

DESCRIPTION OF GammaPRO

2017

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Introduction

GammaPRO is a software for work with semiconductor and scintillation spectrometers of gamma, beta and alpha radiation (such as **TRIO**, **BOSON**, **AirSPEC**, **GCD**, **MCA-527**, **DSPEC**, etc.).

GammaPRO ensures simultaneous and independent control of all the connected analysers and spectrometric devices, and provides all the necessary tools for applied spectrometry. It allows measuring and processing spectra, setting parameters of spectrometric tracts and determining all the relevant metrological characteristics.

GammaPRO employs different algorithms for determining activity in samples (ROI-method with overdetermined matrix, individual peaks analysis method, superposition method). For the analysis of high resolution spectra (spectra received on semiconductor spectrometers) there separate tools (search peaks, Gaussian approximation, identification, plotting efficiency curves, etc.).

GammaPRO has a multi-window, easily customisable interface and provides broad opportunities for work with spectra (mathematical operations, pack processing, application of specific algorithms, conversion and translation to other applications). Automation of routine measurements can be ensured using a bar-code system and counter samples change mechanisms.

GammaPRO has a platform and module structure, which allows supplementing the programme with application modules.

The programme includes plug-in modules:

“Pack” – processing of series of spectra;

“Profile” – measurements in motion (car, railway car version of the spectrometer-radiometer);

“WBC” – whole body radiation spectrometry (in chair and chamber configuration).

System requirements:

Windows XP/Vista/7/8/10;

processor with frequency 1 GHz;

USB 2.0 (for MCA-527, BOSON, MD198, MD198M analyser)

256 MB RAM;

100 MB of free space on the hard drive;

keyboard;

mouse.

1 Starting the programme

To start **GammaPRO**, double click with the left mouse button on the **GammaPRO** icon on the Windows desktop, or go to **Start->Programs->GammaPRO**.



When the programme is started, it detects enabled analysers and their status. If there are many analysers, the starting process may last longer, and the detection progress can be seen on start-up screen of the programme. To terminate the connection with enabled analysers, press **Esc** key on the keyboard.

2 Structure of the programme and its elements

2.1 Main interface elements

When the programme has started, the main window of the programme will appear on the display (Fig.1).

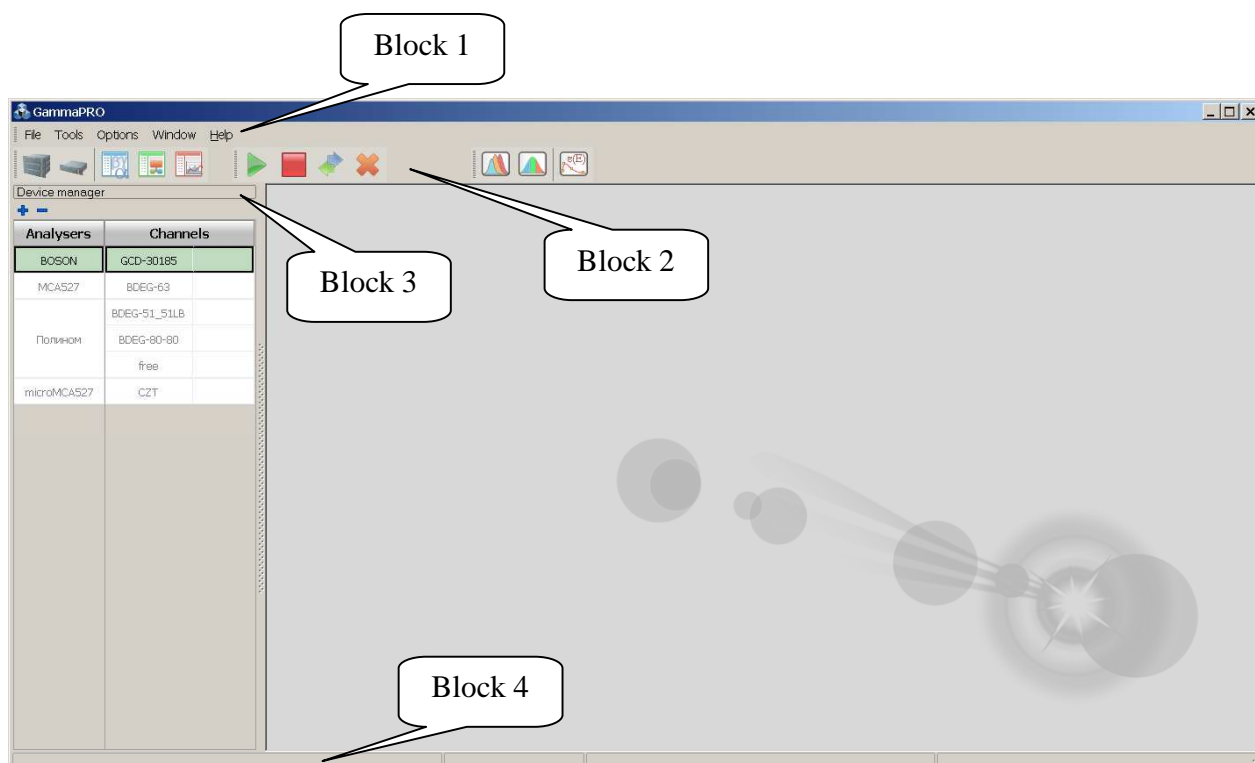


Figure 1. View of **GammaPRO** after its launch

The programme window contains four main blocks:

- main menu of the programme (Block 1);
- main toolbar with buttons providing access to most used dialogues (Block 2);
- device manager (Block 3) – a panel, which ensures switching from one spectrometric tract to the other;
- status bar (Block 4).

2.2 Main menu

The main menu of the programme includes the following items:

File (see Fig.2):

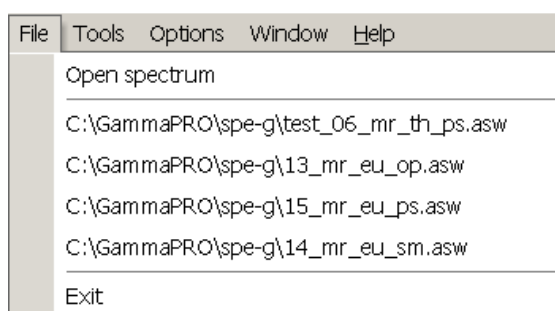


Figure 2. **File** menu items

With the **Open Spectrum** menu item, the user may open a previously saved spectrum in a dialogue window.

Four other items can quickly open recently saved spectra.

Exit is used to close **GammaPRO**.

Tools (see Fig.3):



Figure 3. **Tools** menu items

Pack opens a window for working with several spectra (see section 11).

In the **Tools** section, you will see names of plug-in modules such as **WBC**, **Profile**, etc.

Options (see Fig.4):

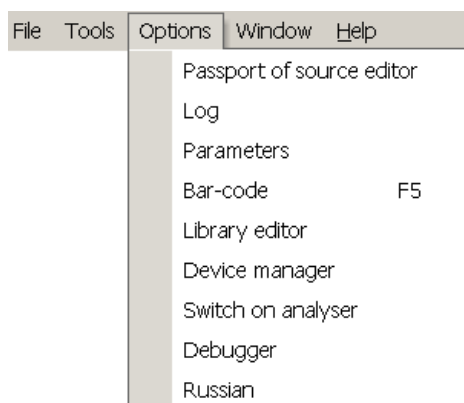



Figure 4. **Options** menu item

Passport of source editor opens a window that allows generating files of passport data of source (see section 13), used in the procedure of generation of efficiency calibration files.

Log opens a log window, which displays saved results of conducted measurements. Data can be sent to the log using Add to log in the menu, which can be displayed by pressing  (**Options**) on the toolbar of the spectrum.

Parameters opens a window with the same name, which contains general settings of the programme (see section 10).

Bar-code opens a window with information about the entered bar-code, from which measurement with automatically completed information about the source can be started. You can display such a window automatically by pressing the F5 hot key.

Library editor is for opening a dialogue, where you can work with radionuclides library files, as well as create and edit your libraries using the existing ones (see section 12).

As **Device manager** (Block 3, Fig.1) can be separated from the left edge of the main programme window and can be closed, then **Device manager** can make this panel visible again.

Switch on analyser allows switching on all the available analysers at once. It means that if analysers are physically connected to the PC and parameters of each connection are entered in the programme, with this item you can skip pressing **Switch On** in the **Device configuration** window (see Fig. 11) for each spectrometric tract separately.

Use **Russian/English** to switch **GammaPRO** interface language. When you use this item, the programme will warn you than a language will change and will close. When you reopen the programme, the interface language will be different.

Window (see Fig.5):

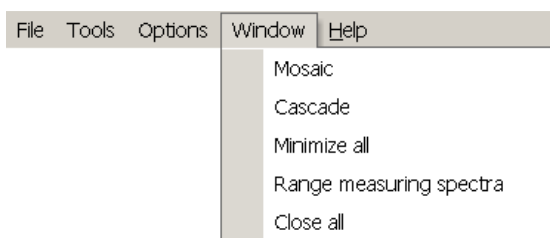


Figure 5. **Window** menu items

Mosaic displays windows of the spectrum as a “Mosaic”. **Cascade** displays windows of the spectrum as a “Cascade”. **Minimize all** minimizes all the windows of the spectrum to the bottom of the main window.

Range measuring spectra ranges the spectra to be measured (those having a status “measurement spectrum”) in the sequence of their opening.

Close all closes all the windows.

Help (see Fig.6):



Figure 6. **Help** menu items

About... brings a dialogue with information about **GammaPRO**, as well as contact information.

Help displays information on how to work with the programme.

2.3 Main toolbar






GammaPRO toolbar looks as shown on Figure 1 (block 2). The panel is divided into groups, which can be moved within the panel, or “separated” from the panel and moved to some other area of the main window of the programme.

The panel contains three groups (see Fig.7):






Figure 7. Groups of the toolbar


The first group **Device manager** contains the following buttons:




-  - **Device configuration**, displays a configuration window of the analyser (device), which is highlighted in the **Device manager** right now (Fig.1, block 3, Analysers column);
-  - **Tract configuration**, displays a configuration window of the spectrometric tract, which is highlighted in the **Device manager** right now (Fig.1, block 3, Channels column);
-  - **Measurement parameters**, displays a window with parameters of measurements for the spectrometric tract, which is highlighted in the **Device manager** right now (Fig.1, block 3, Channels column);
-  - **Calculation parameters**, displays a window with calculation (activity, etc.) parameters for the spectrometric tract, which is highlighted in the **Device manager** right now (Fig.1, block 3, Channels column);
-  - **Spectrum view parameters**, displays a window with parameters of the view of the spectrum (colours of elements of the histogram, background, axes, etc.) for the spectrometric tract, which is highlighted in the **Device manager** right now (Fig.1, block 3, **Channels** column).

The second group **Calibrations** contains the following buttons:

-  - **Energy calibration**, displays energy calibration for the tract, which is highlighted in the **Device manager** right now (Fig.1, block 3, Channels column);
-  - **FWHM and shape calibration**, displays FWHM (full width at half maximum) and shape (left edge shape) calibration of the peak for the tract, which is highlighted in the **Device manager** (Fig.1, block 3, **Channels** column);
-  - **Efficiency calibration**, displays a window of efficiency calibration. The display of this window is not related to the currently selected analyser and tract.

The third group **Measurement** is active only when there is a real connection with a real analyser for the current tract. The group contains the following buttons:

-  - **Start**, starts a measurement in the spectrometric tract, which is highlighted in the **Device manager** right now (Fig.1, block 3, **Channels** column);

-  - **Stop**, stops a measurement in the spectrometric tract, which is highlighted in the **Device manager** right now (Fig.1, block 3, **Channels** column);
-  - **Read**, forced reading of the spectrum from an analyser for the current spectrometric tract, which is highlighted in the **Device manager** right now (Fig.1, block 3, **Channels** column);
-  - **Clear**, clears spectrum buffer in the analyser for the current spectrometric tract, which is highlighted in the **Device manager** right now (Fig.1, block 3, **Channels** column).

The toolbar buttons described above are duplicated in the **Device manager** popup. Thus, for instance, the context menu of the Analysers column looks as shown on Fig.8.

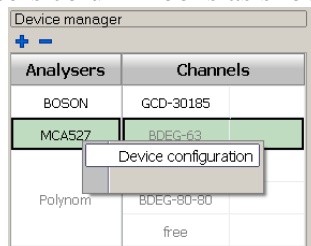


Figure 8. Context menu of the **Analysers** column

Also, the context menu of the **Channels** column looks as shown on Figure 9.

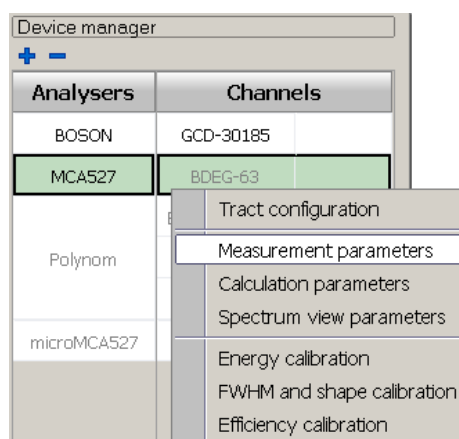


Figure 9. Context menu of the **Channels** column

2.4 Device Manager panel

The **Device Manager** panel (Fig.1, block 3) is intended for switching between analysers (devices) and tracts within a single analyser (if the analyser is multi-tract analyser). This solution allows simultaneously and operatively controlling any number of devices connected to the PC and spectrometric tracts, to start measurements and conduct processing.

To choose the necessary analyser and tract, just click on it with the left mouse button in the table. When selecting a spectrometric tract in the **Channels** column, the analyser corresponding to it is selected automatically. When clicking on the necessary analyser in the **Analysers** column, the first tract will be selected automatically. (Example. On Fig.8 and 9 the current analyser is 'MCA527', the current tract is 'BDEG-63').

As it was noted above, button actions on the toolbar described in section 2.3 will be used for the currently selected tract.

To add or remove an analyser to the **Device Manager** panel there are  and  buttons in the table header (block 1). To remove an analyser from the list of used analysers, select the analyser in the **Analysers** table and press .

The **Channels** column is also divided into two columns, first of which is intended for displaying the name of the tract, but the second has a timer showing the time of measurement left in seconds. If the field is empty, measurement in the channel was stopped or has ended (see Fig. 10).

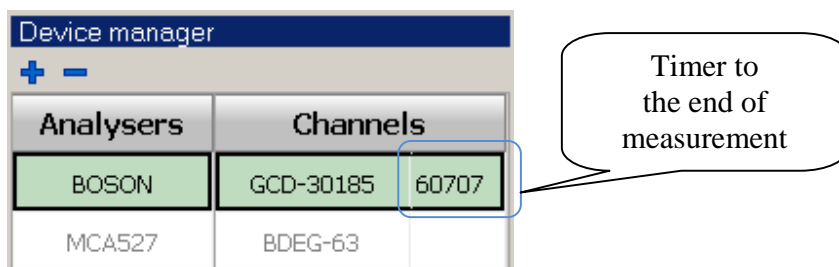



Figure 10

2.4.1 Device configuration window

When you press  on the toolbar or select **Device configuration** in the context menu of the **Analysers** column on the **Device Manager** panel, a window shown on Figure 11 will appear on the display.

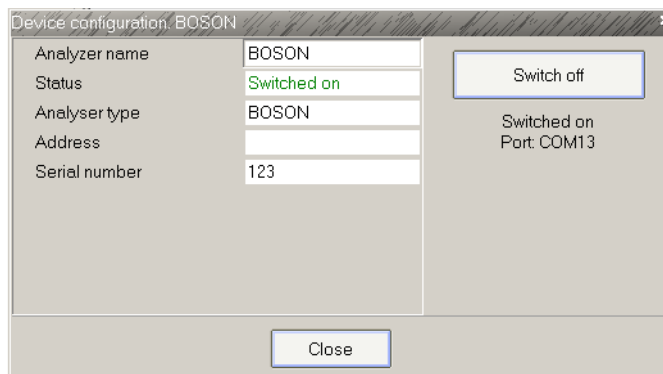


Figure 11. Device configuration window view

Analyser name field – the name of the analyser given by the user to the current analyser and shown in the **Analysers** column on the **Device Manager** panel.

Analyser type field – the type of the analyser from the list of **GammaPRO**-compatible devices.


Address, Port fields – intended for specifying an analyser's IP address in the network, or a device address on the bus, or a serial port number (including virtual) depending on the type of the device. If the field **Address** is not empty, the software attempts to establish connection with the analyzer which has the corresponding IP address. Otherwise, the software addresses all the available serial ports, one after another, attempting to establish connection to the device which has the corresponding serial number.

In the **Serial number** field, the user can enter the serial number of the device to link the specific analyser to the specific position on the **Device Manager** panel. If the serial number is

unknown, leave this field blank, a serial number of the first free device of this type will be populated after the establishment of a connection with the device.

Press **Switch on** on the right side of the **Device configuration** window to establish a connection with an analyser. If the connection has been successfully established, you will see the green **On** value in the **Status** field, but if there is no connection, the programme will show a message about failure to establish a connection.

2.4.2 Tract configuration window

When you press  on the toolbar or select **Tract configuration** in the context menu of the **Channels** column on the **Tract Manager** panel, a window shown on Figure 12 will appear on the display.

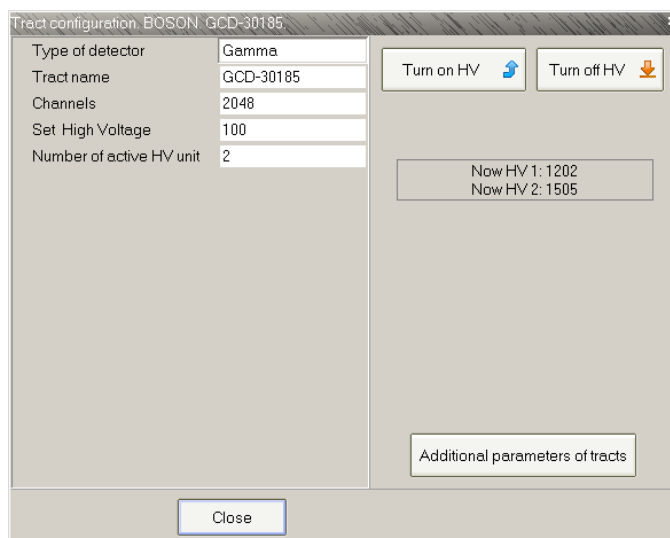




Figure 12. **Tract configuration** window view

In this window, in the **Tract name** field the user may give the current tract a name, which will be displayed in the **Channels** column on the **Device Manager** panel.


The **Tract name** field is intended for selecting the type of the detector (gamma, beta or alpha).

In the **Channels** field, specify the number of channels in the spectrum. Options in the dropdown list of this field depend on the type of the analyser.

The **High Voltage** field is intended for specifying the value of high voltage, which should be set for this type of detector. To actually set high voltage, press , or press  to remove it.

Depending on the analyzer's type, this parameters group may have some additional fields such as, for example, the following:

- **Threshold** which displays the amplitude discriminator value in arbitrary units. This value may vary from analyzer to analyzer, this is why it should be set in accordance with a **spectrometer's** or analyzer's documentation.
- **Ratio CV** which displays the control voltage factor indicating by which value the amplification coefficient should be changed to shift a peak's position by one channel. This parameter is needed for a correct functioning of the reference peak stabilization system or auto adjustment of the spectrometry tract.

You can access specific parameters of the analyser by pressing . It opens a window, which can look differently depending on the analyser type.

If the analyser of this tract is inactive, buttons in the **Tract configuration** window will be greyed out.

2.4.3 Measurement parameters window

When you press  on the toolbar or select **Measurement parameters** in the context menu of the **Channels** column on the **Tract Manager** panel, a window shown on Figure 13 will appear on the display.

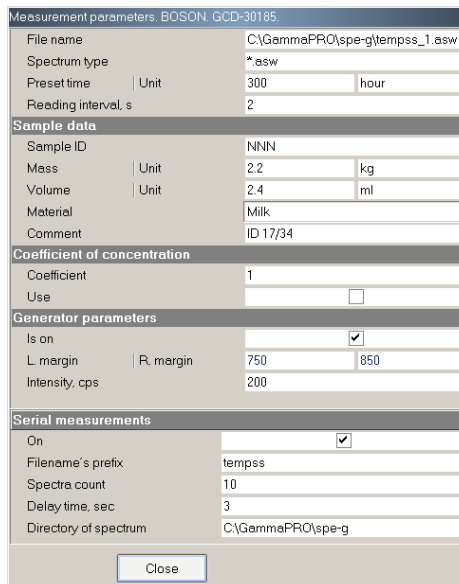



Figure 13. **Measurement parameters** window view

This window contains parameters related to the measurement procedure:

File name – spectrum file name, which will be generated during the forthcoming measurement on this spectrometric tract. The file name should be specified in full format with a path to the location, where the file will be located. To get to the standard file selection dialogue window, click in the field and press , which will appear on the right side of the field.

Spectrum type – spectrum format selection window. The *.asw format is the standard default type of spectrum for **GammaPRO**.

Preset time – exposition of the forthcoming measurement for this tract. The time unit for the **Preset time** value is specified in the **Unit** field.


Reading interval – spectrum reading and displaying interval, sec.

The **Sample data** section contains parameters related to the sample being measured. These data will be further displayed in parameters of the measured spectrum.

Sample ID – the identification number of the countable sample (text field).


Weight, Unit – mass and mass unit of the countable sample.

Volume, Unit – volume and volume unit of the countable sample.

Material – name of the material being measured. It is selected from the list of materials, for which there are data on the permissible content range. To select a material, click in the field and press , which will appear on the right side of the field. Confirm selection of the necessary materials by pressing **Apply** (see section 4.3).

Comment – field for a comment about the forthcoming measurement (2 text rows).

The **Coefficient of concentration** section contains parameters related to the method of preparation of the sample to be measured. These data will be further displayed also in parameters of the measured spectrum.

Coefficient – value of the coefficient of concentration, rel. units. To get help in determining the coefficient of concentration (including cases of radiochemical concentration), the user may open an additional window, where this coefficient will be calculated. To open the additional window, click in the field and press , which will appear on the right side of the field (see Fig.14).

Use – field for enabling or disabling the use of the coefficient of concentration in further calculations.

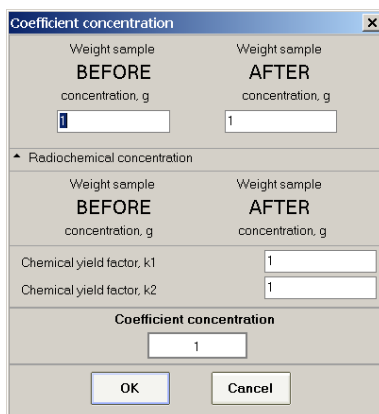


Figure 14. **Coefficient of concentration** window view

The **Retry of measurements** section contains parameters allowing to specify and set retry of measurements in the automatic mode.

On – field to enable the retry of measurements mode.

Template files – file name template.

Iterations – the number of measurements to be conducted.

Pause, sec – field for setting the time between measurements, sec.

Directory of spectrum – the path, where any measured spectra will be saved.

The spectra file names are generated from the specified directory (**Directory of spectrum**) and from the template of field specified in the **Template files** field, plus iteration number and resolution.

