DESCRIPTION OF
GammaPRO

2019

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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 MCA527, BOSON, BINOM, POLYNOM, 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).
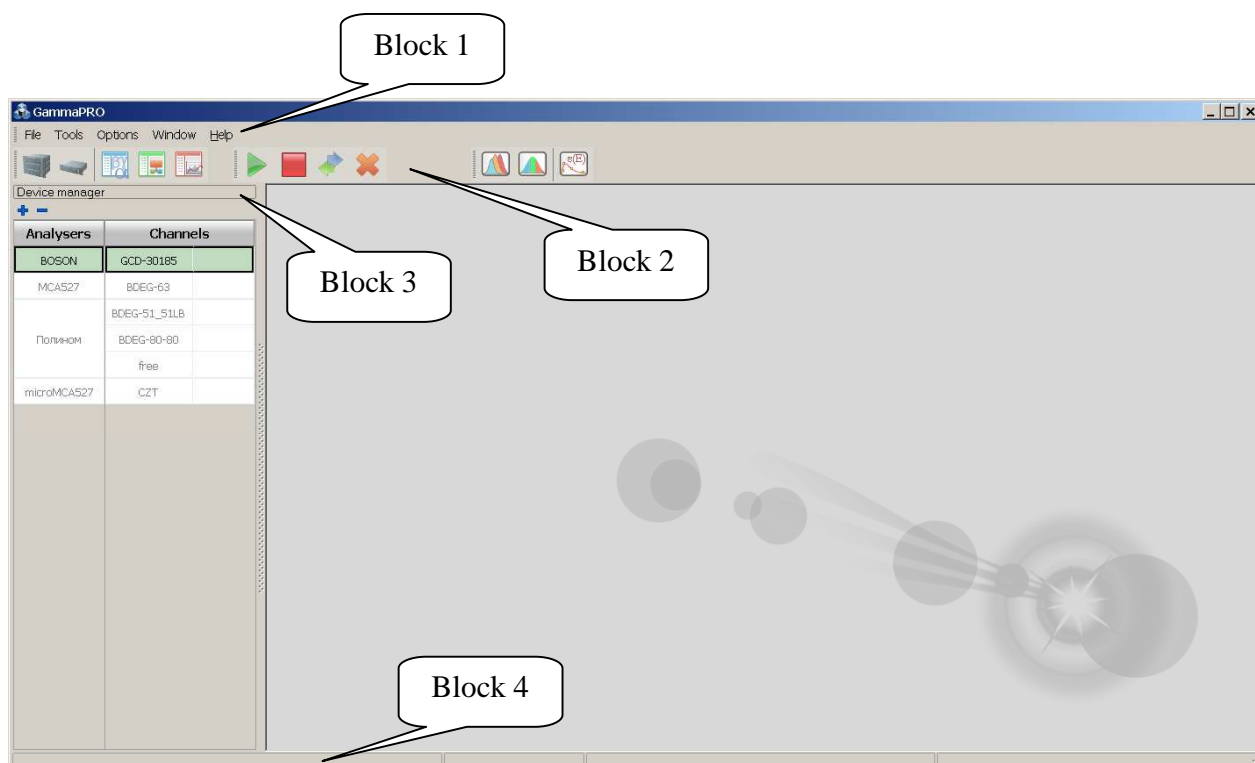
Figure 1. View of **GammaPRO** after its launch

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):
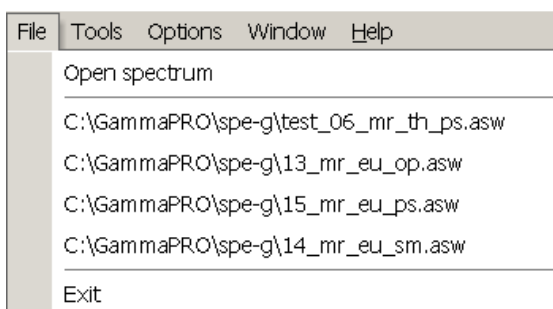
Figure 2. **File** menu items

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):
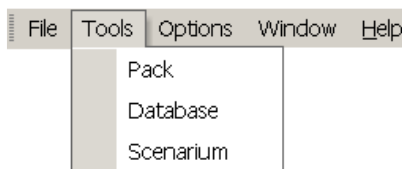
Figure 3. **Tools** menu items

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.
Item **Database** allows data base window opening, the file is specified in the window **Parameters** at insert **Files** (see section 10).
Item **Scenarium** will activate the window of module **Scenarium**, which allows execution of so called script or sequences of operations in the program **GammaPRO,** as well as execute the quality control for spectrometric sections and remote access to the program (See Annex 6).

Options (see Fig.4):
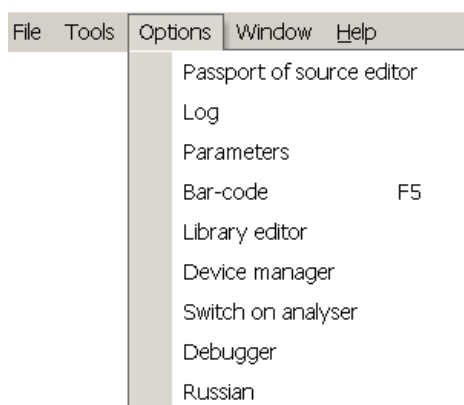
Figure 4. **Options** menu item

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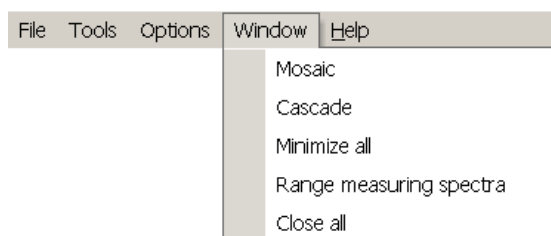
Mosaic displays windows of the spectrum as a "Mosaic". **Cascade** displays windows of the spectrum as a "Cascade". **Minimize all** minimizes all the windows of the spectrum to the bottom of the main window.

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.
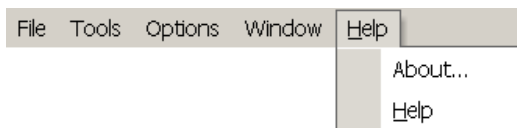
Help (see Fig.6):

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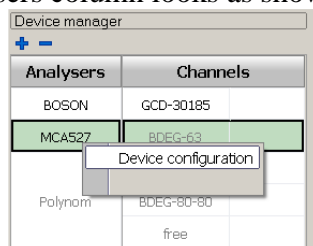
Figure 8. Context menu of the **Analysers** column

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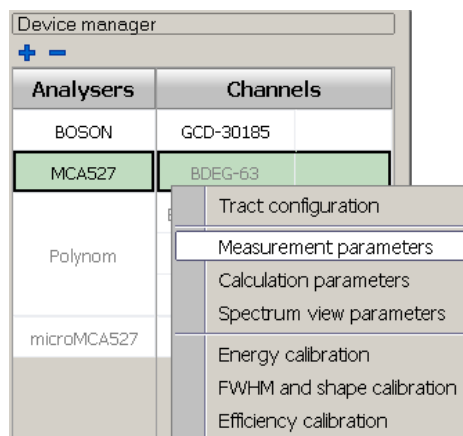
Figure 9. Context menu of the Channels column

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). Pressing the button ➕ will replicate the analyzer and its tracts analogue to the current (specified) in the present list. 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).
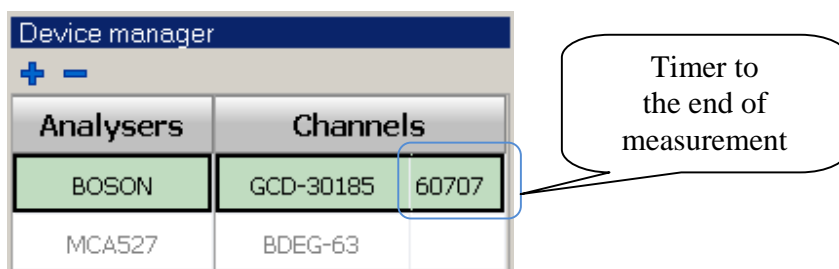
Figure 10

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.
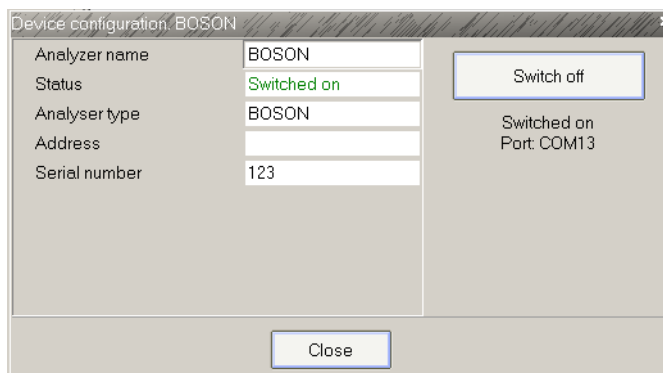
Figure 11. **Device configuration** window view

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.
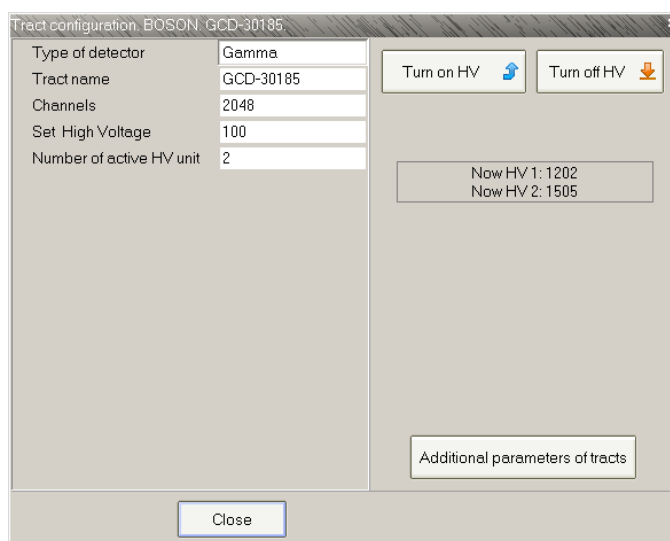
Figure 12. **Tract configuration** window view

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 [Additional parameters of tracts]. 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 [icon] 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.

Distance, mm - distance between the measuring sample and the detector. Allows recalculate the registration efficiency at the present distance. For the correct account the efficiency file (**.efp*) should have efficiency curves for minimum two distances till the detector.

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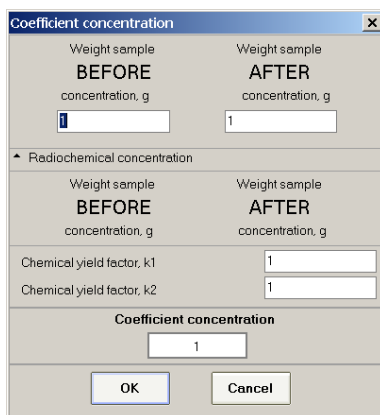
Figure 14. **Coefficient of concentration** window view

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 [icon] on the toolbar or select **Calculation parameters** in the context menu of the **Channels** column on the **Tract Manager** pa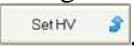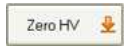nel, a window shown in Figure 15 will appear on the display. This window contains the parameters which will be the spectrum parameters when the spectrum has been acquired.
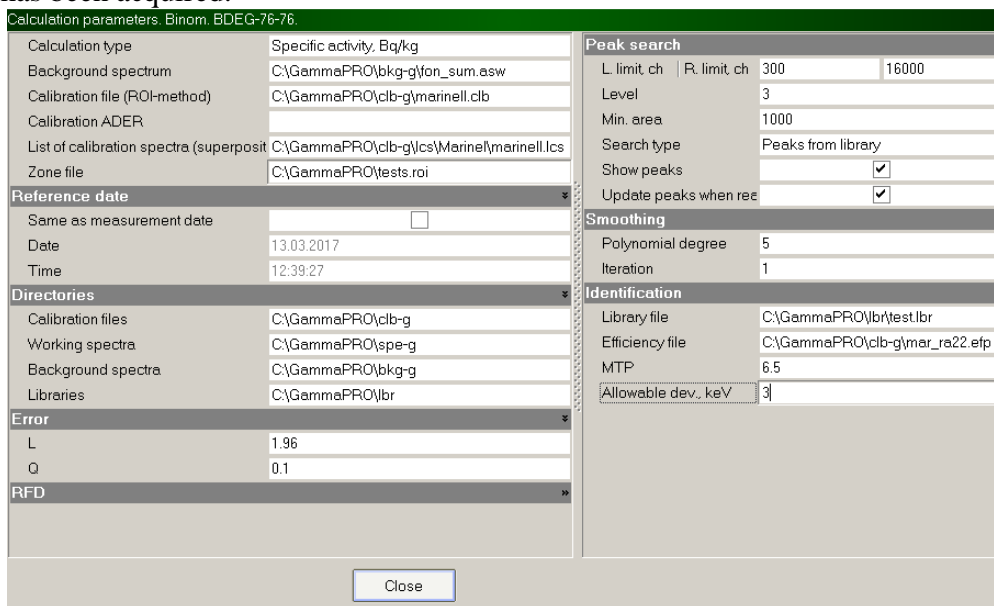
Figure 15. **Calculation parameters** window view

This window contains parameters related to the calculation procedure:

Calculation type – the type of calculation, which determines, which unit will be displayed in the resulting data table (specific activity, volume activity, etc.). Where,

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

'**Specific activity, Bq/g**' means that during the calculation in addition to the activity the specific activity in Bq/g 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;

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

'**RFD, mBq/s·m2**' means that the radon flux density will be calculated in mBq/s·m^2 (see document Methodology of radon flux density measurement);

'**Volumetric activity of Rn-222, Bq/m^3**' means that the volumetric activity of radon will be calculated in Bq/m^3 (see document Methodology of radon volumetric activity measurement);

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

Background spectrum is the path to the background spectrum for this spectrometric tract. A link to this field will be shown in parameters of the measured spectrum.

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

Calibration ADER – path to file of calibration by ambient dose equivalent rate, which will be used automatically, when reading the spectrum and displaying it.

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.

Zone file – path to the file (***.roi**), which contains windows of regions of interest.

The **Error** section contains two parameters **L** and **Q**, which are used in the calculation of errors in the procedure of determining activities using the ROI-method. For the description of values of the b method see Annex 4.

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**, **Bkg spectra** and **Libraries**. These directories will open by default, when standard file selection dialogue windows open.

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.
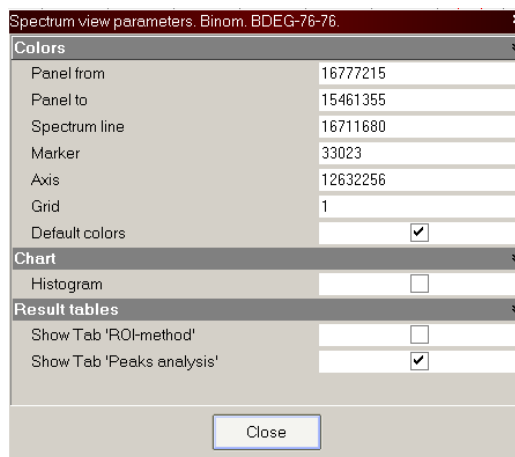

Figure 16. **Spectrum view parameters** window view

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 ![play], then a window of the spectrum to be measured will appear (Fig. 17), which will show a histogram.
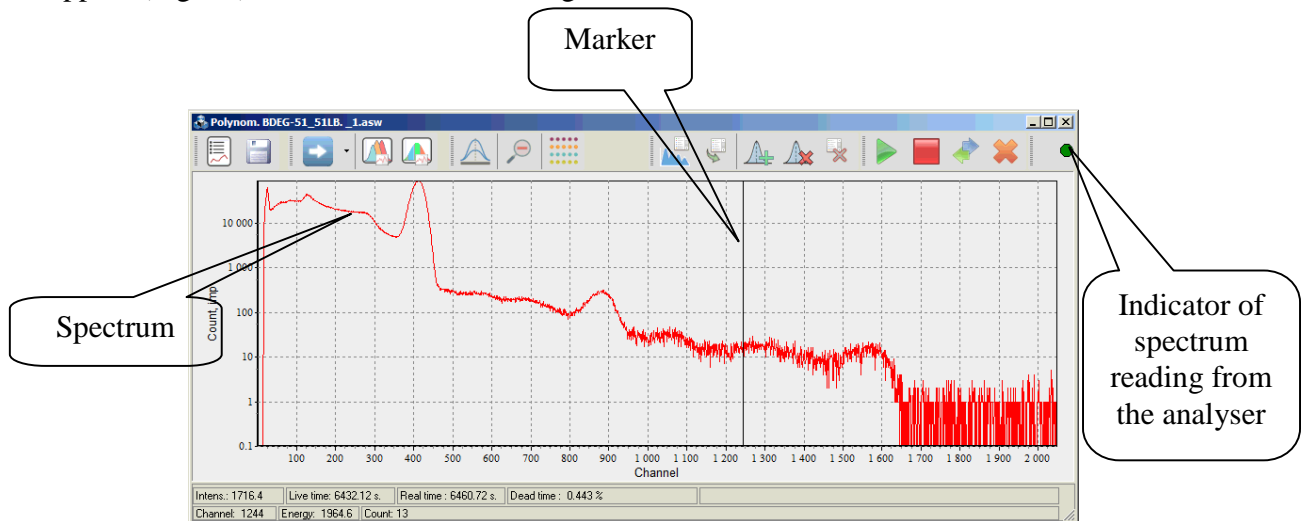

Figure 17. Window of the spectrum to be measured

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.
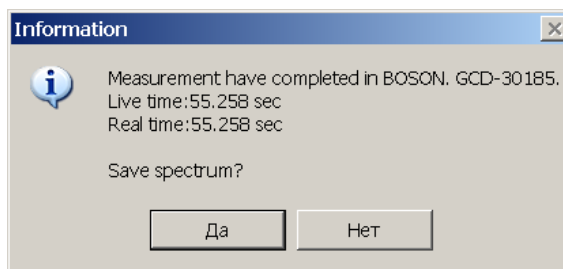
Figure 19

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.

Figure 20. Spectrum parameters window view
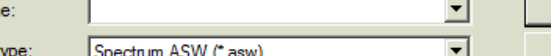
The parameters window can be pinned to the frame of the spectrum. To do this, double click on the window heading, then a window will move to the right side of the spectrum window.

