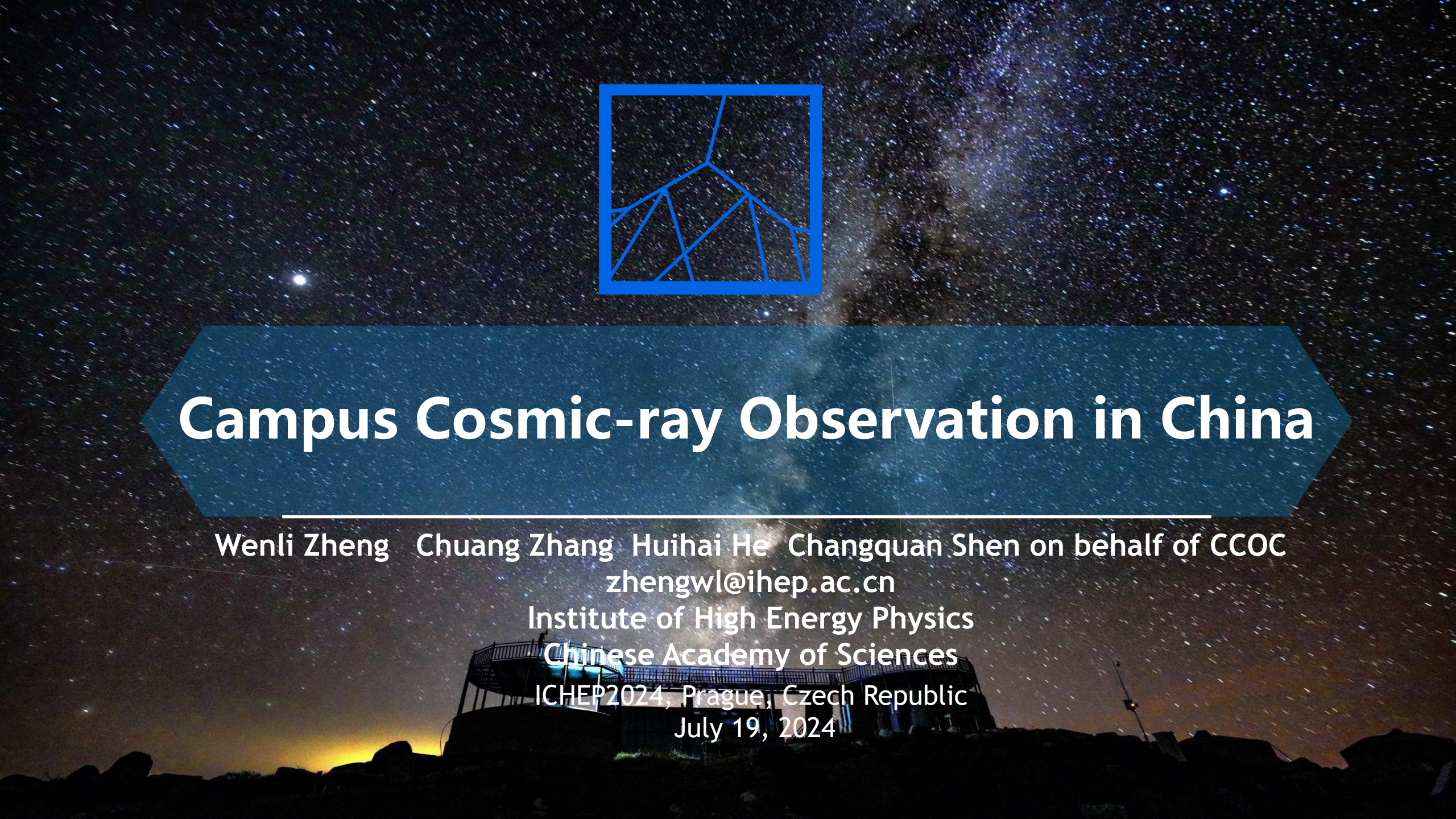


Campus Cosmic-ray Observation in China

Wenli Zheng Chuang Zhang Huihai He Changquan Shen on behalf of CCOC
zhengwl@ihep.ac.cn
Institute of High Energy Physics
Chinese Academy of Sciences

ICHEP2024, Prague, Czech Republic
July 19, 2024

OUTLINE

- About CCOC
- What We Have Done
- What We Plan to Do

About CCOC

Campus Cosmic-ray Observation Collaboration

Why do we conduct cosmic ray observation activities in schools?

- Cosmic rays are naturally available research samples (free of charge), like 'manna from heaven.'
- The instruments and methods for studying cosmic rays are well established and can be learned by students after training, mastered by physics teachers, and are safe to use.
- There are already several hundreds of high schools and universities in many countries around the world with successful experiences.

About CCOC

Campus Cosmic-ray Observation Collaboration

- Established on September 28, 2020
- Connected to the Institute of High Energy Physics (IHEP), Chinese Academy of Sciences (CAS)
- Relying on the Large High Altitude Air Shower Observatory (LHAASO) and *Modern Physics*
- Everyone is a volunteer

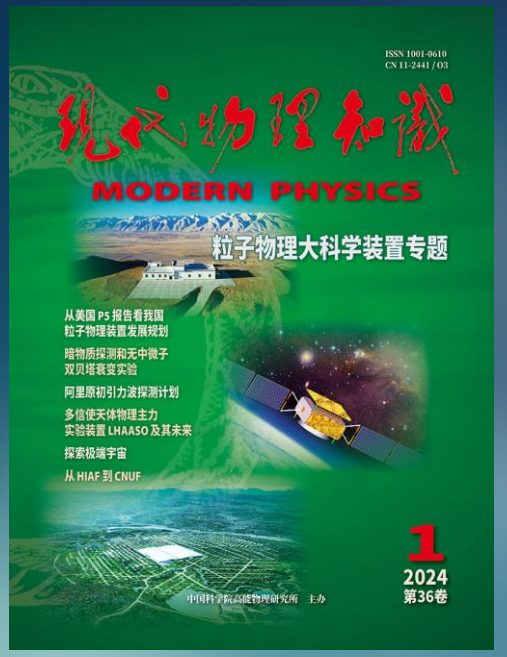
Purpose

- ✓ to set up campus observation stations and network
- ✓ to popularize cosmic-ray knowledge
- ✓ to encourage cosmic-ray study
- ✓ to strengthen collaboration on cosmic-ray observation
- ✓ to facilitate student and teacher training
- ✓ To strengthen relevant international exchanges

