Detector simulation framework for Extreme Energy Events (EEE) Project

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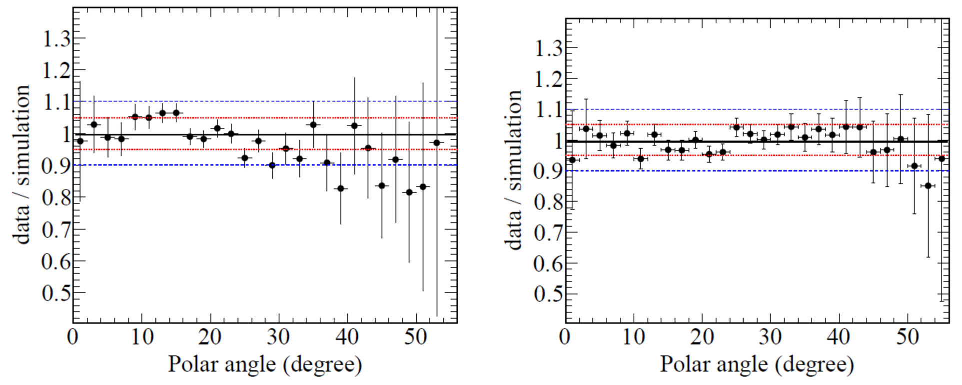
Introduction

EEE is a network of cosmic muon trackers, each made of three Multi-gap Resistive Plate Chambers (MRPC)[1], able to precisely measure the absolute muon crossing time and direction of each single muon at the ground level. The detector network currently has about 60 stations, distributed over an area of 3x10^5 km^2, mostly located within Italian High Schools with the aim of also promoting scientific Outreach. Due to the peculiarities of the individual sites, the response of the telescopes may differ and it is therefore essential to know it in detail. The response of a single MRPC and the combination of three chambers have been implemented in a GEANT4-based framework (GEMC) to study the telescope response and the influence of surrounding materials.

Simulation framework validation

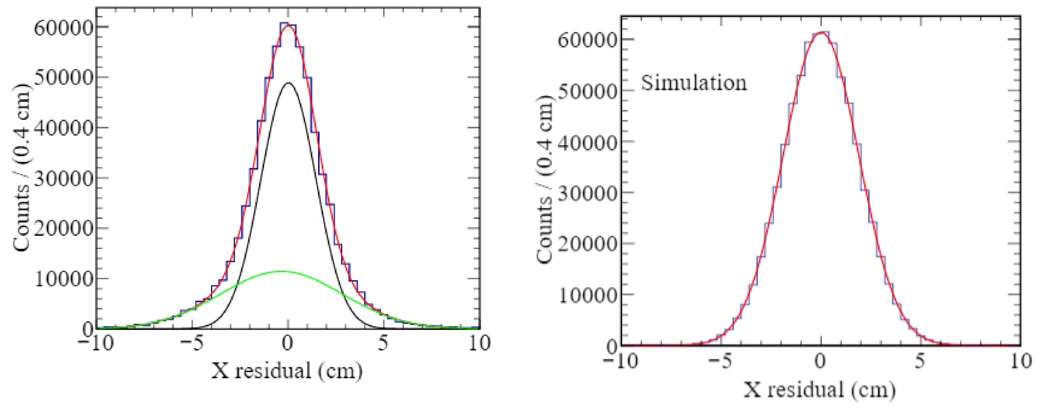
TORI-03 and CERN-01 experimental set-up are implemented in GEMC using their geometry and surrounding. Experimental data have been corrected by weighting each event with the corresponding value of the local efficiency map.



Experimental-simulation ratio of polar angle distribution for TORI-03 (left panel) and CERN-01 (right panel) telescopes.

EEE simulation framework is able to reproduce the absolute observed angular cosmic muon rate within an error of about 5% for polar angle lower than 25° and of 10% for polar angle lower than 38°[11].

In addition to the angular distributions, comparisons were made with other quantities such as spatial resolutions, showing also in this case a good agreement between simulations and real data.



