INTERNATIONAL COSMIC DAY

BOOKLET 2024

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DEAR YOUNG ICD-RESEARCHERS FROM

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The universe is full of mysteries, and together, we have taken one step closer to understanding it. Thank you for sharing your discoveries and enthusiasm at this year's International Cosmic Day (ICD)!

For the 13th time, the International Cosmic Day brought together young minds from all over the world to celebrate science. With over **5900 students from 24 countries around 4 continents**, guided by teachers and scientists, this event was a powerful example of what curiosity and collaboration can achieve. Participants from schools, universities, and research institutes explored the wonders of physics through hands-on experiments, insightful lectures, and inspiring discussions. Scientists shared their latest research, and students proudly presented their results—all contributing to a greater understanding of the cosmos.

To learn how the universe works we have to study the smallest particles as well as the largest celestial objects. You have contributed to creating your own platform for **sharing your research**. Whether you analyzed data from an observatory or performed an experiment yourself: you all learned a lot about cosmic particles on that day.

We hope that the International Cosmic Day gave you an insight into **astroparticle physics**. Maybe you have become interested and it opens a new window for you to explore the universe.

This booklet contains the results of **your discoveries** and some information on the participating groups and the winners of the various contests. If you want to learn more about astroparticle physics, you will also find web links for further information.

Greetings from
Your ICD Team

Discover Cosmic Particles

INTERNATIONAL COSMIC DAY

November 26 I 2024

Cosmic particles, these unnoticed particles that surround us all the time, are the focus of this day. Students, teachers and scientists get together to talk and learn about cosmic particles from space and answer questions like:

What are cosmic particles?
Where do they come from?
How can they be measured?
And what can we learn from them?

Image Credit: DESY, Science Communication Lab

If you want to know more about the secrets they bring and be part of this collaboration, you can find more information here:

https://icd.desy.de
https://www.facebook.com/InternationalCosmicDay

IPPOG International Particle Physics Outreach Group

DESY.

In cooperation with many networks and partners

Global Cosmics .org

ALL PARTICIPATING GROUPS

In 2024, groups from many different cities in different countries took part. Even if you don't know each other, you live in other cities and countries, even on other continents: On this day, you are actively exchanging ideas about your projects and we are united by an interest in researching these invisible particles that pass us by unnoticed all the time. Asking questions, looking for answers, carrying out measurements and exchanging results are the central points of communication between scientists - just as you have done.

In this way, you have experienced for yourself how science functions as a connecting element across national borders, language barriers and cultural differences.

The map shows the locations of the registered participants of 2024 and can be found online at: https://icd.desy.de/map.

THE WINNERS OF ICD2024 CONTESTS

A team from Turkey dove deep into the Circus of Muons and captured the unseen world of cosmic particles. Their epic shot won them the top prize in the **Cosmic Selfie Contest**—a true glimpse into the magic of physics research:

ISTEK ANTALYA LARA SCHOOLS

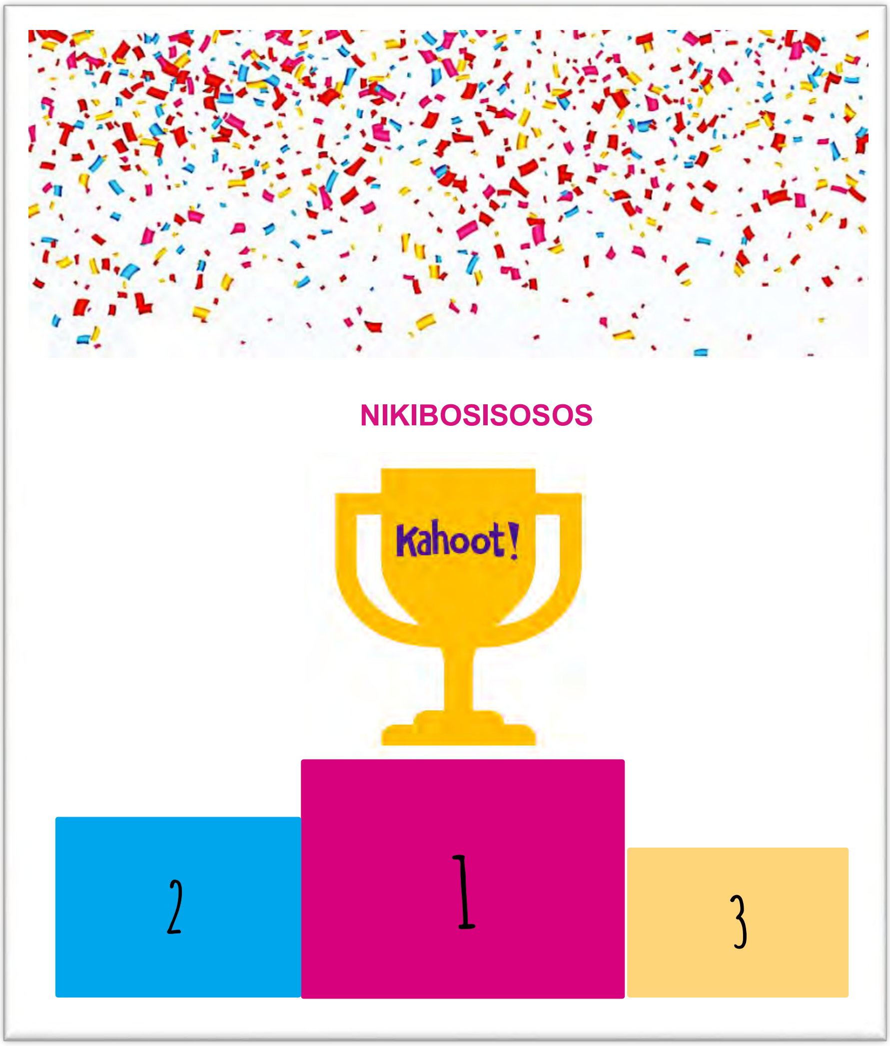
THE WINNERS OF ICD2024 CONTESTS

This hand-painted artwork beautifully captures the vast spectrum of cosmic particle exploration. From deep underwater to the skies, from tiny particles to massive explosions—science knows no bounds. The award for Drawing Contest goes to:

DAISY SAINATO FROM TROPEA

THE WINNERS OF ICD2024 CONTESTS

This year, more than 160 ICD participants took part in the **Kahoot quiz** and you all knew quite a lot about cosmic particles! This year's winner is the user:



Congratulations to all winners. Get in touch with us and you will receive a small surprise from us!

And many thanks also to **everyone** else who participated in the contest! We really enjoyed going through your submissions. They were all great entries and it was not easy for us to choose. We have even received several comics. See for yourself on the next pages …

Nefeli Koulouridi, Anna Kapatsoulia-Modular High School of Patras, MNET

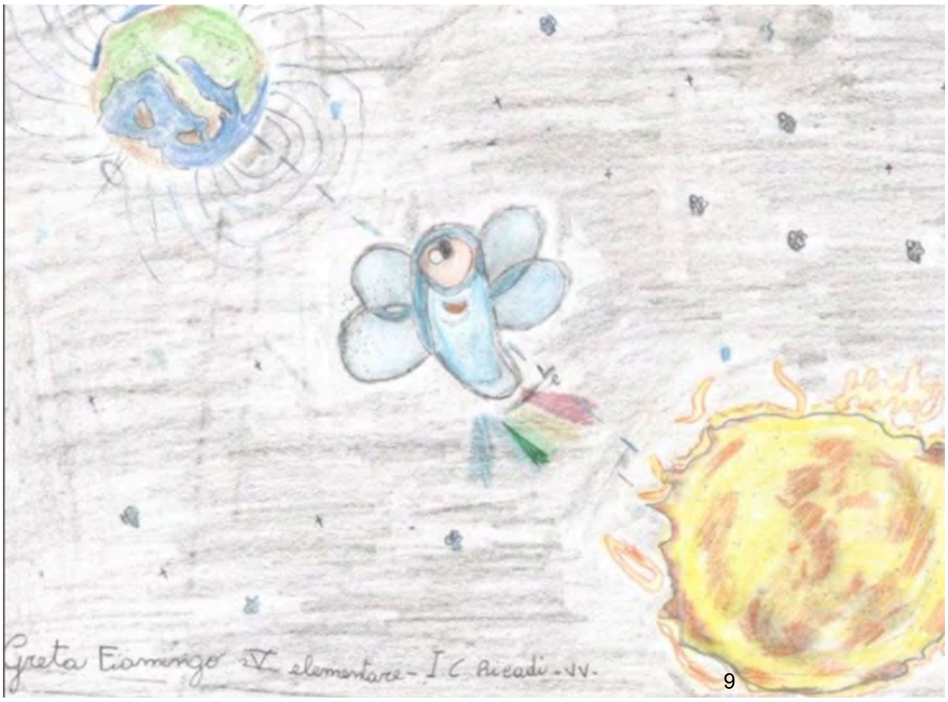
High School of Aigeira

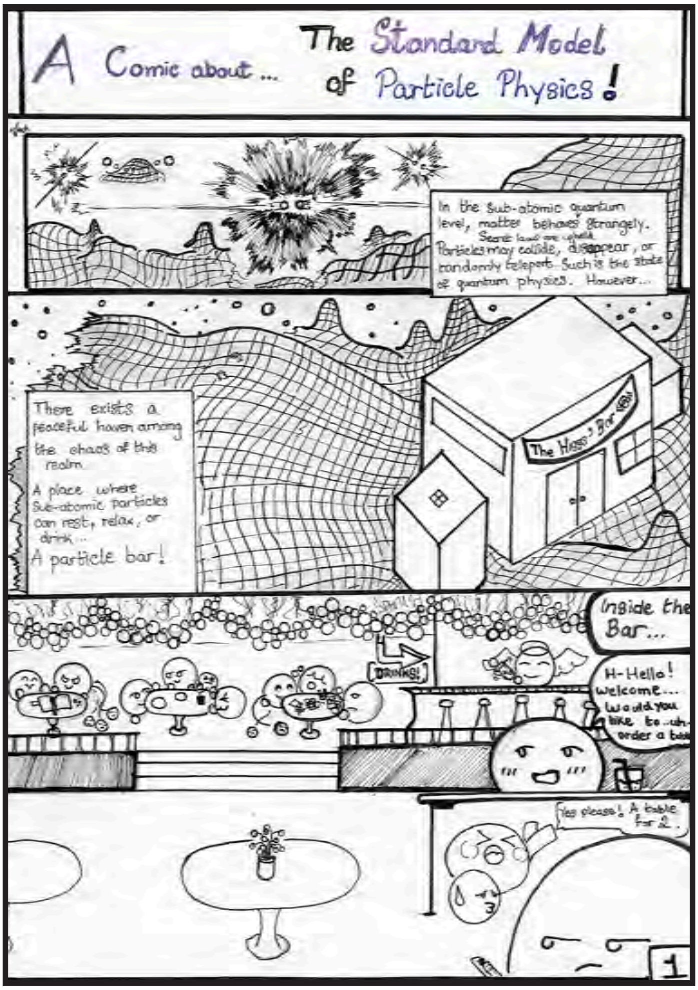
Spyros Michailidis / Andriana Giorgi

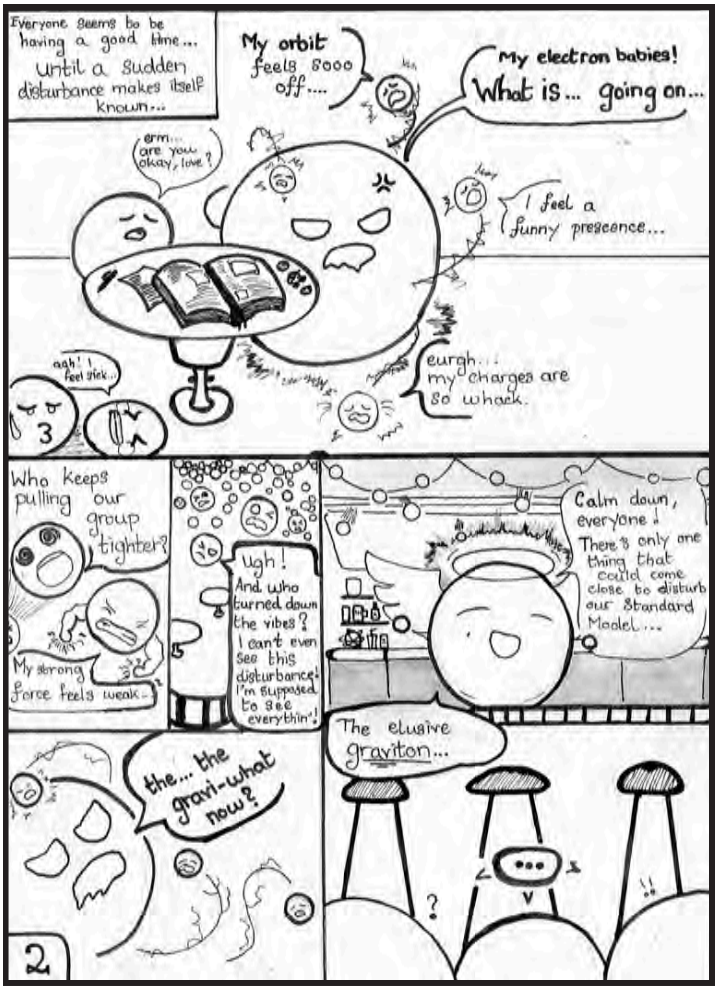
microNET Hellenic Open University

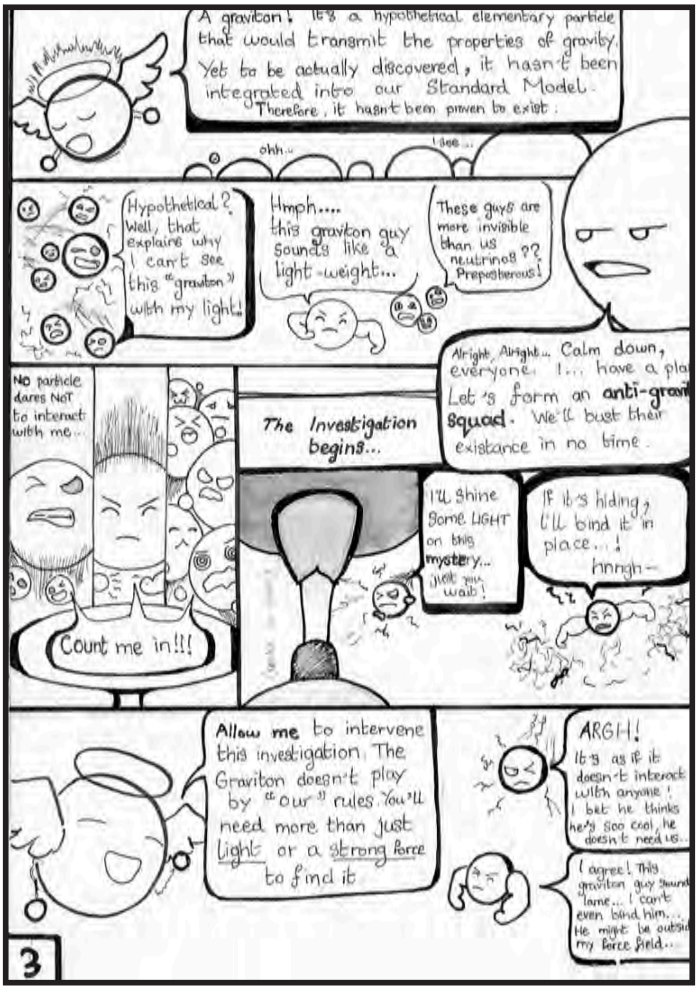

Bouhou
Georgia
1st Highschool of Nafplio

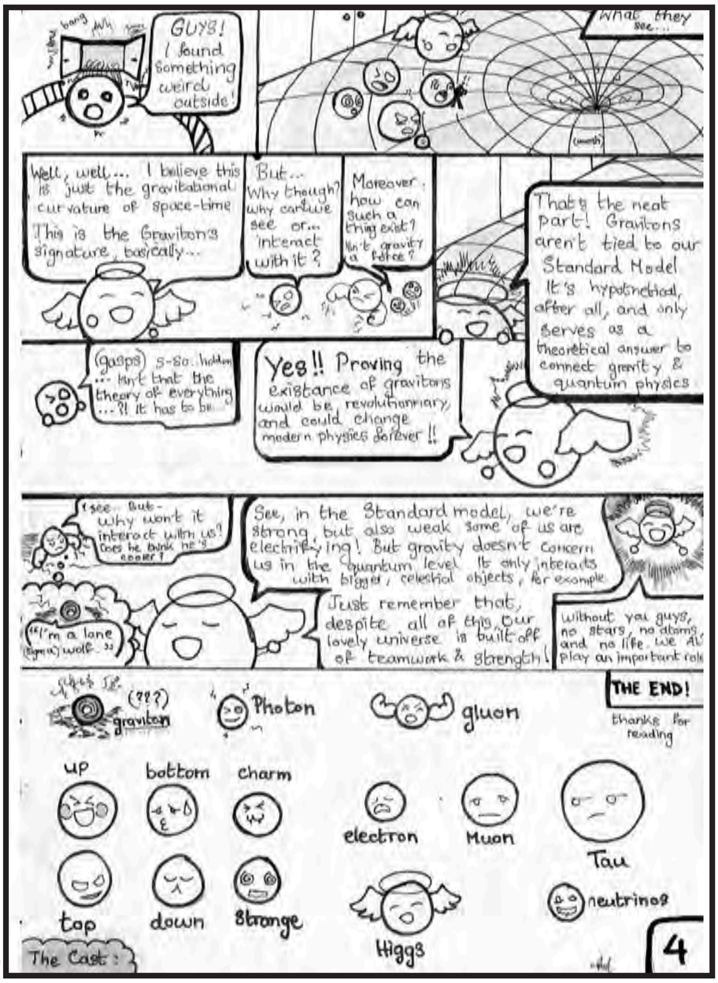

FIND THE WORD
TROPOSPERE
STRATOSPERE
MESOSPERE
NASA


Greta Fiamingo V elementare - I C Ricadi - VV.


A Comic about... The Standard Model of Particle Physics!
In the sub-atomic quantum level, matter behaves strangely. Particles may collide, disappear, or randomly teleport. Such is the state of quantum physics. However...
There exists a peaceful haven among the chaos of this realm.
A place where sub-atomic particles can rest, relax, or drink...
A particle bar!
The Higgs' Bar
Inside the Bar...
DRINKS!
H-Hello! welcome... would you like to..uh.. order a ...
Yes please! A table for 2.
1


Everyone seems to be having a good time... until a sudden disturbance makes itself known...
My orbit feels sooo off....
My electron babies! What is... going on...
erm... are you okay, love?
I feel a funny presence...
agh! I feel sick...
eurgh... my charges are so whack.
Who keeps pulling our group tighter?
My strong force feels weak..
Ugh! And who turned down the vibes? I can't even see this disturbance! I'm supposed to see everythin'!
Calm down, everyone! There's only one thing that could come close to disturb our Standard Model...
The elusive graviton...
the... the gravi-what now?
2


A graviton! It's a hypothetical elementary particle that would transmit the properties of gravity. Yet to be actually discovered, it hasn't been integrated into our Standard Model. Therefore, it hasn't been proven to exist.
ohh..
I see...
Hypothetical? Well, that explains why I can't see this "graviton" with my light!
Hmph.... this graviton guy sounds like a light-weight...
These guys are more invisible than us neutrinos?? Preposterous!
Alright, Alright... Calm down, everyone. I... have a plan. Let's form an anti-graviton squad. We'll bust their existance in no time.
No particle dares NOT to interact with me...
Count me in!!!
The Investigation begins...
I'll shine some LIGHT on this mystery... just you wait!
If it's hiding, I'll bind it in place...! hnngh-
Allow me to intervene this investigation. The Graviton doesn't play by "our" rules. You'll need more than just light or a strong force to find it
ARGH! It's as if it doesn't interact with anyone! I bet he thinks he's soo cool, he doesn't need us..
I agree! This graviton guy sounds lame... I can't even bind him... He might be outside my force field...
3


GUYS! I found something weird outside!
What they see...
Well, well... I believe this is just the gravitational curvature of space-time. This is the Graviton's signature, basically...
But... Why though? Why can't we see or... interact with it?
Moreover, how can such a thing exist? Isn't gravity a force?
That's the neat part! Gravitons aren't tied to our Standard Model. It's hypothetical, after all, and only serves as a theoretical answer to connect gravity & quantum physics
(gasps) s-so.. hidden ... Isn't that the theory of everything ...?! It has to be...
Yes!! Proving the existance of gravitons would be revolutionary, and could change modern physics forever!!
I see.. But- why won't it interact with us? Does he think he's cooler?
"I'm a lone (sigma) wolf."
See, in the Standard model, we're strong, but also weak. Some of us are electrifying! But gravity doesn't concern us in the quantum level. It only interacts with bigger, celestial objects, for example.
Just remember that, despite all of this, our lovely universe is built off of teamwork & strength!
Without you guys, no stars, no atoms, and no life. We All play an important role
THE END!
thanks for reading
The Cast:
(???) graviton
Photon
gluon
up
bottom
charm
top
down
strange
electron
Muon
Tau
neutrinos
Higgs
4

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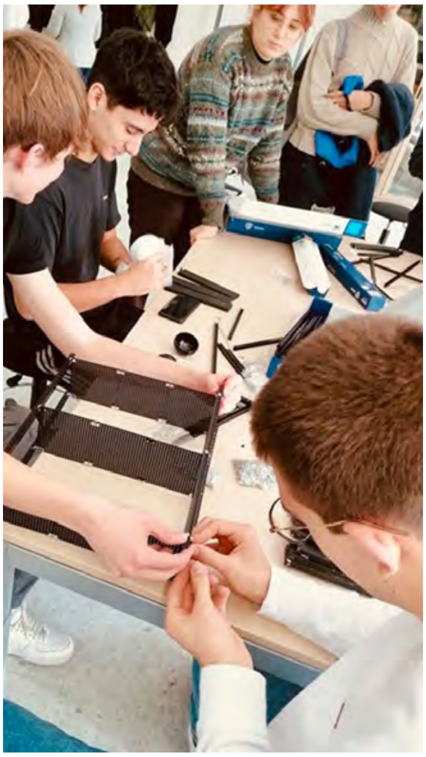

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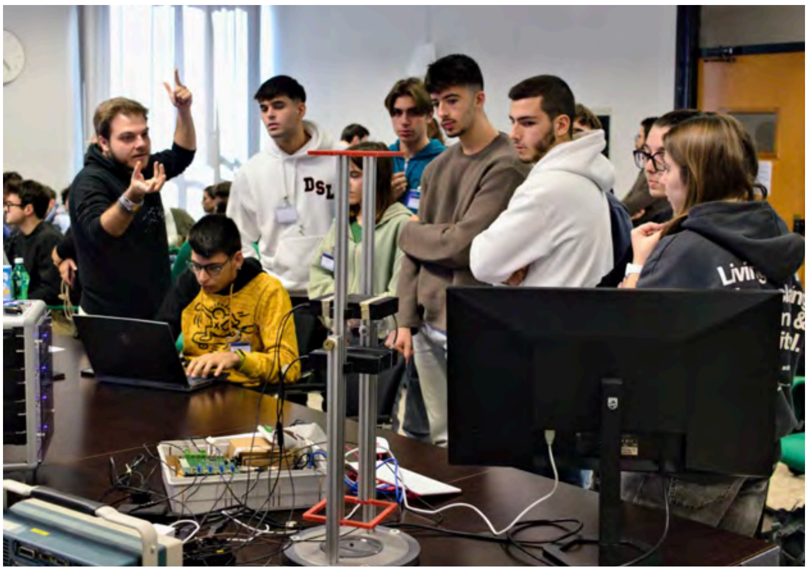

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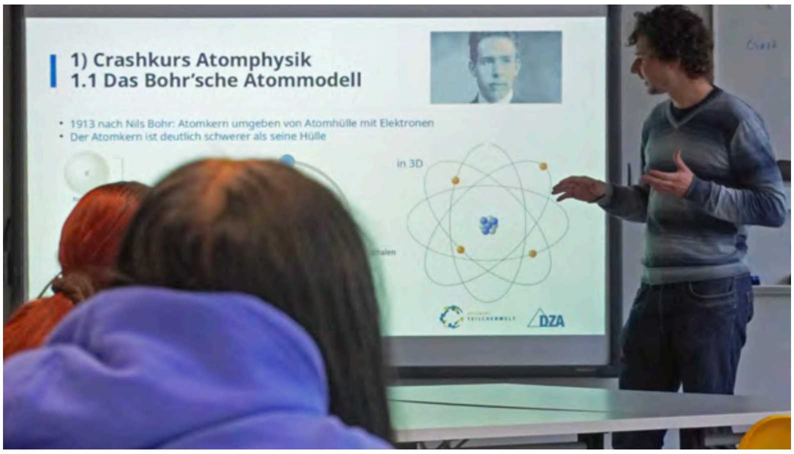

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Dott.ssa Alessia Giampaoli

REPORTS

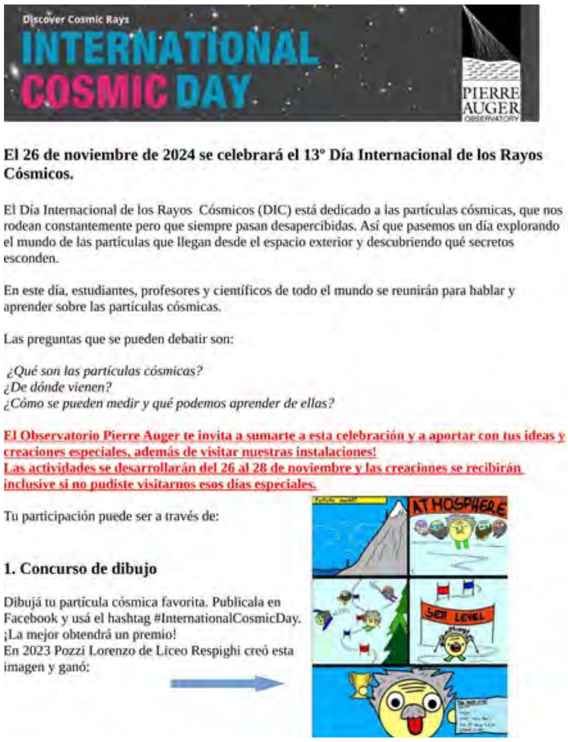
On the following pages, we have compiled your contributions for this booklet. These contributions document your new insights obtained on ICD with images, comments, notes or measurement results and data analysis – as scientists do when they submit and publish a proceeding after a conference. We have sorted the contributions by countries in alphabetical order. Let's start with…

ARGENTINA

ICD 2024 the Auger Observatory Report

December, 2024

The Pierre Auger Observatory celebrated the ICD2024 from Nov 26th to Nov 28th
During the ICD, the main action was at the social networks with a dedicated sticker (Fig.1) and the invitation to participate of the Art and Selfies contests, according the template by the ICD International, translated to Spanish (Fig 2).



Discover Cosmic Rays
INTERNATIONAL COSMIC DAY
PIERRE AUGER

El 26 de noviembre de 2024 se celebrará el 13º Día Internacional de los Rayos Cósmicos.

El Día Internacional de los Rayos Cósmicos (DIC) está dedicado a las partículas cósmicas, que nos rodean constantemente pero que siempre pasan desapercibidas. Así que pasemos un día explorando el mundo de las partículas que llegan desde el espacio exterior y descubriendo qué secretos esconden.

En este día, estudiantes, profesores y científicos de todo el mundo se reunirán para hablar y aprender sobre las partículas cósmicas.

Las preguntas que se pueden debatir son:

¿Qué son las partículas cósmicas?
¿De dónde vienen?
¿Cómo se pueden medir y qué podemos aprender de ellas?

El Observatorio Pierre Auger te invita a sumarte a esta celebración y a aportar con tus ideas y creaciones especiales, además de visitar nuestras instalaciones!
Las actividades se desarrollarán del 26 al 28 de noviembre y las creaciones se recibirán inclusive si no pudiste visitarnos esos días especiales.

Tu participación puede ser a través de:

1. Concurso de dibujo

Dibujá tu partícula cósmica favorita. Publicala en Facebook y usá el hashtag #InternationalCosmicDay.
¡La mejor obtendrá un premio!
En 2023 Pozzi Lorenzo de Liceo Respighi creó esta imagen y ganó:

Figure 1. ICD 2024 commemorative sticker Figure 2. ICD2024 Auger invitation

During 3 days the Pierre Auger Observatory opened the doors to visitor from schools, tourist and local inhabitants, who shared the special proposal to use an touch different detectors, as Geiger counters, scintillators, between others. The observatory received during the ICD2024 **200 visitors**. Figures 3 and 4 show selfies and images of different audiences during the celebration and Figure 5 some artistic creations, part of the “My favorite Cosmic Particle” contest.

Fig 3. Visitors at the Pierre Auger Observatory, in Malargüe, with CR detectors

Figure 4.

Mosaic of different moments of the visitors at the Visitor Center (outside and inside) at Headquarters of Pierre Auger Observatory

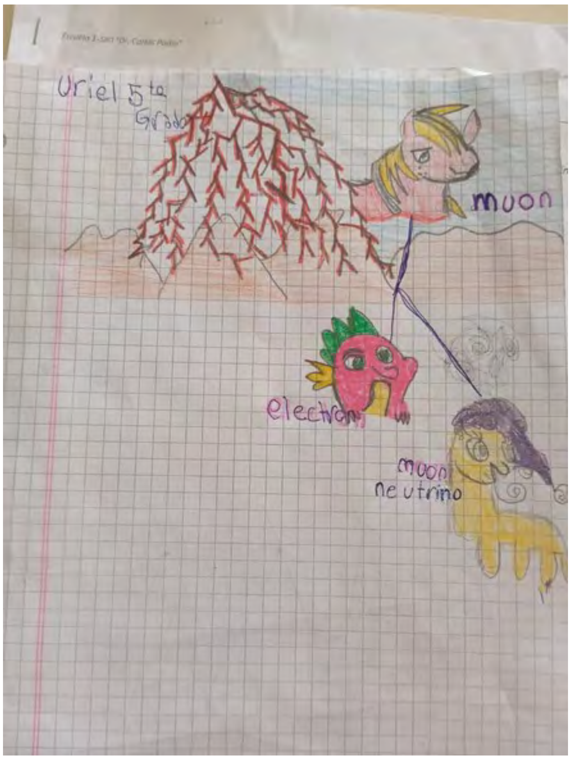


Figure 5.

My favorite cosmic particle contest

The evidence of participation using the #InternationalCosmicDay was at the networks (Figure 5 bottom left) and as a closing action, the Observatory prepared a short for YouTube, a video entitle “Apasionados por los Rayos Cósmicos” (Fig. 6). The full video can be recovered from: https://www.youtube.com/shorts/yrzohJHqZVU

Our special Thanks to our Guides: Ivana Arroyo, Tania Domínguez and Marcela Cogo, the Managers and all the Pierre Auger Staff for this amazing ICD2024.

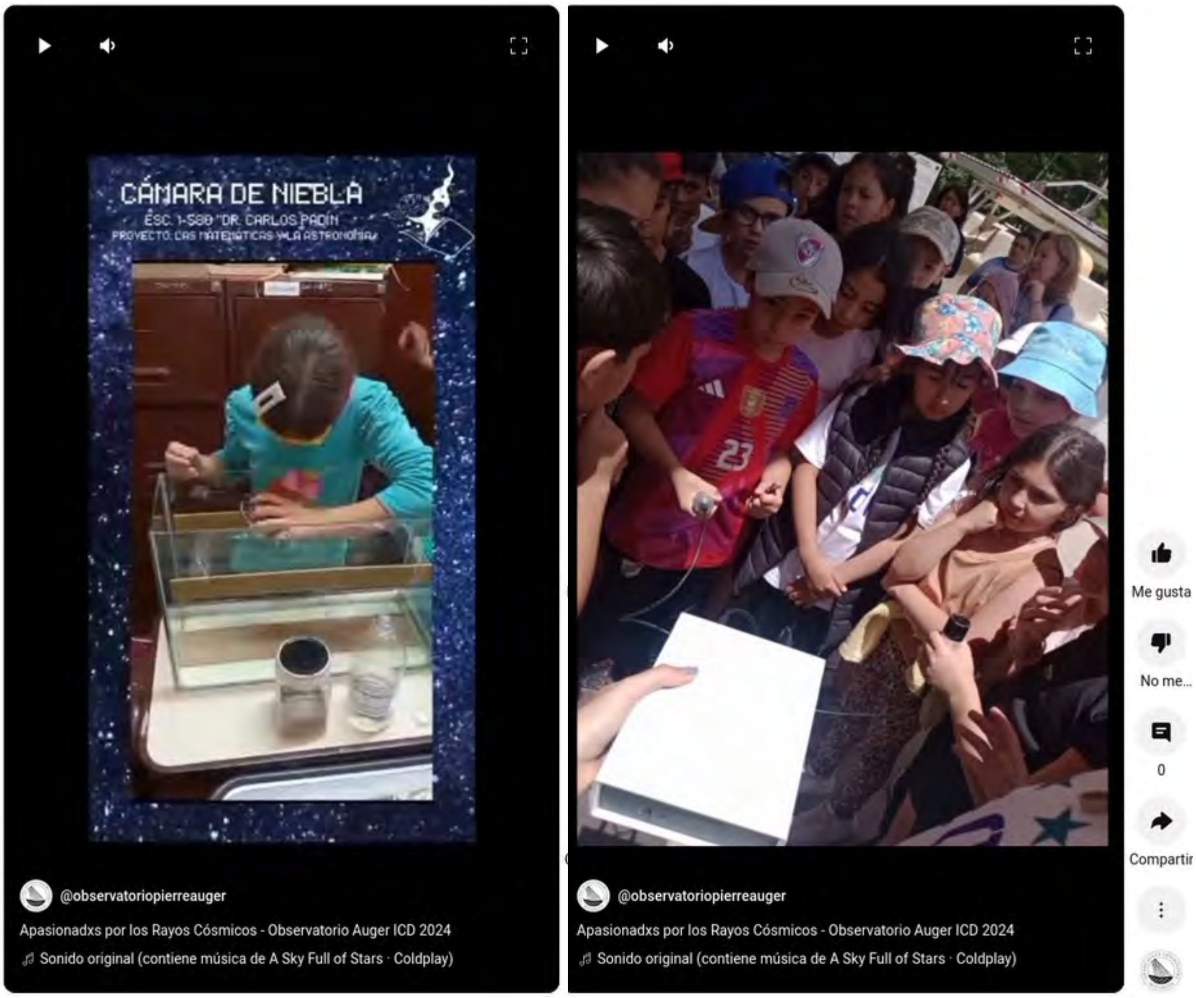
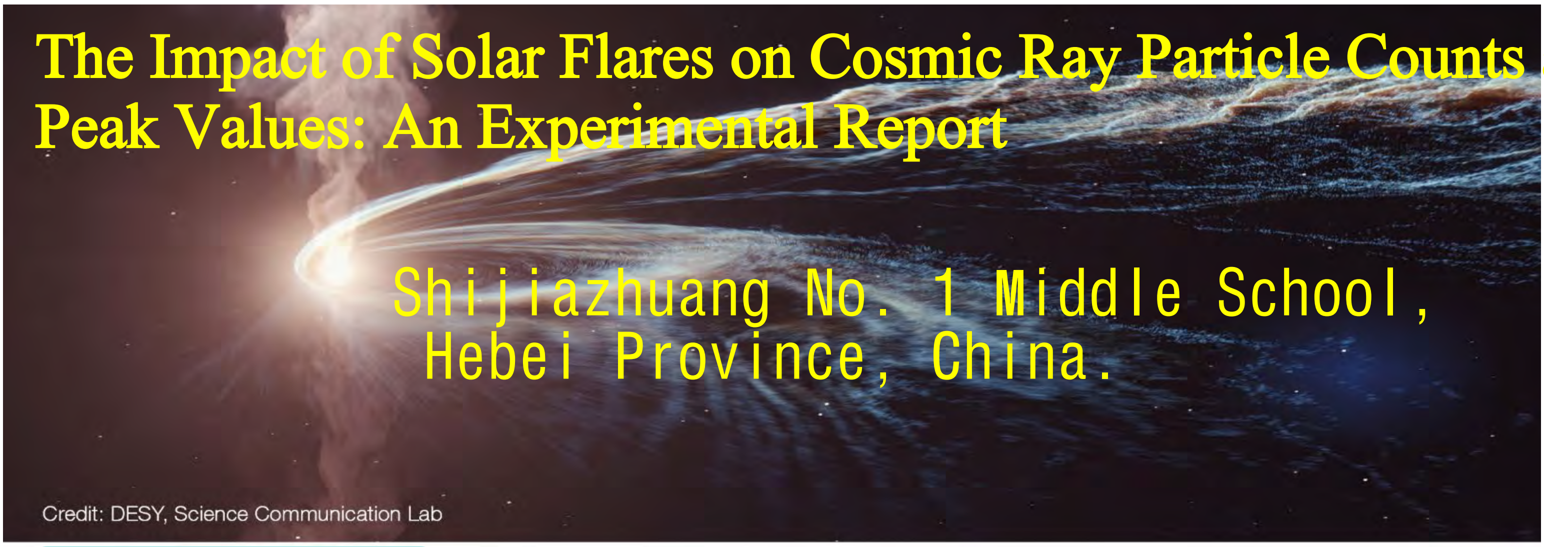


Figure 6. *Apasionados por los Rayos Cósmicos,* youTube short.

CHINA

The Impact of Solar Flares on Cosmic Ray Particle Counts a Peak Values: An Experimental Report



Shijiazhuang No. 1 Middle School, Hebei Province, China.

Credit: DESY, Science Communication Lab

Who are you?

We are from Shijiazhuang No. 1 Middle School, Hebei Province, China. We are members of the Campus cosmic Ray Observation Alliance.

What have you done?

Under the guidance of Professor Shen Changquan and teachers from the Institute of High Energy Physics, Chinese Academy of Sciences , we carried out a study titled "The Impact of Solar Flares on Cosmic Ray Particle Counts and Peak Values."

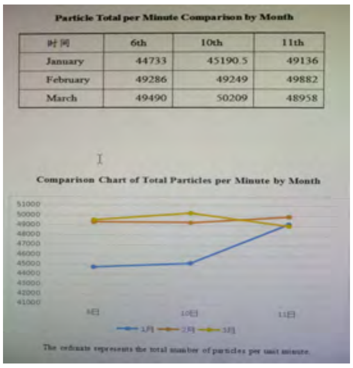
The data we utilized was collected by the cosmic ray detector array at Dongzhimen Middle School in Beijing, China. Located at Dongzhimen Middle School campus (116.439° E, 39.951° N) at an altitude of 46.4 meters, the array is made of 9 detectors arranged in a 3x3 grid with 10-meter spacing, each covering an area of 0.5 square meters.

What did you find out?

Reliable evidences indicate that between Friday, January 6th, 2023, and Wednesday, January 11th, 2023, the sun unleashed three major X-class flares. We documented the total number of particles per minute and peak value totals received by the detectors during these flare events in January. For comparison, we also selected the same time periods in February and March when no solar flares occurred. Below are graphs and plot lines.

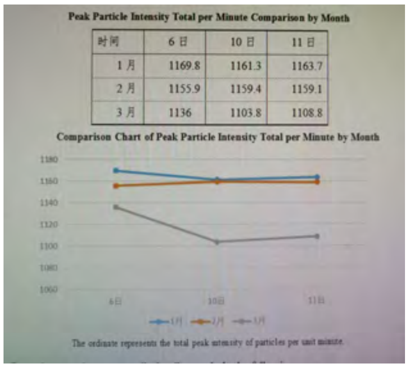
From the data charts, we preliminarily conclude the following:

1. Solar flares did not increase the total number of particles per minute.
2. Solar flares enhanced the peak value of particles per minute.
3. Solar flares led to a decrease in the total number of particles per minute.



Particle Total per Minute Comparison by Month

时间	6th	10th	11th
January	44733	45190.5	49136
February	49286	49249	49882
March	49490	50209	48958



Peak Particle Intensity Total per Minute Comparison by Month

时间	6 日	10 日	11 日
1 月	1169.8	1161.3	1163.7
2 月	1155.9	1159.4	1159.1
3 月	1136	1103.8	1108.8

What's your take-home message?

The energy released by solar flares can affect the high-energy particles of cosmic rays directed towards Earth, causing an energy superposition, thus enhancing the peak value of particles per minute. The total number and peak value of cosmic ray particles per unit minute are affected by solar flares

校园宇宙线观测联盟
Campus Cosmic-ray Observation Collaboration

北京汇文中学
朝阳垂杨柳分校

Measurement of Extensive Air Shower with the CCOC Open Data in 2024

Peking Academy Chaoyang Chuiyangliu Middle School, Beijing, China

Contact: Dr. Jinyan Liu <liujinyan2013nk AT gmail.com>

Credit: DESY, Science Communication Lab

Who are you?

We are from Peking Academy Chaoyang Chuiyangliu Middle School, Beijing, China.

What have you done?

CCOC setups an experiment to measure EAS at Dongzhimen Middle School in Beijing, China. The CCOC Open Data is accessible with all members.

Two types of open data are provided for us to analyze:

- Stat of detectors: amplitudes of signals and rates in each minute.
- EAS Events: amplitudes and time of detectors and the direction of events.

We have following studies with the CCOC Open Data:

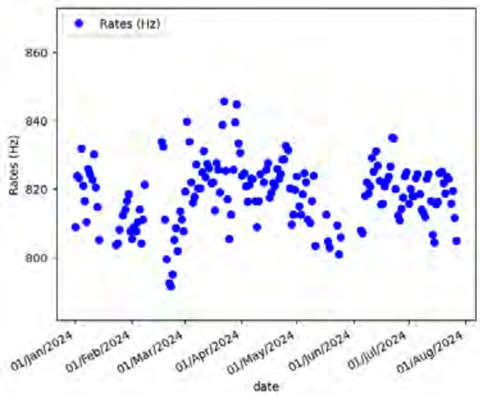
- Data quality monitoring of the open data.
- Measurement of intensity for extensive air showers.

We use VS Code, Jupyter Notebook and Pandas to analysis the data.

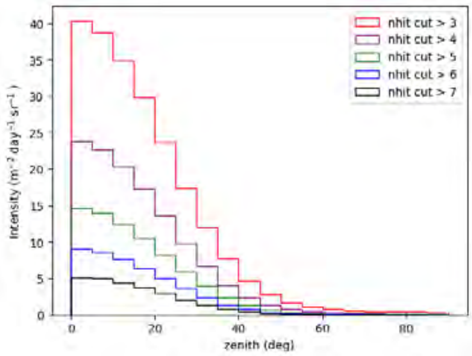
	iday	imin	q0	q1	q2	q3	q4	q5	q6	q7	q8	cnt0	cnt1	cnt2	cnt3	cnt4	cnt5	cnt6	cnt7	cnt8
0	2191	0	157.3	106.2	121.5	132.0	134.9	116.9	119.6	131.3	126.2	4897	5213	5210	5438	5273	5262	5264	5357	5318
1	2191	1	155.8	109.1	121.9	132.3	137.7	116.6	119.6	131.2	124.9	5107	5361	5392	5366	5409	5370	5428	5508	5529
2	2191	2	160.2	109.0	121.3	131.8	138.6	117.6	119.6	132.9	125.5	5037	5286	5423	5380	5344	5331	5316	5405	5434
3	2191	3	155.8	105.9	121.6	130.6	136.4	116.3	118.3	130.8	124.9	5107	5349	5374	5402	5361	5353	5343	5541	5417
4	2191	4	157.7	108.8	121.1	131.6	137.1	116.6	119.2	131.1	125.6	4961	5315	5374	5443	5266	5358	5309	5457	5370

What did you find out?

This year, the detector has been under maintenance since August. Therefore, we are using only the data from the first seven months. The total rates are about 820 Hz.



The EAS intensity is the descending function of the zenith angle. This is due to the depth of atmosphere increasing when zenith angle increases. The detectable energy increases with the increase of nhit cut.



Measurement of intensity for extensive air shower depending on zenith angle near sea level

Beijing Dongzhimen High School, China

Teachers and students in our team

We are from Beijing Dongzhimen High School.





Ying Zhang , Jiayin Zhu , Chong Jin , Shu Wang

Equipment

There's a detectors array on the roof of our school.It consists of 9 scintillation detectors, spaced 10m apart as a 3×3 matrix, each detector have a sensitive area of $0.5m^2$.

It is located at: latitude 39.9°N, longitude 116°E, altitude 46.4m above sea level.