LHAASO and Modern Physics

- 2016: began construction
- Goal: aims at **exploring the origin of high-energy cosmic rays and conducting scientific researches on high energy astrophysical radiation**
- Located 4,410 meters above sea level on Mt. Haizi in Daocheng, Sichuan Province, China, and covers an area of 1.36 km^2
- **Achieved numerous significant scientific results since 2019**

- 1976: **a popular science magazine in Chinese** covering all areas of physics, pure and applied
- serves **the physics community** of researchers, college students, graduate students, high school teachers and other people interested in physics.
- sponsored by the Institute of High Energy Physics, CAS and High Energy Physics Branch of Chinese Physical Society



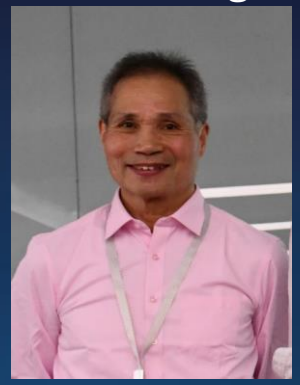
About CCOC

Organization

Advisor
C.Q.Shen

Advisor
W.Q.Zhang

Director
C. Zhang



Vice Director
D.Chen

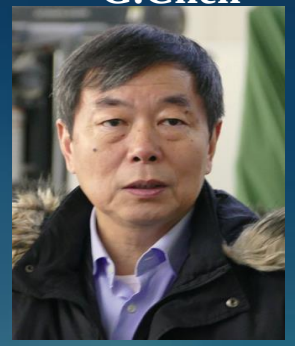
Vice Director
S.W.Cui

Vice Director
S.Wang

TD
H.H.He

Secretary General
W.L.Zheng

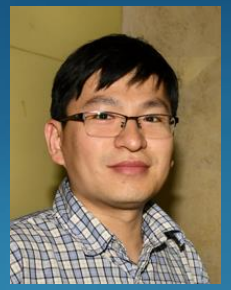
Member of the Council
G.Chen



J.Liu

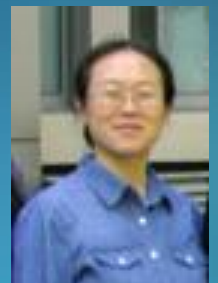
Z.C.Tang

J.L.Xu



Y.D.Cheng

H.M.Zhao



F.R.Zhu

Working Groups

- Technical development WG
  - by H.H. He
- Educational instrument WG
  - by C. Gu
- Campus promotion WG
  - by S. Wang
- Cosmic-ray popularization WG
  - by S.W. Cui
- Secretary service WG
  - by W.L. Zheng

About CCOC

Members: 30 institution members, 6 person members

High Schools (15)

1 Beijing Dongzhimen High School
2 Beijing ChenJingLun High School
3 Beijing Huiwen Middle School Chuiyangliu Branch
4 Shijiazhuang No. 1 High School
5 Zhangjiakou No. 5 High School
6 Jiangyan High School of Jiangsu Province
7 Jiangsu Province Xinghua Senior Middle School
8 Wang Ganchang High School
9 Yangzhou High School of Jiangsu Province
10 Hunan Normal University Affiliated Middle school
11 Luxi High School
12 Quanzhou Yicong High School
13 Shenzhen Overseas Chinese Town Middle School
14 Chengdu Eastern New District No. 4 High School
15 Shanghai Kongjiang Senior High School

Universities(10)

1 Tsinghua University
2 Hebei Normal University
3 Shandong Management University
4 Southwest Jiaotong University
5 Tibet University
6 Sun Yat-sen University
7 Yunnan University
8 Central China Normal University
9 Henan Normal University
10 Shandong University

Institutes(5)

1 Institute of High Energy Physics,CAS
2 511 institute
3 Hefei Institutes of Physical Science,CAS
4 Institute of Energy, Hefei
5 Science and Technology Training Center of CAS

