Rev. 3 - May 5th, 2025

SP5660

RockyRAD

CAEN Tools for Discovery

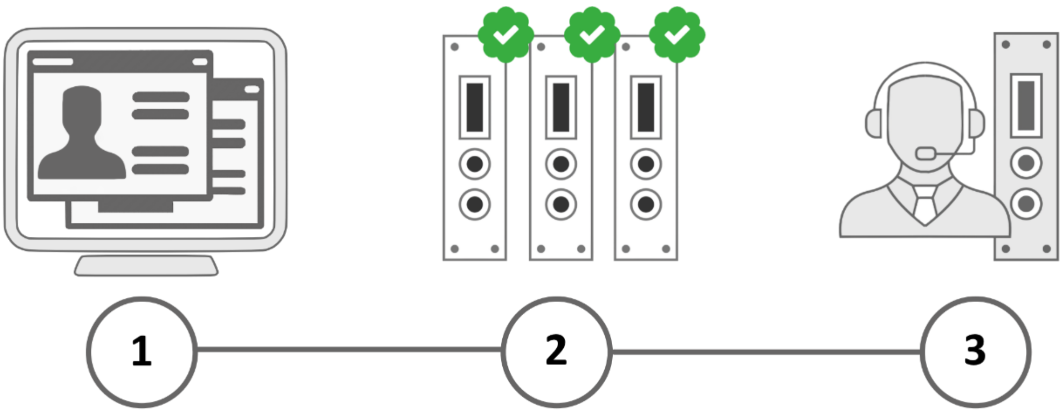
Guide

GD11340

Register your device

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

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



https://www.caen.it/become-mycaenplus-user/

Purpose of this Guide

This QuickStart Guide contains basic information and examples that will let you use RockyRAD in a few steps.

Change Document Record

Date	Revision	Changes
March 26th, 2024	00	Initial release
May 29th, 2024	01	Updated 6.1 Geiger-Müller Counter
June 4th, 2024	02	Updated 6.1 Geiger-Müller Counter
May 5th, 2025	03	Revision focussed on the new RockyBOX additional rock kit. Updated Chap. **2** and **3**. Added Sec. **6.3**.

Symbols, Abbreviated Terms and Notations

DC	Direct Current
USB	Universal Serial Bus
GM	Geiger-Müller
CPM	Counts Per Minute
OS	Operating system

Reference Document

All CAEN documents can be downloaded at:

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

Manufacturer Contacts

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Limitation of Responsibility

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

Disclaimer

Made in Italy

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

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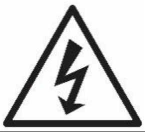
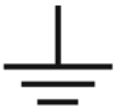
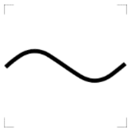
Safety Notices

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

The following HAZARD SYMBOLS may be reported on the unit:

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

The following symbol may be reported in the present manual:

	General warning statement

The symbol could be followed by the following terms:

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

CAUTION: To avoid potential hazards

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

CAUTION: Avoid Electric Overload

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

CAUTION: Avoid Electric Shock

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

CAUTION: Do Not Operate without Covers

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

CAUTION: Do Not Operate in Wet/Damp Conditions

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

CAUTION: Do Not Operate in an Explosive Atmosphere

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

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

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

See Chap. 12 for the Technical Support contacts.

Carefulness with Radioactive Sources

Some Physics experiments related to Gamma spectroscopy proposed in this manual needed radioactive sources.

There are two radioactive source types for educational purpose: sealed and unsealed sources. In the following experiments, sealed sources have been used. This source type is typically easier to use because the radioactive material is deposited in a plastic disk and sealed inside with a durable epoxy. Problems related to possible spills or decontamination are negligible.

Sealed gamma or beta sources of low activity, such as 0,1 µCi or a little bit more, can be handled directly without significant risk, although it is good practice to utilize tongs. Otherwise, sealed gamma sources with high activity, such as 10 µCi or more, should only be handled with tongs.

Nevertheless, when working with radioactive sources, mitigation of radiation exposures is very important. The basic principles of ALARA can give instructions. ALARA (As Low As Reasonably Achievable) is a radiation safety principle for minimizing radiation doses and releases of radioactive materials by employing all reasonable methods. ALARA is not only a sound safety principle for all radiation safety programs but is a regulatory requirement.

The three main principles are related to:

- Time**:** minimizing the time of exposure is the simplest way to directly reduce radiation exposure;
- Distance: doubling the distance between the radiation source and human body means to reduce radiation exposure by a factor of 4;
- Shielding: using absorber materials, such as lead for X-rays and gamma rays and Plexiglas for beta particles, to reduce the radiation reaching the body from a radioactive source is an effective way to reduce radiation exposures.

The radioactive sources for educational purpose have a low level of activity and them storing is a relatively simple matter. Solid sealed sources can be safely stored in the own plastic containers of shipment and then they can be put together in a locked cabinet, possibly with an additional shielding of lead sheets or bricks.

Important Note: Beta and Gamma Radioactive Sources are not included in the SP5660 RockyRAD.

1 Introduction

In a world where the term "radioactivity" often conjures images of perilous atomic bombs and the potential hazards of nuclear waste, it's crucial to recognize that radioactivity is an integral part of our surroundings. Far from being solely associated with danger, when approached with the right knowledge and handling, radioactivity can serve peaceful and constructive human purposes. At the core of this understanding lies the field of Nuclear Physics, a discipline that seeks to analyzes the physical processes governing radioactive phenomena.

RockyRAD is a powerful tool designed by CAEN, company with over 40 years of invaluable collaboration with the High Energy & Nuclear Physics community. Born out of this rich experience and the educational insights gained at the University of Ferrara, RockyRAD is part of a series of educational kits aimed at fostering a comprehensive comprehension of nuclear physics within university and high school laboratories.

RockyRAD, SP5660, is not just a Geiger-Müller counter; it is a portable and compact device that opens a window into the world of gamma and beta radiation. These types of radiation, produced by naturally occurring materials like soil and rocks, can be studied and better understood for various applications. For those who love an interdisciplinary approach, RockyRAD is an invaluable resource. Not only does it promote exciting STEM activities, but it also acts as a catalyst for projects that merge various subjects, such as Physics, Mathematics, Earth Sciences, Statistics, Computer Science, and Geography, creating a comprehensive educational experience.

Comprising a Geiger-Müller compact module, a USB cable, and a set of rock samples, RockyRAD is more than just a collection of components. It's a modular Educational Kit, a versatile tool that empowers users to assemble and configure it according to specific applications and individual preferences. With RockyRAD, users gain the ability to monitor and comprehend the radiation levels in their immediate environment.

This document serves as your comprehensive guide to RockyRAD, providing a hands-on primer on the essential functionalities of the kit.

Product Code	Description
WK5660XAAAAA	SP5660 - RockyRAD

Tab. 1.1: Table of models.

2 Technical Specifications

DETECTOR	Geiger Module GM J305
DISPLAY	OLED 128x64 pixels 1.54”
BATTERY	Rechargeable Li-Ion battery, 3.7Vdc, 10Ah, 37Wh.
INPUT/OUTPUT	• USB Type-C • Bluetooth
ACCESSORIES	• USB type C to USB cable • Included rock samples: Chalcedony, Tephrite, Pyrite, Porphyry, Amethyst, Trachyte, Granite, Rhyolite. • Additional rock samples (RockyBOX): Red Calcite, Chalcopyrite, Pink Jasper, Tiger’s Eye Quartz, Rhyolitic Ignimbrite, Diorite, Megabreccia, Pitchblende.

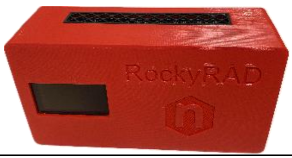
Tab. 2.1: Specifications table.

3 Packaging and compliancy

The SP5660 is a box kit measuring 35x6x23 mm³ (LxHxW), containing a Geiger-Müller counter and a set of rocks and minerals.

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

The content of the delivered package standardly consists of the part list shown in the table below (Tab. 3.1). All the official documentation, experiments, and videos are available on *www.edu.caen.it* or on *www.caen.it* at the product web page.

	Part	Description	Qty
	SP5660	RockyRAD	x1
	Detector	Geiger-Müller Counter	x1
	USB cable	USB type C to USB cable	X1
	Samples	Rocks and Minerals	X8

Tab. 3.1: Part list of the SP5660 delivery kit.

When ordering the RockyBOX, a little box with eight additional rocks is delivered.

	Part	Description	Qty
	RockyBox	Additional Rock kit	x1

Tab. 3.2: Part list of the RockyBOX delivery kit.

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

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

- Inspect containers for damage during shipment. Report any damage to the freight carrier for possible insurance claims.
- Check that all the components received match those listed on the enclosed packing list as in Tab. 3.1.(CAEN cannot accept responsibility for missing items unless any discrepancy is promptly notified.)
- Open shipping containers; be careful not to damage contents.
- Inspect contents and report any damage. The inspection should confirm that there is no exterior damage to the unit such as broken knobs or connectors and that the front panel and display face are not scratched or cracked. Keep all packing material until the inspection has been completed.
- If damage is detected, file a claim with carrier immediately and notify CAEN service (see Chap. 12).
- If equipment must be returned, carefully repack equipment in the original shipping container with original packing materials, if possible. Please contact CAEN service.

