Rev. 4 - July 12th, 2024

i-Spector family Quick Start

Intelligent Silicon Photomultiplier Tube

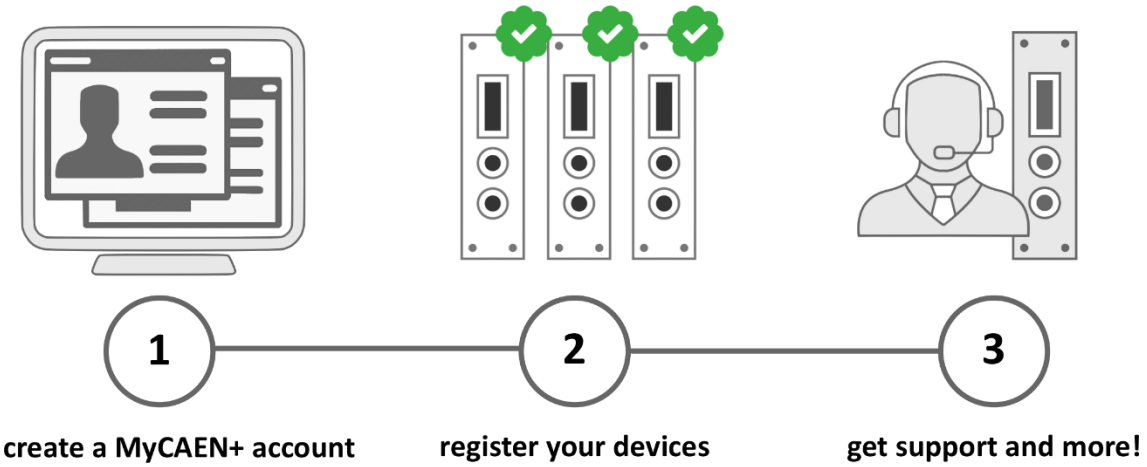
CAEN
Tools for Discovery

Quick Start
GD6745

Register your device

Register your device to your **MyCAEN+** account and get access to our customer services, such as notification for new firmware or software upgrade, tracking service procedures or open a ticket for assistance. **MyCAEN+** accounts have a dedicated support service for their registered products. A set of basic information can be shared with the operator, speeding up the troubleshooting process and improving the efficiency of the support interactions.

MyCAEN+ dashboard is designed to offer you a direct access to all our after sales services. Registration is totally free, to create an account go to https://www.caen.it/become-mycaenplus-user and fill the registration form with your data.



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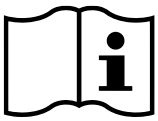
Purpose of this Guide



This Guide contains a brief description of the i-Spector family modules and a quick start guide about their operation.

Change Document Record

Date	Revision	Changes
March 27th, 2019	00	Initial release
July 4th, 2019	01	Revised **Advanced Settings and Configuration.** Information about LoRa network building migrated to UM7047.
November 15th, 2019	02	Revised **Getting Started**
July 12th, 2024	03	Revised ordering options and drawings
July 12th, 2024	04	Complete revision to include: • New CE regulations • Modified ordering options • Added instructions for S2590C model

Symbols, abbreviated terms and notation

ADC	Analog to Digital Converter
FPGA	Field Programmable Gate Array
OS	Operating system
ROI	Region of Interest
IoT	Internet of Things

Reference Document

[RD1] UM7047 – i-Spector Digital Software Development Kit

All CAEN documents can be downloaded at:

https://www.caen.it/support-services/documentation-area/ (**login required**)

Manufacturer Contacts

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

Limitation of Responsibility

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

Disclaimer

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

Made in Italy

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

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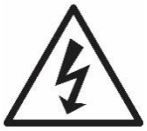
Safety Notices

N.B. Read carefully the "SAFETY, STORAGE AND SETUP INFORMATION, PRODUCT SUPPORT SERVICE AND REPAIR" document provided with the product before starting any operation.

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

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

See Chap. 17 for the Technical Support contacts.

1 Introduction

The i-Spector modules are a family of products designed to operate as full-featured radiation detection systems **for Gamma Spectroscopy and/or Neutron-Gamma Discrimination.** Its profile makes this unit ideal for many portable applications where size, weight and power consumption are important constraints. Depending on the chosen model, the i-Spector is suitable for a wide range of applications:

- PMT replacement in physics experiment
- Laboratory R&D on SiPM technology
- Portable Gamma-Spectroscopy
- Industrial process monitoring
- Environmental Monitoring
- Handheld borders control against illicit traffic of radioactive material
- Neutron detection experiments
- Vehicle/personnel chek-point portals.

The i-Spector units are **all-in-one detector and electronics** instruments based on a **SiPM** area (24×24 mm^2 or 30×30 mm^2), possibly coupled to a scintillation crystal suitable for the chosen application. The i-Spector integrates in a compact **tube-like mechanics** the detection stage, frontend electronics, an integrated power supply for SiPM biasing and, eventually, a digital chain to process onboard the incoming data. The i-Spector can be controlled via Ethernet. A **web-based GUI** allows the user to set the acquisition parameters, see results on plot and perform basic data analysis.

Multiple i-Spector tubes can be connected and controlled from a single PC. The API interface allows to control multiple devices using very simple HTTP requests and JSON vectors.

i-Spector is available as **OEM electronics** to encourage integration in more complex detection systems or in **ASSEMBLY** version, with a suitable scintillation crystal coupled to the SiPM area. The standard assembly is available with CsI for Gamma Spectroscopy and EJ-276 for Gamma-Neutron Discrimination. Other crystals can be mounted on request. The ASSEMBLY unit is enclosed in a light-tight aluminum/plastic tube (Ø 60 mm, h 135 mm), with possibility to unmount the crystal holder and easily change it.

CAEN offers a selection of five models to meet at best the user's needs:

- **i-Spector (S2560)** is the analog base model, designed to replace PMT + preamplifier chain
- **i-Spector PLUS (S2560T)** integrates an additional **Timing Unit**, to perform event timestamping, ToF measurements, coincidence between multiple i-Spector modules and photon counting – COMING SOON
- **i-Spector Digital (S2570)** is a fully-integrated **Gamma Spectrometer**. It embeds a full-featured **MCA** based on 80 MSps, 12-bit ADC and digital charge integration algorithm. It provides as output the acquired energy spectrum, calculated onboard.
- **i-Spector PSD (S2590)** is a compact **neutron detector**, based on a fast plastic scintillation crystal. It hosts a 250 MSps, 12-bit ADC and a microcontroller to perform **real-time pulse shape analysis** for Gamma/Neutron discrimination.

All i-Spector models can be controlled via **Ethernet** through a user-friendly **Web Interface** . The web-based GUI allows to configure and monitor the device, with the possibility to access the spectrum and process it online and view the results of pulse shape analysis. A Software Development Kit is also available, to allow the user to fully **automatize and control the system**. The SDK is based on JSON data exchanged using standard HTTP POST, supported by every modern programming language and operating system (Win/MacOs/Linux/Android/iOS).

Available models are listed below:

Unit	Description	Product Code
S2560E	i-Spector 1" (24x24 mm^2) -OEM	WS2560EXOAAA
S2560F	i-Spector 30x30 mm^2 -OEM	WS2560FXOAAA
S2560E	i-Spector 1" (24x24 mm^2) - CsI ASSEMBLY	WS2560EXAAAA
S2560F	i-Spector 30x30 mm^2 - CsI ASSEMBLY	WS2560FXAAAA
S2560TE	i-Spector PLUS 1" (24x24 mm^2) – OEM (COMING SOON)	WS2560TEXOAA
S2560TF	i-Spector PLUS 30x30 mm^2 – OEM (COMING SOON)	WS2560TFXOAA
S2560TE	i-Spector PLUS 1" (24x24 mm^2) – CsI ASSEMBLY (COMING SOON)	WS2560TEXAAA
S2560TF	i-Spector PLUS 30x30 mm^2 – CsI ASSEMBLY (COMING SOON)	WS2560TFXAAA
S2570E	i-Spector Digital 1" (24x24 mm^2) -OEM	WS2570EXOAAA
S2570F	i-Spector Digital 30x30 mm^2 -OEM	WS2570FXOAAA
S2570E	i-Spector Digital 1" (24x24 mm^2) - CsI ASSEMBLY	WS2570EXAAAA
S2570F	i-Spector Digital 30x30 mm^2 - CsI ASSEMBLY	WS2570FXAAAA
S2590C	i-Spector PSD 24x24 mm^2 – ASSEMBLY	WS2590CXAAAA
S25X0	Assembly kit and service for i-Spector OEM – new version	WS25X0ASSBXA

Table 1.1: table of available models and accessories.

2 Technical Specifications

DETECTOR	SiPM area made of Hamamatsu S14160-60520HS 24x24 or 30x30 mm^2	**ASSEMBLY only** SiPM coupled to CsI crystal 24x24x30 mm or 30x30x30 mm
HIGH VOLTAGE	Tailored for SiPM biasing **Range**: 20-80 V (10 mA) **Accuracy** : 1 mV **Thermal Feedback Accuracy**: 0.01 °C – 1mV	
FRONTEND STAGE	**S2560/S2570** **Preamp Gain** : x 5 **Bandwidth** : > 1GHz **Shaping time**: 180 ns	**S2590**
ANALOG OUTPUT	-4 …. +4 V , 170 mA on the OUT LEMO connector	
TIMING RESOLUTION	7 full event/ch @ 1024 S/event Multi-event Buffer Independent read and write access; programmable event size and post-trigger	
TIMING RESOLUTION	50 ps @ rate <20 kpcs 5 ns @high rates	
NOISE LEVEL	0.75 mV RMS	
MCA	12-bit @ 80 MS/s ADC Nr. of channels: 4096 Resolution @ 100 kpcs : < 0.2% Processing Algorithm : Digital Charge Integration	**Performances** **with CsI(Tl) crystal (24x24x30 mm^3)** Energy range : 30 keV to 30 MeV Energy resolution @ 662 keV : < 6% Non-linearity: < 0.1%
PSD	12-bit @ 250 MS/s ADC Processing Algorithm: Pulse Shape Discrimination	**Performances** **with EJ-276 crystal (24x24x30 mm^3)** FoM ~ 2.50 in 1÷1.5 MeV range FoM > 1.27 in 200-300 keV range.
COMMUNICATION INTERFACE	10/100 Mbps TCP/IP Eth	
SOFTWARE	• Graphical web interface • SDK based on JSON data and standard HTTP post	
MECHANICAL	**Form Factor** Portable Ø 60 mm, h 90 mm, 150 g (OEM) Ø 60 mm, h 135 mm, >500 g (ASSEMBLY)	
ENVIRONMENTAL	**Environment:** Indoor use **Operating Temperature:** 0◦C to +40◦C **Storage Temperature:** –10◦C to +60◦C **Operating Humidity:** 10% to 90% RH non condensing **Storage Humidity:** 5% to 90% RH non condensing **Altitude:** < 2000m **Pollution Degree:** 2 **Overvoltage Category:** II **EMC Environment:** Commercial and light industrial **IP Degree:** IPX0 Enclosure, not for wet location	
REGULATORY COMPLIANCE	**EMC** CE 2014/30/EU Electromagnetic Compatibility Directive	**Safety** CE 2014/35/EU Low Voltage Directive
POWER REQUIREMENTS	@ +12V 250 mA (max.)	

Tab. 2.1: Specifications table

3 Packaging and compliancy

The i-Spector is a portable tube-like unit, supplied as OEM electronics or ASSEMBLY detector with scintillation crystal coupled to the SiPM area:

- S2560/S2560T/S2570/S2570L models are available as OEM or ASSEMBLY with CsI scintillation crystal.
- S2590 is available only in ASSEMBLY with EJ-276 scintillation crystal.

The unit is inspected by CAEN before the shipment, and it is guaranteed to leave the factory free of mechanical or electrical defects.

The content of the delivered package standardly consists of the part list shown in the table below (**Table 3.1**). All the official documentation, firmware updates, software tools, and accessories are available on *www.caen.it* at the product web page.