Example of the first, second, etc. spectrum for the situation on Fig.13:


C:\GammaPro\spe-g\temp_1.asw

C:\GammaPro\spe-g\temp_2.asw

...

C:\GammaPro\spe-g\temp_10.asw

2.4.4 Calculation parameters window

When you press  on the toolbar or select **Calculation parameters** in the context menu of the **Channels** column on the **Tract Manager** panel, a window shown in Figure 15 will appear on the display. This window contains the parameters which will be the spectrum parameters when the spectrum has been acquired.

Calculation parameters: BOSON. GCD-30185			
Calculation type	Specific activity, Bq/g		
Bkg spectrum	C:\GammamaPRO\bkg-g\lon_surn.asw		
Calibration file (ROI-meth)	C:\GammamaPRO\clb-g\marinell.clb		
Calibration ADER			
List of calibration spectra	C:\GammamaPRO\clb-g\lcs\Marinell.m		
Reference date			
On measurement date	<input checked="" type="checkbox"/>		
Date	13.03.2017		
Time	12:39:27		
Directories			
Calibration files	C:\GammamaPRO\clb-g		
Working spectrum	C:\GammamaPRO\spe-g		
Bkg spectra	C:\GammamaPRO\bkg-g		
ROI			
Calculate	<input type="checkbox"/>		
Subtract bkg	<input type="checkbox"/>		
File ROI			
Error			
L	1.2		
Q	0.1		
RFD			
Search peaks			
L. limit	R. limit	10	16000
Level	3		
Min. area	100		
Type search	Peaks from library		
Show peaks	<input type="checkbox"/>		
Update peaks when read	<input checked="" type="checkbox"/>		
Smoothing			
Polynomial degree	5		
Iteration	1		
Identification			
Library file	C:\GammamaPRO\lbr\lib_for_		
Efficiency file	C:\GammamaPRO\clb-g\mar_		
MTP	7		
Allowable dev., keV	3.2		

This window contains parameters related to the calculation procedure:

'**Specific activity, Bq/kg**' means that during the calculation in addition to the activity the specific activity in Bq/kg will also be calculated;

'Volumetric activity, Bq/l' means that during the calculation in addition to the activity the volumetric activity in Bq/l will also be calculated;

'RFD, mBq/s·m²' means that the radon flux density will be calculated in mBq/s·m² (see document Methodology of radon flux density measurement);

'Content' means that the radionuclide content will be calculated in the units of measurement specified by user (this is applicable in the window method, see Section 14).

Calibration file (ROI-method) – path to the calibration file, which will be used for calculation of activity using the ROI-method.

List of calibration spectra (superposition method) – path to the file list of calibration (reference) spectra, which will be used when calculating the activity by the superposition method.

The **Reference date** section contains parameters allowing to set the date of activity in the measurement results.

On measurement date – when the value in this field is enabled, activity will be calculated as at the measurement date, otherwise the date will be taken from the **Date** and **Time** field.

The **Directories** section contains paths to **Calibration files**, Working spectrum and Bkg spectra. These directories will open by default, when standard file selection dialogue windows open.

The **ROI** section contains parameters allowing to calculate the intensity of in the regions of interest. Such intensities are calculated together with and during the calculation of activity using the ROI-method. The result is displayed on the relevant tab on the results panel in the spectrum.

Calculate – the parameter enabling and disabling the procedure of calculation of intensity in regions of interest.

Subtract bkg – the parameter enabling and disabling subtraction of background in regions of interest, when calculating intensities.

File ROI – path to the file, which contains windows of regions of interest.

The **Search peaks** section contains parameters participating in the search of peaks in the spectrum and their displaying.

L.limit, **R.limit** are the boundary channels of the range where the search of peaks will be performed.

Level is the extreme value of the parameter related to the statistical significance of peaks. If this value is exceeded, a peak is accepted and added to the table; otherwise, the peak is rejected. The value of parameter **Level** can vary within the range from 0.5 (all the peaks, even those close to fluctuation peaks, are accepted) to 5 (only the most prominent peaks featuring significant difference from statistical fluctuations are accepted). The optimum value of this dimensionless quantity is 3.

Min.area – the limit value of the peak area in impulses. The peaks with the value above this one are accepted and added to the table, and below this value are rejected.

Type search – one of two possible types of search for peaks in the spectrum ('**Search and Identification**', '**Peaks from library**'). So, the '**Search and Identification**' type searches for all the peaks available in the spectrum and meeting the criteria of the **Search peaks** section. The '**Peaks from library**' type envisages application of preliminary markings according to the loaded radionuclides library file (see the **Library file** field in the **Identification** section).

Show peaks – parameter for enabling displaying of peaks and their parameters in the spectrum.

Update peak when reading – the parameter showing the need to update peak markings in the process of measurement, when the spectrum is constantly changing. If a peak is added in the process of measurement, it is recommended to enable this parameter, otherwise there will be a visual discrepancy between real peaks and marked peaks.

The **Smoothing** parameters control polynomial smoothing of a spectrum relevant for a better peak search and description of peaks by functions. The **Smoothing** parameters include:

Polynomial degree. This parameter defines the degree of the polynomial smoothing to be considered for spectrum peak search. The parameter's value should not exceed 6, and the recommended value is 5.

Iteration. This parameter defines the number of smoothing iterations for spectrum peak search. If this value is 0, no smoothing will be performed. Spectra featuring high statistics should not be smoothed, and the parameter's value for such spectra should remain 0.

The **Identification** section contains parameters participating in the identification of the peaks found in the spectrum.


Library file – path to the radionuclides library file, which will correspond to the measured spectrum. The library file contains a list of radionuclides, their energy values, probability of outputs and half-lives. Library files are generated using the **Library editor** dialogue (see section 12) and are used in the process of calculation of activity using the peaks analysis method.

Efficiency file – path to the efficiency calibration file, which will correspond to the measured spectrum. The efficiency calibration file contains a dependence of the efficiency of registration on gamma-quantum energy and is used in the process of calculation of activity using the peaks analysis method. The efficiency file is generated using the **Efficiency calibration** dialogue (see section 9).

MTP. This parameter is the so called peak thickness factor, or, in other words, the distance at which two peaks are indistinguishable. The value of this parameter is set in arbitrary units in the range between 3 and 10. In case two peaks close to each other are processed separately as if they were singlets (i.e., each peak has its own background substrate) but they are supposed to be processed together (I.e., so that they have a common background substrate), the calculation should consider this parameter and be repeated until the peaks are processed together as a multiplet.

Allowable dev., keV – the energy deviation parameter, within which a peak may be assigned to a characteristic curve of some radionuclide.

2.4.5 Spectrum view parameters window

When you press  on the toolbar or select **Spectrum view parameters** in the context menu of the **Channels** column on the **Tract Manager** panel, a window shown on Figure 16 will appear on the display.

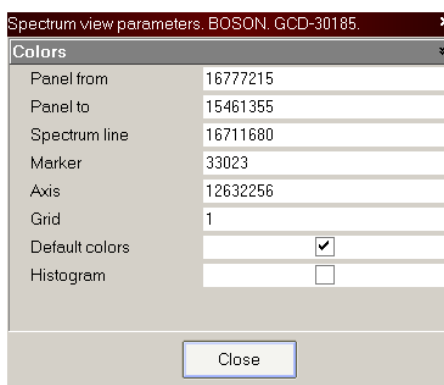


Figure 16. **Spectrum view parameters** window view

This window contains parameters describing the appearance of spectra for this spectrometric tract such as background colour, histogram of the spectrum, grid, axes and marker. When the **Default colors** parameters is enabled, colours will have their default values.

3 Measuring and saving a spectrum


For the purposes of measurements, the user must first select an analyser and a spectrometric tract to work with. To do this, left click on the respective tract in the Device Manager. To perform a measurement, make sure that the selected analyser is connected and a connection with it has been established (see section 2.4.1).

It should be noted that the analysers connected via the USB interface (BOSON, MCA-527, Polynom, etc.) require installation of drivers, which should be installed in addition, after the programme has been installed. When you have connected your device to the PC (by connecting a USB cable and switching it on), Windows will discover a new device in the system

and will offer to install a driver, which is located in the relevant directory of the programme (by name of the device). Specify this path and then Windows will install the analyser.

Before starting measurements, set the time of measurement. This can be done in the **Measurement parameters** window (see section 2.4.3). In this window, you can also set the file name, if needed. Other parameters are also set in the **Measurement parameters** window and in the **Calculation parameters** window, when needed (see section 2.4.4).

When the analyser is ready, control buttons (**Start**, **Stop**, **Read** and **Clear**) on the main toolbar will be clickable and coloured in, otherwise, all the buttons will be greyed out and inactive.

To start a measurement, press , then a window of the spectrum to be measured will appear (Fig. 17), which will show a histogram.

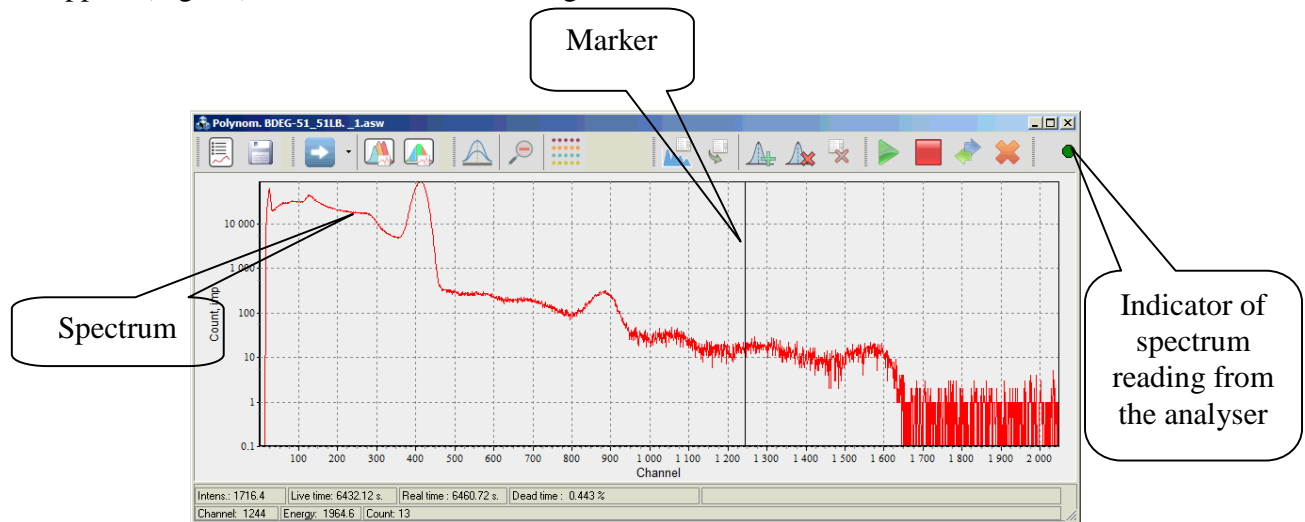



Figure 17. Window of the spectrum to be measured

The window of the spectrum to be measured differs from the spectrum, which is opened, by presence of redundant buttons allowing to control the measurement on the toolbar (see Fig.18).



Figure 18. Group of buttons for control of a spectrometer on the toolbar of the window of the spectrum to be measured

The spectrum to be measured has a connection indicator  on the toolbar, showing the event of programme's contact with the analyser (the indicator gets red, when they exchange data).

After the start, the window with the spectrum is updated with the interval specified in the **Measurement parameters** window (see section 2.4.3).

During a measurement, the **Device Manager** panel will display a countdown timer as shown on Figure 10. When a measurement ends, a message shown on Figure 19 will appear on the display.

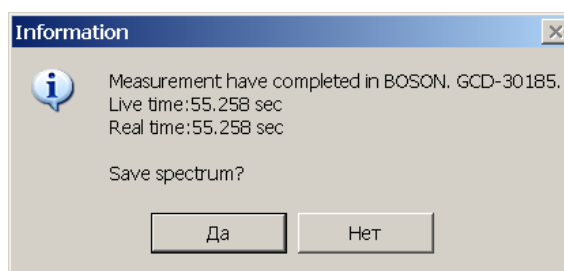





Figure 19

The message is asking whether you want to save the spectrum to a disk. If the spectrum was previously named, then the spectrum will be saved automatically, but if no name was assigned to the spectrum, the programme will offer to enter a new file name and specify its saving location.

To force-stop writing a spectrum in the process of measurement, press . The message shown on Figure 19 will appear on the display again.

If the user closes the spectrum window after a measurement, it can be restored by pressing  on the main toolbar of the programme.

If the user needs to enter or edit parameters of the measured spectrum after the measurement has ended, this should be done in the **Spectrum parameters** window (see Fig. 20), which can be opened by pressing  on the toolbar of the spectrum window. Changes in parameters of any reopened spectrum are made in the same way.

Spectrum parameters

ADC	Channel	1	1
File name		C:\GammaamaPRO\spe-g\new.asw	
Sample ID		NNN	
Spectrum type		*.asw	
Weight	Unit weight	1.5	g
Volume	Unit volume	1.2	ml
Material		Water	
Date and time			
Background		C:\GammaamaPRO\spe-g\bkg.asw	
Calibration		C:\GammaamaPRO\clb-g\marinell.clb	
Comment		ID 17/34	
Coefficient concentration			
Coefficient		1	
Use		<input type="checkbox"/>	
ROI			
Calculate		<input type="checkbox"/>	
Subtract bkg		<input type="checkbox"/>	
Data filename			

Close

Search peaks

L. limit	R. limit	10	16000
Level		3	
Min. area		100	
Type search		Search and Identification	
Show		<input checked="" type="checkbox"/>	
Smoothing			
Polynomial degree		5	
Iteration		1	
Identification			
Library file		C:\ASW2\ini.lbr	
Efficiency file		C:\GammaamaPRO\clb-g\m	
Passport of source			
MTP		6.5	
Allowable dev., keV		3	
Generator			
Power on		<input type="checkbox"/>	

Figure 20. Spectrum parameters window view

The parameters window can be pinned to the frame of the spectrum. To do this, double click on the window heading, then a window will move to the right side of the spectrum window.

4 Work with a spectrum

4.1 Main functions

To open a spectrum, click menu item **File->Open spectrum**. The standard *.asw file format will be suggested by default. However, the software is able to open and edit files of other types. To change the type of a spectrum loaded, select the desired file type in the dropdown list of field **File of type** in the standard dialogue window (see Fig. 20.1).

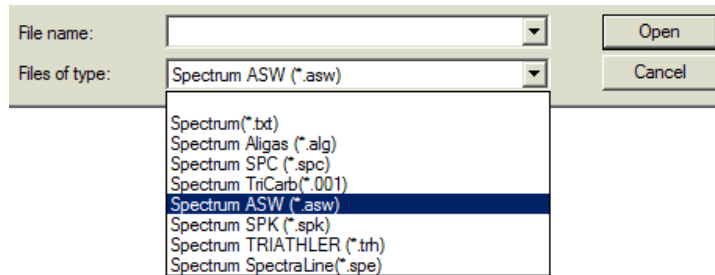


Figure 20.1 Choosing a spectrum type in the standard loading window

Once a spectrum (spectra) is selected, the software displays spectrum window(s) as shown in Fig. 21. Now, the spectrum (spectra) can be processed.

Work with a spectrum may include different tasks, for example, studying the obtained energy distribution, spectrum zooming, processing of individual peaks, printing of a spectrum, energy calibration and so on.



Figure 21. Spectrum window view


Figure 21 displays main elements of the spectrum window.

The status bar displays live, real time values in seconds for this spectrum, as well as dead time in percent.

The **Intens.** field of the status bar displays the aggregate value of intensity across the spectrum, i.e. the integral value of the entire spectrum divided by live time.

If a calibration ADER (ambient dose equivalent rate) file has been uploaded, the last field of the upper status bar will display the ADER value.

The second status bar displays values of the marker position in channels and energy units. The **Count** field displays the count value in the spectrum corresponding to this channel.

The main spectrum working mode, when the mouse cursor looks standard (white arrow), provides the possibility to zoom the spectrum and to drag (move) it on both axes. To zoom a spectrum region (i.e. stretch), set a marker in the left position of the region, press and hold the left mouse button moving it all the way to the right. In the process of dragging, a grey transparent rectangle showing the boundaries of the selected region will appear. A block of information with data of the range boundaries, area and intensity in this range will appear near the region selection. When selected, release the mouse button, and the spectrum will be stretched to the width of the selected region. To return to the previous zoom level, press  on the spectrum toolbar. To return to the initial zoom level (to the full range of the spectrum), double click anywhere in the spectrum.

If you need to move the spectrum left or right along the horizontal axis, press the right mouse button and hold it while moving the cursor in the desired direction. The spectrum will move.

The spectrum toolbar contains the following buttons:



- a button for displaying spectrum parameters as shown on Figure 20.



- a button for saving spectrum data and parameters to a disk. When you press this button, any discovered peaks and their parameters are also saved to a disk. These data are stored in the file with the same name as that of the spectrum, but have an *.asr extension, and the location of this file is the same as that of the spectrum.



- a button for opening the energy calibration window for this spectrum (see section 7).



- a button for opening the FWHM and shape calibration window for this spectrum (see section 8).



- a button for enabling the mode for work with a peak. Thanks to this mode, the user has the possibility to study any peak or multiplet in detail, as well as adjust the peak with describing functions. When you press this button, it gets fixed and the cursor moving around the spectrum field looks like two closed brackets '[]'.

To select a spectrum region, which will be moved to a separate window for work with the peak, set a marker to the left position of region, press and hold the left mouse button moving it all the way to the right (Fig.22). In the process of dragging, a dark transparent rectangle showing the boundaries of the selected region will appear. Then release the mouse button and an additional window with the selected region will appear on the display (see Fig.23).

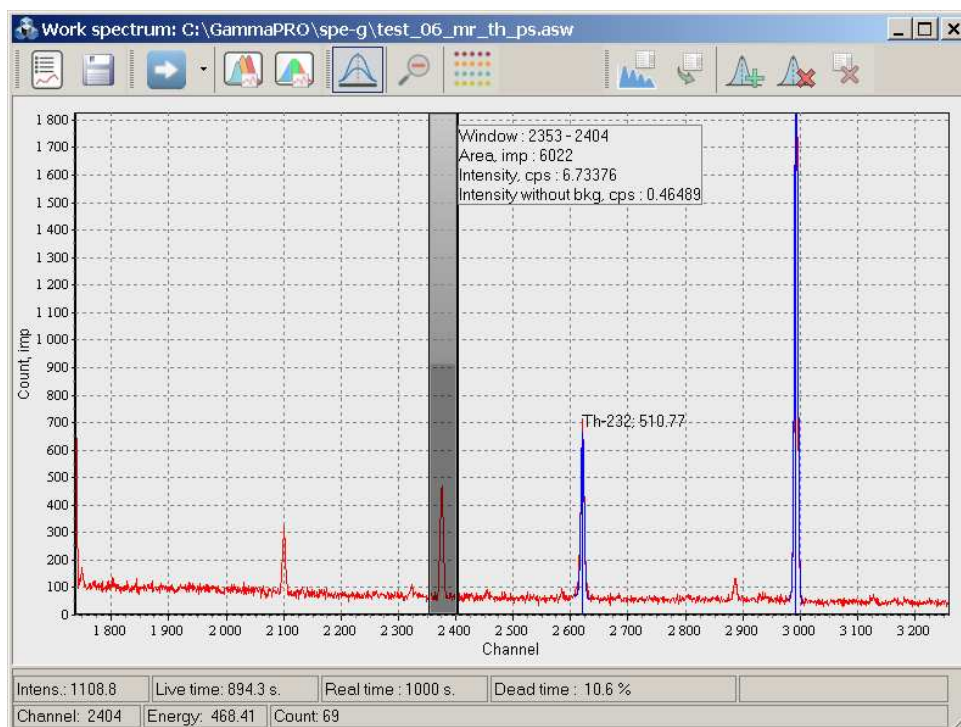


Figure 22

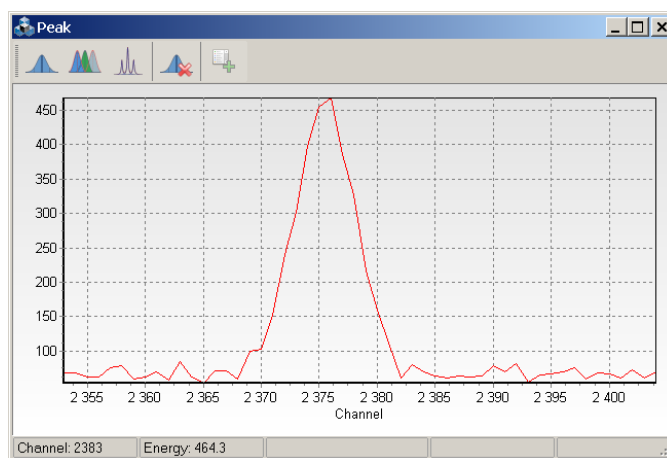



Figure 23. Window for work with a peak view

 - a button displaying a menu with spectrum options. When you press this button, a menu shown on Figure 24 will appear.

Spectrum without bkg – shows the spectrum without spectrum background.

Intensity – switches the vertical axis from the count in impulses to intensity in imp/sec.

Energy range – switches the horizontal axis from the channel scale to the energy scale.

Show ROI – shows regions of interest (ROI) contained in the calibration file (*.clb) for the ROI-method.

Offer a nuclide – a tool aiding in identification of radionuclides, which highlights regions of the spectrum, where peaks for the radionuclide selected from the list should be present (see section 4.4).

Report – generates a protocol for printing of a spectrum.

Autocalibration by source (Cs-137, Co-60, Eu-152, Th-228) – a tool allowing to perform automatic calibration by energy, FWHM and shape of a spectrum with radionuclides most used in spectrometry. The procedure may last several seconds. At the end of autocalibration, the programme will display a message with the results and enter the received values in the spectrum calibration.

Send to (Word, Excel, Matlab) – converts the spectrum to MS Word, MS Excel and Matlab, respectively.



The group of buttons is intended for searching peaks, as well as calculating activities using the peaks analysis method (see section 6).

4.2 Work with a peak

In the peak mode, a window as shown on Figure 23 appears on the display after selecting a spectrum region.

This window has a toolbar with buttons allowing to perform mathematical modelling for the purposes of describing peaks by dependencies, or, in other words, to introduce Gaussian curves (or other functions) in the selected spectrum region.



The (Gaussian) button is intended for introduction of the Gaussian curve in the region of the **Peak** window. The programme determines automatically the centroid of the peak and calculates all the parameters related to this peak. Peak processing results are displayed in a window as shown on Fig. 25.


Peak list									
Channel	Energy	Intens.,cps	Resolution, %	FWHM, keV	FWHM, ch.	Left edge, channel	Amplitude	Area, imp	To calibration
2375.5	462.85	2.8887	0.25962	1.2016	6.1717	5.2414	393.26	2583.4	En... FWHM



Figure 25. View of the **Peak list** window with peak processing results


In the table on Fig.25, the last column contains two buttons allowing to send the results received about this peak to energy calibration (**En...**) and to FWHM and shape calibration (**FWHM**).





