PROCEEDINGS OF SCIENCE

Campus Cosmic-ray Observation Collaboration and Its Activities

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Cosmic rays are natural and readily available. The observation activities of cosmic rays in the middle school can stimulate students' deeper understanding of our nature. Through the construction of the campus cosmic-ray observation network, the cosmic-ray research is brought into the schools, so that students have the opportunity to get a glimpse of the frontier research, receive the real training of modern scientific research, comprehensively improve the scientific and technological quality of teachers and students, and stimulate students ' interest in learning physics. Campus Cosmic-ray Observation Collaboration (CCOC) is a non-profit collaboration unit composed of members voluntarily. It is a trinity of science popularization, personnel training and scientific research. CCOC is supported by the Institute of High Energy Physics, Chinese Academy of Sciences. The activities are mainly based on the large scientific infrastructure project 'Large High Altitude Air Shower Observatory ' (LHAASO) and the popular science journal ' Modern Physics'. This report will give a brief description on CCOC and the activities carried out since the it was established on September 28, 2020, including the setting up campus observation stations and network, popularizing cosmic-ray knowledge, encouraging cosmic-ray study, strengthening collaboration on cosmic-rays observation, facilitating student and teacher training and strengthening relevant international exchanges. CCOC hopes to learn and communicate with international colleagues on how to carry out outreach and education experience in cosmic-ray based on large scientific devices.

38th International Cosmic Ray Conference (ICRC2023)
26 July - 3 August, 2023
Nagoya, Japan

ICRC2023
38th International Cosmic Ray Conference
The Astroparticle Physics Conference

[*] Speaker

PoS(ICRC2023)1631

1. Introduction

Cosmic rays are natural and readily available. The observation activities of cosmic rays in the middle school can stimulate students' deeper understanding of our nature. Through the construction of the campus cosmic-ray observation network, the cosmic-ray research is brought into the schools, so that students have the opportunity to get a glimpse of the frontier research, receive the real training of modern scientific research, comprehensively improve the scientific and technological quality of teachers and students, and stimulate students ' interest in learning physics.

China has carried out researches on alpine cosmic rays long time ago.In 1954,the first cosmic ray laboratory in China was built at a height of 3200 meters in Luoxue Mountain, Yunnan.The world's highest alpine emulsion chamber was established in 1977 at a height of 5500 metres in Gambala Mountain, Tibet.In 1988, Huairou Extended Atmospheric Shower (EAS) Array Launched.In 1990 and 1998, the Cosmic ray Observation Array of China-Japan Cooperation and China-Italy Cooperation was built in Yangbajing,Tibet respectively,Asγ and ARGO.In 2021, the Large High Altitude Air Shower Observation(LHAASO) was compeleted. It is located 4,410 meters above sea level on Mt. Haizi in Daocheng, Sichuan.

LHAASO began its construction in 2016. It consists of three arrays: a ground particle detector array made up of 5,216 electromagnetic particle detectors (EDs) and 1,188 muon detectors (MDs), covering an area of 1.36 km^2; a water Cherenkov detector array (WCDA) consisting of 3120 detector cells, covering an area of 78,000 m^2; and a telescope array (WFCTA) composed of 18 wide-field-of-view Cherenkov telescopes. By employing hybrid measurements of extensive air showers (EAS) through these detector arrays, LHAASO achieves unparalleled sensitivity in detecting ultra-high-energy gamma rays and conducting all-sky surveys for very high-energy gamma ray sources. Additionally, it will provide measurements of the energy spectrum of cosmic rays across an exceptionally broad energy range. LHAASO has become a unique, comprehensive, and open science platform.It has achieved a series of significant scientific achievements.The results have been published in *Nature* and *Science* [1-3].

Modern Physics (MP) is a Chinese language magazine covering all areas of physics, pure and applied. The magazine serves the physics community of researchers, college students, graduate students, high school teachers and other people interested in physics.

