Spectrum Viewer and Calibration

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Contents

List of Figures

1 Introduction

This software is intended for use to calibrate, view, and analyze spectrum collected from various nuclear instrumentation. The document serves as the primary usage document. This software was developed using Python 3.8 and PyQt5 using packages such as Matplotlib and NumPy. The software has been developed into an executable file such that it can be run as any other program, this is done using PyInstaller. All code is considered open source.

This software is very much in beta phase testing, as such bugs and glitches are to be expeceted. You should report such bugs to the developer or care holder of the software upon discovery of such issues.

2 Install and Initial Opening of Software

This software is provided in a zip folder named Spectrum_Viewer.zip, this folder contains all required libraries and packages for the software to run on a Windows configured machine. Before operation the software first must be unzipped, the built in method doing this in Windows10 should suffice. In the unzipped folder, there will be approximately 200 items. To easily locate the executable file, sort by file type and choose Application. The only file that should appear will be Spectrum_Viewer.exe. This can be double clicked and the application will launch in full screen mode.

The interface will a window containing three main areas, shown below in Figure 1. The left most window will be populated when spectrum are being loaded. The right most window will be populated when spectrum are added to the graph. The center section features a full featured graphing utility. This graphing tool bar features the capabiltiy to zoom, pan, save, as well as other varius graphing features. It will be noted that the graph window appears to not fill the screen, this is corrected by navigating to the configure subplots selection. This will open a new dialog box, selection of "Tight_Layout" will adjust the graph to full size. This may need to be repeated once spectrum are added.

3 Discussion of Graph Setup

The graph is initiated to be a energy calibrated, count rate spectrum. The count rate by default is shown in logarithmic scale to reveal small magnitude peaks. The energy by default ranges from 0 to 14MeV, the should encompass to vast majority of all possible energies normally seen, this can be adjusted, but more about that in a later section.

There are currently four seperate main drop downs from the menu bar, these are: File, Edit, View Spectrum Data, and List Mode Data Analysis.

4 File Menu

This menu is primarily used for the loading and saving of calibrated spectrum. The methods are listed below as well as there functions:

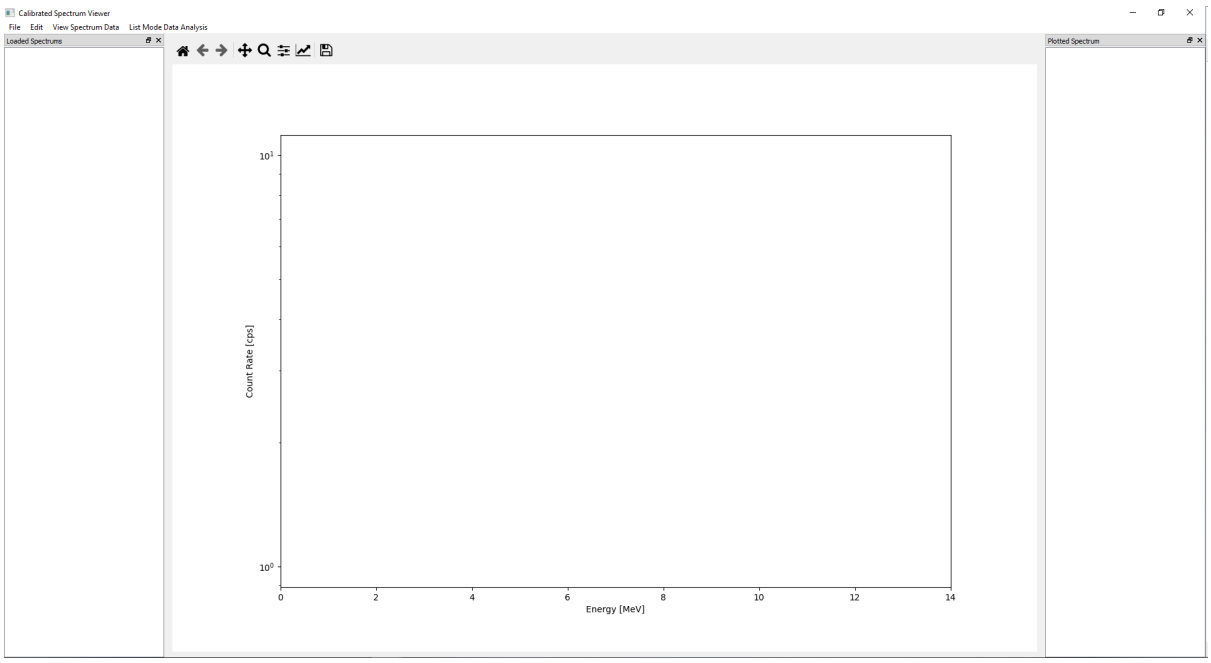

Figure 1: User interface upon initial startup.

4.1 Load New Spectrum

This will open a pop up, this is seen below in Figure 2.
It expects as input:

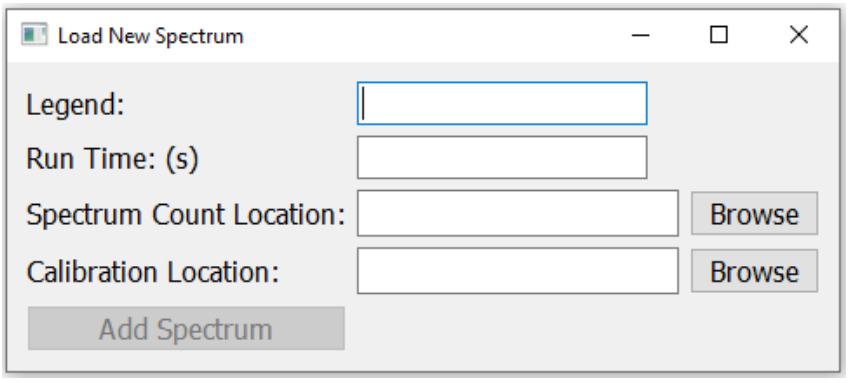

Figure 2: GUI to load new spectrum and calibration.

4.1.1 Legend

The name associated with the calibrated spectrum that will appear in the legend generated during graphing.

4.1.2 Run Time(s)

The total run time of the spectrum accumulation. If left blank, it will default to 1.

4.1.3 Spectrum Count Location

The absolute path to the file containing the spectrum counts on a per channel basis. Will accept plan text(.txt), comma seperated(.csv), and spectrum files(.spe).

4.1.4 Calibration Location

Absolute path to the calibration file generated using the calibrate spectrum feature (discussed in more detail later). This file will be a single column of energy values whose length corresponds to the total number of channels the spectrum was accumulated using.

4.2 Save Spectrum Image

This will save a high quality image, 600dpi, to the file name and location entered in the standard windows file explorer that will be brought up upon selection.

4.3 Save Spe File

Saves the loaded spectrum out to a .spe file format, including the accumulation time. If a non-linear calibration is incorporated, it will fit a linear equation to the data. This is done to ensure an approximate calibration is saved.

5 Edit Menu

The only option is Calibrate Spectrum. This will launch a new window, seen in Figure 3. The main widget features the same functions as that of the calibrated spectrum viewer. The dotted black line that appears is used to track the cursor to help in the identification of peak centroids. Double-right clicking with initiate a input dialog that will take the energy of the peak in MeV. This will be added to the widget on the left-hand side. Double-left clicking will remove the peak-channel pair. There is no limit to the numer of peaks that can be selected, but a minimum of two are required. This window has one drop down in the menu bar:

5.1 Load New Spectrum

This will load the per channel counts in the spectrum. Takes plain texts files as the argument. It expects a single column of data.

