Rev. 1 - 7th December 2022

SP5600E

Educational Photon Kit

CAEN Educational

Guide

GD5383

1.1 Purpose of this Guide

This QuickStart Guide contains basic information and examples that will let you use Educational Photon kit.

1.2 Change Document Record

Date	Revision	Changes
September 2016	00	Initial release.
December 2022	01	Updated §Getting started, §Basic Measurements, §Educational Experiments and §Technical Support. Added New §PID (Product Identifier), §Hardware Description, §Software Description, §Appendix, §Instructions for Cleaning, §Device decommissioning and §Disposal.

1.3 Symbols, abbreviated terms and notation

AMC FPGA	Acquisition & Memory Controller FPGA
DPP	Digital Pulse Processing
FPGA	Field Programmable Gate Array
OS	Operating System
PSAU	Power Supply & Amplification Unit
ROC FPGA	ReadOut Controller FGPA
SiPM	Silicon Photo-Multiplier
GUI	Graphical User Interface
PSAU	Power Supply and Amplification Unit

1.4 Reference Documents

[RD1] DT5720 User Manual

[RD2] UM1935 – CAENDigitizer User & Reference Manual

[RD3] GD2783 - First Installation Guide to Desktop Digitizers & MCA

[RD4] GD7873 - Digital Pulse Processing for SiPM kit

[RD5] DS2626 – SP5600 Power Supply and Amplification

[RD6] DS2628 – SP5650 Sensor Holder for SP5600

[RD7] DS2477 – SP5601 Led Driver Data sheet

[RD8] ED3127 - An educational kit based on a Modular silicon Photomultiplier System

https://www.caen.it/support-services/documentation-area/

1.5 Manufacturer Contacts

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1.6 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.

1.7 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.

1.8 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 (this is true for the boards marked "MADE IN ITALY", while we cannot guarantee for third-party manufactures).

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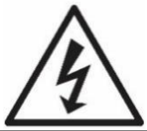
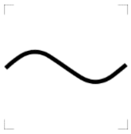
1 Safety Notices

<u>N.B. Read carefully the "Precautions for Handling, Storage and Installation" document provided with the product before starting any operation.</u>

The following HAZARD SYMBOLS may be reported on the unit:

	Caution, refer to product manual
	Caution, risk of electrical shock
	Protective conductor terminal
	Earth (Ground) Terminal
	Alternating Current
	Three-Phase Alternating Current

The following symbol may be reported in the present manual:

	General warning statement

The symbol could be followed by the following terms:

- **DANGER**: indicates a hazardous situation which, if not avoided, will result in serious injury or death.
- **WARNING**: indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- **CAUTION**: indicates a situation or condition that, if not avoided, could cause physical injury, or damage the product and / or its environment.

CAUTION: To avoid potential hazards

USE THE PRODUCT ONLY AS SPECIFIED.
ONLY QUALIFIED PERSONNEL SHOULD PERFORM SERVICE PROCEDURES

CAUTION: Avoid Electric Overload

TO AVOID ELECTRIC SHOCK OR FIRE HAZARD, DO NOT POWER A LOAD OUTSIDE OF ITS SPECIFIED RANGE

CAUTION: Avoid Electric Shock

TO AVOID INJURY OR LOSS OF LIFE, DO NOT CONNECT OR DISCONNECT CABLES WHILE THEY ARE CONNECTED TO A VOLTAGE SOURCE

CAUTION: Do Not Operate without Covers

TO AVOID ELECTRIC SHOCK OR FIRE HAZARD, DO NOT OPERATE THIS PRODUCT WITH COVERS OR PANELS REMOVED

CAUTION: Do Not Operate in Wet/Damp Conditions

TO AVOID ELECTRIC SHOCK, DO NOT OPERATE THIS PRODUCT IN WET OR DAMP CONDITIONS

CAUTION: Do Not Operate in an Explosive Atmosphere

TO AVOID INJURY OR FIRE HAZARD, DO NOT OPERATE THIS PRODUCT IN AN EXPLOSIVE ATMOSPHERE

Do Not Operate with Suspected Failures. If you suspect this product to be damaged, please contact Technical Support.

THIS DEVICE SHOULD BE INSTALLED AND USED BY SKILLED TECHNICIAN ONLY OR UNDER HIS SUPERVISION

DO NOT OPERATE WITH SUSPECTED FAILURES.
IF YOU SUSPECT THIS PRODUCT TO BE DAMAGED, PLEASE CONTACT THE TECHNICAL SUPPORT

THE SAFETY OF ANY SYSTEM THAT INCORPORATES THE DEVICE IS UNDER THE RESPONSIBILITY OF THE ASSEMBLER OF THE SYSTEM

See Chap. 13 for the Technical Support contacts.

2 Introduction

CAEN brings the experience acquired in more than 40 years of collaboration with the High Energy & Nuclear Physics community into the University educational laboratories. Thanks to the most advanced instrumentation developed by CAEN for the major experiments Worldwide, together with the University teaching experience at the University of Insubria, a series of experiments covering several applications has been carried out.

CAEN realized different modular Educational Kits. The set-ups are all based on Silicon Photomultipliers (SiPM) state of-the-art sensor of light with single photon sensitivity and unprecedented photon number capability.

The **Educational Photon Kit**, **SP5600E**, is the system solution to introduce the student to the knowledge of the features of Silicon Photomultipliers (SiPM).The system allows to explore the quantum nature of phenomena that is one of the most exiting experiences a physics student can live.

The Educational Photon Kit comprises:

- Nr. 1 Power Supply & Amplification Unit (PSAU, ID code SP5600). The PSAU supplies the bias for the sensors, features a variable amplification factor up to 50 dB and integrates a feedback circuit to stabilize the sensor gain against temperature variations. Moreover, the PSAU includes one leading edge discriminator/channel and a coincidence circuit for flexible event trigger logic. Sensors housed in dedicated mechanical holders can be directly connected to the PSAU. The PSAU technical specifications are reported in the relevant data sheet, together with the front and rear panel description.
- Nr. 1 Desktop Waveform digitizer (ID code DT5720A), with 2 input channels sampled at 250 MS/s by a 12-bit ADC. The DT5720A runs the Digital Pulse Processing for enhanced triggering and integration capabilities. The Digitizer technical specifications are reported in the relevant User's manual, together with the front and rear panel description.
- Nr. 1 SiPM Holder (ID code SP5650C), housing a Hamamatsu MPPC 1.3 x 1.3 mm^2 model S13360-1350CS. The mechanical structure of the holder allows an easy coupling of the holder itself with the PSAU.
- Nr.1 Ultra-fast LED Driver (ID code SP5601) with pulse width at ns level, tunable intensity, pulsing frequency internally/externally generated and FC interface to either a clear or a Wave Length Shifting (WLS) fiber. The LED technical specifications are reported in the relevant data sheet, together with the front and rear panel description.
- External AC/DC stabilized 12 V power supplies (Meanwell GS40A12-P1J 40 W, 12 V DC Output, 3.34 A).
- Nr.1 Kit cables (ID code FKITSP56) composed of: n.1 LEMO-LEMO cable, n.2 MCX-LEMO cables, n.1 MCX-MCX cables, n.1 Power Cord Adapter (1IN / 3 OUT).
- Nr.1 Pen-Vac Vacuum Pickup Tool (VPV) is an ideal tool for manually offloading absorbers from SP5607. The pickup tool is a self-contained unit and can lift up to 500 grams.
- Nr.1 Optical grease.
- USB cables.
- A LabView™ based software: HERA (Handy Educational Radiation Application).

The different building blocks of the kit can be assembled in a customized configuration, according to the specific application and the user's requirements.

The purpose of this guide is to provide a hands-on primer on the use of the essential functionalities of the kit.

Item description	Code	Image	SP5600AN Educational Premium kit	SP5600C Educational Gamma kit	SP5600D Educational Beta kit	SP5600E Educational Photon kit
SP5600 Power Supply and Amplification Unit	WSP5600XAAAA		yes	yes	yes	yes
DT5720A Desktop Digitizer	WDT5720AXAAA		yes	yes	yes	yes
SP5601 Led Driver	WSP5601XAAAA		yes	no	no	yes
SP5650C Sensor Holder with SiPM	WSP5650XCAAA		yes	no	no	yes
SP5606 - Mini Spectrometer	WSP5606XAAAA		yes	yes	no	no
SP5607 Absorption Tool	WSP5607XAAAA		yes	yes	no	no
SP5608 Scintillating Tile	WSP5608XAAAA		yes	no	yes	no
A315 - Splitter	WA315XAAAAAA		yes	yes	no	no

Tab. 2.1: Building blocks of the kits.

CAUTION: to manage the product, consult the operating instructions provided.

When receiving the unit, the user is strictly recommended to:

- Inspect containers for damage during shipment. Report any damage to the freight carrier for possible insurance claims.
- Check that all the components received match those listed on the enclosed packing list as in Tab. 2.1. (CAEN cannot accept responsibility for missing items unless we are notified promptly of any discrepancies.)
- Open shipping containers; be careful not to damage contents.
- Inspect contents and report any damage. The inspection should confirm that there is no exterior damage to the unit such as broken knobs or connectors and that the front panel and display face are not scratched or cracked. Keep all packing material until the inspection has been completed.
- If damage is detected, file a claim with carrier immediately and notify CAEN service.
- If equipment must be returned for any reason, carefully repack equipment in the original shipping container with original packing materials if possible. Please, contact CAEN service.
- If equipment is to be installed later, place equipment in original shipping container and store in a safe place until ready to install

DO NOT SUBJECT THE ITEM TO UNDUE SHOCK OF VIBRATIONS

DO NOT BUMP, DROP OR SLIDE SHIPPING CONTAINERS

DO NOT LEAVE ITEMS OR SHIPPING CONTAINERS UNSUPERVISED IN AREAS WHERE UNTRAINED PERSONNEL MAY MISHANDLE THE ITEMS

USE ONLY ACCESSORIES WICH MEET THE MANUFACTURER SPECIFICATIONS

3 PID (Product Identifier)

PID is the CAEN product identifier, an incremental number greater than 10000 that is unique for each product[1]. The PID is on a label affixed to the kit suitcase by the opening mechanism (Fig. 3.1).

Fig. 3.1:PID location taking a CAEN Educational kit as an example (the number in the picture and the device model are purely indicative).

The PIS is even stored on each educational kit subparts as shown in Fig. 3.2, Fig. 3.3 and Fig. 3.4.

Fig. 3.2: SP5600 - Power Supply and Amplification Unit: PID position is located on the back panel of the module hosting the power input. Same location is adopted for DT5720A - Desktop Digitizer also.

[1] The PID substitutes the serial number previously identifying the boards.

Fig. 3.3: PID position: on the metal shield for the A315 . Splitter or around the holder for the SP5650C - Sensor Holder with SiPM.

Fig. 3.4: SP5601 – LED Driver PID position: in the back panel of the module hosting the power input.

Note: The serial number is still valid to identify older boards, where the PID label is not present.

4 Hardware Description

As previously mentioned, the Educational Photon Kit is composed of a lot of hardware devices. To better understand their use, this section provides a brief description of the main kit units.

SP5600 - Power Supply and Amplification Unit

- Variable amplification gain (up to 50 dB)
- Low noise, to guarantee high performances of the sensor even with small signals
- Wideband, to comply with the fast sensor response
- Fast leading-edge discriminator and time coincidence
- Provides the bias for the sensors with gain stabilization
- USB 2.0 interface
- Dimension: 150 x 50 x 70 mm^3 (WxHxD)

The SP5600 is a general-purpose Power Supply and Amplification Unit, integrating up to two SiPMs in a mother & daughter architecture allowing easy mounting and replacement of the sensors. The basic configuration features two channels with independent gain control up to 50 dB and provides the bias voltage (up to 130 V) to the sensors with gain stabilization. Each channel can provide a digital output generated by the fast-leading edge discriminators. A timing coincidence of the two channels is also available [RD5].

DT5720A - Desktop Digitizer

- 2 Channel 12 bit 250 MS/s Digitizer
- Digital Pulse Processing for Charge Integration DPP-CI for SiPM
- Best suited for PMT and SiPM/MPPC readout at low and high rates
- Mid-High speed signals (Typ: output of PMT/SiPM)
- Good timing resolution with fast signals (rise time < 100 ns)
- Optical Link and USB 2.0 interfaces
- Dimension: 154 x 50 x 164 mm^3 (WxHxD)

The DT5720A is a 2 Channel CAEN Waveform Digitizers able to perform waveform recording and run online advanced algorithms of charge integration (DPP-CI), i.e. the digital version of the traditional QDC (Charge-to-Digital Converter) [RD4].
Data is read by a Flash ADC, 12-bit resolution and 250 MS/s sampling rate, which is well suited for mid-fast signals as the ones coming from liquid or inorganic scintillators coupled to PMTs or Silicon Photomultipliers. The acquisition can be either channel independent or common through an external signal and the acquired data can be saved for offline analysis.
The acquisition in DPP-CI mode for SiPM is fully controlled by the Hera software, which manages the algorithm parameters, builds plots and saves the relevant information through the USB 2.0 interface of the digitizer (data transfer up to 30 MB/s).
The digitizer runs on real time:

- Self-Trigger using CR-RC digital Time filter algorithm
- Input signal baseline (pedestal) calculation
- Charge Integration (with programmable gate parameters) with pedestal subtraction for energy calculation.

SP5601 – LED Driver

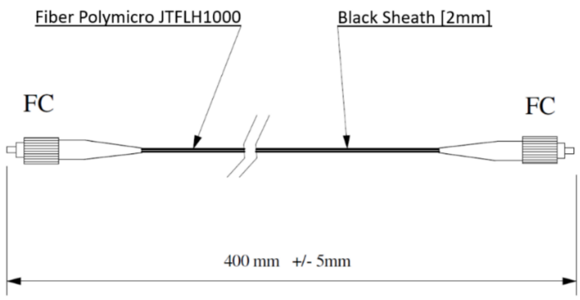
- Width of pulse: 8 ns
- LED color: violet (400nm) 1500 mcd
- Pulse generator: internal/external
- Optical output connectors: FC
- Optical fiber included
- Dimension: 79 x 42 x 102 mm^3 (WxHxD)

The SP5601 is an ultra-fast LED Driver and represents the ideal tool for SiPM tests and characterization, through a triggered light burst of intensity down to a few photons and up to a number saturating the sensors. The SP5601 features tuneable intensity and repetition rate: the LED driver can be triggered either via the internal pulse generator, or via an external source [RD7].

Optical Fiber

The optical signal coming from LED Driver is routed to the sensor through an *optical fiber*, FC interfaced.

Here below, some details about the optical fiber.



Characteristics:

- Step Index;
- Numerical Aperture: 0.37 ± 0.02;
- Full Acceptance Cone: 43.4 degrees;
- Low -OH Silica Core, Hard Polymer Clad;
- Low -OH Core for Vis-NIR Transmission;
- Operating Temperature: –65 ºC to +125 ºC;
- Proof Tested from 100kpsi to 150 kpsi;
- Optional Acrylate, Nylon, or Hytrel® Buffer;

Product Descriptor	Core (µm)	Clad (µm)	Buffer (µm)	Proof Test (kpsi)
JTFLH100010351400	1000 ± 15	1035 ± 15	1400 ± 50	100

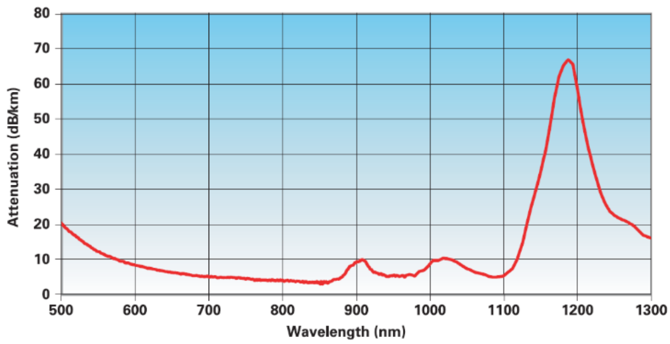


Fig. 4.1: Typical attenuation of the optical fiber.

Optical Grease

The optical coupling grease is a non-curing colourless coupling gel, clear and colourless having moderate viscosity and providing excellent transmission properties well into the near-ultraviolet region. It should be stored at temperatures below 26 °C, preferably above 5 °C, but it retains clarity and fluid property down to -60 °C.

Typical Properties	Value	
Colour	Clear	
Refractive Index @25 ºC	1.466	
Specific Gravity	1.06	
Penetration	300	
Light Transmittance @ 1 cm	300 nm	99.45%
	400 nm	99.99%
	450 nm	99.99%
	500 nm	99.99%
	633 nm	99.99%
	850 nm	99.99%
	1310 nm	99.65%
	1550 nm	99.38%

Tab. 4.1: Typical properties of the optical grease.

SP5650C – Sensor Holder

- Size 20 mm (diameter) x 6 mm (height)
- Analog Out Connector RADIALL: R113425000 (MCX MALE)
- Bias Connector M22-7140542 Female Vertical Socket
- Embedded Hamamatsu MPPC S13360- 1350CS:
- 1.3 x 1.3 mm^2 Active Area
- 667 Number of pixels
- 50 µm Pixel Pitch

The SP5650C holder hosts a 1.3 x 1.3 mm^2 Silicon Photomultipliers. A probe inside the holder senses temperature variations, thus allowing the user to compensate for possible gain instability. The SP5650C is made of a mechanical structure providing an FC fiber connector and a PCB where the SiPM is soldered. Bias voltage for the SiPM and temperature probe output are provided through a 10 pin female socket, while the analog output connector is MCX [RD6].

5 Getting started

This chapter will guide you through the drivers installation of PSAU and Digitizer, as well as the installation of HERA (Handy Educational Radiation Application) software and the first measurements.

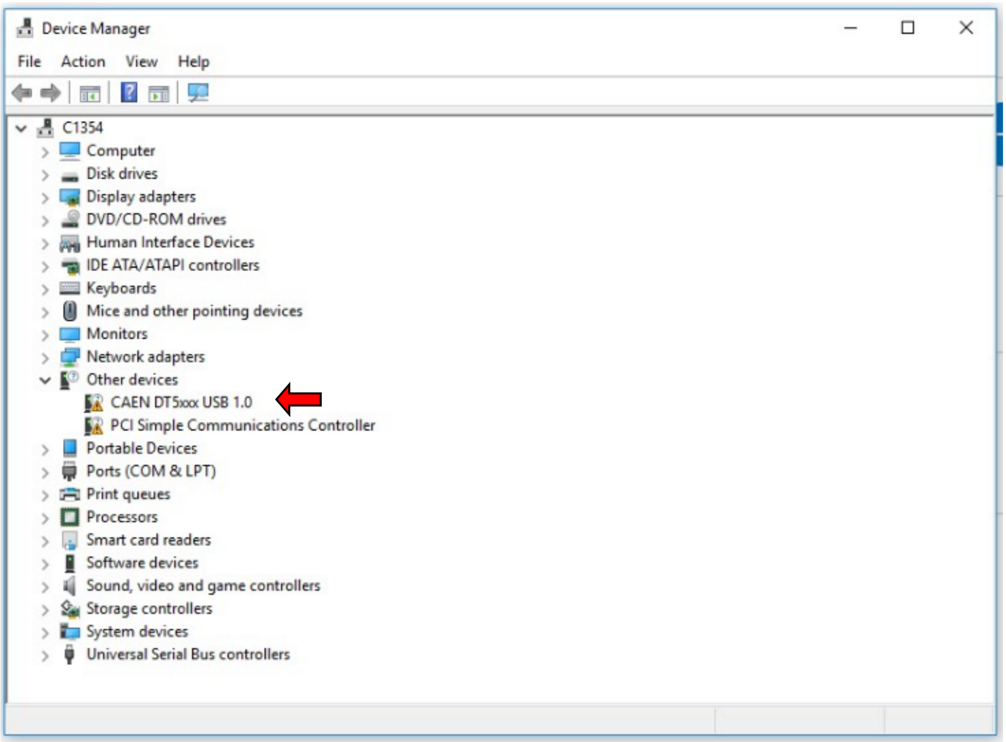
5.1 Software Installation Requirements

OS	Hardware	CAEN drivers required
Microsoft Windows 10 (64-bit)	2 available USB2.0 ports	DT5720 USB driver (32/64-bit) SP5600 USB driver (32/64-bit)

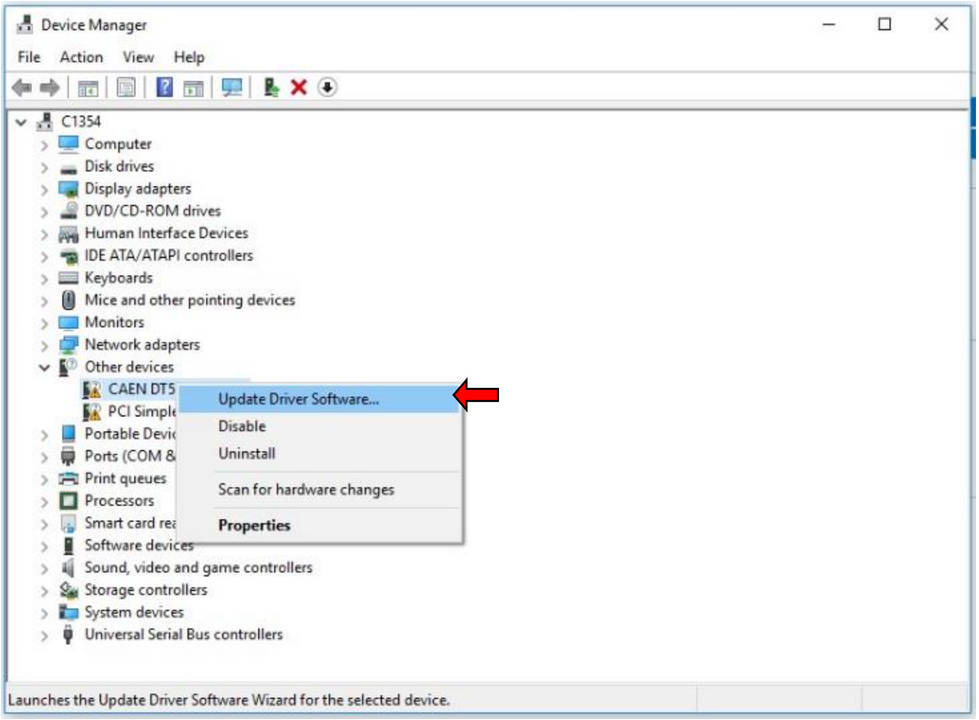
Tab. 5.1: Host PC requirements.

- Download the USB drivers for both DT5720 and SP5600 compliant to the Windows version 64-bit on CAEN website: Educational kit webpage > “Download” > “Software” tab > Driver section (login is required before the download).
- **Install the DT5720 drivers** following the instruction of the setup wizard. The OS will automatically recognize the DT5720 when it is connected to the PC. If the automatic installation fails, perform it manually from the Device Manager by selecting the driver update and pointing to the driver folder you downloaded from CAEN website.

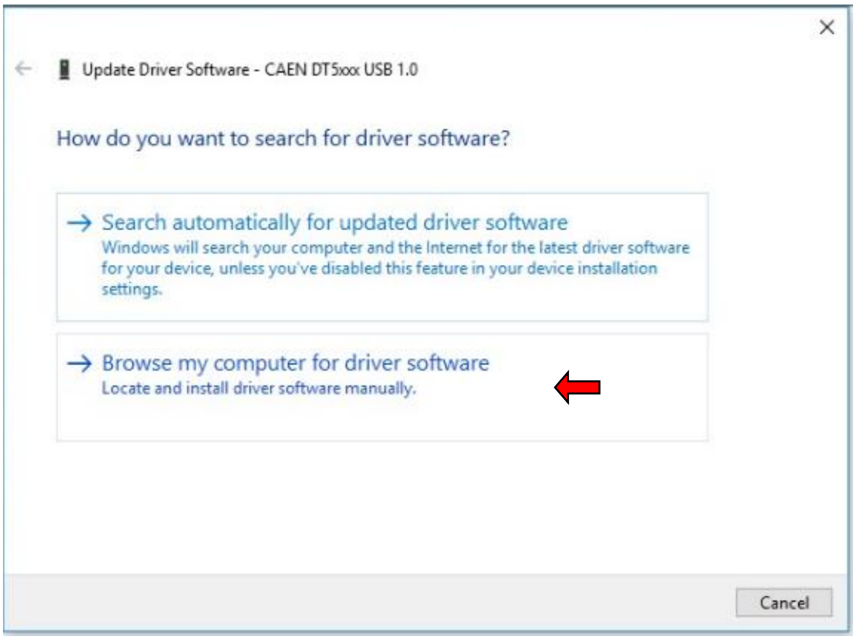
  For example, once connected and powered on the digitizer, you can do it going to Control Panel -> System & Security -> System -> Device Manager. In the Device Manager window, find the unknown **CAEN DT5xxx USB 1.0** in the list **Other Devices**:



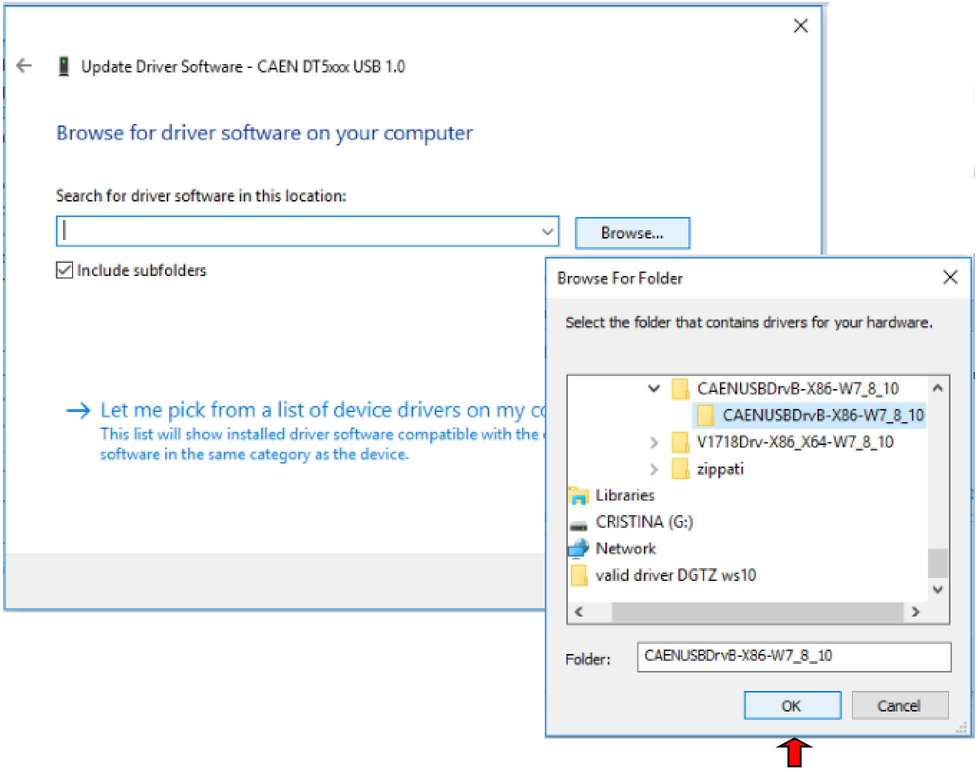
Right click on **CAEN DT5xxx USB 1.0** and select **Update Driver Software** option in the scroll menu.



