PROCEEDINGS OF SCIENCE

Practical Activities for Campus Cosmic Ray Observation in China

Wenli Zheng[a,*] Chuang Zhang[a], Huihai He[a], and Changquan Shen[a] on behalf of CCOC

aInstitute of High Energy Physics, Chinese Academy of Sciences,
19B Yuquan Road, Shijingshan District, Beijing, China

E-mail: zhengwl@ihep.ac.cn, zhangc@ihep.ac.cn, hhh@ihep.ac.cn, shencq@ihep.ac.cn

Cosmic rays, discovered in 1912, are high-energy particles originating from outer space. They carry rich information about celestial evolution and the universe and represent the only material samples, which humans can obtain from beyond the solar system.

Cosmic ray observation touches on the frontiers of particle physics and astrophysics. The methods and instruments used in the experiments include detectors, electronics, computers, automatic control systems, Global Position System , and data transmission and processing, among other modern physics knowledge and technologies.

This report introduces the construction of China's first campus cosmic ray observation station, the establishment of the Campus Cosmic Ray Observation Collaboration, and the expansion of cosmic ray observation activities to many schools in China. It also covers participation in international exchange activities and the achievements made. After five years of development, reflections and recommendations are provided for conducting such activities in different schools and regions.

The results of this series of practical explorations demonstrate that conducting campus cosmic ray observation activities, with students directly guided by scientists and teachers in real scientific research, stimulates students' curiosity, imagination, and desire for exploration. This lays a solid foundation for cultivating innovative talents in the future.

*39th International Cosmic Ray Conference (*ICRC2025*)*
15–24 July 2025
Geneva, Switzerland

ICRC 2025
The Astroparticle Physics Conference
Geneva July 15-24, 2025

*Speaker

ISSN 1824-8039 . Published by SISSA Medialab.

PoS(ICRC2025)1264

1. Introduction

The Institute of High Energy Physics (IHEP), a Chinese Academy of Sciences(CAS) research institute, is China's biggest laboratory for the study of particle physics.

IHEP operates a range of large scientific facilities, including the currently operational Beijing Electron Positron Collider/Beijing Spectrometer/Beijing Synchrotron Radiation Facility, Hard X-ray Modulation Telescope, China Spallation Neutron Source, Large High Altitude Air Shower Observatory(LHAASO)【1】, and Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor. Facilities under construction include the Jiangmen Underground Neutrino Observatory, Ali Cosmic Microwave Background Polarization Telescope, High Energy Photon Source, and enhanced X-ray Timing and Polarimetry mission. Retired facilities include the Tibet ASγ Experiment and Daya Bay Reactor Neutrino Experiment. Projects in the planning or R&D phase include the Space-based High-energy Cosmic Radiation Detection Facility, Circular Electron Positron Collider, and High Energy Underwater Neutrino Telescope.【2】

IHEP has achieved high-level research outcomes and conducts diverse science communication activities based on these large scientific facilities, such as the Campus Cosmic-Ray Observation Collaboration (CCOC).【3】

The CCOC(ccoc.ihep.ac.cn) relying on the large-scale facility LHAASO and the Modern Physics magazine was established on September 28, 2020, affiliated with IHEP, CAS. It aims to promote cosmic ray observation in schools, cultivate innovative talents, and integrate scientific popularization, talent development. Currently the CCOC is composed of 33 institutional members and 6 individual members around China.

The institutional members consist of 17 high schools, 12 universities, 1 primary school and 4 institutes. The CCOC council consists of 1 director, 2 advisors, 3 vice directors and 23 members.

2. Beginning：China’s first campus cosmic-ray observation station

As one of Beijing's popular science education bases, IHEP has co-established an innovation talent training base with Beijing Dongzhimen High School and other institutions since 2012. This base has fully leveraged its function in cultivating innovative talents by enabling secondary school students to enter research institutes, interact closely with scientists, and engage in scientific research activities under the guidance of these experts. It has nurtured innovative young students for numerous middle schools in Beijing. A physicist from IHEP,CAS helped Beijing Dongzhimen High School to establish China's first station in 2016 (Figure1), and also compiled the textbook "Fundamental Course in Cosmic Ray Physics for Secondary School Students" (figure 2). Students cultivated innovative spirit and teamwork awareness through authentic scientific research. The students in that school also made several popular science instruments under the guidance of researchers from IHEP. These instruments included the "Cosmic Ray Visualizer", "Gamma Radiation Detector", "Cosmic Ray Hodoscope" and a portable "Cosmic Ray Intensity Meter".

