The EEE project: telescopes performance and recent results

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1. The EEE Project

The Extreme Energy Event Project (EEE Project) is devoted to the study of Extensive Atmospheric Showers (EAS) through a network of muon telescopes, installed in italian High Schools, with the further aim to introduce young students to the methods and results of particle and astroparticle physics[1][2]. The detection of an EAS is operatively achieved by detecting long distance coincidences in time among secondary muons on ground level. Each telescope is a tracking detector composed of three Multi-Gap Resistive Plate Chambers (MRPCs).
The project started with a few pilot stations taking data since 2008, and it has been constantly extended, reaching at present more than 50 MRPCs telescopes (Figure 1). The EEE Project also joints its scientific interest with a powerful outreach action [1][3]. High schools students are introduced to High Energy Physics making them to participate directly to the construction, at CERN, of the MRPCs, moreover teams of students and teachers are effectively involved, inside their schools, in operating and monitoring the EEE telescopes under the supervision of researchers from scientific institutions. The project is supported by *Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi* [2], *Ministero dell'Istruzione, dell'Università e della Ricerca* (MIUR), INFN and CERN.

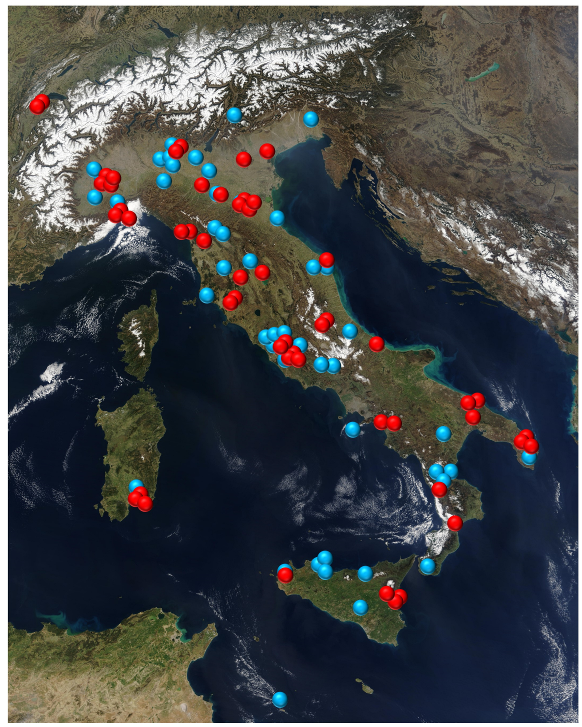

Figure 1. Map of the EEE network sites. They are spread across Italy with two additional stations at CERN, covering an area of above 3×10^5 km^2, spanning more than 10 degrees in latitude and 11 in longitude. The red points correspond to schools hosting a detector, the blue ones to schools participating in the EEE Project even without hosting a detector.

2. The MRPCs telescope stations

The MRPCs used in the EEE Project [4] [5] have six gas gaps of 300 μm,obtained interleaving two glass plates of $164 \times 85 \times 0.19$ cm^3 coated with resistive paint, with five floating glass plates by means of commercial fishing line. They are continuously flushed with a 98% of $C_2H_2F_4$ and 2% of SF_6 gas mixture, and operate in avalanche mode. When an ionizing particle passes through the chamber, a charge avalanche is generated inside each gas gaps. The sum over all the gaps induces a signal on the electrode strips. From the hit strips a signal is transmitted to the two front−end boards (FEAs) to be shaped and then it is fed into two TDCs and into a trigger card sitting inside a VME crate. A six−fold coincidence of the three MRPCs generates the data acquisition trigger.
The absolute time of each event is recorded by means of an external GPS module, in order to correlate the information collected by different telescopes. A weather station completes the muon

Figure 2. Picture of a MRPCs telescope station located in a Lecce's High School: *Liceo Classico G. Palmieri.*

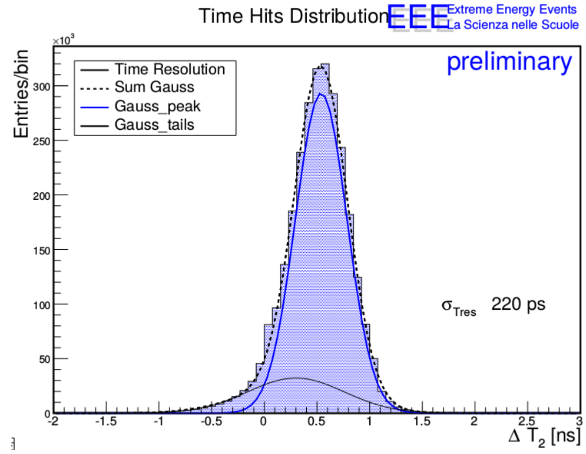

Figure 3. Time distribution obtained as $\Delta T_2 = \frac{T_{Bot}+T_{Top}}{2} - T_{Mid}$, Time resolution is calculated as $\sigma_{T_{res}} = \sqrt{\frac{2}{3}}\sigma_{\Delta T_2}$.

telescope station with the aim of measuring the local value of temperature and pressure. A picture of a EEE Project laboratory inside a school building is shown in Figure 2.