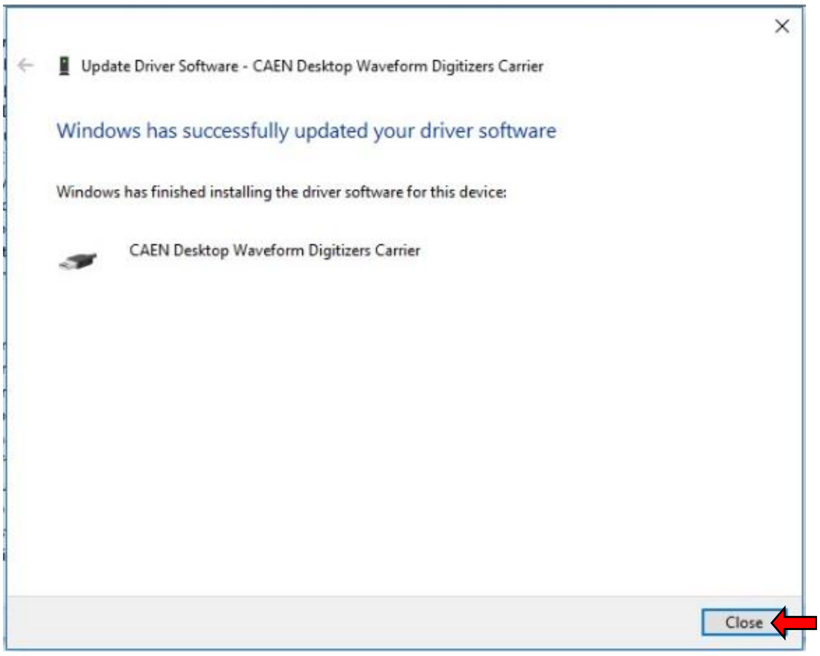
Select **Browse My Computer for driver software**.



Click **[Browse]** to point to the Windows drivers' folder you have previously unpacked, click **[OK]** to include the path in the search and click **[Next]** to continue.



When the driver installation will be completed, click **Close** to close the window.

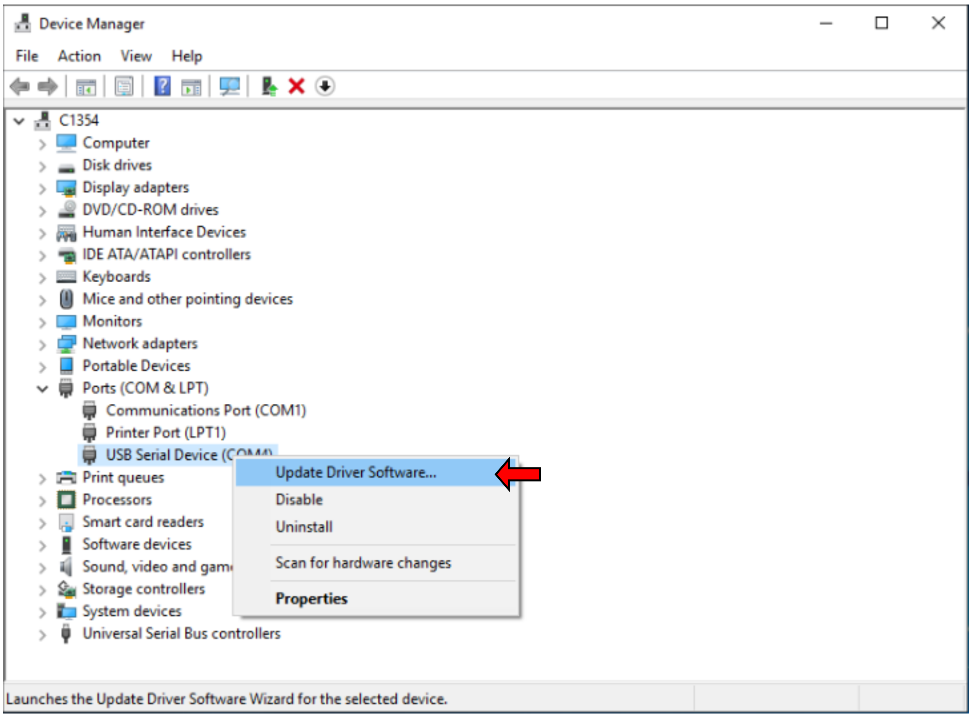


Refer to [RD3] for detailed installation OS-dependent.

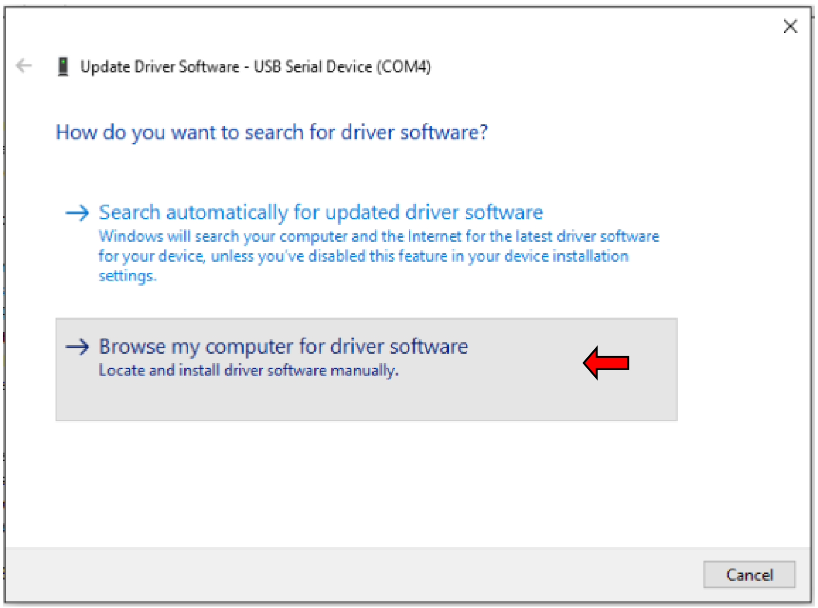
- Connect to the PC and power ON the **SP5600**; the PC will recognize as a new peripheral by the OS. Perform the driver installation manually from the Device Manager by selecting the driver update and pointing to the driver folder you downloaded from CAEN website. Finally, a COMM port will be associated to SP5600.

For example (Windows 10 – 64bit), once connected and powered on the SP5600, you can follow the previous instructions going to Control Panel -> System & Security -> System -> Device Manager -> Controller USB [Ports (COM)] Manager.

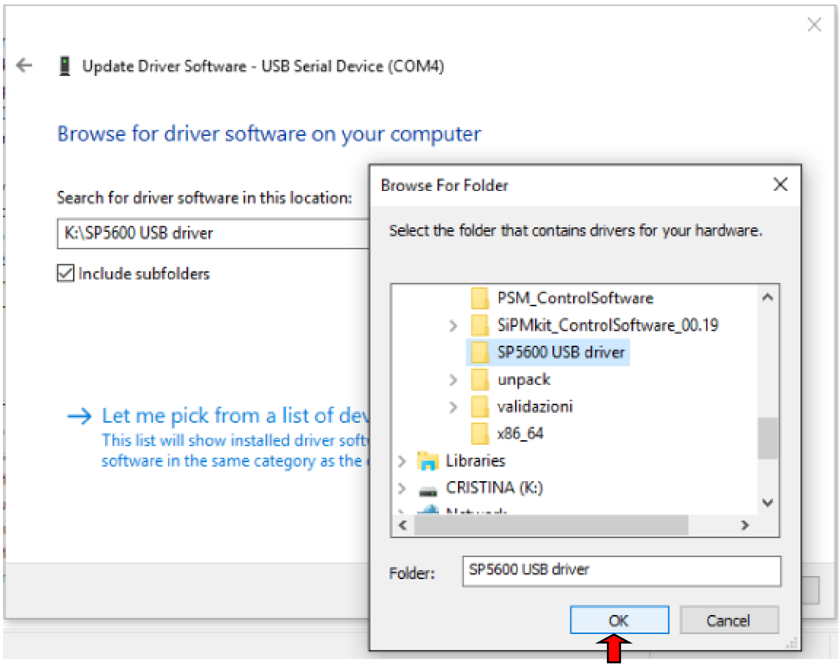
Right click on **USB Serial Device** and select **Update Driver** Software option in the scroll menu.



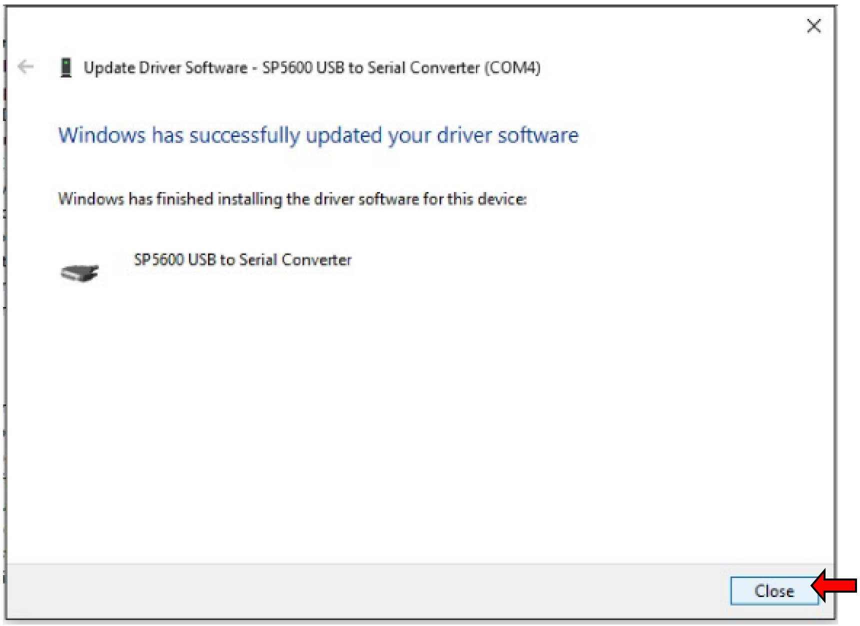
Select **Browse My Computer for driver software**.



Click **[Browse]** to point to the Windows drivers' folder you have previously unpacked, click **[OK]** to include the path in the search and click **[Next]** to continue.



When the driver installation will be completed, click **Close** to close the window.



Finally, a COM port will be associated to SP5600; please check the port number as shown in Fig. 5.1.

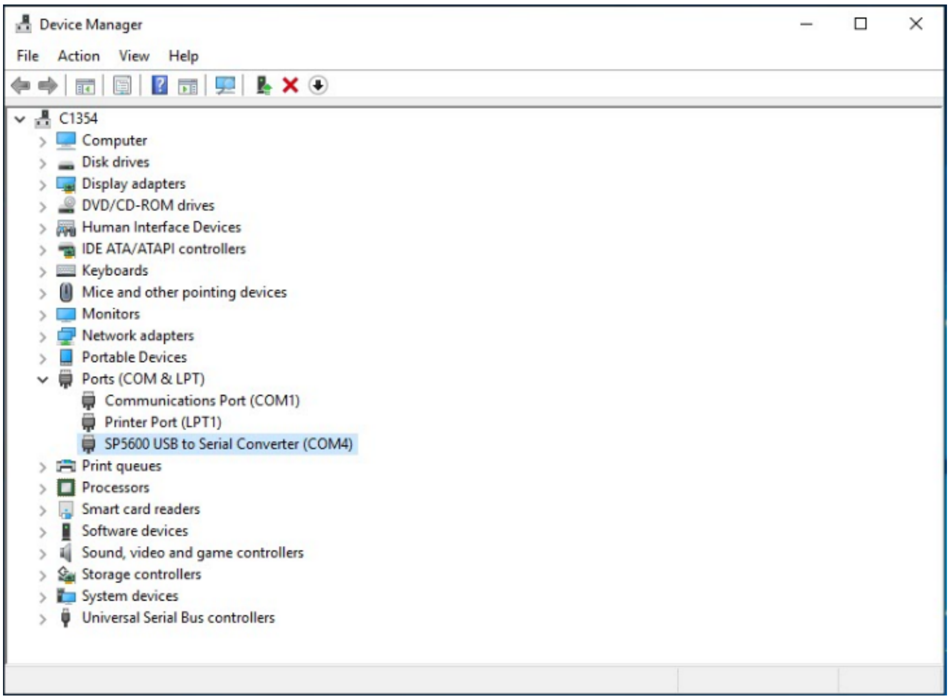


Fig. 5.1: Tracking the PSAU port assignment on a PC running Windows 10.

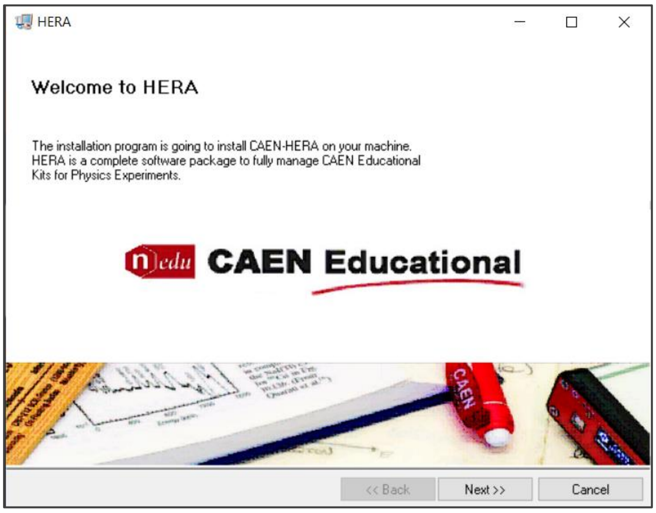
Important Note: HERA rel. 1.0.0 Build: 1.5.21.0103 or higher:

- does not require LabVIEW™ Run-Time Engine. or LabView™ version 2018 (or higher). The installation of LabVIEW™ Run-Time Engine 2018 is already implemented in the HERA.
- does not work with a digitizer USB Driver release < 3.4.7, if running in a 32-bit Windows environment.

5.2 Software Installation

Download the standalone HERA Software full installation package on CAEN website: Educational kit webpage > “Download” > “Software” tab > Application SW section (login is required before the download).

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



The setup automatically creates a link on the PC Desktop.

6 Software Description

When the installation procedure has been completed, the user can run the program by clicking the correspondent icon.

HERA (Handy Educational Radiation Application) is a user-friendly software platform allowing the user to manage the following CAEN Educational kits: SP5600E – Photon kit, SP5600D – Beta kit, SP5600C – Gamma kit, SP5600AN – Premium Version kit.

The simple graphical interfaces help the user to perform its own experimental activity. As shown in the opening window in Fig. 6.1, several ways of operative openings are available. This initial access multiplicity makes the software very flexible and suitable both for expert users as well as for beginner ones. With a simple selection, the user can decide how to execute the activity by choosing the direct access to the suggested experiments or access to devices management.

Via this main GUI, it is possible to visualize the devices status, server messages and, to access to data (log file, data stored, configuration files, etc.).

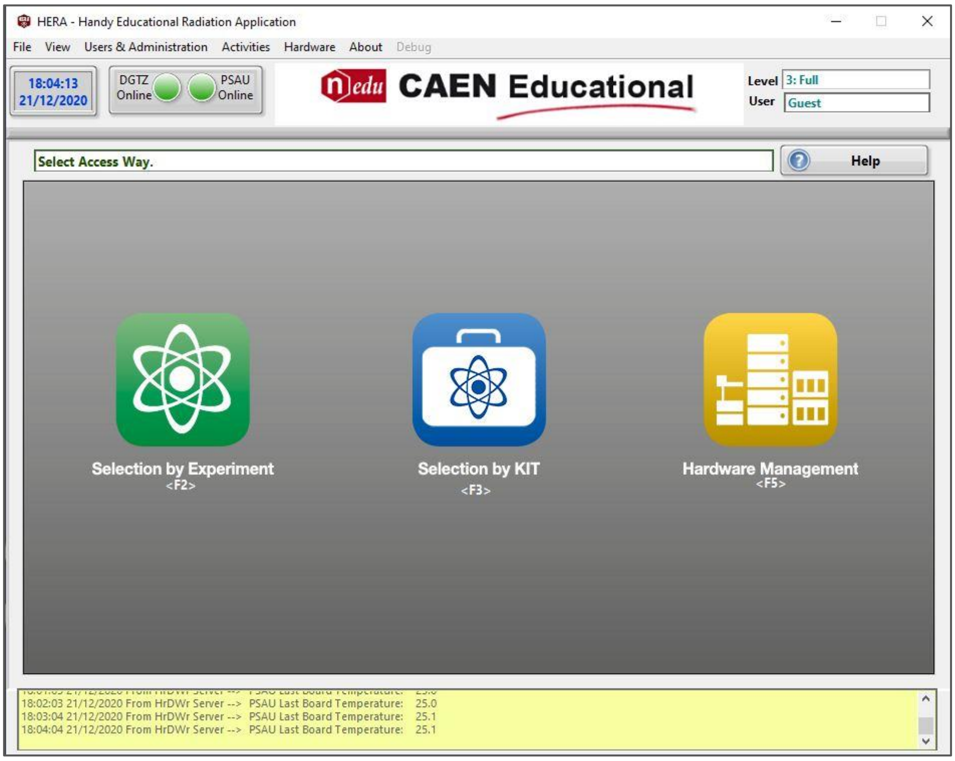
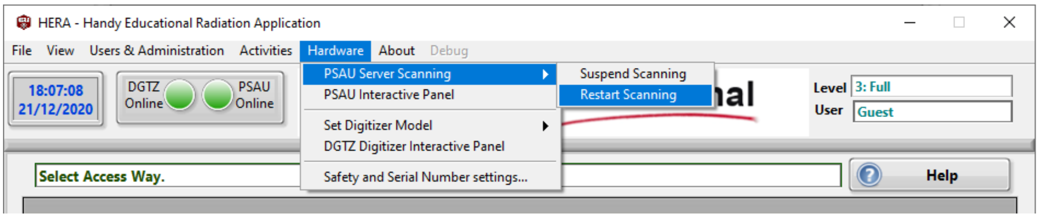


Fig. 6.1: Main GUI of the HERA software.

Before running the software, the user should wait the hardware connection. The software recognises the hardware automatically and start the connection. Two connection indicators, "Online Hardware", are present on the opening window:

- **Green light** means that the connection is ok.
- **Red light** means that there is no connection.
  If the PSAU is power on, but the light colour is red, the software can be forced to search for a new connection via the rescanning procedure from the Verbose Menu: Hardware-> PSAU Server Scanning -> Restart Scanning.



- **Yellow light** means that either the DGTZ is not a DT5720A/C, or its firmware is not compliant with Hera software, and another firmware type is probably running on the board.

The special firmware compatible with HERA Software is the Digital Pulse processing for Charge Integration for SiPM Kit (DPP-CI for SiPM) for DT5720A and the Digital Pulse Processing for Charge Integration and Pulse Shape Discrimination (DPP-PSD) for DT5720C [COMING SOON]. The firmware can be download from CAEN Website. Without any licenses, it will run in a 30-minute-per-power-cycle fully functional trial version.

To upload the firmware on the digitizer, use the CAENUpgrader Software (free download on CAEN Website): https://www.caen.it/products/caenupgrader/

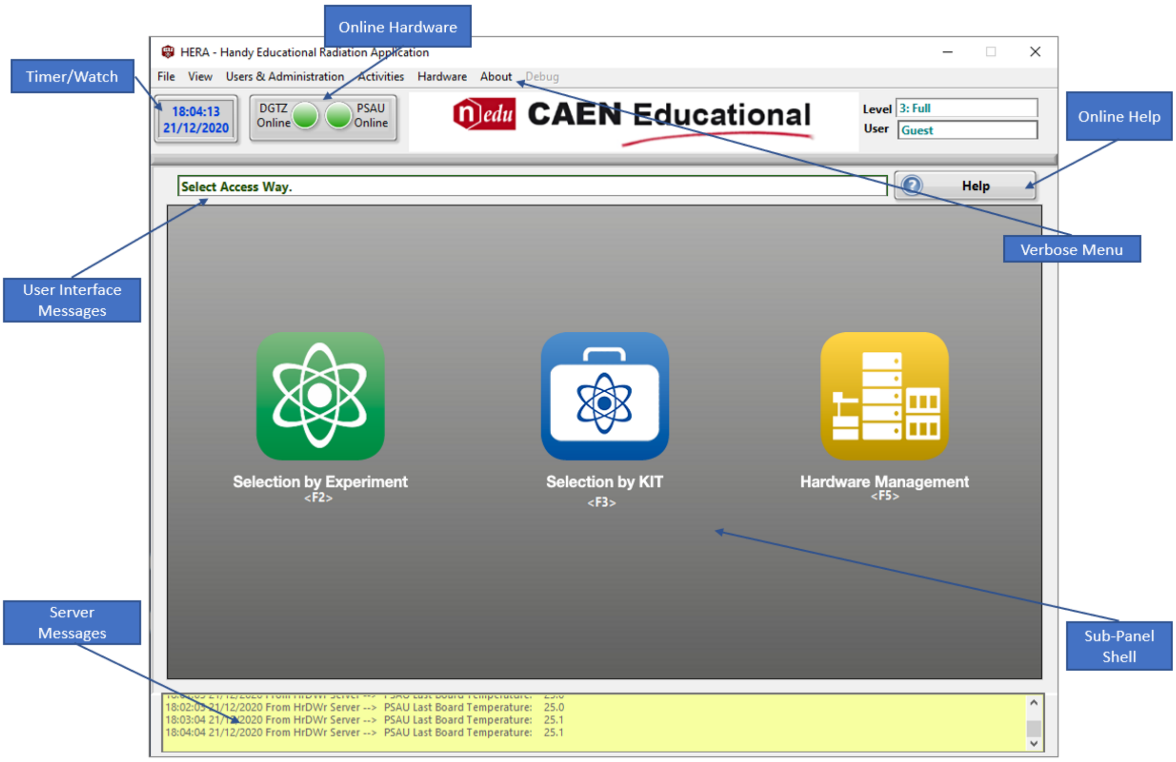


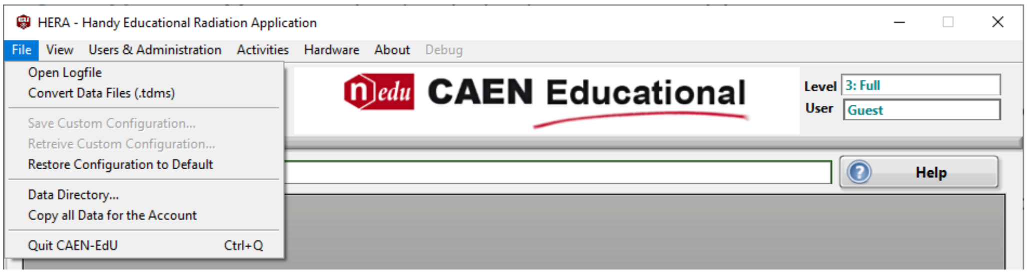
Fig. 6.2: Main GUI Description.

The main features of the GUI are:

- **Timer/Watch:** Time and Date.
- **Online Hardware:** Indicators of the Digitizer (DGTZ) and Power Supply and Amplification Unit (PSAU) status.
- **User Interface Messages:** Operation messages related to user activity.
- **Server Messages:** Messages related to the hardware server activity.
- **Sub-panel shell:** Sub-panel of the initial menu choice.
- **Online Help**: QuickStart guide available for each software window and experimental activity.
- **Verbose Menu:** It is organized into several items (File, View, User & Administration, Activities, Hardware, About menus), each one allowing the user to perform several actions.

– **File Menu**

The user can assess further functionalities by pressing the “File” label on the top left of the GUI. As shown in the picture below, the File Menu is composed by four sections.



The first section gives access to the logfiles and to a special tool for the data file conversion in .txt format. The second section allows the user to save and retrieve a configuration file containing the parameters settings for the DGTZ and the PSAU and, moreover, the default configurations recovery. The third section is focused on data storage management. The user can open the data directory located in ProgramData folder or copy it in another PC location.

The fourth section allows closing the software.

– **View Menu**

Through this menu, the user can enable/disable the display of the server messages in the bottom part of the window.

