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The EEE Project

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Abstract: The EEE (Extreme Energy Events) Project, conceived many years ago by its leader Antonino Zichichi [1], aims to study high-energy extensive air showers through the detection of the shower muon component by means of a network of tracking detectors, namely telescopes, installed in Italian High Schools. The Project is supported by the "Ministero dell'Istruzione, UniversitÃ e Ricerca (MIUR)", "Museo Storico della Fisica e Centro Studi e Ricerche E. Fermi", "Istituto Nazionale di Fisica Nucleare (INFN)" and the European Organization for Nuclear Research (CERN). The single tracking telescope for a school is composed by 3 large ($\sim 2\ \mathrm{m}^2$ each) Multi-gap Resistive Plate Chambers (MRPC). Using a very high precision particle detector based on MRPCs allows a very high accuracy direction reconstruction for energetic showers, together with a very good temporal resolution. In its first phase the telescopes are going to be installed in 23 High Schools located in seven pilot towns all over Italy. In the near future, as soon as new fundings will be provided, the network will be upgraded adding new High Schools and towns. The first muon telescopes have been installed in two schools nearby Rome and in one school nearby Bologna, and are successfully running. By the end of the year 2007, other telescopes will be installed. Here we present the experimental apparatus and its tasks.

Introduction

The EEE Project aims to study Ultra High Energy extensive air showers over a very large surface using an array of muon detectors located inside Italian High School buildings [1][2]. The main goal of the Project is to involve the Italian students in a scientific experiment with a very precise instrument: a muon telescope made of three Multigap

Resistive Plate Chambers (MRPCs)[1], as sketched in figure 1. The modular characteristics of the de-

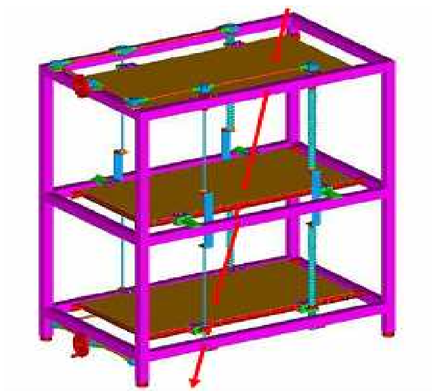

Figure 1: Muon telescope: 3 MRPCs and the mechanical structure. Moving equipments allow to vary the distance between the chambers.

tector design provide 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 is made possible using a GPS unit for each telescope, providing a precision time stamp event by event. The school involvement in the Project started around 2003 with seven pilot towns (see figure 2). The involved stu-

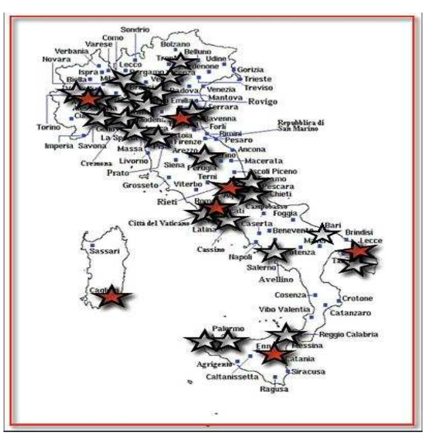

Figure 2: Map of the schools in the EEE Project. The red stars refer to the seven pilot towns.

dents and teachers carried on the construction and tests of their school MRPCs at the CERN laboratories under the supervision of researchers from CERN, INFN and Centro Fermi. Presently, 72 chambers have been built and tested, and the telescopes installation and data taking inside schools has started. Aa soon as the installation will be completed and new fundings will be provided, the network will be upgraded with other schools and towns. The Project, as conceived many years ago by its leader Antonino Zichichi [1], is mainly supported by "Ministero dell'Istruzione, UniversitÃ e Ricerca", "Museo Storico della Fisica e Centro Studi e Ricerche E. Fermi", "Istituto Nazionale di Fisica Nucleare (INFN)" and CERN.

