Rev. 26 - December 16th, 2025

CoMPASS Quick Start

Multiparametric DAQ Software for Physics Applications

CAEN
Tools for Discovery

Guide
GD6300

Purpose of this Manual

The Quick Start Guide contains an example of application of the CoMPASS read-out software release **2.6.3**, which is compliant with the following board firmware versions:

Board Family	Firmware Type	Firmware revision
720	DPP-PSD	**4.29_131.16**
DT5790	DPP-PSD	**4.29_131.16**
725	DPP-PSD	**4.30_136.22**
725S	DPP-PSD	**4.30_136.140**
730	DPP-PSD	**4.30_136.22**
730S	DPP-PSD	**4.30_136.140**
751	DPP-PSD	**4.23_132.09**
751	DPP-PSD	**4.29_132.38**
724	DPP-PHA	**4.29_128.39**
724	DPP-PHA	**4.30_128.81**
780	DPP-PHA	**4.30_128.81**
781	DPP-PHA	**4.30_128.81**
V1782	DPP-PHA	**4.30_128.81**
725	DPP-PHA	**4.29_139.10**
725S	DPP-PHA	**4.29_139.137**
730	DPP-PHA	**4.29_139.10**
730S	DPP-PHA	**4.29_139.137**
740D	DPP-QDC	**4.29_135.17**
2740	DPP-PHA	**2025102402**
2745	DPP-PHA	**2025102402**
2730	DPP-PHA	**TBD**
2740	DPP-PSD	**2025052200**
2745	DPP-PSD	**2025052200**
2730	DPP-PSD	**2025052203**
2751	DPP-PSD	**TBD**

For future release compatibility check the release notes files.

Change Document Record

Date	Revision	Changes
September 28th, 2017	0	Initial Release
November 9th, 2017	1	Added support to CoMPASS for Linux OS.
December 12th, 2017	2	Modified Statistics tab. Added ”Real time playback” in the Offline run.
February 6th, 2018	3	Modified Unfiltered/Filtered plot graphics.
February 23rd, 2018	3.1	Modified Time Selection tab.
May 18th, 2018	4	Modified Sec. **How to Save the Data**

September 27th, 2018	5	Modified Sec. **Software Connection**, Sec. **Start/Stop the acquisition and spectra visualization** and Sec. **How to Save the Data**.
October 19th, 2018	6	Added Sec. **How to create and use Virtual Channels (Add-back)**
January 14th, 2019	7	Modified binary list file format. Updated software GUI to rev. 1.1.0.
March 13th, 2019	8	Updated binary list file format. Added Time stamp limits in Sec. **Save the list of Trigger Time Stamp, Energy, PSD and waveforms**.
July 30th, 2019	9	Updated Sec. **Linux Installation**. Updated Sec. **Start/Stop the acquisition and spectra visualization**. Added Sec. **How to select a ROI** and Sec. **How to reprocess the CoMPASS data files**. Added support to V1782 Octal MCA.
December 13th, 2019	10	Added support to x725S and x730S. Added support to DT5790. Added Sec. **How to power on/off the high voltage (x780 family and DT5790 only)**. Modified Sec. **How to Save the Data**.
April 1st, 2020	11	Added support to DT5780 family. Added Sec. **Dead time evaluation in CoMPASS**. Modified Sec. **Software Connection**, **How to select a ROI**, Sec. **How to power on/off the high voltage (x780 family and DT5790 only)** and Sec. **How to Save the Data**.
August 7th, 2020	12	Added support to x740D family and DPP-QDC firmware. Added Chapt. **Troubleshooting**. Updated Sec. **Software Connection**. Updated Sec. **How to use the Settings Tab**
January 10th, 2021	13	Updated Sec. **How to Save the Data**.
February 17th, 2021	14	Added Section **Digitizer Synchronization Guide**. Modified Sec. **How to use the Settings Tab**.
December 23rd, 2021	15	Added Support to 2740 family. Added Sections **Create a new CoMPASS Project**, **Open a CoMPASS Project**. Updated Sec. **Introduction**, **Software Connection**, **Before starting the acquisition**, **How to configure the channel settings**, **How to Save the Data**, **Digitizer Synchronization Guide** and **Dead time evaluation in CoMPASS**. Completely revised Sec. **How to reprocess the CoMPASS data files**.
January 14th, 2022	16	Added Support to V4718. Updated Sec. **Create a new CoMPASS Project**.
February 8th, 2022	17	Added Support to 2745 family. Updated Sec. **Drivers Installation**, **Create a new CoMPASS Project**. Added Sec. **Save and Load configuration** and **How to (remotely) control CoMPASS from command line or external script** .
February 15th, 2022	18	SNAP installation package available again. Updated Sec. **How to Save the Data** and **How to (remotely) control CoMPASS from command line or external script** .
July 1st, 2022	19	Added support to 2740 and 2745 DPP-PSD firmware. Updated Sec. **How to configure the channel settings** and **Troubleshooting**
September 23rd, 2022	20	Updated board firmware releases compliance table. Updated Sec. **How to Save the Data**

September 13th, 2023	21	Updated **Copyright** Section, Chapt. **Technical Support** and End Page. Updated Chapt. **Troubleshooting**.
November 30th, 2023	22	Updated Sec. **Save the list of Trigger Time Stamp, Energy, PSD and waveforms**.
April 8th, 2024	23	Added support to 2730 DPP-PSD. Added support to A5818 PCI Express Gen 3 CONET2 Controller. Added Sec. **Integrated charge evaluation from CoMPASS saved waveforms**. Updated Sec. **Drivers Installation**, **How to use the Settings Tab**, **How to Save the Data**, **Troubleshooting**.
September 25th, 2024	24	Added Sec. **Integrated charge evaluation from CoMPASS saved waveforms** and **Generalized Time of Flight analysis: the Any to Any ΔT configuration**. Updated Sec. **Hardware Installation**, **Windows Installation**, **Linux Installation**, **How to Save the Data**, **Digitizer Synchronization Guide**, **Troubleshooting**.
March 19th, 2025	25	Extended Multilanguage Support. Updated Sec. **Quick Start Guide**, **How to Save the Data**
December 16th, 2025	26	Added support to 2730 DPP-PHA and 2751 DPP-PSD. Updated Sec. **Save the list of Trigger Time Stamp, Energy, PSD and waveforms**, Sec. **How to create and use Virtual Channels (Add-back)**, Sec. **How to (remotely) control CoMPASS from command line or external script** and Sec. **Digitizer Synchronization Guide** and Sec. **Troubleshooting**. Added Sec. **Batch mode data acquisition using an external script**.

Symbols, abbreviated terms and notation

ADC	Analog-to-Digital Converter
AMC	ADC & Memory Controller
DAQ	Data Acquisition
DAC	Digital-to-Analog Converter
DC	Direct Current
DPP	Digital Pulse Processing
DPP-QDC	DPP for Charge to Digital Converter
DPP-PHA	DPP for Pulse Height Analysis
DPP-PSD	DPP for Pulse Shape Discrimination
LVDS	Low-Voltage Differential Signal
ROC	ReadOut Controller
USB	Universal Serial Bus

Reference Documents

[RD1] W. R. Leo. *Techniques for Nuclear and Particle Physics Experiments*. Ed. by Springer. II ed.

[RD2] AN2506 - Digital Gamma Neutron discrimination with Liquid Scintillators.

[RD3] L.Stevanato et al. “Pulse shape discrimination with fast digitizers”. In: *NIM A* 748 (2014), pp. 33–38.

[RD4] AN6872 - Energy and Timing characterization of two CeBr3 detectors with a DT5730 digitizer and CoMPASS.

[RD5] AN5830 - Comparison between two CAEN MCAs and two CAEN Digitizers.

[RD6] UM8717- 2740/2745 Digitizers User Manual.

[RD7] UM11111 - CAEN Toolbox - Software suite for CAEN Boards User Manual.

[RD8] GD2783 - First Installation Guide to Desktop Digitizers & MCA.

[RD9] V1718 & VX1718 User & Reference Manual.

[RD10] UM7685 - V3718/VX3718 VME to USB-2.0/Optical Link Bridge.

[RD11] UM8305 - V4718/VX4718 VME to USB 3.0/Ethernet/Optical Link Bridge.

[RD12] Technical Information Manual of A2818 PCI Optical Link Controller.

[RD13] Technical Information Manual of A3818 PCI Express Optical Link Controller.

[RD14] UM10551 A5818 PCI Express Gen 3 CONET2 Controller.

[RD15] DS7799 - A4818 USB 3.0 to CONET Adapter Data Sheet.

[RD16] UM1934 - CAENComm User & Reference Manual.

[RD17] UM1935 - CAENDigitizer User & Reference Manual.

[RD18] UM7788 - FELib PHA Parameters User Manual.

[RD19] UM8762 - FELib PSD Parameters User Manual.

[RD20] UM5960 - CoMPASS User Manual.

[RD21] UM4380 - 725-730 DPP-PSD Registers Description.

[RD22] UM6769 - 724-781-782 DPP-PHA Registers Description.

[RD23] UM6771 - 780 DPP-PHA Registers Description.

[RD24] AN2086 - Synchronization of CAEN Digitizers in Multiple Board Acquisition Systems.

All CAEN documents can be downloaded at:
`www.caen.it/support-services/documentation-area`

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Limitation of Responsibility

If the warnings contained in this manual are not followed, CAEN will not be responsible for damage caused by improper use of the device. The manufacturer declines all responsibility for damage resulting from failure to comply with the instructions for use of the product. The equipment must be used as described in the user manual, with particular regard to the intended use, using only accessories as specified by the manufacturer. No modification or repair can be performed.

Disclaimer

The information contained herein has been carefully checked and is believed to be accurate; however, no responsibility is assumed for inaccuracies. CAEN SpA reserves the right to modify its products specifications without giving any notice; for up to date information please visit www.caen.it.

Made in Italy

We remark that all our boards have been designed and assembled in Italy. In a challenging environment where a competitive edge is often obtained at the cost of lower wages and declining working conditions, we proudly acknowledge that all those who participated in the production and distribution process of our devices were reasonably paid and worked in a safe environment (while this is true for the boards marked ”MADE IN ITALY”, we cannot guarantee for third-party manufactures).

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1 Introduction

The function of the Front End electronics in nuclear physics applications is to acquire the electrical charge pulses generated by a detector, to extract the quantities of interest and to convert them into a digital format. These information are then acquired, saved and analyzed by a computer. In most applications, relevant quantities are the particle energy (proportional to the charge released by the particle in the detector) and the time of arrival; in some cases the acquisition is restricted to the pulse counting, actually a "selective" counting, meaning that one or more energy intervals or other criteria are used to select which particles must be counted. In some other cases, it is necessary to discriminate the type of the particle by means of the pulse shape; for example, the γ-n discrimination is based on a detector response variation when stimulated by a gamma or a neutron; this variation leads to a different rise and/or decay time of the pulse. The acquisition system is usually completed by digital logic units whose purpose is to perform (anti)coincidences, generate triggers, vetoes and other signals that take into account the correlation between different channels and may give further information such as the particle position or trajectory.

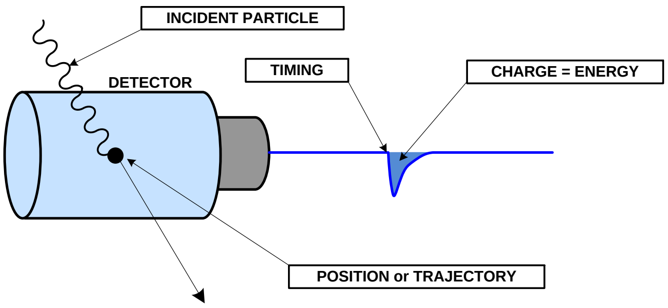


Fig. 1.1: Electrical charge pulse generated by a particle interacting with a detector.

Nowadays, the availability of very fast and high precision flash ADCs permits to design acquisition systems in which the Analog to Digital conversion occurs as close as possible to the detector. In principle, this acquisition system allows to minimize the information loss. Actually, the acquisition will be affected by uncertainties due to the quantization noise and to other sources of electronic noise. In general, the applications that require precise timing measurements are more oriented to the use of high sample frequency digitizers (500 MS/s or more), while the 12-14 bit digitizers are well suited for acquisitions where high energy resolution is a pre-requisite.

In recent years, the use of waveform digitizers for readout of radiation detectors has become popular in many different physics applications: the conventional analog electronics is going to be replaced by a full digital approach, where the detector output (with or without preamplifier, depending on the detector type) is directly connected to the digitizer input. This approach is especially beneficial in multi-parametric acquisition systems, where the analysis involves different quantities and parameters, such as energy, pulse shape and timing. In fact, thanks to Digital Pulse Processing (DPP) it is possible to apply dedicated algorithms online (typically in the FPGAs), to extract the information of interest from the raw waveform. DPP algorithms allow the digitizer to implement in "one single box" the different functionalities of the old fashion TDC, QDC, Peak Sensing ADC, discriminator and other analog and logic modules **[RD1]**. Furthermore, the DPP allows the digital readout to be sustainable in terms of data throughput because the full waveform is not necessarily read out but used for debugging purposes only. This results in an "all-in-one, multi-parametric digital DAQ for physics applications".

CAEN has developed a complete family of waveform digitizers well suited for physics, medical, homeland

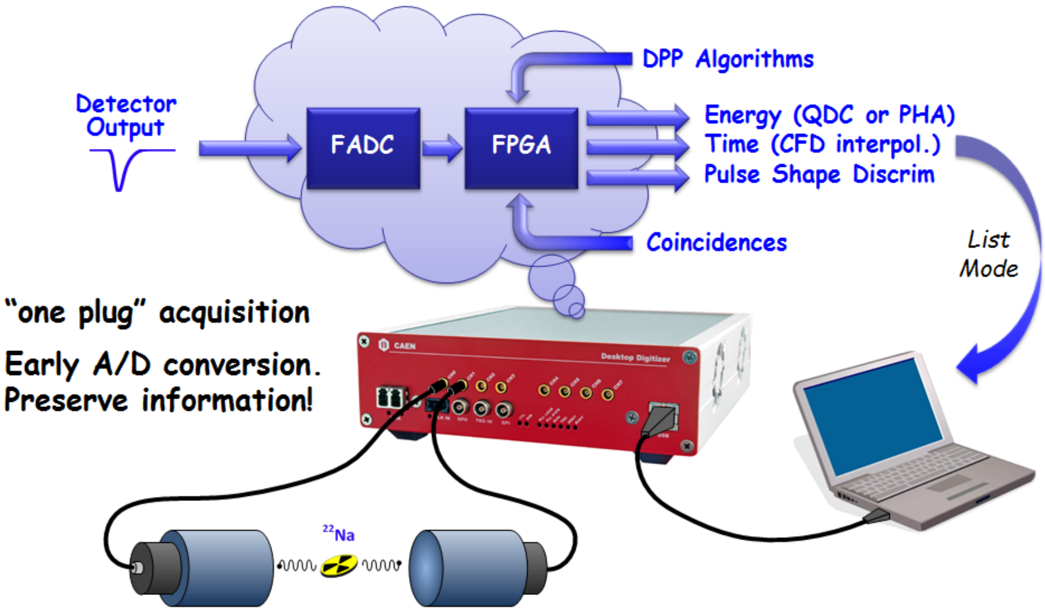


Fig. 1.2: All-in-one Spectroscopy DAQ.

security and industrial applications. They are available in different form factors (VME, Desktop and NIM) as showed in Tab. **1.1**. In addition, CAEN developed also several digital pulse processing algorithms that allows the user to extract a set of significant information like energy, precise timing, PSD and so on **[RD1]**. Tab. **1.2** shows the functionalities supported by the different models and that will be described in the following sections.

MODEL(1)	Form Factor	# channels	Sampling Frequency (MS/s)	# Bits	Input Dynamic Range (Vpp)	Bandwidth (MHz)	DPP firmware
x724	VME	8	100	14	0.5 - 2.25 - 10	40	PHA
	Desktop/NIM	4					
x720	VME	8	250	12	2	125	PSD
	Desktop/NIM	4					
x730	VME	16	500	14	0.5 and 2	250	PHA, PSD
	Desktop/NIM	8					
x725	VME	16	250	14	0.5 and 2	125	PHA, PSD
	Desktop/NIM	8					
x751	VME	8	1000/2000	10	1	500	PSD
	Desktop/NIM	4					
x740D	VME	64	62.5	12	2	30	QDC
	Desktop/NIM	32					
x781	Desktop/NIM	4	100	14	0.3 - 1 - 3 - 10	5	PHA
V1782	VME	8	100	14	Gain: x1, x2, x4, x8 (Gain 1 = 1 Vpp); gain attenuation x0.2 by on-board jumper	5	PHA
x780	Desktop/NIM	2	100	14	Gain: x1, x3, x7, x16	40	PHA
DT5790	Desktop	2	250	12	2	125	PSD
x2740	VME/Desktop	64	125	16	2	50	PHA, PSD
x2745	VME/Desktop	64	125	16	4 - VGA with Gain up to x 100	50	PHA, PSD
x2730	VME/Desktop	32	500	14	4 - VGA with Gain up to x 20	250	PHA, PSD
X2751	VME/Desktop	16	1000	14	2 - VGA with Gain up to x 10	450	PSD

Tab. 1.1: CAEN Waveform Digitizers selection table.

CoMPASS is the new software from CAEN able to implement a Multi-parametric DAQ for Physics Applications, where the detectors can be connected directly to the digitizers inputs and the software acquires energy, timing, and PSD spectra. CoMPASS software has been designed as a user-friendly interface to manage the acquisition with all the CAEN DPP algorithm. CoMPASS can manage multiple boards, even in synchronized mode, and the event correlation between different channels (in hardware and/or software), apply energy and PSD cuts, calculate and show the statistics (trigger rates, data throughput, etc...), save the output data files (raw data, lists, waveforms, spectra) and use the saved files to run off-line with different processing parameters.
CoMPASS Software supports CAEN **first generation digitizers** x720, x724, x725, x730, x740D, x751 digitizer families running the DPP-PSD, DPP-PHA and DPP-QDC firmware, the x780, x781 and x782 **MCA family**, the DT5790 **Pulse Processor** and the **second generation digitizer** x2740, x2745, x2730 and x2751 running the DPP-PSD and DPP-PHA firmware. More details about the supported boards and firmware are given in the following sections.

Model	Waveform Recording	PHA	PSD	CFD	QDC
x730	√	√	√	√	√
x725	√	√	√	√	√
x751	√		√	√	√
x724	√	√			
x720	√		√		√
x740D	√				√
x781	√	√			
V1782	√	√			
x780	√	√			
DT5790	√		√		√
x2740	√	√	√	√	√
x2745	√	√	√	√	√
x2730	√	√	√	√	√
x2751	√		√	√	√

Tab. 1.2: Functionalities implemented in the CAEN digital algorithms and supported by the digitizers.

Note: 725, 730 and 751 series requires the calibration of the ADCs before starting the acquisition. CoMPASS performs the calibration at every start acquisition. 725S and 730S series do not require the ADC calibration.

Note: From now on 725/730 series will include 725 and 725S/730 and 730S respectively unless otherwise specified.

2 Quick Start Guide

2.1 Scope of the Chapter

This chapter is intended to provide the user with a quick guide of the CoMPASS Software, to deal with a DPP-PSD and a DPP-PHA System in a practical use. For a demo purpose we used a gamma source of Cobalt-60 only. The user can refer to **[RD2]** and **[RD3]** for a real neutron – gamma discrimination application, to **[RD4]** for a mixed Energy/Timing measurement application and to **[5]** for a real high resolution spectroscopy application. All steps in this chapter are made with the **730 series (in the DPP-PSD case) and 725 (in the DPP-PHA case)**. The same behaviour can be generalized to the 720, 725, 751, 2740, 2745, 2730 and 2751 series, as well as the DT5790 (for DPP-PSD) and to the 724, 730, 780, 781, 782, 2740, 2745 and 2730 (for DPP-PHA). Exceptions and specific functioning will be explicitly mentioned in the text.

2.2 Hardware Installation

CAEN's DPP-PSD System proposed in the chapter consists of the following CAEN products:

- DT5730S, 8-channel 14-bit 500 MS/s Desktop Digitizer.
- DPP-PSD firmware for 730S series (release 4.29_136.138), running on the Digitizer.
- DT5534, 4 Channel 6 kV/1 mA (4 W) Desktop HV Power Supply Module
- CoMPASS Software for data acquisition, release 2.5.0, running on the host station
- GECO2020 Software for power supply management, release 1.13.1, running on the host station.

The digitizer running the DPP-PSD algorithm receives on channel 0 the signal from a NaI(Tl) coupled with a PMT. The CAEN DT5534 (a 4-channel, HV Programmable Power Supply board) provides the supply to the detector (V_{bias} = 800 V). A Cobalt-60 (^{60}Co) gamma ray source (counting rate $\sim$ 1 kHz) is used. A computer equipped with a Microsoft Windows 11 64-bit OS acts as host station in which the CoMPASS and GECO2020 are running. The communication protocol between the computer and the Digitizer is USB (2.0 version).

Connect the SHV cable for the high voltage power supply to the HV0 connector of the DT5534. Connect the PMT output to the DT5730S CH0. Connect the digitizer and the HV power supply to the PC with the preferred communication interface between USB and Optical link (USB and Ethernet for the power supply).

CAEN's DPP-PHA System proposed in the chapter consists of the following CAEN products:

- DT5725S, 8-channel 14-bit 250 MS/s Desktop Digitizer.
- DPP-PHA firmware for 725S series (release 4.29_139.137), running on the Digitizer.
- DT5521HE, 4 Channel 6 kV/20 µA Desktop HV Power Supply Module
- DT5423, Desktop Linear Power Supply
- CoMPASS Software, release 2.5.0, running on the host station
- GECO2020 Software, release 1.13.1, running on the host station.

The digitizer running the DPP-PHA algorithm receives on channel 0 the signal from a HPGe. The CAEN DT5521H (a 4-channel, HV Programmable Power Supply board) provides the supply to the detector (V_{bias} = 5500 V). The low voltage for the preamplifier is provided by the DT5423 a desktop linear power supply. A Cobalt-60 (60Co) gamma ray source (counting rate $\sim$ 1 kHz) is used. A computer equipped with a Microsoft Windows 10 64-bit OS acts as host station in which the CoMPASS and GECO2020 are running. The communication protocol between the computer and the Digitizer is USB (2.0 version).

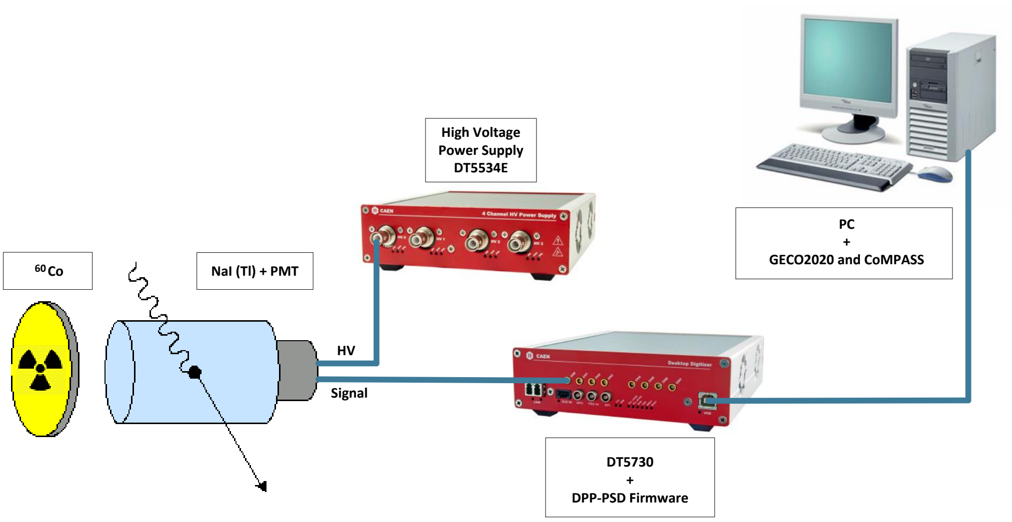


Fig. 2.1: The hardware setup including the digitizer running the DPP-PSD firmware used for the typical medium resolution measurements using NaI(Tl) detectors application.

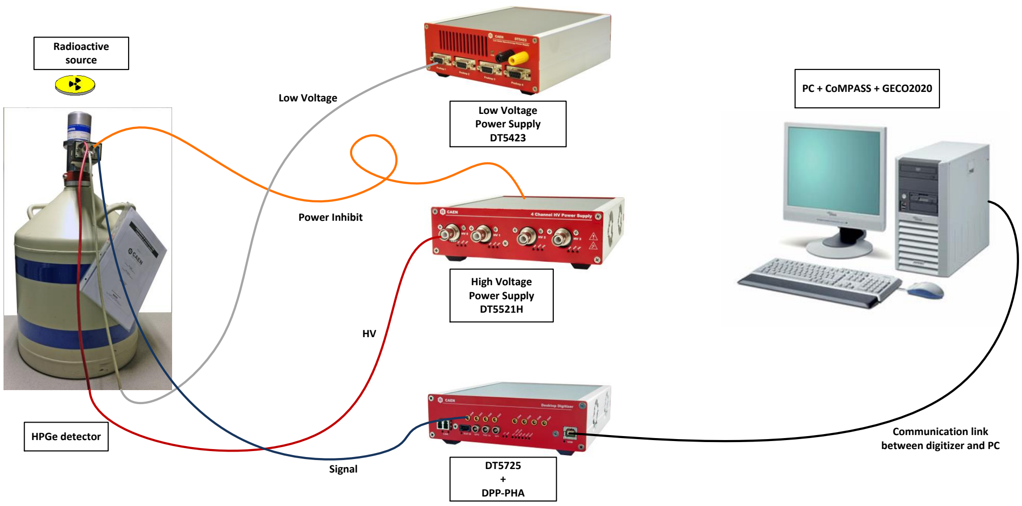


Fig. 2.2: The hardware setup including the digitizer running the DPP-PHA firmware used for a typical high resolution measurements using HPGe detectors application.

Connect the SHV cable for the high voltage power supply to the HV0 connector of the DT5521H. Connect the low voltage to the DT5423 and the inhibit (if any) to the back panel connectors of the DT5521H. Connect the preamplifier output to the DT5725S CH0. Then connect the digitizer and the HV power supply modules to the PC with the preferred communication interface between USB and Optical link (USB and Ethernet for the power supply).

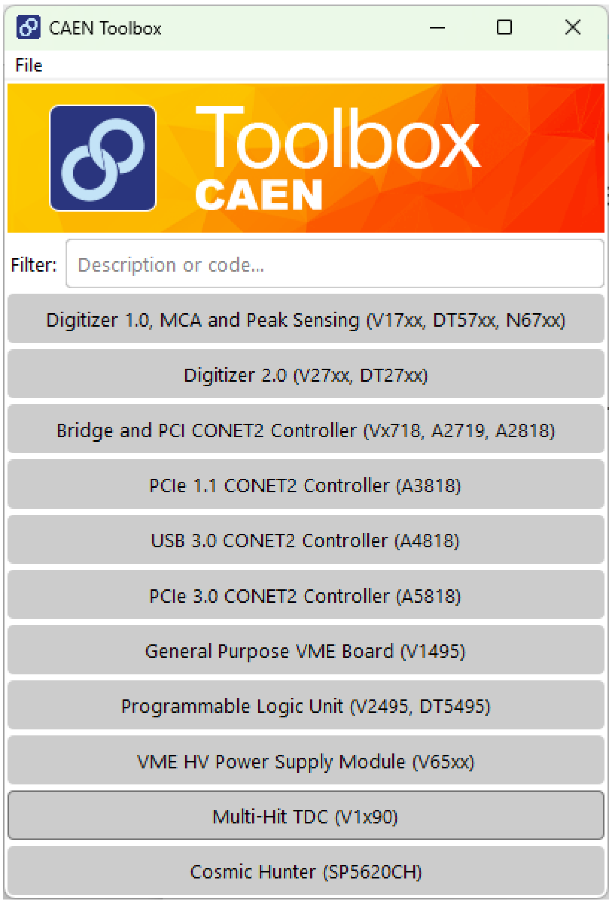
2.3 Firmware and Licensing

The firmware upgrade is an advanced feature that can be performed only in case the user wants to upgrade the current firmware to a new version, or to upload a different firmware on the board. The .cfa file format checks for the board model to ensure that firmware upgrade is made on the correct board.

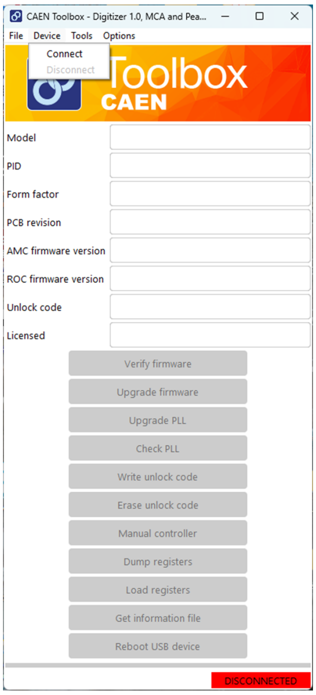
2.3.1 How to install the firmware

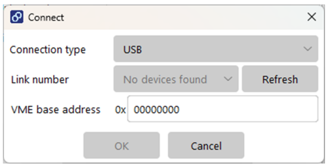
2.3.1.1 V17xx, DT57xx and N67xx digitizers and MCAs

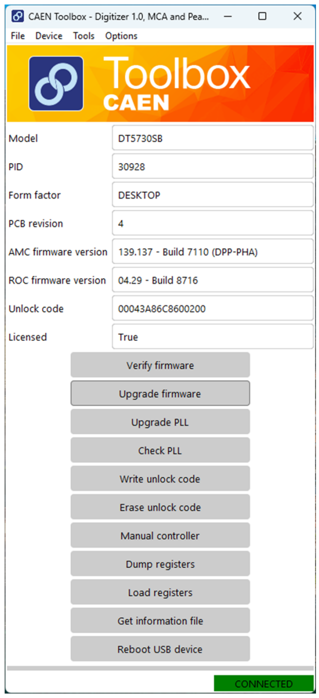
- Download the DPP-PSD Firmware (.cfa) for the 730 series (or for your own digitizer) on CAEN website in the 'Download' area of the DPP-PSD page or from the digitizer page. Download the correct file according to the digitizer family in use.
- Download the CAEN Toolbox software to upload the firmware on your board. The program full installation package for Windows OS is available on CAEN website in the 'Download' area at the CAEN Toobox page.
- Unpack the installation package, launch the setup file and complete the Installation wizard.
- Run the CAEN Toolbox GUI by one of the following options:
  - The desktop icon for the program
  - The Quick Launch icon for the program
  - The .exe file in the bin folder from the installation path on your host
- Select "Digitizer 1.0".



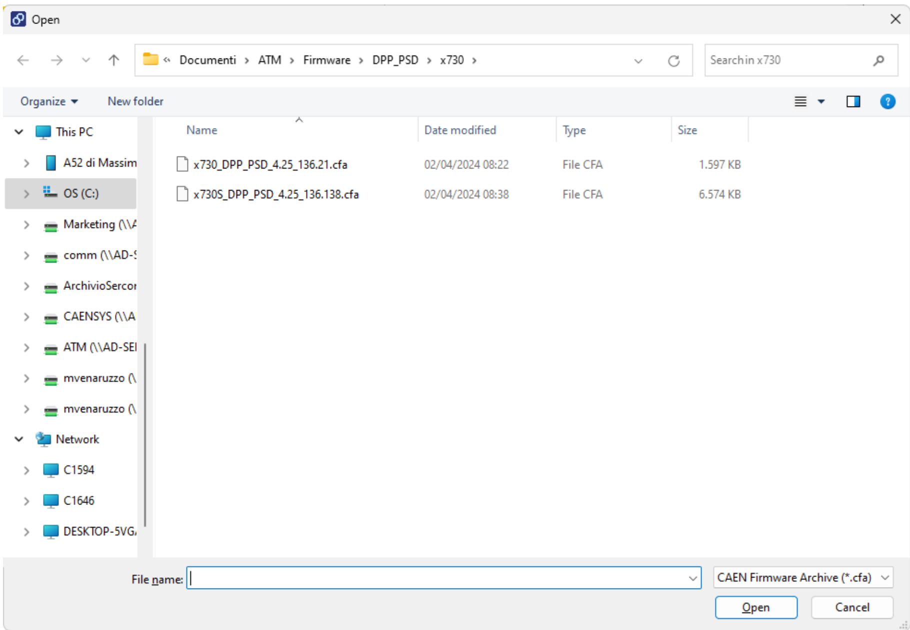
- from the top menu select Device → Connect, insert the digitizer connection parameters and press Connect.



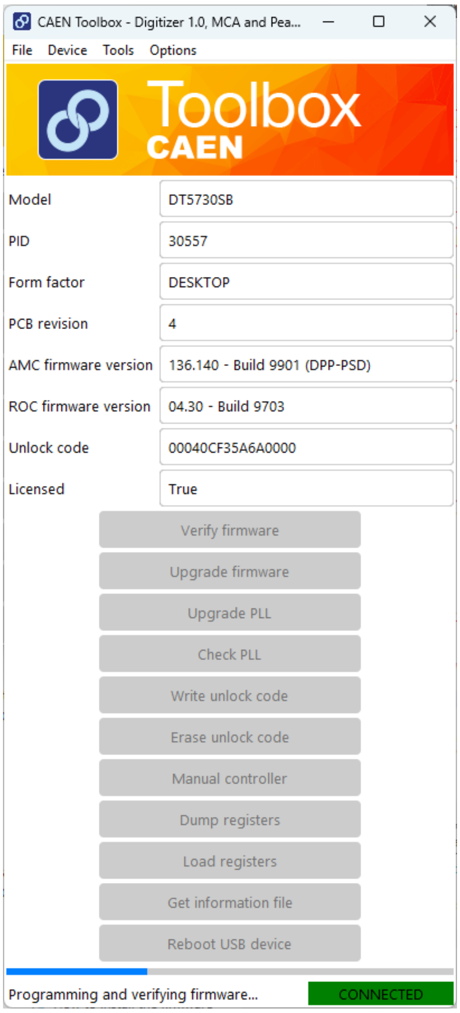




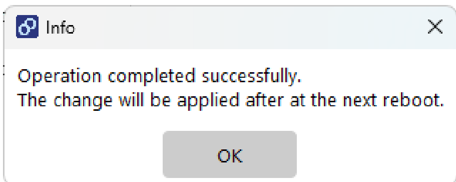
- Select 'Upgrade Firmware'.
- Select the DPP-PSD .cfa firmware file to be uploaded on the digitizer and press Open.



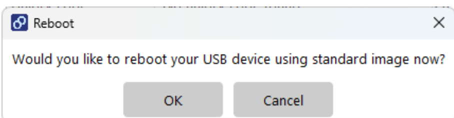
- The digitizer firmware upload will the start automatically and CAEN Toolbox does show the operation progress.



- Once the upload is completed, power cycle the board.



- if the digitizer is a DT57xx one, CAEN Toolbox will notify the user the possibility to proceed with an automatic reboot of the board.



The procedure for installing and upgrading the DPP-PHA firmware is the same.

Note: If the digitizer is connected to the DAQ pc via USB, **do not upgrade the board firmware while running CoMPASS**. The concurrent access to the digitizer flash memory done by CAEN Toolbox and CoMPASS might lead to an interruption of the CAEN Toolbox writing process with a consequent flash memory corruption.

2.3.1.2 V/VX27xx and DT27xx digitizers

This section is of course not related to the specific example described in this chapter. However we do include it as well because the prescription and the advises included here may be easily extended to the V/VX27xx and DT27xx digitizers as well. For this reason it's useful to have here a quick guide about their firmware upgrade as well.
The V/VX27xx and DT27xx digitizers firmware upgrade can be done either using CAEN Toolbox or the embedded Web Interface**[RD6]**. Here the procedure using thee mbedded web interface is shown. The *Firmware* section deals with firmware management.

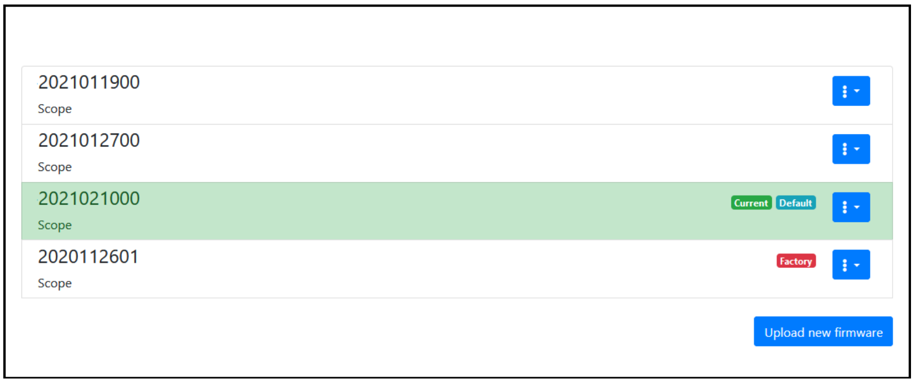


Fig. 2.3: Firmware page.

The Digitizer can store multiple firmware on-board. Such firmware can be either different updates of the same firmware type, or different firmware types (Scope or DPP), indifferently. Each stored firmware is visible on this page. The User can perform a new firmware upload, select which firmware must be loaded on the FPGA at the reboot (Default), and which firmware must be the current operating firmware (Current). The factory firmware (Factory) cannot in any way be deleted and guarantees communication with the board even in case it is compromised with any other firmware.
Firmware settings:

- *Apply*: Sets the firmware as the current operating firmware (green label). The selected firmware is loaded without the need of rebooting the hardware. The current FPGA firmware version is updated in the Board Information of the Dashboard page.
- *Set as default*: Makes the selected firmware the one to be loaded after the device reboot (light blue label).
- *Delete*: Deletes the firmware from the Digitizer memory. Note that the factory firmware (red label) cannot be deleted.
- *See details*: Shows the changelog information for the selected firmware.

The firmware file is a CUP file, which is an archive of files including the firmware for all the programmable components present on the 2740 digitizer (FPGA, CPU, etc.). By upgrading the CUP file, all the components are upgraded at once. The standard name of the CUP file is:

<model>-<type>-<firmware-version>-1GbE.CUP

where

- <model> is the digitizer model (e.g. V2740);

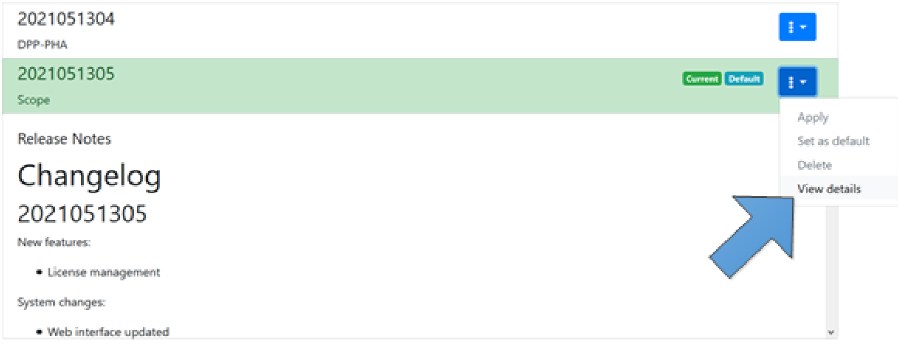


Fig. 2.4: The firmware changelog.

- <type> is the firmware type identifier (e.g. scope);
- <firmware-version> is the firmware version.

Each stored firmware generates a raw in this section, reporting the firmware revision and the firmware type (scope, DPP, etc.) just below.

The upgrade procedure is the following:

- Press the "Upload new firmware" button.
- Use the "Browse" button in the upgrade window to point to the CUP file.
- Press the "Upload" button to start the upgrade.

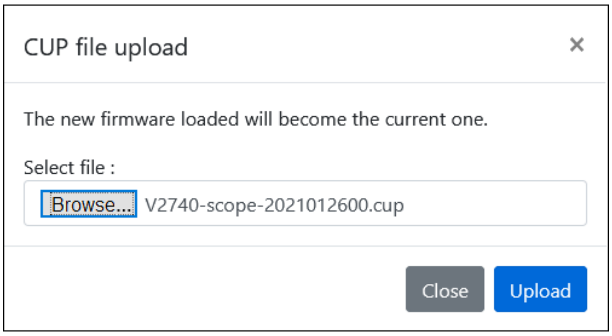


Fig. 2.5: Firmware upgrade window.

- The selected firmware will be automatically set as Current at the end of the process.

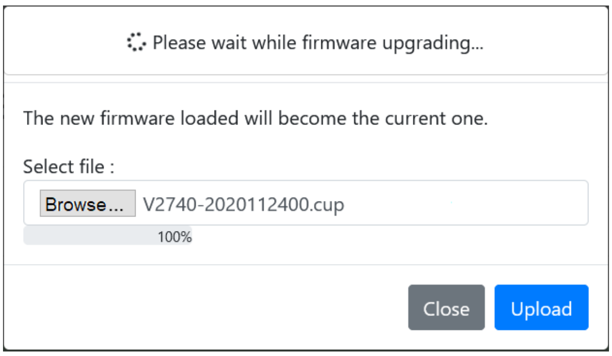


Fig. 2.6: Firmware upgrade done.

- Reboot by the "Reboot device" option to make the new firmware upgrade effective.

Note that when running the CoMPASS Software, the program checks for the firmware loaded in the target Digitizer. If no license is found the software will show it in the "Board Properties" section, and at the start of the acquisition, a pop-up warning message shows up and reports the time left before the acquisition is stopped (trial version). To unlock the DPP firmware and to use it without any time limitation, you need to purchase a license from CAEN. Refer to **[7]** for detailed instructions on how to use CAEN Toolbox and the licensing procedure.

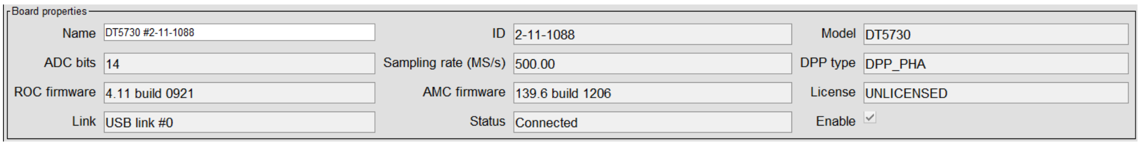


Fig. 2.7: CoMPASS Board Settings section with the indication of a not licensed DPP-PHA firmware.

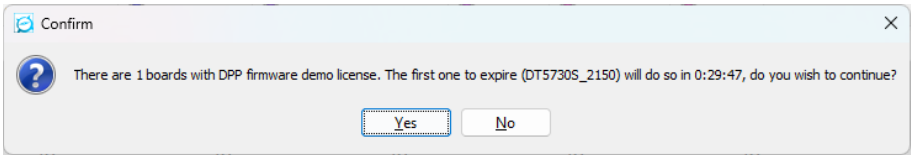


Fig. 2.8: CoMPASS time bomb remaining time warning.

2.4 Software Setup

2.4.1 Drivers Installation

According to the preferred way of connection to the digitizer, users must also take care of proper installation of USB or optical drivers. CAEN provides the drivers for all the different types of physical communication interfaces featured by the specific digitizer and compliant with Windows OS.

- **USB 2.0 Drivers for NIM/Desktop** boards are downloadable on CAEN website (www.caen.it) in the "Software/Firmware" tab of the digitizer/MCA web page (login required).

Note: Windows OS USB driver installation for Desktop/NIM digitizers is detailed in **[8]**.

- **USB 2.0 Drivers for V1718 and V3718 CAEN Bridge**, required for the VME boards interface, are downloadable on CAEN website (www.caen.it) in the "Software/Firmware" tab of the V1718 and V3718 web page (login required).

Note: For the installation of the V1718 and V3718 USB driver, refer to the User Manual of the Bridge **[9] [10]**.

- **USB 3.0 Drivers for V4718 CAEN Bridge**, required for the VME boards interface, are downloadable on CAEN website (www.caen.it) in the "Software/Firmware" tab of the V4718 web page (login required).

Note: For the installation of the V4718 USB 3 driver, refer to the User Manual of the Bridge **[11]**.

- **Optical Link Drivers** are managed by the A2818 PCI card, the A3818 PCIe card or the A5818 PCIe card. The driver installation package is available on CAEN website in the “Software/Firmware” area at the A2818, A3818 and A5818 page (login required)

Note: For the installation of the Optical Link driver, refer to the User Manual of the specific Controller **[12] [13] [14]**.

- **USB 3.0 Drivers for A4818 adapter** are downloadable on CAEN website (www.caen.it) in the “Software/Firmware” tab of the A4818 web page (login required).

Note: For the installation of the A4818 USB 3 driver, refer to the datasheet of the **[15]**.

Note: It is recommended to install the driver before to connect the hardware.

Note: x27xx digitizer family does not require any USB driver to be installed in Windows. They are required in Linux only.

In our case we are going to describe the procedure for USB connection.

2.4.2 How to install the driver (Windows)

- Download the latest release of the USB driver for Windows on CAEN website in the ‘Software/Firmware’ area at the digitizer page.
- Unpack the driver package.
- Power on the Digitizer and plug the USB cable in a USB port on your computer.
- Windows will try to find drivers and, in case of failure the message “Device driver software was not successfully installed” is displayed and the driver needs to be installed manually:
- Go to the system’s ’Device Manager’ through the Control Panel and check for the CAEN DT5xxx USB1.0 unknown device.
- Right click and select Driver software update in the scrolling menu.
- Select the option to ’Browse my computer’ for driver software.
- Point to the driver folder and finalize the installation.

2.4.3 How to install the driver (Linux)

In case of a DT57xx and N67xx digitizer:

- Download the latest release of the USB driver for Linux on CAEN website in the ‘Software/Firmware’ area at the digitizer page.
- Unpack the driver package (tar –zxf CAENUSBDrvB-xxx.tgz).
- Go to the driver folder (cd CAENUSBDrvB-xxx).
- Follow the instructions on the Readme.txt file.
- Type:

```
make
sudo make install
```

- Reboot your machine

In case of a 27xx digitizer:

- Download the latest release of the USB driver for Linux on CAEN website in the 'Software/Firmware' area at the digitizer page.
- Unpack the driver package (tar –zxf CAENDGTZ-USB-Drv-x.y.tgz).
- Go to the driver folder (cd CAENDGTZ-USB-Drv-x.y).
- Follow the instructions on the Readme.txt file.
- Type:

  sudo ./install.sh

  sudo sudo ./regPID.sh in case your Linux distribution is not able to automatically retrieve the Digitizer USB name (CAENDGTZ-USB-{PIDNUMBER})
- Reboot your machine

2.4.4 Libraries

CoMPASS software requires the following embedded CAEN libraries to manage the communication, configuration and readout of the digitizers:

- CAENComm library manages the communication at low level (read and write access). The purpose of the CAENComm is to implement a common interface to the higher software layers, masking the details of the physical channel and its protocol, thus making the libraries and applications that rely on the CAENComm independent from the physical layer. Moreover, **the CAENComm requires the CAEN-VMELib library (access to the VME bus) even in the cases where the VME is not used.** Reference document: **[16]**
- CAENDigitizer is a library of functions designed specifically for the Digitizer family, which supports the DPP firmware. **The CAENDigitizer library is based on the CAENComm library.** Reference document: **[17]**.
- CAEN_FE_lib is a library that can be used to control and acquire data new generation CAEN digitizers. This library is just an interface and does not includes support to any digitizer family. In order to use a digitizer you must install first the respective underlying library. Reference documents: **[18]**, **[RD19]**.
- CAEN_DIG1_lib is the high level library of functions designed specifically for CAEN V/VX17xx, DT57xx, N67xx first generation digitizers. Reference document: N/A.
- CAEN_DIG2_lib is the high level library of functions designed specifically for CAEN 27xx second generation digitizers. Reference document: N/A.

Note: The most updated documentation about the FELib and Dig2 can be retrieved directly from the 27xx digitizer web interface.

Note: The software is stand-alone and does not require the prior installation of the libraries (both for Windows and Linux OS).

2.4.5 CoMPASS Installation

In order to be able to install CoMPASS, the host station needs **Windows 10 build 15063 (or later) or Linux 64 bit OS**.

- **Make sure** that your **hardware** (Digitizer and/or Bridge, or Controller) is **properly installed** (refer to the related User Manual for hardware installation instructions).
- **Make sure** you have installed the **driver** for your OS and the physical communication layer to be used. Driver installation packages are downloadable from CAEN website (**login required**) as reported in the section **Drivers Installation** (refer to the related User Manual for driver installation instructions)

CAEN provides the full installation package for the CoMPASS Software in a standalone version for Windows and Linux OS. This version installs all the binary files and required libraries.

1. Download the CoMPASS Software for your OS from CAEN Website under the path: Home / Products / Firmware/Software / Digitizer Software / Readout Software / CoMPASS
2. Extract the files

2.4.5.1 Linux Installation

In case of Linux OS there are two possible installation procedure:

1. **Procedure 1**:
   - Use the software manager Snap for Linux (refer to `snapcraft.io`).
   - Download the ”compass_version_amd64.snap” file;
   - Install the software by typing
     `sudo snap install compass_version_amd64.snap --dangerous --devmode`

     The `--dangerous` option just means that the package has not been verified by the Snap Store team and the `--devmode` option allows snap, executed in a sandbox, to access the computer disk and peripherals.

     There is no need to check for the minimal requirements as Snap will automatically install all the additional required packages.
2. **Procedure 2**:
   - Download the ”CoMPASS-version.tar.gz” file and unzip it;
   - Please check that your gcc and g++ compiler are $\geq$ 11.4.0, that glibc is $\geq$ 2.34 and that glibcxx is $\geq$ 3.4.30.
   - To install the software type
     `sudo sh install.sh`

     Missing packages are detected by the setup and the user must install them to continue the CoMPASS installation.

2.4.5.2 Windows Installation

Run the executable “CoMPASS_version.exe” and the Setup Wizard will guide you throughout the installation procedure.

The CoMPASS Setup Wizard will first look for already present CoMPASS installation. If it finds it, it will ask the user to first uninstall the previous installation automatically.

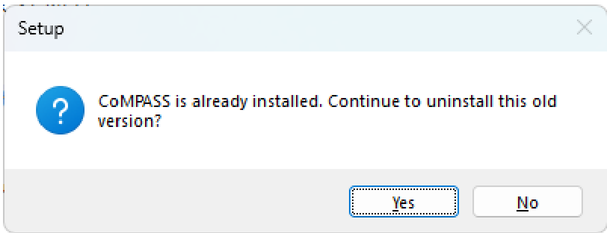


Fig. 2.9: CoMPASS Wizard Dialog Box - Detection of previous CoMPASS installation.

Click Yes to proceed with the old CoMPASS version uninstall.

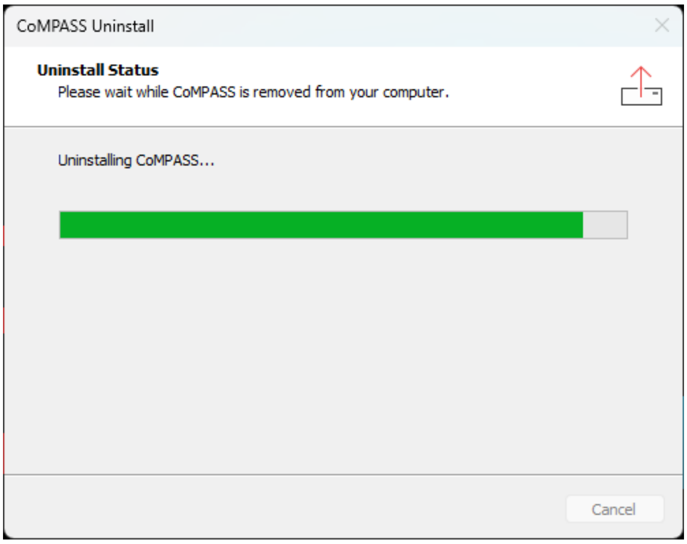


Fig. 2.10: CoMPASS Wizard Dialog Box - Uninstall of previous CoMPASS installation.

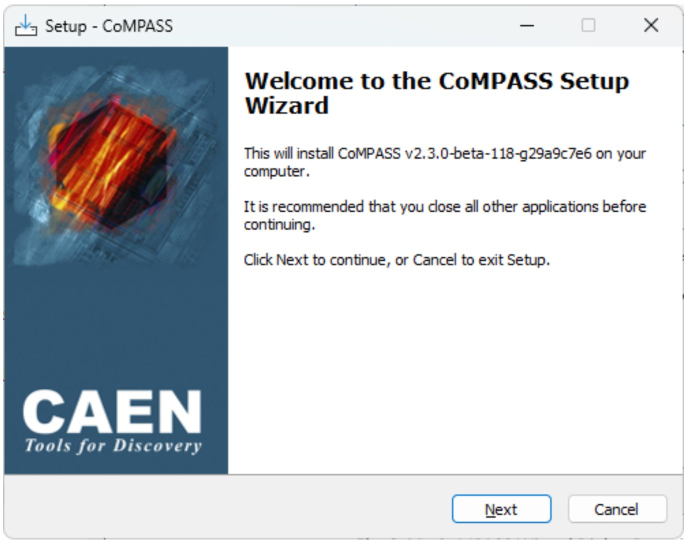


Fig. 2.11: CoMPASS Wizard Dialog Box - Start Installation.

The ComPASS installer looks for the presence on your system of possible incompatible packages; if it finds them a pop up appears asking to remove them before completing the installation.

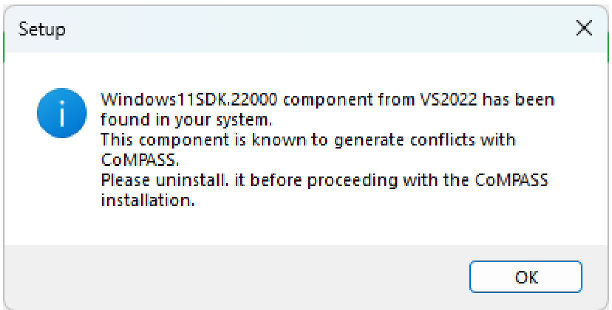


Fig. 2.12: CoMPASS incompatible packages pop up.

The ComPASS installer looks for the presence on your system of the required OS packages; if it does not find them a pop up appears asking to install them.

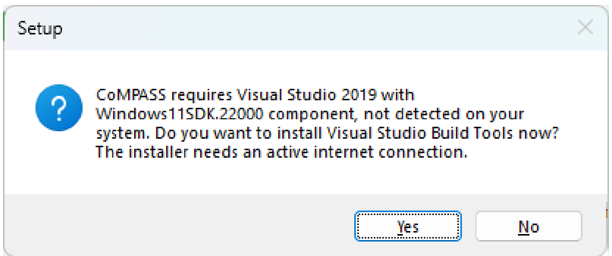


Fig. 2.13: CoMPASS Requirements pop up.

Proceed with the required package installation and then the main Installation Wizard occurs.

Please read the CoMPASS Software License Agreement and select “**I accept the agreement**” to continue the installation. Left click on “**Next**” (or left click on “**Back**” at any time during the installation process to modify the previous settings).

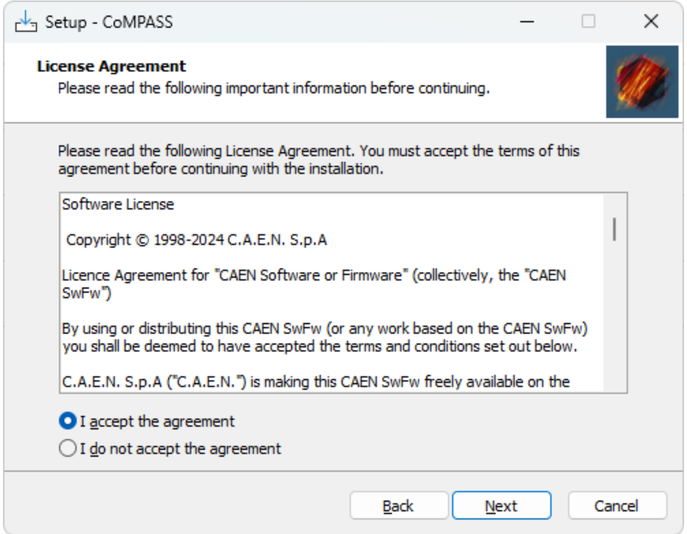


Fig. 2.14: CoMPASS Wizard Dialog Box - License Agreement.

Choose the CoMPASS installation path. By default the C:\CoMPASS path is proposed.

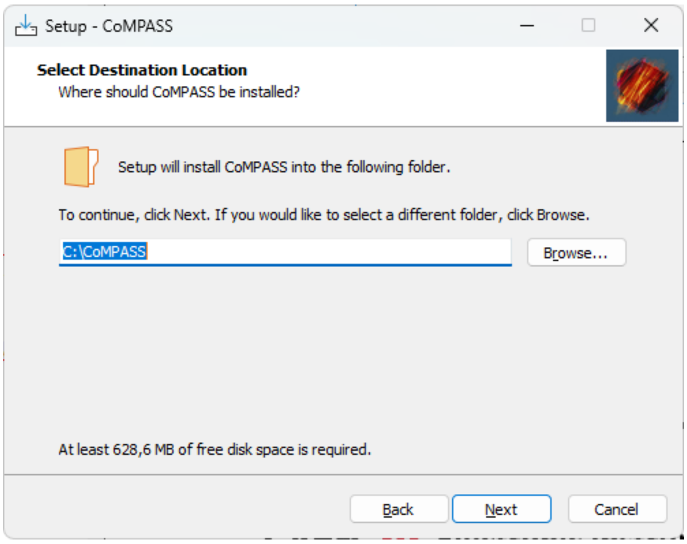


Fig. 2.15: CoMPASS Wizard Dialog Box - Installation path selection.

Press "*Browse*" if you want to change it with a different path.

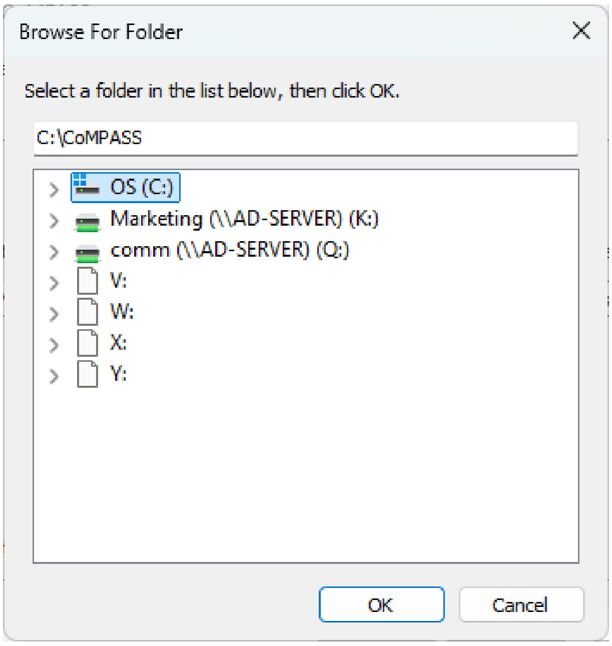


Fig. 2.16: CoMPASS Wizard Dialog Box - Installation path change window.

If the selected installation folder already exist CoMPASS does ask the user for the overwrite confirmation.

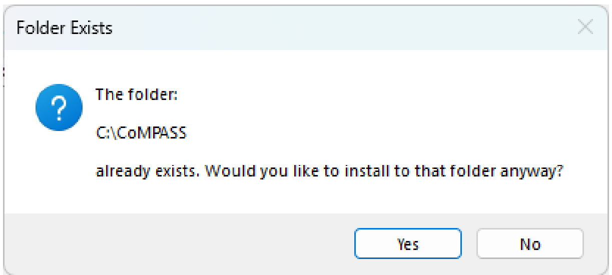


Fig. 2.17: CoMPASS Wizard Dialog Box - Installation folder overwrite confirmation.

Optionally, mark the checkbox labelled "**Create a desktop icon**" to create an CoMPASS icon on your computer Desktop. Left click on "**Next**" to continue.

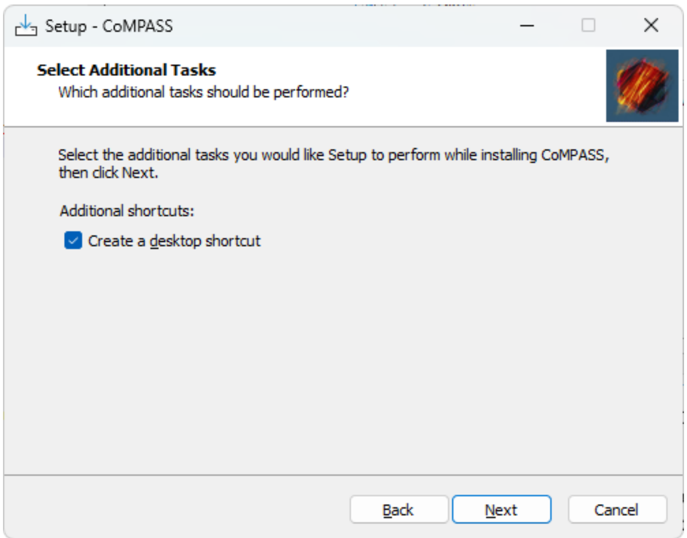


Fig. 2.18: CoMPASS Wizard Dialog Box - Desktop Icon Selection.

Check the installation setting summary window and press “**Install**” when ready to install the CAEN CoMPASS Software.

