Multigap resistive plate chambers for EAS study in the EEE Project

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Abstract

The EEE (Extreme Energy Events) Project, conceived by its leader Antonino Zichichi, is an experiment to study very high-energetic air showers (EAS) through the detection of the shower’s muon component using a network of tracking detectors, installed in Italian high schools. The single tracking telescope is composed of three large area (≈2 m²) Multi-gap Resistive Plate Chambers (MRPCs). The data collected by the telescopes will be used for studies of air showers and also for the search of time correlations between sites which are far apart. The first telescope, recently installed in the Liceo B. Touschek in Grottaferrata (Rome), is successfully running, and other telescopes are going to be installed in a short time in other towns, opening up the way for the first search of long-distance coincidences over a total area of ≈10⁶ km².

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1. Introduction

The EEE Project [1] is designed for being a very large array of particle detectors scattered all over Italian territory, located in high school buildings and in INFN Sections and Laboratories.

The main goal of the EEE Project is to bring Science into the youth’s hearts through the study of the cosmic rays, using a frontier detector built and operated by themselves. Furthermore, the experiment aims to study the Extreme Energy Events class in cosmic rays. To do this, the project is designed to have a modular structure: a standardized setup, a tracking telescope made of three Multi-gap Resistive Plate Chamber MRPC detectors, will be installed in Italian high schools in order to have, once in operation, a grid with two step sizes: a small one (given by the average separation...
of schools within the same city) of the order of hundreds of meters, aimed to measure a single shower; and a larger one of the order of tens or hundreds of kilometers, in order to search for time correlations between sites far apart. The time correlation investigation is made possible by a GPS synchronization of the telescopes.

The project started in 2005 with a first sample of about 20 secondary schools whose students and teachers, supervised by CERN, INFN and Centro Fermi researchers, carried out the construction of the detectors at CERN. Today a set of 72 detectors (24 telescopes) has been built, and installation in the schools started. The network will soon be heavily upgraded.

The experiment is supported by INFN, CERN, Ministro dell’Università e della Ricerca (MIUR), Centro Fermi and conceived by its leader Antonino Zichichi.

2. Detector design

The basic tracking telescope of the EEE Project is composed of three (MRPCs) spaced by 1 m, positioned one above the other as in Fig. 1. This type of MRPCs is a wider and cheaper version of the detector developed for the Time-Of-Flight (TOF) group of the ALICE experiment at LHC [2]. Each MRPC (80 × 160 cm²) is a stack of resistive glass plates, transparent to the avalanches generated inside the gas gaps: the signal induced on the pick up electrodes results as the sum over all the gaps, therefore providing high gain. The detector, operated at about 18 kV, shows high efficiency and a time resolution of the order of 100 ps.

The basic design of the MRPC (Fig. 2) consists of six gas gaps of 300 μm, (filled with a 97% C₂F₄H₂ and 3% SF₆ gas mixture) to enhance streamer-free operation between two resistive plates of glass sheets coated with a resistive paint. Each of the two vetronite panels insulates 24 copper readout strips from the anode and the cathode, respectively. These readout strips are obtained applying a copper tape (2.5 cm wide, gap between strips: 0.7 cm) on the vetronite. Consequently, there are both anode and cathode readout strips, so that a transmission line is created, bringing the signals out to the shorter edges of the MRPC. A twisted pair cable is soldered to the strips; thus a differential signal is transmitted from the MRPC via this cable to PCBs mounted at the two ends of the chamber.

Two honeycomb panels (15 mm thick) ensure the structure which is then enclosed in an aluminium box equipped with standard gas connectors. The gas mixture is continuously flowing through the chambers with a gas flow of about 3 l/h at atmospheric pressure. The high voltage to the MRPCs is applied by means of DC/DC converters which supply up to ±10 kV when powered with 0–5 V.

The signal initiated by a charged particle traversing the detector is induced on the readout copper strips and propagates to both ends of the MRPC where it is readout by front-end cards (24 channels each) equipped with an ultra-fast and low power amplifier/discriminator designed for MRPC operation (NINO ASIC) [3]. A total of 144 channels is therefore used for each telescope, and time measurements are performed using commercial multi-hit TDCs.

On each telescope, the signals coming from the front-end cards will be collected and processed by a trigger card in order to provide information to the VME-based data acquisition system. Ultimately, each telescope will be synchronized by means of GPS in order to get time stamping of the events. Data acquisition based on LabView is being exploited.

3. Performances

In each MRPC of the telescope both the two impact coordinates and the crossing time of a muon are measured.
The two-dimensional information on the cosmic muon impact point is obtained by the hit strip, in one direction, and by the time difference of the signals arriving at the two strip ends in the other direction. Using three impact points (one on each MRPC of the telescope) it is possible to reconstruct the direction of the crossing muon.

By means of a Monte Carlo simulation a geometrical acceptance of 0.34 m$^2$ sr has been obtained for the telescope with chambers at 1 m distance. Furthermore, simulations showed that in this configuration the expected cosmic muon rate is around 40 Hz.

The angular resolution obtained in the reconstruction of the muon zenith angle is better than $0.5^{\circ}$, see Fig. 3. It was found that, due to the very good tracking capability, the telescope can reconstruct the air shower axis direction, using the directions of the reconstructed muons, with an uncertainty smaller than $2^{\circ}$ [4].

### 4. Preliminary tests and results

The detector's construction took place at CERN between spring 2005 and spring 2006 by high schools teachers and students coming from seven pilot towns chosen for the first phase of the project. The detectors have been shipped to Italy to be tested in INFN Sections and Laboratories. After these tests the telescopes will be installed in the schools.

Preliminary tests were aimed at the measurement of the detection efficiency and have been performed in several towns with equivalent results. The efficiency of the MRPCs has been evaluated using scintillators placed above and below the detectors and varying the operating voltages of the chambers. For example, all the tests showed that at an operating voltage around 18 kV the chambers have an efficiency close to 100%, see Fig. 4. Furthermore, some tests have been carried out to evaluate the efficiency when the gas flow was interrupted for a long period: the results show that no relevant decline in the performances became visible in a period of the order of some weeks, see Fig. 5. Preliminary results have also been obtained on the spatial resolution along the strips: the resolution in this coordinate, determined by the time difference in the signal arrival at both ends of the strips, is about 2.5 cm.

### 5. Conclusions

The EEE Project started in 2005 with a first group of Italian high schools from seven pilot towns; the first phase
of the project took place at CERN with the construction of the EEE Project’s MRPC detectors and continued during 2006. Nowadays detectors for 24 telescopes are available.

These detectors have been shipped to Italy and were installed in INFN Sections and Laboratories, or directly in the schools. Preliminary tests performed on the MRPCs in different sites showed that at working voltages (around 18 kV) the chambers have an efficiency close to 100%, and a spatial resolution of about 2.5 cm.

In May 2006, the first telescope was installed in the Liceo B. Touschek in Grottaferrata (Rome) and it is successfully running. Other telescopes will soon be installed and will then start taking data.

References