes that it could be from

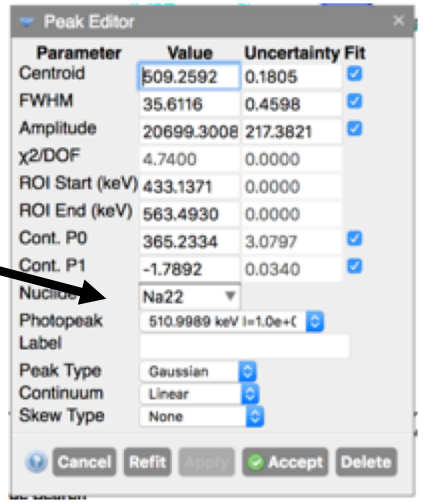
Example 1 (cont):

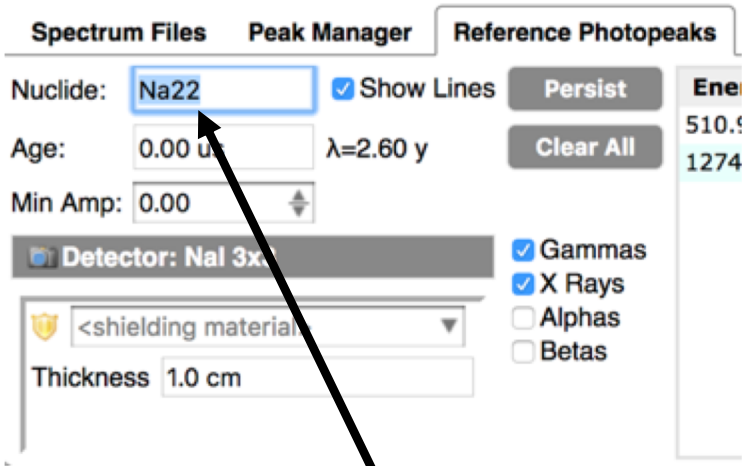
You can also assign nuclides to peaks, in a number of other ways:

By typing the nuclide name into the "Peak Manager" tab

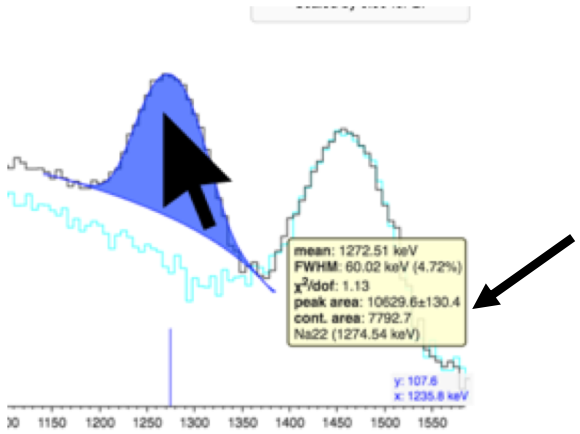


The "Peak Editor" tool (opened by right clicking on peak and selecting "Peak Editor…")





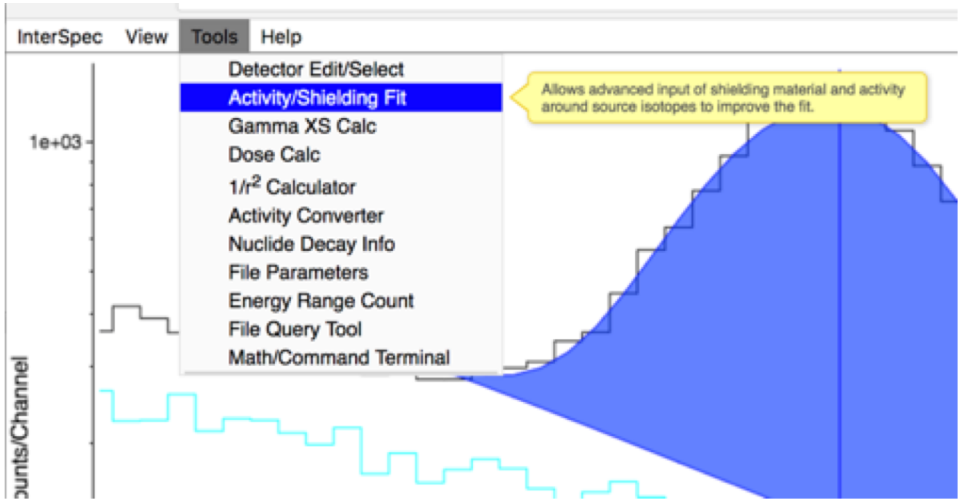
Or if you are showing reference photo-peak lines when you fit for a peak, the peak will automatically be associated with that nuclide

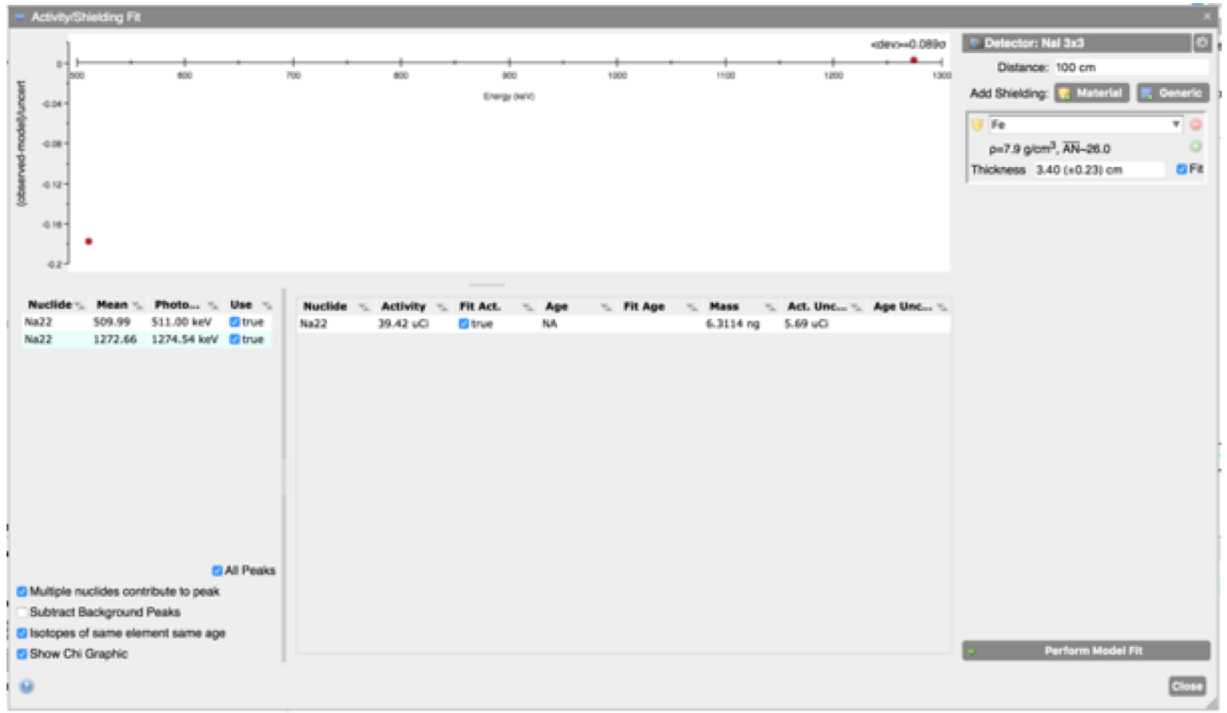


Mousing over a peak causes a pop-up that shows info about the peak, including nuclide

