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Using *First Responder Software* for *Teaching* and *Emergency Response*

NKS-B GammaRayX, 20-21 Oct 2021

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Introduction

- Why teach part time for 38 years?

Introduction

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- Why teach part time for 38 years?
  - Well, it's an invigorating way to go back to basics!

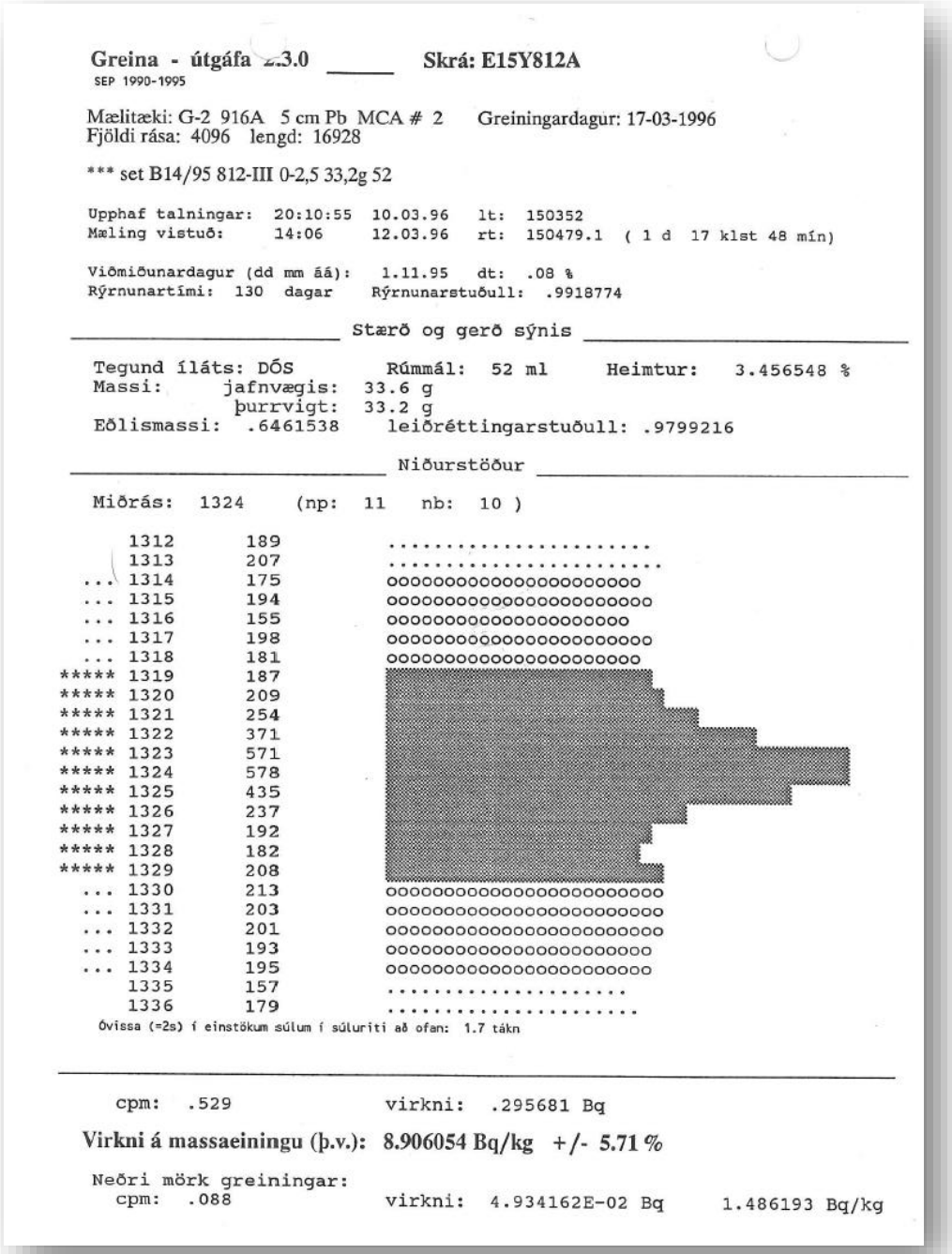
Introduction

What does a gamma spectrum show?

- Radiation from a nuclide
  - Interactions within its atom
  - Interactions within the source
  - Interactions with the environment (of source and detector)
  - Interactions within the detector

If one is only interested in the nuclide, the other factors come as disturbances that must be corrected for.

But the interactions can provide valuable information about the atom, the source the environment (including shielding of the source) and detector.



Greina - útgáfa 2.3.0 _____ Skrá: E15Y812A
SEP 1990-1995

Mælitæki: G-2 916A 5 cm Pb MCA # 2 Greiningardagur: 17-03-1996
Fjöldi rása: 4096 lengd: 16928

*** set B14/95 812-III 0-2,5 33,2g 52

Upphaf talningar: 20:10:55 10.03.96 lt: 150352
Mæling vistuð: 14:06 12.03.96 rt: 150479.1 (1 d 17 klst 48 mín)

Viðmiðunardagur (dd mm áá): 1.11.95 dt: .08 %
Rýrnunartími: 130 dagar Rýrnunarstuðull: .9918774

Stærð og gerð sýnis

Tegund íláts: DÓS Rúmmál: 52 ml Heimtur: 3.456548 %
Massi: jafnvægis: 33.6 g
þurrvigt: 33.2 g
Eðlismassi: .6461538 leiðréttingarstuðull: .9799216

Niðurstöður

Miðrás: 1324 (np: 11 nb: 10)

	1312	189
	1313	207
...	1314	175
...	1315	194
...	1316	155
...	1317	198
...	1318	181
*****	1319	187
*****	1320	209
*****	1321	254
*****	1322	371
*****	1323	571
*****	1324	578
*****	1325	435
*****	1326	237
*****	1327	192
*****	1328	182
*****	1329	208
...	1330	213
...	1331	203
...	1332	201
...	1333	193
...	1334	195
	1335	157
	1336	179