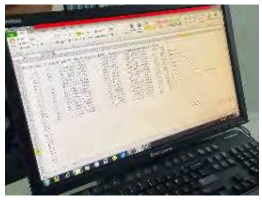
Data Analysis

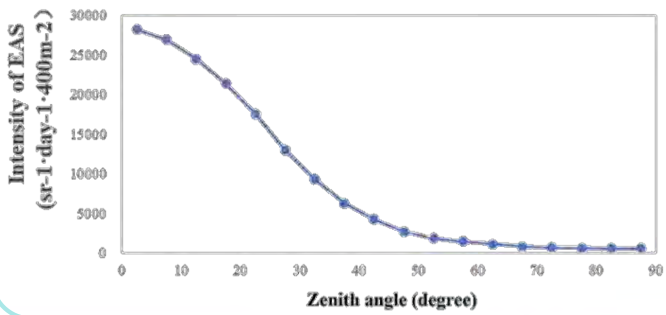
We have done some procedures to reconstruct the measured tracks of EAS, we reconstruct only the EAS event in $400m^2$ covered by our array with coincident fold at least 3.

We analyzed the direction of each EAS event during 0:00 on Nov. 11th to 24:00 on Nov. 18th.

Result

Mean of zenith angle (degree)	Intensity of EAS (sr^{-1} • day^{-1} • $400m^{-2}$)
2.5	28222
7.5	26925
12.5	24469
17.5	21357
22.5	17575
27.5	13000
32.5	9298
37.5	6235
42.5	4204
47.5	2692
52.5	1842
57.5	1450
62.5	1092
67.5	820
72.5	682
77.5	592
82.5	555
87.5	581





Beyond National Borders: Xinghua Middle School Students' Participation in the 13th International Cosmic Day Exchange Activity

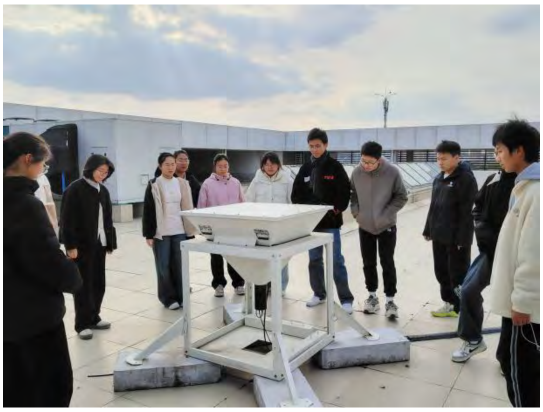
Jiangsu Xinghua middle School, China

On November 26, 2024, the 13th International Cosmic Day (ICD) exchange activity concluded successfully! Fifteen student representatives from the "Digital Intelligence Innovation" science and technology club of Xinghua Middle School in Jiangsu Province took part in this event. Since 2021, our school has been organizing students to engage in this research and exchange for four consecutive years.

The International Cosmic Day is an initiative jointly launched by the German Electron Synchrotron Institute, the International Particle Physics Outreach Group (IPPOG), along with numerous national networks and partners. Serving as a significant international science popularization event, it not only offers a platform for people to gain an understanding of cosmic rays but also facilitates exchanges and cooperation among countries regarding cosmic ray observation and research. This year, young people from various schools and scientific research institutions in 24 countries came together. Under the support and guidance of scientists and teachers, they delved into the particles from the universe through joint video conferences, carried out investigations on them, and shared the newly acquired knowledge.

The student representatives of our school had interactive discussions in English throughout the event with cosmic ray research teams from three different countries within the same group. Moreover, they introduced and demonstrated the "Portable Cosmic Ray Muon Flux Intensity Detection Device Based on Coincidence Event Technology", which was designed and fabricated by them during club activities and after-school hours. Their outstanding performance in the activity not only showcased the scientific research capabilities and innovative spirit of Chinese middle school students but also strengthened the friendship and cooperation with foreign researchers.

During the R&D process, the students encountered multiple technical problems and implementation difficulties. However, through the combined efforts and continuous exploration of the team, they eventually managed to develop this portable cosmic ray muon flux intensity detection and analysis platform, which features stable performance and relatively comprehensive functions. The students also came to realize that scientific and technological innovation is a process of continuous iteration and optimization. In their future studies, they will continue to enhance the performance and functions of the detector, improve the accuracy and stability of the detection signals, and attract more peers to join in the research on cosmic rays.This research has received assistance and support from the Cosmic Ray Observation Alliance established by the Institute of High Energy Physics of the Chinese Academy of Sciences.



This International Cosmic Day exchange activity proved to be a successful international science popularization gathering. Through sharing research results, exchanging scientific research methods and experiences, as well as holding science popularization lectures and exhibitions, it has not only driven the progress and development of international cosmic ray research but also contributed to the prosperity of science popularization and education. It is believed that in the days to come, the International Cosmic Day activity will continue to provide a platform for science enthusiasts and researchers worldwide to exchange and cooperate, jointly accelerating our pace of exploring the unknown world.

Variation of the number of cosmic ray EAS with zenith angle at different air pressures

Jiangyan High School of Jiangsu Province,China

Credit: DESY, Science Communication Lab

Who are you?

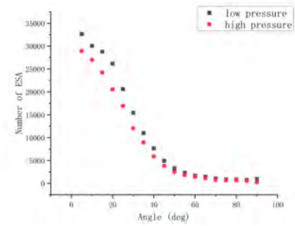
We are from Jiangyan High School in Jiangsu Province, China. Our cosmic ray club currently has 15 students and 3 teachers.

What have you done?

We take the cosmic ray data from Dongzhimen Middle School for the two T=7 days cycles from 4 July 2023 to 10 July 2023 UTC and from 17 December 2023 to 23 December 2023 as the object of study, and fit to get the direction of the EAS instances with no less than 3 detectors conforming to it, and calculate the number of clustered shots N in the range of zenith angle from 0 to 90 degrees and in the range of intervals of 5 degrees, by applying the statistical function of the EXCEL software. .

In order to understand whether the air pressure has an effect on the number of cosmic ray EAS, we select the data of the detector in the time period from 4 July to 10 July 2023 as the low-pressure data, and select the data of the detector in the time period from 17 December to 23 December 2023 as the high-pressure data, and derive the rule of change of the number of cosmic ray EAS with the zenith angle under different air pressures according to the same data processing method as mentioned above.Whether cosmic ray EAS is correlated with air pressure is analysed by comparing the number of EAS in different zenith angle intervals at different air pressures.

What did you find out?



The figure shows that the number of cosmic ray EAS decreases with increasing zenith angle, and after the zenith angle increases to a certain value, the number of EAS decreases significantly and flattens out with zenith angle. and it shows a clear difference in the number of high-pressure and low-pressure cosmic ray EASs with zenith angle. Terrestrial cosmic ray detection can be affected by meteorological conditions, especially changes in air pressure. Fluctuations in air pressure lead to changes in atmospheric density and isobaric surface height, which in turn affects the production layer and absorption of secondary particles, ultimately leading to changes in the number of cosmic rays reaching the ground. Under low-pressure conditions, a relatively high number ofcosmic rays are received; under high- pressure conditions, a relatively low number of cosmic rays are received.

What's your take-home message?

Under low-pressure conditions, a relatively high number ofcosmic rays are received; under high- pressure conditions, a relatively low number of cosmic rays are received.

Exploring the energy spectrum of cosmic rays by a EJ-200 scintillator @Great Bay university, CHINA

Cosmic ray detection team
Jianqi Chen(陈建琪),Shirong Lin(林仕容), Yan Feng(冯焱),Cong Chen(陈聪),Shengda Tang(唐生达),**Yongce Gong(贡庸策)**

Credit: DESY, Science Communication Lab

Abstract

We employed EJ-200 scintillator coupled with a PMT and a DT5751 digitizer to detect cosmic rays. Meanwhile, FLUKA was utilized to simulate the cosmic ray flux arriving at our location, along with the corresponding energy deposition in the EJ-200 scintillator and the energy distribution of the cosmic rays.

Experimental setup and process

Fig.1 EJ-200 +PMT(EJ-200 20×20×4 cm)

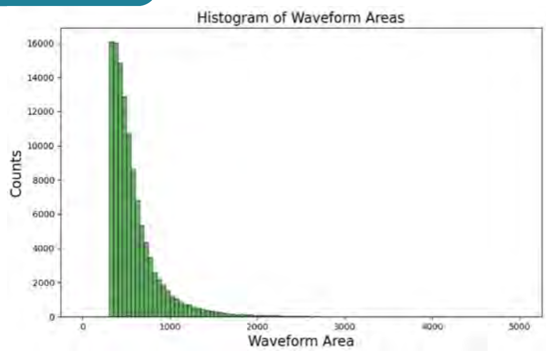


Fig.2 The waveform area versus count distribution of cosmic ray produced by the experiment.

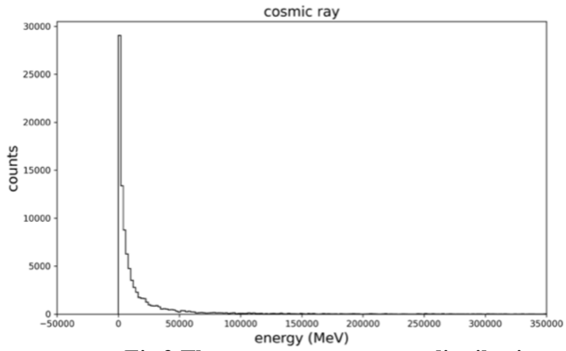


Fig.3 The energy versus count distribution of cosmic ray produced by the FLUKA .

Fgure 1 illustrates the EJ-200 scintillator coupled with a PMT. The PMT was connected to the EJ-200 scintillator and placed inside a black box. The PMT was then linked to the DT5751 digitizer, and signal data was recorded over a duration of 2 hours. During data processing, the baseline was set to 610 to obtain the waveform area distribution of the cosmic ray signals. Additionally, we simulated terrestrial cosmic ray interactions using FLUKA by positioning a cosmic ray source above the EJ-200 scintillator and recording the energy deposition in the scintillator. Finally, we obtained the energy-versus-count distribution of cosmic rays from the FLUKA simulation and compared it with the waveform area-versus-count distribution of cosmic rays from the experimental data.

Analysis and Result

The simulated cosmic ray energy distribution closely matches the experimental data; For a scintillator with dimensions 20 cm × 20 cm × 4 cm (volume: 1600 cm^3), the energy deposition along the 4 cm thickness is 3.62 keV/cm^3, with an average error of 26.8%.

Variation of the number of cosmic ray EAS with zenith angle at different air pressures

I. Background to the issue

The three fundamental questions of cosmic rays: origin, acceleration and propagation, which are still not clearly settled, are one of the major scientific problems at the frontiers of physics in the new century and are of great interest to physicists. Cosmic ray research using the cosmic ray detector array in the school gives us the opportunity to participate in a real-life cutting-edge scientific experiment and receive training in scientific research.

This time we are interested in the spatial distribution of cosmic rays within an Earth day, i.e. the dependence of the number of sea level wide atmospheric clusters on the zenith angle, and the other one is in the air pressure, comparing the number of atmospheric clusters at the zenith angle at different air pressures, and trying to analyse the reasons for this.

II. Data sources

This time we used data collected by detectors at Dongzhimen Middle School in Beijing for our analysis. The following is a brief description of the Dongzhimen Middle School's device and data. The Wide Extended Atmospheric Cluster Shot (abbreviated as EAS) array they used is composed of nine scintillation detectors distributed in a 3 × 3 matrix, each with a sensitive area of 0.5 m2 and a spacing of 10 m from each other. It is located at: latitude = 39 degrees 56 minutes North, longitude = 116 degrees 25 minutes East, and 46.4 metres above sea level. Through electronics, the signals from the detector are digitised, and then a computer continuously collects data and controls all the equipment online. Whenever a cosmic ray charged particle passes through the detector, the GPS time of its passage, the signal amplitude and the fire detector number are recorded and a data file is automatically generated.

II. Data analysis

We take the cosmic ray data from Dongzhimen Middle School for the two T=7 days cycles from 4 July 2023 to 10 July 2023 UTC and from 17 December 2023 to 23 December 2023 as the object of study, and fit to get the direction of the EAS instances with no less than 3 detectors conforming to it, and calculate the number of clustered shots N in the range of zenith angle from 0 to 90 degrees and in the range of intervals of 5 degrees, by applying the statistical function of the EXCEL software. degree zenith angle range interval, the number of clustershots Ni ..Its standard error is $\sigma_N = N^{\frac{1}{2}}$ In the zenith angle θ_1~θ_2 interval range, the corresponding stereo angle $\Omega_i = 2\pi\ (\cos\theta_1 - \cos\theta_2)$ can be found. It is known that the ground detector at Dongzhimen Middle School in Beijing covers an area of S=400m^2, and considering that the cosmic rays are detected by the ground detector at an inclined angle θ, the area of vertical incidence of the cosmic rays within the zenith angle θ_1~θ_2 can be found to be $S \cdot \cos\overline{\theta}_i \left(其中\overline{\theta}_i = \frac{\theta_1 + \theta_2}{2}\right)$.

Based on the above analyses it can be derived that the average number of EAS per zenith angle interval range, per unit of stereo angle, per unit of area and per unit of time is $I_i = \dfrac{N_i}{t \cdot S\cos\overline{\theta}_i \cdot \Omega_i}$. Its standard error is $\sigma_I = \dfrac{\sigma_N}{t \cdot S\cos\overline{\theta}_i \cdot \Omega_i}$.

In order to understand whether the air pressure has an effect on the number of cosmic ray EAS, we select the data of the detector in the time period from 4 July to 10 July 2023 as the low-pressure data, and select the data of the detector in the time period from 17 December to 23 December 2023 as the high-pressure data, and derive the rule of change of the number of cosmic rayEAS with the zenith angle under different air pressures according to the same data processing method as mentioned above.

dates	Average daily atmospheric pressure (hectopascals)
2023.7.4	997
2023.7.5	992
2023.7.6	991
2023.7.7	993
2023.7.8	997
2023.7.9	998
2023.7.10	998
2023.12.17	1038
2023.12.18	1035
2023.12.19	1037
2023.12.20	1041
2023.12.21	1042
2023.12.22	1041
2023.12.23	1037

Whether cosmic ray EAS is correlated with air pressure is analysed by comparing the number of EAS in different zenith angle intervals at different air pressures.

IV. Experimental results

Table 1 below shows the experimental data recording and processing forms, and Fig. 1 shows the comparison of cosmic ray counts EAS at different zenith angles at different air pressures for high and low

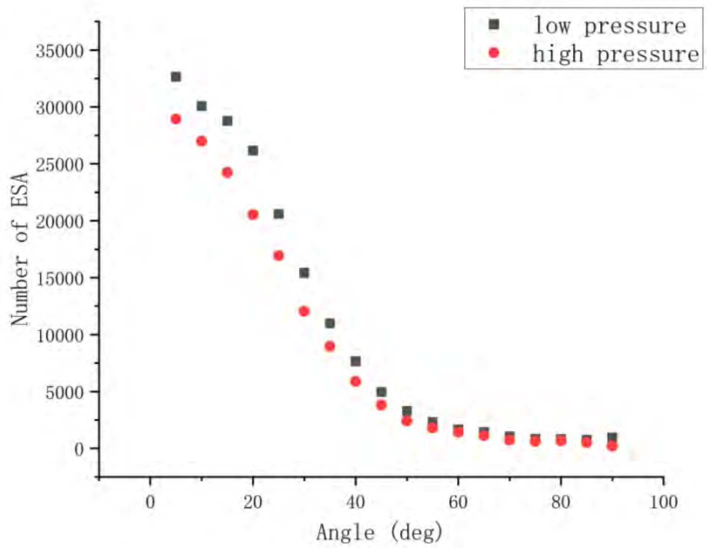


Fig. 1 Variation of cosmic ray number EAS with zenith angle at different air pressures

V. Discussion

1. Variation of the number of cosmic rays EAS with zenith angle

The image in Fig. 1 shows that the number of cosmic ray EAS decreases with increasing zenith angle, and after the zenith angle increases to a certain value, the number of EAS decreases significantly and flattens out with zenith angle.

We know that cosmic rays enter the Earth's atmosphere and interact with atmospheric molecules in nuclear and electromagnetic ways, producing extended atmospheric clustering (EAS). As the density of the atmosphere increases, there are more and more secondary particles, and the number of secondary particles increases quickly. Subsequently, due to the absorption of particles by the atmosphere, the number gradually decreases again with the increase of atmospheric density, so that an extreme value of the particle number occurs at a certain altitude. When detecting cosmic rays on the ground, ground-based detector arrays can detect EAS only if the density of detectable particles reaches a certain value, so the threshold energy at which ground-based arrays can detect EAS increases with decreasing altitude (i.e., increasing atmospheric depth).

As the zenith angle increases, the atmospheric depth increases. Therefore, the threshold energy E at which a ground- based array can detect EAS increases with zenith angle. Since the number of cosmic ray integrals is proportional to E^{-2} ,the number of cosmic ray EAS integrals decreases with increasing zenith angle. The results of the data analysis are in agreement with theoretical predictions.

2. Comparison of the number of cosmic ray EAS at high and low pressure

The image in figure 1 shows a clear difference in the number of high-pressure and low-pressure cosmic ray EASs with zenith angle. Terrestrial cosmic ray detection can be affected by meteorological conditions, especially changes in air pressure. Fluctuations in air pressure lead to changes in atmospheric density and isobaric surface height, which in turn affects the production layer and absorption of secondary particles, ultimately leading to changes in the number of cosmic rays reaching the ground. Under low-pressure conditions, a relatively high number ofcosmic rays are received; under high- pressure conditions, a relatively low number of cosmic rays are received.

Prediction of Near-Earth-Orbit Proton Flux Using a LSTM-Transforer Model

Chongqing Yucai Secondary School, Chin

Credit: DESY, Science Communication Lab

Who are you?

We are a group of high school students passionate in cosmology. We are specifically interested in exploring the application of artificial intelligence in predicting cosmic activities.

What have you done?

We analyzed a dataset spanning from June 2011 to December 2019, containing historical records of solar activity and proton flux levels. This included factors such as solar flare intensity, CME speed, sunspot number, and solar wind parameters. Through data preprocessing and feature selection, we identified correlations between solar activities and proton flux, finding a slight inverse relationship between sunspot numbers and proton flux intensity. Finally, we successfully used a LSTM-Transformer model to predict precise recent near-earth proton flux. We believe our model could contribute to predictions of more intricate cosmic activities.

What did you find out?

We discovered that there is a complex relationship between solar activity and proton flux, which cannot be fully explained through traditional methods. Specifically, there is an inverse relationship between proton rigidity and flux intensity, where higher rigidity corresponds to lower proton flux. Additionally, our hybrid LSTM-Transformer model showed significant improvements in predicting proton flux intensity, achieving an accuracy of 78% on the test set.

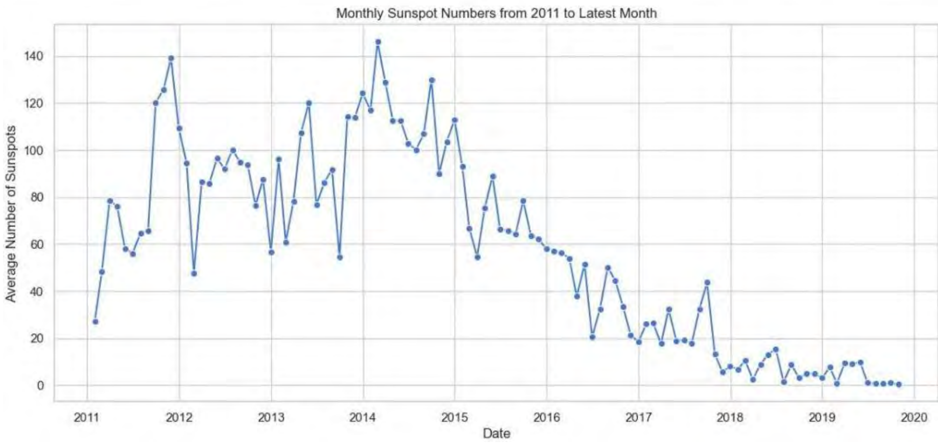
What's your take-home message?

Coupled AI models are excellent predictors of intricate physical relationships

Prediction of Near-Earth-Orbit Proton Flux Using a LSTM-Transforer Model

1. Problem Statement (Background)

Our research began with a curious discovery: when learning about solar flares, which consists mostly of protons, we assumed that there would be an increased number of protons reaching the Earth. However, when doing further research, we discovered a surprising strongly inverse relationship between the two. Theories suggest that this is due to the intricate mechanisms of magnetic field interactions, which cause a increase in geomagnetic stiffness and a shielding effect for protons coming from the sun. We attempted to find qualitative analysis for such phenomena but only found partial explanations pointing to the "chaotic" nature of their combined effect. On one hand, predicting solar activity intensities is challenging due to their complex, chaotic nature, limited observational data, and the intricate dependencies of magnetic and plasma dynamics; on the other hand, high levels of proton flux can post significant changes to satellites, astronauts and communications systems.



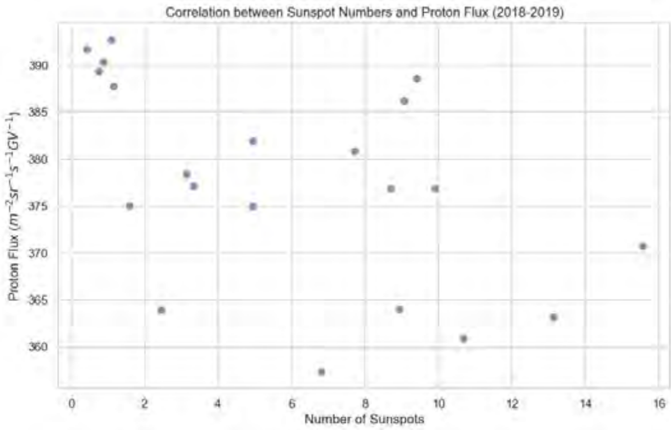
The inverse relationship between sunspots and proton flux

Though intricate, we do not believe that a more precise prediction of solar activities and its consequent effect on cosmic rays on Earth are unachievable. Being able to more accurately predict those interrelated activities using advanced data analysis method would help us get a glimpse into the intricate mechanisms of solar activities and it's effect on near-Earth environments. Traditional forecasting methods like ARIMA and SARIMA capture trends but fail to model the non-linear dependencies and long-term relationships in complex time-series data. The aim of our study was to develop an accurate, robust, and data-driven model for proton flux prediction. By leveraging advanced deep learning techniques, we proposed a hybrid model combining LSTM and Transformer to address these challenges.

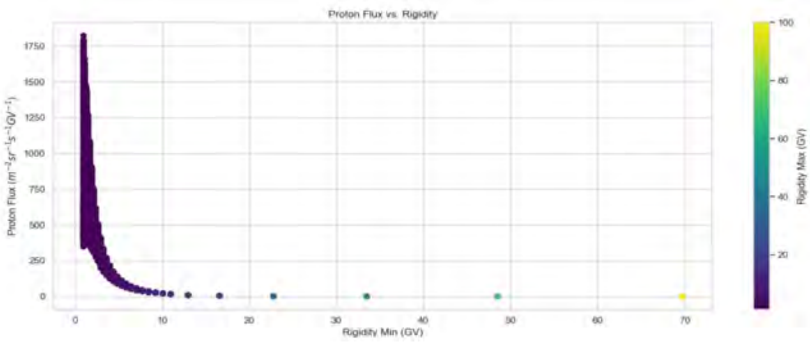
2. Data Processing

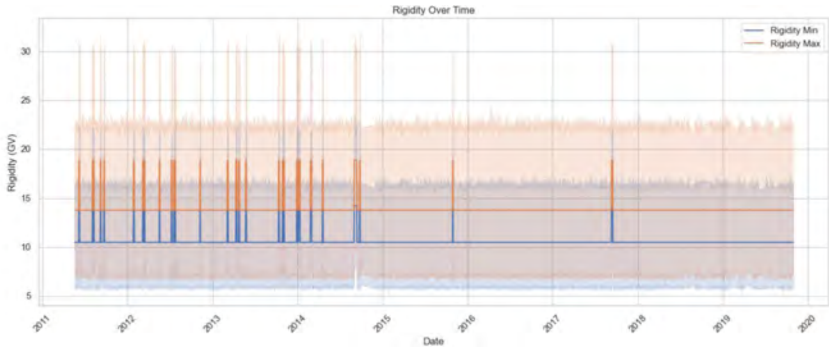
The dataset consists of historical records of solar activity and proton flux levels, sourced from satellite measurements and solar observatories. Key features include solar flare intensity, CME speed, sunspot number, and solar wind parameters such as velocity, density, and magnetic field strength. The proton flux data is provided as time-series measurements at multiple energy levels, which are recorded by the AMS02 detector from June 2011 to December 2019 on a daily basis. Data preprocessing involved handling missing values, removing outliers (e.g., sensor noise or erroneous spikes), and normalizing variables to ensure consistency. Exploratory analysis revealed correlations between solar activities and proton flux, with spikes in proton levels often following high-intensity solar flares or CMEs. Seasonal and periodic trends linked to the solar cycle were also identified, providing critical insights for feature selection and model input design. The cleaned and normalized dataset was split into training (70%), validation (10%), and testing (20%) subsets to ensure robust evaluation.

We did find a slightly inverse correlation (Pearson coefficient = -0.519, p-value = 0.0158) between sunspot numbers and proton flux intensity, which is enough to validate an existing correlation but suggests there might exist influencing factors other than sunspots.

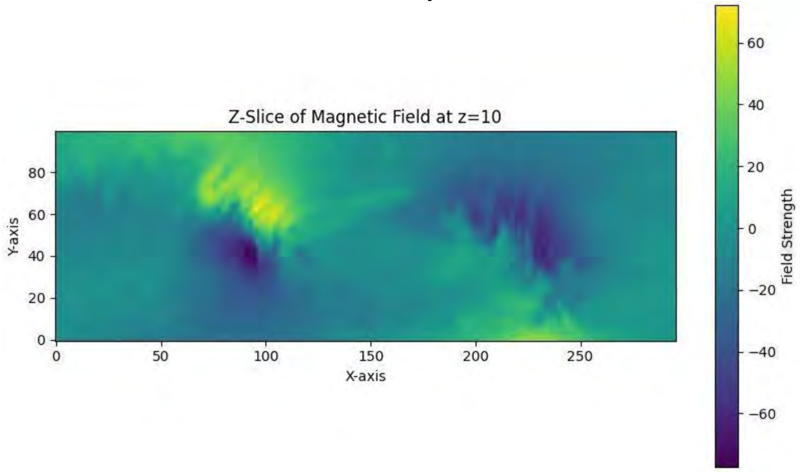


We investigated those factors from several aspects: the change in the protons' characteristics, the change in geomagnetic field (stiffness), and the change in solar magnetic field during solar activities. Note that the relationships are not entirely linear, which cannot be explained on a qualitative basis. Their tendencies will be recorded and encoded in the LSTM model an decoded in the Transformer model.





There is a clear inverse relationship between proton rigidity and flux intensity, with higher rigidity corresponding to lower proton flux, suggesting that only protons with a higher energy will could be captured during more intense solar activity.



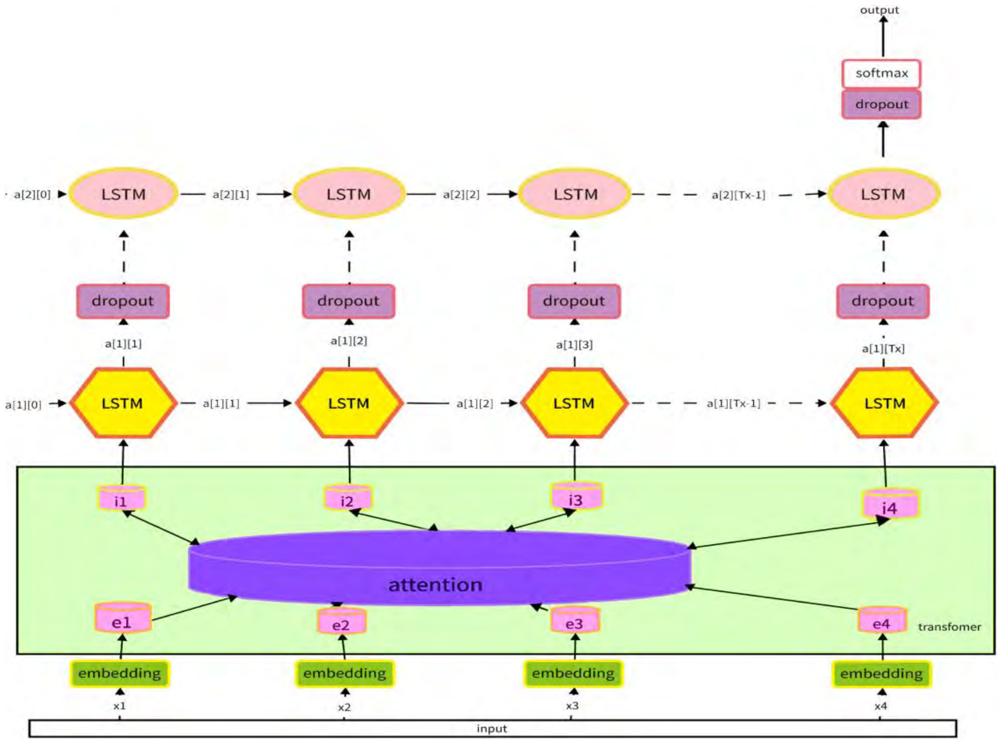
This is a slice of solar magnetic field. We chose those slices that are facing the earth when detected, whose protons released are most influential to those detected by the AMS02 detector.

We also filterized several factors that might cause measurement errors, including the time taken for the protons to travel to earth and the high-energy protons coming from energetic cosmic events other than solar activities.

3 Model Building

3.1Model Schematic

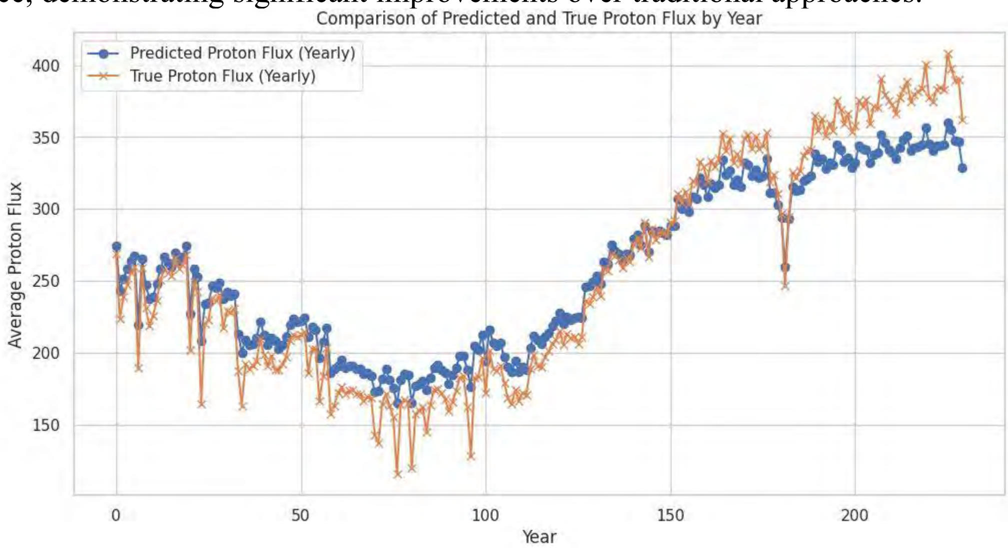
A hybrid LSTM-Transformer model was designed to combine the strengths of both architectures. LSTM layers served as the encoder, capturing long-term dependencies in time-series data, while Transformer layers acted as the decoder, leveraging self-attention to model complex interactions and global dependencies. The Transformer incorporated multi-head attention and position encoding to process sequence relationships effectively. To integrate both components, hidden states from the LSTM encoder were passed to the Transformer decoder. A feedforward layer generated predictions from the combined representations. The model used MSE as its loss function and Adam optimizer for parameter updates, balancing efficiency and convergence speed.



Schematic diagram of our hybrid model

3.2Model Training and Adjustments

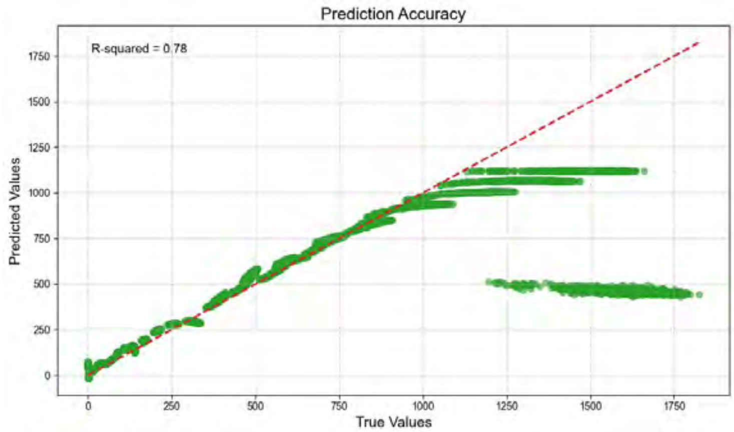
The hybrid model was trained with a batch size of 64 and learning rate of 0.001. Hyperparameters like the number of LSTM neurons (128), Transformer attention heads (8), and embedding dimensions (64) were optimized using grid search. Training involved multiple epochs to minimize loss on the validation set while preventing overfitting. Metrics such as R^2, MAE, RMSE, and MAPE guided evaluation. Systematic adjustments to dropout rates and layer configurations further improved model robustness. Despite computational complexity, the model achieved stable convergence, demonstrating significant improvements over traditional approaches.

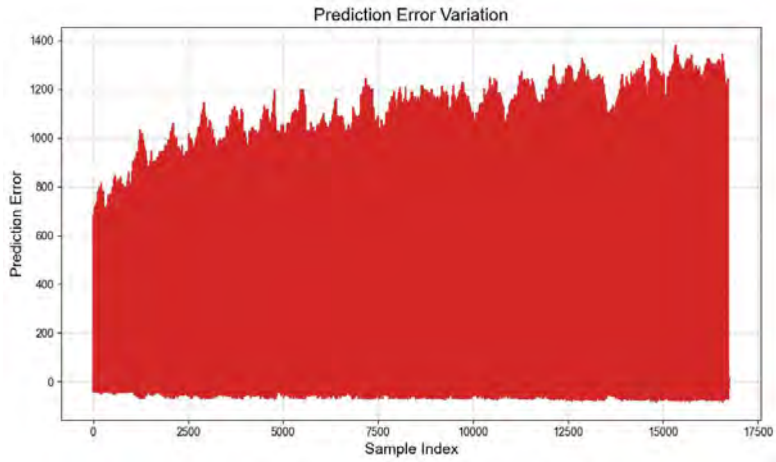



```
100%|██████████| 262/262 [00:31<00:00,  8.20it/s]
R2: 0.7781902551651001
MAE: 84.42505
RMSE: 225.83063
MAPE: 29.23803
Accuracy: 0.7781902551651001
```

4. Error Analysis

The model achieved high accuracy, with an accuracy of 78% on the test set. Error analysis revealed that predictions closely followed observed values, even during significant fluctuations. Scatterplots showed most data points tightly aligned along the ideal prediction line, confirming the model’s precision. While extreme values caused slightly higher MAPE due to small denominators, errors remained minimal and centered near zero. This analysis highlights the model’s reliability for operational water level forecasting while identifying edge cases for further refinement.

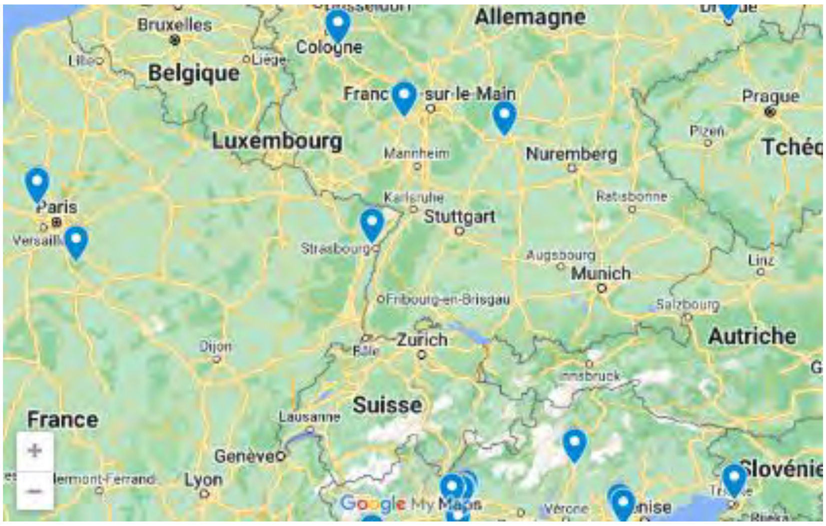




FRANCE

ICD 2024 - Measurements at the Marcel RUDLOFF high school -Strasbourg - FRANCE

GPS coordinates:
Latitude: 48.587
Longitude: 7.697
Altitude: 150 m

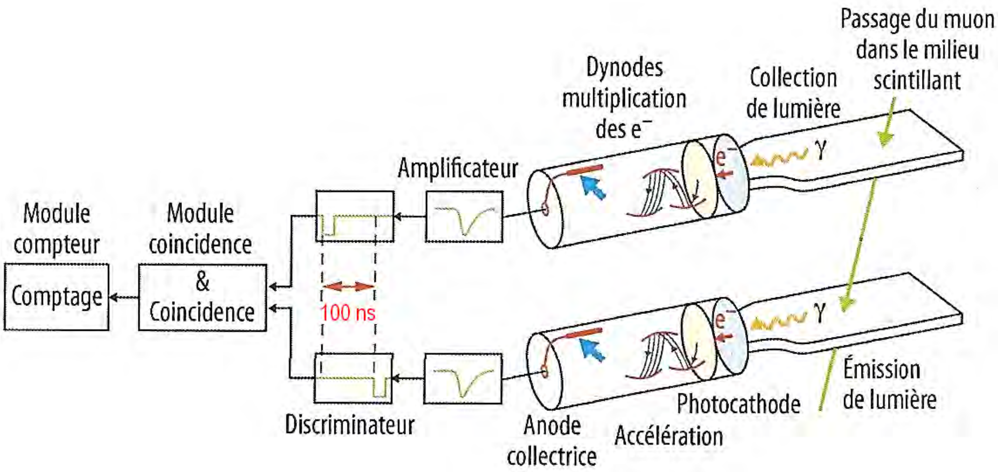


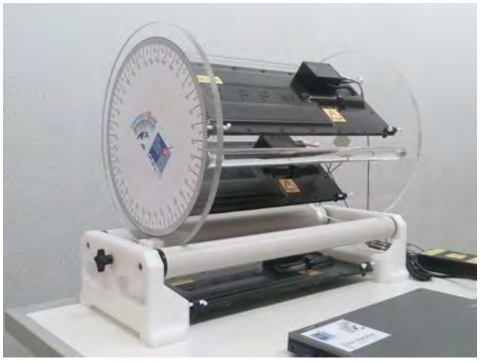
For the ICD 2024, a group of ten students from the Sciences + class carried out measurements on two detectors.

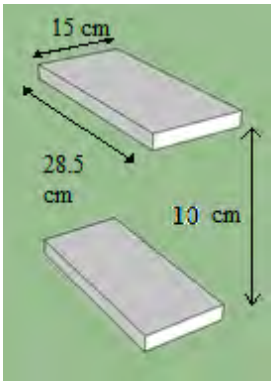
The “Cosmic Wheel” from the “Sciences at School” operation from the CCPM in Marseille and the “Cosmix” case from the CENBG in Bordeaux.

The first detector is composed of two scintillators 10 cm apart. The passage of a muon produces a photon which, through an electrical effect, induces an electron. This is multiplied by 10^6 in the photo multiplier (PM). The principle diagram is given in figure 1.

Document 1

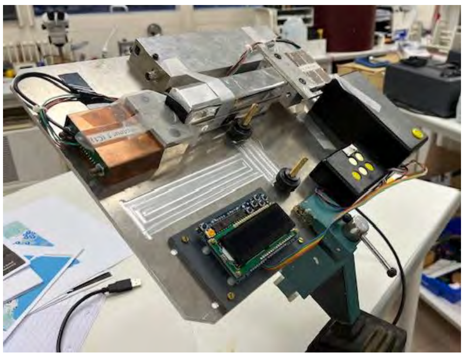




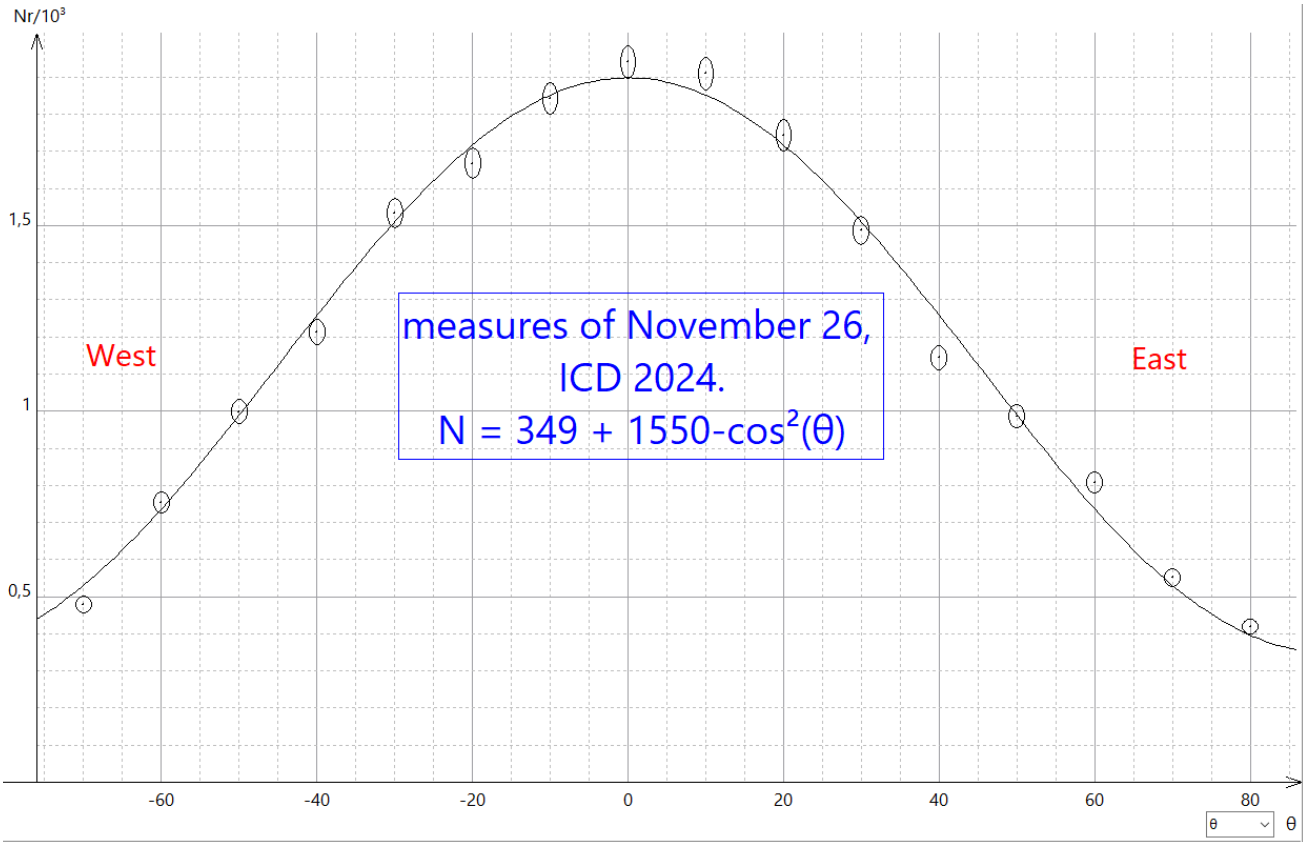


Another group uses the cosmix device from the Bordeaux research center in France. See doc.2. Two bars used in coincidence were used for ground tests of the calorimeter which is part of a "Large Area Space telescope". Each detector includes a scintillator and photodiode.

Document 2.



We present the results (doc.3) obtained with the East-West oriented wheel.
The uncertainty in the angle is $\pm 1°$. The uncertainty on the number N of muons and $\sqrt{N}$.
Modeling by $\cos^2\theta$ is quite satisfactory.

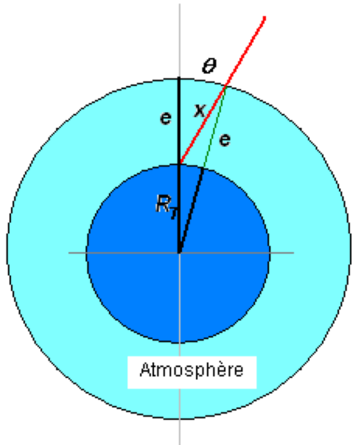


At 0°, the number of muons detected during 10 minutes is 1941. Which gives an average of 3.23 muons per second. Furthermore, a study of N as a function of the distance d between the two scintillators allowed us to find a number of 47.3 muons per second if d tends to zero (two superimposed scintillators). We arrive at a flux of 0.7 muons per second per square centimeter at the measurement location. Which is close to 1 muon per second per square centimeter without the obstacles.

