Exploring Neutrino properties using Atmospheric Neutrinos at ICAL

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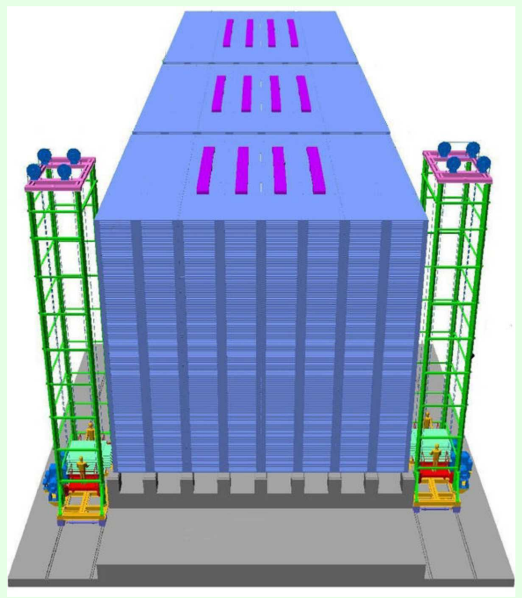
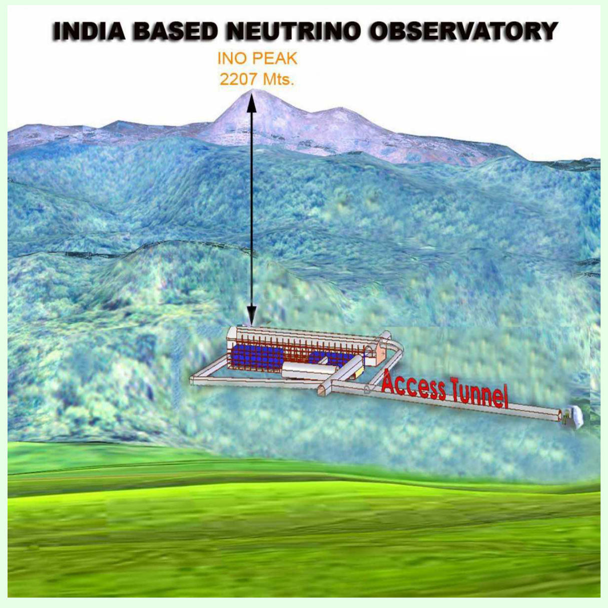
Introduction

I study oscillation parameters of atmospheric neutrinos using Iron CALorimeter (ICAL) detector at the India-based Neutrino Observatory (INO). INO Project is a multi-institutional effort aimed at building a world-class underground laboratory with a rock cover of approx. 1200 m for non-accelerator based high energy and nuclear physics research in India as explained in the Physics White Paper of the ICAL (INO) Collaboration (Pramana - J. Phys (2017) 88 : 79).



