DSP Products by Techno AP

Adjustment Procedure for HPGe Semiconductor Detector

Instruction Manual

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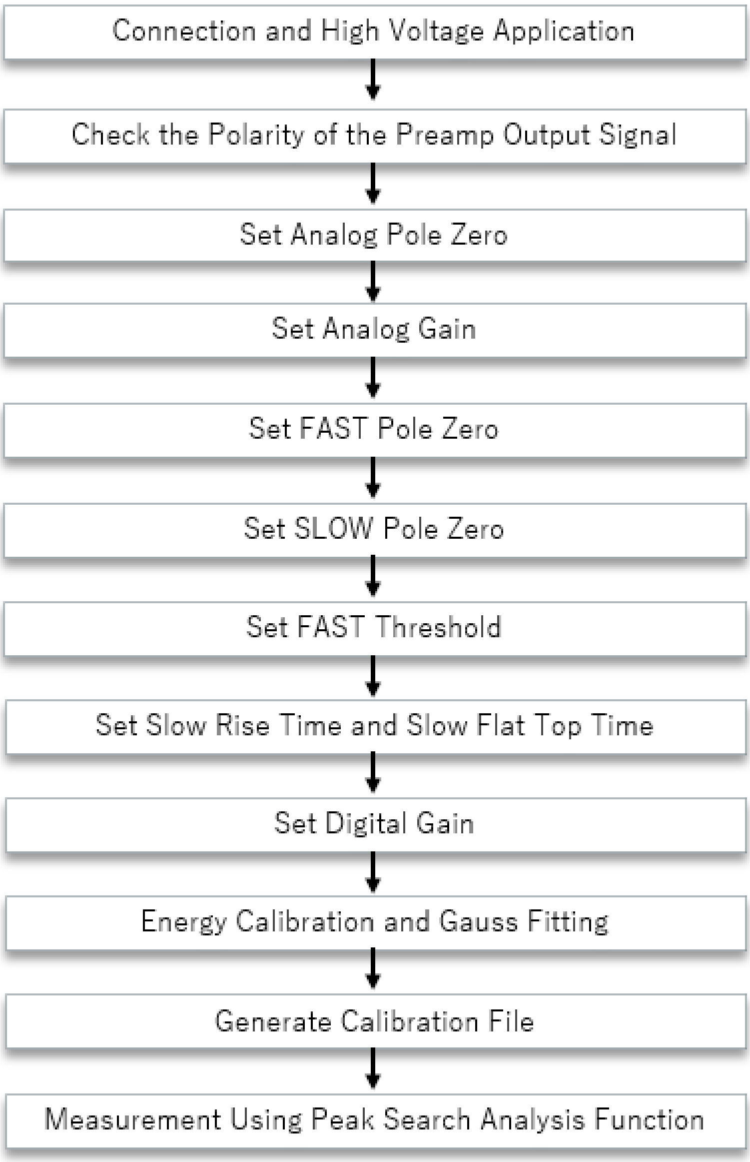
1. Overview

This document describes the adjustment procedure for the HPGe detector, model GEM10-70, using the DSP-equipped product APU101G from Techno AP.

For detailed information on device connections, parameters, troubleshooting, etc., please refer to the respective user manuals.

The flow of the adjustment procedure is as follows.



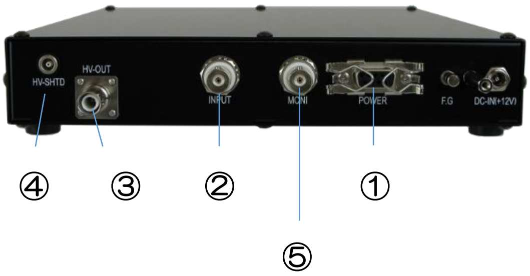
2. Connection and Setup

2.1 Connection and High Voltage Application

Check the cables from the HPGe detector.

① D-sub connector for preamp power
② BNC connector for preamp signal output
③ SHV connector for high voltage application
④ BNC connector for bias shutdown

Note that the signal line and the bias shutdown use the same BNC connector, so caution is required.



The rear panel of the APU101G:

① D-sub connector for preamp power output
② BNC connector for preamp signal input
③ SHV connector for HV (high voltage) output
④ BNC connector for bias shutdown input

Additionally, ⑤ MONI terminal is used for connection to an oscilloscope for adjustments, as described later.

⚠ Confirm the power to APU101G is off, then connect using the same numbers.

The cables ① to ④ have been connected and the setup is complete.

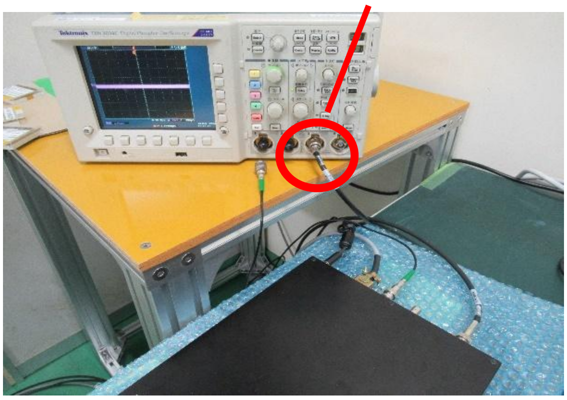
Next, the following will be connected to the APU101G:

⑤ MONI cable
⑥ The included APU101G power cable

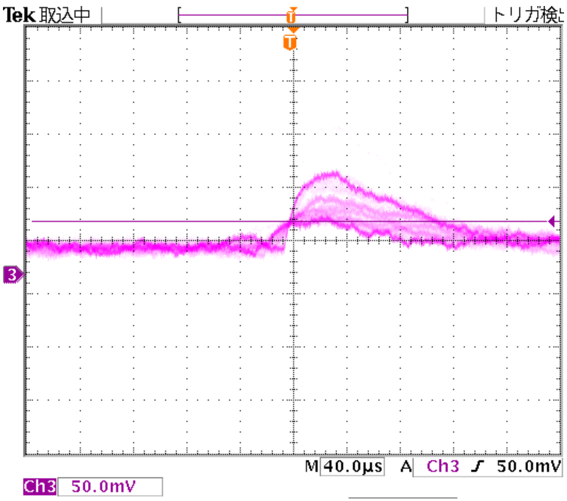
The end of cable for MONI is now unconnected.