	Part	Description	Qty
	i-Spector (S2570E in this picture)	Intelligent Silicon Photomultiplier Tube	x1
	AC/DC Power Supply	12V-45W	X1
	Power supply cable	Standard C13 power supply chord	X1
	Power connector adapter	Adapter cable for + 12V input connector	X1
	Ethernet cable	ETHERNET CAT6 cable L=2MT	X1

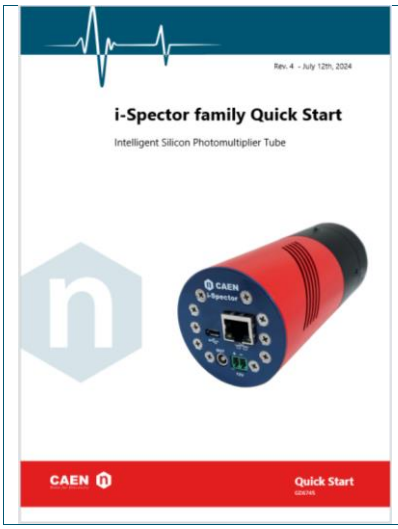
	User guide	GD6745 – i-Spector family Quick Start Guide	x1

Table 3.1: delivered kit.

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. 4.1 .(CAEN cannot accept responsibility for missing items unless any discrepancy is promptly notified.)
- 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 (see Chap. 17)..
- If equipment must be returned, carefully repack equipment in the original shipping container with original packing materials, if possible. Please contact CAEN service.
- If equipment is not installed when unpacked, 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

For a correct and safe use of the module, refer to Chap. 6 and 7.

4 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 product and it is even stored in an on-board non-volatile memory readable via Web Interface (see Chap. 9).

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

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

5 Power Requirements

The i-Spector is powered by a 12V AC/DC stabilized power supply.

The power supply and its chord are included in the delivered kit.

6 Cooling Management

The i-Spector board can operate in the temperature range -20 + 50 °C.

Air flow grids are available on ASSEMBLY models.

EXTERNAL FANS MUST BE USED WHEN THE BOARD IS INSTALLED IN A SETUP WITH POOR AIR FLOW

The user must take in care to provide a proper cooling to the board with external fan if the board is used in an enclosure or if the board is installed in a setup with poor air flow.
Excessive temperature will, in first instance, reduce the performance and the quality of the measurements and can also damage the board.

Please do not close the air flow grids to avoid unit overheating.

If the board is stored in cold environmental, please check for water condensation before power on.

The board has not been tested for radiation hardness. High energy particle can be source of soft error and can damage the FPGA. If used in strong proton or neutron beams, arrange proper shielding or remote the sensor with a custom cable.

7 Installing the device

The device is a standalone unit, that does not require any specific installation.

ONLY QUALIFIED PERSONNEL SHOULD PERFORM INSTALLATION, OPERATIONS

DO NOT INSTALL THE EQUIPMENT SO THAT IT IS DIFFICULT TO OPERATE THE DISCONNECTING DEVICE ON THE BACK PANEL

IT IS RECOMMENDED THAT THE SWITCH OR CIRCUIT-BREAKER IS NEAR THE EQUIPMENT

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

Do not use the device and contact technical support if one of these situations is verified:

- Enclosure integrity is compromised
- Insulation of HV chord is damaged (if present)
- The indication led or display is not performing as required (e.g. led not working, display with incorrect graphic)
- Fans are not working (if present)

8 Hardware Description

In this Chapter we summarize the main hardware features of the i-Spector and the possible fields of application. Here below, we report a table to highlight the differences among the models of the i-Spector family.

	i-Spector S2560	i-Spector PLUS S2560T	i-Spector Digital S2570	i-Spector PSD S2590
Main Application	PMT replacement	Timing measurements	Gamma Spectroscopy	Neutron detection
Availability	OEM, ASSEMBLY			ASSEMBLY
Size	OEM: Ø 60 mm, h 90 mm ASSEMBLY: Ø 60 mm, h 135 mm			
SiPM Area	24x24 or 30x30 mm^2			24x24 mm^2
Scintillation Crystal	CsI, others on request			EJ-276
Scintillation Crystal size	Up to nearly 1.5”			Up to nearly 1”
High Voltage	20-80 V			
Preamplifier	x5, 1GHz BW preamplifier			t.b.d.
Shaping Time	180 ns			t.b.d.
Analog Output	✓	✓	✓	✓
Digital I/Os		✓		
Timing Resolution	-	t.b.d.	-	-
ADC	-	-	12-bit, 80 MS/s	12-bit, 250 MS/s
MCA			✓	✓
PSD				✓
Connectivity	10 Mbps TCP/IP Eth			
Software	Web GUI			

Table 8.1: summary of the hardware features of i-Spector family.

8.1 i-Spector (S2560) and i-Spector PLUS (S2560T)

The i-Spector is designed to replace a classical PMT + preamplifier chain. It is based on a SiPM area followed by front-end analog electronics, it is equipped with a High Voltage (20-80 V) Power Supply for SiPM biasing, a temperature sensor for HV feedback loop, and a microcontroller to implement a graphical web server and provide Ethernet communication interface. The output is a fast amplified analog signal, which can be processed with an external MCA/Digitizer.

The i-Spector PLUS **(COMING SOON)**, with respect to the standard i-Spector, implements an additional Timing Unit which hosts two programmable threshold discriminators, a TDC and a FPGA to perform signal correlation with external signals, event timestamping and coincidences between multiple units.

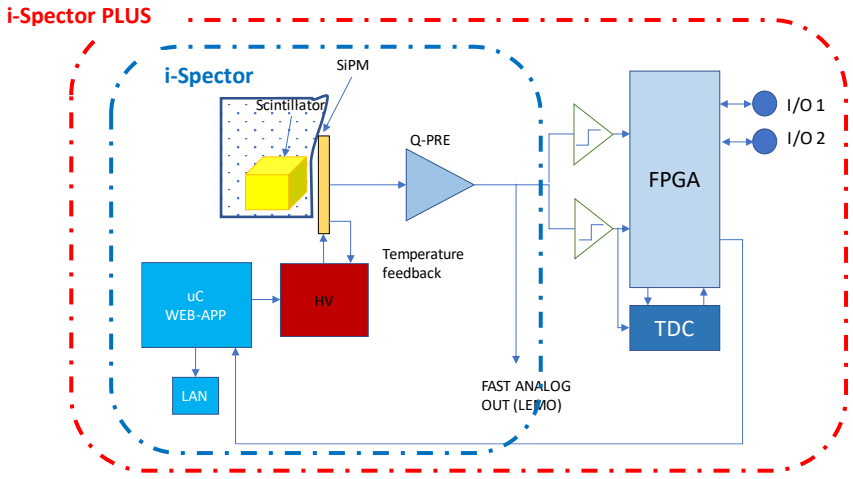
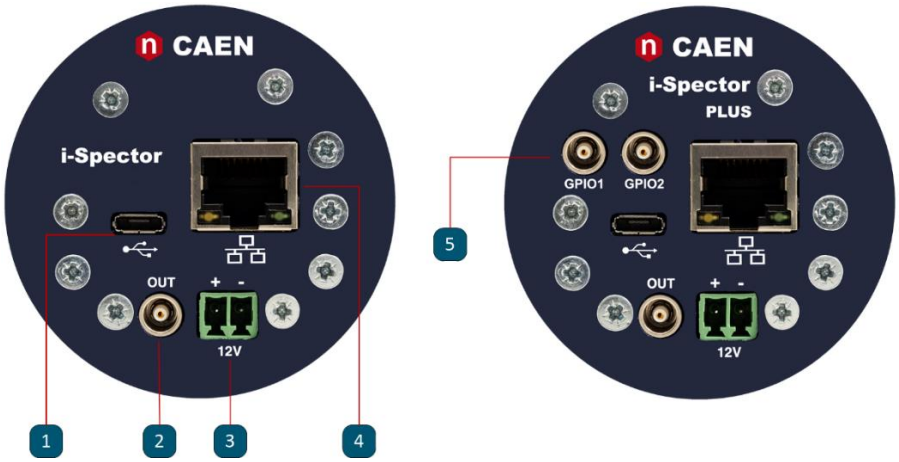


Figure 8.1: i-Spector and i-Spector PLUS block diagram. The scintillator is shown as example and is not included with OEM version.



Number	Description
1	Micro-USB Interface Connector (DEBUG ONLY)
2	Analog preamplifier output on LEMO connector
3	Power Supply Connector (12 V typ.)
4	Ethernet Communication Interface
5	GPIO1/GPIO2 LEMO connector for Timing Unit signals

Figure 8.2: Panel view and description of the i-Spector and i-Spector PLUS models.

8.2 i-Spector Digital (S2570)

The i-Spector Digital is designed to operate as a compact Gamma Spectrometer, replacing the classical chain of detector, preamplifier and MCA. It is based on a SiPM area followed by a front-end analog electronics, it is equipped with a High Voltage (20-80 V) Power Supply for SiPM biasing , a temperature sensor for HV feedback loop, a charge preamplifier, a shaper, a digital **MCA based on Digital Charge Integration** and a microcontroller to implement a graphical web server. The output is a fast amplified analog signal an 4k bins spectrum calculated onboard.

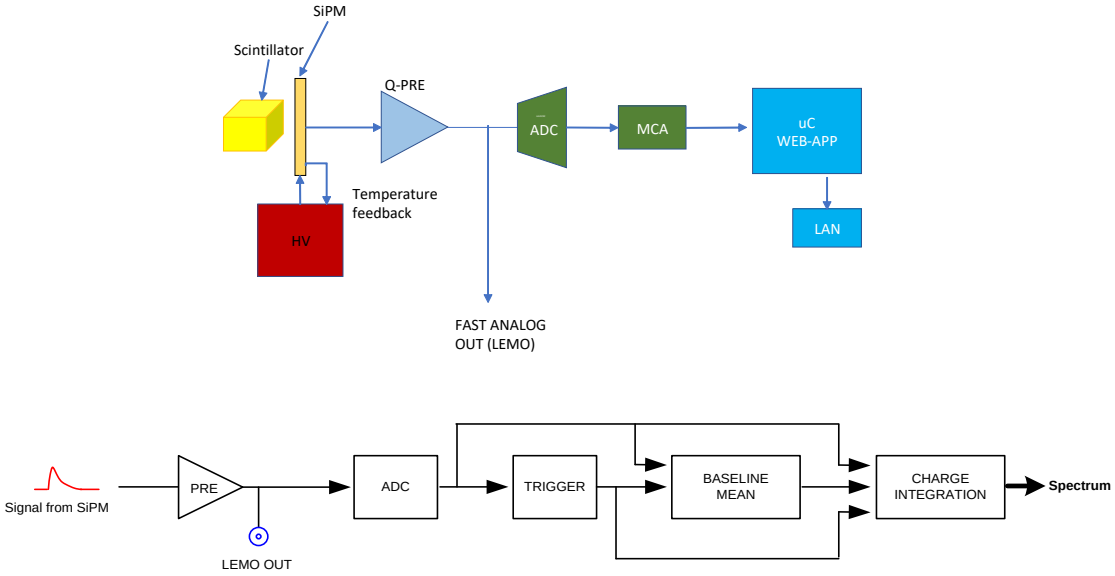
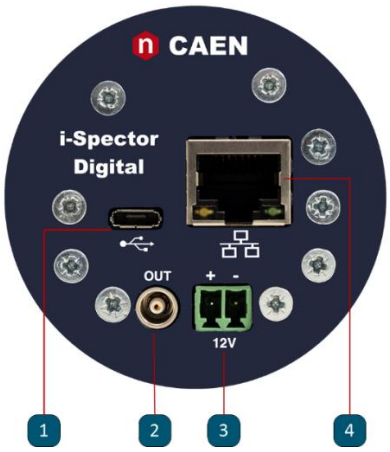


Figure 8.3: i-Spector Digital block diagram. The scintillator is shown as example and is not included with OEM version. In the bottom part the complete MCA chain is shown.

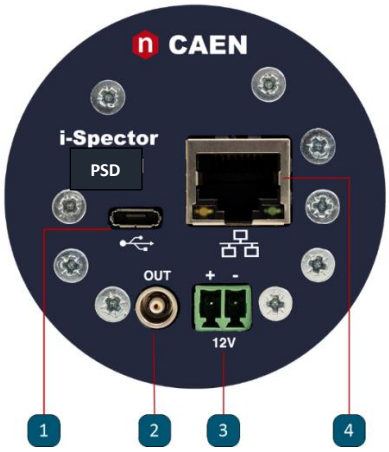


Number	Description
1	Micro-USB Interface Connector (DEBUG ONLY)
2	Analog preamplifier output on LEMO connector
3	Power Supply Connector (12 V typ.)
4	Ethernet Communication Interface

Figure 8.4: Panel view and description of the i-Spector Digital models.