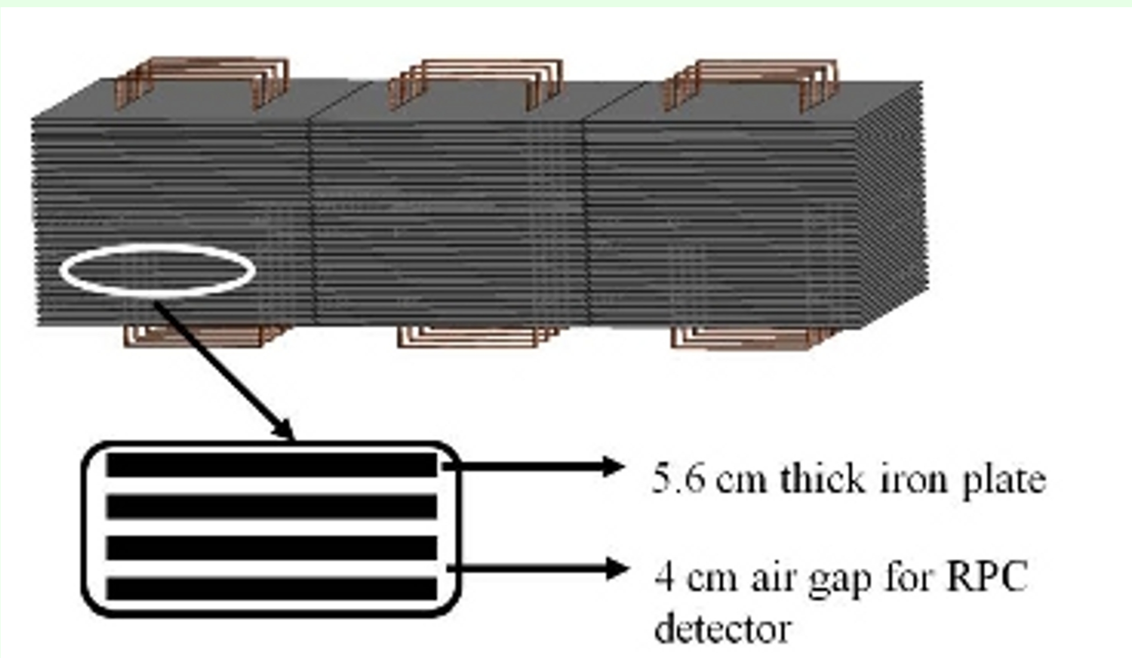


What is the goal of INO?

The primary focus of this experiment is to explore the Earth matter effects by observing the energy and zenith angle dependence of the atmospheric neutrinos in the multi-GeV range. This study will be crucial to address some of the outstanding issues in neutrino oscillation physics, including the fundamental issue of neutrino mass hierarchy.

Components of Project

- Construction of an underground laboratory and associated surface facilities at Pottipuram in Bodi West hills of Theni District of Tamil Nadu, India.
- Construction of a Iron Calorimeter (ICAL) detector consisting of 50000 tons of magnetized iron plates arranged in stacks.
- 29000 Resistive Plate Chambers (RPCs) of size 2 m $\times$ 2 m would be inserted as active detectors in the gap between the iron layers.



Resistive Plate Chamber (RPC): Active Detector

- Resistive Plate Chamber is a gaseous detector. The gas is confined between the two parallel resistive plates made up of glass.
- Whenever a charged particle passes through the gaseous medium, the signal is generated which is induced on the pickup strip.
- The signals from electronic circuits are used to reconstruct the track of charged particle.

