INTERNATIONAL COSMIC DAY

BOOKLET 2023

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DEAR YOUNG ICD-RESEARCHERS FROM

BRAZIL · INDIA · USA · ITALY ·
COLOMBIA · THAILAND · FRANCE · UKRAINE ·
GERMANY · DENMARK · KENYA · PAKISTAN ·
IRAN · UNITED KINGDOM · NEPAL · SPAIN ·
CHINA · JAPAN · MEXICO

thank you all for your participation and contribution to this year's International Cosmic Day (ICD)!

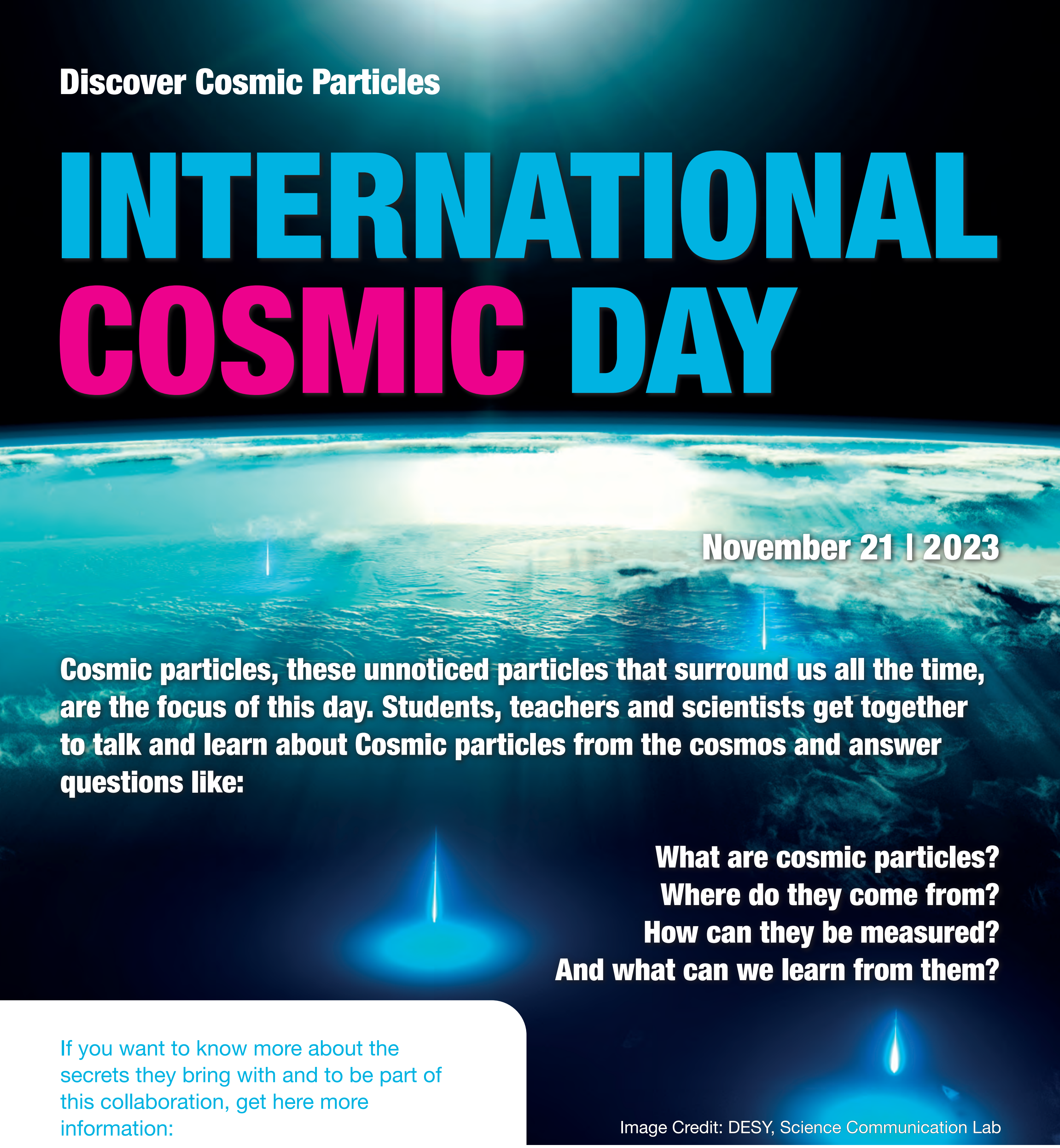
The 12th anniversary of ICD was once more a reason to celebrate: More than **2600 students from 19 countries around 4 continents** under the guidance of teachers and scientists made this day a successful celebration of physics. Participants from various institutions all over the globe such as schools, universities and research institutes performed experiments and attended lectures. We listened to scientists discuss their research and to students who presented their results - all to form a deeper understanding of the world we live in.

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 21 | 2023

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 the cosmos 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 with and to be part of this collaboration, get here more information:

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

International Particle Physics Outreach Group

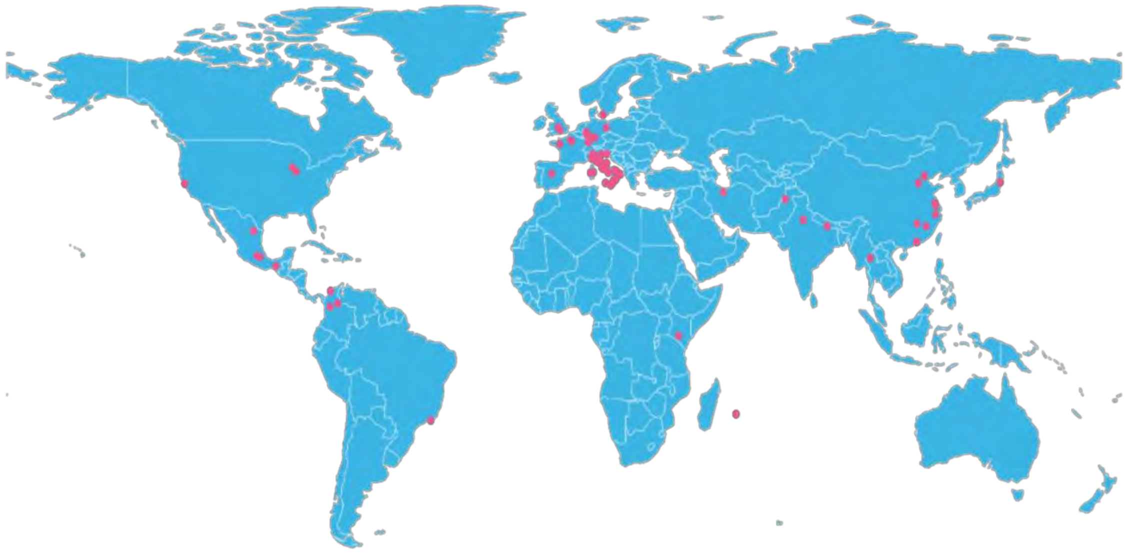
DESY.

In cooperation with many networks and partners

ALL PARTICIPATING GROUPS

In 2023, 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 2023 and can be found online at: https://icd.desy.de/map.

THE WINNERS OF ICD2023 CONTESTS

In the discipline **Cosmic Selfie Contest** the participants investigated particles not only with a detector but also in the VR world. The winners are the students from:

CMU THAILAND

For this lovely selfie with many smiling faces.

THE WINNERS OF ICD2023 CONTESTS

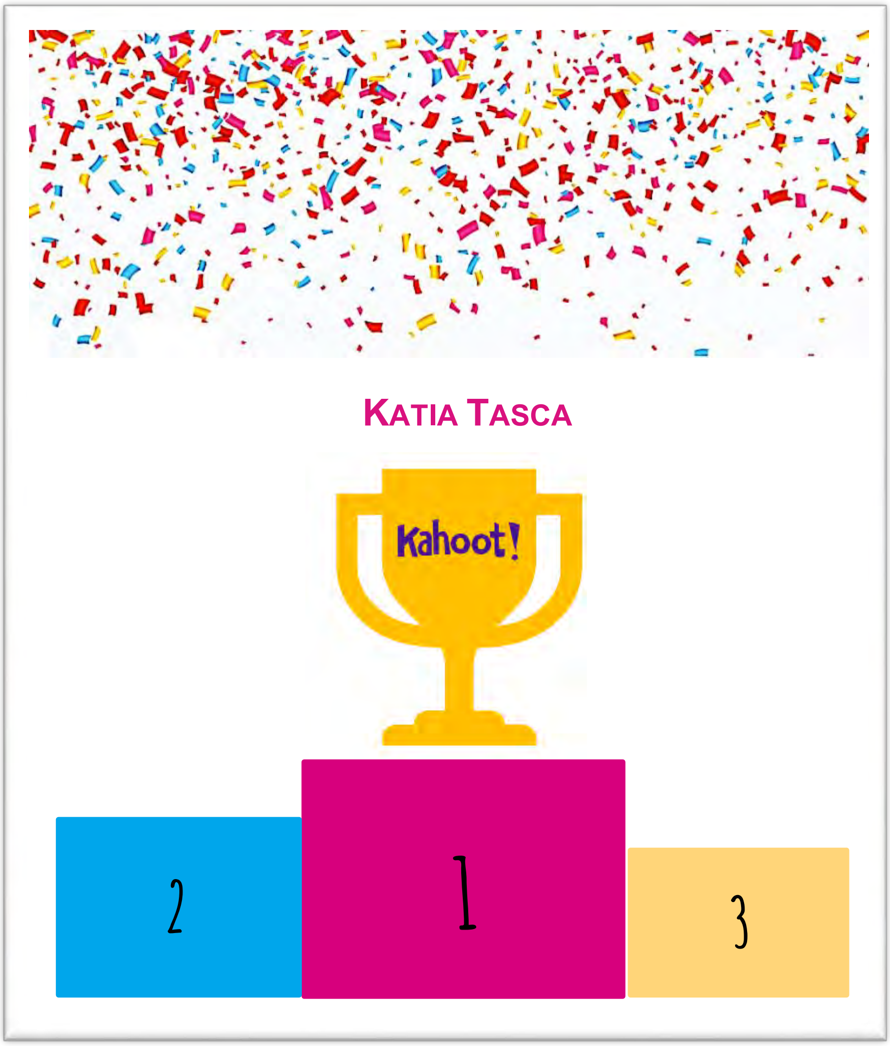
Creativity, flair and expression come together and have resulted in this self-drawn picture not only gracing the cover of this year's booklet but also **winning the Drawing Contest** 2023:

POZZI LORENZO FROM LICEO RESPIGHI

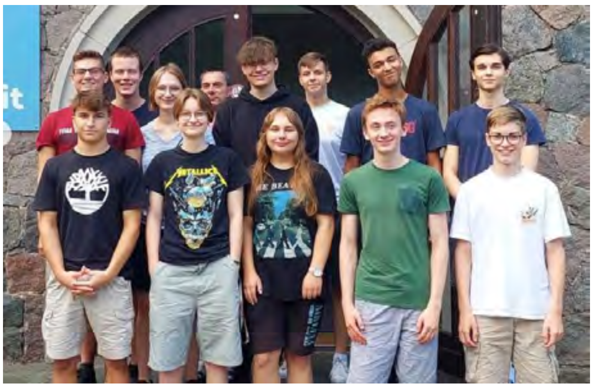
For this picture of a thrilling particle race.

THE WINNERS OF ICD2023 CONTESTS

This year, more than 100 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 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. See for yourself on the next pages …



Pictures from left to right, top to bottom:
Astro Camp - follow.desy,
istituto_francescocalasso,
istituto_francescocalasso,
convittonazionalemariocutelli,
davinci.agherbino, sandrogonzi,
Astro Camp - follow.desy,
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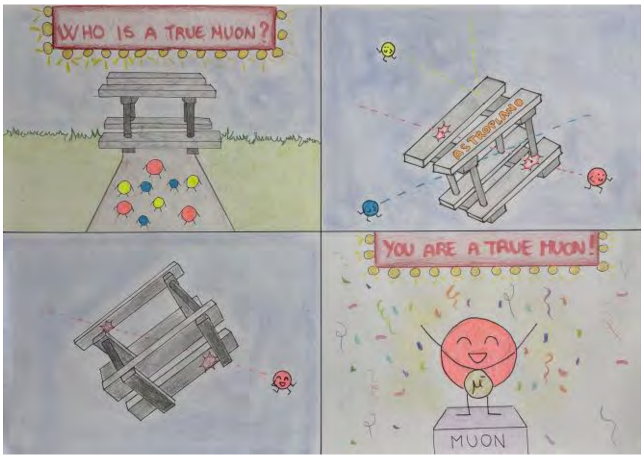
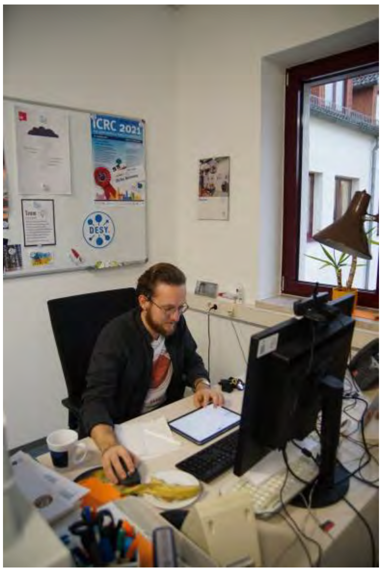
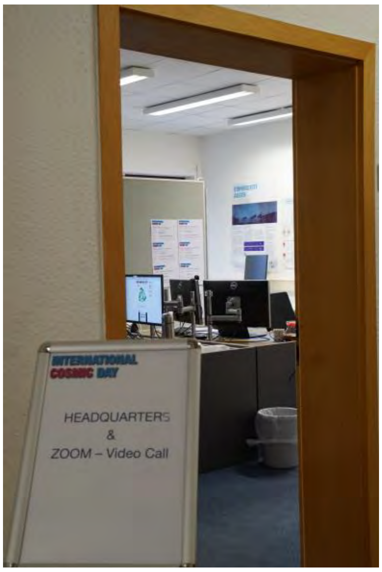
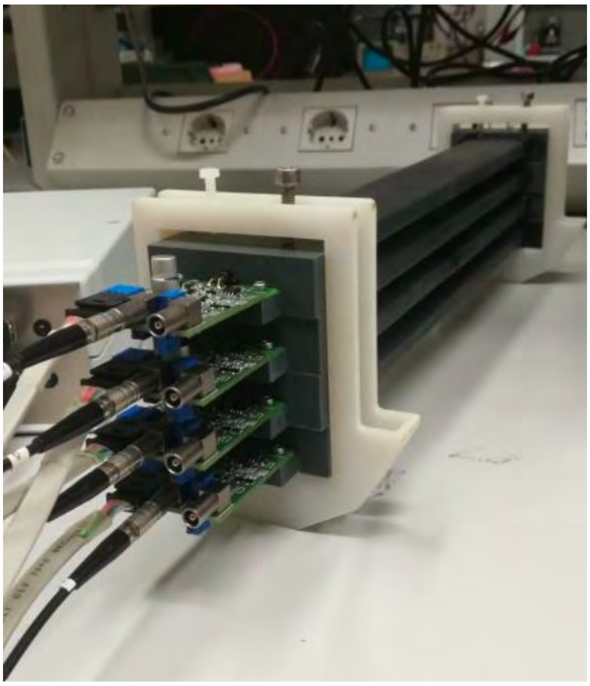


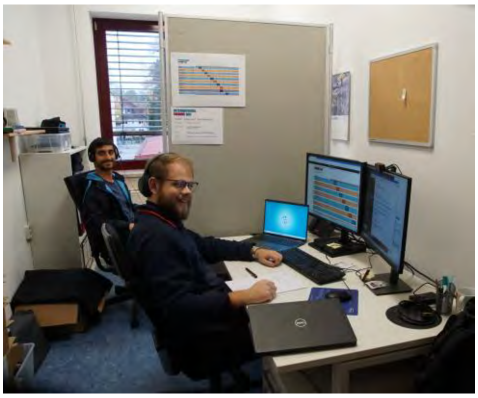
Pictures from left to right, top to bottom:
Heike Prokoph, Liceo Casiraghi, Polo Scientifico Tecnologico E. Fermi Sulmona, INFN - Sezione di Bari, istituto_francescocalasso, Carla Amaro, Laura Maria Valentino

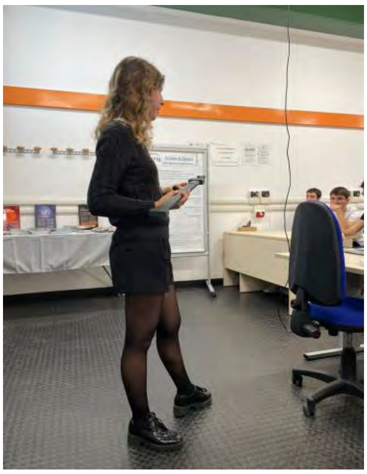




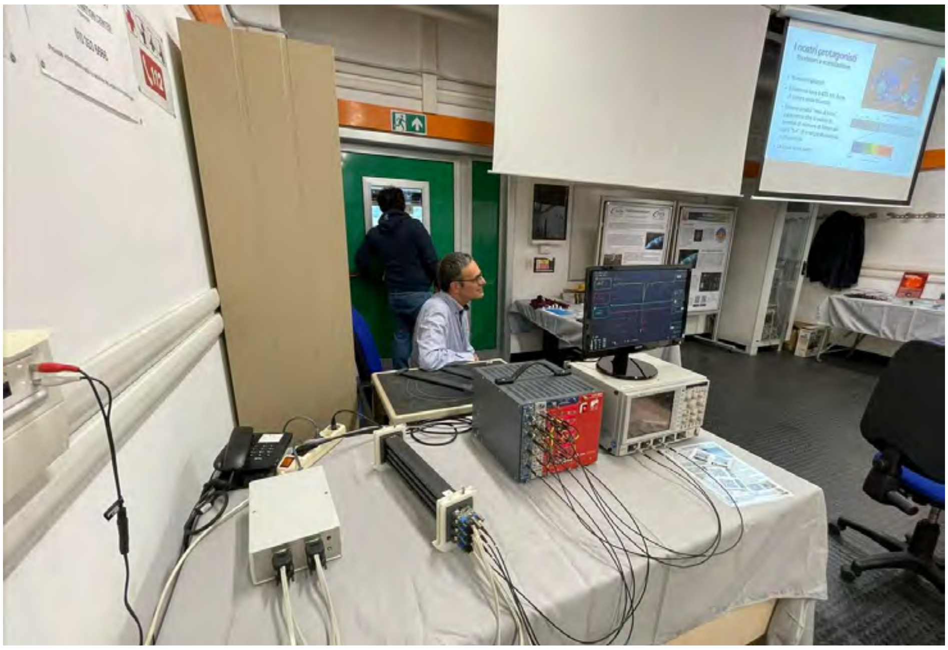


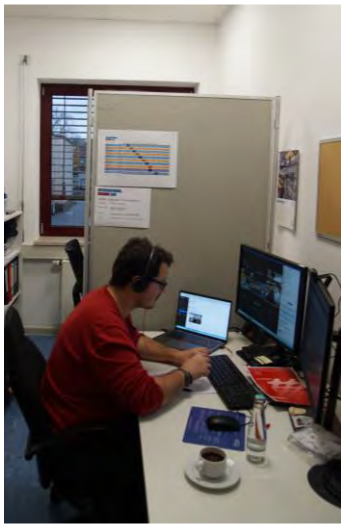
Pictures from left to right, top to bottom:
INFN - Sezione di Bari, Ulrike Schulz, Heike Prokoph, ICD Team – Heike Prokoph, ICD Cookies – Nora Feigl , Carla Amaro, INFN - Sezione di Genova, Manuela Mallamaci





Pictures from left to right, top to bottom: Polo Scientifico Tecnologico E. Fermi Sulmona, Laboratori Nazionali Del Gran Sasso INFN, Heike Prokoph, Lycée Joliot Curie, INFN - Sezione di Bari, Ulrike Schulz, ICD Cake - Heike Prokoph, INFN - Sezione di Bari, INFN - Sezione di Genova





Pictures from left to right, top to bottom: INFN - Sezione di Genova, convittonazionalemario cutelli, INFN - Sezione di Genova, Heike Prokoph, INFN - Sezione di Genova, INFN - Sezione di Genova, Laboratori Nazionali Del Gran Sasso INFN

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…

CHINA

Cloud Chamber Test

@Great Bay university, CHINA

Cosmic ray detection team
Jianqi Chen(陈建琪),Shirong Lin(林仕容),Junsheng Jing(景俊升),Mingyuan Xiao(肖明远),**Yongce Gong(贡庸策)**

Abstract

We developed a novel cloud chamber to study the cosmic ray shielding capability of three metals Fe, Al, and Pb in different thicknesses. Lead shows the best shielding ability as expected since it has the highest atomic number among the three metals.

Experimental setup and process

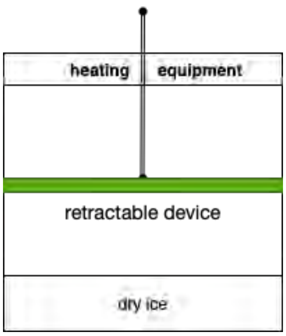


Fig.1 Diagram of our cloud chamber

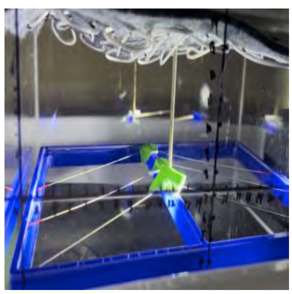


Fig.2 Photograph of cloud chamber

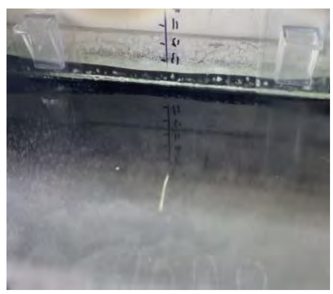


Fig.3 An observed electron track

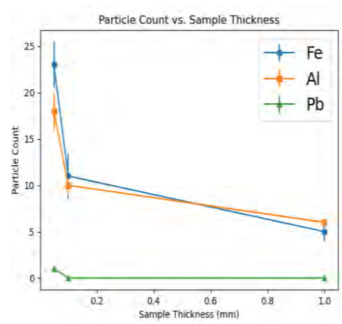


Fig.4 Counts vs Sample thickness

This cloud chamber(see Fig.1) is constructed based on a DIY manual provided by CERN(https://scoollab.web.cern.ch/cloud-chamber). The observable window has a dimension of 30 x 30 x 15 cm. One position adjustable plastic holder(see Fig.2) is installed inside the chamber. The first step is using thorium electrodes to locate the sensitive area of this cloud chamber. Then we put different thickness metals one by one on this plate to count the number of cosmic rays observed under the plate(see Fig.3). Measurements were repeated three times under the same condition and each measurement took 5 minutes. Finally, we did the uncertainty analysis and plotted the average count rate versus the sample thickness(see Fig.4).

Analysis and Result

Our cloud chamber exhibits good sensitivity when positioned 0.7-1.0 cm away from dry ice. With the increase of material thickness, the better shielding ability it shows. Lead has the best shielding ability among the three metals due to it has the highest atomic number.

Measurement of Muon Intensity

北京市东直门中学
BEIJING DONGZHIMEN HIGH SCHOOL

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

Beijing Dongzhimen High School, China

The Team of Cosmic Rays, Ying Zhang, Jiayin Zhu

Who are you?

We are from Beijing Dongzhimen High School, there are 15 students and 2 teachers in our team. Our school joined the Campus Cosmic ray Observation Collaboration (CCOC) in China, and share our data to other schools in the collaboration.

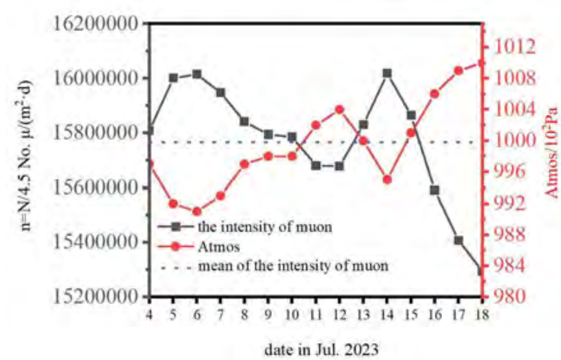
What have you done?

We built a detectors array on the roof of our school.It consists of 9 scintillation detectors, spaced 10 meters apart as a 3×3 matrix, each detector have a sensitive area of 0.5 m^2 . It is located at: latitude 39.9°N, longitude 116°E, altitude 46.4 meters above sea level.

Our detectors can recognize all noise and only record counter of μ. There are 15 students in our team, so that we analyzed the data of one day each one, here is the data from Jul.4th to 18th in 2023.

Date in 2023	N	n=N/4.5 No. μ/(m^2 •d)	Atmos 10^2Pa
4th Jul.	71138440	15808542	997
5th Jul.	72006493	16001443	992
6th Jul.	72064023	16014227	991
7th Jul.	71766801	15948178	993
8th Jul.	71286339	15841409	997
9th Jul.	71074223	15794272	998
10th Jul.	71033989	15785331	998
11th Jul.	70565306	15681179	1002
12th Jul.	70549393	15677643	1004
13th Jul.	71237133	15830474	1000
14th Jul.	72085638	16019031	995
15th Jul.	71389479	15864329	1001
16th Jul.	70158674	15590816	1006
17th Jul.	69341536	15409230	1009
18th Jul.	68829035	15295341	1010

What did you find out?



We add the atmospheric local pressure atmosphere on these days in our table, we found the relationship between the intensity of muon and the pressure. When the atmospheric pressure increases, the depth of the atmosphere increases too, so the intensity of the cosmic rays and muon get lower. With the atmosphere getting thicker, the greater the probability of cosmic rays be absorbed when they through the atmosphere. Which means higher energy of cosmic rays can reach the ground, and lower the intensity of the cosmic rays and muon.

What's your take-home message?

We studied the ICD2022 booklet and joined ICD 2023 online.

Looking forward to communicating with you about our work in next ICD!

Credit: DESY, Science Communication Lab

CCOC from China!

Affiliated to Institute of High Energy Physics, Chinese Academy of Sciences, P.R.China

Who are you?

Campus Cosmic-ray Observation Collaboration

What have you done?

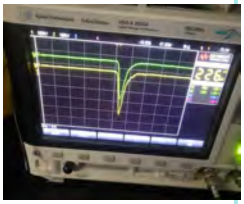
The Campus Cosmic-ray Observation Summer School in 2023 was held at Southwest Jiaotong University from August 25 to 26. Over 80 universities and high school physics teachers and students participated.

Seven expert reports for science popularization and 6 expert reports for cosmic ray observation courses were given. There were 6 teachers from high school given the experience on campus cosmic ray observation. Finally, the participants visited the National Demonstration Center for Experimental Education and the campus cosmic ray observation facility at Southwest Jiaotong University.

Eleven CCOC member institutions participated in ICD 2023, and gave 7 presentations.

Jilei Xu, a member of the campus cosmic-ray working group of the Institute of High Energy Physics, presented a report of "Cosmic ray measurement in a bucket". A simple Cherenkov detector was reported, which is made of a bucket, PMT, and oscilloscope. Cosmic rays can be observed by the PMT and the signals can be seen on the oscilloscope. It is interesting to watch the signal amplitude change while filling the water.

What did you find out?



What's your take-home message?

Welcome to CCOC! More activities more fun!

Measurement of Extensive Air Shower with the CCOC Open Data in 2023

Peking Academy Chaoyang Chuiyangliu Middle School, Beijing, China

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

Who are you?

We are from Peking Academy Chaoyang Chuiyangliu Middle School, Beijing, China. This is the second time that we attend International Cosmic Day.

Our school is a member of the Campus Cosmic-ray Observation Collaboration (CCOC) in China since July 2022. We have following studies with the CCOC Open Data: Data quality of the open data and Measurement of intensity for extensive air showers.

From left to right: Qi Yan, Zixin Tian, Jiayue Chen, Jinyan Liu (Teacher), Yinan Guo, Ruize Zhang

What have you done?

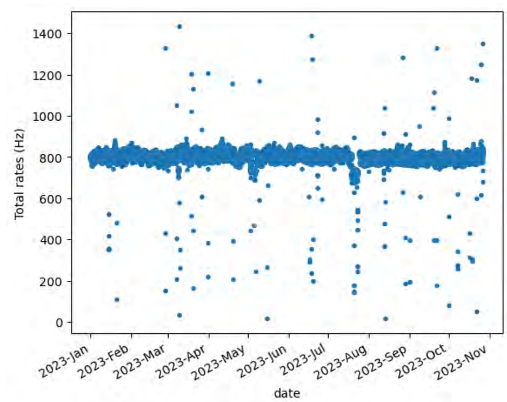
On the roof of Dongzhimen Middle School, a detector array is built to measure Extensive Air Shower (EAS), as shown in the above figure.

Two types of open data are provided for us to analyze: stat of detectors and EAS Events

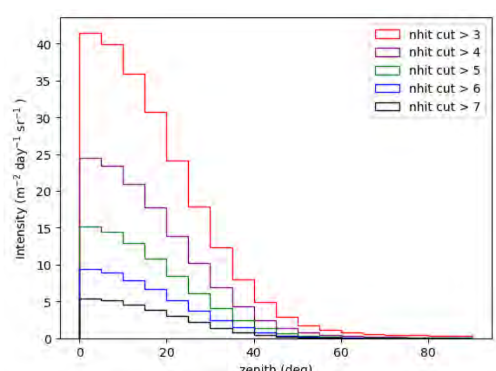
About 300 days of data starting from 1st January 2023 are used. The effective live time T=295 days.

The average EAS intensity I=N÷ (Seff×T×Ω) in each zenith angle range within the unit stereoscopic angle range. For the zenith angle ranging from A to B, it covers a stereoscopic angle Ω=2π (cosA–cosB). detector's effective area Seff=400 m2÷((cosA+cosB) ÷2). We choose 18 bins for zenith angles, ranging from 0 to 90 deg.

What did you find out?



The total rates are about 800 Hz.



The EAS intensity is the descending function of the zenith angle.

Data analysis based on cosmic-ray detector of CCOC

常州工学院

Changzhou Institute of Technology, China

Credit: DESY, Science Communication Lab

Who are you?

We are a group from a university, including two junior, three sophomore students and a lecturer. ①

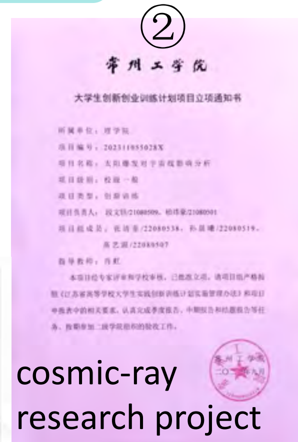
What have you done?

- September 2023, we started a cosmic-ray research project and try to analyse the data provided by Campus Cosmic-ray Observation Collaboration.②
- After data analysis, we find there is no obvious difference in EAS intensity vs zenith angle measured during day(6am to 6pm) and night(6pm to 6am) and four seasons Spring (March to May), Summer(June to August) , Autumn(September to November), Winter(December to February). ③ ④

What did you find out?

①

②


常州工学院

大学生创新创业训练计划项目立项通知书

所属单位：理学院

项目名称：太阳爆发对宇宙线影响分析

项目级别：校级一般

项目类型：创新训练

③

④

What's your take-home message?

Enjoy our presentation in ICD and communicate with more international cosmic-ray friends.

Credit: DESY, Science Communication Lab

Cloud Chamber Test

@Great Bay university, CHINA

Cosmic ray detection team
Jianqi Chen(陈建琪),Shirong Lin(林仕容),Junsheng Jing(景俊升),Mingyuan Xiao(肖明远),**Yongce Gong(贡庸策)**

Abstract

We developed a novel cloud chamber to study the cosmic ray shielding capability of three metals Fe, Al, and Pb in different thicknesses. Lead shows the best shielding ability as expected since it has the highest atomic number among the three metals.

Experimental setup and process

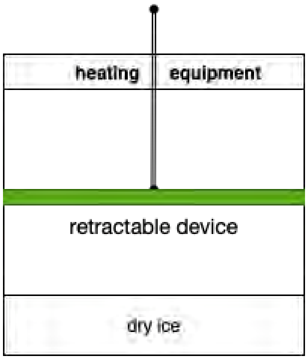


Fig.1 Diagram of our cloud chamber

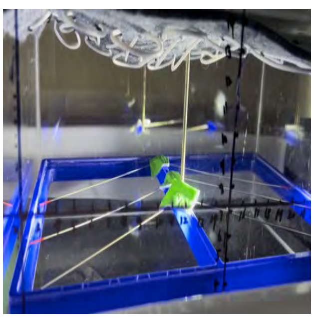


Fig.2 Photograph of cloud chamber

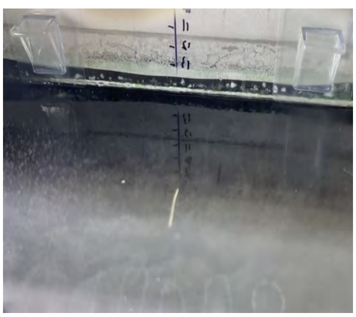


Fig.3 An observed electron track

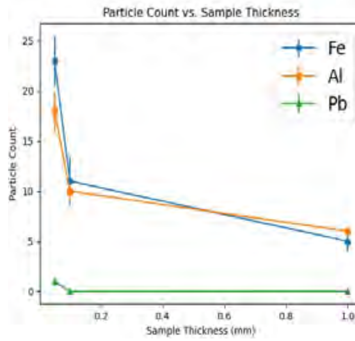


Fig.4 Counts vs thickness

This cloud chamber(see Fig.1) is constructed based on a DIY manual provided by CERN(https://scoollab.web.cern.ch/cloud-chamber). The observable window has a dimension of 30 x 30 x 15 cm. One position adjustable plastic holder(see Fig.2) is installed inside the chamber. The first step is using thorium electrodes to locate the sensitive area of this cloud chamber. Then we put different thickness metals one by one on this plate to count the number of cosmic rays observed under the plate(see Fig.3). Measurements were repeated three times under the same condition and each measurement took 5 minutes. Finally, we did the un... d plotted the average count rate versus the sa... 4).

Analysis and Result

Our cloud chamber exhibits good sensitivity when positioned 0.7-1.0 cm away from dry ice. With the increase of material thickness, the better shielding ability it shows. Lead has the best shielding ability among these three metals due to it has the highest atomic number.

The correlation between cosmic ray events and variations in zenith angle

Han Jinshan[1] Li Bingbing[*2] Cui Shuwang[*2]

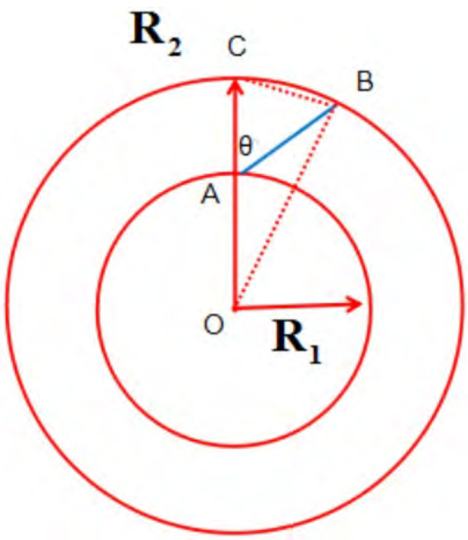
1 Shijiazhuang No. 1 High School, 2 Hebei Normal University

Cosmic rays are high-energy particles, such as protons, neutrons, and atomic nuclei, originating from outer space. They are typically associated with astronomical phenomena in the universe, including supernova explosions and black hole activity. Upon entering Earth's atmosphere, cosmic rays interact with atmospheric molecules and generate secondary cosmic ray particles, resulting in the formation of extended atmospheric showers (EAS). The variation in the distribution of cosmic ray events with zenith angle refers to changes in the number of recorded cosmic ray events within a ground-based array as a function of zenith angle. Zenith angle is related to three-dimensional angles as follows:

$$\Omega = 2\pi \times (\cos\theta_1 - \cos\theta_2)$$

The solid angle gradually increases as the zenith angle changes from 0 to 90 degrees, resulting in an increase in the number of cosmic ray occurrences. However, there exists a relationship between the thickness of cosmic rays passing through the atmosphere (the distance AB in the figure) and the zenith angle.

$$h = \frac{\sqrt{4R_1^2\cos\theta^2 - 4(R_1^2 - R_2^2)} - 2R_1\cos\theta}{2}$$



This phenomenon is closely related to the observer's latitude, serving as the origin of EAS, and it demonstrates an increasing trend with zenith angle at first followed by a decreasing one. When the zenith angle is small, cosmic rays traverse a thinner atmosphere with lower probabilities of scattering and decay. As the zenith angle increases, more cases of cosmic rays occur due to larger three-dimensional angles. However, when the zenith angle becomes larger, although there are also larger three-dimensional angles available for cosmic rays to pass through, they have to travel through thicker atmospheres with higher probabilities of scattering and decay resulting in fewer cases of cosmic rays observed. In summary, the distribution pattern of cosmic ray events exhibits an initial increase followed by a decrease as a function of zenith angle.

Studying the variation of cosmic ray distribution with zenith angles can aid scientists in gaining a deeper understanding of the nature and origin of cosmic rays, as well as the atmospheric influence on them. By analyzing the distribution of cosmic ray cases at different zenith angles, we can unveil the propagation law of cosmic rays in the atmosphere and elucidate the formation mechanism of extensive air showers (EAS), thereby providing crucial insights for research in cosmic ray astrophysics and their origins.

Furthermore, comprehending how cosmic ray event distribution varies with zenith angle can also contribute to optimizing ground array layouts and detector performance, ultimately enhancing detection efficiency and accuracy for cosmic rays. Hence, investigating this variation holds significant scientific significance and practical application value.

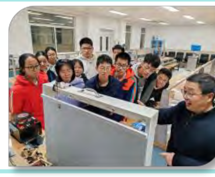
Credit: DESY, Science Communication Lab

Research on ‘the Continuous Cloud Chamber’ for Mobile Sustainable Observation of Cosmic Rays

Jiangsu Xinghua middle School, China

Introduction

We are a high school cosmic ray research group from Xinghua High School of Jiangsu Province, China.Our school is a member of the Chinese School Cosmic Ray Observation League.



Exploration

We have used the cosmic ray array in our school to collect relevant data and conduct data analysis. However, we are still eager to see the motion trajectory of high-energy particles!

Achievements

We’ve seen a diagram of a Wilson cloud chamber in our high school physics textbook, which was an invention by Wilson to detect nuclear radiation. We read online that cloud chambers are also a good way to visualize cosmic rays.This mobile cloud chamber has a higher spatial and temporal resolution than our seniors' works, enabling it to better capture the secondary particles produced by the interaction of cosmic ray particles with the atmosphere.

This portable hybrid cloud chamber can continuously observe cosmic rays in the air for a long period of time.

Perception

In the future, we plan to equip it with an electric or magnetic field to further study the basic properties of cosmic ray particles and their impact on Earth. We will also use it as an educational tool to attract more students to join the field of cosmic ray research.

Credit: DESY, Science Communication Lab

The Muon Intensities Depending On Detector Inclination

江蘇省姜堰中學

JIANGYAN HIGH SCHOOL OF JIANGSU PROVINCE

Jiangyan High School of Jiangsu Province,China

1.Introduction

It is the third time we have participated in International Cosmic Day.

This year, we used the Muon Telescope to investigate how the intensity of muon varies with the inclination of the detector.

2.Equipment

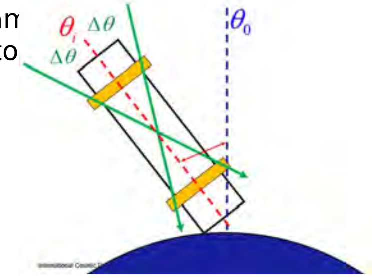
The Muon Telescope, which measures 40 by 40 by 4 centimeters. Our Muon telescope consists of two parallel detector units and an adjustable tilt bracket. Each detector unit can record the number of muon passing through the detector in a certain period of time.

3. Methods

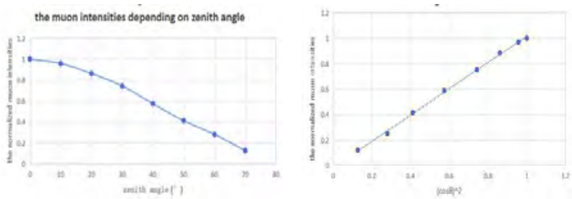
As shown in the figure, the blue dashed line indicates the 0 degree inclination direction. We set the two detectors that are 113 centimeters apart and place them in parallel. The main axis direction is shown by the red dotted line in the figure, indicating the Angle θ between the main axis direction and the 0 degree inclination direction. The muon entering in the direction of the Δθ Angle range can trigger two detectors simultaneously. Set the observation time as t, and calculate the total number of events as n, we will explore the relationship between the inclination θ and the intensity of the muon intensities.

We placed the detector in the direction of due south, first adjusted the inclination of the Muon telescope to 0 degree, recorded the detector data for about 15 minutes, and then screened out the events that triggered the two detectors at the same time from the data, counted the number of N, calculated n.

In the san … of the Muon telescope to … e, until 70 degree.



4. Data analysis



We find that when the detector area and the distance between the detectors are determined, as the Angle of the muon telescope increases, the number of muon per unit time is measured by the detector decreases.There's a nice linear relationship between f and (cosθ)^2.

We believe that the reason for this phenomenon is that as the inclination of the detector increases, the thickness of atmosphere the Muon needs to pass through increases, thus resulting in a

It was a novel experience…

In this cosmic ray event, we learned the method of data screening and processing, We experienced the joy of scientific inquiry and the sense of achievement in overcoming difficulties. It was a novel experience, and we hope to explore the universe more in the future.

Credit: DESY, Science Comm[...]cation Lab

The Muon Intensities Depending On Detector Inclination

江蘇省姜堰中學

JIANGYAN HIGH SCHOOL OF JIANGSU PROVINCE

Jiangyan High School of Jiangsu Province,China

1.Introduction

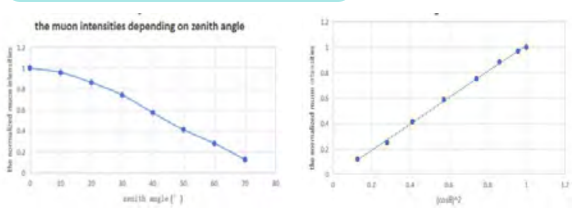
It is the third time we have participated in International Cosmic Day.

This year, we used the Muon Telescope to investigate how the intensity of muon varies with the inclination of the detector.

2.Equipment

The Muon Telescope, which measures 40 by 40 by 4 centimeters. Our Muon telescope consists of two parallel detector units and an adjustable tilt bracket. Each detector unit can record the number of muon passing through the detector in a certain period of time.

4. Data analysis



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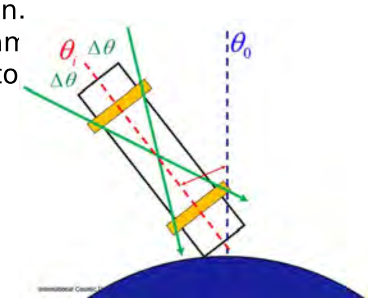


It was a novel experience…

In this cosmic ray event, we learned the method of data screening and processing, We experienced the joy of scientific inquiry and the sense of achievement in overcoming difficulties. It was a novel experience, and we hope to explore the universe more in the future.

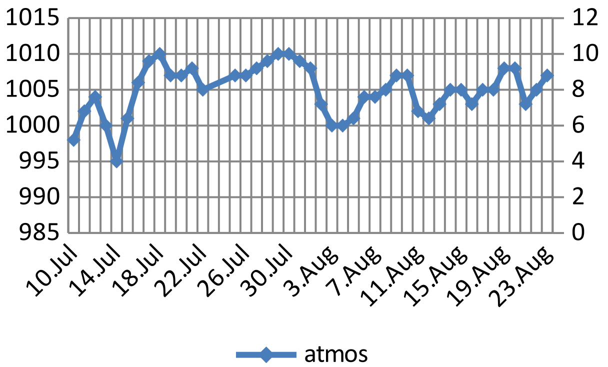
Measurement of cosmic ray Intensity and its relation with atmos

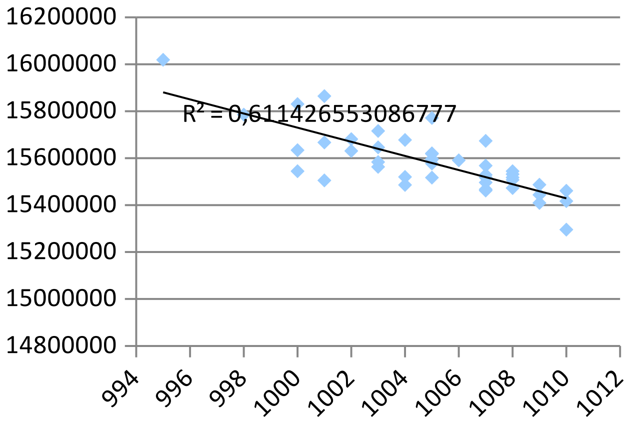
---Jiangxi Pingxiang Luxi Middle Scho

Introduction

Our school joined Campus Cosmic-ray Observation Collaboration (CCOC) in China in July 2022.