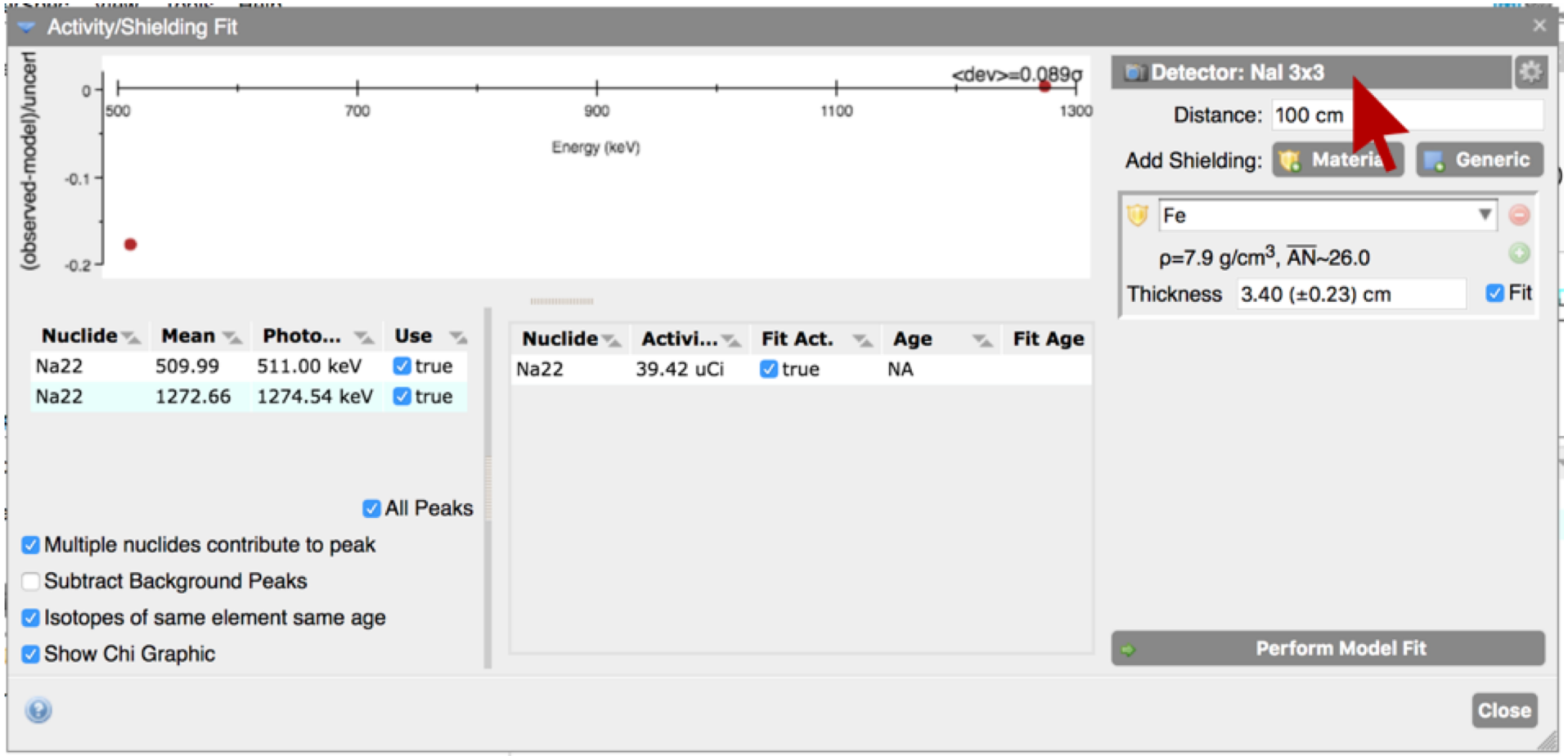
Example 1 (cont):

Fit for the source activity using the "Activity/Shielding Fit" tool



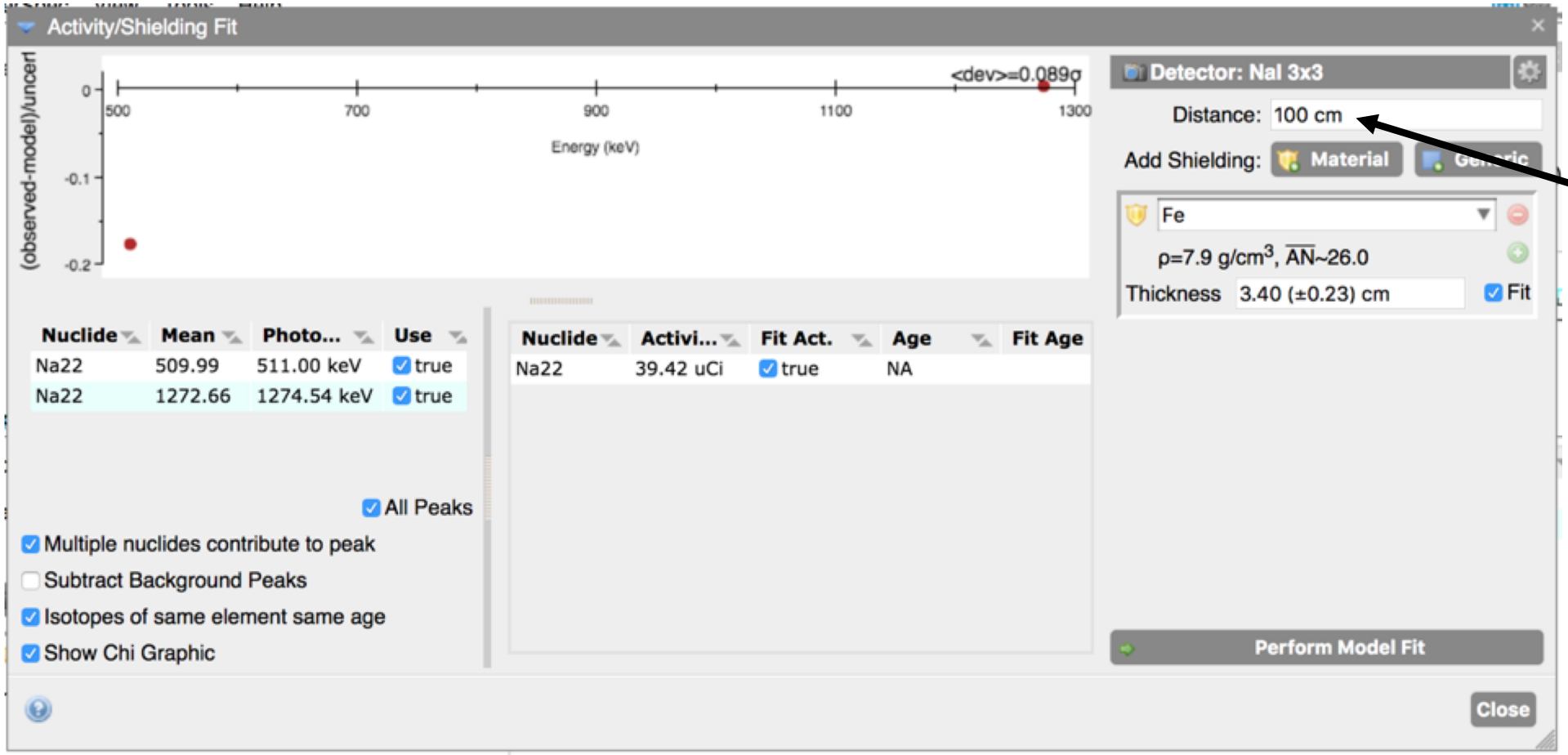


Example 1 (cont):



