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The Extreme Energy Events Project: Cosmic rays at school

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Summary. — The Extreme Energy Events (EEE) Project, conceived many years ago by its leader Antonino Zichichi, aims to study extremely high-energy cosmic rays through the detection of the shower's muon component by means of an array of tracking telescopes distributed all over the Italian territory. The Project involves Italian High Schools in order to introduce young people to particle and astroparticle physics. The detectors for the EEE telescopes are Multigap Resistive Plate Chambers (MRPC) constructed by teams of High School students at the CERN laboratories. In this paper we present an overview of the EEE Project.

PACS 96.50.sd – Extensive air shower.

1. – Introduction

The Extreme Energy Events Project [1] was designed for being a very large array of muon detectors scattered all over the Italian territory (about $10^6\,\text{km}^2$), located in High School buildings and in INFN sections and laboratories.

The main goal of the Project is to bring science into the youngs' heart through the study of the Ultra High-Energy Cosmic Rays, using a very precise and advanced detector built and operated by them: a muon telescope made of three Multigap Resistive Plate Chambers (MRPCs). The modular characteristic of the array design provides a multiple approach to the study of cosmic rays: one can study very high-energy cosmic-ray showers by means of coincidences between telescopes scattered within the same town or all over Italy, even tens or hundreds of kilometers away. The time correlation investigation is made possible by a GPS synchronization of each telescope, providing an event by event precision time stamp.

The schools involvement in the Project started around 2005 with the construction of 24 telescopes to be installed in seven pilot towns (Torino, Bologna, L'Aquila, Frascati, Lecce, Cagliari, Catania): the involved students and teachers carried on the construction

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Fig. 1. – (Colour on-line) Map of the EEE telescopes location updated at 2010. The red stars refer to the 19 towns in which EEE telescopes have been installed. Numbers refer to telescopes installed in the town area.

and tests of MRPCs at the CERN laboratories under the supervision of researchers from "Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi" (Centro Fermi), "Istituto Nazionale di Fisica Nucleare" (INFN) and the "European Centre for Nuclear Research" (CERN).

After this first phase ("pilot phase"), the array has been enlarged ("second phase"). Another set of chambers for 11 telescopes has been built in spring 2009. Nowadays, 35 telescopes have been built and tested; the installation inside schools has been completed in 19 towns, 18 in Italy and 1 in Switzerland (see fig. 1) and data-taking started.

The EEE Project is one of the main programs of Centro Fermi and it is supported by "Ministero dell'Istruzione, Università e Ricerca" (MIUR), and INFN.

2. – Detector description

The muon tracking telescope of the EEE Project is made of three MultiGap Resistive Plate Chambers (MRPCs), positioned one above the other at a distance which can be varied from 40 to 100 cm (see fig. 2).

The EEE Project MRPCs are a cheaper and wider version of the detector developed for the Time of Flight of the ALICE experiment at LHC [2]. Each MRPC ($80 \times 160\,\mathrm{cm}^2$ of active area) is a stack of resistive glass plates: the signal induced on the pick up electrodes results as the sum of the signals over each gap.

The basic design (see fig. 3) of the wide active area MRPC consists of six gas gaps of $300\,\mu$m, filled with a 98% of $C_2H_2F_4$ and 2% of SF_6 gas mixture to enhance the streamer-free operation inside two resistive plates of glass sheets coated with resistive

Fig. 2. – The EEE muon telescope: 3 MRPCs with the mechanical structure. The moving equipment allows to vary the distance between the chambers.

paint.

Two vetronite panels insulate from the electrodes the readout copper strip (24/layer), obtained applying a copper tape (2.5 cm wide) on the vetronite (see strips and inner glasses in fig. 4).

Two honeycomb panels (15 mm thick) ensure the structure which is then enclosed in an aluminium box provided with standard gas connectors.

