

Campus Cosmic-ray Observation Collaboration and its Activities

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Cosmic rays are natural and readily available. Observation of cosmic rays in middle schools can stimulate students' curiosity and interest in nature. Through the construction of the campus cosmic-ray observation network, the cosmic-ray observation is brought into 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, supported by the Institute of High Energy Physics, Chinese Academy of Sciences. Its activities are mainly based on the large scientific infrastructure 'Large High Altitude Air Shower Observatory' (LHAASO) and the popular science magazine 'Modern Physics' (MP). This report will give a brief description on CCOC and the activities carried out since it was established on September 28, 2020, including setting up campus observation stations and network, popularizing cosmic-ray knowledge, encouraging cosmic-ray study, strengthening collaboration on cosmic-ray observation, facilitating student and teacher training and strengthening relevant international exchanges. CCOC hopes to learn from and communicate with international colleagues on how to carry out outreach and education experience in cosmic-ray based on large scientific devices.

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1. Introduction

Cosmic rays are high energy particles from our Galaxy. They are natural and readily available experiment samples for particle physics and high energy astrophysics. Observation of cosmic rays in middle schools can inspire students' curiosity and interest in nature, stimulate their desire to explore both the micro and macro universes, cultivate their inquiry spirit and critical thinking, and help them know basic scientific methods. Through the construction of the campus cosmic-ray observation network, the cosmic-ray research is brought into 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 carried out researches on cosmic rays long time ago. In 1954, the first cosmic ray laboratory in China was built at a height of 3,200 m in Luoxue Mountain, Yunnan. The world's highest emulsion chamber was established in 1977 at a height of 5,500 m in Gambala Mountain, Tibet. In 1988, Huairou Extensive Air Shower Array was launched. In 1990 and 2006, two cosmic ray observation arrays were successively built at Yangbajing, Tibet, i.e. the China-Japan cooperation ASy experiment and the China-Italy cooperation ARGO-YBJ experiment. In 2021, the Large High Altitude Air Shower Observatory (LHAASO) was completed on Mt. Haizi in Daocheng, Sichuan, 4,410 meters above sea level. The LHAASO collaboration has published a series of significant scientific results in *Nature* [1] and *Science* [2-3].

Modern Physics (MP) is a Chinese magazine covering all areas of physics, both pure and applied. The magazine serves the physics community of researchers, college students, graduate students, high school teachers and other people who are interested in physics. MP is sponsored by the Institute of High Energy Physics (IHEP), Chinese Academy of Sciences (CAS) and High Energy Physics Branch of Chinese Physical Society.

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

2. CCOC

CCOC 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. 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.

Currently the CCOC is composed of 25 institutional members and 6 individual members. The institutional members consist of 15 high schools, 7 universities and 3 institutes. The CCOC council consists of 1 director, 3 vice directors and 20 members. Two advisors are invited, one from the IHEP and one from Beijing Dongzhimen High School. Volunteers form 5 working groups (WGs): technical development WG, educational instrument WG, campus promotion WG, cosmic-ray popularization WG and secretary service WG. Members of technical development WG and secretary service WG are from LHAASO and MP respectively.

3. Activities

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

3.1 R&D of instruments

Figure 1 shows the instruments developed by the CCOC advisor, students of high school and technical development WG.