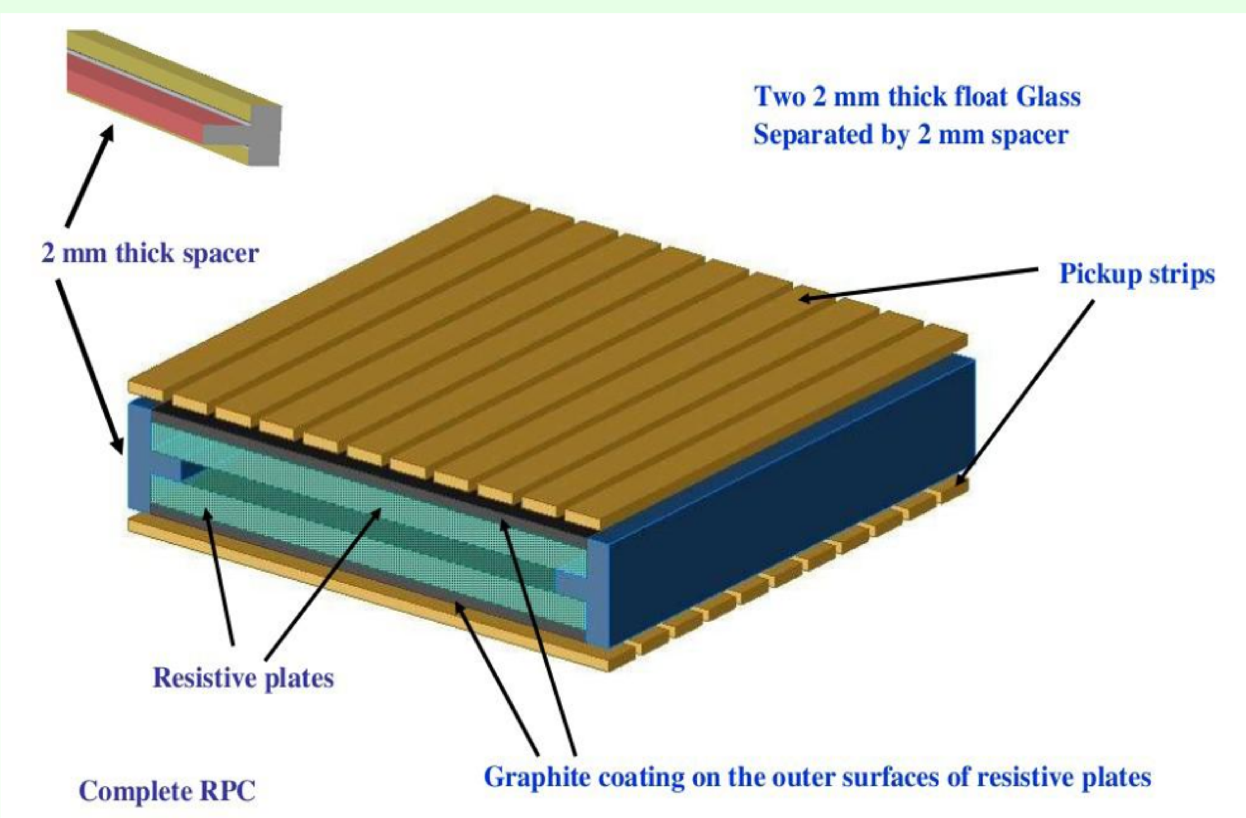


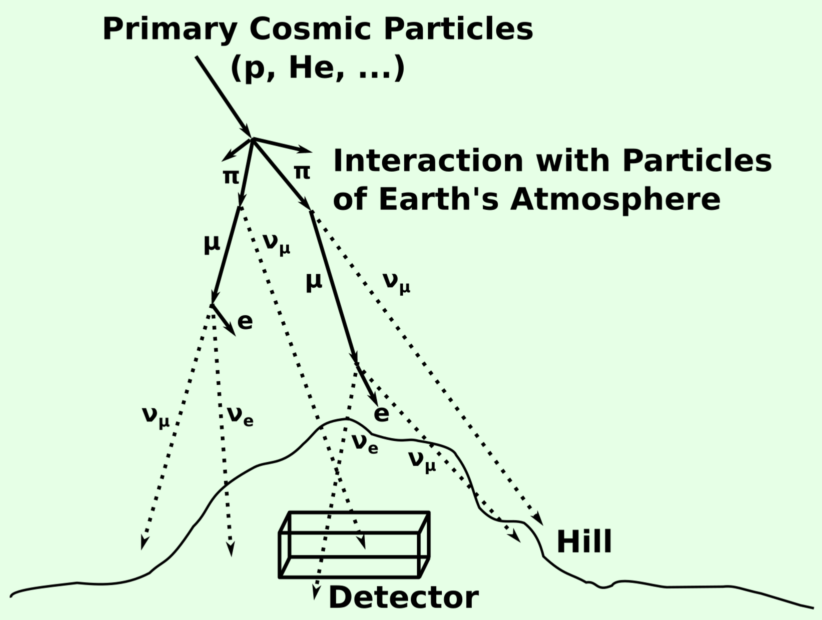
Figure 3: *Schematic layout of RPC*

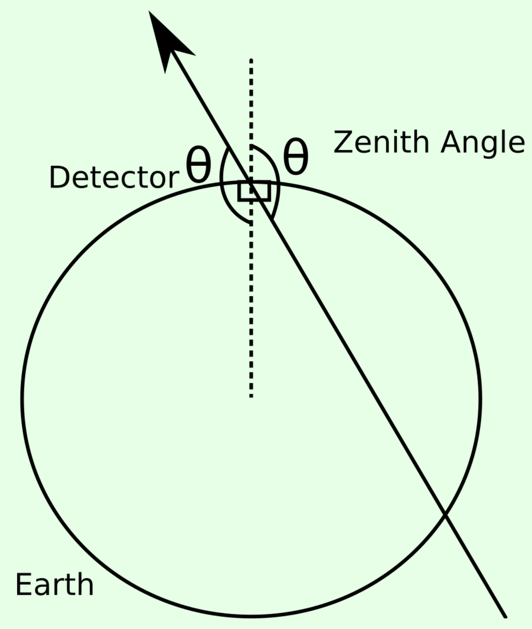
How do INO Detect Neutrino?