Data Analysis





Result

When the atmos increases, the density of the atmosphere increases too. With the atmosphere getting thicker, the greater probability of cosmic rays is absorbed when they through the atmosphere。 Which means higher energy of cosmic rays can reach the ground, and lower the intensity of the cosmic rays and muon。

data message

The data we use is collected by the cosmic ray detector array which locates in the campus of Beijing Dongzhimen High School,Beijing, China.

COLOMBIA

Analysis of Cosmic Ray Flux in Medellin: Angle of Incidence Dependency

Instituto Tecnológico Metropolitano

Who are you?

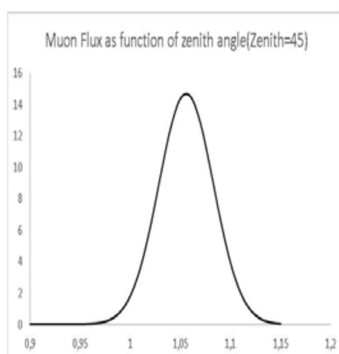
We are students from Instituto Tecnologico Metroplitano who loves science.(Arenas Daniel, Vera Carlos, Gomez Darly,Arroyave Mateo)

What have you done?

In this research, a comprehensive study was conducted on the cosmic ray flux in the city of Medellin, focusing on three specific angles of incidence. Each measurement was taken over a two-minute period to capture precise data under different conditions. Subsequently, the results were graphically analyzed to identify patterns and trends in the cosmic ray flux behavior concerning the selected angles of incidence. Additionally, a statistical analysis was performed to calculate the standard deviation of the measurements, providing a quantitative measure of the data variability.

What did you find out?

We discovered a direct relationship between the angle of incidence and cosmic ray flux as shown in figure. As the angle of incidence increases, the flux decreases. Additionally, our findings revealed low standard deviations in the measurements.



The study demonstrates consistency and provides strong evidence supporting the observed correlation between the angle of incidence and cosmic ray flux. We believe that Science is for everyone, and engaging with communities is essential. Moreover, having the opportunity to participate in this event opens doors for new research in the city, contributing to the development of science in the country

FRANCE

Credit: DESY, Science Communication Lab

Muons underwater

Atelier des deux Infinis of *Roland Garros* high school, Réunion Island

Who are you?

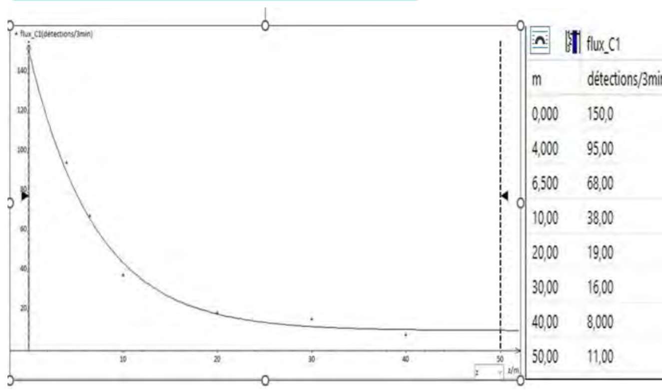
We are a group of students and passionate teachers from two neighboring high schools in the city of Le Tampon (the Club des particules of the Pierre Lagourgue high school, and the Atelier des deux infinis of the Roland Garros high school). From this collaboration was born a common state of mind : scientific mutual aid. This has allowed many people to meet around the same scientific interests and to learn even more. We carry out a wide variety of unusual scientific educational projects, mainly on cosmic rays and particles like muons.

What have you done?

We used the Cosmix portable muon detector. In previous projects, Cosmix has made measurements as a function of altitude (carried on foot to the summit of the Piton des Neiges, the highest point on Reunion Island) and then as a function of latitude (carried on a ship from Reunion Island to a French Antarctic base). But also, the Cosmix has been carried in the tunnel for one of our experiences to show the uptake of muons by rocks.

The biggest challenge and risk we took to carry out this experiment was to completely disassemble our detector to reduce its volume and fit it into our housing! Thanks to underwater experiments, we have found a completely correct order of magnitude of the absorption of muons by seawater: **their number is halved every 5 m!**

What did you find out?



m	détections/3min
0,000	150,0
4,000	95,00
6,500	68,00
10,00	38,00
20,00	19,00
30,00	16,00
40,00	8,000
50,00	11,00

On the water surface we detected 50 muons/min and 4,7 muons/min at 50m depth.
Flow is divided by 2 every 5m with 15 % incertitudes.

What's your take-home message?

Our participation to the International Cosmic Day allowed us to interact on an international level, while also learn more about muons. We had the chance to see the experiences of different countries like China, Japan or Italy. That was an incredible and enriching experience.

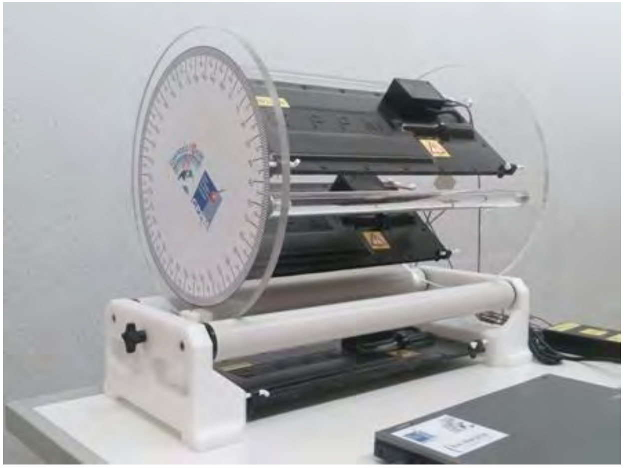
Measurements for Cosmicday 21 Nov. 2023

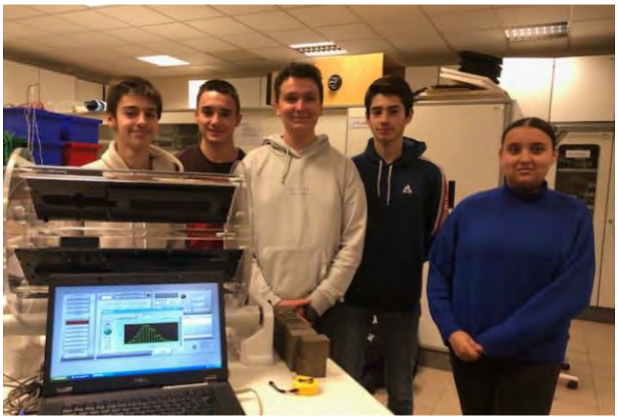
Lycée Marcel RUDLOFF- Strasbourg – France

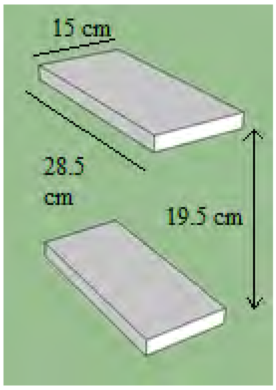
We present the results of measurements carried out using “The Cosmic Wheel”, a muon detector composed of two parallel and adjustable scintillators. The cosmic wheel is a “Science at School” device.

The curve provided represents the cumulative number N of muons arriving in coincidence on the two scintillators as a function of the azimuthal angle θ. The N reading is carried out every 5 minutes with an East-West orientation.

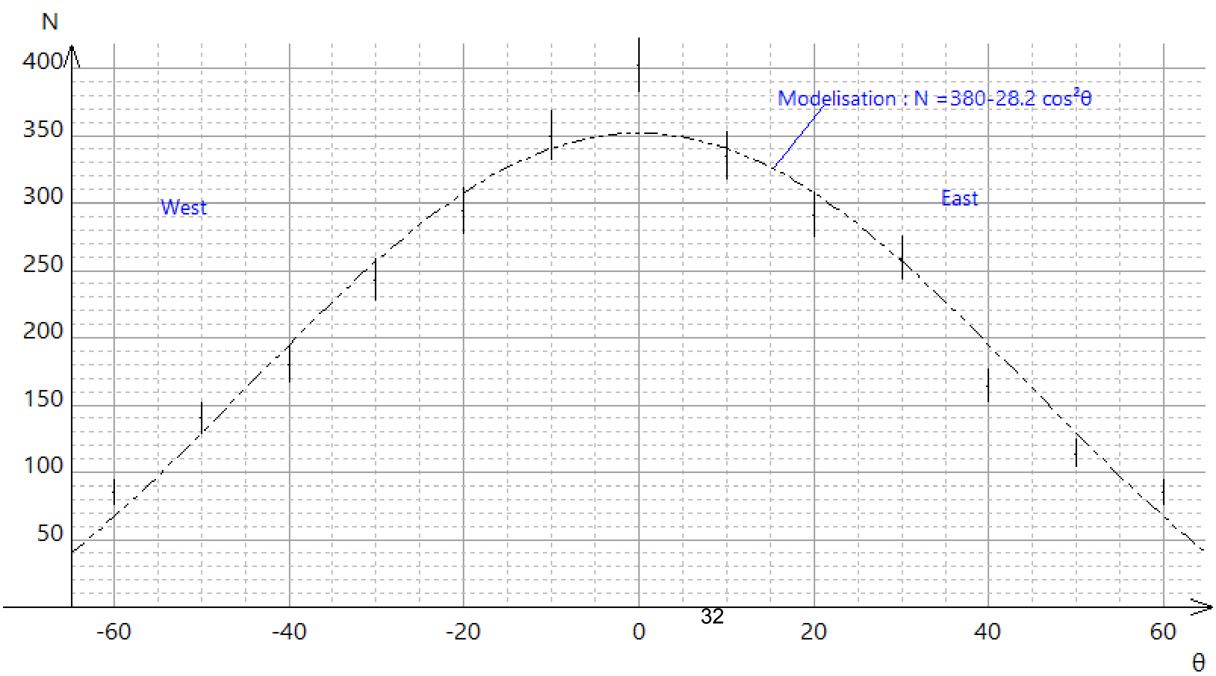
The two detectors, 19.5 cm apart (figure), are powered by photomultipliers: PM 1273 V and PM 1330 V.







Uncertainty on N is calculated by sqrt(N).



Who are you ?

We are the 10th and 11th grade Euro class
We all chose to take part in the ICD to learn about cosmic particles, and how to measure them. Also, it was the first time that we took part in an international event such as the ICD (only 10th and 11th grades ; our high school participated 5 times).
Joliot-Curie is a technical high school. It is localised in Rennes in Britany in France. There is a park near our high school called the Parc des Gayeulles. Also, we try to make the student life focusing on biodiversity because we're planting trees ! The mood feels really good and the professors are really involved into teaching.

What have you done ?

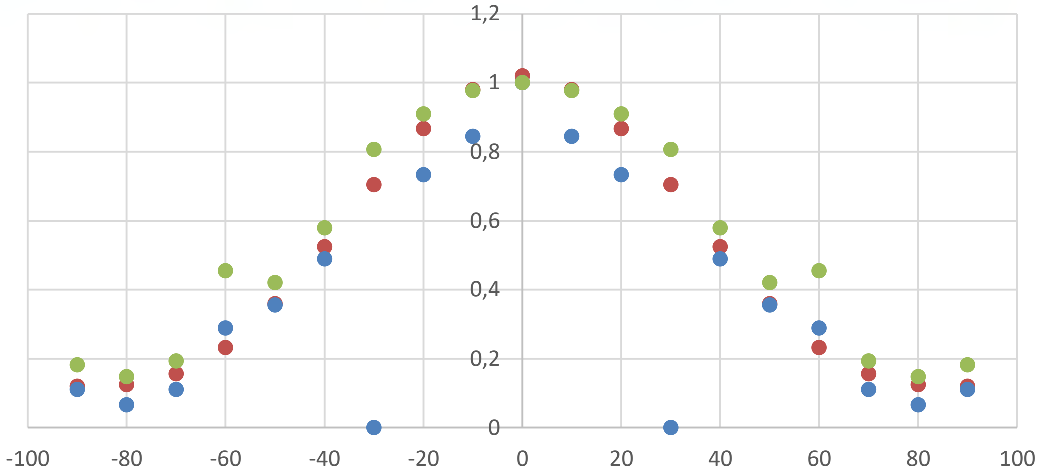
The protocol: One week before ICD, we looked for the threshold which is used to detect muons among noise. The threshold is 17 mV.
On the ICD, we put the muon detector out and we brought cables and the computer in the playground. When all was connected, we started measurements. We planned to do 37 measurements every 5 degrees on 180 degrees. We did 3-minutes measurements during around 2 hours. But we realised that our detector had a problem with saving half of the data. So we started again the measurement every 10 degrees on 90 degrees during 2 minutes because we hadn't enough time to redo it all.

ICD 2023

Lycée Joliot-Curie, Rennes, Franc

Device : This is a muon detector with three scintillators. They are used to detect muons because they shine some light when being crossed. Then, photomultipliers convert the muon's energy to an electric signal. So we connected it to a computer to count muons.

Number of muons vs angle (°)



What did you find out?

When the detector is oriented towards the sky so a lot of muons crosses the three plates.

The orange curve is the model. The blue curve is the results that we obtained by using three scintillators. We could not obtain a proper fit so we questionned aour measuement. One of our scintillators is coming from a second detector, we have tried to calibrate it to our device but apparently the calibration was not good enough. We tried with only our two own scintillators. And we obtained the green curve, that is a better measurement. The horizontal axe is the degrees and the vertical axe is the number of muons. We have made just one side and by symetrie we plotted the second half. All the curve are normalised so that they can be superimposed.

What's your take-home message ?

Our International Cosmic Day was a remarkable journey into the world of cosmic ray research. The hands-on activities, like setting up detectors and measuring cosmic ray flux, made complex theories tangible and real. Collaborating with students worldwide broadened our perspectives, emphasizing the universal curiosity that binds us. The camaraderie among participants created a positive and collaborative atmosphere, turning our learning into a collective exploration that transcended borders. The discussions deepened our understanding of the significance of international collaboration in scientific endeavors.

This experience wasn't just about learning about cosmic rays; it was a thrilling and memorable adventure that sparked our curiosity and passion for astroparticle physics. The global collaboration aspect left a lasting impact, reshaping our perspective on the universe.

Cosmic rays and the muon lifetime

Galileo High School, FRANCE

Who are you?

We are a year 11 European class students from Galileo High School in Cergy, France.

What have you done?

Fisrt of all, to understand what cosmic rays are, where do they come from and what happens when they interact with the atmosphere, we watched a video presented by Elisa Prandini at **https://www.youtube.com/watch?v=UQoQJaUrKhc**. She's a researcher in high energy astrophysics at the university of Padova, Italy.
Then, we worked on the LIDO experiment to find out what is the muon lifetime.

What did you find out?

We found that cosmic rays are high energetic particles moving at almost the speed of light and coming from galaxies and from all the universe. When they hit the atmosphere they generate particle showers including muons which have a very short lifetime.
Using the LIDO experiment we found that the muon lifetime is 2.1027+-0.0017 microsecond within a 95% confindent interval.

What's your take-home message?

The universe is filled of cosmic rays which interact with the atmosphere and create particle showers. One of these particles, the muon, has very short lifetime of just about 2 microsecond.

Credit: DESY, Science Communication Lab

for muons in an old railway tunnel

Atelier des deux Infinis of *Roland Garros* high school, Réunion Island

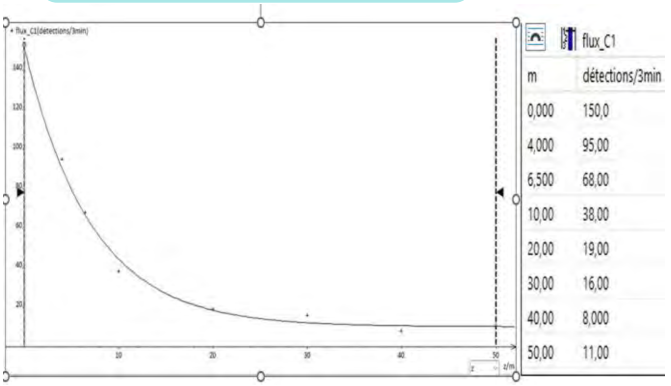
Who are you?

We are a group of students and passionate teachers from two neighboring high schools in the city of Le Tampon (the Club des particules of the Pierre Lagourgue high school, and the Atelier des deux infinis of the Roland Garros high school). From this collaboration was born a common state of mind : scientific mutual aid. This has allowed many people to meet around the same scientific interests and to learn even more. We carry out a wide variety of unusual scientific educational projects, mainly on cosmic rays and particles like muons.

What have you done?

- We used the Cosmix portable muon detector. In previous projects, Cosmix has made measurements as a function of altitude (carried on foot to the summit of the Piton des Neiges, the highest point on Reunion Island) and then as a function of latitude (carried on a ship from Reunion Island to a French Antarctic base). The Cosmix has been carried in the tunnel for one of our experiences. The biggest challenge and risk we took to carry out this experiment was to completely disassemble our detector to reduce its volume and fit it into our housing! Thanks to underwater experiments, we have found a completely correct order of magnitude of the absorption of muons by seawater: **their number is halved every 5 m!** Angular Variation of Muon Flow.This experience has been carried out several times, during the days of the international Cosmic Day. We oriented our detector, which you see in the photo, along the north-south axis and rotated it from west to east. **Acquisition times were 20 minutes. On the x-axis, the detection angles are shown and on the y-axis, the number of muons**

What did you find out?



On the water surface we detected 50 muons/min and 4,7 muons/min at 50m depth.
Flow is divided by 2 every 5m with 15 % incertitudes.

What's your take-home message?

Our participation to the International Cosmic Day allowed us to interact on an international level, while also learn more about muons. We had the chance to see the experiences of different countries like China, Japan or Italy. That was an incredible and enriching experience.

GERMANY


https://smapse.com/gymnasium-villa-elisabeth/

The Gymnasium Villa Elisabeth

The Gymnasium Villa Elisabeth is a state-approved private school in the south of Berlin with an international orientation and a major focus on natural sciences. The school has collaborations with the Technical University for Applied Sciences Wildau (Technische Hochschule Wildau) and the DESY Zeuthen.

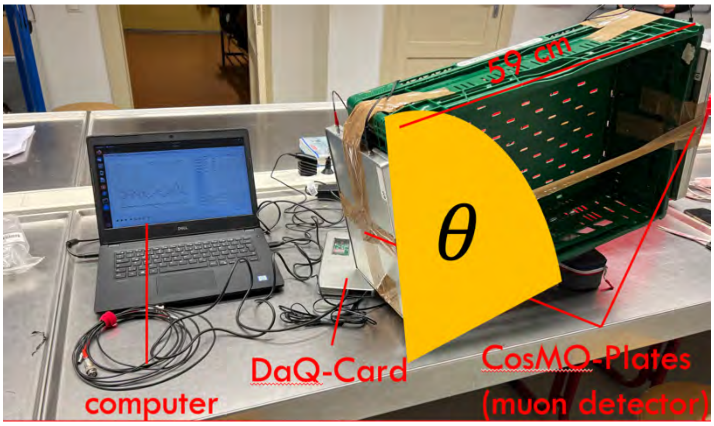
In our 11th year of participation in the International Cosmic Day (ICD) we had again a crash course in particle physics and astrophysics the day before the actual ICD, finally leading to the set-up of first experiments in preparation for the ICD. And again, the organizers had a little help from alumni of the previous year, namely Ben Emrich, Sven Kraftzow, Asmar Mammdova and Dorian Palm. This year we had also a major contribution from some of the participants who had qualified in a summer course in particle physics and during the year at our facilities and who are also involved in the Netzwerk Teilchenwelt; those were Emma Rehfeld, Thoralf Anderlitschka and Anna Siri.

On ICD, we performed a variety of experiments. In the process, the students explored their chances. The experiments conducted and the results obtained are explained in detail on the following pages.

From our side this year´s participants were our students Thoralf Anderlitschka, Emilio Jahn, Germain Gervais, Philipp Mirwald, Emma Rehfeld, Willy Retzlaff, Anna Siry and Yu Fan Zhang as well as their physics teacher Stefan Bläß, PhD. We are one more time particularly grateful to Carolin Gnebner from DESY, Zeuthen, for providing the hardware (muon detectors – CosMO and Kamiokannen) and doing a great job as always in organizing the ICD.

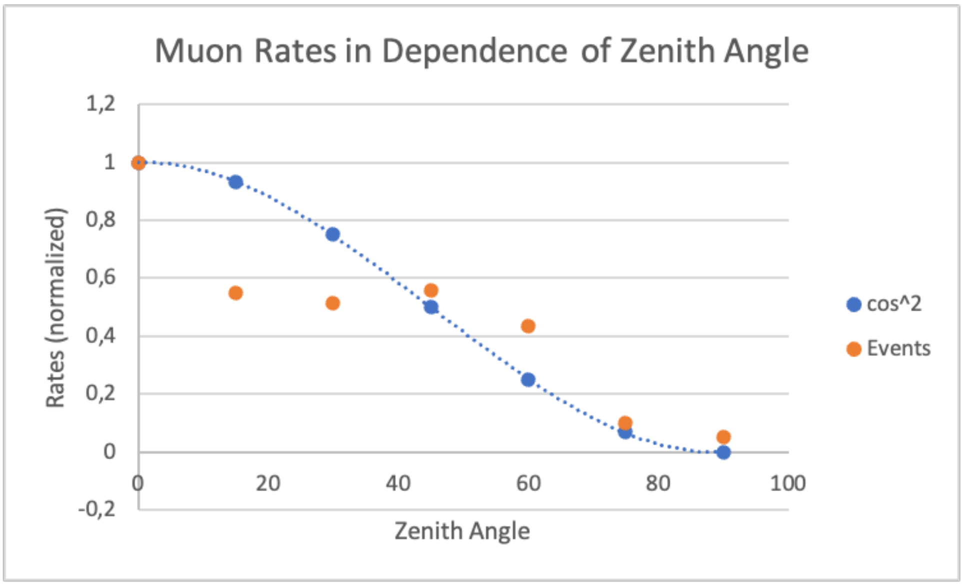
Measuring the zenith angle of incoming muons (using CosMO)

To find out from which direction the Muons are predominantly coming from, two groups each strapped two CosMO scintillator plates to a box so that they kept a fixed distance. After connecting the detectors with a DAQ-Card and a computer for evaluating the incoming data, we started measuring – nominally 20 minutes for each position. Then the structure was turned by 15° (θ on the diagram) and a new run was started.



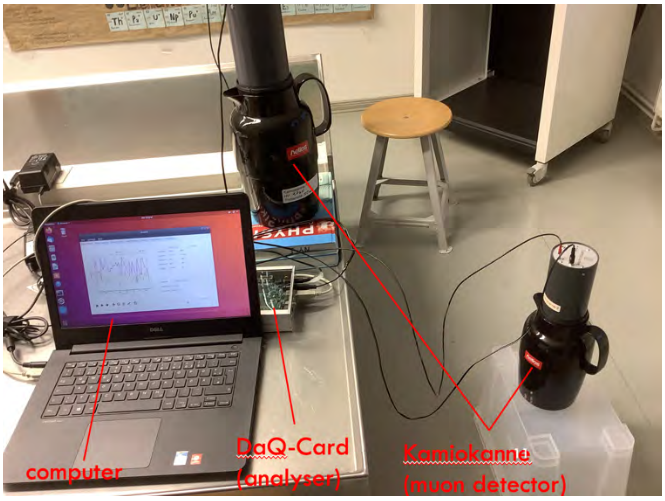
Results and discussion

The measurements are summarized in the chart below, in comparison to a cos²-function. The data show that the majority of muons detected comes from directly above us (zenith). This is because muons are generated in the atmosphere and have a short half life which has for most of them already expired when reaching the suface of the planet. Thus, muons coming in vertically have the shortest distance to travel as compared to muons coming in horizontally. Unfortunately, there is significant deviation from the $\cos^2$-curve which is due to events instead of rates are being depicted here and measuring times were not exactly the same.



(θ)

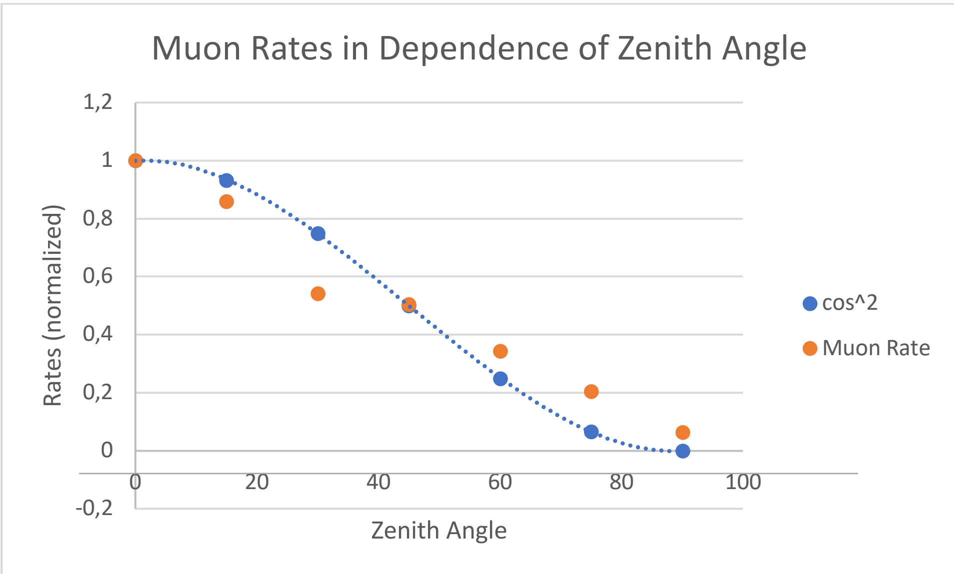
Measuring the zenith angle of incoming muons (using Kamiokannen)



Two other groups did the experiment above using "Kamiokannen". Kamiokannen are coffeepots filled with water and having the cap replaced by a photomultiplier. It is named after the big "Super-Kamiokande" experiment and a coffeepot (German: Kanne), although Kamiokanne detects muons instead of neutrinos.
The groups each positioned one pot on the table and one under the table. In the starting position, both pots stood in a vertical line, the angle in this state is 0°. Then we did the same as we had done with the scintillator-plates. We measured for a period of 30 minutes for each angle set, and angles were changed again in steps of 15°. For that, we moved the lower pot to the side until the angle was right, while keeping a constant distance between the two pots by putting books under the lower pot.

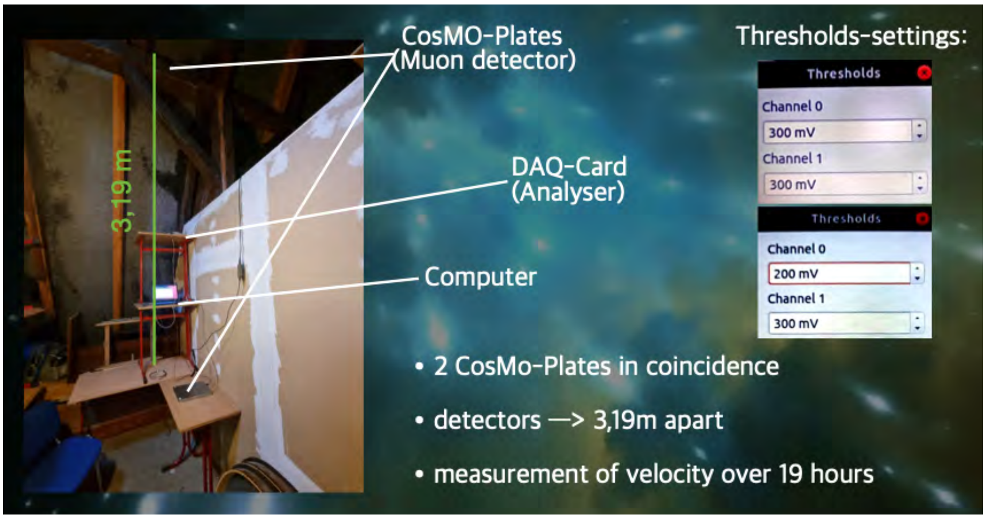
Results and discussion

The results are similar to the results from the zenith angle determination with the scintillator plates. Again the highest number of detected muons is in the position of 0°. It is dependent on the angle so that it decreases as the angle increases. The curve nicely follows a $\cos^2$ dependency with the slight deviations are likely due to the much lower sensitivity of these detectors (as compared to CosMO) in combination with random electromagnetic background noise and voltage peaks in the power net during measurements.

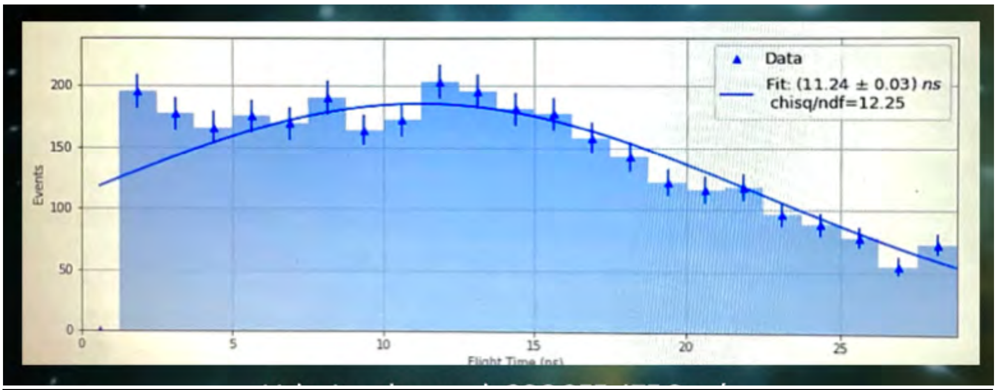


Measuring muon velocity (using CosMO)

To measure the muon velocity, we used 2 muon detectors (scintillator plates) which were aligned vertically 3.19 m apart from each other. We connected the detectors to the DAQ-Card which was connected to a laptop that was running the analyzing-software “Muonic”. The events were measured for varying periods between 2 and 19 hours. The results show the number of muons detected over time of flight, measured as coincidence [standard setting: 100 ns] of an event in the first and second detector.



Results and discussion



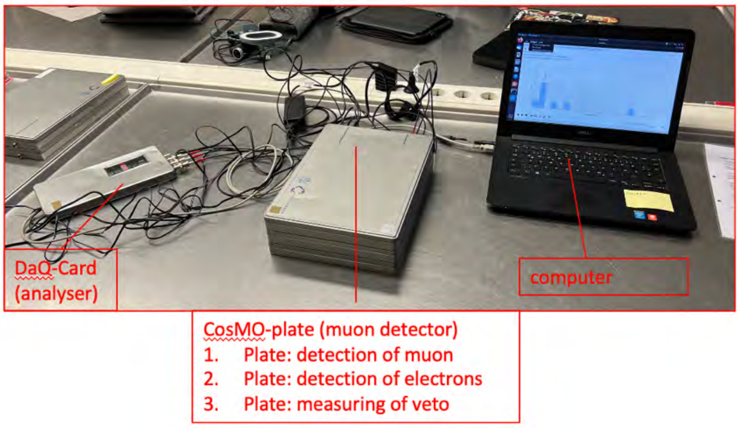
Muons detected show a peak of events at 11.24 ns, which results in a calculated velocity of:

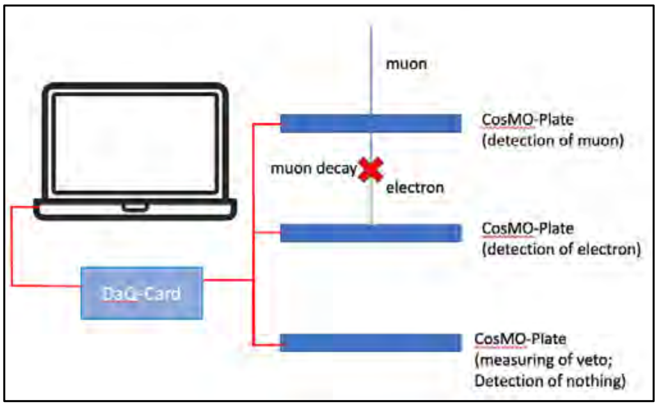
$v = \frac{s}{t} = \frac{3{,}19\ m}{11{,}24 \cdot 10^{-9}\ s}$ =283,807,829.2 $\frac{m}{s} = 0.95c$.

In theory, the muons should have a speed of 0.996c. The curve shown deviates heavily from previous results from a different location and a slightly smaller distance between the two detector plates, which resembled more a smooth Gaussian curve with much fewer events to the "shorter" and "longer" ends of the time range. In order to obtain better results in this location, the experiment was repeated with shorter gate width time windows (30 ns, 70 ns) – both with even higher deviations (data not shown). Further experiments are ongoing to clarify this issue.

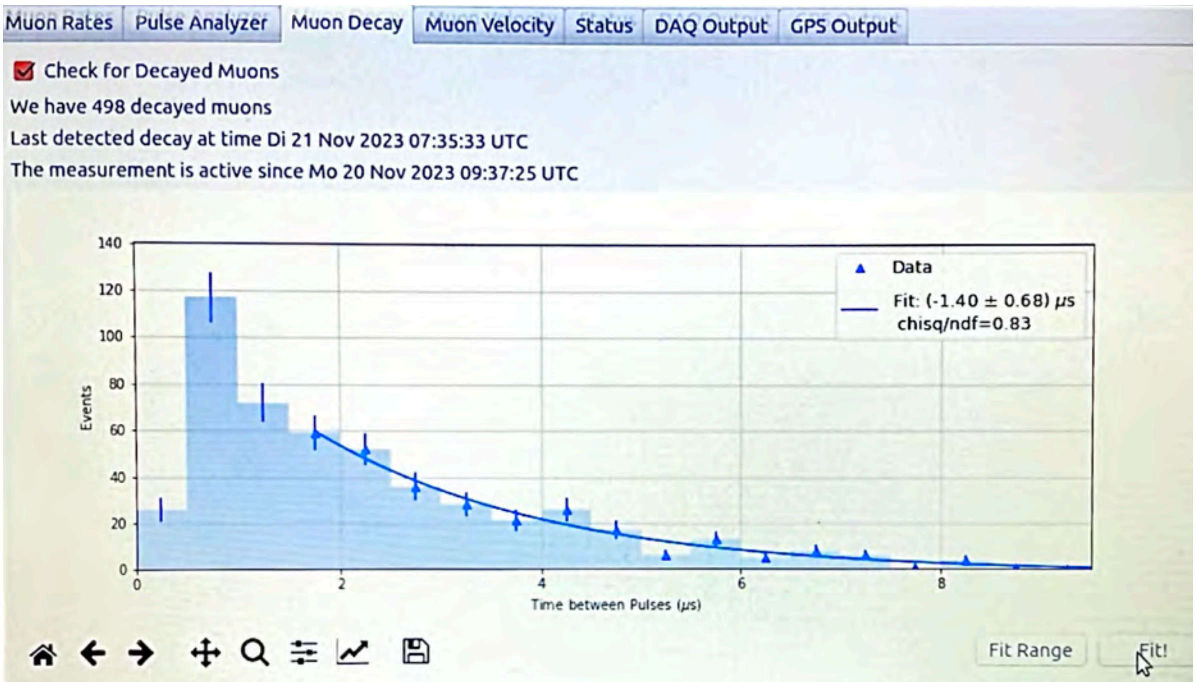
Measuring muon decay time (using CosMO)

To measure muon lifetime, we stacked 3 CosMO detectors on top of each other. The principle of the experiment is measuring the muons in coincidence with electrons, being one of the transformation products of muons. The first detector measures the muon itself, the second detector measures the electron, and the third detector works as a veto, where no pulse is allowed to exclude detecting a muon travelling through all three detectors. Measurements were taken for about 22 h.





Results and discussion



The observed muon decay time over the rather short period of time as indicated along with the fit curve was 1.40 ± 0. 68 μs. Unfortunately, this value is incorrect according to a known software bug and the value is only correctly displayed in the data log – which had not been collected at that time. The correct value will be approximately 2,3 μs here, but the experiment has to be repeated, of course. Nevertheless, it is clear from the time bins that longer measuring time is required to obtain statistically more valid data with more muons detected and less standard deviation.

Muon Measurements

Credit: DESY, Science Communication Lab

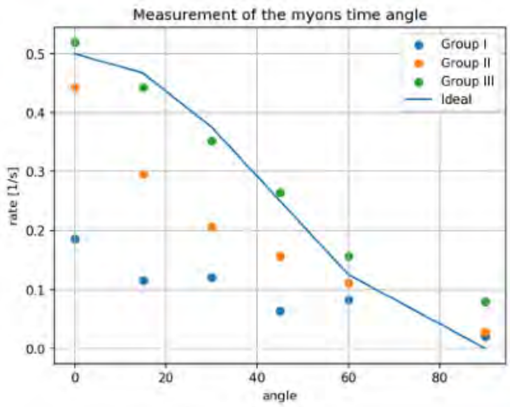
Karlsruhe Institute of Technology
Institute for Astroparticle Physics
Karlsruhe, Germany

17 participants from 8 different schools in Germany

Experiment 1: Zenith Dependency of Cosmic Muons

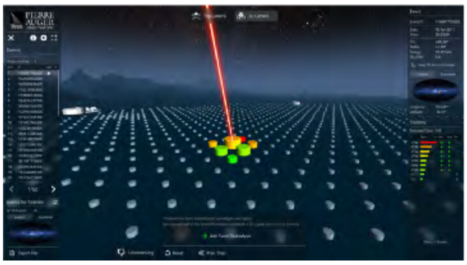
Setup:
- Measurement of muons using scintillation detectors
- Six measurements with different angles between 0°-90°

Results:
- Highest muon rate at zenith
- Lowest muon rate at 90°

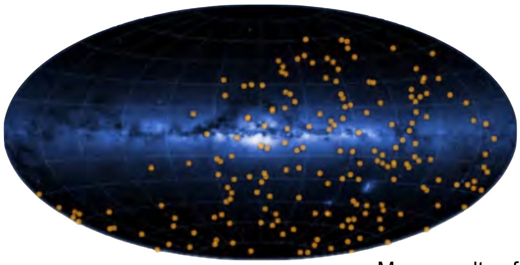


Experiment 2: Pierre Auger Observatory Masterclass

Setup:
- Analysis of real Auger measurements using the Masterclass software



Results:
- Distribution of reconstructed events on skymap



More results of our analysis:
https://augermasterclasses.lip.pt/activities/masterclass/41

INTERNATIONAL COSMIC DAY

NOVEMBER 21 I 2023

Who are you?

The University of Bonn has extended an invitation to 23 students from 11 high schools in the region to visit the Forschungs- und Technologiezentrum für Detektorphysik (FTD) and explore the fascinating realm of cosmic radiation.

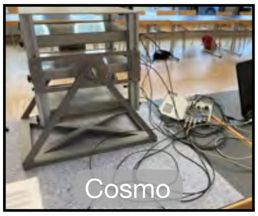
What have you done?

In the morning, we had the opportunity to delve into the latest research in astro-particle physics through a private lecture conducted by Prof. Dr. Manuel Drees. Following the lecture, we engaged in a hands-on experience, making cosmic particles visible through a small, self-made cloud chamber experiment.


DIY Cloud Chamber

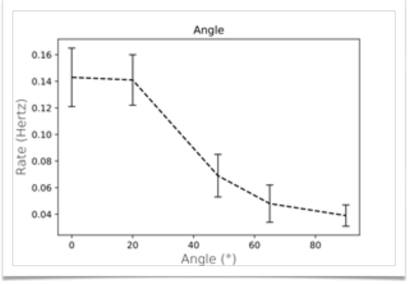
In the afternoon divided into groups and carried out various experiments using Cosmo and Cosmic Watch Detectors:


Cosmic Watch


Cosmo

What did you find out?

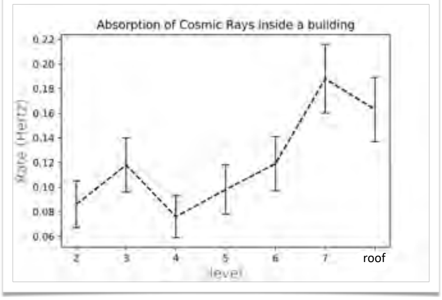
We measured how the cosmic particle flux varies depending on the direction of the measurement:



Larger angles yield lower rates, where 0° indicates a vertical measurement and 90° denotes a horizontal measurement.

We also examined whether the cosmic particle flux is influenced by the structure of a building by conducting measurements on different floors.

Fig. 2: The rates show an increase for higher floors. Surprisingly, on the roof, students measured slightly lower rates compared to floor 7.



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.

Ballonmission 2023

DESY, Germany

We are 16 students (age 16-20) from different places in Germany & Portugal who joined the DESY-organized AstroCamp to perform various experiments including the launch of a weather balloon.

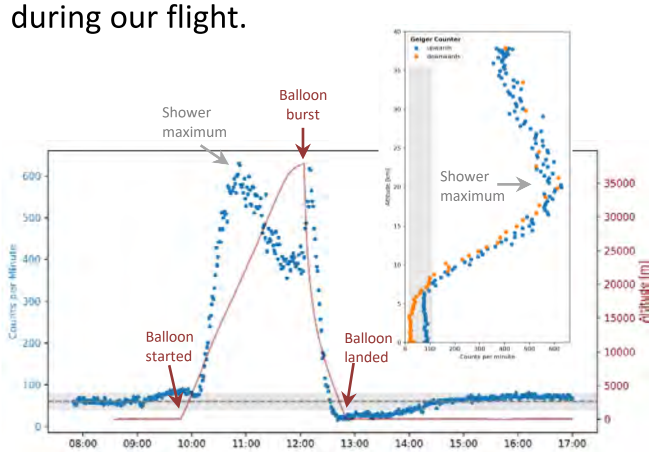
What we have done:

We built a Cosmic Probe – equipped with different detectors to measure cosmic rays, temperature, humidity, and GPS positions – and launched it into the atmosphere on a large weather balloon.

- Flight time: about 3 hours
- Flight Direction: ~120 km to the East
- Max Height: about 39 km

What we find out:

At high altitudes, the number of cosmic rays seen by our Geiger counter is much higher than on ground. The variable counting rates, shown in the figure below, can be explained by the development of air showers initiated by cosmic rays in the atmosphere. We can even see that the air shower maximum is located at ~20km as we passed it twice during our flight.



What's your take-home message?

Being able to work together like scientists, from preparing experiments, building our own detectors, launching the weather balloon, and learn how to analyze and interpret the data, was simply great. Interested in more? **Watch our video!**

Credit: DESY, Science Communication Lab

Search for Cosmic Muons on the International Cosmic Day

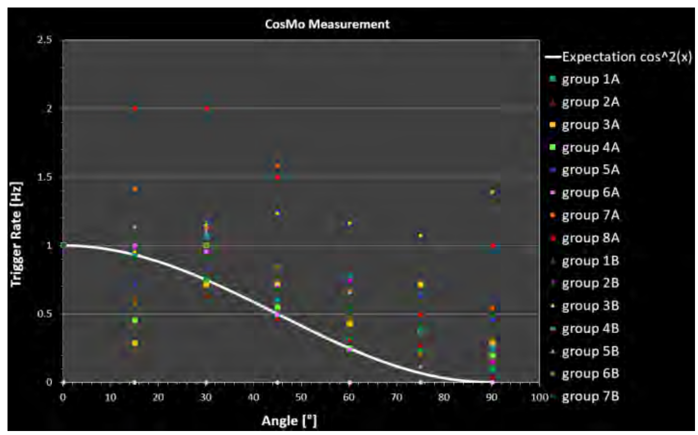
University of Wuerzburg, Germany

Who are you?

We are 27 students from all over lower franconia who came to Wuerzburg for the International Cosmic Day.

What have you done?