The (**Multiplet**) button is intended for introduction of Gaussian curves in the region of the **Peak** window for multiplets (several merged or unresolved peaks). To conduct such a processing, the user should put markers in approximate positions, where the peak centroid can be found. Such function allows describing a multiplet containing no more than 3 peaks. Put markers with a double click in the centroid region. Then press and a calculation will be performed. The

result will be displayed in a window similar to that displayed on Fig.25. In case of incorrect modelling of the describing curve, the user should reset markers and the plotted graph with , mark then once again.

The  (**Multiplet with high resolution**) button has the same intention as , however, it is more fit for describing peaks with high resolution (for example, peaks received on extra-pure Germanium spectrometers, etc.). The function describing each peak has two parts – the Gaussian part and the so-called left exponential edge. The distance in channels from the centroid to the left, where the exponential part starts is the '**Left edge**' (see Fig.25).

For a better adjustment, by pressing  again, you can improve adjustment of the describing curve to experimental values.

To perform processing, you should do preliminary marking and press the  marker. The processing result looks as shown on Fig.26.

The  (**Add peaks to peak list of spectrum**) button on the toolbar in the **Peak** window is intended for adding processed peaks to the spectrum results table. If the peak's area is smaller than the threshold area (specified in the **Min. area** parameter), then the peak addition command will be ignored.

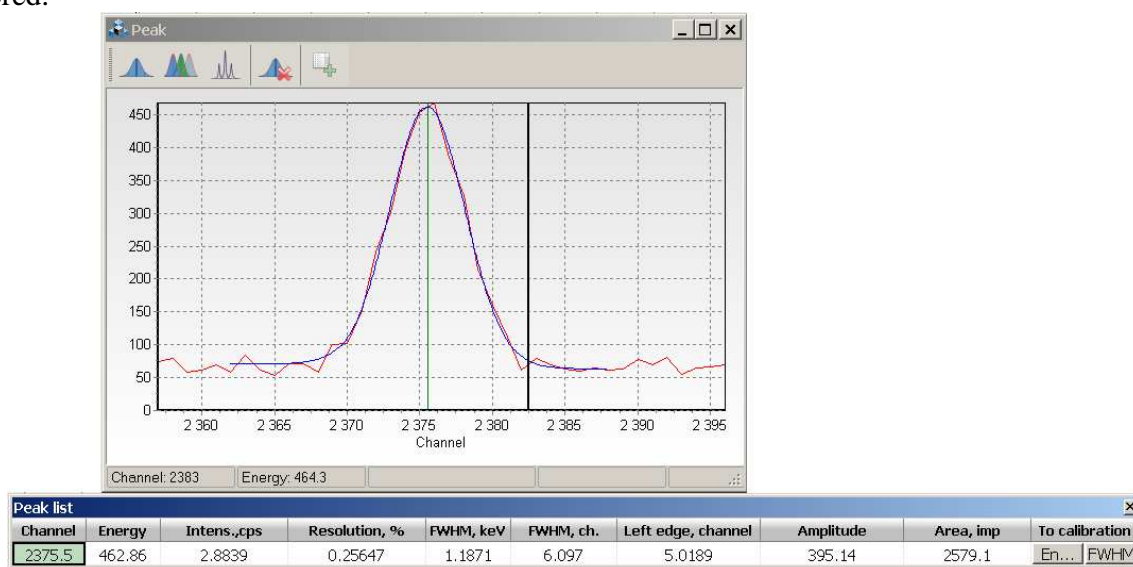


Figure 26. **Peak** and **Peak list** window view


The context menu, which pops up, when you right click on the graph in the **Peak** window, has the same buttons as the toolbar, and also:

Energy range – switching between channel and energy scale;



Logarithm – switching between linear and logarithmic scale;

To printer – printing of the graph in the **Peak** window.

4.3 Material window

The **Material** field in the **Spectrum parameters** window is intended for specifying the type of substance to be measured or its category for the programme. When you press  at the edge of

the field, a window opens (see Fig. 27), which allows managing the files containing information about values of **Permission Level** (PL). The file with the data on PL has a *.mat extension.

 buttons on the toolbar of the **Material** window allow editing the table of materials (to add/delete a material or a radionuclide).  buttons are for saving the edited table or loading a table saved to a disk.



Material / Nuclide	Value	Unit
Chicken meat		Bq/kg
- Cs-137	180	
- Sr-90	80	
Meat without bones		Bq/kg
- Cs-137	160	
- Sr-90	50	
Milk		Bq/kg
- Cs-137	15	
- Sr-90	25	
- I-131	300	
Cheese		Bq/kg
- Cs-137	50	
- Sr-90	100	
Fresh fish		Bq/kg
- Cs-137	130	
- Sr-90	100	
Dried fish		Bq/kg
- Cs-137	260	
- Sr-90	200	
Grain		Bq/kg
- Cs-137	70	
- Sr-90	40	
Flour		Bq/kg
- Cs-137	60	
- Sr-90	30	
Bread		Bq/kg
- Cs-137	40	

Figure 27. **Material** window

4.4 Prompt window

Using the **Offer a nuclide** command in the **Options** menu (see section 4.1, Fig.24) in the measured spectrum with distinct peaks, you can visually identify nuclides from the set library of nuclides *librp.dat*. When you activate the **Offer a nuclide** menu item, a **Prompt** window, which will display the list of radionuclides, will appear on the display (see Fig.28).

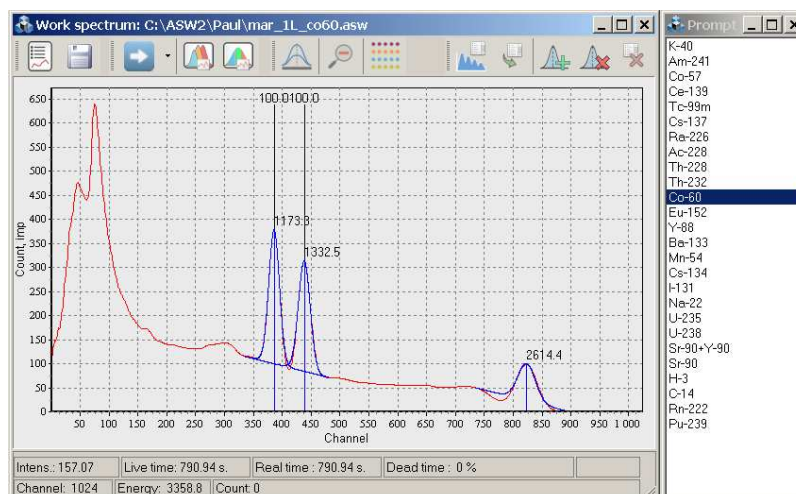


Figure 28

To select items, press on the row with the name of the expected radionuclide with a mouse button. Areas in the spectrum in the region of lines of the respective nuclide are highlighted in white, and are marked with the value of quantum yield for this line.

5 Determining activities of radionuclides by the ROI-method

5.1 Calculation by one spectrum

Sequence of calculation of specific activities of radionuclides

Load a working spectrum (**File->Open spectrum**).

Open the spectrum parameter window by pressing .

Load a spectrum background in the **Background** field and the necessary calibration file (*.clb) in the **Calibration** field.

Then, press the right part of the  button to open a menu offering variants of calculation types (see Fig.29).

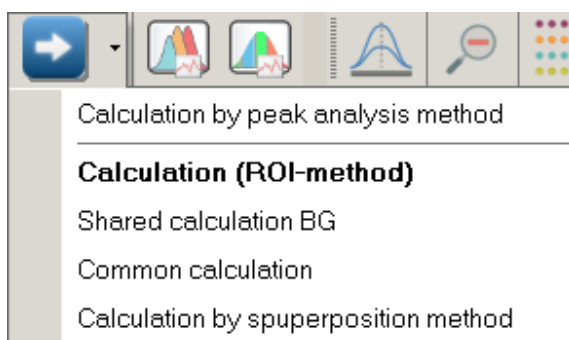


Figure 29. Variants of calculation types

For this task (calculation of activity by one spectrum using the ROI-method) select **Calculation (ROI-method)**

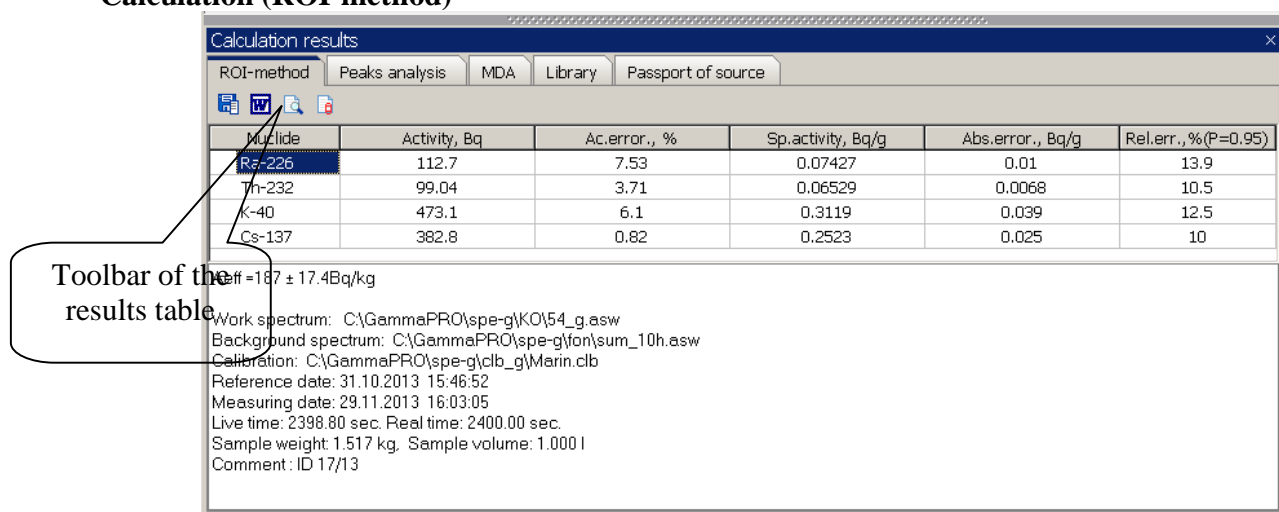


Figure 30. Results window view

A table with measurement results will appear at the bottom of the spectrum window or in a separate window. This table contains columns for '**Nuclide**', '**Activity**', relative error of spectrum shape selection '**Ac.error,%**', as well as columns for specific activity, absolute and relative errors in their determination. If the **Material** field (in the spectrum parameters window) contains instructions about the type of substance to be measured, two more columns **PL** (permission level) and **FC** (factor of conformity) will appear in the results table.





It should be noted that the 'Activity' column contains values corresponding to the countable sample, but 'Sp.activity' (column 4) – those corresponding to the sample. Thus, the coefficient of concentration is taken into account, when calculating specific activity (and so on in column 4).

If relative error in the calculation of activity exceeds 50%, then the MDA (minimum detected activity) value is displayed in the '**Activity**' field instead of the activity value.

The panel with calculation results should not necessarily be within the spectrum window. It can be 'separated' from the left edge of the spectrum by double clicking on the heading of the **Calculation results** panel, or you can drag the panel holding its heading. To return the panel to the spectrum window, double click on the heading of the **Calculation results** window with the left mouse button.


Rows under the table show the value of effective specific activity of natural nuclides A_{eff} , the consolidated factor of conformity, names of the calibration file, background file and work spectrum used, the date as at which the activity has been calculated, as well as weight and volume of the countable sample, if it was taken into account.

After the comment, there is a block by regions of interest, if the spectrum parameters include an indication that it should be calculated and displayed.

If you want to save the results table, there is a toolbar above it containing buttons allowing to convert data in different ways ( - saving data to a txt protocol;  - sending data to MS Word;  - generating a report;  - sending data to a DB.

To save data to a protocol, write its file name in the **Protocol filename** field of the **Parameters** window (**Options->Parameters->Files** tab). The data will be sent to the end of the set text file.

To be able to send data to **MS Word**, **MS Word** should be installed in your **Windows** operating system.

When a report is generated ( button), a window is displayed, where the preview block displays the table of activities and the block of comments (see Fig.31). You can add title information to the page. This option requires a printer installed in the **Windows** operating system.

Report

☒ Title
C:\GammaammaPRO\header_US.rtf

☒ Table of activity

☒ Column1
☒ Column2
☒ Column3
☒ Column4
☒ Column5
☐ Column6
☐ Column7
☐ Column8

☒ A eff.
☒ Factor of conformity
☒ Additional data
☒ Signature

C:\GammaammaPRO\footer_US.rtf

Update Print Save...

Page 1 from 1

Preview **Editor**

BSI BRITISH SCIENTIFIC INSTRUMENTS

MEASUREMENT REPORT

Nuclide	Activity, Bq	Activity, %	Specific, Bq/g	Activity, Bq/g	Activity, % (P=0.95)
Po-210	112.7	7.53	0.0742	0.01	13.9
Pb-210	99.04	3.71	0.0652	0.0068	10.5
Bi-210	43.1	6.1	0.3119	0.039	16.5
At-210	30.6	0.92	0.2023	0.025	10

Aeff=101.417 Bq/g
Total factor of conformity: 0.40, B+dB = 0, B-dB = 0


Work spectrum: C:\GammaammaPRO\pe-g 101.54.gaw
Background spectrum: C:\GammaammaPRO\pe-g 101.54.gaw
Calibration: C:\GammaammaPRO\pe-g 101.54.gaw
Reference date: 31.10.2013 15:46:52
Measuring date: 20.11.2013 10:00:05
Live time: 2556.80 sec. Real time: 2400.00 sec.
Sample weight: 1.517 kg. Sample volume: 1.000 l
Comment: ID 17/13


Conclusion: The measured material meets the requirements

Specialist of laboratory:

Head of laboratory:

Figure 31. **Report** generation window view

After changes have been made (title editing, disabling/enabling fields), press **Update**. There is a **Print** button for printing the page shown in the right part of the window (the so-called preview block). To send the page to **MS Word**, press . To save the page in the *.rtf format, press **Save**.


When you press  on the toolbar in the results table, the **Database record** window will appear, where you can enter additional data not saved in the spectrum (Fig.32).

Database record	
Spectrum filename	C:\Gamma\GammaPRO\spe-g\KO\54_g.o
Background filename	C:\Gamma\GammaPRO\spe-g\for\sum_1
Calibration filename	C:\Gamma\GammaPRO\spe-g\clb_g\Mar
Weight	1517 g
Volume	1 l
Live time	2398.756
Real time	2400
Date of spectrum meas. :	29.11.2013 16:03:05
Date of activity reduction:	31.10.2013 15:46:52
Tract	Gamma
Comment	ID 17/13
Unit of data	Activity, Bq
Geometry	Marinelli
Probe type	Water
Probe name	
N protocol	17/13
Customer	STUK
Database filename C:\ASW2\prob_ash.mdb	
<input type="button" value="Add"/> <input type="button" value="Close"/>	


Figure 32. **Database record** window view

The window on Figure 32 is divided into two tables of fields. The left one, which cannot be edited, contains already known data about the spectrum, but the right one, which can be edited, contains fields for entering missing information. After you have filled the fields, make sure that the **Database filename** field contains the name of the database and press the **Add** button. If the transfer has been successful, you will see a relevant message.

5.2 Common calculation by sample number

According to the requirements of regulatory documents, the results of measurements of specific activities received in different spectrometric tracts, as well as the consolidated factor of conformity of the sample being measured, should be shown in a single protocol of measurement. To fulfil this requirement, use **Common calculation** in the menu of the  **Calculation** button (see Fig.29).

For a correct calculation:

- open spectra of one sample measured in different spectrometric tracts (for example, on a beta and gamma detector);
- make sure that the **Sample ID** field (see **Spectrum parameters** window) displays the same identifier for all the spectra;
- conduct a separate calculation for each spectrum (see section 5.1);
- for one of the spectra you can select **Common calculation** in the menu of the  **Calculation** button.

When you have received the results table, make sure that there is a note about the common calculation (Fig.33), as well as confirm adequacy of the received results.

If there is specific activity calculated in different spectra, its result is averaged taking into account the calculated error.

If there is specific activity calculated in one spectrum (error less than 50%), and only assessments (equal to MDA) in the other spectrum, only the data containing specific activity are used in averaging.

If assessments only (equal to MDA) are available in all the spectra, the smallest of these assessments is displayed as the result for this radionuclide.

Note about
common
calculation

Calculation results					
ROI-method Peaks analysis MDA Library Passport of source					
Nuclide	Activity, Bq	Ac.error., %	Sp.activity, Bq/kg	Abs.err., Bq/kg	Rel.err., % (P=0.95)
Sr-90	< 0.4703	-	< 18.96	-	-
K-40	11.98	-	483.1	48	9.99
Ra-226	< 0.2788	-	< 11.24	-	-
Th-232	< 0.2578	-	< 10.4	-	-
Cs-137	< 0.1201	-	< 4.843	-	-

Aeff = 68.2 ± 16.6 Bq/kg

Common calculate for sample : 17/15

Work spectrum: C:\ASW\complex\fasol1.asw
 Background spectrum: C:\ASW\complex\0001.asw
 Calibration: C:\ASW\complex\38ml.clb
 Reference date: 25.11.2010 09:42:15
 Measuring date: 25.11.2010 09:42:15
 Live time: 21600.00 sec. Real time: 21600.00 sec.
 Sample weight: 0.0248 kg. Sample volume: 0.038 l


Intens.: 2.1076 Live time: 21599.75 s. Real time : 21600 s. Dead time : 0.00116 %
 Channel: 916 Energy: 2602.9 Count: 6

Figure 33. View of the table of the result of common calculation by sample number

5.3 Shared beta – gamma calculation

In cases, when sample measurement is made on a gamma and beta detector, in order to increase accuracy, it is sometimes necessary to consider the results determined in one of spectrometric tracts in calculations of the other one. Thus, for example, when performing measurements in a beta tract taking into account activity ^{137}Cs and ^{40}K in the gamma tract, minimum detected activity ^{90}Sr can be reduced.

For a correct share beta-gamma calculation:

- open spectra of one sample measured in different spectrometric tracts (on a beta and gamma detector);
- make sure that the **Sample ID** field (see **Spectrum parameters** window) displays the same identifier for both spectra;
- conduct a separate calculation for the gamma spectrum (see section 5.1);
- for the spectrum of the beta detector you can select **Shared calculation BG** in the menu of the  **Calculation** button.

When you have received the results table, make sure that there is a note about the shared beta-gamma calculation (Fig.34), as well as confirm adequacy of the received results.

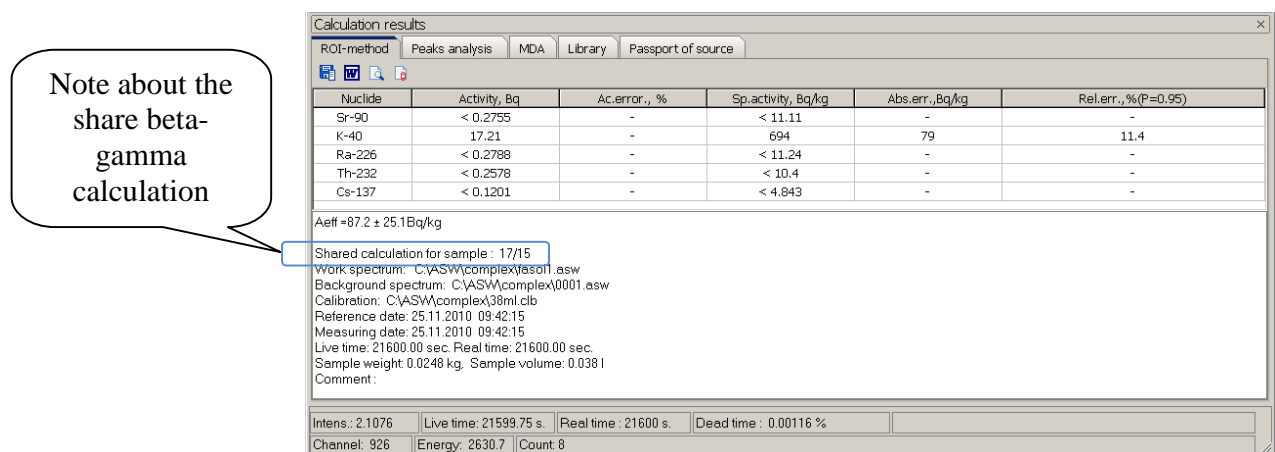


Figure 34. View of the table of the result of shared beta-gamma calculation

5.4 Superposition method

The calculation of activity using the superposition method serves as some kind of control of measurements. After a countable sample has been measured and the calculation has been conducted, the accuracy of calculation of activities may be controlled in the **Superposition** window by selecting the **Calculation by superposition method** in the menu of the **Calculation** button.

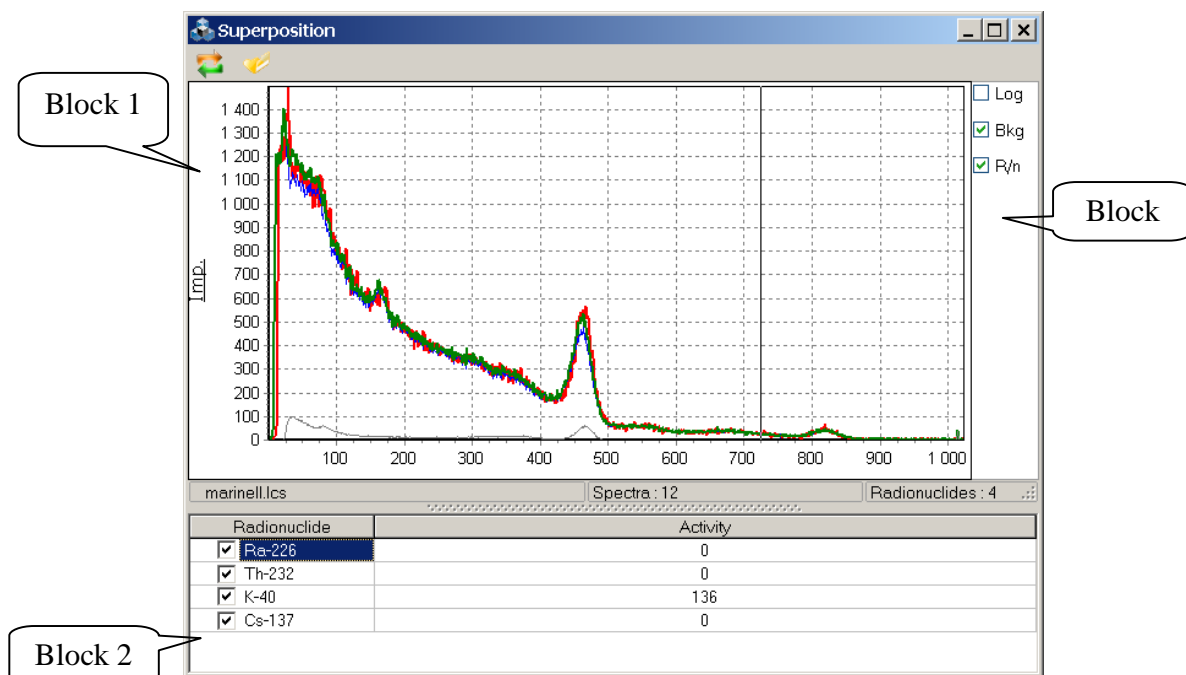




Figure 35. **Superposition** window view

If the calculation has already been performed, the programme displays (Fig.35, block 1) the measured (red) and the estimated (green) spectrum, as well as estimated values of activities of radionuclides (Fig.35, block 2). If the measured and the estimated spectra match, this confirms that the list of radionuclides and their activities match the radionuclide activity of the countable sample.