Select the detector response function you want to use by clicking here

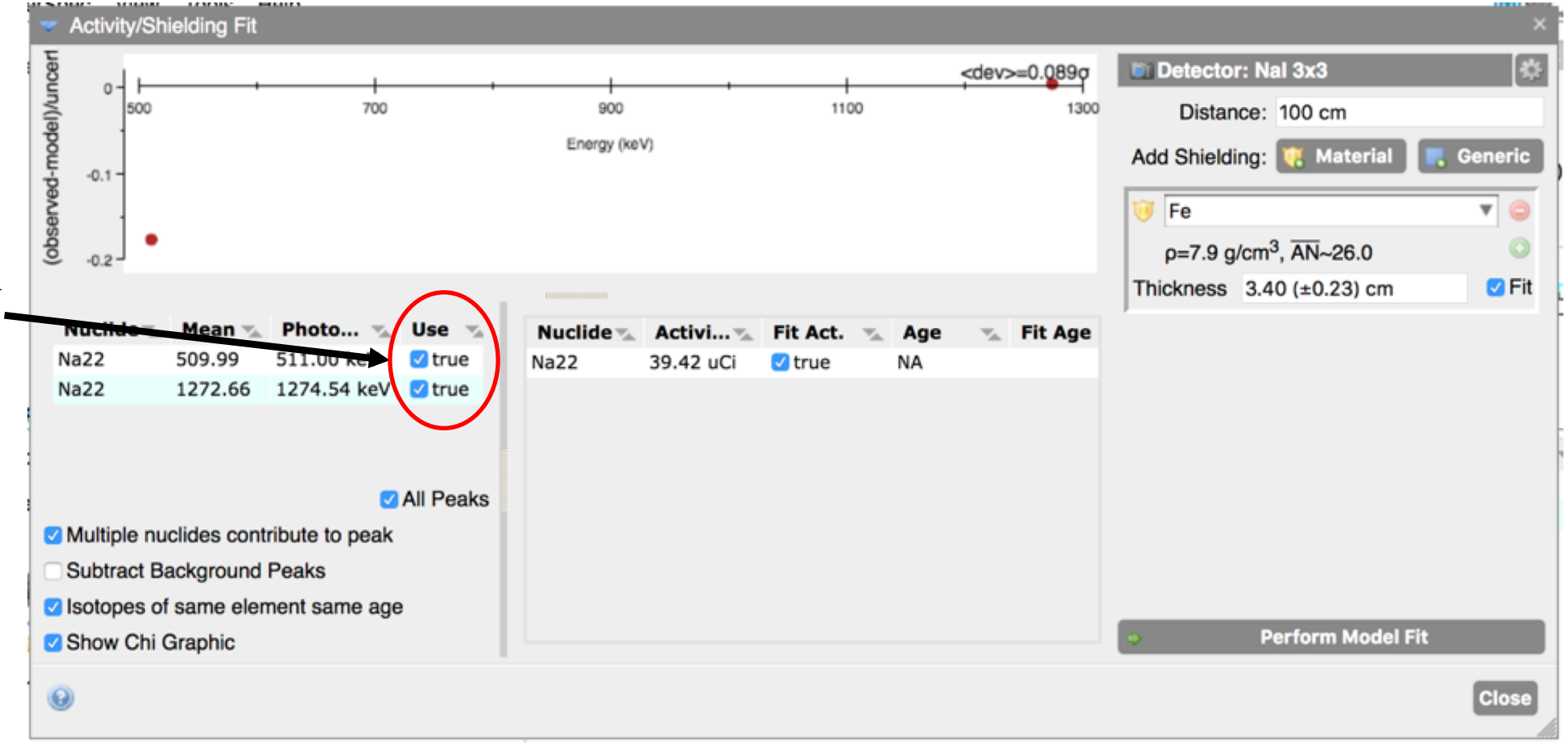
Example 1 (cont)



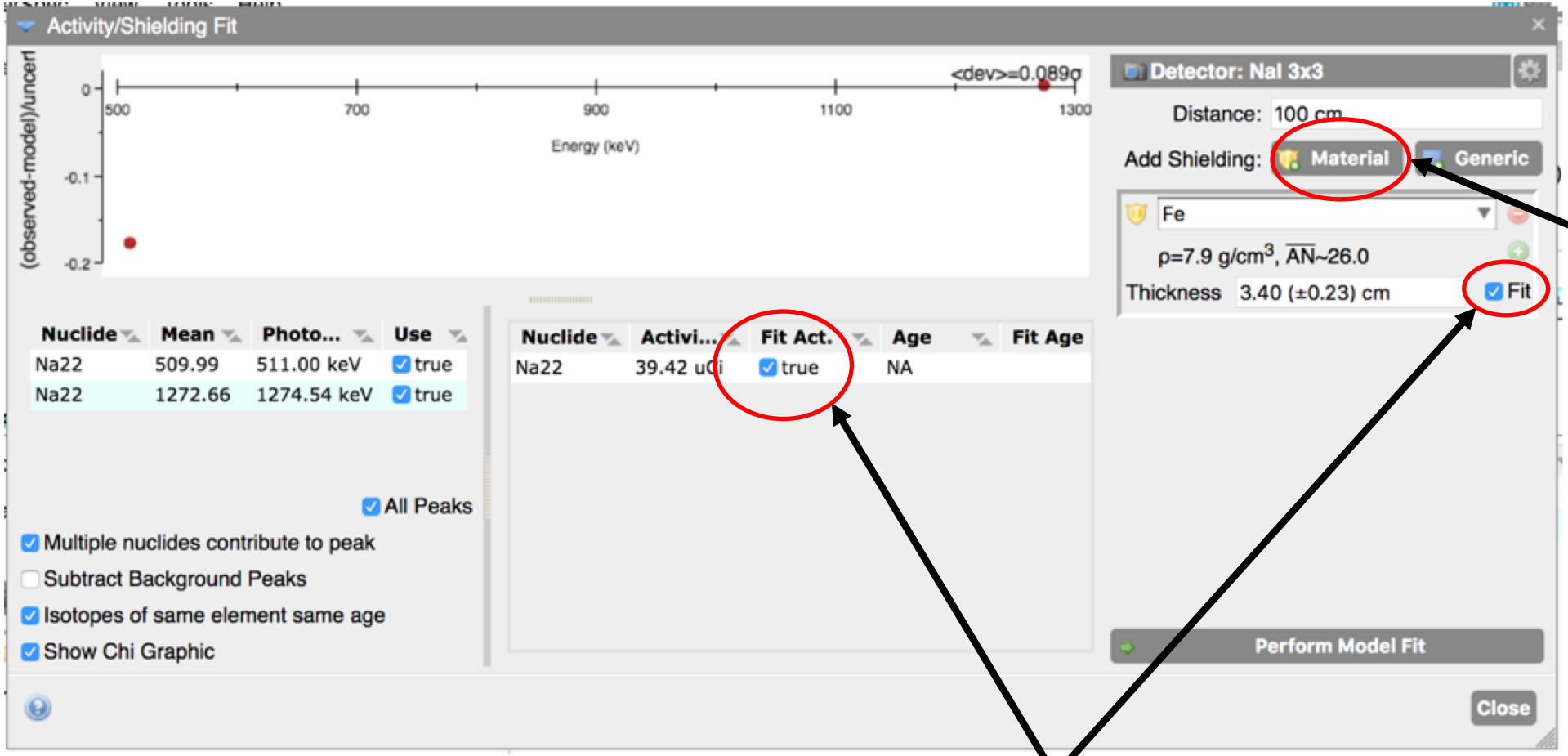
Enter distance of measurement

Example 1 (cont):

Select which peaks you would like to use



Example 1 (cont):