Modern Physics is sponsored by the Institute of High Energy Physics, Chinese Academy of Sciences and High Energy Physics Branch of Chinese Physical Society .

Relying on the large-scale facility LHAASO and the Modern Physics magazine, the Campus Cosmic Ray Observation Collaboration (CCOC) was born.

2. CCOC

CCOC was established on September 28, 2020, affiliated with the Institute of High Energy Physics, Chinese Academy of Sciences. It aims to promote cosmic ray observation and research in schools, cultivate innovative talents, and integrate scientific popularization, talent development, and scientific research. CCOC is dedicated to advancing the construction of the cosmic ray observation network in China, popularizing knowledge about cosmic rays, encouraging cosmic-

ray study, strengthening collaboration on cosmic-ray observation, facilitating student and teacher training conducting scientific research on cosmic rays, strengthening international exchanges.

About the organization, there are two advisors,one from the IHEP,one from Beijing Dongzhimen High School.There are 1 director and 3 vice directors.There are 20 members of the Council.And there are 5 working groups (WG) to complete daily works to run the organization well.They are Technical development WG,Educational instrument WG ,Campus promotion WG, Cosmic-ray popularization WG and Secretary service WG.And people in CCOC are all volunteers. People of Technical development WG and Secretary service WG are from LHAASO and MP.

About the members, there are 25 institutional members and 6 individual members. The institutional members are included 15 high schools, 7 universities and 3 institutes.

3. Activities

Since its establishment, CCOC has organized a diverse range of activities.

3.1 Establishing a network of cosmic ray observation stations in schools, colleges and universities across the country

Jiangyan High School Station was setup in 2022 after the establishment of CCOC. There will be a plan to setup stations in Xinghua High School,Sun Yat-sen University and Tibet University. Figure1 shows the cosmic ray observation array unit and the muon telescope. Figure2 displays the cosmic ray signal curve. Figure3 captures the Technical development WG installing equipment on the rooftop of Jiangyan High School.

Figure 1: The cosmic ray observation array unit and the muon telescope.
Figure 2: The cosmic ray signal curve.

Figure 3: Installing equipment on the rooftop of Jiangyan High School by the Technical development WG of CCOC.

3.2 Pushing forward R&D of instruments

Figure4 shows the instruments developed by the CCOC advisor, students of high school and Technical development WG.

