Cosmic Rays: How to detect radiation from Outer Space and its applications for the study of Climate Change

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January 13, 2023

Abstract

The study of galactic cosmic radiation (GCR) is of great importance nowadays, not only to understand our Universe at a deeper level, but also to help us improve technical advances and environmental conditions. After proving GCR existence with the help of a SiPM detector, along with some of its properties (inverse proportionality to Sun electromagnetic beams, qualitative penetration power...), we moved one step forward and investigated about particular phenomena in which GCR is involved, one of which turns out to be climate change. One of the multiple bonds between these phenomena relies on the possible correlation between GCR rate and cloud condensation nuclei (CCN) formation in the troposphere. Demonstrating detailed models that explain the increase of antrophogenic CCN in clouds would help us design more efficient ways to reduce CCN excess and therefore improve weather conditions. Being inspired by Hess' work on GCR and Hudson's experiments on CCN measurements [Hess 1912; Hudson 1984], we propose an experiment involving in-flight measurements of GCR along with air samples collection. Through more refined and ecological methods, such as the CLOUD experiment, the scientific community has proven that the link between GCR and CCN may not be especially relevant, as there may be other variables or processes of greater importance [Gordon et al. 2017; Kirkby 2001]. All in all, these experimental initiatives promote new and necessary attempts on understanding climate change, so that we are able to reduce the global warming impact on the Earth's biosphere.

I. Introduction

Radioactivity has been one of the most interesting phenomena in Physics since its discovery in the 1890 decade thanks to the work of Henri Becquerel and the Curie Family, among other outstanding scientists [*Becquerel 1896; Curie and Curie 1898*]. The will of the physicists to understand how matter interacts at microscopic levels has led to many practical applications and several ethical debates on how to exploit radioactivity potential along the twentieth century: X-ray radiology, particle detectors, nuclear fission reactors, atomic bombs, hadron-therapy... However, for the most part, the concept of radioactivity was discovered on a "ground" basis: the first experiments studied the nuclear processes and reactions taking place inside matter on

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Earth surface. Therefore, one could wonder that if we put ourselves at a certain altitude, this kind of radiation would be imperceivable; i.e., the higher we rise from the ground, the least radioactive processes we would observe. The first experiments seemed to support that idea (e.g., Kurz 1909; Wulf 1909), discarding the possibility of extraterrestrial radiation. Others suggested exactly the opposite: the existence of extraterrestrial radiation would explain fluctuations in measurements [Gockel 1911; Pacini 1909]. In the middle of this controversy and as an attempt to finally prove the relation between radiation and height, Austrian-American physicist Victor F. Hess repeated the previous experiments in balloon flights in seven different occasions, measuring radiation up to heights of 5350 meters [*Hess 1912*]. As he stated in his article, even when measurements were made at night or solar eclipses, rather than lowering, radiation levels increased proportionally to altitude when a certain height was reached (∼2000 meters above sea level, *asl*). In his own words [*ibid.*]:

"The results of the present observations seem most likely to be explained by the assumption that radiation of very high penetrating power enters from above into our atmosphere, and even in its lowest layers causes part of the ionization observed..."

This set of experiments was crucial on the understanding not only of radioactivity, but also of our Universe: Hess just proved the existence of *extra-terrestrial radiation*, currently referred simply as **cosmic radiation** (CR) or **galactic cosmic radiation** (GCR). His work was later awarded with the Nobel Prize in 1936, becoming one of the most important and memorable experiments in Science History.

The scientific community currently continues to investigate GCR in order to demonstrate the mechanisms through which this cosmic rays can affect our surroundings. There are several investigation directions, but one of the most important ones is related to climate change and atmospheric events. As a consequence of its relevance in Physics and its potential applications to preserve the biosphere, this paper ambitions to prove the existence of GCR through a practical method, as well as a brief scientific discussion of the bonds between GCR and climate change through the study of cloud condensation nuclei (CCN), particles that are of great importance in meteorological conditions.

II. Experimental proof on GCR existence

i. Theoretical hypothesis

Nowadays, there is sufficient experimental proof on the existence of GCR and its origin: for example, the study of supernovae remnants is quite compelling (Tatischeff et al. 2021), even though there are other sources (Active Galactic Nuclei, γ-ray bursts, pulsars...). There are also several mathematical models that explain the behaviour of GCR (e.g., cf. Blasi 2013).

At the time, Hess used two Wulf radiation detectors (similar functioning to electrometers) to take measurements during his flights (cf. Hess 1912). Since then, technology has developed to much more refined standards. And while reading the previous paragraphs, one could ask: *can we prove the existence of cosmic rays without sending our detector to high altitudes?* The answer is affirmative. At first, we must take a deeper look into the theoretical premises that explain the detection of cosmic radiation:

Let's suppose there are extraterrestrial rays coming from outer space. As the Sun is not a source (proved experimentally by Hess), they must come from really far away from our Solar System. Therefore, as these rays must travel light-year distances until they reach Earth before complete dissipation, we will assume this radiation has high-energy levels associated; and therefore, high frequencies (as Planck Hypothesis states):

$$E = hf, \tag{1}$$

where $h \approx 6.62607 \cdot 10^{-34}$ J s^{-1} (Planck constant), and f is the frequency.

We cannot distinguish the nature of this radiation (corpuscular or wavy). If GCR is formed by high-energy particles[1], according to decay laws of radioactivity and the mechanic collisions with other particles in the atmosphere, our cosmic ray will start releasing energy while it turns into different particles due to nuclear reactions. The release of energy, the ionisation of atoms and the decay of particles continues all along the atmosphere, and in the end, less energetic yet charged particles will reach the surface, such as muons.

This phenomena is called *cosmic shower*. The whole process is shown in Figure 1.

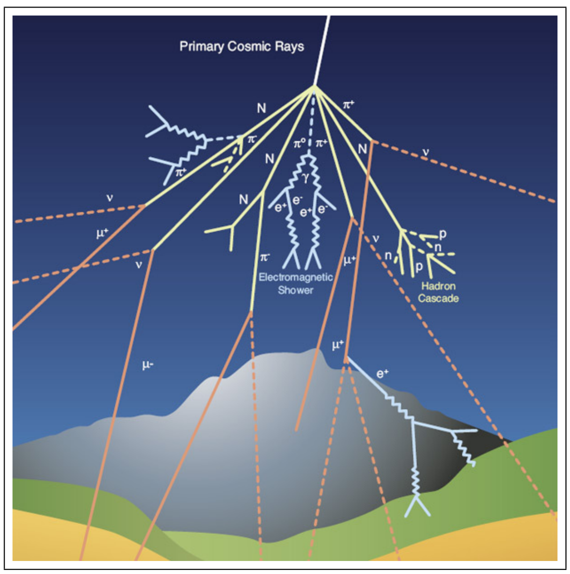


Figure 1: *Cosmic Ray Shower (Source: CERN)*

Therefore, the truth of our hypothesis stands on the detection of these specific charged particles[2].