Óvissa (=2s) í einstökum súlum í súluriti að ofan: 1.7 tákn

cpm: .529 virkni: .295681 Bq

Virkni á massaeiningu (þ.v.): 8.906054 Bq/kg +/- 5.71 %

Neðri mörk greiningar:
cpm: .088 virkni: 4.934162E-02 Bq 1.486193 Bq/kg

Introduction

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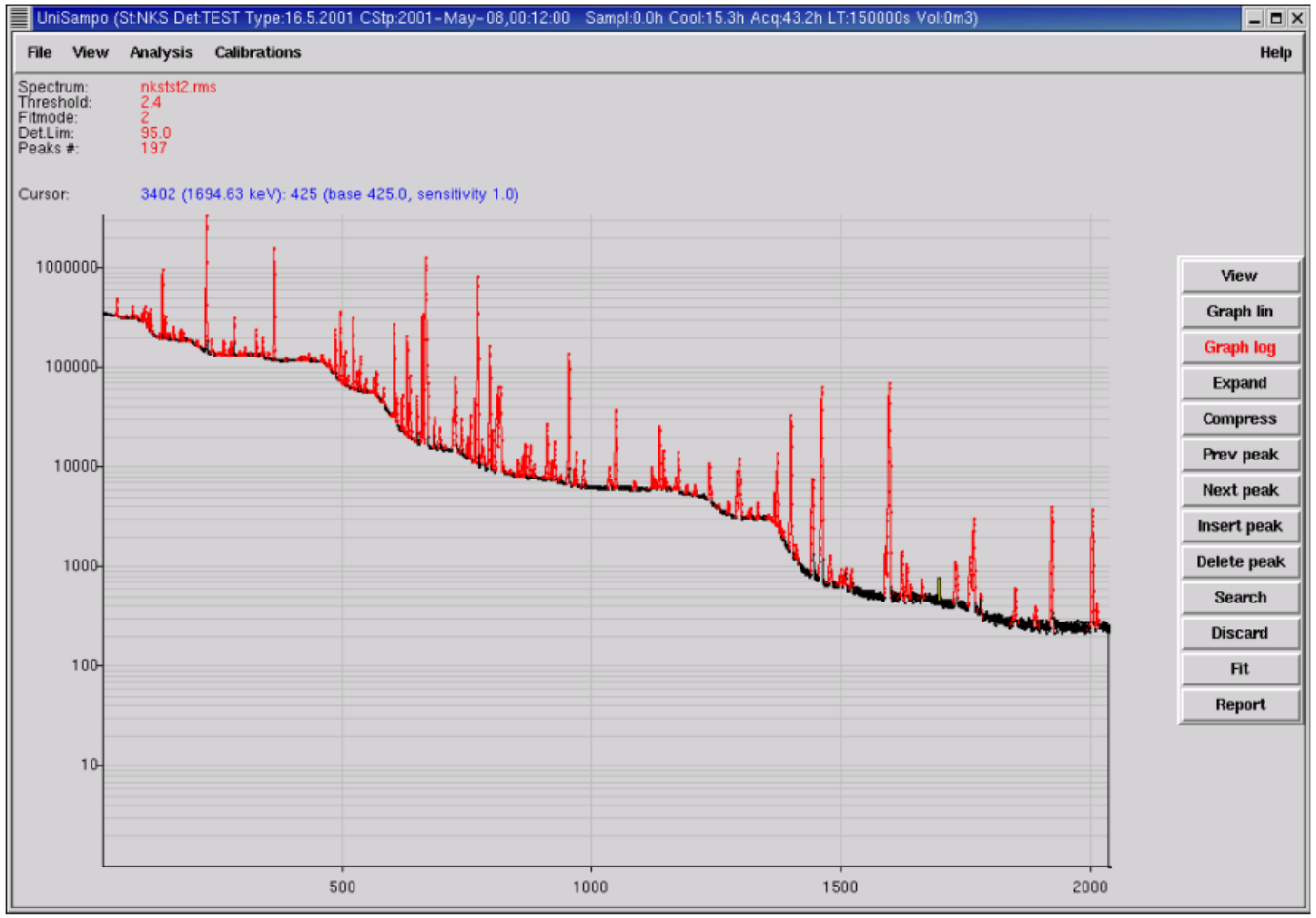
Got to know some excellent Nordic work on gamma spectrometry (including development of software) when starting my work after the Chernobyl accident.

Wrote my own software for (routine) simple analysis of gamma spectra in 1990 to understand the process better (still in use).

Challenges I tried to address:

- Make the software simple to use
- Check the input for consistency
- Try to find errors
- Have a user interface that helps the user to spot if something could be suspicious.

Introduction

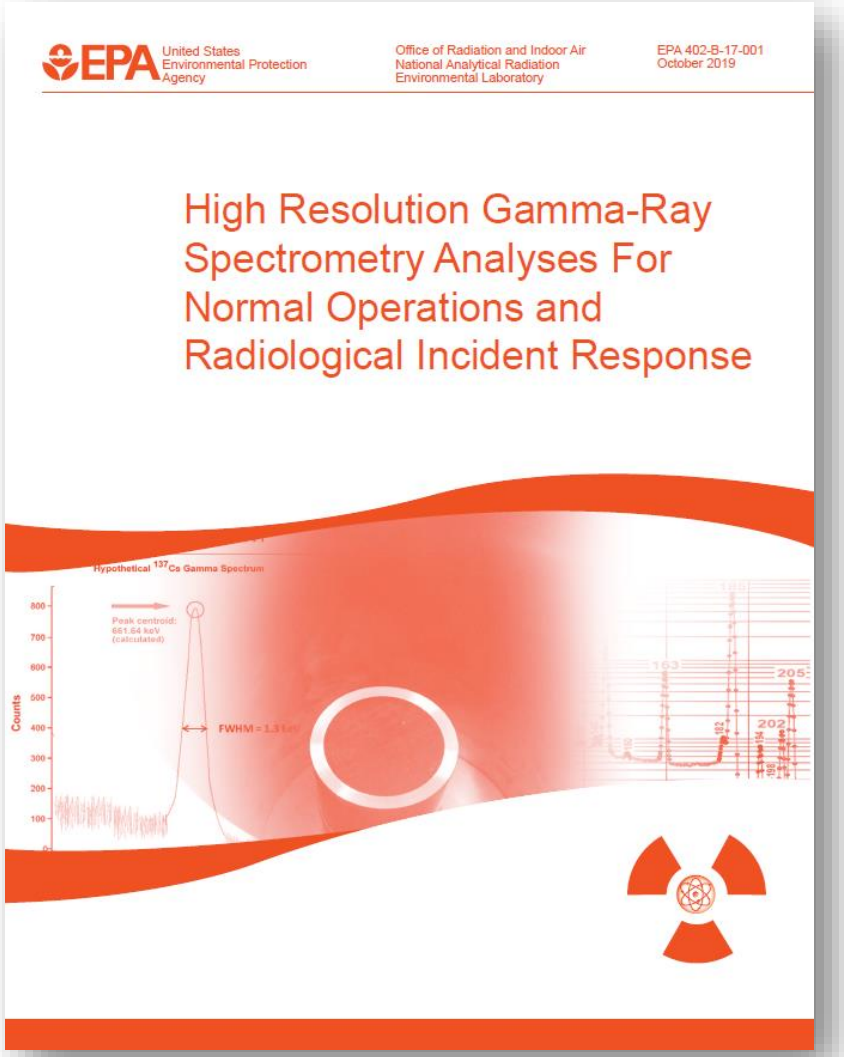


Exercise spectrum, more than 200 peaks will be found with careful analysis.

