Study of VECC Prototype INO ICAL using cosmic ray muon and g4beamline

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In this article we are reporting lower and upper simulated threshold values of VECC prototype INO ICAL RPC detectors. These values are very useful in calibrating the final muons momentum spectrum observed by this detector.

Introduction

India based Neutrino experiment (INO) is a neutrino oscillation experiment. INO is planning to setup a magnetized ICAL. It is used to study the atmospheric neutrinos and to determine the neutrino oscillation parameters. ICAL will use 50 kiloton Iron as target mass and around 30k glass RPCs as active detector element. We created virtual prototype ICAL similar to ICAL working at VECC, Kolkata. This detector stack consists of 12 RPCs spaced with 6cm thick Iron plates having 1.3 Tesla magnetic field. Here we are using G4beamline simulation packages to study the systematic measurement of cosmic ray muons passing through RPCs. G4beamlines, particle tracking and simulation program based on Geant4 and C++[1]. The structure of G4beamline simulation is to first define beam line elements (beam, magnet type and strength), including their geometry, materials, fields etc and then place them along the direction of beam.

Methodology

We use 12 RPCs for our simulation purpose, where each RPC, having area 1 m^2 and of thickness 24 mm [2], separated by Iron plate of area 1 m^2 and of thickness 60 mm. We placed these Iron plates and RPCs inside the magnetic field.

We apply a uniform magnetic field of strength 1.3 T in the Y-axis direction. The muon beam is along Z-axis direction i.e. perpendicular to the plane of detector. When a cosmic ray muon of particular energy passes through the RPC stack, we calculated its radius of curvature and derived the momentum of the muon.

Results and Discussions

Figure1 shows a simulated picture of two muons of momentum 2GeV/c passing through the experimental setup similar to the VECC INO ICAL and clearly showing curvature of tracks. Figure 2 shows a simulated picture of cosmic ray muons passing through one RPC at sea level.

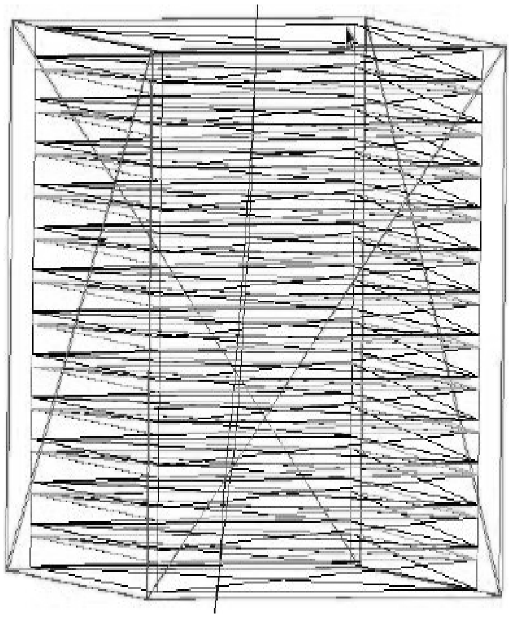

FIG. 1: A simulated picture of two muons of momentum 2GeV/c passing through a RPC stack.

FIG. 2: A simulated diagram of cosmic ray muons passing through one RPC detector at sea level.

Figure 3 shows a curve fitting of second order polynomial to X and Z coordinates of muon tracks in RPC detector stack for 2 GeV/c momentums.

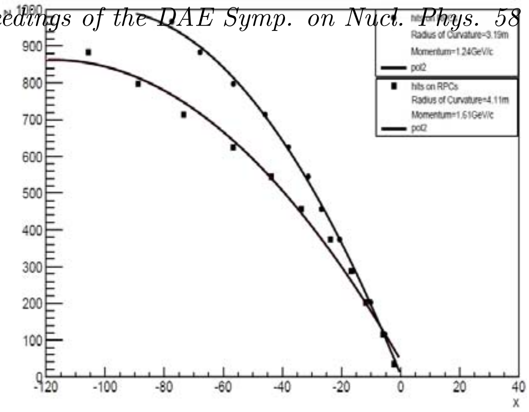

FIG. 3: A second order polynomial to X and Z coordinates of muon tracks in RPC stack for 2 GeV/c.

Figure 4 shows a curve between number of entries (Y axis) and Cosmic Ray Momentum (X axis) at sea level. We obtain this spectrum using single RPC detector and cosmic ray flux at the sea level using g4beamline without using any magnetic field. The purpose of this exercise was to get the shape and scale of the cosmic ray spectrum at sea level. Similar procedure we adopted to get the spectrum as shown in figure 5 using magnetic field of 1.3 T and the experimental setup similar to the VECC prototype INO ICAL as described in above section. We fitted the passing tracks with polynomial two and obtained radius of curvature for each of the passing tracks through the setup and finally derived the momentum of charged particles as shown in figure 5.

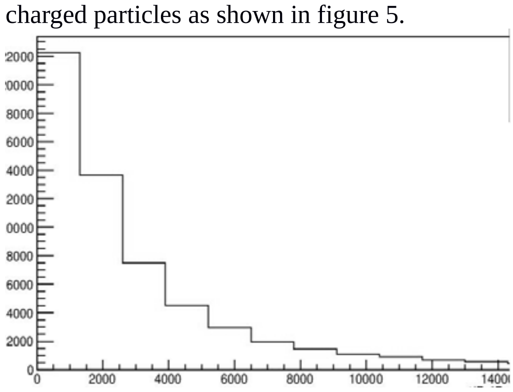

FIG. 4: Cosmic ray muon spectrum plotted between number of entries on Y-axis and momentum on X-axis at sea level.

Figure 5 shows spectrum of cosmic ray with respect to its momentum when muon passes through RPC stack and observed those entries which has same track ID.

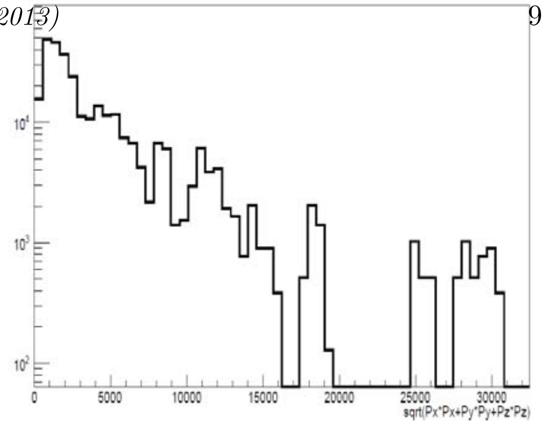

FIG. 5: Cosmic ray muon spectrum plotted between numbers of entries on Y-axis and Cosmic ray momentum on X-axis when muon passes through RPC stack and observed those entries which has same track ID.

Minimum threshold energy of muon that passes through stack of 12 RPC detectors is 1.4 GeV. This ICAL is capable of measuring particle up to 10 GeV/c momentum and above this particle is going through without any bending in the track. Muons having energy up to 0.9 GeV/c are following spiral loop of tracks and muons having energy above this value and below 1.4 GeV/c are not able to pass through all twelve RPC detectors.

We also observed that fixed momentum incident particles are showing variable amount of energy loss depending upon how much length they were traveling inside the different layers of iron sheets and this variation is found to be from 1.63 to 0.16 GeV/c at 02 GeV/c incident muon momentums. All the above simulation results are helping us in calibrating the observed cosmic ray muon momentum spectra [3].

Acknowledgement:

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References:

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[3] Study of cosmic ray muons momentum and charge asymmetry spectra, V. Sharma et al., DAE Sym Nucl. Phys. 58, in press (2013)