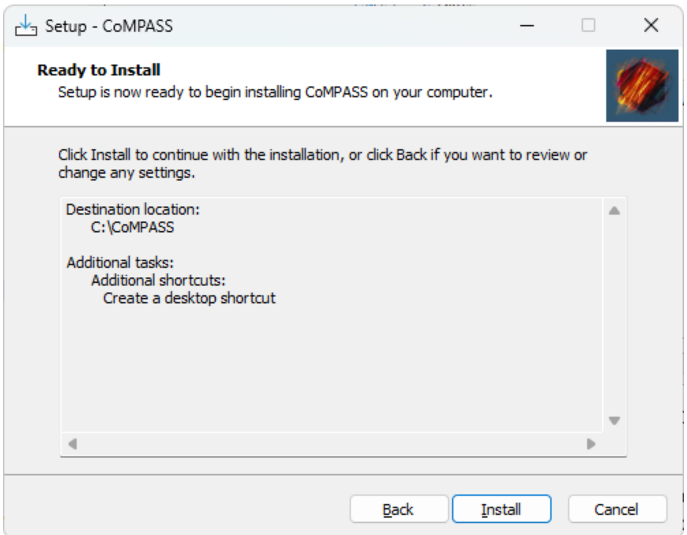


Fig. 2.19: CoMPASS Wizard Dialog Box - Installation.

The CAEN CoMPASS Setup Wizard will extract and install the relevant files.

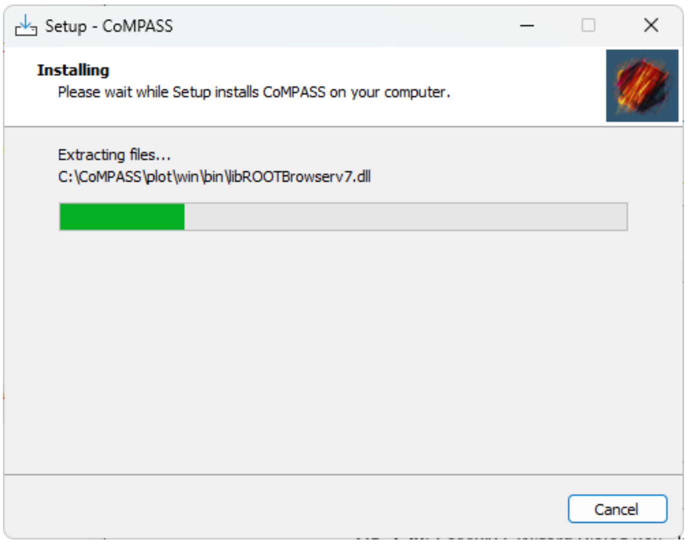


Fig. 2.20: CoMPASS Wizard Dialog Box - Installation progress.

At the end of the installation, the following Dialog Box will appear:

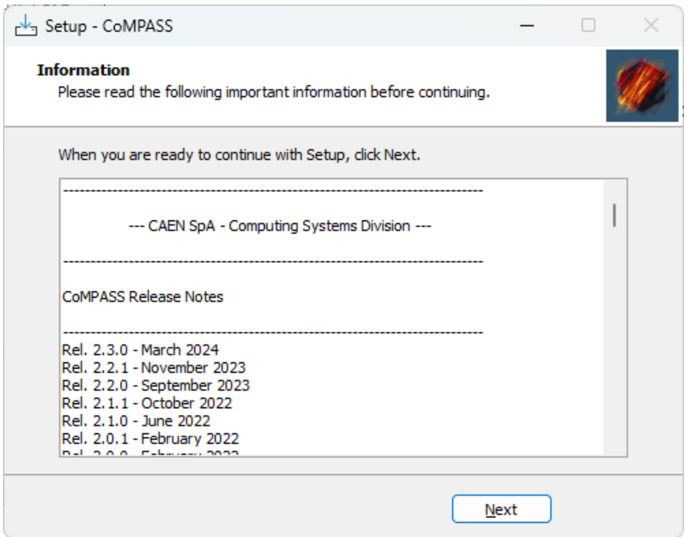


Fig. 2.21: CoMPASS Wizard Dialog Box - Software Release Version Notes.

Please read the Release Notes of the CoMPASS Software before continuing. This document is updated for every official release of CoMPASS and it contains various updated information specific to this software.

To complete the CoMPASS Installation left click on "**Finish**". The CoMPASS Program can be launched by marking the check box "**Launch CoMPASS**" before finishing the installation, or by left clicking on the installed icons in the Start Menu Folder.

Fig. 2.22: CoMPASS Wizard Dialog Box - Finish Installation.

2.5 Software Connection

Once you have installed the required driver for the communication interface and the CoMPASS software you can launch the CoMPASS software and connect it to the DT5730S and DT5725S at the same time.

At the first connection it is required to guarantee firewall access to CAENDPPServer and CoMPASSplot (first time only)

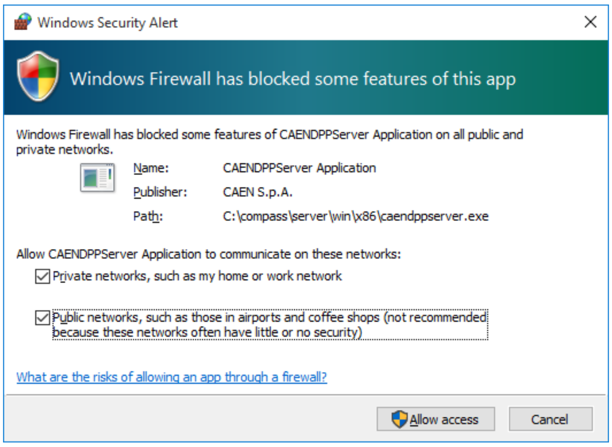


Fig. 2.23: Firewall access to CAENDPPServer.

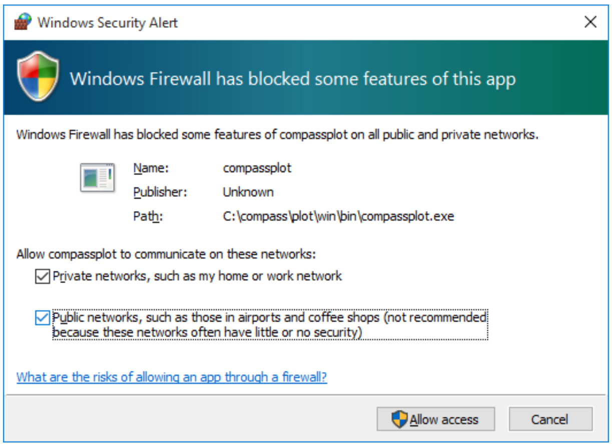


Fig. 2.24: Firewall access to CoMPASSplot.

At the CoMPASS startup both the software configuration GUI (Fig. **2.25**) and the CoMPASS Plot (Fig. **2.26**) will be opened.

Fig. 2.25: CoMPASS Start window.

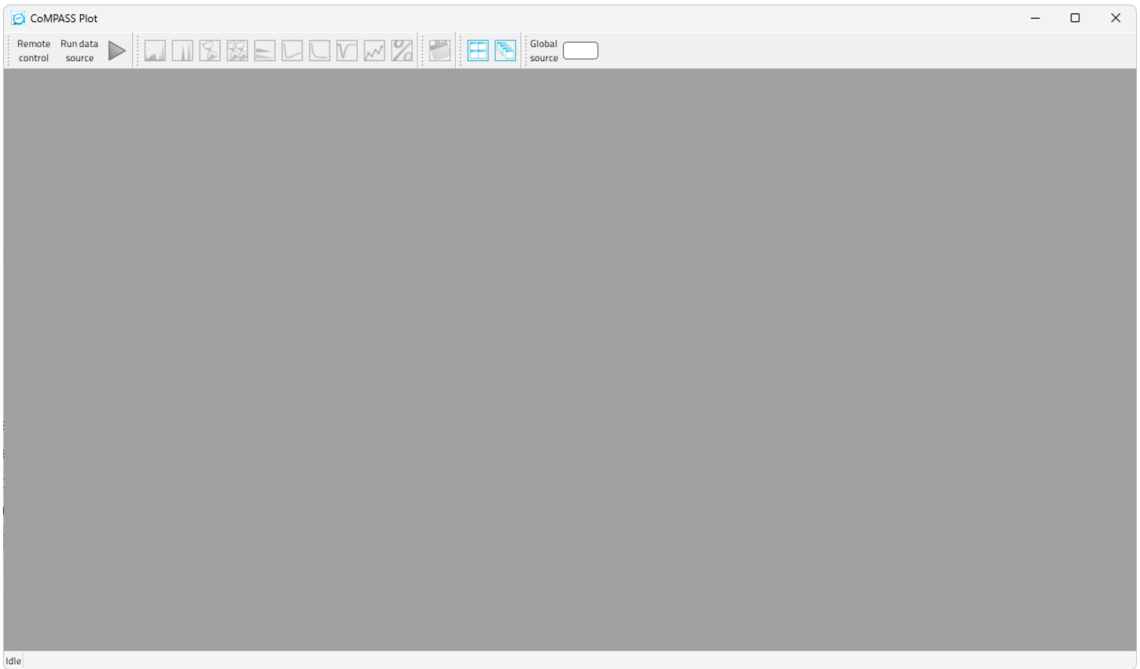


Fig. 2.26: CoMPASS Plot Start window.

From the main panel of the CoMPASS software GUI you can change the software language by selecting **TOOLS -> Select Language**. A popup appears allowing to select the desired language.

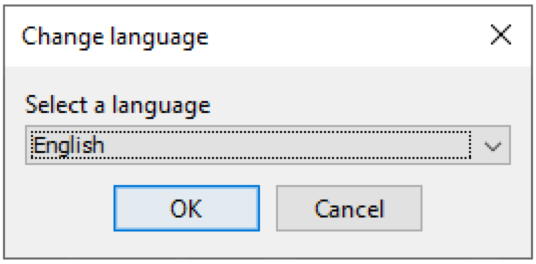


Fig. 2.27: CoMPASS language selection window.

Currently the following languare are supported:

- English
- Chinese
- Japanese
- Korean
- Italian
- French
- German
- Spanish
- Portuguese
- Finnish
- Dutch
- Swedish
- Polish
- Russian
- Ukrainian
- Turkish
- Arabic
- Jewish

More language will come in future releases.

Note: The user is encouraged to contact CAEN at the official support platform to spot possible translation mistakes or to request to extend the multi-language support to a specific language.

2.6 Create a new CoMPASS Project

From the main panel of the CoMPASS software GUI select

FILE -> New Project, or press the button 

A pop-up windows will appear asking the user to select the folder in which the project will be saved. Each project will include all the details about the involved boards, firmware and settings, as well as the acquired data.

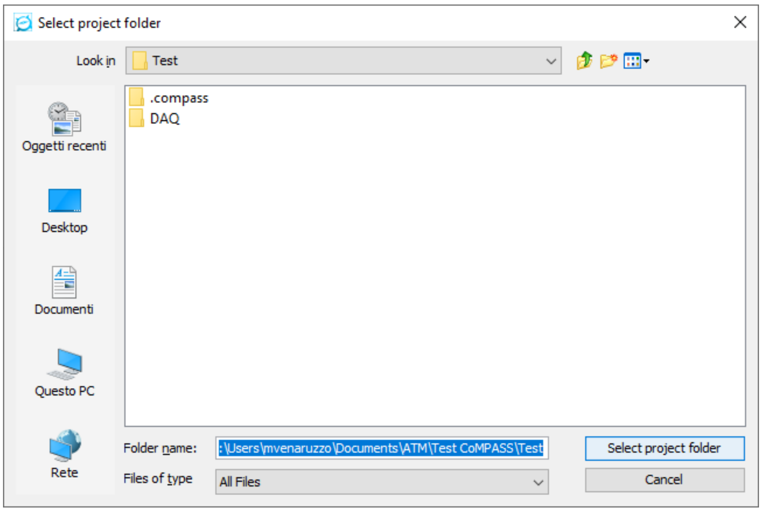


Fig. 2.28: CoMPASS New Project window.

Select an already existing folder or create a new one by pressing the button 

If the selected folder already contains a project, CoMPASS will ask the user to continue, and so erase the folder content, or not.

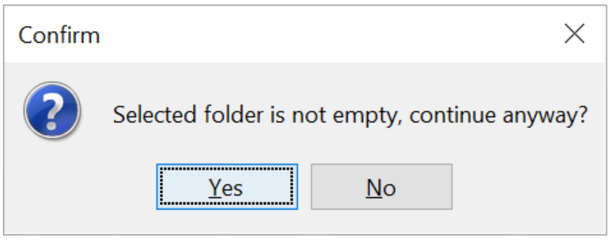


Fig. 2.29: CoMPASS not empty folder warning message.

Pressing yes, CoMPASS prepares the project environment and moves to another window in which the user can choose if add manually one by one the available boards or let CoMPASS scan for all the connected digitizer for any communication interface.

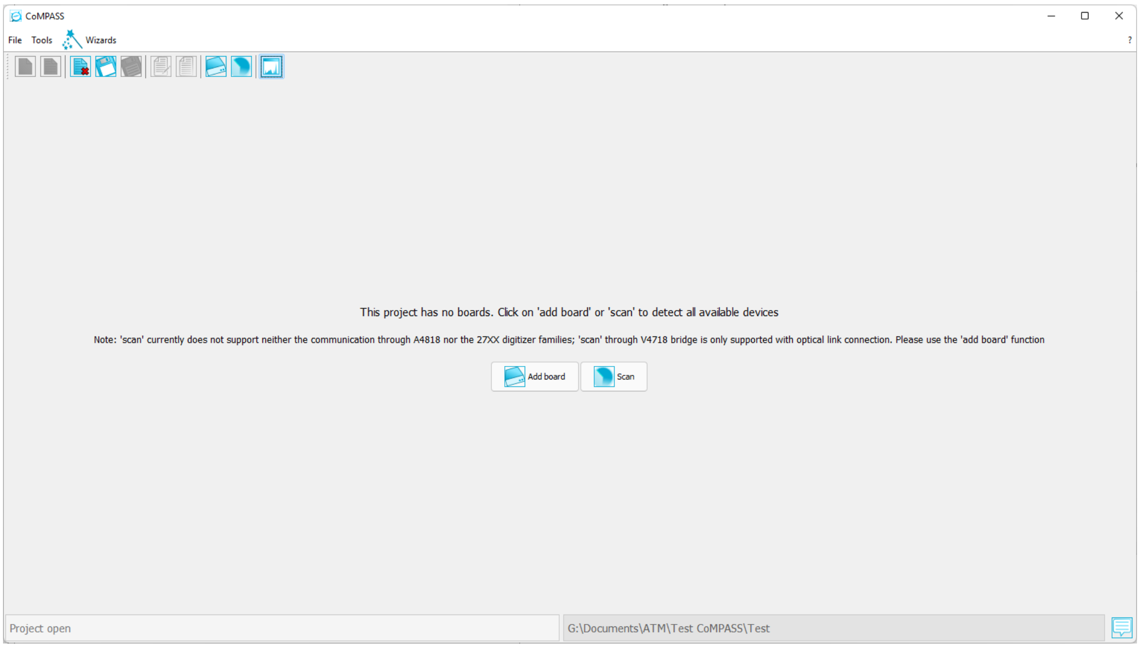
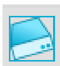
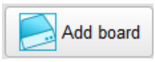


Fig. 2.30: CoMPASS Scan Tab.

Pressing the button  or the 

the user can add a single board manually providing the connection parameters. Press ok to do the connection to the board.

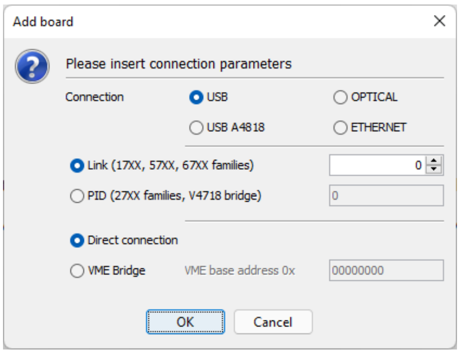
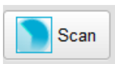


Fig. 2.31: CoMPASS Add Board window.

Pressing the button  or the 

the user let CoMPASS search for all the active connection interfaces searching for the connected boards and automatically to the connection.

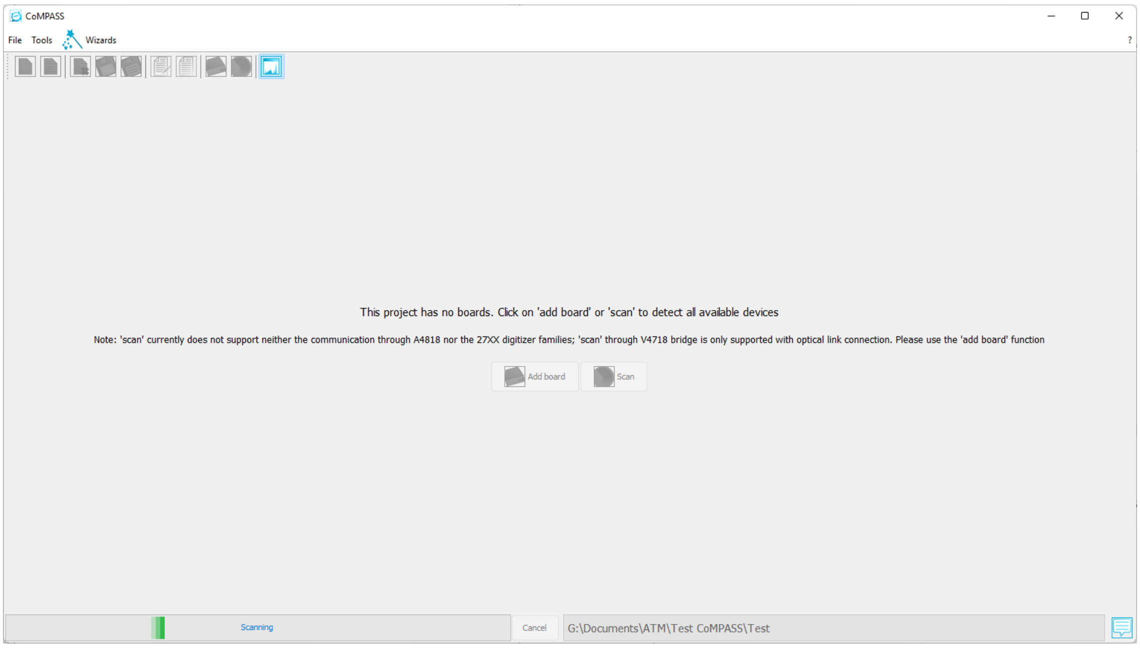


Fig. 2.32: CoMPASS Searching for connected boards.

If a not supported board model or firmware is detected, a popup appears showing some additional information

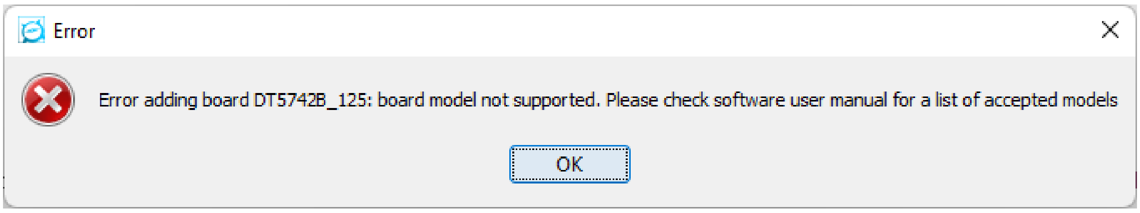


Fig. 2.33: Not supported board model popup.

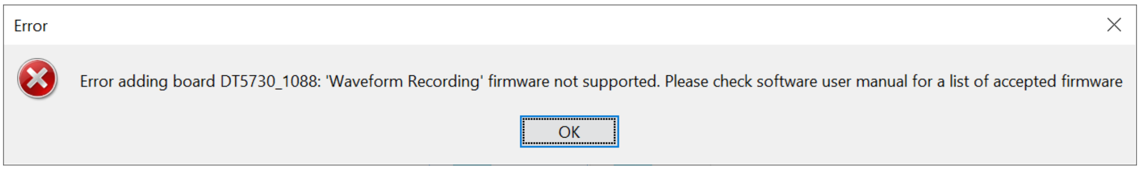


Fig. 2.34: Not supported firmware popup.

After the scan has completed CoMPASS will automatically connect to the found boards and will show the detected boards as:

- list of all the available boards and their status in the CoMPASS Plot Run Data Source Section (Fig. **2.35**)
- different sub-tabs in the Settings tab (Fig. **2.36**);
- separate entries in the CoMPASSPlot Statistics table (Fig. **2.37**).

Two additional tabs are available to set time correlations between channels of the same board or different boards (Fig. **2.38**), and to create virtual channels as sum of individual channels (Fig. **2.39**).

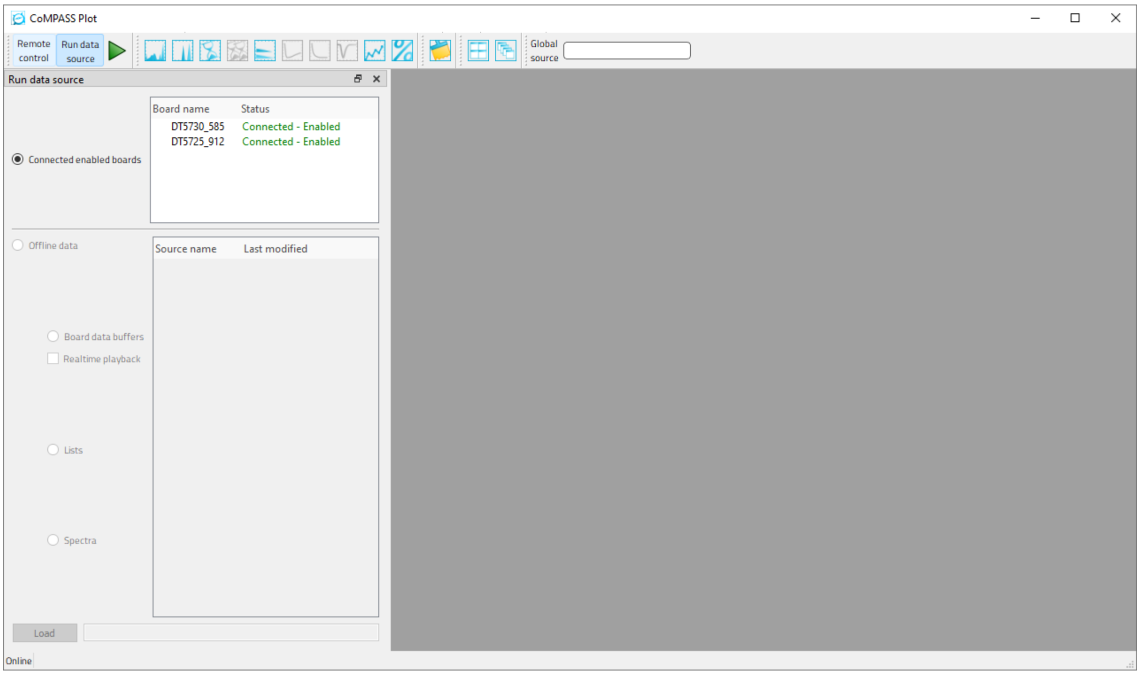


Fig. 2.35: CoMPASS Plot Window - Run data source section.

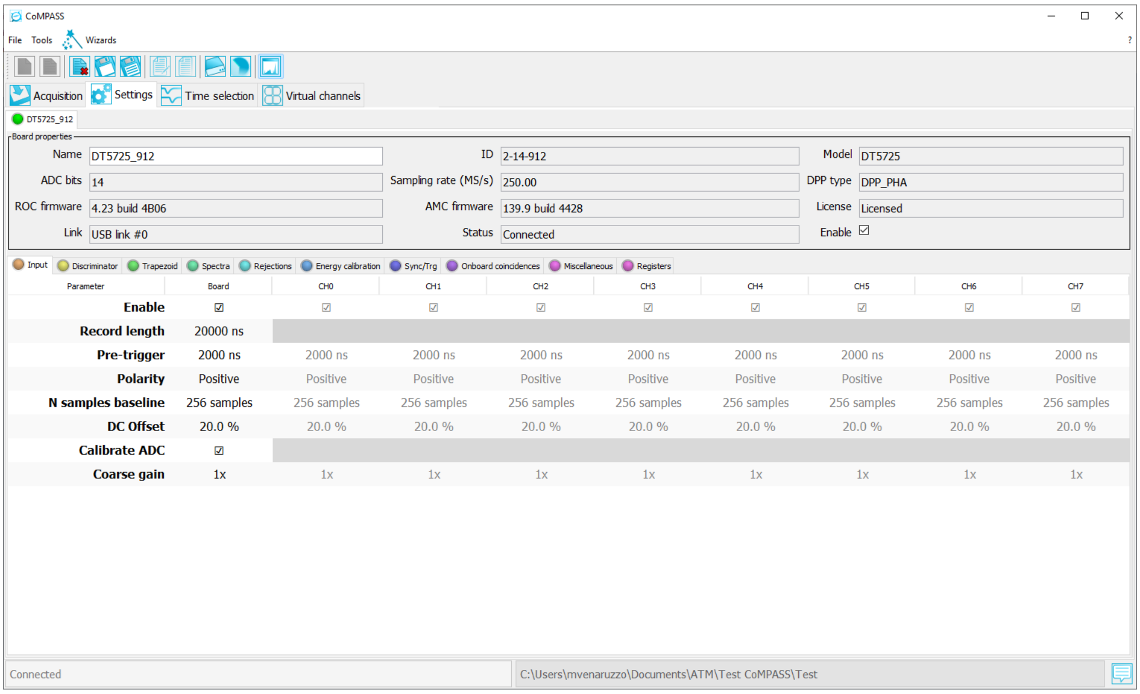


Fig. 2.36: CoMPASS Settings Tab.

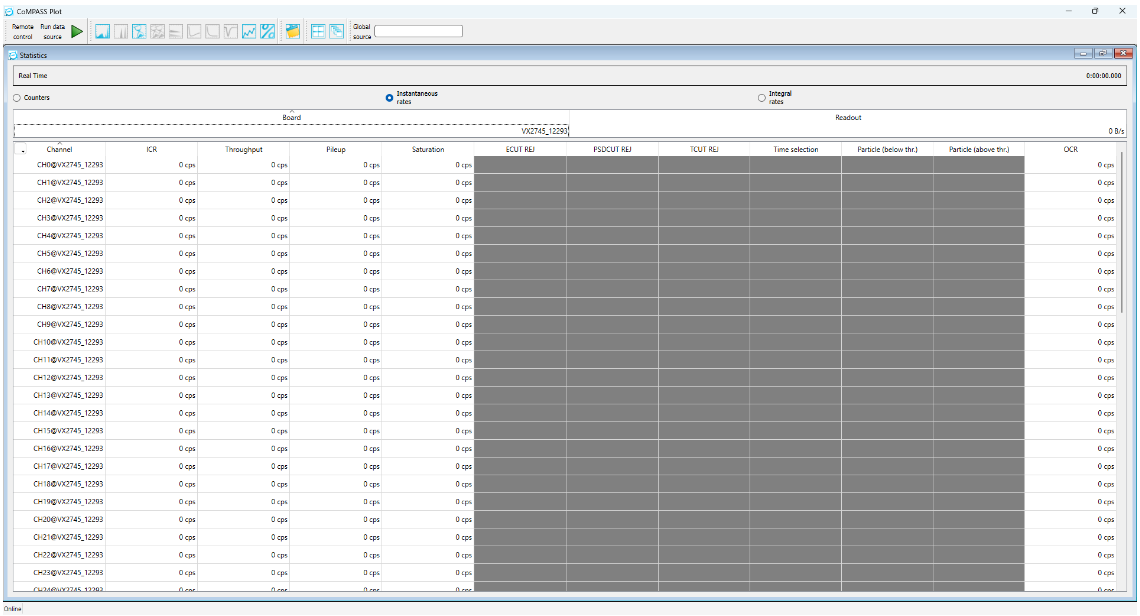


Fig. 2.37: CoMPASSPlot Statistics Table.

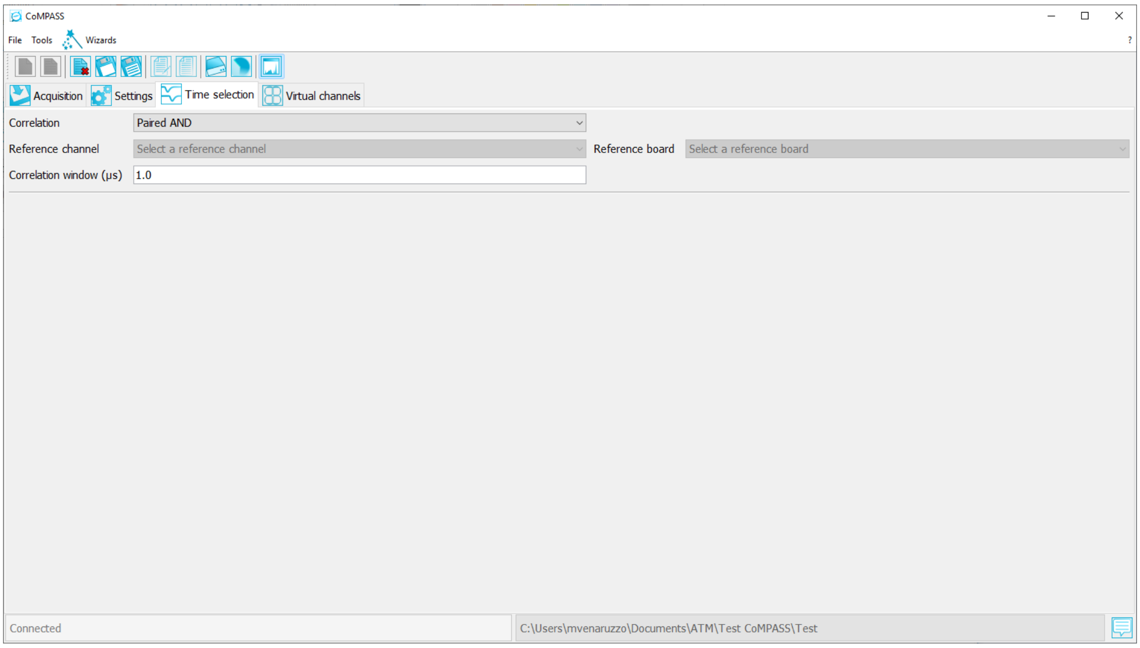


Fig. 2.38: CoMPASS Time Selection Tab.

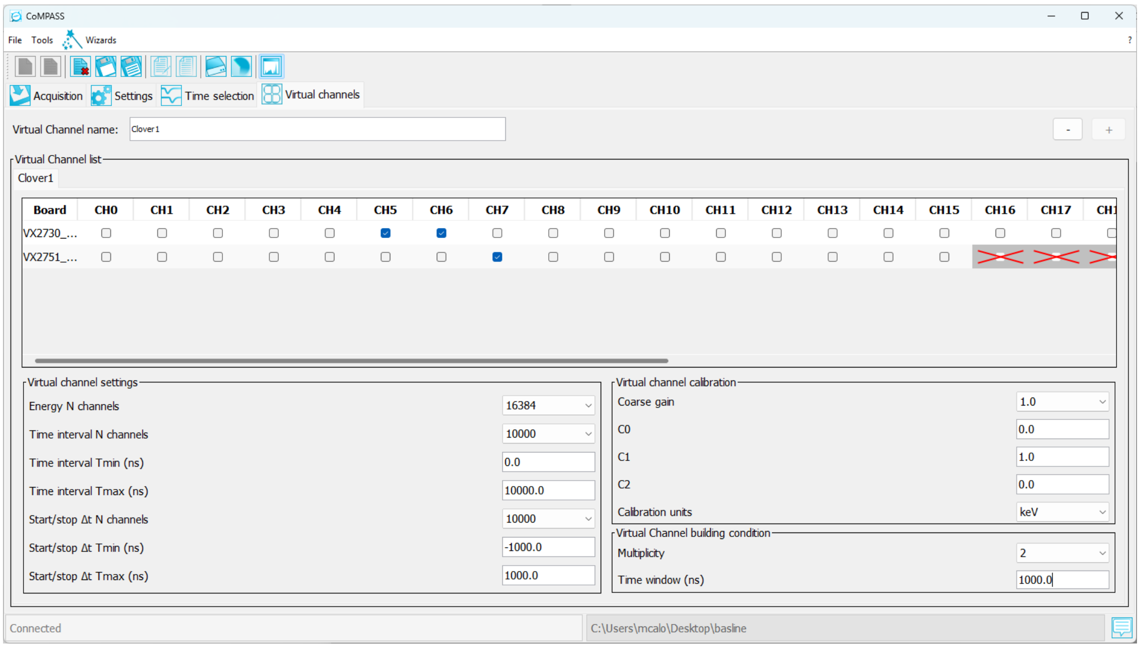


Fig. 2.39: CoMPASS Virtual Channels Tab.

In order to connect and use only a subset of the available boards the user has to click on the Enable tick into the Board Properties section to enable/disable the single digitizer. The corresponding modification will be them shown into the CoMPASS Plot Run Data Source section.

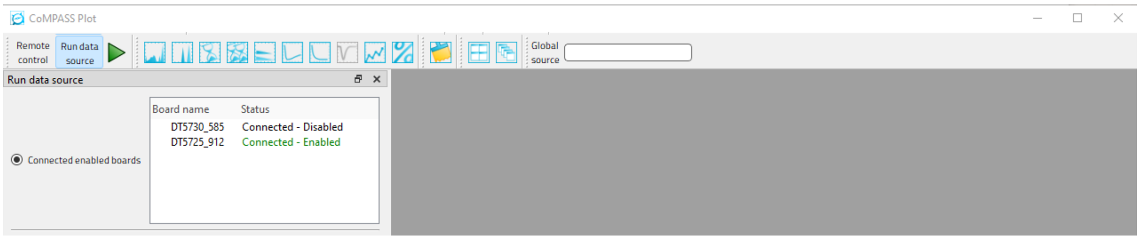


Fig. 2.40: Connected and disconnected digitizer status shown in the CoMPASS Plot Run Data Source section.

2.7 Open a CoMPASS Project

In order to open a previously saved CoMPASS project select

FILE -> Open Project, or press the button 

A pop-up windows will appear asking the user to select the folder in which the project is saved.

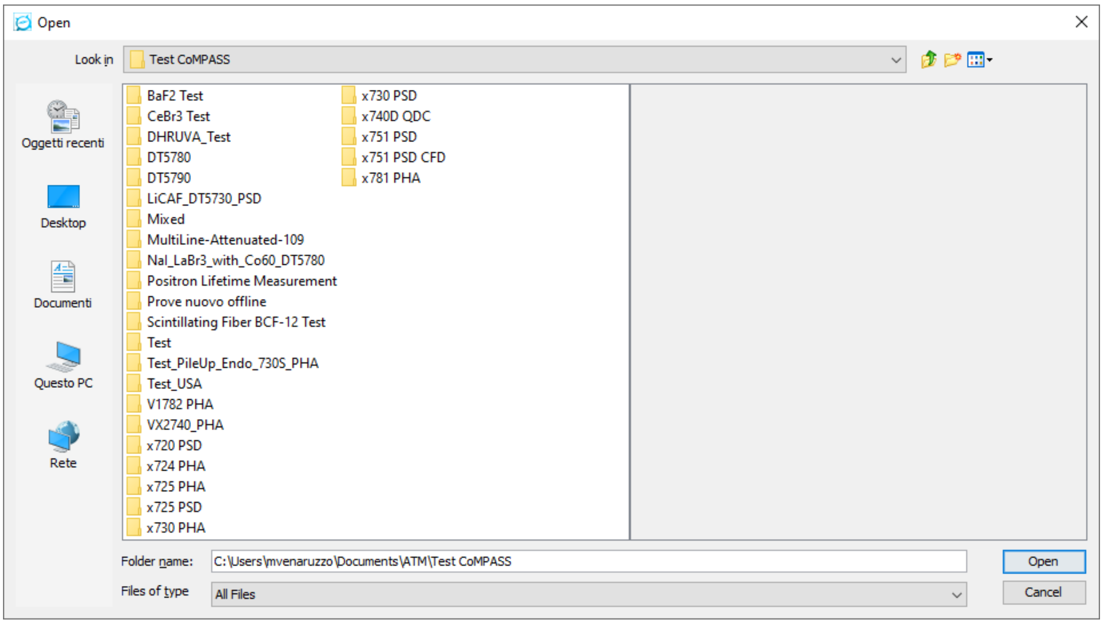


Fig. 2.41: CoMPASS Open Project selection window.

Click on the desired folder. If a project is actually saved in the folder you will see the included boards listed on the right section of the window

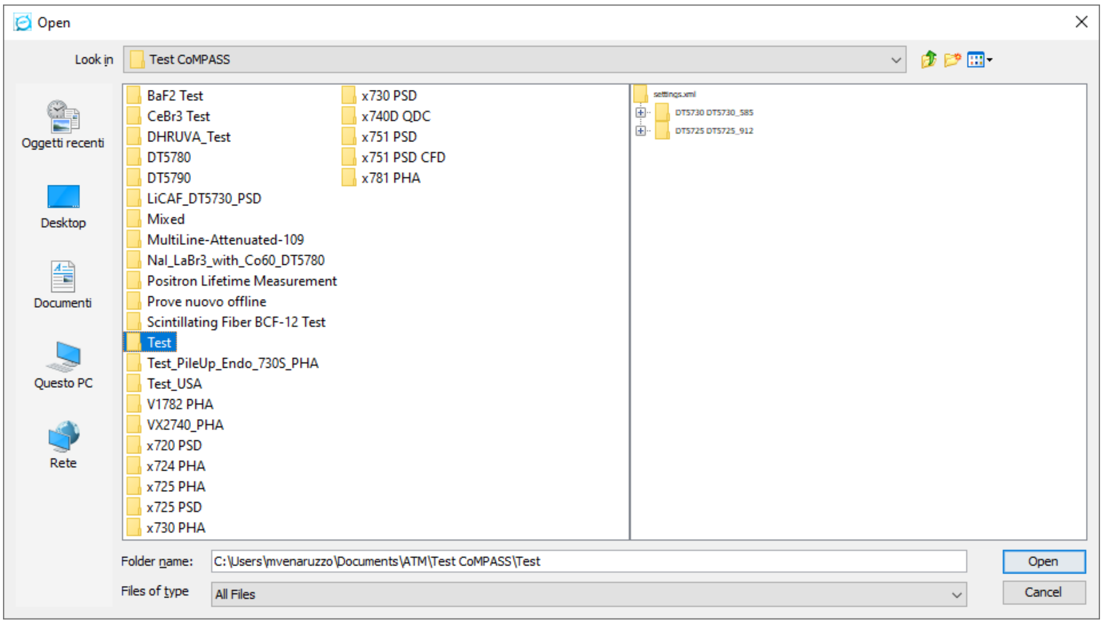


Fig. 2.42: CoMPASS Open Project selection window with the project folder selected.

Click Open to open the project and have the corresponding digitizer settings loaded on the GUI.

If the boards are up and running, they will be automatically connected to the project and enabled and correspondingly displayed in green in the Run Data Source section of the CoMPASS Plot. Otherwise they will be displayed in red if they are disconnected or in grey if they are connected but disabled.

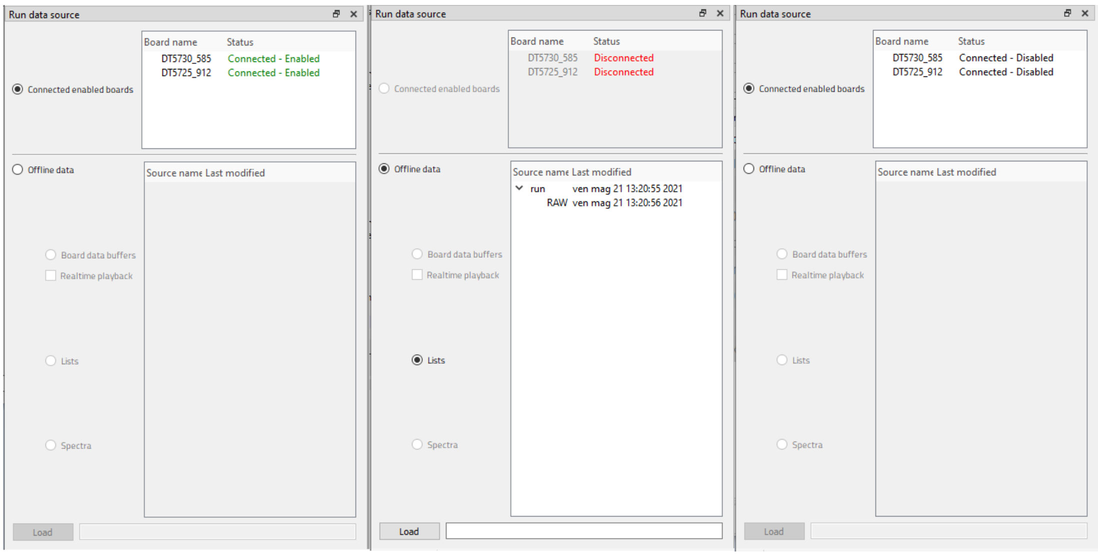


Fig. 2.43: Project board status in the Run Data Source section of the CoMPASSPlot window.

If the project folder includes also saved data, the **Offline data** section becomes selectable. Clicking on the **Offline data**, the below sections (Boards data buffer, List, Spectra) becomes available and selecting one of them the user can check the included data files.

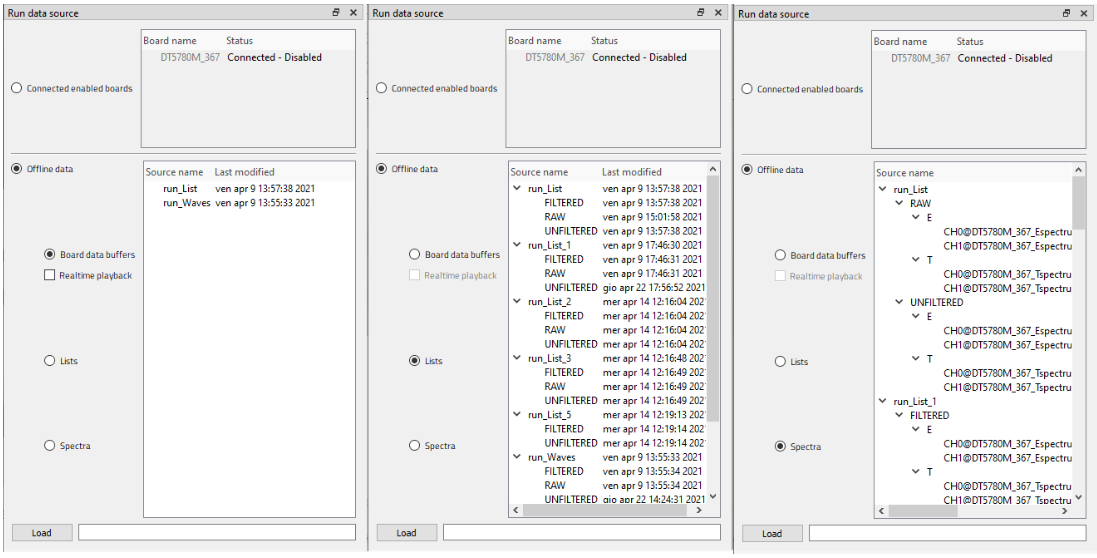


Fig. 2.44: Saved data present in the project folder as displayed in the CoMPASSPlot Window.

How to re-process the previously saved data will be shown and explain in the dedicated section **How to reprocess the CoMPASS data files**.

2.8 Save and Load configuration

In order to save the current project settings configuration select

FILE -> Save configuration file as, or press the button 

A popup will appear allowing to save the current configuration in the CoMPASS CONFIG folder which is by default included in the current project folder.

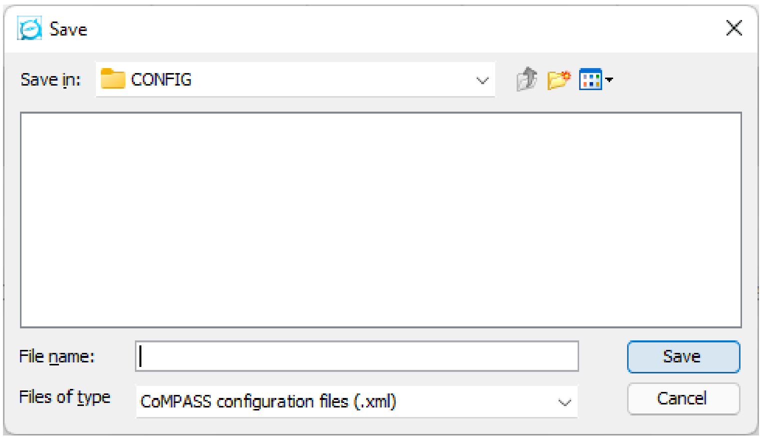


Fig. 2.45: CoMPASS configuration save window.

Type the desired configuration file name and press Save.

In order to load a project settings configuration select

FILE -> Load configuration file, or press the button 

A popup will appear allowing to load the desired configuration from the CoMPASS CONFIG folder.

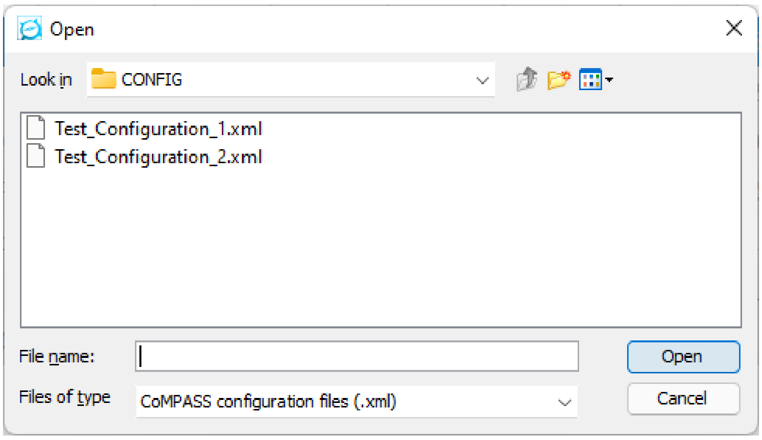


Fig. 2.46: CoMPASS configuration load window.

Select the desired configuration file and press Load. The corresponding settings will then uploaded on the digitizers.

If more then one digitizer is part of the project such Save/Load functionality saves/loads the settings of all the digitizers.

During the Load operation CoMPASS checks the correspondence between the boards whose settings have been saved and the current boards included in the project. If such correspondance is not matched, an error message occurs and no setting is uploaded.

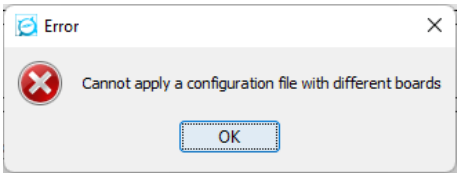
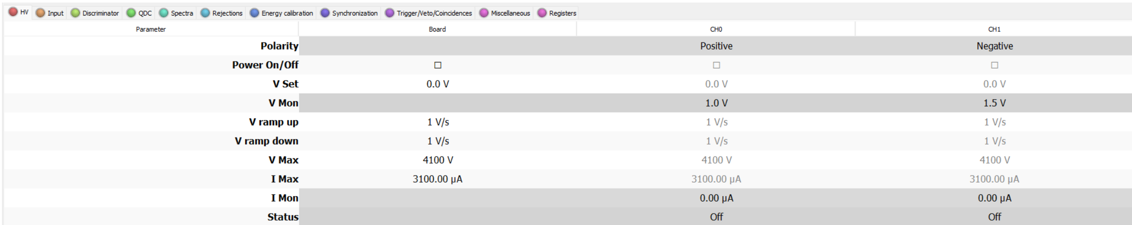


Fig. 2.47: CoMPASS configuration load error.

2.9 How to power on/off the high voltage (x780 family and DT5790 only)

Go into the HV subtab in the Settings tab and set the desired High Voltage value ”V Set” and the maximum current ”I Set” according to your detector specifications.
Set the Maximum allowed Voltage value ”V Max”, beyond which the HV channel goes into protection.
Select the proper values for Ramp UP and ”Ramp DOWN” (”V ramp up” and ”V ramp down” respectively), corresponding to the value of V/sec of voltage ramp.
Starts the HV by setting the Power On/Off field when ready and the check the HV status from the V Mon, I Mon and Status fields.



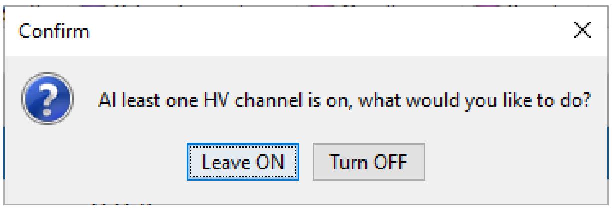
Parameter	Board	CH0	CH1
Polarity		Positive	Negative
Power On/Off	☐	☐	☐
V Set	0.0 V	0.0 V	0.0 V
V Mon		1.0 V	1.5 V
V ramp up	1 V/s	1 V/s	1 V/s
V ramp down	1 V/s	1 V/s	1 V/s
V Max	4100 V	4100 V	4100 V
I Max	3100.00 µA	3100.00 µA	3100.00 µA
I Mon		0.00 µA	0.00 µA
Status		Off	Off

Fig. 2.48: CoMPASS HV Tab.

The channels status can be also checked into the CoMPASS bottom status bar

Fig. 2.49: CoMPASS Status bar.

Note: If the HV is ON and the user disconnects the software from the digitizer, a pop up appears asking the user which action has to be done. If the user decides to leave the HV on, the HV channels will remain ON even at the next connections.



2.10 Before starting the acquisition

Especially in case of a DPP-PHA system, but also for a DPP-PSD system, it is very important to check the pre-amplifier output in an oscilloscope device before feeding the pre-amplified signal into the digitizer input. The user must check that:

- there are no grounding loops;
- the preamplifier output dynamics is not saturated.

In the unlikely event one of the above conditions is found the user must take care of the proper work around.

2.11 How to configure the channel settings

The correct configuration of the channel settings allows the system to reach very precise resolutions in nuclear spectroscopy measurement. For this reason, it is very important to set them properly. This section will guide the user throughout the settings configuration.

Note: As mentioned at the beginning of **2.2** the indication and suggestion that will be provided in this chapter refer to the DT5780 MCA and to the DT5730(S) digitizer with DPP_PSD firmware. When using other board models the corresponding CoMPASS settings may be slightly different. Such variation will be mentioned when appropriate.

The first step is to start the acquisition using the the “Acquisition Mode: Waves” in the **Acquisition** tab in order to check the effects of the setting modifications on the digital filters (Fig. **2.50**).

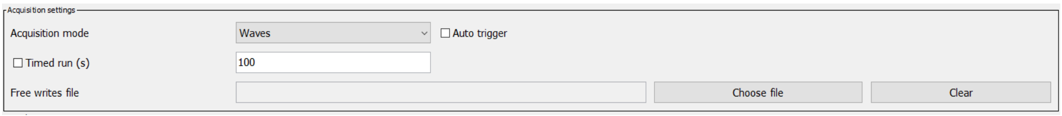


Fig. 2.50: Acquisition Settings section.

In CoMPASS Plot, open the waveform plot pressing the button 

Select into the field ”Global Source” the channel to be displayed.

In order to start the acquisition press the button 

In Acquisition Mode ”Waves”, CoMPASS will automatically check the value of the Event Aggregation parameters. This parameter will be better described later and it corresponds to the number of events that will be collected by the board before send them to the digitizer. Depending on the width of the Record Length, CoMPASS will then evaluate the highest possible value of this parameter and will modify it on behalf of the user in case the current set value exceeds the maximum one (Fig. **2.51**).

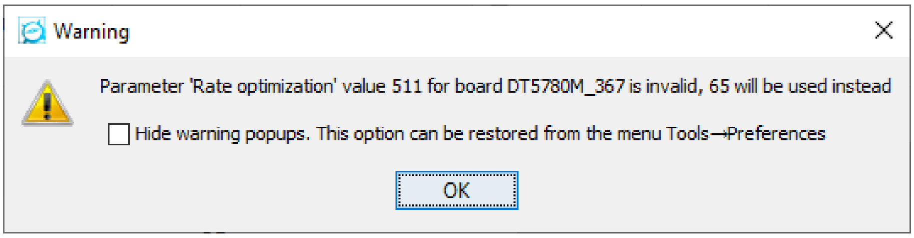
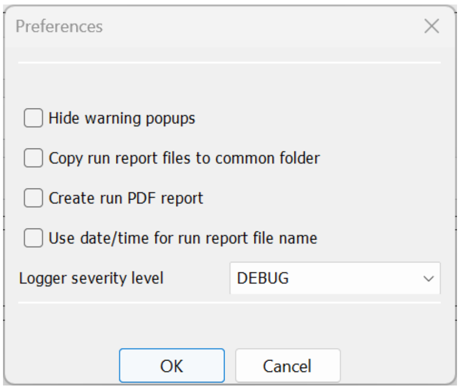


Fig. 2.51: CoMPASS Event Aggregation value warning.

Note: It is possible to hide such kind of CoMPASS warning messages selecting the corresponding option directly on the warning pop up or selecting Tools → Preferences ans selecting the corresponding options.



When warning popups are hidden, the user is in any case notified of their occurrence by the CoMPASS main GUI status bar that becomes partially yellow on the left section and that show a notification triangle on the bottom left corner.

If the board features a not licensed firmware, at the start of the acquisition a popup appears informing the user about how much time remains before the license expires (Fig. **2.52**).

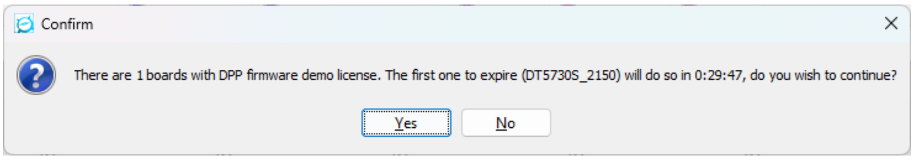


Fig. 2.52: CoMPASS time bomb remaining time warning.

When the license is expired, the user has to:

- disconnect the board by deselecting the Enable option in the Setting tab → Board Properties section
- power cycle the board
- connect again the board by selecting the Enable option in the Setting tab → Board Properties section

2.11.1 How to use the Settings Tab

The Settings Tab and the subtabs there included allows the user to set all the acquisition parameters at the board, group (x740D only) and single channel level. For each parameter, acting on the the "All" column, the modified setting will be applied to all the channel of the board, acting on the "GRn" columns, the modified setting will be applied to all the channel of the group n (x740D only), while acting on the "CHn" column the modified setting will be applied only to the selected channel.

See for example Fig. **2.53** where it has been modified the polarity of channel 0. In this case all channels will have negative polarity, while channel 0 will have positive polarity.

Input | Discriminator | QDC | Spectra | Rejections | Energy calibration | Sync/Trg | Onboard coincidences | Miscellaneous | Registers

Parameter	All	CH0	CH1	CH2	CH3	CH4	CH5	CH6	CH7
Enable	☑	☑	☑	☑	☑	☑	☑	☑	☑
Record length	992 ns								
Pre-trigger	96 ns	96 ns	96 ns	96 ns	96 ns	96 ns	96 ns	96 ns	96 ns
Polarity	Negative	Positive	Negative	Negative	Negative	Negative	Negative	Negative	Negative
N samples baseline	256 samples	256 samples	256 samples	256 samples	256 samples	256 samples	256 samples	256 samples	256 samples
Fixed baseline value	0	0	0	0	0	0	0	0	0
DC Offset	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %
Calibrate ADC	☑								

Fig. 2.53: Example of use of CoMPASS Settings Tab.

In Fig. **2.54** it is shown and example in case of the x740D board. It has been modified the threshold of group 0 and channel 0. In this case all channels will have a threshold of 100 LSB, while group 0 will havea threshold of 50 LSB except for channel 0 that will have a threshold of 10 LSB.

Input | Discriminator | QDC | Spectra | Rejections | Energy calibration | Synchronization | Miscellaneous | Registers

Parameter	Board	GR0	GR1	GR2	GR3	CH0	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9
Threshold	100 lsb	50 lsb	100 lsb	100 lsb	100 lsb	10 lsb	50 lsb	50 lsb	50 lsb	50 lsb	50 lsb	50 lsb	50 lsb	100 lsb	100 lsb
Trigger holdoff	640 ns	640 ns	640 ns	640 ns	640 ns										
Input smoothing	Disabled	Disabled	Disabled	Disabled	Disabled										

Fig. 2.54: Example of use of CoMPASS Settings Tab in case of the x740D family.

Note: The group settings on "GRn" (x740D only) and the individual settings on "CHn" are not modified by the global setting on the "All" column.

2.11.2 DPP-PSD and DPP-QDC System Parameter Optimization

It is possible to visualize a set of analog and digital traces. Start with the visualization of:

- "Input"
- "CFD"
- "Trigger"
- "Gate"

Adjust the Record Length and the Pre-Trigger for a better visualization.

Note: In case you don't see any signal select "Auto Trigger" in the Acquisition Tab to enable the software-trigger. The software will force the board to trigger the events. Then adjust the channel settings as described in the following sections. Once the parameters are correctly set, deselect the "Auto Trigger" option to disable the software-trigger.

If needed, adjust the DC Offset to avoid the saturation of the digitizer dynamic range.

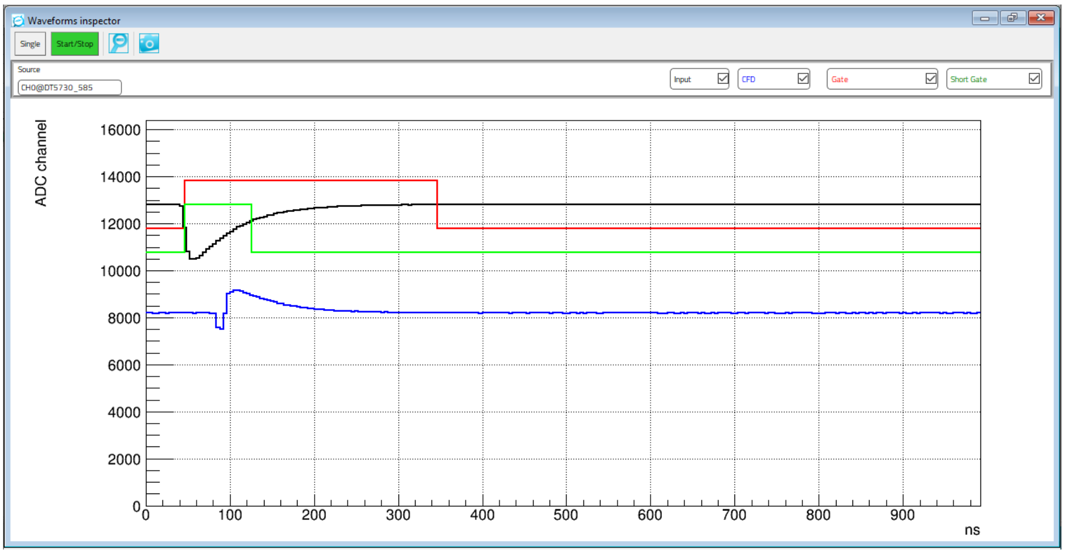


Fig. 2.55: CoMPASS Waveform Plotter window with Input, CFD, Trigger and Gate traces.

Drag and release on the X and Y axes to **zoom in** a region of the plot.

To **zoom out** press the button 

In the CoMPASS main GUI in the Settings Tab there are several sub-tabs in which all the relevant parameters are grouped by functionality.

Note: Any time you change one setting, always press *Enter* on your keyboard to apply the setting.

When two analog traces are shown in the plot (like Input and CFD in Fig. **2.55**), half of the digitizer samples are used for the first trace and the other half for the second trace. In this case the input signal might appear at half of the digitizer sampling. To visualize the trace at full frequency, disable the second trace by selecting the option **”None”**.

Note: In case of 751 family select the option **”Analog Traces Fine Resolution”** in the Input sub tab.

Input

Parameter	Board
Enable	☑
Record length	996 ns
Pre-trigger	96 ns
Polarity	Negative
N samples baseline	256 samples
Fixed baseline value	0
DC Offset	20.000 %
Calibrate ADC	☑
Input dynamic	1.0 Vpp
Analog Traces Fine Resolution	☐

Note: To show/hide one of the traces displayed on the plot you just have to check/uncheck the tick close to the corresponding trace.

2.11.2.1 How to configure the Input Signal settings (DPP-PSD and DPP-QDC)

The first settings to be configured are those related to the Input Signal.

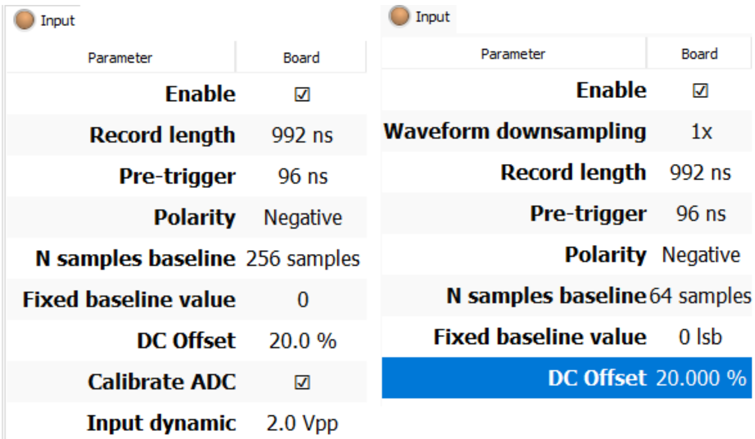


Fig. 2.56: Input subtab for a x730 and, as comparison, 274x digitizer (DPP-PSD).