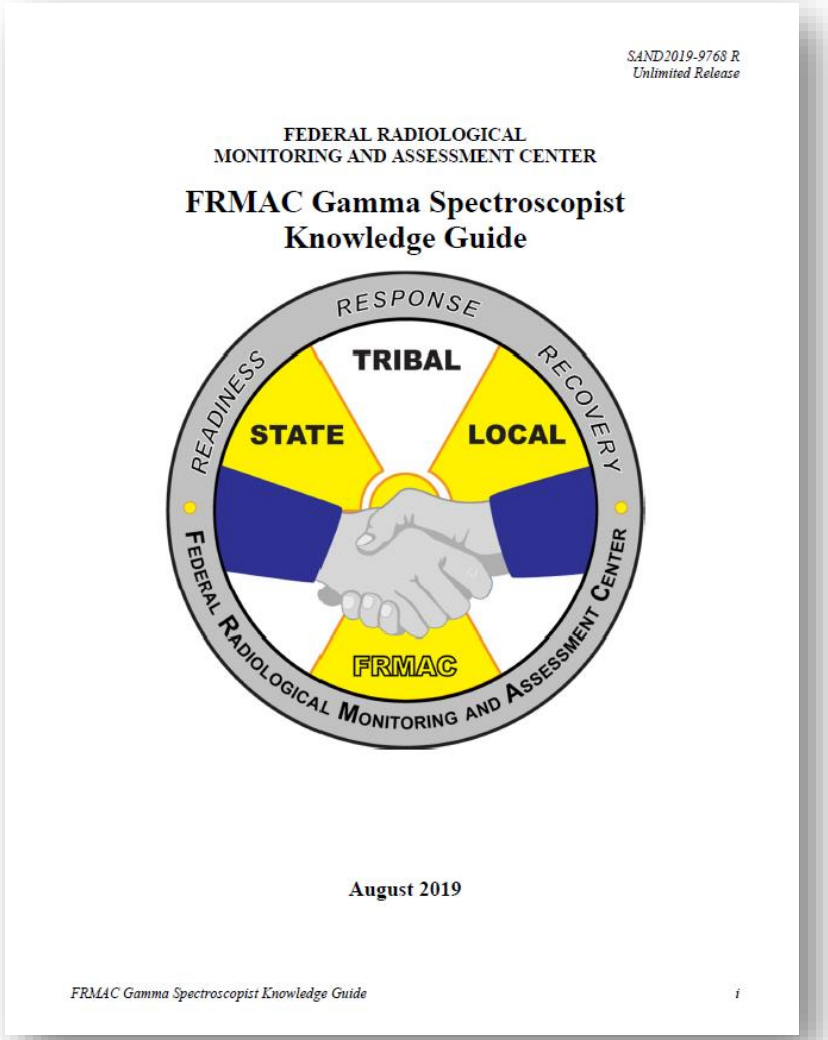
- For dealing with the unexpected in emergency response (and teaching) a completely different tool is needed.

- The image to left is from Mika Nikkinens NKS-43 2001 report, *The Use of Synthetic Spectra to Test the Preparedness to Evaluate and Analyze Complex Spectra*

Emergency response – US guides and software



https://www.epa.gov/sites/default/files/2020-07/documents/guide_for_high_resolution_gamma_spectrometry_analyses_camera_ready.pdf



https://www.osti.gov/biblio/1763003-frmac-gamma-spectroscopist-knowledge-guide-revision

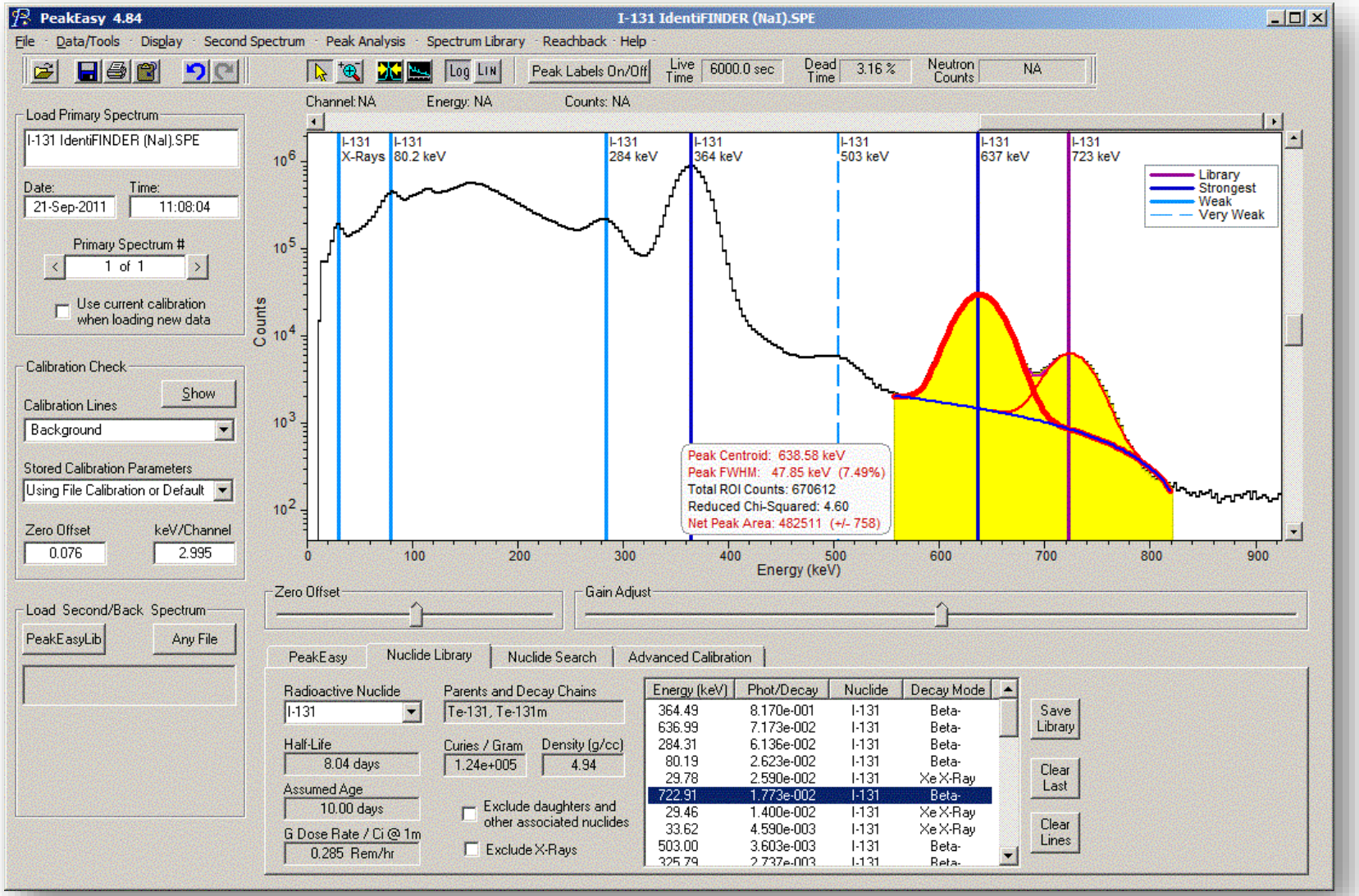
These guides are designed to be:

- easy to read
- yet tackle some of the challenges one can encounter in practice
- deal with the basics of the underlying theory.

The guides can thus also be used for teaching, giving an introduction to gamma spectrometry.

PeakEasy – a handy and versatile tool

- https://peakeasy.lanl.gov
- Can read most types of spectrum files in common use, including those from handheld devices.
- No automatic identification of nuclides, but it provides the user with a lot of information to aid in determining the right nuclide.
- Lightweight (in terms of bytes)
- Has been in use for many years, but it is for U.S. Government Affiliates Only



InterSpec – A recent tool from Sandia National Laboratories

InterSpec is a native or web application to assist in analyzing spectral nuclear radiation data, using a peak-based methodology.