5.2 Calibrate

This loads a drop down menu with the following options:

5.2.1 Linear

Performs a linear least squares regression, ultimately resulting in the calibration being in the form of:

$$y = mx + b \tag{1}$$

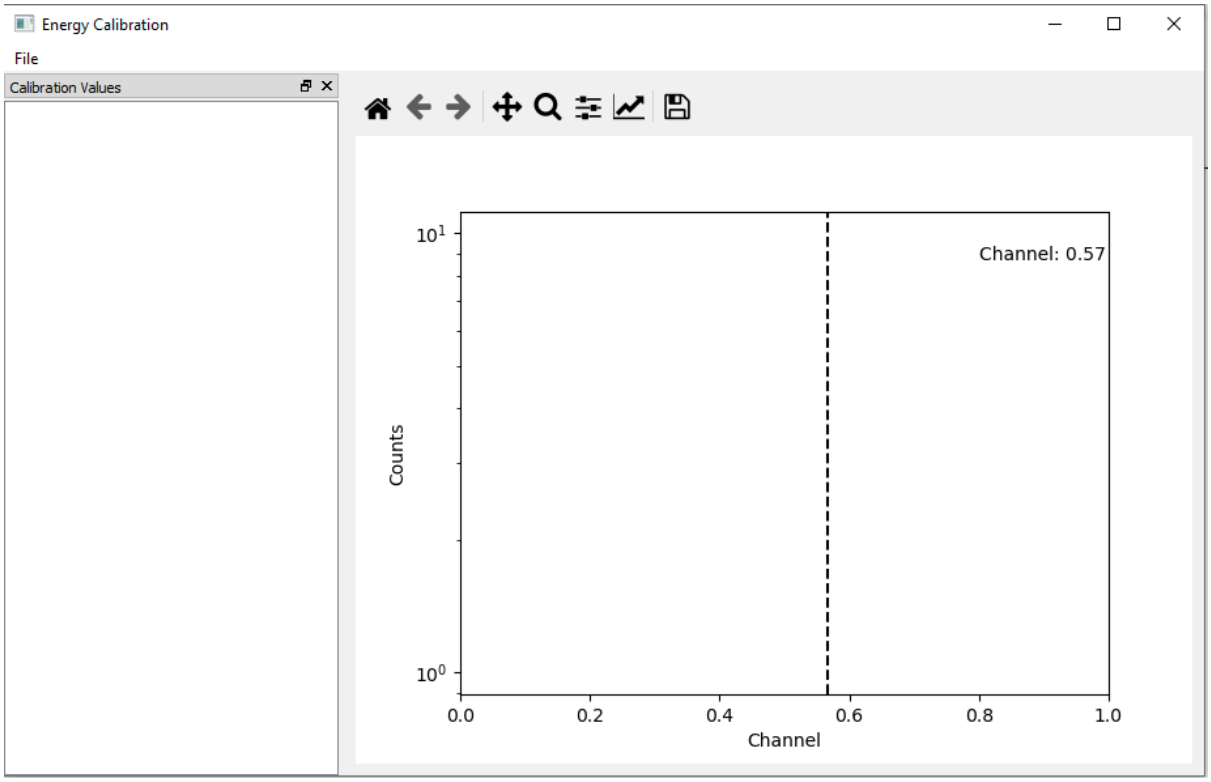

Figure 3: Calibration interface.

5.2.2 Deviation Pairs

Conducts a linear least squares fit, the determines the devaition from this at the known points to create and scale each data point. This can be used to generate a non-linear calibration.

5.2.3 External Calibration

Used if a known slope and intercept are to be input. It will fit the calibration to equation 1.

5.2.4 Segmented Linear

Fits a linear between each successive point of the inputs.

5.3 Save Calibration

Will save a single column of that relate the channel to calibrated energy as a plain text file(.txt) to the specified location.

6 View Spectrum Data

This drop down has options that come directly from the data loaded into the main interface.

6.1 View Energies

This takes a set of energies, in MeV, seperated by commas to draw vertical lines on the graph. These lines will be drawn as a dotted red line.