OUTLINE

- About CCOC
- What We Have Done
- What We Plan to Do

Practice

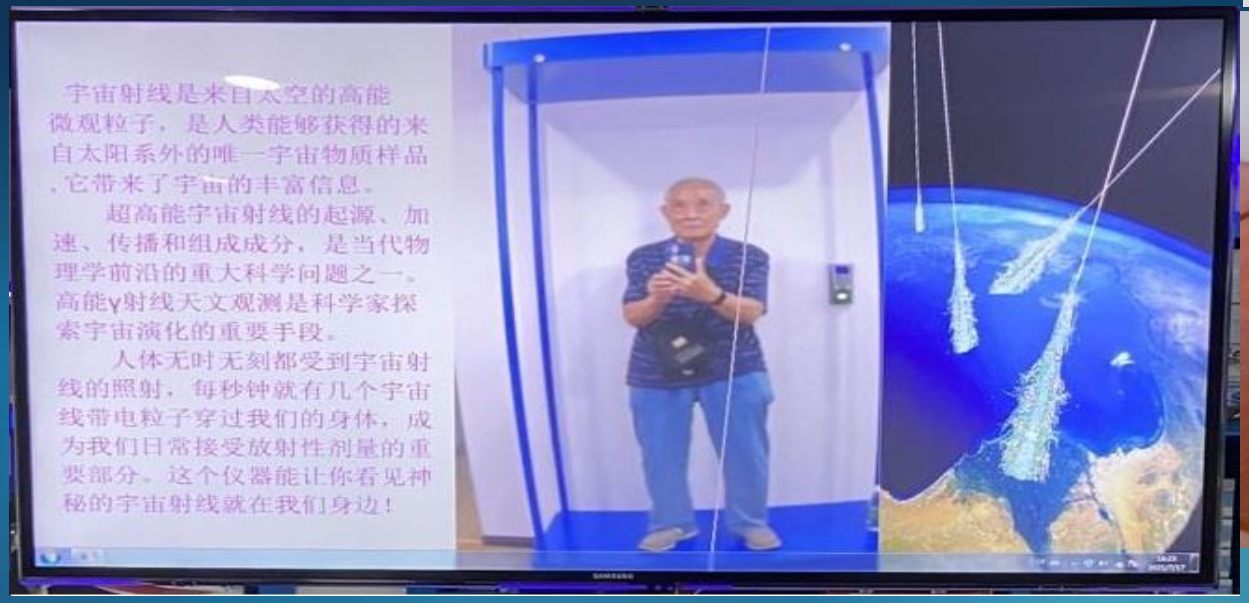
1. Push forward R&D of instruments

Cosmic Ray Detector Array

Muon Telescope

Cosmic Ray Hodoscope

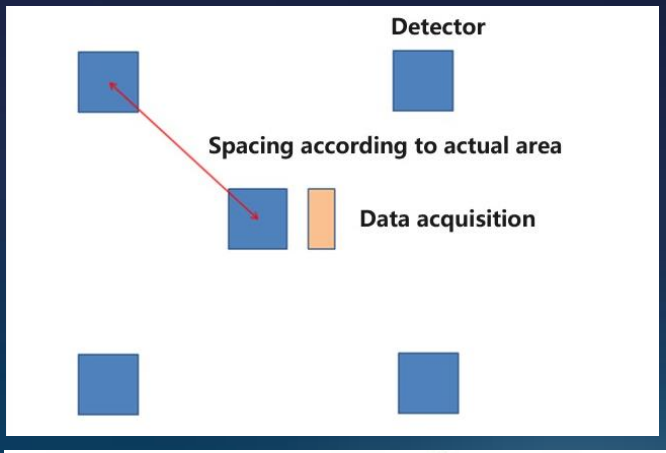
Cosmic Ray Visualizer



Practice

2. Set up cosmic-ray observation stations in campuses

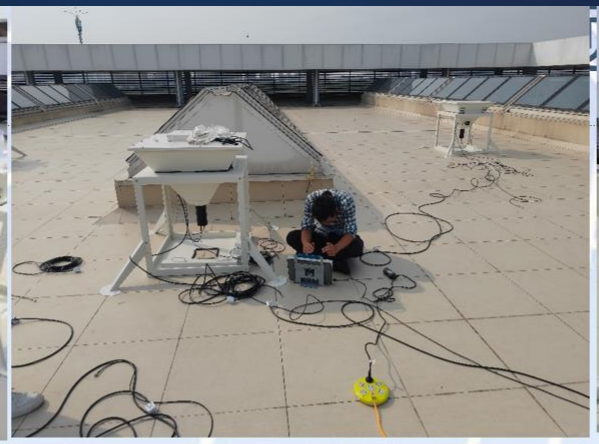
Installation and Commissioning of the Cosmic Ray Observation Equipments at the High Schools

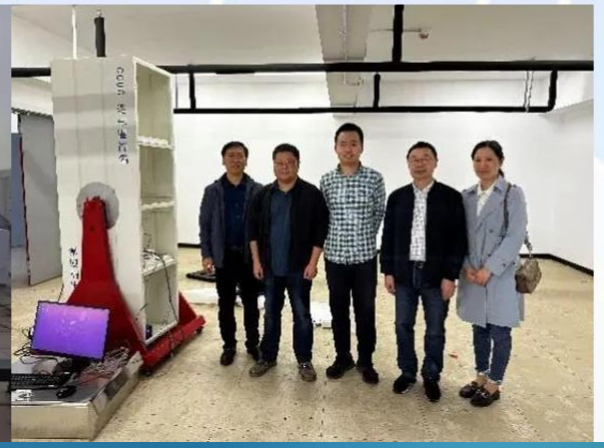


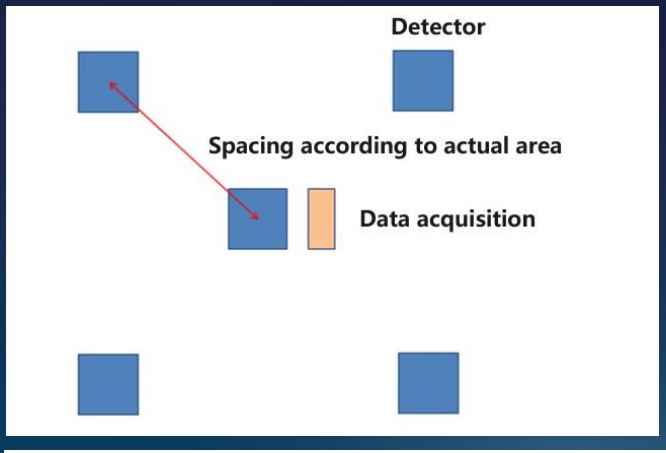
Practice

2. Set up cosmic-ray observation stations in campuses

Installation and Commissioning of the Cosmic Ray Observation Equipments at the High Schools







Practice

3. Measurements and Courses

Cosmic Ray Detector Array

•Measure the Extensive Air Shower (EAS), which is generated by primary cosmic ray

•Measure the direction of EAS if accuracy better than 2 degrees

•Measure the arriving time of particles if accuracy better than 2 nanoseconds

Muon Telescope

- Measure the cosmic ray muon flux in any specific direction (all different zenith angles and different azimuth angles)
- Measure the speed of cosmic ray muon
- Measure the life of muon
- Measure the east-west different effect of cosmic ray flux indused by earth magnetic field

