CAEN Educational

Guide GD6103

SP5600EMU

Emulation Kit

Rev. 0 - October 9th, 2017

Purpose of this Guide

This Quick Start Guide contains the full description of the Emulation and Detection Educational Software for the DT4800 Digital Detector Emulator and the DT5770 Digital Multi-Channel Analyzer. The description is compliant with DT4800 Digital Detector Emulator firmware release **1.6** and DT5770 Digital MCA firmware release **5.02_5.02**. For future release compatibility please check the firmware and software revision history files.

Change Document Record

Date	Revision	Changes
October 9th, 2017	00	Initial Release

Symbols, Abbreviated Terms and Notation

ADC	Analog-to-Digital Converter
DPP	Digital Pulse Processing
MCA	Multi-Channel Analyzer
DDE	Digital Detector Emulator
USB	Universal Serial Bus

Reference Documents

[RD1] UM4150-DT5770 Digital MCA User manual

[RD2] UM5094-DT4800 Digital Detector Emulator User manual

[RD3] UM2088 – DPP-PHA User Manual

[RD4] UM2089 – DPP-CI User Manual

CAEN S.p.A.
Via Vetraia, 11 55049 Viareggio (LU) - ITALY
Tel. +39.0584.388.398 Fax +39.0584.388.959
info@caen.it
www.caen.it

Index

List of Figures

List of Tables

1 Introduction

The "Emulation kit" is based on the CAEN Digital Detector-Emulator (DT4800) together with the Digital Multichannel Analyzer (DT5770). This kit allows the user to perform a series of lab experiments without using a radioactive source and a detector but simulating the signals produced by the interaction of particles with the detecting unit. The goal is to inspire students and guide them towards the analysis and comprehension of different physics phenomena with a series of experiments based on state-of-the art technologies, instruments and methods.”

The massive evolution of digital processors for radiation measurements has highlighted the extreme convenience to develop techniques for emulating the detection and acquisition systems. The process of debugging of systems as digital pulse processors, pulse discriminators, Time-to-Digital/Amplitude converters, etc, requires an ever-increasing effort of processing algorithms that are becoming more and more complex. The possibility to generate test vectors, that are as similar as possible to the actual data produced by the experiment, both in the software simulation and at the hardware level, can extremely reduce the R&D projects time.

All of this can be summarized in the need to generate an electrical signal with completely controlled characteristics, that is compliant to the real output of a radiation detection setup. Although the use of a source and a detector is always the best way to generate a reliable data set, it involves considerable disadvantages, especially during preliminary feasibility studies. The use of the source inherently involves a risk for the health of the experimenters, and in addition requires laboratories equipped in accordance with the regulations in term of use of radioactive substances.
Moreover, the emission spectrum depends on the nature of the source, e.g. the polarization of an X-ray tube or a process of decay. The statistical distribution of the events is Poissonian and usually the user can only control the rate, and has no control on the statistics. The spectrum of noise and the pulse shape are issues on which the experimenter can hardly affect. Furthermore, the natural emission process is not repeatable and therefore it is not possible to evaluate the behavior of different implementations of the processing system on a set of equal data.

It is common practice to use electronic instruments to generate analog signals with similar features to a real experiment dataset. There are instruments able to generate exponential signals with fixed amplitude and Poissonian temporal distribution, that can emulate effects such as pile up. However, they cannot modulate the amplitudes of generated signals according to a generic spectrum of emission.
To overcome this problem hardware tools, called arbitrary waveform generators, have been developed. These instruments can generate long sequences of events at high rate (up to 1 GSPS), which have been synthetized off-line using simulation tools (e.g. MatLab). At present days, the most efficient tools have 1 Gword memory which means about a signal one second long before a repetition or about 10 millions of counts. Obviously, this is not enough for a good statistics of a complex spectrum.

We therefore developed, in collaboration with Nuclear Instruments SrL, a single channel digital instrument for emulating radiation detection systems. The processor is initialized with a reference pulse shape and a statistic distribution of amplitude and time. According to this information, the device generates a stream of events that can be also selectively summed together simulating the pile-up phenomenon. At each pulse can be superimposed some arbitrarily generated noise.

DT4800 Digital Detector Emulator is therefore the only synthesizer of random pulses that is also an emulator of radiation detector signals, with the possibility to configure the energy and time distribution. The stream of emulated signals becomes a statistical sequence of pulses, reflecting the programmed input features. The DT4800 Digital Detector Emulator is able to emulate a radiation source.
DT5770 Digital Multi-Channel analyzer is able to acquire and elaborate signals coming from the DT4800 emulator. The two instruments together reproduce the dataset generation and acquiring in a real decay experiment.

The information of electronic pulses generated by nuclear radiation detectors, are contained in their shape (i.e. a Pulse Shape discrimination is possible between neutrons and gammas in a detector sensitive to both radiations, by looking at the shape of the corresponding pulses), in their timing (i.e. arrival of the pulse compared to a reference starting time "T_0", as in Time Of Flight detectors measurements or in Position Sensitive Detectors) and in their *pulse height*, for those detectors where the relationship between incident radiation energy and detector output pulse height can be re-conducted to direct proportionality (if needed through a calibration curve). For example, a radio-isotopic source emits gamma radiations of different energies and the corresponding different heights of the pulses at the output of the detector can be histogrammed during the counting time.

The Emulation software has been designed as a user-friendly interface to manage the acquisition of emulated signal with pulse height and charge integration algorithms.

The Emulation Kit is a valuable instrument for students approaching the field of experimental Gamma and X-Ray Spectroscopy, with a basic hardware and with no need of specific training to handle radioactive sources in a laboratory. The effective compactness of the two modules of the Emulation Kit allows the user to perform experiments directly on a student's desk, while data elaboration can be performed with the Emulation Software running on a PC and with simple spreadsheet softwares.

Main Functionalities

The Emulation Kit exploits the features of the DT4800 Digital Emulator and the DT5770 Digital MCA allowing:

- Emulator/Pulser operation mode
- Energy spectrum emulation
- Time spectrum emulation
- Pile-up emulation
- Noise emulation
- Continuous reset emulation
- Acquisition of signals coming from detectors, adapting the input dynamic range
- Threshold/trapezoidal trigger generation
- Calculation of the signal energy with charge integration/trapezoidal energy filter
- Manage the baseline calculation and the events pile-up rejection
- Visualization of generated and acquired waveforms and spectra
- Calibrate the device in energy by fitting the peaks of acquired spectra with Gaussian functions, accounting for the underlying background
- Save parameters settings and acquired spectra

The description of this Guide is compliant with the following products:

Board Models	Description	Product Code
DT4800	DT4800 - Single Channel Compact DT4800 Digital Detector Emulator	WDT4800XAAA
DT5770	Digital Multi Channel Analyzer	WDT5770AXAAA

Table 1.1: Building blocks of the kit.

2 Getting Started

Scope of the Chapter

This chapter is intended to give essential information about the hardware included in the Emulation Kit and to provide a Quick Start Guide of the Educational Software, in order to manage the first practical use of the DT4800 DDE and the DT5770 Digital MCA through the GUI.

System Overview

The system consists of the following products:

- DT4800, 1-channel with standard firmware revision **1.6**.
- DT5770, with firmware revision **5.02_5.02**.
- Educational Software running on the user PC.

Hardware description and main functionalities

In this paragraph a brief description of the DT4800 and the DT5770 will be given. Just basic technical specifications of the two devices will be reported, to allow the user to easily manage them and understand their main functionalities.

DT4800

The DT4800 is a single channel instrument for emulating radiation detection systems. The processor is inizialized with a reference pulse shape and a statistic distribution of amplitude and time. According to this information, the device generates a stream of events that can be also selectively summed together simulating pile-up phenomenon. At each pulse can be superimposed an arbitrarily generated noise.

The main features of the DT 4800 Digital Detector System are

- Emulator/Pulser operation mode
- Energy spectrum emulation
- Time spectrum emulation
- Pile-up emulation
- Noise emulation
- USB 2.0 connection
- DLL for automation of emulation process
- Import/Export in CSV format of spectra

Technical specifications of the DT4800 are given in **Table 2.1**.

Energy emulation features	• Single line (16384 selectable levels) • Spectrum emulation (16384 bins with 14 bit resolution) • ± 5.6 V output range, high impedence; ± 2.8 V, 50 Ω termination • 14 bit D/A converter
Time emulation features	• Constant rate emulation • Poisson distribution • Up to 1MCPS, both in constant and statistical emulation • Integrator circuit emulation without pile-up limitation • 20 ns to 1 ms exponential decay time
Signal shape	• Exponential Digital RC Emulator
Noise emulation	• White noise emulation (Gaussian) • Random Walk (baseline drift)
Digital I/O	• 1-input and 1-output programmable • Trigger out • Trigger in
Software and interface	• Windows-based control software • USB 2.0 and Ethernet interfaces

Table 2.1: Technical specifications of the DT4800.

The DT4800 front panel is shown in the following picture. Numbered labels are explained in the table

Figure 2.1: DT4800 Front Panel.

Number	Description
1	Power Led
2	GPO: Trigger Output
3	GPI: External trigger
4	Analog Output Channel
5	Green LED – Analog output channel power on status OFF: channel output disabled ON: channel output enabled

Table 2.2: DT4800 Front Panel description.

The DT4800 back panel is shown the following picture. Numbered labels are explained in the table.

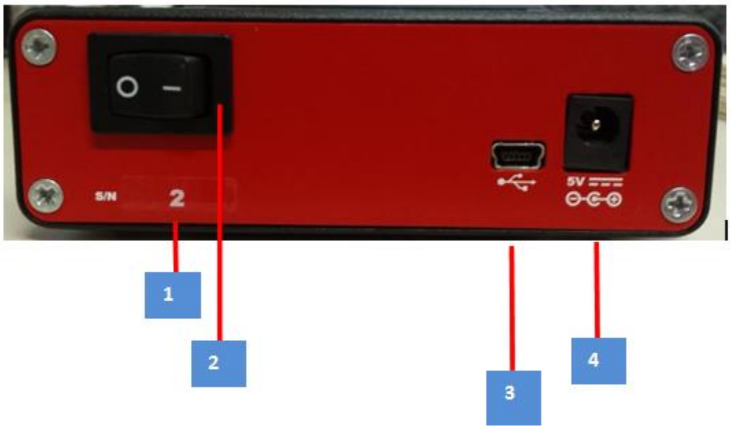


Figure 2.2: DT4800 Back Panel.

Number	Description
1	Serial number
2	ON/OFF switcher
3	Mini USB Interface Connector
4	Power Supply Connector (+5 V central terminal positive)

Table 2.3: DT4800 Back Panel description.

The analog stage has been designed to be at the same time at low noise and at high dynamic. We therefore used AD8045 amplifiers that allow to achieve a noise level of 820 uV rms with rise time of 18 ns or noise level of 200 uV rms with rise time of 30 ns.
A 20 MHz Low Pass filter, called “output” filter in the GUI interface, can be added by the user. If this filter is enabled, the rise time increases to 30 ns.
The analog output is designed to generate a signal amplitude of ± 2.8Vpp, with 50 Ω termination. It is possible to terminate it with high impedance, having a final amplitude of ± 5.6Vpp. In this case it is possible to have multiple signal reflections, if the signal edge is sharp. It is strongly recommended to enable the filter when using high impedance.

The digital outputs provide LVCMOS 0-3.3 V signals, as the inputs can receive signals with amplitude 0-3.3V. Inputs and outputs are protected with anti-ESD diodes.

For further details about the hardware and firmware architecture, please refer to the DT4800 User Manual **[RD2]**.

DT5770

The **DT5770** is a compact desktop system integrating a single 16k-channel Digital MCA and LV power supply capabilities for Gamma and X-ray spectrometry.

DT5770 is ideally suited to elaborate signals produced by high energy resolution detectors, such as **HPGe**, connected to the output of a Charge Sensitive Preamplifier (CSP), even including Transistor Reset Preamplifiers (TRP) for ultra-high count rates, but this MCA can also properly work with PMT-based detectors like **NaI**. In the Emulation Kit, the DT5770 is meant to be used with the DT4800, simulating the source-detector chain.

The Digital MCA operates as a traditional spectroscopy acquisition chain made of Shaping Amplifier plus a Peak Sensing ADC, thus representing a digital replacement of that modules. Thanks to this digital approach, other functionalities become possible, such as calculating the trigger time tag.

The DT5770 features:

- **1x 150 MS/s 14-bit ADC** on single ended input with BNC connector, featuring 4-step configurable input range (1.25 / 2.5 / 5 / 10 Vpp) and adjustable DC offset via a 10-bit DAC on each input in the full range.

- **1x ±12 V (100 mA) and ±24 V (50 mA) PREAMP bias output** through DB9 connector for preamplifier power supply.

The Digital MCA is equipped with a **DPP-PHA Firmware**, that is a Digital Pulse Processing algorithm making the board a spectroscopy acquisition system providing energy spectra (i.e. pulse height histograms) as well as portions of the waveform for debugging, monitoring and pulse shape analysis (see [RD3] for more details on DPP-PHA algorithm). Moreover, the DT5770 supports the **DPP-CI Firmware**, a Charge Integration firmware. The DPP-CI Firmware makes the MCA a spectroscopy acquisition system providing on-line energy (single gate integrated charge), timing information, as well as portions of the waveform for debugging, monitoring and further off-line pulse shape analysis (see [RD4] for more details about the DPP-CI algorithm).

DT5770 houses miniUSB 2.0 and Ethernet interfaces as communication links for configuration, firmware upgrade and data collection.

The following list summarizes what the Digital MCA can do in combination with the Emulation Software:

- receive the signals coming from the DT4800 and adapt to the dynamic range (by the programmable DC offset and Gain);
- detect input pulses and generate a local trigger on them;
- calculate the pulse height by means of digital shaping filters (trapezoidal filters);
- detect pile-up conditions and manage the count loss (dead-time);
- get the spectra internally generated (on-board) through USB or Ethernet link.
- accumulate, plot and save the histograms (energy spectra over up to 16k channels), compensate for the dead-time;
- generate output files (histograms) in a binary or ASCII format.
- run the signal inspector that plots the waveforms of the input signals as well as of the internal filters in order to adjust the parameters of the acquisition;
- perform advanced mathematical analysis on both the ongoing histograms and collected spectra (e.g. peak search, background subtraction, peak fitting, energy calibration, dead time compensation)
- power supply and preamplifier.

Figure 2.3: DT5770 Front Panel.

Figure 2.4: DT5770 Back Panel.

Technical specifications of the DT5770 are given in

Table 2.4, where the characteristics of each element on the front and rear panels are briefly described. For details about the MCA architecture, please refer to the DT5770 User manual [RD1].

MECHANICAL	**Dimensions** 106 W x 38 H x 128 L mm³ (without connectors) 106 W x 38 H x 150 L mm³ (including connectors)	**Weight** 300 g
ENVIRONMENTAL	**Operational Conditions** 0 – 50°C Temperature Range - EMC compliant	
ANALOG INPUT	**Input Features** ▪ BNC connector ▪ Single ended, DC/AC coupled ▪ Both continuous and pulsed reset preamplifiers supported ▪ Impedance: 50 Ω / 1 kΩ (sw selectable) ▪ Positive and negative signals accepted ▪ Programmable 4-step analog coarse gain corresponding to 1.25 Vpp, 2.5 Vpp, 5 Vpp, 10 Vpp ranges ▪ Bandwidth: DC to 30 MHz ▪ Programmable fine gain: 1..100 ▪ Programmable DC offset adjustment on the input in the full scale range	**Number of Inputs** 1
TRP FEATURES	**Transistor Reset Preamplifier Support** ▪ Selectable gains in the range [2:110] in 12 steps. ▪ AC coupling software selectable ($\tau_{shaperAC}$ ~600ns)	
ADC	**Resolution** 14 bits	**Sampling Rate** 150 MS/s
DIGITAL SIGNAL PROCESSING	▪ Manual and automated trigger threshold adjustment ▪ Manual and automated Pole-Zero cancellation; decay time up to 0.65 ms ▪ Digital decimation in programmable steps: 2-4-8 ▪ Digital fine gain ▪ Pile-up rejection and Live Time correction ▪ Baseline restorer with programmable averaging ▪ Adjustable moving average low pass filter to reduce the high frequency noise	
PREAMPLIFIER POWER SUPPLY	**Preamp Features** ▪ DB9 connector ▪ ±12 V,100 mA output (DB9/pin4/pin9) ▪ ±24 V, 50 mA output (DB9/pin6/pin7) ▪ Output voltage tolerance: 2% ▪ Voltage ripple < 5 mVpp **Extra Features** ▪ Aux. analog input, 0 ÷ 10 V (DB9/pin3) ▪ Ext. input for detector’s temperature readout (DB9/pin8)	**Preamp Outputs** 1
OPERATING MODES	▪ Pulse Height Analysis (PHA): 16k-channel pulse height histogram internally built up; 1k-2k-4k-8k-16k rebin options at software level ▪ Oscilloscope mode for waveforms monitoring	
TRIGGER MODES	▪ Internal trigger ▪ External: channel is triggered by external trigger only (GP I/O 1 or GP I/O 2)	

	Connector		Description	Options
ANALOG/DIGITAL I/O	▪ **GP I/O 1 (LEMO, TTL)** ▪ **GP I/O 2 (LEMO, TTL)**	Zin = 50 Ω	Digital Input	Veto
			Digital Input	Gate
			Digital Input	Ext. Trigger
			Digital Input	Reset
		22-Ω terminated	Digital Output	Trigger
			Digital Output	Energy probe
			Digital Output	Pile-up inhibit
			Digital Output	Event rejected
			Digital Output	Baseline suspended
			Digital Output	Acquisition run/stop
			Digital Output	SCA **(COMING SOON)**
			Digital Output	Clock
	▪ **GP I/O 2 (LEMO)**	50-Ω terminated	Analog Output	Input signal
			Analog Output	Fast Trapezoid
			Analog Output	Trapezoid
			Analog Output	Energy data
			Analog Output	Baseline
			Analog Output	Trapezoid - Baseline
OLED DISPLAY	OLED display showing acquisition information • Incoming Count Rate indicator (k counts/s) • Dead time indicator (%) • Acquisition time (hh:mm:ss) • Acquisition Run indicator Dead time pogress bar			
COMMUNICATION INTERFACE	**Ethernet** 10/100BT			**USB** USB 2.0 compliant
FIRMWARE	Firmware can be upgraded via USB/Ethernet			
SOFTWARE	Fully controlled by MC² Analyzer spectroscopy software For developers: general purpose C libraries with demo samples available			
POWER REQUIREMENTS	**Operating Supply Voltage** +5 VDC **Absolute Max. Rating** +5.5 DVC The module can be powered by an external AC/DC stabilized power supply included in the kit (5 VDC, 3.5 A)		**Consumptions (Typ. @ +5 VDC)** 1.5 A	
POWER SWITCH	Tactile switch with integrated pure white LED used to power ON/OFF the device 			

Table 2.4: Technical Specifications of the DT5770.

Hardware Setup

The getting started demo proposed in this Chapter makes use of the DT4800 and the DT5770 **connected via Mini USB to a computer equipped with Microsoft Windows 10 Professional 64-bit OS**. The DT4800 Digital Detector Emulator and the DT5770 Digital MCA drivers are properly installed in the work station. In order to have information on their installation, please refer to the correspondent User Manual available on the CAEN website on the product page.

Both instruments are powered by the external AC/DC stabilized 5V power supply included in the Emulation Kit. Please, use only the power supplies shipped with these instruments and certified for the country of use.

The analog output of DT4800 is sent to the DT5770 Digital MCA through a BNC-BNC cable.

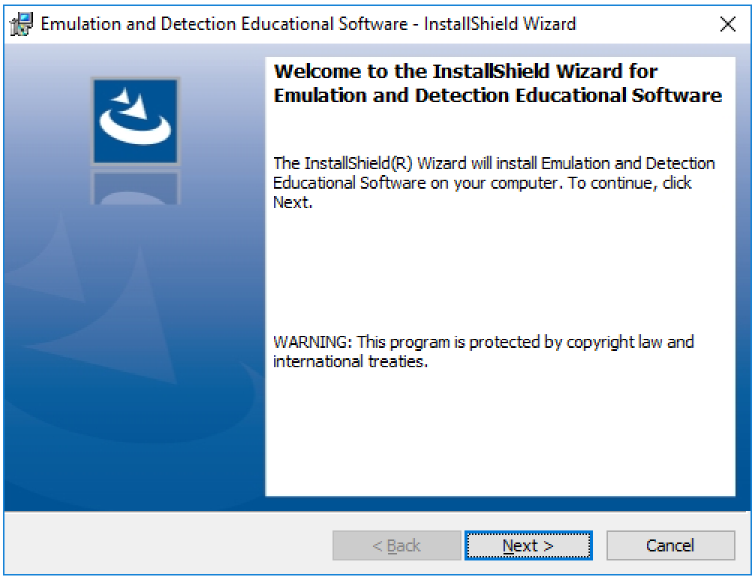
The Emulation Software allows to control the devices, generate an output signal with the Emulator and acquire the signal with the MCA.

Figure 2.5: The hardware setup including the Digital Detector Emulator DT4800 and the Digital MCA DT5770**.**

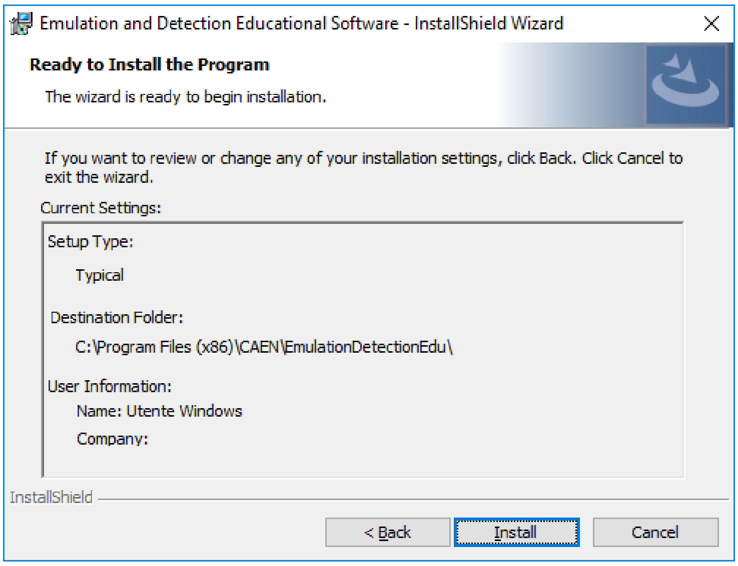
Emulation and Detection Educational Software Installation

The Enulation and Detection Educational Software (also called Emulation Software) is compliant with Windows 7, 8, 8.1 and 10 OS, both 32 and 64 bit.

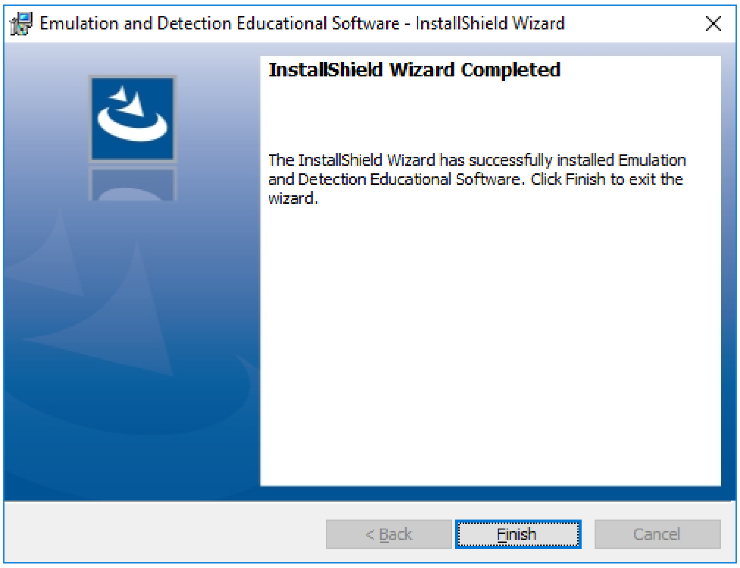
- **Download** the standalone **Emulation Software** installation package on CAEN website in the 'Download' area of the Emulation kit page (**login is required before the download**).
- **Unpack** the **installation package** and **launch, as administrator,** the **setup file.**



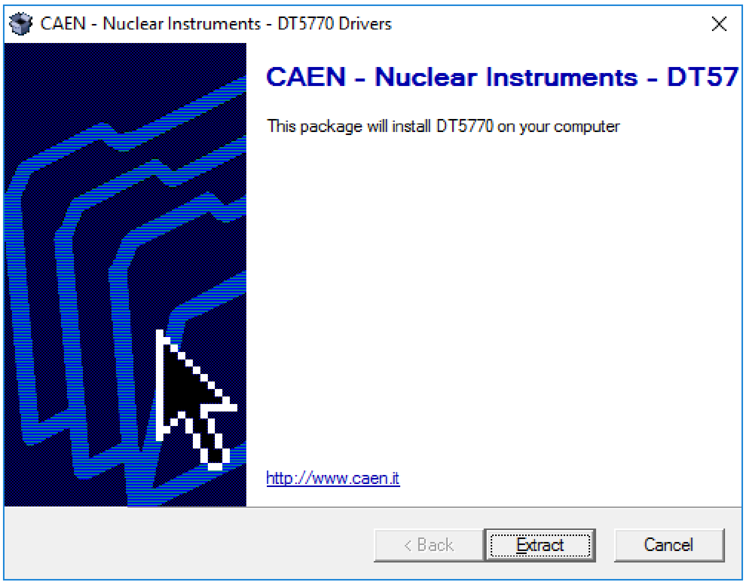
- **If Microsoft .NET is not already installed**, the setup will ask you to install it. The operation may take some minutes.
- **Complete** the **Installation wizard and click "Install".**



- At the end of the installation wizard, click on "Finish"



- After the software installation**, you will be asked to install the DT5770 drivers on your PC.** Click on "Extract" and complete the driver installation following the Wizard instructions.



- The setup will create a Desktop icon.
- Launch the program when the setup is completed.
- See Section **Installation** for requirements and special cases.

Practical Use

The following step-by-step procedure shows how to use the Emulation Software to generate a simple output signal with the Emulator and acquire the same signal with the MCA.

1. Check that the whole hardware is properly connected and powered on (see Figure 2.5).
2. Run the Educational Software GUI, according to one of the following options:
    - The Desktop icon
    - The Quick Launch icon
    - The .exe file in the main folder from the installation path on the user PC
3. Connect to the Emulator and the MCA

    Check both the Emulator and the MCA checkbox and select the DT4800 Digital Detector Emulator and the DT5770 Digital Multi Channel Analyzer from the two drop-down menues. Press the button "**Connect**".