⑦ The LAN cable will be connected to the PC.

Preamp signal output



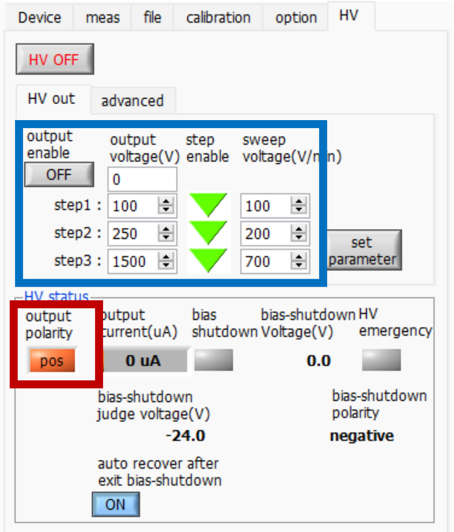
Connect the preamp signal, which is connected to the rear panel (②), to the oscilloscope.



⑧ Turn the POWER switch ON.

Power is supplied to the APU101G, and the preamp power for the Ge detector is also supplied.

When viewing the oscilloscope, you can confirm that the preamp signal is output, even though the high voltage is not applied.



Launch the application and open the "HV" tab.

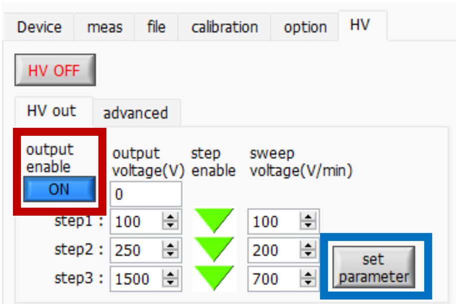
Since the polarity differs for each detector, make sure to check it.

For the HPGe detector, the polarity is positive (pos). Confirm that the setting is set to "pos" in the red box.

APU101G can set the application speed in up to three steps.

In step 3, the Operation Voltage is set. In step 1 and step 2, the sweep speed for the desired voltage is set.

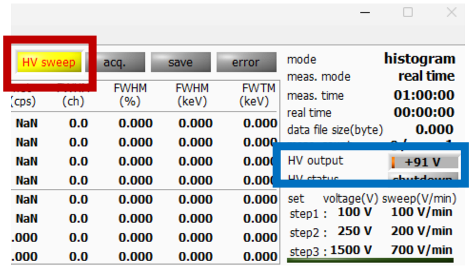
Volutage is swept and applied at 100V/min up to 100V, 200V/min up to 250V, and 700V/min up to 1500V

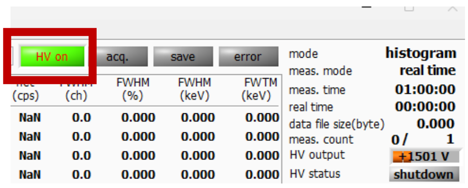


To begin applying high voltage, click the red box and set it to "ON". Clicking the blue box will open a pop-up window. After clicking "OK", the high voltage will be applied according to the settings.

⚠ Do not disconnect the cables while high voltage is being applied, as it may cause damage to the equipment.

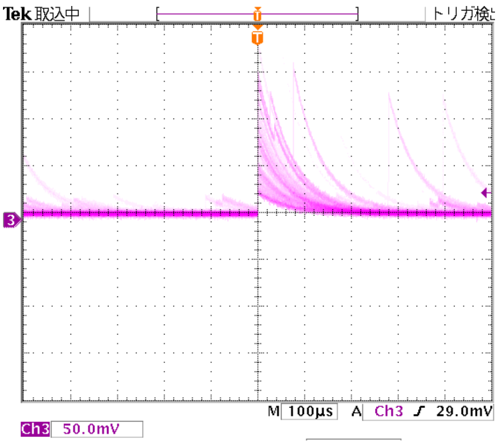
During the high voltage application, the HV sweep will light up as shown in the red frame. The blue frame indicates the monitoring voltage of the current applied voltage.





Once the high voltage application is complete, it will display "HV ON" as shown in the red frame.

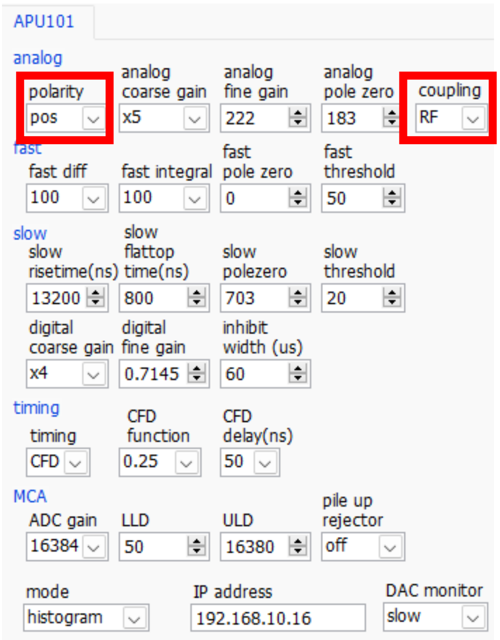
2.2 Verification of Pre-Amplifier Output Signal Polarity



The radiation sources are Am-241, Cs-137, Eu-152, and Co-60.

The oscilloscope image of the preamp signal after high voltage application is shown. Since the signal rises upwards, it confirms that the signal polarity is positive.

Additionally, the signal rises sharply and then exponentially returns to ground level, confirming that the preamp output is of the resistive feedback type.



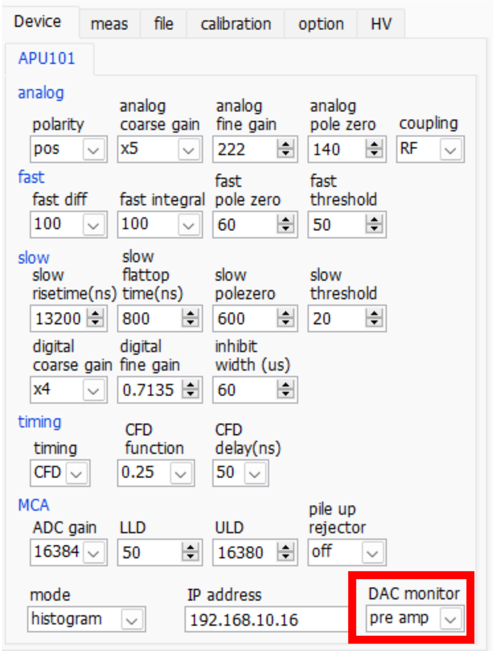
Since the detector's signal polarity has been confirmed as positive on the oscilloscope, set the "polarity" to "pos" in the application. Additionally, since the preamp output type is resistive feedback, set the "coupling" to "RF".