– **User & Administration Menu**

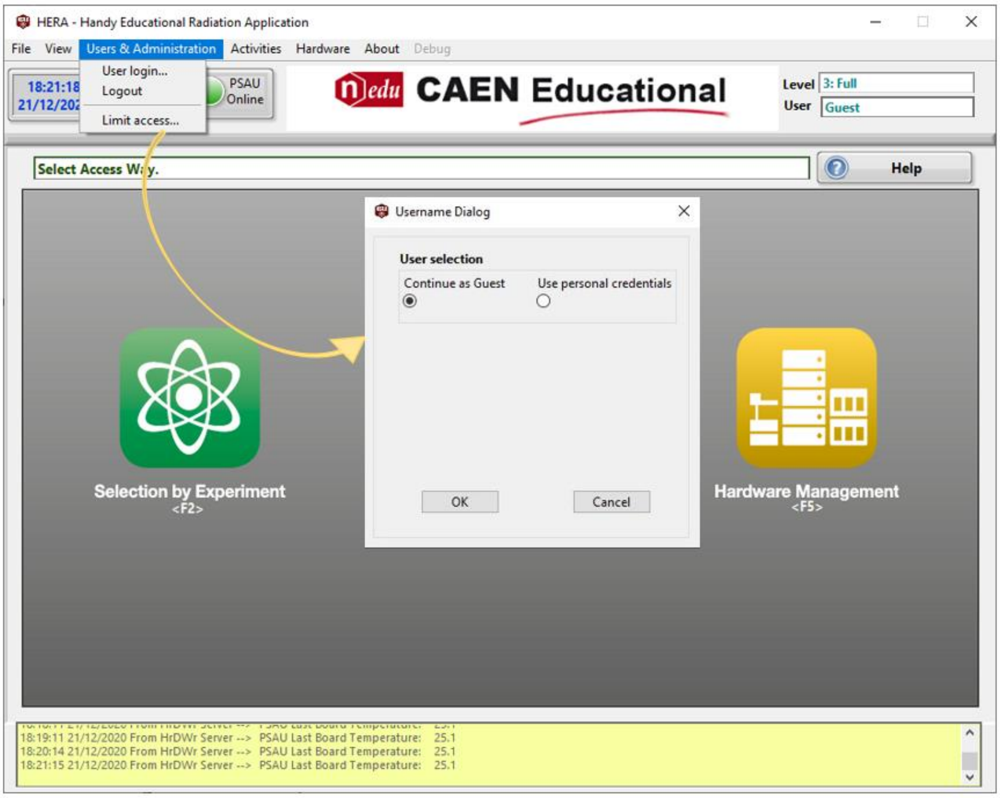
This menu section gives high flexibility to the user in managing the accounts and deciding what each user can access of the software.

For this purpose, two interesting functionalities are available:

User Account

The software can create several accounts via the "User Login" selection. This procedure is advantageous when several people or groups work on the same computer. Once created the account, the software automatically produces the related folder in which data, configuration files, and images can be saved and stored.

Via “Logout” selection, the account goes back to the default "Guest" user.



Software Access Mode

Three access levels to the software are implemented and are available through the "Limit Access…" selection in the drop-down menu. The first one, "Level 1", just gives access to the Hardware Management. The second one, "Level 2", allows the user to access the Hardware Management and the guided procedures to perform the experiments listed in the CAEN Educational Handbook. This access level does not include analysis tools. The third one, "Level 3", gives full access to all software functionalities and all the analysis tools are included.
The initial option, "Selection by Kit", is accessible by all the three access levels.

The user needs the Master Password to change the access mode. The Password is unique, not changeable, and not declared in the embedded Help to give this type of modification power to the tutors only.
This functionality allows to the tutors deciding what each user can access and therefore, structuring the courses depending on the course attendee levels.

The Master Password is the build of the HERA release in use. The build is displayed in the "About HERA" window via the about label in the GUI verbose menu.

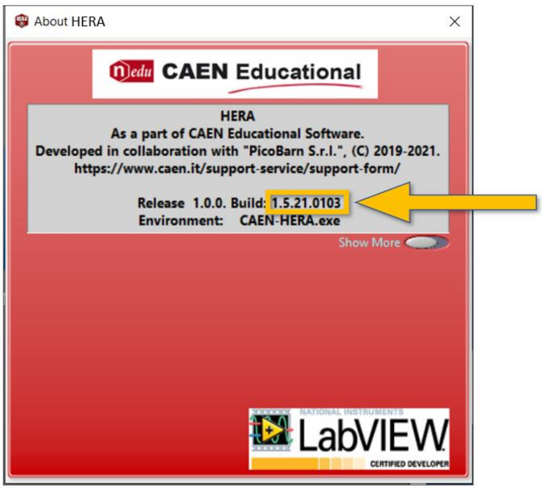
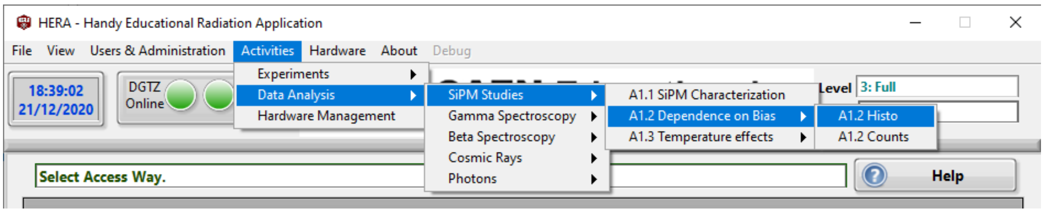


Fig. 6.3: About window.

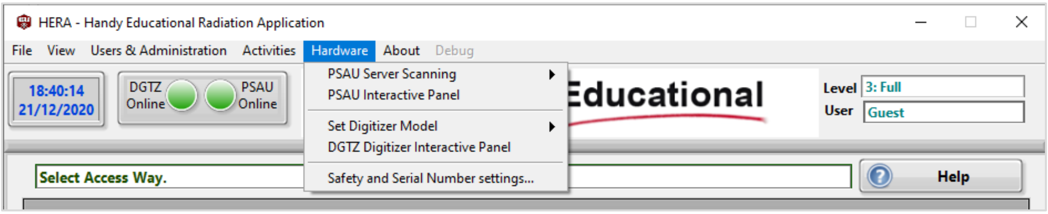
– **Activities Menu**

The "Activities" drop-down menu allows the user to direct access to the experimental activities and to the hardware control panels. Moreover, through it, it is possible the use the analysis tools without connecting to the devices.



– **Hardware Menu**

The "Hardware" drop-down menu is made of three sections useful for the hardware management. The first section gives access to the PSAU Control Panel and to launch again the rescanning procedure when its connection is lost.



Through the second section it is possible to select the digitizer model (DT5720A or DT5720C) and to access the DGTZ Control Panel.

The last section is very important for its preventing action related to the possible detectors damaging:

Detector Safety

The Bias Voltage Limits can be modified from the main window of the GUI only, before selecting the experiment or hardware. The user can set the detector safety condition via the "Hardware" drop-down menu.

This functionality is very important for preventing action related to the possible detectors damaging. The SP5600 module houses two detectors (SiPM). The module provides independent bias voltages (up to 130 V) to the sensors with gain stabilization. The user can apply a safety measure to prevent detector damage due to a wrong and too high bias voltage. Via "Safety and Serial Number Setting…" selection, the user can set the recommended operating voltage for each channel and, discretionary, the serial number to identify the detector itself. The software stabilizes the maximum value of bias voltage that can be applied to the sensor as a percentage (2,5%) of the operating one. To change the voltage limit is requested to modify the value in the "Bias Setting window" (see Fig. 6.4).

– **About**

The "About" leads to a new window including all information related to the software (release, build, etc).

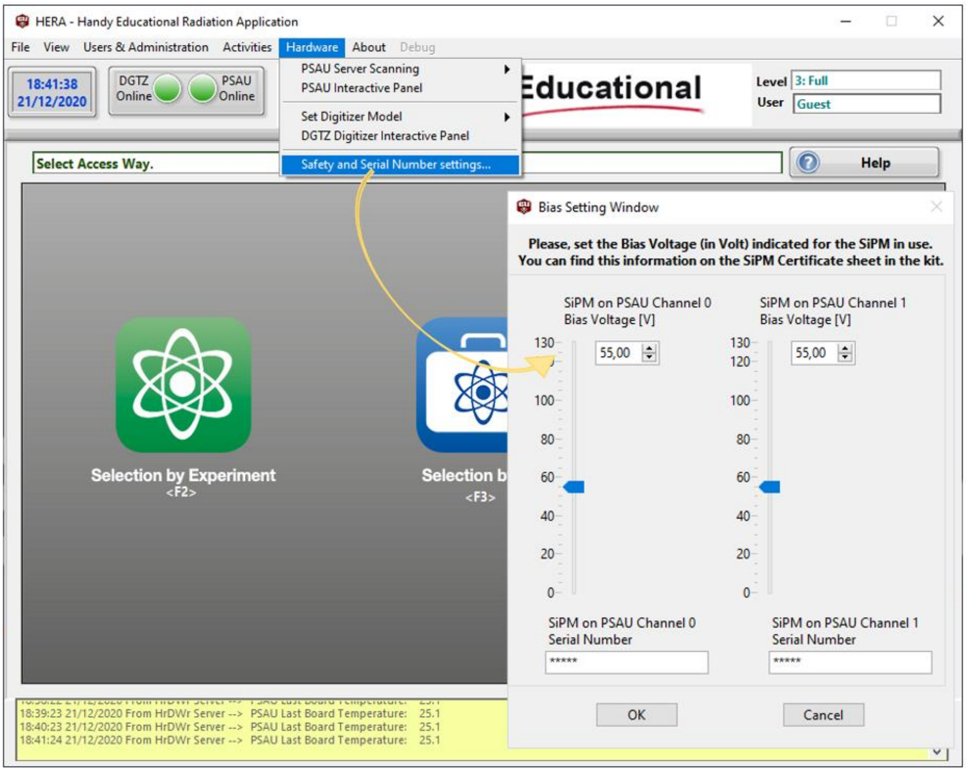


Fig. 6.4: Bias Setting Window.

The Main GUI clearly shows that several ways of operative openings are available:

- “**Selection by Experiment**”: access to experiments frame covering Nuclear and Particle Physics fields.
- “**Selection by Kit**”: access to operative options allowed by the educational kit in use.
- “**Hardware Management**”: direct access to the management of the device parameters and data readout.

The chosen option can be run by double clicking on the relative box or by selecting it and then by the press on the “Select” button.

The user can easily access to the GUI description via the “Help” button. Each window of the software is equipped with a dedicated “Help” button that must be closed before starting any activity.

Selection by Experiment

This option allows the user to access the experiment menu listed in the CAEN Educational Handbook.
By selecting the Physics topic of interest, a series of experiments can be performed. The software programs a predefined settings of the devices and gives a detailed guide into the “Help” button.
The option “Selection by Experiment” can be run by double click on the relative icon or by selecting it and then by pressing the “Select” button.

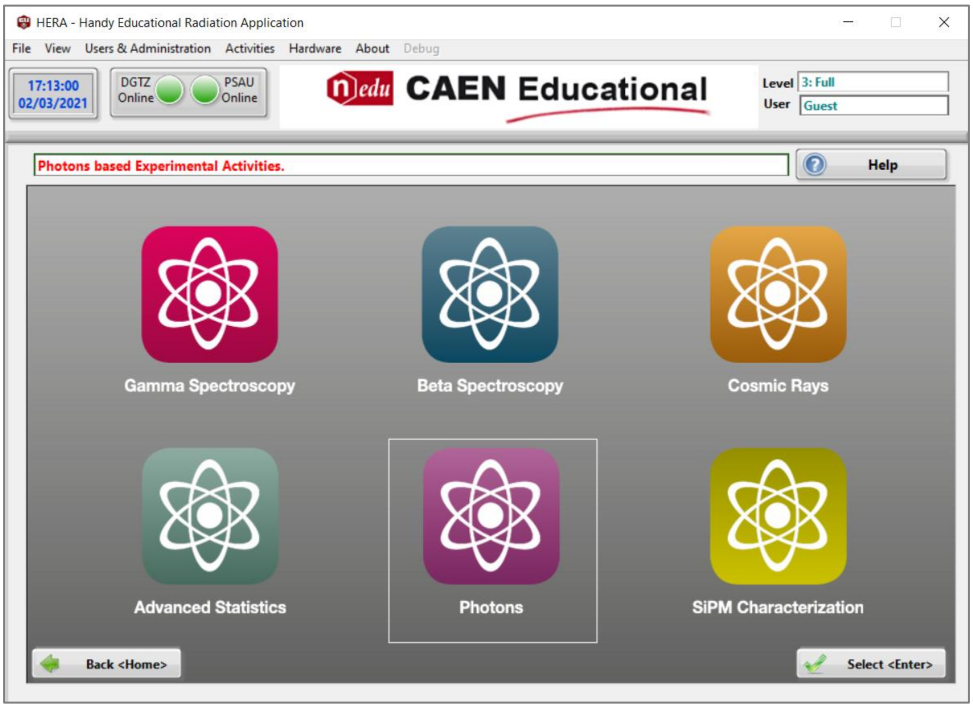


Fig. 6.5: Selection by Experiment.

The “Help” button is present in all the windows in use and provides guides and advice about the experimental procedures.

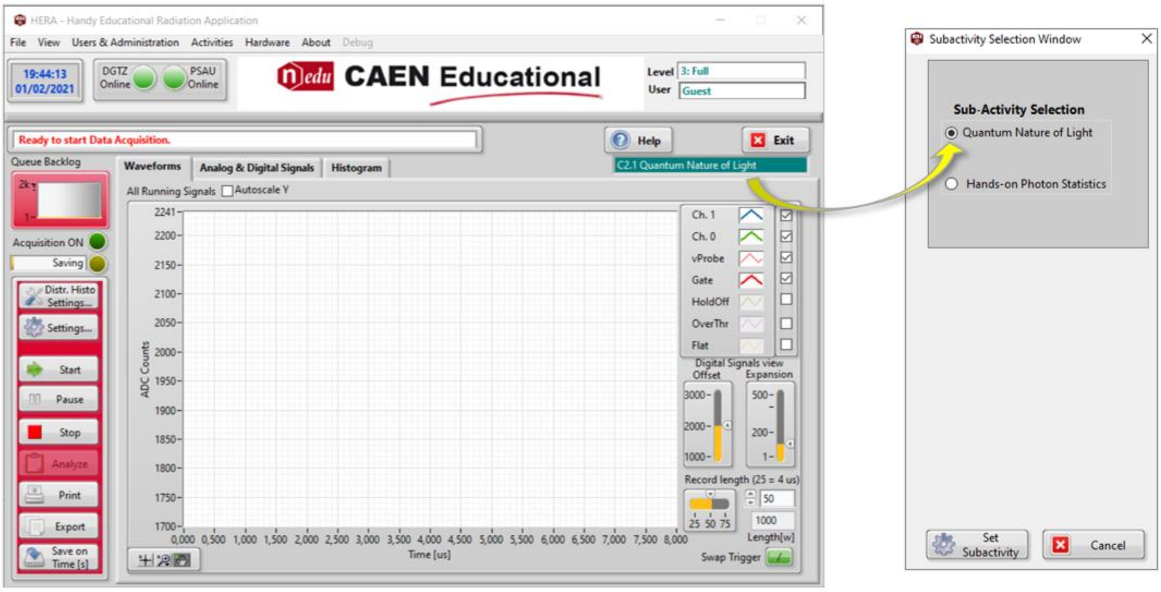


Fig. 6.6: Example of experimental activity.

Selection by Kit

This option allows the user to access the experiment menu listed in the CAEN Educational Handbook.
By selecting the Physics topic of interest, a series of experiments can be performed. The software programs a predefined settings of the devices and gives a detailed guide into the “Help” button.
The option “Selection by Experiment” can be run by double click on the relative icon or by selecting it and then by pressing the “Select” button.
The “Help” button is present in all the windows in use and provides guides and advice about the experimental procedures.

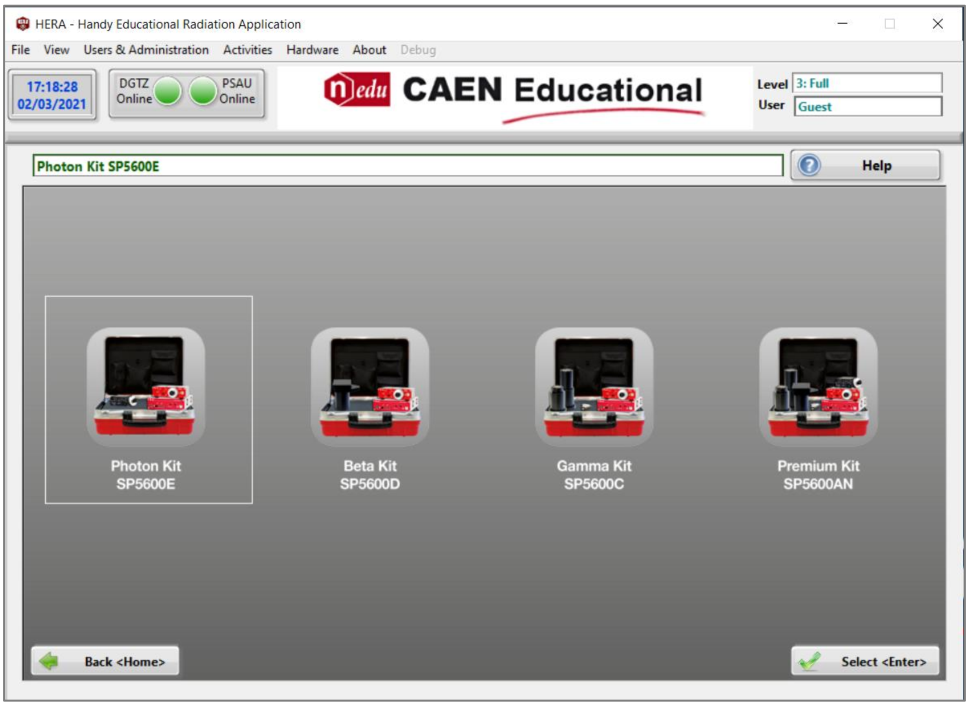


Fig. 6.7: HERA: Selection by kit.

Hardware Management

The main units of the Educational kit, which are common among all the systems, are:

- Power Supply and Amplification Unit (PSAU) - SP5600
- Desktop Digitizer (DGTZ) - DT5720A

The “Hardware Management” section allows the user to manage all the parameters of both PSAU and DGTZ giving the highest flexibility in the operating modes.

With few easy steps, the setting of bias voltage, gain, thresholds, and digital outputs are possible. The digitized signals can be monitored for a real-time fine-tuning of the set-up. Energy spectra, trends of the charge as a function of the time, signal frequency versus threshold, and frequency counting are also displayed in the visualization tabs of the main GUI.

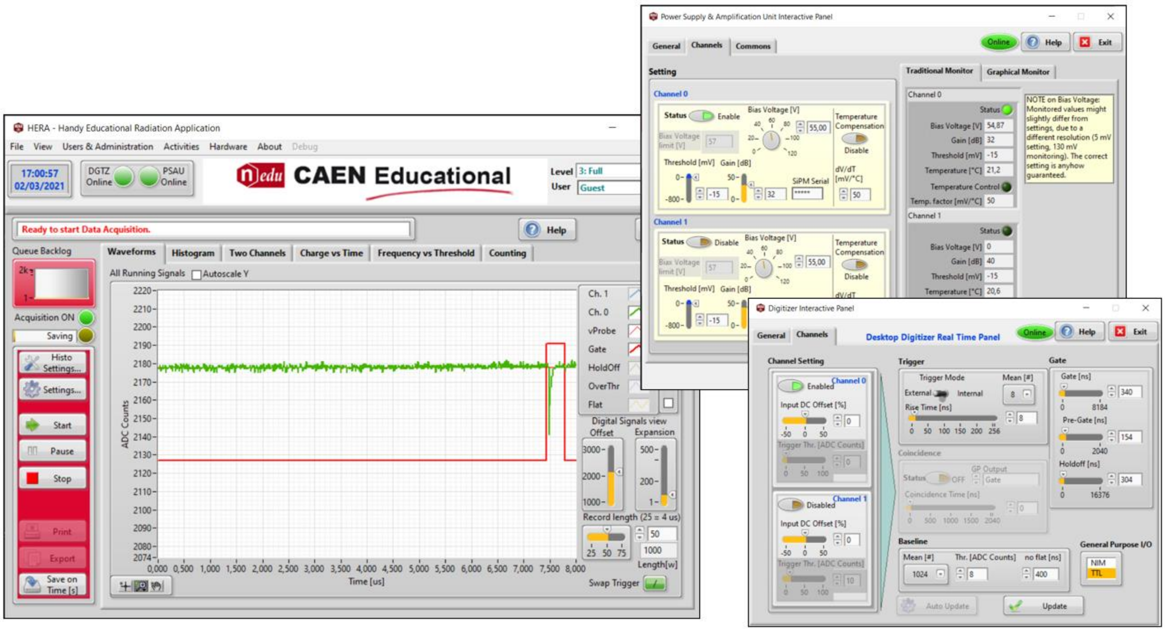


Fig. 6.8: Hardware Management.

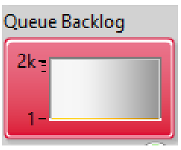
All tabs allow the user to save plots and data on file for the offline analysis processes.

- Main GUI Description

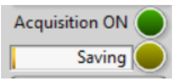
The Main GUI of the HERA software consists of several visualization tabs. These tabs allow the user to visualize and manage the signals of the detector. The “Waveform”, “Histogram”, “Two Channels” and “Charge vs Time” tabs refer to the digitizer (DTGZ). The other two, “Frequency vs Threshold” and “Counting”, refer to the Power Supply and Amplification Unit (PSAU).

Control keyboard

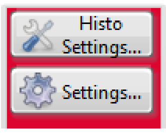
The keyboard on the left side of the GUI allows the user to control and manage the acquisition tabs and to monitor the system status.



“*Queue Backlog*” indicates the number of acquired data (elements) that are waiting for displaying or saving to file, for both the "Waveforms" tab and "Histogram" tab. This element number should normally be equal to zero unless some extra time-consuming operation occurs.

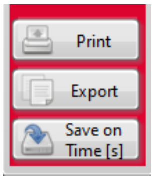


Two *light indicators* provide the system status related to Data Acquisition and Storage.



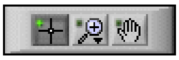
“*Histo Settings...*” button makes available the selection of the different types of histograms for the “*Histogram*” tab.
“*Settings…*” button leads to an additional window providing the options for the channels enabling/disabling for both PSAU and DGTZ, and for setting the run preset according to a fixed time or number of events.

“*Start*” button must be used to launch the acquisition and to visualize the results on the related tabs. To stop the acquisition and/or change to another visualization tab, the user can press the “*Stop*” button. The single shot mode of the waveform can be activated via “*Pause*” button, then the “*Start*” button will change its name to “*Single shot*”. In that case, the plot will be updated and frozen with a single trigger. The continuous data stream can be activated again by pressing the “*Pause*” button.



The last three buttons of the keyboard are related to data storage. The “*Print*” button sends the result visualized in the tab to the selectable printer. The “*Export*” button opens an additional window to export data in two formats. If the "Clipboard" box is selected, a bitmap image to the Clipboard is exported. If the "Excel" box is selected, just numerical data are exported. “*Save on Time*” (or “*Save on #Events*”) button saves data according to the setting previously defined via “*Settings…*” button.

The display of the tabs is equipped with a Graph Palette that allows the user to interact with a graph.



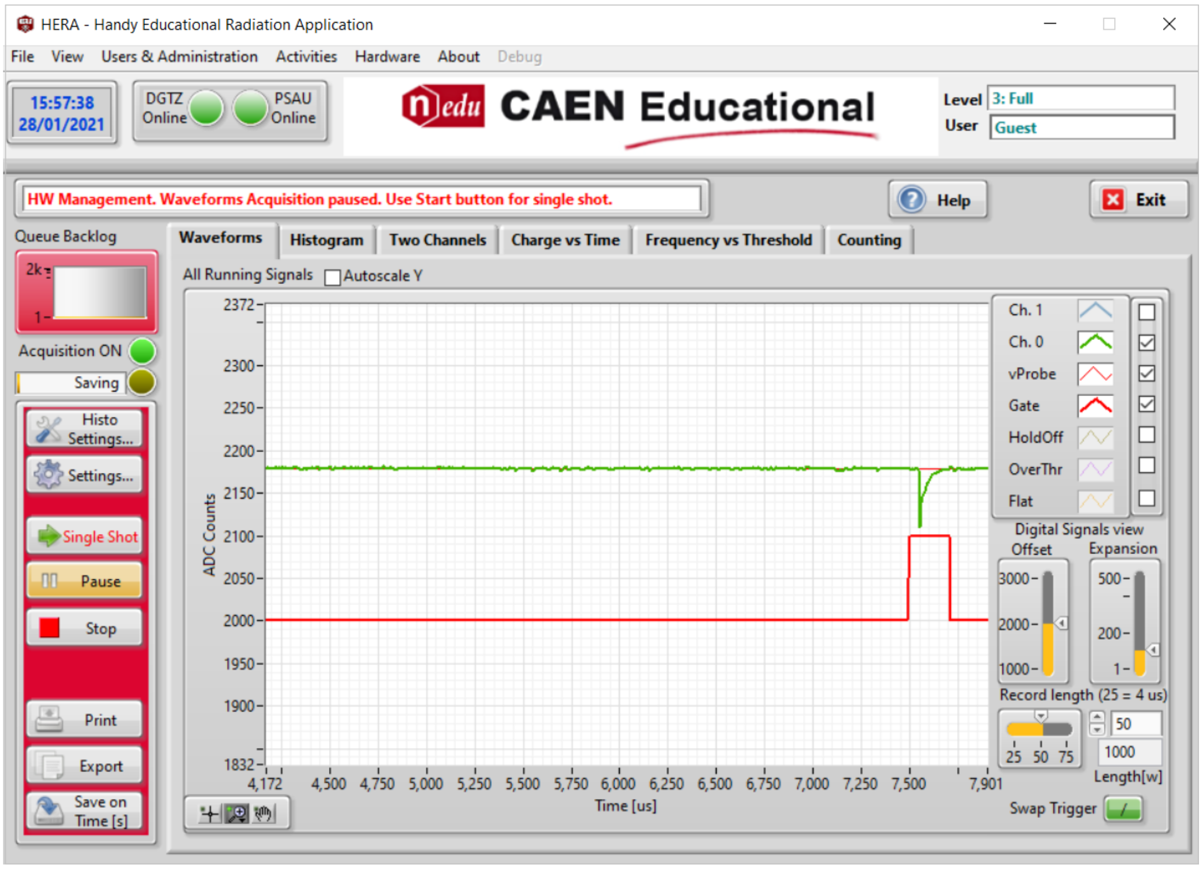
This palette appears always with the following buttons, in order from the left to the right:

- Cursor Movement Tool moves the cursor on the display. If the cursor is not present, it does not work.
- Zoom acts by zooming in and out the display.
- Panning Tool picks up the plot and moves it around on the display.