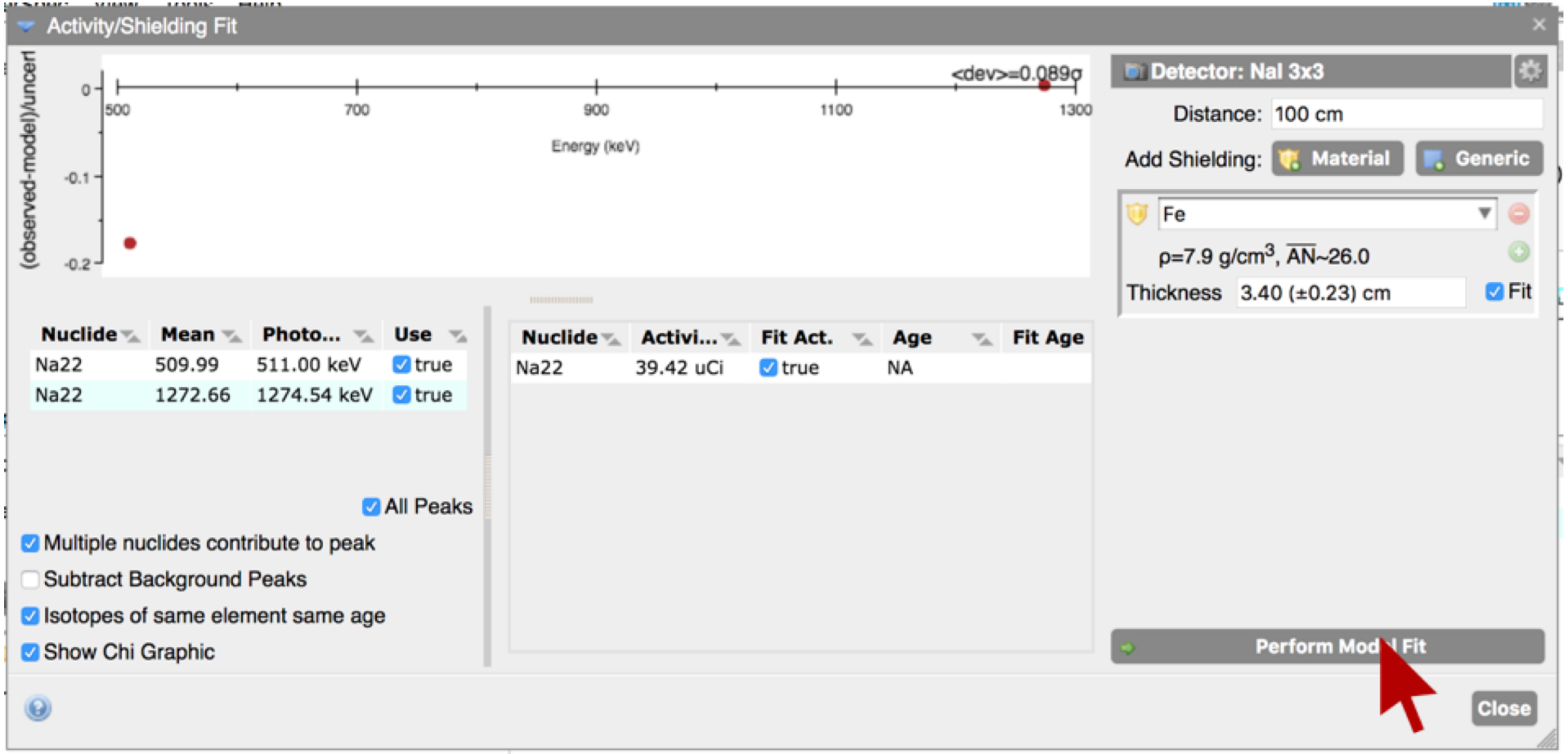


Add a shielding

Here we added a single iron shielding

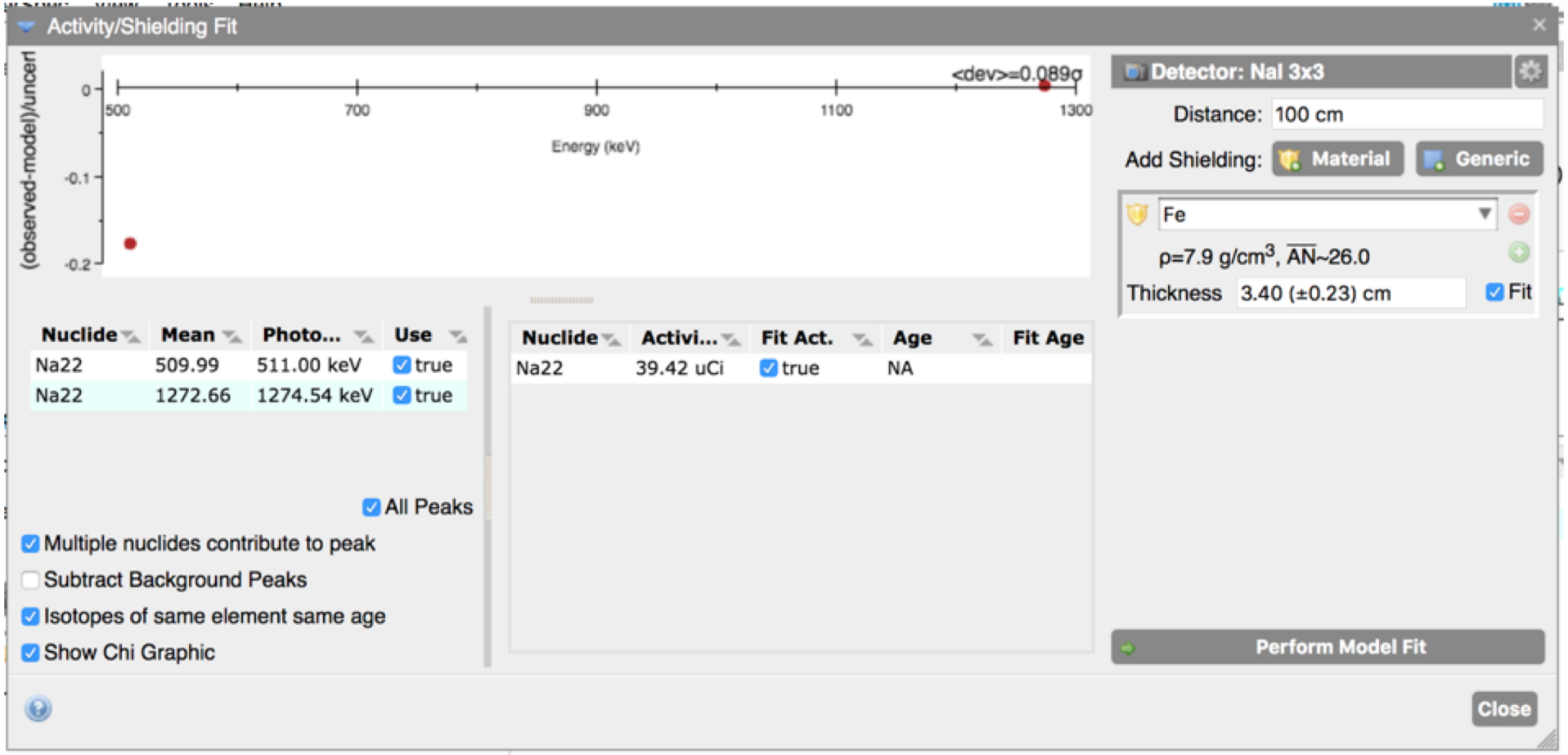
Make sure you are fitting for activity, and shielding thickness

Example 1 (cont)