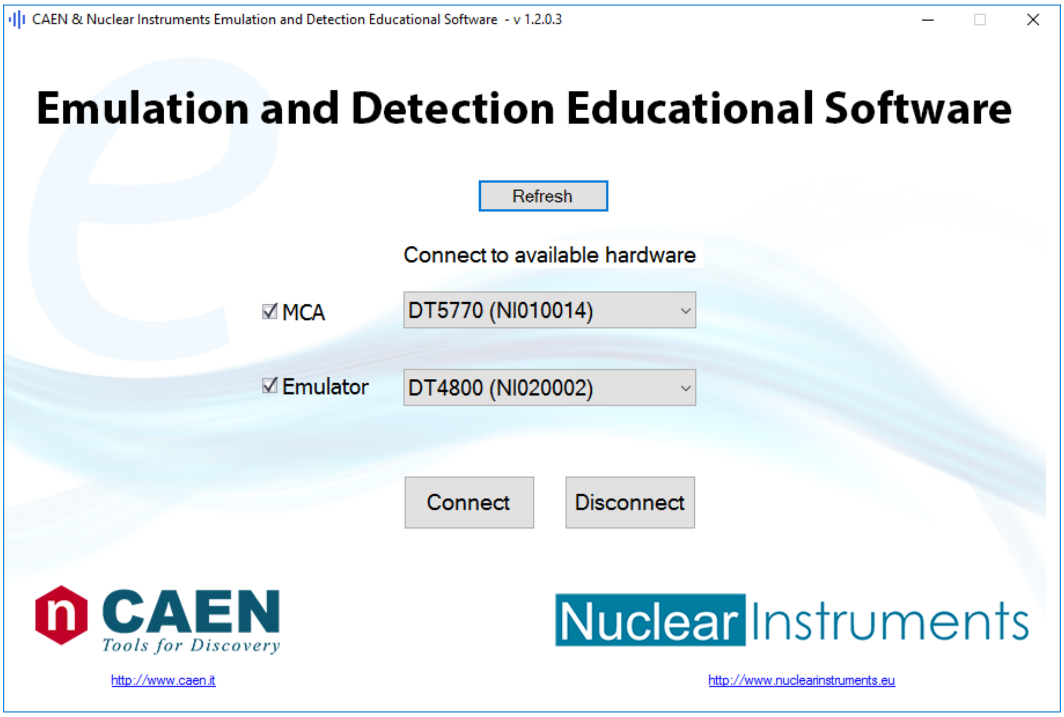


Figure 2.6: The Emulation Software "Connection Manager", which opens after the software start.

4. **GUI**

    The **Educational Software** is a GUI that allows the user to setup and acquire a signal in a very straightforward way. The Software Interface generates exponential shape analog output, with as many piled-up events as half of the DAC frequency. The user can set the analog output signal rate, the amplitude, the rise and fall time of the exponential shape, the white noise contribution as well as the Random walk noise. The GUI also allows to acquire the generated signal with the MCA. The user can set the features for the analog input signal, trigger with a single threshold or with a trapezoidal mode, use the charge integration or the trapezoidal as energy filter, control the baseline calculation and the pile-up rejection.

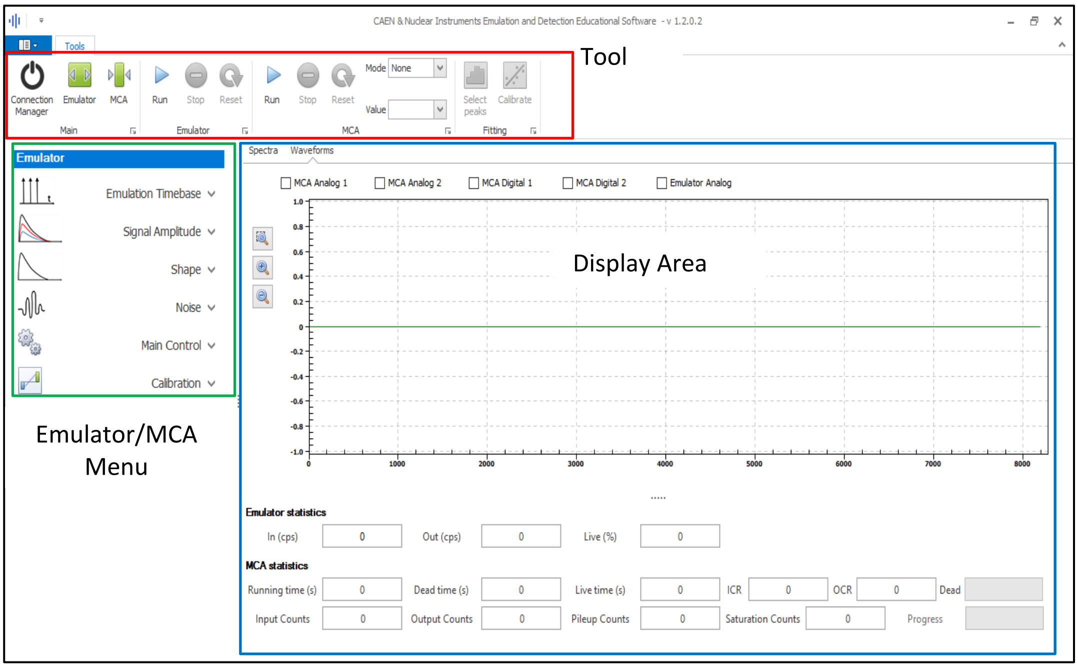


Figure 2.7: the Emulation Software GUI.

5. **Generate the Emulator analog signal**

<u>**Action 1:**</u> Click the arrow on the right of the "**Emulation Timebase**" item of the "**Emulator Menu**". Set the "**Time probability type**" to "**Poisson**" using the drop-down list and change the "**Rate (kcps)**" to 10 kHz.

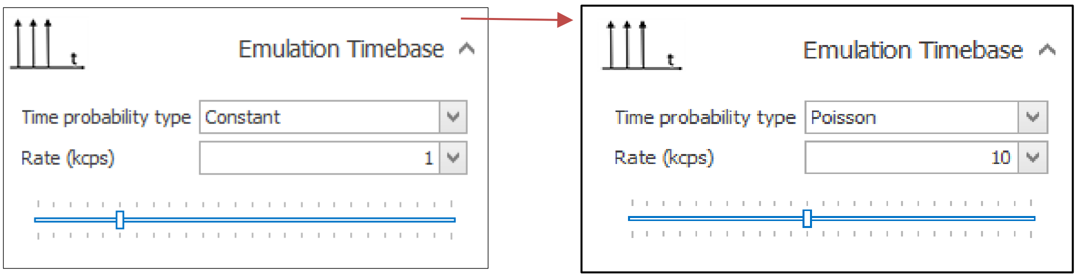


Figure 2.8: the "Emulation Timebase" settings.

Note: The user can change the rate value by either moving the bar pointer, by writing the value in the box or by clicking the arrow at the right of the box and click on the numbers.

<u>**Action 2:**</u> In the Signal Amplitude item of the Emulator Menu, set the "**Amplitude probability**" to **"Constant"** and change the amplitude value "**V**" to 0.5 V.

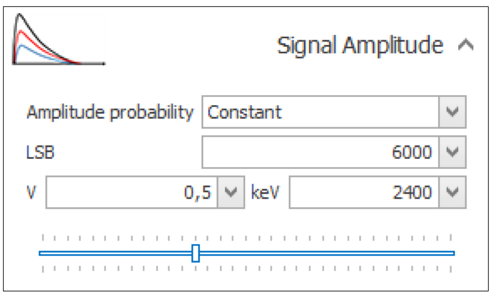


Figure 2.9: the "Signal Amplitude" settings.

Note: The user can change the amplitude value by either moving the bar pointer, by writing the value in the LSB box or the value in Volts in the "**V**" box, or by clicking the arrow at the right of the "**LSB**" or the "**V**" box and click on the numbers.

__Action 3:__ Set the shape parameters: "**Rise Time (us)**" = 0.1 μs and **"Tau (us)**" = 1.0 μs.

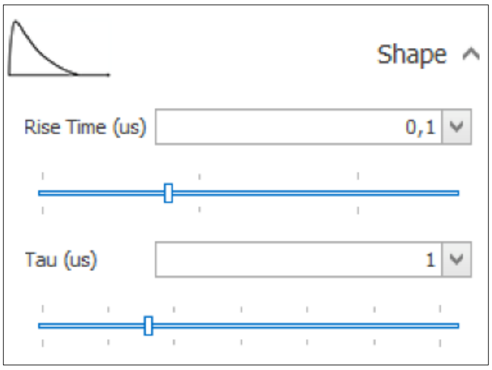


Figure 2.10: the "Shape" menu settings.

Note: The user can change the shape values by either moving the bar pointer, by writing the value in the box or by clicking the arrow at the right of the box and click on the numbers.

Note: If the "**Rise Time**" is set to 0.0 μs, the user is asking for the best the device can provide, i.e. about 7 ns (due to the DAC sampling).

__Action 4:__ Enable the device to generate the output: press "**Run**" in the "**Emulator**" Group Menu of the Tool Bar.

Figure 2.11: the "Emulator" Group Menu of the Tool Bar

6. Check the Emulator analog output

Select the "**Waveforms**" tab in the Display Area and check the "**Emulator Analog**" checkbox to visualize the generated signal. In the following example, it is possible to see the constant signal amplitude, the Poissonian signal time of arrival and the signal shape. The Emulator statistics are reported in the bottom of the Display Area: it is possible to visualize both the set and the generated event rate ("**In (cps)**" and "**Out (cps)**", respectively).

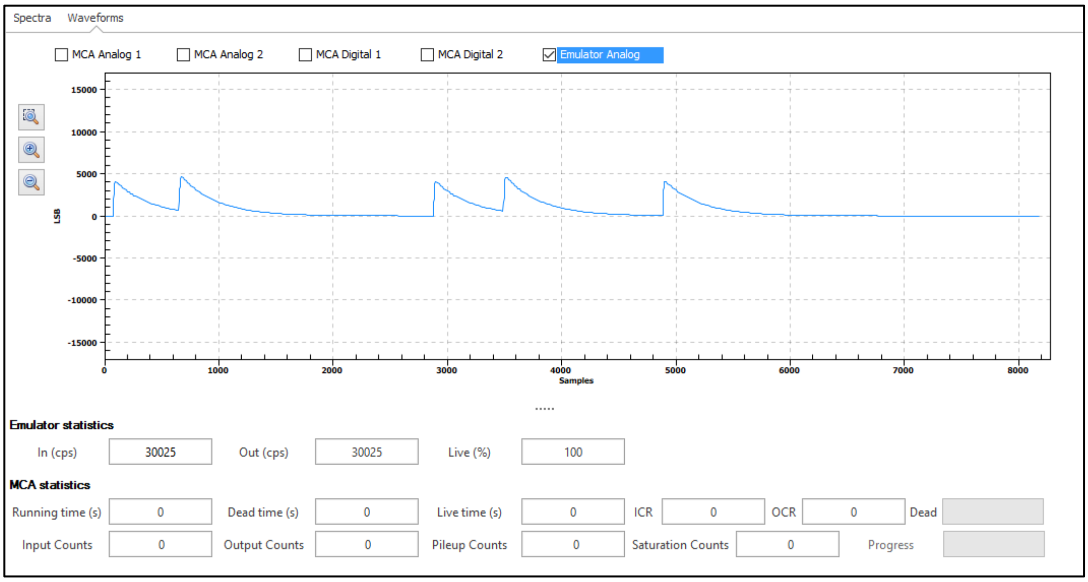


Figure 2.12: The "Waveforms" tab in the Display Area showing the emulated signals.

Note: It is also possible to use an oscilloscope to check the waveform output. Use a 50 Ω termination.

7. Enable the Emulator amplitude generation according to a Spectrum

Action 1: In the **"Signal Amplitude"** item press the button "**Load Spectrum**", which allow to browse and select a spectrum file in the computer. Some examples are provided to the user. Look for the .csv files inside the "Examples" folder in C:\Program Files (x86)\CAEN\EmulationDetectionEdu directory. Select the "cobalto.csv" file.

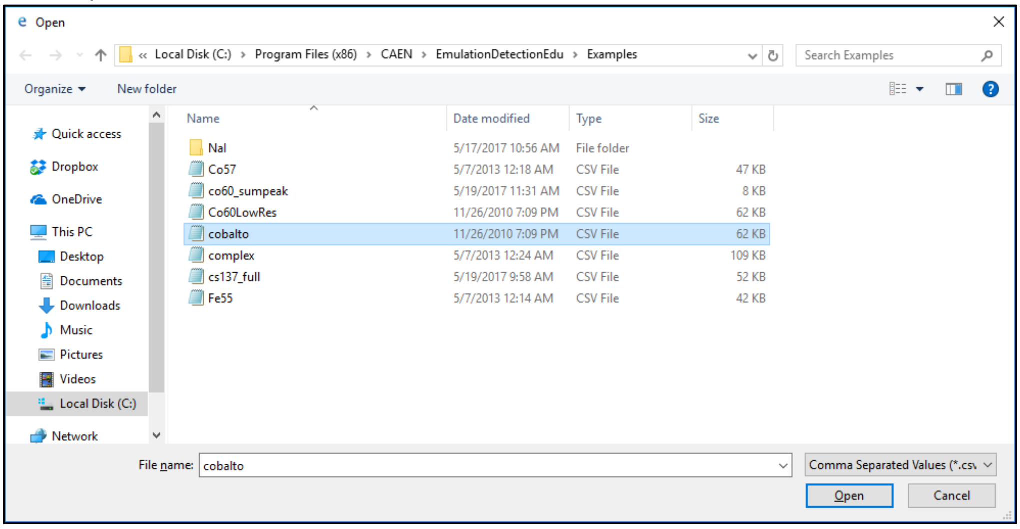


Figure 2.13: The "cobalto.csv" file in the "Examples" folder.

Note: accepted file formats are: .csv (comma separated values), .dat (CAEN spectrum files), .spectrum (digital detector emulator internal spectrum format), .xml (ANSI N42.42)

Action 2: The "Import a custom spectrum from file" window will open. Import the spectrum by clicking **"Import"**.

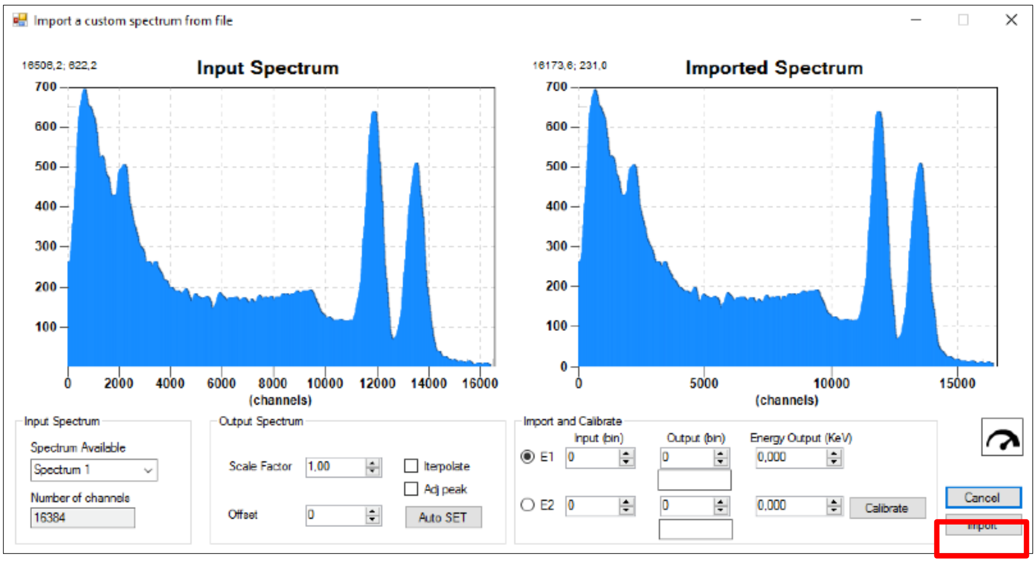


Figure 2.14: the "Import Spectrum" window

Action 3: The “**Amplitude probability**” settings is automatically changed to **“Spectrum”**: the preview of the spectrum will become colored and the parameters relative to the constant amplitude value will not be visible anymore.

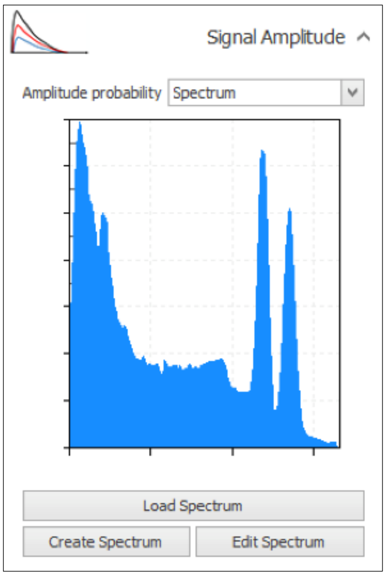


Figure 2.15: The "Signal Amplitude" menu set to generate an energy spectrum.

8. Check the Emulator Spectrum Generation

Select the “**Waveforms**” tab in the Display Area and check the “**Emulator Analog**” checkbox to visualize the generated signal. In the following example, representing the Emulator generated signal according to the spectrum of the isotope ^{60}Co, it can be noticed that the signal amplitude is no longer constant and the signal time of arrival is Poissonian.

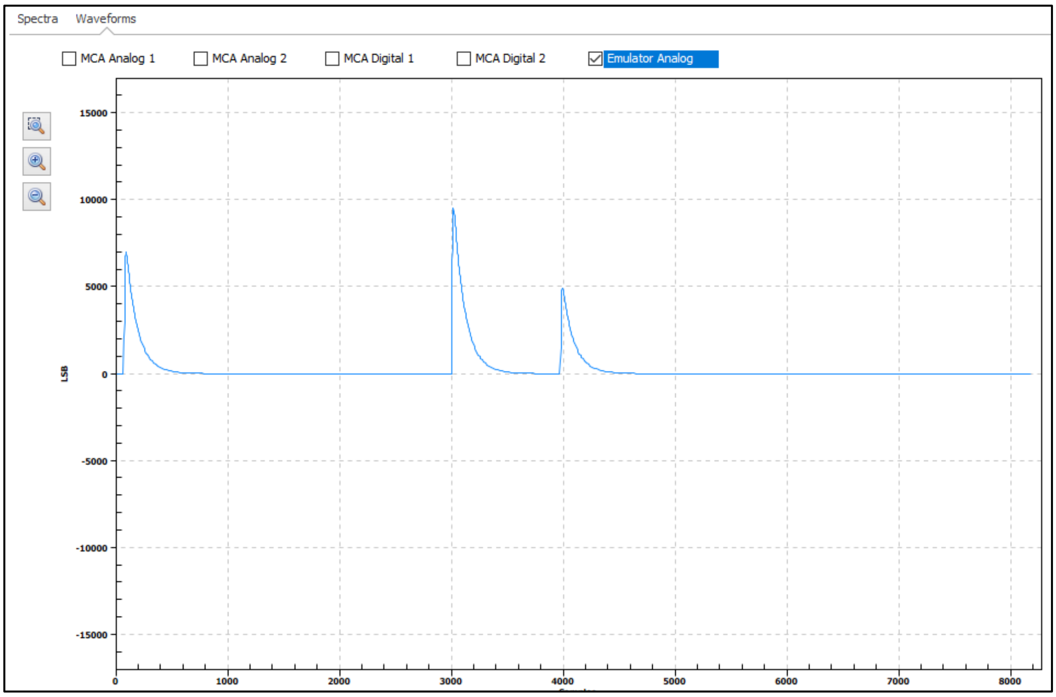


Figure 2.16: plot of the waveforms generated by a Poissonian ^{60}Co spectrum.

Select the "**Spectra**" tab in the Display Area and check the "**Emulator Spectrum**" checkbox to visualize the Spectrum of the Emulator generated signal amplitude. Enhancing the statistics, the spectrum should become similar to the one imported and visible in the Signal Amplitude item of the Emulator Menu.

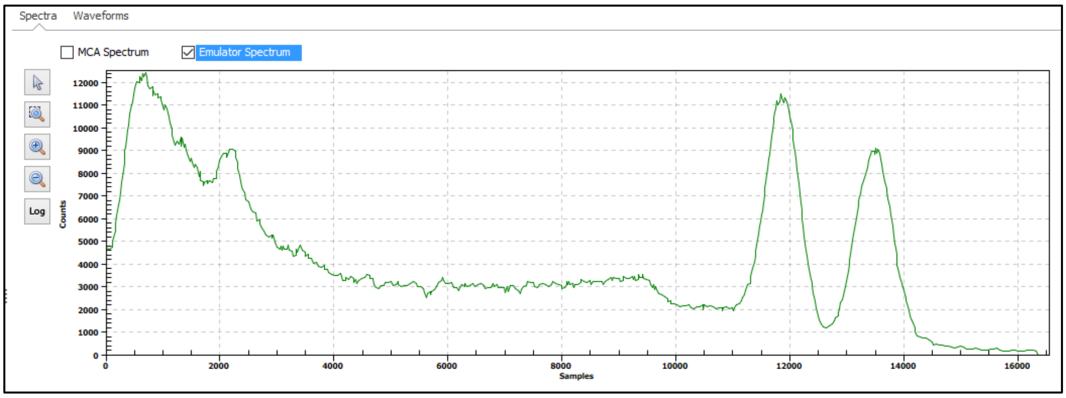


Figure 2.17: plot of the energy spectrum of ^{60}Co generated by the DT4800 Digital Emulator.

9. Acquire an input signal with the MCA

<u>**Action 1**</u>: Keep the same parameters set in the previous steps for the Emulator, but change the "**Digital Gain**" in the "**Main Control**" item of the "**Emulator Menu**" from 1 to 0,3 to prevent the MCA input signal saturation.

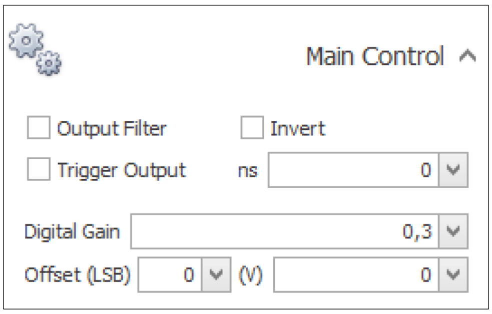


Figure 2.18: The "Main Control" settings.

Action 2: Click the "**MCA**" button in the "**Main**" Group Menu of the Tool Bar and open the "**Analog Input**" item. From the correspondent drop-down menus select the "**50 ohm**" for the "**Input Impedance**" value, the "**Positive**" for the "**Signal Polarity**", the "**Continuos Reset**" as the "**Preamplifier Type**" and "**1.2 V**" as "**Input Range**". Then, by using the "**Offset**" bar pointer, choose the 2000 value.

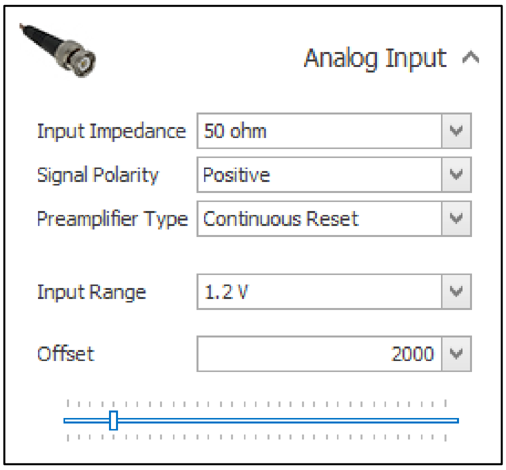


Figure 2.19: the "Analog input" settings.

Action 3: Set the "**Decay Constant (ns)**" in the "**Signal Shape**" item to 1000 ns, which is equal to the decay constant of the signal generated with the Emulator.

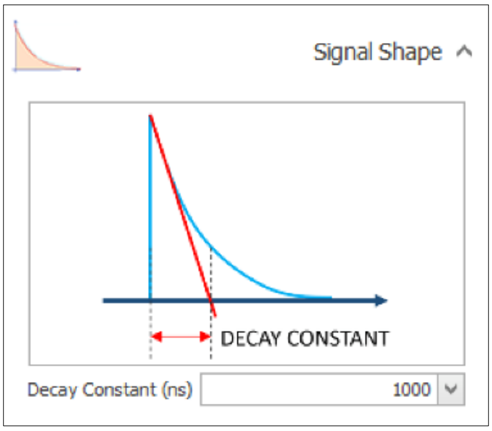


Figure 2.20: the "Signal Shape" settings.

Action 4: Select the "**Trapezoidal Threshold**" as "**Trigger Mode**" in the "**Trigger (FAST)**" item and insert the value of 100 for the "**Threshold (LSB)**", 100 ns for the **"Peaking (ns)"** and 1000 for the "**Hold-off (ns)**" to select only the input signals with amplitude exceeding the 100 LSB value and discard signals occurring during the 1000 ns following the trigger.

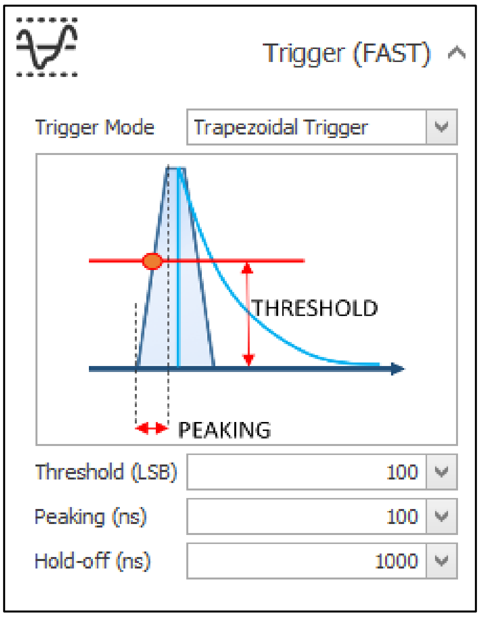


Figure 2.21: The "Trigger (FAST)" settings.

<u>**Action 5**</u>: Use the "**Trapezoidal Filter**" as "**Filter Mode**" in the "**Energy Filter (SLOW)**" item and set the "**Peaking (ns)**" to 1000, the "**Flat Top(ns)**" to 400, the "**Energy Sample (ns)**" to 600 and the "**Digital Gain**" to 1. As a result, the flat top of the trapezoid is really flat and the point in which the energy is sample occurs within this flat region.

