

IAEA-CN290-749

# INTEGRATED EDUCATIONAL KIT FOR RADIATION DETECTION TRAINING



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## 2nd International Conference on Applications of Radiation Science and Technology

**#ICARST2022**

**22 – 26 August 2022**

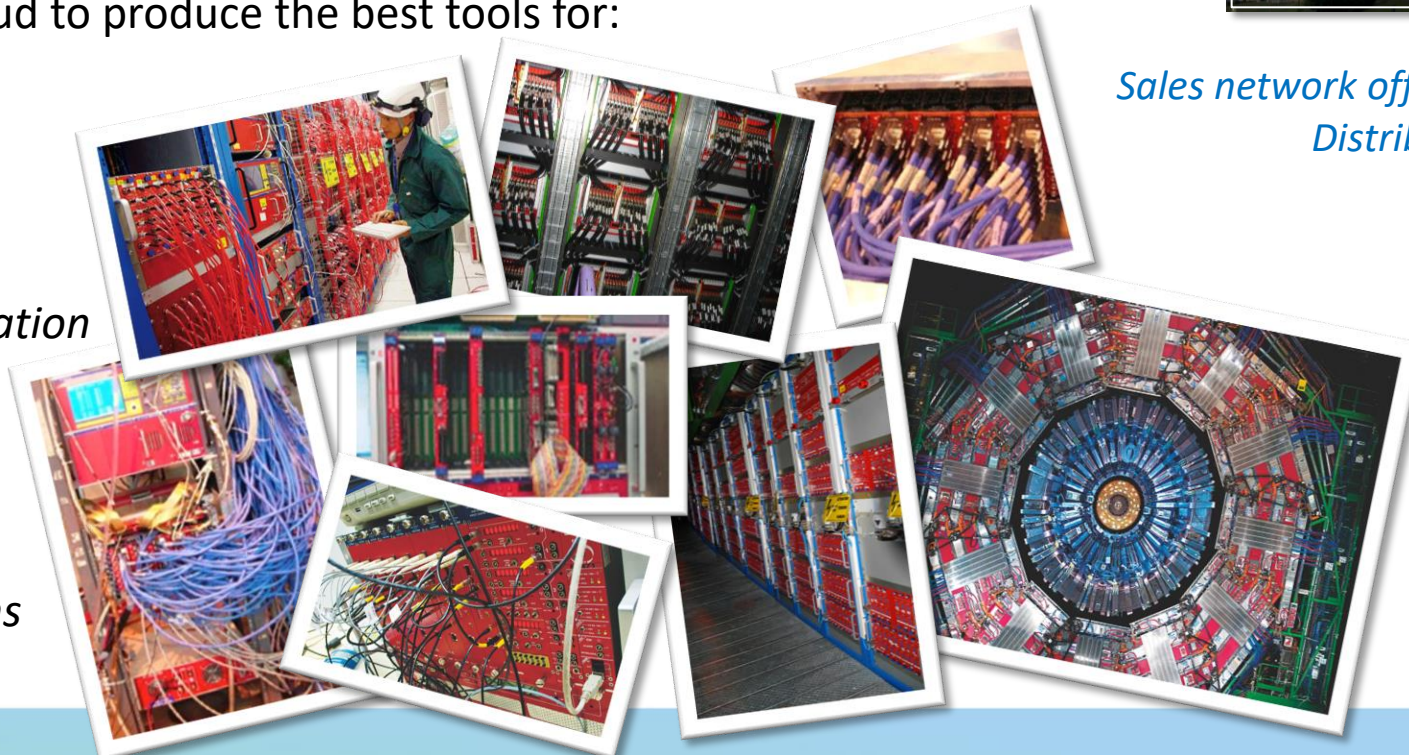
IAEA Headquarters  
Vienna, Austria

Founded in 1979, CAEN S.p.A. (Costruzioni Apparecchiature Elettroniche Nucleare) is an important industrial spin-off of the INFN.

**Core business:** Electronic Instrumentation for physics experiments (world leader)

For more than 40 years CAEN has been providing Scientists and Engineers with the most advanced electronic instrumentation for any particle or radiation detectors. Strong of an extremely close collaboration with the world major research laboratories CAEN is proud to produce the best tools for:

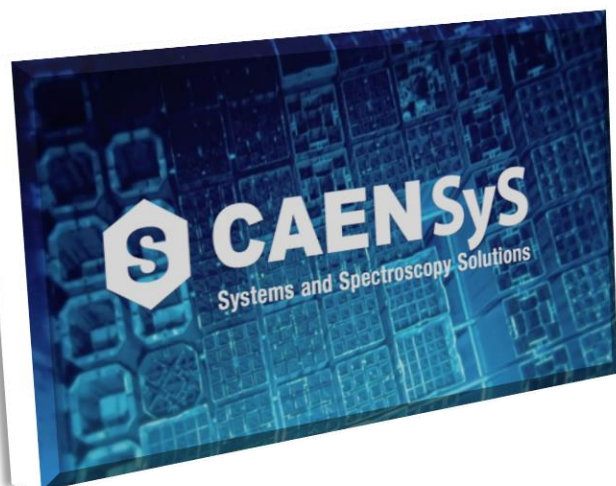
- High Energy Physics
- Astrophysics
- Neutrino Physics
- Dark Matter Investigation
- Nuclear Physics
- Material Science
- Medical Applications
- Homeland Security
- Industrial Applications



