GammaEyes

Manual

Date 2021.08.07

Version 1.0.1

CONTENT

1 Introduction

1.1 Overview

GammaEyes (GE) is a comprehensive gamma spectrum analysis software. It is written in python3 and can run in the Window system.

1.2 Framework

GE is written in python3 and uses the PyQt5 framework to build its GUI interface. Python is a concise and efficient object-oriented programming language. After years of development and the efforts of open-source workers all over the world, it has formed its rich extension library. Using python to develop GE is simple and efficient and is conducive to subsequent upgrade iterations.

1.3 Dependent library

- PyQt5
- Numpy
- Matplotlib
- PyWavelets
- statsmodels
- openpyxl

1.4 Contact information

If you have any questions or suggestions, please contact the author: say@insmea.cn

2 Download

2.1 Download

GE's project address is: https://github.com/Edshree/GammaEyes

You can download the source code of GE from the above project address, or download the executable file of GE:

https://github.com/Edshree/GammaEyes/releases/tag/Win

2.2 Run

Unzip "GammaEyesV1.0.1_WIN.rar".

Run the "GammaEyes.exe" executable file in the "GammaEyesV1.0.1" folder.

3 GUI Interface

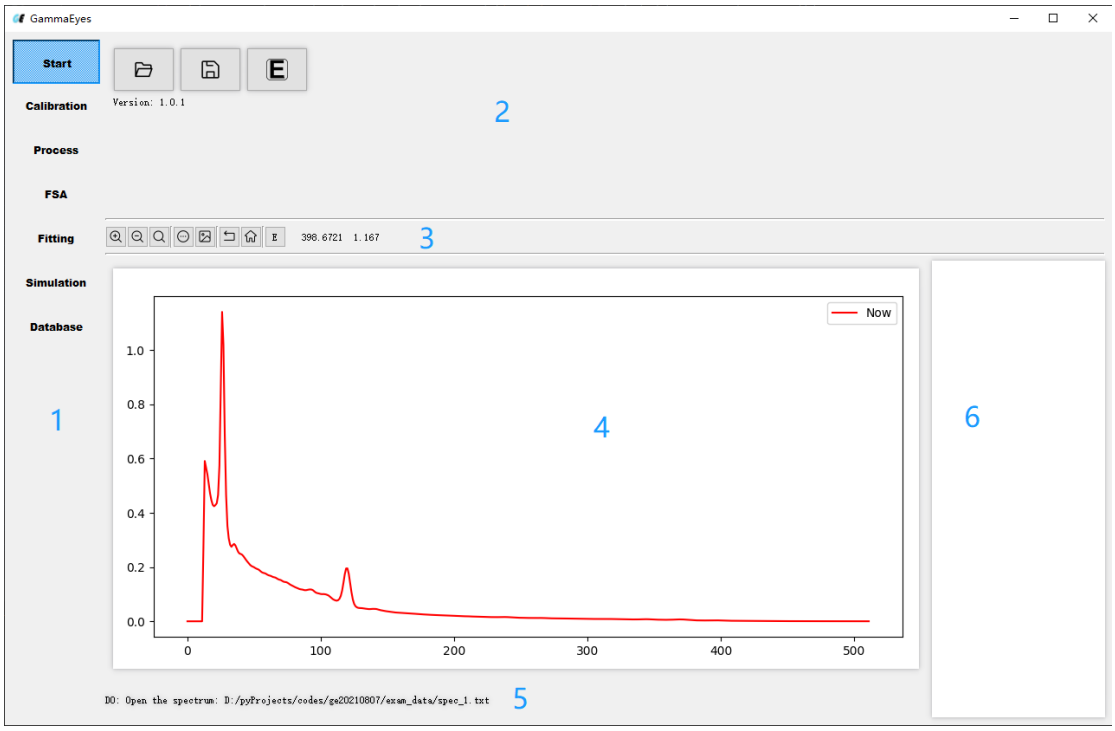


Fig 3-1 GE's GUI interface

The main interface of GE is shown in Fig 3-1, which contains a total of 6 areas. The functions of these areas are as follows:

Table 3-1 Functional area of the GUI interface

Num	Area	Function
1	Navigation	Can be used to switch the spectrum operation functions
2	Function Area	Used for inputting parameters and performing corresponding functional operations
3	Tool Bar	Used for operating figures
4	Figure	Figure display

5	Command out	Used for displaying the completed operation
6	Information out	Output calculation results

3.1 Navigation

Fig 3-2 Navigation area

"Navigation" is shown in Fig.3-2, including 7 buttons: "Start," Calibration," Process," FSA," Fitting," Simulation" and "Database".

3.2 Function Area

The illustrates of each functional areas corresponding to the navigation are displayed in section 4.10.

3.3 Tool bar

Fig 3-3 Function Area

The toolbar is as shown in the Fig.3-3, including 8 buttons and coordinate display. See the table below for details:

Table 3-3 Functional of buttons in toolbar

Button	Name	Function
	Zoom	Press the button, you can use the mouse to drag and zoom the figure
	Back (figure)	Return to the previous figure
	Original figure	Return to the original figure
	Figure setting	Set axis attributes and line attributes
	Save figure	Save current figure
	Undo	Undo the operation on the spectrum
	Reset	Return to the original spectrum
E	Show energy	When pressed, the abscissa is the energy, when not pressed, the abscissa is the channel index
0.392 0.9906	Coordinate display	Display the coordinates of the mouse position in the figure area

3.4 Figure

The figure area is used to display 2 spectra: "after processing" and "before processing", as shown in the figure below. The "Last" line represents the spectrum "before processing", and "Now" represents the spectrum "after processing".

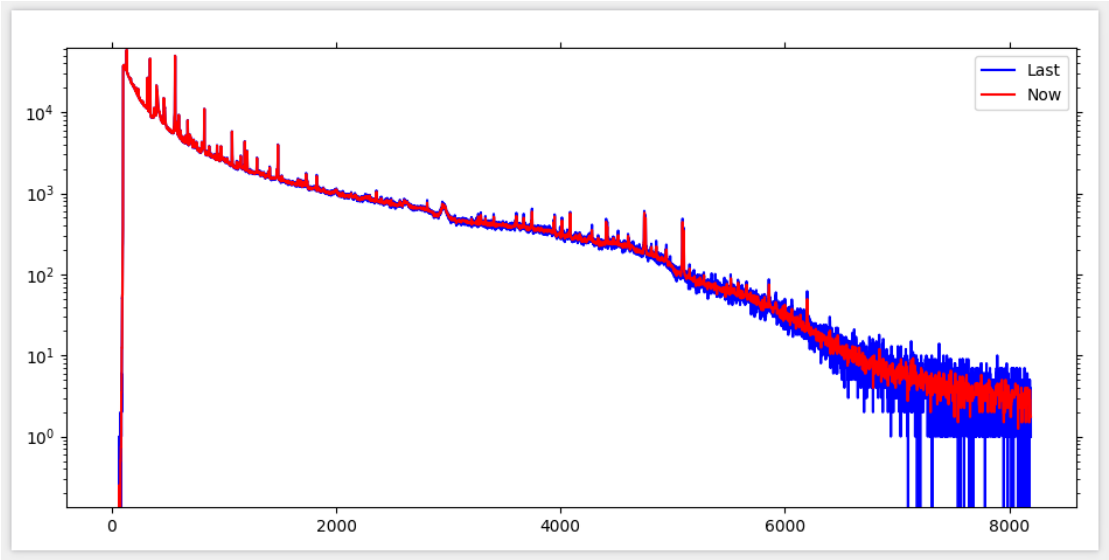


Fig 3-4 Figure area

4 Start

When opening the program or clicking the "Start" button in the navigation area, the functional area will switch to the interface shown in Fig. 4-1.

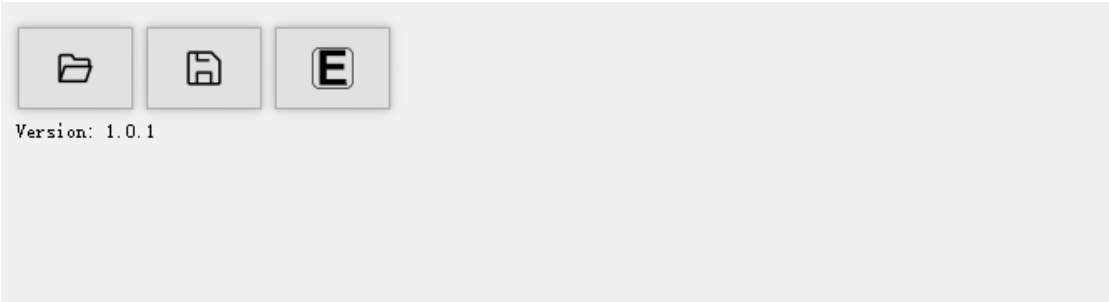
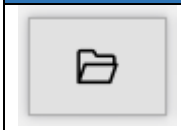
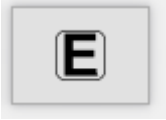


Fig 4-1 “Start” interface

There are three buttons "open spectrum", "save spectrum", "open energy file" and version number in this interface.