We learned a lot about cosmic rays, their origin and the showers of particles that happen when they hit earth's atmosphere. To make particles visible for our bare eyes we built small cloud chambers. With scintillators we counted cosmic muons to measure the muon flux in our classroom and see if it has an angular dependency.



What did you find out?

We saw electrons and alpha particles in the cloud chambers and found out the muon flux gets lower when we oriented the detectors closer to the horizon. Our results of the scintillator measurements is shown in the normalised plot above together with the expectation from theory.

What's your take-home message?

We got an idea how physicists at universities work together in collaborations to find their answers on open questions and got an amazing opportunity to learn something about a new exciting topic none of us had ever heard in school before.

ITALY

MEASURAMENTS WITH THE COSMOCUBE

Monna Agnese Biotechnology
High School - Siena (Italy)

Who are you?

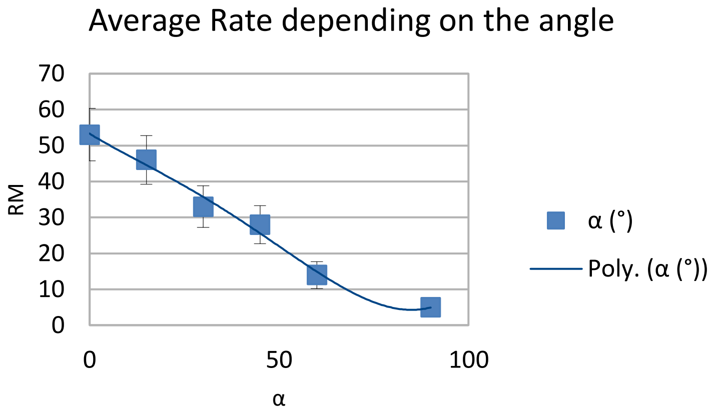
We are Riccardo and Arianna, two students in the last year of Monna Agnese Biotechnology High School in Siena.

What have you done?

We made several measurements with the Cosmocube, changing its angle of inclination, so that we were able to find the origin of cosmic rays.

What did you find out?

RM (min^{-1})	Error RM	α (°)	T (s)	E
53	7	0	333	294
46	7	15	333	257
33	6	30	333	181
28	5	45	333	156
14	4	60	333	76
5	2	90	333	28



What's your take-home message?

Thanks to this experience, we have deepened our knowledge about cosmic rays through laboratory activities that have allowed us to learn their nature and usefulness. We have also learned how to use computer tools, such as Excel to build charts and observe the trend of the cosmic ray frequency at varying angles.

ANGULAR DISTRIBUTION OF COSMIC RAYS

Liceo Scientifico "Aldo Moro", Margherita Di Savoia (BT), Italy

Who are you?

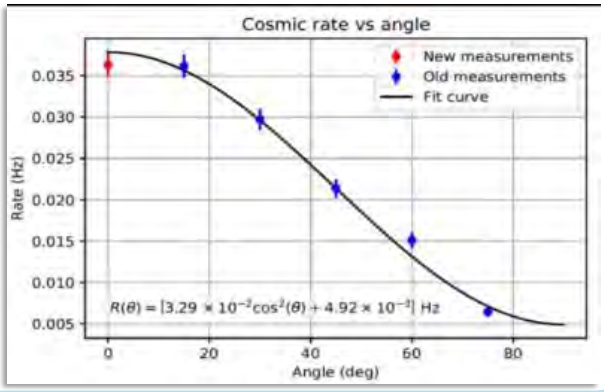
We are a group of students from IISS "Aldo Moro", Margherita di Savoia. This is for us the second year that we had the opportunity to attend this project.

What have you done?

A part of the group stayed at school and attended conference with the INFN that talked to us about cosmic rays, i.e. energetic particles coming from outer space. Also important is the coincidence module together with its three detectors that measure a particle (or noise) and tell us if they have measured something at the same time. It has been observed that the higher the detector rises in our atmosphere, the more the number of particles detected rises to a plateau. Then we learned how the underground laboratories that detect particles work (in Canada, Japan and Italy). We have seen the origin of cosmic rays and their division in contact with the atmosphere, creating cosmic swarms. It has been noted that changing the position or inclination of the detectors also changes the possibility of having coincidences based on the greater or lesser possibility that a subdivision of a cosmic ray passes through all three detectors or more subdivisions touch them at the same time. A type of cosmic ray with lower energy was studied in depth: the solar wind, partially deflected by the Earth's atmosphere, because the part of the solar wind that is not deflected is called polar aurora (since it is visible above all at the poles of the earth).

What did you find out?

The group of 4 students that attended to the workshop at the University Bari studied the frequency of events in an interval of time trough "Catafalchino", a machine that detected data. The detector give us text documents composed by three columns showing the number of events, the time of acquisition and the time difference between measurements. Processing data in a python script we obtained the plot of the cosmic rays rate as a function of the Zenith angle. (As shown in the figure) We fit experimental points with the function, so we get the values. We repeat the analysis considering the presence of the dead time (0,25 s) we get a new curve with… that shows a greater rate than the one rated.



What's your take-home message?

Doing this experience for 2 years brought to our school a new thought process: things around us are never like they look from the outside. We have done new experiments this year with a new machine that is more modern, smaller and way more efficient compared to the one used the year prior. If someone is interested and likes this part of physic, we suggest to participate to these kind of events.

MEASURAMENTS WITH THE COSMOCUBE

Monna Agnese Biotechnology High School - Siena (Italy)

Who are you?

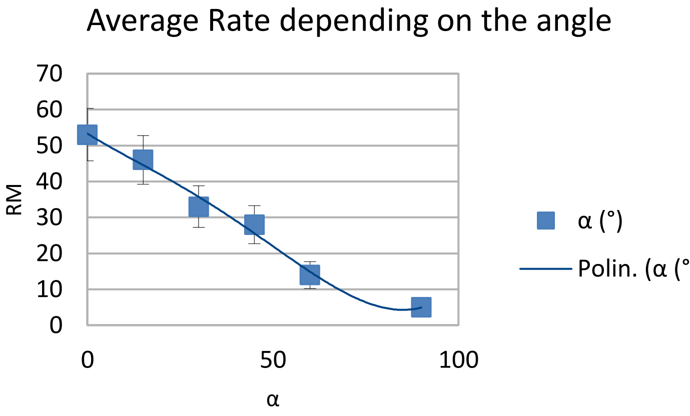
We are Riccardo and Arianna, two students in the last year of Monna Agnese Biotechnology High School in Siena.

What have you done?

We made several measurements with the Cosmocube, changing its angle of inclination, so that we were able to find the origin of cosmic rays.

What did you find out?

RM (min^{-1})	Error RM	α (°)	T (s)	E
53	7	0	333	29
46	7	15	333	25
33	6	30	333	18
28	5	45	333	15
14	4	60	333	7
5	2	90	333	2



What's your take-home message?

Thanks to this experience, we have deepened our knowledge about cosmic rays through laboratory activities that have allowed us to learn their nature and usefulness. We have also learned how to use computer tools, such as Excel to build charts and observe the trend of the cosmic ray frequency at varying angles.

Liceo Scientifico "L.Mossa" - Olbia (SS)

Last year a group of students from a high school in Olbia, were interested in the International Day of Cosmic Rays. On November 21, 2023, the same group of students went to Sassari's University, to attend the International Day of Cosmic Rays.

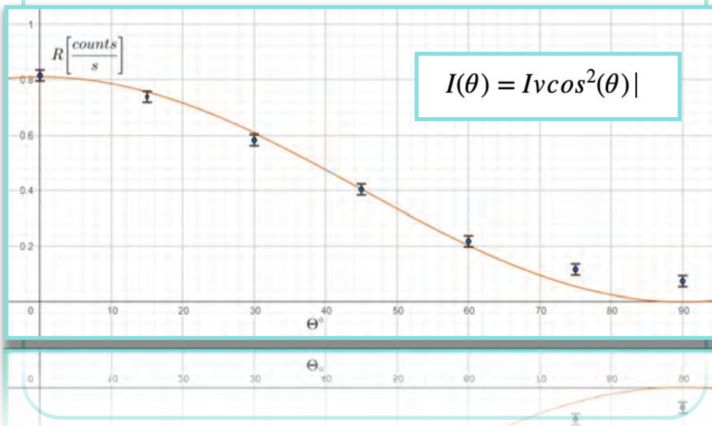
Experience description

1) We started by measuring the amount of cosmic rays that passed through a device every 30 minutes.
2) After each measurement we changed the angle of the device by 15 degrees to reach a total of 7 measurement.
3) Then, with the datas that we've collected we have founded the correlation between the "counts" and the "time": the rate. This measure the number of cosmic rays that went through the device in 30 min.

Theta	Conteggi	time $[s]$	Rate $[conteggi\ s^{-1}]$
0	1626	1995	0,82
15	1376	1865	0,74
30	1093	1876	0,58
45	893	2210	0,40
60	408	1877	0,22
75	268	2315	0,12
90	166	2262	0,07

Results

The goal of the experience was to find the function that describes the correlation between the angle and the number of cosmic rays as a function of time. We transcribed the data on a table and we divided it into four columns.
The first column indicated the angle and then the inclination of the instrument used, the second column shows the number of rays that crossed the machine, in the third we counted the time in seconds and the fourth column "rate" corresponded to the ratio between time and count. We found the function:



Conclusions

From experience we have deduced that the intensity of the wave describing the trend of the cosmic rays depends on the cosine square of the angle that the plates form with the ground and the maximum intensity. In addition, the rays must pass through both plates to ensure that the measurements take place, and a greater number is recorded when the plates are placed horizontally.

ICD 2023 INFN-OCRA

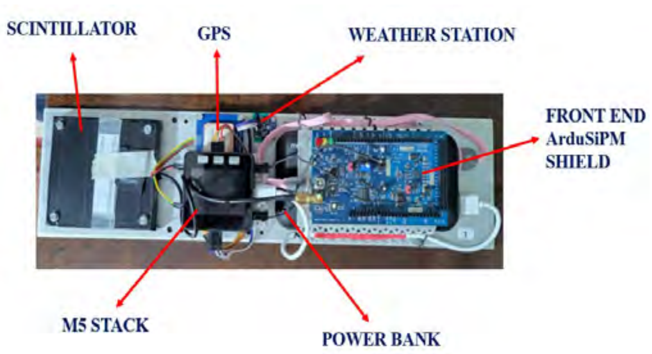
Liceo Scientifico ''Stefano Patrizi'' - Cariati (CS) Italia

Who are you?

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

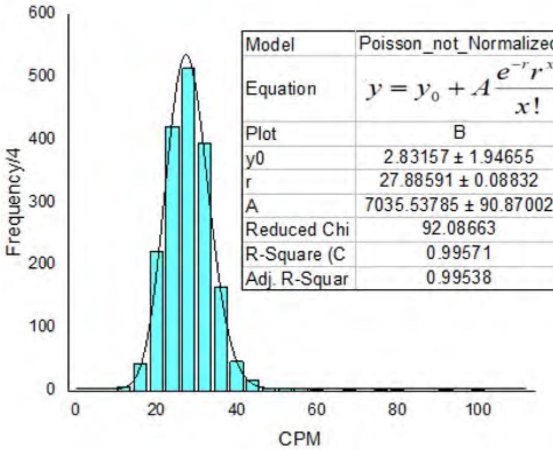
What have you done?

The MoCRiL (Measurements of Cosmic Rays in Lake) project proposes, in an educational manner and using modern measuring instruments, Domenico Pacini's experiment to determine the origin of the natural ionizing radiation that surrounds us at all times. The students, with the collaboration of researchers from the INFN (OCRA collaboration of Cosenza) and the Physics department of UNICAL, trained in the measurement and analysis of data using an ArduSiPM detector inserted in an underwater hermetic tube. The aim of this project is to make students aware and understand the often very difficult path that leads to scientific discovery, sharing ideas and results with other students of different years and schools.



What did you find out?

We analyzed data on the variation of the flux of cosmic rays in the air on different days with different environmental conditions, in preparation for the measurements we will carry out in water, to learn how to use the instrument. An M5Stack microprocessor is used to read the digital signals provided by the ArduSiPM, to store them on a microSD card. The data in the figure shows a distribution of the frequency of counts (29-30/10/2023) that fits very well with a Poisson curve whose central value varies with changes in meteorological conditions. As a result, the standard deviation of the distribution is approximately equal to the square root of the mean value, as expected for events characterized by a small probability of occurring and a large number of trials.



Model	Poisson_not_Normalized
Equation	$y = y_0 + A \frac{e^{-r} r^x}{x!}$
Plot	B
y0	2.83157 ± 1.94655
r	27.88591 ± 0.08832
A	7035.53785 ± 90.87002
Reduced Chi	92.08663
R-Square (C	0.99571
Adj. R-Squar	0.99538

What's your take-home message?

The message that we will take home its that through the analysis of the cosmic rays we can have informations about the cosmos and about the objects that compose him.

Credit: DESY, Science Communication Lab

To the MUONS and back

Liceo Scientifico «A. di Savoia Duca d'Aosta», Pistoia
Istituto Paritario «M. Ficino», Figline Valdarno
Istituto di Istruzione Statale Superiore «E. M. Enriques Agnoletti», Sesto Fiorentino
Liceo Scientifico Statale «L. da Vinci», Florence
Liceo Scientifico Internazionale «N. Machiavelli», Florence
Italy

Our team for the International Cosmic Day

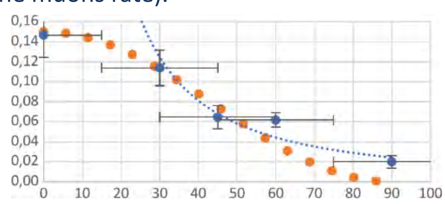
19 students from different High Schools in Tuscany (Italy), most of whom did not know each other before, had the chance to work together for this project. We met at the National Institute of Nuclear Physics in Florence where, with the help of university professors, researchers and Ph.D. students we explored and learned about the phenomenon of the cosmic rays.

The two days of our experience

The first day we got together we explored the history and the theory behind cosmic rays. We learned about the methods that have been used to detect them in the past and the applications (like the muography) that this research has developed toward.
We also got the first look on the detector that we would be using the next day, we were explained how it worked and how we should collect the data to minimize the relative error.
The second day we worked with the detector to collect the data. The experiment consisted in the measurement of the rate of cosmic rays muons at different angles from the zenith. We used a detector of muons made of two plastic scintillators secured on a plastic, rigid structure that could be oriented at will in different angles. In the detector, there was also a small computer which calculated automatically the rate of passage of muons.
We split into two groups, the first one did the practical work by moving the detector at different angles, checking the number of muons and collecting the data. The second one made graphics, data analysis and some slides.

The results

After taking data at certain zenith angles θ (0°, 30°, 45°, 60°, 90°), by changing the time lap for every angle in order to maintain the relative error similar for every rate's measurement, we found that the rate of muons changes as a function of cos(θ), with a minimum at 90° due to the more difficulty of the muons to cross a longer section of atmosphere.
The trend of the function is displayed by the orange curve (on the x-axis there is the zenith angle, while on the y-axis there is the muons rate).



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Our take home message…

This method of measurement is relatively simple while efficient, maintaining the error low, but could be improved by increasing the distance between the two scintillator's plates reducing the error on the angle.
Muons can help us to get to know the Universe and our planet better, from the matter beyond the galaxies to the piramids and volcanoes down on Earth.

INTERNATIONAL COSMIC DAY

INFN PERUGIA · A.D. 1308 unipg DIPARTIMENTO DI FISICA E GEOLOGIA · CRISP ASI-UniPG 2019-2-HH.0

INFN and University of Perugia, Italy

Liceo Scientifico «G. Alessi» – Perugia (PG), Italy
Liceo Classico e Musicale «A. Mariotti» – Perugia (PG), Italy

Abstract

On November 21st 2023, 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 21st 2022, the 12° edition of the International Cosmic Day (ICD 2023) 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. About 30 high-school students took part to the event, along with their teacher: prof.ssa Veronica Palli from Liceo Scientifico G. Alessi and prof. Francesco Tondini from Liceo Classico e Musicale A. Mariotti. 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 $I(\theta) \propto \cos^2(\theta)$ was observed. The pictures below were taken during some of the activities.

Measurement of the Meson's Mean Lifetime

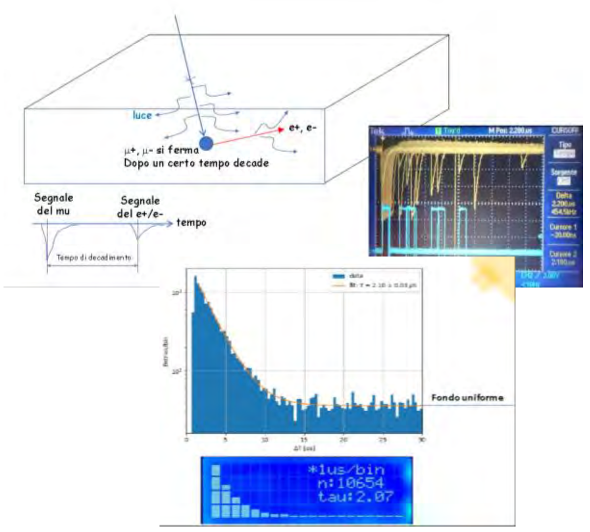
IIS P. Aldi, Grosseto, Italy

Who are you?

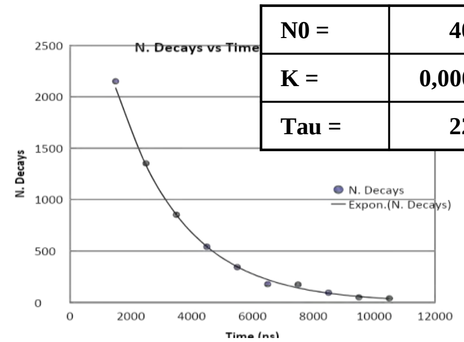
Prof. G. Gargani and Students Fontani David, Garcia Tommaso, Gubinelli Michelangelo, Scotto di Carlo Biagio, e fr~om IIS Pietro Aldi - Liceo Scientifico Guglielmo Marconi.

What have you done?

We conducted explorations of cosmic rays and muons utilizing the CosmoCube. Our investigations encompassed the composition of cosmic rays, their potential sources, and an in-depth examination of muon behavior, all based on the data collected by the CosmoCube.



What did you find out?



N0 =	4090	
K =	0,00045	1/ns
Tau =	2232	ns

Through the use of data collected with the CosmoCube and comparison through graphs, we have been able to demonstrate the average decay time of a muon with a value compatible with literature data.

T = 2,07 microsec (error 7%)

We have identified the predominant composition of cosmic rays, consisting primarily of protons and helium, with uncertain origins likely associated with sources such as supernovae and pulsars. Additionally, we have discovered the crucial role that muons play in particle physics, despite their brief existence. Our utilization of the CosmoCube for muon observation has allowed us to reveal temporal distributions and determine the mean life of the muon.

What's your take-home message?

We successfully employed the CosmoCube to deepen our understanding of muon behavior and conduct temporal analysis of cosmic rays.

AstroPlano: a portable detector for Cosmic rays: Night & Day Distribution

Teachers: Laura M. Valentino, Lucia E. Battistella; Tommaso Montorfano
Student speakers: Alessandro Barretta, Diego Brigaglia, Lorenzo Massante, Vittoria Palma
External tutors: prof. Marco Battaglieri (INFN-Ge), Stefano Grazzi (INFN-Ge)
Participants: M. Ahmed, A. Arisi, F. Benfatto, F. Biancini, L. Bossi, B. Castillo, R. Gasperin, K. Ghobrial, G. Guzzo, F. Maderloni, R. Mary, M. Masciocchi, R. Massante, G. Meletti, I. Meneghello, E.. Moar, V. Modena, F. Moreschi, L. Nava, D. Perugini, D. Pirovano, T. Rovaris, M. Spada , B. Villa.

“Giulio Casiraghi” high school
Cinisello B. (Milan) - Italy

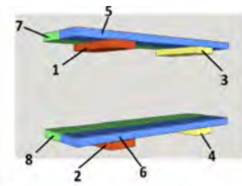
Abstract

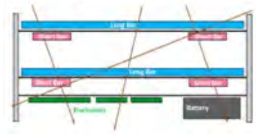
The high School “Giulio Casiraghi” (Cinisello Balsamo - Milano Italy) organized a physics laboratory called ConCERN. Among other activities, in collaboration with the Istituto Nazionale di Fisica Nucleare – Sezione di Genova, we deployed and operated a portable cosmic muon detector, ASTROPLANO.

Experimental Set Up

ASTROPLANO : A prortable MUON DETECTOR

AstroPlano is a portable cosmic muon detector made by twelve extruded plastic scintillator bars (4 longs and four short, forming a matrix), readout by SiPMs coupled to Wave Length Shifter fibers. The detector is sensitive to ionizing particles crossing its acceptance, with angular detection capability. These particles are mostly muons produced in atmospheric showers induced by primary cosmic rays radiation. Muons, resulting from decay of hadrons and leptons, have a decay time of 2.2 μs, travel at (almost) the speed of light and can be detected thank to the relativistic time-dilation Figures on the side show AstroPlano schematic drawing and a picture of mechanical structure.

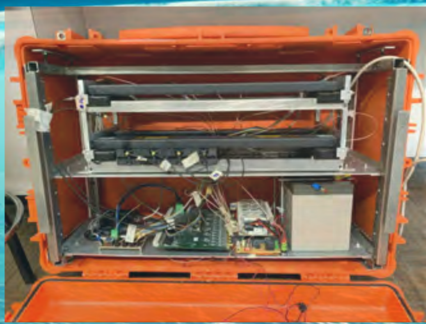




In this study we wanted to find out a possible difference between day and night of the cosmic muon flux. To achieve this goal, we took data, indoor and outdoor, in several runs with the same experimental setting. For the indoor measurements, AstroPlano was placed in the ConCERN lab close to a window. In data analysis, we took into consideration that the building is not symmetric and false asymmetries can exist. The figure below shows the Casiraghi school, the ConCERN lab, and the he AstroPlano detector in front of the window.

AstroPlano can operate in ‘normal’ and ‘angular’ mode. In the first, all angle muons crossing a bar are collected. In the latter, a set of short bars allow one to measure the cosmic flux at different fixed angles. For this measurement, we operate AstroPlano in ‘normal ‘ mode in order to maximizing the data yield and minimizing the statistical uncertainty. Day and night runs were taken from 7 AM to 5 PM and 5 PM to 5 AM, respectively

AstroPlano: a prototype detector for Cosmic rays:

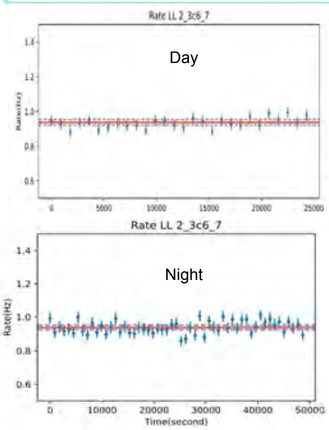


Night & Day Distribution

Giulio Casiraghi
high school
Cinisello Balsamo (Milan) - Italy

Data Analysis

DAY-NIGHT RUNS ANALYSIS: In data analysis we selected counts form short-short and long-long bars coincidence. Results from a run for different combinations of bars, are reported in the table below and shown in the picture.



set-up coincidences	Day - average frequency- Hz		Night - average frequency- Hz	
SS 8_10	0.365	+/- 0.004	0.370	+/- 0.003
SS 9_11	0.343	+/- 0.003	0,348	+/- 0.003
LL 0_1c4_5	0.994	+/- 0.005	0.997	+/- 0.004
LL 2_3c6_7	0.933	+/- 0.005	0.940	+/- 0.004

Notes: Error bars shown in the graphs include statistical and systematic uncertainties. Measured rates vary with the positions of the bar pair considered due to the sky asymmetric coverage of the school building. To avoid to in traduce a false asymmetry, we kept the same position during the experiment. The reduced night runs errors is due to the longer time data taking.

Legend: SS= coincidences with short-short bars; LL= coincidences with long-long bars
Numbers refer to the SiPM identifier. We report two numbers when the low bars are concerned (8_10 and 9_11) while we specified the two SiPM id per each bar when the long bars are considered (2_3c6_7 and 0_1c4_5).

Conclusions

The long bars coincidence rates measured in day/night runs are are reported below :

$$R_{night}= (0{,}954 \; +/- \; 0{,}004 \; +/- \; 0.03) \text{ Hz}$$

$$R_{day}= (0{,}929 \; +/- \; 0{,}004 \; +/- \; 0.03) \text{ Hz}$$

The first (second) uncertainty refers to the statistical (systematic) error. Considering the systematics error associated to the measurement (~3%) the two rates are compatible and we do not observe any difference between day/night cosmic muon rates. This is in agreement with the current scientific literature. (https://www.sciencedirect.com/science/article/pii/S0168900220306719)

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

Liceo “Cecioni“ Livorno, Italy

Who are you?

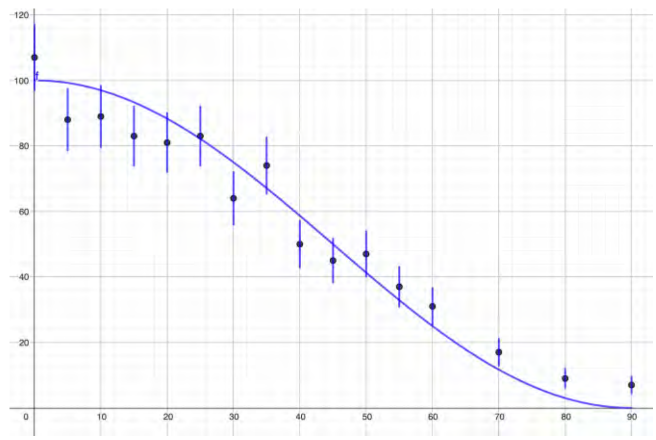
Agnese Panciatici, Samantha Ulivieri, Lisa Vitale, Arianna Signorini, Alberto Menicagli and prof.ssa Elisa Falchini from Liceo “Cecioni”, Livorno

What have you done?

In this scientific experiment, we utilized a cosmic ray detector known as CosmoCube to measure the muon flux as a function of the arrival angle relative to the zenith.
The CosmoCube features two detection planes spaced 12 cm apart. The experimental setup was configured to register muons simultaneously detected by both planes.
Measurements were conducted over a three-minute interval while systematically adjusting the inclination of the CosmoCube from 0 to 180 degrees in 5-degree increments.

What did you find out?

The measurements obtained during the experiment have been plotted in the attached graph. Additionally, a proportional function to the square of the cosine of the angle has been overlaid onto the experimental data. As evident from the graph, this function aligns well with the collected data, indicating a strong correspondence between the observed muon flux and the theoretical expectations based on the square of the cosine of the angle.



What's your take-home message?

Engaging in this experiment has been a truly enriching experience, providing the opportunity to witness a research facility firsthand and spend a day immersed in the world of scientific inquiry. This experience will undoubtedly contribute to our ongoing interest and curiosity in the field of experimental physics.

International Cosmic Day 2023
INFN Catania

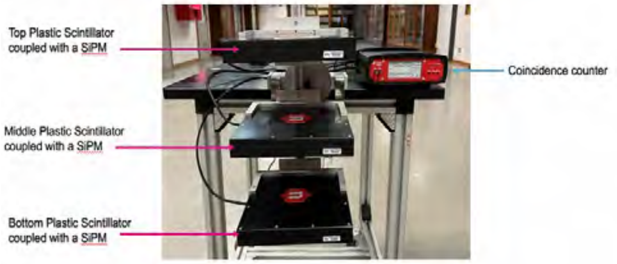
Liceo Classico Europeo Convitto Nazionale Mario Cutelli, Catania, Italy

Who are you?

We are Elena Spampinato and Giulia Di Bartolo, students of the Liceo Classico Europeo Convitto Nazionale Mario Cutelli in Catania

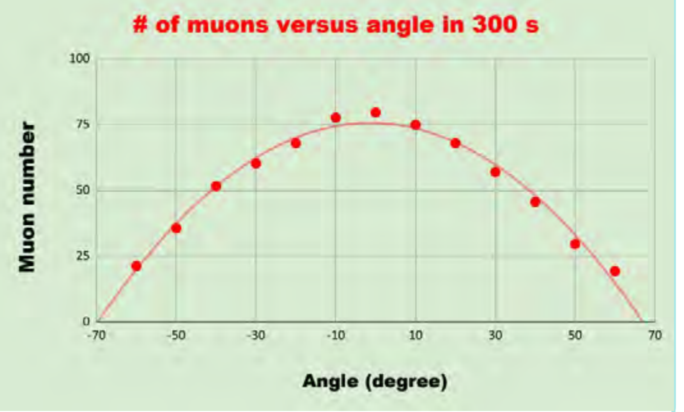
What have you done?

We calculated the flux of muons as a function of the zenith angle, using a muon detector made up of three plastic scintillators coupled to Silicon PhotoMultipliers.



What did you find out?

We found out that the muon flux increases as the angle increases up to 0 degrees, and then decreases again



What's your take-home message?

We learned that physics is not too far from the reality we live in and mostly that it has a real application in our everyday life and we can discover aspects that we don't pay attention to.

Measurement of the muon lifetime with COSMOCUBE

IIS Leonardo Da Vinci, Pisa, Italy

Who are you?

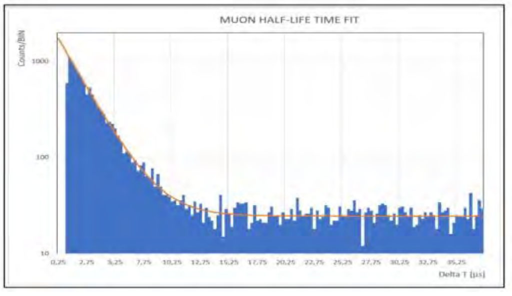
We are Filippo Alessi and Paolo Pierotti, two students ofLeonardo Da Vinci High School in Pisa, Italy

What have you done?

We have detected cosmic rays using a detector called COSMOCUBE, realized by INFN in Pisa.
In particular, since muons lose about 2 MeV of energy per gram per square centimeter of material that they traverse, in our scintillator the muons with less than about 50 MeV will stop. These stopped muons will decay within few microseconds, emitting one electron and two neutrinos. The emitted electron will excite the atoms of scintillator, producing another pulse og light.
We Know that the single decay time is not predictable, since it is a statistical event, but the study of the distribution of many decay times can give us the muon lifetime.

What did you find out?

Studying the distribution of decay times with EXCEL, we have exploited the functions of this software to fit the data, with the mean square method, with an exponential function (signal) superimposed to a constant background (noise).



The free muon decay lifetime has been determined to be: τ = 2,2 ms.

What's your take-home message?

We used a detector to record the passage of cosmic rays. The INFN researchers gave us the recorded data due to a “double signal” : the first due to entering muon and the second due to electron created in the decay process. So we measured the muons lifetime using the spreadsheet EXCEL to fit the data.

Extreme Energy Events Science inside Schools

The EEE experiment @ ICD 2023

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 x 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 POLAR detectors, used aboard of the Nanuq sailboat during the PolarQuEEEst mission, to detect cosmic rays at very high latitudes. In 2019 three POLAR detectors were installed at Dirigibile Italia Arctic Station of CNR in Ny.Alesund, to take long data acquisition. In 2022 the POLAR-02 detector was embarked on board the Amerigo Vespucci, to take data during a 14-days route from Trieste to Genoa.

What have you done?

During the International Cosmic Day 2023 a total of 30 classes of students and teachers (more than 500 participants) belonging to the EEE Project attended the meeting organized by the collaboration. During the meeting students and researcher presented their reports on the analysis on the data, searching for Extensive Air Showers coincidence events detected by POLAR detectors as a function of their distance.

What did you find out?

By studying the coincidence events detected by two pairs of POLAR detectors, the students studied their dependence on the distance between the telescopes

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 Scacchi presented a summary of their work to the other ICD paticipants.

Extreme Energy Events
Science inside Schools

Discover Cosmic Rays
INTERNATIONAL COSMIC DAY

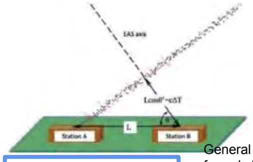
Liceo Scientifico “A. Scacchi”, Bari -Italy

Who are you?

We are the Team EEE (Extreme Energy Event) from Liceo Scientifico “A. Scacchi”, Bari- Italy.

What have you done?

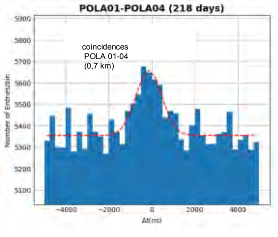
The aim of data analysis is to search for coincidences in two pair of scintillator based cosmic rays detector, POLA 01-04 and POLA 03-04 located in NyÅlesund, Svalbard.
These events in coincidence represents secondary cosmic rays from the same Extensive Air Shower, which are intercepted by the two long-distance detectors as shown in the following figure.



$$f_{acc} = 2 \cdot \Delta t \cdot f_1 \cdot f_2$$

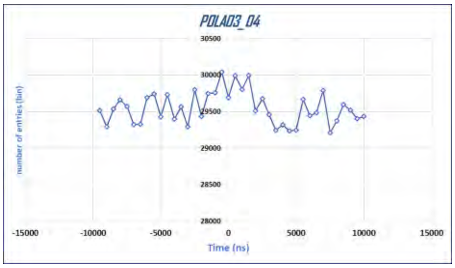
General formula for spurious coincidence

In order to be able to study the coincidences, we had to calculate the number of events which took place in both the detectors in a specific time window from 0 seconds to L/c (s)
After that, we had to create a time's differences distribution of the particles' arrival in the two detectors as shown in the figure and check coincidence.



What did you find out?

To estimate the possible events excess respect to the spurious rate, the number of coincidence events was extracted as a function of the time difference between the arrival of the showers in the two sites. Moreover, we found out that for a greater distance corresponds a minor number of accurate coincidences.



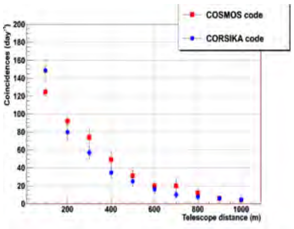
coincidences POLA 03-04 (0,95 km)

The core of our analysis is a comparative estimation of the background of spurious coincidence.
General formula, gaussian fit and horizontal trending gives matching results.
Gaussian fit is the best way to estimate the background when a coincidence peak is clear from the data plot (strong signal). When the signal is weak, the method of horizontal trending gives a good approximation of the background.

What's your take-home message?

We find **8.56 ± 0.27 coincidence/day for POLA- 01 - POLA-04 (L= 0,7 km) and**
3.97 ± 0.29 coincidence/day for POLA- 03 - POLA-04 (L= 0,95 km).

According to the simulation, the number of coincidence/day decreases with distance between detectors.



INTERNATIONAL COSMIC DAY

November 21, 2023

Credit: DESY, Science Communication Lab

Dell'Aquila Staffa
San Ferdinando Trinitapoli

Extreme Energy Events
Science inside Schools

Delta-Time distribution of COSMIC RAYS

Istituto "Dell'Aquila-Staffa" – Trinitapoli (BT) - ITALY

Abstract

The students analyzed the delta-time distribution of the secondary cosmic particles, the muons, as detected by POLA-01, POLA-03, POLA-04 installed in Ny Alesund (Svalbard).

Experimental Setup

Every POLA detectors are made up of two silicon photomultipliers (SiPMs) coupled to every scintillator tile of the detector which have the purpose of collecting light and transforming it into an electrical signal measurable.

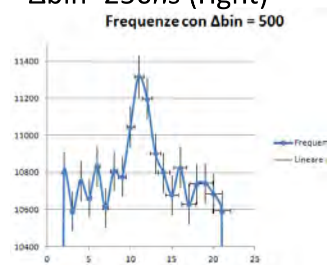
Two data files, which contain the coincidences between the POLA-01/POLA-04 and POLA-03/POLA-04 detectors, have been used in order to evaluate the number of coincidences per day and estimating the variation of this number with the distance of the detectors.

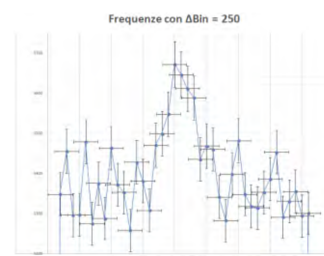
The number of daily coincidences is calculated by the peak of the ΔT frequency distribution from which the background is subtracted and averaged over the number of observation days.

In addiction, the Time of the Flight (TOF) observation is made to verify the direction and the speed of the particles (β value)

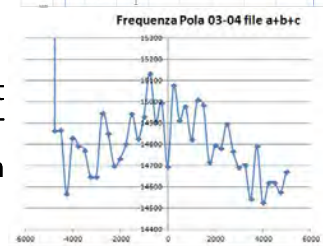
Analysis

The first two plots below show the ΔT frequency distribution between POLA-01 and POLA-03 with Δbin=500*ns* (left) and Δbin=250*ns* (right)

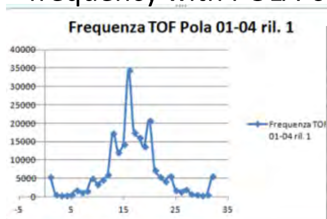


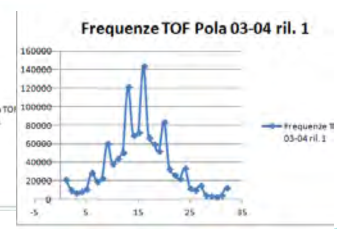


The plot on the right shows the ΔT distribution between POLA-03 and POLA-04



The other two plots are the TOF distribution frequency with POLA-01/04 and POLA-03/04





Results

The observation of the shape of ΔT distribution in POLA-01/POLA-03 are made up of a good data quality. Instead, the observation of the plot in POLA-03/POLA-04 doesn't show an evident peak and so, the quality of the data aren't reliable.

INTERNATIONAL COSMIC DAY

November 21, 2023

Extreme Energy Events

Coincidences between COUPLE of POLA detectors

Liceo *Scientifico Internazionale* ***Luigi Galvani***

Lucrezia Bonafè, Valentina Ciotti, Luca Gardini, Giulia Marucci, Giulia Pizzi, Nicola Romanelli and Rebecca Zuffa.

BOLOGNA, ITALY

Who are you?

Our international school - Liceo Galvani of Bologna - is involved in the Extreme Energy Event (EEE) project since 2006. Here we present our analysis about the data collected on the Svalbard Islands by two couples of detectors: POLA-01 and POLA-04 from June 2019 to April 2020 and POLA-03 and POLA-04 from May 2020 to October 2022.

What have you done?

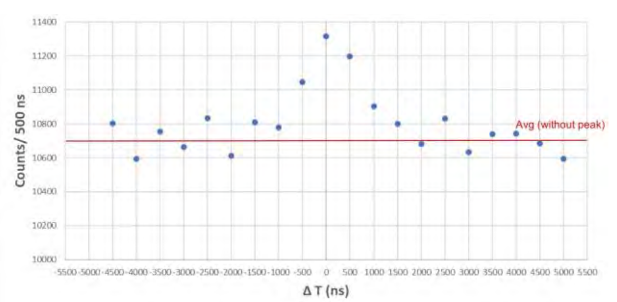
We analyzed the data collected by the POLAR detectors located in Ny Alesund, in Svalbard Islands. In particular we observed two couples of detectors : POLA 1-4, distant 700m and POLA 3-4, distant 950 m. The first couple collected data between June 2019 and may 2020 while the second couple between may 2020 and October 2022. To estimate the number of real coincidences we created the difference distribution of time taken by muons from the same beam when detected by a couple of telescopes POLA01-04 and POLA01-03 respectively, eliminating the amount of accidental coincidences. We found the frequency and percentage of the effective and of the accidental coincidences, the statistical error and the correlation between the distance of the detectors and the percentage of the real coincidences. We analysed the data of POLA 03-04 using a different time range (from -5000 to +5000 and from -9500 to +9500) in order to be more precise.

What did you find out?

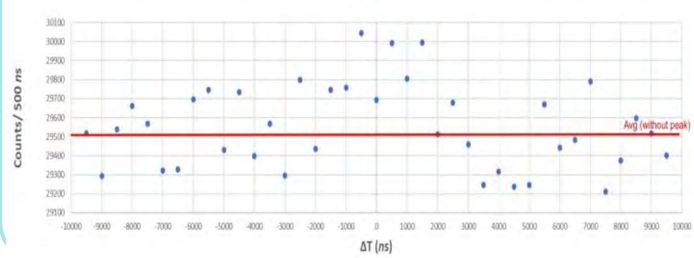
POLA 01-04: $f_{\text{real coincidences}} = (8.4 \pm 3.3) \times 10^5$ Hz → 0.76%

POLA 03-04: $f_{\text{real coincidences}} = (3.6 \pm 1.2) \times 10^5$ Hz → 0.18%

POLA 01-04



POLA 03-04



What's your take-home message?

Our analysis confirmed that the frequency of real coincidences decreases exponentially with the distance between the couple of detectors .

INTERNATIONAL COSMIC DAY

November 21, 2023

EAS coincidences in a pair of synchronized telescopes

Extreme Energy Events
Science inside Schools

Liceo Scientifico «G. Banzi Bazoli»
Lecce (Italy)

Abstract

Extensive air showers (**EAS**) produce time correlated muons, detectable by a cluster of synchronized telescopes. Two muons from the same EAS can reach two different telescopes, giving rise to a **coincidence**, i.e., two events very close in time. We performed an analysis to investigate the dependence of the number of coincidences in a pair of telescopes on the distance between the two of them.

Analysis

The data

We used two samples of data acquired from two scintillator telescopes, Pola01-Pola04 and Pola03-Pola04, both installed in Ny Alesund (Svalbard Islands) by the EEE collaboration.

Our analysis

For each pair of telescopes (L apart), we denote with Δt the time interval between an event recorded by one telescope of the pair and the immediately following one recorded by the other. In addition, we call

- **coincidence** any pair of events with a Δt compatible with that of a pair produced by the same EAS, (in this case we must have |Δt|<L/c)
- **EAS coincidence** any coincidence actually produced by the same EAS,
- **accidental coincidence** any coincidence randomly produced by a pair of not time correlated muons

For each telescope, the histogram of Δt shows

- a gaussian shaped component, in the range $|\Delta t| < L/c$, due to EAS coincidences
- a uniform component, due to accidental coincidences (noise)

To count the EAS coincidences, we estimated the number of accidental coincidences, and subtract them from the number of total coincidences. For this purpose, we fitted the histograms with the function

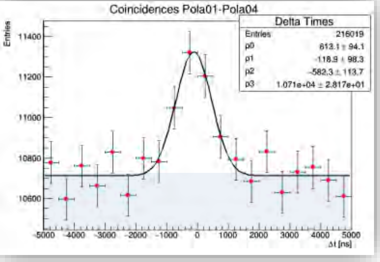
$$f(\Delta t) = p_0 \exp\left[-\frac{(\Delta t - p_1)^2}{2p_2^2}\right] + p_3$$

In this way, p_3 represents the accidental coincidence frequency. So

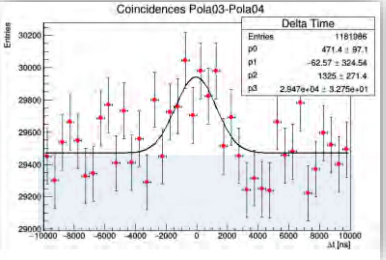
$$\mathbf{N_{EAS} = N_{tot.coinc} - \underbrace{p_3 \times N_{bins}}_{N_{accidental}}}$$

Histograms and plots

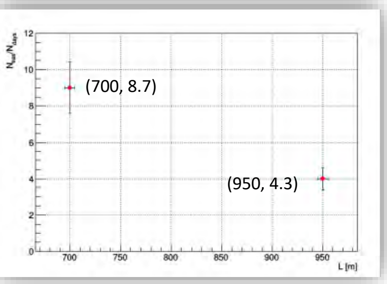
Telescope	L (m)	N_{EAS}/N_{Days}
Pola01-04	700 ± 5	8.7 ± 1.4
Pola03-04	950 ± 5	4.3 ± 0.6



Coincidence distribution POLA01-04



Coincidence distribution POLA03-04



Coincidences per day vs distance between the telescopes

Conclusions

We obtained two points compatible with a decreasing trend in the number of coincidences per day in relation to the distance of telescopes. This is probably due to the more extensive the EAS are, the rarer they are. Therefore, as the distance increases, the probability of having EAS large enough to reach both stations decreases rapidly

INTERNATIONAL COSMIC DAY

Project E.E.E.

Science in Schools

Extreme Energy Events Science inside Schools

Liceo Statale"Cagnazzi"

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

Who are you?