[1] If GCR is a superposition of waves, due to the high energy they have associated, atoms on their way would be ionised, releasing photoelectrons on its way that will produce several atomic and nuclear reactions that have similar effects to the corpuscular case. In practice, GCR can be presented in both ways, specially if we consider De Broglie Hypothesis.

[2] From now on, and with practical purposes, we will consider all these charged particles are "muons"; however, one shall not forget muons might not be the only charged particles that reach the surface.

ii. Preliminaries. *Building a SiPM Cosmic Ray detector*

We will use the following material:

- A Silicon Photon Multiplier (SiPM) detector. It will be helpful to detect the incoming ray.
- Capacitors (10 nF) and resistors (49.9 Ω) to regulate the current flowing through the SiPM detector.
- A non-inverting amplifier to make sure the signal obtained from the SiPM is observable.
- Breadboard and solder material. Necessary for building the detector circuit.
- A black plastic box. It will be used to ensemble all the inner circuit and protect the SiPM of light noise.
- A plastic scintillator to produce a light beam that will travel to the SiPM.
- Reflective foil in order to conduct the light beam to the SiPM.
- An oscilloscope. Necessary for displaying the signal received from the detector.
- Power supplies. Electricity must run through the circuit so it can work.

A schematic of the process would be the following: one muon will hit the scintillator, exciting its atoms and producing a photoelectron that will be concealed thanks to the reflective foil until it hits the SiPM detector. Then, the energy of that photoelectron will produce an electric current that will be amplified and displayed in the oscilloscope. In order to ensure the best surrounding conditions, we need to isolate our detector from light, so that the background noise is considerably reduced. In the following lines we present a brief summary on our assembly process:

1. We soldered the capacitors and resistors along with the SiPM detector in the breadboard as stated in Figure 2A).

2. Once the first part of the circuit has been tested and it works properly, we wrapped the plastic scintillator with the reflective foil and make a "window" which size

should match the SiPM surface, so that the photoelectron can only hit the SiPM detector. We attach the scintillator to the SiPM detector and the breadboard with the help of adhesive material (e.g. duct tape).

3. We placed the detector inside the black box along with the non-inverting amplifier (Figure 2B). We will have previously made holes at the sides of the box in order to let one cable in and two cables out. After joining the whole circuit as stated in Figure 2, we fix our electronics to the box and seal it so that no shed of light might go inside our detector.

4. Finally, we attached the cables to the power supply (the voltage provided to the signal condenser on this experiment will be of 33-33.5 V, whereas the voltage provided to the SiPM detector will be of 3-3.5 V) and the oscilloscope. If we turn everything on, we should be able to observe a signal similar to Figure 4a. After adjusting the scale and the sensitivity of the trigger, we will see a signal similar to figure Figure 4b.

Once the detector is completely operative, we shall start with experimentation.

iii. First experiment. *Detection of incoming radiation*

If we first plug one detector, the oscilloscope will display an electric signal that may remain constant: this current is the one that provides energy to our electronic devices. Adjusting the threshold and scale, the influence of these lower currents (noise) will be removed, showing only pulses that may be unusual, i.e., that at first glance do not come from our electric circuit (see Figure 4b). Then, eventually, some of this energetic pulses may appear on screen.

However, we may ask ourselves: is it really a muon hitting the detector, or is it just a fluctuation in the current? In order to check, we will use two detectors, one on top of another (SiPM from both detectors must be aligned, so that in case one muon hits the first detector, it will hit the second one. See Figure 3). Then, we adjust the oscilloscope so that the signals from both detectors coincide (see Figure 5a).

What are the odds of catching one mutual detection (see Figure 5c)? We could make some easy calculations based on probability: let's consider the flux of our hypothetical cosmic radiation through the top of our detector to be maximum (in other words, the rays are parallel to the normal vector of the top of our detector). At first glance, we could state that the detections of two different muons are independent events, i.e., the probability of them happening is the product of probabilities:

$$P(A_1 \cap A_2) = P(A_1) \cdot P(A_2) = P(A)^2,$$

where A_n is the event: "an electrically charged particle hits the n-th SiPM detector". If we make a generous estimation, assuming that the area our SiPM plaque is 25 millimetres squared (mm^2, our current SiPM detector had $\sim 1mm^2$ surface), and the area of the whole detector surface is 7500 mm^2, the probability in classic terms would be:

$$P(A) = \frac{25}{7500} \approx 0.33 \cdot 10^{-2}.$$

Therefore:

$$P(A_1 \cap A_2) = \frac{1}{90000} \approx 0.11 \cdot 10^{-4}. \qquad (2)$$

If we put this information in perspective, and assuming that one particle hits the detector top surface per second (constant rate), every 90000 seconds (25 hours), one particle would reach both SiPM detectors.

However, once we plug both detectors on, we start to see coincidental signals on the oscilloscope much earlier than expected. In our experiment, three detectors were studied in consecutive 15 minute-intervals. The results are stated in Table 1 and Figure 6. This evidence overpasses our hypothesis, showing us that there might be a link between detections. From now on, we will assume that the detection of muons follows a *Poisson distribution* with