Through visual evaluation of matching of spectra the user may adjust estimated values until the spectra fully match. If full match is still impossible, it may be assumed that the countable sample contains other radionuclides in the countable sample or there is inaccuracy in energy graduation.

The  button is used for selection of a library spectra list file (*.lcs), which is necessary for the calculations. This file is generated at the calibration stage for each measurement geometry (see Paragraph 14.2) and is supplied in the installation package of the spectrometer.

The  button is intended for updating the calculation after uploading a new library spectra list file.

The **Log** checkbox shown on Fig.35 (block 3) provides the possibility to change the scale of the graph of spectra to logarithmic. The **Bkg** checkbox brings the current background spectrum to the graph. The **R/n** checkbox allows displaying on the graph spectra of mononuclides participating in plotting of the common spectrum (green).

The status bar of the **Superposition** window displays information about the currently loaded library spectra list file, the number of these spectra and the number of radionuclides.

6 Determining activities of radionuclides by the individual peaks analysis method

6.1 General statements

The principle of determining activities of radionuclides using the individual peaks analysis method is the possibility to search for peaks automatically, describe each of them using the Gaussian curve (with protracted left exponential edge), further calculate the area and, finally, calculate activities by each identified radionuclide. The ability to identify is conditioned by the possibility to connect to the spectrum a radionuclides library file, which contains reference data on characteristic energy lines, values of their quantum yield, etc. So, if there is a spectrum of a countable sample, a library file (*.lbr, *.bib) and an efficiency file (*.eff), the user may calculate activities of radionuclides.

For the method to work accurately, the user must fill in fields in the **Spectrum parameters** window with relevant values. Main parameters determining the work of the method being described are concentrated in the right table of parameters (see Fig. 36) in **Search Peaks**, **Smoothing**, **Identification** groups.

Spectrum parameters	
ADC	Channel 1 1
File name	C:\GammamaPRO\spe-g\...
Sample ID	18/15
Spectrum type	*.asw
Weight	Unit weight 0.21 kg
Volume	Unit volume 1 l
Material	
Date and time	
Background	C:\GammamaPRO\spe-g\...
Calibration	
Comment	
Coefficient concentration	
ROI	
Search peaks	
L. limit	R. limit 100 14000
Level	3
Min. area	1000
Type search	Search and Identification
Show	<input checked="" type="checkbox"/>
Smoothing	
Polynomial degree	5
Iteration	1
Identification	
Library file	C:\GammamaPRO\lbr\lib_...
Efficiency file	C:\GammamaPRO\clb-g\me...
Passport of source	
MTP	6.5
Allowable dev., keV	3
Generator	
Power on	<input type="checkbox"/>

Figure 36

The **Search peaks** group contains the following parameters:

L.limit, R.limit – range values in channels, where the search of peaks will be performed. Peaks will not be searched for and identified outside this range.

Level – the limit value of the parameter related to the statistical importance of peaks, above which the found peak is accepted and added to the table, and below which the peak is rejected, usually assumed as being equal to 3.

Min.area – the limit value of the peak area in impulses. The peaks with the value above this one are accepted and added to the table, and below this value are rejected.

Type search – one of two possible types of search for peaks in the spectrum ('**Search and Identification**', '**Peaks from library**'). So, the '**Search and Identification**' type searches for all the peaks available in the spectrum and meeting the criteria of the **Search peaks** section. The '**Peaks from library**' type envisages application of preliminary markings according to the loaded radionuclides library file (see the **Library file** field in the **Identification** section). If the user faces the task of determining the activity of certain radionuclides only, '**Peaks from library**' should be used.

Show peaks – parameter for enabling displaying of peaks and their parameters in the spectrum.

The **Smoothing** parameters control polynomial smoothing of a spectrum relevant for a better peak search and description of peaks by functions. The **Smoothing** parameters include:

Polynomial degree. This parameter defines the degree of the polynomial smoothing to be considered for spectrum peak search. The parameter's value should not exceed 6, and the recommended value is 5.

Iteration. This parameter defines the number of smoothing iterations for spectrum peak search. If this value is 0, no smoothing will be performed. Spectra featuring high statistics should not be smoothed, and the parameter's value for such spectra should remain 0.

The **Identification** group contains parameters participating in the identification of the peaks found in the spectrum.

Library file – path to the radionuclides library file, which will correspond to the measured spectrum. The library file contains a list of radionuclides, their energy values, probability of outputs and half-lives. Library files are generated using the **Library editor** dialogue window (see section 12) and are used in the process of calculation of the activity using the peaks analysis method.

Efficiency file – path to the efficiency calibration file, which will correspond to the measured spectrum. The efficiency calibration file contains a dependence of the efficiency of registration on gamma-quantum energy and is used in the process of calculation of activity using the peaks analysis method. The efficiency file is generated using the **Efficiency calibration** dialogue window (see section 9).

Passport of source – a link to the file containing parameters of the source of calibration. The file must contain the list of radionuclides present in the source, description of their geometry, mass, volume, activity and the date of its adjustment. The passport of source file is generated in the **Editor of source passports** dialogue window, which can be opened from the main programme menu **Options->Editor of source passports**. It should be noted that the passport of source file should be specified only during calibration (i.e. to create the efficiency file). To perform calculations for the purposes of determining activities, this field should be left blank.

MTP. This parameter is the so called peak thickness factor, or, in other words, the distance at which two peaks are indistinguishable. The value of this parameter is set in arbitrary units in the range between 3 and 10. In case two peaks close to each other are processed separately as if they were singlets (i.e. each peak has its own background substrate) but they are supposed to be processed together (I.e., so that they have a common background substrate), the calculation should consider this parameter and be repeated until the peaks are processed together as a multiplet.

Allowable dev., keV – the energy deviation parameter, within which a peak may be assigned to a characteristic curve of some radionuclide

In the realisation of the individual peaks analysis method, calibration of the spectrometric tract (or the spectrum) by peak energy, FWHM and shape becomes special. Therefore, before performing the calculation, make sure that the respective calibrations have been made (see sections 7, 8).

6.2 Procedure of calculation of activities by the individual peaks analysis method

6.2.1 Measure the spectrum of the countable sample or load an available spectrum using the main programme menu **File->Open spectrum**.


6.2.2 Information about the source may be entered before, during and after the measurement. In the first and second case, parameters are specified in the fields of **Measurement parameters** and **Calculation parameters** windows.

6.2.3 If parameters of any measured spectrum need to be changed, the **Spectrum parameters** window should be used (see Fig. 36)

6.2.4 Depending on the task, specify one of search types ('**Search and Identification**', '**Peaks from library**') in the **Type search** field (Fig.36).

6.2.4 Among the fields of the **Spectrum parameters** window, which should be completed, there is an **Efficiency file** field. You should enter the name of the calibration efficiency file there (... button). The operator selects the efficiency file according to the type of the countable sample and parameters of geometry of measurement and enters it into the programme using a standard file selection dialogue window.


6.2.5 In the **Library file** field in the **Spectrum parameters** window, specify the name of the radionuclides library file, which contains data about energy lines and other information about radionuclides, which are presumably contained in the sample being measured.

6.2.6 Then, select the **Calculation by peak analysis method** in the menu of the  **Calculation** button (see Fig.29). Then, a panel with results of measurements with the **Peak analysis** tab selected will appear at the bottom of the window. As it was mentioned in p.5.1, the panel with measurement results can be separated from the spectrum frame.

6.2.7. On the **Library** tab of the table, check those radionuclides, the activity of which the user intends to determine. This tab displays data contained in the library file specified in the spectrum parameters window (**Library file** field).

ROI-method		Peaks analysis	MDA	Library	Passport of source
Nuclide/Energy, keV			Half-life, day / Quantum efficiency, %		
<input checked="" type="checkbox"/>	+	Co-60	466607000000		
<input type="checkbox"/>	+	Co-60	1926.1		
<input checked="" type="checkbox"/>	+	Cs-137	10989.6		
<input type="checkbox"/>	+	Mn-54	312.12		
<input type="checkbox"/>	+	Ra-226	584630		
<input checked="" type="checkbox"/>	+	Th-232	5133780000000		
<input type="checkbox"/>	+	Cs-134	754.68		
<input checked="" type="checkbox"/>	+	Eu-152	4868.678526		
<input checked="" type="checkbox"/>	+	Am-241	157857.682492422		
<input checked="" type="checkbox"/>	+	Ba-133	3849.652788		

Figure 37. **Library** tab view

6.2.8 On the toolbar of the spectrum window (Fig.38, block 1), press  (**New search peak and calculation**). If the spectrum has correct calibration by energy, FWHM and shape of the spectrum, the **Peak analysis** tab of the measurement results panel will display information on any discovered peaks (Fig.38, block 3). Also, found highlighted peaks with titles will appear on the spectrum graph (see Fig.38, block 2).

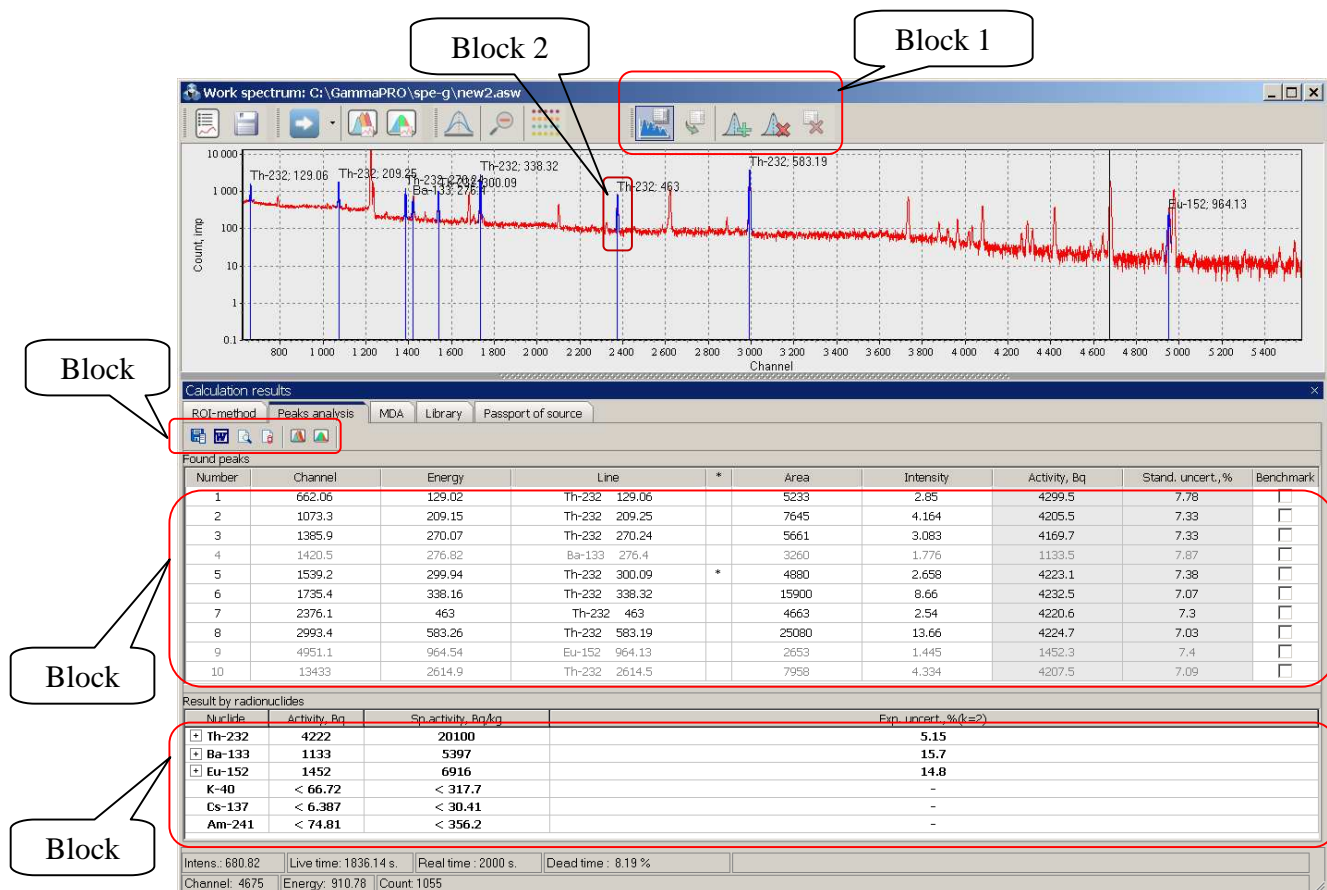


Figure 38. Spectrum window view after peak search

The results panel, under the table with **Found peaks**, has another table **Result by radionuclides**, which contains estimated values of activities of radionuclides.

The **Found peaks** table has the following fields:

- '**Number**' – number in sequence of the found peak;
- '**Channel**' – position of peak centroid in channels;
- '**Energy**' – energy value, keV;
- '**Line**' – characteristic energy lines of gamma radiation for the specified radionuclide;
- '**Area**' – peak area in channels;
- '**Intensity**' – peak intensity in imp/sec;
- '**Activity, Bq**' – radionuclide activity value determined only for this line;
- '**Stand. uncert., %**' – standard relative uncertainty of activity calculation for this line;
- '**Benchmark**' – sign of acceptance of this line as a benchmark. Used for the purposes of improving splitting of merged multiplets into components.


The **Result by radionuclides** table contains the following fields:


- Nuclide** – name of the radionuclide, on which this row contains information;
- Activity, Bq** – weighted average activity in Bq received by averaging activities from the **Found peaks** table considering the uncertainty for each line. If relative expanded uncertainty in the calculation of activity exceeds 50%, then the MDA (minimum detected activity) value is displayed in this field instead of the activity value.





Sp. activity, Bq/kg – specific activity in Bq/kg (parameter depending on the calculation type);


Exp., uncert.% – expanded uncertainty of the result of measurement with coverage factor $k=2$.

The **Result by radionuclides** table, which is being described, may contain two columns **PL** (permission level) and **FC** (factor of conformity), which were described in section 5.1.

In the **Result by radionuclides** table, for each radionuclide, for which activity has been calculated, you can see lines, on which this activity was calculated. To do this, you should press on the  icon located in front of the name of the radionuclide.

6.2.9 Visually analyse adequacy of the plotted mathematical model for each found peak, i.e. evaluate the quality and correctness of description of the Gaussian curve peak. If the peak description is unsatisfactory, it should be deleted or adjusted (see section 19.1). For the purposes of such a visual analysis, for fast zooming of the peak according to the size of the spectrum window, double click on the peak title with the left mouse button, or press  to return to normal zoom.



6.2.10 Then, the result of determining of activities may be converted to a protocol, MS Word, report or database. For these purposes, there is a toolbar similar to that described in section 5.1 and located above the **Found Peaks** table ( - saving data to a txt protocol;  - sending data to MS Word;  - generating a report;  - sending data to a DB).

6.2.11 To save the found peaks and all the other parameters entered in the **Spectrum parameters** window, press . After that, when you open this spectrum, marking with found peaks will be done automatically. The list of peaks and their parameters are saved in the file having the same name as the spectrum, but with an *.asr extension.


To consider background in the calculation of activities, it is necessary to link it in the **Background** field in the **Spectrum parameters** window. The spectrum background should be measured with good statistics, as well as processed similarly to the work spectrum. The table of found and identified peaks of the background spectrum is saved automatically together with the spectrum in the same way. The programme loads the table of background peaks, when opening the work spectrum or when the background spectrum in the work spectrum changes.

6.3 Adjustment of found peaks

Peaks can be searched in two modes '**Search and Identification**' and '**Peaks from library**'. In the first case, the search is made according to the parameters specified in spectrum parameters (search range, smoothing, etc.), and all the peaks meeting these requirements are recorded. In the second case, only those peaks are highlighted, which match the energy lines specified on the **Library** tab.

As shown in section 6.2, when you press , a new search for peaks is performed. To adjust found peaks in order to recalculate their peak area and also activity, use  (**Update calculation for found peaks**), which is also located on the toolbar of the spectrum window. It is used, if the position of peaks is correct, but the description of their curve is incorrect, or when adjustment by the benchmark peak is used.

As peaks are identified automatically, some peaks may be recognised incorrectly, therefore, the identification result may be adjusted manually in the '**Line**' column of the table using the dropdown list with energy lines getting in the energy limit (see **Spectrum parameters** window).

If spectra are complex, you can use curve description adjustment of some peaks by benchmark. If the radionuclide has several peaks and one singlet, the latter may be taken as a benchmark by checking '**Benchmark**' in the table. Then, having loaded the efficiency file, you can make a recalculation by pressing  on the toolbar. For the other peaks (which are not benchmarks),


their estimated height for further processing will be calculated. Thus, the credibility of splitting of multiplets into components will increase.

6.4 Inserting and deleting peaks

The toolbar of the spectrum window contains a group of three buttons as shown on Figure 39 (in a frame).



Figure 39. **Identification** button group view

Thus, the  (**Insert peak mode**) button is intended for toggling to the insert peak mode. In this mode, the mouse cursor becomes a green down arrow (see Fig.40.1). To insert a found peak to the specified position, set a marker in the peak centroid region and double click with the left mouse button, then the peak will be highlighted and added to the table of found peaks (see Fig. 40.2, block 3). For insertion, you can use double click or press the Insert key on the keyboard.

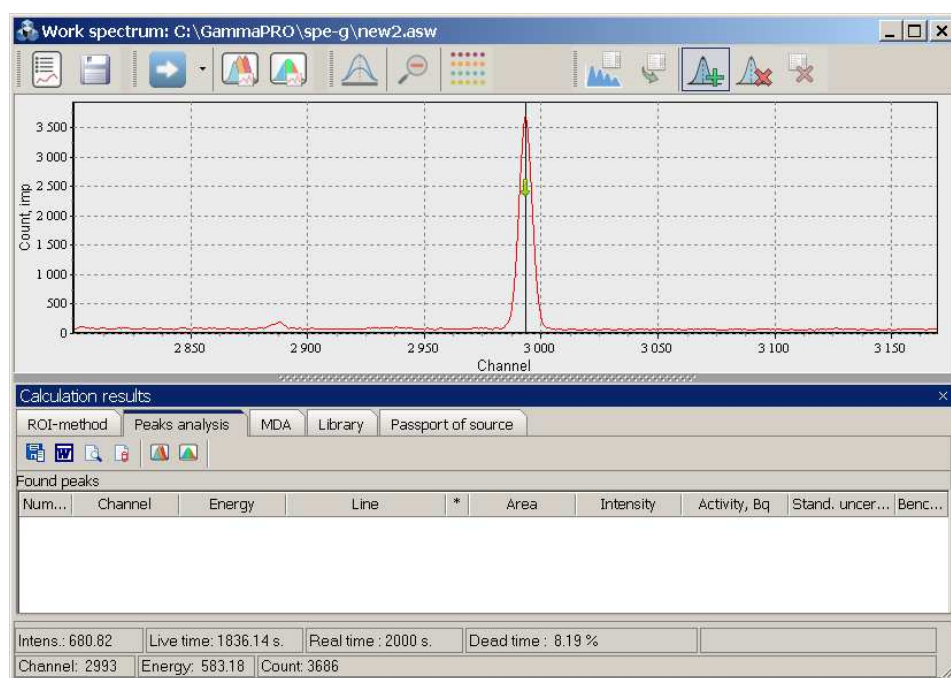


Figure 40.1. Preparation of a marker for peak insertion

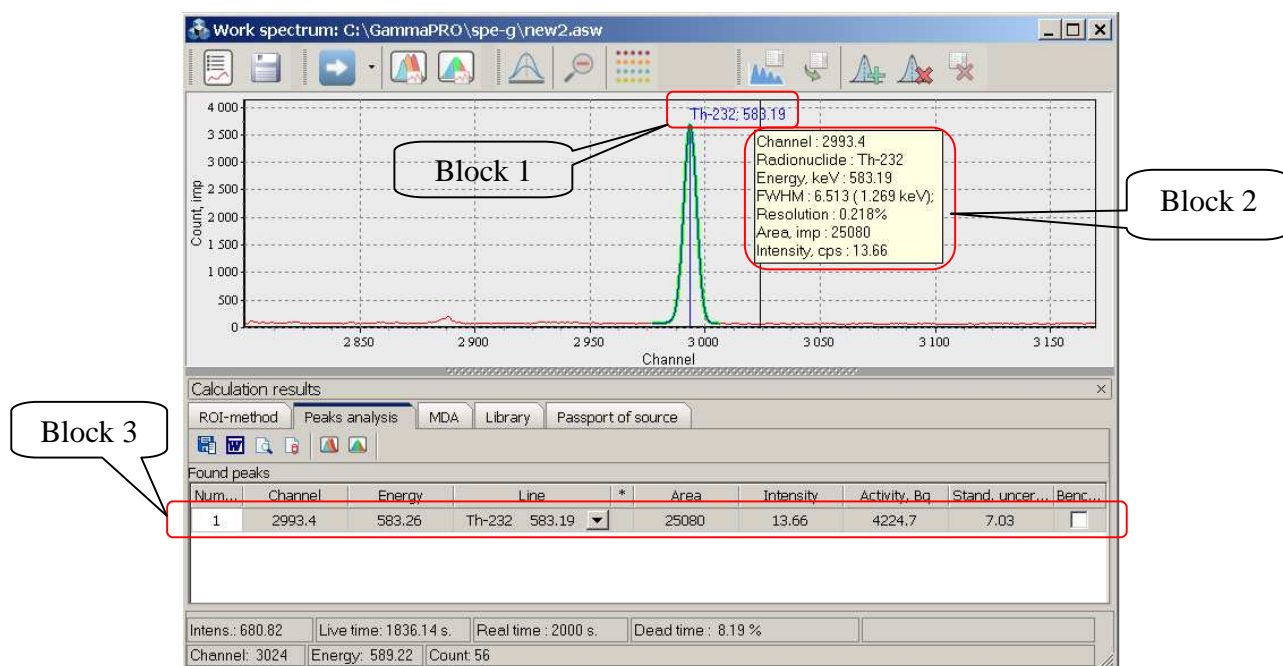


Figure 40.2. New inserted peak

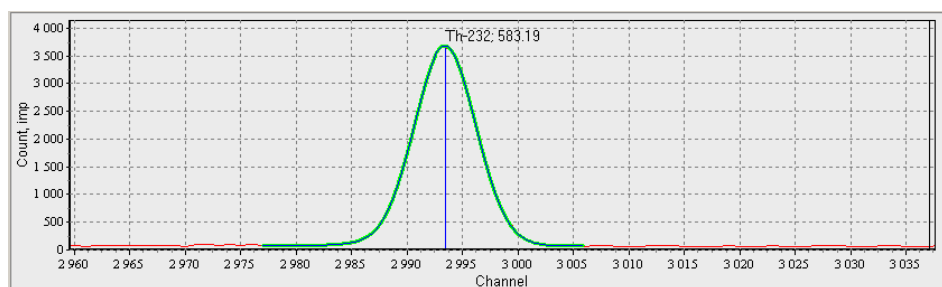


Figure 40.3

A found and described peak in the spectrum has a Gaussian curve outline as shown on Figure 40.3. There is a peak title near the Gaussian curve describing the peak (see Fig.40.2, block 1, and Fig.40.3). If the peak has been identified, the title contains peak energy and the name of the radionuclide.

