Study of cosmic ray muons momentum and charge asymmetry spectra

V. Sharma[1,]*, K. Saraswat, V. Singh[1] and V. S. Subrahmanyam[1]
[1]Department of Physics, Banaras Hindu University, Varanasi - 221005, INDIA
* *email:vivek.bhu.hep@gmail.com*

In this article, we studied cosmic ray momentum and charge asymmetry spectra. Data were collected using India-based Neutrino Observatory prototype Iron Calorimeter (ICAL) working at VECC in Kolkata. Results presented in this article are drawn from the data taken during initial phase of the data taking.

1. Introduction

The VECC ICAL prototype is made for the study of the behavior of resistive plate chamber (RPC) detector using cosmic rays muons during ON and OFF magnetic field having strength around 1.5 Tesla. This prototype consists of twelve layers of RPC detectors including three layers of Bakelite electrode and nine layers of glass electrode. Each detector is sandwiched between layers of around 5 cm thick iron sheet. Each RPC detectors having read out crossed strips to locate the co-ordinate of interaction point. Raw data from stack is used to regenerate the track of passed charged particles. This work is about the study of cosmic ray muons charge ratio (μ^+/μ^-) and its momentum spectrum by reconstruction of tracks in the magnetic field having 500 A current in the coils with layer 3, layer 9 and layer 11 RPC detectors as a trigger for any event.

2. VECC ICAL Detector

The ICAL Prototype detector has 12 RPCs which are interleaved in the gap between 13 layers of iron plates of dimension 2.4m x 2.17m x 0.05m with 50 kton ICAL magnet. By applying a D.C. high voltage to these electrodes, an electric field is generated across the gas gap. A passing charged particle creates an avalanche in the gas inside the detector. High resistivity of the electrodes prevents discharge to spread over entire gas volume. The created electron and positive ion pairs while traveling towards the respective electrodes induces signal on the pickup strips placed over the electrode plates. The generated charge is deposited on a small region of the electrode plate and the spot is slowly recharged by current flowing through the plate. If the electric field is even more intense, a 'spark' breakdown can be initiated by the avalanche. In the conventional single gap RPC for the avalanche mode of operation, mixtures of tetrafluroethane (R-134a) with 2-5% of isobutene are used. The single gap RPC first developed has been replaced by its variants, where electrode materials, gap thickness and geometry have been changed. VECC-SINP developed Bakelite RPCs and in this stack 8 glass RPCs and 4 bakellite RPCs are used. Glass RPCs are running in avalanche mode and here pulse height is in ~mV order and requires amplification using preamplifier. Bakellite RPCs are running in streamer mode and here pulse height is few hundreds mV, so no need for amplification. 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. Each Iron layer is made of ‘C’ and ‘T’ section. 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 five 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 power supply has two current sources and it is operated in master-slave mode [1].

3. Reconstruction of particle track

The processed raw tracks are consisting of many garbage points due to noise generated by electronics or some other means. Therefore, the first step to reconstruct the track was to choose only those tracks which have least noise. After this, such tracks which are not fitted satisfactorily have to be excluded by the assigned cuts to get better fitting. A good fitting track is shown in Figure 1.

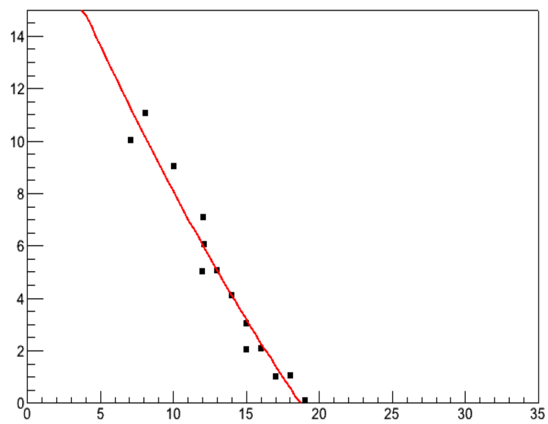

Fig. 1: An example of fitted track after employing cuts. On X-axis strip number and on Y-axis RPC detector numbers are plotted.

After getting a good fit for reconstructed tracks, fitting parameters have to be taken in account for further calculation of momentum and muon charge ratio.

4. Results of Analysis of VECC Data

We know that charged particles travel in circular path in the uniform magnetic field. During ON magnetic field, part of the charged particle circular path takes place due to limited dimension of the detector and the radius of curvature of the track provides information about the momentum of the charge particle. Therefore, when magnetic field is on and uniform over the active volume of the RPC detector stack, the passing charged particles 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. Comparison between final momentum spectrum and momentum spectrum before final cut is shown in Figure 2.

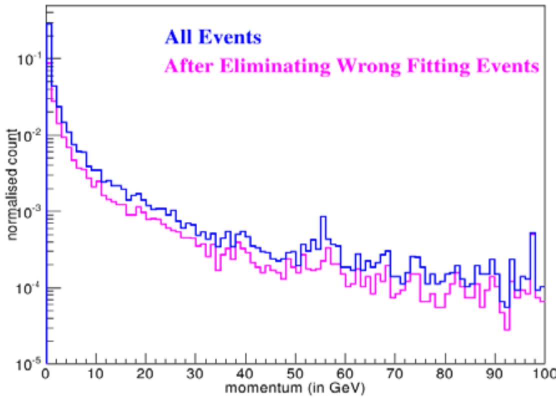

Fig 2: Comparison of final momentum with momentum before final cut.

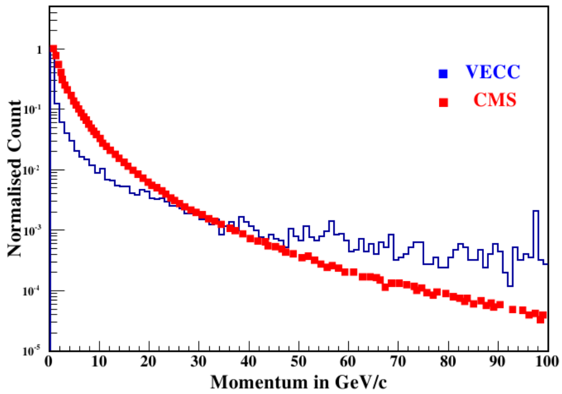

Fig 3: Comparison cosmic ray muons momentum spectrum with the similar spectrum of CMS experiment.

Comparison of final cosmic ray muons momentum spectrum with similar spectrum observed by CMS experiment [2] is shown in Figure 3.

The muon charge ratio with respect to cosmic ray momentum is shown in Figure 4 along with the spectrum observed by BESS, MINOS and L3C experiments.

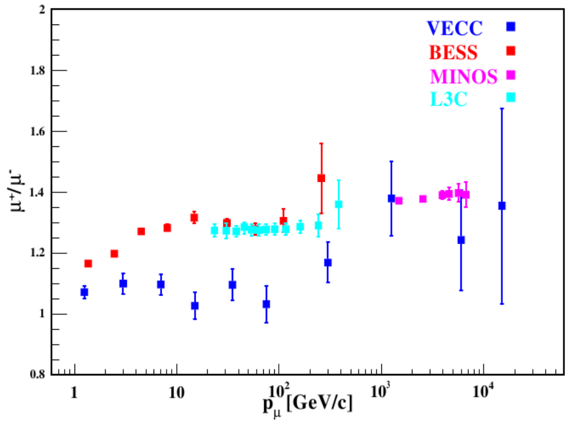

Fig 4: Comparisons of muon charge ratio spectrum with other experimental results [3-5].

Under ground and surface effects on cosmic ray momentum and charge are observed.

Acknowledgments

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