Click here to fit for desired quantities

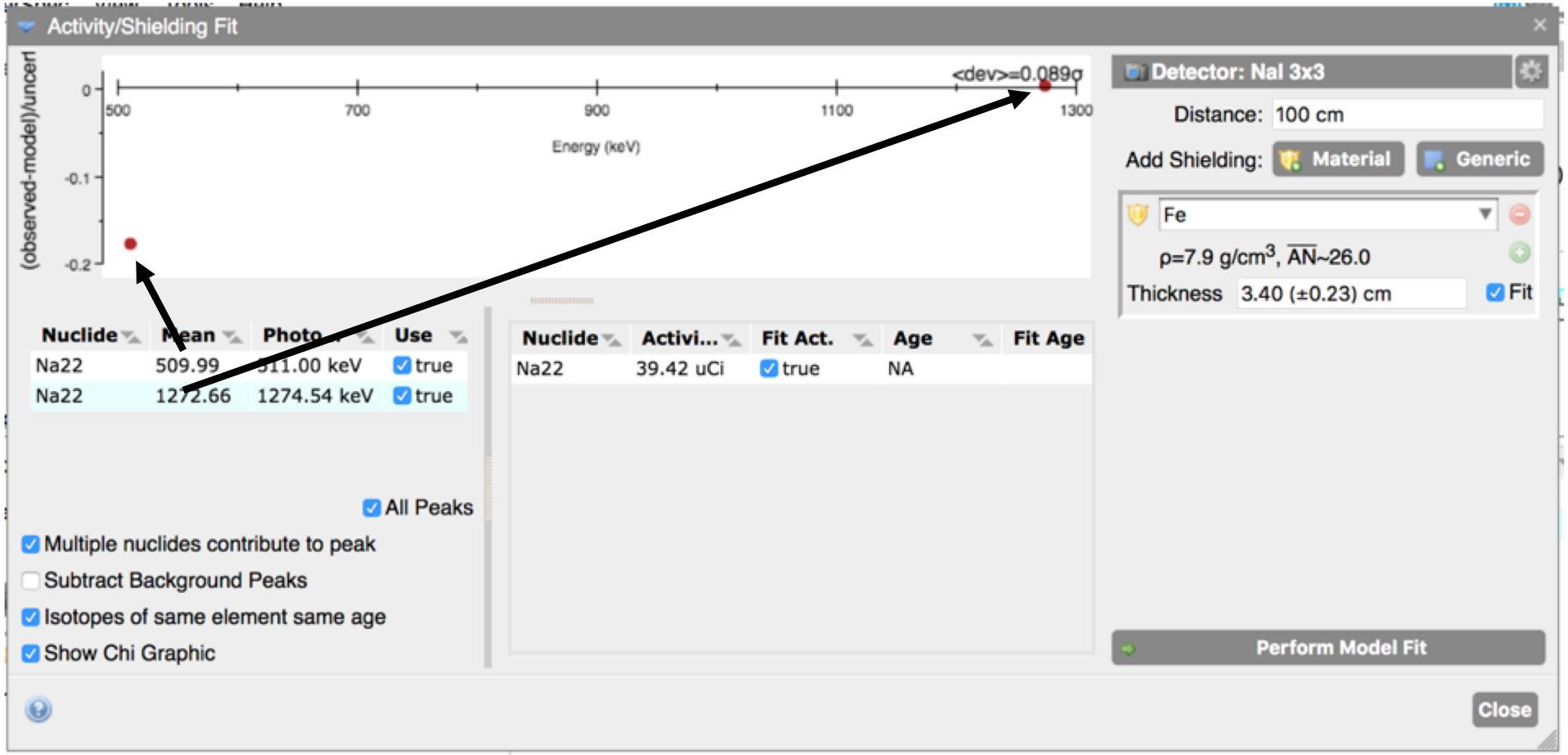
Example 1 (cont)



We fit for 40 uCi of Na22, with 3.4 cm of Iron Shielding

- Truth level: 50 uCi at 3.48 cm Fe - not bad!

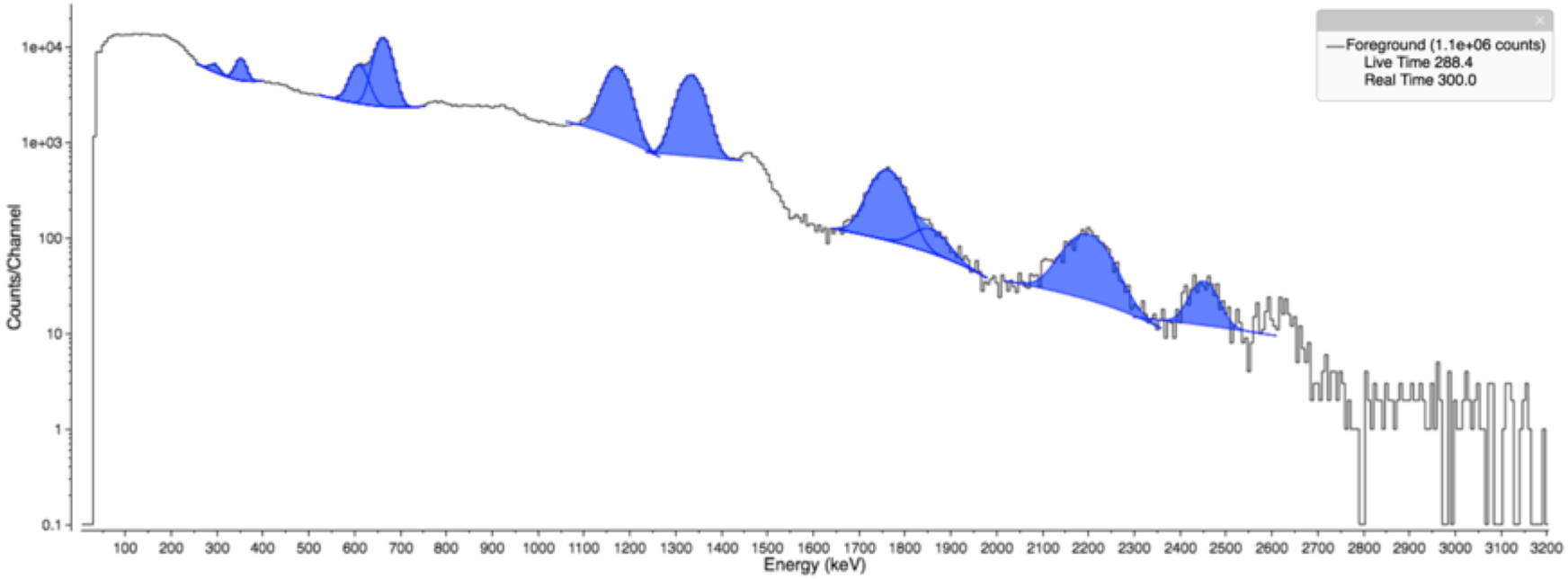
Example 1 (cont)



This "Chi2" graphic shows you how many statistical sigmas the fit peak areas are off from what is predicted for the fit activity and shielding

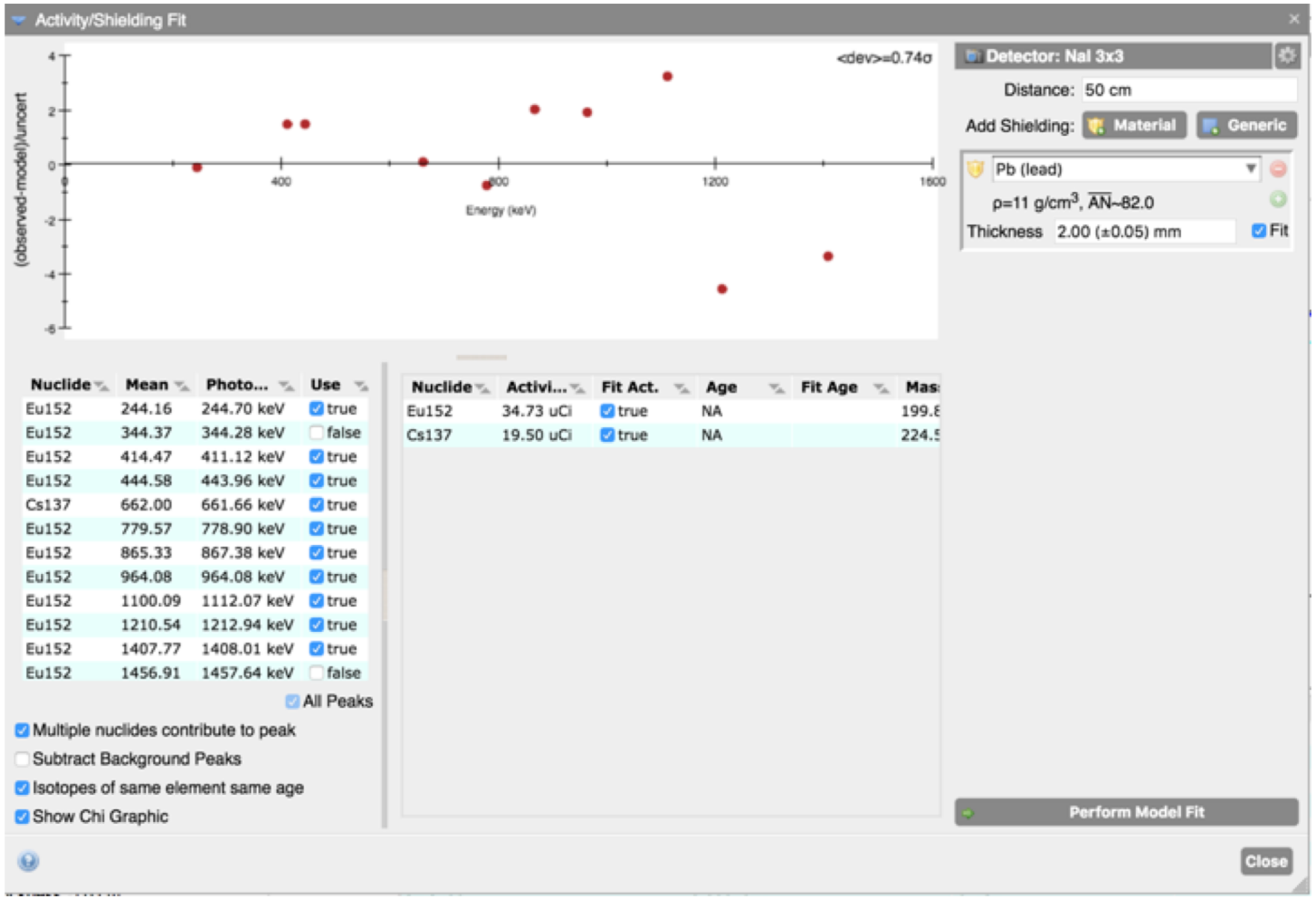
- Here we fit for two quantities (activity and shielding thickness), using two peaks, so both peak areas should be at essentially zero sigmas. If we had more peaks we would expect a distribution ranging between about ±5 sigmas (or maybe a little more)