We are a group of students from the Liceo classico "Cagnazzi" , situated in Apulia. Our names are: Tommaso Segreto, Chiara Clemente, Emanuele Marvulli, Sara Demiri, Sara Petronelli, Rosita Pestrichella, Carlotta Zaccaria, Mariantonietta Cirrottola, from classes 4BES, 3BLC AND 4CLC respectively. The project was supervised and coordinated by our teachers: Anna Palasciano, Maria Rosaria Cornacchia, Romolo Berchicci and promoted by our headmaster, Mr. C. Crapis.

What have you done?

Using data from POLA-01, POLA-03 and POLA-04 detectors, which have been installed at the international scientific base of Ny Alesund (Svalbard Islands, Norway) since 2019, we studied the coincidence events between the three. These events represent secondary cosmic rays belonging to the same atmospheric swarm (Extensive Air Shower, EAS).

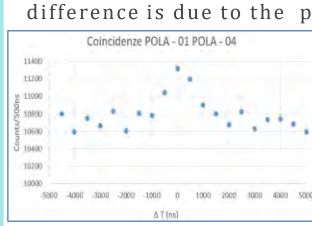
-Analysing data from Pola 01 and Pola 04, we found that the trend of the graph is bell-shaped, centered on Δt=0 ns (coincident events) and with a frequency of 11317. Data was obtained during the period from 06-2019 to 04-2020 and refers to a time interval Δt from -5000 (ns) to +5000(ns), with step 500 (ns).

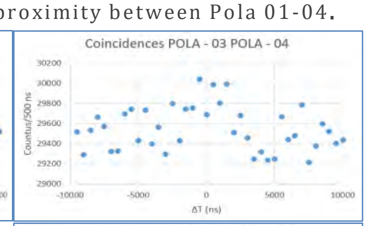
-Analysing data from Pola 03 and Pola 04, we found that at Δt=0 the frequency is 29693, while at the maximum point Δt=-500 ns, the frequency is 30044. Data was obtained between 05/2020 and 10/2022, taking into account Δt from-5000 to +5000, with step +500 ns. On the other hand, Δt from -10000 to + 10000 has been considered, with pitch +500 ns.

To highlight the bell trend, we created the graph of Pola 03 and Pola 04, with step 1000 ns.

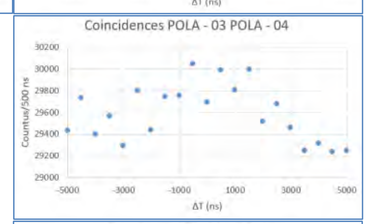
What did you find out?

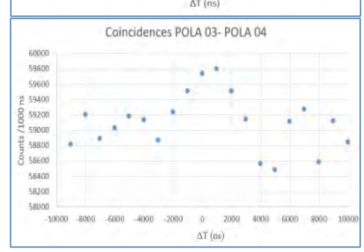
Data comparison shows that, although, POLA 03 – 04 appears with a higher frequency compared to POLA 01 - 04, if we relate them, the values per month are very similar and those of POLA 01 - 04 are higher even if the difference is minimal. Probably the substantial difference is due to the proximity between Pola 01-04.





We have also calculated the events with θ=0 and therefore cosθ=1 and we observed that in the case of Pola 01-04 , Δt=L/c equals 2333 (ns) with a number of about 50 events related to 10 months; in the case of Pola 03-04, Δt equals 3167 (ns) with a number of about 39 events. Thus, by increasing the distance, the number of events decreases.





What's your take-home message?

This experience has given us the opportunity to scan data, process results and reach a reliable conclusion by means of the scientific method. The close encounter with the world of subatomic particles has aroused a great interest in us, which will certainly lead us to further investigations. We truly hope these first attempts will allow us to make a significant contribution to scientific research in the future. Questions and future insights will concern the position of detectors as compared to the sea and to seasons and determination of the number of coincidences based on the seasons

Events in coincidence in POLAR muon detectors: data analysis

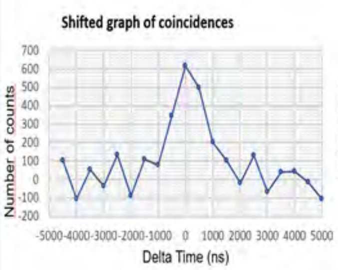
Liceo Scientifico *Giovanni da Procida* Salerno, ITALY

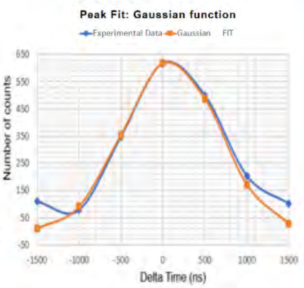
Who are you?

Marcello Imbesi (4D), Francesco Maria Memoli (5A), Francesco Donato Messano (5B), Vittorio Stanzione (5B)

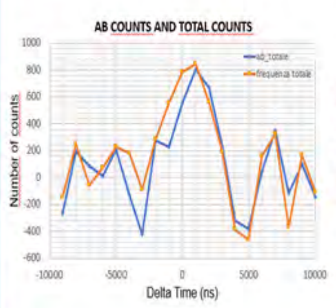
What have you done?

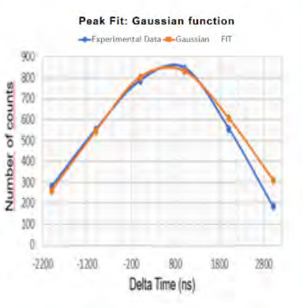
POLA-01 POLA-04 coincidences





POLA-03 POLA-04 coincidences





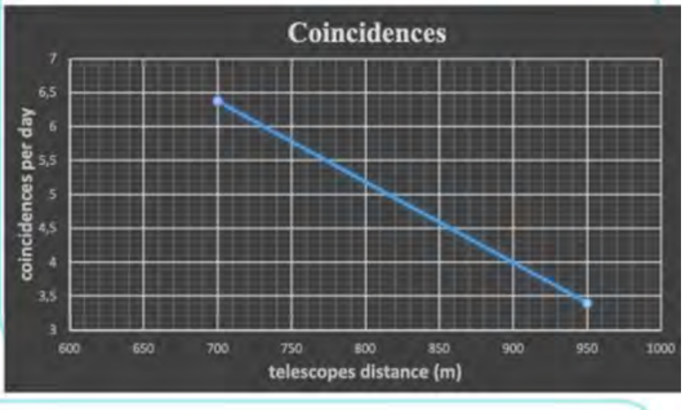
What did you find out?

POLA-01 POLA-04 coincidences

	All data	Peak data only
Total coincidences	2019	1954
#coincidences/day	6,4 ~ 6	6,2 ~ 6

POLA-03 POLA-04 coincidences

	All data	Peak data only
Total coincidences	2986	3219
#coincidences/day	3,4	3,6



What's your take-home message?

- A correct estimate of noise (accidental coincidences) and peak width is crucial.
- Coincidences per day vs telescope distance shows expected behaviour.

Study of coinciding events in PolarqEEEst detectors

Extreme Energy Events
Science inside Schools

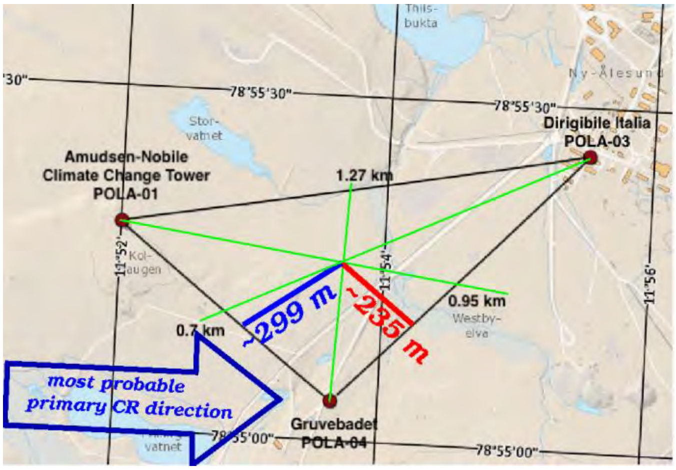
I.T.I.S. G. Marconi, Pontedera (PI)

Who are we?

Manetti Ludovica
Montagnani Ginevra
Reali Lorenzo
Salatti Lorenzo
Salvadori Aurora
Selmi Anna

What have we done?

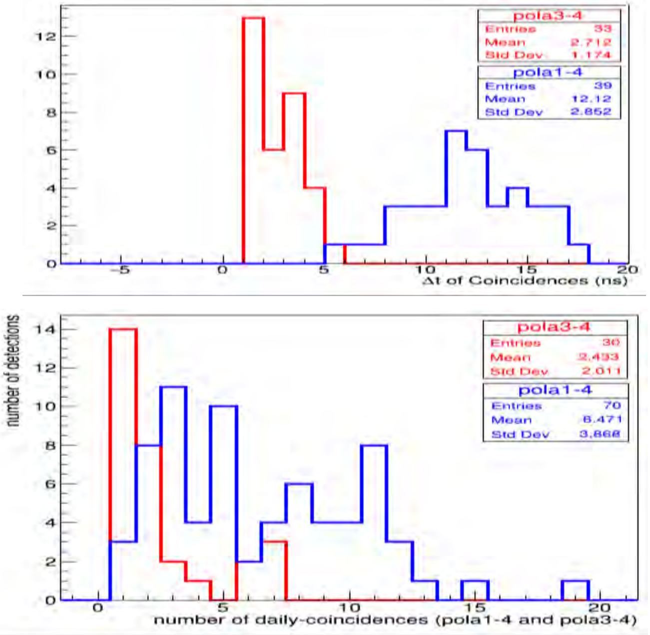
We study the daily rate of coincidences due to Cosmic Rays Showers in two pairs of detectors called (pola01-pola04) and (pola03-pola04)



These detectors belong to the PolarquEEEst experiment located in the North-Pole base of Ny-Alesund at a latitude of ~78.5 degrees.
We also look at the detector-pairs distance dependence of these rates.

What did we find out?

pola1-4 at distance of 700 m have a coincidences rate 2.7 times higher then pola3-4 at a distance of 950 m



Summary:

det. pair	total number of coincidences (*N*)	coincidences frequency (mHz)
pola 1-4	450 ± 20	0.08 ± 0.05
pola 3-4	87 ± 9	0.03 ± 0.02

COSMIC RAYS AT SVALBARD ISLANDS

Extreme Energy Events Science inside Schools

Liceo Scientifico Cavour, Rome- Italy

Who are you?

Francesco Avversari – Patrizio Rizza
Alessandra Di Flumeri – Sara Leonardi

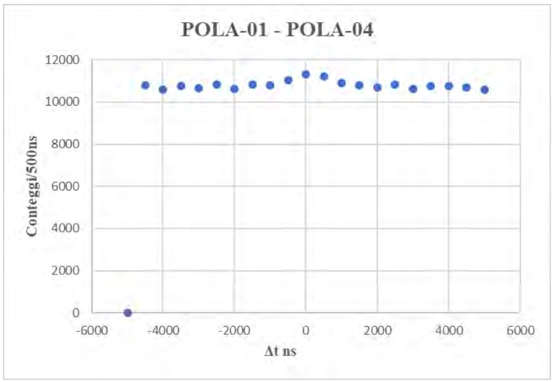
What have you done?

We calculated the number of matching events recorded by two different detectors in a given time window. We have used data from three detectors located on the Svalbard Islands

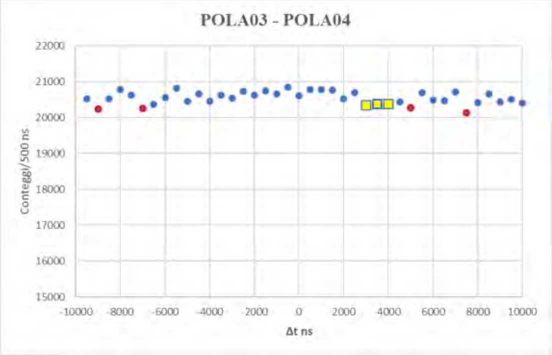
We know the data of the differences between the arrival times of muons on two different detectors This data was used to create a frequency histogram and the corresponding scatter plot. The peaks in the diagram represent real coincidences, while the data lined up below the peaks indicate random coincidences.

For each data series we graphically determined the number of random coincidences and, by difference, the number of actual coincidences per day.

What did you find out?



Coincs=(7±1)day^{-1}



Coincs=(15±4)day^{-1}

What's your take-home message?

The observation intervals are very different, longer intervals correspond to a larger number of observations and the comparison of the data is not significant. If the observation time intervals were comparable, a larger distance between the detectors would correspond to a smaller number of matches. The number of coincidences calculated using the graphical method strongly depends on the estimated value of insignificant coincidences and can only be interpreted as a first approximation estimate of the value sought.

Polar detectors and coincidences

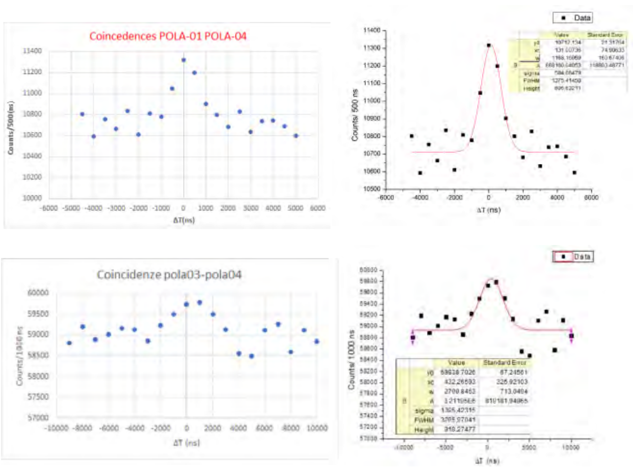
Liceo Scientifico A.Bafile L'Aquila-Italy

Who are you?

Cantalini Elisa 5Bn.o.
Cucchiella Alessandra Aurora 5Bn.o.
Speziale Samuele 4Cs.a.
Canofari Viola 4Cn.o.
Gratti Roberta 4Cn.o.

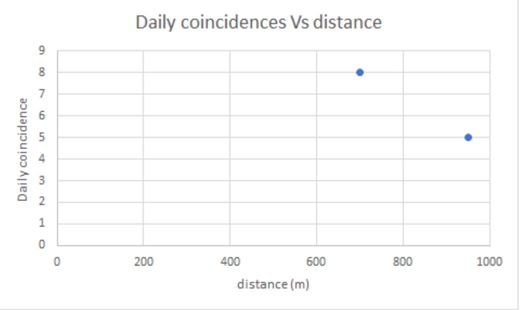
What have you done?

We analyzed data from POLA-01, POLA-03, POLA-04 installed on Ny Alesund scientific base. The graphics show the distribution of the time differences of two events detected in two different stations. We also added a Gaussian fit (right graphics).



What did you find out?

We found out, using the fit, that the number of coincidences from the POLA-01 POLA-04 data is about 1760, which corresponds to about 8 coincidences per day.
From POLA-03 POLA-04 data we found a number of coincidences of 3200, which means about 5 per day.
The plot below shows the daily number of coincidences according to the distance between stations.



What's your take-home message?

As expected we see a peak in the coincidences distribution around a time difference equal to zero. The daily number of coincidences decreases while the distance between stations increases.

INTERNATIONAL COSMIC DAY

November 21, 2023

Data measurements and analysis

Liceo scientifico "Federico II di Svevia Altamura (BA) Italia

Who are you?

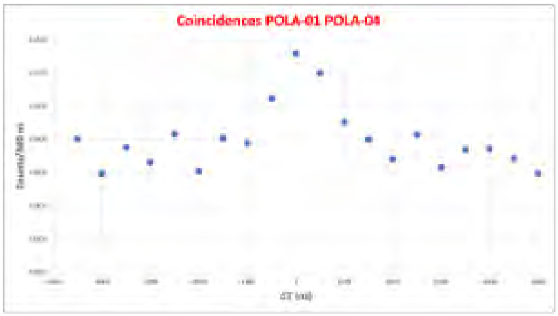
We are a group of students from Liceo scientifico "Federico II di Svevia" directed by Professor S. Piscopo, passionate of physics who have chosen to participate in this project because they were intrigued by the suggestive topic (classes 4^I, 5^I, 3^I, 4^D, 3^D, 4^E, 3^E, 4^M). We worked under the supervision of professors G. Loporcaro, M. L. Pati and A. Perrucci.

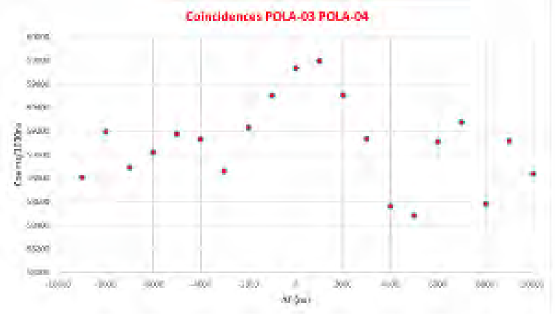
What have you done?

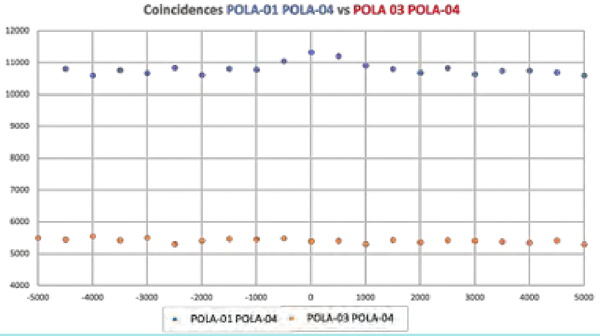
Using data acquired from POLA-01, POLA-03 and POLA-04 detectors, coincidence events between different detectors were studied. After studying and creating graphs showing the coincidence peaks delineating the true passage of the muon swarm, we proceeded to analyze and hypothesize the thesis. Hypothesis: energy levels of swarms as a function of the distance between the two detectors, analysis of the time differences in muons passing through detectors.

What did you find out?

By studying which rays are detected by the detectors placed at greater distances from each other we can understand which shower may have greater energy and thus we can better understand the behavior of the number of coincidences as function of detectors distance.







The plots show the distribution of difference of arrival time of muons in the POLA-01 POLA-04 (upper left) and the POLA-03 POLA-04 (upper right); from the plot it is clear that as the distance between detectors increase the coincidence peak is less visible over the background, as expected (left)

What's your take-home message?

The message that we will take home it is that through the analysis of the data acquired from POLA-01, POLA-03 and POLA-04 detectors we can have informations about the primary cosmic rays and so cosmos.

INTERNATIONAL COSMIC DAY

November 21, 2023

STUDY OF COINCIDENT EVENTS IN POLAR DETECTORS

Liceo Statale Regina Margherita- Salerno, ITALY

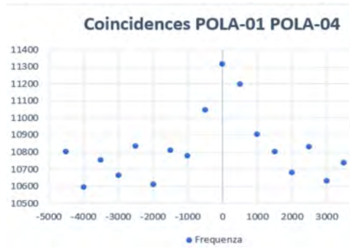
Who are you?

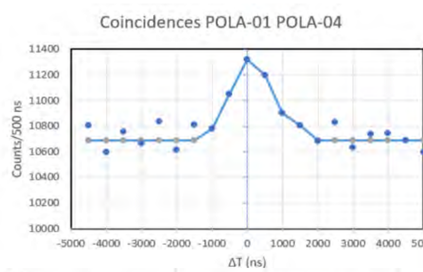
We are one of the schools participating in the EEE Project, organized by **Centro Ricerche Enrico Fermi** , in collaboration with INFN.

What have you done?

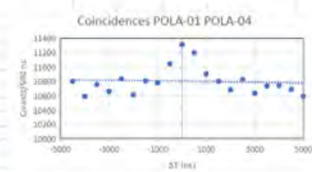
On November 2023 the Regina Margherita High School, participated in the analysis of data acquired by the POLA-01, POLA-03, POLA-04, detectors installed at the international scientific station of Ny Alesund (Svalbard Islands). We analyzed two data files with coincidences between the POLA-01 and POLA-04 and POLA-04 and POLA-03 detectors respectively; the analysis was used to evaluate the number of coincidences per day and to estimate the variation of this number with the distance of the detectors. The results are presented in the following report.

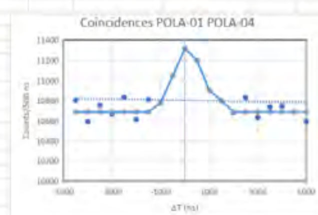
What did you find out?





Classe	Frequenza	Range ΔTmax=L/c	Fondo	F_Classe_i - Fondo	Coincidenze nel Range per classi	Coincidenze nel Range tot.	Grafico
-5000	0	0.00000233333	10689			2211	
-4500	10803		10689	114			10689
-4000	10593		10689	-96			10689
-3500	10754		10689	65			10689
-3000	10663		10689	-26			10689
-2500	10835		10689	146	146		10689
-2000	10611		10689	-78	-78		10689
-1500	10809		10689	120	120		10689
-1000	10778		10689	89	89		10778
-500	11047		10689	358	358		11047
0	11317		10689	628	628		11317
500	11199		10689	510	510		11199
1000	10903		10689	214	214		10903
1500	10801		10689	112	112		10801
2000	10681		10689	-8	-8		10689
2500	10829		10689	140	140		10689
3000	10632		10689	-57			10689
3500	10739		10689	50			10689
4000	10744		10689	55			10689
4500	10686		10689	-3			10689
5000	10595		10689	-94			10689
ro	0						





The graphs show the coincidences between POLA-01 and POLA-04. The peak is found at the frequency of 11137, with 628 coincidences in the class range.

What's your take-home message?

Between POLA 01-04, the peak of detections occurs at 0 ns, this implies that the angle at which the muons arrive is precisely 90°, therefore perpendicular to the horizontal plane and simultaneously in both detectors. Between POLA 03-04 the peak of the coincidences occurs between 0 and 2000 ns, with an angle between 90° and 45°.

EEE PROJECT

Extreme Energy Events
Science inside Schools

Scientific High School “Lorenzo Respighi

Who are you?

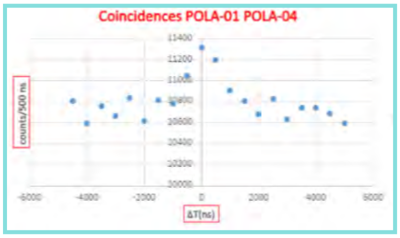
We are a team of 11 students from different classes at the Scientific High School 'Lorenzo Respighi’, in Piacenza. We share a strong interest in scientific subjects and a passion for astrophysics. We have decided to embark on an activity to celebrate the ICD.

What have you done?

We analyzed the experimental data obtained from the POLA-01, POLA03, and POLA-04 detectors of the EEE project, located in the Svalbard Islands, using Excel, following the indicated steps. In comparison to our initial hypotheses, the processed measurements revealed something unexpected. We discussed, verified our steps, and concluded that there must be an explanation; we just needed to find it. We worked as a team but also in subgroups, aiming to read and interpret the experimental measurements. We utilized all acquired knowledge and developed skills to reach a conclusion shared by all. Each of us contributed to the team's work based on individual capabilities and interests, promoting collaboration. The assigned task provided an opportunity to research information about new frontiers in research and technology (such as the PolarQuest2018 expedition) and delve deeper into topics covered in class (such as the Earth's magnetic field). Teamwork proved increasingly effective in building information and achieving the set objectives. In conclusion, we created a presentation narrating our journey and the conclusions we collectively reached.

What did you find out?

The pair of detectors POLA-01 and POLA-04 counted a number of coincidences within the expected window (-2300 ns and +2300 ns), revealing a peak in this range. In contrast, the pair POLA-03 and POLA-04 did not show an obvious peak in the expected window (-3200 ns and +3200 ns). The measurements for the two detector pairs were taken in two different periods. As a result, they are not directly comparable, and the measurement of cosmic background radiation overlaps. We noted that the distance between the two detectors certainly influences the accuracy of coincidence counting. Specifically, 01-04 were 0.7 km apart, while 03-04 were 0.95 km apart. The theoretical model suggests the incidence of the same shower with parallel directions on the two detectors if the distance is approximately 0.5 km. There could be different causes, such as a particular cosmic activity. We chose to delve deeper into the study of the peak highlighted by the pair 01-04. We used Excel's COUNTIF function to obtain a new graph and compared it with the one obtained by following the instructions; the evidence was consistent. The number of non-random coincidences in the 218 days of data collection is estimated at 2122, averaging 10 per day. We then focused on the peak region with two different approaches, selecting time intervals (bins) half the size of those proposed in the instructions to better outline the coincidence window. We observed an asymmetry in the peak bell curve, that we will try to study in future.



What’s your take-home message?

We have certainly improved our teamwork skills: not all of us knew each other initially, we managed to cope with the initial difficulties and together we faced this challenge and expanded our knowledge and skills. We bring home new notions on the behavior of cosmic rays and above all we have seen first-hand the scientific analysis of data obtained from experimental observation.

INTERNATIONAL COSMIC DAY

November 21, 2023

Coincidences Data Analysis

Extreme Energy Events
Science inside Schools

Liceo Scientifico "G.B. Scorza", Cosenza

Who are you?

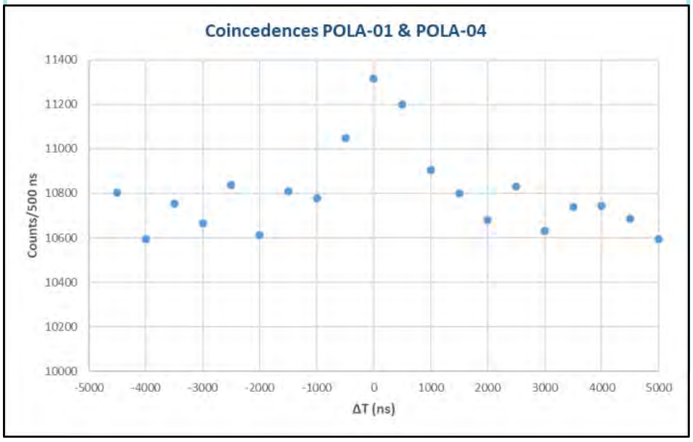
We are a group of students from Liceo Scorza led by our teacher prof. Franco Mollo. Thanks to the partecipation of our school to the EEE Project, we have had the chance to develop our passion for Physics.

What have you done?

We carried out an analysis project. It focuses on the detection of cosmic rays' coincidences revealed by two close detectors (representing secondary cosmic rays that belong to the same Extensive Air Shower (EAS)). We analyzed the data collected by the telescopes POLA-01, POLA-03 and POLA-04, located in the Svalbard Islands from May 2019.

What did you find out?

We compared the number of coincidences detected by the telescopes POLA-01 & POLA-04 with the number of the ones recorded by POLA-03 & POLA-04. We noticed that, in an equal span of time, the closer the detectors are, the greater the number of revealed coincidences is, because it is more likely that two muons belonging to the same EAS are recorded by telescopes closer together.



What's your take-home message?

Never give up when things look tough. The purest essence of scientific experiments is the trial and error method: mistakes must be made to learn from them and eventually achieve success.

Measurement of the muon lifetime with COSMOCUBE

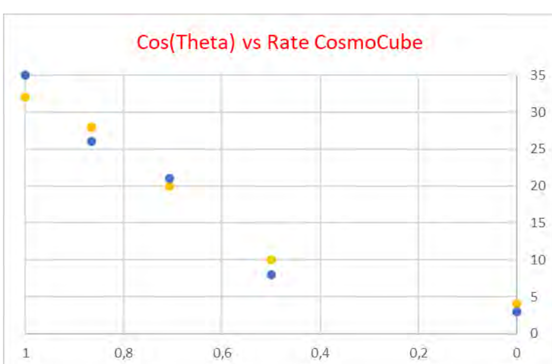
Liceo Scientifico Statale E. Fermi, Massa, Italy

Who are you?

We are five students attending Enrico Fermi, Scientific high school in Massa, Italy.

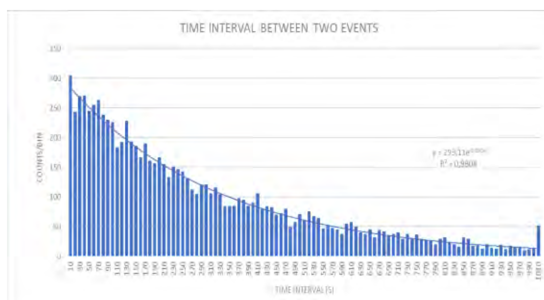
What have you done?

First, we were welcomed in the University and the teachers explained us a few things about cosmic rays. It was nothing new since we already did a few seminaries, but that was the first time we could actually see them live.
We were given some measurements that we used to create a chart and then we used a COSMOCUBE to get a few new measurements. We placed the COSMOCUBE at different inclinations to verify the origin of the rays; we had just a little time so we couldn't really work with the data we got; it was very interesting though.



COSMOCUBE Cosmic ray hodoscope data

What did you find out?



COSMOCUBE Cosmic ray hodoscope data

We didn't know about the existence of an entire field of physics dedicated to cosmic rays. That's actually very interesting, because we understood how many things, we actually still don't know about the world around us. There are still many things to know and discover making the researcher an interesting job for sure. We also learnt how to use different tools we had never seen before, which made the whole thing more fun.

What's your take-home message?

We are very little beings if compared to the whole universe. There are almost endless things to discover out there and doing it could be much more fun than we might expect it to be.

Credit: DESY, Science Communication Lab

International Cosmic Day 2023

Istituto di Istruzione Superiore "Di Poppa – Rozzi", Teramo

Who are you?

We rappresent iis di poppa-rozzi

What have you done?

We talked about dark matter and cosmic rays.
As for cosmic rays, we have said that they are formed by subatomic particles, that is ionized atoms, which are a way to study physical/astrophysical phenomena. After that we did an experiment with the cosmic ray detector (machine used to measure the amount of cosmic rays at certain angles).
After that, we made several measurements at a distance of 300 seconds with different angles.
But when it comes to dark matter, we said that: it includes 95 percent of all matter, 70 percent of which we don't know, and 25 percent is dark matter that we know a little bit more about, and it's thought to be made of particles.

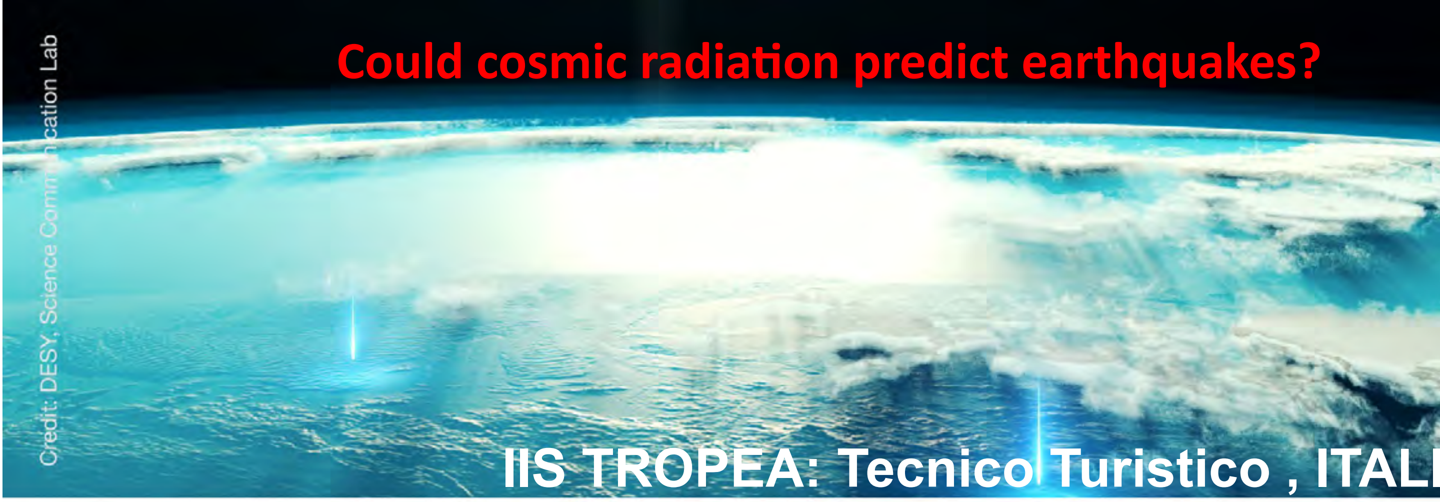
What did you find out?

From the experimentation we have observed that: by changing the angle and turning the machine downwards, the number of cosmic rays decreases, this is because cosmic rays come from above (In fact, the laboratory is located under the mountain because it must be as isolated as possible from cosmic rays, which can disturb electronic equipment).

RC/sec	Event Count	Angle (deg)
1,74	523	[0]
1,45	436	15°
1,15	346	30°
0,88	265	45°
0,59	177	60°
0,29	87	75°
0,22	67	90°

What's your take-home message?

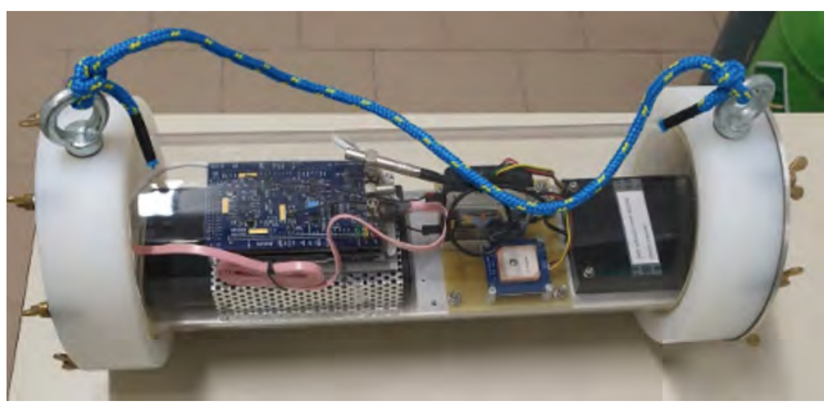
It was very beautiful and interesting. We learned a lot of interesting new things about space and physics. This is an experience that I recommend to everyone.



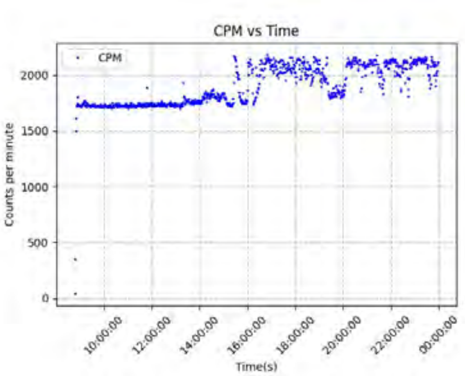
Could cosmic radiation predict earthquakes?

IIS TROPEA: Tecnico Turistico , ITALI

We took part to the lessons given by professor Giuseppe **Fiamingo** about particle physics. Meanwhile we started measuring ionizing particles using two different types of detectors: an ArduSiPM and a Cosmic Hunter, to discover the flow of particles as a function of time. At 11:00 a.m. we followed the lesson of professor Marco **Schioppa** from INFN-UNICAL, and together with other schools from Calabria schools we showed the data analysis and discussed the impact that cosmic rays could have on technology and disasters Natural



Collected data was grouped to form the frequency of particles per minute and reported as a scatter plot

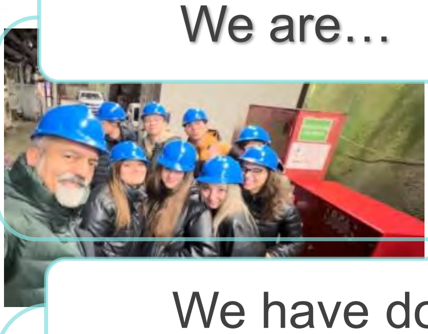


By studying cosmic radiation, we found that we are immersed in a natural background of ionizing particles produced mainly by the interaction of cosmic particles with nuclei in the atmosphere. We discovered that there might be a relationship between cosmic radiation and seismicity.

Magical Ingenuity

IISS "G. Peano – C. Rosa", Nereto, Italy

We are…



We 8 students from the 4BL are attending a Scientific Course. We are interested to know what the universe hides, how it's made and what are it's secrets. Indeed, according to Eden Phillpotts: "The Universe is full of magical objects that wait patiently for our ingenuity to better define themselves".

We have done…

We were welcomed into a conference room where Mr. Nicola Rossi explained the different parts of the laboratory and the tasks that were carried out. Then, Mr. Francesco Salamida introduced us to the physics of cosmic rays, starting from their discovery. In the final part of the morning, Mr. Attanasio Candela showed us an innovative device called the "Cosmic Rays Cube" capable of detecting muons, a fundamental component of cosmic rays. At the end of the conference, around 1:30 p.m., we enjoyed lunch at the canteen, kindly provided by INFN. After lunch, we boarded a shuttle that took us to the entrance of the laboratory, where we met the guide who showed us the three experimental rooms. In Room C, they explained how the Xenon experiment worked, and then we went to Room B, where we were very intrigued by the "Cuore" experiment. Later, they showed us the Roman lead, which is essential for the construction of the structure surrounding the Core experiment. Finally, we went to Room A, where they were building a new experiment called "Dark Side" related to dark matter.

We have found out…

After a Cosmic Rays Cube has been exploited to the rate of muons, a particular particle fast enough to be really thaugh to be observed by any kind of instrument, released when a cosmic ray interacts with the atmosphere, we decided to increase the inclination to discover what this would have implied. Comparing the results obtained we deduced that the frequency continuosly went down. This behaviour is explained by the fact that the thickness of the atmosphere lenghtens the distance travelled by the particles, making them decay before the cube could detect them.

Our take-home message…

Research is fundamental to progress. Nothing should be taken for granted, because we still know very little about our surroundings. Therefore, it is necessary to be curious and persistent in order to achive new discoveries.

ANGULAR DISTRIBUTION OF COSMIC RAYS

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– Tel 0803111707 - 0803106029 (fax0803113053 e-mail:bapc030002@istruzione.it; WEB www.liceocagnazzi.com
Principal: Claudio Crapis.

INFN Bari Group, Italy

Abstract

We are E.Marvulli, C.Zaccaria, C.Clemente and M.Cirrottola, students from Liceo Cagnazzi from Altamura (BA). During the International Cosmic Day (ICD) 2023, we went to the physic department of Bari to analyze cosmic rays.
Coordination: teachers MR.Cornacchia, A.Palasciano, ML.Forte

Experimental Setup

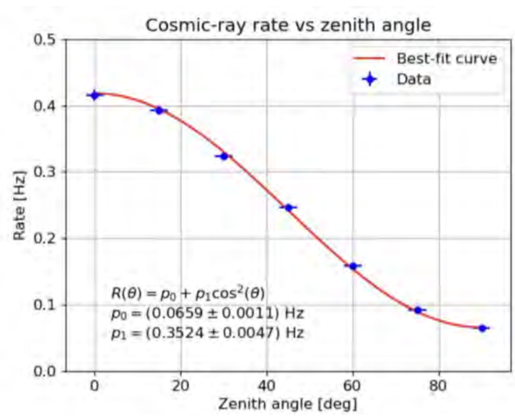
Using a detector, built by the department of physics in Bari, at different angulations we have found different results that show us how rate is influenced by the angle of incidence.
COSMIC-RAY TELESCOPE:
This item detects muons from cosmic rays and allows the evaluation of the angular distribution of their rate.
The experimental setup consists of these parts:
-MECHANICAL FRAME:
It allows the adjustment of both zenithal and azimutal angles to detect rays arriving from a specific direction;
-TWO PLASTIC SCINTILLATOR MODULS:
They consist of plastic scintillator tiles (SiPM);

-READOUT ELECTRONICS
It allows the comunicati0n between the board and the RasberryPi;
-A dedicated ELECTRONIC BOARD that allows you to read sensor signals and it returns a “digital” signal of coincidence that detects the passage of muons on both scintillators.

Analysis

The signals generated by the SiPMs (silicon photomultiplaiers) were visualized using an oscilloscope and thanks to a LED.

After an observation we constructed the graph of the arrival rate of the μ as a function of the angle. The relationship that exists between the rate and the angle with function cos²(θ)



The higher frequency is when 0°≤ θ ≤ 45°

Results

We had the opportunity to live this experience of scientific collaboration, with several students from the province of Bari and with the physicists of the department, that allowed us to understand better what cosmic rays are and to work in a team, improving our relational skills.
A special thanks to the INFN researchers who helped and guided us in this wonderful activity.

ANGULAR DISTRIBUTION OF COSMIC RAYS

INFN Bari Group, Italy

Abstract

During the ICD 2023, the INFN-Bari researchers let eight schools coming from the province of Bari collect cosmic ray using a new experimental setup (telescope) in order to study the muons angular distibution.

Experimental Setup

The experimental setup consists of three parts: two scintillator tiles, a mechanical structure and the readout electronics.

The mechanical structure consists in a frame that allows the adjustment of the cosmic rate angle (2 angles: zenithal and azimutal);

The two scintillator tiles, which consist of a lightening material, detect charged particles like muons. These are coupled to 2 SPM (Silicon PhotoMultiplier, 3mm*3mm) which collect the scintillation light and convert it in an amplified electrical signal.

The readout electronics consist in a printed board which implements the coincidence of analog signals, which is controlled by Raspberry Pi. This setup verifies that each sensor has reached a threshold (the four of them go over this threshold in the same moment, generating a logic signal “1”).

A transformer keeps the voltage stable to 42 volt.

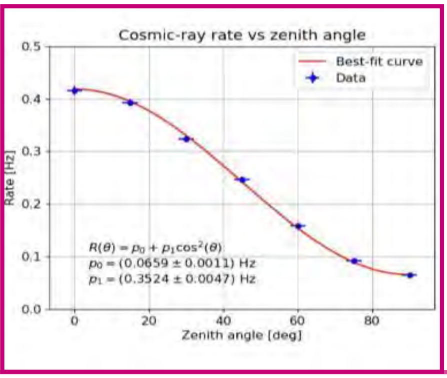
Analysis

We analysed the muon rate in function of the zenith angle. The expected distribution is:

$$R(\theta) = R(\theta; p_0, p_1) = p_0 + p_1 \times \cos^2(\theta)$$

Our aim is to extimate the value of p_0 and p_1 parameters. First, we should estimate p_0 by choosing the angle value of 90°. Then, we estimate p_1 when the cosine is equal to one.

Finally, using a Python code we find the best fit curve and calculate the exact values of the p_0 and p_1 parameters.



Results

Looking at the rate-angle graph, it can be seen that the measurements can be fitted with a $cos^2(\theta)$ curve. When the detection angle is higher, the rate of muons decreases. The rate increases along the vertical direction.

ANGULAR DISTRIBUTION OF COSMIC RAYS

Credit: DESY, Science Communication Lab

INFN Bari Group, Italy

Group description

Our groups were mixed as we were coming from eight different high schools. In the first part of the morning, Prof. Elisabetta Bissaldi gave us a lecture about cosmic rays, their effects on the atmosphere and the measurements that can be done concerning them (direct and indirect). Afterwards, we split into several working groups, in order to collect the data and analyze it. At the end, two students had the opportunity to show the results during the International DESY video call.

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. I.I.S. «Da Vinci-Agherbino» (Noci)
6. Liceo Scientifico «E. Amaldi» (Bitetto)
7. Liceo Scientifico «Salvemini» (Bari)
8. Liceo Scientifico «Scacchi» (Bari)
9. Liceo Scientifico «Federico II» (Altamura)
10. I.I.S.S. «Aldo Moro» (Margherita di Savoia)

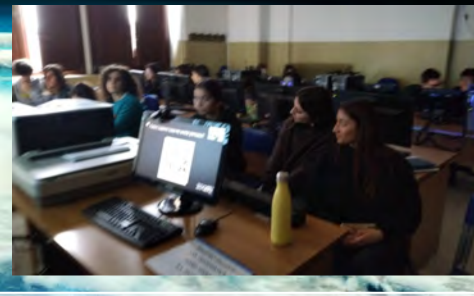
Group pictures

Liceo Scientifico « A. Scacchi» Bari

Chiara Benedetto
Giulio Capriati
Alessandro Di Monte
Andrea La Sorsa

INTERNATIONAL COSMIC DAY

Credit: DESY, Science Communication Lab



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INFN OCRA, Milano, Italy

Abstract

The third-year class, section B specializing in classical studies at the "Cagnazzi" Upper Secondary School Cagnazzi in Altamura, followed an online webcast, conducted by professor Caccianiga. The teachers that took part in this project are: Mrs. M.R. Cornacchia, Mrs. A.Palasciano and the headmaster Mr. C.Crapis.