- Muon Neutinos interact with iron nuclei and produce Muons which are detected by RPC detectors.
- The muon neutrino produces negatively charged muon (μ^-) whereas antineutrino produces positively charged anti-muon (μ^+). The muon and anti-muon bend in opposite directions under the influence of magnetic field.

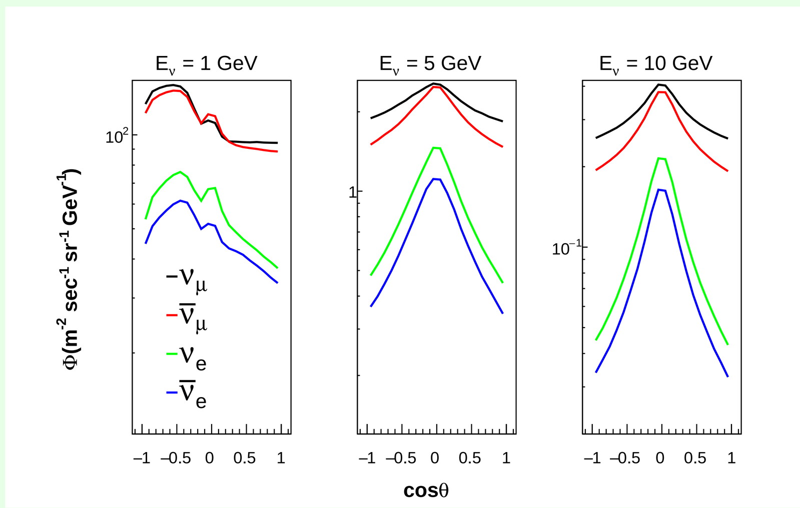
Atmospheric Neutrinos

- The atmospheric neutrinos are produced when the cosmic ray particles interact with the nuclei of atmosphere.
- The atmospheric neutrinos change their flavor on passing thorugh Earth which is called neutrino oscillation.





Neutrino Flux at INO



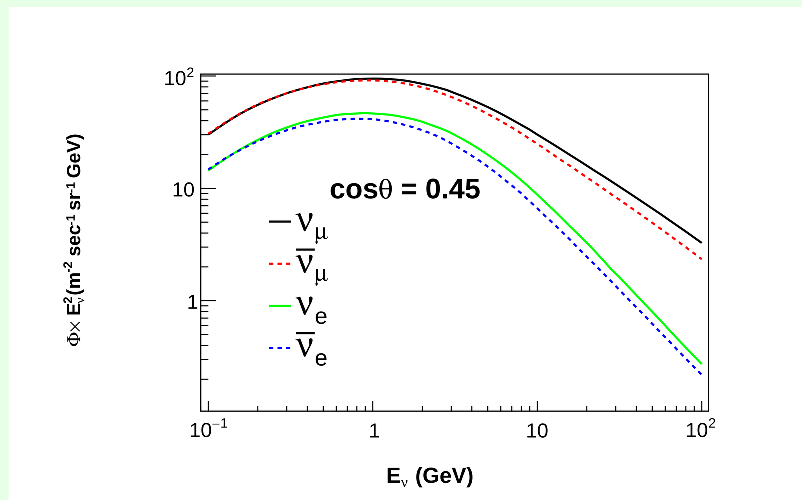
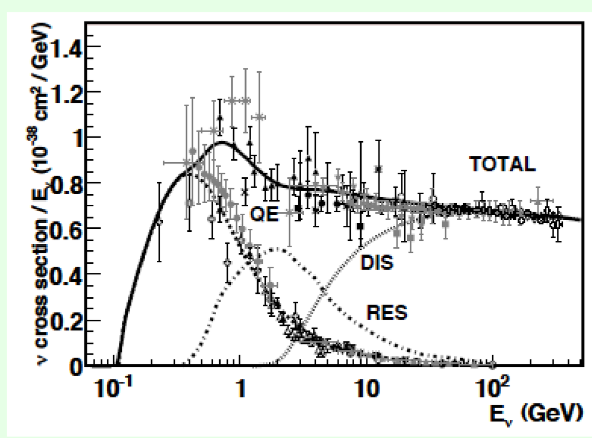


Figure 5: *Zenith angle dependence of the neutrino flux averaged over azimuthal angles are shown for three different energies in the left plot whereas Energy dependence of neutrino flux is shown in right figure for* $\cos\theta = 0.45$.*(Data Table: Phys. Rev. D92, 023004 (2015))*