If the preamp signal is observed to dip downward, it indicates a negative polarity signal, so set the "polarity" to "neg" in the application.

If the preamp output fluctuates in a sawtooth pattern with a ± large swing, and a signal is observed in the middle, the preamp is of the transistor reset type. In this case, set the "coupling" to "TR".

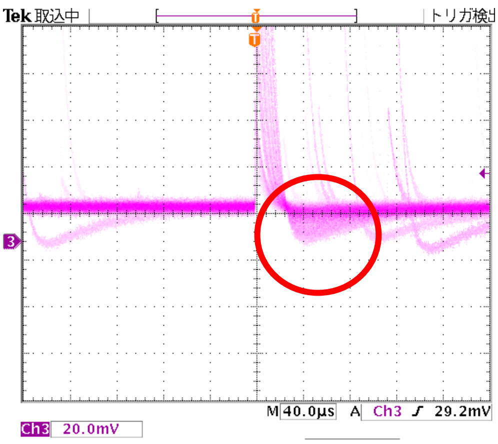
Now, connect the preamp signal currently attached to the oscilloscope to the INPUT terminal of the APU101G.

2.3 Analog Pole Zero Adjustment



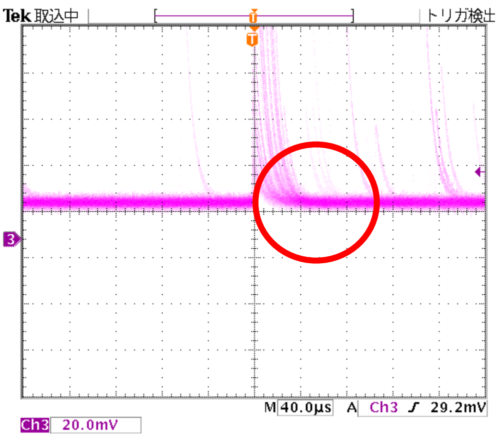
Connect the monitor output from the ⑤ MONI terminal on the rear panel to the oscilloscope.

In the application, select "pre amp" as the type of monitor signal under "DAC monitor".

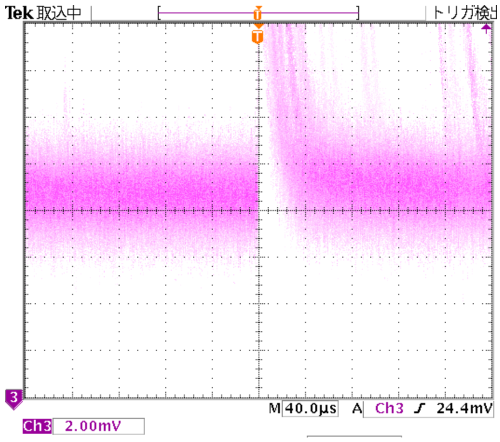


Upon checking the oscilloscope, it was observed that the waveform undershoots after the falling edge.

Next, adjust the "analog pole zero" in the application.

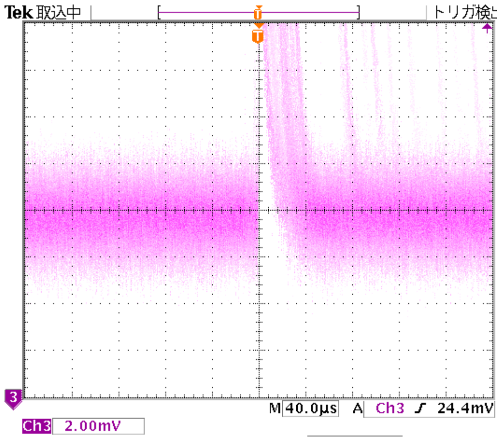


By increasing the value of "analog pole zero," the overshoot has been eliminated. The current "analog pole zero" value is 190 digits.



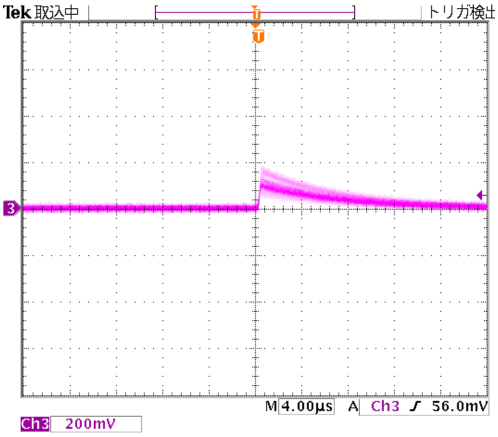
When the voltage range was changed from 20mV to 2mV, a slight overshoot was still observed.

Even though adjustments seemed sufficient at the 20mV range, expanding the range revealed that further adjustments were needed.



The "analog pole zero" value was adjusted to 183 digits, and the overshoot was completely eliminated.
Depending on the oscilloscope's range, it is easy to mistakenly assume the adjustment is complete, even when further adjustment is necessary. Therefore, please ensure that final adjustments are made at a lower voltage range.
Adjusting the analog pole zero has a significant impact on energy resolution.
It is essential to fine-tune the adjustment in 1-digit increments to avoid any undershoot or overshoot after the signal's fall.

2.4 Analog Gain Adjustment



We will adjust the analog gain of the APU101.

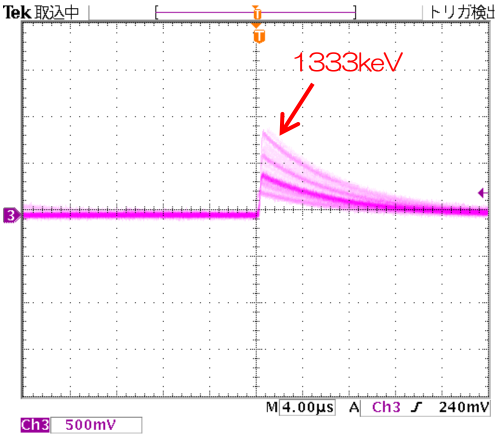
The preamp from the monitor output is used to change the vertical and horizontal scales of the oscilloscope.

