13th CRIS-MAC 2024

Cosmic-Ray International Studies and Multi-messenger Astroparticle Conference

CRIS-MAC 2024

Fostering Curiosity and Learning: The Journey from Tool Development to Practical Education.

Trapani, ITALY

17-21 June 2024

A. Cortopassi[1], P. Garosi [1], A. Maggiora[2], C. Mattone [1], F. Rogo[1]

(1) CAEN S.p.A., Viareggio, Italy ---- (2) INFN, Torino, Italy

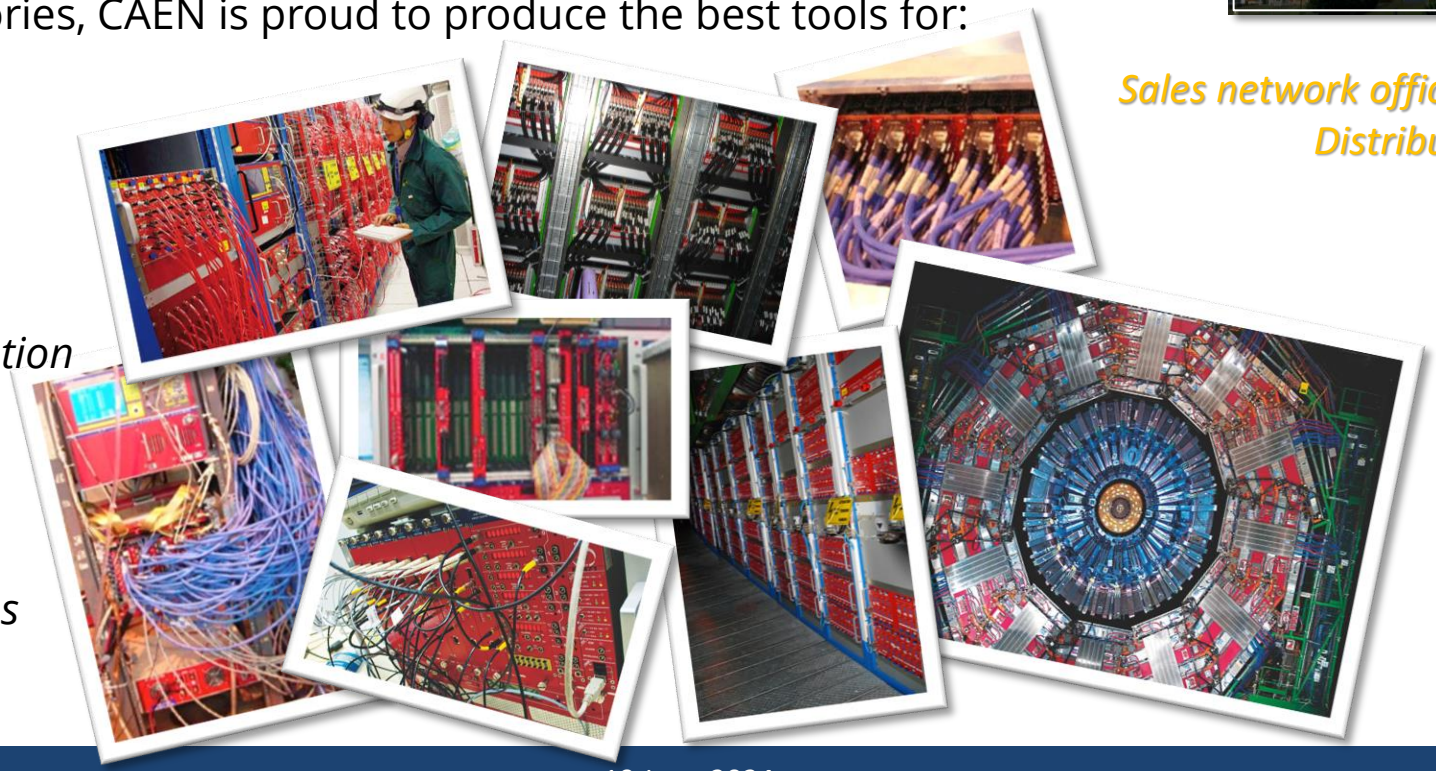
CAEN Electronic Instrumentation

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

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

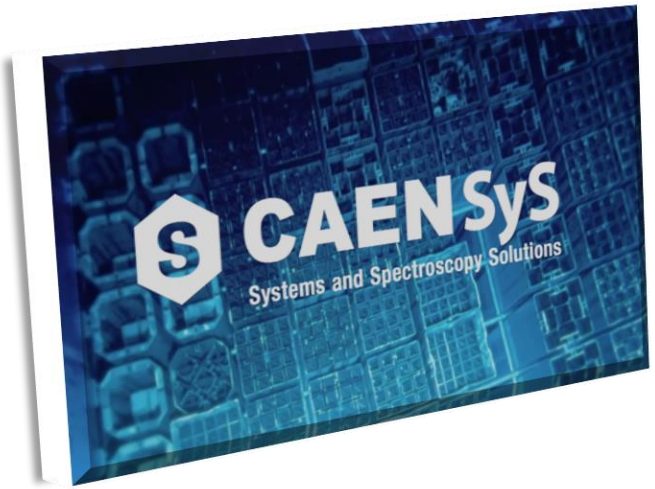
For more than 40 years CAEN has been providing Scientists and Engineers with the most advanced electronic instrumentation for any particle and radiation detectors. Thanks to the experience gained through the close collaboration with the world major research laboratories, CAEN is proud to produce the 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

CAEN RFID s.r.l. (2003)

- UHF RFID Readers
- RFID Tags

CAENels s.r.l. (2010)

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

CAENqS s.r.l. (2012)

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

Increasing Interest in Outreach and Education in Physics

Recent trends show a significant increase in outreach and educational programs developed by universities and research institutions.

Focus on making physics and other scientific disciplines more accessible and engaging to a broader audience.

Goals of Outreach Initiatives