Experimental Setup

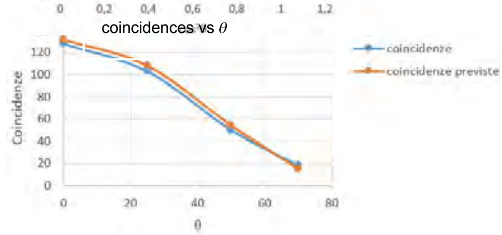
The conductor of the experiment, professor L. Caccianiga, showed the history of the cosmic rays discovery, its nature, the machines used to reveal them and the experimental equipment in research centers.
The webcast involved us through a series of questions, whose answers could be chosen between a few options.
For the study of cosmic rays, the particles that were found on the earth's surface are the MUONS.
The experimental equipment used is called cosmic Hunter made by three scintillators (kept in three black boxes) connected to a coincidence counter.

If the three scintillators record something at the same time, the number of recorded coincidences increases.
A qualitative analysis was made putting 3 scintillators next to each other:the coincidences number was low!
These are particles generated by the same swarm.
Next, the measurement was made by placing the three scintillators on top of each other and spaced by two books.
The experimental equipment was placed in different positions based on the vertical of the support surface .
The acquisition of the data lasted three minutes for each position .
The rate was measured in Hz, from the coincidence number (N),divided in 180 seconds.

Analysis

In the grid the results obtained:

coincidences N	θ	$\cos^2\theta$	$A=N/\cos^2\theta$	coincidenze previste
128	0	1	128	132,07
103	25	0,82	125,4	108,48
50	50	0,41	121,01	54,57
18	70	0,12	153,87	15,45
		media A	132,07	



The data obtained matches the results expected($Np=Am\cos^2\theta$).

Results

Taking on the role of physicists, this project proved to be very fascinating and increased our interest and our knowledge,especially in light of the fact that we had already worked with data analysis in the EEE project,prior to this event.

INFN OCRA
Outreach Cosmic Ray Activities

INFN PADOVA
Istituto Nazionale di Fisica Nucleare Sezione di Padova

Dipartimento di Fisica e Astronomia Galileo Galilei

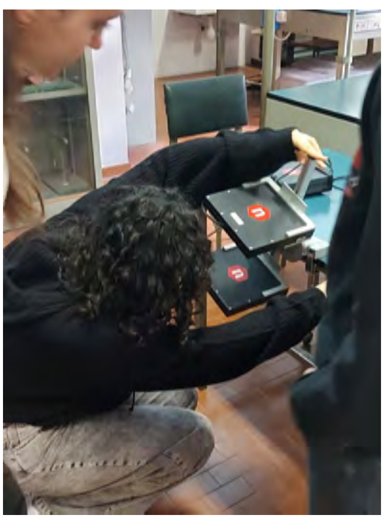
International Cosmic Day 2023

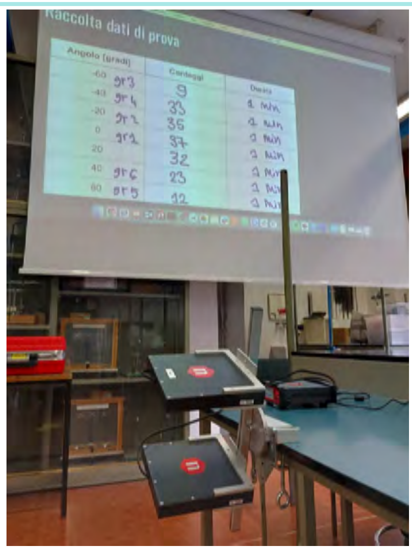
INFN Padova Division and Department of Physics and Astronomy, University of Padova, Italy

Who are you?

The International Cosmic Day 2023 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 30 students from 6 upper secondary schools: Licei Scientifici “Curiel”, “Fermi”, and Liceo Classico “Tito Livio” from Padova, Liceo Scientifico “Alberti” from Abano Terme, Liceo Scientifico “Newton-Pertini” from Camposampiero, and Liceo Scientifico “Rolando Da Piazzola” from Piazzola sul Brenta.





Credit: DESY, Science Communication Lab

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Cosmic Rays

I. I. S. Leon Battista Alberti, Abano Terme, Italy

Who are you?

Abadianni Riccardo, Casagrande Marco, Celadin Emma, Finco Francesca, Salmaso Tancredi

What have you done?

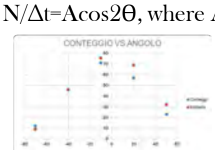
The first day, we attended a theorical lesson where we discovered what cosmic rays are, we talked about their effects and aspects. Then, we took part of a zoom meeting with the observatory MAGIC located on the Canary Islands. The second day we did an experiment with the cosmic rays.

OBJECTIVE: to estimate the dependence of the cosmic rays' rate on the angle of incidence.

TOOLS AND EQUIPMENTS: muon telescope, timer (±0,01s)

EXPERIENCE DEVELOPMENT: Initially, set the angle of incidence of the muon telescope, then start the muon telescope as soon as the timer starts (there is a human reaction error of ±0,2s). Wait until the timer (120s) is done and stop the muon telescope (there is a human reaction error of ±0,2s). After that, write down the data on table, analyse them, compare them to the standard model (=cos^2(α)*78) and make a graph.

COMMENTS: the experiment is successful, all the values are acceptable, except for the 20°C value which is out of the error allowed. The graph of the distribution of the data is shown to be compatible with the theoretical model, according to the law: $N/\Delta t = A\cos 2\Theta$, where A is the normalization constant.



What did you find out?

- What is a cosmic ray: They are super energetic atomic/subatomic particles that travel through space at an high speed, and sometimes hit Earth too. These particles are mainly protons but there are also: helium nuclei, electrons, ganma rays, nuetrinos and muons.
- How cosmic rays are observed: Cosmic rays are observed through the effects they produce (ionization or Cherenkov radiation); but we don't observe the primary cosmic ray particle (for that we need to be in outer space), instead we see the effects that the secondary particles produce inside the atmosphere.
- Where cosmic rays come from: Cosmic rays that we measure on Earth can be divided into 3 classes, depending on the energy that they're carryng. These 3 classes also defines the origin of these particles: 1° class are the low energy particles form the Sun; 2°class are medium energy particles from our galaxy (supernova remnants); and the 3° class are high energy particles from other galaxies (black holes).
- What particles reaches ground level of the Earth: Only two types of particles can reach the surface level of the Earth, and these are: muons, elemental particles that can be seen as heavy electrons; and neutrinos, a subatomic particle characterized by the fact that it rarely interacts with matter. The other type of particles tends to be reabsorbed by the atmosphere.
- How the rate of muons arriving on earth changes: Through the practical way we discovered that the rate of muons (ratio between the muons measured in a frame of time, and the time interval) changes with the angle of measure. We clearly saw that the highest rate observed was measured when we were looking upwards with a right angle. This rate can also change depending on other circumstances, but we did not focus on that.
- How analyze the data collected: The information collected was then analyze, by comparing the measured rates, at different angles, with the ideal rates that we expected (calculated with an equation). Then we used Excel to produce some table to present, with their respected graph, showing if the rate measured coincided with the rate obtained with the equation, considering the error related to the measurement.

What's your take-home message?

Before this experience most of us had no idea what cosmic rays were. It's incredible to think that these particles arrive from the most remote corners of the universe. It was very nice to measure these cosmic rays and compare all the measurements. We met new people and learned new things. This experience was very beautiful and interesting.

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Credit: DESY, Science Communication Lab

Cosmic Rays

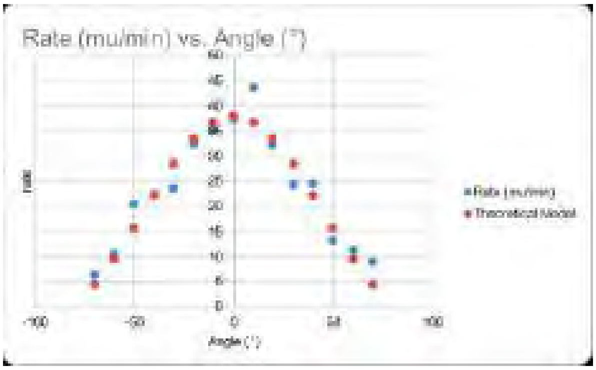
Liceo Scientifico Eugenio Curiel, Padova, Italy

Who are you?

Lyceum Curiel Padua, Italy

What have you done?

We have learnt from these two days some knowldge about particles from space. There were some introduction lessons that explained what are these particles and where they come from. Then we did an experiment to calculate the number of particles presented on the laboratory thanks to the muon detector, in this case we collected the data in a period of times by changing the angles of inclination. We did a graphic and discussed it with other schools.



What did you find out?

Cosmic rays are atomic or subatomic particles that arrive on earth. They consist mainly of protons, but also of helium nuclei, electrons or gamma rays. This flow of cosmic rays is directed towards the earth, and their path depends on their mass and their electric charge. Only some cosmic rays manage to pass through the atmosphere and, after they are absorbed, generate secondary particles. Cosmic rays can be observed via ionizationthe: charged particles that move in a medium they strip electrons from atoms of the material. But they can also be observed via Cherenkov radiation: particles that they move at a speed greater than that of light in the medium and emit a light signal. We can use the production of cosmic rays secondary and study its interaction with the material.

What's your take-home message?

Studying cosmic rays helps us learn more about how things work in space. It shows that we need fancy tools and teamwork with people around the world to explore what we don't know. This kind of research is really important because it not only gives us answers but also makes us ask more questions, pushing the limits of what we know.

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Credit: DESY, Science Communication Lab

Cosmic Rays

Liceo Fermi Italy, Padova

Who are you?

Our names are Gallo Sofia, Pajaro Lidia, Fogliano Gabriele, Gastaldello Lisa and Dugo Francesco. We are 5 male and female students of the Enrico Fermi High School of Science who, out of personal passion and interest, have chosen to investigate an interesting aspect of modern physics: cosmic rays.

What have you done?

Our project was to estimate the dependence of the number of muons arriving at a certain surface in a limited period of time with the angle of incidence.

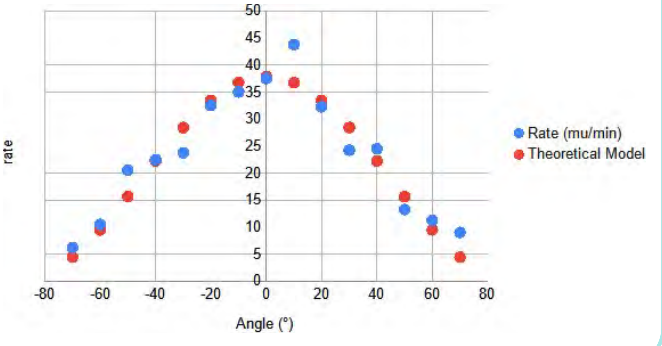
To do this, we used a muon telescope consisting of:

- two scintillators
- a lead plate
- acquisition system
- mount capable of rotating the telescope

We made measurements of the muons and then compared them with those of the other groups; finally, we analyzed the data, through the creation of graphs and tables.

What did you find out?

The number of muons depends on the direction in which you look since perpendicular to the Earth's surface the space traveled by muons is less than the space traveled by muons in any other direction



What's your take-home message?

This experience allowed us to enter what is the world of modern-day physics. We had the opportunity not only to see and use professional instrumentation to carry out concrete experiments, but in doing so we were joined by experts in the field. In doing so, we were able to hear their stories and experiences of working and student life, which further brought them closer to what our world is all about. In general, what passed most is the spirit of cooperation between universities and schools and their respective students, all working side by side with the same goal.

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Cosmic Rays

IIS Newton - Pertini (Camposampiero),Italy

Who are you?

Alessandro Talon, Alice Piatto, Nirash Tissera, Roberto Kola, , Giulia Bevilacqua. IIS Newton - Pertini (Camposampiero).

What have you done?

During this experience, with the help of a two-plate telescope, we detected the amount of muons reaching the ground during a period of 2 minutes. The experience was repeated for angles from -70° to +70°, every 10 degrees. We started the chronometer and the telescope measuring system at the same time, and after 2 minutes, the number obtained is reported in the table. The measurements were repeated 2 times for each angle. The detection system consist of: a plastic scintillator, a photodetector and a small front-end electronic board. Charged particles passing through the telescope scatter energy within the scintillators by ionization, producing a light signal. The light produced by the scintillator is converted into an electrical signal through a photosensor. The information is processed and the number of coincidence signals is shown.

What did you find out?

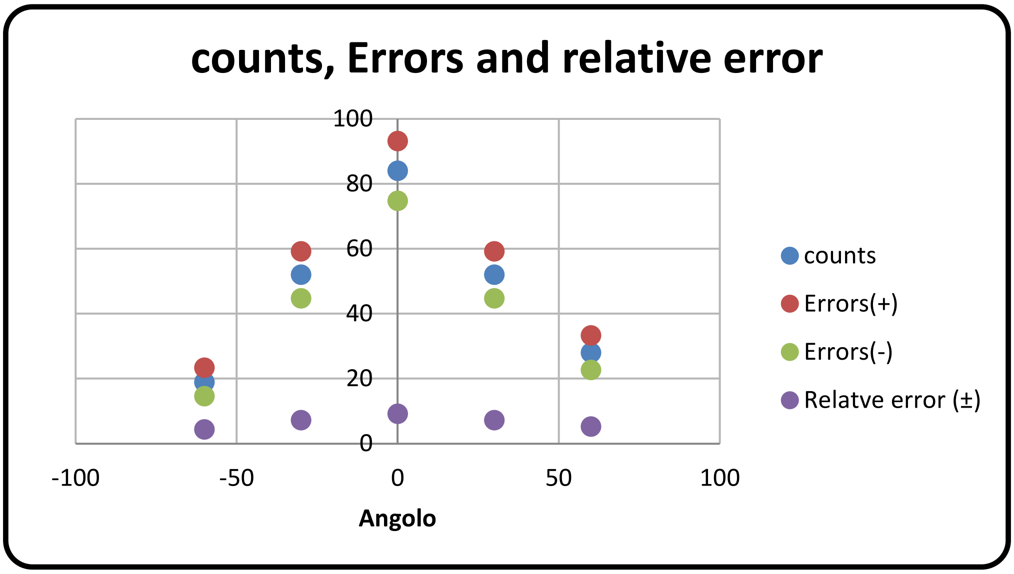
By analyzing the collected data, we concluded that the number of muons reaching the ground is greater when the telescope is perfectly vertical and the number of particles decreases proportionally to the inclination one gives the telescope. Visualizing the collected data in a diagram, we see that the curve represented can be traced back to the A(cos^2(x)) curve where A is a normalizing constant. In the graph obtained, one must also take into account the error in the data-taking step, which can be traced back to a time factor or to the number of muons that have passed through the microscope plates.

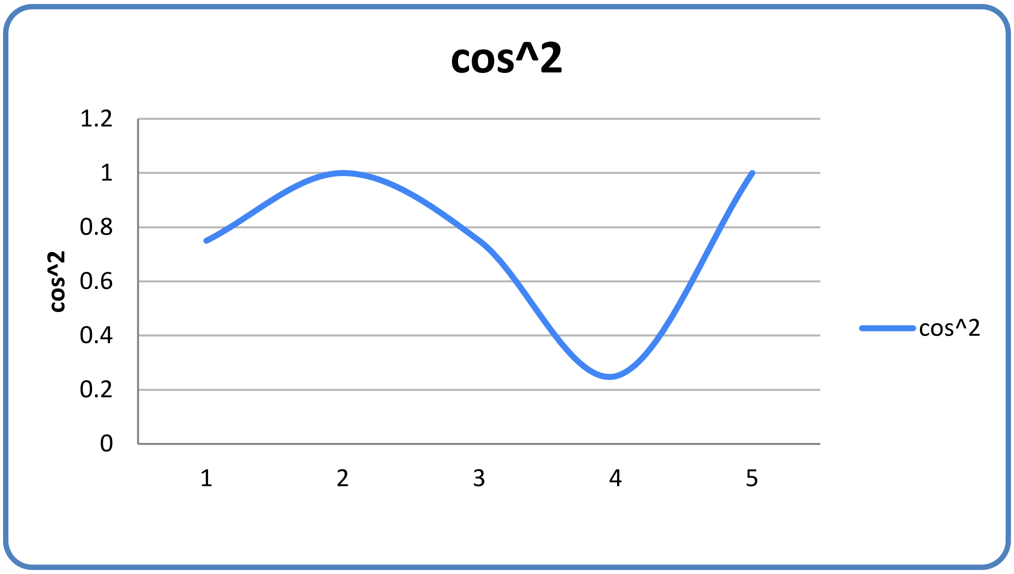
What's your take-home message?

This experience taught us a lot and opened our minds for different possibilities that we could undertake in the future. Our favorite part was during the second lecture where we experienced and analyzed through numbers and charts what cosmic rays really are.

IIS Newton - Pertini (Camposampiero),Italy

Charts made through our groups' analysis





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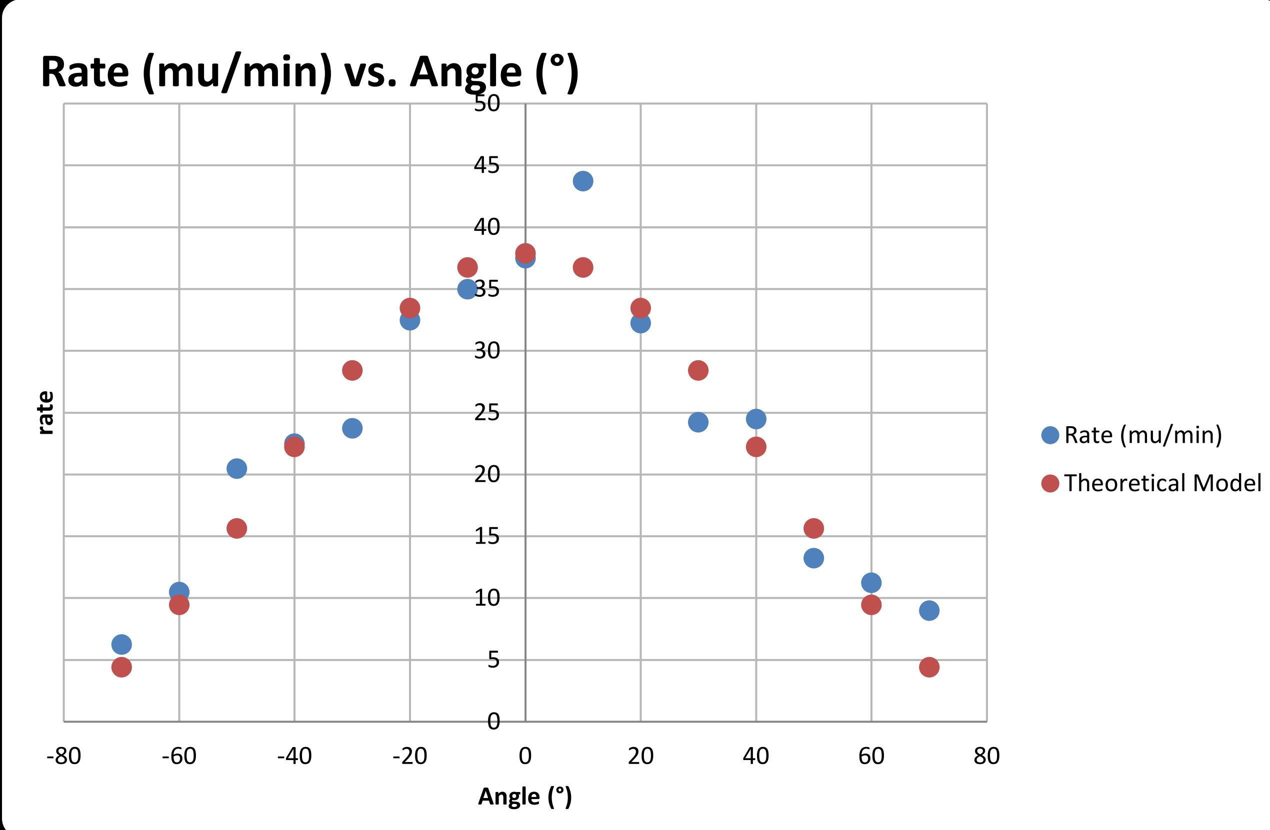
IIS Newton - Pertini (Camposampiero),Italy

Final results obtained through everyone's research



IIS Newton - Pertini (Camposampiero),Italy

Some photographs of the telescope used:

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International Cosmic Day

Rolando da Piazzola, Padova, Italy

Who are you?

Gioele Milan, Lorenzo Morbin, Irene Ceccato, Elena Betto, Francesco Bettella

What have you done?

1. We have measured the muon flux with the scintillator at different angles for 2 minutes each;
2. We reported the data obtained in an excel graph and in an excel tab.

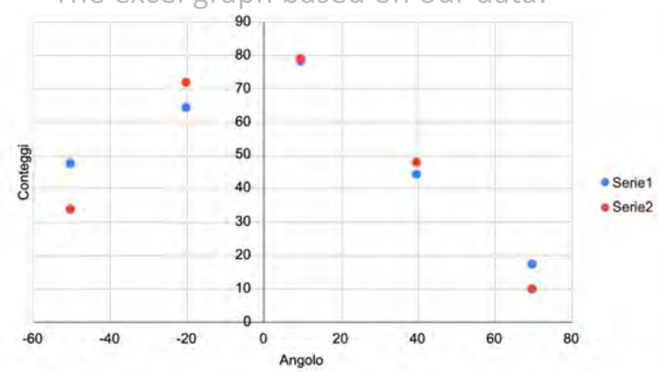
The excel tab with our data:

Angolo	Conteggi	Errore	Errore relativo	Rate
-50	47	6,8556546	0,145864991	33,4672488
-20	64	8	0,125	71,52479995
10	78	8,831760866	0,113227703	78,55755114
40	44	6,633249581	0,150755672	47,5327512
70	17	4,123105626	0,242535625	9,475200054

A	numero di interpretazione
81	81,35267578

What did you find out?

The excel graph based on our data:



We found out the muon flux varies according to the angles in which we pointed the scintillator. The highest flux value was measured by aiming at the zenith, because the path through the atmosphere is shorter.

We also found out the muon's number is given by the formula

$$N = A\cos^2\theta$$

What's your take-home message?

We learned a lot of informations about the cosmic rays such as what they are, how to study them and why we study them. We had the opportunity to do some experiments that allowed us to improve our teamwork skills in a new work place.

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

International Cosmic Day

Classical Highschool “Tito Livio”, Padova, Italy

Who are you?

We are Nicolò Buscema, Zeno Maria Fracanzani, Leonardo Gullo, Irene Pennelli and Matilde Trolese. We are students of the italian classical highschool “Tito Livio”, situated in Padua, Italy.

What have you done?

We have been given the opportunity to participate at the International Cosmic Day through the organisation of the I.N.F.N (National Institute of Nuclear Physichs). On the day of the event, 11/21/2023, after receiving the necessary informations related to cosmic rays, we got the chance to work with a professional and industrial particle detector which was able to detect the flow of a particular particle: the muon. Then we have been asked to organize the data we collected and compare them with those of other groups. Finally we were able to enter an online meeting and listen to the results of the research operated by differents groups all over the world.

What did you find out?

We found out that the flow of muons is much higher and more dense, the more the particle detector is oriented perpendicularly to the ground.
We also learnt that the majority of cosmic rays originates from the death of stars located outside our galaxy and that only a minor part has its source in the Sun; that the path which this rays follow can be modified by the presence of electromagnetic fields; that they are composode mainly by protons, but also by electrons, muons and neutrinos; that there are various types of instrument and methods utilized to detect the flow of these subatomic particles; and much more.

What's your take-home message?

Thanks to this experience we can consider ourselves pretty well informed about the general traits natural phenomen, the cosmic ray, such as its origin, the hystory of its studies, its composition and the peculiar behavior of some of the particles that it is made of.

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

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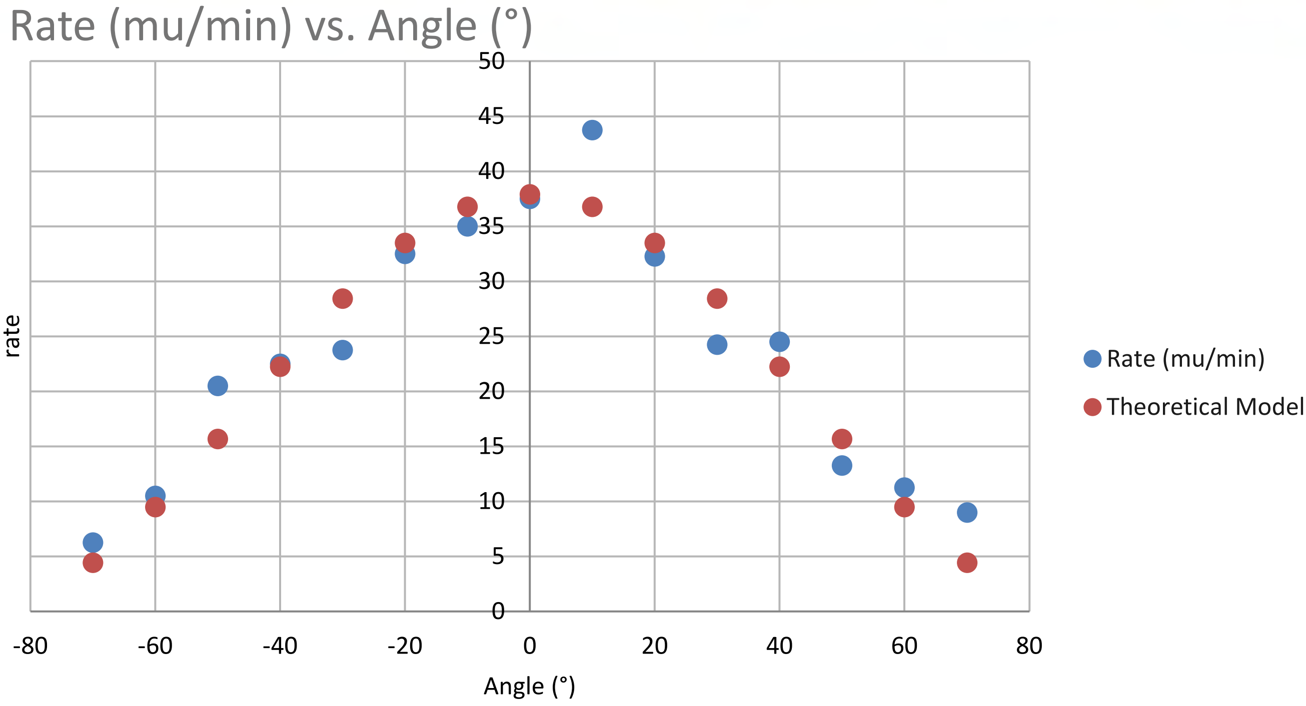
Credit: DESY, Science Communication Lab

International Cosmic Day

Classical Highschool "Tito Livio", Padova, Italy



ANGULAR DISTRIBUTION OF COSMIC RAYS

Credit: DESY, Science Communication Lab

INFN Bari Group, Italy

Who are you?

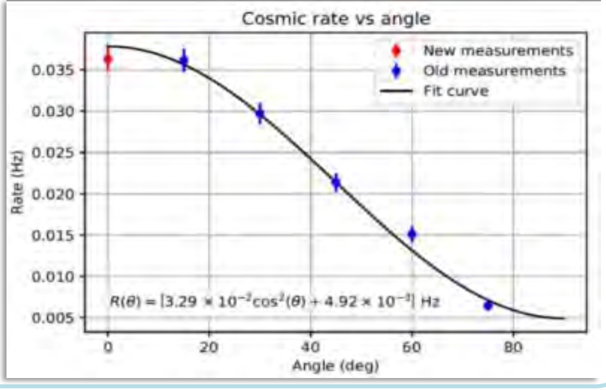
We are a group of students from IISS "Aldo Moro", Margherita di Savoia. This is for us the second year that we had the opportunity to attend this project.

What have you done?

A part of the group stayed at school and attended conference with the INFN that talked to us about cosmic rays, i.e. energetic particles coming from outer space. Also important is the coincidence module together with its three detectors that measure a particle (or noise) and tell us if they have measured something at the same time. It has been observed that the higher the detector rises in our atmosphere, the more the number of particles detected rises to a plateau. Then we learned how the underground laboratories that detect particles work (in Canada, Japan and Italy). We have seen the origin of cosmic rays and their division in contact with the atmosphere, creating cosmic swarms. It has been noted that changing the position or inclination of the detectors also changes the possibility of having coincidences based on the greater or lesser possibility that a subdivision of a cosmic ray passes through all three detectors or more subdivisions touch them at the same time. A type of cosmic ray with lower energy was studied in depth: the solar wind, partially deflected by the Earth's atmosphere, because the part of the solar wind that is not deflected is called polar aurora (since it is visible above all at the poles of the earth).

What did you find out?

The group of 4 students that attended to the workshop at the University Bari studied the frequency of events in an interval of time trough "Catafalchino", a machine that detected data. The detector give us text documents composed by three columns showing the number of events, the time of acquisition and the time difference between measurements. Processing data in a python script we obtained the plot of the cosmic rays rate as a function of the Zenith angle. (As shown in the figure) We fit experimental points with the function, so we get the values. We repeat the analysis considering the presence of the dead time (0,25 s) we get a new curve with… that shows a greater rate than the one rated.



What's your take-home message?

Doing this experience for 2 years brought to our school a new thought process: things around us are never like they look from the outside. We have done new experiments this year with a new machine that is more modern, smaller and way more efficient compared to the one used the year prior. If someone is interested and likes this part of physic, we suggest to participate to these kind of events.

Credit: DESY, Science Communication Lab

Discovering cosmic rays!

Omnicomprensivo Bertrando Spaventa Institute, in Abruzz

Who are you?

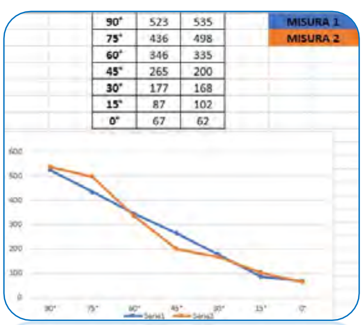
We are 6 students of the Bertrando Spaventa institute of Città Sant'Angelo of the applied sciences course and during the day of November 21st on the occasion of the Cosmic Day we had the opportunity to visit the national laboratories of Gran Sasso (both the surface headquarters than the underground one). During the visit we listened to interesting lessons on particle physics given by two physicists and an engineer, visited the underground laboratory and observed a curious experiment focused on the study of cosmic rays...

What have you done?

Us students, had the opportunity to experience the world of particle physics through a small-scale experiment which involved the detection of cosmic rays through a special instrument: the Telescope.

This type of telescope is completely different from the model we commonly know, it is in fact a box and inside of it there are 4 levels equipped with detectors which, if crossed by particles (in this case muons, which are the most penetrating ones) convert them into energy, then into light signals and then into an electrical signals.

The experiment consisted of collecting data, registered in a table, which reported the number of interactions every 300 seconds (5 minutes) that the telescope recorded with different degrees of inclination (15°,30°,45°,60°, 75 °, 90°).



What did you find out?

90°	523	535
75°	436	498
60°	346	335
45°	265	200
30°	177	168
15°	87	102
0°	67	62

Once the table was filled in, it was noted that as the degree of inclination of the cosmic ray detector increased, the number of events recorded decreased drastically, this is because not only does the muon have to travel further to reach the surface of the detection device, but also because of the decay time to which muons are subject. This process is explained through the application of Einstein's laws of relativity, which in this case replace those of classical kinematic as muons are truly particular particles, whose speed is close to the speed of light.

What's your take-home message?

We brought back home a lot from this wonderful experience, not only through the visit in the underground laboratory, but also through this experiment which made us notice how many interactions there are during our daily life between us and these curious particles, which we do not notice unless using instruments designed for their specific detection. We have therefore verified Einstein's principle of relativity of which this experiment gives us direct confirmation and we have discovered how beta decay works. It was a day full of discoveries and innovations that can only be acquired here at the Gran Sasso laboratory.

International Cosmic Day 2023
INFN Catania

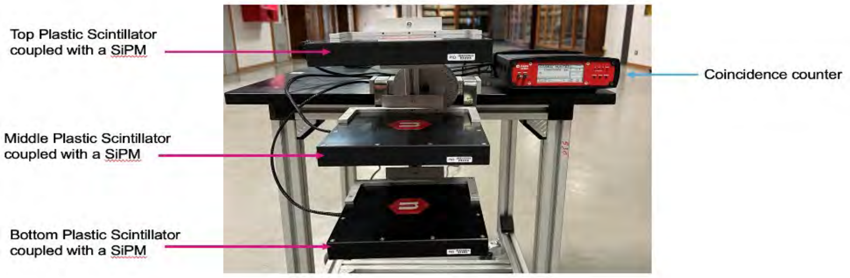
I.T. ARCHIMEDE, Catania, Italy

Who are you?

We are students from “I.T. ARCHIMEDE”, a technical institute in Catania, Sicily (Italy).
Different sectors of our school have participated: computer science, telecommunication, electronics and automation.

What have you done?

We have started with a presentation by Prof. A. Insolia about Astroparticle Physics to explain the cosmic rays in great detail.
These particular rays are charged particles from space. They are mainly composed of protons and helium nuclei. During his presentation, prof Insolia showed possible sources of cosmic rays such as SuperNova remnants and AGN. The interaction between cosmic rays and the atmosphere produces the secondary cosmic rays. The study of cosmic rays sources is very difficult because the direction of these rays changes during their path. Still, despite this, we can measure these indirectly, through the Extensive Air Shower they generate.
Cosmic rays are studied for several reasons: for example, these rays, with their interactions, could give information about the cosmic environment and eventually, it would be possible to learn about the violations of Einstein’s relativity theory.
In the second part of the day, we had a laboratory experience: it was based on the measurement of the muon flux as a function of the inclination angles.



We have used three different layers so that we can get very precise data and understand if the signal is generated by a muon.

International Cosmic Day 2023

I.T. ARCHIMEDE, Catania, Italy

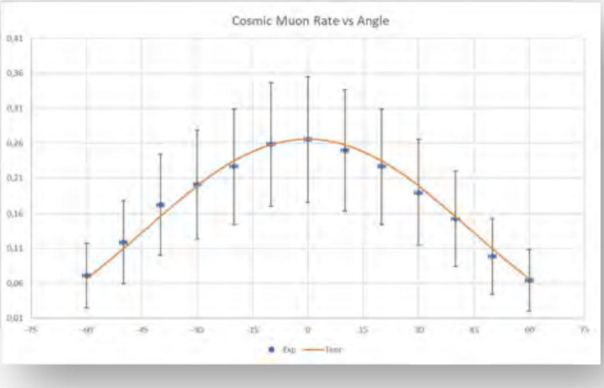
What did you find out?

We have done different measurements of cosmic rays, each of them 300 s long, by moving the inclination angle.
Then, we compared the experimental data with the theoretical prediction.

Angolo (gradi)	Conteggi	tempo (s)
-60	21	300
-50	36	300
-40	52	300
-30	60	300
-20	68	300
-10	78	300
0	80	300
10	75	300
20	68	300
30	57	300
40	46	300
50	30	300
60	19	300

$$R(\theta) = R(\theta = 0)cos^2\theta$$

R rate
θ zenith angle
Data normalized at θ = 0



What's your take-home message?

The message we carry in our minds after this day is the importance of knowing our world and always having the courage to accept the evolution of scientific knowledge.

ITIS Galileo Galilei Arezzo

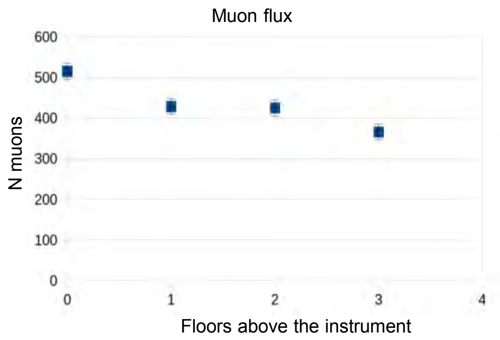
Who are you?

Baldi Gabriele, Donati Tommaso, Duranti Filippo, Fiumi Nicola, Grosu Bogdan Daniel, Piccinotti Niccolò of the 4ABA-5ABA of ITIS Galileo Galilei

What have you done?

We have done measures of muon flux with cosmocube (it is an instrument to detect muons) at different floors of a building. We observed the effect of a lead cage around the detector and we measured muon flux outside.

What did you find out?



This graphic represents the muon rate in function of the number of floors over the instrument. The number of floors changes significantly the rate.

What's your take-home message?

It was an experience that has allowed us to know different realities, in particular research institutions who work in this field and to meet other students interested.

Credit: DESY, Science Communication Lab

The fascinating world of cosmic rays

Liceo Scientifico "A.Einstein", Teramo, Italia

Who are you?

We are Bassetti Riccardo, Colmenares Camilo, Di Massimo Ilenia, Lamoratta Paolo, Moriconi Maria Vittoria, Scaramuzzi Chiara, Valerii Cesare. We are seven students interested in the world of physics, who visited the Gran Sasso National Laboratory, to broaden our knowledge on this matter.

What have you done?

On November 21st 2023,for the International Cosmic Day, we went to L'Aquila to visit the LNGS, administered by INFN. In the morning we listened to a lesson about what are the cosmic rays, the neutrinos and the dark matter and what is the main task of the LNGS, which is to host experiments that need a low radioactive background. This is why the laboratories are built underground. We visited them, after the initial lesson, accompanied by researchers. We saw the four main experiments of LNGS: "CUORE", "LUNA", "BOREXINO" and "XENON1T". We were amazed by the complexity of these projects, but also by the incredible size of the structures required by the experiments.

What did you find out?

After that, we were introduced to the Cosmic Ray Cube (CRC). The CRC is a detector able to recognise the muons, the most penetrating component of secondary cosmic rays. The muon is a particle that has the same electric charge as the electron, but it is about 200 times heavier and has a very short average life time. So by using the software developed by the LNGS and the app Cosmic Rays Live, we took the measurements of how many muons were detected by the CRC in five minutes at different angles and we found out that by increasing the angle more muons were captured by the CRC.

What's your take-home message?

After this experience we discovered aspects of physics which are not known by the majority of the population. This made us reflect about how wide is the universe and increased our curiosity about it. We learnt that to be a researcher you must be very patient if you want to get some results. This is what we bring back home.

El Mago del Tiempo, the Time Wizard

Scientific High School "Lorenzo Respighi", Italy

Who are you?

We are the 1^B class and a group of students from the third, fourth, and fifth years of the high school L. Respighi in Piacenza. We share the passion for STEAM disciplines, with a particular focus on Astrophysics and together we joined an AstroHackathon.

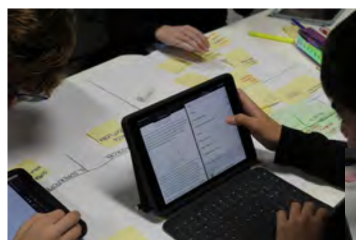
What have you done?

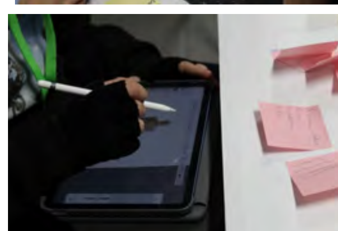
On the morning of November 21, 2023, we participated in the "AstroHackathon" event organized by our school, on the occasion of the ICD.

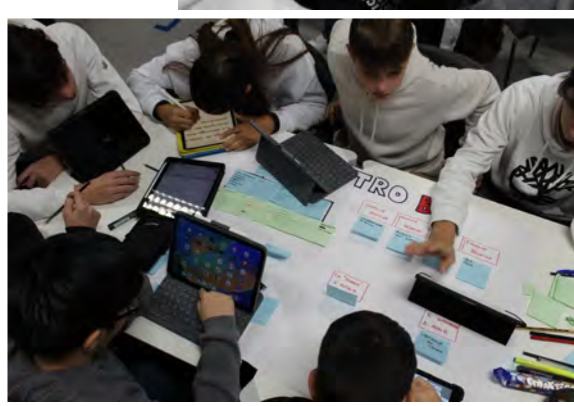
The day's activities were structured in 3 phases: introduction, training, and contest. Initially, we attended an introductory seminar on cosmic radiation, after which we prepared for the Hackathon with a training session inspired by the movie "Fantastic 4" (2005), which we had already watched. In the second phase, we divided into 4 groups, with the goal of analyzing one of the Fantastic 4 (character, superpower, and cosmic particle responsible for the superpower). In the third phase, the four teams competed in the actual contest during which we built our superhero: the graphical representation, the character description, the identification of the superpower, and the cosmic particle associated with it.

At the end of the day, a high-profile jury determined the winner of the contest.

Some pics of the day







El Mago del Tiempo, the Time Wizard

Scientific High School "Lorenzo Respighi", Italy

You introduce yourself

We were divided into 4 teams, led by older students who served as tutors, and each member had a designated role: writer, designer, scientist. The target was to invent a student endowed with a superpower acquired through interaction with cosmic rays and to identify the specific cosmic particle responsible.

The Muon… relativistic or not?

This picture is created by Lorenzo Pozzi, Martina Rocca and Noemi Scarico

According to classical physics, the muon takes 5.05 × 10^(-5) seconds to cross the atmosphere, a time period exceeding its average lifespan. Nevertheless, we are still able to detect muons on the Earth's surface; this is because, while traveling at a speed close to that of light, they experience time dilation, as predicted by modern physic.

El Mago del Tiempo

This picture is created by Lorenzo Pozzi

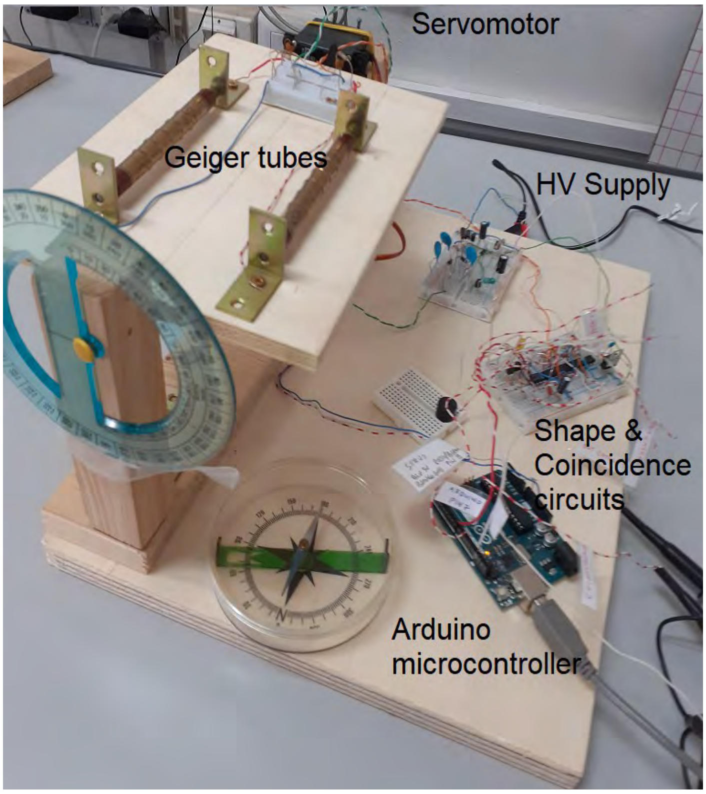
The superpower of the Time Wizard is the ability to control the flow of time. Just like the muon that moves at 99.9% of the speed of light, this superpower allows the student to slow down time around themselves and thus postpone the deadline for tasks when they need "more time."

What's your take-home message?

Thanks to this activity, we approached cosmic rays and became acquainted with astroparticles. Additionally, we gained insights into some new frontiers of research and European centers of excellence. It was an opportunity to work as a team and strengthen the bonds among us.

Introduction
Our Institute is a high secondary school (Scientific Lyceum “Lorenzo Mossa”) with around 1000 students located in Olbia, a town of around 60,000 inhabitants in the north of Sardinia, an insular region of Italy in the western Mediterranean Sea.
We are an interclass group (15-17 years old) of 8 students interested in scientific topics.