Button	Function
	Click the "Open Spectrum" button to select the spectrum file that needs to be processed or analyzed, and the spectrum will be displayed in the figure area.
	Click the "Save Spectrum" button to set the path, and the software will save the current spectrum in the figure area.
	Click the "Open Energy File" button to select the energy file that matches the spectrum. Note that the energy file should be an array of the same length as the energy spectrum, which indicates the energy of each channel

This previous version supports opening ".txt", ".Chn", ".Spe", ".TKA", ".mca" files. Note that GE does not read energy when reading them, and the user needs to input additional energy file.

5 Calibration

The Calibration currently have two functions: "Energy Calibration" and "FWHM Calibration".

5.1 Energy Calibration

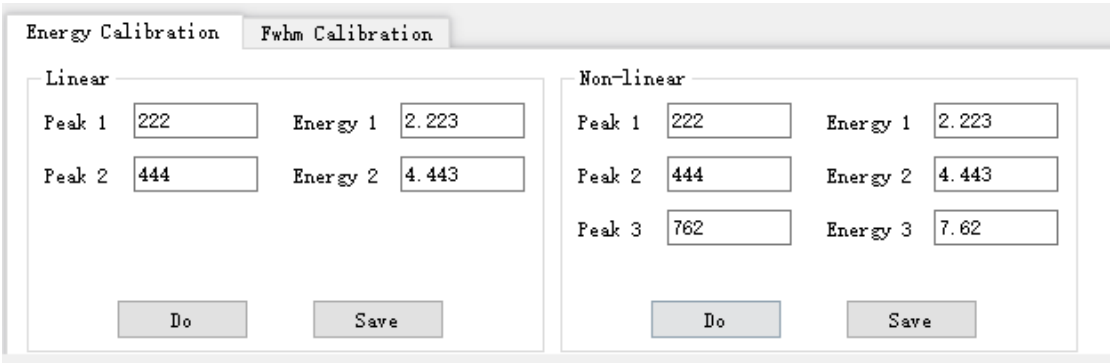


Fig. 5-1 Energy Calibration interface

The energy calibration is used to calibrate the relationship (curve) between energy and channel address. This part provides two different curves to calibrate: a straight line (Linear) and a parabola (Non-linear). Generally speaking, the linear calibration is suitable for the spectrum with a small energy region, such as 0-3MeV; when the energy region is wider, such as 0-12MeV, the parabolic calibration is more accurate. Note that in the energy calibration part, GE uses interpolation to calculate the parameters of the energy scale curve.

The operation of these two calibration methods is the same:

1. Input channel and corresponding energy.
2. Click "Do" to complete the scale.
3. The energy calibration curve will be displayed in the figure area, and various parameters will be output in the information output area.
4. Click "Save" and select the save path to save the energy array.

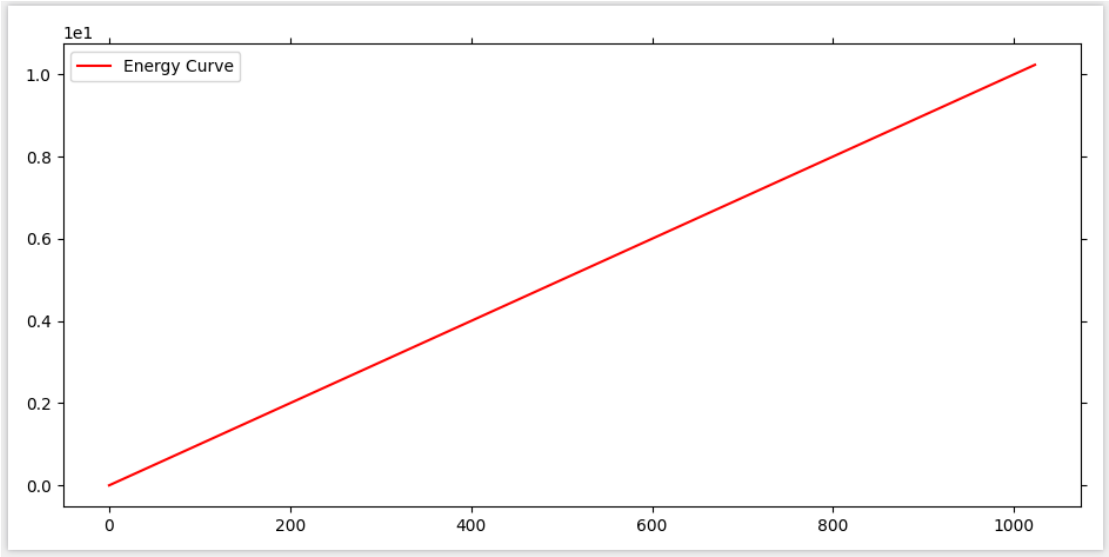


Fig. 5-2 Energy curve

```
Finish the FWHM calibration
═══════════
The curve is: E = k*Chan+b
═══════════
k: 0.009999999999999998
b: 0.0030000000000001137
═══════════
```

Fig. 5-3 Result output

5.2 Fwhm Calibration

The Fwhm calibration refers to calculate the Fwhm corresponding to each energy. GE provides three kinds of Fwhm curves: MCNP model, CEAR model and linear model. The formulas of these three curves are shown below.

MCNP: $Fwhm = a + \sqrt{b(Energy + c * Energy^2)}$

CEAR: $Fwhm = d * Energy^e$

LINEAR: $Fwhm = k * Energy + b$

GE's Fwhm calibration adopts a fitting method, so you can add multiple

data points in the table, and you can choose to add or delete data points by right-clicking in the table area.

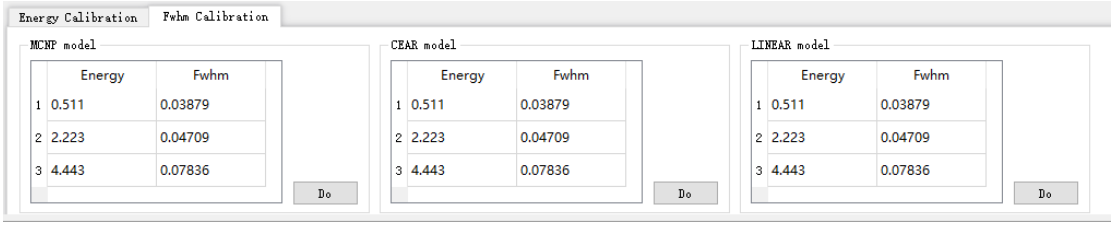


Fig. 5-4 Fwhm Calibration interface

The operations of the three models are also the same:

1. Input energy and the corresponding Fwhm.

2. Click "Do" to complete the calibration.

3. At this time, the Fwhm calibration curve will be displayed in the figure area, and various parameters will be output in the information output area.