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).
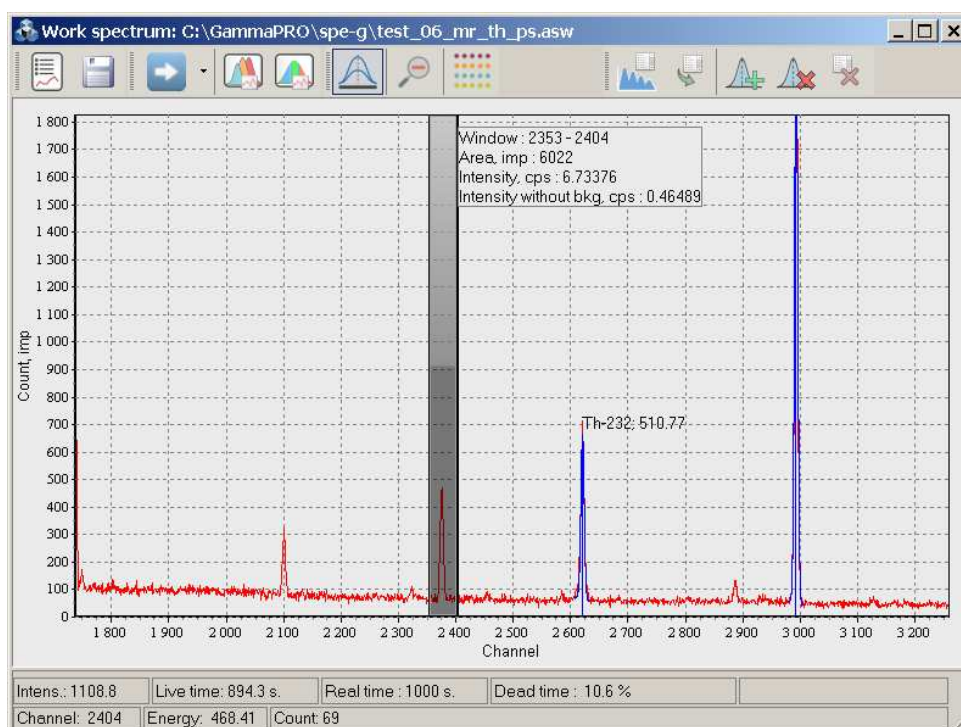
Figure 22
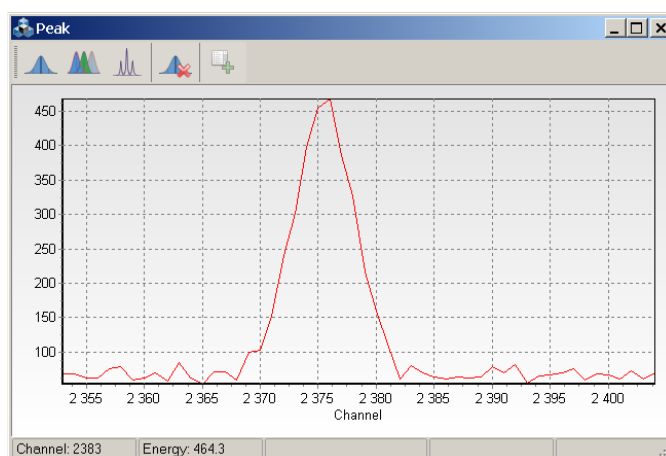
Figure 23. Window for work with a peak view

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

- button, which provide the measurement result panel opening.

Results
Add to log
Panorama window
Send to pack
Logarithm
Show background
Hide spectrum
Spectrum without bkg
Reference spectrum
Intensity
Energy range
Show ROI
Offer a nuclide
Report
Autocalibration by source ▶
Send to... ▶
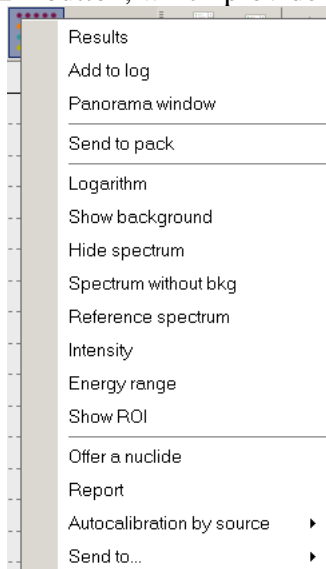
Figure 24. Menu **Options** of the spectrum window

Items in this menu are mainly intended for service and have the following functions:

Results – opens a panel of measurement results.

Add to log – sends measurement results to a log.

Send to pack – opens this spectrum in the **Pack of spectra** window.

Panorama window - when opened, this window (see Fig. 24.1) displays that part of a spectrum which is marked by scaling in the main spectrum window. The semi-transparent rectangle can be moved by user which automatically changes the scaling in the main spectrum window. The opposite is also true: changing the scale and zooming the spectrum's regions is automatically displayed in the **Panorama window.**
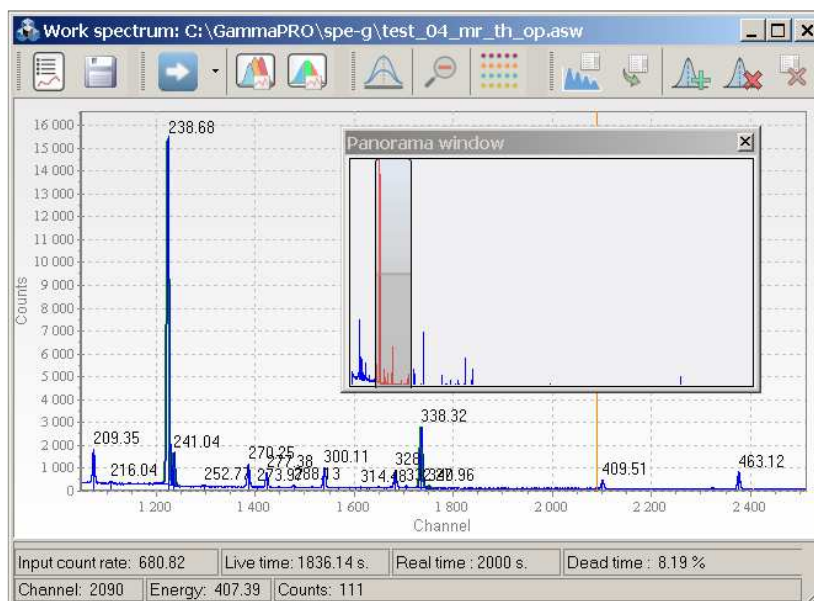
Figure 24.1. The Panorama window of a spectrum.

Logarithm – enables a logarithmic scale for spectrum display.

Show background – shows the background spectrum.

Hide spectrum – hides the spectrum.

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.

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 ![icon] 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 ![icon], mark then once again.

The ![icon] (**Multiplet with high resolution**) button has the same intention as ![icon], 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 ![icon] again, you can improve adjustment of the describing curve to experimental values.

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

The ![icon] (**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.

Channel	Energy	Intens.,cps	Resolution, %	FWHM, keV	FWHM, ch.	Left edge, channel	Amplitude	Area, imp	To calibration	
2375.5	462.86	2.8839	0.25647	1.1871	6.097	5.0189	395.14	2579.1	En...	FWHM
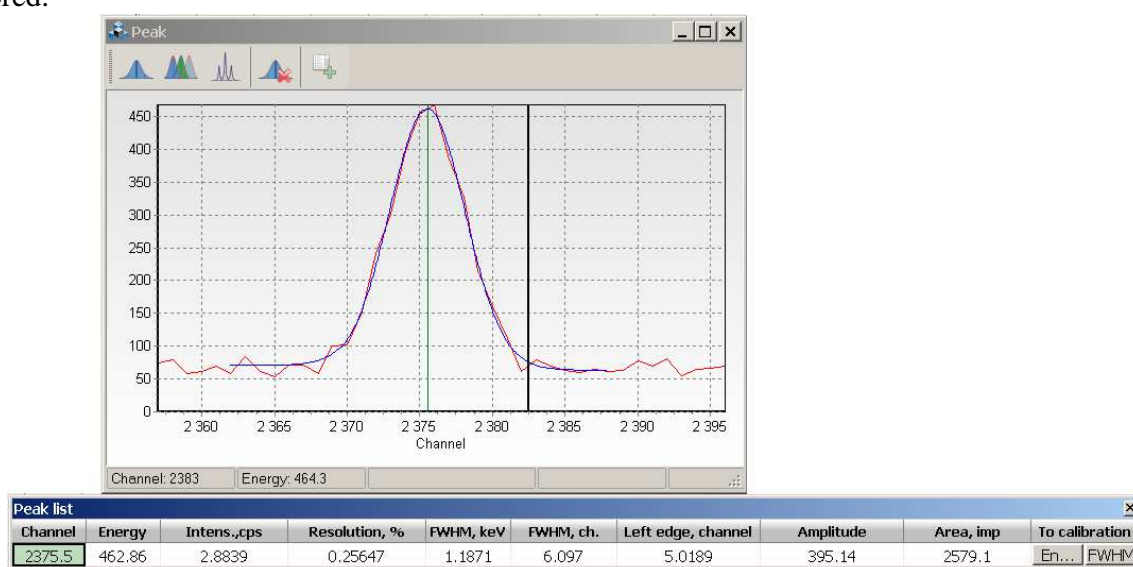
Figure 26. **Peak** and **Peak list** window view

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.

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).
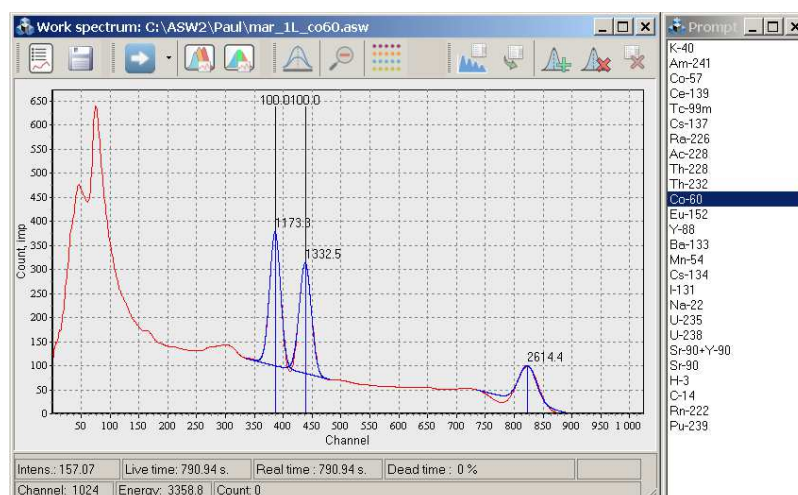
Figure 28

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).
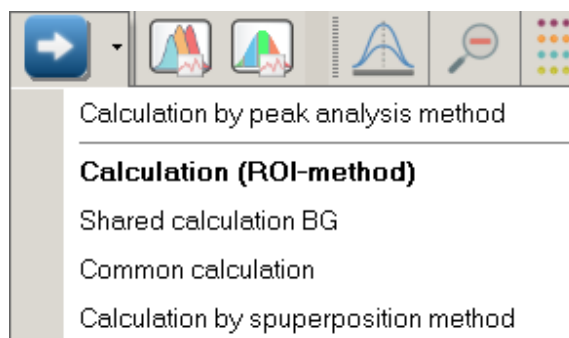
Figure 29. Variants of calculation types

For this task (calculation of activity by one spectrum using the ROI-method) select **Calculation (ROI-method)**
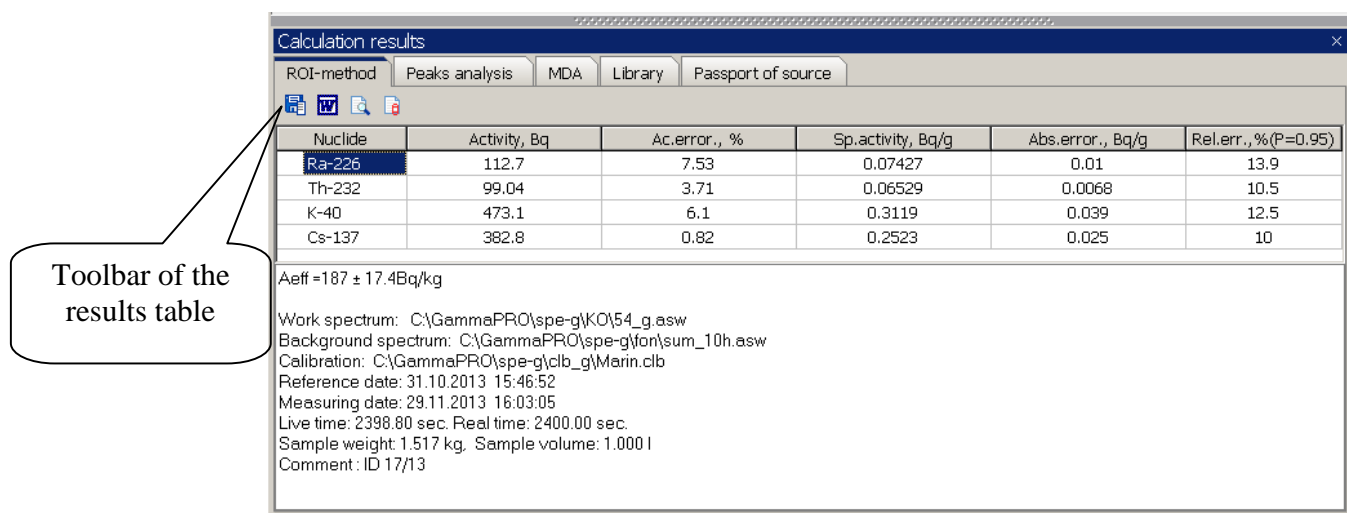
Figure 30. Results window view

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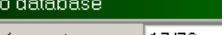
If you want to save the results table, there is a toolbar above it containing buttons allowing to convert data in different ways (⊞ - saving data to a txt protocol; 🅆 - sending data to MS Word; 🔍 - generating a report; 🔲 - sending data to a DB.

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**.**

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**.
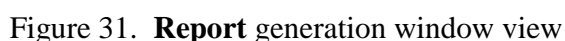
Pressing the button in instruments panel of results table will cause the window **Database of measurements (**see.p.6.6 and Fig.41.1**)** and additional window for data input, which are not saved in spectrum (Fig.32).

When the fields are filled with the data, the button **Add** should be pressed. At successful transfer the corresponding message will appear.

Figure 32. Window **Add to database**

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.

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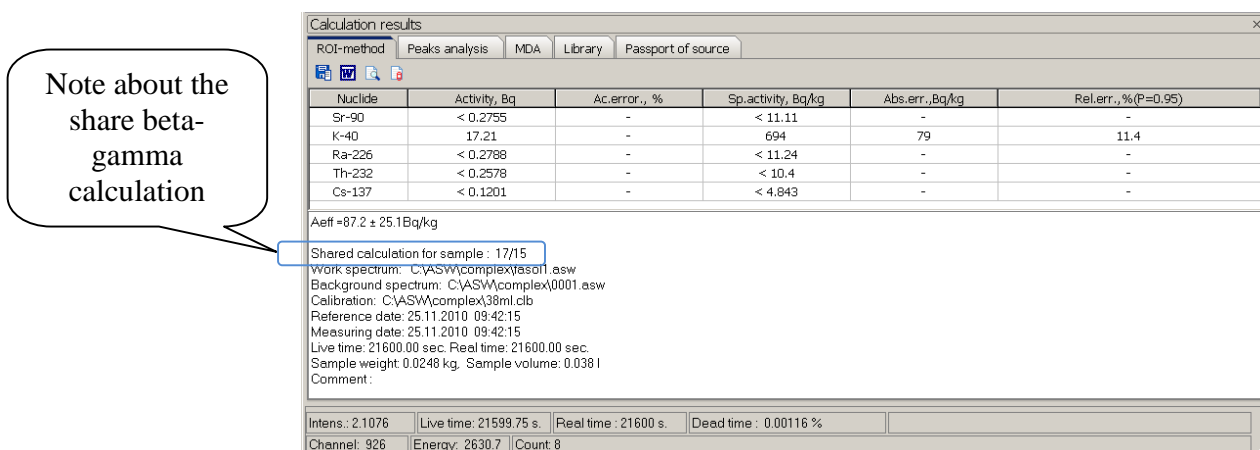
Figure 34. View of the table of the result of shared beta-gamma calculation

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.
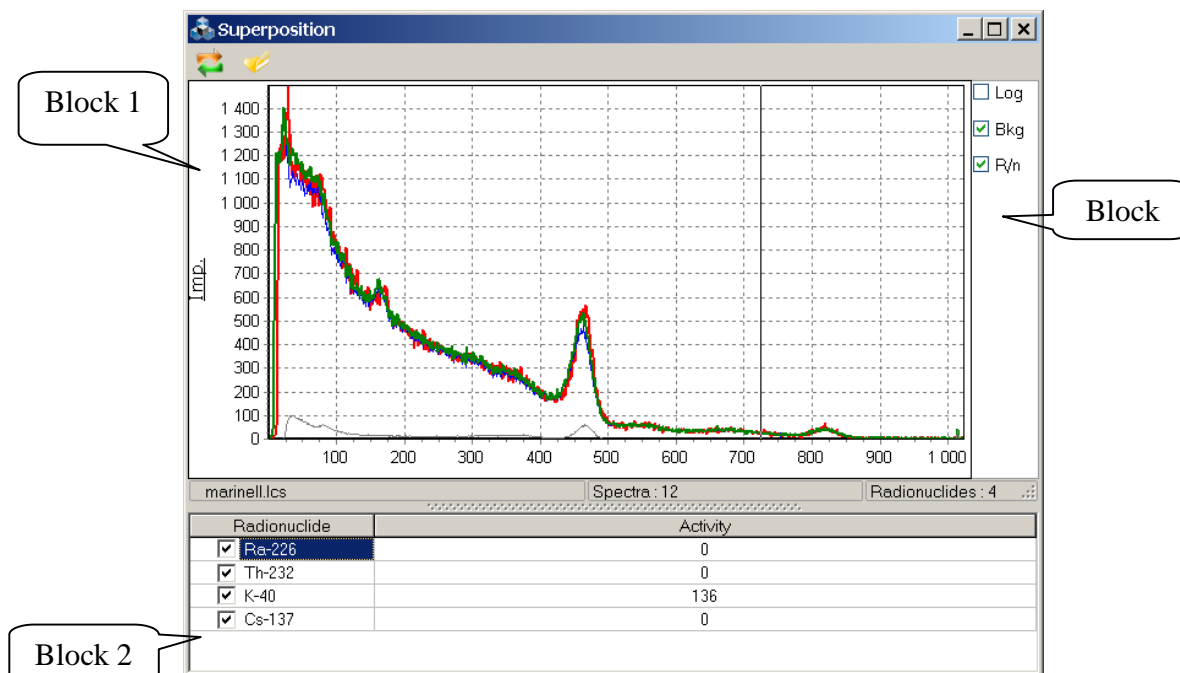
Figure 35. **Superposition** window view

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 Paragraph14.2) 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.

5.5 Regions of Interests

Typical task for spectrometry is the work with regions of interest (ROI, zones) in a spectrum. Regions of interest are intervals in a spectrum (in channels or energy units), where intencity of count rate is important for the activity evaluation or solution of other radiometrical tasks.

For operation with ROI the operator should open the field **Caclulation result** in a spectrum by pressing the button ![icon] in the instruments panel of spectrum window. Then go to the Tab **Zones** in the appeared window (see Fig.35.1)
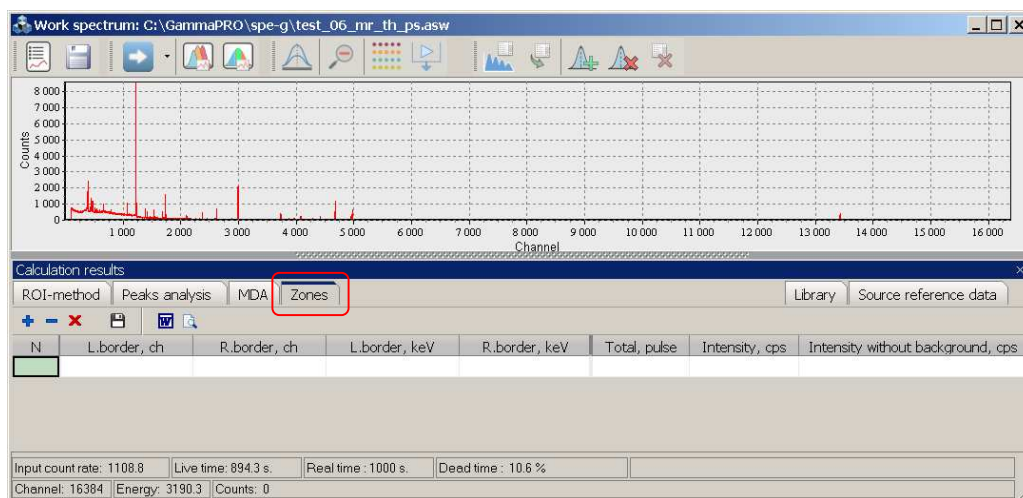
Figure 35.1. View of the spectrum and Tab **Zones**

To add ROI to the table the button ![icon] should be pressed over the table.

