Nuclear and Particle Physics Experiments for Schools and Universities

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Educational Product Manager

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CAEN India Director

CAEN
Tools for Discovery

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

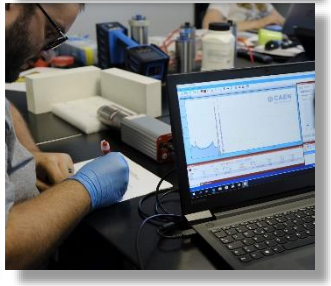
Impact

- *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.



Università degli Studi dell'Insubria

Università degli Studi di Ferrara

universidade de aveiro

Erasmus Mundus JMD on Nuclear Physics

Latin American alliance for Capacity buildING in Advanced physics LA-CoNGA physics

NI Nuclear Instruments

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.

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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

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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

2018

2019

2024

Webinars

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!

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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.

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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*


SP5600C
Edu Gamma Kit


SP5701
EasyPET Kit


SP5700
EasyPET

SP5620CH
Cosmic Hunter


SP5600AN
Premium Version


SP5600EMU
Emulation Kit

SP5630EN
Environmental kit


SP5600D
Edu Beta Kit

SP5630ENP
Environmental kit Plus


SP5600E
Edu Photon Kit

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Tools for Discovery

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

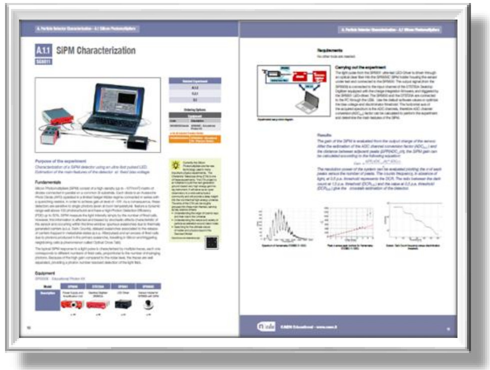
Pulse Processing: Open FPGA

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

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A lot of experiments on handy!

Nuclear Physics and Radioactivity

γ Spectroscopy

SP5600C

- ✓Detecting γ-Radiation
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SP5600D

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Nuclear Imaging - PET

SP5701

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

γ Environmental Radioactivity (outdoor)

SP5640

- ✓Environmental monitoring in land field
- ✓ Ground Coverage Effect on the Environmental
- ✓ Human Body Radioactivity
- ✓ Environmental detection as a function of the s
- ✓ Radioactivity maps production
- ✓ Radiological evaluation of the building materia
- ✓ Geochemical and mineral exploration

γ Environmental Radioactivity (indoor)

SP5630EN

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

GM Detectors

SP5660

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

Particle Physics

Photons

SP5600E

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

Cosmic Rays

SP5620CH

- ✓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
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Particle Detector Characterization

SP5600E

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- ✓ Measurement of Photomultiplier Plateau Curves

Pulse Processing: Open FPGA

coming soon

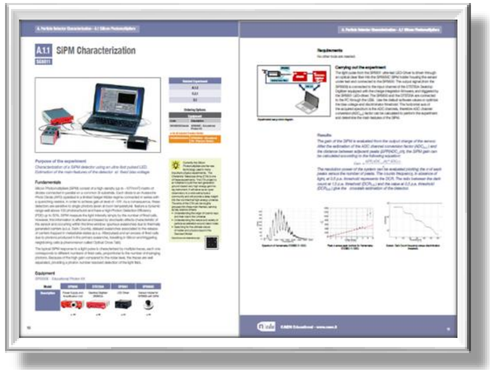
SP5650

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

SP5600AN

Advanced Statistics..

Short Guide



Main Topics:

- *Experiment task*
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- *Equipment list*
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- *Quick guide*
- *Experimental results*

Detailed Guide

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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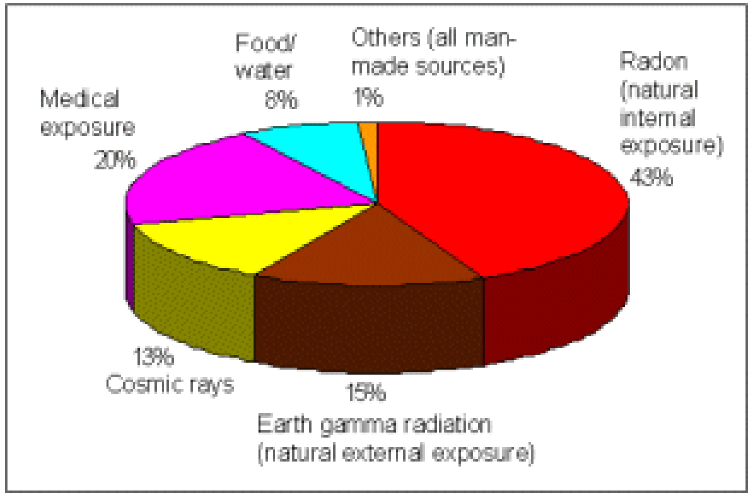
Environmental Radioactivity

Radiation is a natural part of our environment!

Radioactive sources:

- *Natural*: NORM (Naturally Occurring Radioactive Material), soil, water, air and food contribute to our exposure to ionizing radiation
- *Cosmic rays*
- *Industrial*: nuclear elements produced by industry
- *Medicine*: nuclear medicine
- *Military*



https://www.who.int/ionizing_radiation/env/en/

Radioisotope types

Natural radionuclides

[mean abundance]:
- ^{40}K [2-2.5] %
- $^{238,235}U$ [2-2.5] ppm
- ^{232} Th [8 -12] ppm
- All has an half life $T_{1/2}$ > than the age of the solar system

Cosmic rays

Muons -> The intensity depends on the altitude and direction (N/S vs E/W)

Radionuclides from cosmic rays
- ^{14}C,^{7}Be,^{3}He

Energy Distribution in Cosmic Rays
W. G. Pollard
Phys. Rev. ***44****, 703 – Published 1 November 1933*

Artificial radionuclides

- From bombs or Nuclear power plants (ex. ^{137}Cs, actinides)
- Industrial (^{133m}Xe, ^{133}Ba, ^{241}Am) and medical (^{19}F, ^{67}Ga) radioistopes

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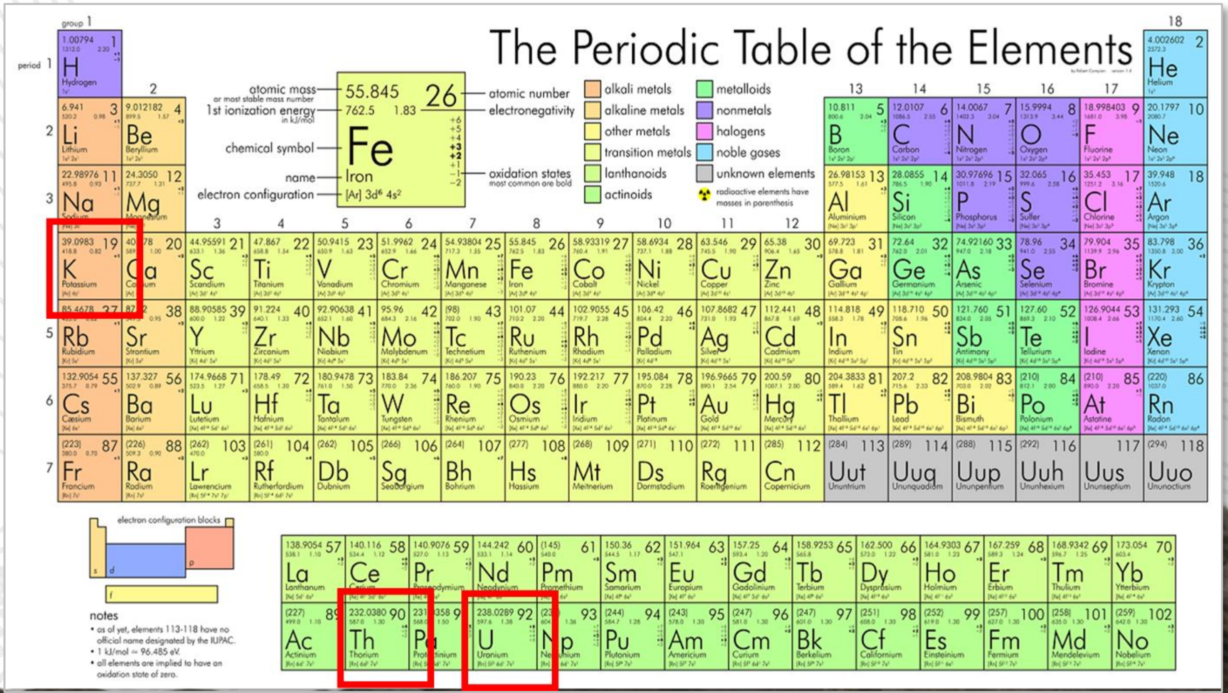
Natural Gamma Emitters

During the creation of the Earth, most of the elements initially produced were radioactive and they have been decayed to more stable forms.

The original radioactive elements still present on Earth are those that have a halftime comparable to the Earth. They are responsible for environmental radioactivity and internal warming of the planet and originate from elements very heavy without stable isotopes.
They mostly decay through the α and β channels



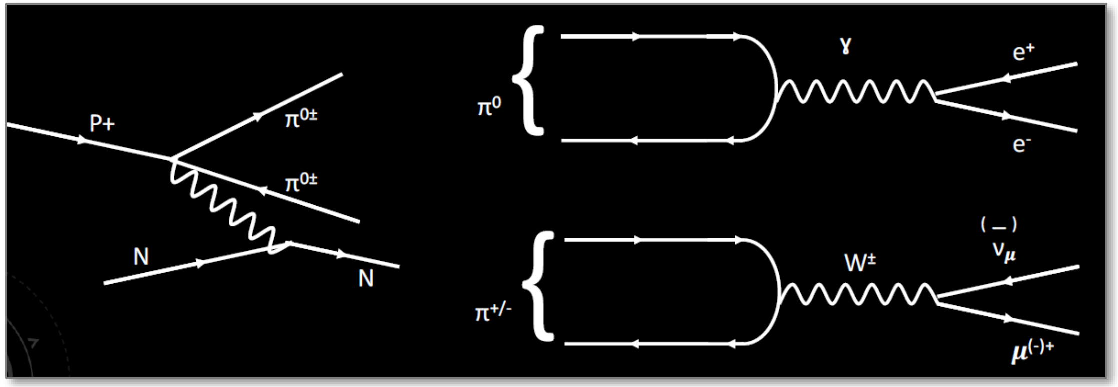
Element	Radioisotopes	Isotopic Adundance	Half time	Tipycal Adundance
Potassium	^{40}K	0.012%	1.3×10^{9} anni	0.02 g/g [2%]
Uranium	^{238}U	99.3 %	4.5×10^{9} anni	2-3 μg/g [ppm]
Thorium	^{232}Th	100 %	14.1×10^{9} anni	8-12 μg/g [ppm]

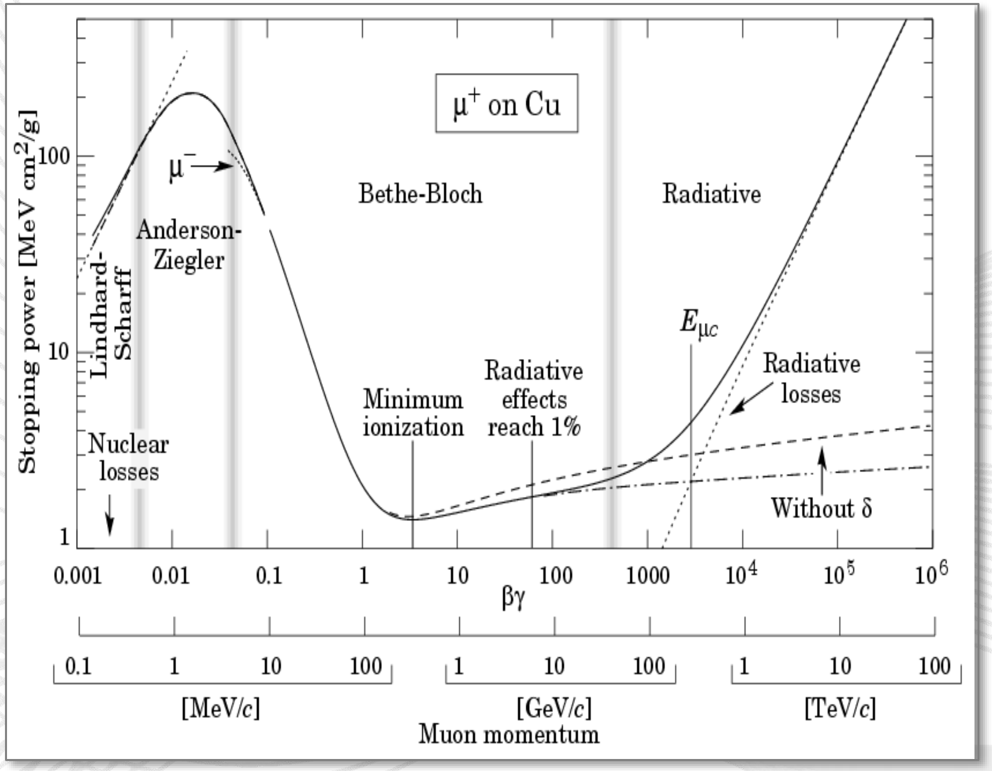
1 ton of rock

~2-3 g di U
~ 8-12 g di Th
~ 20-25 kg di K

Cosmic Rays

High energy cosmic protons collide with atmospheric nuclei and produce **hadrons showers.** The only decay that is interesting due to long lifetime are pion channels.
π^0 channel decay produce **$e^\pm$** but in atmosphere the did not have a long rage. Otherwise **$\pi^\pm$ decay $\mu^\pm$** in and they have a longer range





The Cosmic rays at sea level are made by high energy muons (**mean energy 4 GeV**), pions, proton and other soft component.

- The soft component is about 30% of total CR flux (according to PDG, 2017)
- The high energy protons fraction is 3.5% of total high energy muon flux
- Energy spectrum flat above 1GeV, than from range 10-100 GeV flux goes as $E^{-2.7}$

Muons $\{m_\mu = 105.7\ MeV/c^2\}$

- Electromagnetically interaction (or weakly)
- Not stable -> $\tau(\mu) = 2.2\times10^{-6}$s
- Produced at ~15km altitude
- Mean energy @ground ~4GeV
- Mean high μ energy flux at sea level (PDG)

$$I_v = 0.82 * 10^{-2} \frac{1}{sr*s*cm^2}$$

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Educational Kits Suitable for Young Students Also!

Interesting educational program focused on the environment that surrounds us!

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NEW Educational kits suggested for the environmental radioactivity experiments

Indoor solutions!

SP5630EN
Environmental kit

SP5630ENP
Environmental kit Plus

SP5660
RockyRAD

SP5640
Gamma EDU

Outdoor solutions!

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Tools for Discovery

NEW SP5630 Environmental kit

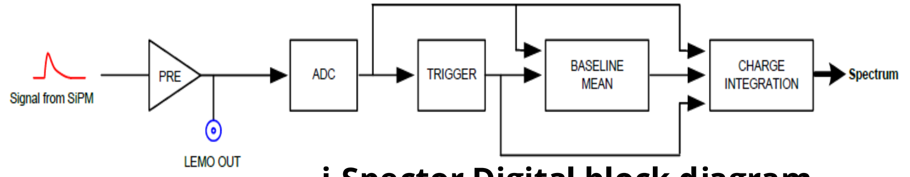
Environmental gamma radiation measurements with SiPM based instrumentation!

Samples

S2570 - i-Spector Digital

Web-based GUI for unit control and data analysis

- The system is based on a SiPM area 18 ×18 mm^2 **Hamamatsu S14160-60520HS** 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 x 18 x 30 mm^3
- Energy Range: 30 keV to 3 MeV
- Energy Resolution (FWHM): <6 % @ 662 keV
- Connectivity: Ethernet
- Software: Web GUI



i-Spector Digital block diagram

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NEW SP5630ENP Environmental kit Plus

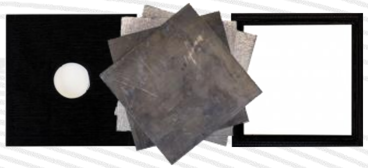
Gamma Radiation and Shielding Laboratory

The **SP5630ENP Environmental kit Plus** guide the users towards the development of complementary measurement techniques based on counting and on the analysis of the spectrum. The main goal is the study of the absorption of the gamma rays passing through matter thicknesses and the related observations about the different crossed materials. It is a user-friendly system for Advanced Labs based on the latest technologies and instrumentation.

S2570D i-Spector Digital
18x18mm^2 - CsI ASSEMBLY

BGO scintillating crystal

SP5630EN
Environmental kit Plus



Shielding Kit

Samples

Web-based Software

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γ Environmental Radioactivity (indoor)

			Equipment											
Section	**Subsection**	**Experiment**	SP5600C	SP5600D	SP5600E	SP5600AN	SP5600EMU	SP5700	SP5701	SP5620CH	**SP5630EN** ★	SP5640	SP5630ENP ★	SP5650
Nuclear Physics and Radioactivity	**γ Environmental Radioactivity (indoor)**	*Energy calibration of System based on LYSO crystal*									●		●	
		Background Measurements									●		●	
		Fertilizer and photopeak identification									●		●	
		IdentificationTest Sample									●		●	
		Soil sample identification									●		●	
		Samples Comparison									●		●	
		Radon passive measurements									●		●	

Recommended kits

SP5630ENP Environmental kit Plus **SP5630EN Environmental kit**

Alternative Choice

SP5640 GammaEDU **Samples**

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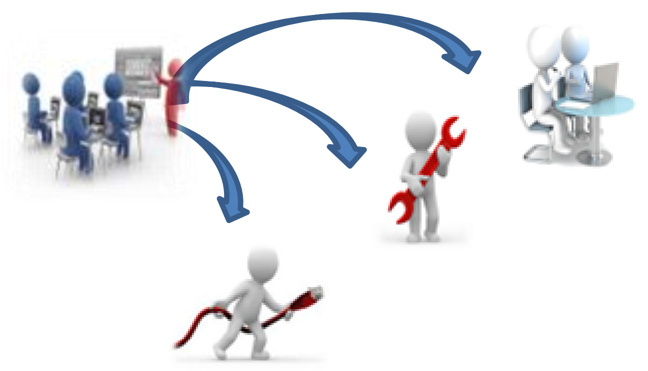
Hands-on

SP5630EN – Environmental Kit



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NEW Educational kits suggested for the environmental radioactivity experiments

Indoor solutions!

SP5630EN
Environmental kit

SP5630ENP
Environmental kit Plus

SP5660
RockyRAD

SP5640
Gamma EDU

Outdoor solutions!

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Tools for Discovery

NEW GammaEDU - SP5640

Portable detection backpack for environmental radioactivity!

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

Suitable for High School Students!

RADIOLAB

INFN Istituto Nazionale di Fisica Nucleare

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NEW GammaEDU - SP5640

Tablet

Tablet 10’ with GammaEDU Application

Digital MCA Unit - S2580 - GAMMASTREAM

- High Voltage Power Supply (0 ÷ +1500V/500 μA) - Charge Sensitive Preamplifier - digital Multi-Channel Analyzer (12-bit and 62.5 MHz ADC) for scintillation spectroscopy
- Coupled with NaI(Tl) with a 14-pin PMT
- Full stand-alone operation with embedded CPU, data storage (SSD) unit, and power supply for up to 6/8 hours operation
- Wired and wireless connectivity via USB, Ethernet, Wifi and Bluetooth
- Acquisition modes: PHA, PHA with time stamp, Signal Inspector

General Properties

Density(g/cm^3)	3.67
Melting point(K)	924
Wavelength of emission peak(nm)	415
Light output(Photons/Mev)	40,000
Decay time(ns)	264
Cleavage plane	(100)
Hygroscopic	Yes
Refractive index	1.85
Hardness(Mho)	2

NaI(Tl) Scintillator

Thallium doped sodium iodide, NaI(Tl), is the most widely used scintillation material, it has the greatest light output and convenient emission range

Dimension: 0.3 l

Applications

- Environmental Gamma detection and spectroscopy
- Mapping of potential radon-prone areas
- Environmental monitoring in land field
- Geochemical and mineral exploration
- Statistics
- Customs protection and border control

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NEW GammaEDU App

Measurement Results

Geolocation
Picture
^{40}K, ^{214}Bi, ^{208}Tl Isotopes CPS
^{40}K, ^{238}U, ^{232}Th Abundances

Data

Displayed on Google Earth
.kmz file
Easy to share

Interface

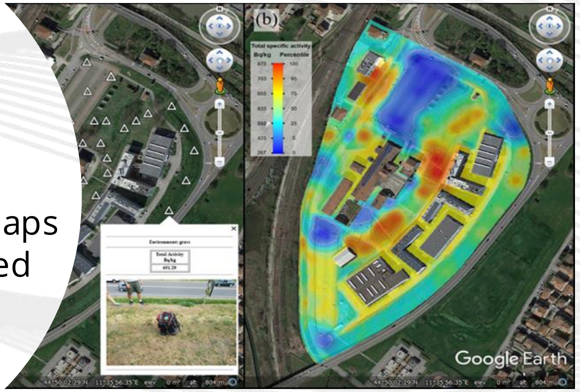
Bluetooth connection

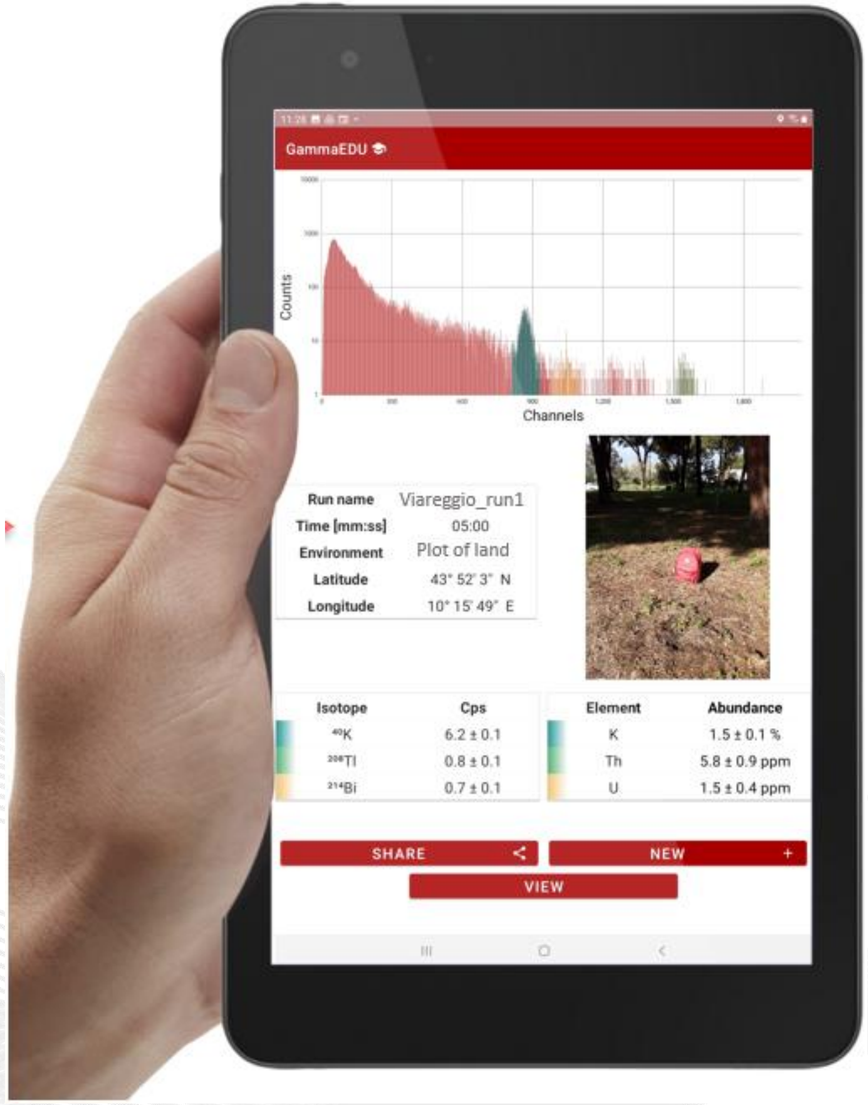
Maps development

Studies in the field of earth sciences

Coming SOON

New software for creating maps with color intensity associated with local radioactive contribution!