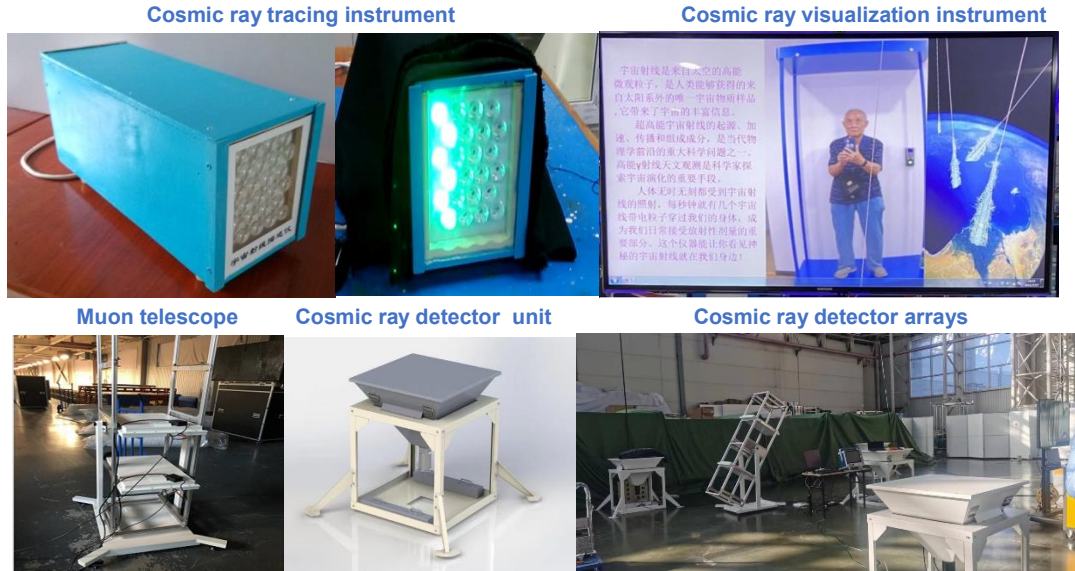


Figure 1: Instruments developed by CCOC.

CCOC stations in Jiangyan High School (Figure 2) and Sun Yat-sen University were setup in 2022. Construction of stations in Xinghua High School and Tibet University is ongoing. Figure 2 captures the technical development WG installing equipment on the rooftop of Jiangyan High School.



Figure 2: Picture of CCOC station in Jiangyan High School during installation.

3.2 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 has been created. The data from existing campus stations are stored there. The data can be shared by all the members of CCOC. CCOC website (ccoc.ihep.ac.cn) was incorporated with the database center.

3.3 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". Figure 3 lists the contents of the courses.

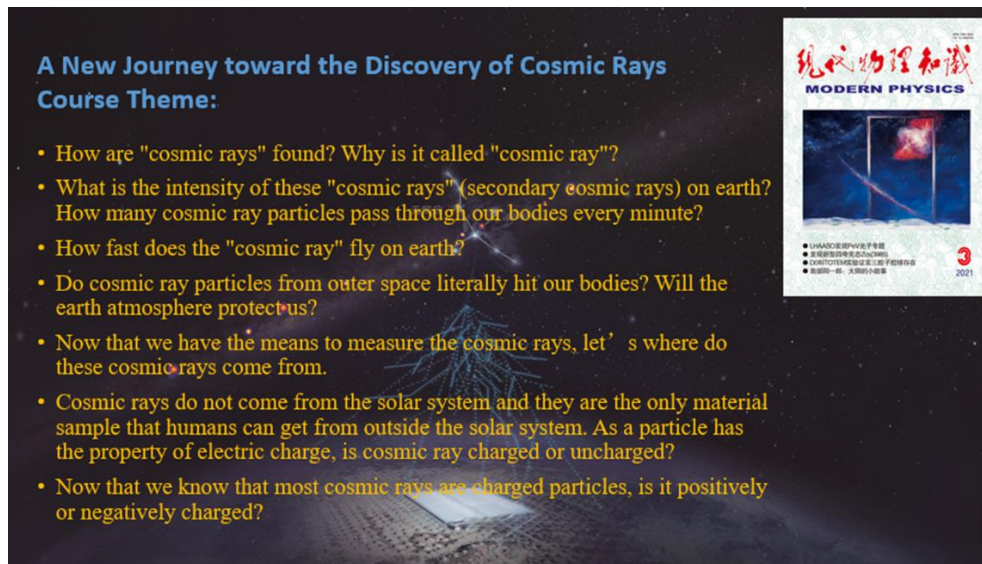


Figure 3: Contents of the courses.

3.4 Carrying out the measurements

Integrating observation instruments with the courses, the following cosmic ray measurements were carried out on campuses: the direction of an EAS with accuracy better than 2° ; the arriving time of a muon with accuracy better than 2 ns; the cosmic ray muon counting rate (flux) in any specific direction; the speed of cosmic ray muons with an accuracy of about 10%; the lifetime of muons with an accuracy of about 10%; the east-west effect of cosmic ray flux induced by geomagnetic field.