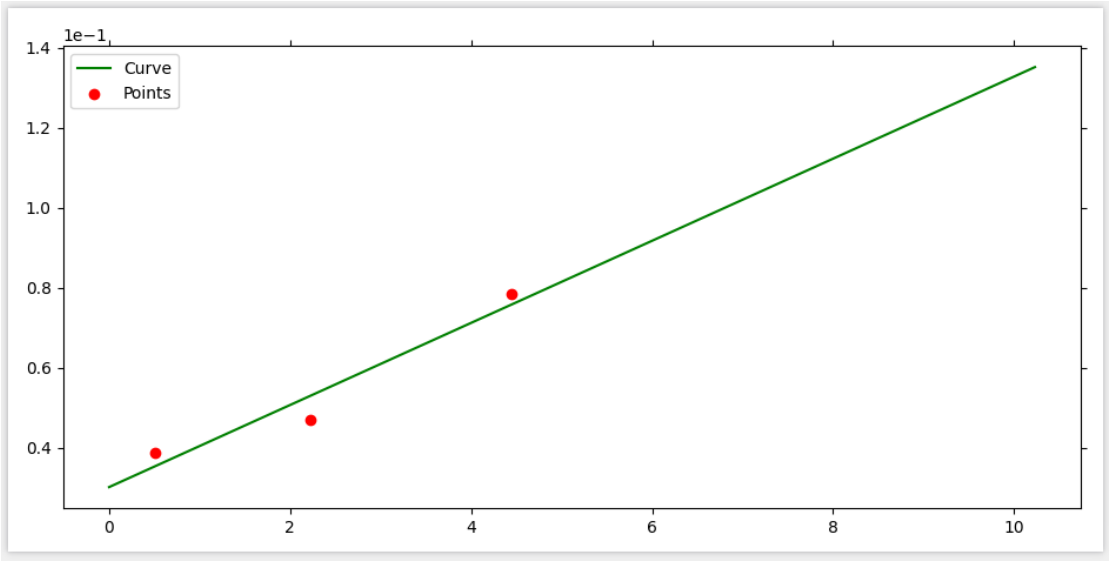


Fig. 5-5 Fwhm curve

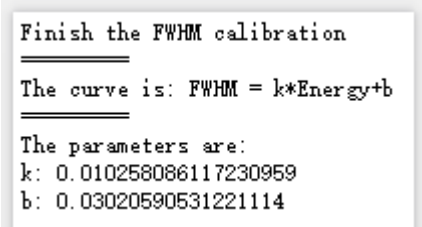


Fig. 5-6 Result output

6 Process

6.1 Find Peaks

The peak finding algorithm in the processing module is automatic peak finding. If you need to accurately determine the peak positions of a ROI region, you can refer to the "fitting" module. GE's peak search provides two algorithms, one is morphology peak search, namely "Auto", the parameter meaning can be found in []; the other is wavelet transform automatic peak search, namely "Auto Cwt" For the meaning of the parameters, please refer to [].

The steps are:

1. Input parameters.

2. Click "Do" to complete automatic peak search.

3. At this time, the peak search result will be displayed in the figure area, and the information output area will output the peak position and the corresponding energy.

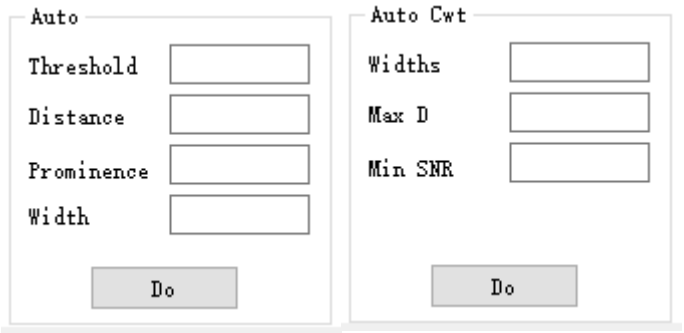


Fig. 6-1 Peak finding interface

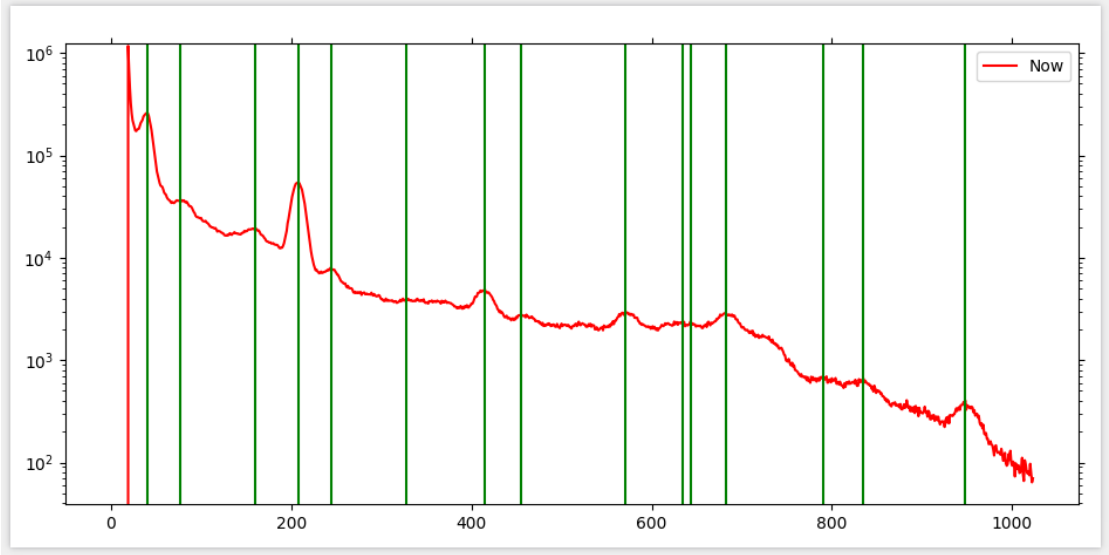


Fig. 6-2 Peak finding figure

```
Find 15 peaks
They are:
40 chan
77 chan
160 chan
208 chan
244 chan
328 chan
415 chan
455 chan
571 chan
634 chan
643 chan
682 chan
790 chan
835 chan
948 chan
```

Fig. 6-3 Peak finding result output

6.2 Denoise

GE has collected 4 denoising algorithms: multi-point second-order fitting denoising, low-pass filtering denoising, wavelet denoising, and EMD transform denoising.

The steps of the first three algorithms are as follows:

1. Input parameters.
2. Click "Do" to complete noise reduction.
3. At this time, the spectrum after denoising will be displayed in the figure area.

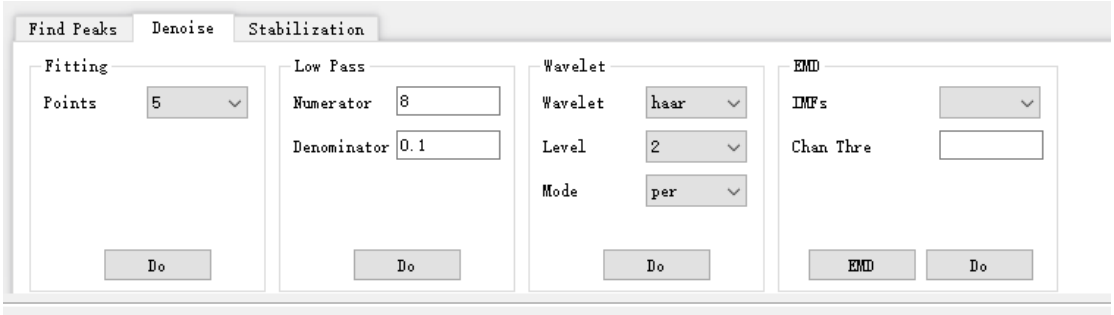


Fig. 6-4 Denoising interface

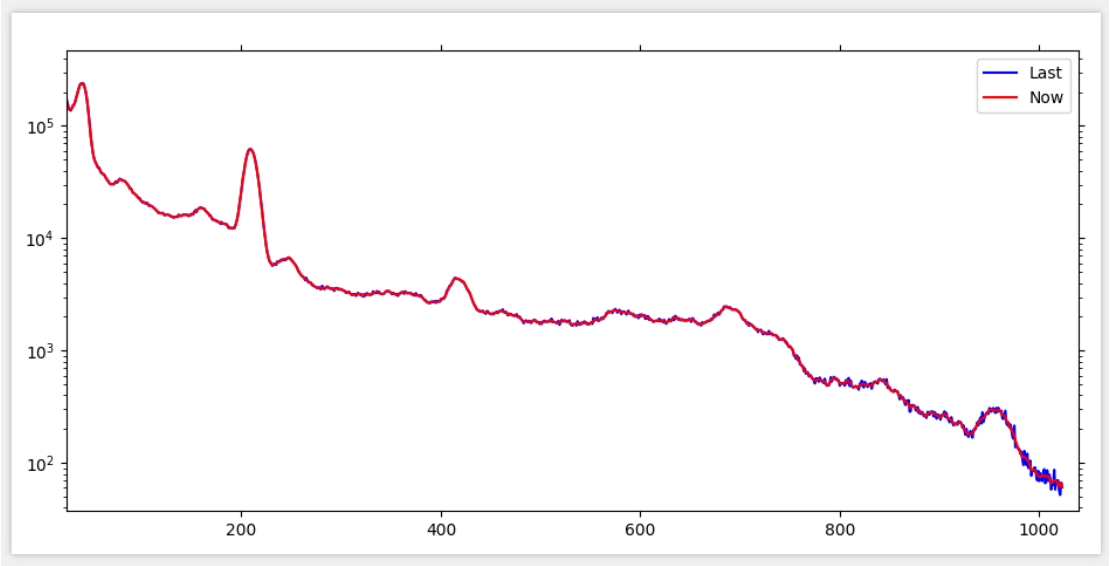


Fig. 6-5 Denoising figure

Note that the steps of EMD denoising are: first click the "EMD" button to perform EMD transformation on the spectrum, select the removed "IMFs", enter the pre-domain of the channel address, and finally click "Do" to complete the noise reduction.

