

# Manual

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# Nuc Scout

Portable Gamma Identifier – Quantifier – Dose Rate Meter

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Referenced Documents

*Software-Manual dVISION*

*Software-Manual dCONFIG*

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## 1. Nuc Scout operation

### 1. 1. Power management

After finishing the sampling the instrument enters automatically into standby state. For shipment or if the unit is not used for longer periods, It can be turned off completely (all electronics disconnected from battery – delivery state). The cycle “Power Off” can be chosen and started to turn off the instrument. To turn on the unit again the power adapter needs to be connected for a short time.



- 1) Battery charge indicator (red LED)
- 2) USB interface
- 3) Connector for power adapter
- 4) Button to wake up from standby
- 5) Alert indicator (red LED)
- 6) Antenna for wireless communication
- 7) Connector for gamma probes

The unit is powered by an internal rechargeable NiMH battery. A power adapter to charge the battery is included in delivery. It must be connected to the receptacle (3) at the rear panel of the NucScout. While charging the charge indicator (1) is lighted. It will turn off if the charge process is finished. To prevent the battery against deep discharging, a safety circuit disconnects the electronics completely from the battery if the voltage drops below 10.5V. Please note that the safety circuit works independently on the main switch. The instrument is ready for operation as soon as the battery voltage reaches 11.5V. The charging process is in progress as soon as the power adapter is connected independent on the main switch state. It takes about one hour to re-charge a completely discharged battery.

### 1. 2. Important hints for battery maintenance

The instrument contains high quality NiMH battery packs of leading manufacturers. This technology provides a high power density, long life time a high transportation safety. Some hints should be noticed to maximize the battery performance.

**Do not store the instrument with discharged battery even for short periods.** NiMH batteries undergo a certain self-discharge which discharges the battery even if no load is connected. This may result in deep discharge and can damage the battery pack. Charge the battery to 50...75% of the capacity before longer storage. Recharge the battery at least every six month.

**Switch of the instrument if it is not in use.** This can be done by the implemented "Power off" cycle. The instrument consumes power even in standby modus resulting in continued discharging. If the battery is exhausted, the deep discharge protection circuit will disconnect the electronics, but cannot avoid self-discharge (see previous item)

**Charge the battery within the temperature range from 10°C to 30°C.** In case of higher or lower temperatures, the battery cannot reach its full capacity. To protect the battery, the charge process will be interrupted if the temperature exceeds approximately 43°C.

**Recharge the battery even if it is not completely discharged.** The capacity lost by the aging process can be minimized by operation between 20% and 80% of the capacity.

**Remove the power adapter after charging.** The integrated charge controller monitors the battery state continuously and provides a conservation charge. However, this cycle will accelerate the aging process of the battery.

### 1. 3. Touch screen operation

The Nuc Scout is controlled by touch screen menus. The power consumption of the display as well as the backlight is very high compared with the other electronics. Therefore, the display will be switched off automatically after an adjustable period. The time span (max. 255 Seconds) can be set by the instrument set-up function of the operation software.

To activate the display, press the small push button (4) below the display. All other required inputs are realized by dynamic touch buttons on the screen. The screen will hold the display page which has been selected before the display was switched off.

### 1. 4. Communication interfaces (USB, Net Monitors wireless)

The instrument offers a Net Monitors wireless interface as well as an USB port (2) for communication. Note, that the wireless interface will be disconnected automatically if an USB connection has been established. Therefore, both ports can be used only alternatively. The wireless interface is only activated if a measurement is in progress (configurable for permanent contact). To operate the wireless interface a Net Monitors network coordinator (connected to PC through USB cable) is required.

### 1. 5. Data storage (SD Card) and transfer to PC

All acquired data will be stored on a 2GB memory card (SD standard). This allows the storage of more than 780.000 records. If a large number of data has been stored, the download of data can take several minutes. The transfer rate is limited during sampling for compatibility with various communication channels including modems etc. If the sampling has been stopped, the transfer can be accelerated by a factor of seven. To access this feature, the touch button "CARD READER" must be pressed. Now, the unit communicates at increased transmission rate until the button "BACK" will be

pressed. In the operational software dVISION, the check box “Card Reader” (below the buttons connect/disconnect) must be checked too. Please note that only the USB cable connection can be used for the accelerated communication. dVISION offers the possibility to download data selectively by selection of the desired time period. Older data can remain on the SD card without the need to load the data once more.

## 1. 6. Menu navigation

In order to minimize the power consumption, the display will be turned off automatically after an user adjustable time span. It switches on in case of a pending alert or if the button (4) below the display is pressed. This button is also used to toggle the backlight. It appears the last selected display page.

### Main page

In standby mode, this page shows the instrument name, the name of the actual configuration (with the date of the last update) and the selected measurement cycle. Touch the **CYCLE** button to call a list containing all pre-defined cycles to select another cycle if desired. Now the measurement can be started by pressing the **START** button. It is necessary that a memory card is inserted and a valid cycle has been selected before. All information about the status of sampling is displayed during cycle execution:

- Date/time (with black background if the clock needs to be set)
- Name of the processed cycle
- Time span from the start of the whole sampling period (total sample time)
- Time span from the begin of the running interval
- Number of the executed step and step count of the running cycle
- Remaining data memory (number of data records which can be stored)

Several buttons are available at the main page to enable the access to various display pages. It is possible to show recent readings, data stored on memory card, component configuration etc. The cycle execution can be stopped by the button **STOP**.

### Module information and options

These pages show the module information as well as the actual setting of the module options. The menu can be called from the main menu by touching the **INFO** button. Use the **TOGGLE** button to toggle between the several pages.

Module information:

- Software version
- Serial number
- Date of manufacturing
- Date of the last software update

Options:

- Pre-set start time if the option “Synchronized start” is enabled

- Operation mode and time scheduling of the clock switch (not installed)

Use the **BACK** button to return to the main menu or the **CONFIG** button to show the actual configuration of the various components.

#### Component configuration

This menu shows the actual settings of the configuration parameters of each component. The user can check them for validity but it is not possible to make any changes. Components can be selected by the buttons **NEXT** and **LAST**. If not all parameters can be shown on one page, the others are accessible using the **TOGGLE** button.

#### Selecting the cycle

This menu allows the selection of the sampling cycles which have been transferred to the instrument before. A touch sensitive list with the names of all available cycles appears after calling from main menu by the button **CYCLE**. If more than five cycles have been stored, the list can be scrolled by the **TOGGLE** button. A touch at the desired cycle name will select the cycle for execution. Touch the **BACK** button to return to the main menu without a new selection.

#### Recent readings display

This page is only available if a cycle is in progress. Use the button **RECENT** to call the recent readings page from the main menu. The results are updated once per second to show the actual sampling results. This feature implements the functionality of a directly displaying meter. The buttons **NEXT** and **PREVIOUS** can be used to toggle between count rate, battery voltage and total number of detected counts within the running sampling interval.

#### Displaying calculated results

All acquired data will be written to the memory card at the end of each sampling interval. To show the results, the **INTERVAL** button at the main page has to be touched. A list containing all calculated activities of the single nuclides and the dose rate appears on the screen. The buttons **NEXT** and **PREVIOUS** can be used to show the averaged count rate and battery voltage. As soon as new interval data are available, the display will be updated. If the **TOGGLE** button is touched repeatedly, all nuclides of the list are shown with their statistical limits followed by the spectrum plot. When the spectrum is shown, the buttons **NEXT** and **PREVIOUS** are used to select the shown region of the spectrum. For a 512 channel spectrum, three display pages are required. The spectrum will be scaled automatically with respect to channel maximum within the viewed area. The pages overlapping each other for several channels to ensure that each peak appears completely in the graphic. Vertical lines show the position of peaks defined by the recently used nuclide list.