- *Stimulate Interest in Science:* Create engaging content and hands-on activities to capture the curiosity of diverse audiences.
- *Promote Understanding:* Simplify complex concepts to enhance comprehension of fundamental principles of physics.
- *Inspire Future Scientists:* Encourage young students to pursue careers in science through inspirational programs and role models.

Interactive Workshops

Public Lectures and Seminars

Collaborative Projects

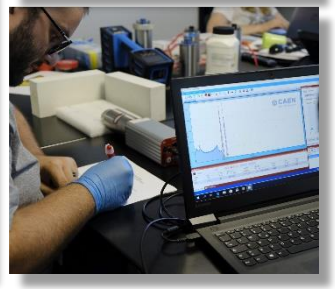
Impact

- *Increased Engagement:* Higher participation rates in science fairs, workshops, and educational programs.
- *Enhanced Understanding:* Improved comprehension of scientific concepts among participants.
- *Future Scientists:* Growing interest in STEM careers among young students.

Educational Project

CAEN brings the experience acquired in more than 45 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.



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.

Educational Events

PhD schools

Outreach and Masterclass

University and PhD Laboratory courses

RESEARCH TOOLS

Tailored courses to meet trainee's needs

High school Laboratory courses

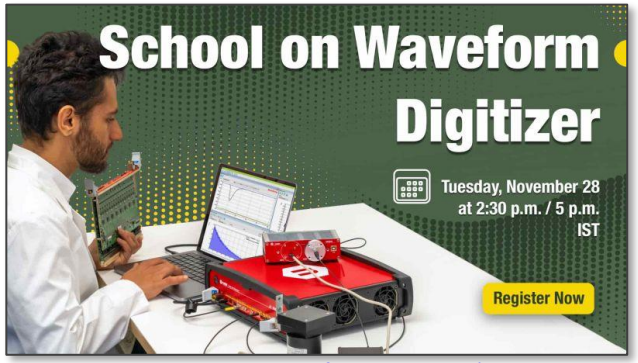
Training courses for High School teachers

Courses and schools also available on-site

CAEN Educational Training

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

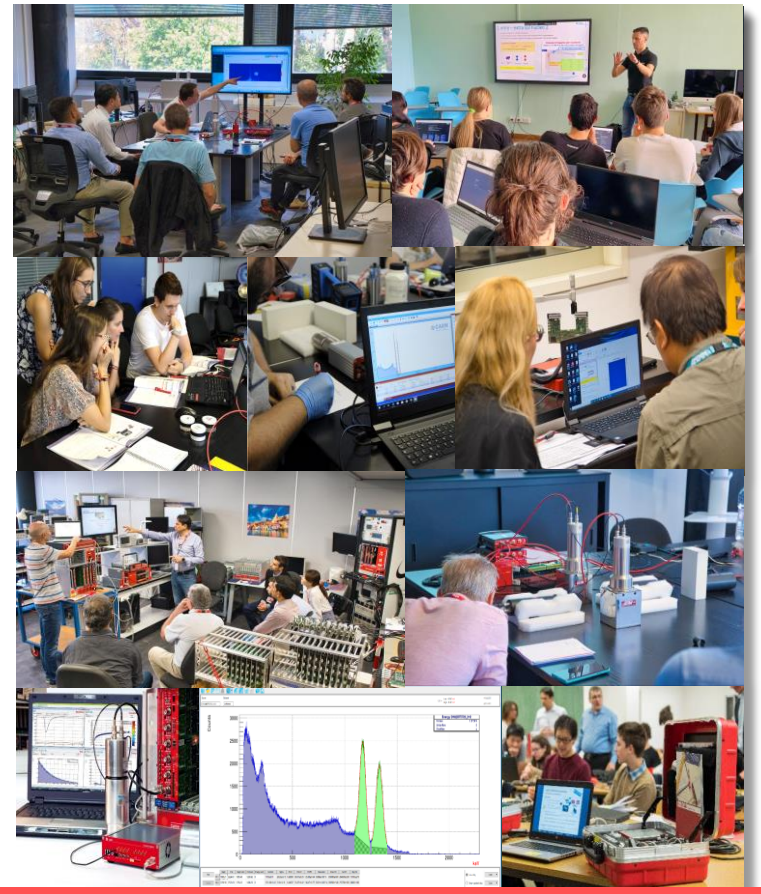
- Students' educational level (from high school to PhD)
- Applications (from pulse processing electronics to nuclear safety)
- Expert users



