Resistive Plate Chambers for Experiments at
India-based Neutrino Observatory (INO)

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INO Collaboration

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Collaborating institutions/universities

AMU, BHU, BARC, CU, DU, HRI, UoH, HPU, IITB, IITK, IGCAR, IMSC, IOP, LU, NBU, PU, PRL, SINP, SMIT, TIFR, VECC
Plan

- Physics motivations for INO
- India-based Neutrino Observatory (INO)
- INO Detector (ICAL)
- Resistive plate chamber (RPC) for ICAL
- Test results
- Future Plans
Physics Motivations for INO

• To reconfirm the oscillation through appearance and disappearance of neutrinos.

• To measure the neutrino oscillation parameters $|m^2_{31}|$, $\sin^22\theta_{23}, \theta_{13}$ more precisely.

• To determine neutrino mass hierarchy, whether normal ($m^2_3 > m^2_1$) or inverted ($m^2_3 < m^2_1$).
India-based Neutrino Observatory (INO)

- A underground facility at PUSHEP in Nilgiri Mountains in South India, about 90 km from Mysore.

- A single 22 m wide, 120 m long and 30 m in height experimental hall will be constructed at the end of a 1.5 km long tunnel.

- At least 1 km of rock overburden in all directions.

- INO will have 50 kiloton Iron CALorimeter (ICAL) capable of detecting atmospheric $\nu_\mu$ / $\bar{\nu}_\mu$ interactions.

- May also host some other experiments (e.g. neutrinoless double beta decay searches) which require low cosmic ray background environment.
INO Detector:
A Magnetized Iron CALorimeter (ICAL):

• Three modules, each of the size $16\text{m} \times 16\text{m} \times 12\text{m}$ and of mass 17 kilotons.
• In each module 140 layers of iron plates and RPCs.
• $6\text{ cm}$ thick iron plates separated by 2.5 cm, with Resistive Plate Chambers (RPCs) as active element.
• Total mass of 51 kilotons.
• The cavern can accommodate another replica of the above detector so that if necessary, a 100 kiloton mass detector can be constructed.
• Magnetic field $\sim 1$ Tesla allows the determination of muon charge so that $\nu_\mu$ and $\bar{\nu}_\mu$ can be studied separately.
Iron CALorimeter (A detector for INO)

- Mass: 51 kilo ton (or 100 kilo ton)
- Dimension: $48\text{m} \times 16\text{m} \times 12\text{m}$
- 140 layers of iron plates
- Magnetic field $\sim 1$ Tesla
**RPC for INO**

- Two 2 mm thick float Glass
- Separated by 2 mm spacer

**Components:**
- 2 mm thick spacer
- Pickup strips
- Resistive plates
- Complete RPC
- Graphite coating on the outer surfaces of resistive plates
INO will have the provision to change the active part of the detector.
Why RPC?

- Built from simple and common materials.
- Low fabrication cost per unit area.
- Easy to construct and operate.
- Simple signal pick up and readout system.
- Large detector area coverage.
- High efficiency (>90%) and time resolution (~1ns).
- Particle tracking capability.
  Two dimensional (x and y) readout from the same chamber.
- Long term stability.
Resistive Plate Chamber (RPC) in INO

- RPC unit dimension: 2 m x 2 m
- RPC width: 6 mm
- Pick up strip width: 3 cm
- No. of RPC units / Road / Layer: 8
- No. of Roads / Layer / Module: 8
- No. of RPC units / Layer: 192
- Total no. of RPC units: ~26000
Test results of glass RPC

- Glass RPCs have been tested both in streamer and avalanche mode.
- 2 RPCs 30cm x 40cm are tested in avalanche mode for >14 months.
- Aging problem still not solved for glass RPCs in streamer mode.
Glass RPC Efficiency

Freon 134a : 62%
Argon : 30%
Isobutane : 8%

RPC Timing Studies
Why Bakelite RPC?