The gas mixture is continuously fluxed inside the chambers with a gas flow of about

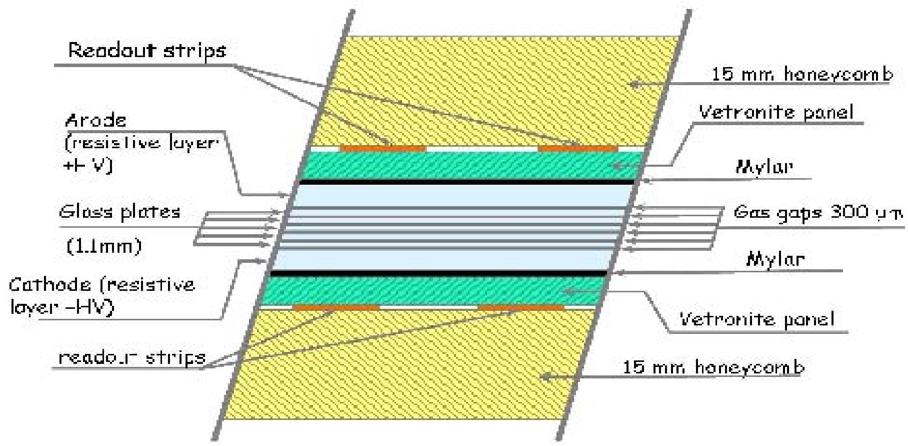

Fig. 3. – The EEE Project MRPC design.

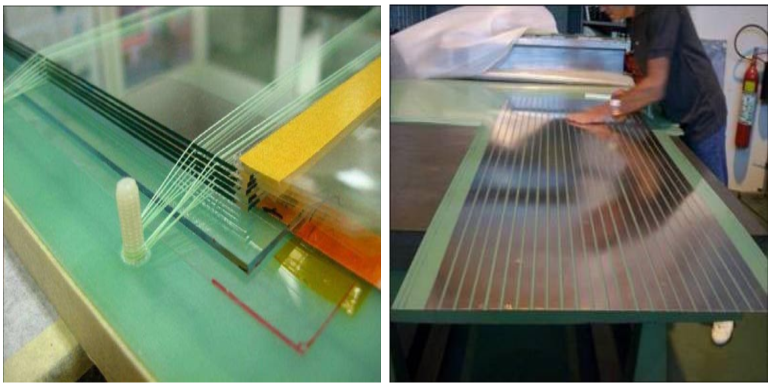

Fig. 4. – Particular of the MRPC inner glass layers and copper strips.

1.5 l/h at atmospheric pressure.

The high voltage to the MRPC electrodes is applied by means of DC-DC converters which supply up to $\pm 10\,\text{kV}$ when powered with 0–5 V. The detector, operated at about 19 kV, shows high efficiency and time resolution of the order of 100 ps [3].

The signal initiated by a charged particle traversing the detector is formed on the readout copper strips and proceeds to both ends of the MRPC where they are read by front-end cards (24 channels each) provided with an ultra-fast and low power consumption amplifier/discriminator designed for MRPC operation (NINO ASIC) [4]. A total of 144 channels is then used for each telescope and time measurements are performed using commercial multi-hit TDCs.

The signals coming from the front-end cards on each telescope are collected and processed by a trigger card in order to provide information to the VME-based data acquisition; each telescope is equipped with a GPS module in order to get time stamp of events. Data acquisition based on LabView is used. For each telescope MRPC both the two impact coordinates and the crossing time of a muon are measured. The two coordinates information on the cosmic-muon impact point is obtained by the hit strip, coordinate x, and by the time difference of the signals arriving at the two strip ends, coordinate y (see fig. 5). Using the impact points in the three chambers it is possible to reconstruct the direction of the crossing muon.

By means of Monte Carlo simulations a geometrical acceptance of $0.34\,\text{m}^2\,\text{sr}$ has been obtained for the telescope with chambers located at a distance of 1 m (see fig. 6). Furthermore, simulations showed that in this configuration the cosmic-muon expected rate is about 35 Hz, in agreement with the experimental value. The angular resolution obtained in the reconstruction of the muon zenith angle is better than $0.5°$. It was found that, due to the very good tracking capability, the array can reconstruct the air shower axis direction, using the directions of the reconstructed muons, with an uncertaintly smaller than $2°$ [5, 6].

