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The EEE Project

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The new experiment "Extreme Energy Events" (EEE) to detect extensive air showers through muon detection is starting in Italy. The use of particle detectors based on Multigap Resistive Plate Chambers (MRPC) will allow to determine with a very high accuracy the direction of the axis of cosmic ray showers initiated by primaries of ultra-high energy, together with a high temporal resolution. The installation of many of such 'telescopes' in numerous High Schools scattered all over the Italian territory will also allow to investigate coincidences between multiple primaries producing distant showers. Here we present the experimental apparatus and its tasks.

1. Introduction

Since the first evidence of the existence of the Cosmic Rays (CRs), dating back to Victor Hess in 1912, an increasing interest grew, for the phenomenon of particles coming from the Space as well as for the detection techniques devoted to measure the secondaries produced in the interaction with the upper atmosphere and arriving down to the ground. The higher the energy of an incoming cosmic ray, the larger the area to be covered in order to measure the induced Extensive Air Shower (EAS) generated so far. Given the peculiarities of the CR flux, the interest to take many data with various kind of detectors widely distributed, aims to confirm (or not) the indications of primaries violating the so-called GZK cut-off (see for example [1] for a review, and references therein). A unified framework for explaining the spectrum behavior at energies above 10^{15} eV is still missing, in particular for what regards the details of the slope changes as well as for the existence of a CRs energy upper limit, or not.

The EEE Project is designed for being a very large array of particle detectors scattered over the whole Italian territory and located inside High Schools buildings and INFN Sections and Laboratories. This set up has the peculiar characteristic of having, once in operation, a double grid pace: a small one (given by the average separation of Schools within the same city), order of hundreds meters, aimed to measure a single shower; a larger one, order of tens or hundreds kilometers, in order to search for correlations between two (or more) primaries. The detectors array inside the same city is sensible to EAS with an energy threshold $\sim 10^{18}$ eV. Using the data coming from different cities it would be possible to search for the existence of a "shower of primaries" formed outside the Earth's atmosphere by means of different mechanisms, from astrophysical [3, 4, 5, 6, 7, 8, 9, 10] to exotic ones (for review [2]).

The review presented in [10] gives a new estimate of the multiple primaries rate provided some years ago in [4], keeping in mind the design and the perspectives of the present experiment.

2. Detector design

The basic idea of the detector is that it has to be able to reconstruct the directions of the incoming muons produced by the interaction of a primary with an air nucleus. The muons mainly proceed directly to the ground without interacting, hence the detection of many of them allows a very accurate measure of the primary's direction. The detector used in this project is a telescope consisting of three Multigap Resistive Plate Chamber

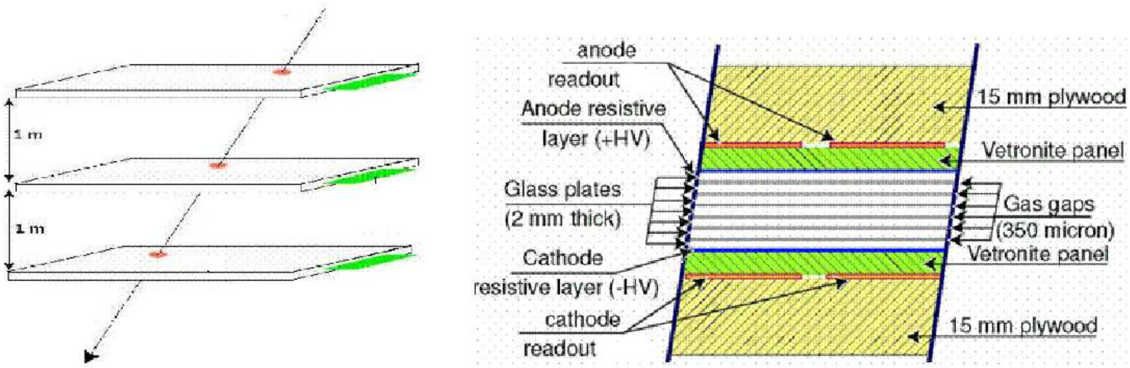

Figure 1. (left) Scheme of the three MRPC detectors constituting the single telescope and (right) prototype of the MRPC chamber and inner layers.

