PROCEEDINGS OF SCIENCE

Involving high school teams in the upgrade phase of the Extreme Energy Event Project: a review of recent activities

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The Extreme Energy Events (EEE) Project was born to include scientific, outreach and educational purposes. It is designed to detect and study high energy cosmic rays through the detection of the extensive air shower's muon component through an array of muon telescopes based on Multigap Resistive Plate Chambers (MRPC) GPS synchronized.

The telescopes are organized in local clusters and single telescope stations distributed all over the Italian territory and installed mainly in high schools buildings. These unconventional working sites offer young learners the opportunity to get in touch with the world of high energy physics research. Every year hundreds of students and teachers are involved in the activities. The EEE Collaboration regularly schedules on-line activities: monthly meetings, masterclasses and seminars. Activities focusing on the upgrade phase of the EEE Project have been carried out in the last two years, with enormous success and participation. This contribution will present a general overview of the EEE outreach activities and the future plan.

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1. Introduction

The EEE Project aims to study cosmic rays by detecting secondary muons on the Earth surface generated by the primary cosmic rays interaction in atmosphere; the Project was also born with the educational purpose to involve high school students in cosmic rays physics. EEE muon telescopes are installed in Italian high-school buildings and physics laboratories and two detectors are located at CERN. The EEE detectors array cover an area of more than $10^5\ km^2$, it is the largest MRPC-based system (Figure 1).

Figure 1: Map of EEE telescopes and schools participating in the EEE Project.

Each telescope is composed of 3 large area (0.82 x 1.58) m^2 MRPCs [1]. Chambers till 2019 were operated with a continuous flow of a gas mixture made of $C_2H_2F_4$+ SF_6 that are Green House Gases (GHG). The EEE Collaboration is carrying out an ecological transition to substitute the gas mixture used in the MRPCs chambers [2]. This transition foresees the use of an alternative green mixture mainly based on $C_3H_2F_4$ with the addition of He or CO_2.

This new mixture shows a significant lower Global Warming Potential (GWP) that allows to reduce the emission of gases contributing to the greenhouse effect [3]. In the past few years high schoolers have been involved in this upgrade phase of the Project regarding the choice of this ecological gas mixture for the MRPCs gas detectors.

2. Students involvement in the EEE Project

Pupils and teachers are actively involved in the experiment from the first steps of the Project [4, 5]. Students come to CERN to construct the MRPCs - the main components of the telescopes - under the EEE researches supervision. After the final performance validation, the MRPCs are sent to school institutes, where they are installed and commissioned. Coordinated data taking period (RUN) have been performed since 2014 during each school year, providing a huge amount of candidate muon tracks.

During the year pupils are involved in the daily monitoring of the telescope installed in their schools reporting data acquisition conditions. Together with these hardware-related operations they learn how to perform the analysis of EEE data and delve into this aspect attending masterclasses.

The EEE Collaboration engages with schools through plenty of local, national and international outreach activities.

Two usual appointments are the International Cosmic Day (ICD) [6] and the International Muon Week (IMW) [7] . During the ICD participants are introduced to cosmic particle physics attending lectures and analysing data. Each year the Collaboration chooses a different analysis to perform with the data acquired with EEE telescopes. During the latest IMW, the students calculated muon speed using a data sample acquired by the telescope placed in their school, using the new eco-friendly mixture, they also elaborated a scientific report and presented their analysis and results during the IMW.

On top of the yearly events, students get the chance to share their work during the monthly Run Coordination Meetings. The development, by the EEE researchers, of an user-friendly and portable cosmic ray detector, named Cosmic Box (CB), allowed pupils to perform several analysis such as the measurement of the muon rate as a function of the altitude, since they can bring the CB everywhere. The CB is composed of two parallel scintillator planes, the light signals are read by SiPM provided with a display to monitor the acquisition rate. It can be operated with a single and double coincidence trigger.

Several high schools, from all over Italy, carried out measurements with the CB detectors from the sea level (and also underground) to more then 2000 m altitude, to investigate the dependence of the cosmic ray flux on the altitude.

Figure 2: Cosmic Box used to study muon rate at different altitude. From left to right: -20 m under ground level, 750 m and 2112 m above sea level.

Some of them also investigated the influence of the atmospheric conditions on the cosmic ray flux monitoring atmospheric temperature and pressure. Since the measurement campaigns are normally extra-curricular activities, the teachers collaboration is crucial. After the fieldwork participants analyse their data and prepare a report that can show during Run Coordination Meeting, where they can improve their communication skills. An encouraging aspect is the fact that schools of different towns decided to work together. Collaboration among pupils is an important aspect of our educational aim to prepare them for teamwork.

During the monthly meeting students have been involved in the upgrade phase of the Project regarding the choice of the ecological gas mixture for the MRPCs gas detectors, with the aim to raise awareness among them about this topic and to promote a deeper understanding of this phase. Some students carried out their analysis testing the efficiency of chambers installed in their school fluxed

with the new eco-friendly mixture and presented their results during the monthly Run Coordination meeting.

The EEE Collaboration designed and developed also portables cosmic ray detectors, named POLA, to perform measurements on the flux of cosmic rays at extreme latitudes [8]: the PolarquEEEst experiment. As per EEE Project tradition POLA detectors were assembled at CERN by Italian, Norvegian and Swiss high schools. Data from the PolarquEEEst mission are also available for schools analyses and are used also in EEE masterclasses.

3. Conclusion

The EEE Project provides a great opportunity for young people to being fully involved in all aspects of a scientific Collaboration. They can actively contribute and participate in the EEE research activities. High schoolers have the chance to experience all the steps of the physics research, from data analysis to the discussion of results, carring out independent analysis.

The EEE Project has an intense outreach programme based on the direct involvement of pupils for a full school year or more, it is a long term commitment that comes with tangible opportunities to acquire new skills. Online activities allow reach out to a wide audience and are recording an outstanding number of participants, however the Collaboration is also planning to increase the number of in presence events, in order for attendees to be more engaged.

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