Simulation study of electron reconstruction with thin iron plates in ICAL/INO

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Motivation

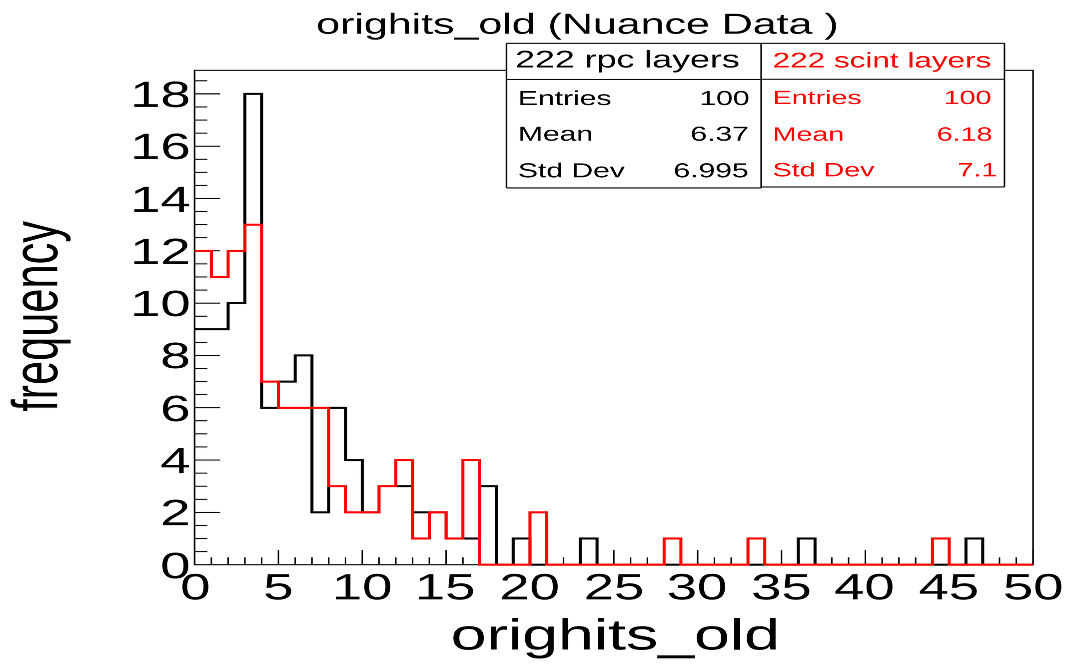
It has been shown [1] that electrons from sub GeV energy atmospheric neutrino interactions are sensitive to leptonic δ_{CP}, *independent of hierarchy*. Muon neutrinos are also sensitive to δ_{CP} at these energies, but the effect is less visible.

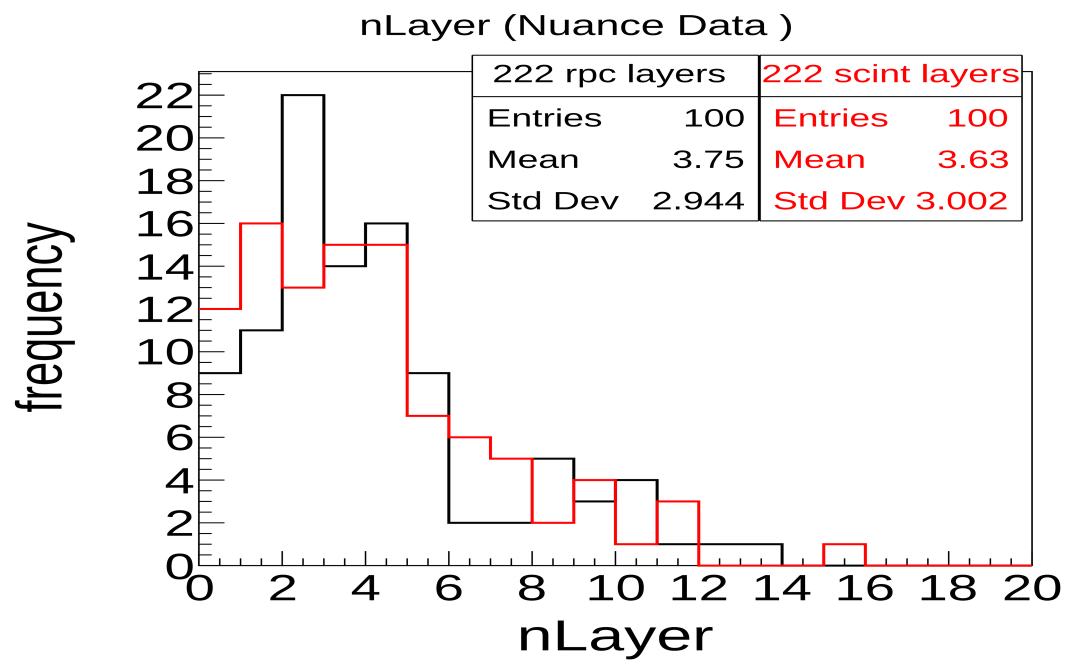
Introduction

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 we study the reach of ICAL through its possible modifications to detect electrons from CC ν_e events, in order to determine the sensitivity to the CP phase δ_{CP} .