8.3 i-Spector PSD (S2590)

The i-Spector PSD is a portable **neutron detector system**. The unit is full-featured with a Front-End stage designed to sum up analog signals from SiPM and preserve scintillation time response , integrated HV for SiPM biasing, a 250 MSps 12-bit ADC and a microcontroller to perform **real-time pulse shape analysis**. It can be controlled through Ethernet and it provides as output an analog amplified signal, a 4k channels energy spectrum and a PSD scatterplot calculated onboard.



Number	Description
1	Micro-USB Interface Connector (DEBUG ONLY)
2	Analog preamplifier output on LEMO connector
3	Power Supply Connector (12 V typ.)
4	Ethernet Communication Interface

Figure 8.5: Panel view and description of the i-Spector PSD model.

8.4 i-Spector ASSEMBLY

All i-Spector models are available in assembly version, with SiPM area coupled to a suitable scintillation crystal. In particular, standard assembly are available as reported in the following:

- S2560/S2560T/S2570 - **CsI** scintillation crystal for Gamma particles detection, available in **24x24x30** mm^3 (approx. 1x1x1.2 $inch^3$), **30x30x30** mm^3 (approx. 1.2x1.2x1.5 $inch^3$).
- S2590 – **EJ-276** scintillation crystal for Gamma-Neutron discrimination, available in **24x24x30** mm^3

Note: under certain circumstances, EJ-276 plastic scintillators can show a degradation when exposed for long time to oxygen. This results in a slight colouration of the material, leading to a decrease of the light output of approx. 25 % in 51 – 76 mm size samples. *The excellent pulse shape discrimination properties however are unchanged*. It is advised that storage for a long time is done under nitrogen or an inert gas atmosphere. Aluminium-encapsulated samples are filled by the producer with Argon, prior to hermetic sealing.

i-Spector ASSEMBLY is provided enclosed in a light-tight aluminium/plastic tube, with aeration grids for electronics passive cooling, as shown in **Figure 8.6.** Depending on the model , the front panel is identical to what is stated in the precious paragraphs.

The scintillation crystal is housed in the black DELRIN (hard plastic) holder, which is screwed up to the red aluminium tube hosting the electronics. The holder is divided in two sections and it can be easily open thanks to four set screws which fasten together the two plastic parts. In this way, the crystal inside can be easily removed, inspected and replaced as well as other compatible crystals can be coupled to the SiPM area.

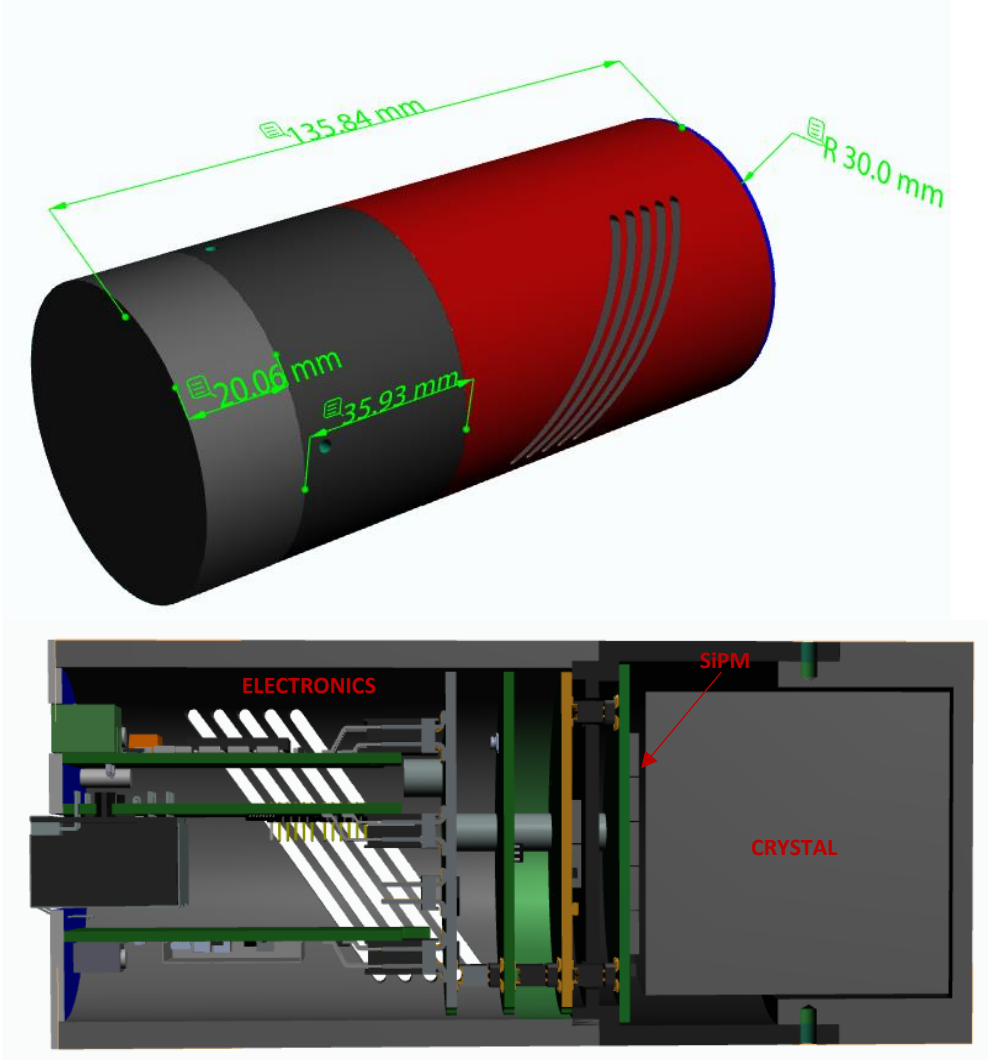


Figure 8.6: general view (top) and cross-section view (bottom) of the i-Spector in ASSEMBLY version. The dimensions of the external housing (here in mm) are identical for all models. In the bottom view, is shown the maximum possible dimensions for a scintillation crystal (ø 1.5" x 1.5" h) housed in the standard holder.

9 Getting Started

In this Chapter, we give a step-by-step procedure to guide the user in quickly setting up the i-Spector and performing basic measurements with a radioactive source.

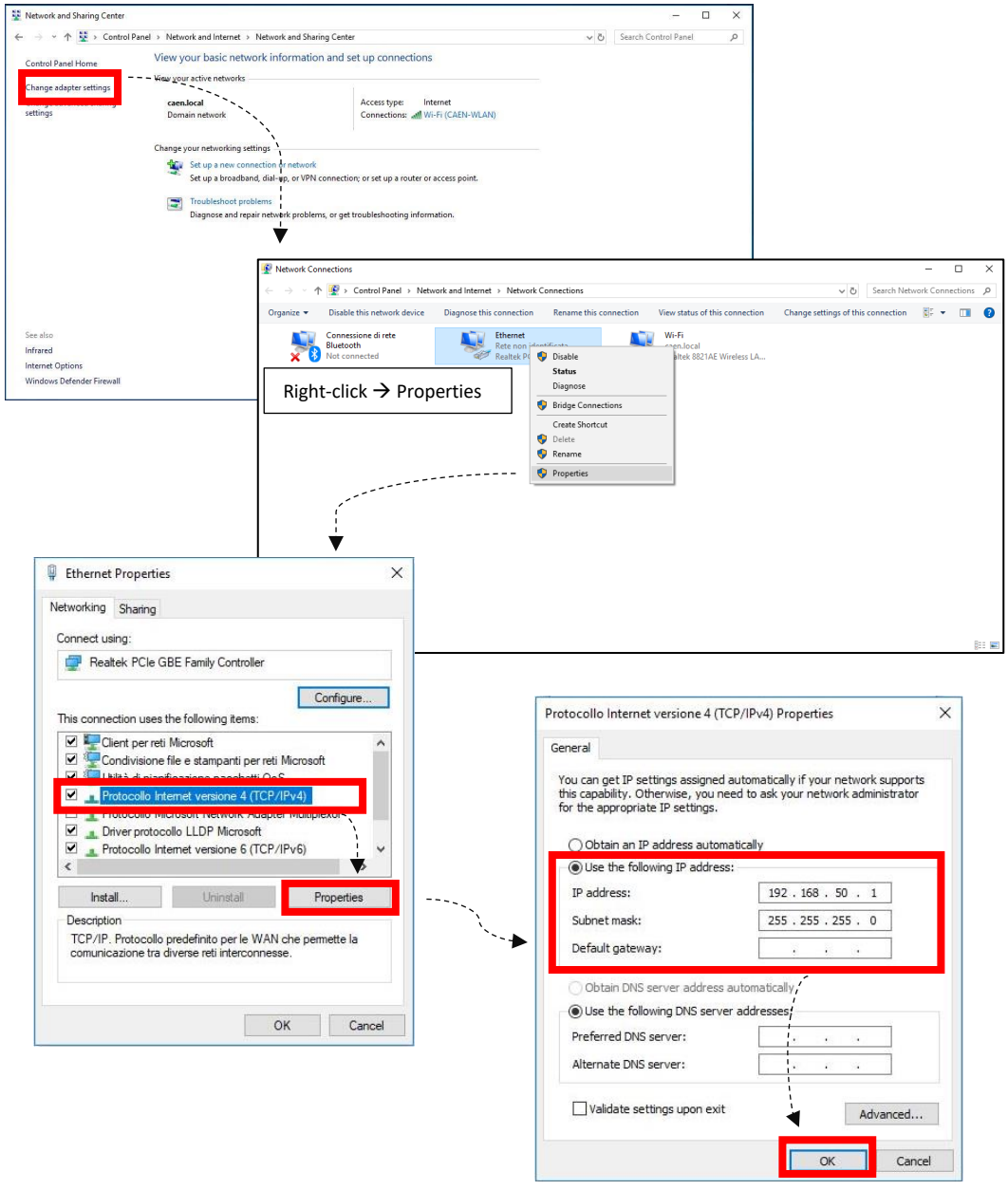
The measurements shown in this chapter are based on i-Spector Digital (S2570D) in ASSEMBLY version with CsI crystal. The unit is connected via Ethernet to a PC with Windows 10 OS. This procedure can be easily extended to other operating systems and i-Spector models, when the described features are supported.