School on waveform digitizer (28 November 2023): Overview · Indico (caen.it)

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*

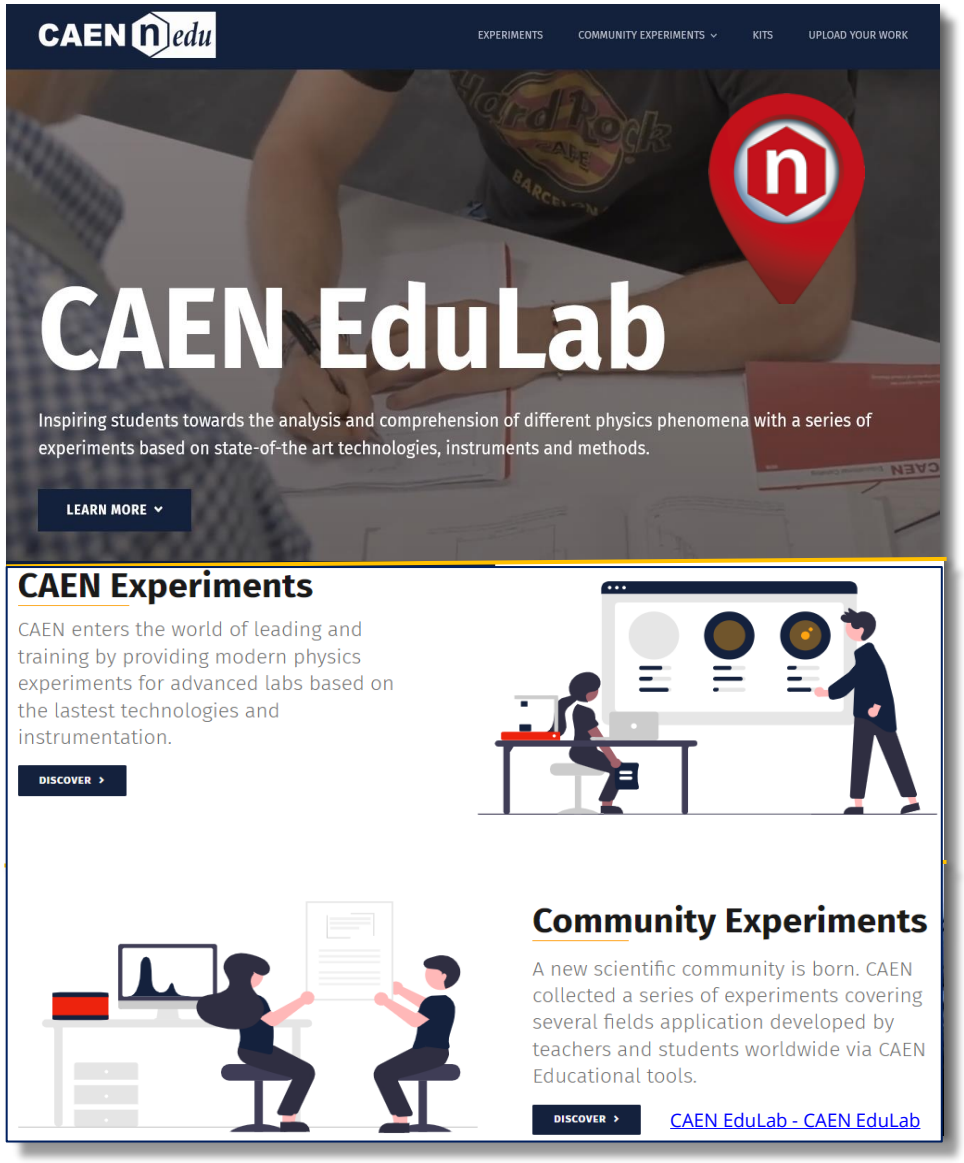


All courses, taught by expert instructors and academics, are balanced between software, theoretical lessons and practical lab exercises to provide the maximum benefits:

- 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!

