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SpecFIDLER User Manual

Software Version 2.5.0

March 2023

Mitchell J Myjak
Scott J Morris
Jesse A Willett

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99354

Executive Summary

The Spectroscopic Field Instrument for Detection of Low Energy Radiation (SpecFIDLER) allows response teams to detect and quantify plutonium contamination on the ground. Notional scenarios include dispersion from a weapon accident, or the launch failure of a space probe containing a radioisotope thermoelectric generator. Unlike other instruments, the thin-window sodium iodide detector is sensitive to the low-energy gamma rays emitted by plutonium isotopes. The system supports both mobile survey as well as stationary sampling.

This manual provides information about installing, maintaining, and troubleshooting the SpecFIDLER. The scope of this document includes the physical hardware, software for data acquisition, and algorithms for data analysis. Recent changes to the software and algorithms aim to streamline the operation of the system.

Acronyms and Abbreviations

γpm	gammas per minute
cpm	counts per minute
DFM	Digital Field Monitoring
dpm	disintegrations per minute
MDA	minimum detectable activity
NaI:Tl	thallium-doped sodium iodide
ROI	region of interest
RSL	Remote Sensing Laboratory
SNL	Sandia National Laboratories
SpecFIDLER	Spectroscopic Field Instrument for Detection of Low Energy Radiation
USB	Universal Serial Bus

Contents

Figures

1.0 Introduction

The Spectroscopic Field Instrument for Detection of Low Energy Radiation (SpecFIDLER) allows response teams to detect and quantify plutonium contamination on the ground. The system contains the following components:

- Thallium-doped sodium iodide (NaI:Tl) detector with a thin beryllium window.
- Bridgeport Instruments usbBase for detector readout.
- Enclosure containing a rechargeable battery and Universal Serial Bus (USB) hub.
- Battery power switch and power indicator on the outside of the enclosure.
- USB cables to the detector and an external tablet computer.

Figure 1 depicts the components of the SpecFIDLER in their representative setup. The tablet computer may be mounted on the back side of the unit or carried separately.

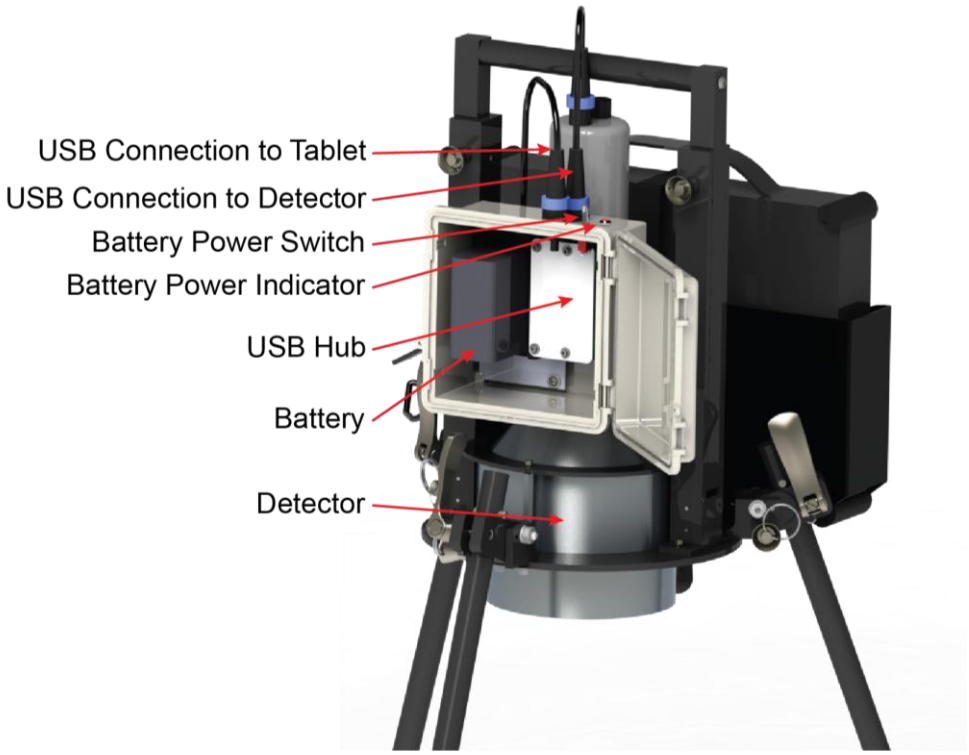

Figure 1. Components of the SpecFIDLER.

The remainder of this manual describes the setup, operation, calibration, and maintenance of the SpecFIDLER. The appendices provide additional information about the configuration file, settings file, and algorithms employed for data analysis.

2.0 Setup

This section describes how to assemble the SpecFIDLER for deployment, disassemble the unit for storage, transport the unit to another location, and install the software on the tablet.

2.1 Assembly

To assemble the SpecFIDLER, follow the procedure below.

1. Open the shipping container and remove the Velcro hold-down strap. Grasp both handles (Figure 2) and lift the unit straight out.

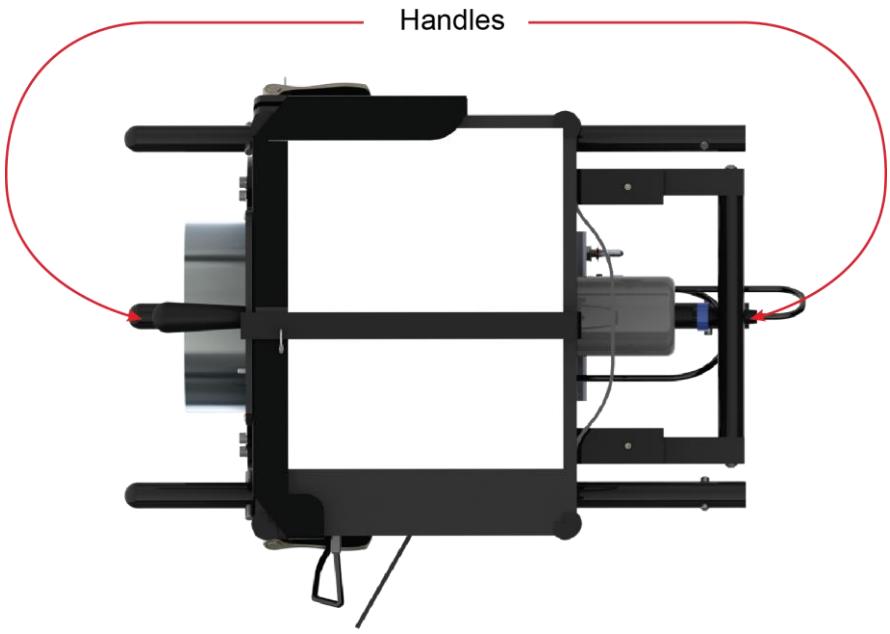

Figure 2. Handle locations.

2. Extend the top handle by pulling the pins (Figure 3) and lifting straight up until the desired height is reached. Use the pins to lock the handle into place.

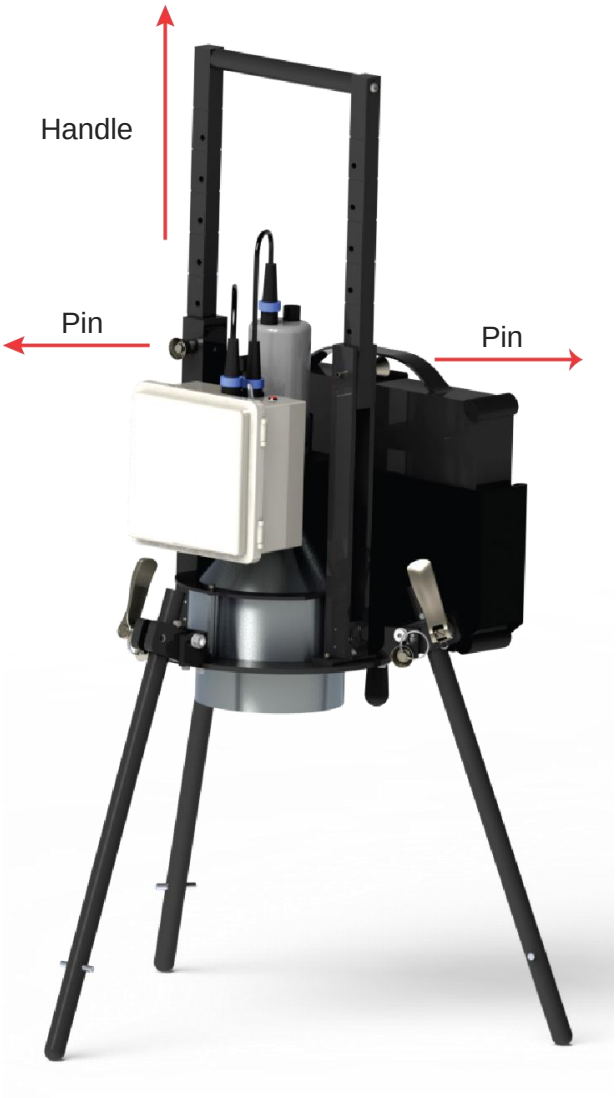

Figure 3. Extending the top handle.

3. Loosen the leg locks (Figure 4) and extend the legs down. Swing the legs out by pulling the pin, swinging the leg, and inserting into the second hole. Lock the legs in place. Consider tying rubber gloves onto each leg to prevent contamination.

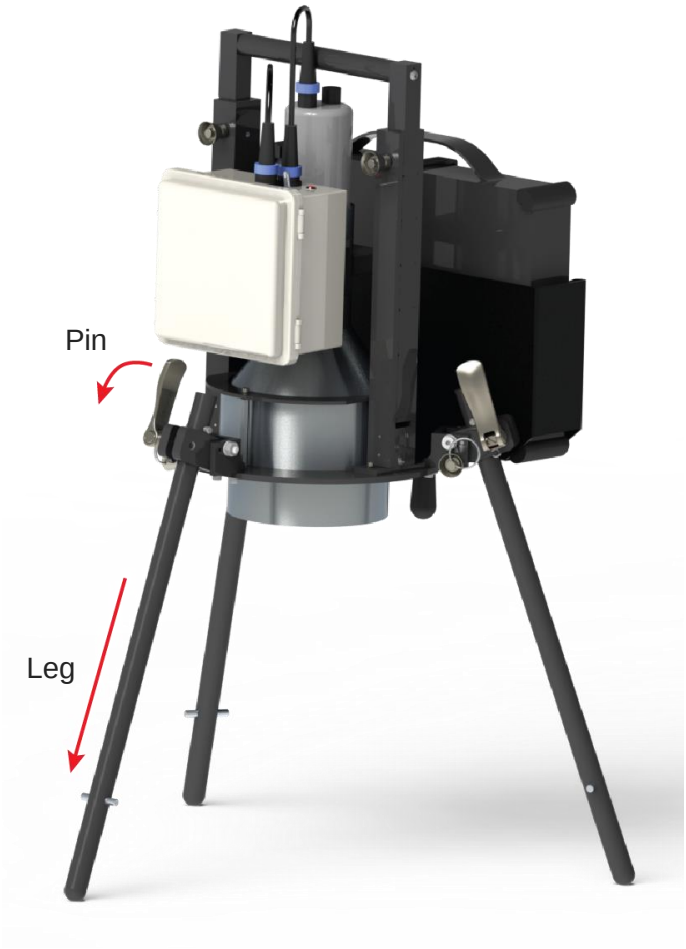

Figure 4. Extending the legs.

4. Carefully remove the cover from the fragile beryllium window (Figure 5), ensuring that it is not scratched or damaged in any way.

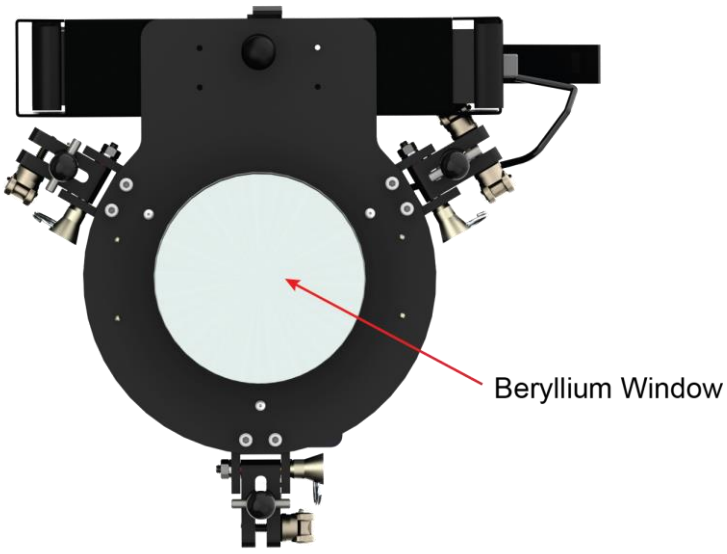

Figure 5. Beryllium window.

NOTE: Beryllium is a potentially hazardous material that is controlled by most industrial hygiene groups. However, solid beryllium metal, alloys, ceramic objects, and finished products, such as the detector window used in the SpecFIDLER instrument, pose no special health risks unless their use or handling generates airborne aerosols or surface contamination. For example, if the window gets scratched, scraps of beryllium may become airborne and inhaled or land on exposed skin. Exposure can occur by inhaling particles from aerosols, by getting loose particles on the skin, or by cutting the skin with sharp edges of materials. Damaged beryllium objects should be handled with care to avoid injury from sharp pieces and dispersal of beryllium dust.

5. Ensure that the USB cables are connected properly to the enclosure (Figure 6). However, do not connect the USB cable to the tablet yet.

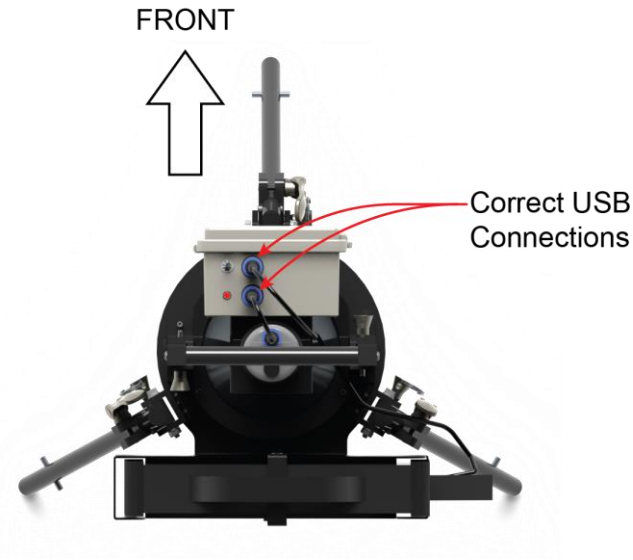

Figure 6. USB connections.