We calculated the additional distance traveled by muons arriving at a non-zero θ angle (doc. 4)

Indeed, based on the diagram in the figure below, it appears that
$(R_T + e)^2 = R_T^2 + x^2 - 2xR_T.\cos(\pi - \theta)$
by solving the equation: $x^2 + 2xR_T.\cos(\theta) - e^2 - 2eR_T = 0$.

The positive solution is : $x = \sqrt{R_T^2 \cos^2\theta + e^2 + 2eR_T} - R_T.\cos\theta$.



Document 4

As an example, for an inclination of 30° we obtain
x = 35 km for an atmosphere thickness of 30 km (if we assume that the muons are produced at 30 km altitude). In the end, by rotating our set by 30° we "insert" an additional layer of air of 5 km.

We studied the parameters that change N from 1941 ± 44 muons at $\theta = 0^\circ$ to the number 1488 ± 39 muons at $\theta = 30^\circ$.

- The decay of muons over 5 km.
- Energy lost by muons in the air
- Expansion of duration

We point out to the students the difficulty of solving the problem exactly because the muons do not arrive with the same speed! Thus, the probability of disintegration varies between 10% and 30%. $(p(d) = 1 - e^{\frac{-5}{\gamma.L_0}})$.

Thus, the number of muons will go from 1941 to $0.7 \times 1941 \leq$ N $\leq 0.9 \times 1941$. That is:**1359 ≤ N ≤1750**.
We find at 30° **N = 1488** after an additional 5 km journey. This is therefore a satisfactory result.

LES MUONS DANS LE SUD DE LA FRANCE

LYCEE EINSTEIN Bagnols Sur Cèze, FRANCE

Credit: DESY, Science Communication Lab

Who are you?

We are 33 students 15 years old, living in the south of France and in 1st year of secondary school. We worked in groups by 4.

What have you done?

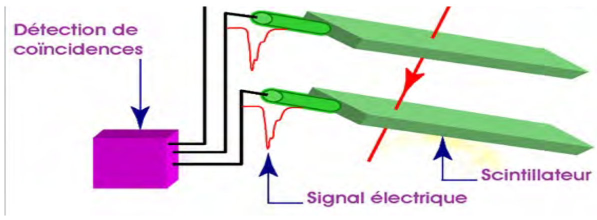
We understood the origin of muons by discovering an exhibition entitled 'The mystery of cosmic rays'.

Then we used the cosmodetector loaned by the 'sciences à l'école' organization, to count the muons. We set the high voltages on the two plates at around 1000V and the threshold voltage at 15mV.

Each group launched a count every 20s during 10 minutes (30 counts per group).

What did you find out?

We used the number of muons coinciding on the two plates.



Average number of muons : 33

Standard deviation : 5,7

Surface area of the scintillator : 0,0432 m^2

Number of muons per second per square metre: 38

The uncertainties associated with the measurement of surface area and time are neglected.

Uncertainty : 2 muons

What's your take-home message?

We can detect invisible particles that fall on us from space : muons

Angular distribution of muons arrival direction

Lycée Vauban, Brest, France

Credit: DESY, Science Communication Lab

Who are you?

A team of 23 students preparing for H.N.D. in network computing and cybersecurity and their teachers, from Lycée Vauban, a high school in Brest, a port city at the western end of mainland France.

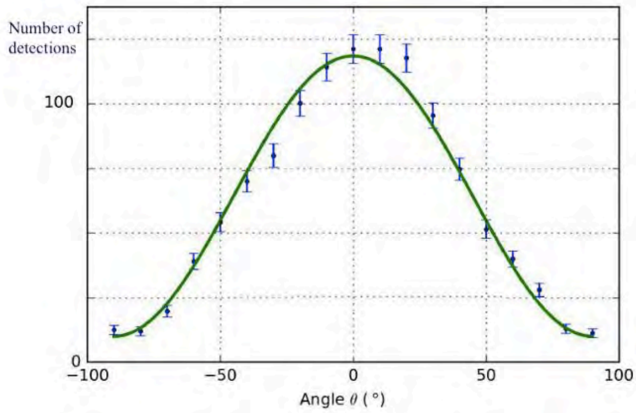
What have you done?

Using a cosmodetector lent by the "Sciences at school" facility in order to promote scientific culture, we conducted a set of experiments to determine the characteristics of cosmic muons.

During the ICD, we participate to a call and exchange with different universities and labs.
We also took part in the online quiz and the selfie contest.

What did you find out?

In the classroom, we studied during 2h the angular distribution of muons arrival direction.



The number of muons detected as a function of the zenith angle depends on various factors: the length of time they travel through the atmosphere, the decay of the muons, the initial energy spectrum of the muons…

What's your take-home message?

We learnt a lot about cosmic rays and the constitution of our Universe. It was very interesting to exchange with other students and scientists from other countries.
We had fun spending time together during the ICD !

RADIOCOSMOS – (ICEF, France)

Contributors : Juliette ARAGNOU, Sylvaine BRUNET (teacher), Madeleine CHARTON, Alexandre CILIA, Clémence DE CLERCK, Charlie FAUVEL, Amaury GALLOT, Samuel LEPICARD (teacher), Paul MAS, Stella MAS, Anna NELLOU, Alexandre SONNTAG

Introduction

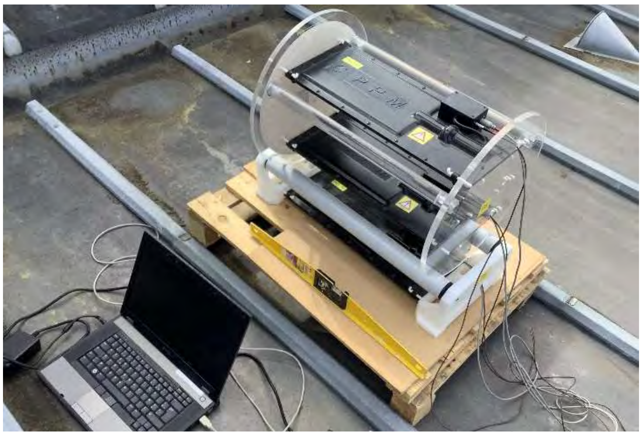
RADIOCOSMOS is a group of 10 high school students from the French Catholic Educational Institution of Fontainebleau (ICEF) who participated in a multi-year radioprotection workshop.

Summary of Work Completed

Measurements of cosmic muon flux were conducted using equipment provided by the Paris Observatory and its organization "Sciences à l'école."

Equipment Used

- Detector with superimposed plane scintillators (see Figure 1)
- Muon discrimination by coincidence on 3 scintillators.



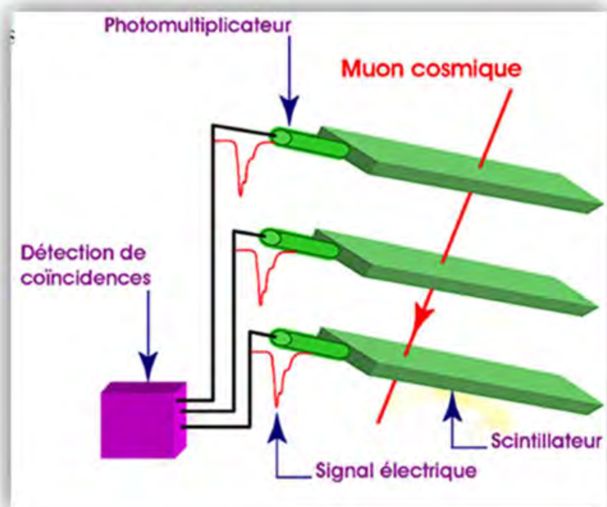


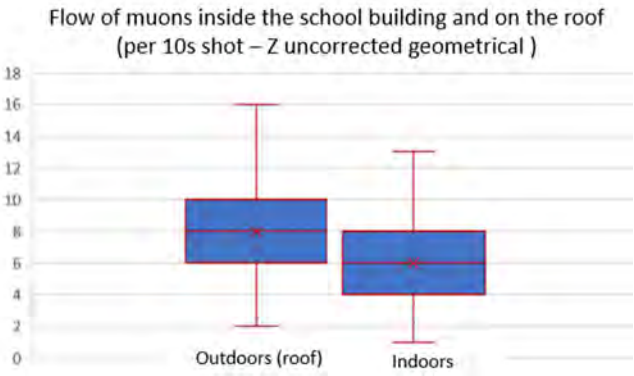
Figure 1. « Cosmic wheel » for muon detection

Obtained results provide an average flux of $\varphi = 4.2 \times 10^5$ muons per square centimeter per year after geometric correction related to the solid angle captured by the equipment.

Study of different parameters on the Cosmic Muon Flux

The group compared series of indoors and outdoors measurements of muon flux and then quantified the effect of attenuation by walls, see Figure 2 below.

The group also compared series of measurements as a function of azimutal angle and thus quantified the attenuation effect by the thickness of the crossed atmosphere, see Figure 2 below.



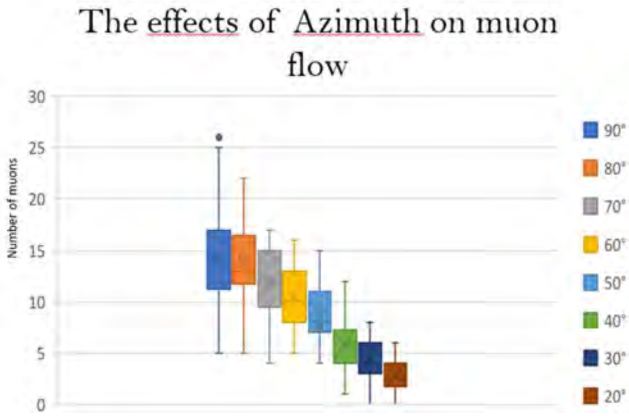


Figure 2. Attenuation of muons by walls (left) and by the crossed atmosphere (right)

Dose Calculation

- Calculation of energy dE deposited by muons in the human body by ionization (Bethe-Bloch formula $dE = 2\ MeV/g/cm^2$).
- Calculation of absorbed dose $D_{abs} = \varphi \times dE = 1.34 \times 10^{-4}$ Gy/year.
- Calculation of associated annual effective dose $D_{eq} = D_{abs} \times Q \times Fc$, where Q is the radiation-type weighting factor (Q=1 for muons) and Fc is the organ weighting factor (Fc = 1 for muon radiation).

Results lead to an average annual effective dose of 1.34×10^{-4} Sv/year = 0.134 mSv/year.

Comparison with Average Annual Dose in France

The dose associated with cosmic muon radiation calculated by our group (0.134 mSv/year) does not represent a significant portion of the average annual exposure to ionizing radiation in France (Dav = 6.5 mSv/year), see Figure 3.

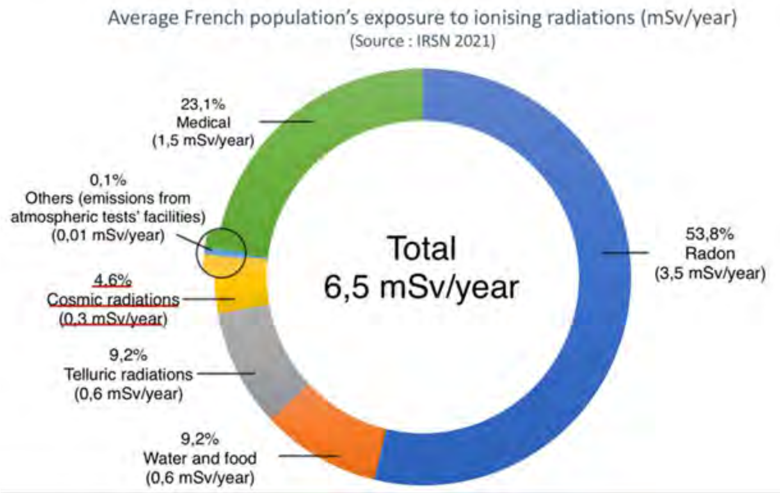


Figure 3. Comparison of average French population's exposure to ionizing radiation

Conclusion

Using the detection equipment provided by the Paris Observatory, numerous measurements of cosmic muon flux were conducted by the ICEF student group, enhancing their understanding of the properties and effects of this type of radiation.

This work was first presented to radiation protection experts at a symposium held in the city of Avignon in May 2023.

GERMANY

International Cosmic Day

University of Bonn, Germany

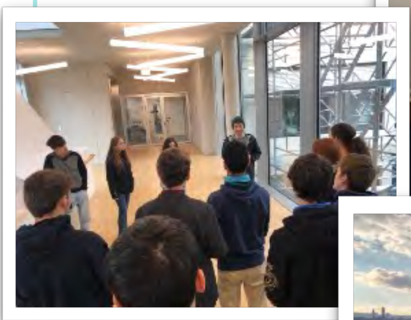
Credit: DESY, Science Communication Lab

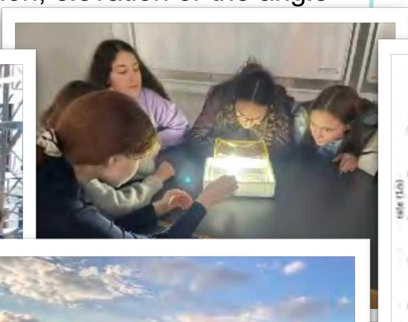
Who are you?

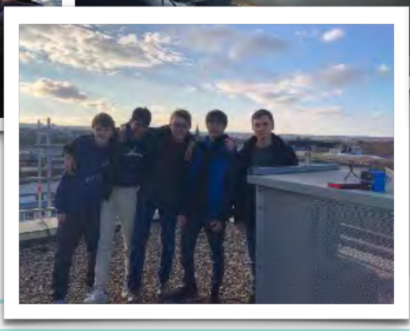
We are students from 10 different schools in Bonn (Germany) and the surroundings.
All students are between 15 and 18 years old. We are a collection of science enthusiasts who have come together to learn and share knowledge about cosmic rays.

What have you done?

First we listened to two interesting lectures about the EUCLID mission and cosmic rays. Then we built our own fog chambers using dry ice, isopropyl, a metal plate and a plastic box. Using these we could visualize the paths of ionizing particles by using the effect of condensation. After lunch we split into two groups. One group started with a guided tour of the detector physics center in Bonn, while the other group focused on collecting data with the "Cosmic Watch“ detectors.
In the experiments we tried to study the rate of cosmic particles and the decency on environmental factors, such as the location, elevation or the angle at which they arrive.







Guided tours (left), Cloud Chamber Workshop (upper right), Roof Measurement (lower right)

What did you find out?

During the lectures, we learned that the EUCLID telescope scans a third of the observable sky and covers a much wider field of view than the HUBBLE or JWST telescopes. We also discussed the discovery of cosmic rays in the early 20th century and how this breakthrough laid the foundation for advancements in astrophysics and particle physics.
During the experiments, we observed that the rate of cosmic particle detection increased inside a building with increasing floors. Additionally, we analyzed flight data collected by a student in Bonn this year, demonstrating that the flux of cosmic rays is strongly dependent on altitude, with higher fluxes observed at greater heights.

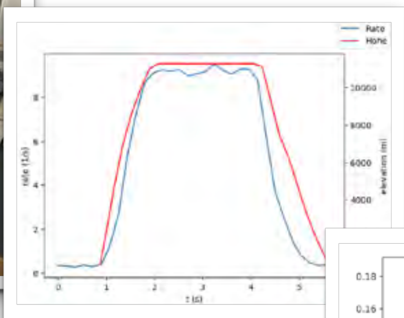


Figure 1.) Rates (blue) and Elevation (red) vs. time

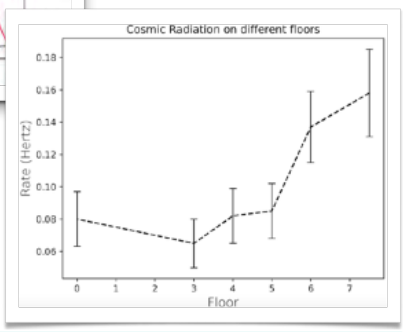


Figure 2.) Rates and dependence of the floor of the physics building

What's your take-home message?

The constant influx of secondary cosmic particles is thoroughly characterized and studied, but the origin of primary cosmic particles remains incompletely understood. Integrating studies involving measurements on Earth's surface, observations in space, astronomical findings, and theoretical insights will contribute to a more comprehensive understanding of cosmic radiation in the future.

ICD 2024 Villa Elisabeth

The Gymnasium Villa Elisabeth is a state-approved private school located in the southern part of Berlin, with an international focus and a strong emphasis on the natural sciences. The school collaborates with the Technical University of Applied Sciences Wildau (Technische Hochschule Wildau) and DESY Zeuthen.

This year marked our 12th participation in the International Cosmic Day (ICD). As in previous years, we started the event with an intensive crash course in particle physics and astrophysics, which prepared us for the actual ICD activities. This led to the setup of our first experiments in preparation for the ICD itself.

On the day of the ICD, we carried out a range of experiments, providing students the opportunity to explore their potential and apply their knowledge. The experiments we conducted and the results we obtained are explained in detail in the following pages.

This year's participants included our students Dominick Blex, Nikita Sarpultsev, Valerii Kovalinskyy, Till Göttling, Karl Sperling, David Subtire and Annalena Scholz along with our physics teacher, Dr. Stefan Bläß. We are once again especially grateful to Carolin Gnebner from the DESY Zeuthen for providing the necessary hardware (muon detectors – CosMO and Kamiokannen) and for her outstanding work in organizing the ICD event.

The team of young scientists

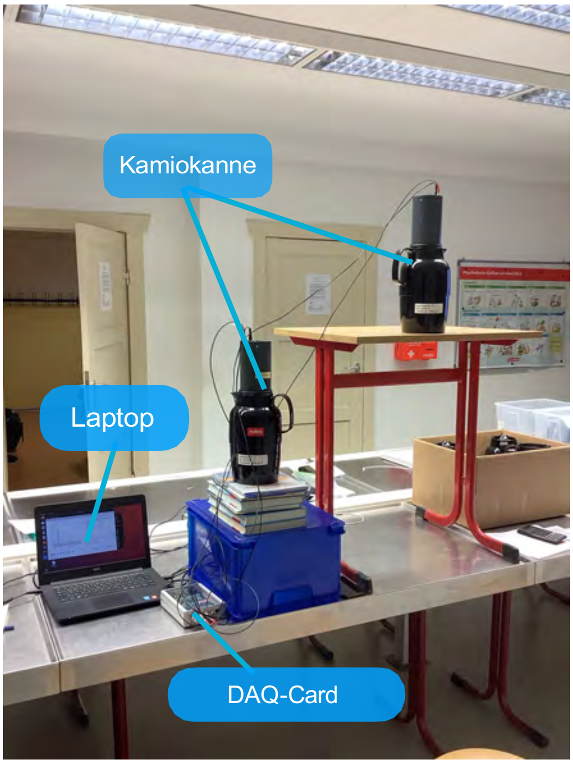
Measuring the zenith angle of incoming muons (using Kamiokannen)

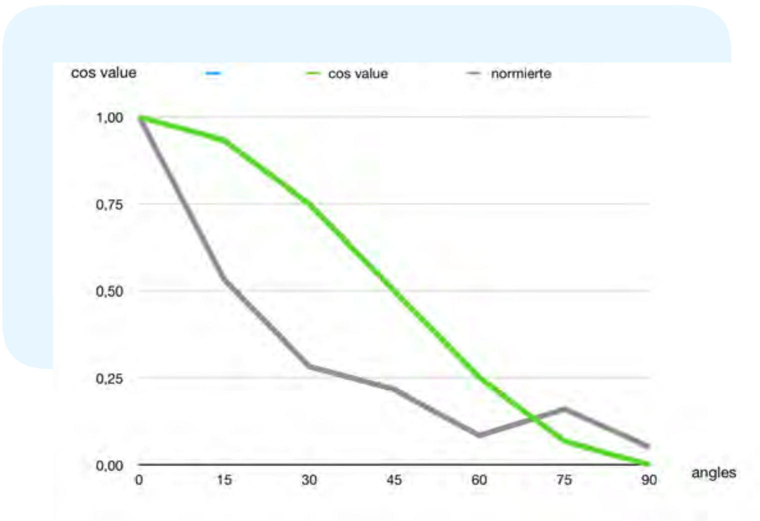
One group conducted an experiment using "Kamiokannen." These "Kamiokannen" are essentially coffeepots filled with water, with the lid replaced by a photomultiplier tube. The name is derived from the large "Super-Kamiokande" experiment and the German word "Kanne" (which means coffee pot), although the Kamiokannen are used to detect muons rather than neutrinos.

Students placed one pot on top of the table and the other beneath it. In the starting position, the two pots were aligned vertically, with the angle between them being 0°. The setup and procedure followed the same approach as the scintillator plate experiment. We measured the number of detected muons for 30 minutes at each angle, changing the angles in steps of 15°. To adjust the angle, the lower pot was shifted sideways while ensuring the distance between the two pots remained constant by placing books underneath the lower pot.

Results

The results closely resemble those from the measuring the zenith angle of incoming muons (using CosMO) experiment. The number of detected muons is highest when the angle is 0° (the vertical position). As the angle increases, the number of detected muons decreases. The distribution of muons follows a cosine squared (cos2) cos2) dependence, with slight deviations likely due to the lower sensitivity of these detectors (compared to CosMO), as well as random electromagnetic background noise and voltage fluctuations in the power supply during the measurements.





Measuring the muon velocity

Experimental Setup and Results Summary

The experiment aimed to measure the velocity of muons using two CosMO detectors positioned at distances of 2.45 meters and 3.17 meters. Both detectors were aligned on a vertical axis and connected to a DAQ card, which transmitted data to a laptop running the Muonic software. An event was recorded when a muon passed through both detectors within a 100-nanosecond interval.

For the 2.45-meter setup, the calculated velocity was $2{,}25 \times 10^8$ m/s, which corresponds to 78% of the speed of light and falls within a physically plausible range. In the 3.17-meter setup, the calculated velocity was $4{,}18 \times 10^8$ m/s, equivalent to 144% of the speed of light. This result is physically impossible, indicating potential systematic errors in the measurement process.

Results and Discussion

The 2.45-meter setup produced results that were consistent with theoretical expectations, suggesting that the experimental method was functioning correctly in this configuration. However, in the 3.17-meter setup, the lower detector consistently recorded fewer events than the upper detector. Despite multiple calibration attempts, this discrepancy persisted.

Further investigation using a radiation meter unexpectedly revealed higher radiation intensity near the upper detector. This observation interferes with the assumption that muons, which originate in the atmosphere, would equally affect both detectors. The higher measured velocity in the 3.17-meter setup likely resulted from calibration errors, timing inaccuracies in the DAQ card, or external interference affecting the detectors' functionality.

These findings highlight the need for improved calibration and synchronization of the measurement system. Current experiments focus on verifying the 2.45-meter setup under controlled conditions to validate its reliability while addressing the systematic errors identified in the 3.17-meter configuration. By minimizing external disturbances and refining the methodology, more accurate measurements of muon velocity can be achieved.

Experimental Setup and Results Summary

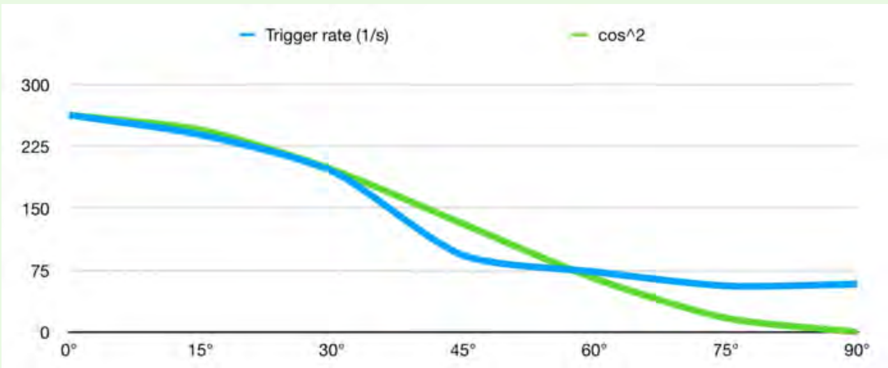
To measure the zenith angle of incoming muons, two groups mounted two CosMO scintillator plates on a box, keeping them at a fixed distance. After connecting the detectors to a DAQ card and a computer for data analysis, we began the measurements. Each measurement run lasted approximately 20 minutes for each position. After each run, the structure was tilted by 15° (starting from 0° on the diagram), and a new run was started with the new position.

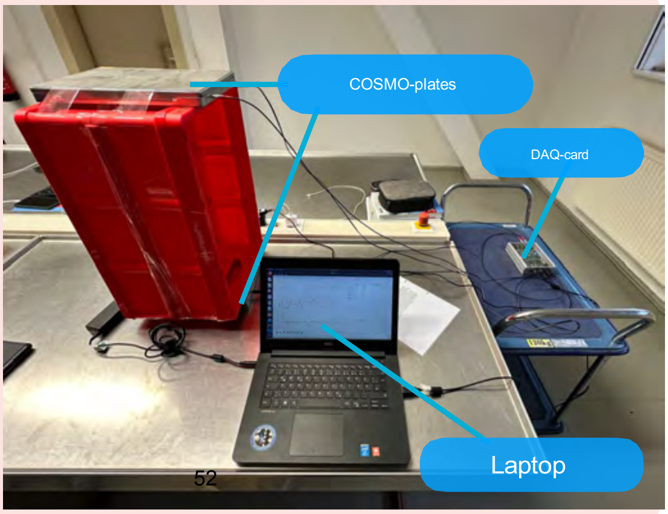
Results and Discussion

The results are summarized in the diagram below, comparing the measured data to a theoretical cosine function. The data show that most of the detected muons are coming from directly above (the zenith). Therefore, muons arriving vertically have the shortest path to travel, which increases their likelihood of being detected compared to muons arriving from more horizontal angles.

However, there is significant deviation from the expected cosine curve. This discrepancy can be attributed to two main factors:

1. **Event-based Data Representation:** The chart shows event counts rather than event rates. Since event counts depend on the total measurement time at each position, this leads to some inconsistencies in the data.
2. **Unequal Measurement Times:** The measuring times were not exactly the same for each angular position. Since the structure was turned by 15° increments, the exposure time at each angle may not have been equal, which could affect the comparison with the ideal cosine distribution.





Measuring muon decay time

Experimental Setup and Results Summary

The CosMO experiment aimed to measure and analyze the decay characteristics of muons using three CosMO detectors connected to a DAQ box and a computer running Muonic software. The setup involved aligning the detectors vertically, with Channels 0, 1, and 2 representing different thresholds and functions: Channel 0 detected incoming muons, Channel 1 monitored muons or electrons as they passed through, and Channel 2 acted as a veto, overwriting signals from the other channels when applicable. The DAQ box was connected to the computer via USB, and the software was calibrated to ensure consistent threshold values across the detectors.

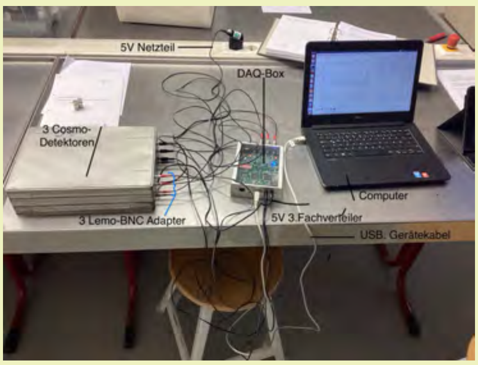
During the experiment, the detectors recorded time intervals between muon decay events. Data from each channel were visualized in real-time, showing pulse rates (in Hz) over time. The team conducted measurements over approximately 22 hours, resulting in an exponential decay curve characteristic of muon decay.

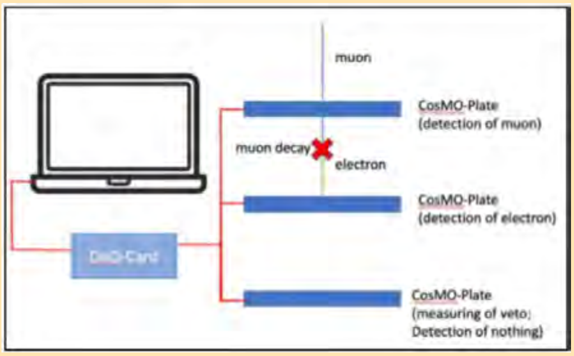
Results and Discussion

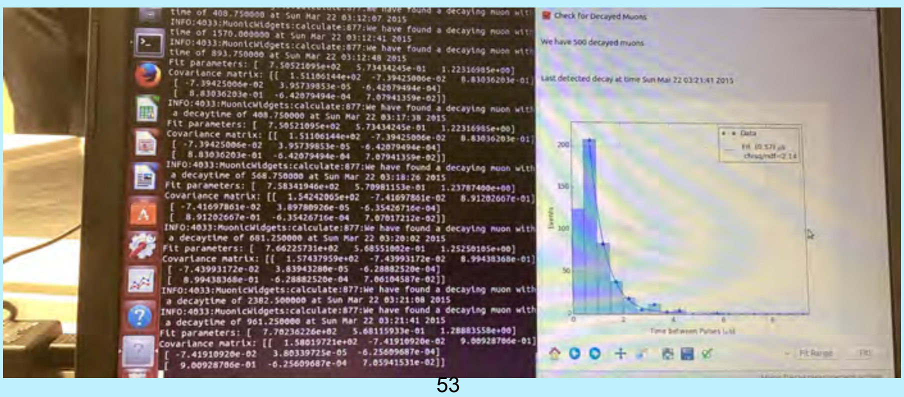
The experiment yielded a measured muon decay rate of approximately 1.58 microseconds. While this value closely matches theoretical predictions, it deviates from the expected muon lifetime of 2.2 microseconds in the rest frame. Potential sources of error include limitations in the detection apparatus, such as miscalibration of thresholds or variations in detector sensitivity, and the possibility that some muons entered the system at specific angles, bypassing certain detectors.

Each detector's threshold influenced the detection sensitivity and signal intensity, resulting in varying output amplitudes across the channels. These discrepancies were visible in the software's graphical representation and likely contributed to the observed deviations in decay measurements.

Despite these challenges, the experiment successfully demonstrated the fundamental principle of muon decay, showcasing its exponential time distribution. Future improvements, such as enhanced calibration procedures and adjustments to detector positioning, could help reduce measurement errors and yield results that align more closely with theoretical values.







On the trail of astroparticles

TU Dresden - astroparticles physics

Who are you?

We are german students between the age of 12 and 18 from Saxony and Brandenburg, who share the same interest: astroparticles physics.

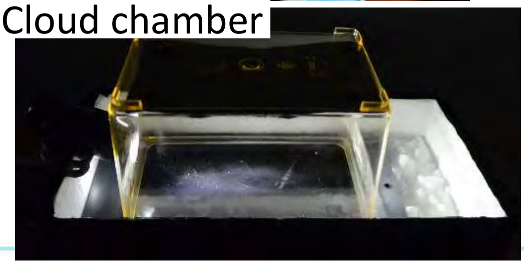
What have you done?

We researched astroparticals with 3 experiments:

1. Kamiokannen-experiment

2. Scintillation counter

3. Cloud chamber



What did you find out?

- Immerse yourself in the world of astroparticles physics
- elemental particles: e.g. electron, muons, various quarks and bosons
- "Cherenkov radiation" as a way of detecting muons (by using photomultipliers, like in the Kamiokannen-experiment)

→ thereby discovery of chamber in Cheops pyramid

→ indirect detection of cosmic radiation

- using the cloud chamber to visualize electrons, muons, alpha-particles

What's your take-home message?

If you hold your finger to the sun, billions of neutrinos pass through finger nail every second and don't influence you.

GREECE

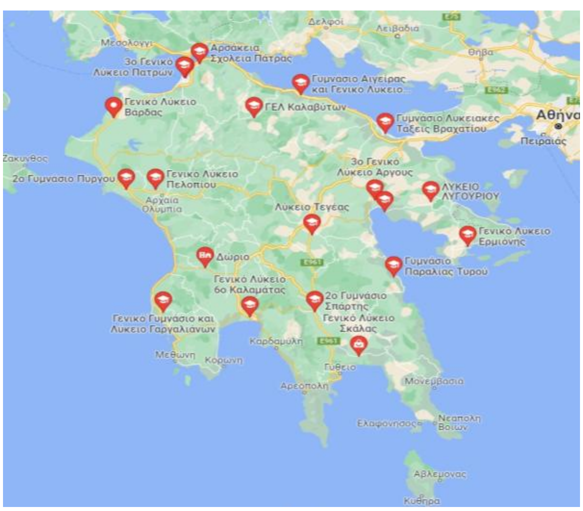
μNet: The Hellenic Network of Educational Cosmic Ray Telescopes

Credit: DESY, Science Communication Lab

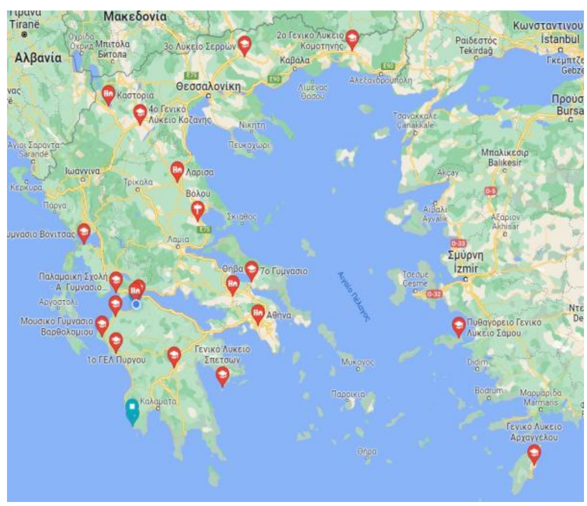
Physics Laboratory/Hellenic Open University, Greece

Presentation of the Network

The Physics Laboratory of the Hellenic Open University (HOU) launched the μNet project to introduce Greek high school students to experimental Particle and Astroparticle physics. Within this framework, students construct, test, and operate their own telescopes to observe high-energy cosmic rays, replicating the experimental processes of renowned 20th-century scientists who made significant discoveries about matter and fundamental interactions in the universe.
As part of the μNet project, 20 educational cosmic ray telescopes were installed in Greek high school laboratories, while remotely operated devices deployed at the Hellenic Open University campus are made accessible to over 50 schools annually. Schools equipped with μCosmics detectors and those participating in distance educational activities form the μNet network, Greece's first school network of educational cosmic ray telescopes.



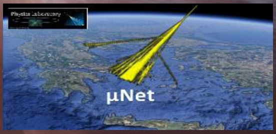
20 Telescopes in person



40 Remote Telescopes

The above maps show the locations of the schools participating in the μNet network marked with a **red** pin.

μNet: The Hellenic Network of Educational Cosmic Ray Telescopes



Credit: DESY, Science Communication Lab

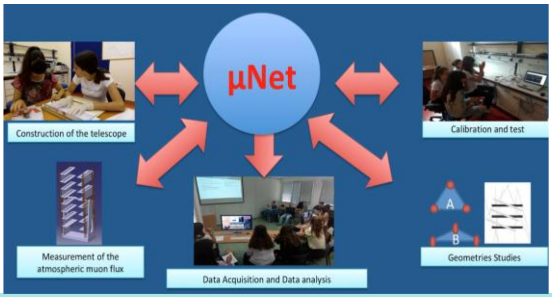
Physics Laboratory/Hellenic Open University, Greece

μCosmics Detector

The Physics Laboratory of HOU constructed a low cost, small-scale and portable cosmic ray telescope, the μCosmics detector. The detector (Fig. below) comprises three detector units, a PC-based oscilloscope and a PC for monitoring and storing the data. The detector unit is very small, easy to carry and weighs about 6 kg. The resolution of the μCosmics telescope is about 5 degrees while the recording rate is about 10 showers per hour, which is sufficient even for the short duration of a high school class period.

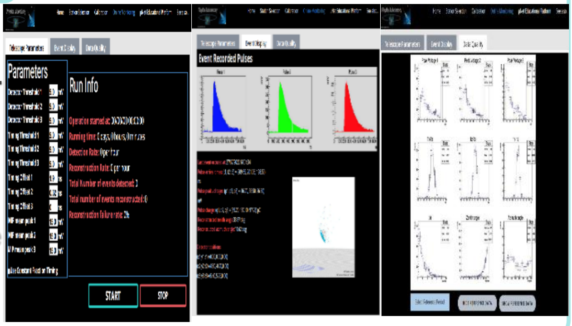
μNet educational activities

The μNet educational program includes a series of educational activities that are carried out by students under the guidance of their teachers. When the collection of data is over (at the end of the school year) the students estimate the detection rate as well as the arrival distribution of air showers and compare with other measurements from other schools.



The online web app for the telescope operation

A web-based application allows for the calibration and operation of the telescopes (https://mnet-online.eap.gr). Each school monitors the detection rate and the reconstruction rate of air showers. The acquired pulses for each detected shower and the direction of the reconstructed shower are presented as an animation. The last tab of the online monitoring page is used to show histograms that present the data quality of the telescope.



Results

Both schoolteachers and students substantially improved their knowledge about cosmic rays. The students present their results by covering all the activities of the program, from the construction to the operation of the telescope, and participating in conferences and seminars both domestically and internationally.

Modular High School of Patras

High School of Kato Achaia

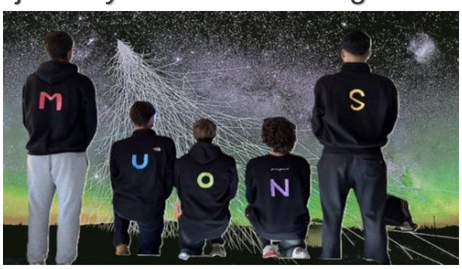
8ο High School of Patras

Credit: DESY, Science Communication Lab

Physics Laboratory/Hellenic Open University, Greece

Presentation of our Project

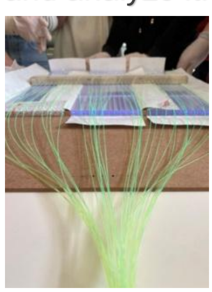
For the first time this year, Greece is participating in International Cosmic Rays Day! The Physics Laboratory of the Hellenic Open University provides young people from across Greece with the opportunity to take part in the event, supporting and guiding them on their journey to understanding cosmic rays!

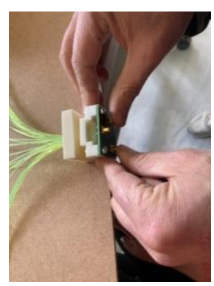


Students and teachers from the High School of Kato Achaia and the Modular High School of Patras, who participate in the Educational Cosmic Rays Telescopes network, microNet (μNet), successfully coordinated for the third consecutive year by the Physics Laboratory of the Hellenic Open University, presented the μCosmics detection system to young people from around the world. They also showcased the program's annual educational activities and their findings from detecting cosmic rays!

Students receive training on high-energy cosmic rays and their detection. They also learn to construct, assemble, and operate the μCosmics educational telescope. Additionally, they are taught how to calibrate the telescope, collect data, and analyze it.

Nefeli Koulouridi, Anna Kapatsoulia-Modular High School of Patras, MNET





Modular High School of Patras

High School of Kato Achaia

8º High School of Patras

Physics Laboratory/Hellenic Open University, Greece

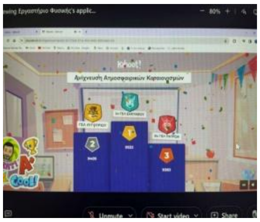
Credit: DESY, Science Communication Lab

μCosmics detector station architecture

- 3 particle detectors in a triangle arrangement on the ground
- Data Acquisition System (Data AcQuisition-DAQ)
- Computer system for storing and processing data
- GPS antenna for recording absolute time

μCosmics operating principle

- Three detectors consisting of two layers of 12 scintillator plates, where cosmic particles impinge and deposit energy
- This energy causes scintillation, i.e. light, which is collected by optical fibers that penetrate the scintillator material.
- Optical fibers guide the light to a
- photomultiplier which converts it into an
- electrical signal (pulse)

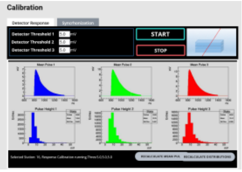


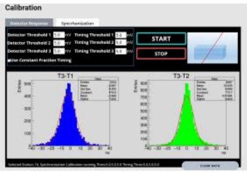
μNet activities

When the collection of data is over the students estimate the detection rate as well as the arrival distribution of air showers and compare with other measurements from other schools.

The students present their results by covering all the activities of the program, from the construction to the operation of the telescope, and participating in conferences and seminars.

A web-based application allows for the calibration and operation of the telescopes

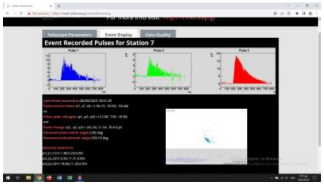




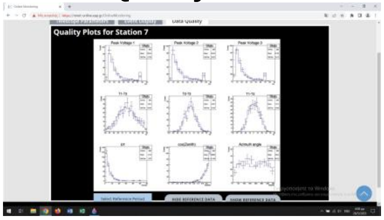
Students participate in the two-day conference "Days of Particle and Astroparticle Physics" held on the HOU Campus and present their results.

Telescope Parameters

Event Display



Data Quality



ITALY

International Cosmic Day 2024

INFN and University of Siena

Itis Galileo Galilei, Arezzo (AR)

Credit: DESY, Science Communication Lab

Who are you?

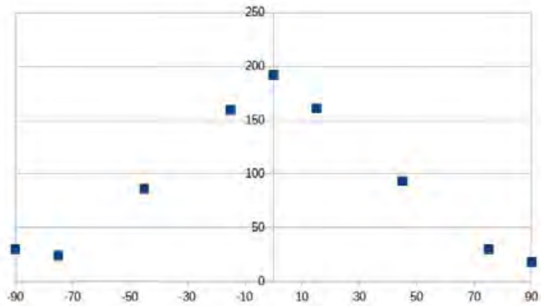
We are 4 italian secondary school students: from right to left Francesco Peruzzi, Niccolò Belardini, Gabriele Baldi and Lorenzo De Piano

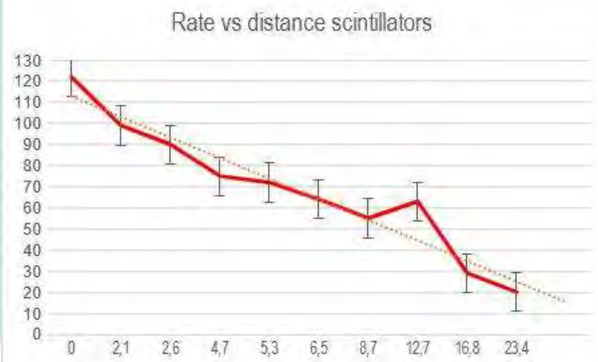
What have you done?

We learned about cosmic rays and astroparticle physics. We worked with other schools and students to measure the cosmic ray flux variation in function of the cosmic cube inclination and we also measured the acceptance of two scintillators changing their distance

What did you find out?

In the graphics below we show our measurements and results





What's your take-home message?

We participated to ICD 2024 in Siena and became researchers for a day learning how to use cosmic ray detectors,

International Cosmic Day 2024

ISIS Fossombroni, Grosseto, Italy

Who are you?

We are Manuel Gabrielli and Davide De Santis, we are from the 5th STEM Scientific High School of ISIS Fossombroni in Grosseto.

What have you done?

We saw a brief introduction to cosmic rays in the atmosphere.
We studied the behavior of muons when they arrive on Earth,
using the CosmoCube.
This is a box with two parallel tiles that are capable of capturing muons.
We measured the number of triggers, the times a muon hits both tiles.
The measurements were carried out with a cube angle of 0°, 30°, 45°, 60°, 90°, to observe how the number of triggers varies.

What did you find out?

We found that the frequency with which muons hit the tiles is maximum when the cube is tilted by 0°, so when the two tiles ae ground.
Otherwise, the frequency is minimum when the two tiles are perpendicular to the ground, with an cube's inclination of 90°.
We also noticed that the number of triggers per 100 seconds remains constant over time.
Since they are experimental mesuraments, we calculated the errors, too.

What's your take-home message?

We saw experimental physics for the first time, applied for a scientific experiment that allowed us to acquire new knowledge about the subject.

Investigation of Muon Flux as a Function of Zenith Angle Using CosmoCube

Credit: DESY, Science Communication Lab

Liceo Scientifico Cecioni, Livorno, Italy

Who are you?