NEW Educational Website



Innovative Scientific Network

Caen introduces a global platform for Modern & Nuclear Physics education, enabling seamless sharing of experiments for students and professionals.

Interactive and User-Friendly Resources

The platform also features interactive tools that enhance communication and collaboration among members, along with comprehensive guides tailored specifically to each user's needs.

CAEN Educational Products

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

From the radioactive decays (β and γ) 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) and on FPGA programming.

SP5660
RockyRAD

SP5622B
Detection System Plus

SP5640
Gamma EDU

SP56050
Open FPGA Kit

Nuclear Physics and Radioactivity

- *γ Spectroscopy*
- *β-Radiation*
- *Nuclear Imaging – PET*
- *γ Environmental Radioactivity (indoor)*
- *γ Environmental Radioactivity (outdoor)*
- *GM detectors*

Advanced Statistics based on Silicon Photomultiplier Detectors

Particle Detector Characterization

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

Particle Physics

- *Photons*
- *Cosmic Rays*

Electronics:

- *Pulse Processing*
- *FPGA Programming*

SP5700
EasyPET

SP5620CH
Cosmic Hunter

SP5600AN
Premium Version

SP5600EMU
Emulation Kit

SP5630EN
Environmental kit

SP5600D
Edu Beta Kit

SP5600C
Edu Gamma Kit

SP5630ENP
Environmental kit Plus

SP5701
EasyPET Kit

SP5600E
Edu Photon Kit

A lot of experiments on handy!

Nuclear Physics and Radioactivity

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

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

Nuclear Imaging - PET
- ✓Basic Measurements: γ Spectroscopy and System Linearity
- ✓Positron Annihilation Detection
- ✓Two-dimensional Reconstruction of Source
- ✓Spatial Resolution

γ Environmental Radioactivity (outdoor)
- ✓Environmental monitoring in land field
- ✓ Ground Coverage Effect on the Environmental Monitoring
- ✓ Human Body Radioactivity
- ✓ Environmental detection as a function of the soil distance
- ✓ Radioactivity maps production
- ✓ Radiological evaluation of the building materials
- ✓ Geochemical and mineral exploration

γ 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

GM Detectors
- ✓Statistics: Uncertainty as a function of live time
- ✓Environmental Background
- ✓Lead Shielding Effect on Environmental Radioactive Background
- ✓Detecting Ionizing-Radiation
- ✓Samples Comparison

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

Photomultiplier Tube (PMT)
- ✓ Measurement of Photomultiplier Plateau Curves

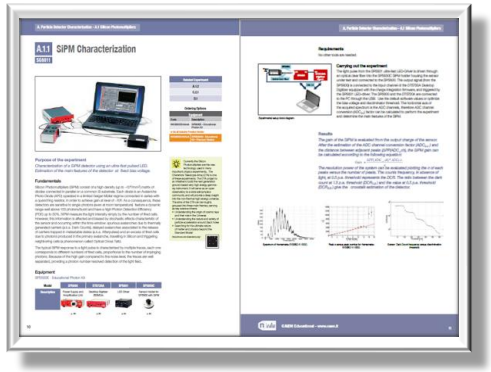
Pulse Processing: Open FPGA

coming soon

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

Advanced Statistics..

Short Guide



Main Topics:
- *Experiment task*
- *Short description*
- *Equipment list*
- *Requirements*
- *Quick guide*
- *Experimental results*

Detailed Guide

Guide Topics:
- *General Information*
- *Introduction*
- *Physics Pills*
- *Required Equipment*
- *Getting Started*
- *Experimental Procedure*
- *Results*
- *Links related to this topic*

A lot of experiments on handy!

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Cosmic Rays

- ✓Statistics
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- ✓Random Coincidence
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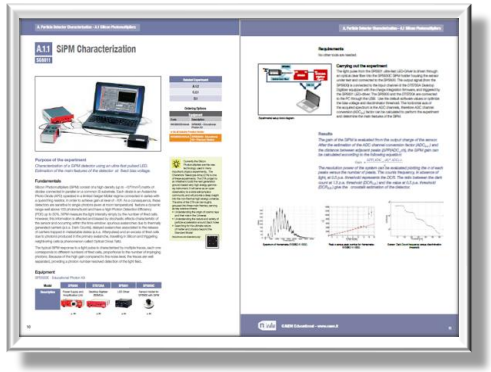
- ✓Waveform digitizer with leadin

Advanced Statistics..

