

Outreach activities of the Extreme Energy Events Project

M. Garbini,^{a,b,*} M. Abbrescia,^{c,d} C. Avanzini,^e L. Baldini,^{f,e} R. Baldini Ferroli,^g G. Batignani,^{f,e} M. Battaglieri,^h S. Boi,^{i,j} F. Carnesecchi,^k C. Cicalò,^j L. Cifarelli,^{l,b} F. Coccetti,^a E. Coccia,^m A. Corvaglia,ⁿ D. De Gruttola,^{o,p} S. De Pasquale,^{o,p} L. Galante,^q G. Gemme,^h I. Gnesi,^{a,r} S. Grazzi,^{s,h} D. Hatzifotiadou,^{b,k} P. La Rocca,^{t,u} Z. Liu,^v G. Mandaglio,^{s,u} A. Margotti,^b G. Maron,^w M. N. Mazziotta,^d A. Mulliri,^{i,j} R. Nania,^b F. Noferini,^b F. Nozzoli,^x F. Palmonari,^{l,b} M. Panareo,^{y,n} M. P. Panetta,^{a,n} R. Paoletti,^{z,e} C. Pellegrino,^{aa} L. Perasso,^h O. Pinazza,^b C. Pinto,^{ab} S. Pisano,^{a,g} F. Riggi,^{t,u} G. Righini,^{ac} C. Ripoli,^{o,p} M. Rizzi,^d G. Sartorelli,^{l,b} E. Scapparone,^b M. Schioppa,^{ad,r} G. Scioli,^{l,b} A. Scribano,^{z,e} M. Selvi,^b M. Taiuti,^{ae,h} G. Terreni,^e A. Trifirò,^{s,u} M. Trimarchi,^{s,u} C. Vistoli,^{aa} L. Votano,^{af} M. C. S. Williams,^{k,v} A. Zichichi^{a,l,b,k,v} and R. Zuyeuski^v

^aMuseo Storico della Fisica e Centro Studi e Ricerche “Enrico Fermi”, Rome, Italy

^bINFN Sezione di Bologna, Bologna, Italy

^cDipartimento Interateneo di Fisica, Università di Bari, Bari, Italy

^dINFN Sezione di Bari, Bari, Italy

^eINFN Sezione di Pisa, Pisa, Italy

^fDipartimento di Fisica, Università di Pisa, Pisa, Italy

^gINFN Laboratori Nazionali di Frascati, Frascati (Rome), Italy

^hINFN Sezione di Genova, Genoa, Italy

ⁱDipartimento di Fisica, Università di Cagliari, Cagliari, Italy

^jINFN Sezione di Cagliari, Cagliari, Italy

^kCERN, Geneva, Switzerland

^lDipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy

^mGran Sasso Science Institute, L'Aquila, Italy

ⁿINFN Sezione di Lecce, Lecce, Italy

^oDipartimento di Fisica, Università di Salerno, Salerno, Italy

^pINFN Gruppo Collegato di Salerno, Salerno, Italy

^qTeaching and Language Lab (TLLab), Politecnico di Torino, Torino, Italy

^rINFN Gruppo Collegato di Cosenza, Cosenza, Italy

^sDipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università di Messina, Messina, Italy

^tDipartimento di Fisica e Astronomia, Università di Catania, Catania, Italy

^uINFN Sezione di Catania, Catania, Italy

*Speaker

^vICSC World laboratory, Geneva, Switzerland

^wINFN, Laboratori Nazionali di Legnaro, Legnaro, Italy

^xINFN Trento Institute for Fundamental Physics and Applications, Trento, Italy

^yDipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy

^zDipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Università di Siena, Siena, Italy

^{aa}INFN-CNAF, Bologna, Italy

^{ab}Physik Department, Technische Universität München, Munich, Germany

^{ac}CNR Istituto di Fisica Applicata "Nello Carrara", Sesto Fiorentino (Firenze), Italy

^{ad}Dipartimento di Fisica, Università della Calabria, Rende (Cosenza), Italy

^{ae}Dipartimento di Fisica, Università di Genova, Genova, Italy

^{af}INFN Laboratori Nazionali del Gran Sasso, Assergi (L'Aquila), Italy

E-mail: marco.garbini@cref.it

The Extreme Energy Events Project (EEE) represents a breakthrough in outreach activities in Cosmic Ray Physics: high school students are protagonists of an experiment to measure Extensive Air Showers at ground. They start their experience at CERN with the construction of the three high performing Multigap Resistive Plate Chambers constituting the telescope that is then installed inside their school; then they take care of the telescope operation and data analysis. Presently 60 telescopes are installed in Italy and, since 2014, coordinated data taking have been performed during each school year providing a huge amount of candidate muon tracks. Every year hundreds of students and teachers are involved in the activities directly correlated to EEE. The COVID-19 pandemic has strongly affected the experimental activities of the EEE Project. However in the last two years the online activities were strengthened, with an intense programme of collaboration meetings, masterclasses, and hugely successful topical seminars. Starting from the fall of 2021, the improvement of epidemiological situation made it possible to start some of the EEE activities in presence.