Except the spectrum view, an additional navigation menu direct above the control buttons is visible. These buttons are used to select any data record within the card memory for display. The button in the middle selects the last acquired record while the other buttons scroll the data memory forward and backward by a factor of one or ten. If the current cycle has been finished, the new data appear immediately on the screen.

The headline of the display shows the time stamp and, if available, the GPS coordinates of the selected data record. To return to the main page touch the **BACK** button.

## Alert Handling

In case of pending alerts, the display shows a list of components which have generated these alerts. The display is turned on automatically if necessary. An optical and acoustical alert will be generated immediately. It is required to confirm the alert status by the touch button **CONFIRM**. Alert conditions are checked at the end of each sampling interval. If a continuous sampling cycle has been chosen, the alert will be re-set as soon as the alert condition disappears. The alert settings may be changed by the customer using the configuration software dCONFIG. All necessary steps are described by the chapter “user specific settings”.

## **1. 7. The integrated GPS receiver**

The Nuc Scout is equipped by an internal GPS receiver. The coordinates (latitude, longitude), the altitude, and the deviation of the GPS fix are saved for each data record. This information is visible on the menu page for interval data as well as in the data management software dVISION. The exported text files will only contain longitude and latitude which appear directly beside the time stamp of the data record. It is possible to export the sampling data into a GIS compatible KML format. This file format can be opened directly by Google Earth™.

If the instrument will be moved during a sampling interval, the geographic average is stored. Every five seconds, the position will be fixed and averaged over the whole interval.

The shown deviation is only an indicator for the accuracy of the position depending on the signal quality. The real deviation for one point can be higher than shown.

The coordinates are presented on the display as decimal degrees with a resolution of six decimal places followed by a character for the geographic direction. The software dVISION uses positive or negative signed values instead of these characters:

0...90° northern hemisphere	= 0...+90
0...90° southern hemisphere	= 0...-90
0...90° eastern hemisphere	= 0...+180
0...90° western hemisphere	= 0...-180

If no GPS receiver is installed or the satellite signal is too poor, the text “GPS not available” appears on the screen instead of the coordinates. After starting a new sample, the receiver needs a few minutes to detect all available satellites.

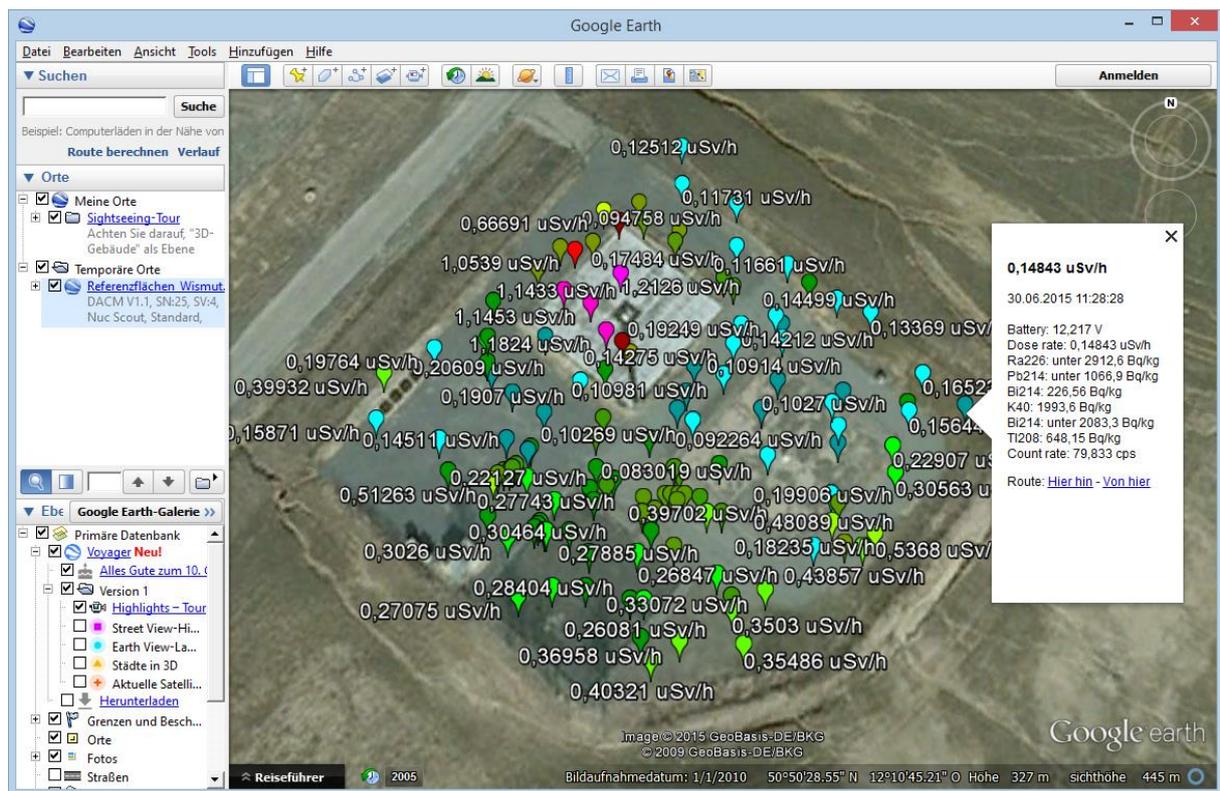
## **1. 8. PC Software**

The Nuc Scout is based on SARAD’s DACM instrumentation platform. Thereby, all system specific properties like configuration possibilities, instrument control functions, and the manner of data handling are available. The operational software dVISION as well as the configuration software dCONFIG comes with the instrument. The software runs under Windows (XP ... Win10). There are separate software manuals for both programs which will be referenced by this text.

## 2. Mapping

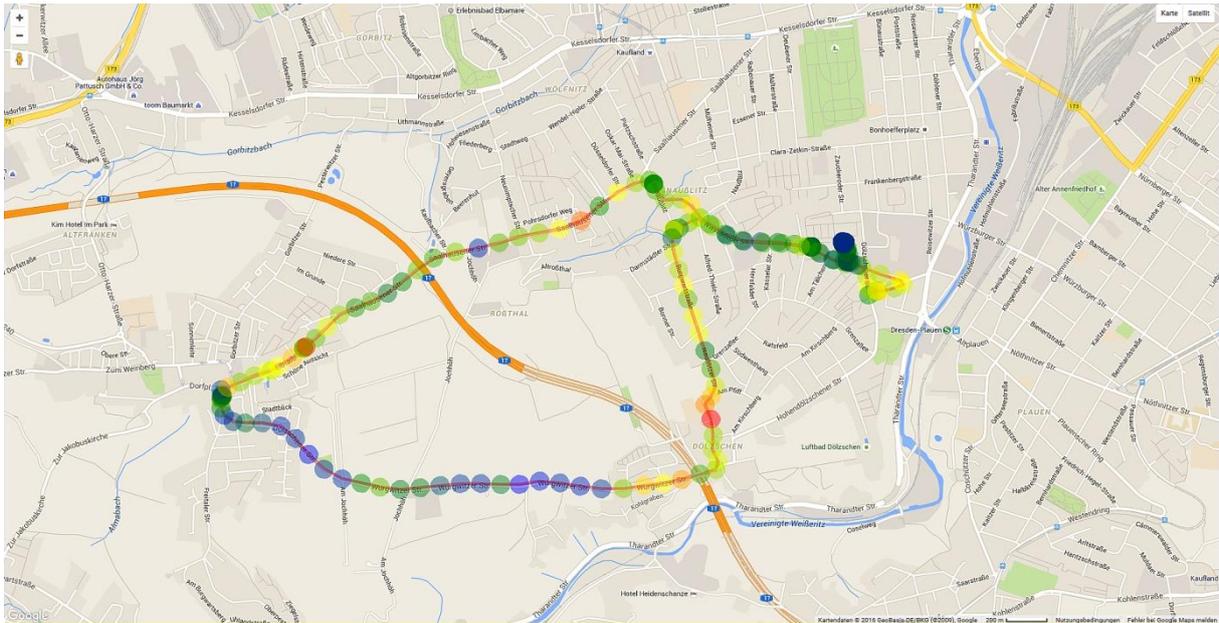
Because the Nuc Scout stores the geographical position in parallel with the obtained results as a time distribution, the instrument is perfectly fitted to mapping applications. Results such as dose rate and nuclide-specific activities are shown in dVISION's integrated map (Google Maps™). The variation of results is indicated by a spectrum of colours to point hot spots or high active regions. Furthermore, the data can be exported to KML file format. Refer dVISION manual how to create KML files. The most available GIS solutions also support the KML format for detailed analysis or extended graphic functionality.

