29th International Cosmic Ray Conference Pune (2005) **8**, 25-28

Muon-Induced Air Showers Affecting CMS Tracking Detector

A. Mahrous[a], M.M. Sherif[b], O. A. Moussa[b], M. Orabi[b], A. Ali[a] and Y. Assran[c]
(a) Physics Dept., Faculty of Science, Helwan University, Cairo, Egypt.
(b) Physics Dept., Faculty of Science, Cairo University, Giza 12613, Egypt.
(c) Physics Dept. Faculty of Engineering, Suez Canal University, Egypt
Presenter: M. M. Sherif (hepl2cu@mailer.eun.eg), egy-sherif-MM-abs1-he15-oral

The CMS (Compact Muon Solenoid) tracing detector could be affected by atmospheric muons produced by ultra high energy cosmic rays. We study the propagation of such energetic muons by injecting air showers normally to the CMS location. Energetic showers produced be primary protons have been simulated using the QGSJET model depending on the Monte Carlo technique. The simulated showers within the energy range $10^{13} \sim 10^{20}$ eV have been developed to study the energy spectrum of the produced muons reaching the ground, and that penetrating the CMS cavern. The later should be detected as a background in the CMS detectors. Upon our simulations, the cutoff energy of muons penetrating the CMS cavern was equal 58 GeV, and this amount of energy could be produced by air showers of primary energy greater than 10^{13} eV.

1. Introduction

The Large Hadronic Collidor (LHC) at CERN will accelerate protons to energies 7×10^{12} eV in the 27 Km tunnel beneath the French/Swiss border. We have measured cosmic ray particles with energies almost 8 orders of magnitude above this. Currently, the energy record is held by a particle observed by the Fly's Eye experiment which carried an energy of 3.2×10^{20} eV [1]. Primary cosmic rays suffer a series of subsequent collisions with the Earth's atmosphere, forming the so-called atmospheric cascade. The muon production process begins with the interaction of a primary cosmic ray with an atmospheric nucleus. A pion is produced which may interact with another atmospheric nucleus or decay into a muon. If a muon is produced it may decay and stop in the atmosphere or it may penetrate to the surface or underground [2]. Surface muon observations have significant responses from approximately 10 GeV to several hundred GeV, while underground muon observations extend up to slightly above 1000 GeV, which can penetrate to long depths under the ground. Our paper concerning such penetration to the CMS cavern at CERN, and its effect on the tracking system of the experiment.

2. Geomagnetic Cutoff

The geomagnetic field prevents low-energy particles from reaching the ground level. This leads to the concept of geomagnetic cutoff, which means a rigidity threshold for CR particles, which can reach a certain geographical location. The geomagnetic cutoff rigidity is estimated by a simple empirical formula:

$$P_{cut} = 60 \times \left(\frac{1 - \sqrt{1 - \cos\theta . \cos^3 \beta}}{\cos\theta . \cos\beta} \right)^2$$

Where P_{cut} is expressed in GeV, β is the geomagnetic latitude and θ is the angle between the incoming particle velocity and the geomagnetic East-West direction. We have calculated the geomagnetic cutoff rigidity for the CMS location, it was equal 5 GeV.

3. Simulation Results

The energy spectrum of muons reaching the ground level produced by primary protons are shown in logarithmic scale as in figure 1 and figure 2. The four curves in figure 1 are corresponding to primary energies, from down to up, 10^{13} eV, 10^{14} eV, 10^{15} eV and 10^{16} eV respectively. The four curves in figure 2 are corresponding to primary energies, from down to up, 10^{17} eV, 10^{18} eV, 10^{19} eV and 10^{20} eV respectively. We used the QGSJET model in Aires V.2.2.4 to produce such air showers after setting the geomagnetic conditions at the CMS location.

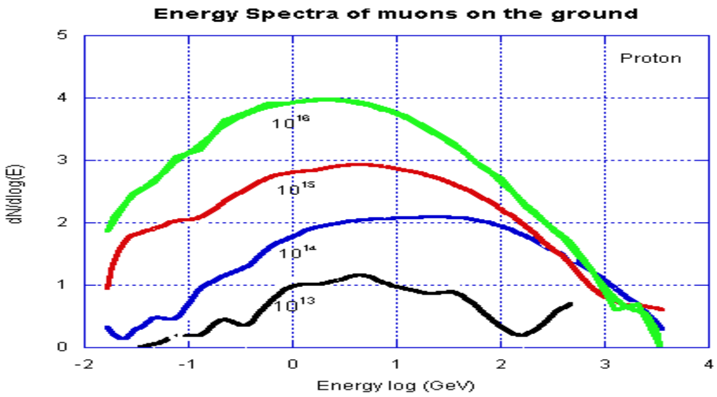

Figure1. The energy spectrum of muons reaching the ground level produced by primary protons. The four curves are corresponding to primary energies, from down to up, 10^{13} eV, 10^{14} eV, 10^{15} eV and 10^{16} eV respectively.