Example 2:



For this problems we are told the same 3x NaI detector was used, but no background was provided, and shielding is lead

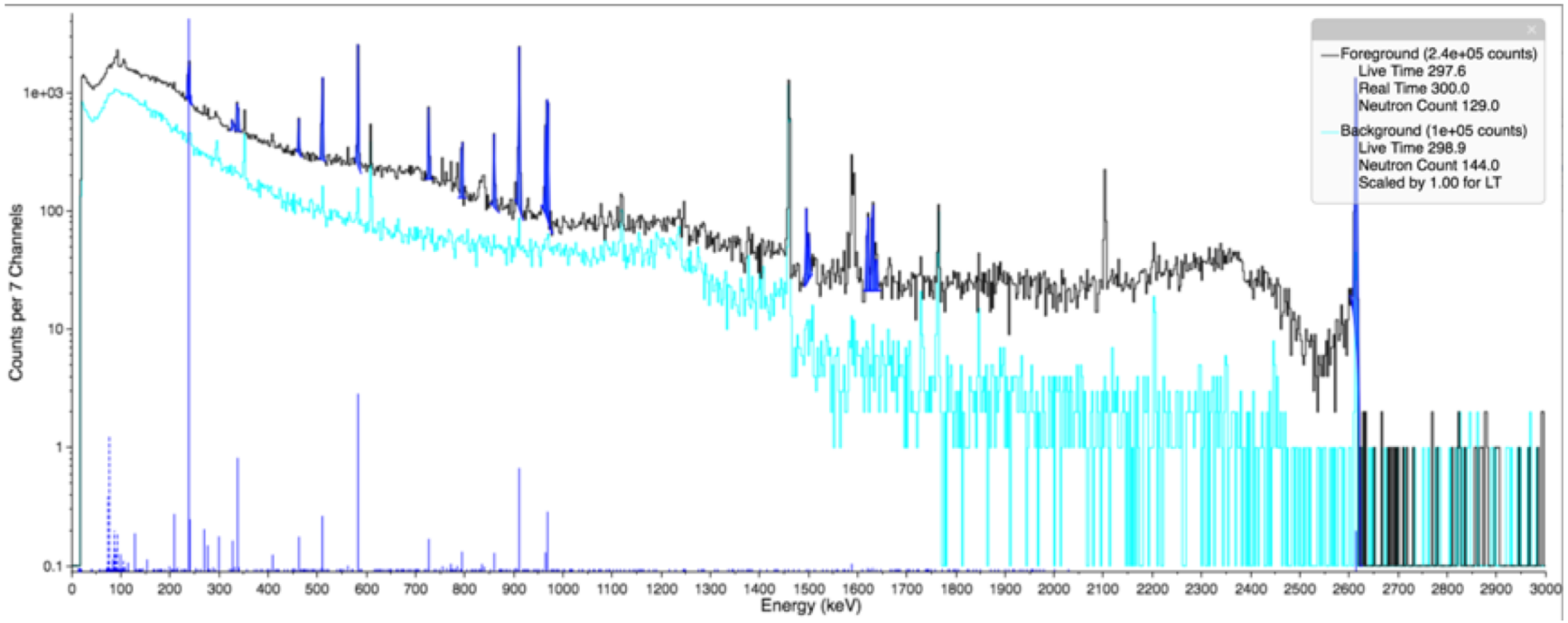
Example 2 (cont):



Truth is: 45 uCi Eu152, 25 uCi Cs137, with 0.1765cm Pb Shielding

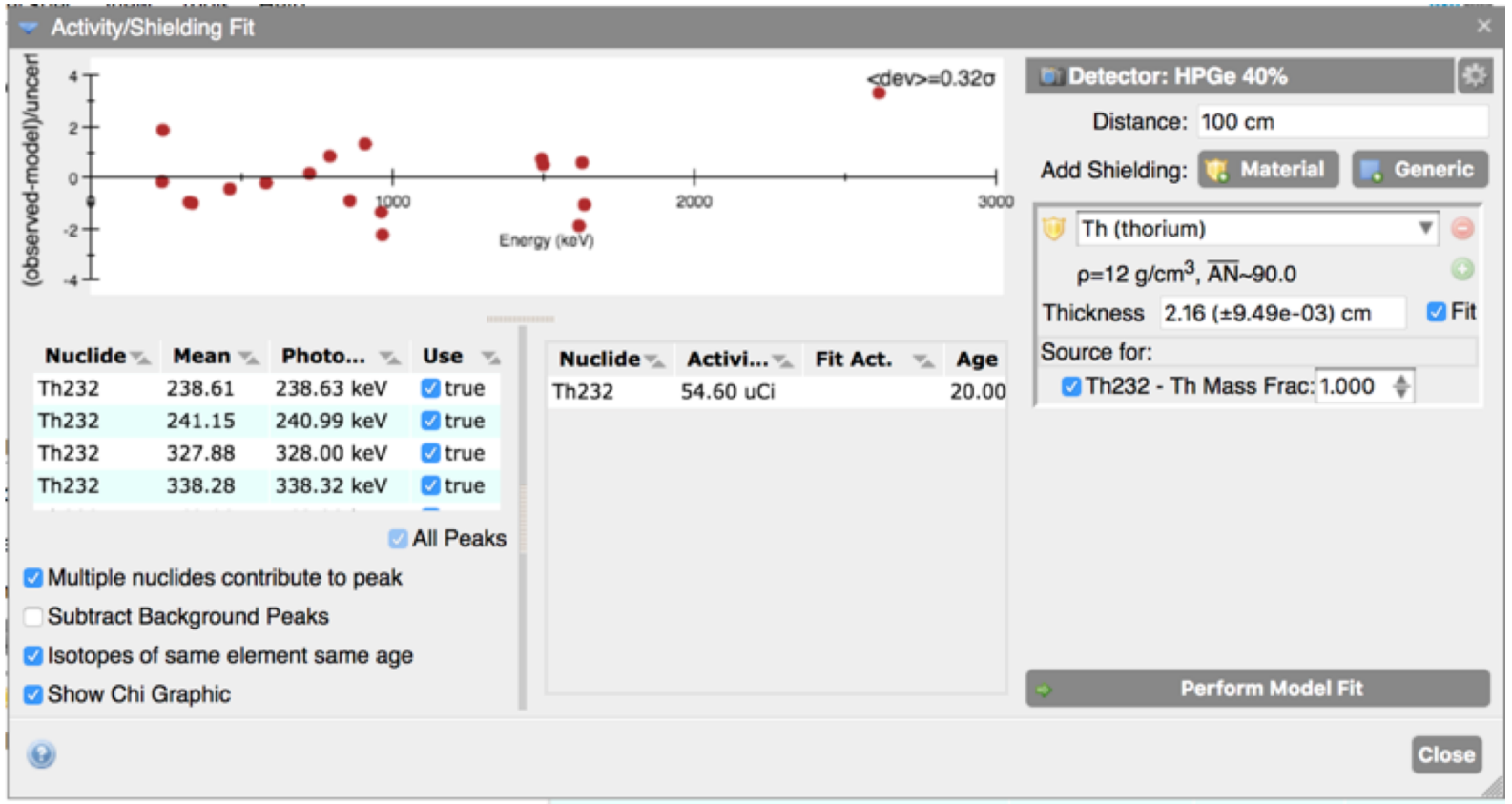
Example 3:

A chunk of Thorium metal is is measured at 1m, using a 40% HPGe detector – determine activity.