Short Guide



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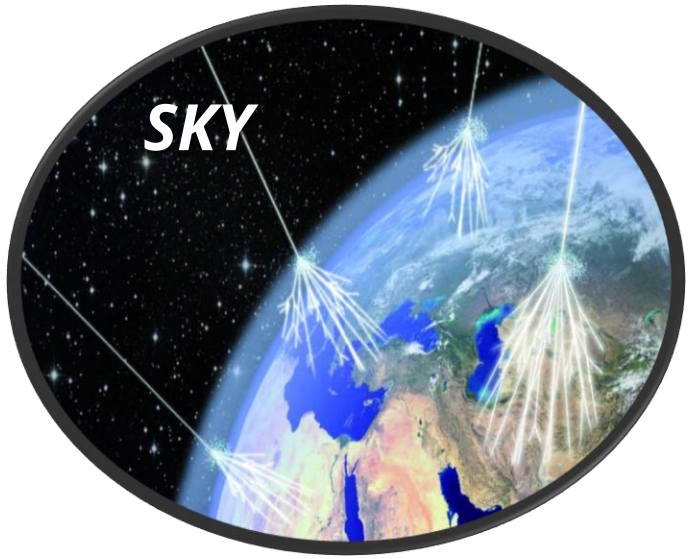
Educational Kits Suitable for Young Students

Interesting educational program focused on the environment that surrounds us!



Cosmics

Section	Subsection	Experiment	Equipment									
			SP5600C	**SP5600D**	SP5600E	SP5600AN	SP5600EMU	SP5700	SP5701	**SP5620CH**	SP5630EN	SP5640
Particle Physics	**Cosmic Rays**	*Muons Detection*		✸		✸				✸		
		Muons Vertical Flux on Horizontal Detector		✸		✸				✸		
		Muons Spectrum		✸		✸						
		Zenith Dependence of Muons Flux		✸ O ⅄		✸ O ⅄				✸ ⅄		
		Triple coincidence								✸ ◎		
		Cosmic Shower Detection								✸ ◎		
		Random Coincidence								✸		
		Detection Efficiency								✸ ◎ +		
		Cosmic Flux as a function of the altitude								✸		
		Environmental and Cosmic Radiation								✸		
		Absorption Measurements								✸		
		Solar Activity Monitoring								✸		

Recommended kits

SP5600D
Educational Beta kit

SP5600AN
Premium Version kit

SP5620CH
Cosmic Hunter

Alternative Choice

SP5608
Scintillating Tile

SP5609
Telescope Mechanics

SP5622
Detection System

This symbol suggests the kit use for young students!

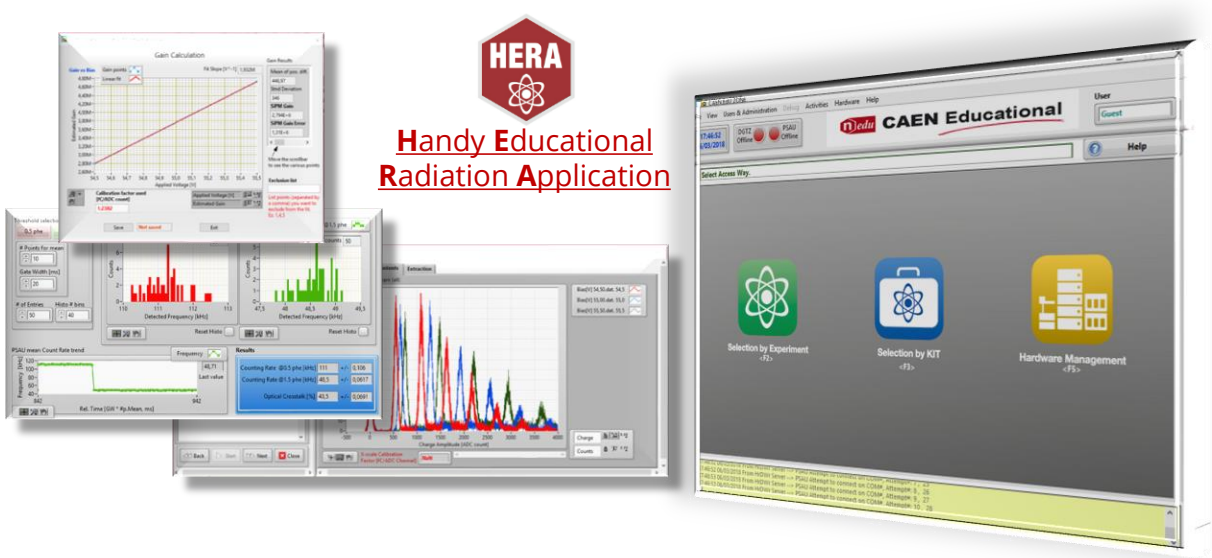
Educational Beta and Premium Kit

SP5600D

Educational Beta kit

SP5600AN

Educational Premium kit



SP5600 - Power Supply and Amplification Unit

- Two channels
- Independent biasing (max 120 V, 100 µA)
- 2 stage amplification [500 MHz bandwidth, tunable gain up to ~ 50 dB]
- Fast leading-edge discriminator (±2V)
- Coincidence logic
- active feedback control on V_{bias} for Gain stabilization (granularity: 0.1 °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
- 2 Vpp input range
- Optical Link and USB 2.0 interfaces