Note: If one of the controls of the Graph Palette does not work, that interaction type is not permitted for the specified graph. The graph palette is always composed of the three controls, even if not all of them are used.

Waveform tab

The “Waveform” tab shows the traces of the analog and digital signals read out from the digitizer. The signals visualization can be enabled/disabled by selecting the related box on the legend on the right side.



The analog signals are the traces of the input channels (Ch.1 and Ch.0) and the virtual probe, i.e. the baseline signal.

The digital signals are the Gate (red), the Over Threshold (violet), the HoldOff (brown) and the Flat (yellow):

- “Gate” represents the width of the signal integration.
- “Holdoff” means the veto width for the generation of other gates.
- “Over Threshold” is generated when the signal is over the set threshold.
- “Flat” stands for the veto width for the baseline calculation.

The “Digital Signal View” section on the window right side includes the graphical controls for the digital traces. These traces can be amplified via the “Expansion” cursor and moved in a vertical direction via the “Offset” cursor.

The “Record length” control allows the user to change the time scale of the acquisition window, from 4 µs to 12 µs.

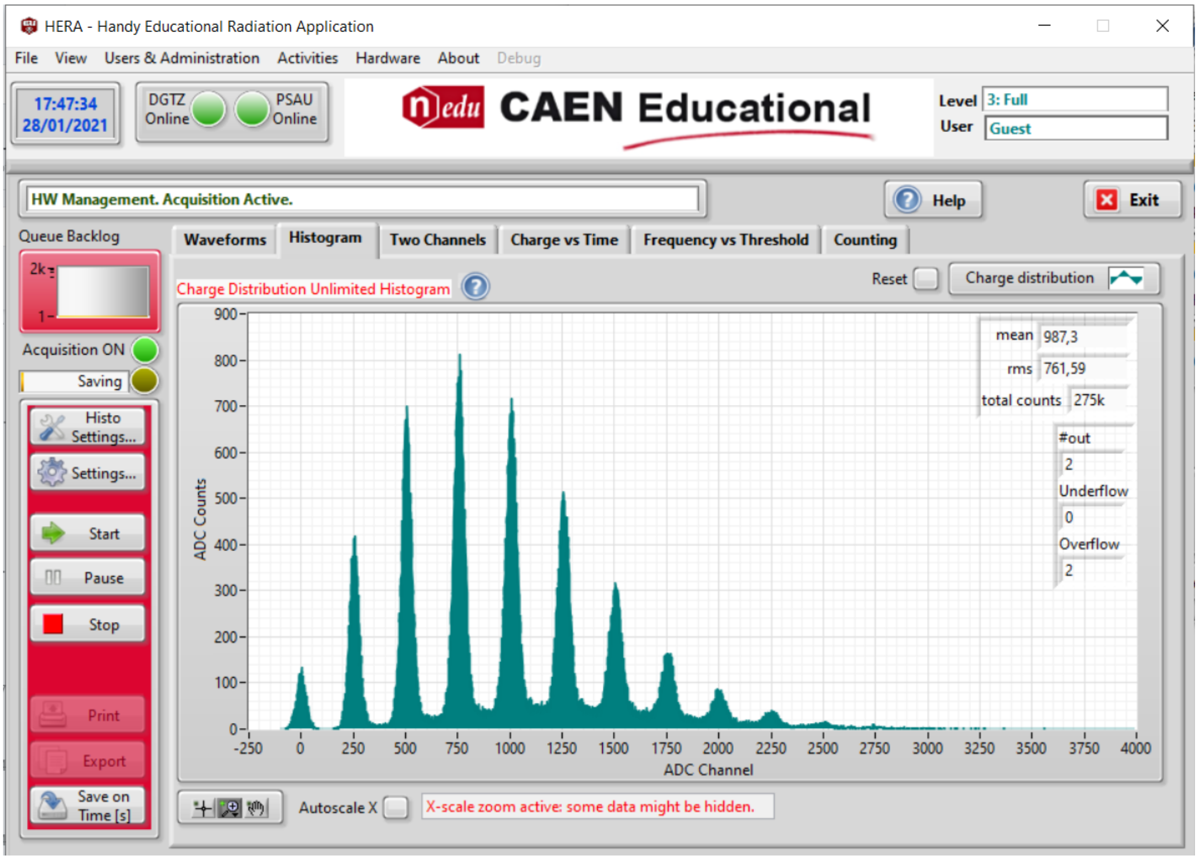
The “Swap Trigger” button enables/disables the rising edge stabilization of the gate on the time scale.

The acquisition conditions for the data saving, previously set via the "Setting…” button on the control keyboard, can be applied simply by pushing the “Save on…” button during the acquisition run.

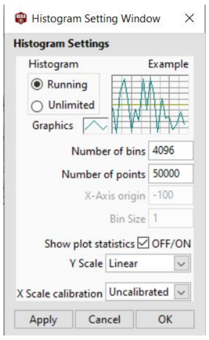
If the system is not in acquisition mode, the "Save on..." button only allows the data storage of the displayed waveform without any constraints in time or in events. The data will be saved in .TDMS format. The waveforms data format is described in detail in the Appendix.

Histogram tab

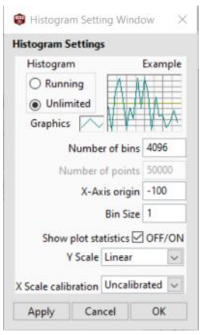
The “Histogram” tab shows the histogram of the active channel according to the PSAU and DGTZ settings.



Via “Histo Settings...” button, the user can enable/disable the general statistics on the display right side, choose the Y scale as linear or logarithmic, and the histogram types. HERA software supports two different histograms:



The "*Running Histogram*" accumulates data until the number of entries defined in the "*Number of points*" parameter is reached. The user can set this value in the Histogram Setting Window via "*Histo Settings...*" button of the Control keyboard. Data is overwritten by the new events. The number of bins, bin size and starting X point are automatically set by the software.
This kind of histogram processing is useful when the hardware conditions are changed during the measurement, to check how the system response evolves. For example, the user can try to change the L.E.D. intensity during the acquisition and observe how the histogram changes.



The "*Unlimited Histogram*" accumulates data with no limits in the number of entries of the Y-axis. Differently from the "Running Histogram", the user must provide the properties of the X scale in order to determine the histogram range:

- the *origin* of the histogram means the minimum plotted charge value;
- the *number of bins* determines the end of the plotting window;
- the *bin size*, i.e. bin width.

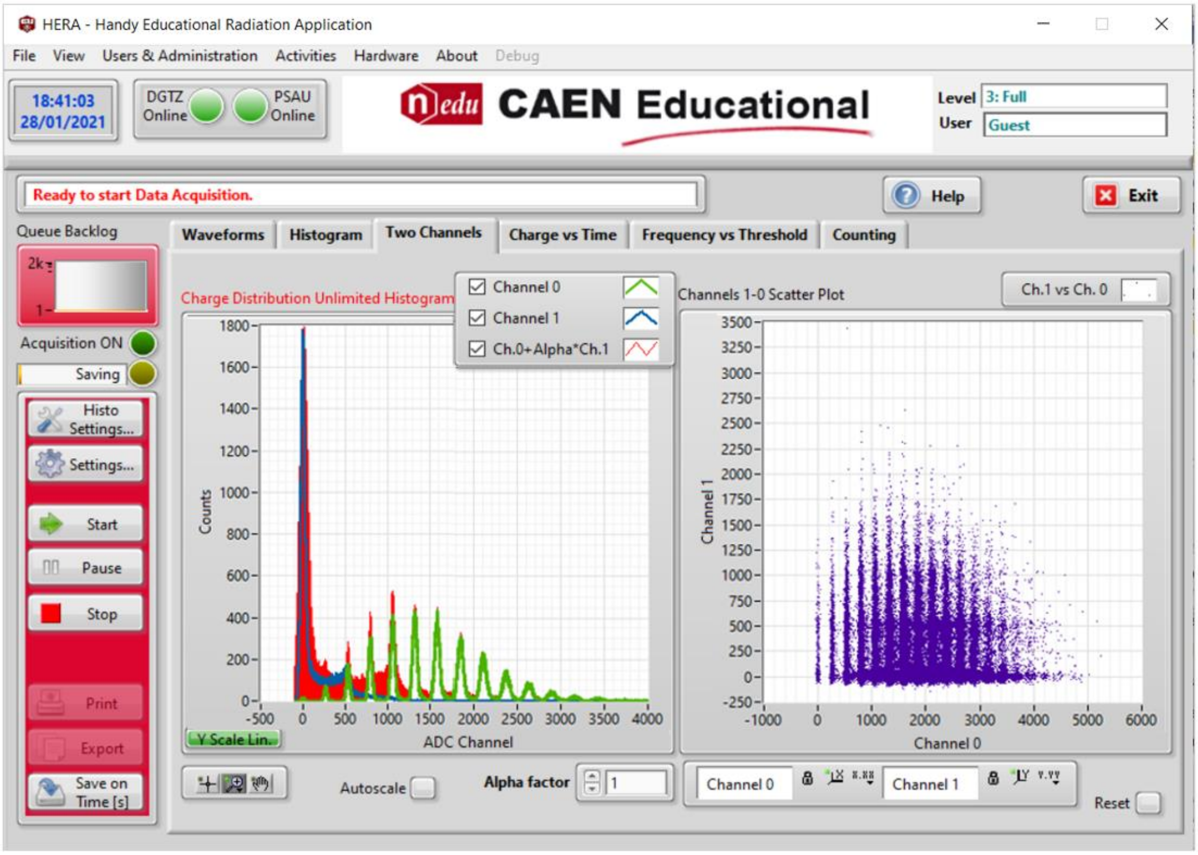
The Unlimited Histogram can be used to make comparisons between measurements taken in the same setup conditions. Note: the hardware setup must not be changed during the measurement.

The acquisition conditions for data saving, previously set via the "Setting…" button, can be applied through the "Save on…" button during the acquisition run.
If the system is not in acquisition mode, the "Save on..." button allows the data storage without any constraints in time or in events. The data will be saved in .TDMS or ASCII formats. The histograms data format is described in detail in the Appendix.

Note: Because of the automatic and variable setting of the bin size, the *Running Histogram* is not suitable for comparison purposes. This histogram type does not guarantee the same acquisition conditions.
Conversely, the *Unlimited Histogram* is suitable for comparison among spectra due to its setting properties in terms of the number of bins, bin size and starting X point.

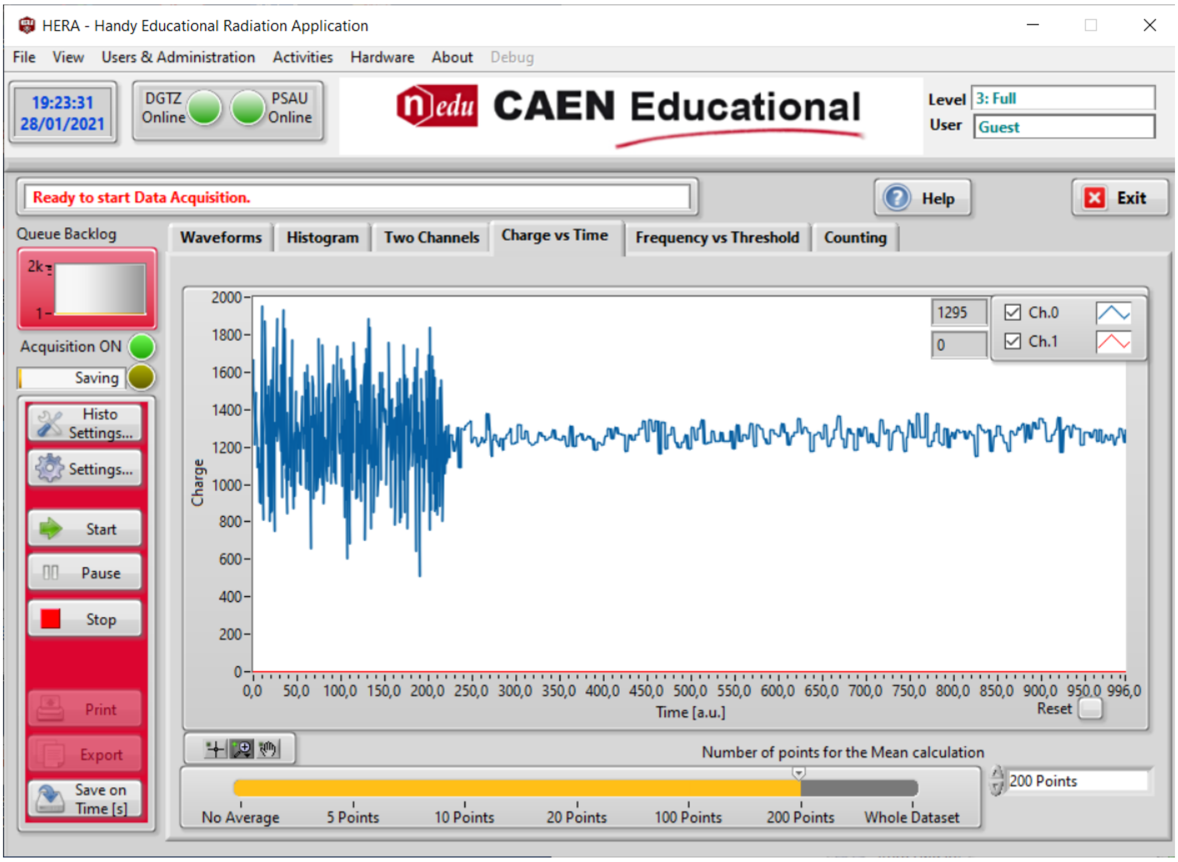
Two Channels tab

The "*Two Channels*" tab allows the user to manage the histogram plots from the two channels of the digitizer simultaneously. It is possible to plot and reset the two histograms, the histogram sum, and their correlation.
The *graph on the left side* contains the histogram plots of both channels and the sum plot. Each plot can be enabled or disabled trough the relative box in the legend. The sum of the histograms is defined as the histogram resulting from adding channel0's histogram to channel1's histogram multiplied by an *alpha factor*. Common x-axis origin, number of bins and bin size can be set via "*Histo Settings...*" button for all the spectra. All graphs can be reset at the same time via the "*Reset*" button in the lower part of the window.
The *graph on the right side* shows a scatter plot of the signals from the two sensors, after being integrated in the specified time window (look at the displayed "*Gate*" in the *Waveforms tab*). This tab might help for specific applications relying on simultaneous use of the two detectors, e.g. when using the scintillator tiles for cosmic ray experiments or two spectrometry heads for ^{22}Na positron annihilation detection.
The histograms saving is described in detail in the Appendix.



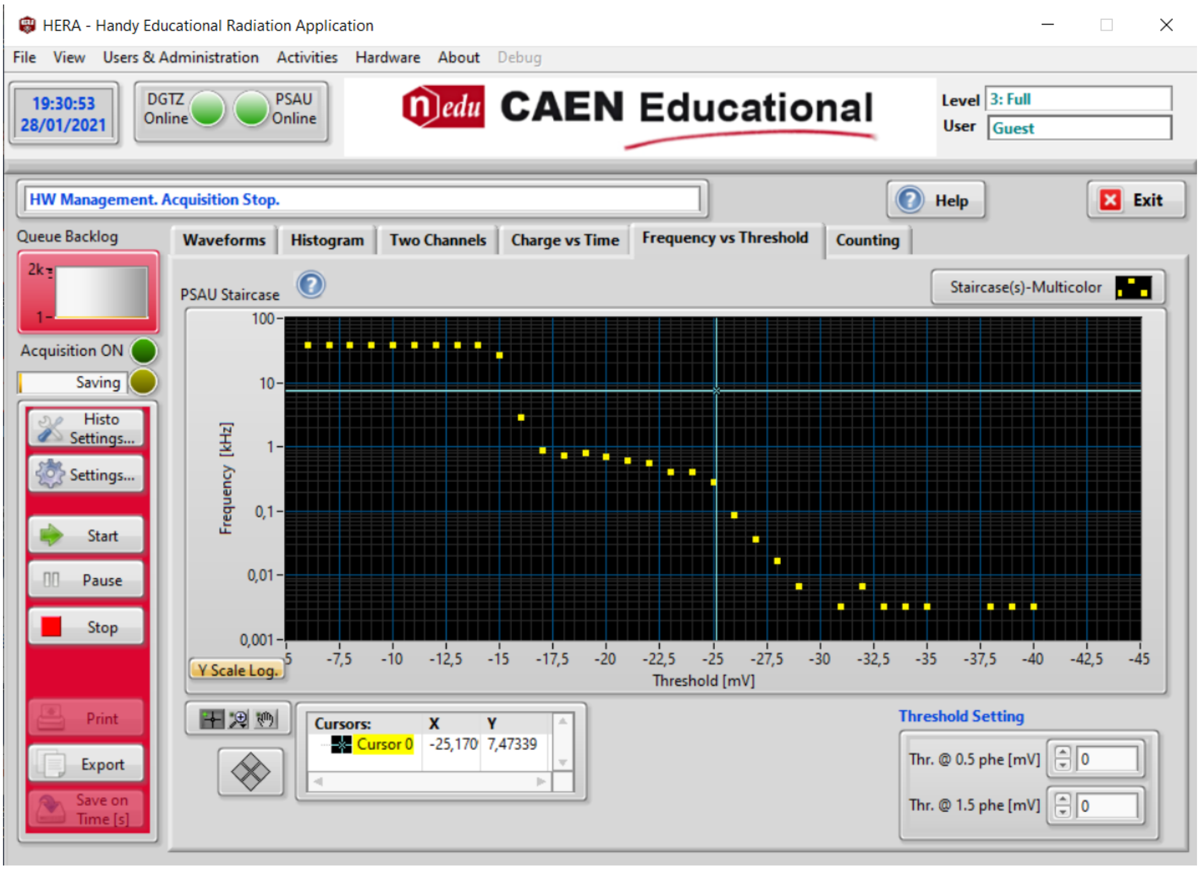
Charge vs Time tab

The “*Charge vs time*” tab plots the signal charge versus time. The user can change the number of charges for the plotted mean. The plot can be stored pushing the “*Save on..*” button.
During the acquisition, the conditions for data saving, previously set via the "*Setting…*” button, can be applied simply by pushing the "*Save on...*" button. If the system is not in acquisition mode, the "*Save on...*" button allows the user to storage the data of the displayed plot without any condition related to the number of entries or acquisition time and the data will be saved in .TDMS format. The Charge vs Time data format is described in detail in the Appendix.

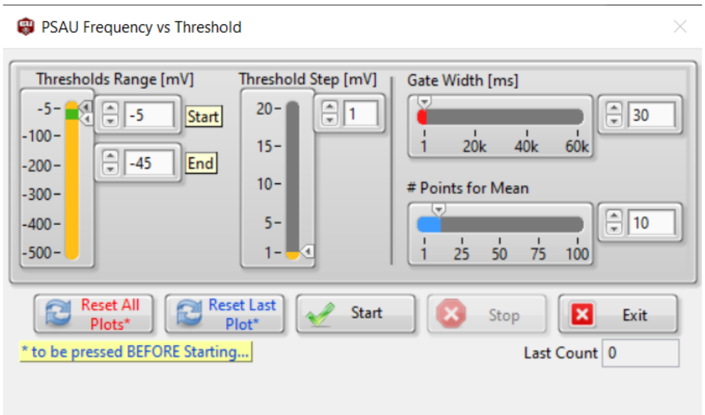


Frequency vs threshold tab

The "*Frequency vs Threshold*" tab allows the user to interact with the PSAU in order to produce the so-called "SiPM staircase": the plot shows the frequency of the signals which are over the threshold, during a threshold scan from the minimum up to maximum threshold value.



After pressing the "*Start*" button on the control keyboard, the user can change the *limits of the scan*, the *step*, the number of read point which produces the *mean* plotted value and the *gate width* for the counting via an additional window, *"Frequency Scan Setting"*.

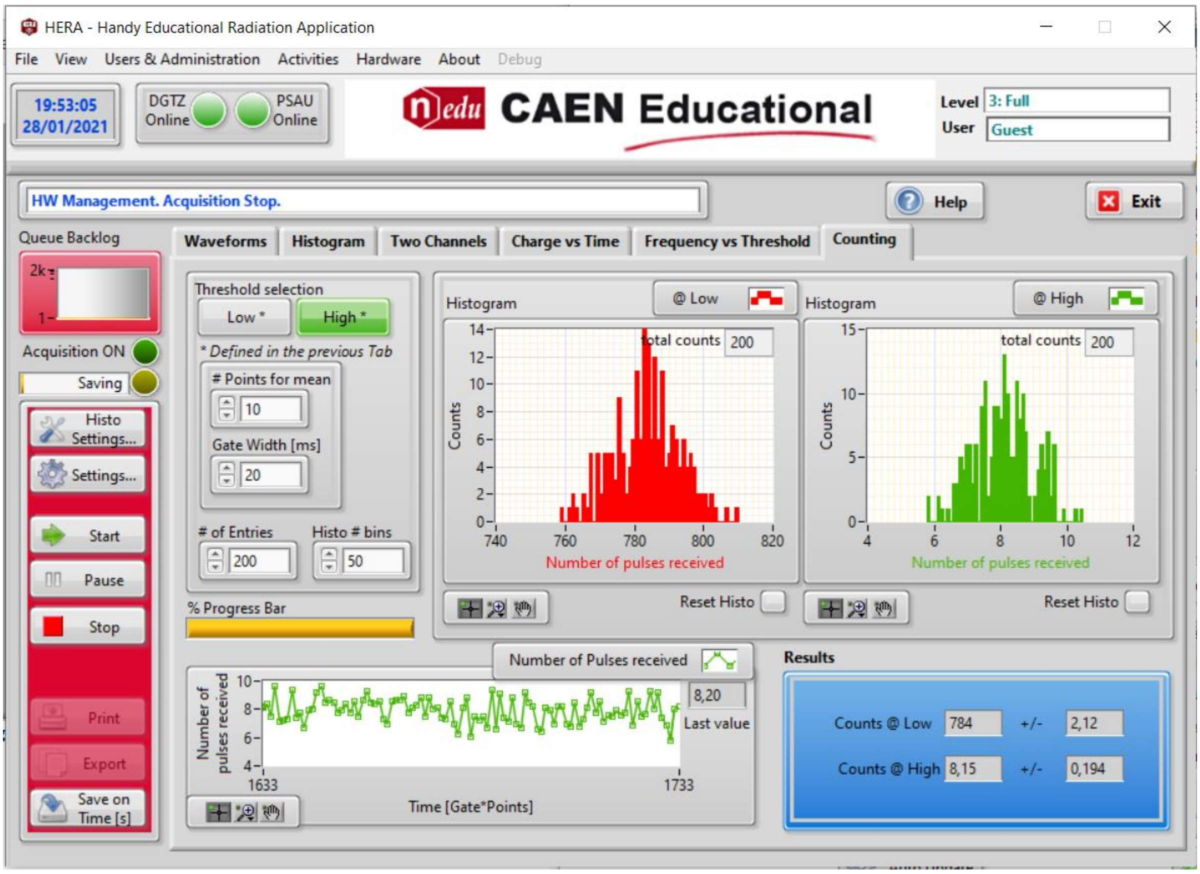


Once the acquisition is completed, the user can choose two threshold values and respectively write them in the two boxes, in the lower part of the window. These two threshold values will be transmitted to the *"Counting"* tab for further analysis.

To store the information included in this tab, the user can employ the *"Export"* button on the control keyboard.

Counting tab

The “Counting” tab shows three plots for which the user can change the number of points for the plotted mean value and the gate width for the counting.
The graph in the lower part plots the frequency trend of the signals over the threshold set in the PSAU Interactive Panel for the active channel or over the threshold value corresponding to the Low/High button selection, set in the previous tab. The two histograms show the distribution of the mean number of counts referred to the two threshold values (Low and High). The mean values of these distributions are displayed in the blue box, together with their uncertainty. The number of histogram entries and bins can be set by the controls “# of Entries” and "Histo # bins".



The “Save on..” button allows the user to save the plots content at the end of the acquisition. The data format is described in detail in the Appendix.

- Power Supply & Amplification Unit (PSAU) Interactive Panel

The PSAU Interactive Panel is fully dedicated to the management of the Power Supply and Amplification Unit (PSAU). It is composed of three tabs: “General”, “Channels” and “Commons”.

