Status of INO Experiment

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(on behalf of INO Collaboration)
@International Workshop on Next generation Nucleon Decay and Neutrino Detector, Paris, France
4th November 2014
Outline

• Introduction
• Status of Experiment
  • Detector
  • Magnet
  • Trigger
  • Electronics
  • Simulation
  • Laboratory site development
• Conclusions
Brief History

- Atmospheric neutrino experiments study neutrinos produced by cosmic ray interactions in the atmosphere.
- First observed at Kolar Gold Fields (KGF), India and East Rand Proprietary Mine, South Africa in 1964.
- During 1980s, massive underground detectors to search for proton decay studied atmospheric neutrinos as the major source of background.
- In 1988, Kamiokande Experiment observed the deficit of atmospheric muon neutrinos compared to Monte Carlo prediction. Similar results were reported by the IMB experiment followed by Soudan-2 & MACRO.
- In mid 1990s, Kamiokande data showed that the deficit of $\mu$-like events depended on zenith angle.
- In 1998, Super-K-experiment concluded that atmospheric neutrino data gave evidence for $\mu$ neutrino oscillation.
- Atmospheric neutrino experiments have been contributing substantially in our understanding of neutrino masses and mixing angles.
India Based Neutrino Observatory

• Create experimental Facility to carry out experiments in the field of particle and astroparticle physics.

• Underground laboratory with ~1km around rock cover access through 2km long tunnel.

• Probe neutrino properties using atmospheric neutrinos and complementary to ongoing effort worldwide.

• ICAL with charge identification ability, will be able to address question about neutrino mass ordering.

• Created facility will support other experiments. Neutrino-less Double Beta Decay and Dark Matter Search experiment foreseen in the near future.
First atmospheric neutrino was reported from Kolar Gold Field, India.

- long tradition of carrying out experiments deep underground.
- ~30 muon/year/m²/sr at KGF, increased by a factor of ~100 at INO

Detection of atmospheric neutrino at Kolar Gold Field in 1965
INO Collaboration

- Nearly 100 scientists from 23 research institutes & universities all over India.
- One of the largest basic science projects in India in terms of man power.

Ahmedabad: Physical Research Laboratory
Aligarh: Aligarh Muslim University
Allahabad: HRI
Bhubaneswar: IoP, Utkal University
Calcutta
Lucknow: Lucknow University
Madurai: American College
Mumbai: BARC, IIT-Bombay, TIFR, CMEMS
Mysore: University of Mysore
Srinagar: University of Kashmir
Varanasi: Banaras Hindu University

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INO site: Bodi West Hills

90 58’ N, 77 16’ E, Pottipuram Village, Theni District Tamil Nadu State
Warm, low rainfall area, low humidity throughout the year

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INO site: Bodi West Hills

INO Facilities at Pottipuram

50 kton ICAL Neutrino Detector
INO-ICAL detector

Strip width: 3 cm
Timing resolution: ~1ns
Position resolution: 5 mm

R134a(C2H2F4): Isobutane(C4H10): Sulphur Hexaflouide(SF6):: 95.5:4.3:0.2
## INO-ICAL Detector

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ICAL</th>
<th>ICAL-EM</th>
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<tbody>
<tr>
<td>No. of modules</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Module dimensions</td>
<td>$16.2 \text{m} \times 16 \text{m} \times 14.5 \text{m}$</td>
<td>$8 \text{m} \times 8 \text{m} \times 2 \text{m}$</td>
</tr>
<tr>
<td>Detector dimensions</td>
<td>$49 \text{m} \times 16 \text{m} \times 14.5 \text{m}$</td>
<td>$8 \text{m} \times 8 \text{m} \times 2 \text{m}$</td>
</tr>
<tr>
<td>No. of layers</td>
<td>150</td>
<td>20</td>
</tr>
<tr>
<td>Iron plate thickness</td>
<td>56mm</td>
<td>56mm</td>
</tr>
<tr>
<td>Gap for RPC trays</td>
<td>40mm</td>
<td>40mm</td>
</tr>
<tr>
<td>Magnetic field</td>
<td>1.3 Tesla</td>
<td>1.3 Tesla</td>
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<tr>
<td>RPC dimensions</td>
<td>$1950 \text{mm} \times 1910 \text{mm} \times 30 \text{mm}$</td>
<td>$1950 \text{mm} \times 1910 \text{mm} \times 30 \text{mm}$</td>
</tr>
<tr>
<td>Readout strip pitch</td>
<td>30mm</td>
<td>30mm</td>
</tr>
<tr>
<td>No. of RPCs/Road/Layer</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>No. of Roads/Layer/Module</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>No. of RPC units/Layer</td>
<td>192</td>
<td>16</td>
</tr>
<tr>
<td>No. of RPC units</td>
<td>$28,800 \ (107,266 \text{m}^2)$</td>
<td>$320 \ (1,192 \text{m}^2)$</td>
</tr>
<tr>
<td>No. of readout strips</td>
<td>3,686,400</td>
<td>40,960</td>
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</tbody>
</table>
Industrial Fabrication of RPC gap