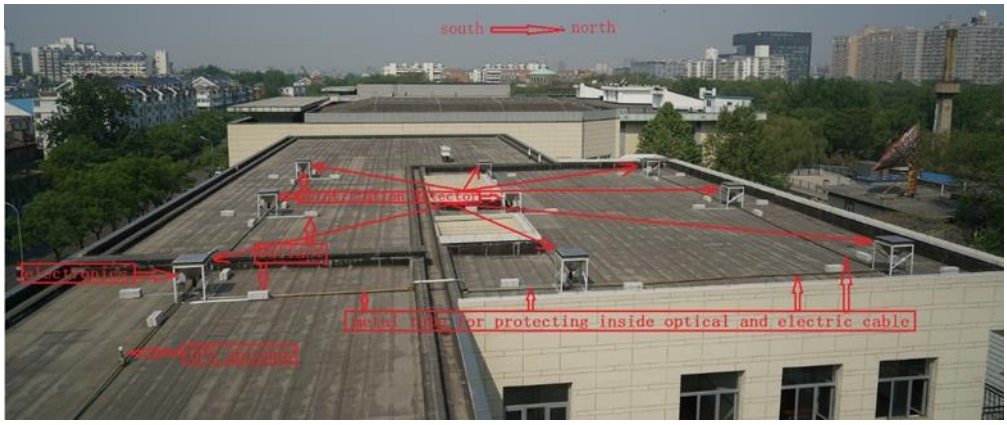


Figure 1: Cosmic Ray Detector Array of Dongzhimen High School.

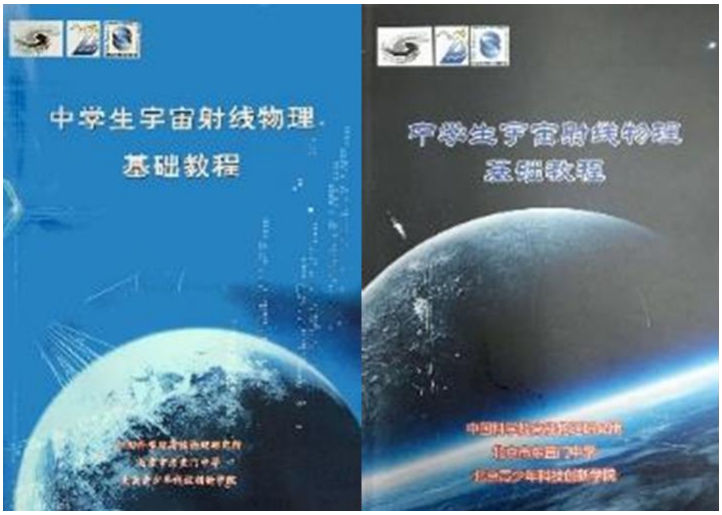


Figure 2: Introductory Guide to Cosmic Rays.

3. Development

3.1 Setting up many observation stations and network

The CCOC optimized the station design for enhanced public interest in science. The new campus cosmic ray observation includes cosmic ray detector arrays and muon telescopes (figure 3 and figure 4). The cosmic ray detector arrays is used to measure the Extensive Air Showers (EAS), which are generated by primary cosmic rays in the atmosphere. Each cosmic ray detector array consists of 5 scintillation detectors with a spacing of about 10 meters in a triangular arrangement. The time resolution of the scintillation detector is better than 2 ns. The trigger multiplicity of the array can be adjusted from 3 to 5, under which the shower direction can be measured with a certain accuracy. A series of scientific practices suitable for students can be carried out on the data of the detector array. The muon telescope, consisting of 2 scintillation detectors whose distance can be adjusted, is used to measure the cosmic ray muon flux in any specific direction (different zenith and azimuth angles), the speed and life time of cosmic ray muons, etc.

Now there already have been 7 campus cosmic-ray observation stations, which 4 at high schools and 3 at universities.