1. Open the Input subtab. You can choose if setting the parameters for all the digitizer channels at the same time or setting them differently channel by channel (see Sec. **How to use the Settings Tab**).
2. Enable the used channels.
3. Adjust the ”Record Length” and ”Pre-Trigger” to cover the full pulse duration in the waveform plot. Note that the record length is not used for the charge integration (list mode).
4. Select the proper “Input Range”, which corresponds to the input dynamic range of the digitizer in order to get all the pulses, even in pile-up. Possible choices are 0.5, 2 Vpp for 725(S) and 730(S) family, 1 Vpp and 2 Vpp are the only possibilities for the 751 and 720 (DT5790) families respectively, 2 Vpp is the only possibility for the 2740 family, while the 2730, the 2745 and the 2751 families feature a Variable Gain Amplifier (VGA) that allows setting the analog gain in dB. The 2730 and 2745 can achieve gains up to x20 and x100 respectively, starting from a dynamic range of 4 Vpp; the 2751 can achieve up to x10 starting from a dynamic range of 2 Vpp.
   The correct setting of the Input Range is a compromise between the digitizer dynamics saturation and the use of too few channels of the spectrum. The input range corresponds to the Coarse Gain of the analog chain.
   In our example we choose 2.0 Vpp.
5. Select the input pulse “Polarity” choosing between “Positive” and “Negative”.
6. Adjust the input signal baseline calculation. Both the Threshold parameter, i.e. the trigger threshold, and the charge integration are referred to the baseline value. CoMPASS provides two options for setting the baseline:
   - Baseline mean calculation, where the DPP-PSD algorithm calculates online the input signal baseline through a mean filter over a number of samples set by the “N sample Baseline” parameter;
   - Absolute baseline, where a fixed baseline value is set by the ”Fixed baseline value” parameter.

   The user must choose either one of the two methods. The plotting of the input signal and the baseline can help to check the effect of the setting.

   The baseline remain frozen for the whole duration of the maximum value between the gate and the trigger hold-off parameters. To freeze it for the whole signal width you must adjust the gate and trigger hold-off parameters. When choosing the fixed value for the baseline, the baseline remains frozen for the whole acquisition window.

   We choose the first baseline calculation method, i.e. the automatic baseline calculation.

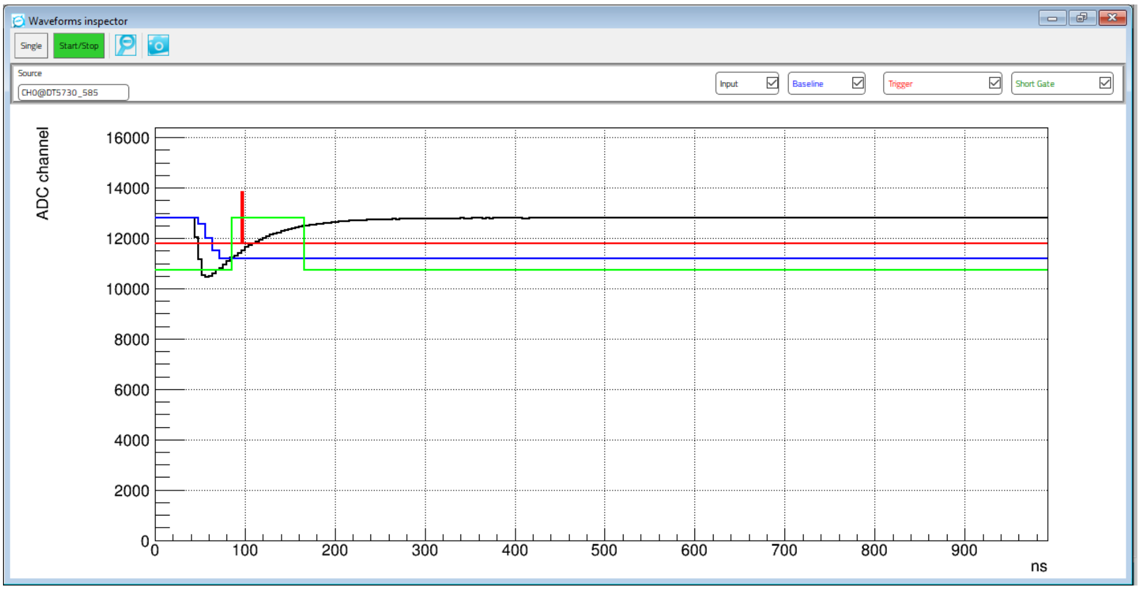


Fig. 2.57: Waveform plot showing a not proper baseline calculation.

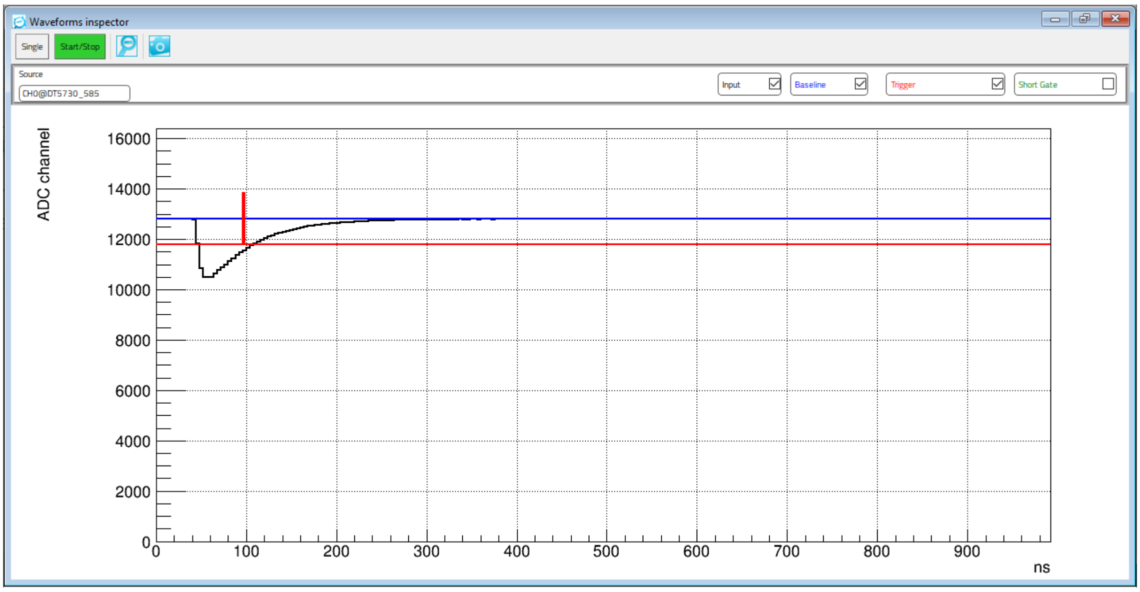
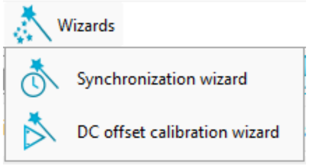


Fig. 2.58: Waveform plot showing a proper baseline calculation.

Note: For 751 series, the baseline freeze lasts for a longer time than the greater value between Long Gate and Trigger Hold-off.

7. Adjust the "DC Offset", i.e. move the baseline level of the input signal upward or downward in the dynamic scale to cover the full width of the pulse itself, thus avoiding saturation. It is usually recommended to move the baseline upward for negative pulse, downward for positive signals. Mid-scale are fine for bipolar signals, or for small pulses. In case of saturation (both in the upper or lower limit) the algorithm stops any calculation. In our example we set DC Offset = 70%.

8. It is also possible to calibrate the DC Offset following the Wizard steps (refer to **[20]**).



Note: Make sure that no input is connected to the channels.

Note: The DC Offset calibration parameters are saved into the project, so every time the project is opened the calibration is reloaded. For a new project it is required to perform the calibration for the first time.

9. Enable the "Calib ADC" (x725, x730 and x751 only) to make CoMPASS calibrating the ADCs of the digitizer. To have good performances, it is required to leave this option enabled. The ADC calibration is made at every start run.

The result of these settings is shown in the following figure.

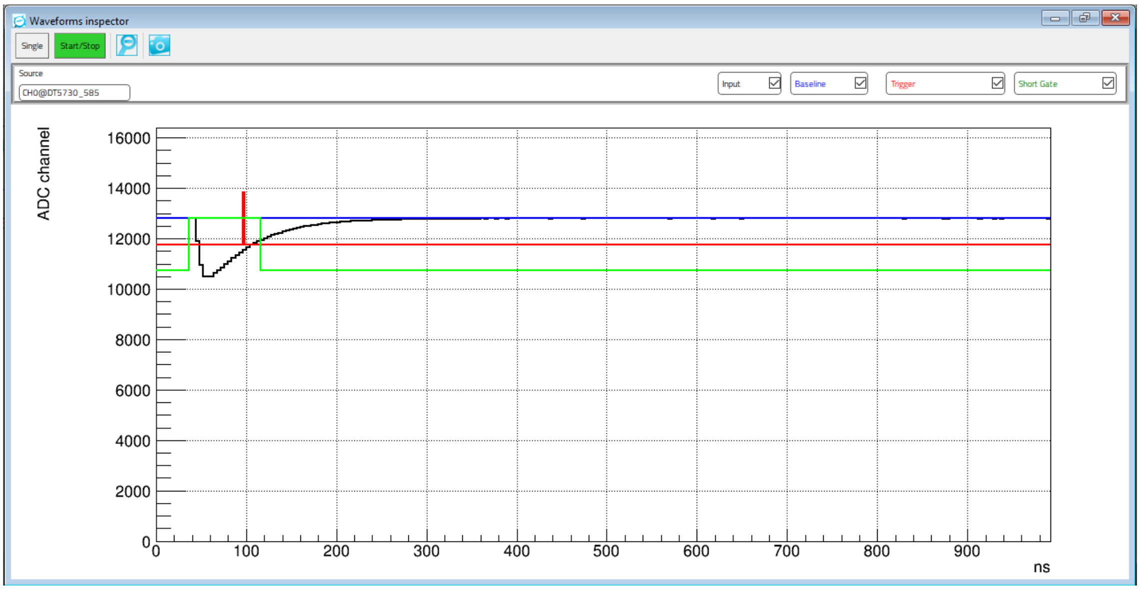


Fig. 2.59: Waveform plot window showing the effect of changing the Input settings.

It is now possible to set the trigger threshold, which in our case is defined as the relative absolute value of the trigger threshold with respect to the baseline (see next Section).

Note: When adjusting the DC Offset of a digitizer the user should keep in mind that the digitized samples are represented in a 0-(2^{Nbit}) LSB (least significant bit) scale (when Nbit is the number of bit of the digitizer ADC) but the digitizer input dynamic range scale is **not calibrated** and cannot be used as a reference for *absolute measurements* like a standard oscilloscope but just for *relative* ones (e.g. counting, timing, energy discrimination).
The 0-Volt level of the input signal does not correspond to the 0 in the ADC scale. The conversion from LSB to Volt (1 LSB = (Input dynamic range in Vpp)/2^{Nbit}) could be useful to check the relative difference between consecutive samples, but there might be small discrepancies between the "real" signal amplitude and what is observed in the waveform plot. In addition, there are also small differences in the DC offset among each channel: in absence of input signals and for a fixed DAC value programmed, the same value on each channel, few mV discrepancy are expected because of various effects, such as tolerances in offset and gain of the DACs regulating the DC Offset on the input stage of the ADCs, as there's not internal calibration (HW calibration) for that. A compensation for such effects can be done in the software if required.

Note: (V17xx, N67xx, DT57xx only) In CoMPASS the digitizer DC Offset can be calibrated with the dedicated Wizard. After such calibration, setting the same DC offset value in all the digitizer channel allows to have the baseline level in all of them.

Note: V27xx digitizer input dynamic range scale is **calibrated** and so can be used as a reference for *absolute measurements* like a standard oscilloscope.

2.11.2.2 How to set the Trigger (DPP-PSD and DPP-QDC)

Since the trigger fires at the zero-crossing of the CFD signal (refer to **[20]** for further details) first enable the visualization of the:

- "Input"
- "CFD"

Select the tab "Discriminator" from the "Settings" window.

Discriminator

Parameter	Board
Discriminator mode	Leading edge
Threshold	100 lsb
Trigger holdoff	1024 ns
CFD delay	6 ns
CFD fraction	75%
Input Smoothing	Disabled

Discriminator

Parameter	Board
Discriminator mode	Leading edge
Threshold	150 lsb
Trigger holdoff	296 ns
CFD delay	144 ns
CFD fraction	100%
Smoothing factor	4 samples
Charge smoothing	☐
Time filter smoothing	☐

Fig. 2.60: Discriminator subtab (DPP-PSD)

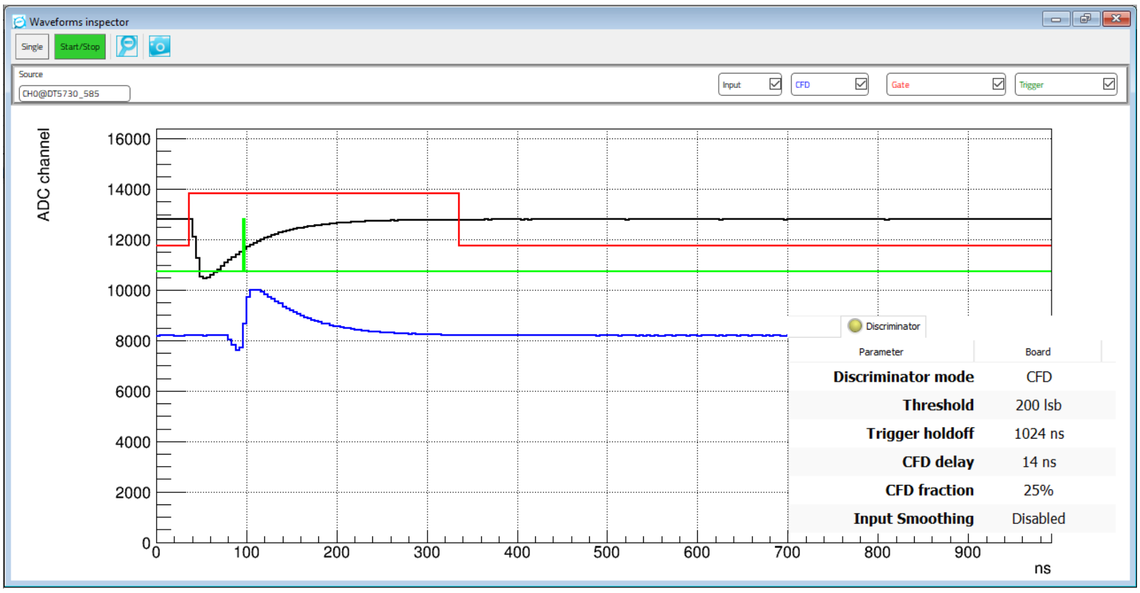


Fig. 2.61: "Discriminator" tab settings and the visualization of the CFD settings and corresponding effect on the signal inspector window.

Note: DPP-QDC firmware does not feature CFD discriminator but Leading Edge only.

1. Start by setting the **"Discriminator Mode"** to **Leading Edge** or **CFD** (in our example it is CFD).
2. Set the CFD parameters, **CFD fraction** and **CFD Delay** value (see **[20]** for further details) in order to have a steep shape in the zero crossing region. Fraction is usually set to 25% Try to avoid cases where the "CFD Delay" is too long or too short which are represented in the following figure. On the left the value is underestimated, on the right it is overestimated.

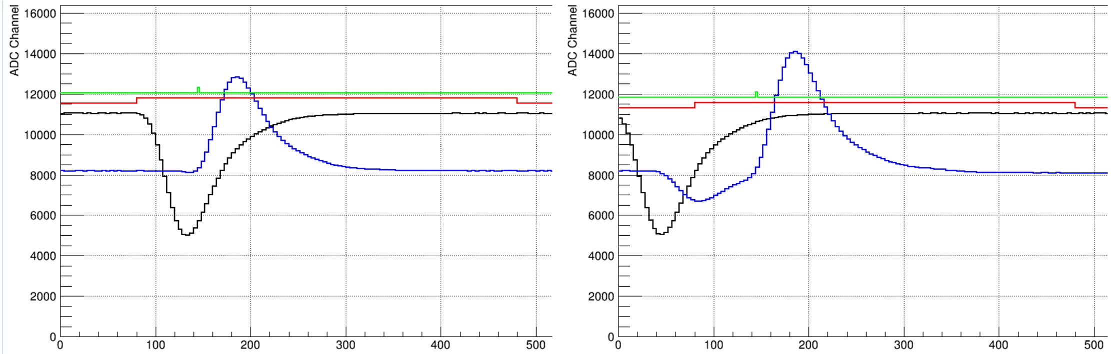


Fig. 2.62: Two examples where the "CFD delay" is not correctly set. In the left the value is underestimated, on the right it is overestimated.

The correct value for our example is 12 ns.

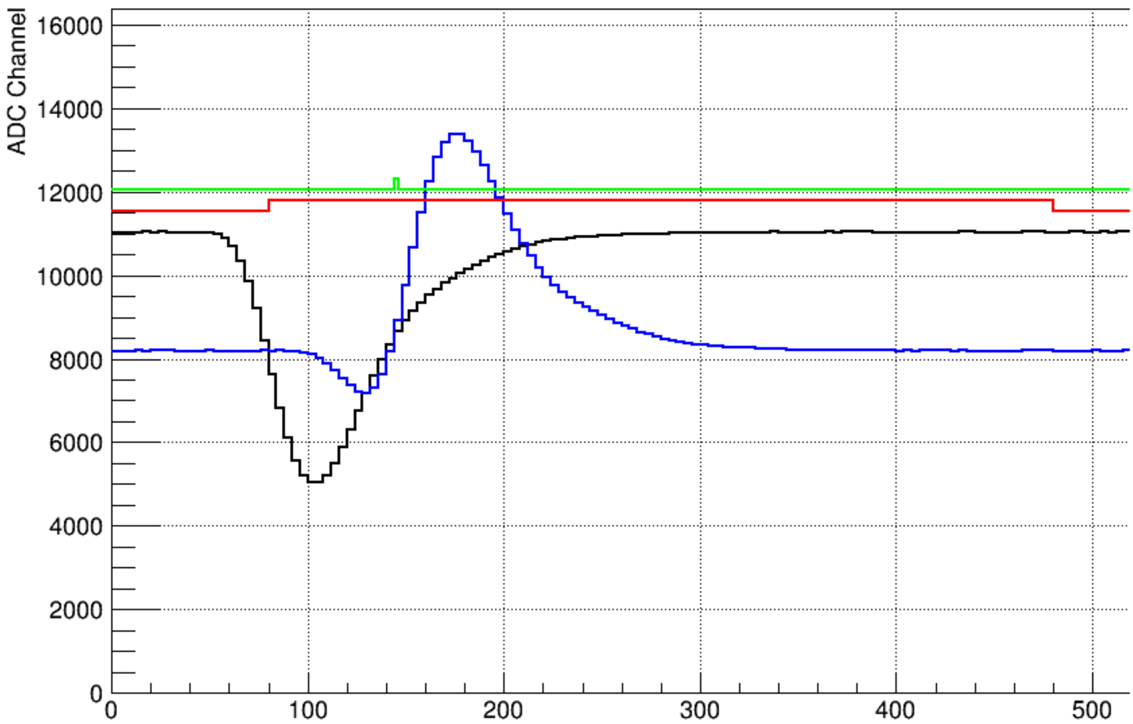


Fig. 2.63: Set the CFD Delay to have the a steep shape in the zero crossing region.

3. Set the **"Input Smoothing"** factor to **2**. When the signal presents high frequency noise or fast spikes, it is convenient to smooth it before processing the trigger. Higher values are needed in case of signal coming from noisy detectors.
4. The **"Trigger Hold-Off"** enables a time window after the trigger, where any other triggers are inhibited. Make sure to set the proper value of the Trigger Hold-Off according to your signal width,

especially in case of high frequency signals. Check the correct value by enabling the visualization of the "Trigger Hold-Off" trace. The Trigger Hold-Off goes in steps of 8 ns (all boards except 725 - 16 ns - and 724/781/780/V1782 - 80 ns). We set the Trigger Hold-Off value to 512 ns.

Note: The "trigger hold-off" detects the self-trigger generated by the channel. It does not detect trigger signals coming from the TRG-IN connector or from the Global Trigger configuration.

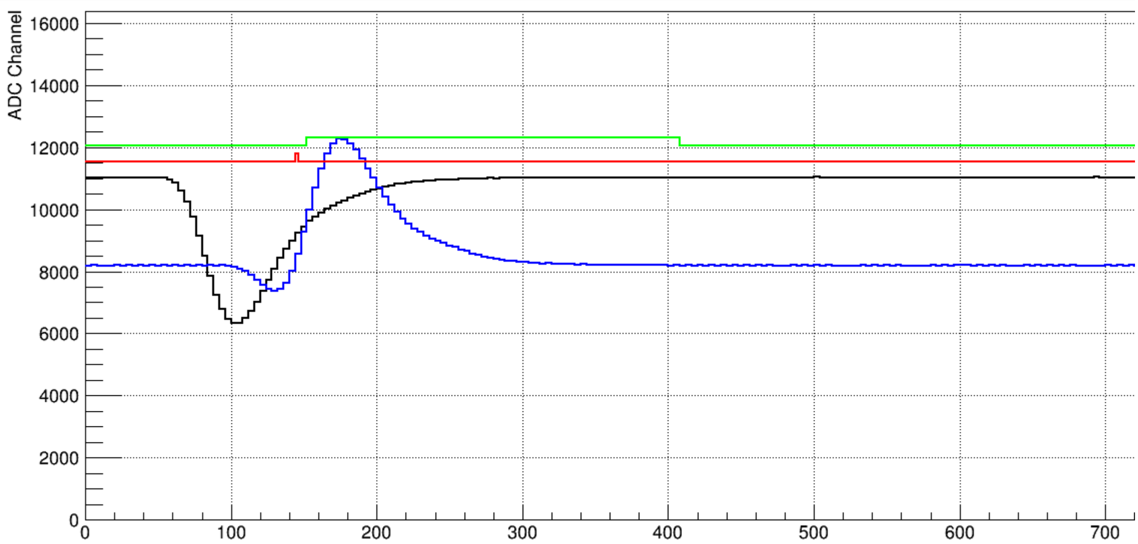
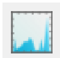


Fig. 2.64: Set the value of the Trigger Hold-Off according to your signal width, especially in case of high frequency signals

5. Set the **"Threshold"** value to avoid the noise level of the CFD signal.

   To correctly set the Threshold value, open the "Energy Histogram" window pressing the button 

   Zoom in in the lowest region of the spectrum and reduce the threshold level until you get a peak close to zero. You are now triggering below the noise level. Set then a value slightly higher to trigger on real pulses.

Note: According to the detector conditions it is possible to have particularly noisy input signals. In this case *the lower region of the spectrum is cut off*. To overcome this issue set a greater value of CFD smoothing to use a greater number of sample for the CFD signal. In this way high frequency noise will be significantly reduced.

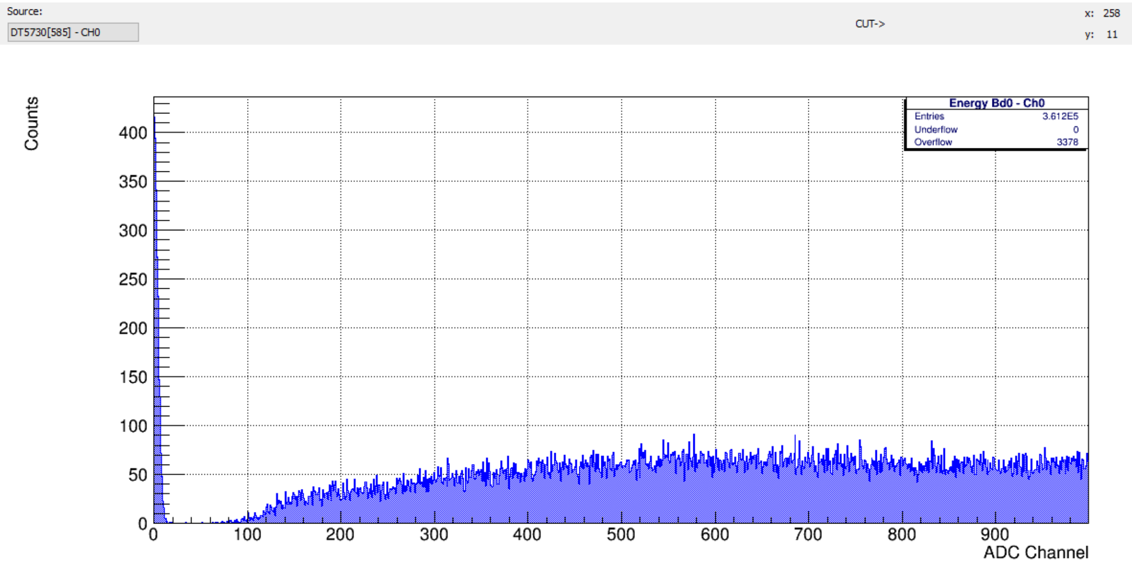


Fig. 2.65: Low energy region of the energy spectrum. The noise peak is clearly visible on the leftmost region.

In our example, we can reach up to about 10 keV.

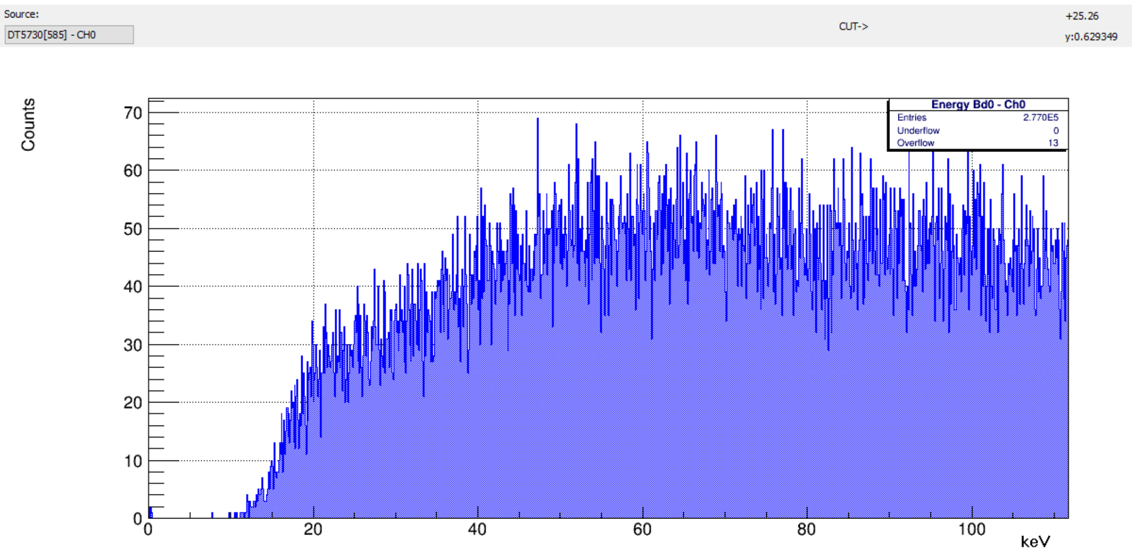


Fig. 2.66: Low energy region of the energy spectrum. Increasing the threshold value the noise peak disappears.

2.11.2.3 How to set the Energy and PSD Filter (DPP-PSD and DPP-QDC)

The precise configuration of the Energy and PSD Filter strongly affects the final resolution and the PSD capabilities of the measurement; therefore it is very important to fine tuning the "QDC" sub tab settings.

The user must take care of the proper size of the two integration gates, **Gate** and **Short Gate** and of the **Pre-Gate** so that no portion of the input signal is lost.

Select the following traces:

- "Input"
- "CFD"

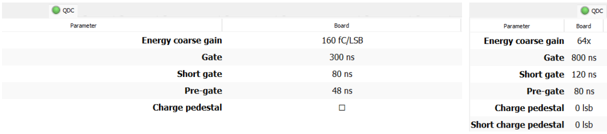


Fig. 2.67: QDC subtab (DPP-PSD)

- “Gate”
- “Short Gate”

First adjust the “Pre-gate” value in the Energy Filter Tab. This value corresponds to the number of ns the gate will start before the trigger. Indeed the input signal is delayed by the “Pre-trigger” value, so that the gate can start before the trigger.

If too short values of the Pre Trigger are set, the firmware automatically adjusts them to the minimum correct value.

Note: In case of 720 series:

$$\text{Pre}-\text{gate} \leq \text{Pre}-\text{trigger}-32\text{ns} \quad (2.1)$$

In case of 751 series

$$\text{Pre}-\text{gate} \leq \text{Pre}-\text{trigger}-8\text{ns} \quad (2.2)$$

In case of 740D series

$$\text{Pre}-\text{gate} \leq \text{Pre}-\text{trigger}-112\text{ns} \quad (2.3)$$

We set the pre-gate value to 60 ns.

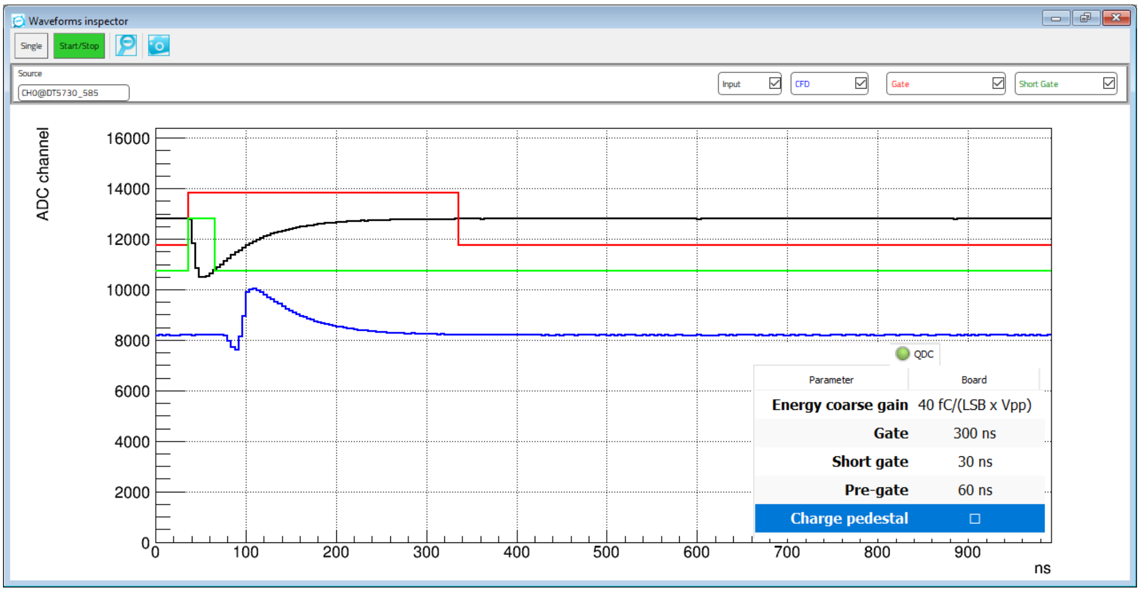
Setting the “Short Gate” and the “Gate” widths enables the firmware to integrate the input pulse and calculate the charges Q_{short} and Q_{long}. Set the Short Gate and Gate widths to the proper value according to the input signal. In this example we choose 30 ns for the Short Gate and 300 ns for the Gate.

Note: In case of CFD the pre gate must be set accordingly to the input pulse to make the gate integrate from the beginning of the signal. It might be possible that pre gate > short/long gate. In case of Leading Edge Discrimination pre gate < short gate < long gate.

Once the DPP-PSD parameters have been properly set, it is possible to plot the Energy Histogram of the gamma-ray source. For a complete Neutron-Gamma discrimination, the software allows for a 2D-plot of Energy vs PSD. The PSD parameter is calculated as reported in **[20]**.

Note: In the Waves acquisition mode it may happens that a lot of data are processed and transmitted, so that the Digitizer memory can go full and some data are lost. You can check it through the red “BUSY” LED on the Digitizer front panel. Usually this happens when you have high frequency input signals, and/or the “Record Lenght” window is big. Conversely in the List acquisition mode, the overall data throughput of the Digitizer is significantly reduced since only few data are transmitted (Trigger Time Stamp and Charge), and the busy state can disappear.

Note: When acquiring in List mode it is recommended to disable the waveforms to avoid data loss. From the Acquisition window select **”Acquisition: List”**.



2.11.3 DPP-PHA System Parameter Optimization

It is possible to visualize a set of analog and digital traces. Start with the visualization of:

- "Input"
- "Trapezoid-BL"
- "Trigger"
- "Peaking"

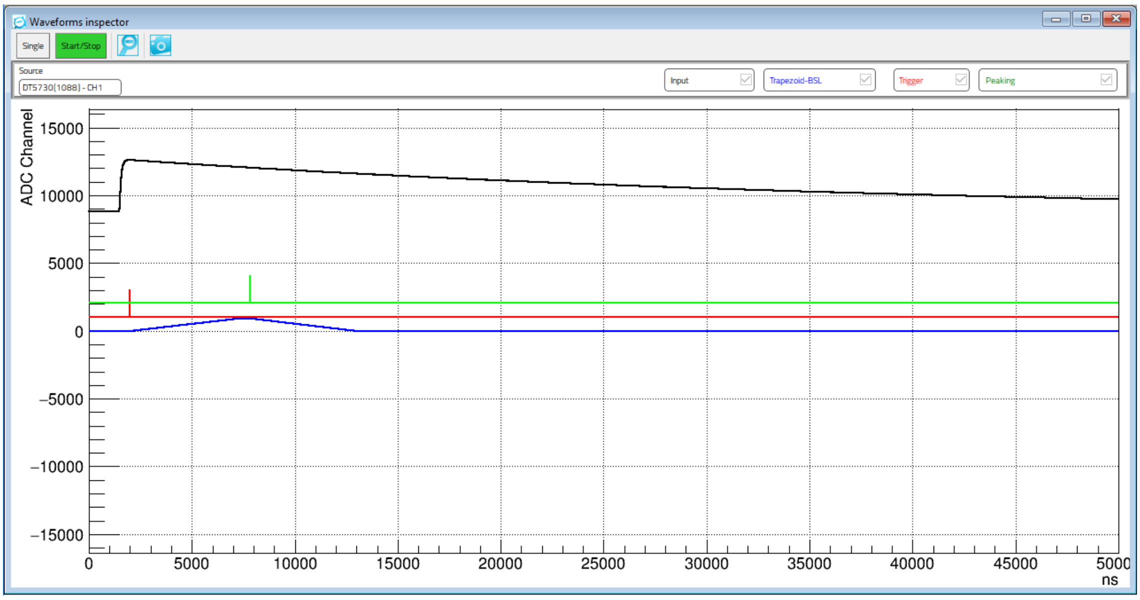


Fig. 2.68: CoMPASS Waveform Plotter window with Input, Trapezoid, Peaking and Trigger traces.

Adjust the record length for a better visualization.

Note: In case you do not see any signal, select "Auto Trigger" in the Acquisition Tab to enable the software-trigger. The software will force the board to trigger the events. Then adjust the channel settings as described in the following sections. Once the parameters are correctly set, unselect the "Auto Trigger" option to disable the software-trigger.

Drag and release on the X and Y axes to **zoom in** a region of the plot.

To **zoom out** press the button 

In the CoMPASS main GUI in the Settings Tab there are several sub-tabs where all the relevant parameters are grouped by functionality.

Note: Any time you change one setting always press *Enter* in your keyboard to apply the setting.

Note: To show/hide one of the traces displayed on the plot, you just have to check/uncheck the tick close to the corresponding trace.

2.11.3.1 How to configure the Input Signal settings (DPP-PHA)

The first settings to be configured are those related to the Input Signal.

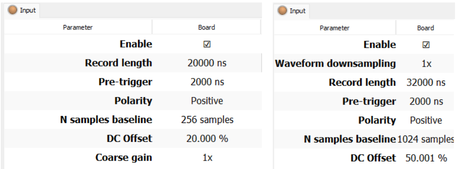


Fig. 2.69: Input subtab for a x725 and, as comparison, 274x digitizer (DPP-PHA).

1. Open the "Input" Tab. You can choose if setting the parameters for all the digitizer channels at the same time or setting them differently channel by channel (see Sec. **How to use the Settings Tab**).
2. Enable the used channels.
3. Using the measurement of the pre-amplified pulses from an oscilloscope device (refer to Sect. **Before starting the acquisition**) it is possible to check what is the pulse height range. It is important to select the proper "Input Range", which corresponds to the input dynamic range of the digitizer in order to get all the pulses, even in pile-up. Possible choices are 0.3, 1, 3, and 10 Vpp for x781; 0.5, 2 Vpp for 725 and 730 family; x1, x3, x7, x16 for the x780; x1, x2, x4, x8 for the V1782; 0-40 dB for the 2745 digitizer family; 0-29 dB for the 2730 digitizer family; not available for 724 and the 2740 digitizer families. The correct setting of the Input Range is a compromise between the digitizer dynamics saturation and the use of too few channels of the spectrum. The input range corresponds to the Coarse Gain of the analog chain.
   In our example we choose the x1 option..
4. Select the input pulse "Polarity" choosing 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. The input will always appear as positive in the waveform inspector.
5. Adjust the "DC Offset", i.e. move the baseline level of the input signal upward or downward in the dynamic scale to cover the full width of the pulse itself, thus avoiding saturation. Since all pulses will appear as positive, it is recommended to move the baseline downward in the ADC scale.

   We set DC Offset = 20% to have the input signal baseline around 1000 LSB counts. You can safely go below this value, only check that the input does not saturate around 0. In that case, the algorithm stops any calculation and increases the dead-time. It is also important to check that the signal does not saturate in the upper limit of the dynamics (16k LSB).

   The result of these settings is shown in the following figure.

Note: When adjusting the DC Offset of a digitizer the user should keep in mind that the digitized samples are represented in a 0-(2^{Nbit}) LSB (least significant bit) scale (when Nbit is the number of bit of the digitizer ADC) but the digitizer input dynamic range scale is **not calibrated** and cannot be used as a reference for *absolute measurements* like a standard oscilloscope but just for *relative* ones (e.g. counting, timing, energy discrimination).
The 0-Volt level of the input signal does not correspond to the 0 in the ADC scale. The conversion from LSB to Volt (1 LSB = (Input dynamic range in Vpp)/2^{Nbit}) could be useful to check the relative difference between consecutive samples, but there might be small discrepancies between the "real" signal amplitude and what is observed in the waveform plot. In addition, there are also small differences of in the DC offset among each channel: in absence of input signals and for a fixed DAC value programmed, the same value on each channel, few mV discrepancy are expected because of various effects, such as tolerances in offset and gain of the DACs regulating the DC Offset on the input stage of the ADCs, as there's not internal calibration (HW calibration) for that. A compensation for such effects can be done in the software if required.

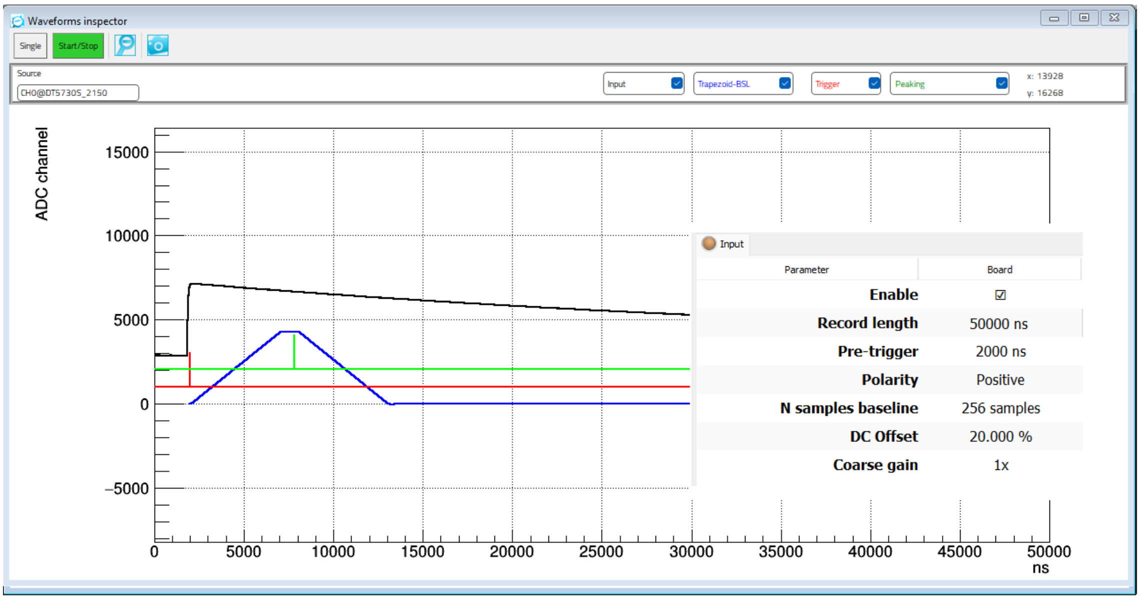


Fig. 2.70: "Input Signal" settings and corresponding effect on the waveform plot window.

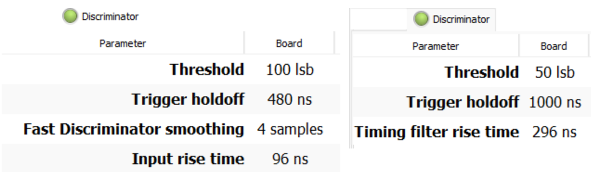
Note: In CoMPASS the digitizer DC Offset can be calibrated with the dedicated Wizard. After such calibration, setting the same DC offset value in all the digitizer channel allows to have the baseline level in all of them.

2.11.3.2 How to set the RC-CR2 Trigger (DPP-PHA)

Since the trigger fires at the zero-crossing of the RC-CR^2 signal (refer to **[20]** for further details) first enable the visualization of the:

- "Input"
- "RC-CR^2"

Select the tab "Discriminator" from the "Settings" window.



Discriminator

Parameter	Board
Threshold	100 lsb
Trigger holdoff	480 ns
Fast Discriminator smoothing	4 samples
Input rise time	96 ns

Discriminator

Parameter	Board
Threshold	50 lsb
Trigger holdoff	1000 ns
Timing filter rise time	296 ns

Fig. 2.71: Discriminator subtab (DPP-PHA)

Note: In the V1782 and in the 27xx family the RC-CR2 has been replaced by the Triangular filter. Correspondigly the **"Input Rise Time"** parameters has been replaced by the **"Fast discriminator Rise Time"**.

1. Start by setting the **"Fast Discriminator Smoothing"** factor to **16**. All the other settings have to be tuned according to the smoothing factor (i.e. once you change this value you have to repeat the whole procedure described in this section).

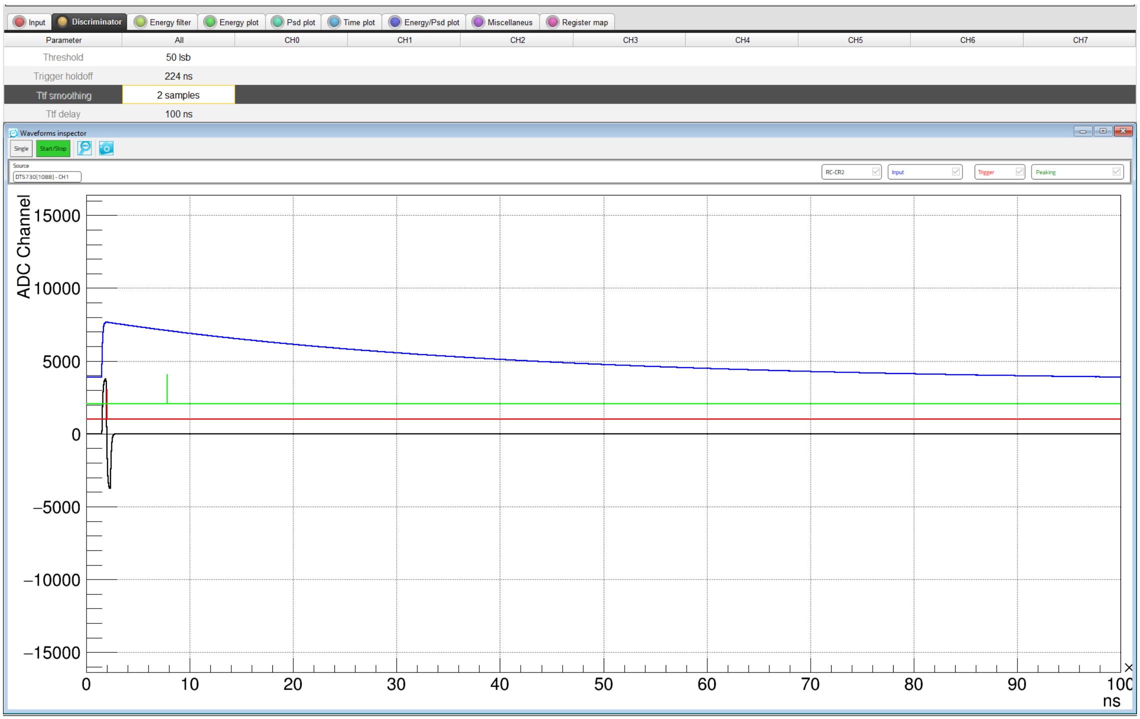


Fig. 2.72: "Discriminator" tab settings and the visualization of the RC-CR^2 settings and corresponding effect on the signal inspector window.

2. Set the **"Input Rise Time"** value (see **[20]**. Set the Input Rise time at the same value of the input signal rise time. Try to avoid cases where the "Input Rise Time" is too short and where the "Input Rise Time" is too long, which are represented in the following figure. On the left the value is underestimated, on the right it is overestimated.

   The correct value for our example is 0.1 µs.

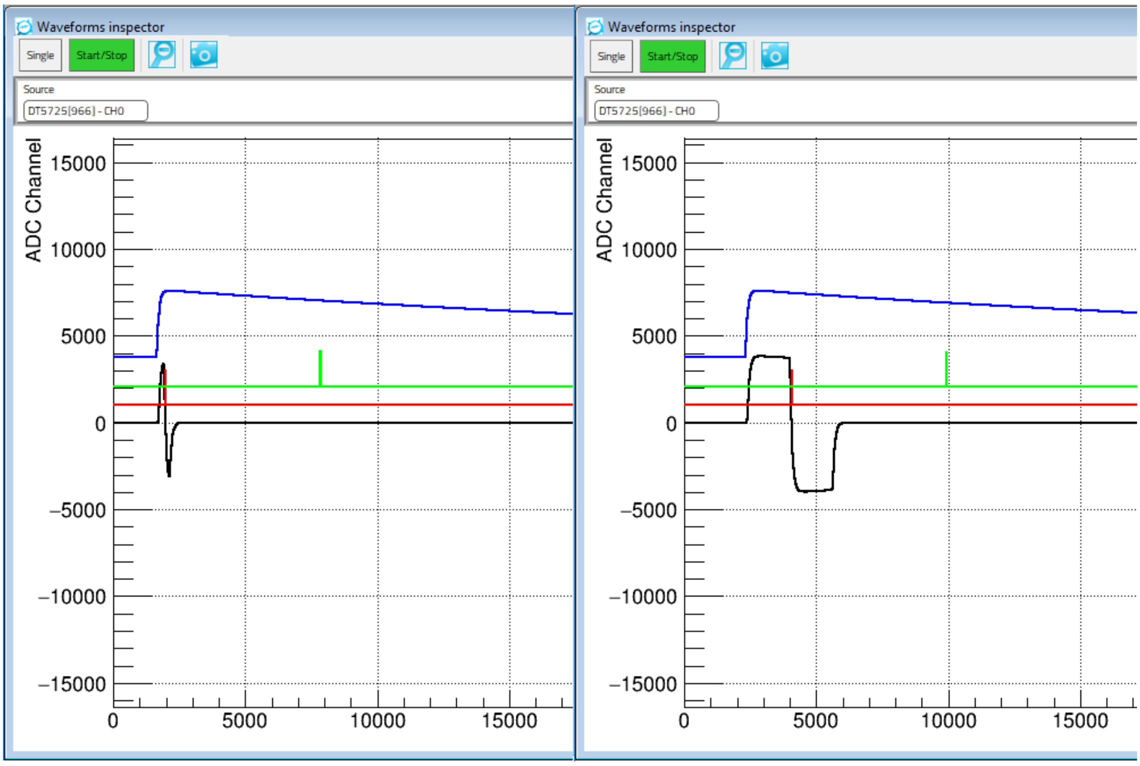


Fig. 2.73: Two examples where the "Input Rise Time" is not correctly set. In the left the value is underestimated, on the right it is overestimated.

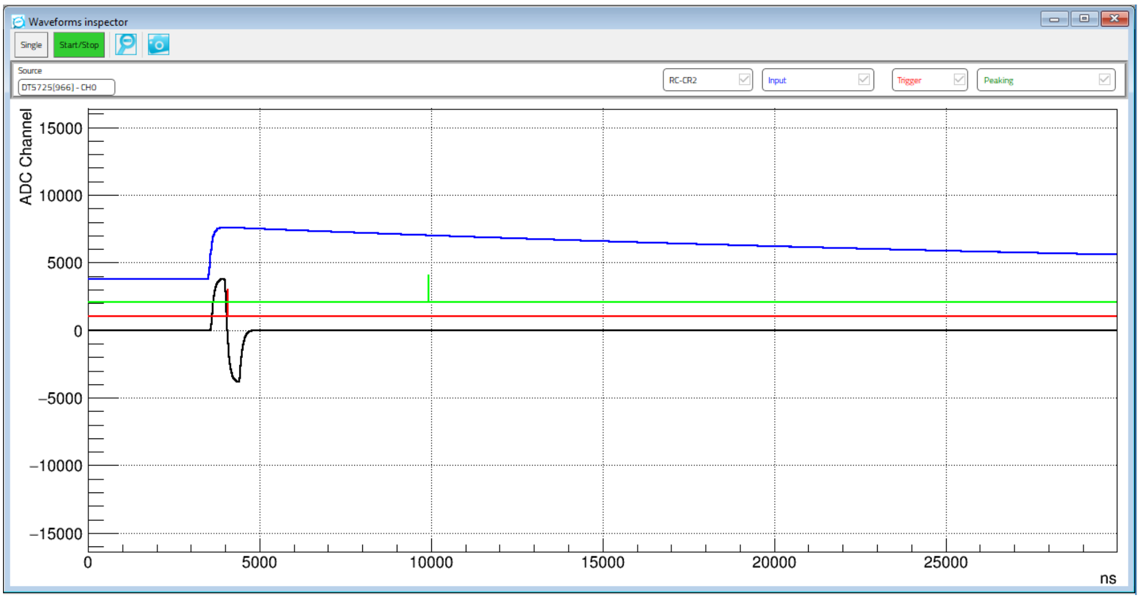


Fig. 2.74: Set the Input Rise time at the same vale on the input signal rise time.

3. In case the RC-CR^2 shows an overshoot (see Fig. **2.75**), set the **"Trigger Hold-Off"** value as long enough to eventually include the overshot inside it. The algorithm then inhibits any trigger occurring during the whole "Trigger Hold-Off" duration. Check the correct value by enabling the visualization of the "Trigger Hold-Off".

   In case there is no overshoot set the minimum value of Trigger Hold-Off to cover the RC-CR^2 signal.

Note: The ”trigger hold-off” detects the self-trigger generated by the channel. It does not detect trigger signals coming from the TRG-IN connector or from the Global Trigger configuration.

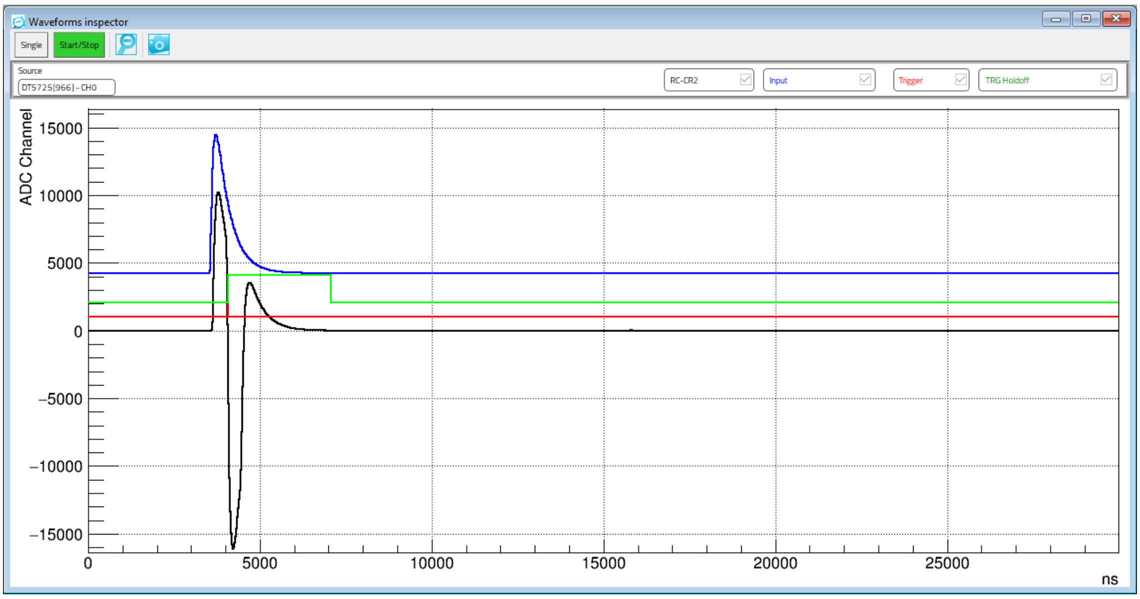


Fig. 2.75: RC-CR^2 signal with an overshoot. Set the Trigger Hold-Off to cover the overshoot and avoid re-triggering.

In our example, we set 1.8 µs.

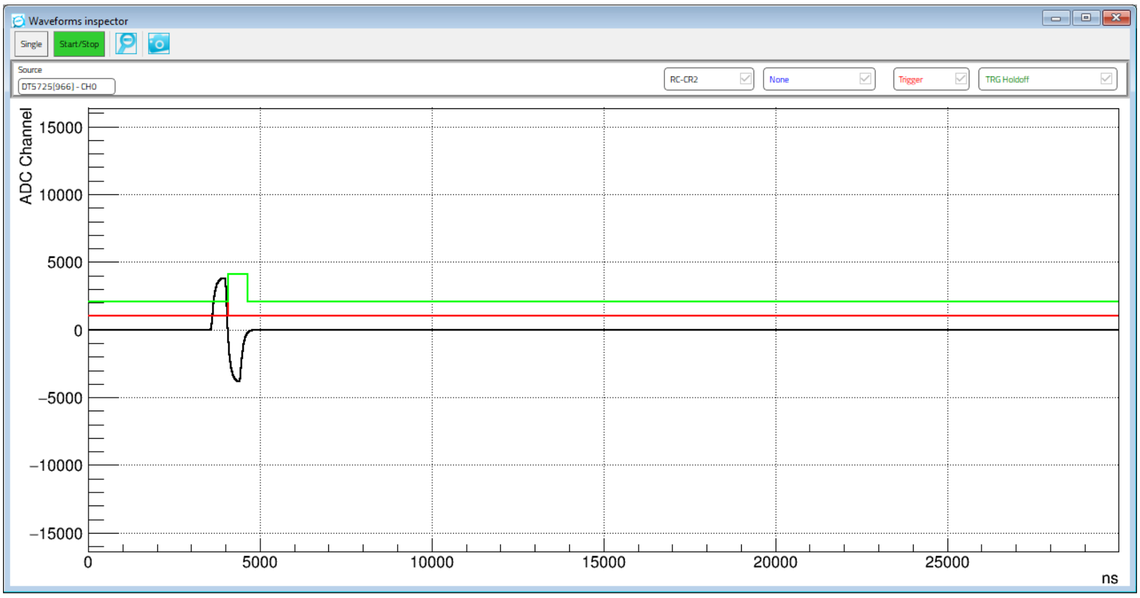


Fig. 2.76: RC-CR^2 signal with no overshoot. Set the Trigger Hold-Off to cover the RC-CR^2 signal width.

4. Set the **“Threshold”** value to avoid the noise level of the RC-CR^2 signal. You can visualize the “Threshold” Analog trace on the Signal Inspector Window.

   To correctly set the Threshold value, open the “Energy Histogram” window pressing the button

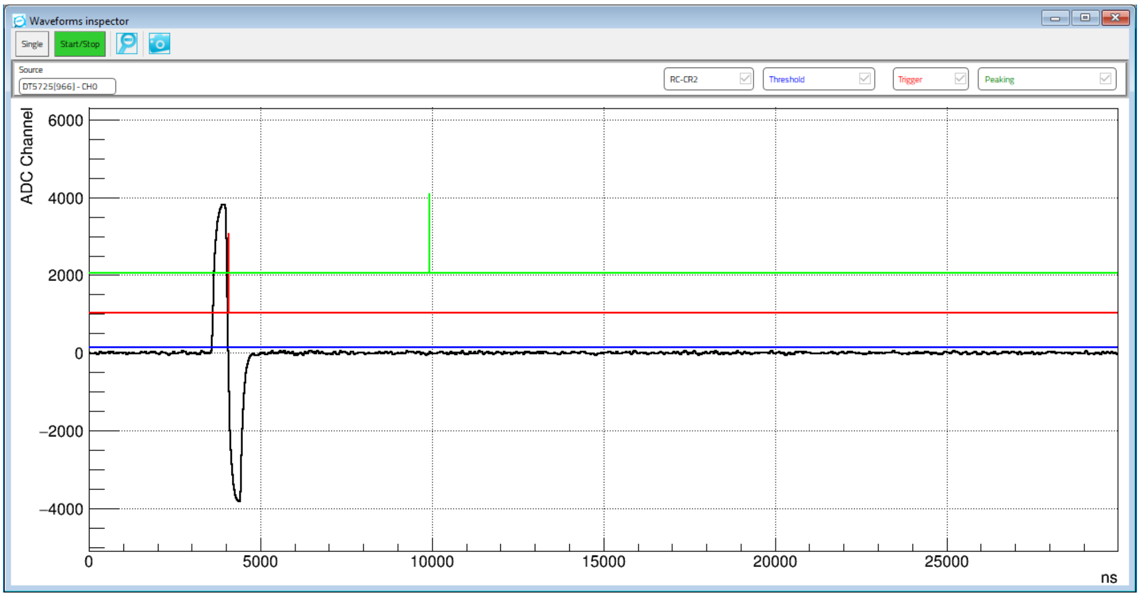
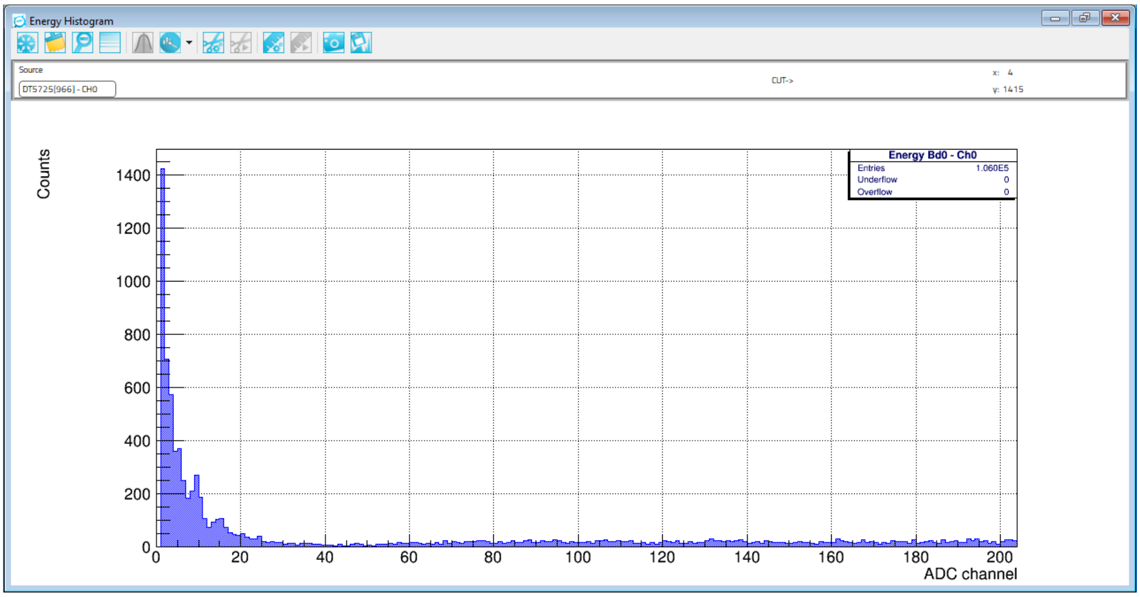


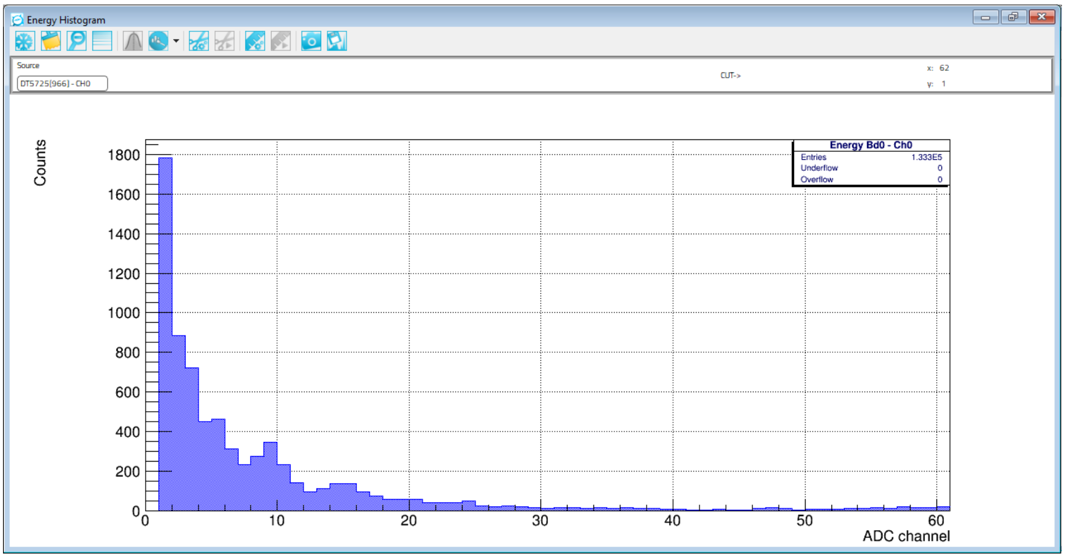
Fig. 2.77: RC-CR^2 signal and its threshold. Set the threshold value to avoid the noise level of the RC-CR2 signal.