The full-scale of the APU101 monitor output is ±1V.

For an energy full-scale range of 1.5MeV, the peak of the 1333keV@Co-60 will be approximately 880mV.

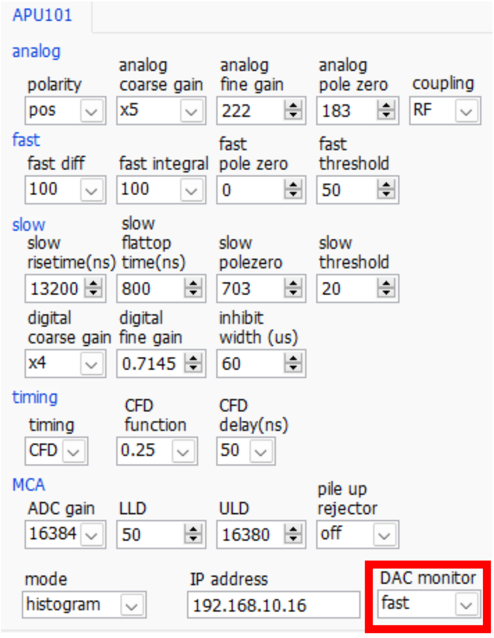
880mV ≒ 1333keV ÷ 1500keV × 1000mV

Before adjustment, with "analog coarse gain" set to x2 and "analog fine gain" set to 100, the signal height was still observed to be small.



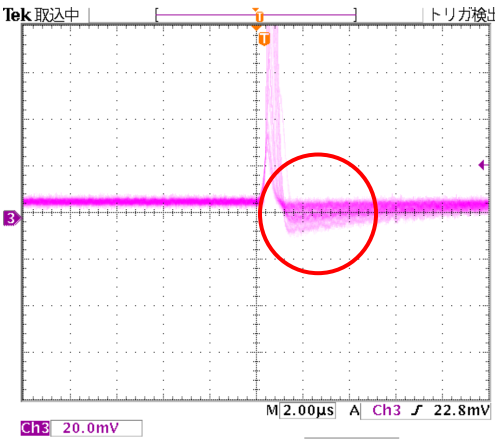
By setting the "analog coarse gain" to x5 and the "analog fine gain" to 222, the waveform of the 1333keV Co-60 signal was adjusted to approximately 880mV, with a clear and well-defined peak.

2.5 FAST Pole Zero Adjustment

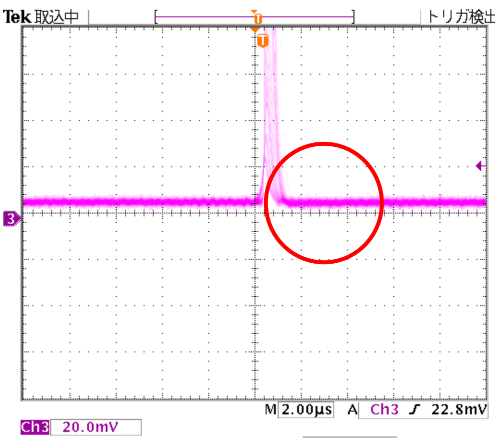


In the application, select "fast" for the monitor signal type. The waveform of the monitor output will switch to the fast signal.

The fast signal is based on the preamp signal, with differential and integral processing performed by the timing filter amplifier circuit. It is related to the acquisition of time information, Baseline Restore, and the timing for starting energy acquisition.

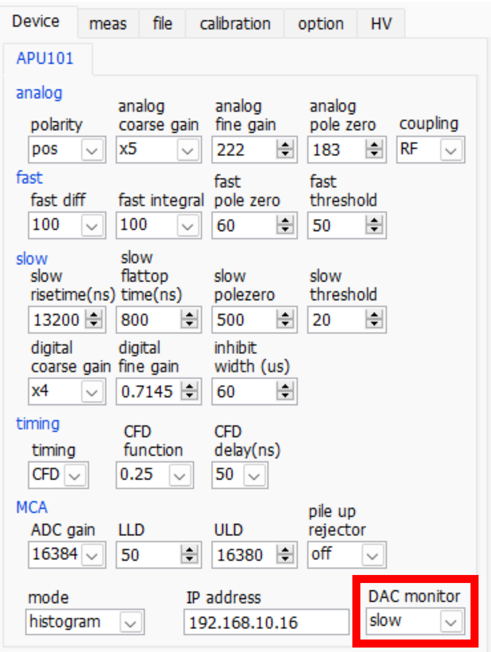


This is the oscilloscope image of the fast signal before adjustment. It can be seen that there is an undershoot after the waveform's falling edge.



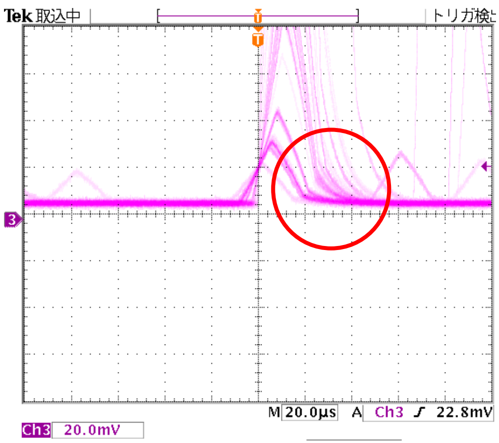
This is the adjustment after setting the "fast pole zero" value to 100 digits in the application, eliminating the undershoot.

2.6 SLOW Pole Zero Adjustment

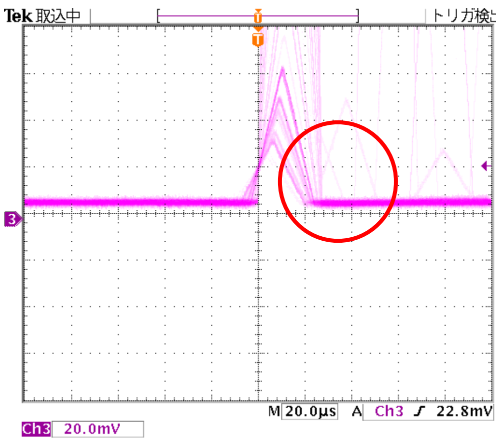


In the application, select the "slow" monitor signal type. The waveform type of the monitor output will switch to the fast signal.