While performing a mapping measurement, the velocity of movement must be matched to the sampling interval and the expected counting statistics. If only dose rate shall be mapped, sampling intervals of 10 to 30 seconds are suitable. Assuming a walking speed of about one meter per second, a grid of 10 to 30 meters is achieved. Sampling results as well as GPS coordinates are interpolated while moving the instrument. Passing the area several times, the resolution becomes better and better by that interpolation process. For nuclide activity analysis we recommend prolonged sampling intervals and the measurement at fixed grid positions. The screen shot below shows a typical example for dose rate mapping at a test site with three different test pads. The whole area with a size of 70 x 70 meters was crossed at randomized paths with normal walking speed and a sampling interval of ten seconds.



Results shown in Google Earth™

The next example shows a test run over various road surfaces. Areas with increased activity are red colored.



Results shown in dVISION

### 3. NaI Gamma probe

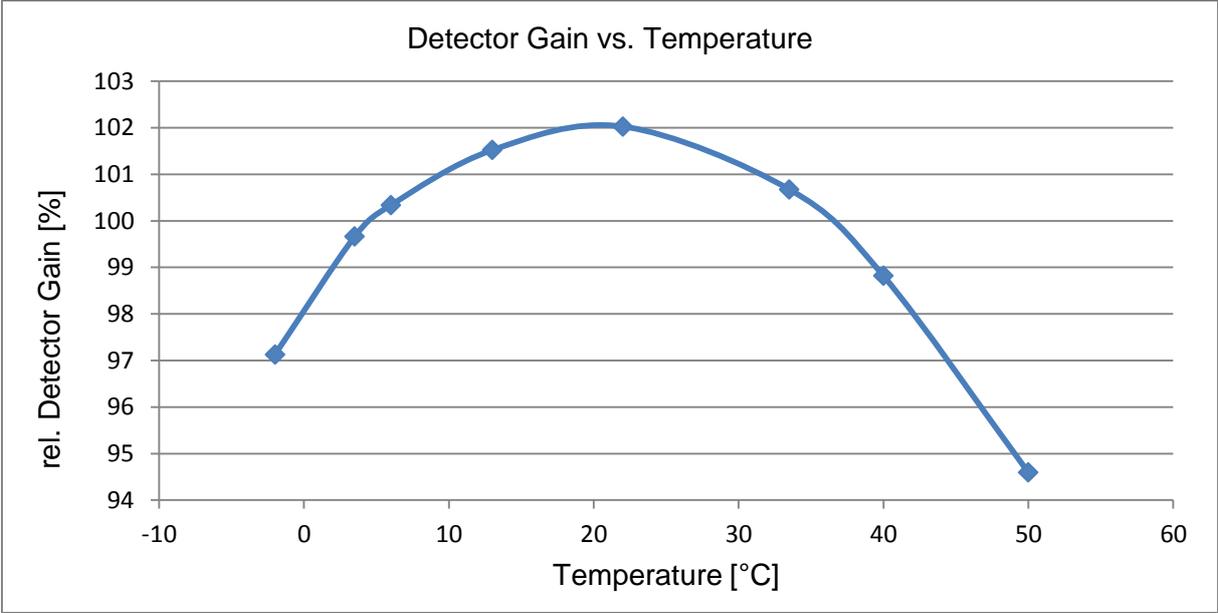
#### 3. 1. General hints for operation

The gamma probe contains a 2" x 2" NaI(Tl) detector, a photo-multiplier, a high voltage supply and the electronic circuits for signal conditioning. The probe is shielded against magnetic fields and compensated against temperature variations. The electric connection between probe and instrument is realized by a single cable, connected to the electronic box. The pulses are processed by the subsequent spectroscopy module. The supply voltage for the probe is provided by the instrument.

Photo-multipliers are vacuum tubes with a high number of internal electrodes. Therefore, they are sensitive against mechanical shocks. Even the scintillator crystal must not be exposed to mechanical stress. Do not expose the probe to strong sun light.

#### 3. 2. Temperature compensation

Sodium Iodide crystals as well as photo-multipliers show a significant temperature-dependency of efficiency and gain. Therefore, the signal gain must be regulated with respect to the ambient temperature. In case of the NucScout this is done by an electronic circuit, by the way the usage of test sources is not necessary. The electronic compensation stabilises the signal within a range of 0°C to 40°C with a maximum variation of  $\pm 2\%$ . A peak will be detected reliably by the PSV nuclide identification within this range (see also chapter "Calculation of the measuring quantity and nuclide identification"). If the unit is used out of this temperature limits, a calibration under the expected conditions must be carried out. After rapid temperature changes, the probe should be tempered at least one hour before usage. The graphic below shows that the maximum of the detector signal will be reached at approximately 22°C. For higher and lower temperatures the signal will be lowered. The energy calibration is performed at 35°C resulting in a slight peak shift to right between 5°C and 35°C and a slight shift to left outside this range.

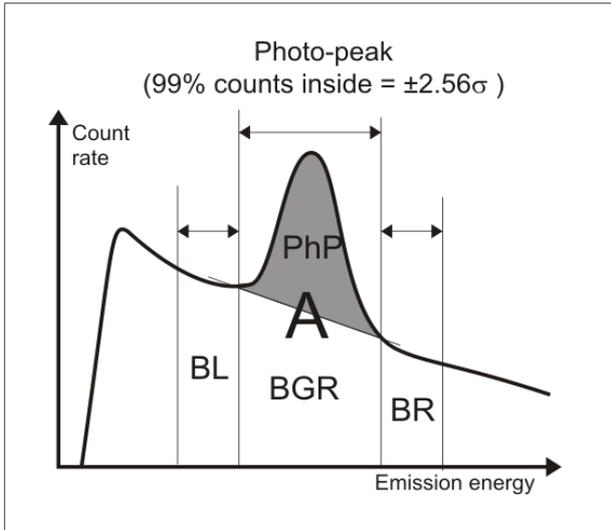


## 4. Calculation of the measuring quantity and nuclide identification

Based on the acquired spectra, the local dose rate as well as the activities of seven single nuclides (nuclide list) on user's choice will be determined. For the single nuclide analysis, two different procedures are at disposal (Trapezoid or Peak Shape Verification PSV) that can be also selected by the user. The PSV analysis is pre-set by the manufacturer.

### 4.1. Trapezoid Method

With the trapezoid method, the background to be subtracted will be determined by a linear



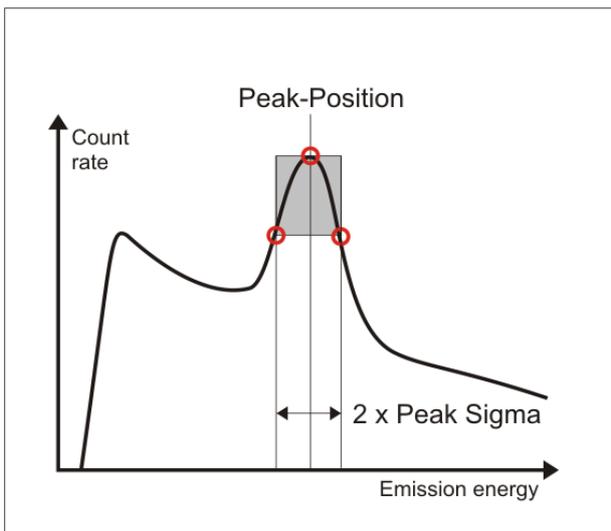
interpolation of the assumed background left (BL) and right (BR) of the emission line. To obtain a minimum detection limit, the ranges used for background estimation are defined by the half of the full peak width. Thus, the estimated pulse number in the background (BGR) will be identical with the sum of the pulse numbers of BL and BR. So the net pulse number in the photo peak (PhP) will be a result from the difference of the total pulse (A) in the peak range and the estimated background:

$$\text{PhP} = A - (\text{BL} + \text{BR})$$

The Trapezoid Method will only deliver reliable results if the background within the peak range and the background ranges can be assumed to be linear.