9.1 Ethernet Connection to the PC

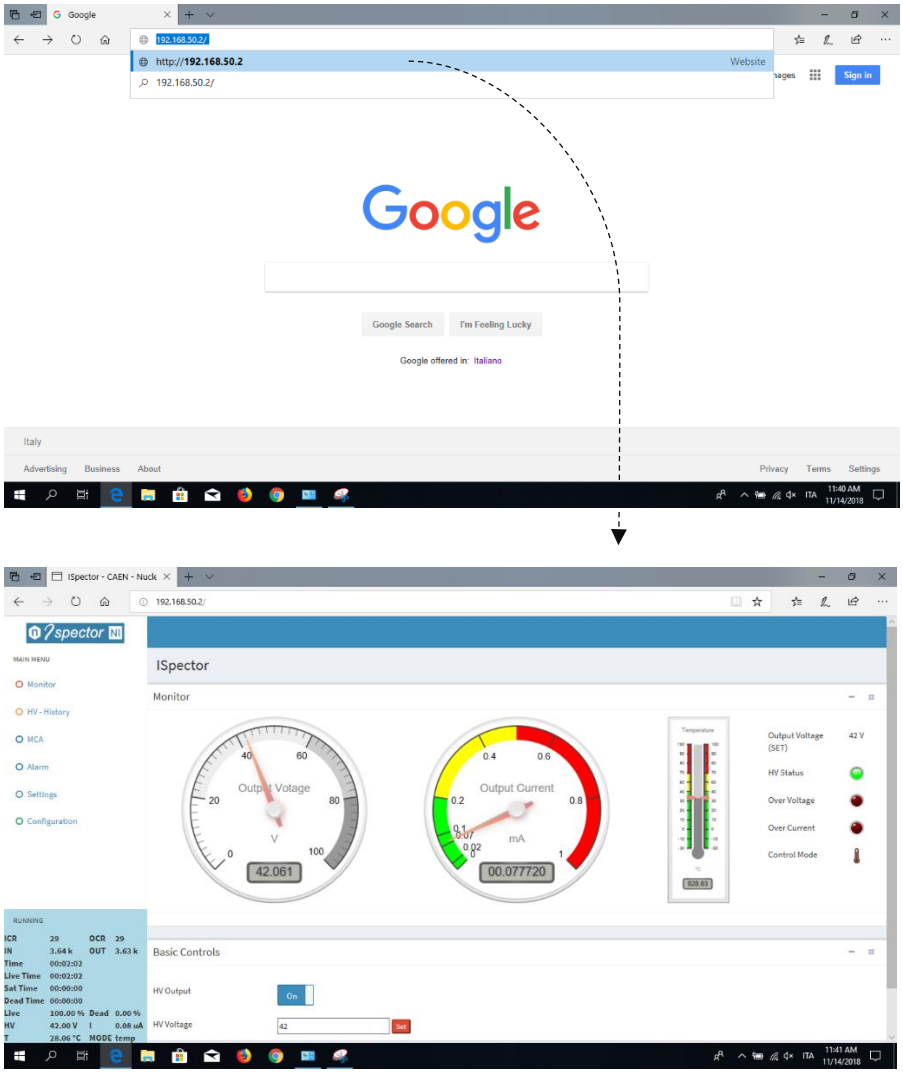
Note: the **default IP address** of the i-Spector for Ethernet connection is **192.168.50.2**

1. Power ON the i-Spector feeding + 12 V at the green supply voltage connector
2. Connect the Ethernet cable from i-Spector to the PC.
3. Configure the Ethernet network of your PC from the “Network and Sharing Center”, as shown below.

1



4. Wait around 30 s, then open a web page (Microsoft Edge browser is suggested) and enter the web address **192.168.50.2**. The homepage of the graphical web interface will open.



5. Now you are ready to use your i-Spector!

9.2 Setting the High Voltage

After opening the Web Interface, the *Monitor* Tab will appear, showing the measured High Voltage parameters (Output Voltage and Current) and the Temperature value used for the HV feedback loop. The temperature sensor is placed very near to the SiPM, so that this temperature can be considered as the real temperature of the sensor.

Note: the **maximum measured output current is 1 mA**

Note: the **Output Voltage and the relative temperature feedback loop are pre-set with the optimal values for the SiPMs** installed on the i-Spector. When powering the i-Spector, the High Voltage goes automatically ON, so that it is possible to see the analog output signal even without using the Web Interface.

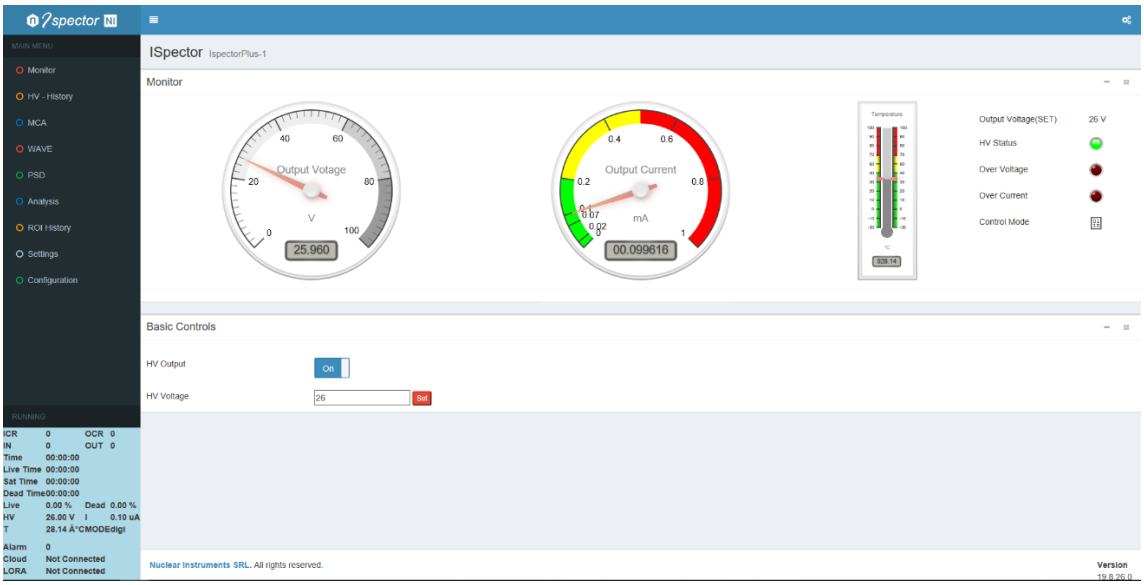


Figure 9.1: the *Monitor* tab of the i-Spector Web Interface

Other basic monitor parameters are shown on the right top part of the window, like the Voltage set point, the HV status, the occurrence of Over Voltage/Over Current conditions and the feedback Control Mode (temperature or digital).

The Output Voltage can be changed manually using the "**Basic Controls**" to set the voltage set point and switch on the High Voltage module.

WARNING: if changing the Output Voltage set point, please pay attention not to damage the SiPMs. Read carefully the SiPMs datasheet for maximum allowed voltage and check the advanced HV Control parameters in the *Settings* tab.

More advanced settings can be done using the "HV Control" menu in the *Settings* tab (see **Figure 9.2**). Here you can set the following parameters:

- HV output switch ON/OFF
- HV output voltage
- Enable/Disable the temperature or digital feedback loop
- Compliance Voltage (protection on the max. output voltage)
- Over Current Protection (mA)
- Thermal Protection (°C) (value = 0 means the protection is disabled)
- Ramp speed (V/s) when switching ON/OFF the HV
- SiPM Temperature Coefficient for the bias feedback loop (default = -34 mV/°C @25°C)
- Status of the HV on start-up
- Enable/Disable saving of a given parameters set on flash, to make it loaded by default

The parameters are set after pressing the *Apply* button.

Note: all the parameters for the "HV Control" menu, **are pre-set with the optimal values for the SiPMs** installed on the i-Spector. It is possible to change these settings and define them as default by storing the values on flash.

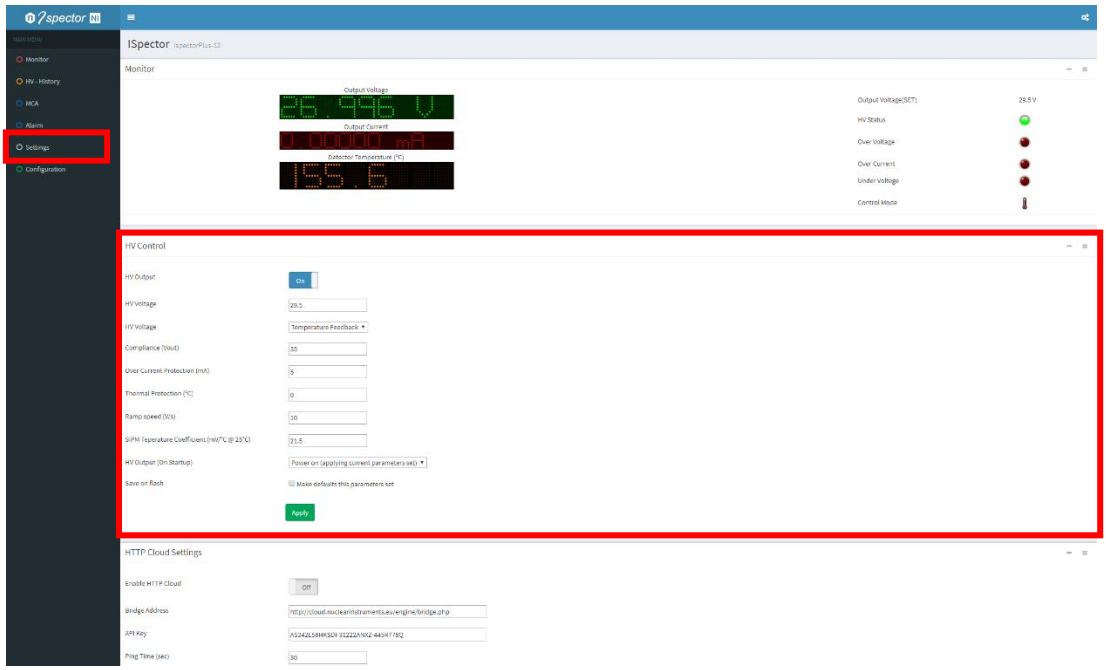


Figure 9.2: the HV Control menu in the *Settings* tab of the i-Spector Web Interface

9.3 SiPM signal at the oscilloscope

Using all versions of i-Spector, it is possible to monitor the fast output signal of the preamplifier using the OUT LEMO connector on the front panel of the unit. This can be useful to check the correct operation of the instrument and to process the analog signal with an external electronics system.

Note: using factory settings stored on the instrument, it is not needed to connect the i-Spector to the PC in order to see the output analog signal, it is sufficient to switch the unit ON.

In order to visualize the analog signal on oscilloscope, follow the steps below:

1. Place a radioactive source in front of the i-Spector
2. Switch ON the i-Spector. By default, the High Voltage will also be switched ON with the pre-set set point
3. Connect the LEMO OUT to an oscilloscope and check the signal. You should see the typical energy and time distribution of exponential pulses given by a radioactive source (see **Figure 9.3**)

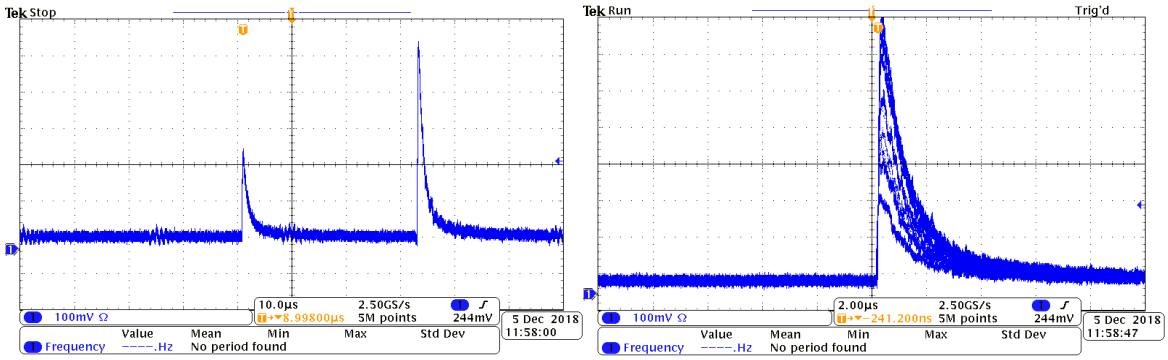


Figure 9.3: the OUT signal of a i-Spector Digital coupled with a CsI(Tl) crystal and exposed to a ^{60}Co source. The typical time and energy distribution of pulses given by a radioactive source is clearly visible at the oscilloscope. The decay time of the signal is compliant with the crystal specifications.

