Risø NaI(Tl) Gamma Spectrometer

Software User's Manual on Version 1.3

Revision 1.3
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READ THIS MANUAL CAREFULLY BEFORE YOU START TO DO ANYTHING!

Please make a copy of all folders in this disk onto your own PC.

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1 Acquisition Software: GammaAcq

1.1 System Requirements

- Windows 7/8/10 x64 should be installed in advance.
- Your computer should have at least 3 GB of disk space available.

1.2 Software Installation

GammaAcq is used to acquire and display gamma spectra of samples and calibration standards.

To install GammaAcq software:

- If necessary, close and uninstall any previously-installed GammaAcq software.
- Install hardware driver first:
  i. Unplug the gamma detector USB cable from the PC if it is connected.
  ii. Insert the Risø Gamma Software Flash Drive into a USB port on your PC.
  iii. Open \Software\Driver\ folder in USB drive, run installation file **BPI-MDS-2.0.14.exe**. Follow the Setup Wizard as shown in Figure 1.1-1.2, accept all the default settings, and click "Next". As shown in Figure 1.3, uncheck all the components but keep the "**USB Drivers for eMorpho"**, and then complete the Setup Wizard.

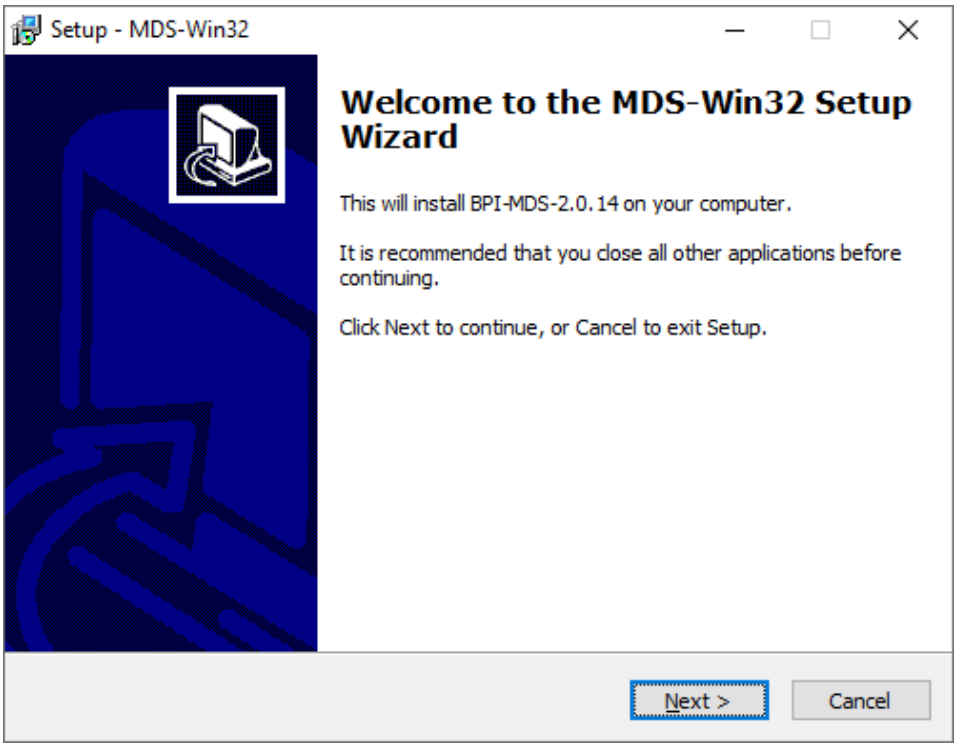

Figure 1.1: Driver Setup Wizard.

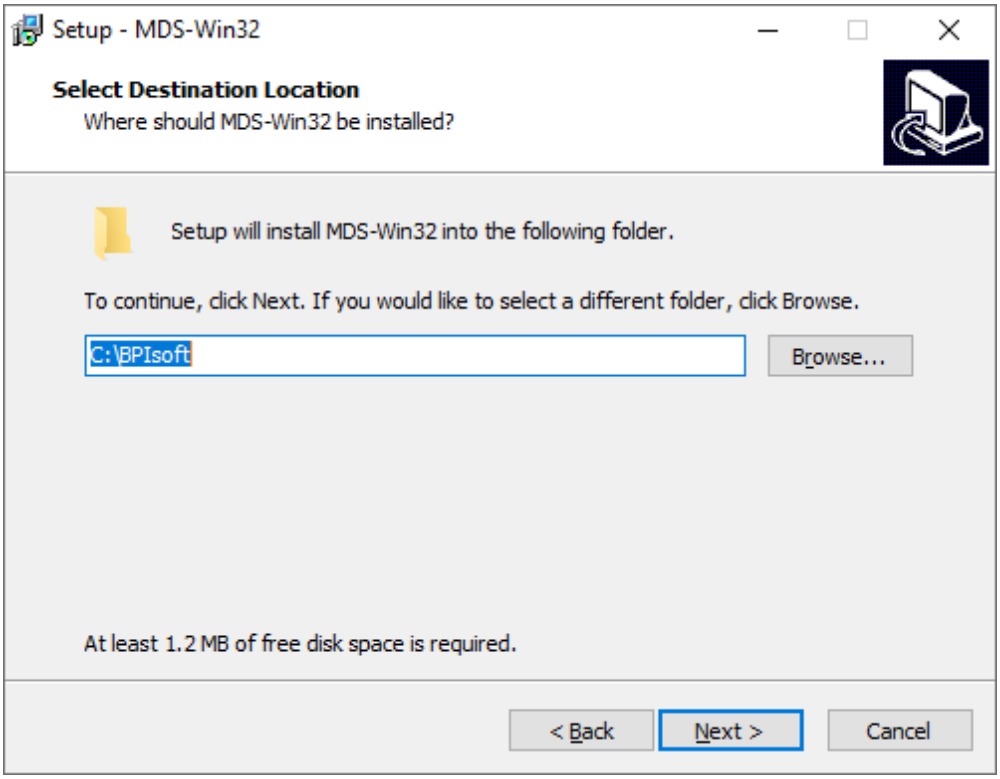

Figure 1.2: Select setup destination folder.

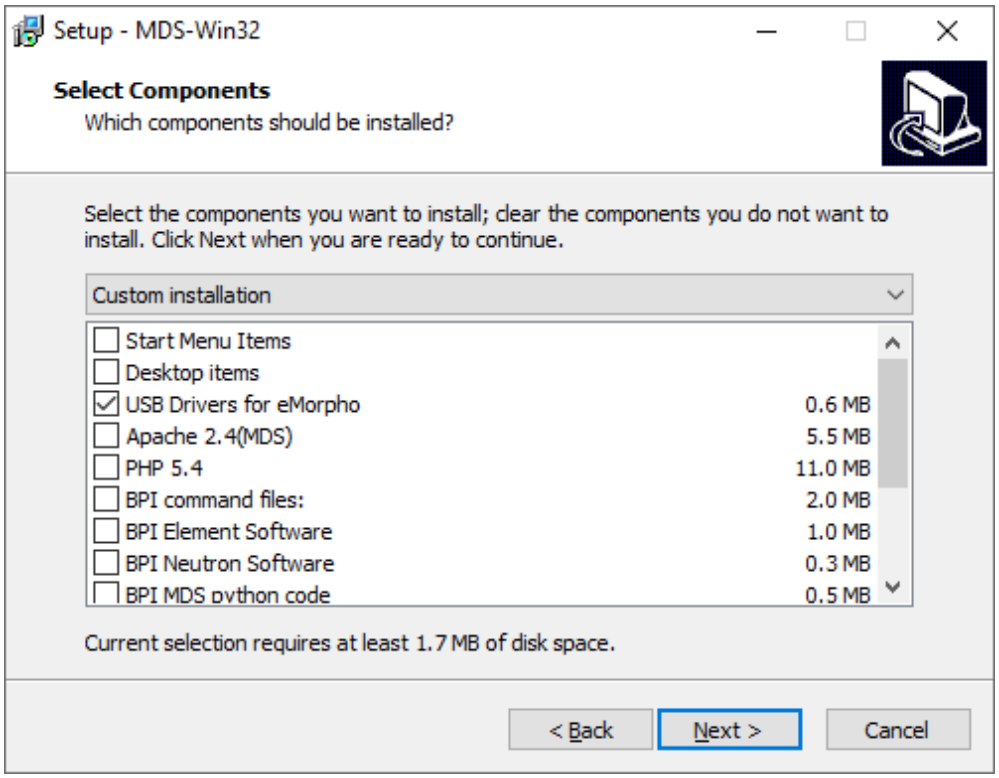

Figure 1.3: Select component USB Drivers for eMorpho for installation.

