India-Based Neutrino Observatory

Development of Glass Resistive Plate Chambers for INO

M. Bhuyan[a], V.M. Datar[b], S. Dhuldhaj[a], S.D. Kalmani[a], S.M.Lahamge[a], N.K. Mondal[a], P. Nagaraj[a], S. Pal[a], L.V. Reddy[a], A. Redij[a], D. Samuel*[a], M.N. Saraf[a], B.Satyanarayana[a], R.R. Shinde[a], P.Verma[a]

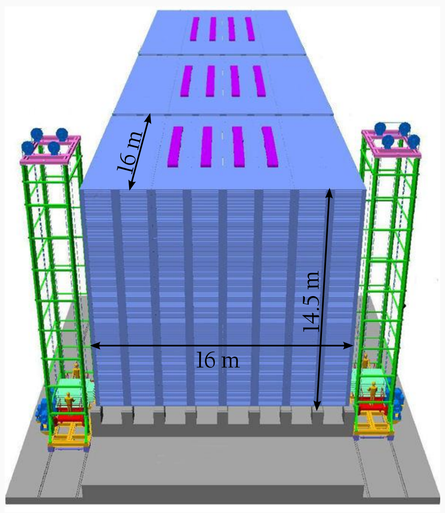
a Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai.

b Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai.

* samuel@tifr.res.in

Abstract: The India-based Neutrino Observatory (INO) collaboration is planning to set up a magnetized Iron CALorimeter (ICAL) to study atmospheric neutrinos and to precisely determine the neutrino oscillation parameters. ICAL uses 50kton Iron as target mass and about 28000 glass Resistive Plate Chambers (RPC) as active detector elements. Starting with small RPCs of 30cm x 30cm in size, we have developed full size 2m x 2m RPCs. A detector stack comprising of 12 layers of RPCs of 1m x 1m in area is in continuous operation for the last 4 years. A similar cosmic ray stand of 5 layers of RPCs of 2m x 2m in area is also operating successfully for the past 2 years. We present here the recent results of the studies performed with these detectors.

About INO-ICAL



Schematic of the ICAL Detector

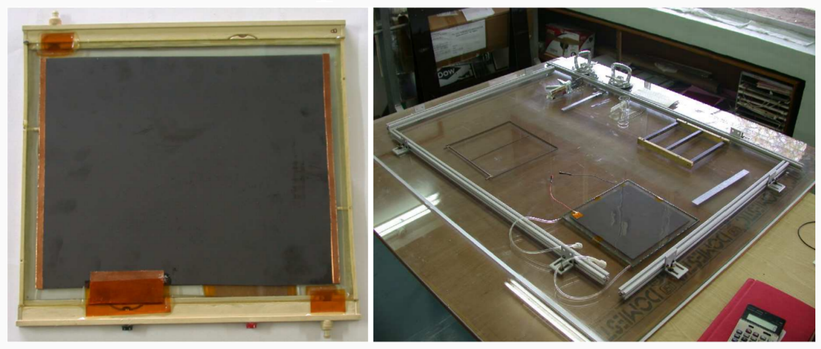
DETECTOR PARAMETERS

- 3 modules each of size 16m x 16m x 14.5m.
- 150 layers of RPCs interleaved by Iron plates (56mm thick)
- 64 (8 x8) RPCs per layer per module.
- Total of 28,800 RPCs of size 1.84m x 1.84m x24mm, with 64 strips (30mm pitch) on either read-out planes.
- Magnetic field of 1.3 Tesla

MAIN GOALS

- Unambiguous and more precise determination of oscillation parameters using atmospheric neutrinos.
- Study of matter effects through electric charge identification, leading to determination of sign of Δm^2_{23}.
- Study of CP violation in the leptonic sector and possible CPT violation studies.
- Study of very-high energy neutrinos and multi-muon events.

RPC Development



The first fully assembled small area prototype RPC gas gaps (left panel) along with various RPC assembly jigs developed locally (right panel).

The signal pick-up panels were made up of poly-isocyanurate foam board with reinforced poly-aluminum foil facers on both sides. Gas inlet and outlet ports were implemented by fabricating special nozzles which have standard nipples for holding the plastic gas tube. With the experience obtained in the designing of the small area RPCs, the group advanced towards the designing of large area RPCs.

About 30,000 Glass of about 2m x 2m will be needed for the ICAL detector. The first experimental activities started with the development of small size RPCs at TIFR.

Several RPCs of 30 cm x 30 cm in size were built using 2 mm thick standard Asahi float glass procured from the local market.

High voltage is applied across the electrodes by means of a semi-resistive coating. A mixture of dry colloidal graphite powder and industrial lacquer in about 1 : 8 ratio by weight along with thinner used for consistency. This mixture was sprayed uniformly on the cleaned glass electrode surfaces using a standard paint spray gun typically used in the auto shop. We obtained a low, but uniform,resistance of 100 - 200 kΩ/ using this technique.