After the pressing, the first line, filled with values on default, will appear. The fields in the columns **L.border,ch**, **R.border,ch**, **L.border,keV, R.border,keV** are available for editing. The user could change the boarders of each zone himself directly in the table, the corresponding fields in linked columns will change in accordance to the energy calibration (see Fig.35.2).
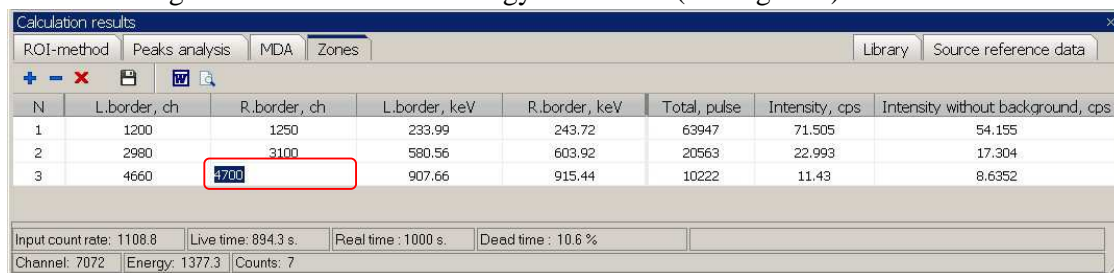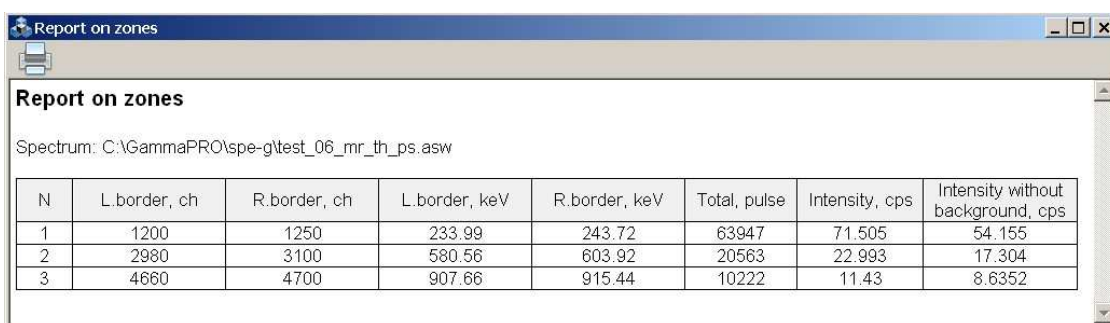
Figure. 35.2. Tab **Zones** view. ROI set up in the table

The fields of the columns **Total, pulse**, **Intesity, cps**, **Intensity without background,cps** are not acceptable for the alteration by the user, the calculated values are displayed there by the program. For ex.: the fields of the column **Total, pulse** have sum qualnity of the pulses in the interval, specified for the present line. The fields of the column **Intensity,cps** have the pulses count rate in the interval, specified for the present line. And in the fields of the column **Intensity without background,cps** there are the count rate values after deduction of background spectrum count rate for the same energy range.

To delete the lines in the table (delete ROI) they should be marked and the button in the instruments panel over the table should be pressed. To clear the table the button should be pressed.

To save the current table in zones file (*.*roi*) the button should be pressed. If zones file for the present spectrum has not been specified, the program will offer to enter the name and indicate the catalogue for recording via a standard dialogue window. Then zones file will be automatically connected to the present spectrum and will be assigned into the field **Zone file** in the window **Spectrum parameters** (see. Fig.20). In case there is already a link between zones file to the spectrum, the program will offer to rewrite it with a new content.

The user could access the record function for ROI table into the report. Then it is necessary to press the button over the table, then the window will appear as shown in Fig 35.2.

Report on zones

Spectrum: C:\GammaPRO\spe-g\test_06_mr_th_ps.asw

N	L.border, ch	R.border, ch	L.border, keV	R.border, keV	Total, pulse	Intensity, cps	Intensity without background, cps
1	1200	1250	233.99	243.72	63947	71.505	54.155
2	2980	3100	580.56	603.92	20563	22.993	17.304
3	4660	4700	907.66	915.44	10222	11.43	8.6352

Fig. 35.3. Report window by ROI

The content of the report is available to print out and copy into other text editors and electronic tables.

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 *(*.efp*)*, 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.

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).

Nuclide/Energy, keV	Half-life, day / Quantum efficiency, %
K-40	466607000000
Co-60	1926.1
Cs-137	10989.6
Mn-54	312.12
Ra-226	584630
Th-232	5133780000000
Cs-134	754.68
Eu-152	4868.678526
Am-241	157857.682492422
Ba-133	3849.652788

Figure 37. **Library** tab view

6.2.8 On the toolbar of the spectrum window (Fig.38, block 1), press [icon] (**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).
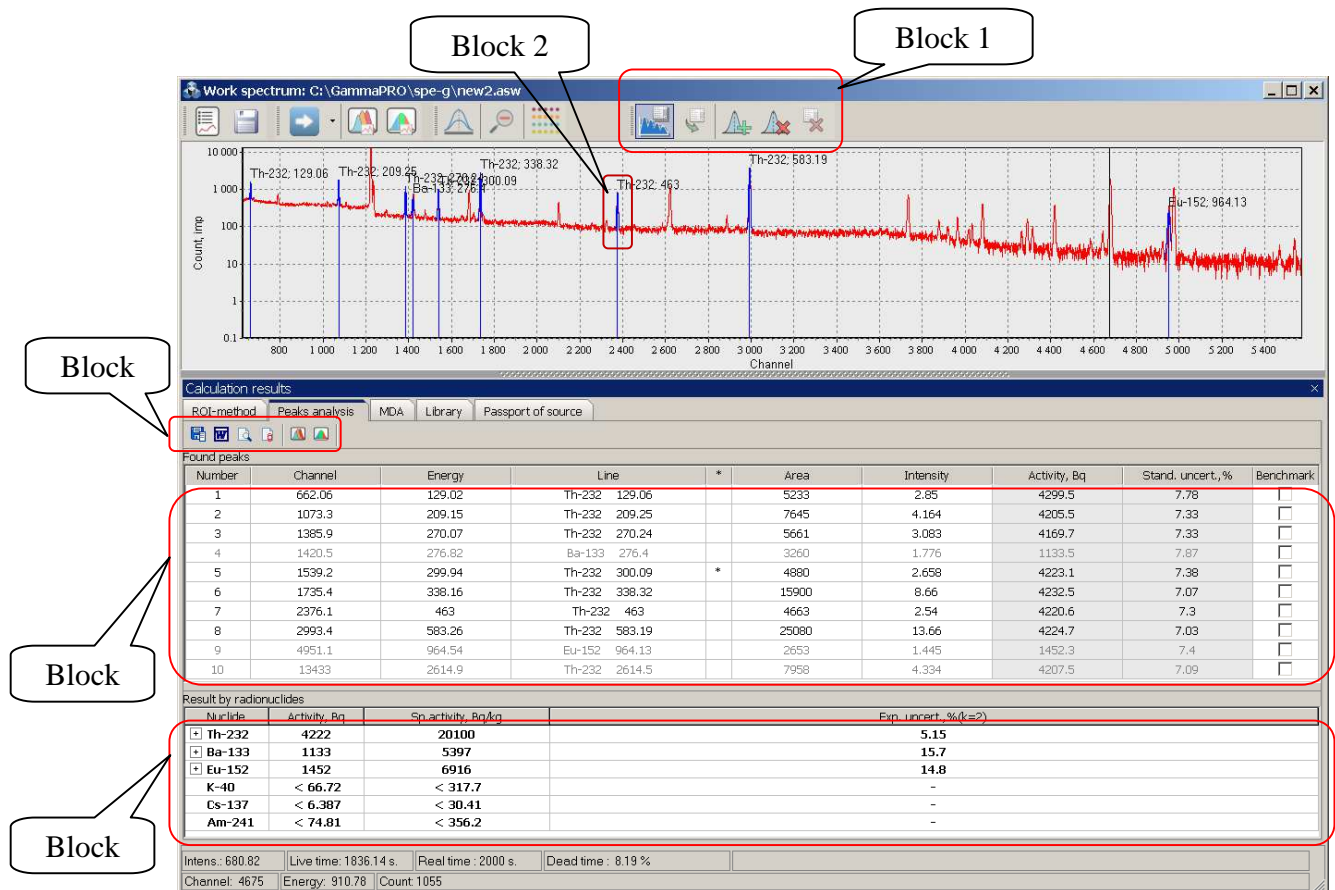
Figure 38. Spectrum window view after peak search

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 uncertainly for each line. If relative expanded uncertainly 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 Bg/kg (parameter depending on the calculation type);

Exp., uncert.% – expanded uncertainly 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; �W - 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.
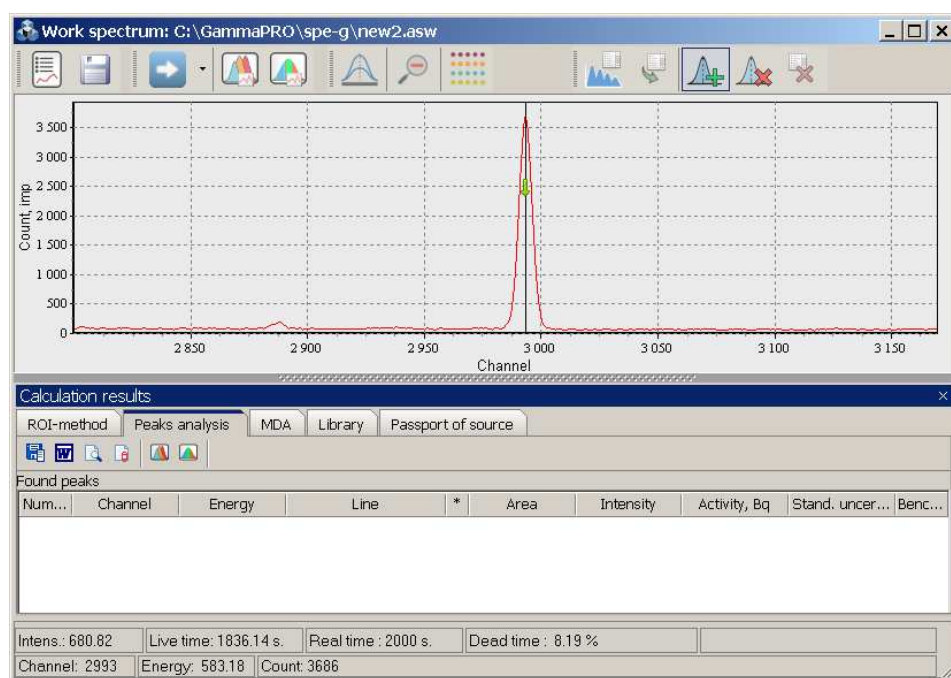
Figure 40.1. Preparation of a marker for peak insertion
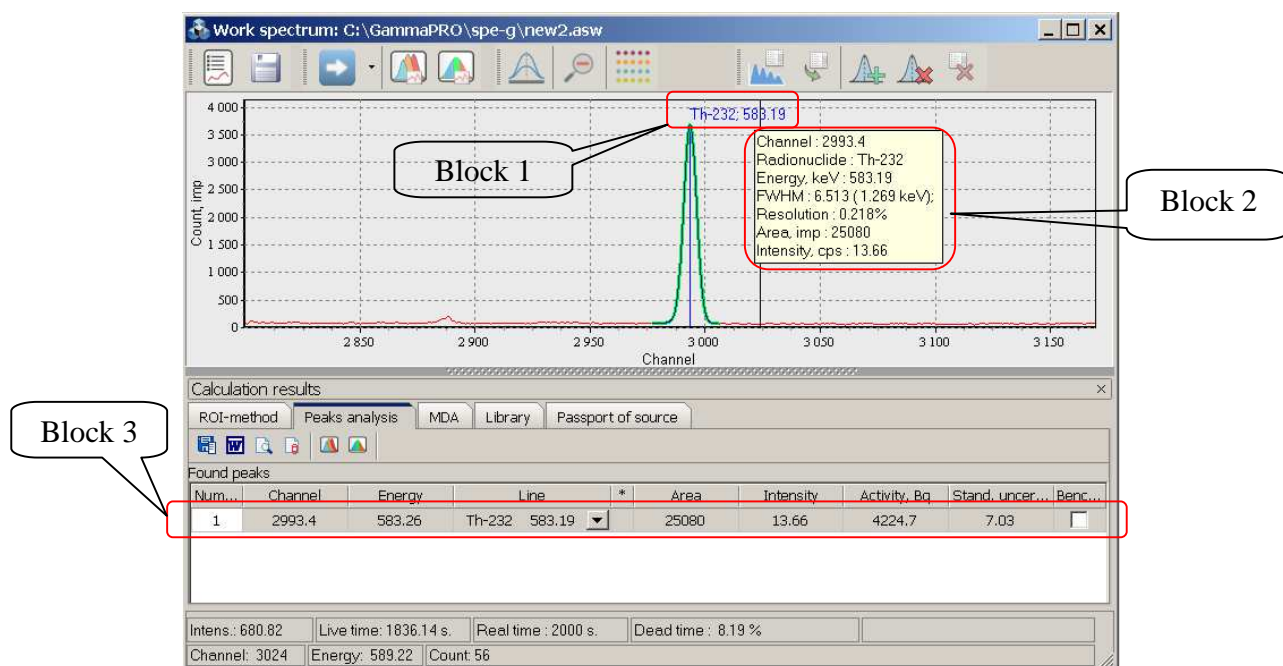
Figure 40.2. New inserted peak
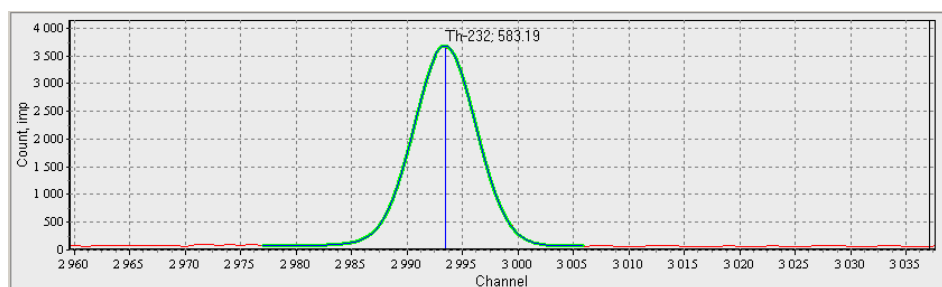
Figure 40.3

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.
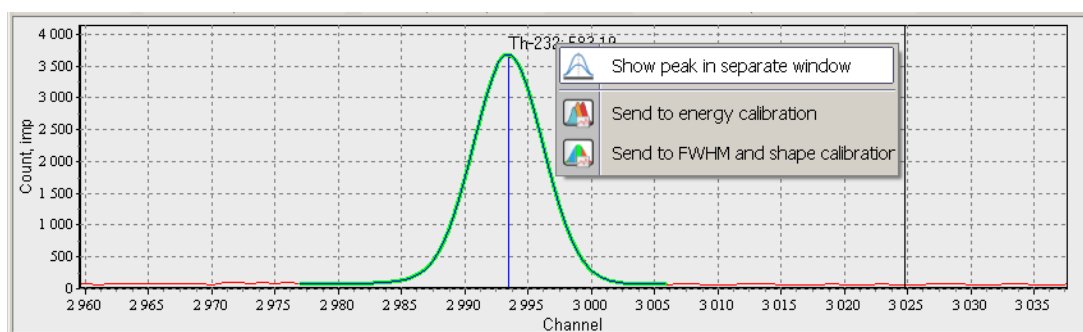
Figure 40.4

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-method | Peaks analysis | MDA | Library | Passport 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	☐
2	1073.3	209.15	Th-232	209.25		7645	4.164	4205.5	7.33	☐
3	1385.9	270.07	Th-232	270.24		5661	3.083	4169.7	7.33	■
4	1420.5	276.82	Ba-133	276.4		3260	1.776	1133.5	7.87	☐
5	1539.2	299.94	Th-232	300.09	*	4880	2.658	4223.1	7.38	■
6	1735.4	338.16	Th-232	338.32		15900	8.66	4232.5	7.07	■
7	2376.1	463	Th-232	463		4663	2.54	4220.6	7.3	☐
8	2993.4	583.26	Th-232	583.19 ▼		25080	13.66	4224.7	7.03	■
9	4951.1	964.54	Eu-152	964.13		2653	1.445	1452.3	7.4	☐
10	13433	2614.9	Th-232	2614.5		7958	4.334	4207.5	7.09	☐

Figure 41. Selection of peaks for sending to calibration

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

6.6 Database

The program **"GammaPRO"** allows not only to save the measurement results into database (DB) file but also to operate with it directly in the program. For successful work with DB, the availability of those database file (*.accdb*) is required and the path to it is specified in the window **Parameters** in insert **Files** in the field **Database filename** (see section 10, Fig.52.1).

To activate the database the operator should select the item **Tools->Database** in the program main menu **"GammaPRO".** The window **Database of measurements** will appear as presented in Fig 41.1. The figure shows that the window has several units. Unit 1 (Fig.41.1) comprises the list of the saved records as a Table, where the spectrum name, sample number as well as the data and the measurement time of the present record spectrum are specified. Unit 2 – instrument panel for the record table control, it contains the button for the spectrum restoration from DB, record delete and filtration (search) adjustment button by DB.
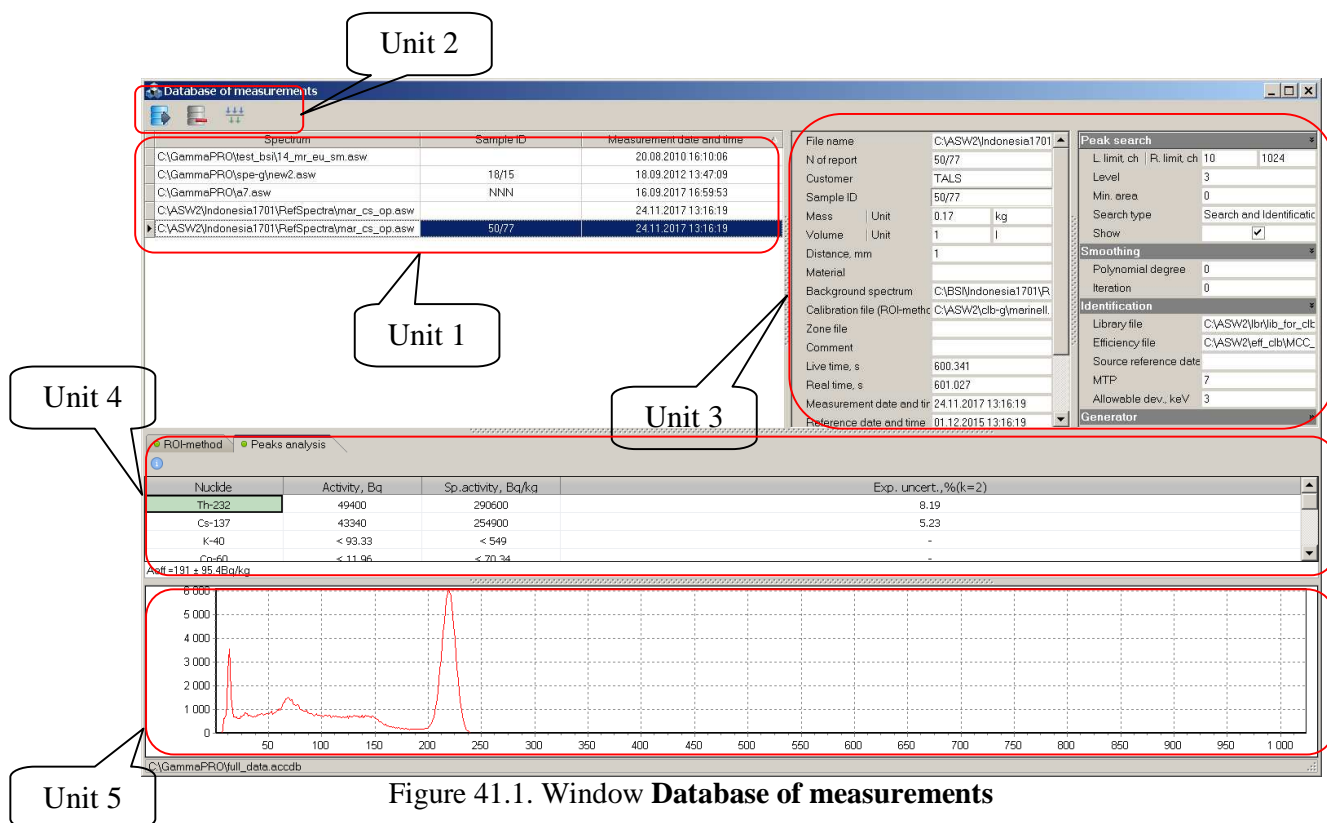
Figure 41.1. Window **Database of measurements**

Unit 3 has standard fields with the parameters of the current spectrum (selected in Unit 1 table).

