

Development of the CREDO Detector application for cosmic ray measurement

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Abstract

Cosmic radiation was discovered in 1912 by Victor Franz Hess. His research in subsequent decades contributed to numerous groundbreaking discoveries and advanced modern particle physics.

It remains a subject of study in particle physics and astrophysics conducted at specialized observatories. The CREDO-edu project introduces novel radiation detectors for school and home use, utilizing readily available USB cameras. The self-contained measurement program will help disseminate knowledge about cosmic radiation among school youth, while simultaneously enabling scientists to collect larger datasets.

1 Introduction

The CREDO (Cosmic Ray Extremely Distributed Observatory) project involves utilizing commonly owned CCD cameras (found in old phones or laptops) as low-budget and easily accessible detectors capable of registering charged particles from secondary cosmic radiation reaching Earth's surface. Besides measuring this radiation, it can also serve to search for hypothetical Cosmic Ray Ensembles (CRE) arising from the decay of supermassive particles formed in the early Universe. Existing cosmic ray observatories are unable to capture extensive particle cascades due to their limited detection surface area. For this reason, CREDO focuses on creating a distributed network of detectors - utilizing a network of smaller systems with an effective surface area comparable to Earth's dimensions.

Within the educational branch CREDO-edu, school students use the CREDO Detector application to transform their devices into portable research systems. Conducting measurements, collecting data, analyzing them, and formulating their own conclusions would not only result in acquiring practical scientific skills and popularizing research methodology, but also encourage cooperation and collaborative discovery.

In this work, we present software that transforms commonly available webcams into low-budget cosmic ray detectors, significantly expanding the measurement capabilities available both at home and at school.

2 Evaluation of Camera Reliability

Monitoring and Analysis Methodology

To carry out the experiment, two different USB cameras were used, each connected to a separate laptop. Both cameras remained powered on without interruption for several consecutive days, operating

in standby mode: powered, with the video stream available, with the video stream available, and the camera recording and sending images to the computer (even if they are not stored). This setup simulates real-world continuous operation conditions, without the need to store large volumes of data.

Approximately every 10 hours, a manual test was performed. This consisted of measuring the external temperature of each camera and capturing sample images. These images were later used to assess whether continuous operation and heat buildup had any effect on image quality or caused the appearance of false events.

The image analysis was conducted using a Python script developed specifically for this purpose, in combination with the OpenCV library. Each image was converted to grayscale, and statistical values were computed, such as the **standard deviation of pixel intensity**, which quantifies the variability of brightness across pixels. As the lenses are covered, the whole image is constant (e.g., a static background), an increase in standard deviation is indicative of *digital noise*. This noise may result from lighting conditions, sensor degradation, thermal interference, or signal transmission issues.

In addition to statistical analysis, the script was adapted to detect **anomalous events**, defined as sudden changes in brightness or the appearance of visual artifacts that should not be present. These “events” are not necessarily caused by actual events; rather, they are often *false positives*-signals misinterpreted as meaningful events due to minimal fluctuations in the image. To increase system sensitivity and observe whether the number of these errors grew over time, the **event detection threshold was intentionally set very low**. This ensured that even minor perturbations were logged as events, allowing us to assess whether the frequency of false positives increased with prolonged use, possibly due to rising thermal noise or sensor instability.

This procedure enabled an objective and systematic comparison of both cameras under identical testing conditions, focusing on thermal stability, visual consistency, and susceptibility to noise and false event generation.

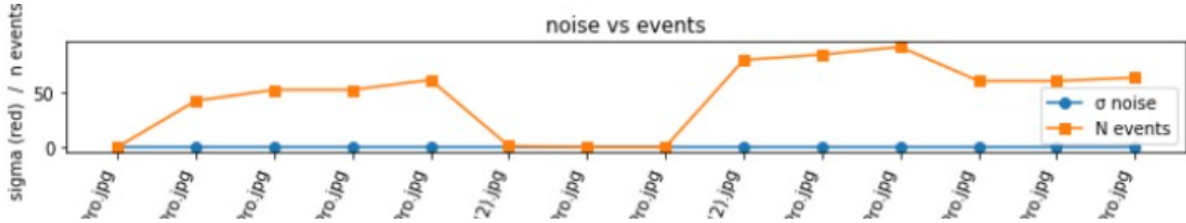


Figure 1: Time evolution of standard deviation and number of events.