*Sales network offices in Italy, Germany, USA, India  
Distributors in more than 30 countries.*



## Spin-off activities:



### CAEN SyS – CAEN Spectroscopy Division (2016)

- Safety
- Security
- Laboratories

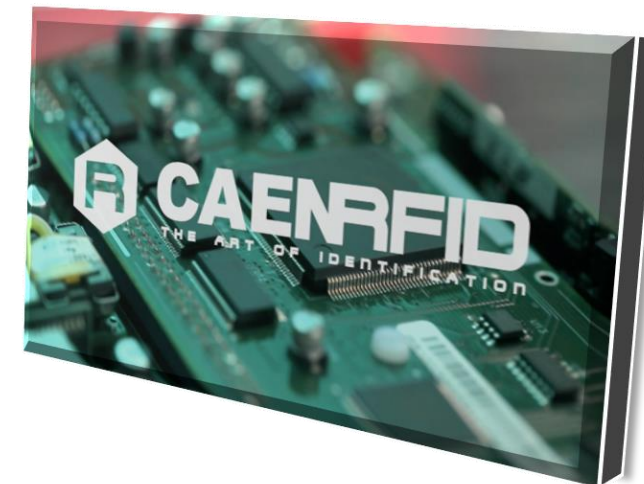
### CAENels s.r.l. (2010)

- Magnet Power Supplies
- Precision Current Measurement
- DCCTs
- Beamline Electronic Instrumentation
- FMC and mTCA.4



### CAEN RFID s.r.l. (2003)

- UHF RFID Readers
- RFID Tags



### CAENqS s.r.l. (2012)

- Information Security
- Managed Security Services
- Technologies Consulting
- Risk Assessment & Vulnerability
- Compliance Consulting



CAEN brings the experience acquired in 40 years of collaboration with the **High Energy & Nuclear Physics** community into the educational laboratories Worldwide.

CAEN enters the world of learning and training by providing **modern physics experiments for Advanced Labs** based on the latest technologies and instrumentation.



## Main Scientific Collaborations:

University of Insubria (IT)

University of Aveiro (PT)



## Goals

- ❖ Inspire students and guide them towards the analysis and comprehension of different physics phenomena with a series of experiments based on **state-of-the art technologies**, instruments and methods
- ❖ **Target the experiment depending on the student educational level.** With this approach, the experiments proposed can be performed at high school level (grade 11,12) science classes up to undergraduate physics laboratory and PhD courses.



PhD schools  
**Outreach and Masterclass**  
University and PhD Laboratory courses  
**RESEARCH TOOLS**  
Tailored courses to meet trainee's needs  
**High school Laboratory courses**  
Training courses for High School teachers  
Courses and schools also available on-site  
Training Course for ERASMUS Mundus Program



CAEN offers training courses for different types of experiments used in educational laboratories by targeting them depending on:

- ❑ Students' educational level (from high school to PhD)
- ❑ Applications (from pulse processing electronics to nuclear safety)
- ❑ Expert users



## Courses:

- *Nuclear Physics*
- *Quantum Physics*
- *Environmental Radioactivity*
- *Cosmic Rays*
- *Emulation systems*
- *Nuclear Imaging*
- *Detectors Characterization*
- *Statistics*
- *Digital Pulses Processing*
- *FPGA Programming (Sci Compiler based)*
- *Electronic Products*



All courses, taught by expert instructors and academics, are balanced between software, theoretical lessons and practical lab exercises to provide the maximum benefits:

- Discussion and constructive interaction with the other users and the expert staff
- Practical Hands-on focused on the concepts covered in class lesson
- Practical exercises on CAEN hardware and software tools

Reference materials are also provided!

**PRISMA SCHOOL 2018**  
Photosensors and Signal Processing in Particle Detectors  
Mainz, 12 - 16 March 2018

The School addresses master students and beginning PhD students aiming to work with particle detectors based on photosensors. It will introduce the concepts and technologies including light creation, propagation and detection as well as the associated electronics for signal processing and digitization.

**School program**  
Morning sessions will consist of lectures, which cover the fundamentals and prepare for the afternoon laboratories. Working in small groups, the participants will get acquainted with the aspects through practical exercises: Silicon Photo-multiplier characterization, signal emulation and cosmic-ray muon detection.

**Organized by**  
Ulrich Oberlack, Cornelia Wirth, Andrea Broggio, Quinn Weiland, Holger Heide, Lars Wieser (TU Mainz), PRISMA Cluster of Excellence

**Further information**  
<https://prisma-school2018-mainz.de/>  
Email: [prisma.school2018@tu-mainz.de](mailto:prisma.school2018@tu-mainz.de)

**PRISMA+ SCHOOL 2022**  
Photon Detection and FPGAs in Particle Detectors  
Mainz, 26 - 30 September 2022

The School addresses master students, PhD students and postdoctoral researchers aiming to work with particle detectors based on photosensors and FPGAs. It will introduce the concepts and technologies including light creation, propagation and detection as well as the associated electronics for signal acquisition.