Unit 4 has two tabs **ROI-method** and **Peaks analysis.** Each of the inserts has a table with the calculation results of the activity, errors etc, which were obtained on the stage of calculation wt the work with the current spectrum (see p.p. 5.1, 5.2, 5.3, 6.2). In dependence on the calculation method, the data are kept on one or another insert. And if the calculation was made by both methods, then the data will be presented on both inserts accordingly. For additional signalization on the calculation results presence, for the current record, there is a mark ⬤ near the name of the insert. Above the table with the calculation results there is a button ⓘ, which allow to see in a separate window the additional data on the executed measurement (see Fig.41.2).
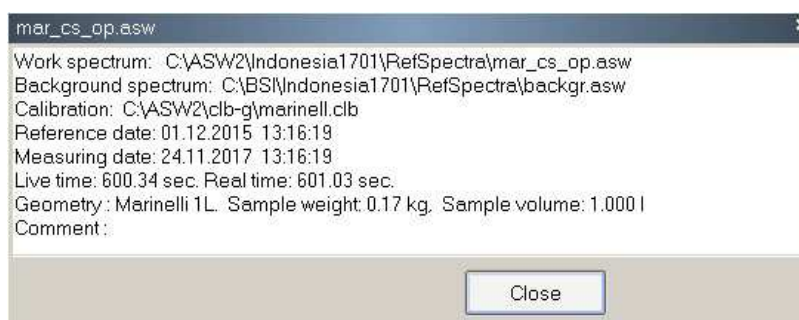
Figure 41.2. Additional data window on the executed calculation

The unit 5 (Fig.41.1) shows the diagram of the spectrum, marked in table, where there are channels by X axis and count rate values in pulses by Y axis.

New records in DB could be added directly from the spectrum window by the button 🔳, situated in the inserts **ROI-method** and **Peaks analysis,** placed in the window **Calculation results** (see Fig.30 and Fig.38, unit 5)**.**

To filtrate the records by database there is a search instrument which is activated by the button in instruments panel (Fig.41.1, unit 2). When that button is pressed, the window **Filter** appears as shown in Fig. 41.3.

Figure 41.3. Window **Filter**

Changing the values of the present window fields, the user can make filtration and search by data base, switching the time period for spectra measurement. For the application of the specified search parameters the button **Filter** should be pressed, the table (Fig.41.1, unit 1) will display only records which correspond the specified search criteria.

As data base save all content of the measured spectrum, it could be restored and a new spectrum will be absolutely identical to the initial one, including the name of the file. To execute the present procedure, the required record in the table should be marked and the button should be pressed. If the spectrum file with that name already exists then the program will inform that. To avoid the rewriting of the existing spectrum with the same name, the name of the file will added with '_db'.

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 window 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.
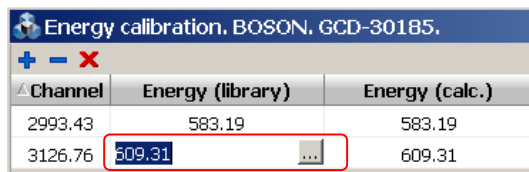
Figure 43.1

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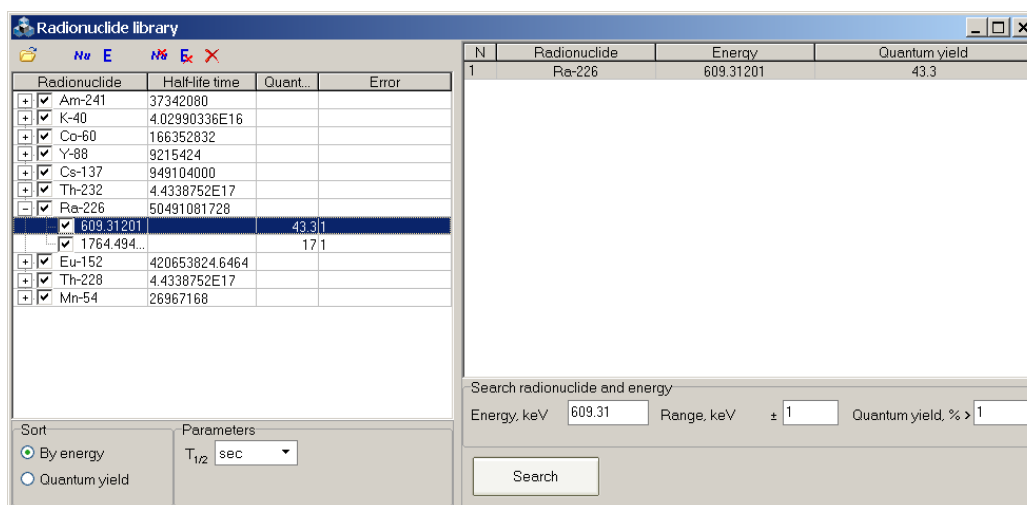
Figure 43.2 Window of energy selection from the library

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.
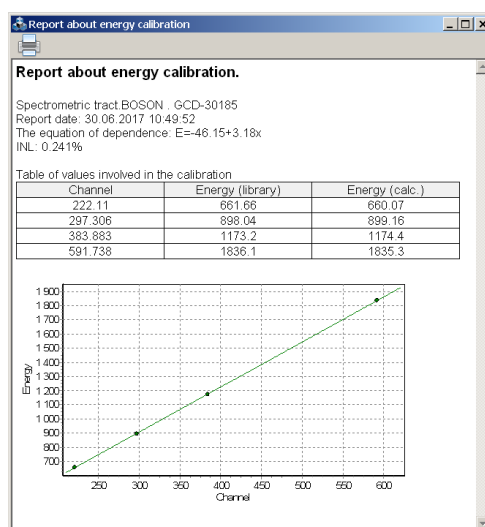
Figure 44. Energy calibration report view

To print a report, press [icon].

To perform energy calibration for the specific work spectrum, open this spectrum and press [icon] 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).
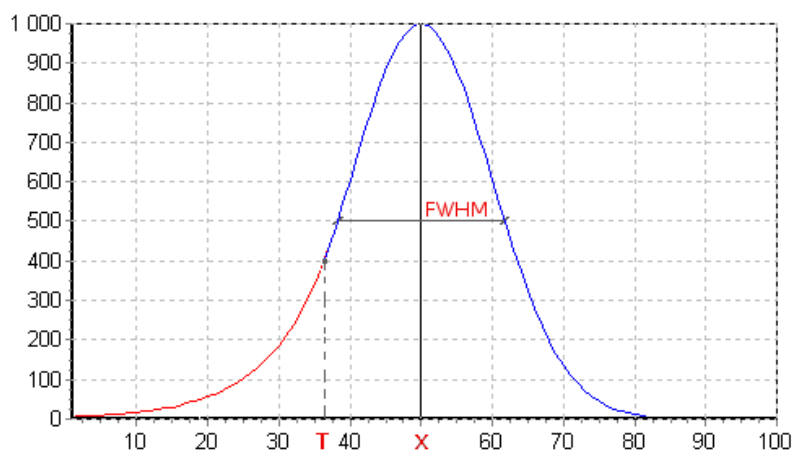
Figure 45. Shape of the graph describing a peak

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.
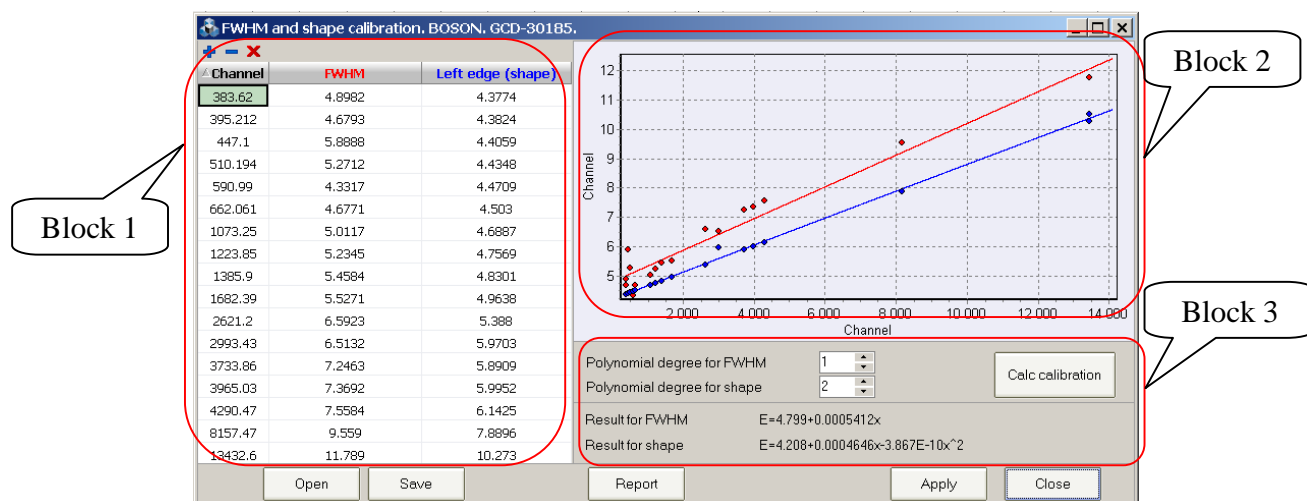
Figure 46. **FWHM and shape calibration** window

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.

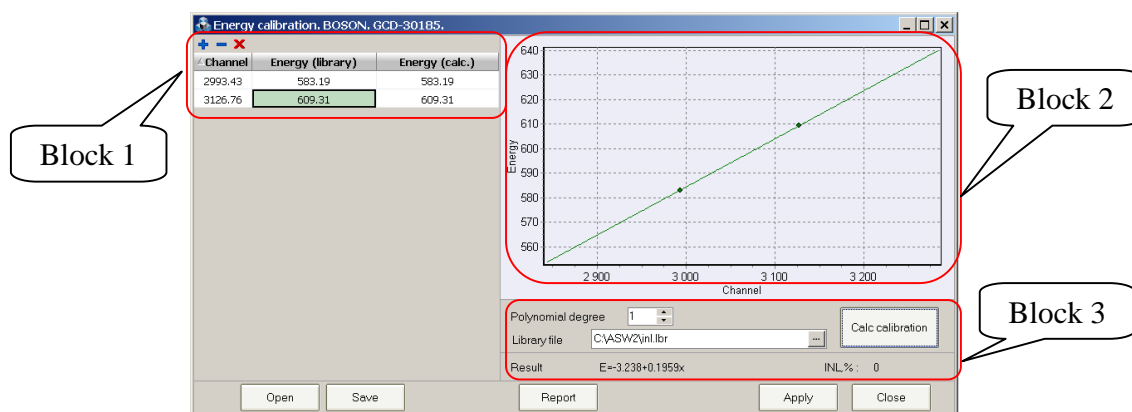Thus, Fig.46 shows calibration consisting of a certain number of points, which describe the dependence of FWHM and shape on channel in the spectrum. To calculate functional dependences, the user should press **Calc calibration** (Fig.46, block 3), and the received formula will be displayed in the **Result 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.
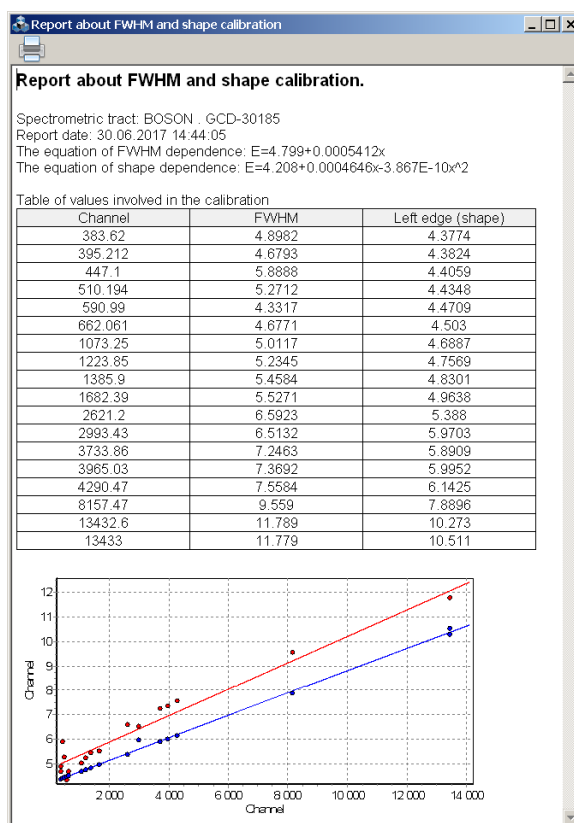
Figure 47. FWHM and shape calibration report view

To print a report, press [icon].

To perform FWHM and shape calibration for the specific work spectrum, open this spectrum and press [icon] 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 polynomic 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 ^{54}Mn, ^{57}Co, ^{109}Cd, ^{113}Sn, ^{137}Cs, ^{139}Ce, ^{152}Eu, ^{241}Am, ^{243}Am, ^{226}Ra (with daughters), ^{228}Th (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 ![ε(E)] on the toolbar of the programme. Choose tab **Efficiency calibration** which is the first tab in the window's title.
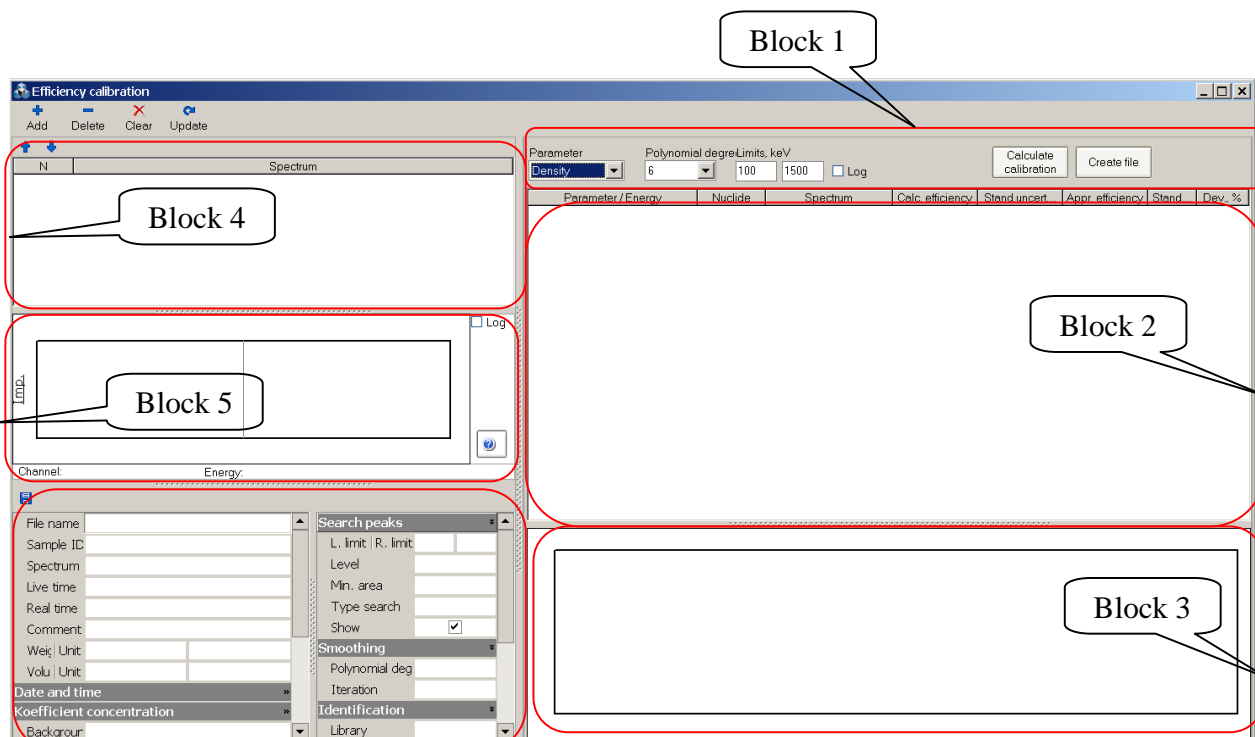
Figure 48. **Efficiency calibration** window view

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).

Figure 49. Ranging of spectra

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

- **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.

- **Geometry** – name of geometry of measurement, for which calibration by efficiency is created. It is not optional text parameter, which value will be saved in the efficiency file and will show in the data field about implemented calculation (see fig. 41.2). In the drop list of this field is offered conventional labels for often used geometries ('Mar' – Marinelli, 1L; '38_' – container, 38ml; '250' – cuvette, 250ml; etc.).