TORI-03 track X coordinate residual (left) and simulation (right)

Conclusion:

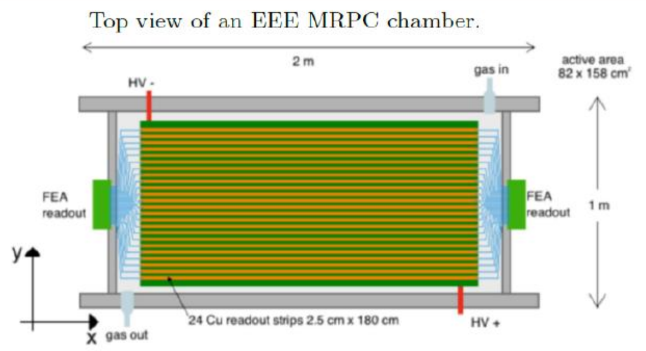
The EEE Simulation framework is a valuable tool to study the detector performance in terms of: efficiency, angular and spatial resolutions, and dependence on telescope set-up (including detector geometry and surrounding materials). Simulations permit to correct the response of different detectors in the EEE network in order to achieve the systematic precision requested by the study of small effects. simulation framework can be used to investigate new directions, such as the use of cosmic muons for building tomography, extending the current scope of the EEE Collaboration.

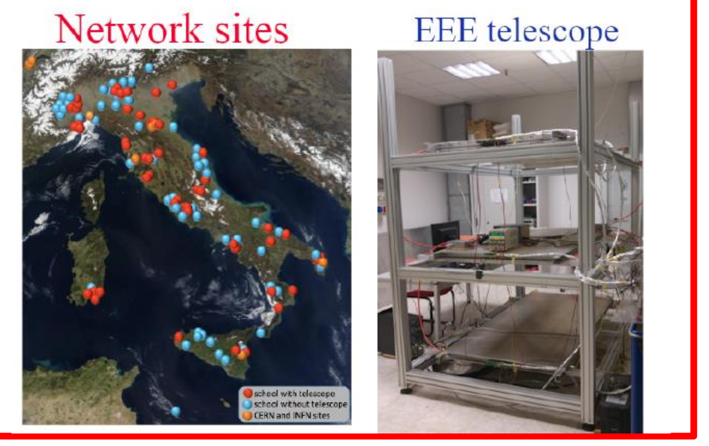
EEE Network & Studies

About 60 operative sites in different dislocations:

- single stations;
  - Study muon flux decrease due to solar events [2][3]
  - Study of Anisotropy at sub-TeV scale [4]
  - Study of muon decay into up-going events [5]
  - Determination of telescopes performance [6]
- city clusters (2-4 telescopes),
  - Search coincidences b\w near telescopes [7]
  - Search of long distance correlations [8]

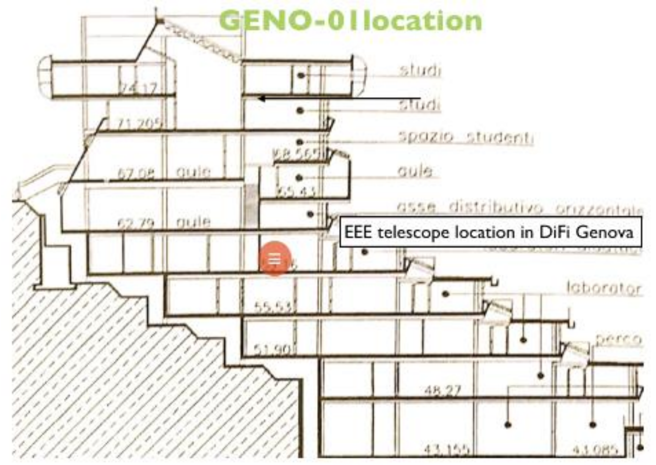
Top view of an EEE MRPC chamber.

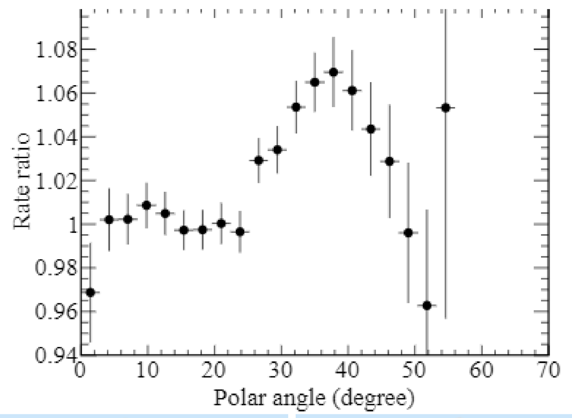


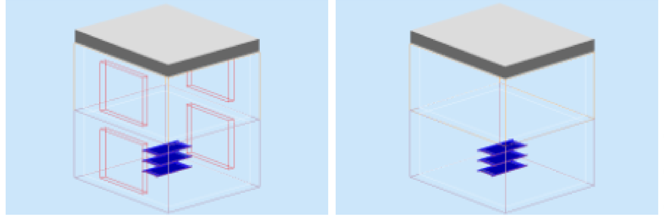


Effect and Sensitivity of surrounding material

For a correct comparison of different telescopes it is therefore important to evaluate the effect of the location. As mentioned, the EEE telescopes are often placed in rooms with variable thickness of concrete walls and roof. Detailed drawings of the building are not always available for a thorough assessment of the experimental conditions.