(MRPC) spaced of 1 m, one over the other as in as in Figure 1 (left). This kind of detector is robust, allows to track the secondary muons of an EAS with an angular resolution less than 0.5^o (see Figure 2 (left)), thanks to a space resolution of the track impact point of the order of the centimeter, and time resolutoin of the order of hundred of picoseconds.

The basic design of the MRPC consists of six gas gaps of 350 μm to enhance streamer-free operation inside two resistive plates of glass sheets coated with a resistive paint. Two vetronite panels insulate the readout copper strips from the anode and the cathode. The signal initiated by a charged particle transversing the detector is formed on such strips and proceed to both ends: the time difference of the signals arriving at the two strip ends gives the coordinate along the copper line. A honeycomb support and aluminum boxes complete the mechanics. The two coordinates of the impact point of a muon are then measured in each chamber.

The gas filling mixture consists of 93% $C_2F_4H_2$ and 7% SF_6: the first tests were performed with gas fluxing. Inside the Schools the chambers will operate with no gas fluxing due to security reasons. The apparatus will be tested to determine the gas refilling duty cycle needed to mantain its very high efficiency (close to 100%) for many weeks or months.

3. Performance of the telescope and reconstruction of axis direction

In each MRPC chamber of the telescope both the two impact coordinates and the crossing time of a muon are measured. From the position of the three impact points (one per plane) it is possible to reconstruct the direction of the crossing muon.

Taking into account the design of the MRPC telescope we performed Monte Carlo simulations in order to evaluate the detector geometrical acceptance. A sample of 10^7 muons, with incoming direction uniformly sampled on the upper hemisphere surrounding the detector, has been generated. The resulting overall geometrical acceptance, whose details are shown in Figure 2 (right), is $0.34\ m^2 sr$. The telescope acceptance can, of course,

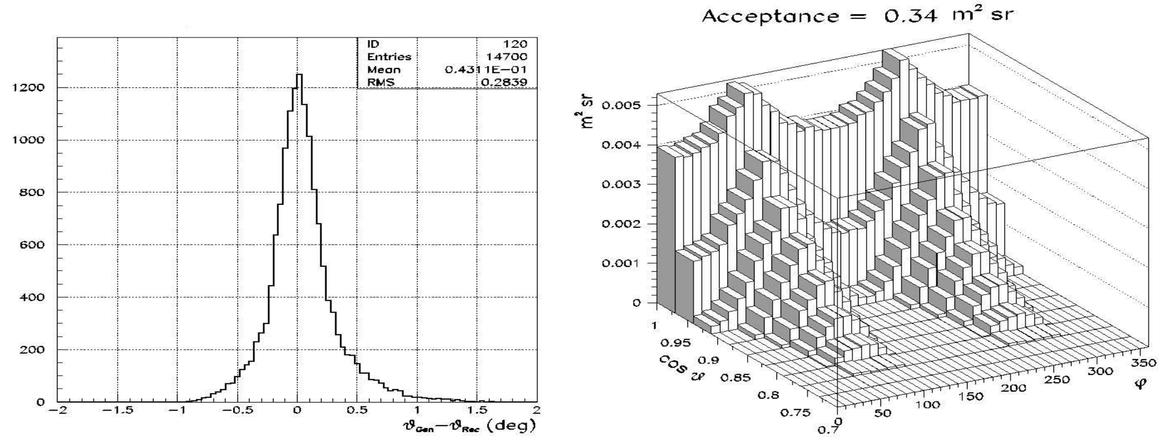

Figure 2. (right) Geometrical acceptance of the telescope in bins of Φ and $\cos(\theta)$. The total acceptance is 0.34 $m^2 sr$ and (left) difference between the generated and the reconstructed muon direction zenith angle.