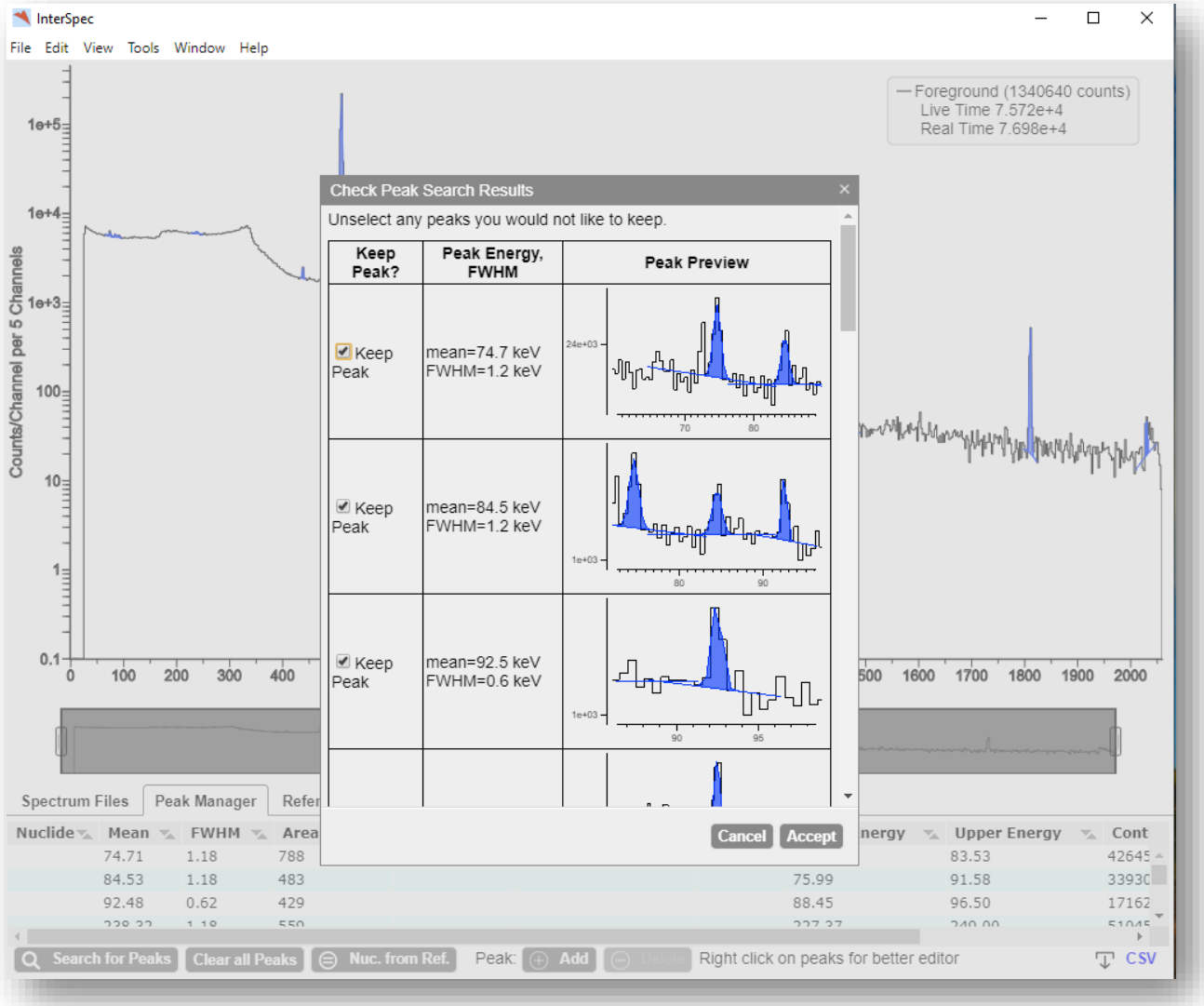
Common uses include
- **identifying nuclides** present
- determining source **activity**
- **shielding** amounts
- **source age** or other nuclear reactions present.

InterSpec also provides a number of **other tools** useful for analyzing radiation data including
- spectral **file format converting**
- **dose rate** calculations
- interactive **nuclide decay and reference information**
- gamma **cross section calculations**
- and more.

InterSpec can open data files from most common spectral radiation detectors (e.g., most NaI, HPGe, LaBr, CLYC, CsI, etc. based systems) and assist in their analysis.

From <https://github.com/sandialabs/InterSpec>

InterSpec – additional info

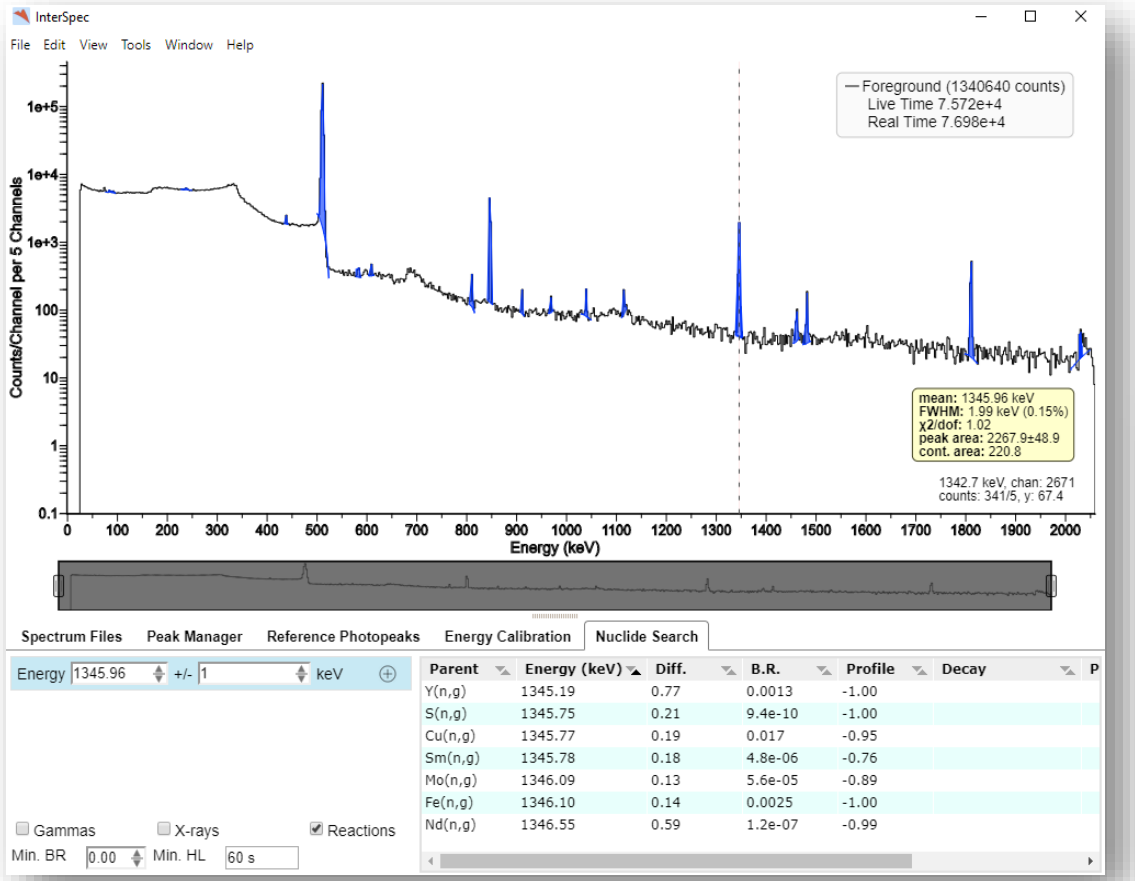


InterSpec is freely available to all and designed according to similar principles as PeakEasy.
It has a number of useful tools and it can read and write many common file formats

- Activity/Shielding Fit
- Gamma XS Calc
- Dose Calc
- 1/r2 Calculator
- Activity Converter
- Flux Tool
- Nuclide Decay Info
- Detector Response Select
- Make Detector Response
- File Parameters
- Energy Range Count
- File Query Tool