General tab

The “General” tab contains “Board ID and Global Status” frame with information about the PSAU firmware release, Serial Number and COM Port. The “Last PSAU Hardware Error” frame shows the last Error Code of the library which the PSAU stands on. Moreover, the Temperature History plot shows the temperature of the board and of both two detectors.

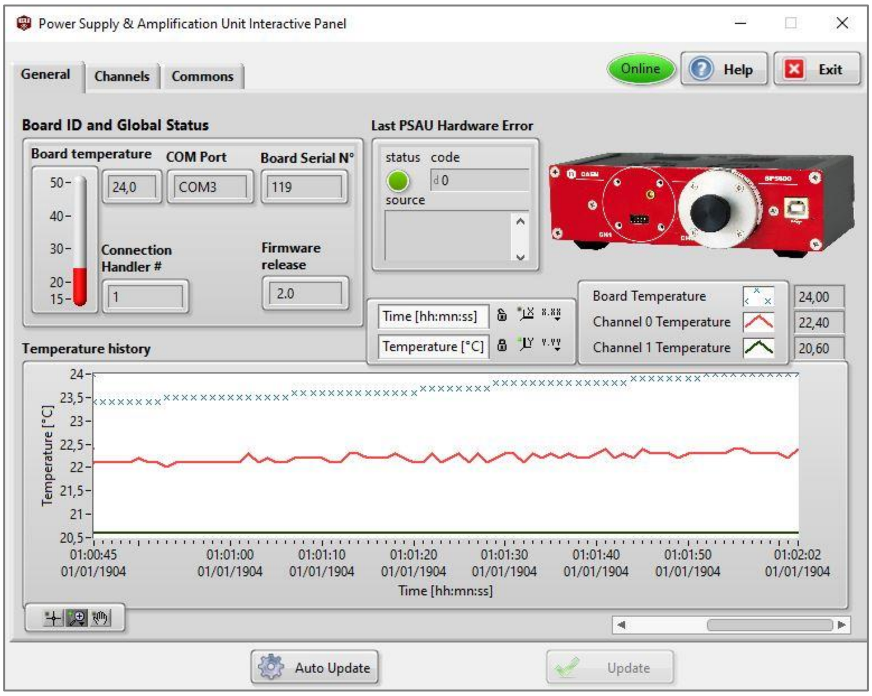


Fig. 6.9: PSAU General Tab.

The PSAU library return codes displayed in the General tab are summarized in the following table.

Error code	Value	Meaning
PSAU_Success	0	Operation completed successfully
PSAU_InvalidComPortError	-1	Error related to the COM port
PSAU_TooManyClientsError	-2	Max. nr. of PSAUs simultaneously manageable exceeded
PSAU_CommunicationError	-3	Communication error
PSAU_InvalidHandleError	-4	Invalid device handler
PSAU_InvalidHandleError	-5	Unspecified error
PSAU_InvalidCommandError	-6	Invalid command error
PSAU_InvalidParameterError	-7	Invalid parameter error
PSAU_DeviceNotFound	-8	Device error (i.e., hardware or firmware issue)

Tab. 6.1: PSAU library return codes.

Channels tab

The "Channels" tab is composed of two sections: Setting and Monitor. The first one, on the left side, provides the switchers for the two channels enabling the settings of the bias voltage, the gain, the discriminators threshold, and the temperature compensation. The temperature compensation requires the setting of the coefficient “dV/dT” for both the channels. The compensation acts on the bias of the sensor to keep its gain constant, according to the voltage linear dependence as a function of the temperature. For both channels, the SiPM serial number is visualized according to the initial setting via “Safety and Serial Number Setting…” selection in the “Hardware” drop-down menu.

Two different graphical visualizations are provided to monitor the set parameters and verify channels status. An important note is shown to underline that the setting and monitoring of Bias Voltage have different resolutions due to the hardware.

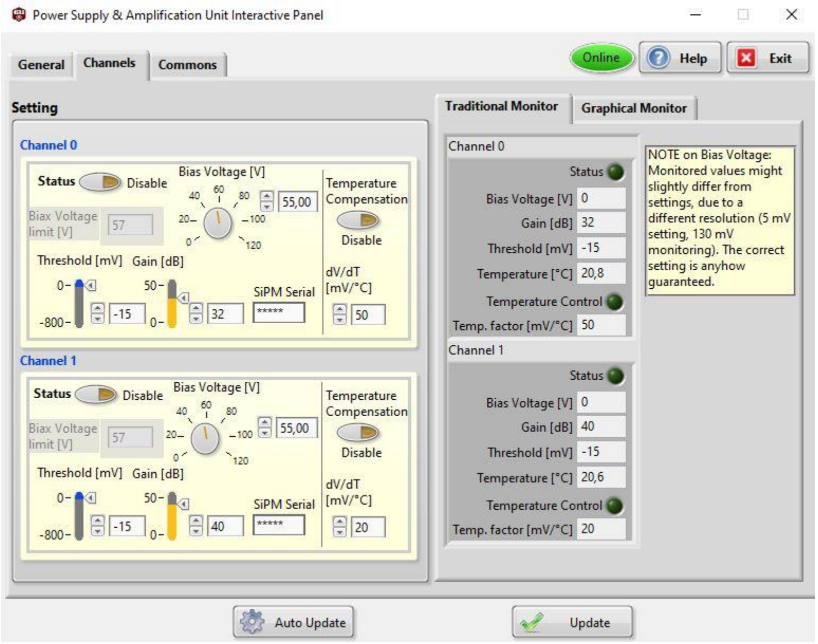


Fig. 6.10: PSAU Channels Setting Tab.

Commons tab

The "Common" tab allows to user to set the width of both signals produced as digital outputs. The output level can be set as NIM or TTL standard and the polarity of the discriminator edge can be selected. The coincidence can be activated when both PSAU channels are switched on. The coincidence signal is provided on digital output of the selected channel and its width can be set in the Coincidence section of this tab.

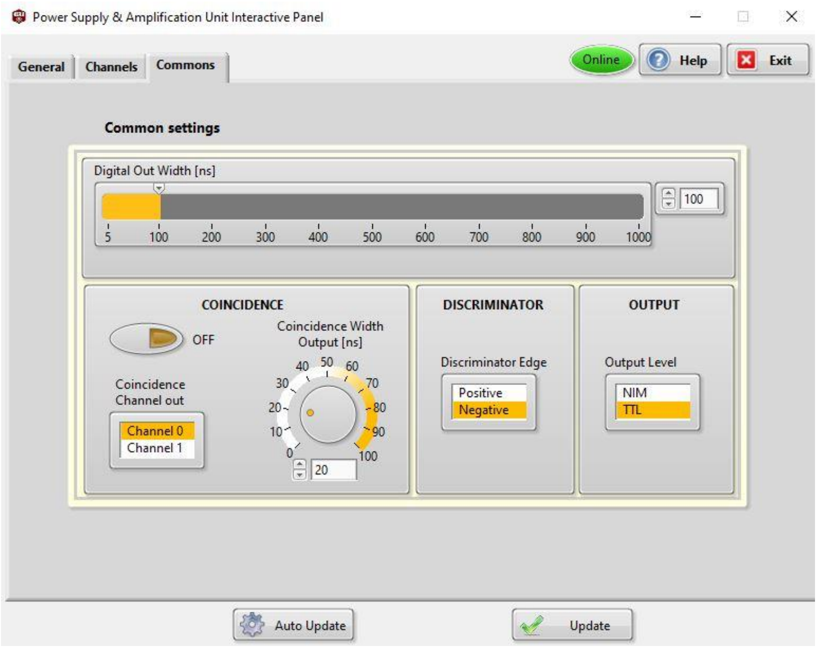


Fig. 6.11: PSAU Commons Setting Tab.

Important Note: The “Update” button must be selected for all settings change to apply them correctly. The lack of this operation leaves the default settings unchanged.
The “Auto Update” button executes the updating process automatically.

- Desktop Digitizer Interactive Panel

The Digitizer Interactive Panel allows the user to:

- check the digitizer connection and status (online/offline)
- check the model and serial number, revision, and firmware of the device
- overwrite default values with new ones for both input channels
- set Coincidence, Trigger mode, Gate and Baseline parameters.

The Digitizer Window is composed of two tabs: “General” and “Channels”.

General tab

The “General” tab contains the “*Unit ID and Characteristics*” and “*Last Digitizer Error received*” frames:

- *Handle Number*: once the device is opened, the function returns a handle that becomes the unique identifier of that device; any access operation to the device will take place according to its handle.
- *ROC & AMC Firmware release*: these fields contain the current firmware release running on the mainboard (i.e. on the ROC FPGA) and on the mezzanine (i.e. on the AMC PFGA). Moreover, a message box related to firmware compatibility.
- *Serial* and *Model Number*, *PCB revision*
- *Last DGTZ Error received:* any error given back by the CAEN Digitizer library which the program stands on, is reported in the field code.

The DGTZ library return codes are summarized in the Tab. 6.2.

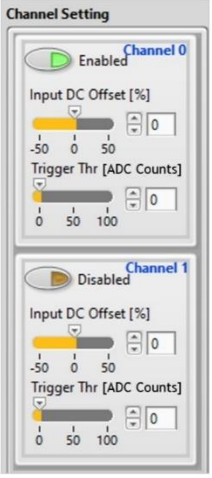
Error code	Value	Meaning
CAEN_DGTZ_Succes	0	Operation completed successfully
CAEN_DGTZ_CommError	-1	Communication error
CAEN_DGTZ_GenericError	-2	Unspecified error
CAEN_DGTZ_InvalidParam	-3	Invalid parameter
CAEN_DGTZ_InvalidLinkType	-4	Invalid Link Type
CAEN_DGTZ_InvalidHandler	-5	Invalid device handler
CAEN_DGTZ_MaxDevicesError	-6	Maximum number of devices exceeded
CAEN_DGTZ_BadBoardType	-7	Operation not allowed on this type of board
CAEN_DGTZ_BadInterruptLev	-8	The interrupt level is not allowed
CAEN_DGTZ_BadEventNumber	-9	The event number is bad
CAEN_DGTZ_ReadDeviceRegisterFail	-10	Unable to read the registry
CAEN_DGTZ_WriteDeviceRegisterFail	-11	Unable to write into the registry
CAEN_DGTZ_InvalidChannelNumber	-13	The Channel is busy
CAEN_DGTZ_ChannelBusy	-14	The channel number is invalid
CAEN_DGTZ_FPIOModeInvalid	-15	Invalid FPIO Mode
CAEN_DGTZ_WrongAcqMode	-16	Wrong acquisition mode
CAEN_DGTZ_FunctionNotAllowed	-17	This function is not allowed for this module
CAEN_DGTZ_Timeout	-18	Communication Timeout
CAEN_DGTZ_InvalidBuffer	-19	The buffer is invalid
CAEN_DGTZ_EventNotFound	-20	The event is not found
CAEN_DGTZ_InvalidEvent	-21	The event is invalid
CAEN_DGTZ_OutOfMemory	-22	Out of memory
CAEN_DGTZ_CalibrationError	-23	Unable to calibrate the board
CAEN_DGTZ_DigitizerNotFound	-24	Unable to open the digitizer
CAEN_DGTZ_DigitizerAlreadyOpen	-25	The Digitizer is already open
CAEN_DGTZ_DigitizerNotReady	-26	The Digitizer is not ready to operate
CAEN_DGTZ_InterruptNotConfigured	-27	The Digitizer has not the IRQ configured
CAEN_DGTZ_DigitizerMemoryCorrupted	-28	The digitizer flash memory is corrupted
CAEN_DGTZ_DPPFirmwareNotSupported	-29	The digitizer DPP firmware is not supported in this lib version
CAEN_DGTZ_InvalidLicense	-30	Invalid Firmware License
CAEN_DGTZ_InvalidDigitizerStatus	-31	The digitizer is found in a corrupted status
CAEN_DGTZ_UnsupportedTrace	-32	The given trace is not supported by the digitizer
CAEN_DGTZ_InvalidProbe	-33	The given probe is not supported for the given digitizer's trace
CAEN_DGTZ_UnsupportedBaseAddress	-34	The Base Address is not supported, as in case of DT and NIM devices
CAEN_DGTZ_NotYetImplemented	-99	The function is not yet implemented

Tab. 6.2: Digitizer library return codes.

Channels tab

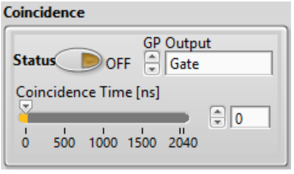
The "Channels" tab consists of five sections: *Channel Setting, Coincidence, Trigger, Gate,* and *Baseline*.

- *Channel Setting Section*



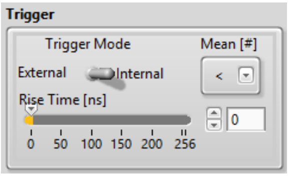
The *Channel Setting* section contains:
the switches to enable/disable the two channels of the digitizer.
"Input DC Offset" is a percentage shift of the input range scale (=2 V_{pp}), allowing the dynamic range to be shifted from -2.0/0 V up to 0/2.0 V. -50% is its minimum value and it corresponds to -2.0/0 V dynamic range. 0% corresponds to a -1.0/+1.0 V dynamic range, and +50% corresponds to 0/2.0 V dynamic range.
"Trigger Threshold" is related to the settings of the *Trigger* section of this software panel, and it is available only when the internal trigger mode is selected.
The internal trigger mode uses a CR-RC digital filtering algorithm. After digitalization, the DPP applies the digital filter to the raw input pulse to create a shaped bipolar pulse (called *DELTA*). The trigger and internal gate are generated as soon as the *DELTA* signal is greater than a programmable digital threshold, which is the "trigger threshold".

- *Coincidence Section*



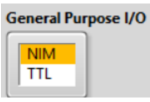
The *Coincidence* section allows the user to select the coincidence mode if both the channels are switched on.
"Coincidence Time" represents the width of the discriminator signal of each channel. Two signals are in coincidence if all of them exceed their own threshold during this time width.
"GP Output" allows the user to choose the signal output on the "GPO" of the digitizer front panel between: *Coincidence*, *Gate* and *Discrimination*.

- *Trigger section*



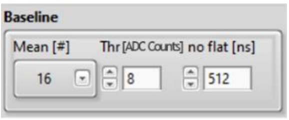
The *Trigger* section allows the user to select external or internal trigger mode. If "*External Mode*" is selected, the digitizer waits for a trigger signal on the "TRG IN" front panel connector. If the "*Internal Mode*" is selected, the digitizer is able to self-detect the signals, according to the trigger parameters.
The purpose of the digital filter is to improve the signal-to-noise ratio by attenuating the low frequencies, (using a numerical differentiator filter) and to smooth out the high frequency noise (using a smoothing function). This filter averages a certain number of samples within a moving window.
"Mean" represents the number of sampling used by the average window; the selectable values are 1, 2, 4, 8, 16 and 32.
Rise Time is the rise time of the input signal, used in the calculation of the signal *DELTA*.

- *General Purpose I/O section*



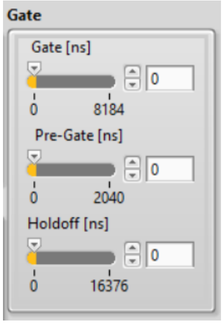
General Purpose I/O section allows the user to set input and output levels as NIM or TTL.

- *Baseline Section*



The *Baseline* section contains the controls for the baseline evaluation.
The *"Mean"* parameter is the number of samples for the average calculation of the baseline. The value 0 disables the baseline restoration. The "Threshold" represents the value on DELTA, over that the baseline calculation is frozen, and "*no flat"* is the veto for the calculation of baseline.

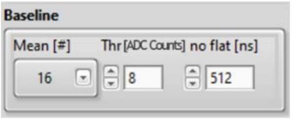
♦ *The Gate Section*



The *Gate* section consists of three parameters.

- *"Gate"* represents the width of the gate signals.
- *"Pre-Gate"* is the time between the gate generation and the trigger leading edge.
- "*Holdoff*" is a veto for the generation of other gates.

♦ *Baseline Section*



The *Baseline* section contains the controls for the baseline evaluation.
The "*Mean"* parameter is the number of samples for the average calculation of the baseline. The value 0 disables the baseline restoration. The "Threshold" represents the value on DELTA, over that the baseline calculation is frozen, and "*no flat"* is the veto for the calculation of baseline.

Important Note: The "Update" button must be selected every time to communicate and apply the selected parameters to the DGTZ. The lack of this operation leaves the default settings unchanged.
The "Auto Update" button executes the updating process automatically.

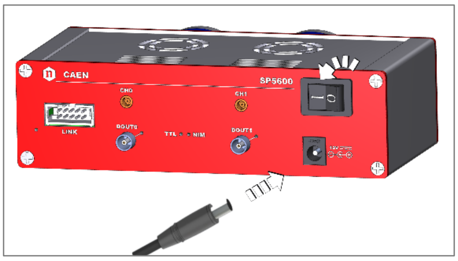
7 Basic Measurements

This manual section is dedicated to the simple and practical use to perform the first basic measurements by using the Educational Photon Kit.

7.1 Enjoying the first SiPM spectrum & measuring the Dark Count Rate

7.1.1 Kit Configuration

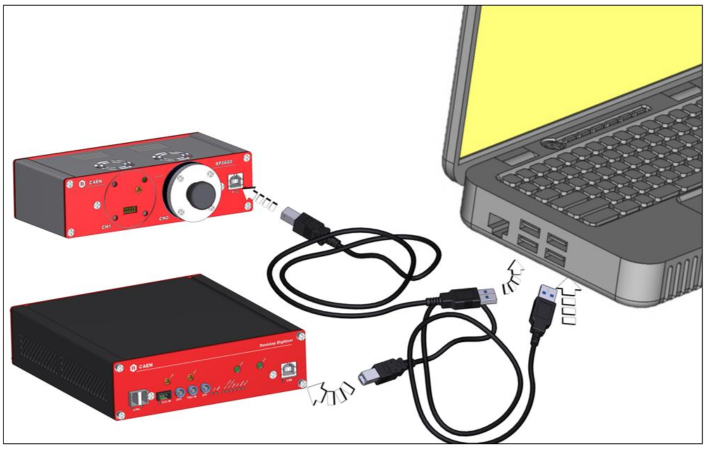
- Required elements: PSAU + Digitizer + Oscilloscope
- Cabling instructions:
  - The main units of the kit must be power on.



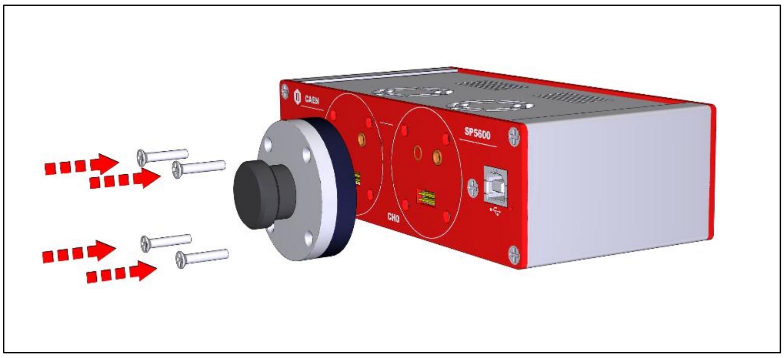
SP5600 – Power Supply and Amplification Unit.

DT5720A – Desktop Digitizer.

  - SP5600 (PSAU) and DT5720A (DGTZ) shall be connected to the PC via USB cables.



  - The sensor (included in the SP5650C) shall be plugged on a PSAU input channel (for example channel 0, as default in the software pre-settings).



- The output analog signal from the PSAU ("CH0" on the rear panel) must be connected to the input channel of the DGTZ.

- Getting the system alive:
  - Run the program by clicking the HERA icon.

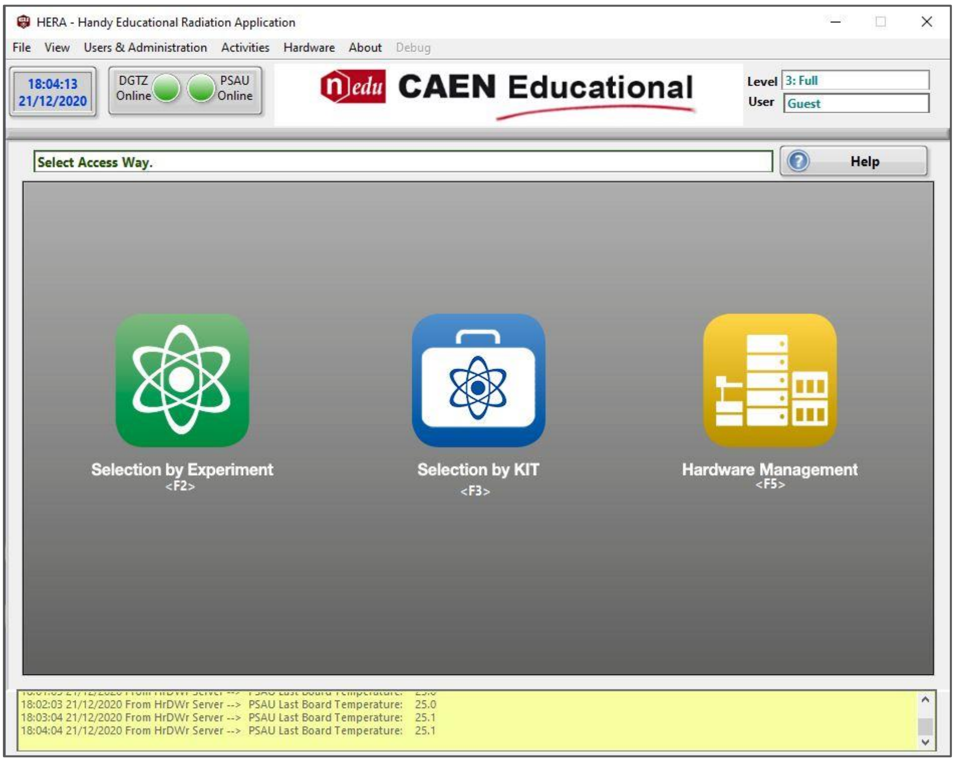


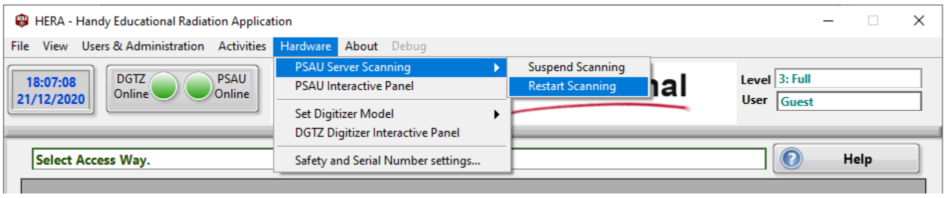
Fig. 7.1: Main GUI of the HERA software.

  - Before running the software, wait the hardware connection. The software recognises the hardware automatically and start the connection. Two connection indicators, "Online Hardware", are present on the opening window:

    Green light means that the connection is ok.

    Red light means that there is no connection.

If the PSAU is power on, but the light colour is red, the software can be forced to search for a new connection via the rescanning procedure from the Verbose Menu: Hardware-> PSAU Server Scanning -> Restart Scanning.



Yellow light means that either the DGTZ is not a DT5720A/C, or its firmware is not compliant with Hera software, and another firmware type is probably running on the board.

Once the system is running, the first action to take is properly biasing the detector and setting the right gain to avoid saturating the PSAU amplifier.

As far as the optimal bias voltage of the sensor, it is suggested to stick to the value reported on the sensor ID card, which may be set in the Power Supply & Amplification Unit Interactive Panel (Fig. 7.2). The Panel can be easily opened via “Hardware” drop-down menu or via the “Hardware Management” access.

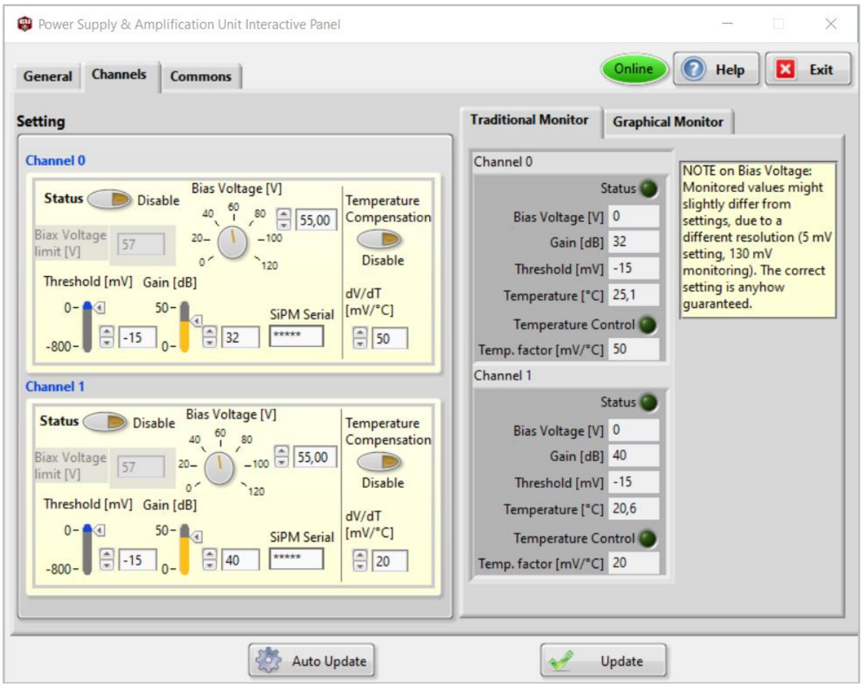


Fig. 7.2: Power Supply & Amplification Unit Interactive Panel.

Enable the channel in use and set the optimal bias voltage. At the same time, the amplification factor can be set and, since the SiPM for the current measurement will not be illuminated and only a few cells are expected to fire, a high value can be used, e.g. 40 dB.