9.4 How to see waveforms and digital traces

The *Wave* tab can be used as an embedded oscilloscope to check waveforms and digital traces like trigger, integration gate, pile-up inhibit, etc. Moreover, in this tab it is possible to modify the acquisition parameters according to the given input exponential signals. The *Configuration* menu includes the following:

- *Trigger Threshold* (LSB): threshold for the derivative trigger
- *Post Trigger Inhibit* (ns): set the time after a trigger for which any other trigger is inhibited
- *Pre Integration* (ns): set how much time before the trigger the charge integration is started
- *Integration* (us): set the charge integration gate
- *Gain*: set the energy digital gain to be applied to the spectrum
- *Pileup Inhibition* (us): set the time after the integration gate for which the acquisition of any other event acquisition is inhibited
- *Pileup Penality* (us): set the trigger inhibition gate to be opened after a pile up
- *Baseline Inhibition* (us): set the time after the integration gate for which the baseline is not calculated
- *Baseline Length* (samples): set the number of samples used to calculate the baseline
- *Target Mode*: set the acquisition mode as Free Running or with a targe in Time (ms) or Counts
- *Target Value*: set the target value in time or counts, accordingly to the Target Mode

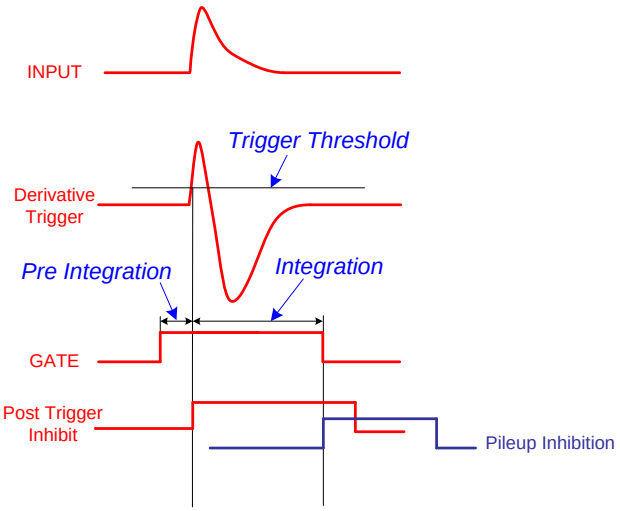


Figure 9.4: diagram summarizing the most important parameters of the charge integration algorithm

Note: when coupled to a crystal, the i-Spector comes with a pre-set optimal configuration. The pre-set parameters should allow to immediately see waveforms and digital traces, and, in principle, there is no need to change them.

1. Place the i-Spector in front of your radioactive source
2. Power On the module and connect to the Web Interface
3. Surf into the *Wave* tab
4. Choose the desired record length time in the top bar (from 12.8 µs to 52.4 ms)
5. You should see an exponential analog signal and the related digital traces (like Trigger, CRG INT, …) as shown in **Figure 9.5**

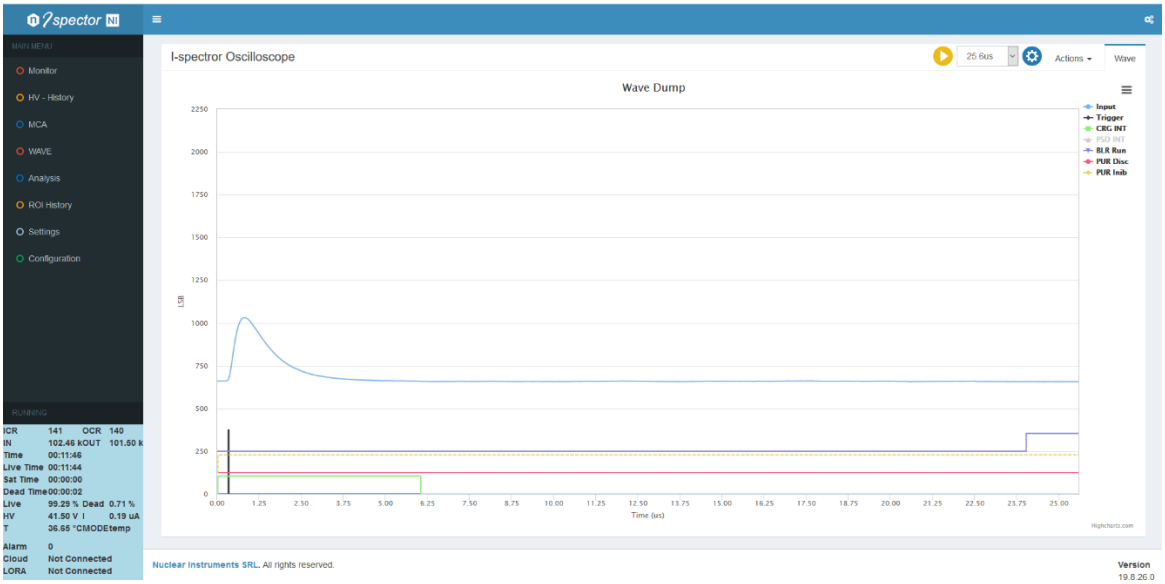


Figure 9.5: the *Wave* tab showing an exponential signal coming from environmental radioactivity. The trigger (black) and charge integration gate (green) are shown accordingly among the digital traces.

6. If needed press the gear icon to open the *Configuration* menu and modify the acquisition parameters. It is possible to change parameters using the sliders or the numeric table.

7. In order to dump waveforms on file, press the button. The number of saved waveforms is shown in the plot title, as shown below. When pressing the button, the waveform file can be saved in .csv format. The waveforms are saved in sequence on a single line.

9.5 How to acquire a spectrum (S2570/90)

The *MCA* tab is completely dedicated to the energy spectrum acquisition with i-Spector Digital or i-Spector PSD.

Note: when coupled to a crystal, the i-Spector comes with a pre-set optimal configuration. The pre-set parameters should allow to immediately see waveforms and digital traces, and, in principle, there is no need to change them.

1. Place a radioactive source in front of the i-Spector
2. Power On the module and connect to the Web Interface
3. Surf into the *MCA* tab
4. You should see a spectrum growing up, as shown in **Figure 9.6** for a ^{60}Co source.

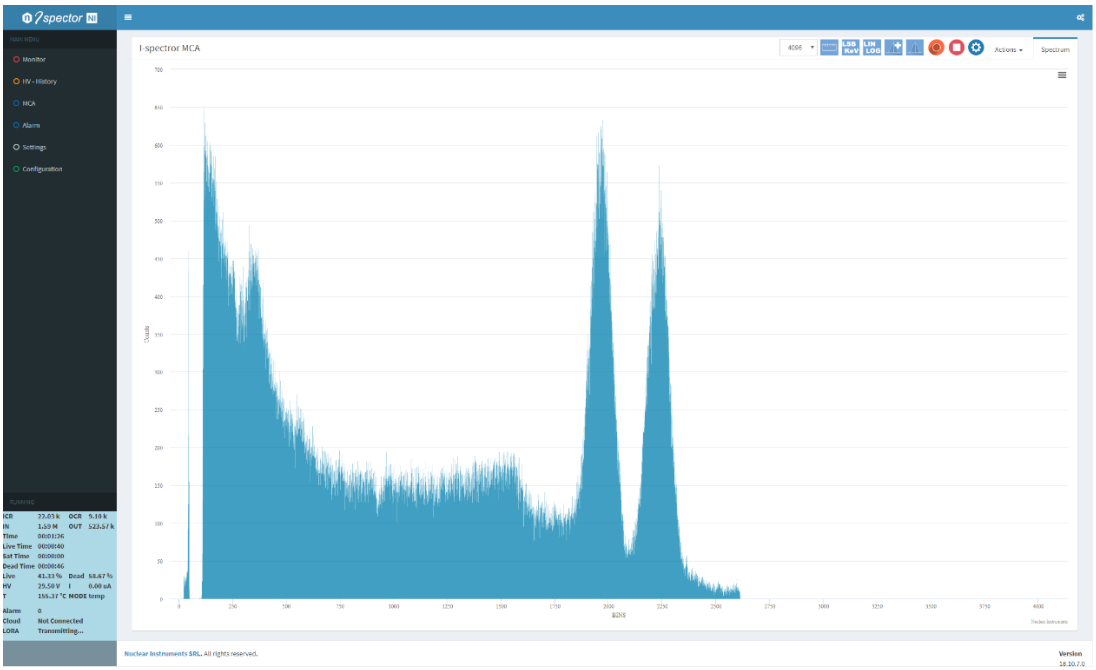
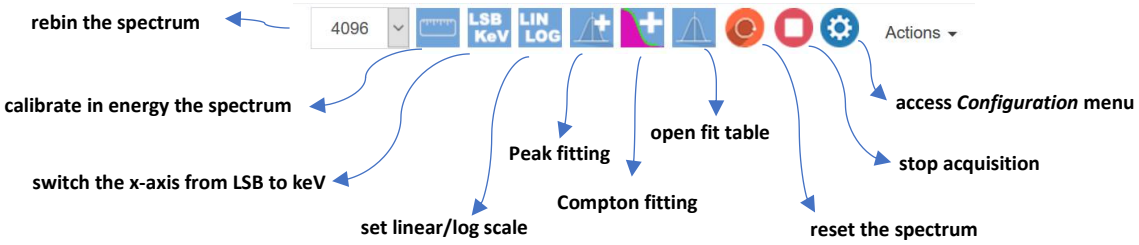


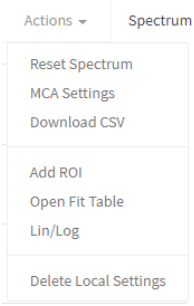
Figure 9.6: a ^{60}Co spectrum, shown in the Web Interface, acquired with a i-Spector Digital

The Web Interface allows to:

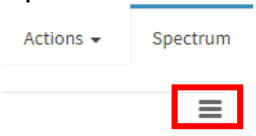


Moreover, it is possible to access two additional menus:

- **Actions** (self-explicative)



- **Export:** allows the user to export the spectrum as image or data



The ***Configuration*** menu can be accessed by clicking on the **gear icon** in the top bar (see **Figure 9.7**). Refer to the previous paragraph for a complete description of parameters meaning.

The parameters are set after pressing the *Apply* button. It is possible to reset the spectrum when pressing *Apply,* by enabling the relative option.

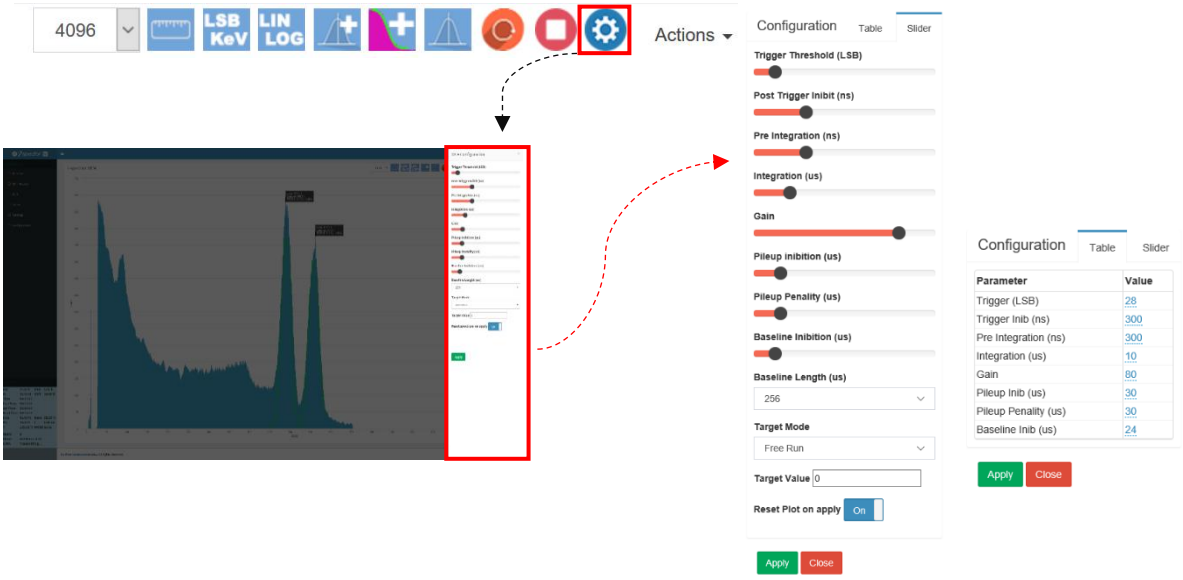


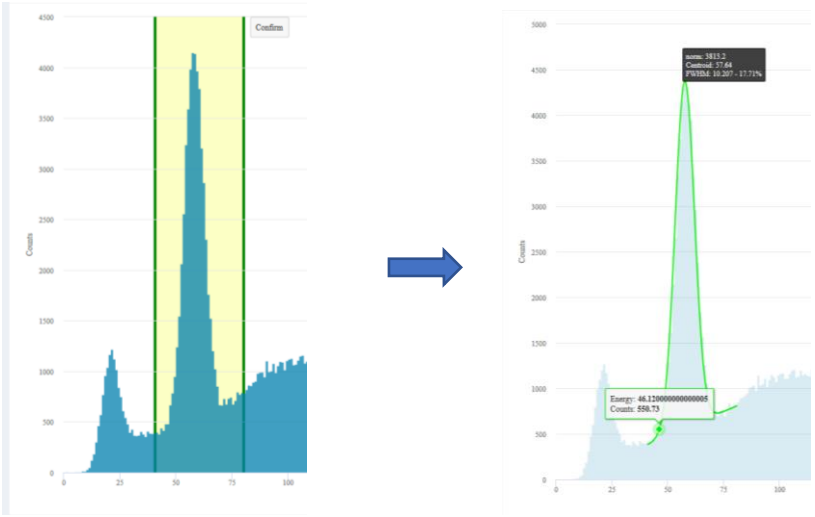
Figure 9.7: the MCA configuration menu (in *Slider* or *Table* mode), to adjust the MCA settings and the Charge Integration algorithm parameters.