Neutrino Interaction Cross-section



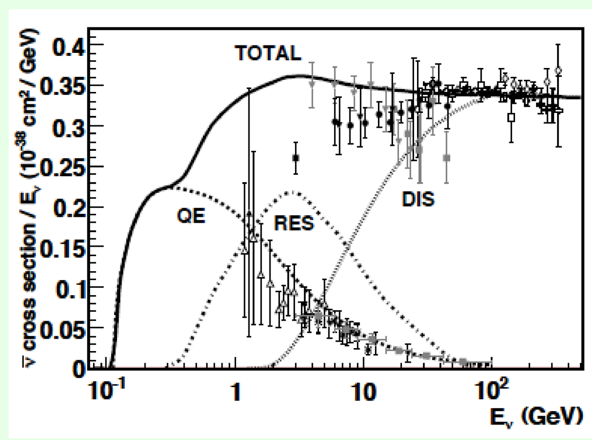
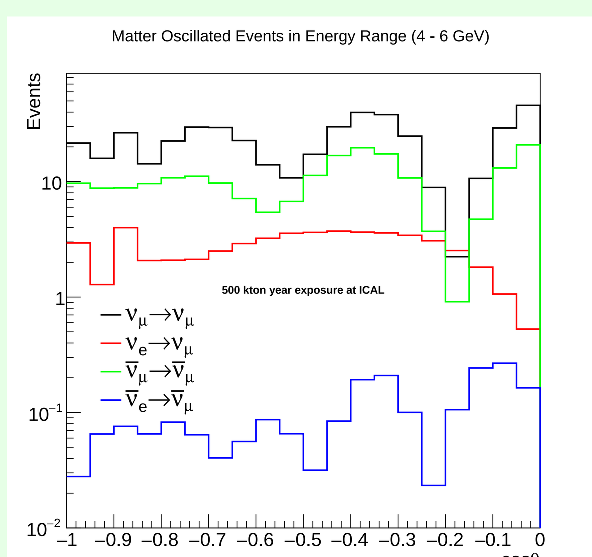


Figure 6: *Total neutrino (left) and antineutrino (right) per nucleon CC cross sections (for an isoscalar target) divided by neutrino energy and plotted as a function of energy. (Rev. Mod. Phys. 84, 1307 (2012))*

Neutrino Events at INO-ICAL



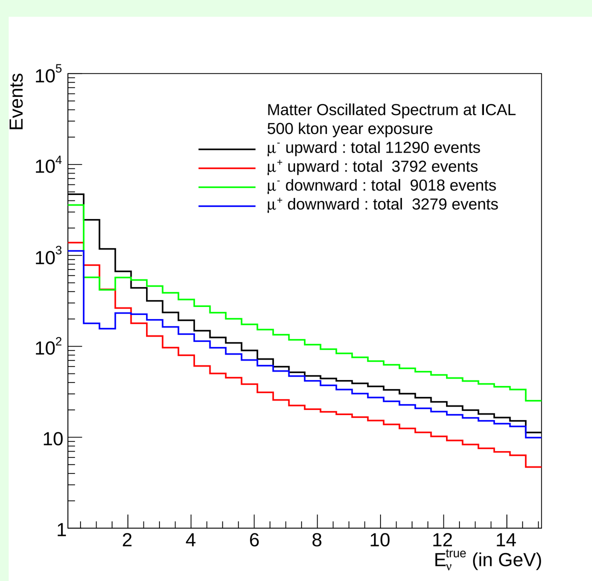


Figure 7: *Matter oscillated events without detector properties for 500 kton year exposure at ICAL and* $N_\mu = N_{\mu\mu} + N_{e\mu}$ *in the right plot.* ($\theta_{13} = 8.5°, \theta_{12} = 34°, \theta_{23} = 45°, \Delta m^2_{21} = 7.5 \times 10^{-5}\, eV^2, \Delta m^2_{31} = 2.5 \times 10^{-3}\, eV^2, \delta_{CP} = 0$, *Normal Hierarchy)*

More info : http://www.ino.tifr.res.in

11th International Neutrino Summer School, May 2018, Schloss Waldthausen, Mainz/Germany