- TXT File
- CSV File
- PCF File
- 2006 N42 File
- 2012 N42 File
- CHN File
- Integer SPC File
- Float SPC File
- ASCII SPC File
- GR130 DAT File
- GR135v2 DAT File
- IAEA SPE File
- HTML File

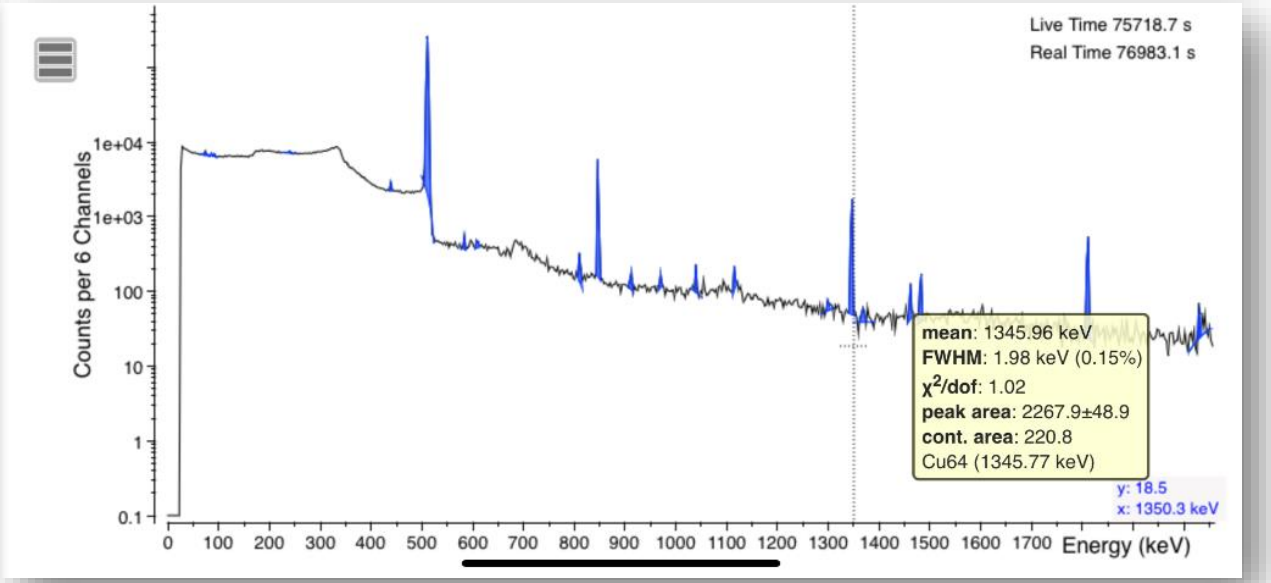
InterSpec – available for different platforms



InterSpec is <u>lightweight</u> in bytes (PC version < 200 MB), does <u>not require to be installed</u> and is also offered for different platforms:

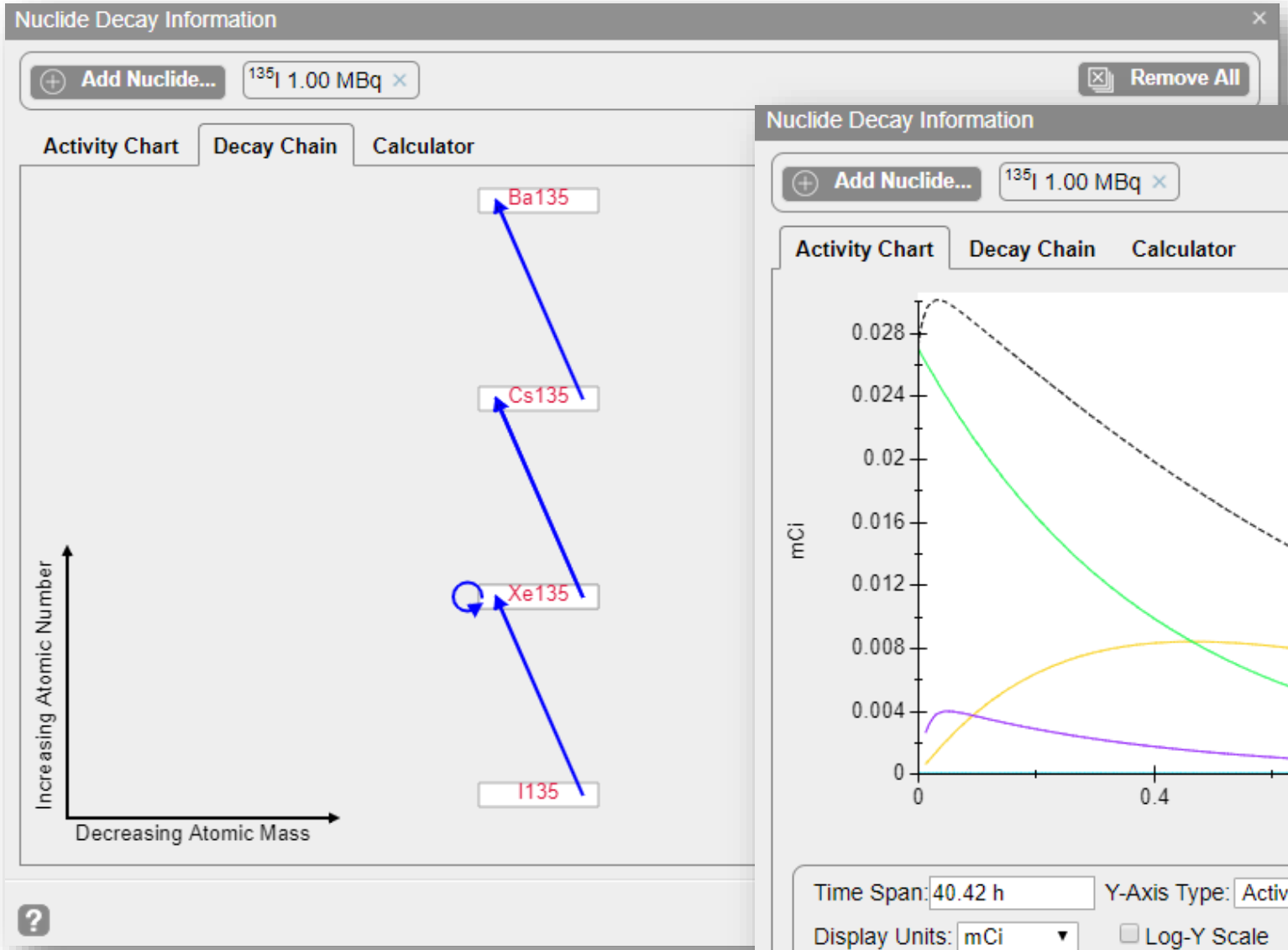
- Windows, Linux, macOS, iOS (and iPadOS), Android
- The source code is also available for own use.