41st International Conference on High Energy physics - ICHEP2022

6-13 July, 2022

Bologna, Italy

1. Introduction

The Extreme Energy Events Project (EEE) [1] is a Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi (CREF) and Istituto Nazionale di Fisica Nucleare (INFN) experiment with dual role: it is devoted to the detection and study of cosmic rays at ground and to encourage scientific culture, through the direct involvement of Italian high school students in all the phases of the experiment. Indeed, the EEE experiment is a network of 60 cosmic muon tracking detectors (telescopes) installed in Italian high-school buildings and physics laboratories spanning an area of more than 10^5 km^2 , from CERN to Sicily. Figure 1 shows the distribution of the telescopes on the Italian territory: the red circles are the telescopes installed inside high schools, the orange are the ones installed inside INFN units and at CERN; the blue circles show the schools participating in the EEE Project without telescopes. Nowadays each year hundreds of students participate in the EEE Project activities.



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

The EEE muon tracking telescope (figure 2 left) is composed of three large area ($80 \times 160 \text{ cm}^2$) Multigap Resistive Plate Chambers (MRPCs). The basic design of the EEE MRPC is shown in figure 2 (right): it is a stack of resistive glass plates enclosing six gas gaps $300 \mu\text{m}$ thick ($250 \mu\text{m}$ for the chambers built since 2015). The chambers are operated at about 20 kV and, till 2020,

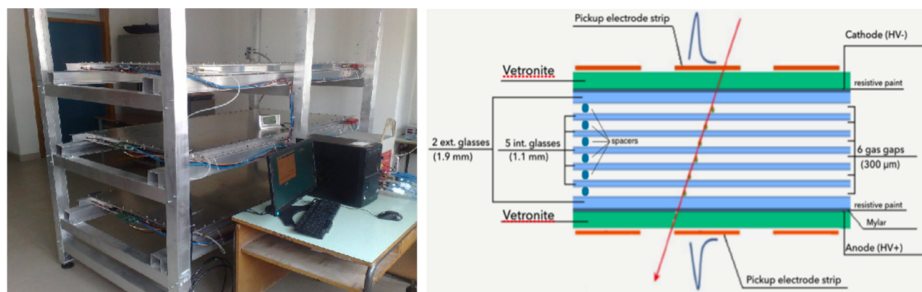


Figure 2: Left: one of the EEE telescopes, consisting of three MRPC chambers. Right: inner structure of a MRPC.

fluxed with a 98%-2% mixture of $C_2H_2F_4$ and SF_6 . The EEE telescopes have high performance [2] both in terms of spatial resolution ($\sigma_{longitudinal} \sim 1.5$ cm, $\sigma_{transverse} \sim 1.0$ cm) and of time resolution, $\sigma_{time} \sim 240$ ps. For most of the chambers, the detection efficiency is better than 90%. The telescopes are GPS synchronised for offline analysis on time correlated events. Data from each station are sent to the Bologna INFN CNAF for the track reconstruction and storage.

2. Students' involvement and outreach activities

The outreach programme of the EEE Project is focused on the direct involvement of Italian high school students in the experiment: students and teachers participate in all the phases of the experiment from the construction of the MRPC detectors to their installation, commissioning, and operation. Nowadays EEE involves about 100 Italian high schools (60 of them host a detector). The MRPCs are built at CERN by high-school teams, supervised by EEE researchers, as shown in figure 3. This is the starting point of their path in experimental cosmic ray physics: they learn



Figure 3: Phases of MRPCs construction at CERN.

how to build a particle detector starting from common materials (i.e. glass, fishing line, copper tape). Together with a better understanding of the working principle of the detectors during their week at CERN they can taste the researchers' work and life. After construction, the three MRPCs (the telescope) are sent and installed inside the school with their help. Then they take care of the commissioning of the telescope, the data acquisition operations, and the detector monitoring, see figure 4 (left).