### 4.2. PSV Method

A photo line (peak) appears within the scintillation spectrum as a Gaussian curve superimposed to the background.



This photo line is clearly defined by its characteristic parameters  $\mu$  and  $\sigma$ . The parameter  $\mu$  meets the position of the peak (peak position) within the spectrum while  $\sigma$  determines the width of the peak. The peak width is a function of emission energy and is a characteristic for each detector. The PSV analysis is based on the comparison of the peak shape ( $\mu$ ,  $\sigma$ ) to be expected from the detector calibration with that real shape determined from a measurement.

For this purpose, the spectrum will be smoothed by means of a suitable filter in order to suppress the statistical fluctuations within the counting channels. In the range of each peak as defined in the peak list will be searched for a maximum ( $\mu$ ). If a maximum is present the accompanying turning points ( $\sigma$ ) shall be determined. If the parameters will be in coincidence with the values of the detector

calibration the area of the peak (net pulses) can be determined by means of shape parameters independently upon the background. The PSV analysis guarantees that only “real” photo line will be verified. Furthermore, just the real range of spectra of the peaks (c. double half-width) is needed. So the peaks that are directly situated side by side can be clearly separated and calculated. Another advantages are given by compensating small spectrum shifts (e.g. by temperature fluctuations).

The following table refers to the advantages and disadvantages of both analysis methods and their preferred use.

	Advantages	Disadvantages	Use
Trapezoid	Lowest detection limit  Highest accuracy	Requires a linear background in the peak range and left and right of it  Calculates values for any convex spectrum course  Sensitive for slight spectrum shifts	Lab works with known samples  Efficiency calibration with specific calibration sources
Peak Shape Verification (PSV)	Allows slight spectrum shifts  Verifies only „true“ photo peaks  Also correctly calculates peaks being directly side by side	Higher detection limit  Greater statistical error	All kinds of field measurements and „in situ“ analyses

### 4. 3. Calculation of the nuclide-specific activity

In order to be able to determine the activity of a nuclide within a sample, in addition to the net pulse number (N) in the photo peak are required: the measuring time (T), the transition probability of the emission line selected (P) and the counting yield (efficiency  $\eta$ ) of the detector. The transition probability is a constituent of the peak information of an entry in the peak list. The efficiency must be determined by a previous calibration. It contains both the energy-dependent response curve of the detector and the geometry effects and absorption effects of the sample or between detector and sample, resp. The activity of a nuclide can be calculated as follows:

$$A = \frac{N}{T * P * \eta}$$

#### 4. 4. Calculation of the dose rate

In order to calculate the local dose rate, at first, the energy-dependent photon-flow  $\Phi(E)$  in the radiation field needs to be determined. Base for it is the measured energy spectrum of the detector as well as its efficiency characteristic with taking a homogeneous radiation field for granted.

$$\Phi(E) = \frac{R(E)}{\eta(E) * F}$$

R(E) counting rate of the detector at the photon energy E

$\eta(E)$  efficiency of the detector for the photon energy E

F cross-sectional area of the detector

The energy-dependent dose rate can be determined by using the energy-dependent mass energy – absorption- coefficient of air  $\mu(E)$ :

$$\frac{H(E)}{t} = \Phi(E) * E * \mu(E) = \frac{R(E)}{\eta(E) * F} * E * \mu(E)$$

H(E)/t dose rate (dose H / time t)

$\mu(E)$  mass energy-absorption-coefficient of air

Now, the dose rate for the whole energy range in the spectrum is given by the equation:

$$\frac{H}{t} = \int_0^{3MeV} \frac{R(E)}{\eta(E) * F} * E * \mu(E) dE$$

The integration is performed numerically, i.e. the partial dose contributions are being summed up. This procedure will secure a correct determination of the dose rate, independent on nuclide vector, by means of which the radiation field is generated. So a calibration of a Cs-137 reference source keeps its validity for natural radiation fields likewise.

## 5. Tools for Gamma Detectors

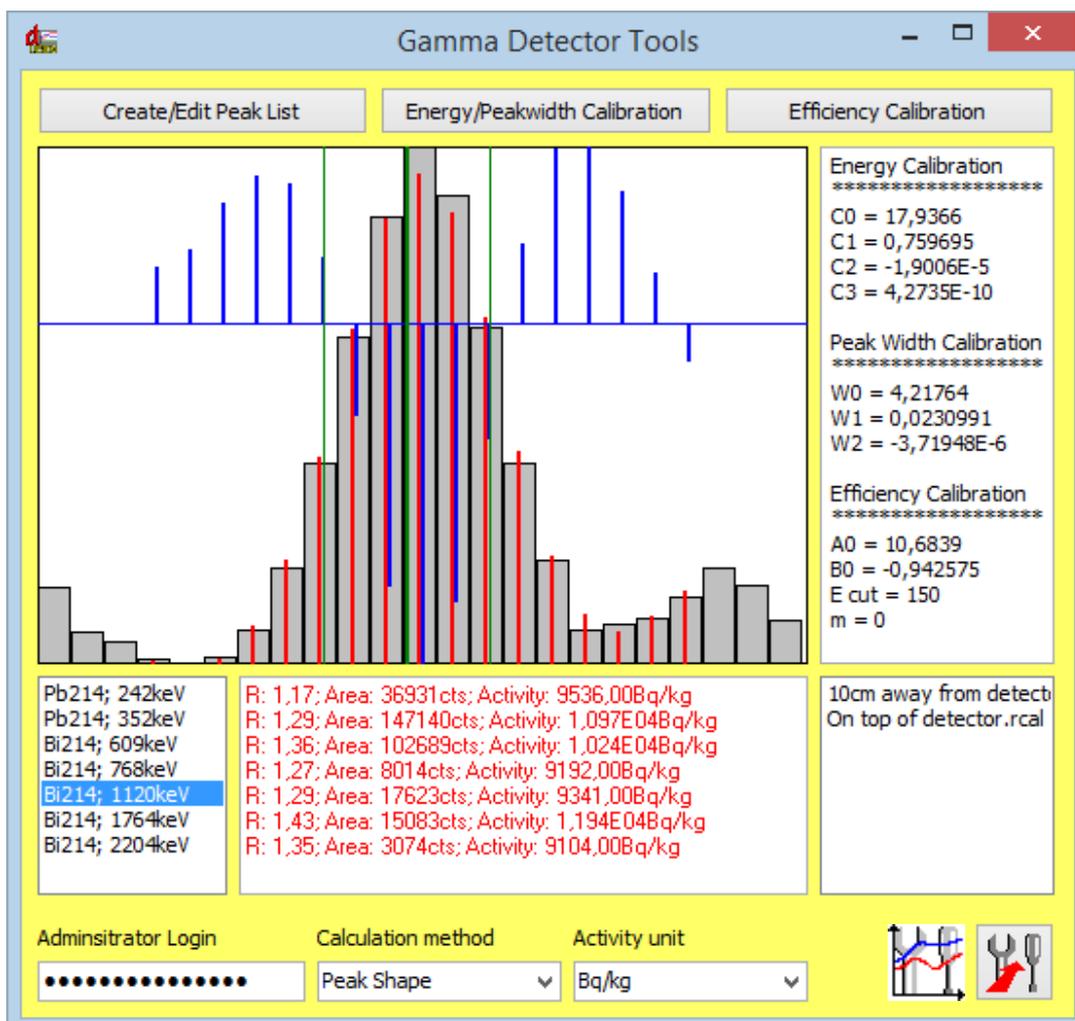
The software dVISION as a part of the delivery volume offers a set of tools that are required for the configuration and the operation of gamma detectors. They are summarized in a window which has to

be opened via the switch area “Tools”  in the spectrum view of dVISION. The following functions are implemented:

- Detector calibrations
- Editing of the nuclide list used for analysis
- Selection of the calculation method and the physical unit of the result
- Selection of predefined measuring geometries for the quantitative analysis
- Detailed analysis of the recently displayed spectrum

Except changing the peak list, a password is required to manipulate parameters.