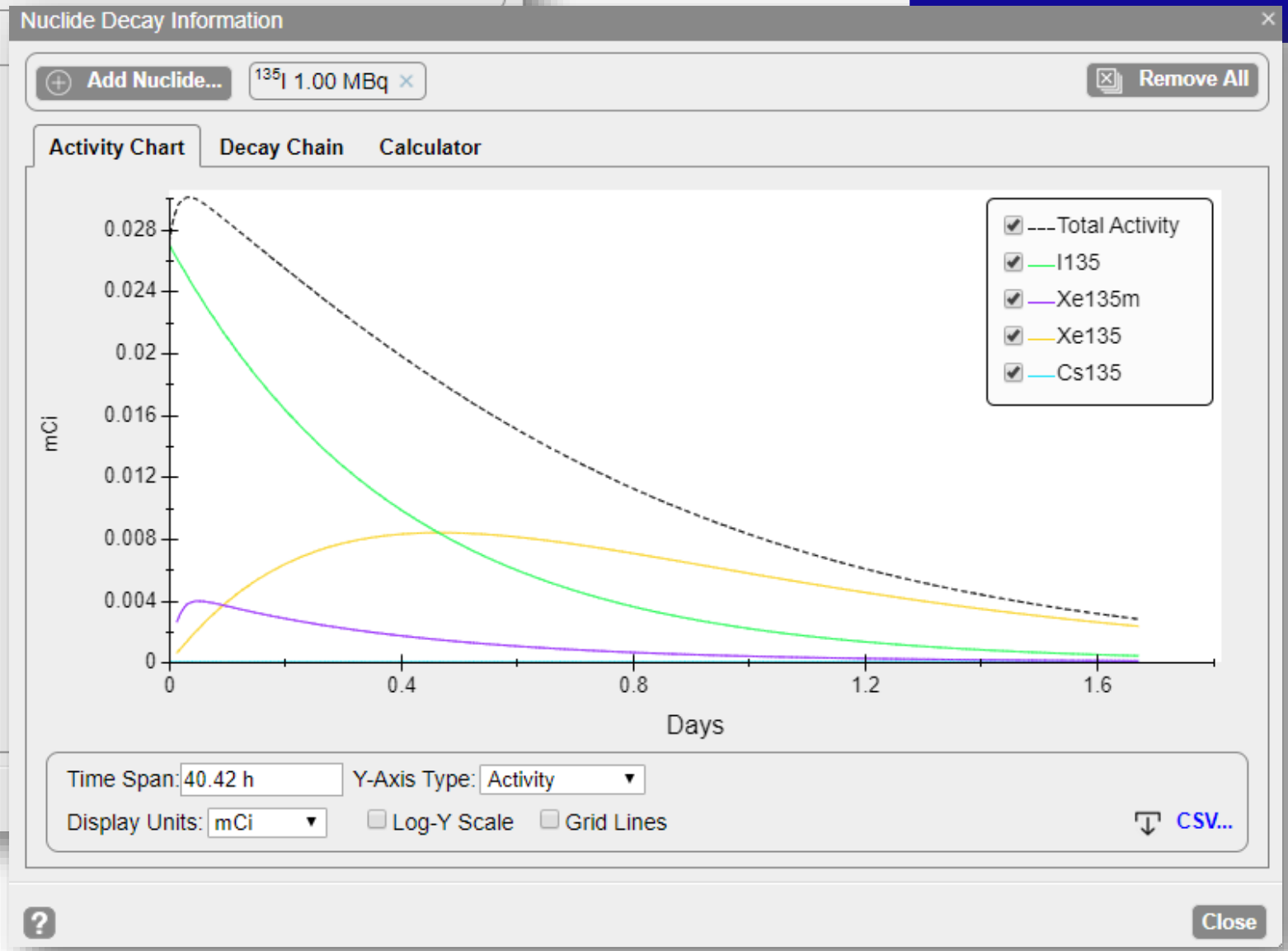
PC format to the left and smartphone (iPhone) below



(what is the use of a smartphone without proper gammaspectrometric software?)