6. Charge the lithium-ion battery if necessary.

7. Install the lithium-ion battery inside the enclosure. Ensure that both battery contacts make a good connection; unfortunately, the battery holder is very tight.

8. Turn on the power using the switch and verify that the red light is illuminated. If not, double-check the battery connections.

9. Finally, connect the USB cable to the tablet. The tablet may be placed in the pocket on the frame behind the detector.

NOTE: If the tablet is connected to the SpecFIDLER before turning on the power switch, then the tablet will supply power rather than the internal battery. This configuration works fine but will shorten the tablet's battery life. The red light is illuminated in either case.

2.2 Disassembly

Disassembly is the reverse of assembly:

1. Unplug the tablet and turn off the power using the switch.
2. Remove the lithium-ion battery.
3. Place the cover back onto the detector to protect the fragile beryllium window.
4. Retract the top handle and the legs.
5. Finally, place the unit back into the storage container.

If the legs become contaminated, they may be removed. Loosen the leg locks, twist the legs such that the long end of the pin faces the center of the instrument (Figure 7), and drop the legs down through the clamps.

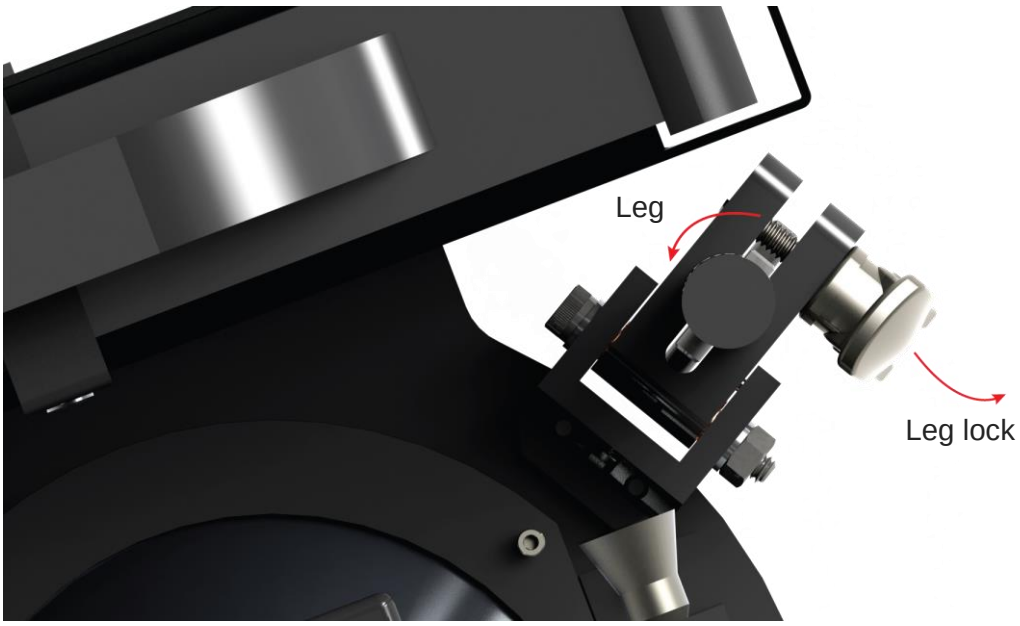

Figure 7. Detector leg removal, viewed from top of instrument looking downward.

NOTE: The long side of the pin must face away from the threads on the leg lock. Otherwise, the pin will not fit through the hole.

2.3 Transportation

Often it is necessary to load the SpecFIDLER into a vehicle and transport it to another measurement location. For shorter trips, the following steps are recommended:

1. Remove any protective gloves from the legs to avoid contaminating the vehicle.
2. Place the cover back onto the detector to avoid damaging the beryllium window.
3. Lay the unit on its side, orienting the unit so that other objects do not contact the detector. Secure the unit so that it does not slide around.

For longer trips, consider packing the unit back into the storage container.

NOTE: Protect the fragile beryllium window at all times.

2.4 Software Installation

The SpecFIDLER software is integrated with the Digital Field Monitoring (DFM) software on the Consequence Management tablet. Normally, the tablets come preloaded with all the requisite programs and utilities. However, follow the procedure below if it is necessary to install, upgrade, or repair the SpecFIDLER software:

1. The installation package consists of two files: **setup.exe** and **Installer.msi**. Copy these files to a temporary folder on the tablet.

2. Uninstall the existing SpecFIDLER software if necessary. The data and configuration files are retained.

NOTE: All versions of the SpecFIDLER software must be uninstalled first.

3. Next, install the SpecFIDLER software. Locate the temporary folder and run **setup.exe**. Click **Next** and select the installation folder (Figure 8). Click **Next** two more times. If a dialog appears asking to confirm security access to the installer, select **Yes**.

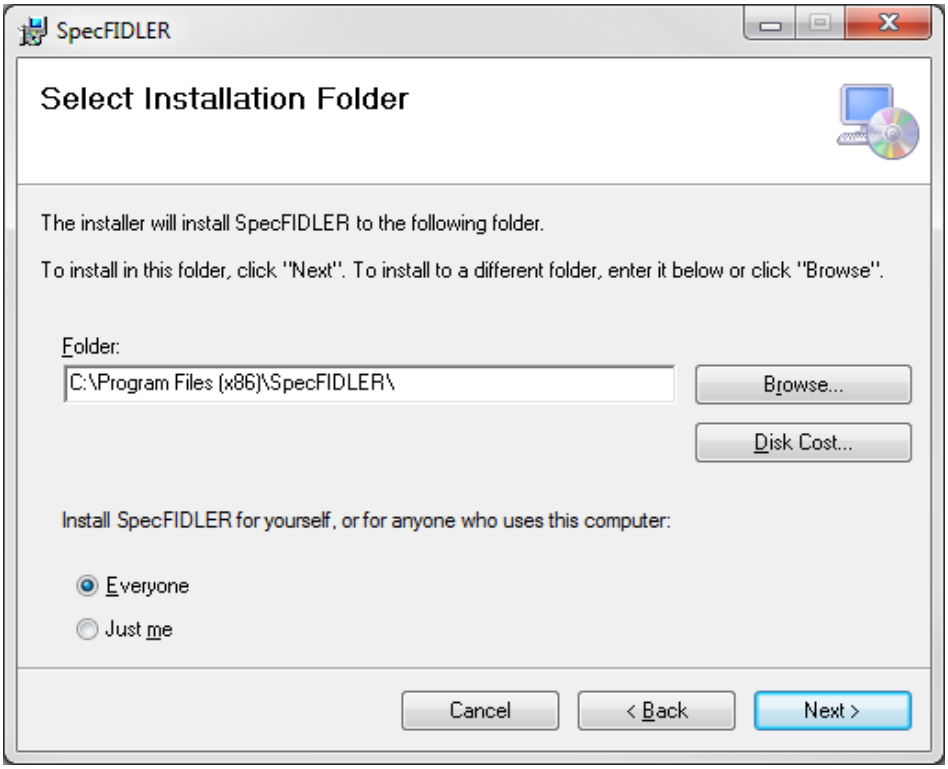

Figure 8. SpecFIDLER setup wizard.

NOTE: The **eM_DLL.dll** file in the installation folder is a custom version of the Bridgeport Instruments library. It has bug fixes and additional features applied. Do not replace this file with the stock version provided by Bridgeport Instruments; otherwise, runtime errors will occur.

4. Use the procedure in Section 2.1 to assemble the SpecFIDLER and connect the USB cable to the tablet.

5. Associate the Bridgeport Instruments usbBase with the correct driver. Run **Zadig** from the **SpecFIDLER** folder in the Start Menu. Select the **eMorpho** device from the drop-down. (If this option does not appear, select **Options->List All Devices** from the menu.) Change the driver to **WinUSB** and click **Install Driver** (Figure 9).

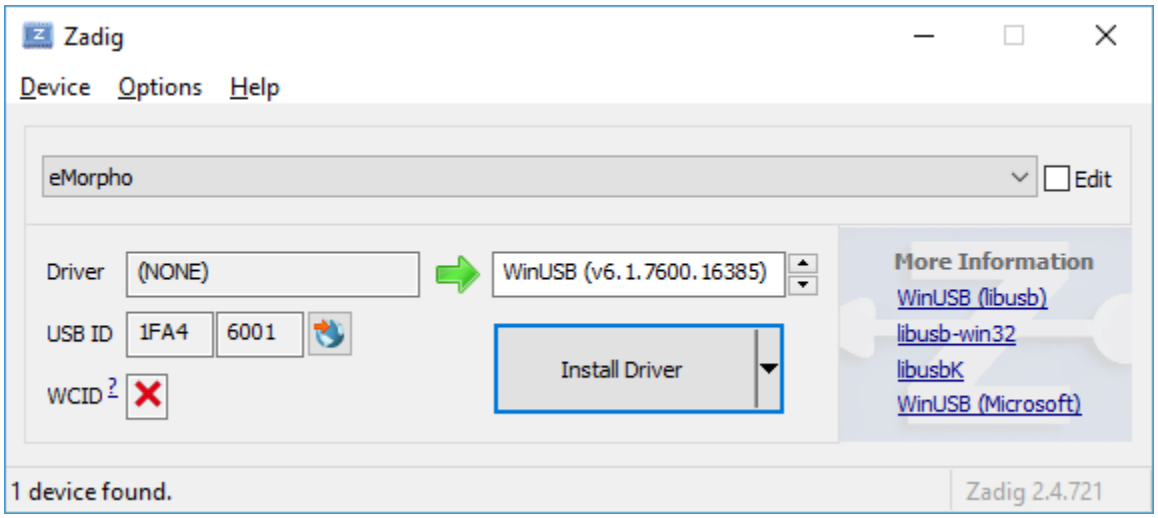

Figure 9. Zadig configuration.

NOTE: The new version of the software requires the **WinUSB** driver rather than **lib-usbwin32**. The **libusbK** driver is also acceptable. The software will fail if the correct driver is not associated with the usbBase.

6. Use the procedure in Section 5.1 if upgrading from an older version of the software to version 2.

3.0 Operation

The SpecFIDLER software is called by the DFM software on the tablet. Click the **Launch SpecFIDLER** button to begin.

The tabs along the right side of the main screen (Figure 10) switch between various modes. The **Rate** and **Spectra** tabs acquire data from the detector. The **Source term** tab defines the mixture of nuclides in the source term. The **Analysis** tab computes the nuclide quantities. The **Batch** tab reprocesses historical data. The **Energy cal** tab and **Efficiency cal** tabs handle the detector calibration. Finally, the **Settings** tab allows operators to adjust and save parameters.

Note that the **Source term**, **Energy cal**, and **Efficiency cal** tabs serve a dual role: *creating* and *displaying* the present source term and detector calibrations. The **Settings** tab specifies the *default* parameters. These roles should become clearer in the following discussion.

The remainder of this section describes how to operate the SpecFIDLER for both mobile survey and stationary sampling. These procedures assume that the detector has already been calibrated. Section 4.0 describes the calibration process.

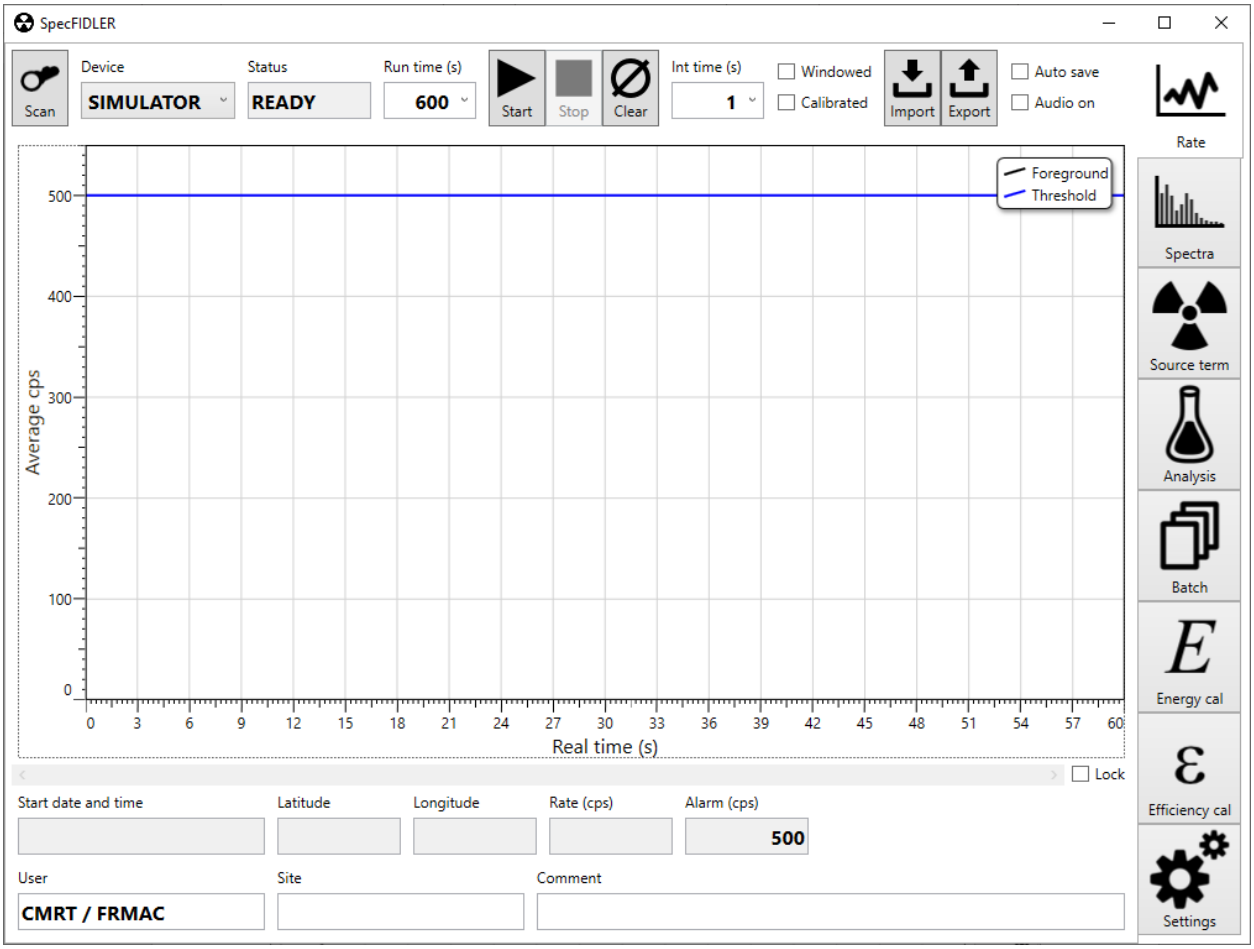

Figure 10. Main screen showing various tabs.