**School program**  
Morning sessions will consist of lectures, which cover the fundamentals and prepare for the afternoon laboratories. Working in small groups, the participants will get acquainted with the subjects through practical exercises: Silicon Photo-multiplier characterization, FPGA programming and cosmic-ray muon detection.

**Local Organizers and Instructors**  
Nicolas Berger, Andrea Broggio, Victoria Durand, Ulrike Oberlack, Stefan Schoppa, Hans-Vincent Glaser, Michael Wirth, Michael Wirth (TU Mainz, PRISMA+ Cluster of Excellence)

**Invited Speakers**  
Albert Lladres (University Erlangen-Nürnberg)  
Lutz Schmitt (Fraunhofer)

**Further information**  
<https://schola.mpg-mainz.de/>  
Email: [prisma.school2022@tu-mainz.de](mailto:prisma.school2022@tu-mainz.de)

Caen lays the foundations of a **New Scientific Community** with the realization of a repository section in the New Educational Webpage, fully dedicated to the CAEN customers scientific works.

- A new scientific net totally focus on Modern & Nuclear Physics Education World
- A “place” opened to **everyone**, from young to Ph.D. students, from technicians to professors.
- Everyone can upload and **share its own experiment** to the "Educational Community" members to exploit the capabilities of the educational products.
- All the **jobs** can be **tagged** with relevant information (Institute, topic, language, job type etc.) so to ease the navigation of the site and the search engine by the use of filters and interact with other members of the community.
- **Guides for each educational level are available.** This material makes easier the analysis and comprehension of different physics phenomena with a series of experiments based on state-of-the art technologies, instruments and methods.

The screenshot shows the CAEN EduLab website interface. At the top, there is a navigation bar with the CAEN logo and 'edu' sub-brand, and menu items for 'EXPERIMENTS', 'COMMUNITY EXPERIMENTS', 'KITS', and 'UPLOAD YOUR WORK'. A prominent blue banner reads 'UNDER CONSTRUCTION ...almost ready!'. Below this, the main heading 'CAEN EduLab' is displayed in large white letters. A sub-heading states: 'Inspiring students towards the analysis and comprehension of different physics phenomena with a series of experiments based on state-of-the art technologies, instruments and methods.' A 'LEARN MORE' button is visible. The page is divided into two main sections: 'CAEN Experiments' and 'Community Experiments'. The 'CAEN Experiments' section features an illustration of a person at a computer workstation and a person pointing at a large screen displaying data. The 'Community Experiments' section features an illustration of two people sitting at a desk, one pointing at a screen showing a graph. Both sections include a 'DISCOVER' button and a link to 'CAEN EduLab - CAEN EduLab'.

A wide range of experiments covering **Nuclear and Particle Physics fields!**

From the radioactive decays ( $\beta$  and  $\gamma$ ) to the cosmic rays, from the light quanta to the advanced statistics and from the nuclear imaging to the emulation of the radioactive processes. Moreover, a new product line is fully focused on environmental radiation (indoor and outdoor).

## Nuclear Physics and Radioactivity

- $\gamma$  Spectroscopy
- $\beta$ -Radiation
- Nuclear Imaging – PET
- $\Gamma$  Environmental Radioactivity (indoor)
- $\Gamma$  Environmental Radioactivity (outdoor)

## Particle Detector Characterization

- Silicon Photomultiplier (SiPM)
- Photomultiplier Tube (PMT)

## Advanced Statistics based on Silicon Photomultiplier Detectors

## Particle Physics

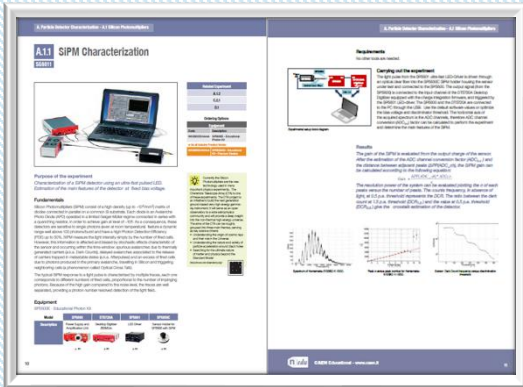
- Photons
- Cosmic Rays

## Pulse Processing: Open FPGA





## Short Guide



### Main Topics:

- Experiment task
- Short description
- Equipment list
- Requirements
- Quick guide
- Experimental results

## Nuclear Physics and Radioactivity

### $\gamma$ Spectroscopy

- ✓ Detecting  $\gamma$ -Radiation
- ✓ Poisson and Gaussian Distributions
- ✓ Energy Resolution
- ✓ System Calibration: Linearity and Resolution
- ✓ A comparison of different scintillating crystals: Light Yield, Decay Time and resolution
- ✓  $\gamma$ -Radiation Absorption
- ✓ Photonuclear cross-section/Compton Scattering cross-section