The calibration of the detector and the selection of the nuclide list will be explained in details in the sections “Detector calibration” or “Definition of the nuclide list”, resp.



The window contains a graphic area in which the spectrum range in the environment of the selected emission line is displayed. Beneath it, two list boxes are placed that contain the information of the

emission lines in the nuclide list just selected. A click on a nuclide in the left box will select this nuclide for display in the graphic area. In the box next to it will appear the results of the analysis. It might be either a calculated activity or the reason why the verification went wrong (e.g. no maximum had been found or an invalid peak shape).

The spectrum channels are displayed as grey bars in the graphic. They will be summarized in its type, thus, a constant peak width will result independent on the position in the spectrum. The red lines show the spectrum range after smoothing by means of filter while the blue line will display the second derivative of the filtered spectrum. Here a zero crossing means the position of the inflection. The green vertical lines display the position of the expected value deducted from detector calibration for the peak position and its width (Sigma). The meaning of these parameters will be explained in detail in the section "Calculation of the measuring quantities and nuclide identification".

The right part of the window displays the polynomial coefficient of the used detector calibration. There is a list box by means of which you can select pre-defined measuring geometries. They meet an efficiency calibration carried out for this geometry. The calibrations are saved as binary files (extension „\*.rcal“) in the subdirectory "CAL". The list box displays the names of all the files available in this directory. More data whatever can be added by the user. This will be done within the framework of the efficiency calibration.

There are list fields in the lower window range for selecting the activity unit to be used and the calculation method to be used. The access to the calibration functions and the selection of the analysis method are protected by code. It must be entered in order to enable the relevant control elements.

All the changes done will have an immediate impact on the activity values calculated from the spectrum so that the result of the manipulation can be checked at once.



The switch area „Transfer“  will enter all the performed settings (incl. nuclide list and calibrations) into the instrument. As long as the analysed measuring data are still available in the instrument storage they can be loaded from the instrument under usage of the new settings. This will e.g. enable the analysis of a complete measuring series with different nuclide lists. In order to make the changes effective on the instrument you must start a new measurement but which can be again cancelled at once.

## 6. 1. Retrospective data analysis

This function was implemented to apply a changed configuration of the instrument to already saved data files (\*.dvb). Use the function to

- analyse present data files by usage of various editable nuclide lists
- apply changed calibration parameters (such as sampling geometry) to the acquired data
- apply recent calculation algorithm to data acquired with instruments running under older firmware versions

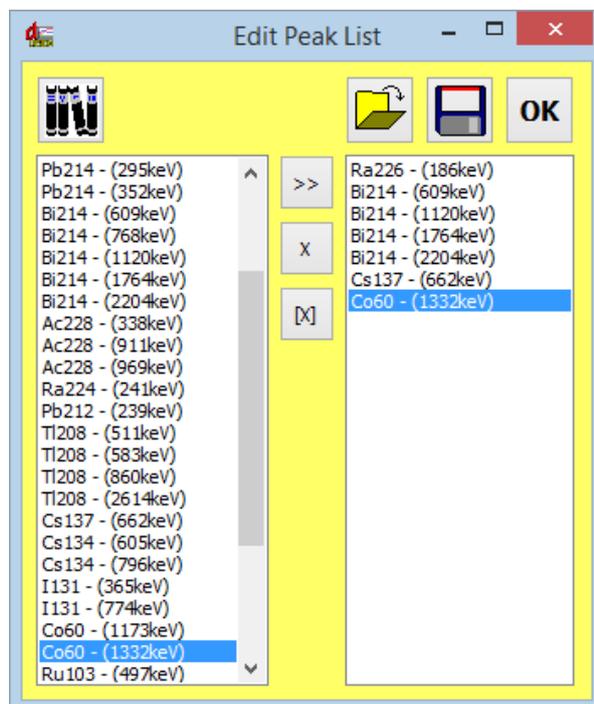
In a first step, the configuration to be applied should be edited using the "Gamma Detector Tools" as described in the following chapters. Use any acquired spectrum (from instrument or data file) which

allows the derivation of the desired parameters (e.g. reference spectrum of calibration sources for calibration parameters). In the next step the  button opens a dialog window to select the file to which the new settings shall be applied. After selecting a file, the diagram view shows the new calculated results. These results can be exported in the same manner like the original data. Please note that the original data file (\*.dvh) remains unchanged.

Attention: Use this function only for identical hardware (same device, same detector).

## 6. Definition of the nuclide list

By means of the nuclide list (also called peak list) you will determine what emission lines shall be identified and quantified. The nuclide list contains a selection of seven emission lines at a maximum which will be displayed later as measured values and stored, respectively. Due to the flexible handling of the list the different peak lists can be used on an acquired spectrum. The selection of the emission lines will be performed by the help of a library which will be part of the delivery volume of the operating software dVISION the contents of which can be edited by the user.



Each line of the file contains the name of the nuclide the emission energy as well as the transition probability of the photo peak. These entries are separated by tab stops. By means of the Windows Editor you can add any nuclides. But note, that the names of the nuclides shall have only five characters at a maximum, the emission energy shall be entered as an integer value in the unit "keV" and the transition probability in percentage (here are floating point numbers allowed).

The tools for gamma detectors offer an easy possibility to edit the nuclide list. These can be called on from the spectrum view of dVISION. Clicking the switch area "Edit/ Create Peak list" will open a dialog window that contains at the right side a list box for the nuclide library, and at

the right side a further list box with selected emission lines.

First of all, by means of the switch area „Library“  a library must be loaded.

The **switch areas** between both lists perform the following manipulations:

- [x] will delete all entries from the nuclide list
- X will delete the selected entry from the nuclide list
- >> will take over the entry into the nuclide list as selected in the library

At a maximum, seven nuclides can be assigned to the nuclide list. Therefore, possibly, you should remove that photo lines not needed any longer, before you will add new lines.

By means of the switch areas „Open“  and „Save“  you can store the nuclide lists made out or you can load them. By means of the switch area “OK” the new list will be taken over. The transfer to the instrument shall be done by clicking the switch area „Transfer“  in the tools for gamma detectors. Precondition for it is an opened connection to the instrument.

## 7. Detector Calibration

Several calibrations are required for the identification and quantification of radiation sources.

### Definition of the energy range

will fix the energetic upper limit of the spectrum to be analysed (adjustment of the detector signal to the ADC entry of the multi-channel analyser)

### Energy calibration

is used for the positional determination of a peak within the spectrum (assignment of the ADC channels to the emission energy)

### Peak-Width calibration

will fix for the **trapezoid method** the width of the peak ranges and the background ranges. For the PSV analysis, it delivers the anticipated comparison value to the actually measured peak width.

### Efficiency calibration

compensates the energy-dependent response curve of the detector as well as the absorption in the probe or between probe and detector, resp.

The instrument will be delivered with being completely calibrated. There are, on your choice, different efficiency calibrations for common standard applications. But in case of special applications, a new calibration might be required.

While the setting of the energy range is being done from the hardware part by means of a potentiometer on the probe the required calibrations can be performed very easily and quickly per software. Preconditions for doing it are suitable calibrating standards.