When hovering a cursor over the peak title, a popup prompt appears (see Fig.40.2, block 2) containing peak parameters, such as channel, energy, radionuclide name, FWHM, resolution, area and intensity. Once the cursor is at the 1332.5 keV peak's title, there appears a pop-up hint which displays the Peak-to-Compton ratio. For the 5.9 keV peak, the Peak-to-Background ratio will be shown.

To select a peak, left click on its title. If you double click on the title, this peak will stretch according to the length of the spectrum.

If you right click on the title, a popup menu will appear as shown on Figure 40.4.

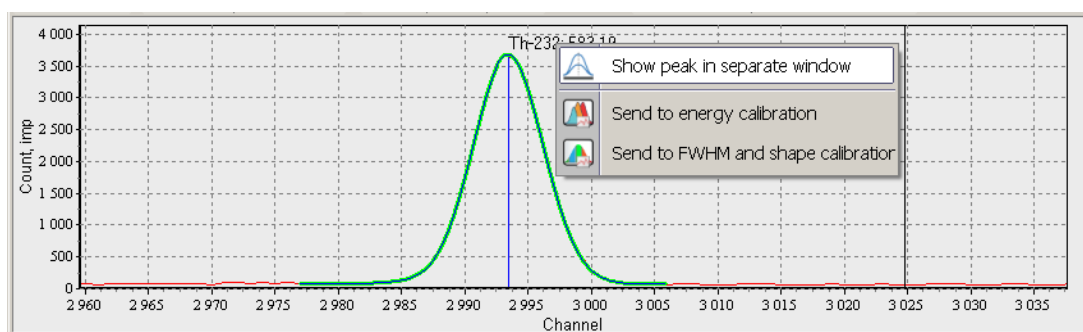






Figure 40.4

In this menu, **Show peak in separate window** selects this peak and opens it in the **Peak** window (see section 4.2).



Send to energy calibration and **Send to FWHM and shape calibration** make it possible for the user to add data of the peak being viewed to energy calibration and FWHM and shape calibration.



The  (**Delete peak**) button of the toolbar of the spectrum window is intended for the deletion of a peak from the list of found peaks.

The procedure of deletion of a peak is as follows. Exit the insert peak mode by pressing  again, so that the cursor returns to its standard view. Then select a peak to delete. To do this, you can use peak selection in the table by selecting the peak you need. You can also select a peak by left clicking on the peak title. In either case, the peak will have a bold green outline and the row corresponding to it will get selected in the table. When a peak has been selected, press  on the toolbar of the spectrum menu.

If you want to delete all the found peaks, there is a  (**Delete all**) button.

6.5 Sending of a list of peaks to calibration

The toolbar above the table of **Found Peaks** contains additional buttons   (see Fig.38, block 5). These buttons are intended for sending of data about found peaks to peak FWHM and shape calibration. It should be noted that even though the information about the FWHM and shape value is not available in the **Found Peaks** table, this information is stored in the programme and may be sent to dialogue windows generating FWHM and shape calibrations.

To send data to calibration, in the tables of found peaks select those peaks, which you want to convert (see Fig.41), and press  (**Send selected peaks to energy calibration**) or  (**Send selected peaks to FWHM and shape calibration**), depending on the target calibration.

Calculation results

ROI-methodPeaks analysisMDALibraryPassport of source

Found peaks


Num...	Channel	Energy	Line	*	Area	Intensity	Activity, Bq	Stand. uncert...	Benc...
1	662.06	129.02	Th-232 129.06		5233	2.85	4299.5	7.78	<input type="checkbox"/>
2	1073.3	209.15	Th-232 209.25		7645	4.164	4205.5	7.33	<input type="checkbox"/>
3	1385.9	270.07	Th-232 270.24		5661	3.083	4169.7	7.33	<input type="checkbox"/>
4	1420.5	276.82	Ba-133 276.4		3260	1.776	1133.5	7.87	<input type="checkbox"/>
5	1539.2	299.94	Th-232 300.09	*	4880	2.658	4223.1	7.38	<input type="checkbox"/>
6	1735.4	338.16	Th-232 338.32		15900	8.66	4232.5	7.07	<input type="checkbox"/>
7	2376.1	463	Th-232 463		4663	2.54	4220.6	7.3	<input type="checkbox"/>
8	2993.4	583.26	Th-232 583.19		25080	13.66	4224.7	7.03	<input type="checkbox"/>
9	4951.1	964.54	Eu-152 964.13		2653	1.445	1452.3	7.4	<input type="checkbox"/>
10	13433	2614.9	Th-232 2614.5		7958	4.334	4207.5	7.09	<input type="checkbox"/>

Figure 41. Selection of peaks for sending to calibration

When you press these buttons, a dialogue window of the relevant calibration will open.

7 Energy calibration

Before identification, it is necessary to match the energy value with the analyser's channel number, i.e. perform energy calibration of the spectrometer. Spectra of standard sources of γ radiation are entered for this purpose. The spectrum, which participates in energy calibration, must contain several well-shaped peaks. The procedure should be periodically repeated depending on the stability of operation of the source of high voltage, amplifier and analyser.

For energy calibration of a selected spectrometric tract, select this tract on the **Device manager** panel. Then, press  and a dialogue windows will appear on the display as shown on Figure 42.

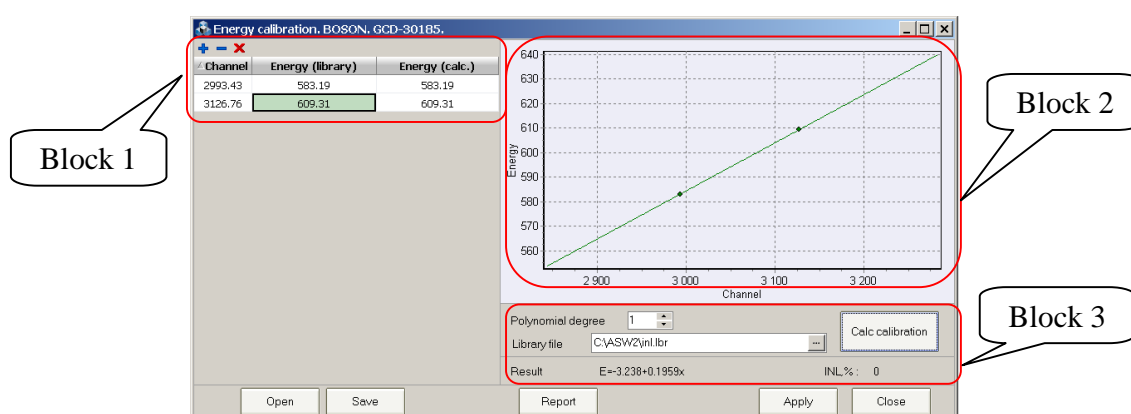


Figure 42. Energy calibration window

On the left side of the window, there is a table (Fig.42, block 1) containing three columns 'Channel', 'Energy (library)', 'Energy (calc.)'. The table contains information about lines (peaks), which are the basis for energy calibration.

Thus, Fig.42 shows calibration consisting of two points, which describes the dependence of energy on channel in the spectrum. To calculate functional dependence, the user should press the

Calc calibration button (Fig.42, block 3), and the received formula will be displayed in the **Result** field. Also, after the calculation, the graph (Fig.42, block 3) will show the found dependence.

If there are more than two points in the table, the programme may determine the parameter of integral nonlinearity (INL), which is displayed in the **INL** field in block 3. Also, in this case a polynomial dependence of second degree can be built. To do this, set the value of **2** in the **Polynomial degree** field.

The user may add and remove points from the table. To do this, use **+** (**Add item**) and **-** (**Delete item**), which are located above the table. Thus, if you press **+**, a new row will appear in the table, which the user should fill with values of the field in the '**Channel**' and '**Energy (library)**' columns.

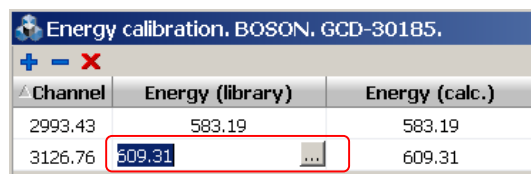
If you want to start generating a new calibration, there is a **✗** (**Delete all**) button located above the table. When you press this button, the table will keep two rows, which are minimally necessary for plotting a straight-line correlation. You can edit the table by editing fields in these rows.

Data can be brought to the table in several ways:

- from the table of found peaks in a processed spectrum (section 6.5, Fig.41);
- from the window for work with peak (section 4.2, Fig.25);
- from the peak title context menu (section 6.4, Fig. 40.4).

To get a prompt of the library energy value in the field of the '**Energy (library)**' column, in the editing mode there is a possibility to open a library window (see Fig.43.1). This function is available, if a library file is specified in the **Library file** field.

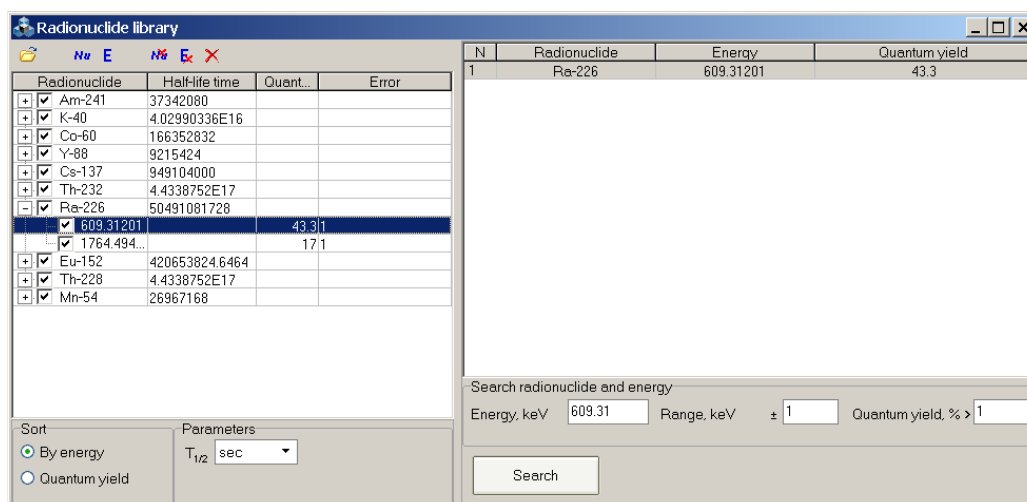
To open the library window, press **...** at the right edge of the field.



Channel	Energy (library)	Energy (calc.)
2993.43	583.19	583.19
3126.76	609.31	609.31

Figure 43.1

Then, a window for selection of an energy line from the library will appear on the display (Fig.43.2).



Radionuclide	Half-life time	Quant.	Error
Am-241	37342080		
K-40	4.02990336E16		
Co-60	166352832		
Y-88	9215424		
Cs-137	949104000		
Th-232	4.4338752E17		
Ra-226	50491081728		
Eu-152	420653824.6464		
Th-228	4.4338752E17		
Mn-54	26967168		

Figure 43.2 Window of energy selection from the library

The user may select a radionuclide and a line from the list provided in the left table. When you double click on the selected energy, the library window will close and the energy value will be populated in the table field of the **Energy calibration** window.

You can also use library search. For this, in the **Energy, kev** field in the right portion of the **Radionuclide library** window, specify an approximate energy value, which should be found in the library and having specified the range of search in the next field, press **Search**. As a result, the right table will display lines corresponding to the set condition. The user may select the required variant from the list by double clicking on the respective row with the left mouse button.

When you have received the searched functional dependence for energy calibration, it should be applied to the current spectrometric tract. To do that, press **Apply** at the bottom of the **Energy calibration** window.

To save to a file and load all the calibration data, use **Save** and **Open**, respectively.

The **Energy calibration** window allows the user to generate a text report to receive and print summary information. For this purpose, there is a **Report** button in the bottom part of the window. When the calibration is over and you press this button, the window shown on Fig.44 will appear.

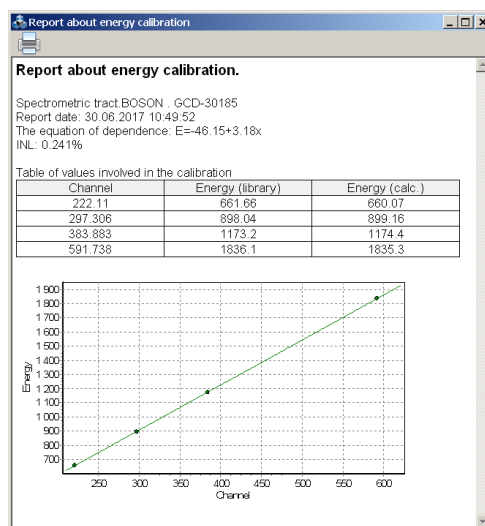



Figure 44. Energy calibration report view

To print a report, press .

To perform energy calibration for the specific work spectrum, open this spectrum and press  on the toolbar of the spectrum window, and then a dialogue window similar to that shown on Figure 42 will appear. The only difference will be the availability of an additional button **Apply to tract** at the bottom of the **Energy calibration** window. This button is intended for the applicable of the new calculated calibration to the spectrometric tract, which corresponds to the spectrum being viewed.

8 FWHM and shape calibration

FWHM (full width at half maximum) calibration is a procedure of searching functional dependence of the FWHM parameter on the channel in the spectrum.

The term 'peak shape calibration' in **GammaPRO** is defined as a search for dependence of T parameter (the so-called 'left edge') on the peak centroid channel in the spectrum. T parameter is the

distance in channels from the peak centroid to the left, after which the peak is described with exponential dependence rather than Gauss (see Fig.45).

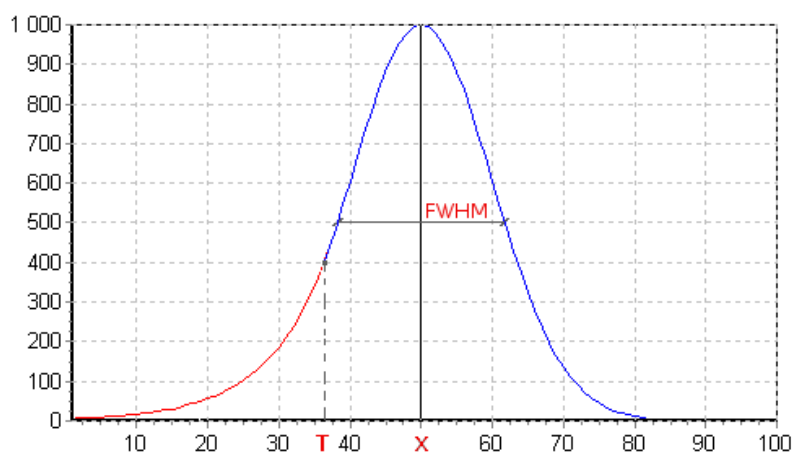



Figure 45. Shape of the graph describing a peak

For FWHM and shape calibration of a selected spectrometric tract, select this tract on the **Device manager** panel. Then, press  and a dialogue windows will appear on the display as shown on Figure 46.

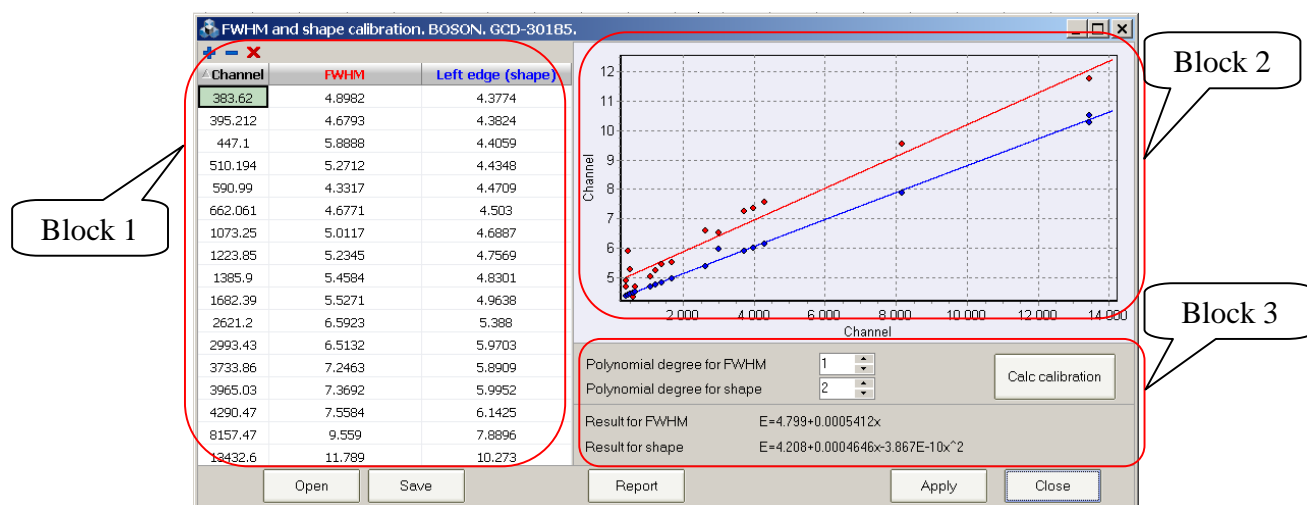


Figure 46. FWHM and shape calibration window

On the left side of the window, there is a table (Fig.46, block 1) containing three columns '**Channel**', '**FWHM**', '**Left edge (shape)**'. The table contains information about lines (peaks), which are the basis for FWHM and shape calibration.

Thus, Fig.46 shows calibration consisting of a certain number of points, which describe the dependence of FWHM and shape on channel in the spectrum. To calculate functional dependences, the user should press **Calc calibration** (Fig.46, block 3), and the received formula will be displayed in the **Result for FWHM** and **Result for shape** fields. Also, after the calculation, the graph (Fig.46, block 3) will show the found dependences.

If there are more than two points in the table, polynomial dependences of second degree can be built. To do this, set the value of **2** in the **Polynomial degree for FWHM** and **Polynomial degree for shape** fields.

The user may add and remove points from the table. To do this, use **+** (**Add item**) and **-** (**Delete item**), which are located above the table. Thus, if you press **+**, a new row will appear in the table, which the user should fill with values of the field in the '**Channel**', '**FWHM**' and '**Left edge (shape)**' columns.

If you want to start generating a new calibration, there is a **✗** (**Delete all**) button located above the table. When you press this button, the table will keep two rows, which are minimally necessary for plotting a straight-line correlation. You can edit the table by editing fields in these rows.

Data can be brought to the table in several ways:

- from the table of found peaks in a processed spectrum (section 6.5, Fig.41);
- from the window for work with peak (section 4.2, Fig.25);
- from the peak title context menu (section 6.4, Fig. 40.4).

When you have received the searched functional dependences for FWHM and shape calibration, they should be applied to the current spectrometric tract. To do that, press **Apply** at the bottom of the **FWHM and shape calibration** window.

To save to a file and load all the calibration data, use **Save** and **Open**, respectively.

The **FWHM and shape calibration** window allows the user to generate a text report to receive and print summary information. For this purpose, there is a **Report** button in the bottom part of the window. When the calibration is over and you press this button, the window shown on Fig.47 will appear.

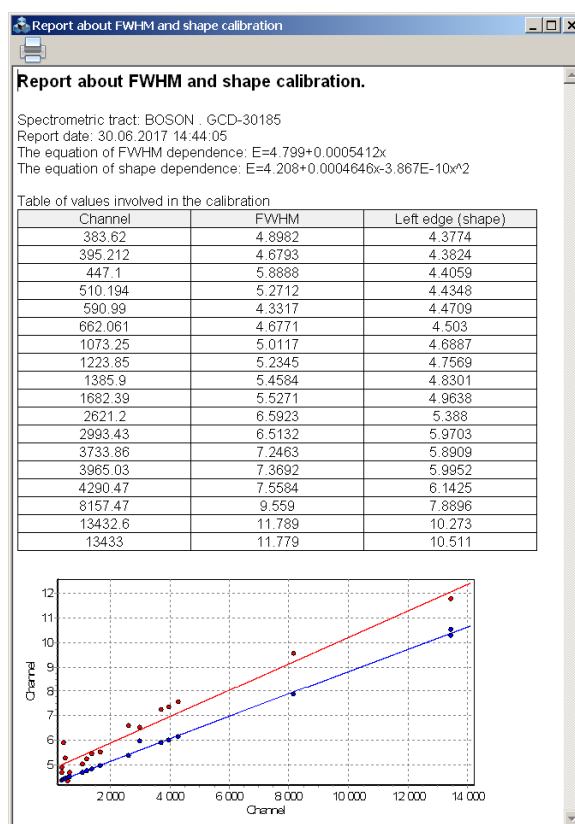



Figure 47. FWHM and shape calibration report view

To print a report, press .

To perform FWHM and shape calibration for the specific work spectrum, open this spectrum and press  on the toolbar of the spectrum window, and then a dialogue window similar to that shown on Figure 46 will appear. The only difference will be the availability of an additional button **Apply to tract** at the bottom of the **FWHM and shape calibration** window. This button is intended for the applicable of the new calculated calibration to the spectrometric tract, which corresponds to the spectrum being viewed.

9 Efficiency calibration

9.1 General statements

The calibration of a spectrometer by registration efficiency is performed using the activity measures reproducing the geometry and properties of gamma-ray absorption of the countable sample.

As a result of calibration, energy dependence of registration efficiency in peaks of complete absorption of gamma quanta radiated by sample (reference) measures is determined. When it is necessary to take into account absorption of gamma-quanta in the material of a bulk spectrometric preparation, energy dependences of registration of gamma-quanta are determined using several sets of reference bulk measures with different density of filler materials.

The calibration process is conditionally broken down into four stages:

- measurement of spectra of sample activity measures or receiving these spectra via calculations using a specialised programme, which simulates interaction of radiation with the substance;
- processing of spectra for the purposes of searching, identification and determining areas of peaks;
- calculation of efficiency of registration of gamma-quanta based on gathered spectra of the set of sample measures and approximation of energy dependences of efficiency of registration of gamma-quanta;
- creation and saving of an *.efp calibration file.

The dependence of efficiency of registration of ε_n on energy of gamma-quanta E_n is described by functional dependence 9.1:

$$\varepsilon_n(E_n) = \exp(A_0 + A_1 \ln E_n + A_2 (\ln E_n)^2 + A_3 (\ln E_n)^3 + A_4 (\ln E_n)^4 + A_5 (\ln E_n)^5 + A_6 (\ln E_n)^6) \quad (9.1)$$

where A_i are polynomial coefficients determined in the process of calibration, $i=0..6$.

Annex 2 shows an *.efp file format.

Since registration efficiency calibration is the basis for correctness and accuracy of measurements, these operations must be fulfilled by a highly qualified specialist, or a representative of the company in charge of supply and setting of the gamma spectrometer.

9.2 Selection of radionuclides for calibration

Calibration requires sample measures of activity or calibration sources (hereinafter referred to as calibration sources) with activity within the range (1 - 100) kBq, produced based on working

standards of radionuclide solutions of the 1st order ⁵⁴Mn, ⁵⁷Co, ¹⁰⁹Cd, ¹¹³Sn, ¹³⁷Cs, ¹³⁹Ce, ¹⁵²Eu, ²⁴¹Am, ²⁴³Am, ²²⁶Ra (with daughters), ²²⁸Th (with daughters), etc.