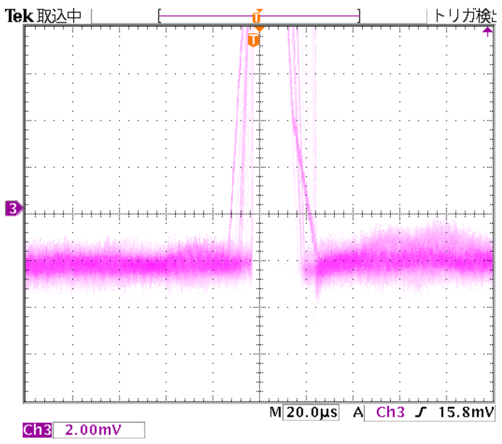
The slow signal is a waveform processed by the Trapezoidal Filter based on the preamp signal. Since the amplitude of the slow signal represents the energy information itself, proper adjustment is crucial.



It has been confirmed that there is an overshoot, and the "slow pole zero" setting needs to be adjusted.

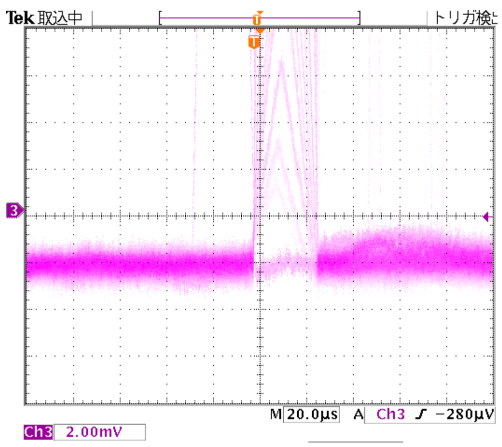


By adjusting the "slow pole zero" value to 711 digits, a smooth slow waveform without overshoot or undershoot was achieved.



As with the adjustment of the "analog pole zero," the voltage range on the oscilloscope was changed from 20mV to 2mV, and undershoot was observed.

Even though it seemed like the adjustment was fine with the 20mV voltage range, it became clear that further adjustments were needed when switching to the 2mV range.

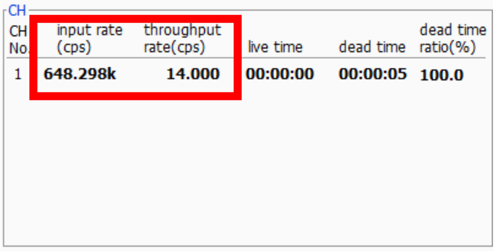


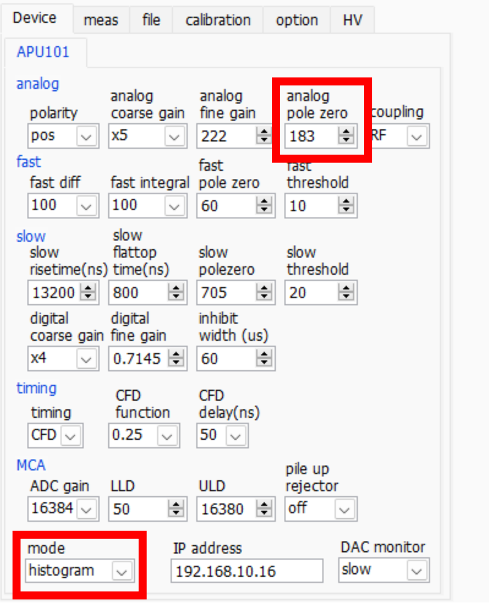
Adjusting the "slow pole zero" to 708 digits completely eliminated the undershoot, confirming that the adjustment was successfully made.

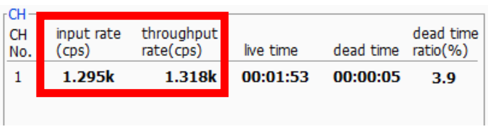
The "slow pole zero" value has a significant impact on energy resolution. Even a 1-2 digit difference can have a large effect, so it is important to conduct repeated measurements in the actual environment to determine the optimal adjustment value.

Additionally, the "slow pole zero" value itself is dependent on the detector, and it may vary. Always make adjustments while verifying the settings on the oscilloscope.

2.7 FAST Threshold Adjustment







Set the application's mode to "histogram" and start the measurement.

By focusing on the input rate in the application status, it was confirmed that the input rate is 600 kcps and that the counting rates of the input rate and throughput rate are unbalanced.

When checking the spectrum in this state, it was confirmed that no data appeared.

This phenomenon occurs because the setting of the "fast threshold," which is the threshold for the fast signal, is too low, causing noise to be counted excessively.

By gradually increasing the value of the "fast threshold" and setting it to 50 digits, both the input rate and through rate stabilized at similar levels.

The "fast threshold" plays a significant role in the baseline restoration calculation for the slow waveform.
It is a crucial setting for achieving optimal energy resolution.

2.8 Slow Rise Time and Slow Flat Top Time Adjustment

Slow rise tmie	Slow flat top time	Analog
13200 ns	800 ns	6 us
4400 ns	800 ns	2 us

The settings for "slow rise time" and "slow flat top time" are critical factors for accurately measuring energy resolution.

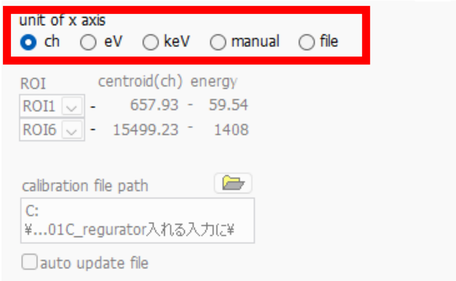
For the GEM10-70, the default values for "slow rise time" and "slow flat top time" are provided in the table on the left.

The optimal settings can vary depending on factors such as the manufacturer of the Ge detector, its efficiency, the type of detector (e.g., planar or coaxial), and the installation environment.

To determine the optimal settings for your measurement environment, it is necessary to adjust the "slow rise time" (within the range of 5μs to 16μs) and "slow flat top time" (within the range of 500ns to 1000ns) based on the default values, perform repeated measurements, and analyze the dependence between resolution and both parameters.

In comparison to the analog time constant, "slow rise time" is typically 2.0 to 2.4 times the analog time constant.