Moreover, for the sake of clarity, the feedback system for the SiPM gain stabilization against temperature variations can be disabled.

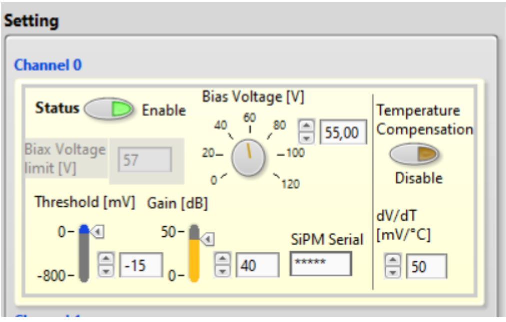


Fig. 7.3: PSAU - Channel 0 Settings.

Important Note: The "Update" button must be selected for all settings change to apply them correctly. The lack of this operation leaves the default settings unchanged.
The "Auto Update" button executes the updating process automatically.

As long as the SiPM is biased and the oscilloscope is properly triggered (an edge trigger, in manual mode, with a threshold at the -10 mV level should be suitable), the SiPM signal is expected to appear on the oscilloscope display, with a waveform similar to what is shown in Fig.7.4**.**

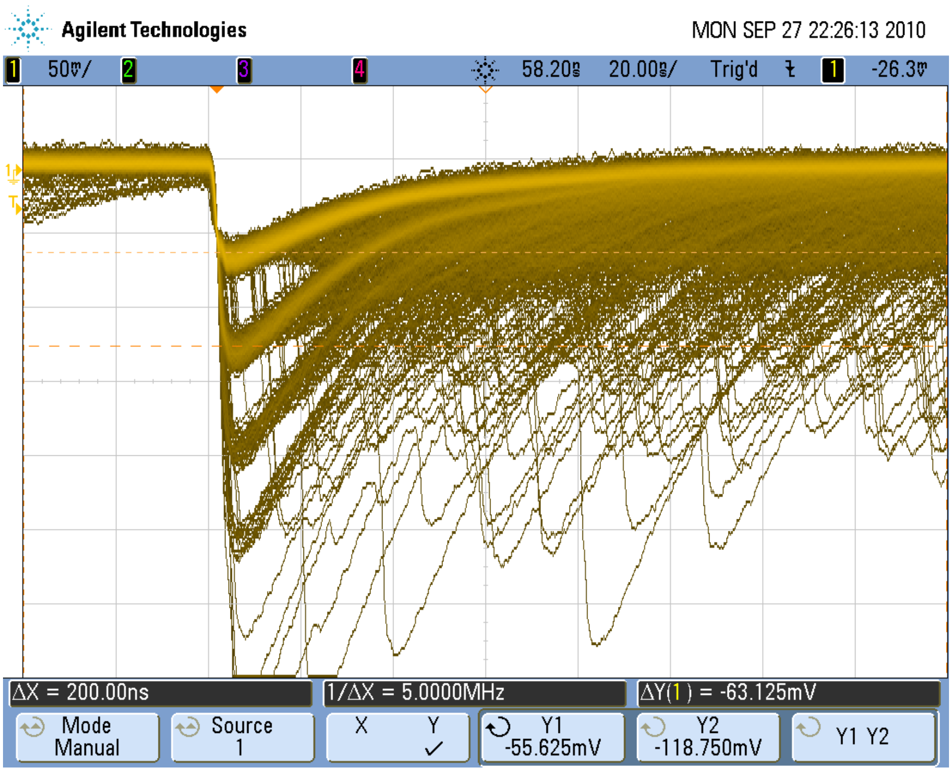


Fig.7.4: SiPM output signal for a not illuminated sensor. Bias: 55 V; Gain: 40 db. Peak-to-peak distance: 63.13 mV.

The different bands in the signal output correspond to avalanches in the cells triggered by the thermal generation of the charge carriers or by the photons associated to the avalanche development (optical cross-talk).

The SiPM Geiger-Mueller multiplication factor is actually corresponding to the area underneath the single cell signal. However, the peak-to-peak distance provides a fair indication of the overall system gain, useful for

- checking the SiPM gain dependence on the over-voltage with respect to the breakdown
- set the amplification factor and avoid saturation effects

- set the discriminator threshold to generate a trigger condition and integrate the signal or perform counting experiments.

A useful entry-level parameter is the Dark Count Rate (DCR) of the SiPM under study, namely the frequency with which avalanches occur for thermal or optical crosstalk (OCT) effects. It is a standard procedure to quantify the DCR as the counting frequency with a threshold corresponding to 0.5 x single photo-electron (p.e.) peak ($DCR_{0.5}$) and to measure the OXT as

$$OCT = \frac{DCR_{1.5}}{DCR_{0.5}}$$

Being the numerator the Dark Count Rate with a threshold at 1.5 photoelectron peak.

The DCR vs threshold can be precisely measured with the Kit. However, a fair indication can be obtained with the Oscilloscope, if the option to measure the triggering frequency is offered. In case, it is worth to exploit this feature to cross check the values against the factory measurements and as reference value for the most advanced procedures. As exemplary illustration, the DCR measurement at 0.5 Photoelectron threshold is shown in Fig. 7.5.

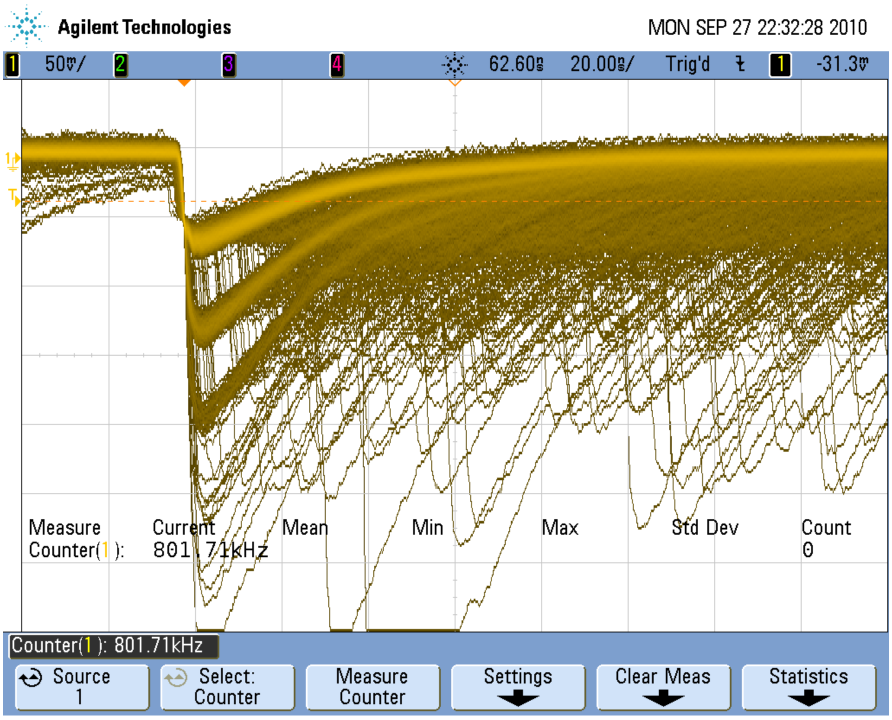


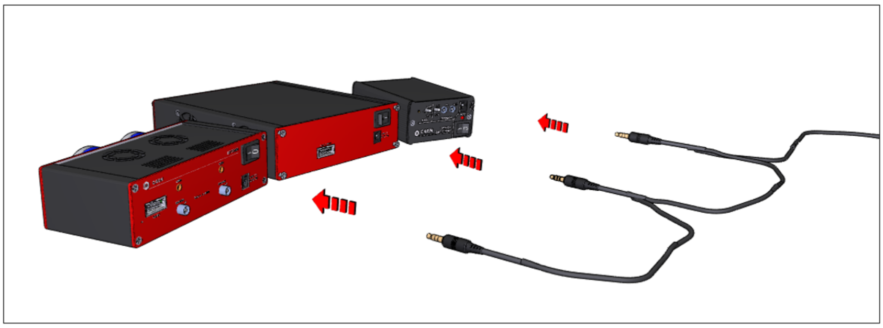
Fig. 7.5: DCR 0.5 measurement at the oscilloscope. The frequency drops to ~206 kHz increasing the threshold to 1.5 p.e. (not shown).

By now and before moving to the next step, the user can gain further knowledge on the system, playing with the bias and the amplification factor and measuring the peak-to-peak and DCR variations.

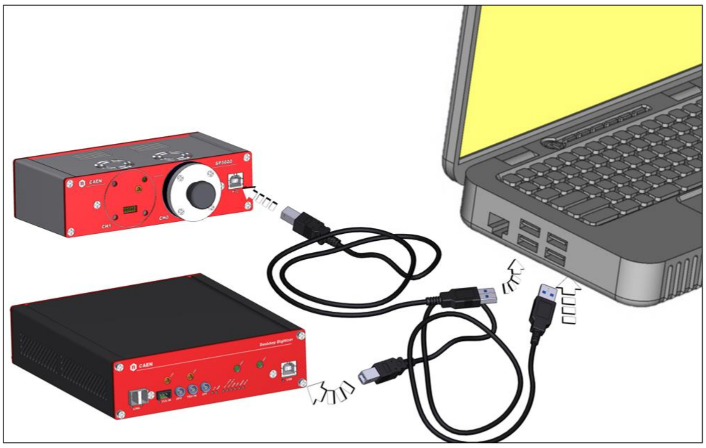
7.2 Can you see the light? SiPM illuminating; triggering & integrating

7.2.1 Kit Configuration

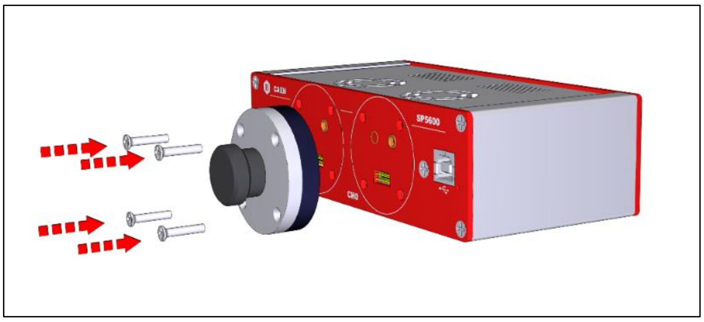
- Required elements: PSAU + Digitizer + LED driver + Oscilloscope
- Cabling instructions:
    - The 12V power supply is able to power PSAU, DGTZ, and SP5601 (LED) thanks to the power cord adapter (1 IN / 3 OUT).



    - SP5600 (PSAU) and DT5720A (DGTZ) shall be connected to the PC via USB cables.

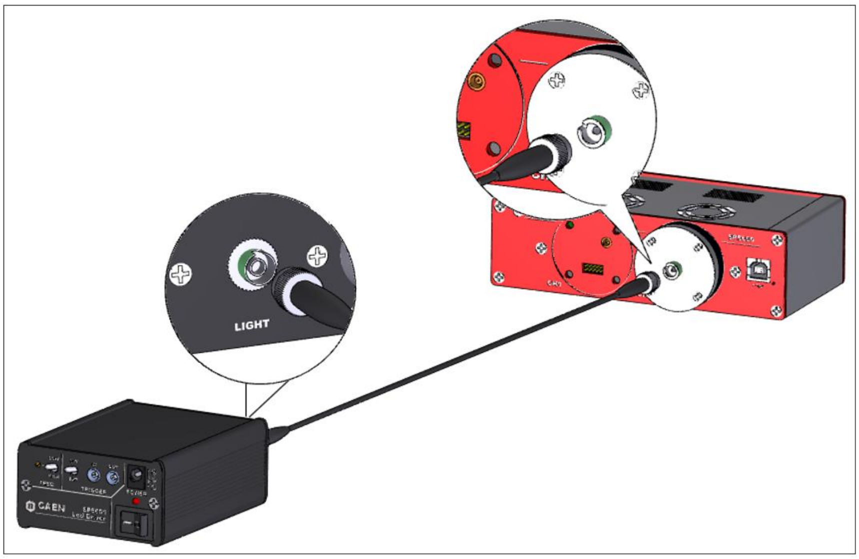


    - The sensor (included in the SP5650C) shall be plugged on a PSAU input channel (for example channel 0, as default in the software pre-settings).

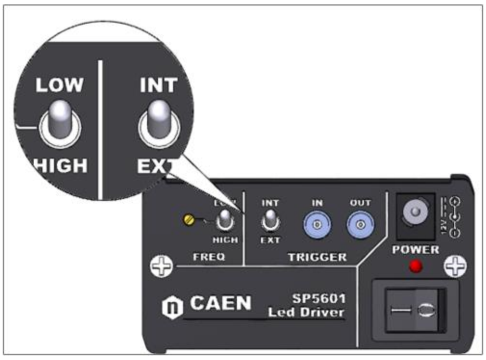


    - Remove the black cap of the LED output light on the front panel and the black cap of the sensor holder SP5650C.
    - The fiber caps must be removed to have the connection between light source and photodetector.

- The LED output light (front panel) shall be directed to the SiPM through the FC terminated clear fiber.

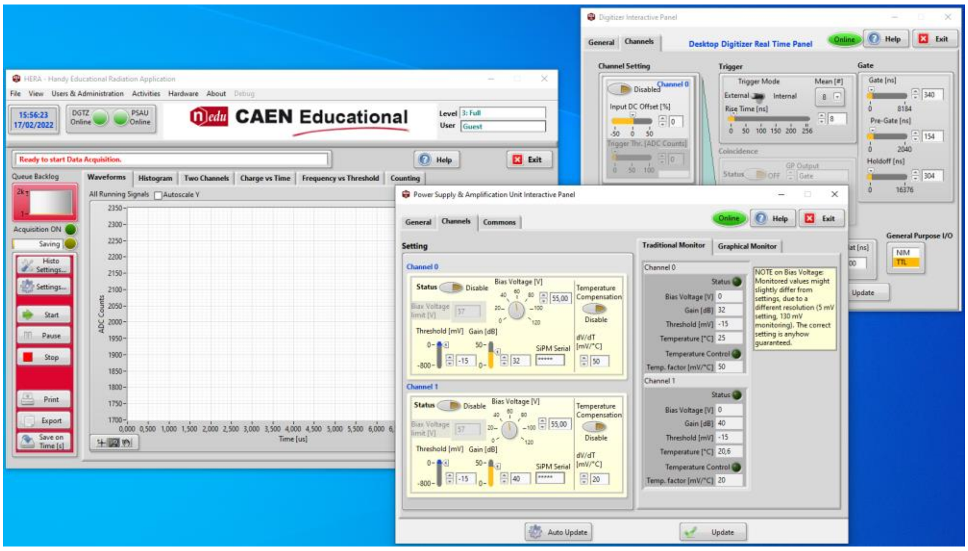


- Low frequency and internal trigger must be set on the rear panel of the LED Driver.



- Cabling among the kit elements depend on the undertaken measurement (see below).

- Getting the system alive:
  - Power on the kit elements
  - Run the program by clicking the HERA icon and wait for the hardware connection. The software recognises the hardware automatically and starts the connection. Keep attention to the two connection indicators status.
  - Select the Hardware Management access.



- Bias the SiPM via Power Supply & Amplification Unit Interactive Panel (“Hardware” drop-down menu). Set an initial amplification factor as of 0.
- Initially no setting of the Digitizer and Main GUI windows are required.

7.2.2 Obtaining a multi-photon peak spectrum

The multi-photon peak spectrum fully exploits the SiPM potential, and it is the reference quantity for the detector characterisation and qualification. It corresponds to the output signal spectrum for an illuminated SiPM and carries information about the detector gain and noise, the photon number resolving capability and even the DCR and the cross talk; concerning the light source, it allows to characterize the statistics of the emitted photons. More will be reported in the following, after the first spectrum is obtained through a two-step procedure:

- **Step 1: amplification factor and intensity tuning [LED driver + PSAU + Oscilloscope]**

The LED driver features the possibility to generate internally or externally the light pulse frequency; for the sake of simplicity, internal generation is considered here and the toggle switch on the back plane of the LED driver shall be set accordingly. The pulse frequency can be selected via a multi-turn rotary meter in the [6;500] kHz range.

When internal generation is chosen, a synchronization output signal in TTL logic is provided from the DOUT plug on the back panel. In order to know the frequency and as a trigger for the SiPM output visualization, it is recommended to look at the synch signal at the oscilloscope.

Once this is done, the SiPM output from the PSAU can be properly displayed showing a number of fired cells by far exceeding what is due to the DCR and cross-talk.

Looking at the scope track, the LED intensity can be tuned and the amplification factor regulated to avoid saturating the dynamic range and inducing an artefact in the spectrum (Fig. 7.6 and Fig. 7.7).

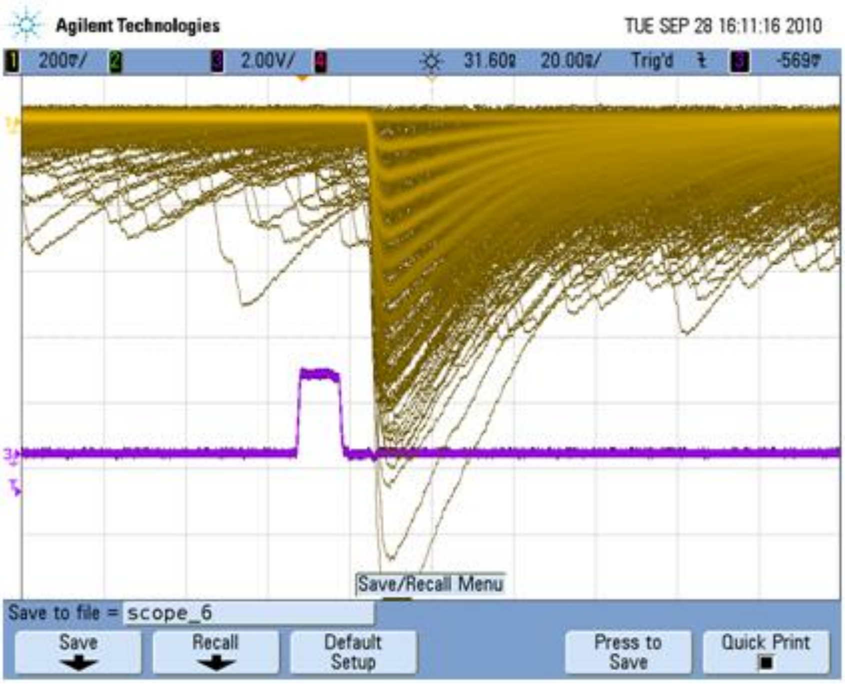


Fig. 7.6: Analog output from the SiPM under test, illuminated the LED. The purple track, used as a trigger, corresponds to the synchronization signal form the LED driver.

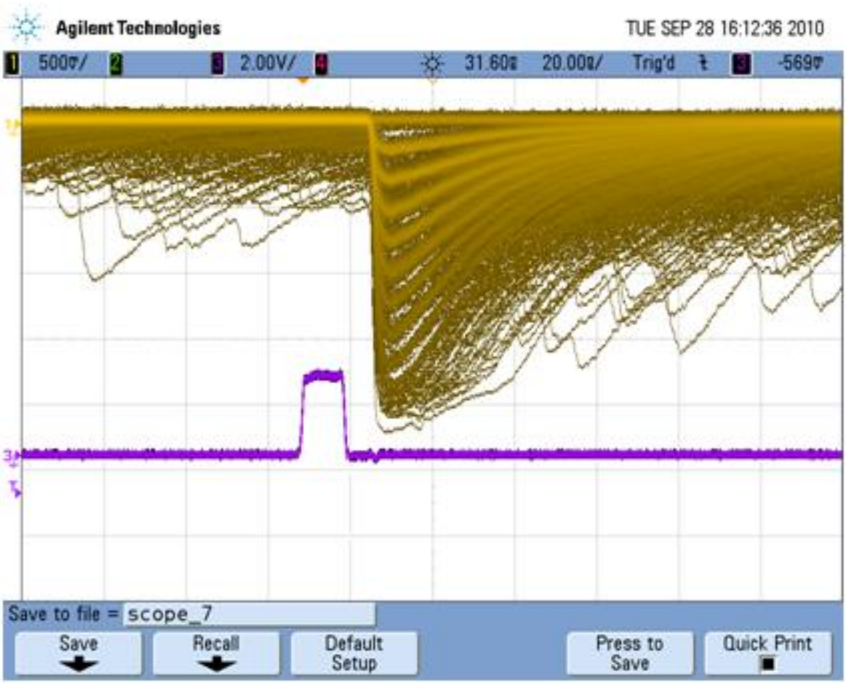


Fig. 7.7: Analog out from SiPM under test, showing onset of saturation due to a too large amplification factor.

- **Step 2: signal digitization**

In order to digitize the SiPM output, the kit has to be configured as follows:

- Cabling:
  - The output signal form the PSAU has to be connected to the input of the Digitizer, either channel 0 or 1

- The output analog signal from the PSAU ("CH0" on the rear panel) must be connected to the input channel of the DGTZ.

- The Synchronization signal from the LED will provide the trigger edge to the Digitizer. The Trigger Out signal of the LED must be connected to the TRG IN plug of the DGTZ. On the rear panel of the LED, take care to verify that the trigger switch to "INT", which means internal mode, and to plug the LEMO cable in the Trigger "OUT" hole.

- HERA Software: in the Digitizer Interactive Panel (Fig. 7.8).
    - Select EXTERNAL trigger mode.
    - Enable the channel (for example ch 0).
    - Accept default values for the GATE and BASELINE sub-panels.

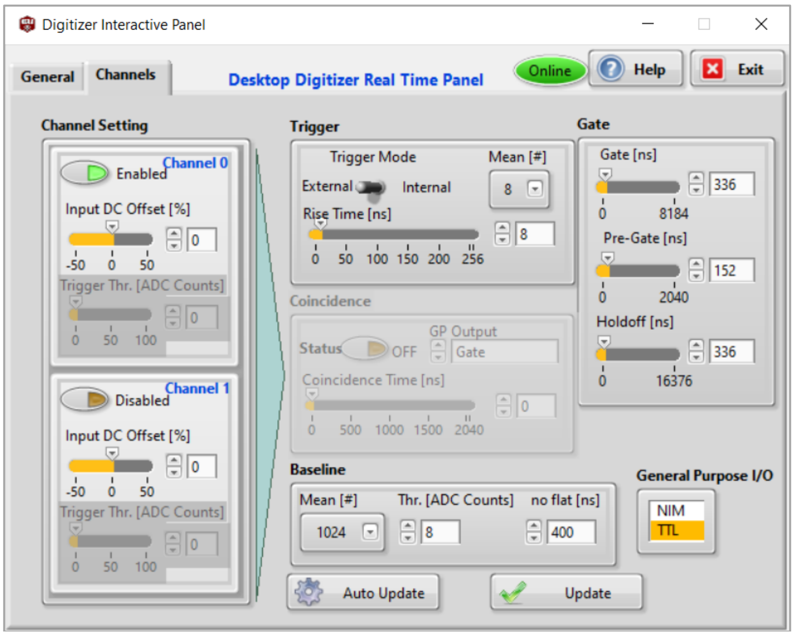


Fig. 7.8: The DIGITIZER control panel.

By now, the system is ready for digitizing the signal but, rather than doing it in a blind way, it is worth taking a guided tour of the system features, going to the visualization panel and switching on the Waveforms tab.

The Waveform tab displays the most relevant information:

a. The digitized analog Input;

b. The signal Baseline (labeled as vProbe);

c. The integration Gate triggered externally or internally by the Digital Pulse Processor.

The *baseline* can be calculated according to the parameters specified in the corresponding sub-panel, namely (Fig. 7.8):

- The number of samples used to calculate the *mean* value
- The *threshold,* used to avoid including in the mean value signals which could bias the baseline value. Whenever the signal exceeds the threshold while the baseline is being updated, the averaging procedure is frozen
- The *no flat time*, specifying the time interval between two updates of the baseline value. The flat time can also be shown in the WAVE display.

The *GATE* actually defines the integration time, and its edge may be triggered in different ways. Once the gate is open, its characteristics are associated to three parameters, specified in the gate sub-panel (Fig. 7.8):

- *gate*[ns] represents the width of the gate signals
- The *pre-gate*, fully exploiting the digital power for the optimal timing with respect to the signal. It defines the position of the gate with respect to the trigger edge, with the possibility to anticipate it, to compensate for the different timing in the signal routing.
- The *holdoff* time, a user's defined veto following a gate opening. The holdoff can also be shown in the waveform display.

For the sake of clarity in the display, every signal can be offset and magnified, enabled or disabled via the commands located on the right side of the waveform tab.

Fig. 7.9 is showing the waveform tab for the SiPM illuminated by the LED, for optimal tuning of the baseline and notably of the pre-gate and the gate width, depending on the time development of the SiPM signal. It is worth remarking here that the LED driver was designed to provide light pulses with a few ns duration (see the technical specifications), so the time development is dominated by the sensor response.

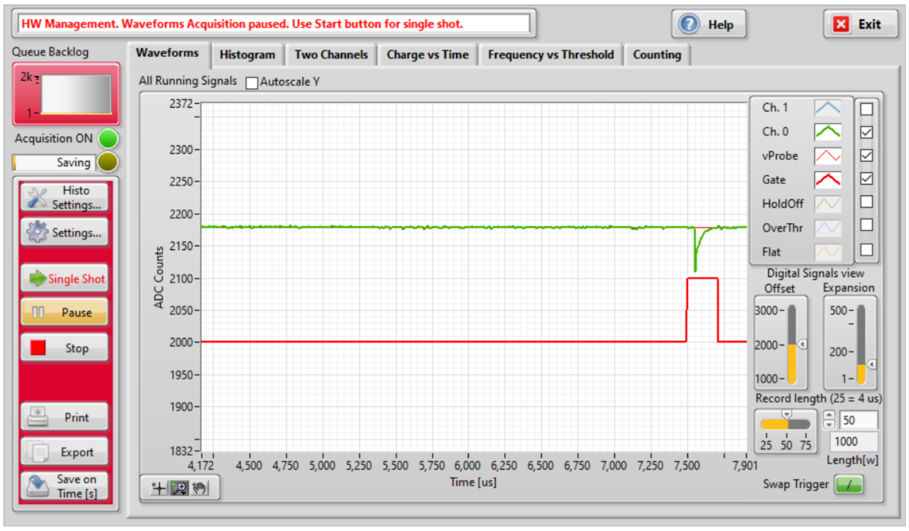


Fig. 7.9: The WAVE display of the GUI.

