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Theoretical and simulation study of gamma initiated particle showers in the atmosphere

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ABSTRACT

In the present work, we carry out simulations to study the development of particle showers generated by photons as primary cosmic rays. We aim to determine whether or not it is possible to detect a Gamma Ray Burst (GRB) generated by an external source to the Earth with a Cherenkov detector placed at 4600 m.a.s.l.. We compare the results of the simulations with theoretical models that describe the behavior of the showers at the detector level. In addition, we will be able to establish the characteristics of a detector to be implemented in the future. We used ARTI, the LAGO-CORSIKA simulation chain in order to generate the gamma initiated particle showers in the atmosphere to obtain the information of the secondaries that reach the site of study.

INTRODUCTION

In the present work, the viability of observation from ground of GRBs in the energy range 1 GeV and 1 T eV will be done by analyzing the results of a simulation in CORSIKA. We will study the possibility of detection, by an Cherenkov detector, of a GRB by placing the detector at 4 600 m.a.s.l. (altitude of the town of Arequipa, where the future detector will be held), by simulating 1 000 showers initiated by photons with energies between 1 GeV and 1 TeV and then we will analyze the results by plotting several important parameters in the development of a shower from the information obtained from the secondary particles that reach such indicated height.

METHODOLOGY

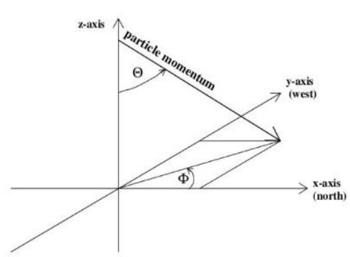

Fig. 1.0. Coordinate system in CORSIKA used to fixed the input values for the simulation.

To simulate the showers generated by gamma rays the LAGO-CORSIKA package was used [1]. The input parameters to consider were the primary energy (E_0) of the primary particle, the zenith and azimuth angles (θ, ϕ), the level of observation (h) and the atmosphere model. We need to filter accurately the data obtained from the simulation before we analyze it. For this, an script written in Python was used so we could get a better filtered data with the components that we will use for the plotting.[2] After that, we are going to calculate the mean number of secondary particles of each type (γ, e^-, e^+, μ^-, μ^+) that reach at 4 600 m.a.s.l. for each primary energy E_0 of the primary particle and the density of the lateral distribution.

RESULTS

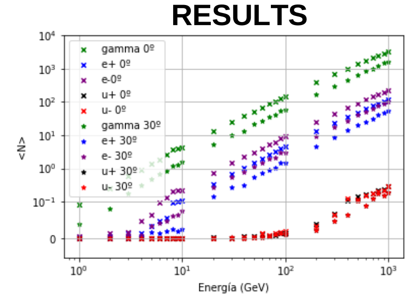

Fig. 2.0. Mean number of all secondary particles reaching at 4 600 m.a.s.l. vs primary energy for zenith angles 0° (x) and 30°(*).

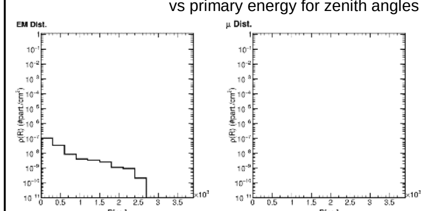

Fig. 3.0. Left. Lateral Distribution of the Electromagnetic component of the shower for a primary energy of the photon of 1 GeV. Right. Lateral Distribution of the muonic component of the shower for an primary energy of the photon of 1 GeV.

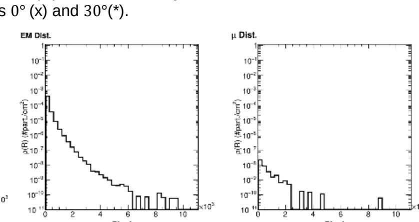

Fig. 4.0. Left. Lateral Distribution of the Electromagnetic component of the shower for a primary energy of the photon of 100 GeV. Right. Lateral Distribution of the muonic component of the shower for an primary energy of the photon of 100 GeV.

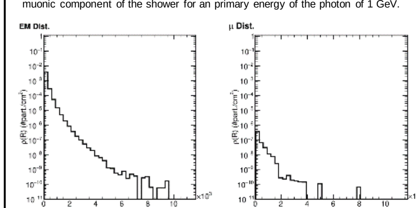

Fig. 5.0. Left. Lateral Distribution of the Electromagnetic component of the shower for a primary energy of the photon of 500 GeV. Right. Lateral Distribution of the muonic component of the shower for an primary energy of the photon of 500 GeV.

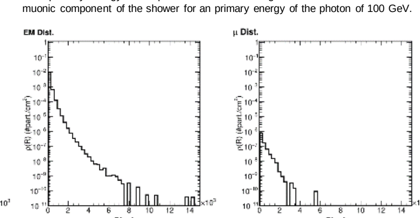

Fig. 6.0. Left. Lateral Distribution of the Electromagnetic component of the shower for a primary energy of the photon of 1 TeV. Right. Lateral Distribution of the muonic component of the shower for an primary energy of the photon of 1 TeV.

CONCLUSIONS

The advantage of WCD lies in the fact that many photons are expected to arrive during a GRB, most of them capable of creating pairs in water tanks with enough energy for the Cherenkov emission. [2] Therefore, through this work we can say that the future detector to be installed at such height should have a radius equal to 300 cm. Furthermore, it would be very convenient to find sources of GRBs whose photons generated when entering the Earth's atmosphere have $\theta = 0°$ since they have a greater number of secondary particles than when $\theta = 30°$. Additionally, it would be good to do an study of the energy distribution for the first bin ($R = 300$ cm) since this would help us to finally decide if the photons that reach the height of 4 600 m.a.s.l. have enough energy ($E > 1\ MeV$) whose created pairs will be able to emit Cherenkov radiation.

BIBLIOGRAPHY

[1] ARTI: LAGO Simulations. http://lagoproject.net/
[2] D. Allard, C. Alvarez, H. Asorey et al. (2009).Water Cherenkov Detectors response to a Gamma Ray Burst in the Large Aperture GRB Observatory. (LAGO Collaboration).