2.9 Digital Gain Adjustment

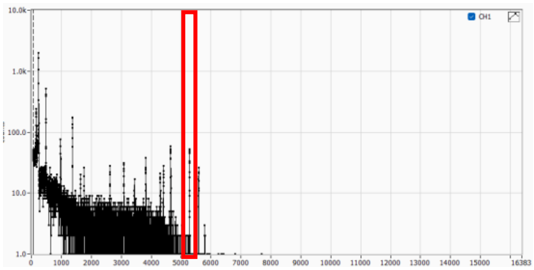


Set the application mode to "histogram" and start the measurement.

Please check the "ch" box in the calibration tab.

Adjust the digital gain in accordance with the analog gain's full-scale setting.

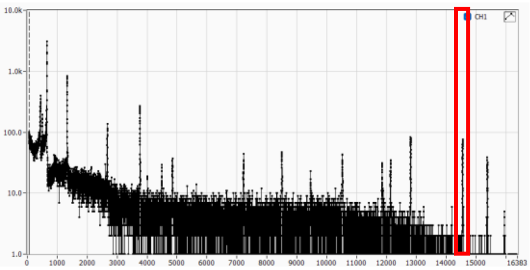
To adjust for an energy full scale of 1.5 MeV, if the ADC gain (X-axis resolution) is set to 16384, 1333 keV@Co-60 should be adjusted to approximately 14550 channels.



The calculation for this adjustment is:

14550 digits ≒ 1333 keV / 1500 keV * 16384 digits

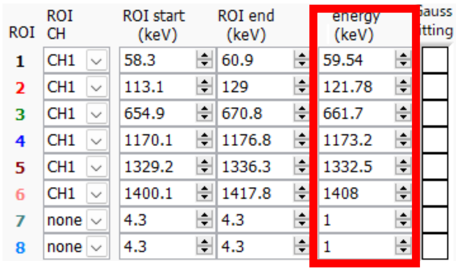
Before adjusting the digital gain, the 1333 keV peak was found around 5000 channels, indicating that the digital gain was too low.



Adjust the "digital coarse gain" and "digital fine gain" to achieve the target of 14550 digits for the 1333 keV peak.

By adjusting the "digital coarse gain" and "digital fine gain," the 1333 keV peak was successfully adjusted to 14550 digits.

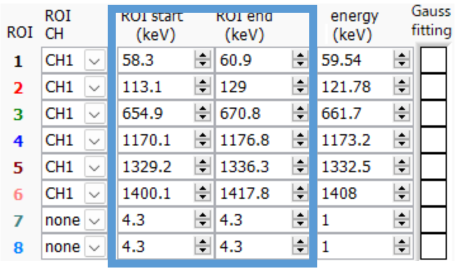
2.10 Energy Calibration and Gauss Fitting



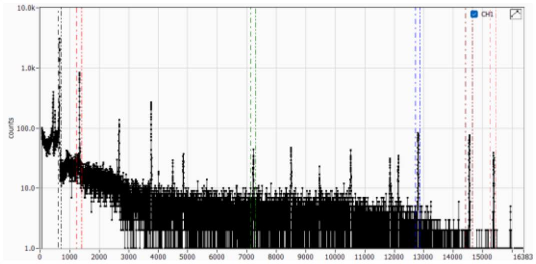
Energy calibration involves converting the scale of the X-axis from channels (ch) to energy units such as keV, by setting the ROI for known energy peaks.

Display the calibration tab in the application.

For example, when using Cs-137, Eu-152, Am-241, and Co-60 sources, enter the known energy values in the energy field as shown in the red box.

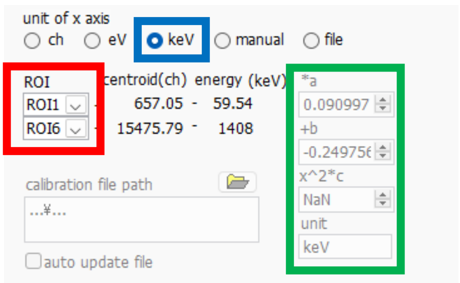


In the blue box, for ROI start and ROI end, input the channel information while reviewing the spectrum, or you can drag the ROI lines on the spectrum with your mouse to set them.



After entering the values for ROI start and ROI end, the spectrum will display the vertical lines at these points, as shown in the image.

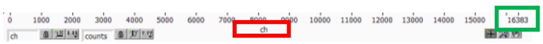
Energy calibration will be performed based on two known energy points: 59.54 keV and 1408 keV.



Select ROI1 (59.54 keV) and ROI6 (1408 keV) in the red box for the ROI selection.

By checking the box for keV in the blue box, energy calibration using a linear equation (ax + b) will be performed, as shown in the green box.

Before Energy Calibration



After Energy Calibration

The X-axis of the spectrum has now been converted to energy units. For the maximum value, the channel number 16383 corresponds to 1504 keV after calibration.

At this point, the calibration is performed using a linear equation (ax + b), but more precise energy calibration can be done using a quadratic equation, which will be described later.

Before Calibration

ROI No.	peak (ch)	centroid (ch)	peak (count)	gross (count)	gross (cps)	net (count)	net (cps)	FWHM (ch)	FWHM (%)	FWHM	FWTM
ROI1 :	651.00	650.71	24.103k	178.984k	207.397	160.026k	185.430	6.4	0.989	6.438	11.736
ROI2 :	1328.00	1328.25	6.223k	77.933k	90.305	47.590k	55.145	7.4	0.558	7.415	13.518
ROI3 :	7205.00	7205.55	294.000	8.130k	9.421	3.347k	3.878	12.9	0.180	12.947	23.602
ROI4 :	12774.00	12774.83	682.000	11.960k	13.859	11.037k	12.789	16.5	0.129	16.506	30.089
ROI5 :	14510.00	14508.86	596.000	10.191k	11.809	9.913k	11.487	17.3	0.119	17.256	31.456
ROI6 :	15332.00	15330.94	266.000	4.829k	5.596	4.536k	5.256	17.9	0.116	17.855	32.548
ROI7 :	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.000	0.000
ROI8 :	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.000	0.000

