Study of cosmic ray muons tracks recorded by prototype ICAL (Kolkata): Zenith angle distribution

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Introduction

The India-based Neutrino Observatory (INO) collaboration is moving fast towards setting up a magnetized Iron CALorimeter (ICAL) to study atmospheric neutrinos and to determine the neutrino oscillation parameters with high precision. In final phase ICAL uses 50kton Iron as target mass and ~30000 glass Resistive Plate Chambers (RPC) having dimension 2m x 2m x 0.002m and 4m x 2m x 0.002m as active detector elements [1]. A prototype RPC detector stack comprising 12 layers of RPCs of glass and bakelite having area 1m x 1m is in continuous operation with and without magnetic field having strength 1.5 Tesla for the last two years. We present here the recent results of the studies performed with this experimental set up.

The surface of the earth is constantly struck by cosmic ray particles arriving from high in the atmosphere. Most of the surface flux (80%) is

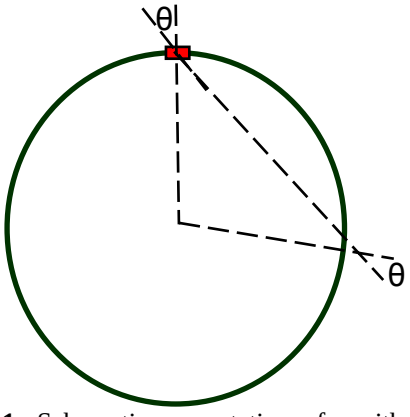

Fig. 1: Schematic presentation of zenith angle (θ) at the detector location.

due to muons resulting from the decay of pions produced by high altitude interactions of the primary cosmic rays (mostly protons) with atmospheric nuclei. The zenith angle dependence of cosmic ray muons in the high energy range has been the center of lively interest of current science. The subject is of central importance, since an anomalous, isotropic muon component which did not exhibit the $\sin^{-1}\theta$ enhancement expected for muons from pion and kaon decay would signal the existence of a strongly-produced massive parent particle with a strong branching ratio for decay into muons. The above mentioned physics could be achievable if few more RPCs are placed above the present prototype arrangement.

Prototype at VECC, Kolkata

A prototype set up consists of 12 layers of resistive plate chamber having electrode made of glass and bakelite of area 1m x 1m. RPC is sandwiched with 5cm thick iron plates with 5cm gap. Total 12 RPCs are working out of which nine resistive plate chambers have glass and three have bakelite electrodes.

Fig. 2: Prototype ICAL detector at VECC, Kolkata [2].

Each RPC has 32 pick up strips along x- and y-axis. Both types of RPCs are using two separate gas mixing and distribution systems. The whole tracking detectors are kept inside a magnetic field and continue to be in operation for last more than two years. A total of 4 coils, each having 5 turns and wound perpendicular to the plane of the Iron plates make up an electromagnet which can be magnetized up to 1.6 Tesla. The complete set up of prototype ICAL as shown in figure 2 is taking data with and with out magnetic field at VECC, Kolkata.

Results

In the presence of magnetic field, charged particle takes a curved path. Therefore, when magnetic field is on and uniform over the active area of the RPC the passing charged particles will follow circular path and only part of that path will be observed as a curved trajectory and with the help of the curvature of trajectory muon momentum could be derived. In the absence of magnetic field muon will follow a straight track as shown in Figure 3. In this article we present work related to the magnetic field off data.

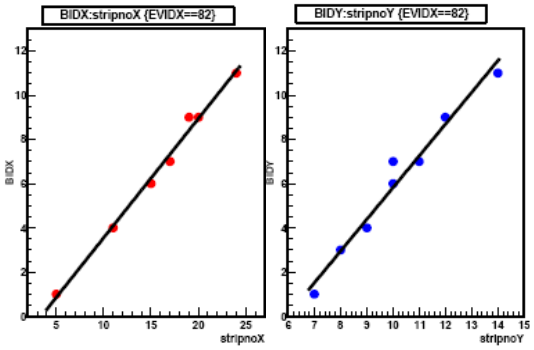

Fig. 3: A glimpse of straight tracks recorded by ICAL detector during magnetic field off at VECC, Kolkata.

The zenith is the direction pointing directly above a particular location i.e. it is one of two vertical directions at the location, orthogonal to a horizontal flat surface there as shown in Figure 1, angle distribution of the comic rays specially muon tracks during magnetic field off was made by fitting a straight line using moderate selection criteria to the x- and y- strip hits in the detector. The x- and y- strip hit points are shown in figure 3 and best fitted straight line is representing a cosmic ray track.

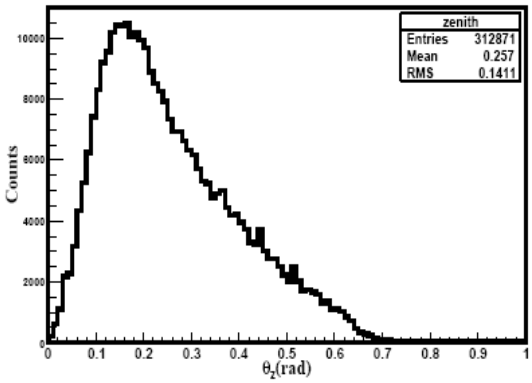

Fig. 4: The zenith angle distribution of cosmic ray muons measured using the prototype stack at VECC, Kolkata.

The zenith-angle distribution of high energy muons is of great importance because, in the conventional picture of high-energy interactions, the dominant source of muons is the decay of pions and kaons; and the competition between decay and capture of these parent particles produces an enhancement of the muon intensity at large zenith angles which is a definite, testable consequence of the theory. The zenith angle distribution of all energy muon tracks at sea / surface level is shown in Figure 4. It can be seen from figure 4 is that the mean and rms values of the distribution are 0.257 and 0.1411, respectively. The observed values of similar parameters of the zenith-angle distribution using prototypes at TIFR Mumbai PRC system were 0.2447 and 0.1125, respectively [2] and both values are very close to the expected ones.

References

[1] Y. P. Viyogi, INO six monthly meeting at VECC, Kolkata (2011).
[2] M. Bhuyan et al., INO poster in Lepton-Photon Symposium, at TIFR, Mumbai (2011)

Acknowledgment

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