Zoom in in the lowest region of the spectrum and reduce the threshold level until you get a peak close to zero. You are now triggering below the noise level. Set then a value slightly higher to trigger on real pulses.



Note: According to the detector / pre-amplifier conditions it is possible to have particularly noisy input signals. In this case *the lower region of the spectrum is cut off*. To overcome this issue set a greater value of RC-CR^2 smoothing to use a greater number of sample for the RC-CR^2 signal. In this way high frequency noise will be significantly reduced. Remember to adjust again the Input Rise Time and Trigger Hold-off in case you change the smoothing factor.

In our example, we can reach up to about 10 keV.

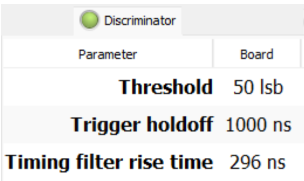


2.11.3.3 How to set the Triangular Filter (DPP-PHA, 2740 and 2745 families only)

Since the trigger fires at the zero-crossing of the RC-CR^2 signal (refer to **[20]** for further details) first enable the visualization of the:

- “Input”
- “Fast Triangle”

Select the tab “Discriminator” from the “Settings” window.



Discriminator

Parameter	Board
Threshold	50 lsb
Trigger holdoff	1000 ns
Timing filter rise time	296 ns

Fig. 2.78: Discriminator subtab for the 2740 and 2745 families (DPP-PHA)

Choose the desired value of “Timing filter rise time” from a range of 0.08 to 2.0 µs. Set the Threshold value to avoid the noise level of the fast trigger itself and arm the trigger filter. The trigger will fire on the derivative signal of the fast trapezoid.

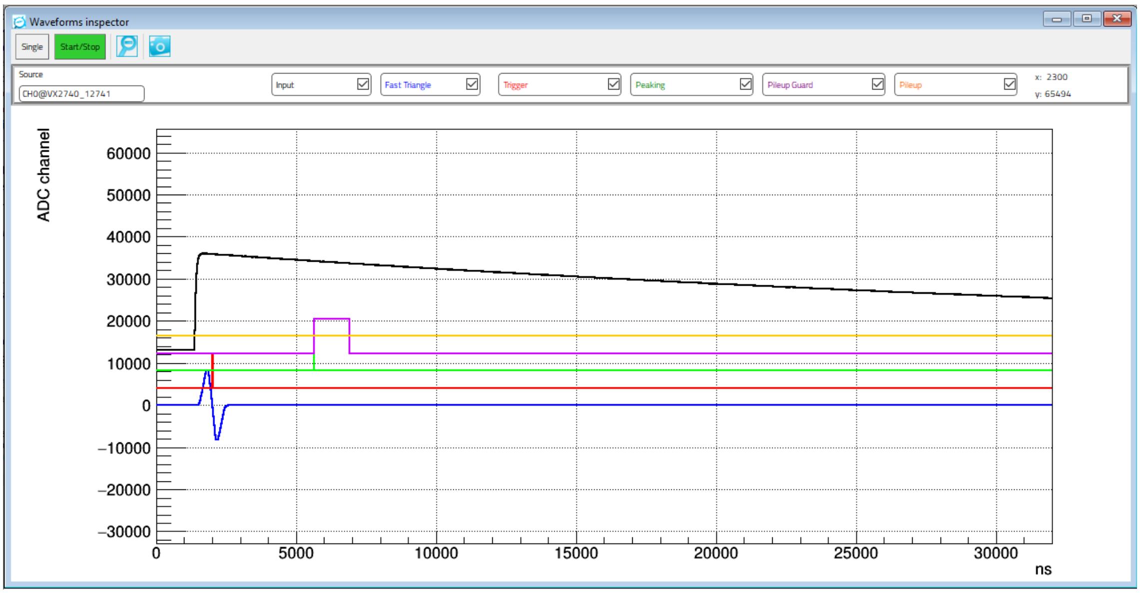


Fig. 2.79: Signal inspector window for the 2740 and 2745 families with Input signal and Triangular filter .

2.11.3.4 How to set the Trapezoid (DPP-PHA)

The precise configuration of the Trapezoid strongly affects the final resolution measurement; therefore it is very important to fine tuning the Trapezoid settings.

Trapezoid

Parameter	Board
Trap. rise time	5.000 µs
Trap. flat top	1.000 µs
Trap. pole zero	50.000 µs
Peaking time	80.0 %
N samples peak	1 sample
Peak holdoff	0.960 µs
Energy fine gain	1.000

Fig. 2.80: Trapezoid subtab (DPP-PHA)

The user must take care of:

- Checking that the trapezoid is correctly shaped;
- Evaluating the energy value (see the Peaking trace) in the flat top region of the trapezoid.

The two typical measurement setups that we are going to discuss are:

1. Low rate (up to few hundreds of Hz) and very high precision measurement;
2. High rate (up to tens of kHz), where the result is a compromise between high resolution and dead-time.

Before starting, set the value of "Trap. pole zero", which corresponds to the input decay time. If the exact value is unknown set an approximate value. The fine tuning of this parameter is described in Sec. **Pole-Zero Adjustment**.

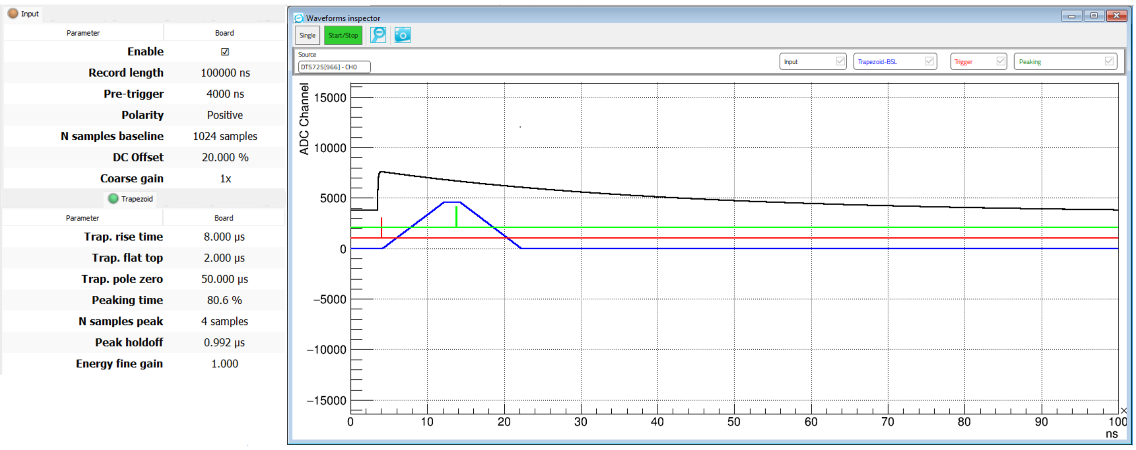
Select now the following traces:

- "Input"

- “Trapezoid-BL”
- “Peaking”
- “Trigger”

Note: The baseline of “Trapezoid - BL” trace should be at 0.

1. In the *low rate* case it is recommended to set a high value of **“Trap. rise time”** (Trapezoid rise time), as for example **6** µ**s**. Considering it in the analogy of the analog chain (refer to **[20]**) it corresponds to about 2-3 µs of shaping time.
   Then set a value of **“Trap. flat top”** (Trapezoid flat top), as for example **1** µ**s**. Check that the flat top region is really flat. Adjust – if necessary – the Peaking position (**“Peaking time”**) and the number of samples (**“N sample peak”**) for the energy mean calculation. Finally for very low rate set the maximum value of number of samples for the baseline calculation (**“N sample baseline”**), i.e. 16K (see the Input tab).



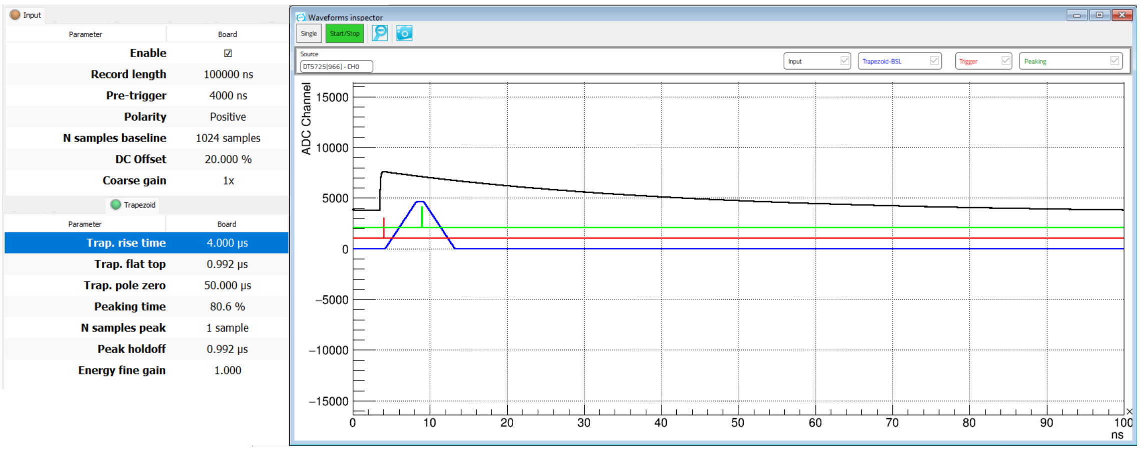
Note: In case of x730 the sum of Trapezoid Rise Time and Flat Top Time should not exceed 8 µs. Suggested settings for x730 are 6-7 µs of Rise Time and 1 µs of Flat Top.
In case of x725 the sum should not exceed 16 µs.

Note: In case of x724 and x781 with PHA legacy firmware the Trapezoid Rise Time and Flat Top Time have a maximum value of about 10 µs. Their sum should not exceed 15 µs.

Note: In case of x724 and x781 and V1782 the Trapezoid Rise Time and Flat Top Time have a maximum value of about 40 µs. Their sum should not exceed 40 µs.

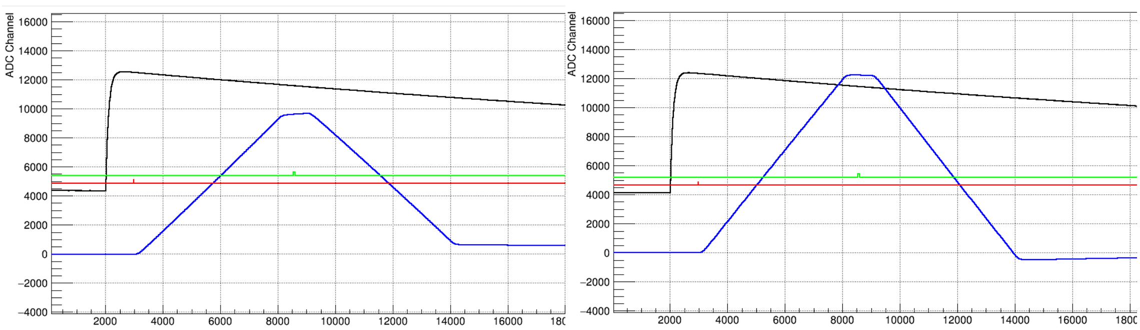
2. In the *high rate* case (tens of kHz) it is recommended to set a lower value of **“Trap. rise time”**, as for example **3-4** µ**s**. For a rate greater than 20 kHz it might be convenient to set **“Trap. rise time” = 1** µ**s**. Set also **“Trap. flat top” = 1** µ**s**, only check that the flat top region is really flat. Adjust – if necessary – the Peaking position (**“Peaking time”**) and the number of samples (**“Ns peak”**) for the energy mean calculation in the flat region. Finally decrease the value of number of samples for the baseline calculation (**“Ns baseline”**). A dedicated study of the impact of the Ns baseline in the final resolution can be made.

Both in case of low rate and high rate it is very important to have a flat **“Flat Top”** region. The **“Peaking”**, which corresponds to the samples where the pulse energy is evaluated, should be taken in the flat region. Adjust the **“Peaking time”** and the **“N sample peak”** values accordingly.

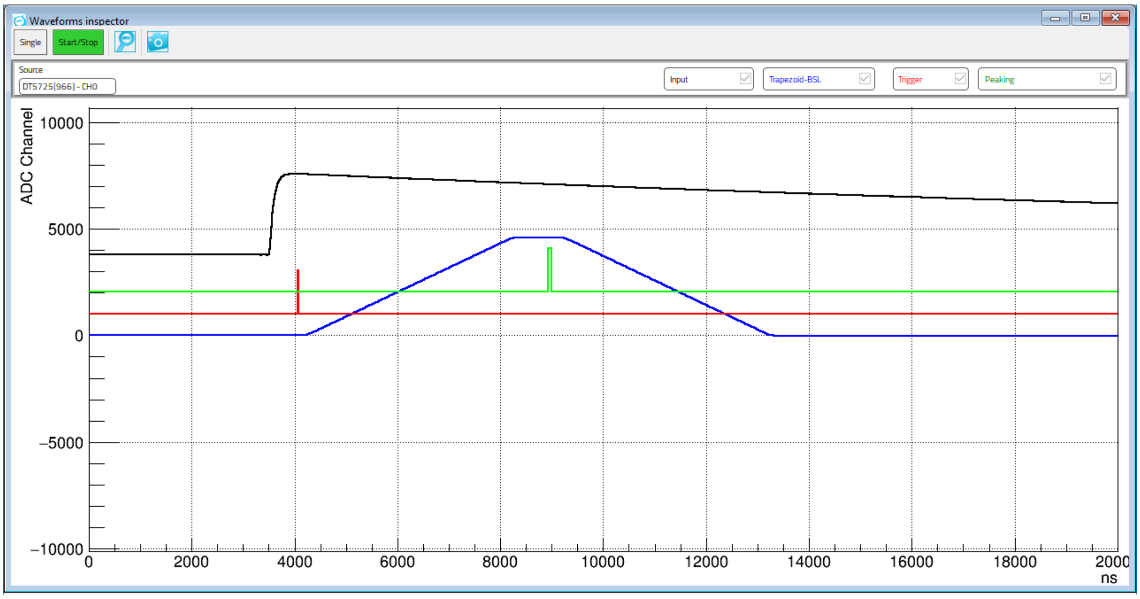


2.11.3.5 Pole-Zero Adjustment

The pole-zero adjustment is very important for a correct evaluation of the trapezoid baseline and consequently for a correct evaluation of the energy value. The user must adjust the **"Trap. Pole Zero"** according to the Pre-Amplifier decay time. Fine adjustments can be done looking at the zoom of the Trapezoid trace (or Trapezoid-Baseline) in order to have no undershoot nor overshoot. The two cases are shown in the following figure, where on the left the Trapezoidal Pole Zero has been set too high giving an undershoot, and on the right the Trapezoidal Pole Zero has been set too low thus giving an overshoot.

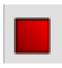


When the Pole-Zero is correctly compensated, the Trapezoid will not make any overshoot nor undershoot.


Waveforms inspector
Single
Start/Stop
Source
DT5725[966] - CH0
Input
Trapezoid-BSL
Trigger
Peaking
ADC Channel
10000
5000
0
−5000
−10000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
2000
ns

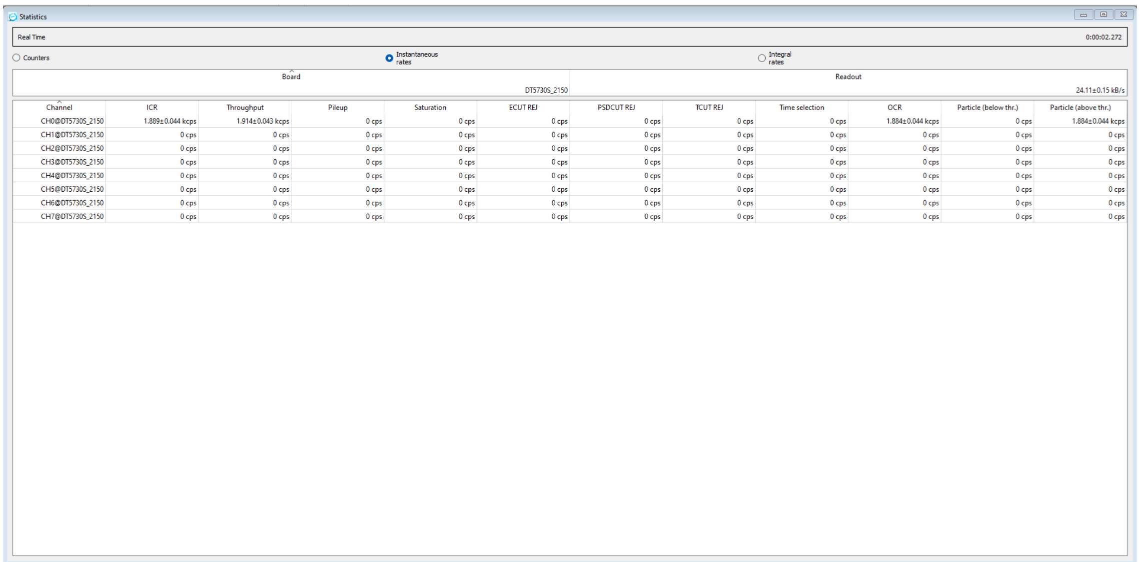
2.12 Start/Stop the acquisition and spectra visualization

Once you have configured the acquisition, stop the current run and select the ”List Only” acquisition mode in the Acquisition Tab.

Then press PLAY  to start the acquisition, STOP  to stop it.

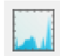
The acquisition will be started or stopped for all the channels.

Check the readout rate in the ”Statistics” section in the dedicated table in CoMPASSPlot.



Channel	ICR	Throughput	Pileup	Saturation	ECUT REJ	PSDCUT REJ	TCUT REJ	Time selection	OCR	Particle (below thr.)	Particle (above thr.)
CH0@DT5730S_2150	1.889±0.044 kcps	1.914±0.043 kcps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	1.884±0.044 kcps	0 cps	1.884±0.044 kcps
CH1@DT5730S_2150	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps
CH2@DT5730S_2150	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps
CH3@DT5730S_2150	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps
CH4@DT5730S_2150	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps
CH5@DT5730S_2150	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps
CH6@DT5730S_2150	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps
CH7@DT5730S_2150	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps	0 cps

Fig. 2.81: Digitizer readout rate.

To see the energy spectrum, open the “Energy Histogram” window pressing the button 

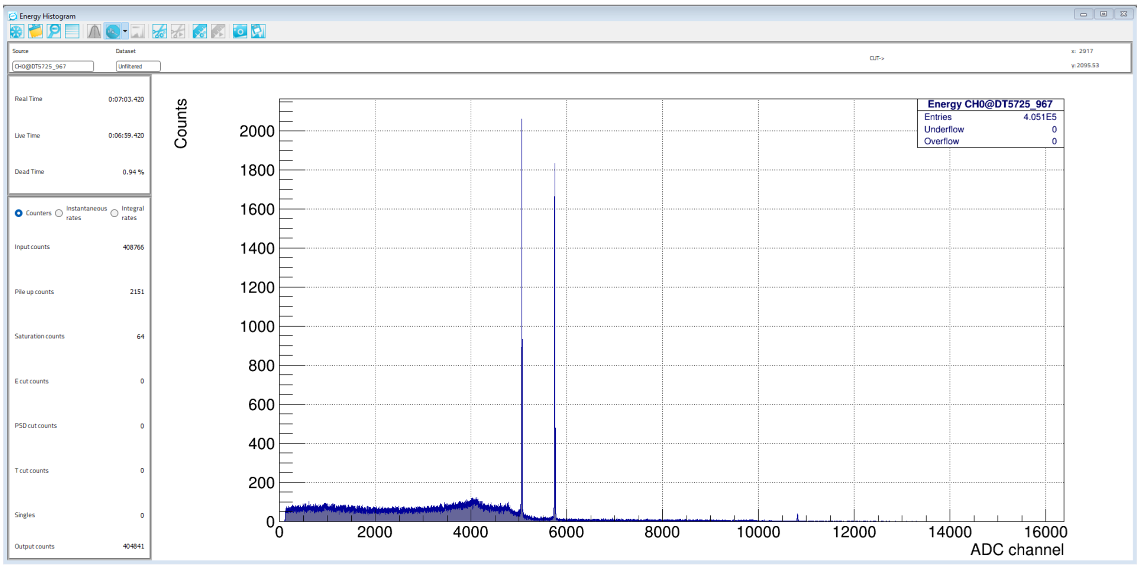


Fig. 2.82: Energy Plot of the ^{60}Co gamma source detected by an HPGe detector and digitized with a DT5725 + DPP-PHA.

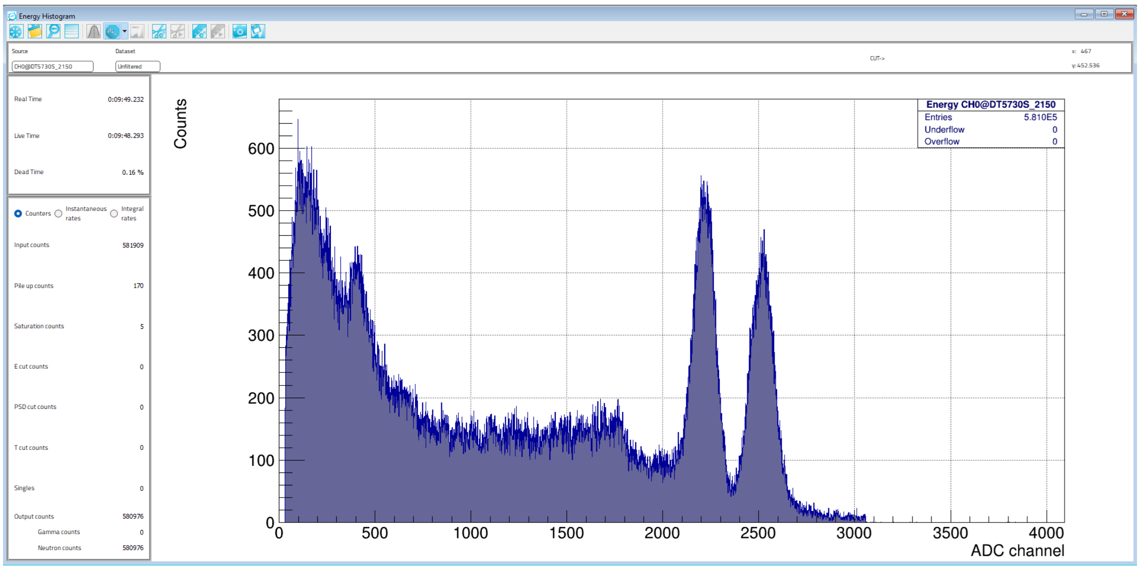
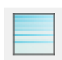


Fig. 2.83: Energy Plot of the ^{60}Co gamma source detected by an NaI detector and digitized with a DT5730 + DPP-PSD.

A box on the left side of the energy histogram summarize the current acquisition statistics: Real, Live and Dead Time, the total number of Input Counts, the number of counts rejected by the applied selections (if any) and the total number of Output Counts ie those that passed all the applied selections.

If needed, enable the logarithmic scale by pressing the button 

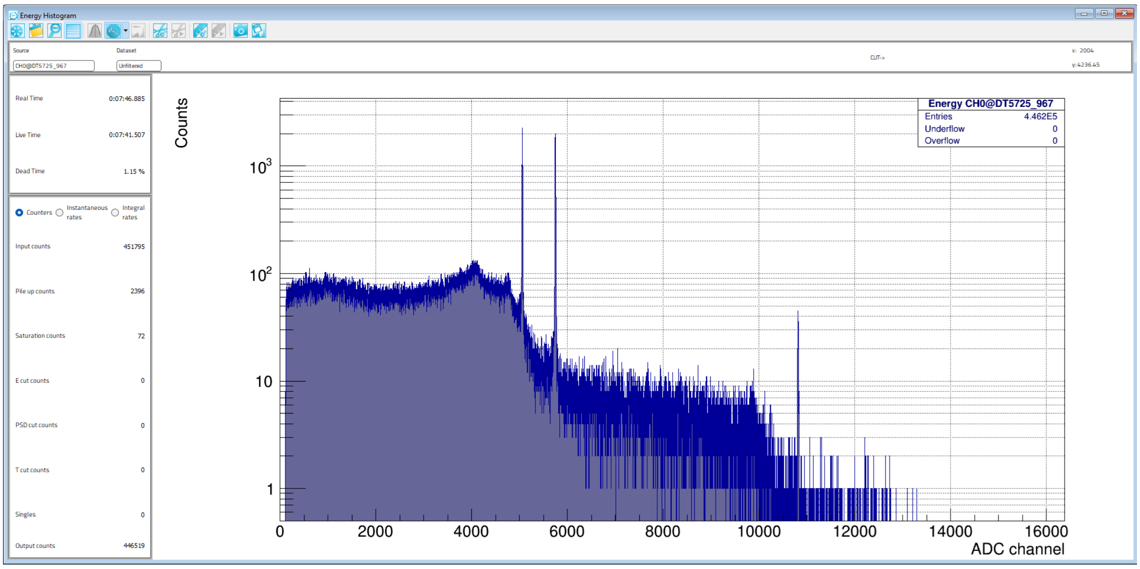


Fig. 2.84: Energy Plot of the ^{60}Co gamma source detected by a HPGe detector and digitized with a DT5725 + DPP-PHA. Log Scale.

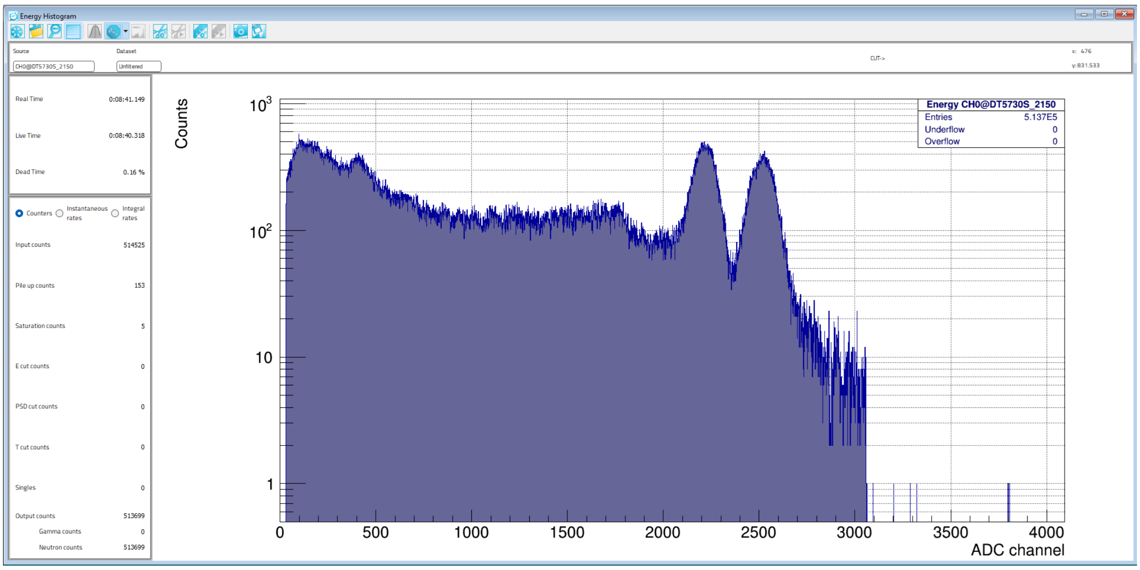
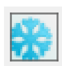
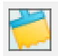


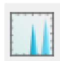
Fig. 2.85: Energy Plot of the ^{60}Co gamma source detected by a NaI detector and digitized with a DT5730 + DPP-PSD. Log Scale.

To zoom in a specific area press the mouse left button on the histogram axis and drag the mouse cursor.

To unzoom press the button 

To freeze the spectrum update press the button 

To reset the spectrum press the button 

To see the PSD spectrum (DPP-PSD only), open the “PSD Histogram” window pressing the button 

Select the channel to be displayed into the Source combo box.

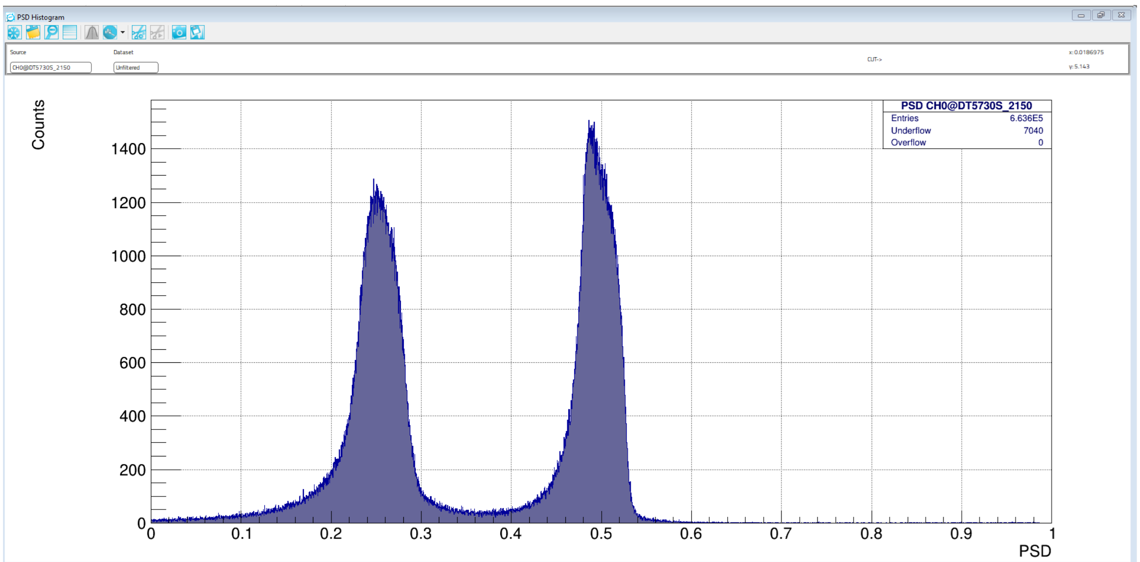
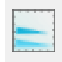


Fig. 2.86: PSD spectrum.

To see the 2-D scatterplot spectrum (DPP-PSD only), open the “Scatterplot” window pressing the button 

Select the channel to be displayed into the Source combo box.

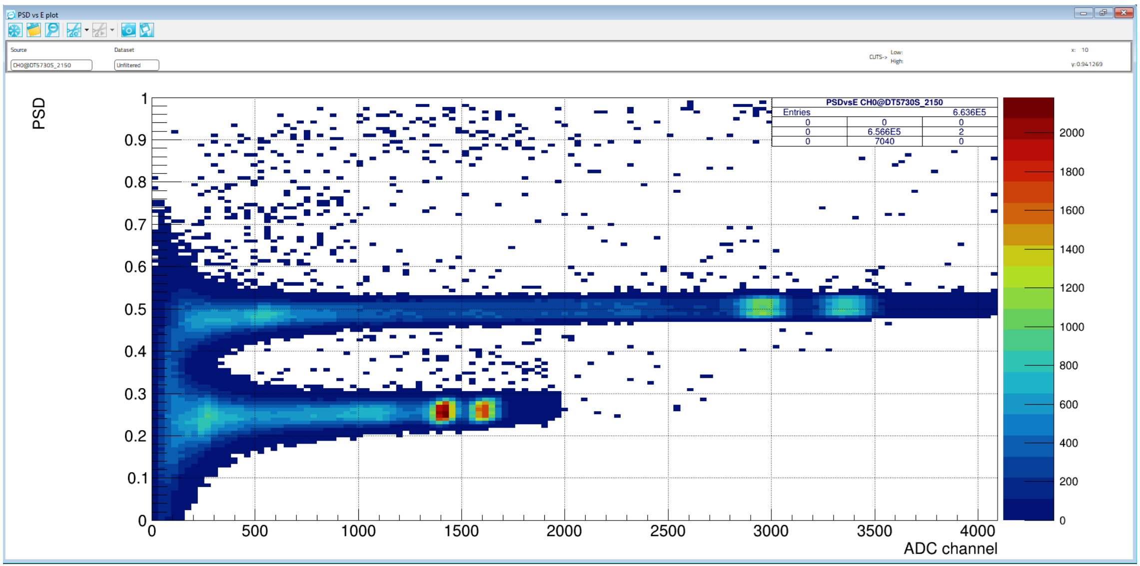
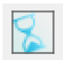


Fig. 2.87: Two dimensional PSD vs Energy scatterplot.

To see the single channel interval distribution spectrum, open the “Time Histrogram” window pressing the button 

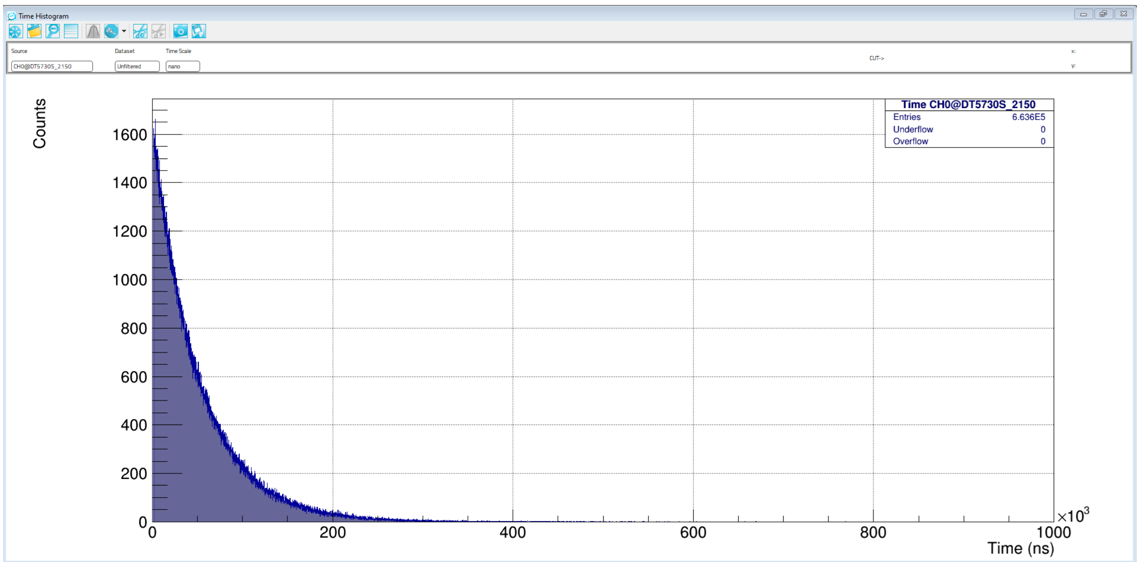


Fig. 2.88: Single channel interval distribution.

Select the channel to be displayed into the Source combo box.

Time correlation between channels can be enabled in the ”Time Selection” tab (for more information see **[20]**). On-board coincidences can be enabled through the ”Onboard coincidences” tab (refer to **[20]** for more details):

1. **Paired AND**: the software correlates the digitizer channels n and n+1, i.e. Ch0 with Ch1, Ch2 with Ch3 and so on by evaluating the time difference T_{Chn+1} - T_{Chn};
2. **Ch_ref AND any**: it corresponds to the option **Common Start** in the traditional analog electronics with TDCs. One channels is meant to provide the reference time (T_{start}) while all the others will be the evaluated with respect to it (T_{stop}). The user must specify the reference channel in the **Starting channel** field. The width of the correlation window (in µs) has to be specified in the **Correlation window** field.
3. **Ch_ref veto**: the reference channel acts as a veto for the other channels. Filtered events have a time difference with respect to the reference channel greater than the correlation window. The user must specify the reference channel in the **Starting channel** field. The width of the correlation window (in µs) has to be specified in the **Correlation window** field.
4. **Bd_ref veto**: the reference board acts as a veto for the other boards. The veto signal is the logical OR of the reference board channels signal. The veto width (in µs) has to be specified in the **Correlation window** field.

The Δt, E vs E, Δt vs E plots become available only when the time correlation between channels are enabled. Depending on which kind of time correlation the user has selected, the same will be applied to these plot and will affect which channels will be displayed: channel n and n+1 in case of "Paired AND", refence channel and one of the others (according to the user choice) in case of "CH_ref AND any".

To see the Δt between two channels distribution spectrum, open the "Tof Histogram" window by pressing the button 

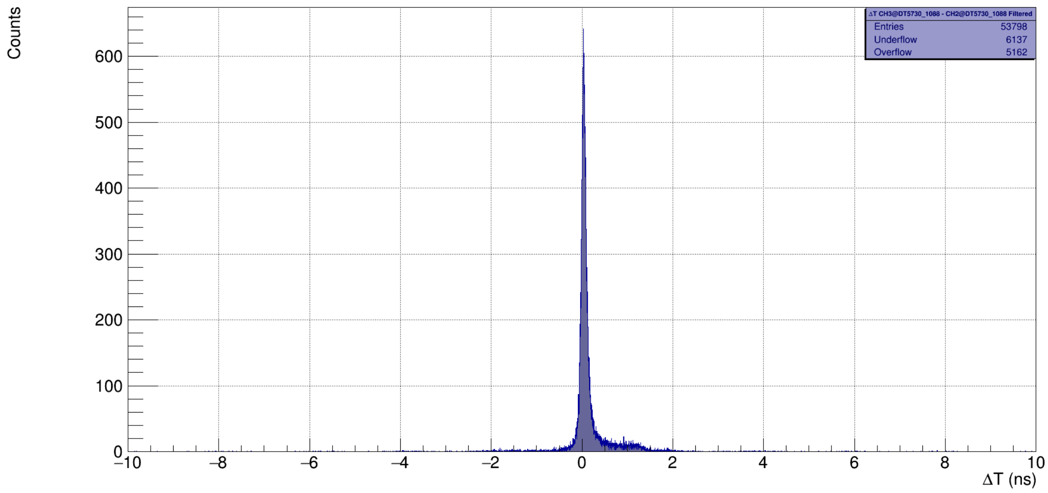


Fig. 2.89: Time difference between channel n and n+1.

To see the 2D Energy vs Energy between two channels distribution spectrum, open the “E vs E Histogram” window by pressing the button 

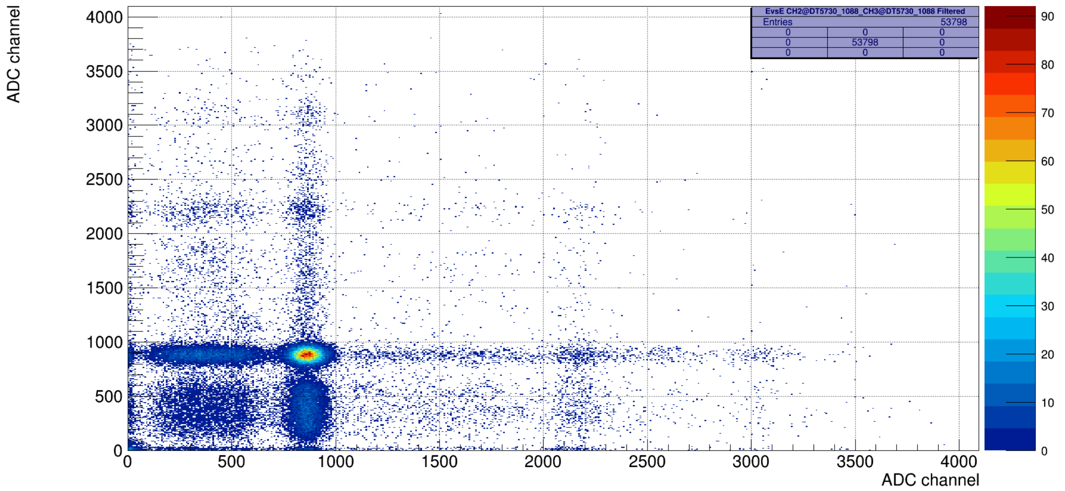
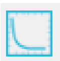


Fig. 2.90: E vs E distribution between channel n and n+1.

To see the 2D Δt vs Energy between two channels distribution spectrum, open the “E vs E Histogram” window by pressing the button 

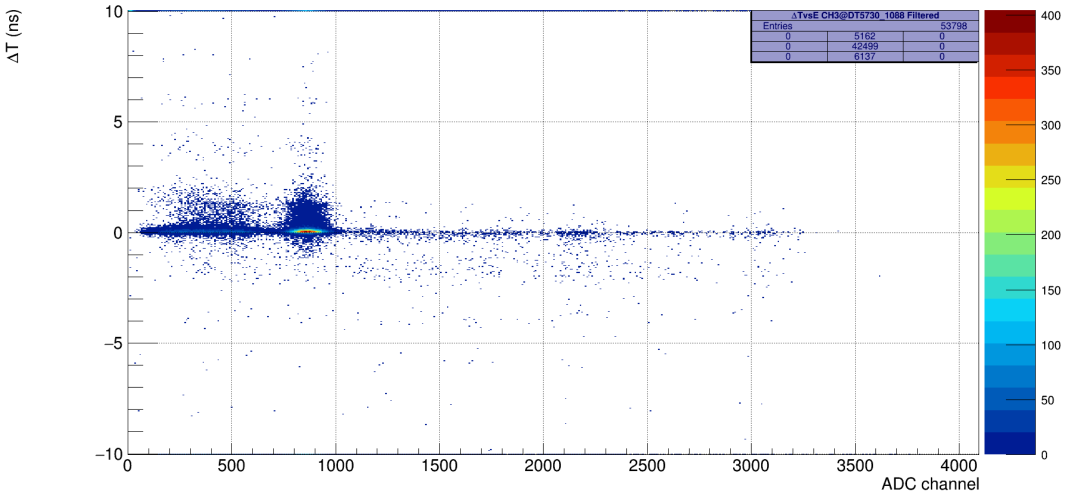


Fig. 2.91: E vs E distribution between channel n and n+1.

Note: To change the spectra limits and number of channels select the ”Spectra” tab.

Spectra

Parameter	All
Energy N channels	4096
PSD N channels	4096
Time intervals N channels	8192
Time intervals Tmin	0.000 µs
Time intervals Tmax	1000.000 µs
Start/stop Δt N channels	8192
Start/stop Δt Tmin	-10 ns
Start/stop Δt Tmax	20 ns
2D Energy N channels	512
2D PSD N channels	512
2D Δt N channels	512

To see the Multi Channel Scaler (MCS) graph pressing the button

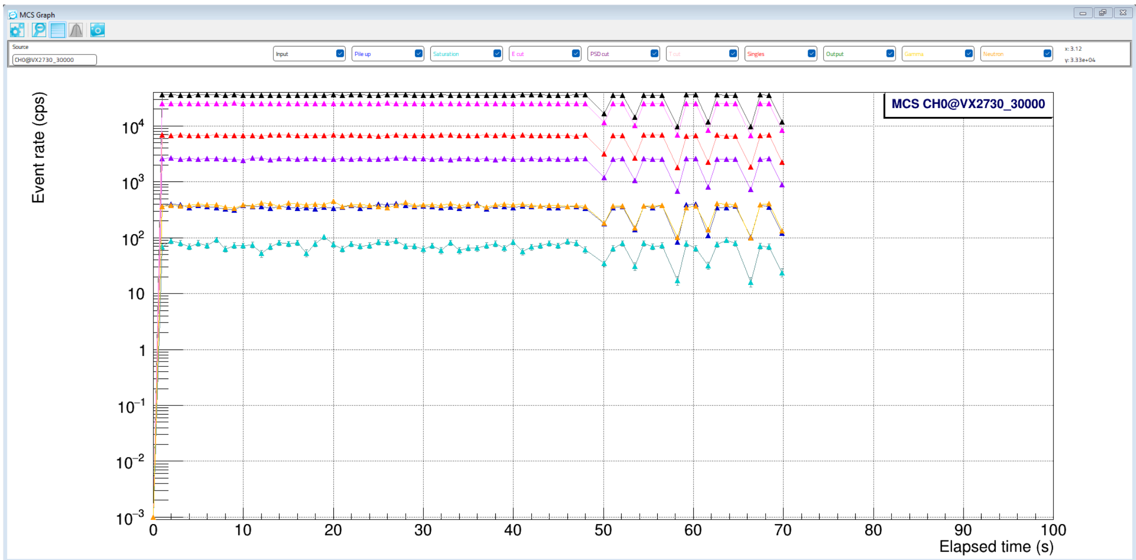


Fig. 2.92: Multi Channel Scaler graph.

The Graph shows the cps vs time for the raw, unfiltered and filtered data (see Sec. **How to set Energy, PSD and Time selections for more details**). In order to set the MCS graph properties the user have to open the ”Settings” sub-window by pressing the

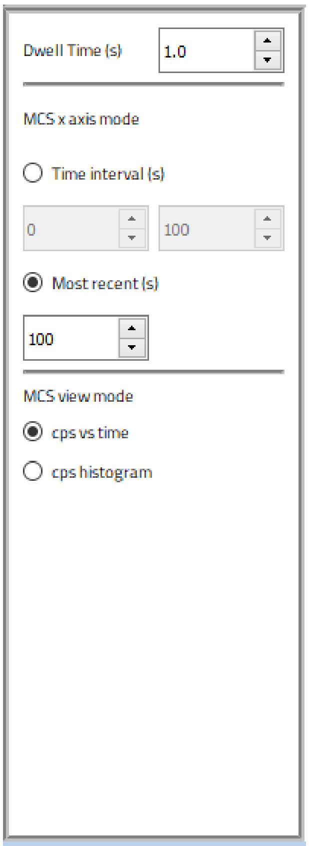


Fig. 2.93: Multi Channel Scaler graph settings.

The user can set the MCS graph Dwell time (in seconds), MCS X Axis mode (”Time interval (s) or ”Most recent (s)”) and MCS view mode (”cps vs time” or ”cps histogram”).

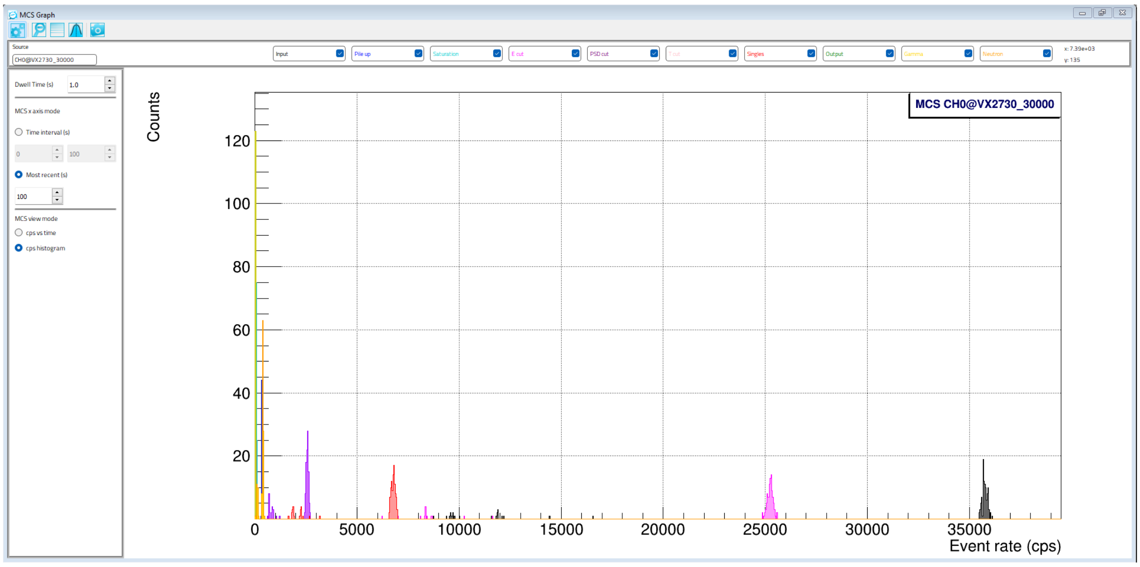


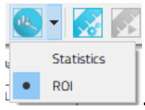
Fig. 2.94: Multi Channel Scaler histogram.

2.13 How to Calibrate the Spectrum

The software allows the user to calibrate a spectrum from counts to keV/MeV using two interpolating functions: Linear and Quadratic. For the first function, the user must define at least a couple of values, while for the second the user must define at least three values. It is also possible to define more points; the algorithm will then compute the best fit of the defined points.

The user can select a Region of Interest (ROI) of the spectrum and take the mean value of the distribution for the energy calibration.

2.13.1 How to select a ROI

Open the ROI management window by pressing the  and selecting "ROI" 

.
The following tab will appear on the bottom side of the spectrum window.

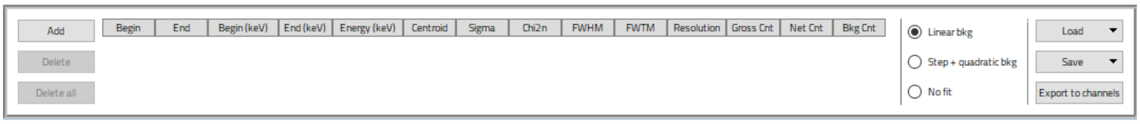


Fig. 2.95: ROIs management tab.

Zoom in (drag and release the mouse to zoom in) in the spectrum region of the relevant peaks to select the ROI.

Click on the "Add" button or right click on the plot to add a new ROI, then left click on the histogram to select the left limit of the ROI then drag and right click to define the ROI right limit.

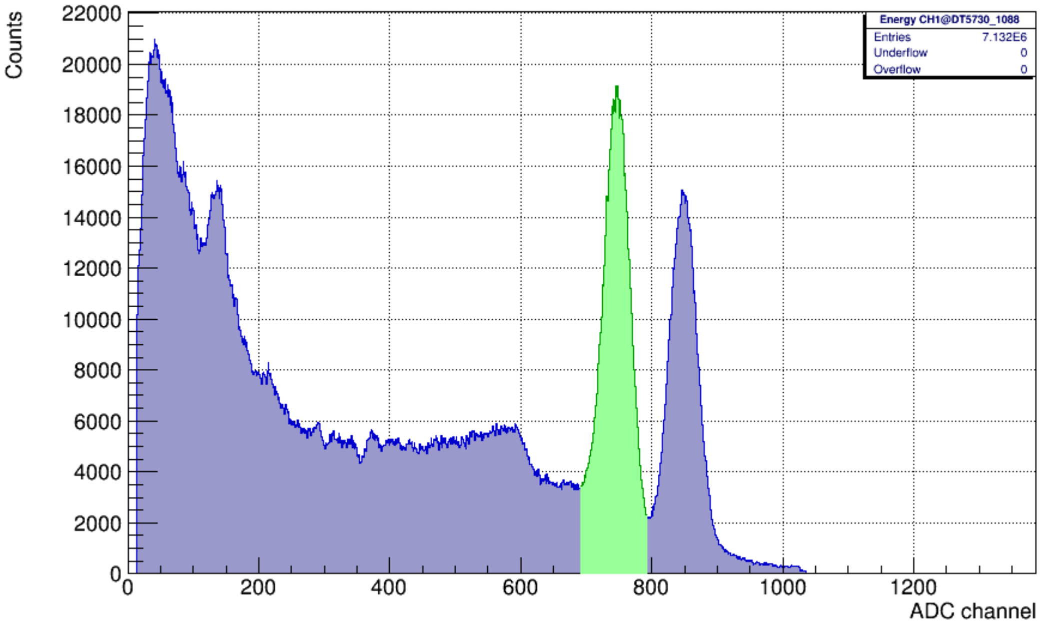


Fig. 2.96: ROI limits setting for the first peak.

The ROI limits will be automatically written in the ROI tab.

Repeat the same procedure for the second peak:

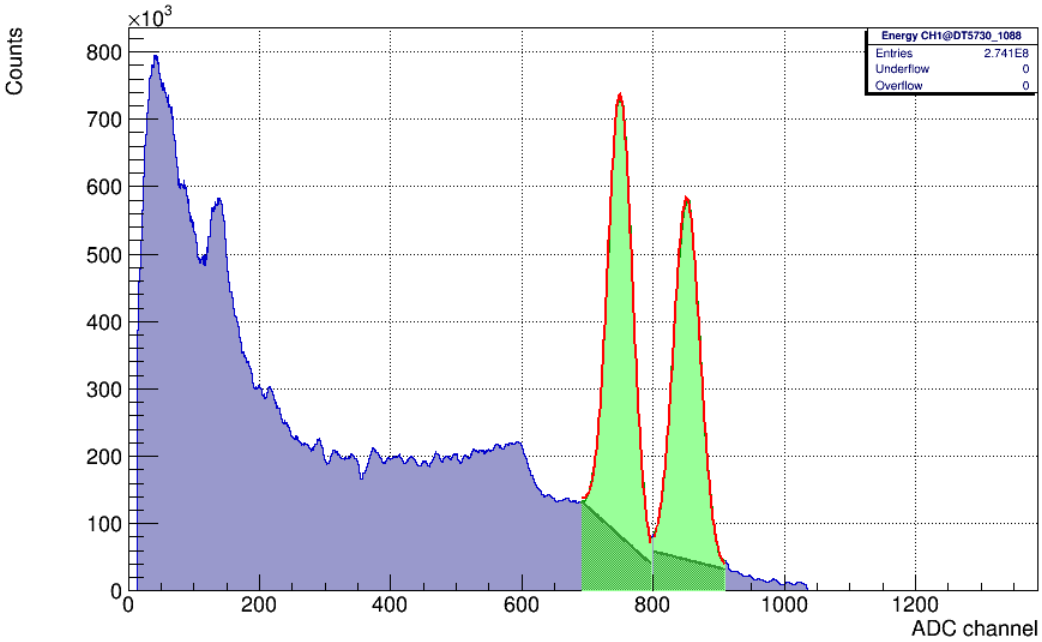
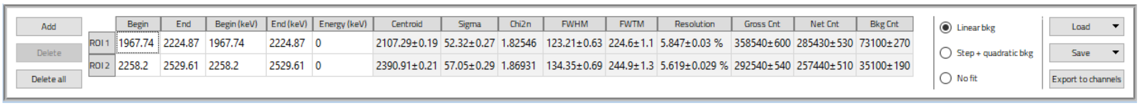


Fig. 2.97: ROI limits setting for the second peak.

Select the background type you want to be used for the peak fit (Linear or Quadratic + Step Function). CoMPASS will then automatically fit the peak and evaluate the peak centroid, sigma, FWHM, FWTM, fit χ^2, resolution percentage, gross counts, net counts and background counts. All the analysis results are then reported in the ROI management tab.



	Begin	End	Begin (keV)	End (keV)	Energy (keV)	Centroid	Sigma	Chi2n	FWHM	FWTM	Resolution	Gross Cnt	Net Cnt	Bkg Cnt
ROI 1	1967.74	2224.87	1967.74	2224.87	0	2107.29±0.19	52.32±0.27	1.82546	123.21±0.63	224.6±1.1	5.847±0.03 %	358540±600	285430±530	73100±270
ROI 2	2258.2	2529.61	2258.2	2529.61	0	2390.91±0.21	57.05±0.29	1.86931	134.35±0.69	244.9±1.3	5.619±0.029 %	292540±540	257440±510	35100±190

Fig. 2.98: ROIs analysis results.

If the option ”No Fit” is chosen, CoMPASS will evaluate the histogram centroid, sigma, FWHM, FWTM, percentage resolution and gross counts only.

Press on the Save button to Save the single plot ROIs (”Save”) or the whole project ROIs, i.e. the ROIs of all the spectra of all the channels (”Save project ROIs”).

Press on the Load button to Load from an external file the single plot ROIs (”Load”) or the whole project ROIs ie the ROIs of all the spectra of all the channels (”Load project ROIs”).

Press on the ”Export to channels” to export the current plot ROIs to the corresponding plots of the other channels.

The results of the ROIs definition and analysis are saved into the run folder at the end of the acquisition in a text file.

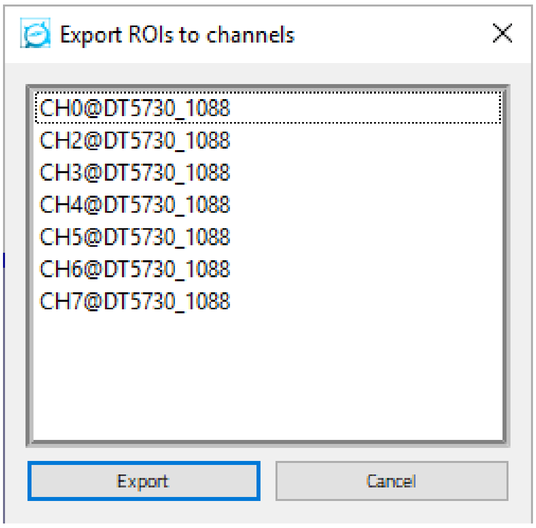


Fig. 2.99: ROIs export panel.

2.13.2 Calibration Procedure

Open "Calibration Setup" window by pressing the button 

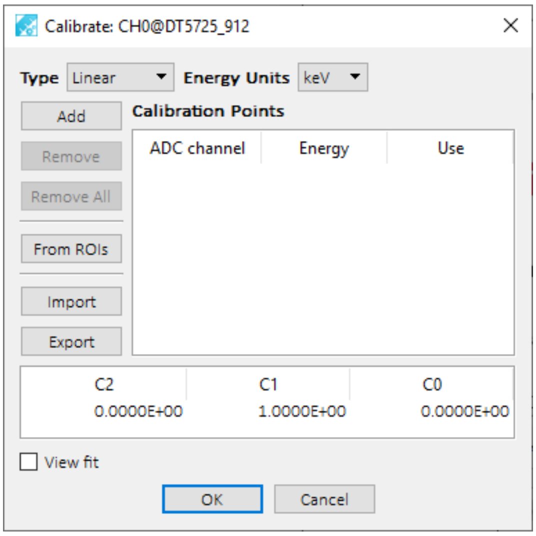


Fig. 2.100: CoMPASS Spectrum Energy Calibration Window.

1. Select the calibration Type (Linear or Quadratic) and the Energy Units in which the energy spectrum will be calibrated (keV or MeV)
   - Linear calibration is according to the formula

$$\text{Energy} = \text{C0} + \text{C1} \times \text{Channel} \tag{2.4}$$

   - Quadratic calibration is according to the formula

$$\text{Energy} = \text{C0} + \text{C1} \times \text{Channel} + \text{C2} \times \text{Channel}^2 \tag{2.5}$$

2. Zoom on the histogram area in which the peak you want to use as a calibration point is present. Left click on the peak centroid to enter its value into the ”ADC Channel” field or write it explicitly
3. Click on the Add button
4. Repeat the points 2 and 3 including at least 2 calibration points in case of the Linear calibration or at least 3 points in case of Quadratic calibration

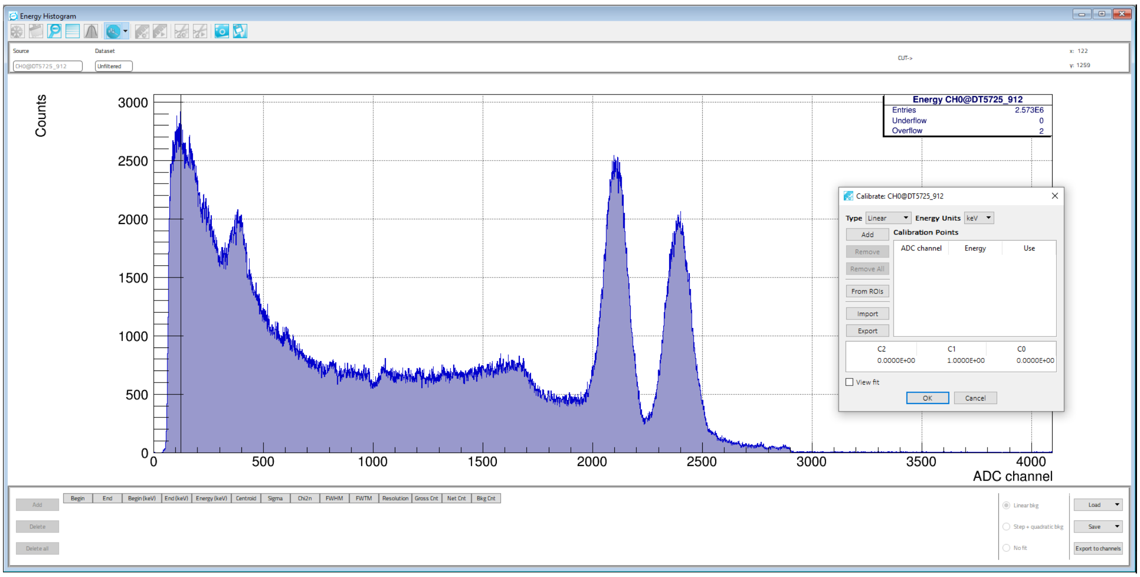


Fig. 2.101: CoMPASS Spectrum Energy Calibration Procedure.

or alternatively press the button "From ROIs" to automatically import the ROIs centroid and then writing the corresponding energy value.