Example 3 (cont):

Truth: 2.54 cm sphere of Thorium



Some things to note:

- Thorium self attenuates – InterSpec can account for this, but always assumes source is a sphere
- X-rays present in spectrum implying little or no shielding – InterSpec also fit for no additional shielding outside Th
- Single and double escape peaks, and 511 keV peak.

InterSpec isn't magic:

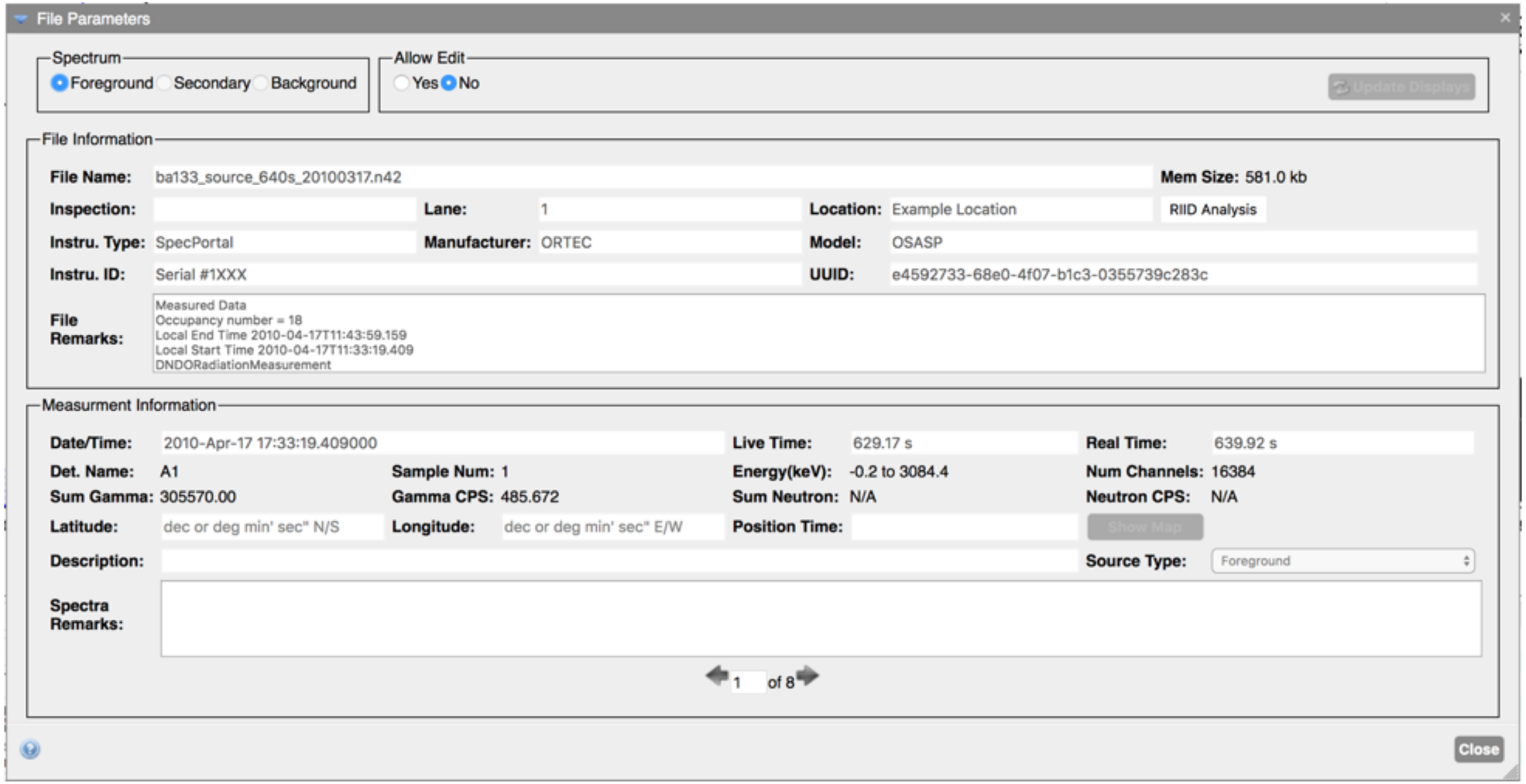
- If you have a source with a single peaks, you can only fit for a single quantity: Activity, or Shielding amount. You cant fit for shielding type (atomic number), or nuclide age.
- Fitting for shielding type, it is best to have multiple peaks over a wide energy region. Also, fitting for shielding type is best done for HPGe detectors, with sources that have many peaks.
- If you can fit for a nuclide age depends on if the gamma signature of the nuclide changes over time
- It assumes a qualified analyst is performing the analysis. Lots of things can be messed up, like assigning the wrong nuclide to a peak, not realizing a nuclide needs to be aged, etc

InterSpec Caveats

- It is currently a "in my personal time" project, but we are looking for funding sources
- It does have a few hundred unit tests, as well as a end-to-end testing mechanism (none of these are in the publicly available code), but it is, in general, not strictly validated. The assumption is that the qualified analyst using the program could catch any issues/errors.
  - But if you do find any bugs, let me know – I would love to fix them!
- The help documentation needs a lot more work