As we can see in 1, neither the standard deviation nor the number of detected events increases as the cameras remain powered on. This indicates that the cameras can be used without concern for potential errors arising after a few days of uninterrupted operation.

Camera Used During the Experiment

The **Vakoss WS-3355** camera was used as the main device throughout the experiment. This model was selected due to several practical and technical factors that facilitated the initial development of the analysis system and allowed the establishment of a stable and controlled testing methodology.

Reasons for Selection

- **Wired connection (USB 2.0):** Unlike wireless models, its stable USB connection eliminated issues related to interference or latency.

- **Moderate resolution:** Its maximum resolution of 640×480 produced lighter files, which sped up image processing during script development. This was particularly useful for performing repeated tests and fine-tuning the detection algorithm.
- **Predictable standby behavior:** It did not exhibit background synchronization or power-saving interruptions, making it ideal for simulating real-world passive monitoring conditions.

Technical Specifications

Specification	Value
Video Resolution	640×480 / 320×240
Photo Resolution	640×480 / 320×240
Frame Rate	30 fps
Viewing Angle	60°
USB Interface	USB 2.0

Table 1: Main specifications of the Vakoss WS-3355 camera.

Camera Settings and Resolution Considerations

In addition to resolution, most webcams allow for adjustments of internal settings such as brightness, contrast, automatic exposure, or white balance. However, in our experiment, these parameters were left at their default values, as their influence on noise analysis was minimal or negligible under stable lighting conditions.

The only setting that proved relevant was the **capture resolution**. When configuring the Vakoss WS-3355 camera at its maximum resolution (640×480), a slight improvement in visual detail was observed, which facilitated the detection of artifacts or anomalous patterns. Nonetheless, this setting also introduced several disadvantages in low-end webcams: increased visual noise, higher demand on system resources, more visible compression artifacts, and possible performance issues such as latency or freezing in suboptimal conditions.

Therefore, while it is technically possible to modify various internal settings of the camera, only the resolution had a noticeable impact on the outcome of the experiment.

3 Measurement of radiation sources

3.1 Experimental Procedure

All measurements were carried out in a regular laboratory room. Three independent detectors were operated in parallel:

- **Webcam detectors** *TC101 Titanium* - (1), *Micro Webcam Targus* - (2). The lens was permanently covered with opaque insulating tape to block visible light. A bespoke `Python/CREDO` script¹ analysed the greyscale video stream in real time and flagged ionising-particle hits; each accepted frame incremented the event counter N_C .
- **Geiger-Müller counter** (model *BOH-45*). The tube was biased from an external high-voltage supply and its anode pulses were sent to a scaler (*Poly Digit-1*) used merely as a pulse counter. The counting gate was opened and closed *manually*: the operator pressed the start/stop key on the scaler the moment a stopwatch indicated the beginning and end of the nominal 10-minute interval.

¹See Appendix 4 for a brief algorithmic description.

Consequently the live time carries the same human-reaction uncertainty quoted for the camera acquisition. The intrinsic dead-time of the tube/electronics is unknown and was therefore neglected in the present analysis.

Ten-minute measurements

The sensitive window of the GM tube and the camera sensor plane were aligned coaxially, both at a distance of $d = 1,0 \pm 0,1$ cm from the surface of the source. Geometry was kept fixed by mounting the GM tube on a rigid stand; the webcams rested on its own tripod. The same arrangement was preserved for the background run (empty stage).

Four targets were investigated:

1. ^{60}Co ($A_{\text{Co}} \approx 37$ kBq; $E_\gamma = 1173, 1332$ keV),
2. ^{22}Na ($A_{\text{Na}} \approx 37$ kBq; $E_\gamma = 511, 1274$ keV),
3. ^{137}Cs ($A_{\text{Cs}} = 9.25$ kBq; $E_\gamma = 662$ keV)²,
4. **Laboratory background.**

Each acquisition lasted $t = 600 \pm 0.6$ s, as measured with a handheld stopwatch. The stopwatch was started and stopped manually, which introduces an additional (human-reaction³) component to the timing uncertainty. For each isotope, we recorded raw event counts from cameras and GM.