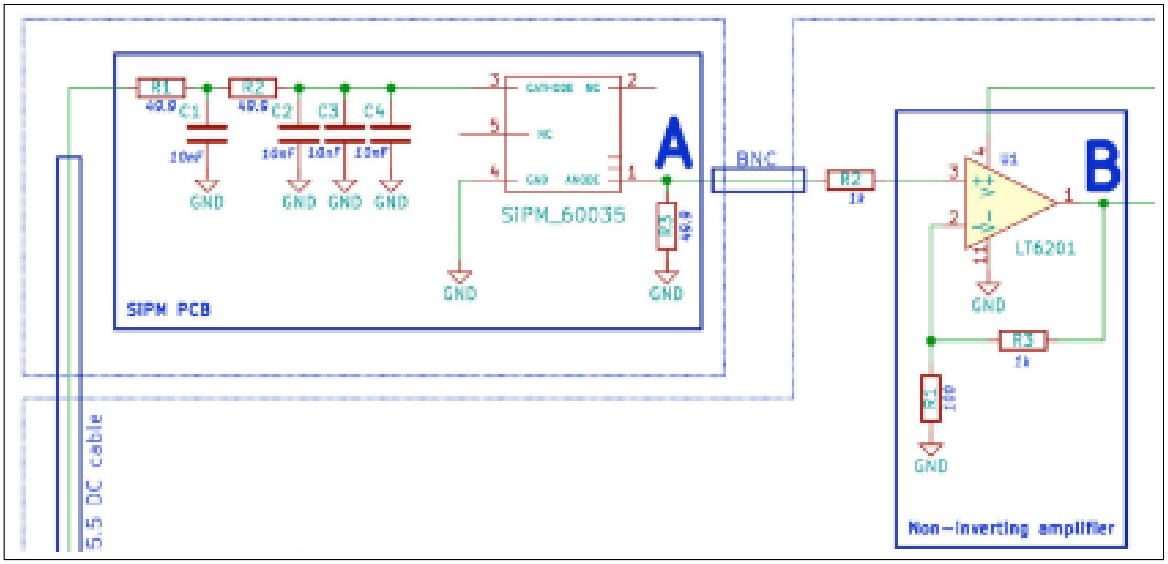


Figure 2: *Electronics of our GCR detector.*

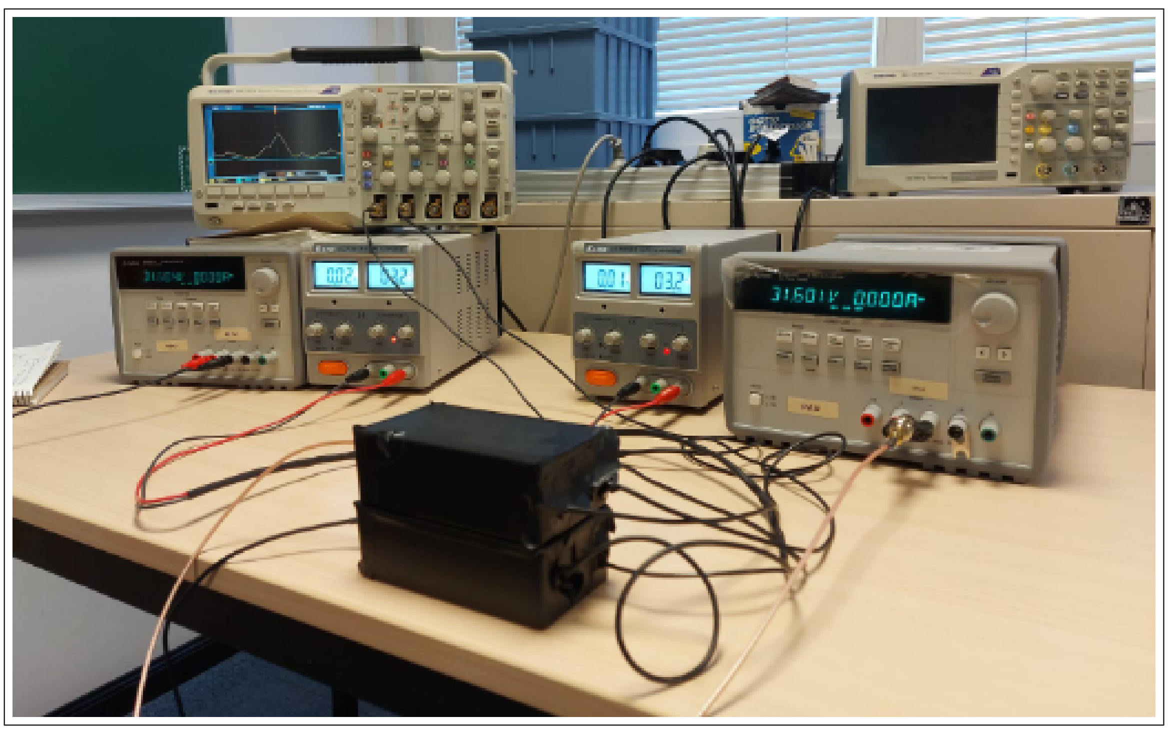
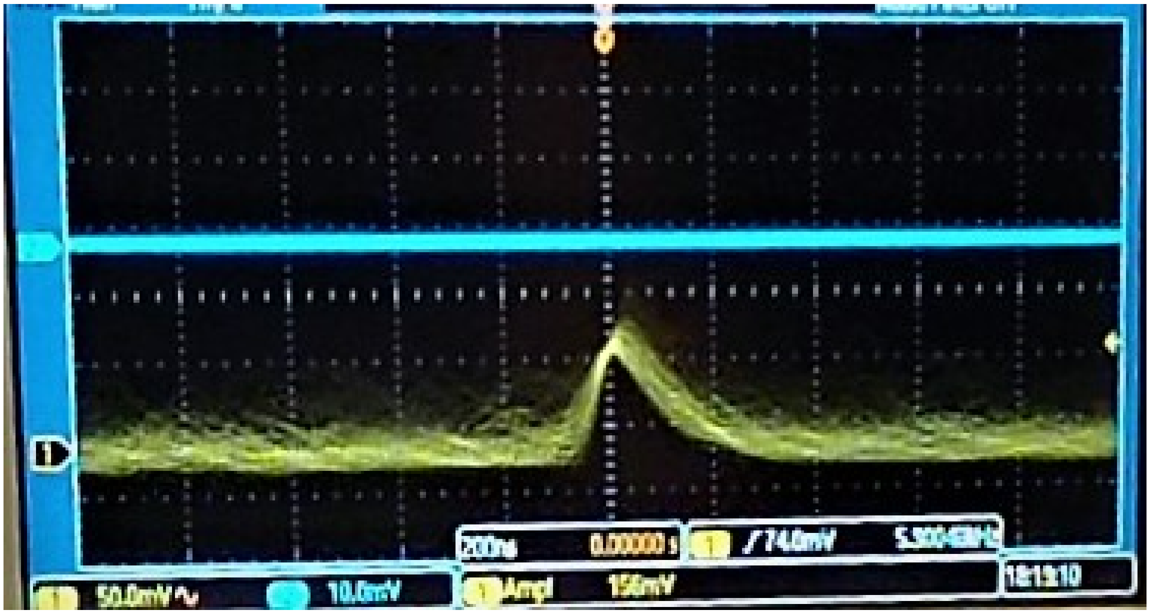
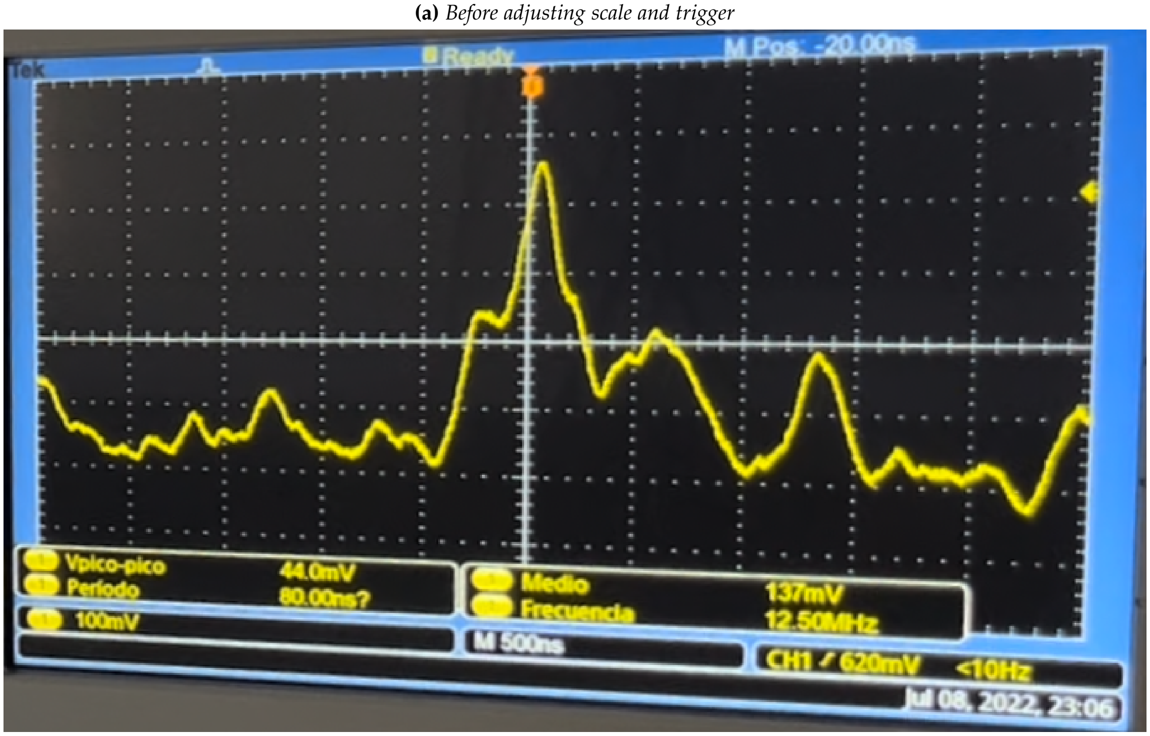