3.1 General Settings

Before acquiring data for the first time, take a moment to examine the **Settings** tab (Figure 11). The various parameters configure the display, specify the default background and detector calibrations, and define the available source terms. All parameters and tables are fully editable. Rather than describing each parameter here, the following sections reference the parameters that pertain to the functions at hand.

All parameters are stored in a file named **settings.xml** in the SpecFIDLER working directory (**c:\fidler** by default). Click **Save** to save the parameters to the settings file. Alternatively, click **Revert** to discard all changes and reload the settings file. The software will also prompt whether to save changes on exit.

To transfer parameters to another computer, click **Export** to write a file on the first device, and **Import** to read the file on the second device. The software will merge the imported parameters into the existing settings file.

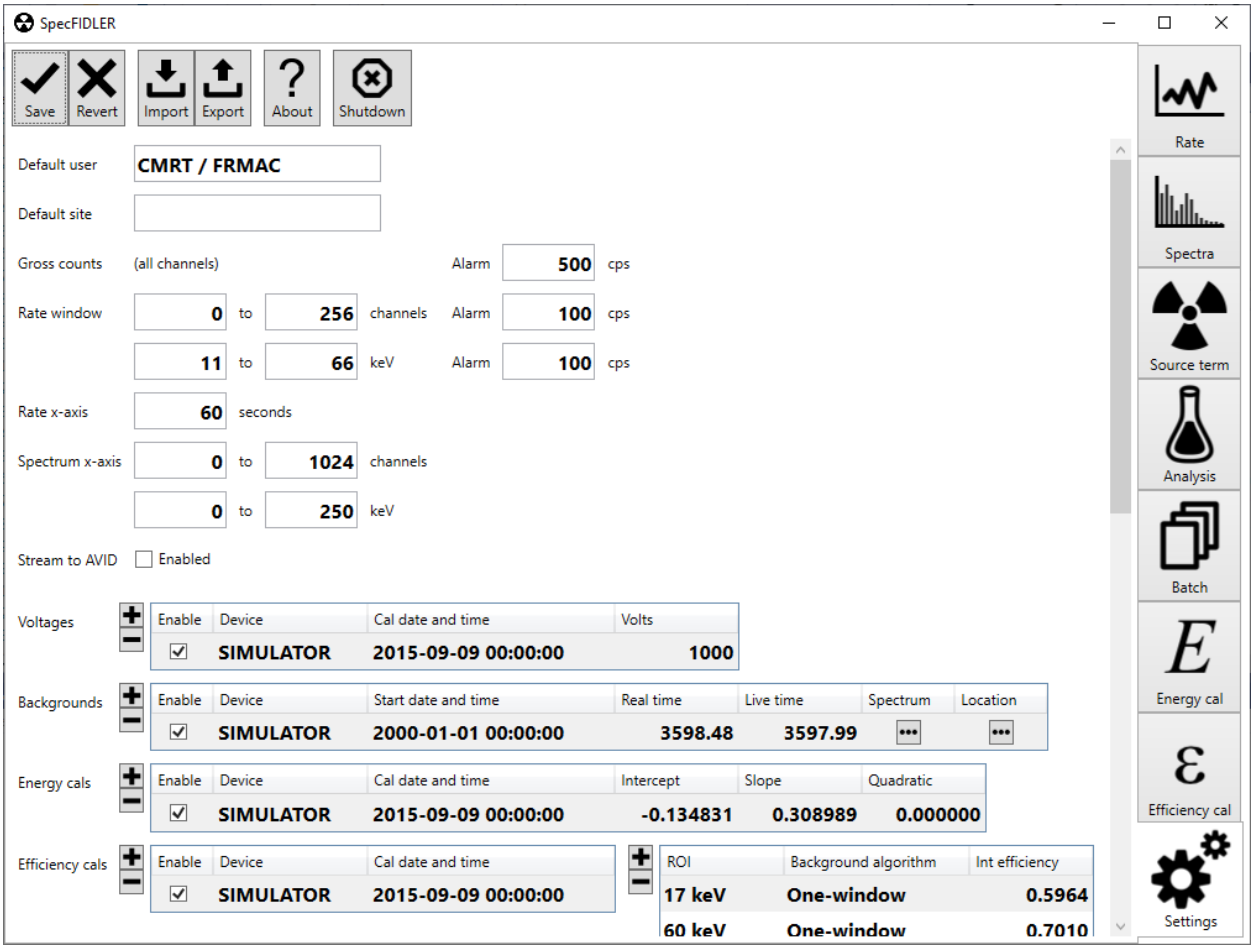

Figure 11. **Settings** tab.

3.2 Mobile Survey

To use the SpecFIDLER for mobile survey, carry the unit by the top handle, keeping the detector a uniform distance from the ground. Retract the legs if more convenient.

NOTE: Never set the detector face down on the ground without the tripod legs extended. The beryllium window will be damaged.

Use the **Rate** tab (Figure 12) to acquire data. The main plot displays the count rate versus time in black, along with the alarm threshold in blue. Time 0 indicates when the measurement started. Spikes in the count rate indicate potential hotspots that may warrant further sampling.

The **Device** drop-down near the top left indicates the present detector. Typically, only one detector is connected to the tablet, so only one serial number appears in the drop-down list. The **SIMULATOR** option uses simulated data for training purposes, and the **(none)** option disconnects from all detectors. Changing the selection may take a few seconds due to the high voltage needing to be ramped up or down. If a message appears regarding a voltage not being specified, refer to Section 4.1 to perform a voltage calibration.

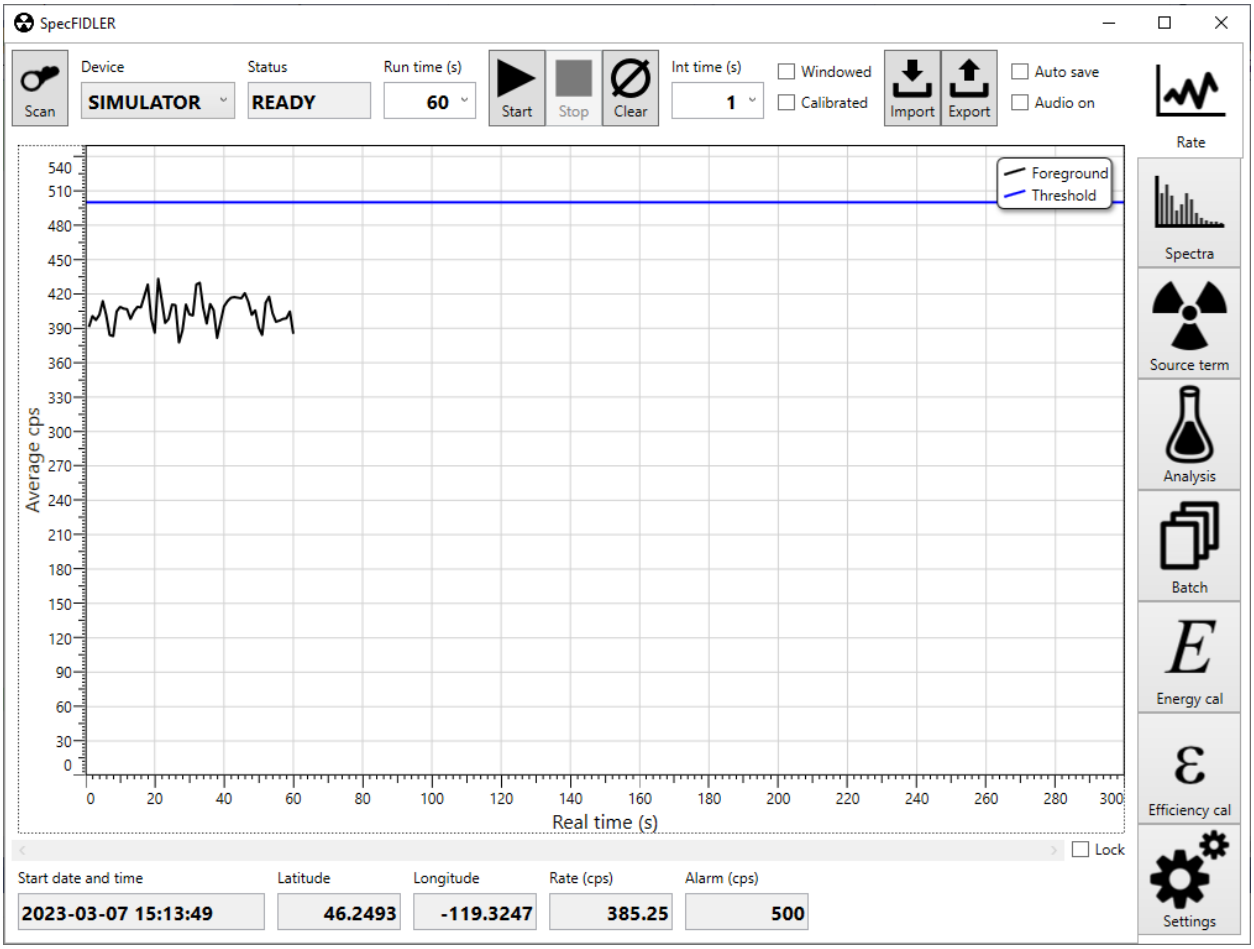

Figure 12. **Rate** tab.

To connect to a different detector, first set the **Device** to **(none)**. Unplug the old detector from the tablet and plug in the new detector. Click **Scan** to refresh the list of detectors, then select the new detector from the **Device** drop-down.

The **Status** text box displays the present connection state:

- **BUSY**: Scanning for devices or ramping high voltage.
- **INACTIVE**: No detector connected.
- **READY**: Detector connected but not acquiring data.
- **RUNNING**: Detector acquiring data.
- **CLOSING**: Shutting down software.
- **ERROR**: A communication error occurred. Try connecting to the detector again.

The **Run time** drop-down specifies the total run time in seconds. Type in a value or choose an option from the list.

Click **Start** to begin the data acquisition and **Stop** to end the data acquisition before the total run time has elapsed. Click **Start** again to accumulate additional data. Note that the total run time may need to be increased to continue. Click **Clear** to discard accumulated data.

The **Int time** drop-down specifies the integration time. For example, a value of 3 means that the count rate is computed over the previous three seconds, while still updating every second. The plot is regenerated when the integration time changes. The integration time only affects the plot and not the exported files or streamed data.

The **Windowed** and **Calibrated** checkboxes control the count rate displayed in the plot, along with the associated alarm threshold. Clear **Windowed** to integrate the gross counts across the entire spectrum. The alarm threshold is set by the **Gross counts** controls in the **Settings** tab. Select **Windowed** but clear **Calibrated** to integrate the spectrum between two channels. Finally, if the energy calibration is valid, select both **Windowed** and **Calibrated** to integrate the spectrum between two energies in keV. The window bounds and alarm threshold are set by the appropriate **Rate window** controls in the **Settings** tab.

Use the scroll bar at the bottom of the plot to navigate through the data. The **Lock** checkbox prevents the graph from scrolling when new samples are added. Use the **Rate x-axis** field in the **Settings** tab to control the amount of data shown. A value of zero auto-scales the x axis.

Below the plot, the **Start date and time** indicates when the data acquisition initially began. The **Latitude** and **Longitude** provide the present GPS location. The **Rate** shows the present count rate after applying the selected integration time and windowing technique. Finally, the **Alarm** text box indicates the present alarm threshold.

Returning to the toolbar, click **Import** to read a previous data file in CSV format. The present detector is disconnected and data acquisition disabled. After viewing data, click **Clear** and change back to the desired **Device**.

Click **Export** to write a data file in CSV format. The file contains one row for each second of data. Each row specifies the sample number, UNIX timestamp, real time in microseconds, GPS

location, count rates, and 4096-channel spectrum. The first channel of the spectrum is the live time in microseconds. The UNIX timestamp corresponds to the end of the one-second sample. By default, the file is saved to a subfolder of the working directory (**c:\fidler** by default). The file can be loaded into AVID for processing.

Use the **Auto save** check box to automatically write a data file in CSV format when acquisition stops. The file name contains the device serial number as well as the start date and time.

The **Audio on** checkbox enables audible alarms. The software plays a sound whenever the count rate exceeds the alarm threshold.

In summary, a typical operating procedure might comprise the following:

- Select the correct **Device**.
- Check **Audio on** and **Auto save**.
- Change the **Run time** to 3600 seconds and click **Start**.
- Carry the detector around and listen for alarms. Adjust the alarm threshold as needed.
- Use the **Windowed** and **Int time** features for greater sensitivity, if needed.
- Make note of any hotspots for subsequent sampling.

3.3 Streaming to AVID

As an alternative to viewing data within the SpecFIDLER software, operators may stream data to AVID for visualization and processing. This feature requires AVID 2022 Update 1 or later.

To enable streaming, check the box beside **Stream to AVID** in the **Settings** tab. Open AVID and configure the SpecFIDLER stream manager to connect to the SpecFIDLER software. Provide the IP address where the software is running (usually the local address 127.0.0.1) and the port number (4002 by default). The port number is defined in the settings file, as explained in Appendix B.

The SpecFIDLER software then transmits the sample data each second while acquisition is running. The data includes the UNIX timestamp, GPS location, count rates, 4096-channel spectrum, and present energy calibration. Here the UNIX timestamp corresponds to the beginning of the one-second sample.

3.4 Stationary Sampling

To use the SpecFIDLER for stationary sampling, extend the legs and place the unit over the desired location. The detector should be 0.3 m from ground level with the legs extended. The first measurement should be a representative background that matches the terrain type as closely as possible. Subsequent measurements can then use that background to determine the amount of contamination. However, analysis can be performed without a background if needed.

Use the **Spectra** tab (Figure 13) to acquire data and display the accumulated spectrum. The plot superimposes the accumulated foreground in black and the present background in red. Plutonium isotopes generally have one peak around 17 keV, whereas Am-241 has two peaks at 17 and 60 keV.

The **Rate** and **Spectra** tabs display the same data and share many of the same controls. As a reminder, select the **Device** and check the **Status**. Enter the desired **Run time**, then use **Start** and **Stop** to control the data acquisition. **Clear** the accumulated data to start over.