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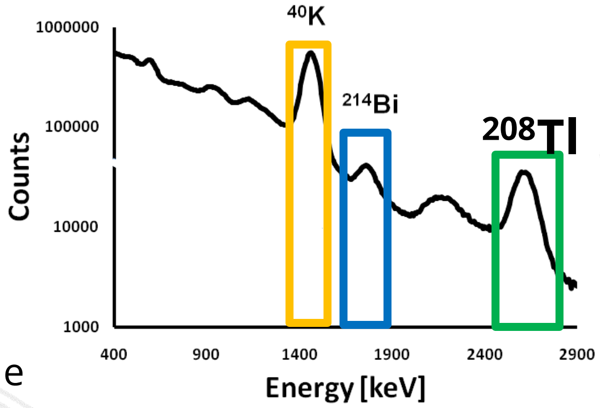
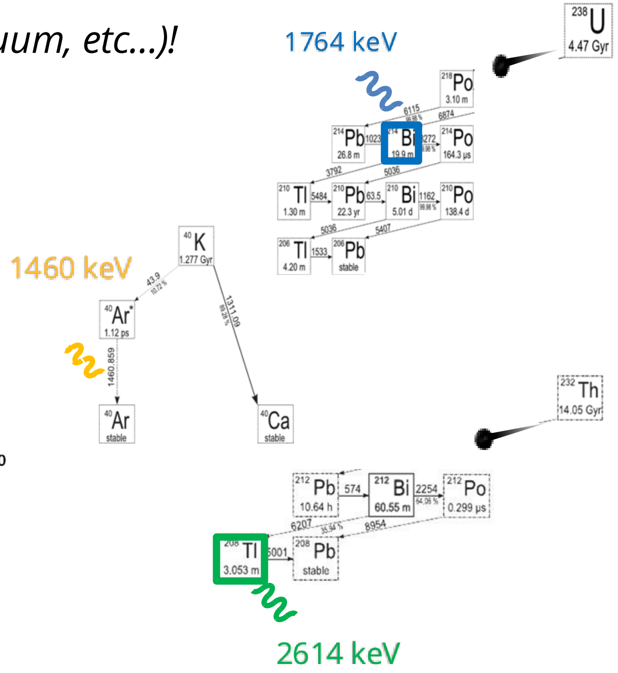
ROI Definition & Spectra Analysis

Definition of the **Region(s) of Interest (ROI)** of the energy spectra. These windows are used to define the photopeak regions required to calculate the correspodant areas (integral of the ROI).

NOTE: *In every ROI there are different contribution effects (photopeak, compton continuum, background continuum, etc...)!*

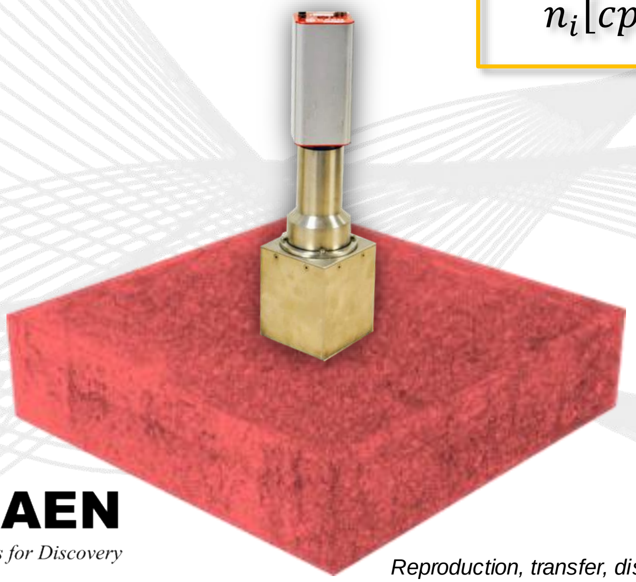
Window	Isotope	Photopeak Energy (keV)	ROI (keV)
Potassio	^{40}K	1460	1370-1570
Uranio	^{214}Bi	1765	1660-1860
Torio	^{208}Tl	2614	2410-2810





Count rate: number of counts per unit of time

$$n_i[cps] = \frac{N_i[conteggi]}{T[s]}$$



Calibration: from counts to the abundancies

N(cps) = A·S

S = A⁻¹·N

$$N(cps) = A \cdot S \qquad S = A^{-1} \cdot N$$

S is the sensitivity coefficient of the detector

$$A = N \cdot S^{-1}$$

Calibration site characterized by known abundancies (A) of U, Th and U.

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γ Environmental Radioactivity (outdoor)

Section	Subsection	Experiment	Equipment									
			SP5600C	SP5600D	SP5600E	SP5600AN	SP5600EMU	SP5700	SP5701	SP5620CH	SP5630EN	**SP5640**
Nuclear Physics and Radioactivity	**γ Environmental Radioactivity (outdoor)**	*Environmental monitoring in land field*										●
		γ Environmental Detection as a function of the soil distance										●
		Radioactivity maps production									●	●
		Mapping of potential radon-prone areas									●	●
		Geochemical and mineral exploration									●	●

Recommended kits

SP5640
GammaEDU

Alternative Choice

SP5630EN
Environmental kit

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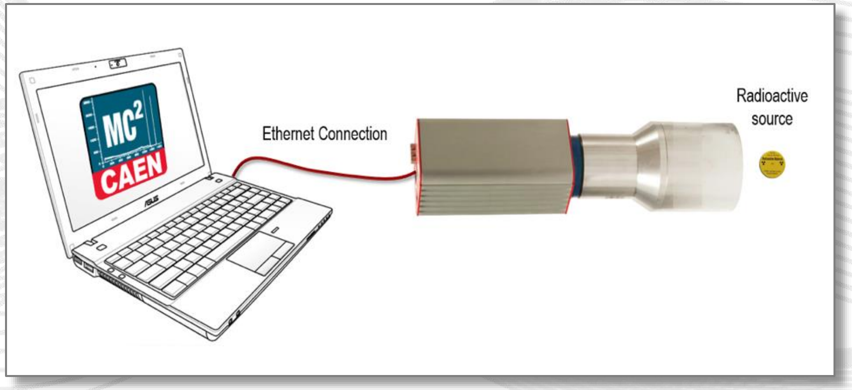
Tools for Discovery

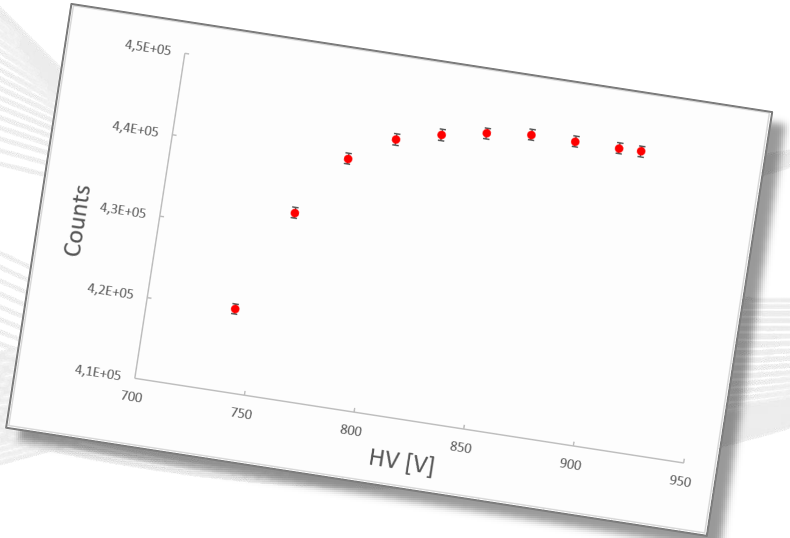
Photomultiplier Tube (PMT)

Recommended kits

SP5640
GammaEDU

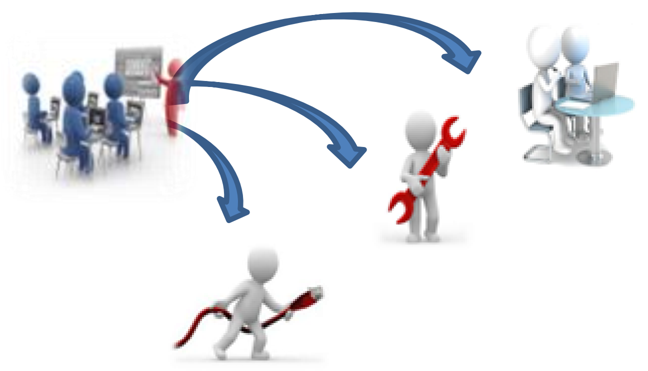
			Equipment									
Section	**Subsection**	**Experiment**	SP5600C	SP5600D	SP5600E	SP5600AN	SP5600EMU	SP5700	SP5701	SP5620CH	SP5630EN	**SP5640**
Particle Detector Characterization	**Photomultiplier Tube (PMT)**	*Measurement of Photomultiplier Plateau Curves*										●





Hands-on

SP5640 – GammaEDU



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Indoor solutions!

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Environmental kit

SP5630ENP
Environmental kit Plus

SP5660
RockyRAD

SP5640
Gamma EDU

Outdoor solutions!

CAEN
Tools for Discovery

NEW

RockyRAD

Portable geiger counter for nuclear radiation

Geiger module

- Geiger Module GM J305
- Display OLED 128x64 pixels 1.54”
- Measuring range: 10 nSv/h – 50 μSv/h
- Sensitivity: 44 CPS/10 μSv/h (relative to ^{60}Co)
- Size: 71 * 136 * 43.8 mm^3
- Bluetooth connection

Battery-powered

- Rechargeable Li-Ion battery, 3.7Vdc, 10Ah, 37Wh
- Power Consumption ~ 0.05W
- Power Supply: 5 V (USB-C)

Set of Rocks and Minerals included

Each RockyRAD kit includes diverse rock samples for immediate detection experiments.

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NEW App

Key Features

Start new measurement sessions
Capture photographic evidence linked to specific readings
Specify measurement intervals
Organize and review collected data effectively

Display information

Total Counts
Counts Per Minute
Equivalent Dose Rate

Interface

Bluetooth connection

RockyRAD application requires Android™ mobile with Android™ release from 11.

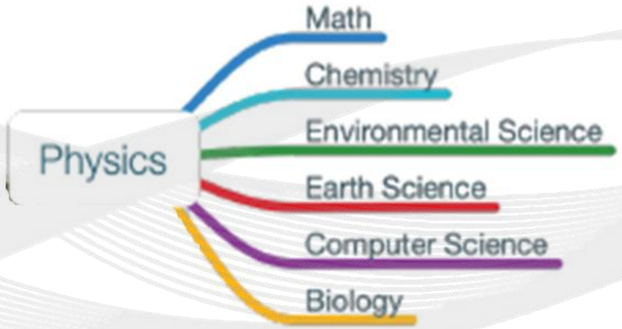
GM Detector

Section	Subsection	Experiment	SP5600C	SP5600D	SP5600E	SP5600AN	SP5600EMU	SP5700	SP5701	SP5620CH	SP5630EN	SP5640	**SP5660**
Nuclear Physics and Radioactivity	**GM Detector**	*Statistics: Uncertainty as a function of live time*											✸
		Environmental Background											✸
		Lead Shielding Effect on Environmental Radioactive Background											✸
		Detecting Ionizing Radiation											✸
		Samples Comparison											✸

Equipment

Recommended kits

SP5660
RockyRAD



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RockyRAD_ References

CPM	Estimated Dose Rate [nSv/h]	Environment and Comments
14-34	114-274	Typical natural background radiation, corresponding to an annual dose of 1-2.4·10^3 μSv.
28-48	228-388	Represents an increase of 10^3 μSv per year compared to the typical background, aligning with the public exposure limit.
281	2282	The standard annual exposure limit for radiation workers in the nuclear industry, equating to 2 ·10^4 μSv.
493	4000	Exposure at this level during high-altitude flights is generally safe due to the limited duration of flights. The same dose rate near a ground-based source would necessitate caution and protective measures, highlighting the importance of exposure context.
6000	48720	Maximum detectable scale by the Rockyrad device.

[1] United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation, united nations scientific committee on the effects of atomic radiation (UNSCEAR) 2008 report, volume I: Report to the general assembly, with scientific annexes A and B-sources. United Nations, 2010.
[2] ICRP, International Commission on Radiological Protection. "Dose limits". ICRPedia. ICRP. Retrieved 26 April 2022.
[3] Directive 2013/59/Euratom - protection against ionising radiation". European Agency For Safety And Health At Work. European Agency For Safety And Health At Work. Retrieved 26 April 2024.
[4] Shea, M.A.; Smart, D.F. (August 2001). Comment on Galactic Radiation Dose to Air Crews. 27th International Cosmic Ray Conference. Bibcode:2001ICRC...10.4071S.

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Hands-on

SP5660 – RockyRAD

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NEW Educational kits dedicated to the Cosmic Rays detection

SP5620CH – Cosmic Hunter

SP5622B – Detection System Plus

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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.

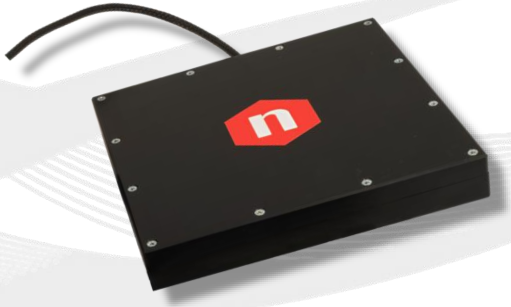
SP5621 Coincidence Unit

- 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.

- ***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***

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°



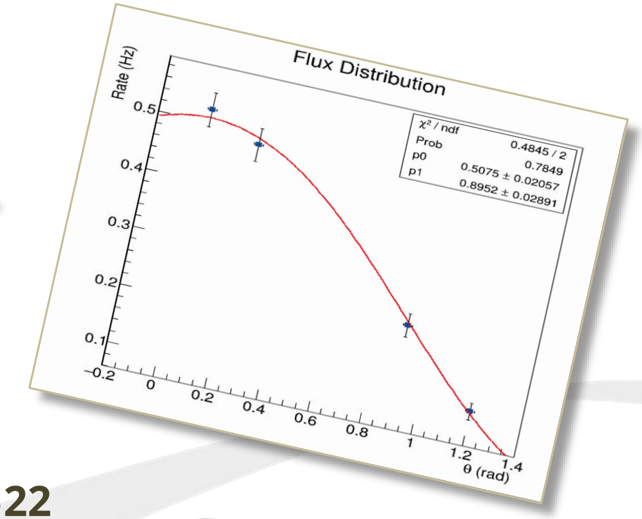
NEW Cosmic Hunter – SP5620CH

- ***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***

Additional Tools

SP5609
Telescope Mechanics

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



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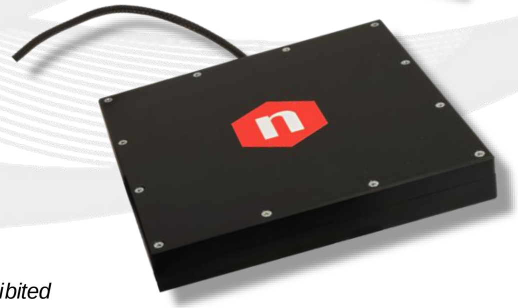

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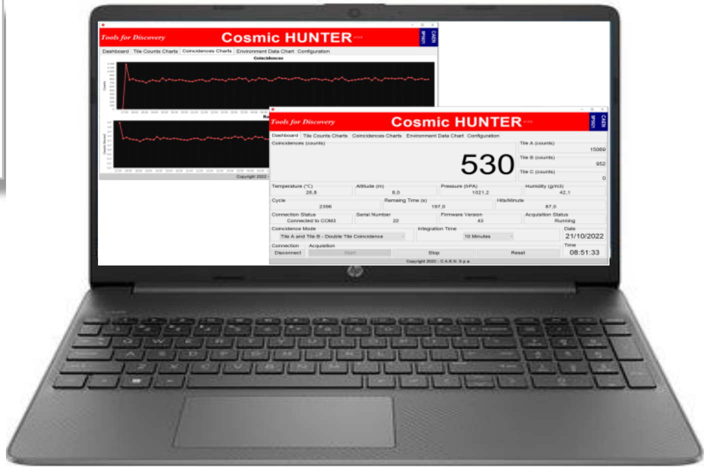
NEW Cosmic Hunter – SP5620CH

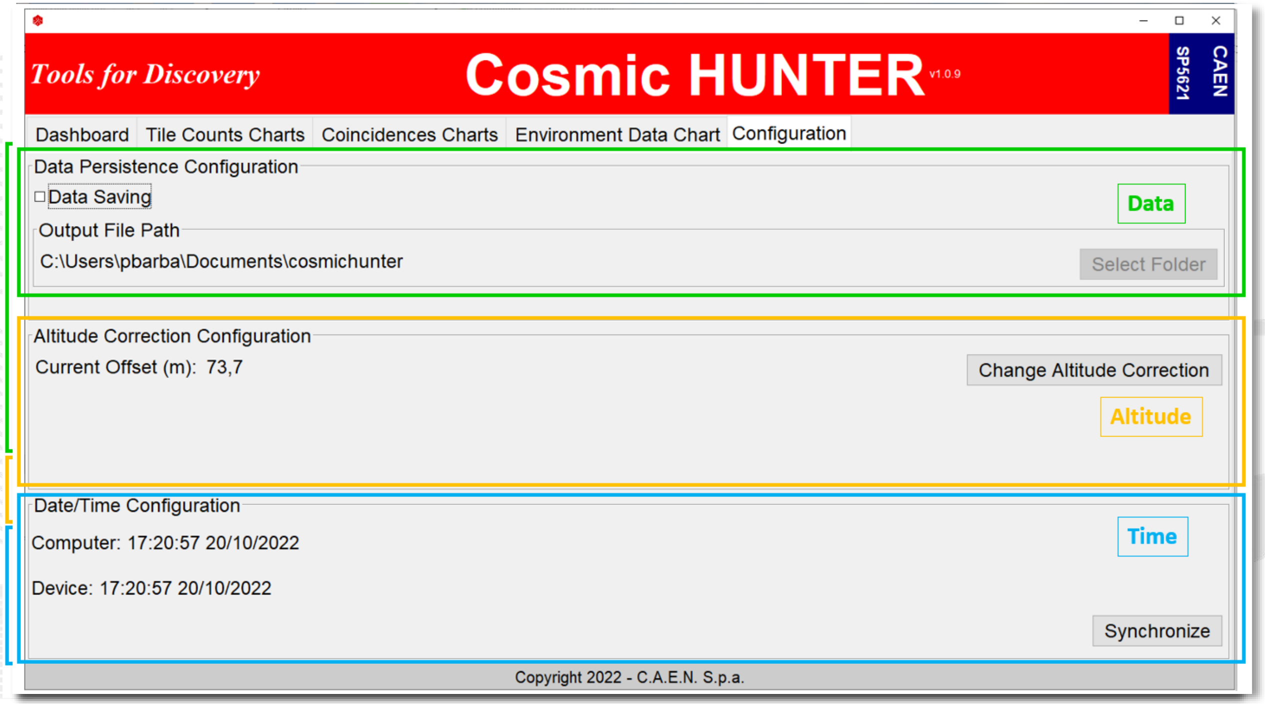
CSMHUNT-2019114164338

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

Cosmic Hunter Software



- ***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***
- ***New Management Software***



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Cosmics

Section	Subsection	Experiment	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

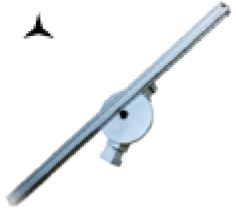
SP5600AN
Premium Version kit

SP5620CH
Cosmic Hunter

Alternative Choice

O


SP5608
Scintillating Tile

⅄


SP5609
Telescope Mechanics

◎


SP5622
Detection System

This symbol suggests the kit use for young students!

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Outreach & Balloon Experience

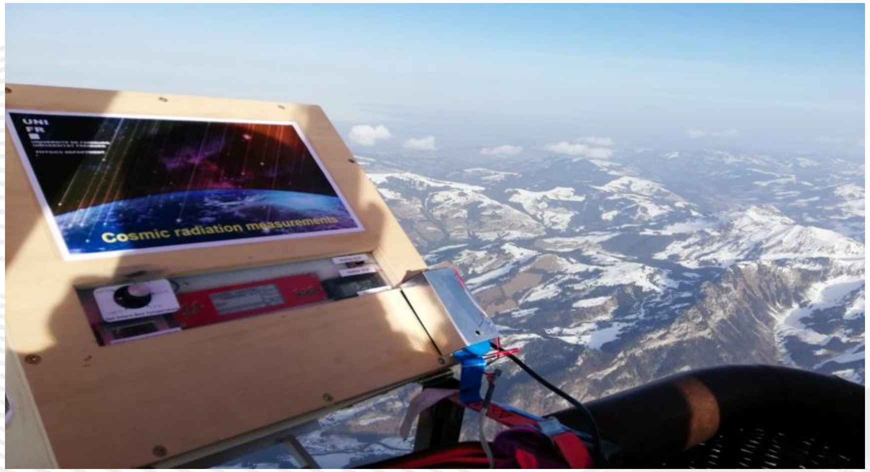
INFN OCRA Outreach Cosmic Ray Activities

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

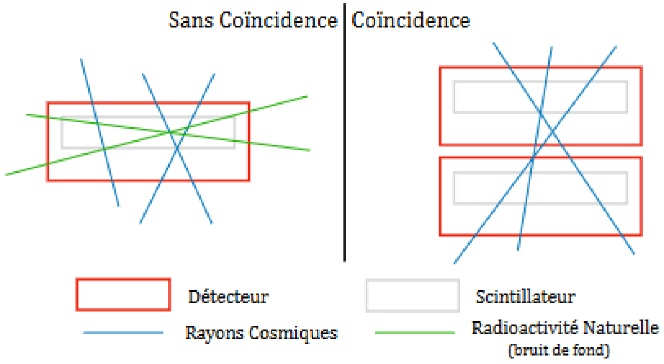


FIGURE 18 – Schéma expliquant le principe de coïncidence entre deux détecteurs à rayons cosmiques

FIGURE 26 – Photos de prises de mesure.

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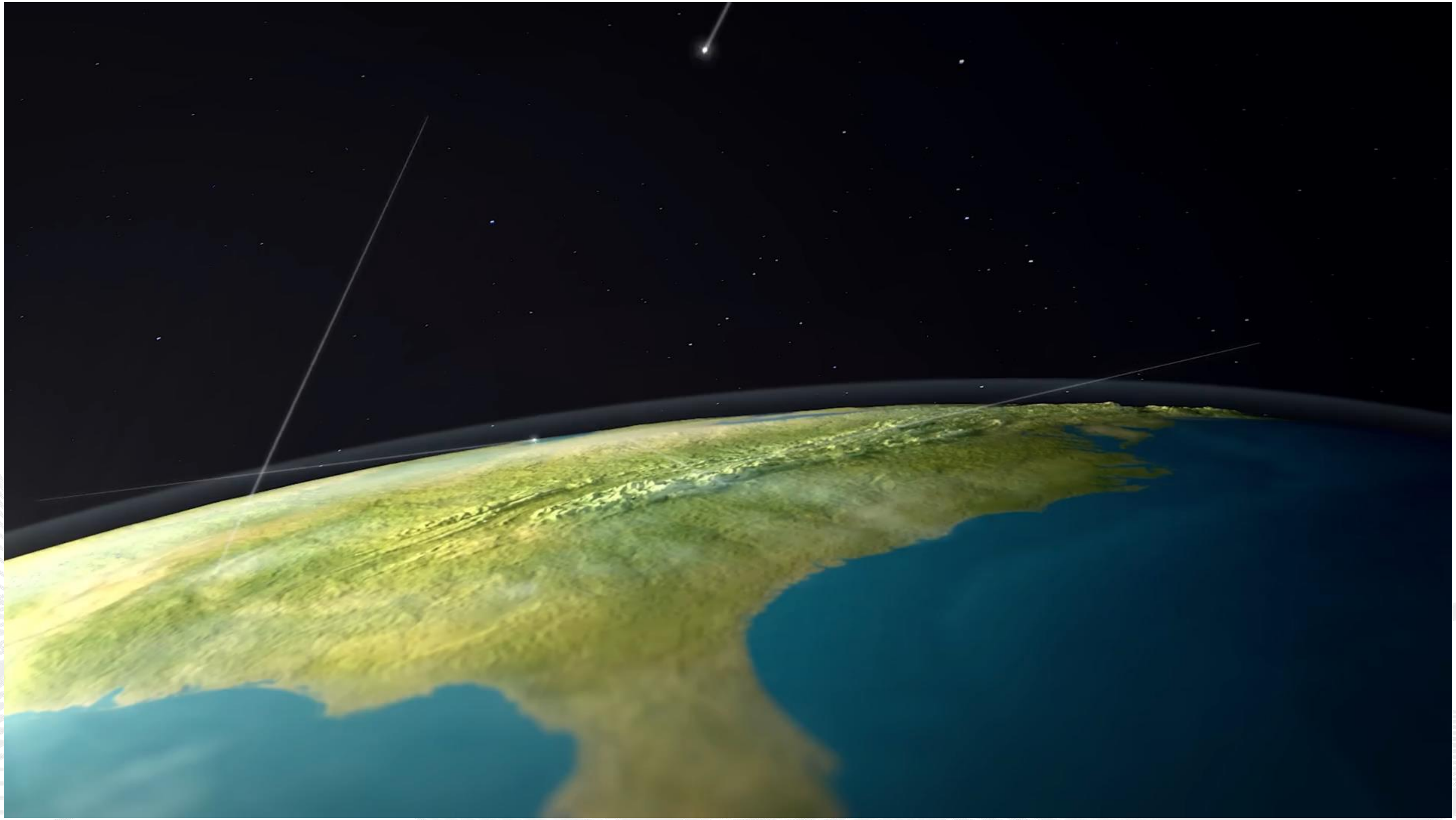
Research Application



The Absurd Search For Dark Matter

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Hands-on

SP5620CH – Cosmic Hunter

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Tools for Discovery

NEW Educational kits dedicated to the Cosmic Rays detection

SP5620CH – Cosmic Hunter

SP5622B – Detection System Plus

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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 Needs SW interface
- ❑ SD card to download data

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Thank you!