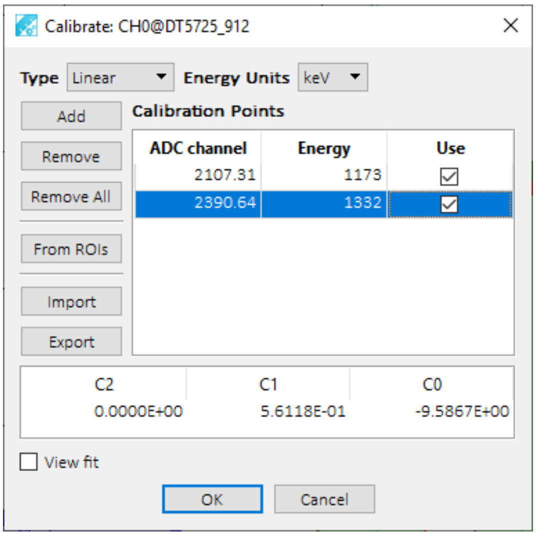


Fig. 2.102: CoMPASS Spectrum Energy Calibration Window (Calibration points imported from ROIs).

5. Click on the checkbox "Use" if you want to select/remove one or more calibration point
6. Press "Export" to export on an external file the calibration points and coefficient
7. Press "Import" to import from an external file the calibration points and coefficient

Click on the "View fit" tick in order to open the spectrum fit plot.

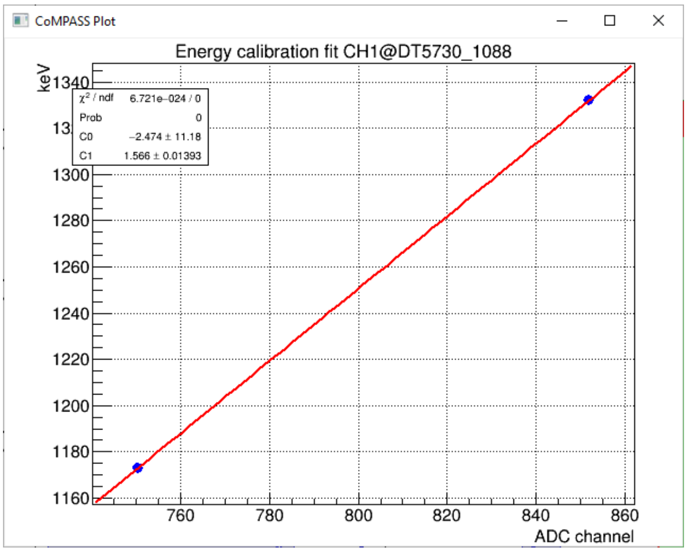


Fig. 2.103: Calibration Fit.

To apply the calibration press the ”Calibrate” button 

Note: Once the calibration is applied, the calibration parameters C0, C1, C2 are saved into the *run.info* file contained in the project folder under the path ”DAQ\run”.

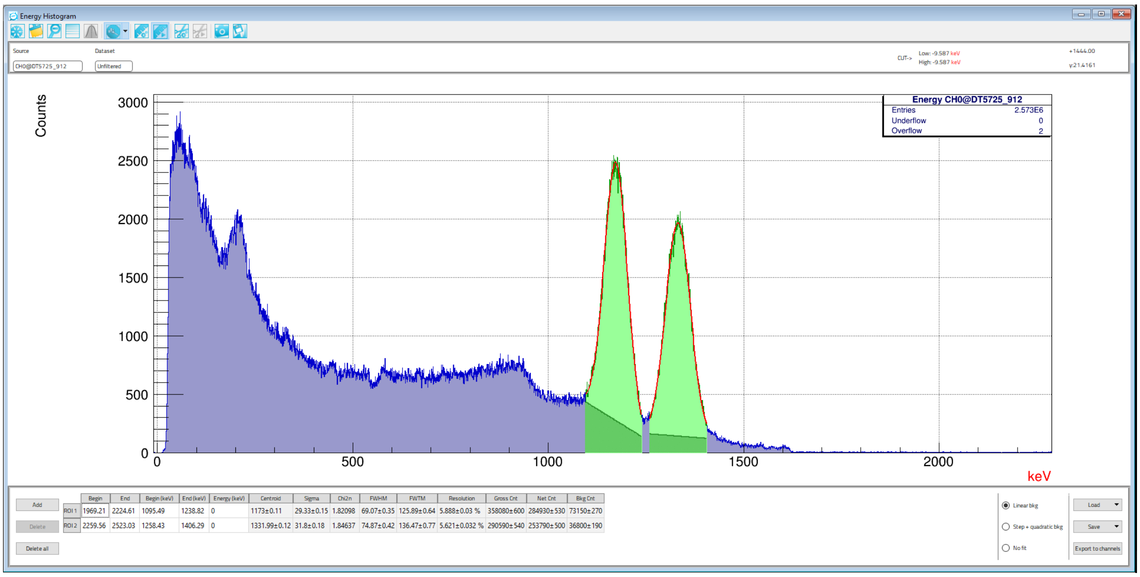
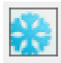


Fig. 2.104: CoMPASS calibrated Energy Spectrum.

2.14 How to Fit the Spectrum

The software allows the user to fit the spectrum peaks with the desired fitting function.

In order to fit a peak freeze the spectrum update pressing the button 

Zoom into the desired area by pressing the mouse left button and the histogram axis and dragging the mouse cursor.

Open the fit panel pressing the button 

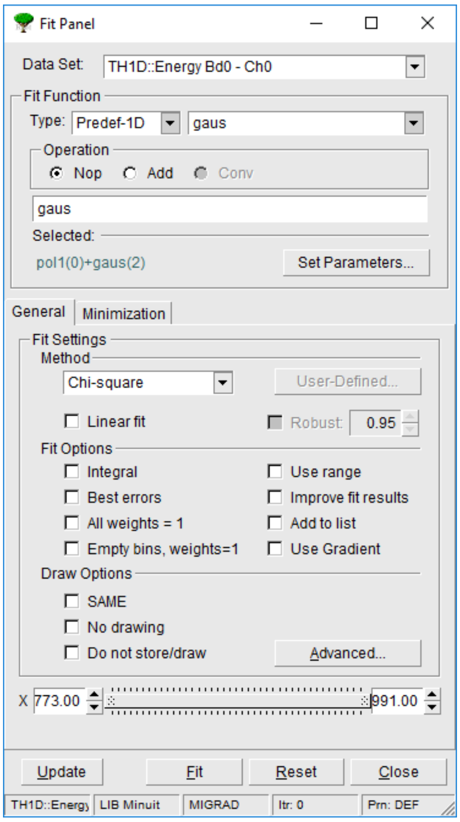


Fig. 2.105: CoMPASS Fit Panel.

Set the fit function, the fit limits, the desired option to enable and press ”Fit”.

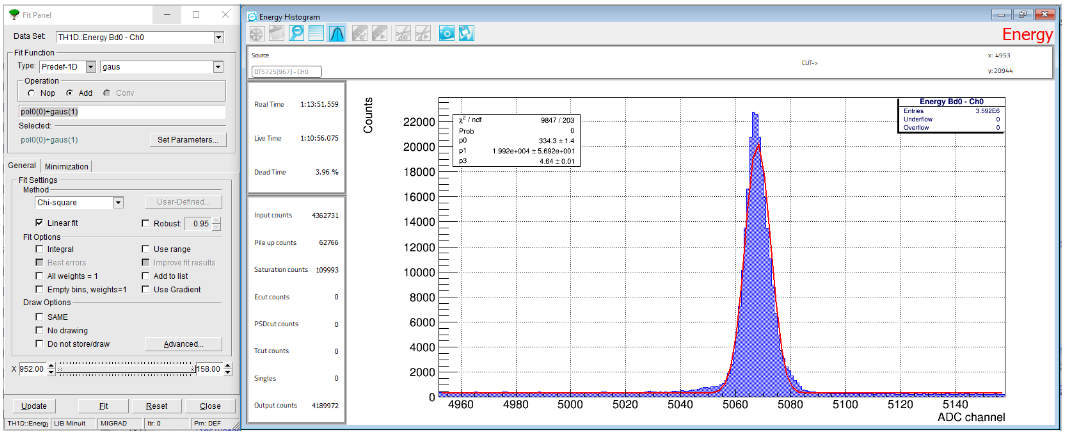
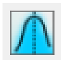
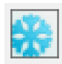


Fig. 2.106: Energy Peak Fit.

Once finished, close the Fit panel and press the Fit button . At this point the freeze button  becomes available; click it to let the plot run again.

2.15 How to set Energy, PSD and Time selections

The CoMPASS Software allows the user to set data selections on the Energy, PSD, Scatterplot and Time histogram. The data selection can involve one or more quantities at the same time. There are two ways of setting and applying the data selection:

Directly on the plot by pressing the button 

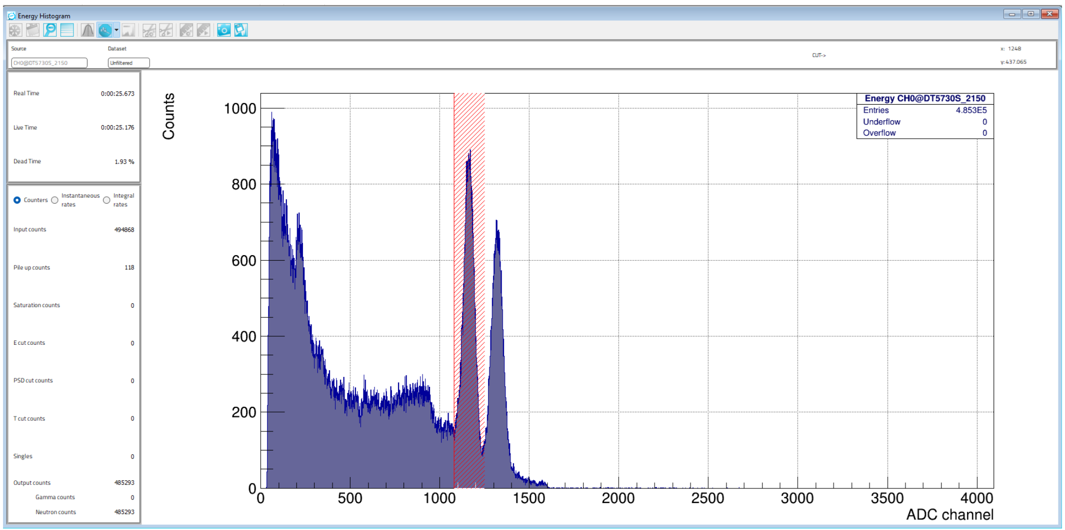
1. 

Fig. 2.107: Energy cut definition procedure using the plotter.

A cursor will then become available and the user have to click on the histogram points that will be the ”Low Cut” and ”High Cut”.

Note: In the case of a Time Histogram, only a ”Low Cut” can be applied.

To apply the cut the user have to press the button 

2. Through the main GUI select in the ”Rejections” tab the cut to be applied in each spectrum.

When the cut on a quantity has been applied, in the corresponding histogram an additional combo box (”Dataset”) will appear allowing the user to select the data to display:

- ”Unfiltered” data, before the cut
- ”Filtered” data, after the cut

	Rejections
Parameter	Board
Saturation rejection	☑
Pileup rejection	☑
PUR gap	1000 lsb
E low cut	0.000
E high cut	0.000
E cut enable	☐
PSD low cut	0.000
PSD high cut	0.000
PSD cut enable	☐
Time intervals low cut	0 ns
Time intervals cut enable	☐

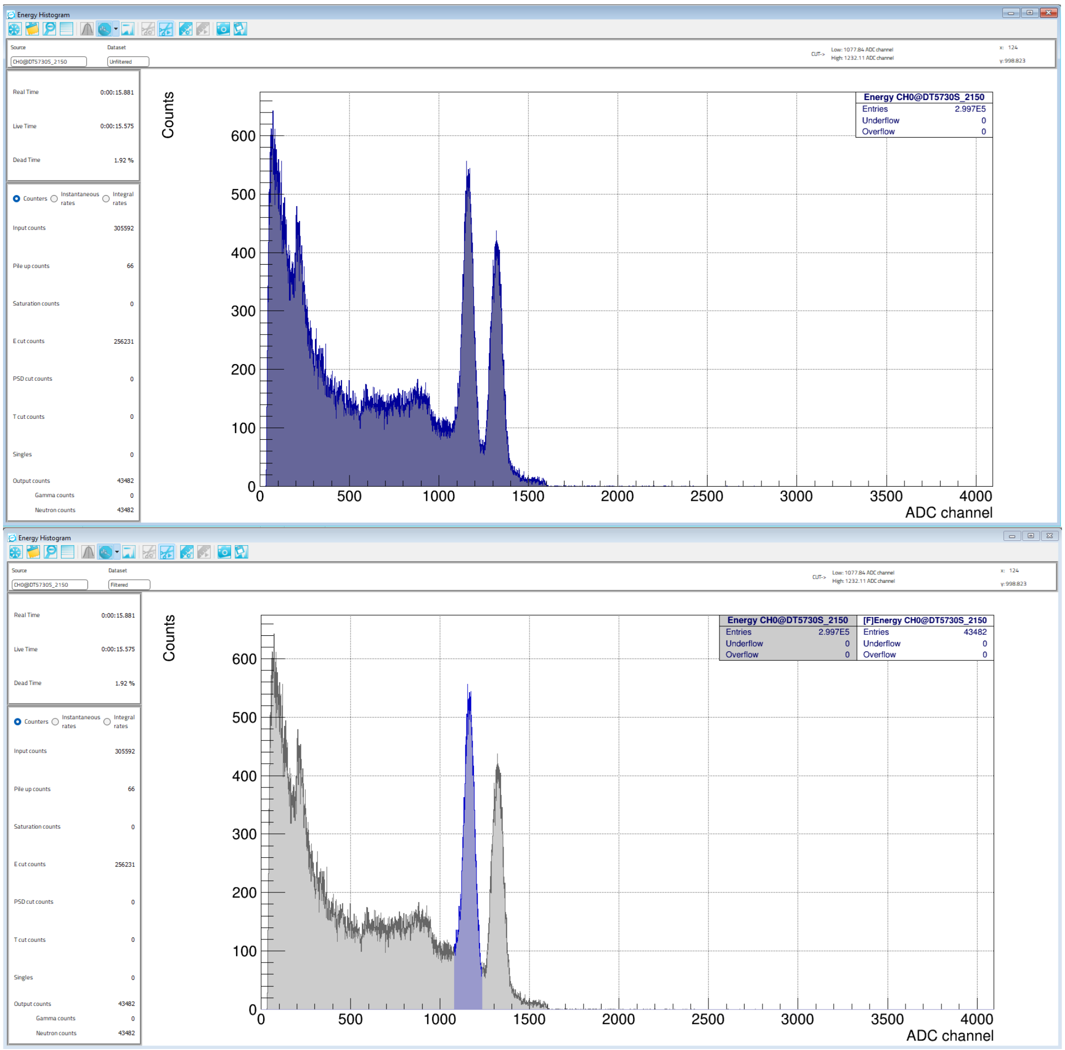


Fig. 2.108: Unfiltered (top) and filtered (bottom) data in the energy histogram.

The user can also apply a two dimensional cut on the Energy-PSD, Energy vs Energy and ΔT vs Energy scatterplot.

The user has first to define the PSD cut and then the Energy one clicking inside the scatterplot.

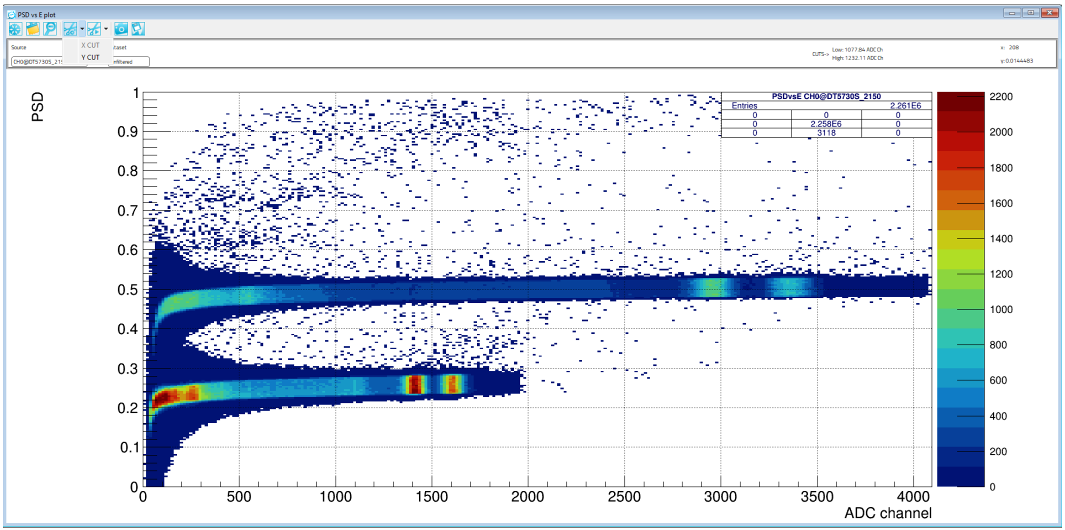


Fig. 2.109: Two dimensional cut selection.

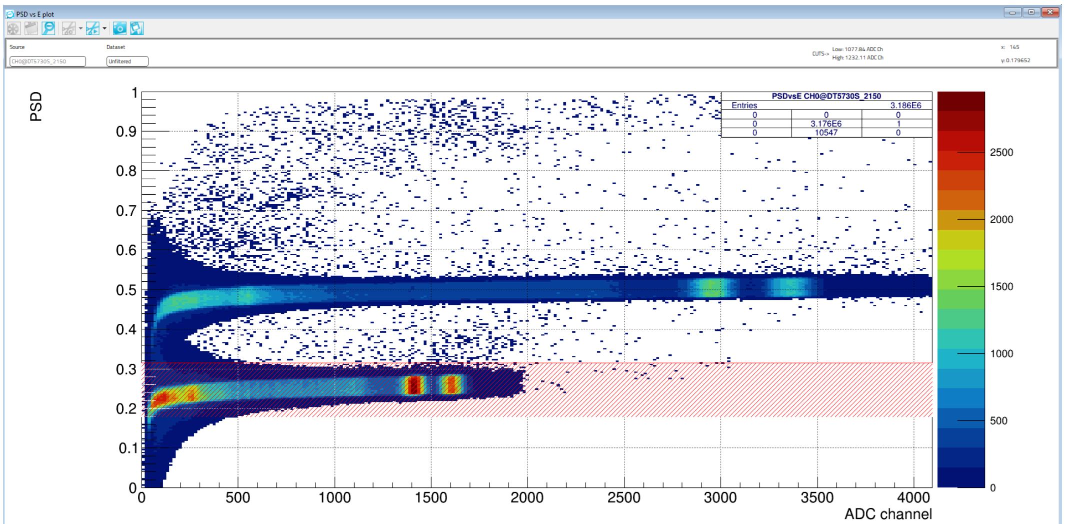


Fig. 2.110: PSD cut definition of the Energy-PSD scatterplot.

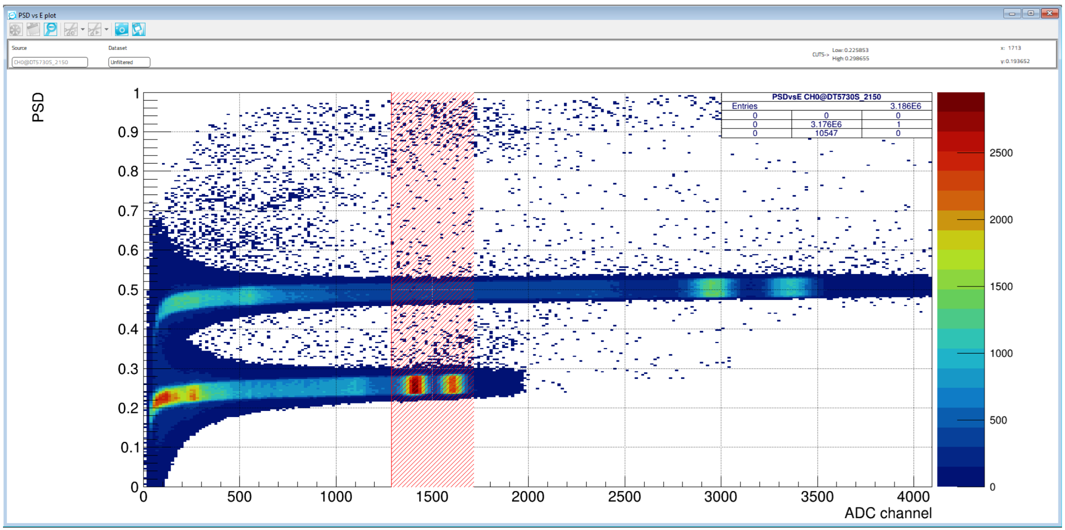
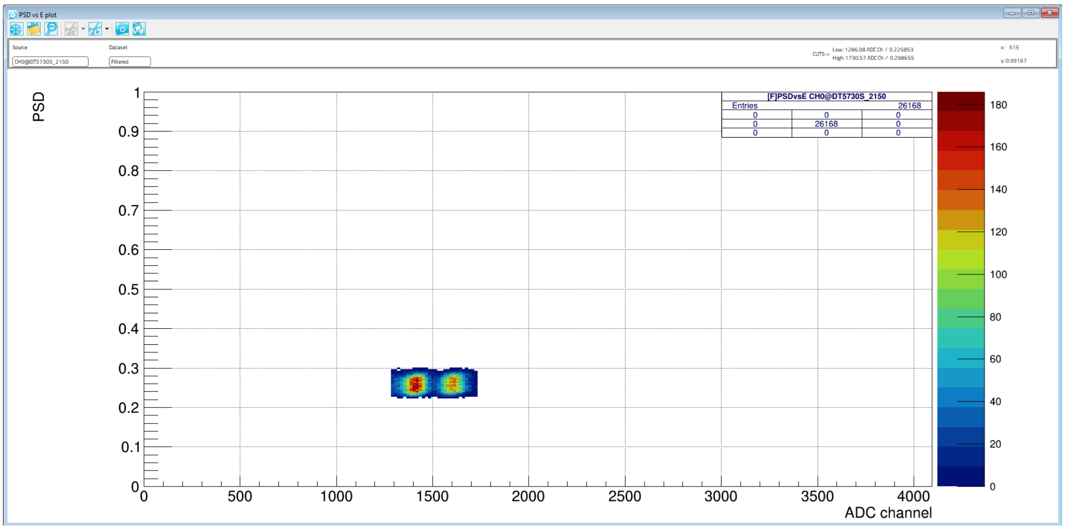


Fig. 2.111: Energy cut definition of the Energy-PSD scatterplot.

The results of the selection is shown in the following picture.



2.16 How to create and use Virtual Channels (Add-back)

Users that operate with segmented detector (like Clover detectors) or need to do an Event Building operation can do the job using the **Virtual Channel Tab**.

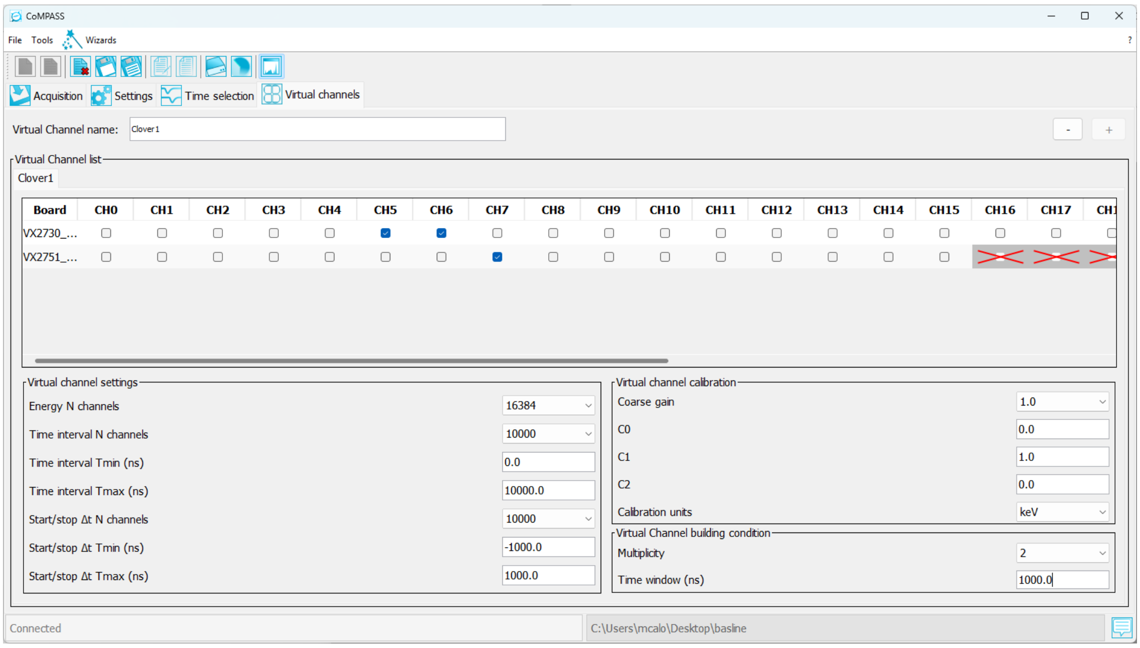


Fig. 2.112: CoMPASS Virtual Channels Tab.

Note: Before proceeding with the event building make the **energy calibration** of the individual channels to perform the correct energy summing.

The ”Virtual Channel list” section allows the user the possibility to create multiple virtual channels by clicking on the ”+” symbol. They are displayed as tabs. Each of these tabs displays all the available dpp channels of the connected boards. The user may combine the desired channels by selecting the corresponding boxes. The multiplicity of the participating channels and the width of the event building time window (in ns) can be declared at the ”Event building condition” section. For a selection of n number of dpp channels and m ($m \leq n$) multiplicity, an add-back event will be built if there are hits from minimum m channels.

Fig. 2.113: Virtual Channels Tab - Event building condition section.

The created virtual channel will contain the summed energy of the selected dpp channels. The time-stamp of the built events is the average of the single events time-stamps. No filters can be applied on the virtual channel events because they are already filtered according to the same selection set for the events coming from the single channels, i.e. an event discarded by the energy/PSD/time/correlation filter applied in the single channels is not used in the event building procedure.

In the ”Virtual channel settings” section select the number of channels and the limits of all the spectra that you are interested to display.

The Add back energy spectrum shows a number of bins equal to the sum of the single spectra bins.

Fig. 2.114: Virtual Channels Tab - Virtual channel settings section

The Virtual channels calibration is a two-step procedure:

- first you have to perform the energy calibration of all the channels involved in the Add back building according to the procedure explained in Sec. **Calibration Procedure**.

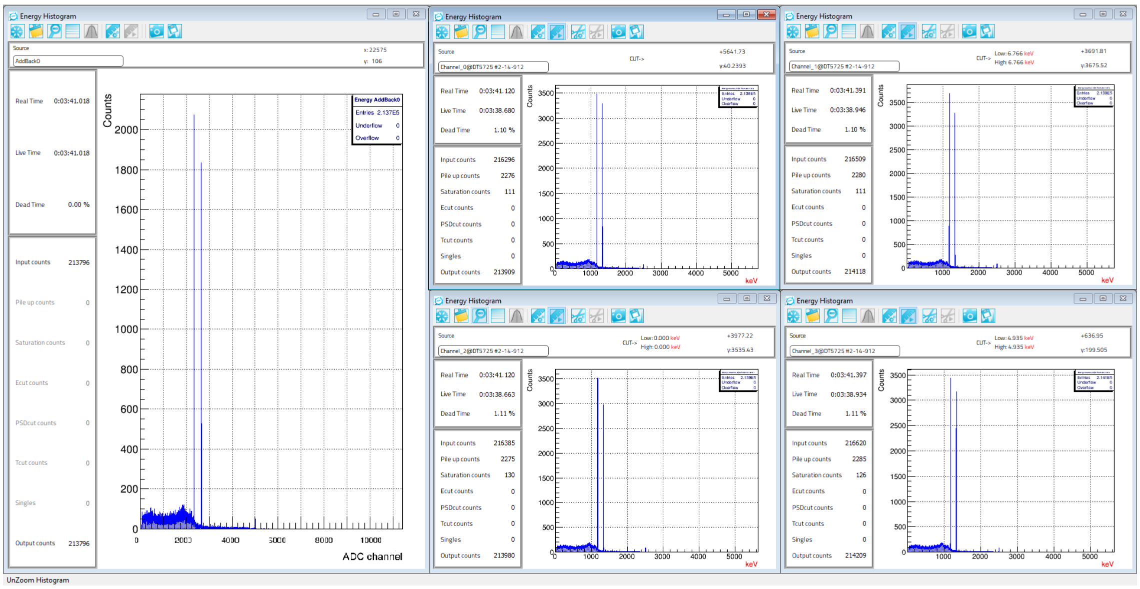


Fig. 2.115: Virtual channels calibration - first step.

- finally perform the Add back energy spectrum calibration as per the procedure explained in Sec. **Calibration Procedure**

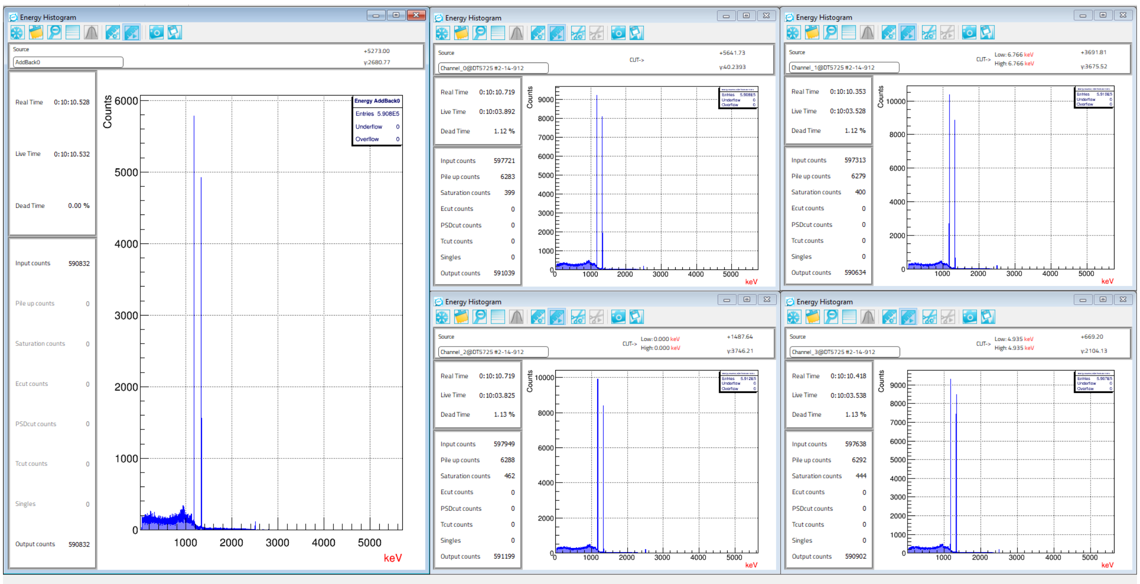


Fig. 2.116: Virtual channels calibration - second step.

The Add back calibration parameters are shown in the ”Virtual channel calibration” section.

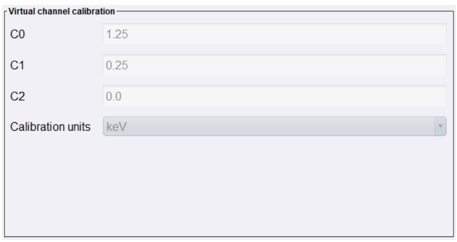


Fig. 2.117: Virtual channel calibration section.

When the data acquisition is running one can check the Virtual Channel ICR and OCR in the statistics window of CoMPASSPlot.

Channel	ICR	Throughput	Pileup	Saturation	ECUT REJ	PSDCUT REJ	TCUT REJ	Time selection	OCR	OCR (Event Group)	OCR (Master Trigger)	Particle (below thr.)	Particle (above thr.)
CH5@VX2730_30000	1.921±0.061 kcps	1000±31 cps	0 cps	0 cps					1.919±0.061 kcps				
CH6@VX2730_30000	1.917±0.061 kcps	1000±31 cps	0 cps	0 cps					1.915±0.061 kcps				
CH7@VX2751_51014	381±27 cps	200±14 cps	0 cps	0 cps					381±27 cps			0 cps	381±27 cps
Clover1@VIRTUAL	1000±31 cps								961±31 cps				

Fig. 2.118: Virtual channel statistics.

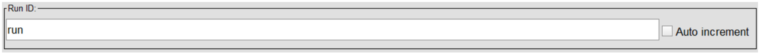
2.17 How to Save the Data

It is possible to save data in different ways:

1. Save the board data buffers data
2. Save the Energy, Time, PSD, ΔT and MCS spectra
3. Save the 2D PSD vs E, E vs E and ΔT vs E spectra
4. Save the list of Trigger Time Stamp, Energy, PSD and possibly waveform for each event

5. Save a picture of the Energy, PSD, Time, ΔT, Waveforms and 2D spectrum

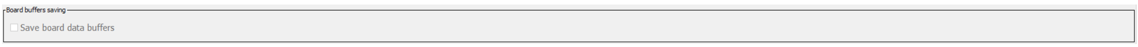
Select the run name and tick the ”Auto increment” box to increase the run index at every start acquisition.



All saved files are available in the project folder, under the ”DAQ\run” sub-folder. For each run, **run.info** and **settings.xml** files are saved, reporting general run information and the board settings respectively.

2.17.1 Save the board data buffer file

In order to save the board data buffer file the user must select the **”Save boards data duffer”** option tick into the Board buffers saving section of the Acquisition Tab.



The board data buffer file is saved into a proprietary file format and can be processed again performing an offline run where the user can run again the full acquisition possibly setting different data selection.

2.17.2 Save the list of Trigger Time Stamp, Energy, PSD and waveforms

In order to save a list file in which the Trigger Time Stamp, Energy, PSD and possibly waveform samples information are included, the user must select the **”Save raw data”** and/or **”Save unfiltered data”** and/or the **”Save filtered data”** tick into the List Saving section of the Acquisition Tab:

1. **Raw data** correspond to all the events acquired by the digitizer including pile-up and saturation events. Raw data are useful if the user would like to evaluate the acquistion dead time by his/her own (see Sec. **Dead time evaluation in CoMPASS**).
2. **Unfiltered data** correspond to the events acquired by the digitizer excluding pile-up and saturation events
3. **Filtered data** correspond to the events that passed the filters in the ”Rejection” tab of the Settings window and in the Time Selection tab (if any).
4. **Save event building data (this option is currently unavailable)**.
5. **Save master trigger data (this option is currently unavailable)**.

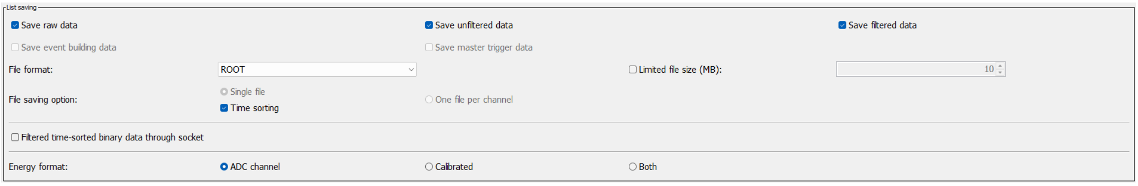
Per each of the above kind of data, the user has two possible choices:

1. save one file per each enabled channel: the file is generated for filtered and/or unfiltered data under the path ”DAQ\run\RAW/FILTERED/UNFILTERED”.
2. save one single file in which the data from all the enabled channels are included: the file is generated for filtered and/or unfiltered data under the path ”DAQ\run\RAW/FILTERED/UNFILTERED”. This single file can be *time ordered* if the option ”Time sorting” is selected.

The energy information can be saved in ADC channel, keV/MeV (in case of energy calibration), or both.

The user can also customize the maximum size of the list chunk file. As soon as the set size is reached, CoMPASS will automatically close the chunked file and open a new one.

The available file formats are root (.root), *Comma Separated Values* (.csv) and Binary (.bin).



1. In case of **.root** format, a TTree is generated with all the information. The TTree name is "Data" and it contains the following TBranches:
    - Channel (Short)
    - Timestamp (Long Long Int)
    - Board (Short)
    - Energy (Short)
    - EnergyShort (DPP-PSD case only) (Short)
    - Flags (Integer)
    - Probe (Integer)
    - Samples (if enabled) (TArrayS)
2. In case of **.csv** format, the first row indicates the meaning of the subsequent values, which are:
    - PSD (+ waveform) = Time stamp, Energy, Energy short, Flags, (samples);
    - PHA (+ waveform) = Time stamp, Energy, Flags, (samples).

Note: The time stamp is expressed in ps and it has the following limits for all the supported digitizer families: $[0,2^{64}]$ ps.

3. In case of **.bin** format, the output file is represented as follows:

Header	(16 bit, 0xCAEx)
Board	(int, 16 bit)
Channel	(int, 16 bit)
Time Stamp (ps)	(int, 64 bit)

if bit 0 of the Header is 1:

Energy (ch)	(int, 16 bit)

if bit 1 of the Header is 1:

Energy (keV/MeV)	(double, 64 bit)

if both bit 0 and of the Header are 1:

Energy (ch)	(int, 16 bit) +	Energy (keV/MeV)	(double, 64 bit)

if bit 2 of the Header is 1, the following field is present:

Energy Short (ch)	(int, 16 bit)
Flags	(bit-by-bit, 32 bit)

if bit 3 of the Header is 1, the following fields are present:

Waveform code	(int, 8 bit)
Number of Wave samples to be read	(int, 32 bit)
Sample1 ... SampleN	(int, 16 bit each)

Note: In the **.bin** format, the Header is present just once at the beginning of the file and not in each event.

The **x** in the Header is:

- bit 0: if 1, Energy in Channels is present
- bit 1: if 1 ,Energy in KeV/MeV (according to the calibration) is present
- bit 2: if 1, Energy short is present
- bit 3: if 1, Waveform samples are present

Waveform codes are listed below:

1	Input
2	RC-CR (DPP-PHA firmware only)
3	RC-CR2 (DPP-PHA firmware only)
4	Trapezoid (DPP-PHA firmware only)
5	Baseline
6	Threshold
7	CFD (DPP-PSD firmware only)
8	Trapezoid-Baseline (DPP-PHA firmware only)
33	Fast Triangle (x27xx DPP-PHA firmware only)
41	Smoothed Input (DPP-PSD firmware only)

Flags are listed below:

0x1	A dead-time is occurred before this event (includes input stage saturation and board memory full conditions. x724 family DPP-PHA firmware release < 128.64 only.)
0x2	Time stamp roll-over
0x4	Time stamp reset from external
0x8	Fake event
0x10	A memory full is occurred before this event
0x20	A trigger lost is occurred before this event
0x40	N triggers have been lost (N can be set through bits[17:16] of register 0x1n84 in case of x725 and x730 family **[RD21]** or through bits[17:16] of register 0x1nA0 in case of x724, x780, x781 and V1782 family **[RD22][RD23]**)
0x80	The event is saturating inside the gate (DPP-PSD) - The trapezoid is saturating (DPP-PHA)
0x100	1024 triggers have been counted
0x200	First event after a board busy condition
0x400	The input is saturating
0x800	N triggers have been counted (N can be set through bits[17:16] of register 0x1n84 in case of x725 and x730 family **[RD21]** or through bits[17:16] of register 0x1nA0 in case of x724, x780, x781 and V1782 family **[RD22][RD23]**)
0x1000	Event not matched in the time correlation filter
0x4000	Event with fine time stamp
0x8000	Piled-up event
0x80000	Identifies a fake event reporting a PLL lock loss
0x100000	Identifies a fake event reporting an over-temperature condition
0x200000	Identifies a fake event reporting an ADC shutdown

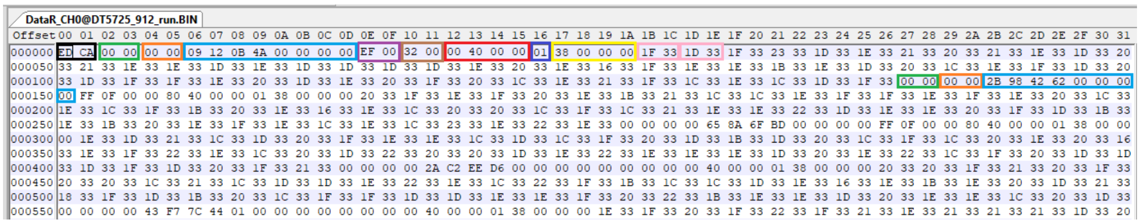
Note: When more than one of the listed condition applies to the same event, flags do sum up. For example a pile-up event in which input has saturated will be flagged as 0x8000 (pile-up event) + 0x400 (input is saturating), so flag will be 0x8400.

Note: In digitizers of generation 1.0, the *Fine TimeStamp* calculation is not always performed; it depends on the board model and the firmware type. Therefore, the flag is raised only when the calculation occurs. In digitizers of generation 2.0, instead, the *Fine TimeStamp* calculation is always performed; consequently, the flag is raised only when it is considered reliable.

Here an example of how to read a binary list file in case of DPP-PSD (enabled options: ADC Channel and waveform with 56 samples):

where the colors correspond to:

- black = header = 0xCAED → Energy is in channels, Energy short and samples are present



- green = board = 0
- orange = channel = 0
- light blue= time stamp = 0x4A0B1209 = 1242239497 (dec) ps
- purple = ELong = 0xEF = 239 ch
- brown = Eshort = 0x32 = 50 ch
- red = flags
- yellow = number of samples = 0x38 = 56 (dec)
- pink = wave samples

After 56 samples data start again from board, channel, etc...

The user has also the possibility to access the filtered list files generated by CoMPASS through a socket and redirect them directly to his/her own post-processing code. The user just need to select the **”Filtered time-sorted binary data through socket”** to access this functionality. In the CoMPASS installation folder under the path

”C:\CoMPASS\demo” in Windows

and

”/CoMPASS-vX.Y.Z/demo in Linux”

a C++ demo code allowing the user to access the data through the socket is provided. The user can write his/her own code starting from this demo code.

The TCP/IP port used by CoMPASS can be set by the user. In case this port is already used by any other process, CoMPASS will display a warning message. If the port 0 is selected, once the socket is started, the Port Selection panel will be updated with the choosen port. The user can compile and execute the demo code using CMake and the CMakeLists.txt file in the demo folder. Following the structure of the packet sent through data socket:

Header	(64 bit)

Event 0:

Board	(int, 16 bit)
Channel	(int, 16 bit)
Time Stamp (ps)	(int, 64 bit)

if bit 0 of the Header is 1:

Energy (ch)	(int, 16 bit)

if bit 1 of the Header is 1:

Energy (keV/MeV)	(double, 64 bit)

if both bit 0 and of the Header are 1:

Energy (ch)	(int, 16 bit) +	Energy (keV/MeV)	(double, 64 bit)

if bit 2 of the Header is 1, the following field is present:

Energy Short (ch)	(int, 16 bit)
Flags	(bit-by-bit, 32 bit)

if bit 3 of the Header is 1, the following fields are present:

Waveform code	(int, 8 bit)
Number of Wave samples to be read	(int, 32 bit)
Sample1 ... SampleN	(int, 16 bit each)

Event 1:

Board	(int, 16 bit)

...

The header is structured as follow:

Fixed word	(16 bit, 0xCAEx)
Payload Type	(uint, 16 bit)
Packet Size	(uint, 32 bit)

The **x** in the Header is:

- bit 0: if 1, Energy in Channels is present
- bit 1: if 1 ,Energy in KeV/MeV (according to the calibration) is present
- bit 2: if 1, Energy short is present
- bit 3: if 1, Waveform samples are present

The payload type is fixed to be 0x0. The packet size is referred to the size of the event section only, ignoring the header size.

2.17.3 Save the spectra

All the spectra can be saved choosing between two options:

- save selected spectra at the end of the run;
- save selected spectra periodically, with a programmable period (minimum is 0.1 s).

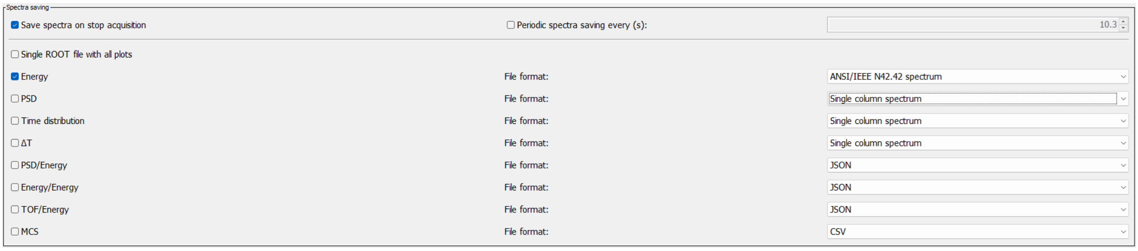
Both options can be checked together.
The available file formats are:

1. Energy spectrum
   - Single column spectrum (.txt)
   - 3 column spectrum (.txt3)
   - ANSI/IEEE N42.42 spectrum (.n42)
   - PC-Toolkit spectrum (.tka)
   - IEC 1455 spectrum (.iec)
   - IAEA spectrum data file (.spe)
   - JSON
2. PSD spectrum
   - Single column spectrum (.txt)
   - JSON
3. Time distribution spectrum
   - Single column spectrum (.txt)
   - 3 column spectrum (.txt3)
   - JSON
4. ΔT spectrum
   - Single column spectrum (.txt)
   - 3 column spectrum (.txt3)
   - JSON
5. 2D PSD vs E spectrum
   - Comma Separated Values (.csv)
   - JSON
6. 2D E vs E spectrum
   - Comma Separated Values (.csv)
   - JSON
7. 2D ToF vs E spectrum
   - Comma Separated Values (.csv)
   - JSON
8. MCS spectrum
   - Comma Separated Values (.csv)

In the Energy three columns text file the order of the columns is: channel number, counts, energy (given as low edge of the calibrated histogram bin) and it includes the calibration parameters and the Real/Live time information.

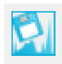
In the Time distribution three columns text file the order of the columns is: channel number, counts, time value (given as low edge of the histogram bin) and it includes Real/Live time information.

In the ΔT three columns text file the order of the columns is: channel number, counts, ΔT (given as low edge of the histogram bin) and it includes the Real/Live time information.

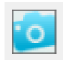


It is also possible, selecting the related option, to save all the spectrum in a single ROOT file.

One file for each enabled channel is generated for filtered and/or unfiltered spectra under the path ”DAQ\run \FILTERED/UNFILTERED”. If no cuts are applied to the spectrum, only the unfiltered one is saved.

The user can also save a spectrum ”on the fly” by pressing the  in the plot window. The spectrum is saved under the path ”DAQ\run\UNFILTERED” or ”DAQ\run\FILTERED” according to the format specified in the Acquisition Tab - Spectra Saving section.

2.17.4 Save an image of the energy, PSD, time, ΔT 2D spectrum and MCS graph

In order to save a picture of the energy, PSD, time and 2D spectrum, the user must press the button  in the plot window. The picture is saved in the .png format under the path "DAQ\run\SCREENSHOTS".

2.17.5 The run_name_info.txt file

At the end of each run, CoMPASS automatically saves a text file in which several useful information about the just completed run are included. The name of this file is the same as the run name (so it can be customized changing the run name in the Acquisition tab) to which a "_info" suffix is added.

Such file includes the following infomation:

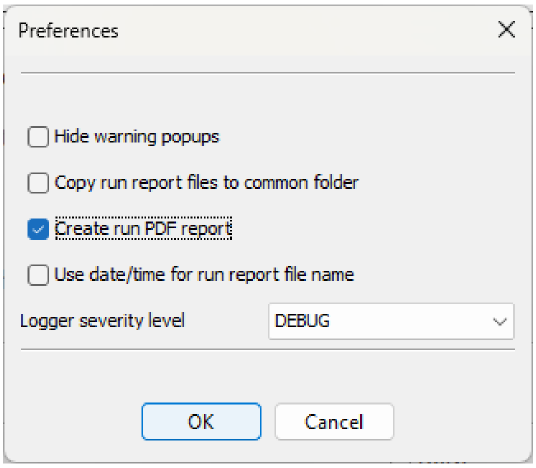
- the run ID
- the run start date and time
- the run stop date and time
- channel by channel:
  - Energy calibration coefficients and units;
  - Real time as hh:mm:ss.000;
  - Live time as hh:mm:ss.000;
  - Dead time as percentage;
  - Input counts and average rate (cps);
  - Pile up counts and average rate (cps);
  - Saturation counts and average rate (cps);
  - E cut (events rejected because of energy selection) counts and average rate (cps);
  - PSD cut (events rejected because of PSD selection) count sand average rate (cps);
  - T cut (events rejected because of time selection) counts and average rate (cps);
  - Singles (events rejected because not matching the time correlation selection) counts and average rate (cps);
  - Output counts and average rate (cps);
  - (DPP-PSD only) "Particle 1 name" (events tagged as "Particle 1 name") counts and average rate (cps). "Particle 1 name" can be specified by the user in the Particle ID tab;
  - (DPP-PSD only) "Particle 2 name" (events tagged as "Particle 2 name") counts and average rate (cps). "Particle 2 name" can be specified by the user in the Particle ID tab;

2.17.6 Report generation

CoMPASS allows the user to automatically generate a report of the current run at the end of the acquisition. In order to enable this funcionality, before staring the data acquisition run, select from the CoMPASS main menu Tool → Preferences. The Preferences popup will appear allowing the user to select the report generation option.

Report will be generated in PDF format and, for each of the enabled boards and channels will include:

- Board Information
- Run Start/Stop date and time



- Run statistics information
- Pictures of the spectra

The run report is saved within the specific run folder.

Selecting the option ”Copy run report file to a single folder”, CoMPASS will save all the PDF report files as well as the TXT run info files within the same folder that currently is

”C:\Users\<USER_NAME>\AppData\Local\Compass\data.

CoMPASS report generation functionality is still preliminary. Report format and content will be improved in the following releases.

2.18 How to reprocess the CoMPASS data files

CoMPASS allows the user to reprocess all the files saved during a data taking run, be they a board buffer, a list file or a spectrum.

As explained in the section **Open a CoMPASS Project**, when opening a project including data saved in one or more previous acquisition, in the CoMPASSPlot the **Offline data** section becomes available. Clicking on the **Offline data**, the below sections (Boards data buffer, List, Spectra) becomes available and selecting one of them the user can check the included data files.

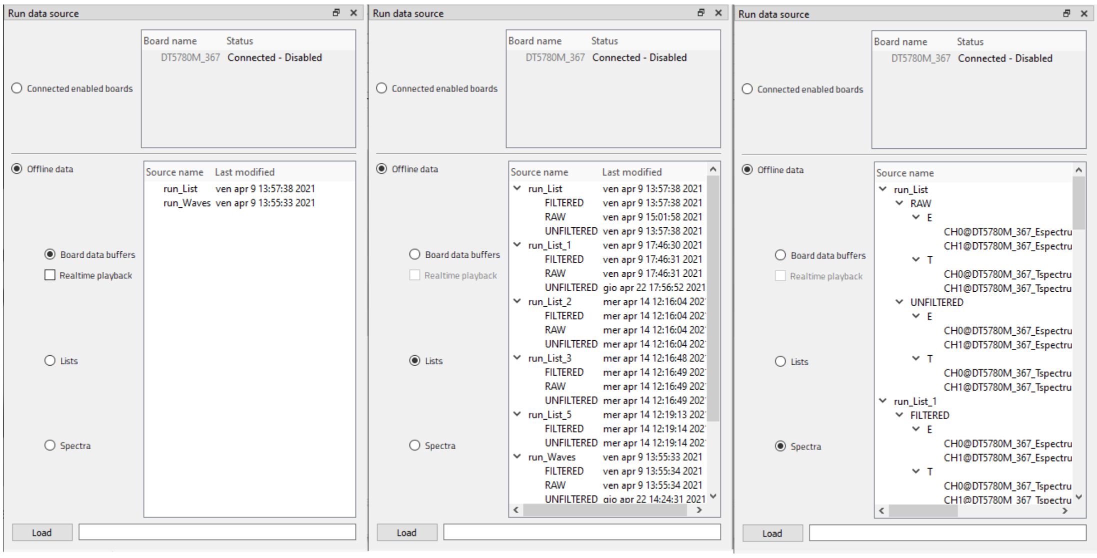


Fig. 2.119: Saved data present in the project folder as displayed in the CoMPASSPlot Window.

2.18.1 How to reprocess the Board data buffer data files

CoMPASS allows the user to re-run previous acquisitions starting from the most preliminary data files coming from the digitizer and not even decoded by the software, the so called *Board data buffers*. Such data allows to rerun a previously exactly an a normal run except for what concern the board(s) parameters settings that cannot be modified anymore. The rest of the software capabilities remains unchanged: the user can display the spectra, apply data selection (see Sec. **How to set Energy, PSD and Time selections**) and save new list and spectra files.

The CoMPASS main GUI will reflect the above by disabling all the parameters and setting that cannot be changed in the current offline condition.

In order to perform a such kind of offline run, you have to select the *Board data buffer* option, select the run in the displayed list of runs and then press the *Load* button or double click on the run to load it. You can also select the speed of the run reproduction. Default is high speed, otherwise select **Real time playback** for reproducing the run at the real speed.

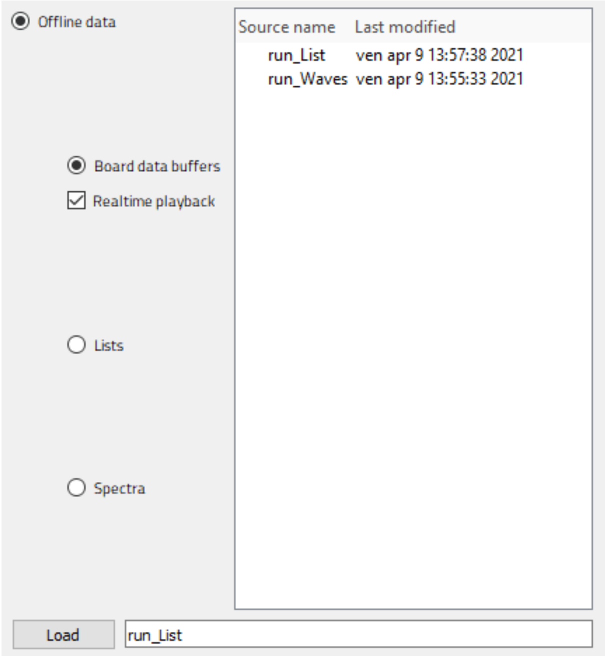


Fig. 2.120: Offline run - Board data buffer option.

The offline run kind is also reflected in the main GUI status bar

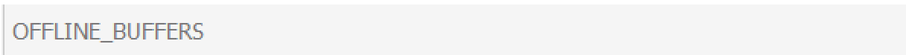


Fig. 2.121: Offline run - Board data buffer option - GUI status bar.

and in the CoMPASSPlot Status bar.

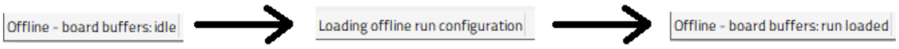


Fig. 2.122: Offline run - Board data buffer option - GUI status bar.

Press Play to start the run. All the functionalities of the CoMPASSPlot (available plots, ROI management, calibration, event selection) are available as well as the data saving functionalites.

Note: It is not possible to save an offline data file while performing an Offline run on Board data buffer files.

While the run is being processed the information about the original run duration and the current processing time are displayed in the Statistics tab top bar.

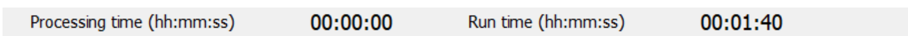


Fig. 2.123: Processing time and original online run duration.

2.18.2 How to reprocess the List data files

CoMPASS allows the user to re-run previous acquisitions starting from list data files that are the data coming from the digitizer but already decoded by the software and, depending on which kind of list file is used (Raw, Unfiltered and Filtered), possibly passed through some kind of selection.

Besides of being not possible anymore to change the board parameters, depending on what kind of List file is used for the offline processing, some functionalities are not available anymore. For example:

- Add-Back and Time correlation are possible only if **a single time ordered list file** has been saved
- Raw and Unfiltered list file cannot be saved anymore if the offline processing is done with an Unfiltered or Filtered list file respectively, i.e. it's not possible to "go back" in data saving as the events that would have been included in the Raw or Unfiltered list file have been already removed
- It's not possible to save a single time ordered list file if in the online acquisition the option "one file per channel" was selected.

The rest of the software capabilities remains unchanged: the user can display the spectra, apply further data selection (see Sec. **How to set Energy, PSD and Time selections**) and save new list and spectra files.

The CoMPASS main GUI will reflect the above by disabling all the parameters and setting that cannot be changed in the current offline condition.

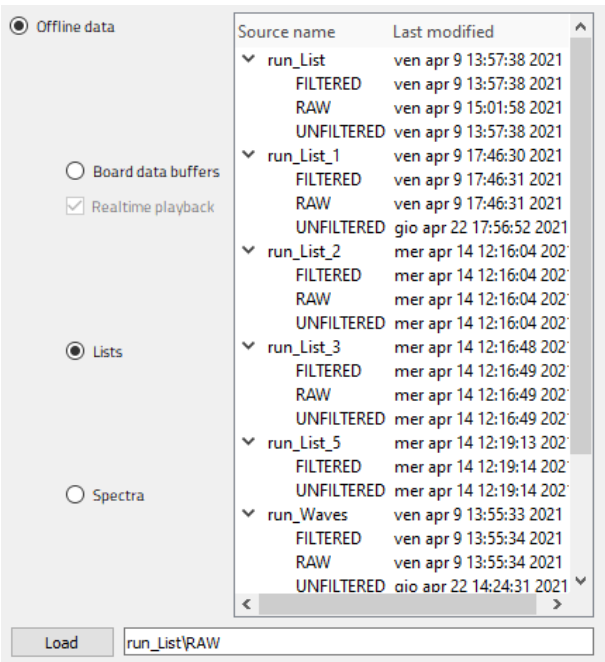


Fig. 2.124: Offline run - Board data buffer option.

In order to perform a such kind of offline run, you have to select the *List* option, select the run in the displayed list of runs and then press the *Load* button or double click on the run to load it.

Also in this case, the offline run kind is also reflected in the main GUI status bar and and in the

CoMPASSPlot Status bar.

Press Play to start the run. All the functionalities of the CoMPASSPlot (available plots, ROI management, calibration, event selection) are available as well as the data saving functionalities with the limitation above described.

Also in this case, while the run is being processed the information about the original run duration and the current processing time are displayed in the Statistics tab top bar.

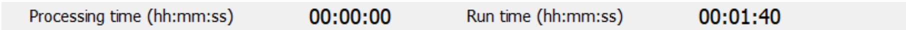


Fig. 2.125: Processing time and original online run duration.

2.18.3 How to reprocess the Spectra files

CoMPASS allows the user to re-process any kind of spectra (Energy, PSD, Time and ΔT) taken in a previous acquisition. When processing a spectrum the spectrum rebin and manually set of the calibration coefficient are the only settings that will remain settable in the CoMPASS main GUI. All the others will be disabled.

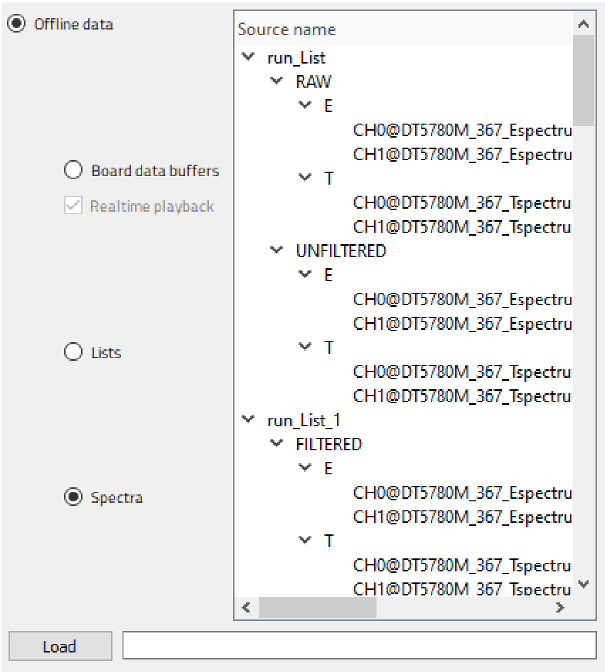


Fig. 2.126: Offline run - Spectra option.

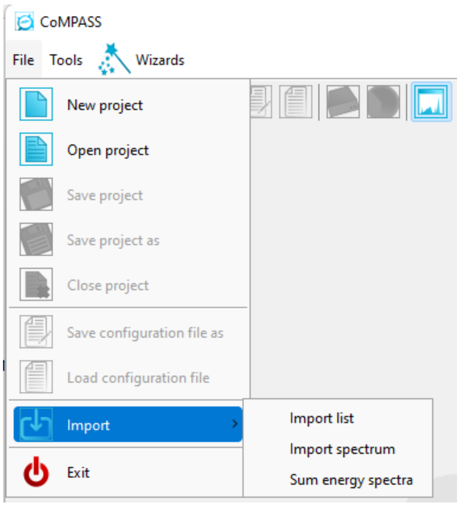
The procedure to be followed to load a spectrum is similar to the one described here above so you have to select the *Spectra* option, select the spectrum in the displayed list and then press the *Load* button or double click on the spectrum to load it.