DO NOT SUBJECT THE ITEM TO UNDUE SHOCK OF VIBRATIONS

DO NOT BUMP, DROP OR SLIDE SHIPPING CONTAINERS

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

USE ONLY ACCESSORIES WICH MEET THE MANUFACTURER SPECIFICATIONS

4 PID (Product Identifier)

PID is the CAEN product identifier, an incremental number greater than 10000 that is unique for each product[1]. The PID is on a label affixed to the product (Fig. 4.1 and **Errore. L'origine riferimento non è stata trovata.**).

Fig. 4.1: PID location on SP5660 (the number in the picture is purely indicative).

Fig. 4.2: PID location on SP5660 box (the number in the picture is purely indicative).

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

5 Power Requirements

The SP5660 is equipped with an internal rechargeable Li-Ion battery rated at 3.7V DC, 10Ah, and 37Wh. The power supply cord is included in the delivered kit, enabling user to recharge or power the system using the USB plug connector (+5V).

Fig. 5.1: Power supply cord connected to SP5660.

6 General Description

The RockyRAD - SP5660, shown in Fig. 6.1, is composed of a Geiger-Müller counter and a set of rock samples from different origins, allowing users to immediately begin their detection experiments.

Fig. 6.1: RockyRAD – SP5660.

6.1 Geiger-Müller Counter

Geiger-Müller radiation counter represents the core of the RockyRAD educational kit. A Geiger-Müller tube (G.M. tube) is a gas-filled device that reacts to individual ionizing events, thus enabling them to be counted. A G.M. Tube consists of an electrode at a positive potential (anode) surrounded by a metal cylinder at a negative potential (cathode), as shown in Fig. 6.2. The cathode forms part of the envelope or is enclosed in a glass envelope. Ionizing events are initiated by particles entering the tube through the window or the cathode and colliding with the gas molecules. The gas filling consists of a mixture of one or more rare gasses and a quenching agent. Quenching is the termination of the ionization current pulse in a G.M. tube. Effective quenching in the G.M. tube is determined by the combination of the quenching gas properties and the value of the anode resistor.

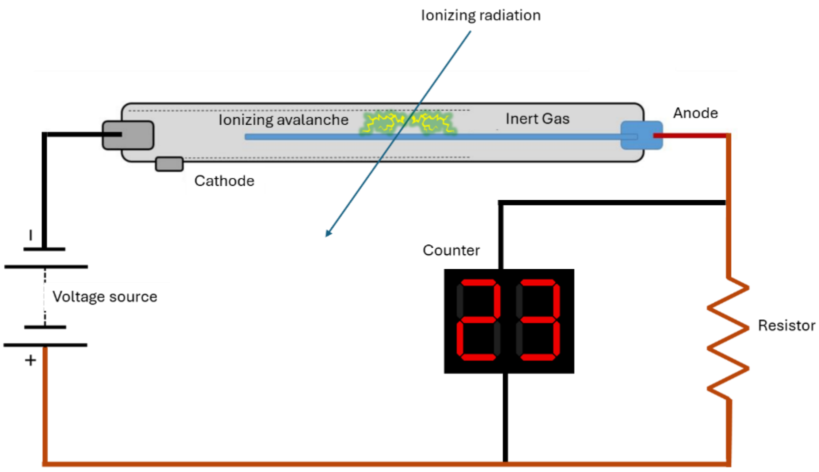


Fig. 6.2: General scheme of Geiger-Müller Counter.

In these devices, the collected charge is independent of primary ionization. In addition to ionization, phenomena such as excitation followed by the emission of visible and ultraviolet light occur. A small portion of these photons results in the emission of photoelectrons that generate new ionization through the avalanche multiplication process. In the operating region of a Geiger-Müller counter, only a single primary pair is sufficient to initiate a complete avalanche discharge. Consequently, the amplitude of the output pulse is no longer a measure of primary ionization. This implies that a Geiger counter is suitable for use as a radiation counter rather than in spectroscopy experiments.
The "characteristic curve of the counter", a typical graph created by plotting applied voltages on the x-axis and the count rate (recorded pulses in a time interval T) on the y-axis, is shown in Fig. 6.3.

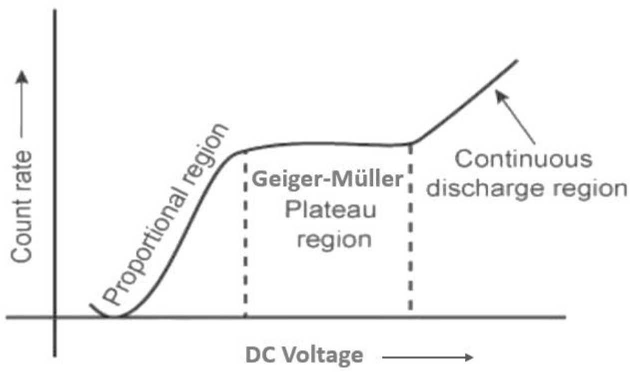


Fig. 6.3: Geiger-Müller counter: plateau graph.

This curve features a region with a small slope spanning hundreds of volts, known as the counter "plateau".
The counter operating voltage is chosen to be approximately 1/3 of the entire plateau to ensure that any variations in the counter supply voltage V do not take it outside the working region. However, applying a higher voltage can produce spurious charges within the detector.
Depending on their geometry, Geiger-Müller tubes (G.M. tubes) are intended to detect alpha particles, beta particles, gamma, or X-radiation.
The GM tube in the SP5660 has a glass thickness that prevents the detection of alpha particles but, at the same time, is thin enough to allow the detection of beta particles, gammas, and X-rays.
Counters for gamma rays operate due to ionization caused by electrons produced through the photoelectric effect, Compton effect, or pair creation from the interaction of gamma rays with the walls or the filling gas. Due to the low probability of interaction with gas, reliance is placed on interaction with walls, requiring windowless counters with significant thicknesses of metal walls.

Diameter (mm)	10±0.5
Length (mm)	107±3
Material	Glass
Initial Voltage (V)	≤350
Plateau area (V)	360-440
Recommendation operating voltage (V)	380
Working temp. range (°)	-40~55
Detecting	γ β

Tab. 6.1: GM Counter tube model J305 specifications.

The GM counter included in RockyRAD is a compact, detector designed for monitoring gamma, beta and X-rays. Equipped with a ESP32 board, 1.54" display, and a power button, the device also includes a USB-C connector on the side for battery charging.

Measuring range	10 nSv/h – 50 µSv/h
Sensitivity	44 CPS/10 µSv/h (relative to ^{60}Co)
Device Background	0.2 CPS
MCU Operating Voltage	3.3 V
Power Consumption	0.05W
Temperature range	-5°C ~ +40°C ≤10%
Power Supply	5 V (USB-C)
Dimension	71 * 136 * 43.8 mm^3

Tab. 6.2: The key specifications of the RockyRAD radiation detection system, highlighting its measurement range, sensitivity, and operational features in a compact and efficient design.

As shown in Fig. 6.4, during a measurement, the display provides information about the battery status, sound mode, date, and time. It also presents the measurement results every minute. Specifically, it shows the total count of the ongoing measurement (CNTS), the average counts per minute (CPM), and the equivalent dose rate (nSv/h), which represents the physical quantity used to quantify the interaction between radiation and matter, taking into account the type of radiation.

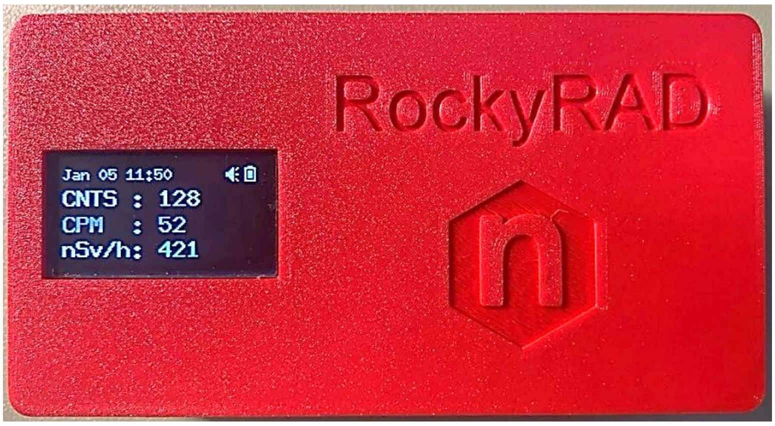


Fig. 6.4: Display information: battery status, sound mode, date and time, total counts (CNTS), counts per minute (CPM) and equivalent dose rate (nSv/h).

While the instrument produces an audible sound when it detects an ionizing particle, it does not have predefined alarm thresholds.

The GM counter is a tool that, in addition to detecting the presence of ionizing radiation, allows for the estimation of dose. It is essential to clarify what is meant by dose. For the assessment of exposure to ionizing radiation, special quantities called dosimetric quantities have been developed. These are based on measuring the energy deposited by radiation in the material they traverse and correlating it with the actual health risk. The effects of ionizing radiation only manifest when there is an imparting of energy to the medium it passes through. In particular, the damage to biological tissues is directly related to the absorbed energy per unit mass. This is accounted for by the quantity *Absorbed Dose, D*, defined as the ratio of the average energy transferred by ionizing radiation to matter in a certain volume element and the mass of matter contained in that volume element. The international unit of absorbed dose is the *Gray* (*Gy*)[2].

Using absorbed dose alone is not sufficient to measure exposure in radiation protection and estimate associated risk. This is because the effects of radiation depend not only on the absorbed dose but also on the type of radiation. Equal doses delivered by different types of radiation result in different biological damages. To account for the varying harmfulness of incident radiation, radiation weighting factors, *wR*, have been introduced. The product of the average absorbed dose in an organ or tissue, *DT*, multiplied by the radiation weighting factor, *wR*, is termed the *Equivalent Dose* in the tissue or organ *T*, *HT* (*HT = wR * DT*). The unit of measurement for equivalent dose is the *Sievert* (*Sv*) (or it can be measured in *rem* or *roentgen (R): 1 Sv = 100 rem*).