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Magnet Design

ICAL MAGNET  QTY - 3
Size :-  16(L) x 16(W) x 15(H) meter
COIL SIZE :-  15m x 8m
Ampere-Turn :- 80,000 AT
Max. Design Value:- 100,000 AT
Max. Power requirements in each magnet:—
<150KW (Coils & Power Supply)
Each coil gap = 1300mm x 80 mm

- Soft Iron Plates
- Copper Coils
- Power Supply
- Coil Cooling System

60 kA-turn

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**ICAL Trigger Scheme**

- Trigger criteria based on event topology alone.
- Distributed and hierarchical architecture.
- Detector module segmented to generate local trigger.
- Combination of local triggers produces global trigger.
- Global trigger latches event data.

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Electronics system for ICAL

Major elements

- Front-end board
- RPCDAQ board
- Segment Trigger Module
- Global Trigger Module
- Global Trigger Driver
- Tier1 Network Switch
- Tier2 Network Switch
- DAQ Server
- VLSI, FPGA and ASIC chips; high density connectors
Detector Simulation and Event Reconstruction

**Neutrino Event Generation**

\[ \nu_e + X \rightarrow A + B + \ldots \]
Generates particles that result from a random interaction of a neutrino with matter using theoretical models.

**Event Simulation**

\[ A + B + \ldots \text{ through RPCs + Mag.Field} \]
Simulate propagation of particles through the detector (RPCs + Magnetic Field)

**Event Digitisation**

\[(x,y,z,t) \text{ of } A + B + \ldots + \text{ noise + detector efficiency}\]
Add detector efficiency and noise to the hits

**Event Reconstruction**

\[(E,p) \text{ of } \nu + X = (E,p) \text{ of } A + B + \ldots\]
Fit the tracks of \( A + B + \ldots \) to get their energy and momentum.

**Output:**
- i) Reaction Channel
- ii) Vertex Information
- iii) Energy & Momentum of all Particles

**Output:**
- i) \( x,y,z,t \) of the particles at their interaction point in detector
- ii) Energy deposited
- iii) Momentum information

**Output:**
- i) Digitised output of the previous stage (simulation)

**Output:**
- i) Energy & Momentum of the initial neutrino

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Detector Simulation

CC events (without oscillations)

- $\sigma/E$ in [1GeV - 15GeV]

$\sqrt{a^2/E + b^2}$ fit

$\chi^2/\text{ndf}$: 13.96/28

- $a = 0.742 \pm 0.009$
- $b = 0.302 \pm 0.004$

$E_v - E_\mu = E_{\text{had}}$ (GeV)
Room to improve: reconstruction software and improved in analysis method.

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Neutrino Mass Matrix

ICAL will play an important role to determine these parameter more precisely

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IICHEP at Madurai

- Plan to build and commission mini ICAL (20 X 8 X 8) at IICHEP within 2.5 years
- Nodal center for all INO related activities
- Responsible for running all activities at the INO underground lab.
- Will be involved in detector R & D for future project
Activities @ Bodi Hills

- 26.82.5 ha. of revenue land at Pottipuram village was transferred to DAE
- Transfer document signed on 28th December, 2011
- Fencing work has completed

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Activities @ Bodi Hills

Receiving sump at INO Site 12
lakhs litre capacity

14/03/2014 14:37

Detailed Survey work

14/03/2014 14:59

INO Site Fence work

14/03/2014 15:16

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Current Status

• Pre-project activities started with an initial grant of ~ $10 M
• Site infrastructure development and Tunnel, cavern (3 – 4 years)
• Development of INO centre at Madurai (moving fast)
• Construction of an engineering prototype module (2.5 years)
• ICAL Detector (one module per year)
• Detector R & D is now complete.
• DPR for Detector and DAQ system is ready
• White paper on Physics is ready
• Industrial production of RPC will start soon
Thank You For Your Kind Attention