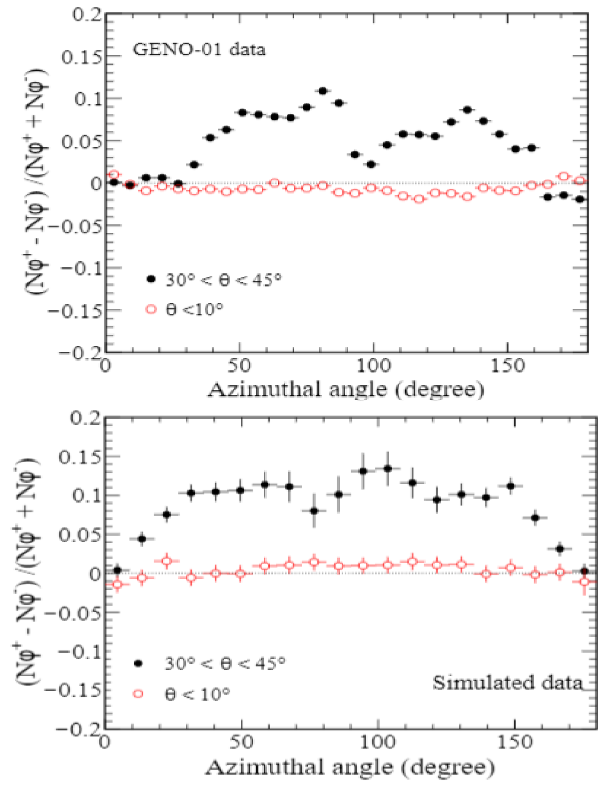






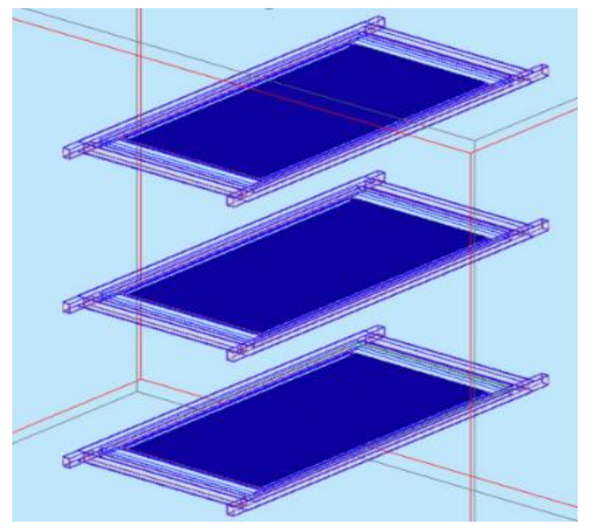
In addition to the effects due to the material overlying the telescopes, lateral obstacles such as the presence of a wall or the presence of a window near the detector must also be considered. Simulation results show that even such a little detail affects the measured angular distributions. Such a significant sensitivity, is an interesting feature that demonstrates how muons can used to perform a scan of surrounding materials (muon tomography [12]).

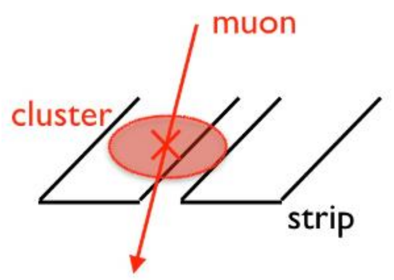
Furthermore, in some cases the conformation of the site is particularly complicated (top figure).However, such complicated cases, as for example the telescope installed at the Physics Department of the University of Genova (GENO-01), made it possible to verify the sensitivity of the simulations to such situations. The telescope is located under many floors and the building is surrounded by a mountain on one side and a valley on the other, defining an asymmetric shielding for cosmic rays (left).