The EEE detector

At the sea level muons are the most abundant cosmic ray shower component since they interact weakly with matter and can be detected inside schools. Furthermore muon reconstruction allows to determine the shower axis direction with very good accuracy. The EEE detector is a muon telescope made of 3 MRPCs at a distance that can be varied from 40 to 100 cm (see figure 1). The High School students constructed the MRPCs of their telescope during dedicated stages at the CERN laboratories. The students work was properly organized in assembly line; some images can be seen in figure 3.

Figure 3: Students involved in the construction of their telescope MRPCs at the CERN laboratories.

Each MRPC (80 x160 cm^2 active area) consists of six gas gaps obtained interleaving two glasses (see figure 4), coated with resistive paint and acting as electrodes, with five floating glasses. Commercial nylon fishing line (300 $\mu\mathrm{m}$ thick) is used as spacer

1. Such MRPCs are a wider and cheaper version of the detectors developed by the Time-Of-Flight group of the ALICE experiment at LHC [3].

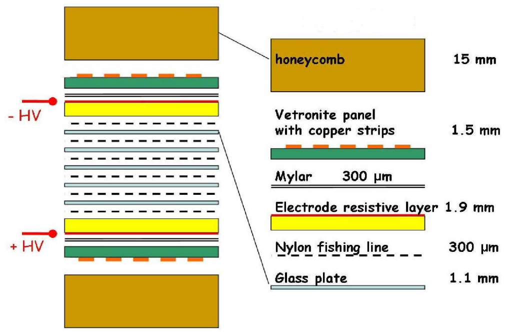

Figure 4: Schematic view of the structure of the MRPC.

between glasses. The chamber is filled with a mixture of 98$\%$ of $C_2F_4H_2$ and 2 $\%$ of SF_6 and is operated in avalanche mode [3]. The high voltage to the electrodes is provided by DC-DC converters which give voltages up to $\pm$10 kV when powered with 0-5 V [4][5]. The signal induced on the pick-up copper strips is the sum over all the gaps. The Δ HV at the electrodes is about 18 kV, with a time resolution of the order of 100 ps [6]. The signal collected on the strips is sent to front end electronics based on ultra-fast channel amplifier/discriminator cards based on NINO-ASIC chips [7]. A total of 144 channels provides time measurements on each telescope using commercial multi-hit TDCs. The Data Acquisition system is VME based controlled by a LabView Program running on a PC which is connected to a VME crate via a CAEN USB-VME bridge. The acquired data can be analyzed by students by means of a user friendly software package properly designed to monitor the detector functionality [8].

The telescope performance

The EEE telescope acceptance has been evaluated by generating 10^7 muon tracks with incoming direction uniformly sampled. Then, considering each track reconstructed only if it crossed all the chamber planes, the acceptance as a function of the zenithal (θ) and azimuthal (ϕ) angle has been evaluated, as shown in figure 5. The integrated angular acceptance is 0.34 $\mathrm{m}^2\mathrm{sr}$ if the chambers are at one meter from each other. The muon reconstruction angular resolution from the simulation is better than 1° for the θ angle, and better than 2° for the ϕ muon angle [1].

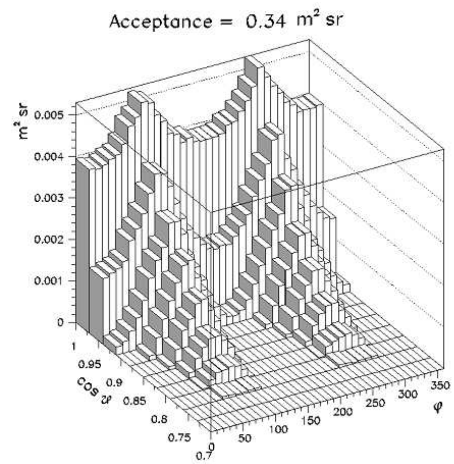

Figure 5: EEE telescope acceptance. The integrated acceptance is 0.34 $\mathrm{m}^2\mathrm{sr}$ for chambers spaced 1 meter from each other.

Another simulation has been carried on to evaluate the resolution in the reconstruction of the shower axis direction. We used two different methods: by taking into account the position and arrival time of the shower front at ground (at least 3 not aligned telescopes are used) and by considering the mean value of the reconstructed muon directions. The results show that almost 70% of the events are reconstructed with an angular uncertainty smaller than $14°$ with the first method (figure 6-1), and smaller than 2° with the second one (figure 6-2).

