PROCEEDINGS OF SCIENCE

Outreach Cosmic Ray Activities (OCRA): a program of Astroparticle Physics Outreach Events for High-School Students

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Among the many outreach activities organized by the Istituto Nazionale di Fisica Nucleare (INFN), OCRA (Outreach Cosmic Ray Activities) includes those related to astroparticle physics, with particular emphasis on cosmic rays. In particular, OCRA coordinates all the fourteen INFN Sections that participated in the 2018 edition of the International Cosmic Day, an astroparticle physics outreach event for high-school students from all over the world. In addition to the standard ICD program, a competition was launched for the 800 students participating in the ICD at INFN throughout Italy whose thirty winners participated in a three-day science camp at the Gran Sasso National Laboratories (LNGS) in April where they were involved in the measurement of the cosmic ray flux as a function of the atmospheric depth and zenith angle using a detector made by 4 scintillator layers and read out by SiPMs (Silicon Photomultipliers), the Cosmic Ray Cube. Some details on the science camp, as well as the ICD 2018 summary and other local activities coordinated by OCRA will be reported.

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1. Introduction

Cosmic radiation, invisible to human eyes, encompasses all the fundamental problems of modern physics: from the origins and evolution of the Universe to the current composition of known forces up to the intimate structure of matter. From the study of this radiation all the modern theories and knowledge of the world around us were born. On the other hand, cosmic radiation is easily intercepted and can be "made visible" through simple telescopes of particle detectors, so that it represents in itself an excellent educational laboratory to introduce non-experts, especially students, to the study of physics and fundamental phenomena of nature. The study of cosmic radiation is also closely related to other major themes of modern astrophysics, from dark matter to gravitational waves and neutrino oscillations and much more. To speak of cosmic rays therefore means to speak of the exploration of the Universe in all its forms.

OCRA – Outreach Cosmic Ray Activities was born in 2018 as a national outreach project of INFN with the aim of collecting, within a national framework, the numerous public engagement activities in the field of cosmic ray physics already present at a local level in the divisions and laboratories. Currently 17 local groups are members of OCRA, 4 more are likely to join this year!

2. International Cosmic Day

The International Cosmic Day (ICD) [1] is an astroparticle physics outreach event for high-school students and brings together students and various physics outreach projects from all over the world. Groups of scientists, teachers, and students meet for one day to learn about cosmic rays and perform an experiment with atmospheric muons. All participating groups investigate an identical question: the zenith angle distribution of atmospheric muons. In fact, they try to answer this task with an experiment that can be performed and analyzed in one day and try to answer the following questions: is the number of air shower particles arriving from the horizon the same as from the zenith? How it is possible to measure the rate of air shower particles for different directions? What is the angular distribution of the cosmic muon flux? The students are enabled to work together like in an international collaboration, discussing their results in joint video conferences at the end of the day.

In 2018, 14 of the INFN divisions currently adhering to OCRA participated to the ICD, gathering almost 800 students. Almost half of these participants (42%) were girls. The core program shared by all INFN sites included an introductory seminar, the measurement of the cosmic muon flux at various angles on site, the analysis of the data and an exchange with groups from all over the world to conclude the day. In addition, each division added complementary elements to the program according to their possibilities, like laboratory visits, exchange with researchers and other staff about their careers or the presentation of a cloud chamber.

At the end of the day all students and teachers were invited to answer a short questionnaire to evaluate their satisfaction, rating several aspects from 0 (not true at all) to 5 (fully agree). A summary of all answers given by the students is shown in Figure 1. As can be seen, general satisfaction was rather high, with an average vote of 4.1, and the event corresponded well to the expectations of the students (average vote 4.0). The contents were interesting and well presented (rated 4.4 and 4.2, respectively) and the students were satisfied with the organization, giving it an average vote of 4.0. The question that received the lowest rating with 3.5 was the one investigating if the prior knowledge of the students was sufficient to follow the event. As a result, the possibility

of the preparation of introductory material that the students will receive prior to the event is being discussed. A total of 89% of all participating students said that they would recommend the event to their fellow students.

The teacher questionnaires showed similar results, with the general satisfaction even higher with an average rating of 4.5. Of the 67 teachers that answered the questionnaire, 64 would like to participate again with their students in the following year.