6.3 Stabilization

GE has two options for spectrum stabilization: "2 reference peaks" and "3 reference peaks". The former uses 2 peaks as reference peaks for spectrum stabilization and a linear energy calibration curve, while the latter uses 3 reference peaks and a quadratic energy calibration curve.

Take "2 reference peaks" as an example, the operation steps of stabilizing spectrum are as follows:

1. Select the number of points for spline interpolation.
2. Enter the energy of the first reference peak, the current channel address, and the standard channel address after spectrum stabilization.
3. Enter the energy of the second reference peak, the current channel address, and the standard channel address after spectrum stabilization.
4. Click the "Do" button to complete the spectrum stabilization.

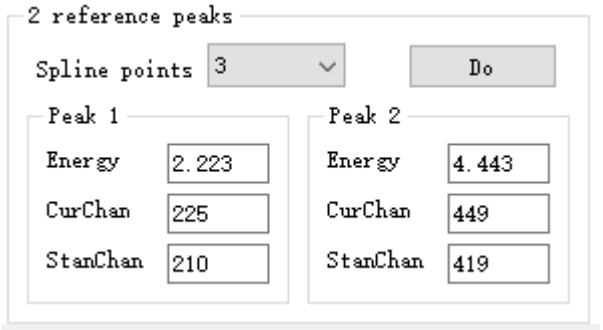


Fig. 6-6 Stabilization interface

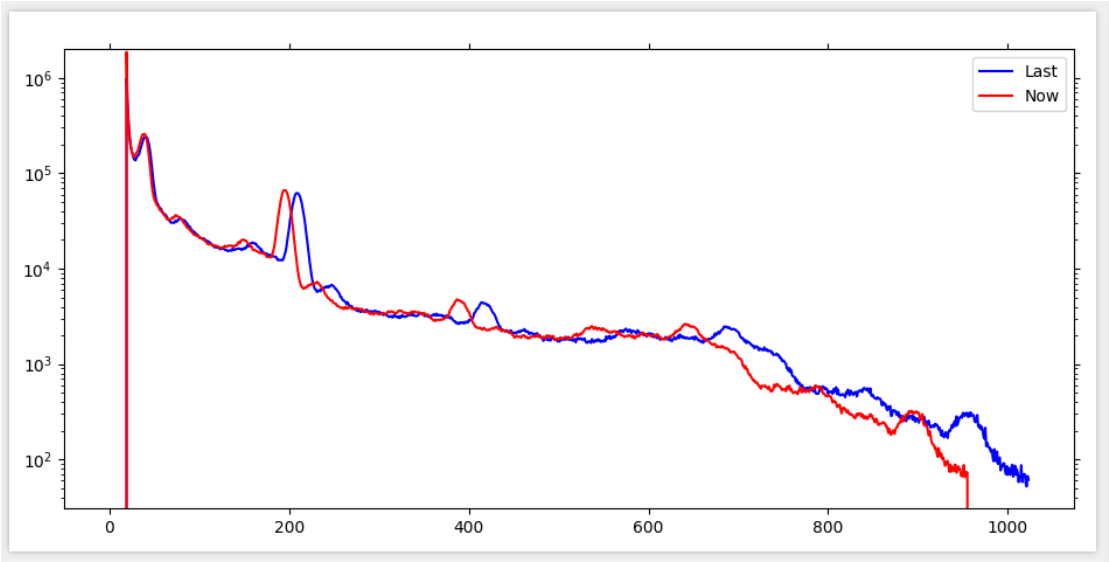


Fig. 6-7 Stabilization figure

7 Full Spectrum Analysis

7.1 LLS

LLS refers to the traditional library least squares method for analyzing gamma spectrum. For this method, it is necessary to predict the sample library and the element composition table corresponding to the library. This method requires the preparation of the sample spectra library and the element content table corresponding to the library in advance.

Their format is fixed, the library file is an M*N matrix (.txt), M represents the number of spectrum channels, N represents the number of spectra in the library, and the library composition table is an N*K matrix (.txt), K is the number of elements in the sample. There are

examples of these two files in the "exam_data" folder under the program path:

(“fsa_lib_512_52.txt” and “fsa_cont_52_13.txt”).

After making the library file and the library composition table, LLS analysis can be performed. The steps are as follows:

1. Click the "Library" button to select the spectrum library file.
2. Click the "Composition" button to select the library composition table file.
3. Click the "Spectrum" button to select the spectrum to be analyzed.
4. Click the "LLS" button and wait for the analysis to complete.

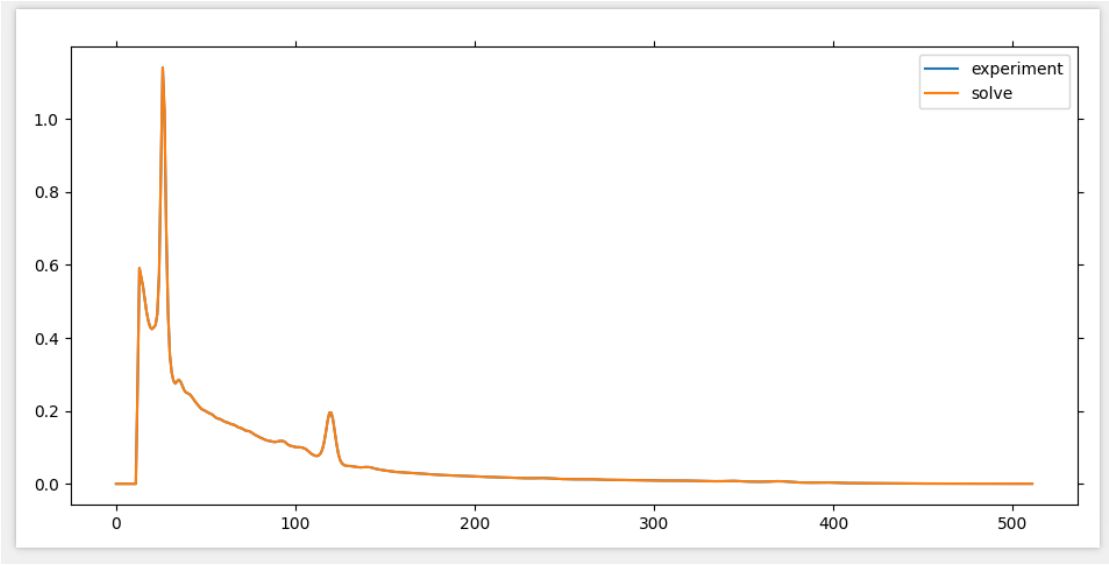


Fig. 7-1 LLS figure

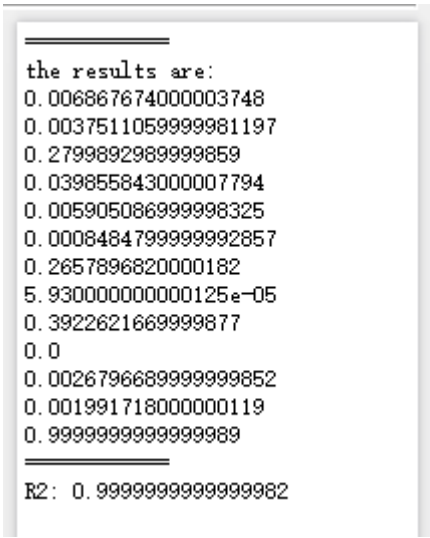


Fig. 7-2 Result output

7.2 WLLS

The WLLS method is similar to the LLS method that it also needs to make and read the library file and the composition table file. GE's WLLS provides two types of weighting: weighting based on standard deviation (std) and weighted file (else).

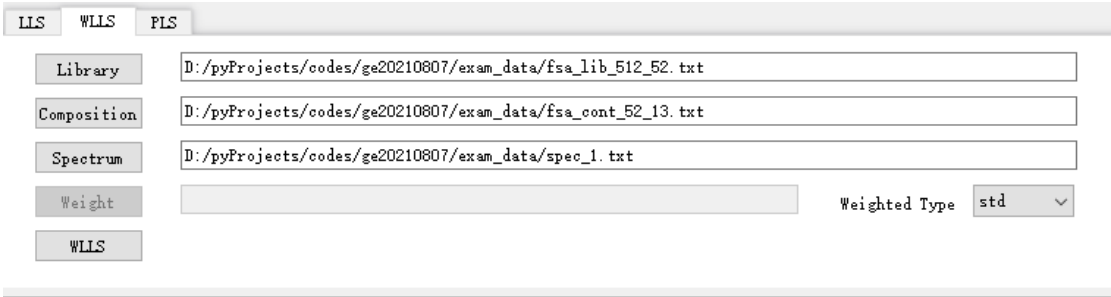


Fig. 7-3 WLLS interface

Click the "WLLS" button in “std” mode to complete the analysis.