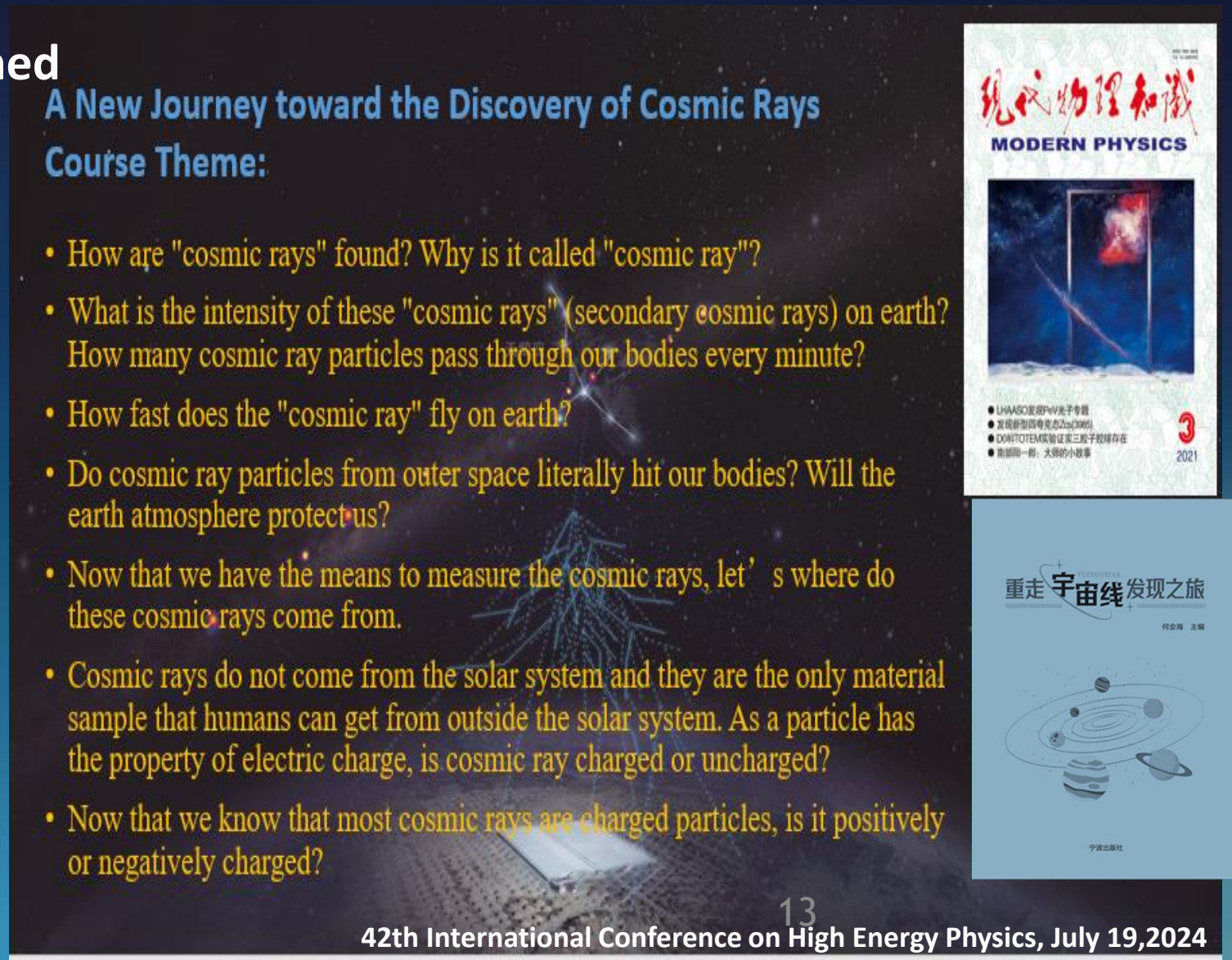
Practice

3. Measurements and Courses

14 lessons are designed and published serially on Modern Physics, with a book currently being published

Objective:

- Reignite curiosity and interest
- Stimulate the desire for inquiry
- Develop the habit of asking questions
- Enhance confidence in problem-solving
- Master basic scientific methods
- Cultivate innovative thinking



Practice

4. Facilitate the cosmic-ray observation and study

- Create the cosmic-ray observation database
- The data from existing campus stations are stored
- The data can be shared by all the members of CCOC
- Incorporated with CCOC website (ccoc.ihep.ac.cn)