Also in this case, the offline processing kind is also reflected in the main GUI status bar and and in the CoMPASSPlot Status bar.

The CoMPASSPlot available functionalities are ROI management, calibration and spectrum subtraction.

2.18.4 How to sum the energy spectra

In order to sum more energy spectra created by CoMPASS you have to select File → Sum energy spectra.



The Add spectrum selection windows will then appear and you can then select the spectrum to be added.

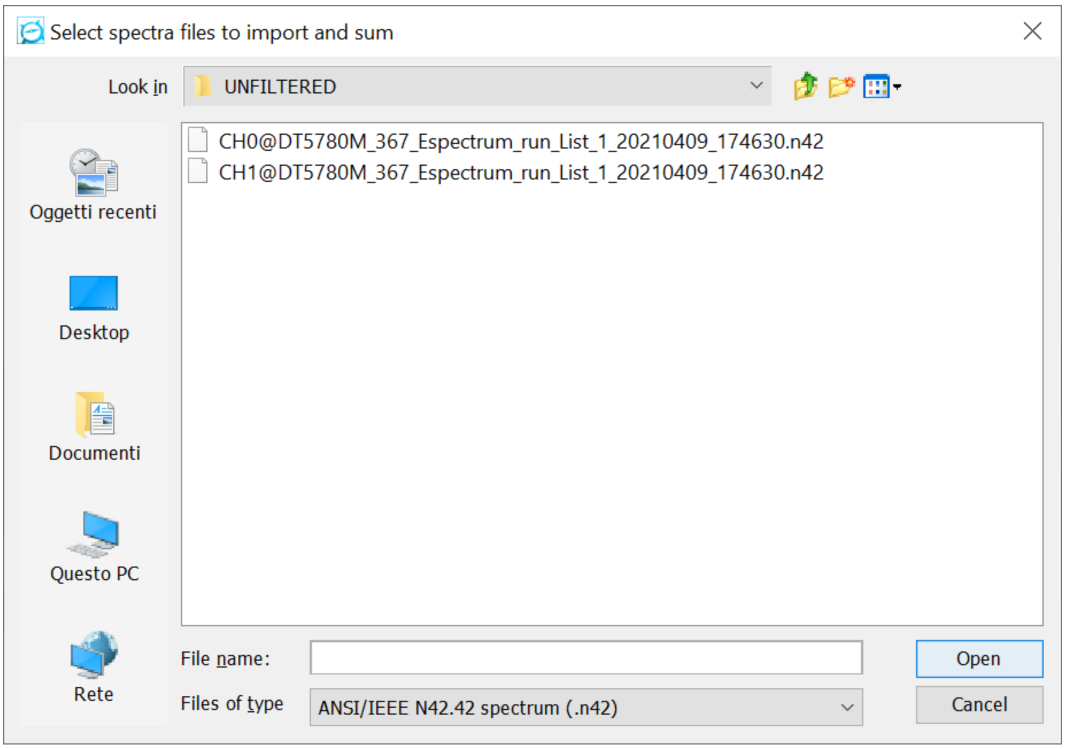


Fig. 2.127: Sum spectrum selection window.

CoMPASS will the make a copy of the original spectra and include them in the project-like folder structure.

CoMPASS will notify the user in case of possible issues with the spectrum format.

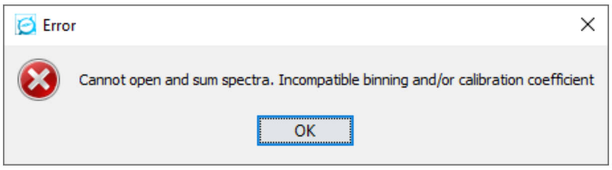


Fig. 2.128: Example of error in the spectrum import and sum.

In case of no issues, CoMPASS import and sum the spectra in the CoMPASSPlot window and then you can apply all the CoMPASSPlot tools (ROI management, calibration, spectra subtraction).

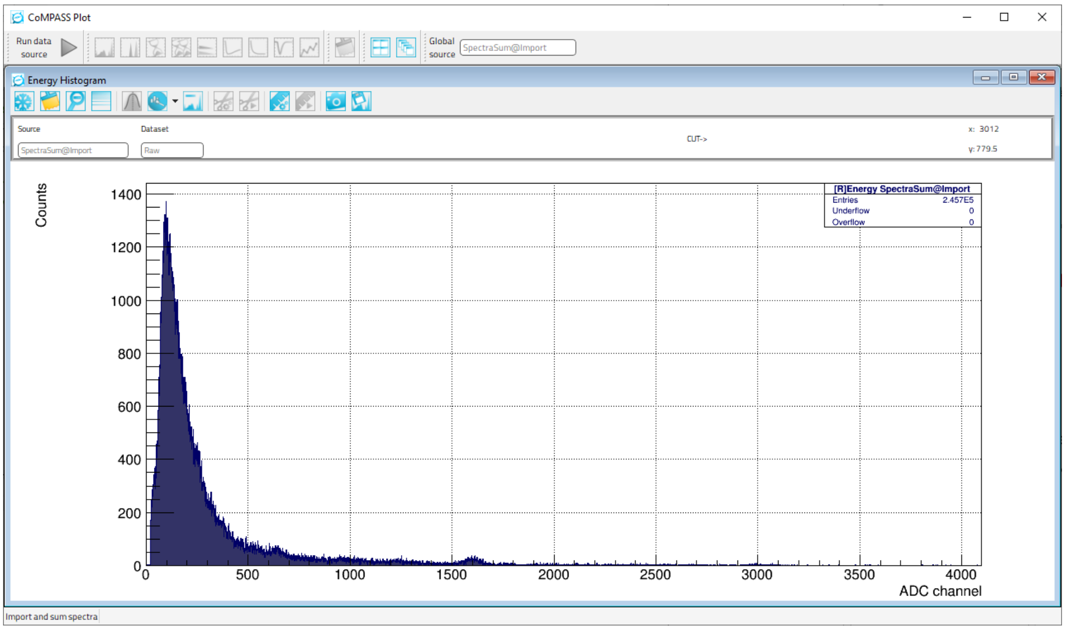


Fig. 2.129: Imported and summed spectra.

2.18.5 How to subtract two energy spectra

In order to subtract two energy spectra (eg the background from a main spectrum), you have to press on the button 

A dedicated pop up to select the spectrum to subtract will appear.

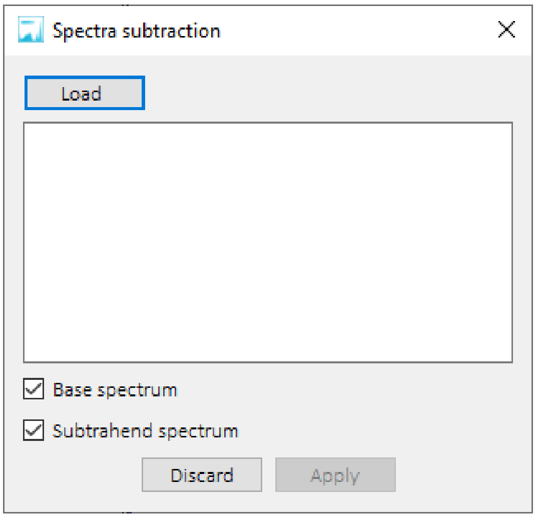


Fig. 2.130: Spectra subtraction popup.

Press the load button to open the spectrum selection window.

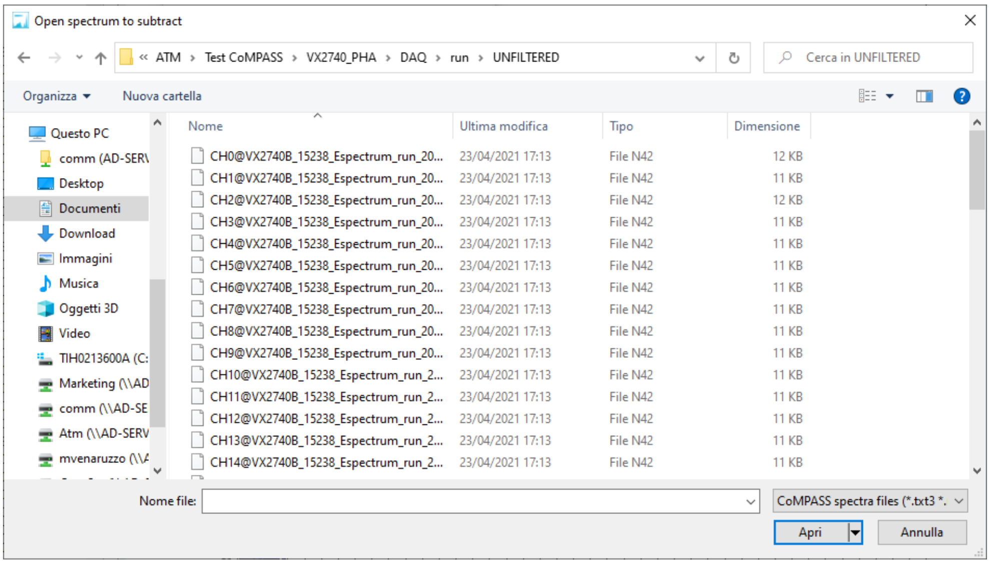


Fig. 2.131: Spectrum to be subtracted selection window.

Select the spectrum to subtract and press Open. The selected spectrum path will be then displayed in the dedicated popup.

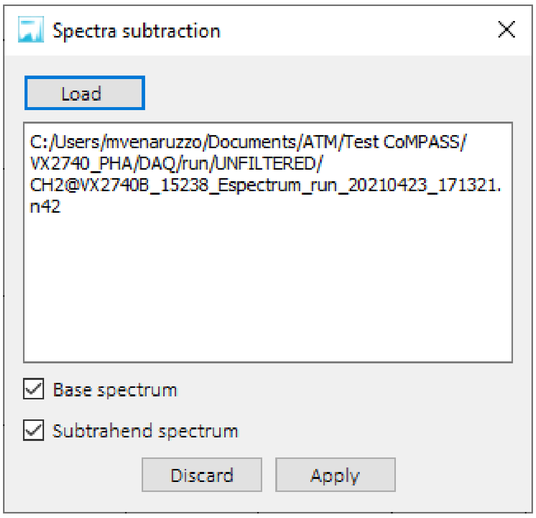


Fig. 2.132: Spectra subtraction popup with spectrum to be subtracted path.

If the two spectrum are not compatible in terms of number of channels or calibration coefficients, CoMPASS will notify the user with a popup and the subtraction operation cannot be performed.
Otherwise, if not such issue occur CoMPASS will shown in the same plot both the spectrum normalized one to each other by means the total number of events.

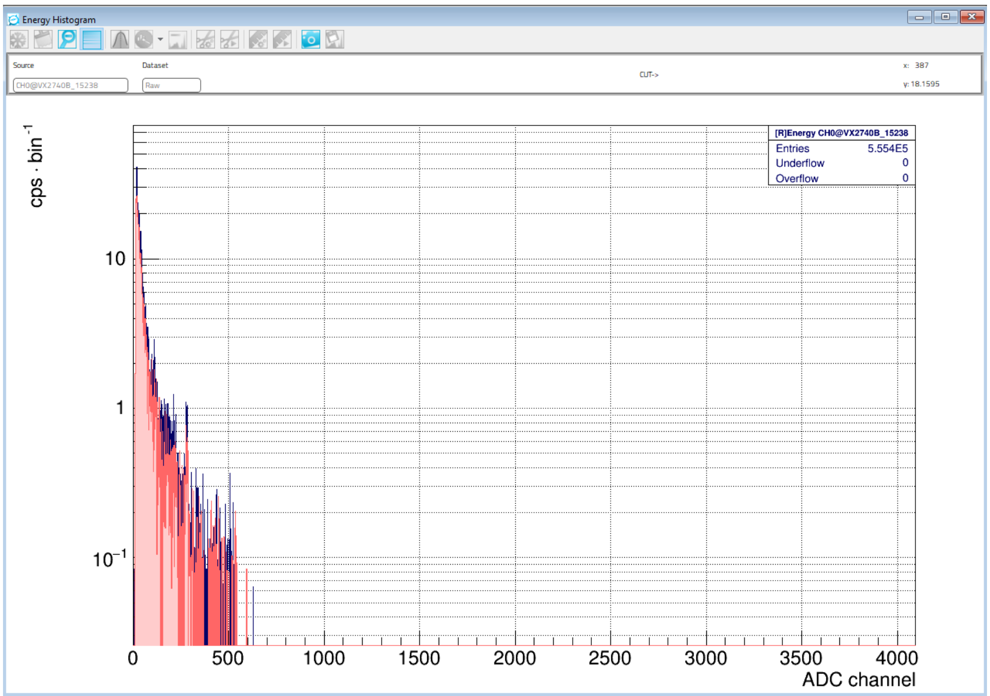


Fig. 2.133: Main and subtrahend spectrum.

You can see separately the original spectrum and the subtrahend one selecting *Base Spectrum* or *Subtrahend spectrum* respectively. Press the button Apply to proceed with the spectrum subtraction. The resulting spectrum will be then shown in the same window.

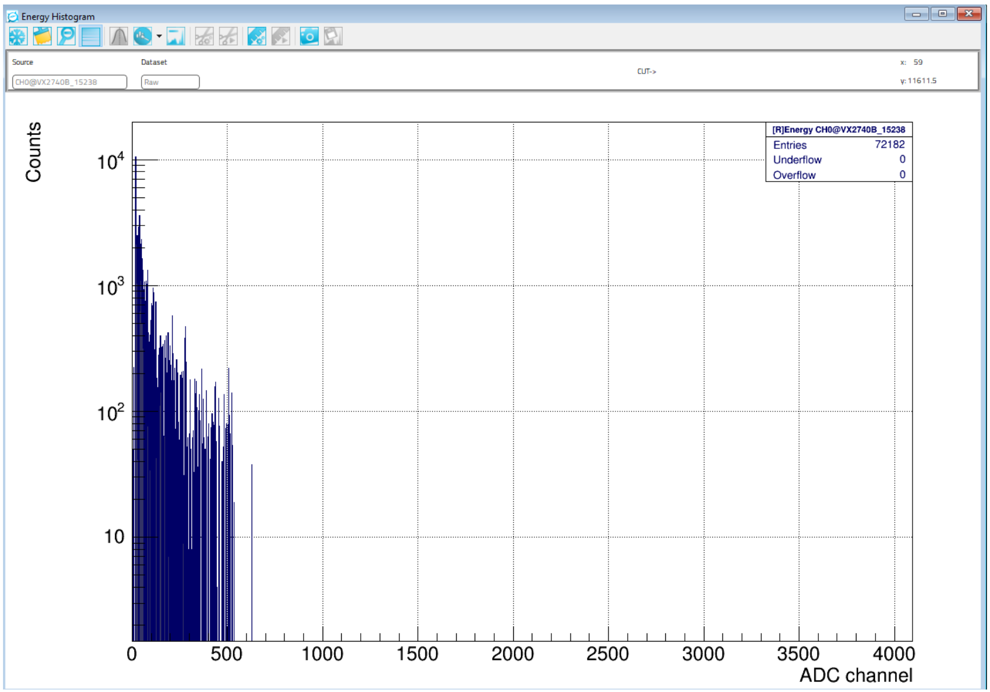
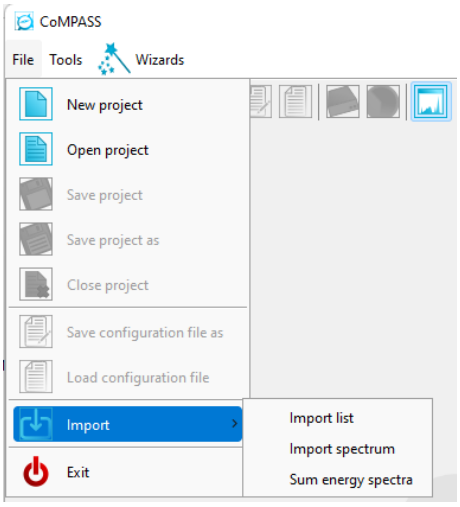


Fig. 2.134: Subtracted spectrum.

On the resulting spectrum you can still apply the CoMPASS ROI management tools for your preliminary basic analysis.

2.18.6 How to import a spectrum

In order to import in CoMPASS a spectrum in one of the supported formats, you have to select File → Import spectrum.



The Import spectrum selection windows will then appear and you can then select the spectrum to be imported.

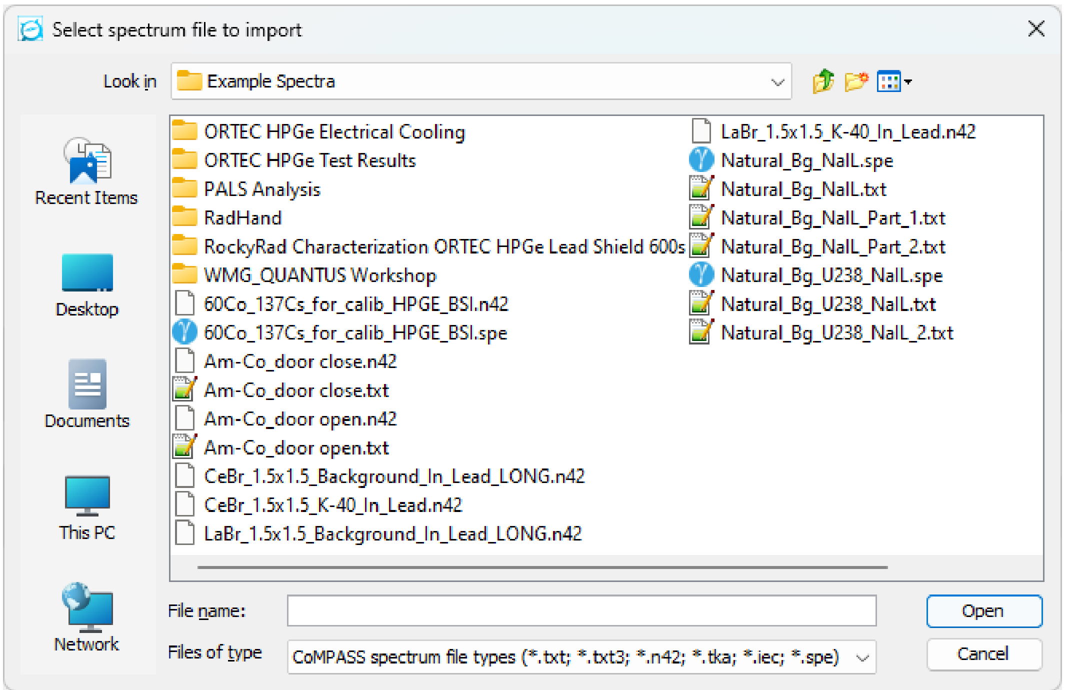


Fig. 2.135: Import spectrum selection window.

If the imported spectrum is a .txt, a .txt3, a .CSV or a JSON file, the ambiguity about its content has to be removed before importing it; for this reason CoMPASS shows a pop-up asking the user which kind of spectrum is going to be imported.

CoMPASS will the make a copy of the original spectrum and include in a project-like folder structure.

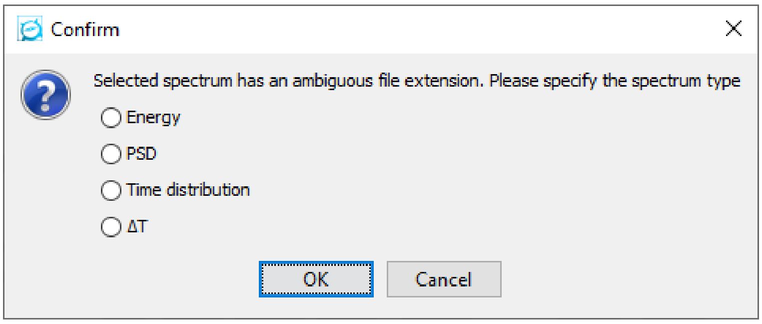


Fig. 2.136: Import spectrum type selection window example.

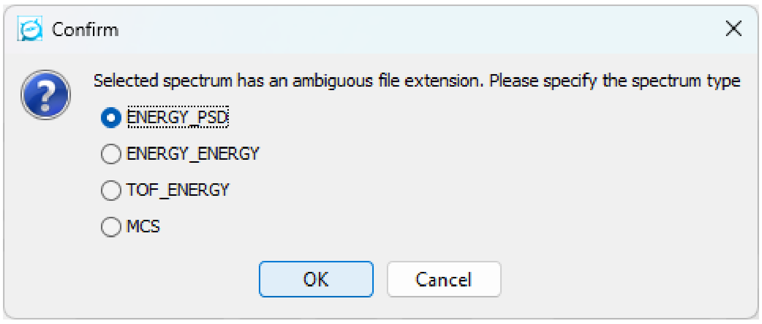


Fig. 2.137: Another import spectrum type selection window example.

CoMPASS will notify the user in case of possible issues with the spectrum format.

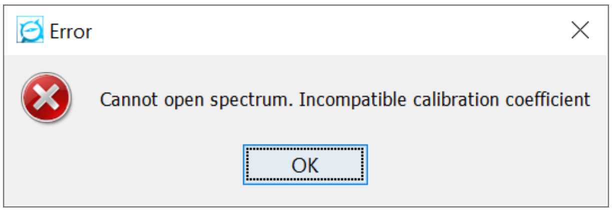


Fig. 2.138: Example of error in the spectrum import. Incompatible calibration coefficient.

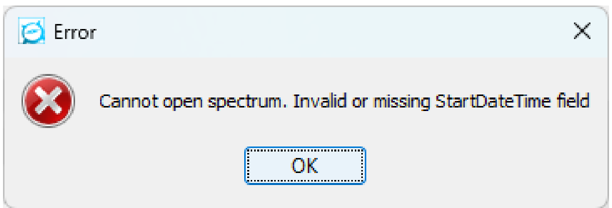


Fig. 2.139: Example of error in the spectrum import. Invalid or missing mandatory information.

In case of no issues, CoMPASS import the spectrum in the CoMPASSPlot window and then you can apply all the CoMPASSPlot tools (ROI management, calibration, spectra subtraction).

Note: Spectrum files not generated by CoMPASS may be imported provided that they are in one for the format supported by CoMPASS.

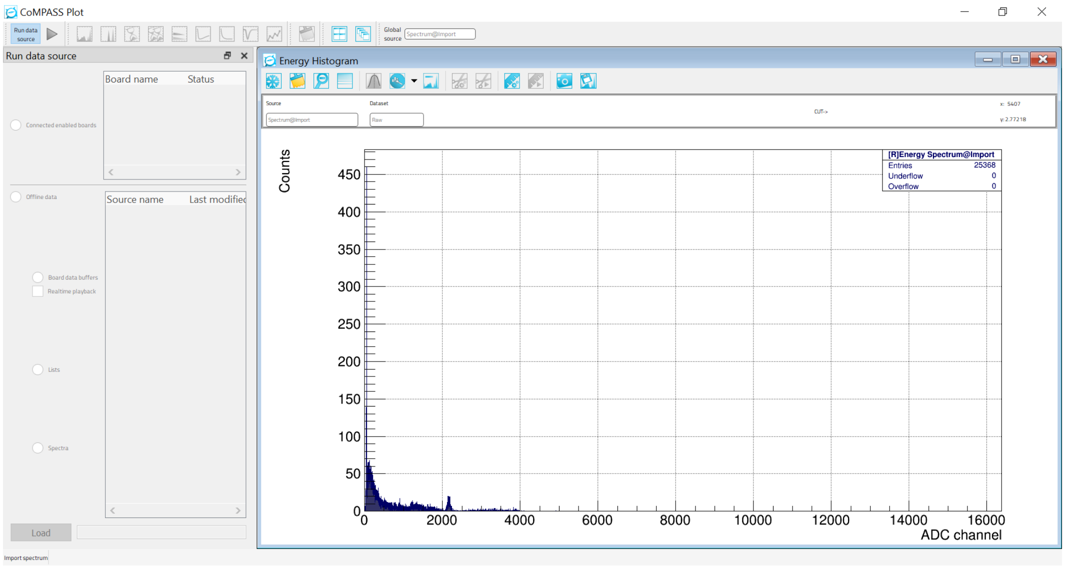
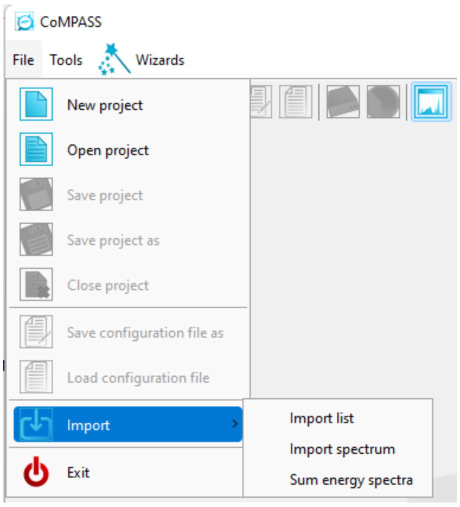


Fig. 2.140: Imported spectrum.

2.18.7 How to import a list

In order to import in CoMPASS a list file in one of the supported formats, you have to select File → Import list.



CoMPASS will the make a copy of the original list file and include in a project-like folder structure.

CoMPASS will notify the user in case of possible issues with the spectrum format.

In case of no issues, CoMPASS import the list file and allows to run process the list file and to apply the events rejection criteria (saturations, pile-up, energy, psd and time selection). If the imported list file is a single time sorted file, the channel correlation selection and the AddBack functionality are also available. If the list files includes the waveform sample, the waveform display (if running in Waves mode) is available as well. In addition, as in the Import spectrum case, you can apply all the CoMPASSPlot tools (ROI management, calibration, spectra subtraction).

New list and spectrum files can be saved with some limitation:

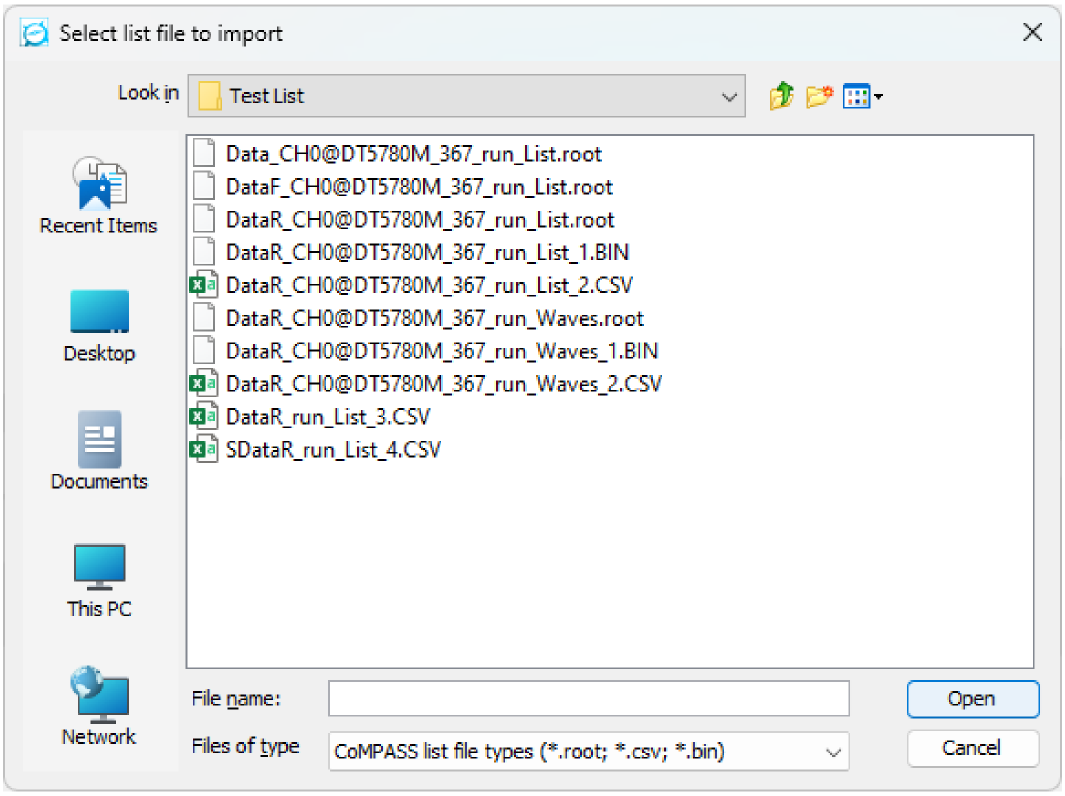


Fig. 2.141: Import list selection window.

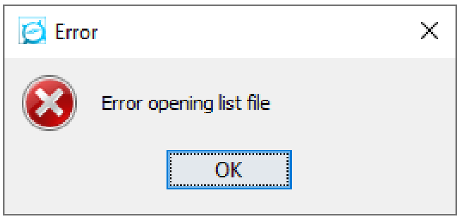


Fig. 2.142: Example of error in the list import.

- when processing a Raw List, it's possible save again a Raw list in a different format, Unfiltered list and Filtered List;
- when processing an Unfiltered List, it's possible save again an Unfiltered list in a different format and Filtered List only;
- when processing a Filtered List, it's possible save again an the same Filtered list in a different format and Filtered List with more restrictive selection criteria only.

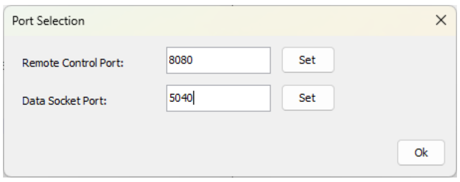
2.19 How to (remotely) control CoMPASS from command line or external script

For those users who have the requirement to (remotely) control CoMPASS from an external script or software, CoMPASS now allows such possibility.

The mandatory requirement is that CoMPASS has to be up and running in the pc connected to the digitizer(s). Then the user can enable the CoMPASS remote control pressing the button Remote control in the CoMPASSPlot window top ribbon. When such remote control is selected, CoMPASS starts an internal HTTP server that stays listening for HTTP request coming from the client whatever is its implementation (C, C++, Java, Python, MATLAB, LabVIEW, ecc).
CoMPASS uses only the HTTP 'GET' request method among the available ones, and can be controlled by properly setting the URL path and optionally a query string.
Once the remote control is enabled the user can easily test it with a web browser by typing the URL with the base path:

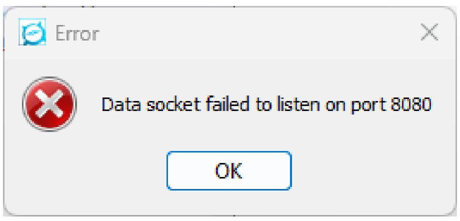
```
http://IP_ADDRESS:8080/compass/
```

where `IP_ADDRESS` is the IP Address of the computer in which CoMPASS is running, e.g. localhost, 192.168.0.1, etc... The `IP_ADDRESS` is followed by `:8080`, which is an example of the Remote Control port. This port can be configured from the "Tools" pull-down menu in the CoMPASS window by selecting "Port Selection":



Note: To make the changes effective, please press "Set" each time a port is modified.

If the selected port is not available, the software will automatically assign another port to ensure proper functionality of the features. If the same port is chosen for both Remote Control and Data Socket, CoMPASS will display an error message to warn the user that this configuration is not allowed.



Commands can be sent by appending a '/' and the command name to the base path of the URL

```
http://IP_ADDRESS:8080/compass/COMMAND
```

The list of available commands is:

- `START` to start the acquisition;

Fig. 2.143: CoMPASS browser remote control window example.

- `STOP` to stop the acquisition.

A specific configuration file can be uploaded by appending a query string (beginning with the '?' character) to the base path in the URL:

```
http://IP_ADDRESS:8080/compass?loadConfigFile=file.xml
```

The same rule applies if the user wants to set acquisition parameters:

```
http://IP_ADDRESS:8080/compass?PARAMETER_NAME=value
```

where

- `PARAMETER_NAME` is the parameter name;
- `value` is one of the allowed value for that parameter.

The parameters and the corresponding allowed values are:

- `runId` which is the name of the run;
- `timedRunEnabled`. Allowed values: TRUE, FALSE;
- `autoIncrementRunId`. Allowed values: TRUE, FALSE.
- `timedRunDuration`. Allowed values: integer value corresponding the run duration in seconds.

It is also possible to set more than one parameter at a time in the query string, with parameter=value pairs separated by the & character:

```
http://IP_ADDRESS:8080/compass?PARAMETER_NAME_1=value&PARAMETER_NAME_2=value
```

The user should avoid to load the configuration file and modify one of the above listed parameters in the same HTTP request because it is not guaranteed the order to the requested implementation. It is on the contrary recommended to first load the configuration file in a specific HTTP request and then, in required, modify the needed parameters in an second HTTP request.

The CoMPASS remote control infrastructure uses some of the standard HTTP response code and one custom. They are:

- `OK_200` = 200;
- `FORBIDDEN_403` = 403;
- `NOTFOUND_404` = 404;
- `INTERNALSERVERERROR_500` = 500;
- `NOTIMPLEMENTED_501` = 501;
- `CANNOTOVERWRITE_599` = 599.

In order to provide to the users and example of the implementation of an HTTP client, CAEN provide a C++ based demo code included in the CoMPASS installation folder at the path

"C:\CoMPASS\demo" in Windows

and

"/CoMPASS-vX.Y.Z/demo" in Linux.

Such demo uses the `libcurl` library and shows all the remote control functionalities with some acquisition examples including recursive acquisitions with the same or different configuration files and with some pause time between consecutive runs.

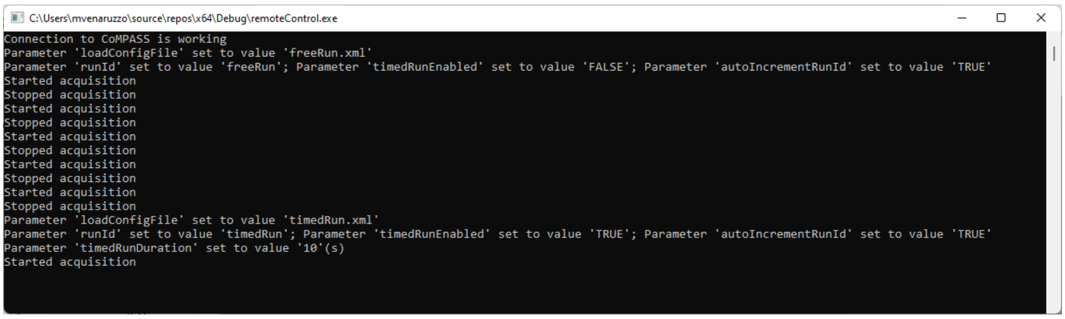


Fig. 2.144: CoMPASS remote control demo code output.

Such demo can be the starting point for people willing to develope their external (remote) CoMPASS control in C++ or can be inspiration for those user willing to develop it in other programming environment.

Note: The user can download the `libcurl` library at the link https://curl.se/libcurl/.

Note: After saving the CoMPASS project, if *Remote Control* is selected, the selection will persist even after the project is closed and reopened.

3 Digitizer Synchronization Guide

This chapter will guide the user to synchronize two or more CAEN digitizers running a DPP firmware. The first section is focused on the VME boards, the second section on the Desktop and NIM boards, the third section on the new VME27XX and Destop DT57XX boards while the forth section on a mixed system composed by V17XX and V27XX boards. This document is based on **[RD24]**.

3.1 Synchronization of the VME V17XX digitizers

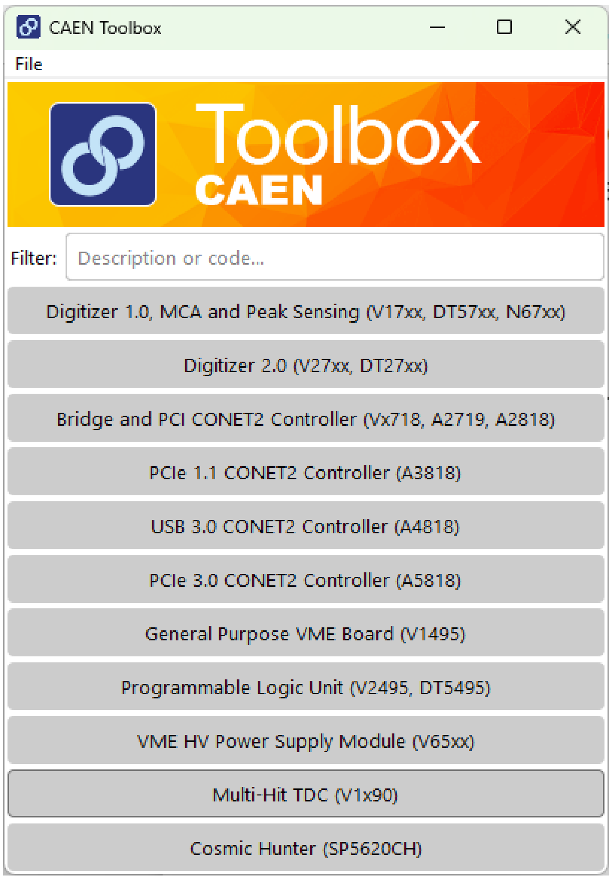
In the following, one V17XX digitizer acts as the master board while the others act as slaves. The idea is to lock the clocks of all the digitizers and to propagate the start of run in a daisy chain configuration.

Required software:

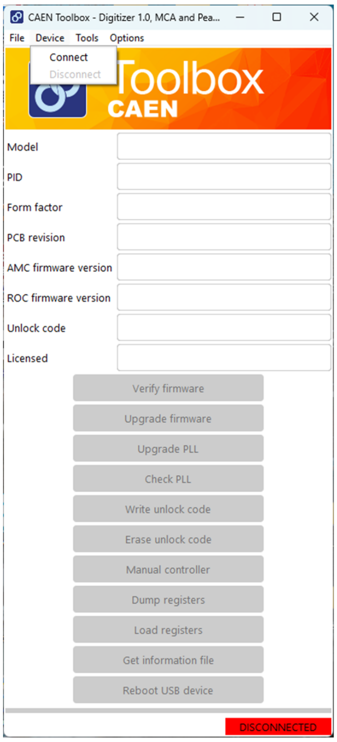
- CAEN Toolbox;
- CoMPASS

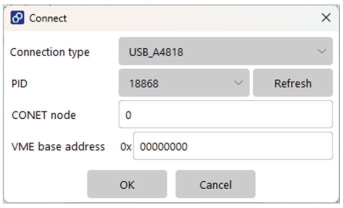
Phase 1: the **clock synchronization**:

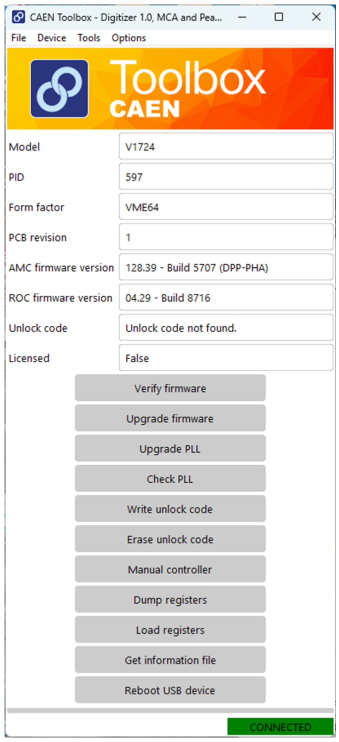
1. The PLL of master must be reprogrammed to provide in the CLOCK OUT the 50 or 62.5 MHz frequency depending on the slave board.
   - Open CAEN Toolbox, select "Digitizer 1.0".



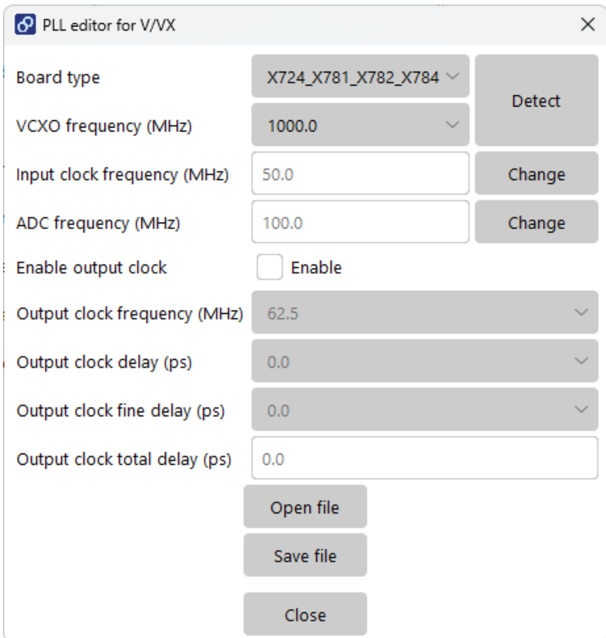
- from the top menu select Device → Connect, insert the digitizer connection parameters and press Connect.



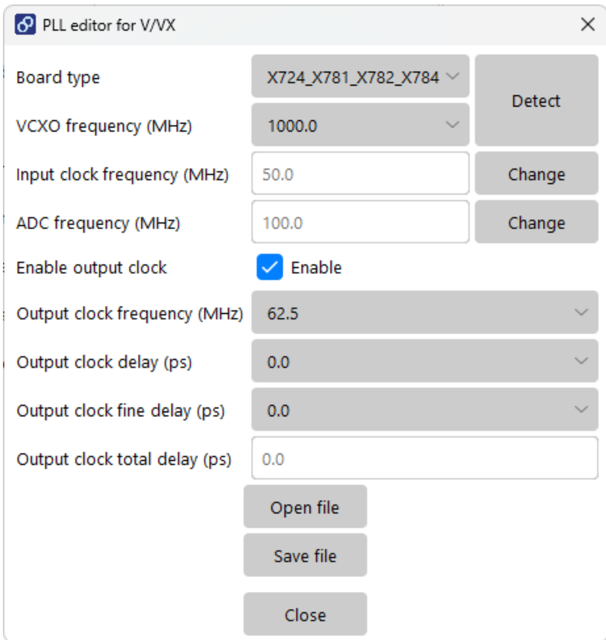




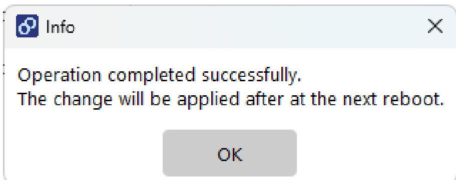
- if the master digitizer is a V1720, V1724, V1740D, V1751 or V1782, select Tools → PLL Editor from the top menu. The PLL Editor will open. Press "Detect" button to detect the currently connected digitizer.



- Tick ”Enable clock output” and select the clock output frequency depending on the slave digitizer model. Set the Clock output delay if required.

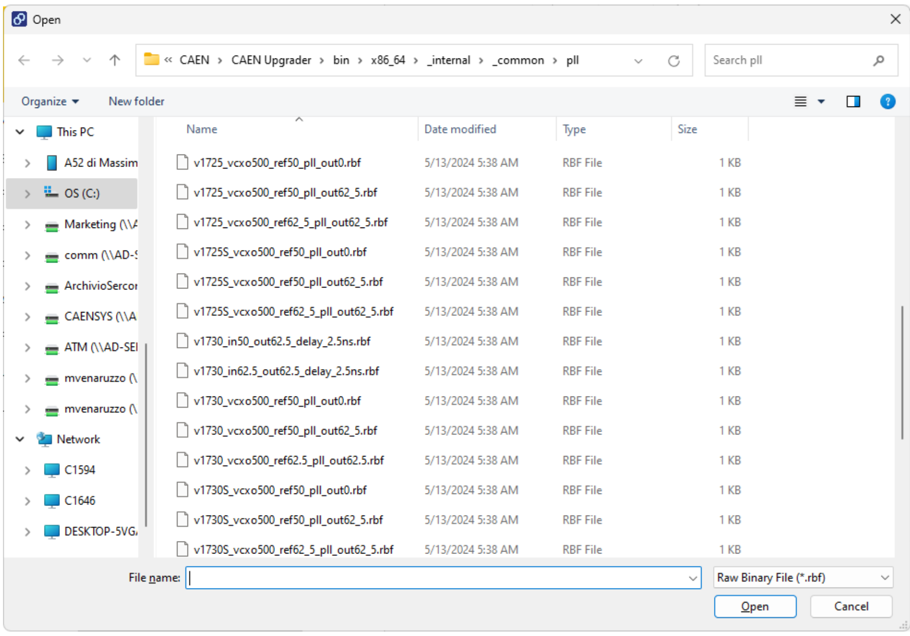


- Press ”Save” button to save the PLL .rbf file to the desired location on the pc and close the PLL editor.
- Press the ”Upgrade PLL” button and select the PLL .rbf file previously generated. CAEN Toolbox will automatically start the file upload and the PLL programming. Once the file upload is completed the following message appears.



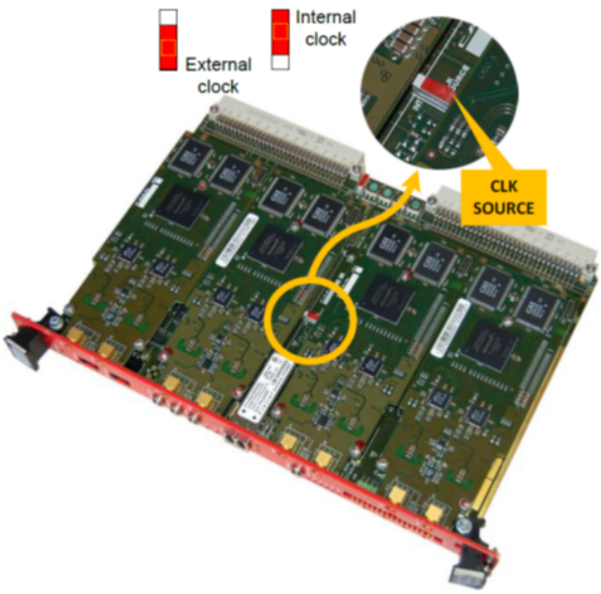
- Power off and on the crate to apply the new PLL configuration.

• if the master digitizer is a V1725(S) or a V1730(S) user can follow the same procedure described here above or press directly the ”Upgrade PLL” button.
  - In the browser folder, select the file corresponding to the board model like ”v1725_vcxo500_ref50_pll_out62_5.rbf” and press open.

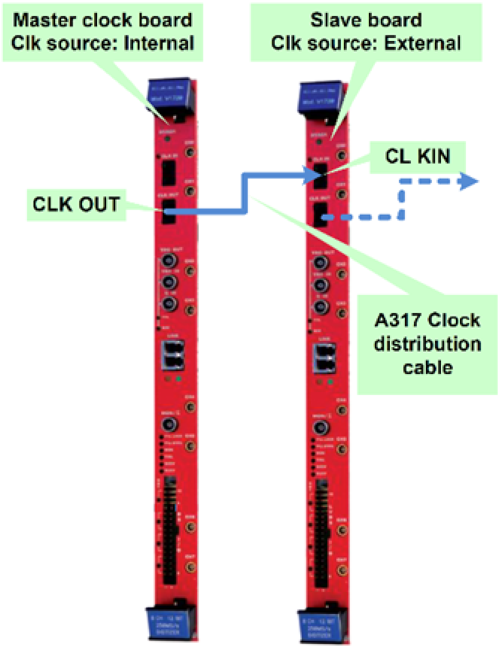


– CAEN Toolbox will automatically start the file upload and the PLL programming. Once the file upload is completed the same previous message appears.

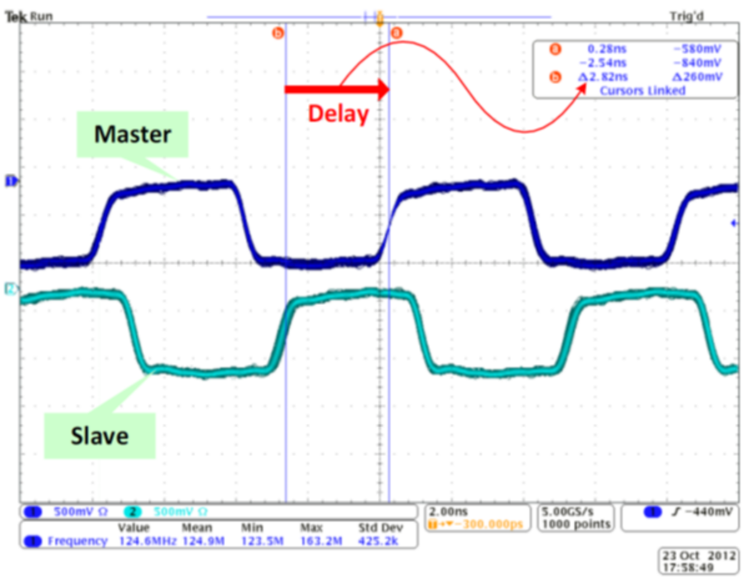
- The PLL of the slave must be reprogrammed to accept in input the 62.5 MHz frequency only if it is a V1725(S) a V1730(S) or a V1740D. All the other digitizer families are indeed already programmed to accept in input the 50 MHz frequency. Other digitizer families have to be programmed to provide in output the 50 MHz only if they are not the last board of the chain.
  – From CAEN Toolbox follow the same procedure above described to connect to the slave board
  – Depending on the digitizer model, proceed with the PLL file generation or selection from the available list files as described in the above paragraphs.
  – Upgrade the PLL firmware into the V17XX.
- Power off the crate.
- Move the DIP switch of the V17XX (slave) from internal to external



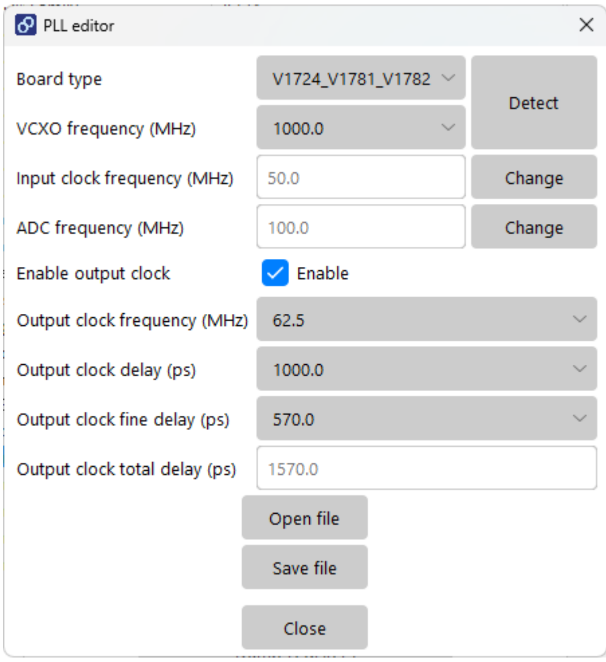
- Connect the A317 cable from the CLOCK OUT connector of master to CLOCK IN connector of slave



- Switch on the crate. The CLOCK IN led of the slave board must be ON; The PLL LOCK led of both boards must be ON.
- To verify that the two clocks are latched and to measure the delay between them, it is possible to provide to the TRG OUT connector the clock and check it from an oscilloscope. In CoMPASS, go into the Sync/Trg tab within **each single board** Settings Tab and select **TRG OUT mode** → **Sampling clock**
- Connect the TRG OUT connector output of each board to an oscilloscope and the check:
  - There is no reciprocal jitter between each other.
  - Measure the delay according to the following scheme



- Reprogram the master board with a PLL file with a delay value as closest as possible to the measured one.

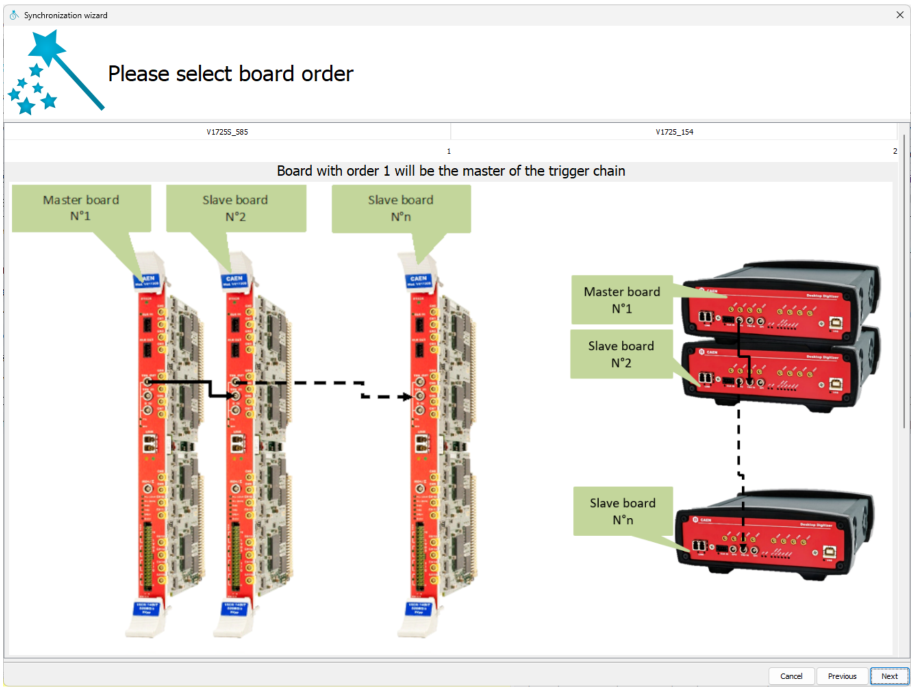


Note: In case of a system composed by digitizer of different families and including V1725(S) and V1730(S) digitizers, it is recommended to put such modules at the end of the chain. They will then receive the 50 MHz reference clock and propagate the 62.5 MHz reference clock to the other V1725(S) and V1730(S).

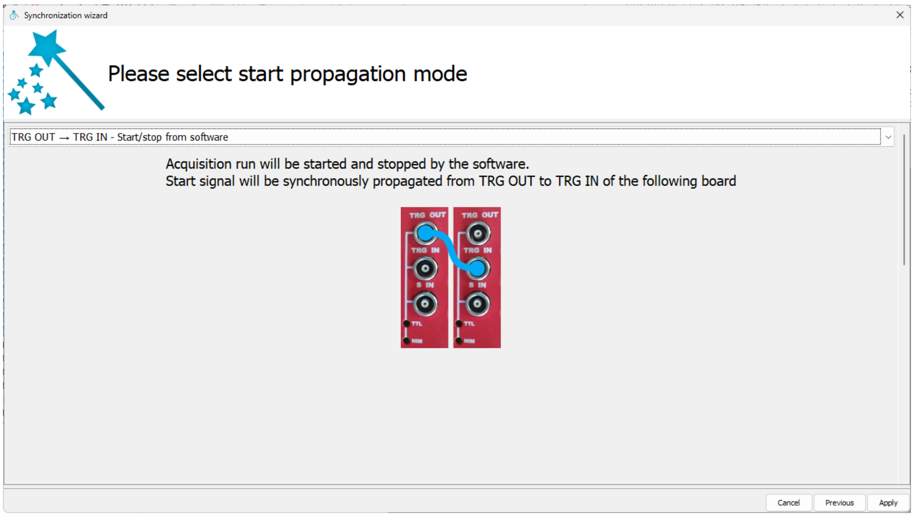
In case the clock of a slave board has been modified to accept an external clock frequency different from 50 MHz, when the clock source it set back to the internal one, before using again the digitizer, the user must remember to program the board PLL again with the default 50 MHz PLL file. Missing such digitizer reprogramming might lead either to the impossibility for the digitizer to lock the PLL or to a digitizer wrong events timestamp information provision.

Phase 2: the ***start_acquisition* propagation**.

1. Connect the TRG OUT connector of master V17XX with TRGIN connector of the first slave V17XX through a LEMO-LEMO cable and proceed this way building a daisy chain with all the digitizer belonging to the system.
2. Open the CoMPASS software and select ”Menu → Synchronization wizard”. In the second tab, set the board order



3. In the third tab, choose one of the available *start_acquisition* propagation option, for example the TRGOUT_TRGIN_OUT option:



4. You can adjust the run delay from master to slave by providing a single pulse into the two boards and check the reported time stamp. This step is not fundamental, the relative delay can be adjusted offline by software.

The two boards are now synchronized and the customer can start the acquisition by pressing the START button in CoMPASS.

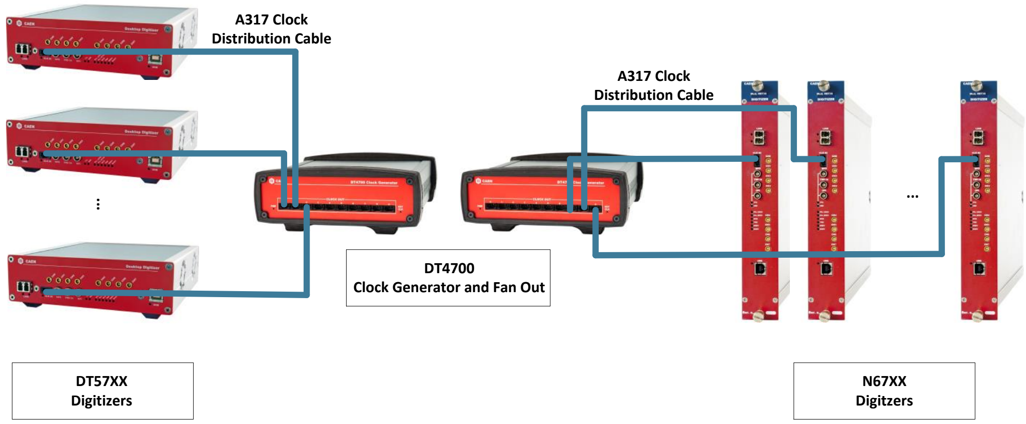
3.2 Synchronization of the Desktop DT57XX and NIM N67XX digitizers

In the following, one DT57XX/N67XX digitizers acts as the master board while the others act as slaves for what concern the *start_acquistion* signal propagation only. The clock signal are, on the contrary distributed in FAN OUT mode because the DT57XX/N67XX digitizers do not feature the CLK OUT connector. A clock generator like the DT4700 model is then required in such a configuration.

Required software: CoMPASS only.

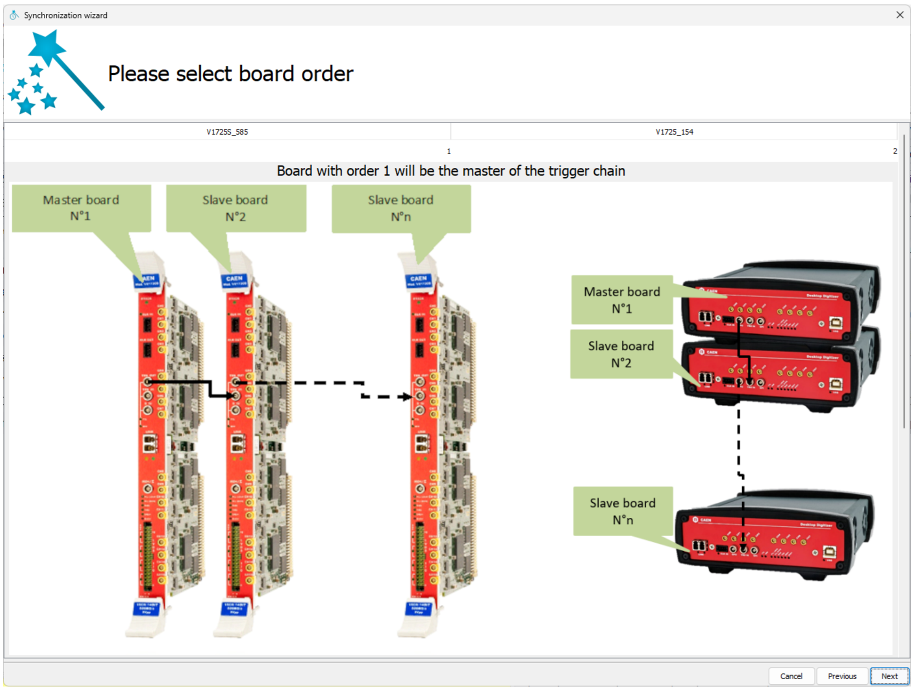
Phase 1: the **clock synchronization**:

1. There is no need to reprogram the digitizer PLL in this case because the DT57XX/N67XX boards are already configured to work with the 50 MHz input clock. It is just required to configure the digitizer so that the reference clock is the external one instead on the internal one. This is done automatically by CoMPASS during the synchronization wizard.
2. There is no need to check the reference clock delay among the boards because the clock is provided to all the digitizers in FAN OUT mode.
3. Connect the A317 cable from the DT4700 CLOCK OUT connector to the DT57XX/N67XX CLOCK IN connector.