In “else” mode, you need to click the "Weight" button to select the weighted file. The weighted file is an M*1 column vector (.txt).

8 Fitting

8.1 Scintillator

The peak fitting interface of the scintillator detector is shown in Fig. 8-1.

The meanings of these parameters are:

Energy Fixed: Whether to fix the peak center energy

Left: The leftmost channel address of the ROI area

Right: The address of the rightmost channel in the ROI area

Bg: background parameters

Energy: peak center energy

Amp: Peak height

Sigma: Half-width parameter

Step: Step function parameters

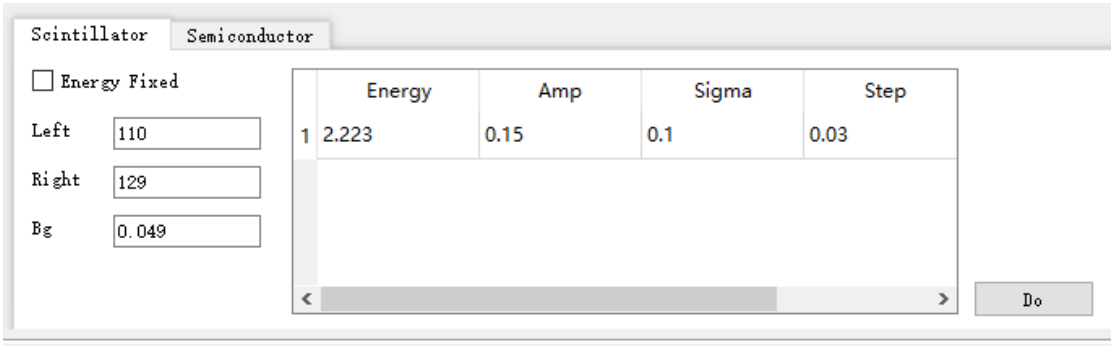


Fig. 8-1 Scintillator fitting interface

After setting all the parameters, you can click "Do". Fig. 8-2 shows the fitting effect.

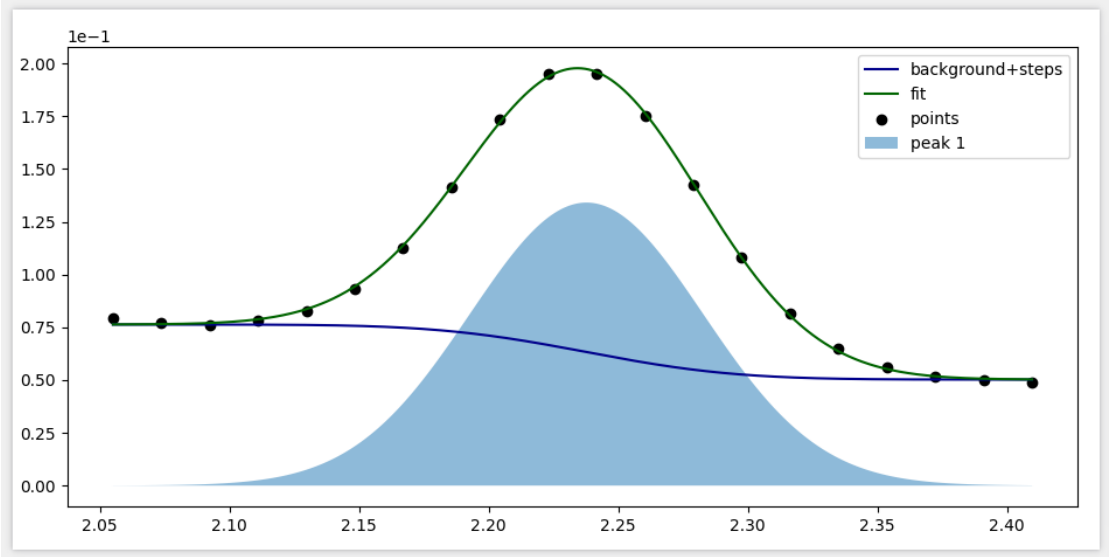


Fig. 8-2 Scintillator fitting figure

The information output area on the right shows the parameters in the fitting results.

```
==========
the parameters are:
Bg: 0.05021309014357575
----------
E 1: 2.237755197842592
Amp 1: 0.13407317087765638
Sigma 1: 0.045015216675118534
Step 1: 0.013045135167410927
==========
Area 1: 85.25976615367873
R2: 0.9995069621935703
```

Fig. 8-3 Scintillator fitting result

GE allows users to add multiple peaks. Right-click in the blank area of the table and the operation options of the table will appear. Click "Add" to add a new peak. Select a column, right-click and click "Delete" to delete the peak. Fig. 8-4 shows the fit using multiple peaks.

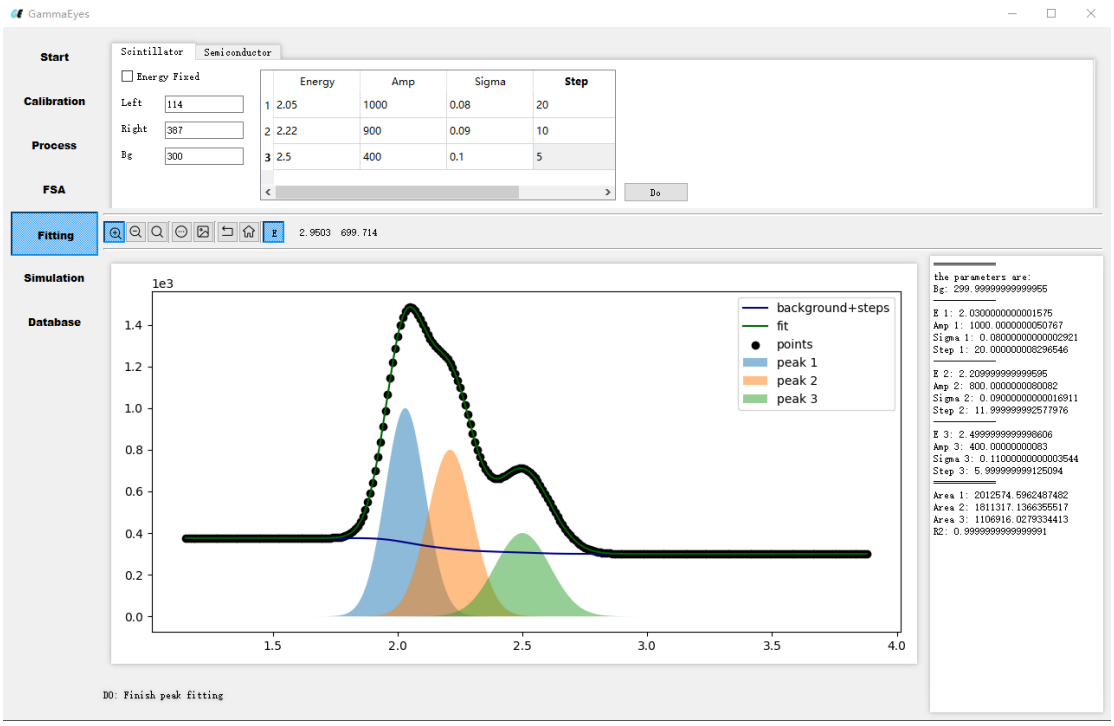


Fig. 8-4 Multimodal overlap fitting

8.2 Semiconductor

GE's semiconductor detector spectrum fitting only includes the fitting of ordinary Gaussian peaks and does not include the fitting of special peak shapes such as Ge triangle, Boron's Doppler broadening, and annihilation peaks of HPGE detectors. For the fitting of these peaks, it is recommended to use PEAKFIT software. The fitting interface of the spectrum of the semiconductor detector in GE is shown in Fig. 8-5, where:

Energy Fixed: Whether to fix the peak center energy

Left: The leftmost channel address of the ROI area

Right: The address of the leftmost channel in the ROI area

Bg: background parameters

E0: peak center energy

Amp: Peak height

Sigma: Half-width parameter

A l-skew: amplitude parameter of left skew

B l-skew: left skew width parameter

A tail: tail's amplitude parameter

B tail: tail's width parameter

A step: amplitude parameter of the ladder

Left skew is caused by incomplete charge collection. Both tailing and steps are considered background components. The amplitude parameter A step of the steps is usually 0.001-0.003 times the peak area, and it increases with the increase of energy. And the tail's amplitude parameter A tail is 0.1-0.01 times the peak amplitude. The tail is more obvious at the low energy and strong peaks [Citation].