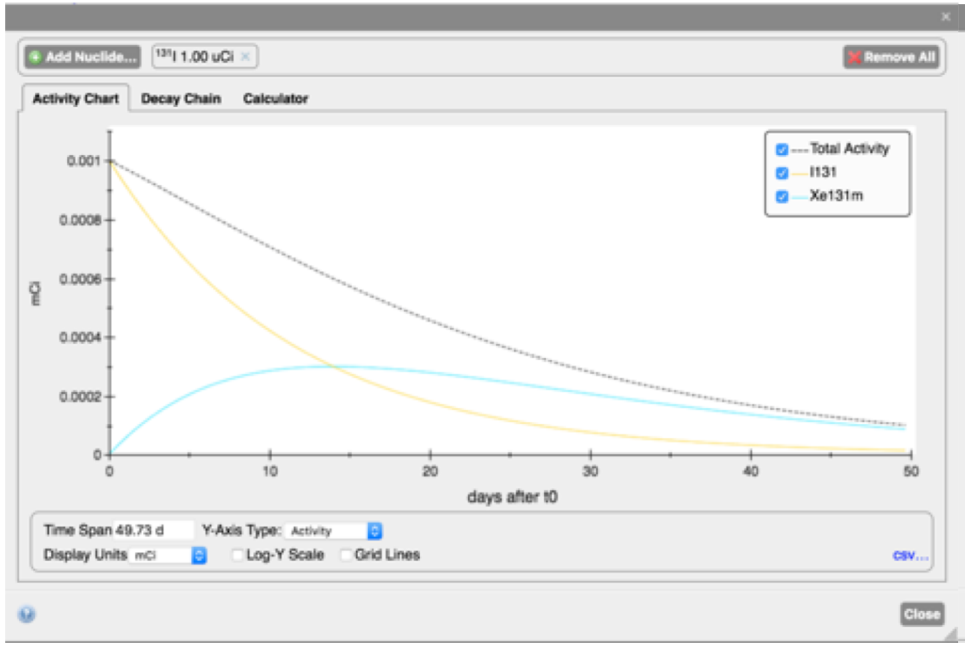
Other useful things in InterSpec

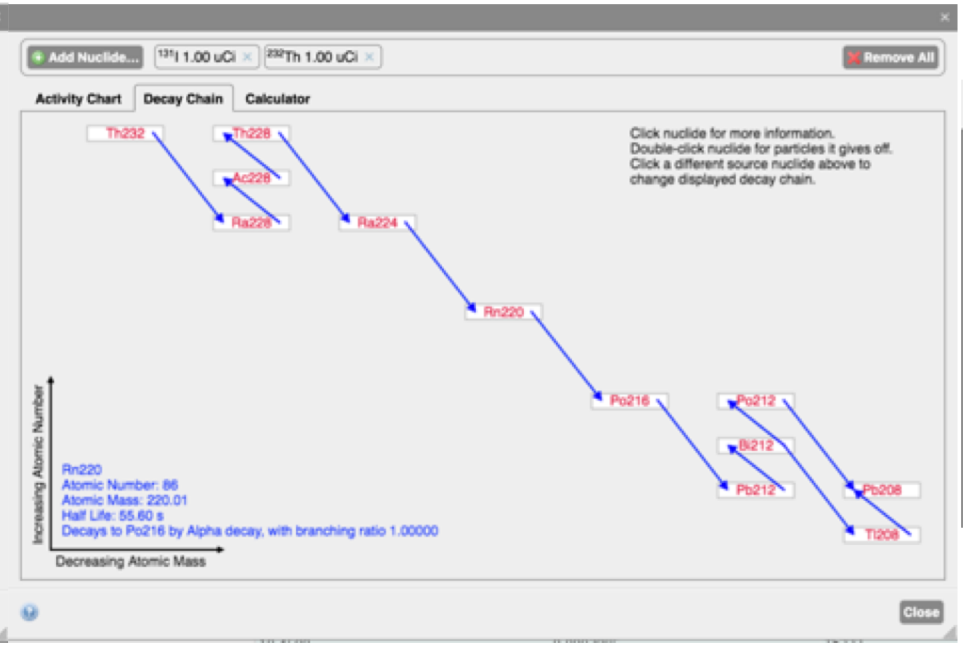
File Meta-Information

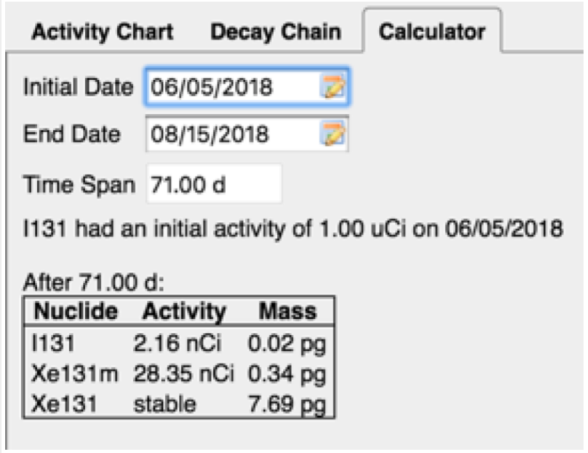


Spectrum files often contain lots of extra information that are useful to figure things out. InterSpec can show you a lot of this information, including: GPS coordinates, date/time, RIID analysis results, user entered notes, serial numbers, and more

Nuclide Decay:



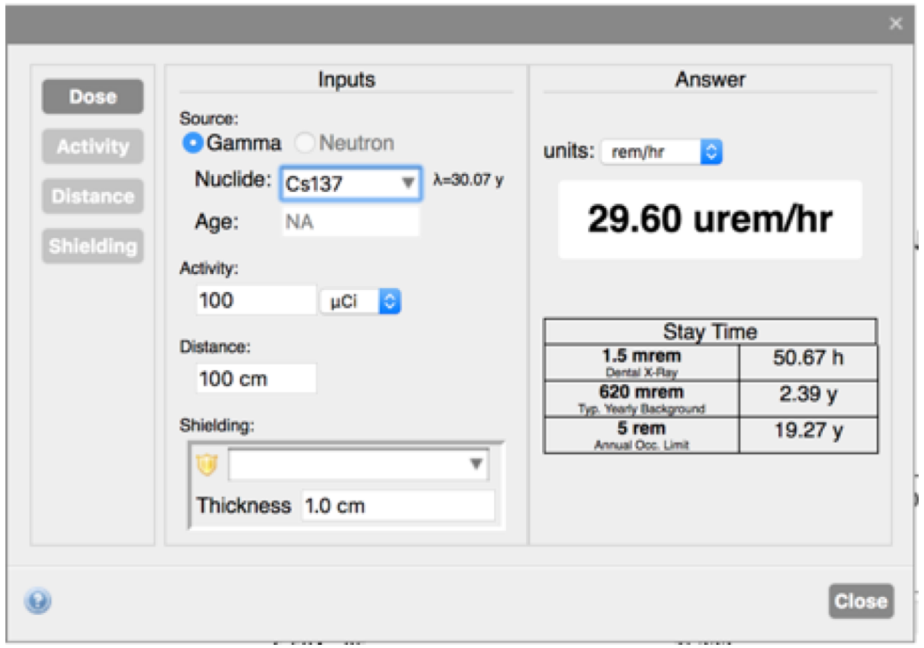


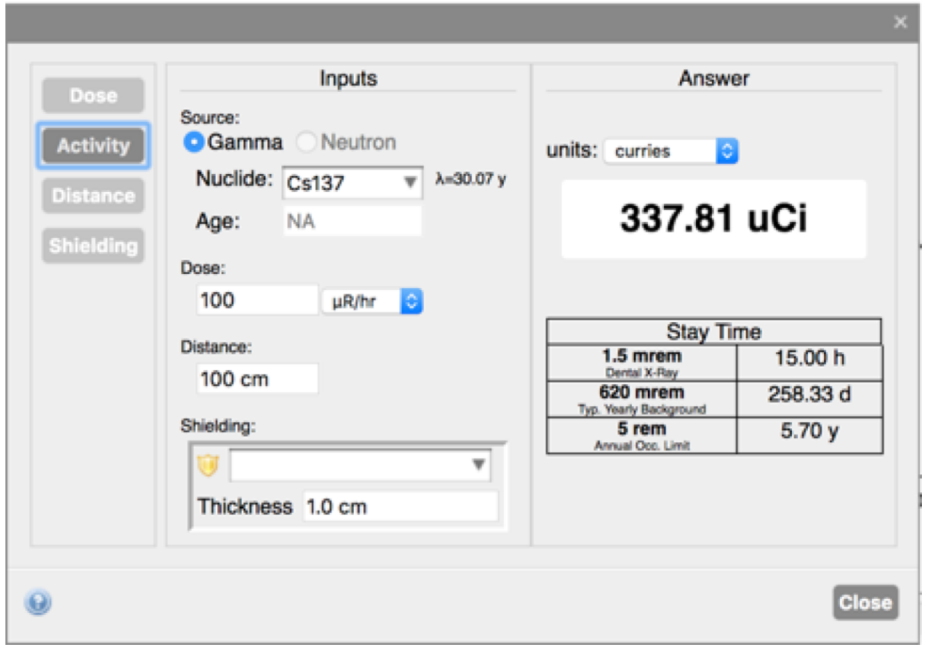


Flexible nuclide decay information (including export to CSV), reference decay information, and decay calculation

- The nuclide database is quite comprehensive

Dose:





- Either calculate expected dose from a nuclide with a given activity, shielding, and distance
- Or if you have the dose (like from a pager-style detector, or identiFINDER, etc), you can calculate activity
- And similar for distance/shielding