Data Center Website


ccoc.ihep.ac.cn/datacenter/

校园宇宙线数据中心

首页 图集 校园站点 校园宇宙线联盟

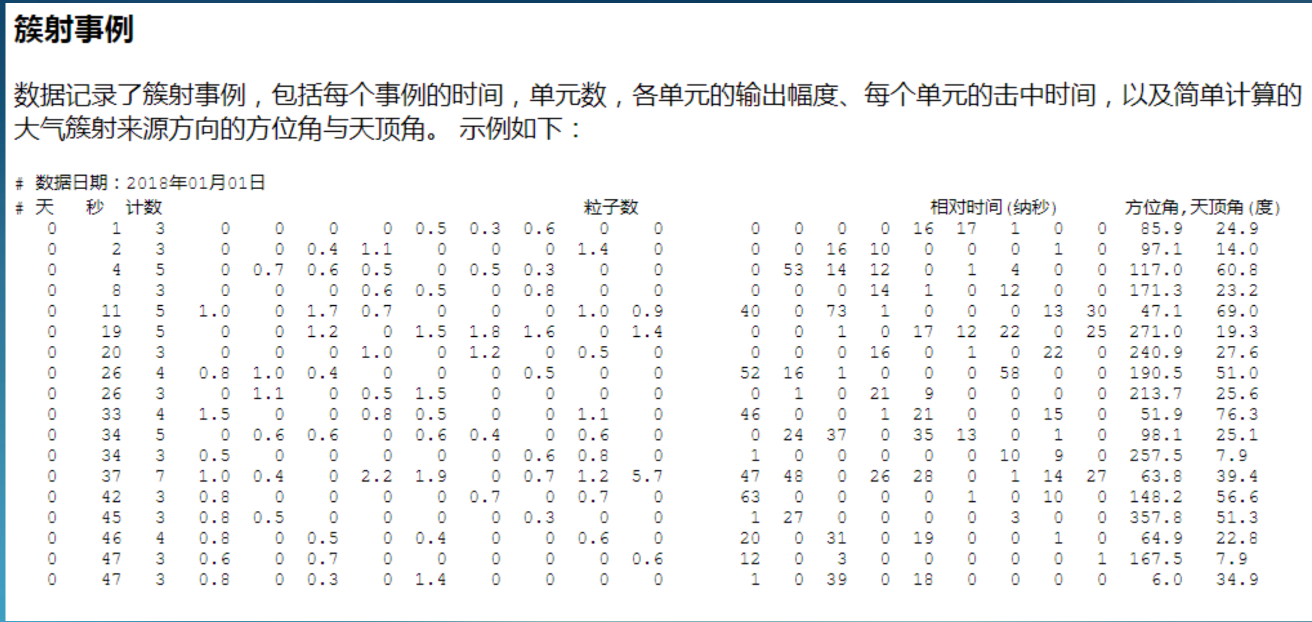
欢迎！

这里是校园宇宙线联盟数据中心。

依托校园宇宙线联盟，作为一个高能物理及宇宙线科研与科普结合的项目，我们通过布置在中学校园和高等院校里的小型探测阵列进行宇宙线观测，推动科学前沿与教育教学的有机结合。同时通过共享这些探测站点的数据，不具备建设条件的学校也可以参与到其中。

本网站将提供科学数据展示，原始数据共享，培训文档等功能。具体请查看相应的页面。

数据中心分享平台提供现有站点的历史数据查询和下载功能，网站上也提供数据处理的教程。可供感兴趣的学校使用，进行数据处理，进行自己的学生科普实践和宇宙线研究。 数据平台上的提供的数据包括文本格式和ROOT格式，包括全部的初级数据和相应的在线刻度数据，以及经过选择和重建的大气簇射事例。 数据平台上还提供了部份事例的示意图以及统计信息图表。


簇射事例

数据记录了簇射事例，包括每个事例的时间，单元数，各单元的输出幅度、每个单元的击中时间，以及简单计算的大气簇射来源方向的方位角与天顶角。 示例如下：

数据日期：2018年01月01日

# 天	秒	计数	粒子数									相对时间 (纳秒)									方位角，天顶角 (度)	
0	1	3	0	0	0	0	0.5	0.3	0.6	0	0	0	0	0	0	16	17	1	0	0	85.9	24.9
0	2	3	0	0	0.4	1.1	0	0	0	1.4	0	0	0	16	10	0	0	0	1	0	97.1	14.0
0	4	5	0	0.7	0.6	0.5	0	0.5	0.3	0	0	0	53	14	12	0	1	4	0	0	117.0	60.8
0	8	3	0	0	0	0.6	0.5	0	0.8	0	0	0	0	0	14	1	0	12	0	0	171.3	23.2
0	11	5	1.0	0	1.7	0.7	0	0	0	1.0	0.9	40	0	73	1	0	0	0	13	30	47.1	69.0
0	19	5	0	0	1.2	0	1.5	1.8	1.6	0	1.4	0	0	1	0	17	12	22	0	25	271.0	19.3
0	20	3	0	0	0	1.0	0	1.2	0	0.5	0	0	0	0	16	0	1	0	22	0	240.9	27.6
0	26	4	0.8	1.0	0.4	0	0	0	0.5	0	0	52	16	1	0	0	0	58	0	0	190.5	51.0
0	26	3	0	1.1	0	0.5	1.5	0	0	0	0	0	1	0	21	9	0	0	0	0	213.7	25.6
0	33	4	1.5	0	0	0.8	0.5	0	0	1.1	0	46	0	0	1	21	0	0	15	0	51.9	76.3
0	34	5	0	0.6	0.6	0	0.6	0.4	0	0.6	0	0	24	37	0	35	13	0	1	0	98.1	25.1
0	34	3	0.5	0	0	0	0	0	0.6	0.8	0	1	0	0	0	0	0	10	9	0	257.5	7.9
0	37	7	1.0	0.4	0	2.2	1.9	0	0.7	1.2	5.7	47	48	0	26	28	0	1	14	27	63.8	39.4
0	42	3	0.8	0	0	0	0	0.7	0	0.7	0	63	0	0	0	0	1	0	10	0	148.2	56.6
0	45	3	0.8	0.5	0	0	0	0	0.3	0	0	1	27	0	0	0	0	3	0	0	357.8	51.3
0	46	4	0.8	0	0.5	0	0.4	0	0	0.6	0	20	0	31	0	19	0	0	1	0	64.9	22.8
0	47	3	0.6	0	0.7	0	0	0	0	0	0.6	12	0	3	0	0	0	0	0	1	167.5	7.9
0	47	3	0.8	0	0.3	0	1.4	0	0	0	0	1	0	39	0	18	0	0	0	0	6.0	34.9

Practice

5. Communications

Campus Cosmic Ray Observation Summer School (2021-2023)

- Popular science reports on large scientific facilities
- Cosmic ray observation courses
- Experience exchange on campus observation activities
- Visiting the lab

Practice

5. Communications

Coordinate the members to participate the ICD、IMW、IMC in China；CCOC Seminar with DESY

Discover Cosmic Rays

INTERNATIONAL COSMIC DAY

10 YEARS

November 10 | 2021

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 Rays 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?