### $\beta$ -Radiation

- ✓ Response of a Plastic Scintillating Tile
- ✓  $\beta$  Spectroscopy
- ✓  $\beta$ -radiation: Transmission through Matter
- ✓  $\beta$ -Radiation as a Method to Measure Paper Sheet Grammage and thin layer thickness

### Nuclear Imaging - PET

- ✓ Basic Measurements:  $\gamma$  Spectroscopy and System Linearity
- ✓ Positron Annihilation Detection
- ✓ Two-dimensional Reconstruction of Source
- ✓ Spatial Resolution

### $\gamma$ Environmental Radioactivity (outdoor)

- ✓ Environmental monitoring in land field
- ✓  $\gamma$  Environmental Detection as a function of the soil distance
- ✓ Radioactivity maps production
- ✓ Mapping of potential radon-prone areas
- ✓ Geochemical and mineral exploration

### $\gamma$ Environmental Radioactivity (indoor)

- ✓ Energy calibration of System based on LYSO crystal
- ✓ Background Measurements
- ✓ Fertilizer and photopeak identification
- ✓ Identifications Sample Test
- ✓ Soil sample identification
- ✓ Samples Comparison
- ✓ Radon passive measurements

## Particle Physics

### Photons

- ✓ Quantum Nature of Light
- ✓ Hands-on Photon Counting Statistics

### Cosmic Rays

- ✓ Statistics
- ✓ Muons Detection
- ✓ Muons Spectrum
- ✓ Muons Vertical Flux on Horizontal Detector
- ✓ Zenith Dependence of Muons Flux
- ✓ Random Coincidence
- ✓ Detection Efficiency
- ✓ Cosmic Flux as a function of the altitude
- ✓ Cosmic Shower Detection
- ✓ Environmental and Cosmic Radiation
- ✓ Absorption Measurements
- ✓ Solar Activity Monitoring

## Particle Detector Characterization

### Silicon Photomultiplier (SiPM)

- ✓ SiPM Characterization
- ✓ Dependence of the SiPM Properties on the bias voltage
- ✓ Temperature Effects on SiPM Properties

### Advanced Statistics based on Silicon Photomultiplier Detectors

- ✓ An Educational Kit Based on a Modular SiPM System
- ✓ A simple and robust method to study after-pulses in Silicon Photomultipliers
- ✓ Background removal procedure based on the SNIP algorithm for  $\gamma$ -ray spectroscopy

### Pulse Processing: Open FPGA

- ✓ Analog signal acquisition and waveform Visualization
- ✓ Waveform digitizer with leading edge trigger
- ✓ .....

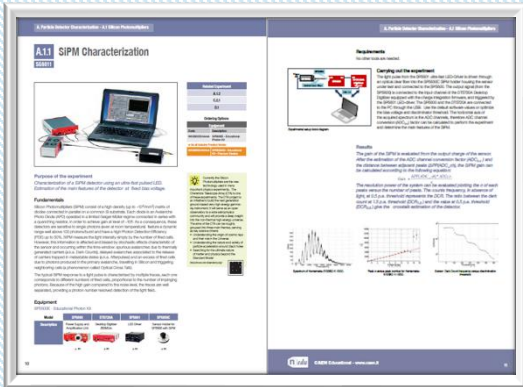
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### Guide Topics:

- General Information
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- Physics Pills
- Required Equipment
- Getting Started
- Experimental Procedure
- Results
- Links related to this topic

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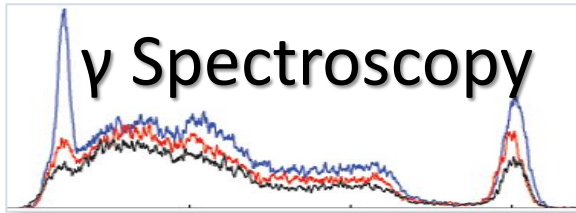


## Detailed Guide



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Section	Subsection	Experiment	Equipment											
			SP5600C	SP5600D	SP5600E	SP5600AN	SP5600EMU	SP5700	SP5701	SP5620CH	SP5630EN	SP5640	SP5630ENP	SP5650
Nuclear Physics and Radioactivity	γ Spectroscopy	Detecting $\gamma$ -Radiation	*			*	*				*	*	*	*
		Poisson and Gaussian Distributions	*			*	*						*	*
		Energy Resolution	*			*	*				*	*	*	*
		System Calibration: Linearity and Resolution	*			*	*				*	*	*	
		A comparison of different scintillating crystals: Light Yield, Decay Time and resolution	*			*							*	
		$\gamma$ -Radiation Absorption	*			*					*	*	*	
		Photonuclear cross-section/Compton Scattering cross-section	*			*	*				*	*	*	