For example, the students of Beijing Dongzhimen High School carried out the course learning in laboratory, mastered data processing methods in practice, experienced the research process and wrote research reports, communicated directly with high level students in video conferences and participated in International Cosmic Day activities from 2016 to 2022. They have developed cosmic ray tracing instrument and cosmic ray visualization instrument. 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》.

3.5 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 Beijing Dongzhimen High 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 representatives visited the Dongzhimen High School cosmic ray laboratory in 2021. Figure 4 shows the training courses and workshops from 2020 to 2022.



Figure 4: Pictures of CCOC training courses and workshops from 2020-2022.

3.6 Organizing the international exchanges

CCOC organized its members to participate in the 9th session in 2020, the 10th session in 2021, and the 11th session in 2022 of the "International Cosmic Day" events (Figure 5), as well as the "International Muon Week" event in 2023. During these events, various units including the cosmic ray WG of IHEP, the cosmic ray course group of Beijing Dongzhimen High School, the cosmic ray observation group of Peking Academy Chaoyang Chuiyangliu Middle School, the cosmic ray WG 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 their progresses in campus cosmic ray observation in recent years. Students had the opportunity to exchange experimental methods and achievements.

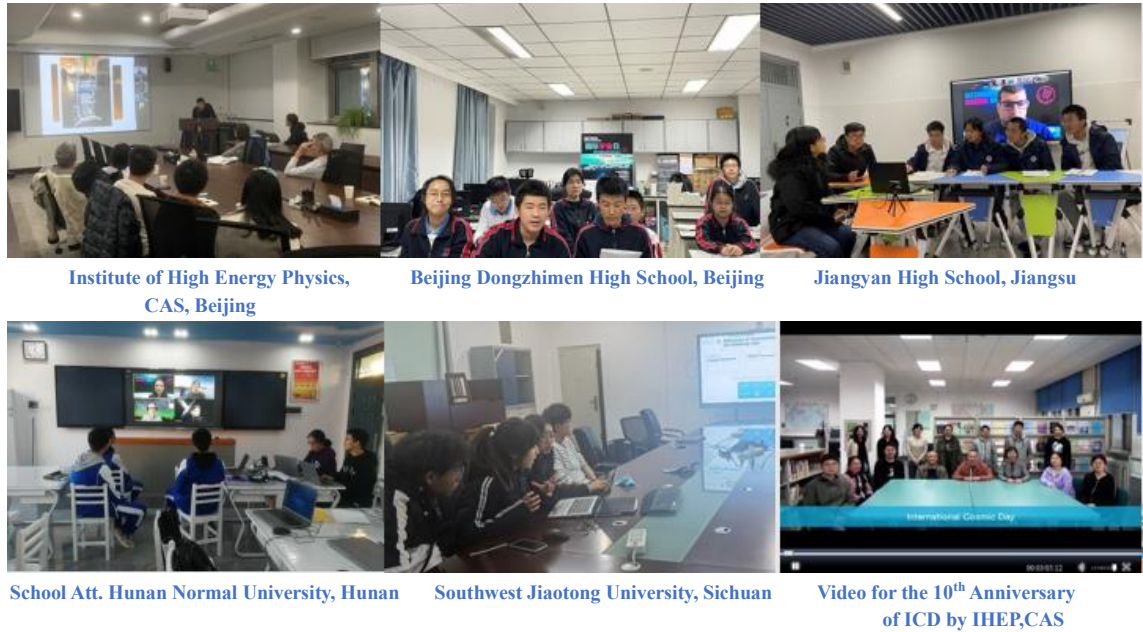


Figure 5: Pictures of CCOC participation of ICD.

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. Figure 6 is the poster of the exchange seminar with DESY. Figure 7 is the venue at IHEP,CAS.



Figure 6: The poster of the exchange seminar with DESY.

Figure 7: The Venue at IHEP, CAS.

4. Conclusions

The Campus Cosmic Ray Observation activities 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 future plan of CCOC is to advance the construction of observation stations in different latitudes and different altitudes, use data from LHAASO for a real analysis and develop a mobile APP for visualizing cosmic ray-related data, etc.

References

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