After Calibration

ROI No.	peak (keV)	centroid (keV)	peak (count)	gross (count)	gross (cps)	net (count)	net (cps)	FWHM (ch)	FWHM (%)	FWHM (keV)	FWTM (keV)
ROI1 :	59.57	59.54	25.352k	188.011k	207.518	168.111k	185.553	6.4	0.989	0.591	1.077
ROI2 :	121.75	121.78	6.544k	81.862k	90.355	49.995k	55.182	7.4	0.559	0.681	1.242
ROI3 :	661.59	661.64	303.000	8.496k	9.377	3.495k	3.857	12.9	0.180	1.188	2.167
ROI4 :	1173.13	1173.21	713.000	12.541k	13.842	11.560k	12.759	16.5	0.129	1.514	2.760
ROI5 :	1332.59	1332.49	628.000	10.665k	11.772	10.375k	11.452	17.3	0.119	1.588	2.894
ROI6 :	1408.10	1408.00	279.000	5.072k	5.598	4.764k	5.258	17.9	0.117	1.643	2.994
ROI7 :	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.000	0.000
ROI8 :	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.000	0.000

Once calibration is completed, the ROI information in the top-right corner of the application will convert the values for FWHM and FWTM from channels to keV.

The full width at half maximum (FWHM) energy at 1333 keV is often used as an indicator of the quality of Ge semiconductor detectors and measurement modules.

In the blue box, ROI 5 has been set to 1333 keV. The energy resolution is displayed as 1.588 keV.

Depending on the environment, you should generally expect a range between 1.6 keV and 1.9 keV.

ROI No.	peak (keV)	centroid (keV)	peak (count)	gross (count)	gross (cps)	net (count)	net (cps)	FWHM (ch)	FWHM (%)	FWHM (keV)	FWTM (keV)
ROI1 :	59.52	59.50	339.000	2.452k	222.909	2.230k	202.697	6.5	0.996	0.596	1.093
ROI2 :	121.82	121.79	88.000	1.064k	96.727	716.000	65.091	7.5	0.561	0.685	1.203
ROI3 :	661.85	661.85	5.000	67.000	6.091	67.000	6.091	10.3	0.143	0.950	-Inf
ROI4 :	1173.50	1173.49	11.000	162.000	14.727	137.000	12.485	12.4	0.097	1.144	-Inf
ROI5 :	1332.08	1332.05	10.000	128.000	11.636	128.000	11.636	-Inf	-Inf	-Inf	-Inf
ROI6 :	1408.37	1408.40	5.000	54.000	4.909	54.000	4.909	14.2	0.092	1.302	-Inf
ROI7 :	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.000	0.000
ROI8 :	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.000	0.000

During the initial startup or when measuring weak samples with low radiation intensity, there may be times when counts are low and it takes longer for data to accumulate.

In such cases, accurate calculation results may not be obtained.

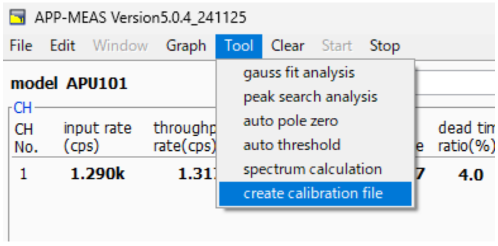
ROI	ROI CH	ROI start (keV)	ROI end (keV)	energy (keV)	Gauss fitting
1	CH1	58.3	60.9	59.54	☒
2	CH1	113.1	129	121.78	☒
3	CH1	658.8	665.6	661.7	☒
4	CH1	1170.1	1176.8	1173.2	☒
5	CH1	1329.2	1336.3	1332.5	☒
6	CH1	1400.1	1417.8	1408	☒
7	none	4.3	4.3	1	☐
8	none	4.3	4.3	1	☐

By enabling the "Gauss fitting" as shown in the blue box, more accurate results can be obtained even shortly after starting the measurement.

ROI No.	peak (keV)	centroid (keV)	peak (count)	gross (count)	gross (cps)	net (count)	net (cps)	FWHM (ch)	FWHM (%)	FWHM (keV)	FWTM (keV)
ROI1 :	59.52	59.49	686.000	5.120k	222.609	4.581k	199.188	6.5	0.997	0.596	1.086
ROI2 :	121.73	121.75	195.000	2.248k	97.739	1.343k	58.399	7.5	0.561	0.685	1.248
ROI3 :	661.30	661.74	11.000	153.000	6.652	66.000	2.885	13.0	0.180	1.193	2.174
ROI4 :	1173.31	1173.13	25.000	345.000	15.000	277.000	12.065	16.2	0.127	1.488	2.712
ROI5 :	1332.17	1332.50	21.000	286.000	12.435	265.000	11.511	16.3	0.112	1.498	2.730
ROI6 :	1407.36	1407.87	12.000	153.000	6.652	119.000	5.153	19.0	0.124	1.750	3.190
ROI7 :	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.000	0.000
ROI8 :	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.000	0.000

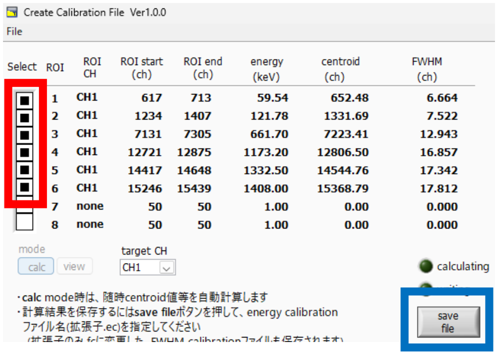
With "Gauss fitting" turned ON, the calculation results for the same count rate show reasonable values, despite the low count.

2.11 Generation of Calibration File



Energy calibration using a quadratic equation requires a calibration file.

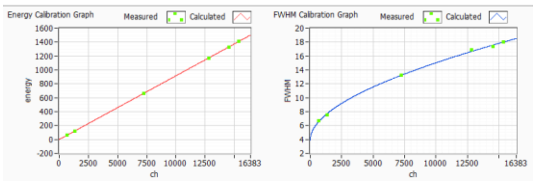
The calibration file is generated using the spectrum and ROI information, so please ensure the spectrum has a sufficient number of counts before generating the file.