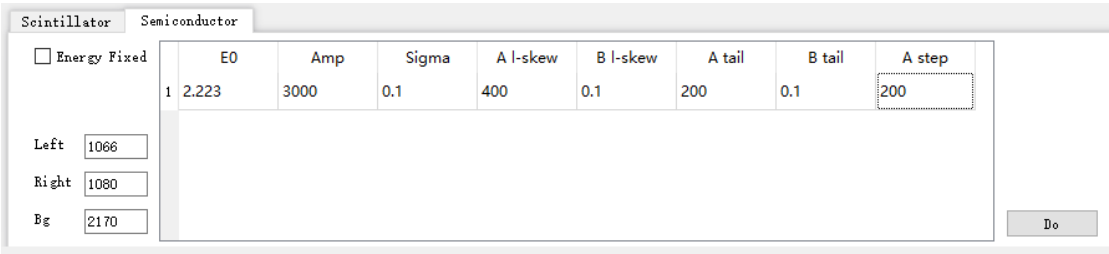


Fig. 8-5 Semiconductor fitting interface

After setting the parameters, click "Do" to complete the fitting. The fitting result is shown in Fig. 8-5 and 8-6.

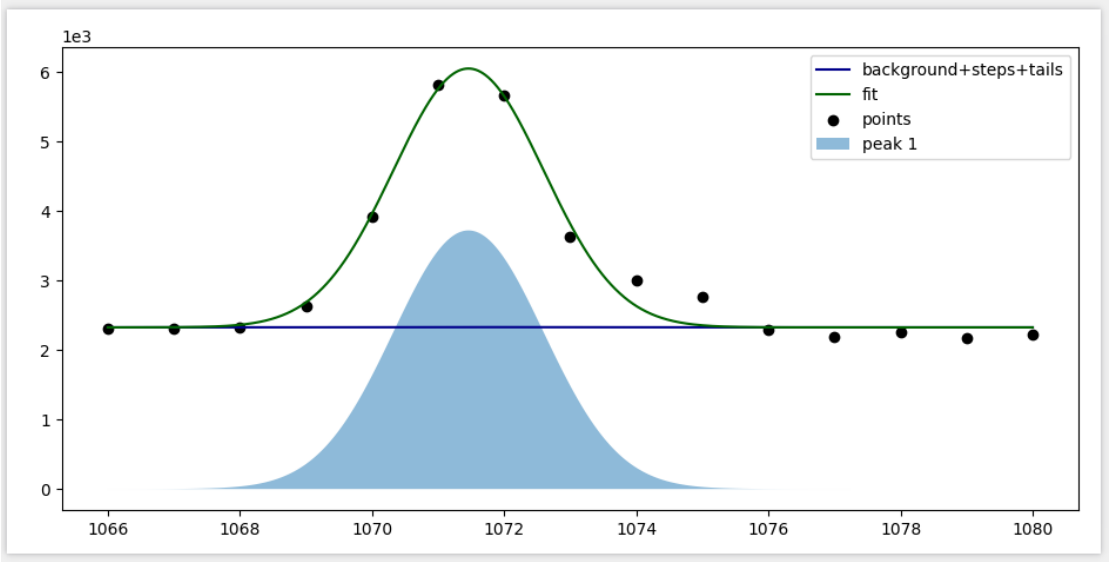


Fig. 8-6 Semiconductor fitting figure

```
==========
the parameters are:
Bg: 2327.569445856171
----------
E 1: 1071.4652563670056
Amp 1: 3509.4527500995764
Sigma 1: 1.1370111863426344
A l-skew 1: 2081.2465281316736
B l-skew 1: 0.10367893052969453
A tail 1: 33.71256416763823
B tail 1: 0.1041162250669875
A step 1: 2.3595850167504782e-07
==========
Area 1: 1136793.2982735096
R2: 0.9799720643807318
```

Fig. 8-7 Semiconductor fitting result

The fitting of the spectrum of the semiconductor detector can also add multiple peaks, and the operation is the same as that of the scintillator detector.

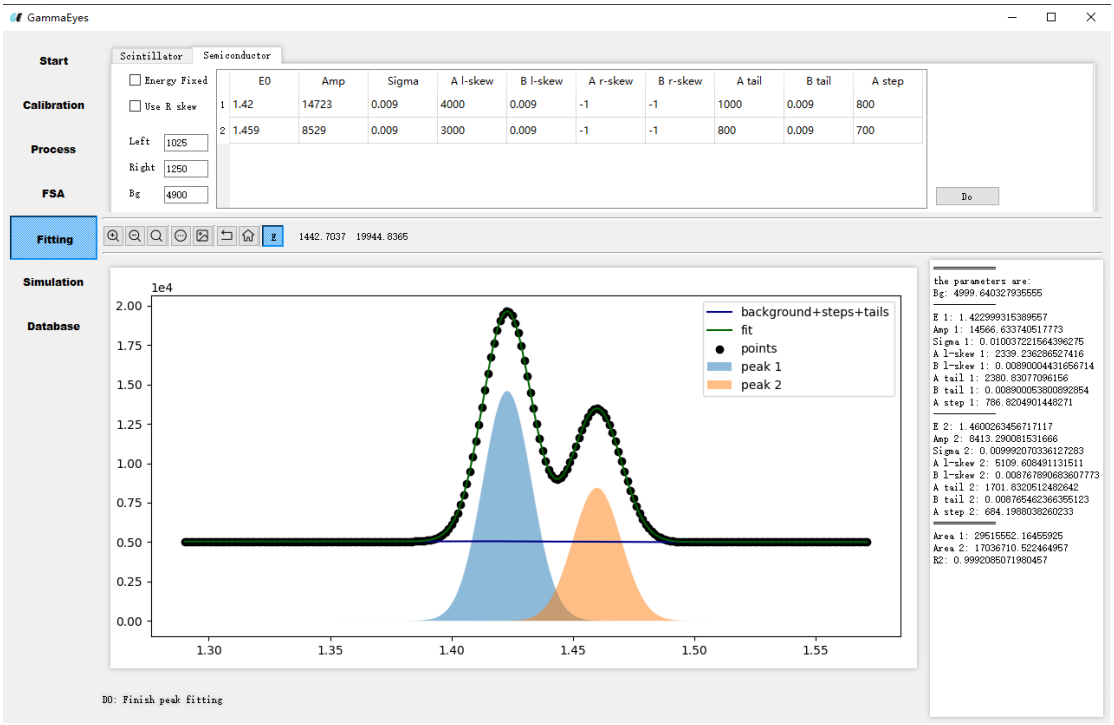


Fig. 8-8 Fitting result of semiconductor when multiple peaks overlap

9 Simulation data process

9.1 Broadening

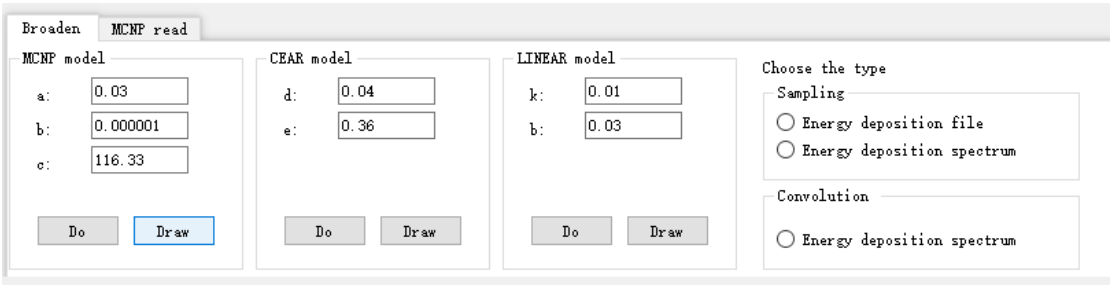


Fig. 9-1 Broadening interface

The broadening interface is shown in Fig. 9-1. GE provides 3 types of Fwhm curves for broadening. Enter the corresponding curve parameters and click "Draw" to verify the correctness of the Fwhm curve. Note that you need to read an energy file first.