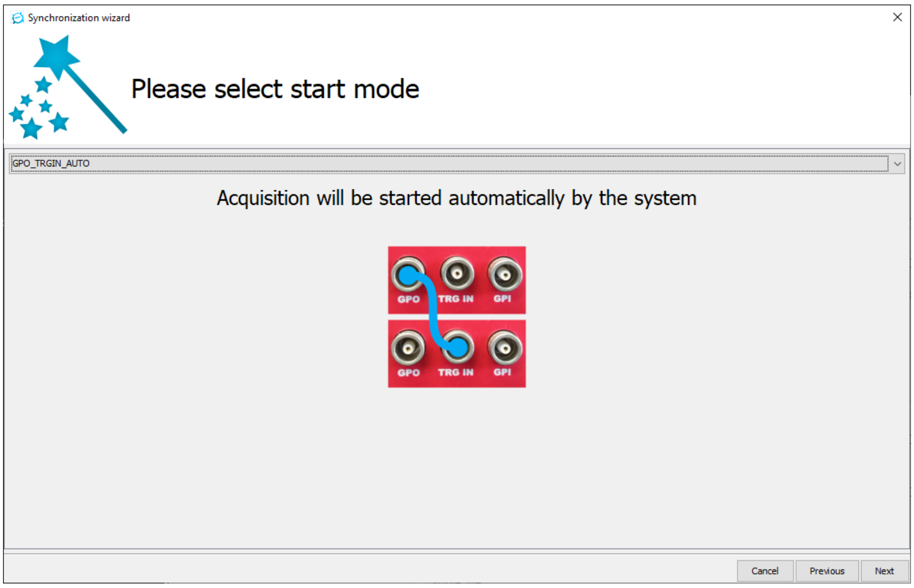


Phase 2: the ***start_acquisition* propagation**.

1. Connect the GPO OUT connector of master DT57XX/N67XX with TRG IN connector of the first slave DT57XX/N67XX through a LEMO-LEMO cable and proceed this way building a daisy chain with all the digitizer belonging to the system.
2. Open the CoMPASS software and select ”Menu → Synchronization wizard”. In the second tab, set the board order



3. In the third tab, choose one of the available *start_acquisition* propagation option, for example the GPO_TRGIN_AUTO option:



4. You can adjust the run delay from master to slave by providing a single pulse into the two boards and check the reported time stamp. This step is not fundamental, the relative delay can be adjusted offline by software.

The two boards are now synchronized and the customer can start the acquisition by pressing the START button in CoMPASS.

3.3 Synchronization of the VME V27XX and desktop DT27XX digitizers

In the following, one V27XX/DT57XX digitizer acts as the master board while the others act as slaves. The idea is to lock the clocks of all the digitizers and to propagate the start of run in a daisy chain configuration.

Required software:

- CoMPASS only

The **clock synchronization** and the ***start_acquisition* propagation** are done together through the CoMPASS Synchronization Wizard

1. Connect the A319 cable from the CLOCK OUT connector of the master to CLOCK IN connector of slave

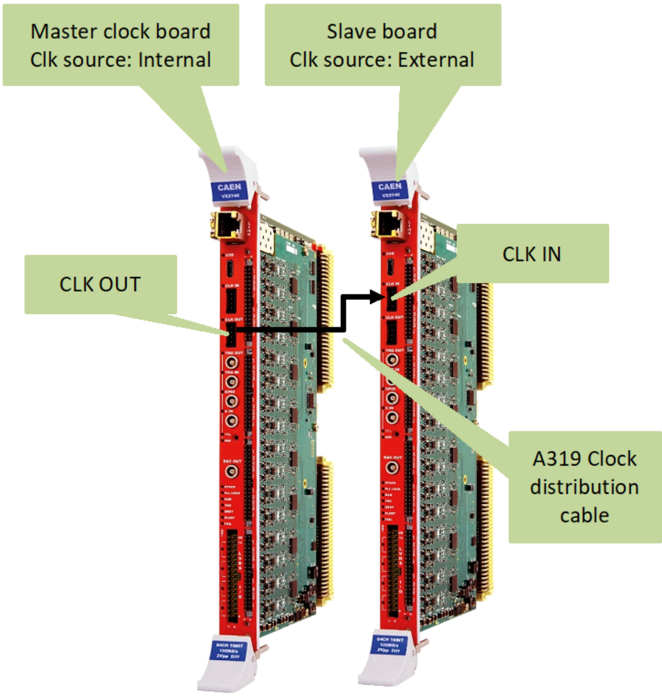


Fig. 3.1: V/VX27xx case.

2. There is no need of additional cable connection because the start_acquisition signal is propagated from the master to the slave(s) by the A319 cable

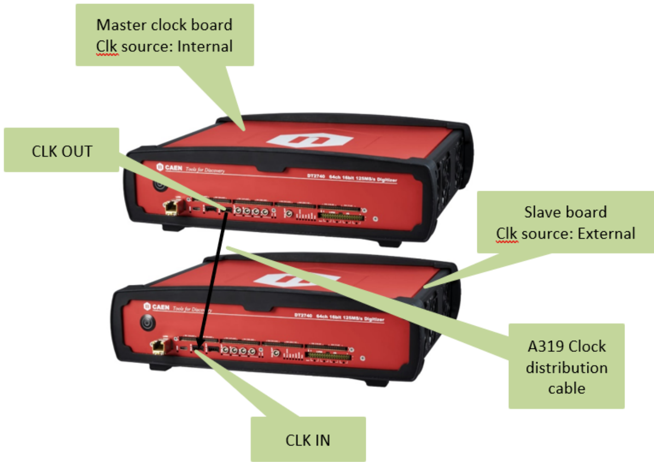
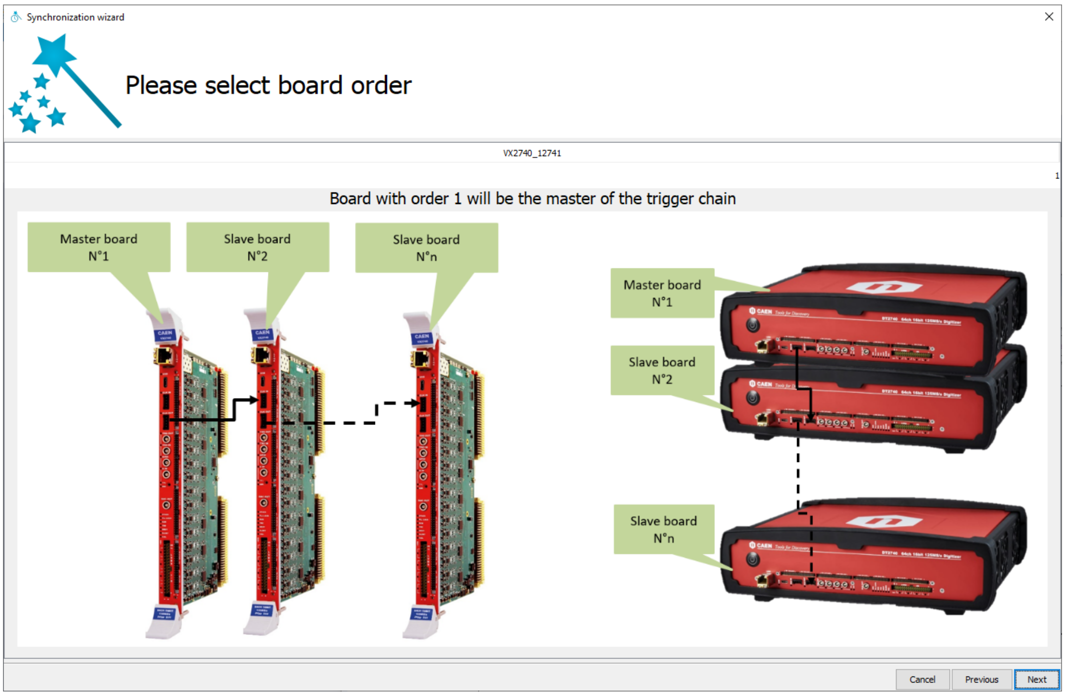
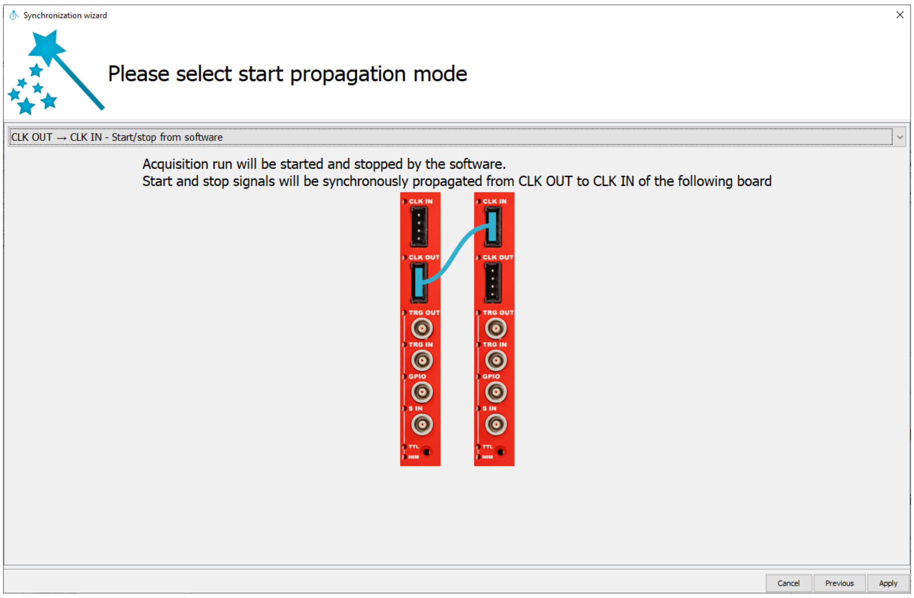


Fig. 3.2: DT27xx case.

3. Open the CoMPASS software and select "Menu → Synchronization wizard". In the second tab, set the board order



4. In the third tab, choose one of the available *start_acquisition* propagation option, for example ”CLK OUT → CLK IN - Start/stop from software” option:



5. Press Apply to have CoMPASS applying the synchronization settings
6. The CLOCK IN led of the slave board must be ON; the PLL LOCK led of both boards must be ON.
7. You can adjust the run delay from master to slave by providing a single pulse into the two boards and check the reported time stamp. This step is not fundamental, the relative delay can be adjusted offline by software.

The two boards are now synchronized and the customer can start the acquisition by pressing the START button in CoMPASS.

3.4 Synchronization of the VME V17XX and V/VX/DT27XX digitizers

When it is required to synchronize a systerm composed by a mixed 17XX and 27XX, the advice is to group the 17XX and the 27XX digitizer together and to setup the system in order to get the 17XX digitizer as the firsts in the chain. In this way there will bi a single discontinuity point between the last 17xx and the first 27xx.

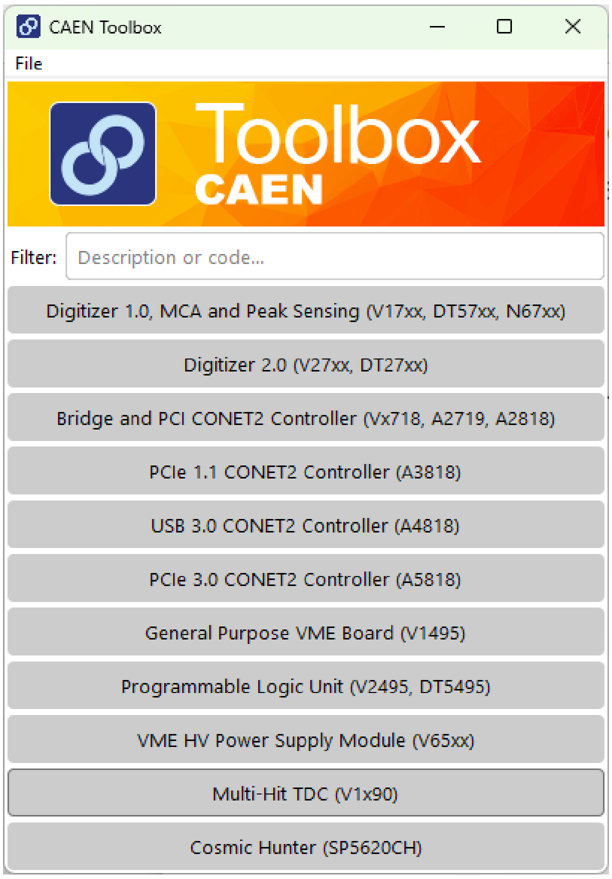
In the following, a V17XX digitizer acts as the master board while a V27XX act as slaves. The idea is to lock the clocks of all the digitizers and to propagate the start of run in a daisy chain configuration.

Required software:

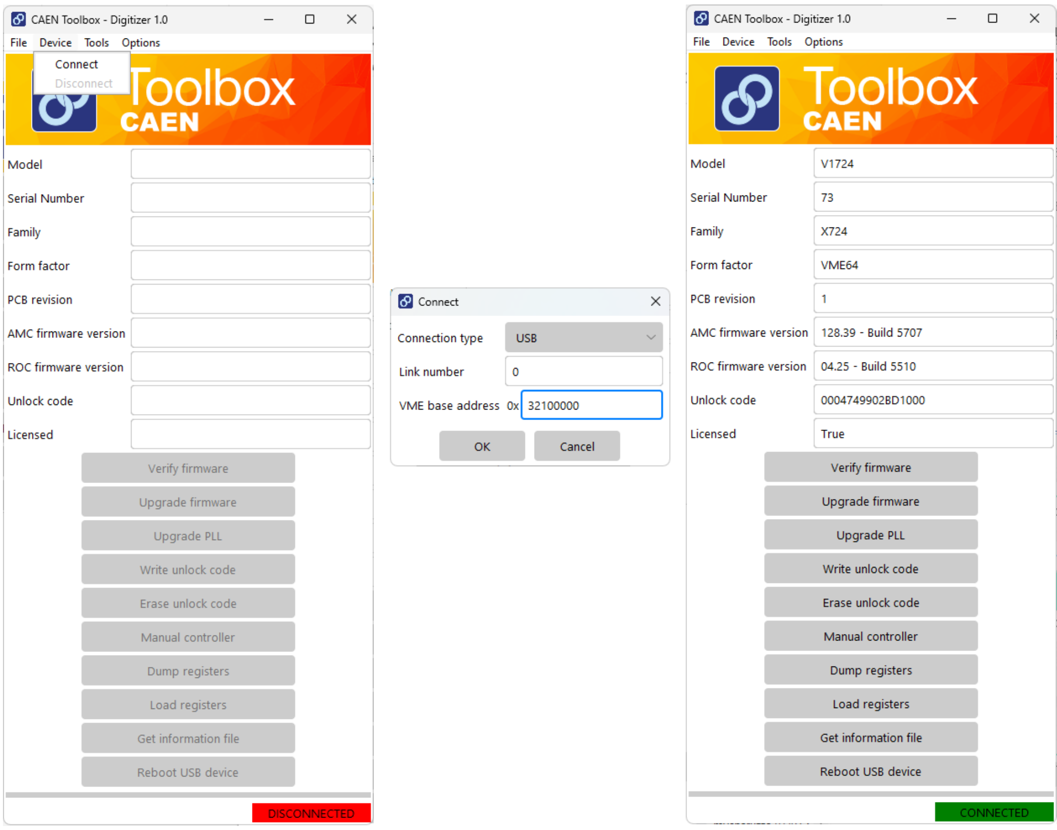
- CAEN Toolbox
- CoMPASS

Phase 1: the **clock synchronization**:

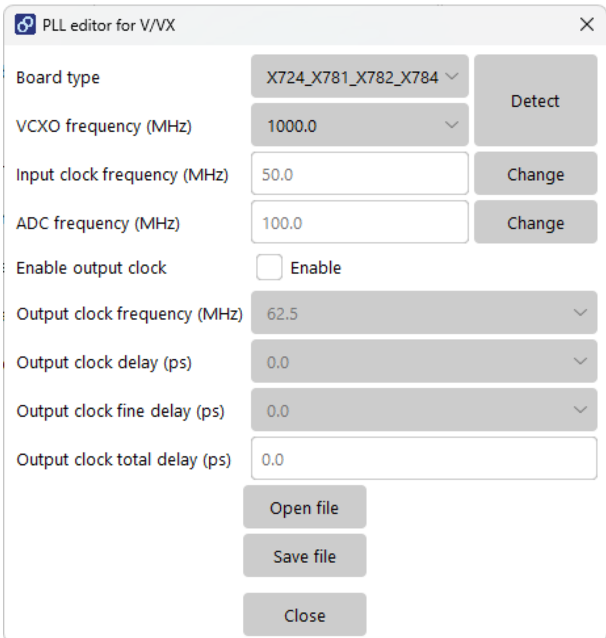
1. The PLL of the V17xx must be reprogrammed to provide on the CLOCK OUT connector the 62.5 MHz frequency.
   - Open CAEN Toolbox, select "Digitizer 1.0".



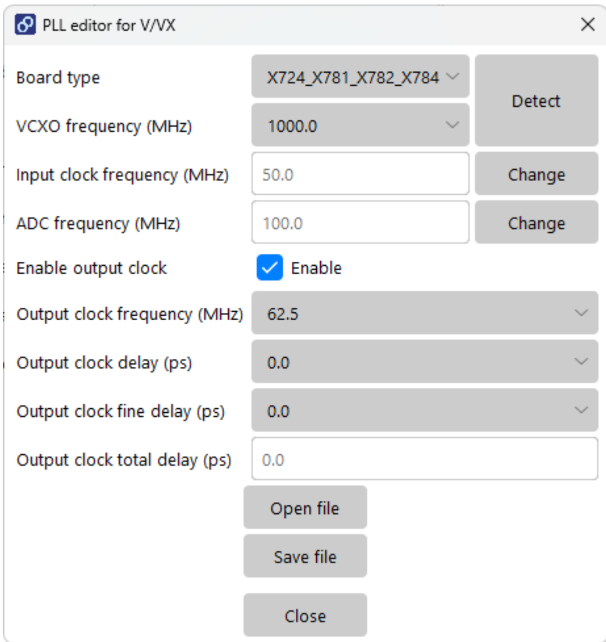
- from the top menu select Device → Connect, insert the digitizer connection parameters and press Connect.



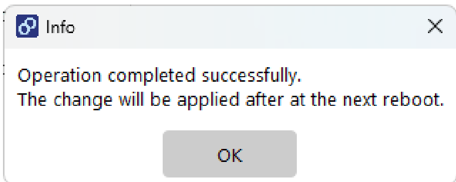
- if the master digitizer is a V1720, V1724, V1740D, V1751 or V1782, select Tools → PLL Editorfor V/VX from the top menu. The PLL Editor will open. Press "Detect" button to detect the currently connected digitizer.



– Tick ”Enable clock output” and select the clock output frequency depending on the slave digitizer model. Set the Clock output delay if required.

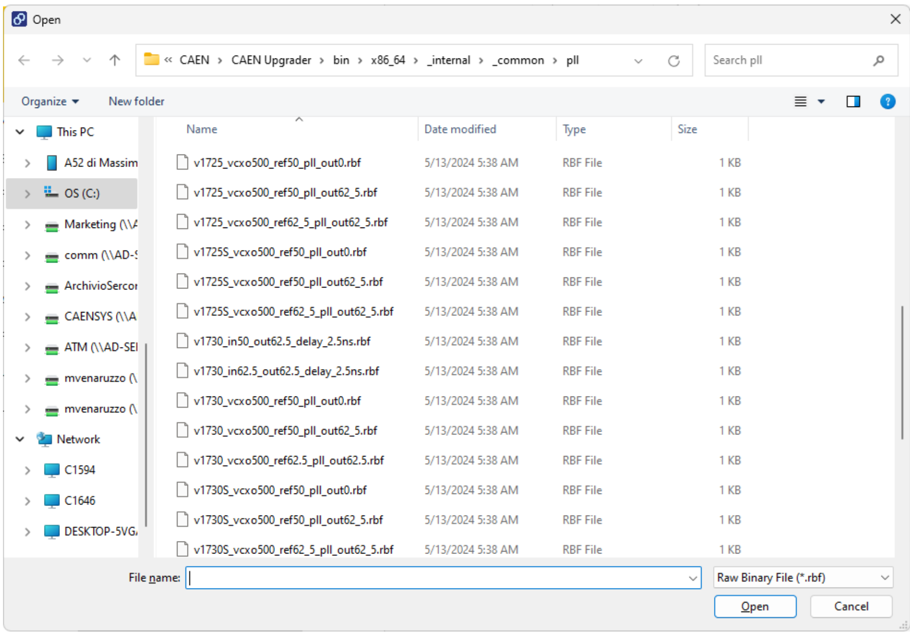


– Press ”Save” button to save the PLL .rbf file to the desired location on the pc and close the PLL editor.
– Press the ”Upgrade PLL” button and select the PLL .rbf file previously generated. CAEN Toolbox will automatically start the file upload and the PLL programming. Once the file upload is completed the following message appears.



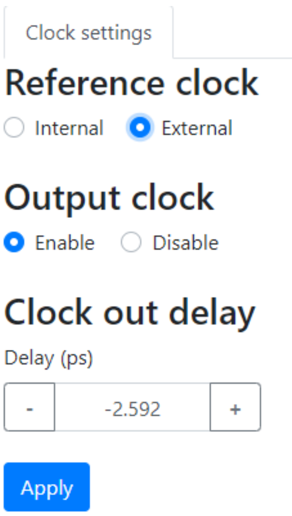
– Power off and on the crate to apply the new PLL configuration.

- if the master digitizer is a V1725(S) or a V1730(S) user can follow the same procedure described here above or press directly the ”Upgrade PLL” button.
  – In the browser folder, select the file corresponding to the board model like ”v1725_vcxo500_ref50_pll_out62_5.rbf” and press open.

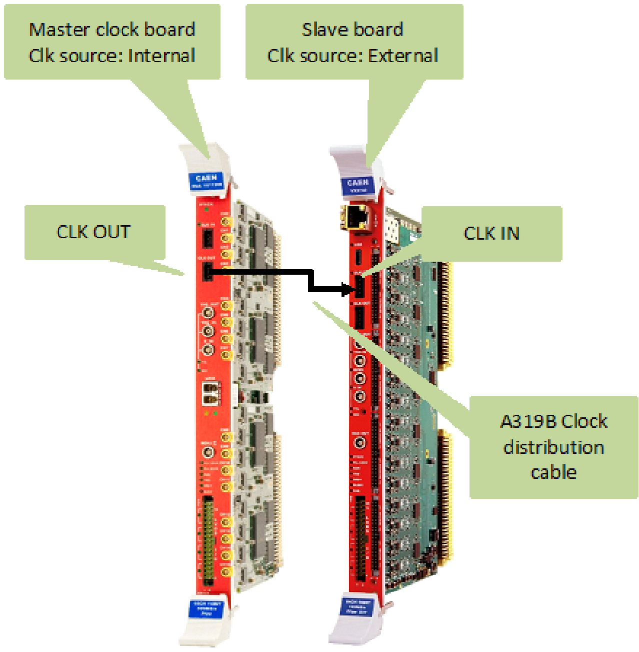


- CAEN Toolbox will automatically start the file upload and the PLL programming. Once the file upload is completed the same previous message appears.

- The PLL of the slave already accept in input the 62.5 MHz clock and it must be programmed to accept the external clock signal.
  - Open the VX27XX/DT27XX Web Interface, select ”Clock Settings”.
  - Select Reference clock ”External”, Output clock ”Enable” and press Apply for the slave board



– Connect the A319B cable from the CLOCK OUT connector of the master to CLOCK IN connector of slave

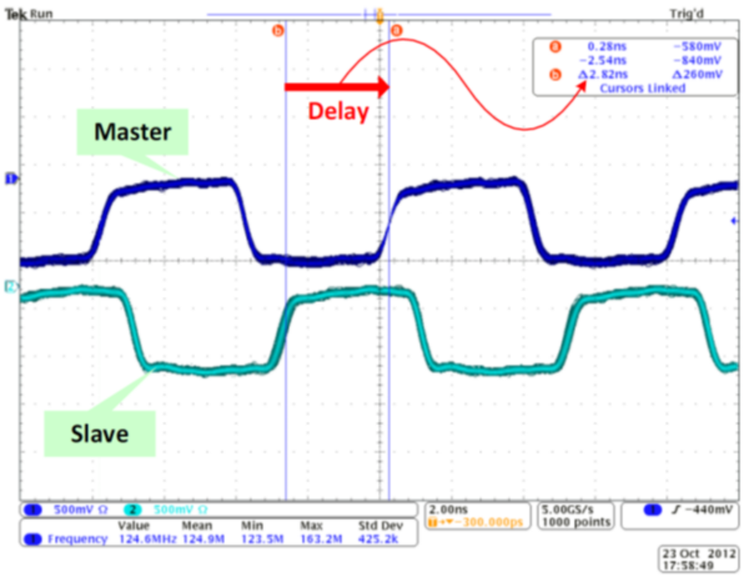


– Switch on the crate. The CLOCK IN led of the slave board must be ON; the PLL LOCK led of both boards must be ON.

– To verify that the two clocks are latched and to measure the delay between them, it is possible to provide to the TRG OUT connector the clock and check it from an oscilloscope. In CoMPASS, go into the Sync/Trg tab within **each single board** Settings Tab and select **TRG OUT mode** → **PLL clock**

– Connect the TRG OUT connector output of each board to an oscilloscope and the check:

  * There is no reciprocal jitter between each other.
  * Measure the delay according to the following scheme

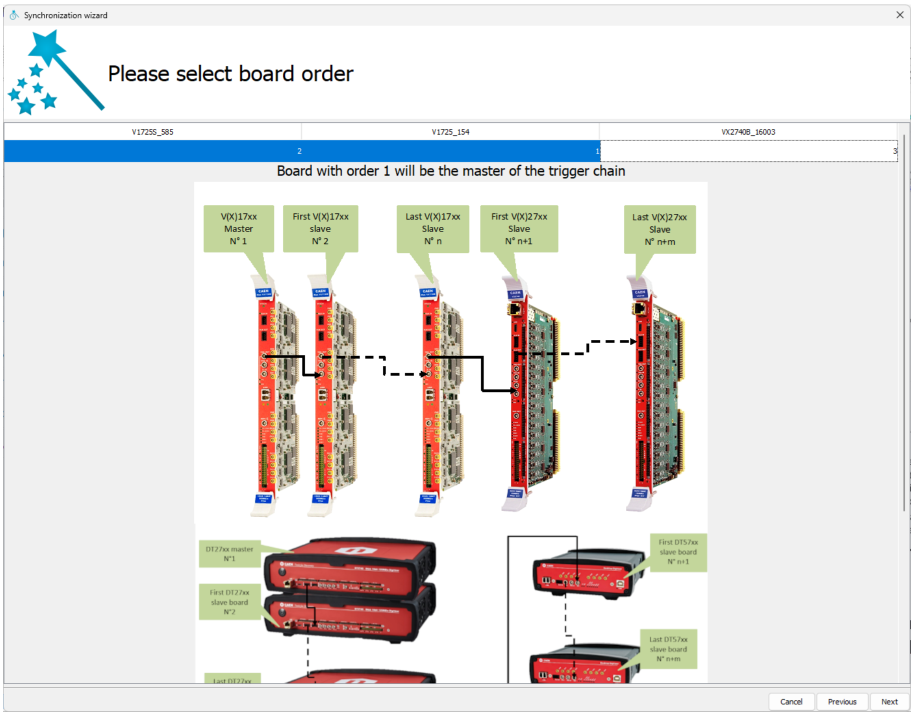


> **In case the clock of a V17XX slave board has been modified to accept an external clock frequency different from 50 MHz, when the clock source it set back to the internal one, before using again the digitizer, the user must remember to program the board PLL again with the default 50 MHz PLL file. Missing such digitizer reprogramming might lead either to the impossibility for the digitizer to lock the PLL or to a digitizer wrong events timestamp information provision.**

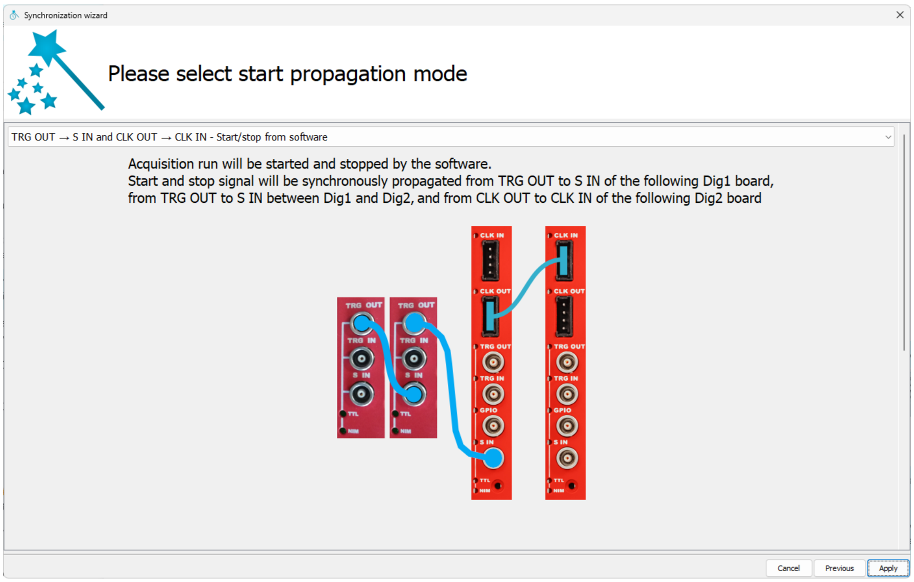
Phase 2: the ***start_acquisition* propagation**.

(a) All the V17XX possibly present in the chain must be daisy chained with the TRG OUT - S IN connection. Connect the TRG OUT connector of master V17XX (or the last V17xx slave) with S-IN connector of the first slave V27XX through a LEMO-LEMO cable. The rest of the slaves 27xx (if any) can be daisy chained simply connectin the CLK-OUT and CLK-IN 4 pin connector as explained in the previous section.

(b) Open the CoMPASS software and select "Menu → Synchronization wizard". In the second tab, select the board order



(c) In the third tab, choose one of the available *start_acquisition* propagation option, for example the TRG OUT → S IN and GPO → GPI option:



(d) You can adjust the run delay from master to slave by providing a single pulse into the two boards and check the reported time stamp. This step is not fundamental, the relative delay can be adjusted offline by software.

The two boards are now synchronized and the customer can start the acquisition by pressing the START button in CoMPASS.

3.5 Synchronization of the Desktop DT57XX/NIM N67XX and DT27XX digitizers

This section may include two kind of operative scenarios:

1. one or more DT27XX and one DT57XX (Case A)
2. one or more DT27XX and more DT57XX (Case B)

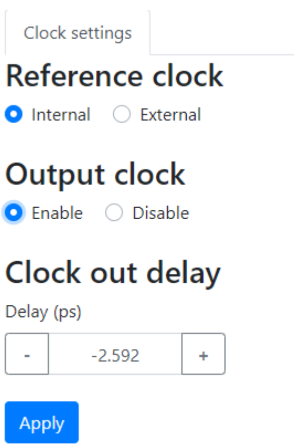
In the first case, no additional hardware is required, and the (last) DT27XX acts as the master board while the DT57XX and the slave one. In the second case a DT4700 Clock Generator is required in order to provide the 62.5 MHz reference clock to all the digitizers; the (last) DT27XX acts as the master board while the DT57XX and the slave one for what concern the propagation of the start_acquisition signal only.

Required software:

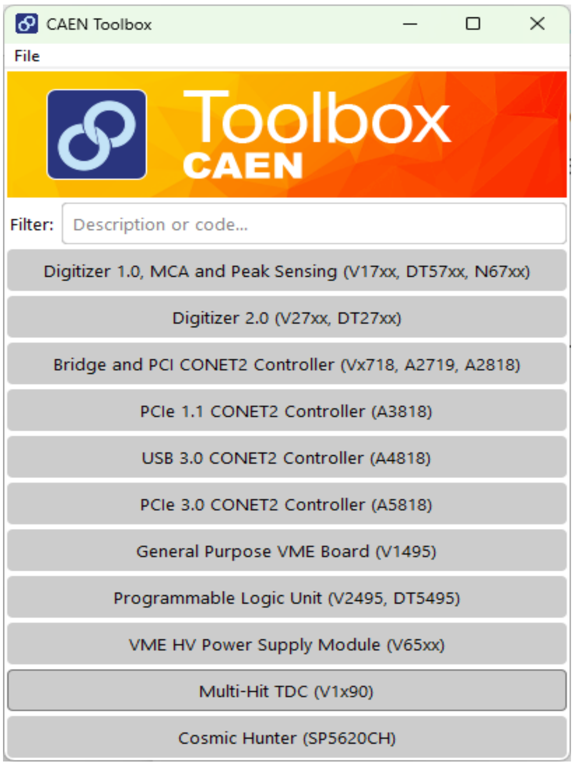
- VX27XX/DT27XX Web Interface;
- CAEN Toolbox
- CoMPASS

Phase 1: the **clock synchronization**:

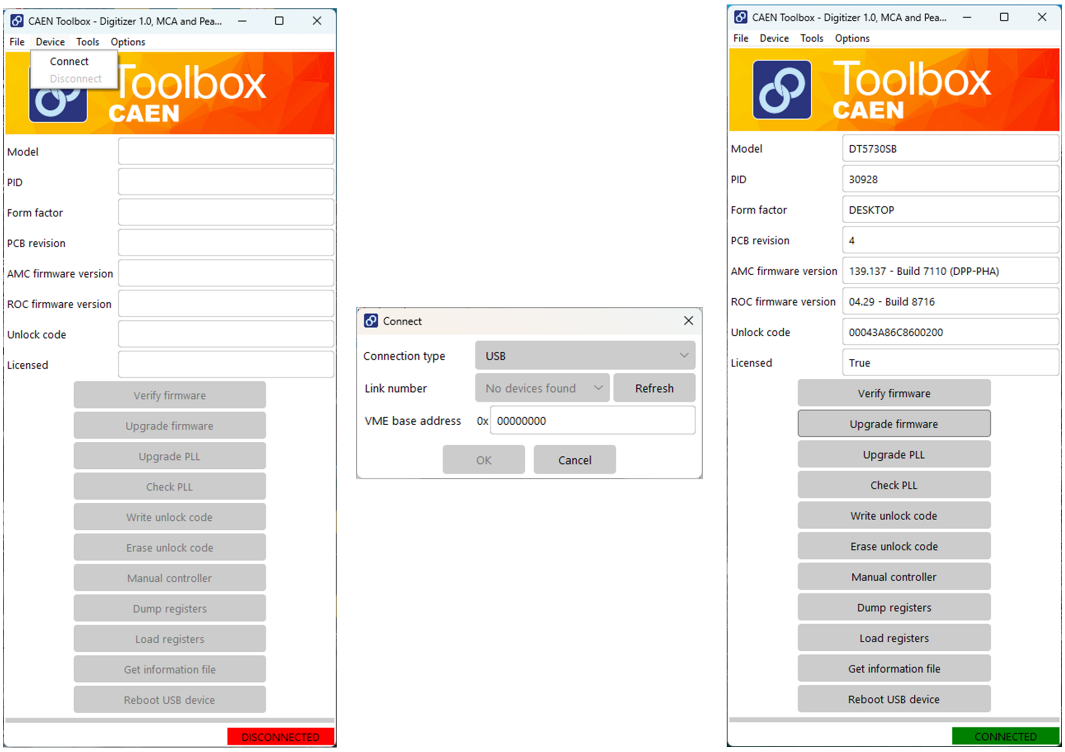
1. **In Case A**, the PLL of the master must be reprogrammed to provide the CLOCK OUT (62.5 MHz).
   - Open the DT27XX Web Interface, select ”Clock Settings”.
   - Select Reference clock ”Internal”, Output clock ”Enable” and press Apply for the master board

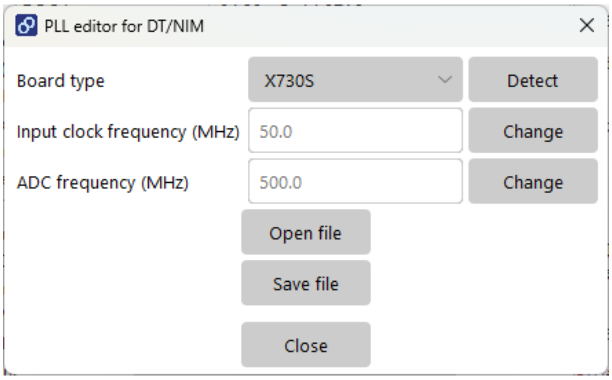
2. The PLL of the slave must to be reprogrammed to accepts the 62.5 MHz clock. This can be done using CAEN Toolbox (TO BE IMPLEMENTED)
   - Open CAEN Toolbox, select ”Digitizer 1.0”.



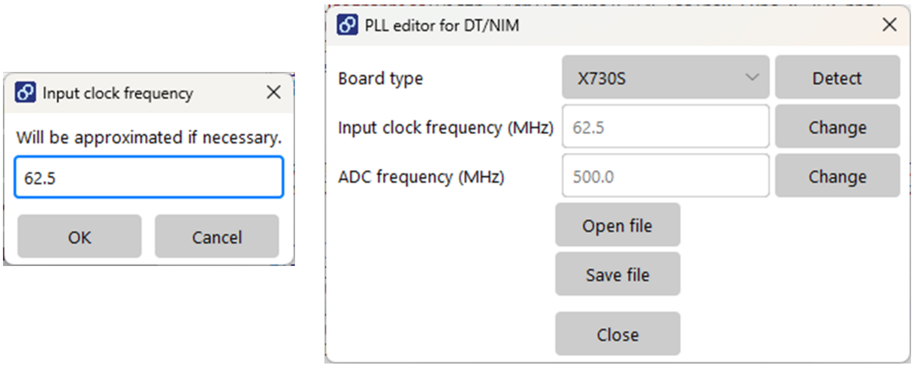
- from the top menu select Device → Connect, insert the digitizer connection parameters and press Connect.



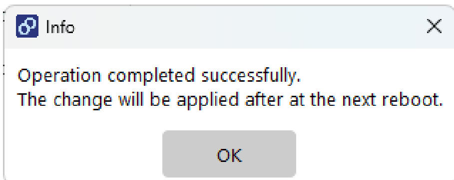
- Select Tools → PLL Editor for DT/NIM from the top menu. The PLL Editor will open. Press "Detect" button to detect the currently connected digitizer.



  – Press "Change" button to modify the accepted Input clock frequency. Then press "Ok" to confirm



  – Press "Save" button to save the PLL .rbf file to the desired location on the pc and close the PLL editor.
  – Press the "Upgrade PLL" button and select the PLL .rbf file previously generated. CAEN Toolbox will automatically start the file upload and the PLL programming. Once the file upload is completed the following message appears.



  – Power off and on the crate to apply the new PLL configuration.

3. Connect the A319B cable from the CLOCK OUT connector of the master to CLOCK IN connector of slave

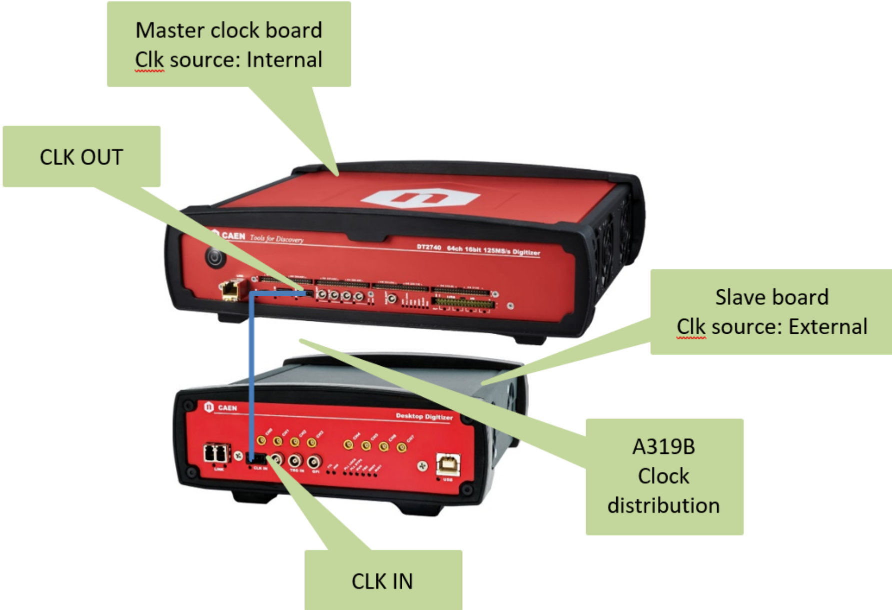


Fig. 3.3: Case A.

4. **In Case B**, it is required to program the PLL of the DT57XX because by default it accept the 50 MHz clock only. To perform this operation, follow the instruction detailed for **Case A**.

5. Connect the A317 cable from the DT4700 CLOCK OUT connector to the DT57XX CLOCK IN connector and the A319B cable from the DT4700 CLOCK OUT connector to the DT27XX CLOCK IN connector.

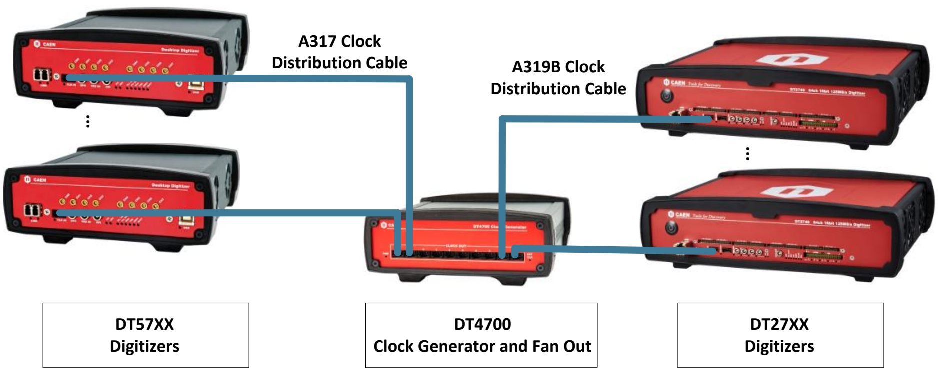


Fig. 3.4: Case B.

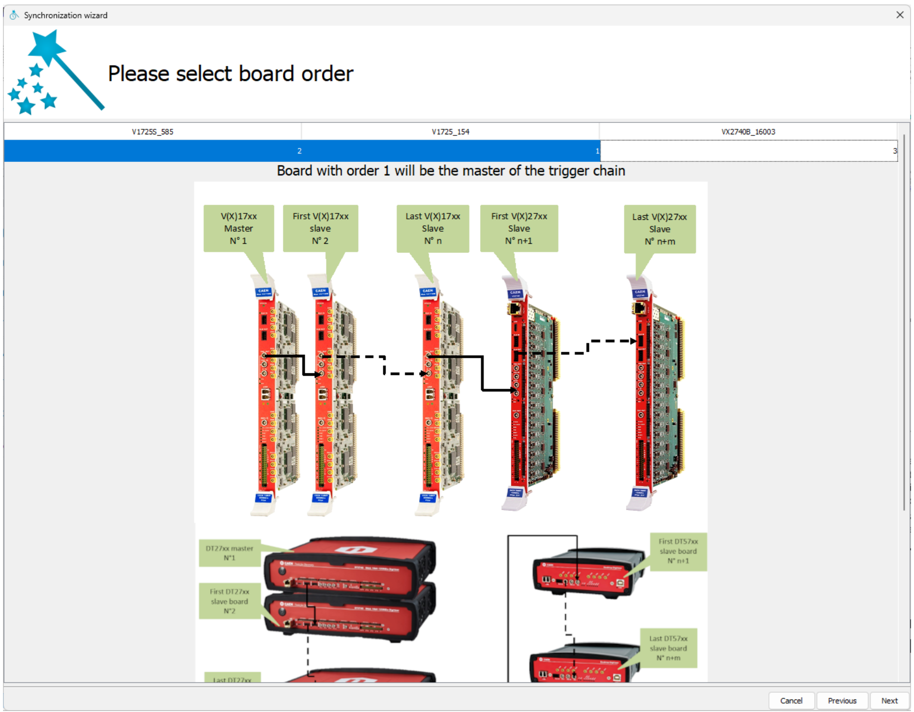
6. The CLOCK IN led of the all the board must be ON; the PLL LOCK led of all the boards must be ON.

7. There is no need to check the reference clock delay among the boards because the clock is provided to all the digitizers in FAN OUT mode.

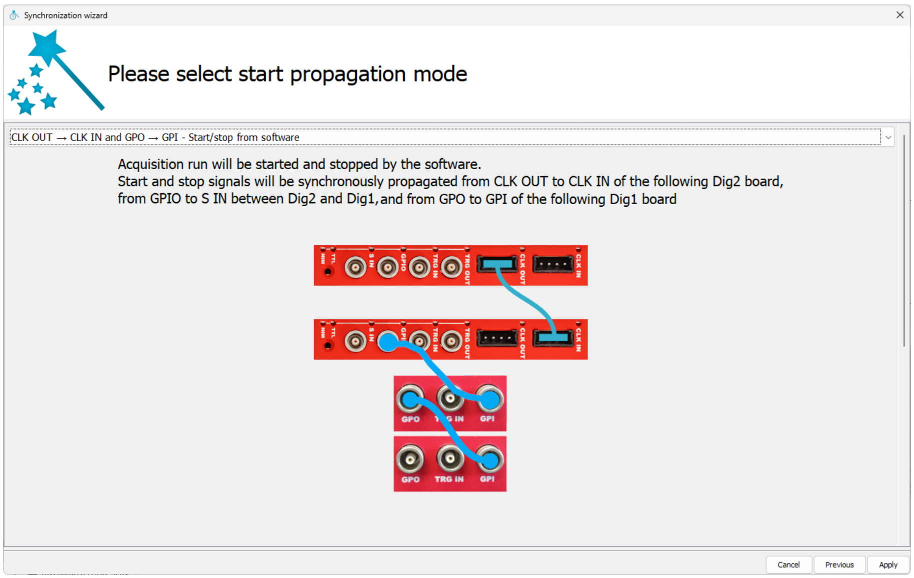
In case the clock of a DT57XX/N67XX slave board has been modified to accept an external clock frequency different from 50 MHz, when the clock source it set back to the internal one, before using again the digitizer, the user must remember to program the board PLL again with the default 50 MHz PLL file. Missing such digitizer reprogramming might lead either to the impossibility for the digitizer to lock the PLL or to a digitizer wrong events timestamp information provision.

Phase 2: the ***start_acquisition*** **propagation**.

1. In both Cases A and B Connect the GPIO connector of master (or the last) DT27XX either with the GPI of the first slave DT57XX through a LEMO-LEMO cable. The rest of the DT57xx slaves (if any) have to be daisy chained through the GPO-GPI connectors. If more DT27xx are included in the system they can be daisy chained using the CLK OUT - CLK IN connector chain as explained in the dedicated section.
2. Open the CoMPASS software and select "Menu → Synchronization wizard". In the second tab, select the board order



3. In the third tab, choose one of the available *start_acquisition* propagation option, for example the CLK OUT → CLK IN and GPO → GPI option.



4. You can adjust the run delay from master to slave by providing a single pulse into the two boards and check the reported time stamp. This step is not fundamental, the relative delay can be adjusted offline by software.

The two boards are now synchronized and the customer can start the acquisition by pressing the START button in CoMPASS.

4 Dead time evaluation in CoMPASS

CoMPASS provides a dead time estimation based on the data coming from the board and allows the user to have access to the same data to evaluate the deadtime by his/her own. CoMPASS indeed allows the user to save the *Raw* acquisition data, i.e. including the saturations and pileup events usually not included in the spectra but required to provide the dead time estimation. The list file includes a column in which additional information about each event is included and coded in a flag (see Sec. **Save the list of Trigger Time Stamp, Energy, PSD and waveforms**).

Note: In case of onboard coincidence, CoMPASS is not able to evaluate the correct dead time, since it cannot calculate statistics from events that are processed in coincidence directly by the firmware.

4.1 Dead time estimation with the DPP-PSD firmware

The deadtime percentage is estimated by CoMPASS as:

$$1 - \frac{(\text{output\_events} + \text{events\_discarded\_by\_user\_selection} + \text{saturation\_events})}{\text{input\_events}} \tag{4.1}$$

The critical point is how to properly estimate the number of input events. In order to do it, CoMPASS sums up the following events:

- output events going into the energy spectrum;
- events rejected by user selection, if any;
- events rejected by the software time sorting algorithm;
- events rejected because of the saturation of the digitizer input stage;
- pile up events counted twice because, in case of two overlapping events within the integration gate, the second one will not have its own trigger and the pile up rejector algorithm will tag only the first one;
- the so called ”poissonian events”.

The last point goes as follows and it is the sum of two kind of events:

- estimated lost events during the Trigger Hold-Off time: using a recursive procedure, a Poisson distribution is generated whose average value λ is the ICR × Trigger Hold-Off time.

  $$P(\text{n\_events\_lost\_during\_THO}) = \frac{\lambda^n}{n!}e^{-\lambda} \tag{4.2}$$

  where λ = ICR × Trigger Hold-Off.

  The starting point is the first ICR and then with a recursive procedure improves the estimation at each iteration;
- estimated lost events during a memory full condition: when an event is tagged with the *memory full* flag (0x10) the software does a small Montecarlo simulation in which it emulates a Poisson distribution whose average value is the ICR × Memory Full time. The time interval used for this simulation is the difference between the timestamp of the events tagged with the *memory full* flag and the last event without this flag.

Note: in the DPP-PSD firmware case, no estimation of lost events during the saturation of the input stage is performed. This is due to the fact that in the DPP-PSD firmware there is no parameter that allows the software to know the decay time of the input signal and because the typical signals used in the DPP-PSD case are fast and so the probability of a signal overlap during an input stage saturation is low unless the input rate is very high. This means that a correction taking into account this effect will be a higher order correction.

4.2 Dead time estimation with the DPP-PHA firmware

The deadtime percentage is estimated by CoMPASS as:

$$1 - \frac{(\text{output\_events} + \text{events\_discarded\_by\_user\_selection} + \text{saturation\_events})}{\text{input\_events}} \tag{4.3}$$

As in the previous case, the critical point is how to properly estimate the number of input events. In order to do it, CoMPASS sums up the following events:

- output events going into the energy spectrum
- events rejected by user selection, if any
- events rejected by the software time sorting algorithm
- events rejected because the saturation of the digitizer input stage
- pile up events
- the so called ”poissonian events”

The last point goes as follows and it is the sum of two kind of events:

- estimated lost events during the Trigger Hold-Off time: using a recursive procedure, a Poisson distribution is generated whose average value λ is the ICR × Trigger Hold-Off time.

  $$P(\text{n\_events\_lost\_during\_THO}) = \frac{\lambda^n}{n!}e^{-\lambda} \tag{4.4}$$

  where λ = ICR × Trigger Hold-Off.

  The starting point is the first ICR and then with a recursive procedure improves the estimation at each iteration;
- estimated lost events during a saturation of the input range: if an events is flagged as saturated, the software does a small Montecarlo simulation in which it emulates a Poisson distribution whose average value is the ICR × Saturation time. The time interval used for this simulation is the signal Trapezoid Decay Time taken as the best estimation of the time required for the digitizer/MCA input stage to come out of the saturation condition.

  $$P(\text{n\_events\_lost\_during\_input\_saturation}) = \frac{\lambda^n}{n!}e^{-\lambda} \tag{4.5}$$

  where λ = ICR × Trapezoid Decay Time.

  If the first emulated events falls in the time interval that is the minimum value between the trapezoid decay time and the distance between the saturated event and the first following good event then this emulated event is included in the ICR and the emulation proceed. If this events falls outside that time interval or also after a time corresponding to the trapezoid decay time, it is assumed that event would have been detected and so not added to the ICR. When the latter case occurs, the Montecarlo emulation is stopped.

5 Integrated charge evaluation from CoMPASS saved waveforms

In Waves acquisition mode, CoMPASS allows to save on the list files one of the analog traces produced by the digitizer in addition to the onboard processed information (timestamp, integrated charge or pulse height, PSD). In order to specifically save the input signal waveform samples, the user has to select ”Input” as first trace in the CoMPASSPlot Waveform Inspector plot. The number of saved samples depend on the Record lenght parameter set into the CoMPASS Settings → Input tab.

The user can take benefit of this information for further offine processing and analysis such as evalating the input signal rise time or recalculate the input signal integrated charge to reproduce the spectrum provided by CoMPASS.

5.1 Integrated charge evaluation from waveforms

In order to try to reproduce the integrated charge information provided by the digitizer equipped with the DPP-PSD firmware and CoMPASS, the user should keep in mind the following:

- in the Waveform Inspector, the LSB unit of the Y scale refers to the digitizer ADC number of bit (Nbit). For example, a 14 bit ADC, allows a sample evaluation scale between 0 and 16348 LSB. In general:

$$1\ \text{LSB} = \frac{\text{digitizer\_input\_dynamic\_range\_in\_Vpp}}{2^{\text{Nbit}}} \tag{5.1}$$

- in the Energy spectrum, the units of the X scale (tagged as ADC channels) are not related to the digitizer ADC number of bit but refers to the arbitrarily units with which the digitizer provides the information of the integrated charge. Tipically, the digitizer inner integrator is a 16bit integrator that so provides the integrated charge over a 64K bin range.

Let's now describe and example of charge integration supposing the following condition:

- the use of a x730 14 bit 500 MS/s digitizer with a 2 Vpp dynamic range
- to feed the digitizer with a 750 mV high and 100 ns wide square pulse

In case of a x730 digitizer configured to use the 2 Vpp dynamic range:

$$1\ \text{LSB} = \frac{2\text{Vpp}}{2^{14}} \approx 0.12\ \text{mV} \tag{5.2}$$

Note: The digitizer belonging to the first generation do not feature a calibrated input range. For this reason the above formula shows a ”≈” and not an ”=”.

When digitized, the above mentioned 750 mV pulse results in a pulse amplitude of 6250 LSB.

The charge content of such pulse is:

$$Q[\text{pC}] = (V \times \Delta t)/Z_{in} = (750\ \text{mV} \times 100\ \text{ns})/50\ \Omega = 1500\ \text{pC} \tag{5.3}$$

where 50 Ω is the x730 digitizer input impedance.

Note: This is the calculation in the simplified case of a square pulse. In case of a real detector pulse, the charge has to be calculated as a sum of the single sample contribution.

Note: in x725 and x730 digitizers, charge sensitivity values are different for the 0.5 Vpp and 2 Vpp dynamic ranges. CoMPASS shows a single value for both that already takes into account the different dynamic range value.

At this stage, the charge sensitivity parameter comes in play. The charge sensitivity weights the charge contect of each bin of the energy spectrum and it is provided in fC/LSB units. This parameter is accessible by the user in the CoMPASS Settings → QDC tab.

In our example, supposing to consider a charge sensitivity of 80 fC/LSB, to convert that charge value into channels unit that then will be used to fill the spectrum, we have:

$$Q[ch] = Q[pC]/Charge\_sensitivity = 1500\ pC/80\ fC/LSB = 18750\ LSB\ (or\ ADC\ ch) \tag{5.4}$$

over a range 64K (65535) ADC ch.

Such charge value is given on 14 bit range (16K ADC ch) by CoMPASS that removes the last 2 less significant bit. So that value of 18750 ADC ch in CoMPASS becomes 18750/4 = 4688 ch.

In addition, CoMPASS allows to do an additional spectrum rebin so, for example in a case of a rebinning on 4K (4096 ADC ch), the final value in the spectrum of the original charge content will be 4688 / 4 = 1172 ch.

CAEN provides a ROOT based demo code included in the CoMPASS installation folder at the path

”C:\CoMPASS\demo” in Windows

and

”/CoMPASS-vX.Y.Z/demo” in Linux

that performs the integrated charge evaluation starting from the saved input signal waveform samples saved into the list files.

Use of this script requires ROOT to be installed into the local computer.

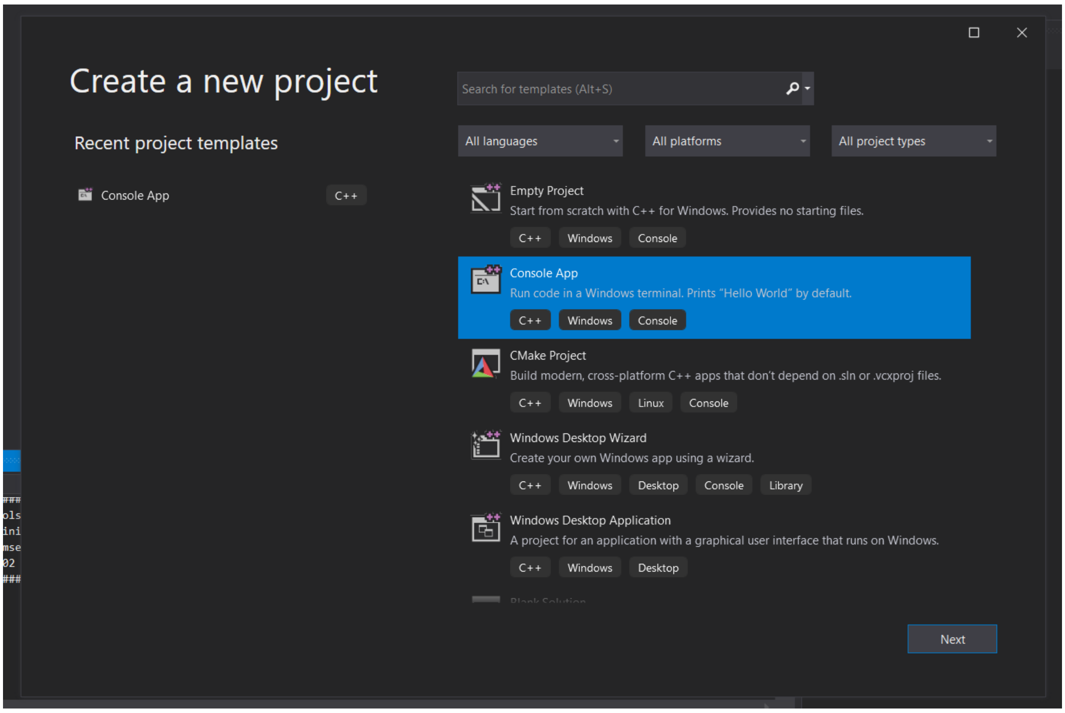
In order to perform this analysis the user is required to provide in input to the script a list file in one of the CoMPASS available format (ROOT, BIN, CSV) taking care of performing the data acquisition producing this file in `Waves` mode. In fact, only when running in `Waves` mode and selecting in the CoMPASS Signal Inspector the trace ”Input” as first analog trace CoMPASS will save the input signal samples in the list file.

5.2 Windows operation

In the following, the instruction about how to operate the code in Windows with Visual Studio 2019 are provided.

5.2.1 Create a Visual Studio project

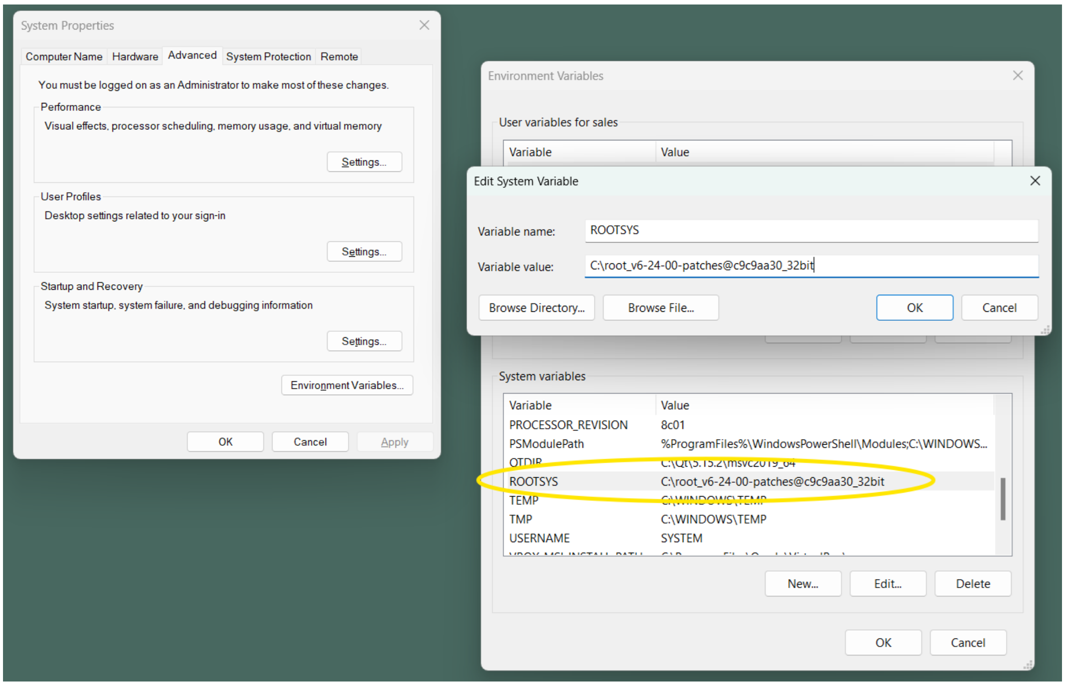
1. Open Visual Studio;
2. Click on "Create a New Project". Or click on "Continue without code". Then, from main menu, click on File → New → Project;
3. Choose Console App;



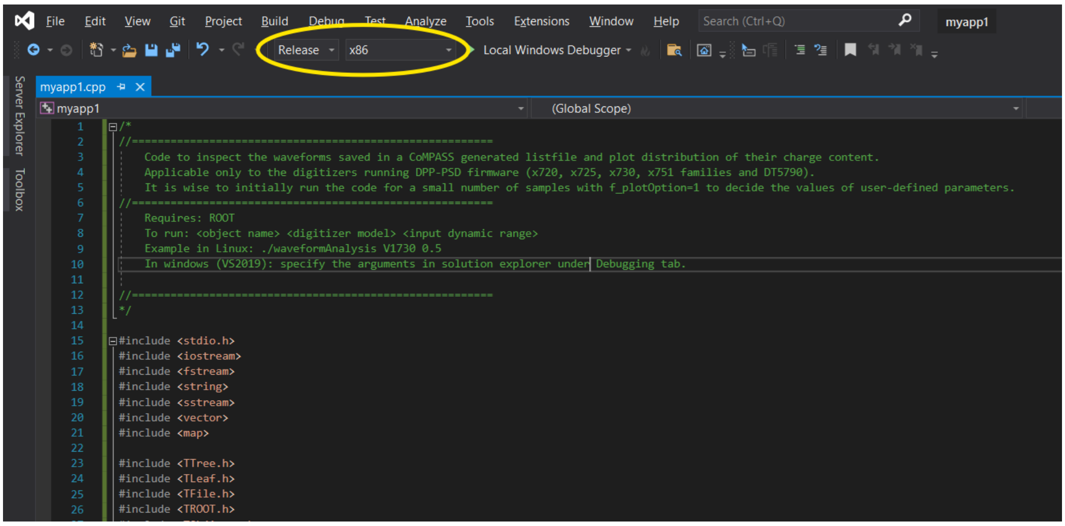
4. Choose a name for the project, e.g. *myapp1*;
5. Under Location, choose a directory where you want to store the project files and the codes;
6. Click Create;
7. This will create a new directory myapp1 inside the chosen location. This will also create a project file, solution file and a C++ file of same name inside this new directory;
8. Replace the content of the new C++ file with the content of the C++ code you want to run. For the present example, replace the content of myapp1.cpp by waveformAnalysis.cpp.;
9. Now link the ROOT libraries with the project as instructed below.