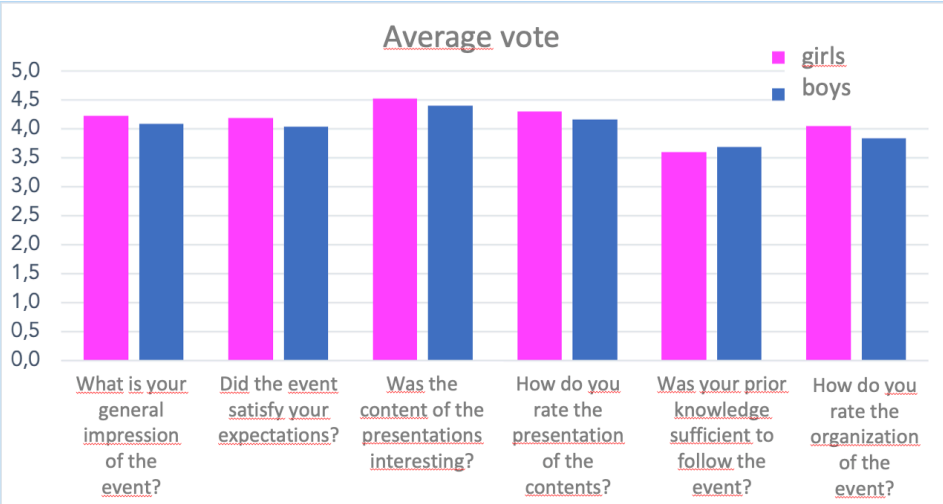

Figure 1: OCRA ICD student questionnaire results.

During or following the event, every participating division, in collaboration with the schools, prepared one or more summary pages of the event that was then published in the ICD booklet [2]. All students taking part in the ICD in the framework of the OCRA collaboration were invited to participate in a competition for the OCRA Science Camp at Gran Sasso.

3. OCRA Science Camp at Gran Sasso

Two students for each OCRA ICD 2018 site were selected among the almost 800 participants, based on a competition: working in groups of two, the students were invited to submit a 3-page article on the event and their experience. Every division then selected the best article and the winning couple was invited to the OCRA Science Camp at the Gran Sasso in Italy. In addition, 5 teachers from different schools in Italy accompanied the students as chaperons during the camp activities. The participating students were between 16 and 18 years old.

The science camp took place from April 14 to 17, 2019. The local organizers were the Gran Sasso Science Institute (GSSI) located in L'Aquila and the Laboratori Nazionali del Gran Sasso (LNGS), both members of the OCRA collaboration.

The activities involved introductory seminars, a series of measurements in the field, the analysis of the data by the students under guidance of the researchers and a visit to the LNGS underground laboratories. Figure 2 shows the students during some of the activities.

The measurements aimed at determining the dependence of the cosmic ray flux on the altitude by means of a set of measurements carried out in several places around the Gran Sasso massif in central Italy. All data taking was carried out with the Cosmic Ray Cube (CRC). A dedicated article on the scientific results and the perception of the students as evaluated from questionnaires ante and post activity is under preparation.

Figure 2: Photos of camp activities: measurements at different heights, seminars and data analysis, Cosmic Ray Cube.

4. Cosmic Ray Cube (CRC)

For the science camp and for some ICD OCRA locations the Cosmic Ray Cube (CRC) muon tracking system has been employed. This telescope is composed of 4 double-plane horizontal scintillation levels, orthogonal to each other. Each plane consists of four solid scintillator strips of 4 x 1 x 26 cm^3 size with a wavelength-shifter fiber inside carrying the light produced by interaction with a penetrating particle to one end of the strip where it is collected by a Silicon PhotoMultiplier detector (SiPM) which generates an electrical signal firing a blue LED. The system is composed of 48 electronic channels allowing the 3D reconstruction of crossing muons. Two front-end boards have been designed to provide voltage bias and read out the SiPMs enclosed in the system to monitor the working parameters. A controller board unit permits to select different trigger levels and allows for data acquisition for off-line analyses. The CRC is depicted on the left in Figure 3.

A dedicated computer software (on the right in Figure 3) and a smartphone application have been developed to observe the 3D event display of the telescope connected to the network, together with other CRC cubes connected from elsewhere. The app (Cosmic Rays Live) can be downloaded from both Google Play and Apple Store. In this way the students have a powerful tool to get closer to the world of cosmic rays.