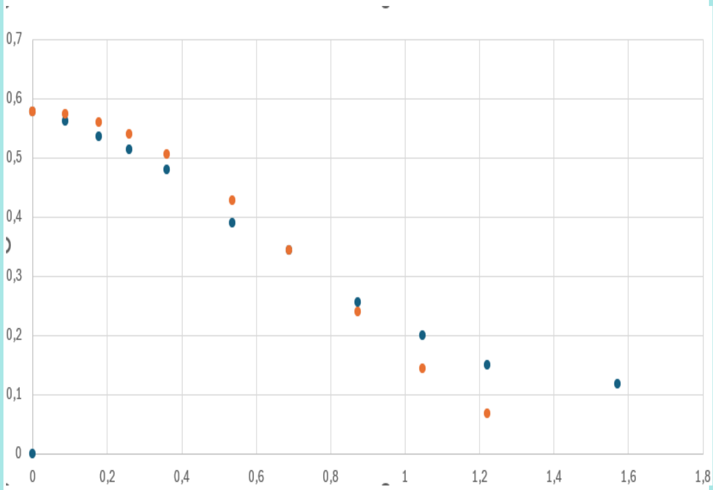
Nicolò De Crescenzo, Sofia Falcitelli, Giacomo Diamanti, Tommaso Bigioli
Liceo Scientifico Cecioni, Livorno Italia

What have you done?

We have used a cosmic Ray cubic detector to measure the frequency of interactions in function of the zenith angle.

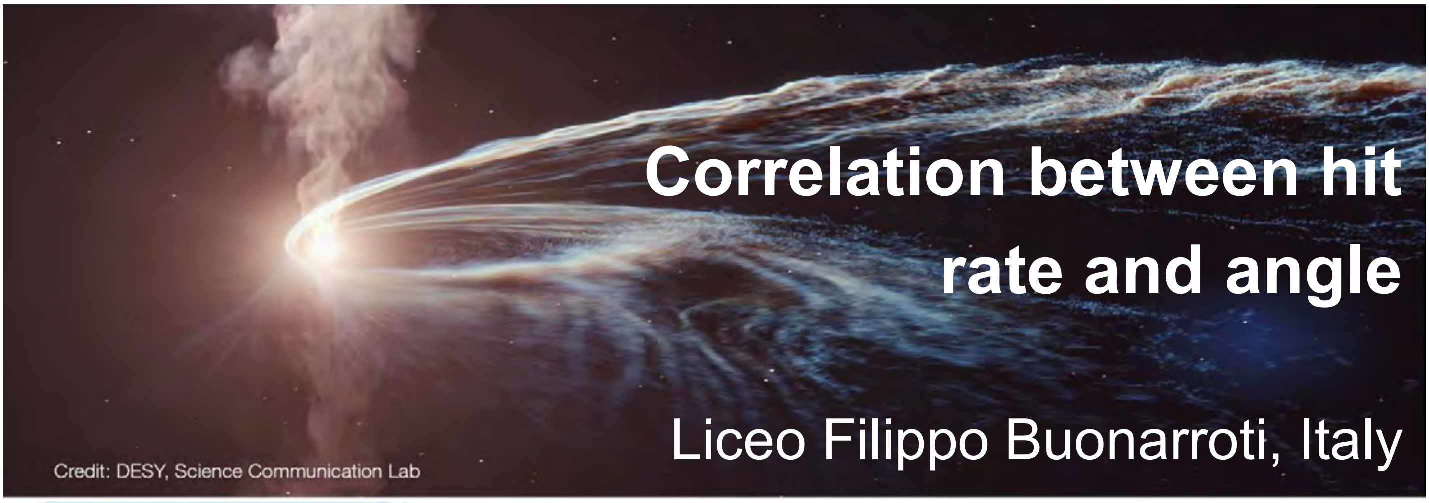
What did you find out?

We found out that the frequency of interactions is described by the cosine squared function.



What's your take-home message?

Being involved in this experiment was a truly enriching experience, as we had the opportunity to get to know a research facility firsthand and immerse ourselves in the world of scientific research for a day. The universe sends us signals that are invisible to us but, if we have the ability to measure them, they can help us understand what surrounds us. This experience will undoubtedly contribute to our continued interest and curiosity in the field of experimental physics.



Correlation between hit rate and angle

Liceo Filippo Buonarroti, Italy

Credit: DESY, Science Communication Lab

Who are you?

Pedro Cassettari De Mello Franco, Enrico Pizzorusso, Antonio Pizzolante, Emma Ferra, Kristina Progri, Valerio Carillo.

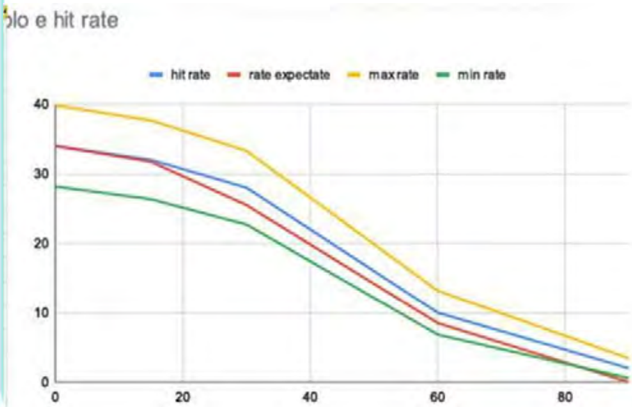
What have you done?

Using the cosmic kube we measured the hit rate and the number of events in 5 minutes. Then we repeated the same process tilting the Kube at multiple angles to the horizontal axis(0°,15°,30°,60°,90°). We then made a plot with hit rate as the X and angles as y axis. This study shows how the number of muons decreases the more the amount of atmosphere , even if this particle hardly reacts with matter.

What did you find out?

“Measured hit rates correspond to the blue line of the graph, the error of thee measures is the area between the green and the yellow curve.”

We observed the measured hit rate related to the angles confirms the theoretical prediction, to which it should follow the ***cos²(angle)*** distribution (red curve).



What's your take-home message?

Measurements must always be confronted to the theory

noise-distribution

ITI-Marconi – Pontedera (Pisa) - Italy

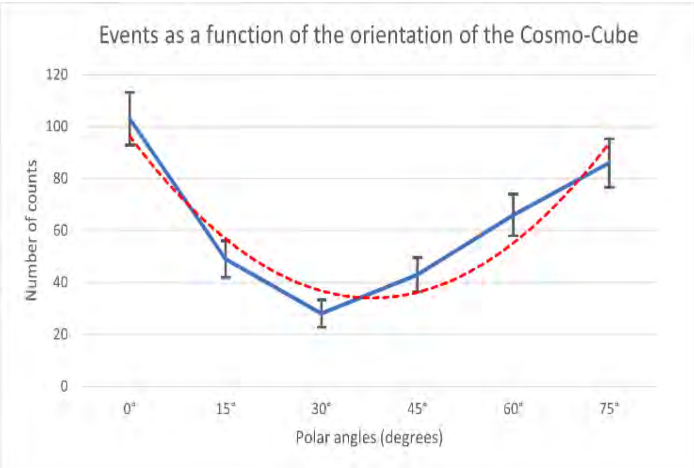
Credit: DESY, Science Communication Lab

Who are you?

Alessandro Scuffi
Ludovica Zanobini
Mattia Trevisani
Matilde Casati
Princi Edoardo
Virginia Pizzi

What have you done?

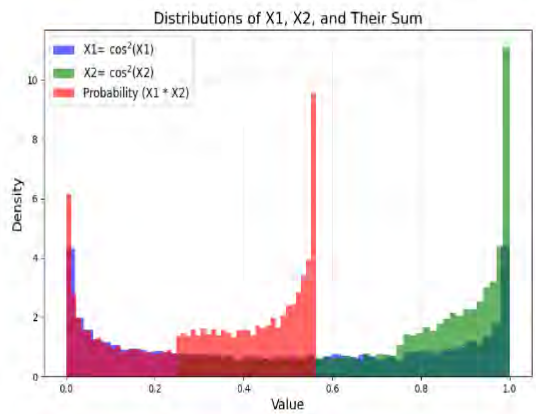
We measured the number of events based on the inclination angle of the Cosmic-Cube.



The graph represents the data aquired with the cosmic cube with their relative error and a fit of the curve.

What did you find out?

We found out that the phase difference between the two scintillators caused an increase of counted events due to the arrival of cosmic rays from the back of the Cosmic-Cube. We also ran a simulation to compare our data.



What's your take-home message?

We understood that the physics of cosmic rays is beautiful.

International Cosmic Day 2024

IIS Enzo Ferrari, Rome - Italy

Credit: DESY, Science Communication Lab

Who are you?

Our class, 3F, had the opportunity to participate in ICD, mentored by ASI researchers. We are Saba, Giulia, Dario, Federica and Jordi.

.

What have you done?

We discussed issues regarding the study of cosmic rays, and the impacts of cosmic radiations on human space exploration. That day we continued to explore this field with a practical demonstration in a laboratory, where we were able to see cosmic rays that were measured with a special instrumentation, for educational purposes. We also shared the results with other groups of students from all over the world during the International Cosmic Day video call.

What did you find out?

We found out the risks of space exploration, wich are: isolation, distance from the earth, gravitational force, hostile environnement, and in particular the effects of the cosmic radiations on the human body, including how our cells and DNA react to the damage they create.

What's your take-home message?

We learned important things about our universe that can be useful even if we won’t personally go to space, since cosmic rays can influence life on earth, and learing is always a good way to expand our horizons.

Credit: DESY, Science Communication Lab

International Cosmic Day 2024

Radiation in space

IIS Enzo Ferrari, Rome - Italy

Who are you?

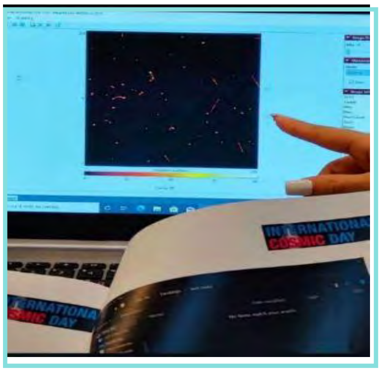
Our class, 3F, had the opportunity to participate in ICD, mentored by ASI researchers
We are Cristel, Arianna and Asia.

What have you done?

We have studied the phenomenon of radiation in space, focusing on cosmic rays and their discovery. Furthermore, we analyzed the effects of ionizing radiation on astronauts and the protective role of the Earth's magnetosphere.

What did you find out?

We have discovered that cosmic rays are highly penetrating radiation coming from outside the Earth's atmosphere. They are composed mainly of charged particles, as demonstrated by Bruno Rossi and Arthur Compton. Their distribution at ground varies according to magnetic latitude. Furthermore, astronauts in space can be exposed to doses of radiation equivalent to hundreds or thousands of chest X-rays, making the role of Earth's magnetosphere as a protective barrier crucial.



What's your take-home message?

Cosmic radiation represents a significant challenge for space missions, but research and technologies, such as ALTEA and LIDAL, are essential to measure the specific properties of the cosmic radiation in space to optimize the development of mitigation techniquesand mitigate its effects, contributing to the safety of astronauts.

Credit: DESY, Science Communication Lab

International Cosmic Day 2024

The experiment

IIS Enzo Ferrari, Rome - Italy

Who are you?

Our class, 3F, had the opportunity to participate in ICD, mentored by ASI researchers.
We are Elisa, Gaia, Giada, Mia.

What have you done?

In this experiment, we recorded particles over four sessions of 5 minutes each, using a cosmic ray detector. The data was collected in two orientations, which the sensor had: horizontal and vertical. During each session we measured the quantity of various particles, including muons (or cosmic rays at ground), alpha particles, beta particles, and photons. he` softare` of the instrument automaticall` recognized the nature of the particles ased` on the analsis` of the trac` in the detectorWe then analyzed these quantities of particles to explore their behavior and variations in different orientations.

What did you find out?

We found that the quantity of the particles varied depending on the type of particle and the orientation of the sensor.

e` have compared the numer` of particles collected in the different measurement sessions`e` find out that`even in a small eposed` area`the detector has een` ale` to detect all sources of radiation`including cosmic rays, oth` in horizontal and vertical exposure. he` numer` of detected particles`in the same time exposure, varies from session` his` depends on to` effects`

.. statistical fluctuations, for which the measured value is similar, but not always exactly coincident, to the average value expected;
2) systematic fluctuations, which are effects that depend on the instrument and the data-taking techniques. As an example, gamma radiation's count strongly depend on illumination conditions, that must be taken into account and corrected for a precise data analysis.

What's your take-home message?

The experiment showed that cosmic rays' particle quantities vary with the sensor's orientation and differe in each data taking session. We have highlighted and discussed possible effects due to statistical fluctautions and systematic fluctuations in measurements, which is typical of this kind of scientifici experiments. Muons were more frequent, while alpha and beta particles showed smaller differences. Photons' quantities were less reliable due to the lighting conditions. This highlights the importance of orientation in cosmic rays' measurements.

International Cosmic Day 2024
The experiment
IIS Enzo Ferrari, Rome - Italy
Credit: DESY, Science Communication Lab

Grafico muoni
Numero muoni
Sessioni
muoni orizzontali
muoni verticali

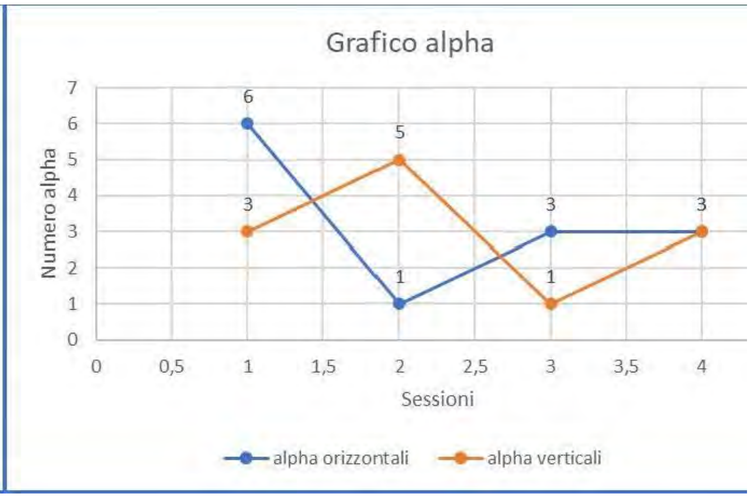


Grafico alpha
Numero alpha
Sessioni
alpha orizzontali
alpha verticali

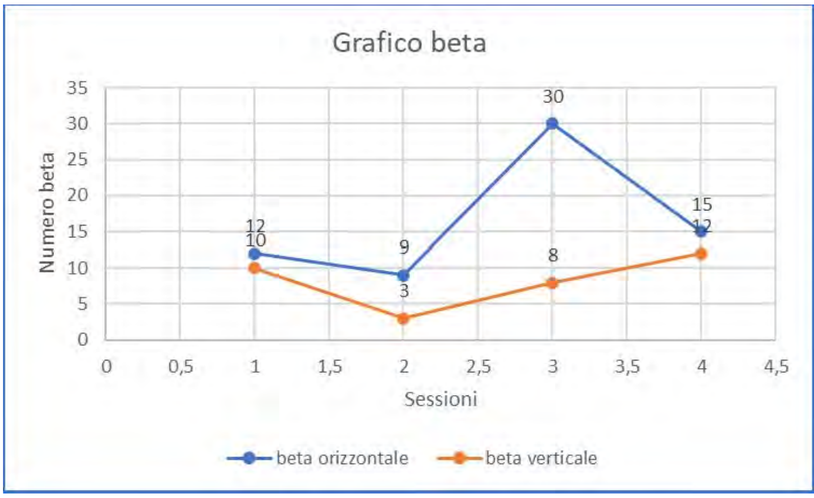


Grafico beta
Numero beta
Sessioni
beta orizzontale
beta verticale

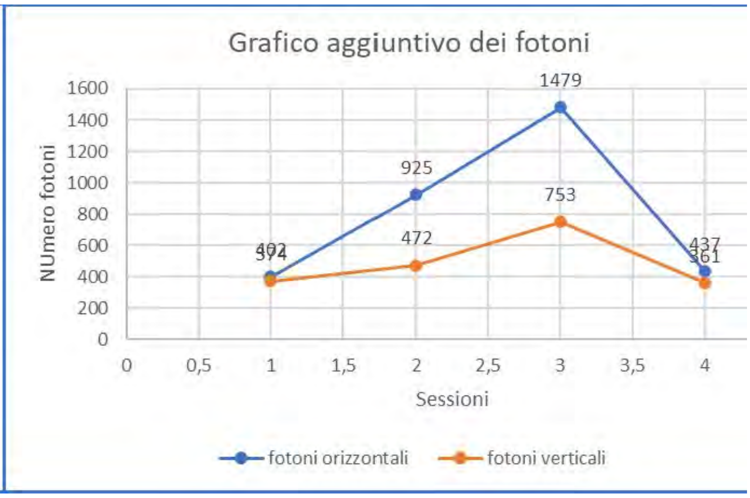


Grafico aggiuntivo dei fotoni
NUmero fotoni
Sessioni
fotoni orizzontali
fotoni verticali

ANGULAR DISTRIBUTION OF COSMIC RAYS

INFN Bari Group, Italy

Abstract

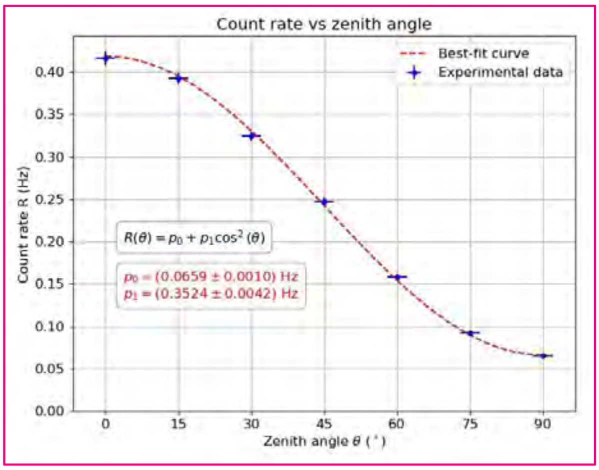
On the International Cosmic Day, eight groups from different high schools of the Puglia region met in the Physics Department of the University and Polytechnic of Bari, where they measured the flux of cosmic muons at sea level as a function of zenith angle, using a dedicated Cosmic Ray telescope. The results confirmed that the cosmic muon flux decreases as the angle increases.

Experimental Setup

The experimental apparatus is made up of three parts: the mechanical frame, the scintillator tiles and the read-out electronics. The mechanical structure consists in a frame that can be tilted according a certain angle that can be read by a protractor. This allows the measurement of the cosmic ray rate at sea level at a chosen angle for a couple of hours. The scintillator tiles are enclosed in two dark boxes, and are coupled to Silicon Photomultipliers (SiPMs). Two different kinds of SiPMs are used, with a dimension of 1x1 mm^2 and 3x3 mm^2 for each box. These SiPMs are powered by a voltage of 42 V. The signal coming from the sensors is then transmitted to an acquisition board that implements the trigger logic and consequently a RaspberryPy increments a counter and writes the output data files. The trigger logic consists in the coincidence of the crossing of a threshold of both the signals coming from the two scintillators. To monitor the acquisition process a red led lights up whenever a cosmic ray impinges both the dark boxes, and an oscilloscope is used to visualize both the analog and digital signals.

Analysis

We aimed at modeling the experimental data which we have obtained with the cosmic ray instrument. We employed python codes to analyze data. The instrument catches secondary cosmic rays whose flux varies according to the zenith angle, which is the angle that the ray forms with the vertical direction. The rate is calculated by dividing the total number of events by the acquisition time. We produced following plot, showing the cosmic ray muon rate as a function of the zenith angle:



A fitting routine was used to find the parameters of the function that described the data more accurately. Since the instrument has a dead time between one acquisition and the following one, that is, a time interval in which it cannot detect any event, the effective rate is calculated by dividing the measured rate by (1 - rate x dead time). By doing this so, we were able to correct the rate for the instrument dead time.

Results

We were able to fit the measurements presented in the rate vs angle plot with a $\cos^2(\theta)$ function. This proves that when the detection angle is higher, the rate of muons decreases. The rate shows an increase along the vertical direction.

ANGULAR DISTRIBUTION OF COSMIC RAYS

INFN Bari Group, Italy

Group description

We are a group of 33 high school students. The first part of the morning was dedicated to presentations, describing the main properties of cosmic rays, such as their composition, possible sources, classification and the detection mechanism. Afterwards, we focused on measuring the angular distribution of cosmic rays by mean of an instrument specifically developed by researchers of INFN Bari. In order to organize the work, we were divided in three groups of about 10 students each, each analyzing one of the three main parts of the experience of the experimental setup: the general introduction, the experimental setup and the data analysis. Two students presented our results during am international call organized by DESY, and involving other students from several countries.

Schools involved

1. Liceo Scientifico «E. Fermi» (Bari)
2. Liceo Statale «C. Cafiero» (Barletta)
3. Liceo Classico «Cagnazzi» (Altamura)
4. Liceo Scientifico «O.Tedone» (Ruvo di Puglia)
5. Liceo Scientifico «E. Amaldi» (Bitetto)
6. Liceo Scientifico «Salvemini» (Bari)
7. Liceo Scientifico «Federico II» (Altamura)
8. I.I.S.S. «Aldo Moro» (Margherita di Savoia)

Group pictures

Cosmic ray angle

Liceo scientifico Temistocle Calzecchi Onesti, Italy

Credit: DESY, Science Communication Lab

Who are you?

We are the students of Liceo scientifico Temistocle CalzecchiOnesti, Fermo, Italy

Participants: Aprea Luca, Minnetti Roberto, Cipolletti Filippo, Bugiardini Filippo, KananeeMeriem, Mochi Lorenzo, Giulia Ciccalè

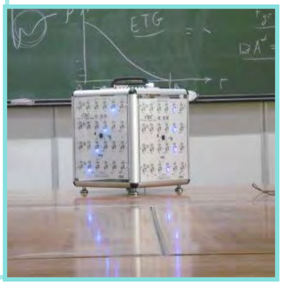
Tutor: Maria Rita Felici

What have you done?

The purpose of the experiment is to determine the frequency of inclination of the cosmic rays with a maximum inclination of 60 degrees.

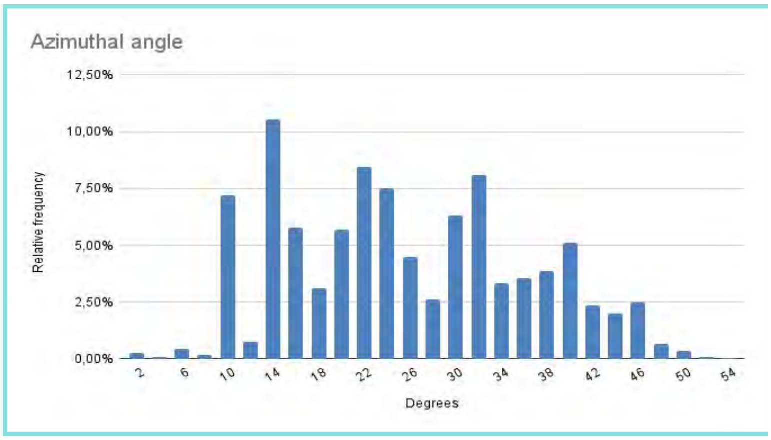
We worked on a detector called “cosmic cube” created by the collaboration of OCRA-INFN.

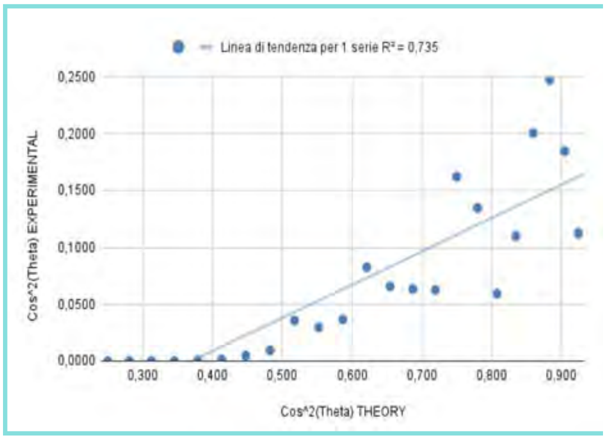
We acquired 1 minute of data every 30 minutes with the cosmic rays live app, specifically with the cosmic cube placed in the Gran Sasso National Laboratories . We ran out of time due to the app going on a break down so we had to measure the data every 15 minutes instead of 30. This was our first time working on a shared project so we had a hard time but in the end we managed to complete it. After we acquired the data, we put them on an excel squaresheet and with some excel commands we calculated the angolation of the cosmic rays.



What did you find out?

The graph represented is very similar to that of the theory and the relationship between experimental theta cosine and theoretical theta cosine without the use of the small degrees., show a regression line of 73%





MUON'S AVERAGE LIFETIME

Istituto Lorenzo Rota, Calolziocorte, Italy

Who are you?

We are five students of the last year of scientific high school from the institute "Lorenzo Rota", Calolziocorte.

What have you done?

We went to the University of Milano Bicocca and, after a short theoretical introduction, we went to see the various laboratories:

- muon's average lifespan;
- spark chamber;
- cosmic ray cube;
- double pyramid telescope;
- cloud chamber;
- scintillator made with lego.

In the second part of the day, we focused on the first experiment, which is the average lifetime of the muon.

What did you find out?

After calculating the lifetime of a muon we came to the conclusion that it's impossible for them to reach earth's surface unless we apply the laws of Einstein's theory of relativity.

$$v = c = 3 \cdot 10^8 \frac{m}{s}$$
$$t = 2{,}2 \cdot 10^{-6} s$$

- without relativity

$$s = v \cdot t = 3 \cdot 10^8 \frac{m}{s} \cdot 2{,}2 \cdot 10^{-6} s = 660 m$$
$$t = \frac{16000 m}{3 \cdot 10^8 \frac{m}{s}} = 5{,}3 \cdot 10^{-5} s$$

- with relativity

$$\beta = 0{,}9988 \qquad t = 5{,}33 \cdot 10^{-5} s$$
$$\gamma = \frac{1}{\sqrt{1-\beta^2}} = 20{,}42 \qquad t' = \frac{t}{\gamma} = 2{,}61 \cdot 10^{-6} s$$
$$e^{-\frac{t'}{\tau}} = e^{-\frac{2{,}61 \cdot 10^{-6} s}{2{,}2 \cdot 10^{-6} s}} = e^{-1{,}1863} \approx 0{,}31$$

What's your take-home message?

We are constantly exposed to cosmic rays, studying them is essential to deepen our understanding of cosmic matter and energy.

The hidden world of cosmic rays in Florence

I.I.S.T.L "B. Russel - I. Newton" (FI), Liceo Classico Statale "Michelangiolo" (FI), Liceo Scientifico Statale "L. da Vinci" (FI), Liceo Scientifico Statale "A. Gramsci" (FI), Istituto Paritario "M. Ficino" (FI), Educandato Statale "SS. Annunziata" (FI), I.S.I.S.S. "Cicognini - Rodari" (PO), I.S.I.S. "A. Gramsci - J. M. Keynes" (PO), Liceo Statale "C. Salutati" (PT)

ITALY

Credit: DESY, Science Communication Lab

Who are you?

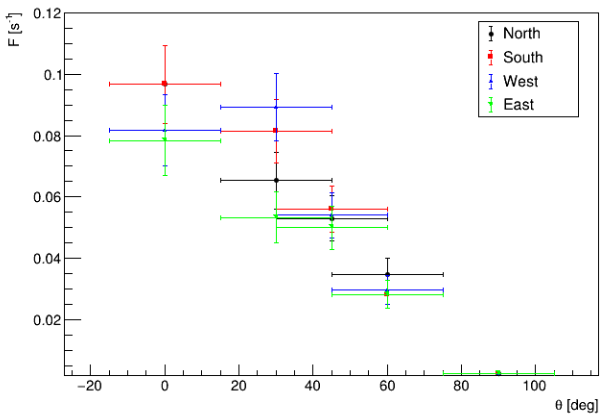
We are a group of teenagers interested in astroparticle physics. We want to share our passion for physics with our peers around the world.

What have you done?

In two days, we carried out extensive research into the phenomenon of cosmic rays. We measured the rate of atmospheric muons reaching the ground. We analysed the data obtained by varying the zenith and azimuth angles of incidence. For this purpose, we used Bruno Rossi's apparatus, consisting of three aligned Geiger tubes and a circuit with triodes. This allowed us to detect the triple coincidence of muons, in order to select the direction of the incoming particles.

What did you find out?

We found out that by changing the pointing direction of the instrument, the recorded muons rate changes. The maximum value of the rate is recorded when the zenith angle is 0°, while the minimum value is obtained in the direction perpendicular to the zenith.



The rate decreases as the zenith angle increases: this trend is the same for each azimuth direction.

What's your take-home message?

Through this experience, we met new friends who share the same passion for physics and we learnt how to cooperate with each other.

The EEE experiment @ ICD 2024

Credit: DESY, Science Communication Lab

Who are you?

Extreme Energy Events Project – "Science inside Schools" (EEE) is a Centro Fermi and INFN joint educational and scientific initiative studying cosmic rays, carried out with the essential contribution of high school students and teachers.

EEE consists of a network of about 60 cosmic muons tracking detectors, installed in High Schools and controlled by students; the EEE detectors are deployed over an area covering more than 10° in latitude and 11° in longitude, corresponding to more than 3×10^5 km^2.

The physics research interests include the properties of the local muon flux, the detection of extensive air showers, and the search for possible long range correlations between far telescopes. Data from all telescopes are centrally collected, reconstructed and distributed to the students.

Regular videoconferences, masterclasses, meetings and visits are organized with the involvement of all institutes.

In 2018, our students were involved in the assembly of the POLA-R detectors, used aboard of the Nanuq sailboat during the PolarQuEEEst mission, to detect cosmic rays at very high latitudes. In 2019 three POLA-R (POLA-01, POLA-03, POLA-04) detectors were installed at Ny.Alesund in collaboration with CNR to take long data acquisition. In 2022 the POLA-02 detector was embarked on board the Amerigo Vespucci, to take data during a 14-days route from Trieste to Genoa.

Since few months the EEE telescopes in Italy are restarting operation after major upgrades.

What have you done?

During the International Cosmic Day 2024 100 students and teachers, belonging to the EEE Project, met in presence at Centro Fermi (and many others were connected online). During the meeting students and researcher presented their reports on the analysis on the data, searching for evidence of the 10th May 2024 Solar Flare both in the POLA-R and EEE detectors.

What did you find out?

The students were provided with one month of data form POLA-R detectors and some EEE telescopes. As first part of the data analysis they studied the correlation between the muon rate and the atmospheric pressure; after applying the barometric correction to the measured cosmic muon rate they were able to clearly identify the Forbush decrease in the muon rate due to the Solar flare.

What's your take-home message?

The event has been characterized by great participation and enthusiasm among the EEE students, that were involved in the discussion of their scientific results, profiting of this initiative to improve their skills and to learn the challenging aspects of a scientist's life. During the general call the students from Liceo Banzi Bazoli presented a summary of their work to the other ICD participants.

EEE Telescopes and Forbush effect

IIS "Andrea Bafile”; L’Aquila, Italy

Who are you?

Alice Angelucci, Fabrizio Harja, Manuel Marsilli (5Dsa), Angelo Serpetti (4Eno), Viola Canofari, Roberta Gratti (5Cno).

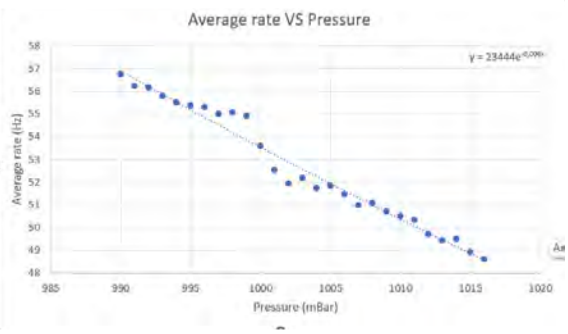
What have you done?

We analized data coming from EEE detectors to show the Forbush effect happened on May 10^{th} 2024.

This effect refers on a decrease of cosmic ray flux due to an intense solar flare.

We took into account data from Vicenza, L’Aquila, Pola EEE Telescopes.

First of all we corrected data considering the effect of barometric pressure and made the n.1 graph. From the fit we obtained the coefficient alfa to correct the rates.

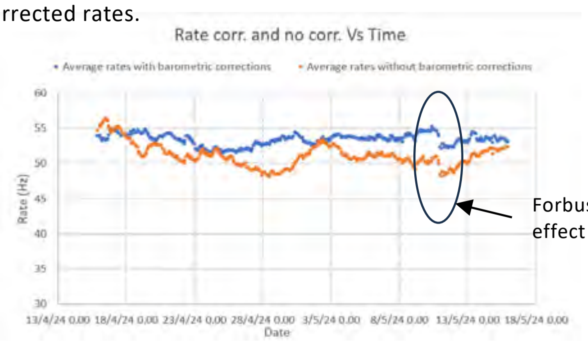


After that, we compared graphs of the corrected rate and the one without barometric correction versus time.

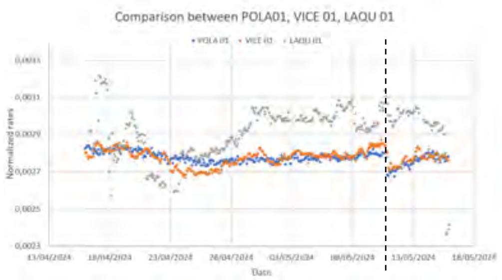
In order to analize data, we considered binning of two hours and we obtained the n.2 graph

What did you find out?

We highlighted in the graph the evidence of Forbush effect, that lead the decrease of cosmic rays rate. The trend of the rates is more stable for the data with barometric corrections and so the Forbush effect is more evident for corrected rates.



In graph 3 we compared data from different telescopes. The effect is clearly visible for VICE 01 and POLA 01, not the case for LAQU 01.



What's your take-home message?

EEE telescopes are capable of detect Forbush effect. Forbush effect infact is clearly visible for POLA-01 and VICE 01 dataset as a rapid decrease in the events rate on May 10th. Instead for LAQU 01, the variable trend of the normalized rate suggests the existence of other effects that can influence the distribution of the rates, in addition to the barometric effect.

Forbush Decrease

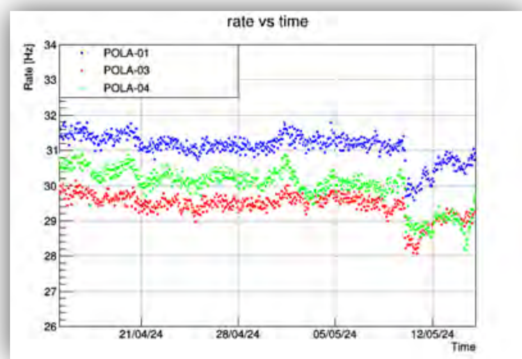
Liceo <<G. Banzi Bazoli>>, Lecce, Italy

We are students from the "G. Banzi Bazoli" scientific high school in Lecce, Italy. We are part of the **EEE collaboration**, which aims to study cosmic rays using a network of MRPC detectors spread across Italy and four scintillator detectors (POLA-R). Three of these telescopes (pola01, pola03, and pola04) are located in the Svalbard Islands.

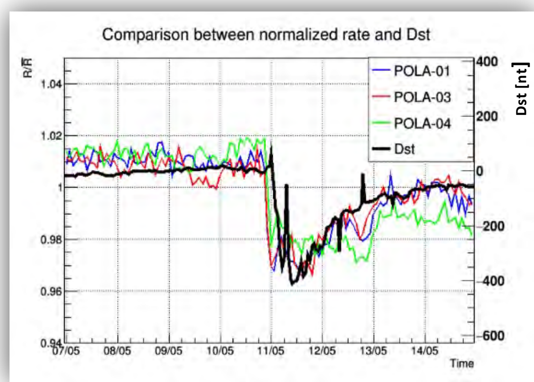
What have you done?

The aim of our analysis is to investigate the behavior of the secondary cosmic ray flux during the magnetic storm of May 11–13. To achieve this, we analyzed three data samples acquired from 16/04/2024 to 15/05/2024 by the scintillator telescopes Pola-01, Pola-03, and Pola-04.
First, we corrected the rate of secondary cosmic rays for the barometric effect and then plotted it against time, focusing on the time window during which the geomagnetic storm occurred.
We also used data provided by the **World Data Center for Geomagnetism, Kyoto,** regarding the Dst index, which quantifies the intensity of a magnetic storm, and compared the flux trend with that of the Dst index, to highlight any possible correlation between these two quantities.
We performed our analysis with ROOT.

What did you find out?



This graph shows a decrease in cosmic ray flux during the magnetic storm.



This graph shows a strong correlation between the flux and the dst index.

What's your take-home message?

We observed that during a magnetic storm, the flux of secondary cosmic rays decreases (**Forbush decrease**) because the solar wind strengthens the Earth's magnetic field, providing greater shielding from cosmic rays.

INTERNATIONAL COSMIC DAY

Project E.E.E. – Science in the schools

LICEO STATALE "CAGNAZZI"
70022 Altamura (BA) P.zza Zanardelli, 30 -
– Tel 0803111707 - 0803106029 (fax) 0803113053 e-mail:bapc030002@istruzione.it; WEB: www.liceocagnazzi.edu.it

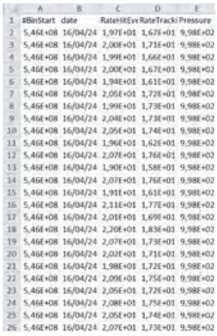
Who are you?

We are a team of students from the project EEE of the Liceo Cagnazzi, situated in Apulia (south of Italy),from the classes 3B ES, 3C CL, 4B LC and 5C CL. The project was coordinated by the teachers Maria Rosaria Cornacchia, Anna Palasciano and Maria Saveria Vicino. -Principal Claudio Crapis

What have you done?

We analyzed and compared the data collected by detectors BOL0-02, CAGL-01 e POLA-01, installed respectively in Bologna, Cagliari and Ny Alesund (Svalbard, Norway) during the period from 16 April 2024 to 15 May 2024. The intention of this study was to identify the Forbush's Effect, which happened on 10 May 2024.

We noticed that there is an inverse relation between the Rate Hit Events section and the Pressure: when the pressure increases, the rate decreases.
This is the the Barometric Effect.



	A	B	C	D	E
1	#BinStart	date	RateHitEve	RateTrack	Pressure
2	5,46E+08	16/04/24	1,97E+01	1,67E+01	9,98E+02
3	5,46E+08	16/04/24	2,00E+01	1,71E+01	9,98E+02
4	5,46E+08	16/04/24	1,99E+01	1,66E+01	9,98E+02
5	5,46E+08	16/04/24	2,00E+01	1,67E+01	9,98E+02
6	5,46E+08	16/04/24	1,94E+01	1,61E+01	9,98E+02
7	5,46E+08	16/04/24	2,05E+01	1,72E+01	9,98E+02
8	5,46E+08	16/04/24	1,99E+01	1,73E+01	9,98E+02
9	5,46E+08	16/04/24	2,04E+01	1,73E+01	9,98E+02
10	5,46E+08	16/04/24	2,05E+01	1,74E+01	9,98E+02
11	5,46E+08	16/04/24	1,96E+01	1,62E+01	9,98E+02
12	5,46E+08	16/04/24	2,07E+01	1,76E+01	9,98E+02
13	5,46E+08	16/04/24	1,90E+01	1,58E+01	9,98E+02
14	5,46E+08	16/04/24	2,07E+01	1,76E+01	9,98E+02
15	5,46E+08	16/04/24	1,91E+01	1,61E+01	9,98E+02
16	5,46E+08	16/04/24	2,11E+01	1,77E+01	9,98E+02
17	5,46E+08	16/04/24	2,01E+01	1,69E+01	9,98E+02
18	5,46E+08	16/04/24	2,20E+01	1,83E+01	9,98E+02
19	5,46E+08	16/04/24	2,07E+01	1,73E+01	9,98E+02
20	5,46E+08	16/04/24	2,02E+01	1,71E+01	9,98E+02
21	5,46E+08	16/04/24	1,98E+01	1,72E+01	9,98E+02
22	5,46E+08	16/04/24	2,09E+01	1,75E+01	9,98E+02
23	5,46E+08	16/04/24	2,05E+01	1,72E+01	9,98E+02
24	5,46E+08	16/04/24	2,08E+01	1,75E+01	9,98E+02
25	5,46E+08	16/04/24	2,05E+01	1,74E+01	9,98E+02
26	5,46E+08	16/04/24	2,07E+01	1,73E+01	9,98E+02

Then we moved on with the barometric correction of the data through the relation:

Corrected Rate = Measured Rate/exp(αΔP)

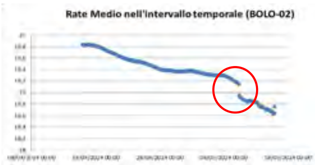
where α is the value of the barometric coefficient, determined experimentally, while ΔP is the difference between the measured pressure and a reference pressure set at 1000 mbar.

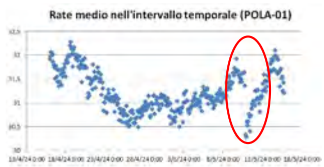
What did you find out?

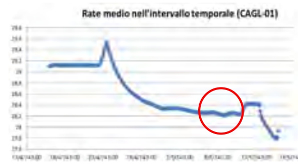
With the purpose of observing the result of the Forbush Effect it was essential to:

- correct the muons' rate measured according to the Barometric effect.

The Forbush Effect will be identified into the minimum of the generated graphic.







Analysing the graphic of the corrected rate, we noticed in all 3 detectors a clear decrease of about 4-5% of the cosmic rays' number in the period around 10 May, then we were able to see the Forbush's Effect.

The different latitude and the different weather of the sites, where the detectors are placed, didn't influence the cosmic rays' detection.

Using the percentage decrease, the effect is the same.

What's your take-home message?

This experience gave us the opportunity to analyse the data, develop the results and come to a reliable conclusion through the scientific method. The close contact with subatomic particles' world prompted in us a great interest, that will lead us to further investigations, of course. We really hope that these attempts can give a relevant support to scientific research in the future.

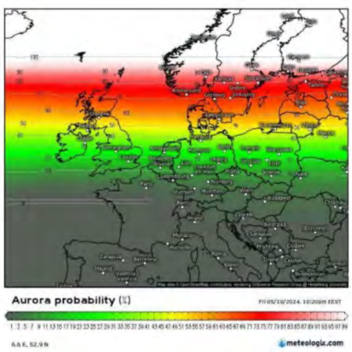
Who are you?

We're a group of students from the last three years of Liceo Scientifico Federico II di Svevia, Altamura. We're from different classes and we are coordinated by professor Giovanna Loporcaro.

What have you done?

We analysed data collected by EEE Project telescopes concerning the variations of the muon flux during the Solar Flare on the 10th May 2024. For each chosen file, Vicenza, Bologna, Cagliari and L'Aquila, we have calculated the barometric correction coefficient and made a final graph reporting medium rate, corrected by barometric coefficient, in function of the date.

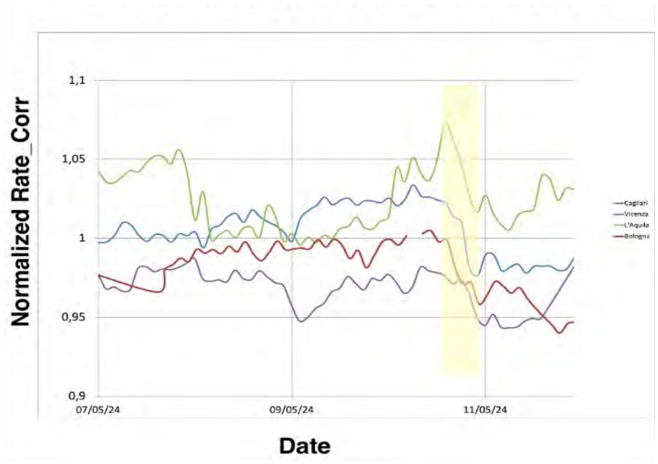
We have reported below the distribution of the flare in the northern emisphere.



What did you find out?

Here we report the graphs showing the EEE muon rate measured by the telescopes in Bologna, Vicenza, L'Aquila e Cagliari. The plots show the muon rate corrected fot barometric effect and normalised to the avarage rate of the telescopes .

Normalized Muon Rate



What's your take-home message?

In the four Italian cities whose data we analyzed, the graphs show a simultaneous decrease in rates Starting from the early afternoon of May 10th. This indicates that the solar flare creates a shielding effect, preventing cosmic rays from reaching Earth's atmosphere, known as the Forbush effect.

The Forbush Effect

Liceo Scientifico Internazionale Luigi Galvani

M. Benni, J. Castellucci, M. Ciccone, D. De Rosa, Y. Feraru, Marucci, L. Patricolo, A. Pollicoro, A. Santi, L. Taglio, E. Tassinari, R. Zuffa.

BOLOGNA, ITALY

Credit: DESY, Science Communication Lab

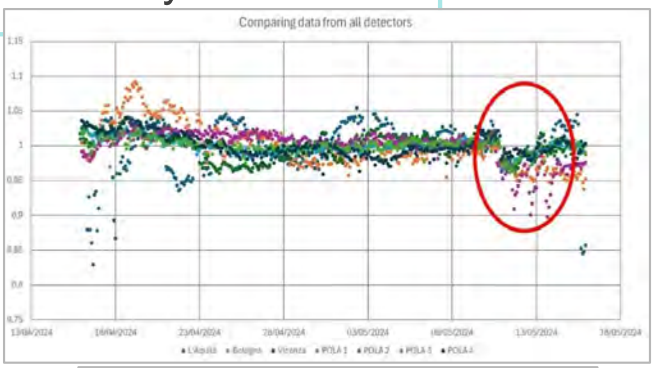
Who are you?