- Open the \Software\GammaAcq\ folder on USB drive and run Window installer file *Risø Gamma Spectroscopy Acquisition.msi*. If you are using Windows 7/8 (or a 64-bit version of Windows) you must right click on it and select *Run as administrator*.
- Follow the Installation Wizard and finish installation.
- The program is located in the default installation folder: "C:\Program Files\Risoe\Risoe Gamma Spectrometer\Acquisition\GammaAcq.exe"

1.3 Software Introduction

After software installation, connect the USB cable from the NaI gamma detector to the PC, and double click the *GammaAcq* to start the program.

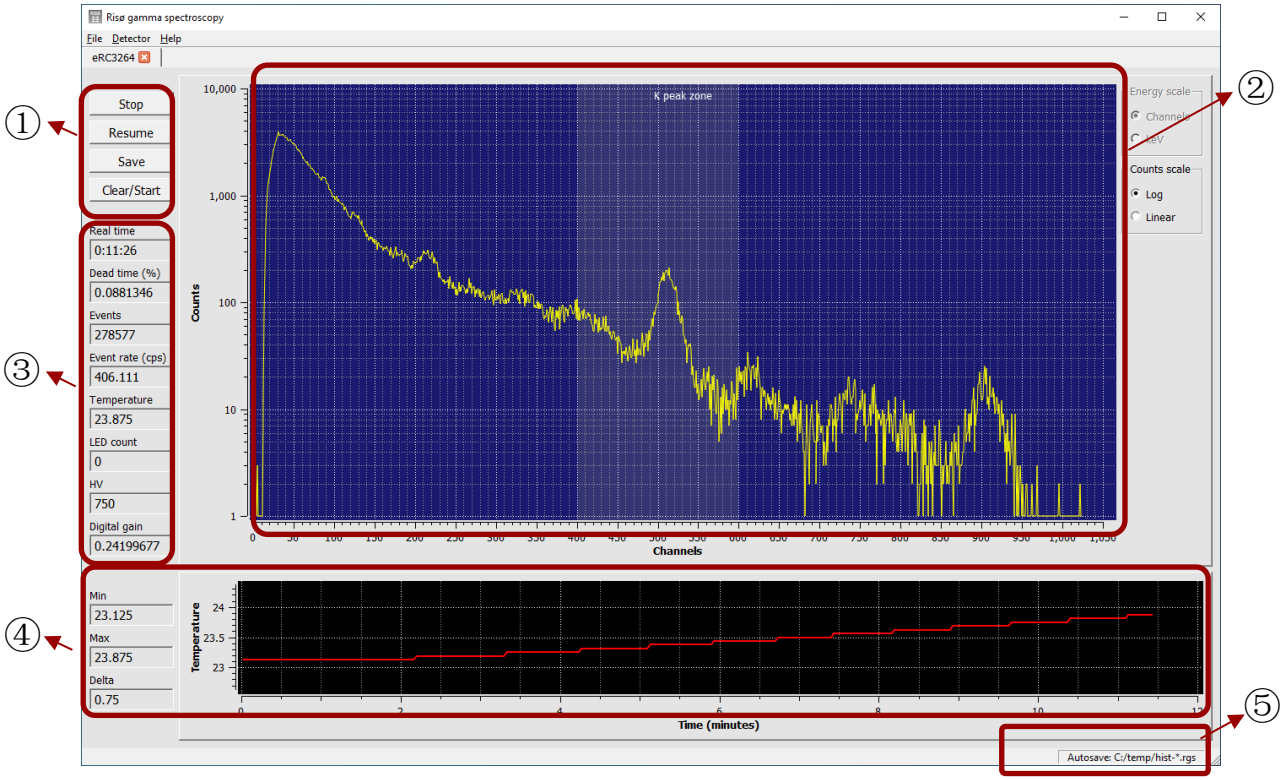

Fig. 1.4: Graphic User Interface of *GammaAcq* software. ① command buttons, ② gamma spectrum histogram, ③ counting/setting parameters, ④ temperature of the detector, and ⑤ information bar.

First Time Running:

Fig. 1.4 shows user interface from *GammaAcq* when the software runs for the first time a few seconds after the NaI gamma detector has been connected to the PC. When the *GammaAcq* software is started, the run time is shown in the "*Real time*" window (see ③ in Fig. 1.3); even though no gamma counts are displayed in graph ②.

The *GammaAcq* user interface include ① command buttons (top left), ② the measured gamma spectrum (middle), ③ counting/setting parameters (middle left), ④ detector temperature (bottom), and ⑤ information bar (bottom right corner).

If you run *GammaAcq* when the NaI detector is not connected to the PC, it is only possible to open previously saved gamma spectra.

1.4 Set Detector Parameters

When the detector is connected to the PC for the first time, and the *GammaAcq* software is started, the HV and Digital gain (③ in Fig. 1.4) are randomly set. These values are usually different from the suggested values in the detector *specification sheet*. When you click the "Clear/S*tart*" button, usually the appropriate parameters from the *specification sheet* will be loaded from the non-volatile memory in the detector. In case that the software is not able to load these parameters automatically after clicking "Clear/S*tart*" button, you have to set them manually (as described in section 1.4.1).

The position of gamma spectrum in the histogram chart is determined by

i. The HV and Digital Gain parameters in the detector, and
ii. The temperature in the lab where the detector is installed.

As the temperature in your lab might be different from the gamma spectrometry lab at DTU Physics, it is necessary to readjust these parameters after the detector is installed on site.

To ensure appropriate determination of these parameters, the detector must have been installed in the lab for at least one day. Since the electronics in the detector heats the NaI scintillator and all other parts of the detector, fine tuning of these parameter should preferably be carried out after the detector has been connected to the PC and the *GammaAcq* software has run for at least 5 hours. The temperature change is monitored by the software and is shown in ④ (Fig. 1.4).

1.4.1 Detector Gain Setting

1. Place a ^{40}K calibration standard cup on the detector
2. Click *Menu – Detector – Gain Setting*, and the *Gain Setting* Window opens (Fig. 1.5):

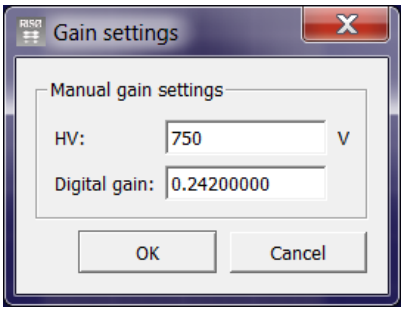

Fig. 1.5: Gain Setting Window

3. The HV and Digital Gain settings in Fig. 1.5 are just an example. You have to set the high voltage HV and Digital gain according to the values suggested in the NaI Detector *Specification sheet* included in the \Documents\ folder on USB flash drive.
4. Click *OK*.
5. Click *Restart*. The parameters will then be loaded to the detector and the detector will run with these parameters. Meanwhile, the counting time "*Real time*" will be reset to zero and start to count again.
6. After about 2-5 minutes, watch the position of the ^{40}K peak. If the ^{40}K peak is too far away from channel 500 (i.e more than ±100 channels), then adjust the *HV* and/or the *Digital Gain* in Gain Setting Window to move the ^{40}K peak to channels nearby channel 500.
   a. If the ^{40}K peak is to the right of channel 500, then first try to reduce the *Digital Gain* a little at a time. This will move the ^{40}K peak to the left (i.e. towards lower energy). If the *Digital Gain* is increased the spectrum will move to the right (i.e. towards higher energies).
   b. The recommended HV from the NaI Detector *Specification sheet* should be used for the first try. In general, a higher HV moves the ^{40}K peak to right and a lower HV moves the ^{40}K peak to the left.
   c. If the ^{40}K peak moves out of the whitish region (from chennal 400-600, Figure 1.4), you must change the Digital gain to move this peak back into this region. Otherwise it will be difficult to find this peak in the the analysis software GammaCalibration & DoseRateCalculator.

