Hadron Energy Resolution of the ICAL Detector

Anushree Ghosh

Harish-chandra Research Institute , Allahabad, India

Abstract. Energy of hadronic shower inside Iron Calorimeter Detector has been calibrated using single pion events. Total hit multiplicity is taken into account for calibrating the energy . GEANT4 has been used for the simulation.

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INTRODUCTION

India based Neutrino observatory(INO) is a proposed underground physics laboratory in which major activity will be in neutrino physics. The proposed detector is large mass magnetized iron calorimeter (ICAL) with charge identification capability and will use atmospheric neutrino as source in first phase of INO. The detector will have a modular structure of total size 48m X 16m X 12m. About 6cm thick magnetized iron plate will be used as an absorber and Resistive plate chamber made of glass of dimension 2m X 2m will be used as active detector element [1].

INTERACTION OF NEUTRINO WITH DETECTOR

The atmospheric neutrino inside the detector go through the quasi-elastic charge current (CC) interactions, resonance interactions at low energy(up to a few GeV) and deep-inelastic scattering (DIS) at higher energies. All CC interaction events produce the associated leptons. DIS produce large number of hadrons while resonance interactions produce at most one pion along with the lepton[1].

Why hadron energy calibration is important

In the first phase, INO will look for the confirmation of first oscillation dip as a function of L/E $_\nu$ (L is path length of neutrino and E_ν is neutrino energy), precise measurement of the oscillation parameters and determination of mass hierarchy; measurement of E_ν plays a crucial role here. To reconstruct the neutrino energy both muon and hadrons energy has to be measured precisely:

$E_\nu = E_\mu + E_h$

Muon energy can be reconstructed with high resolution from track length inside the detector. For hadrons, fluctuation in energy loss is much larger than electromagnetic process and hit multiplicity is taken into account to calibrate the hadrons energy.

GEANT4 SIMULATION

GEANT4 [2] is used for simulation. It is a simulation toolkit for simulating the passage of particle through matter. It includes the complete range of functionality including tracking, geometry, physics models and hits.

Having the information of total number of hits for a particular energy, this information is used to get the resolution of hadron energy by digitizing the hits.

For hadron energy calibration:

- Single pion(π^+) has been used
- 10,000 events have been run for each calculation.
- The data from only one strips –either X strip or Y strip – are used to get rid of ghost hits.

The number of hits obtained for different fixed energy gives Gaussian distribution:

$$f(N_h)=A_0(\exp(-(x-x_0)^2/2\sigma^2)) \text{ --------------(1)}$$

Where N_h = number of hits

X_0, σ =parameters.

These parameters can be determined by fitting N_h as a function of pion energy where the fitted function

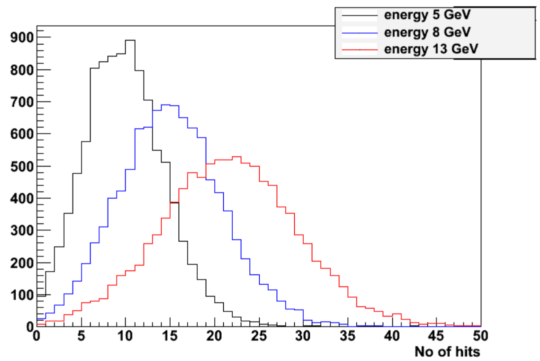

FIGURE 1. This plot shows the hit distribution at various energies of single pion for 10000 events.

is

$N_h=N_0(1-\exp(-E/E_0))$ (Red line in FIGURE 3) -- (2)

Where N_0, E_0= parameters of calibration.

However, in 4-18 GeV energy range number of hits shows linear dependence on energy (blue line in FIGURE 3):

$N_h=c*E+d$ -----------------(3)

Hence to determine the resolution function this linear relation (eq.3) has been used and has been fitted by the the approximate form

$\Delta n_h/n_h=\sigma/E_\pi=a/\sqrt{E_\pi}+b$ ----------------------------(4)

Fig.4 shows the variation of σ as a function of energy E_π. The data are fitted with the function described in eq.(4). The fitted parameters are:

a=0.67√GeV

b=0.17

which give the energy dependence of the resolution σ.

In the present simulation study we have used charged pion events.To optimize the hadronic response of the detector, GENIE[3] will be used at the interface of GEANT4.

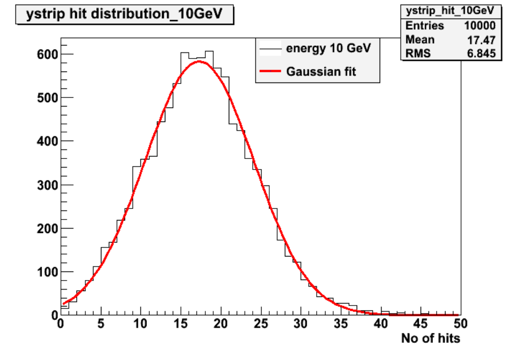

FIGURE 2. This plot shows the Gaussian fit of hit distribution for a particluar energy E_π. Here E_π=10 GeV.

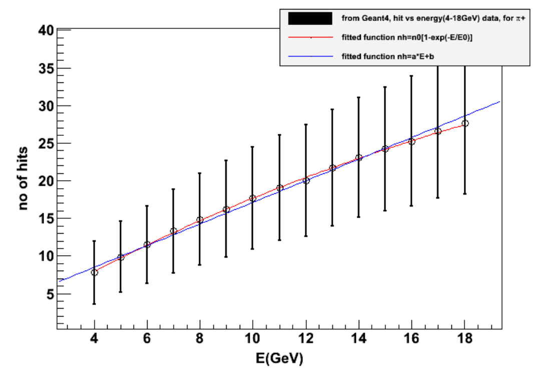

FIGURE 3. This plot shows the average number of hits as a function of energy fitted by eq.(2).

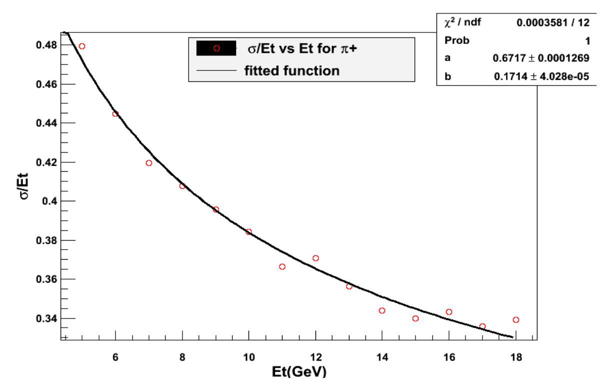

FIGURE 4. This plot shows variation of σ as function of energy of pion. E_t=pion energy.

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