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):

$$Eff=f(-1343, 1307, -5133, -1649, 248.2, -19.85, 0.6592)$$

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.
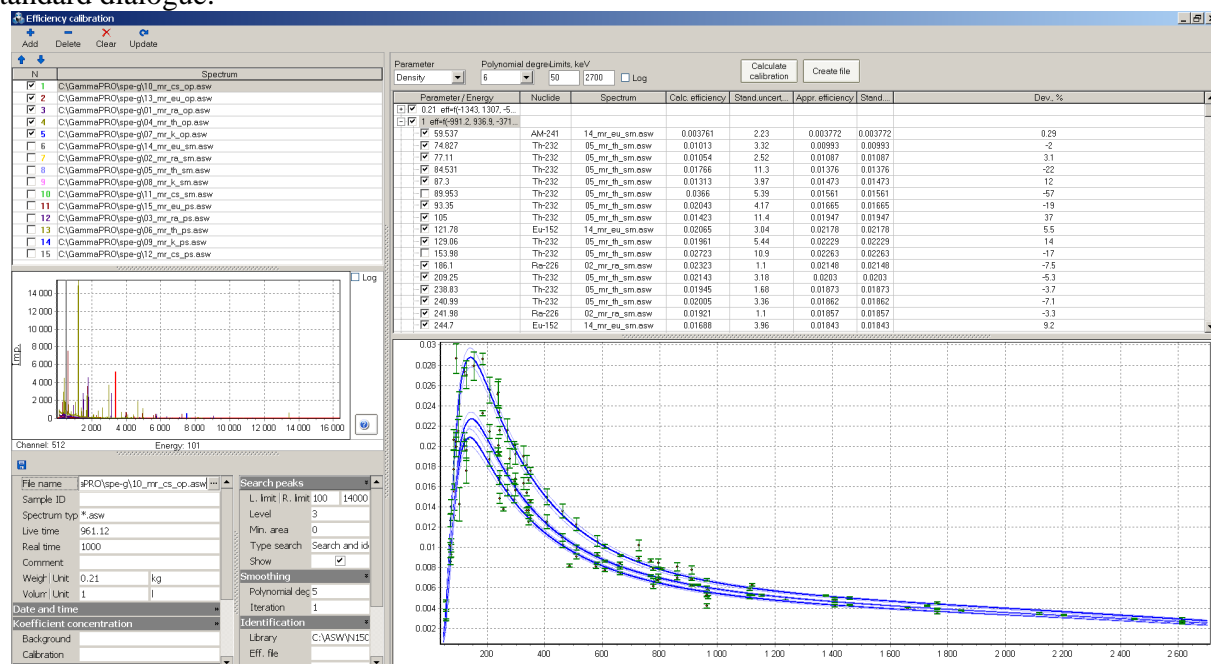
Figure 50. **Efficiency calibration** window view after calculation of dependence of efficiencies on energy
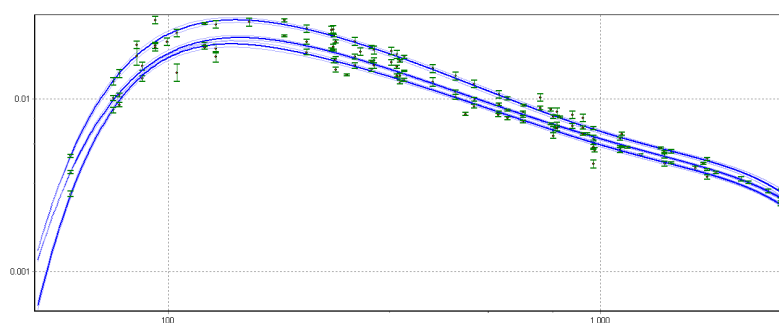
Figure 50.1 View of efficiency curves on a logarithmic scale

9.4 Management of spectra

To load and delete spectra in the **Efficiency calibration** window, use 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 [icon] 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 [icon] 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.
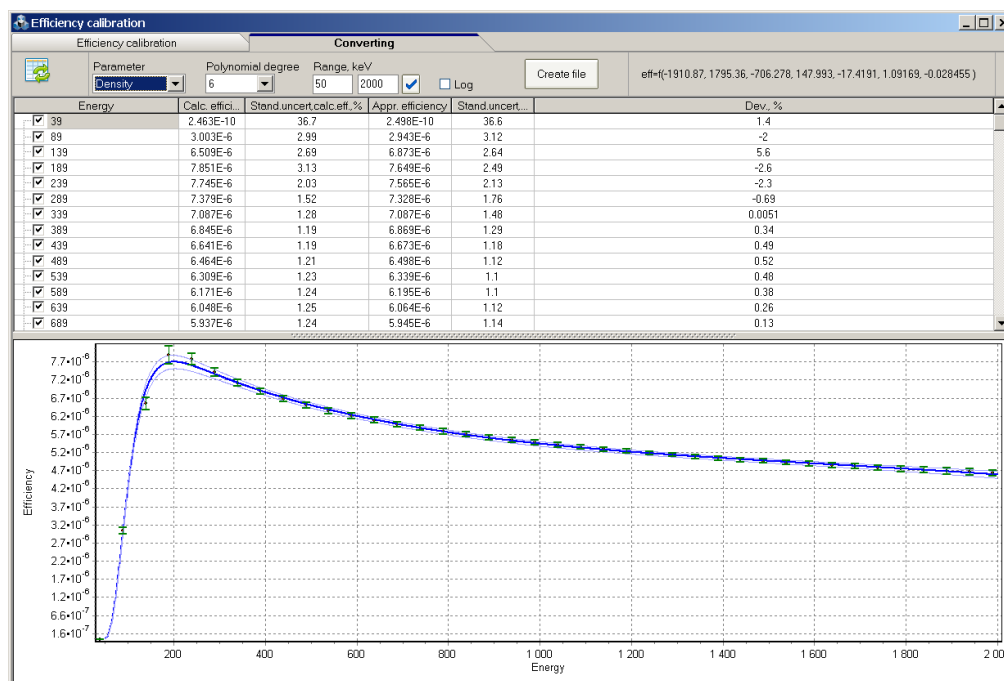
Figure 50.3. Tab Converting

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).
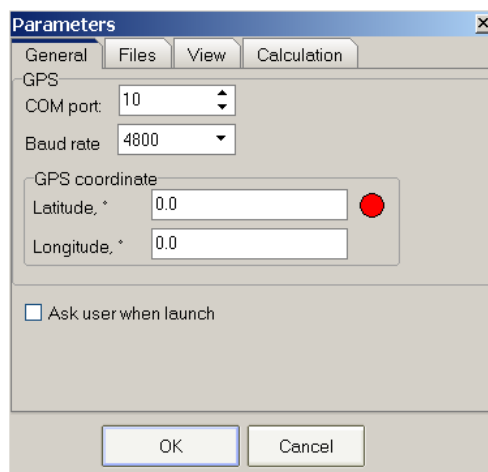
Figure 51. **Parameters** window view

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.
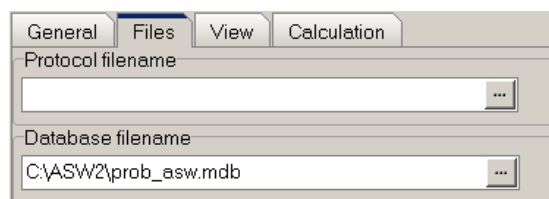
Figure 52.1 **Files** tab view

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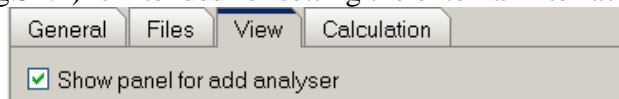
Figure 52.2 **View** tab view

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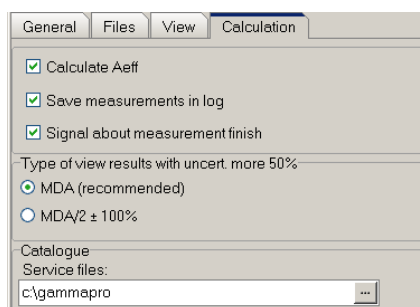
Figure 52.3 **Calculation** tab view

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):

$$A_{eff} = A_{Ra} + 1.30 \cdot A_{Th} + 0.090 \cdot A_K \qquad (10.1)$$

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.).
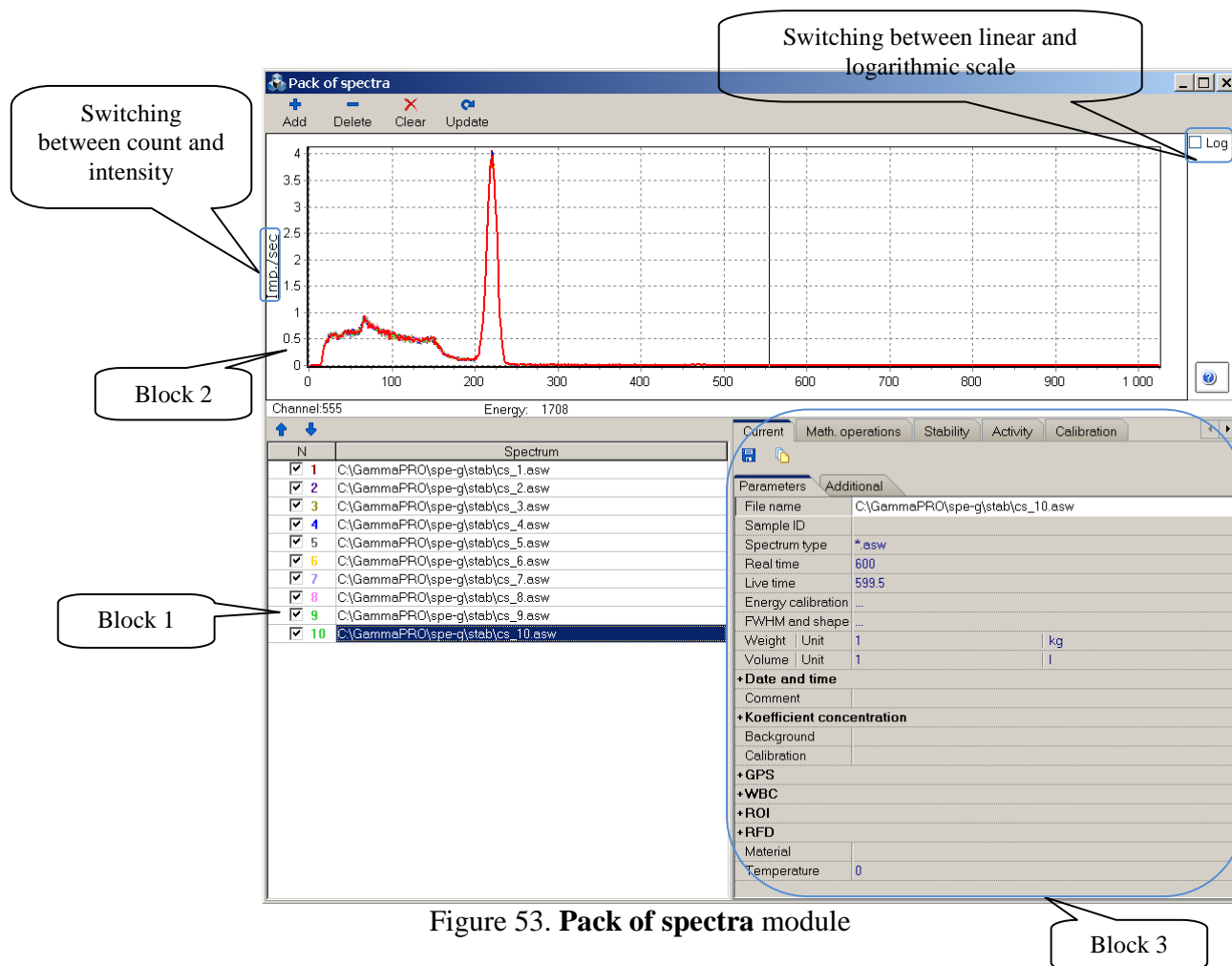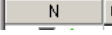
Figure 53. **Pack of spectra** module

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 [N], 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: [icon] (**Save current change**) and [icon] (**Template**). The first is for saving changes made to fields of the **Parameters** and **Additional** tabs. The [icon] 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 [icon] (**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.
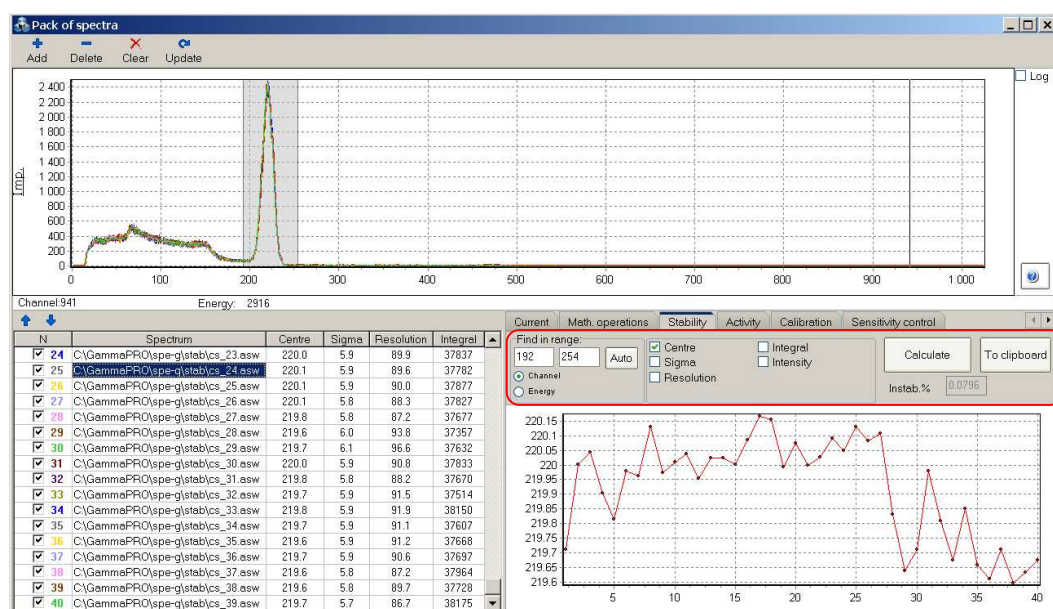
Figure 56

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.
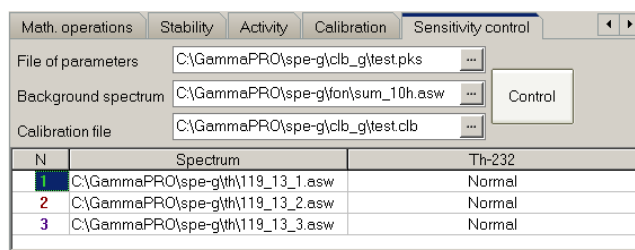
Figure 57. **Sensitivity control** tab view

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

The required spectra are selected in the main table to execute that operation. In insert fields **Background control** sequentially load the background spectrum and calibration file for windows method (or ROI file). Press the button **Control**. The result looks as it is shown in Fig. 58. From calibration file in the present case the program takes only energy windows which also could be specified in ROI file (*.roi*).

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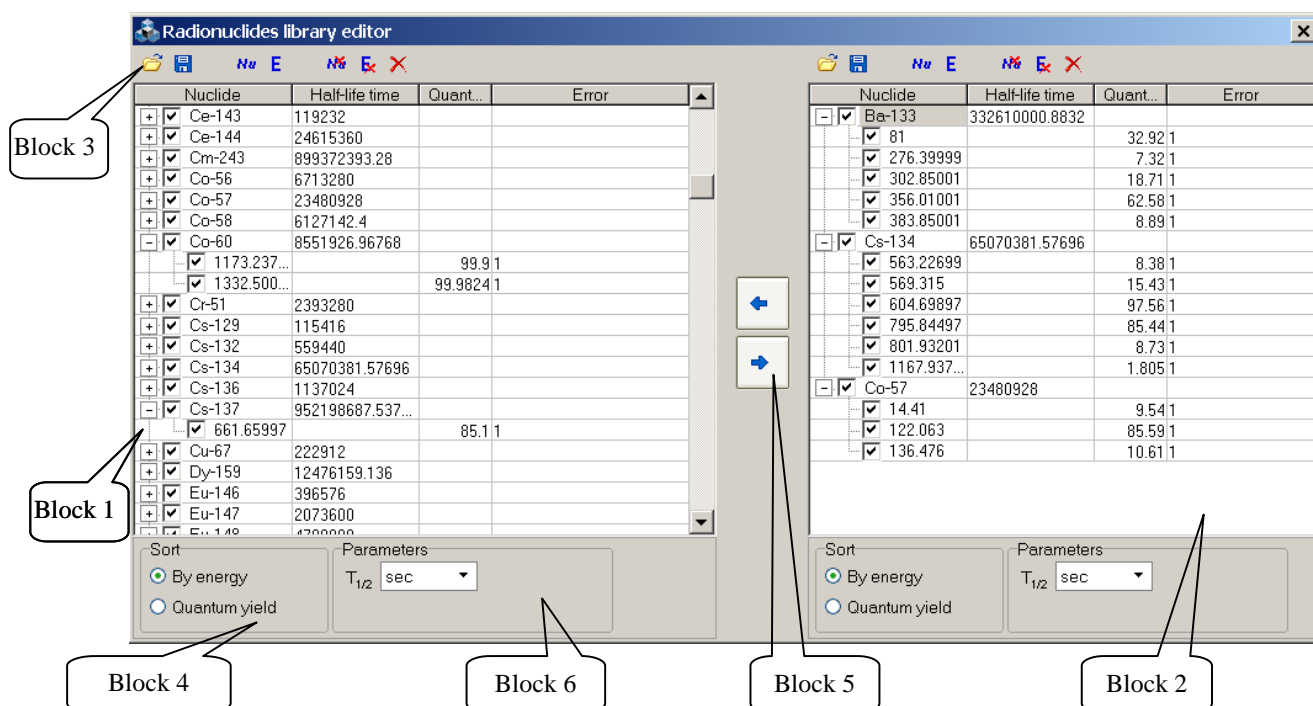
Figure 60. **Radionuclides library editor** window view

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 [icon]. Then select necessary radionuclides and press [icon] (**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 [icon] (**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 [icon] (**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 [icon] (**Delete selected radionuclides**) and [icon] (**Delete selected energies)**, respectively. To clear the entire table, use the [icon] (**Remove all**) button.

When you have finished editing the table, you can save it in any of the two formats. To save, press [icon] (**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.

Figure 61. Passport of source editor window

A passport of source file contains a list of radionuclides, their activity, uncertainly, 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).