9.6 How to set a ROI (S2570/90)

After you are satisfied with the MCA settings and the acquired spectrum, **you can create a ROI to fit, for example, a peak of interest with a Gaussian shape or a Compton edge with its special fitting tool**.

Here we show the procedure to fit a peak with a Gaussian shape. To do this, follow the procedure given below:

- Press  to add a ROI on the spectrum
- Use the mouse to **drag and resize** the ROI to suit the peak of interest
- Once you are satisfied, **click *Confirm*** button near the ROI. The fitting Gaussian curve and a label reporting the main fitting parameters (**normalization, centroid** and **FWHM)** will appear for each defined ROI, as shown below.



Note: the fitting procedure is automatically performed with an algorithm based on Gaussian fitting and the background subtraction selected from the Fit Table (see below) .

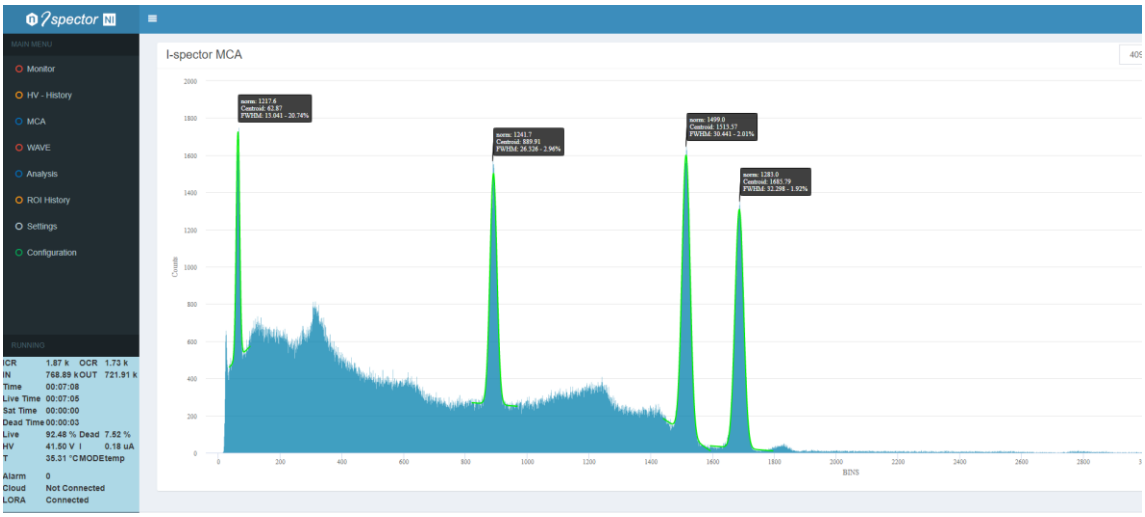


Figure 9.8: a ^{60}Co and ^{137}Cs spectrum with fitted peaks.

The complete **fit table**, reporting the fitting parameters for each ROI, is shown by clicking on *Actions* → *Open fit table.*

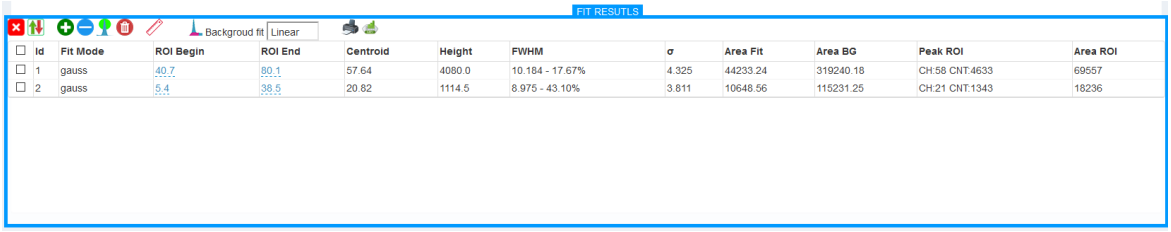


Figure 9.9: the fit table with two Gaussian peaks fitted with Linear background subtraction.

The fit table is reporting, in each line the paramters of a ROI, including the parameters of the fit.

From the fit table top bar, it is possible to:

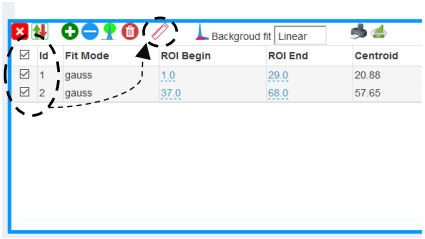
- Stack the fit table below the spectrum
- Add manually a ROI
- Delete a group of selected ROIs
- Perform peaks autodetection. This is alternative to the manual ROI selection and fitting. The found peaks are automatically fitted and included in the fit table.
- Delete all ROIs
- Perform energy calibration
- Show background fit on spectrum plot. The background is highlighted in magenta.
- Backgroud fit Linear Select background fit type: *constant*, *linear, quadratic, cubic, 4th order, 5th order*
- Print the current fit table
- Save the current fit table in .csv format

Note: the **ROIs and fit parameters are saved in the user web browser**. Even if the browser is closed, the data are saved in a special web browser storage and retrieved at the following connection to the instrument. It is possible to delete the local settings by clicking *Action* → *Delete Local Settings*

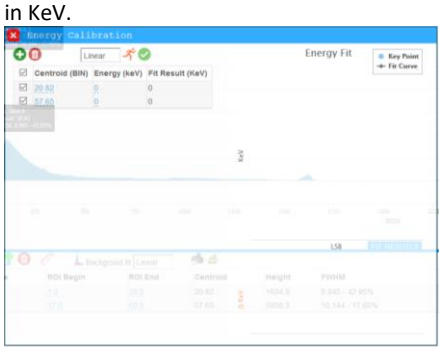
9.7 How to calibrate the spectrum in energy (S2570/90)

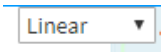
After one or more ROIs are set, it is possible to easily calibrate the spectrum x-axis in energy. To do this, follow the procedure below:

- Open the fit table and check the ROIs to base the calibration on. After checking, press 



- The calibration window will open, reporting the centroid of the selected ROIs. Enter the corresponding energy in KeV.



- Choose the fit mode (linear, quadratic , cubic, 4th order, 5th order) 

- Run the calibration procedure by pressing  . The fit results will be shown in a plot.

- Apply the calibration  . The window will be closed and a message of successful calibration is shown in the bottom part of the web browser

- It is now possible to visualize the x-axis of the spectrum in keV. It is possible to switch from keV to LSB and vice versa by pressing the icon 

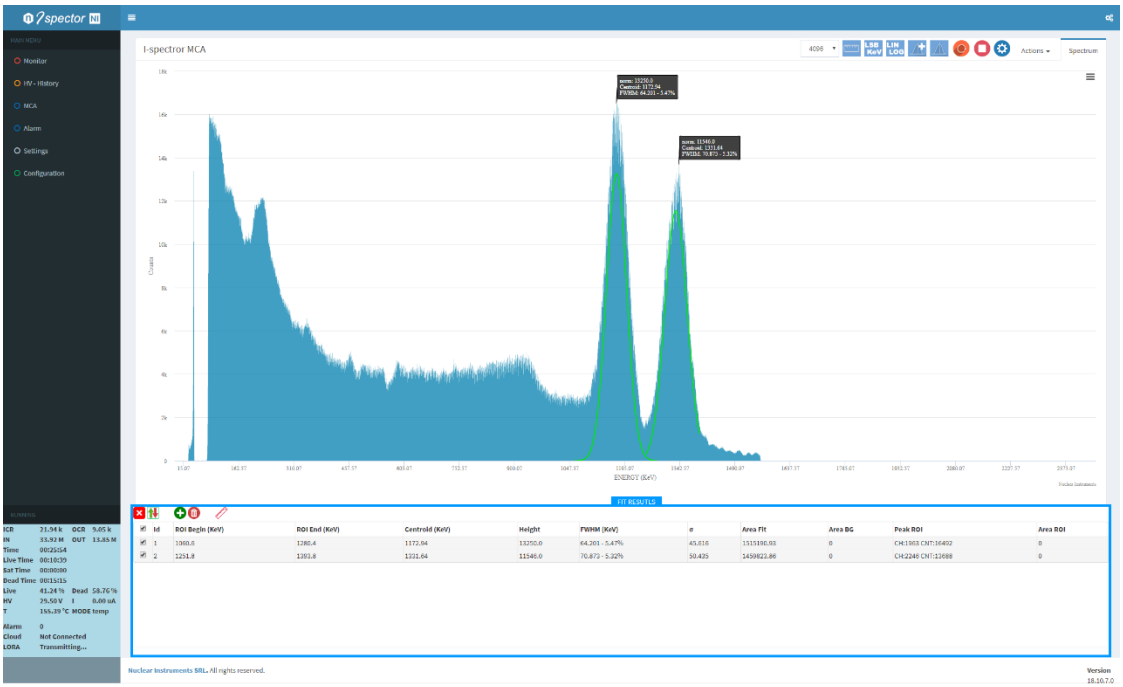


Figure 9.10: a ^{60}Co spectrum calibrated in energy. The parameters in the fitting labels and in the fit table are expressed in energy.

Note: the **energy calibration is saved in the user web browser**. Even if the browser is closed, the data are saved in a special web browser storage and retrieved at the following connection to the instrument. It is possible to delete the local settings by clicking *Actions* → *Delete Local Settings*

9.8 How to set an alarm (S2570)

It is possible to set alarms based on the ROIs defined by the user. The user can define a maximum threshold of counts in a certain ROI to activate an alarm and eventually perform some operations on the system. To do this follow the steps below:

- Surf into the *Analysis* tab and press to add an alarm. It is possible to add alarms related to the spectrum (X/Gamma Spectrum ROI) or to the PSD plot (Neutron/Gamma Discriminator ROI- COMING SOON)

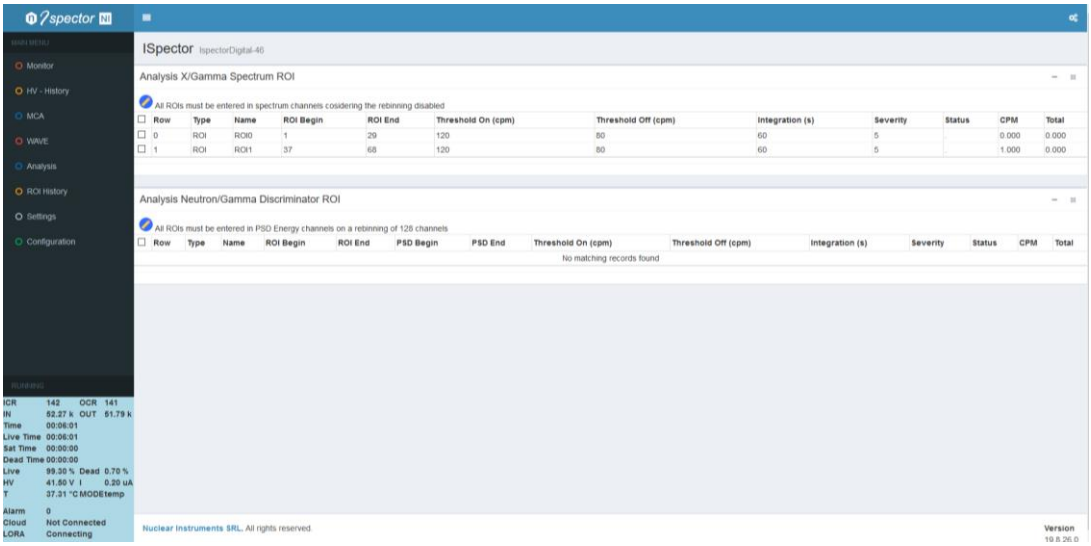


Figure 9.11: the Alarm tab of the i-Spector Web Interface.