Recommended



Alternative Choice





SP5600E – Educational Photon kit



SP5600D – Educational Beta kit



SP5600C – Educational Gamma kit



SP5600AN – Educational kit  
Premium Version



SP5600E – Educational Photon kit



SP5600D – Educational Beta kit



SP5600C – Educational Gamma kit



SP5600AN – Educational kit  
Premium Version



SP5600 - Power Supply  
and Amplification Unit

- Two channels
- Independent biasing (max 120 V, 100  $\mu$ A)
- 2 stage amplification [500 MHz bandwidth, tunable gain up to  $\sim$  50 dB]
- Fast leading-edge discriminator ( $\pm$ 2V)
- Coincidence logic
- Active feedback control on  $V_{\text{bias}}$  for Gain stabilization (granularity: 0.1  $^{\circ}$ C)
- USB 2.0 interface

DT5720A - Desktop  
Digitizer



- Digital Pulse Processing for Charge Integration DPP-CI
- Good timing resolution with fast signals (rise time < 100 ns)
- 2 channels
- Stand-alone
- 250 Ms/s, 12 bits
- $\pm$ 1V input range
- Optical Link and USB 2.0 interfaces



SP5600E – Educational Photon kit



SP5600D – Educational Beta kit



SP5600C – Educational Gamma kit



SP5600AN – Educational kit Premium Version

## SP5601 LED Driver



- LED color: violet ( $\lambda_{\text{peak}} = 420 \text{ nm}$ )
- Peak current: 120 mA
- Luminous intensity: 9500 mcd @20mA
- Width of pulse: 8ns
- 30° half-view angle
- Pulse generator: internal/external
- Optical fiber included

## SP5650C - Sensor holder with SiPM

- HAMAMATSU - MPPS S13360- 1350CS
  - Effective photosensitive area : 1.3 x 1.3mm<sup>2</sup>
  - Pixel pitch : 50  $\mu\text{m}$
  - Number of pixels : 667
- Temperature sensor



• Photons  
• SiPM Characterization



SP5600E – Educational Photon kit



SP5600D – Educational Beta kit



SP5600C – Educational Gamma kit



SP5600AN – Educational kit  
Premium Version



## SP5608 - Scintillating Tile

- Sensitive volume:  $47 \times 47 \times 10 \text{ mm}^3$
- Scintillator: polystyrene
- Directly coupled on HAMAMATSU MPPS S13360- 6050CS
  - Effective photosensitive area :  $6 \times 6 \text{ mm}^2$
  - Pixel pitch :  $50 \mu\text{m}$
  - Number of pixels : 14400
- n° 20 Paper and Aluminum sheets

• *Beta Spectroscopy*  
• *Cosmics*

# Additional Tools

# Educational Beta Kit Description (1)



SP5600E – Educational Photon kit



SP5600D – Educational Beta kit



SP5600C – Educational Gamma kit



SP5600AN – Educational kit Premium Version

## Additional SP5608 - Scintillating Tile



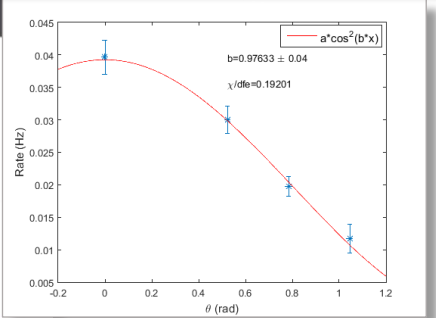
## SP5609 - Telescope Mechanics



Telescope Mechanics allows the easy construction of a muons telescope. It is composed of :

- Rotary axis with desk support
- Clamps with screws
- Angle brackets kit

## Suggested Application



- Double coincidence
- Zenith Dependence of Muons Flux



# Educational Gamma Kit Description



SP5600E – Educational Photon kit



SP5600D – Educational Beta kit



SP5600C – Educational Gamma kit



SP5600AN – Educational kit Premium Version

## SP5606 Mini-Spectrometer

- Mechanical structure for optimal SiPM to crystal coupling
- Scintillating Crystals: CsI, LYSO, BGO (6 x 6 x 15 mm<sup>3</sup>)
- One SiPM embedded HAMAMATSU MPPS S13360- 6050CS
  - Effective photosensitive area : 6 x 6 mm<sup>2</sup>
  - Pixel pitch : 50 μm
  - Number of pixels : 14400



## SP5607 Absorption Tool



### Spacers:

- one 4mm thick, five 10 mm thick;

### Aluminum Absorbers:

- one 4mm thick, five 10 mm thick;