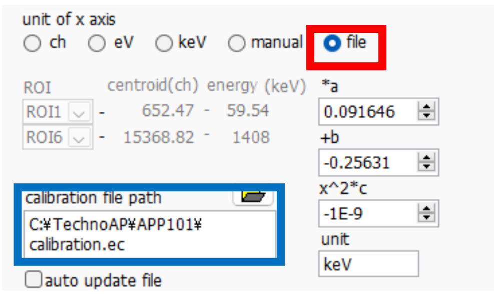
When the spectrum is acquired in "histogram" mode, click on "Tool" → "Create calibration file".

Using ROI1 through ROI6, generate the calibration file. As shown in the red box, check the relevant ROIs.

Click "Save file" to generate and save the calibration file. Close the pop-up application by clicking "File" → "Close".



Based on the selected ROIs, energy calibration and FWHM calibration are calculated instantly, and the result graph is displayed.

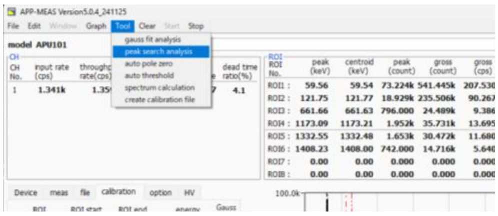


To apply the quadratic equation, select the "File" option in the red box and choose the calibration file you generated earlier.

When measuring unknown materials or materials emitting a wide range of energies, having only 8 ROIs may not be sufficient. Additionally, manually adjusting the ROIs can be time-consuming, and there may be variations due to individual preferences in ROI settings.

The next feature, "Peak Search Analysis", automatically detects peaks, applies Gaussian fitting, and calculates errors, allowing measurements to be performed easily and accurately for any type of sample without the complexity of manual adjustments.

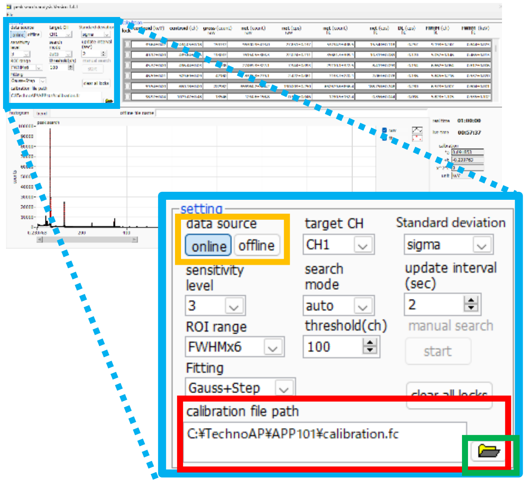
2.12 Measurement using Peak Search Analysis function



Open the Peak Search Analysis.

Click on "Tool – Peak Search Analysis."

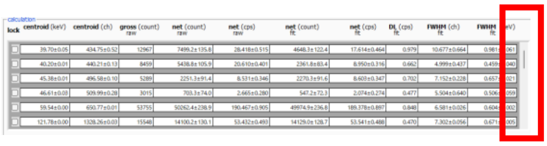
The Peak Search Analysis screen will open.



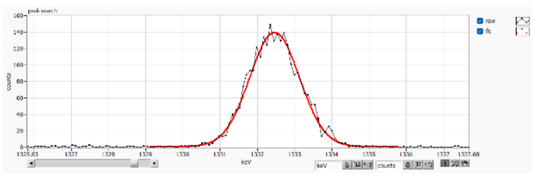
First, set the calibration file you created earlier in the file selection field, as shown in the red box.

Click the folder icon in the green box and select the file from the pop-up window.

Since we will use it in real-time during measurement, the data source in the orange box was set to "online."

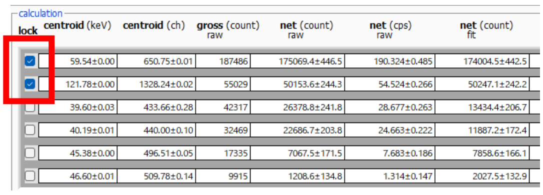


At this point, start the measurement from the main application. Once the measurement begins, the histogram will automatically update, and the peaks detected by Peak Search will be added to the "calculation" section one after another. You can use the scroll bar in the red box to view the calculated values for each peak.



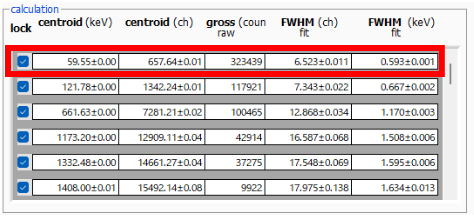
As the histogram updates, you will see the raw data (black) and Gaussian fit (red) applied, as shown in the image on the right. In this case, we will focus on the following five peaks:

- 59.54 keV @ Am-241
- 121.78 keV @ Eu-152
- 661.7 keV @ Cs-137
- 1173.2 keV @ Co-60
- 1332.5 keV @ Co-60



lock	centroid (keV)	centroid (ch)	gross (count) raw	net (count) raw	net (cps) raw	net (count) fit
☑	59.54±0.00	650.75±0.01	187486	175069.4±446.5	190.324±0.485	174004.5±442.5
☑	121.78±0.00	1328.24±0.02	55029	50153.6±244.3	54.524±0.266	50247.1±242.2
☐	39.60±0.03	433.66±0.28	42317	26378.8±241.8	28.677±0.263	13434.4±206.7
☐	40.19±0.01	440.00±0.10	32469	22686.7±203.8	24.663±0.222	11887.2±172.4
☐	45.38±0.00	496.51±0.05	17335	7067.5±171.5	7.683±0.186	7858.6±166.1
☐	46.60±0.01	509.78±0.14	9915	1208.6±134.8	1.314±0.147	2027.5±132.9

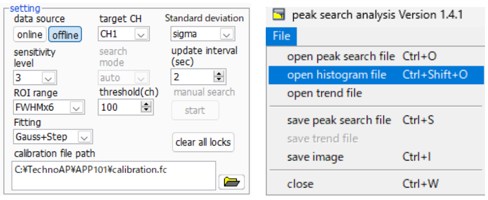
By checking the boxes as shown in the red box, the calculation results will be displayed in the upper section.



This shows the result of maintaining the five target peaks.

From the calculation results, various information such as energy resolution, errors, and count rate can be obtained.

In this case, the energy resolution at 1332.5 keV after 1 hour of measurement is found to be 1.595 keV, which is excellent.



The Peak Search Analysis also has a function to reload and recheck previously acquired data.

As shown in the red box, you can select "offline" and choose "File - Open histogram file" to load the file.

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