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Experimental and simulation study of cosmic muons detected with a water Cherenkov detector of the LAGO collaboration

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ABSTRACT

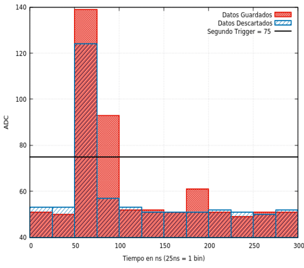
In the present work we study the secondary cosmic ray flux registered in a water Cherenkov detector (WCD) produced by the interaction of cosmic rays in the atmosphere. The detector employed is part of the array of the LAGO collaboration. A secondary trigger is used to filter noise from the electronics in addition to specific processes such as singular photons and thermionic emission. A study of the muon decay time was performed, as long as the Michel electron spectrum that results from the muons decay process. The LAGO simulations toolkit ARTI was used, that connects CORSIKA to simulate the atmospherics propagation of particles and GEANT 4, for the detector simulation. ARTI was used to estimate and compare the muon flux arriving at a WCD, and the response of the detector using real data.

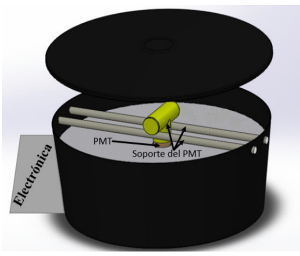
INTRODUCTION

At sea level, together with neutrinos, muons are the most abundant particles produced by the interaction of primary cosmic rays in the atmosphere. Due to their relative stability and small cross section, these particles can be detected over a wide range of altitudes. As a consequence, its study covers many aspects of cosmic ray physics and it is a good starting point for entering the world of high energy physics.

One of the main goals of this work is to replicate known results about the muon but by using a different method of analysis to clean up the experimental data. This work aims to find the mean lifetime of the muon and the spectrum of Michel electrons. To meet these objectives, it is necessary to clean up (filtering process) the data and characterize the background spectrum. The second main purpose is to estimate and compare the simulated muon flux arriving at a WCD placed in Lima, and the response of the detector using real data.

METHODOLOGY

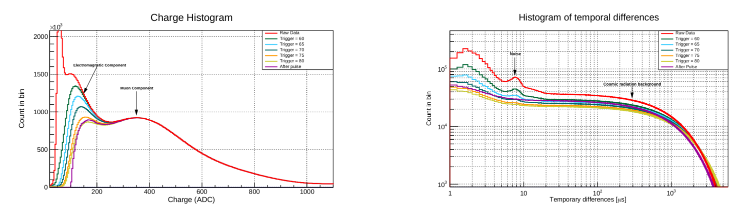




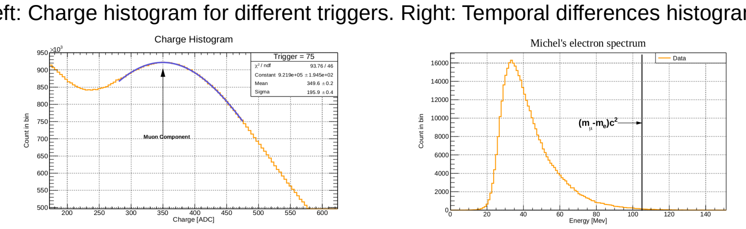
Before analyzing the data, it is necessary to filter its components. To do this, a Python analysis program determines which pulses correspond to the muon. Also, besides selecting the pulses which fulfill our imposed conditions, the analysis program produces the event temporal differences and the charge histograms, as well as it selects the electron charges through certain conditions. In addition, the analysis program also calculates the Michel electron spectrum.

To estimate the muon flux arriving at a WCD in Lima, the ARTI[1] package was used and the response of the detector using real data. In addition, another program was developed to analyze the path that muons travel within the detector. Finally, the GEANT4[2] package was used to simulate the interaction of muons with the water inside the detector, in order to estimate their energy and the Michel spectrum.

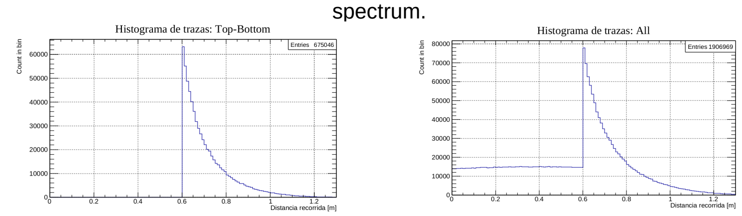
RESULTS



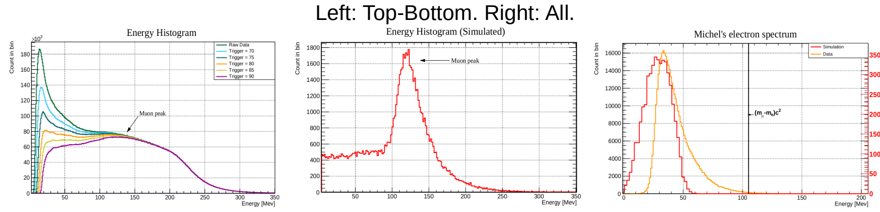
Left: Charge histogram for different triggers. Right: Temporal differences histograms.



Left: Charge histogram (trigger = 75 ADC), and its adjustment. Right: Michel's electron spectrum.



Histogram of the distance traveled by the muon inside the detector. Left: Top-Bottom. Right: All.



Left: Energy spectrum for different triggers. Right: Temporal differences histograms. Center: Energy spectrum (simulated).

CONCLUSIONS

The half-life of the muon in water was measured, giving a value of τ = 2,101±0.025 µs. This value shows a clear consistency with the current accepted value (τ = 2.1969811 ± 0.0000022 µs). Finally, a Michel electron energy spectrum, corresponding to the energy of electrons produced by the muon decay was obtained approximately. Also it was possible to estimate and compare the simulated muon flux arriving at a WCD placed in Lima, and the response of the detector using real data..

BIBLIOGRAPHY

[1] ARTI: LAGO Simulations. http://lagoproject.net/
[2] Geant4: An object-oriented toolkit for simulation in HEP Geant4 Web page: S. Giani. http://cern.ch/geant4