The calibrating functions are accessible via the spectrum view in the operational software dVISION. There you will find - in the right side upper corner of the window – a button used to open the tools for gamma spectroscopy. The various functions will be explained in detail in the following paragraphs.

### 7. 1. Definition of the Energy Range

The energy range is fixed by the amplification as set on the probe. By means of a potentiometer at the rear of the gamma probe (photo) you can adjust the dynode voltage of the photo multiplier. If you turn in a clockwise direction, the amplification will be increased. Resulting from this



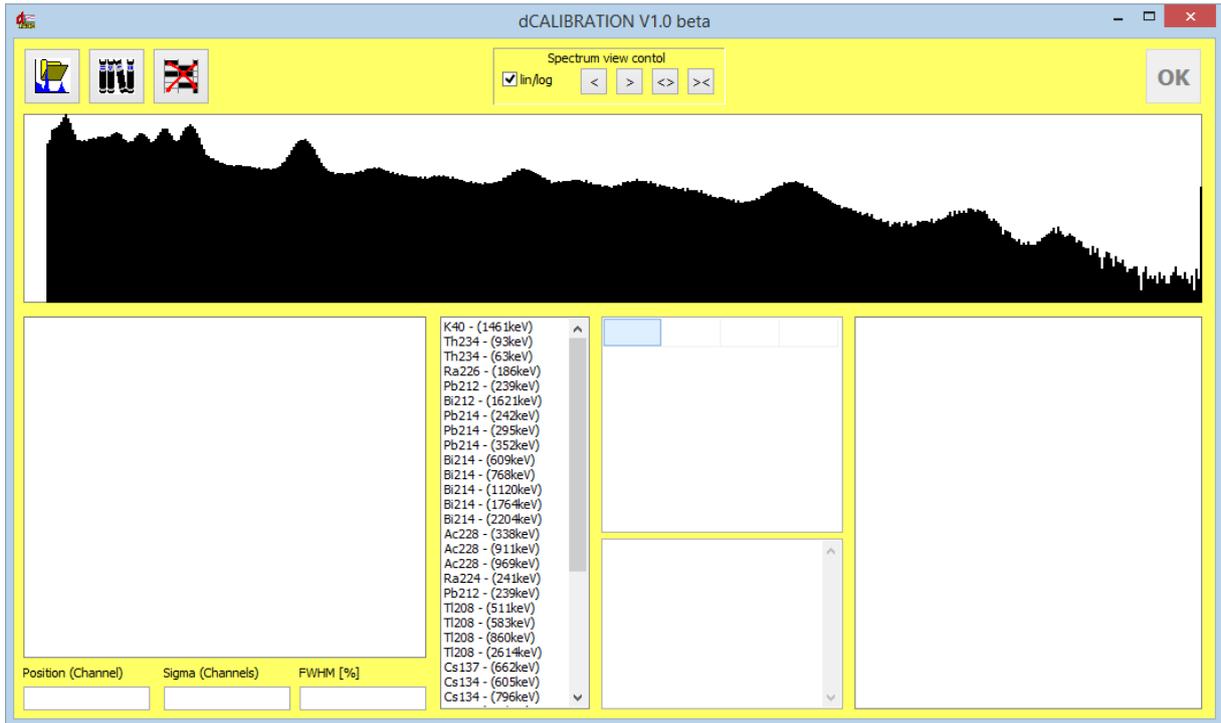
the photo peaks will be shifted to the right, and in this way the measuring range will be limited. Vice versa, the measuring range will be extended by turning the potentiometer in a counter-clockwise direction. A greater amplification will result in a slight reduction of the peak width, the maximum counting rate will be reduced by the increased dynode current though. The instrument, when delivered, has a setting for a measuring range of c. 3 MeV, so Tl-208, likewise will be in the spectrum. The lower limit (threshold of pulse recognition) of the energy range can be adjusted by means of the configuration software (dCONFIG). With instrument delivery, it is approx. 25 keV. An increase of amplification might be purposeful, for example, if you want to make measurements in a range below 25 keV.

Please note: When setting the energy range, pay attention, that the peak to be analysed and being in the most right position shall not be directly at the spectrum boundary. Conditioned by the methods of analysis an additional distance from the right boundary will be required at an amount of the peak width.

## **7. 2. Energy calibration and peak width calibration**

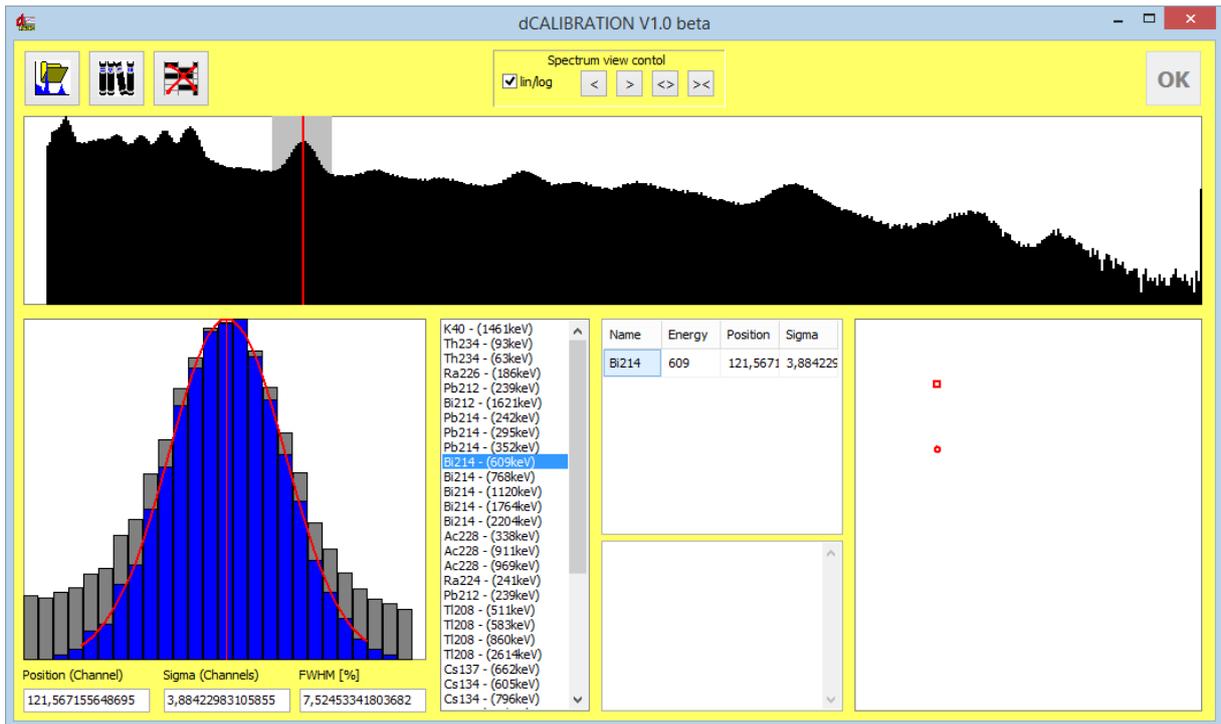
The calibration of energy and peak width will be performed in one single step. At the beginning, a calibrating spectrum will be taken by means of the instrument that should contain photo lines as many as possible in the whole energy range. We recommend to use a solid radium or thorium test source. The measuring time shall be selected in such a manner that the statistical fluctuations of the single counting channels will not result in a falsification of the Gaussian profile of the peaks. Now, the acquired data can be loaded from the instrument by means of dVISION, and the calibrating spectrum can be displayed. The button "CAL" in the upper right-side corner of the window will open the tools for gamma detectors. After having entered the administrator code the switch area "Energy/Peak width calibration" will be at your disposal. An interactive window will be opened that already will contain the calibrating spectrum. The following steps shall be carried out:

1. Open a nuclide library. This text file must contain that photo lines as used for calibration. The Installation of the software dVISION contains the standard library file "Gamma-Library.txt".