Figure 3: *Final setup for the experiment.*

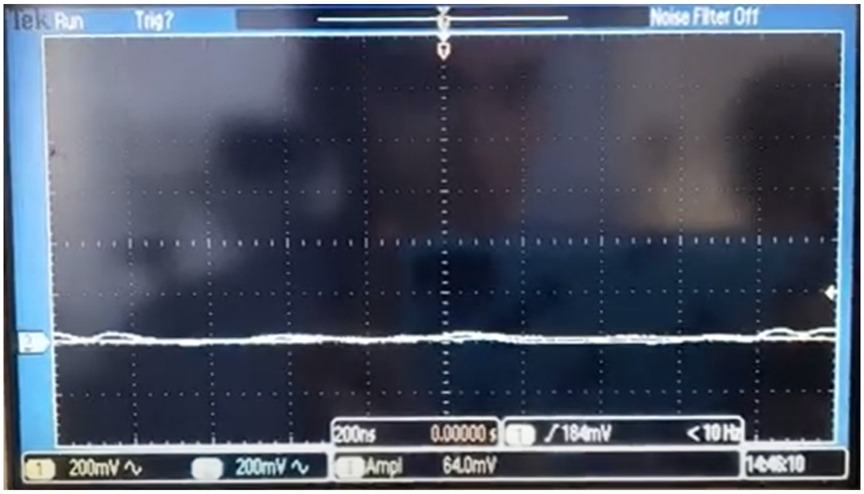


(a) *Before adjusting scale and trigger*

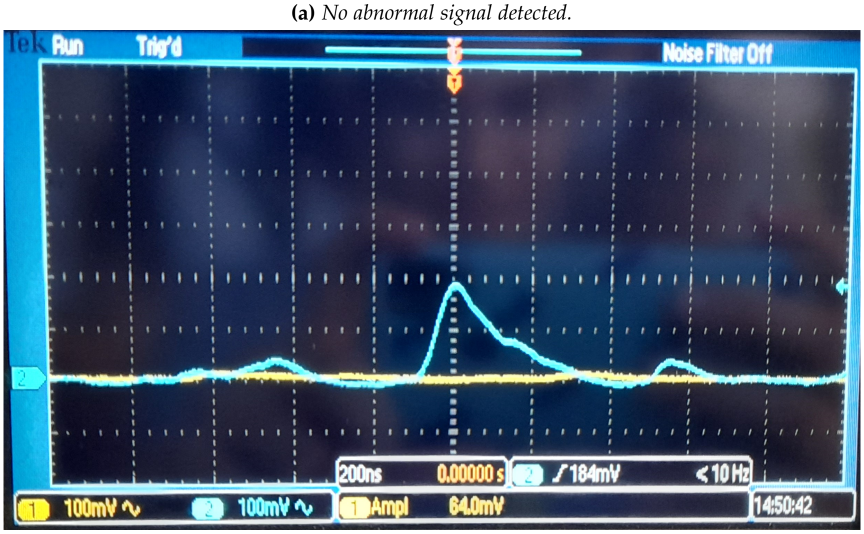


(b) *After adjusting scale and trigger*

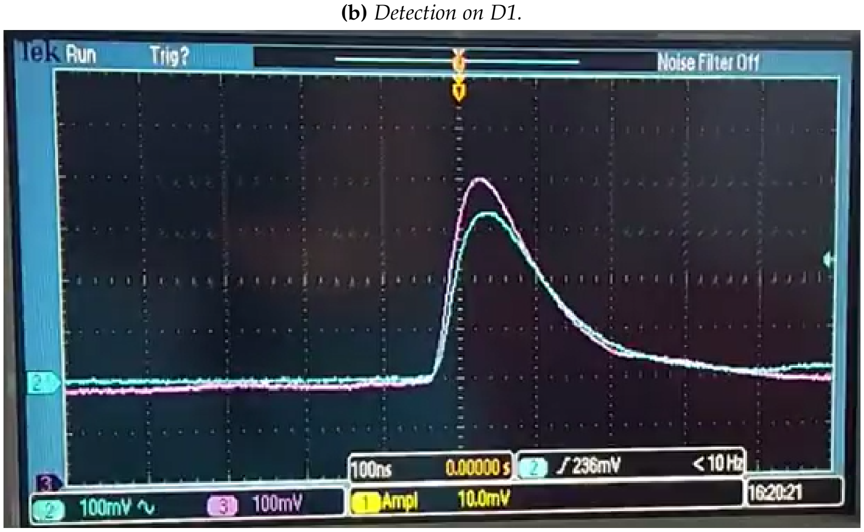
Figure 4: *Signal detected displayed by the oscilloscope.*



