PROCEEDINGS OF SCIENCE

Simulation study of electron reconstruction with thin iron plates in ICAL

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The proposed magnetized Iron Calorimeter (ICAL) detector to study atmospheric neutrinos and anti–neutrinos at the India based Neutrino Observatory (INO) is a 50 K ton detector which will have a magnetic field of 1.3 T. The default geometry of ICAL has 56 mm thick iron plates as the interaction material (target), separated by 40 mm gaps in which the active detectors the resistive plate chamberes (RPCs) will be placed. This makes ICAL sensitive to muons with energy in the range ∼1–20 GeV, produced in charged current (CC) interactions of atmospheric ν_μ and $\bar{\nu_\mu}$ with iron.

It was shown that sub–GeV ν_e and $\bar{\nu_e}$ charged current events are sensitive to the leptonic CP phase δ_{CP} irrespective of the neutrino mass hierarchy. In our new study we explore the possibility of detecting sub–GeV ν_e and $\bar{\nu_e}$ in ICAL for different combinations of iron plate thickness, air gaps and different types of active detectors. Energy resolutions for electrons with energy < 1 GeV were obtained for cases with RPC and scintillator as active detectors with 18 mm thick iron and 40 mm thick air gap and compared with each other and also the resolutions for DUNE experiment. In this case, number of hits per layer can be used to reject pion background from electron events.

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1. Introduction

It has been shown [1] that electrons from sub GeV energy atmospheric neutrino interactions are sensitive to leptonic δ_{CP}, independent of hierarchy. Muon neutrinos are also sensitive to δ_{CP} at these energies, but the effect is less visible.

The magnetised 50 kton iron calorimeter detector ICAL proposed to be built at INO was designed with a focus on detecting 1–20 GeV muons from charged current events of ν_μ and $\bar{\nu_\mu}$ in the detector, to determine the neutrino mass ordering/hierarchy. Here the study of reach of ICAL through its possible modifications in its geometry (decreasing the Iron thickness from 56 mm to 18 mm) to detect electrons from CC ν_e events, in order to determine the sensitivity to the CP phase δ_{CP} is done .

2. Comparison between RPC and Scintillator as an active detector

In this study thinner iron plates: 25 mm instead of design 56 mm are used. Also choice of RPC and plastic scintillator as active detector is explored. Two parameters: maximum of hits in the x or y-planes (orighits_old) and number of layers (nLayer) are used for analysis. From Fig. 1 it can be seen that RPC and scintillator detector both have similar response to the electrons.

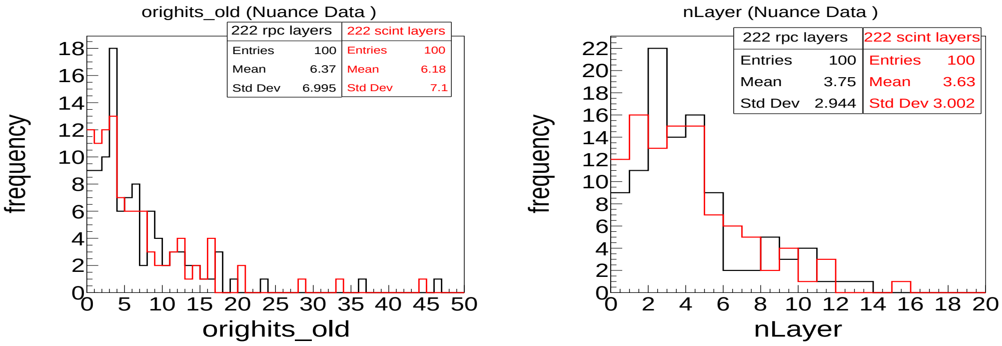

Figure 1: Left: Total hits ($orighits\_old$) obtained using 222 RPC layers and plastic scintillator with 25 mm iron plates; Right: nLayer results for 222 RPC and scintillator layers with 25 mm iron.

3. Electron versus pion signals and Rejecting pion events through S/L

Since both electron and pions produce showers we need to distinguish the true electron events from pion events. In Fig.2 nLayer and orighits_old are plotted for electrons and pions of 1 GeV and cos $\theta = 0.5$ with 250 iron layers having 18 mm thickness and 40 mm air gap and 249 RPC layers. While both nLayer and orighits_old histograms are narrow for electrons, the pion distribution shows large asymmetric tails since they undergo strong interaction. Hence reconstruction for electron is expected to be better than pions. The ratio of orighits_old (S) and nLayer (L) for energy of 1 GeV and cosθ 0.5 is also shown Fig.3. The S/L ratio is larger for electrons than pions; hence a cut on this ratio can be used to reject neutral current (NC) background dominated by pions.