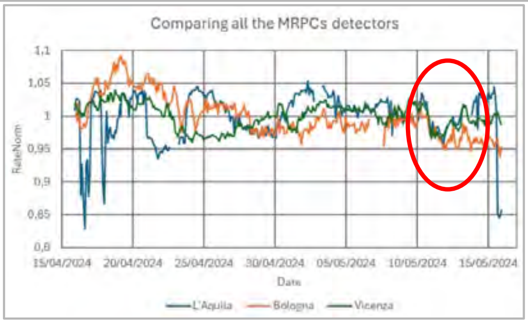
Our international school - Liceo Galvani of Bologna - has been involved in the Extreme Energy Event (EEE) project since 2006. Here we present our analysis of the data collected by the Svalbard Islands' detectors POLA01, POLA03 and POLA04, Bologna's detectors POLA02 and BOLO02, Cagliari's detector CAGL01, L'Aquila's detector LAQU01 and Vicenza's detector VICE01 between 16/04/2024 and 15/05/2024.

What have you done?

In this analysis we study and compare variations in muon flux during the Solar Flare event beginning on May 10, 2024.
We were given different sets of data from 8 different detectors regarding the period between the 15th of April 2024 and the 15th of May 2024
These data sets included the pressure and the rates of events expressed in both HitEvents and TrackEvents.
In the data analysis we corrected the rates based on the relative pressure using a calculated barometric coefficent, then we studied the variations of the mean rate of Hit and Track events during the 30 days, both with and without the barometric correction. Since HitEvents could also take into account events that are not muons we decided to continue our analysis with the rates of TrackEvents with the barometric correction. By normalising these data we were able to compare the fluctuations of all the detectors, highlighting the correlations between the rate decrease and the solar Flare.

What did you find out?

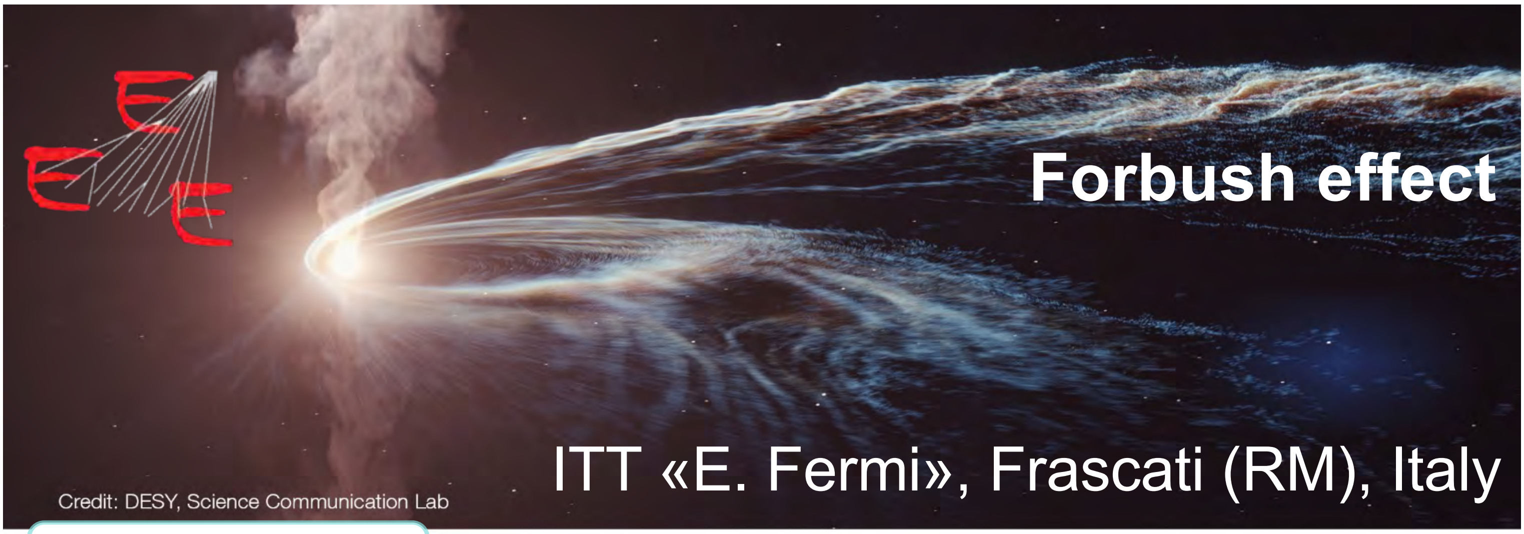




We found out that all the detectors show a decrease around 4% between 10/05 and 13/05 even if there are differences in fluctuation between POLA and MRPC detectors. RateHit and RateTrack data show the same decrease in muon flux, even though RateHit's data is shifted upwards on the graph. Rates fluctuate less with barometric correction than without correction.

What's your take-home message?

Our analysis confirmed that, according to literature on the Forbush effect, the rate of events decreases due to the interference of coronal mass expulsions (CMEs) with the interplanetary magnetic field (IMF), in agreement with the results of many papers, e.g. M. Abbrescia *et al.*'s E.P.J. Plus (2013) 128: 62.



Forbush effect

ITT «E. Fermi», Frascati (RM), Italy

Credit: DESY, Science Communication Lab

Who are you?

We are a group of students from the ITT «E. Fermi di Frascati (E. Cannone, A. Cataldo, F. Englaro, G. Fatelli, N. Luciani, C. Profili), physics enthusiasts, coordinated by Prof. G. Conforto. We worked with the guidance and support of Prof. E. Purchi.

What have you done?

We analyzed with Excel the data of the VICE-01 and POLA-01 stations, making barometric corrections on the muon rate, in the period between mid-April and mid-May 2024. We built several graphs showing the trend of the muon rate (secondary cosmic rays) to search the effects due to the exceptional geomagnetic storm (CME) of 10/05/2024. We compared the data with those of the neutron detection station of the University of OULU.

What did you find out?

We detected the Forbush Effect on May 10, due to a significant solar coronal mass ejection (CME). The phenomenon caused visible effects in Italy and was also detected by the scientific station in Oulu.

What's your take-home message?

EEE telescopes with the new gas mixture correctly detected the event of May 10, 2024. It was an exceptional event classified as a G5 (max) level magnetic storm! Events of this type can cause blackouts and collapse of some electrical networks, damage to transformers, prevent the propagation of radio waves in some areas, degrade communications with satellite navigation systems for a few days.

Observation of Forbush decrease

Liceo Scientifico “A. Scacchi”, Bari - Italy

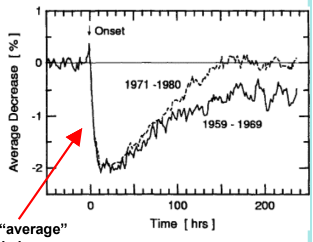
Who are you?

We are the team EEE (Extreme Energy Events) from Liceo “A. Scacchi”, Bari-Italy

What have you done?

It was carried out a correlation analysis between neutron counting rates from the neutron monitor station, OULU, and the muon rate from three EEE muon telescopes, during the Forbush Decrease on May 10th, 2024.

Forbush Decrease (FD) is an important transient variation of the cosmic ray flux characterized by a rapid percentage decrease.



plot of “average” Forbush decrease

For our observation we had to take in consideration the barometric effect, a consequence of the mass absorption of muons in the Earth’s atmosphere.

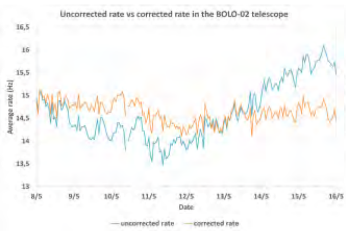


Fig. 1 *Uncorrected rate vs corrected rate in the BOLO-02 telescope*

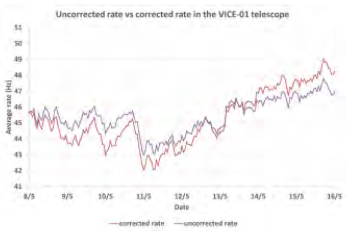


Fig. 2 *Uncorrected rate vs corrected rate in the VICE-01 telescope*

What did you find out?

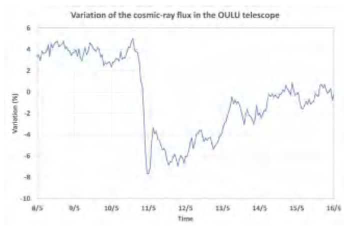


Fig. 3 *Variation of the cosmic-ray flux in the OULU telescope*

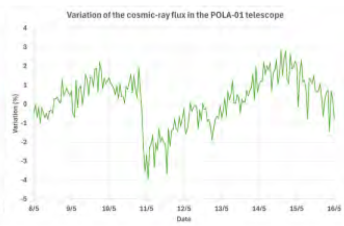


Fig. 4 *Variation of the cosmic-ray flux in the POLA-01 telescope*

After correcting the data measured by the telescopes for the pressure variations, the count rate in the telescope was extracted and plotted as a function of the time, for the period May 7 to 16, as shown in **Fig. 3** and **Fig 4.** In conclusion, we compared the cosmic-ray flux of the EEE telescopes with the neutron flux of the Oulu neutron station, as shown in **Fig. 5.**

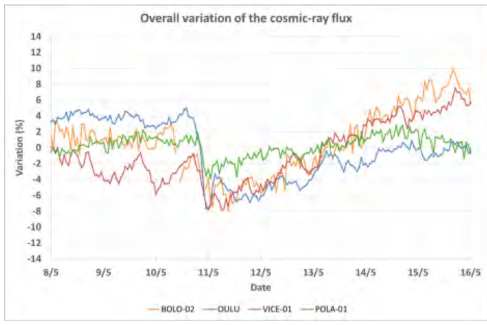


Fig. 5 *Overall variation of the cosmic-ray flux*

What's your take-home message?

The data extracted by the three telescopes were found to be highly correlated with those measured by neutron monitor stations, although this is more sensitive to low-energy primaries, whereas muons detected in the POLA-01, BOLO-02 and VICE-01 EEE telescopes originate from higher-energy events in the atmosphere.

Forbush Effect Data Analysis

Liceo scientifico G.B. Scorza, Cosenza, Italy

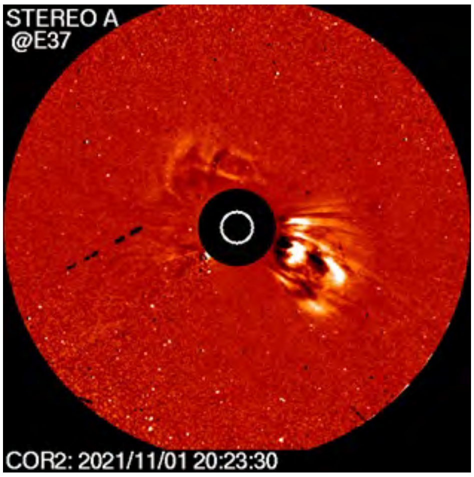
Credit: DESY, Science Communication Lab

Who are you?

We are a group of high school students from Liceo Scorza (Veronica Granata 5G, Anastasia Spataro 5Bbio, Lorenzo Cavalcanti 5Bbio, Giuseppe Bosco 5Bbio, Cristina Giardiello 4 A, Mattia Mazzuca 5G and the Physics student at Unical Salvatore Giordano), led by our teachers Prof. Franco Mollo and Prof. Daniela De Salvo.

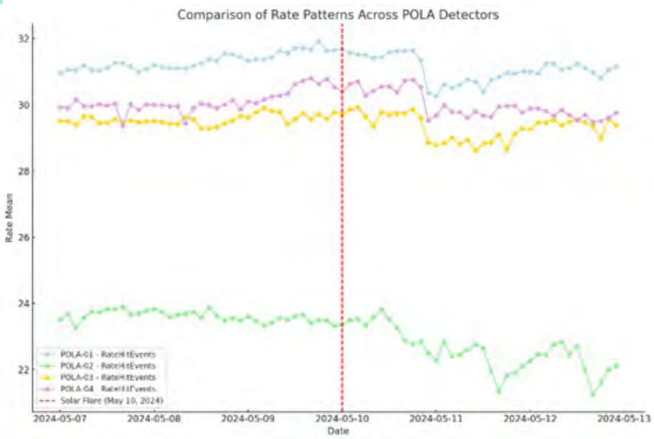
What have you done?

We've carried out a data analysis to check if the Forbush Effect caused by the extreme Geomagnetic Storm that had its peak on May 10th affected in any way the rate of the cosmic rate measured.



What did you find out?

After correcting the data according to the barometric effect, we created a scatter plot to highlight the cosmic rays' rate as a function of time. We did that for different EEE detectors (both MRPCs based telescopes and POLA-R) and verify that the Forbush effect definitely lowers the cosmic rays' rate.



What's your take-home message?

Scientific reaserch is tough, but if you have passion, every problem will eventually be overcome!

Headline

Institution or School, Country

Credit: DESY, Science Communication Lab

Who are you?

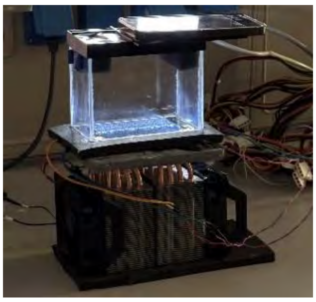
We are two students from the Jean Monnet high school in Mariano Comense (CO) from class 4B of the scientific high school of applied sciences. Carpani Giulia, Kovalchuk Nazariy

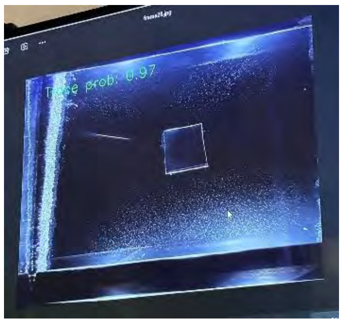
What have you done?

The cloud chamber is an instrument used to visualize the paths of subatomic particles, such as muons from cosmic rays. It contains oversaturated alcohol vapor in a low-temperature environment. When a muon passes through, it ionizes gas molecules along its path, creating condensation nuclei. The vapor condenses around these ions, forming visible trails of droplets. Muons, produced by cosmic rays interacting with air molecules, travel at near-light speeds and leave straight tracks in the chamber, allowing their observation and study.

What did you find out?

Using the cloud chamber, we discovered how to identify subatomic particles from cosmic rays, such as muons and other charged particles. This has provided a better understanding of the interaction of cosmic rays with the Earth's atmosphere.
Cosmic rays are high-energy particles from outer space that enter the Earth's atmosphere. When these particles hit atoms in the atmosphere, they produce a cascade of secondary particles, including muons, electrons, photons and other unstable particles, which can be visualised in the cloud chamber.





What's your take-home message?

Following an unsuccessful analysis of the cloud chamber data, we learnt that experiments are not always successful, but that does not mean they are useless.

Training of an AI used for the detection of particle trails

Jean Monnet, Mariano Comense, Italy

Credit: DESY, Science Communication Lab

Who are you?

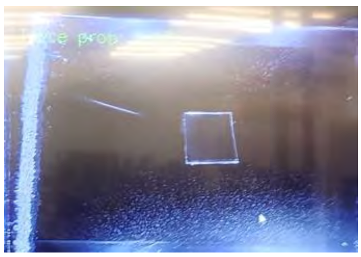
We are Stefano Passaretti, Edoardo Zanella, Riccardo Iannantuoni, Nikolas Dimarzio and Gabriel Vozza.

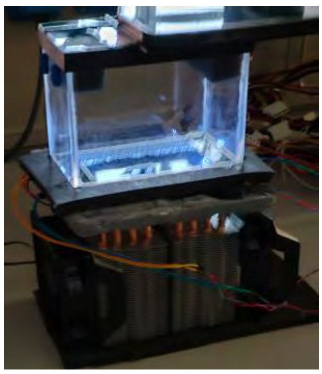
What have you done?

In the afternoon we tried to train an AI used to detect trails left by particles, for example, muons. First, we made a video with a phone of the inside of a cloud chamber. Then we proceeded to examine many photograms from the video, and we classified every photo based on the presence or absence of a trail. After we finished, we uploaded all the information on an AI that learnt from our decisions.

What did you find out?

Unfortunately, we failed because there weren’t enough photos with trails. However, it’s all part of the scientific method, so we learnt how to do actual research and how to keep going experimenting.





What's your take-home message?

Failure isn’t always bad, in fact, failure from a scientific point of perspective is always a success.

ICD 2024

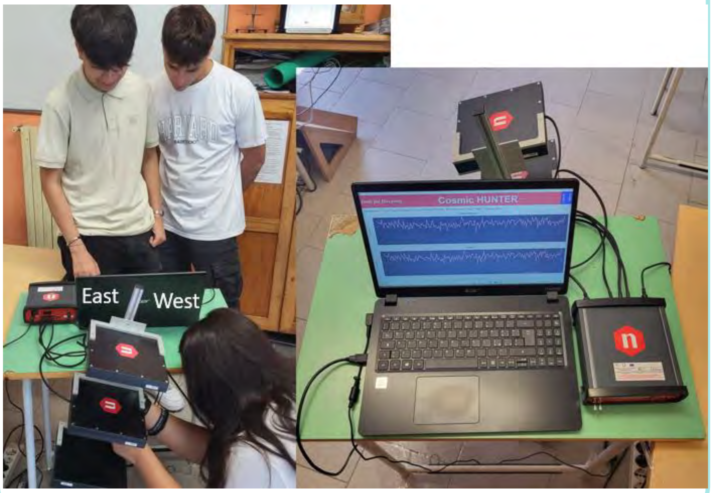
Liceo Scientifico ''Stefano Patrizi'' - Cariati (CS) Itali

Who are you?

We are the alumns of the IV-A and IV-B

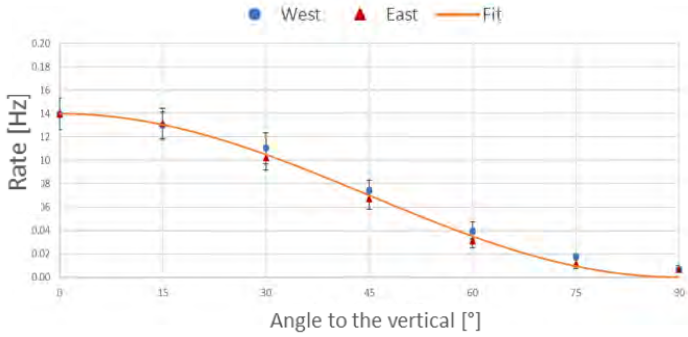
What have you done?

As a cosmic ray detector we used the Cosmic Hunter, a CAEN educational instrument based on silicon photomultipliers (SiPM), it consists of a coincidence detector unit together with three 15cm x 15cm scintillating plastic tiles.
The supplied mechanics allow the orientation of the detector at different angles and an adjustable geometry depending on the distance between the tiles. In our case the distance between the tiles was 13.5cm and we acquired triple coincidences.

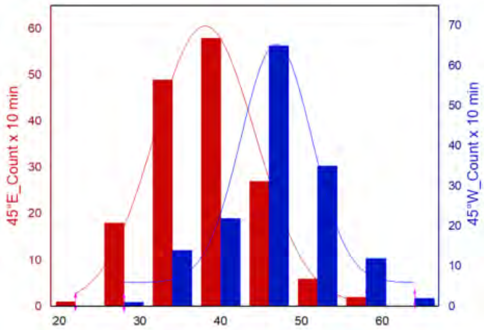


What did you find out?

The measurement of the cosmic ray flux as a function of the azimuth angle, from east and west, shows a behavior like the square cosine function.



Comparison of the frequency histograms at 45° east and west shows evidence of the east-west effect due to the interaction of cosmic rays with the Earth's magnetic field, which favors the west as the direction of arrival.



What's your take-home message?

The message we will take home is that through the analysis of cosmic rays we can gain insights into cosmic phenomena and the laws that govern them.

ANGULAR DISTRIBUTION OF COSMIC RAYS

Liceo Statale Luca de Samuele Cagnazzi

Altamura, (BA) P.zza Zanardelli, 30
Tel. 0803111707
email : bapc030002@istruzione.it
Web : www.liceocagnazzi.edu.it

Credit: DESY, Science Communication Lab

Abstract

We are A. Basile, M. Crapuzzo, E. Lorusso and V. Perrucci, students of the Cagnazzi high school in Altamura(BA). During the International Cosmic Rays Day 2024, we went to the Physics department of Bari to analyze cosmic rays. Coordinators: Professors M.R. Cornacchia, A. Palasciano, A. Farella and M.S. Vicino. School principal: Claudio Crapis.

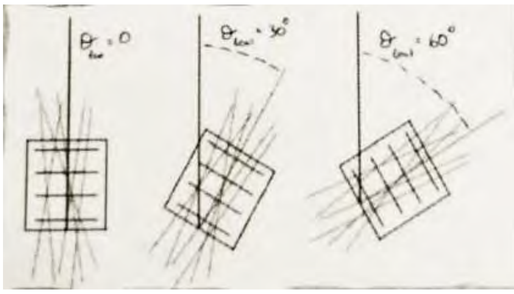
Experimental Setup

The experiment uses a telescope that can be tilted at different angles, which can be measured by a protractor placed on the sides. The telescope thus can measure the rate of cosmic rays at different angles and show how the rate is affected by the angle at which it is measured.
When muons pass through the telescope, a red LED lights up, and the data is recorded on a computer. We used this data to conduct our experiment. The experimental apparatus consists of these components:

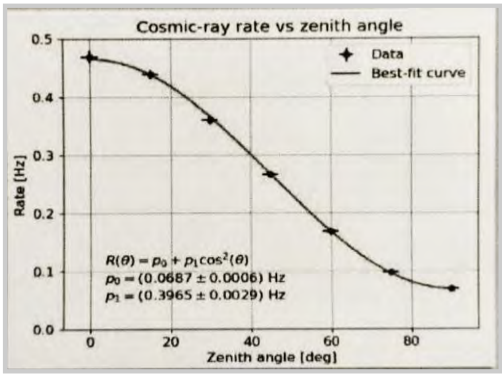
- Mechanical frame: allows adjustment of the zenith angle.
- Two plastic scintillator modules, read laterally by sensors called silicon photomultipliers (SiPM).
- Dedicated readout electronics that allows the sensor signals to be read and return a coincidence signal that detects the passage of muons on both scintillators.

Analysis

We verified how the flux of muons varies as a function of the angle they form with the local zenith. We also measured the rate of these particles interacting with the detector at different angles (R=N of particles/Δt).

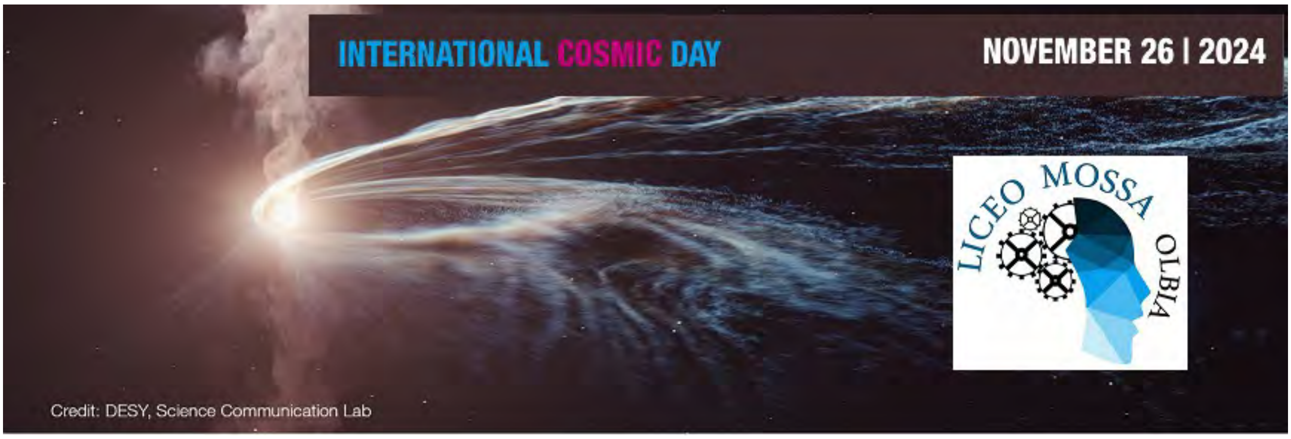


We then created a graph, through which we showed that the distribution of measured values can be described using the function $\cos^2\theta$



Results

We were given the opportunity to have this collaborative experience with other students from our region and researchers from the physics department, which helped us not only to learn more about what cosmic rays are but also to learn and work as a team. Special thanks to the researchers from INFN Bari who helped and followed us during the activity.



Introduction

We are a group of students from the Mossa High School in Olbia, located in northern Sardinia, interested in studying cosmic rays. Last year, we examined the distribution of cosmic ray flux as a function of zenith angle. This year, we attempted to replicate the experiment conducted by the Italian physicist Domenico Pacini more than 100 years ago, which, along with Hess's experiments, demonstrated the existence of cosmic rays. Pacini used electroscopes to measure the ambient electric charge in the sea at various depths, showing that it decreased, thus hypothesizing the presence of a significant ionizing cause in the atmosphere, involving penetrating radiation, independent of the direct action of radioactive substances in the ground.

Geiger counter inside the waterproof container

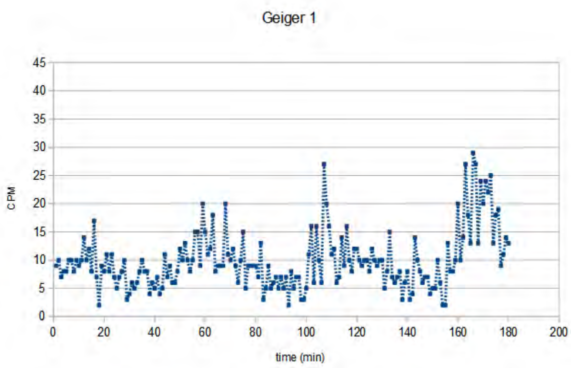
Experimental Set-up

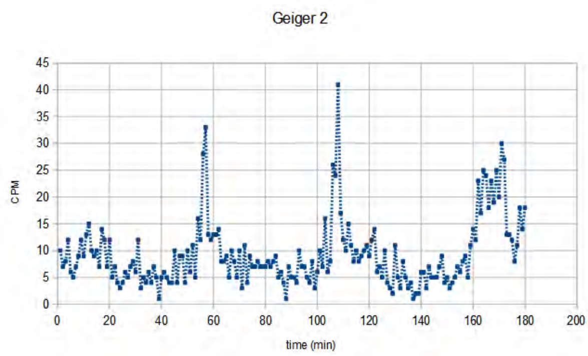
The technology used to reproduce the experiment is vastly different from what was available 100 years ago. We used two GammaScout Geiger counters, which can record the number of signals detected per minute, store the data, and later transfer it to a PC.

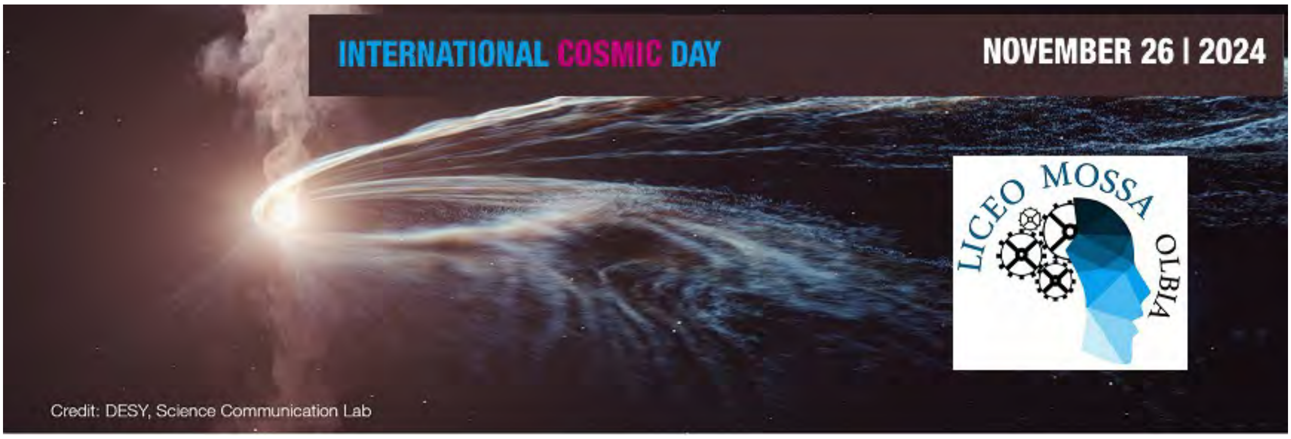
The Geiger counters were placed inside a waterproof container and lowered into the water using a graduated rope marked at 50 cm intervals. Using a dinghy, two teams of students departed from the Olbia Naval League pier. The dinghy was anchored several hundred meters from the shore at a location with a seabed depth of about 6 meters. The Geiger counters were submerged at six different depths, spaced 50 cm apart, for five minutes, down to a maximum depth of 3 meters. Four additional teams of students repeated the measurements at roughly the same location, resulting in a total of six sets of data.

Report of our results

These two graphs show the counts per minute (CPM) measured by the two Geiger counters during the three trips of the dinghy from the pier to the anchoring point and during the measurement phase. The drop in counts during depth measurements and the rise when returning to the pier are evident.







The count-per-minute (CPM) measurements were plotted on a Cartesian graph as a function of depth. One of the most significant data sets is shown in fig.1. It clearly demonstrates a decrease in counts as depth increases, followed by a saturation of values beyond 200 cm.

Depth (cm)	CPM
0	12,4
50	9,0
100	8,6
150	7,0
200	6,0
250	5,8
300	5,8

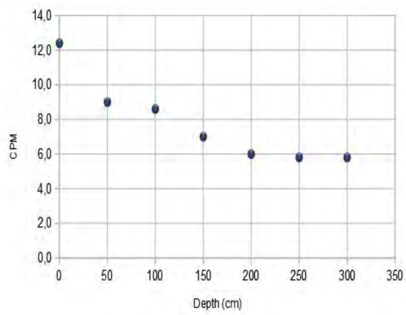


Fig.1

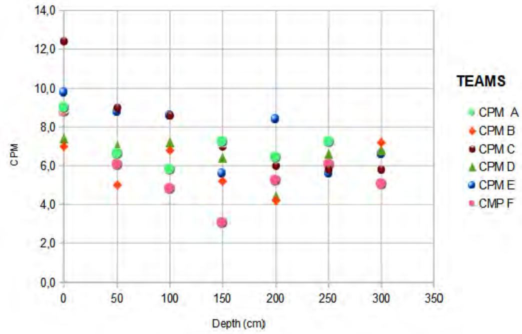
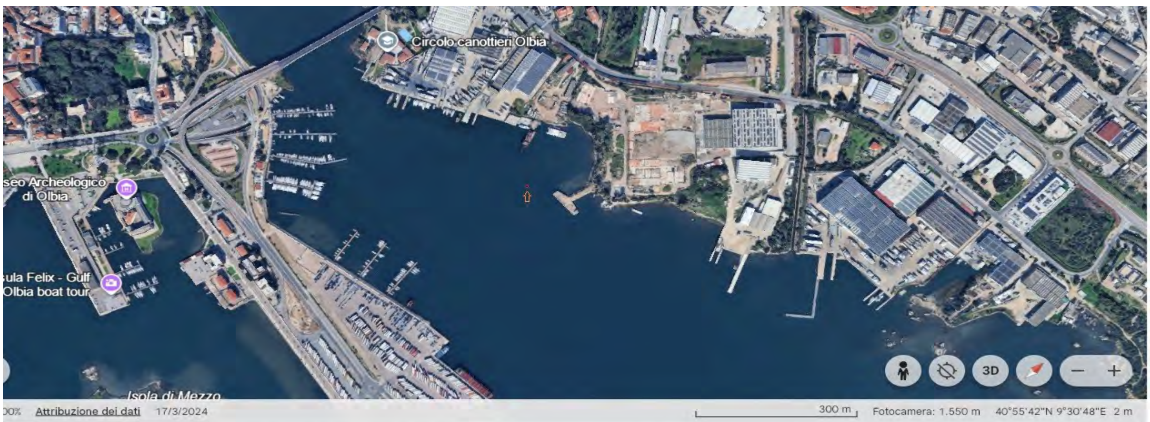


Fig.2

The second graph (fig.2) displays all six sets of measurements from the six teams. Although there is considerable variability among the values, the general trend of decreasing counts with increasing depth is evident.
A relative increase in counts observed at 2 meters could be attributed to the presence of ionizing particles emitted by algae and/or encrustations of marine organisms likely present along the anchor chain of the buoy where the boat was moored. This phenomenon of radioactive elements (i.e. Thorium 232) accumulation by certain marine organisms, such as coralline algae, is well-documented in scientific literature.

Next projects

In the future, we plan to conduct measurements in more open waters with deeper seabeds and, as a countercheck, take measurements near seabeds rich in algae.



Gulf of Olbia

INFN OCRA Outreach Cosmic Ray Activities

INFN PADOVA Istituto Nazionale di Fisica Nucleare Sezione di Padova

Dipartimento di Fisica e Astronomia Galileo Galilei

International Cosmic Day 2024

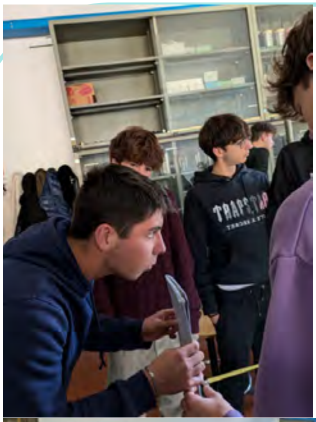
INFN Padova Division and
Department of Physics and Astronomy, University of Padova, Italy

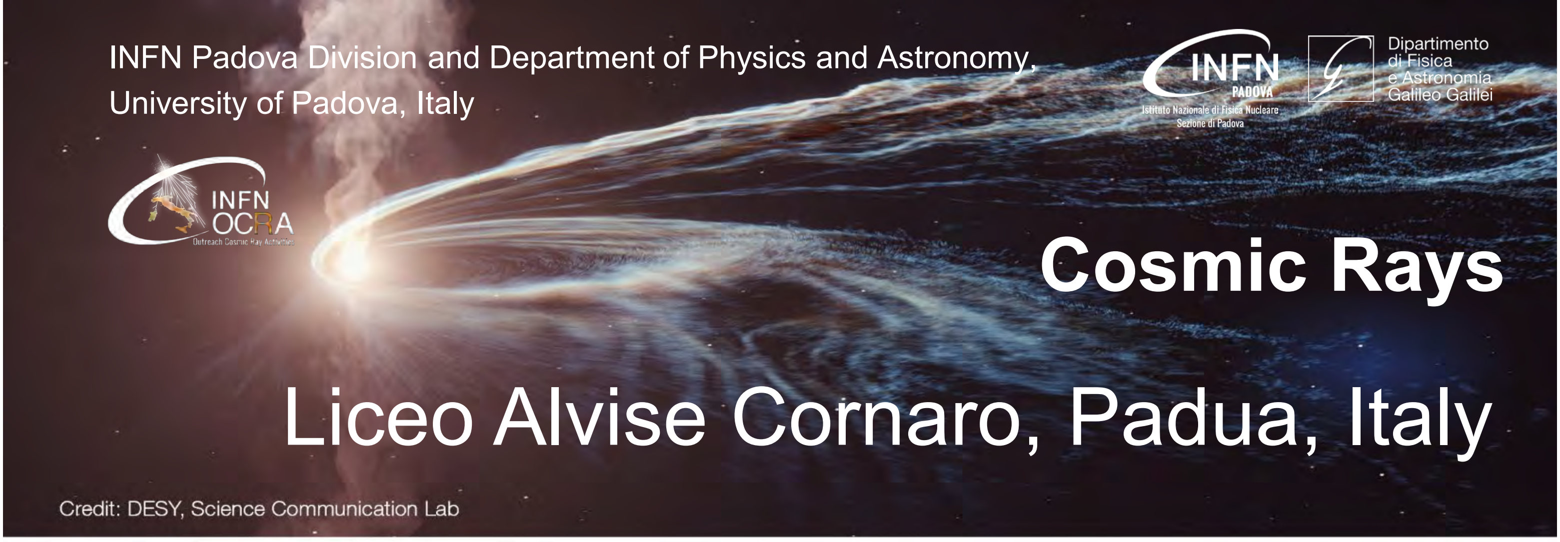
Credit: DESY, Science Communication Lab

Who are you?

The International Cosmic Day 2024 in Padova was organized by the OCRA group of the INFN Padova Division and the Department of Physics and Astronomy of the Padova University. The activities took place at the Department of Physics.

The researchers from INFN and University were joined by 36 students from 11 upper secondary schools: Licei Scientifici “Cornaro”, “Curiel”, “Fermi”, “Nievo”, and Liceo Classico “Tito Livio” from Padova, Liceo Scientifico “Da Ponte” from Bassano, Liceo Scientifico “Newton-Pertini” from Camposampiero, Liceo Scientifico “Morin” from Mestre, Liceo Scientifico “Rolando Da Piazzola” from Piazzola sul Brenta, Liceo Scientifico “Galilei” from Selvazzano, and Liceo “Benedetto Tommaseo” from Venice.





INFN Padova Division and Department of Physics and Astronomy, University of Padova, Italy

INFN OCRA

Cosmic Rays

Liceo Alvise Cornaro, Padua, Italy

Credit: DESY, Science Communication Lab

Who are you?

We are three students form the fifth class of Liceo Cornaro in Padua: Fiocco Ilaria, Montecassiano Matteo, Orfano Leonardo

What have you done?

We attended two lectures at the University of Padua, where we were introduced to the study of Cosmic Rays. During the first session, there was an introductory lesson on the origin and study of these rays, including a brief mention of the history of the scientists who worked on them. We learned how the instruments that detect cosmic rays work and during the second session we used one of these detectors to conduct a study: we calculated the function that links the rate of passage of the rays with the inclination angle of the detector.

What did you find out?

Cosmic rays are atomic and subatomic particles that come to Earth and they can have a very high energy. Entering the atmosphere, they generate a particle shower. At ground level we can measure muons (subatomic particle). The detector marked the passage of muons and we found that by increasing the angle with the normal, the number of muons reported decreased. The trend of the transition as a function of angle can be studied by means of a graph.The model is the graph of the mathematical function is n*(cosx)^2. Where x is the inclination of the telescope, and n is the flux of particles on the vertical (n= 221 in 6 min)

What's your take-home message?

We learned about the Cosmic Rays, particles that come from the space which are still being studied nowadays. We have also seen how the world of physic is structured about this topic.

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University of Padova, Italy

INFN OCRA

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Dipartimento di Fisica e Astronomia Galileo Galilei

Cosmic Rays

Liceo Scientifico Eugenio Curiel, Padua, Italy

Who are you?

We are three students from Liceo scientifico Curiel in Padua.

What have you done?

We observed, analyzed and calculated the possible amount of muons thanks to a specific "telescope" positioned at different angles

What did you find out?

We managed to see the amount of mouns in that specific place with specific angles and we grouped these results into a graph

What's your take-home message?

Working in group not only makes the experience more efficient, but more funny and interesting too.

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INFN Padova — Dipartimento di Fisica e Astronomia Galileo Galilei

Cosmic Rays

Liceo Scientifico E. Fermi, Italy

Credit: DESY, Science Communication Lab

Who are you?

Aduso Cesare, Stolfi Letizia, Trivelloni Rebecca

What have you done?

We attended a preparatory lesson about cosmic rays, and we learned about what those are, from where they come, how we can study them, and why it is useful to do so. In another meeting we proceeded to take some measurements with a muon detector.

We then collected the data measured by our team and the other groups. We inserted the data found in a table, and we made a graph.

What did you find out?

We found out that the muons that we managed to measure are secondary particles and we can consider them as messengers from remote regions of the space and by studying them we can learn more about our galaxy and other cosmic phenomenons that take place far from us.

What's your take-home message?

There’s so much more we still don’t know about the Universe, and so much more we could find out in the future, and research is the only means we have to keep going in this field.

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Dipartimento di Fisica e Astronomia Galileo Galilei

INFN OCRA Outreach Cosmic Ray Activities

COSMIC RAYS AND MUONS

Liceo scientifico Ippolito Nievo, Italy

Credit: DESY, Science Communication Lab

Who are you?

We are 3 students from Liceo Scientifico Ippolito Nievo in Padua, Italy: Matilde Barigazzi, Riccardo Tormene and Shan Yu Zhou.

What have you done?

On November 26 2024. the ICD, many students from different schools gathered at the department of physics of the University of Padua. During the morning, the professors gave us an introduction to cosmic rays, atomic and subatomic particles. Then they showed us different scintillators and explained their use. After that it was our time to take some measurements and we were divided in four groups. The aim was to measure the number of muons that passed through the two scintillating tiles of the telescope at a certain angle, so we had to verify the relation between the muon rate and the inclination of the detector. At the end we made a short presentation about the work we've done.

What did you find out?

Our analysis showed a clear trend: the number of muons detected depends strongly on the angle of tilt of the detector. We observed the highest count of particles around 0°, where the telescope was oriented vertically. This aligns with theoretical expectations, as muons traveling vertically experience the least atmospheric resistance. As the angle increased or decreased from the vertical, the number of particles detected dropped significantly, reflecting the increased atmospheric thickness muons need to penetrate at lower angles. These findings confirm the correlation between the flux of cosmic ray particles and the angle of observation, providing a practical demonstration of muon attenuation as predicted by particle physics models.

What's your take-home message?

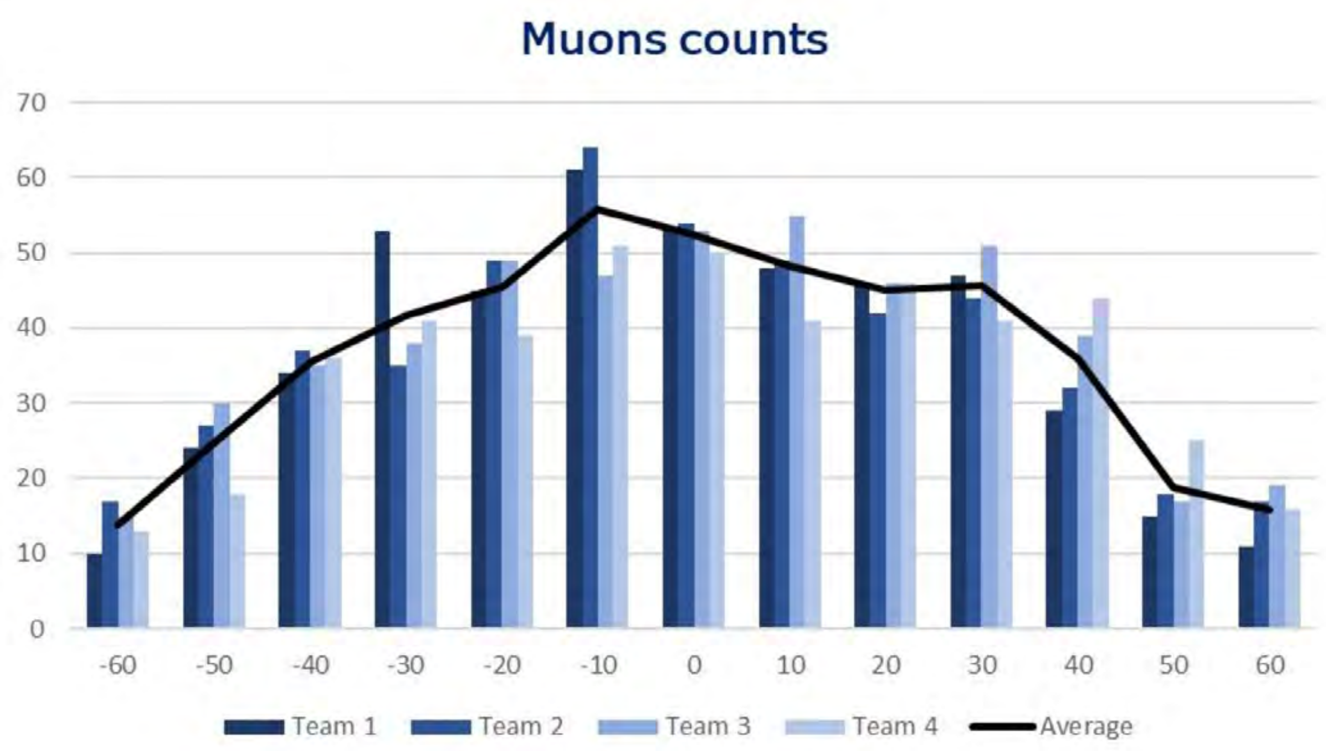
An important takeaway from this experience was the extraordinary connection between our planet and the universe, which often goes unnoticed in daily life. For example a fact that many people don't know is that every second, on every square centimeter of Earth's surface, subatomic particles, like muons, reach us.