- It is possible to add/delete ROIs manually or directly copy the parameters of the ROIs defined in the fit table

- It is possible to define the following parameters for the alarm:
  - **Name**
  - **ROI Begin** (basing on 4096 channels, regardless of the spectrum rebinning)
  - **ROI End** (basing on 4096 channels, regardless of the spectrum rebinning)
  - **Threshold On (cpm)** : defines the minimum count rate for which the alarm is activated
  - **Threshold Off (cpm)** : defines the minimum count rate for which the alarm stays active
  - **Integration (s)**: defines the time used for the count rate calculation. In critical situations, for example when radiation dose could change suddenly, it is suggested to set a low integration time (1-2 s suggested)
  - **Severity**: a flag (a number) sent to define the severity of a given alarm
  - **Alarm** boxes are used to set what to do in case of Alarm (cpm over Threshold On):
    - **Local** : the GUI top bar starts blinking in yellow/red and the alarm can be read also via API
    - **HTTP** : send the alarm to the cloud server
    - **USB** : send a message via USB (COMING SOON feature)
  - **Notification** boxes are used to set what to do in case of Notification (cpm below Threshold Off):
    - **HTTP** : send the notification to the cloud server
    - **USB** : send a message via USB (COMING SOON feature)
  - **Enable:** if checked the Alarm is enabled

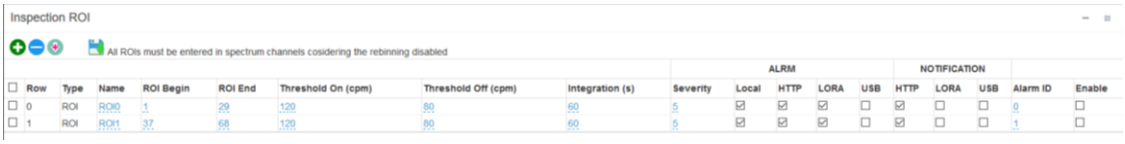


Figure 9.12: the Alarm settings

- Save settings by pressing in the top bar

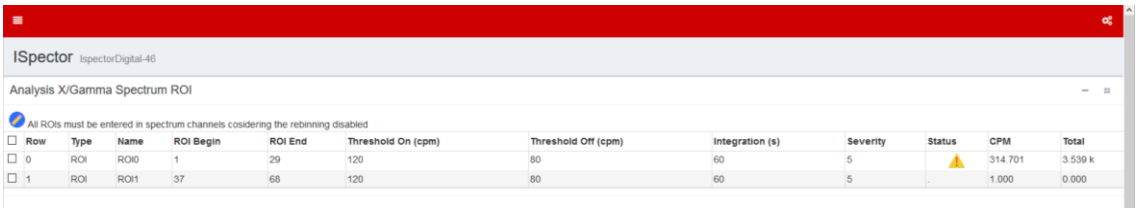


Figure 9.13: example of an alarm issued for a ROI in the energy spectrum. The GUI is blinking yellow/red and the status of the ROI is highlighted with a warning signal.

9.9 How to see PSD results (S2590)

S2590 model allows to perform Pulse Shape Discrimination, together with the same functions of S2560 and S2570. It is still possible to see waveforms, digital traces and spectrum.

The algorithm used for PSD calculation uses the following parameters (*Configuration* menu):

- *Trigger Threshold* (LSB): threshold for the derivative trigger
- *Trigger Inhibit* (ns): set the time after a trigger for which any other trigger is inhibited
- *Pre Integration* (ns): set how much time before the trigger the charge integration is started
- *Integration* (us): set the charge integration gate
- *Gain*: set the energy digital gain to be applied to the spectrum
- *Pileup Inhibition* (us): set the time after the integration gate for which the acquisition of any other event acquisition is inhibited
- *Pileup Penality* (us): set the trigger inhibition gate to be opened after a pile up
- *Baseline Inhibition* (us): set the time after the integration gate for which the baseline is not calculated
- *Baseline Length* (samples): set the number of samples used to calculate the baseline

- *Integration PSD (us):* set the gate to measure the tail of the pulse
- *Delay PSD (us):* set the delay of the *Integration PSD* gate with respect to the beginning of the charge pre-integration.
- *Gain PSD:* set a multiplication value for the PSD output value.

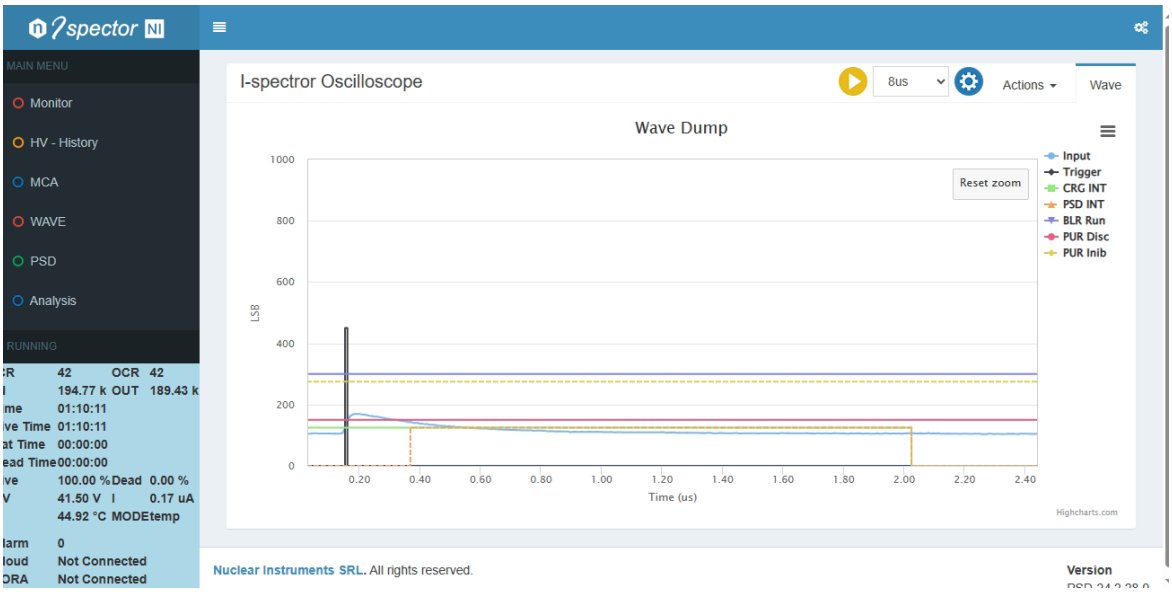


Figure 9.14: example of the wave monitor tab for PSD measurements. In orange, the *Integration PSD* gate, set to measure the pulse falling tail.

PSD value is calculated as the ration between the total charge of the pulse and the charge measured within the PSD integration gate, which represents the tail of the pulse. Results are shown in the PSD tab as a Energy vs. PSD scatter plot. The profile of the scatter plot is shown on the right and can be used to calculate the Figure of Merit (FoM) through Gaussians fit.

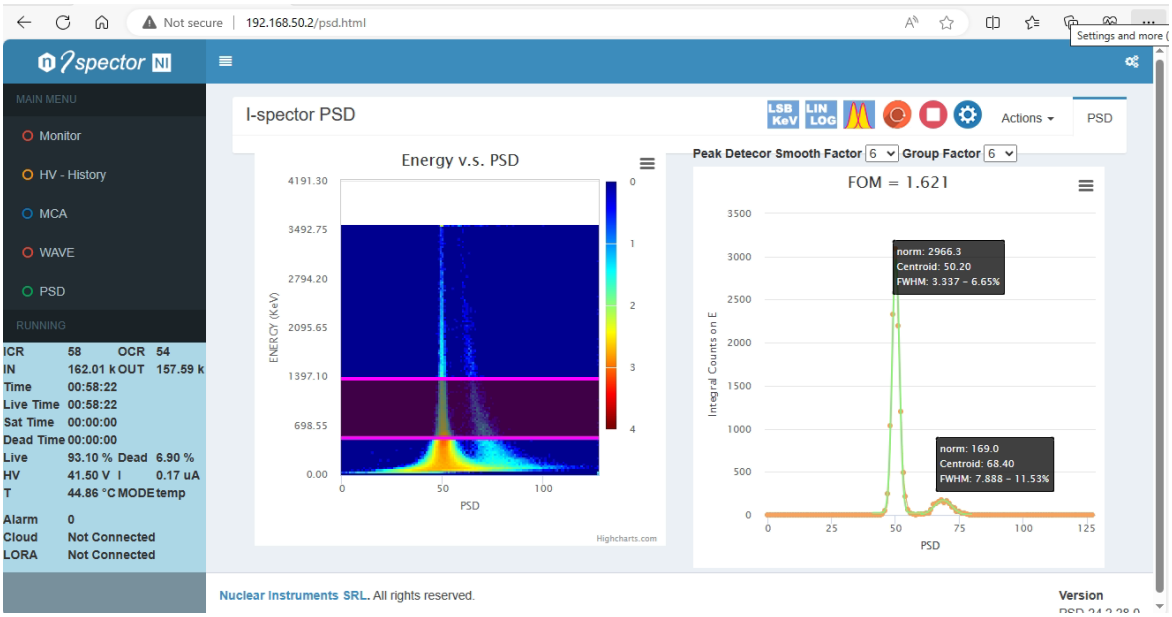


Figure 9.15: example of the PSD tab view. On the left it is possible to see the PSD vs. E scatter plot. On the right, it is possible to see the PSD vs. Integral counts for an interval of Energies that can be selected on the scatter plot with the magenta cursors.

9.10 Monitoring the unit

A complete monitor window is present in the bottom left angle of the Web Interface window (see **Figure 9.16**). This window summarizes the following information:

- Acquisition Status (Running, Stop , ….)
- Input Count Rate (ICR) and Output Count Rate (OCR)

- Total number of events in input (IN) and output (OUT) of the spectrum. The OUT is the real number of events in the spectrum, while IN includes also discarded events
- Total Time, Live Time, Saturation Time and Dead Time. Live and Dead Time are also expressed in percentage.
- Set point of the HV and monitor current
- Temperature and Feedback Loop Mode (temp or digital)
- The number of ROIs for which alarm status is ON (Alarm)

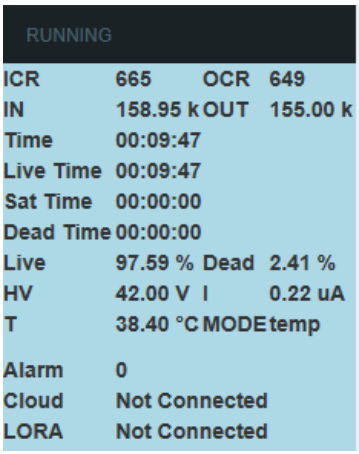


Figure 9.16: the monitor parameters of the i-Spector

In the *HV-History* tab, it possible to monitor the Output Voltage (1 mV resolution), Current (100 nA resolution) and Temperature trend over time on chart (see **Figure 9.17**).

Note: the instrument stores the last 1-hour history in the internal memory, while the user can retrieve the complete history chart if maintaining the *HV-History* tab open in the web browser.