Five-interval stability run

To verify short-term stability, a second campaign was carried out on ^{60}Co . Counts were taken continuously for 25 minutes with the same geometry as in the previous section, but the live stream was split into five successive 5-minute blocks, without stopping the measurement. For each block, we recorded raw counts.

3.2 Results

Table 2 lists the raw counts as well as the derived count rates ($R_{\text{GM}/C} = N_{\text{GM}/C}/t$). Statistical uncertainties follow from Poisson statistics ($u_N = \sqrt{N}$) and were propagated to the rate via $u_R = \sqrt{\left(\frac{u_N}{t}\right)^2 + \left(u_t \frac{N}{t^2}\right)^2}$.

Table 2: Ten-minute measurements with the Geiger-Müller counter (GM) and two CMOS webcams.

Source	GM counter		Camera 1 (Titanum)		Camera 2 (Targus)		t [s]
	N	R_{GM} [cps]	N	R_{C1} [10^{-2} cps]	N	R_{C2} [10^{-2} cps]	
^{60}Co	18 179	30.30 ± 0.23	15	2.50 ± 0.65	58	9.66 ± 1.27	600.6
^{22}Na	4 215	7.03 ± 0.11	7	1.17 ± 0.44	53	8.77 ± 1.21	604.3
^{137}Cs	2 874	4.79 ± 0.09	4	0.66 ± 0.33	20	3.33 ± 0.75	602.0
Background	360	0.60 ± 0.03	0	-	0	-	600.6

Results of the five-interval stability run for the ^{60}Co source are presented in Table 3.

²Information on the activity was taken from the labels attached to the samples, whereas the decay-energy data came from the JANIS software.

³The accuracy of the time measurement was estimated as: 1 s for ten minutes measurements, 3 s for five-interval stability run, assuming a rectangular distribution, the type-B standard uncertainty is $u = \frac{d}{\sqrt{3}}$.

Table 3: Five successive (5 minutes) blocks for the ^{60}Co stability test. Rates are in counts per second.

Detector	Time interval [min]					Sum
	0-5	5-10	10-15	15-20	20-25	
$N_{C1} \pm u_N$	15 ± 4	11 ± 3	15 ± 4	16 ± 4	11 ± 3	68 ± 8
$R_{C1} \pm u_R$ [cps]	0.05 ± 0.01	0.04 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.045 ± 0.006
$N_{C2} \pm u_N$	17 ± 4	24 ± 5	21 ± 5	20 ± 4	27 ± 5	109 ± 10
$R_{C2} \pm u_R$ [cps]	0.06 ± 0.01	0.08 ± 0.02	0.07 ± 0.02	0.07 ± 0.01	0.09 ± 0.02	0.07 ± 0.01

In the next two subsections (a) and (b) we analyse these two data sets introduced above: the 10-minute acquisitions and the five consecutive 5-minute blocks.

(a) Calibration curves

The first pair of plots, Fig. 2, displays the raw count-rate pairs (R_{Ci}, R_{GM}) for each radionuclide. No function is fitted here - our intention is solely to illustrate the monotonic rise of the webcam rate with increasing GM rate; the trend is evident but not strictly linear.