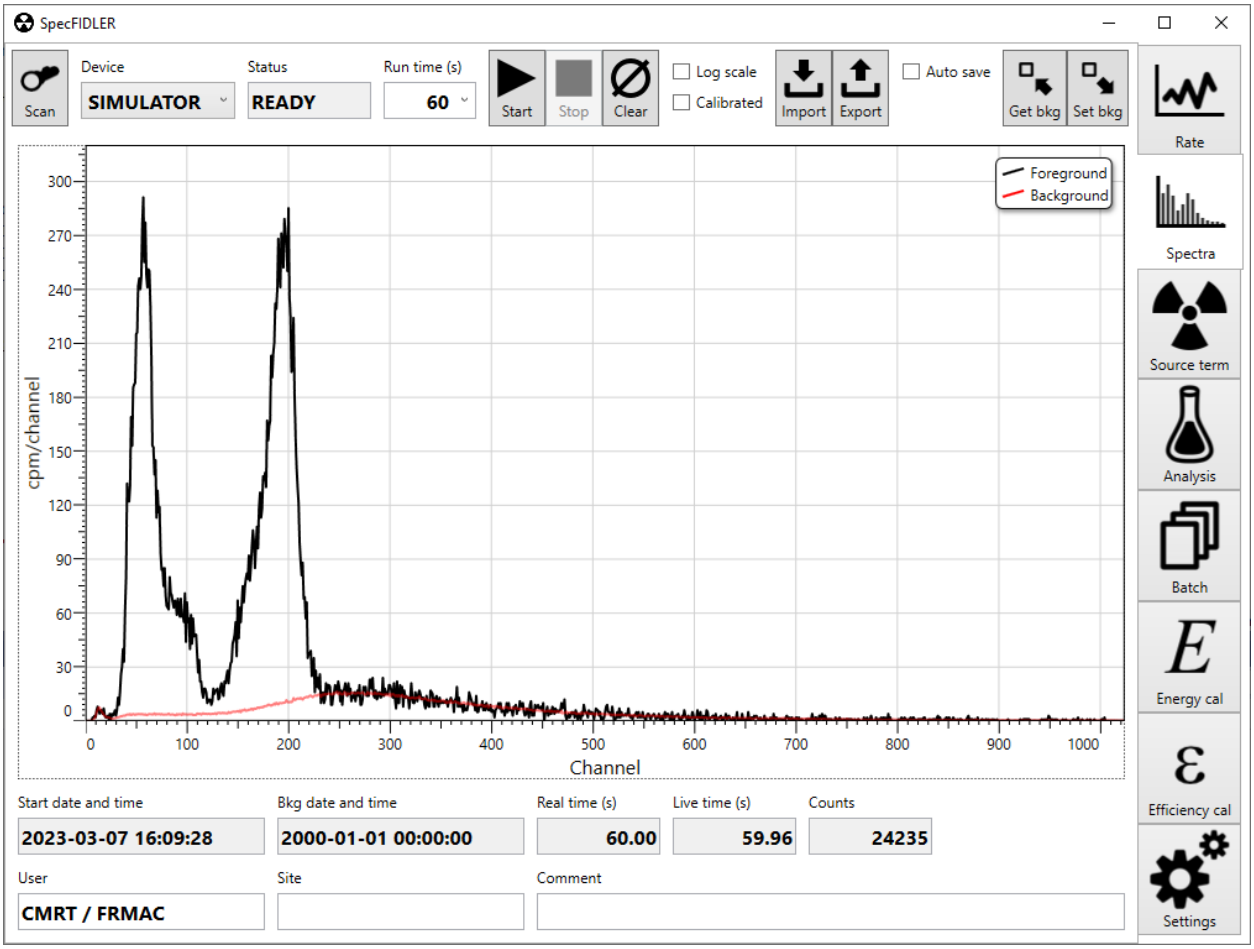

Figure 13. **Spectra** tab.

The **Log scale** checkbox places the y-axis on a logarithmic scale. The **Calibrated** checkbox controls whether the x-axis has units of channels or energy in keV. Use the **Spectrum x-axis** fields in the **Settings** tab to adjust the bounds of the x-axis.

Below the plot, the **Start date and time** indicates when the data acquisition initially began. The **Bkg date and time** identifies the corresponding background. The **Real time**, **Live time**, and **Counts** display the accumulated statistics. Finally, the **User**, **Site**, and **Comment** are saved in the N42.42 file.

Returning to the toolbar, click **Import** to read a previous data file in N42.42 format. The present detector is disconnected and data acquisition disabled. This action also replaces the background and detector calibrations with the values read from the file. After viewing data, click **Clear** and change back to the desired **Device**. This action reloads the default background and detector calibrations from the settings.

Click **Export** to write a data file in N42.42 format. The file contains the start date and time along with the accumulated real time, live time, and spectrum. The present background and detector calibrations are included as well. Unlike the CSV files generated from the **Rate** tab, only the final accumulated spectrum is saved; thus, the time series is not displayed on import.

Use the **Auto save** check box to automatically write a data file in N42.42 format when acquisition stops. As before, the file name contains the device serial number as well as the start date and time.

Click **Get bkg** to load the default background from the settings. The background is taken from the **Backgrounds** table in the **Settings** tab. The software selects the row that has **Enable** checked, matches the **Device**, and has the latest **Start date and time**. In addition to the background, the **User** and **Site** are taken from the **Default user** and **Default site** at the top of the view.

Click **Set bkg** to store the background in the settings as the new default for the device. The **Default user** and **Default site** are set as well. Older backgrounds may be disabled or removed in the **Settings** tab using the **−** button, if desired.

In summary, a typical operating procedure might comprise the following:

- Position the detector above the background location.
- Select the correct **Device**.
- Check **Auto save**.
- Change the **Run time** to 300 seconds and click **Start**.
- Edit the **User**, **Site**, and **Comment** to describe the location.
- Click **Set bkg** to set the default background for subsequent data acquisitions.
- Position the detector above the first hotspot.
- Edit the **Comment** to describe the location.
- Check **Auto save**. Click **Clear** and **Start**.
- Repeat for subsequent hotspots.

3.5 Source Term

Use the **Source term** tab (Figure 14) to define the mixture of nuclides in the source term. The software can take a previous source term and apply aging calculations to create a new source term. The two tables display the nuclides, mass fractions, and activity fractions of each constituent in the mixture, before and after aging.

Click **Load** to bring in one of the **Available source terms** from the settings. The **INITIAL** table is populated with each nuclide, mass fraction, and activity fraction in the mixture. The **Name** of the source term and all fields in the table are editable. Click **Add** to append a new row and **Remove** to delete the highlighted row.

Either the mass fraction or the activity fractions may be supplied. The two buttons in the left panel select which set of fractions will be used for the calculations. For example, if **Activity fractions** is selected, the mass fractions are calculated from the activity fractions.

Now enter the **Age** in years and click **Calculate**. The **CORRECTED** table is populated with the nuclide, mass fraction, and activity fraction of the decay-corrected source term. The **Cal date and time** is also updated. Set the **Age** to zero if no decay corrections are needed.

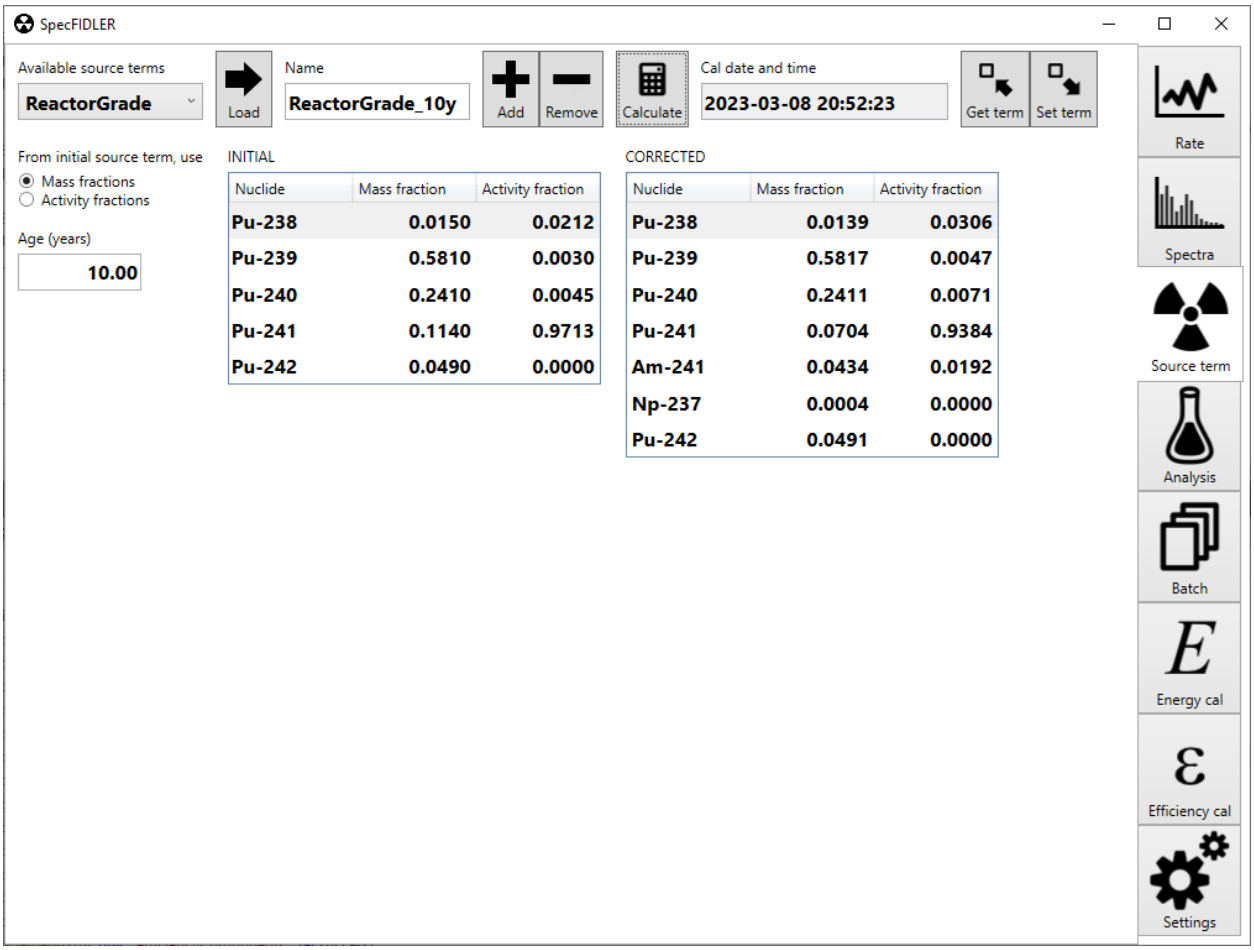

Figure 14. **Source term** tab.

Click **Get term** to load the source term from the settings. The source term is taken from the respective table in the **Settings** tab. The software selects the row that has **Enable** checked and has the latest **Cal date and time**.

Click **Set term** to store the source term in the settings. Subsequent runs of the software then load this mixture by default.

NOTE: The new source term overwrites any existing source term having the same **Name**.

3.6 Nuclide Analysis

After collecting a stationary sample, use the **Analysis** tab (Figure 15) to compute the nuclide concentrations. The main plot displays the foreground spectrum in black, the background spectrum in red, and each region of interest (ROI) in blue. The background regions adjacent to each ROI are highlighted in red as well. The controls in the left panel specify various input parameters for the nuclide analysis. The tables at the bottom display the computed results in the specified units.

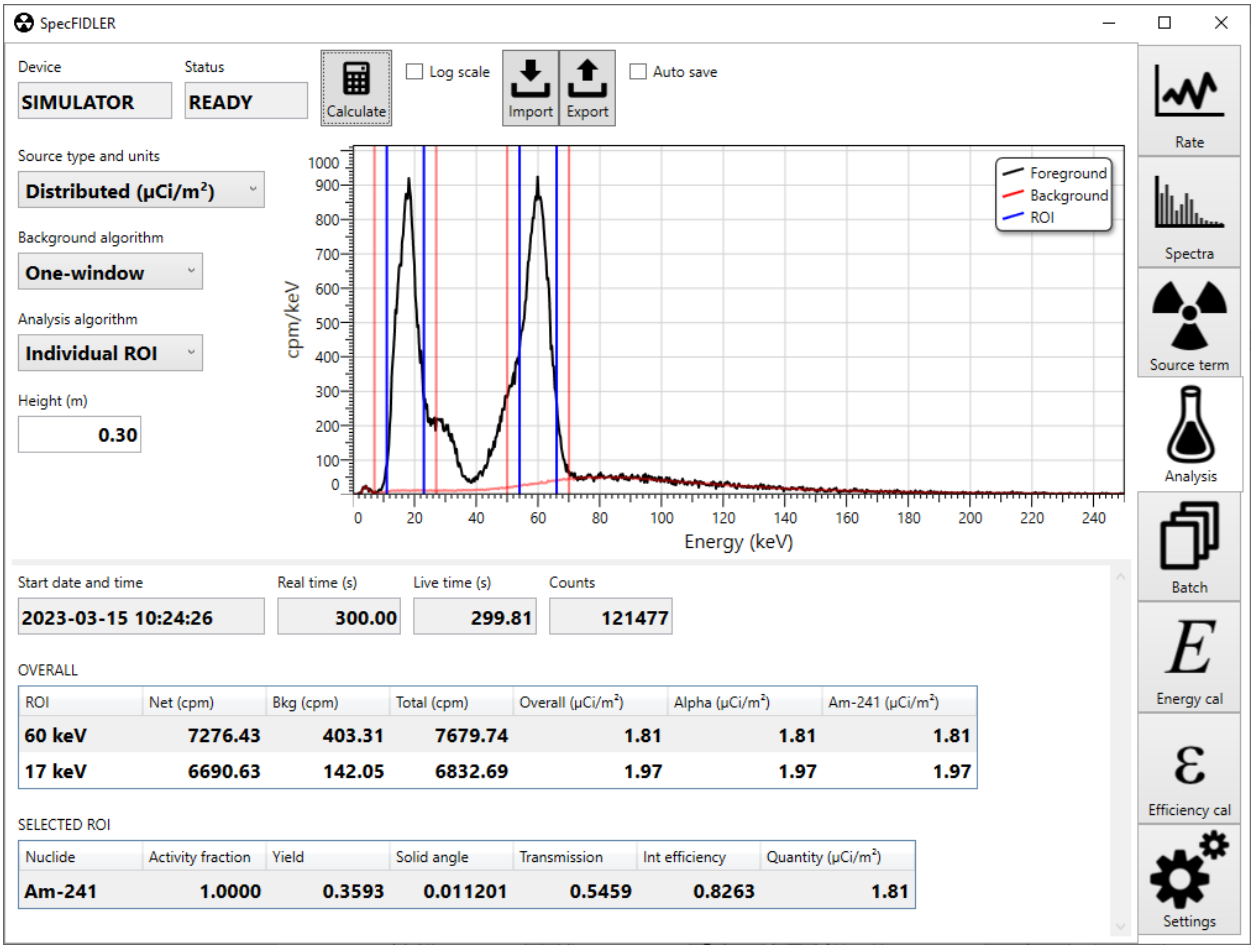

Figure 15. **Analysis** tab.