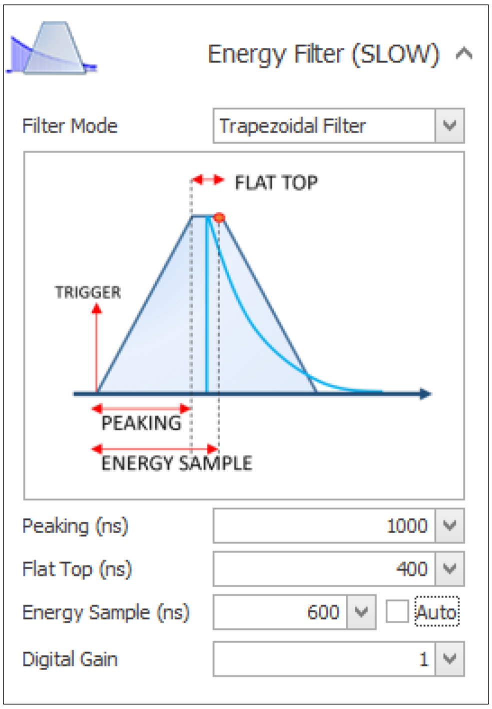


Figure 2.22: the "Energy Filter (SLOW)" settings.

<u>**Action 6**</u>: In the "**Baseline Restorer**" item the "**Baseline Inhibit (ns)**" and the "**Baseline Length (samples)**" should be set to 2000 and 1024, respectively, by inserting the value in the box correspondent to the first parameter and by selecting the correct option in the drop-down menu for the second parameter. In this manner, the baseline calculation starts to be frozen from the trigger and for all the signal duration, while it is enabled again for 1024 points before the occurring of a new trigger.

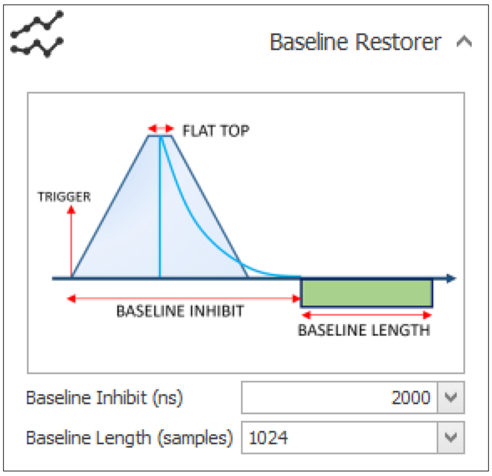


Figure 2.23: the "Baseline Restorer" settings.

Action 7: The "**Pileup Rejector Time (ns)**" parameter in the "**Pileup Rejector**" item should be equal to 2000, ensuring the discard of signals occurring during the decay time of a previous signals. In this way, the problems related to the calculation of the energy of overlapping signals are avoided.

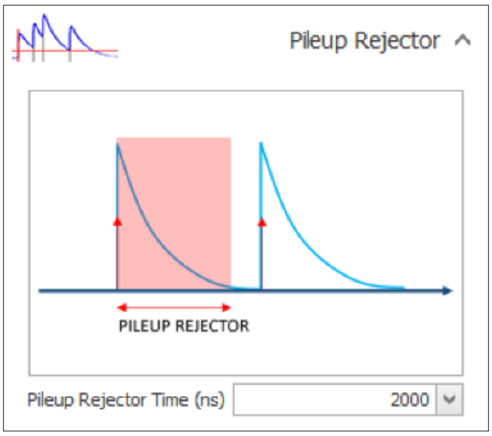


Figure 2.24: the "PileUp Rejector" settings.

Action 8: Press the "**Run**" button in the "**MCA**" Group Menu of the Tool Bar to enable the MCA spectrum acquisition. In order to set the acquisition length basing on the number of counts or in the time, select the **"Live Time"**, **"Total time"** or the "**Counts**" item in the "**Mode**" drop-down menu and insert the desired "**Value**" before pressing the "**Run**" button. A complete explanation of the "Mode" options is given in **MCA Menu** section.

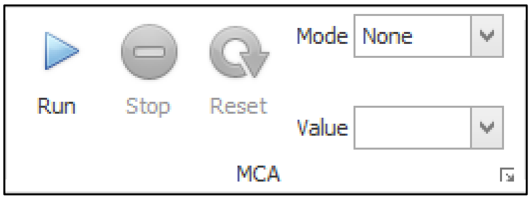


Figure 2.25: the MCA Group Menu of the Toolbar.

10. Check the MCA signal acquisition

Action 1: The visualization of the MCA signals in the Display Area can be controlled in the "**Monitor**" item of the "**MCA Menu**". Associate the "**Input Signal**" to the "**Analog 1**" and the "**Trapezoidal - baseline**" to the "**Analog 2**". The "**Digital 1**" and the "**Digital 2**" should be set to visualize the "**Trigger**" and the "**Peaking**", respectively. Select the "**Main Trigger**" as "**Monitor Trigger**". Leave the other parameters unchanged.

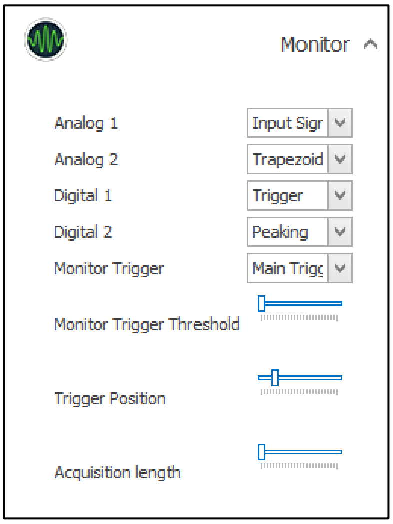


Figure 2.26: the "Monitor" menu settings.

Action 2: Select the "**Waveforms**" tab in the Display Area and check all the checkboxes related to the MCA. In the graph of the Display Area the four signals chosen in the "**Monitor**" of the "**MCA Menu**" can be visualized. Below the checkbox a legend will appear to understand the signal color code.

If needed, use the  button to zoom on a rectangular region around the signals. Please check that the trapezoid parameters have been chosen correctly. In particular, control that the trapezoid top is really flat and that the energy sample occurs within the flat top region. The fact that the trapezoid signals does not have overshoots or undershoot means that the time constant has been set correctly.

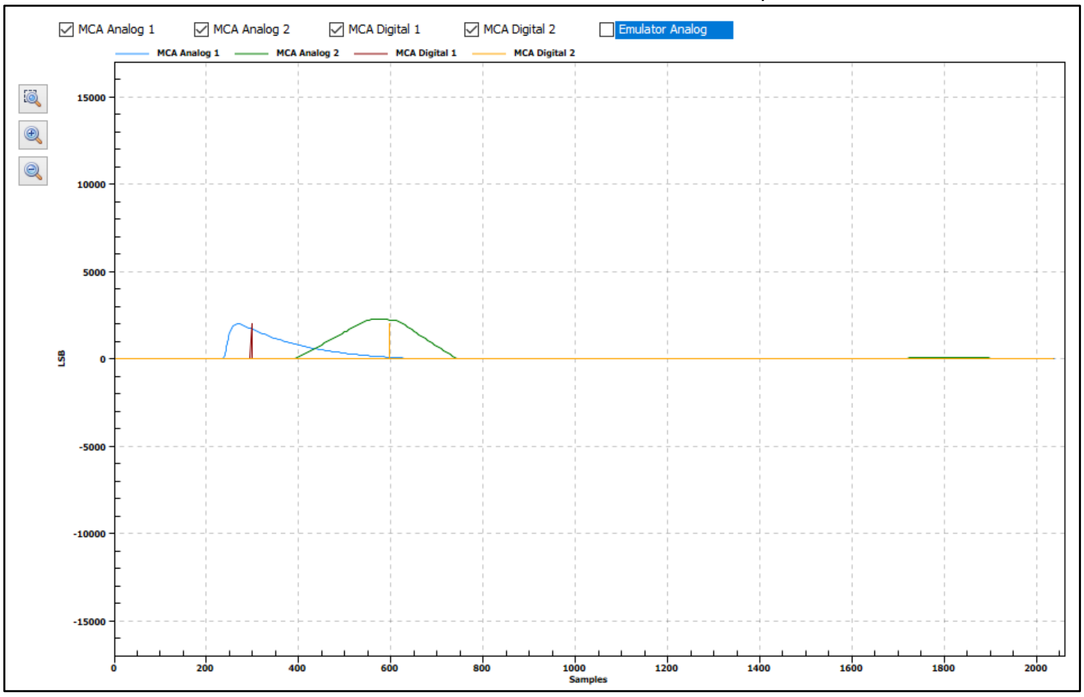


Figure 2.27: the Display Area showing the Digital and Analog Traces of the MCA as set in the "Monitor" menu.

Action 3: Select the "Spectra" tab in the Display Area and check the "MCA Spectrum" checkbox. Continuing to accumulate events the spectrum acquired with the MCA will become similar to the one generated by the Emulator. In this example, it is possible to appreciate all the features of the ^{60}Co spectrum.

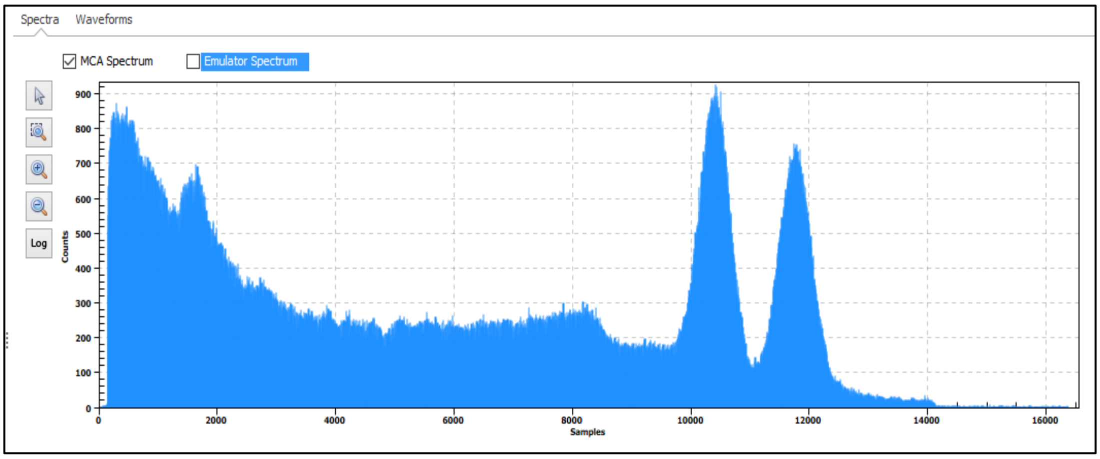


Figure 2.28: the Display Area showing the ^{60}Co spectrum as acquired by the MCA.

3 Software Interface

Introduction

The Emulation and Detection Educational software allows to manage the communication and to set the parameters for the signal generation and acquisition. In particular the software can fully manage the settings and operation of DT4800 Digital Detecor Emulator and DT5770 MCA. This chapter is intended to give to the user a complete description of all the functionalities of the Emulator and the MCA that can be set through the software interface.

Installation

The Emulation Software is compliant with Windows 7, 8, 8.1 and 10 OS, both 32 and 64 bit.

Download the standalone Educational Emulation Software full installation package on CAEN website in the "Download" area of the Emulation Kit page (login is required before the download).

Unpack the installation package, launch, as administrator, the setup file, and complete the Installation wizard. See Section

Emulation and Detection Educational Software for further details.

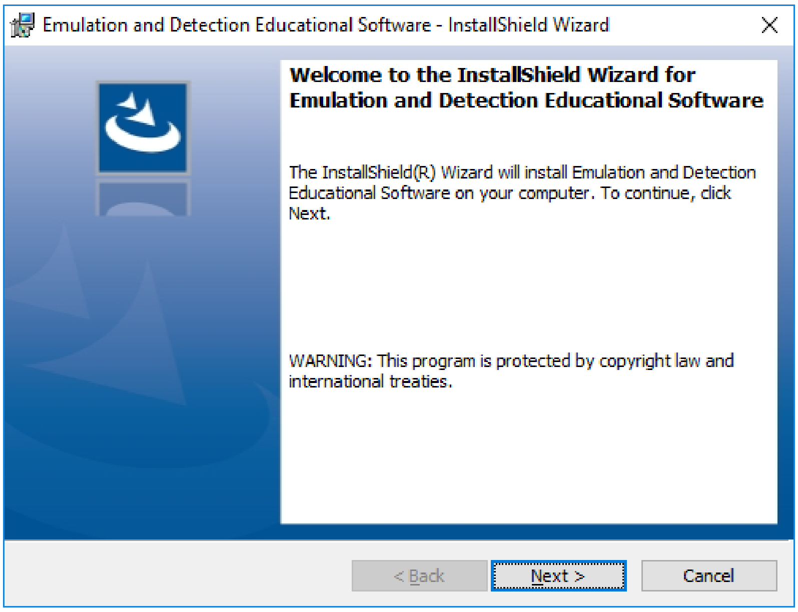


Figure 3.1: screenshot of the Emulation and Detection Educational Sotware installation wizard.

The setup automatically creates a link on the PC Desktop.

Requirements

The software requires Microsoft .NET 4.0 or higher.

Program Execution

The user can run the program in three ways:

- The **Desktop icon** of the program
- The **Quick Launch** icon if the program
- The **.exe file** in the installation path on the user PC.

When the program is opened, it automatically lists the available Emulator and MCA connected to the PC via USB in the "Connection Manager" window.

The user can check the checkbox of the type of device ("**MCA**" and/or the "**Emulator**") that should be connected and choose the specific device from the correspondent drop-down menu. If your devices are not present try to press the **"Refresh"** button to perform another devices scan.

Then press the "**Connect**" button to connect the selected devices and open the GUI.

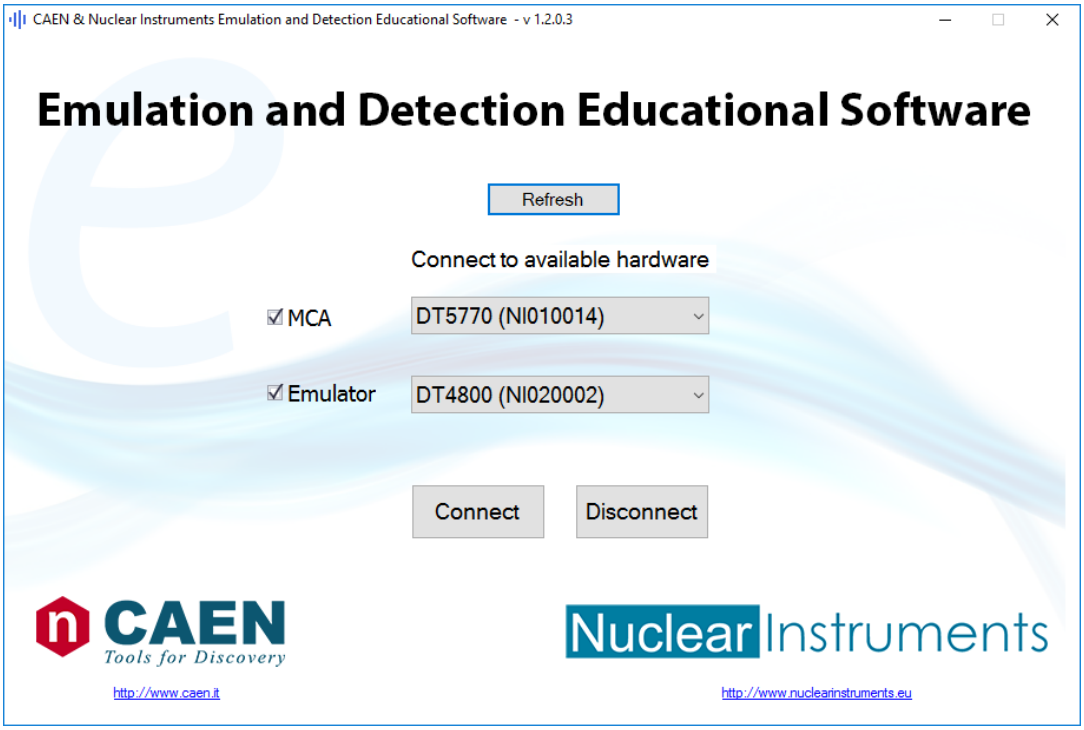


Figure 3.2: the "Connection Manager" window listing the available devices.

User Interface

The Software interface is particularly indicated for quickly setting the instruments. The GUI Interface enables the Emulator to generate an analog output: the user can set the analog output signal rate, the amplitude, the rise and fall time of the exponential shape, and the noise contributions. The GUI also allows to acquire the generated signal with a MCA. The user can set the features for the analog input signal, trigger with a single threshold or with a trapezoidal mode, use the charge integration or the trapezoidal as energy filter, control the baseline calculation and the pile-up rejection.

The GUI is divided in various sections:

- File Menu: it is accessible by clicking the blue button in the top left corner of the GUI and allows to save and load the parameter settings, save the MCA spectrum and exit the GUI;
- Tool Bar: is the bar on the top of the GUI containing the main controls related to the Emulator signal generation and MCA signal acquisition;
- Emulator/MCA Menu: it appears on the left of the GUI and allows the user to set all the parameters of the Emulator and the MCA;
- Display Area: it is the part of the GUI including the graph and a box in the bottom part to visualize the device statistics

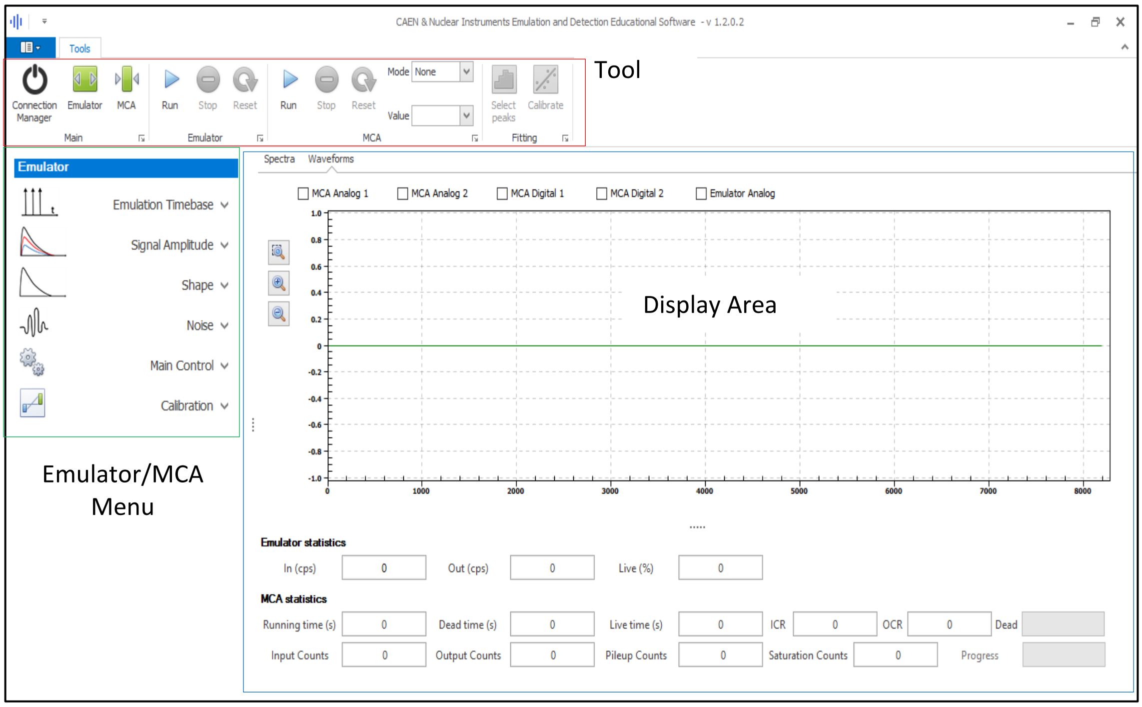


Figure 3.3: the Emulation and Detection Software GUI.

File Menu

The user can assess further functionalities by pressing the "**File Menu**" button on the top left of the GUI.

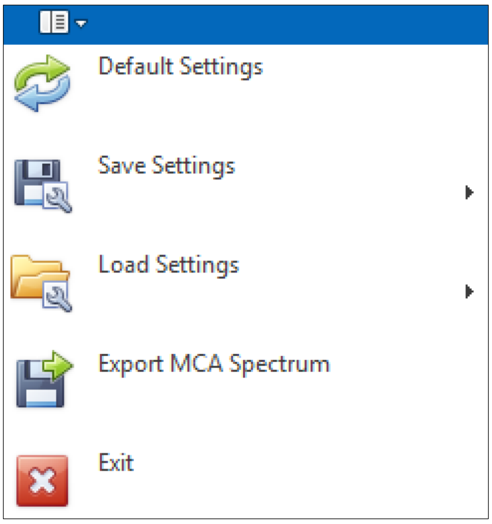


Figure 3.4: the "File Menu".

- "**Default Settings**": it clears each parameter and sets the default ones, as they appear when the GUI is started.
- "**Save Settings**": it has sub-items accessible by clicking on the arrow on the right to save the parameters setting for the Emulator and the MCA in a .nis file (see **Accepted File Formats** for more detail on this file extension). The selection of each sub-item opens a browser window to select the folder destination and the file name.

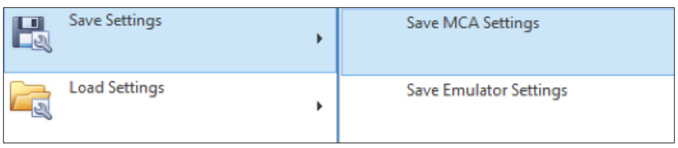


Figure 3.5: the "Save Settings" options of the "File menu".

- "**Load Settings**": it has sub-items accessible by clicking on the arrow on the right to load the parameters setting for the Emulator and the MCA trough a .nis file (see **Accepted File Formats** for more detail on this extension). The selection of each sub-item opens a browser window to select the setting file to be loaded.

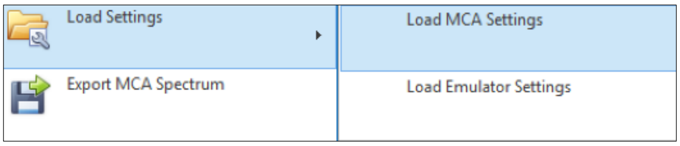


Figure 3.6: the "Load Settings" options of the "File menu".

- "**Export MCA Spectrum**": it allows to save the spectrum acquired with the MCA in .csv, .xml and .n42 formats specifying the destination folder and the file name (for further details see **Accepted File Formats**).

- "**Exit**": it closes the GUI.

Tool Bar

The Tool Bar is divided in four different sections, identified as Group Menu:

- "**Main**"
- "**MCA**"
- "**Emulator**"
- "**Fitting**"

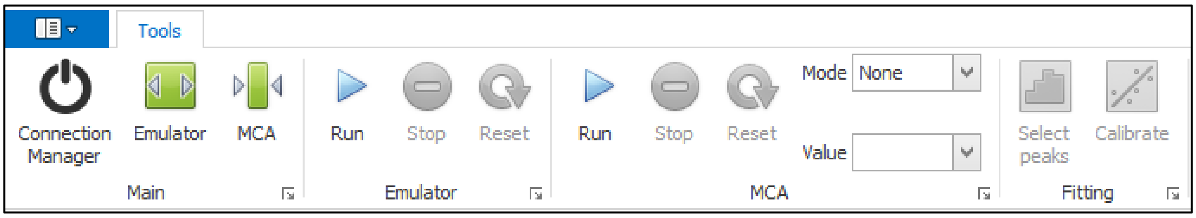
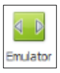


Figure 3.7: the Tool Bar of the software GUI.

The "**Connection Manager**" button in the "**Main**" Group Menu opens the "**Connection Manager"** window, the same appearing when the software starts. The "Connection Manager" allows the user to disconnect and connect again the selected devices without losing any parameter.



The "**Emulator**" button in in the "**Main**" Group Menu shows in the left region of the GUI a Menu to see and set all the parameters related to the Emulator functionalities (all the details are available in Section **Emulator Menu**).

The "**MCA**" button in in the "**Main**" Group Menu shows in the left region of the GUI a Menu to see and set all the parameters related to the MCA functionalities (all the details are available in Section **MCA Menu**).

The "**Run**" button is present both in the "**MCA**" and in the "**Emulator**" Group Menu. It is used to start the MCA signal acquisition and the Emulator output signal generation, respectively. When it is pressed, it becomes disabled and the "**Stop**" and the "**Reset**" buttons that were previously disabled are now enabled (see **Figure 3.8**). In addition, when the MCA is running, the "**Select peaks**" in the "**Fitting**" Group Menu can be selected to proceed with the MCA energy calibration (more information can be found in Section **Calibrate the MCA in Energy**).
In the example below the "**Run**" button has been pressed for both the MCA and the Emulator devices.

Figure 3.8: the Tool Bar of the GUI, after "Run" button was pressed for both the Emulator and the MCA.

The “**Stop**” button is present both in the “**MCA**” and in the “**Emulator**” Group Menu. It is used to stop the MCA signal acquisition and the Emulator output signal generation, respectively. When it is pressed, it becomes disabled, together with the “**Reset**” buttons, while the “**Run**” buttons will be enabled.

The “**Reset**” button is present both in the “**MCA**” and in the “**Emulator**” Group Menu. It is used to reset the MCA signal acquisition and the Emulator output signal generation, respectively. When it is pressed, the acquisition is stopped, the spectra are cleared and a new acquisition is started again.

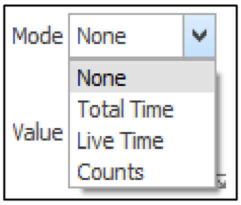
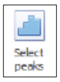
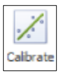


Figure 3.9: the "Target" menu of the "MCA" Group Menu.

The MCA spectrum acquisition can proceed continuously or it can be targeted in time or in counts. This condition can be achieved by selecting the “**Total Time**”, **“Live time"** or “**Counts**” in the “**Mode**” drop-down menu of the “**MCA**” Group Menu. In the “**Value**” box the user can define the value that must be reached to stop the MCA spectrum acquisition, expressed in seconds or in number of events, depending on the chosen “Mode”. When this functionality is exploited to control the MCA spectrum acquisition, in the bottom box of the Display Area, in the section dedicated to the MCA statistics, the “**Progress**” Bar is enabled. The green portion of the “**Progress**” Bar will be updated with a percentage corresponding to the instantaneous acquisition time or number of counts with respect to the target “**Value**”. The procedure to acquire a MCA spectrum targeted in time/counts will be explained in Section **Acquire and save a MCA Spectrum**.