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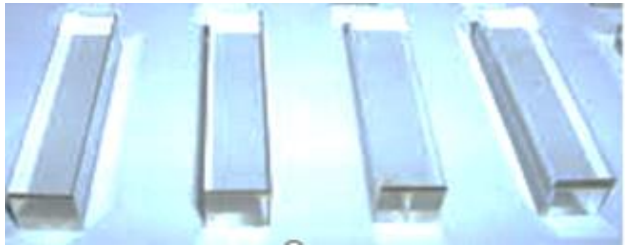
Spares Slides
SP5630EN

Samples

LYSO (Lu1.8Y.2SiO5:Ce) (Cerium-doped Lutetium Yttrium Orthosilicate) Scintillating Crystal

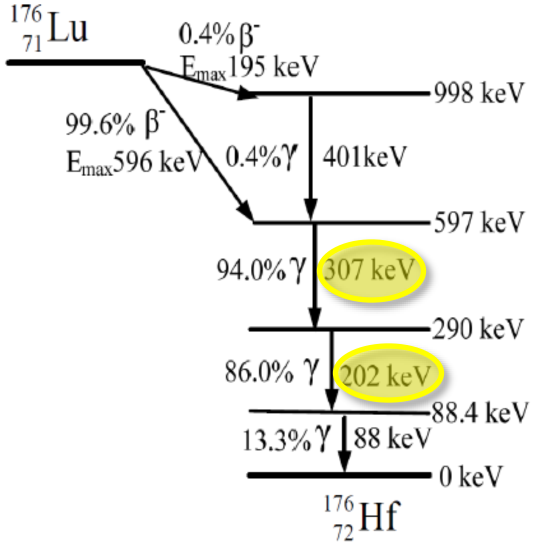
Scintillator based on Lutetium (Lu) like **LSO** and **LYSO** (**Lu1.8Y.2SiO5:Ce**) are usually used in PET applications thanks to their high stopping power (high Z), high light yield and very short decay time (very fast signals). It is a non-hygroscopic scintillator.



Properties	Value
Cleavage Planes	None
Decay Constant (ns)	40
Density (g cm^{-3})	7.1
Emission Spectral Range (nm)	380-480
Melting Point (K)	2323
Peak Scintillation Wavelength (nm)	420
Photons/MeV	32000
Radiation Length (cm)	1.15
Refractive Index at Peak Emission	1.81
Solubility (g/100g H_2O @ 300K)	Insoluble
Stability	Good
Structure	Cubic

2,6% of the natural Lu is ^{176}**Lu**, a radioisotope with a long half life decaying via two different beta decays followed by gamma emissions.

$T_{1/2} \sim 3{,}6 \times 10^{10}\ y$



Potassium Phosphate fertilizer

Rocks

Test Sample

One of the radioactive objects of common use, in past especially.

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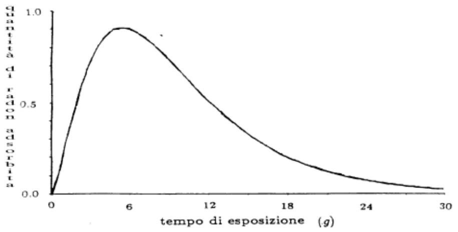
Samples (2)

Canisters of Activated Carbon for Radon Passive Measurements

- Diameter: 10 cm
- Height: 3 cm
- Content: 70 g of activated carbon



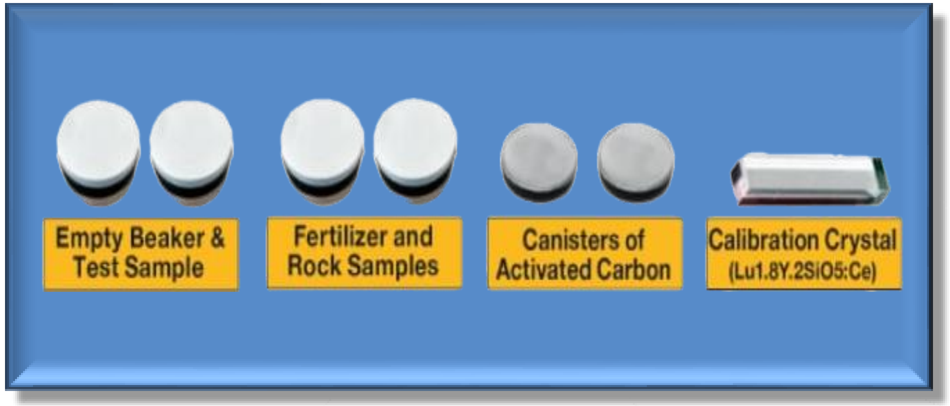
The activated carbons are enclosed in metal containers called "canisters".
Covered by a thin double-mesh metal mesh (diffusive barrier).
The diffusion barrier serves to eliminate the air flows inside the basket, which can favor the re-emission of radon.

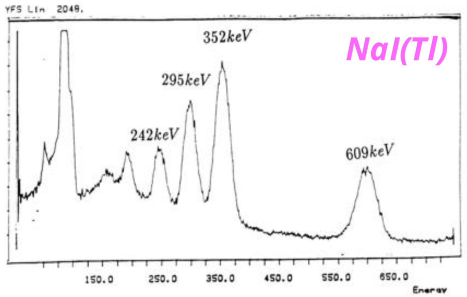
The method consists in carrying out gamma spectrometry measurements on the baskets after the radon has been adsorbed by them!

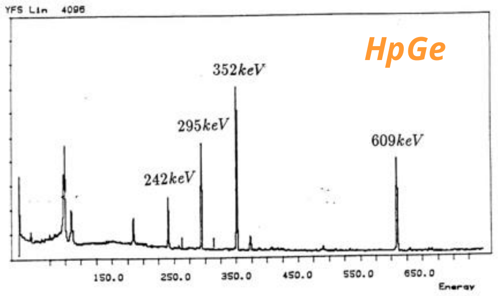
After 6-7 days, the loss due to decay prevails over the accumulation by adsorption.

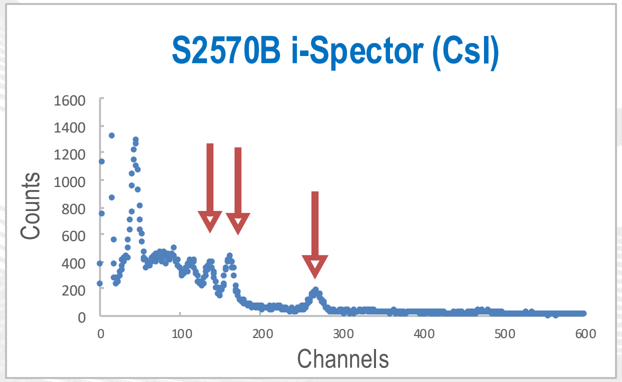
Features:

- useful for short-term measurements: 2 - 7 days
- strong dependence of the response on humidity









Gamma Energy lines:

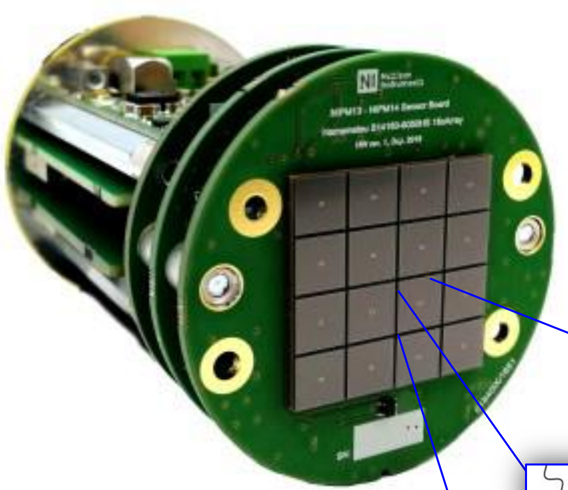
- 295 keV and 352 keV from ^{214}Pb
- 609 keV from ^{214}Bi

i–Spector Digital [S2570B-S2570D]

S2570B

S2570D

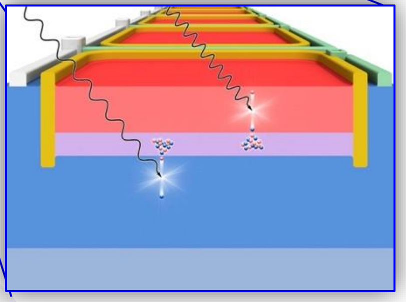
Almost equal except for their mechanics and for the components distribution on the PCBs!



- The systems are based on a SiPM area 18×18 mm^2 **Hamamatsu S14160-60520HS**

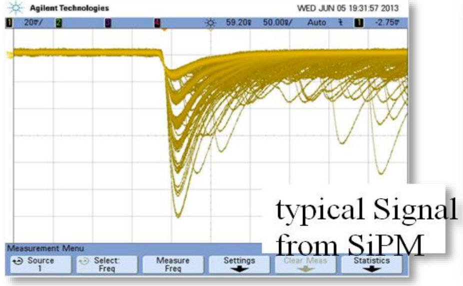
  All SIPMs of the area are connected in parallel to increase the active area of the matrix.

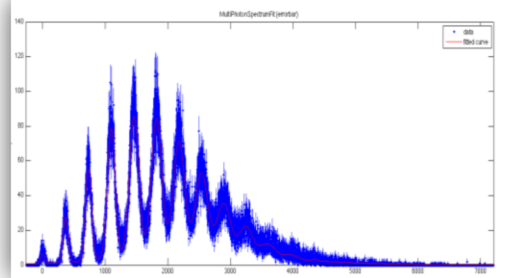
Silicon Photomultiplier (*SiPM*) are high density (up to $10^4/mm^2$) matrix of diodes with a common output, working in Geiger-Müller regime.
Each cell is a pixel with a binary signal.
It can detect a single photon!



- *High Gain*
- *Low Voltage*
- *High photon number resolving power*
- *Wide dynamic range*
- *Good timing capability*
- *Low cost*
- *Withstanding to magnetic field*

The high uniformity of pixel structure guarantees no avalanche fluctuations



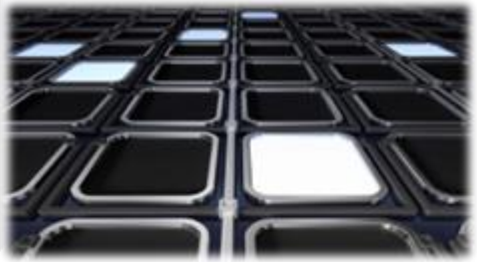


Linear response if the average number of photoelectrons/pixel is less than one

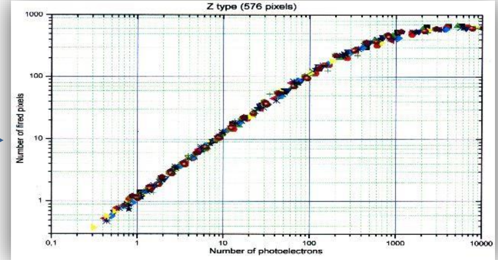
Number of pixel determines the SiPM **dynamic range**

Binary information

Analog information



$A = \Sigma A_i$



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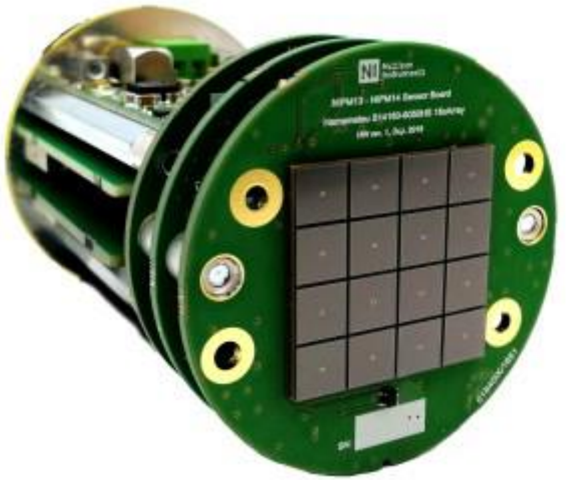
i–Spector Digital [S2570B-S2570D]

Almost equal except for their mechanics and for the components distribution on the PCBs!

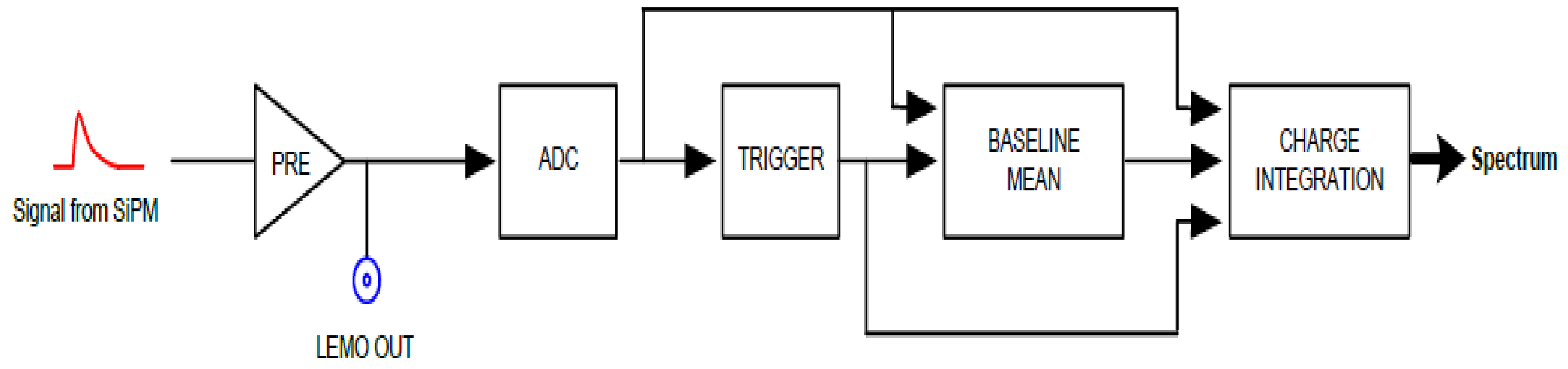


- The systems are based on a SiPM area 18 ×18 mm^2 **Hamamatsu S14160-60520HS**

  All SIPMs of the area are connected in parallel to increase the active area of the matrix.
- They integrate a shaper, a peak stretcher and a peak ADC to implement a simple MCA (4K).
- Scintillator Crystal: CsI 18 x 18 x 30 mm^3
- Energy Range: 30 keV to 3 MeV
- Energy Resolution (FWHM): <6 % @ 662 keV
- Connectivity: Ethernet
- Software: Web GUI

TECHNICAL SPECIFICATIONS

Supply Voltage	8-13V (12 V typ.)
Power consumption	3W max.
Preamplifier bandwidth	>1GHz
Preamplifier gain	x 5
Shaping time	180 ns
Output signal	- 4 … +4 V , 170 mA
HV Power supply	20-80 V (10mA)
HV accuracy	1 mV
Thermal feedback accuracy	0.01°C - 1mV
MCA nr. of channels	4096



[i-Spector Digital block diagram]

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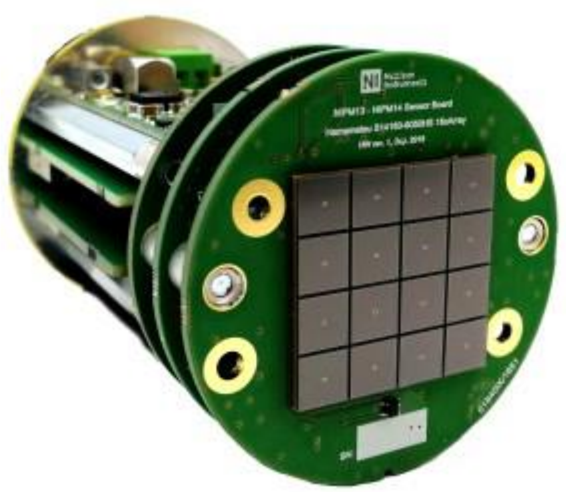
i–Spector Digital [S2570B-S2570D]

Almost equal except for their mechanics and for the components distribution on the PCBs!



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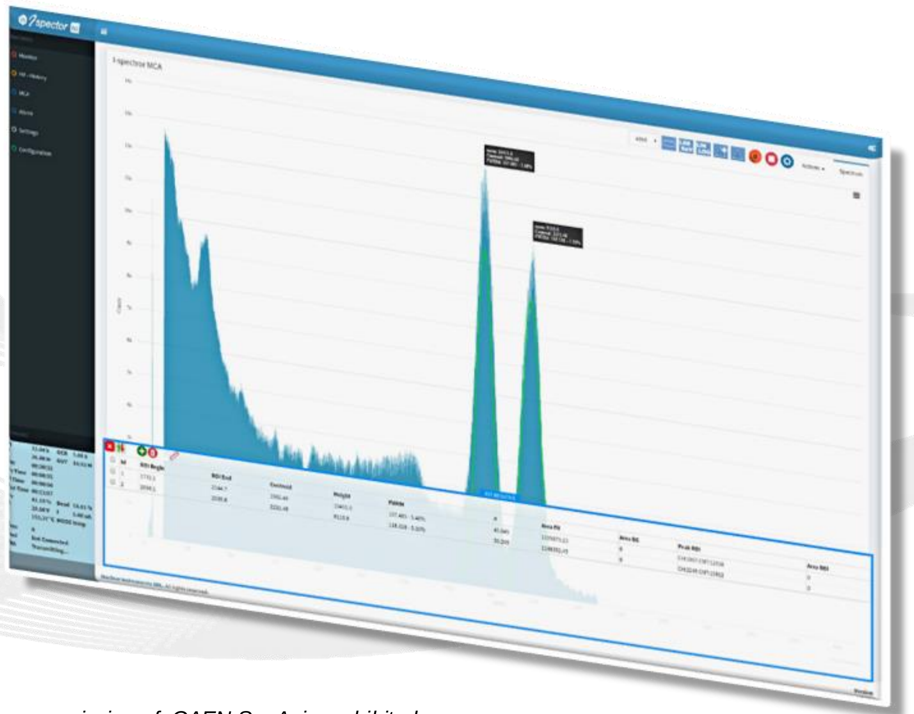
Output signal	- 4 … +4 V , 170 mA
HV Power supply	20-80 V (10mA)
HV accuracy	1 mV
Thermal feedback accuracy	0.01°C - 1mV
MCA nr. of channels	4096

Web-based GUI for unit control and data analysis

i-Spector Digital can be easily controlled through its dedicated web graphical user interface, with no needs to install a dedicated software. The user can configure the module and visualize the acquired spectrum.
Thanks to the internal circular memory buffer, the last 1-hour recording can then be downloaded by the web interface.



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Tools for Discovery

i–Spector Digital [S2570B-S2570D]

S2570B

S2570D

Almost equal except for their mechanics and for the components distribution on the PCBs!

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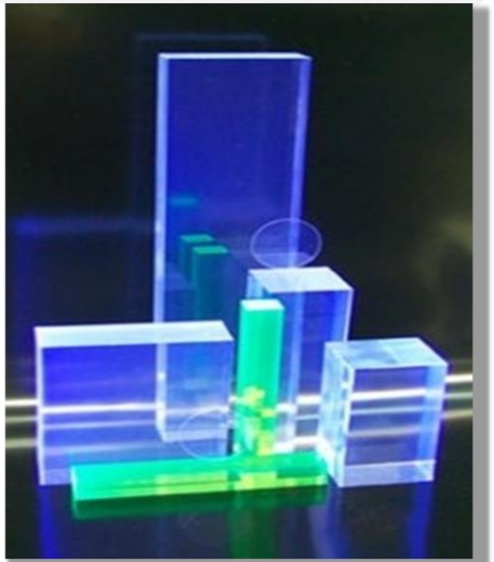
- They integrate a shaper, a peak stretcher and a peak ADC to implement a simple MCA (4K).
- Scintillator Crystal: CsI 18 x 18 x 30 mm^3
- Energy Range: 30 keV to 3 MeV
- Energy Resolution (FWHM): <6 % @ 662 keV
- Connectivity: Ethernet
- Software: Web GUI

CsI(Tl) information:
This scintillator offers a high light yield and emits at a wavelength very suitable for silicon photomultipliers (SiPMs). Typical applications include arrays of this material used in security imaging systems, such as baggage scanners.

BGO information:
A relatively hard, high density, non-hydroscopic crystal with good gamma ray absorption. Often used for PET imaging and high energy physics applications as Compton shields.



Properties	CsI	BGO
Cleavage Planes	None	None
Decay Constant (ns)	1000	300
Density (g cm^{-3})	4.51	7.13
Emission Spectral Range (nm)	350-725	350-650
Gamma and X-ray absorption coefficients (cm^{-1})	0.48 at 660keV 10.00 at 100KeV	-
Melting Point (K)	894	1323
Peak Scintillation Wavelength (nm)	550	480
Photons/MeV	52000	8500
Radiation Length (cm)	1.86	1.13
Refractive Index at Peak Emission	1.78	2.15
Solubility (g/100g H_2O @ 300K)	44.0	Insoluble
Stability	Slightly Hygroscopic	Good
Structure	BCC	Cubic
Thermal Conductivity (W·m^{-1}·K^{-1}) @ 300K	1.13	-
Transmission Range (nm)	240-70000	470-7500

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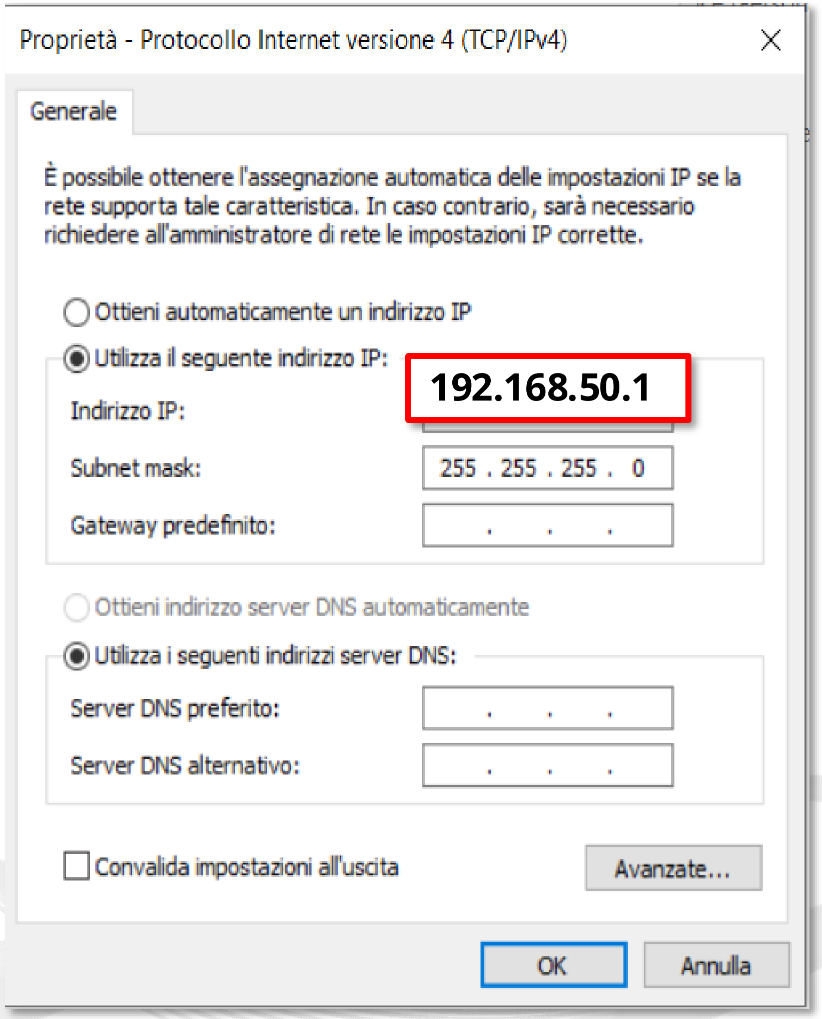
Tools for Discovery

