Simulation of a Stack of Resistive Plate Chambers

Muzamil A. Teli[1],* Supratik Mukhopadhyay[2],
Nayana Majumdar[2], and Waseem Bari[1]
[1]Department of Physics, University of Kashmir, Srinagar, 190 006, India and
[2]Applied Nuclear Physics Division, Saha Institute of Nuclear Physics , Kolkata - 700064, India

Introduction

The India based Neutrino Observatory (INO) project is a multi - institutional[1] effort wherein the primary purpose is building of world class laboratory for non accelrator based high energy and nuclear physics research in India[2].The primary goal of INO is to study the atmospheric neutrinos. The main detector proposed to be built at the INO is the magnetised Iron CALorimeter (ICAL) with a mass of 50 kton. In ICAL, 5.6 cm thick iron plates act as the target, whose 151 layers are interleaved with the Resistive Plate Chambers.[3]. Single gap Resistive Plate Chambers (either of glass or Bakelite) of 2m x 2m in size are going to be used as the active detector element for the INO-ICAL experiment[4]. The primary mechanism for particle detection in INO - ICAL is via tracking of Muons produced inside the detector mass by the charged current neutrino interactions. The main purpose of tracking is simultaneous determination of energy as well as the direction of the charged particle [5]

In INO - ICAL composed of three modules, about 30,000 RPCs are to be used as the active detector elements for for simultaneous measurement of energy as well as the direction of charged particle. These active detector elements, made up of a pair of 3mm thick glass separated by 2mm spacers, will be inserted in the gap between the iron layers. These will be operated at a high voltage of about 10 KV in avalanche mode [3],

The present investigation involves a RPC, a type of which is used in the RPC experiments at SINP Kolkata. The RPC is composed of two $2mm$ thick bakelite plates with a dimensionality of $30cm \times 30cm$. The two plates are separated by a gas gas gap of $2mm$.The gas composition that has been used for the present purpose consists of Argon, Isobutane and Freon. Argon acts as the target, Isobutane acts as the absorbent of photons produced from recombination process and Freon limits the the amount of free charge in the gas. A graphite coating in done on the outer surface of the two bakelite plates for uniform applicaion of high voltage. Pick - up strips made of copper are used for collection of signal. These pick - up strips are covered with $100\mu m$ thick mylar sheets to isolate them from graphite layers. This represents the basic geometry of a single RPC. This is then developed to a stack of 24 RPCs modelled in the same form as that of the ICAL. A program based on CERN(European centre for Nuclear Research) library GEANT4(Generation and Tracking)[6] package is used for detector simulation and its response for the neutrino event. i.e, Propagation of muons and hadrons through the detector volume [7].

When a muon passes through a chamber, There is loss in energy of the incoming particle and gain by the target. Thus ionisation takes place resulting in the formation of primary electrons and ions[8]. As the electrons are knocked out of the gas atoms. These electrons in turn hit other atoms resulting in the formation of charged secondaries. Since the electrons are lighter in weight than ions, these electrons after multiplication and attachment move towards the anode resulting an avalanche there. When the charge carrier multiplication is maximum at the avalanche, the net electric field within the detector will be the effective electric field due to the avalanche and the external electric field. This influences the gas - gain giving rise to space - charge ef-

*Electronic address: `telimuzamil001@gmail.com`

fect. As the electrodes are transparent to the signal, this process induces signal on metallic strips of the pickup panel which are mounted on either side of the chamber and are nominally at ground potential. These signals are then collected after a small but precise time delay. Finally the signal from the detector is processed and stored.

Results

On firing a beam of 50,000 muons, the distribution of energy deposition is given below; Here the detector is modelled in such a way so

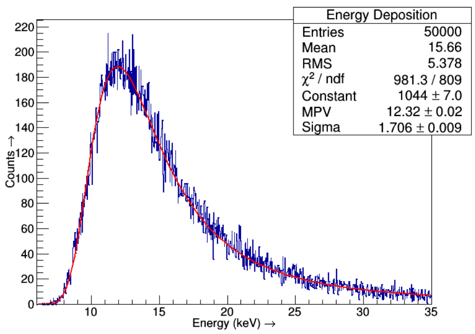

FIG. 1: Energy Deposition in Gas Chamber.

that the smearing of both position and angular coordinates takes place. The distribution is fitted with the Landau fitting which represents the most suitable one as the detector thickness is very small. The results are in good agreement with[9] . The difference in statistics may be due the number of active layers.

Next we calculated the momentum resolution for a beam of 50,000 muons projecting through the detector stack of 24 RPCs; Momentum resolution (σ/P_{in}) is defined as the standard deviation central width of a function fitted to the distribution. Angular Momentum Resolution is given as;

$$R = \frac{\sigma}{P_{in}} \quad (1)$$

Where P_{in} represents the input momentum for the projected beam.

It has been found that momentum resolution for muons decreases below the energies

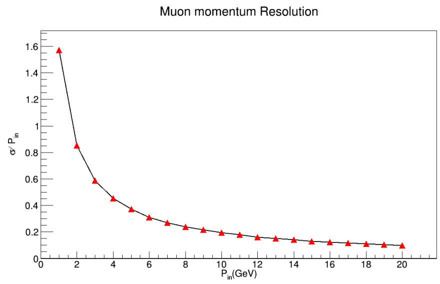

FIG. 2: Resolution of Muon Momentum.

of 200GeV.The decreasing trend is due to the reason of multiple scattering. The results are in good agreement with [10].

In conclusion, ICAL simulations depict that the detector has a good response to muons, including the identification of their energy, momentum etc. The results are used to perform the physics analysis of atmospheric neutrinos with ICAL and other physcis analysis.

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