As long as the GATE is properly defined, the system is ready to record the spectrum, displayed in the HISTOGRAM tab. Exemplary illustration of the multi-photon peak spectrum are shown in Fig.: 7.10.

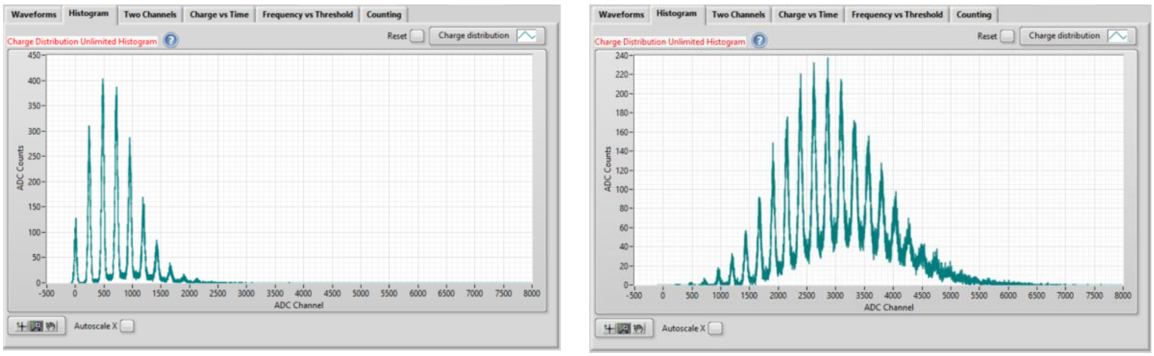


Fig.: 7.10: Multi-photon peak spectrum at two different LED intensities.

The multi-photon peak spectrum provides several information about the system in use; it is worth recalling here the fundamentals:

- The SiPM multiplication factor can be measured by the peak-to-peak distance, knowing that the system is characterized by a charge LSB of 40 fC/ADC channel and the SiPM signal is amplified by an amplification factor set by the user. The linearity and the dynamic range of the sensor can be studied as well.
- The photon number resolving power can be obtained at glance and its dependence on the SiPM biasing conditions studied
- A genuine multi-photon peak spectrum fit can provide further insight, namely:
  - A measurement of the width of the Gaussian peaks against the number n of cells, where a trend of the form

    $$\sqrt{\sigma_0^2+\sigma_1^2 \times n^2}$$

    Is expected, being σ_0 related to the zero-photon peak width, so to the system noise, and σ_1 provides an indication of the cell-to-cell variation of the characteristics.
  - An independent measurement of the DCR and the crosstalk, as long as these terms are included in the fitting function
  - An information on the statistics of the emitted photons, usually retained to be Poissonian.
- Moreover, the SiPM biasing can be optimized, trading-off the avalanche triggering efficiency and the spectrum quality, possibly affected by the spurious dark counts in the gate window.

8 Educational Experiments

The Educational Photon kit allows to perform experiments that have to do with quantum nature of the light. Exploring the quantum nature of phenomena is one of the most exiting experiences a physics student can live.

The set-up is based on Silicon Photomultipliers (SiPM) state of-the-art sensor of light with single photon sensitivity and unprecedented photon number capability. In the field of light sensing and related appliances and instrumentation, SiPM are expected to have the same impact the transistor had: well beyond the replacement of thermoionic valves, it triggered a revolution opening up new and unforeseen perspectives. As a consequence, it is quite natural to get started with activities aimed to introduce the student to the knowledge of the features of this class of sensors.

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

The experiments proposed by CAEN in Modern Physics field are listed in Tab. 8.1.

Section	Subsection	Reference ID	Experiment
Particle Detector Characterization	**Silicon Photomultiplier (SiPM)**	6011	SiPM Characterization
		6012	Dependence of the SiPM Properties on the Bias Voltage
		6013	Temperature Effects on SiPM Properties
Particle Physics	**Photons**	6221	Quantum Nature of Light
		6222	Hands-on Photon Counting Statistics

Tab. 8.1: Physics Experiments performed via the Educational Kit – Premium version.

8.1 SiPM Characterization (SG6011A)

Purpose of the experiment:

Characterization of a SiPM detector using an ultra-fast pulsed LED. Estimation of the main features of the detector at fixed bias voltage.

Fundamentals:

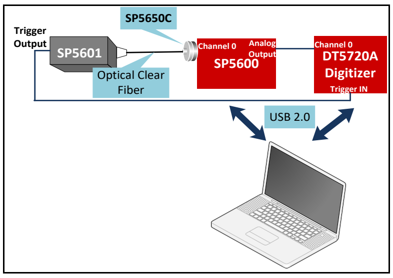
Silicon Photomultipliers (SiPM) consist of a high-density (up to ~10^4/mm^2) matrix of diodes connected in parallel on a common Si substrate. Each diode is an Avalanche Photo Diode (APD) operated in a limited Geiger-Müller regime connected in series with a quenching resistor, in order to achieve gain at level of ~10^6. As a consequence, these detectors are sensitive to single photons (even at room temperature) feature a dynamic range well above 100 photons/burst and have a high Photon Detection Efficiency (PDE) up to 50%. SiPM measure the light intensity simply by the number of fired cells. However, this information is affected and biased by stochastic effects characteristic of the sensor and occurring within the time window: spurious avalanches due to thermally generated carriers (a.k.a. Dark Counts), delayed avalanches associated to the release of carriers trapped in metastable states (a.k.a. Afterpulses) and an excess of fired cells due to photons produced in the primary avalanche, travelling in Silicon and triggering neighbouring cells (a phenomenon called Optical Cross Talk). The typical SiPM response to a light pulse is characterized by multiple traces, each one corresponds to different numbers of fired cells, proportional to the number of impinging photons. Because of the high gain compared to the noise level, the traces are well separated, providing a photon number resolved detection of the light field.

Requirements:

No other tools are needed.

Carrying out the experiment:

The light pulse from the SP5601 ultra-fast LED-Driver is driven through an optical clear fiber into the SP5650C SiPM holder housing the sensor under test and connected to the SP5600. The output signal (from the SP5600) is connected to the input channel of the DT5720A Desktop Digitizer equipped with the charge integration firmware and triggered by the SP5601 LED-driver. The SP5600 and the DT5720A are connected to the PC through the USB. Use the default software values or optimize the bias voltage and discriminator threshold. The horizontal axis of the acquired spectrum is the ADC channels, therefore ADC channel conversion ($ADC_{c.r.}$) factor can be calculated to perform the experiment and determine the main features of the SiPM.



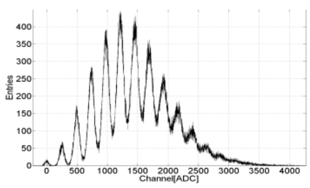
Experimental setup block diagram.

Results:

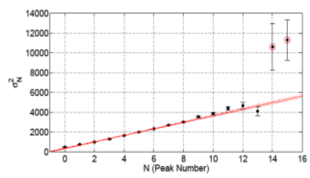
The gain of the SiPM is evaluated from the output charge of the sensor. After the estimation of the ADC channel conversion factor ($ADC_{c.r.}$) and the distance between adjacent peaks (ΔPP(ADC_ch)), the SiPM gain can be calculated according to the following equation:

$$Gain = \frac{\Delta PP(ADC\_ch) * ADCc.r.}{e}$$

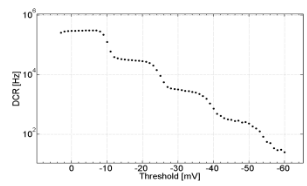
The resolution power of the system can be evaluated plotting the σ of each peaks versus the number of peaks. The counts frequency, in absence of light, at 0.5 p.e. threshold represents the DCR. The ratio between the dark count at 1.5 p.e. threshold ($DCR_{1.5}$) and the value at 0.5 p.e. threshold ($DCR_{0.5}$) give the crosstalk estimation of the detector.



Spectrum of Hamamatsu S10362-11-100C.



Peak σ versus peak number for Hamamatsu S10362-11-100C.



Sensor Dark Count frequency versus discrimination threshold.

8.2 Dependence of the SiPM Properties on the Bias Voltage (SG6012A)

Purpose of the experiment:

Study the dependence of the main SiPM figures of merit on the bias voltage. Measurement of the breakdown voltage and identification of the optimal working point. The experiment requires the use of the LED source included in the kit.

Fundamentals:

The main features of the SiPM are expected to depend on the bias voltage or, more specifically, on the overvoltage, the voltage in excess of the breakdown value:

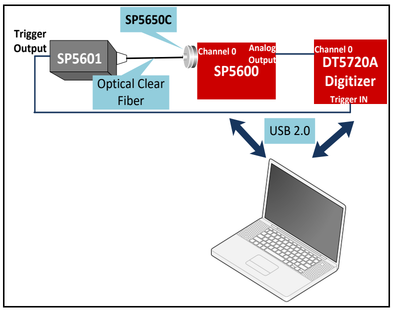
- The gain is expected to depend linearly on the overvoltage
- The triggering efficiency, i.e. the probability for a charge carrier to generate an avalanche by impact ionization, increases with the overvoltage till a saturation value is achieved. As a consequence, the Photon Detection Efficiency (PDE) increases together with the stochastic events (Dark Count Rate, Cross Talk and After Pulses) affecting the sensor response.

Actually, spurious events are expected to grow super-linearly and the determination of the optimal working point requires the definition of a proper figure of merit. Referring to the photon number resolving capability of the SiPM, the bias can be set to optimize the resolution power, i.e. the maximum number of resolved photons.

Requirements:

No other tools are needed.

Carrying out the experiment:

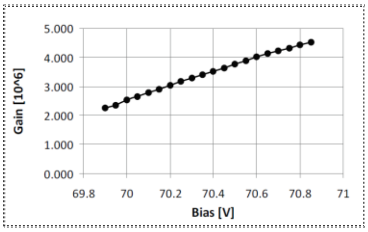


Experimental setup block diagram.

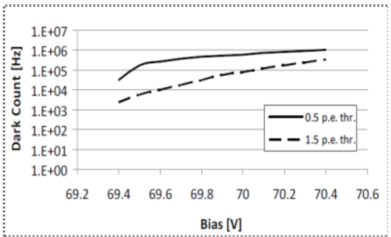
Mount one of the sensors (SP5650C) on the SP5600 and connect the analog output to the input of the DT5720A digitizer. Optically couple the LED and the sensor via the optical fiber, after having used the index matching grease on the tips. Set the internal trigger mode on the SP5601 and connect its trigger output on the DT5720A trigger IN. Connect via USB the modules to the PC and power ON the devices. Through the HERA graphical user interface (GUI), properly synchronize the signal integration and, for every voltage value, record the photon spectrum and measure directly the Dark Count and the Optical Cross talk. The measurement of the After Pulse is also possible but it requires most advanced analysis techniques.

Results:

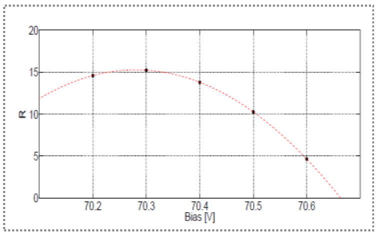
As exemplary illustration, the trend of the gain vs. the bias voltage is shown, allowing as well the measurement of the breakdown voltage corresponding to the value at zero gain. The optimal working point by a measurement of the resolution power on the multi-photon peak spectrum is also shown.



SiPM gain versus bias voltage.



Dark count versus bias voltage.



Scan of the resolution power R as a function of the bias voltage.

8.3 Temperature Effects on SiPM Properties (SG6013A)

Purpose of the experiment:

Gain, noise and photon detection efficiency (at fixed bias voltage) are affected by temperature. The student is driven through the measurement of the dependence of these critical figures.

Fundamentals:

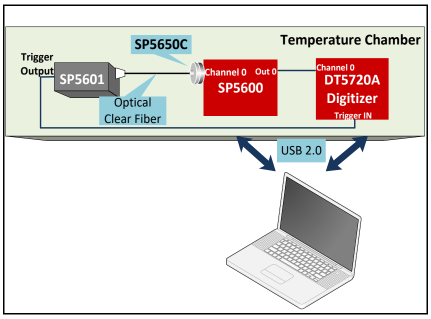
The gain in a SiPM biased at fixed voltage changes with temperature since the breakdown voltage V_{br} does it. Gain stabilization is a must and can be pursued tracking the V_{br} changes and adjusting the bias voltage accordingly. The rate of variation depends on the sensor, through the material properties. Noise depends on the thermal generation of charge carriers, so a significant dependence is expected as well.

Requirements:

A temperature-controlled box/room is essential.

Carrying out the experiment:

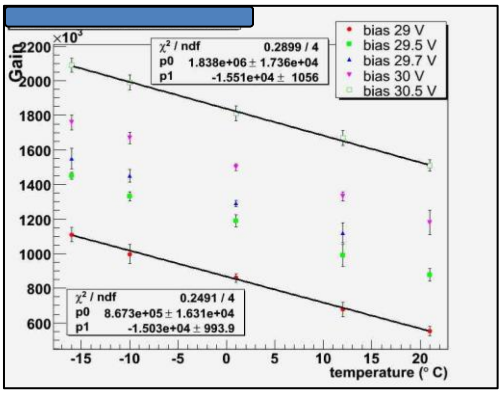
In a temperature-controlled box, mount one of the sensors (SP5650C) on the SP5600 and connect the analog output to the input of the DT5720A digitizer. Optically couple the LED and the sensor via the optical fiber, after having used the index matching grease on the tips. Set the internal trigger mode on the P5601 and connect its trigger output on the DT5720A trigger IN. Connect via USB the modules to the PC and power ON the devices. Through the HERA graphical user interface (GUI), properly synchronize the signal integration and, for every temperature & voltage value, record the photon spectrum and measure directly the Dark Count and the Optical Cross talk.



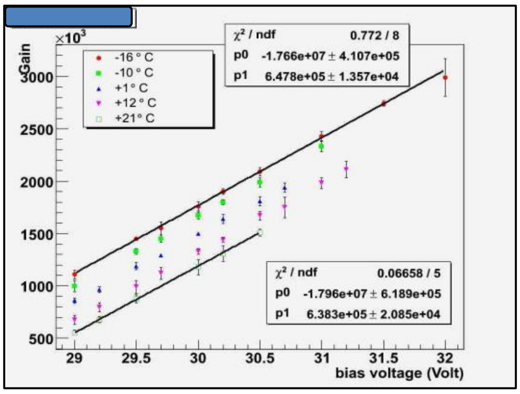
Experimental setup block diagram.

Results:

Figures show the dependence of the gain upon temperature at various voltages and the voltage dependence at various temperatures. By the two set of results, the temperature coefficient of the sensor, i.e. the variation of the breakdown voltage with temperature, can be measured.



SIPM gain as a function of temperature, at different bias voltage values.



SiPM gain as a function of the bias voltage, at different temperature values.

8.4 A Quantum Nature of Light (SG6221A)

Purpose of the experiment:

Exploring the quantum nature of light thanks to bunches of photons emitted in a few nanoseconds by an ultra-fast LED and sensed by a state-of-the-art detector, a Silicon Photomultiplier (SiPM).

Fundamentals:

In the XVII century the concept of wave-particle duality was developed, starting from the wave nature of light postulated by Huygens to the Einstein Photoelectric Effect, which postulates light quanta existence.

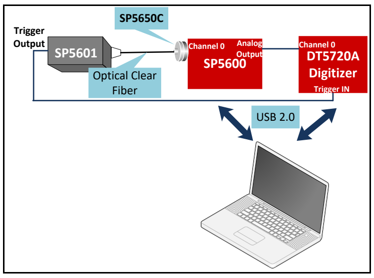
A basic principle of quantum mechanics is complementarity: each quantum-mechanical object has both wave-like and particle-like properties. With this approach the photon is at the same time wave and particle, but they can never be observed simultaneously in the same experiment, not even if the uncertainty principle is successfully bypassed.

Requirements:

No other tools are needed.

Carrying out the experiment:

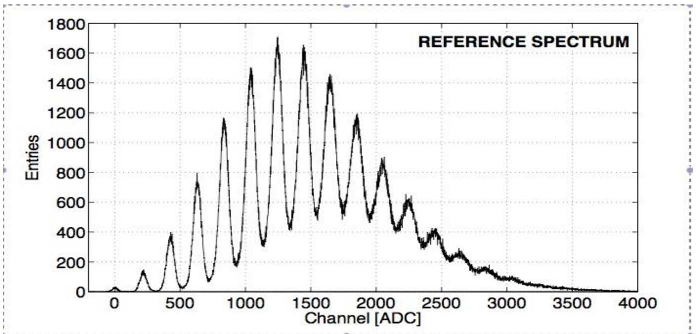
Plug in the SP5650A into one channel of SP5600 and connect the analog output to DT5720A channel 0. Remove the protection cover of the SP5601 and SP5650A, spread the optical grease on both ends of the optical fiber and connect them. Use internal trigger mode on SP5601 and connect its trigger output on the DT5720A trigger IN. Connect via USB the modules to PC and power ON the devices. Use the default software values or optimize the parameters to acquire the light spectrum. In the spectrum of the SiPM response to a light pulse, every entry corresponds to the digitized released charge, measured integrating the electrical current spike during a pre-defined time interval. The peaks correspond to different number of cells fired at the same time by incoming photons.



Experimental setup block diagram.

Results:

This detector can count the number of impacting photons, shot by shot, allowing to observe how the light is composed by photons. Moreover, the SiPM measures the light intensity simply by the number of fired cells.



Spectrum of the photons emitted by a LED Driver and detected by a Silicon Photomultiplier.

8.5 Hands-on Photon Counting Statistics (SG6222A)

Purpose of the experiment:

Statistical properties of the light pulses emitted by a LED driver.

Fundamentals:

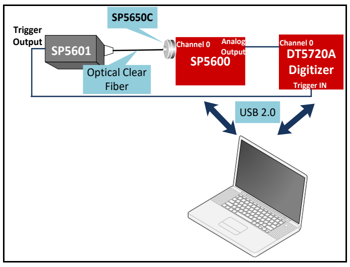
The typical SiPM response to a light pulse is characterized by multiple traces, each one corresponds to different numbers of fired cells, proportional to the number of impinging photons. Because of the high gain compared to the noise level, the traces are well separated, providing a photon number resolved detection of the light field. Spontaneous emission of light results from random decays of excited atoms and it is expected to be Poissonian. SiPM can count the number of impacting photons, shot by shot, opening up the possibility to apply basic skills in probability and statistics while playing with light quanta displaying the spectrum of the SiPM response to a high statistics of pulses. The spectrum is composed by a series of peaks, each ones correspond to different number of cells fired at the same time. Each peak is well separated and occurs with a probability linked at first order to the light intensity fluctuations. In SiPM the homogeneity of the response is quite high, however, since fired cells are randomly distributed in the detector sensitive area residual differences in the gain become evident broadening the peak. A key point in the analysis technique was the estimation of the area underneath every peak, essential to reconstruct the probability density function of the emitted number of photons per pulse. An easy procedure is to consider each peak as a gaussian, so spectra recorded in response to photons impacting on the sensor can be seen as a superposition of Gaussians, each corresponding to a well defined number of fired cells

Requirements:

No other tools are needed.

Carrying out the experiment:

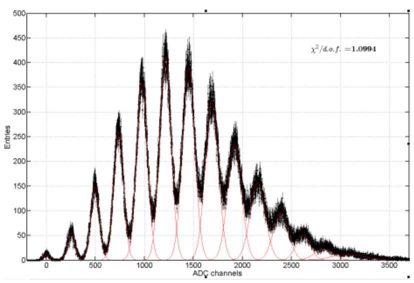
Plug in the SP5650A into one channel of SP5600 and connect the analog output to DT5720A channel 0. Remove the protection cover of the SP5601 and SP5650A, spread the optical grease on both ends of the optical fiber and connect them. Use internal trigger mode on SP5601 and connect its trigger output on the DT5720A trigger IN. Connect via USB the modules to PC and power ON the devices. Use the default software values or optimize the parameters to perform the experiment.



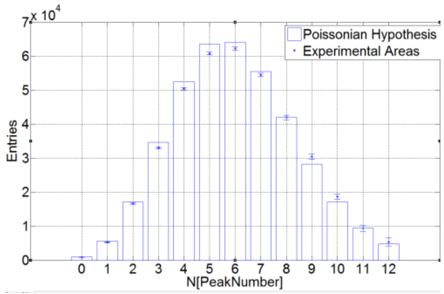
Experimental setup block diagram

Results:

The probability density function of the emitted number of photons per pulse can be estimated by the evaluation of the area underneath every peak. Two different hypothesis can be investigated to evaluate the statistical model and mean number of photoelectrons: Model Independent (the mean photon number is nothing but the mean) and Poissonian hypothesis (mean value obtained by presuming a pure Poissonian behaviour and by referring to the probability P(0) of having no fired cell when the expected average value). A complete and more complex analysis that include also considerations about detector structure is reported in the Educational Note [RD8].



Photoelectron spectrum probing a LED source measured with a Hamamatsu SiPM. The Individual Gaussians are shown in red..



Data from the light spectrum compared to a simple Poissonian.

9 Appendix

Data Storage

The HERA system allows the user to save data in several ways:

- Save data during the run (streaming mode).
- Save the data for an offline run (snapshot mode).
- Save an image.
- Export data in Excel.

The generation of the files due to the experimental activity deserves a dedicated discussion and it is referred to the step-by-step guides of each experiment.
All directories and files are generated under the following path: *C:\ProgramData\HERA\UserName .*
Where *UserName* is the name of the logged user. If no specific username is chosen, the default name used is “Guest”.
The list of the directories created by the HERA system during Hardware Management usage is the following:

- PSAU Temperatures
- Waveform
- Histograms
- Charge-Time
- TDMS

HERA generates several file formats: ASCII (.txt), binary (.dat), and another special file format of Labview (.TDMS) format.
National Instruments defined a new flexible technical data management (TDM) data model, which is accessible through LabVIEW, LabWindows™/CVI™, Measurement Studio, SignalExpress, and DIAdem.
The TDMS file format saves both the raw data and the metadata in the binary format in one file with the .TDMS extension.
When creating or opening a .TDMS file, HERA automatically creates a .TDMS_index file, used to speed up random access to the .TDMS file.
The .TDMS files can be open via a simple Add-In for Microsoft Excel (https://www.ni.com/example/27944/en/) or by using the "Convert data files (.TDMS)" in the File Menu.

PSAU Temperature

Regardless of the type of acquisition and the tab in use, a new file (ASCII format) is stored at every change of date (Log file type).

.txt Structure			
Typical Filename	PSAU_Temperature_*date(mmm-dd-yy)*.txt	Ex.: *PSAU Temperature_ Jan-15-21.txt*	
General	ASCII File, readable by any text editor. Fixed length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** absent		
Organisation:		***Name***	***Type***
Structure	5 columns		
Separation character	TAB		
Channels	Channel(s): 5	Date	Date (O.S. format)
		Time	24 h format
		Board Temperature	Decimal float
		Ch.0 Temperature	Decimal float
		Ch.1 Temperature	Decimal float
Data Format	Decimal separator: point (.)		
Data Type Recorded	Single points of measures		
Length	Depends on the running time of the Main Program		

Waveform tab

In addition to the waveforms export in a Bitmap Image to the Clipboard or "Excel" numerical data via the “Export" button, the Waveforms can be saved in both modes, streaming, and snapshot. The generated files are in .TDMS format (see Tab. 9.1).

Folder	Streaming Mode	Snapshot Mode
Waveform	.TDMS *streaming*	--
TDMS	--	*.TDMS*

Tab. 9.1: Waveforms saving scheme.

- *Streaming Mode*

TDMS Structure		
Typical Filename	*Activity Acronym_*Wave*(Time or events xx)_date(mm-dd-yy)*-T-*time(hhmm).TDMS*	Ex.: *HRDW_Wave(#Evn 1000)_01-08-21-T-1155.TDMS*
General	TDMS Structure (NI standard), readable by Excel with "TDM Importer Plugin".	
File Properties recorder	**Dataset Conditions:** string record (*)	
Organisation:		**Name**
Existing Groups	Group(s): 1	Analog Waveforms
Channels	Channel(s): 2	Trace Ch. 1
		Trace Ch. 0
Channel Range	0..4095	
Data Format	DT_Float (floating point double precision, 64 bits)	
Data Type	Array	
Length	Depends on the acquisition time or # of triggers	

- *Snapshot Mode*

TDMS Structure		
Typical Filename	*Activity Acronym _Wave.TDMS*	Ex.: *SiPM_Wave.TDMS*
General	TDMS Structure (NI standard), readable by Excel with "TDM Importer Plugin".	
File Properties recorder	**Dataset Conditions:** string record (*)	
Organisation:		**Name**
Existing Groups	Group(s): 2	Analog Waveforms
		Digital Waveforms
Channels	"Analog Waveforms" Channels: 2	Trace Ch. 1
		Trace Ch. 0
	"Digital Waveforms" Channels: 5	Virtual Probe
		Gate
		Hold Off
		Over Threshold
		Flat
Channel Range	0..4095	
Data Format	DT_Long (Long 32 bits integer)	
Data Type	Arrays	
Length	Depends on the x scale extension of the Waveform plots originating the file	

Histogram tab

The histograms can be export in a Bitmap Image to the Clipboard and in "Excel" numerical data via the "Export" button. Moreover, as the waveforms saving, the histograms can be saved in streaming and snapshot mode. The generated file formats are summarized in Tab. 9.2.