COSMIC RAYS AND MUONS

Liceo scientifico Ippolito Nievo, Italy

Credit: DESY, Science Communication Lab

Final graph



INFN Padova Division and Department of Physics and Astronomy,
University of Padova, Italy

COSMIC RAYS

Liceo Tito Livio, Padua, Italy

Credit: DESY, Science Communication Lab

Who are you?

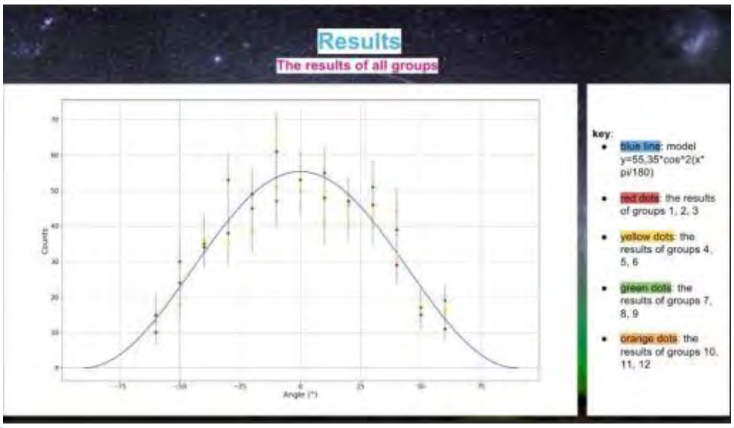
We are Riccardo, Federico and Anna, and we attend the classical high school Tito Livio, in Padua.

What have you done?

The activities were divided in two days: in the first meeting we learned some introductive information about cosmic rays like their substance, their origin or their presence on the Earth, and then we visited the Poleni museum. In the second meeting, we made some experiments in order to better understand the identity of the cosmic rays. After that we prepared a power point, with a summery of our experiments made during the morning, and we presented it to other schools in a videocall.

What did you find out?

With the experiments made we found out that comic rays surround us every day, in every moment. Our goal was to estimate the dependence of the cosmic ray rate on the angle of incidence, so we used a telescope for muons. Then we arranged a graphic based on this information, and we saw that the dependence of the cosmic ray rate on the angle of incidence can be described as the $\cos^2$ function.



What's your take-home message?

This experience has taught us the importance of the cosmic rays and the influence on our lives, but also has improved our skill in teamwork and research.

Credit: DESY, Science Communication Lab

International Cosmic Day

Liceo Jacopo Da Ponte, Italy

Who are you?

Our names are Bevilacqua Sophia, Bordignon Stefano and Sonda Vittorio. We are currently enrolled in our fourth year of scientific high school (grade 12).

What have you done?

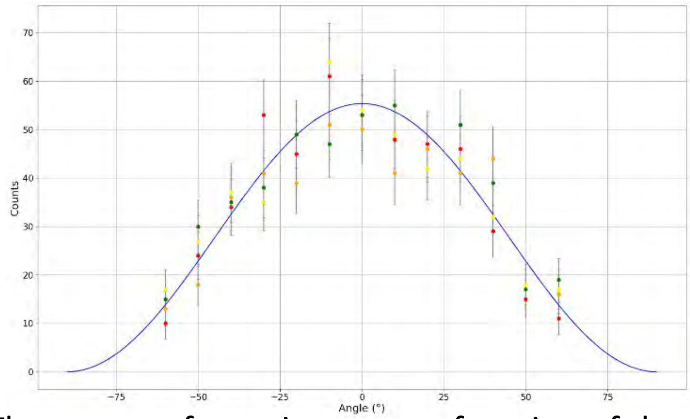
In the initial session, we were instructed in the fundamental concepts of astronomy, including supernovae, black holes and stellar objects. Subsequently, the focus shifted toward cosmic rays, namely particles that reach Earth with high speed, such as muons, gamma rays, protons, and helium nuclei.

Then we learned how physicists study cosmic rays, in order to introduce the experiment we were going to carry out during the following lesson.

During the second lesson we used a telescope, which in this context is a scintillator detector, to analyze the relationship between the dectetor's inclination(zenith angle) and the number of particles(predominantly muons) passing through it.

The Poisson distribution is used to estimate the uncertainty.

What did you find out?



The counts of cosmic rays as a function of the angle are well interpolated from a curve whose equation is the graph of the mathematical function $c = n \cdot \cos^2 x$; where x is the angle (°) on the horizontal axis, c is the counts on the vertical axis, n is the maximum flux that occurs for $\theta = 0°$(particles arriving perpendicular to the earth's surface).

In order to reduce uncertainty we used the mean of the data we recorded at each angle. We obtained a total count of 221 in 6 minutes, giving an average rate of 0.615 per second.

What's your take-home message?

We learned the importance of the cosmos, understanding that it is made up of many unstable particles that constantly bombard us. We also had the opportunity to see how difficult it is to achieve a research result, which requires different skills. This experience underlined the vital role of interdisciplinary collaboration, modelling expertise and teamwork in scientific progress.

INFN Padova Division and Department of Physics and Astronomy, University of Padova, Italy

INFN OCRA

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Dipartimento di Fisica e Astronomia Galileo Galilei

Cosmic rays

Liceo Scientifico Ugo Morin, Mestre, Italy

Credit: DESY, Science Communication Lab

Who are you?

- We are three fourth-year students form the "Morin" high school in Mestre, Venezia.

What have you done?

- Our goal was to estimate the dependence of the cosmic ray rate on the angle of incidence. So we took and analyzed the muon counting data detected with a muon telescope.

What did you find out?

- We found that there is a correlation. Here there is the graph of the Mathematical function of n*cos2 x. Where x is the inclination of the telescope, and n is the flux of particles on the vertical.

What's your take-home message?

We had the opportunity to understand in a small part how the university and scientific world develops with serenity and passion. Bringing home an instructive experience that increased our curiosity.

INFN Padova Division and Department of Physics and Astronomy,
University of Padova, Italy

Our experience with cosmic rays

Liceo Scientifico Ugo Morin, Mestre, Italy

Credit: DESY, Science Communication Lab

Who are you?

We (Enrico, Simone, and Nicola) are three students from U. Morin Scientific High School in Mestre (VE). We chose to study cosmic rays on the occasion of the ICD, with the help of INFN and the University of Padua. We have a strong passion for physics and particularly enjoy studying astronomy, so this experience was a perfect fit for our interests.

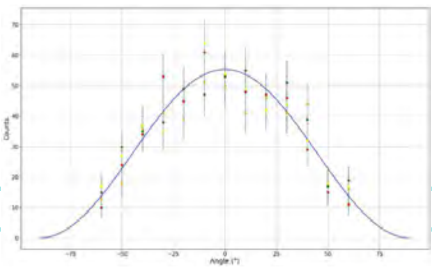
What have you done?

During the International Cosmic Day, we measured the rate of muons per minute using a telescope consisting of two metal plates positioned 28 centimeters apart, designed to detect only the muons that are perpendicular to the plates.

For each measurement, we adjusted the telescope to a different angle, starting from -60 degrees, then moving to -50 degrees, and continuing up to 60 degrees. Each measurement lasted 90 seconds.
We then calculated the error of each measurement, which is approximately equal to the square root of the number of coincidences, and recorded the data in a table. Finally, we created a graph using the data from the table, adding the error too in order to get the most clarity possible.

What did you find out?

At the end of our experience during this year's ICD, we concluded the following: when we pointed our telescope perpendicular to the ground (at zero degrees), we registered significantly more muons per minute than when we oriented the telescope parallel to the ground (at sixty degrees). This outcome can be easily explained. When the telescope is not perpendicular to the ground, it observes a thicker layer of the atmosphere compared to when it is positioned at 0 degrees. This is because when cosmic rays collide with the Earth's atmosphere, the particles interact with air molecules, splitting into various sub-particles (this is also known as particle shower). These sub-particles continue interacting with the air, and the more atmosphere the cosmic ray encounters, the fewer particles—specifically muons—reach the surface, and consequently, our telescope.



What's your take-home message?

We took home a lot from this experience. Thanks to the ICD we discovered the world of cosmic rays and research about this topic. We are very happy to have been able, even if for a short time, to experience the university environment.

INFN Padova Division and Department of Physics and Astronomy, University of Padova, Italy

INFN OCRA

Cosmic rays

IIS Rolando da Piazzola, Piazzola sul Brenta, Italy

Who are you?

We are Davide Zambolin, Rachele Pedini and Tommaso Ceccato, students from the high school Rolando da Piazzola.

What have you done?

We participated in a project organized by INFN in Padua. First they explained what cosmic rays were and how we could measure them, then we did an activity in which we had to solve a riddle using a concave mirror. At the next meeting we measured how many cosmic rays were passing through an instrument consisting of two plates connected to a display where the number was written. Then we made a graph with the collected data and a powerpoint, which we displayed later in a video conference with other schools.

What did you find out?

We measured muon rates at angles from -60° to +60° and observed that the counts peaked near 0° while decreasing at higher angles, consistent with the expected $\cos^2\theta$ dependency. Our data aligned well with theoretical predictions, with slight deviations at extreme angles likely due to instrument or noise limitations. With a reduced chi-square value of 2.06, we confirmed the angle-dependent behavior of muon flux.

What's your take-home message?

During this wonderful experience we learned a lot about muons and cosmic rays, but this is not the only thing we brought home. This work improved our teamwork skills and our ability in problem-solving, and also let us build strong connections with the other participants.

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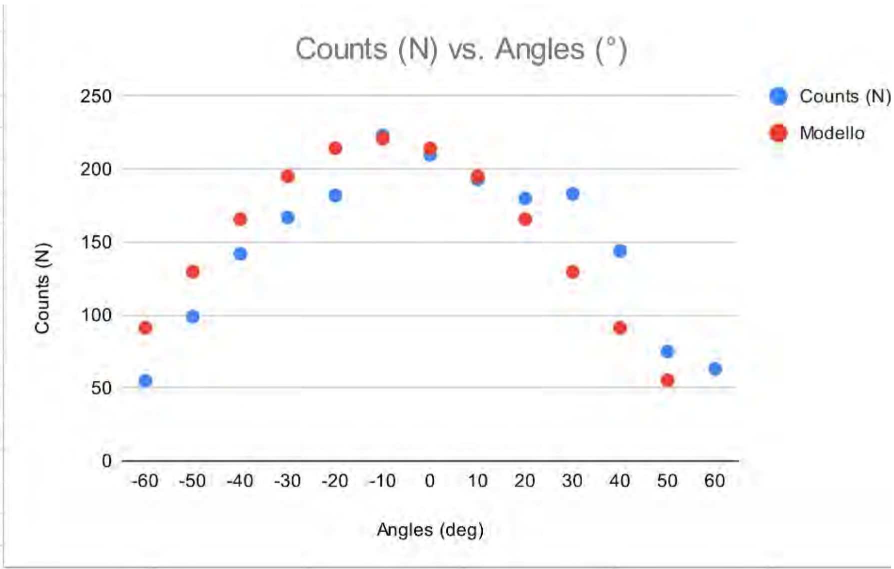
INFN OCRA Outreach Cosmic Ray Activities

Cosmic rays

IIS Rolando da Piazzola, Piazzola sul Brenta, Italy

Credit: DESY, Science Communication Lab

Angles (°)	Counts (N)	incert (√N)	Model
-60	55	7,416198487	55,25
-50	99	9,949874371	91,31187637
-40	142	11,91637529	129,6881236
-30	167	12,92284798	165,75
-20	182	13,49073756	195,147911
-10	223	14,93318452	214,3360346
0	210	14,49137675	221
10	193	13,89244399	214,3360346
20	180	13,41640786	195,147911
30	183	13,52774926	165,75
40	144	12	129,6881236
50	75	8,660254038	91,31187637
60	63	7,937253933	55,25
Normalizz per modello			
221	in 6 min		
Chisq/ndf		Norm da interpolaz	
2,060133541		221,4084328	mu in 6 min
		0,6150	mu al secondo
		55,35210821	



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Dipartimento di Fisica e Astronomia Galileo Galilei

MEASUREMENTS OF COSMIC RAYS

Liceo Galileo Galilei, Selvazzano, Italy

Credit: DESY, Science Communication Lab

Who are you?

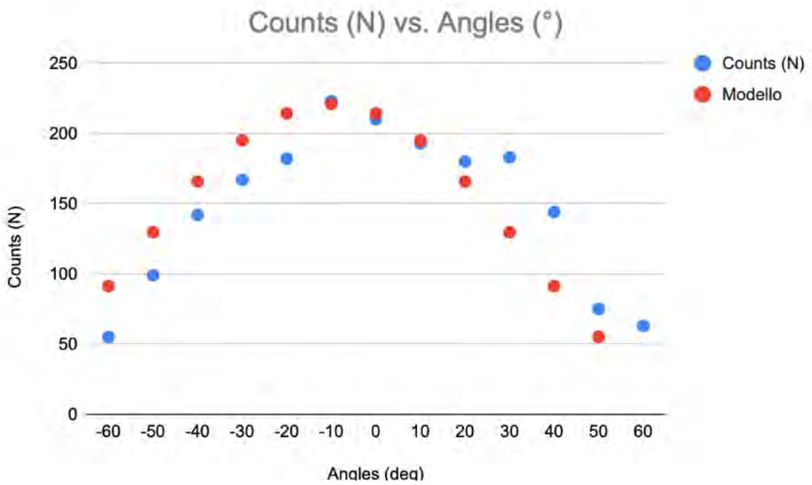
We are Elena Janna, Tullio Voltan, Giulio Lauropoli, students of Galileo Galilei High School in Padova.

What have you done?

We learned what cosmic rays are, and how to measure them. Then we did some measurements with a muon telescope, and different angles of inclination. We were divided into 12 groups, and every group took the measurements at five different angles. Then we made a graph with all the data we collected, and we analized it, comparing it with the teorethical graph.

What did you find out?

We found out that the graph is the graph of the mathematical function n*cos^2*x, where x is the inclination of the telescope, and n is the flux of particles on the vertical. In order to have the smallest uncertaninty possible, we used the sum of the data we recorded at each angle. We obtained values of n=221 in 6 min, and n=0,615 per sec.



What's your take-home message?

Thanks to this amazing experience, we learned that we are constantly surrounded by particles coming from all the Universe, and we had the opportunity to measure them, with the instruments we are so lucky to have in the University and INFN of Padua.

INFN Padova Division and Department of Physics and Astronomy,
University of Padova, Italy

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Dipartimento di Fisica e Astronomia Galileo Galilei

INFN OCRA Outreach Cosmic Ray Activities

MEASUREMENT OF COSMIC RAYS

Liceo G.B. Benedetti, Venezia, Italy

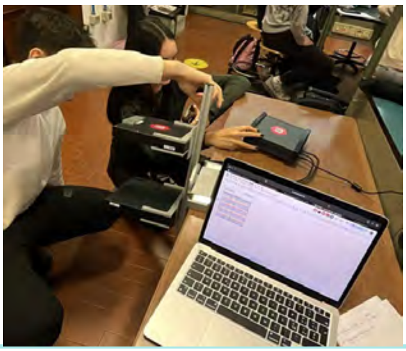
Credit: DESY, Science Communication Lab

Who are you?

We are Linda Molin, Aurora Tagliapietra, and Kevin Buzatu, students of class 5Da at the Benedetti-Tommaseo High School in Venice.

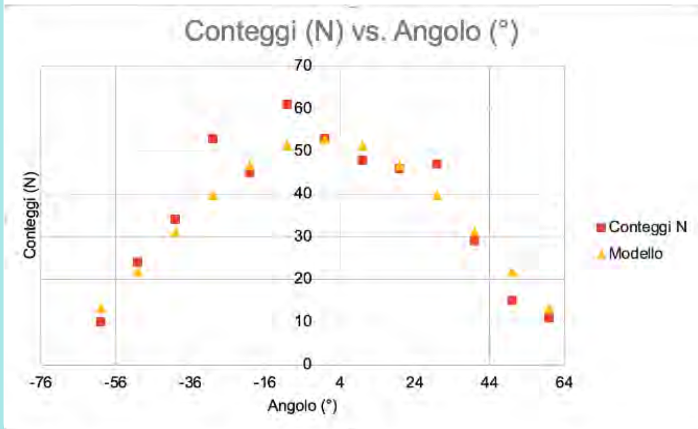
What have you done?

As Group 2, we had the incredible opportunity to participate in a project on cosmic rays at the University of Padua. We were divided into small groups, with each group assigned to conduct a specific measurement. Later, the groups were merged, and each larger group was tasked with creating a PowerPoint slide to present during the video call for International Cosmic Day. This collaborative effort allowed us to combine our findings and share them with participants from around the world.



What did you find out?

Each group conducted a measurement, and by comparing our results with those of the other groups, we discovered a pattern: as the angles increased, the data formed a curve with a cosine-squared trend. In order to have the smallest uncertainty we used the sum of the data we recorded at each angle. We obtained n=221 in 6 min, and n=0,615 per sec.



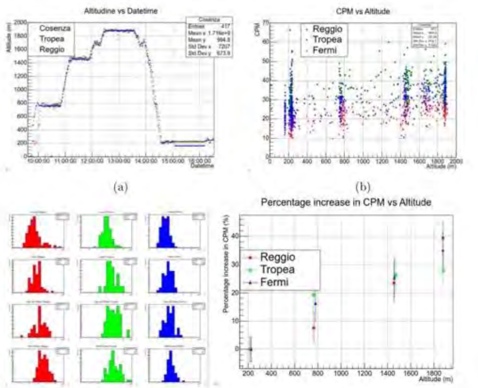
What's your take-home message?

Collaboration and data analysis are vital in scientific research, enabling discoveries beyond individual efforts. This project sparked our curiosity about cosmic rays and physics, inspiring a deeper interest in exploring the universe and scientific methods.

Cosmic Rays: Measurement from Cosenza to Botte Donato Refuge: 240-1880 m Altitude Range

LICEO SCIENTIFICO 'TROPEA

We participated in the particle physics lessons held by Teacher Giuseppe Fiamingo in the Aula Magna of our high school. Subsequently we attended seminars conducted by experts from the INFN in Milan. Meanwhile, we have started measuring ionizing particles using the ArduSiPM and Cosmic Hunter detectors to analyze the particle flux as a function of time. At 12:00 PM, we joined a video call organized by DESY in Hamburg, which was also attended by Great Bay University and Kenyatta University, discussing our experience based on the measurement of the flux of cosmic rays at different altitudes, ranging from 240 to 1880 meters above sea level, starting from Cosenza at the Botte Donato refuge in Sila Grande. This experiment was organized by INFN-OCRA of Cosenza and saw the partecipation of 80 students from various Calabrian high schools.

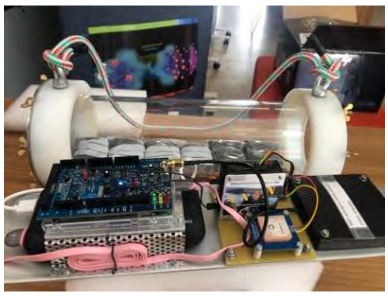


By D. Passarelli (UNICAL)

Figure 9: Data recorded by the three apparatus during the journey to the Botte Donato refuge: a Altitude, b CPM, c histograms of CPM data in each stop, d percentage variation of the CPM with altitude.

Tab. 1

CPM	ALTITUDINE	
30	220,56	UNICAL
36	752,36	Lanzino Park
39	1471,41	Fago del Soldat
38	1880,26	Botte Donato



By Marco SCHIOPPA (UNICAL)

From our measurements, we observed that the cosmic ray flux increases with altitude (Tab.1). This trend is evident from the data collected, which shows a significant rise in the detected particle flux as elevation increases. These observations highlight how higher altitudes provide a clearer insight into cosmic ray interactions and their behavior in the atmosphere.

Measurement of the Cosmic Rays rate at different altitudes in the range 240-1880 masl form Cosenza to Botte Donato refuge in Sila Grande

High School «A. Volta», Reggio Calabria, Italy

Credit: DESY, Science Communication Lab

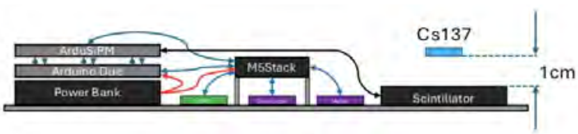
Who are you?

We are fifth grade students of Scientific High School – 5Dsa

What have you done?

The topic chosen was the measurement of the number of Cosmic Rays per unit of time counted by an ionizing particle detector at different altitudes in the range 220-1880 masl.

Ionizing particles are detected using the commercial instrument ArduSiPM, designed by INFN researchers in Rome 1. It consists of an Arduino DUE board on which the acquisition module is mounted. The latter has two functions: to power a SiPM (Silicon Photomultiplier) and to read the electrical signal that this SiPM produces every time its active area is hit by even a single photon of the visible spec- trum



What did you find out?

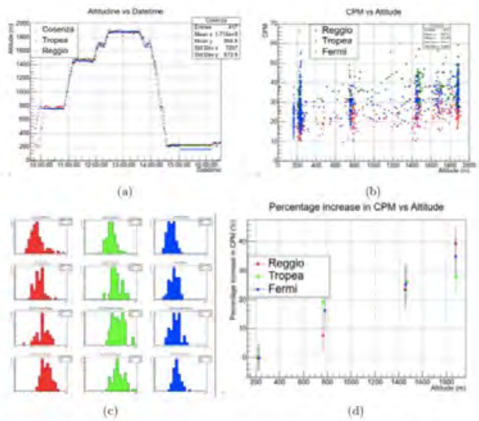


Figure 9: Data recorded by the three apparatus during the journey to the Botte Donato refuge: a Altitude, b CPM, c histograms of CPM data in each stop, d percentage variation of the CPM with altitude.

The CPM measurement is affected by a natural fluctuation determined by the Poisson law for the rare casual events. The standard deviation (or rms) is a good descriptor of the fluctuations this variable is affected by. The rms of all distributions (9 (c)) is about 5 counts per minute and the rms of the mean value is about 3%. Systematic errors are present due to natural radioactivity, atmospheric pressure and temperature variations.

What's your take-home message?

The analysis of cosmic rays at higher altitudes than sea level confirmed that the intensity of these rays increases with altitude. This phenomenon is due to the reduction of the atmospheric screen which, at higher altitudes, allows less attenuation of cosmic particles. The data collected supports the theory that atmospheric density plays a crucial role in modulating the intensity of cosmic rays reaching the Earth's surface.

Measurement of the Cosmic Rays rate at different altitudes in the range 240-1880 masl form Cosenza to Botte Donato refuge in Sila Grande

High School «A. Volta», Reggio Calabria, Italy

Credit: DESY, Science Communication Lab

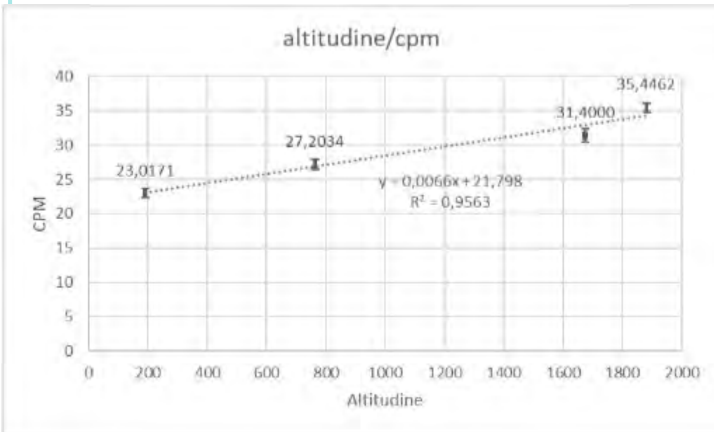
Who are you?

We are fifth grade students of Scientific High School – 5Dsa

What have you done?

Four stops have been planned on the journey to the Botte Donato refuge: Roberta Lanzino municipal park (780 masl), Fago del Soldato (1450 masl), Botte Donato refuge (1880 masl) and University of Calabria (200 masl). Each stop duration was of about 30 minutes

What did you find out?



What's your take-home message?

The instrument measure an increase in CPM with altitude. The percentage increase in the CPM variable with altitude is approximately linear and the slope λ can be determined by linear regression of all the data, and it results to be $\lambda = (0.020 \pm 0.003)\%/m$. This means that the CPM of each of the three instruments increases on average by 0.02

Exploring the Impact of Cosmic Rays through Outreach Activities

Liceo Scientifico G. Vailati, Genzano di Roma, Italy

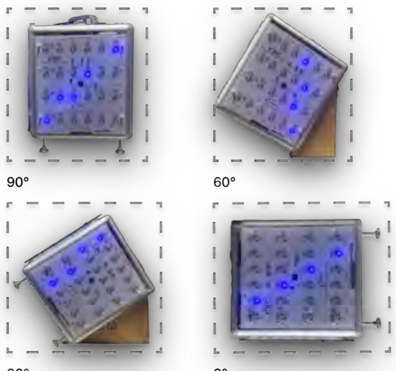
Credit: DESY, Science Communication Lab

AUTHORS

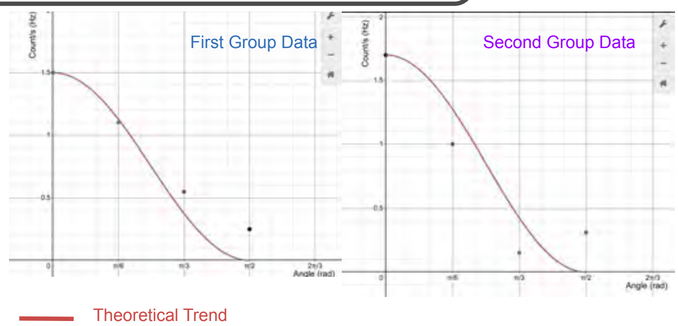
Chander Yuvraj, Alciator Federico, Bocci Leonardo, Domenicone Matteo, Melodia Arianna, Nardi Emanuele, Tesei Nico, Vanore Thomas, Zazza Niccolò.

OUR SETUP

We used a Cosmic Ray Cube to detect muons.
The detector is made of four layers of scintillator bars paired with Silicon Photomultipliers (SiPMs).
The surface of each layer is 30x30 cm^2.
When a muon passes through the scintillators, they emit light, which is captured by the SiPMs and converted into an electrical signal. The signals from the SiPMs are sent to a coincidence circuit that counts the arriving particles.
This configuration ensures that only the particles passing through all layers are counted, improving accuracy and reducing false positives.
We have made measurements at different angles, analyzing how muon rates differentiate, according to the orientation of the muon detector.



OUR RESULTS



The goal of the experiment is to measure the rate of air shower particles as a function of the zenith angle and verify the law

$f(\theta) = k \cdot \cos^2(\theta)$

where k is the frequency at the angle $\theta = 0$.
We performed the measurements in 2 different conditions and in both data sets the flux at $\pi/2$ appears greater than the expected value, likely due to the irregular morphological structure of the building where the measurements took place.
By measuring the number of counts in fixed time intervals we also verified that these are random events as they follow Poisson distribution.

CONCLUSIONS

The Cosmic ray experiment offered us a taste on the high energy particles physics, while giving an idea on how physics experiments are done and the importance of working as a team.

International Cosmic day

Liceo Scientifico IIS Bafile, L’Aquila Italy

r

Credit: DESY, Science Communication Lab

Who we are:

We are three students from Liceo Bafile of L’Aquila, Teresa Graziani, Sofia Santilli e Aurora Scarsella.

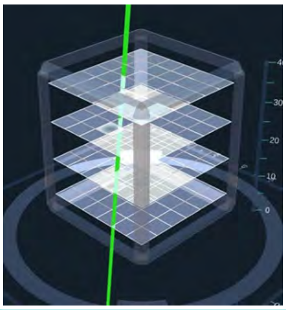
What we have done

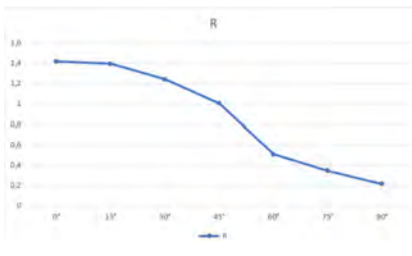
During *Cosmic Day* , hosted by the INFN institute, we had the opportunity to dive into the fascinating world of cosmic rays.
We assisted on a deep explanation on what cosmic rays are, how they interfere with earth and how we can detect them.
These high -energy particles, originating from space, interact with Earth's atmosphere in complex ways, offering a unique view into the physics of the universe.
A highlight of the day was the presentation of the Cosmic Rays Cube, an interactive project, together with the App, to detect cosmic rays, and to analyze the datas the bring us.

What we found out

We have collected several data related to CRC, which show the frequency of cosmic rays. It was interesting to get involved in the actual data collection of this experiment. Here are the data we collected:

α	$\bar{R}$	ΔR	$cos^2 α$
0°	1,417	0,043	1
15°	1,393	0,107	0,93
30°	1,24	0,1	0,75
45°	1,003	0,117	0,5
60°	0,507	0,013	0,25
75°	0,343	0,067	0,07
90°	0,213	0,017	0





We achieved a better knowledge of how this phenomenon works, and we learned the importance of the new scientific technology developments.
It’s beautiful to explore the universe that surrounds us, and to discover all the big and little secrets and sounds that it hides from us.

INTERNATIONAL COSMIC DAY 2024

I.I.S. «Amedeo D'Aosta», L'Aquila.

We are the students of class 5A of Liceo delle Scienze Applicate, Institute «Amedeo D'Aosta» in L'Aquila.

We used the cosmic box, connected to an application (Cosmic Rays Live), to measure the number of particles after 100, 200, and 300 seconds, varying the inclination of the cosmic box seven times.

We reported the data in a table by calculating the mean of the particle rates and their absolute error. We made two graphs: one with the average rate as a function of alpha, and the second with alpha as a function of the average rate.

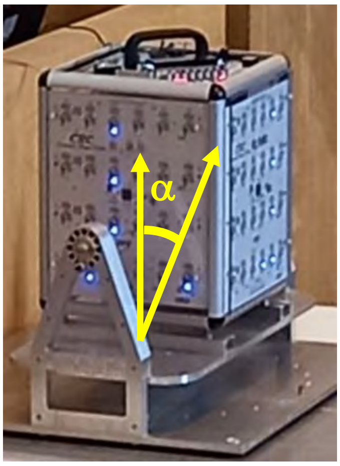


Fig.1: The cosmic ray detector.

a (°)	r100 (Hz)	r200(Hz)	r300 (Hz)	rm (Hz)	Ea (Hz)
0	1,52	1,36	1,41	1,43	0,08
15	1,31	1,36	1,51	1,39	0,1
30	1,23	1,13	1,28	1,21	0,08
45	1,1	1,04	0,92	1,02	0,09
60	0,53	0,5	0,49	0,51	0,02
75	0,4	0,33	0,3	0,34	0,05
90	0,2	0,21	0,21	0,21	0,005

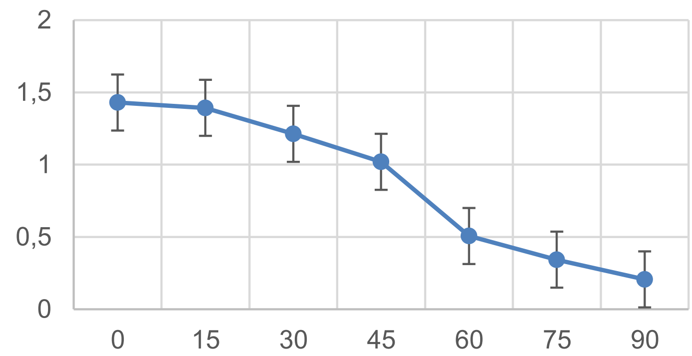


Fig.2: Rate vs θ.

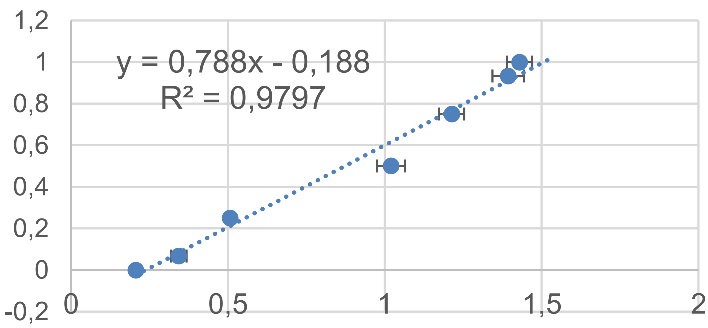


Fig.3: Rate vs $\cos^2\theta$.

Figures show that the average rate decreased as a $\cos^2\theta$ function.

Conclusion. We have verified the expected dependence of the cosmic ray flux rate on the $\cos^2$ of the azimutal angle.

The Silent Messengers of the Universe

"C. D'Ascanio" Scientific High School, Montesilvano (PE), Italy

Credit: DESY, Science Communication Lab

Who are you?

We are Shakira De Felice, Riccardo Silli, Michele Gnoni, Daniele Tina, Paolo Di Francesco e Jacopo Abbonizio, six students from "C. D'Ascanio" Scientific High School in Montesilvano (PE), passionate about physics and science in general, which provide us with the tools to understand even a small part of the world we live in from a different perspective, satisfying our curiosity.

What have you done?

We conducted an experiment using a cosmic ray detector to measure rates every 100 seconds. After three measurements, we varied the angle and repeated the measurements up to 90 degrees. We observed that the rate decreased as the angle increased.

The average rate's trend closely matched the trend of $\cos^2$(angle), as shown in the first graph. This similarity is due to the theoretical relationship between the angle and the rate of detected cosmic rays, which follows a cosine-squared pattern.

From the graph relating $\cos^2$(angle) and R, we derived the **slope (m)** and the **intercept (q)** by considering the values of the two points closest to the trend line. We successfully calculated the equation of the line describing R and compared it with the actual R values, finding very similar results. In the final graph, the trend lines practically coincide, indicating a strong correlation.

What did you find out?

Why does the rate decrease with increasing angle?

Geometric effect: The detector is most sensitive to cosmic rays arriving perpendicularly to its surface. When the angle increases, the perpendicular component of the cosmic ray flux decreases, reducing the number of particles detected.

The relationship between the rate of detecting cosmic rays and the angle follows a cosine squared function. This is because the flux of cosmic rays reaching the detector can be described by the formula:

- $\mathbf{R=R_0 \cdot \cos^2(\theta)+q}$

This relationship arises because the cosine of the angle represents the perpendicular component of the cosmic ray flux relative to the detector's surface.

By calculating the equation of the line, we can now approximately predict the rate variation even without the cosmic ray detector.

What's your take-home message?

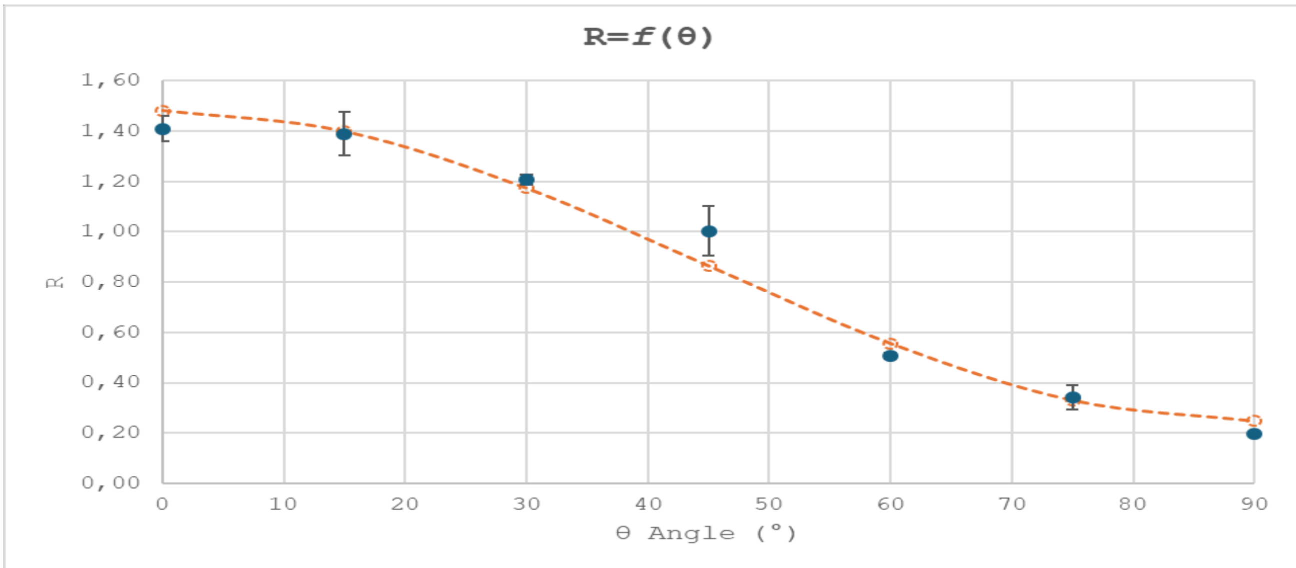
There is something incredible in our world that we often cannot perceive with our senses, but can only understand through reason. Cosmic rays serve as silent yet powerful messengers, carrying the secrets of distant galaxies and the fundamental forces that shape our cosmos.

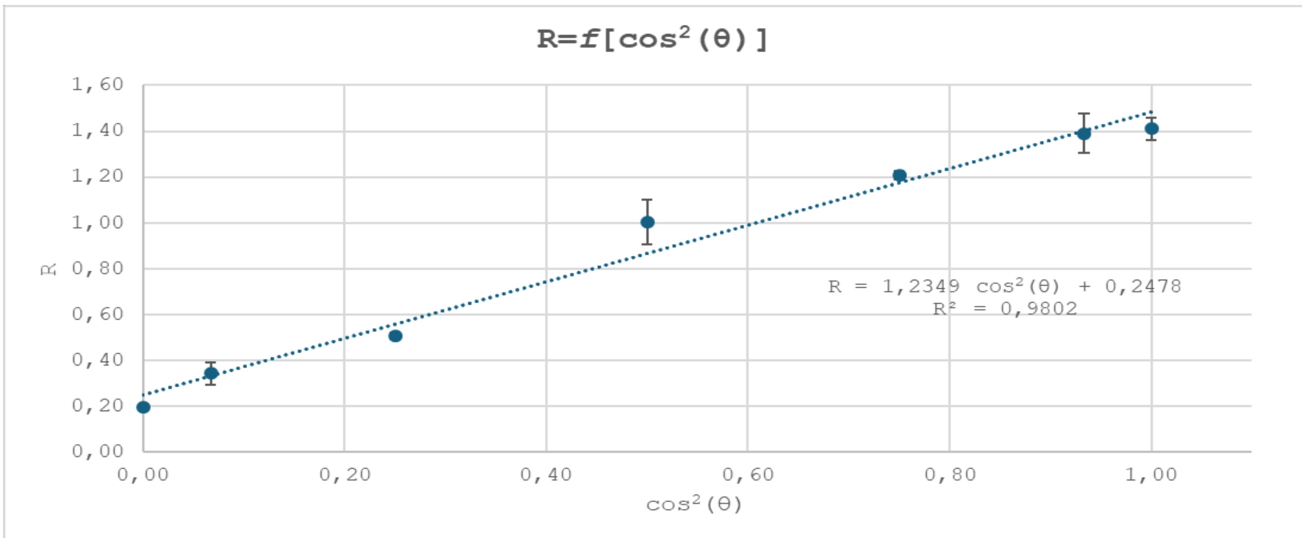
Data collection and graphs

“C. D'Ascanio” Scientific High School, Montesilvano (PE), Italy

Credit: DESY, Science Communication Lab

θ Angle(°)	Rate1	Rate2	Rate3	$\overline{R}$	cos^2(angle)	σ = ST deviation	R=1,2349 cos^2(θ)+0,2478
0	1,48	1,37	1,38	1,41	1,00	0,050	1,48
15	1,29	1,38	1,50	1,39	0,93	0,086	1,40
30	1,22	1,18	1,22	1,21	0,75	0,019	1,17
45	1,13	0,99	0,89	1,00	0,50	0,098	0,87
60	0,52	0,51	0,49	0,51	0,25	0,012	0,56
75	0,41	0,32	0,30	0,34	0,07	0,048	0,33
90	0,20	0,19	0,20	0,20	0,00	0,005	0,25





WHISPERS FROM THE SPACE

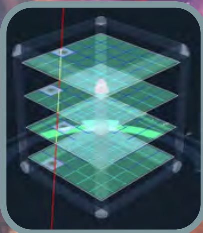
THE COSMIC RAYS EXPERIMENT

Credit: DESY, Science Communication Lab

Omnicomprensivo Popoli, Scientific School

Who are you ?

We are six Italian guys from small towns in Abruzzo. Because of our interest in STEM subjects, we were chosen to participate to this convention in the LNGS.



What have you done ?

After having been lectured on cosmic rays, we analysed the structure of the Cosmic Rays Cube with Professor Attanasio Candela, and we experienced the precence of cosmic particles in the air.
Under his supervision, we teamed up for an experiment, which consisted in detecting the flow of Cosmic particles. Changing the Cube’s inclination from 0° to 90° every 15°, we made three measurements every 100 seconds, with the INFN app “Cosmic Rays Live” on our smartphones.

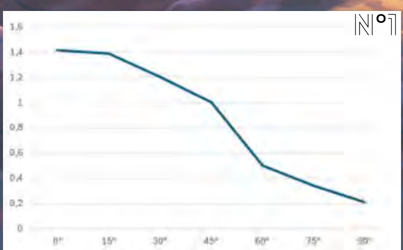
What did you find out ?

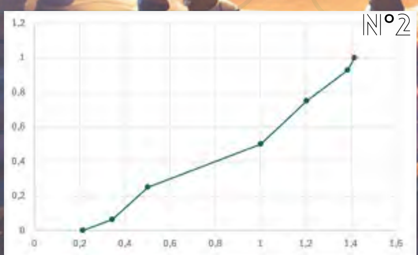
At the beginning, we discovered the presence of cosmic rays around us. Their interaction with the atmosphere releases several types of particles, such as muons, whose flow we proceeded to analyse.
After having collected our measurements, we wanted to track the relation between the flow (rate) and the inclination (angle) of the CRC.
For this purpose, we traced two graphs, one with coordinates (angle;rate), the other with (rate;cosine squared). Through the study of these graphs, we noticed that the first one is smilar to the positive half of the Gaussian Bell curve, whereas the second one is similar to a linear function.

What’s your take-home message?

This experience stimulated our interests in scientific subjects, because we personally witnessed the deep connection among different branches of Science (mathematics, chemistry, physics...).

Our take-home message is the realisation that the Universe is not as far as one could think, but it participates in our every-day life in some aspects that only scientific research can explain.





Who are you?

We are Chiara Carducci and Gloria Paponetti, from the Liceo Scientifico Albert Einstein in Teramo.

What have you done?

On this day we have learnt about cosmic rays, how they work and how they are measured.

Professor Salamida from University of L'Aquila gave us some information about the story of the discovery of Cosmic Rays and their definition. Cosmic rays are particles with positive charges, that move at a very high speed, divided into two categories:primary cosmic rays which give rise to a shower of particle when they enter the atmosphere and interact with air, molecules, and the secondary ones, which are formed by the collision of the primary ones with atmospheric gases.

Some cosmic ray particles may reach the soil: muons, for example that is, particles with a negative charge ,can be studied using the Cosmic Rays Cube. Attanasio Candela, the engineer from MeGS laboratory described us its structure and the ability of it to catch the passage of particles contained in the shower of cosmic rays.

Afterwards, we made some measurements of the flux of rays with the cube at different angles each 100 sec, then we wrote them down on a chart and observed how the values change .

What did you find out?

We found out that the cosmic rays flux decreases with the increase of the angle because of the difficulty muons encounter in passing the atmosphere. In fact, at a 90° angle, muons had to pass fom below, to be captured, meaning they would have to cross the diameter of Earth and that's impossible due to their very short life (2,2 microseconds).

To sum up the optimal position to catch rays is vertical, so that muons have to travel less distance from space.