6.2 Change Zoom Location

Changes the minimumum and maximum energies shown on the graph. Much like a zoom feature.

6.3 Calibration Energies

Takes a set of values, seperated by commans to draw vertical lines representing calibration energies. These will appear as solid black lines.

6.4 Count Rates

Will display the count rate of all loaded spectrum in counts per second. If a time of 1 second has been entered for the accumulation time, the value displayed will be the total number of counts in the total spectrum.

6.5 ROI Uncertainties

This will compute the gross count rate, net count rate, and the associtate uncertainties for each in a specified region of interest. The gross count uncertainties are found using $\sigma = \sqrt{N}$, where σ is the standard deviation and N is the number of counts in the region of interest. The net uncertainty is found using equation 2, where σ_F and σ_B are foreground and background standard deviations respectively.

$$\sigma_{net} = \sqrt{\sigma_F^2 + \sigma_B^2} \tag{2}$$

7 List Mode Data Analysis

For data collected using a digitizer, or similiar equipment, this menu features numerous options to analyze and save various data. This has the expectation of time dependent data being collected, i.e. a source is being pulsed using a logic pulse. With detector and sync pulse data both being captured and recoreded as raw data.

7.1 View Time Decay

This is used to generate a plot of multiple region of interest pulse arrival times relative to the sync pulse. This must be run after having used the list mode data set of tools. The first pop up will request the number of data sets to be plotted. After selection of this, the windows file explorer will be generated. It will expect a file that is two columns, the first being time stamps, the second being a number of counts accumulated during the time step. This will be repeated for the total number of files selected. Several additional windows will appear that request additional information regarding the frequency, duty cylce, and location of region dividers. All of which are optional. The data will be

processed and plotted in the window upon clicking the "Process" button. A high quality image, 600dpi, can be saved with the selection of the "Save Image" button.

7.2 Analyze List Mode Data

This is the primary interface for loading and manipulating time dependent data. As such an entire section is dedicated to this later in this document.

7.3 Detection Probability

7.3.1 Theory

This is used to determine the time required to reach 99% detection probability. Poisson and Gaussian Statistics are implemented in their respsective regimes, less than 30 counts for Poisson and any number of counts greater than 30 for Gaussian. For Poisson statistics, the distribution is only dependent on the mean, μ, in this case the mean is taken as the number of counts, this is seen in equation 3. Gaussian statistic distribution is dependent on a mean, μ, and variance, the mean is again taken to be the number of counts and the standard deviation to be $\sigma = \sqrt{N}$, the distribution function is seen in equation 4.

$$P = \frac{\mu^k exp\left(-\mu\right)}{k!} \tag{3}$$

$$P = \frac{1}{2\pi\sigma^2} exp\left(\frac{\left(\mu - k\right)^2}{2\sigma^2}\right) \tag{4}$$

An example of a foreground and background distribution plotted together are seen in Figure 4. The background distribution is used in conjunction with a maximum false alarm rate, one alarm per eight hours is the default, to find a threshold to be used to determine the detection probability.

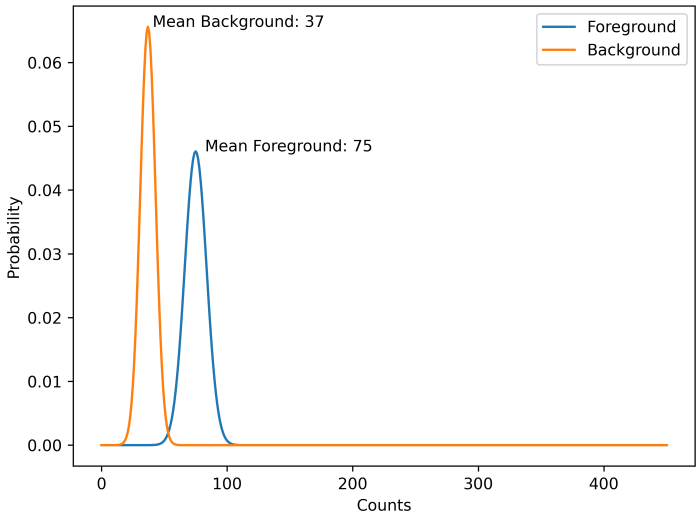

Figure 4: Probability distribution functions for a foreground and background plotted together.