2.1. The coordinated data acquisition

At present all data from the network stations are transferred and stored at the central computer facility of the INFN, the *Centro Nazionale Analisi Fotogrammi* CNAF [6], where events are analyzed and particle tracking procedure is implemented. In November 2014 a first coordinated data taking, Pilot Run, was performed with several telescopes running simultaneously. Afterwards a large number of telescopes of the EEE array participated in Run1 (2015) and Run2 (2016) with 40 telescopes involved and 15 billion of events collected. The current run, Run3, started in October 2016. Up until now the EEE network of telescopes has collected more than 30 billion of cosmic tracks.

3. The EEE Multigap Resistive Plate Chambers performance

3.1. The single MRPC performance

The performance of a single MRPC was measured at the CERN Proton Syncrotron facility. A detailed report of the set−up and the beam−test results has been already described in [7]. The chamber efficiency vs. the high voltage was measured, with the value at plateau reaching 100%. Time resolution, obtained as the σ of the strip mean time distribution, is 141 ps without corrections. A value of 70 ps can be obtained, implementing corrections for pulse width, time slewing and time jitter corrections. Spatial resolution, measured along the strip length is ~ 0.8 cm.

3.2. The telescope performance measured using cosmic rays

The efficiency vs. HV curves for each telescope are measured, inside school buildings. Two scintillators are placed above and below the detectors, providing the trigger on cosmic muons passing through the 3 chambers. All the measurements showed an efficiency higher than 90% at a plateau of 17/19 kV [3][4][5]. This value is compatible with that measured on a single chamber in a test beam.

Time and spatial resolution for the MRPCs telescope have been measured with cosmic muons in the EEE stations, during the Run2 period. Preliminary results have been reported in [8], here a short summary is delineate.

The time and space resolutions are obtained by studying the distributions of the impact time and the impact point of a cosmic particle in the three MRPCs, assuming the same resolution for each MRPC. The distribution of the quantity shown in Figure 3 was studied. The distribution data fit presents two Gaussian contributions and the time resolution obtained from the convolution sigma $\sigma_{T_{res}Tot}$ is ~ 220 ps. The $Y-$coordinate particle impact point, along the short side of the chamber, is defined by the fired strips; the $X-$coordinate along the strip direction is reconstructed as the difference of the signal arrival time at the strips ends, measured by the TDCs. A strip calibration has been applied and the distribution along the strip direction is shown in Figure 4. Also this distribution data fit presents two Gaussian contributions, the convolution sigma $\sigma_{Y_{res}Tot}$ is ~ 2.00

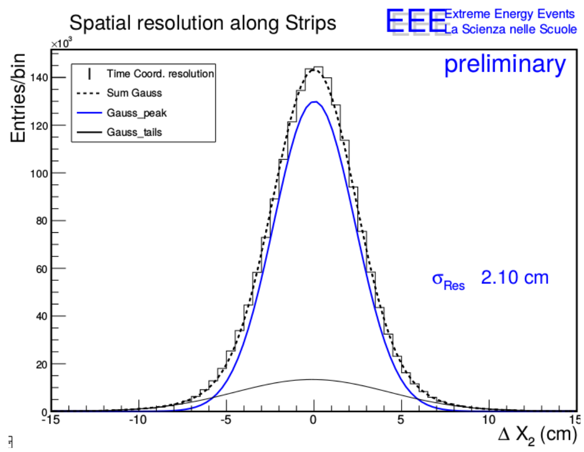

Figure 4. Spatial distribution along the strip direction obtained as $\Delta X_2 = \frac{X_{Bot}+X_{Top}}{2} - X_{Mid}$, The spatial resolution is calculated as $\sigma_{X_{res}} = \sqrt{\frac{2}{3}}\,\sigma_{\Delta X_2}$.

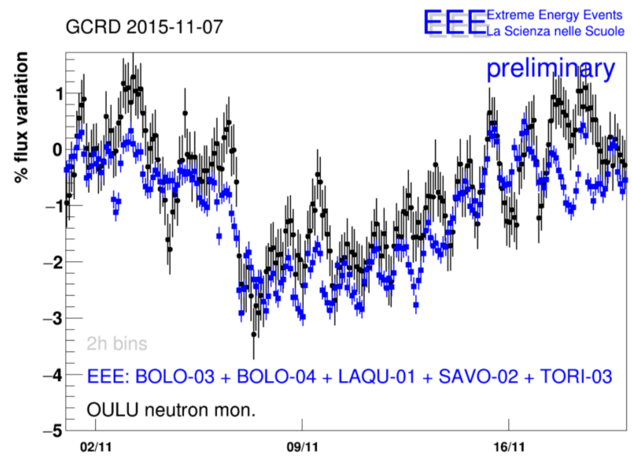

Figure 5. Forbush decrease observed by means of muon rates averaged on 5 EEE telescopes (squares) compared with Neutron rates from the Oulu station in Finland (circles).

cm. The spatial distribution obtained along the short side is 1.0 cm. The performance for a single MRPC is better than that measured during Run2, as expected. When used with secondary cosmic rays many factors can affect these results: the electronic noise, strip miscalibration or multiple scattering can produce a second data population of tracks with larger resolution.