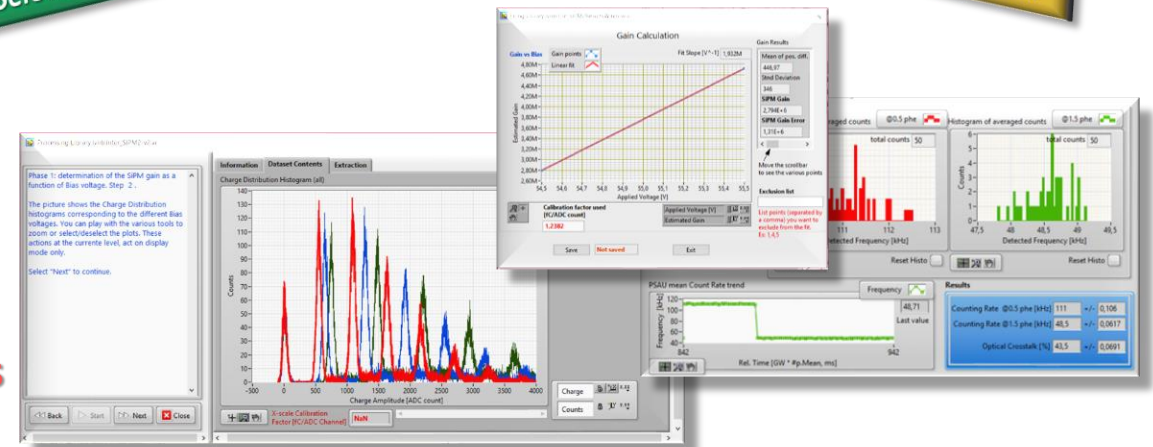
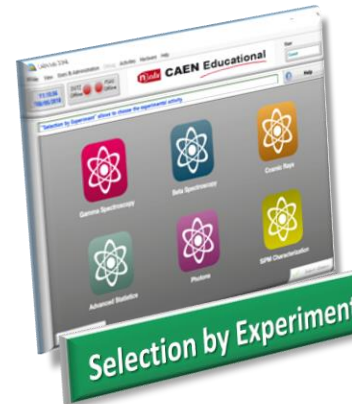
### PMMA Absorbers:

- one 4mm thick, five 10 mm thick.

γ Spectroscopy



- Help and QuickStart Guide online
- Three Access Levels to the software functionalities:
  - Level 1 - Hardware Management
  - Level 2 - Hardware Management + Experiments
  - Level 3 - Full Access (Analysis Tools)



Analysis Tools are implemented in the software itself!



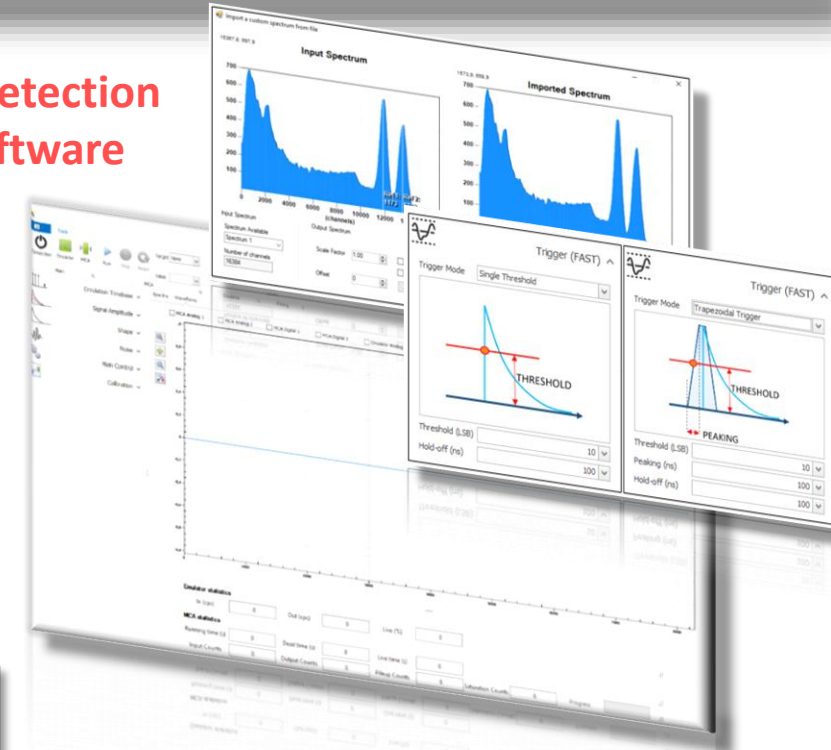


**SP5600EMU – Emulation kit**

• **Gamma Spectroscopy**  
• **Pulse Processing**

## Emulation and Detection Educational Software

- Energy spectrum emulation
- Gamma radioactive isotopes database access
- Continuous pre-amplifier emulation
- Signal analysis: PHA and CI pulse processing



## DT4800 - Micro Digital Detector Emulator

- Pulser / Emulator operating modes
- Real Energy spectrum emulation
- Time distribution emulation (Poissonian)
- Noise emulation
- Continuous pre-amplifier emulation
- Nuclides database
- User Friendly Control SW with Graphical User Interface
- MiniUSB interface



## DT5770 - Digital Multichannel Analyzer

- Compact portable 16k Digital MCA (150MS/s)
- Suited for high resolution Gamma Spectroscopy
- Support continuous and pulsed reset preamplifiers
- Software selectable coarse and fine gain
- DB9 connector for preamplifier power supply
- Different acquisition modes available: CI and PHA for energy calculation and signal inspector for an easy setup and signal monitoring
- MiniUSB and Ethernet communication interfaces