The “**Select peaks**” button in the “**Fitting**” Group Menu is enabled only when the MCA is running. When it is pressed, on the bottom of the Display Area the statistics are cleared and a new table appears. It allows to define one or more regions in the spectrum acquired by the MCA to be fitted with a Gaussian function and corrected for a linear underlying background. When at least two peaks are fitted, the “**Calibrate**” button in the same Group Menu will be enabled to assess the energy calibration procedure for the MCA, shown in detail in Section **Calibrate the MCA in Energy**.



The “**Calibrate**” button in the “**Fitting**” Group Menu is enabled only when at least two peaks are fitted in the MCA spectrum trough the tool appeared in the bottom of the Display Area with the “**Select peak**” button pressing. It enables the user to calibrate in energy the MCA by associating to the selected peaks the desired energy values. Refer to Section **Calibrate the MCA in Energy** for further details.

Emulator Menu

The "**Emulator Menu**" can be visualized on the left of the GUI by pressing the button "**Emulator**" in the "**Main**" Menu Group of the Tool Bar.

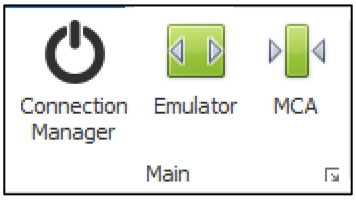


Figure 3.10: the "Main" menu in the Tool Bar.

The "**Emulator Menu**" has 6 items:

- "**Emulation Timebase**": it is dedicated to the setting parameters related to the time signal generation;
- "**Signal Amplitude**": it is dedicated to the setting parameters related to the amplitude signal generation;
- "**Shape**": it is used to change the generation signal shape parameters;
- "**Noise**": it is used to change the generation signal noise parameters;
- "**Main Control**": it contains some additional parameters on the output signal;
- "**Calibration**": it contains the parameters for the Emulator Energy Calibration.

In the following each item will be described in detail.

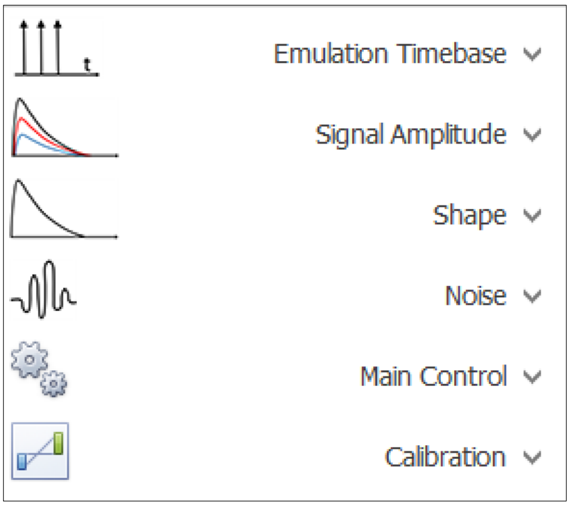


Figure 3.11: the "Emulator Menu".

At the start all the "**Emulator Menu**" items are collapsed. In order to see each item and to change all the parameters inside, click on the arrow on the right of the item label. Click again on the same arrow in order to collapse the item.

EMULATION TIMEBASE

The user can choose among two internal options, "**Constant**" and "**Poisson**" (random) rate, or use an external source.

It is possible to set the rate value in the range 0,05-1000 kHz either moving the bar pointer, by writing the value in the adjacent box or by clicking the arrow at the right of the box and click the desired numbers.

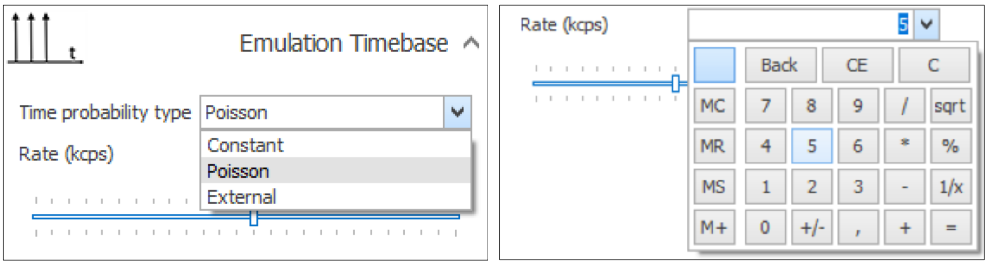


Figure 3.12: the "Emulation Timebase" menu, where different settings input mode are shown.

SIGNAL AMPLITUDE

It is possible to select a "**Constant**" value of amplitude or values of the amplitude distributed according to a spectrum loaded by a file or created by the user.

The "**Constant**" value can be set by either moving the bar pointer, by writing the value in the LSB box or the value in Volts in the V box or the value in keV in the correspondent box (if a calibration has already been performed), or by clicking the arrow at the right of the boxes and clicking on the numbers. The LSB value ranges between 0 and 16000.

When the "**Load Spectrum**" button is pressed, the software opens a folder browser that allows the user to select a file. For details about the accepted file formats please refer to the Section **Accepted File Formats**.

The "**Create Spectrum**" button opens a new window with a tool that enables the user to create a custom amplitude distribution by specifying peaks position, width, type and number of counts and/or exploiting a database of isotope decay energies. In both cases, a preview of the spectrum is then shown in the plot below and the "**Edit Spectrum**" button is enabled.

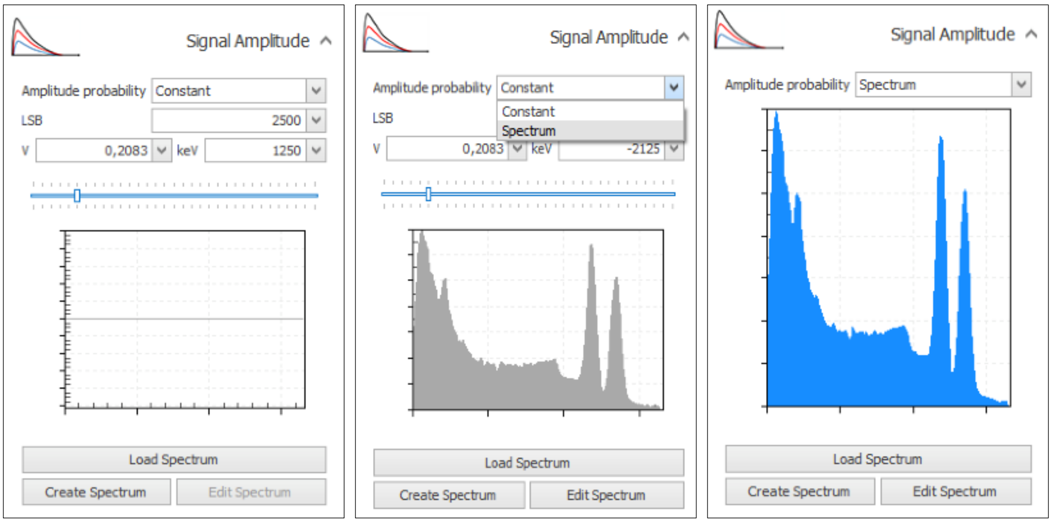


Figure 3.13: the "Signal Amplitude" menu, with settings to emulate a constant amplitude signal (left) and settings to load an energy spectrum (right).

SHAPE

The Software Interface generates exponential shapes. The user can set the "**Rise Time**" (from 0 to 20 µs) and the "**Tau**" (from 0.02 to 1000 µs) (i.e decay time) in µs. Values can be changed by either moving the bar pointer, by writing the value in the box or by clicking the the arrow at the right of the box and click on the numbers.

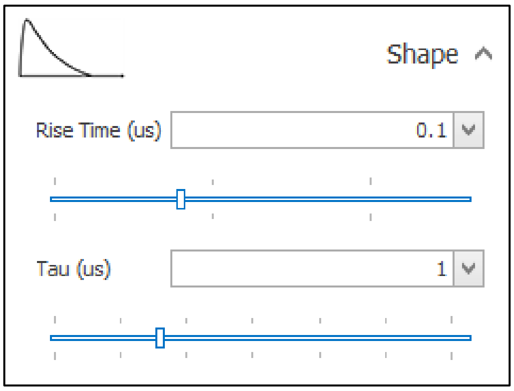


Figure 3.14: the "Shape" menu of the Emulator Group menu.

Note: If the "**Rise Time**" is set to 0.0 µs, the user is asking for the best the device can provide, i.e. about 7 ns (due to the DAC clock).

NOISE

The user can add a white noise to the output signal by setting the sigma of the Gaussian distribution of the noise amplitude ("**Gaussian**") by either moving the bar pointer, by writing the value in LSB or in Volts in the correspondent boxes or by clicking on the arrow on the right of the boxes and click the desired numbers.
The user can also add a baseline drift to the output signal by using the "**Random Walk**" option. The value can be set by either moving the bar pointer, by writing the value in LSB or in Volts in the correspondent boxes or by clicking on the arrow on the right of the boxes and click the desired numbers.

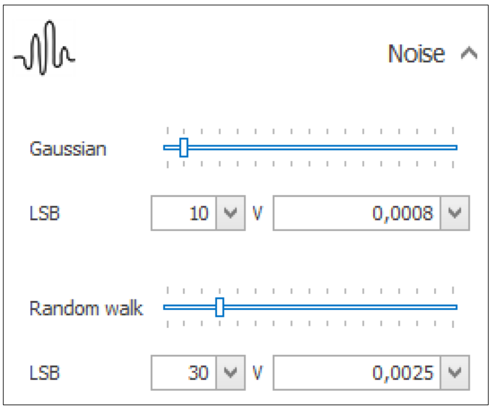


Figure 3.15: the "Noise" menu of the Emulator Group menu.

MAIN CONTROL

"Output filter": A LC 7th order filter (analog Bessel filter) is inserted on the output. It can reduce the output noise by a factor of 5 and it can improve the signal shape. Consequently, the lowest Rise time increases from 7 ns to 16 ns.

"Invert": If selected, the polarity of the output changes.

"Trigger Output": It enables the output of the internal trigger, with the possibility to change the widths in the range between 20 ns and 1000 ns.

"Digital Gain": A digital amplification of the output signal between 0 and 2 is applied at the end of the processing chain. Therefore, the whole output is multiplied by the digital gain, including the offset.

"Offset": The reference offset is expressed as a fraction of 216 quantization levels, i.e. between -2.2 V and +2.2 V. The offset is applied before the gain stage.

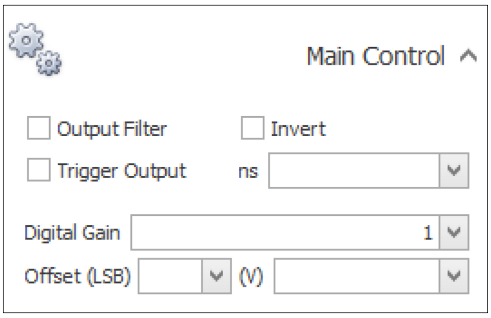


Figure 3.16: the "Main Control" menu of the Emulator Group menu.

CALIBRATION

The user can visualize the calibration parameters or set a new linear energy calibration. This latter action can be achieved by inserting two reference values (either in LSB or in Volts), assign to them the desired value in energy (keV) and press "**Calibrate**" to set the calibration. After the calibration setting, the Emulator Waveforms and Spectra can be visualized in keV and the user can set the output energy directly in energy, according to the physical source that they want to emulate.

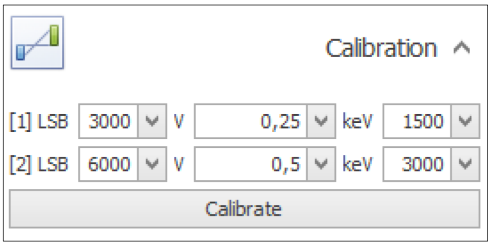


Figure 3.17: the "Calibration" menu of the Emulator Group menu.

Import an Energy Spectrum from File

Select the "**Signal Amplitude**" item in the Emulator Menu and press the "**Load Spectrum**" button. A folder browser is used to choose the spectrum file to be imported. The acceptable file formats are: .csv (comma separated values), .dat (CAEN spectrum files), .spectrum (digital detector emulator internal spectrum format) and .xml (ANSI N42.42) (see the Section **Accepted File Formats** for further details). Then the GUI opens the "**Import a custom spectrum from file**", that allows to upload the spectrum, to make preliminary operations on the spectrum itself and to perform the energy calibration. Some spectrum are provided to the user in the "Examples" folder in "C:\Program Files(x86)\CAEN\EmulationDetectionEdu".

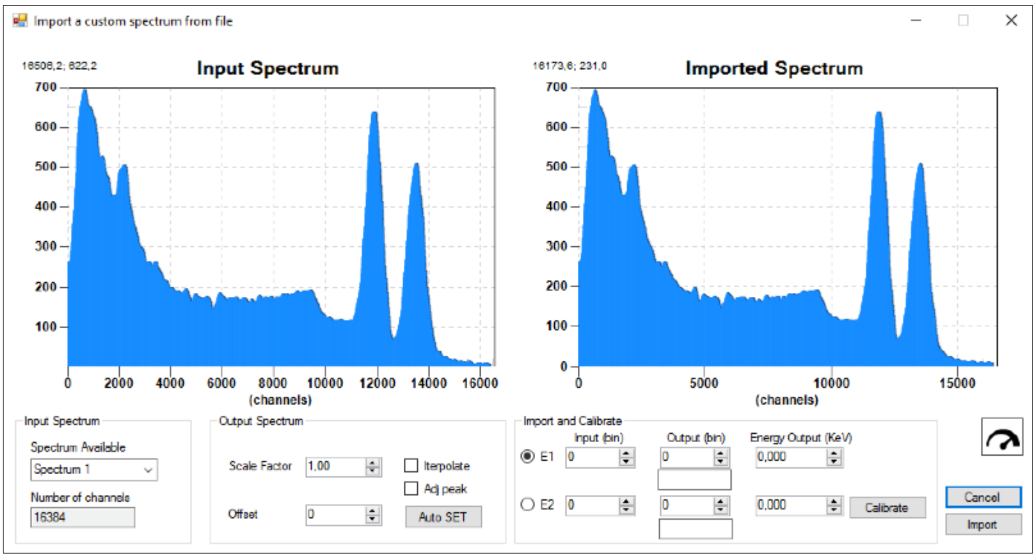


Figure 3.18: the "Import a custom spectrum from file" window.

The **"Input Spectrum"** is the spectrum as taken from the file.

The **"Imported Spectrum"** is the spectrum as imported by the device. Some operations can be made on the input spectrum; the plot "**Imported Spectrum**" allows to see in real-time the effect of those operations.

"Spectrum Available" works for multiple ANSI N42.42 spectra, where it is possible to select the desired spectrum.
"Number of channels" corresponds to the number of channels of the DAC device, 16384.

In the **"Output Spectrum"** box, it is possible to set a **"Scale factor"** and an **"Offset"** values. The first allows to rebin the x-axis of the spectrum. The second allows to set an offset of the x-axis (in number of channels).
The tool allows to adjust the dynamic of the input spectrum to the resolution of 16384 bins of the instrument. By checking the **"Interpolate"** button, the scaling is performed by means of a linear interpolation, otherwise each new bin is created on the basics of the nearest value of the bin on the left. The function of **"Adj Peak"** sets the highest peak of the input spectrum at the value 65535.

It is also possible to calibrate the instrument through the box **"Import and Calibrate"**. Refer to Section **Calibrate the Emulator in Energy** for more details.

Press "**Import**" to import the selected spectrum. A preview of the spectrum is then shown in grey color in the plot inside the Signal Amplitude item.

Selecting the "**Spectrum**" as "**Amplitude probability**" the spectrum becomes colored and the Emulator output signal amplitudes will be produced with values distributed following the loaded spectrum when the "**Run**" button in the "**Emulator**" Group Menu of the Tool Bar will be pressed.

Calibrate the Emulator in Energy

The device can be calibrated in energy. All plots can be then visualized with the x-axis in keV and the user can set the output signal amplitude directly in an energy value, according to the physical source to emulate.

Press the "**Calibration**" item in the Emulator Menu to visualize the calibration parameters or to set a new energy calibration. Put two reference values (either in LSB or in Volts) and assign to them the desired value in energy (keV). Press "**Calibrate**" to determine the linear fit function passing through the two points and set the Emulator calibration.

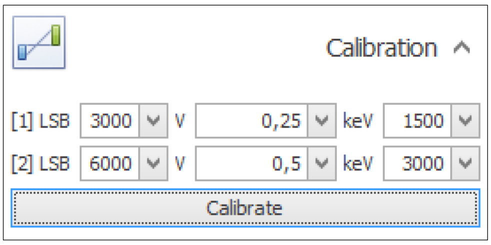


Figure 3.19: correspondance between LSB and energies in the "Calibration" menu of the Emulator section.

It is also possible to calibrate the device through the box **"Import and Calibrate"** in the "**Import a custom spectrum from file**" mode, when the spectrum is imported at the first time (pressing the "**Load Spectrum**" button) or in the following when it can be edit (pressing the "**Edit Spectrum**" button). In fact, if a spectrum has been previously loaded (see the Section **Import an Energy Spectrum from File**), then it appears in the input spectrum window allowing the user to calibrate it. In the example below, a ^{60}Co spectrum is reported.

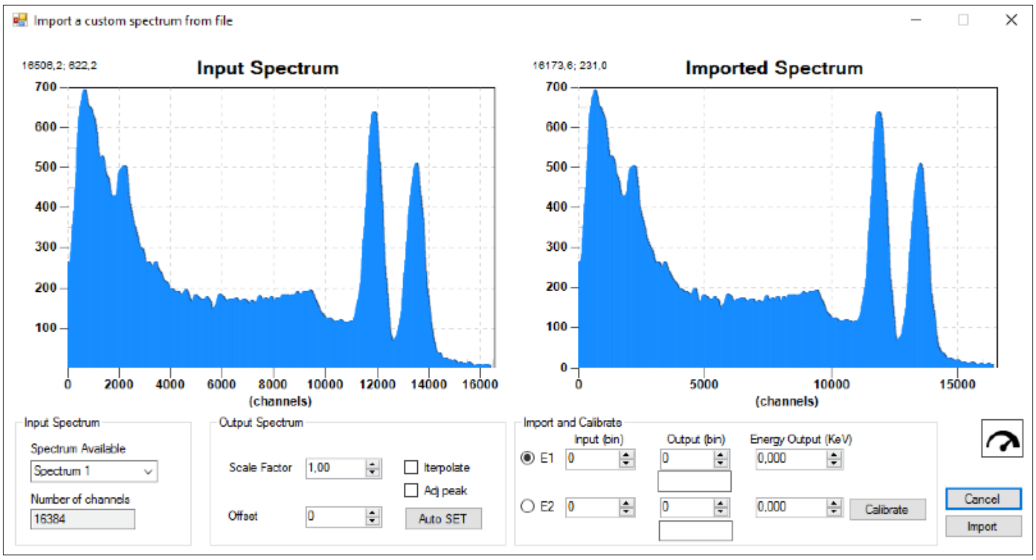


Figure 3.20: the "Import a custom spectrum from file" window, used to calibrate a spectrum in energy.

Double click on one of the two peaks of the "**Input Spectrum**", insert in the "Energy" window that opens the correspondent energy in keV and press "**OK**". The "**Ref1**" marker appears in the plot at the selected channel, showing the value of the assigned energy. Make double click on the second peak to assign the second energy value.

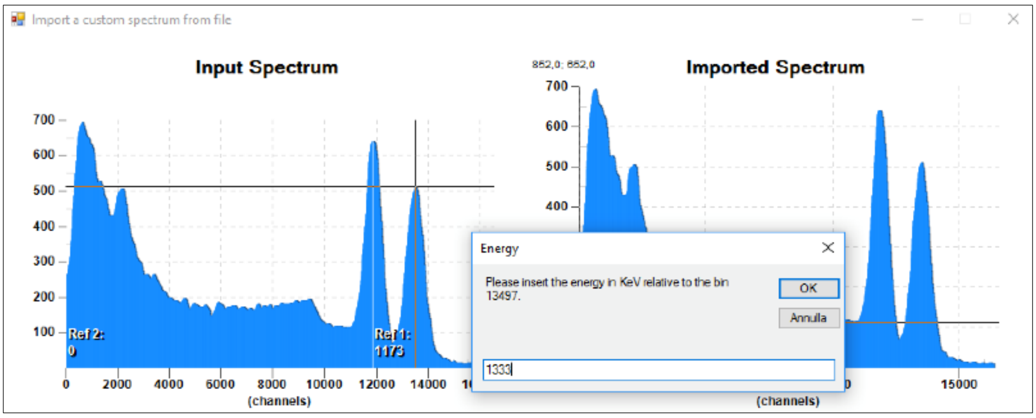


Figure 3.21: spectrum energy calibration through the "Import a custom spectrum from file" window.

The values of the selected peaks in channel and in energy are reported in the "**Import and Calibrate**" box.

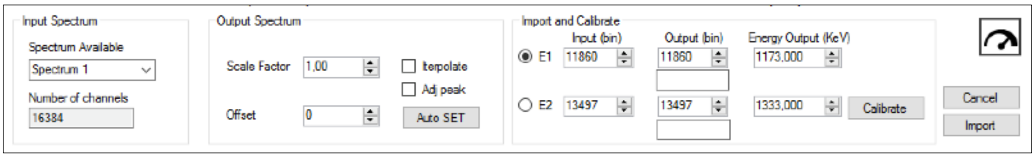
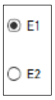


Figure 3.22: the "Import and Calibrate" box in the "Import a custom spectrum from file" window.



Selecting "**E1**" or "**E2**" allows to change between the first and the second calibration point to change the energy.

Press "**Calibrate**" to apply the calibration, "**Cancel**" to cancel the calibration.

The "**Conversion**" button changes the scale of the "**Imported Spectrum**" between Channels, Voltage and Energy.

As an example, the Cobalt 60 Spectum will be imported with the energy scale as x-axis.

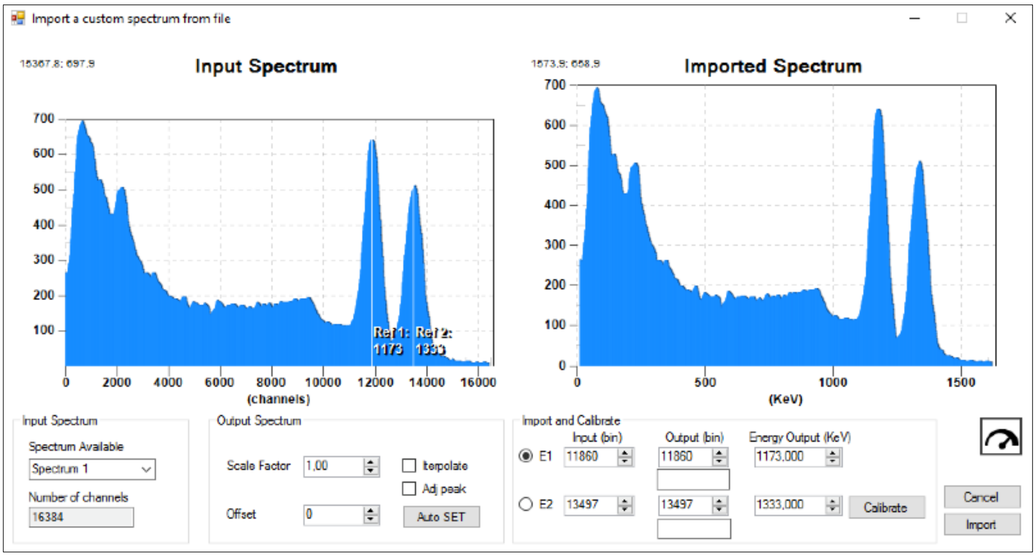


Figure 3.23: an example of energy calibration in the "Import a custom spectrum from file" window.

The user can calibrate the instrument also through the "**Isotopes Database**" tool during the creation or the editing of a custum spectrum. For further details, see the Section **Generate an Energy Spectrum with Isotopes Database**.

Generate an Energy Spectrum with the Emulator Internal Tool

A tool has been implemented in the GUI to allow the user to generate a custom spectrum by adding specific lines and setting their widths and their number of counts. It is also possible to select the radioactive lines of specific elements of the periodic table (Section **Generate an Energy Spectrum with Isotopes Database**).

Press the "**Create Spectrum**" button in the Signal Amplitude item of the Emulator Menu and the "**Spectrum Creator**" window will be opened.

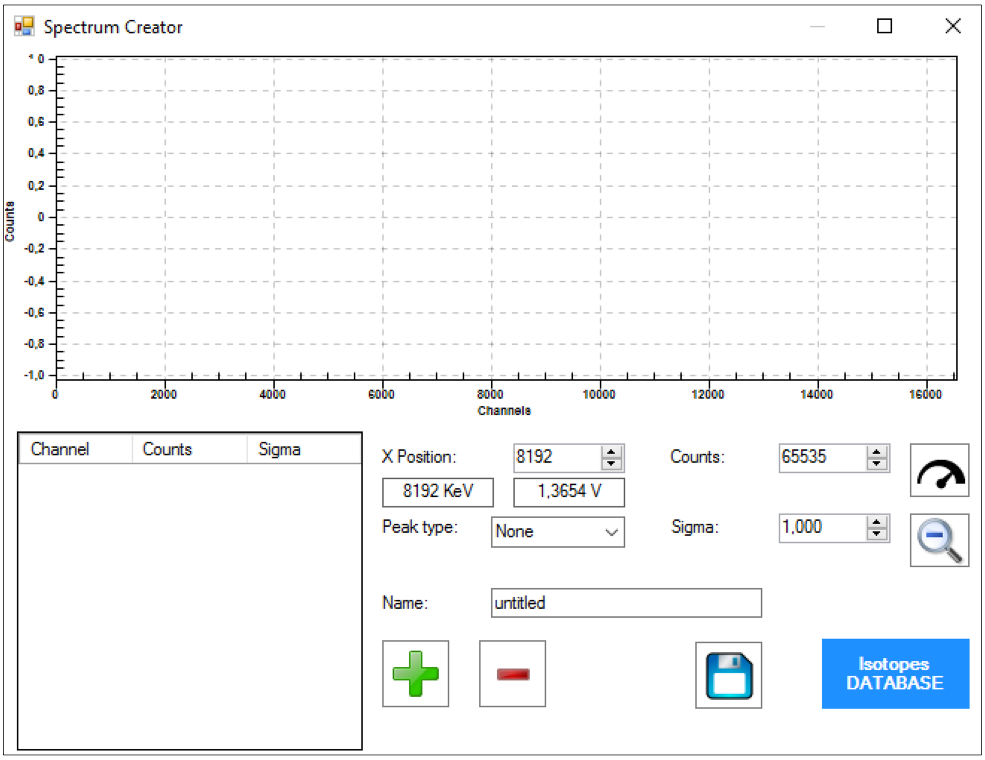


Figure 3.24: the "Spectrum Creator" window.