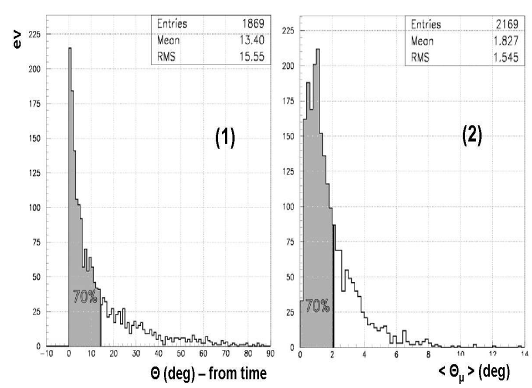

Figure 6: Reconstruction resolution of shower axis direction (see the text).

Preliminary test results

Before final installation inside schools preliminary tests have been performed. The tests are made in order to check that everything is working correctly in the telescope. The MRPC efficiency has been evaluated by means of scintillators placed above and below each chamber and varying the voltage applied to the MRPC. The tests showed that at voltages around 18 kV all the MRPC show an efficiency close to 100%. As an example we report in figure 7 the efficiency curves for 3 MRPCs of a telescope. Other measurements were performed

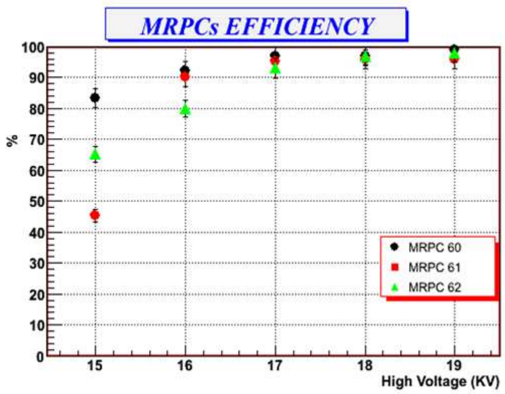

Figure 7: Efficiency measured for the MRPCs of a school telescope: at Δ HV of about 18 kV it is around 95%.

to evaluate the detector spatial resolution which results to be about 1 cm^2 [6]. Furthermore we measured the reconstructed muon zenith angle for events with only 1 hit per chamber (about 10% of all triggers). In figure 8 we show a comparison between the muon reconstructed zenith angle from data (solid line) and from Monte Carlo simulation (dashed line).

Conclusions

The EEE Project, conceived by A. Zichichi many years ago, started around 2003 involving High Schools of 7 pilot towns. The first phase of the Project, concerning detector construction by students and teachers from Italian High Schools, took place at CERN in 2005-2006 and a total of 72 chambers were built. Preliminary tests performed on the built MRPCs showed that the efficiency is close to 100% at operating ΔHV = 18 kV, the time

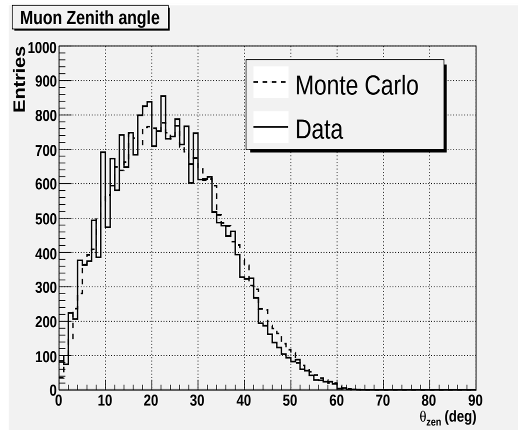

Figure 8: Reconstructed muon zenithal angle from data (solid line) and Monte Carlo (dashed line).

resolution is of the order of 100 ps and the spatial resolution is about 1 cm^2, in agreement with the expected performances. The installation and data taking phase inside schools started and by the end of 2007 many telescopes will be running in the 7 pilot towns. The installation will proceed in the future and, as soon as new funding will be provided, the network will be upgraded.

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