1.4.2 Spectra Saving Preference

After the appropriate parameters have been set, the detector can be used. You need to specify the folder and file name for the spectrum to be saved.

This step is necessary in case you have changed a new sample cup.

1. Click "Clear/*Start*" button, the *Acquisition saving settings* pop-up window opens (see Fig. 1.6):

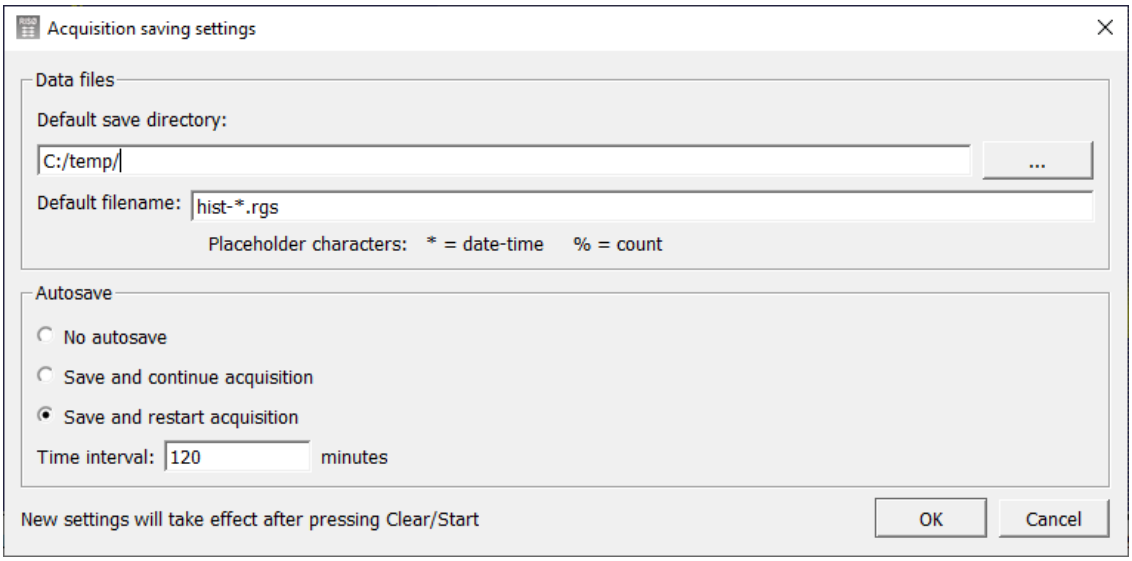

Fig. 1.6: Aquisition save setting window

2. For the two autosave options, type in your folder or click the button on the right to find a folder in which you would like to save the spectrum.

3. Type in a default file name, e.g. cup and sample name. The date and time information at the moment when the spectrum to be saved will be added into the file name by replacing "*" automatically by the software.
4. Choose one of the Autosave options (default is *No autosave*).
   a. *"No autosave"*: spectrum must be saved manually after it reaches the target counting time, by clicking "*Save*" button on top left corner of GammaAcq User Interface. In this case, the set file folder and file name is not valid anymore.
   b. "*Save and continue histogramming*": the spectrum is automatically saved after a given elapsed counting time, e.g. 2 hours (120 minutes). The counting will continue and the new counts will be added to the next spectrum to be saved. The counting time for each automatically saved spectrum will be 2 h, 4 h, 6 h…, if the "*Time interval*" is set to 120 minutes.
   c. "*Save and restart histogramming*" means you can save a spectrum automatically after counting for e.g. 2 hours (120 minutes), then the counting restarts from 0 (counts are not added to the previous spectrum). The counting time for each automatically saved spectrum will be 2 hours.

5. **Click "OK" botton. This step will clear all the current counts and start new counting.**

   If you would like to change the acquisition saving settings, e.g. for file name/folder or time interval, but you also would like to keep the current counting, then you can click on menu "Detector" – "Acquisition saving settings", there will be a same window as the one pops-up when you Click "Clear/Start" button, to allow users to make changes. All the changes will take effect after users click "OK" button.

1.5 Start Acquisition

After clicking on the "Clear/S*tart*" button and close the window, the acquisition starts and the "*Real time*" is reset to zero. If the detector has just been connected to the PC, you can see that the temperature starts to increase in the temperature window (see bottom graph in Fig. 1.7). It usually takes a few hours before the whole detector/lead shield system reaches thermal equilibrium, depending on the room temperature in the lab.

To achieve the best measurement accuracy, we suggest users to wait for at least 5-6 hours after the detector is connected to the PC and the *GammaAcq* software is started, before you start acquisition.

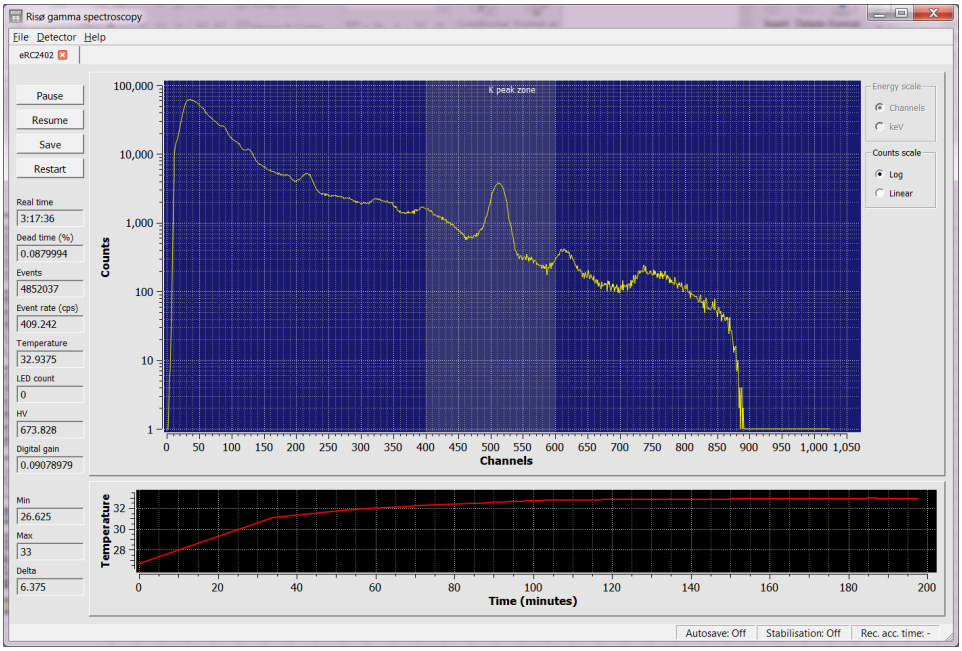

Fig. 1.7: The bottom graph shows how the temperature of the gamma detector typically changes with time after the system has been started.