The **Device** and **Status** on the top left reflect the detector state in the **Rate** and **Spectra** tabs. Below the plot, the **Start date and time** indicates when the data acquisition initially began, and the **Real time**, **Live time**, and **Counts** display the accumulated statistics.

On the left side, the **Source type and units** specifies whether the analysis is performed for a distributed source or a point source, and in units of microcuries or becquerels. The point source option may be useful when analyzing a small sample (for example, a hot particle) underneath the detector.

The **Background algorithm** defines how the nuclide analysis computes the background. Select **One-window** to use a background measurement collected previously. Select **Three-window** to extrapolate the background counts from the background regions to the left and right of the ROI. The **One-window** method is generally more accurate, but the **Three-window** method may be useful if a representative background is not available.

The **Analysis algorithm** determines how the quantities in each ROI are linked. Select **Individual ROI** to compute the results for each ROI independently. The activity fractions from the specified source term are used to scale the total quantity. Select **Linked ROI** to propagate results from one ROI to another. Specifically, the quantity of Am-241 is calculated first using the net counts in the 60 keV ROI. The activity fractions are then adjusted for the 17 keV ROI to provide a consistent quantity of Am-241. This option is useful when the fraction of Am-241 is not known precisely.

The **Height** should match the actual detector height. Recall that the default height with the legs extended is 0.3 meters.

Returning to the toolbar, click **Calculate** to run the nuclide analysis. The results are displayed in the two tables at the bottom. The **OVERALL** table provides the count rates and computed quantities for each ROI. The **SELECTED ROI** table lists the activity fraction, sensitivity parameters, and individual quantity for each nuclide in the source term. Select a different row in the **OVERALL** table to display the values for each ROI.

Make note of the quantities displayed in the **OVERALL** table. Separate columns provide the overall quantity of all nuclides in the source term, the quantity of all alpha emitters, and the quantity of just Am-241. If using the **Individual ROI** method, the 60 keV ROI calculations are usually the most accurate, since the gamma rays are less affected by surface roughness and other uncertainties. If using the **Linked ROI** method, the 17 keV ROI calculations incorporate the corrected activity factors.

Depending on the **Source type and units**, the quantities may be reported as activities (such as microcuries) or areal concentrations (such as microcuries per square meter). If a quantity is less than the minimum detectable activity (MDA), the text **< MDA** will appear instead.

The **SELECTED ROI** table provides more information about the factors that went into the calculation. The **Yield** specifies the gamma emissions in the ROI per decay. The **Solid angle** is computed for gamma emissions directly underneath the detector. The **Transmission** factor accounts for the air attenuation between the ground and the detector. For distributed sources, this factor also integrates the activity over an infinite disc, accounting for changes to the solid angle and path length. Finally, the **Int efficiency** gives the calibrated intrinsic efficiency.

Returning to the toolbar once again, the **Log scale** checkbox in the toolbar places the y-axis of the plot on a logarithmic scale, as before.

Click **Import** to read a previous data file in N42.42 format. Like the corresponding button on the **Spectrum** tab, the present detector is disconnected, data acquisition is disabled, and the background and detector calibrations are replaced. In addition, the software reads the input parameters and calculated results from the data file, if present.

NOTE: The source term is not saved to the data file. The calculated results will be different if the source term changed.

Click **Export** to write the data and analysis results to a file in N42.42 format. The analysis results are written to the file in the same units as the calculations. Use the **Auto save** check box to automatically perform the analysis and export the results.

3.7 Batch Analysis

Use the **Batch** tab (Figure 16) to reprocess historical data. The table in the center lists the file names being processed, the associated input parameters for the nuclide analysis, and a summary of the computed results. The controls at the bottom display the full results for the selected row.

Click **Import** to read data files in N42.42 format. A window appears to select a **Parent directory**. The table is populated with all files with an .n42 extension in that directory, along with any subdirectories. Files that were exported from the **Energy cal** or **Efficiency cal** tabs are excluded so the calibration information is not lost. The software displays a message indicating the number of files read and skipped.

After performing any desired updates, click **Export** to write the data and analysis results. A window appears to select a new **Parent directory**. The data files are saved to this directory using the same relative paths and filenames.

NOTE: Exporting to the old **Parent directory** overwrites the data files.

Click **Add** to append additional rows to the table. A window appears to select one or more files. As before, calibration files are skipped. Click **Remove** to delete the selected rows from the table.

Use the controls below the toolbar to specify which modifications to apply to the nuclide analysis. Choose a **Source term** and optionally a new **Source type and units**, **Background algorithm**, and **Analysis algorithm**. Select one or more rows in the table or click **Select all**. Finally, click **Calculate** to update the results for the selected rows.

The **Report** button writes a summary of the computed results in CSV format. The file contains one row for each data file. Each row specifies the device, user, site, comment, GPS location, start date and time, real time, live time, and quantities for each ROI using the selected units.

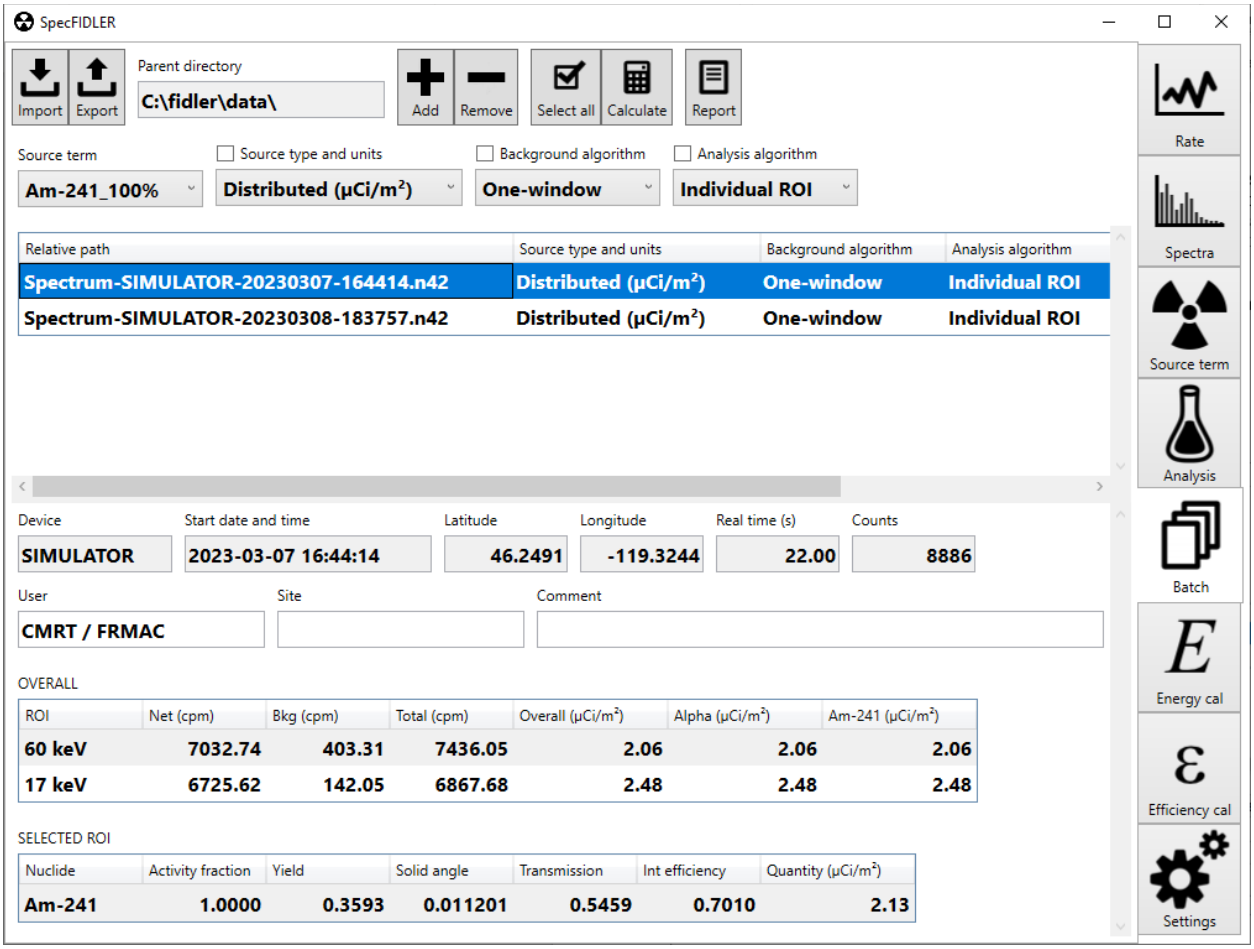

Figure 16. **Batch** tab.

3.8 Shutdown

When data acquisition and analysis is complete, click **Shutdown** in the **Settings** tab to shut down the SpecFIDLER and return to the DFM software. Alternatively, close the window using the **X** in the upper right corner. The shutdown process takes a few seconds to ramp down the bias voltage and disconnect from the usbBase.

NOTE: Do not unplug the tablet from the detector until the usbBase is disconnected. This may be done by shutting down the software or by changing the **Device** to **(none)**.

4.0 Calibration

The SpecFIDLER requires several calibration steps before use: a voltage calibration performed when commissioning a detector, an energy calibration performed daily, and an efficiency calibration performed daily. The remainder of this section details the calibration procedures.

4.1 Voltage Calibration

The voltage calibration establishes the bias voltage for the detector. The detector must have a voltage listed in the **Settings** tab; otherwise, data acquisition will be disabled. The voltage calibration should only need to be performed when commissioning a new detector unless the performance changes significantly over time.

An Am-241 source is necessary to perform the voltage calibration. The goal is to have the spectrum meet two requirements (Figure 17). First, the 13 keV x-ray should be visible as a shoulder to the 17 keV peak. Second, and more importantly, the 60 keV peak should return to background prior to channel 250.

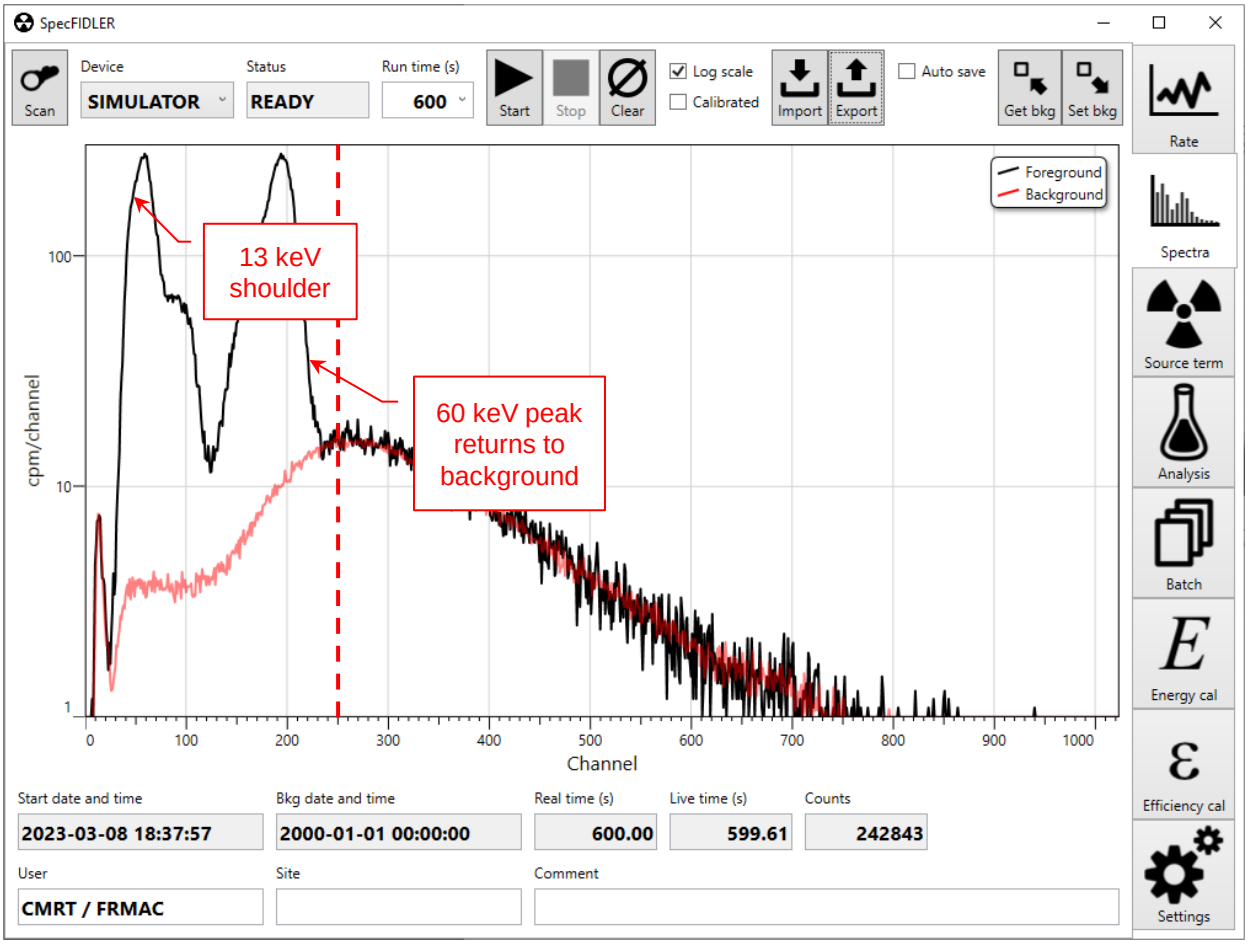

Figure 17. Am-241 spectrum with good high voltage setting.

Use the following procedure to perform the voltage calibration:

- Place the Am-241 source on the ground directly underneath the detector.
- Go to the **Settings** tab and click the **+** button next to **Voltages**.
- Set **Volts** to 1000 and ensure that **Enabled** is checked.
- On the **Spectrum** tab, change the **Run time** to 300 or 600 seconds and click **Start**.
- Adjust the voltage up or down as needed.
- After each change, change the **Device** to **DISCONNECTED** and then to the original serial number. This action applies the new bias voltage to the detector.