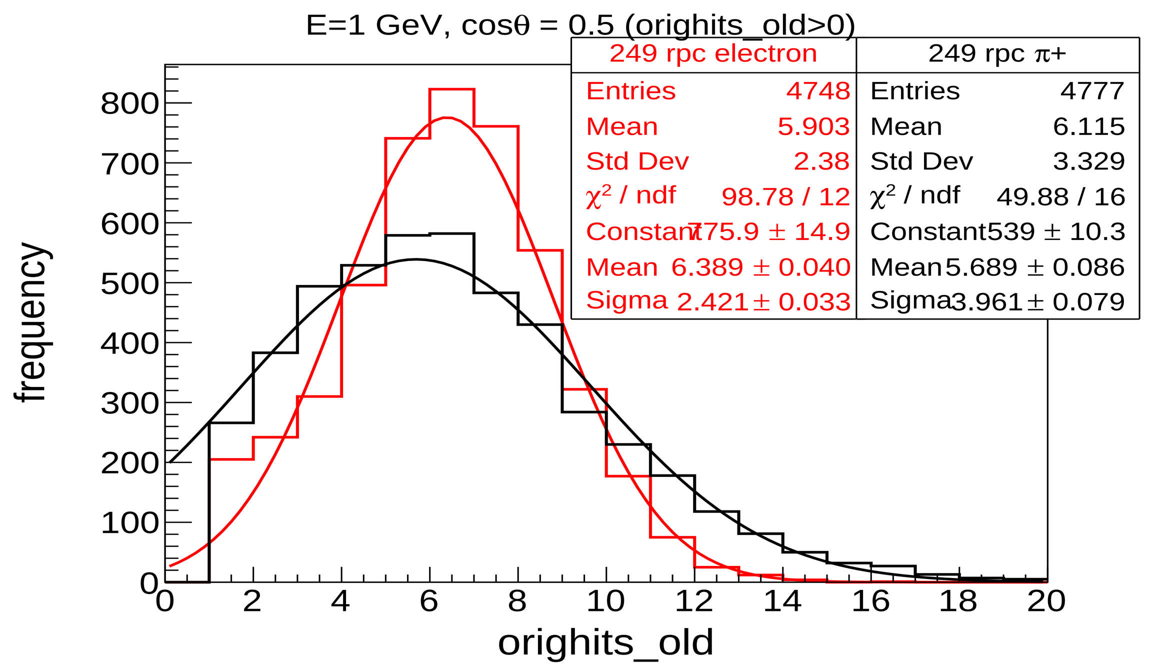
RPC vs Scintillator

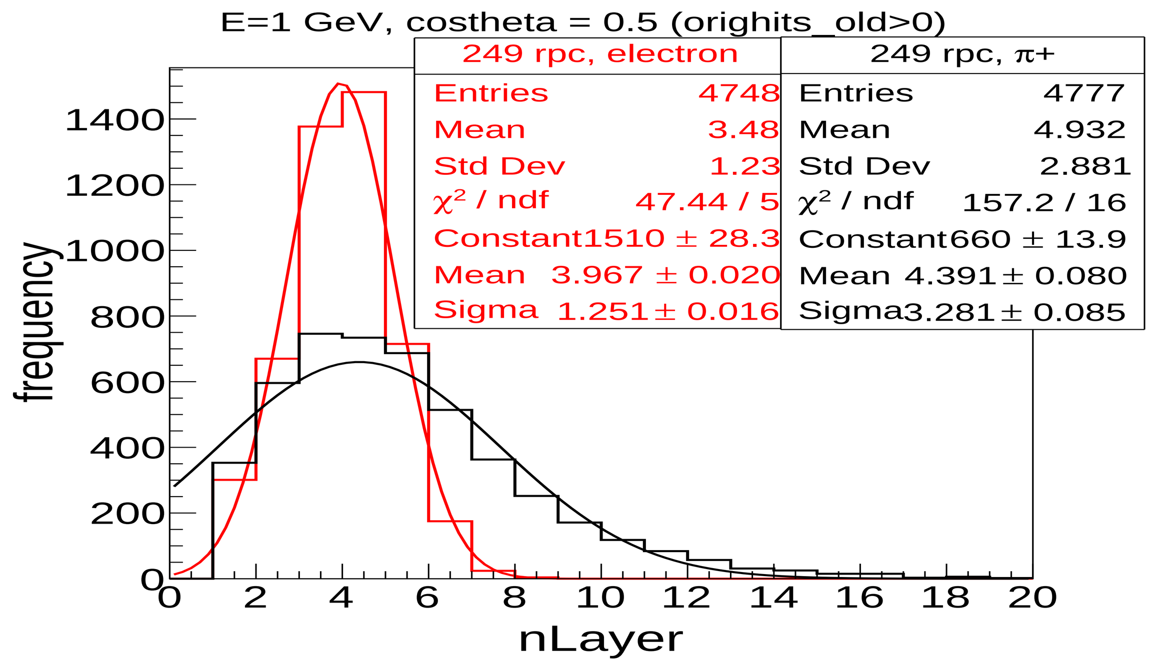
- Using thinner iron plates: 18 mm instead of design 56 mm.
- Also exploring choice of RPC and scintillator as active detector.
- Two parameters: maximum of hits in the x or y-planes (orighits_old) and number of layers (nLayer) are used for analysis.





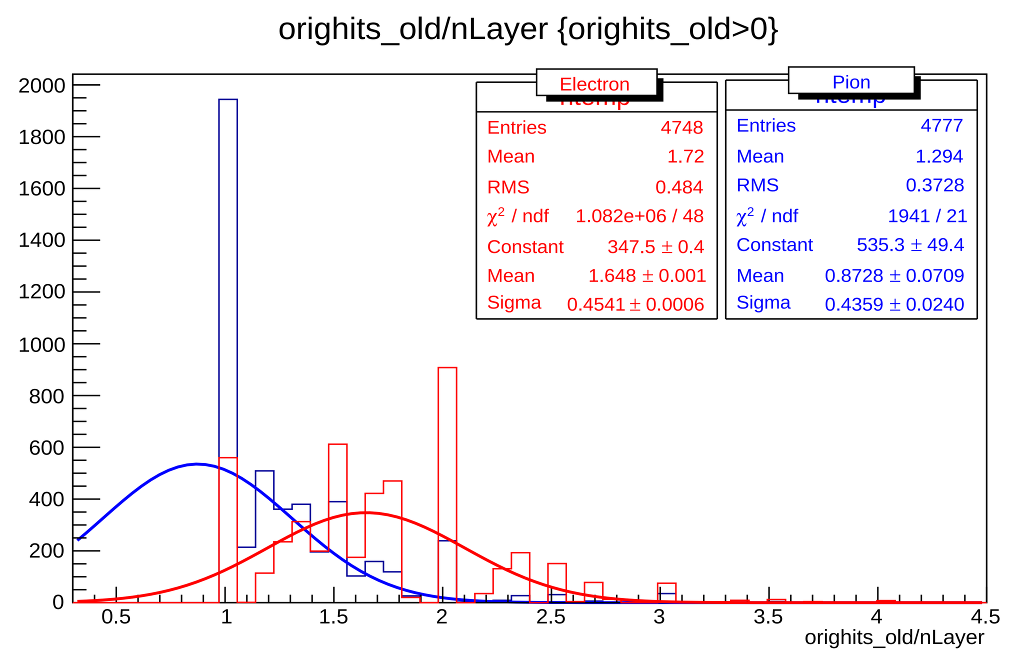
Electron versus pion signals





- nLayer and orighits_old histograms are narrow and symmetric for electrons.
- Pions show typical large tail due to strong interactions.
- Hence, expect better energy reconstruction for electrons than pions.

Rejecting pion events through S/L



- S/L = orighits_old/nLayer (hits per layer)
- S/L is larger for electrons than pions.
- An S/L cut allows to remove more of the NC (pi) background events than CCe events and so clean up our sample.