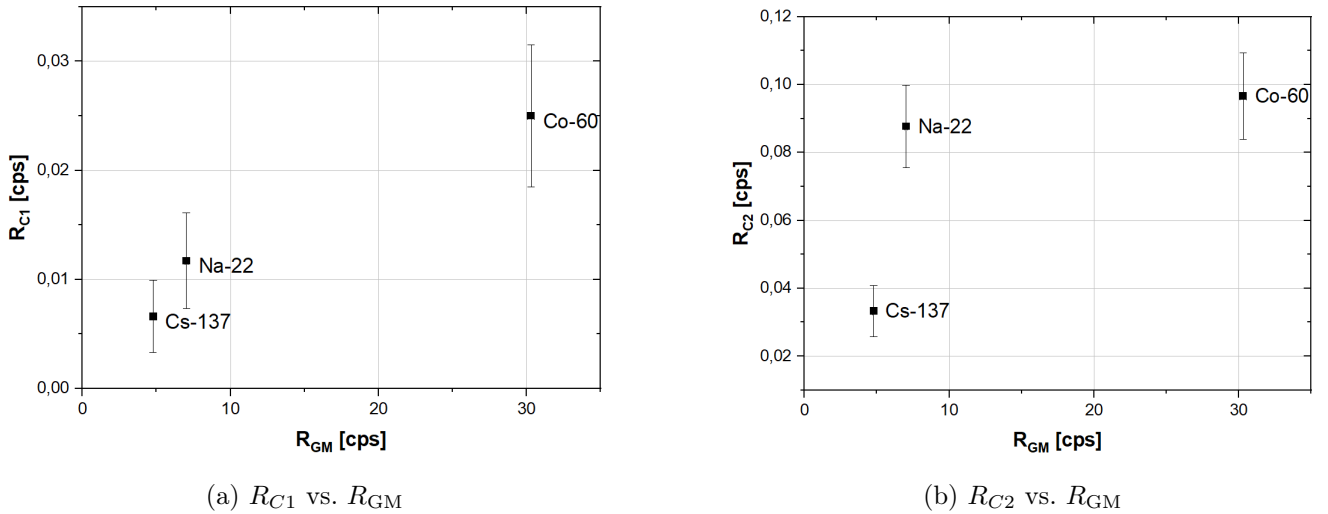


Figure 2: Raw rate correlations between the GM counter and the two webcams. Error bars correspond to one standard uncertainty u_{RC} .

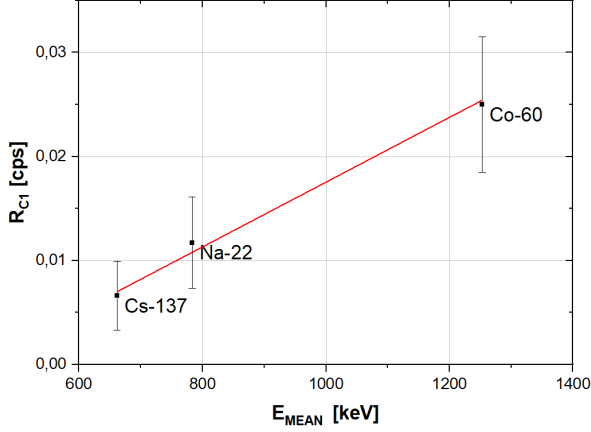
For nuclides that emit more than a single γ line, the counting efficiency of a webcam depends on the full energy spectrum rather than on any particular transition. To compare detectors on equal footing we therefore use the intensity-weighted mean photon energy,

$$E_{\text{MEAN}} = \frac{\sum_i E_i I_i}{\sum_i I_i},$$

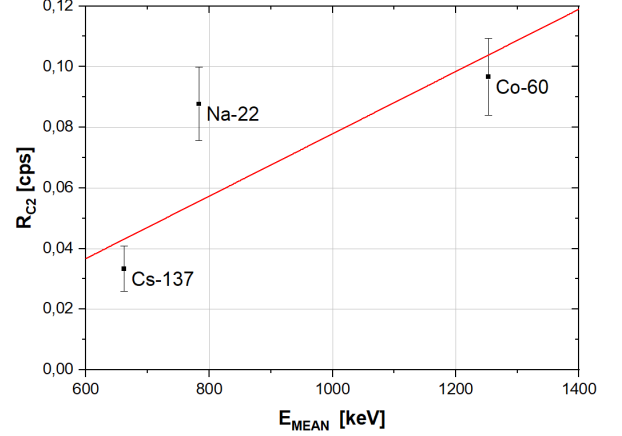
where E_i is the line energy and I_i its emission probability per 100 decays. Using the intensities listed in **NuDat 3.0** (NNDC) we obtain $\langle E \rangle_{^{60}\text{Co}} = 1253$ keV and $\langle E \rangle_{^{22}\text{Na}} = 783.5$ keV. For ^{137}Cs the single 662 keV transition is used directly ($E_{\text{MEAN}} = 662$ keV).

In Fig. 3 we plot the webcam rates against E_{MEAN} . The three sources differ in nominal activity and those label values are several years old, so any trend with energy can only be interpreted *qualitatively*.