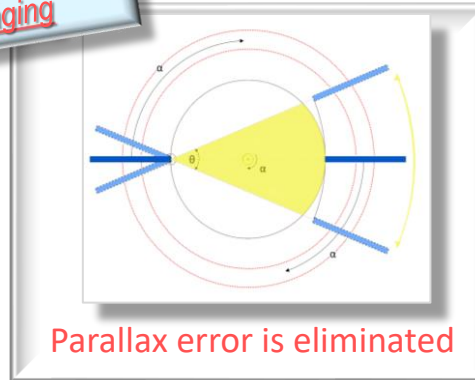


**SP5701 – EasyPET kit**



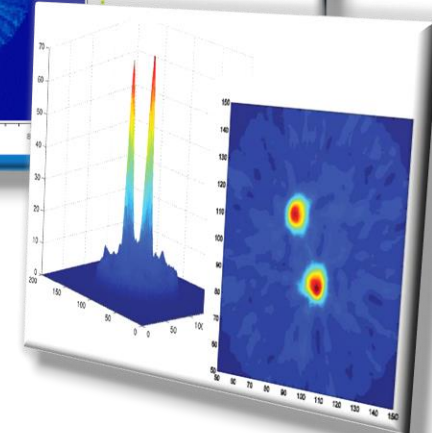
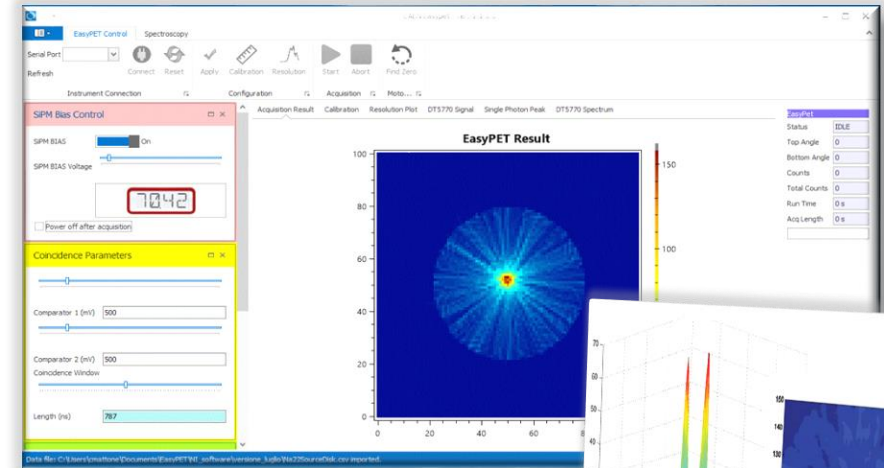
[Link to Video](#)

**Gamma Spectroscopy  
Nuclear Imaging**



Parallax error is eliminated

Patent pending Aveiro University



**SP5700 - EasyPET**

- Two detectors, each composed of a LYSO scintillator crystal optically coupled to a SiPM
- Printed Circuit Board (PCB) equipped with electronics used for SiPMs supply voltage, signal readout and coincidence detection
- Two stepper motors
- Microcontroller unit responsible for controlling EasyPET parameters, driving the stepper motors and communicating with the computer
- Holders for radioactive source.



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- Support continuous and pulsed reset preamplifiers
- Software selectable coarse and fine gain
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**NEW**



**SP5630EN – Environmental kit**

- Gamma Spectroscopy
- Env. Radioactivity Indoor

*Environmental gamma radiation measurements with SiPM based instrumentation!*

**S2570 - i-Spector Digital**

- The system is based on a SiPM area  $18 \times 18 \text{ mm}^2$ . All SiPMs of the area are connected in parallel to increase the active area of the matrix.
- It integrates a shaper, a peak stretcher and a peak ADC to implement a simple MCA (4K).
- Scintillator Crystal: CsI  $18 \times 18 \times 30 \text{ mm}^3$
- Connectivity: Ethernet
- Software: Web GUI