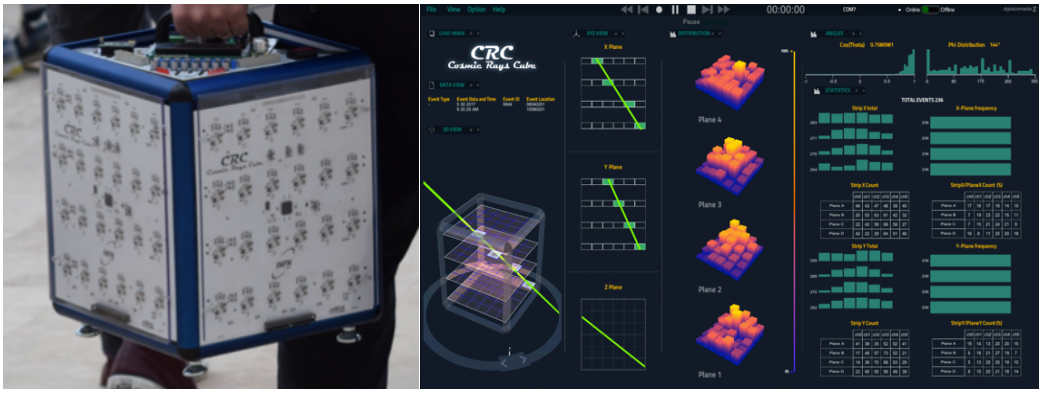

Figure 3: The CRC and its software application.

5. Other local activities

This section summarizes only a small part of the activities organized at a local level in the various INFN divisions participating in OCRA (Bari, Catania, Cosenza, LNGS, Florence, Genoa, L'Aquila, Lecce, Milan and Milan Bicocca, Naples, Padua, Pavia, Perugia, Pisa/Siena, Rome and Rome Tor Vergata, Sassari/LNS, Trento/TIFPA Trieste, Turin) and depicted in Figure 4, but many others make up the variety of the initiatives of the whole OCRA collaboration.

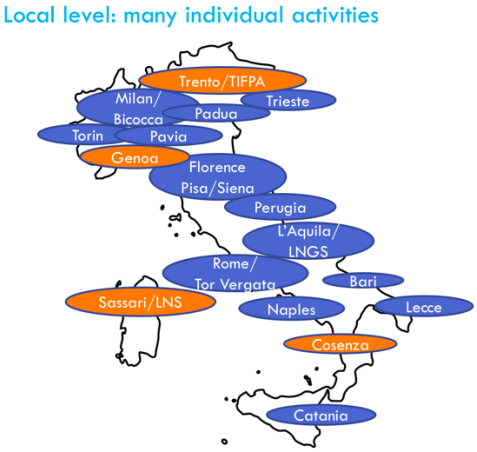

Figure 4: OCRA INFN divisions (the divisions joining this year are indicated in orange)

5.1 Lecce

The INFN division in Lecce is among the six sites involved in the large-scale production of the Scintillator Surface Detector (SSD) for the upgrade of the Pierre Auger Observatory [3]. An Italian Educational Program "Alternanza Scuola-Lavoro" is active in High Schools on a national level and allows the students to consolidate and expand the knowledge acquired at school via internships in private or public working environments. Within this framework, the Lecce division has initiated a project that allows the students to work together with a researcher to build the SSD for the upgrade. They participate actively to the construction, calibration and test of the detectors. The variety of the proposed activities, which range from the assembly of mechanical parts to data analysis and programming, allows students to approach activities in line with their own aptitudes but also to experiment tasks and challenges that are not usually provided in the contexts of school. The activities carried out so far involve 10 schools in Apulia for a total of around 6000 hours of internship. In Figure 5 some students are working in the detector's laboratory.

Figure 5: Students in Lecce at work.

5.2 Milan

Within the OCRA project, the INFN Milan group organizes astroparticle summer workshops for High School students. These workshops are full-time and last two to three weeks. During these workshops, around 10 students from the Milan area are provided with the possibility to do hands-on astroparticle physics: they analyze data from the Pierre Auger Observatory and the Borexino experiment, follow classes on cosmic rays, neutrinos and dark matter and build detectors such as a cloud chamber and scintillators. Being the group rather small, it is possible to interact directly with the students and to have them think and reach on their own solutions in response to physics challenges, making them experience what it feels like to be part of the scientific community. Figure 6 shows some students during the workshop.