4. Recent Physics Results

The inhomogeneous grid of telescopes allows a multiple, thrilling, approach to the study of cosmic rays: *as a single detector* the EEE telescope is a high precision tracking detector that can study the flux of secondary cosmic muons, their arrival directions and upward−going particles; *as telescopes cluster* in the same town, it aims to study the properties of the EAS in which muons are originated; eventually *as an array* using sites far apart, it makes possible to investigate time correlations between different EAS events. Most of the data collected during the coordinated runs have been analyzed and many results have already been published [9 - 12]. In this paper we will briefly focus on a few examples of analyses performed with EEE telescopes network.

Each single telescope is able to monitor the local flux of the cosmic muons therefore the network is able to detect the Galactic Cosmic-Ray flux Decreases, GCRDs, associated to solar phenomena such as Coronal Mass Emissions (Forbush decreases) or solar flares. Figure 5 shows a typical Forbush decrease observed with different stations contemporaneously by adding up data set from six telescopes. The measured trend (decrease and recovery phase) is well in agreement with the cosmic neutron flux measured by a neutron monitor in OULU [12][13].

Telescopes placed in the same city can detect EASs using couples of telescopes, with a relative distance ranging from a few hundreds of meters to a few kilometers. Figure 6 shows, as an example, the time-difference spectrum obtained between two telescopes in Savona placed at a relative distance of about 1.2 km. To achieve this result, the time difference has been corrected, event by event, for the time delay between the two telescopes caused by the propagation of the wave front of the shower.

5. Summary

The EEE Project successfully combines its scientific results with an educational approach. During the 2016, more than 500 young students and 100 teachers have been involved in the project. Every year new schools join the project, thus the MRPCs network continuously increases its surface coverage. The EEE telescopes efficiency shows the durable, stability of the MRPCs and their performance confirms the EEE Project‘s capability of studying the EAS main proprieties, as shown by the recent physics results.

REFERENCES

1. A. Zichichi, Progetto “La Scienza nelle Scuole” - EEE: Extreme Energy Events (So-

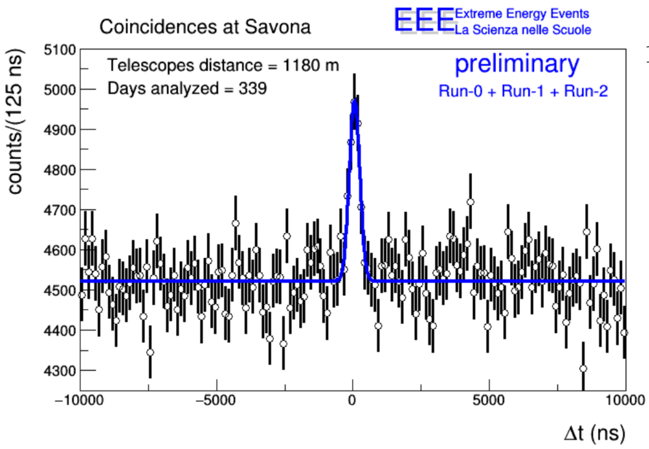

Figure 6. Time difference distribution measured between 2 EEE telescopes placed at a relative distance of 1.2 km in Savona.

cietà Italiana di Fisica, Bologna, 2004).
2. Centro Fermi web site: http://www.centrofermi.it/eee.
3. M. Abbrescia et al., The EEE project: cosmic rays, multigap resistive plate chambers and high school students, JINST 7 (2012) P11011.
4. M. Abbrescia et al., Extreme Energy Events Project: construction of the detectors and installation in Italian High Schools, Nucl. Instrum. Meth. A **588** (2008).
5. S. An et al., Multigap resistive plate chambers for EAS study in the EEE Project, Nucl. Instrum. Meth. A **581** (2007) 209−212
6. CNAF web site: https://www.cnaf.infn.it/en/.
7. M. Abbrescia et al., Performance of a six gap MRPC built for large area coverage, Nucl. Instrum. Meth. A 593 (2008) 3.
8. M. Abbrescia et al., Recent results and performance of the multi-gap resistive plate chambers network for the EEE Project, 2016 JINST 11 C11005
9. M. Abbrescia et al., First results from Run1 of the Extreme Energy Events experiment, PoS(ICRC2015), 2015.
10. M. Abbrescia et al., Looking at the sub TeV sky with cosmic muons detected in the EEE MRPC telescopes, Eur. Phys. J. Plus 130 (2015) 187.
11. M Abbrescia et al., A study of upward going particles with the Extreme Energy Events telescopes, Nucl. Instrum. Meth. A 816 (2016) 142−148.
12. M. Abbrescia et al., Results from the observations of Forbush decreases by the Extreme Energy Events experiment, PoS(ICRC2015), 097, 2015
13. M. Abbrescia et al., The EEE experiment project: status and first physics results, Eur. Phys. J. Plus **128** (2013) 62.