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

Image Credit: DESY, Science Communication Lab

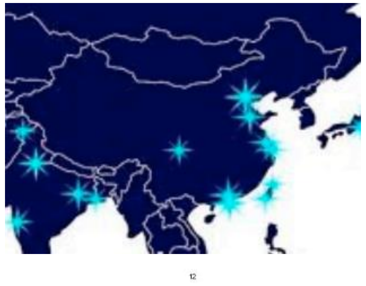
https://icd.desy.de
https://www.facebook.com/InternationalCosmicDay

IPPOG · Netzwerk Teilchenwelt · DESY · Fermilab · QuarkNet

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



CCOC,we are from China!

校园宇宙线联盟

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

Who are we?

Campus Cosmic-ray Observation Collaboration

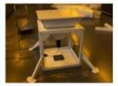
What have we done?

Campus Cosmic-ray Observation Collaboration (CCOC) organized to participate in the activities of international Cosmic Day 2021 in China.

Six CCOC member institutions participated in the 2021 event.

Liu Jia, member of the campus cosmic-ray working group of the Institute of High Energy Physics, associate researcher of the core backbone of the Large High Altitude Air Shower Observatory (LHAASO) project, presented a report of "LHAASO and Campus Cosmic-ray Observation", focusing on the completion of LHAASO, major innovative achievements and the progress of the CCOC in promoting the campus cosmic-ray observation project.

What did we find out?



What's your take-home message?

More activities in ICD! More fun!

An Investigation on the Relationship of Cosmic Muon Flux and Zenith Angle

中国人民大学附属中学

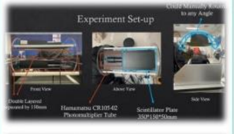
High School Affiliated to Renmin University of China

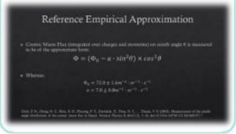
Who are you?

Lang Ji, Yinglun Ma, Shuangyi Zhou, Fengyi Wang, Shangchen Wu
A team of student-body Cosmic Ray enthusiasts dedicated to explore and publicize particle physics in high schools
Directed by Xiaohui Chen, Xiangcui Lei, Yaping Cheng, Ran Han

What have you done?

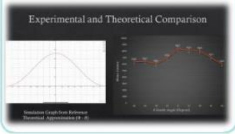
An investigation on the relationship between Muon Flux with Zenith Angle





What did you find out?

A great qualitative fit between experimental data and referenced approximation



What's your take-home message?

- A maximum Muon Flux at 0 degree zenith angle
- Continuous symmetrical decline of Muon Flux with increasing/decreasing zenith angle
- A qualitative validation is made to the reference empirical approximation
- The results of our experiment can be utilized in interpreting the internal structure of concealed objects, (e.g. nuclear plants) and cosmic ray detection in outer space.

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

北京市东直门中学

Beijing Donzhimen High School

1. Equipment

When a very high energy primary cosmic ray arriving atmosphere, it collides with air nuclei, and by interaction produces a several secondary particles. All secondary particles with very high energy collide with air nuclei again, through strong or electric-magnetic interaction produce more secondary particles. Such cascade interaction forms a great number of particles flight down as a shower. Such phenomenon is called as Extensive Air Shower (EAS).

On the roof of our school, we built a detectors array to measure EAS, as shown in Figure 1. It consists of 9 scintillation detectors, spaced 10 meters apart as a 3×3 matrix and each detector has a sensitive area of 0.5 square meters . It is located at: latitude 39.933°N, longitude 116.417°E, altitude 46.4 meters above sea level. The electronics digitalize each signal from detectors, a computer continuously acquires data and controls all the equipment online. Whenever a charged particles of cosmic ray passes through our each detector, the GPS time with nanosecond accurancy, amplitude of signal, and triggered detector's location are recorded.

Fig. 1. An EAS array on the roof of our school.

2. Data analysis

Some procedures to reconstruct the measured tracks of EAS have done. they reconstruct only the EAS event in 400 square meters covered by our array with coincident fold ≥3. We analyzed the direction of each EAS event during t=3 days since Beijing time 0 o'clock on 16th October 2021, and obtained the events number Ni in each range of the i=9 zenith angle uniform ranges from 0 ° to 90 °. Its standard error σi=Ni0.5 . For the zenith angle range A to B, it covers a stereoscopic angle Ω=2π (cos A–cos B), and the effective area of the array is 400m2 ×COSθi (θi is the median of zenith angle range i). By this way, we get the average EAS intensity Ii=Ni÷ (3×Ωi×COSθi) in each zenith angle range within the unit steradian range and 1 day. Its standard error σIi =σi÷ (3×Ωi×COSθi).

江苏省姜堰中学

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

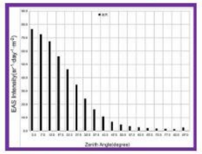
江苏省姜堰中学

Jiangyan High School of Jiangsu Province,China

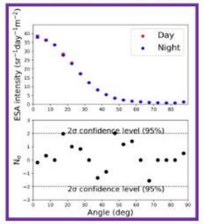
Our Team

Jiangyan High School of Jiangsu Province,China

Data Analysis



↑ *The EAS intensity of cosmic rays decreases with the increase of zenith angle*



↑ *The comparison of cosmic ray EAS at different zenith angles of day and night*

Experimental conclusion

We found that the EAS intensity of cosmic rays decreases with the increase of zenith angle. After the zenith angle degree increases to a certain value, the EAS intensity decreases significantly and becomes gentle with zenith Angle.

We also found that there is no significant difference in the change of cosmic ray EAS intensity with zenith angle during the day and night. This shows that solar activity has little effect on the EAS intensity of cosmic rays observed on the ground.

Xinghua High School of Jiangsu Province Successfully Participated in the 10th International Space Day Exchange Activity

江苏省兴华中学

Xinghua High School of Jiangsu Province, China

Who are you?