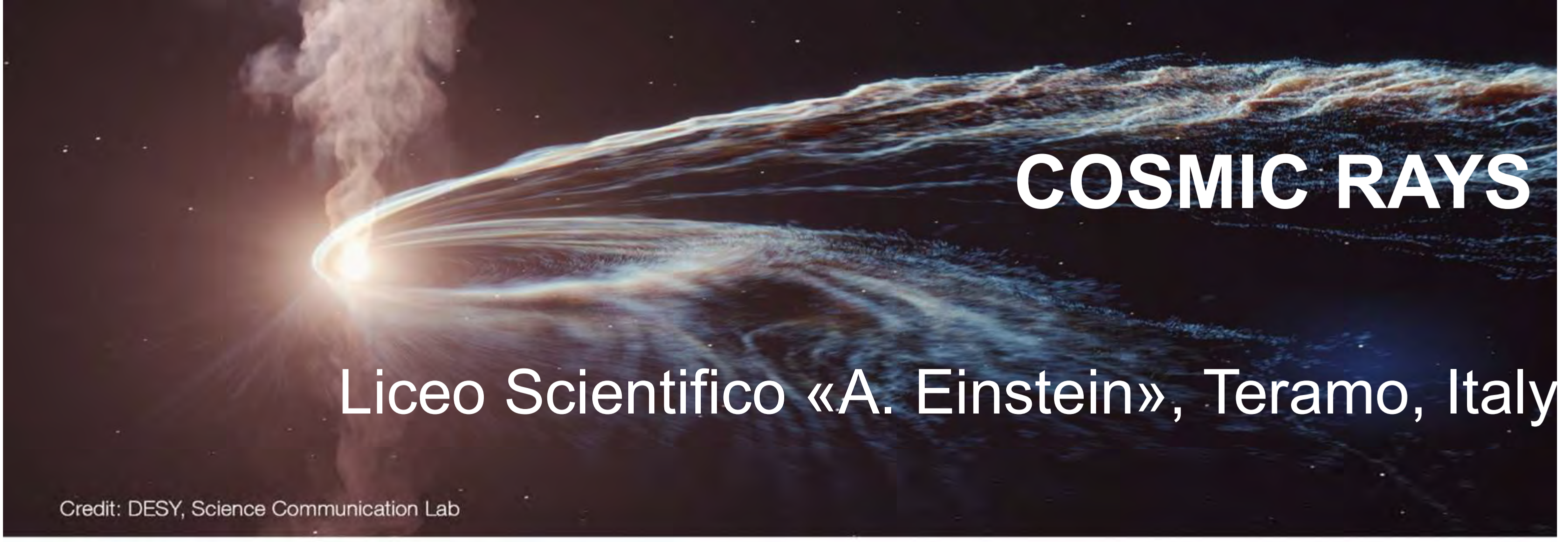
Event count divided by 100	Rate (t=100s)	Rate (t=200s)	Rate (t=300s)	Media	$\cos^2\theta$	ΔR
0	1,470	1,300	1,470	1,413	1	0,133
15	1,350	1,330	1,550	1,410	0,93	0,08
30	1,330	1,150	1,220	1,233	0,75	0,083
45	1,160	1,090	0,890	1,046	0,5	0,156
60	0,500	0,500	0,490	0,496	0,25	0,006
75	0,390	0,360	0,250	0,333	0,066	0,083
90	0,190	0,170	0,250	0,203	0	0,033

What's your take-home message?

We have discovered the importance of cosmic rays to understand the Universe, but also because of the energy they create, which can't be reproduced on Hearth by any accelerator. We have also became aware that our region, Abruzzo, plays an important role in this field, thanks to MeGS laboratory.

COSMIC RAYS

Liceo Scientifico «A. Einstein», Teramo, Italy



Who are you?

Hello There! We are Chiara Romani and Filippo Di Giuliantonio, two students from Liceo Scientifico Albert Einstein in Teramo. This is what we discovered during the 13th International Cosmic Rays Day.

What have you done?

We took part in a lecture at the Gran Sasso National Laboratory in which professors and scientists enlighted us on different topics.

Firstly, Nicola Rossi from the LNGS, told us about the structure, crew and ongoing researches of the laboratories.

Then, Francesco Salamida, a professor from University of L'Aquila, told us about how cosmic rays were discovered, how they are detected on a large scale and what they are.

From his words, we understood that cosmic rays are mostly protons, and ionised particles too, which hit nucleons of our atmosphere at very high speed giving origin to secondary cosmic rays, which consist in particular of muons, that eventually hit the ground.

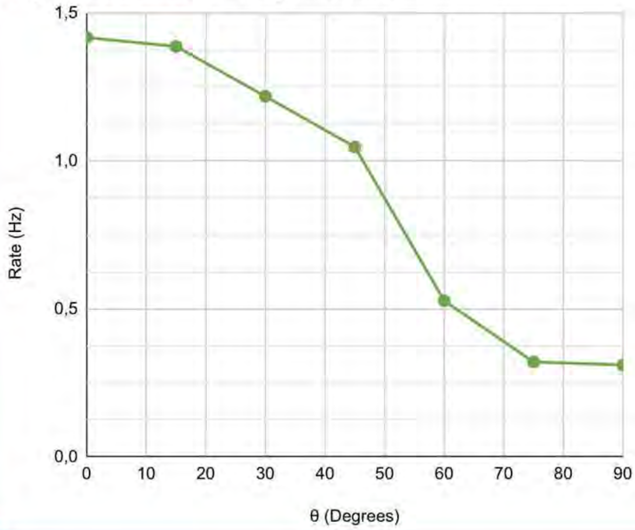
At last, Attanasio Candela, from LNGS too, introduced us the Cosmic Rays Cube (CRC), that is an instrument able to detect especially secondary cosmic rays.

Made of four layers with twelve plastic scintillators each that are placed to form a grid, the CRC presents two faces with 48 leds in total, 12 for layer, connected to such scintillators. These, lighting up, show the direction of the rays.

With this instrument we made some measurments.

What did you find out?

Through a newly developed app, connected to the CRC system, we observed the change of muons' detection rate by tilting the Cube: we noticed that by having the zenith angle of the instrument increased, the flux of the detected particles decreased. This behaviour depends on the changing thickness of atmosphere's layer. Since muons' life is consistingly short, about 2 microseconds, a longer passing, besides allowing an increase of the chances of being absorbed, means a reduction of the number of particles that hit the ground, hence being detected.



What's your take-home message?

It has been for sure a gripping experience, which confirmed our love for Physics. To tell the truth, there has been a sentence by Attanasio Candela stuck in our heads since that day: «Research is creativity».

Hands-On Exploration of Cosmic Rays

Liceo Scientifico E.Fermi Sulmona,Italy

Who are you?

We are a group of students from Liceo Scientifico E.Fermi in Sulmona,Italy

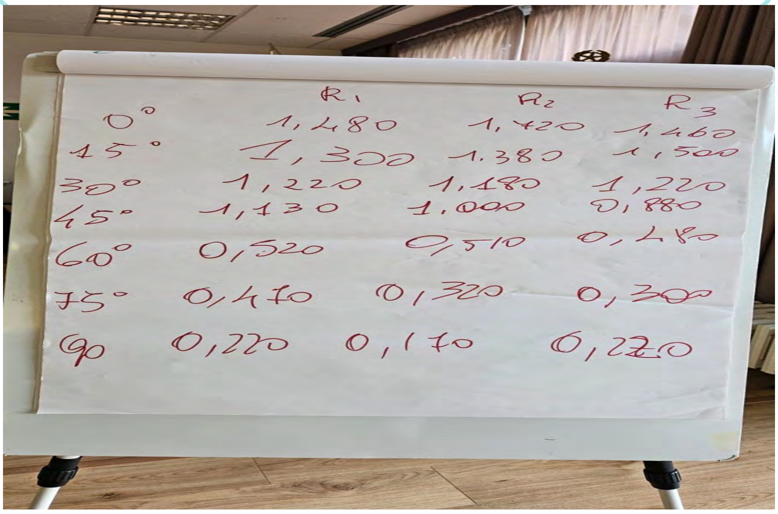
What have you done?

On November 26, during the International Cosmic Day at the LNGS we collected and analyzed data relating to the frequency of cosmic rays, collected thanks to the use of the Cosmic Ray Cube.

The Cosmic Ray Cube is a portable device designed to detect cosmic rays, particularly muons; using an application connected to the CRC, we analyzed the frequency of cosmic rays passing through the device.

What did you find out?

We found out that by tilting the cube used to intercept the cosmic rays from the standard position with an inclination equal to zero degrees up to the maximum inclination of ninety degrees, the cosmic rays intercepted by this become less and less. We have therefore observed that as the inclination increases, the number of intercepted rays is smaller: the two quantities are inversely proportional.



What's your take-home message?

During the International Cosmic Day we ha the opportunity to understand that physics is not only about theoretical laws and numbers, but also a concrete field of research. This experience mad us reflect about the important of researchers, who works to discover new amazing physical phenomena.

A Day at LNGS

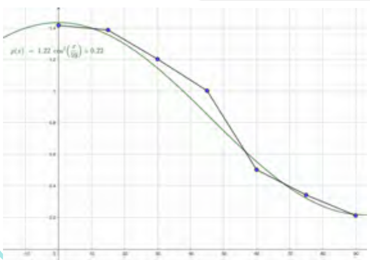
“Enrico Mattei”, Vasto, Italy

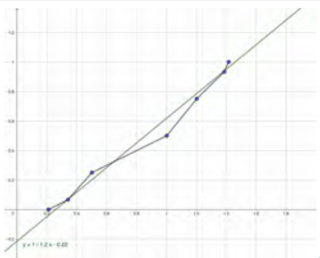
Credit: DESY, Science Communication Lab

What have you done?

We attended a lesson about cosmic rays and it was presented us a machine called “CRC” (Cosmic Rays Cube) capable of detecting those cosmic rays and sending data to a software which show visually and numerically information about cosmic rays.
Then we downloaded an application named “Cosmic Rays Live” which can get in connection with the software and show its information on your mobile devices. We used it to write down the rate of cosmic rays detected by the CRC rotated by 15 degrees at time from 0 to 90 in a time span of 100 seconds with 3 measurements at a time. We then calculated the medium rate of cosmic rays detected at each rotation of the CRC and drew the graph of those data. We also created a graph of the medium rate detected with the cosine squared of each angle of rotation of CRC and we saw that they were in a linear proportion.

α	R_1	R_2	R_3	$\bar{R}$	ΔR	$cos^2(\alpha)$
0°	1,480	1,380	1,390	1,417	0,063	1
15°	1,280	1,380	1,500	1,387	0,113	$\frac{2+\sqrt{3}}{4}$
30°	1,210	1,190	1,210	1,203	0,013	$\frac{3}{4}$
45°	1,120	1,000	0,890	1,003	0,117	$\frac{1}{2}$
60°	0,510	0,530	0,470	0,503	0,033	$\frac{1}{4}$
75°	0,410	0,320	0,300	0,343	0,067	$\frac{2-\sqrt{3}}{4}$
90°	0,210	0,200	0,230	0,213	0,017	0





Who are you?

We are a group of six students from Vasto, in Abruzzo, Italy. We attend the last year of Applied Sciences at the high school “E.Mattei”.

What did you find out?

This experience provided us with valuable insights into the interaction between cosmic rays and Earth’s atmosphere, as well as the methods used in scientific research to study these phenomena.
Key Findings:
-Understanding Cosmic Rays: cosmic rays are high-energy particles originating from space that constantly bombard Earth. When they interact with molecules in the atmosphere, they produce a cascade of secondary particles. The CRC enabled us to detect these particles and understand their distribution and frequency.
-Particle Detection: the CRC is designed specifically for educational purposes, allowing students to observe particles produced by cosmic rays in real time. By analyzing the data, we could visualize patterns and recognize the omnipresence of cosmic radiation on Earth’s surface.
-Scientific Methodology: using the Cosmic Rays Live app, we learned how to handle and interpret scientific data. This involved collecting measurements, analyzing variations in particle detection rates.

What's your take-home message?

This day has first of all conveyed to us all the interest and commitment that scholars and workers in this sector put into it every day, to discover new things about the world we live in and how it works. Through the lessons of experts in the field, we learned about the existence of cosmic rays, their composition, the history of their discovery and many other curiosities.
In addition, by carrying out the experiment it was possible to see in a more concrete way how cosmic rays arrive on earth and with which instrument they can be detected.
This is why this day was very significant for us and allowed us to learn new information about a mysterious and fascinating subject like physics.

Who are you?

We are the third and fifth agricultural technicians of Di Poppa Rozzi Institute of Teramo

What have you done?

We made some measurements, we measured using the cube the number of muons that pass through all 4 of its layers, changing the inclination, we made 3 measurements collected in a table and of which we calculated the average

Angle	Measure 1	Measure 2	Measure 3	Average
0	1.47	1.37	1.42	1.48
15	1.35	1.38	1.48	1.40
30	1.26	1.11	1.22	1.19
45	1.22	0.95	0.92	3.09
60	0.49	0.50	0.48	0.49
75	0.42	0.31	0.31	0.35
90	0.20	0.21	0.23	0.21

What did you find out?

We observed how by changing the inclination of the cube, the number of muons that manage to pass through it for all 4 layers is much lower, this means that the muons do not fall perpendicular to the ground but also obliquely.

What's your take-home message?

Many particles arrive from the atmosfere and «bombard» the Earth, which we can measure using a Cube shaped machine

INTERNATIONAL COSMIC DAY

@ INFN LECCE ITALY

Credit: DESY, Science Communication Lab

2024 ICD Edition @ INFN Lecce

For the 2024 ICD edition, we hosted in Lecce 95 students from 9 high schools from the Lecce, Taranto, and Brindisi districts.
The schools participating in the ICD were mainly «scientific» or «applied science» but also «classic» schools. 16 to 18 years old students.

Participating Schools

- Liceo "E. Majorana" – Brindisi
- IISS "L. Da Vinci" – Maglie
- Liceo "G. Ferraris" – Taranto
- Liceo "De Sanctis -Galilei" – Manduria
- Liceo "G. Stampacchia" – Tricase
- Liceo "A. Vallone" – Galatina
- IISS "Virgilio-Redi" – Lecce
- IISS "Trinchese" – Martano
- Liceo "F. Calasso" – Lecce

ICD Activities

We measured the cosmic rays flux vs Zenith angle. Since the very beginning the students could work on dataset using COLAB.

During the day, the students, in small groups, could experience with the Pierre Auger Control Room, the Planetarium, and the Cloud Chamber.

International Cosmic Ray 2024

Liceo Virgilio Redi - Lecce

Who are you?

We are Giorgio Schiavone, Antonio Pati, Matteo Maiorano, Gabrielle Scazzi, Giulio Faggiano, Federico Versienti, Maria Ingrosso and Marta Quarta from LICEO VIRGILIO-REDI, Lecce.

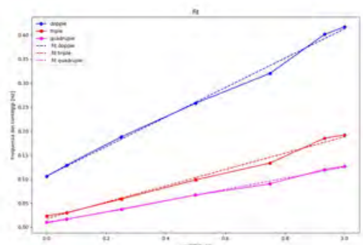
What have you done?

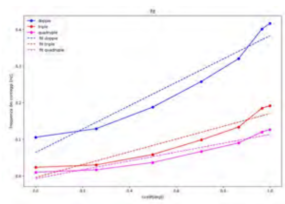
During International Cosmic Day we experienced something incredibly fascinating. The day began with a presentation on cosmic rays, which were the main topic. We've learned what they are, who studied them, how to observe them, and why they are useful.

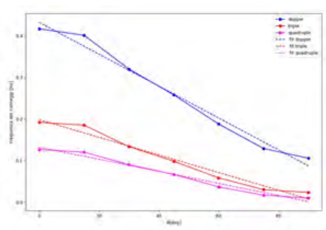
Later, we performed cosmic ray measurements using a scintillator detector, CORAM (COram RAy Mission). Thanks to this detector, we collected data and made a report at the end of our "cosmic trip."
During Comic Day we could also experience the cloud chamber which demonstrated to us the existence of cosmic rays.
After that, we could visit the magnificent planetarium where we've seen different planets, nebulous and supernovae.

What did you find out?

We show the three plots of the measured flux as a function of the cos^2(θ), cos(θ), and zenith angle θ. Superimposed we put the linear fit. In each plot, the double, triple, and quadruple coincidences are shown. The better fit is obtained with the flux as a function of cos^2(θ). In this case, the residuals, meaning the squared sum of the residual of each point with respect to the value estimated by fit, are lower.

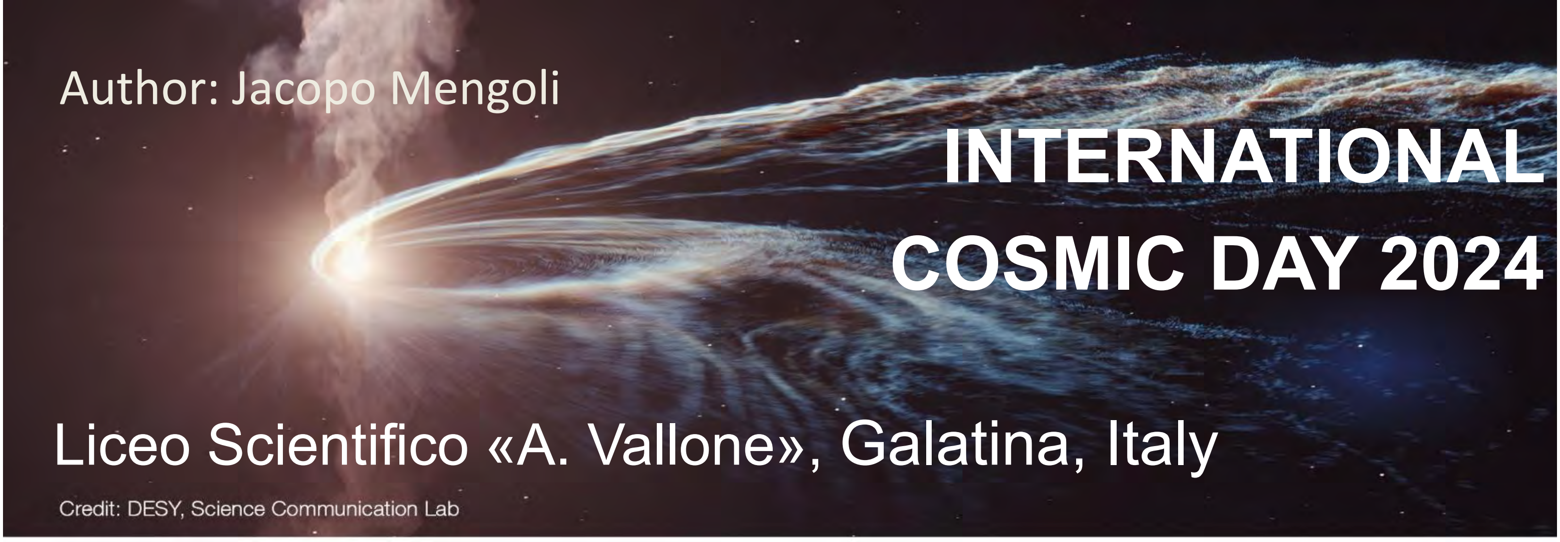






What's your take-home message?

International Cosmic Day allowed us to measure the cosmic ray flux, data analysis, and results presentation. The flux as a function of the zenith angle was measured. As expected, the cosmic ray flux decreases as the angle increases, being maximum for θ=0, therefore for particles perpendicular to the Earth's surface.



Author: Jacopo Mengoli

INTERNATIONAL COSMIC DAY 2024

Liceo Scientifico «A. Vallone», Galatina, Italy

Credit: DESY, Science Communication Lab

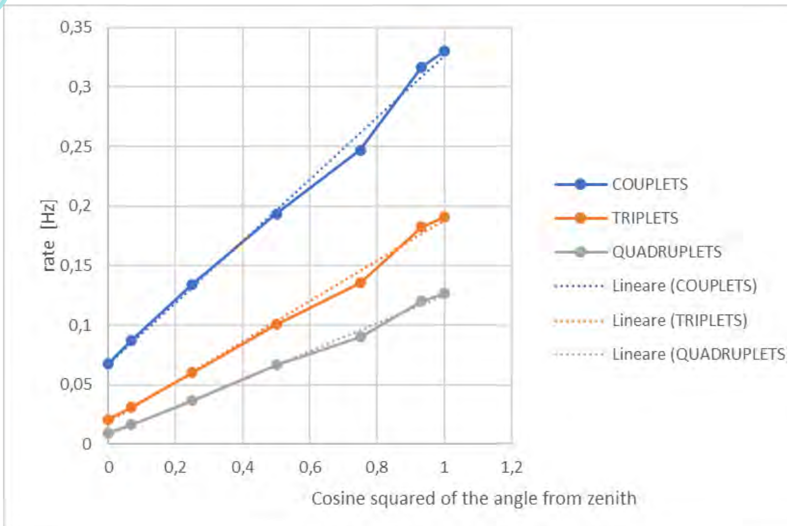
I'm a student of the high school Liceo Scientifico "A.Vallone" in Galatina, a town in southern Italy. I participated in the lesson about cosmic rays organized by INFN and the University of Salento, in Lecce.

Cosmic rays are particles of different natures that come from space. Their origin is mostly uncertain, but we know that a part of them is produced by the Sun. At sea level, we mostly detect muons.

We analyzed the data taken using a particle detector developed by INFN.
The detector consists of four scintillator plates x, y, w, and z each with light sensors. When a particle hits the scintillator produces light that can be detected. Interposed, there are lead plates that help to select particles.
We take data for 10 min registering the counting every 3 seconds.
We tilted the detector to observe what happens varying the zenith angle.
We started with the detector perpendicular to the table surface and then varied the angles.

As the angle varied and the value of the cosine increased the measured value decreased. Each value had to be divided by 3 to determine the rate of particles per second. We calculated the average value for two-fold, three-fold, and four-fold coincidences.
These indicate the number of particles that pass through the detector each second.
As the number of plates increases the number of particles that will pass through them diminishes, so triple measurement is minor than double measurement, this is due to the detector acceptance.
This process was done for each angle.
Analyzing data, we produced different plots to compare how the particle flux is related to the angle, the cosine of the angle, and the square cosine of the angle.

RESULTS
- The counting rate measured is inversely proportional to the zenith angle. Increasing the angle the number of particles measured decreases.
- As expected, the rate is directly proportional to the squared cosine of the zenith angle.



ANGULAR DISTRIBUTION OF COSMIC RAYS

I.I.S.S. "ETTORE MAJORANA" - Brindisi

4ASQ (Corsa Nicolò, Lai Bryan, Ricciardi Francesco)

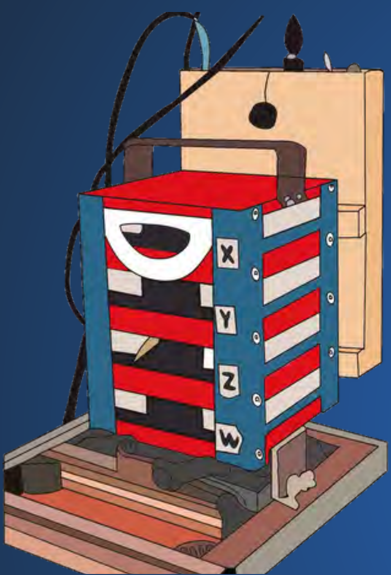
3BSQ (De Benedittis Fabrizio, De Benedittis Federico)

2ASQ (Ligorio Simone, Prete Lorenzo)

INTRODUCTION

On the 26th of November, the International Cosmic Day, we studied and analyzed Cosmic Rays with the support of the University of Lecce. Cosmic Rays are high-energy particles, such as protons, electrons, and atomic nuclei, as well as gamma rays. These particles travel close to the speed of light and have almost unknown origins since their path is constantly altered by gravitational forces. The most likely origin theories are energetic astrophysical events (like Supernova explosions, Pulsars, etc...). While in space, they are Primary Cosmic Rays and, by hitting atoms in our atmosphere, they split into Secondary Cosmic Rays, made mostly of muons.

EXPERIMENTAL SETUP

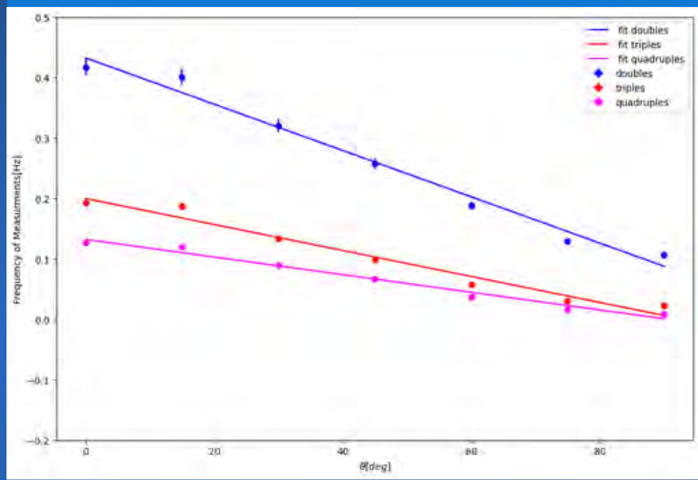


To detect Cosmic Rays we used CO.RA.M (COsmic RAys Mission), a scintillator detector. When muons pass through a detector layer, they generate light, which is collected by optical fiber and converted into a small electric signal by photodiodes. In our case, the instrument had 4 labeled layers (X, Y, Z, W) interposed with iron absorbers, to allow only the most penetrating particles to pass.

The detector can be rotated to analyze the variation of the counting rate with the Zenith angle. The measurements were made by recording the number of cosmic rays every 3 seconds. Then we considered the Counting Rate meaning particles per second. The data taken was repeated with different angles.

ANALYSIS

Measurements Graph:



Frequency of measurments (Hz): number of signals registered by the scintillators per second

θ (deg): angle of incidence of the cosmic rays

RESULTS

Ultimately, we've concluded that cosmic rays truly come from outside the Earth by observing how the Rate diminishes when the angle is increased (which means that particles pass through a bigger atmosphere path).

Our take-home message is that the universe is far more complex than it seems and that, even if someone could think otherwise, there are many mysteries left to unravel and a real necessity for young, passionate, and brilliant scientists to expand our perspective on the laws of nature.

International Cosmic Day

NOVEMBER 26 | 2024

ICD 2024

A day as astrophysicists

I.I.S.S.Trinchese Martano, Italy

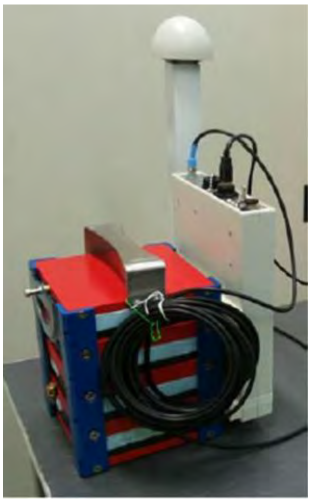
Credit: DESY, Science Communication Lab

Who are you?

Students: Luca Antonio Conversano 3^DSA, Giacomo and Marco 3^AS.

What have you done?

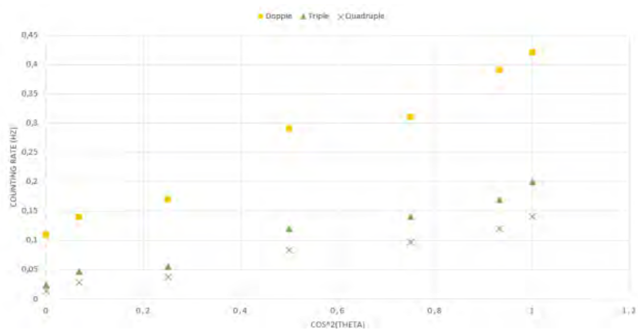
We attended a seminar by Professor Daniele Martello on the cosmic rays physics, to understand what they are and how they move through space. Then we had the opportunity to use a detector of cosmic rays to measure their flux as a function of the zenith angle. Next Professor Francesco De Palma guided us through the data analysis, helping us understand the relation between the zenith angle and cosmic ray flux. After the data analysis, we presented our results to other students from around Italy and many other foreign countries, confronting them as real scientists. In the end, we visited the astrophysics laboratories of INFN.



To perform the measurement we used a detector named CORAM (Cosim RAy Mission) composed of 4 scintillator layers put in coincidences.

What did you find out?

We found that the cosmic ray flux follows a linear path that depends on the cosine squared of the measurement angle. We learned a lot about cosmic rays, the instruments used to reveal them, and the international experiments about cosmic rays running all over the world.
We could also enter the world of scientific research, learning how to formally present results, take measurements, and confront results to improve both the experiments and the instruments used.



What's your take-home message?

Science is a beautiful discipline that helps us understand the world around us and knows no borders. It unites everyone with the only purpose of satisfying our curiosity.

Whispers from the Universe
Exploring Cosmic Rays

Liceo Scientifico G.Stampacchia, Tricase, Ital

Who we are

Our team consists of Alessandro Borlizzi, Andrea Zacchino, Manuel Ponzo, Francesca Morciano, Lorenzo Cosi, Rocco Corrado, Melissa Longo Biasco, Riccardo Bottaru, and Nino Licchetta. We are high school students attending the 4th and 5th classes. We had the chance to participate in International Cosmic Day, during which we learned what cosmic rays are and how they can be detected. We realized to deal with charged particles and photons originating from both galactic and extragalactic sources. They continue to be a key focus of ongoing Physics research due to their potential to advance our understanding of the Universe. Primary cosmic rays do not reach the Earth's surface because of their interaction with the atmosphere, giving rise to secondary particles, such as muons, which can be detected through ground-based experiments, like the Pierre Auger Observatory in Argentina.

What we have done

We have used **CORAM (Cosmic RAy Mission)**, a device consisting of four layers of plastic scintillators that detects the passage of muons and, therefore, allows us to measure the frequency of these cosmic secondary particles (rate in Hz). We have selected these counts in three types, depending on double, triple, and quadruple coincidences through contiguous layers, every 3 seconds for about 10 minutes. The device has been placed on an inclinable platform: using a goniometer and a plumb line, we have measured the **zenith angle θ**.

We repeated the measurement of the rate for the following values of θ: 0°, 15°, 30°, 45°, 60° and 75°. We entered our data into a Python code to highlight the relationship between the muon rate and the zenith angle θ. We plotted the graph of the rate as a function of θ, as a function of the cosine of θ and as a function of the square of the cosine of θ. We have calculated the quantity *E* which suggests the best linear fit *p(x) = ax+b:*

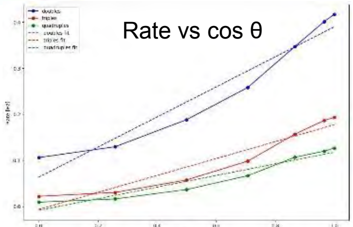
$$E = \sum_{j=0}^{k} |p(x_j) - y_j|^2$$

What we find out

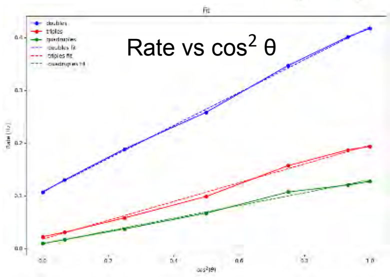
Based on our data analysis, we drew the following conclusions.

As expected, the muon rate decreases as the zenith angle θ increases, due to the absorption by the atmosphere.

The curved shape of the first graph shows that the two quantities are not linearly related, but more likely a cosine law is followed.



The second graph suggests a quadratic relationship between the cosmic ray flux and the cosine of θ.



The fit of the third graph confirms that the previous hypothesis is the most likely.

What our take-home message is

In conclusion, this experience has provided valuable insight into the fascinating world of cosmic rays and their detection. By participating in International Cosmic Day, we learned about the methods used to study these high-energy particles developing also a deeper understanding of the complex interactions that occur when cosmic rays collide with Earth's atmosphere. Our data analysis allowed us to explore the relationships between phenomena and mathematical models that describe them. We have found it very interesting and charming!

INTERNATIONAL COSMIC DAY

Liceo «Galileo Ferraris»

Taranto

Credit: DESY, Science Communication Lab

Who are you?

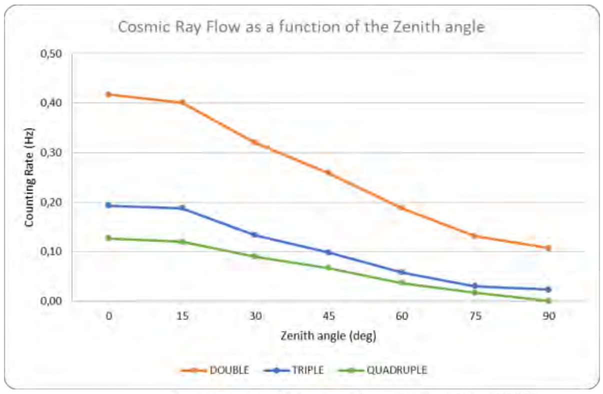
We are Ivan Vozza, Elisa Cuscela, Gabriele Sebastio, Francesco Santese, Luca Loscialpo, Danilo Marcianó, Silvio Ghenghi, Sofia Maria Ricci, Serena Esposito, Diana De Cristofaro, Elena Solidoro, Gennaro Gabriele Canfora and Giorgia Fanelli, students of the Ferraris High School in Taranto, and we attend scientific and linguistic courses.

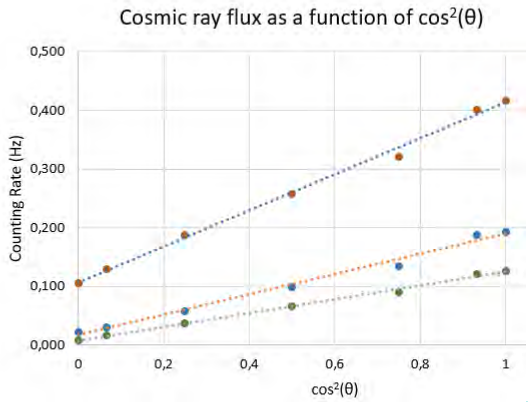
What have you done?

We attended seminars on cosmic ray physics an estimated the cosmic ray flux as a function of the zenith angle. Cosmic rays are high-energy particles that come from space and constantly bombard the Earth. Many of the particles are charged, and their path are influenced by magnetic fields in space. When primary cosmic rays enter the Earth's atmosphere, they interact with nuclei of atoms such as nitrogen and oxygen, producing a cascade of secondary particles. The secondary particles generated (such as muons, neutrons, pions and gamma photons) lose energy during their propagation through the atmosphere, reducing the number of particles reaching the earth's surface. The detection of cosmic rays is achieved by Ground-based observatories such as the Pierre Auger Observatory (Argentina) or through detectors as CORAM (Cosmic Ray Mission). CORAM uses a combination of sensors, such as scintillators and photodetectors, to detect the passage of high-energy particles. When a cosmic ray interacts with the detector, it produces a small flash of light, which is then captured by the photodetectors and converted into an electrical signal. Then these signals are processed and analyzed to determine the energy and trajectory of the cosmic rays. The apparatus, used at the University of Salento, consisted of four layers of scintillators, each measuring 14.5x14.5x1 cm^3, separated by layers of iron, which were used to select more penetrating particles. Particle detection is based on the concept of coincidence, which compares signals from various scintillators within a time window. The coincidences are then classified as follows: single: signal from only one layer; double: from two adjacent layers; triple: from three adjacent layers; quadruple: from all four layers. Procedure: 1. Data were collected for approximately ten minutes at each angle between 0° and 90°. 2. Particle counts C were recorded every three seconds. 3. The rate R was calculated using the formula: $R = C/T$.

What did you find out?

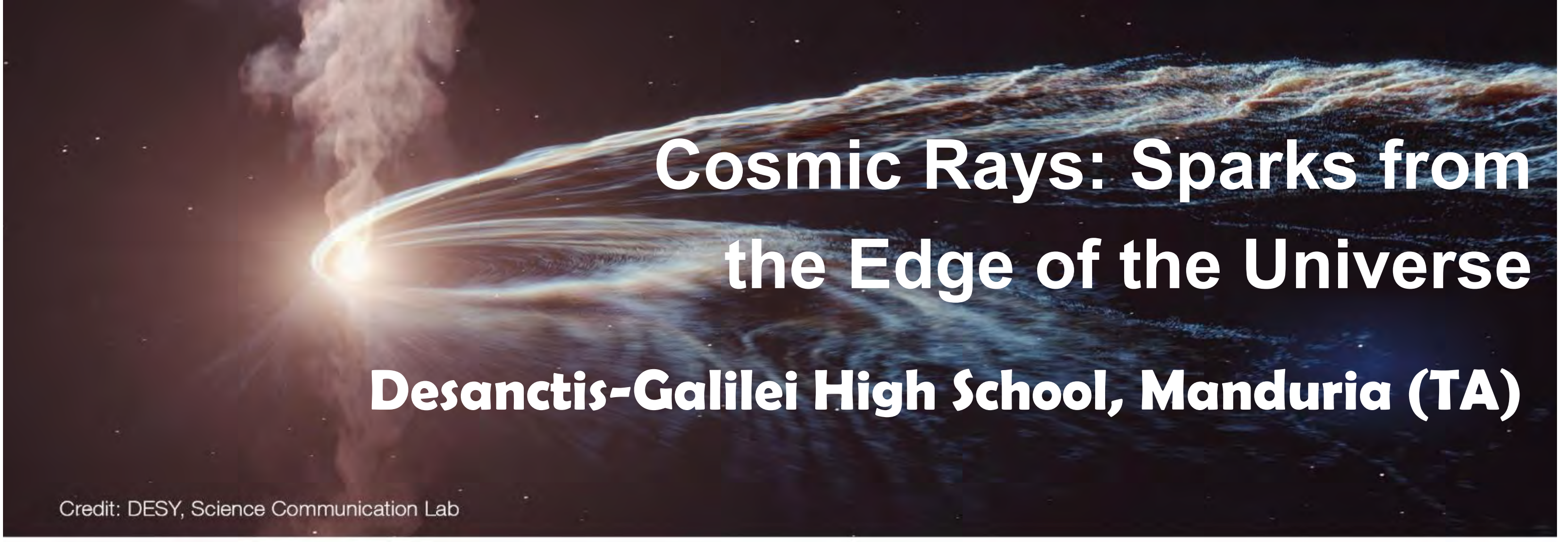
The average count distribution, recorded at regular intervals, allowed us to observe the variation in cosmic ray flux with the angle of inclination. We represented the data in two graphs. In the first one, we observed the averages of double, triple, and quadruple coincidences as the zenith angle varied. We noticed that as the value of the angle increased, the cosmic rays flux decreased. In the second one, we observed the averages of the double, triple and quadruple coincidences as the square of the cosine of the zenith angle varied. We noticed that the cosmic ray flux increased.





What's your take-home message?

The International Cosmic Ray Day was highly educational and engaging. It provided valuable insights and moments of reflection, with a well-organized structure. We appreciated the opportunity to explore topics rarely covered in traditional education and interact with experts working in the field, which makes the experience truly enriching. The international collaboration was a highlight, stimulating exchanges between countries and cultures. However, some of us suggested extending the program duration would have allowed for a more in-depth exploration of each activity. Overall, the day at the University of Salento was both enjoyable and informative. It sparked our curiosity and inspired participants to delve deeper into the study of cosmic rays.



Cosmic Rays: Sparks from the Edge of the Universe

Desanctis-Galilei High School, Manduria (TA)

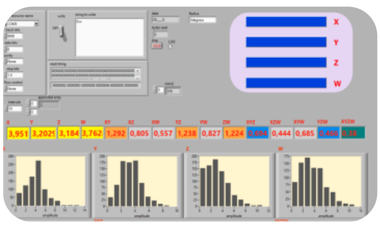
Credit: DESY, Science Communication Lab

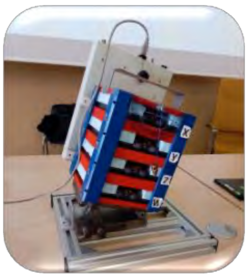
Who are you?

Students: Di Palmo Daniele, Brigante Antonio, Schiavoni Paolo, D'Amico Chiara, Fazzi Letizia, Stasi Maria Carmen, Buccolieri Flavio, Dimaggio Alessandro, Scaglioso Davide, Brunetti Federico, Lomartire Michele Pio, Matarrese Emiliano, Carruggio Matteo, Degirolamo Mattia, Dimaggio Gabriele, Pignataro Vittoria, Polito Cosimo, Pulieri Marco, Chimienti Flavio. Teachers: Musardo Giulia and Tomaselli Marialuisa.

What have you done?

During the day, we attended a seminar on cosmic rays, visited the planetarium, and saw the cloud chamber, which allowed us to observe cosmic ray tracks. Finally, we participated in an experiment using the CORAM detector (COsmic RAy Mission), consisting of 4 scintillator detectors that, when a cosmic ray passes through, can detect light through optical fibers (WLS) and photodetectors and give back an electrical signal. The scintillator layers are separated by iron absorbers to select the most penetrating particles, namely muons. The detector records the signals every 3 seconds and a graphical interface shows the values detected by a single layer (single X, Y, Z, W), and the coincidences. These are the values recorded simultaneously by: two adjacent layers (double coincidence), three layers (triple), and four layers (quadruple), and are reported on the interface in the form of histograms.

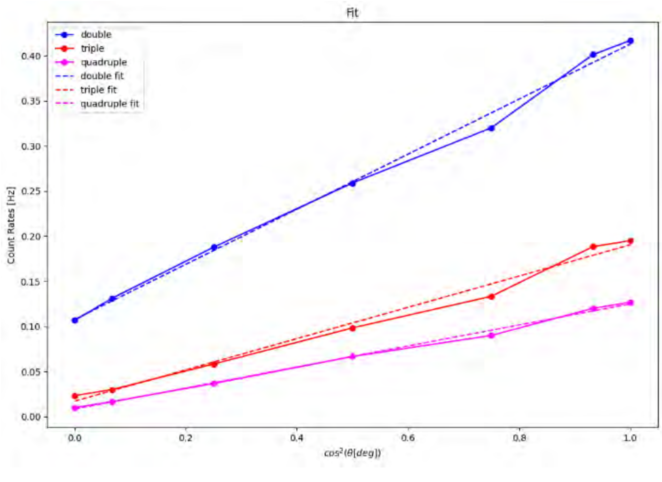




What did you find out?

https://colab.research.google.com/drive/1MWvreAsD5AsQLwHgNDaph-0Mi112rzQL?usp=sharing

We used the Python calculation program to analyze the data collected by tilting the detector at different angles. Through Python, we obtained the graphs of the counting rate as a function of the angle θ, the cosθ, and the cos^2θ. Fitting linearly the 3 graphs, we found that the residuals are smaller for the fit made with cos^2θ.



What's your take-home message?

Thanks to this experience, we expanded our scientific knowledge and became even more interested in science. The interactive methods, which were very different from the usual high school ones, got us involved and made us really curious about cosmic rays.

INTERNATIONAL COSMIC DAY
2024

Liceo L. Da Vinci-Maglie (LE)

Lorenzo Giancane (5H), Manuel Vallet (5C)

Credit: DESY, Science Communication Lab

Abstract

The International Cosmic Day, held on November 26, 2024, allowed students from different schools to come together to learn more about cosmic rays. Thanks to the equipment provided by the INFN in Lecce, we had the opportunity, guided by scientists and professionals, to record and analyze data collected performing cosmic ray measurements.
The main focus of the research was to analyze the trend of the cosmic rays flux as the zenith angle varies.
After a brief introduction, this analysis will be reported below.

Introduction

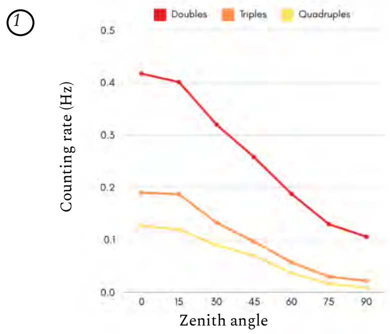
Cosmic rays are particles and nuclei of heavy atoms that strike the Earth in an almost uniform manner. Their discovery is attributed to the Austrian physicist Victor Hess, who received the Nobel Prize in Physics for this discovery in 1936. Although their origin is still unknown, it is believed that high-energy events, such as supernovae and supermassive black holes, generate them, accelerating the particles to extremely high speeds. Identifying the origin of this phenomenon is very complicated also because these rays are deviated by the magnetic fields of celestial bodies encountered along their path, making it impossible to determine their origin.
When these rays interact with the Earth's atmosphere, colliding with it, they release energy, causing phenomena such as the Northern and Southern Lights.

Experimental Setup

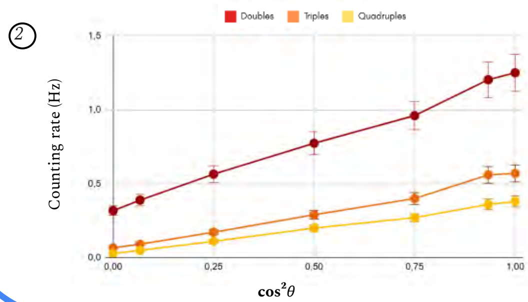
To collect the data, we used CORAM (COsmic RAy Mission), a four-level device capable of emitting a light pulse when the particles pass.
This pulse is then captured by a photosensor and transformed into an electrical signal. The device measures the frequency with which cosmic rays pass through the various layers as a function of the zenith angle (graph 1).
Values were collected at different angles and later divided by 3, to obtain a value relative to the single second. The collected values are also shown in graph 2, where the cosmic ray flux is plotted as a function of $\cos^2$ of theta angle.

Analysis

Zenith angle graph



Graph relating to the $\cos^2$



Acknowledgements

We are grateful to INFN Lecce for allowing us to live this experience, and to Principal Annarita Corrado for allowing us to participate in this project.

Conclusion

From the data analysis, it turned out that the cosmic rays flux detected by the CORAM decreases as the inclination of the device increases.
This happens because the greater the inclination, the further the particle will have to travel, thus increasing the probability that it will be absorbed by the atmosphere or collide with the particles in the air.