NOTE: Setting the bias voltage above 1200 V is not recommended. Do not exceed 1500 V or the detector may be damaged.

4.2 Energy Calibration

The energy calibration translates a channel number to the corresponding energy in keV. These conversion factors are created by presenting a source to the instrument, acquiring a spectrum, and selecting the proper peak. It is recommended to perform the energy calibration daily prior to deployment. Although the software supports different sources, the energy calibration can be completed using Am-241 alone. Thus, the following discussion uses Am-241 for illustration.

Use the **Energy Cal** tab (Figure 18) to perform the energy calibration. The main plot displays the foreground spectrum in black, the fitted peaks in red, and each region of interest (ROI) in blue. The table of peaks appears to the left, and the computed calibration coefficients on the bottom.

The **Device** and **Status** indicate the present detector and connection status. Use the **Spectrum** tab to select the detector and control data acquisition. The live spectrum is also visible in the **Energy cal** tab if **Show foreground** is checked.

Once the live spectrum has smooth peaks, click **Add** to append a new row to the table. This action makes a reference copy of the live spectrum. Thus, one can restart the data acquisition with a different calibration source and add another peak, if needed. Select a row in the table to display the associated reference spectrum. Click **Remove** to delete unneeded entries.

For each row, select the **Peak** in the first column and click on the corresponding peak in the plot. The **Channel** is computed automatically. If necessary, adjust the **Fit range** to achieve a good fit. Alternatively, manually input the desired **Channel**.

Click **Calculate** to compute the calibration coefficients. This action updates the **Cal date and time** at the top, along with the **Intercept**, **Slope**, and **Quadratic** terms at the bottom. For a two-point calibration, the **Quadratic** term will be zero. The software performs various checks to ensure the calibration makes sense and displays a warning message if something appears wrong.

The **Log scale** checkbox places the y-axis on a logarithmic scale.

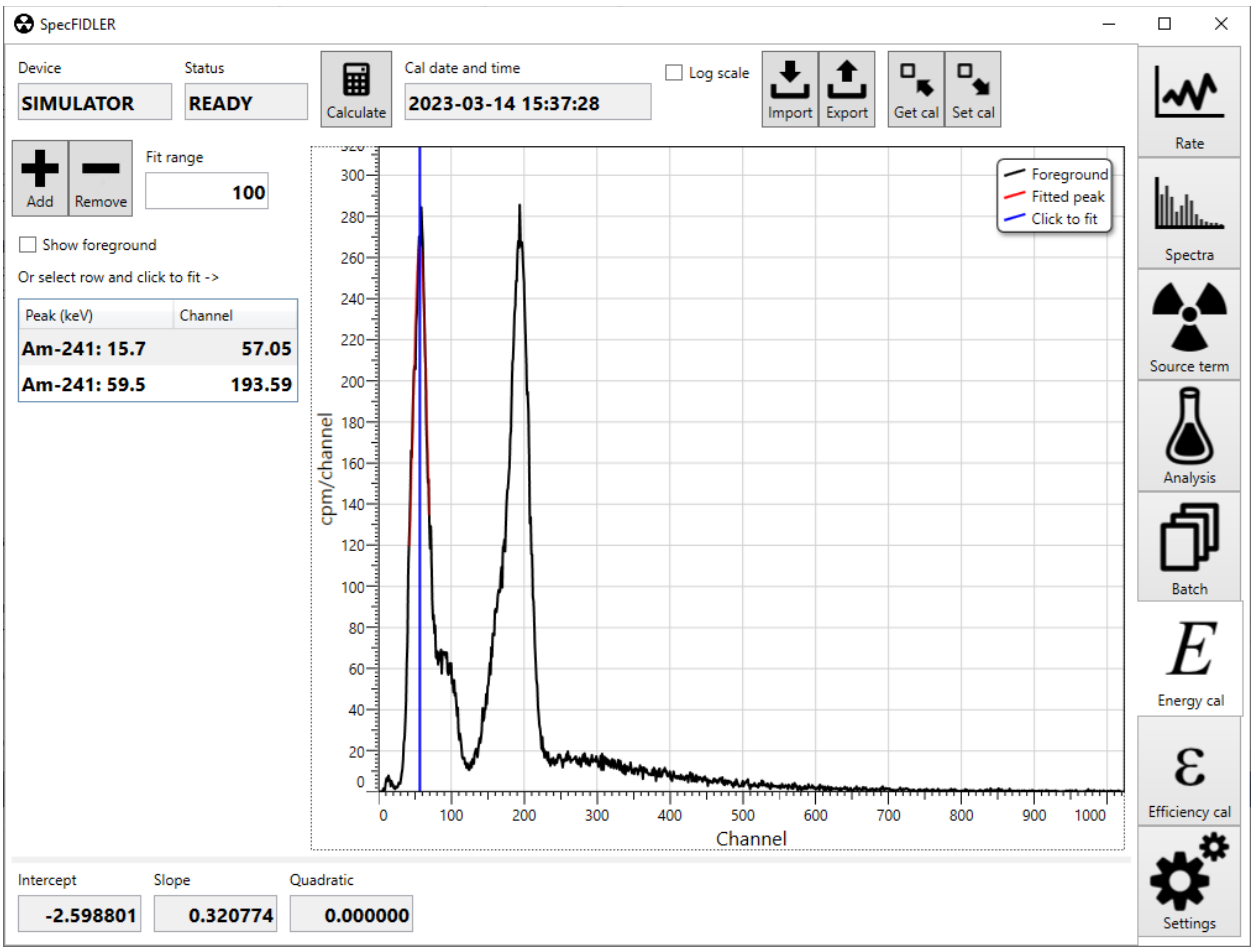

Figure 18. **Energy Cal** tab.

The **Import** and **Export** buttons read and write data files in N42.42 format. The data files exported by the **Energy cal** tab contain all the reference spectra in addition to the foreground spectrum.

Click **Get cal** to load the default energy calibration from the settings. The calibration is taken from the **Energy cals** table in the **Settings** tab. The software selects the row that has **Enable** checked, matches the **Device**, and has the latest **Cal date and time**.

Click **Set cal** to store the energy calibration in the settings as the new default for the device. Older energy calibrations may be disabled in the **Settings** tab by clearing the **Enable** checkbox, or removed completely using the **−** button, if desired.

In summary, a typical calibration procedure might comprise the following:

- Position the detector at a known background location.
- Place the Am-241 source on the ground directly underneath the detector.
- On the **Spectrum** tab, change the **Run time** to 300 seconds and click **Start**.
- On the **Energy cal** tab, click **Add** two times once data acquisition is complete.

- Change the **Peak** columns to **Am-241: 15.7** and **Am-241: 59.5**.
- Select each row and click the corresponding peaks in the plot.
- Click **Calculate** to compute the energy calibration.
- Click **Export** to save the energy calibration to an N42.42 file.
- Click **Set cal** to store the energy calibration in the settings.

4.3 Efficiency Calibration

The efficiency calibration determines the intrinsic efficiency of the detector for each ROI. Like the energy calibration, it is recommended to perform the efficiency calibration daily prior to deployment. Although the software supports different sources, typically just Am-241 is used. An activity of 2 µCi is recommended.

Use the **Efficiency Cal** tab (Figure 19) to perform the efficiency calibration. The main plot displays the foreground spectrum in black, the background spectrum in red, each ROI in blue, and each background region in red. The input parameters for the calibration appear to the left, and the table of computed efficiencies on the bottom.

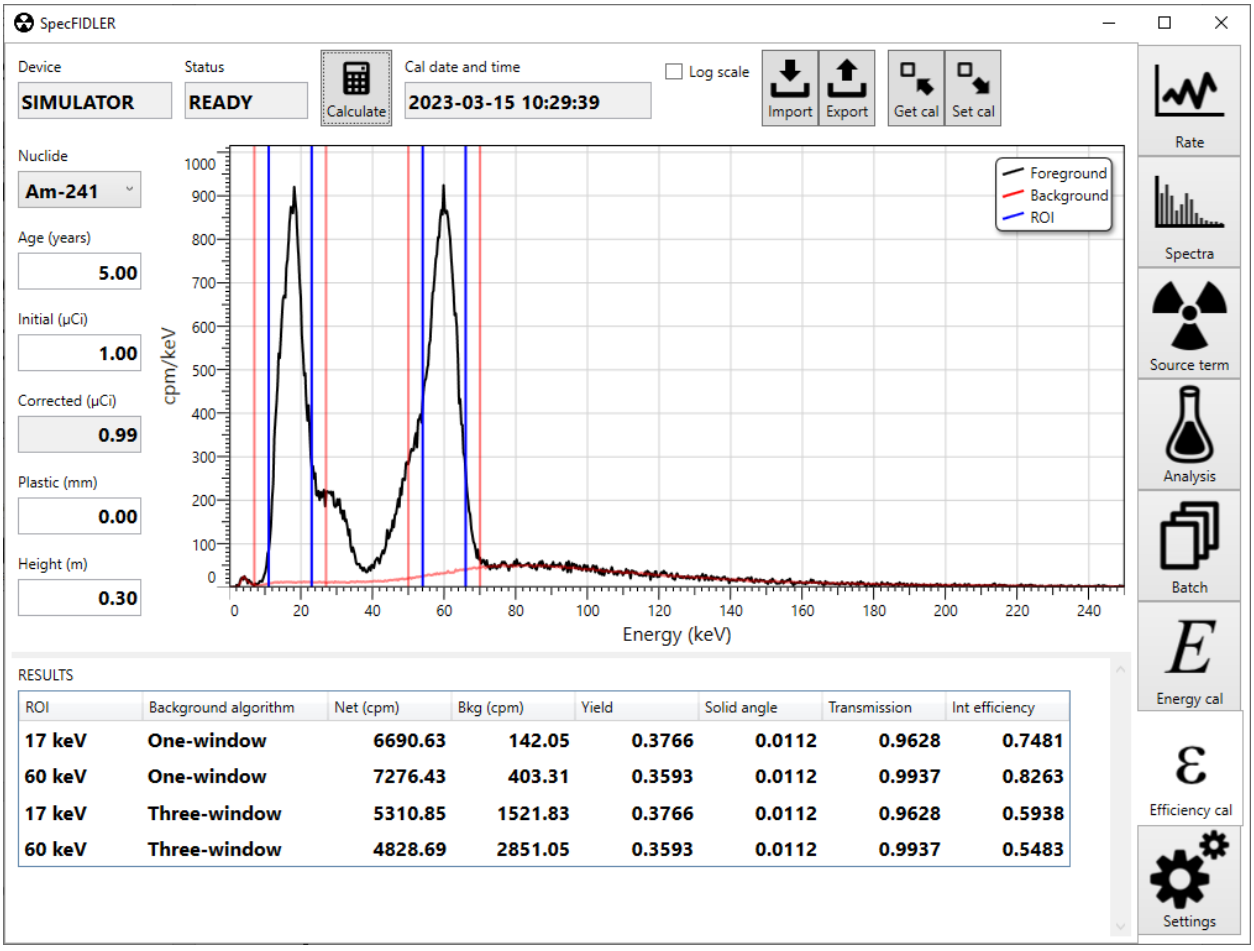

Figure 19. **Efficiency Cal** tab.

As before, the **Device** and **Status** indicate the present detector and connection status. Use the **Spectrum** tab to select the detector and control data acquisition.

On the left side, specify the **Nuclide** used for the efficiency calibration, the **Age** in years, and the **Initial** activity in microcuries. The software automatically computes the **Corrected** activity. Also specify the **Plastic** thickness on top of the source, in millimeters, if using a non-electroplated source, along with the actual **Height** of the detector.

Returning to the toolbar, click **Calculate** to perform the efficiency calibration. This action updates the **Cal date and time** at the top, along with table of results at the bottom. As with the energy calibration, the software performs various checks to ensure the calibration makes sense and displays a warning message if something appears wrong.

One row appears in the table for each ROI and background method (one-window and three-window). The count rates, sensitivity factors, and computed intrinsic efficiency are all listed. As with the nuclide analysis, the **Yield** specifies the gamma emissions in the ROI per decay. The **Solid angle** is computed for gamma emissions directly underneath the detector. The **Transmission** factor accounts for the air attenuation between the ground and the detector.

The **Log scale** checkbox places the y-axis on a logarithmic scale, as before.

The **Import** and **Export** buttons read and write data files in N42.42 format. The data files exported by the **Efficiency cal** tab contain additional information about the efficiency calibration as remarks.

Click **Get cal** to load the default efficiency calibration from the settings. The calibration is taken from the **Efficiency cals** table in the **Settings** tab. The software selects the row that has **Enable** checked, matches the **Device**, and has the latest **Cal date and time**.

Click **Set cal** to store the efficiency calibration in the settings as the new default for the device. Older efficiency calibrations may be disabled in the **Settings** tab by clearing the **Enable** checkbox, or removed completely using the **−** button, if desired.

In summary, a typical calibration procedure might comprise the following:

- Collect the background as described in Section 3.4.
- Perform the energy calibration as described in Section 4.2.
- Keep the same Am-241 spectrum from the energy calibration.
- On the **Efficiency cal** tab, set the **Nuclide** to **Am-241**.
- Also specify the **Age**, **Initial** activity, **Plastic** thickness, and detector **Height**.
- Change the **Peak** columns to **Am-241: 15.7** and **Am-241: 59.5**.
- Click **Calculate** to compute the efficiency calibration.
- Click **Export** to save the energy calibration to an N42.42 file.
- Click **Set cal** to store the efficiency calibration in the settings.

5.0 Maintenance

This section discusses common maintenance tasks for the SpecFIDLER and gives suggestions for troubleshooting.

5.1 Version Information

Click **About** in the **Settings** tab to display the software version and other information.

5.2 Upgrading from Previous Versions

Newer versions of the SpecFIDLER software are not completely compatible with the settings used for older versions. In general, the software will read most parameters from the old settings file; however, some calibration steps need to be repeated. Use the following procedure when upgrading:

1. When opening the software, a warning message appears that about the settings format having the incorrect format. Dismiss this message as it is expected.

2. Go to the **Settings** tab and confirm that the **Voltages** appear correct.

3. If upgrading from version 1, delete all **Efficiency cals** from the **Settings** tab. Older versions of the software used a different method to perform the efficiency calibration. Thus, these calibrations are invalid and will show as blank.