The diagram will show a preview of the custom spectrum and in the table on the bottom left will be reported all the peaks position, number of counts and widths. The x-axis of the diagram is in channel unit, but the scale can be changed in Volt and keV units through the "**Conversion**" button .

Point the cursor on the diagram and double click to add a line in the desired position. A pop-up window will appear, allowing to write the corresponding value of height. The number 65535 is the maximum value allowed. Press "**OK**" to add the peak in the diagram and the values in a line of the table.

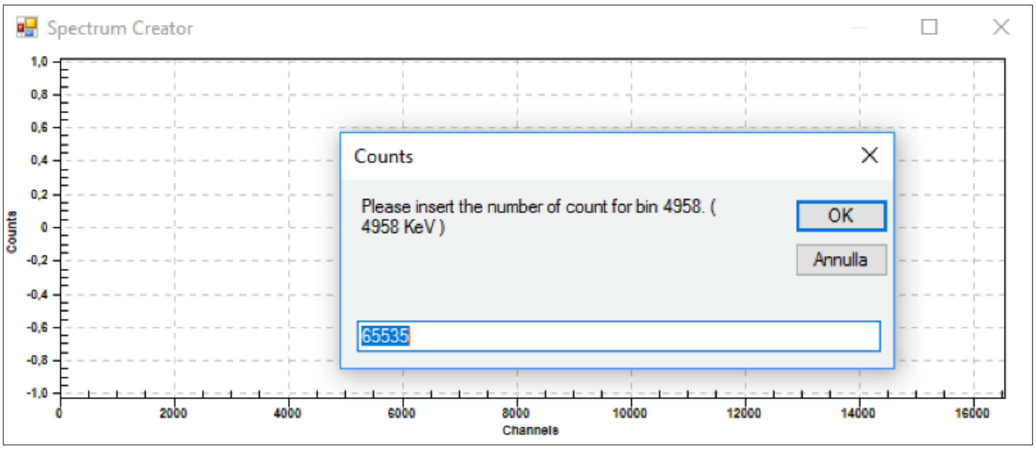


Figure 3.25: line creation with the "Spectrum Creator" tool.

Select the **"Peak type"** between **"Gaussian"** and **"Rectangular"**. The **"Sigma"** value, which is expressed in channel unit , corresponds to the sigma of the Gaussian function in the first case and to the width of the rectangle in the second.

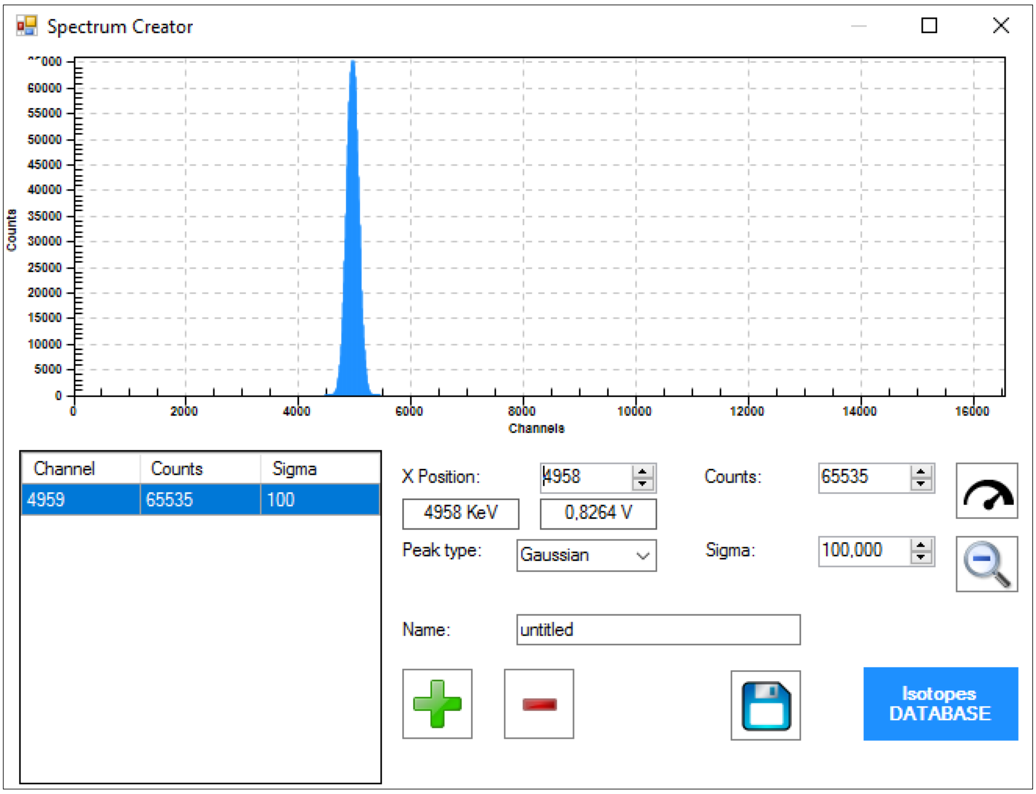


Figure 3.26: settings of the line characteristics with the "Spectrum Creator" tool.

Alternativly, the user can write directly the position of a peak using the "**X Position**" boxes to insert the value in channel, in keV or in Volt. Then the user can complete the other information (number of counts, peak type and width) and press the "+" button to add the peak to the diagram and to the table. The "–" button delete the selected row of the table.

The tool allows to save the spectrum in its internal file format .spectrum through the "**Save**" button . Specify the file **"Name"** before pressing the "**Save**" button, which will open a browser window to select the destination folder.

The spectrum is represented on a scale with maximum resolution of 14 bits, compatible with the Emulator resolution.

Generate an Energy Spectrum with Isotopes Database

From the "**Spectrum Creator**" window (open pressing the "**Create Spectrum**" button in the Signal Amplitude item of the Emulator Menu) click on "**Isotopes DATABASE**".

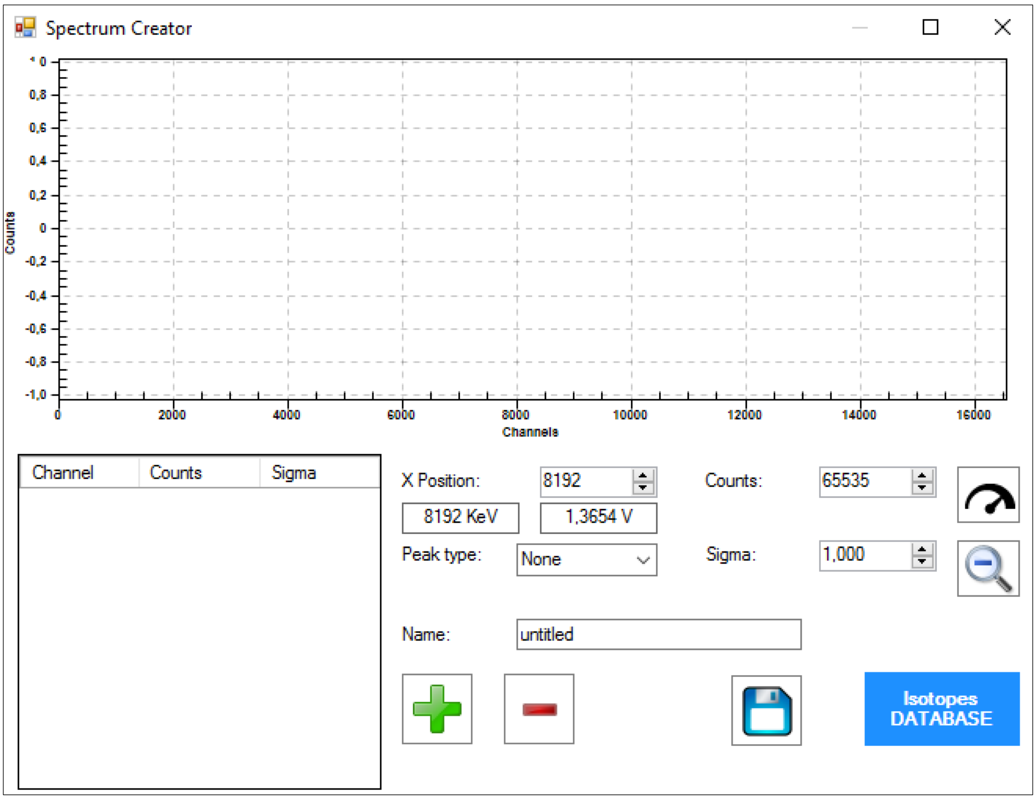


Figure 3.27: the "Spectrum Creator" tool to generate a spectrum from the "Isotopes DATABASE".

The "**PERIODIC TABLE**" window will be shown, allowing the user to select one element whose decay line has to be added in the spectrum. Here, for example, the Co (Cobalt) has been selected.

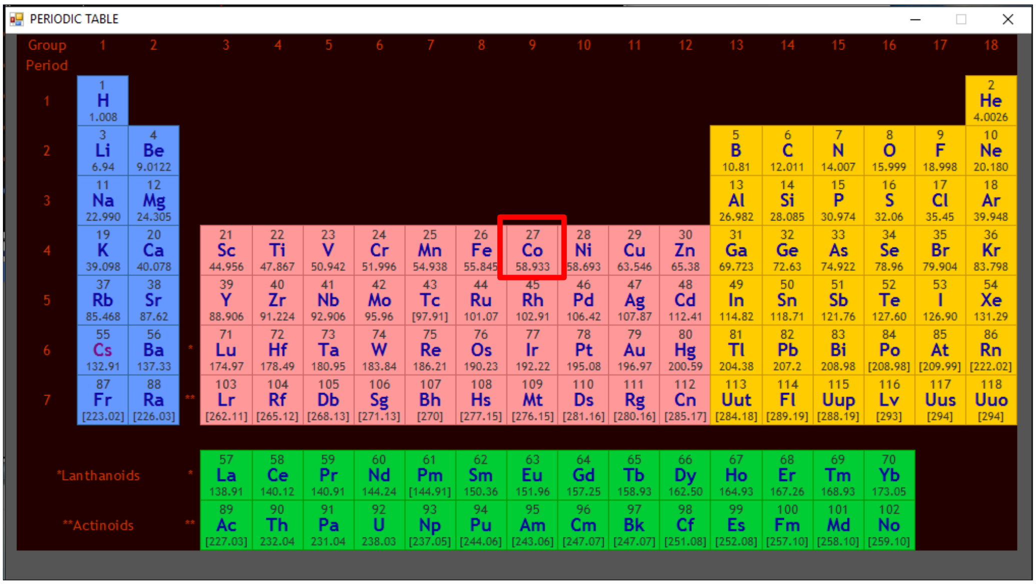


Figure 3.28: the "PERIODIC TABLE", which opens after pressing the "Isotopes DATABSE" button. In this example we select the element Co (Cobalt) to acces the "Peak Isotope" window.

The list of the isotopes of the selected element will then appear in a new window ("**Peak Isotope**"). Scrolling the bar it is possible to select the desired one. For the example reported here the ^{60}Co has been chosen. Click on the name of the isotope in blue is possible to open the "**Decay Selector**" window.

Figure 3.29: the "Peak Isotope" window for Cobalt (Co), where all the available Cobalt isotopes are listed indicating the numbers Z and N, the Half Life and the Abudance.

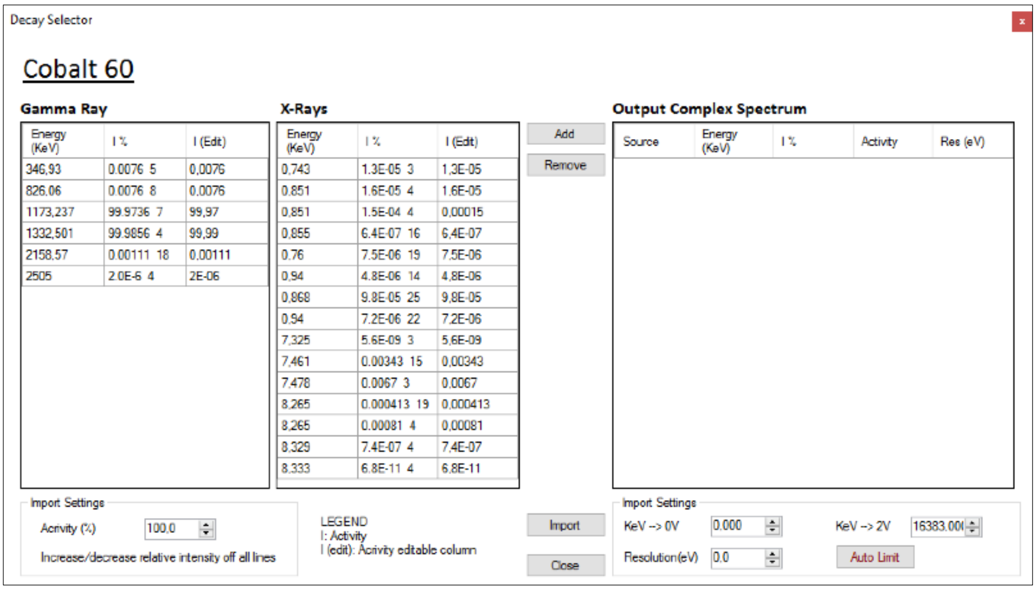


Figure 3.30: the "Decay Selector" window for the Cobalt 60 element. Gamma Ray and X-Rays lines are listed on the left.

The "**Decay Selector**" shows on the first column the list of ^{60}Co emitted "Gamma Ray", on the second the list of "X-Ray" lines. The user can select the desired lines and add them to the output spectrum. For example select the 1173 and 1332 keV Gamma Ray lines, and click "Add". Click "Remove" to remove undesired lines from the output spectrum.

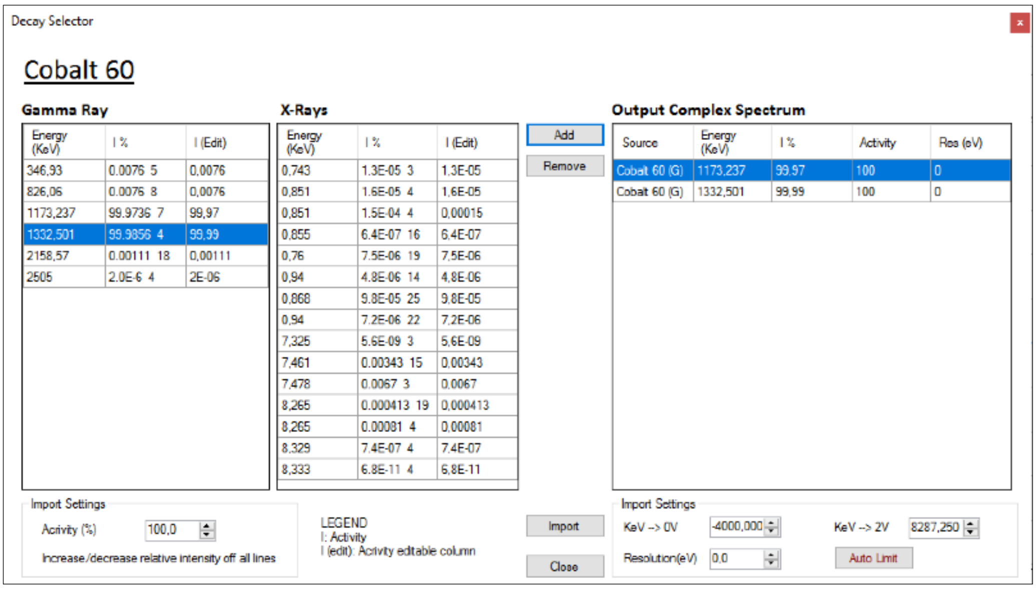


Figure 3.31: selection of Gamma Ray lines for Cobalt 60 to be added to the output spectrum.

The column **I %** represents the relative intensity of the line of the isotope. The column "**I (Edit)"** allows the user to edit the activity (relative cps) of the selected line.

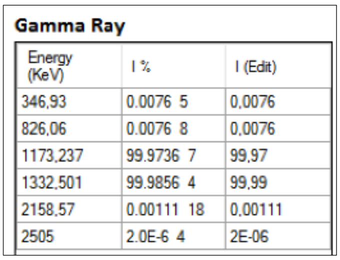


Figure 3.32: the Gamma Ray lines list.

The activity can be edited also from the "**Output Complex Spectrum**" table ("**Activity**"), together with the resolution of the line ("**Res (eV)**") expressed in eV.

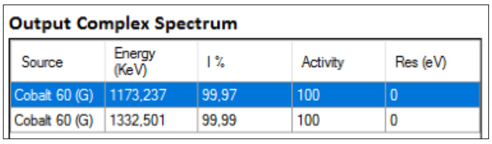


Figure 3.33: lines of Cobalt 60 added to the Output Complex Spectrum lines list.

The user should make sure that the selected lines are in the calibrated range of energy of the DT4800 Digital Detector Emulator. If an energy calibration has already been performed on the device, the user can refer to the values of "**keV → 0V**" and of "**keV → 2V**" in the "**Import settings**" box to understand if the lines of the spectrum will be accepted. If the energy calibration has not been set or it is not appropriate for the spectrum lines the user wants to insert, the tool allows to perform an energy calibration by setting the energy in keV unit corresponding to 0 V and the energy corresponding to the full scale of 2 V to fit the dynamic of the output spectrum. Changing those values will automatically re-calibrate the device. Press "**Auto Limit**" to find the best calibration for the designed spectrum.
"**Resolution(eV)**" allows to set the desired Gaussian resolution in eV unit for all lines of the spectrum. A resolution equal to 0 eV corresponds to mono-energetic lines.

Figure 3.34: the "Import Settings" bar for the Output Spectrum in the "Decay Selector" window.

Note: The resolution of the spectrum lines can be set both from the "**Decay Selector**" and the "**Spectrum Creator**" windows.

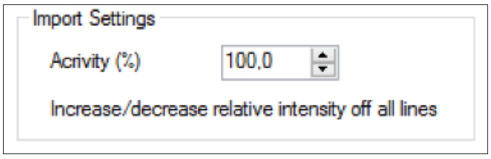


Figure 3.35: the "Import Settings" bar for all lines listed in the "Decay Selector" window.

This "**Import Settings**" box allows to select the relative activity of the current isotopes when a complex mixture of isotopes is selected. The "**Activity (%)**" value acts to all the lines of the current isotope.

Finally, click "**Import**" to import the spectrum with the desired settings, or "**Close**" to cancel it.
The spectrum will appear in the "**Spectrum Creator**" window and can be saved through the "**Save**" button  in the file format .spectrum by specifying the file name and the destination folder in the browser window.

Modify an Emulator Spectrum

Click the "**Edit Spectrum**" button in the Signal Amplitude item of the Emulator Menu. The button at the start is disabled and it becomes enabled when a custom spectrum has been created and imported or when a spectrum file has been loaded.

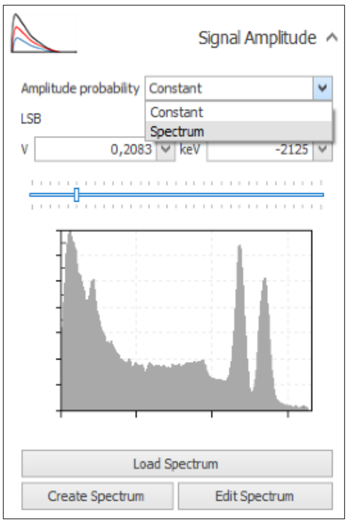


Figure 3.36: settings of the "Signal Amplitude" menu to import an energy spectrum.

If the spectrum has been previously loaded from a file, the "**Import a custom spectrum from file**" will appear, allowing to change the scale, the offset and the energy calibration. Otherwise, the "**Spectrum Creator**" allows to modify the custom spectrum by changing all the parameters of the lines, by adding or remove the lines and by changing the energy calibration.

MCA Menu

The "**MCA Menu**" can be visualized on the left of the GUI by pressing the button "**MCA**" in the "**Main**" Menu Group of the Tool Bar.

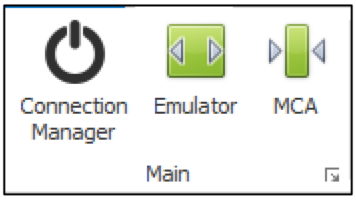


Figure 3.37: the "Main" Menu Group of the Tool Bar.

The "**MCA Menu**" has 7 items:

- "**Analog Input**": it is dedicated to the setting parameters related to the analog input of the MCA;
- "**Signal Shape**": it is dedicated to the setting parameters related to the input signal shape;
- "**Trigger (FAST)**": it is used to change the trigger mode and the related settings;
- "**Energy Filter (SLOW)**": it is used to change the energy calculation mode and the related settings;
- "**Baseline Restorer**": it contains some additional parameters for the Trapezoidal Energy Filter mode;
- "**Pileup Rejector**": it is dedicated to the setting parameters related to the pileup signals rejection;
- "**Monitor**": it is used to set the plotted analog and digital traces and some of their features.

In the following, each item will be described in detail.

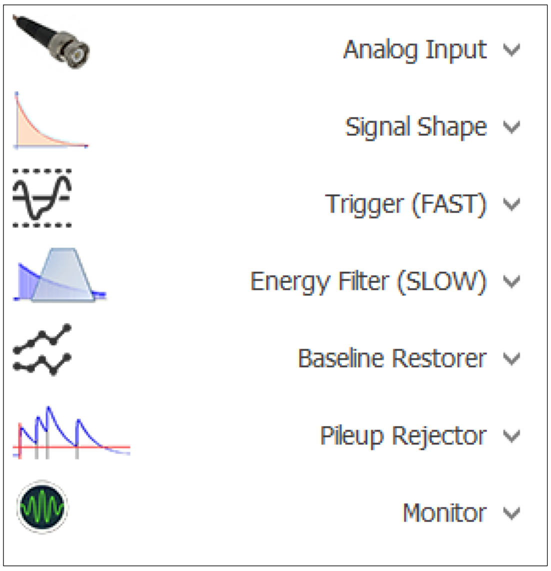


Figure 3.38: the "MCA Menu".

At the start all the "**MCA Menu**" items are collapsed. In order to see each item and to change all the parameters inside, click on the arrow on the right of the item label. Click again on the same arrow in order to collapse the item.

ANALOG INPUT

"**Input Impedance**": the user can choose among "**50 ohm**" and "**1 kohm**".

"**Signal Polarity**": the user can choose among **"Positive"** and **"Negative"**. Since the algorithm works with positive pulses only, by setting "**Negative**" the algorithm will invert the digital samples of the input.

"**Preamplifier Type**": it is possible to select "**Continuous Reset**" or "**Transistor Reset**". The shaping time of the Transistor Reset is about 1.6 µs.

"**Input Range/Gain**": if the "**Continuous Reset**" has been choosen as "**Preamplifier Type**", the user can select the proper **"Input Range"** between 1.25, 2.5, 5.0 and 10.0 V. It should correspond to the input dynamic range of the digitizer and it is a compromise between the digitizer dynamics saturation and the use of too few channels of the spectrum. If the selected "**Preamplifier Type**" is the "**Transistor Reset**", it is possible to set the "**Gain**", whose options are: 2, 5, 7, 11, 16, 21, 33, 40, 50, 70, 88 and 110.

"**Offset**": it can be set by moving the bar pointer, by writing the value in the adjacent box or by clicking the arrow at the right of the box and click the desired numbers. When acquiring a positive polarity signal, the user should use a value around 2000 LSB or above to avoid saturation around 0. Always check that the signal is not saturating on the upper level of the dynamics, otherwise the dead time will increase. When acquiring a negative polarity signal you can use also offset values below 2000 LSB. The upper limit for the MCA offset is 16380 LSB.

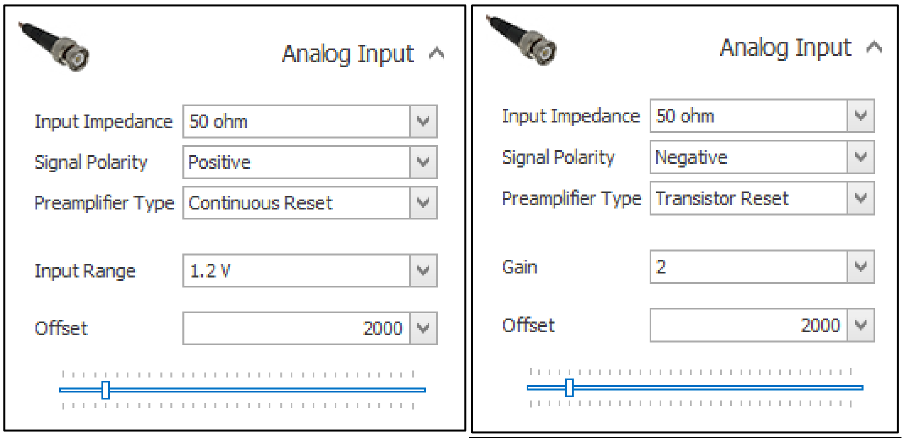


Figure 3.39: the "Analog Input" menu in the MCA Group Menu, with two different settings.

SIGNAL SHAPE

The signal "**Decay Constant (ns)**" should be set equal to the input signal decay constant, as it is used by the trapezoidal trigger. If the decay time is wrong, the trapezoidal trigger is not correctly shaped and the board does not acquire events.

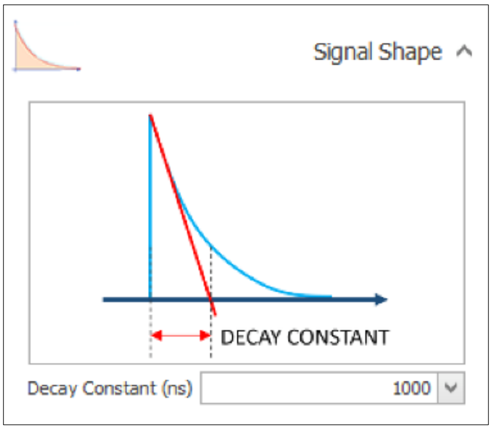


Figure 3.40: the "Signal Shape" menu in the MCA Group Menu.

TRIGGER (FAST)

The user can choose between two different types of "**Trigger Mode**" to identify the input pulses: "**Single Threshold**" and "**Trapezoidal Trigger**".

In the first case, it should be specified the “**Threshold (LSB)**”, which is the value in LSB of the signal amplitude that a signal has to exceed to be accepted, and the “**Hold-off (ns)**”, which is the minimum time interval expressed in ns that has to occur between two triggers.
Also in the second case the user has to insert the “**Threshold (LSB)**” and the “**Hold-off (ns)**”, but they are referred to the fast trapezoid itself, and the threshold crossing arms the event selection. In addition, the **“Peaking (ns)”** represents the trapezoidal trigger rise time in ns.

