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Abstract. The Extreme Energy Events (EEE) experiment consists in a network of cosmic muon tracker telescopes, each made of three Multi-gap Resistive Plate Chambers (MRPC), able to precisely measure the absolute muon crossing time and the muon integrated angular flux at the ground level. To investigate the MRPC telescope response and performance, a simulation tool was developed in GEMC, software package based on GEANT4 libraries. The framework was validated by comparing simulations with the EEE experimental data. Detailed description of telescope response is fundamental to carry on the physics program of the EEE project, and it could open other research avenues, such as using the telescope in combination with other detectors to perform a (muon) tomography of material surrounding the telescope. In this paper, the EEE simulation framework will be presented reporting results and discussing further applications.

1. Results and Discussions

The Extreme Energy Events (EEE) experiment [1,2] deployed a network of about 60 cosmic muon detectors sparse in an area of 3×10^5 km^2. The EEE network acts as a gigantic telescope that, precisely measuring cosmic muon rates and arrival times, looks at the sky in a complementary way than traditional optical telescopes. The EEE main goal is to study high-energy cosmic rays, and some recent results published by the EEE Collaboration include: observation of the Forbush effect [3], searches for anisotropies in the cosmic ray intensity [4], and long distance correlation in secondary muons [2].

Each station of the EEE network, that defines a "telescope" for cosmic rays (mainly muons), is made of three Multigap Resistive Plate Chambers (MRPC) [5] specifically designed to achieve good tracking and timing capability, low construction costs, and an easy assembly procedure [6]. The three MRPC chambers are placed one above the other with the top and the bottom chambers at a distance of 50 cm from the middle chamber in the most common working configuration resulting in an angular acceptance of 2.23 sr.

All EEE detectors, based on the same MRPC technology, may present slightly different experimental configurations (e.g. the distance between the chambers and the absolute orientation w.r.t. the North are not always the same). Moreover, the measured rate is affected by the material surrounding the detector that is different for each telescope since they are hosted in rooms located in non-dedicated buildings (high schools or university labs). Therefore, the interpretation of experimental observations (cosmic ray absolute rates and angular distributions) requires a reliable MonteCarlo simulation of the detectors response and experimental conditions.

The EEE simulation tool implemented by using the GEMC [8] framework, based on GEANT4 libraries [7], includes: single cosmic muon generation based on an improved Gaisser parametrization of the muon flux at the Earth level (see [9–12]), propagation through materials surrounding the detector and a parametric description of the MRPC response to charged particles, experimental trigger emulation and track reconstruction [13].

To validate the simulation tool, we selected two telescopes known to be very stable in time and hosted in building with roof and walls easy-to-implement in simulations: TORI-03 telescope, hosted in the High School in Turin, working with the most common configuration 50/50 cm distance between the chambers; CERN-01 telescope, hosted by CERN, working with top/bottom chambers distanced by 44/44 cm. The comparison between single-muon rates measured by

TORI-03 and CERN-01 and the simulations, corrected by the experimental detector efficiency (as described in Refs. [13, 14]), are reported in figure 1. The agreement within 5% at small θ

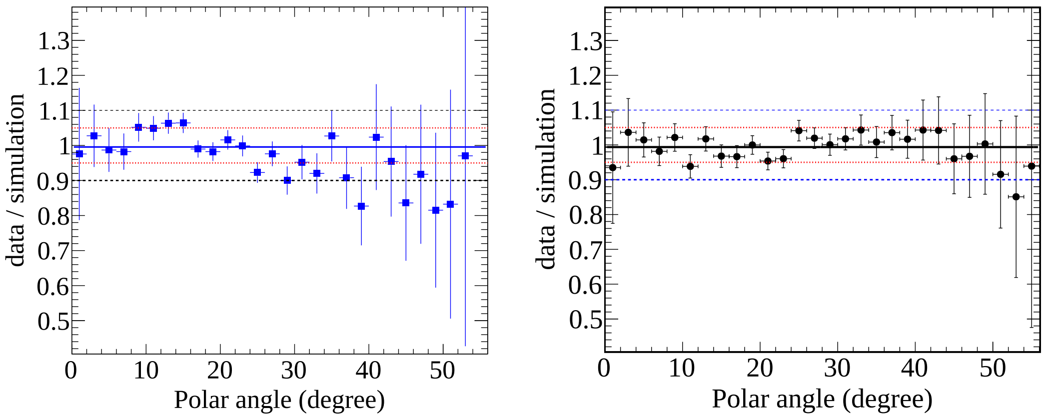

Figure 1. Experimental-simulation ratio of polar angle distribution for TORI-03 (left panel) and CERN-01 (right panel) telescopes.