3. – Detector construction and installation

The first phase of detectors construction took place between spring 2005 and spring 2006 by high schools teachers and students from 7 pilot towns chosen all over Italy: the high school students constructed the MRPCs of their own telescope during dedicated

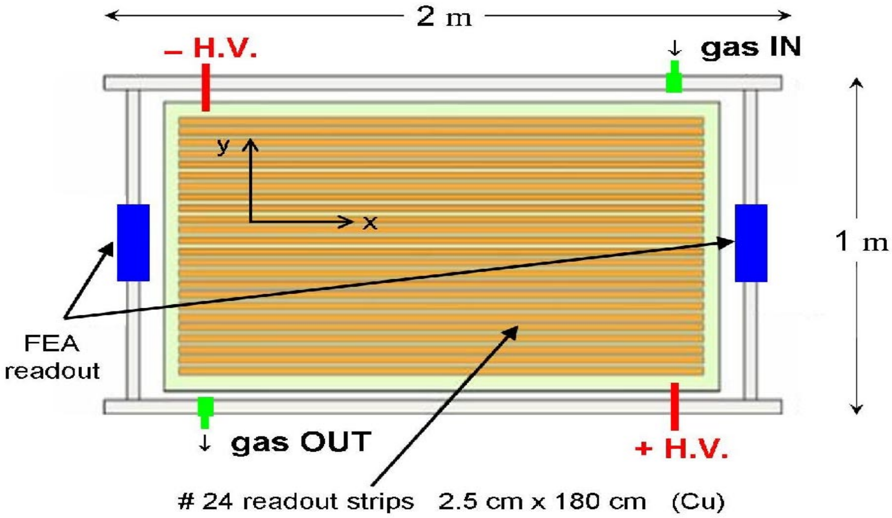

Fig. 5. – Schematic top view of the MRPC.

"stages" at the CERN laboratories and realized how to transform basic components of common use to a very high-precision instrument.

The students work was properly organized in assembly line with the support of researchers and technicians by Centro Fermi, INFN and CERN. After the construction, the detectors have been shipped to Italy to be tested inside INFN sections and laboratories. Preliminary tests concerning the measurement of the detection efficiency show the same

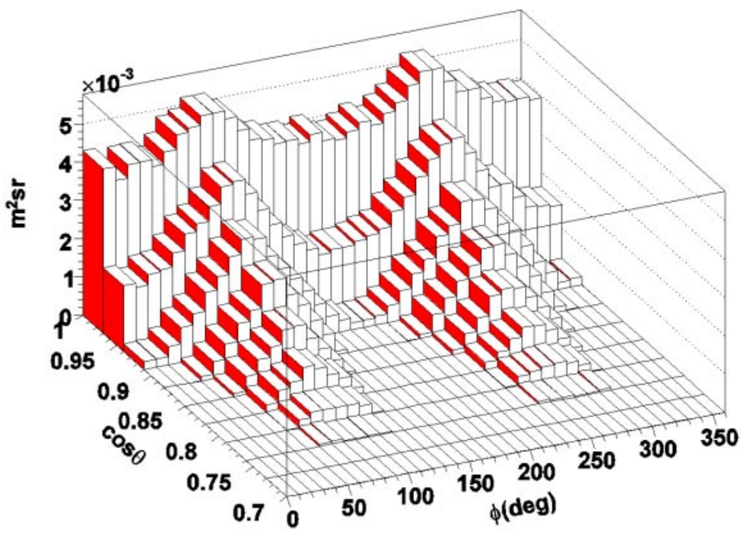

Fig. 6. – EEE telescope acceptance. The integrated acceptance is $0.34\,\mathrm{m}^2\,\mathrm{sr}$ for chambers spaced 1 meter from each other.