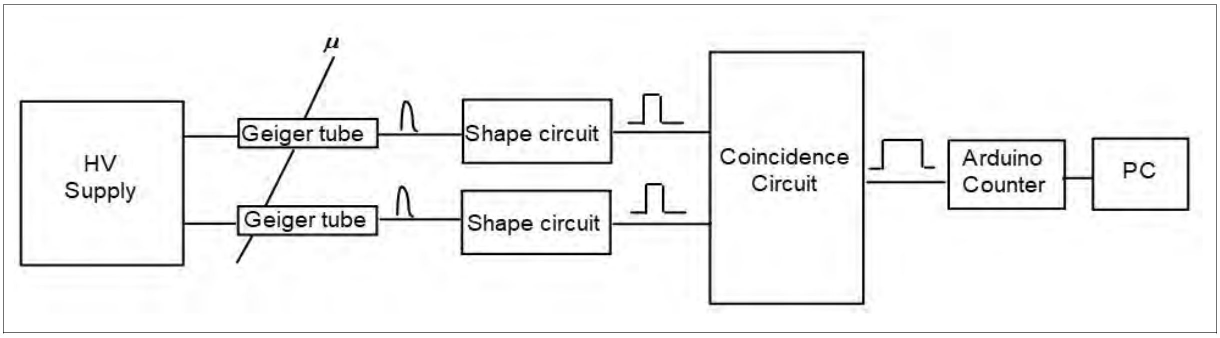
Experimental Set-up



We used a home-built detector (muon telescope), already used last year, consisting of two SBM-20 Geiger tubes placed on a rotating tablet using a servomotor controlled by a PC via the Arduino microcontroller. The measurements can be carried out remotely by controlling the PC with the Teamviewer software.

The signals from the two tubes are sent to some shape circuits and a coincidence circuit. When there is a coicidence a LED flashes and a buzzer beeps. The coincidence signals are counted by Arduino.

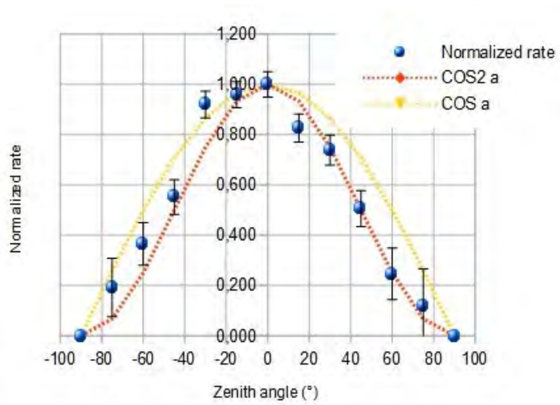
We addressed some questions regarding cosmic rays: a) the origin of secondary cosmic rays and how to detect them with a muon telescope using the coincidence technique; b) their angular distribution with respect to the zenith; c) the interaction of charged particles with the magnetic field and how they are deflected d) the East-West asymmetry of the cosmic ray flux.



Report of our results

Rate measurements were carried out at different zenith angles, each lasting 24 hours. From each value we subtracted the flux measured for an angle of 90° which corresponds to the random coincidences between the two Geiger tubes. Finally we normalized the data with respect to the maximum value obtained at 0°.

Rate 24 h (raw data)	Rate with subtracted background	Relative error √N/N	Zenith angle α	Normalized rate	COS^2 α	COS α
			-90	0,000	0,000	0,000
360	74	0,12	-75	0,192	0,067	0,259
427	141	0,08	-60	0,365	0,250	0,500
499	213	0,07	-45	0,552	0,500	0,707
641	355	0,05	-30	0,920	0,750	0,866
656	370	0,05	-15	0,959	0,933	0,966
672	386	0,05	0	1,000	1,000	1,000
605	319	0,06	15	0,826	0,933	0,966
571	285	0,06	30	0,738	0,750	0,866
481	195	0,07	45	0,505	0,500	0,707
381	95	0,10	60	0,246	0,250	0,500
332	46	0,15	75	0,119	0,067	0,259
286	0		90	0,000	0,000	0,000



The rate distribution with respect to the zenith angle follows the typical bell shape, due to the fact that thickness of atmosphere increases with low values of zenith angle, therefore the flux of muons at the earth's surface decreases.

The data fit well with curve $\cos^2\alpha$ rather then $\cos\alpha$ as theory predicts.

Data on the graph show a slight difference in the number of counts in 24 hours between West (negative angles) and East (positive angles), this could be an evidence of the East-West asimmetry in agreement with the fact that most cosmic rays are positive particles. Error bars are the square root of counts over counts, $\sqrt{N}/N$ according to a Poissonian distribution.

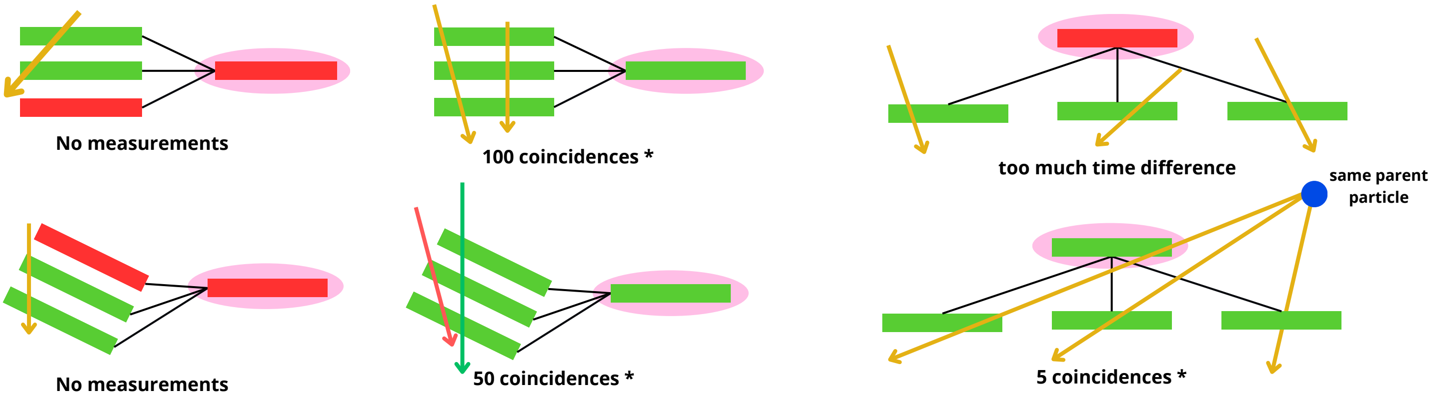
Liceo Scientifico “Da Vinci” - Gallarate (VA)

Leonardo Cutrì - 5A LSA

Who are you?

My name is Leonardo Cutrì and I am a fifth grade student at the "Leonardo da Vinci" high school in Gallarate, Varese. My class enthusiastically participated in the conference organized by the INFN in Milan. The objective was to learn in depth about cosmic rays and how they appear in various areas of the universe.

In the first part of the lesson we saw how detectors and the coincidence meter work. In particular we have seen how the measurement varies based on the mutual position of the detectors.

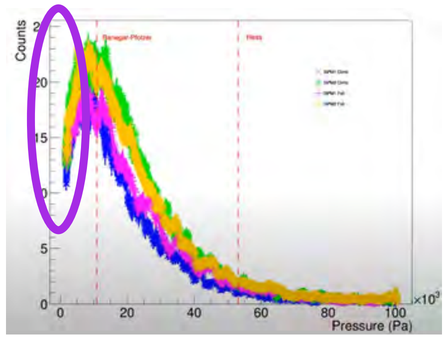


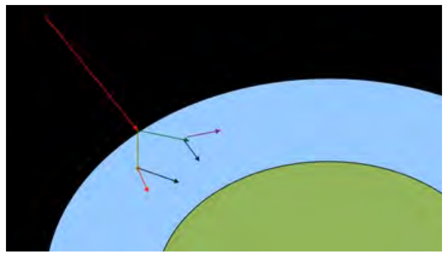
(*) Carried out in the same period of time, we will have more measurements for the detectors arranged in column.

How cosmic rays were discovered?

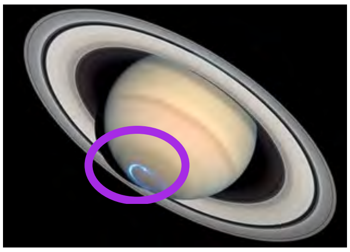
Victor Hess, on board a hot air balloon, found, through data analysis, that cosmic rays come from outside the Earth because no decreases occurred during the ascent. Furthermore, they did not come from the sun because he tried to take measurements during an eclipse or at night and saw that the values did not vary.

Actually, the rays we measure do not come directly from space because they are blocked by the atmosphere. The primary cosmic ray, impacting the atmosphere, splits into many secondary cosmic rays, these are the rays that we, and Hess, measure. This also explains why beyond a certain altitude the number of secondary rays decreases (as seen in the graph).



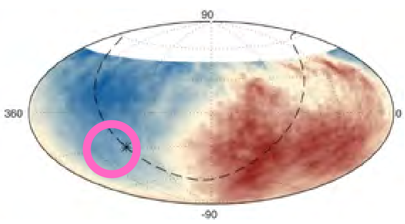


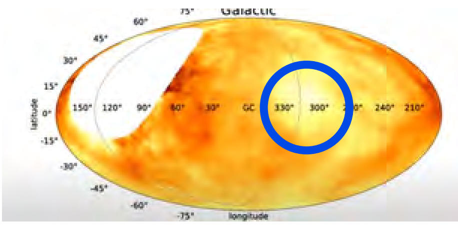
Next we talked about the Northern/Southern Lights and how they are also present on other planets in the solar system! These are caused by the collision between charged electric particles coming from the Sun (the solar wind) and the atmosphere of the various planets or by the presence of a magnetic field. The color is determined by the gas the particles come into contact with.



Jupiter's Northern Lights are not visible to the human eye, but are in the ultraviolet range!

To reach the Earth with sufficient speed, the particles must be accelerated and this occurs thanks to very strong magnetic fields on a small scale or weak magnetic fields on a very large scale. From the graphs below we can see that cosmic rays do not arrive from **our galaxy**. One hypothesis is that they come from the **Centaurus A** galaxy, one of the most active, with **two lobes** formed by plasma that generate a strong magnetic field.





What's your take-home message?

My take-home message is that we are surrounded by invisible particles even though we don't realize it. I understood where these come from and how they are measured and studied in my country too. It will be interesting to know, individually, what effects these cause on our body and what measures we can take to ensure that these are not harmful to our health.

EEEs and Auroras

Liceo TCO, Fermo

Who are you?

Adriano Basso and Andrei Massaroni, students of liceo TCO, Fermo, 5th year. Supervised by Mrs. Maria Rita Felici.

What have you done?

We led a research about the interaction of cosmic rays and geomagnetic storms(the solar events that generate auroras). The idea behind the project was born on November 5th, due to a strong geomagnetic storm (G3) that made auroral lights visible at Italian latitudes (43 N in our case). After the wonderful view, many questions were generated: the research team was already familiar with cosmic rays(check the previous booklets), so the question with the interaction of them with events like magnetic storms was totally natural, so that's what generated this research.

What did you find out?

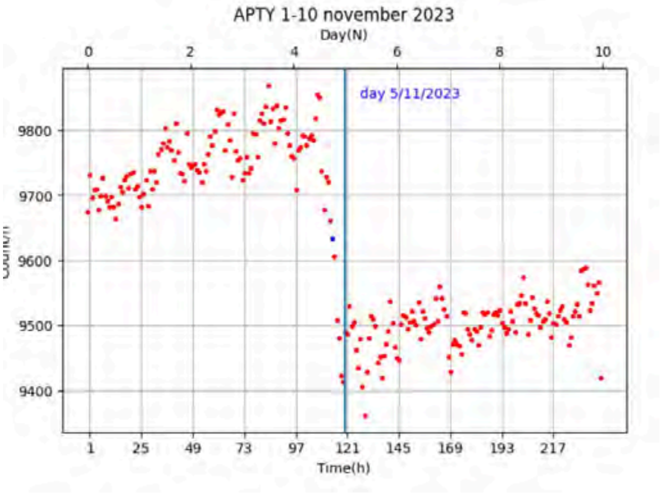
We learnt about the Forbush Effect and we confirmed it through the observation of neutron monitors(nm); old but stable machinery that measures cosmic rays since the 50s. We chose a set of nm, variating in latitude and altitude, and then plotted the data in sets of 1 hr each from the 1st of Nov. to the 10th. We used python to plot the data and we also marked with a line the day of the event. The plots show a neat decrease near the happening of the event (the picture that follows was taken Nov. 5th 17:13 UTC), confirming the theory behind Forbush Effect. We are happy with the results!

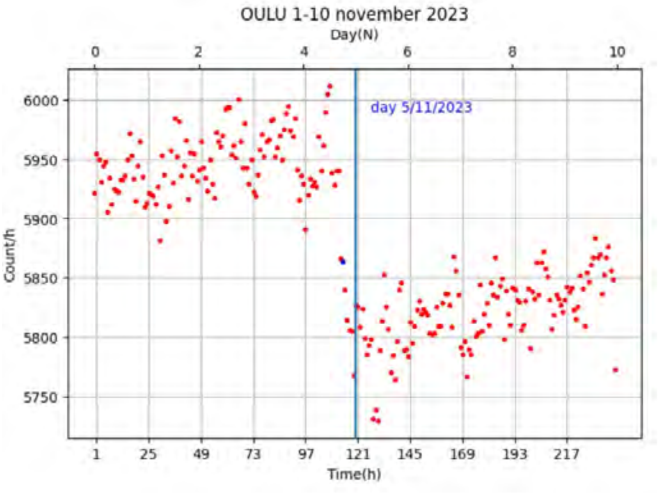
What's your take-home message?

To seize the day, how a picture of a wonderful sky could generate a scientific research.

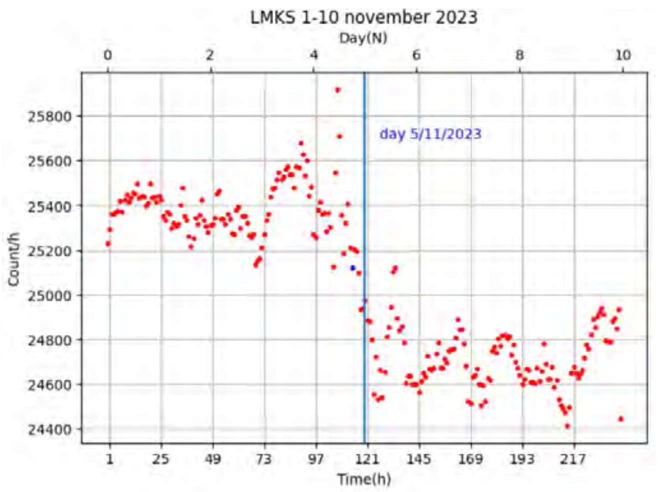
Picture of the aurora(43 N!), taken by Andrei Massaroni

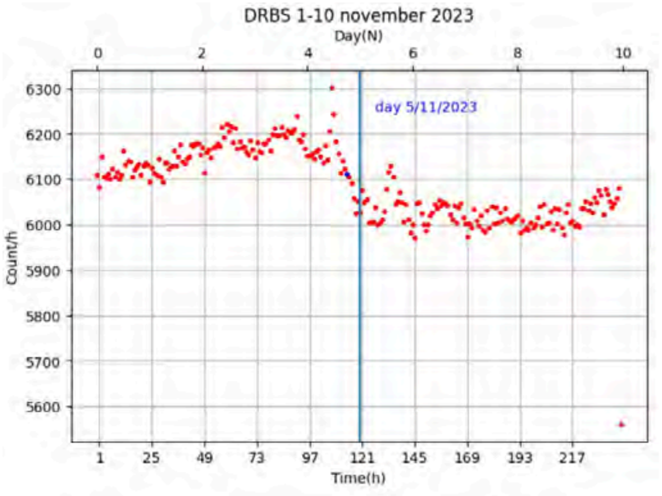
Plots of OULU and APTY, the Forbush Effect is clear





Plots of LMKS and DRBS, the Forbush Effect is clear





Neutron monitors data

NM NAME	LATITUDE	ALTITUDE(asl)	% DECREASE
OULU	65.05 N	15 m	2,5%
APTY	67.57 N	181 m	2,7%
LMKS	49.20 N	2634 m	2,7%
DRBS	50.10 N	225 m	2,4%
ATHN	37.97 N	260 m	2,1%

Due to the variations in altitude and latitude, all data has been normalized to be compared with the others. The decrease percentage is a good term of value because it's comparable.

Credit: DESY, Science Communication Lab

Seasonal variation of cosmic ray flux with MoCRiL

High School "A. Volta", Reggio Calabria, Italy

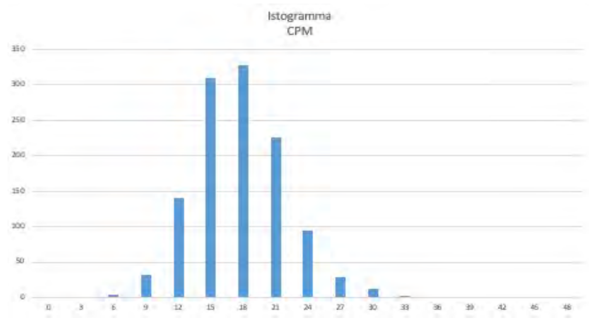
Who are you?

We are fourth grade students of a Scientific High School – 4Dsa

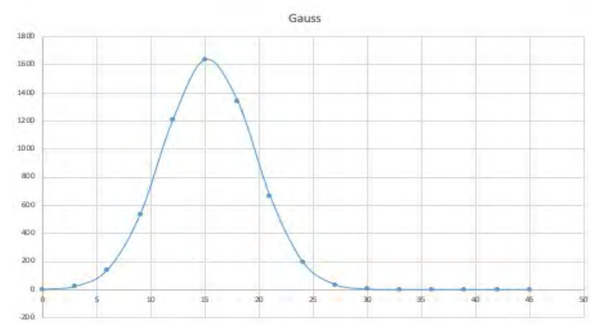
What have you done?

- Since last year we have been making measurements on cosmic rays with MoCRiL and are collecting and analyzing numerous data
- The objective we set ourselves this year is to analyze the seasonal variation of the flux of cosmic rays (period October 2023-May 2024)
- In this presentation we will show you the results (October-November) of these analyses:
  - *CPM trend as a function of time*
  - *Correlation of CPM with temperature and atmospheric pressure*

What did you find out?



Graphic CPM
Gaussian



What's your take-home message?

From the analysis of the data acquired so far, we have noticed that the CPM trend follows a Gaussian distribution quite well

Seasonal variation of cosmic ray flux with MoCRiL

High School "A. Volta", Reggio Calabria, Italy

Who are you?

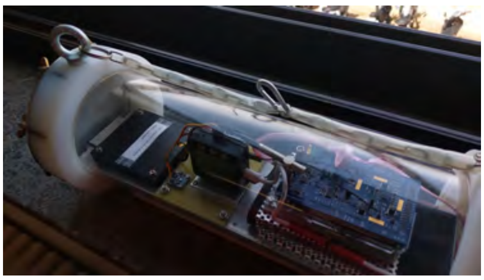
We are fourth grade students of a Scientific High School – 4Dsa

What have you done?

- **MoCRiL** is a real underwater laboratory and aims to demonstrate that the nature of the ionizing radiation that surrounds us is of extraterrestrial origin and not from the earth's crust.

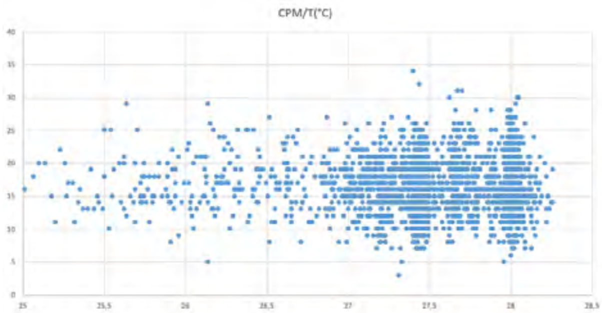
The instrument consists of:

- **An ArduSiPM**
- **A** digital sensor to monitor pressure, temperature and humidity inside the plexiglass cylinder.
- **A GPS** sensor to take into account the time and location.
- **An** accelerometer/gyroscope sensor to take into account the tilt of the entire instrument.
- **A** microcontroller to manage all devices and for the network connection. –
- **A microSD** card to save data (inside the M5Stack).
- **A PowerBank** to power the entire device.
- **Power and connection cables.**
- **Adapter to insert the SD** card into a computer.
- **Watertight plexiglass tube** equipped with o-ring gaskets and wing nuts for screwing the closing caps.

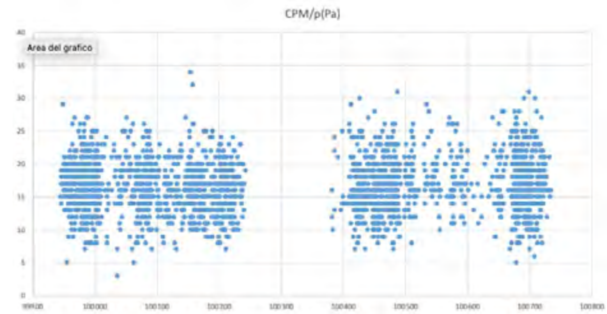


What did you find out?

CPM/T(°C) Correlation



CPM/p(Pa) Correlation



What's your take-home message?

As regards the correlation between CPM and temperature and CPM and pressure, the few data analyzed do not highlight any marked correlation, when instead a correlation between CPM and atmospheric pressure is expected.

ICD 2023

Liceo «Margherita di Castelvì, Sassari, Italy

Who are you?

We are some students of the last class (the 5M) of the Linguistic High School "Margherita di Castelvì" in Sassari. Our names are **Eleonora Basoli**, **Elisabetta Orani**, **Alessia Pinna** and **Asia Sechi.**

The teacher who accompanied us to the event is Prof. **Sergio Demelio**, our teacher of Mathematics and Physics.

What have you done?

On November 21st, we went with our teacher in the Department of Mathematics and Physics of the University of Sassari to the event ***"International Cosmic Day"***, locally organized by Dr **Davide Rozza**.

After a series of interesting presentations and seminars, cosmic rays were measured with the detector present in the event room. A series of measurements were made measuring the number of cosmic rays in a certain time interval (about 2000 seconds) and at various angles (theta = 0, 15, 30, 45, 60, 75, 90 degrees). It has been noted that the rate of counts (counts per unit of time) varies with the angle.

What's your take-home message?

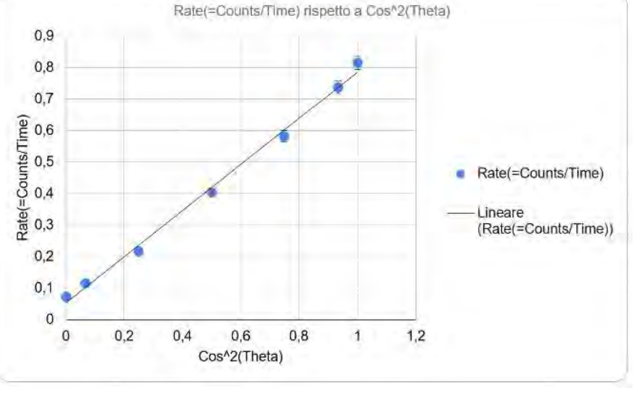
The participation in this event allowed us to know an important and interesting physical phenomenon that has many repercussions even in everyday life; something not present in the school program, but that deepens our knowledge. As a high school language student, we approached something far from our field and addressed ourselves in understanding other types of paths to choose for the future. It also allowed us to take a look at how you can do research in a field of scientific physics studies.

We would like to thank the researchers who were friendly and helpful in answering our questions and filling our doubts.

What did you find out?

Looking at the relation from a qualitative point of view it is desirable that the dependence of the rate of the counts on angle is (in the range of angles considered) of the type $\cos^2$ (theta), where theta is the angle with the the zenith axis.

To verify this type of relation we made a graph with an excel sheet (wich we enclose), putting in x-axis the $\cos^2$(theta) variable and in y-axis the rate of the counts (namely the counts on the time interval, for each angle in which the measurement was made). It is actually possible to verify that, almost within the uncertainty calculated by error propagation, the data are aligned along a line, which shows the correctness of the assumed relation on $\cos^2$ (theta).



In figure: the graph obtained from data elaboration of the experimental data, which shows the expected relation on $\cos^2$(theta) of the count rate

Who are you?

We are 12 students from ''Liceo Scientifico e Linguistico G. Marconi'', in Sassari (IT).

What have you done?

We attended a very interesting lesson on cosmic rays held by experts, researchers and young people who were about to enter this sector.
We also measured the cosmic rays passing through a Cosmic Hunter during a specific period of time to determine the rate (rapport between Counts and Time).
We also learnt about the two theories of Einstein and Newton, the difference between them and how they are connected to the main theme.

	A	B	C	D
1	ICD - 2023			
2	Theta	Counts	Time	Rate
3	0	1626	1995	0.8150376
4	15	1376	1865	0.7378016
5	30	1093	1876	0.5826226
6	45	893	2210	0.4040724
7	60	408	1877	0.2173681
8	75	268	2315	0.1157667
9	90	166	2262	0.0733864

What did you find out?

We discovered the existence of several projects and new research sites in this area. And surely what are cosmic rays, antimatter, some particles whose existence we did not know and also the history and evolution of the tools, theories, places and projects that have brought us up to this point in the research for the discovery of cosmic rays and their origin.

What's your take-home message?

Cosmic rays are particles and atomic core, which move almost at the speed of light, coming from the Cosmos to which both the Earth and all other celestial bodies are exposed. Whether their nature, where the kinetic energy of the particles is distributed out of fourteen orders of magnitude, both their origin, which can be the Sun, stars and phenomena such as novae and supernovae, can vary. The unit of measurement of the energy of cosmic rays is the electron volt, which corresponds to the kinetic energy of a tennis ball launched at a speed of 100 km/h.

Azimuthal dependence of the Cosmic Ray flux with the CosmoCube

I.T.I.S. G. Marconi, Pontedera (PI)

Who are we?

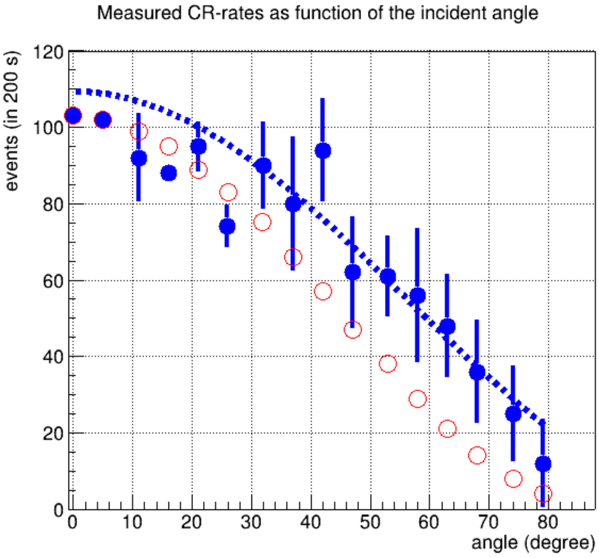
Manetti Ludovica
Montagnani Ginevra
Reali Lorenzo
Salatti Lorenzo
Salvadori Aurora
Selmi Anna

What have we done?

We study the azimuthal dependence of the cosmic ray flux using two scintillators (out of the 4 available) of the CosmoCube.
To perform the measurements we built a support with a scale to record the inclination of the CosmoCube during each step at the various angles.
In the picture below we show our setup.

What did we find out?

We verified the dependence from the cosine square of the azimuthal angle
We compare the measurements (blue circles) to what we would expect taking into account the physical dimensions of our scintillators and the solid angle defined in our setup (red open circles).
The measurements follows the expectation within the experimental errors.

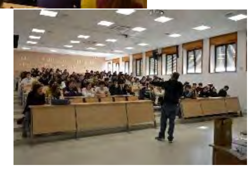


INTERNATIONAL COSMIC DAY

@ INFN LECCE ITALY

Credit: DESY, Science Communication Lab

2023 ICD Edition @ INFN Lecce



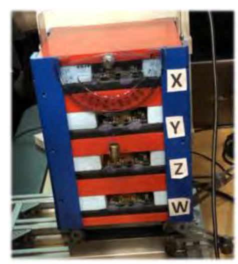
For the 2023 ICD edition, we hosted in Lecce 95 students from 10 high schools from the Lecce, Taranto, and Brindisi districts.
The schools participating in the ICD were mainly «scientific» or «applied science» but also «classic» schools. 16 to 18 years old students.

Participating Schools

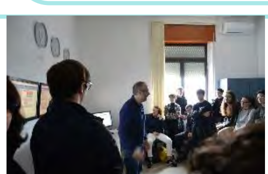
- Liceo "C. De Giorgi" – Lecce
- Liceo "Capece" – Maglie
- Liceo "G. Ferraris" – Taranto
- Liceo "De Sanctis -Galilei" – Manduria
- Liceo "G. Stampacchia" – Tricase
- Liceo " A. Vallone" – Galatina
- IISS "Virgilio-Redi" – Lecce
- IISS "Trinchese" – Martano
- Liceo "F. Calasso" – Lecce
- Liceo "G. Banzi Bazoli " – Lecce

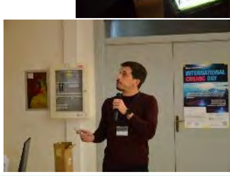
ICD Activities

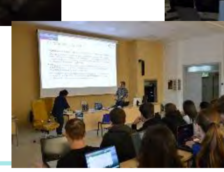
We measured the cosmic rays flux vs Zenith angle. Since the very beginning the students could work on dataset using COLAB.



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







Angular distribution of secondary cosmic rays flux

Liceo Scientifico "G. Banzi Bazoli", Lecce, Italy
Students: G. Consales, S. Pennetta, C. D'Abbraccio

Abstract

Cosmic rays (CRs) are high-energy particles, mainly protons, that move at a speed close to the speed of light. The interaction of the primary CR with the atmosphere gives rise to a shower of particles, called secondary CR. Only a portion of these particles, mostly muons, can be detected by ground-based telescopes. Our goal was to study the behavior of the muon flux as the local zenith angle decreased starting from zero. For this purpose, we used data acquired by a scintillator telescope called CORAM.

Experiment

The telescope

CORAM is a telescope made of four scintillator layers (named X, Y, Z, W) interspersed with iron absorbers. Each layer consists of plastic scintillators and photodetectors (APD). Events involving 2, 3, or 4 layers at the same time (coincidences) can be identified in a fixed time interval ($\Delta t = 3s$).

Data acquisition

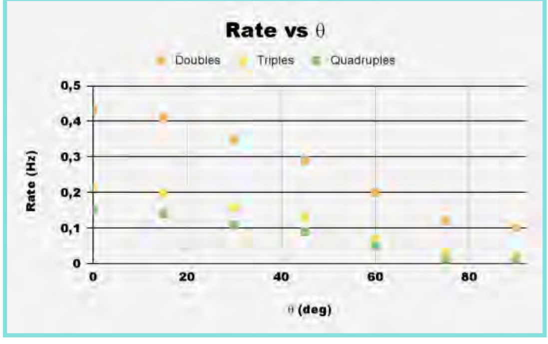
Data was continuously acquired by CORAM for about ten minutes, registering counts for a big number of 3sec gaps, while the instrument was positioned at a certain value of θ, the angle that it made with the local zenith. Data was collected by recording the two-fold, three-fold, and four-fold coincidences.

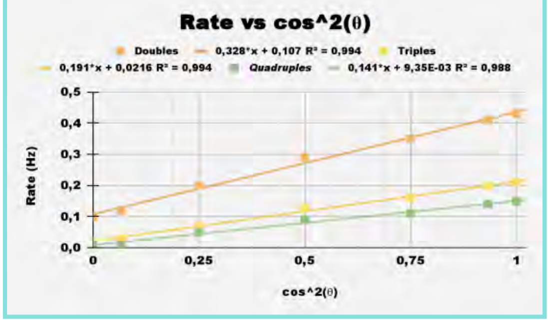
count w	count xy	count yz	count zw	av./3 sec	count xyz	count yxw	av./3 sec	count xyzw	av./3 sec
4,15	1,34	1,3	1,22	0,43	0,76	0,5	0,21	0,44	0,15
3,99	1,28	1,2	1,18	0,41	0,71	0,48	0,2	0,41	0,14
3,69	1,11	1,03	0,98	0,35	0,56	0,38	0,16	0,32	0,11
3,71	0,91	0,83	0,83	0,29	0,47	0,29	0,13	0,26	0,09
3,66	0,6	0,6	0,6	0,2	0,26	0,16	0,07	0,14	0,05
3,31	0,36	0,35	0,4	0,12	0,13	0,057	0,03	0,044	0,01
3,26	0,33	0,28	0,33	0,1	0,09	0,044	0,02	0,035	0,01

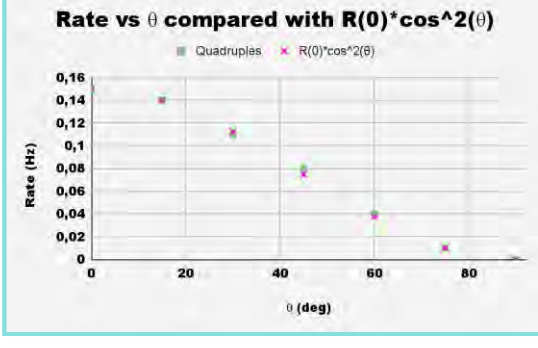
Our analysis

We considered doubles, triples and quadruples events. We made two graphs representing the rate (number of hitting particles per second) as a function of the zenith angle, in the first graph, simply θ, and in the second graph cos^2 (θ). In the end, because they related to muons whose direction was closer to the telescope axis, we analyzed only the quadruples comparing R vs θ with R(0)*cos^2(θ) in the third graph.

Plots and graphs







Conclusions

We can conclude that, as expected, the decrease in the zenith angle leads to an increase in the rate of muons per second. We also verified that there is a linear dependence between the muon rate and cos²θ. So, there is a direct proportionality between the particles' flux and the cos²θ

$$R(\theta) = R(0)\cos^2\theta$$

INTERNATIONAL COSMIC DAY

Francesco Calasso, Lecce (LE)

Who are you?

We are De Lumè Francesco, Latino Valentina, Serra Alessandra, Trotta Manuel and Zabini Beatrice from Liceo Francesco Calasso, Lecce with our teacher Mrs. Congedo.

What have you done?

On November 21st, we attended a conference on Cosmic Rays at the University of Lecce and we learned many concepts concerning cosmic rays. It was very interesting because we didn't know anything about cosmic rays. With the help of our teacher, we produced some graphics.

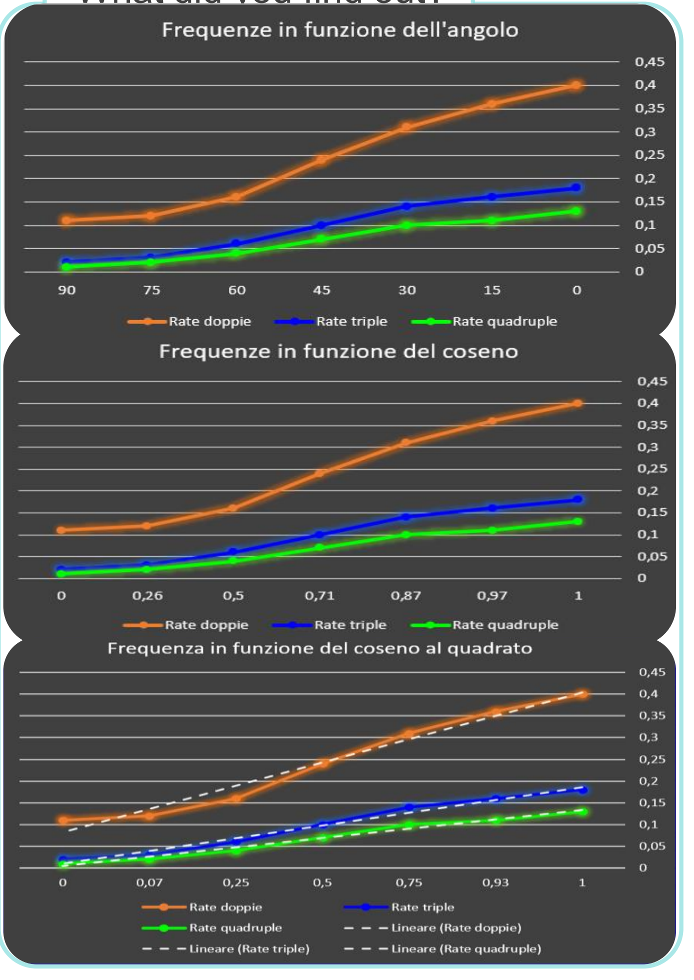
Cosmic rays are substantially high-energy protons and atomic nuclei that move through space at nearly the speed of light.

They originate from the sun and from outside the solar system, from distant colliding galaxies.

We used a detector made of four scintillator layers interposed with iron absorbers. This type of detector is usually called a cosmic ray telescope.

Then we recorded the measurements considering events with at least two layers, therefore 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 changes considering the zenith angle. By analyzing the directions of arrival of these particles as a function of the angle they form with the local Zenith, it is discovered that the maximum flux occurs for θ=0°, i.e. for particles arriving perpendicular to the earth's surface. The flow decreases continuously as the angle between the direction of incidence and the zenith increases. At 90° the flow is minimal. The distribution of the measured values can be described using a $\cos^2$ function.

A cosmic experience

«Cosimo De Giorgi» High school, Italy

Who are you?

We are students from Lecce, a little town in South Italy, who participated to the "International Cosmic Day" at the University of Salento.

D. J. Antonelli, F. Bardicchia, L. Bonanno, V. Calignano, T. De Luca, I. De Paolis, S. Garcia Scatigna, S. Longo, A. Mohamad Khaled, F. Stano.

What have you done?

We started with theoretical lessons, during which we learned all about Cosmic Rays: what they are, where they probably originate from, and their potential practical application. While the lessons were taking place, a miniature version of Cosmic Rays Detector (CORAM), started recording the passage of cosmic rays.

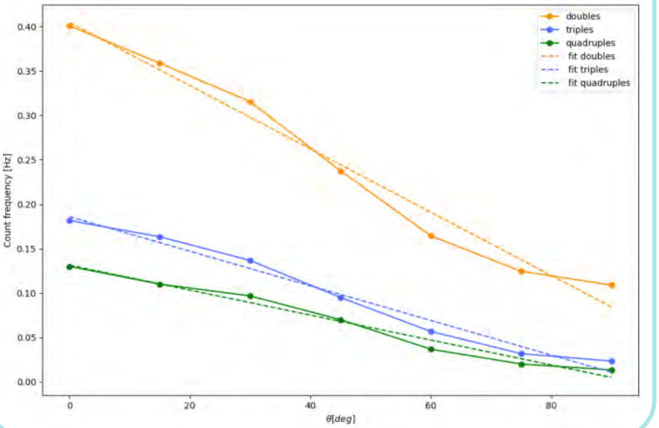
Afterward, we moved on to a control room to understand how Cosmic Rays are detected and studied in the *Pierre Auger Observatory*, in Malargüe, Argentina.

Then, we had a tour of a lab where we could see a Cloud Chamber, a particle detector that can visualize the passage of ionizing radiation and therefore makes the observation of Cosmic Rays possible.

Lastly, we attended a worldwide conference to present the results of the measurements performed during the day.

What did you find out?

With the data detected by CORAM, we plotted a graph that shows the number of Cosmic Rays counted by two (doubles), three (triples), or four (quadruples) adjacent layers of the detector as a function of the angle (θ) at which it has been placed relatively to the perpendicular to the ground. As a result, we can state that the greater the angle was, the less Cosmic Rays passed through the detector layers, as expected.



What's your take-home message?

Cosmic Rays are a massive subject of study that is engaging for anyone: they apply to numerous fields in our lives even though we do not notice. These insignificantly small particles weave the fabric of space and yet act unnoticeably. They are the foundation of astroparticle physics and serve as a means to understand the universe.

INTERNATIONAL COSMIC DAY 2023

LICEO DE SANCTIS – GALILEI, MANDURIA (TA) - ITALY

Who are you?

We are Greco Alessandro, Guarino Eleonora, Mazza Aurora, Nigro Davide and Zannetti Alice from Liceo De Sanctis - Galilei, Manduria with our teachers Mrs. Marialuisa Tomaselli and Mr. Carmelo Cosimo Prisciano.

LICEO DE SANCTIS-GALILEI

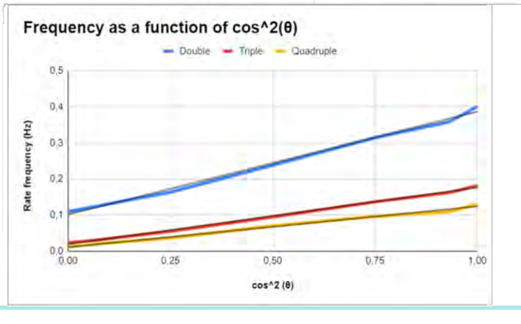
What have you done?

On Tuesday 21st of November, we attended a conference on Cosmic Rays. It was organized by the INFN of Lecce, held at the University of Salento (LE). After visiting various laboratories, we made up a clearer idea about the definition of cosmic rays. They are high-energy radiations originating from the Sun and outside the solar system. When they hit the Earth, the cosmic rays collide producing a shower of particles called secondary cosmic rays.

What did you find out?

Angle (θ)	XY	YZ	ZW	Double mean	Double rate	XYZ	YZW	Triple mean	Triple rate	XYZW	quadruple rate
0.0	1,241	1,173	1,201	1,205	0,4016666667	0,64	0,451	0,5455	0,1818333333	0,39	0,13
15.0	1,12	1,033	1,077	1,076666667	0,3588888889	0,565	0,412	0,4885	0,1628333333	0,33	0,11
30.0	0,979	0,905	0,947	0,9436666667	0,3145555556	0,483	0,339	0,411	0,137	0,29	0,09666666667
45.0	0,729	0,702	0,714	0,715	0,2383333333	0,338	0,232	0,285	0,095	0,21	0,07
60.0	0,526	0,465	0,481	0,4906666667	0,1635555556	0,205	0,126	0,1655	0,05516666667	0,11	0,03666666667
75.0	0,394	0,357	0,367	0,3726666667	0,1242222222	0,116	0,067	0,0915	0,0305	0,059	0,01966666667
90.0	0,372	0,294	0,318	0,328	0,1093333333	0,102	0,039	0,0705	0,0235	0,036	0,012

We performed measurements of the cosmic rays flux as a function of the zenith angle. We used a detector named CORAM made of 4 scintillator layers (X, Y, Z, and W). In the data analysis, we considered only the two-fold, threefold, and four-fold coincidences. In the graph, we show the cosmic rays rate as a function of the cos2 of the zenith angle.



What's your take-home message?

After seeing all the laboratories we can confirm that this was an instructive and formative experience. We learned a lot about the experiments that the scientific community conducts and saw with our own eyes how some of them work. We were impressed, and we certainly got closer to the universe and to this wonderful subject which is Physics.

International Cosmic Day

Liceo «Galileo Ferraris» Taranto

Who are you?

Hello! We are students from Taranto, a town in the south of Italy, near the sea and other beautiful Italian things! The name of our school is "Ferraris - Quinto Ennio" and we are all students of the fifth and last year. We are 12: 10 of us frequent the scientific course, 1 the classic one and another 1 the linguistic course. Our names are: Lorenzo Carrieri, Sara Giuliano, Claudio Ingrosso, Gabriele Zaza (5AS), Simone Abbracciavento (5BS), Matteo Fasano, Matteo Francesco Loscialpo, Jagajit Riccardo (5CS), Riccardo Carrara, Francesco De Vincentis (5DS), Rossana Sette (5AC) e Francesco Fabrizio Trombettiere (5CL).

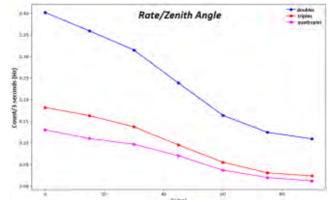
What have you done?

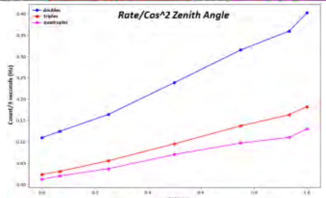
We have learned about cosmic rays. They are particles and nuclei of heavy elements that reach the Earth in the form of showers. They were discovered thanks to the contemporary and complementary studies of the physicists Hess and Pacini. Cosmic rays have a high energy, high velocity and, most of them, are refracted or reflected by the magnetic field of the Earth. We don't exactly know where they come from, but they are one of the causes of genetic mutations.