INTERNATIONAL COSMIC DAY

Francesco Calasso, Italy (LE)

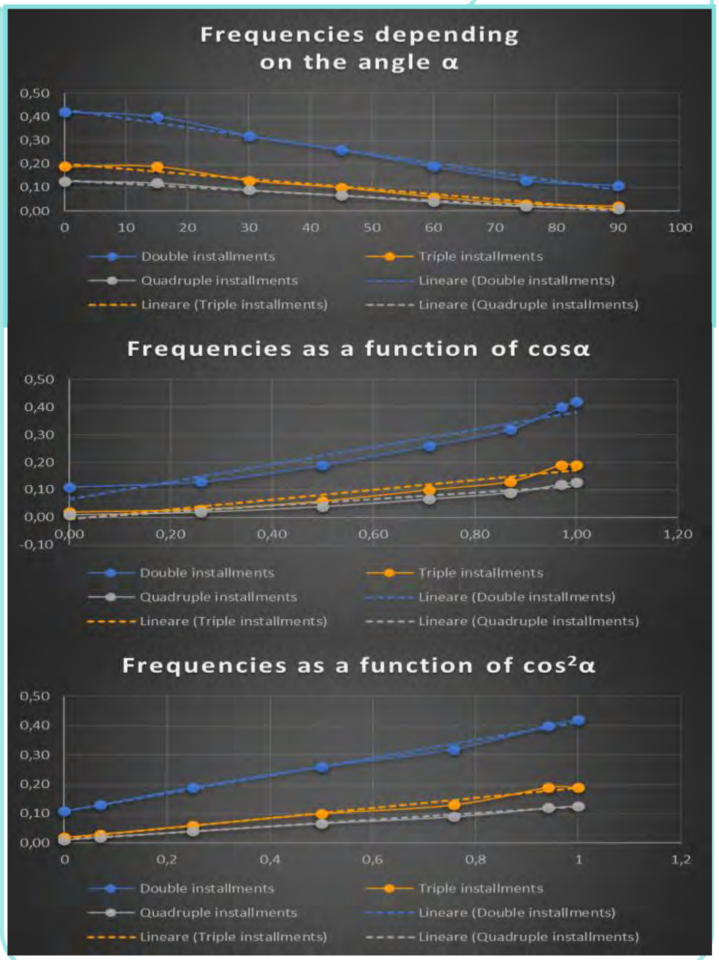
Who are you?

We are students of the high school Francesco Calasso, Lecce: Siria Marcuccio, Rosario Greco, Giulia Ruggieri, Francesco Rutigliano, Alessia Nobile, Aurora Campobasso, Cristian Stomeo. We love physics and with the help of our teacher, Mrs. Congedo, we prepared this contribution for the International Cosmic Day.

What have you done?

On November 26th, on the occasion of the International Cosmic Day, we attended a conference at the Department of Mathematics and Physics Ennio De Giorgi and learned many concepts about cosmic rays.
Cosmic rays are high-energy protons and atomic nuclei moving in space close to the light speed. They originate from the Sun, outside the solar system, and distant colliding galaxies. We used a detector made of four scintillator layers interposed with iron absorbers. This object is called CORAM (Cosmic Ray Mission). Then we recorded the measurements of the adjacent layers, considering the double, triple, and quadruple coincidences. The cosmic ray flux was measured as a function of the zenith angle.

What did you find out?



What's your take-home message?

We discovered that the flux of muons at the ground level is not uniformly distributed. By analyzing the measurements performed using CORAM at different angles with the local Zenith, it is discovered that the maximum flow occurs for $\theta=0°$, i.e. for particles arriving perpendicular to the Earth's surface. The flux decreases continuously as the angle between the direction of incidence and the zenith increases. At 90° the flux is minimal. The distribution of the measured values can be described using a cos^2 function.

INTERNATIONAL COSMIC DAY

A.D. 1308 unipg DIPARTIMENTO DI FISICA E GEOLOGIA

INFN PERUGIA

CRISP ASI-UniPG 2019-2-HH.0

Credit: DESY, Science Communication Lab

INFN and University of Perugia, Italy

Liceo Scientifico «G. Alessi» – Perugia (PG), Italy

Abstract

On November 26th 2024, high-school students and their teachers took part to International Cosmic Day in Perugia, organized by INFN and University of Perugia, Italy. The students were involved in the design and construction of a muon detector, as well as in the analysis of the data. The students measured the intensity rate of the cosmic muons as function of their incoming directions.

The International Cosmic Day

On November 26st 2024, the 13° edition of the International Cosmic Day (ICD 2024) was celebrated worldwide. In Italy, the event was organized by the *Outreach. Cosmic Ray Activities* (OCRA) network of INFN, the National Institute of Nuclear Physics. In Perugia, ICD was organized locally by INFN-Perugia and by the Department of Physics and Geology of the University of Perugia. Coordinated by prof. Nicola Tomassetti, ICD-Perugia involved various activities with the participation of university students and researchers: Alessio Ubaldi, Chiara Campioni, David Pelosi, Francesco Faldi, Maura Graziani, Nicola Tomassetti. 15 high-school students from Liceo Scientifico Galeazzo Alessi of Perugia took part to the event, along with their teacher prof.ssa Veronica Palli. Outreach activities for the International Cosmic Day in Perugia are supported by the *Italian Space Agency*, agreement ASI-UniPG 2019-2-HH.0.

Conclusions

At ICD, high-school students learned about cosmic rays, particle detection, and data analysis. The ICD gave to them the opportunity to work, for a day, as researchers in astroparticle physics.

The activities

After an introduction on the physics of cosmic rays and their detection techniques, all students and their teachers were actively involved in the construction of a particle detector, to be used as a telescope for cosmic muons. The students were also involved in the analisis of muon data They were able to determine the ground muon intensity I (#counts/second) and its dependence on the zenith angle θ. A dependence of the type $\mathrm{I}(\theta) \propto \cos^2(\theta)$ was observed. The pictures below were taken during some of the activities.

JAPAN

Journey Through Radiation Detection: Cosmic Watch & Radiacode

Accel Kitchen, Japan

Credit: DESY, Science Communication Lab

Presenters

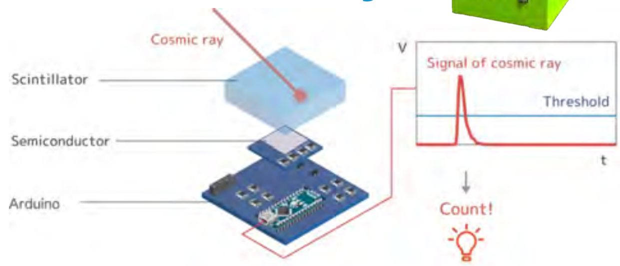
Karin ITO
Shibuya Makuhari Junior High School
Participating student since August 2024

Manaka SASAKI
School of Health Sciences, Tohoku University
Mentor of Accel Kitchen

1. Assembling Cosmic Watch @Tohoku University

The Cosmic Watch is a small, simple scintillation cosmic ray detector. Karin assembled one herself while learning about how it works.
The device consists of three main components: a scintillator, a light sensor with SiPM, and an Arduino. When cosmic rays pass through the scintillator, they generate light inside it. The sensor detects this light and converts it into electrical signals via the SiPM. When these signals exceed its threshold, they are recorded as individual counts.

Image 1 shows the scintillator and sensor with SiPM. Optical grease is applied to the central sensor to prevent light refraction at the boundary. In Image 2, the scintillator and sensor are secured together, with the scintillator wrapped in aluminum foil to contain the light. Image 3 shows this assembly wrapped in light-blocking tape, which prevents external light from creating noise. The final step is attaching the circuit board—then it's complete!



2. Measuring Monazite Radiation Using Radiacode @home

Radiacode

Radiacode is a pocket-sized Geiger counter and gamma spectrometer with a CsI(Tl) scintillator.
It measures counts, spectra, and radiation dose.
The device connects to your smartphone via Bluetooth for real-time data viewing, and you can export the data as XML or TXT files!

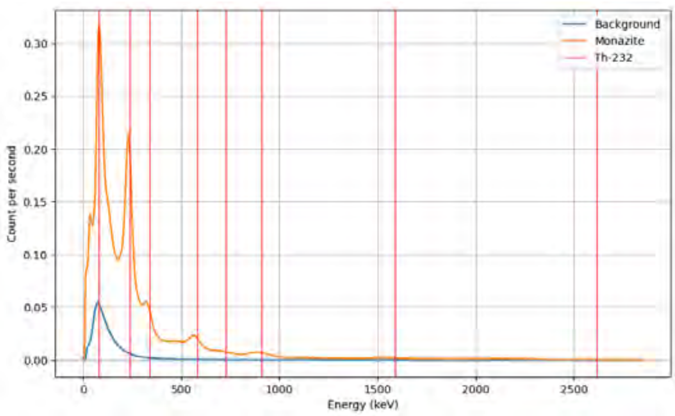
Method

1. Prepare two Radiacodes.
2. Attach monazite(≒1cm^3) to the scintillator part.
   (The other one is for background measuring.)
3. Measure for 1 week from October 31 to November 7.
4. Create graphs of CPS by energy level using Google Colaboratory.

Results

When analyzing the CPS - Energy spectrum from our data, we observed distinct peaks at specific energy levels. The Radiacode smartphone app identified these peaks as signatures of the Thorium-232 decay series. Referencing the Th-232 decay series energies from the dataset built into Radiacode, we added red lines to the spectrum chart. These lines aligned almost perfectly with the positions of the energy peaks.

Monazite, one of the phosphate minerals, is found in igneous rocks like granite. Since these rocks form relatively slowly, they incorporate small amounts of impurities such as thorium and uranium. Our experiment detected gamma rays being emitted from the thorium present in the monazite.

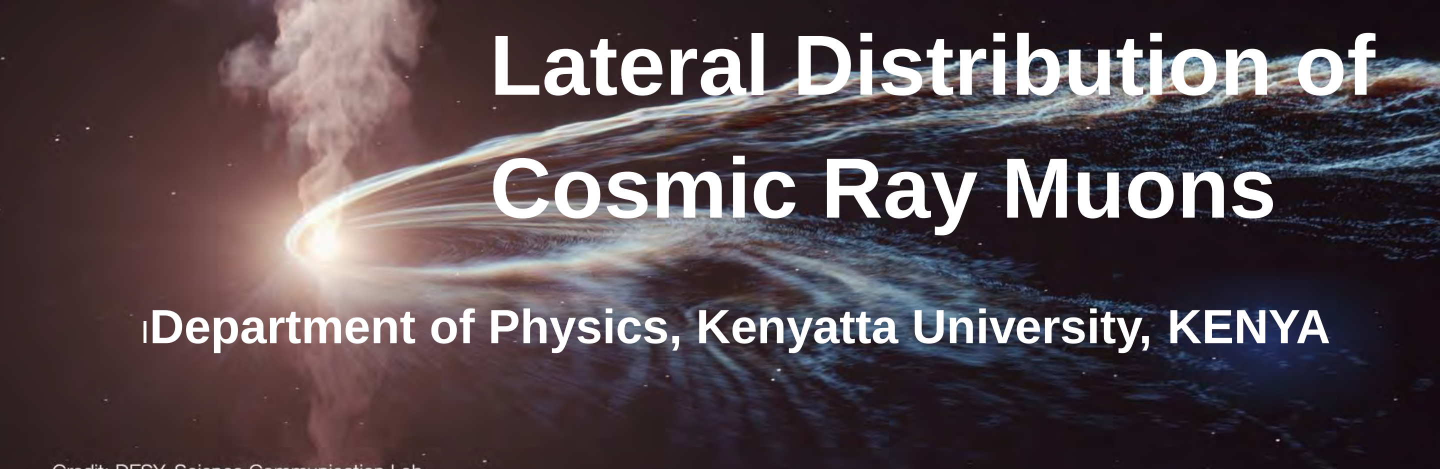


Feel free to contact us if you are interested!
info@accel-kitchen.com
加速キッチン合同会社

KENYA

Lateral Distribution of Cosmic Ray Muons

Department of Physics, Kenyatta University, KENYA



Credit: DESY, Science Communication Lab

Who are you?

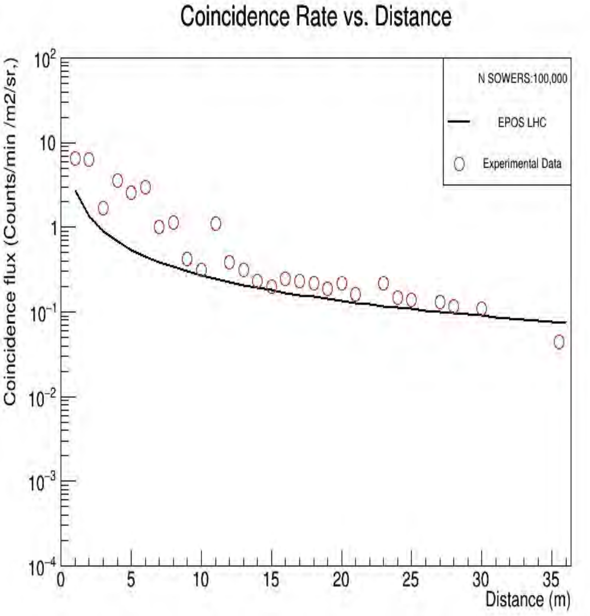
We are a research group comprising of **postgraduate students** – Veronicah Kihagi, Samuel Chege, Jack Kisingu, our **supervisors** – Naftali Kimani, Livingstone Ochilo, Nadir Hashim in the Department of Physics at Kenyatta University and our **international mentor** – Claus Grupen from Siegen University.

What we did

The International Cosmic Day 2024 provided an opportunity for undergraduate students to learn about cosmic rays through lectures and hands-on sessions on the measurement of cosmic ray muons.

- ❑ **Detectors and instrumentation**
- NaI(Tl) detectors, plastic scintillators
- NIM – signal processing
- ❑ **Measurements and simulations**
- Coincidences over distances up to 36 m
- Simulation of EAS using CORSIKA

What we find out



- ❖ Coincidence rate reduces with distance between the detectors
- ❖ Agreement between data and simulation
- ❖ Estimated primary composition using NKG function fit

See publication

Enhancing the knowledge of the Extensive Air Showers (EAS)

- Cosmic ray muons - a robust component of EAS that can be measured on the ground and beyond
- EAS – provides a means to understand the composition of cosmic ray particles and their interactions in the atmosphere.

For more information contact: hashim.nadir@ku.ac.ke

MEXICO

Exploring the Muon Flux

Universidad de Monterrey, México

S.A. Contreras Díaz, L.F. López Rosales, A. Luna de la Garza, P. Martínez Neira, L.E. Paredes Cruz, F. Suárez Mobarak, J. Villarreal Salazar, A. Santos-Guevara, O. Aquines-Gutiérrez, and H. Martínez-Huerta

Credit: DESY, Science Communication Lab

Who are you?

We are 7 university students from the astronomy group AstroUDEM and tree research professors gathered at **the University of Monterrey in Nuevo León, Mexico**, on November 21-28 to learn about cosmic particles, science and celebrate the International Cosmic Day 2024.

What have you done?

Our work focused on measuring and understanding the muon flux. We began with discussions on elementary particles, astronomy, and cosmology, then on cosmic rays and some statistics.

To prepare for experimental work, we utilized the Muon Flux App[a] to simulate expected results, with each student reporting muon flux values over one hour for varying energies, angles, and at the altitude of San Pedro Garza García, N. L., México (540 m a.s.l.).

We then conducted an experiment to measure cosmic ray flux using two Geiger Müller (GM), a Counters 513610[b], a Coincidence Box 5138[b], several metal plates, and an arm base[b]. The GM tubes were carefully aligned to ensure directional accuracy, and 6 cm of metal absorber plates were placed between them to guarantee the muons had sufficient energy.

The setup, illustrated in the images, involved spacing the GM detectors 15 cm apart from the plates.

Measurements were taken over 24 hours for zenith angles ranging from 0° to 90°. The collected data, along with corresponding error estimates, are reported in the next section.

The app also allowed us to see that, at the highest energies, the simulated data are closer to the measured values. However, it's important to note that these simulations are for illustrative purposes and do not account for the design or specific properties of our experimental setup. Also, many uncertainties, such as the building structure, wall thickness, weather conditions, detector configurations, and surrounding mountains, influenced the measurements, and are not included in the simulated data.

a.Muon Flux App webpage (21.Nov.2024): https://apkpure.com/es/muon-flux/it.android.muonflux
b. Frederiksen Muon Observatory

Exploring the Muon Flux

Universidad de Monterrey, México

S.A. Contreras Díaz, L.F. López Rosales, A. Luna de la Garza, P. Martínez Neira, L.E. Paredes Cruz, F. Suárez Mobarak, J. Villarreal Salazar, A. Santos-Guevara, O. Aquines-Gutiérrez, and H. Martínez-Huerta

Credit: DESY, Science Communication Lab

What did you find out?

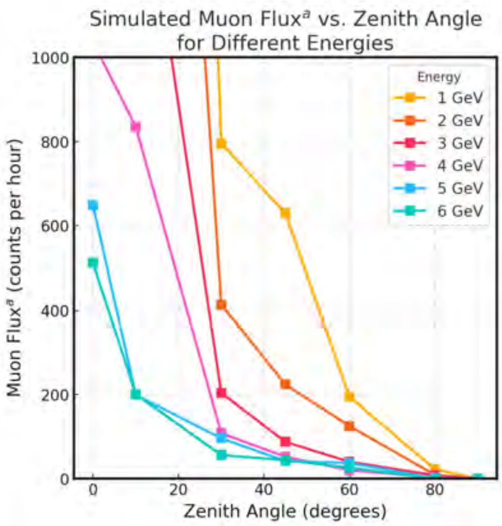


Fig. 1

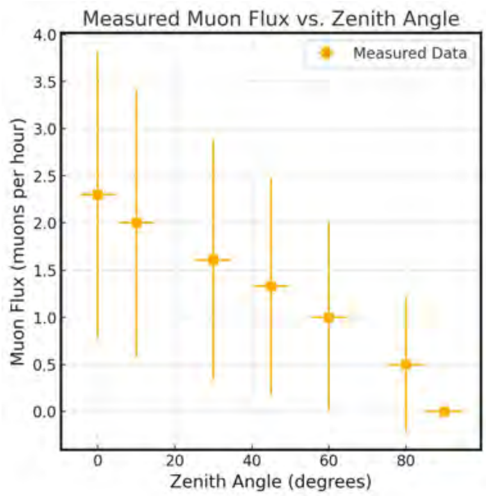


Fig. 2

Fig. 1 shows the simulated[a] muon flux as a function of the zenith angle for different energies (1–6 GeV). The muon flux decreases as the zenith angle increases, with a more pronounced decline at higher angles due to the increased atmospheric path length. Muons arriving vertically (at small zenith angles) experience less attenuation, while those at larger angles have a greater probability of energy loss or decay. The simulations confirm that flux values depend strongly on the muon energy, with higher energies maintaining a detectable flux even at moderate zenith angles.

Fig. 2 shows the measured muon flux as a function of the zenith angle, with angular ($\Delta\theta=\arctan(L/D)$) and statistical ($\Delta r=\sqrt{N}/T$) uncertainties included, which are reflected as error bars in the graph. D is the effective diameter of the Geiger tubes (28.6 mm) and L is the separation between the two outermost detectors including the plates (36 cm).

At smaller zenith angles (~0°), the muon flux is at its highest, indicating that muons arriving vertically experience less atmospheric attenuation. As the zenith angle increases, the flux decreases significantly, approaching zero at 90°. For us, this trend reflects the longer path length through the atmosphere for muons arriving at larger angles, leading to increased energy loss and a higher probability of decay.

The data aligns with expected behavior previously tested with the simulations[a], though uncertainties due to environmental factors, such as building structures, wall thickness, weather conditions, and nearby mountains, may have influenced the measurements, particularly at larger zenith angles.

What's your take-home message?

Understanding cosmic ray muon flux provides crucial insights into elementary particles and their interactions with the Earth's atmosphere. The work done in this week integrates theoretical discussions and experimental practices to enhance engagement and comprehension of fundamental physics. We learned how cosmic ray science is conducted, from simulations to collaborative and patient efforts in data collection, analysis, and discussion. This experience highlights to us the importance of combining theory, experimentation, and collaboration to inspire curiosity and deepen our understanding of the universe.

Protoresearchers looking for Astroparticles

Universidad Autónoma de Chiapas, México

Credit: DESY, Science Communication Lab

We are Karla Sofía Sánchez Granadillo, Luz Elena García Ramos, Sebastian Aguilar Toledo and Juan Daniel Bonifaz Partida first semester's physics students with a deep passion for understanding the universe. We are eager to expand our knowledge through both theoretical and practical experiences and aspire to contribute meaningfully to the scientific community

What have you done?

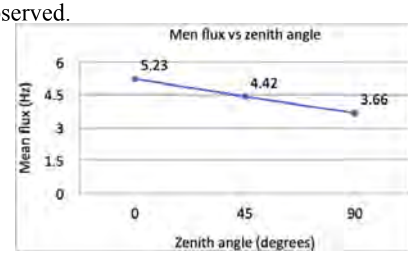
We had the opportunity to engage in several fascinating experiments and discussions. One of the experiments is Escaramujo, a scintillation particle detector. We also got to know Jaguarito, a water Cherenkov particle detector that is part of the LAGO (Latin American Giant Observatory) project. We performed fluorescence experiments that allowed us to explore the behavior of light and materials, which gave us a better understanding of the principles and its applications. We also performed some observations at the Sun with a telescope. To complete our practical work, we attended a talk about Astro-articles. The discussion provided a detailed explanation of their origins, how do they interact with the Earth's atmosphere, and their significance in understanding fundamental questions about the universe. Everything deepened our appreciation of the complexity and importance of studying cosmic phenomena.

Data taking and analysis

The team

What did you find out?

We measured the flux of cosmic rays (muons) as a function of zenith angle by using Escaramujo. We discovered a higher number of particle detections at a 0-degree of zenith angle. The data revealed signal in the particle coincidences depending on the angle of the two detection plates. This correlation between angle and particle detection is shown in the plot, a decrease in the average number of detections as the angle increases from 0 to 90 degrees is observed.



What's your take-home message?

It was fascinating to realize how tangible science can be. Phenomena that may initially seem abstract became much more accessible when observed through practical experiments. We also learned that things we often consider irrelevant can become surprisingly impressive when we pay closer attention to them. This experience highlighted just how extraordinary nature is and how much it can reveal when we take the time to explore it.

THAILAND

Preliminary Study on Portable Muon Detector Calibration with Ship-Borne Neutron Monitor

Credit: DESY, Science Communication Lab

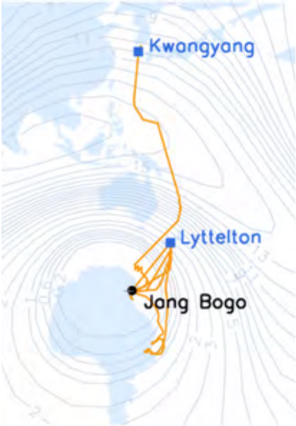
Mahidol Wittayanusorn School, Thailand

Who are you?

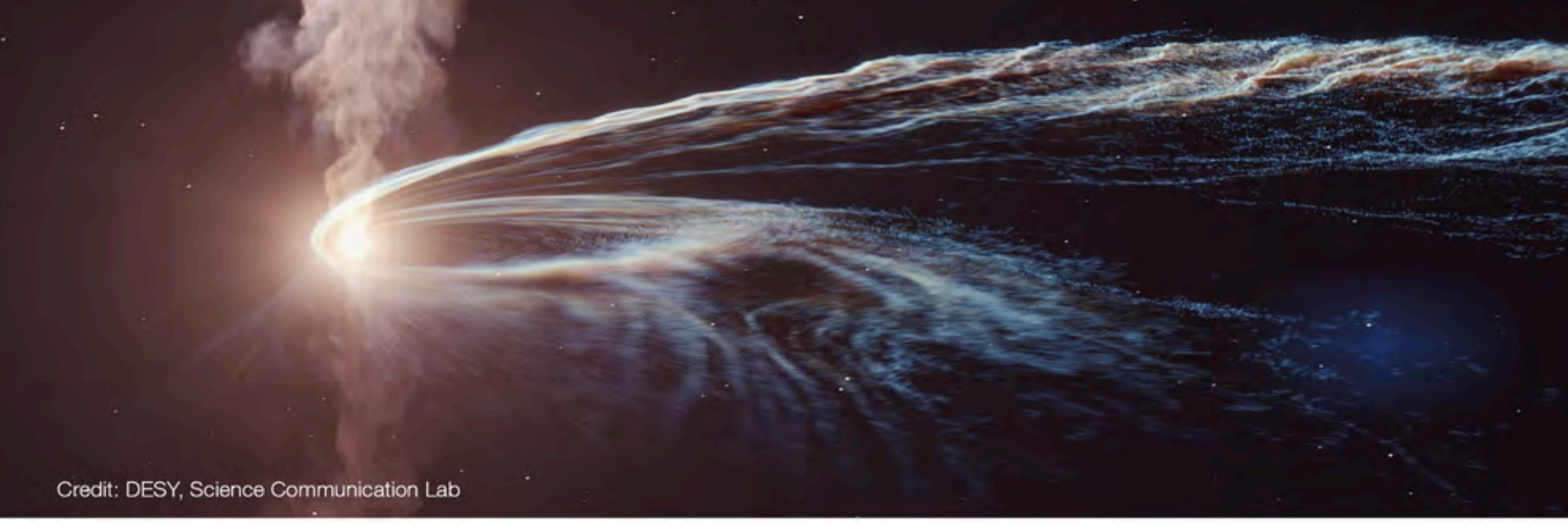
We are a student science project group focused on the **Cosmic Watch**, which detects muons. Our team consists of three students, two advisor teachers, and a collaboration with Chiang Mai University, Thailand. Our mission is to understand the nature of muons and verify whether the Cosmic Watch can accurately detect muons.

What have you done?

In our experiment, we used the Cosmic Watch detectors, an educational tool designed to detect muons, aboard the South Korean icebreaker ARAON alongside the Changvan Neutron Monitor, which provides higher statistical accuracy. Using data from the Changvan Monitor, we calibrated the Cosmic Watch to study the latitude dependence of muon detection.

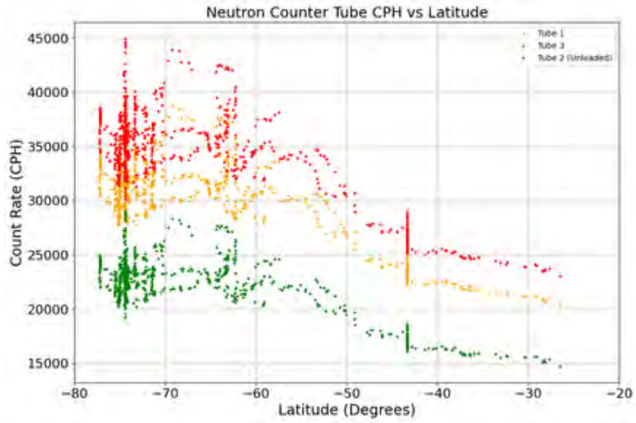


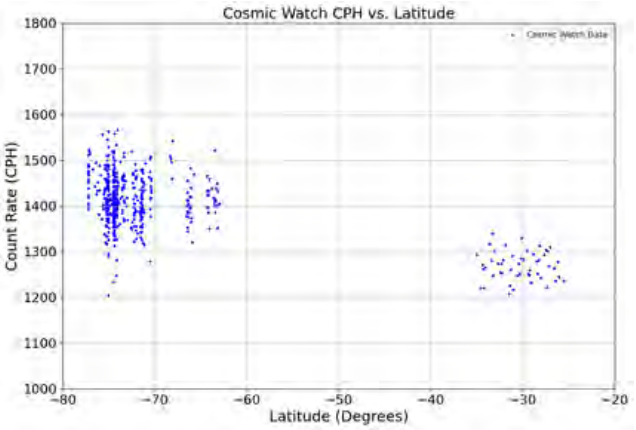
The data collecting path from December 2023 to April 2024. The Cosmic Watch data that we are processing consists of SiPM voltage, Event count and timestamp for each event. Using ARAON's GPS, we collected data on latitude. Median latitude per hour is used to synchronize with the count rate data.

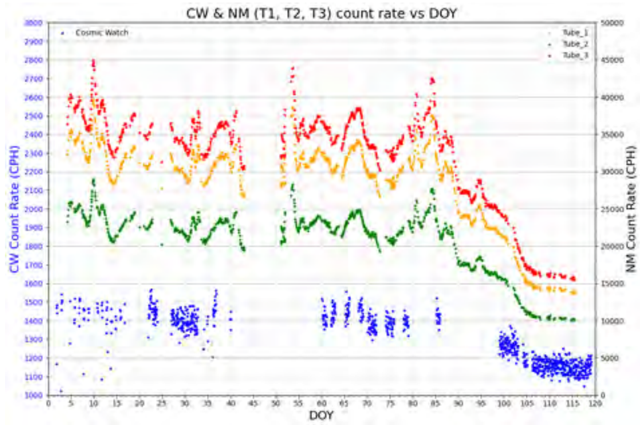


What did you find out?

Trends for the Cosmic watch and Neutron monitor closely resembles each other,







Cosmic Watch has the potential to be a portable detector for studying muon latitude dependence. Although the cosmic watch has a low precision while recording data during rapid latitude changes, this can be improved by using more cosmic watches to increase the statistical significance. This makes it an effective educational tool for studying muon latitude dependence and, in the future, for studies on atmospheric dependence.

What's your take-home message?

As we explore cosmic rays further, we find them truly fascinating as they hold the key to uncovering the secrets of the vast universe. With curiosity and effort, there's nothing you can't achieve.

TURKEY

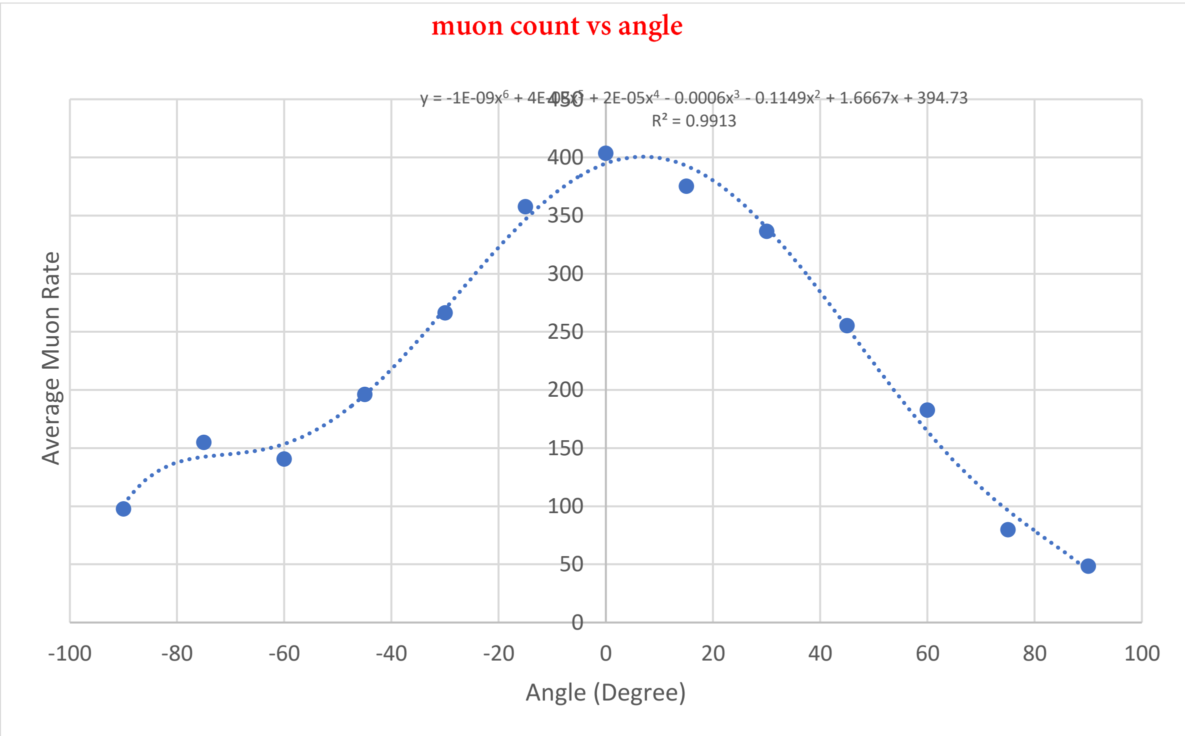
International Cosmic Day Nov 26, 2024

In the scope of International Cosmic Day Workshop, the students listened to a lecture about the cosmic particles and apparatus used to investigate cosmic radiation. The participants learned about the studies of cosmic particles, the origin of pions and muons, Then, the lecturer encouraged the students to discuss possible questions to the available data

The workshop consisted of a data-analysis task distributed among 6 groups of students, who worked with the datasets collected from the Cosmo-Mill detector. Each group was assigned a data set corresponding to a specific year from 2016-2021. The students evaluated the maximum and minimum rates of muons detected at zenith angles between -90 to 90 degrees. Thereafter, the data were recorded in the table and the average values of the muon rates were calculated and plotted against the zenith angles on the graph using Excel.

angle	year	2016	2017	2018	2019	2020	2021	av. Muon rate
-90	min	15	20	25	20	15	10	97.75
	max	50	235	350	71	75	287	
	av	32.5	127.5	187.5	45.5	45	148.5	
-75	min	25	20	25	28	20	10	155
	max	75	860	360	82	75	280	
	av	50	440	192.5	55	47.5	145	
-60	min	40	80	40	74	70	27	140.58
	max	160	230	380	139	155	292	
	av	100	155	210	106.5	112.5	159.5	
-45	min	70	100	85	131	95	35	196.25
	max	275	380	370	266	270	278	
	av	172.5	240	227.5	198.5	182.5	156.5	
-30	min	100	160	140	193	160	40	266.42
	max	445	395	410	387	390	377	
	av	272.5	277.5	275	290	275	208.5	
-15	min	125	210	180	270	205	24	357.58
	max	570	580	565	522	520	520	
	av	347.5	395	372.5	396	362.5	272	
0	min	125	250	255	193	250	38	403.67
	max	600	680	610	670	605	568	
	av	362.5	465	432.5	431.5	427.5	303	
15	min	125	255	250	10	230	52	375.25
	max	570	620	615	598	610	568	
	av	347.5	437.5	432.5	304	420	310	
30	min	110	210	200	136	210	63	336.42
	max	460	560	540	528	520	500	

	av	285	385	370	332	365	281.5	
45	min	70	160	135	200	160	41	255.25
	max	340	400	420	389	395	353	
	av	205	280	277.5	294.5	277.5	197	
60	min	45	110	95	123	90	33	182.58
	max	200	240	510	245	260	240	
	av	122.5	175	302.5	184	175	136.5	
75	min	20	40	55	52	40	8	79.917
	max	95	140	120	130	140	119	
	av	57.5	90	87.5	91	90	63.5	
90	min	15	20	30	28	10	4	48.5
	max	50	80	65	75	60	145	
	av	32.5	50	47.5	51.5	35	74.5	



The range of the average rate of muons was from 48.5 to 403.67. As shown on the graph, the data are not symmetrical in respect to y-axis. Hence, the distribution of muons detected from the angles with positive sign is not identical to the rates of muons corresponding to the angles with negative sign. The graph has a trendline of a polynomial equation of 6th degree ($y = -1E-09x^6 + 4E-08x^5 + 2E-05x^4 - 0.0006x^3 - 0.1149x^2 + 1.6667x + 394.73$). The correlation coefficient was very close to 1 ($R^2 = 0.9913$), which indicates that the trendline function fits almost precisely to the data.

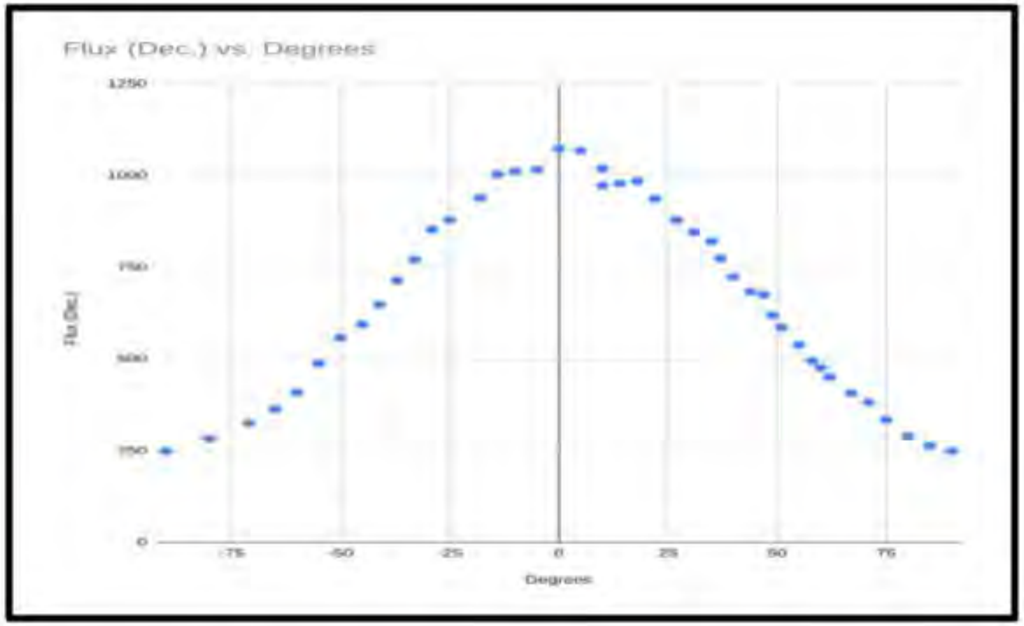
USA

Winamac Community High School Physics
Winamac IN, USA

Angle Study

Procedure:

Angles describe how an object is rotating when said object is fixed on a certain axis. We used angle study by rotating our CRMD (Cosmic Ray Muon Detector) to find if different angles provided different results. We measured from (-90°, 90°), and our teacher continued to measure different angles for more results throughout the day. The angles we measured gave us varying amounts of particles, such as a full cycle at 0° reading 1,073 particles, and a full cycle at 90° reading 249 particles.

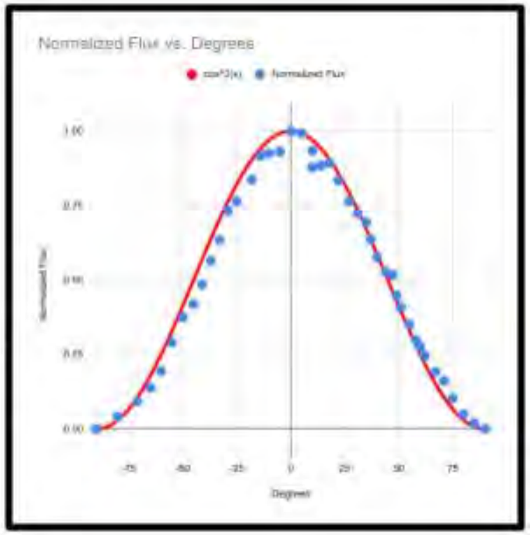


Conclusion:

The angle at which our CRMD was rotated did have an impact on the measurements. A rotation of 0 degrees gave the highest flux and a rotation of ±90 degrees gave the least flux.

Questions for further study:

- **What if you turn it upside down?**
- **What if our measurements were taken outside instead of in the classroom**
- **What if the CRMD stood vertically instead of laying horizontally?**
- **What if we did a shower study with more than one CRMD, and set each one at different angles?**



SUMMARY

The Earth is constantly bombarded by **high-energy** particles from the cosmos. A continuous flux of primary cosmic particles hits the atmosphere, interacts with air atoms and produces a large number of new particles. We do not feel or see these particles although they constantly penetrate us. Although cosmic rays are not directly visible, they affect us in many ways.

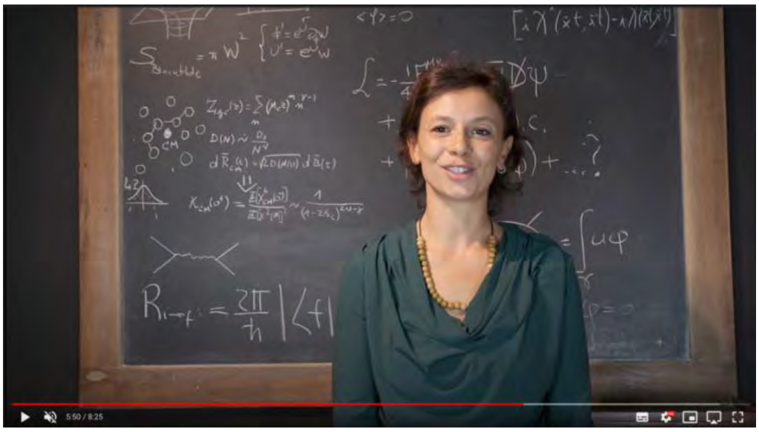
It is only possible to detect cosmic particles and to explore their properties with special equipment. Scientists are trying to find out what kind of **sources** generate cosmic particles and what mechanisms accelerate them to such extremely high energies. Cosmic particles also help to understand the physical processes that take place in our universe during the birth, life and death of stars and galaxies.

To better understand our universe, worldwide collaborations of astroparticle physicists have formed to prepare larger and more sensitive **experiments**.

Besides cosmic rays, which consist of charged particles, other particles also reach us from space. These are on the one hand the uncharged neutrinos, which are difficult to detect, and on the other hand the electromagnetic radiation: gamma rays. These **messengers** can be summarized as cosmic particles.

If you want to learn more about this, check out our online lectures:

What is astroparticle physics?



What are cosmic rays?

How can cosmic particles be measured?

Many of you have been worked on and measured the zenith angle distribution of air shower particles. The goal is to measure the rate of **muons** produced in extended air showers as a function of the zenith angle.

Those of you who have done this measurement have seen that the rate reaches its maximum when pointing the detector points, towards the zenith. As you increase the **zenith angle**, i.e. tilt the detector more and more towards the horizon, the muon rate decreases. From this we conclud that most of the cosmic rays reach us from above.

This result is easy to understand if you consider where the muons come from. The muons are produced in the upper atmosphere of the Earth, at an **altitude** between 10 and 15 kilometers above sea level. This is the distance they have to travel when they hit us from straight above.

Muons that reach us from a **horizontal direction**, i.e. at a large zenith angle, have to travel a much greater distance, more than 400 km. Then remember that muons have a very short **lifetime**: On average, they decay after only two millionths of a second, they decay. Therfore muons travel as fast as possible - at over 99% of the speed of light – the farther the distance, the higher is the probability that they decay before reaching us. Consequently, the larger the zenith angle at which we point our detector, the lower the measured muon rate.

If you want to analyze more data yourself, you can do it with Cosmic@Web.

In the video we explain how to do it.

LEARN MORE

If you want to know more about cosmic particles and astroparticle physics, here are a few links.

Have fun on the trail of science!

MORE ABOUT MUONS AND COSMIC RAYS

Discovery of a previously unknown "void" in the Great Pyramid at Giza in Egypt using muography:

http://www.scanpyramids.org/

Comic about Cosmic Ray from NASA:

http://www.nasa.gov/pdf/752017main_CRaTER_minicomic.pdf

IceCube – Life at the South Pole:

http://icecube.wisc.edu/pole/life

Video "The fantastic voyage of Nino the neutrino" from INFN:

http://www.youtube.com/watch?v=dhkCMO1lG7g

Outreach website astroparticle group at DESY:

https://astro.desy.de/outreach

MORE ABOUT NOBEL PRIZES IN PHYSICS

Nobel Prize in Physics 2015 "for the discovery of neutrino oscillations":

http://www.nobelprize.org/nobel_prizes/physics/laureates/2015/press.html

Nobel Prize in Physics 2017 "for decisive contributions to the LIGO detector and the observation of gravitational waves":

https://www.nobelprize.org/nobel_prizes/physics/laureates/2017/

MORE OUTREACH PROGRAMS FOR STUDENTS

Netzwerk Teilchenwelt – Overview over astroparticle and particle physics outreach programs in Germany:

http://www.teilchenwelt.de

OCRA – Public engagement activities in the field of cosmic rays of the National Institute of Nuclear Physics (INFN):

https://web.infn.it/OCRA/

Extreme Energy Events (EEE) – Science inside Schools - Overview over an astroparticle physics outreach program in Italy:

http://eee.centrofermi.it/

Pierre Auger Observatory – public release of Pierre Auger Observatory cosmic-ray data:

https://opendata.auger.org

QuarkNet – Overview over physics outreach programs in the USA:

https://quarknet.i2u2.org

IPPOG – The International Particle Physics Outreach Group:

http://ippog.web.cern.ch/

IceCube Masterclass – Analyze IceCube data:

http://icecube.wisc.edu/outreach/masterclass

International Particle Physics Masterclasses – Analyze particle physics data:

https://ippog.org/imc-international-masterclasses

Fermilab:

http://ed.fnal.gov/home/students.shtml