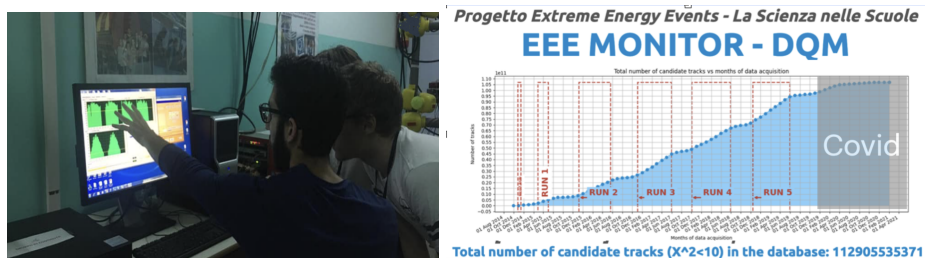


Figure 4: Left: students monitoring the school telescope operations. Right: number of candidate muon tracks as a function of time, during the EEE coordinated runs.

Since 2014, coordinated data taking have been performed during each year and more than 100 billion of candidate muon tracks have been collected and used for many analyses, see for example [3], [4], [5] and [6]. Every month the students participate in the Run Coordination Meetings devoted to the network operation. During these meetings they can present updates on their ongoing analyses, discuss tests and detector updates.

The Pandemic strongly affected the experimental operations and data taking has been interrupted, see figure 4 (right). However, since March 2020, an intense programme of online collaboration meetings, masterclasses and topical seminars were organized with enormous success. As shown in table 1, the students were involved in many activities such as the International Cosmic Day [7], the European Researchers Night [8] and many others on a local basis.

Event	Date	How	Participants	Main Focus
Run Coordination Meeting	16/03/2022	Online	350	Material Science
Run Coordination Meeting	16/02/2022	Online	350	Physics with Arduino
Run Coordination Meeting	26/01/2022	Online	380	Detection of Hunga-Tonga volcanic eruption with the POLA detectors at
Run Coordination Meeting	15/12/21	Online	220	rEEEstaring
Meeting EEE Project at Erice	17-19/11/21	In Person/Online	50/250	Masterclass on gas mixtures
International Cosmic Day	10/11/21	Online	300	PolarquEEEst Data Analysis
Run Coordination Meeting	13/10/21	Online	350	Program of activities for year 2020-2021
European Researcher night	24/09/21	Online	100	PolarquEEEst live form Svalbard
Run Coordination Meeting	26/05/21	Online	170	Physics and physical technologies for cultural heritage
Run Coordination Meeting	14/04/21	Online	500	Masterclass on Data Quality Monitor of EEE
Run Coordination Meeting	10/03/21	Online	500	Women in Science
Run Coordination Meeting	03/02/21	Online	475	Quantum Mechanics

Table 1: Main events organised by the EEE Collaboration since the beginning of the Pandemic.

Every six months students and teachers were invited to collaboration meetings usually held at Ettore Majorana Foundation and Centre For Scientific Culture in Erice (Sicily). The in-person meetings are unique occasions during which students participate in masterclasses, measurement campaigns and general lectures on cosmic ray physics. The students are again protagonists and usually they present to the audience their experience, analysis and results. Two measurements have been carried out in such meetings and the results have been published including the participating high-school students and teachers in the author list [9] [10].

In November 2021 the EEE Collaboration, finally organised the first in-person meeting after COVID. The meeting was focused on the Ecological Transition of the EEE Project that is going to use new gases in the detectors to reduce the environmental impact of the experiment.

Another project, born inside the EEE Collaboration is the PolarquEEEst experiment. It is devoted to the measurement of the cosmic ray flux up to the far North latitudes using telescopes made of scintillators built by high school students at CERN. The project started in Summer 2018, with the installation of the telescopes inside two high schools and on the "Nanuq" that circumnavigated the Svalbard archipelago [11]. In 2019 the detectors were installed at Ny Alesund positioned a few hundred meters from each other, operating as an observatory similarly to the EEE network.

3. Conclusions

The EEE Project has a strong and innovative outreach programme based on the direct involvement of young students in all the phases of a cosmic ray experiment. The experiment allows the students to experience all the steps of the research, from the construction and commissioning of a detector to the data analysis and results report. Every year hundreds of students are involved in the experiment also thanks to a continuously enriched programme. Due to the Pandemic the EEE Collaboration has set up a strong online programme that kept the students engaged and now we are ready to restart the experimental activities with the new challenge of the green transition of the EEE telescopes, by operating them with an ecological gas mixture. The EEE Project has also established collaborations with other outreach programmes such as the INFN Outreach Cosmic Ray Activities [12] and with the International Particle Physics Outreach Group (IPPOG) [13].

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