Nevertheless, a weighted least-squares line $R_C = a E_{\text{MEAN}} + b$ is fitted (using the statistical uncertainties u_{R_C} as y -errors) to gauge how strongly each device responds to increasing photon energy.



(a) R_{C1} vs. E_{MEAN}



(b) R_{C2} vs. E_{MEAN}

Figure 3: Webcam count rate as a function of mean γ -energy. Solid red lines: weighted linear fits described in Table 4.

Table 4: Linear fit parameters for calibration curves.

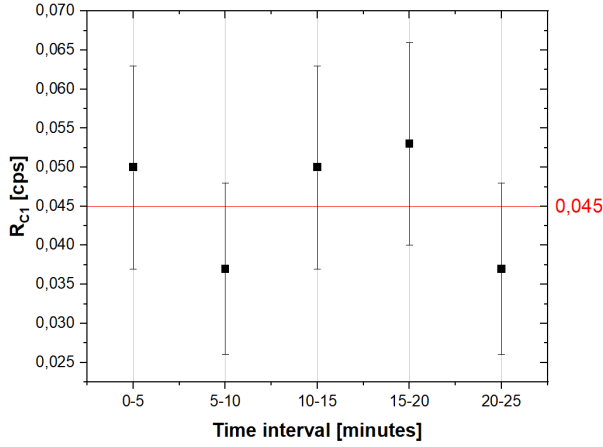
	a [$10^{-5}/\text{cps}$]	b [cps]	χ^2_{red}
Camera 1	3.11 ± 0.31	-0.014 ± 0.002	0,06
Camera 2	10.3 ± 7.5	-0.02 ± 0.06	9,08

The regression analysis in Fig. 3 reveals that webcam sensitivity generally increases with photon energy, but the two devices exhibit substantially different behaviors. Camera 1 demonstrates a nearly linear response over the 0.66–1.25 MeV range, as evidenced by an excellent reduced chi-square ($\chi^2_{\text{red}} \approx 0.06$). In contrast, Camera 2 shows a much steeper initial rise and then plateaus near the ^{22}Na data point, leading to a poor fit ($\chi^2_{\text{red}} \approx 9$). This suggests that Camera 2’s efficiency may saturate at energies around 0.8 MeV or be influenced by unaccounted factors in the annihilation photon regime. Since the source activities are unequal and potentially outdated, the slopes derived here should be treated as qualitative indicators of relative sensitivity. Nonetheless, Camera 2 clearly offers higher absolute counts at lower energies, whereas Camera 1 provides a more predictable and consistent response across the tested energy range.

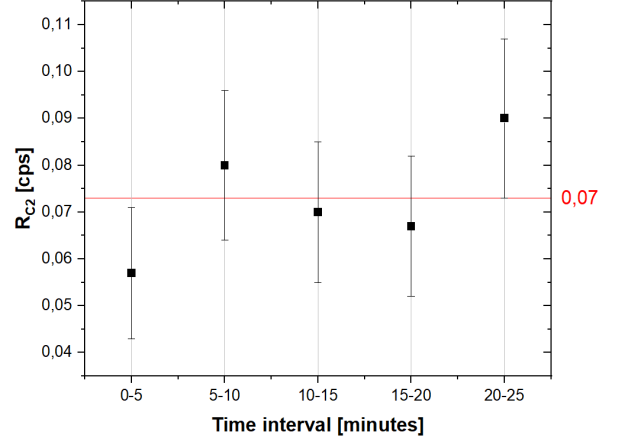
(b) Stability check

Figure 4 uses the five 5-minute block rates listed in Table 3 for ^{60}Co . The horizontal red line corresponds to the sample-means: $\bar{R}_{C1} = 0.045$ cps and $\bar{R}_{C2} = 0.070$ cps. The stability investigation yields the following observations:

- **No global drift.** All five consecutive 5-minute blocks lie within one standard deviation of their respective means (red line in Fig. 4).
- **Behaviour of Camera 1.** After an initial $\simeq 5$ -minute warm-up phase, the readings fluctuate symmetrically about the mean with no discernible trend.
- **Behaviour of Camera 2.** Mild oscillations emerge after the second block (5–10 min), yet every point remains within its individual uncertainty u_R .