To study the flow of cosmic rays we used a detector called CORAM (COsmic RAy Mission). It's made by four scintillator layers separated by iron absorbers. The scintillators are made by a specific material that emits light when crossed by the particles. This light is collected and transmitted, using optic fibers, to a photo-detector, whose job is to convert these light pulses into electric signals. Since there are four scintillator layers X, Y, Z, W, we can register four different types of signals based on the number of consecutive layers that record an interaction: singles (X, Y, Z, W), doubles (XY, YZ, ZW), triples (XYZ, YZW) and quadruples (XYZW). We positioned the CORAM in seven zenith angles (from 0° to 90° and every successive angle differentiates itself from the previous one by 15°) and we carried out seven different measurements of ten minutes each. Then we calculated the counting rate by dividing the counting frequency by three seconds.

What did you find out?

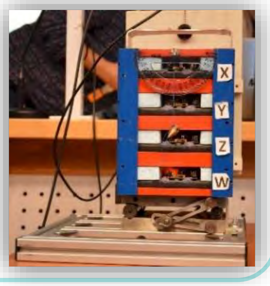
angle	xy	yz	zw	average of doubles/3sec	xyz	yzw	average of triples/3sec	xyzw	quadruples/3sec
0	1,241	1,173	1,201	0,402	0,640	0,451	0,182	0,390	0,130
15	1,120	1,033	1,077	0,359	0,565	0,412	0,163	0,330	0,110
30	0,979	0,905	0,947	0,315	0,483	0,339	0,137	0,290	0,097
45	0,729	0,702	0,714	0,238	0,338	0,232	0,095	0,210	0,070
60	0,526	0,465	0,481	0,164	0,205	0,126	0,055	0,110	0,037
75	0,394	0,357	0,367	0,124	0,116	0,067	0,031	0,059	0,020
90	0,372	0,294	0,318	0,109	0,102	0,039	0,024	0,036	0,012





The first graph represents the variation of the cosmic rays flux depending on the zenith angle. The line of doubles has a much steeper decline phase than the triples and quadruples, which tend to get closer and closer as the zenith angle increases.

The second graph represents the variation of the cosmic rays flux according to the squared cosine of the zenith angle. The line of doubles has a much steeper upward trend than the triple and quadruple lines. Compared to the previous graph, these two lines tend to move away from each other as the squared cosine of the zenith angle increases.



What's your take-home message?

Participating in this initiative was very interesting because it intends to bring young people to admire the beauty of the Universe. Studying the physical phenomena of the Universe evokes all the mysteries of our existence: the concept of infinity, the matter, the speed of light, the space. All this awakens in us the thirst for knowledge, the love for physics, and the desire to discover ever-new worlds.

Credit: DESY, Science Communication Lab

A day among cosmic rays

Liceo Scientifico Stampacchia

Tricase - Italy

About us

Our names are Veronica Piscopiello, Davide Agostini, Francesca Panico, Alessandro Morciano, Giuseppe Tagliaferro, Marta Licchetta and Daniele Massafra, seven students in the last year of high school. We had the chance to do an exciting trip across the discovery of cosmic rays. We have learnt that they are charged particles and photons coming from galactic and extragalactic sources. Cosmic Rays do not reach the ground because they interact with the atmosphere generating showers of secondary particles, such as muons, that can be detected by ground-based experiments, as at Pierre Auger Observatory in Argentina.

What we have done

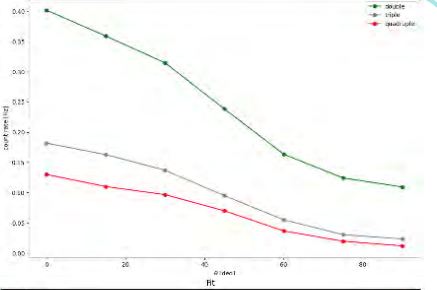
During this day, experts of the Departments of Physics in Unisalento have shown us how to use CORAM. It is a device able to measure the rate of secondary muons that pass through four scintillators (named X,Y,Z,W). When a layer is crossed by a muon, it emits a light pulse that is converted into an electrical signal thanks to photodetectors. The experiment consists of collecting the numbers of single, double, triple, quadruple coincidences (that occur when respectively one, two, three or four layers are crossed by a muon) and analyzing the relationship between them and the zenith angle.

In particular, the rate in Hz is calculated as the ratio between the average number of events during an interval of 3 seconds .

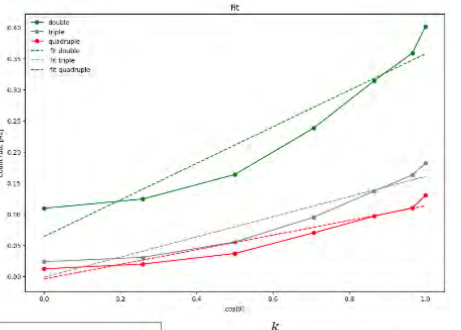
Eventually we used a Python code in order to plot graphs and to fit our data.

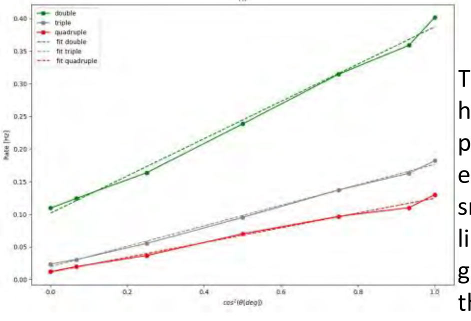
What we have found

First, we have plotted the rate (counts per second) as a function of the zenith angle theta. The wavy shape of the decreasing curves suggests a cosine-like behavior.



So, we have tried to analyze the rate as a function of the cosine of theta. The upward concavity is quite similar to a parabola. As a result, we have fitted the count rate as a function of the squared cosine of theta.





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

The above quantity tells us how far the experimental points are from the expected values: the smaller E, the better the linear fit. The last graph gives a lower values of E than the previous one.

Our report

Overall, we have managed to experimentally report phenomena we weren't aware of before this exciting and interesting event: the fall of muons to the ground triggered by cosmic rays. Based on the analysis of the collected data through CORAM, we conclude that the rate of muons (number of these particles per second) is likely proportional to the squared cosine of the zenith angle. We thank the researchers of INFN in Lecce and our teacher, Daniela Orlando, for the opportunity to try in a day what scientists do in their lives. Our iconic local idiom, in this case, becomes: "Sun, sea, and cosmic "*ientu",* from University of S*alentu".*

International Cosmic Day

IISS «Salvatore Trinchese», Italy

Who are you?

We are 12 students from the high school IISS "Salvatore Trinchese" located in Martano, Puglia, Italy. G.Greco, C. Ciccarese, A. Solazzo, M. Marrocco, A. Sicuro, S. Zaminga, N. Fiore, A. Mittaridonna, D. Pirla, N. Amato, G. Petrachi, F. Macchia.

What have you done?

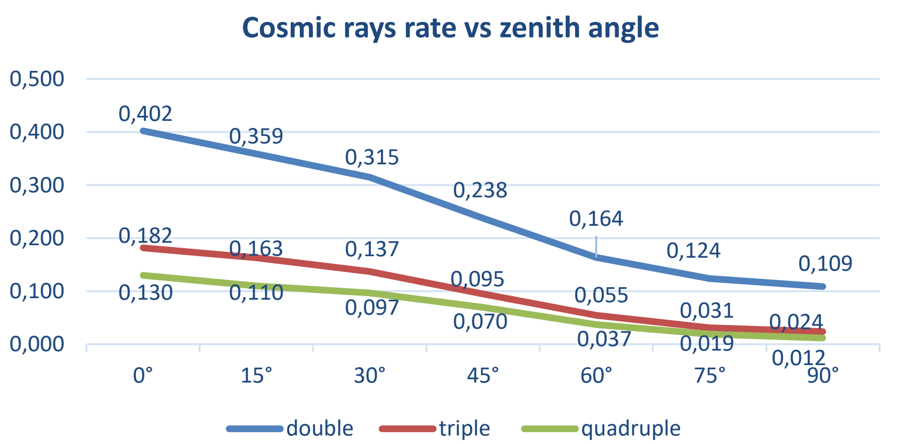
On 21st November our group of students visited the national nuclear physic institute site in the "Università del Salento". In the first hours of the seminar, we were introduced to cosmic rays. We got the basic knowledge from qualified scientists and professors who work on cosmic rays and we could live the experience of active research.

In the second part of the event, we experienced the data-acquisition and learned how to read and interpret the collected data.

We measured the cosmic rays flux using a detector named CORAM. This detector is made with 4 scintillator layers interposed with iron absorbers.

Thanks to CORAM we observed and measured the frequency of cosmic rays as a function of the Zenith angle. We noticed that the greater the inclination is, the lower the rate of particles detected, as expected.

We show in the plot the two-fold, three-fold, and four-fold coincidences.



What's your take-home message?

Scientific research is one of the most exciting things to be part of.

By knowing more and more about all the new developments, we have been only discovering that what we know is always too little.

Happy research to everybody!

INTERNATIONAL COSMIC DAY 2023

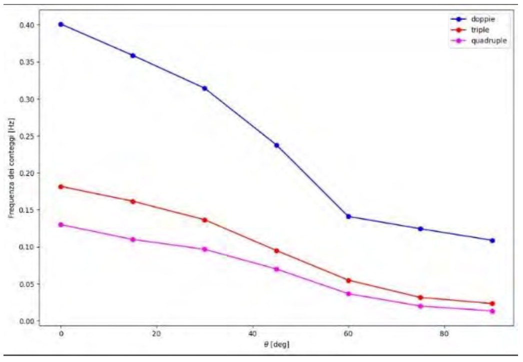
Liceo «Virgilio-Redi», Italia

Who are you?

We are a group of students from Virgilio Redi in Squinzano (Lecce - Italy) and we are passionate about scientific experiments in physics. Students: S. Marangione, M. B. Leuci, D. Negro, S. Capone, S. Blasi, M. C. Miglietta, T. Paladino.

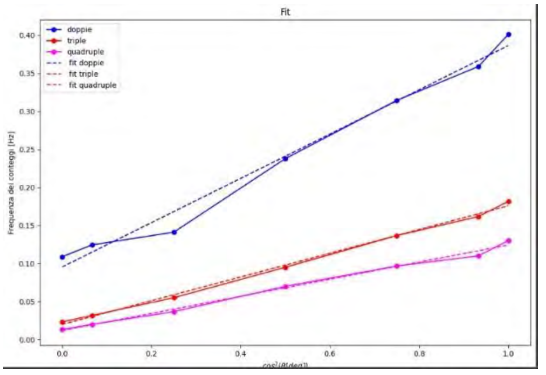
What have you done?

At first, we used Python code to streamline the calculation work.
We began by analyzing the frequency of cosmic rays captured by the detector, classifying them into three categories: doubles, triples, and quadruples. From the graph, it's immediately evident that higher-order rate (triples and quadruples) have a lower frequency compared to doubles. However, as the angle θ increased, the frequency decreased in all three cases.
Afterward, we performed another calculation of the counting rate based on the square of the cosine of the angle. This was an attempt to achieve a more linear trend. Subsequently, using Python, we plotted the fit for the three data set.



What did you find out?

Out of personal curiosity, we conducted a comparison between the data collected during the analysis of 2022 and that of 2023. Upon recalculating various graphs, a decrease in the frequency of doubles, triples, and quadruples can be observed. We aren't scientists and lacking the necessary instrumentation, we can only hypothesize theories for this decrease.
It could be due to particular climatic conditions, such as obstacles (clouds), or possibly related to different analysis timings. Nevertheless, this is the essence of science: analysis and speculation based on solid foundations that drive our society forward.



What's your take-home message?

Science is a way to bring together different places and thoughts, and this day has proven that. Despite not having much knowledge in the field and the appropriate requirements for research, thanks to this experience, we felt like real scientists for a day.

Discover Cosmic Particles

INTERNATIONAL COSMIC DAY

November 21 I 2023

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 the cosmos 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?

Aula Caianiello, Dipartimento di Fisica E. Pancini
Ore 9:00

Become a Scientist for a Day

Discover the world of cosmic rays like an astroparticle physicist.

Local Organizers:
Carla Aramo, Roberta Colalillo, Antonio Iuliano, Luigi Lavitola, Laura Valore

Con la partecipazione del
Liceo Cuoco-Campanella di Napoli

Local Webpage:
https://agenda.infn.it/event/38598/

Image Credit: DESY, Science Communication Lab

INFN OCRA Outreach Cosmic Ray Activities

INFN NAPOLI

International Particle Physics Outreach Group

DESY.

In cooperation with many networks and partners

12th International Cosmic Day

INFN, Napoli Division
Università degli studi di Napoli «Federico II

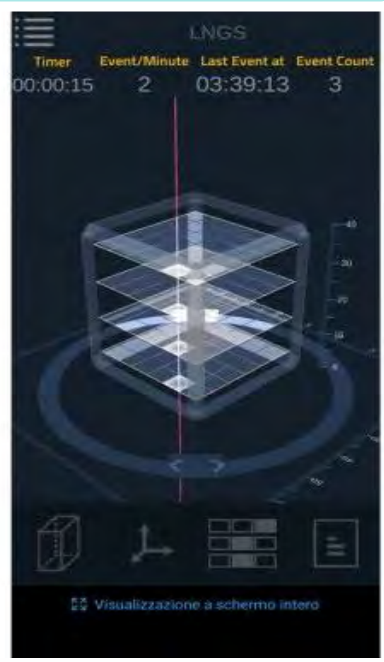
Credit: DESY, Science Communication Lab

Who are you?

We are 39 students attending the third and fifth grade class of the Liceo Cuoco-Campanella, a Scientific High School in Napoli, Italy. We spent an interesting and inspiring day at the Physics Department "Ettore Pancini" of the Federico II University. In Napoli, as in many other Italian cities, the activity is included in OCRA (Outreach Cosmic Ray Activities), the INFN program that coordinates, at the national level, the scientific outreach activities in the field of cosmic rays.

What have you done?

We looked for cosmic muons, particle invisible to human eys, using the Cosmic Ray Cube and the app Cosmic Rays Live.



INTERNATIONAL COSMIC DAY

VINCENZO CUOCO CAMPANELLA, ITALY

Who are you?

We are a group of 4 boys from the "Vincenzo cuoco Campanella" school in Naples who participated in the International Cosmic Day on November 21, 2023: Antonio Cardillo, Antonio Roscigno, Manuel Costagliola, Marco Cavaliere.

What have you done?

Cosmic rays are atomic nuclei coming from space. First of all we learned their story. Charles Coloumb noticed that an electroscope was naturally discharged which meant that there was something capable of breaking through the walls of his instrument. But those who discovered the cosmic origin of these rays were
Domenico Pacini and Victor Hess. Pacini, examining the intensity of flux of the cosmic rays in water, noticed a decrease with increasing depth. Similarly, Hess noticed an increase in the intensity of the cosmic rays as the altitude of a hot air balloon increased. They measured it with an electroscope.

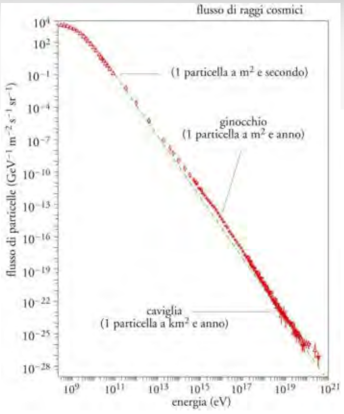
We then talked about the most elementary particles that make up matter, useful for the following discussion.

INTERNATIONAL COSMIC DAY

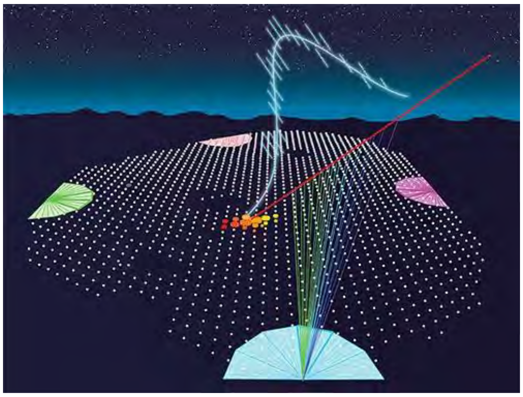
VINCENZO CUOCO CAMPANELLA, ITALY

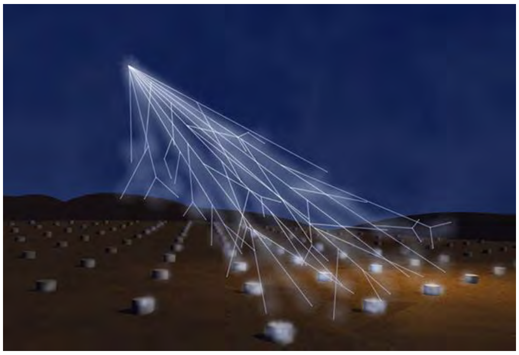
What have you done?

After we talked about the cosmic-ray flux, the number of primary cosmic rays as a function of the energy. Cosmic-ray energy is measured in electronvolt (eV). The minimum energy is of the order of 1 GeV (10^9 eV), while the most energetic particles have an energy of 10^{20} eV. We already talked about the relationship according to which as the altitude of cosmic rays increases the flux increases. Moreover, as it is shown in the picture on the right, when the primary energy increases, the flux decreases.



Cosmic rays do not all have the same energy but are classified into enormous energy ranges, more than 11 orders. Even the largest particle accelerator, LHC, reached an energy of 10^17 eV, i.e. 1000 eV less than the maximum energy recorded in cosmic rays.





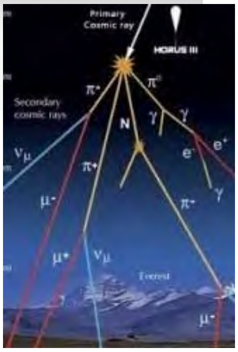
Based on the energy of the rays we find different types of measurements: up to 10 TeV the measurements are direct, from here onwards the measurement will be indirect. By direct measurement we mean that detectors are carried out via satellites, whereas the use of indirect measurements is closely linked to the atmospheric showers that form from primary cosmic rays interacting with atmospheric molecules.
The primary rays above 10 Tev enter the atmosphere 15 km above the ground and the protons of the cosmic rays collide with the nitrogen of the atmosphere and form secondary particles or the atmospheric shower mentioned above. So for indirect measurements there are two main detection facilities: the Pierre Auger Observatory in Argentina and the telescope Array in Utah. The Auger Observatory use two measurement techniques, fluorescence telescopes that measure the light produced by the deexcitation of nitrogen and oxygen molecules, previously excited by cosmic particles, and surface arrays, which in Auger consist of water Cherenkov detectors, in TA of scintillators.

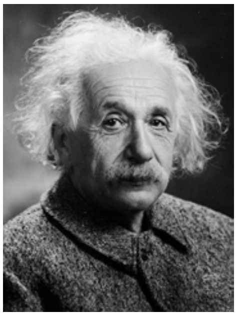
INTERNATIONAL COSMIC DAY

VINCENZO CUOCO CAMPANELLA, ITALY

What have you done?

The previously mentioned shower is composed of three components: electromagnetic, hadronic and muonic component.
The Hadronic component which constitutes the total 1 percent of the shower.
The electromagnetic component from electrons, photons and positrons.
The muon component. Muons are strongly penetrating particles belonging to the electron family even if the mass of the muon is 200 times greater than that of the electron. The muon is then highly unstable and decays after 2.2 millionths of a second, becoming neutrinos and electrons.





Subsequently we talked about how muons reach the ground: since the decay time of a muon is 2.2 microseconds and its speed is that of light, the distance it should travel is 660 m but in reality it travels 15 km. To explain this we use Einstein's special relativity. For Einstein's special relativity in a reference system that goes at the speed of light with respect to an earthly observer, space shrinks and space dilates. Therefore to arrive at saying that the distance traveled is 15 km we must calculate the product between the speed of light and the time which we find through Lorentz constant.

In the final part of the day we did an experiment using the Cosmic ray cube but before doing this experiment we talked about the zenith angle.
The zenith angle is the angle between the vertical direction coinciding with the zenith of the earth and the impact angle of the muon's trajectory. The greater the Zenith angle, the smaller the quantity of particles that reach the telescope. This happens because, having a greater zenith angle, the muon will have traveled more distance

Finally we used the cosmic ray cube in our experiment. This is an indirect measurement tool related to the muon flux. It consists of 4 layers with 6 bars per layer. These are plastic scintillators which when a charged particle passes inside it produces a scintillation light. This light manifests itself with the external LEDs of the instrument. We know that the particles that penetrate the CRC are only muons because they are the only particles capable of penetrating the 4 planes. The data received from the three-dimensional survey are then converted into two-dimensional data.

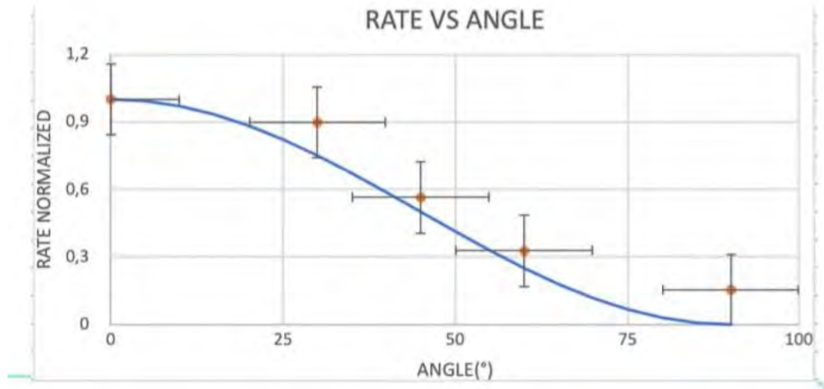
INTERNATIONAL COSMIC DAY

VINCENZO CUOCO CAMPANELLA, ITALY

What have you done?

The experiment, we talked before, consisted of detecting for different angles the quantity of muons that passed through the cube of cosmic rays per minute. The results confirm that as the zenith angle increases, the number of muons decreases. the orange points are the data while the blue curve represent the cos2 theta, that is the expected curve

angolo di zenit/num. di misurazioni	0°	15°	45°	60°	90°
misurazione 1	52	50	33	19	6
misurazione 2	50	41	26	13	10
misurazione 3	54	49	29	19	8



What did you find out?

We have discovered everything about cosmic rays, a topic whose name is frightening and might seem difficult to understand. In reality we discovered a lot of things that we didn't know and the topic wasn't so difficult.

What's your take-home message?

The message we take home from this experience is that nothing is difficult but it just needs to be explained well. And also that very often we live with things we know nothing about, for example cosmic rays before that day.

ICD 2023

Liceo Cuoco Campanella, Napoli, Italy

Who are you?

We are students of Liceo Cuoco Campanella of Naples in Italy

What have you done?

In this project we have explained what we have done during the International Cosmic Day held at the Physics Department “E. Pancini” of the University of Naples “Federico II”, also headquarters of the INFN, Naples Division.

What did you find out?

We have studied how cosmic rays are born, we have analyzed their trajectory thanks to the cosmic rays cube and we have learnt what they are made of.

What's your take-home message?

We think the cosmic rays are very important and interesting, we suggest you to study it for your personal instruction.


Credit: DESY, Science Communication Lab


NOW WE ARE GOING TO TALK ABOUT THE DETAILS OF COMSIC RAYS

Understanding Cosmic Rays

Cosmic rays are high-energy particles originating from various sources in outer space, for example when a massive stars explodes in a supernova, it produces cosmic rays. They can consist of protons, atomic nuclei, electrons, photons, neutrinos.

Effects of Cosmic Rays on Earth

Cosmic rays can interact with the Earth's atmosphere, producing secondary subatomic particles and contributing to the formation of ionizing radiation. This radiation can impact climate, biological organisms, and even technological systems.

Among these secondary particles, there are muons.

How can cosmic rays reach Earth?

They can't reach Earth's surface directly due to the protective layer of the atmosphere. Instead, when these high-energy particles collide with atoms in the Earth's atmosphere, they create a cascade or shower of secondary particles, including muons, ions, electrons, and others. These secondary particles can reach the surface and are detected as secondary cosmic rays. Muons, which are the most penetrating component of cosmic-ray showers, have a lifetime of 2,2 millionths of a second and without the Albert Einstein’s law of relativity they can’t arrive on the Earth. In fact, according to the relativity law, time expands and space shrinks and therefore secondary particles manage to reach the ground.

Detecting and Studying Cosmic Rays

Various instruments and detectors are used to observe and study cosmic rays. These include ground-based observatories, space-based telescopes, and particle detectors. Understanding cosmic rays provides insights into the universe's composition and behavior.

We will use a simple instrument, the cosmic ray cube, to study the flux of cosmic muons at the ground.

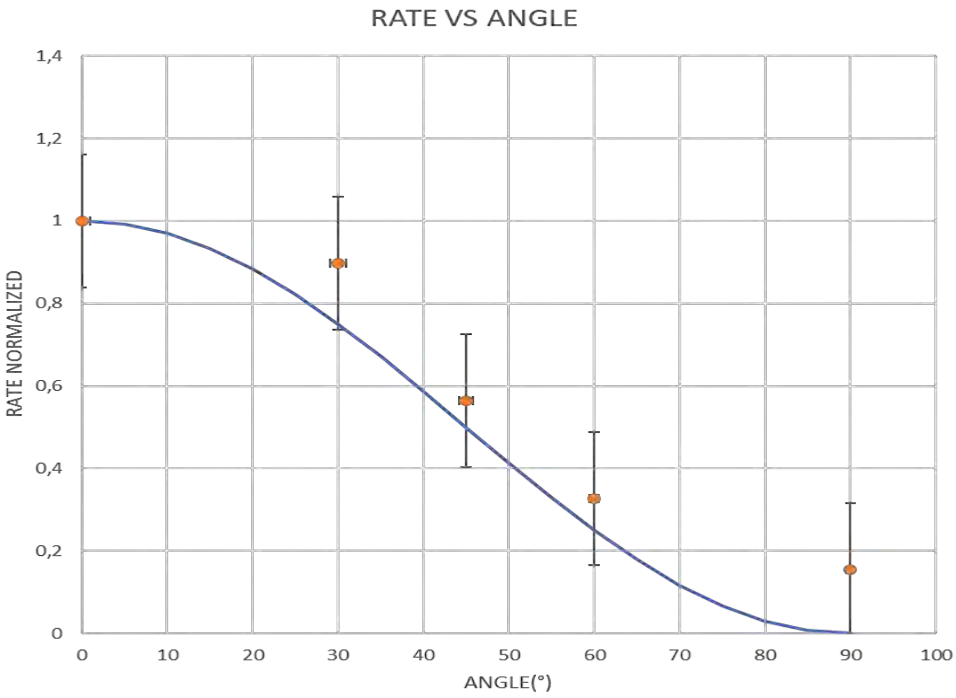
Cosmic Rays Cube

The cosmic rays cube is a machine thanks to which it is possible to measure how secondary cosmic rays reach the Earth in a given time. It is divided into various layers made up of scintillator bars. When a charged particle crosses a bar, produces a light that is collected and carried to the end of the bar thank an optical fiber. The light is detected by a photonsensor, and transformed into an electrical signal, which turn on leds placed on two lateral faces of the cube. The lighted leds show the particle trajectory.

During the ICD we used this cube to analyze the flux of secondary cosmic rays, in particular muons, as a function of the zenith angles, the angle formed by the zenith line and the trajectory of the particle.

The data is shown in the slides below:

Ω	COUNT 1	COUNT 2	COUNT 3	AVERAGE
0	52	50	54	52
30	50	41	49	47
45	33	26	29	29
60	19	13	19	17
90	6	10	8	8



The Future of Cosmic Ray Research

Search for cosmic rays aims to deepen our understanding of astrophysical phenomena, particle physics, and space exploration. Advancements in technology and ongoing experiments contribute to unlocking more cosmic ray mysteries.

This project was created by :

ALESSANDRO IANNOTTA

CARMINE MANZO

MATTIA CASTALDI

SALVATORE PAGANO

ICD 2023

Liceo Scientifico Cuoco-Campanella, Napoli, Italy

Who are you?

We are four teenagers from VINCENZO CUOCO high school.
We are in the third year of mathematical scientific high school and are part of the 3D class.
Our names are: Dalila Ercole, Francesca Impareggiabile, Matteo Riccio and Francesco Santoro

What have you done?

The main topic of the lesson was cosmic rays, that are atomic nuclei produced in the cosmos and reaching us. Initially Marie Curie discovered radioactivity thanks to her study, she thought that it had a terrestrial origin. Years later, in '30s, Pacini and Hess discovered that there is also a radiation came from the space. We have seen that there are two very important points of observation, two observatories: 1)"Pierre Auges Observatory" located in Argentina with an area of 3000 km^2, which measures the density of particles. This is one of the things that Auger measures, but not the only. 2)The "Telescope Array"(TA) experiment in Utah. Both Auger and TA use fluorescence telescopes, while, as ground detectors, Auger uses Water Cherenkov detectors and scintillators, while TA uses only scintillators.

The atmosphere is part of the detector, since it is the medium by which the shower develops and also the medium by which light reaches the detectors. The incoming charged particles have an unknown source, since they are deflected by magnetic fields, but it is assumed that various particles come from Centaurus A, a galaxy in the constellation of the Centaurus.

In particular, we focused on muons, particles of the lepton family (subatomic particles) and particles that constitute one of the component of a cosmic-ray shower, which is formed by the interaction of a primary cosmic ray with the Earth's atmosphere. The flux of muons is not evenly distributed but has a maximum if you have a zenith angle equal to 0. Muons have an average life of 2.2 milliseconds and reach the surface of our planet.

In particular, we focused on muons, particles of the lepton family (subatomic particles). The flow of muons is not evenly distributed but is maximum if you have an Alpha angle equal to 0
The latter have an average life of 2,2 milliseconds and reach the surface of our planet.

Following classical relativity we know that: s=V •T in this case T is the muon life time, which is 2,2 • 10^{-6} s, v is c since they travel almost at the speed of light. s=c • T->s=3.8•10^{8} m/s • 2.2 • 10^{-6} = 660 m so according to classical physics, they cannot reach us.

Einstein's relativity:

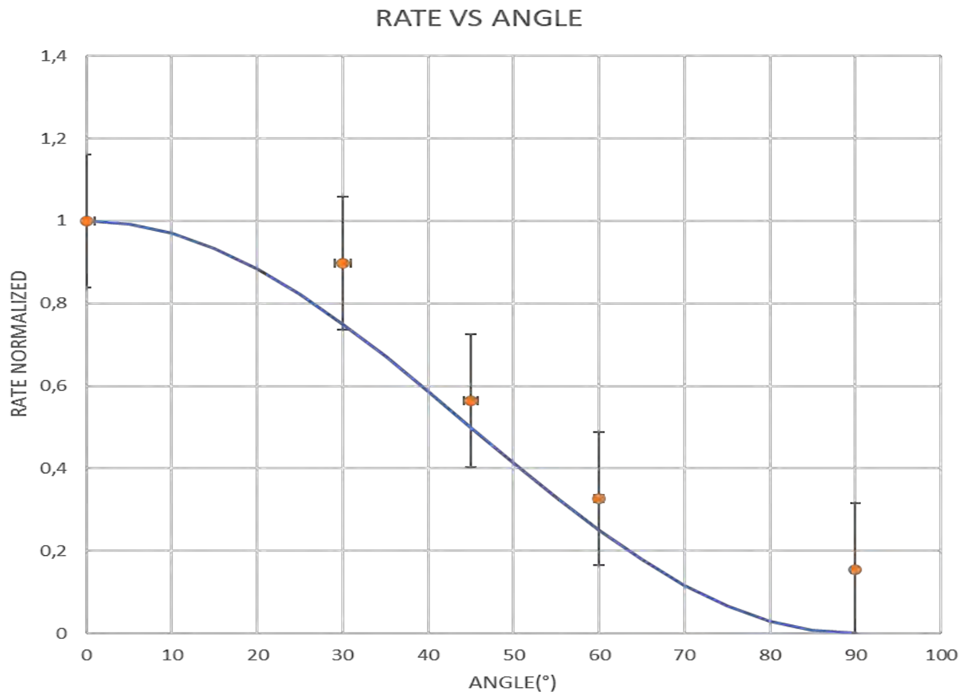
Einstein tells us that when particles move at a speed close to that of light, TIME dilates, that is, Delta t= y(Lorentz factor)•t0, and SPACE shrinks L=L0/y. Then there is a relationship between proper time and space, t0 and L0, measured by the observer in the frame of solidarity with the event and the time and space, t and L, measured by an external observer. For example, in the reference system integral with muons, the atmosphere is 600m thick and they can travel all the way to Earth in 2.2 microseconds. To conclude, for the observer at the ground, the life time of muons is larger; while for muons, the distance to be covered is shorter. In both cases, muons can reach us on Earth.

What is the Cosmic Ray Cube?

A telescope consisting of 4 layers inside which there is a plastic scintillator (bars of material inside which there is an optical fiber that captures the light that has been released and carries it to the end of the bar). When a charged particle passes through the bar it produces a light, how this light is generated? When the particle hits the material and the electron/muon transmits energy to the electron of the material that jumps to a later orbit, this then returns to the starting orbit and in the process releases an energy in the form of light (scintillation).

At the ends of the bars there are SiPMs (light detectors) that absorb the scintillation light and turns on the telescope LEDs. Each layer has 2 planes on which there are 6 bars each and overlapped in the opposite way. We then put into practice the arguments learned in the last few hours. We performed an experiment: find the number of muons that pass through the telescope in a minute, based on the angle of the CRC. Addition, with the Cosmic Rays Live App there is the possibility to connect to one of the sites where the telescopes are located, to reconstruct the three-dimensional trajectory of the particles. We use its projections on the xz and yz planes. The data can be automatically saved on your mobile phone and used for different types of analysis.

The intent was to identify the number of muons passing through the telescope in a minute, as a function of the angle of the CRC. Considering the size of the CRC, we can say that by tilting the cube by a certain angle, we are only considering muons with that zenith angle.
We counted muons thanks to a special app, which is much more accurate in counting than a person. The final result confirmed that the higher the angle is, the lower the flux of muons through the telescope becomes.



What did you find out?

At the beginning of the ICD, we did not know about cosmic rays and everything about them.
During the meeting we learned many things about cosmic rays and their detection. At the end, we were able to analyze the data collected and present them in a video conference with other students who joined this initiative and discovered this interesting part of physics.

What's your take-home message?

It was a pleasant and formative experience, we learned a lot about a topic previously unknown to us. It was fun to work in groups and compare with other students, and work with new and interesting tools. It is an experience that each of us will surely remember, and that will perhaps lead someone to understand that this is the path he wants to follow.

Credit: DESY, Science Communication Lab

International Cosmic Day

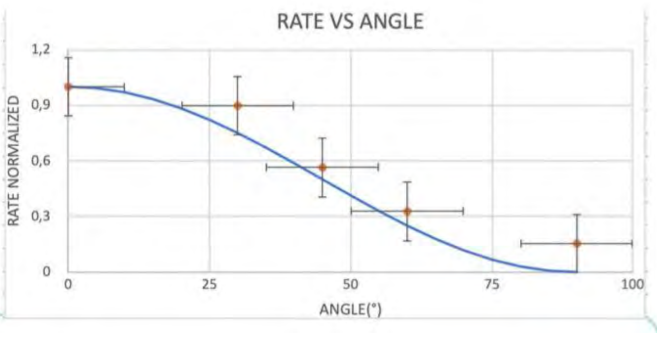
Vincenzo Cuoco Campanella, Naples Italy

Who are you?

We are Flavia Albano, Alessandra Di Somma, Ilaria Iermano, Caterina Nurri

What have you done?

During the ICD we've participated to, we talked and learnt about cosmic rays, their history, what they are and the tools to reveal their "travel". The Cosmic Rays Cube (CRC) is a detector used to study and analyze the secondary particles produced by cosmic rays in the Earth's atmosphere. Cosmic rays are high-energy nuclei produced in the deep space. It's composed of four scintillator layers that produce light when a charged particle passes. The light is read by SiPMs, the electrical signal produced by it turns on the leds which indicate visually the passage of the particles. The cube mostly sees muons, which are the most penetrating particles of a cosmic shower.



What did you find out?

The professors explained that cosmic rays were discovered in 1912 by Victor Hess, an Austrian physicist. During a flight at an altitude of over 5,000 metres, Hess noticed a significant increase in ionizing radiation, contrary to what was expected. This led him to conclude that the radiation was coming from outer space and not only from the earth. This discovery paved the way for understanding cosmic rays and their effects on Earth. Cosmic Rays have energies that vary in a wide range. Their energy is expressed in the unit of measurement called **electronvolt** (**ev**) and goes from about 10^8 ev (or 100 MeV) up to 10^{20} eV, the equivalent of the kinetic energy of a tennis ball thrown at 100 km/h. The number of cosmic rays that arrives on Earth with energy around 1 GeV (=10^9 eV) is about 1 per m^2 per second, but it becomes 1 per m^2 per year at 10^6 GeV and even only 1 per km^2 per century at the highest energies ever observed (10^{20} eV). When cosmic rays travel through the atmosphere, produce a shower of particles, among which are muons.

Muons are subatomic particles that belong to the lepton family. They are similar to electrons, but have a mass about 200 times greater. Muons are unstable and decay to other lighter particles, such as electrons and neutrinos, which are produced in large quantities during high-energy particle collisions, such as those in particle accelerators. And thanks to the cosmic rays cube, we can detect cosmic muons coming to Earth.

What's your take-home message?

During this day we spent at university we had the opportunity to discover and deepen a branch of physics that before then we didn't know of. It was interesting to participate in experiments with new tools, such as the cosmic rays cube, but most of all it has been exiting to expose what we did in a conference with schools from all around the world who had the same experience.

International Cosmic Day

Liceo Scientifico Cuoco-Campanella, Napoli, Italy

Who are you?

We are: Victoria Duello, Emmanuel Siesto, Emanuele Peluso, Francesco Lieto.

What have you done?

In this day that we spent in the university of Monte Sant'Angelo, we followed a lesson which we talked about particles present in space , but we also talked mostly about muons and how they come to earth. Then we looked at thecosmic rays cube, a detector that allows us to see muons in the place where we are. Then, after this observation, we divided into groups since we had to build a speech in English, a powerpoint and graphics to present the results of our measurements to the rest of the participants of INTERNATIONAL COSMIC DAY around the world. After listening to others we talked and explained our work. We did quizzes and the winners won water battles and gifts.

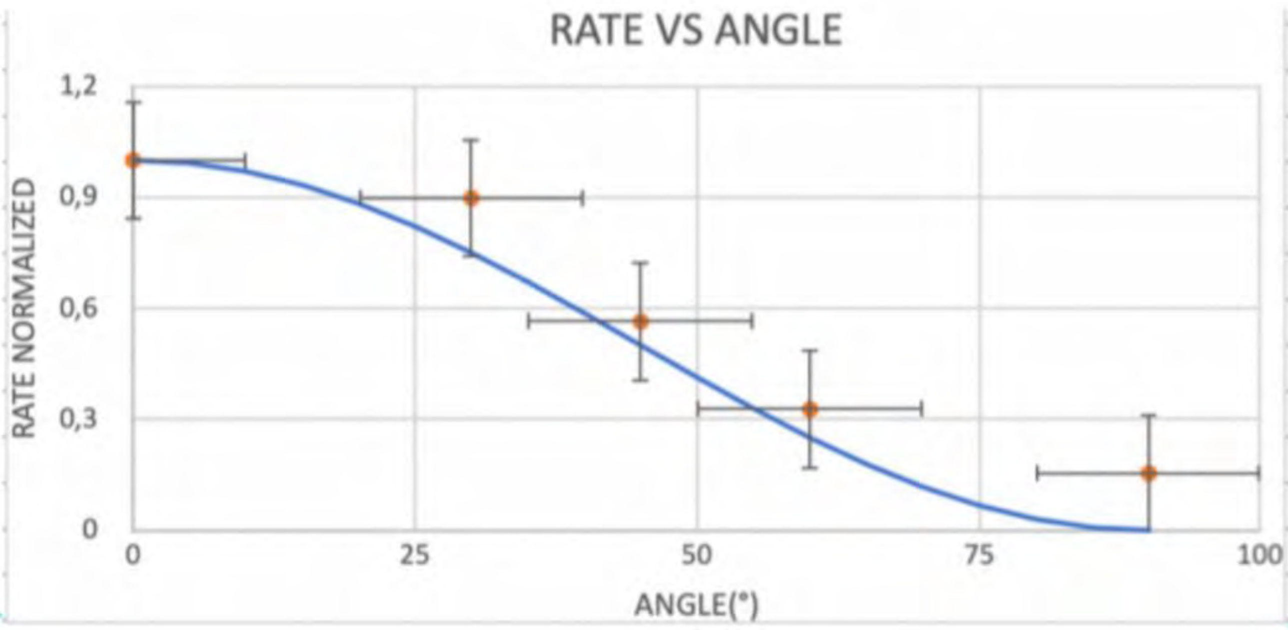
What did you find out?

We found graphs that reflected the peculiarities of the rate of muons arriving on Earth as a function of the zenith angle. We understood from the explanations provided by the teachers that muons continuosly hit the Earth. We also discovered that in each hemisphere there are "laboraties " where cosmic rays are studied; our teachers work for the laboratory located in Argentina.

What's your take-home message?

Basically we can say that the lesson on muons was very fascinating.It's amazing how these subatomic particles can cross matter and how muon detectors help us to study them. It made me think about how vast and fascinating the particles world is.


Credit: DESY, Science Communication Lab


RATE VS ANGLE
RATE NORMALIZED
1,2
0,9
0,6
0,3
0
0
25
50
75
100
ANGLE(°)

ICD 2023

Liceo Scientifico Cuoco-Campanella,Napoli, Italy

Who are you?

Umberto Lauro, Daniele Pagliarulo, Giuseppe Naso, Mario Razzini

What have you done?

During the lesson we discussed cosmic rays and how they get there. To demonstrate this we used cosmic rays cube. We measured the travel of muons, which are components of cosmic-ray showers, with varying angles of the cosmic rays cube

What did you find out?

- The muon flux on the ground is not evenly distributed, because if we analyzed the directions from which muons come from the local zenith we would find that the maximum flux is obtained when the angle is 0°, therefore for particles reaching perpendicularly to the earth's surface.

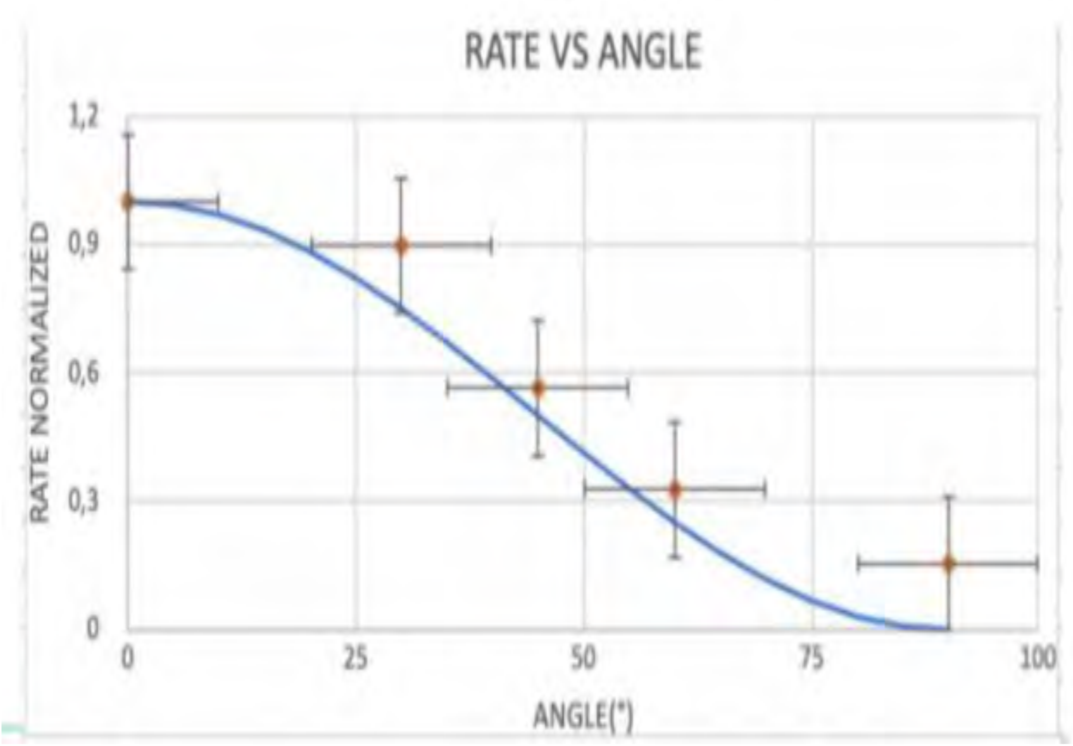
What's your take-home message?