Environmental Kit QuickStart

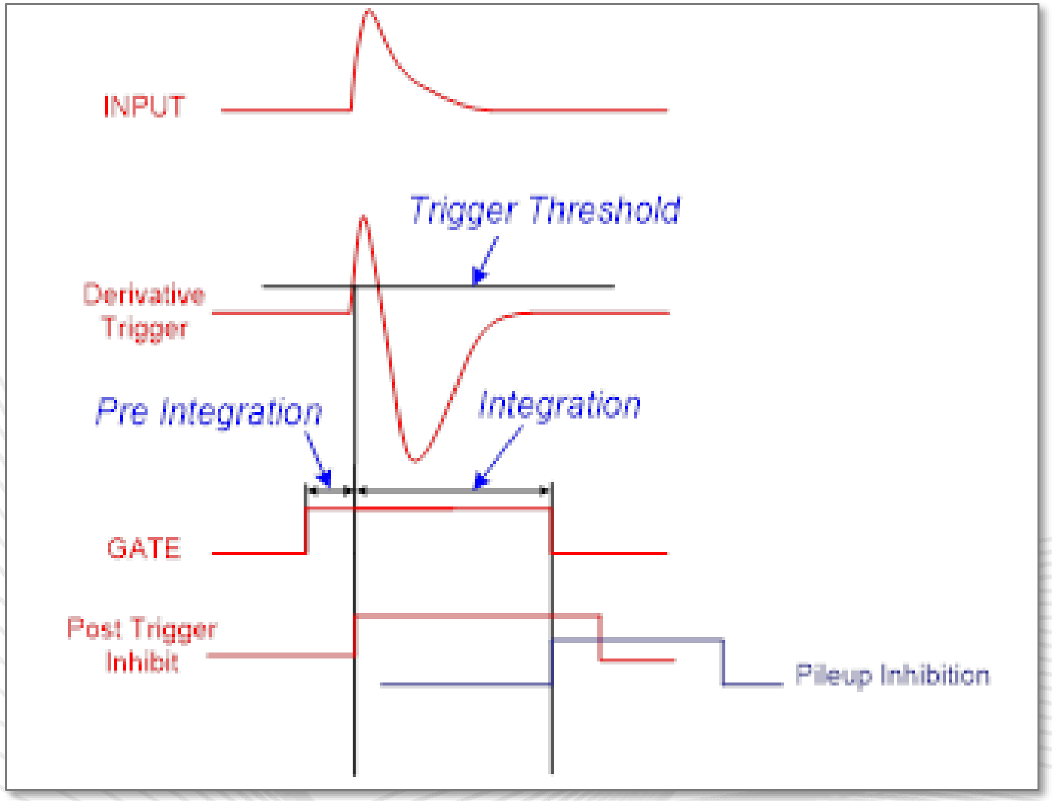
1. **Unboxing and Assembling**
2. **Software Setup**
3. Energy calibration of the system based on LYSO crystal (time base = 10’)
4. Calibration verification and tuning with Potassium Chloride sample (time run = 30’)
5. Background measurement (time run = 30’)
6. Rock sample Spectrum (time run = 30’)
7. Test sample radiation identification
8. Analysis of spectra and superposition
9. Passive Radon Measurements

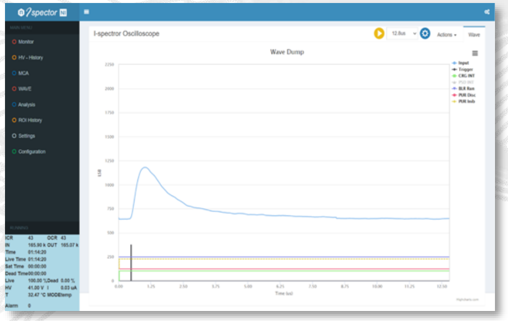
Software Setup

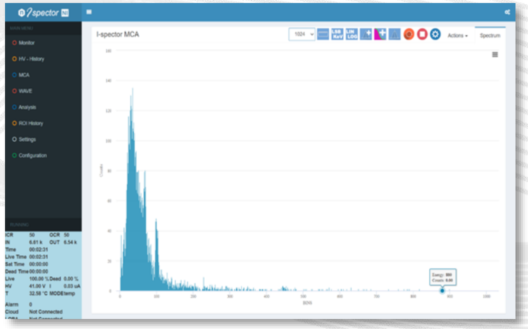
- **IP address** of the i-Spector for Ethernet connection is **192.168.50.2**
- Configure the Ethernet network of the PC from the "Network and Sharing Center"
- Open a web browser (**Microsoft Edge browser is suggested**) and enter the web address **192.168.50.2**. The homepage of the graphical web interface will open.



Software Setup - Parameters of the charge integration algorithm







- *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

CAEN Tools for Discovery

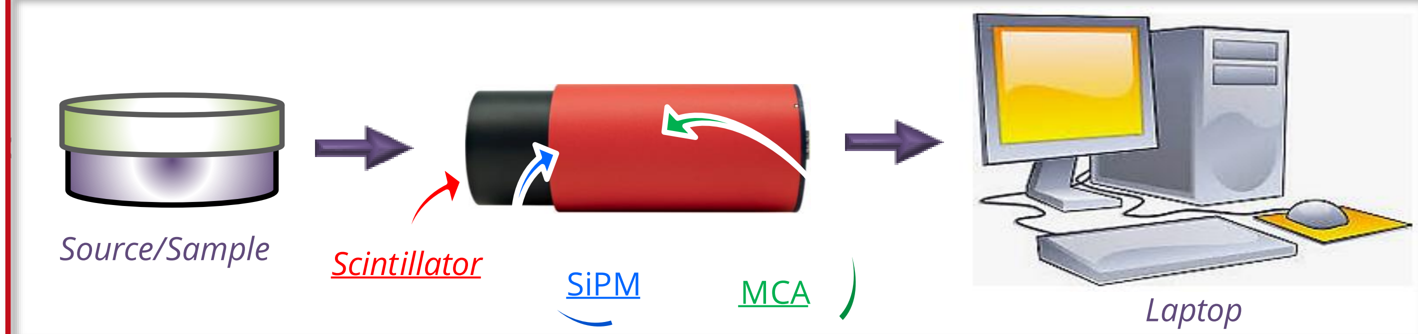
Experimental activity

1) **How to use the i-Spector Digital**

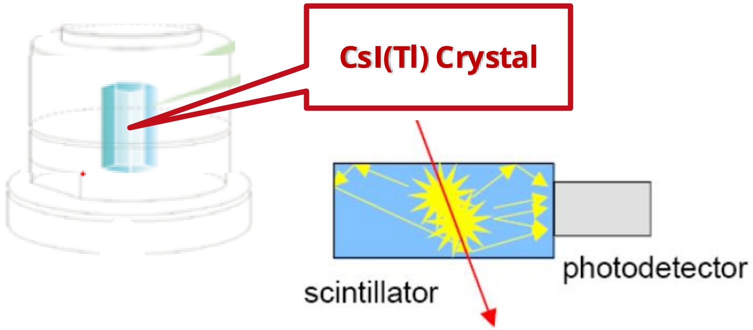
2) Energy calibration of the system based on LYSO

3) Background measurement (time run = 30’)

4) Calibration verification and tuning with Potassiur



Scintillator



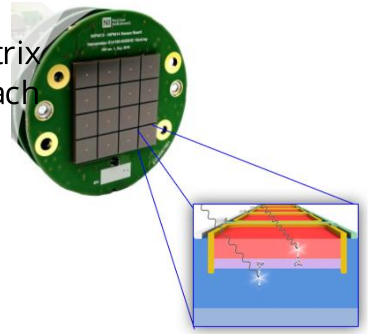
Energy deposition by an ionizing particle:

- Generation of light
- Transmission of scintillation light
- Detection

CsI(Tl) has a light output of 54 photons/keV and average decay time of about 1 µs for γ-rays

Silicon Photomultiplier (SiPM)

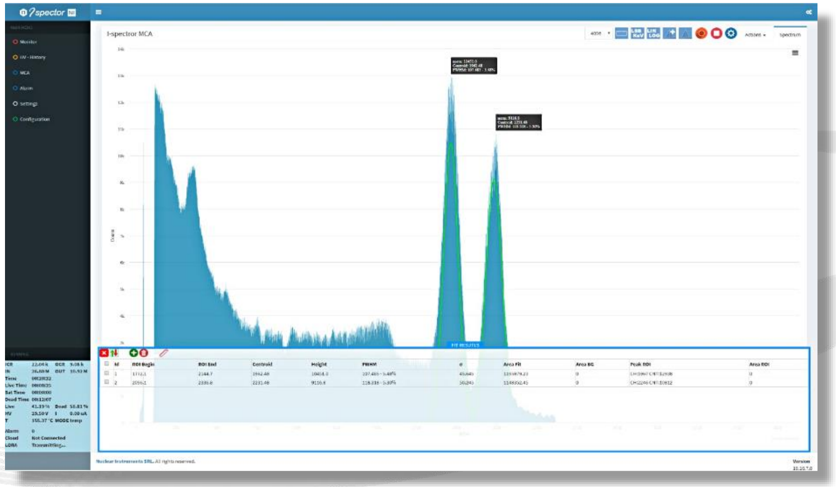
Silicon Photomultiplier (SiPM) is detector made of a matrix of silicon cells (diodes). Each dinode is a pixel with a binary signal. It can detect a single photon!



Photosensors detect and transform the light produced by the scintillator into an electrical signal. This signal is proportional to the energy released inside the crystal by the interacting particle

Electronics & Analysis Software

The output pulses are proportional to the energies of the incident radiation, the ADC is used combined to a Multichannel Analyzer (MCA) to generate energy distributions (spectra) of radioactive samples



Experimental activity

1) How to use the i-Spector Digital

2) Energy calibration of the system based on LYSO crystal (time base = 10')

3) Background measurement (time run = 30')

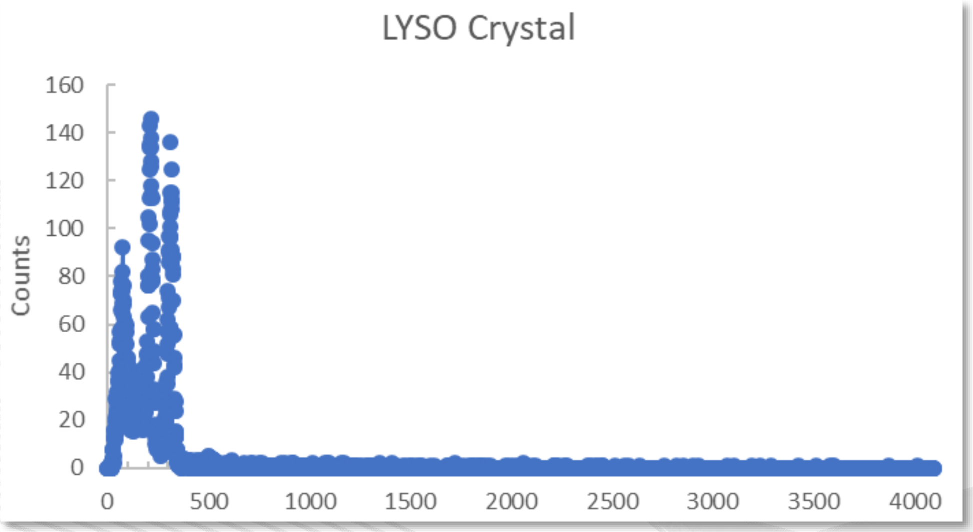
4) Calibration verification and tuning with Potassium Chloride sample (time run = 30')

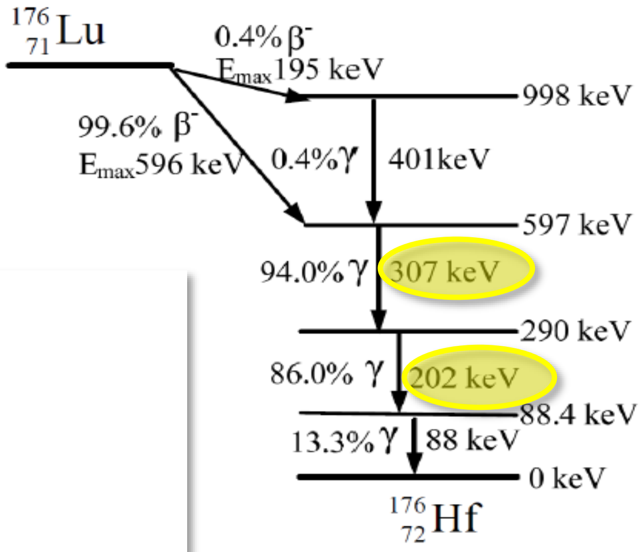
5) Rock sample Spectrum (time run = 30')

6) Test sample radiation identification

7) Analysis of spectra and superposition

8) Passive Radon Measurements





Scintillator based on Lutetium (Lu) like LYSO (Lu1.8Y.2SiO5:Ce) *has an high stopping power (high Z), high light yield and very short decay time (very fast signals).*

2,6% of the natural Lu is ***^{176}Lu****, a radioisototope with a long half life decaying via two different beta decays followed by gamma emissions.*

CAEN Tools for Discovery

Experimental activity

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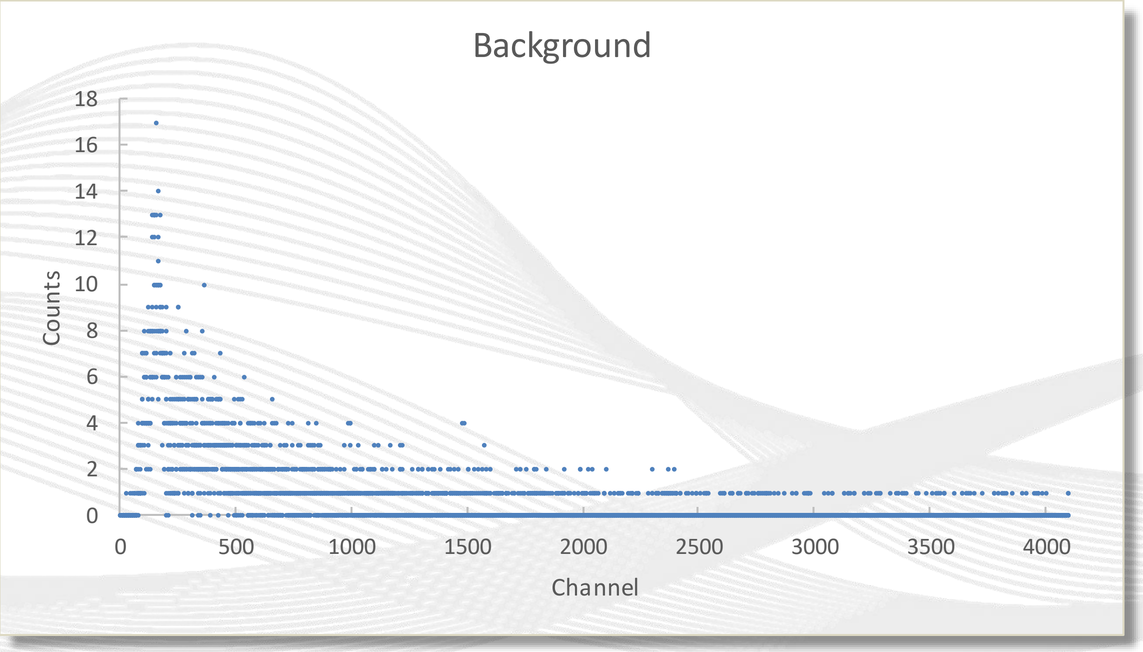

CAEN
Tools for Discovery

Experimental activity

1) How to use the i-Spector Digital
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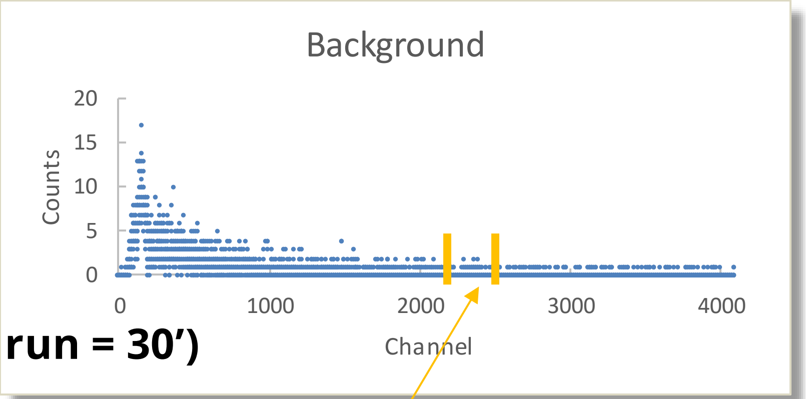
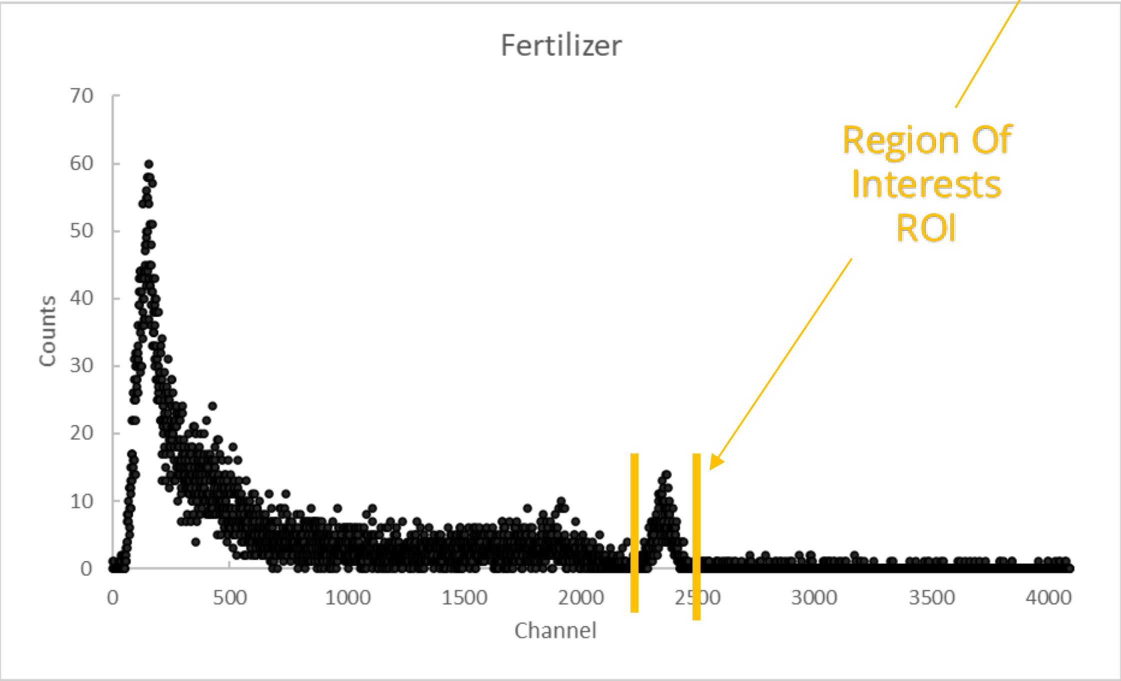


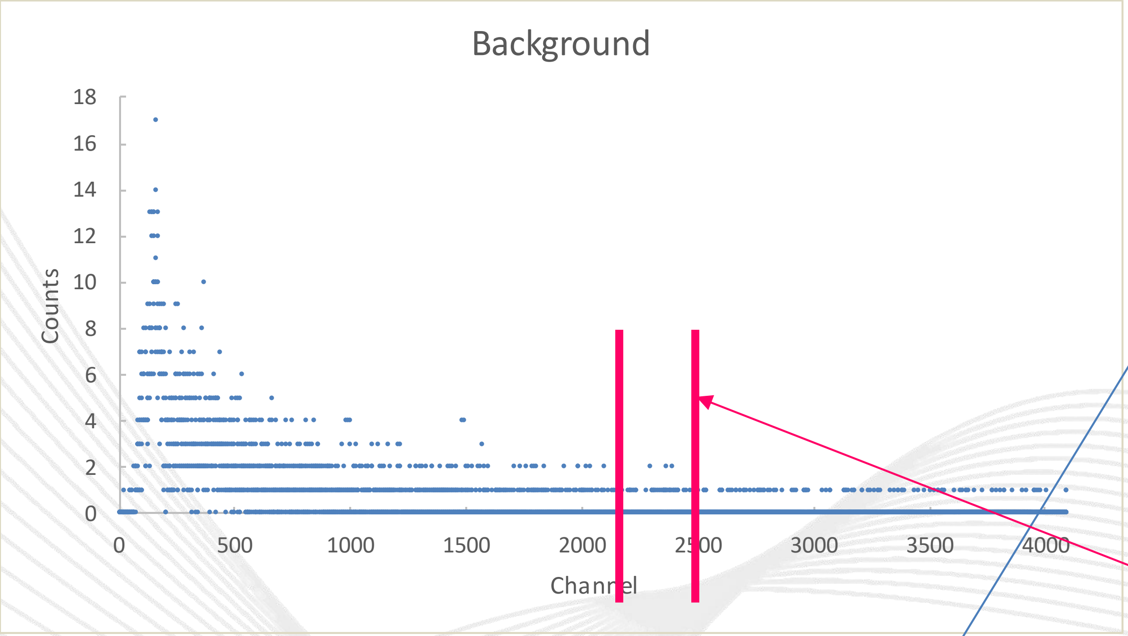


Experimental activity

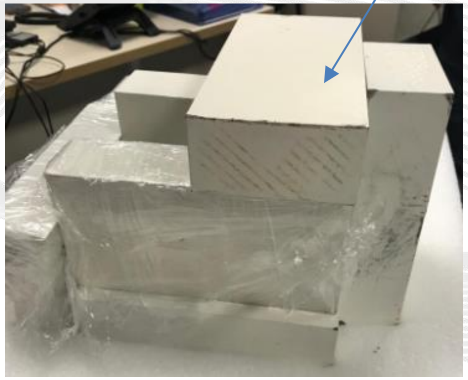
Fertilizer – Potassium Chloride

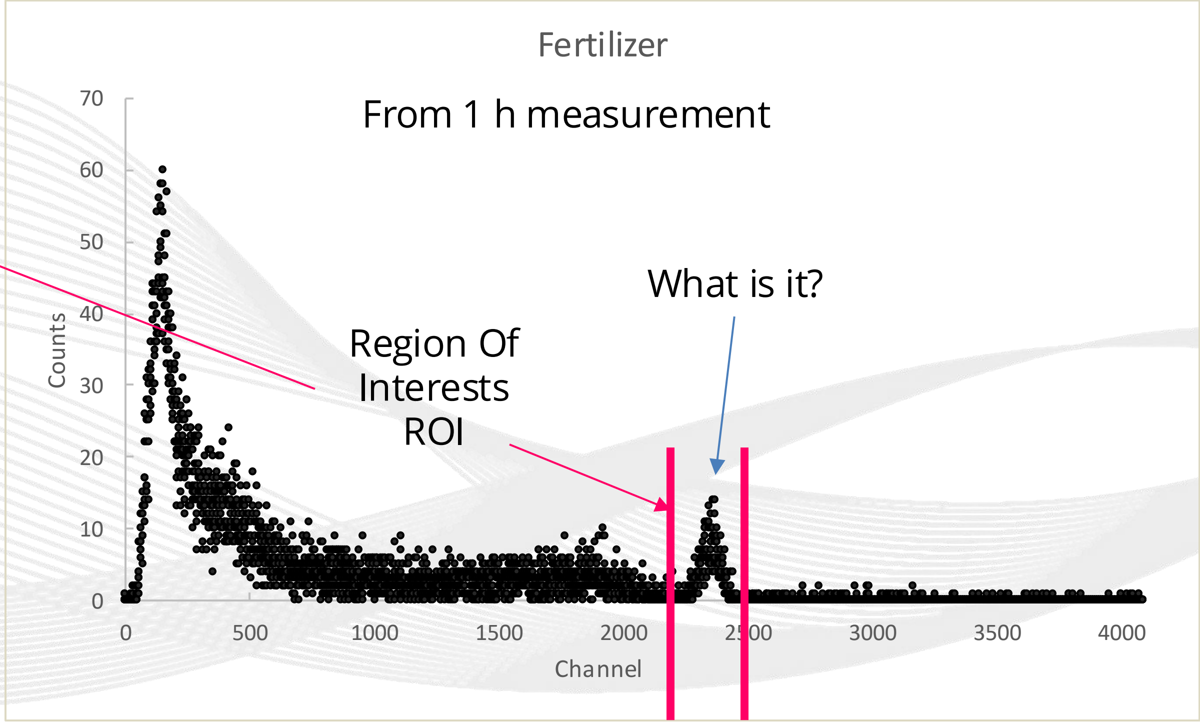
For our hands on take a 30 min spectra with the Potassium Chloride sample