The probability distribution functions are then numerically integrated using trapeziodal rule. The integration of this must sum to exactly one. The foreground and background cumulative density functions, along with the threshold is seen in Figure 5.
Using the cummulative density function and the threshold, the detection probability is

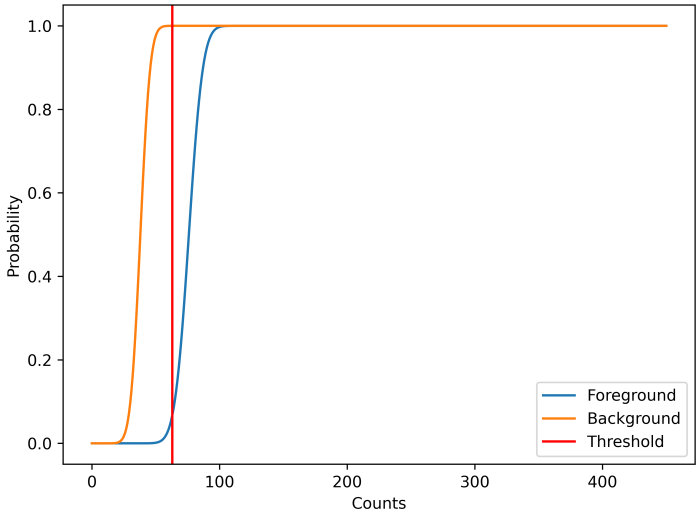

Figure 5: Cummulative density function with detection threshold indicated.

found as $1 - f_{cdf}$ where f_{cdf} is the foreground cummulative density function evaluated at the threshold index.

7.3.2 Implementation

Two files are required for this to work, a background and a foreground, these are selected in this order. The files are generated using the "Save ROI" method in the "List Mode Reader" interface. The files take a two column form with a time of arrival and energy as the two columns. A window will appear to set the first time step to begin integrating. This is due to statistical fluctuations at extremely low count fields. A total of 181 time steps are taken over the entire length of the accumulated time.

It should be noted that this portion may take a significant portion of time to run due to have to generate, and integrate 362 discrete functions.

Upon completeion of the analysis, the software will automatically bring up a windows file explorer to save the data points out, to be used for generation of a video. This will then generate a plot of the probability of detection versus time, the software will indicate the point at which the detection probability rises above 99% for the first time. Care should be taken by the user to ensure the start point has not removed prudent data, but is high enough to remove any erroneous data points.

7.3.3 Save Probability Video

This generates a video from the probability data saved using the detection probability function. It expects as input a two column file with time in the first column and a detection probability in the second. It saves as an mp4 file type.

8 List Mode Viewer

This window is launched from within the main spectrum viewer application. Upon launching there are four individual graphs, seen in Figure 6. This is used to split the list mode data acquired using the sync pulse and detector data. This will split that data relative to a sync pulse with an offset, with the data before the divider being referenced herein as region 1 and data after the divider as region 2.