The activity of the calibration source is chosen based on the condition that, when setting a spectrum in the working geometry of measurement, “dead” time does not exceed (4-5)%.

The quantity and radionuclide composition of calibration sources for the efficiency calibration task in the range of energies 50 – 3000 keV is chosen, assuming that no less than 4 efficiency values, which correspond to different energies of gamma-quanta, should be received in the interval of energies 50-200 keV, and also energies must correspond to the beginning, middle and end of the energy range, and no less than 4 efficiency values meeting the same requirements should be received in the interval of energies 200-3000 keV.

9.3 Efficiency calibration procedure


9.3.1 Measure spectra of sample measures or simulate these spectra using the programme implementing calculation methods.

9.3.2 Generate files of passport data of calibration sources. To do this, use the **Passport of source editor** window, which can be opened from the main programme menu **Options-> Passport of source editor** (see section 13).

9.3.3 Process the spectra received in p.9.3.1 for the purposes of searching, identification and determining areas of peaks as described in section 6.

9.3.4 For each spectrum of the calibration source, set its own file of passport data. To do this, specify a link to the file of passport data in the **Passport of source** field in the **Spectrum parameters** window of each spectrum.

9.3.5 Save processed spectra to a disc.

9.3.6 Open the **Efficiency calibration** window (see Fig. 48) by pressing  on the toolbar of the programme. Choose tab **Efficiency calibration** which is the first tab in the window's title.

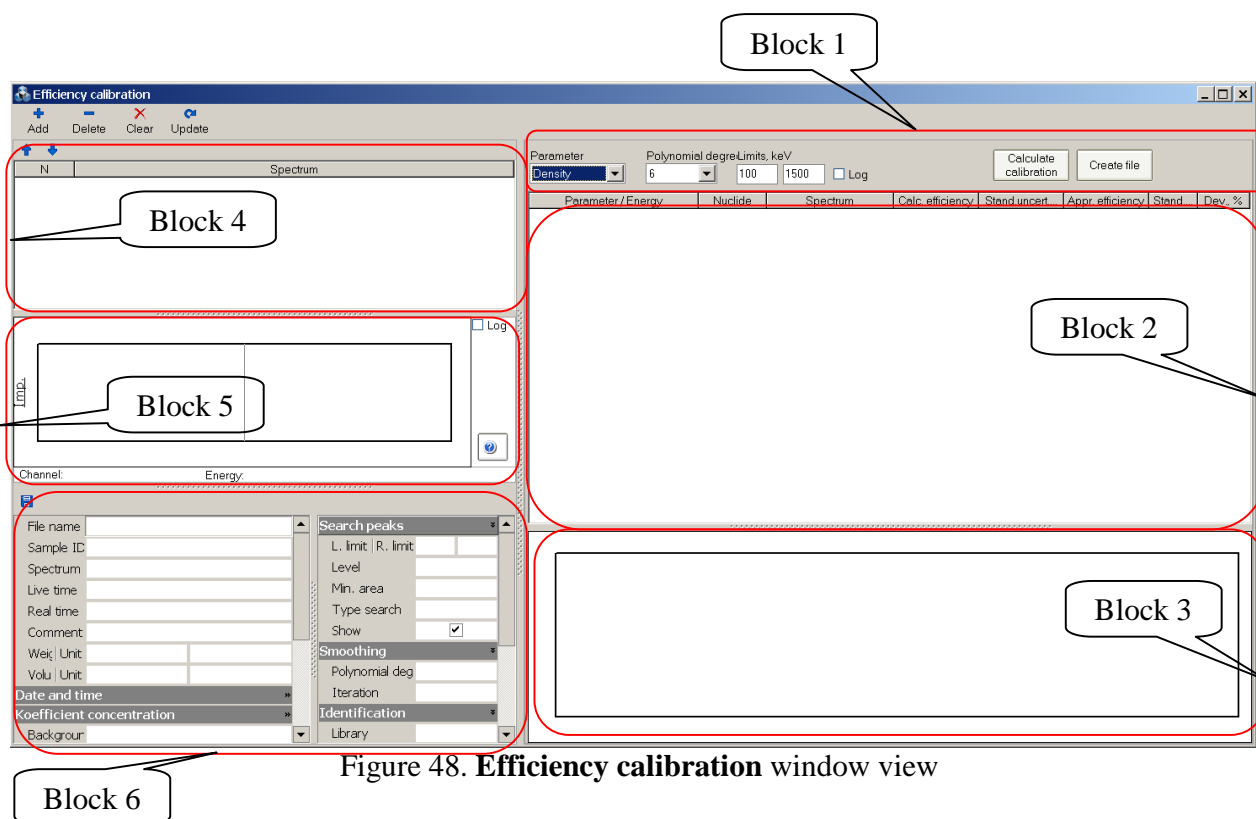


Figure 48. Efficiency calibration window view

9.3.7 In tab **Efficiency calibration**, using **Add** on the toolbar, load all the calibration spectra, then range them in such a way that the spectra with one density (or other parameter) are grouped. (See example on Fig.49).

<div> <div>↑</div> <div>↓</div> </div>	
N	Spectrum
<input checked="" type="checkbox"/> 1	C:\ASW\spc\01_ms_ra_op.asw
<input checked="" type="checkbox"/> 2	C:\ASW\spc\04_ms_th_op.asw
<input checked="" type="checkbox"/> 3	C:\ASW\spc\07_ms_k_op.asw
<input checked="" type="checkbox"/> 4	C:\ASW\spc\10_ms_cs_op.asw
<input checked="" type="checkbox"/> 5	C:\ASW\spc\02_ms_ra_sm.asw
<input checked="" type="checkbox"/> 6	C:\ASW\spc\05_ms_th_sm.asw
<input checked="" type="checkbox"/> 7	C:\ASW\spc\08_ms_k_sm.asw
<input checked="" type="checkbox"/> 8	C:\ASW\spc\11_ms_cs_sm.asw
<input checked="" type="checkbox"/> 9	C:\ASW\spc\03_ms_ra_ps.asw
<input checked="" type="checkbox"/> 10	C:\ASW\spc\06_ms_th_ps.asw
<input checked="" type="checkbox"/> 11	C:\ASW\spc\09_ms_k_ps.asw
<input checked="" type="checkbox"/> 12	C:\ASW\spc\12_ms_cs_ps.asw

Spectra of samples with density 0.2 g/cm³

Spectra of samples with density 1 g/cm³

Spectra of samples with density 2 g/cm³

Figure 49. Ranging of spectra

9.3.8 Set parameters of the efficiency curve (Fig. 48, block 1):

- **Parameter** (Density) – the parameter, according to which the programme will plot different curves. Thus, for instance, when the list of spectra contains samples with three different densities of material 0.2 g/cm³, 1 g/cm³ and 2 g/cm³, the programme will plot three independent efficiency curves. Then, when a file with these curves is used, the programme will interpolate values of efficiencies taking into account the real density of material of the countable sample.


- **Polynomial degree** – the parameter determining the polynomial degree, which will be calculated for the purposes of describing experimental dependence of registration efficiency on the energy of gamma-quanta.

- **Range, keV** – the range of energies, within which the dependence of the registration efficiency on the energy of gamma-quanta will be built.

9.3.9 Press **Calculate calibration** (Fig. 48, block 1), then the table (Fig. 48, block 2, and Fig.50) will show a tree with data on efficiencies, and the graph below will display the curves approximating calculated points of values of efficiencies (Fig. 48, block 3, and Fig.50).

For each parameter (density), polynomial coefficients of approximation are displayed (near the value of this density), which look like this (example):

$$\text{Eff}=f(-1343, 1307, -5133, -1649, 248.2, -19.85, 0.6592)$$

9.3.10 The points, which are at a good distance from the curve, are rejected by unchecking the relevant row in the table, and the appearance of the curve changes automatically. To change the energy range for calculation of efficiency curve, specify the values in the fields and click button .

9.3.11 To explore the shape of received curves, you can toggle the scale to the logarithmic mode. To do this, you should check **Log** located on the panel (Fig.48, block 1). The appearance of the graph will change, and will look as shown in Fig.50.1.

9.3.12 When the appearance of efficiency curves has finally shaped, an efficiency calibration file for the accepted measurement geometry is created, which has a unique name and an *.efp extension. To do this, press **Create file** and then enter the name of the new calibration file in a standard dialogue.

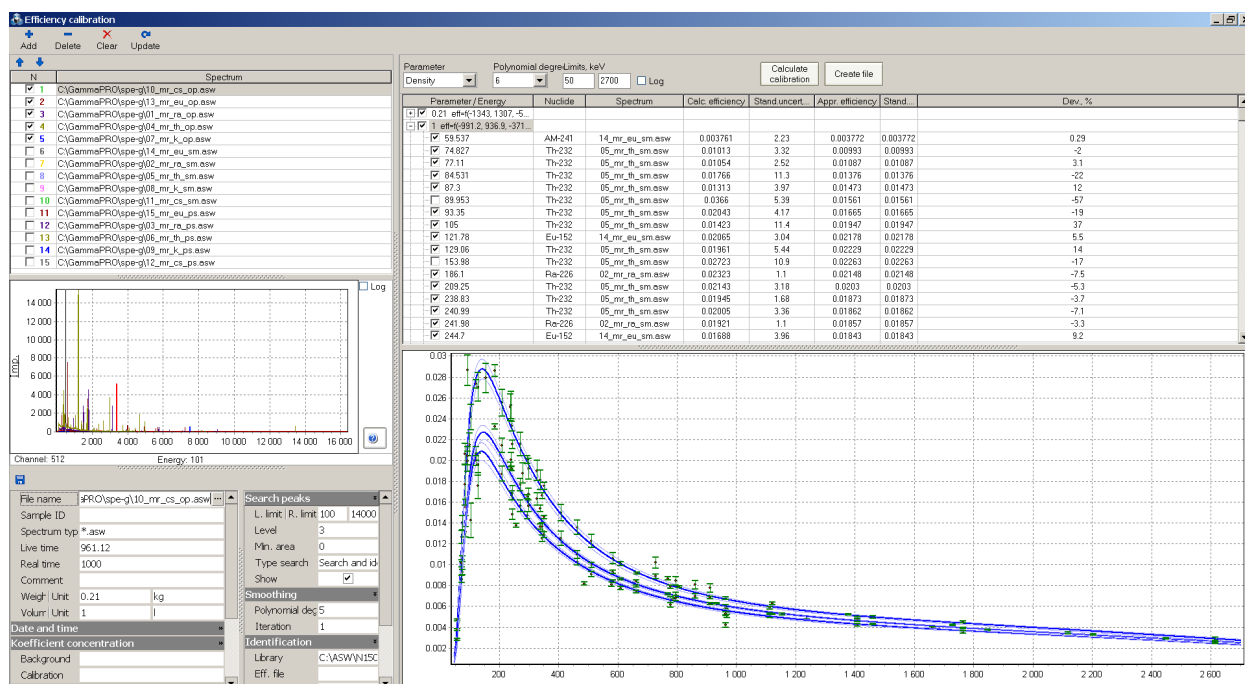


Figure 50. Efficiency calibration window view after calculation of dependence of efficiencies on energy

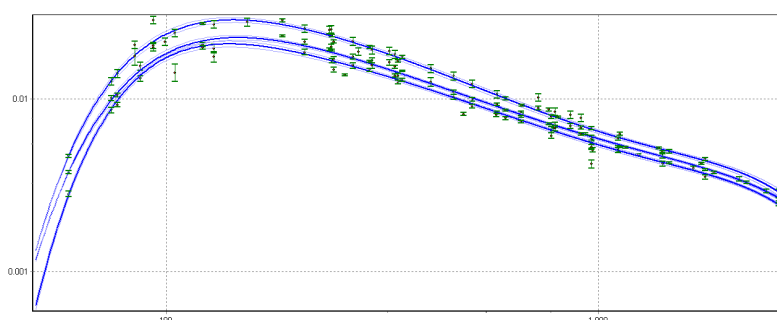


Figure 50.1 View of efficiency curves on a logarithmic scale

9.4 Management of spectra

To load and delete spectra in the **Efficiency calibration** window, use **Add**, **Delete**, and **Clear** buttons on the toolbar of the window.

After spectra have been loaded, their list appears in a table (Fig.48, block 4) or as shown on Figure 50. Histograms of spectra are displayed on a graph (Fig.48, block 4 or Fig.50).


To show or hide a histogram of a spectrum, check or uncheck it in the first 'N' column of the table.

The information with parameters of the current (selected in the table) spectrum is displayed on the panel under the graph of spectra (see Fig.48, block 6). To be noted, the histogram of the current spectrum is displayed on a graph with a bold red line.

To move the current spectrum up or down the table, use **↑** or **↓** buttons.

9.5 Creating an efficiency file project

As creation of an efficiency file may take a longer time, saving a current configuration of calibration spectra, selected energies and parameters for further operation might be relevant. To this end, one can save the current configuration as a separate project file. What is more, all the spectra, library files and passport data files will be moved to a common directory featuring a certain structure.

To create a project file, click button  in the toolbar of tab **Efficiency calibration**. A window will appear on the screen. In this window, specify the name of the project and directory, where the project itself and all the relevant files will be moved (one is recommended to create a new directory) (see Fig. 50.2).

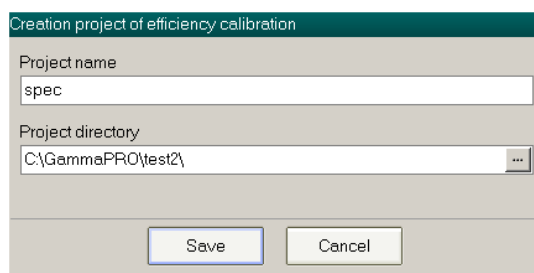




Figure 50.2 Window requesting the name of an efficiency file project and a directory for it

Click button **Save** to create three subdirectories **SPC**, **LBR** and **PKS** in the project's directory specified by user. The spectra, library files and passport data files related to them will be automatically copied to the respective subdirectories. In the project's directory, there will appear a *.pef file which contains the data on the project's parameters.

Later on, when **GammaPRO** is closed and then opened again, the user will be able to load the project by clicking button  in the toolbar of tab **Efficiency calibration** and selecting the saved project's file there. The software will automatically load all the spectra and restore the configuration saved, so that the user will be able to continue creating the efficiency calibration file.

9.6 Creating an efficiency file from a text table

Tab **Converting** in window **Efficiency calibration** is used to convert the text table (text file) which contains three value columns (energy, efficiency and standard uncertainty) to the efficiency file of the **GammaPRO** format.

To this end, the user should choose tab **Converting** (see Fig. 50.3) and open the text file by clicking button  in the tab's toolbar. Once the file is opened, the software immediately starts to perform calculation in accordance with the parameters (degree of a polynomial, energy range) specified in the toolbar. These parameters are changed in the same way as in tab **Efficiency calibration**. The values in the table can also be turned on and off by ticking each row in the first column named Energy. The resulting polynomial function of the detection efficiency versus energy will be displayed in the toolbar.

When calibration is created, it should be saved as an *.efp file by clicking button **Create file** in the tab's toolbar.

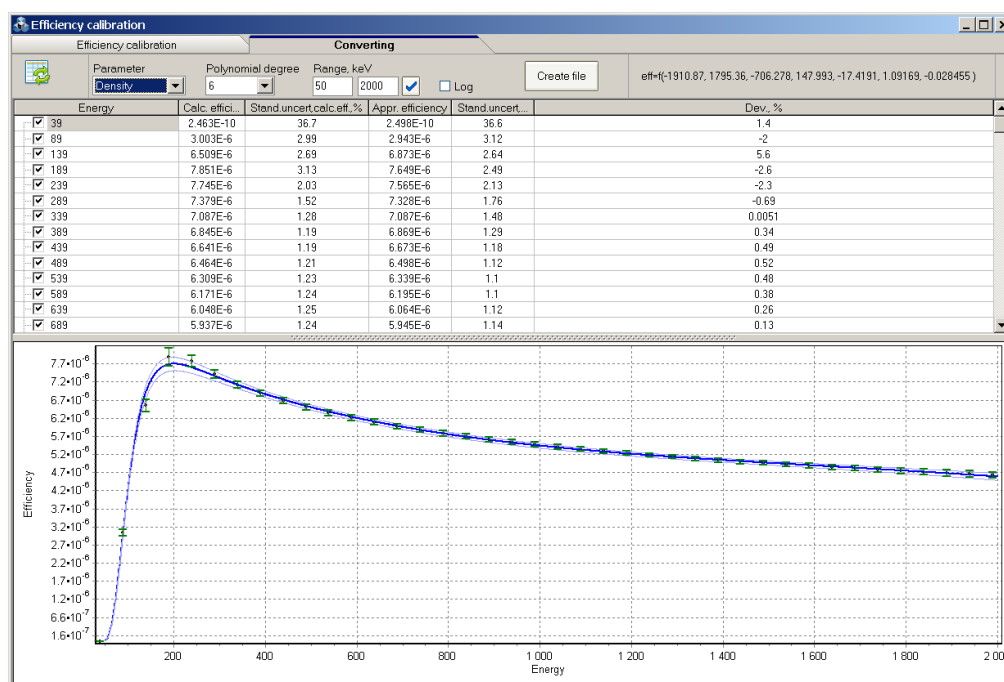


Figure 50.3. Tab Converting

10 Parameters

The **Parameters** window of the table is intended for setting some details of work of the programme. It can be opened from the main menu **Options->Parameters** and contains 4 tabs **General**, **Files**, **View**, **Calculation** (see Fig.51).

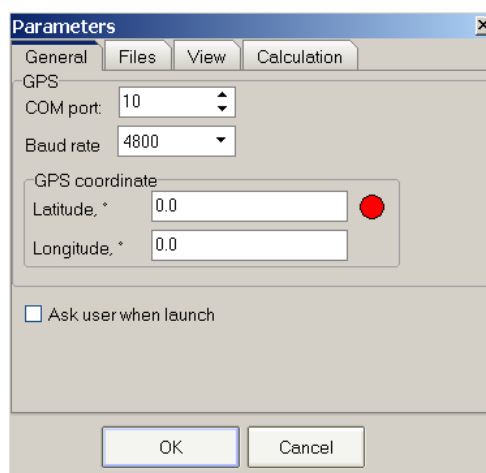


Figure 51. **Parameters** window view

The **General** tab (Fig. 51) contains a block of parameters **GPS**, which has two fields for setting a GPS satellite navigation unit. If a GPS receiver is connected and data are correct, the current coordinates can be sent to fields of the **GPS coordinate** group.

The **Files** tab (Fig. 52.1) contains the name of the database file for saving the results of calculation of activities of radionuclides (**Database filename** field) and the protocol filename (**Protocol filename** field), which can contain the consolidated result of measurements in a text format.

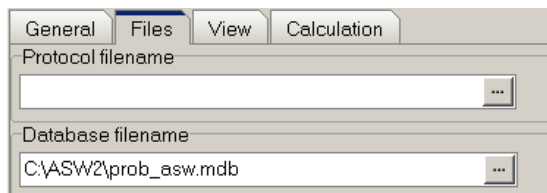


Figure 52.1 **Files** tab view

The **View** tab (Fig.52.2) is intended for setting the external interface of the device manager.

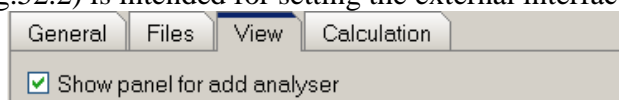


Figure 52.2 **View** tab view

The **Calculation** tab (Fig.52.3) is intended for setting some aspects related to measurements and the procedure of calculation of activities.

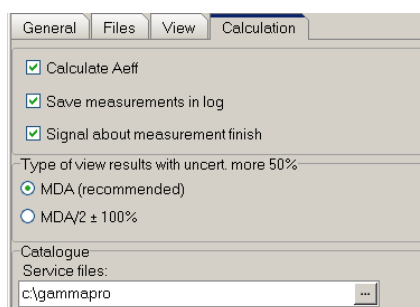


Figure 52.3 **Calculation** tab view

The **Calculation** tab contains several blocks containing the following fields:

Calculate Aeff – an indicator telling the programme that it needs to calculate a parameter of efficient activity, which is determined according to formula 10.1 (for details see Annex 5):

$$A_{\text{eff}} = A_{\text{Ra}} + 1.30 \cdot A_{\text{Th}} + 0.090 \cdot A_{\text{K}} \quad (10.1)$$

where A_{Ra} is specific activity of radionuclide Ra-226, Bq/kg;

A_{Th} is specific activity of radionuclide Th-232, Bq/kg;

A_{K} is specific activity of radionuclide K-40, Bq/kg.

Efficiency activity is determined, when activities are calculated according to the ROI-method or peak analysis method and is displayed on the results panel as shown on Fig.30. The calculation is made, if there is a calibration for determining activities of natural radionuclides (NRN).

Save measurement in log – an indicator telling the programme that it needs to automatically send the measurement results to a log in the process of saving a measured spectrum.

Signal about measurement finish – a checkbox, which allows to enable and disable a sound signal at the end of spectrum writing.

Type of view results with uncert. more 50% – an item for choosing the format of display of the measurement result with expanded uncertainty above 50%. Values may be displayed in two formats:

"<MDA"

"MDA/2 ± 100%".

The first result output variant is more correct from the point of view of metrology.

11 Pack of spectra

The **Pack of spectra** module is opened from the main programme menu **Tools->Pack**. It is intended for work with any series of spectra (display, mathematical operations, determination of stability, calculation of activities, etc.).