The Prototype Detectors

As part of detector design, development and characterization studies for INO, 3 prototypes were designed which are in continuous operation now.

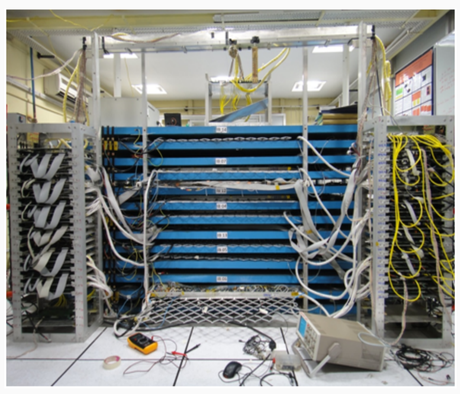
Prototypes at TIFR, Mumbai

- 2 prototypes (Non-Magnetised), are operational at TIFR
- Prototype 1: Size: 1m x 1m; Strips: 32 per plane; Layers: 12
- Prototype 2: Size: 2m x 2m; Strips: 64 per plane; Layers: 5
- RPC Material: Glass

Prototype at VECC, Kolkata

- 1 prototype (Magnetised) is operational at VECC
- Size: 1m x 1m; Strips: 32 per plane; Layers: 12
- RPC Material: 9 Glass RPCs and 3 Bakelite RPCs
- Magnetic Field: 1.5 T (Max)

The Prototype Detector at TIFR, Mumbai



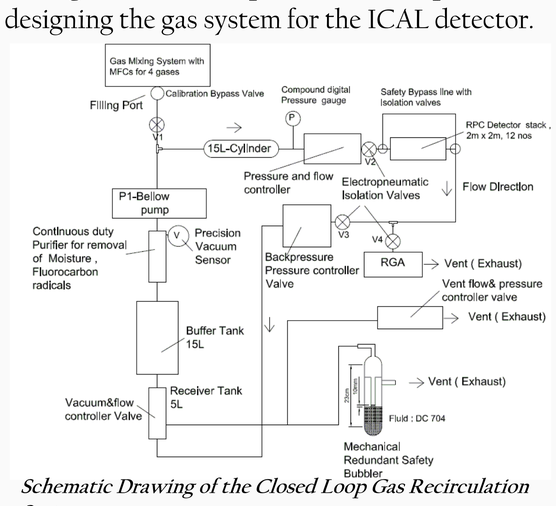
The Prototype Detector at VECC, Kolkata

Gas Recirculation System

A gas mixing unit capable of mixing individual gas components and control the mixed gas flow through the detector chambers has been designed and developed with the help of a local industry. A lot of progress has been made in designing the gas system for the ICAL detector.

Gas System Features

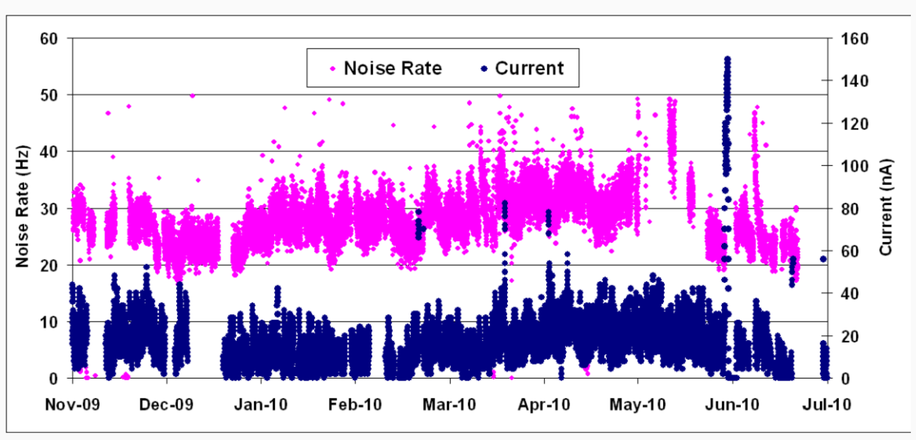
+ 4 channel gas mixing module (filling/top-up of Isobutane, Freon R134A, Argon and SF6
+ Pressure balance system to maintain and control pressure within safe limits
+ Total Capacity: 140 l
+ Continuous duty gas purification system to remove moisture,and other radicals
+ Contamination removal upto 2ppm.
+ Dynamic pressure loss: Not more than 80 mbar



Schematic Drawing of the Closed Loop Gas Recirculation System

Results from the TIFR Prototype

The prototypes were used to study and monitor the long term stability and effeciency of the detector and the related electronics. Once the detectors were stabilised, studies on cosmic muons were also carried out using them.