Folder	Streaming Mode	Snapshot Mode
Histogram	*.txt* (ASCII)	*.txt* (ASCII) [Under request]
TDMS	--	*.TDMS* [Under request]

Tab. 9.2: Histograms saving scheme.

- *Streaming Mode*

.txt Structure

Typical Filename	*Activity Acronym*_Charge_Histo*(*Time *or* events xx)_*date(mm-dd-yy)*—Time *(hhmm)*.txt	Ex.: *HRDW_Charge_Histo(Time 10)_02-10-21 Time 1610.txt*	
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** string record (*)		
Organisation:		***Name***	***Type***
Structure	2 columns		
Channels	Channel(s): 2	ADC Channel	Decimal float
		Counts	Integer
Data Format	Decimal separator: point (.)		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

- *Snapshot Mode*

.txt Structure

Typical Filename	*Activity Acronym*_Charge_Histo_*date(mm-dd-yy)*-Time-*time(hhmm)*.txt	Ex.: *HRDW_Charge_Histo_01-25-21 Time 1048.txt*	
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** string record (*)		
Organisation:		***Name***	***Type***
Structure	2 columns		
Channels	Channel(s): 2	ADC Channel	Decimal float
		Counts	Integer
Data Format	Decimal separator: point (.)		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

TDMS Structure

Typical Filename	*Activity Acronym*_Charge_Histo.*TDMS*	*Ex.: HRDW_Charge_Histo.TDMS*
General	TDMS Structure (NI standard), readable by Excel with "TDM Importer Plugin".	
File Properties recorder	**Dataset Conditions:** empty	
Organisation:		***Name***
Existing Groups	Group(s): 1	Charge Histogram
Channels	Channel(s): 2	X coord
		Histo(X)
Data Format	DT_Float (floating point double precision, 64 bits) DT_Long (long 32 bits integer)	
Data Type Recorded	Array	
Length	Depends on the number of bins present in the Histograms	

Two Channels tab

The storage of the histograms in the *Two Channels tab* can be occurred in snapshot mode only, as showed in Tab. 9.3.

Folder	Streaming Mode	Snapshot Mode
Histogram	--	.txt (ASCII), 2 separate files
TDMS	--	.*TDMS* (2 files) [Under request]

Tab. 9.3: Two channels saving scheme.

- Snapshot Mode

.txt Structure

Typical Filename	Hardware Management (generic)Ch*x*(channel number)_*date(mm-dd-yy)*-Time-*time(hhmm)*.txt A file is generated for each channel.	Ex.: *Hardware Management (generic)Ch1_02-09-21 Time 1238.txt*	
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** string record (*)		
Organisation:		***Name***	***Type***
Structure	2 columns		
Channels	Channel(s): 2	Rate bin	Decimal float
		Counts/bin	Integer
Data Format	Decimal separator: point (.)		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histograms		

TDMS Structure		
Typical Filename	*Activity Acronym*_2Ch_Charge_Histo.*TDMS*	Ex.: *HRDW_2Ch_Charge_Histo.TDMS*
General	TDMS Structure (NI standard), readable by Excel with "TDM Importer Plugin".	
File Properties recorder	**Dataset Conditions:** empty	
Organisation:		***Name***
Existing Groups	Group(s): 2	Channel 0 Histogram Channel 1 Histogram
Channels	Channel(s): total 4, (2 per group)	X coord Histo(X)
Data Format	DT_Float (floating point double precision, 64 bits) DT_Long (long 32 bits integer)	
Data Type Recorded	Array	
Length	Depends on the number of bins present in the Histograms	

<u>**Charge vs Time tab**</u>

The Charge vs Time data can be saved in streaming and snapshot mode. The generated file formats are summarized in Tab. 9.4.

Folder	Streaming Mode	Snapshot Mode
Charge-Time	.TDMS streaming	--
TDMS	--	*.TDMS* (2 files) [Under request]

Tab. 9.4: Charge vs Time saving scheme.

- <u>*Streaming Mode*</u>

TDMS Structure		
Typical Filename	*Activity Acronym*_ChargeVSTime(Time *or* events xx)_*date(mm-dd-yy)*-T-*time(hhmm).TDMS*	Ex.: *HRDW_ChargeVSTime(Time 5)_02-09-21-T-1245.TDMS*
General	TDMS Structure (NI standard), readable by Excel with "TDM Importer Plugin".	
File Properties recorder	**Dataset Conditions:** string record (*)	
Organisation:		***Name***
Existing Groups	Group(s): 1	ChargeVSTime
Channels	Channel(s): 2	Charge DGTZ-Ch.0 Charge DGTZ-Ch.1
Data Format	DT_Float (floating point double precision, 64 bits)	
Data Type Recorded	Array	
Length	Depends on the acquisition time or # of triggers	

- *Snapshot Mode*

TDMS Structure

Typical Filename	*Activity Acronym*_ChargeVSTime.*TDMS*	Ex.:*HRDW_ChargeVSTime.TDMS*
General	TDMS Structure (NI standard), readable by Excel with "TDM Importer Plugin".	
File Properties recorder	**Dataset Conditions:** empty	
Organisation:		***Name***
Existing Groups	Group(s): 1	ChargeVSTime
Channels	Channel(s): 2	Trace Ch. 0
		Trace Ch. 1
Channel Range	Full range	
Data Format	DT_Float (floating point double precision, 64 bits)	
Data Type	Array	
Length	Depends on the acquisition time or # of triggers	

Counting tab

The Counting tab data can be saved in snapshot mode only. The generated file formats are summarized in Tab. 9.5.

Folder	Streaming Mode	Snapshot Mode
Histogram	--	3 files *.txt* (ASCII)
TDMS	--	*.TDMS*

Tab. 9.5: Counting saving scheme.

- *Snapshot Mode*

.txt Structure

Typical Filename	• *ActivitymAcronym*_Counts_HistoFrequency_*date(mm-dd-yy)* Time *time(hhmm)*.txt • *ActivityAcronym*_Counts_HistoLeft_*date(mm-dd-yy)* Time *time(hhmm)*.txt • *ActivityAcronym*_Counts_HistoRight_*date(mm-dd-yy)* Time *time(hhmm)*.txt	Ex.: • *HRDW_Counts_HistoFrequency_01-23-21 Time 1219.txt* • *HRDW_Counts_HistoLeft_01-23-21 Time 1219.txt* • *HRDW_Counts_HistoRight_01-23-21 Time 1219.txt*	
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** string record (*)		
Organisation:		***Name***	***Type***
Structure	2 columns (all)		
Channels	Channels: 2 (Histo Left and Right)	X coord	Decimal float
		Histo(X)	Integer
Channels	Channels: (HistoFrequency)	Freq. or #of pulses	Decimal float
		Event Index	Integer
Data Format	Decimal separator: point (.)		
Data Type	Array(s)		
Recorded Length	Depends on the number of events present in the Plot		

TDMS Structure		
Typical Filename	*ActivityAcronym*_Counts_Histo.*TDMS*	Ex.: *HRDW_Counts_Histo.TDMS*
General	TDMS Structure (NI standard), readable by Excel with “TDM Importer Plugin”.	
File Properties recorder	**Dataset Conditions:** empty	
Organisation:		***Name***
Existing Groups	Group(s): 3	Count Histogram Left Count Histogram Right Frequency
Channels	Channel(s): total 6, (2 per group)	X coord
		Histo(X)
Data Format	DT_Float (floating point double precision, 64 bits) DT_Long (long 32 bits integer)	
Data Type Recorded	Array	
Length	Depends on the number of bins present in the Histograms	

(*) Dataset Conditions description

STRING Structure	
type	ASCII STRING, readable by any text editor. Variable. Terminated by \n (new line == 0x13 character). The string can be read abruptly until footer, and reproduced in any desirable context (comment, reports, screen fields,…)
HEADER	*** Start of Header ***
FOOTER	*** End of Header ***
Number of Records	56
Structure of records	*Description* <tab> *value* <nl> .OR. *Description* <nl> *Value* <nl>
Data Type Recorded	Single points of measures
Length	Fixed: 56 + 5 lines.
Contents	Example of a typical Dataset Condition header follows (with sample values) *** Start of Header *** Signature: HERA Writer V 1.0 Separator TAB Decimal Separator . Date: 05/01/2021 Time: 10.51.45 Username: Description: Dataset Channels: 2 Dataset Samples: 200 Data taking Conditions: Dataset metadata Date / Time creation: 20210105-T105144 User:

Activity code: 25
Sub-Activity code: 0
Sub-Activity: D2 After-Pulses studies

PSAU settings:
Channel in use: 0

Channels setting follow:
Ch.: 0
SiPM Serial: *****
Bias Voltage [V]: 55,00
Gain [dB]: 32,00
Threshold [mV]: -15,00
Channel Temperature [°C]: 25,50
T Compensation: Off
dV/dT 50,00
Ch.: 1
SiPM Serial: *****
Bias Voltage [V]: 55,00
Gain [dB]: 32,00
Threshold [mV]: -15,00
Channel Temperature [°C]: 21,00
T Compensation: Off
dV/dT 20,00

DGTZ settings:
Model: DT5720A
Model #: 9
Serial #: 812
Channel 0 Status: On
Channel 1 Status: Off
DC Offset 0: 0
DC Offset 1: 0
Trigger Mode: FALSE
Trigger Rise Time: 8
Trigger Mean: 8
Trigger 0 Thresh.: 0
Trigger 1 Thresh.: 10
Gate Mode: FALSE
Gate Width|Pre|Hold: 340 | 154 | 304
Baseline Mean|Thresh.|NoFlatTime: 1024 | 8 | 4008
Coincidence Status: FALSE
Coincidence on GPO|Time: 0 | 0
*** End of Header ***

Notes: <nl> stays for “new line character”. <tab> stays for Tab character.

Important Note:
Legend of the *Activity Acronyms*

- *HRDW:* Hardware Management
- *SiPM:* SiPM Experiments
- *ADV-AfterP:* Advanced Statistics Experiment (After-Pulses)
- *BETA:* Beta Spectroscopy Experiments
- *GAMMA*: Gamma Spectroscopy Experiments
- *PHOTONS*: Photons Experiments
- *COSMICS:* Cosmic Rays Experiments

Files generated during experimental activities.

The files generated during experimental activities are saved in different data formats. In addition to the previous data saving, each experimental activity generates a directory every time the activity is undergoing or has been completed. The file and directory names, the structure, and contents of these directories must not be changed. Moreover, no files can be added to those directories because it would affect data analysis procedures with different issues, including wrong results or the inability in performing the analysis.
The file formats are ASCII (.txt) and binary (.dat).
The .dat files contain direct binary copy of data in memory. Data represent a single histogram and is composed of two arrays of the same number of elements. This number depends on the number of bins included in the Histogram saved.
Arrays represent respectively the bin values sequence (float) and the counts per bin (integer).
No header or footer is present, so no data length information is present.
Arrays are aligned one after the other and data representation is, in the order: Double Precision Float (64 bits) and Long integer (32 bits). Therefore, the physical structure of the file is the following:

First array	Element 0	DB_F 7	DB_F 6	DB_F 5	DB_F 4	DB_F 3	DB_F 2	DB_F 1	DB_F 0
First array	Element 1	DB_F 7	DB_F 6	DB_F 5	DB_F 4	DB_F 3	DB_F 2	DB_F 1	DB_F 0
First array	Element 2	DB_F 7	DB_F 6	DB_F 5	DB_F 4	DB_F 3	DB_F 2	DB_F 1	DB_F 0
First array	…	DB_F 7	DB_F 6	DB_F 5	DB_F 4	DB_F 3	DB_F 2	DB_F 1	DB_F 0
First array	Element n	DB_F 7	DB_F 6	DB_F 5	DB_F 4	DB_F 3	DB_F 2	DB_F 1	DB_F 0
Second array	Element 0	I32 3	I32 2	I32 1	I32 0				
Second array	Element 1	I32 3	I32 2	I32 1	I32 0				
Second array	Element 2	I32 3	I32 2	I32 1	I32 0				
Second array	…	I32 3	I32 2	I32 1	I32 0				
Second array	Element n	I32 3	I32 2	I32 1	I32 0				

Tab. 9.6: Physical structure of the .dat files. Each coloured box indicates a single byte (8 bits).

Since no array length is prepend, the only way to locate and separate the two blocks is to consider that the first one must occupy the 2/3 of the total number of bytes and the second one the remaining 1/3.
Data are in Little Endian coding (Windows). Double Float is in 64-bit IEEE double-precision format.
For example, a .dat file of 72,000 bytes, contains:

1. The DB_Float array in the first 48,000 bytes
2. The I32 array in the following 24,000 bytes

And this principle must be used to locate and separate them.

- **Section A1: Silicon Photomultipliers**

The following table reports the organization of the data files generated by HERA during the experimental activities of Section A: Silicon Photomultipliers.

File generating experiment	Folder	Generation during the run	Description
A1.1 *Histogram TAB*	**20-1-DateTime-Histo_aaaa..**	• .dat (histogram binary) • .txt (ASCII) • Dataset Condition .txt	• Histogram of charge in binary • ASCII translation of the histogram • Dataset Condition.txt logfile
A1.2 *Histogram TAB*	**20-2-DateTime-Histo_aaaa..**	• ***n*** .dat (histogram binary) + • ***n*** .txt (ASCII) + • Dataset Condition .txt	• Histogram of charge in binary • ASCII translation of histogram • Dataset Condition.txt logfile.
A1.2 *Counting TAB*	**20-2-DateTime-Count_aaaa..**	• ***n*** .txt (counts summary) • Dataset Condition .txt	• Summary of measured counts • Dataset Conditions.txt logfile
A1.3 *Histogram TAB* (generates a series of directories. User can flag the directories with a mnemonic to find them during analysis)	**20-3-DateTime-Histo_aaaa..**	• ***n*** .dat (histogram binary) • ***n*** .txt (ASCII) • Dataset Conditions .txt • Temperat. Monitor.wvf • Temperat. Monitor.txt	• Histogram of charge in binary • ASCII translation of histogram • Dataset Condition.txt logfile • Temperature trends (binary waveform) • Temperature trends (ASCII)
A1.3 *Counting TAB* (generates a series of directories. User can flag the directories with a mnemonic to find them during analysis)	**20-3-DateTime-Count_aaaa..**	• ***n*** .txt (ASCII) • Dataset Condition .txt • Temperat. Monitor.wvf • Temperat. Monitor.txt	• Summary of measured counts • Dataset Condition.txt logfile • Temperature trends (binary waveform) • Temperature trends (ASCII)
in background for **all experiments**	**PSAU Temperatures**	.txt (ASCII) New file at every change of date (Log file type	

Tab. 9.7: Data saving scheme of the Experiments Section A1.

Activity 20.1: A1.1- SiPM Characterization

.txt Structure

Typical Filename	20-1-Raws_SiPM Basic.txt		
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** string record (*)		
Organisation:		***Name***	***Type***
Structure	2 columns		
Channels	Channel(s): 2	ADC Channel	Decimal float
		Counts	Integer
Data Format	Decimal separator: point (.)		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

.dat Structure (histogram Binary)

Typical Filename	20-1-Raws_SiPM Basic.dat		
General	Direct Binary. Used by Analysis procedure only. Not recommended for custom analysis.		
File Properties recorder	**Not applicable**		
Organisation:		***Name***	***Type***
Structure	Cluster of 2 elements		
Elements	Arrays	Not applicable	Decimal float
		Not applicable	Long Integer
Data Format	Not applicable		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

.txt Structure (Dataset Conditions)

Filename	Dataset Conditions.txt
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).
File Properties recorder	**Dataset Conditions:** string record (*) without Header and Footer
Organisation:	No further structures are present
Data Format	Decimal separator: point (.)

Activity 20.2: A1.2 - Dependence of the SiPM Properties on the Bias Voltage [Histogram TAB]

.txt Structure

Typical Filename	20-2-Raws_Bias[V] xx,xx.txt	Ex.: *20-2-Raws_Bias[V] 55,20.txt*	
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** string record (*)		
Organisation:		***Name***	***Type***
Structure	2 columns		
Channels	Channel(s): 2	ADC Channel	Decimal float
		Counts	Integer
Data Format	Decimal separator: point (.)		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

.dat Structure (histogram Binary)

Typical Filename	20-2-Raws_Bias[V] xx,xx.dat	Ex.: *20-2-Raws_Bias[V] 55,20.dat*	
General	Direct Binary. Used by Analysis procedure only. Not recommended for custom analysis.		
File Properties recorder	**Not applicable**		
Organisation:		***Name***	***Type***
Structure	Cluster of 2 elements		
Elements	Arrays	Not applicable	Decimal float
		Not applicable	Long Integer
Data Format	Not applicable		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

.txt Structure (Dataset Conditions)

Filename	Dataset Conditions.txt
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).
File Properties recorder	**Dataset Conditions:** string record (*) without Header and Footer
Organisation:	No further structures are present
Data Format	Decimal separator: point (.)

Conditions are replicated in the file names. Never change the names of the .bin files.

<u>Activity 20.2: A1.2 - Dependence of the SiPM Properties on the Bias Voltage [Counting TAB]</u>

.txt Structure (Dark Count vs Bias) *Summary of measured counts*

Typical Filename	20-2 Dark_Bias[V]*xx,yy*.txt *<u>Never change filename and contents of this file.</u>*	Xx,yy indicates Bias conditions in Volts	
General	ASCII File, readable by any text editor. Fixed length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** absent		
Organisation:	Name and value per line	***Name***	***Type***
Structure	2 columns, 7 rows (fixed)		
Separation character	TAB		
Channels	Channel(s):	Rate 0.5	Decimal float
		Rate 0.5 error	Decimal float
		Rate 1.5	Decimal float
		Rate 1.5 error	Decimal float
		OCT	Decimal float
		OCT Error	Decimal float
Data Format	Decimal separator: O.S. dependent (" , " or " . ")		
Data Type Recorded	Single points of measures during execution of the experiment		
Length	Fixed		

.txt Structure (Dataset Conditions)

Filename	Dataset Conditions.txt
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).
File Properties recorder	**Dataset Conditions:** string record (*) without Header and Footer
Organisation:	No further structures are present
Data Format	Decimal separator: point (.)

<u>**Activity 20.3: A1.3 - Temperature Effects on SiPM Properties [Histogram TAB]**</u>

.txt Structure

Typical Filename	20-3-Raws_Bias[V] xx,xx -Temp[°C] xx.txt	Ex.: *20-3-Raws_Bias[V] 55,00 -Temp[°C] 30.txt*	
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** string record (*)		
Organisation:		***Name***	***Type***
Structure	2 columns		
Channels	Channel(s): 2	ADC Channel	Decimal float
		Counts	Integer
Data Format	Decimal separator: point (.)		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

.dat Structure (histogram Binary)

Typical Filename	20-3-Raws_Bias[V] xx,xx -Temp[°C] xx.dat	Ex.: *20-3-Raws_Bias[V] 55,00 -Temp[°C] 30.dat*	
General	Direct Binary. Used by Analysis procedure only. Not recommended for custom analysis.		
File Properties recorder	**Not applicable**		
Organisation:		***Name***	***Type***
Structure	Cluster of 2 elements		
Elements	Arrays	Not applicable	Decimal float
		Not applicable	Long Integer
Data Format	Not applicable		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

.txt Structure (Dataset Conditions)

Filename	Dataset Conditions.txt
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).
File Properties recorder	**Dataset Conditions:** string record (*) without Header and Footer
Organisation:	No further structures are present
Data Format	Decimal separator: point (.)

Conditions are replicated in the file names. Never change the names of the .bin files.
The file "*Temperature Monitor.wvf*" is used internally by the Analysis procedure. Not provided for custom analysis. Never change the name file of this file.
The "Temperature Monitor.txt" file = ASCII translation of the Waveform TM file.

.txt Structure (Temperature Monitor)

Filename	Temperature Monitor.txt		
General	ASCII File, readable by any text editor. Fixed length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** absent		
Organisation:		***Name***	***Type***
Structure	4 columns		
Separation character	TAB		
Channels	Channel(s): 4	Timestamp	Date Time (O.S. format)
	PSAU Board	Y[0]	Decimal float
	PSAU Ch. 0	Y[1]	Decimal float
	PSAU Ch. 1	Y[2]	Decimal float
Data Format	Decimal separator: O.S. dependent (" , " or " . ")		
Data Type Recorded	Single points of measures during execution of the experiment		
Length	Depends on the running time of the Experiment		

Activity 20.3: A1.3 - Temperature Effects on SiPM Properties [Counting TAB]

Summary of measured counts

Typical Filename	20-3-Dark_Bias[V] xx,xx -Temp[°C] xx *Never change filename and contents of this file.*	Ex.: *20-3-Dark_Bias[V] 55,00 - Temp[°C] 28.txt*	
General	ASCII File, readable by any text editor. Fixed length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** absent		
Organisation:	Name and value per line	***Name***	***Type***
Structure	2 columns, 7 rows (fixed)		
Separation character	TAB		
Channels	Channel(s):	Rate 0.5	Decimal float
		Rate 0.5 error	Decimal float
		Rate 1.5	Decimal float
		Rate 1.5 error	Decimal float
		OCT	Decimal float
		OCT Error	Decimal float
Data Format	Decimal separator: O.S. dependent (“ , “ or “ . “)		
Data Type Recorded	Single points of measures during execution of the experiment		
Length	Fixed		

.txt Structure (Dataset Conditions)

Filename	Dataset Conditions.txt
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).
File Properties recorder	**Dataset Conditions:** string record (*) without Header and Footer
Organisation:	No further structures are present
Data Format	Decimal separator: point (.)

- **Section C2: Photons**

The following table reports the organization of the data files generated by HERA during the experimental activities of Section C2: Photons.

File generating experiment	Folder	Generation during the run	Description
C2.2 *Histogram TAB*	**24-2-DateTime-Histo_aaaa..**	• .txt (ASCII) • .dat (histogram binary) • Dataset Condition .txt	• Histogram of charge in binary • ASCII translation of the histogram • Dataset Conditions.txt logfile
in background for **all experiments**	**PSAU Temperatures**	.txt (ASCII) New file at every change of date (Log file type	

Tab. 9.8: Data saving scheme of the Experiments Section C2.

Activity 24.2: C2.2- Hands-on Photon Counting Statistics

.txt Structure

Typical Filename	24-18-Raws_LEDS[n] 0,00.txt		
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).		
File Properties recorder	**Dataset Conditions:** string record (*)		
Organisation:		***Name***	***Type***
Structure	2 columns		
Channels	Channel(s): 2	ADC Channel	Decimal float
		Counts	Integer
Data Format	Decimal separator: point (.)		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

.dat Structure (histogram Binary)

Typical Filename	24-18-Raws_LEDS[n] 0,00.dat		
General	Direct Binary. Used by Analysis procedure only. Not recommended for custom analysis.		
File Properties recorder	**Not applicable**		
Organisation:		***Name***	***Type***
Structure	Cluster of 2 elements		
Elements	Arrays	Not applicable	Decimal float
		Not applicable	Long Integer
Data Format	Not applicable		
Data Type Recorded	Array(s)		
Length	Depends on the number of bins present in the Histogram		

.txt Structure (Dataset Conditions)

Filename	Dataset Conditions.txt
General	ASCII File, readable by any text editor. Variable length records. Terminated by \n (new line == 0x13 character).
File Properties recorder	**Dataset Conditions:** string record (*) without Header and Footer
Organisation:	No further structures are present
Data Format	Decimal separator: point (.)

Note: Conditions are replicated in the file names. *Never change the names of the .bin files.*

10 Instructions for Cleaning

The equipment may be cleaned with isopropyl alcohol or deionized water and air dried. Clean the exterior of the product only.
Do not apply cleaner directly to the items or allow liquids to enter or spill on the product.

10.1 Cleaning the Touchscreen

To clean the touchscreen (if present), wipe the screen with a towelette designed for cleaning monitors or with a clean cloth moistened with water.
Do not use sprays or aerosols directly on the screen; the liquid may seep into the housing and damage a component. Never use solvents or flammable liquids on the screen.

10.2 Cleaning the air vents

It is recommended to occasionally clean the air vents (if present) on all vented sides of the board. Lint, dust, and other foreign matter can block the vents and limit the airflow. Be sure to unplug the board before cleaning the air vents and follow the general cleaning safety precautions.

10.3 General cleaning safety precautions

CAEN recommends cleaning the device using the following precautions:

1) Never use solvents or flammable solutions to clean the board.
2) Never immerse any parts in water or cleaning solutions; apply any liquids to a clean cloth and then use the cloth on the component.
3) Always unplug the board when cleaning with liquids or damp cloths.
4) Always unplug the board before cleaning the air vents.
5) Wear safety glasses equipped with side shields when cleaning the board.

11 Device decommissioning

After its intended service, it is recommended to perform the following actions:

- Detach all the signal/input/output cable
- Wrap the device in its protective packaging
- Insert the device in its packaging (if present)

THE DEVICE SHALL BE STORED ONLY AT THE ENVIRONMENT CONDITIONS SPECIFIED IN THE MANUAL, OTHERWISE PERFORMANCES AND SAFETY WILL NOT BE GUARANTEED

12 Disposal

The disposal of the equipment must be managed in accordance with Directive 2012/19 / EU on waste electrical and electronic equipment (WEEE).

The crossed bin symbol indicates that the device shall not be disposed with regular residual waste.

13 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
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SAFETY, STORAGE AND SETUP INFORMATION
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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/wp-content/uploads/2022/11/Safety_information_Product_support_W.pdf

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