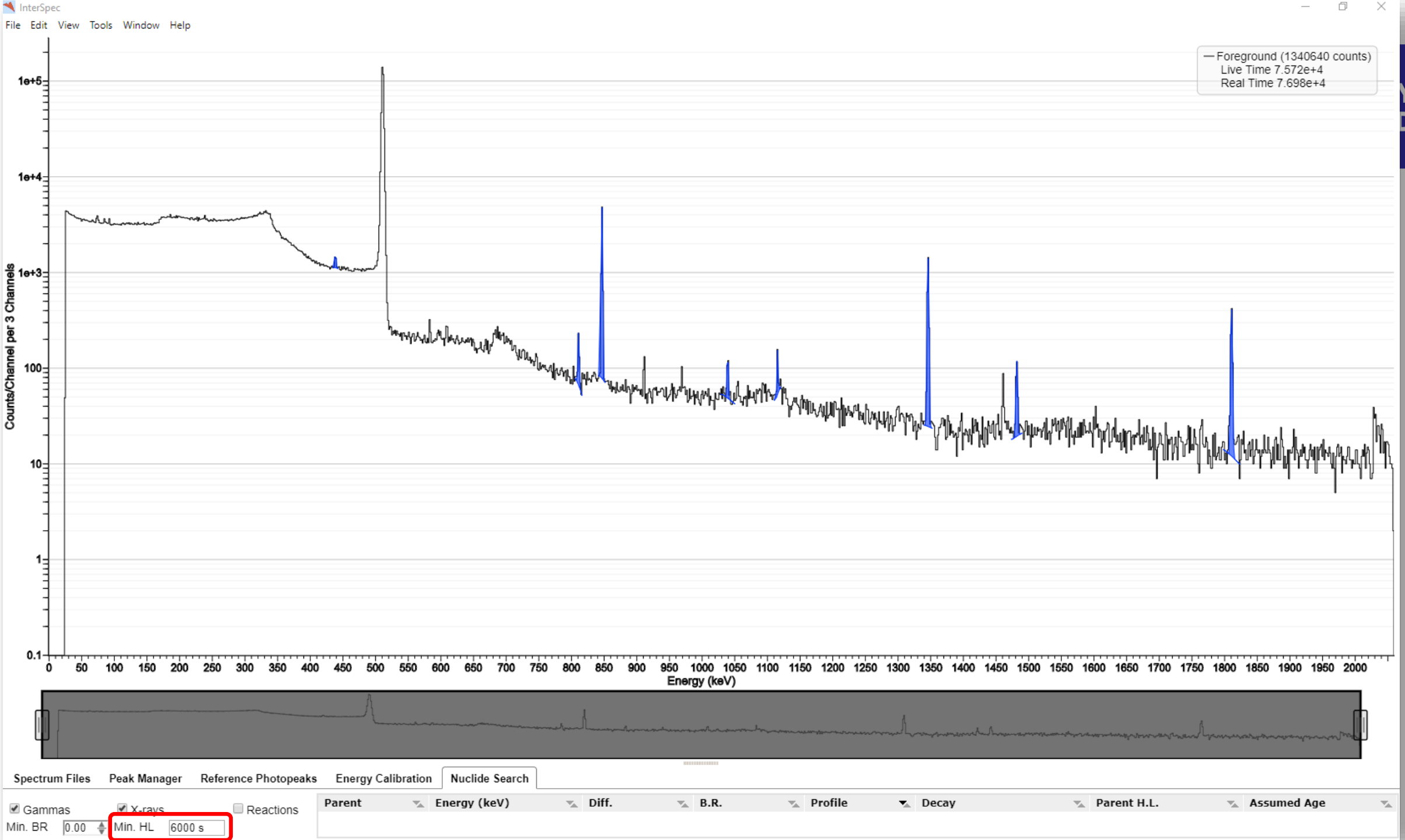
InterSpec: Example of tools

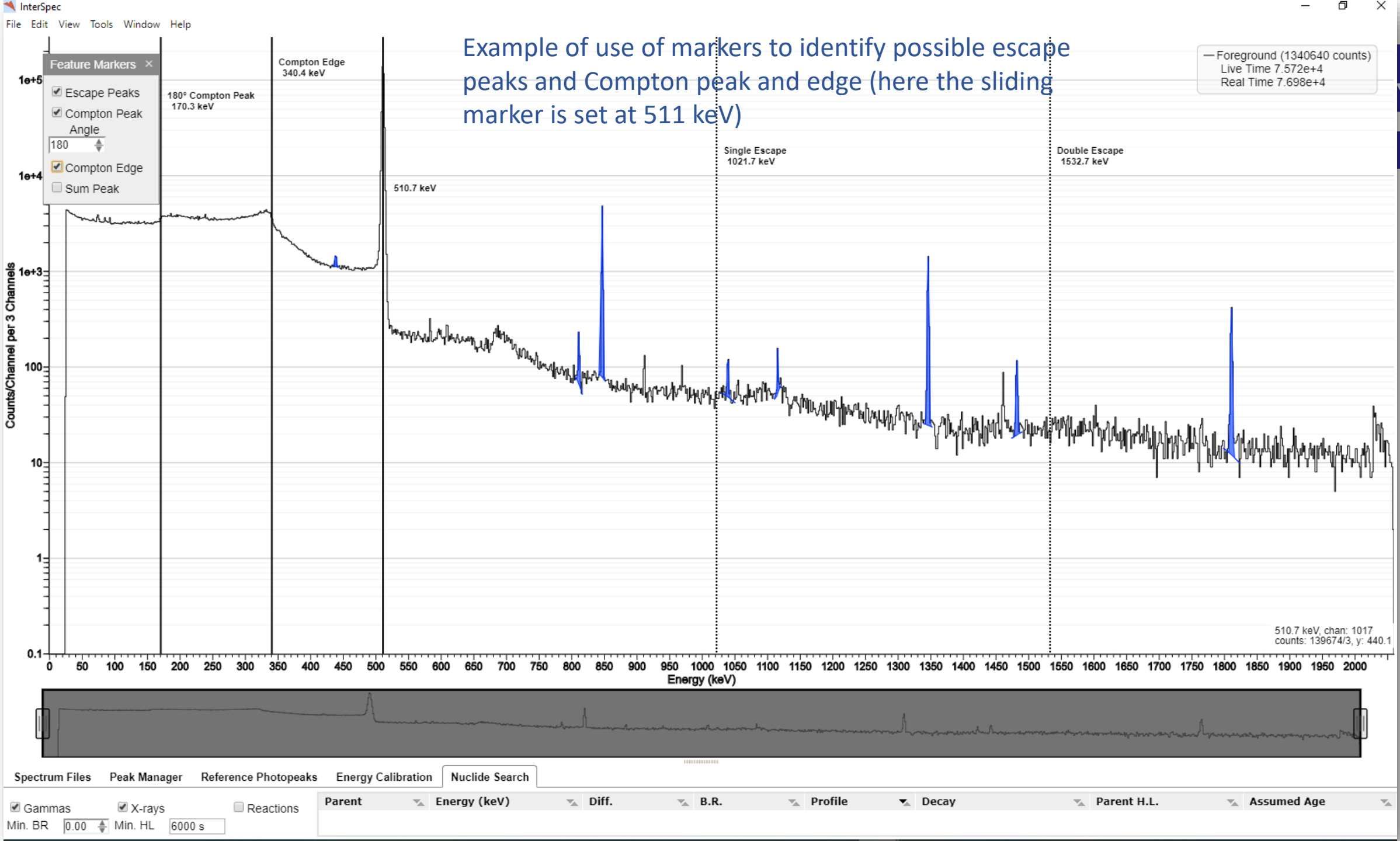


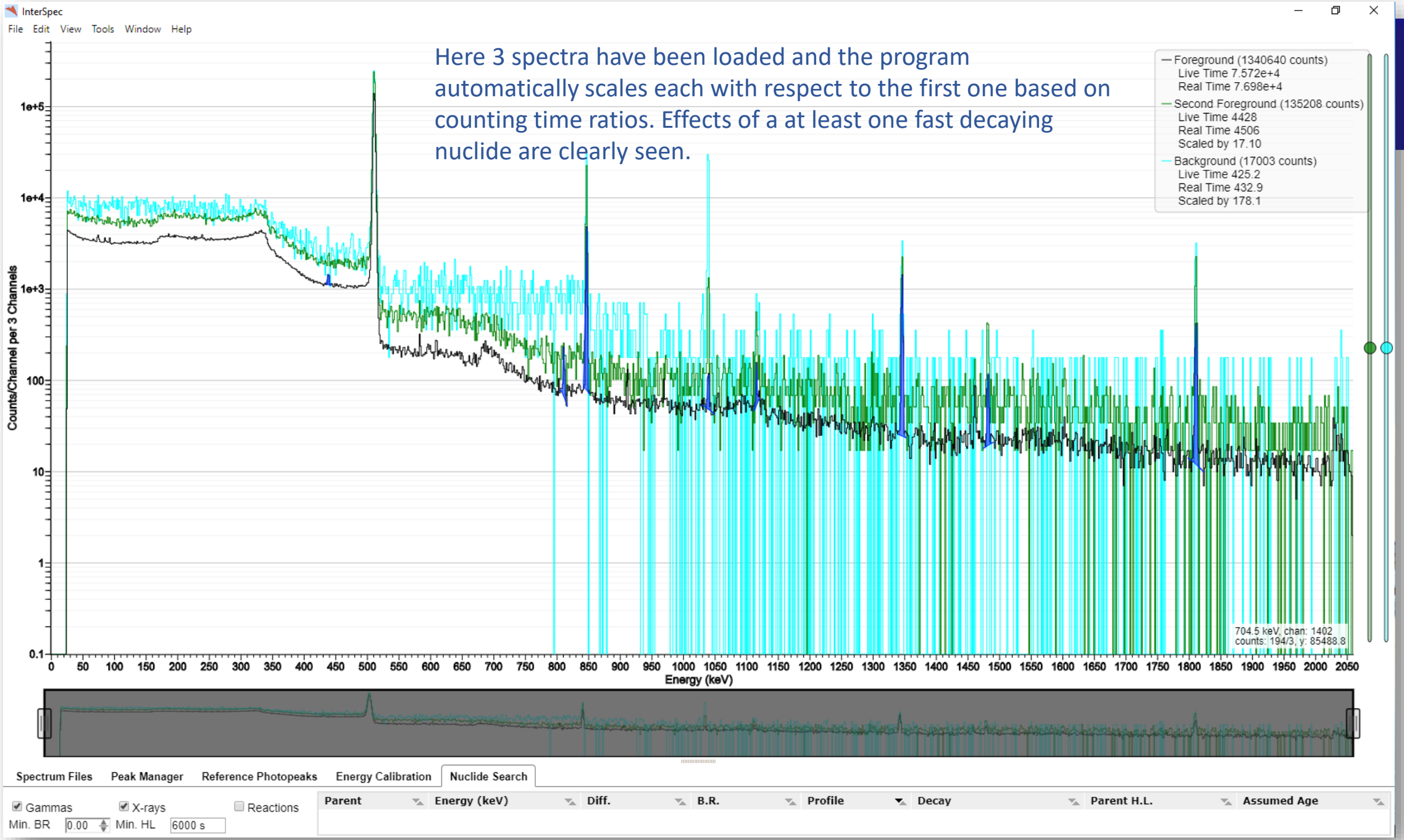


Use in an exercise for students

- Lab exercise measuring a neutron activated sample
- Short lived radionuclides are thus possible
- By default, InterSpec assumes it does not need to identify nuclides with a H.L < 100 min (6000 s), but this can be changed
- **Question to students**: If there are short lived radionuclides in the sample, **can we use their decay rate in addition to their spectral information to identify them**?
- It would be nice to be able to use list mode data acquisition and store and time stamp each event.
  - Here the focus is however on what can be done with simple robust equipment and procedures that can be explained quickly to first responders and students.


