Measuring the distributions of atmospheric muons at sea level

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Introduction

The primary cosmic rays consisting of protons, alpha particles and heavy nuclei interact with the air molecules upon entering the atmosphere. The most abundant particles produced are pions which decay to muons and muon neutrinos which bombard the Earth surface [1]. For a given particle, propagating in the atmosphere, the probabilities of decay and interaction become a function of energy, altitude and zenith angle. A fair knowledge of the atmospheric muon distributions at Earth is a prerequisite for the simulations of cosmic ray setups and rare event search detectors. The goal of this work is to develope a compact setup for the measurements of energy and zenith angular distribution of muons. We also report the vertical flux of muons at sea level.

Energy and angular distribution of atmospheric muons

There are recent works which improve our understanding of the muon distributions at the sea level [2]. The vertical flux of muons as a function of energy follows a modified power law described by

$$I(E, \theta = 0) = I_0 \, N \, (E_0 + E)^{-n}, \qquad (1)$$

where I_0 is the vertical ($\theta = 0$) muon flux integrated over energy. The parameter E_0 accounts for energy loss due to both the hadronic as well as electromagnetic interactions with air molecules. The ratio of pathlengths of a muon from an inclined direction to that of a muon from the vertical direction is obtained in terms of vertical distance d, the zenith angle θ and

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FIG. 1: The setup for the muon measurements.

the Earth's radius R using a simple geometrical picture as [2]

$$D(\theta) = \sqrt{\left(\frac{R^2}{d^2}\cos^2\theta + 2\frac{R}{d} + 1\right)} - \frac{R}{d}\cos\theta. \qquad (2)$$

The zenith angle distribution of energy integrated flux in terms of $I_0 = \Phi(\theta = 0)$ is obtained as

$$\Phi(\theta) = I_0 \, D(\theta)^{-(n-1)}. \qquad (3)$$

The above formulae are used to simulate the incident muon distribution for acceptance calculations of the present setup.

The measurements

Looking at the equations 1 and 3 the power n which appears in the energy distribution is the same as that appears in the angle distribution. It means that knowing one distribution it is possible to extract the other one. In the present work, we aim to develope technique for angle distribution using Liquid scintillators enclosed in bars of length 1 meter and the

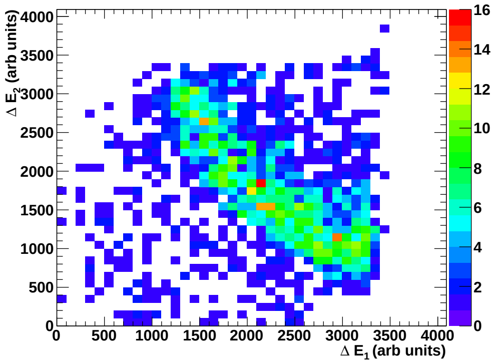

FIG. 2: The correlation in the signals from the two ends of the same detector.

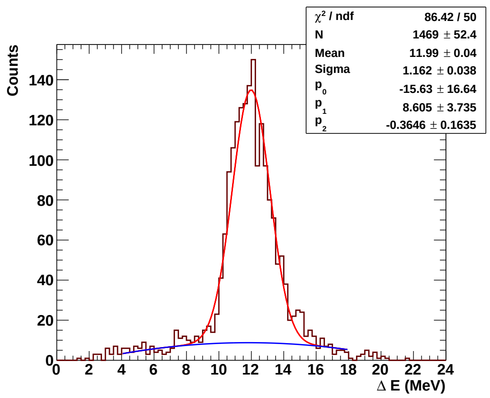

FIG. 3: The Arithmatic mean of the signal from the two ends of the same detector.

cross section 6cm × 6cm as shown in Fig. 1. The signals are obtained from both sides of bars as well in coincendence of the two bars to reject neutral as well as low energy particles. One plot between the signals from the two ends of a detector is given in Fig 2. It shows that the detector response to muons is linear with its distance from the readout. Figure 3 shows the arithmatic mean of the signals from readouts at two ends. It gives a peak corresponding to the energy deposited in the detector. The spectra shown here correspond to a time of 3444 seconds. Number of muons and their count rate have been obtained using different configurations namely by varying the distance (44.3 cm and 18 cm) between the bars. These sets of data are used to obtain the systematic error which is mainly due to the misalignment of the bars.

Acceptance and efficiency calculations

Acceptance of different configuration has been obtained by the simulation program in which we use Eq. 3 with (n=3.09 and R/d=174). The efficiency is measured by inserting a third scintillator bar between the two bars. The number of counts obtained from 3 bar coincidence is divided by the counts obtained by the coincidence of the topmost and bottommost bar to get the efficiency is 89.92 ±2.8 ± 7.32.

Summary

This report summarizes the measurements of atmospheric muon flux at sea level. The mean vertical muon flux obtained by various sets of measurements is 79.92 ±0.69 ± 7.32 where the first error is the statistical and the second is the systematic error. The simple technique of position determination using the bars can potentially be used for measuring the angular distibution. These measurements are under progress and will be reported during the conference.

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References

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