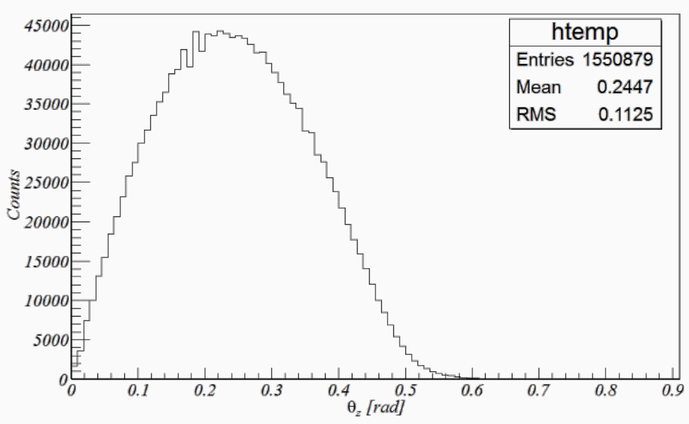


The noise rate and the current measured over a period of time. The stability of the noise rates show the consistent performance of the detector

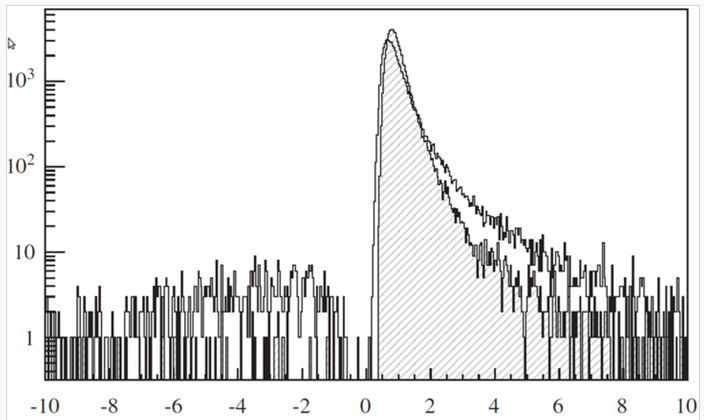
The zenith angle distribution of the muon tracks was made by fitting a straight line to the X and Y Side hits in the detector.

To demonstrate the capabilities of the prototype stack and the feasibility of distinguishing between up-coming and down-going muons, a study on the velocity of the cosmic-muons was made.

Preliminary results showed the (v/c) distribution having values greater than 1. To correct for these issues, the strip to strip variations in timing were also taken into account in the calibration data. This minimized the anomalies that were seen. Studies are being made to refine the timing measurement and calibration processes.

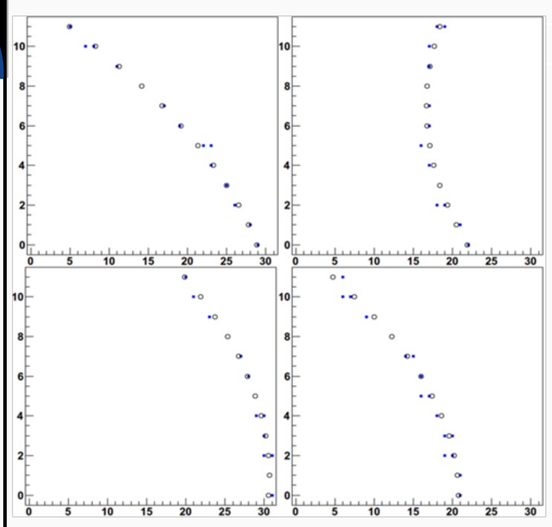


The zenith angle distribution of cosmic muons measured using the prototype stack.



The distribution of the velocity of cosmic-muons

Results from the VECC Prototype



A glimpse of few curved tracks. The blue dots are the data points and the hollow circles are the points from the second order fit

In the prototype at VECC, a total of 4 coils, each having 5 turns, wound perpendicular to the plane of the Iron plates make-up an electromagnet which weighs about 50 tons (~0.1% of the main ICAL) and which can be magnetized up to 1.6 Tesla.

The presence of the magnetic field makes the particles take a curved trajectory which makes the analysis of data different from the analysis of the data from the TIFR prototype stack.

In a crude first attempt to study the data, a second order polynomial function was used to fit the curved tracks. The second order coefficient reflects the curvature of the tracks and thus indirectly the charge of the particle (assuming the arrival direction of particles to be from the top).

Summary/ Future Work

The INO collaboration through the development studies of RPCs has now proceeded to transfer the technology to the industry for mass production of RPCs. At present various studies are being done in the other aspects of the detector.

There is an ongoing study on sealed RPCs where the results are optimistic. We could prove that the RPCs can be safely operated without flushing out the gas for almost a month, reducing the gas costs drastically and other environmental effects.

The RPCs are planned to be operated in the avalanche mode thus requiring fast amplifiers. A lot of effort is put in the development of the front-end electronics for the RPCs.

The RPCs designed for the ICAL experiment will host individual DAQ boards laid on top of each of them. These DAQ boards have several units like the Pulse Shape Monitor, Temperature, Pressure and Humidity Monitors, Noise Rate Scalers, TDCs etc. The design of these RPC-DAQ boards and communication protocols are currently under study.

ICAL being a low event rate experiment a efficient trigger system is an absolute neccessity. A modular trigger system has been proposed and is currently being tested.