The infographic (Fig. 6.5) and the data provided by the RockyRAD Geiger counter offer a detailed framework for understanding radiation exposure in various environments.

It is recommended to refer to Tab. 6.3 for typical operating ranges when using RockyRAD. Starting at the lower end, typical natural background levels represented in the table help establish what is considered normal or baseline radiation exposure. This concept is visualized in the infographic as part of everyday environmental radiation.

As the table progresses to mid-range values, it indicates increased radiation levels that may be due to specific locations or activities. These levels are comparable to exposures from common medical procedures or increased environmental exposure, as illustrated in the infographic. It's important to note that while the RockyRAD provides dose rates per unit of time, the infographic in some cases shows total dose per event, offering a different perspective on exposure assessment. Higher values in the table are akin to the limits set for radiation workers, providing a visual benchmark within the infographic for what is deemed safe over a year of occupational exposure. At the uppermost level, the highest values measured by the RockyRAD, especially those approaching its maximum detection limit, align with the infographic's depiction of scenarios of extreme exposures during nuclear accidents.

By integrating the table's data with the visual cues from the infographic, it becomes easier to see how these measurements relate to daily activities, professional limits, and extraordinary events, enhancing the understanding of radiation safety and risk assessment across various contexts.

[2] 1 *Gray* corresponds to the absorption of 1 *joule* in 1 *kg* of matter ($1\ Gy = 1\ J\ kg^{-1}$). The absorbed dose can also be expressed in *rad*, a previously used unit of measurement (*1 Gy = 100 rad*).

CPM	Estimated Dose Rate [nSv/h]	Environment and Comments
14-34	114-274	Typical natural background radiation, corresponding to an annual dose of 1-2.4·10³ µSv.[3]
28-48	228-388	Represents an increase of 10³ µSv per year compared to the typical background, aligning with the public exposure limit.[4]
281	2282	The standard annual exposure limit for radiation workers in the nuclear industry, equating to 2 ·10⁴ µSv.[5]
493	4000	Exposure at this level during high-altitude flights is generally safe due to the limited duration of flights[6]. 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.

Tab. 6.3: Range of Counts Per Minute (CPM) and corresponding estimated dose rates in nanosieverts per hour (nSv/h), contextualizing different radiation exposure levels from natural background to occupational settings. The CPM ranges from typical environmental background levels to the maximum detectable limit of the RockyRAD device, illustrating various scenarios: natural background exposure, a slight increase over this which aligns with public exposure limits, the occupational exposure limit for nuclear industry workers, typical levels during high-altitude flights and the maximum detectable scale of the device.

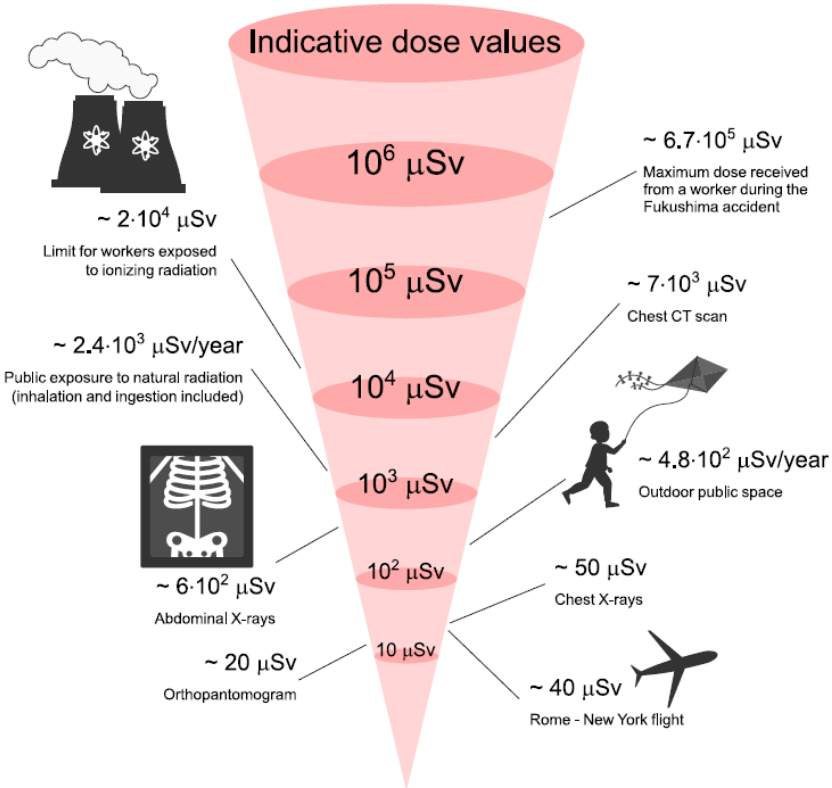


Fig. 6.5: Indicative radiation dose values in microsieverts (µSv), comparing exposure levels from everyday activities and medical procedures to extreme cases like nuclear accidents . This helps visualize the scale of radiation exposure in various contexts.

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[3] 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.

[4] ICRP, International Commission on Radiological Protection. "Dose limits". ICRPedia. ICRP. Retrieved 26 April 2022.

[5] 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.

[6] 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.

6.2 Rocks and Minerals

The inclusion of various rocks in the RockyRAD kit is designed to delve into and highlight the range of natural radioactivity found within geological materials. Each rock selected for the kit acts as a representative example, revealing distinct mineral compositions and geological processes that can significantly impact natural radioactivity levels.
Rocks such as granite and rhyolite are iconic representatives of major igneous rock types and are known to contain minerals with fluctuating concentrations of radioactive elements like uranium and thorium. The decay of these elements over time releases radiation that can be detected with a Geiger counter.
Examining these rocks offers not only a hands-on way to understand the use of a Geiger counter but also provides an educational experience that enables a direct examination of the relationship between geology and radioactivity. This practical approach aims to enhance awareness of the significance of geological sciences and the presence of natural radiation in our everyday environment.

6.2.1 Chalcedony

Chalcedony is a special kind of rock that's made up of tiny crystals of quartz and moganite all mixed together.
This rock is known for its cool colours, like soft blues, pinks, and purples. It can also be white or grey, and sometimes it has neat stripes. Chalcedony comes in different shapes too, like smooth rounded ones or big lumpy masses.
Renowned for its use in jewellery and decorative arts, chalcedony has been cherished throughout history! The ancient Greeks and Romans, for example, valued it for carving intricate cameos and creating ornate jewellery pieces. Its versatility and ability to take a high polish make it a favoured choice for crafting gemstones, beads, and cabochons.
One cool thing about chalcedony is that some folks think it has magical vibes. They believe it can bring a sense of calm and balance. In different cultures, it's seen as a protector, keeping away bad vibes and bringing in the good ones.
Whether admired for its visual beauty, utilized in artistic creations, or embraced for its metaphysical qualities, chalcedony stands as a testament to the fascinating diversity found within the realm of minerals. Its timeless appeal continues to captivate those with an appreciation for the natural wonders of the Earth.

6.2.2 Tephrite

Tephrite is an igneous and volcanic rock with distinctive leucitic crystals, contributing to understanding of volcanic processes and the Earth's geological history. It is characterized by its composition and texture.
Tephrite is formed through volcanic activity, specifically as a product of the cooling and solidification of magma or lava. The rock is classified as a fine-grained or aphanitic basaltic rock, meaning its crystals are too small to be easily identified without the aid of a microscope.
Leucite, a prominent mineral in tephrite, is a feldspathoid mineral that forms in silica-undersaturated environments. Tephrite's mineral composition often includes feldspar, augite, and olivine, in addition to leucite.
Geologically, tephrite is associated with certain types of volcanic environments and can be found in various regions around the world.
Tephrite's name is derived from the Greek word "tephra," which means "ash," underscoring its volcanic origin.

6.2.3 Pyrite

Pyrite, also known as "fool's gold," is a sulfide mineral characterized by its brassy-yellow or gold-like metallic luster. Composed primarily of iron (Fe) and sulfur (S), it crystallizes in the cubic system, forming cubic, octahedral, or pyritohedral crystals.
This mineral's colour ranges from pale brass-yellow to a deep gold hue, exhibiting a shiny and reflective metallic luster. Pyrite is relatively hard, and it possesses a relatively high density.
It is commonly found in various geological settings, including sedimentary rocks, metamorphic rocks, and certain ore deposits. It often forms in association with other sulfide minerals and may be present in coal beds and specific sedimentary formations.
Historically, pyrite has earned the moniker "fool's gold" due to its visual resemblance to gold, leading many to mistake it for the precious metal. Despite its deceptive appearance, pyrite itself does not contain gold.
In terms of industrial uses, pyrite has significance in the production of sulfur dioxide and sulfuric acid. It has also found applications in the manufacturing of certain types of batteries.
Pyrite's unique appearance, historical associations, and industrial applications contribute to its significance in the field of mineralogy and make it an intriguing mineral for collectors and researchers alike.

6.2.4 Porphyry

Porphyry is a type of igneous rock characterized by a porphyritic texture, where large crystals known as phenocrysts are embedded in a fine-grained matrix. The term "porphyry" comes from the Greek word "πορφύρα" (porphyra), meaning purple, which historically referred to the purple-red form of this rock valued in antiquity. The colour of porphyry can vary widely, including red, brown, green, and purple shades, depending on the specific mineral composition and the geological environment in which the rock formed.