2. Mark the limits of the first peak that is intended to be used for calibration. In order to set the markings you should click – by means of the right mouse key at the right side, by means of the left mouse key at the left side – beside the peak. The peak range is highlighted in grey colour in the spectrum and appears separately in the graphic box under the spectrum. The limits shall be set in such a manner that the whole peak will be contained. The limiting channels will be used for a linear background subtraction. The blue bars show the net peak after this subtraction. With sufficient statistics and a correct range selection the net peak should appear symmetrically. A Gaussian curve (red line) that represents the modelled peak with mean and standard deviation is overlaid. These parameters and the peak width resulting from it (Sigma or FWHM, resp.) will be displayed in the text fields beneath it.

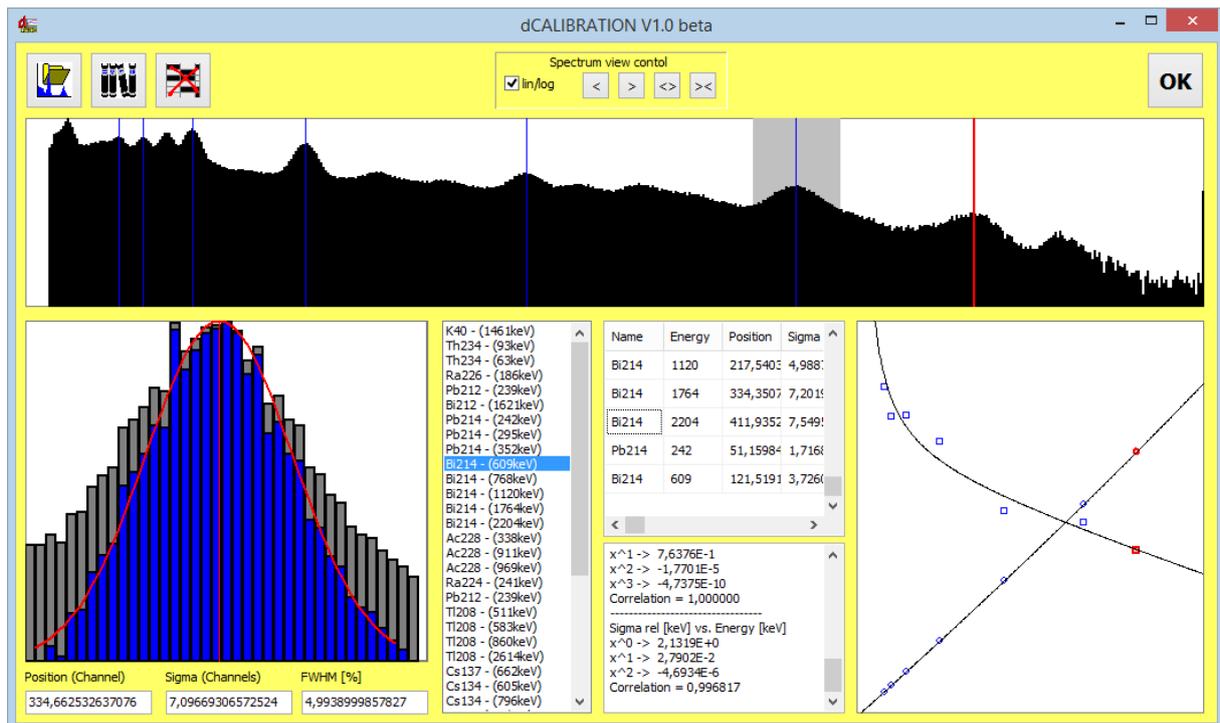
A double-click on to the nuclide in the library that corresponds with the selected peak will add its pieces of peak information to the list of calibrating points (right-hand side beside the nuclide library). The graphic box at the right down side will display the first data points for energy and FWHM.



3. Repeat that steps as given under point 2 for the next peaks. Already with adding the second data point the calibrating curves will be calculated. But you should consider that a polynomial of third order will be expected as a calibrating curve. Therefore, four data points at a minimum should be used. At a maximum, nine data points can be used. At the same time, the peak width calibration will be performed by using the Sigma calculated of the single peaks. This will be described by a polynomial of second order.

In order to remove a peak from the list it will be sufficient to double-click in the corresponding line of the calibration point list. The text field beneath it contains the calculated coefficients of the polynomial for various instrument-specific definitions of the calibrating function.

If there might be the need for using more than one spectrum the spectra can be sequentially imported. The calibrating points already entered remain existent.



The calculated coefficients will be taken over by means of the button „OK“. The calibrating parameters can be entered into the instrument by clicking the button “Transfer”  (precondition is an opened connection to the instrument).

### 7. 3. Efficiency calibration

In order to correctly calculate the activity of a nuclide, in addition to the knowledge of the emission probability of the used photo peak, the energy-dependent counting yield of the detector must be taken in account. On the one hand, it is dependent on the detector sensitivity and, on the other hand, on the absorption in the sample or the shielding between sample and detector, resp. In case of nearly homogeneous samples and emission lines greater than 100 keV the efficiency can be described very well by means of a function of the following equation:

$$\eta(E) = \frac{R(E)}{Z} = A * E^B$$

with:

- $\eta(E)$     Detector efficiency for the photo peak with the emission energy E
- $R(E)$     energy-dependent counting rate of the detector
- $Z$         decay rate of the relevant photo line of the emission energy E
- $E$         emission energy
- $A, B$     equation parameters of the approximation function

From this, an easy and quick possibility is given for efficiency calibration by means of a reference sample. Geometry and density of the reference sample should correspond at a good approximation with those of the samples to be analysed. Generally, only two emission lines will be required. Due to

the function course one line should be below 300 keV, another line above a 1,000 keV. The calibration will be very easy if all the required lines are existent in one spectrum.

Precondition for the efficiency calibration is an energy and peak width calibration of the instrument already performed. Firstly, a measurement of the reference sample shall be performed. The measuring time should be taken in such a manner that the expected statistical error of the achieved counting sums can be neglected in the photo peaks that are used for calibration.

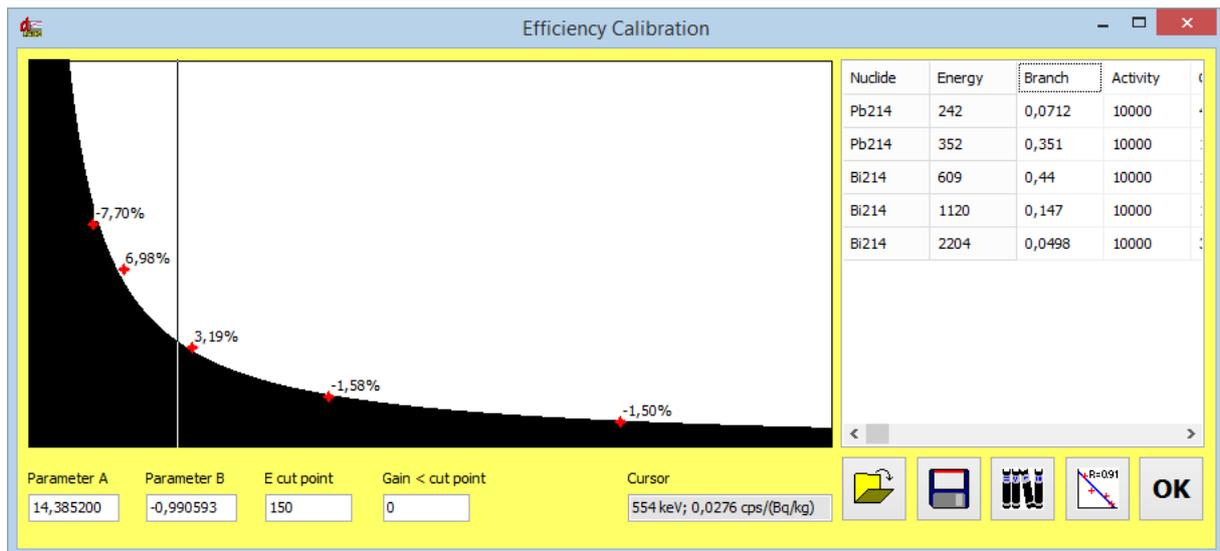
After having loaded the measured values the tools for gamma detectors can be opened from the spectrum display. After entry of the administrator code the switch area "Efficiency Calibration" will be accessible. In order to simplify the calibration, first of all, the peak list should be adjusted in such a way that all the emission lines needed for calibration are contained. (Refer to section "Definition of the peak list"). With a correct energy calibration and sufficient counting statistics, corresponding net counting pulses (peak area) will appear for the selected peaks in the result box of the tool window. They will be taken over jointly with the parameters of the selected peaks for the efficiency calibration.