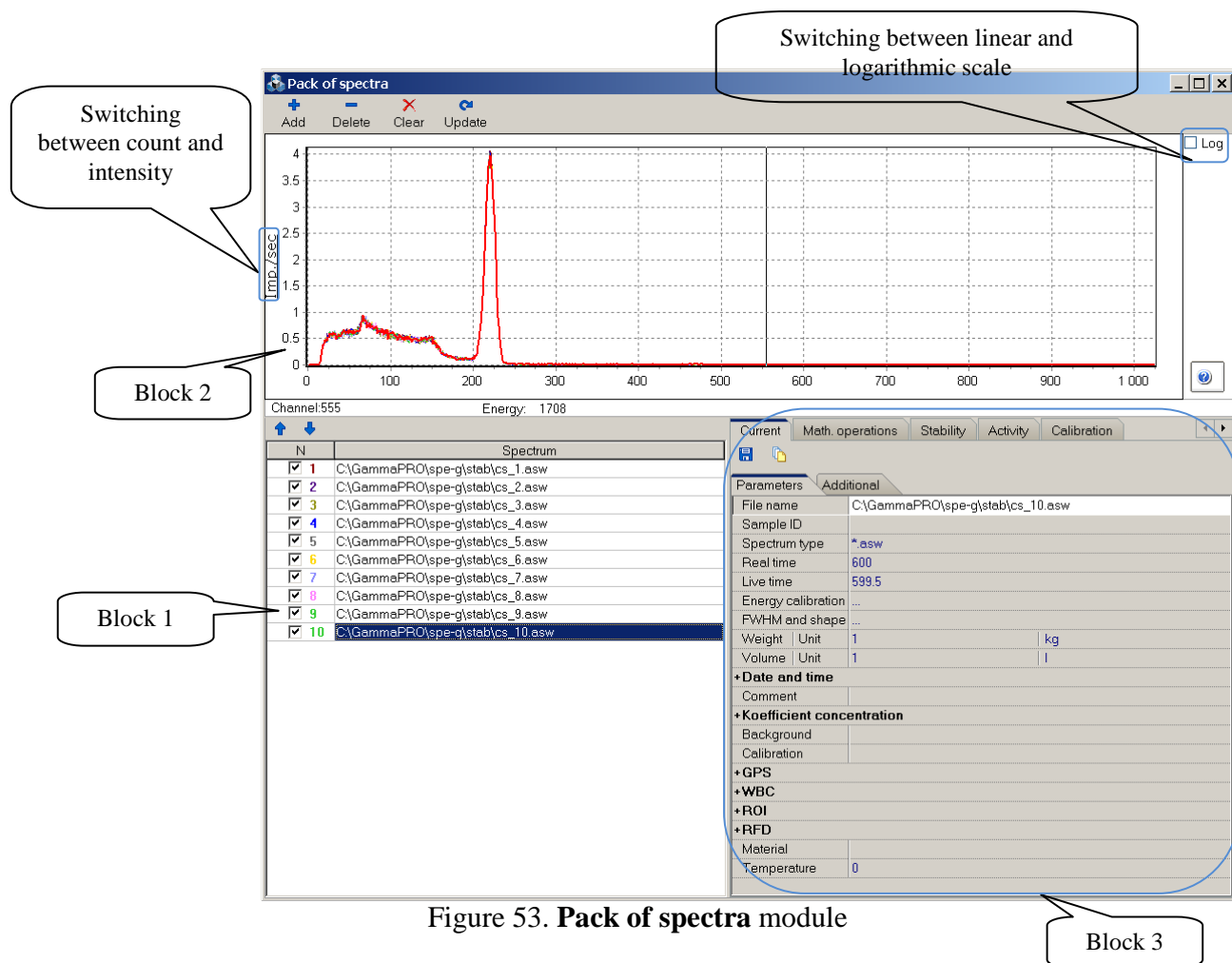
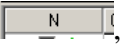


Figure 53. Pack of spectra module




The **Pack of spectra** module consists of three main blocks and a menu (Fig.53).

Block 1 is a table, which contains the list of loaded spectra. The first column of the table contains a spectrum number in sequence and a checkbox, which shows whether this spectrum should be displayed in block 2. When you press on the column header , it enables or disables displaying of all the spectra.

The second column contains filename of spectra with their paths. Columns 3, 4 and 5 are intended for the display of results by determination of stability (see below).

If a cursor is set in any row, the spectrum concerned is shown on the graph in red. You can select one, two and even all the rows in the table. The last selected spectrum has a red bold line on the graph. To select several spectra, press and hold Ctrl on the keyboard and press on the row you want to select with the left mouse button. If you want to deselect a row, press with a left mouse button on any selected table cell. A left double click on any row causes standard opening of a spectrum within **GammaPRO**.

Block 2 contains a graph, which displays on the selected spectra in the table on a single automatic scale.

Press the  **Add** button in the menu to add spectra to the table, or press the  **Delete** button to delete, first selecting necessary spectra in the table. To delete all the spectra at once, press  **Clear**.

Block 3 is intended for management and all kinds of operations in the **Pack of spectra** module. It consists of several tabs (**Current**, **Math. operations**, **Stability**, **Activity**, **Calibration**, **Sensitivity control**, **Background control**, **Normalization**, **Map**), each of which is responsible for respective functions.

The **Current** tab (see Fig.53) displays all the information about parameters of the last selected spectrum in the table (block 1). The list of parameters on the **Parameters** and **Additional** tabs fully duplicates the list provided on the “**Spectrum parameters**” tab (see Fig.20 and Fig.36) when you work with the spectrum window.





There are two buttons on the toolbar of the **Current** tab:  (**Save current change**) and  (**Template**). The first is for saving changes made to fields of the **Parameters** and **Additional** tabs. The  button provides the user with a **Template** tool, which is intended for measuring one or several parameters of selected spectra. When you press this button, the **Template of parameters** window (see Fig.54) will open.

Figure 54. **Template of parameters** window

Edit one or more parameters and check this field on the right. Then, in the main list of spectra, select the spectra, to which these changes should be applied, then press **Apply** in the header

of the **Template of parameters** window. As a result, you will see a message about the manipulation you have made.

The  (**Get parameters of current spectrum**) button is necessary in the cases, when it is necessary to get parameters of one spectrum and use them as a template for other spectra.

The **Math. operations** tab consists of 3 blocks (Fig.55) and is intended for summing and subtracting spectra.

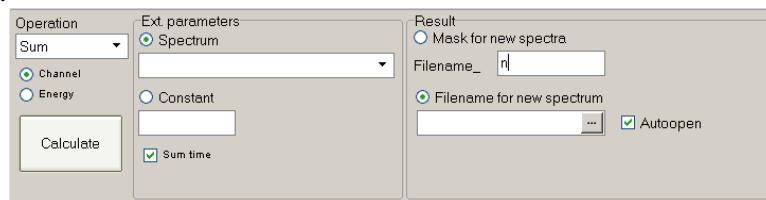



Figure 55. **Math. operations** tab content

To add several spectra and make them one:

- select the spectra intended for summing in the main table (Fig.53, block 1);
- select '**Sum**' in the dropdown list of the **Operation** field (Fig.55);
- select the option corresponding to the type of summing (channel-by-channel or in the energy scale);
- in the **Ext.parameters** block, select **Spectrum** as shown on Fig. 55, the field with the dropdown list should be empty;
- in the **Result** block, select **Filename for new spectrum**, press  in the field below and select a path and the name for the sum spectrum.
- press **Calculate**. A new summary spectrum will be created as a result of the actions above.

There is a **Sum time** checkbox in the **Ext.parameters** block. It is intended for changing the type of the resulting summary spectrum by time criterion. Thus, for instance, you should check this checkbox, when summing spectra of the same type received from one detector or from one source. By doing this, you will sum count and time in the resulting spectrum. Thus, we will receive an averaged spectrum with improved statistics. In other case, when summing spectra from difference sources, disable the "**Sum time**" mode. Then the resulting spectrum will have time as the first spectrum being summed (the so-called adjustment to the time of the first spectrum).

To add several spectra with one spectrum:

- select the spectra intended for summing in the main table (Fig.53, block 1);
- select '**Sum**' in the dropdown list of the **Operation** field (Fig.55);
- select the option corresponding to the type of summing (channel-by-channel or in the energy scale);
- in the **Ext.parameters** block select **Spectrum** as shown on Fig. 55;
- in the field with the dropdown list select the spectrum, with which you will sum the spectra selected in the table;
- in the **Result** block, select **Mask for new spectra**, and in the field below enter a mask, for new spectra, to make them different from the original ones;
- press **Calculate**.

As a result of this, files of spectra summed with one spectrum will be created on a disk.

To subtract a spectrum from several spectra, you should do the same operations with the exception of the type of operation in the **Operation** field. You should select '**Sub**' here.

Spectra can be summed and subtracted with a constant. To do this, in the above-mentioned algorithms specify **Constant** instead of **Spectrum** and enter the constant value in the field below.

The **Stability** tab is intended for determining stability of the spectrometric tract by spectra. Thus, for instance, to receive a graph of dependence of the ^{137}Cs radionuclide peak position in a spectrum on time, the set of spectra should be measured in an automatic mode. Load the received pack of spectra to the **Pack of spectra** module. Select all the spectra. On the **Stability** tab (Fig.56, block 1) in the **Find in range** block, specify the approximate location of the peak, check **Centre** and press **Calculate**. Fill in columns 3, 4 and 5 in the module table. The graph on the **Stability** tab will show the dependence you seek. You can copy the received graph to clipboard by pressing **To clipboard**. To make selection of the window with the peak easier, use Auto (in the **Find in range** block). This button gets fixed in this state, when you press it. Then, you can double click with a marker on the spectrum in the place of the left window edge and then in the place of the right edge. The graph range will get selected (see Fig.56). Then you can press **Calculate** again.

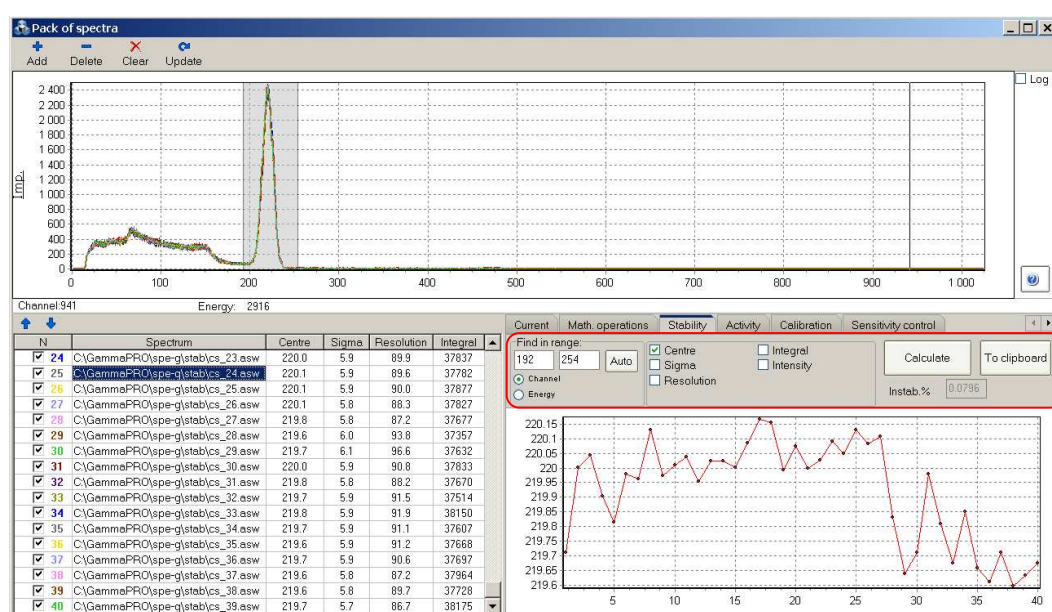


Figure 56

Sigma, **Resolution**, **Integral** and **Intensity** checkboxes are intended for displaying on the graph not only the centroid of the peak, but also FWHM (full width at half maximum) value, resolution value calculated based on the peak shape, as well as integral and intensity. The **Find in range** group contains an option for entering window edges in channels and in energy values (keV).

The **Sensitivity control** tab (Fig. 57) is intended for detector sensitivity control. The programme evaluates the difference between measured and passport values of activities of radionuclides in the control sample taking into account errors in their determining.

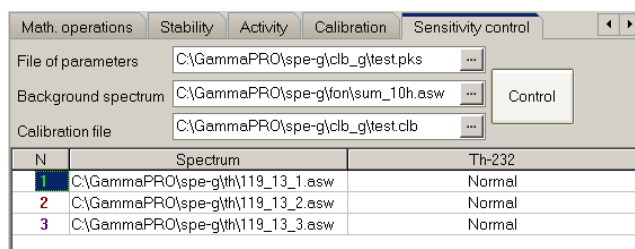


Figure 57. Sensitivity control tab view

Select necessary spectra in the main table to perform the control. In tab fields, consecutively load the file of passport data of the control samples, the background spectrum and the file of calibration by ROI-method. Press **Control**. The result looks as shown on Fig. 57.

The **Background control** tab (Fig.58) is intended for a standard mathematical operation, which allows evaluating the unchangeability of the unit background by comparing the measured spectrum with the background spectrum.

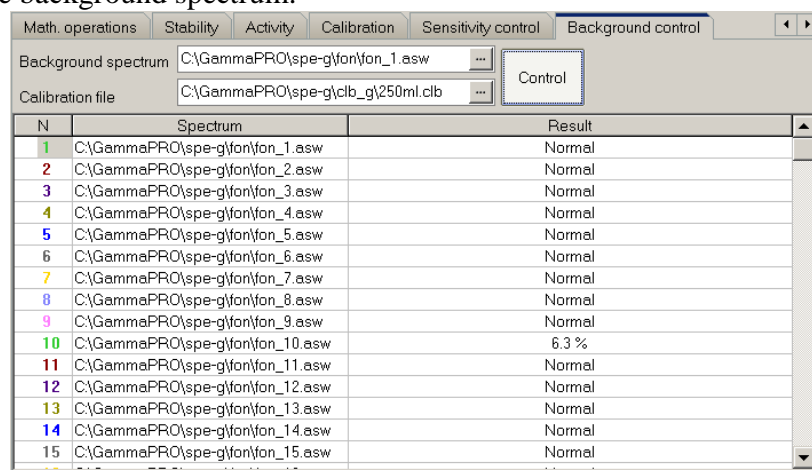


Figure 58. Background control tab view

Select necessary spectra in the main table to perform this operation. In fields of the **Background control** tab consecutively load the background spectrum and the file of calibration by ROI-method. Press **Control**. The result looks as shown on Figure 58.

The **Activity** tab (Fig.59) is intended for the calculation of activity of radionuclides using the ROI-method. For a series of spectra, the procedure is the same as for a single spectrum (see section 5.1).

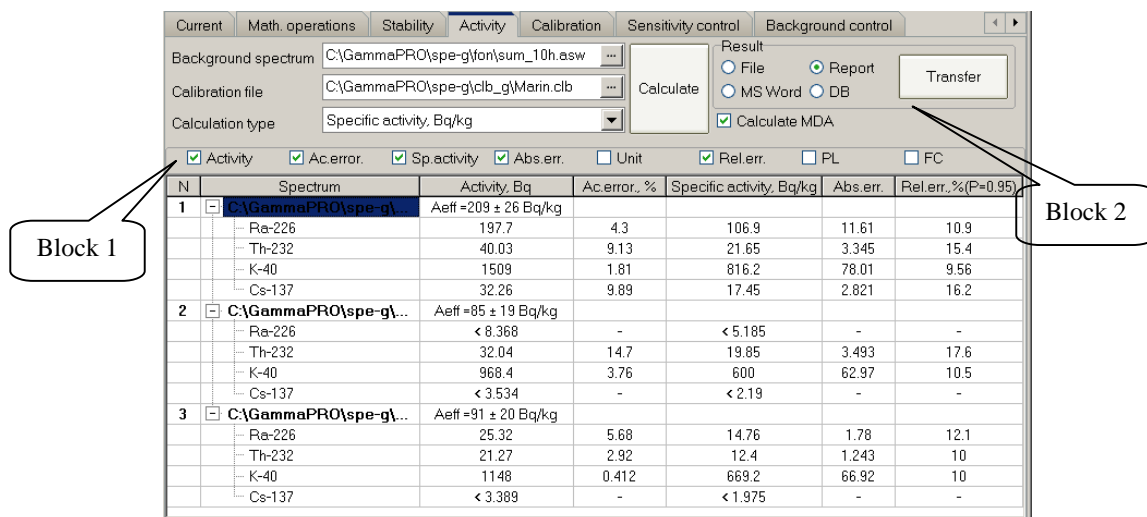



Figure 59. Activity tab view

It is possible to calculate activities for a series of spectra from the **Activity** tab only using one calibration file and one background spectrum. To do this, select necessary spectra in the main table. In tab fields, consecutively load the background spectrum and the calibration file. Press the **Calculate** button. The result looks as shown on Fig. 59.

Block 1 on Fig. 59 has checkboxes, which will show the column in the results. Calculated activities and errors are shown in table as a tree. To look at the values of any specific spectrum, press on  **F** in the respective row and hidden data fields will appear. If you need to show all the values at once, press on the **Spectrum** column heading, when you press again, all the fields will be hidden.

Under block 2 (Fig.59), there is the **Calculate MDA** checkbox. When checked, the table will display minimum detected activity and specific (volume) activity instead of activity, when relative error is higher than 50%.

Block 2 on the **Activity** tab is for exporting results to data storages, for example, a text file, **MS Word**, a report and a database. Check one of the options in block 2 and press **Transfer**. The content of the resulting table will be transferred according to the selection.

12 Radionuclides library editor

The radionuclides library editor is intended for generation of files, which are used in the calculation of activities, identification of radionuclides and for other spectrometric tasks. These files should be shown in the **Library file** field in the **Identification** section of the **Spectrum parameters** window (Fig.20 and Fig.36).

A library file contains the list of radionuclides with respective energy lines and their quantum outputs. The programme can handle library files of two types (***.bib** and ***.lbr**). The first one (***.bib**) is a text file and has a structure of the so-called ini-file; the second one (***.lbr**) is also a text file, but it has other, more old-fashioned structure. Both files may be formatted and edited manually (in any text editor), or you can also use the **Radionuclides library editor** module.

To open the editor, select **Options->Library editor** in the main programme menu. A window shown on Figure 60 will appear on the display.

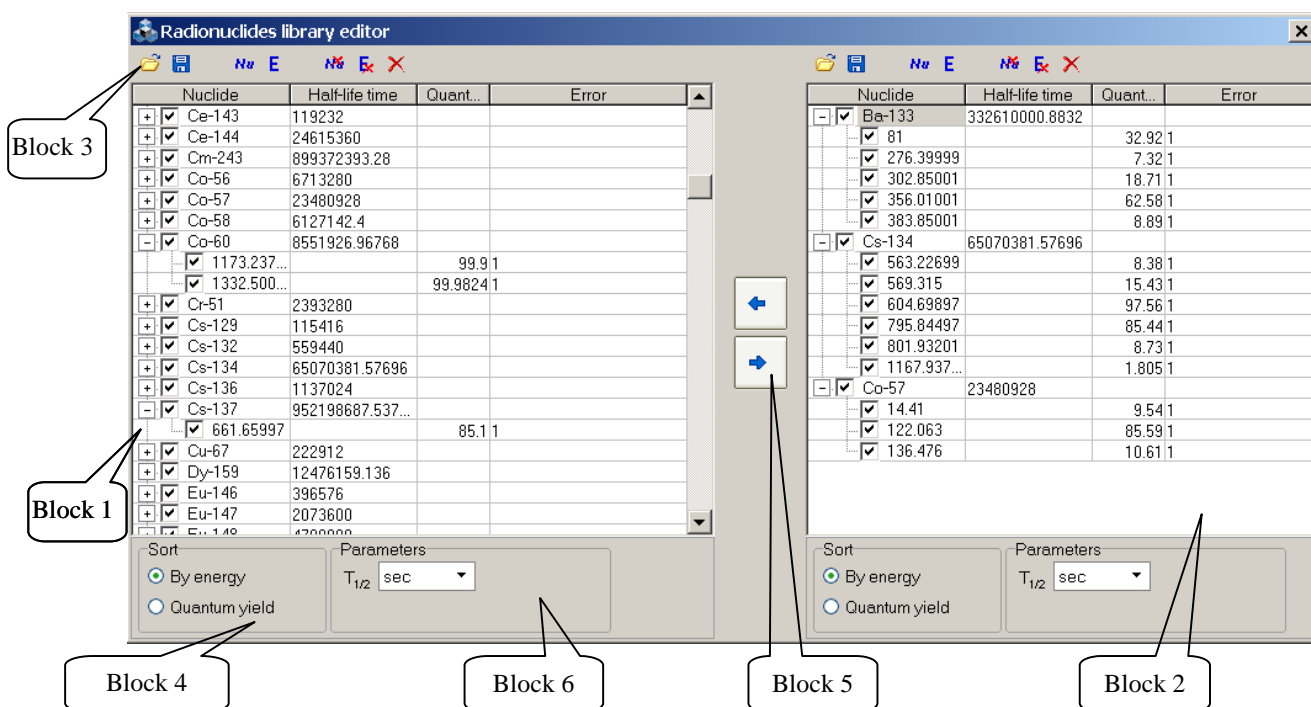


Figure 60. **Radionuclides library editor** window view

It looks like two symmetrically located blocks, which contain a table (block 1 and 2, Fig. 60), a toolbar and a block of display parameters (blocks 3 and 4). The functionality of the blocks is absolutely the same, which allows forming libraries using elements of both. Use arrow buttons (block 5, Fig. 60) to move radionuclides from one library to the other.


The **GammaPRO** installation package usually contains one or more libraries, from which you can make individual libraries for specific tasks. To do this, you need to load an already available library from the toolbar editor to the left block using . Then select necessary radionuclides and press (**Copy selected radionuclides**). Selected items will appear in the right table, then you can add something to it, edit and save it. Items from the right table can be copied to the left table in the same way.

To edit names of radionuclides, energies, etc., double click on the current value with the left mouse button and the field will switch to the editing mode. To finish editing, press Enter.

To add a radionuclide to the table, press (**Add radionuclide**). A new row with the name of the radionuclide 'Nu' with one energy line will appear. The new row will appear above the currently selected row. To add a radionuclide to the end of the table, deselect the current selection. To do this, left click on the field under the table, to the right of the **Parameters** group (Block 6, Fig. 60). The new row should be edited according to characteristics of the item to be added.

To add energy line of a radionuclide, select this item with a cursor and press (**Add energy**) on the toolbar. In the new row, you should replace default values with necessary ones (energy, quantum output, quantum output error).

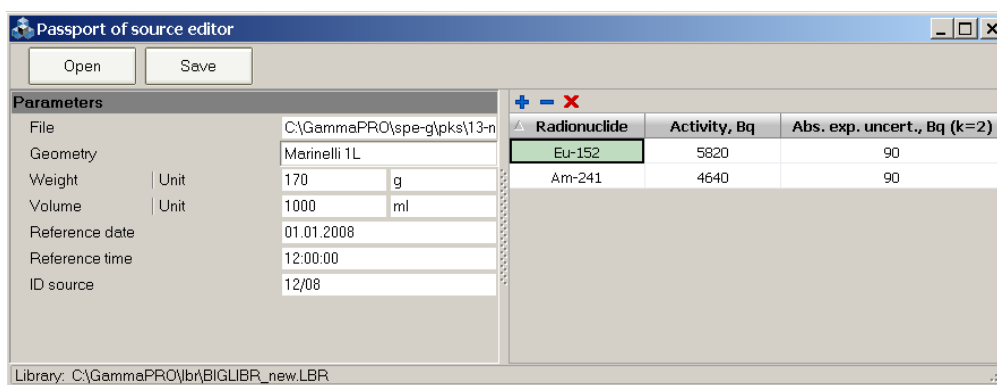
To remove a radionuclide and its energy lines, use (**Delete selected radionuclides**) and (**Delete selected energies**), respectively. To clear the entire table, use the (**Remove all**) button.

When you have finished editing the table, you can save it in any of the two formats. To save, press  (**Save library file**) on the respective toolbar. Please note that the *.lbr library format does not support saving of the so-called “checking/unchecking” of items and their lines.

13 Reference source library editor

The Reference source library editor is intended for generation of files of passport data of sources, which are used during efficiency calibration of the spectrometer. These files should be shown in the **Source reference data** field in the **Identification** section of the **Spectrum parameters** window (Fig.20 and Fig.36).

To open the editor, select **Options-> Reference sources library editor** in the main programme menu. A window shown on Figure 61 will appear on the display.



Radionuclide	Activity, Bq	Abs. exp. uncert., Bq (k=2)
Eu-152	5820	90
Am-241	4640	90

Figure 61. Passport of source editor window

A passport of source file contains a list of radionuclides, their activity, uncertainty, as well as other parameters describing the source.