1.6 Remarks on gamma acquisition

- As the NaI scintillation gamma detector is very sensitive to temperature change, users are advised to install the gamma spectrometer in a lab with a stable temperature, preferably <±1 °C change within 24 hours.
- Some air conditioner stops running, when the *set temperature* of the air conditioner has been reached. It will then start to cool again, when the room temperature is out of its *set temperature* range. This will cause fluctuations in the room temperature, which will result in a broadening of the spectrum and thus reduce the measurement accuracy. In this case, you are advised to use an external temperature logging device, e.g., USB TC-08 from Pico Technology Limited to monitor temperature change to identify a relatively stable period for your measurement. The temperature sensor should be attached directly to the side of the NaI crystal.
- The temperature sensor on the detector is actually located in the electronics part of the detector and is not able to monitor the temperature change of the scintillation crystal precisely.
- If the temperature change is >0.5°C within 24 hours, users are suggested to set the counting time to about 2 hours for each spectrum. The analysis software *GammaCalibration* and *DoseRateCalculator* are able to handle multiple spectra input to correct spectrum drift due to temperature change. In this way, the broadening of the gamma peaks is minimised and the measurement accuracy improved.
- The "*Dead time (%)*" shows if the detector setting is appropriate or not. Usually a dead time value as high as >0.1-0.2% can be expected if you measure calibration standards. For the natural samples, it is usually <<0.1%.
- The "*Event rate (cps)*", i.e., counts per second, on the left side of the spectrum histogram window shows the level of the measured radioactivity. For example, the counting rate of the background cup usually is about 3-5 cps, a weak natural sample is usually between 5-8 cps, and higher activity samples could reach 20-30 cps.

- The "*LED counts*" is for the future development on the software and is not activated in this version of *GammaAcq* software.
- The automatic peak search algorithm employed in the analysis software requires clear specific peaks from ^{40}K, U- and Th-series to perform adequately. For weak samples, it is suggested to count each spectrum for at least two hours.
- The duration of measurement time depends on the radioactivity contained in the sample, and on the desired total uncertainty on the dose rate.
- For low activity samples, the background counting plays an important role for the accuracy of the determination of the radioactivity and dose rate. Therefore, it is necessary to count the background cup just before and right after counting low activity samples.
- **The spectra files can be opened using a text editor, but we strongly suggest you do not change anything in it. If you do so, you may not be able to open them in the analysis software *GammaCalibration* and *DoseRateCalculator*.**

2 Calibration Software: GammaCalibration

2.1 System Requirements

- Windows 7/8/10 x64 should be installed in advance.
- Your computer should have at least 2 GB of disk space available.
- Microsoft Excel for Windows® should be installed in advance.

2.2 Software Installation

This software does not have to be installed on the same PC as *GammaAcq* is installed.

A. Install the MATLAB Runtime:

1. Unzip installation file *MATLAB_Runtime_R2019b_win64.zip* from folder in Risø Gamma Software Flash Drive: \Software\MCRInstaller9.7\. Since the installation file is a large file, you may need to copy/unzip it to the hard disk on you PC to speed up the installation process.
2. Run setup.exe after unzip.

B. Install the GammaCalibration software:

1. If necessary, close and uninstall any previously-installed *GammaCalibration* software.
2. Open folder \GammaCalibration\ on the USB drive, and unzip the installation file *GammaCalibrationInstaller_v1.3.zip*. Run *GammaCalibrationInstaller.exe* after unzip. If you are using Windows 7/8 (or a 64-bit version of Windows) you must right click on *GammaCalibrationInstaller.exe* and select *Run as administrator*.
3. In the first step, the button "*Connection Settings*" (see Fig. 2.1), should be ignored. Simply press "*Next*" button.
4. Follow the setup procedure and finish the installation. Keep the default installation folder: C:\Program Files\Risoe\Risoe Gamma Spectrometer\GammaCalibration\.

In the beginning of the installation, the installer will install a third party runtime engine and this process may take a few minutes, depending on the performance of your PC.

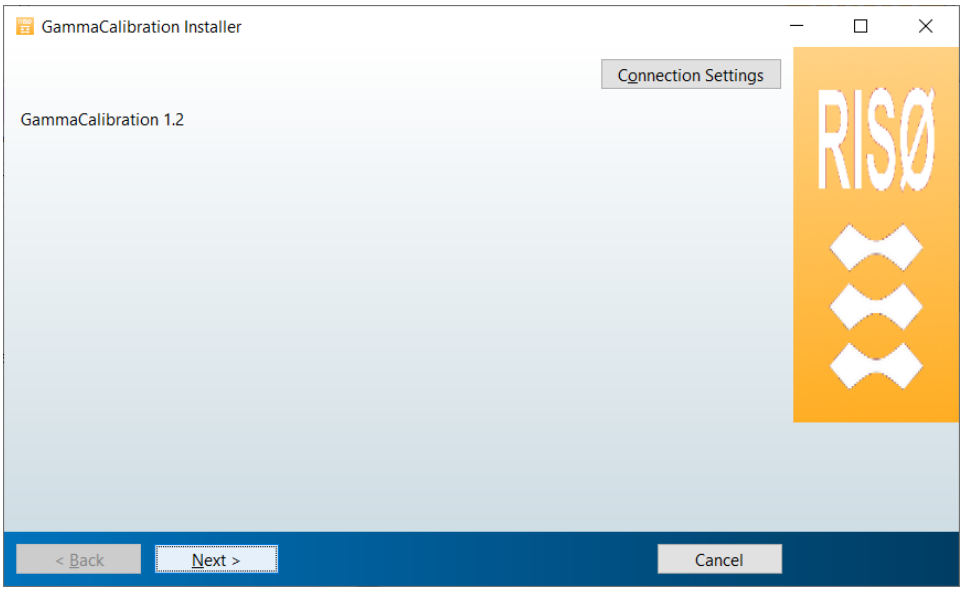

Fig. 2.1 The first step of installation. Simply choose "*Next*".

2.3 Software Introduction

When you start to run the *GammaCalibration* program, it will take one or more minutes to load a third party runtime engine before the user interface shows up as in Fig. 2.2. Sometimes, it may be advantageous to maximise the program window and adjust its size to match your screen resolution.

- The *GammaCalibration* software has a simple user interface and is used for handling calibration spectra, including spectra for Energy Calibration Standards, Calibration Background and ^{40}K, ^{238}U and ^{232}Th Detection Efficiency Calibration Standards. This program is essentially for the determination of the detector's detection (counting) efficiencies of ^{40}K, ^{238}U and ^{232}Th.
- The background spectrum and the ^{40}K, ^{238}U and ^{232}Th standards spectra are drift corrected automatically according to the *Energy Calibration Standards spectrum*, after they are loaded.
- On the right side of the gamma spectra plot, the user can choose to view the spectrum on either log or linear scale. You can also switch the x-axis of spectrum between channel and energy (keV) after you have loaded the energy calibration spectrum.
- You can save the spectra plot into image files, i.e. .png, .jpg, .tif files or in vector image format in .pdf, by moving the mouse to the top right corner of the spectra graph and click the first icon.

Fig. 2.2 User interface for calibration.

2.4 Start Calibration

- *Before users measure all the calibration standards in their own labs, the calibration spectra in the folder on the USB stick: \Spectra of Calibration Standards\ can be used for practice purposes, so the users can become familiar with the software.*
- *Users have to measure all the calibration spectra after the Risø Gamma Spectrometer is installed in their own laboratories, to achieve an accurate determination on the dose rate of the samples.*
- *There is no fixed sequence to follow when measure all 11 calibration cups. But we recommend that you measure background at least 3 times, one before, one in the middle, and one after you measure all other calibration cups.*

2.4.1 Load Energy Calibration Standard Spectrum

In the "I. Energy Calibration Standard" panel, after clicking "1. Load Spectrum" button, there will be a pop-up window to allow you to select spectrum. Here you can either load one or multiple spectra files, in case you saved spectra e.g. for every 2 hours. The total counting time will be shown automatically once loading is finished.