**Samples**



**Empty Beaker & Test Sample**

**Fertilizer and Rock Samples**



**Canisters of Activated Carbon**



**Calibration Crystal (Lu1.8Y.2SiO5:Ce)**

*Web-based GUI for unit control and data analysis*



**SP5630EN – Environmental kit Plus**

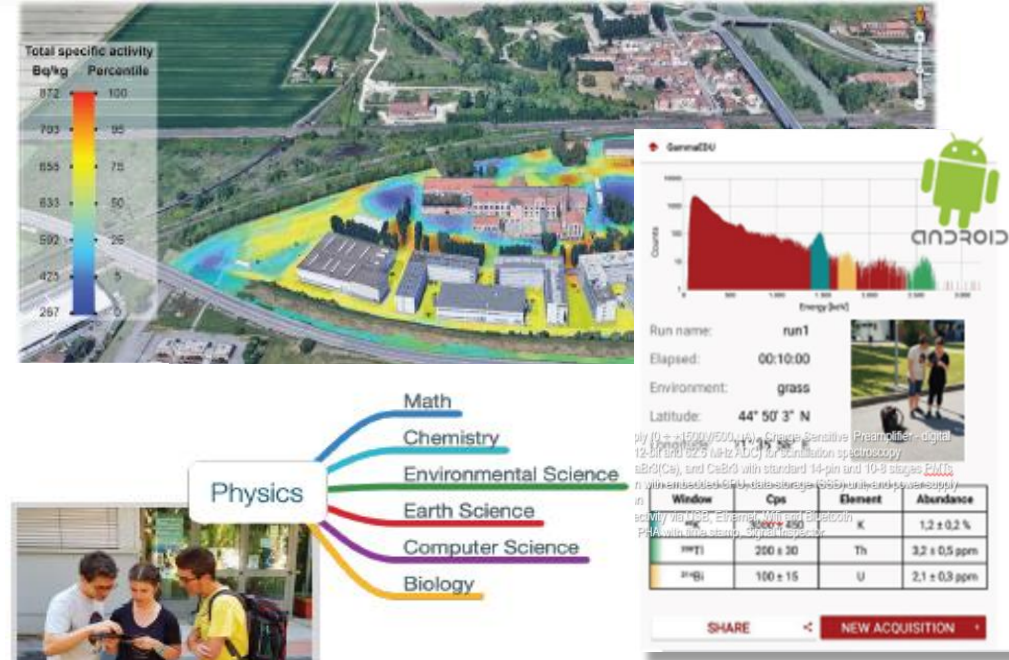


Aluminium and Lead absorbers & BGO Crystal



## Portable detection backpack for radioactive materials!

- Suitable for High School Students!
- NaI(Tl) (0.3 liter) Scintillator Crystal coupled to a PMT
- Power Supply included
- Identification of Natural Radiation [ $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ ]
- Autonomy up to 6-8 hours
- Tablet included with GammaEDU Application
- Bluetooth and Wi-Fi Connectivity
- Geolocation and ability to view the map



## Digital MCA Unit - S2580 - GAMMASTREAM

- High Voltage Power Supply (0 ÷ +1500V/500  $\mu\text{A}$ ) - Charge Sensitive Preamplifier - digital Multi-Channel Analyzer (12-bit and 62.5 MHz ADC) for scintillation spectroscopy
- Specialized for NaI(Tl), LaBr<sub>3</sub>(Ce), and CeBr<sub>3</sub> with standard 14-pin and 10-8 stages PMTs
- Full stand-alone operation with embedded CPU, data storage (SSD) unit, and power supply for up to 8 hours operation
- Wired and wireless connectivity via USB, Ethernet, Wifi and Bluetooth
- Acquisition modes: PHA, PHA with time stamp, Signal Inspector





Cosmic Rays

*A very simple cosmic Muon telescope!*

**SP5620CH – Cosmic Hunter**

- Based on SiPM detectors and plastic scintillating tiles.
- Up to 3 scintillating tiles management
- No fixed geometry
- No Needs SW interface
- SD card to download data

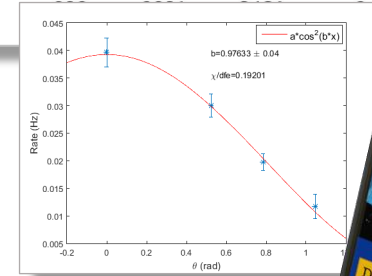
**High School level!**

[Link to customer application](#)



CSMHUNT-2019114164338

num	coinc	date	time	sec	RecTime	TOP	BOTTOM	EXT	COINC
1	T-B	14/1/2019	16:53:45	601	600	6552	8395	0	529
2	T-B	14/1/2019	17:3:45	1201	600	6838	8652	0	655
3	T-B	14/1/2019	17:13:44	1801	600	6649	8582	0	522
4	T-B	14/1/2019	17:23:44	2401					
5	T-B	14/1/2019	17:33:44	3001					



**SP5609 - Telescope Mechanics**

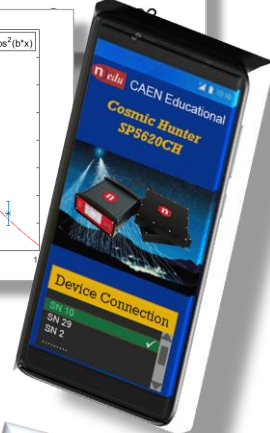
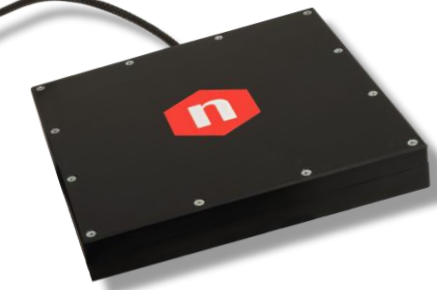
- Rotary axis with desk support
- Clamps with screws
- Angle brackets kit

Additional Tools

**SP5622 - Detection System**

Each unit consists of:

- Plastic scintillator (15 x 15 x 1 cm<sup>2</sup>)
- Front-end electronic board
- AdvanSiD NUV-SiPM (4 x 4 mm<sup>2</sup>) mounted in the tile corner at 45°



Thanks for your attention!



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## 2nd International Conference on Applications of Radiation Science and Technology

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