Setting the threshold value corresponds to set the LLD (lower level discrimination) of the energy spectrum. The user can check from the histogram which value corresponds to the set threshold level. The Trigger Hold-Off should be long enough to inhibit other triggers due to noise but it should not lead to discard useful events.

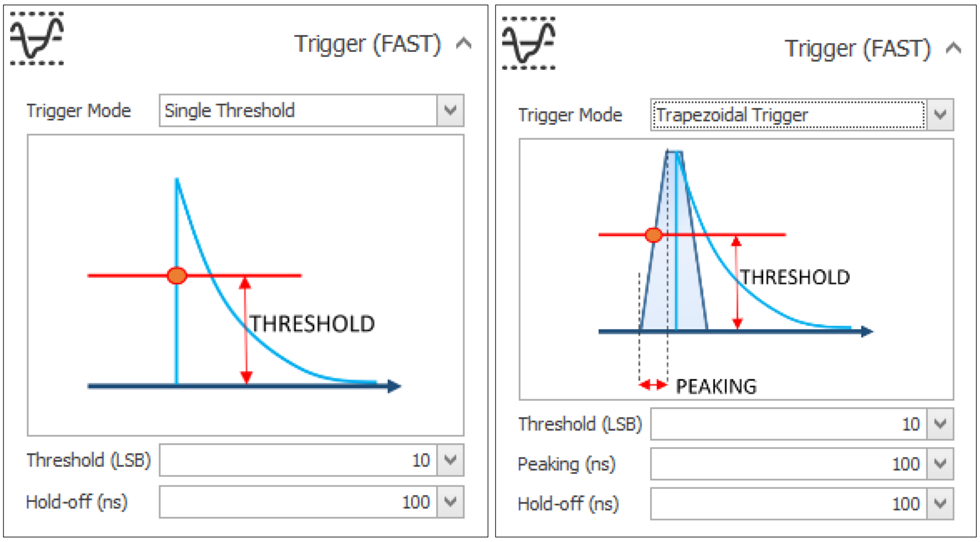


Figure 3.41: the "Trigger (FAST)" menu in the MCA Group Menu, with two different settings.

ENERGY FILTER (SLOW)

Two “**Filter Modes**” have been implemented to calculate the energy of the input pulses: the “**Trapezoidal Filter**” and the “**Charge Interation**”.

The “**Trapezoidal Filter**” is able to transform the input signal into a trapezoidal signal whose amplitude is proportional to the input pulse height (energy). The **“Peaking (ns)”** represents the trapezoid rise time and corresponds to the Shaping Time times a factor of 2/2.5. In case of high rate signal, the trapezoid **“Peaking (ns)”** value should be reduced in order to avoid pile-up effects, choosing a compromise between high resolution and pile-up rejection. The “**Flat Top (ns)**” is the length of the flat region of the trapezoid. The energy value of the input pulse is evaluated as the height of the trapezoid in the “**Energy Sample (ns)**” point. The user must check that the trapezoid top is really flat and that the samples used for the energy calculation lies within the flat region. The “Auto” checkbox allow to set automatically the position of the point in which is sampled the energy at the 80% of the trapezoidal flat top region.

The “**Charge Integration**” allows the user to define the “**Integration Time (ns)**” to establish the time duration of the signal amplitude summing. It is also possible to specify a “**Pre-gate (ns)**” to open the integration gate before the starting of the input signal. The result of the integration, the area below the signal, is retained to be proportional to the pulse energy.

In both the “Filter Modes” the user can also insert a “**Digital Gain**”, choosing a value between 0 and 20.

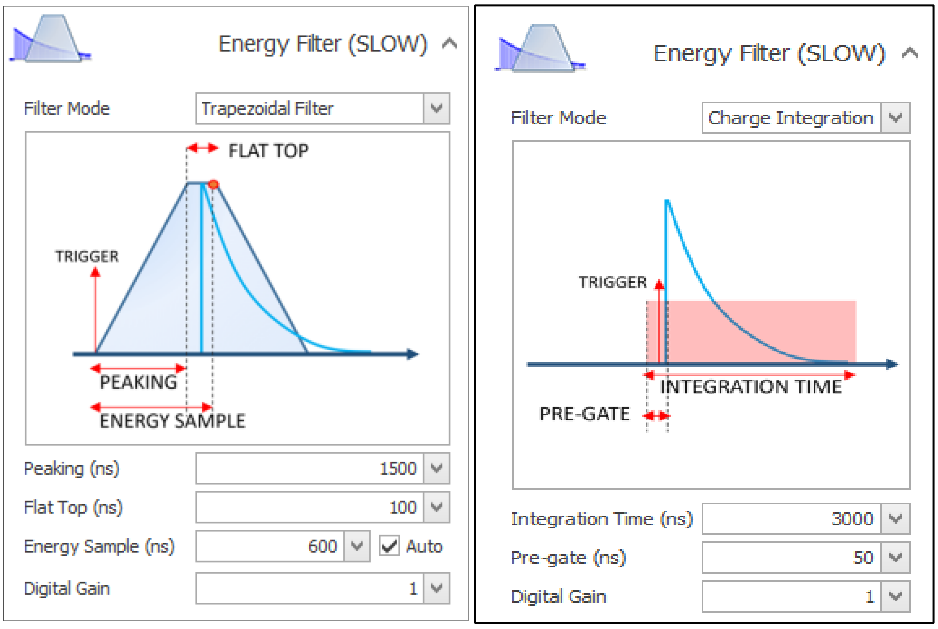


Figure 3.42: the "Energy Filter (SLOW)" menu in the MCA Group Menu, with two different settings.

BASELINE RESTORER

The energy filter includes also a baseline restorer that operates on the trapezoidal filter output and calculates the baseline by averaging a programmable number of points "**Baseline Length (sample)**" before the start of the trapezoid. It is possible to choose among 16, 64, 128, 256, 512, 1024 and 4096 sample points. When a trigger occurs, the baseline calculation is then frozen for the "**Baseline Inhibit (ns)**" duration, as its mean value is used for the height calculation.

In case of high resolution measurements, it is strongly suggested to increase the number of "**Baseline Length (sample)**". Furthermore, the user should set the "**Baseline Inhibit (ns)**" value beyond the trapezoid end, thus reducing the noise on the baseline calculation. In case of high rate, these values must be reduced to avoid pile-up effects.

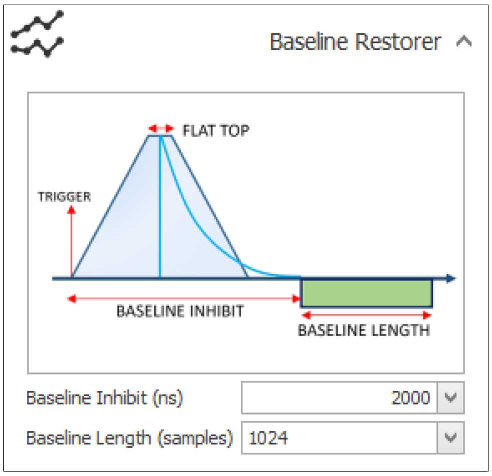


Figure 3.43: the "Baseline Restorer" menu in the MCA Group Menu.

PILEUP REJECTOR

The user can insert a "**Pileup Rejector Time (ns)**" value in ns starting from the signal input to reject all the possible pulses occurring during the desired time duration. In this way it is possible to avoid problems in the calculation of the energy of superimposed pulses.

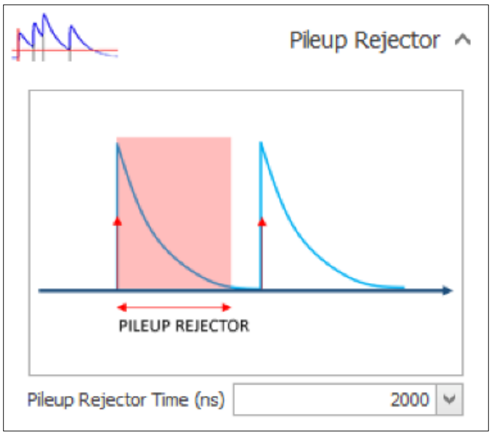


Figure 3.44: the "Pileup Rejector" menu in the MCA Group Menu.

MONITOR

"**Analog 1**"/ "**Analog 2**": it is possible to visualize one of the following signals in the Display Area by checking the "**MCA Analog 1**" or "**MCA Analog 2**": "**Input Signal**", "**Trigger**", "**Trigger CR-RC**", "**Trapezoidal**", "**Trapezoidal - baseline**", "**Baseline**" and "**Energy**".

"**Digital 1**"/ "**Digital 2**": it is possible to visualize one of the following signals in the Display Area by checking the "**MCA Digital 1**" or "**MCA Digital 2**": "**Trigger**", "**Peaking**", "**Saturation Inhibit**", "**Baseline Inhibit**" and "**Pileup Inhibit**".

"**Monitor Trigger**": the user can choose among three modalities: "**Self Trigger**", "**Main Trigger**" and "**Free Running**". In **"Main Trigger"** mode the trigger is the one specified in the **Trigger (FAST)** menu. In **"Self Trigger"** mode the **auto trigger is enabled** and acquisition is armed when triggering on the input signal itself (the threshold is specified through the "Monitor Trigger Threshold" bar pointer). Finally, in **"Free Running"** mode measurements are performed continuously, **without waiting for trigger events**.

"**Monitor Trigger Threshold**": when the "**Monitor Trigger**" is set to "**Self Trigger**", this bar pointer sets the trigger threshold to select the input signals.

"**Trigger Position**": the bar pointer allows to change the position of the trigger signal in all the acquisition window.

"**Acquisition Lenght**": the bar pointer can be used to reduce the sampling frequency by means of performing an average value of a programmable number of consecutive samples. It is useful when dealing with particularly slow signals, which require to set values that are not within the usually allowed range. The decimation applies to the energy filter only, while timing filters parameters are not affected. The decimation might have also benefits in terms of noise, since it averages a certain number of samples to make a new sample.

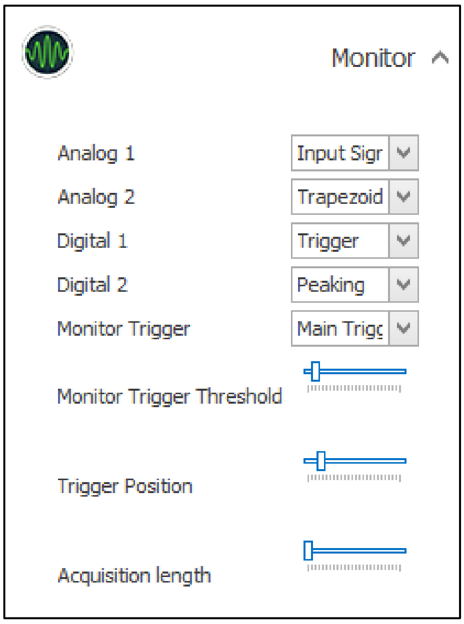


Figure 3.45: the "Monitor" menu in the MCA Group Menu.

Acquire and save a MCA Spectrum

In order to acquire a MCA Spectrum, the Emulator parameters should be set to properly generate the output signal. Press the "**Emulator**" button in the "Main" Group Menu of the Tool Bar and use the various item to obtain the desired output signal. In particular, the user should load or create a spectrum to control the output signal amplitude distribution, as explained in Section **Emulator Menu**. Then press the "**Run**" button in the "**Emulator**" Group Menu to generate the Emulator output.

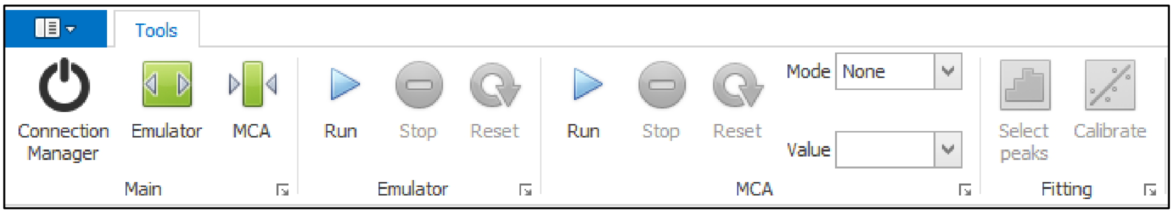


Figure 3.46: the software GUI Tool Bar before the "Run" button has been pressed.

The MCA acquisition parameters can be set by selecting the MCA Menu through the "**MCA**" in the "**Main**" Group Menu of the Tool Bar. Then click the "**Run**" button in the "**MCA**" Group Menu of the Tool Bar, select the "**Spectra**" tab of the Display Area and check the "**MCA Spectrum**" to enable the visualization of the MCA Spectrum acquisition.

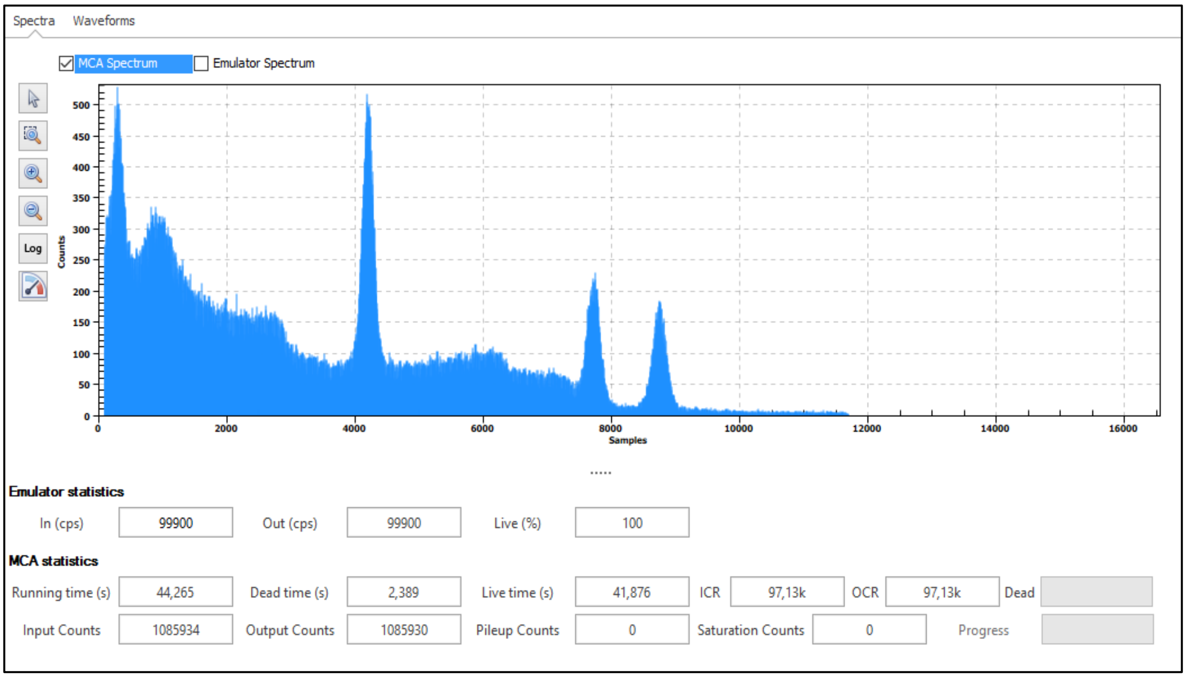


Figure 3.47: the Display Area of the GUI showing the MCA spectrum during an acquisition.

The available actions that can be performed on the spectrum, as the zoom, the application of the logarithmic scale on the y-axis or of the energy calibration on the x-axis, are described in the Section **Display Area**. In the same section the statistics reported for the Emulator and the MCA in the bottom region of the Display Area are explained.

It is also possible to control the acquisition of the MCA Spectrum in terms of total number of acquired events or in time of acquisition. For this purpose, select **"Total Time"**, **"Live time"** or "**Counts**" in the "**Mode**" drop-down menu in the "**MCA**" Group Menu of the Tool Bar. Then insert the desired time in seconds or the number of events in the "**Value**" box. To make effective the targeting of the MCA acquisition please stop and run again the acquisition. The user can control the progress of the acquisition through the "**Progress**" bar in the "**MCA statistics**" in the bottom of the Display Area.

Finally, the MCA Spectrum can be saved in .csv, .xml and .n42 formats by clicking the “**Export MCA Spectrum**” in the “**File Menu**” window (for further details see **Accepted File Formats**), specifying the destination folder and the file name.

Calibrate the MCA in Energy

The user can calibrate the MCA in energy and visualize the MCA spectra and the waveforms with the x-axis and the y-axis, respectively, in energy units.
In order to start the procedure, the “**Run**” button in the “**MCA**” Group Menu should be pressed to acquire a spectrum. Select the “**Spectra**” tab in the Display Area and check the “**MCA Spectrum**” checkbox. Then press the “**Select peaks**” in the “**Fitting**” Group Menu so that a table in the bottom of the Display Area appears in place of the Emulator and MCA statistics box.

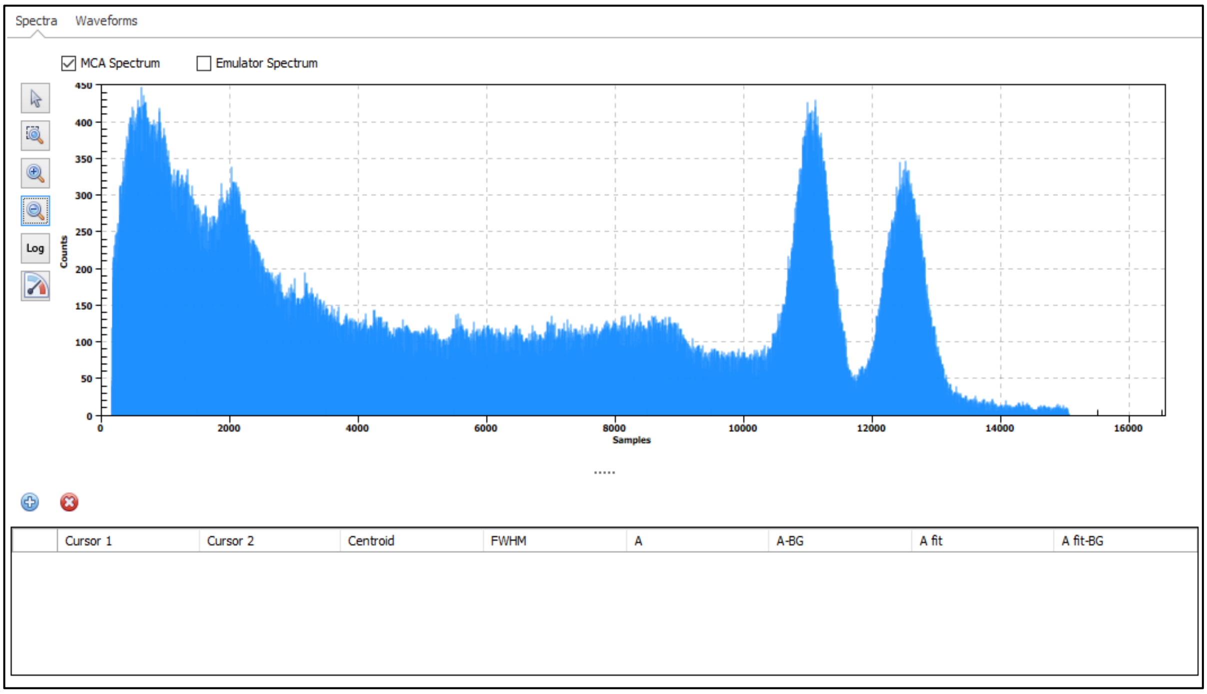


Figure 3.48: the "Display Area" of the GUI after the “Select Peaks” button has been pressed. The fitting table is visible in the bottom of the “Display Area”.

Note: When the “**Select peaks**” button is pressed, the checkbox of all the sources except the “**MCA Spectrum**” will automatically be unchecked. In addition, the checkbox selection is disabled till the “**Select peaks**” button will not be pressed again, hiding the cursors, the fit functions and the table on the bottom of the Display Area and showing again the devices statistics box. Please notice that in this way the cursors and the fit functions are not deleted; by pressing again the “Select peaks” button the table, the cursors and the fit functions will be shown on the Display Area.

In the table it is possible to add rows and remove selected rows by pressing the “**Add**”  and “**Remove**”  buttons. To select a row click on the arrow in the first table column.

When a row has been added, the user has to click in the box correspondent to the label “**Cursor 1**” to insert the channel number that represents the left edge of the fitting region. By pressing enter the number will be effectively introduced in the table and a vertical red line will appear in the Display Area graph at the inserted value. At the line is associated a label indicating the number of the row, “**1**” in this case. Repeating the same procedure for the “**Cursor 2**”, the fitting region is defined and a Gaussian function will be used to fit the peak, together with a linear function to account for the underlying background. The area underneath the Gaussian function is plotted in green, while the area below the linear function is represented in red. The row of the table will also be populated with the results of the fit:

- “**Centroid - Ch**” represents the mean value of the Gaussian fit function expressed in number of channels;

- "**FWHM – Ch (%)**" indicates the FWHM (2.35 times the Gaussian standard deviation) of the fit functions expressed in number of channels, while in parenthesis is reported in percentage the ratio between the FWHM and the Centroid, i.e. the percentage Energy Resolution;
- "**A**" and "**A fit**" represent the area of the region defined by the cursors, respectively obtained by summing all the entries of the MCA acquired spectrum ("**A**") and by expoiting the Gaussian fit function ("**A fit**");
- "**A-BG**" and "**A fit-BG**" represent the area of the region defined by the cursors corrected with the area of the background contribution calculated from the linear fit, respectively obtained by summing all the entries of the MCA acquired spectrum ("**A-BG**") and by expoiting the Gaussian fit function ("**A fit-BG**").

Clicking again on the "**Add**" button it is possible to add a new row, insert the number of channels to define a new region around the peak and fit the peak itself. In the example (see **Figure 3.49**)the two peaks of the Co 60 spectrum are adequatly fitted with two Gaussian functions and the background of each peak is modeled with a linear function.

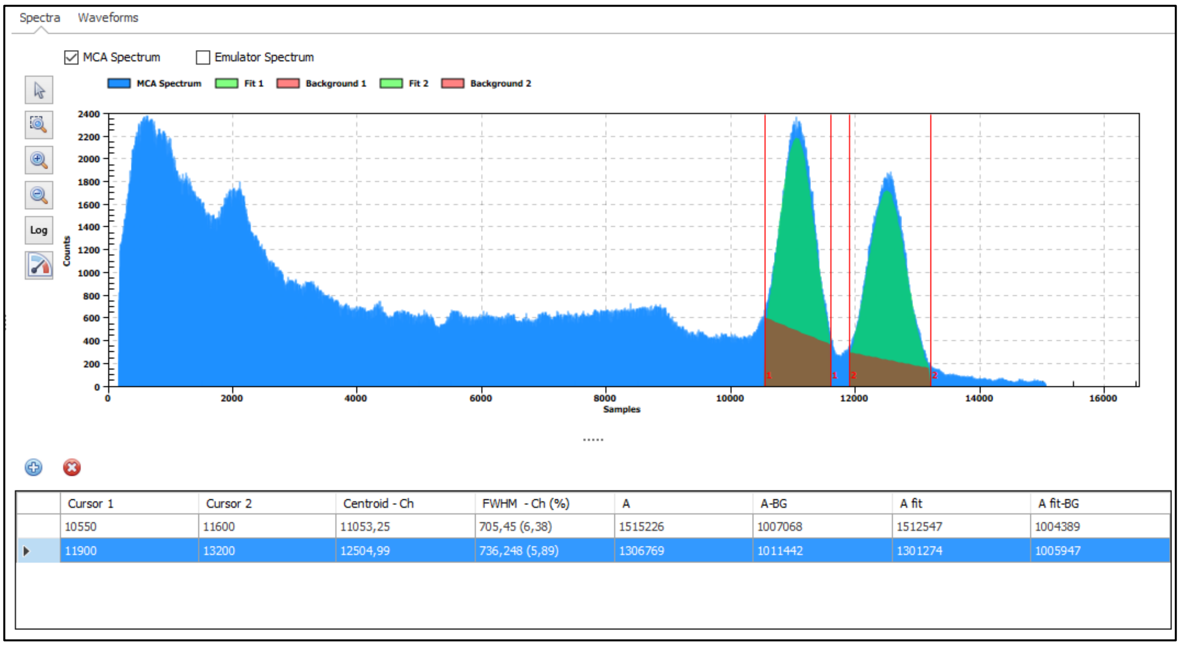


Figure 3.49: fit of two peaks of the ^{60}Co spectrum acquired by the MCA. The fitting parameters are written in the fitting table in the bottom part of the Display Area.

When at least two peaks have been fitted it is possible to use these information to calibrate the MCA Spectrum in Energy. In fact, the "**Calibrate**" button in the "**Fitting**" Group Menu of the Tool Bar is enabled. Clicking on it the "**Energy Calibration**" window will be opened (see **Figure 3.50**). It contains a number of rows corresponding to the number of fit performed on the MCA Spectrum. The first column reports the "**Peak (LSB)**", which is the mean value of the Gaussian fit fuction expressed in channels. In the second column labeled "**Energy (keV)**" the user can associate to the peak the corresponding energy in keV by clicking on the box, inserting the desired value and pressing the enter. It is also possible to add and remove rows/data points by using the "**Add**" and "**Remove**" buttons. When all the reference points have been considered and associated to the desired value, press the "Calibrate" buttons to calculate the linear interpolation between them and load the MCA energy calibration.

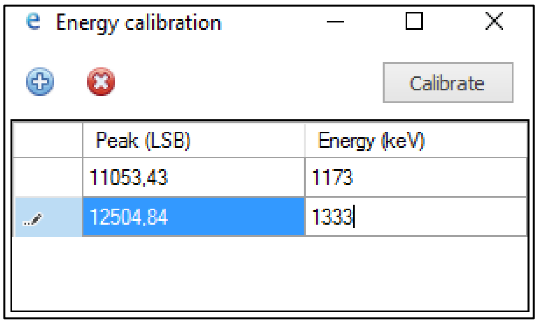


Figure 3.50: the "Energy calibration" window, which opens after the "Calibrate" button in the "Fitting" Group Menu of the Tool Bar has been pressed.

Now it is possible to visualize the MCA spectra od the GUI in energy units on the x-axis through the

"**Conversion**"  button. In addition, with this visualtization mode the fit parameters in the table in the bottom of the Display Area are expressed in energy. In particluar the label of the third and of the fourth columns becomes "**Centroid - keV**" and "**FWHM - keV (%)**". The example below reports the Co 60 spectrum and the correspondent table after the use the energy visualization mode.