Fertilizer



Lead shielding to reduce environmental background





Experimental activity

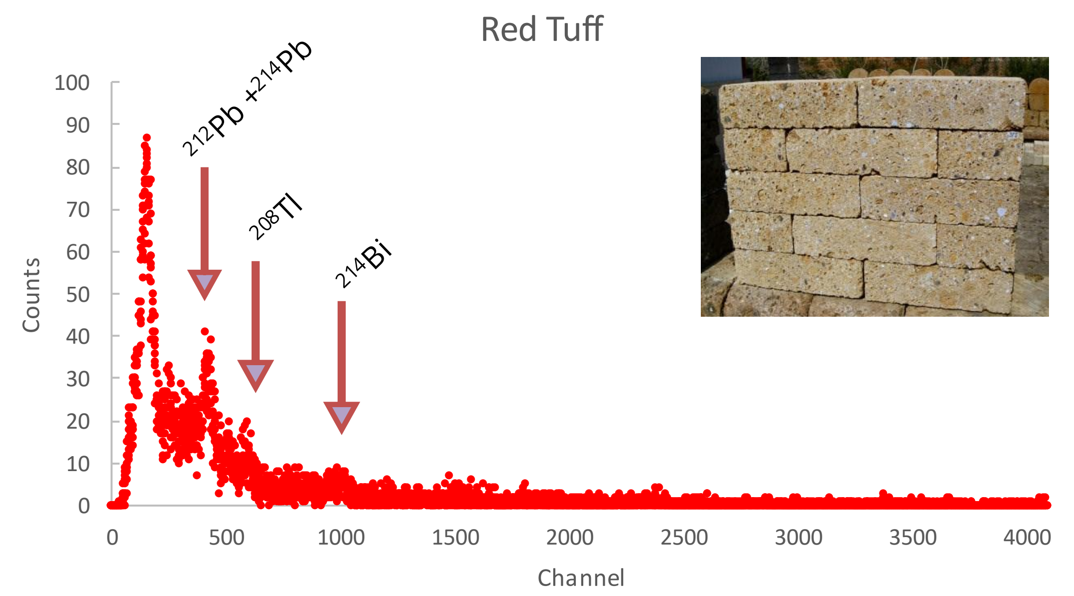
1) How to use the i-Spector Digital
2) Energy calibration of the system based on LYSO crystal (time base = 10’)
3) Background measurement (time run = 30’)
4) Calibration verification and tuning with Po
5) **Rock sample Spectrum (time run = 30’)**
6) Test sample radiation identification
7) Analysis of spectra and superposition
8) Passive Radon Measurements

U-238

99.98% 0.02%		
Pb214	26.8 minutes	53.2 (1.1%) 242.0 (7.46%) 295.2 (19.2%) 351.9 (37.1%) 785.9 (1.09%)
At218	2 seconds	-----
Bi214	19.7 minutes	609.3 (46.1%) 768.4 (4.89%) 806.2 (1.23%) 934.1 (3.16%) 1120.3 (15.0%) 1238.1 (5.92%) 1377.7 (4.02%) 1408.0 (2.48%) 1509.2 (2.19%) 1764.5 (15.9%)

Th-232

Bi212	60.6 minutes	39.9 (1.1%) 727.3 (6.65%)
64.06% 35.94%		
Po212	304 nsec	--------
Tl208	3.1 minutes	277.4 (6.31%) 510.77 (22.6%) 583.2 (84.5%) 763.1 (1.81%) 860.6 (12.4%)



CAEN Tools for Discovery

Experimental activity

1) How to use the i-Spector Digital
2) Energy calibration of the system based on LYSO crystal (time base = 10’)
3) Background measurement (time run = 30’)
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5) Rock sample Spectrum (time run = 30’)
6) **Test sample radiation identification**
7) Analysis of spectra and superposition
8) Passive Radon Measurements

Thorium Lantern Mantle

Rare earth uranium oxide

Uranium Glazed Pottery

Decades-Old Lenses

Uranium glass beads

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Tools for Discovery

Experimental activity

1) How to use the i-Spector Digital
2) Energy calibration of the system based on LYSO crystal (time base = 10’)
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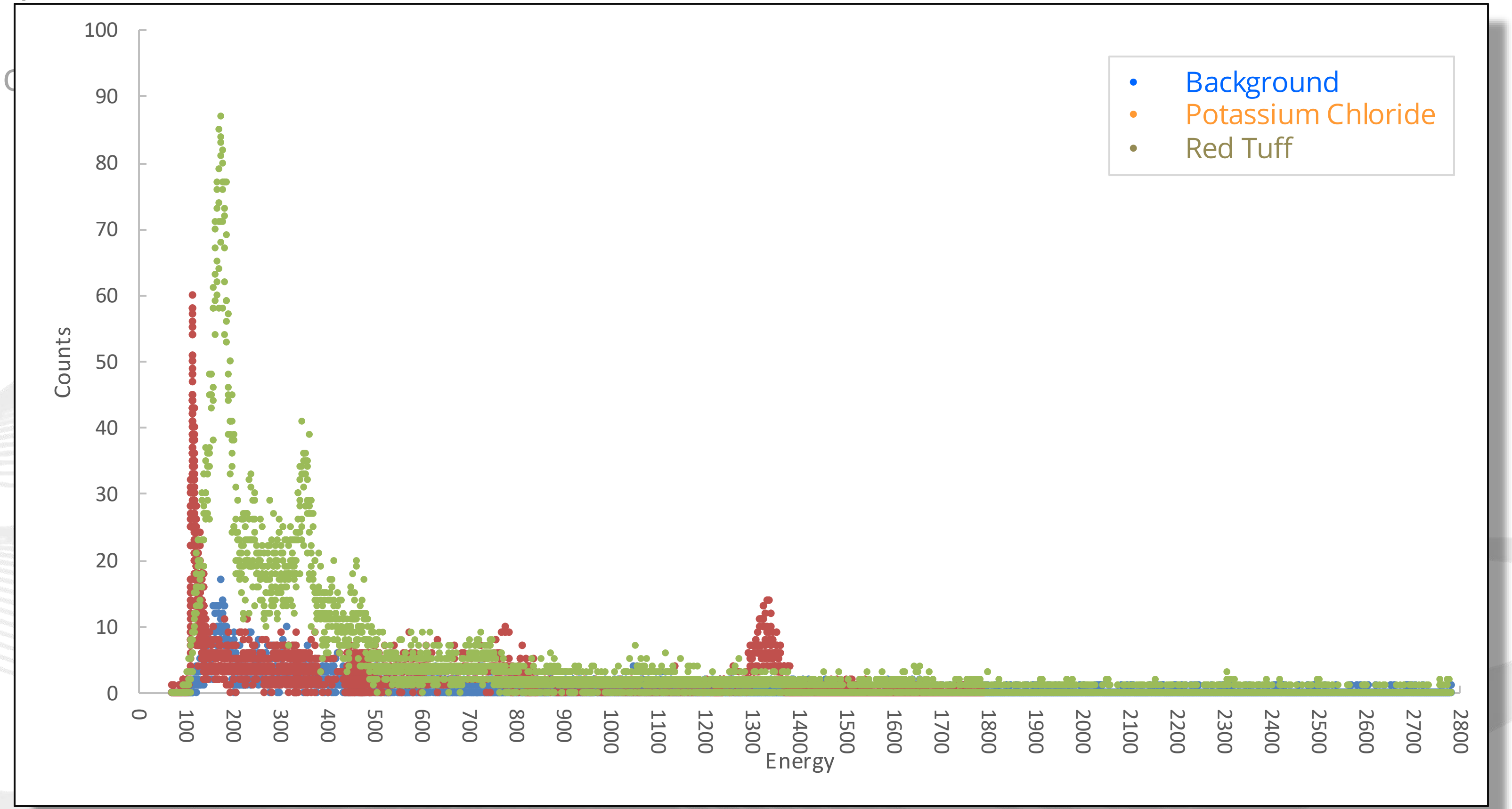
5) Rock sample Spectrum (time run = 30’)
6) Test sample radiation identification
7) **Analysis of spectra and superposition**
8) Passive Radon Measurements

Superimposed spectra



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Tools for Discovery

Experimental activity

1) How to use the i-Spector Digital

2) Energy calibration of the system based on LYSO crystal (time base = 10’)

3) Background measurement (time run = 30’)

4) Calibration verification and tuning with Potassium Chloride sample (time run = 30’)

5) Rock sample Spectrum (time run = 30’)

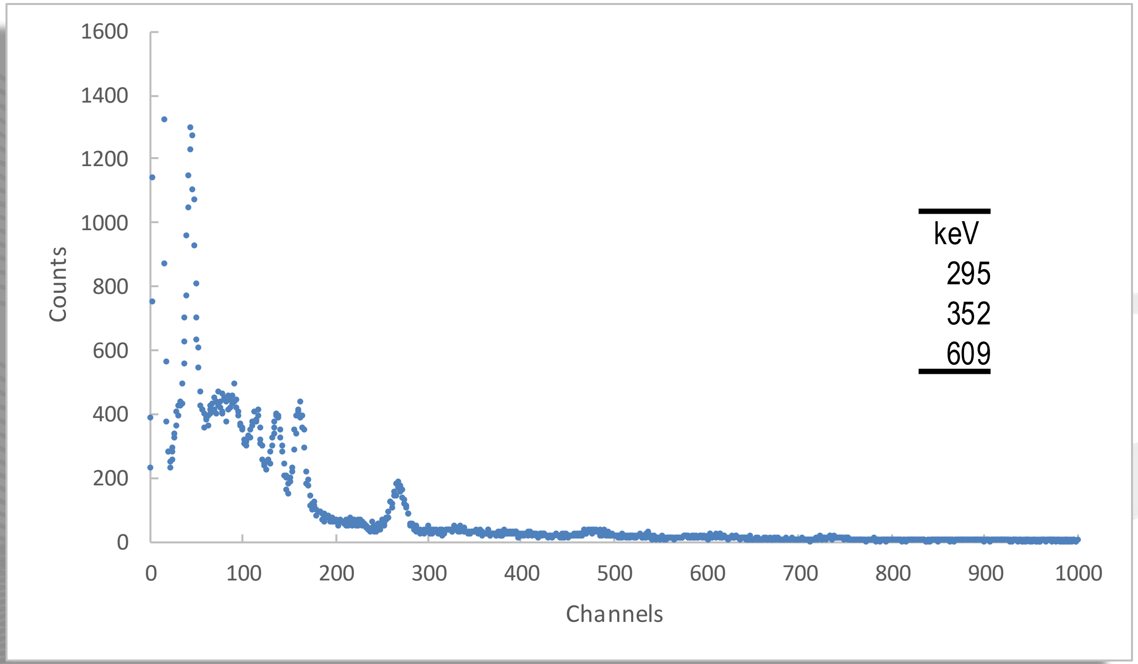
6) Test sample radiation identification

7) Analysis of spectra and superposition

8) Passive Radon Measurements (time run=60’)

Canisters of Activated Carbon

Measurement of the adsorbed radon activity



The amount of adsorbed radon by the canisters can be evaluated via the detection of the gamma rays emitted by the ^{214}Pb e dal ^{214}Bi.
Among the many available gamma emissions, the following nuclei are used as they are formed in a short time from the decay of Radon:

- 295 keV and 352 keV from ^{214}Pb
- 609 keV from ^{214}Bi

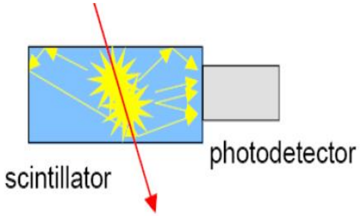
CAEN Tools for Discovery

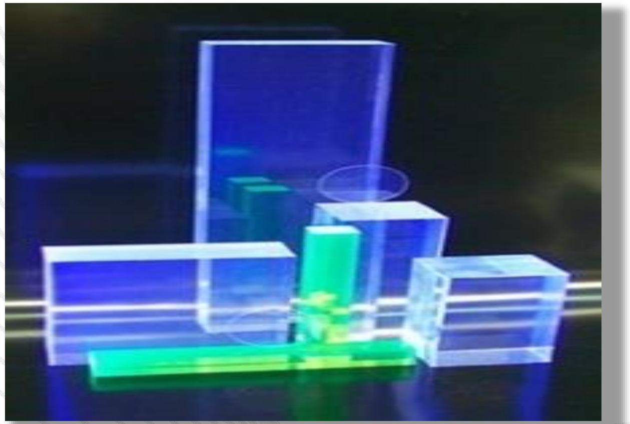
Spares Slides SP5640

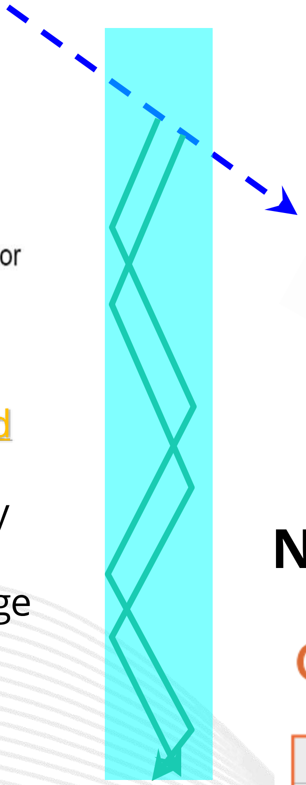
GammaEDU Description - Scintillator

Energy deposition by an ionizing particle:

- Generation of light
- Transmission of scintillation light
- Detection







What are scintillators used for?

- To measure the energy released
- To measure the passage time of radiation

Thallium doped sodium iodide, **NaI(Tl)**, is the most widely used scintillation material, it has the greatest light output and convenient emission range

Inorganic (crystalline structure)
Up to 40000 photons per MeV
High Z
Large variety of Z and ρ
Un-doped and doped
ns to μs decay times
Expensive

Organic (plastics or liquid solutions)
Up to 10000 photons per MeV
Low Z
ρ~1g/cm^3
Doped, choice of emission wavelength
ns decay times
Relatively inexpensive

General Properties

Density(g/cm^3)	3.67
Melting point(K)	924
Wavelength of emission peak(nm)	415
Light output(Photons/Mev)	40,000
Decay time(ns)	264
Cleavage plane	(100)
Hygroscopic	Yes
Refractive index	1.85
Hardness(Mho)	2

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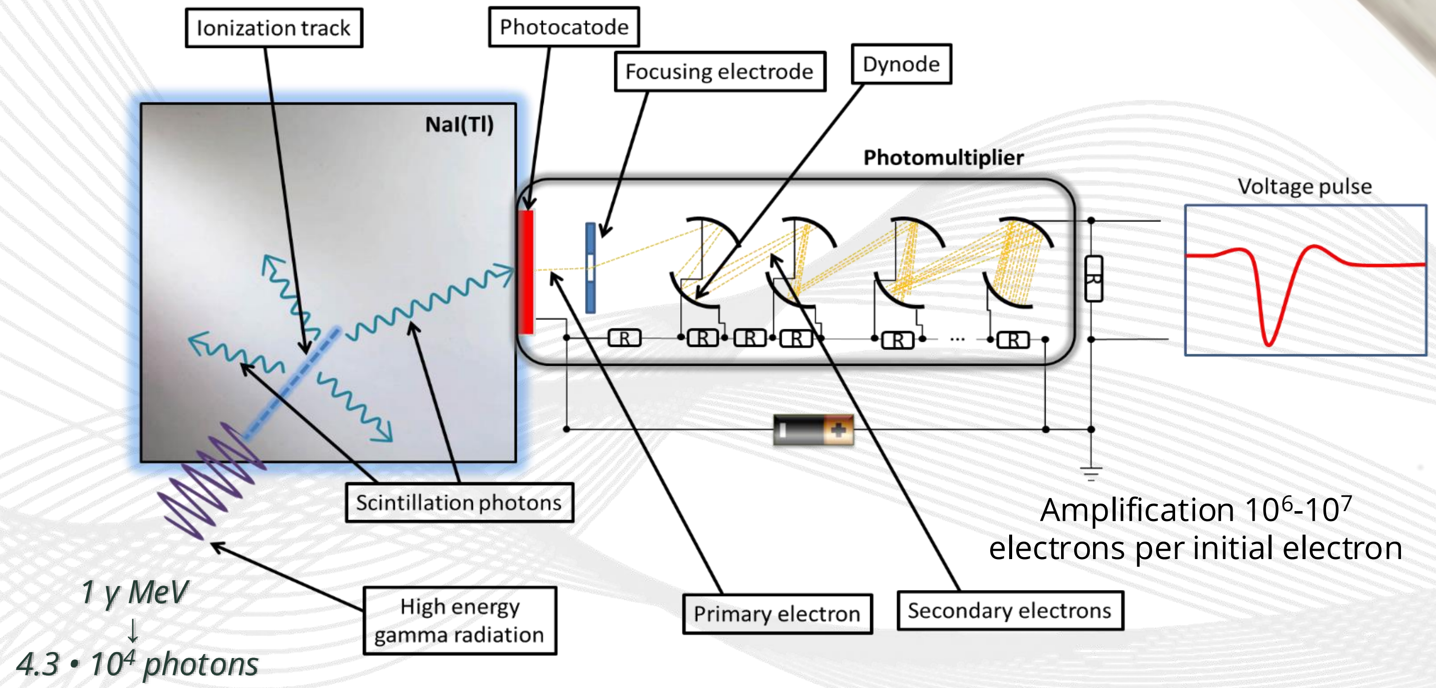
Tools for Discovery

GammaEDU Description - Photodetector

Photodetector ➝ From photons to electric current!

Photomultiplier Tubes (PMT) are composed of a photocathode, collection optics and multiplier section. The overall electrical signal is collected at the anode.

- *PMT collects and transforms the light produced by the scintillator into an electrical signal*
- *The intensity of the output current pulse is proportional to the energy of the incident photon!*



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Tools for Discovery

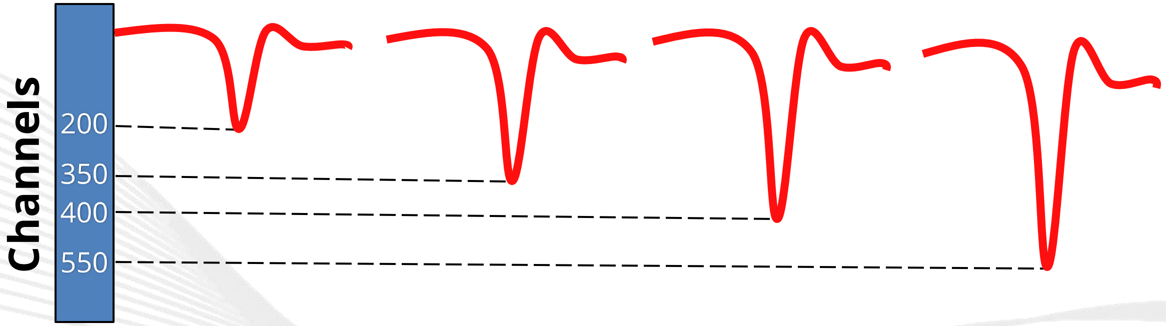
GammaEDU Description – γ stream

CAEN Gamma *stream* [S2580] is a compact and portable system for gamma ray spectroscopy with scintillation detectors, which provides an active **Multi-Channel Analyzer** (MCA) integrated in a 14-pin photo-multiplier tube (PMT) base.

Gamma *stream* fully integrates in a stand-alone device the high voltage to bias the PMT, the preamplifier to shape the signal from detector, and the MCA for a complete Pulse Height Analysis online.

Gamma *stream* makes easy the measurements with scintillation detectors **NaI(Tl)** [0.3l] with no need of additional cables.

- High Voltage Power Supply (0 ÷ +1500V/500 μA)
- Charge Sensitive Preamplifier
- digital Multi-Channel Analyzer (12-bit and 62.5 MHz ADC) for scintillation spectroscopy
- Specialized for NaI(Tl), LaBr3(Ce), and CeBr3 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 6÷8 hours operation
- Wired and wireless connectivity via USB, Ethernet, Wifi and Bluetooth
- Acquisition modes: PHA, PHA with time stamp, Signal Inspector



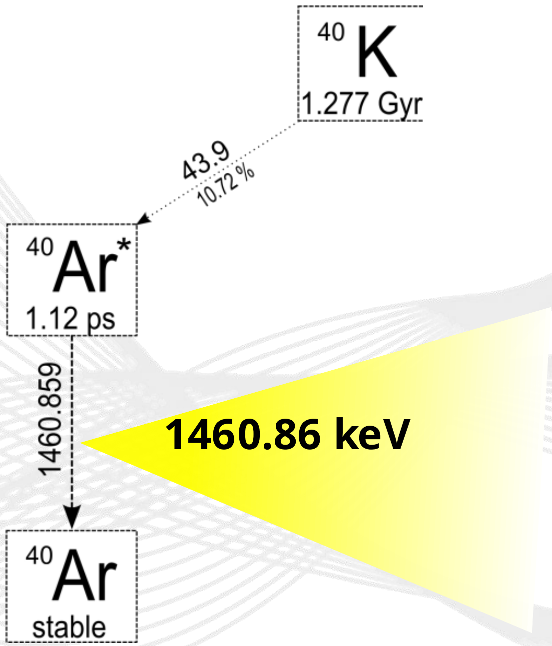
The acquisition channel is proportional to the energy of the incident photons!

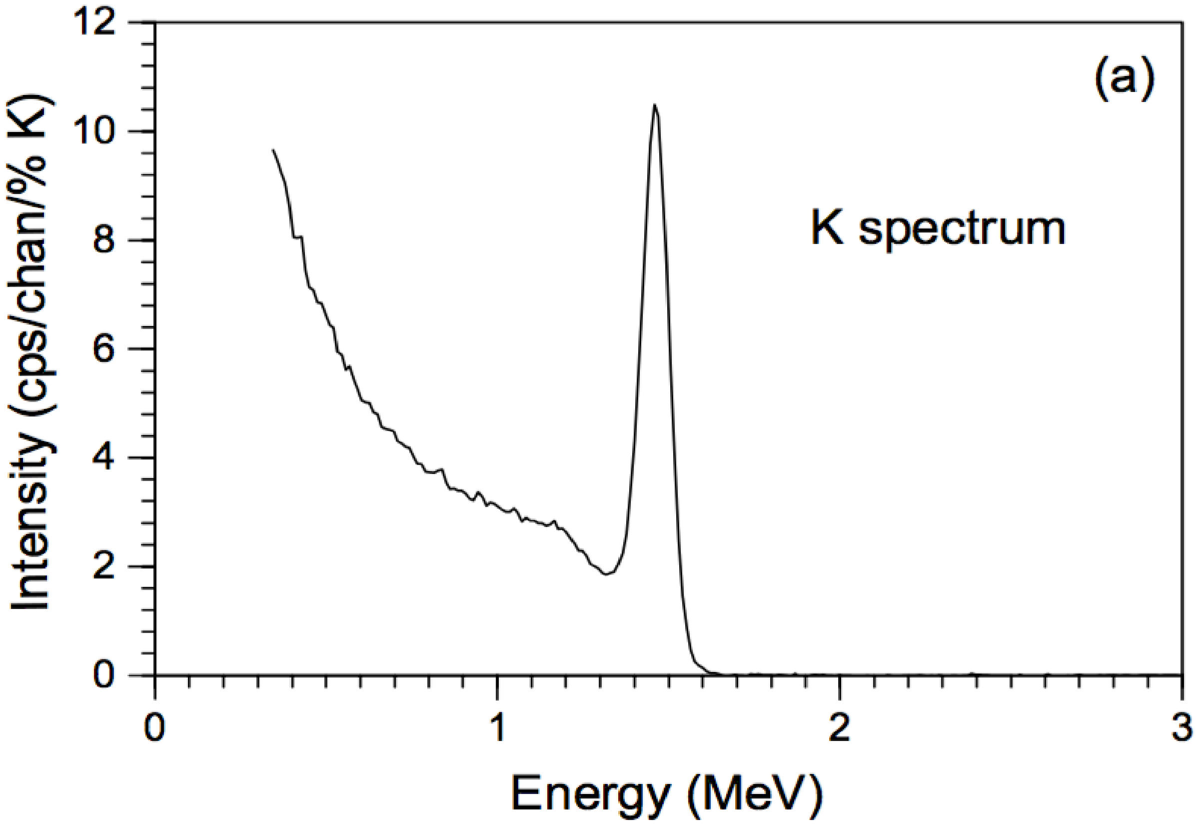
CAEN Tools for Discovery

Energy Spectrum

The MultiChannel Analyzer MCA classifies input pulses base on their height saving them in a memory and are associated to an ADC. The output of every channel can be visualized in a pulse amplitude spectra.
An Analog-to-Digital Converter (ADC) generates a digital signal proportional to the amplitude of an input pulse. Since these output pulses are proportional to the energies of the incident radiation, the ADC can be used combined to a MultiChannel Analyzer (MCA) to generate energy distributions (spectra) of radioactive samples.