GE has two broadening algorithms: sampling method and convolution method. In the sampling method, the energy deposition file can be read (the energy deposition file refers to a column vector (.txt file), and each number represents the value of the deposited energy during simulation), and you can also read the energy deposition spectrum after frequency statistics also. The convolution method can only read the energy deposition spectrum.

The sampling method is more in line with the true detection principle and does not lose statistical fluctuations, but when the number of particles is large, the calculation time of the sampling method is very large.

Select the algorithm for broadening and the type of file to be read, such as selecting the energy deposition file of the convolution method, as shown in Fig. 9-2.

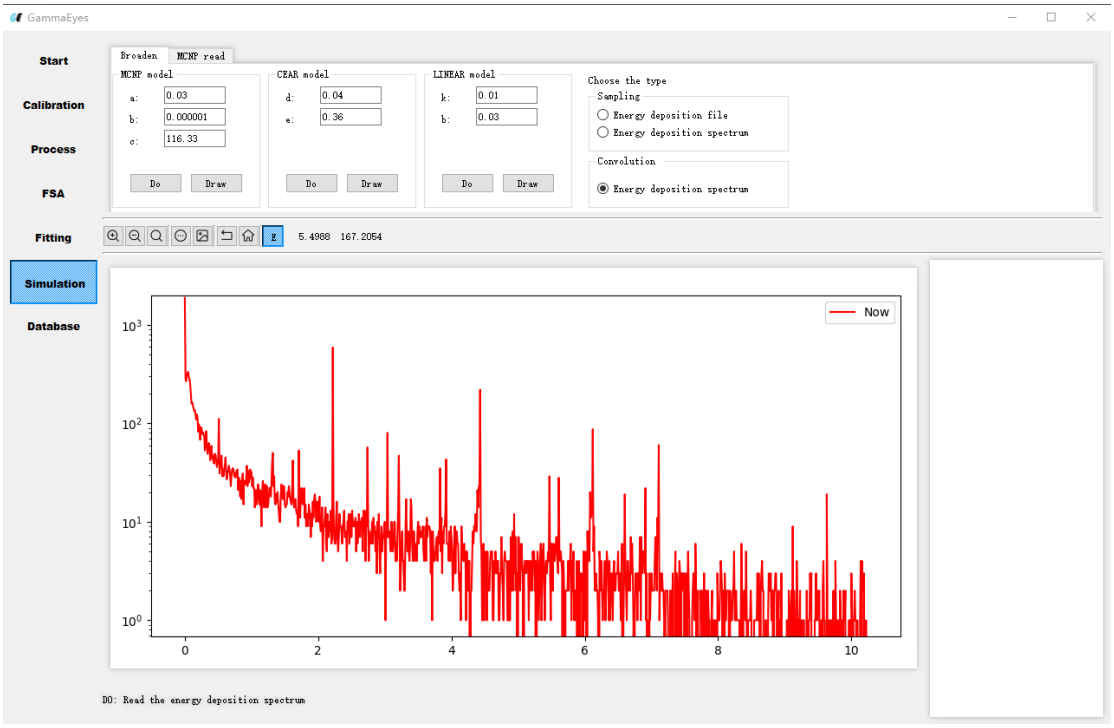


Fig. 9-2 Read energy deposition file

Click "Do" and wait for the calculation. The energy spectrum after broadening is shown in Fig. 9-3.

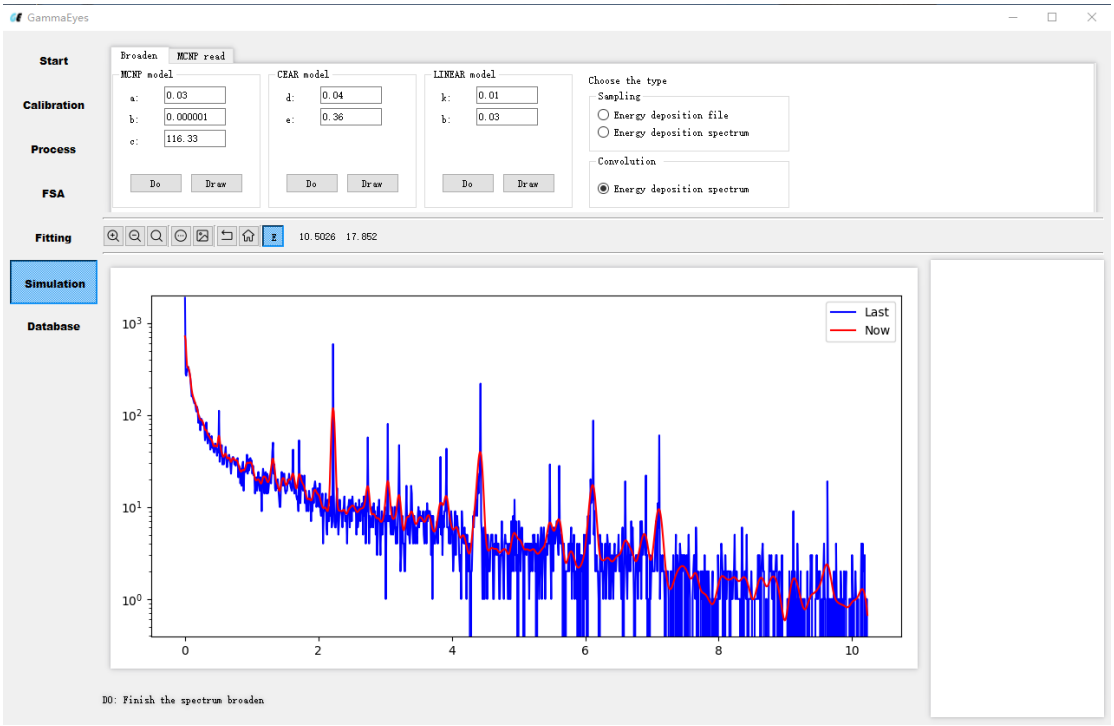


Fig. 9-3 Energy spectrum after broadening

9.2 Read the MCNP output file

Read the MCNP output file as shown in Fig. 9-4, click the "Open" button,

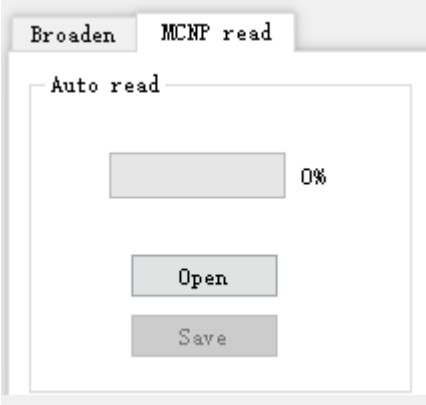


Fig. 9-4 MCNP output file reading interface

Select the output file to be read out (multiple selection is supported), as shown in Fig. 9-5.

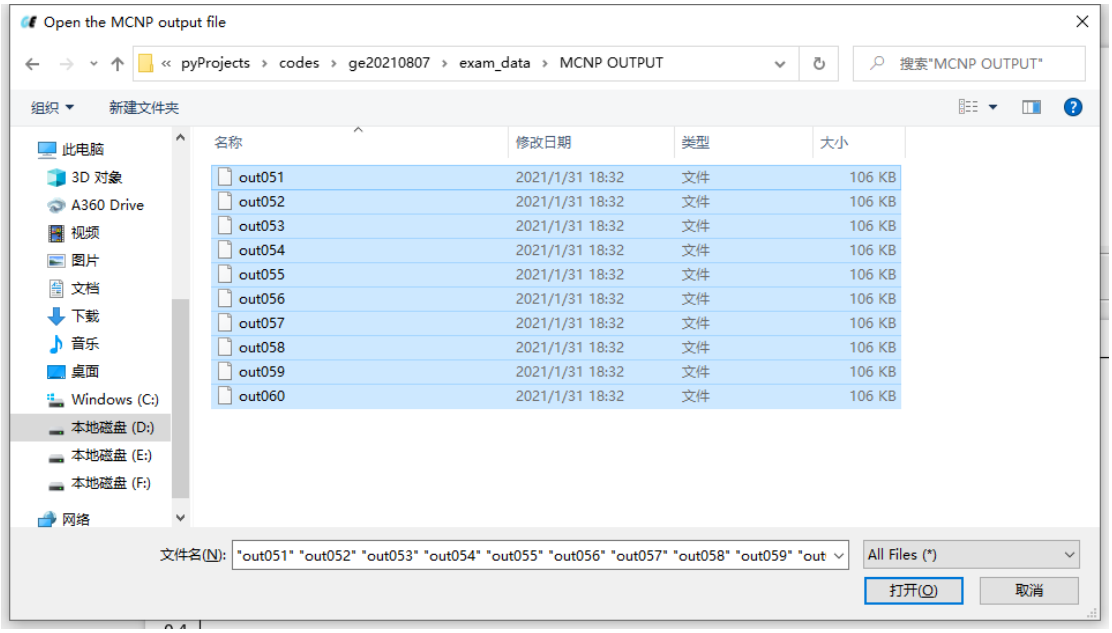


Fig. 9-5 Select MCNP output file

Wait for the read to complete.