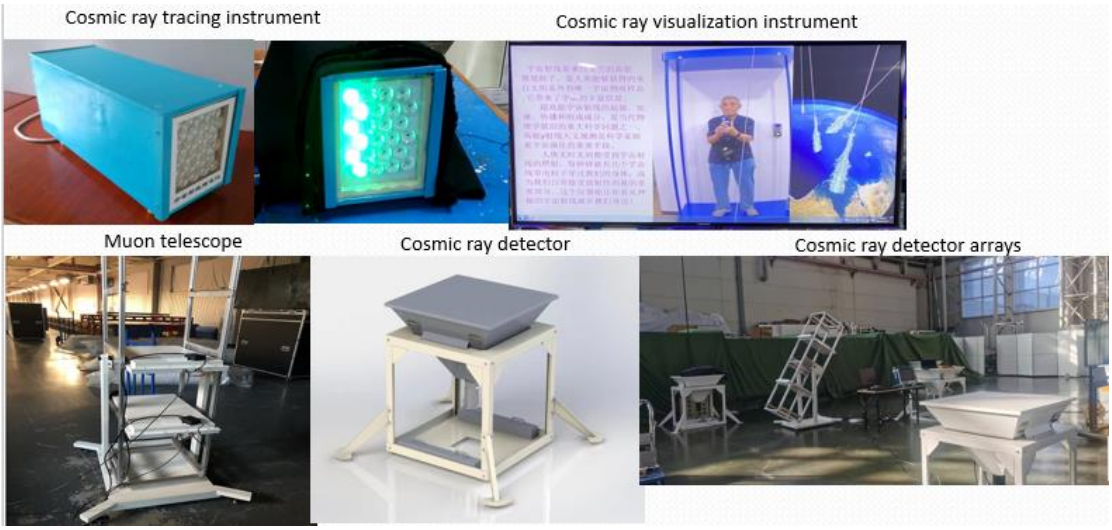

Figure 4: the instruments developed by CCOC

3.3 Facilitating the cosmic-ray observation and study

Since the CCOC establishment, it has formulated the "Charter of the Campus Cosmic Ray Observation Collaboration " and the "Interim Measures for Data Openness and Use in the Campus Cosmic Ray Observation Collaboration". These documents outline the functions of the CCOC, the rights and obligations of its members, the organizational structure, and other relevant details. According to these regulations, the data generated from cosmic ray observation experiments conducted by the members should be shared within the entire unit and made accessible to the public users.

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

3.4 Carrying on cosmic-ray education

We have developed a series of courses called "A new journey towards the discovery of Cosmic Rays", and the contents of the courses have been published in "Modern Physics". Figure5 is the contents of the courses.

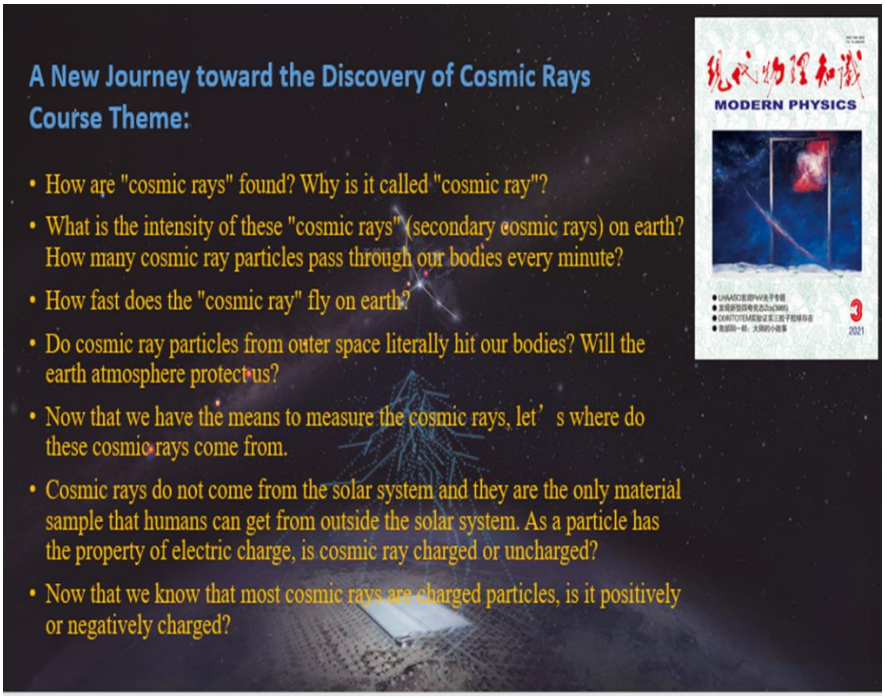

Figure 5: The course theme published on the MP.

3.5 Carrying out the measurements

Integrating observation instruments with the courses, the following cosmic ray measurements were carried out on campuses. By using the cosmic ray detector array, these measurements are carried out: extensive air shower (EAS), which is generated by primary cosmic ray; the direction of EAS with accuracy better than 2° degree; the arriving time of EAS with accuracy better than 2 nanosecond; the energy of EAS with core inside the array; the cosmic ray muon counting rate (flux). By using the muon telescope, these measurements are carried out: the cosmic ray muon flux in any specific direction (all different zenith angles and different azimuth angles); the speed of cosmic ray muon; the life of muon; the east-west different effect of cosmic ray flux indused by earth magnetic field.