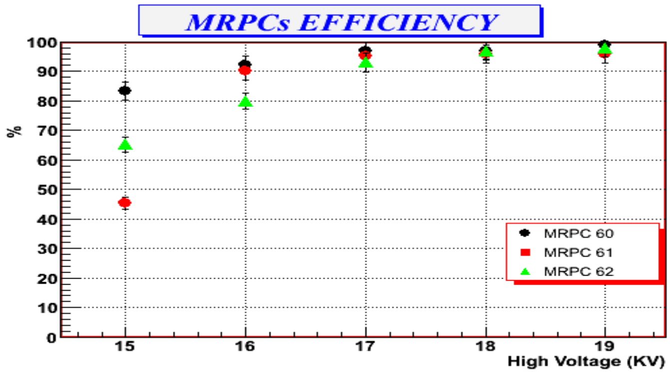

Fig. 7. – The MRPC efficiency measured for a set of three MRPCs as a function of the applied high voltage.

results for all chambers: detectors efficiency at 19 kV close to 100% (see fig. 7) and spatial resolution of the order of some cm^2 [3].

After the preliminary tests, the installation inside the schools of the 7 pilot towns took place and data taking started during 2007. The data collected will be used to search for coincidences over a total area of about $10^6\,\mathrm{km}^2$.

Because of the good results obtained the array is going to be enlarged. In 2009, the second phase of the EEE Project started with the construction of chambers for 11 telescopes. At present they are being installed.

4. – The role of researcher and student

Although the main target of the EEE Project is to detect and study extreme energy cosmic rays, which still has unknown aspects, the young students involvement is equally dominant. It is not just about teaching the physics of cosmic rays in detail, but also to give an educational role to a scientific experiment on a national scale.

The involvement of schools offers young students the opportunity to get in touch with the world of research as active player and not just as listeners. Students are actively involved in all phases of the project under the supervision and help of technical staff and researchers. Indeed:

1. Students build the three MRPC that set up their telescope at CERN laboratories, in collaboration with researchers (see fig. 8).

2. When the construction is completed, researchers organize scientific and technical training internships at INFN sections to introduce teenagers to the research world and to show them what the meaning of "doing research" is.

3. Once the necessary hardware devices has been moved to school, researchers and students install the telescope.

4. When telescopes are acquiring data, the students must ensure their correct working status: instruction manuals are prepared for this purpose. They contain all the necessary information and procedures to be followed to perform periodic (daily, weekly

Fig. 8. – Student involved in the construction of their MRPC telescope at the CERN laboratories.

and monthly) checks successfully. A software control panel has been prepared to allow students to check quickly the working status of the detectors (see fig. 9).

5. All the telescopes located in schools were inaugurated by the Project leader, Prof. Antonino Zichichi, in order to create a collaboration group between researchers and school students and teachers: in the pictures in fig. 10 we can see the inauguration of ITIS Nobili (May 2007) and Liceo Galvani (December 2009) EEE telescopes.

6. During the year seminars concerning physics of cosmic rays and particle detectors are also organized to educate students and teachers and to stimulate their curiosity towards this branch of physics.