By clicking on the button "Efficiency calibration" the calibrating window will be opened. Before, an query to enter the activity of the reference sample will appear. This value is used as a pre-setting for all the peaks included in the calibration. If all the peaks of a nuclide or a decay series are in a radioactive equilibrium so there will be no need of more entries later. Here likewise, we recommend e.g. radium or thorium samples.

The calibrating window, at the left side, contains a graphic range to display the relevant efficiency calibration function. Below the graphic range, energy and efficiency will be given for the relevant cursor position. Small red crosses will mark the calibrating points determined from the available reference measurement and the activity pre-setting.

The table in the right window range contains all the emission lines needed for calibration. The fields for activity and counting rate can be edited. This allows entering the true values for all nuclides theirs activities do not fit with the previously input. Furthermore, the peak list can be increased (or reduced) in order to include calibrating points from other samples (with manual input of activity and count rate).

A click on the button „Library“  will open the selection dialogue. Of course, for these emission lines both the counting rate and the reference activity shall be entered.



If you now click on the button „Calibration“  the program will calculate the approximation best possible of the afore- described function for all the calibrating points used. The resulting deviation of the single markings from the functional value should amount to some percentages at a maximum, otherwise the reference activities assigned to the lines shall be checked and possibly changed in the table right beside the graphic. If greater deviations remain existent in spite of correct entries, one or several lines might be unsuitable for calibration, e.g. by superimposing of another line or insufficient counting statistics.

Furthermore, switch areas to store and load of efficiency calibrations are at your disposal. More particulars for their management can be found in the section “Tools for gamma detection”.

## 8. NucScout Hardware and virtual spectrometers

The NucScout is equipped with a 512 channel spectrometer. The hardware can be fitted physically to the requirements of the used detector. The setup contains parameters like pulse threshold, ADC resolution, channel offset, sampling point.

In parallel to the hardware settings, the spectrometer may be configured with respect to the desired sampling results. These parameters do not affect the spectrum acquisition but define the interpretation of the achieved data. Typical parameters are efficiency calibration and nuclide list.

Virtual spectrometers allow the assignment of various kinds of result calculations to the one unique spectrometer hardware. The NucScout implements four virtual spectrometers called SPEC1\_A to SPEC1\_D. This technology offers a number of possibilities for the usage within the sampling cycles:

- Using various nuclide libraries (seven emission lines each) simultaneous. For example, libraries for natural, medical, technical and nuclear sources can be defined.
- Using various geometry calibrations for different tasks
- Using several detectors with different hardware characteristics
- Zooming out spectra windows with higher physical resolution

Each of the four virtual spectrometers can be configured independently by using the “Tools for gamma detectors” (see chapter 5 to 7). The spectrometers may be used within a cycle exclusive or in any combination (see manual dVISION). The commonly used hardware results in two limitations:

- 1) The hardware configuration must be identical for all spectrometers used at the same time. If two or more spectrometers with different hardware configurations are used within one cycle, the last order spectrometer defines the applied parameters (e.g. SPEC1\_D if SPEC1\_B and SPEC1\_D are activated)
- 2) If virtual spectrometers are activated or deactivated for periods within the cycle basic interval, all of them must use the same timing. The spectrometer hardware will be started and stopped at any status change (active to inactive or inactive to active) of any spectrometer.

## 9. Count rate indication

The Signal of the gamma probe is also tied to an independent detector input. The input offers a comparator stage defining the pulse threshold for the detector signal while the subsequent counter presents the count rate. Both, comparator and counter can be configured, e.g. to obtain a sampling result from the count rate.

## 10. User specific settings

The instrument is based on the DACM platform, which provides flexible tools for custom specific configurations. Each of the functional blocks, the so-called components, can be configured and controlled separately using the PC software dCONFIG. Changing the configuration requires caution and should be carried out by skilled persons only (administrator). Erroneous settings may result in a male function of the instrument. Before changing anything, the operator should read the recent configuration from the unit and save it on PC as configuration file. If necessary, this file can be written back to the unit in case of trouble. Each component offers a specific configuration window in dCONFIG for all available configuration parameter. The dCONFIG software manual informs of the procedures to access the various configuration windows.

### 10. 1. Changing alert settings for dose rate and nuclide activity

#### Configuration window of component SPEC1 (SPEC1\_A...SPEC1\_D)

Generally, two independent alert thresholds are available for activity results. The physical unit of the entered thresholds is equal to the one of the calculated result (e.g. Bq/kg). One or more nuclides as well as the dose rate may be assigned to each of these thresholds. The selection of alert sources is done by the list boxes “Alert 1 Source” and “Alert 2 Source” in the lower area of the configuration window. These boxes contain all nuclides defined by the recently used nuclide list, and additionally, the dose rate. Marking one or more of the check boxes forces the alert check of the related result(s). If one of the results exceeds the threshold level (“Alarm 1 Threshold” and “Alarm 2 Threshold”), the alert becomes activated. The alert function can be disabled by selecting the item “inactive” instead of “DOUT4” from the list box “Alert output”.

### 10. 2. Changing the alert level for the count rate

#### Configuration window of components CNT1

The alert threshold for the count rate can be configured in the configuration window of component CNT1 (“Alarm if count rate becomes higher than”). The alert can be disabled in the same manner as described for the radiometric measures if the item “inactive” will be selected from the list box “Alarm index higher than”.

### 10.3. Suppression of optical and acoustical alerts

#### Cycle definition chart

The instrument allows generating silent alerts. That means, optical and/or acoustical signalling devices can be disconnected. The connection between the alert output “DOUT4” and the buzzer/LED can be interrupted by two additional switch contacts (DOUT2: buzzer; DOUT3: LED). These switches can be controlled by activating/de-activating them within the cycle definition. In normal alert mode (allowed), both switches are activated. To suppress one of the devices, the related output just needs to be de-activated (see manual dCONFIG).

### 10.4. Enabling of the wireless interface in standby mode

#### Configuration window of component DOUT2

The power supply for the wireless interface can be switched on/off with the status of the switch output DOUT5. The output can be controlled during the measurement by the cycle definition chart (see dCONFIG). The configuration window offers the possibility to define the status of the output during standby. Use the list box “Reset status” either to turn on („active“) or turn off (“inactive“) the interface. After delivery, the reset status is set to „inactive“.

## Appendix

Assignment of components in dCONFIG

Name	Funktion im NucScout	Komponenten-Gruppe
DOUT2	Enable acoustic alert	Switch outputs
DOUT3	Enable optic alert	Switch outputs
DOUT4	Alert output	Switch outputs
DOUT5	Power supply ZigBee	Switch outputs
DOUT6	Power supply Nal electronics	Switch outputs
DOUT7	Power supply Nal probe	Switch outputs
CNT1	Gros counter	16 bit counters
BATT	Battery voltage measurement	Internal sensors
SPEC1 (A-D)	Gamma spectrometer	Spectrometer
CMP1	Gros counter threshold level	Voltage comparator input