Ex. Monochromatic photons beam





Energy Spectrum

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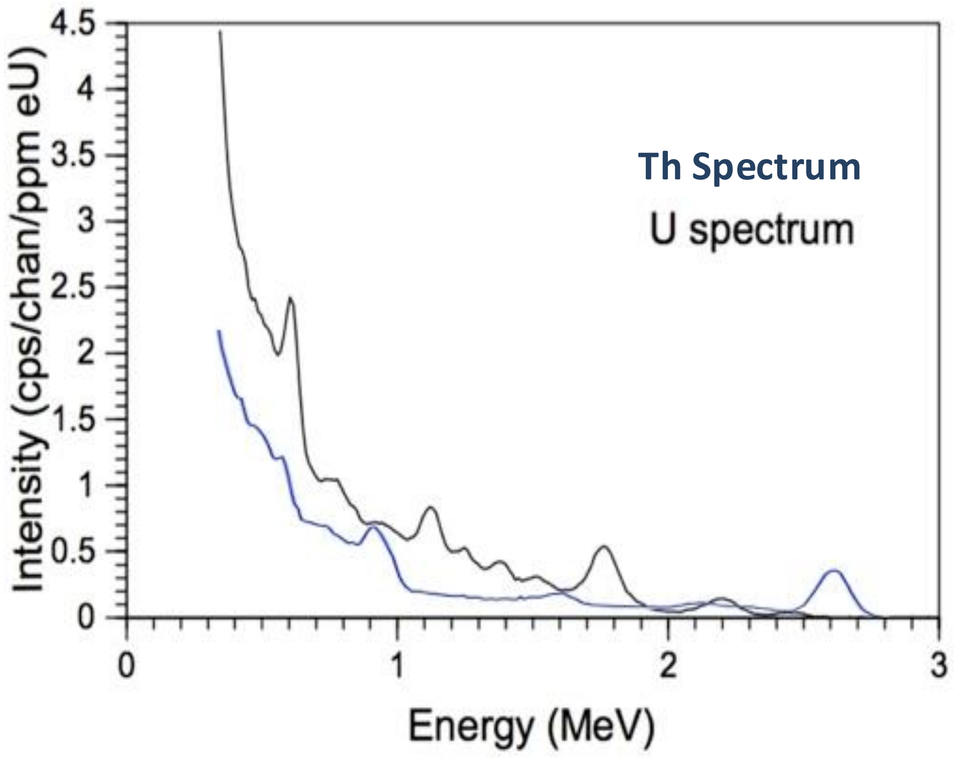
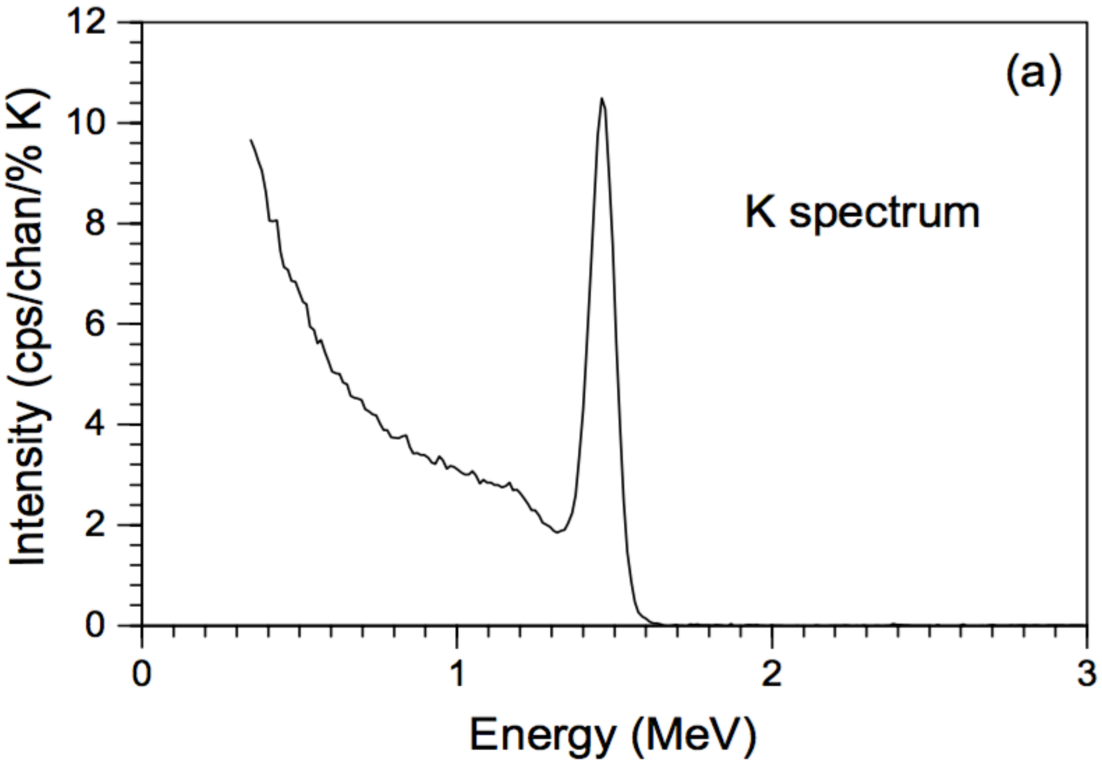
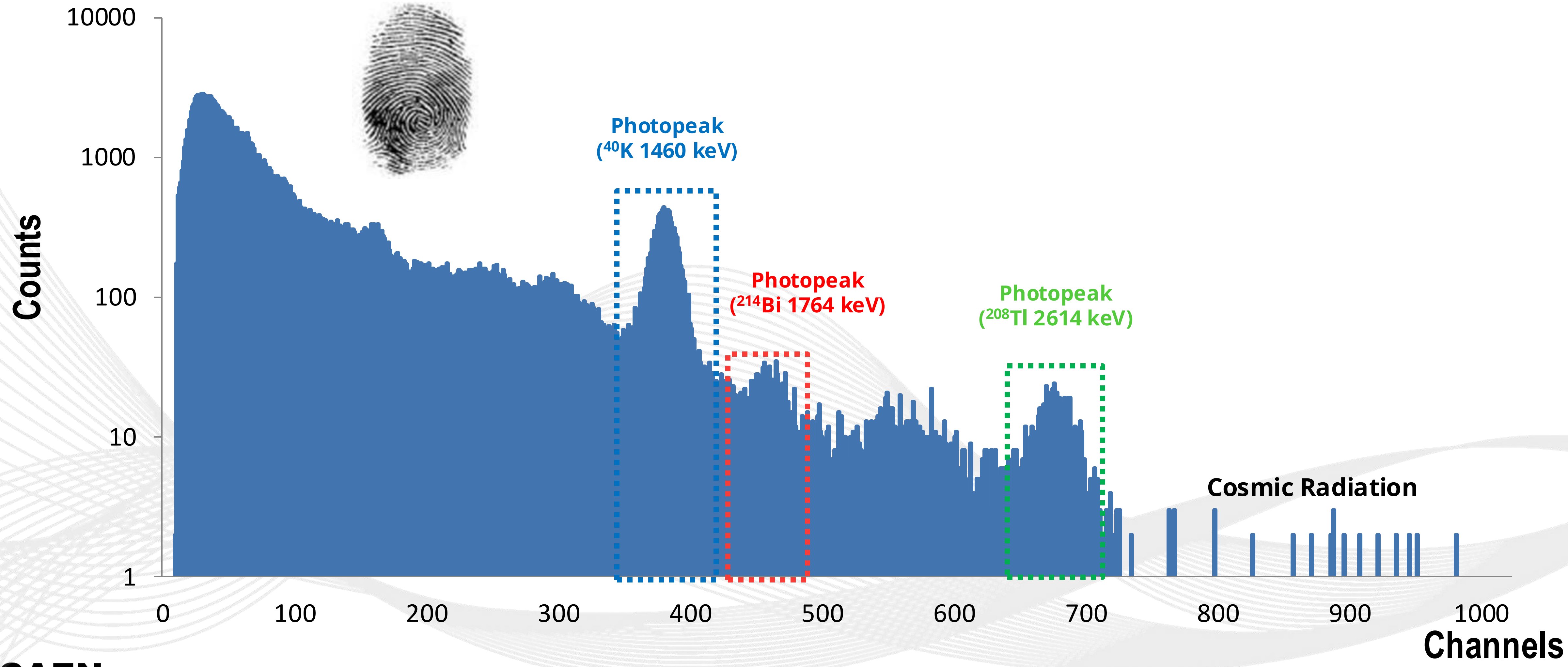




Typical Gamma Spectra

The photopeaks charatcterize the gamma spectrum. Each photopeak corresponds to the photons coming into detector with an energy value equal to the emission ones. These photons release all their energy into detector.



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Tools for Discovery

Typical Gamma Spectra

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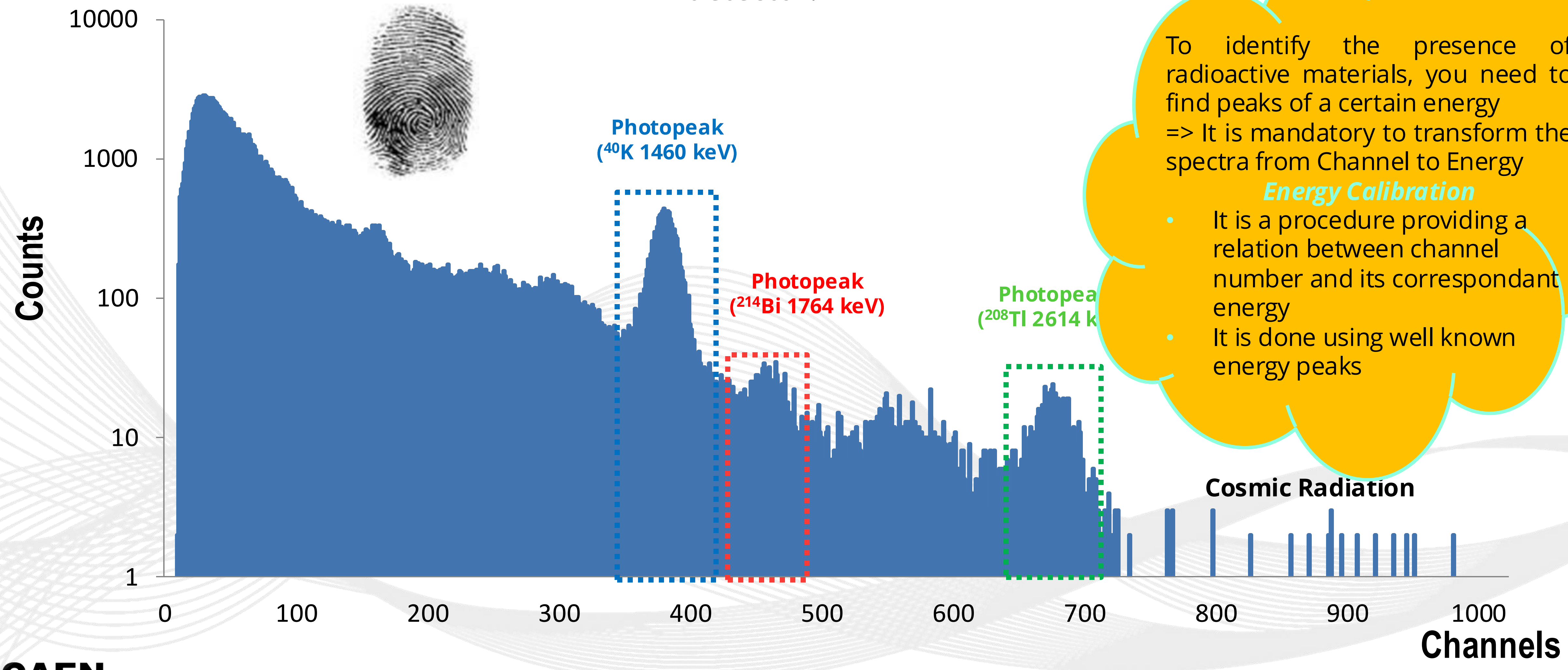

To identify the presence of radioactive materials, you need to find peaks of a certain energy
=> It is mandatory to transform the spectra from Channel to Energy

Energy Calibration

- It is a procedure providing a relation between channel number and its correspondant energy
- It is done using well known energy peaks

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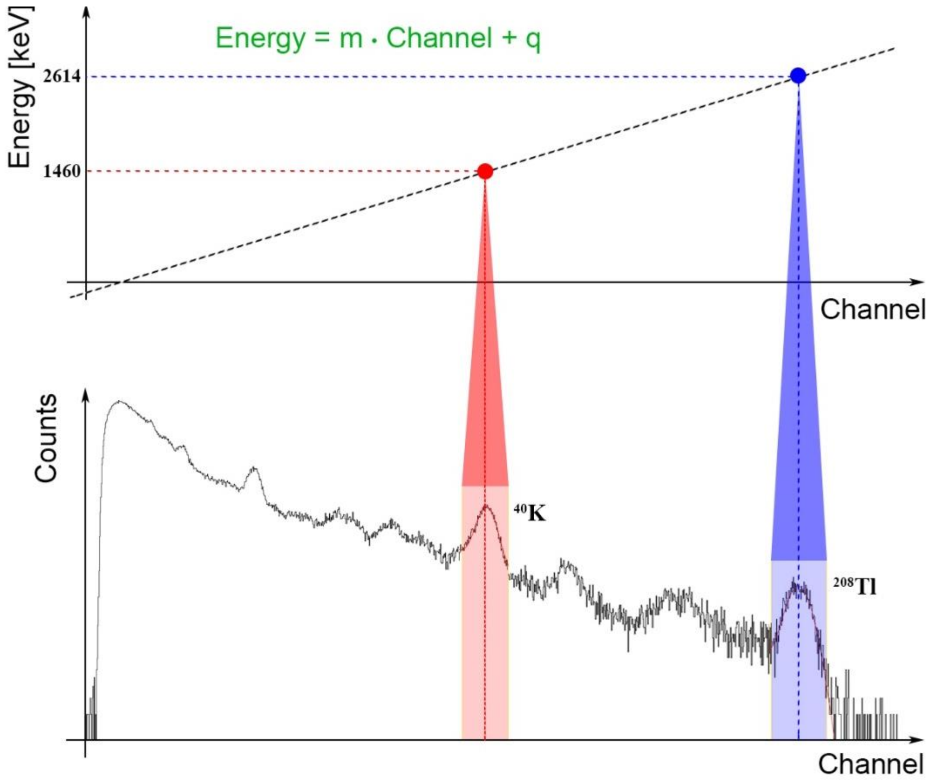
Energy calibration

In the energy range of the environmental measurements the calibration in energy corresponds to a linear transformation

=> Knowing the energy of 2 peaks it is possible to extract the equation of the line from 2 points

Multichannel Calibration



^{40}K => E_K = 1460 keV
^{208}Tl => E_{Th} = 2614 keV

^{208}Tl is coming from the radioactive chain of the ^{232}Th and is the highest energy gamma from natural sources

$A = (E_{Th}, Ch_{Th})$
$B = (E_K, Ch_K)$

$$\frac{Ch - Ch_K}{Ch_{th} - Ch_k} = \frac{E - E_k}{E_{th} - E_k}$$

$$\frac{Ch - Ch_K}{Ch_{th} - Ch_k} = \frac{E - 1460\ keV}{(2614 - 1460)keV}$$

CAEN Tools for Discovery

GammaEDU use

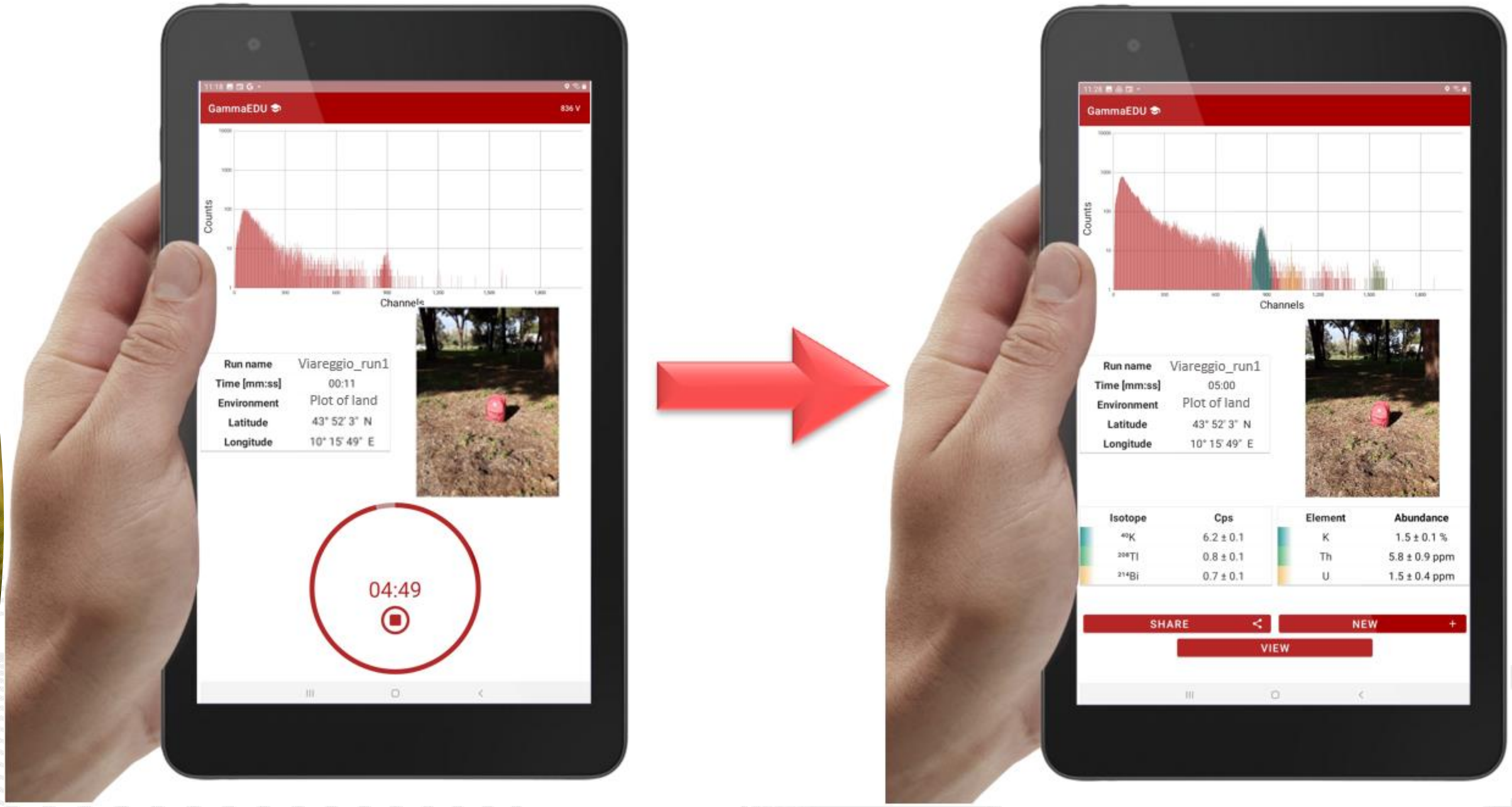
- Press the power button
- Verify that the status light is green
- Place the backpack at the point of interest

GammaEDU use (2)

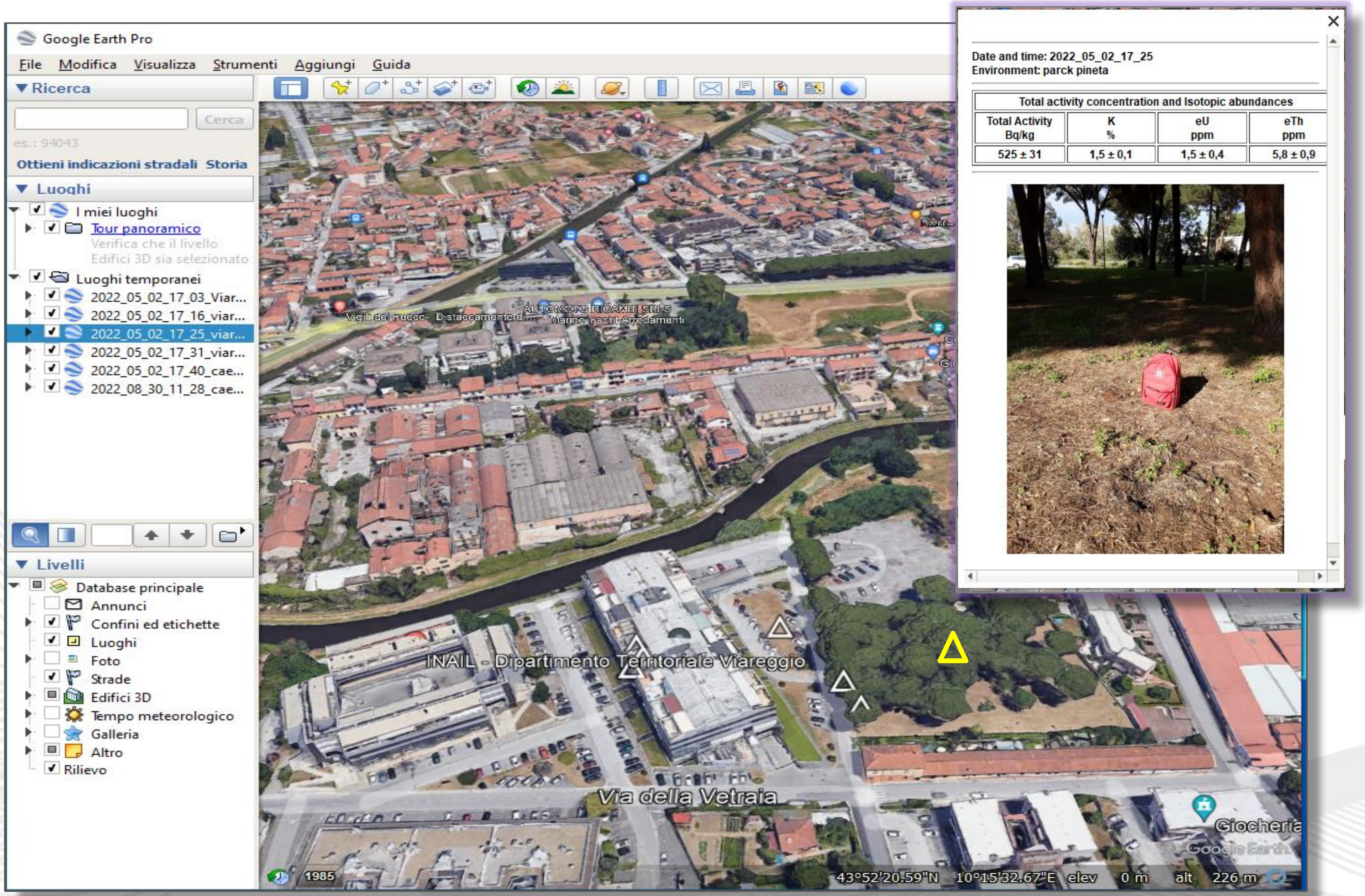
- Activate the tablet and connect it via Bluetooth to the instrument
- Connect the tablet to a WIFI network
- Launch GammaEDU App
- Select «New Acquisition»

GammaEDU use (3)

GammaEDU use (4)



Google Earth



CAEN, Viareggio

Typical abundancies

^{40}K	0.02 g/g [2%]
^{238}U	3 μg/g [ppm]
^{232}Th	10 μg/g [ppm]

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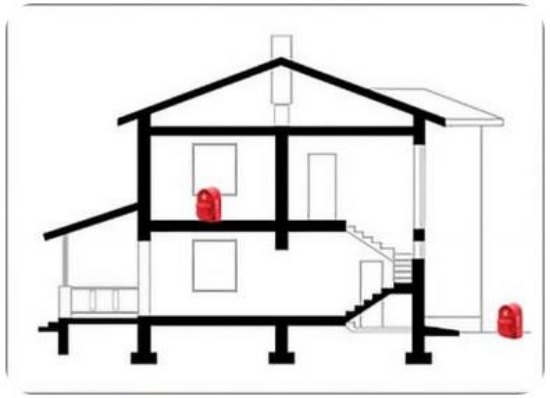
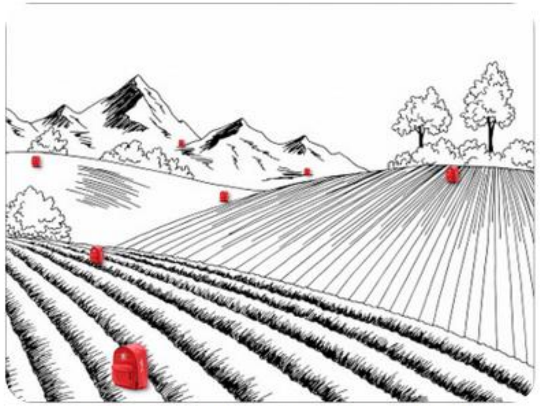
Tools for Discovery