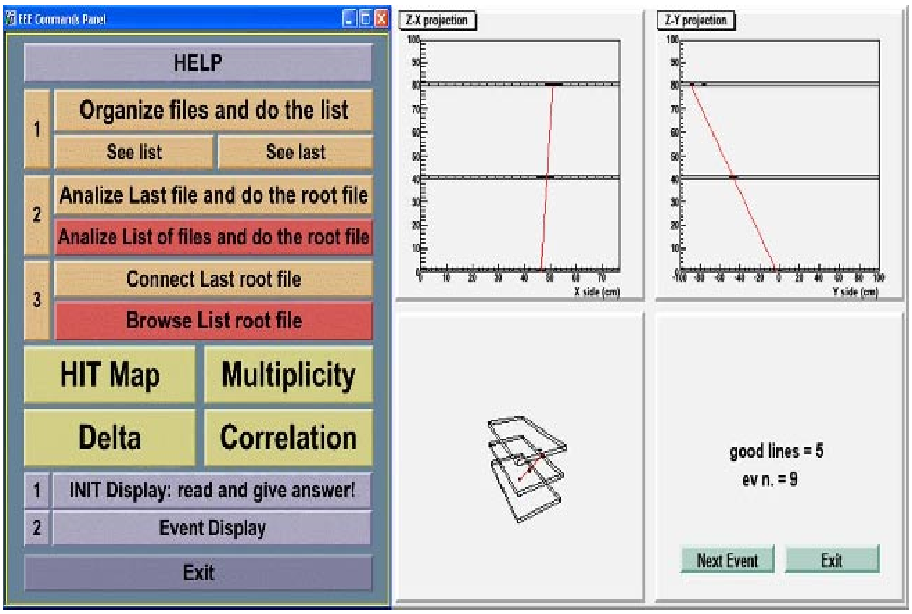

Fig. 9. – Control panel and an example of event display that students can produce by themselves.

Fig. 10. – Pictures of the EEE telescopes inauguration in two schools located in the Emilia Romagna area.

5. – Status of the EEE Project in the Emilia Romagna area

Bologna is one of the 7 pilot towns chosen all over Italy for the first phase of the Project; Liceo E. Fermi, Liceo A. Sabin and Liceo L. Galvani in Bologna and ITIS L. Nobili located in Reggio Emilia, are involved in the Project from the beginning; students and teachers went to CERN between spring 2005 and spring 2006 to construct their detectors. Three other MRPCs were built by INFN-Bologna researchers who set up the telescope installed inside INFN laboratories with the aim to develop and test hardware and software devices.

The installation phase (inside schools) started in 2007. The first two school telescopes installed in the Emilia Romagna area, under the supervision of Bologna researchers was the ITIS L. Nobili and then the Liceo E. Fermi one. After a setup period followed by a training period, the telescopes started commissioning runs during 2007. In the same period the installation phase took place inside Liceo L. Galvani where first data have been collected since mid-June 2008. The installation inside Liceo A. Sabin started in 2008 and the telescope started data taking during spring 2009 (fig. 11).

Concerning the INFN telescope, it was working as test stand since 2006: in fact all MRPCs built at CERN by students from the Bologna area have been tested inside an INFN laboratory before their final installation in schools. Nowadays, the telescopes located inside INFN Bologna laboratories, Liceo Galvani, Liceo Fermi, Liceo Sabin and ITIS Nobili have been running in continuous mode, *i.e.* not programmed stop of data aquisition were imposed even if some telescopes had some hardware problems which were fixed in the shortest time delay. Data have been collected in all telescopes located inside pilot schools and data analysis is going on.

During the second phase of the EEE Project, in spring 2009 a new telescope has been constructed by students and researchers and it will be installed by the beginning of 2011 inside the Liceo G. Marconi in Parma.

6. – Conclusion

The EEE Project aims to study the extremely high-energy cosmic rays through the detection of the muon component of extensive air showers. The main goal of the experiment

Fig. 11. – Satellite picture of Bologna where 4 telescopes are installed.

includes a direct involvement of young Italian students from high schools in order to bring science in their hearts.

Up to now, the EEE Project went through a first pilot phase during which 24 telescopes have been built and installed; nowadays, the telescopes are taking data.

Due to the strong collaboration between schools and research institutions, a large sample of data for coincidences search has been collected. The analysis is going on and some first results have been published [7].

Due to the encouraging results obtained a second phase of the EEE Project started in 2009. Detectors for other 11 telescopes have been built and they are going to be installed in the next months.

The upgrade of the array will give us more information on cosmic-rays showers and will both improve the search for high-energy events and extend to a larger number of young students the opportunity to collaborate to a very exciting scientific experience.

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