- Surface smoothness of glossy-finish melamine coated bakelite sheet is comparable to glass.
- Bakelite sheet is more flexible than glass and it is unbreakable.
- Bakelite sheet can be made 1.2 m in width and any size in length.
- Bulk resistivity of bakelite can be controlled adjusting the ratio of the phenol and melamine.
Bakelite RPC

- This RPC brought from China and tested in SINP.
- Dimension of the RPC: 30cm × 30cm.
- Thickness of each plate: 2mm
- Gas gap between two plates: 2mm
- Width of each pick up strip: 3cm
High voltage testing of Bakelite RPC using Cosmic Ray at SINP/VECC
Arrangement of the scintillators and the RPC in SINP
Schematic representation of cosmic ray setup
Experimental setup

- Dimension of the RPC: 30cm × 30cm
- Width of the pick up strip: 3cm
- Dimension of the big scintillators (SC1 & SC2): 25cm × 35cm
- Dimension of the finger scintillator (SCF): 4cm × 20cm & 2cm × 20cm

- Trigger signal = SC1 .AND. SC2 .AND. SCF

- Efficiency = \( \frac{\text{(RPC count with signal in coincidence with trigger)}}{\text{(Trigger count)}} \)
Power supply and the read out system
• RPCs are operated in premixed mode.

• There is the provision to use it in flow mode using Mass Flow Controller (MFC).

Gas mixing control panel in SINP
Gas Mixture

- **Argon**: To provide the efficient gas amplification.
- **Isobutane**: To absorb UV photon. It is the “photon quench gas”
- **Freon (R134a)**: To control charge and physical size of streamer. It is the “electron quench gas”.
Test result of Chinese RPC
Efficiency curve for RPC

- The Trigger rate is around 0.31/cm²/min.
- Plateau region has been found from voltage 7.5 KV onwards at efficiency 91%.
Test of stability for Chinese RPC

- Curve is showing the constancy of the efficiency at a particular high voltage.

- Average efficiency $(92.7 \pm 1.9)\%$ have been observed.
Fabrication of RPC using local Bakelite sheet
Results of Resistivity Measurement of Bakelite Sheet (Grade P-1001 and Superhylam )

- Resistivity varies from $1.5 \times 10^{11} \ \Omega\text{-cm}$ to $5.8 \times 10^{10} \ \Omega\text{-cm}$ with voltage for P-1001.

- Superhylam is a melamine coated Bakelite.

- For Superhylam $\rho \sim 2 \times 10^{11} \ \Omega\text{-cm}$ at 6 KV.
I-V Characteristics of Bakelite (Grade P-1001 and Superhylam)

For grade Grade P-1001

For Superhylam

I-V plot for Natural colour Bakelite

- Temp: 32.6°C

I-V plot for Melamine coated Bakelite

- Temp: 22.0°C
- Humidity: 82%
Test of RPC made in VECC

- RPC is made by white melamine coated superhyylam bakelite.

- Dimension of the RPC: 30 cm X 30 cm.

- It is tested using premixed gas of Argon, Iso-Butane and R-134a (34:6.8:59.2).

- RPC is operated in Streamer mode.
Efficiency curve

- The Trigger rate is ~0.3/cm²/min.
- Plateau region has been found from voltage 7.5 KV onwards at efficiency >91%.
- At 9 KV current through the RPC ~5 µA.
Long term stability test of RPC made by Superhylam Bakelite
Efficiency Vs Day

- RPC operated continuously for 38 days.
- RPC is tested at 8 KV.
- Efficiency decreases from a value ~92% to 82% within 38 days.
Trigger rate Vs Day

Plot of Trigger rate vs Time for Ar: Iso-B: Freon(R134a)=34:6.8:59.2 of RPC IB2
Current in two channels

Current in Channel 1

Current in Channel 2

28/06/07  IHEP, China
Noise rate Vs Day

- Noise rate increases with time.
Humidity and Temperature

Humidity Vs Day

Temperature Vs Day
Study of some properties of Bakelite (P-120) and construction of new RPC
I-V Characteristics of Bakelite (P-120)
Results of Resistivity Measurement of Bakelite Sheet (P-120)

\[ \rho \approx 9 \times 10^{12} \ \Omega \text{–cm at 6 KV.} \]
Complete RPC made by P-120
I-V plot for RPC IB3

- Current is ~600nA at 9 KV.
Efficiency plot for RPC IB3

- Efficiency starts to decrease after a certain HV.
Present status of INO

• Simulations on detector geometry and material is done.
• Site for the experiment has been fixed.
• R & D on Glass RPC is going on in TIFR and BARC.
• R & D on Bakelite RPC is going on in SINP and VECC.
• A prototype of ICAL will be tested at VECC.
• Magnet for prototype is Ready.
Future plans

- Testing of 1m x 1m Chinese RPC.
- RPC testing using the gas system of VECC.
- Measurement of time resolution of RPC.
- Installation of Lab View and starting on line monitoring.
- Construction of pick up panel using G-10.
We are beginning to learn to manage large collaboration

Welcome to all International collaborators........
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