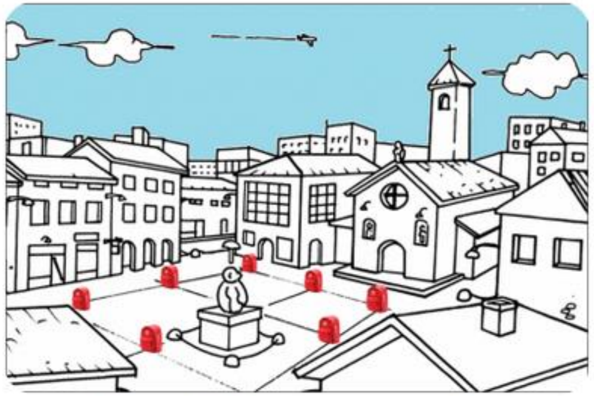
Suggested Experiments



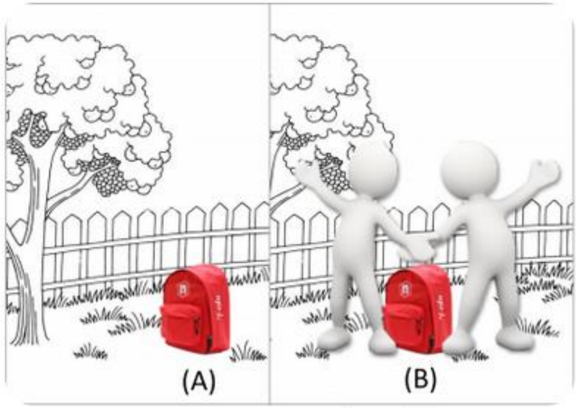
Radiological evaluation of the building materials



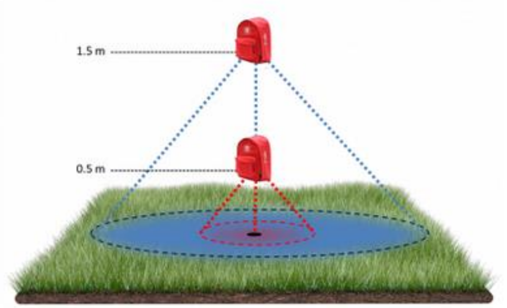
Geochemical and mineral exploration



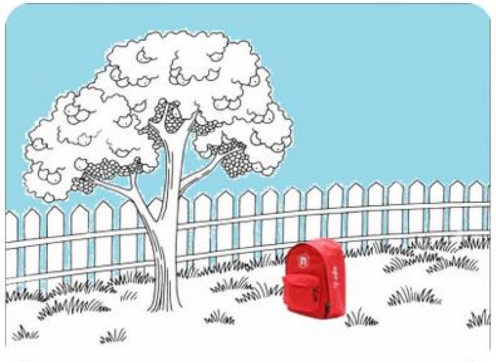
Radioactivity maps production



Human body Radioactivity

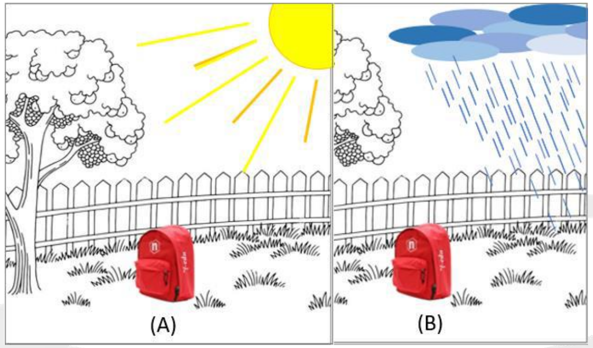


γ Environmental detection as a function of the soil distance



Environmental monitoring in field

Ground coverage Effect on the Environmental Monitoring



Soil water content evaluation with gamma ray spectroscopy

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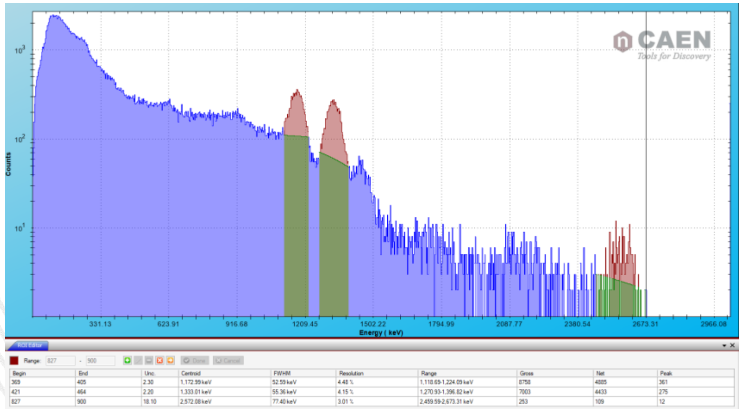
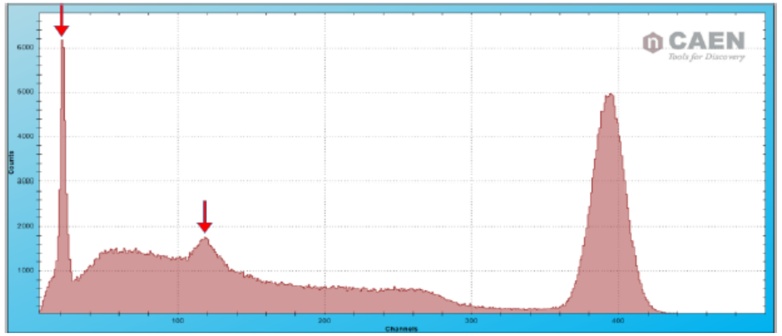
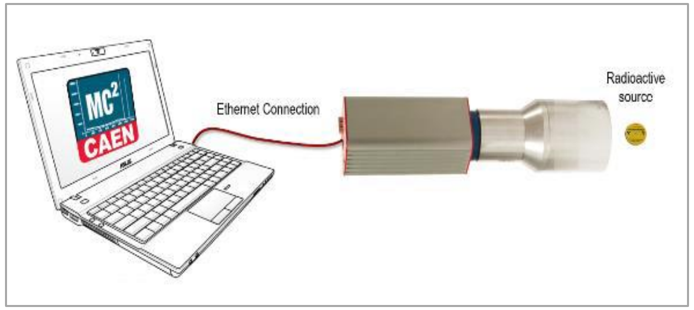
Additional Experiments



Activity of the ^{60}Co



Study of the 137Cs spectrum: the backscatter peak and X rays



Measurement of Photomultiplier Plateau Curves

Detecting γ-radiation

Poisson and Gaussian Distribution

Energy Resolution

System Calibration: Linearity and Resolution

γ-Radiation Absorption

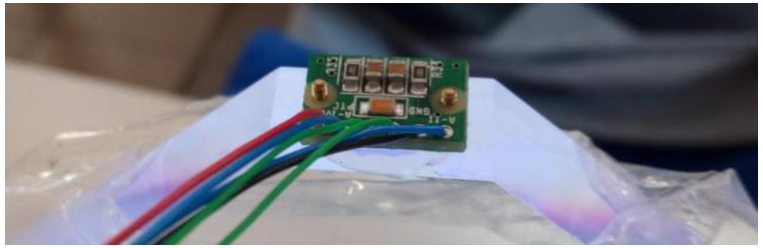
Photonuclear cross-section/Compton Scattering cross-section

Spares Slides SP5620CH

Detection System SP5622

Each unit consists of:

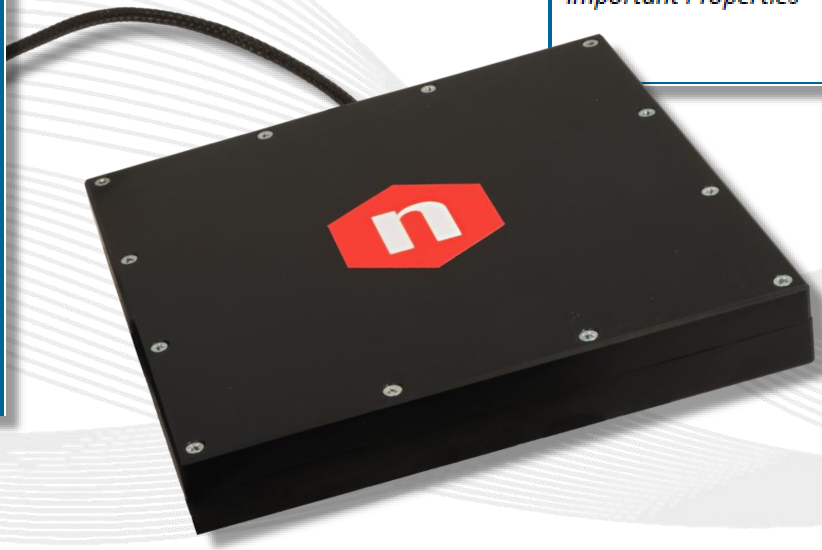
- Plastic scintillator, Polystyrene-based (15 x 15 x 1 cm^2)
- Front-end electronic board (transconductance amplifier and a fast discriminator)
- SiPM ASD-NUV4S-P (4 x 4 mm^2) mounted in the tile corner at 45°



Feature	Value
Scintillator type	UPS-923A
Density	1.06
Refractive index	1.60
Absorption coefficient [cm^{-3}]	0.01-0.003
Softening [K]	355-360
Hygroscopic	no
Emission peak [nm]	425
Light Output [% of anthracene]	60
H/C ratio	1.0
Rise time [ns]	0.9
Decay time [ns]	3.3
Light attenuation length [cm]	400
Important Properties	• High light output • Good transparency • Short decay time

Feature	Value
Effective active area	4 x 4 mm^2
Number of cells	9340
Cell size	40 μm × 40 μm
Cell fill-factor	60 %
Quenching resistance	800 $k\Omega$
Cell capacitance	90 *fF*
Recharge time constant	70 *ns*
Photon Detection Efficiency	43 %
Breakdown voltage	Typical: 26 *V* Min: 24 *V* Max: 28 *V*
Recommended Overvoltage range	Min: 2 *V* Max: 6 *V*
Dark Count Rate	< 50 kHz/mm^2 @ 2 V OV < 100 kHz/mm^2 @ 6 V OV
Gain	3.6×10^6

Geometrical, Electrical and Optical Typical Characteristics of **ASD-NUV4S-P** @ 20°C.



CAEN Tools for Discovery

Experimental activity

1) **Statistics**
2) Muons Detection
3) Muons Vertical Flux on Horizontal Detector
4) Random Coincidence
5) Detection Efficiency
6) Cosmic Flux as a function of the altitude
7) Zenith Dependence of Muons Flux
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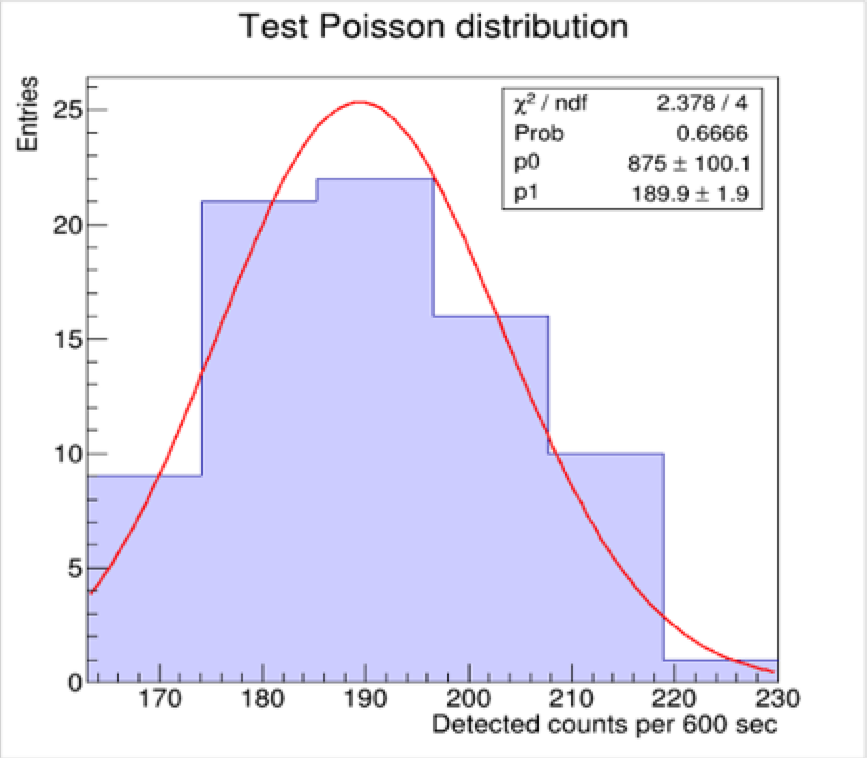
The Poisson distribution of the cosmic rays can be experimentally verified via the data analysis and the treatment of their statistical uncertainty

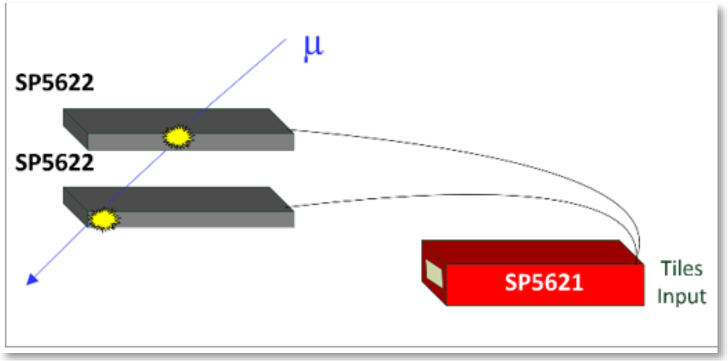


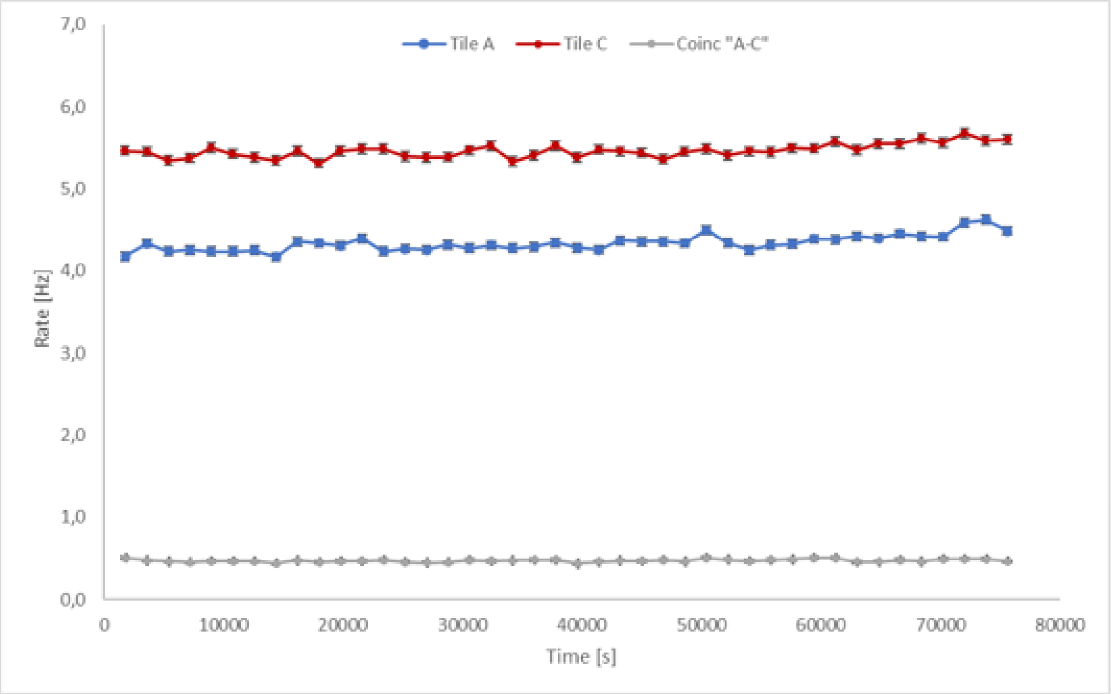
Poissonian distribution of cosmic rays [Fit: $y = p0 * (p1^x/x!) * e^{-p1}$].

CAEN Tools for Discovery

Experimental activity

The double tile coincidence has a key role in the cosmic ray detection. It shall be used to reduce the random counts, select the solid angle, and measure the cosmic rate.

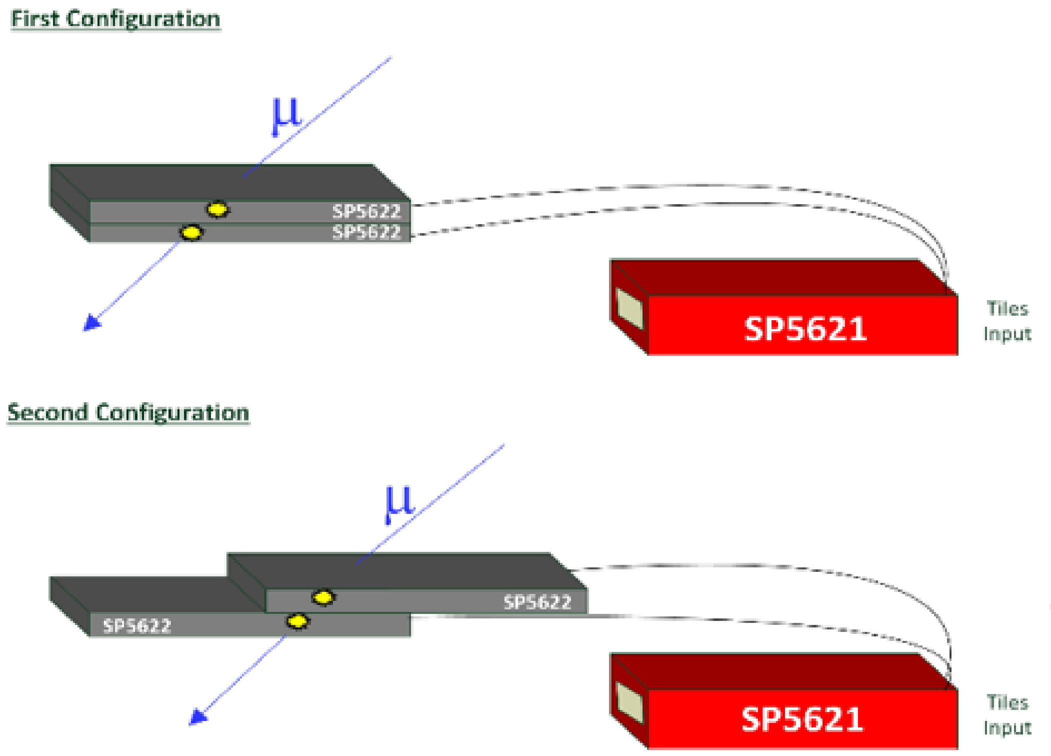




Counts Rate of the single tiles and their coincidence as a function of the time.

Experimental activity

The integral intensity of vertical muons is: $I_v \approx 82\ m^{-2}s^{-1}sr^{-1}$ and their flux for horizontal detectors is $\approx 1\ cm^{-2}min^{-1}$ at energies higher than 1 GeV at sea level



Considering the integration over the solid angle, the expected cosmic rate due to the geometry system can be estimated and the detection efficiency can be evaluated.

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Tools for Discovery

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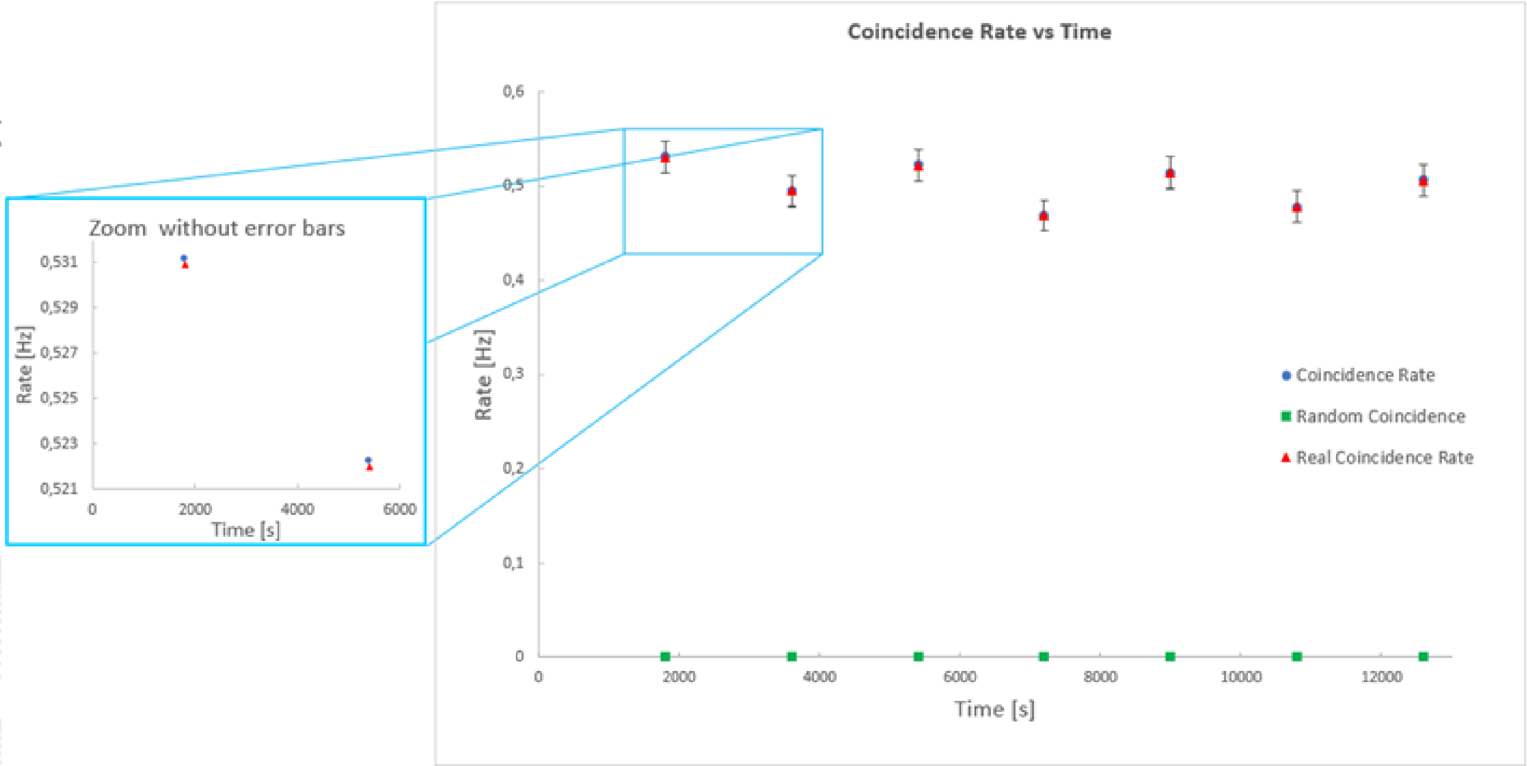

Trend of the Counts Rate and Random Rate as a function of the time.
The plot on the left side is an enlargement of the main plot and underlines the deviation between the measured coincidence rate and the real one, obtained via the random rate subtraction.