and ∼10% in the whole polar angle acceptance, and the mean value of the ratio resulting to be around unity, demonstrate that the EEE simulation framework is able to reproduce the absolute observed angular cosmic muon rate in different working and set-up conditions.

EEE telescopes often work in different surrounding material conditions. We investigated this effect by simulating the telescope working

Simulation of a telescope working in a room (parametrized with walls of 30 cm concrete thickness) at the first floor a building of two floors, in two different building configurazions: one with large windows in both floors and the other without, shows difference on counting rates fot the two configurations up to 8% at polar angle larger enouhìght to intercept the windows [13]. Such a significant sensitivity stresses the importance to take into account the possible distorsion in counting rate due to morfology of building hosting the telescope, but on the other hand shows the interesting feature to use muons as a proble to scan the surrounding materials [15]. Experimental evidence of this effect was observed in real data in the telescope hosted in the University of Genoa where the singular structure of the building hosting the telescope produces a counting rate asymmetry with respect the azimuthal angles at polar angles larger than 30 degree.

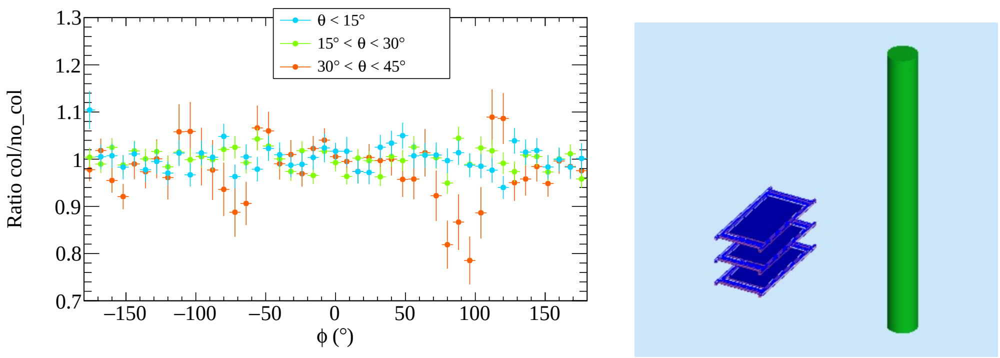

Figure 2. Ratio of the simulated rates for muons of 0.2-2 GeV energy obtained by using a geometry with an iron column at a side of the telescope and by a telescope working in a free space (left panel). Rendering of the simulation with the iron coulumn (left panel).

This effect has been reproduced and interpreted with the simulation (see details in [13, 16]).

A further example of the features provided by the simulation tool is reported in figure 2, where we report the ratio of the simulated muon counting rates as a function of the azimuthal angle, registered by a telescope working with an iron cylindrical coulumn 5 metres tall placed 4 metres far from its long side and one working in a free space, by using muons of 0.2-2 GeV. The choice of low energy muons is to amplify the shadow effect of the culomn. The ratio (left panel of figure 2) shows a sensitive reduction of counting rate for polar angle higher than 30 degree at azimuthal angles arount +90 degree due to the presence column shadow. This proves how the telescope is able to locate the angular position of absorver material, like the column in this case.

2. Conclusion

The EEE Collaboration developed a full simulation framework, implemented in GEMC, to study the response of the cosmic muon telescopes of its network. Simulation tool was validated with experimental data. It is a valuable tool to study the detector performance: efficiency, angular and spatial resolutions, and dependence on telescope set-up. It can be used to compare and correct the response of different EEE telescopes for precise measurement of cosmic ray flux due to the Forbush effect. It can also be used to investigate new directions, such as for example the use of the cosmic muons for building tomography. The tool is ready to be interfaced with Corsika events generator [17] for the investigation of extensive air showers with the EEE telescop network.

Acknowledgments

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