(a) *No abnormal signal detected.*



(b) *Detection on D1.*



(c) *Detection on both D1 and D2.*

Figure 5: *Coincidental signals in two different detectors (D1, D2).*

Detections within several time intervals

	Detector 1		Detector 2		Detector 3	
Interval (min.)	Counts	Counts/min	Counts	Counts/min	Counts	Counts/min
0-15	3 ± 0.3	0.250 ± 0.025	1 ± 0.1	0.0667 ± 0.0067	1 ± 0.1	0.0667 ± 0.0067
15-30	2 ± 0.2	0.133 ± 0.013	1 ± 0.1	0.0667 ± 0.0067	3 ± 0.3	0.250 ± 0.025
30-45	1 ± 0.1	0.0667 ± 0.0067	1 ± 0.1	0.0667 ± 0.0067	2 ± 0.2	0.133 ± 0.013
45-60	5 ± 0.5	0.333 ± 0.033	2 ± 0.2	0.133 ± 0.013	1 ± 0.1	0.0667 ± 0.0067
60-75	3 ± 0.3	0.250 ± 0.025	1 ± 0.1	0.0667 ± 0.0067	1 ± 0.1	0.0667 ± 0.0067
Total	14 ± 1.4	0.186 ± 0.019	6 ± 0.6	0.08 ± 0.008	8 ± 0.8	0.107 ± 0.011

Table 1: *Electric signals detected by three different pairs of detectors in four consecutive 15 minute-intervals, along with the radiation ratio associated to each detector and interval of time. We have considered a 10% uncertainty on detections.*

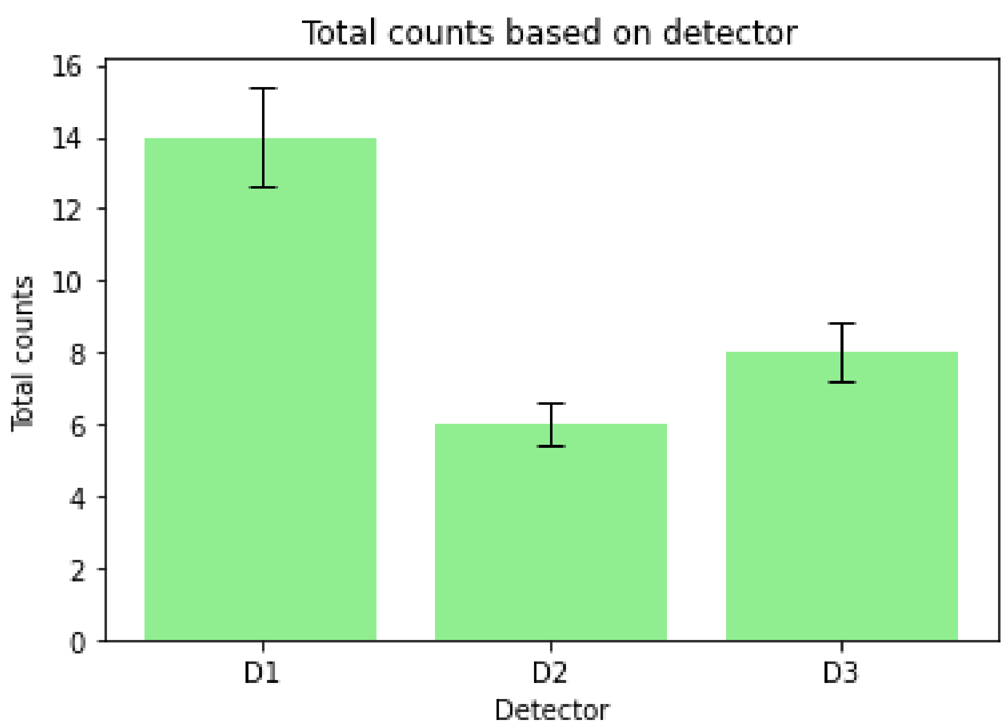


Figure 6: *Bar plot depicting the total amount of detections in Table 1. The error bars correspond to the uncertainty of the global detection on each device.*

a standard deviation (std) of $\sigma = \sqrt{n}$, where n stands for the amount of counts in our measurement.

iv. Second experiment. *Understanding the nature of this radiation*

The previous experiment showed us that some sort of radiation is making the detectors to trigger. However, we do not know the source yet: *where does this radiation come from? Can we assure it comes from cosmic rays and not from terrestrial radiation or other electromagnetic events?* In order to get an idea, we will try study the bond between the Sun position and the incidence rate on our detector. Therefore, we will take two different angles into account: the azimuthal angle and the zenith angle. To do so, we will use a smartphone device equipped with a sun zenith and azimuthal angle measurement application. We may consider the following Type A uncertainties in our experiments:

- We suppose we could have missed 10% of the measurements for data analysis (systematic error).
- When measuring the zenith angle, we will assume a 5° uncertainty as a consequence of instrumental imprecision. When measuring the azimuthal angle, we managed to reduce that uncertainty to 4° by using a different application.
- We consider a time of reaction of $1/60$ seconds from reception to display and counting the detection.

With this information, and along with the Poisson distribution model as our Type B uncertainty, we obtain the results depicted in Tables 2, 3 and Figures 7, 8. Therefore, we can take the following conclusions:

1. The incision of GCR does seems to be inversely proportional to the zenith angle of the Sun: the bigger the angle, the lower the detection rate goes. Therefore, we can state that cosmic radiation does not come from the Sun, rather than from somewhere else in the cosmos[3]. What is more, this result suggests that cosmic radiation is negatively affected by solar electromagnetic beams (EMB) (for further information, cf. *Becker Tjus, J. et al. 2020*).
2. Figure 7 presents a correct lineal regression of our data ($R = 0.95 \approx 1$), therefore our experiment is accurate.
3. The incision of GCR seems to remain constant with the variation of the azimuthal angle. Therefore, at a local range, there is no privileged direction in which cosmic rays are more common.
4. Even though the regression between azimuth angle and detection rate might not be lineal (in Figure 8, $R = 0.01 \approx 0$), we would recommend more observations in order to reduce the considerable errors associated to our parameters, and then check if lineal regression is valid.

v. Third experiment. *Test on the power of penetration of cosmic radiation*

We deduced from the previous experiment that radiation must come from the sky. However, if we really want to test our cosmic shower hypothesis, we have to prove that the detection rate depends on the height. We could simulate the following situation: two aligned detectors are displayed, however, one of them lies under a layer of solid material. In order to do so, we will place different material sheets between the union of two detectors. By doing so, we are checking if particles are blocked by the material between detectors, i.e., if height affects detection rate. Type A and Type B uncertainties are the same ones as in the previous experiment. The results are stated in Table 4 and Figure 9.