Porphyry forms during the slow cooling of volcanic magma, which allows the formation of large phenocrysts, followed by rapid cooling that forms the finer matrix. This dual cooling process results in the distinctive texture of porphyry. The phenocrysts in porphyry typically consist of quartz, feldspar, or other minerals, while the groundmass can be aphanitic to glassy in texture.

Due to its durability and aesthetic appeal, porphyry has been extensively used throughout history in architecture and sculpture. In ancient Rome, porphyry was a prized material for monumental works and imperial sculptures, often associated with power and prestige. The source of much of this material was the Eastern Desert of Egypt, from quarries in the Mons Porphyrites region, which were exploited extensively in the Roman period.

In modern times, porphyry is used for a variety of construction and decorative purposes, including paving stones, building facades, and interior decoration. Its resistance to weathering and wear makes it suitable for outdoor applications, particularly in areas subjected to heavy foot traffic or vehicular use.

Porphyry deposits are found in various locations around the world, including Italy, Mexico, and the United States, among others. The specific properties and applications of porphyry can vary depending on the composition and origin of the rock, making it a versatile material in the construction and decorative industries.

6.2.5 Amethyst

Amethyst is a well-known and widely appreciated violet variety of quartz, recognized for its enchanting purple hue which can range from light lavender to deep, intense royal purple. This gemstone's colour is attributed to irradiation and the presence of iron impurities within its crystalline structure, which leads to complex lattice substitutions that bring about its distinctive coloration.

In terms of its physical properties, amethyst possesses a vitreous luster and is transparent to translucent. With a Mohs hardness of 7, it's both durable and suitable for a variety of jewellery applications. This mineral is typically found in hexagonal crystal systems and lacks cleavage, meaning it breaks with a conchoidal fracture, akin to glass.

Amethyst's geographical distribution is extensive, with significant deposits found in Brazil, Uruguay, Russia, and South Korea, among other regions. Brazilian and Uruguayan locales, in particular, are renowned for their large amethyst geodes, which are often mined for both gemstone and decorative purposes. The Four Peaks Mine in Arizona is notable within the United States for producing amethyst with a reddish-purple hue.

The gemstone is not only valued for its beauty but also for its historical significance and purported metaphysical properties. The Ancient Greeks believed amethyst could prevent intoxication, a notion reflected in the gemstone's name, derived from the Greek "amethystos," meaning "not intoxicated".

For those interested in amethyst as a gemstone for jewellery or as a collector's item, it's important to consider the gem's colour, clarity, and cut. High-quality amethyst typically displays a deep purple colour with minimal inclusions and is well-cut to highlight its luster and colour.

6.2.6 Trachyte

Trachyte is an extrusive igneous rock predominantly composed of alkali feldspar, with a fine-grained texture that often includes minor amounts of dark-coloured minerals such as biotite, amphibole, or pyroxene. The volcanic equivalent of the plutonic rock syenite, trachyte typically showcases a light coloration, though it can appear black if composed mainly of glass.

This rock is characterized by a porphyritic texture, where large, well-formed sanidine crystals (phenocrysts) are set in a fine-grained groundmass. These phenocrysts can be quite large, making trachyte's texture one of its distinctive features. Trachyte can have a rough texture, a characteristic that is reflected in its name, derived from the Greek word "trachys," meaning rough.

Trachyte forms in volcanic regions and is believed to have originated from the crystallization and abstraction of iron, magnesium, and calcium minerals from a basaltic parent lava. This process results in a composition that is rich in alkali metals and relatively low in silica, distinguishing trachyte from other volcanic rocks like basalt, andesite, and rhyolite.

Geographically, trachyte is found in various volcanic regions, including the Aeolian arc in Italy and the Campi Flegrei volcanic field. It's also present in ocean islands, continental rift valleys, mantle plumes, and back-arc extension zones like the northern Aegean Sea. Notable locations include Skye in Britain, the Rhine district in Europe, and volcanic regions in Italy such as Rome, Naples, and the island of Ischia.

6.2.7 Granite

Granite, a coarse-grained igneous rock, predominantly consists of quartz, feldspar (both plagioclase and alkali feldspar), and mica. It forms from the slow cooling and solidification of magma deep within the Earth's crust, which allows large crystals to grow. This process classifies granite as a plutonic rock, distinguishing it from volcanic rocks that cool rapidly at the surface.

The scientific study of granite involves understanding its formation, which is linked to tectonic processes such as the melting of continental crust material. Granite is often associated with mountain-building regions where continental collision occurs, leading to the thickening of the crust and subsequent melting due to increased temperature at depth.

Granite's mineral composition, specifically the ratio of quartz to feldspar and the type of feldspar present, can vary, leading to different types and colours of granite. This variability is a subject of study in petrology to understand the conditions under which different types of granite form.

Granite plays a significant role in geology not only as a record of crustal processes but also due to its economic importance as a major construction material and its use in countertops due to its durability and aesthetic appeal.

6.2.8 Rhyolite

Rhyolite, a volcanic rock with a fascinating story etched in its composition, emerges from the Earth's dynamic processes. Defined by its fine-grained texture, rhyolite is primarily composed of quartz, feldspar, and mica. What sets it apart is its origin in explosive volcanic eruptions, where magma rich in silica cools rapidly upon reaching the surface.

Rhyolite, an extrusive igneous rock, is characterized by its high silica content, typically ranging between 69% to 77%. It is the volcanic equivalent of granite, with a composition that includes minerals such as quartz, plagioclase, and lesser amounts of orthoclase, biotite, and amphibole, among others. The texture of rhyolite is predominantly aphanitic to porphyritic, indicating rapid cooling at the surface which inhibits the growth of large crystals, although larger crystals (phenocrysts) may be present within a finer matrix.

From a geophysical perspective, the formation of rhyolite involves processes such as fractional crystallization, where a mafic source magma evolves into a more felsic composition, and anatexis, the partial melting of crustal rocks. These processes contribute to the silica enrichment characteristic of rhyolitic magma. Due to its high viscosity, rhyolitic magma impedes the effusion of volatiles, leading to the potential for explosive volcanic eruptions. This viscosity is a function of the magma's silica content and temperature, with rhyolite magmas typically erupting at temperatures between 800°C to 1000°C.

Rhyolite's occurrence is predominantly associated with tectonic settings that promote crustal melting and magma differentiation, such as convergent plate boundaries and continental hotspots. Its presence indicates significant geological processes that contribute to the diversification of the Earth's crustal compositions.

6.3 Rocks and Minerals in RockyBOX

In addition to the samples already described in Sec. **6.2**, the kit has been enriched with a further selection of eight specimens, chosen to represent a variety of lithotypes of geological, geochemical and radiometric interest. These rocks and minerals provide opportunities for in-depth study of the origin of Earth materials, their composition, and, in some cases, their relevance in the context of natural radioactivity measurements. A brief description of each is provided below.

6.3.1 Red Calcite

Calcite is a common carbonate mineral with the chemical formula $CaCO_3$. The "red" variety is distinguished by the presence of iron impurities, primarily hematite, which give it a deep reddish-brown color. It forms by chemical precipitation from calcium- and bicarbonate-rich waters, typically in sedimentary environments, but also as a hydrothermal vein filling. From a geochemical point of view, red calcite maintains the same structure as pure calcite, but with local enrichment in iron. Its natural radioactivity is usually negligible, although it may contain trace amounts of radium-226 if formed in mineralized environments.

6.3.2 Chalcopyrite

Chalcopyrite ($CuFeS_2$) is the most abundant copper sulfide in the Earth's crust and the primary industrial source of copper. It is recognized by its characteristic brassy yellow color and metallic luster, often accompanied by colorful iridescent tarnish. It crystallizes from hydrothermal fluids, often in association with pyrite, bornite, and other sulfides, and is found in vein systems, skarn deposits, porphyry copper systems, and VMS (volcanogenic massive sulfide) settings. Chemically stable, it generally does not display significant natural radioactivity, although trace concentrations of uranium and thorium may occur in complex mineralized systems.

6.3.3 Pink Jasper

Pink jasper is a variety of microcrystalline chalcedony, itself a cryptocrystalline form of quartz. Its pink coloration results from finely dispersed iron oxides such as hematite. Jasper forms in sedimentary or volcanosedimentary environments, where silica precipitates from colloidal solutions, often in the presence of organic material or metallic oxides. Structurally compact with a conchoidal fracture and dull luster, it is composed almost entirely of silicon dioxide (SiO_2) and presents negligible levels of natural radioactivity.

6.3.4 Tiger's Eye Quartz

Tiger's eye is a fibrous variety of quartz known for its chatoyancy—a silky, banded appearance caused by the pseudomorphic replacement of crocidolite (an iron-rich amphibole) by silica. Its golden and brown bands result from finely intergrown iron oxides. This mineral forms in metamorphic-hydrothermal environments where silica-rich, oxidizing fluids alter iron-bearing rocks. Chemically dominated by SiO_2 with minor iron, it does not present significant natural radioactivity, although the original crocidolite precursor may contain trace radioactive elements

6.3.5 Rhyolitic Ignimbrite

Rhyolitic ignimbrites are volcanic pyroclastic rocks formed by the deposition of pyroclastic flows (nueés ardentes) during explosive eruptions of rhyolitic magmas. They are composed of glass shards, quartz and feldspar crystals, and sometimes pumice and welded fiamme. Geochemically, they are highly silicic (>70% SiO_2) and often enriched in naturally radioactive elements such as uranium, thorium, and potassium-40. These rocks are commonly associated with large calderas and silicic volcanic fields, and are among the primary geologic sources of radiometric anomalies in volcanic terrains.