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 be 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).
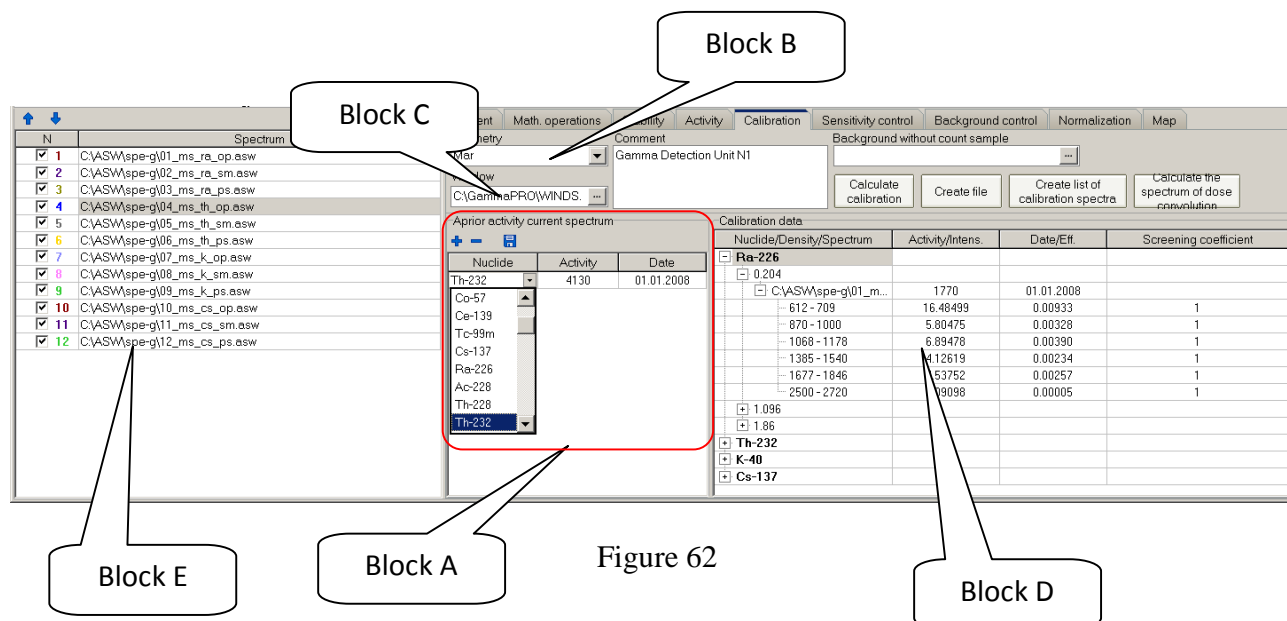
Figure 62

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 ROI-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:

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

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_{j_i} 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 $\dfrac{S_{j_i}}{A_i}$ 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:

$$C_{ijr} = \frac{S_{j_{ir}}}{A_{ir}}, \quad r = \rho_{0...}\rho_{d,} \quad (14.4.2)$$

where $\rho_{0...}\rho_d$ is the density of reference samples used for calibration, g/cm³;

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);

$\rho_{0...}\rho_d$ are the density values of the reference samples used for calibration, g/cm³;

d is the number of density values used for calibration;

$S_{j_{ir}}$ 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 License

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/cm³
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⁻¹Bq⁻¹)
                                                             in work windows
                                                             (rows) and for
0.008251  0.016280  0.002369  0.002162  0.001555  0.004037   each density
0.007594  0.014390  0.002190  0.001980  0.001367  0.003551   (columns)
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 $\mathbf{E_n}$ is made using the formula:

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

```
 [Main]                                    Main block heading.
Count=3                                    Number of densities.
En_1=50                                    Interval of energies,
En_2=3000                                   to which the curve corresponds.
[Item_1]                                   First curve block heading.
Ro=0.19                                    Density corresponding to the first curve.
dA=0.000120673701486547                    First error approximation error.
A0=100.952521999333                        Coefficient  A0
A1=-193.624766139809                       Coefficient  A1
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
```

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.

```
[Main]                          Main section name.
Count_nuclide=4                 Number of nuclides in KO.
Date_reference=43412.9568       Data, on which the activity is
                                adjusted.
Massa=0.314                     Mass of the source.
Volume=0.25                     Volume of the source.
Unit_weight=kg                  Mass unit.
Unit_volume=l                   Volume unit.
Geometry=Marinelli              Name of geometry
Number=11/17                    Table number of source


[Nuclide_1]                     First radionuclide section name.
Activity=5400                   Activity, Bq.
Abs_Err=540                     Absolute error, Bq.
Name=Ra-226                     First radionuclide name.


[Nuclide_2]                     Second radionuclide section name.
Activity=2100                   Activity, Bq.
Abs_Err=210                     Absolute error, Bq.
Name=Th-232                     First radionuclide name.
…
```

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:

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

where X_j is unknown (sought) activity of jth nuclide in the countable sample, Bq;
A_j is activity of jth radionuclide, Bq in the reference sample;
$(S_i)^j$ is count in i^{th} window of the library (reference) spectrum of jth 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):

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

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 jth radionuclide:

$$\varepsilon_j = L * \sigma_j, \qquad (3)$$

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

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

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 jth radionuclide in the countable sample is assumed to be equal to the random component of the measurement error σ_j

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

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:

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

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:

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

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:

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

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;

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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:

$$A = \frac{\sum A_i w_i^2}{\sum w_i^2},$$

(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:

$$u_A = \sqrt{\frac{1}{\sum w_i^2}}$$

(10)

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

$$U_A = u_A \cdot k$$

(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:
$$A_{Eff} = A_{Ra} + 1.30 A_{Th} + 0.090 A_K;$$
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:
$$A_{Eff} \pm \Delta_{Eff}, \text{ Bq/kg.}$$

Annex 6. Scenarium Module

6.1 Application

The module **Scenarium** presents the detached program, which could be launched from the program **"GammaPRO"** and separately as well. The module is intended for the sequences of spectrum procession operations and other actions in the program **"GammaPRO"**. Module **Scenarium** also provides the remote access to the program **"GammaPRO"** by internet by the specified IP address.

As module **Scenarium** actually provides the access to the instruments of the program **"GammaPRO"** by protocol TCP/IP, the user could create own program modules which will send the commands identified by the program **"GammaPRO"**. The list and description of the commands of module **Scenarium**, executed by the program **"GammaPRO"** is listed in section 6.6 of the present annex.

6.2 Start of Scenarium module

To launch the module **Scenarium** from the programm **"GammaPRO"** it is necessary to select the item "**Инструменты**->**Сценариум**" in the main menu or start the program *scen-mod.exe* in work catalog of the program **"GammaPRO"**.

At the start of *scen-mod.exe* with parameter "1", module interface will be in Russian, with parameter "0" - in English. Also the parameter "*connect*" could be applied as a second one. In that case after the module launch automatically will be made the attempt to connect the server. For example:

C:\gammapro\Scen-mod.exe 2 connect   // *Module start in manual mode with English interface and automated connection*

When module is opened, the window will appear on the screen as shown in Fig. A6.1.

Module **Scenarium** is connected to the program **"GammaPRO"** via IP. At the start of the module directly from **"GammaPRO"**, the automated connection is made and the sign "*Connection with 127.0.0.1*" (see Fig. A6.1, unit 4) appears. If connection is set up, the control buttons in the instruments panel will be color as shown in Figure A6.1(Unit 1). Otherwise several buttons will be grey color.

If connection is absent it could be set up pressing the first button in instruments panel of the window **Scenarium.** The module **Scenarium** after the successful connection automatically will send the require command for the presented in **"GammaPRO"** spectrometric sections (**GET_TRACTS_NAME**), and also make the control buttons in the instruments panel available.

Figure A6.1. Main window of **Scenarium** module
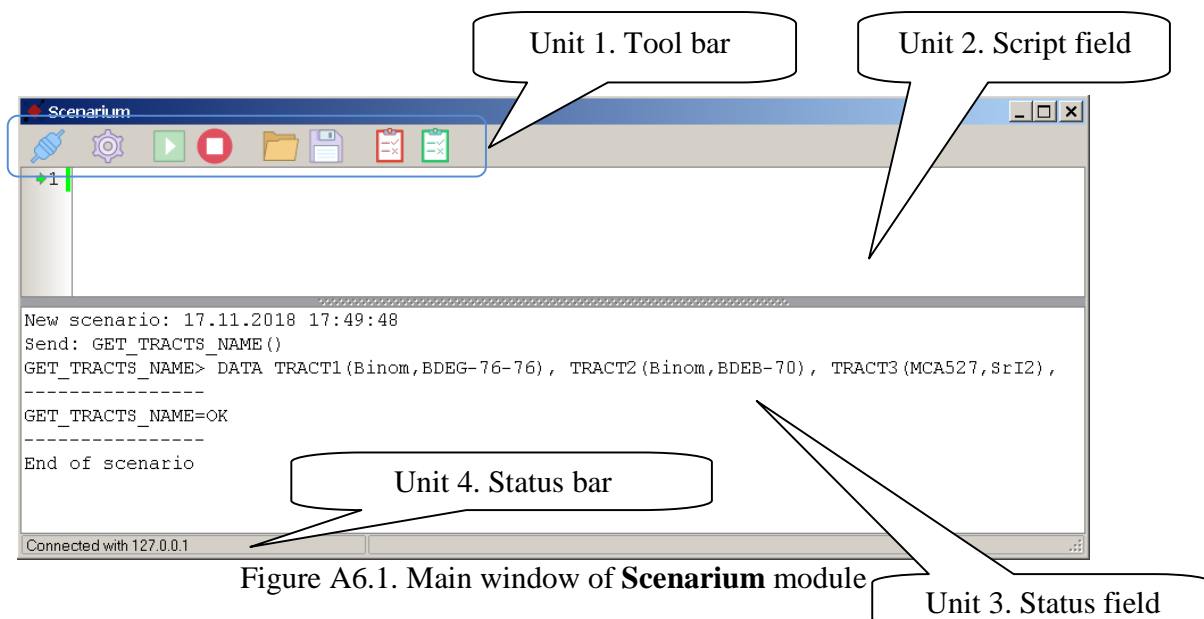
Application TCP/IP as data base exchange protocol provide possibility to send the commands from the module **Scenarium** to the program "**GammaPRO**" (server) by network in remote mode. At the module start from the remote PC where the program "**GammaPRO**" is not installed, the destination IP address and computer (to connect and send commands) portal number should be specified. It should be done with adjustment window (see Fig.A6.2), which is initiated by the button ![icon] (Parameters) in instruments panel.

Figure A6.2. Access adjustment window to the program "**GammaPRO**"
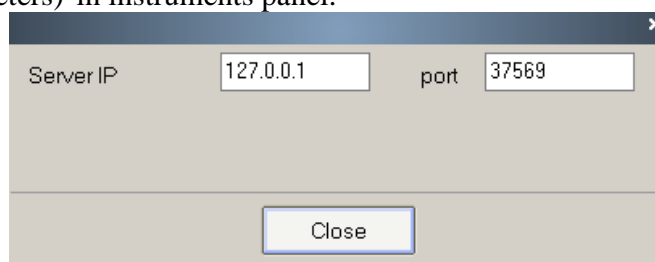
6.3 Scenarium module interface

Fig A.6.1 shows the outer views of the module **Scenarium**. In the upper part of the window the instruments panel is placed (see Fig. A6.3):

Figure A6.3 Instruments panel of module **Scenarium**

The panel has the following buttons:

![icon] - **Connection to server**. Press this button and connect to the program **"GammaPRO"** with application of the parameters, shown in Fig.A6.2.

- **Parameters**, call the window of parameters connection to the server (program **"GammaPRO"**).

- **Scenarium execution start**. Pressing this button will start the module **Scenarium,** start the execution of the commands (script) sequence, specified in the field below the instruments panel (see Fig. A6.1, unit 2).

- **Stop scenarium execution**. Pressing this button, the module **Scenarium** will stop the current script as well as send the command **BREAK** to stop the executing command on the server.

- **Open scenarium file.** Call for the standard dialogue window to load saved before scenarium file (***.*srm*).

- **Save scenarium file**. Call for the standard dialogue window to save to disc the current scenarium of displayed in scenarium field (see Fig A6.1, unit 2).

- **Quality assurance (ROI-method)**. Call for the window **Quality assurance (ROI-method)**, which provide the quality assurance procedures by the ROI-method procession (see section 6.4 in the present annex).

- **Quality assurance (peaks analysis method)**. Call for the window **Quality assurance (peaks analysis method)**, which provide the Quality assurance procedures by the peaks analysis method (see section 6.5 of the present annex).

The script field is below the instruments panel in the window of the module **Scenarium**. There the user is able to create its own script on the basis of the commands, available in the section 6.6 of the present attachment.

To make the script compilation easier the user could apply so called tip for available commands list. Press the buttons *Ctrl+Space* will display the drop dawn list of the commands, available in the module. The user can select the required command in the list by the buttons arrows on the keyboard and press *Enter*, then the specified command will appear in the script field (see Fig.A6.4).

When the available command name is entered, the module automatically offers to enter the command parameters in the specified sequence. It is organized as a pop-up tip (See Fig.A6.4).
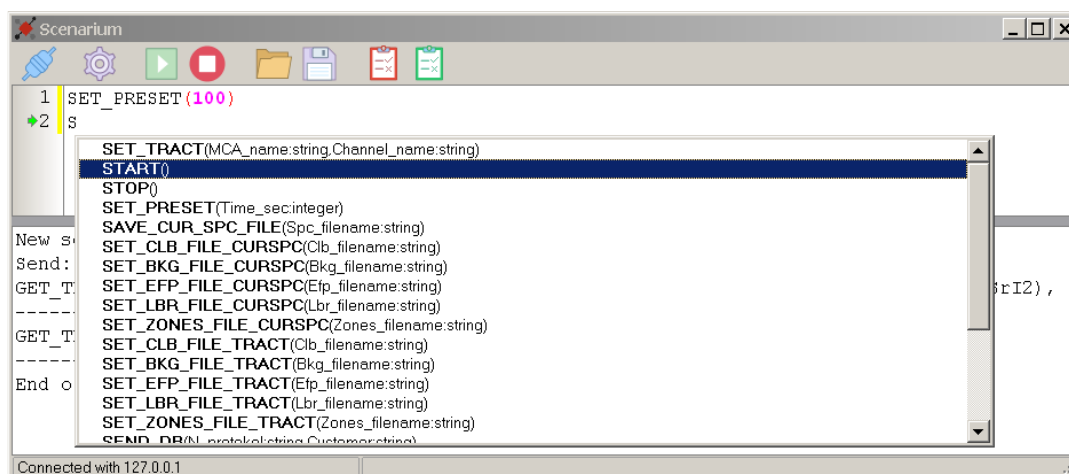
Figure A6.4 Drop down commands list
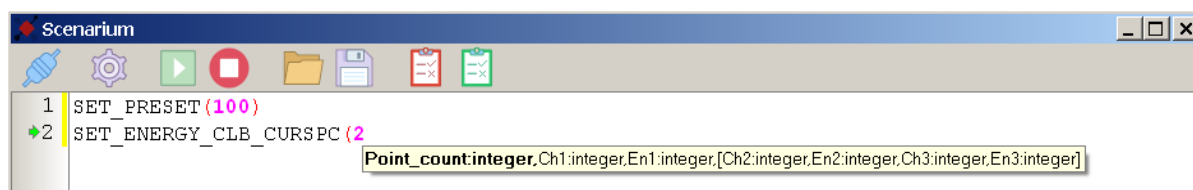
Figure A6.5. Pop up tip for command parameters and their order

The command parameters listed in the tip in square brackets are not obligatory and could be absent. Thus, for example, figure A6.5 shows the pop-up tip for the command **SET_ENERGY_CLB_CURSPC** , set the energy calibration values where the first parameter of the command is the number of dependence points to be set up. Further the second and the third parameters of the command are the number of the channel and energy value of the first point. If the first parameter of the present command is equal to 1, i.e. only one calibration point is specified, and then no more parameters will be required. If the first parameter is equal to 2 and more than the channel number value and energies for the point 2 and more accordingly should be specified.

Below the script field there is a state field. There the module **Scenarium** displays the data on the current execution of the script, display the time clip of script start, sent commands and received replies. Thus, Fig. A6.6 shows the state field view where the script execution result, comprising two commands **SET_PRESET** and **OPEN_SPC_FILE** is shown.
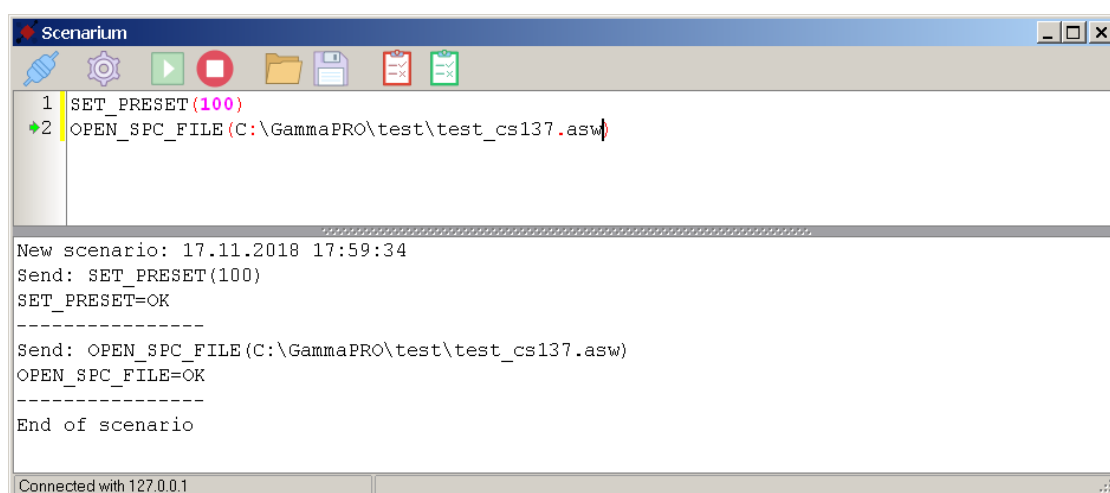
Figure A6.6 Module window after script execution

The very bottom of the module **Scenarium** window has the state line where in the first field the information on the connection to server state is specified (see Fig. A6.1, unit 4).

6.4 Quality assurance (ROI-method)

The pressing the button module opens the window **Quality assurance (ROI-method)** (see Fig.A6.7). That window is intended for execution of test measurement sequence to form the results to evaluate the correct operation of the spectrometric sections. The application of that chapter uses the procession methods based on ROI-method, applied mainly for scintillation spectrometers of low resolution.

As shown in figure A6.7, the spectrometric section Quality assurance comprises several tasks **Gain adjustment**, **Energy calibration adjustment**, **Background test**, **Sensitivity test**. Those tasks parameters are collected in groups. The present tasks will be executed consequently at the start of the present chapter.

The preliminary stage of control also is the setting of the present section where the operations are executed (see Fig. A6.7, unit 1).
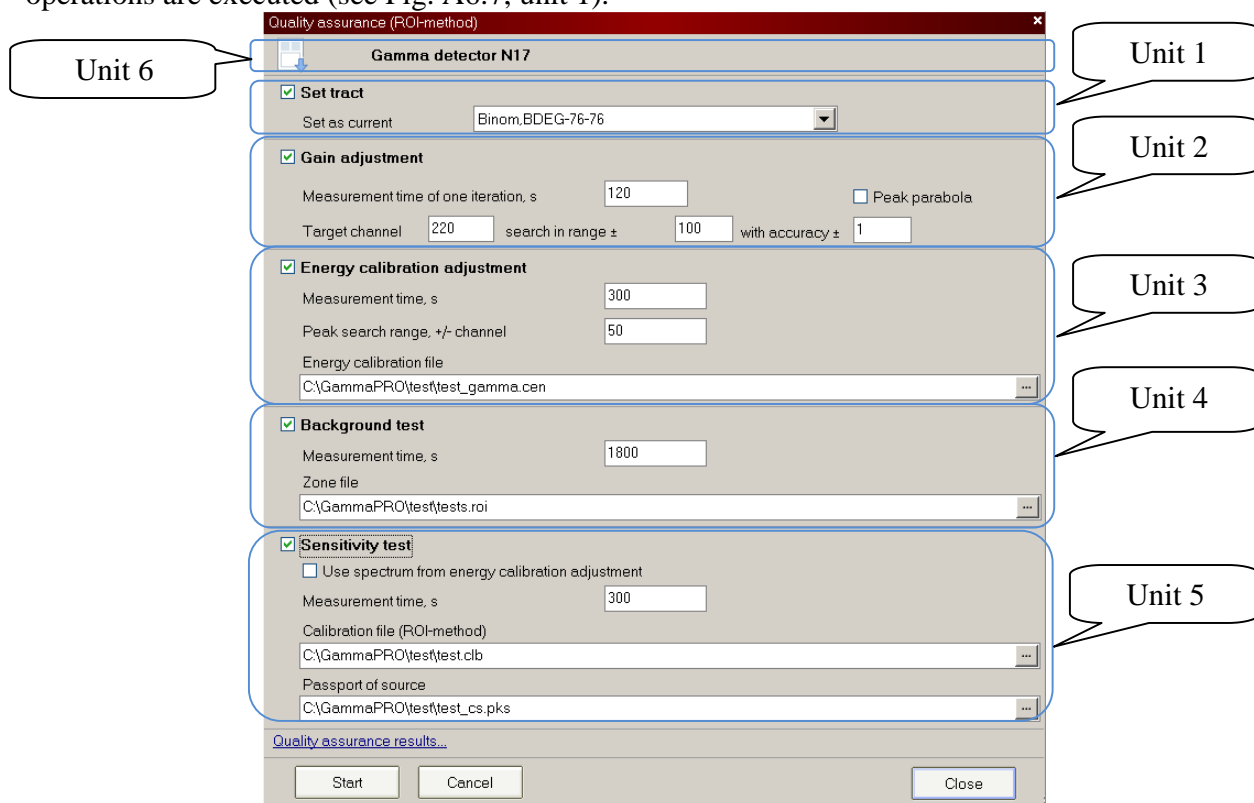
Figure A6.7 Window **Quality assurance (ROI-method)**

The quality assurance stage **Gain adjustment** makes the setting ("adjustment") of peak into the specified spectrum channel by the amplification factor change for the present spectrometric section. As the present process is iteration one, the important parameter in the current adjustment is **Ratio CV** (See section 2.4.2). The parameter **Measurement time of one iteration,s** shows the program the measurement time of one spectrum till the definition of the current position of the searched peak which should be set up in position, specified in the field **Target channel**. The peaks search is made in value range specified in the field **search in range** ± from target channel. The adjustment is over when the peak is in the position of the target channel ± value specified in the field **with accuracy** ± (see Fig.A6.7, unit 2).