We can see that the more isolating material in between, the less radiation will be detected.

[3]We can then discard the terrestrial radiation hypothesis: if this rays came from the floor, there would not be a significant change in detections, which is not what we observe from our experiment.

Detections within 15 minutes at constant polar angle		
Zenith (°)	Counts	Counts/min
0 ± 5	25.0 ± 5.0	1.67 ± 0.33
15 ± 5	21.0 ± 4.6	1.40 ± 0.31
30 ± 5	14.0 ± 3.7	0.93 ± 0.25
45 ± 5	9.0 ± 3.0	0.60 ± 0.20
60 ± 5	3.0 ± 1.7	0.20 ± 0.12
75 ± 5	3.0 ± 1.7	0.20 ± 0.12
90 ± 5	0.0 ± 3.3	0.00 ± 0.22

Table 2: *Radiation rate from a detector in 15 minute-intervals when the Sun was placed at the zenith angle stated. The uncertainties were calculated taken the previously mentioned considerations into account. For null values of counts, the uncertainty considered is the mean of uncertainties taking the remaining measurements.*

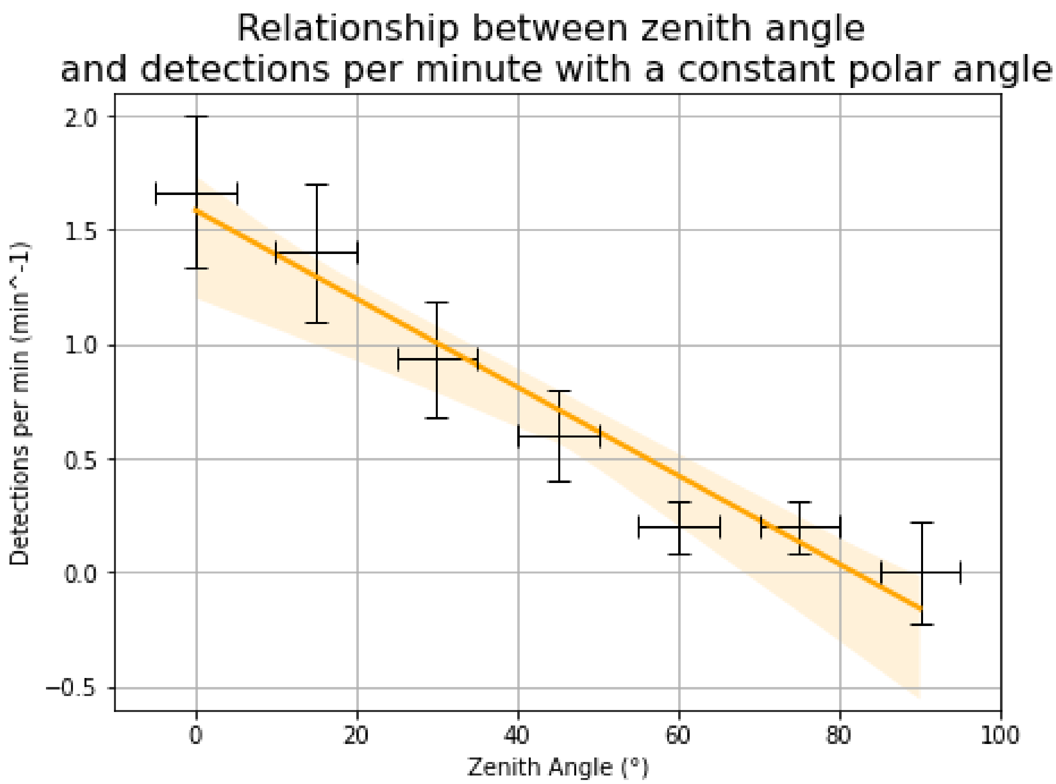


Figure 7: *Graphical representation of Table 2, along with a linear regression of our data ($y \approx (-0.0194 \pm 0.0019)x + (1.58 \pm 0.10)$, linear regression coefficient: $R = 0.95$).*

Detections within 15 minutes at constant zenith angle		
Azimuthal (°)	Counts	Counts/min
0 ± 5	10.0 ± 3.2	0.67 ± 0.21
45 ± 5	13.0 ± 3.6	0.87 ± 0.24
90 ± 5	11.0 ± 3.3	0.73 ± 0.22
135 ± 5	10.0 ± 3.2	0.67 ± 0.21
180 ± 5	12.0 ± 3.5	0.80 ± 0.23

Table 3: *Radiation rate from a detector in 15 minute-intervals when the detector was placed at the azimuth angle stated in relation to the Sun.We consider a symmetry of the problem, therefore, we will only measure up to 180 °.*