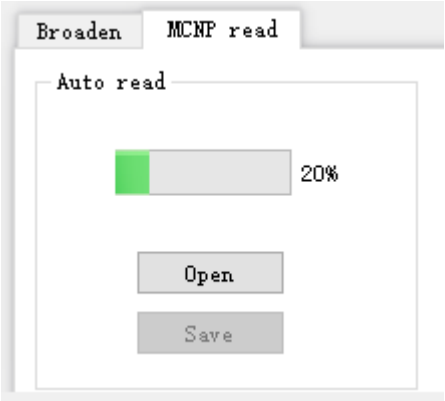


Fig. 9-6 Wait for the read

Click the "Save" button, select the save path, and the output spectrum of the MCNP simulation will be saved as an EXCEL file.

10 Database

10.1 PGNAA database

The interface for querying the PGNAA database is shown in Fig. 10-1. Enter the Z value of the query element and click the "Search" button. The table area on the right will display the spectral line of the element, and the figure area will display the spectral line of the element. Pay attention to the horizontal line of the figure. The coordinate unit is "keV".

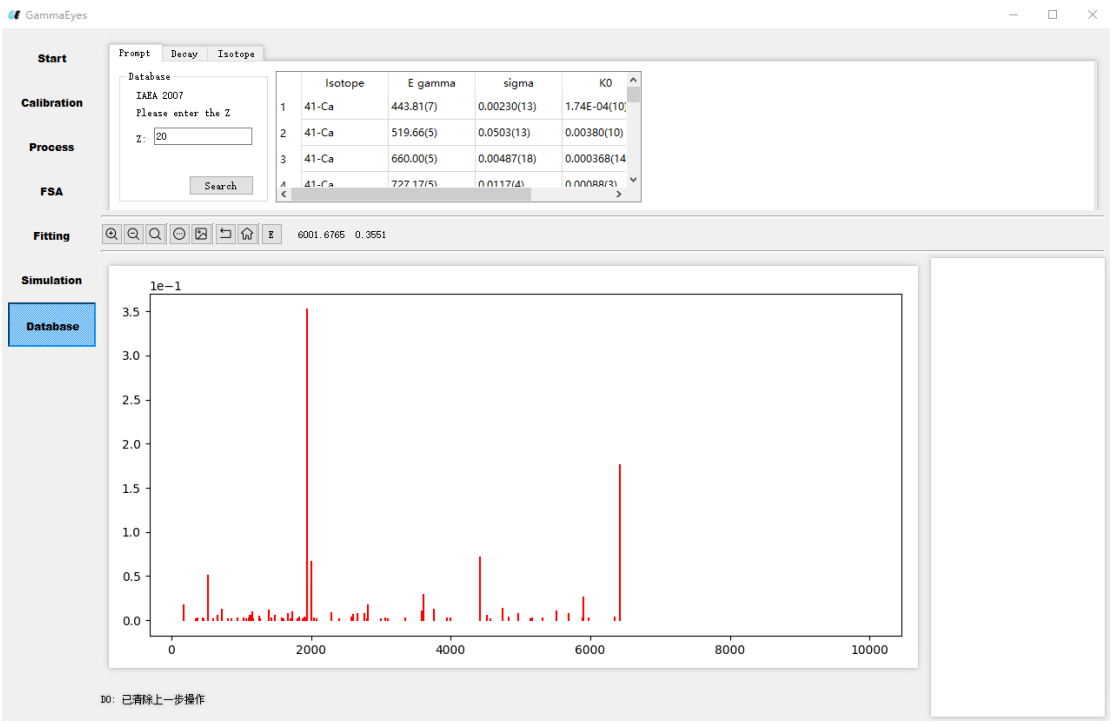


Fig. 10-1 PGNAA database query interface

10.2 NAA database

The interface for querying the NAA database is shown in Fig. 10-2. Enter the Z value of the query element and click the "Search" button. The table area on the right will display the spectral line of the element, and the figure area will display the spectral line of the element. Pay attention to the horizontal line of the figure. The coordinate unit is "keV".

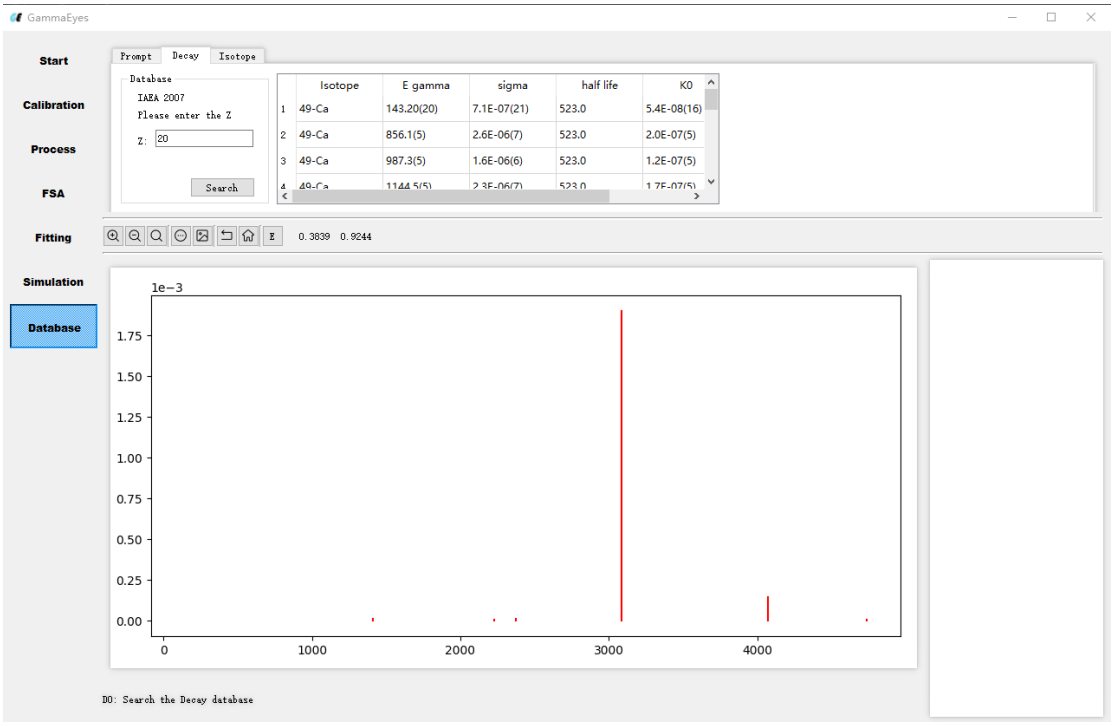


Fig. 10-2 NAA database query interface

10.3 Isotope database

The isotope abundance data query interface is shown in Fig. 10-3. Enter the Z value of the query element, click the "Search" button, and the table area on the right will display the abundance table of the element.

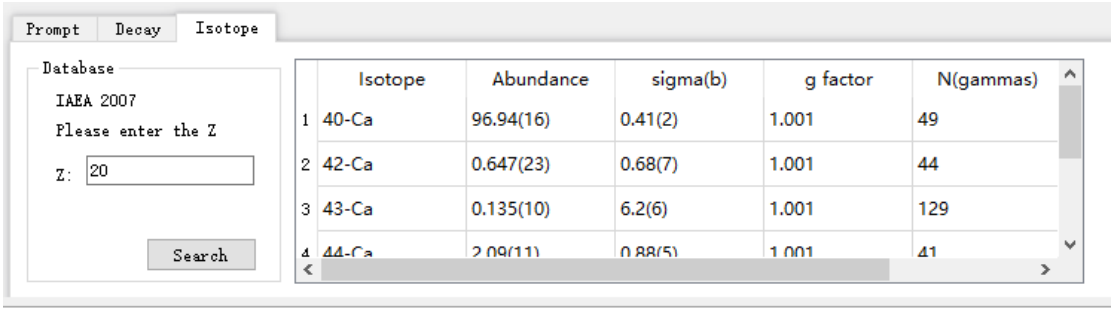


Fig. 10-3 Isotope database query interface