Figure 61 shows an example of completion of the form in the **Reference sources library editor** window.

Complete the following fields in the left part of the window:


Geometry – source geometry, the text field may be filled manually or its value can be selected from a dropdown list.

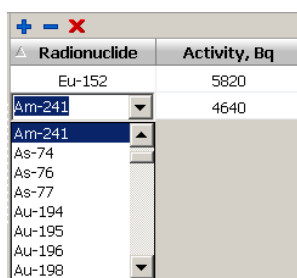
Mass | Unit – source weight and weight unit.

Volume | Unit – source volume and volume unit.

Reference date and **Reference time** – date and time of adjustment of activities specified in the table to the right. Please note that all the activities in the table must be adjusted to this date and time.

ID source – source identifier or number, a text field.



On the right side of the **Reference sources library editor** window there is a table, where the user should enter data about radionuclides present in the source. To add a row, press  (**Add radionuclide**) above the table. Then, it is necessary to fill empty fields with values from the source certificate. To make it easier to enter the data about the name of the radionuclide, the user may select it from the list, which appears in the editing mode in the '**Radionuclide**' field (see Fig.61.1).



Radionuclide	Activity, Bq
Eu-152	5820
Am-241	4640
Am-241	
As-74	
As-76	
As-77	
Au-194	
Au-195	
Au-196	
Au-198	

Figure 61.1 Selection of a radionuclide from the library

To make a dropdown list available, it should be loaded from a library file in format described in Section 12. To load a library file, double click on the status bar of the window and load the required file using a standard file selection dialogue. The name of the loaded file will be shown on the status bar.

To delete a row or clear all the list of radionuclides shown in the table, use  (**Delete radionuclide**) and  (**Delete all radionuclides**) buttons, respectively.

To finish the creation of a passport of source file, save it as a file. To do this, press **Save** on the toolbar of the window and specify a new filename.

To load an existing passport of source file for viewing and editing, use the **Open** button.

14 Calibration for activity calculation by the ROI-method

14.1 General provisions

The **GammaPRO** software enables calculation of (specific) activity of radionuclides in a count sample by the ROI-method considering calibration files which contain calibration sensitivity coefficients calculated in accordance with paragraph 14.4.

The software also enables direct calculation of calibration sensitivity coefficients.

Calibration of detection sensitivity of a spectrometer is performed by means of activity reference samples featuring the shape of and gamma radiation absorption within the count sample.

The calibration can be regarded to consist of the following stages:

- acquisition of spectra irradiated by reference activity samples or calculation of such spectra by means of special purpose software which simulates interaction between radiation and matter;
- acquisition of background spectrum;
- creating a *.clb calibration file and saving it.

The format of a *.clb file can be found in Appendix 1.

A proper calibration underlies correct and accurate measurements. This is why such an operation shall be performed by a skilled expert, alternatively, an employee responsible for delivery and adjustment of the spectrometer.

14.2 Creating a calibration file

14.2.1 Acquire spectra of reference samples or simulate these spectra by means of software which implements calculation methods.

14.2.2 Load module **Pack of spectra** (see section 11).

14.2.3 Load all the calibration spectra into this module and then sort them, so that the spectra of a radionuclide are grouped together (refer to the example in Fig. 49).

14.2.4 Make sure that the parameters of the samples' spectra such as mass, volume, energy calibration are correct, and background spectrum is chosen. These parameters are displayed in tab **Current-Parameters** and additional tab **Current- Additional** (see Fig. 53, block 3).

14.2.5 Select tab **Calibration** in module **Pack of spectra** and specify a radionuclide, its activity (in Bq) and the corresponding certification date for each spectrum in block **Aprior activity of current spectrum** (see Fig. 2, block A).

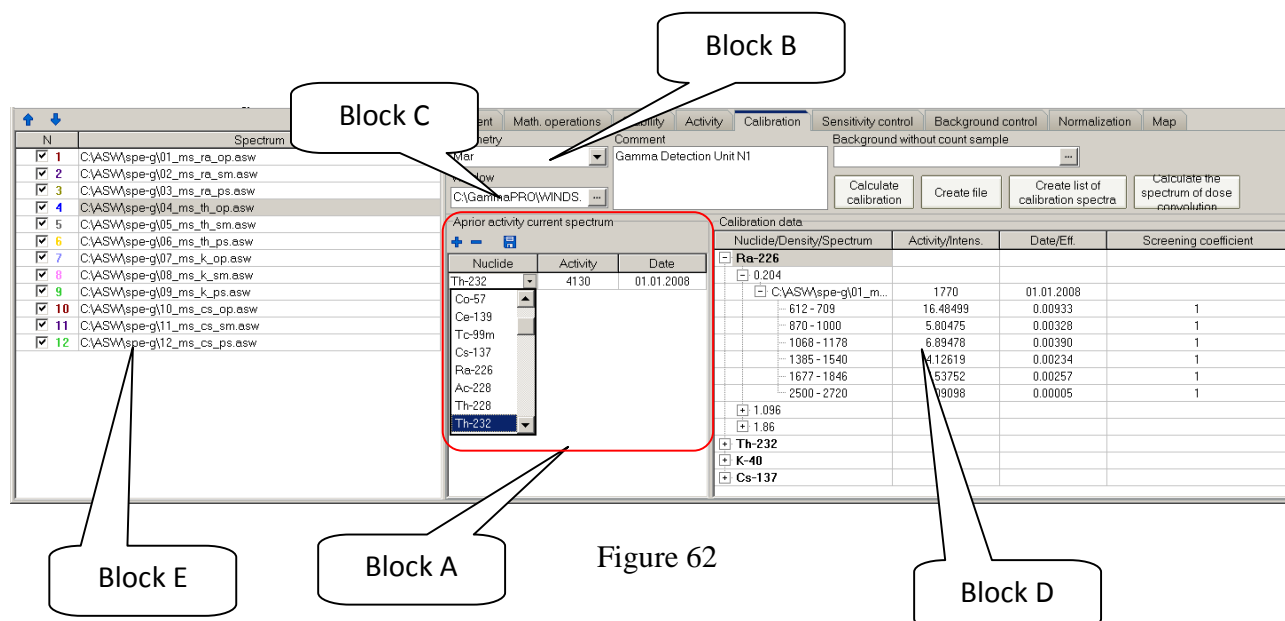


Figure 62

To this end, mark the first spectrum in the spectrum list (Fig. 62, block E) and click button (see Fig. 62, block A). In column **Nuclide** of the string which will appear below, choose the radionuclide from the drop-down list. Specify the activity or radionuclide concentration in the reference sample in column **Activity**. Specify the certification date of the radionuclide activity or concentration in column **Date**. Then click button to save the data. The procedure described is applied to each spectrum in the main table (Fig. 62, block E).

14.2.6 Choose appropriate geometry in field **Geometry** (Marinelli 1L, 0.25L vessel and so on, see Fig. 62, block B).

14.2.7 In field **Window** (see Fig. 2, block C), specify the file which contains the data on the energy regions to be considered in calculation (see paragraph 4.1 of Appendix 4).

14.2.8 If necessary, fill in field **Comment**.

14.2.9 Click button **Calculate calibration**.

14.2.10 All the calculated calibration sensitivity coefficients will appear as a tree structure in field **Calibration data** (see Fig. 62, block D).

14.2.11 Click button **Create file** to save the calculation results as a calibration file (*.clb) to disc (see Appendix 1).

14.2.12 By clicking button **Create list of calibration spectra**, one can create a calibration spectra list file (*.lcs) which is used for activity calculation by the superposition method (see section 5.4). It is recommended to create separate folders for calibration spectra, background spectra and list file.

14.3 Calibration for content calculation

In case the spectrometer should be calibrated in units of measurement different from Bq, for example, mass fraction, percent and so on, the calibration procedure remains the same as described in section 14.2. The certified values of the samples and their units of measurement are specified in the table (Fig. 62, block A) with no changes according to paragraph 14.2.5. At the same time, one must additionally edit the output calibration file (*.clb) and specify the proper units of measurement in the string containing the radionuclide's name as shown in the example below.

```
...
4
Cs-137 (Unit="kBq/sq.m")
1 1.000
K-40 (Unit="Bq/kg")
1 1.000
Ra-226 (Unit="%")
1 1.000
Th-232 (Unit="ppm")
1 1.000
...
```

If the measurement unit is not specified, it is presumed to be Bq by default.

In order to obtain the result of calculation of radionuclide content in user's units of measurement, switch the calculation mode to **Content** (see section 2.4.4, Fig. 15).

14.4 Calibration coefficients

The ultimate goal of calibration of a spectrometric tract by the windows method is generation of a matrix of calibration coefficients, each of which corresponds to the energy window, radionuclide and density of a reference sample.

The number of energy windows is selected to be equal or exceeding the number of the radionuclides used for calibration. The energy windows as such are determined by regions of interest which are related to full energy peaks for each radionuclide used for calibration.

Calibration sensitivity coefficients are calculated in accordance with the formula for count rate in each j :th window of an acquired spectrum of a count sample:

$$S_j := \sum_i \frac{X_i}{A_i} \cdot S_{ji} + S_{bj}, \quad i=1..m \quad (14.4.1),$$

where m is the number of unknown radionuclides in the count sample;

X_i is the unknown activity (to be calculated) of the i :th radionuclide in the count sample featuring a certain density ρ_x , Bq (Bq/kg);

A_i is the activity of the i :th radionuclide in the "reference" sample featuring a certain density ρ_x , Bq (Bq/kg);

S_{ji} is the count rate in the j :th window of the "reference" spectrum of the i :th radionuclide excluding the background count rate, cps;

S_{bj} is the count rate in the j :th window of the background spectrum, s^{-1} .

Value $\frac{S_{ji}}{A_i}$ in formula (14.4.1) is the sensitivity coefficient for window j , radionuclide i and density ρ_x . Considering this, the formula for calculation of calibration sensitivity coefficient s is as follows:

$$C_{ijr} = \frac{S_{jir}}{A_{ir}}, \quad r = \rho_0 \dots \rho_d, \quad (14.4.2)$$

where $\rho_0 \dots \rho_d$ is the density of reference samples used for calibration, g/cm^3 ;

C_{ijr} is the sensitivity coefficient for window j and radionuclide i in the spectrum of a sample featuring density r , cps/Bq (cps/Bq·kg);

$\rho_0 \dots \rho_d$ are the density values of the reference samples used for calibration, g/cm^3 ;

d is the number of density values used for calibration;

S_{jir} is the count rate in window j of the spectrum of reference sample with radionuclide i featuring density r excluding background count rate, cps;

A_{ir} is the activity of radionuclide i in the reference sample featuring density r , Bq (Bq/kg).

For each measurement geometry, the result of calibration (a *.clb file) is an own matrix of sensitivity coefficients in accordance with formula 14.4.2.

15 Licence

A standard version of **GammaPRO** is protected by a USB license dongle. This means that the USB license dongle should be inserted in the PC when the software is being launched or operated. The root directory of the dongle must contain file *sn_key.dat*. The file mentioned contains the generated coded data on the dongle in question. If there is no license data, the software will perform in the demo mode during 10 minutes, then it will warn about demo version status and terminate the operation. During this 10 minute demo mode, measurements cannot be started, and there will appear messages warning about missing license.

Thus, **GammaPRO** is in the demo mode if:

- no USB licence dongle is inserted in the PC;
- there is no *sn_key.dat* file in the root directory of the license dongle;
- the USB licence dongle does not comply with the data contained in file *sn_key.dat*.

Annex 1. Calibration file structure (*.clb)

The content of the calibration file is italicised.

Marinelli	Name of geometry of measurements				
ADC Polynom S/N 16	Three rows for any comments				
BDEG-63-63					
6	Number of working windows				
612.0 709.0 0.99 0.97 0.95	Bottom and top edges of work windows, as well as				
870.0 1000.0 0.99 0.97 0.95	coefficients of shielding for each density and window.				
1068.0 1178.0 0.98 0.95 0.92					
1385.0 1540.0 0.99 0.97 0.95					
1677.0 1846.0 0.99 0.97 0.95					
2500.0 2720.0 0.99 0.97 0.95					
4	Number of radionuclides in the matrix				
Ra-226 (Unit="kBq/sq.m")	Radionuclide and units of measurement				
3 0.200 0.900 1.700	Number of attested densities and density in g/cm ³				
Th-232					
3 0.200 0.900 1.700					
K-40					
3 0.200 0.900 1.700					
Cs-137					
3 0.200 0.900 1.700					
0.012518 0.004974 0.006181 0.004008 0.004754 0.000082	Sensitivity,				
0.012386 0.004851 0.005869 0.003725 0.004530 0.000085	for the first				
0.011181 0.004716 0.005408 0.003491 0.004011 0.000103	nuclide (c ⁻¹ Bq ⁻¹)				
	in work windows				
	(rows) and for				
	each density				
	(columns)				
0.008251 0.016280 0.002369 0.002162 0.001555 0.004037					
0.007594 0.014390 0.002190 0.001980 0.001367 0.003551					
0.007546 0.013330 0.002031 0.001896 0.001381 0.003587					
0.000385 0.000529 0.000504 0.001908 0.0 0.0					
0.000364 0.000570 0.000556 0.002064 0.0 0.0					
0.000343 0.000473 0.000474 0.001720 0.0 0.0					
0.030660 0.000012 0.000003 0.0 0.0 0.0					
0.028320 0.000020 0.000006 0.0 0.0 0.0					
0.027240 0.000025 0.000008 0.0 0.0 0.0					

Annex 2. Efficiency file structure (*.efp)

Efficiency **Eff** calculation for energy **E_n** is made using the formula:

$$\text{Eff}(E_n) = \text{Exp}[A_0 + A_1 \ln E_n + A_2 (\ln E_n)^2 + A_3 (\ln E_n)^3 + A_4 (\ln E_n)^4 + A_5 (\ln E_n)^5 + A_6 (\ln E_n)^6].$$

```
[Main]
Count=3
En_1=50
En_2=3000
[Item_1]
Ro=0.19
dA=0.000120673701486547
A0=100.952521999333
A1=-193.624766139809
A2=113.539550219905
A3=-31.4152431368484
A4=4.55284676290508
A5=0
A6=0
A_up0=-239.089407209938
A_up1=154.712894929183
A_up2=-37.6090565833576
A_up3=4.0180585277374
A_up4=-0.160073518024323
A_up5=0
A_up6=0
A_down0=-242.411794019549
A_down1=156.961174786668
A_down2=-38.1739234808294
A_down3=4.07993324404847
A_down4=-0.162573133753684
A_down5=0
A_down6=0

Count_point_eff=8
Point_eff1=Ra-226;186.1;0.0289146;0.036
Point_eff2=Ra-226;241.98;0.0230479;0.036
Point_eff3=Ra-226;295.21;0.0201344;0.036
Point_eff4=Ra-226;351.92;0.0176451;0.036
Point_eff5=Ra-226;609.31;0.01006;0.036
Point_eff6=Ra-226;768.36;0.00867296;0.036
Point_eff7=Ra-226;1120.3;0.00628238;0.036
Point_eff8=Ra-226;1764.5;0.00447472;0.036
[Item_2]
Ro=1
dA=6.98283591165722E-5
A0=-472.240982213604
A1=394.832631929211
A2=-135.275425911041
A3=24.0371788273522
A4=-2.32009207827529
A5=0.113556756070361
A6=-0.00213719932431744
```

```
Main block heading.
Number of densities.
Interval of energies,
to which the curve corresponds.
First curve block heading.
Density corresponding to the first curve.
First error approximation error.
Coefficient A0
Coefficient A1
-//-
-//-
-//-
-//-
-//-
-//-
```

Polynomial coefficients of the upper boundary of the confidence interval of the efficiency curve

Polynomial coefficients of the lower boundary of the confidence interval of the efficiency curve

Annex 3. Passport of source file structure (*.pks)

The content of the passport of source file is italicised. The file has a structure of a standard INI file.

<i>[Main]</i>	Main section name.
<i>Count_nuclide=4</i>	Number of nuclides in KO.
<i>Date_reference=18.04.06</i>	Data, on which the activity is adjusted.
<i>Massa=0.314</i>	KO mass.
<i>Volume=0.25</i>	KO volume.
<i>Unit_weight=kg</i>	KO mass unit.
<i>Unit_volume=l</i>	KO volume unit.
<i>Geometry=Marinelli</i>	Name of geometry
<i>[Nuclide_1]</i>	First radionuclide section name.
<i>Activity=5400</i>	Activity, Bq.
<i>Abs_Err=540</i>	Absolute error, Bq.
<i>Name=Ra-226</i>	First radionuclide name.
<i>[Nuclide_2]</i>	Second radionuclide section name.
<i>Activity=2100</i>	Activity, Bq.
<i>Abs_Err=210</i>	Absolute error, Bq.
<i>Name=Th-232</i>	First radionuclide name.
<i>...</i>	

Annex 4. Calculation of confidence interval for measurement error

4.1 ROI-method

$(S_i)^x$ count in each i “window” in the spectrum of the countable sample may be presented as:

$$(S_i)^x := \sum_j \frac{X_j}{A_j} \cdot (S_i)^j, \quad (1)$$

where X_j is unknown (sought) activity of j^{th} nuclide in the countable sample, Bq;

A_j is activity of j^{th} radionuclide, Bq in the reference sample;

$(S_i)^j$ is count in i^{th} window of the library (reference) spectrum of j^{th} nuclide, c^{-1} .

The process of calculations is as follows:

- calculate the speed of count in windows; subtract background count speeds from measured ones;
- select activities of nuclides in the mixture using the method of the least-square method according to the system of linear equations (1);
- calculate random errors in activities of radionuclides (σ_j).

A random error includes a statistical component and an error due to mismatch of the measured spectrum with the sum of contributions from spectra of sample sources.

The error range of the activity measurement result (specific activity) $\Delta(0,95)_j$ (with confidence probability $P=0,95$) is found according to the formula (in percent):

$$\Delta(0.95)_j = K[Q + \varepsilon_j], \quad (2)$$

where Q is the non-excluded systematic error of measurement. The value of Q is set in window Calculation parameters of subsection Error (see section 2.4.4);

ε_j is confidence random error component of j^{th} radionuclide:

$$\varepsilon_j = L \cdot \sigma_j, \quad (3)$$

where Student's criterion $L=1.96$ (at confidence probability $P=0.95$). The value of L is set in window Calculation parameters of subsection Error (see section 2.4.4);

K is coefficient determined from the table depending on the θ / σ_j relationship.

Table 1

K	0.76	0.74	0.71	0.73	0.76	0.78	0.79	0.8	0.85
θ / σ_i	0.8	1	2	3	4	5	6	7	8

θ value in percent is determined according to the formula

$$\theta = 1.1 \cdot \sqrt{\theta_1^2 + \theta_2^2 + \theta_3^2 + \theta_4^2}, \quad (4)$$

where θ_1 is spectrometer sensitivity coefficient error ($\theta_1 = 7\%$);

θ_2 is countable sample measurement error ($\theta_2 = 1\%$);

θ_3 is error due to a countable sample density error ($\theta_3 = 3\%$);

θ_4 is methodical error due to mismatch between the countable sample and sample composition ($\theta_4 = 5\%$).

If the ratio $\theta/\sigma_j < 0.8$, the value of the confidence error of specific activity measurement result of the j^{th} radionuclide in the countable sample is assumed to be equal to the random component of the measurement error σ_j

$$\Delta(0.95)_j = K\sigma_j$$

If the ratio $\theta/\sigma_j > 8$, the value of the confidence error of activity measurement result (specific activity) of radionuclides in the countable sample is assumed to be equal to the confidence residual bias of the range of the measurement result Q .

$$\Delta(0.95)_i = Q.$$

In **GammaPRO**, the following values of coefficients are used when calculating the confidence range of measurement error:

$L=1.96$; (see parameter L in section 2.4.4)

$Q=0.1$ (10 %) (see parameter L in section 2.4.4).

4.2 Determining activities of radionuclides by the individual peaks analysis method

Select a single peak or a multiplet in the measured spectrum. Determine areas of the peaks. Calculate the radionuclide activity of a single peak according to the formula:

$$A_n = \frac{S}{t \varepsilon_n k}, \quad (5)$$

where A_n is the radionuclide's activity, Bq;

S is peak area, imp;

t is live spectrum writing time, sec;

k is quantum output of the selected radionuclide line;

ε_n is full efficiency of registration of quanta of this energy, c^{-1}/Bq .

Efficiency is found according to the formula:

$$\varepsilon_n = \exp(A_0 + A_1 \ln E_n + A_2 (\ln E_n)^2 + A_3 (\ln E_n)^3 + A_4 (\ln E_n)^4 + A_5 (\ln E_n)^5 + A_6 (\ln E_n)^6), \quad (6)$$

where E_n is energy corresponding to the gravity centre of the peak, keV;

A_i is polynomial coefficients approximating dependence of efficiency on energy.

The standard total relative uncertainty of the activity is calculated in the following way:

$$u_A = \sqrt{u_S^2 + u_\varepsilon^2}, \quad (7)$$

where u_S is the standard relative uncertainty of peak area S ;

u_ε is the standard relative uncertainty of detection efficiency ε_n

u_S is determined in the following way:

$$u_s = \frac{1}{n_s} \sqrt{\frac{n + 2 \cdot n_b}{t}}, \quad (8)$$

where n_s is the count rate in the peak without taking background into account, pulse/sec;

n is the count rate delivered by both the source and the background, pulse/sec;

n_b is the count rate delivered by background only, pulse/sec;

u_ε is determined by the value of the uncertainty of the efficiency which is considered as a polynomial function similar to (6) and calculated at the stage of efficiency calibration.

Activity values calculated for a few peaks (i) of one and the same radionuclide are averaged in the following way:

$$A = \frac{\sum A_i w_i^2}{\sum w_i^2}, \quad (9)$$

where i is the peak number;

w_i is the contribution of peak i . This value is inverse of u_{Ai} ;

A_i is the activity of the radionuclide calculated by peak i , Bq;

The total relative uncertainty of the activity is hence equal to:

$$u_A = \sqrt{\frac{1}{\sum w_i^2}} \quad (10)$$

The expanded uncertainty of the activity measured is expressed by the following formula:

$$U_A = u_A \cdot k \quad (11)$$

where k is the coverage factor, $k=2$.

Annex 5 Calculation of specific effective activity of natural radionuclides

The value of specific effective activity A_{Eff} is calculated by **GammaPRO** using the formula:

$$A_{Eff} = A_{Ra} + 1.30A_{Th} + 0.090A_K;$$

where A_{Ra} , A_{Th} and A_K are specific activities of ^{226}Ra , ^{232}Th and ^{40}K in the countable sample, respectively.

Absolute error A_{Eff} (Δ_{Eff}) is calculated according to the formula:

$$\Delta_{Eff} = \sqrt{\Delta_{Ra}^2 + (1.30 \times \Delta_{Th})^2 + (0.090 \times \Delta_K)^2},$$

where Δ_{Ra} , Δ_{Th} and Δ_K are absolute errors of specific activities of ^{226}Ra , ^{232}Th and ^{40}K in the countable sample, respectively.

The results of calculation of specific effective activity in natural radionuclides in countable samples are recorded as:

$$A_{Eff} \pm \Delta_{Eff}, \text{ Bq/kg.}$$

REVISION HISTORY

Any revisions to be made to this manual should be registered in the table.

[illegible]