For some special cases there could be necessity to study the peak not as Gauss curve but as parabola. It could be useful for the search of quasi-centroid in the alpha radiation spectrum, received on scintillation spectrometer based on ZnS(Ag) crystal (see Fig. A6.8).
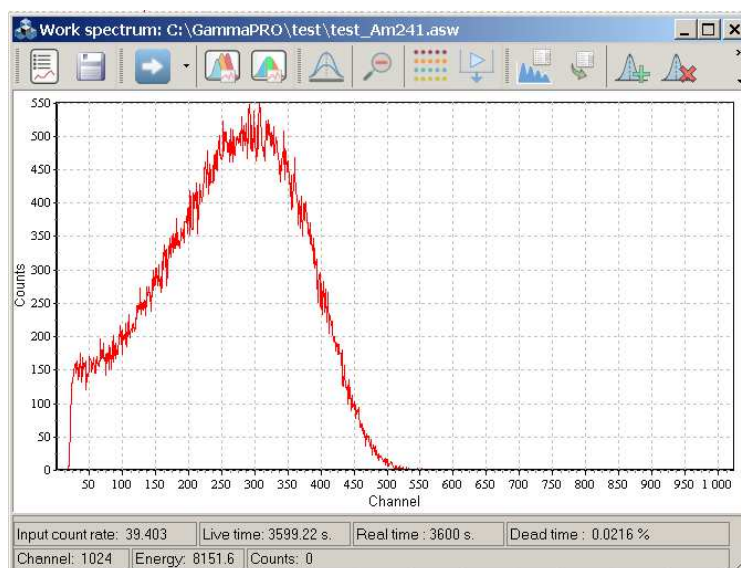
Figure A6.8 Alpha radiation spectrum on the spectrometer based on ZnS(Ag)

For this case the checkmark **Peak parabola** should be selected.

Quality assurance stage **Energy calibration adjustment** (fig.A6.7, unit 3) makes the peaks search in the specified range and assigns them the adequate energy values, specified in energy calibration file (***.cen**). The parameter **Measurement time,s** indicates to the program the exposition for spectrum measurement where peaks search will be made. The range (one for all peaks) for the search of the peaks there are specified in the field **Peaks search range**. The path and energy calibration file name, in accordance to which the peaks search will be done, should be specified in the field **Energy calibration file**. Thus, for example, in accordance to figure A6.7, if the calibration file has two points 220 channel (661.7 keV) and 830 channel (2614.5 keV), then the program will search in the measured spectrum he peak within the range of 170 – 270 channels and will assign it the energy value of 661.7 keV, then the peak search in the range of 780 – 880 channel will be made and the value of 2614.5 keV will be assigned.

For some cases, for example, for the adjustment of beta spectrometric section (see Fig. A6.9), possible adjustment of energy calibration only in one point could be required. Then the calibration file should have only one point.
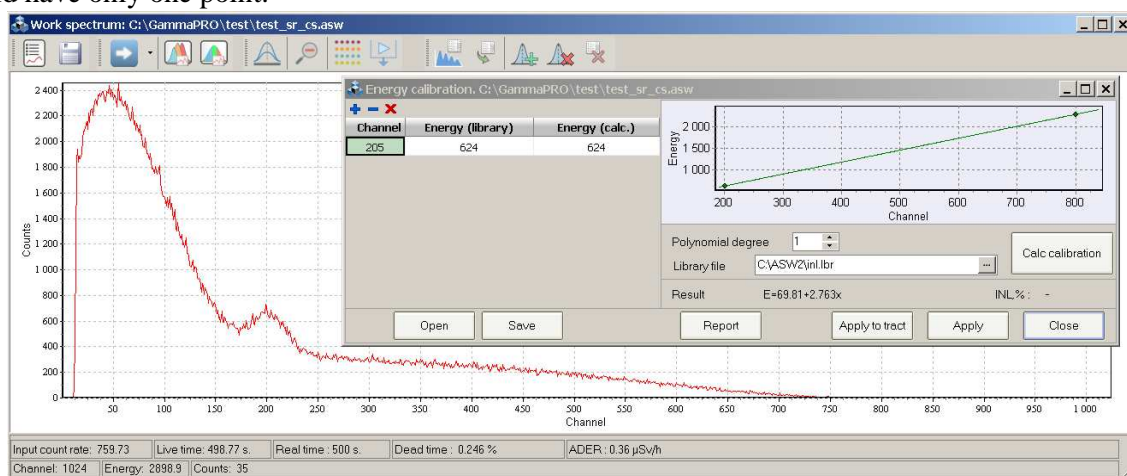
Figure A6.9 Radionuclides Sr-90-Y-90+Cs-137 spectrum on the spectrometer based on scintillation plastic and calibration window by energy

The Quality assurance stage **Background test** (Fig.A6.7, unit 4) valuates the background spectrum change in comparison to the current background spectrum specified in the section **Calculation parameters** in the program **"GammaPRO"** (see section 2.4.4). The content of the background control procedure in the present operation is the same as shown in section 11 of the present document. Thus, the program vauates the deviation of the count rate in the specified windows with the account of the statistical component in measured again and current saved background spectrum. The result (norm or significant deviation) are displayed in the state field as well as the report on the Quality assurance.

In the field **Measurement time** the exposition of the background spectrum acquisition for the control should be specified. The path and file name (***.roi**) with energy ranges to evaluate the deviations, should be specified in the field **Zone file**.

The Quality assurance stage **Sensitivity test** (fig.A6.7, unit 5) makes the evaluation of the spectrometer sensitivity change in time. The contents of the sensitivity control procedure in the present operation are the same as listed in section 11 of the present document. The program makes the standard sample spectrum measurement, calculates radionuclides activity and compares the obtained results to the passport data for the samples with errors account. The result (norm or significant deviation) is displayed in the state field as well as Quality assurance report.

The standard sample spectrum acquisition exposition should be specified in the field **Measurement time**. If the standard samples for energy calibration and sensitivity control are the same, then the spectrum obtained on the stage of **Energy calibration adjustment** could be applied. Then set up only checkmark in indicator **Use spectrum from energy calibration adjustment.** The additional measurement will not be done then.

The path and calibration file name (***.clb**) are specified in the field **Calibration file (ROI-method)** by activity of calibration factors, which allow calculation of radionuclide activities in the standard sample (see section 5.1). The source (standard sample) passport data file (***.pks**) is specified in the field **Passport of source** (see section13).

When parameters in the window **Quality assurance (ROI-method)** (fig. A6.7) are filled, the user could start the control operations execution. The button **Start** in window bottom should be pressed, and then the module will compile script on the basis of the specified parameters and will launch its execution. The process of the executing operations could be seen in state field (see fig. A6.10).

To secure the logic and remote access during the Quality assurance execution, the user should not operate with spectra in the program "GammaPRO" as it could result in the change of the current path or close of the seen current spectrum.
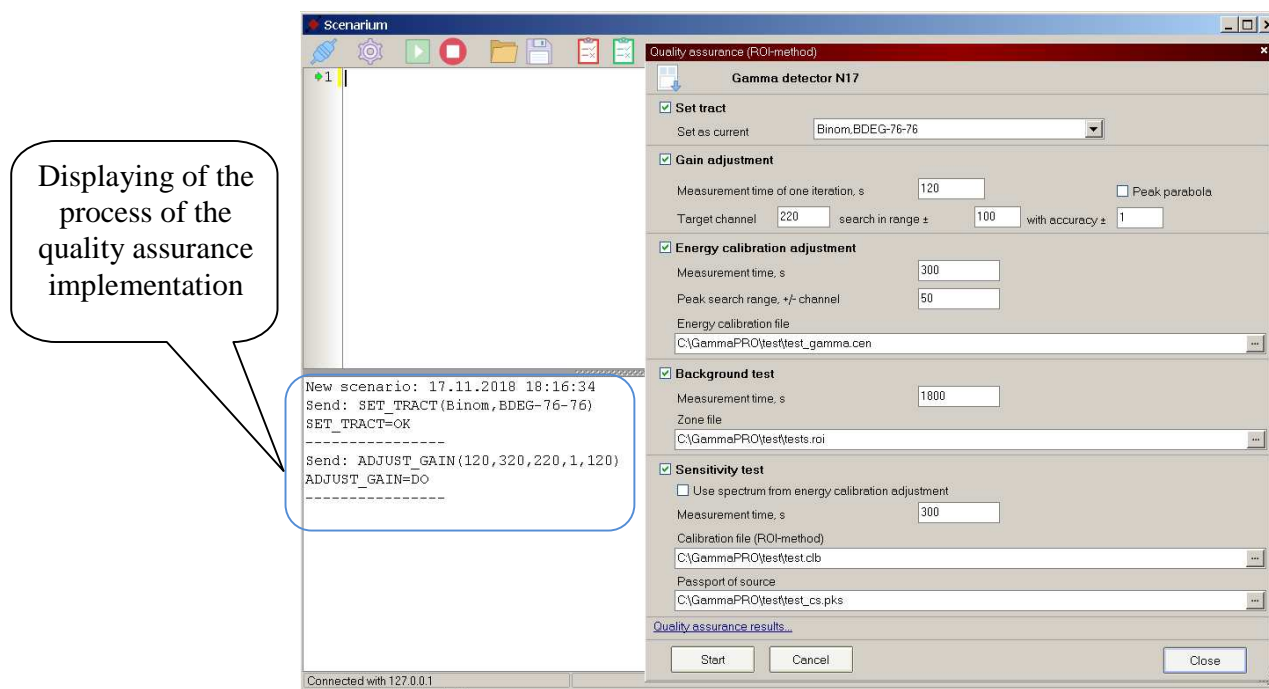
Figure A6.10. State field in the process of Quality assurance

When the Quality assurance script is over, the user could see and analyze the control results in the report clicking the sign **Quality assurance results…** in the bottom of the window.

The necessity to have Quality assurance parameters for each path is obvious as the program **"GammaPRO"** provides measurements by several spectrometry sections. The concept «template» is applied to simplify the task.

To create the parameters templates for the present spectrometric path, the user should fill them duely in the window **Quality assurance (ROI-method).** Then press the button in instruments panel of that window and the window with the name **Quality assurance templates** (см.рис.A6.12) will appear.
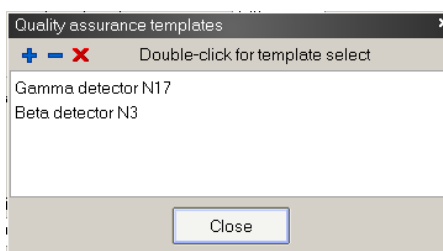
Figure A6.12. Window **Quality assurance templates**

Further press the button ✚ (**Create a new template base on the current parameters**) in instruments panel of that window and enter the name of a new template in appeared dialogue window. A new template will appear after pressing the button **OK** in the list of the window **Quality assurance templates**. To call the parameters of any template, its name should be clicked in the list by double click.

6.5 Quality assurance (peak analysis method)

Pressing the button [icon] the module will open the window **Quality assurance (peak analysis method)** (see Fig.A6.13). Analogue to the previous type of test, described in section 6.4 of the present attachment, this window is intended for execution of test measurements sequence to form the results for correct and duly operation of spectrometric paths. The application of the present section applies the procession methods, based on peak analysis method, applied for precision spectrometers with high resolution.
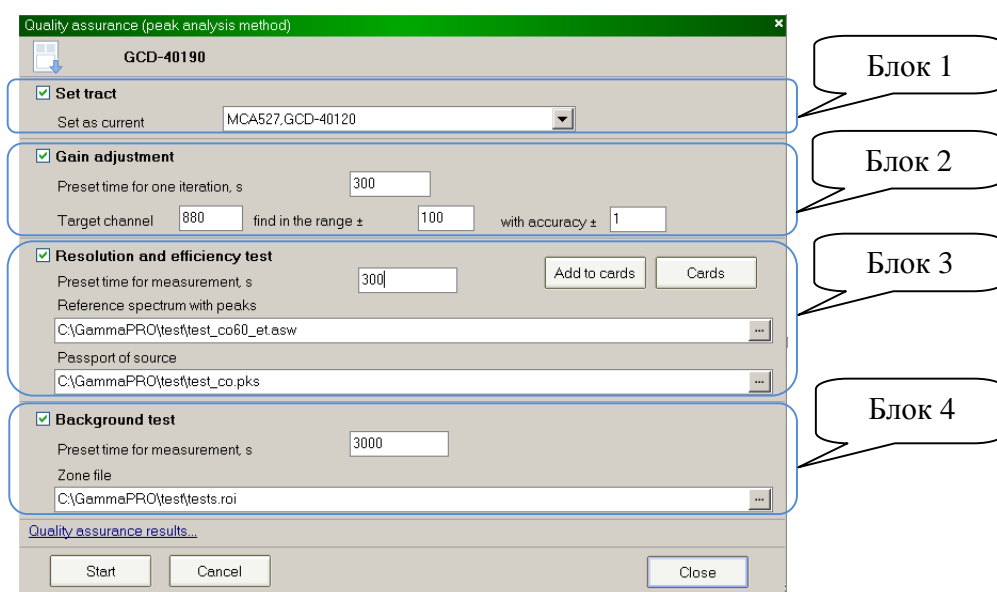
Figure A6.13. Window **Quality assurance (peak analysis method)**

The figure A6.13 shows that the Quality assurance in spectrometric path for peaks analysis method comprises the following tasks: **Gain adjustment**, **Resolution and efficiency test, Background test**. Those tasks parameters are collected in groups. The present tasks will be executed sequentially at the start of the present section.

The preliminary stage of the control is the setting of the specified path where operations will be executed (see Fig. A6.13, unit 1).

The Quality assurance stages **Gain adjustment and Background test** are absolutely identical to the Quality assurance by ROI-method (see section 6.4. of the present annex).

The Quality assurance stage **Resolution and efficiency test** is intended to evaluate permanence and repeatability of spectrometric characteristics as peaks position in standard sample, energy resolution and registration efficiency of gamma quanta by full absorption peaks. Within the frames of the present control the user should fill the field **Preset time for measurement,s** , where standard sapmple measurement exposition, which is applied to value the mentioned metrological characteristics, is specified. Also the reference spectrum of the control sample (***.asw**) in the field **Reference spectrum with peaks** should be specified as well as the source (standard sample) passport data file (***.pks**) in the field **Passport of source**. Reference spectrum of the standard sample should have marking, i.e. have information of the searched peaks, used by the program to control the position, resolution and efficiency. As information of the found peaks are in the file with the same name as the spectrum but with resolution ***.asr**, the user should draw attention to the presence of that file in the catalogue, written

in the field **Reference spectrum with peaks.** Reference sample spectrum should be prepared before in the program "**GammaPRO**", i.e. energy calibration and calibration by FWHM and peak form should be made. Also the peaks to the searched peaks table should be selected (added). A large peak number is not recommended because it will provide the excess of the statistic information on the stage of result form in the report. With the account of the radionuclides in the available control sample it is enough to have the points at the beginning, middle and end of energy range.

When parameters in the window **Quality assurance (peak analysis method)** is filled (fig. A6.13) the user start the control operations. The button **Start** in the bottom of the window should be pressed, then the module will compile the script based on the specified parameters and will start its execution. The executing operations run could be seen in state field.

When Quality assurance script is over, the control results could be seen and analyzed in the report, activating it by the sign <u>**Quality assurance results…**</u> in window bottom.

To save the results and run the characteristics change in time statistics, the obtained data could be saved. Press the button Add to cards (see Fig. A6.13, unit 3). To see the statistics by the executed controls, the user should press the button **Cards** and the window **Cards** will appear on display (see Fig. A6.15).

N	Date	Tract	Reference spectrum	Line, keV	Channel ref.	Channel cur.	Resolution ref.,keV	Resolution cur.,keV	Efficiency ref.	Efficiency cur.
1	23.09.2018 17:15:41	BINOM	test_co60_et.asw	661.7	3395.3	3395.2	1.21	1.25	0.00314	0.00313
	23.09.2018 17:16:10	BDEG-76-76		1332.5	7059.1	7059.3	1.75	1.73	0.00207	0.00198
2	24.09.2018 17:18:03	BINOM	test_co60_et.asw	661.7	3395.3	3395.3	1.21	1.23	0.00314	0.00313
	24.09.2018 17:18:32	BDEG-76-76		1332.5	7059.1	7059.2	1.75	1.73	0.00207	0.00199
3	25.09.2018 17:19:58	BINOM	test_co60_et.asw	661.7	3395.3	3394.8	1.21	1.2	0.00314	0.0031
	25.09.2018 17:20:28	BDEG-76-76		1332.5	7059.1	7058.7	1.75	1.72	0.00207	0.00208
4	26.09.2018 17:30:11	BINOM	test_co60_et.asw	661.7	3395.3	3396.4	1.21	1.19	0.00314	0.003
	26.09.2018 17:30:41	BDEG-76-76		1332.5	7059.1	7059.9	1.75	1.79	0.00207	0.00212
5	28.09.2018 17:32:07	BINOM	test_co60_et.asw	661.7	3395.3	3394.7	1.21	1.2	0.00314	0.00319
	28.09.2018 17:32:36	BDEG-76-76		1332.5	7059.1	7058.2	1.75	1.75	0.00207	0.00205

Figure A6.15. Window **Cards**

Window **Cards** has two units. The first unit has common information on the executed procedures of resolution and efficiency control in digital view. The lower unit shows the graphical information. The diagram has three relative parts: *Channel*, *Resolution* and *Efficiency*. Each part of diagram synchronously reflects the table data. The numbers of the executed control by order are shown in X axis. The total line for all graphics connects the data, which belong to one energy line. If necessary the graphics colors could be changed, the button [button icon] should be pressed and graphic type should be selected. Appears window **Chart parameter** and the lines color could be selected as well as display of the graphic could be switched off (see Fig A6.16).
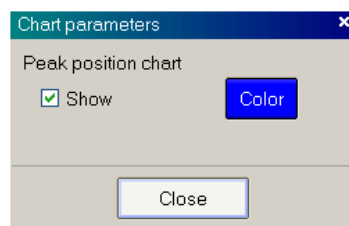
Figure A6.15. Window **Chart parameters**

6.6 Scenarium module commands

When script is formed the several rules should be observed:
- all commands should start from the first symbol of line in script field;
- no empty lines between the lines with commands;
- only one command in one line;
- no spacings when commands parameters are specified;
- no spacings and punctuation marks in the name of a command.