At 13:30 GMT on November 10, 2021, nine students from Xinghua High School of Jiangsu Province successfully participated in the 10th International Space Day international exchange activity!

The Video Call

The students of Xinghua High had an interactive discussion in English with five other cosmological ray research teams from different countries and showed foreign researchers their experimental data and research conclusions drawn through their cosmic ray detection device made by the open programming.

International Cosmic Day

The activity on the International Cosmic Day is intended to make more people pay attention to the cosmic rays existing around them at all times, encourage college and middle school students to collect cosmic ray data, exchange research methods and results, and directly participate in the forefront of contemporary cosmic ray research.

By means of such global joint activity, students, teachers, scientists, the general public, or anyone interested, will have a broad understanding of such questions: What are cosmic rays? Where do cosmic rays come from? And how to measure cosmic rays?

In 2019, Xinghua High School of Jiangsu Province and the Chinese Academy of Sciences established the relationship of 'cooperation between the Chinese Academy of Sciences and Xinghua High'. In order to cultivate more backup talents for scientific and technological innovation and give more students the opportunity to join the talent plan under the guidance of colleges and universities, Xinghua High has promoted their school-running philosophy 'Institutional Cooperation, Joint Development for the Cultivation of Innovative Talents' to the 'Taizhou Excellent Education Project', aimed at further promoting the improvement of students' scientific and technological attainments while continuously pushing forward quality-oriented education. As a consequence, the core members of the program will be engaged as mentors for the building of the Local Integrated Practice and Research-based Learning Curriculum.

To carry out cosmic ray research in middle schools is an effective way to combine science popularization with scientific research. When scientists and schools work together, with

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EAS Changed With Zenith Angle

湖南师范大学附属中学

The High School Attached To Hunan Normal University

Ⅰ.Background

Cosmic rays usually consist of high-energy particles from space. On the way high-energy cosmic rays shoot from space to earth, they need to pass through the atmosphere and it is the time that they interact with atomic nuclei in the atmosphere, knocking out various secondary particles. These secondary particles will interact with atomic nuclei in the atmosphere again during the flight, producing more secondary particles, which are sprinkled from the air to the earth like a rainstorm, and conducting cascade reactions continue to occur in this way. This process is also known as "air shower". More specific, these secondary particles produced by cosmic rays repeatedly act to produce more secondary particles until the average energy is equal to a certain critical value, and the number of secondary particles reaches the maximum value, which is called shower maximum. After that, the particles gradually decay or are affected by the atmosphere. Absorption, so that the number of secondary particles gradually decreases.

High-energy cosmic rays can form "showers" with large area, which produce a large number of secondary charged particles reaching the ground almost simultaneously.

By measuring these charged particles arriving at the same time, the "shower" cases can be obtained. Scientists usually study on cosmic rays by indirectly detecting these "showers" reaching the surface of the earth. In general, the higher the energy of cosmic rays, the larger the shower area that reaches the surface. In practical experimental setup, detector array are often used for detection.

In this article, we analyzed the data detected by the detector array of Dongzhimen Middle School in Beijing, China(39.933°N latitude, 116.417°E longitude, 46.4 meters above sea level). The detector array is composed of 9 scintillation detectors, separated by 10 meters, set in a 3×3 matrix pattern, and the sensitive area of each detector is 0.5 square meters.

ANALYSIS OF THE DETECTOR COUNTING RATE

西南交通大学

Southwest Jiaotong University, China

Team Introduction

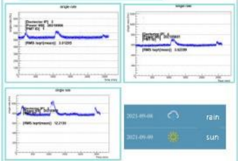
We are the Institute of Astroparticle Physics which consists of 12 teachers, 5 doctoral candidates, some master degree candidates and undergraduates.

What have we done?

Southwest Jiaotong University has five ed detector arrays, which are placed on the roof of the teaching building. The five detectors upstairs transmit the information to the clock synchronization system downstairs through the photoelectric composite cable, and then store it in the computer, so that we can process the data offline.

We focus on the reasons for the change of counting rate, such as whether the atmosphere pollution in Chengdu will lead to the change of counting rate, and whether the counting rate will change suddenly during the period of thunder and heavy rain.

What did we find out?



This is the chart drawn by our team. It is the counting rate of the three detectors collected on September 8. From these three diagrams, we can see that the change of the counting rate has the same trend, and the sudden change of those curves maybe affected by the outside.

The take-home message

We analyzed the data of five detectors, focusing on the study of counting rate, and analyzed the relationship between atmospheric environment and sudden change of counting rate curve.

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

宇宙线EAS强度随方位角的变化

Beijing Donzhimen High School

3. Result

The experimental data are listed in table 1 below, and the corresponding curves are shown in Figure 2.

sequence number i	1	2	3	4	5	6	7	8	9
Range of zenith angle	0°-10°	10°-20°	20°-30°	30°-40°	40°-50°	50°-60°	60°-70°	70°-80°	80°-90°
Mean of zenith angle	5°	15°	25°	35°	45°	55°	65°	75°	85°
Measured counts in 3 days Ni	8284	19047	19442	11969	5613	2584	1281	570	172
Standard deviation of Ni $\sigma_i = Ni^{0.5}$	91	138	139	109	74.9	50.8	35.8	23.9	13.1
Covered steradian Ωi(sr)	0.09546	0.2835	0.4629	0.6282	0.7744	0.8972	0.9926	1.058	1.091
Intensity of EAS Ii(sr⁻¹·day⁻¹·400m⁻²) = Ni÷(3·Ωi·cosθi)	29038	23188	15449	7753	3417	1674	1018	694	603
Standard deviation of Ii $\sigma_{Ii}=Ni^{0.5}÷(3·Ωi·cosθi)$	319	166	111	71	48	33	28	29	46

Table 1. Measurement data for EAS intensity

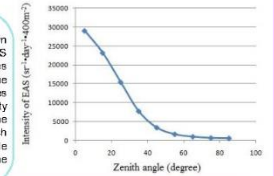


Figure 2. The EAS intensity depending on zenith angle.