SP5608 - Scintillating Tile

- Sensitive volume: 47 x 47 x 10 mm^3
- Scintillator: polystyrene
- Directly coupled on HAMAMATSU MPPS S13360- 6050CS
  - Effective photosensitive area : 6 x 6 mm^2
  - Pixel pitch : 50 µm
  - Number of pixels : 14400
- n° 20 Paper and Aluminum sheets
- Teflon tape

Educational Beta and Premium Kit

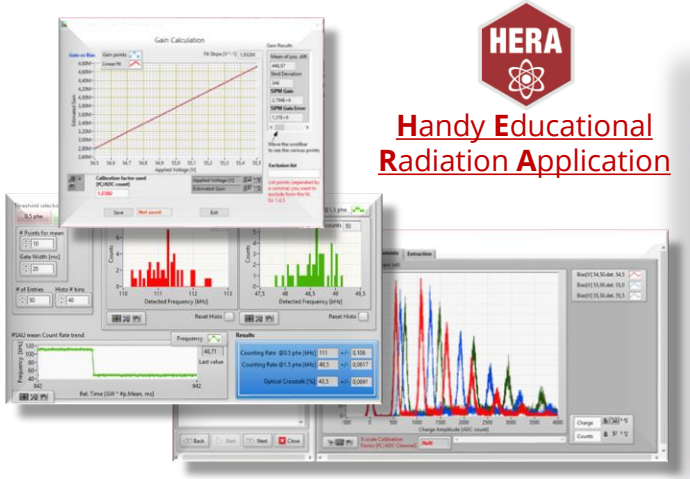
Additional Tools

SP5600D

Educational Beta kit

SP5600AN

Educational Premium kit



HERA

Handy Educational Radiation Application

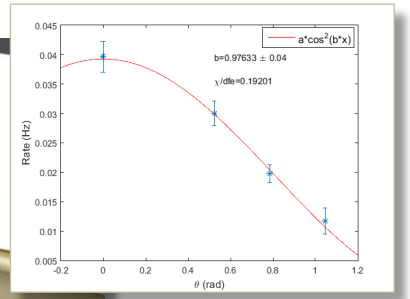
SP5609 - Telescope Mechanics

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 Applications

- Double coincidence
- Zenith Dependence of Muons Flux



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NEW Educational kits dedicated to the Cosmic Rays detection

SP5620CH – Cosmic Hunter

SP5622B – Detection System Plus

NEW Cosmic Hunter – SP5620CH

A very simple cosmic Muon telescope!

The system consists of two scintillating tiles and a central board that counts the coincidences between the detectors, displaying the count on a numeric display.

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

SP5621
Coincidence Unit

- The main unit houses a microcontroller based on the ESP32, the e-book display, and some interface and coincidence circuits.
- The output of the electronics is LVDS, and the board is powered by 5V.
- The operational commands relate to the type of coincidence (double, single, or even triple), the integration time, and the commands via the START, STOP, and RESET buttons.

SP5622
Detection System

Each unit consists of:
- Plastic scintillator (15 x 15 x 1 cm^2)
- Front-end electronic board (transconductance amplifier and a fast discriminator)
- SiPM (4 x 4 mm^2) mounted in the tile corner at 45°

NEW Cosmic Hunter – SP5620CH (1)

Additional Tools

Cosmic Hunter Software

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	600	6621	8481	0	503
5	T-B	14/1/2019	17:33:44	3001	600	6647	8480	0	495

- ***Based on SiPM detectors and plastic scintillating tiles.***
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SP5609 Telescope Mechanics