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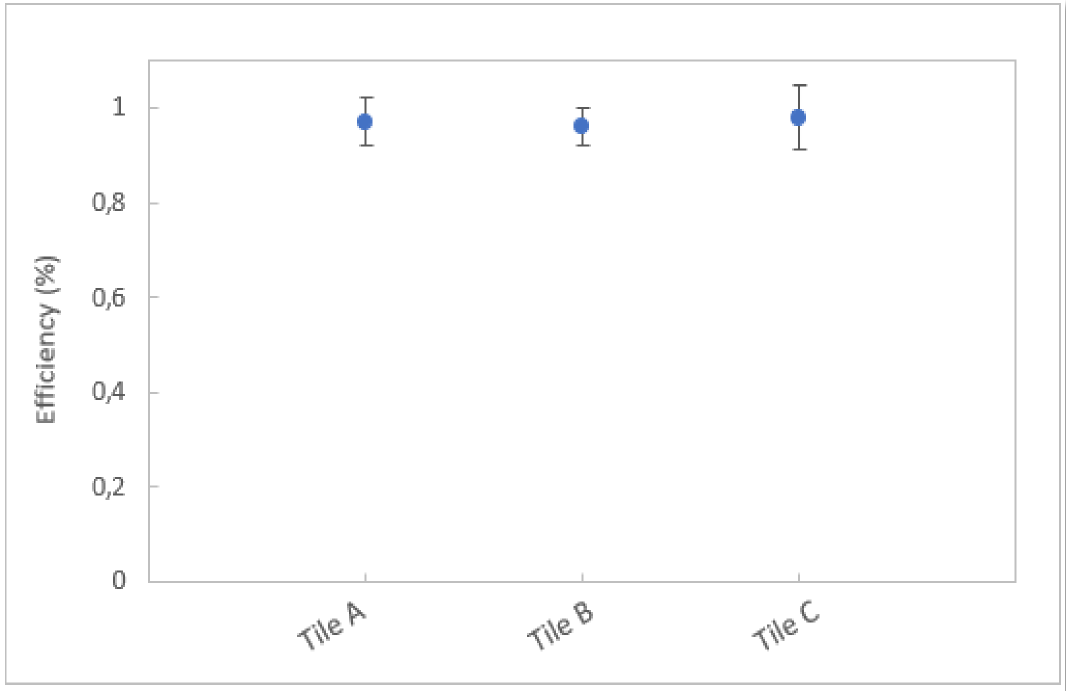
Experimental activity

$N_{AC} = \varepsilon_A * \varepsilon_C * N_0$ and $N_{ABC} = \varepsilon_A * \varepsilon_B * \varepsilon_C * N_0$ → $\varepsilon_B = N_{ABC} / N_{AC}$



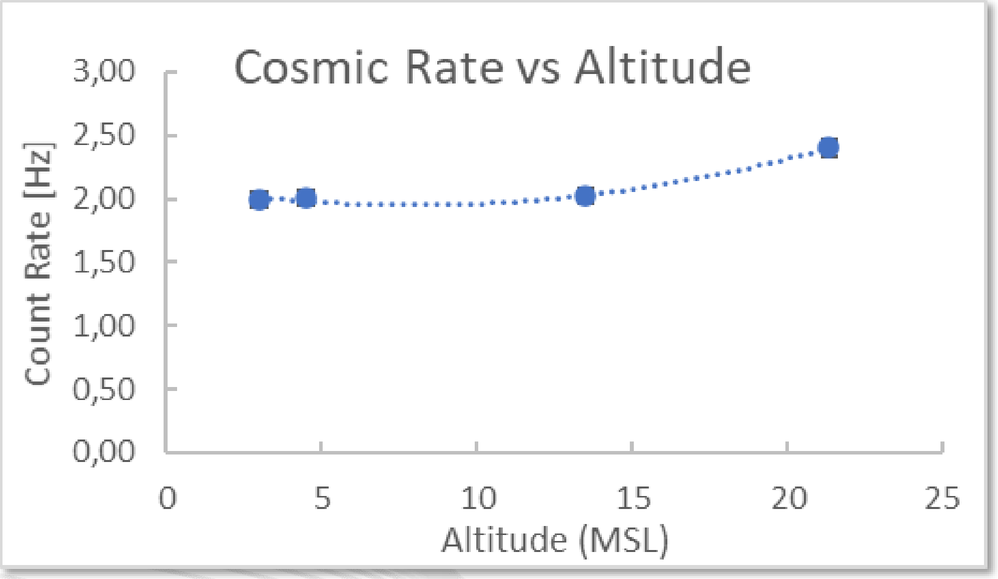
Additional tools

- n.1 SP5622 - Detection System
- n.1 DT1081A - Four-Fold Programmable Logic Unit and n.1 Cable Adapter

CAEN Tools for Discovery

Experimental activity

The experiment proves in a simple way the not terrestrial origin of the cosmic radiation. For a better comprehension of the cosmic flux behaviour as a function of the altitude, it is suggested to cover the floor with lead bricks.



https://www.chateau-doex.ch/en/Z4237/festival-des-ballons-homepage

Prof. Hans Peter Back

Albert Einstein Center for Fundamental Physics, University of Bern

Link to customer application

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Tools for Discovery

Experimental activity

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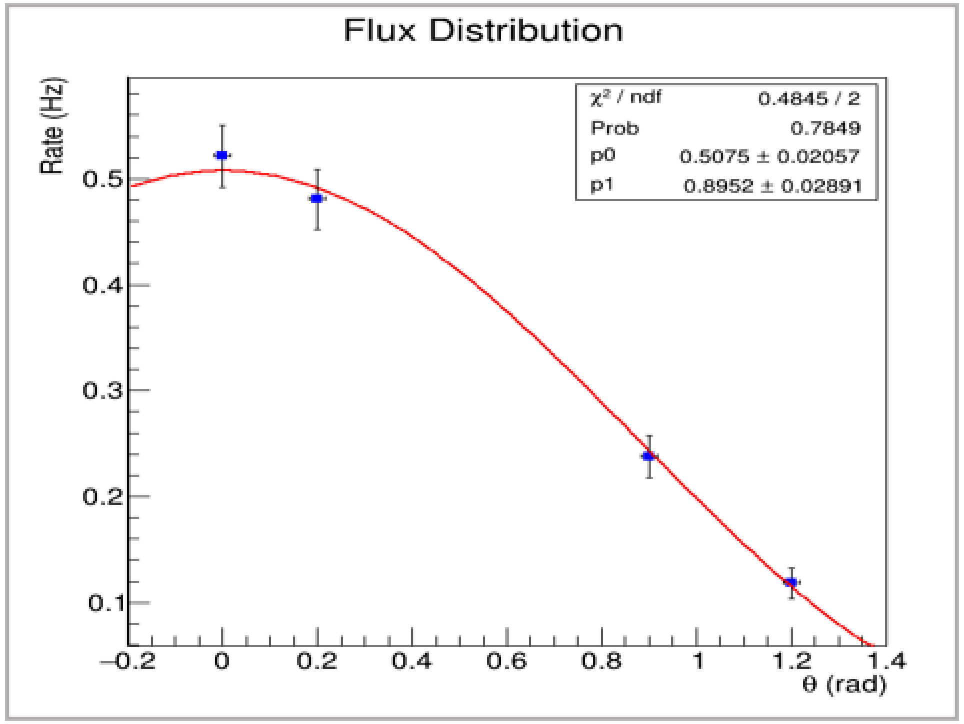
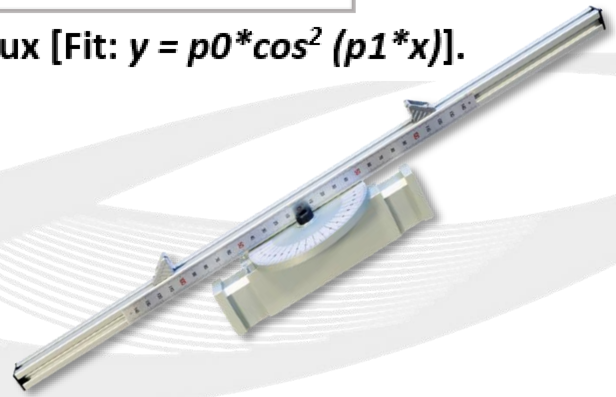


Zenith angle dependence of the muons flux [Fit: $y = p0*\cos^2(p1*x)$].

Additional tools

SP5609 - Telescope Mechanics



CAEN Tools for Discovery

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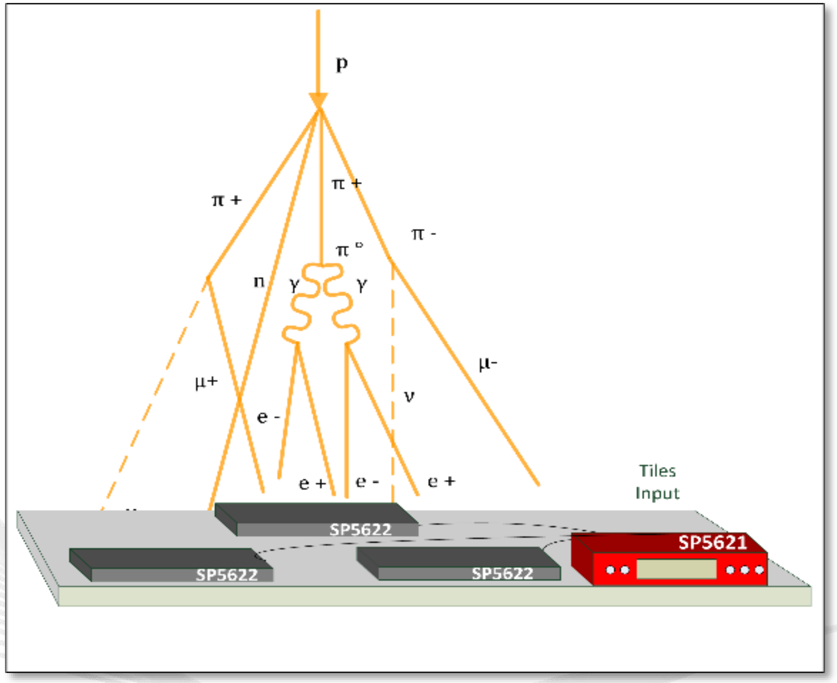
Observation of the cosmic ray showers, namely cascades generated by cosmic rays interacting in the atmosphere.



Additional tools

- SP5622 - Detection System

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Tools for Discovery

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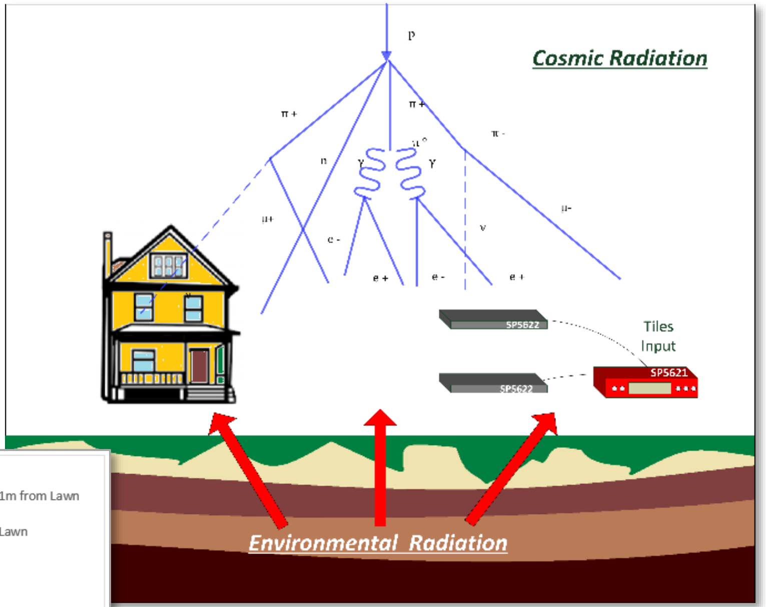

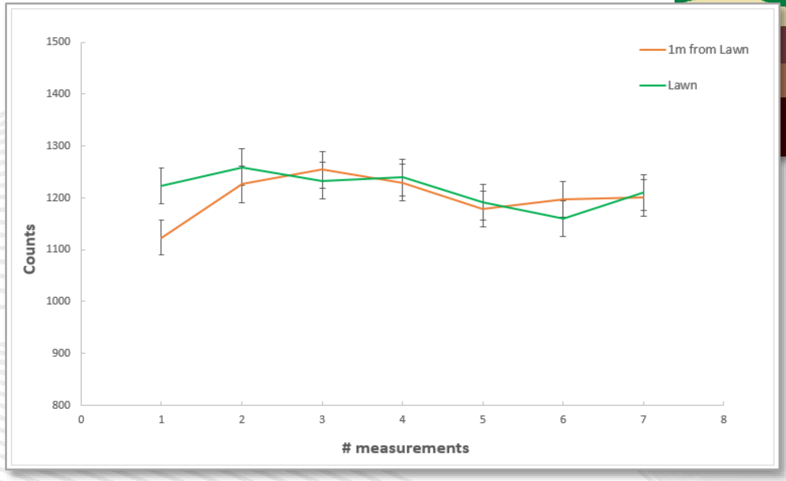

The students may get acquainted with the presence of natural radioactivity by identifying environmental and cosmic contributions via simple comparison of the counting measurements at different height.

Experimental activity

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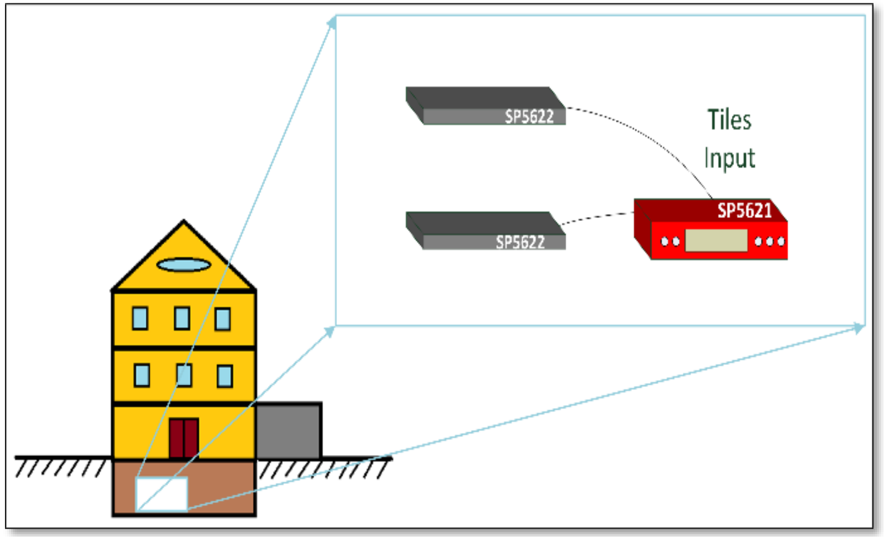
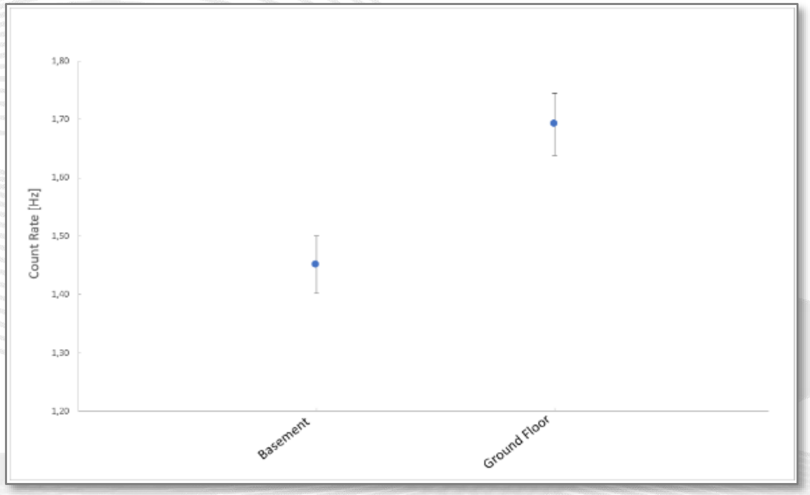
10) **Absorption Measurements**
11) Solar Activity Monitoring

The main goal of the experiment is the verification of the absorption of the cosmic rays passing through a matter thickness and the related observations about the crossed material.





The students may estimate the absorption extent by comparing the results of the measurements performed underground or inside a building or a cave, and outside, without any matter barrier. Moreover, by knowing the thickness, some hypothesis about the average density of the material can be expressed.

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Tools for Discovery

Experimental activity

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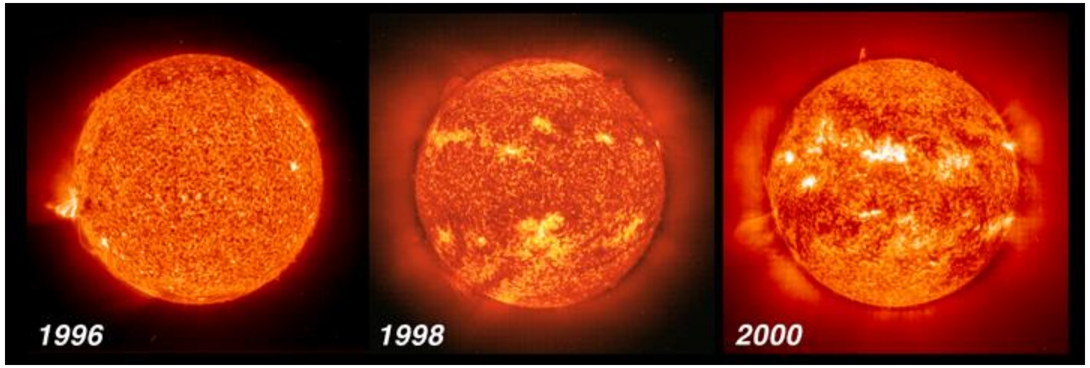
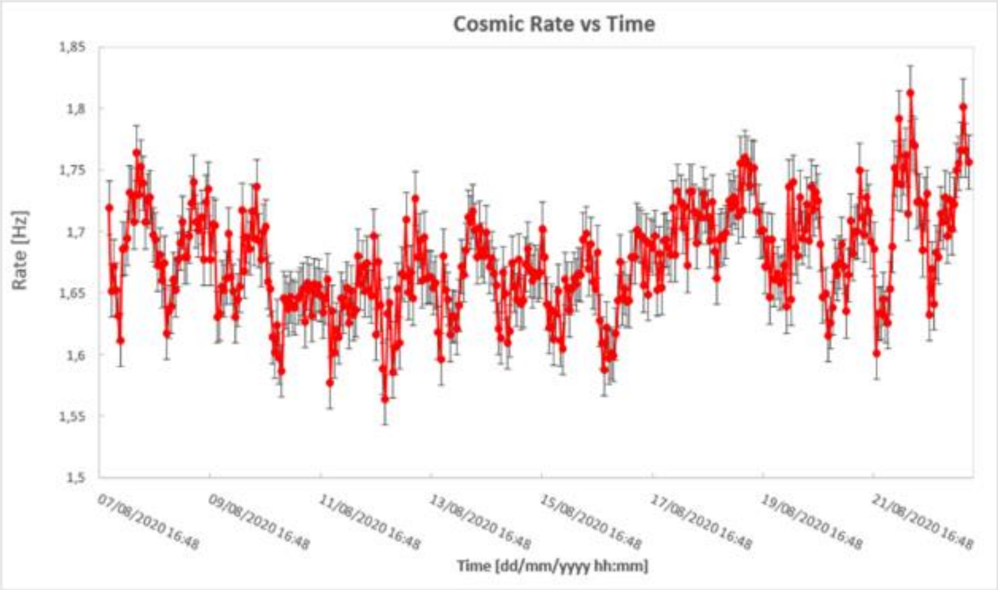
11) **Solar Activity Monitoring**





The typical cosmic rate night /day trend can be sometimes modified due to solar activity changes.

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Tools for Discovery

Spares Slides
SP5640

Educational Kits Description

SP5600E – Educational Photon kit

SP5600D – Educational Beta kit

SP5600C – Educational Gamma kit

SP5600AN – Educational kit Premium Version

SP5600 - Power Supply and Amplification Unit

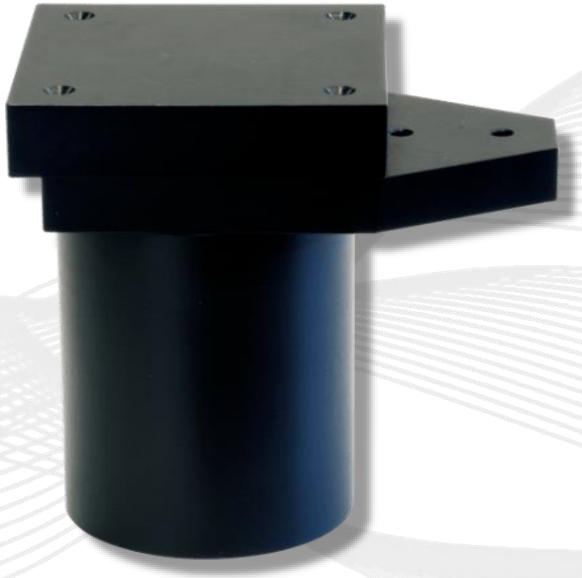
- Two channels
- Independent biasing (max 120 V, 100 μA)
- 2 stage amplification [500 MHz bandwidth, tunable gain up to ~ 50 dB]
- Fast leading-edge discriminator (±2V)
- Coincidence logic
- Active feedback control on V_{bias} for Gain stabilization (granularity: 0.1 ºC)
- USB 2.0 interface

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
- ±1V input range
- Optical Link and USB 2.0 interfaces

CAEN
Tools for Discovery

Educational Beta Kit Description



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

- Beta Spectroscopy
- Cosmics

CAEN
Tools for Discovery

Educational Beta Kit Description

SP5600E – Educational Photon kit

SP5600D – Educational Beta kit

SP5600C – Educational Gamma kit

SP5600AN – Educational kit Premium Version

Additional Tools

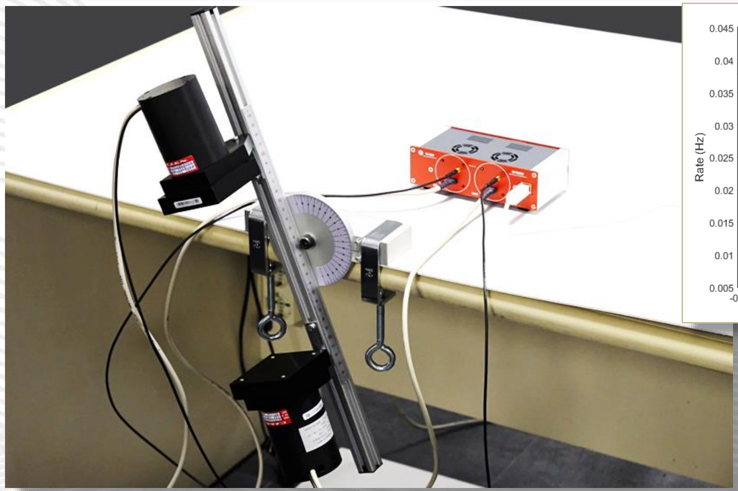
Additional SP5608 - Scintillating Tile

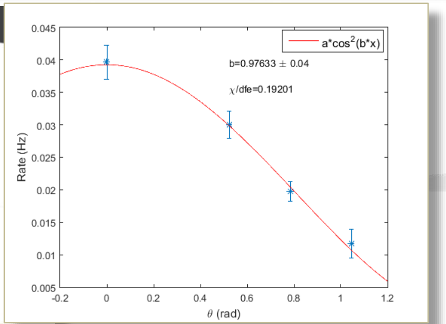
SP5609-Telescope Mechanics

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 Kits - HERA Software

SP5600D Educational Beta kit

SP5600C Educational Gamma kit

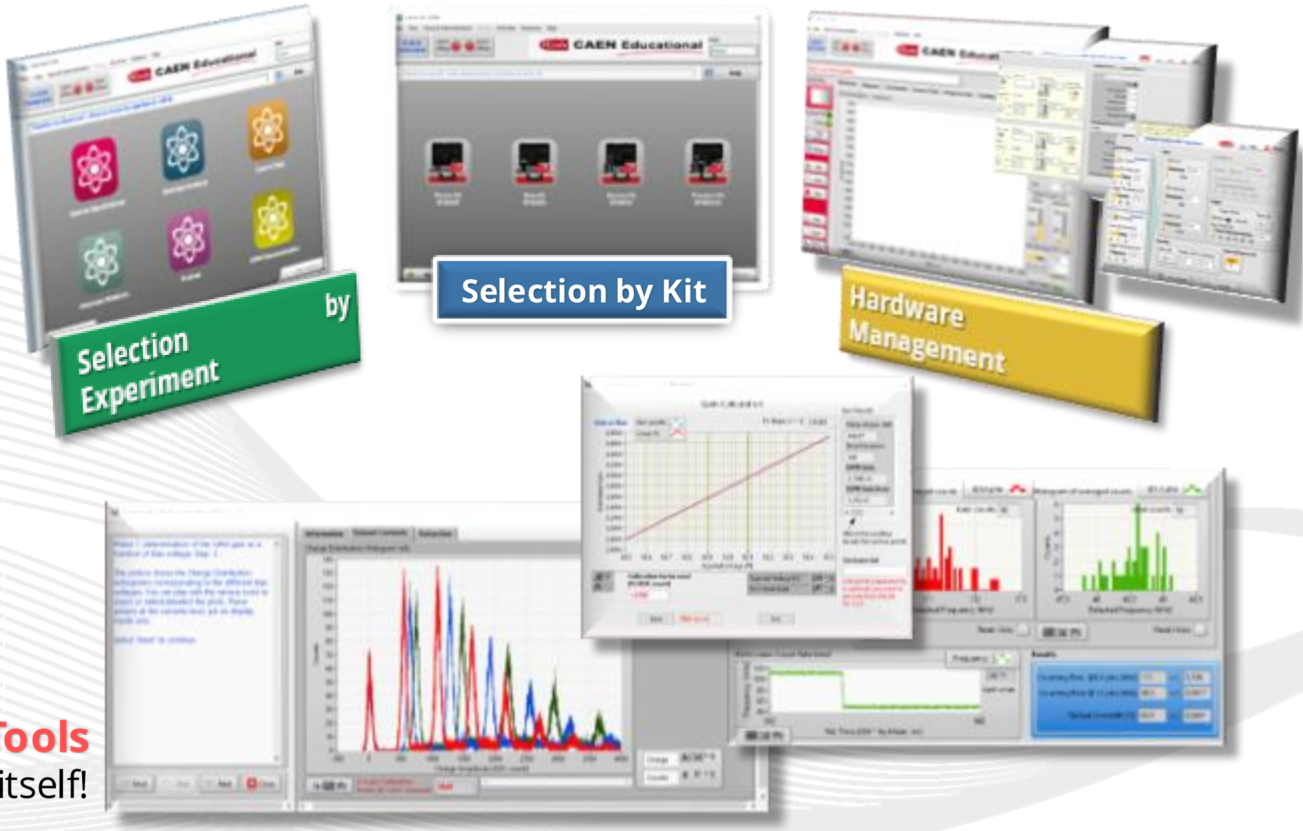
SP5600AN Educational kit Premium Version

SP5600E Educational Photon kit

HERA

Handy Educational Radiation Application

- **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!

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Tools for Discovery

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