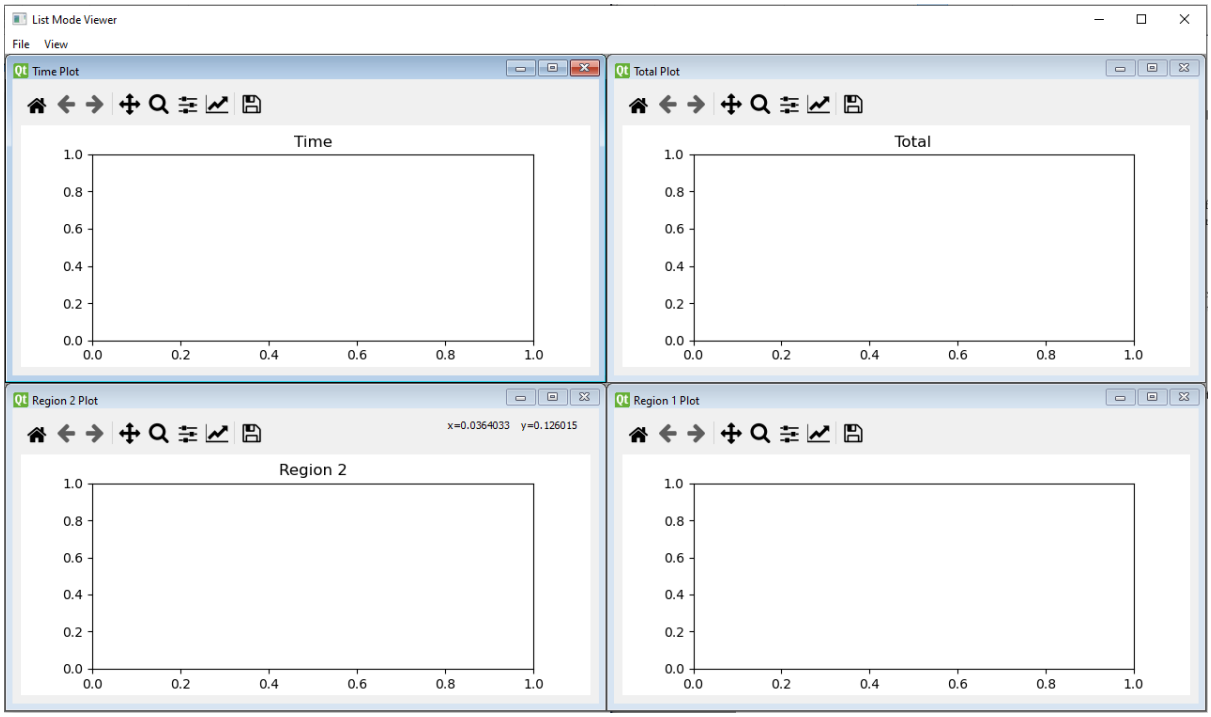

Figure 6: Initial launching of list mode viewer

The top left graph will display the arrival of the pulse relative to the sync pulse. Top right will display the total spectrum as well as split data (region 1 & 2). Bottom left will display only the region 2 spectrum, and the bottom right will display region 1 data.

8.1 File Menu

8.1.1 Load New Data

This launches the interface seen in Figure 7. The sync pulse and detector pulse are comma seperated files, corresponding to there respective files. It is expected that the comma seperated file will be in the form of having time, in nanoseconds, in the first column and a channel number being the second column. Once the files are loaded, the browse buttons with change to green. The final option is to add a calibration file, having been generated using the "Calibrate Spectrum" functionality. This is required to generate detection probability.

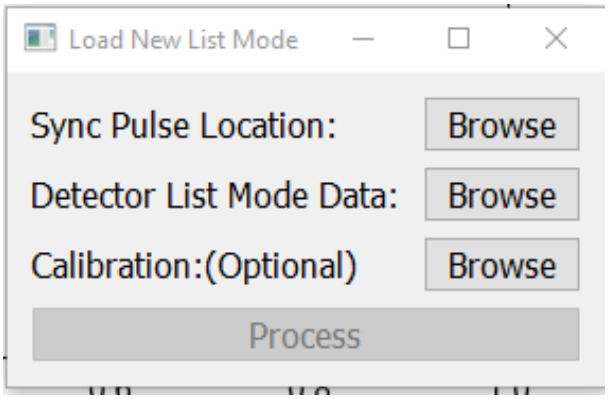

Figure 7: List mode viewer data loader