6.3.6 Diorite

Diorite is an intermediate intrusive igneous rock with a medium-grained holocrystalline texture. It is mainly composed of plagioclase (andesine), amphiboles, biotite, and minor quartz. It forms by slow cooling of intermediate magmas in the deep crust, typically in subduction-related settings. Chemically, it contains moderate silica levels (55-65%), with variable amounts of Al, Fe, Mg, Ca, Na, and K. Diorite exhibits moderate natural radioactivity due to the presence of potassium-bearing feldspars and micas, which may contain potassium-40.

6.3.7 Megabreccia

The term megabreccia refers to a clastic rock composed of large, angular rock fragments (often exceeding 1 meter in size) embedded in a finer matrix. It forms during high-energy geological events such as submarine landslides, caldera collapse, tectonic faulting, or meteorite impacts. Its chemical composition depends on the lithologies of the included clasts. Some megabreccias may contain radioactive fragments, especially if derived from granitic, volcanic, or mineralized rocks. For this reason, they may display variable and locally elevated natural radioactivity.

6.3.8 Pitchblende

Pitchblende is a massive variety of uraninite, a mineral composed primarily of uranium dioxide (UO_2), often with mixed uranium and lead oxides (U_3O_8, PbO). It precipitates from hydrothermal fluids rich in uranium, typically in vein deposits or reducing sedimentary basins. Black and dense, it is strongly radioactive and represents the main natural source of uranium. Historically, pitchblende has been essential for uranium extraction and nuclear fuel production. Due to its high radioactivity, it is particularly useful for calibrating and testing gamma radiation detectors.

7 RockyRAD Interface

The RockyRAD application serves as your gateway to harnessing the full capabilities of your RockyRAD Geiger counter, effectively transforming your Android device into a command centre for radiation detection. Designed with intuition in mind, the application ensures user-friendliness, enabling seamless interaction with your RockyRAD device and facilitating the process of conducting precise measurements and documenting results.
Key features of the application include the ability to start new measurement sessions, capture photographic evidence to be associated with specific readings, specify measurement intervals, and effectively organise and review the data collected. The user interface is crafted to provide a fluid experience, guiding you from the initial setup to the eventual sharing and examination of the logged information.
In addition to these functionalities, the RockyRAD application offers the flexibility to export measurement logs in CSV format. This feature allows for the extraction of detailed data records from the application, enabling users to download and transfer the logs to a personal computer for further data processing or analysis in various software environments that support CSV files.
As you prepare to explore the capabilities of RockyRAD, the initial step is to install the application from the Android Play Store. The forthcoming sections of this manual will delineate the installation steps, describe how to search for and obtain the app, and provide a comprehensive exploration of its features and operational instructions.

7.1 System Requirements

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

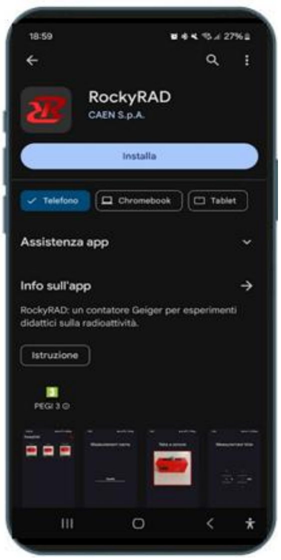
7.2 App Installation

To ensure full functionality of your RockyRAD Geiger counter with your Android device, including data recording, analysis, and sharing capabilities, it's essential to install the accompanying software application. Please follow these steps to install the RockyRAD application, or scan the QR code provided below:

Scan this QR code to download
the RockyRAD app from Google Play

Fig. 7.1: RockyRAD App QR code.

- **Navigate to the android store:** unlock your android device and locate the 'play store' application. tap the icon to open the store.
- **Search for the application:** once in the play store, use the search function at the top of the screen and type in RockyRAD. select the search result that corresponds to the official RockyRAD application.



- **Install the application:** after selecting the RockyRAD application from the search results, you will be directed to the application's page. here, tap on the 'install' button. the download and installation will begin automatically.
- **Open the application**: after the installation is complete, an 'open' button will appear in place of the 'install' button. tap 'open' to launch the application, or alternatively, you can find RockyRAD icon in your device's app drawer to start the application.

Fig. 7.2: RockyRAD app icon.

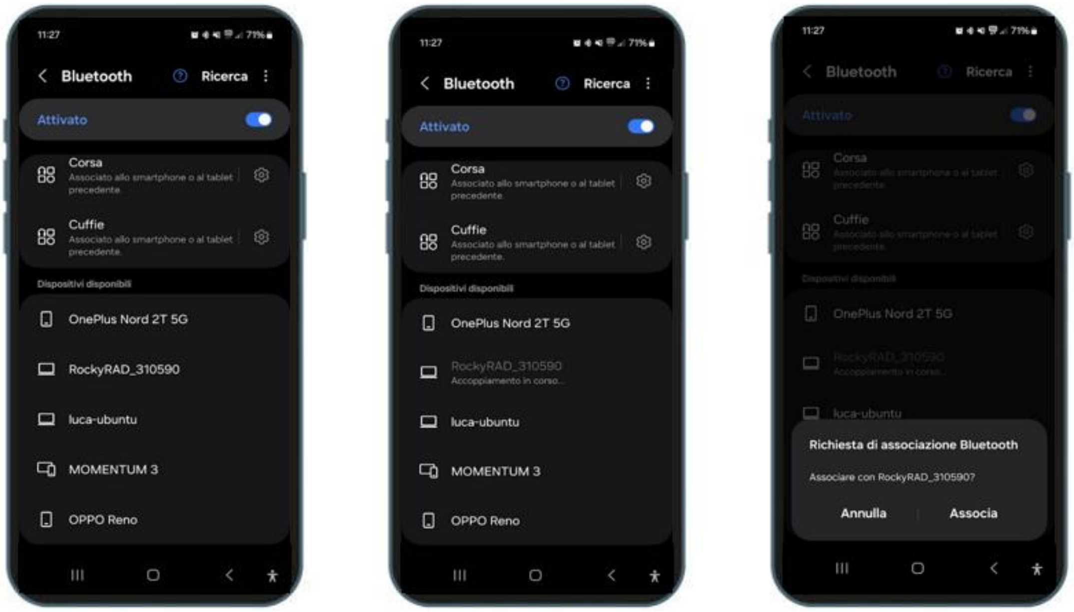
- **Grant necessary permissions:** Upon first launch, the application may request certain permissions to operate effectively. These permissions can include access to the device's camera, storage, and Bluetooth functions. Please review and accept these permissions for optimal application performance.

7.3 Device Connection

To establish a Bluetooth connection between your Android device and the RockyRAD Geiger counter, please follow the instructions below:

- Ensure that the RockyRAD Geiger counter is switched on.
- On your Android device, access the 'Settings' application. This can typically be found in the app drawer or by swiping down from the top of the screen to open the notification panel and tapping the settings gear icon.
- Within 'Settings', scroll to and select 'Bluetooth'. Ensure Bluetooth functionality is enabled; if not, switch it on. The device will automatically begin to search for nearby Bluetooth-enabled devices.
- From the list of available devices, locate RockyRAD. Select this device to initiate the pairing process.
- The Android device and RockyRAD should connected now. A confirmation message will appear once the connection is successfully established.
- To verify the connection, observe the indicators on both the Android device and the RockyRAD Geiger counter. Ensure that data is being transmitted accurately.
- If the devices do not connect on the first attempt, ensure that the RockyRAD Geiger counter is not currently paired with another device, as this may prevent a new connection. Also, check that both devices are within the recommended range for Bluetooth connectivity (typically 10 meters/33 feet without obstructions).
- Should any issues persist, restart both the Android device and the RockyRAD Geiger counter and repeat the pairing process.

By following these steps, you should be able to seamlessly connect the RockyRAD Geiger counter to your Android device via Bluetooth.

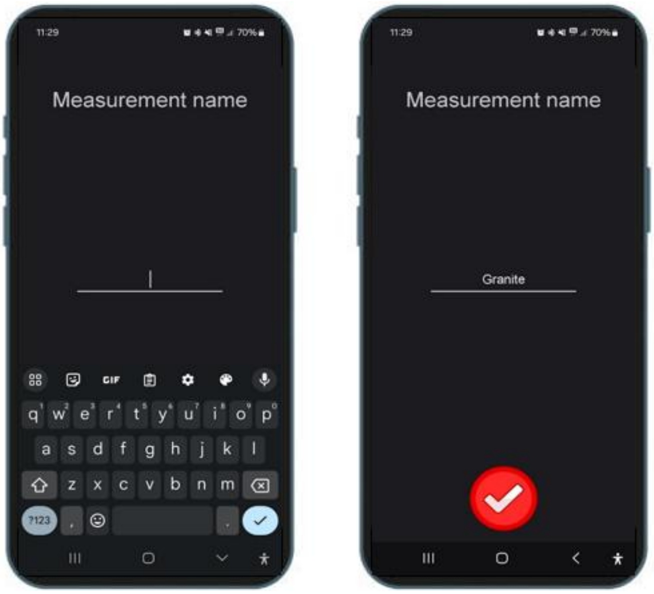


7.4 App Interface

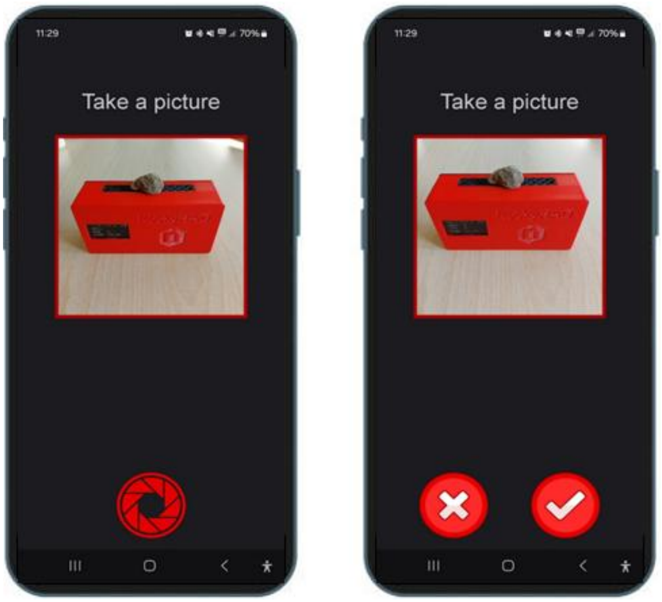
Upon opening the application, users are invited to follow these steps to initiate a new measurement with the RockyRAD Geiger counter:

- **Initiate a new measurement:** from the application's home screen, begin by tapping the '+' icon, [+], to start a new measurement process.