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

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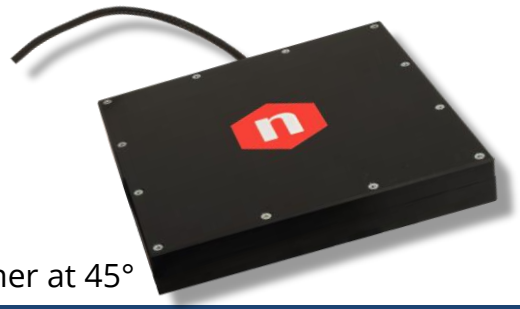
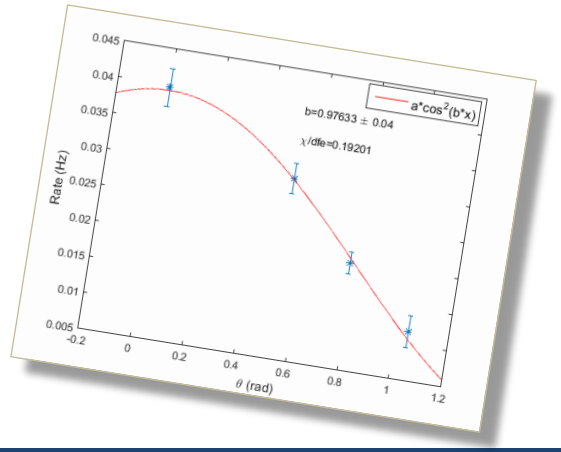
Each unit consists of:
- Plastic scintillator (15 x 15 x 1 cm^2)
- Front-end electronic board
- SiPM (4 x 4 mm^2) mounted in the tile corner at 45°





Outreach & Balloon Experience

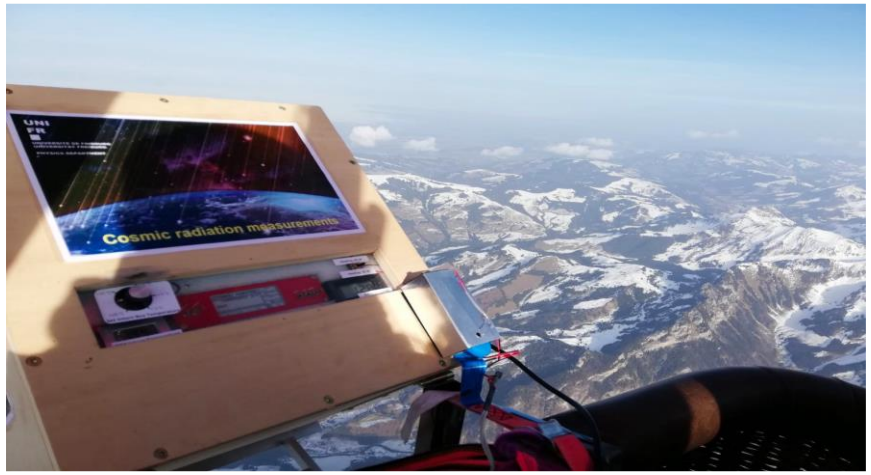
INFN OCRA
Outreach Cosmic Ray Activities
OUTREACH
COSMIC RAY ACTIVITIES

Les Rencontres de Physique de la Vallée d'Aoste

The INFN OCRA project involved many high school students with experiments measuring cosmic rays in Aosta (IT) and at high altitudes.

Commemorative balloon flight 25 January 2020



Prof. Hans Peter Back

Albert Einstein Center for Fundamental Physics, University of Bern

High School Student's Educational Experience

Jonas Hoecker — Volée 2019-2021

Mr. Fluckiger

Radiographie terrestre avec les rayons cosmiques

Quel est le taux de rayons cosmiques en fonction de l'altitude et de la profondeur géologique ? Théorie et mesures.