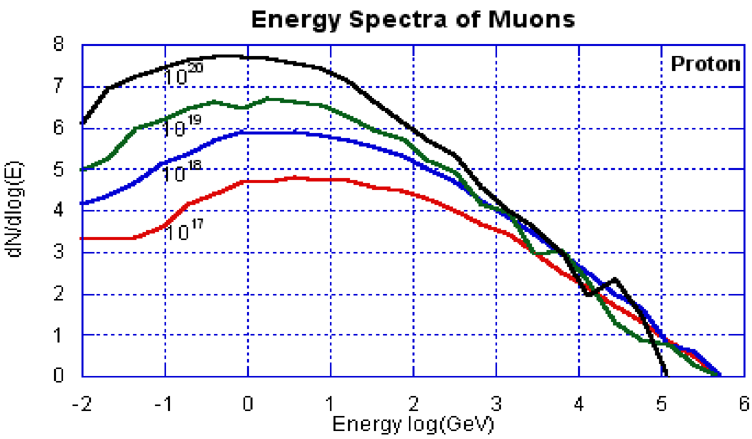

Figure 2. The energy spectrum of muons reaching the ground level produced by primary protons. The four curves are corresponding to primary energies, from down to up, 10^{17} eV, 10^{18} eV, 10^{19} eV and 10^{20} eV respectively.

The energy spectrum of muons on the ground level was the input for the Monte Carlo simulation package to calculate the muons penetrating the CMS cavern. The construction of molasses and rock material above the cavern have been set as in [3].

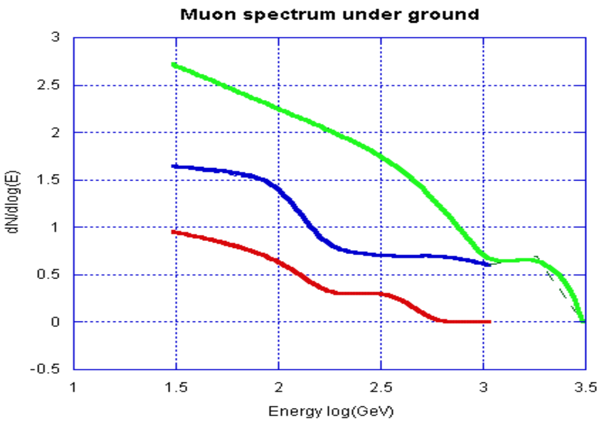

Figure 3. The energy spectrum of muons penetrating CMS cavern which produced by primary protons. The three curves are corresponding to primary energies, from down to up, 10^{14} eV, 10^{15} eV and 10^{16} eV respectively.

The energy spectrum of muons penetrating through CMS cavern initiated by primary protons are shown in logarithmic scale as in figure 3 and figure 4. The three curves in figure 3 are corresponding to primary energies, from down to up, 10^{14} eV, 10^{15} eV and 10^{16} eV respectively. The four curves in figure 4 are corresponding to primary energies, from down to up, 10^{17} eV, 10^{18} eV, 10^{19} eV and 10^{20} eV respectively. The energy spectrum curve for propagating muons corresponding to energy 10^{13} eV was not drown since all the produced muons of that shower have been absorbed during their passage through the cavern.

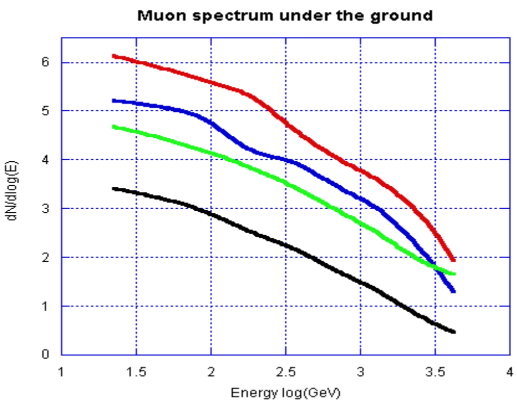

Figure 4. The energy spectrum of muons penetrating CMS cavern which produced by primary protons. The four curves are corresponding to primary energies, from down to up, 10^{17} eV, 10^{18} eV, 10^{19} eV and 10^{20} eV respectively.

4. Conclusions

We studied the propagation of energetic atmospheric muons produced by high energy cosmic ray protons traveling through the soil above CMS cavern. Our simulations showed that muons with energy less than 58 GeV could not be able to penetrate to the cavern and will be completely absorbed in the soil. Such energetic muons could be produced by air showers with primary proton energy > 10^{13} eV. The muons produced by higher energies can penetrate to the CMS cavern and could be detected as a background.

5. Acknowledgments

We thank the Authorities at CERN for their help especially the CMS team. We thank J. Ellis for his helpful discussion

References

[1] Dawson R., High Energy Phenomenology, UNICAMP Campinas, Brazil, July 13-17, 1998.
[2] Duldig M., Muon Observations, Space Science Reviews 93: 189-208, 2000.
[3] Alessandro B., et. al. , ACORDE, a cosmic ray detector in ALICE, ICRC, 1203-1206, 2003.