- **Name the measurement**: you will be prompted to enter a descriptive name for the measurement. Choose a name that will help you easily identify the measurement in the data store.

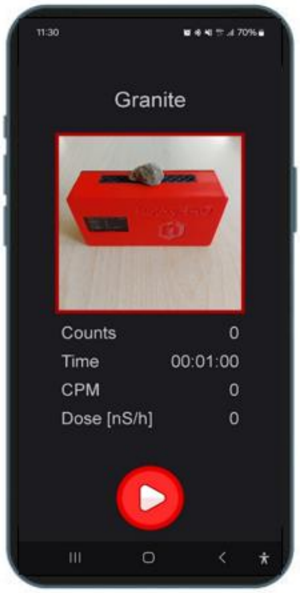


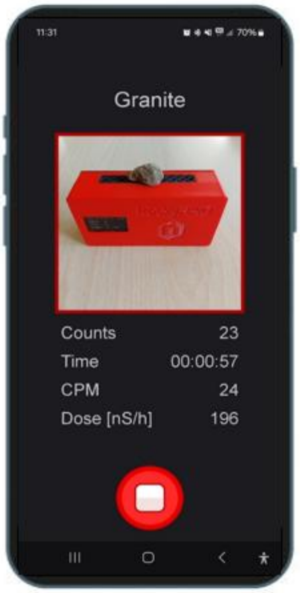
- **Capture a photo:** use the application's camera feature to take a photograph of the Geiger counter in proximity to the rock sample. This visual reference is crucial for correlating the measurement with the specific sample.



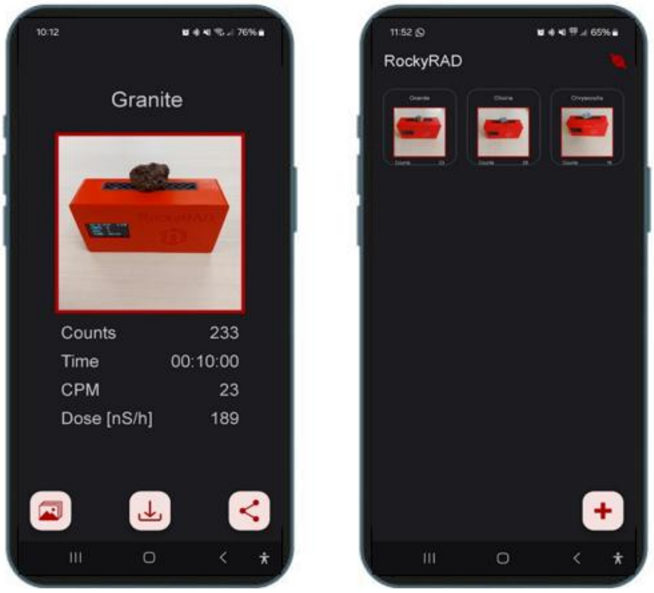
- **Set measurement duration**: specify the duration for which the measurement should be taken. Ensure that the time frame is adequate to gather sufficient data for accurate analysis.

- **Start the measurement:** with the details set, press the 'play' button, , to begin the measurement. The application will now start recording data from the RockyRAD Geiger counter.





- **Share or review results:** once the measurement is complete, you may opt to share the results using the share button located to the right, . Alternatively, to review historical data, select the history button on the left, .



- **Export Data in CSV Format:** To facilitate further analysis or archiving, the application provides a feature to export your measurement logs in CSV format. After completing a measurement, utilize the centrally located 'Export' button, , to save the data. This option enables you to download the logs and employ them in various data analysis tools on your computer, ensuring that your records are always accessible and manageable outside of the application environment. The data file of the measurement is a matrix (see Fig. 7.3), whose last two columns represent respectively: Count Per Minute (CPM) and Dose Rate [nSv/h].

DateTime	CPM	Dose
2024_03_18_09:38	20	162
2024_03_18_09:39	22	178
2024_03_18_09:40	21	163
2024_03_18_09:41	23	186
2024_03_18_09:42	21	164
2024_03_18_09:43	20	162
2024_03_18_09:44	22	165
2024_03_18_09:45	21	170
2024_03_18_09:46	23	166
2024_03_18_09:47	20	162
2024_03_18_09:48	22	167
2024_03_18_09:49	21	170
2024_03_18_09:50	23	168
2024_03_18_09:51	21	170
2024_03_18_09:52	20	169
2024_03_18_09:53	22	178
2024_03_18_09:54	21	170
2024_03_18_09:55	23	186
2024_03_18_09:56	20	171
2024_03_18_09:57	22	178
2024_03_18_09:58	21	172
2024_03_18_09:59	23	186

Fig. 7.3: example of .csv file.

8 Educational Experiments

The CAEN RockyRAD is an educational tool designed to facilitate and support environmental radioactivity experiments. Minerals and materials from the Earth's soil are the most common sources of natural radiation.
RockyRAD is not just a learning tool, but a bridge between the ancient allure of rocks and the tangible realities of everyday life. For those who love an interdisciplinary approach, RockyRAD is an invaluable resource. Not only does it promote exciting STEM activities, but it also acts as a catalyst for projects that merge various subjects, such as Physics, Mathematics, Earth Sciences, Statistics, Computer Science, and Geography, creating a comprehensive educational experience.
This section represents an overview of the experiments proposed by CAEN using the RockyRAD. Each experiment has its own identification code (reference ID). For each ID, a step-by-step guide that includes a detailed description to perform the experiment is or will be available on the CAEN Educational web page very soon (https://edu.caen.it/). The experiments address the essence of the phenomenon as well as exemplary illustrations of their use in different application fields, complemented by basic and advanced statistical exercises.

The experiments proposed by CAEN are listed in **Tab. 8.1**. Some experiments are identified by (*) symbol, it means that they require an extra tool (i.e. adsorption materials, radioactive source, etc.).

Section	Reference ID	Experiment	Additional tool
Nuclear Physics and radioactivity	6160H	Statistics: Uncertainty as a function of live time	No
	6161H	Environmental Background	No
	6162H*	Lead Shielding Effect on Environmental Radioactive Background	Lead blocks
	6163H	Detecting Ionizing-Radiation	No
	6164H	Samples Comparison	No
	6112H	Poisson and Gaussian Distributions	No

Tab. 8.1: Physics Experiments performed via the RockyRAD. If the symbol (*) is present, extra tools are needed to perform the experiment.

8.1 Statistics: Uncertainty as a function of live time (ID.6160H)

Purpose of the experiment:

Study of relationship between uncertainty analysis and the duration of data acquisition.

Fundamentals:

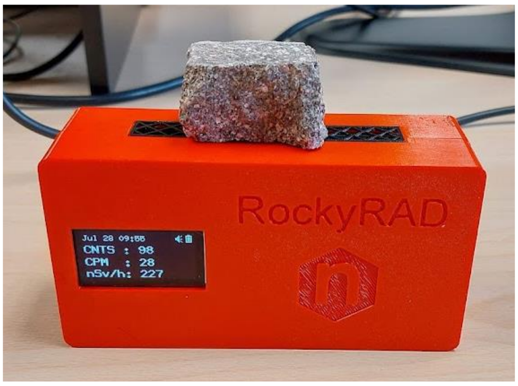
In the experimental Physics field, the accurate assessment of uncertainties is paramount to ensure the reliability and precision of measurements.
Measurement, an essential aspect of scientific inquiry, inherently involves some degree of uncertainty. Uncertainty refers to the range within which the true value of a physical quantity is expected to lie. Two key dimensions of uncertainty are relative uncertainty and absolute uncertainty.
Relative uncertainty, often expressed as a percentage, gauges the precision of a measurement in relation to the size of the measured quantity. It is calculated by dividing the absolute uncertainty by the measured value and multiplying by 100.
Absolute uncertainty is the quantitative measure of the range within which the true value of a measured quantity is expected to lie. It is typically expressed in the same units as the measured quantity. The determination of absolute uncertainty involves considering various factors, including instrumental limitations and experimental procedures.
Live time, as a parameter in this experiment, represents the duration for which data is actively collected. By systematically varying the live time during measurements, we aim to observe the influence of this temporal factor on both relative and absolute uncertainties. The statistical nature of measurements becomes apparent as we analyze how uncertainties change as a function of live time.