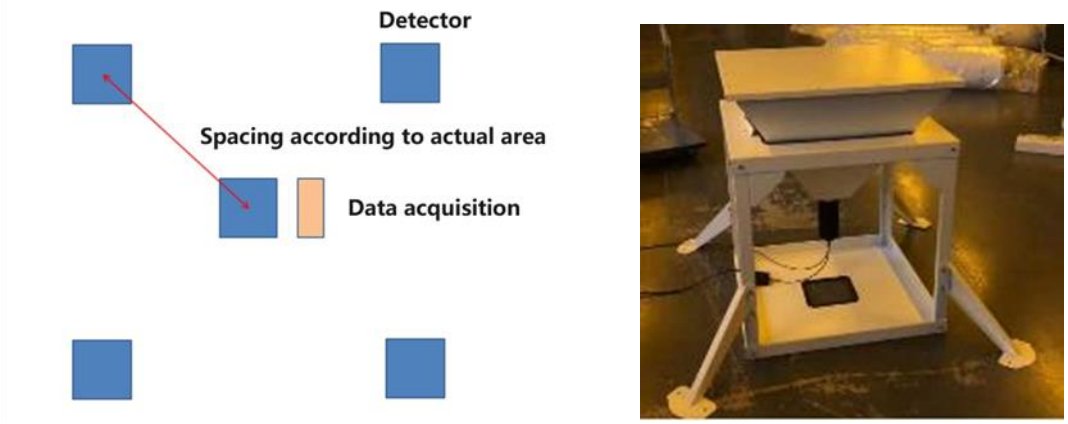


Figure 3: Schematic of the Arrays and A Scintillation Detector.

Figure 4: Schematic of the Muon Telescope and Physical Object.

3.2 Creating the database center and APP

The CCOC has established a cosmic ray observation database to achieve data sharing. The data from existing campus stations is stored. Current Status is Dongzhimen High School data is available from 2018-present. The data can be shared by all the members of the CCOC for public access. It is requested based download after scientific review. The CCOC data center website is http://ccoc.ihep.ac.cn/datacenter/ (figure 5).

The CCOC also set up a virtual cosmic ray observatory: "Digital Twin" of physical detection systems. Its core concept is an immersive platform that combines cosmic ray science with interactive exploration to boost user engagement through knowledge-rich content layers, continuous discovery mechanisms and gamified learning experiences. The App named as COSLink / "宇联" in Chinese (figure 5). Its core features are interactive station network map, real-time event visualization, historical data analytics and station performance ranking.

Figure 5: The Show of the Website of Data Center and APP.

3.3 Developing the course "Retracing the Journey of Cosmic Ray Discovery" and publish a textbook and articles in MP

The CCOC has designed 14 lessons of "Retracing the Journey of Cosmic Ray Discovery", such as the following contents (figure 6):

a) What are cosmic rays?

How can experiments demonstrate that these "rays" originate from outer space and are high-energy particles traveling at speeds very close to that of light?

b) How many cosmic rays pass through the human body per second?

By experimentally counting the number (flux) of cosmic rays, we can explore whether these high-energy particles, which constantly and unnoticed traverse the human body, pose any harm to humans.

c) What is an Extensive Air Shower?

Through coincidence measurement experiments, we can investigate what an extensive air shower is. In 1938, the great scientist Pierre Auger discovered extensive air showers using this method.

d) Isn't the sun the most likely source of cosmic rays?

Guide students to determine through experiments whether the sun is a source of cosmic rays.

e) Are cosmic rays charged or neutral particles?

Allow students to verify or refute their hypotheses through experiments.

f) If cosmic rays are charged particles, are they positively or negatively charged?

Encourage students to test their conjectures by measuring differences in the intensity of certain effects caused by cosmic rays.

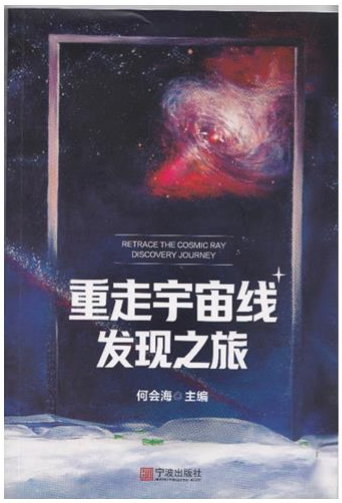
g) What other characteristics do cosmic rays have?