- *You only need to load the Energy Calibration Standard Spectrum/Spectra once for every calibration process.*
- *After loading of the Energy Calibration Standard spectrum, you have to save the data into a MS Excel sheet first by clicking on "2. Save Data" button.*
- *The energy calibration spectrum is used as a common reference for correcting the spectra of the background, the detection efficiency calibration spectra, and the unknown samples. It is therefore important, that any temperature change during counting is as small as possible in order to reduce systematic uncertainties. If temperature change is more than ±1 °C for the planned counting period, it is advisable to collect multiple spectra each with a counting time of about 2 h (e.g. 10 spectra each of 2 h duration) for the same sample.*

2.4.2 Load Calibration Background Spectrum

- *The background spectra measured along with other calibration standards are not necessary to be the same as the one you measure along with the sample. Therefore we name them "Calibration Background" and "Sample Background", respectively.*

- It is recommended to continuously measure the background spectrum whenever the NaI gamma spectrometer is not counting samples.
- It is recommended to measure *Calibration Background* spectra at least three times, e.g. before, during and after you measure all other calibration standard cups.
- You load abovementioned multiple *Calibration Background* spectra, and the total counting time will be shown automatically once loading is finished. These spectra will be averaged after normalisation to the counting time to obtain an averaged background count rate.
- You only need to load the *Calibration Background* spectrum once for every calibration process.

2.4.3 Load Spectra of ^{40}K, ^{238}U and ^{232}Th Detection Efficiency Calibration Standards

- You can load multiple spectrum files from the same nuclides.

- You need to do this for all nine supplied cups (K1-3, U1-3 and Th1-3). You can first load K1, U1 and Th1, and save the result into one data file, then do the same for K2, U2 and Th2, and finally for K3, U3 and Th3.
- Input Information of ^{40}K, ^{238}U and ^{232}Th Detection Efficiency Calibration Standards
  - ❖ You need to type in the activities and their relative uncertainties from source materials for ^{40}K, ^{238}U and ^{232}Th. These are listed in the *Specification Sheet* on the USB stick in folder: *Documents*\.
  - ❖ You need to type in above required activity information every time you load a spectrum for a new set of calibration cups.
- Save each set of ^{40}K, ^{238}U and ^{232}Th data into a MS Excel sheet, and finish all three sets in the same way.
- After having saved each data set of K, U, Th, you can press "*Clear Spectra*" button to delete all ^{40}K, ^{238}U and ^{232}Th spectra and their activity information, before you load a new set of spectra. The source material uncertainty will be kept by default. However, these all 9 cups of K, U and Th calibration standards were randomly selected from different fabrication batches; therefor you should check carefully the *Specification Sheet* and update source material uncertainty if it is necessary.

In order to avoid mistakes in your future use of the Risø Gamma Spectrometer, before you save all the calibration data, please make a good plan on your folder structure, e.g. make a folder according to calibration date, such as: c:*Gamma Calibration\December 2019*\. After you finish saving all the calibration data, it is advisable that you do not modify the name of either the data file or the folder, because these folder and file information are all recorded in the corresponding data file.

2.5 Calibration Data Files

There should be a total of four Excel spreadsheet files in the calibration data folder. Table 2.1 lists each sheet that should be included in each file.

Table 2.1: Spreadsheet in the Calibration data files

File	Sheet	Notes
Energy Calibration Data File	Energy Calib. Standard Spectrum	Sum of all loaded and drift corrected Energy Calibration Standard spectra
	Energy Calibration Centroids	To be used for drift correction of all other spectra
	Total Spectrum Counting Time	Sum of total counting time for all loaded Energy Calibration Standard spectra
	Energy Calibration Coefficients	These are for energy calibration
	Original Spectra Files	Original Energy Calibration spectra files and their locations
Detection Efficiency Calibration Data Files	K-40 Efficiency_cpks	Column A and B: ^{40}K counting efficiency and uncertainty, [counts·ks^{-1}]
	U-238 Efficiency_cpks	Column A and B: ^{238}U counting efficiency and uncertainty, [counts·ks^{-1}]

(K1U1Th1, (K2U2Th2, K3U3Th3)	Th232 Efficiency_cpks	Column A and B: ^{232}Th counting efficiency and uncertainty, [counts·ks^{-1}]
	Spectrum Counting Time	Sum of counting time for each nuclide [ks]
	Activities & Un	Activity and Relative Uncertainty from source material [%]
	Original Spectra Files	Original spectra files and their locations for each nuclide
	Correction Reference File	The Excel data file with Energy Calibration spectra used for drift correction of all efficiency calibration spectra

2.6 Remarks on GammaCalibration

- If you load multiple (N) Energy Calibration Standard spectra, the first N-1 spectra are drift corrected to the last (Nth) spectrum. After that, all first N-1 drift corrected spectra are summed up with the last spectrum and this summed spectrum will be used as drift correction reference for all other spectra.
- You can show the spectrum in energy scale (keV) only after you have loaded Energy Calibration Standard spectrum.
- You can toggle between hide/show any spectra by clicking corresponding spectra names in the legend.
- You can change colour, line width and line style for any spectra by right clicking on one of spectrum.
- You can move the legend to somewhere else or change the fonts in the legend and so on, by right clicking within the legend window.
- If you would like to clear Energy Calibration spectrum and load another one, the spectra of Calibration Background and K, U and Th standards will also be cleared, if they have been loaded.
- If you would like to clear Calibration Background and load another one, the spectra of and K, U and Th standards will also be cleared, if they have been loaded.
-

3 Dose Rate Determination Software: DoseRateCalculator

3.1 System Requirement

- Windows 7/8/10 x64 should be installed in advance.
- Your computer should have at least 2 GB of disk space available.
- Microsoft Excel for Windows® should be installed in advance.

3.2 Software Installation

A. To install the DoseRateCalculator software:

1. If necessary, close and uninstall any previously installed *DoseRateCalculator* software.
2. Open the folder *DoseRateCalculator* on USB drive, and unzip installation file *DoseRateCalculator_Installer_v1.3.zip*. Run *DoseRateCalculator_Installer_v1.3.exe* after unzip. If you are using Windows 7/8 (or a 64-bit version of Windows) you must right click on the *DoseRateCalculatorInstaller_v1.3.exe* and select *Run as administrator*.
3. Follow the setup procedure and finish the installation. The default installation folder is *C:\Program Files\Risoe\Risoe Gamma Spectrometer\DoseRateCalculator*\.

You should install GammaCalibration software first, otherwise you should install MATLAB Runtime before starting to install DoseRateCalculator software.

B. To install uncertainty calculation library:

Install \Software\Uncertainty Library\Metas.UncLib.Setup V2.2.5 in default folder: C:\Program Files (x86)\METAS

3.3 Software Introduction

When you start to run the *DoseRateCalculator* program, it will take a couple of minutes to load a third party runtime engine before the user interface appears (see Fig. 3.1). Sometimes you may need to maximise the program window and adjust its size to match your screen resolution.

i. In the *DoseRateCalculator* software, first you load previously saved calibration data (MS Excel files) in *GammaCalibration* software.
ii. Then you load *Sample Background* spectrum.
iii. Finally, you load *New Sample* spectrum and start calculation.
iv. On the right side of the gamma spectra plot, there are some buttons to allow you to view spectrum either in log scale or linear scale. You can also switch the x-axis of spectrum between channel and energy (keV), after you load the Energy Calibration Standard data. You can turn on region of interest (ROI) after you properly type in ROI.
v. You can save the spectra plot into image files, i.e. .png, .jpg, .tif files or in vector image format in .pdf, by moving mouse to the top right corner of the spectra graph and click the first button.

3.4 Load Calibration Data

- Load all MS Excel sheets you saved in *GammaCalibration* program.
- You can load only one data file for *Energy Calibration Standard*. The loaded file and folder will be shown in the windows on the right.
- You have to load multiple sets (at least 3 sets) of data for ^{40}K, ^{238}U and ^{232}Th *Efficiency Calibration Standards*.
- If you have purchased more than three sets of calibration standards, you are allowed to load more than three sets of *KUTh Efficiency Calibration* data. The folder in which the data files are located will be shown in the window on the right.
- If above file or folder are too long, they will be shown partly in the windows. You can move your mouse curser above these windows to show all contents.
- You can clear all Calibration Data by click on "Clear Calibration Data" button.