8369 mots — Rendu le 7 Janvier 2020

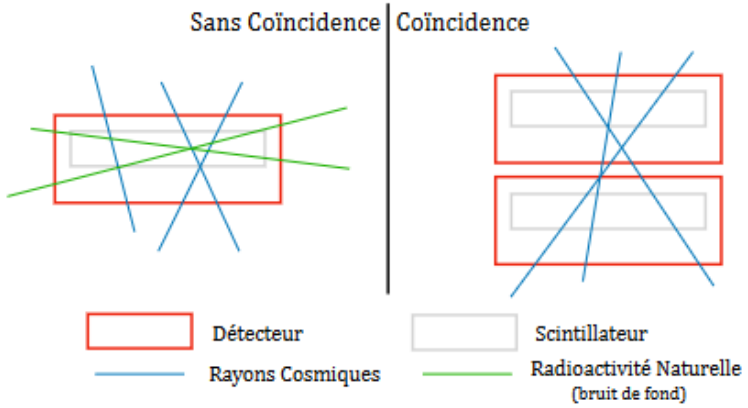
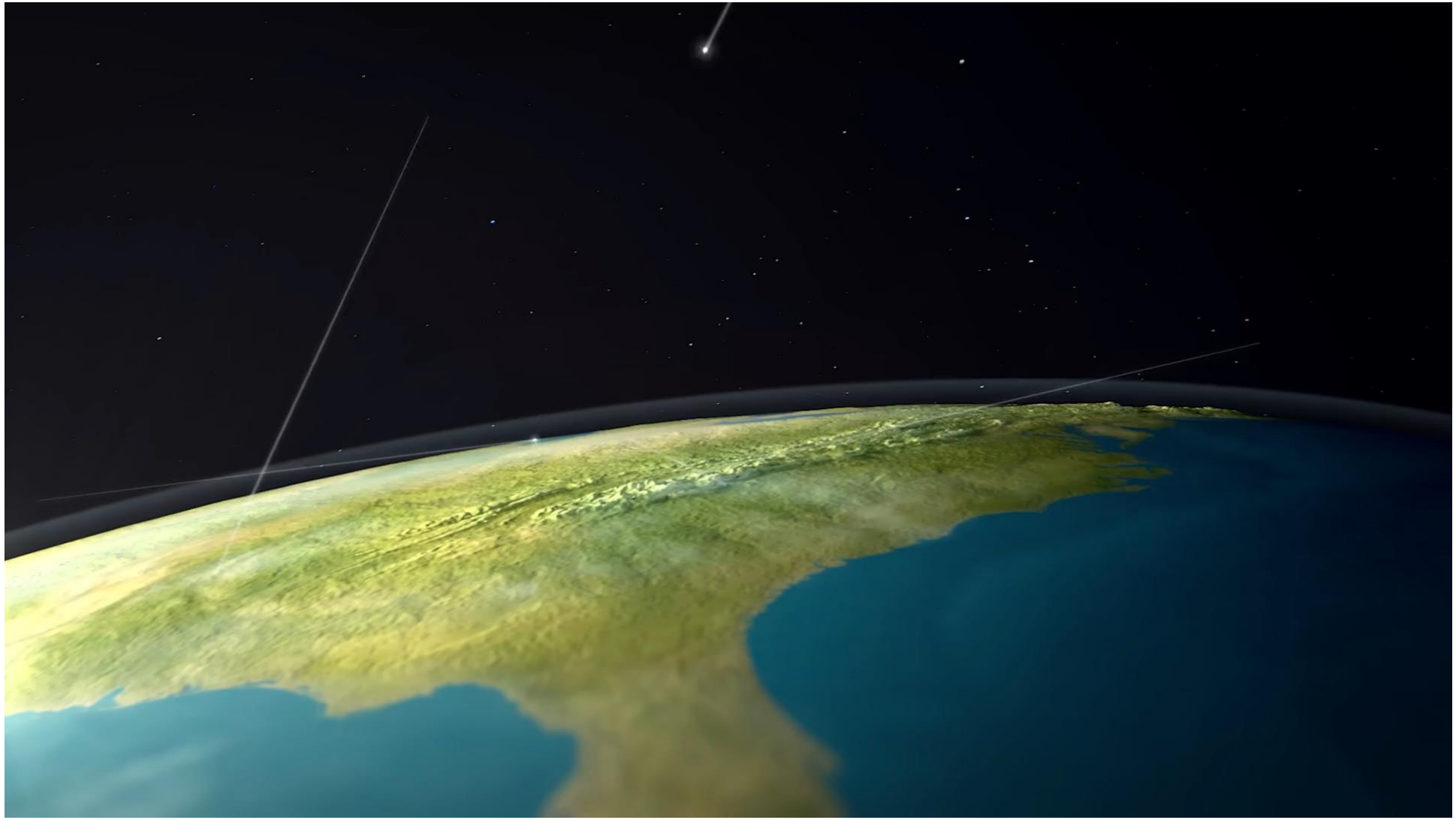


FIGURE 18 – Schéma expliquant le principe de coïncidence entre deux détecteurs à rayons cosmiques.

FIGURE 26 – Photos de prises de mesure.

Research Application

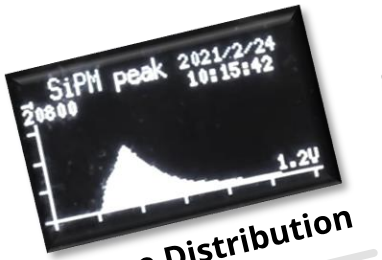


The Absurd Search For Dark Matter

[Coming SOON] Detection System Plus – SP5622B

Compact solution for Cosmic Rays Detection!

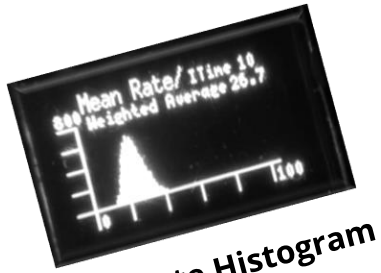
- Standalone
- External Trigger system for laboratory setups
- Fully compatible with Cosmic Hunter
- Based on SiPM detector and plastic scintillating tile
- Analog and Digital Outputs
- No Need of SW interface
- SD card to download data



Charge Distribution

Time Distribution

Cosmic Rate vs time



Mean Rate Histogram

Visualization Display

Setup Display

Thanks for your attention!

Paola Garosi on behalf of CAEN SpA

educational@caen.it