σ/E for low energy electrons

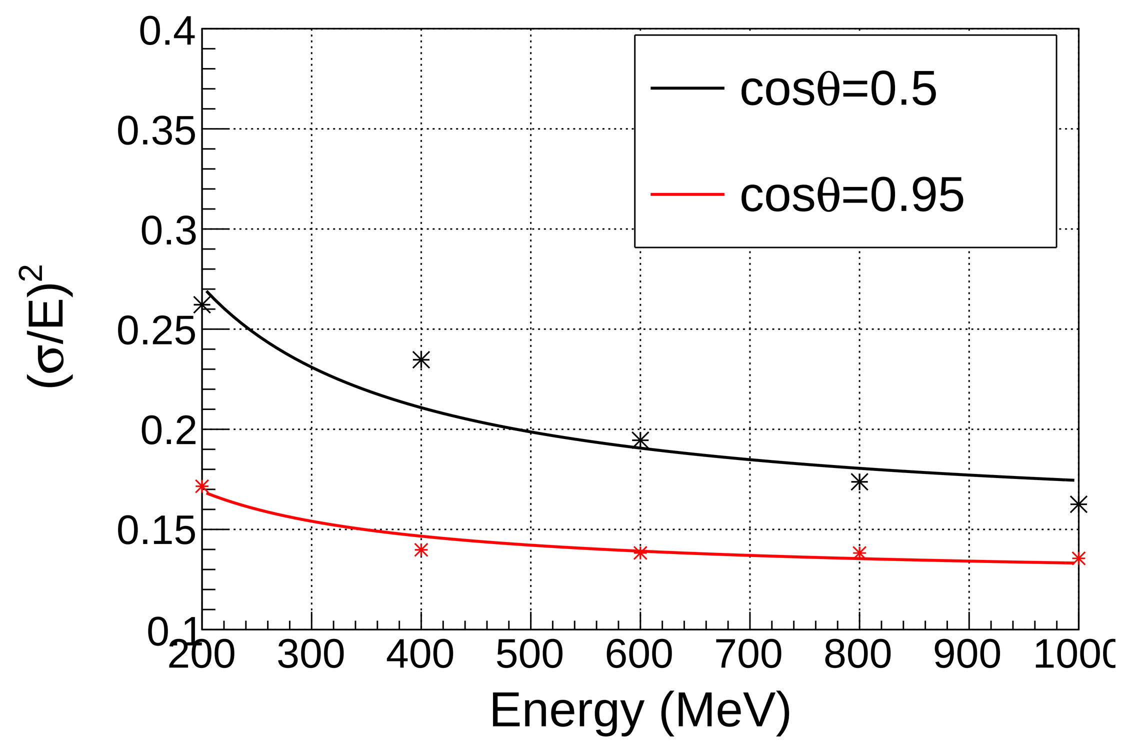
- **To calculate the energy resolution for electrons using ICAL with thinner 18 mm iron plates**

ICAL Preliminary

- The energy resolution may be expressed as

$$\frac{\sigma}{E} = \frac{\Delta n(E)}{\bar{n}(E)} = \frac{\text{rms}}{\text{mean}} . \quad (1)$$

Here the mean and rms refer to the mean and rms of the histogram of the hits distribution.



- Results for fixed electron energies, $E_e = 200, 400, 600, 800, 1000$ MeV and two values of polar angle, $\cos\theta = 0.50, 0.95$ were obtained and parameterized by

$$\frac{\sigma}{E} = \sqrt{\frac{a^2}{E} + b^2} . \quad (2)$$

- The values of a, b were obtained as follows.

$\cos\theta$	a^2	b^2	a	b
0.50	0.024	0.150	0.156	0.39
0.95	0.009	0.124	0.095	0.35

- It was shown in Ref. [1] that a 15% energy resolution is required to have a reasonable sensitivity to (a large fraction of the range of) δ_{CP}.
- In general, $\sigma/E = 15\%/\sqrt{E}$ is achievable by a modified ICAL with thinner plates at low energies (0.1–1.2 GeV) relevant for the CP phase study, there is a large E-independent contribution from b that can in principle spoil the sensitivity.
- The study used information only on the total number of hits and the number of layers containing hits.

Summary and Future Plans

- ICAL at INO was proposed to study the neutrino mass ordering through muons produced in CC interactions of ν_μ on iron in the 1–20 GeV energy range, *independent* of δ_{CP}.
- Sub-GeV atmospheric neutrinos (ν_e) sensitive to δ_{CP}, *independent* of mass ordering [1].
- A simulations study of the sensitivity of ICAL to sub-GeV electrons using thinner 18 mm iron plates (rather than design value of 56 mm) was done.
- The energy resolution, calculated using Eq. 2, are listed in the Table. An E-independent large value of b was found.
- Plan to include energy loss/deposited information in 10 mm scintillators, 18 mm iron with 12 mm air gap, to improve resolution.
- Complete a detailed analysis of sensitivity to δ_{CP} for thin ICAL; probe other physics.

References

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