The following nominations are used at each line formation:

$$\textbf{COMMAND(Param1:string,[Param2:integer])}$$

COMMAND – command name.
Param1 and **Param2** – command parameters. Parameters, marked with square brackets, could be absent.
string, **integer** – parameter type:
    string – line, symbols set except the comma;
    integer – integer-valued;
    real – real.

Program **"GammaPRO"** will revert the line when any command is over:
COMMAND=OK#10#13
For example, reply to the command **SET_TRACT**(*BOSON*,*BDEG*) will be as follows:
SET_TRACT=OK#10#13
If the command is not immediate, i.e. continuous, the program **"GammaPRO"** will first return the line:
COMMAND=DO#10#13
and then, after it is over
COMMAND=OK#10#13
If the commands were executed with error, for example, due to incorrect parameters, the reply will be as follows:
COMMAND=ER#10#13
#10#13 – ASCII symbols of line end LF(*line feed*) and CR (*carriage return*) accordingly. If the command means the return of any result, the reply will be as a line and format depends on the command itself (see commands description below).
For example, the full reply to the command **FIND_PEAK_FOR_EN**(*100,300,661.7,0*) will be as follows:

FIND_PEAK_FOR_EN> CH=220.5
FIND_PEAK_FOR_EN=OK
Each line, returned by the server, has the symbols combination at the end #10#13.

The program "**GammaPRO**" provide execution of the following commands:

SET_TRACT(*MCA_name:string,Channel_name:string*)
The command of path set up with the name *Channel_name* in analyzer *MCA_name* current.
MCA_name – the name of the analyzer, specified in the program "GammaPRO";
Channel_name – the name of the channel, specified in the program "GammaPRO" for the analyzer with the name *MCA_name*.

BREAK
Command to break the current executing command. If no command is running, the command is ignored.

START
 Command to start measurement in the current path.

STOP
 Command to stop measurement in the current path.

SET_PRESET(*Time_sec:integer*)
 Command to set up the measurement time for the current patha.
 Time_sec – measurement time, s.

PAUSA(*Time_sec:integer*)
Command to pause in the script with duration *Time_sec*.
Time_sec – pause duration, s.

ADJUST_GAIN(*Left_border:integer,Right_border:integer,Target_channel:integer, Allowed_deviation:integer,Time_sec:integer*)
Command to start amplification adjustment procedure for the current path. It sets up the searched peak in the specified range in the target channel by iteration method, changing theamplification factor (or control voltage in dependence on analyzer type). The adjustment procedure stops when the peak is in the range of *Target_channel ± Allowed_deviation*.
 Left_border, Right_border – left and right interval boarder in a spectrum, where peak search will be made, channel;
 Target_channel – target channel where the program will try to set up the searched peak;
 Allowed_deviation – allowed deviation from the target channel where the procedure will be stopped, channel;
 Time_sec – measurement time of one iteration at the fitting of a peak, s.

ADJUST_GAIN_PARAB(*Left_border:integer,Right_border:integer,Target_channel:intege r, Allowed_deviation:integer,Time_sec:integer*)
Command executes the analogue procedure as ADJUST_GAIN, but at the peak procession with the aim to define centroid as a descriptive function is not Gauss function but a parabola.

FIND_PEAK_FOR_EN(*Left_border:integer,Right_border:integer,Energy:real,Type:integer,[Num_point:integer]*)

Command makes the peak search in the specified interval for the current spectrum. Additionally in dependence on the type specified in a parameter Type the command makes the following functions:

Type = 0 - no functions;

Type = 1 - adds point to calibration by energy for the present spectrum and makes the recalculation of the functional dependence for the current spectrum;

Type = 2 - corrects the value of the point in calibration by energy with a number *Num_point* for the present spectrum and makes the recalculation of the functional dependence for the current spectrum and current path.

For the case *Type* = 1 or *Type* = 2 the value *Energy* is taken as the energy value for a new or correcting point in calibration. For the case *Type* = 0 or *Type* = 1 the value *Num_point* should not be specified.

Left_border, Right_border – the left and the right interval boarder in a spectrum, where the peak search will be done, channel.

If the peak is found, the command returns the result as a line:

FIND_PEAK_FOR_EN > CH=220.5

FIND_PEAK_PARAB_FOR_EN(*Left_border:integer,Right_border:integer,Energy:real,Type:integer,[Num_point:integer]*)

Command makes the analogue procedure as FIND_PEAK_FOR_EN, but at the peak procession with the aim to define centroid as a descriptive function is not Gauss function but parabol.

OPEN_SPC_FILE(*Spc_filename:string*)

Command opens the spectrum with the name *Spc_filename*. If the path for the present file is not specified then the program will search the spectrum in the catalogue by default, specified in a section Calculation parameters (see section 2.4.4).

SAVE_CUR_SPC_FILE(*Spc_filename:string*)

Command saves the current spectrum under the name *Spc_filename*.

CALC_ROI_METHOD

Command calculates radionuclide activity by ROI-method for the current spectrum with the application o fthe calibration file and background spectrum, specified in the present current

spectrum. Actually the present command emulates the button press -> Calculation (ROI-method) (см. Section 5.1 the present document).

SET_CLB_FILE_CURSPC(*Clb_filename:string*)

Command links the calibration file *Clb_filename* (***.clb**) with the current spectrum. When the present command is executed in the window Spectrum parameter for the current spectrum in the field Calibration file (ROI-method) will be specified *Clb_filename*. If the path for the present calibration file is not specified, the program will search that file in the calibration catalogue by default, specified in the section Calculation parameters (see section 2.4.4).

SET_BKG_FILE_CURSPC(*Bkg_filename:string*)

Command sets up the spectrum file *Bkg_filename* as background for the current spectrum.

After the execution of the present command in the window Spectrum parameters for the current spectrum in the field Background spectrum the file *Bkg_filename* will be specified. If the path for the spectrum *Bkg_filename* is not specified, then the program will search that file in the background catalogue by default, specified in the section Calculation parameters (see section 2.4.4).

SET_EFP_FILE_CURSPC(*Efp_filename:string*)
Command links the efficiencies file Efp_filename (***.efp***) with the current spectrum.
After the execution of the present command in the window Spectrum parameters for the current spectrum in the field Efficiency file will be specified the file *Efp_filename*. If the path for the file *Efp_filename* is not specified, the program will search that file in calibration catalogue by default, specified in the section Calculation parameters (see section 2.4.4).

SET_LBR_FILE_CURSPC(*Lbr_filename:string*)
Command links library file *Lbr_filename* (***.lbr***) with the current spectrum. After the execution of the present command in the window Spectrum parametersa for the current spectrum in the field Library the file *Lbr_filename* will be specified. If the path for the file *Lbr_filename* is not specified, then the program will search that file in the calibration catalogue by default, specified in the section Calculation parameters (see section 2.4.4).

SET_ZONES_FILE_CURSPC(*Zones_filename:string*)
 Command links the region of interests file *Zones_filename* (***.roi***) with the current spectrum. After the execution of the present command in the window Spectrum parameters for the current spectrum in the field Region of Interest file the file *Zones_filename* will be specified. If the path is not specified for the file *Zones_filename*, the program will search that file in the calibration catalogue by default, specified in the section Calculation parameters (see section 2.4.4).

SET_CLB_FILE_TRACT(*Clb_filename:string*)
Command analogue to SET_CLB_FILE_CURSPC, but the action refers to the current path. After the execution of the present command the file *Clb_filename* will be specified in the field Calibration file (ROI-method) in the window Calculation parameters (see section см. разд.2.4.4).

SET_BKG_FILE_TRACT(*Bkg_filename:string*)
Command analogue to SET_BKG_FILE_CURSPC, but the action refers to the current path. After the execution of the current command the file Bkg_filename will be specified in the field Background spectrum in the window Calculation parameters (see section 2.4.4).

 SET_EFP_FILE_TRACT(*Efp_filename:string*)
Command analogue to SET_EFP_FILE_CURSPC, but the action referse to the current path. After the execution of the present command the file *Efp_filename* wyill be specified in the field Efficiency file in the window Calculation parameters (see section 2.4.4).

SET_LBR_FILE_TRACT(*Lbr_filename:string*)
Command analogue to SET_LBR_FILE_CURSPC, but the action refers to the current path. After the execution of the present command the file *Lbr_filename* will be specified in the field Library in the window Calculation parameters (see section 2.4.4).

SET_ZONES_FILE_TRACT(*Zones_filename:string*)

Command analogue to **SET_ZONES_FILE_CURSPC**, but the action refers to the current path. After the execution of the present command the file *Zones_filename* will be specified in the field Region of interests file in the window Calculation parameters (see section 2.4.4).

PEAKS_CLEAR_ALL

Command clears the list of the searched peaks in the current spectrum (see p.6.4 of the present document).

PEAKS_FIND_NEW

Command searched the peaks in the current spectrum in accordance to its parameters and modes (see p.6.2.8 of the present document).

PEAKS_UPDATE

Command updates the characteristics of the searched peaks in the current spectrum in accordance to its parameters and modes (see p.6.3 of the present document).

PEAKS_FIND_PARAMS(*Left_border:integer,Right_border:integer,Min_sq:real,Type_search:integer,Smoothing_range:integer,Smoothing_count:integer,MTP:real,Energy_dev:real*)

Command of the parameters setting for the correct activity calculation by the peak analysis method (see p.6.1 of the present document).

Left_border, Right_border – left and right interval boarders where the peaks search is made, channel;

Min_sq – minimal peak area to discard the peaks in search process, pulses;

Type_search – search type: 0 – search and identification, 1- peaks of library;

Smoothing_range – smoothing polynomial degree (2-6);

Smoothing_count – smoothing iterations quantity;

MTP – peak thickness multiplier (3-10);

Energy_dev – energy deviation, where in the limits the peak could be recorded by a characteristic line of a certain radionuclide, keV.

SEND_DB(*N_protokol:string,Customer:string*)

Command to send all measurements results in data base.

N_protokol – protocol number;   *Customer* - customer name.

SEND_WORD (*Type_calc:integer*)

Command to send the measurements results table into the editor MS Word. In dependence to the parameter *Type_calc* the data will be sent to MS Word from the calculation table by ROI-method and calculation table by peaks analysis:

Type_calc – results table search: 0 – ROI-method, 1- peaks analysis method.

SEND_REPORT(*Type_calc:integer,DoPrintNow:integer*)

Command opens master report window and compiles the report for the current spectrum in accordance to the current parameters (see p.5.1). In dependence to the parameter *Type_calc* data will be sent to MS Word from calculation table by ROI-method and calculation table by peaks analysis method:

Type_calc – results table selection: 0 – ROI-method, 1- peaks analysis method;

DoPrintNow – parameter, pointing the necessity of report immediate print: 0 - do not print, 1- print right now.

SET_REPEAT_MEAS_PARAM(*IsOn:integer,Iteration_count:integer,Pausa:integer,*
Template:string,Directory:string)

Command allows to specify the parameters of the repeated measurements (see p.2.4.3) for the current path.

IsOn – switch on (IsOn=1)/switch off (IsOn=0) measurements repetition mode;

Iteration_count – measurements repetition quantity;

Pausa – pause duration between the measurements, s;

Template – template for spectrum name file;

Directory – path to the catalogue where the measured spectra are saved in the catalogue.

SET_HV(*IsOn:integer,Value_HV:integer,Type_value:integer)*

Command for high voltage ON and OFF for the current path.

IsOn – switch on (*IsOn*=1)/switch off (*IsOn*=0) of high voltage;

Value_HV – target value of the setting high voltage. In dependence on analyzer type *Value_HV* could be so called control voltage (See Analyzer Manual).

Type_value – value type *Value_HV*. 0 – high voltage, 1 – control voltage.

SET_ENERGY_CLB_TRACT(*Point_count:integer,Ch1:integer,En1:integer,[Ch2:integer ,En2:integer,Ch3:integer,En3:integer]*)

Command executes the setting for energy calibration points values for the current path and automatically recalculates a new functional energy dependence on the channel.

Point_count – number of the point to be set up. In dependence on these parameter the number of channel-energy pairs are defined as parameters for the present command.

Ch1, Ch2, Ch3 etc. – the channel number in a spectrum for the point under number 1, 2, 3 etc. accordingly;

En1, En2, En3 – energy for the point under number 1, 2, 3 etc accordingly.

For example:

Command **SET_ENERGY_CLB_TRACT**(*3,220,661.7,677,1173.2,820,2614.5*) provides energy calibration as shown in Fig. A6.16:
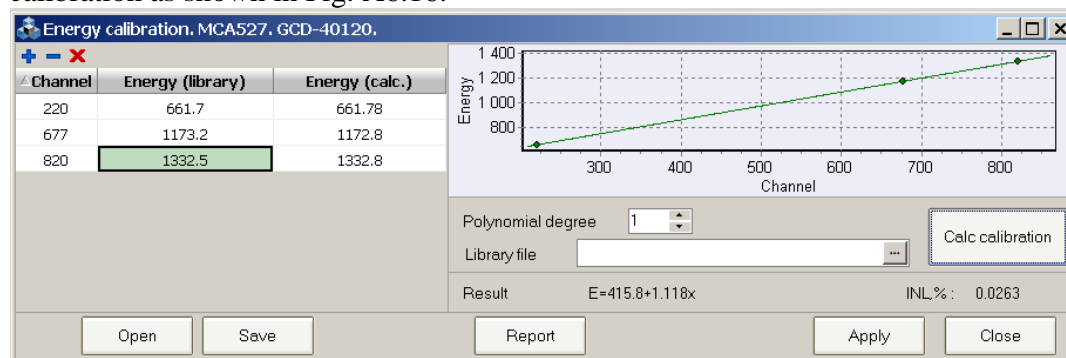

Figure A6.16. Window Energy calibration

SET_ENERGY_CLB_CURSPC(*Point_count:integer,Ch1:integer,En1:integer,[Ch2:intege r,En2:integer,Ch3:integer,En3:integer]*)

Command analogue to **SET_ENERGY_CLB_TRACT**, but the action refers to the current spectrum.

TEST_BKG(*Zones_filename:string,[Base_bkg_filename:string])*

Command executes the procedure of background control for the current spectrum. In case if optional parameter *Base_bkg_filename* is not specified, the current spectrum will be compared to the current background spectrum for the present path.

Zones_filename – region of interests file (***.roi**). Statistic comparison will be made by energy intervals specified in that file.

Base_bkg_filename – background file, which could act as basic one instead of current path background spectrum.

Command provides the result as a message:

TEST_BKG> OK

What means that the background is normal, or :

TEST_BKG> DEV=*nn*

What means the background is out of a norm and deviation is significant and is equal to ***nn***%.

TEST_SENS(*Clb_filename:string,Pks_filename:string,[Base_bkg_filename:string])*

Command executes the sensitivity control procedure for the current spectrum. In case the optional parameter *Base_bkg_filename* is not specified, the control will be made with the account of the current background spectrum for the present path.

Clb_filename – calibration file for activity calculation by ROI-method (***.clb**);

Pks_filename – passport data file for a source (reference sample) (***.pks**);

Base_bkg_filename – background spectrum, which could act as a basic one instead of current path background spectrum.

Command provides the result as a message:

TEST_SENS> OK

What means that sensitivity is normal, or :

TEST_SENS> RN1(Cs-137)=*nn1*, RN2(Ra-226)=*nn2*,

What means that sensitivity is out of a norm and deviation is significant for radionuclide number number 1 and number 2 and makes ***nn1***% and ***nn2***% accordingly. In brackets at key word RN1 and RN2 the name of radionuclide and deviation is specified.

TEST_SENS_TEMP(*Num_saved_spc:integer;Clb_filename:string,Pks_filename:string,* *[Base_bkg_filename:string])*

Command analogue to **TEST_SENS**, but the action refers not to the current spectrum but to the spectrum saved in memory by the command **STORAGE_CURSPC_TEMP**.

Num_saved_spc – spectrum number saved in the memory of the program "GammaPRO".

STORAGE_CURSPC_TEMP(*Num_spc:integer)*

Command of the current spectrum record into the program memory under the number *Num_s*pc. Parameter *Num_spc* should be equal not more than 2.

TEST_RESEFF(*Etalon_spc_filename:string,Pks_filename:string)*

Command executes the control procedure of resolution and efficiency for the current spectrum.

Etalon_spc_filename – name and path to reference sample standard spectrum file. The present spectrum should have marks, i.e. the file with the same name and extension ***.asr** should be in the same catalogue as reference spectrum, (see p.6.2.11);

Pks_filename – passport data for a source (reference sample) (***.pks**). Command provides the result as a message:

TEST_RESEFF> OK

What means, that resolution and efficiency are normal, or :

TEST_RESEFF> NOT_OK

What means the resolution and efficiency are out of a norm.

With no dependence to positive or negative result of a test the info line will follow:

TEST_RESEFF> DATA PEAK1(*en,ch_et,ch,ch_Ok,res_et,res,res_Ok,eff_et,eff,eff_Ok*),
PEAK2(*en,ch_et,ch,ch_Ok,res_et,res,res_Ok,eff_et,eff,eff_Ok*),…

where *en* – line energy, keV;

ch_et – peak position in standard spectrum, channel;

ch – peak position in the current spectrum, channel;

ch_OK – feature of negligible deviation of peak position: 0 – deviation is out of a norm, 1-normal;

res_et – peak resolution in spectrum of a standard, keV;

res – peak resolution in the current spectrum, keV;

res_OK – feature of negligible resolution deviation: 0 – deviation is out of a norm, 1-normal;

eff_et – efficiency by a peak in spectrum of a standard, channel;

eff – efficiency by peak in the present spectrum, channel;

res_OK – feature of neglibible efficiency deviation.

For example:

TEST_RESEFF> DATA PEAK1(*661.7,220.0,220.1,1, 1.7,1.8,0,0.0021,0.0021,1*),
PEAK2(*1332.5,770.0,770.1,1, 1.5,1.5,1,0.0018,0.0018,1*), This reply means that the standard spectrum marks have two peaks with energies 661.7 keV and 1332.5.

WAIT_MEAS_END

Command executes waiting for the completion of the current measure for the current path. In case if the measurement is not over the commands will be as follows:

WAIT_MEAS_END=DO

At a moment when measurement is over or stopped, the program will return the command:

WAIT_MEAS_END=OK

GET_TRACTS_NAME

Request command for the list of the available spectrometric paths in the program "GammaPRO". In reply to the present command the reply will return as follows:

GET_TRACTS_NAME> DATA TRACT1(*name_mca,name_channel*),
TRACT2(*name_mca,name_channel*), **TRACT3**(*name_mca,name_channel*), where
name_mca – analyzer name; *name_channel* – channel name in analyzer name_mca.

For example:

GET_TRACTS_NAME> DATA TRACT1(*BOSON,GCD-4020*),
TRACT2(*BINOM,BDEG-63-63*), TRACT3(*BINOM,BDEG-76-76*),

That reply means that at the present moment in the program "**GammaPRO**" in devices manager (see Fig.1, unit 3) has three paths: one analyzer with the name *BOSON* with one path with the name *GCD-4020*, and one analyzer *BINOM* with two paths *BDEG-63-63* and *BDEG-76-76*.

REQUEST_MESSAGE(*Str:string,[Caption:string]*)

The present command does not send the request to the program "**GammaPRO**", but just stops the execution of the script, started from the module **Scenarium** and provides the message, specified in *Str*. Optional parameter C*aption* allows to put the line in the name of the message in dialogue window.

REVISION HISTORY

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

Revision	Nos of pages				Total number of pages in the document	Document No.	Our ref. of accompanying document and date	Signature	Date
	Revised	Replaced	new	Annulled					
24					65				26.07.2016
25					65				09.07.2016
30					71				19.10.2017
40					94				17.11.2018
41					93				28.01.2019