For example, these are the activities of Beijing Dongzhimen High School.They stimulate interest by expert reports, carry out the course learning in laboratory, master data processing methods in practice, experience the research process and write research reports, communicate directly with high level students in video conference and participate in International Cosmic Day activities for many years from 2016 to 2022. They have great achievements：For student production, they have developed cosmic ray tracing instrument and cosmic ray visualization instrument. For student papers: they have submitted 4 papers, such as《Discover the Mysterious Cosmic Rays》、《Variation of Cosmic Ray Muon Intensity with Zenith Angle》、《Measuring the Variation of Cosmic Ray Intensity with Zenith Angle》、《Qualitative Study on the Relationship between Extensive Atmospheric Shower Intensity and Atmospheric Pressure near the Ground》.

3.6 Organizing training courses and workshops

CCOC organized a series of science communication activities, including the "International Cosmic Day Video Conference," "Cosmic Ray Knowledge and Data Acquisition and Analysis Methods" online and offline training sessions, the "International Cosmic Day Report Meeting" at Dongzhimen Middle School, the "Starry Sky Program - Professional Development Series for High School Science Teachers," the "Campus Cosmic Ray Observation Alliance Summer Exchange Training Session," the "2022 Campus Cosmic Ray Observation Summer School," and online meetings for exchanging activities related to campus cosmic ray observation.

More than 500 physics teachers and students from universities and high schools across the country participated in the exchange training sessions. The meeting issued certificates for teachers attending exchange training. Some epresentatives visited the Dongzhimen High School cosmic ray laboratory in 2021. Figure6 shows the training courses and workshops from 2020 to 2022.

Figure 6: The training courses and workshops.

3.7 Organizing the international exchanges

CCOC organized its members to participate in the 9th edition in 2020, the 10th edition in 2021, and the 11th edition in 2022 of the "International Cosmic Day" events, as well as the "International Muon Week" event in 2023. During these events, various units including the Cosmic Ray Working Group of the Institute of High Energy Physics, the Cosmic Ray Course Group of Dongzhimen, the Cosmic Ray Working Group of Southwest Jiaotong University, Jiangyan High School in Jiangsu Province, Xinghua High School in Jiangsu Province, and the Affiliated Middle School of Hunan Normal University showcased the progress made in campus cosmic ray observation in China in recent years. Students had the opportunity to exchange experimental methods and achievements. Figure7 shows CCOC participation of ICD.

Figure 7: CCOC participation of ICD

Figure 8: The poster of the exchange seminar.

On March 15, 2022, for promoting international exchanges and cooperation in campus cosmic ray observation and related science communication, the CCOC held a seminar on science communication and outreach in particle astrophysics in collaboration with the German Electron Synchrotron DESY. On May 11, 2022, the Global Cosmic Group Meeting of the International Particle Physics Outreach Group (IPPOG) was held online, and the CCOC was invited to attend and gave a presentation. We know that the activities of ' International Cosmic Day ' are also created by several scientists from all over the world to plan new things for fun. We are more confident and interested in doing CCOC well. Figure8 is the poster of the exchange seminar with DESY.

4. Conclusions

The Campus Cosmic Ray Observation Activities can provide students with the opportunity to participate in cutting-edge scientific research;enable students to develop independently and grow around scientists; receive authentic training in modern scientific inquiry, and enhance the overall scientific literacy of both teachers and students;foster students' interest in studying physics and broaden the international perspective of teachers and students.

The next plan of CCOC in the future is to advance the construction of observation stations in different latitudes; use data from LHAASO for a real simulation analysis and develop a mobile APP for visualizing cosmic ray-related data.

References

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Acknowledgments

The authors gratefully acknowledge the support from the following people: D.Chen, G.Chen, J. Liu, H. M. Zhao, X. L. Bian, Z. C. Tang, Y. D. Chen, J. Yu, S. Wang, J.Z.Wang, L. M. Song, Y. O. Jiang, S. Z. Chen, B. Zhou.