4. Click **Save** to save the settings file in the updated format.

One can also manually specify all parameters in the **Settings** tab, including the **Backgrounds**, **Energy cals**, and **Efficiency cals**. However, it is usually easier to simply repeat the calibrations.

5.3 Replacing usbBase

Occasionally a usbBase will stop communicating with the SpecFIDLER software. The cause of this issue is unknown, but it seems to occur most frequently when first commissioning a detector. Use the following procedure to exchange a base:

1. Unplug the old base from the USB hub.

2. Carefully cut the plastic heat shrink between the old base and the detector.

3. Unplug the old base from the detector.

4. Plug the new base onto the detector, taking care to line up the key on the detector end with the notch on the base socket.

5. Replace the heat shrink. The outer diameter of the usbBase is about 2.25”.

6. Perform a voltage calibration, energy calibration, and efficiency calibration on the new base.

5.4 Log Files

The SpecFIDLER software saves daily log files to the SpecFIDLER working directory (**c:\fidler** by default). These log files contain more detailed information about warnings and errors encountered by the software.

Appendix A – Configuration File

The SpecFIDLER software uses a configuration file named **SpecFidler.exe.config** to define general application parameters. This file is in the same directory as the application **SpecFidler.exe**.

The values of most interest are as follows:

- **configuration/log4net/file**: Base path for log files.
- **appSettings**: Defines the working directory and enables simulated mode.

An example configuration file appears below.

```
<?xml version="1.0" encoding="utf-8"?>
<configuration>
  <configSections>
    <section name="log4net"
             type="log4net.Config.Log4NetConfigurationSectionHandler,
             log4net"/>
  </configSections>
  <log4net>
    <root>
      <level value="INFO"/>
      <appender-ref ref="RollingFileAppender"/>
    </root>
    <appender name="RollingFileAppender"
             type="log4net.Appender.RollingFileAppender">
      <appendToFile value="true"/>
      <file value="C:\fidler\SpecFIDLER.log"/>
      <layout type="log4net.Layout.PatternLayout">
        <conversionPattern value="%date{HH:mm:ss} %-5level %logger{1} -
            %message%newline%exception"/>
      </layout>
      <lockingModel type="log4net.Appender.FileAppender+MinimalLock"/>
      <maxSizeRollBackups value="10"/>
      <maximumFileSize value="100KB"/>
      <rollingStyle value="Size"/>
      <staticLogFileName value="true"/>
    </appender>
  </log4net>
  <appSettings>
    <add key="WorkingDir" value="C:\fidler\"/>
    <add key="Simulated" value="true"/>
  </appSettings>
```

(truncated)

```
</configuration>
```

Appendix B – Settings File

The SpecFIDLER software uses a settings file named **settings.xml** to store all user parameters. Many but not all values may be modified through the user interface. This file is stored in the SpecFIDLER working directory (**c:\fidler** by default).

The software also has default settings built in. These defaults are loaded first, and then the settings file overrides the defaults. This mechanism allows the software to function if the settings file is missing or has the wrong version. The software issues a warning message in this case.

An example settings file appears below, with annotations describing each section.

First are general preferences, such as the y-axis scale, user name, and so forth.

```
<?xml version="1.0" encoding="utf-8" ?>
<SpecFIDLER>
  <audio>false</audio>
  <calibratedData>false</calibratedData>
  <fitRange>100</fitRange>
  <logarithmicScale>false</logarithmicScale>
  <site></site>
  <user>CMRT / FRMAC</user>
  <windowedSpectrum>false</windowedSpectrum>
```

The **alarmThresholds** section defines the count rate thresholds for the audible alarm.

```
  <alarmThresholds>
    <channelWindow>100</channelWindow>
    <energyWindow>100</energyWindow>
    <grossCounts>500</grossCounts>
  </alarmThresholds>
```

The **backgrounds** section provides the background measurements for each device. Location information is saved with the background.

```
  <backgrounds>
    <background>
      <enabled>true</enabled>
      <deviceId>SIMULATOR</deviceId>
      <acquisitionDate>2000-01-01T00:00:00</acquisitionDate>
      <realTime>3598.480</realTime>
      <liveTime>3597.989</liveTime>
      <spectrum>1 1 2 3 4 7 12 27 50 92 171 300 374 (truncated) </spectrum>
      <latitude>46.349149028339191</latitude>
      <longitude>-119.27910736043991</longitude>
      <accuracy>1</accuracy>
    </background>
  </backgrounds>
```

The **efficiencyCalibrations** section gives the efficiency calibrations for each device. One component exists for each ROI and background algorithm. The **intrinsicEfficiency** specifies counts per incident gamma in the ROI.

```
<efficiencyCalibrations>
  <efficiencyCalibration>
    <enabled>true</enabled>
    <deviceId>SIMULATOR</deviceId>
    <calibrationDate>2015-09-09T00:00:00</calibrationDate>
    <efficiencyComponents>
      <efficiencyComponent>
        <region>17</region>
        <backgroundAlgorithm>OneWindow</backgroundAlgorithm>
        <intrinsicEfficiency>0.596370309</intrinsicEfficiency>
      </efficiencyComponent>
      <efficiencyComponent>
        <region>59.5</region>
        <backgroundAlgorithm>OneWindow</backgroundAlgorithm>
        <intrinsicEfficiency>0.70102444</intrinsicEfficiency>
      </efficiencyComponent>
      <efficiencyComponent>
        <region>17</region>
        <backgroundAlgorithm>ThreeWindow</backgroundAlgorithm>
        <intrinsicEfficiency>0.466786589</intrinsicEfficiency>
      </efficiencyComponent>
      <efficiencyComponent>
        <region>59.5</region>
        <backgroundAlgorithm>ThreeWindow</backgroundAlgorithm>
        <intrinsicEfficiency>0.472717231</intrinsicEfficiency>
      </efficiencyComponent>
    </efficiencyComponents>
  </efficiencyCalibration>
</efficiencyCalibrations>
```

The **energyCalibrations** section gives the energy calibrations for each device.

```
<energyCalibrations>
  <energyCalibration>
    <enabled>true</enabled>
    <deviceId>SIMULATOR</deviceId>
    <calibrationDate>2015-09-09T00:00:00</calibrationDate>
    <yIntercept>-0.13483146067415</yIntercept>
    <slope>0.308988764044944</slope>
    <quadratic>0</quadratic>
  </energyCalibration>
</energyCalibrations>
```

The **models** section provides the measurements used by the simulator. The spectrum is truncated; a full spectrum will include 4096 values.

```
<models>
  <model>
    <enabled>false</enabled>
    <name>Background</name>
    <acquisitionDate>2000-01-01T00:00:00</acquisitionDate>
    <realTime>3598.480</realTime>
    <liveTime>3597.989</liveTime>
    <spectrum>1 1 2 3 4 7 12 27 50 92 171 300 374 (truncated) </spectrum>
  </model>
  <model>
    <enabled>true</enabled>
    <name>Am-241</name>
    <acquisitionDate>2000-01-01T00:00:00</acquisitionDate>
    <realTime>3599.183</realTime>
    <liveTime>3596.861</liveTime>
    <spectrum>1 4 1 1 8 10 22 53 81 172 283 402 460 (truncated) </spectrum>
  </model>
  <model>
    <enabled>false</enabled>
    <name>Ba-133</name>
    <acquisitionDate>2000-01-01T00:00:00</acquisitionDate>
    <realTime>900.000</realTime>
    <liveTime>899.200</liveTime>
    <spectrum>3 19 21 21 37 49 49 43 26 26 26 8 6 6 (truncated) </spectrum>
  </model>
  <model>
    <enabled>false</enabled>
    <name>Cs-137</name>
    <acquisitionDate>2000-01-01T00:00:00</acquisitionDate>
    <realTime>900.000</realTime>
    <liveTime>899.200</liveTime>
    <spectrum>6 32 36 36 41 44 44 37 17 17 17 (truncated) </spectrum>
  </model>
</models>
```

The **output** section enables auto saving and provides additional parameters for the output files, such as the instrument information given in the .n42 file. Note that the **instumentClassCode** and **detectorCategoryCode** must have one of the enumerated values in the N42.42 schema.

```
<output>
  <autoSaveRate>false</autoSaveRate>
  <autoSaveSpectrum>false</autoSaveSpectrum>
  <autoSaveAnalysis>false</autoSaveAnalysis>
  <instrumentManufacturerName>
    Pacific Northwest National Laboratory
  </instrumentManufacturerName>
  <instrumentModelName>Scintillation Crystal</instrumentModelName>
  <instrumentClassCode>Radionuclide Identifier</instrumentClassCode>
  <instrumentComponentName>SpecFIDLER Software</instrumentComponentName>
  <detectorCategoryCode>Gamma</detectorCategoryCode>
  <detectorKindCode>NaI</detectorKindCode>
</output>
```

The **nuclides** section provides various parameters for nuclides of interest. The **key** is a unique identifier. The **halfLife** is in years whereas the **specificActivity** is in becquerels per gram.

```
<nuclides>
  <nuclide>
    <key>Am-241</key>
    <name>Am-241</name>
    <category>Am241</category>
    <single>true</single>
    <halfLife>4.3220e+02</halfLife>
    <specificActivity>1.2696e+11</specificActivity>
    <decayProduct>Np-237</decayProduct>
    <branchingRatio>1.0000e+00</branchingRatio>
    <emissions>
      <emission>
        <region>17</region>
        <yield>3.7660e-01</yield>
      </emission>
      <emission>
        <region>59.5</region>
        <yield>3.5925e-01</yield>
      </emission>
    </emissions>
  </nuclide>
  <nuclide>
    <key>Th-228</key>
    <name>Th-228</name>
    <category>Alpha</category>
    <single>false</single>
    <halfLife>1.9116e+00</halfLife>
    <specificActivity>3.0346e+13</specificActivity>
    <decayProduct></decayProduct>
    <branchingRatio>1.0000e+00</branchingRatio>
    <emissions>
      <emission>
        <region>17</region>
        <yield>8.6000e-02</yield>
```

```
      </emission>
    </emissions>
  </nuclide>
  <nuclide>
    <key>U-232</key>
    <name>U-232</name>
    <category>Alpha</category>
    <single>false</single>
    <halfLife>6.8900e+01</halfLife>
    <specificActivity>8.2738e+11</specificActivity>
    <decayProduct>Th-228</decayProduct>
    <branchingRatio>1.0000e+00</branchingRatio>
    <emissions>
      <emission>
        <region>17</region>
        <yield>1.1000e-01</yield>
      </emission>
    </emissions>
  </nuclide>
  <nuclide>
    <key>Pu-236</key>
    <name>Pu-236</name>
    <category>Alpha</category>
    <single>false</single>
    <halfLife>2.8580e+00</halfLife>
    <specificActivity>1.9608e+13</specificActivity>
    <decayProduct>U-232</decayProduct>
    <branchingRatio>1.0000e+00</branchingRatio>
    <emissions>
      <emission>
        <region>17</region>
        <yield>1.3000e-01</yield>
      </emission>
    </emissions>
  </nuclide>
  <nuclide>
    <key>Np-237</key>
    <name>Np-237</name>
    <category>Alpha</category>
    <single>false</single>
    <halfLife>2.1440e+06</halfLife>
    <specificActivity>2.6027e+07</specificActivity>
    <decayProduct></decayProduct>
    <branchingRatio>1.0000e+00</branchingRatio>
    <emissions>
      <emission>
        <region>17</region>
        <yield>1.0030e+00</yield>
      </emission>
    </emissions>
  </nuclide>
  <nuclide>
    <key>Pu-237</key>
    <name>Pu-237</name>
    <category>Alpha</category>
```

```
    <single>false</single>
    <halfLife>1.2375e-01</halfLife>
    <specificActivity>4.5091e+14</specificActivity>
    <decayProduct></decayProduct>
    <branchingRatio>1.0000e+00</branchingRatio>
    <emissions>
      <emission>
        <region>17</region>
        <yield>5.2000e-01</yield>
      </emission>
    </emissions>
  </nuclide>
  <nuclide>
    <key>Pu-238</key>
    <name>Pu-238</name>
    <category>Alpha</category>
    <single>true</single>
    <halfLife>8.7700e+01</halfLife>
    <specificActivity>6.3360e+11</specificActivity>
    <decayProduct></decayProduct>
    <branchingRatio>1.0000e+00</branchingRatio>
    <emissions>
      <emission>
        <region>17</region>
        <yield>1.0630e-01</yield>
      </emission>
    </emissions>
  </nuclide>
  <nuclide>
    <key>Pu-239</key>
    <name>Pu-239</name>
    <category>Alpha</category>
    <single>false</single>
    <halfLife>2.4110e+04</halfLife>
    <specificActivity>2.2950e+09</specificActivity>
    <decayProduct></decayProduct>
    <branchingRatio>1.0000e+00</branchingRatio>
    <emissions>
      <emission>
        <region>17</region>
        <yield>4.6600e-02</yield>
      </emission>
    </emissions>
  </nuclide>
  <nuclide>
    <key>Pu-240</key>
    <name>Pu-240</name>
    <category>Alpha</category>
    <single>false</single>
    <halfLife>6.5640e+03</halfLife>
    <specificActivity>8.3947e+09</specificActivity>
    <decayProduct></decayProduct>
    <branchingRatio>1.0000e+00</branchingRatio>
    <emissions>
      <emission>
```

```
      <region>17</region>
      <yield>1.0340e-01</yield>
    </emission>
  </emissions>
</nuclide>
<nuclide>
  <key>Pu-241</key>
  <name>Pu-241</name>
  <category>None</category>
  <single>false</single>
  <halfLife>1.4350e+01</halfLife>
  <specificActivity>3.8239e+12</specificActivity>
  <decayProduct>Am-241</decayProduct>
  <branchingRatio>1.0000e+00</branchingRatio>
  <emissions>
    <emission>
      <region>17</region>
      <yield>2.6115e-05</yield>
    </emission>
  </emissions>
</nuclide>
<nuclide>
  <key>Pu-242</key>
  <name>Pu-242</name>
  <category>Alpha</category>
  <single>false</single>
  <halfLife>3.7500e+05</halfLife>
  <specificActivity>1.4572e+08</specificActivity>
  <decayProduct></decayProduct>
  <branchingRatio>1.0000e+00</branchingRatio>
  <emissions>
    <emission>
      <region>17</region>
      <yield>8.7100e-02</yield>
    </emission>
  </emissions>
</nuclide>
<nuclide>
  <key>Pu-244</key>
  <name>Pu-244</name>
  <category>Alpha</category>
  <single>false</single>
  <halfLife>8.0000e+07</halfLife>
  <specificActivity>6.7747e+05</specificActivity>
  <decayProduct>Pu-240</decayProduct>
  <branchingRatio>9.9770e-01</branchingRatio>
  <emissions>
    <emission>
      <region>17</region>
      <yield>5.6900e-02</yield>
    </emission>
  </emissions>
</nuclide>
```