Measure some properties of cosmic rays.

h) Some exploratory experiments

For example, measuring the energy spectrum of cosmic rays, the absorption length of cosmic rays in the atmosphere, and the speed of light (although cosmic rays are not light, their speed is very close to that of light). Once the campus cosmic ray project reaches a certain scale, collaborative experiments among multiple schools can be conducted, such as studying the geographic latitude effect of cosmic rays and how cosmic ray flux varies with altitude.

Throughout this series of experiments, students will gain a preliminary understanding of the microscopic world, master some simple statistical analysis methods, and apply mathematical knowledge from middle and high school, such as solving polynomial equations, geometric algorithms, series, and trigonometric functions. Additionally, students will engage in hands-on exploration with specific questions in mind, leading to a deeper comprehension. Finally, they will summarize their findings in papers and reports, and may even represent China in International Cosmic Day activities.




重走宇宙线发现之旅

Figure 6: The Text Book and the Article From the MP.

4. Practice

The CCOC has organized a series of science communication activities, including the campus cosmic ray observation summer schools from 2020-2025 (figure 7), coordinating the members to participate the International Cosmic Day (figure 8), International Muon Week and International Masterclass (figure 9) in China to explore cutting-edge research and engage in global exchanges. There are popular science reports on large scientific facilities, cosmic ray observation courses, experience exchange on campus observation activities and visiting the lab arranged during the summer schools.

Since its establishment, the CCOC has successfully organized and participated in the International Cosmic Day activities from 2020 to 2024. Starting with one participating institution during the 2016-2019 period, the event has now grown up to 10 institutions. This initiative has broadened the international perspectives of high school teachers and students while fostering global exchanges in science popularization and science education.

Participation in activities of ICD, IMW and IMC is detailed in Table 1.

Year/Unit	ICD	IMC	IMW
2016-2019	1		
2020	4		
2021	6		
2022	6		
2023	10		3
2024	9	8	4
2025		2（Targeted Invitation）	5

Table 1 CCOC Activities of ICD, IMW and IMC

Figure 7: Pictures of CCOC training courses and workshops in 2023 and 2025.

Figure 8: Pictures of CCOC Members in the International Cosmic Day in 2023.

Figure 9: Pierre Auger Observatory IMC 2025 -"A Day as a Scientist".

5.Output

Schools have garnered many prestigious accolades after they attended the campus cosmic ray observation activities. Teachers and students at the schools have been awarded many innovation talent grants.

The CCOC has been awarded multiple distinctions and competitive funding. 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. The CCOC has earned the title of "Top-Performing Team" in the Chuangyijia Innovation Initiative.

6.Conclusion and Next Plan

The CCOC provides the teachers and students with the opportunity to participate in cutting-edge scientific research, enable them to develop independently and grow around scientists. They receive authentic training in modern scientific inquiry. The CCOC enhances the overall scientific literacy and broad the international perspective of both teachers and students.

The next plan of the CCOC is to utilize IHEP's major research infrastructures and CCOC's network for impactful science popularization, use data from LHAASO for a real simulation analysis, develop the cosmic ray track detectors and visualization instrument, collaborate with science museums (in Beijing, Shanghai, Hefei, Macau, etc.) to organize campus cosmic ray observation activities.

References

[1] LHAASO Collaboration. The LHAASO Science Book [J]. Chin. Phys. C, 2022, 46(3): 030001.

[2] https://ihep.cas.cn/gk/jj/

[3] W. L. Zheng et al., "Campus Cosmic-ray Observation Collaboration and its Activities," in Proc. 38th Int. Cosm. Ray Conf. (ICRC2023), 2023, p.1631.

Acknowledgments

The authors gratefully acknowledge the support from the following people: J.Liu, D.Chen, S.W.Cui, Y.Zhang, G.Chen, Z.C.Tang, Y.D.Chen, J.B.Ye, L.M.Song, J.Yu, H.M.Zhao, C.M.Zhao, L.Dang, S.Weng, N.Y.Cheng, X.Wu, Y.J.Wang, X.L.Bian.