4. Discussion

When the primary cosmic ray flights down through atmosphere, the number of EAS particles increases first, then it decreases gradually after reaching a maximum value since the energy of all particles reduces and decaying or stoped probability increase. The higher the initial energy, the more EAS particles survive and reach ground. Only when the detectable particle density reaches threshould value of the ground detector array, such EAS can be detected. Therefore the energy threshold of detectable EAS of a ground array increases with the increase of atmospheric depth.

When zenith angle increases, the depth of the atmosphere increases. Therefore, for a ground array the detectable EAS energy threshold E increases with the increase of the zenith angle. Because the integral intensity of isotropy primary cosmic ray is approximately proportional to E-2, the EAS intensity is the descending function of zenith angle.

Outputs

- A seed of science has already begun to sprout in the hearts of the students.
- Six Stations have been setup.
- Projects for teachers' practice have been approved.
- One book has been published.
- A cosmic ray science education base has been approved.
- The observation activity was selected as an Excellent Science Popularization Activity for National Science Popularization Day 2022.

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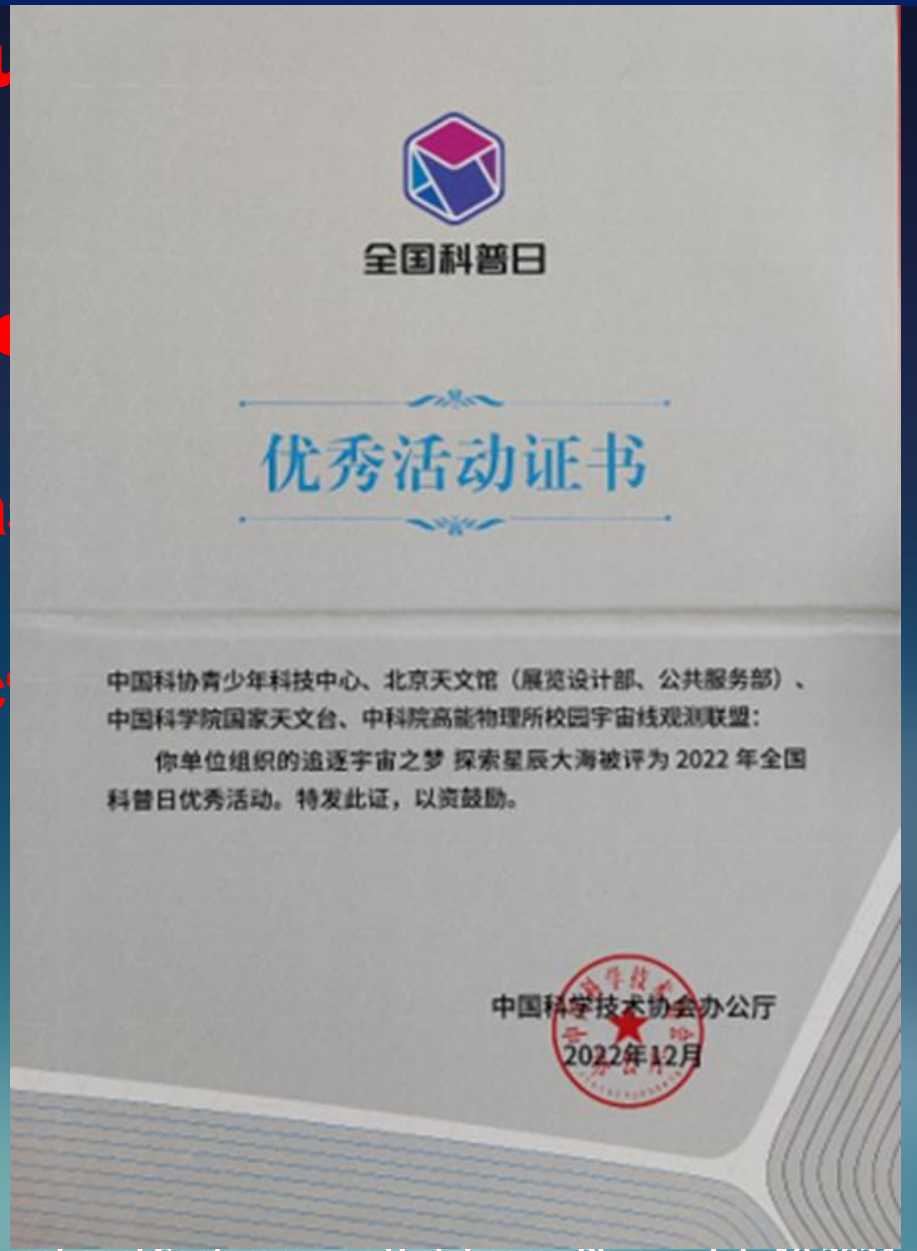

OUTLINE

- About CCOC
- What We Have Done
- What We Plan to Do

What We Plan to Do

Conclusion and Next Plan

Conclusion:

- Providing students with the opportunity to participate in cutting-edge scientific research,enable students to develop independently and grow around scientists
- Receiving authentic training in modern scientific inquiry, and enhancing the overall scientific literacy of both teachers and students
- Fostering students' interest in studying physics
- Broadening the international perspective of teachers and students

Next Plan:

- ✓ Advancing the construction of observation stations in different latitudes
- ✓ Using data from LHAASO for a real simulation analysis
- ✓ Developing a mobile APP for visualizing cosmic ray-related data、a game and a competition for disseminating the cosmic ray knowledge

What We Plan to Do

Challenges

- Fully leverage the enthusiasm and initiative of established schools in conducting observation activities
- Fully utilize the capabilities of the equipment
- Expand research content and achieve deeper integration of science and education
- Sustainable funding support

Q&A