InterSpec
File Edit View Tools Window Help
Foreground (1340640 counts)
Live Time 7.572e+4
Real Time 7.698e+4
Counts/Channel per 3 Channels
1e+5
1e+4
1e+3
100
10
1
0.1
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000
Energy (keV)
Spectrum Files
Peak Manager
Reference Photopeaks
Energy Calibration
Nuclide Search
Gammas
X-rays
Reactions
Min. BR 0.00
Min. HL 6000 s
Parent
Energy (keV)
Diff.
B.R.
Profile
Decay
Parent H.L.
Assumed Age


InterSpec
File Edit View Tools Window Help
Example of use of markers to identify possible escape peaks and Compton peak and edge (here the sliding marker is set at 511 keV)
Feature Markers
Escape Peaks
Compton Peak
Angle
180
Compton Edge
Sum Peak
180° Compton Peak
170.3 keV
Compton Edge
340.4 keV
510.7 keV
Single Escape
1021.7 keV
Double Escape
1532.7 keV
Foreground (1340640 counts)
Live Time 7.572e+4
Real Time 7.698e+4
Counts/Channel per 3 Channels
Energy (keV)
510.7 keV, chan: 1017
counts: 139674/3, y: 440.1
Spectrum Files
Peak Manager
Reference Photopeaks
Energy Calibration
Nuclide Search
Gammas
X-rays
Reactions
Min. BR
0.00
Min. HL
6000 s
Parent
Energy (keV)
Diff.
B.R.
Profile
Decay
Parent H.L.
Assumed Age


InterSpec
File Edit View Tools Window Help
Here 3 spectra have been loaded and the program automatically scales each with respect to the first one based on counting time ratios. Effects of a at least one fast decaying nuclide are clearly seen.
Foreground (1340640 counts)
Live Time 7.572e+4
Real Time 7.698e+4
Second Foreground (135208 counts)
Live Time 4428
Real Time 4506
Scaled by 17.10
Background (17003 counts)
Live Time 425.2
Real Time 432.9
Scaled by 178.1
Counts/Channel per 3 Channels
Energy (keV)
704.5 keV, chan: 1402
counts: 194/3, y: 85488.8
Spectrum Files
Peak Manager
Reference Photopeaks
Energy Calibration
Nuclide Search
Gammas
X-rays
Reactions
Min. BR
Min. HL
6000 s
Parent
Energy (keV)
Diff.
B.R.
Profile
Decay
Parent H.L.
Assumed Age

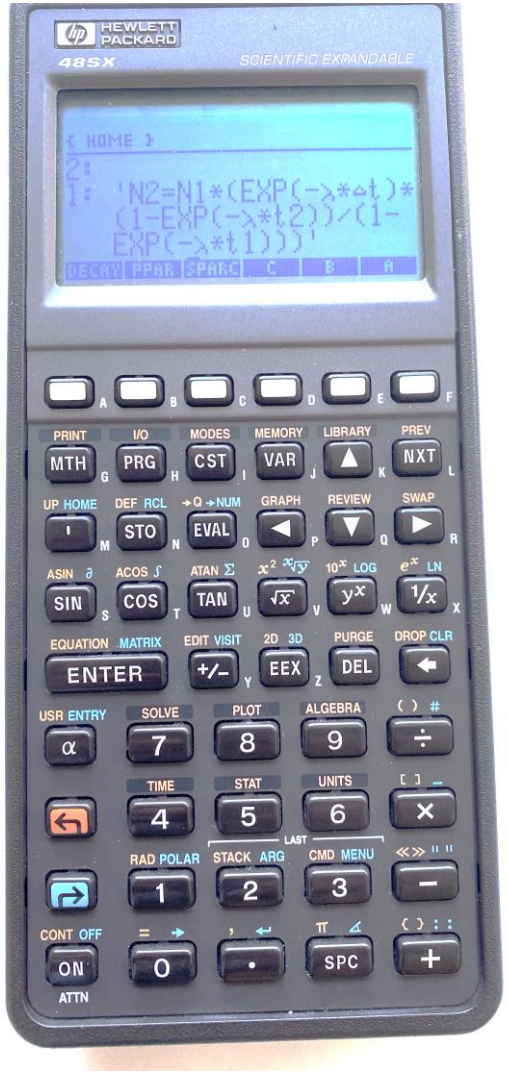
Theory: Ratio of net peak areas subject to decay

$$\frac{N_2}{N_1} = \frac{e^{-\lambda \Delta t}(1 - e^{-\lambda t_2})}{1 - e^{-\lambda t_1}}$$

Δt is the time difference between the beginning of measurement #1 and measurement #2

The decay rate λ is the only unknown and can be solved numerically from the equation

In this case the equation solver in a HP48SX calculator (from 1990) was used, it should be easier with more modern devices incl. smartphones.



Results

Two gamma lines were examined in the exercise, one fast decaying at 1039 keV and another with a slower decay rate at 1346 keV. Results by gamma spectrometry was that these were Cu-66 and Cu-64. These results were to be validated by comparison of the observed decay rate with the reference value for these nuclides.

					Cu-66 1039 keV		Cu-64 1346 keV	
Spectrum	**Δt**	**t (sec)**	**t (min)**	**t (h)**	**N**	**s**	**N**	**s**
#1	0	433	7.2	0.1	**313**	**18**	27	6
#2	668	4506	75.1	1.3	**127**	**12**	**217**	**15**
#3	668	76983	1283	21.4	132	15	**2268**	**49**

				95% confidence interval		
	Reference value		**Estimated**	**lower**	**upper**	
Cu66	**5.12**	**min**	**5.46 min**	4.8	6.0	**minutes**
Cu64	**12.7**	**h**	**12.8 h**	9.3	18.2	**hours**

Useful simplifications of equations and procedures

- If **both measurements begin at the same time** (so the longer is just a continuation of the shorter one without the counting having been stopped):

if $\Delta t = 0$ then $e^{-\lambda \Delta t} = 1$ and

$$\frac{N_2}{N_1} = \frac{1 - e^{-\lambda t_2}}{1 - e^{-\lambda t_1}}$$

A simple procedure to obtain the half-life of a radionuclide from the ratio of measured peak areas in a gamma spectrum

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If the **second measurement starts the count again from zero** and is of the **same length as the first one**, the ratio of the net peak areas has a very simple form and it is easy to solve the equation to obtain the decay rate and half-life directly:

If $t_1 = t_2$

$$\frac{N_2}{N_1} = e^{-\lambda \Delta t}$$

and

$$t_{1/2} = \Delta t \frac{\ln(2)}{\ln\left(\frac{N_1}{N_2}\right)}$$

At last

It would be nice to hear from anyone else who has been using *InterSpec* or doing *similar experiments* as described here, in the chat or e-mail: sep@hi.is

Thank you!