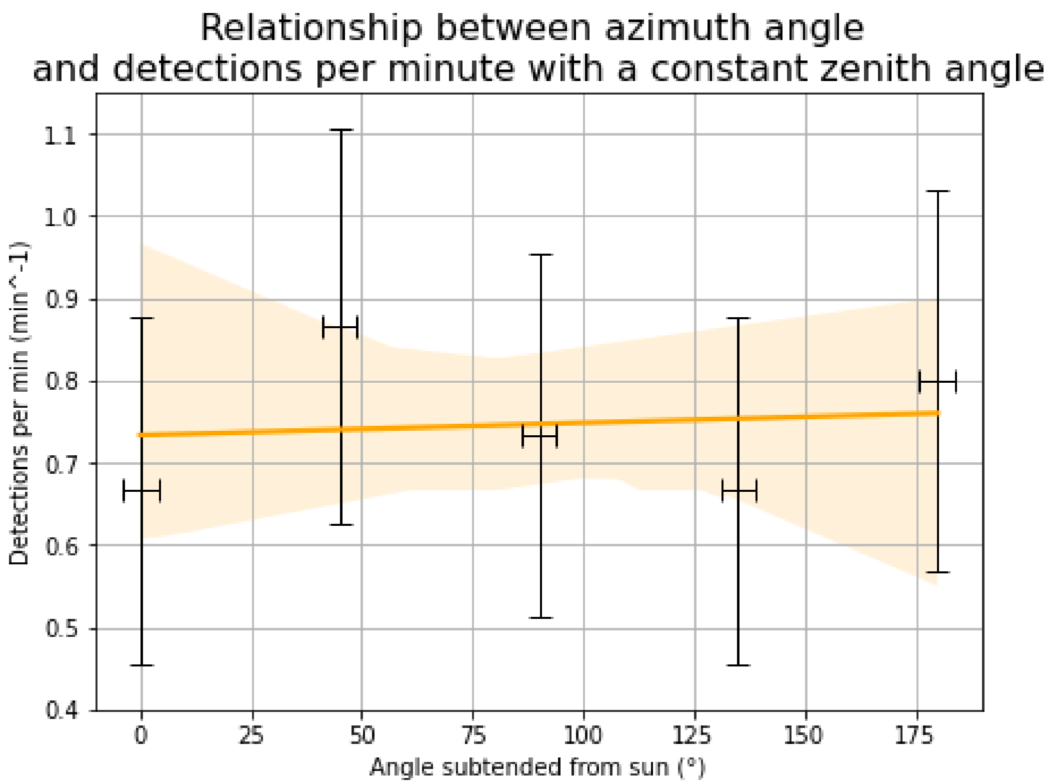


Figure 8: *Graphical representation of Table 3, along with a linear regression of our data ($y \approx (-0.0002 \pm 0.0070)x + (0.733 \pm 0.077)$, linear regression coefficient: $R = 0.01$).*

Single (S) and mutual (M) detections within 15 minutes

	S detections		M detections	
Material	Counts	Counts/min	Counts	Counts/min
None	32.0 ± 5.7	2.13 ± 0.37	25.0 ± 5.0	1.67 ± 0.33
Iron	34.0 ± 5.8	2.27 ± 0.39	14.0 ± 3.7	0.93 ± 0.25
Lead	34.0 ± 5.8	2.27 ± 0.39	13.0 ± 3.6	0.87 ± 0.24
Aluminium	31.0 ± 5.6	2.07 ± 0.37	16.0 ± 4.0	1.07 ± 0.27

Table 4: *Radiation rate of two aligned detectors displayed as described in Chapter II, Section v. The "single" detections stand for the ones that were only made by the detector on top (D1, see Figure 5b), whereas "mutual" detections stand for the ones that were collected in both detectors (see Figure 5c). Single detections in the detector at the bottom (D2) have not been taken into account.*

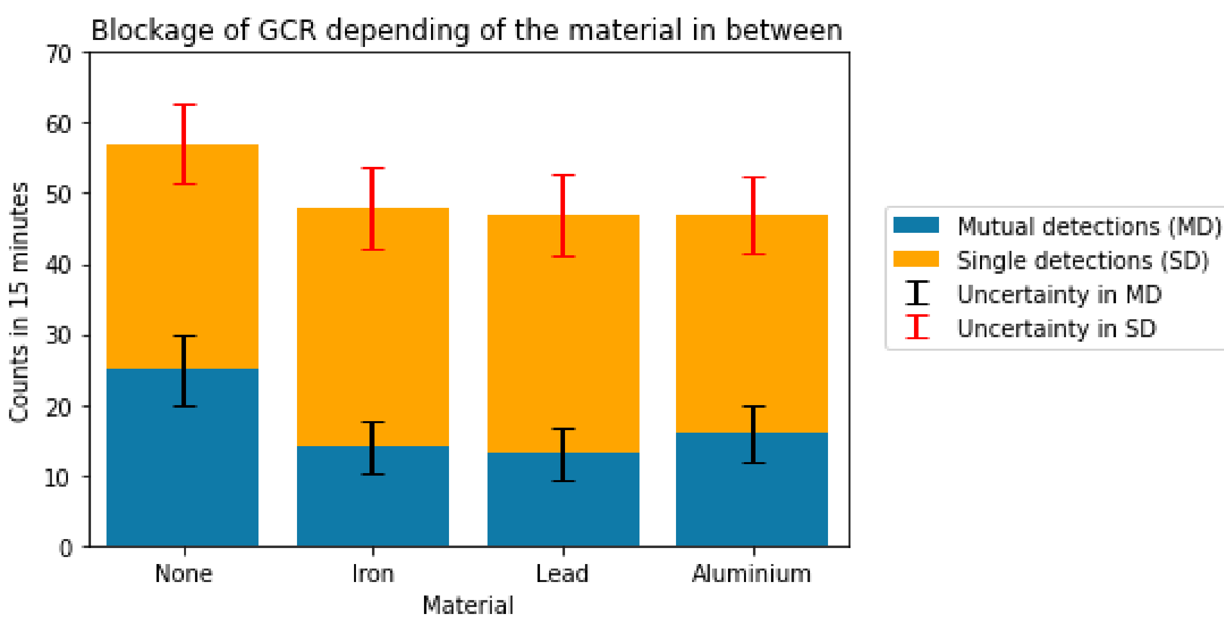


Figure 9: *Stacked bar graph of Table 4.*

Therefore, we can state that our hypothesis is true: the cosmic shower fits the experimental results. Once we have introduced GCR and some details about its nature, we will move to the next topic of this document: the connection between GCR and climatology and climate change.

III. Links between CCN and GCR. Experimental approach

i. Theoretical hypothesis

In his work, Hess stated that it did not seem to be a certain correlation between atmospheric conditions and radiation observation. However, recent studies that we will discuss at the end of this document claim that GCR has indeed a bond with atmospheric conditions, being the first a variable that may alter the second. As an example, it is interesting to take a look at **CCN and cloud formation**:

While studying the differences between maritime and continental clouds, it was determined that one of the main differences between these two types of clouds was the amount of particles that composed each one of them: the so called *cloud concentration nuclei* (CCN) [*Squires 1952, 1956*]. Since the late 1960s, several researchers have measured the CCN concentration in the atmosphere [*Hudson 1993* and the references therein]. From these experiments, we can extract several conclusions, from which we can remark the following:

1. We can classify CCN in two wide categories: *anthropogenic* and *non-anthropogenic*. In the last decades, the amount anthropogenic CCN has become significantly larger than non-anthropogenic CCN. These particles compose most of the continental clouds.
2. Even though CCN are not a big concern in continental clouds (they are mostly composed of these particles), the appearence of CCN in maritime clouds has increased in the last years, leading to structural changes that may result in the formation of continental clouds in the open seas. This may alter the weather conditions, as maritime clouds are more significant to climate study.
3. The most common CCN particles are sulfuric acid (H_2SO_4), water (H_2O) and ammonia (NH_3) vapors. Recent studies have also proven the particular importance amines and diamines have in CCN nucleation and coalescence [*Korhonen et al. 1999*].
4. The excess of CCN in the atmosphere could contribute to cloud scavenging, producing a double effect: the promotion of the greenhouse effect, due to the increase of greenhouse gases and aerosols; and the Twomey effect [*Feingold et al. 2003; Twomey 1977*], which lowers the local temperature due to a cloud albedo increase caused by a higher CCN concentration.