be varied changing the distance between the MRPC planes so that for example, reducing the distance between the three planes, it is possible to reconstruct muons at larger zenith angles.
Another simulation has been performed in order to evaluate the expected muon rate in one telescope, due to the cosmic muons steady flux. The inputs to the simulation are the known flux and angular distribution of cosmic muons at ground. With this procedure we find that the expected muon rate per telescope is equal to $36\ Hz$. That result has been confirmed with a full Monte Carlo simulation of the primary flux, the shower production and propagation down to the sea level and the muon detection in the telescope.
We also studied the telescope capability to reconstruct the shower axis direction. Using the position and arrival time of the shower front on the detectors at ground (at least three non aligned detectors are needed) 70% of the reconstructed shower axes have an angular uncertainty smaller than 14^o (Figure 3 (left)).
Thanks to the telescope excellent tracking capabilities it is possible to reconstruct the shower axis direction using the reconstructed muons direction. As shown in Figure 3 (right) 70% of the reconstructed shower axes have an angular uncertainty smaller than 2^o. The accuracy increases with the number of muons hitting the detectors even if this method can provide informations on shower axis direction even when less than three telescopes are hit (which is otherwise impossible using arrival times).

4. Project plan

The EEE Project will last at least 10 years and has to cover the whole Italian territory as much as possible, in order to obtain a grid over more than 300.000 km^2. The actual plan is designed to follow the natural distribution of candidate Schools, characterized by a closer spacing within each city of order of hundreds meters and a larger one between one city and the other, of order hundreds of kilometers. Where a INFN Section is present, an additional telescope will be installed also there.
The financing institutions in Italy are “Museo Storico della Fisica and Centro Studi e Ricerche Enrico Fermi” in Rome, the MIUR - Ministero dell’Istruzione Università e Ricerca and INFN - Istituto Nazionale di Fisica

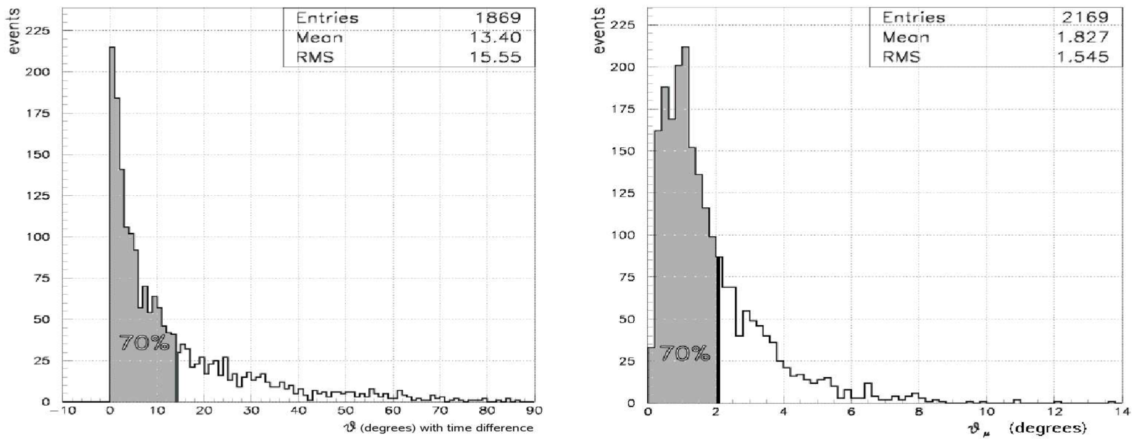

Figure 3. Angular resolution of the reconstruction of the shower axis direction (left) taking into account the arrival time information and (right) the recosntructed muons. The shaded areas shows that 70% of the events are reconstructed with an angular uncertainty smaller than 14^o (left) and 2^o (right).

Nucleare.
The present status of the apparatus consists of the full construction and testing of advanced prototypes of 21 MRPC performed in the CERN facilities. These first telescopes will be installed in seven piloting Schools by the end of the year 2005, while the construction of more detectors is ongoing and fastly proceeding.

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