Figure 6: Milan students summer workshop

5.3 Naples

"A scuola di astroparticelle" [4] is a High School competition, within the OCRA local activities, promoted by the INFN division of Naples, in collaboration with the Physics Department "Ettore Pancini" of the Federico II University of Naples, and the CNR-SPIN and CNR-ISASI Institutes. In 2018/2019, the activities, carried out by the students during all the school year under the Italian Educational Program “Alternanza Scuola-Lavoro”, involved 18 schools in Campania for a total of 21 projects on current topics of scientific research: the origins and study of the Universe, cosmic rays and gravitational waves, environmental radioactivity, methods of health physics, nanotechnologies and quantum technologies, as well as technical aspects related to the development of photon and particle detectors, such as the telescope in the Toledo subway station of Naples and its Multimedia Totem from which the idea of the project was born. For the final two-day event [5] at the end of May the 600 students were involved in various activities: the preparation of the poster section, the opening press conference and the presentation of their work to the jury both in the poster session and in the two plenary sessions. Figure 7 depicts the winning school of this year’s edition. In spite of the great effort that was necessary for the realization of their projects as well as during the two days of final activities, the students expressed great enthusiasm that they will pass on to the general public during the "European night of researchers" SHARPER in Naples and Caserta at the end of September, when they will be not only spectators but also protagonists in communicating their passion for science!

Figure 7: Prize-giving for the "S. Cantone" high school in Pomigliano d'Arco.

5.4 Rome

The group of Rome, in collaboration with the Cariati scientific high school and with the l'ABProject (a company specialized in light balloon flight), realized a stratospheric balloon launch in order to measure the flux of cosmic rays as a function of the altitude. The launch of MoCRiS (Measurement of Cosmic Ray in Stratosphere) started in Camigliatello Silano and reached an altitude of 34.111 meters. After the burst, the payload landed, with the help of a parachute, 100 km away from the launch site, near Parenti. The payload contained various instruments: a GPS using the GlobalStar messaging system to track the balloon, a GPS for data synchronization, two GoPro cameras, a pressure and temperature monitor, a system to capture meteoric dust and two ArduSiPM [6] scintillator detectors for measuring the cosmic ray flux.

The project allowed the interaction between the world of school, of research and of technology and it provided to all students the possibility to learn from a wide spectrum of experiences [7]. The collected data allowed us to study the physics of the atmosphere, the dependence of the flow of cosmic rays on the quota and the verification of the Regener-Pfotzer flux at about 1 Pa pressure and 20 km of altitude. More than 2000 spectacular photos showing the earth from the stratosphere were collected. One of the photos, shown in Figure 8 on the upper left, was chosen by EPOD (Earth Picture of the Day, sponsored by NASA and administered by the Universities Space Research Association) as photo of the day on June 25, 2019. It shows the southern coast of Italy with a quarter moon just above the earth's horizon.

Figure 8: Photos of the MoCRiS launch: moon over Calabria, Apulia, Basilicata and the Ionian Sea (EPOD Jun 25,2019), the MoCRiS team, the assembled nacelle.

6. Conclusions and future activities

OCRA is the first necessary step for a greater collaboration and coordination between the INFN divisions with outreach initiatives in the field of cosmic rays. The fact that 21 divisions have adhered or will be adhering in the near future clearly shows the need for an initiative of this kind. The long-term goal foresees equipping each location with a CRC, which will allow for coordination for the activities of the ICD, the starting point of the network, and to make the students perceive the fact that they are part of a network project at national level. Furthermore, the divisions will be able to collaborate on the development of new activities, complementary to those already proposed, which will enrich the proposals in the next years. Also, for the students' science camp in 2020 it will be possible to rely on an activity already tested and validated by the Rome group, i.e. the launching of a balloon with instrumentation for the measurement of cosmic rays [7]. Furthermore, a masterclass with public data dedicated to the outreach activities of the Pierre Auger Observatory is being defined [8].

OCRA is part of the Cosmic Steering Committee of the International Particle Physics Outreach Group (IPPOG) and will as such collaborate at an international level on the development and coordination of outreach activities in the field of astroparticle physics.

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