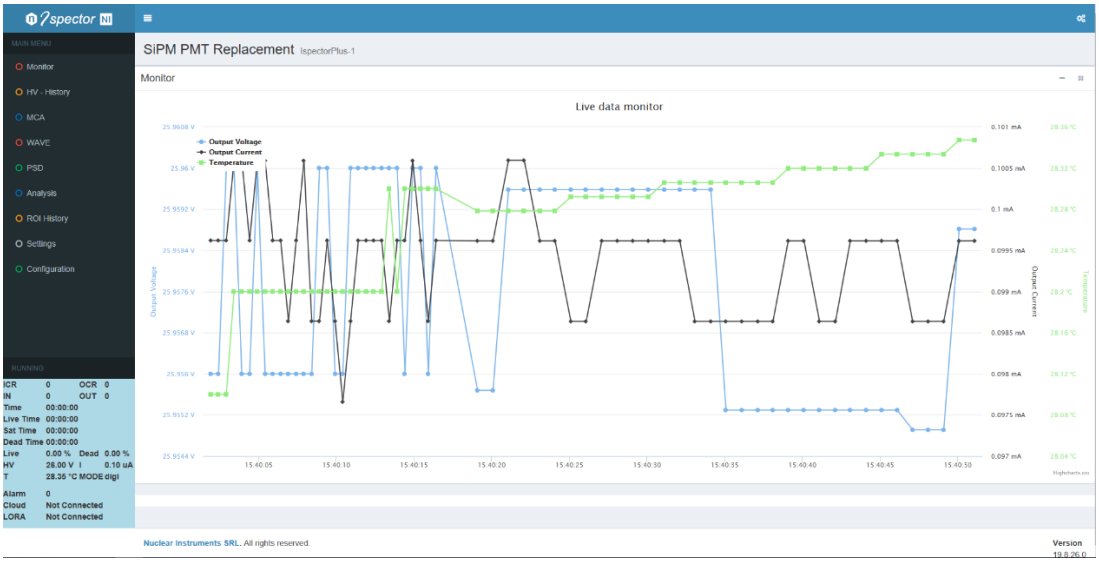


Figure 9.17: the HV/Temperature History chart.

In the *ROI History* tab, it possible to monitor the most important parameters of the live acquisition(see **Figure 9.18**). In particular it is possible to monitor:

- **Energy ROI**: input and output counts for the alarmed ROIs
- **Events**: total input and output counts
- **Rate**: ICR, OCR, Live percentage, Temperature

The ***Configuration*** menu can be accessed by clicking on the **gear icon** in the top bar (see **Figure 9.18**Figure 9.7). It is possible to set the number of points to be stored for each parameter, the sampling period (from 1 s to 1 hour) and enable/disable the history plotting.

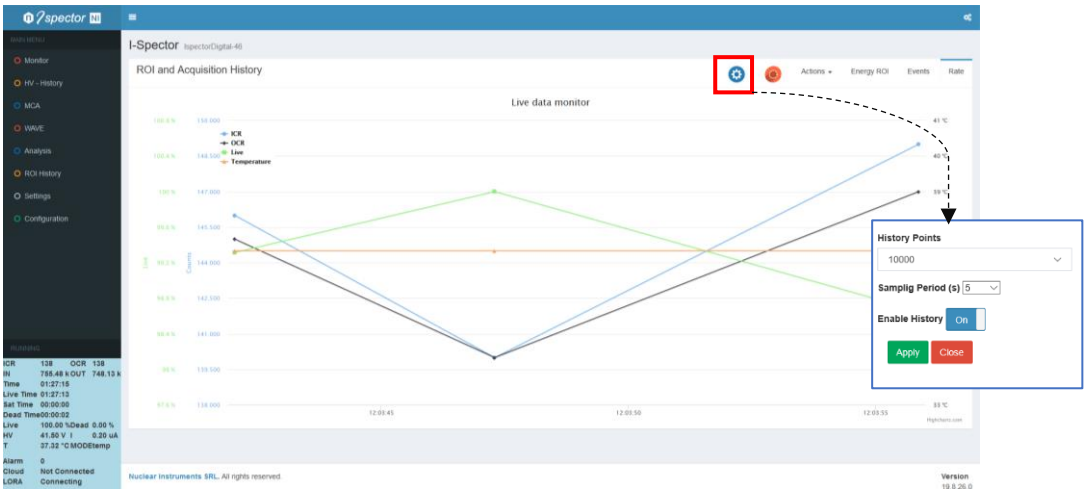


Figure 9.18: the *Rate* chart in the ROI History Tab, showing ICR, OCR, Live Time and Temperature.

10 Advanced Settings and Configuration

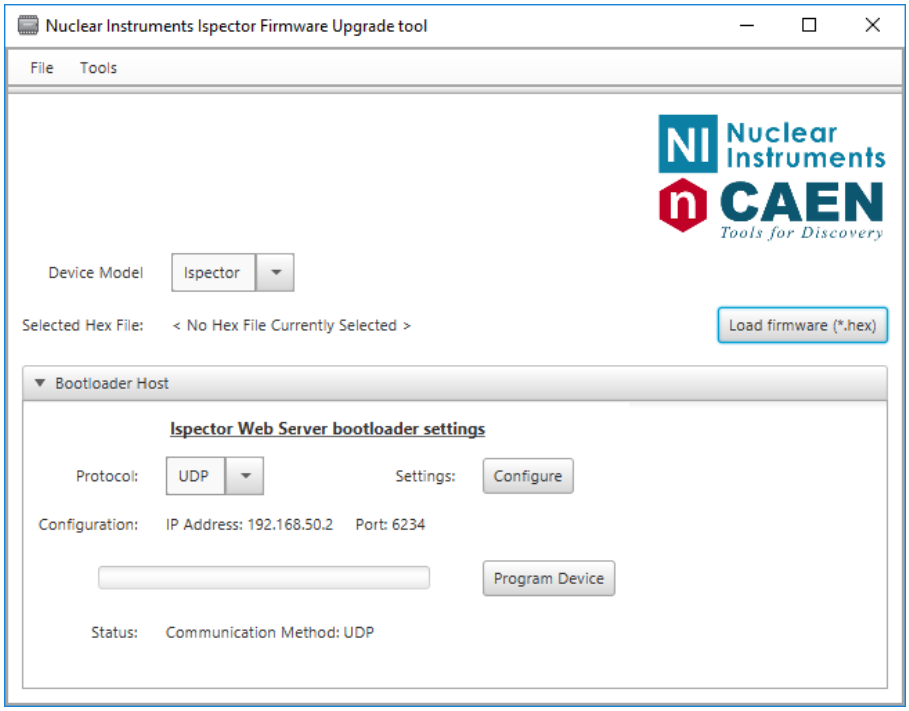
10.1 How to upgrade the unit

10.1.1 Upgrading the Web Interface

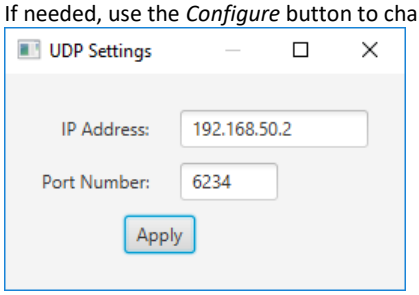
The Web Interface is directly loaded on the CPU of the i-Spector and can be upgraded using the *i-Spector Upgrader* tool, available for free download on CAEN website. The current Web Interface released can be read in the bottom right angle of the GUI.

In order to upgrade the Web Interface to the latest available version, follow the steps below:

- Download from CAEN website the *i-Spector Upgrader* tool and the *.hex* file to upgrade the CPU
- Unpack the *i-SpectorUpgrade.zip* and launch the .jar file (Java RTE is required)



- Press *Load firmware (*.hex)* and browse into PC folders to choose the CPU firmware file downloaded from CAEN website
- If needed, use the *Configure* button to change the i-Spector IP address and press *Apply*



- With the i-Spector still OFF, press *Program Device*
- Switch ON the i-Spector within 30 seconds: the tool will find the unit and upgrade the CPU
- Wait until a successful programming message is shown
- Switch OFF/ON the i-Spector

10.1.2 Upgrading the FPGA firmware

The FPGA firmware can be upgraded using the *Configuration* tab of the Web Interface. To perform a FPGA firmware upgrade on the i-Spector, follow the steps below:

- Download the FPGA firmware (*.rpd file) from CAEN website
- Connect the i-Spector to the Ethernet port of your PC and access the Web Interface
- Surf into the *Configuration* tab
- Press *Upgrade FPGA firmware*
- In the opening web page, choose the *.rpd* file to be uploaded
- Press *Upload* and wait until the process is ended with a confirmation message
- Reboot the i-Spector

10.2 Ethernet Configuration

It is possible to monitor and define the Ethernet settings from the *Configuration* tab. It is possible to read the device information, like the **serial number, hardware and firmware revision**. Moreover, it is possible to set the MAC address and IP address of the instrument.

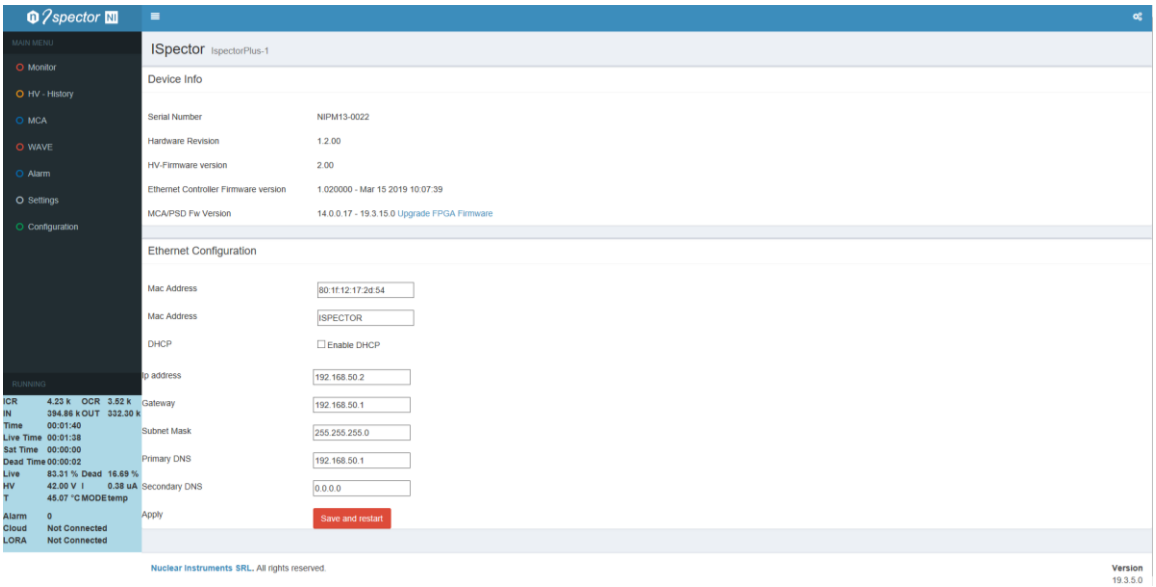


Figure 10.1: the *Configuration* tab for Ethernet settings.

10.3 Global Controls

The Global Controls Menu  (icon in the top right angle of the web browser window) allows to:

- **Save Settings on flash**, to define the current settings (MCA, acquisition mode, HV, Ethernet, ….) as the default settings of the instrument
- **Reboot,** to reboot the instrument to apply the changes written in the flash
- **Load settings from file**
- **Save settings on file**

11 Software Development kit

i-Spector Digital S2570 and S2590 models can be managed via remote control using a specific **Software Development Kit** (SDK) based on HTTP API, Python or C# coding. The SDK is available in Python and C# for free download at

https://github.com/NuclearInstruments/IspectorSDK-Python

https://github.com/NuclearInstruments/IspectorSDK-CSHARP

Refer to **[RD1]** for more details.

12 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.

12.1 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.

12.2 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.

12.3 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

13 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

14 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.

15 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:

A paper copy of the document is delivered with CAEN boards.

The document is downloadable for free in PDF digital format at:

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

CAEN GmbH
Brunnenweg 9
64331 Weiterstadt
Phone +49 (0)212 254 4077
Mobile +49 (0)151 16 548 484
info@caen-de.com
www.caen-de.com

CAEN Technologies, Inc.
1 Edgewater Street - Suite 101
Staten Island, NY 10305
USA
Phone: +1 (718) 981-0401
Fax: +1 (718) 556-9185
info@caentechnologies.com
www.caentechnologies.com

CAEN S.p.A.
Via Vetraia 11
55049 - Viareggio
Italy
Phone +39 0584 388 398
Fax +39 0584 388 959
info@caen.it
www.caen.it

CAENspa INDIA Private Limited
B205, BLDG42, B Wing,
Azad Nagar Sangam CHS,
Mhada Layout, Azad Nagar, Andheri (W)
Mumbai, Mumbai City,
Maharashtra, India, 400053
info@caen-india.in
www.caen-india.in

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