Fig. 3.1 User interface of DoseRateCalculator program.

3.5 Quality check on the Calibration Standard

- After you select and load detection efficiency calibration data files, there will be a pop-up window "Check_Calib_Quality" for you to check their quality, as shown in Figure 3.2. This is to ensure quality of the measurement on the calibration standards, and to ensure you have loaded the proper data files, before carrying out an analysis on your samples. This is done by checking if the overdispersion between three loaded detection efficiencies are within a reasonable percentage.

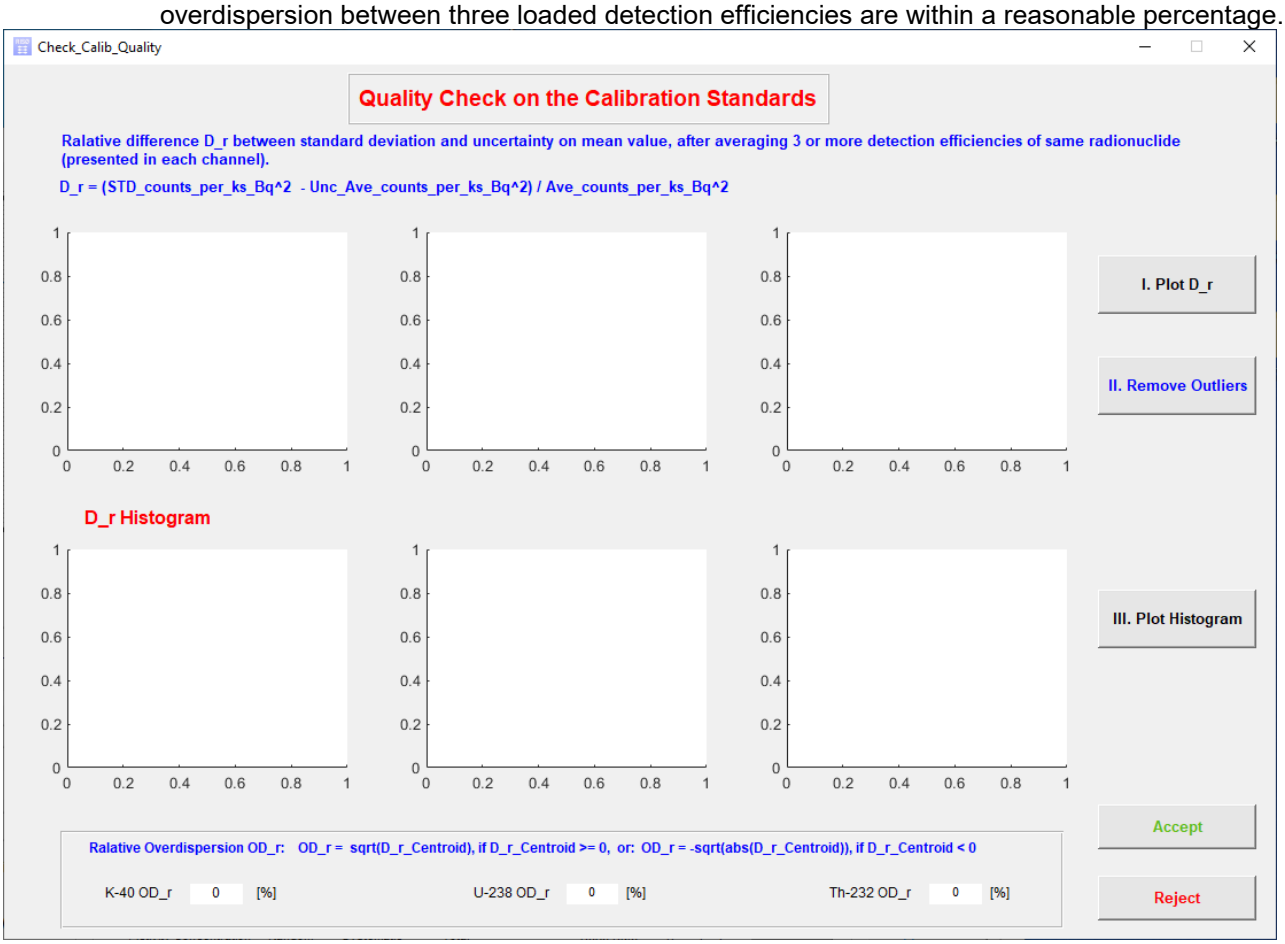

Figure 3.2: "Check_Calib_Quality" window

- There will be a warning message box "Quality Check Warning!", as shown in Figure 3.3. Please read it and follow the instruction on it, and DO NOT click "OK" button on this message box.

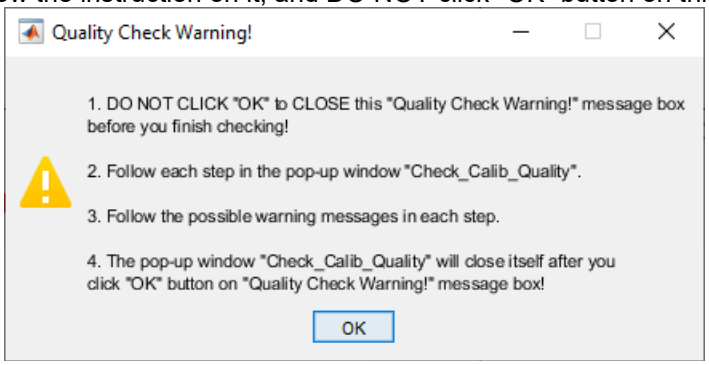

Figure 3.3: "Quality Check Warning!" message box

- In "Check_Calib_Quality" window, click buttons from "I. Plot D_r", to "II. Remove Outliers", and to "III. Plot Histogram", as shown in Figure 3.4.

- At this point, you have a chance to save all these plots into image files if you feel necessary.