For the other functionalities available on the left of the plot see the Section **Display Area.**

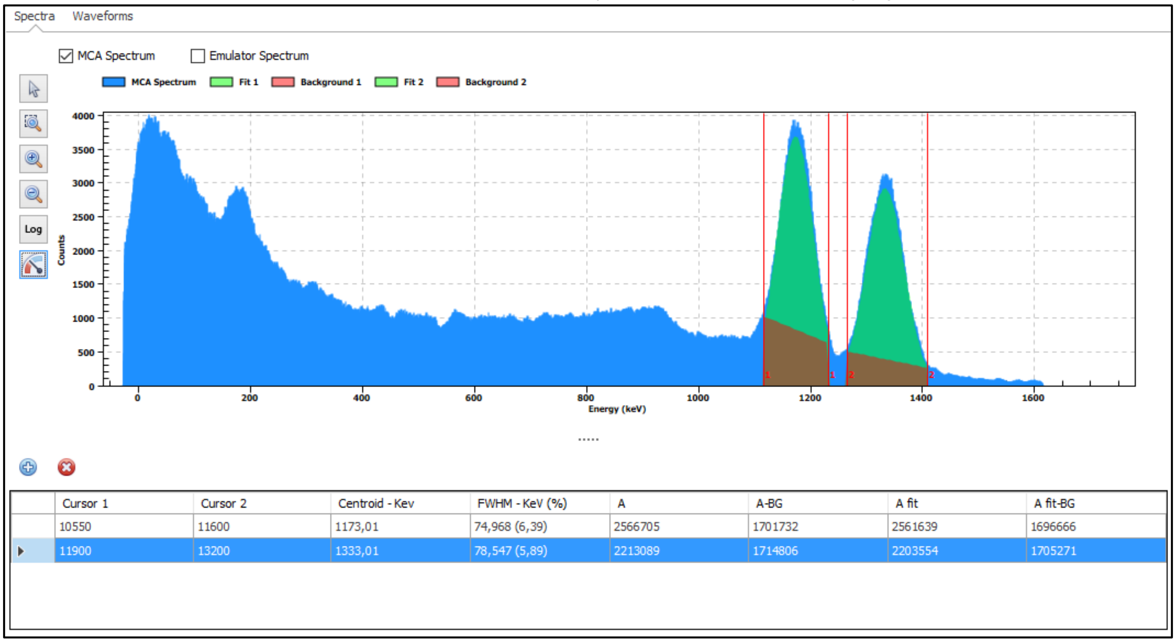


Figure 3.51: the MCA spectrum after energy calibration through peaks fitting. The X-axis scale of the plot has been converted in energy according to the energy calibration.

Display Area

The display area of the GUI gives a complete Real-time graphical overview of the operating status of the Emulator and of the Multichannel Analyzer. It contains two tabs:

- "**Spectra**"
- "**Waveforms**"

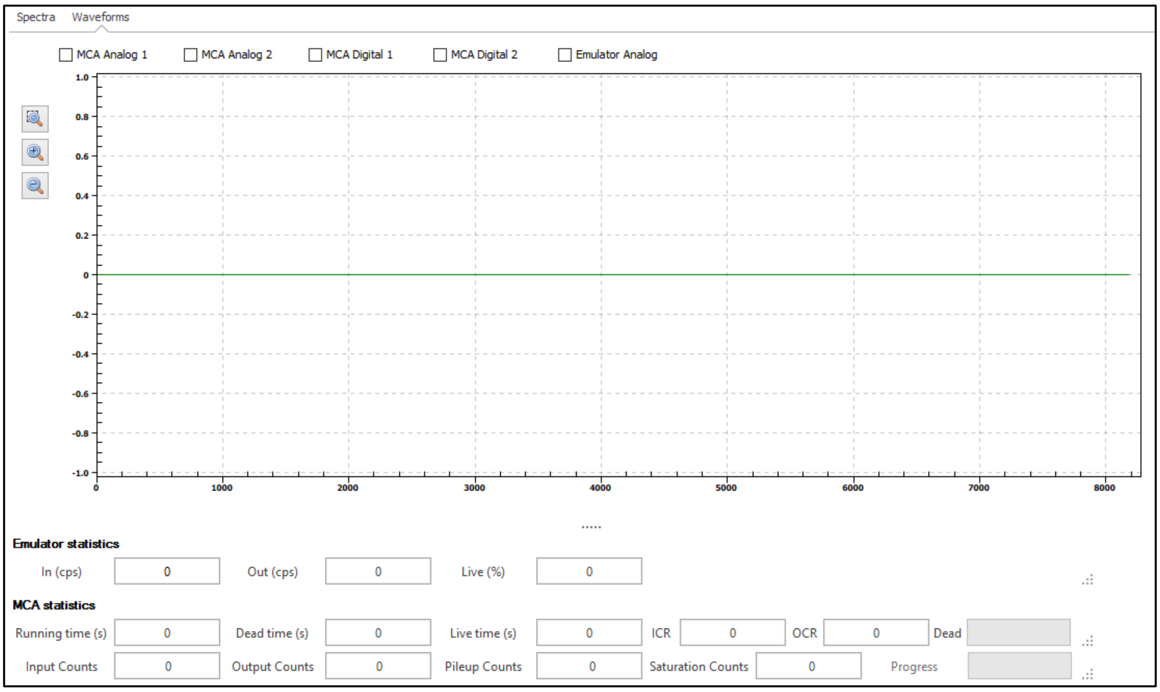


Figure 3.52: the "Display Area" of the GUI.

In each tab it is possible to chose which is the source of signal to be visualized by checking the correspondent checkbox.

On the left some tools are aviable to change the zoom, the unit of the x-axis and the scale of the y-axis.

On the bottom, when the acquisition is running, it is possible to see the statistics of the Emulator and of the Multichannel Analyzer: more details are available in Section **Emulator and Multichannel Analyzer Statistics**.

When the button "**Select Peaks**" in the "**Fitting**" Menu Group of the Tool Bar is pressed, a table appears in this part to insert or remove the cursors defining the peaks for the MCA energy calibration. For further descriptions please see Section **Calibrate the MCA in Energy**.

Waveforms

The **"Waveforms"** tab shows the shape preview of the signals. It works as a real oscilloscope. It is possible to visualize the "**Emulator Analog**" signal, two "**MCA Analog**" signals and two "**MCA Digital**" signals. The MCA signals assigned to the various visualizible channels can be set in the "**Monitor**" item of the MCA Menu. In order to visualize a signal, the correspondent checkbox must be checked. It is possible to check more than one checkbox at a time. When a checkbox is checked, a legend appears below the checkboxes to show the color code of the signals reported in the plot.

Note: The "**Run**" buttons of the source signals that the user wants to visualize should be selected in the correspondent Emulator and/or MCA Menu Group in the Tool Bar.

As an example, in the picture below the "**MCA Analog1**" checkbox representing the input signal and the "**Emulator Analog**" signal have been checked.

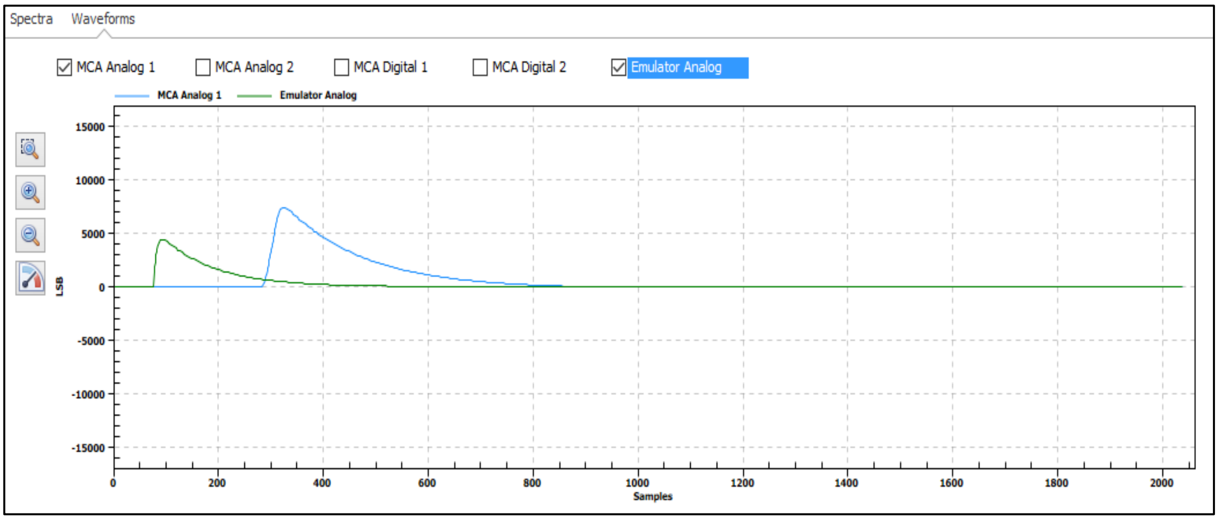


Figure 3.53: the "Waveforms" tab of the Display Area showing the two enabled traces ("MCA Analog 1" and "Emulator Analog").


The "**Zoom**" button allow to select a rectangular x-y region of the graph to be zoomed.


The "**Horizontal Zoom**" button allows to select a x range of the graph to be zoomed.


The "**Undo Zoom**" button allows to reset to the default the zoom of the graph.


The "**Conversion**" button allows to change the y-axis unit between LSB and Energy (keV) and the x-axis unit between Samples and Time (us).

Note: The "**Conversion**" button is visible and working only if an energy calibration has already been performed for all the sources of signal selected. If a selected signal can not be converted in energy, pressing the "**Conversion**" button, the checkbox of the non-calibrated signal will automatically be unchecked. In addition, the non-calibrated signal checkbox is disabled till the "**Conversion**" button will not be pressed again to return to LSB unit mode.

<u>**Spectra**</u>

The **"Spectra"** tab shows a real-time view of the "**Emulator Spectrum**" and the "**MCA Spectra**", also simultaneously. When a checkbox is checked to select the spectrum source, a legend appears below the checkboxes to show the color code of the spectra reported in the plot.

Note: The "**Run**" buttons of the source spectra that the user wants to visualize should be selected in the correspondent Emulator and/or MCA Menu Group in the Tool Bar.

In the example two Cobalt 60 spectra are shown, one generated by the Emulator and the other acquired with the MCA.

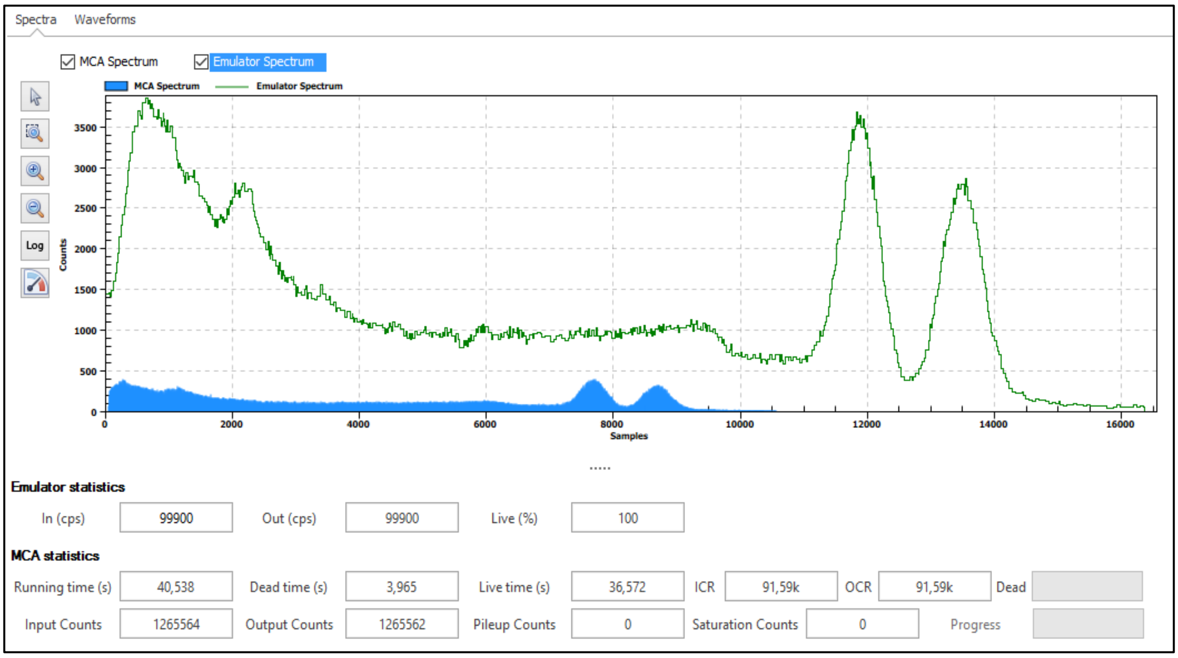


Figure 3.54: the "Spectra" tab of the Display Area showing the ^{60}Co spectrum generated by the emulator (green) and acquired by the MCA (blue). The statistics box is visible in the bottom part.

 The "**Cursor**" button transforms the cursor in a cross and allows to select a point of a spectrum. The coordinates of the selected point can be visualized in the "**Coordinates**" box inside the graph on the top right corner.

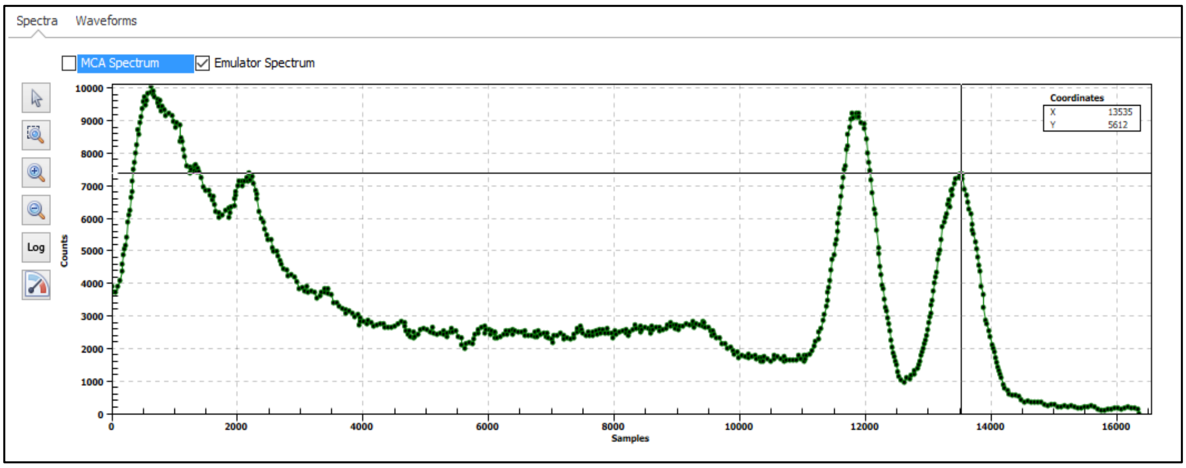


Figure 3.55: a point of the Emulator spectrum selected with the "Cursor" button. The "Coordinates" box is visible in the top right corner.

 The "**Zoom**" button allow to select a rectangular x-y region of the graph to be zoomed.

 The "**Horizontal Zoom**" button allows to select a x range of the graph to be zoomed.

 The "**Undo Zoom**" button allows to reset to the default the zoom of the graph.

 The "**Conversion**" button allows to change the x-axis unit between LSB and Energy (keV).

Note: The "**Conversion**" button works only if an energy calibration has already been performed for all the sources of spectrum selected. If a selected spectrum can not be converted in energy, pressing the "**Conversion**" button the checkbox of the non-calibrated spectrum will automatically be unchecked. In addition, the non-calibrated spectrum checkbox is disabled till the "**Conversion**" button will not be pressed again to return to LSB unit mode.

The "**Log**"/ "**Lin**" button allows to change the y-axis scale between the logarithmic and the linear one.

<u>Emulator and Multichannel Analyzer Statistics</u>

The statistics for the Emulator and the MCA are shown in the box on the bottom of the display area. They are always visible, except when the "Select Peak" button in the "Fitting" Group Menu has been selected. The statistics are populated only when at least one of the connected devices is running (the "**Run**" button in the "**Emulator**" or the "**MCA**" Menu Group of the Tool Bar are selected).

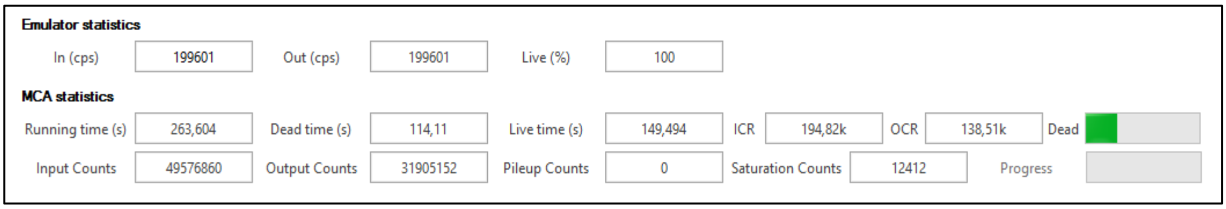


Figure 3.56: The statistics box in the bottom part of the Display Area.

"**Emulator statistics**":

- "**In (cps)**": is the ideal number of events per second that should be generated in accordance with the programmed statistic;
- "**Out (cps)**": is the generated number of events per second that actually takes into account the possible limitations due to pile-up or saturation of the output analog stage;
- "**Live (%)**": is the ratio between the number of events per second that should be generated and the number of events per second actually generated ("**In (cps)**"/ "**Out (cps)**").

"**MCA statistics**":

- "**Running time (s)**": is the total amount of time the MCA is running, measured in seconds;
- "**Dead time (s)**": is the total amount of dead time, expressed in seconds, mainly due to pile up and saturation events;
- "**Live time (s)**": is the effective acquisition time of the MCA, measured in seconds, calculated as the difference between the "**Running time (s)**" and the "**Dead time (s)**";
- **"ICR"** : Incoming Count Rate, expressed in kcps
- **"OCR"** : Output Count Rate, expressed in kcps
- **"Dead"**: is the Dead time progress bar, as shown in the DT5770 display;
- "**Input Counts**": is the number of events at the input of the MCA;
- "**Output Counts**": is the number of events acquired and processed by the MCA;
- "**Pileup Counts**": is the number of events that are discarded due to the pile-up rejection setting parameters;
- "**Saturation Counts**": is the number of events that are discarded due to acquisition rate saturation;

- "**Progress**": is a bar that is enabled when the MCA acquisition control on the total number of recorded counts or on the acquisition time is selected (in the "Target menu" of the Tool Bar). The "Progess" bar shows the percentage progression of the MCA acquisition in terms of number of counts or time.

Accepted File Formats

The accepted file formats are the following:

- **Comma Separated Values (.csv).** It is the file format that can be adopted to load a spectrum for the Emulator signal amplitude generation and to save the MCA Spectrum. The values are organized in column format. Each value begins a new paragraph:

  Value #1
  Value #2
  Value #3
  ……..

  The values represent the probability and are quantized to 16 bits (from 0 to 65535). The number of bins is equal to 16384 (14 bits). If a lower number of bins is inserted, the remaining samples are automatically set to zero.

- **CAEN digitizer files (.dat)**. The histogram data written in two columns with the format

  Number_of_sample_#1 Energy_value_#1
  Number_of_sample_#2 Energy_value_#2
  …….

  can be used to load a spectrum for the generation of the Emulator sugnal amplitude.

- **Spectrum files (.spectrum)**. This is the internal spectrum file format. Any Emulator spectrum created by the GUI have this file format. The load of an Emulator spectrum supports this format. It has a header with 6 lines and then each channel content is written in a row between in the form: <value_type> channel_value </value_type>.

- **ANSI N42.42 (.xml)**. This is the standard ANSI N42.42 file format. It can be used to load a Spectrum to generate the Emulator Signal Amplitude and to export the MCA acquired Spectrum.

- **Settings file (.nis).** This is the internal setting file format. The saving and the loading of the settings parameters through the GUI will have this format. It is constituted by a list of parameters name with the correspondent value in the form: <Parameter_name> Parameter_value <Parameter_name>.

4 Experiments with the Emulation Kit

The Educational Emulation kit allows the user to perform experiments that have to do with radioactive γ decays.

In 1895 the radioactivity was discovered by H. Becquerel and in 1903 the Nobel Prize in Physics was assigned to Curie spouses for their studies on these phenomena. Radioactivity is around us and getting to know it experimentally is essential for physics students.
When an unstable nucleus decays in a cascade leading to a stable nuclide, it emits α or β or γ quanta or a combination of them. Gamma rays are high energy photons and the spectroscopy of the emitted γ rays is instrumental for understanding the mechanism of the interaction with matter, the fundamentals about detection and the underlying nuclear physics. Moreover, it is relevant in basic and applied fields of science and technology, from nuclear to medical physics, from archaeometry to homeland security.

This section represents an overview of the experiments proposed by CAEN using the Emulation kit of your choice. Each experiment has its own identification code (reference ID). For each ID, a step by step guide that includes a detailed description to perform the data analysis of the physical process is available on the CAEN Educational web page. The experiments address the essence of the phenomenon and it is complemented by basic statistical exercises.

The experiments proposed by CAEN with the Emulation Kit are listed in
Table 4.1.

Reference ID	Experiment
6112	Poisson and Gaussian Distribution
6113	Energy resolution
6114	System calibration: linearity and resolution
6117	Photonuclear cross-section/Compton scattering cross-section
6118	Study of the ^{137Cs} spectrum: the backscatter peak and X rays
6119	Activity of the ^{60Co}

Table 4.1: Experiments performed via the Emulation Kit.

Poisson and Gaussian Distribution (ID.6112)

Purpose of the experiment

Study the statistical distribution of the counting rates of a gamma radioactive source. Comparison of the data to the Poisson distribution, turning into a Gaussian as the mean number of counts grows.

Fundamentals

The number of radioactive particles detected over a time Δt is expected to follow a Poisson distribution with mean value μ. It means that for a given radioactive source, the probability that n decays will occur over a given time period Δt is given by:

$$P_\mu(n) = \frac{\mu^n}{n!}e^{-\mu}$$

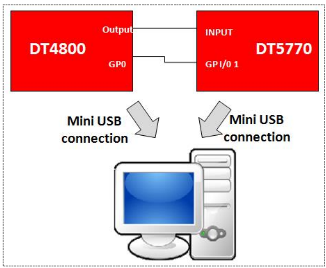
where **μ is proportional to the sample size and to the time Δt and inversely proportional to the half-life $T_{1/2}$ of the unstable nucleus**. As long as μ grows, the probability $P_\mu(n)$ is well approximated by a Gaussian distribution:

$$P(n) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-(n-\mu)^2}{2\sigma^2}}$$

where $\sigma = \sqrt{\mu}$ is the standard deviation.

Carrying out the experiment

To perform the experiment, connect the DT4800 output to the input channel of the MCA DT5770 and use the DT4800 GP0 as digitizer "trigger IN". The Emulation Software allows to generate exponential decay signals with programmable rise time and fall time and it is possible to emulate signals from a real energy spectrum linked to a radioactive source with variable activity.



Experimental setup block diagram for the experiment.

- Load a spectrum from the "Examples" folder in the "C:\Program Files(x86)\CAEN\EmulationDetectionEdu" directory.
- Record the emulated spectrum several times, changing the **Counting Target** (from few hundreds to several tenths of thousands), the **Time Target** (from seconds to some minutes) and the **Trigger Threshold** (from 50 LSB to 1000 LSB) using the "Mode" drop-down menu in the Tool Bar.
- While recording, read the **"instantaneous" count rate** in the "Statistics" Area**.** The **count rate r_i** is defined as

  $$r_i = \frac{x_i}{t_i}$$

  where x_i is the number of counts recorded at live time t_i. You can read this value directly in the **"OCR"** box, for example every 5 seconds.
- For each spectrum take note of the **total acquisition time** and the values of the **"instantaneous" count rate r_i.** You can also export the recorded spectra to **elaborate data in a spreadsheet program**. The MCA Spectrum can be saved in .csv format by clicking "**Export MCA Spectrum**" in the "**File Menu**", specifying the destination folder and the file name. The .csv file will appear as a list of the counts for each energy bin of the spectrum.
- For each spectrum, **calculate the average number of decays per time interval μ,** using the following formula:

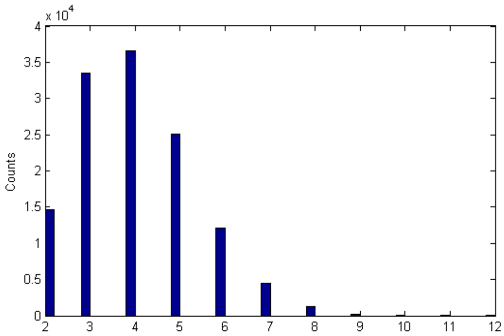
$$\mu = \frac{\text{total counts}}{\text{acquisition time}}$$

You can read these values in the “Statistics” area, in the “Output counts” and “Live time” boxes.

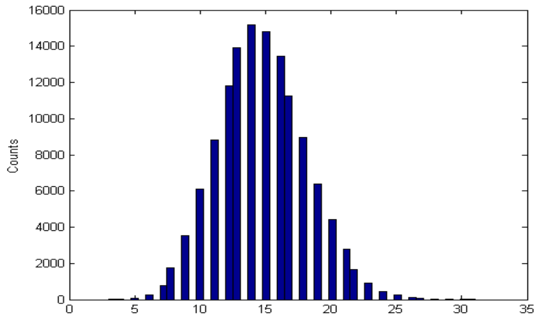
- Plot the histogram of **“instantaneous” count rates r_i versus the frequency of occurrence**.

Results

Changing the MCA counting target, the signal frequency and/or the trigger threshold, the total number of counts changes, with a probability density function moving from a Poissonian to a Gaussian shape. For Gaussian distributions it is possible to fit the data with a Gauss function, using μ as the mean and its square root for the standard deviation, σ. You can verify for which spectrum a Poisson distribution comes out and you can find the minimum total counts number for which the experimental histogram is well approximated by a Gaussian distribution.



Poissonian distribution.



Gaussian distribution.

Energy resolution (ID.6113)

Purpose of the experiment

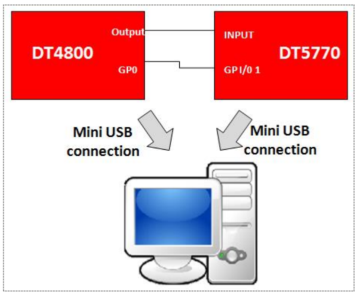
The analysis of the spectrum of the deposited energy by a γ ray in a detector discloses the essence of the interaction of high energy photons with matter and allows to learn by doing the detector related effects.