The experiments described in *Hudson 1993* take a look at chemical processes, such as combustion and ions and aerosol particles bonding together to form CCN. However, new experiments have been looking for other variables that may interfere with these processes, such as GCR. As mentioned in the introduction, the objective of this paper is to infer an experiment with which one could study the link between GCR and cloud formation.

ii. Methodology

If we take into consideration the idea that Hess carried out in order to prove the existence of GCR, one can come up with a primal approach on solving the CCN-GCR issue: launching both GCR and CCN detectors to upper layers in the atmosphere so that both levels can be measured simultaneously and studied in order to find any proportionality between the two concepts. The following chapter on this document will try to describe an experiment proposal based on this concept.

Firstly, we need to describe a list of materials and equipment needed. These items are grouped and listed below:

- **GCR detector**. We shall use a considerably more refined prototype than the one described in Chapter II, Section ii (p. 3), as circuits and other electronic components may require a better sealing against the pressure variations between atmosphere layers. We would also need to install a software that allows the recording of detections (AI training would be helpful on distinguishing valid electric pulses).
- **CCN detector**. As an guidance to fulfil proper measurements, we will follow the example of *Hudson 1984*. Therefore, a cloud chamber as described in this reference would be used following the indications arranged both in the document and the references therein. Once we have concealed the sample into the cloud chamber, it will be studied afterwards in the laboratory.
- **Unmanned aircraft/drone**. Nowadays, it is possible to control the measurement remotely with the help of the proper software and hardware, even though the cost might be higher.

Secondly, we will describe the procedure that will be followed:

1. The first step is to send both GCR and CCN detectors to the upper troposphere layers with the help of the drone. Once the detectors are placed, we adjust the position of the cloud chamber so that a sample of the air can be collected; meanwhile, the GCR detector will register the radiation activity in the region. We could collect more samples at different heights and times with the help of additional cloud chambers and the proper energy supply.

2. After having obtained the desired amount of information, the drone would procede to land back to the laboratory, where we will study the samples, along with the detections recorded. The objective is then to stablish the correlation between CCN concentration and GCR rate.

iii. Results

At first glance we cannot make sure there is a certain correlation between CCN concentration and GCR rate. Fortunately, there have been research groups that have simulated this experiment in order to answer this question. One of the most interesting ones was developed by British physicist Jasper Kirkby, who proposes the study of cloud formation through recreations of the atmospheric conditions in the troposphere with the help of technology developed at the European Organization for Nuclear Research (Centre Européenne de Recherche Nucléaire, CERN) in 2001: The *Cosmics Leaving OUtdoor Droplets* (CLOUD) experiment [*Kirkby 2001*]. Kirkby and his crew theorised about an ion-aerosol clear-sky mechanism and designed the CLOUD experiment in order to test the influence of GCR in the formation of ions that may contribute to the appearance of CCN according to their model [*Carslaw et al. 2002*].

The results obtained were not completely conclusive: the influence of different variables may cause that there is not such a great correlation between GCR and CCN formation. One of the solutions to this problem may be the design of better mechanical models and a more profound understanding on the cloud formation mechanism (for further information, cf. *Gordon et al. 2017; Pierce 2017*).

IV. Ethical dimension of GCR study

After all the experimentation and details described in this document, the importance of the GCR study is undeniable. Since the discoveries of Victor Hess, many scientists have tried to understand the nature of cosmic radiation not only for intellectual and theoretical purposes, but also for humanitarian purposes: if we are able to verify the elemental bonds between GCR and climate change through different phenomena, such as cloud formation via CCN concentration (in which mankind plays a detrimental role through the excessive emission of greenhouse particles), we could develop proper strategies on reducing the negative effects, being able to improve the environmental conditions. In Kirkby's own words [*Kirkby 2001*]:

"*The observation of an apparent connection between cosmic rays and global climate offers a unique opportunity for particle physics to make a major contribution to the problem of global warming —at a relatively modest cost.*"

Furthermore, we have exposed different experiments that, if done properly, might not be as contaminant as traditional methods, such as the CLOUD experiment or in-flight measurements [e.g. *Hess 1912; Hudson 1984*]. These new avant-garde methods propose cheaper and more environmentally-friendly ways of studying GCR and CCN, therefore, their implementation is undoubtedly worthy.
The study of climate change is very important in order to help preserve the biosphere in planet Earth, where we, human beings, belong. These experiments are then crucial to help prevent catastrophic events caused by the global temperature rise.

V. Conclusions

GCR has been a prolific topic since the twentieth century, when a first prove on its existence was provided by Victor Hess. Nowadays there are several ways of proving the properties of this radiation, such as the inverse proportionality to Sun EMB and the apparent indifference of the azimuth angle when measuring, giving a hint about the probable local homogeneity of GCR.

What is more, in the last decades, the scientific community has taken new research directions in order to find the possible relations between GCR and atmospheric phenomena. CCN, which plays a determinant role on cloud formation and weather conditions, could seem to be affected by GCR if we take the cosmic shower theory into account, theory that we have proven to be appropriate. However, after some experiments, summarised in *Pierce 2017*, we have not been able to confirm a strong correlation between CCN formation and GCR rate through our current models. Therefore, there is certainly a model yet to describe that explains phenomenology more accurately. More experiments will then need to be designed in order to move towards that model that will help us comprehend climate change at a more profound level.

Acknowledgements

We would like to thank Daniel Kerzberg, Manuel Artero and Jelena Strišković for their guidance on both the theoretical background and the experiments described in Chapter II. We would also like to thank Catalunya La Pedrera Foundation, IFAE and the BIYSC Staff group for the opportunity given to develop this research project. Special thanks to David Hernando for being always a supporter in our work during the laboratory sessions and Óscar Blanch for his comments on the preliminary drafts of this document.

All figures and tables have been elaborated by our research team and/or tutors, except for Figure 1, which intellectual property belongs to CERN, as stated in the footnote. All references have been extracted from original works and/or the references therein. The lack of title or any other information in the reference is due to an impossibility to find the original work through academic search engines (Google Scholar).

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