Requirements:

No other tool is needed.

Carrying out the experiment:

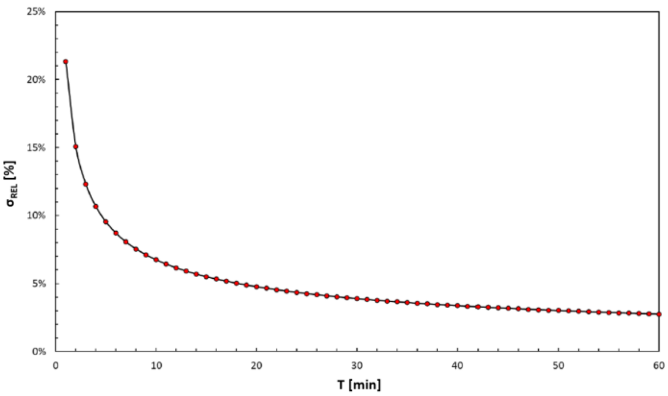
The experiment involves several data-taking with different acquisition time.
Begin by placing the GM detector on the desk and powering on the system. The experiment could be performed with or without a rock sample. GM detector will immediately initiate measurements and record data every minute during acquisition. The detected particles are counted and displayed on the monitor (CNTS), along with the average counts per minute (CPM) and dose (nSv/h). The system produces a sound for each detection.



Experimental setup block diagram.

Results:

The experiment explores how the relative uncertainty evolves with varying live times, providing insights into the impact of data acquisition duration on the precision of our measurements. This experiment not only provides valuable insights into the statistical aspects of measurements but also sheds light on the dynamic relationship between uncertainty and the temporal dimension of data acquisition.



Relative uncertainty as a function of the live time.

T [min]	*σ_{REL} [%]*	*σ_{ASS} [cpm]*
1	*21*	*4.7*
5	*10*	*2.1*
15	*6*	*1.2*
30	*4*	*0.9*
60	*3*	*0.6*
120	*2*	*0.4*

Experimental results.

8.2 Environmental Background (ID.6161H)

Purpose of the experiment:

Estimation of the measurement of the background radioactivity.

Fundamentals:

The main contributors to the background energy spectrum are the gamma radiations that originate from naturally occurring radioactive isotopes dispersed in the environment and the materials that surround the detector, and the radiations whose origin can be traced to cosmic rays. To properly identify a sample from radioactivity point of view, the background must be acquainted. The background radioactivity measurement must be obtained without using any sample, specifically with the GM tube window free.

Requirements:

No other tool is needed.

Carrying out the experiment:

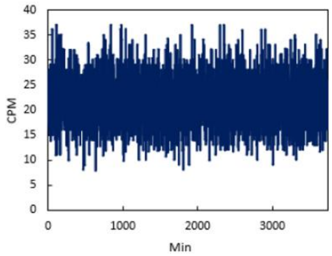
Place the GM detector on the desk if you are indoors or on an outdoor surface. Power ON the system. The GM detector immediately starts measurements and records data every minute of acquisition. The background counts must be acquired in the absence of samples, specifically with the GM tube window uncovered. The detected particles are counted and displayed on the monitor (CNTS), along with the average counts per minute (CPM) and dose (nSv/h). The system produces a sound for each detection. A significant statistical dataset is necessary for an accurate estimation of the environmental background. It is recommended to conduct an acquisition for at least 24 hours.

Experimental setup block diagram.

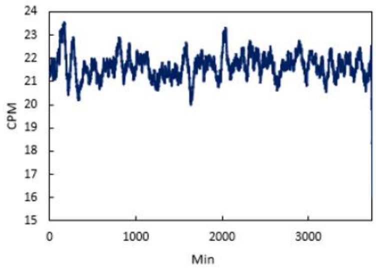
Results:

The user can check for the presence of environmental radiation by observing non-zero counts on the GM counter. The statistical analysis of the distribution of this background plays a crucial role in accurately estimating the radioactive contribution of the samples under investigation.
An example of the typical measurement outcome is shown in the table and figures provided below. However, it is important to note that the measured background value strongly depends on the environment in which the detection is carried out.

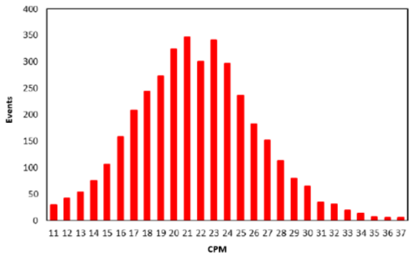
CPM Max	37.0
CPM Min	11.0
CPM Mean	22.0
σ_{STAT}	0.1
STD	4.5
Live Time [m]	3739



CPM - Raw data.



CPM - Moving average (1h).



CPM Distribution.

8.3 Lead Shielding Effect on Environmental Radioactive Background (ID.6162H)

Purpose of the experiment:

The experiment aims to analyze the impact of lead shielding on the environmental background particles detected by the GM detector.

Fundamentals:

For precise spectral measurements, resolution in energy and signal-to-noise ratio are the key parameters. Therefore, it is crucial to shield the detector with lead to minimize background. Lead is the most widely used material for shielding due to its high density and atomic number. The photoelectric absorption cross-section predominates at energies above 0.5 MeV, making it effective in easily absorbing relatively hard external background gamma rays (such as those at 1.46 MeV from 40K). Owing to its high density, thin layers of a few centimeters of Pb significantly reduce background for typical gamma-ray detectors. Additionally, it can eliminate many components of cosmic rays, although thicknesses of about 10 cm contribute to the background with secondary radiation due to cosmic interaction with the lead itself. It is often used in the form of rectangular "bricks." Common lead exhibits a notable level of natural radioactivity; if refined, it may still contain 210Pb, a product of the decay of 226Ra, with a half-life of 20.4 years. While some types of Pb exhibit an activity of around 1.5 Bq/g, more refined lead is an order of magnitude or two below this value.

Requirements:

Lead blocks are required.

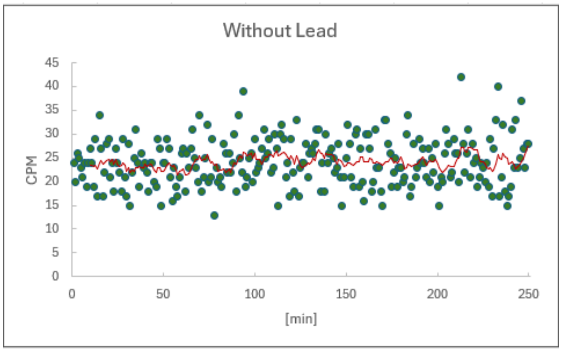
Carrying out the experiment:

The experiment involves two data-taking phases: one with lead blocks covering and one without. Begin by placing the GM detector on the desk and powering on the system. The GM detector will immediately initiate measurements and record data every minute during acquisition. Background counts, essential for calibration, should be obtained in the absence of samples, specifically with the GM tube window uncovered. It is advisable to conduct a background acquisition for a minimum of 2 hours.
Upon completing the background measurement, cover the GM detector entirely with lead blocks. Maintain the same acquisition time to facilitate straightforward background subtraction.

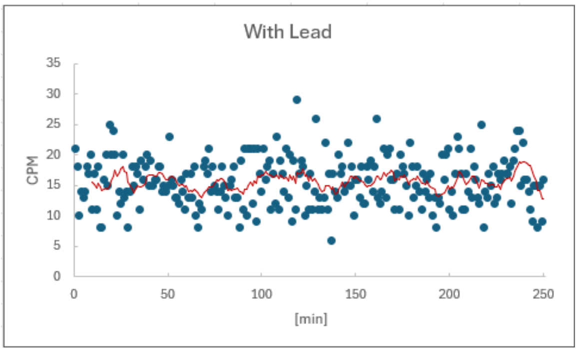
Experimental setup block diagram.

Results:

The user can easily check how lead blocks reduce the gamma radioactivity from the background, by comparing the results obtained by GM detector with and without lead blocks. The subsequent results illustrate how the mean counts per minute (CPM) decrease from approximately 24 to around 15 when lead shielding is employed.



No shielding. CPM - Raw data in green and moving average (10 min) in red.



Lead Shielding. CPM - Raw data in blue and moving average (10 min) in red.

8.4 Detecting Ionizing-Radiation (ID.6163H)

Purpose of the experiment:

Radioactivity detection by using a GM detector.

Fundamentals:

In the Nuclear Physics field, ionizing particles play a pivotal role in understanding the fundamental building blocks of matter. These particles possess sufficient energy to liberate electrons from atoms, a process known as ionization. This ionization capability stems from their inherent ability to penetrate matter and impart energy to atomic structures. Ionizing particles in nuclear physics include alpha particles, beta particles, and gamma rays. Alpha particles consist of two protons and two neutrons, making them relatively massive and charged. Beta particles can be either electrons (β^-) or positrons (β^+) and can interact with atomic electrons. Gamma rays are electromagnetic waves of extremely high energy and no mass.

A GM detector is a device specifically designed to detect ionizing radiation. The operational principle of the GM detector hinges on the ionization generated by incoming radiation. Within the GM detector, there exists a gas-filled chamber, typically containing a low-pressure inert gas, and a central wire electrode running along the chamber's axis.

The detector applies a high voltage between its outer casing (anode) and the central wire electrode (cathode), thereby creating an electric field within the gas-filled chamber. When ionizing radiation enters the detector, it interacts with the gas atoms, leading to the formation of ion pairs positively charged ions and free electrons.