5.2.2 Link ROOT libraries with a project in Visual Studio

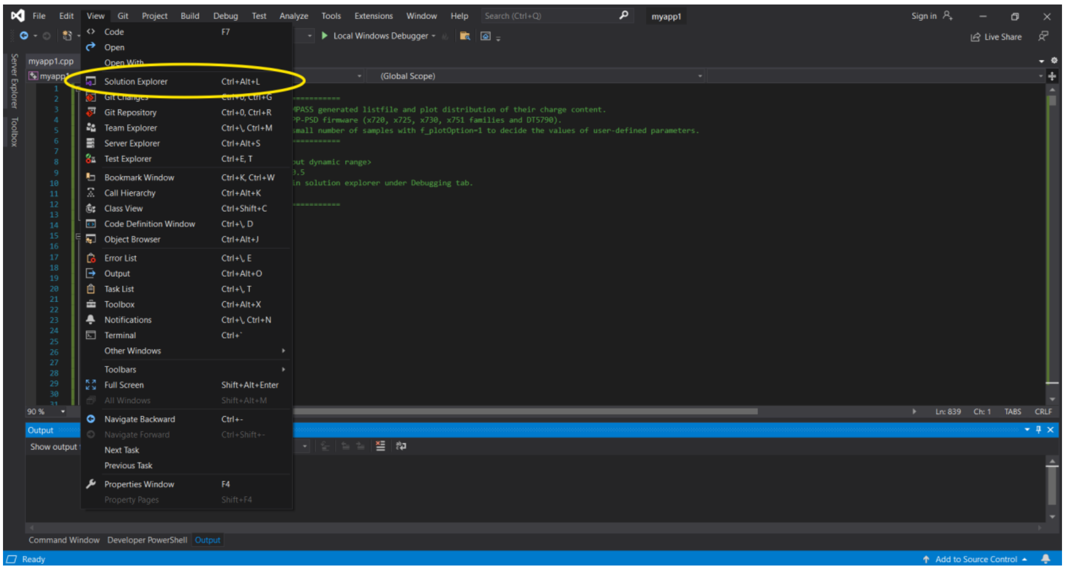
1. The path to the installed ROOT directory should be saved as an environment variable ROOTSYS in Windows (accessible from Windows settings application);



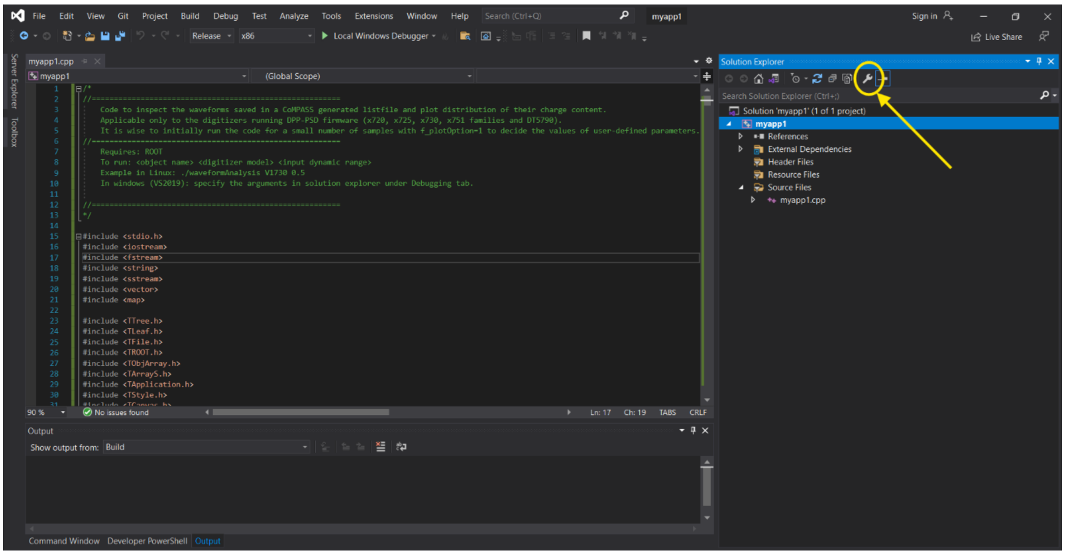
2. The code should run with any of the recent ROOT versions. Take note of the platform (32-bit, 64-bit) and the C++ standard (C++ 14, C++ 17 etc.) for the installed ROOT version. This example uses 32-bit Root v6.24.00 with ISO C++ 14 Standard. The platforms in Visual Studio should be chosen accordingly from the Properties page of Solution Explorer.
3. Choose the configurations for code compilation from the given options. In the present case, it will be compiled in Release mode for 32-bit version. They should be selected as shown below.



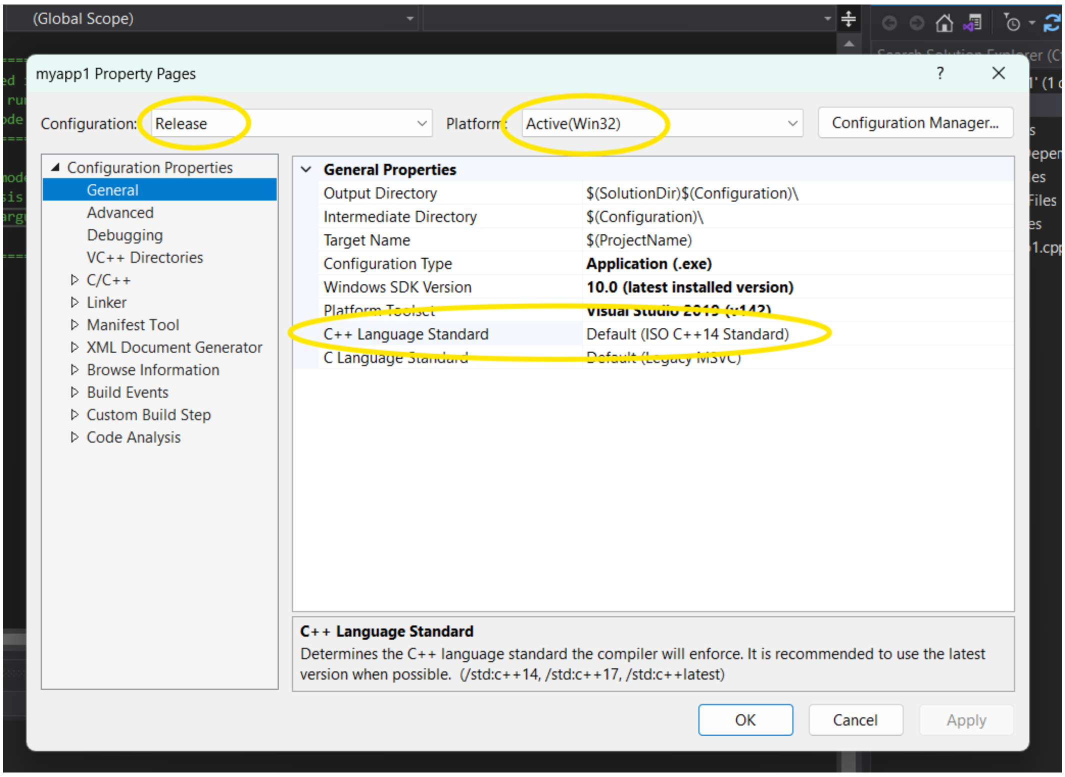
4. From main menu, click on View → Solution Explorer to open the Solution Explorer tab, if it is not already open.



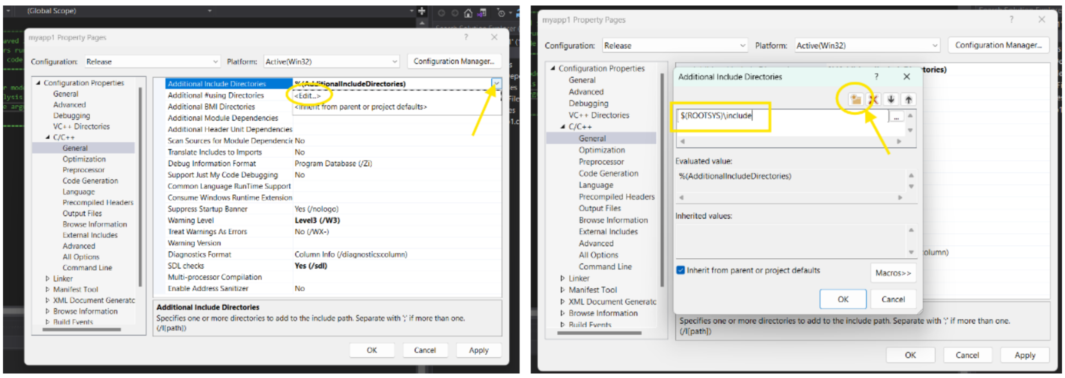
5. In the Solution Explorer tab, click on the project name (*myapp1*, in the present case), click on the Properties icon to open the Properties window. This can also be accessed by right clicking on the project name and clicking on Properties;



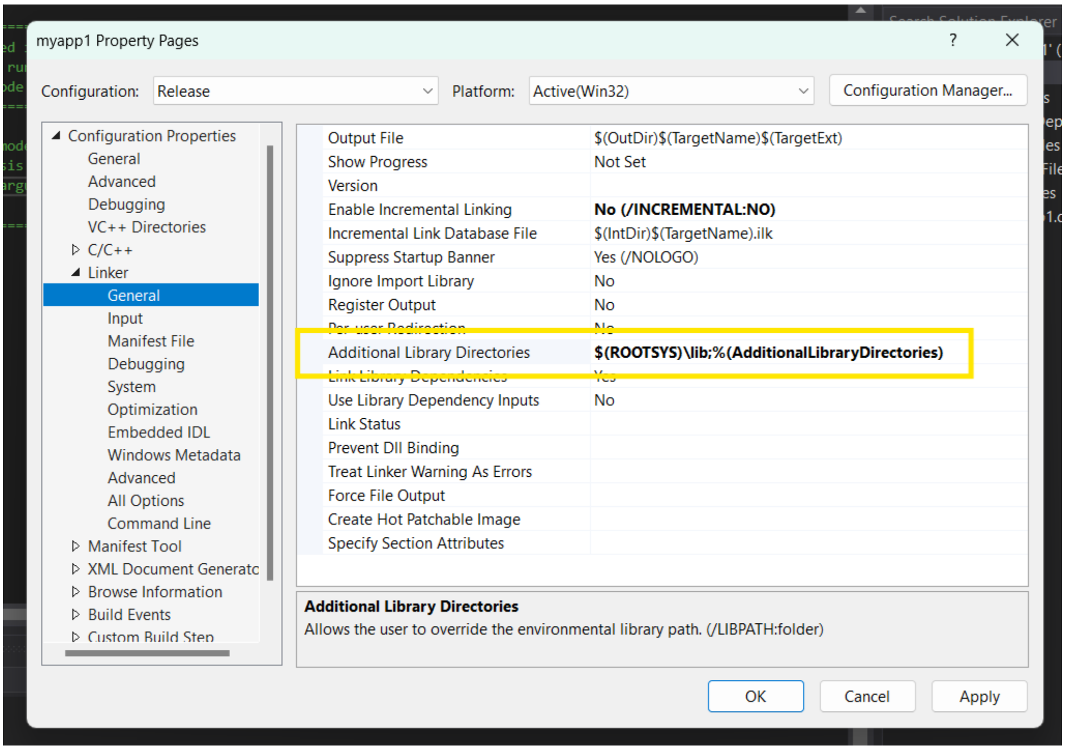
6. In the properties page, be careful to make all the modifications for the intended configuration and platform i.e. Release mode, 32-bit. Under Configuration Properties, click General. Select the preferred C++ standard from the field C++ Language Standard;



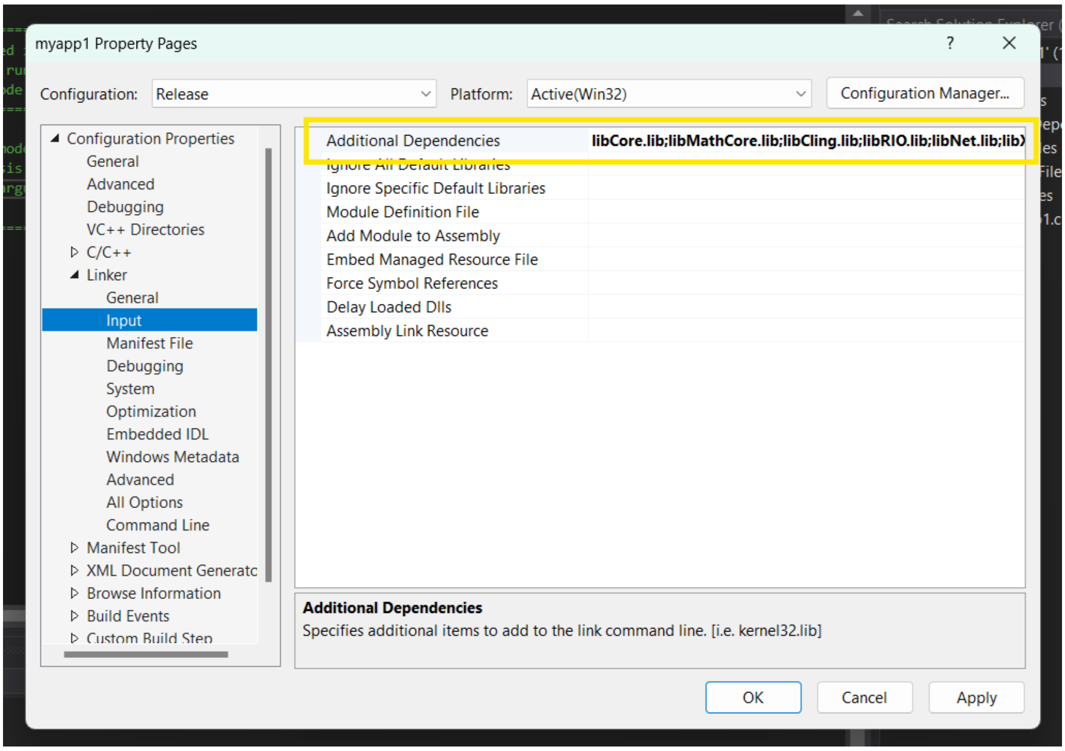
7. Under C/C++-> general: Expand and Edit the Additional Include Directories field. Click on New line icon. Add $(ROOTSYS)\include and press Ok.



8. Following the same method, go to Linker->General, expand and Edit Additional Library Directories. Add $(ROOTSYS)\lib and press Ok.



9. Under Linker → Input, expand and edit Additional Dependencies



Add ROOT libraries required to build the project (one library name per line), e.g.:

`libCore.lib, libRIO.lib, libHist.lib, libGraf.lib, libGpad.lib, libTree.lib.`

5.2.3 Build, run and terminate a project

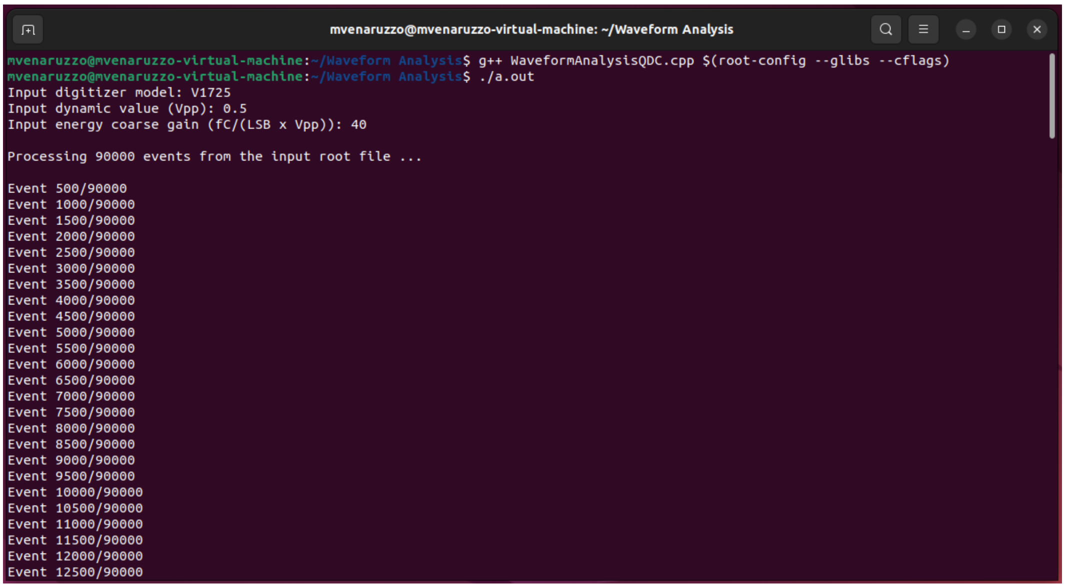
1. Always open the .vcxproj file to edit, compile, debug and run the code;
2. To build the project, from the main menu click on Build → Build Solution;
3. If it succeeds, run it by clicking Debug → Start Without Debugging;
4. To terminate a project that is running on ROOT: from the ROOT plot canvas, click File → Quit ROOT to end the ROOT session. Then press any key to close the console window.

5.3 Linux operation

To run the code in Linux, the user should compile and execute it outside ROOT with the following commands:

```
g++ WaveformAnalysisQDC.cpp $(root-config --glibs --cflags)
./a.out
```

The script does then ask the user to enter few additional information, the digitizer model, the used Input Dynamic Range and the used charge sensitivity (see the following section).



5.4 Analysis example

In the following an example of such waveform analysis is provided. The original data acquisition has been taken with a V1725 digitizer equipped with the DPP-PSD firmware and running in Waves mode to get the waveform samples within the saved list file. List data file have been saved in ROOT format.

Before proceeding with the code compilation, in the source code the user is asked to provide, besides the list data file path, some information about the acquisition settings as shown in the following picture.

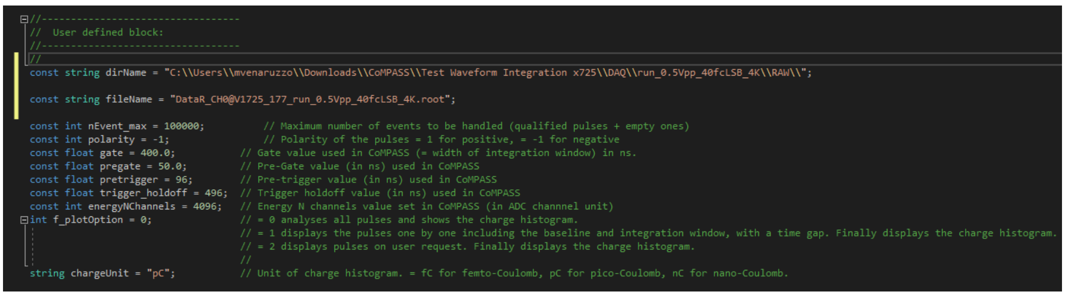


Fig. 5.1: Charge integration script source code excerpt showing the user defined block.

They are required to reproduce as much as possible the same results displayed by CoMPASS in its energy spectrum.

After the code compilation and before starting the processing, the script does ask the user to enter few additional information, the digitizer model, the used Input Dynamic Range and the used charge sensitivity.

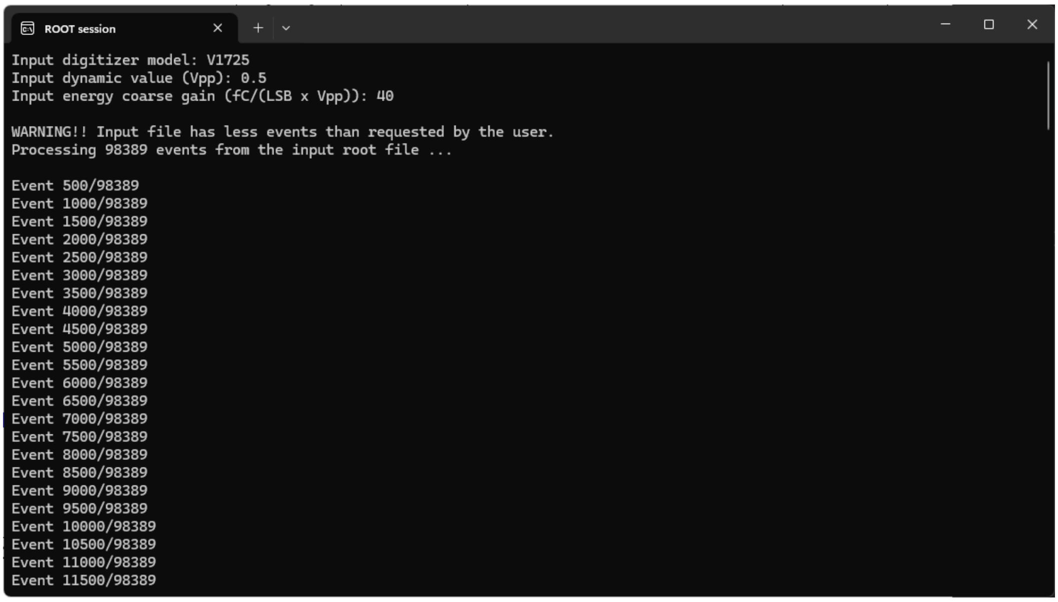


Fig. 5.2: View of the charge integration script I/O console.

Depending on the option selected in the source code, the script may display one by one the event raw waveform, the calculated baseline and the charge integration gate limits.

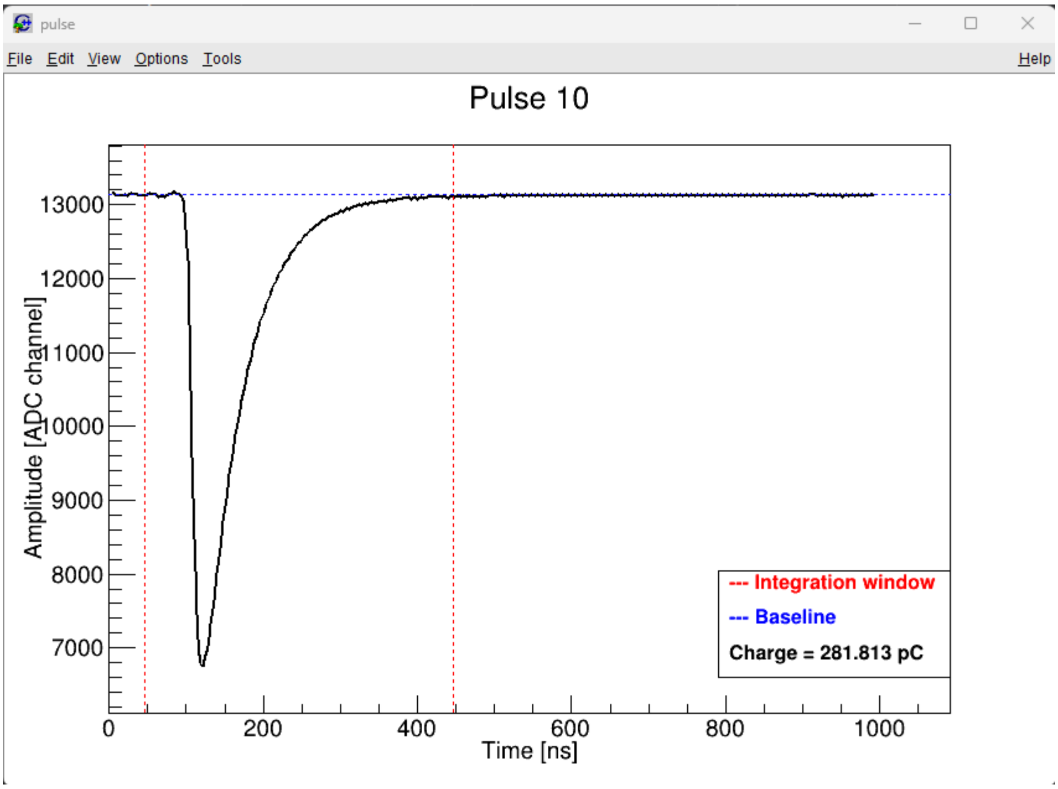


Fig. 5.3: Example of a raw waveform displayed by the charge integration processing code. Blue dashed line is the calculated signal baseline, red dashed lies are the charge integration gate limits.

At the end of the data processing, the script does show 3 plots:

- the charge integration histogram in ADC channels units as displayed by CoMPASS for comparison
- the charge integration histogram in ADC channels units as calculated by the script from the raw wave-form
- the charge integration histogram in charge units (fC, pC or nC)

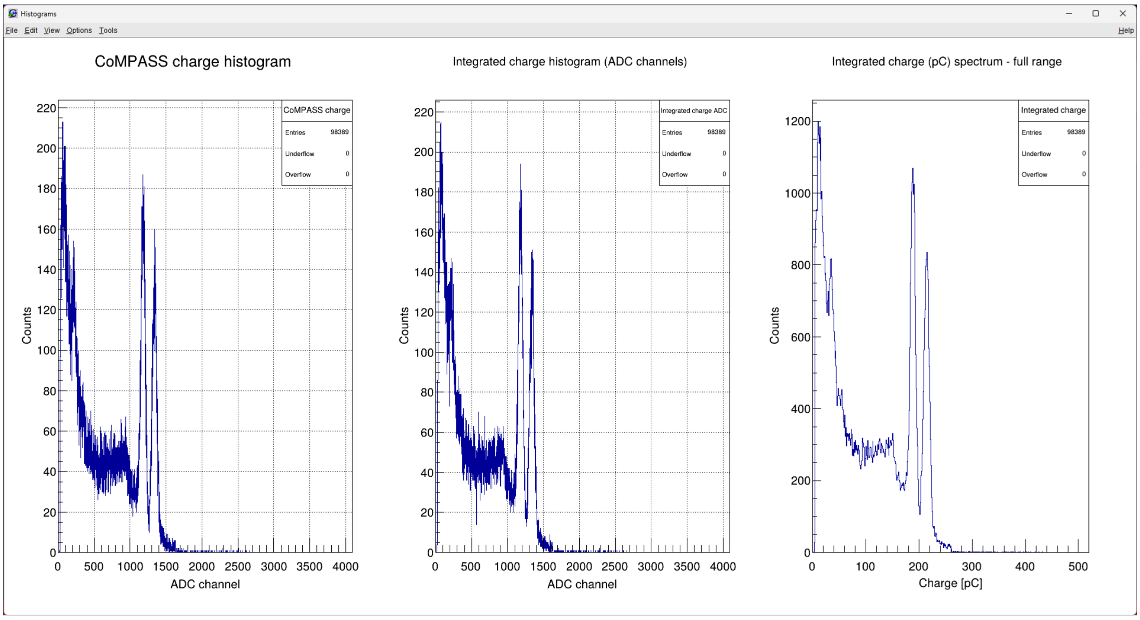


Fig. 5.4: Charge integrated histogram result in charge (left plot) and ADC channel (right plot) units.

6 Generalized Time of Flight analysis: the Any to Any ΔT configuration

In many experimental scenarios it is required be able to perform a timing analysis (ΔT) in which the reference T_0 is provided not by a single fixed detector but, alternatively, by all the detectors used in the experimental setup. Such kind of analisys is sometimes called *Any to Any ΔT analysis*.

Such kind of analysis requires a flexibility in the choice of the reference detector that currently is not available within the CoMPASS infrastracture. For this reason, CAEN provides a ROOT based demo code included in the CoMPASS installation folder at the path

"C:\CoMPASS\demo" in Windows

and

"/CoMPASS-vX.Y.Z/demo" in Linux

that performs such analysis with the required flexibility. Single board and multiboard scenarios are managed by such script that allows to define energy selection criteria too.

Use of this script requires ROOT to be installed into the local computer.

In order to perform this analysis, the user is required to provide to the script a **single time sorted list file** in whatever format generated by CoMPASS (ROOT, BIN or CSV). **The code does not work with multiple input files and with a non time sorted files**.

6.1 Windows operation

Follow the same general instruction provided in the corresponding section of the Chapter **Integrated charge evaluation from CoMPASS saved waveforms**.

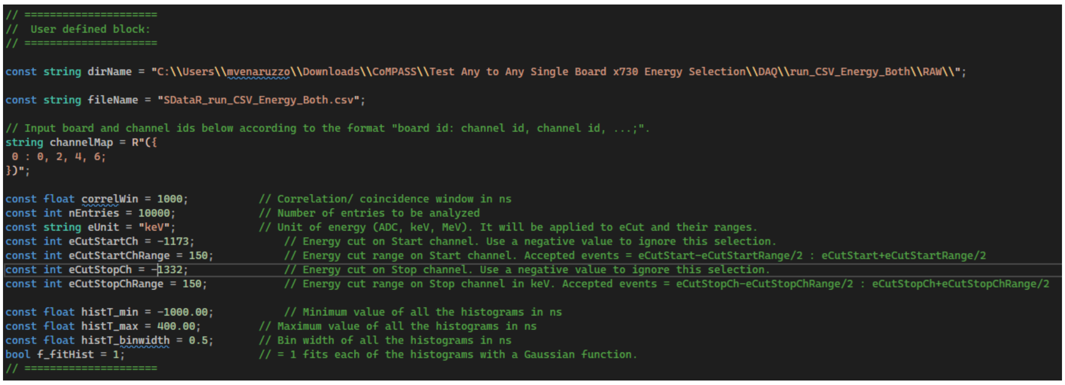
6.2 Linux operation

Follow the same general instruction provided in the corresponding section of the Chapter **Integrated charge evaluation from CoMPASS saved waveforms**.

6.3 Any to any analysis without energy selection example

In the following an example of such analysis is provided. The original data acquisition have been performed with a DT5730 digitizer equipped with the DPP-PSD firmware. 4 out of 8 channels have been used (0, 2, 4, 6). Single time sorted list data file have been saved in CSV format.

Before proceeding with the code compilation, in the source code the user is asked to provide, besides the list data file path, some information about the acquisition settings as shown in the following picture.



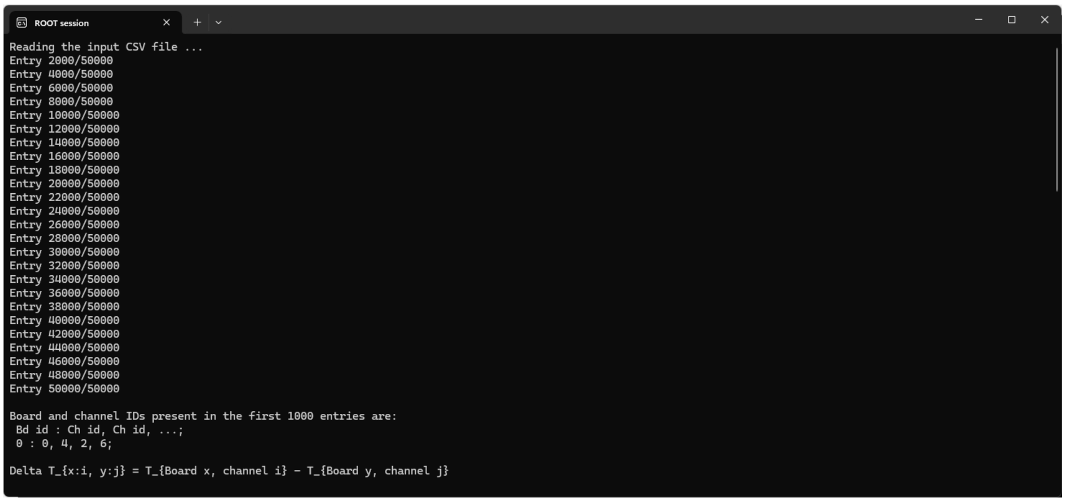
```
// ====================
//  User defined block:
// ====================

const string dirName = "C:\\Users\\mvenaruzzo\\Downloads\\CoMPASS\\Test Any to Any Single Board x730 Energy Selection\\DAQ\\run_CSV_Energy_Both\\RAW\\";

const string fileName = "SDataR_run_CSV_Energy_Both.csv";

// Input board and channel ids below according to the format "board id: channel id, channel id, ...;".
string channelMap = R"({
 0 : 0, 2, 4, 6;
})";

const float correlWin = 1000;          // Correlation/ coincidence window in ns
const int nEntries = 10000;            // Number of entries to be analyzed
const string eUnit = "keV";            // Unit of energy (ADC, keV, MeV). It will be applied to eCut and their ranges.
const int eCutStartCh = -1173;             // Energy cut on Start channel. Use a negative value to ignore this selection.
const int eCutStartChRange = 150;          // Energy cut range on Start channel. Accepted events = eCutStart-eCutStartRange/2 : eCutStart+eCutStartRange/2
const int eCutStopCh = -1332;              // Energy cut on Stop channel. Use a negative value to ignore this selection.
const int eCutStopChRange = 150;           // Energy cut range on Stop channel in keV. Accepted events = eCutStopCh-eCutStopChRange/2 : eCutStopCh+eCutStopChRange/2

const float histT_min = -1000.00;          // Minimum value of all the histograms in ns
const float histT_max = 400.00;        // Maximum value of all the histograms in ns
const float histT_binwidth = 0.5;      // Bin width of all the histograms in ns
bool f_fitHist = 1;                    // = 1 fits each of the histograms with a Gaussian function.
// ====================
```

Fig. 6.1: Any to Any ΔT analysis script source code extract showing the user defined block. Energy selection range reference values are set at negative values to have the script ignoring them.

They are required to be modified according to the user's specific analysis requirements.

Note: The energy selection range reference values have to be set at a negative value to have the script ignoring them.

After the code compilation, the script immediately starts the event processing, the ΔT histogram building and, if the corresponding option has been selected, the histogram fit.



```
ROOT session
Reading the input CSV file ...
Entry 2000/50000
Entry 4000/50000
Entry 6000/50000
Entry 8000/50000
Entry 10000/50000
Entry 12000/50000
Entry 14000/50000
Entry 16000/50000
Entry 18000/50000
Entry 20000/50000
Entry 22000/50000
Entry 24000/50000
Entry 26000/50000
Entry 28000/50000
Entry 30000/50000
Entry 32000/50000
Entry 34000/50000
Entry 36000/50000
Entry 38000/50000
Entry 40000/50000
Entry 42000/50000
Entry 44000/50000
Entry 46000/50000
Entry 48000/50000
Entry 50000/50000

Board and channel IDs present in the first 1000 entries are:
 Bd id : Ch id, Ch id, ...;
 0 : 0, 4, 2, 6;

Delta T_{x:i, y:j} = T_{Board x, channel i} - T_{Board y, channel j}
```

Fig. 6.2: View of the Any to Any ΔT analysis script I/O console.

At the end of the data processing, the script does show the histograms with the corresponding fit results.

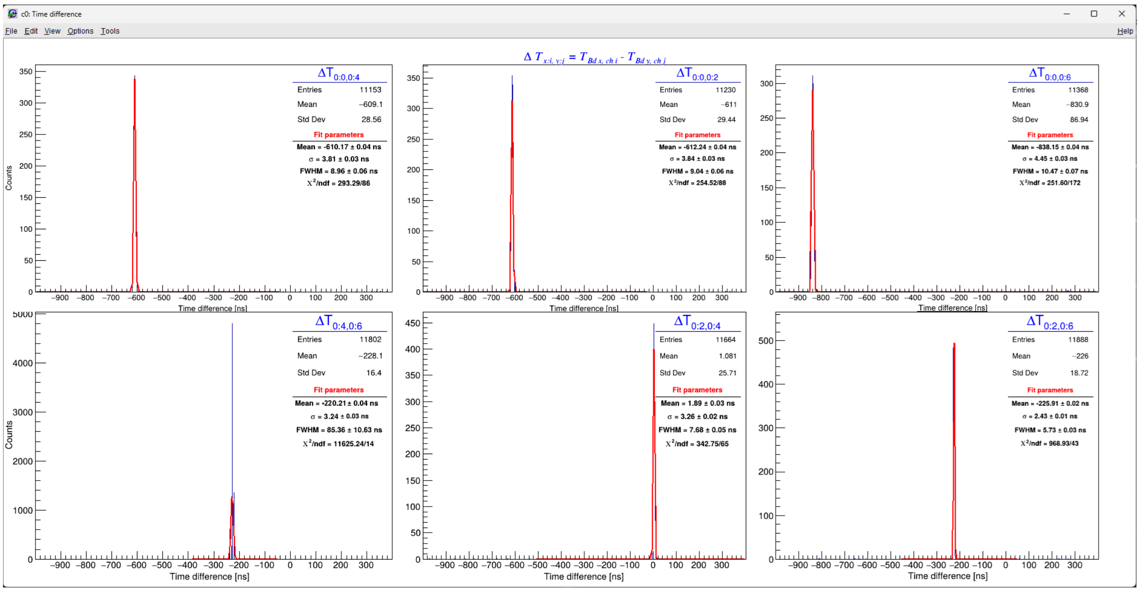


Fig. 6.3: Any to Any ΔT analysis results - ΔT spectra.

6.4 Any to any analysis with energy selection example

In the following an example of such analysis is provided. The original data acquisition have been performed with a DT5730B digitizer equipped with the DPP-PSD firmware. 4 out of 8 channels have been used (0, 2, 4, 6). Single time sorted list data file have been saved in CSV format.

Before proceeding with the code compilation, in the source code the user is asked to provide, besides the list data file path, some information about the acquisition settings as shown in the following picture.

```
// ====================
//  User defined block:
// ====================

const string dirName = "C:\\Users\\mvenaruzzo\\Downloads\\CoMPASS\\Test Any to Any Single Board x730 Energy Selection\\DAQ\\run_CSV_Energy_Both\\RAW\\";

const string fileName = "SDataR_run_CSV_Energy_Both.csv";

// Input board and channel ids below according to the format "board id: channel id, channel id, ...;".
string channelMap = R"({
 0 : 0, 2, 4, 6;
})";

const float correlWin = 1000;           // Correlation/ coincidence window in ns
const int nEntries = 10000;             // Number of entries to be analyzed
const string eUnit = "keV";             // Unit of energy (ADC, keV, MeV). It will be applied to eCut and their ranges.
const int eCutStartCh = 1173;               // Energy cut on Start channel. Use a negative value to ignore this selection.
const int eCutStartChRange = 150;           // Energy cut range on Start channel. Accepted events = eCutStart-eCutStartRange/2 : eCutStart+eCutStartRange/2
const int eCutStopCh = 1332;                // Energy cut on Stop channel. Use a negative value to ignore this selection.
const int eCutStopChRange = 150;            // Energy cut range on Stop channel in keV. Accepted events = eCutStopCh-eCutStopChRange/2 : eCutStopCh+eCutStopChRange/2

const float histT_min = -1000.00;           // Minimum value of all the histograms in ns
const float histT_max = 400.00;         // Maximum value of all the histograms in ns
const float histT_binwidth = 0.5;       // Bin width of all the histograms in ns
bool f_fitHist = 1;                     // = 1 fits each of the histograms with a Gaussian function.
// ====================
```

Fig. 6.4: Any to Any ΔT analysis script source code exctract showing the user defined block.

They are required to be modified according to the user's specific analysis requirements. In this case the user has to specify the energy selection range for the channel that will act as start and the channels that will act as stop. All the stop channels will share the same energy range selection settings.

Note: The energy selection range reference values have to be set at a positive value to have the script using them.

After the code compilation, the script immediately starts the event processing. It builds the energy spectrum showing the areas corresponding to the users defined energy selection ranges and builds the ΔT histogram in which the evens are those passing the user's energy selection. If the corresponding option has been selected, the histogram is fitted.

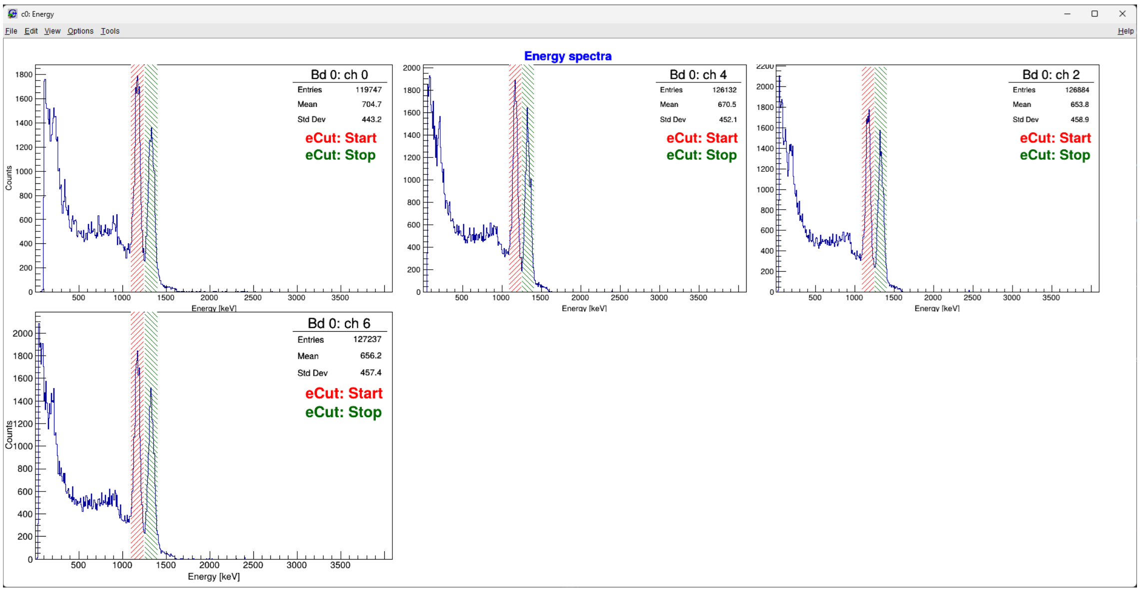


Fig. 6.5: Any to Any ΔT analysis results - Energy spectra with selection areas.

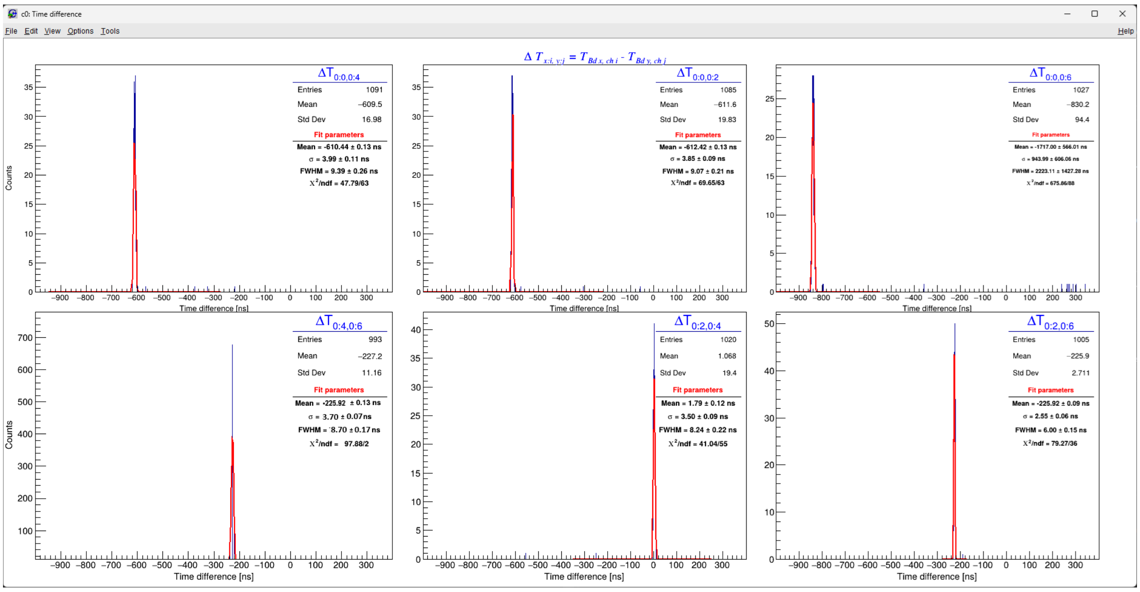


Fig. 6.6: Any to Any ΔT analysis results - ΔT spectra.

7 Batch mode data acquisition using an external script

One may need to run repetitive acquisitions over time to look for possible changes in the experimental results over a long duration. It may be required to do a parameter scanning by acquiring data several times with a different parameter value for each run. In these types of situations it could be convenient to let the data acquisitions run repetitively without any human interaction. In addition, experimental condition may restrict the user to access the data acquiring PC locally. For this purpose an example code written in C++ is provided with CoMPASS inside the demo folder which allows to access CoMPASS from a remote PC and control running it with different settings.

7.1 How to use the code?

- After adding the boards in CoMPASS, click on ”Remote Control” in CoMPASS Plot window to enable remote access of CoMPASS from another PC.
- Check connectivity by typing *http://<ipAddress>:8080/compass/* in a browser where *ipAddress* is the IP address of the PC where CoMPASS is running. This should display a message ”Welcome to CoMPASS data acquisition remote control”, if the connection is successful. If one is accessing from the same computer where CoMPASS is running, they should use *http://127.0.0.1:8080/compass/*.
- One can run the code in two modes:
    1. Batch mode with different settings: in this case different CoMPASS configuration files can be used for the runs and the acquisitions can be for different duration. One must create the config files (inside CONFIG folder of the CoMPASS project) in advance. The config file names, acquisition duration and run IDs should be specified in the *userParametersFile.txt* file.
    2. Batch mode with identical settings: this mode runs with the same config file and for same duration with auto-incremented runID. Data will be saved periodically after completion of each run. A single config file should be created in advance and kept inside the CONFIG folder of the CoMPASS project. In case of manual configuration, the configurations should be set on the CoMPASS gui before starting the acquisition. In this mode, the auto-incrementation of runID is enabled by default.
- To compile and run:
    - **Linux**: In a terminal, type the following lines to compile and run the code.

      ```
      g++ batchAcquisition.cpp -o batchAcquisition
      ./batchAcquisition
      ```

    - **Windows (Visual Studio)**:
      Create a new project and add the batchAcquisition.cpp file to the project. Set the project to use C++17 standard. Include the library ws2_32.lib as an additional dependency in the project properties (under Linker → Input). Build and run the project.

The user needs to make sure that no folder is already present inside the CoMAPSS project directory having the same name as the runID specified in the *userParametersFile.txt* file. Otherwise, the run will not start.

7.2 Input parameters file

The input parameters for the code are read from a text file specified by the user. By default the code looks for a file named *userParametersFile.txt* in the same folder where the executable is located. To use a different file name or path, the user needs to provide its name (with correct path) as an argument while running the code.

- **Linux**:

  ```
  ./batchAcquisition newParametersFileName.txt
  ```

- **Windows (Visual Studio)**:
  Specify the new parameters file name in the "Command Arguments" field of the Debugging section of project properties.

In the *userParametersFile.txt* file, order of the inputs needs to be preserved. No field should be left blank. Multiple values for a parameter can be specified in a single line separated by commas. Lines starting with # are treated as comments and ignored. The input parameters are described below according to their order of appearance in the file.

1. **Server IP address** (string): IP address of the computer where CoMPASS is running. For local connection, use 127.0.0.1.
2. **Server port number** (integer): Port number for remote connection to CoMPASS. Default is 8080.
3. **Server wait time** (integer): Time in seconds to wait after sending a command to the server before sending the next command. A high event rate acquisition may need a longer wait time.
4. **Acquisition duration** (list of integers): Duration(s) of data acquisition in seconds. If there is a single value, it will be used for all the acquisitions. The actual run time will be slightly shorter than the specified duration due to the time taken by the server to process the commands.
5. **Config file names** (list of strings): Name(s) of the CoMPASS configuration file(s) to be used for the acquisitions. The config files should be present inside the CONFIG folder of the CoMPASS project. If there is a single value, it will be used for all the acquisitions. If the value is "0", manual configuration mode will be enabled. In that case, the user should set the configuration on the CoMPASS GUI before starting the acquisition. The runID, its auto-incrementation and duration for each run must be set in the *userParametersFile.txt* file.
6. **Run IDs** (list of strings): Run ID(s) to be used for the acquisitions. If there is a single value, it will be used as the base run ID and automatic incrementation of Run ID will be enabled. New folders with the auto-incremented runIDs will be created if data saving is enabled. If multiple values are specified, they will be used for the corresponding acquisitions.
7. **Number of acquisitions** (integer): value of this parameter is used only in the identical settings mode. It specifies the number of times the acquisition should run. If set to 0, the acquisition will run indefinitely until stopped manually from the CoMPASS GUI.

Example of a typical *userParametersFile.txt* file is given below:

```
# Server ip address
127.0.0.1
# Server port number
8080
# Time (in s) to wait for server to process requests
8
#
# Acquisition durations in seconds
120, 180, 240, 60, 1800
# CoMPASS config files
```

```
  config1.xml, config2.xml, config3.xml, config4.xml, config5.xml
  # Run IDs
  run1, run2, run3, run4, run5
  # Number of acquisitions
  15
# End of file
```

8 Troubleshooting

CoMPASS helps the user in identifying a the origin of a possible error condition by means of popup that appear and inform the user about the occurred error condition and provides additional information. In the following some examples and in Tab. **8.1** a summary of the most common troubleshooting is provided.

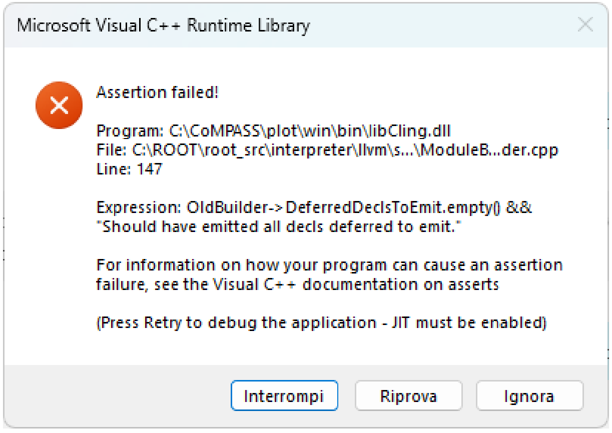


Fig. 8.1: First example of Assertion Failed Error at the CoMPASS Startup.

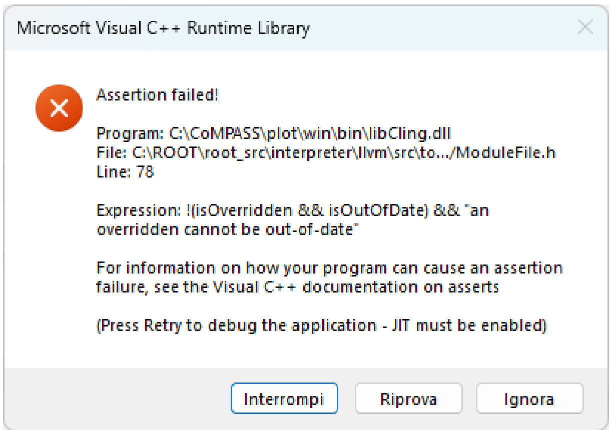


Fig. 8.2: Second example of Assertion Failed Error at the CoMPASS Startup.

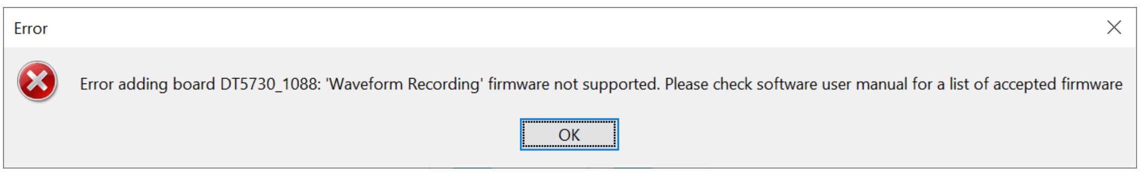


Fig. 8.3: Not supported firmware error popup.

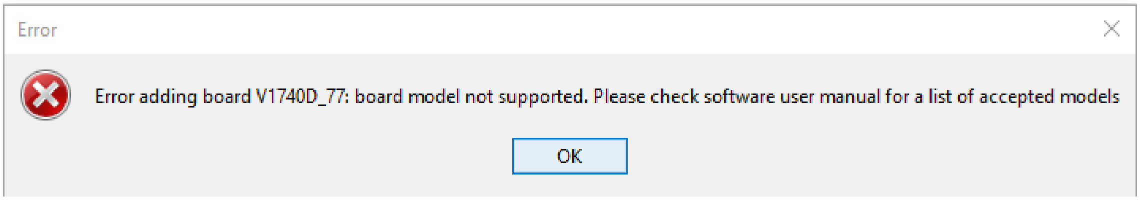


Fig. 8.4: Not supported board model error popup.

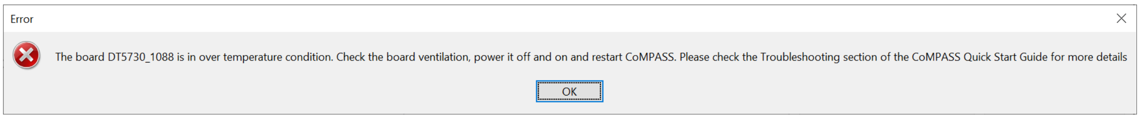


Fig. 8.5: Overtemperature error popup.

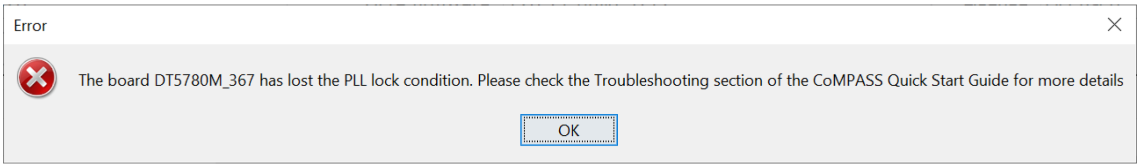


Fig. 8.6: PLL Lock loss error popup.

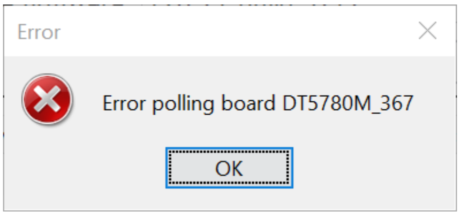


Fig. 8.7: Polling (communication interrupt) error popup.

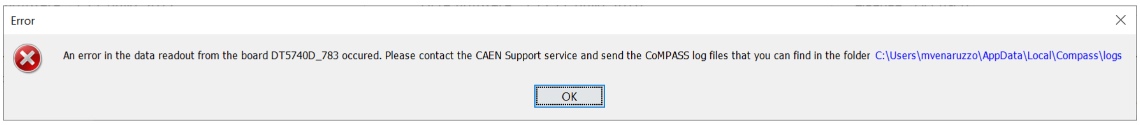


Fig. 8.8: Data readout error popup.

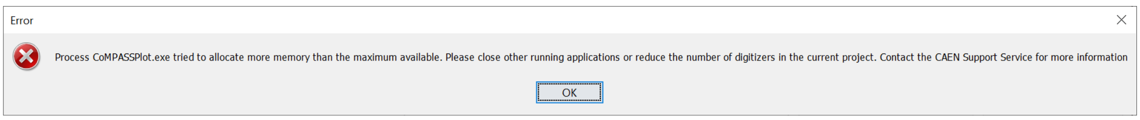


Fig. 8.9: Memory allocation error popup.

	CoMPASS Issue	Fixes
0	(Linux Only) CoMPASSPlot does not start and shows exit value -139	Your Linux distribution is missing some CoMPASSPlot required dependecies. Remove CoMPASS and install it again using the SNAP package instead of the .tz.gz one.
1	(Almalinux Only) CoMPASSPlot requires GLIBC 2.35 or higher and GLIBCXX 3.4.30 or higher which are not available for Almalinux 9.4 or lower	Change yiu Linux OS distribution to one supporting these libraries versions or install CoMPASS using the SNAP package.
2	(Linux on Virtual Machine Only) CoMPASS shows some graphical issues like icons or buttons or menus not well displayed	Change the graphical enviroment used by your Linux distribution running on the Virtual Machine (eg to Gnome, KDE or Xorg)
3	(Windows only) CoMPASS does not start the installation wizard automatically	Try launching the installer ".exe" file from PowerShell using the following command: *.\CoMPASS_v2.6.0-Setup.exe /LOG="test.log"»*
4	CoMPASS GUI or CoMPASSPlot do not start or an Assertion fails occurs as per the first example above shown (*.cpp file mentioned) (Windows only)	Check the CoMPASS dependencies installation in your pc. The following software has to be present: 1. CoMPASS 2. Windows SDK AddOn 3. Windows Software Development Kit - Windows 10.0.19041.685 4. Visual Studio Build Tools 2019 5. Microsoft Visual Studio Installer 6. Microsoft Visual C++ 2015-2019 If one of them is not present, contact the CAEN Support service.
5	Assertion failed as per the first or second example above shown (*.cpp or *h file mentioned)	This error occurs at the CoMPASS startup and is related to some incompatibilities between the SDK required by the CoMPASS embedded ROOT and another possible ROOT version or the Visual Studio 2022 SDK 10.0.22000 already installed on the pc. Try to remove any ROOT and the mentioned Visual Studio 2022 SDK 10.0.22000 already installed on the pc and install CoMPASS again. After that you may try to reinstall your own ROOT distribution. Visual Studio 2022 SDK 10.0.22000 in, on the contrary not compatible with CoMPASS.
6	Board not supported	Check the Quick Start Guide for a list of supported boards.
7	Firmware not supported	Check the Quick Start Guide for a list of supported firmware.

8	Over temperature error: CoMPASS has detected that the digitizer is overheated.	Check that the digitizer is properly ventilated: • If you are using a desktop digitizer, please verify that the fans are not blocked and that there is enough space on both lateral sides for a proper air flow; • If you are using a VME or NIM digitizer, please check that the crate is a ventilated model, that the fans are not blocked and that there is enough space on both lateral sides (in case of a minicrate) or on the top and bottom side (in case of a vertical crate model) for a proper air flow.
9	PLL lock loss: CoMPASS has detected a digitizer PLL lock loss condition. This condition is due to a loss of the reference clock.	Check the digitizer front panel LED status. If the PLL Lock LED is off or blinking proceed with the following steps: • If you are using an external clock signal, please check that the external clock is active and that the cable connection into the digitizer CLK_OUT/CLK_IN connectors is properly done. • If you are not using an external clock signal first power cycle the board. If the PLL Lock LED remains off, the digitizer PLL needs to be reprogrammed. Use CAEN Upgrader software to do the PLL reprogramming. • In case of VME digitizers, please check that the CLOCK EXT/INT switch is in the right position. Remember to properly reprogram the PLL using the CAEN Upgrader software every time you switch from EXT to INT and viceversa even if the PLL Lock led is on.
10	ADC Shutdown: CoMPASS has detected a shutdown of the digitizer ADC.	Typically this condition is due to board overheating. Follow the instructions reported for the board Overtemperature condition.
11	Error polling: CoMPASS has lost the communication with the board.	Check that the digitizer is ON and that the USB or the Optical link cable is properly connected.
12	Readout error: an error occurred during the data readout from the board or from the offline run file.	Contact the CAEN Support Service .
13	Memory allocation: Process CoMPASSPlot.exe tried to allocate more memory than the maximum available.	Close other running applications or reduce the number of digitizers in the current project. Contact the CAEN Support Service for more information

Tab. 8.1: CoMPASS Troubleshooting cases.

9 Technical Support

To contact CAEN specialists for requests on the software, hardware, and board return and repair, it is necessary a MyCAEN+ account on www.caen.it:

https://www.caen.it/support-services/getting-started-with-mycaen-portal/

All the instructions for use the Support platform are in the document:


CAEN
Tools for Discovery

SAFETY, STORAGE AND SETUP INFORMATION

PRODUCT SUPPORT AND SETUP INFORMATION

INFORMAZIONI SU SICUREZZA STOCCAGGIO E INSTALLAZIONE

ASSISTENZA E RIPARAZIONE DEL PRODOTTO

CE UK CA

A paper copy of the document is delivered with CAEN boards.
The document is downloadable for free in PDF digital format at:

https://www.caen.it/safety-information-product-support

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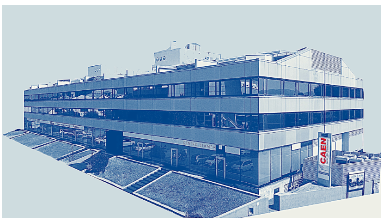

GD6300 - CoMPASS Quick Start - Multiparametric DAQ Software for Physics Applications rev. 26 - 00117-10-DGT28-MUTX

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