The **peaks** section lists possible peaks for the energy calibration. The **energy** has units of keV.

```
<peaks>
  <peak>
    <source>Am-241</source>
    <energy>15.7</energy>
  </peak>
  <peak>
    <source>Am-241</source>
    <energy>59.5</energy>
  </peak>
  <peak>
    <source>Ba-133</source>
    <energy>31.6</energy>
  </peak>
  <peak>
    <source>Ba-133</source>
    <energy>80.9</energy>
  </peak>
  <peak>
    <source>Cd-109</source>
    <energy>22.1</energy>
  </peak>
  <peak>
    <source>Cd-109</source>
    <energy>88.0</energy>
  </peak>
  <peak>
    <source>Co-57</source>
    <energy>122.1</energy>
  </peak>
  <peak>
    <source>Cs-137</source>
    <energy>32.1</energy>
  </peak>
</peaks>
```

The **rateWindows** section provides the options for the rate chart time binning.

```
<rateWindows selected="1">
  <seconds>1</seconds>
  <seconds>2</seconds>
  <seconds>3</seconds>
  <seconds>5</seconds>
  <seconds>10</seconds>
  <seconds>15</seconds>
  <seconds>30</seconds>
  <seconds>60</seconds>
</rateWindows>
```

The **regions** section lists the ROI for analysis. The **key** is a unique identifier. The **order** specifies the analysis order. The **energyLow** and **energyHigh** are the ROI bounds in keV. The **backgroundLow** and **backgroundHigh** define the background region in keV for the three-window method. The **airAttenuationCoefficient** gives the linear attenuation coefficient for air,

in units of inverse meters. Finally, the **plasticAttenuationCoefficient** provides a similar value for the plastic on top of the calibration source.

```
<regions>
  <region>
    <key>17</key>
    <name>17 keV</name>
    <order>2</order>
    <energyLow>11.0</energyLow>
    <energyHigh>23.0</energyHigh>
    <backgroundLow>7.0</backgroundLow>
    <backgroundHigh>27.0</backgroundHigh>
    <airAttenuationCoefficient>1.2640e-01</airAttenuationCoefficient>
    <plasticAttenuationCoefficient>
      4.7021e+01
    </plasticAttenuationCoefficient>
  </region>
  <region>
    <key>59.5</key>
    <name>60 keV</name>
    <order>1</order>
    <energyLow>54.0</energyLow>
    <energyHigh>66.0</energyHigh>
    <backgroundLow>50.0</backgroundLow>
    <backgroundHigh>70.0</backgroundHigh>
    <airAttenuationCoefficient>2.1003e-02</airAttenuationCoefficient>
    <plasticAttenuationCoefficient>
      8.6226e+00
    </plasticAttenuationCoefficient>
  </region>
</regions>
```

The **runTimes** section provides the options for the run time.

```
<runTimes selected="600">
  <seconds>30</seconds>
  <seconds>60</seconds>
  <seconds>90</seconds>
  <seconds>180</seconds>
  <seconds>300</seconds>
  <seconds>600</seconds>
  <seconds>1200</seconds>
  <seconds>1800</seconds>
  <seconds>3600</seconds>
</runTimes>
```

The **sourceTerms** section lists the mixtures of nuclides defined for analysis.

```
<sourceTerms>
  <sourceTerm>
    <enabled>false</enabled>
    <name>ReactorGrade</name>
    <calculationDate>2000-01-01T00:00:00</calculationDate>
    <constituents>
      <constituent>
        <nuclide>Pu-238</nuclide>
        <massFraction>1.5000e-02</massFraction>
      </constituent>
      <constituent>
        <nuclide>Pu-239</nuclide>
        <massFraction>5.8100e-01</massFraction>
      </constituent>
      <constituent>
        <nuclide>Pu-240</nuclide>
        <massFraction>2.4100e-01</massFraction>
      </constituent>
      <constituent>
        <nuclide>Pu-241</nuclide>
        <massFraction>1.1400e-01</massFraction>
      </constituent>
      <constituent>
        <nuclide>Pu-242</nuclide>
        <massFraction>4.9000e-02</massFraction>
      </constituent>
    </constituents>
  </sourceTerm>
  <sourceTerm>
    <enabled>true</enabled>
    <name>Am-241_100%</name>
    <calculationDate>2000-01-01T00:00:00</calculationDate>
    <constituents>
      <constituent>
        <nuclide>Am-241</nuclide>
        <massFraction>1.0000e+00</massFraction>
      </constituent>
    </constituents>
  </sourceTerm>
```

(truncated)

```
</sourceTerms>
```

The **streaming** section specifies the local IP address and port number of the streaming server. Set the IP address to 0.0.0.0 to accept any incoming connections.

```
  <streaming>
    <enabled>false</enabled>
    <ipAddress>0.0.0.0</ipAddress>
    <portNumber>4002</portNumber>
  </streaming>
```

The **voltages** section gives the high voltage setpoints for each device.

```
  <voltages>
    <voltage>
      <enabled>true</enabled>
      <deviceId>SIMULATOR</deviceId>
      <calibrationDate>2015-09-09T00:00:00</calibrationDate>
      <volts>1000</volts>
    </voltage>
  </voltages>
```

The **window** section specifies the bounds for the rate window. The **channelLow** and **channelHigh** are used for uncalibrated spectra. The **energyLow** and **energyHigh** are used for the calibrated spectra.

```
  <window>
    <channelLow>0</channelLow>
    <channelHigh>256</channelHigh>
    <energyLow>11</energyLow>
    <energyHigh>66</energyHigh>
  </window>
```

Finally, the **xAxis** section specifies the bounds for the x-axis on the plots. The **channelLow** and **channelHigh** are used for uncalibrated spectra. The **energyLow** and **energyHigh** are used for the calibrated spectra.

```
  <xAxis>
    <channelLow>0</channelLow>
    <channelHigh>1024</channelHigh>
    <energyLow>0</energyLow>
    <energyHigh>250</energyHigh>
  </xAxis>
</SpecFIDLER>
```

Appendix C – Algorithms

This appendix describes the algorithms used for background subtraction, energy calibration, efficiency calibration, and nuclide analysis. These algorithms incorporate the simplified calibration procedure developed by the Remote Sensing Laboratory (RSL) [Okada 2018]. In addition, the calculation framework draws heavily from the spreadsheet developed at Sandia National Laboratories (SNL) [Enghauser 2019].

C.1 Background Subtraction

The one-window method uses a prior background measurement to compute the net count rate in counts per minute (cpm):

1. Integrate the counts in the foreground spectrum between the ROI energy limits, interpolating between channels.

2. Divide the result by the live time to compute the total count rate C.

3. Repeat the above for the background spectrum to compute the background count rate B.

4. Subtract $C - B$ to compute the net count rate N.

In contrast, the three-window method extrapolates the background counts from adjacent regions in the spectrum:

1. Integrate the counts in the foreground spectrum between the ROI energy limits, interpolating between channels.

2. Divide the result by the live time to compute the total count rate C.

3. Repeat the above for the left and right windows adjacent to the ROI to compute the count rates L and R.

4. Use the following formula to compute the net count rate:

$$N = C - \frac{1}{2}\left(\frac{L}{\Delta E_L} + \frac{R}{\Delta E_R}\right)\Delta E_C$$

   where ΔE_L, ΔE_R, and ΔE_C denote the energy span of each window (keV).

C.2 Energy Calibration

Clicking on a peak in the **Energy Cal** tab causes the software to fit the peak to a Gaussian function and report the center channel. This process involves the following steps:

1. Find the local maximum near the click. The search distance is specified by **FitRange**.
2. Find the local minima on either side. Again, the search distance is specified by **FitRange**.
3. Find the points halfway in amplitude between the minima and maximum.
4. Use a truncated-Newton optimization algorithm to minimize the mean squared error between the spectrum and the Gaussian function

$$a \exp\left(-\frac{(i-\mu)^2}{2\sigma^2}\right) + b$$

   between the two half maximum points. The value b specifies a constant baseline underneath the peak, which should be accurate enough for the present purpose.
5. Record the center channel μ.

To calculate the coefficients of the energy calibration, the software uses the truncated-Newton optimization package again to compute the quadratic regression between the channel numbers and associated peak energies. If only two peaks are specified, the software computes the linear regression instead.

The software then checks the results to ensure that the slope of the energy calibration remains positive and varies by less than 10% across the ROI range. In addition, the software verifies that the regression matches the actual peak energies to within 5%. Any unusual findings cause the software to display a warning message.

C.3 Efficiency Calibration

To compute the intrinsic efficiency ε of each ROI, the software uses the following formula:

$$\varepsilon = \frac{N}{k\ Q\ Y\ S\ T}$$

Here N is the net count rate in the ROI (cpm), k is a unit conversion factor (dpm/µCi), Q is the decay-corrected source activity (µCi), Y is the yield of the nuclide in the ROI, S is the solid angle fraction for a point source directly underneath the detector, and T is the transmission factor through the intervening plastic and air.

It is assumed that the detector has the same intrinsic efficiency to all gamma emissions in the ROI. As the width of the ROI is relatively small, and the low-energy gamma emissions from transuranic nuclides are consistent, this assumption should not introduce significant error.

The solid angle fraction S is the ratio of the detector area to the surface area of a sphere with radius h:

$$S = \frac{R^2}{4h^2}$$

where R is the detector radius (m).

The transmission factor T is the product of two terms:

$$T = \exp\left(-\mu_p\ d\right) \exp\left(-\mu_a\ h\right)$$

where μ_p is the linear attenuation coefficient of the plastic (1/m), d is the plastic thickness (m), μ_a is the linear attenuation coefficient of the air (1/m), and h is the detector height (m). Both attenuation coefficients are taken at the mean energy of the ROI with representative densities. For greater accuracy, the mean path lengths should be used in place of the plastic thickness and height; these values are about 10% larger than the straight-line distances given a detector height of 0.30 m. In practice, other sources of error will dominate.

C.4 Nuclide Analysis

Given a source term with a mixture of nuclides, the software first calculates the overall quantity Q in each ROI:

$$Q = \frac{N}{\sum_i (F_i\, Y_i)\, S\, T\, \varepsilon\, k}$$

Here N is the net count rate in the ROI (cpm), F_i is the activity fraction for one nuclide, Y_i is the yield of that nuclide in the ROI, S is the solid angle fraction for a point source directly underneath the detector, T is the transmission factor through the air, ε is the intrinsic efficiency in the ROI, and k is a unit conversion factor. This formulation supports both point sources and distributed sources.

The activity fractions are computed from the mass fractions specified by the source term, and then scaled to sum to one:

$$\sum_i F_i = 1$$

As before, the solid angle fraction S is the ratio of the detector area to the surface area of a sphere with radius h:

$$S = \frac{R^2}{4h^2}$$

where R is the detector radius (m).

For a point source, the transmission factor T is simply

$$T = \exp\left(-\mu_a\, h\right)$$

where μ_a is the linear attenuation coefficient of the air (1/m) and h is the detector height (m). For a distributed source, the transmission factor integrates activity from differential area dA over infinite disc D, accounting for changes to the solid angle and path length:

$$T = \iint_D \frac{h^2}{h^2 + r^2} \cos\varphi \exp\left(-\mu_a \sqrt{h^2 + r^2}\right) dA$$

Here r is the radial offset to dA, whereas φ represents the angle between the vertical line through the detector center and the line from the detector center to dA. The first term accounts for the decrease in solid angle as dA moves further away from the detector. The second term accounts for the decrease in geometric efficiency as emissions from dA intercept the detector at an angle. The final term specifies the air attenuation over the path.

The corresponding integral

$$T = \int_0^{2\pi} \int_0^{\infty} \frac{h^3}{(h^2 + r^2)^{3/2}} \exp\left(-\mu_a \sqrt{h^2 + r^2}\right) r \, dr \, d\theta$$

has the solution

$$T = 2\pi h^2 \left(\exp(-\mu_a h) + \mu_a h \, \mathrm{Ei}(-\mu_a h)\right)$$

where Ei represents the exponential integral.

The unit conversion factor k depends on the selected **Source type and units**. For a point source, the result Q will be in µCi, Bq, or kBq. For a distributed source, Q will be in µCi/m^2 or Bq/m^2.

The software also calculates the overall MDA in each ROI:

$$MDA = \frac{2.71 + 4.66\sqrt{B}}{\sum_i (F_i \, Y_i) \, T \, S \, \varepsilon \, k\sqrt{t}}$$

Here B is the background count rate in the ROI (cpm), t is the live time, and all other terms are the same as before.

The quantity and MDA of an individual nuclide are equal to the overall values multiplied by the activity fraction F_i. The software highlights the computed quantity of Am-241 as well as the sum of all alpha emitters.

If the ROI computations are performed independently, the results may well be different for each ROI. One source of uncertainty is the relative abundance of Am-241 versus other isotopes. The “independent” method assumes that the specified activity fractions are fixed. However, the quantity of Am-241 can be deduced from the 60 keV ROI and then propagated to the 17 keV ROI. The “linked” method implements this approach. The calculations proceed as above, but the 17 keV results are then adjusted as follows:

1. Copy the quantity Q_i of Am-241 from the 60 keV ROI to the 17 keV ROI.

2. Scale the activity fraction F_i for Am-241 to obtain the desired value of Q_i.

3. Scale F_i for all other isotopes so that $\sum_i (F_i \, Y_i)$ is the same as before. This returns the overall quantity Q in the 17 keV ROI to its original calculated value. This step assumes that the source term defines other isotopes besides Am-241.

4. After the above steps, $\sum_i F_i \neq 1$. Thus, scale Q and all F_i so that $\sum_i F_i = 1$ once more.

Note that the 17 keV ROI will specify the new activity fractions, but the 60 keV ROI will still contain the original ones.

C.5 References

Grove Software, Inc., “RadDecay 3.0”, July 2006.

C Okada, “The SpecFIDLER”, December 2018.

M Enghauser, “SNL_SpecFIDLER_V000” Excel spreadsheet, November 2019.

Appendix D – Licensing

The SpecFIDLER software uses the libftdi and libusb-win32 libraries, which are individually released under version 2.1 of the GNU Lesser General Public License. The text of this license is included in Section D.1 for reference. Please contact the authors if the relevant object and/or source code is desired to relink the software with modified versions of these libraries.

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```
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