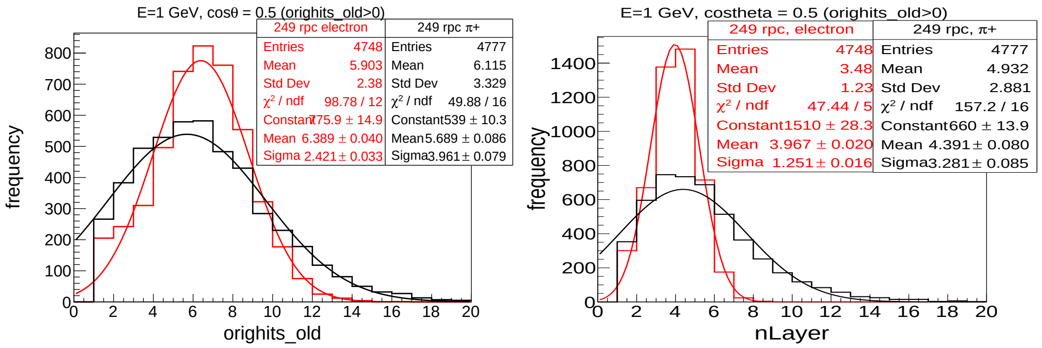

Figure 2: Left: Total hits (*orighits_old*) histograms and Right: nLayer for electron and pion these two histograms are narrow and symmetric for electrons. Pions show typical large tail than electron.

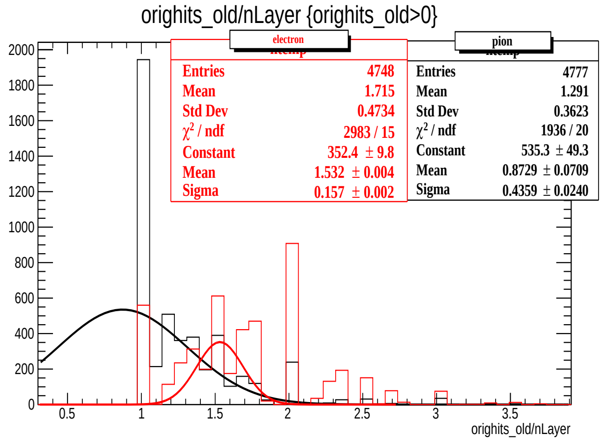

Figure 3: nLayer/orighit old for electrons (red) with 1 GeV energy, with angle cosθ = 0.5, in comparison with pions (black) with the same energy and angle

4. Calculation of σ/E for low energy electrons

We use the framework used in Ref. [4] to estimate the energy response of hadrons and electrons. The energy resolution σ can be expressed in terms of the mean $\bar{n}$ and RMS width Δn of the hits distribution obtained from orighits_old for a given electron energy, E:

$$\frac{\sigma}{E} \equiv \frac{\Delta n}{\bar{n}} = \sqrt{\frac{a^2}{E} + b^2} \tag{1}$$

The first term in R.H.S. is stochastic term which is because of presence of fluctuation in physical development of shower and second term depends on the geometry of the detector. The resolution σ/E is shown in Fig. 4 as a function of E. The values of a and b from the fit tabulated in Table.1 show that an electron energy resolution of σ/E = 15% is achievable in the 0.1–1.2 GeV energy range by thin ICAL.

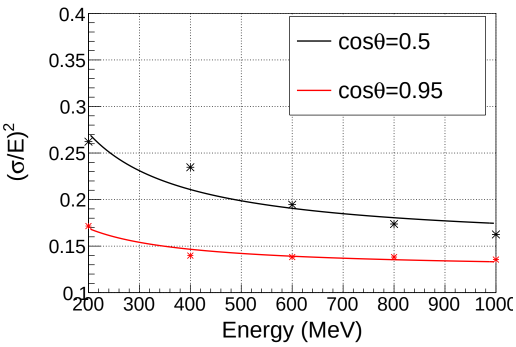

Figure 4: $(\sigma/E)^2$ vs E for electrons with energy from 0.2–1.0 GeV for $\cos\theta = 0.5, 0.95$.

$\cos\theta$	a^2	b^2	a	b
0.5	0.0242	0.15	0.156	0.39
0.95	0.00896	0.1242	0.095	0.35

Table 1: Value of parameters a and b after fitting the data using eq. 1 for $\cos\theta = 0.5$ and 0.95

5. Conclusion and discussion

With thinner iron plates it is found that resolution of 15% is achievable that will be relevant to study CP phase using electron neutrino CC events in ICAL. But the value of b is a bit large that can reduce resolution for electron. The plan is to use energy deposition information also to improve the resolution. For further studies detailed analysis for δ_{CP} for “thin ICAL” will be done.

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