Fundamentals

For γ-energy less than 2MeV, the interaction with matter is dominated by Compton scattering and Photo-absorption. The analysis of the Compton continuum of the deposited energy and of the photo-peak conveys information on the characteristics of the decaying isotope as well as the effects due to the system noise, the detected photon statistics, the stochastic terms and the intrinsic resolution of the detector. The experiment presumes to use ^{60}Co. The ^{60}Co source is particularly interesting due to its clear energy photopeaks at 1.17 and 1.33 MeV. We can use these peaks to **evaluate the energy resolution** of the detector used to measure the ^{60}Co spectrum.

Carrying out the experiment

To perform the experiment, connect the DT4800 output to the input channel of the MCA DT5770 and use the DT4800 GP0 as digitizer "trigger IN". The Emulation Software allows to generate exponential decay signals with programmable rise time and fall time and it is possible to emulate signals from a real energy spectrum linked to a radioactive source with variable activity.



Experimental setup block diagram for the experiment.

- Load the spectrum cobalto.csv from the "Examples" folder in
- the "C:\Program Files(x86)\CAEN\EmulationDetectionEdu" directory. Refer to Section **Import an Energy Spectrum from File**.
- Record the spectrum with the MCA (see Section **Acquire and save a MCA Spectrum**), visualize the MCA spectrum plot, select the two peaks in order to perform a gaussian fit to evaluate their FWHM (see Section **Calibrate the MCA in Energy**).
  After performing the peaks fitting through the **"Select Peaks"** button, the FWHM of the peaks are shown in the bottom part of the Display Area of the Emulation Software

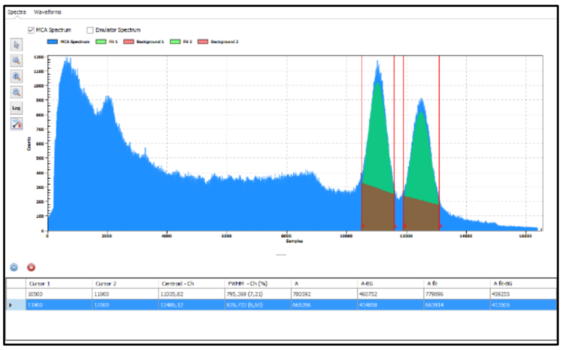
Results

The figure shows the ^{60}Co gamma spectrum recorded by the DT5770 with a very low threshold (10 LSB). The two gamma photopeaks at 1.17 MeV and 1.33 MeV are clearly visible, as well as the Compton continuum on their left. It is possible to perform a fit of the peaks and estimate the energy resolution by using the formula

$$\text{Energy Resolution} = \frac{\text{FWHM}_{\text{peak}}}{\mu_{\text{peak}}} * 100 \sim 4\%$$

$\text{FWHM}_{\text{peak}}$ = full width at half maximum of the peak
μ_{peak}= channel number of the peak centroid

The energy resolution in percentage is also indicated in the fit table under FWHM – Ch (%)



Fit of the two peaks of the ^{60}Co spectrum through the "Select Peaks" utility.

System calibration: linearity and resolution (ID.6114)

Purpose of the experiment

Recording and comparing the γ energy spectra of several radioactive sources is the main goal of the experiment. The photo-peaks are used to calibrate the response of the system and to measure the energy resolution.

Fundamentals

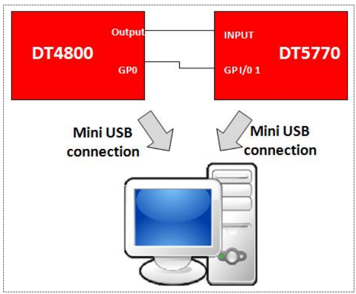
Linearity and energy resolution are the main figures of merit of a spectrometric system. In the proposed experiment, deviations in the linearity may be due to the front-end electronics saturation. The student is guided through the analysis of the response curve using a series of isotopes from hundreds of keV up to the MeV energy.

At the same time, the energy resolution of the system is measured by the width of the photo-peaks.

This is following an initial activity on the optimization of the operating parameters by the analysis of the photo-peak position and the resolution for a single isotope

Carrying out the experiment

To perform the experiment, connect the DT4800 output to the input channel of the MCA DT5770 and use the DT4800 GP0 as digitizer "trigger IN". The Emulation Software allows to generate exponential decay signals with programmable rise time and fall time and it is possible to emulate signals from a real energy spectrum linked to a radioactive source with variable activity.



Experimental setup block diagram for the experiment.

- Use the three spectra in the "NaI" folder in the "C:\Program Files(x86)\CAEN\EmulationDetectionEdu\Examples" directory, which are real spectra recorded with a NaI detector with identical configuration. The spectra of ^{57}Co, ^{60}Co and ^{137}Cs are available.
- For every spectrum in the folder load the .csv file in the Emulation Software and record it with the MCA.
- While recording you can visualize the MCA spectrum, click "Select peaks" and perform Gaussian fits, in order to **identify the Centroid Channel and the FWHM percentage for every peak.** You should take note of these values for further data elaboration.
- You can export every recorded MCA spectra for data elaboration with a spreadsheet program.

Note: <u>There is no need to calibrate the MCA spectra in energy in order to complete this experiment</u>. The student can identify the ADC channels and then associate to every peak and energy by reading the Isotopes Database tables. This could be an advantage for students approaching the use of the software and it also avoid the need to explain the Energy Calibration meaning and procedure.

Results

The student can collect in a table the characteristics of every peak.

	Peak Energy (keV)	Centroid channel	FWHM(%)
^{57}Co	~ 122	~ 200	~ 43.50
^{137}Cs	~ 662	~ 1334	~ 19.57
^{60}Co	~ 1170	~ 2790	~ 7.35
^{60}Co	~ 1330	~ 3278	~ 5.22

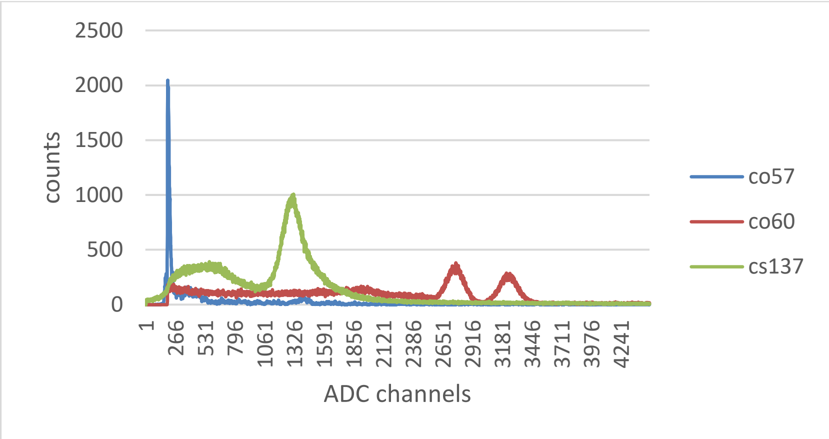
The data collected from the peaks analysis for each acquired spectrum.

The data can be taken directly from the fit parameter shown in the plot window of the Emulation Software or, alternatively, from a data elaboration starting from the exported MCA spectra. In this case the FWHM (%) is given by

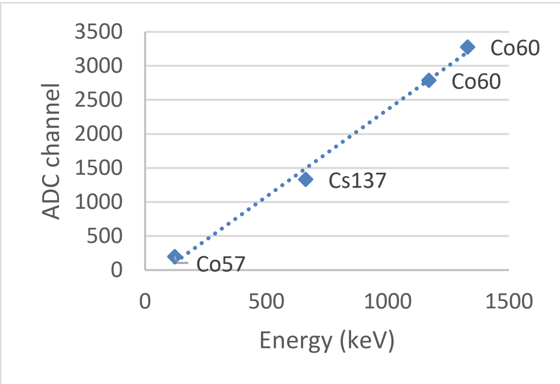
$$\frac{FWHM_{peak}}{\mu_{peak}} * 100$$

$FWHM_{peak}$ = full width at half maximum of the peak expressed in ADC channels unit
μ_{peak}= channel number of the peak centroid

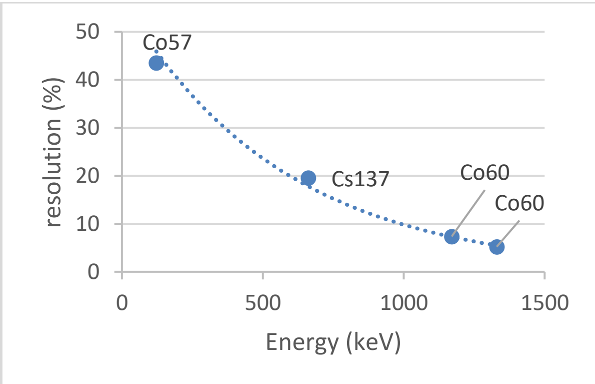
By fitting the photo-peaks with a Gaussian curve, the system linearity as a function of energy is verified. The peak widths are determining the energy resolution.



Plot of three acquired spectra.



Plot of the ADC channel centroid of the peak as function of the energy of the peak.



Plot of the resolution (FWMH (%)) as function of the peak energy for all the acquired spectra.

Photonuclear cross-section/Compton scattering cross-section (ID.6117)

Purpose of the experiment

Determination of the ratio of the effective cross-sections due to Compton and Photoelectric effects as a function of photons energy.

Fundamentals

In the energy range up to 2MeV, gamma rays interact with matter by two processes:

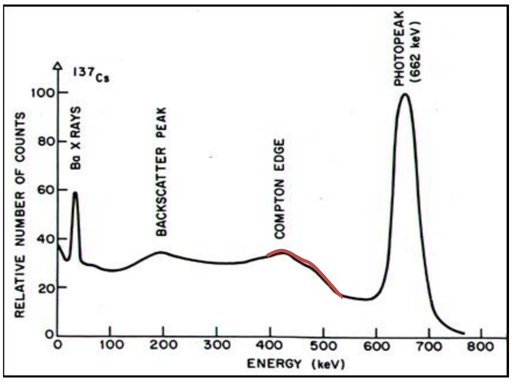
- **Photoelectric Effect**, dominant at energy less than *100KeV*. In this process the photon energy is completely transferred to a bound atomic electron

$$\gamma + atom \rightarrow ion + e^-$$

- **Compton Scattering**, linked to the elastic collision between electrons and photons and relevant at 1MeV energy level

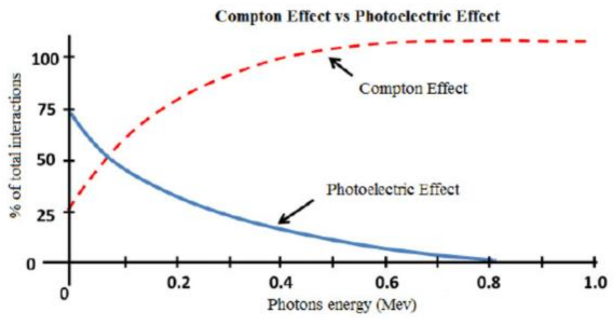
$$\gamma + e^- \rightarrow \gamma' + e^-$$

The predominant mode of interaction depends on the energy of the incident photons and the atomic number of the material with which they are interacting.
From the acquired γ-spectrum, it is possible to estimate the fraction of events due to Compton scattering and those caused by the photoelectric. In fact, a typical *γ* spectrum is structured as in the following picture.



The theoretical ^{137}Cs spectrum. The Compton Edge part is highlighted in red.

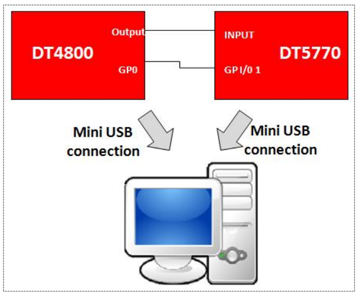
The **photopeak** is due to the photoelectric effect, while Compton scattering is responsible for the **Compton continuum** (from 200 to 450 keV in the picture above). In particular, it is possible to identify a **Compton Edge**, which is the point where the Compton continuum turns into the photopeak structure. The ratio of the events occuring at the photopeak and at the Compton edge is used to determine the ratio of the two effective cross-sections as a function of the energy of the photopeak.
According to the theory, the (Photoelectric/Compton) ratio should decrease with increasing energy, as can be inferred from the following plot.



Theoretical plot of the relative percentage of total interactions as function of the photons energy for Compton and Photoelectric effect.

Carrying out the experiment

To perform the experiment, connect the DT4800 output to the input channel of the MCA DT5770 and use the DT4800 GP0 as digitizer "trigger IN". The Emulation Software allows to generate exponential decay signals with programmable rise time and fall time and it is possible to emulate signals from a real energy spectrum linked to a radioactive source with variable activity.

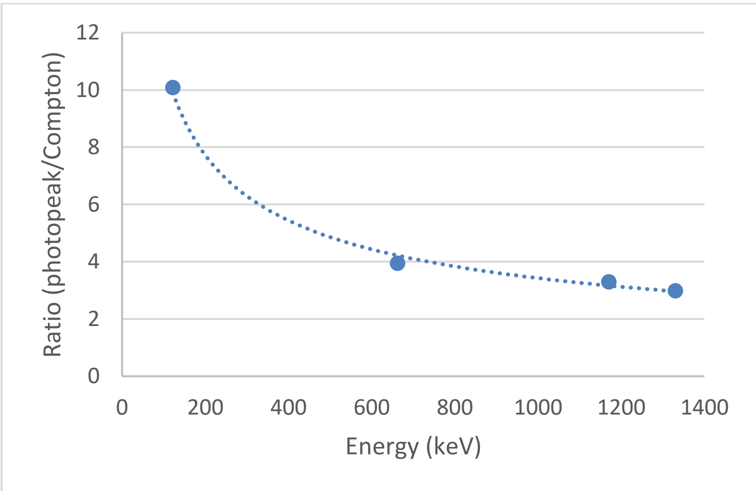


Experimental setup block diagram for the experiment.

- Load each spectrum in the "NaI" folder in the "C:\Program Files(x86)\CAEN\EmulationDetectionEdu\Examples" directory.
- Record spectra with the MCA
- Identify the peaks and assign to each of them an energy by reading the tables in the Isotopes Database
- For every peak calculate the ratio (counts of the photopeak)/(counts of the Compton Edge)
- The student can export the recorded MCA spectra into a spreadsheet software to plot them all together

Results

By using several radioactive sources simulated by DT4800, the energy dependence of the ratio between the cross-sections of the two phenomena can be examined, by verifying that the Photoelectric Effect cross section decreases with increasing energy compared to the Compton Scattering cross section.



Plot of the photopeak/Compton ratio as function of the peak energy.

Study of the ^{137}Cs spectrum: the backscatter peak and X rays (ID.6118)

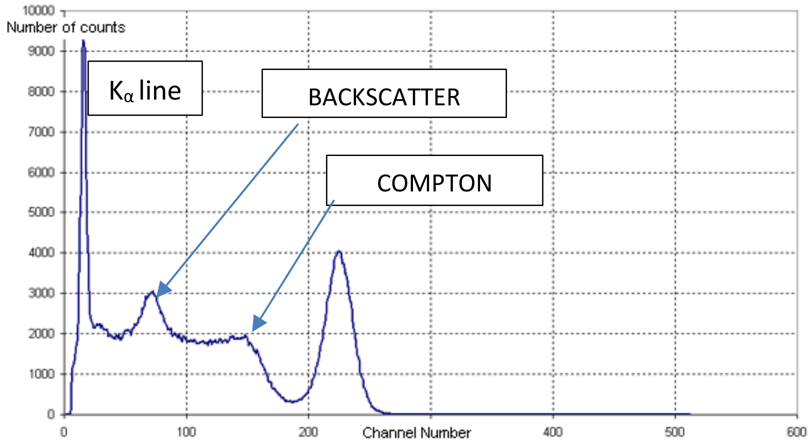
Purpose of the experiment

Study the characteristics of the ^{137}Cs spectrum, with special relevance given to the low energy spectrum. The student can learn effects related to the experimental observation of a gamma decay and have basical information about the experimental setup used in gamma spectroscopy. Estimate the energy of the backscatter peak and of the K_α line.

Fundamentals

In experiment **Photonuclear cross-section/Compton scattering cross-section**, a Compton effect vs. Photoelectric effect comparison, starting from a gamma spectrum, has been proposed. The Compton effect is linked with experimental issues, since it is caused by the interaction of photons with the electrons instrument that measure the gamma radiation.

In a real detector setup, some photons can and will undergo one or potentially more Compton scattering processes (e.g. in the housing material of the radioactive source, in shielding material or material otherwise surrounding the experiment) before entering the detector material. This leads to a peak structure, the so-called **backscatter peak.**



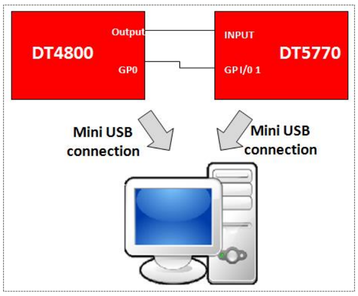
Theoretical ^{137}Cs spectrum. The main features of this spectrum are indicated.

The basic principle for the backscatter peak formation is the following: gamma-ray sources emit photons isotropically, some photons will undergo a Compton scattering process with a scattering angle close to 180° and some of these photons will subsequentely be detected by the detector. The result is an excess of counts in the Compton part of the spectrum, the so-called backscatter peak (see the figure). This peak has an energy approximately equal to the photopeak energy minus the Compton edge energy.

The ^{137}Cs gamma photopeak at 661 keV is responsible also for a low energy emission (i.e. emission of an X-ray). This is due to the decay mechanism of ^{137}Cs: it decays via β decay into an excited state of barium-137, which than passes to the ground state, giving rise to the 661 keV photopeak. Emission of a 661 keV γ photon is not the only way excited barium gives off its energy. In some cases barium-137 can transfer its energy to an electron of its 1s atomic shell ("internal conversion"). The hole in the 1s shell is replenished from higher shells. This process gives rise to the emission of the characteristic **X radiation of barium**, which is the K_α line nearly at 32 keV (X rays are photons in the range 100 eV-100 keV)

Carrying out the experiment

To perform the experiment, connect the DT4800 output to the input channel of the MCA DT5770 and use the DT4800 GP0 as digitizer "trigger IN". The Emulation Software allows to generate exponential decay signals with programmable rise time and fall time and it is possible to emulate signals from a real energy spectrum linked to a radioactive source with variable activity.



Experimental setup block diagram for the experiment.

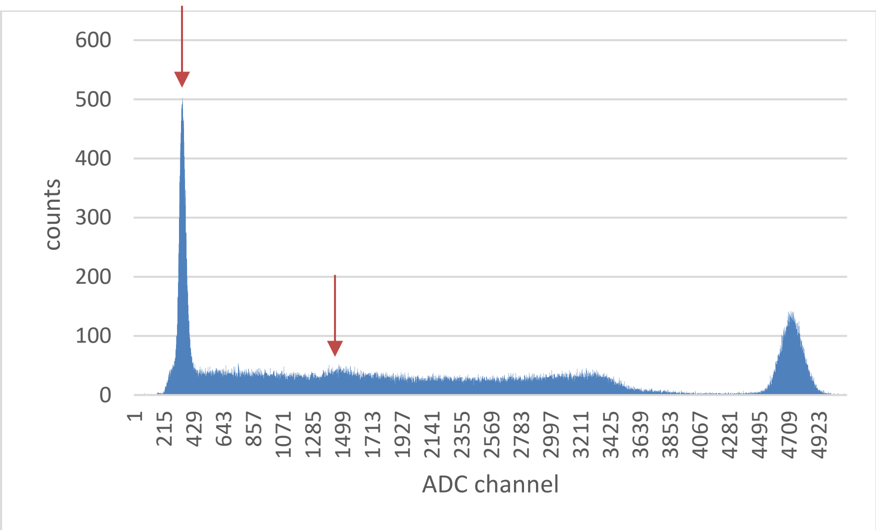
- Load the spectrum "cs137_full.csv" from the "Examples" folder in the "C:\Program Files(x86)\CAEN\EmulationDetectionEdu" directory.
- Record the spectrum with the MCA and export the MCA spectrum
- Export the recorded spectra to elaborate data in a speadsheet software.
- Calibrate the spectrum in energy using the 661 keV photopeak an its Compton Edge at nearly 450 keV (in the Emulation software or externally)

Note: **Collect a sufficient amount of data while acquiring with the MCA,** since the backscatter peak is very weak in this spectrum and it could be easily confused with the fluctuations noise.

Results

As a preliminary analysis the student can plot the entire spectrum and identify the photopeak and its Compton Edge in order to calibrate in energy the spectrum itself. After converting ADC channels in energy, it is possible to focus on the low energy part.

The student can plot the low energy part of the recorded spectrum and identify the backscatter peak and the K_α line. After calibrating the spectrum it is possible to estimate the energy of the backscatter and K_α peaks and compare them with theoretical predictions.



Plot of the ^{137}Cs spectrum acquired by the MCA. The backscatter peak and the Kα line are indicated with the red arrows.

Activity of the ^{60}Co (ID.6119)

Purpose of the experiment

Determine the activity of a ^{60}Co source from its gamma spectrum. Learn about the meaning of the sum peak, visible in the spectrum of some radioactive sources.

Fundamentals

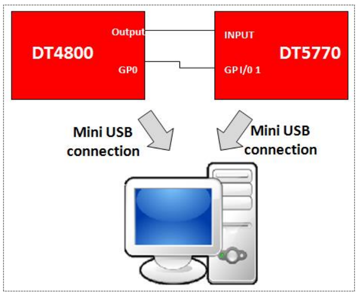
In previous experiments we outlined several times the fact that the ^{60}Co spectrum shows two distinct gamma photopeaks in its spectrum, respectively corresponding to photons γ1 and γ2 at 1.17 and 1.33 MeV. For the purposes of this experiment, we can assume that each of these gamma rays are isotropically distributed. In other words, if γ1 departs in a particular direction, γ2 can go in any direction that it wishes. There is a certain probability that γ2 will go in the same direction as γ1. If this occurs the energies of γ1 and γ2 will be summed in the detector. Hence, a **sum peak** will show up in the spectrum, nearly at 2.5 MeV.
We can **estimate the activity of the source** by calculating the counts under the two main peaks and under the sum peak, i.e. calculating their area ∑. For the case of ^{60}Co, we have that the counts under the sum peak can be evaluated as

$$\Sigma_{SUM} = \frac{\Sigma_1 \Sigma_2}{A\, t}$$

Where ***A* is the activity of the source** and *t* is the acquisition time.
Therefore, fitting the peaks with a gaussian and calculating their area, it is possible to **estimate the activity of the ^{60}Co source used to record the available spectrum.**

Carrying out the experiment

To perform the experiment, connect the DT4800 output to the input channel of the MCA DT5770 and use the DT4800 GP0 as digitizer “trigger IN”. The Emulation Software allows to generate exponential decay signals with programmable rise time and fall time and it is possible to emulate signals from a real energy spectrum linked to a radioactive source with variable activity.



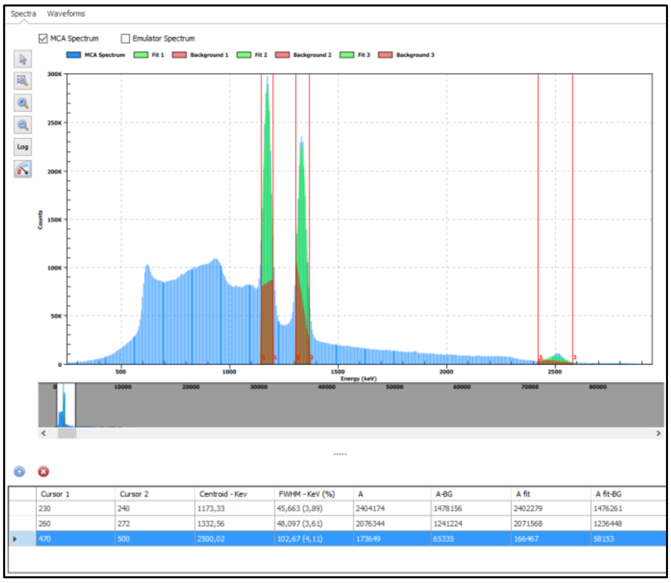
Experimental setup block diagram for the experiment.

- Load the spectrum “co60_sumpeak.csv” from the “Examples” folder in the “C:\Program Files(x86)\CAEN\EmulationDetectionEdu” directory.
- Record the spectrum with the MCA (<u>be sure to record the spectrum in the high energy range</u>) using an appropriate MCA Input Range.
- Identify the three peaks and fit them with the “Select peaks” button.
- Calibrate the spectrum in energy using the two main peaks with the “Calibrate” button.
- Read the value (A-BG) in the Fitting Parameters, which gives the counts under every peak (once the background is removed).
- Repeat the procedure several times with different acquisition time. (take note of the time target used every time and the correspondent peak areas).

Note: <u>No need of spreadsheet data elaboration in this experiment:</u> the entire experiment can be completed **using only the Emulation Software**

Results

The student should verify that, after the spectrum calibration, the sum peak is nearly at 2.5 MeV. From the formula given above, using the live time in seconds, the student can estimate de activity of ^{60}Co directly in Bq. A calculation made for a spectrum acquired over 100 seconds gives an activity of nearly 264 kBq.



The ^{60}Co complete spectrum acquired by the MCA DT5770 and plotted by the Emulation Software

5 Technical Support

CAEN experts can provide technical support at the e-mail addresses below:

support.nuclear@caen.it
(for questions about the hardware)

support.computing@caen.it
(for questions about software and libraries)

educational@caen.it
(for questions about Educational Solutions)

CAEN SpA is acknowledged as the only company in the world providing a complete range of High/Low Voltage Power Supply systems and Front-End/Data Acquisition modules which meet IEEE Standards for Nuclear and Particle Physics. Extensive Research and Development capabilities have allowed CAEN SpA to play an important, long term role in this field. Our activities have always been at the forefront of technology, thanks to years of intensive collaborations with the most important Research Centres of the world. Our products appeal to a wide range of customers including engineers, scientists and technical professionals who all trust them to help achieve their goals faster and more effectively.

CAEN S.p.A.
Via Vetraia, 11
55049 Viareggio
Italy
Tel. +39.0584.388.398
Fax +39.0584.388.959
info@caen.it
www.caen.it

CAEN GmbH
Klingenstraße 108
D-42651 Solingen
Germany
Tel. +49 (0)212 254 4077
Mobile +49 (0)151 16 548 484
Fax +49 (0)212 25 44079
info@caen-de.com
www.caen-de.com

CAEN Technologies, Inc.
1140 Bay Street - Suite 2 C
Staten Island, NY 10305
USA
Tel. +1.718.981.0401
Fax +1.718.556.9185
info@caentechnologies.com
www.caentechnologies.com

CAEN
Tools for Discovery

Electronic Instrumentation

GD6103 - SP5600EMU Emulation Kit Guide Rev. 0 - October 9th, 2017
00000-15-DDE48-MUTX