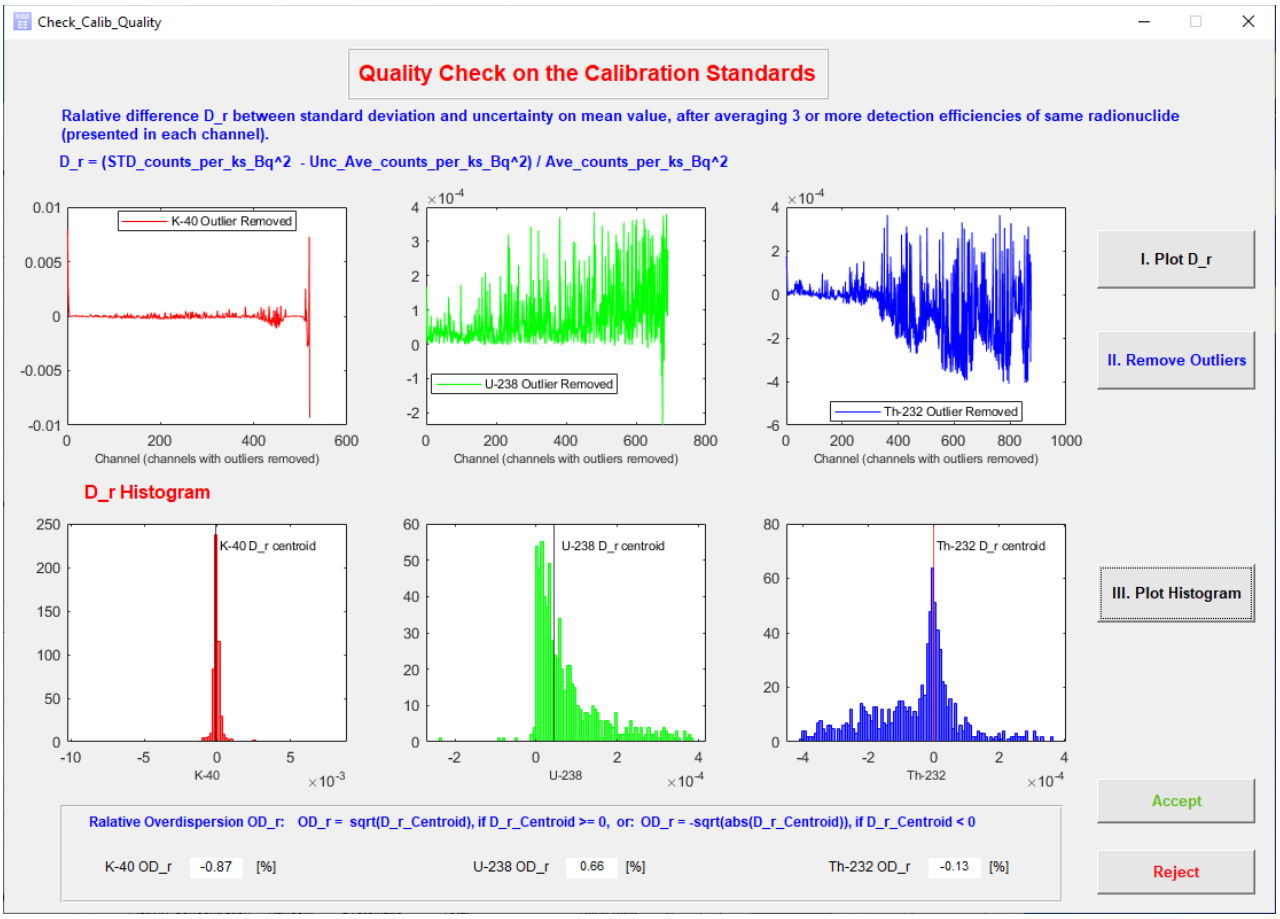

Figure 3.4: "Check_Calib_Quality" window showing

- If your calibration standard were properly measured and you have loaded the proper files, you may easily discover that the program find their obvious centroids from histograms of D_r (relative difference). If reasonable overdispersion values OD_r for ^{40}K, ^{238}U and ^{232}Th, e.g are within ±5%. you can click "Accept" button to go back to the main user interface "DoseRateCalculator".
- In case all the centroids are found, but one or more OD_r values are above ±5%, then you are suggested to click "Reject" button to load proper data files.
- In case you loaded wrong calibration data file, the program could not find one or more centroids itself, and there will be a message box to suggest you to click "Reject" button and load proper data files.

3.6 Load Sample Background Spectrum

- This *Sample Background* spectrum is the one you measured either before or after you measure your new samples.
- You are recommended to measure multiple times and load them all in this step to make an average.
- The loaded files and folder will be shown in the window on the right. If the file and folder names are too long, they will be shown partly in this window. You can move your mouse curser above this window to show all contents.

- The total counting time of all loaded *Sample Background* spectra will be summed and shown in the counting time window on the right.

3.7 Load New Sample Spectrum

3.7.1 Load Spectrum

- You can load multiple spectra files for the *New Sample*.
- The total counting time of all loaded *New Sample* spectra will automatically appear in "Counting Time" window.
- Check carefully if the file is the right one in the file name and folder window.
- **You can load spectrum of the K-40, U-238, or Th-232 calibration standard as "Unknown Sample" and calculate the contained activity. In this case, first you have to check one (and only one) of the checkbox above the "1. Load Spectrum" button. Then you load new spectrum. In the "Sample Weight", you enter 1 kg.**

3.7.2 Input Sample Weight

- Input sample weight in kg.

3.8 Define Region of Interest (ROI)

- You are allowed to adjust the ROI for the spectrum analysis.
- The default setting on ROI of 60-960 channel usually works fine.
- A practical selection on the start channel of ROI is between 45-80. It is not allowed to select a start channel lower than 45.
- In case the spectrum shifted to either left or right side, the general rule is that you set the start channel of ROI to a channel somewhere in the middle between X-ray peak (the first prominent peak) and the first prominent Th series peak (usually the second prominent peak). The end channel of ROI can be selected as the channel in the valley at the right side of the last Th series peak (2.61 MeV), e.g. channel 960.
- Different ROIs could give different results, but the variation between them should not be enormous, e.g. should be <1%. Otherwise please check if the specific peaks of ^{40}K and U series and Th series from sample spectra are aligned perfectly to the Calibration Spectra.
- Figure 3.5 shows the software user interface after loading all spectra and the ROI is shown (in the next page)

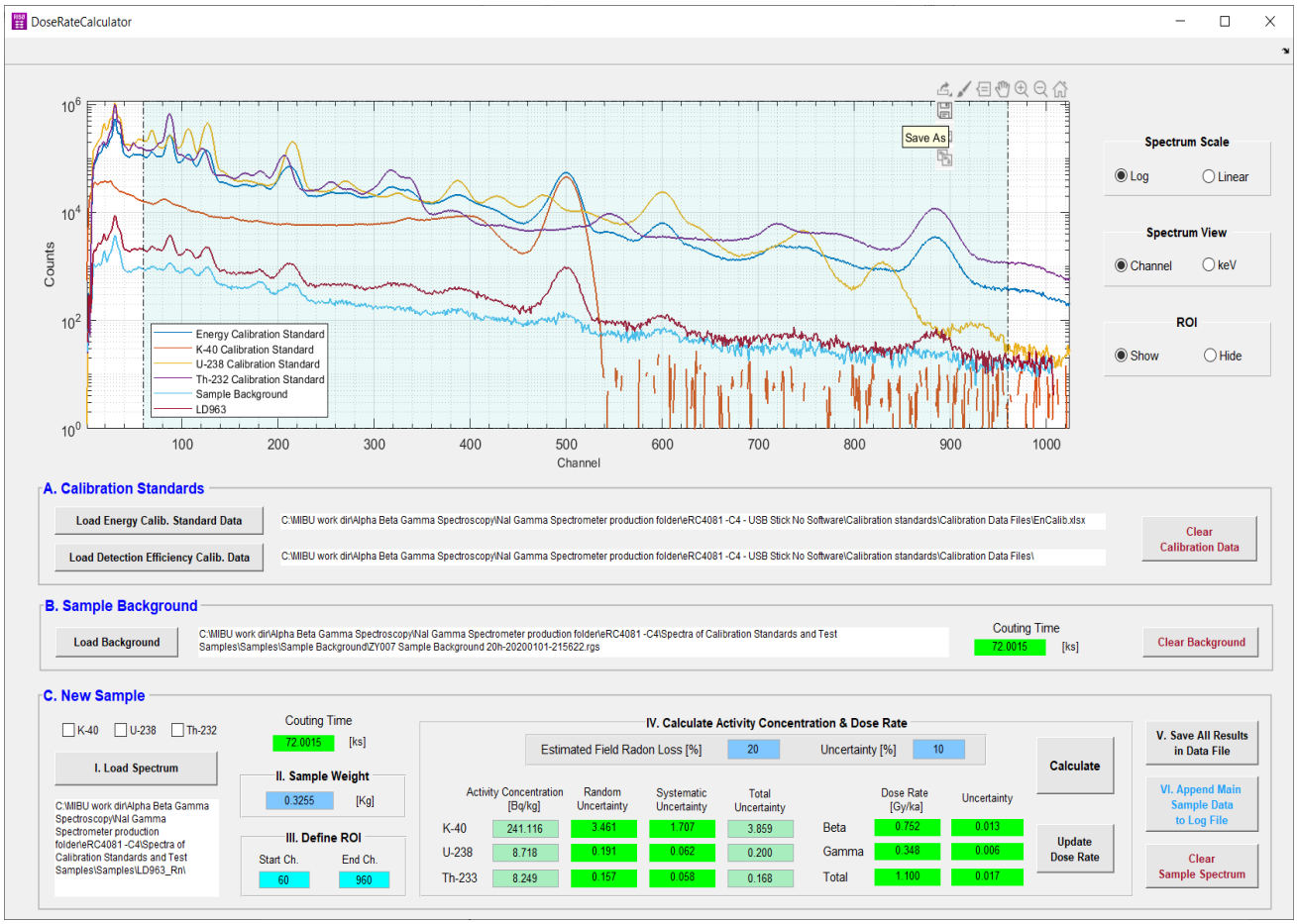

Figure 3.5: All gamma spectra are loaded and ROI is shown.