Simulation & Parametrization

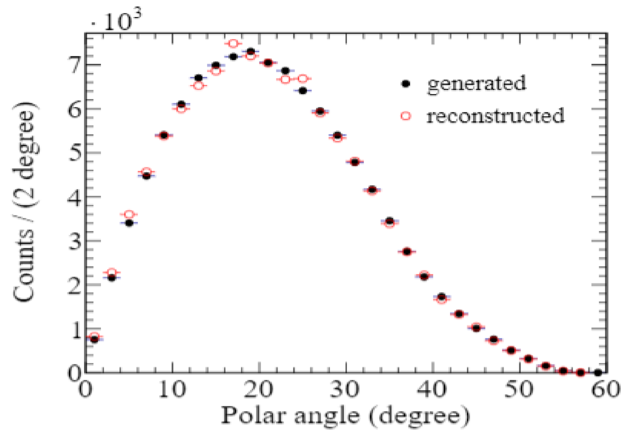
A detailed description of the MRPC geometry and materials has been implemented in GEMC. To mimic a generic room where a real telescope is located, the three chambers are inserted in a box whose walls are made of concrete with variable thickness. More complicated geometries of the surrounding materials have also been implemented.





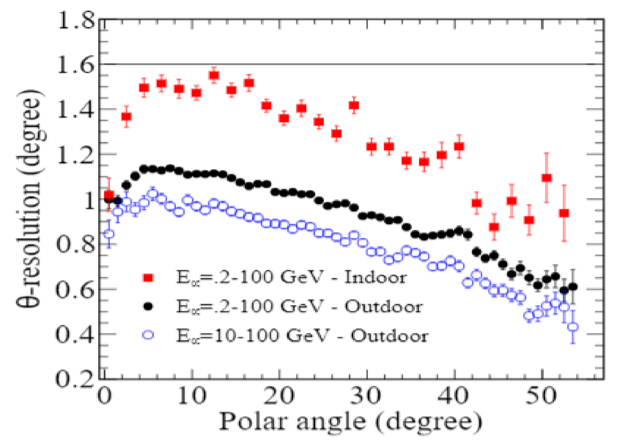
The MRPC response was parametrized based upon the measured performance of the chambers. Events generated with GEMC are pre-processed to mimic the hardware trigger and generate pseudo-data to be fed to the standard EEE data reconstruction chain.

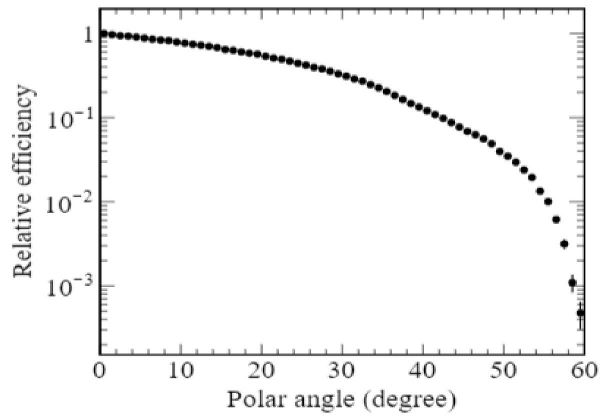
Single-muon events are generated according to the model described in Ref.[9]. The azimuthal distribution is considered to be uniform. The polar angle distribution is taken from an improved [10] Gaisser-like parametrization.



Resolution & Efficiency

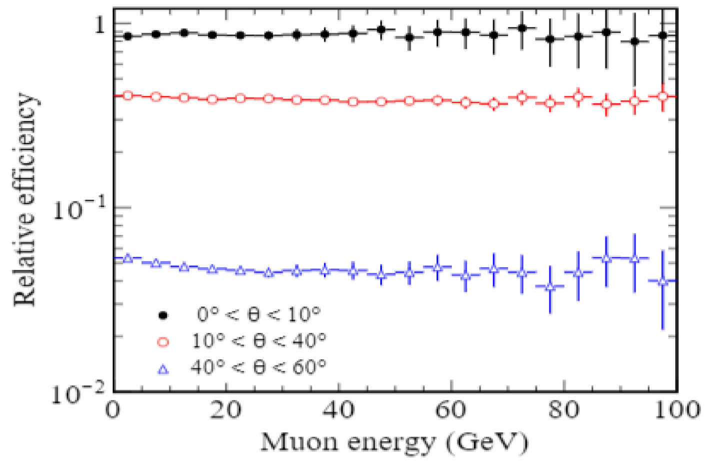
The telescope polar angular resolution (Right) has been evaluated by generating muons according to the improved Gaisser energy distribution in the (10-100) GeV energy range to minimize multiple scattering of crossing particles.





The relative detection efficiency, obtained as the ratio of detected and generated muons, as a function of the polar angle (left) for outdoor telescope, and muons generated in the full energy range (0.2-100 GeV). The distribution has been normalized to the value corresponding to vertical tracks.

The relative detection efficiency as a function of muon energy for different intervals of track polar angle (right). The distributions are normalized to the maximum value corresponding to θ= 0°.



Reference:

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