(a) Camera 1



(b) Camera 2

Figure 4: Five consecutive 5-minute blocks. Horizontal red line - overall mean.

- **Recommended acquisition time.** Recording at least two consecutive 5-minute blocks (≥ 10 min total) suppresses the Camera 1 warm-up transient and averages out the Camera 2 oscillations, thus providing the best achievable precision for both detectors.

3.3 Concluding remarks

The campaign unmistakably demonstrated a strong rise in count rates whenever a sealed γ -emitting source was placed in front of the set-up, verifying that both CMOS webcams respond to high-energy photons under laboratory conditions. This proof-of-principle detection of ambient γ -radiation is essential for the CREDO project, as it confirms that inexpensive, widely available sensors can serve as complementary nodes in a distributed cosmic-ray network. The quantitative calibration and stability tests reported above therefore provide a solid experimental baseline for future long-term field deployments.

4 CREDO Python Script

The **Python** routine controlling the webcams follows a self-contained workflow that streams video, suppresses visible light, and turns the sensor into a low-cost γ -particle detector. It was developed by the authors on the basis of an original prototype by Prof. A. F. Żarnecki, coordinator of the CREDO-edu project. After opening the selected camera (`cv2.VideoCapture`) it discards the first few dozen frames so that the automatic gain can stabilise. During this initial phase the code calculates two reference maps for each pixel: a running mean V_{mean} and a running maximum V_{max} . Both are updated with an exponential moving average whose time-constants are chosen so that slow drifts (e.g. temperature) are tracked, whereas short spikes are analysed for possible events. For every subsequent frame, the program derives an adaptive threshold

$$V_{\text{thr}} = M_{\text{thr}}(V_{\text{max}} - V_{\text{mean}}) + A_{\text{thr}},$$

where the factors M_{thr} and A_{thr} are user-set multipliers. A dimensionless *significance map*

$$S = \frac{V - V_{\text{mean}}}{V_{\text{thr}}}$$

is then obtained by normalising the current grayscale image V . If the N_{thr} -st brightest pixel satisfies $S > 1$, the frame is tagged as an *event*. Metadata such as time-stamp, frame index, peak signal and peak significance are buffered in memory; simultaneously the script writes three PNG files to disk (raw frame, flat-field-corrected frame, diagnostic overlay).

The frame is then analysed, to check whether enough (at least P_{thr}) event pixels are next to each other. To achieve this, an algorithm gets the list of all hot pixel coordinates and checks (one by one) whether there are other pixels in 3x3 square centred on it. After a frame was confirmed to have an event, simple geometry analysis is used to determine whether the event was a perpendicular, vertical or horizontal impact. As of now, the algorithm isn't able to analyse more than one event on a frame.

Even while an event is processed, the background maps continue to evolve, so that the algorithm remains responsive to gradual changes in sensor noise. At regular intervals (every N_{max} frames) the mean and maximum of the entire sensor are logged for later trend analysis. The run terminates after receiving a keyboard interrupt or the end-of-file marker, whereupon the software prints a concise event table and releases all resources. Thanks to NumPy vectorisation, the processing chain operates in real time at ~ 30 fps for VGA resolution without any external dependencies beyond OpenCV and the standard scientific stack.

5 User manual for school students

A user manual was written. It contained step-by-step instructions for:

- Installing Python
- Installing Visual Studio Code
- Installing libraries required for running the CREDO application
- Downloading the CREDO application
- Running the application

The manual was detailed and written in a simple language so that anyone, even students, can understand it and easily follow the instructions.

6 Summary

The project is based on utilizing cheap and commonly available devices, specifically USB cameras. This enables students to conduct measurements in schools and at home, which increases the number of collected data points. Through this approach, benefits from the project are gained not only by scientists, but also by children who will learn more about cosmic radiation, become familiar with selected aspects of contemporary physics, learn the basics of data analysis, and gain insight into how scientific teams work. This conclusion effectively demonstrates how the CREDO project bridges the gap between professional scientific research and educational outreach, transforming accessible technology into valuable research tools while simultaneously fostering scientific literacy among students.