3.9 Calculate Activity Concentration & Dose Rate

3.9.1 Field Radon Loss Ratio

- Here you input field radon loss ratio and its uncertainty according to your own experience on the specific samples. The default value of 20% ± 10% is what we usually use at DTU Physics for OSL dating.

3.9.2 Update Dose Rate

- After calculation of activity concentrations, if you find it is necessary to update the field radon loss ratio, you can just click "Update Dose Rate", after you type in new values of field radon loss ratio and its uncertainty. You will obtain an update on the dose rate calculated based on the new field radon loss ratio.

3.10 Save Results

- All the result of *New Sample* will be saved in an MS Excel file.
- The folders and file names of all calibration data will also be saved in this result data file.
-

- All individual parts of systematic uncertainties and random uncertainties will also be saved in this data file.
- From this data file, you can inspect the quality of three (or more) sets of detection efficiency calibration standards, by checking their overdispersion (OD) values.

3.11 Append Data to Log File

- Click "VI. Append Main Sample Data to Log File" button can allow you to save all main information of the sample.
- If you select an existing log file to append data into it, there will be a pop-up window asking you to "confirm save as", as shown in Figure 3.6. Click "Yes" to append data. If the file is a new file, this pop-up window will not appear.

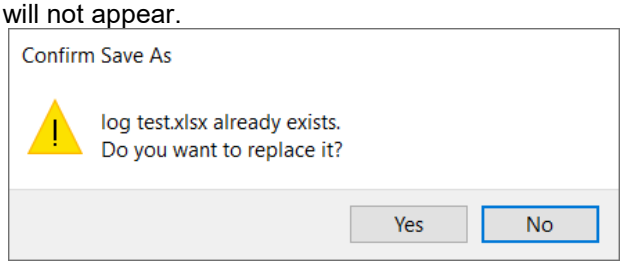

Figure 3.6: Confirm append date to an existing log file.

- After you click "Yes" in the above window, there will be a pop-up window, as shown in Figure 3.7, to allow you to enter information such as cup code, sample code, cup cast date and counting date.

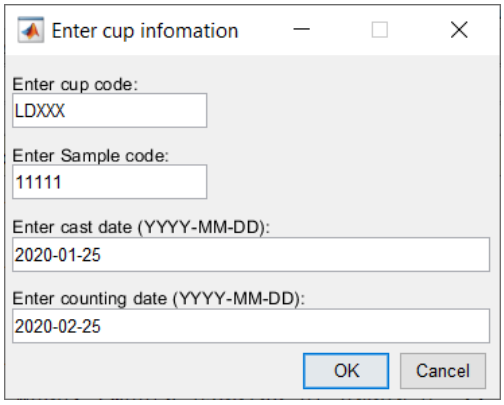

Figure 3.7: Pop-up window for entering cup information.

- Figure 3.8 shows the content of the saved log file, as an example.

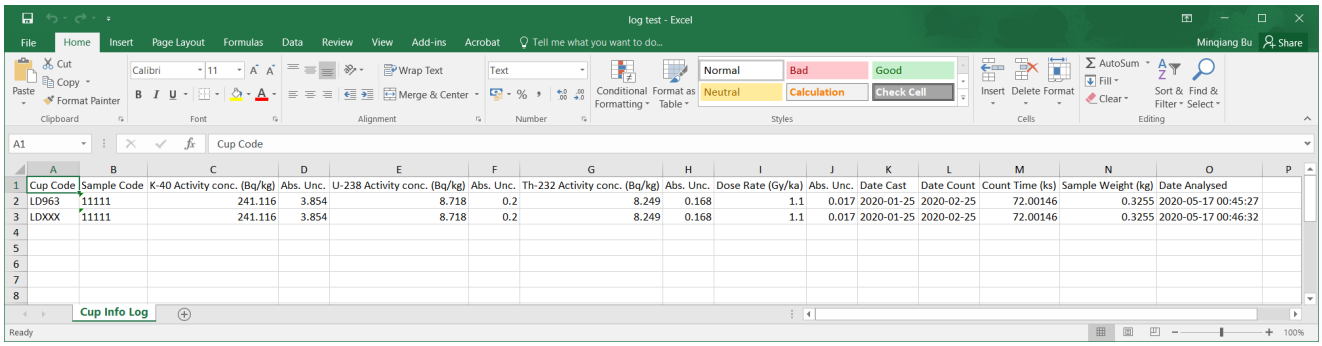

Figure 3.8 content of the saved log file.

3.12 Start New Analysis

- Click "Clear Sample Data" button on the bottom right corner.
- All input and output data for the previous sample will be cleared.
- You can start a new analysis on the next unknown sample without loading calibration data again.

3.13 Sample Data File

The contents of sample Excel spreadsheet file is listed in Table 3.1.

Table 3.1: Spreadsheet in the sample data files

Sheet	Notes
Calibration Files	Excel data files used for calibration
Sample_Bg Ori. Spectra File	Column A and H list the original *Sample Background Spectra* files and original *Sample Spectrum* files, number of files in these two columns depends on the total number of the loaded spectra
Sample Original Spectrum	Each column is one original sample spectrum, number of columns depends on the total number of the loaded sample spectra
Drift Corrected Spectrum	Each column is one drift corrected sample spectrum, number of columns depends on the number of the loaded sample spectra
Count Time_SW_etc	Sum of counting time from all individual loaded sample spectra, sample weight contained in the sample cup, and Start channel and End channel of ROI for analysis
Activity Con._Dose Rate	Sample Activity concentrations for **^{40}K, ^{238}U and ^{232}Th**, and their Random, Systematic and Total Uncertainties, and determined dry dose rate, including beta dose rate, gamma dose rate and total dose rate and their uncertainties. The estimated radon lose ratio and its uncertainty are also recorded here.
Individual Uncertainty	The individual items contributing to the random and systematic uncertainties are included here. Random uncertainty includes fitting error from full-spectra analysis, and counting error from counting statistics. Systematic uncertainty includes the overdispersion (OD) values between 3 (or more) loaded Detection Efficiency Calibration cups (e.g. K1, K2 and K3) of same radionuclide, and manufacturer uncertainty brought by these same cups. These two items are listed in relative value (%). Then the total systematic uncertainty is listed in absolute value. From above OD values, user could find how close (good quality) that three (or more) Detection Efficiency Calibration cups of same radionuclide are. This OD value is derived from the counting of each calibration cups, therefore only a long enough (e.g. 10-20 or more hours) total counting time could give the true value.

3.14 Remarks on DoseRateCalculator

- You can show spectrum in energy scale only after you have loaded Energy Calibration Standard spectrum.
- You can toggle between hide/show any spectra by clicking corresponding spectra names on the legend.
- You can change colour, line width and line style for any spectra by right click on one of spectrum.
- You can only change their line width or line style one by one.
- You can move the legend to somewhere else or change the fonts in the legend and so on, by right clicking within the legend window.
- **This DoseRateCalculator can also be used to calculate dose rate based on the ^{40}K, ^{238}U and ^{232}Th activities you obtained by other methods, such as from a high resolution gamma spectrometer. Type in activities and uncertainties in the corresponding windows (in light green colour), and press "Update Dose Rate" button, you will get the dose rate results.**