•The muon flux on the ground is not evenly distributed, because if we analyzed the directions from which muons come from the local zenith we would find that the maximum flux is obtained when the angle is 0°, therefore for particles reaching perpendicularly to the earth's surface.

To measure how muon flux arrives on earth we need a rays cube, we need to change the angle each time to check the amount of muons coming in based on the position of the cube as:(0°,30°,45°,60°,90°), and we get the following results:

OMEGA	CONTEGGIO 1	CONTEGGIO 2	CONTEGGIO 3	MEDIA
0°	52	50	54	52
30°	50	41	49	47
45°	33	26	29	29
60°	19	13	19	17
90°	6	10	8	8


Credit: DESY, Science Communication Lab


RATE VS ANGLE
RATE NORMALIZED
1,2
0,9
0,6
0,3
0
0
25
50
75
100
ANGLE(°)

International Cosmic Day

Who are you?

We are 3 students from the Liceo Scientifico T. Campanella in Naples, who participated at the International Cosmic Day.
Ercolano Emanuela , Esposito Alessia, and Zunico Valentina.

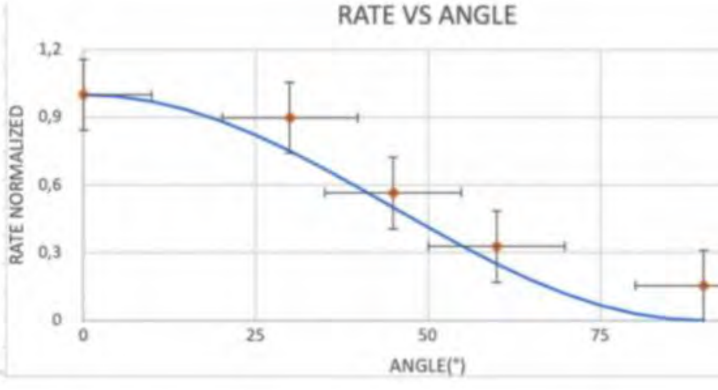
What have you done?

We attended an event in which we have been told about cosmic rays, muons and the CRC (Cosmic Rays Cube) that detects the flux of these particles. A muon is a particle belonging to the lepton family, with a charge equal to or opposite to the electron and a mass equal to 206.8 times that of the electron. It is unstable and subject only to weak and electromagnetic interactions. Then we carried out an experiment with the detector through the 'Cosmic Rays Live' application which transcribes all the data detected by the instrument. The CRC is equipped with LEDs that light up as the particles pass, allowing the trajectory of the latter to be followed with the naked eye.We built a table in which it was reported the number of times that, at intervals of 1 or 2 minutes, at a certain inclination of the telescope the LEDs were turned on, so we counted how many times the passage of particles occurred.

What did you find out?

During the experiment with the cube, we observed that when the LEDs were turned on in all the shelves of the CRC, we witnessed the passage of the muons. This was because muons are particles that penetrate deeper into the Earth than the others. We also saw that, by the time the telescope was at 0° compared to the Zenith, the passage of particles was greater. Conversely, when the telescope tilted a certain angle with respect to the Zenith, the flux of muons decreased.

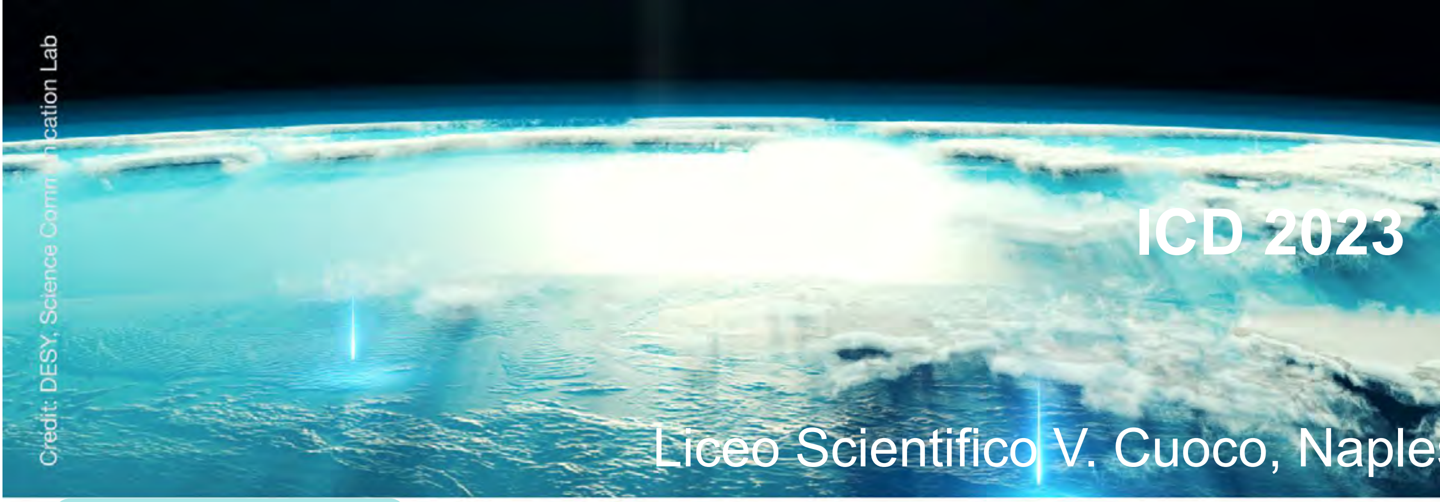
Zenith / count	0°	15°	45°	60°	90°
1.	52	50	33	19	6
2.	50	42	26	13	10
3.	54	49	29	19	8



Avarage: 52

What's your take-home message?

The first thing that the Cosmic Day made us reflect on is how important research is and how it constantly progressing. From a scientific standpoint, it has made us aware of the existence of other particles. Previously, we were only familiar with protons, neutrons, and electrons. Now, we know about muons, and we imagine that there are many others, both already discovered and yet to be discovered.

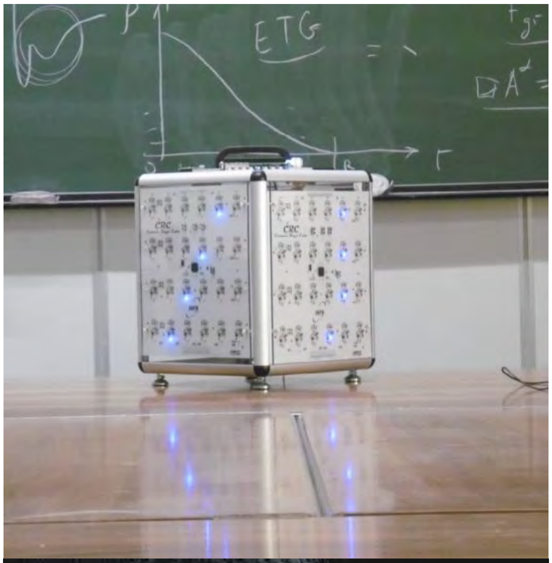


who are you?

We are students from Naples of "Vincenzo Cuoco" scientific high school, who recently participated together with other schools from other countries at the international cosmic day: Francesco Saverio Cirillo, Francesco Karol Iodice, Giosuè Buonomo

what have you done?

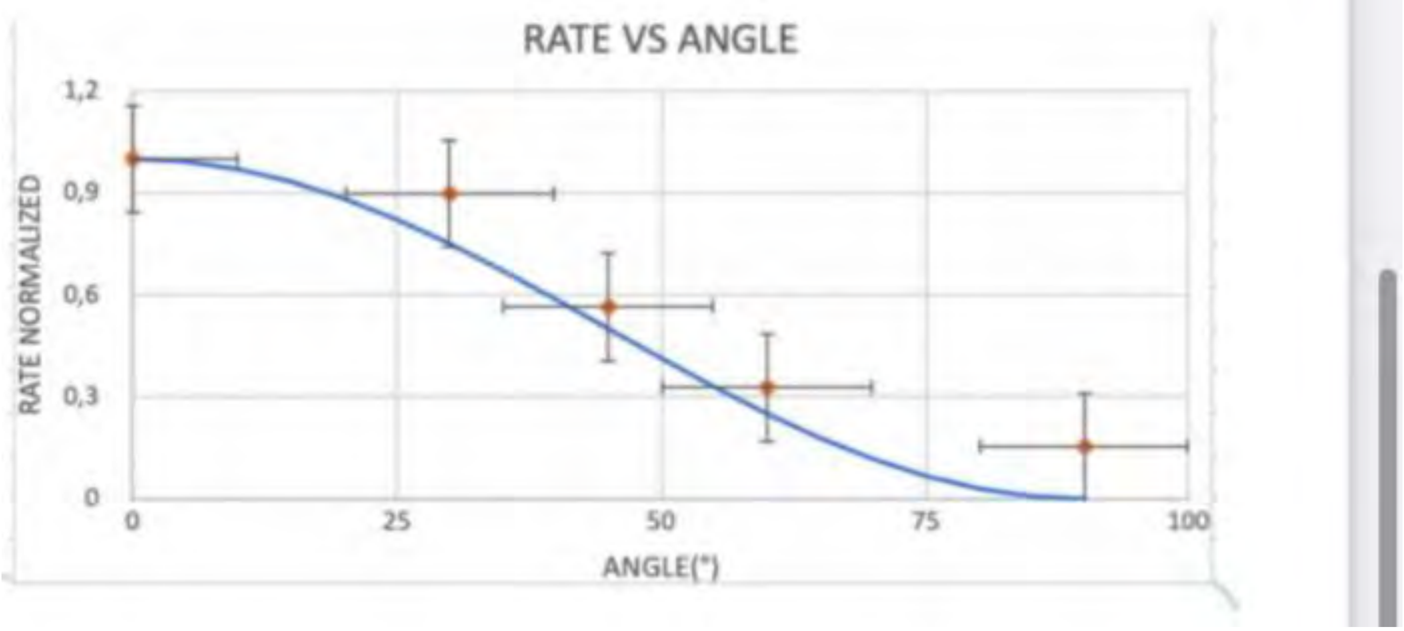
Today, we delved into the subject of cosmic rays, unraveling their discovery attributed to Victor Hess. We were enlightened on the benign nature of these celestial visitors upon Earth, arriving en masse and posing no harm to humans at low altitudes. Astonishingly, our bodies are incessantly traversed by these cosmic rays. Comprising hadronic, electromagnetic, and muonic elements, the latter being unstable particles similar to electrons but have mass 200 times greater than electrons, hurtling through space at the speed of light. The focal point of our session shifted to the apparatus scrutinizing these particles—the cosmic ray cube. Comprising four rows of scintillating rods, each signaling the passage of muons. Notably, as muons traverse the cube, distinct lights illuminate in accordance with the incident angle of the cosmic ray. Our engagement extended to an experiment involving the flux of muons of cosmic rays traversing the cube within a minute. Iterating this process with varied cube angles, we observed a proportional decrease in the number of particles as the angle increased.



What have you done?

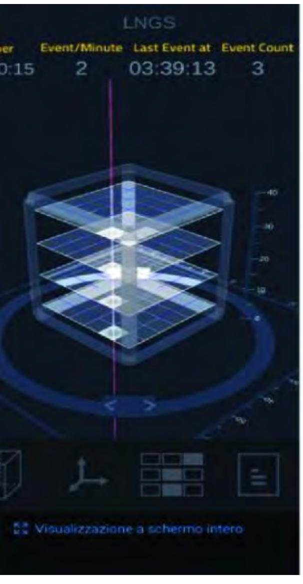
Finally we used the cosmic cube in our experiment. This tool is specifically designed to the muon flux. It consists of 4 layers each one provided with 6 rods of plastic scintillators which detect the passage of particles and light up. We know that muons are the only particles able to penetrate the 4 layers of the tool and so the only particle to be analyzed via the CRC

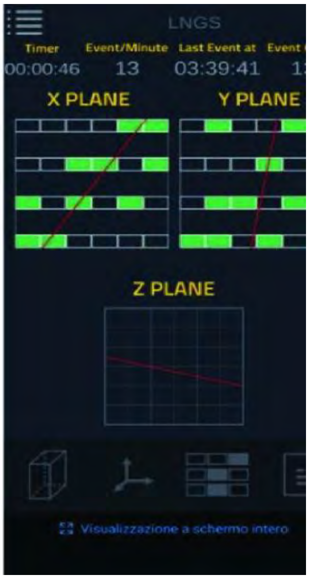
angolo di zenit/num. di misurazioni	0°	15°	45°	60°	90°
misurazione 1	52	50	33	19	6
misurazione 2	50	41	26	13	10
misurazione 3	54	49	29	19	8



What did you find out?

The key takeaway emphasizes the significance of cultivating curiosity about our surroundings, even in seemingly modest and straightforward aspects, as every facet conceals a realm of hidden complexities.





What's your take-home message?

The initial impact of Cosmic Day prompts contemplation on the criticality of ongoing research and its perpetual advancement. Scientifically, it has heightened our awareness of the presence of additional particles. Traditionally, our understanding was limited to protons, neutrons, and electrons. Presently, the realm of knowledge encompasses muons, leading us to envision the existence of numerous others, both currently unveiled and awaiting discovery.

ICD 2023

Vincenzo Cuoco-Campanella, Italy

Who are you?

We are three students from Naples at the Vincenzo Cuoco scientific high school. Together with other schools we participated in the International Cosmic Day. We are Sara Sabatino Alessandra Amato Paola Improta.

What have you done?

On this day we witnessed the explanation of cosmic rays, they told us how they were discovered and who discovered them (Victor Hess). They then explained to us that cosmic rays arrive on earth as showers and do not have a harmful effect on humans, at low altitude, in fact the human body is constantly crossed by them. Cosmic rays are made up of an hadronic, electromagnetic and muonic component. Muons are unstable particles that are part of the same family as electrons but they have mass 200 times greater than electrons and travel at the speed of light.

Than they showed us the instrument that analyzes these particles, that is, the cube of cosmic rays, it is made up of four rows of scintillating rods that indicate the passage of muons. When the passage occurs, in fact on each row a different light will turn on based on the the angle of the ray that passes through it. With this instrument we carried out an experiment in which we counted the number of muons that passed through the cube in a minute and we repeated the counting several times by changing the angle of the cube, thus observing that by increasing the angle the number of particles decreased, because they cross more atmosphere to get to the detector.

	0°	15°	45°	60°	90°
M1	52	50	33	19	6
M2	50	41	26	13	10
M3	54	49	29	19	8
media	52	46	29	17	8

Headline

Institution or School, Country

What did you find out?

We addressed a very interesting and little-known topic and for this reason it aroused curiosity in everyone.

What's your take-home message?

The important message to take with you is to always be in favor of discovering new things, even if little known, it is precisely these that contain more secrets to discover

International Cosmic Day

Vincenzo Cuoco, Naples

Who are you?

We are students of the “Vincenzo Cuoco” scientific high school, who recently participated together with other schools from other countries at the International Cosmic Day: Federica Scarlato, Federica Riccio, Riccardo Abbondante

What have you done?

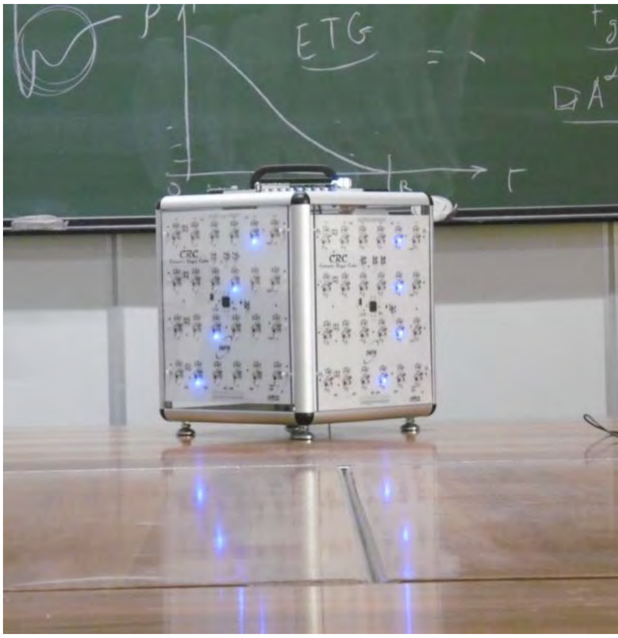
We were presented with the idea of cosmic rays reaching the Earth from space and, as soon as they enter in the atmosphere, they produce many muons. Muons are unstable, electron-like particles, but they have a mass that is 200 times greater. Every second we are crossed by hundreds of muons, which do not lose much energy and contribute to the natural radioactive dose. They have an average lifespan of 2.2 millionths of a second, they reach the surface and are able to pass through several layers of rock.

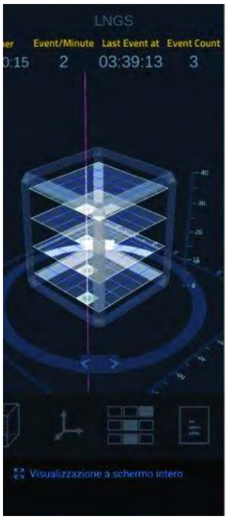
They are unstable particles, as they decay into something else during their lifetime, and this process takes place in 2.2 millionths of a second.

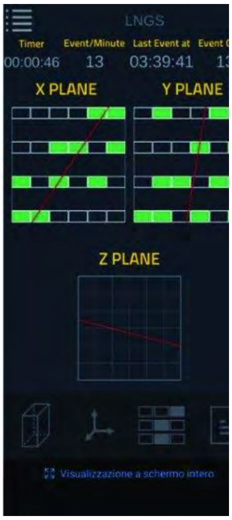
Muons reach the ground (the cosmic ray loses energy once it enters the atmosphere). The speed of the muon is close to the speed of light. At that speed they can travel 660 m. The flux of muons that reaches the ground is not uniformly distributed, to define the flux we consider the Zenith angle (when the angle increases, the number of muons decreases, at 90° the flow is minimum, while at 0° it is maximum). We talk about flux, because with any telescope you don't have the ability to analyze all the muons that arrive, but only a certain amount.

Subsequently, we were introduced and shown the operation of the instrument that allows us to analyze particles, a telescope called: Cosmic Ray Cube

It is made up of 4 planes of sparkling rods (scintillators), so called because once crossed by muons, they produce light, which is captured by an optical fiber, until it reaches its end, there acts the SiPM (a light detector). If the particle pass through all the 4 layers, it's a muon.



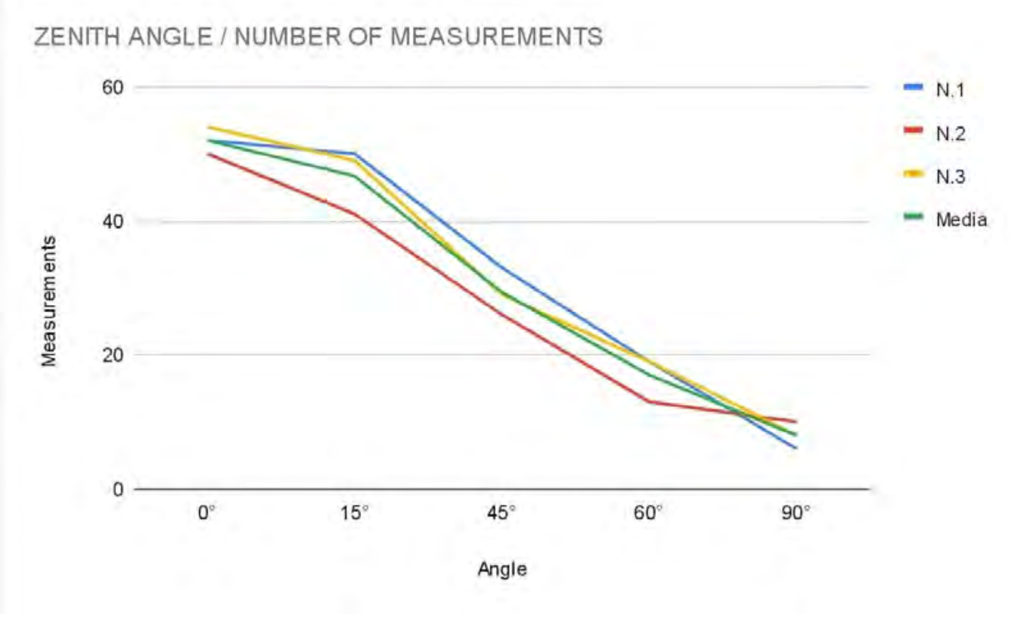




For each floor there are 6 rods aligned orthogonally to each other, to which your SiPM is associated.

With this device we carried out an experiment that consisted of counting muons in a certain amount of time and we repeated this activity by changing the angle of the Cosmic Cube

Zenith Angle/Number of Measurements	0°	15°	45°	60°	90°
N. 1	52	50	33	19	6
N.2	50	41	26	13	10
N.3	54	49	29	19	8



What did you find out

We delved into a very interesting topic that we never had the opportunity to deal with at school, it was very stimulating to be able to independently process the scientific data and see the results

What's your take-home message?

The take-home message is that it is important to take an interest in what surrounds us even if it seems to be small and simple, because everything hides a world

International Cosmic Day

V.Cuoco-T.Campanella, Italy

Who are you?

We are a group of 3 boys from "V.Cuoco-T.Campanella" high school, we are from Naples and, on November 21th 2023, we participated in the International Cosmic Day: Capogrosso Enzo, Picco Bruno, Roscigno Carmine

What have you done?

They have introduced us to the concept of cosmic rays, atomic nucleus coming from space. First of all, we have been told about the history behind the discovery of such rays. The first to notice the existence of these rays was Alessandro Volta, later Domenico Pacini and Victor Hess had found out about their cosmic origins.

Then, we've talked about the most elementary particles which build matter

Furthermore, we talked about the energy linked to cosmic rays. There is a relationship between the altitude of cosmic rays, the flux and the energy perceived. At higher altitudes, rays with a lower energy are not expired yet, so we can track them. The same rays cannot be tracked at lower altitudes.

International Cosmic Day

V.Cuoco-T.Campanella, Italy

What have you done?

Cosmic rays produce in atmosphere particle showers, in which we can find different components. There are three which are: the electromagnetic component, from electrons, photons and positrons, the hadronic component which is 1% of the tothe total s and the muonic ent, based on muons a type of particles we focused on.

Muons are a very unstable particle, belonging to the same family as the electron, but being 200 times greater of an electron. Their peculiar instability brings them to decay after 2.2 millionths of a second.

Muons travel at lightspeed and in the 2.2 microseconds they exists they should cover a distance of 660 m, while we can see they travel for 15km before decaying. To explain this phenomena we had to use Einstein's special relativity. When a particle travels at lightspeed the space shrinks while time dilates.

Finally we used the cosmic cube in our experiment. This tool is specifically designed to the muon flux. It consists of 4 layers each one provided with 6 rods of plastic scintillators which detect the passage of particles and light up. We know that muons are the only particles able to penetrate the 4 layers of the tool and so the only particle to be analyzed via the CRC

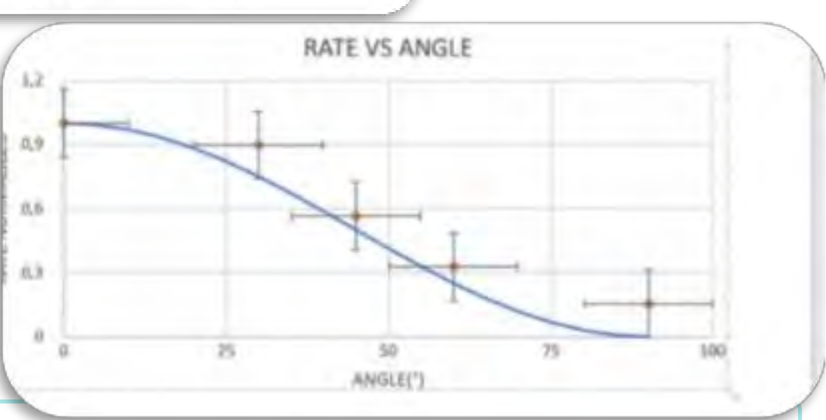
International Cosmic Day

V.Cuoco-T.Campanella, Italy

What have you done?

The experiment consisted in counting the different amount of muons detected by the Cube from different angles. We both used the Cube and the software linked to the cube that provided us to precise numbers. The experiment confirm that the more the angles the less muons trespass the cube. This happens because, having a greater zenith angle, the muon will have traveled more distance

angolo di zenit/num. di misurazioni	0°	15°	45°	60°	90°
misurazione 1	52	50	33	19	6
misurazione 2	50	41	26	13	10
misurazione 3	54	49	29	19	8



What did you find out?

We found out many information about a topic we wouldn't normally treat at school, and so deepened our knowledge about particles and the microscopic world, as well as the usage of specific tools and softwares.

What's your take-home message?

The take-home message is that even something that may seem as simple as microscopic particles who exists just for 2.2 microseconds, may have lots of secrets hidden behind and may be the subject of numerous experiments.

JAPAN

Radiation Imaging using a Web Camera

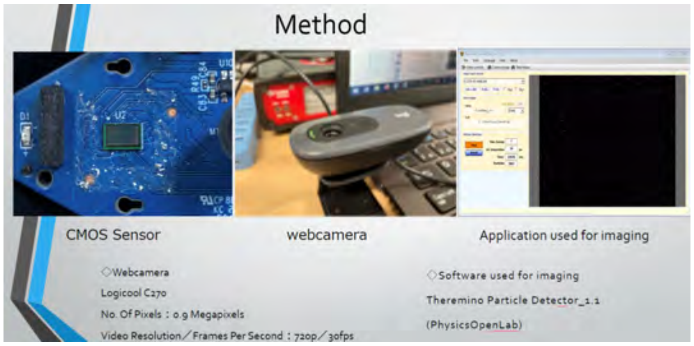
Webcam

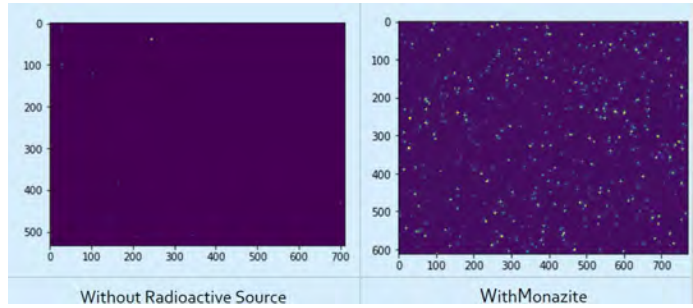
Shibumaku Senior High School 2nd Year HS **St. Mary's International School Tokyo Grade 12**

Aito Uchida **Taka Hayashi**

This is a brief overview of research we have been conducting over the past 2 years.

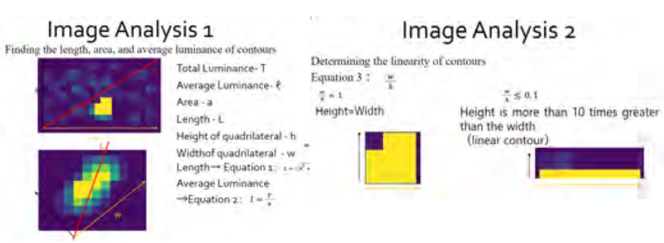
We used web cameras that you can buy on amazon to image and measure radiation. Originally, we began imaging cosmic rays, but since the sensor was small and so the incidences were low, we decided to use radiation sources such as Strontium-90, Americium-241, Europium-152 and measure radiation released from them.

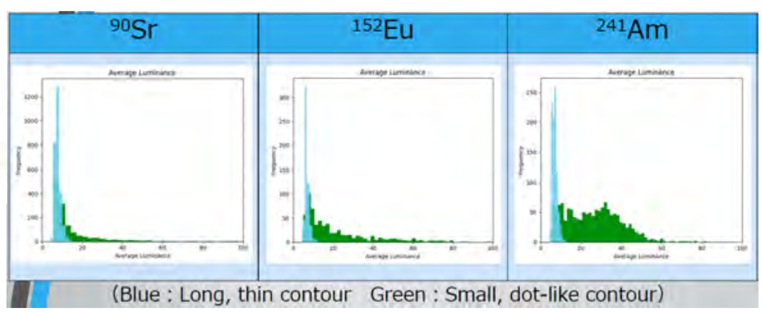




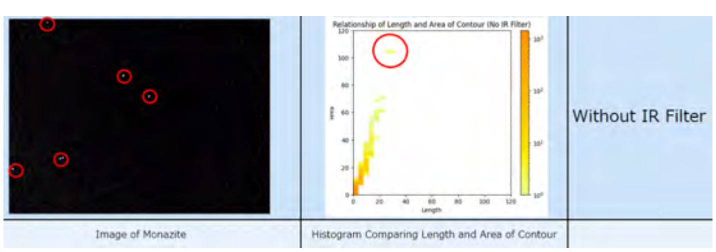
To measure radiation, we placed the radiation source in front of the sensor, then covered the camera with aluminum foil to block out visible light. You can see here some of the images we took with various radiation sources.

What we found from these images is that there were a few different types of tracks left behind by radiation. There were small white dots, as well as long thin contours. The characteristics of these tracks were similar to that of radiation observed with a cloud chamber, so we used this as a reference to determine what kind of tracks correspond to what type of radiation.





With image analysis using Python, we were able to differentiate gamma and beta rays as can be seen in the graph. The blue is the long thin contours, the green is the small dotted contours. Gamma rays have higher energy than beta rays, and from this graph, this is clear.



By removing a thin IR (Infra-red) filter that was on the sensor, we were also able to measure alpha radiation as can be seen in the image and graph.

In conclusion, we were successfully able to quantify the characteristics of the radiation tracks imaged by the web camera which allowed for differentiation by radiation types.

KENYA

Lateral Distribution of Cosmic Ray Muons

Department of Physics, Kenyatta University, KENYA

WHO WE ARE

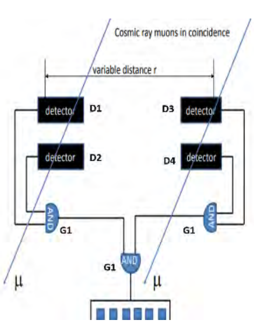
V.N.Kihagi, S.M.Chege, J.Kisingu, N. Kimani, L. Ochilo, N. Hashim

What we did

Measurements and simulation of cosmic ray muons

Experimental facilities

- ✓ NIM(Nuclear Instrument Module
- ✓ Solid scintillators (NaI(Tl)
- ✓ Photomultiplier tubes

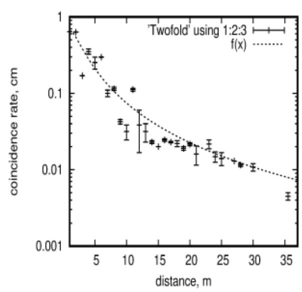


Experimental set up

- ✓ Two-fold coincidences
- ✓ Four detectors with two sets in coincidence.
- ✓ 3-AND gates
- ✓ Distance between detectors varied up to 36 meters

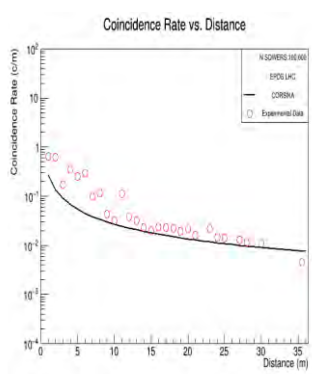
What we found out

NKG function is consitent with the data



Measurements of two-fold coincidences

- ✓ Count rates decrease with increase in distance.
- ✓ Data is consistent with the NKG function



Comparison of MC simulations with the measurements

- ✓ MC simulations using CORSIKA EPOS LHC.
- ✓ The measurements are close to the MC simulations.

Enhanced understanding of the EAS

- ✓ The CR muon coincidence rate decreases with increase in distance
- ✓ The decoherence curves helps one to understand the EAS

MEXICO

INSPIRANDO TU MEJOR VERSIÓN | UDEM

Credit: DESY, Science Communication Lab

Ciencia: Viaje al Conocimiento

Universidad de Monterrey, México

H. Martínez-Huerta, O. Aquines-Gutiérrez, A. Santos-Guevara

Who are you?

We are four university students and five research professors gathered at **theUniversity of Monterrey in Nuevo León, Mexico**, on November 22, with 60 students to learn about science and celebrate the International Cosmic Day 2023.

What have you done?

We held and designed an outreach workshop this year and invited 60 high school students (8th grade) to visit our university.

We prepare an outreach program with a series of talks and engaging activities. We covered the selected topics below in physics and mathematics to foster interest and understanding of the science of elementary particles in matter and astrophysics:

- the scientific method,
- the elementary components of matter,
- the formation of stars,
- Cosmic rays,

and topics of applied mathematics,

- mathematics in decision-making, and
- the description of electrical networks.

Acknowledgments to our Invited Speakers:

Carlos Emilio Cantú Magaña
Daniela Regina González Angulo Garza
Isaac Yael Cantú Fernández
Mariana Samperio Cuevas
Profa. Dra. Pamela J. Palomo Martínez
Prof. Dr. Lino Gustavo Garza

What did you find out?

We found a valuable opportunity to connect with students, spark their curiosity, encourage students to explore these subjects more deeply and motivate them to pursue further studies in science, technology, engineering, mathematics, or other academic fields.






What's your take-home message?

According to some students -*science and technology are everywhere, and it is essential to understand the world around us... it helps us know what everything is made of and what is up there.*

For the speakers and organizers, it was an incredibly motivating experience to share and get feedback from the questions and curiosities of these young people. We will all be looking forward to celebrating Science and the ICD with new and improved activities next year.

FCFM-UNACH, Chiapas, México

ICD 2023

Who are you?

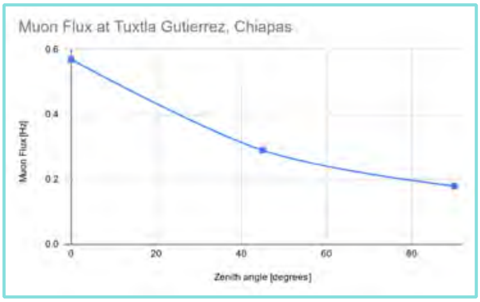
We are 4 students from the school of scientific and technological studies of the state of Chiapas (CECYT), campus 01 San Fernando.

What have you done?

We were at a conference on International Cosmic Day, given by PHD. Karen Caballero Mora. In this conference we learned about cosmic rays, in the theoretical part we explored the fundamentals of astroparticles and the different experiments around the world. In the practical part we learned the multiple disciplines that are involved in this branch of physics, such as the electronics, programming and physics.

What did you find out?

We did a practice in the muon scintillator detector called Escaramujo, in which we found a relationship between the angle and the frequency of arrival of the muons as seen in the following plot:



What's your take-home message?

The learning acquired in this experience, the visit to UNACH was very fun because the things learnt in this activity were astroparticles, cosmic rays and the national and international experiments such as the Escaramujo project and the Cherenkov water detector "Jaguarito". It was very interesting and fun, giving us a pleasant experience of knowledge and learning.

SPAIN

Lycée français International Molière

Talk about Cosmodetection with Danemark

LFI Molière , Villanueva de la Cañada, SPAIN

Who are you?

Students aged 17 to 18 from the LFI Molière Space Club in Spain near Madrid.

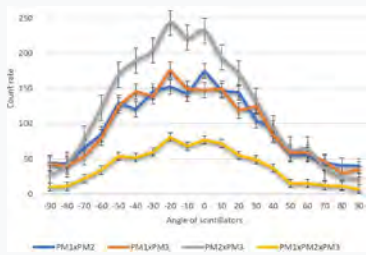
What have you done?

- An exchange by video call with the students of the Prins Henrik high school in Copenhagen, Denmark.

- Descriptions of the equipment and experiments.
- Carrying out a live measurement.

What did you find out?

- The angle of origin of the muons.



- That not all detections were identified as muonic without a coincidence phenomenon.
- A friendly partnership with students from Denmark!

What's your take-home message?

Learn without limits and have fun!

THAILAND

Credit: DESY, Science Communication Lab

Cosmic Ray Research at A.A.A.R.T.

Chiang Mai University, Thailand

Who are you?

We are a research group focused on cosmic rays and neutrinos. We have 1 lecturer, 1 postdoc, 1 RA, 8 grad students. Our mission is to conduct cutting-edge research and to disseminate our findings to the youth, fostering their motivation and sparking inspiration.

What have you done?

We have various activities:

- IceCube Virtual Reality
- Cosmic Watch
- Latitude Survey
- Rosie & Gibbs
- Video Clip

A group of students engaged with the IceCube VR experience. We conducted experiments utilizing the Cosmic Watch device. Our collection includes a Thai-language edition of a series of comic books produced by the IceCube Collaboration. Additionally, we have documented the narrative of our research in a video segment.

What did you find out?

We measure cosmic rays at ground level compared to the 9th floor. The different is about 11%.

Location	Count rate
Ground (310 m asl)	1.379
9^{th} Floor (340 m asl)	1.533

What's your take-home message?

When we learn together, we have more fun. Never stop exploring!
Come and join us at Chiang Mai University!

USA

Impact of Smoke from Canadian Wildfires on Cosmic Ray Flux

New Trier Township High School, Northfield, Illinois, United States

Authors

Evelyn Fang, Katelyn Fang, Sophia Yang, Lindsay Ye, and Maya Zacks

Motivation and Process

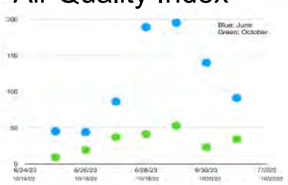
We wanted to learn if dense smoke from wildfires would change the cosmic ray flux. Since barometric pressure influences flux, we found the change of muon events per millibar of pressure in the smoke and on non-smoke days.

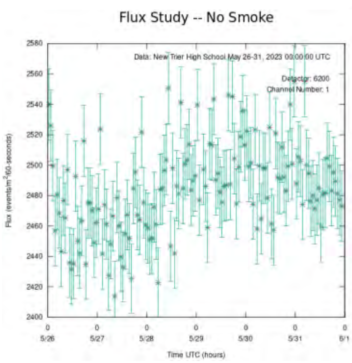
Diagrams and Data

Clear Weather

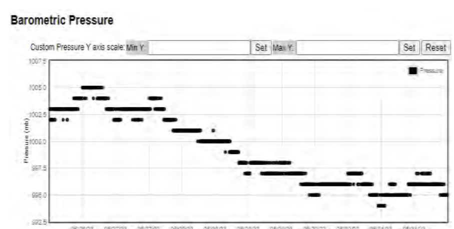
Typical AQI in clear weather compared to smoke.

Air Quality Index

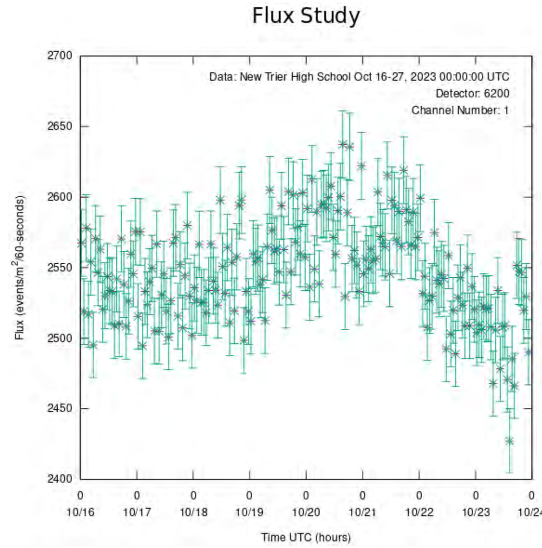


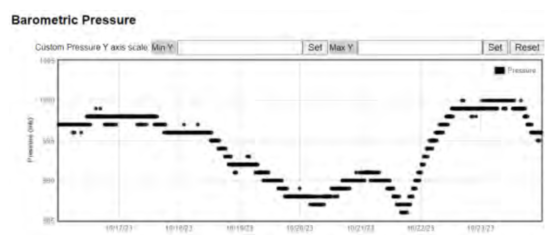


Flux in clear period – May 2023



Corresponding barometric pressure May 2023





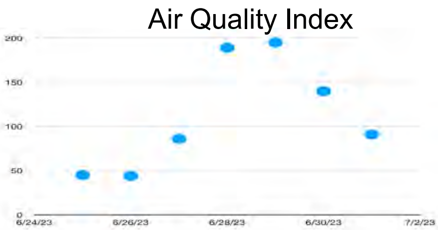
Flux and Pressure – October 2023

May	Flux	Pressure mB
Low Flux	2555	1003
High Flux	2631	996
1 mb = 10.9 events		

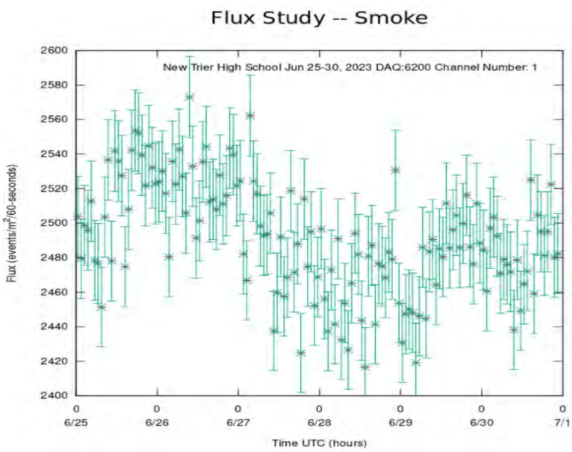
October	Flux	Pressure mB
Low Flux	2510	998
High Flux	2580	986
1 mb = 5.8 events		

Diagrams and Data

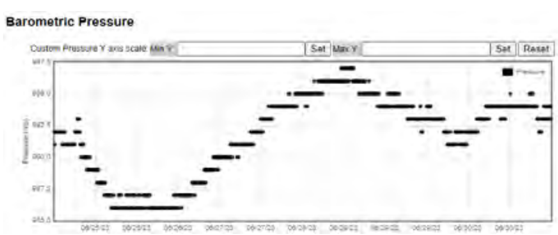
Smoke



AQI during Smoke Times



Flux in smoke period – June 2023



Corresponding barometric pressure June 2023

June-Smoke	Flux	Pressure mB
Low Flux	2593	997
High Flux	2605	986
1 mb = 1.1 events		

What did you find out?

Using the Air Quality Index (AQI) we were able to see which days were clear and which had smoke.

We compared the change in flux per change in millibar of pressure in each data set. In low AQI air (clean air), the change in the number of events per change in pressure was 5.8 events/mB and above. In the high AQI air (smoky) the change in the number of events per change in pressure was 1.1 events/mB.

It was difficult to measure the exact time of low and high pressures and match them with the corresponding time of the flux. There may be some errors in the selection of data points. The flux was measured in bins of 3600 seconds. The pressure was reported every 300 seconds. Determining the best time for the pressure was estimated from the Barometer graphs.

What's your take-home message?

The relationship of muon events to the barometric pressure (mb), during the month of June–where there were significant and measurable amounts of smoke compared to other clear weeks, May to October–the cosmic ray flux decreased on the smoke days. When there is more smoke, there is less cosmic ray muon flux.

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.

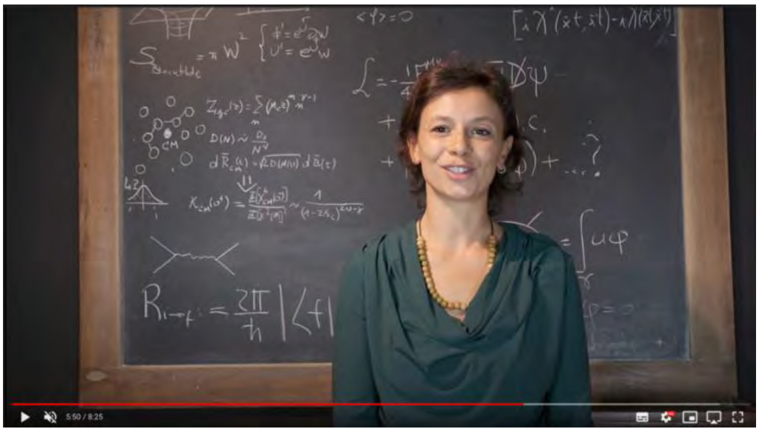
It is only possible to detect cosmic particles and to explore their properties with special equipment. Scientists are trying to find out what kind of **sources** generate cosmic particles and what mechanisms accelerate them to such extremely high energies. Cosmic particles also help to understand the 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:

http://www.physicsmasterclasses.org

Fermilab:

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