These free electrons, accelerated by the electric field, travel towards the central wire, inducing additional ionization events through collisions with other gas atoms. This cumulative effect, known as an electron avalanche, generates a detectable electrical pulse. This signal is then amplified and processed by the detector's electronics.

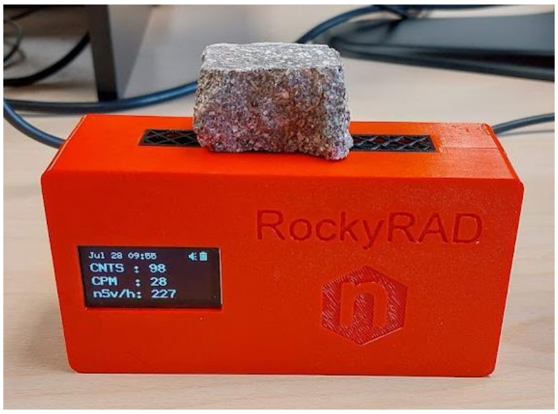
Requirements:

No other tool is needed.

Carrying out the experiment:

The experiment involves two data-taking phases: one with rock sample and one without. Begin by placing the GM detector on the desk and powering on the system. The GM detector will immediately initiate measurements and record data every minute during acquisition. Background counts, essential for calibration, should be obtained in the absence of samples, specifically with the GM tube window uncovered. It is advisable to conduct a background acquisition for a minimum of 2 hours.

Upon completing the background measurement, place the rock sample in the middle of the open window of the GM detector. Start the new acquisition maintaining the same acquisition time to facilitate straightforward background subtraction.



Experimental setup block diagram.

Results:

The student is provided with an opportunity to familiarize themselves with the presence of radioactivity within a given rock sample through a straightforward measurement technique. This involves a comparative analysis of the detected counts using a GM (Geiger-Muller) detector, both in the presence and absence of the rock sample.

The comparison between the counts with and without the rock sample serves as a means of assessing the radioactivity associated with the specific geological material. An increase in detected counts when the rock sample is present suggests the emission of ionizing radiation from the sample. This increase is indicative of the radioactive properties of the rock, as certain minerals within the sample may naturally emit alpha, beta, or gamma particles, contributing to the overall ionization observed by the GM detector.

CPM Max	37.0
CPM Min	11.0
CPM Mean	22.0
σ_{STAT}	0.1
STD	4.5
Live Time [m]	197

Environmental background.

CPM Max	37.0
CPM Min	15.0
CPM Mean	27.2
σ_{STAT}	1.3
STD	5.9
Live Time [m]	197

Rhyolite Rock.

8.5 Samples Comparison (ID.6164H)

Purpose of the experiment:

The objective of the experiment is to analyze and compare the detected counts originating from rocks of different origins.

Fundamentals:

The radioactivity of rocks varies significantly depending on their geological origin, with different types of rocks contributing distinctively to the overall radiation background. The composition of the Earth's crust contains various radioactive elements, and the concentration of these elements in rocks can vary based on factors such as the rock type and the geological processes that formed them.
Granitic rocks, for example, often exhibit higher concentrations of radioactive elements such as uranium, thorium, and potassium. These rocks contribute to elevated levels of ionizing radiation due to the decay of these radioactive isotopes. On the other hand, sedimentary rocks like limestone may have lower concentrations of these radioactive elements, resulting in comparatively lower radioactivity.
The different contributions of rocks to radioactivity are crucial in understanding natural background radiation and its variations across geological regions. This knowledge not only has implications for scientific studies but also plays a role in applications such as radiological assessments, mineral exploration, and environmental monitoring. Additionally, it underscores the importance of considering the geological context when interpreting measurements from radiation detection experiments, as the types of rocks present can influence the observed radiation levels.

Requirements:

No other tool is needed.

Carrying out the experiment:

The experiment involves several data-taking sessions, depending on the number of rocks under investigation. Begin by placing the GM detector on the desk and powering on the system. The GM detector will immediately initiate measurements and record data every minute during acquisition. Background counts, essential for calibration, should be obtained in the absence of samples, specifically with the GM tube window uncovered. It is advisable to conduct an acquisition for a minimum of 2 hours.
Upon completing the background measurement, place the first rock sample in the middle of the open window of the GM detector. Start the new acquisition, maintaining the same acquisition time to facilitate straightforward background subtraction. Repeat the procedure by using the other rock samples.

Experimental setup block diagram.

Results:

The primary aim of this experience is to investigate the variations in ionizing radiation levels exhibited by several geological samples. Furthermore, it not only serves as a practical application of radiation detection principles but also encourages participants to apply scientific methods in data analysis and interpretation. The experiment opens avenues for discussions on the geological factors influencing radioactivity, contributing to a broader understanding of the complex interplay between rocks and ionizing radiation.

	Background	*Leucitic Tephrite*	*Granite*	*Porphyry*	*Trachyte*
Max	37.0	47.0	40.0	40.0	33.0
Min	11.0	20.0	15.0	15.0	15.0
Mean	*22.0*	*33.6*	*25.4*	*25.4*	*24.8*
σ_{STAT}	*0.1*	*0.4*	*0.9*	*0.9*	*0.9*
STD	4.5	5.6	5.4	5.4	4.6
Live Time [m]	197	197	121	35	28

CPM Comparison: Analyzing experimental results obtained with various rock samples.

8.6 Poisson and Gaussian Distributions (ID.6112H)

Purpose of the experiment:

Study the statistical distribution of the counting rates of a rock sample. Comparison of the data to the Poisson distribution, turning into a Gaussian as the mean number of counts grows.

Fundamentals:

The number of radioactive particles detected over a time Δt is expected to follow a Poisson distribution with mean value μ. It means that for a given radioactive source, the probability that n decays will occur over a given time period Δt is given by:

$$P_{\mu}(n) = (\mu^{n} / n!) \cdot e^{-\mu}$$

Where μ is proportional to the sample size and to the time Δt and inversely proportional to the half-life $T_{1/2}$ of the unstable nucleus. As long as μ grows, the probability $P_{\mu}(n)$ is well approximated by a Gaussian distribution:

$$P(n) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-(n-\mu)^2}{2\sigma^2}}$$

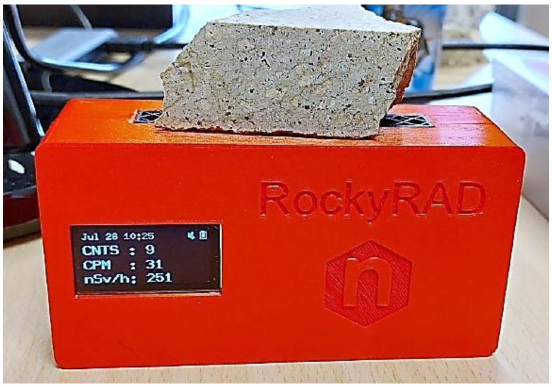
Where $\sigma = \sqrt{\mu}$ is the standard deviation.

Requirements:

No other tool is needed.

Carrying out the experiment:

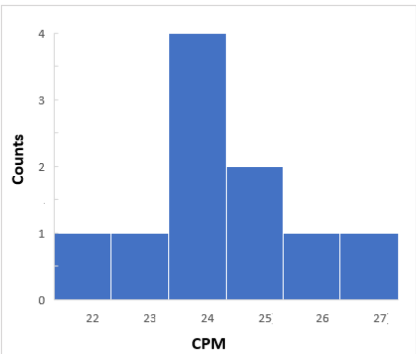
The experiment consists of two data collection sessions with varying acquisition times. The initial session is intended to be brief, while the subsequent one is designed to be more extended.
Begin by placing the GM detector on the desk and powering on the system. The experiment could be performed with or without a rock sample. GM detector will immediately initiate measurements and record data every minute during acquisition. The detected particles are counted and displayed on the monitor (CNTS), along with the average counts per minute (CPM) and dose (nSv/h). The system produces a sound for each detection.



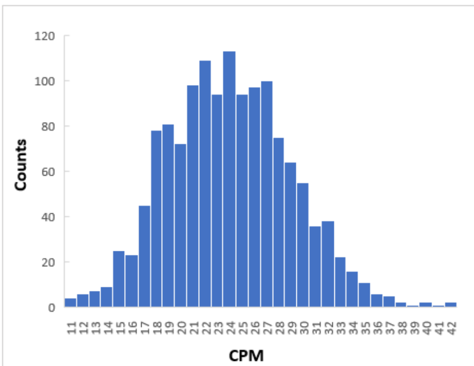
Experimental setup block diagram.

Results:

Changing the counting window, the number of counts changes, with a probability density function moving form a Poissonian to a Gaussian shape. The student may play with the data, fitting them and comparing the expectations to the measurement.



Poissonian distribution.



Gaussian distribution.

9 Instructions for Cleaning

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

9.1 Cleaning the Touchscreen

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

9.2 Cleaning the air vents

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

9.3 General cleaning safety precautions

CAEN recommends cleaning the device using the following precautions:

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

10 Device decommissioning

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

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

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

11 Disposal

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

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

12 Technical Support

To contact CAEN specialists for requests on the software, hardware, and board return and repair, it is necessary a MyCAEN+ account on www.caen.it:

https://www.caen.it/support-services/getting-started-with-mycaen-portal/

All the instructions for use the Support platform are in the document:

CAEN
Tools for Discovery

SAFETY, STORAGE AND SETUP INFORMATION
PRODUCT SUPPORT SERVICE AND REPAIR

INFORMAZIONI SU SICUREZZA STOCCAGGIO E INSTALLAZIONE
ASSISTENZA E RIPARAZIONE DEL PRODOTTO

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

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

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

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