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Preliminary results from India-based Neutrino Observatory detector R&D programme

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Abstract. We are currently developing and studying the performance of glass RPC prototypes, under the INO detector R&D programme. While we were successful in building and characterising a large number of chambers using local glass, these have met with severe aging problems after a few months of continuous operation. We have then built a couple of RPCs using a Japanese glass. We report in this paper on our long term stability tests of these RPCs. We also present some of our recent results on tracking of cosmic ray muons in a stack of glass RPCs.

Keywords. India-based Neutrino Observatory; resistive plate chamber; results.

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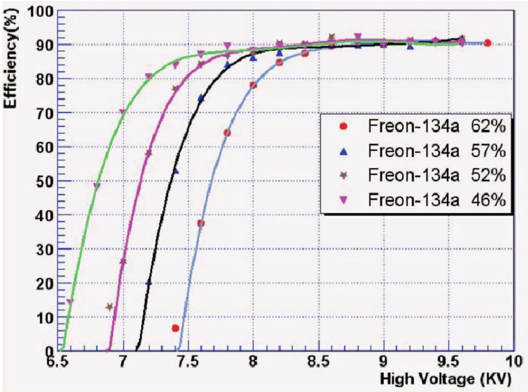
1. Introduction

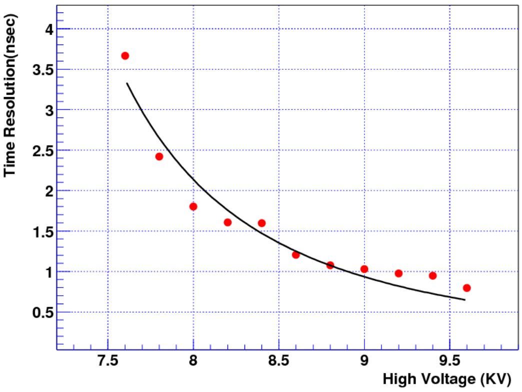
India-based Neutrino Observatory (INO) collaboration is proposing a large magnetized iron tracking calorimeter weighing 50 kton, using atmospheric neutrinos as source [1].

The proposed detector will have modular structure of lateral size 48 m × 16 m and will consist of a stack of 140 layers of 6 cm thick iron plates interleaved with resistive plate chamber (RPC) detector layers. A total of about 27,000 RPCs of dimension 2 × 2 m will be needed for this experiment. A dedicated effort for development of RPC detectors, leading to their large scale production is in progress.

A large number of single gap glass RPCs of area 30 × 30 cm as well as a few of area 120 × 90 cm were developed, using float glass procured from the local market. The voltage–current characteristics of these detectors were studied. The noise rate



(a) Efficiency plateaus



(b) Timing resolution

Figure 1. A couple of earlier RPC results.

was found to be a reliable way of monitoring the stability of the RPC. Figure 1a shows plots of the RPC efficiency as a function of the detector bias voltage for different gas mixtures. Plateau efficiencies of over 90% have been obtained for all the gas mixtures beyond a bias voltage of 8.5 kV. Figure 1b shows the timing resolution σ as a function of bias voltage. As can be seen from the plot, the timing resolution improves with the increase of detector bias voltage and reaches a value of about 1.2 ns in the plateau region [2,3].

2. Long term stability tests of INO RPCs

Glass RPCs operating in the streamer mode are known to be stable and have a long lifetime (more than 5 years) as evidenced by the successful operation of these chambers by the Belle Collaboration. However, those made by us earlier had a much shorter lifetime [4,5]. While the problem of short lifetime of our glass RPCs is being investigated, we fabricated a few RPCs of dimension 40 × 30 cm using

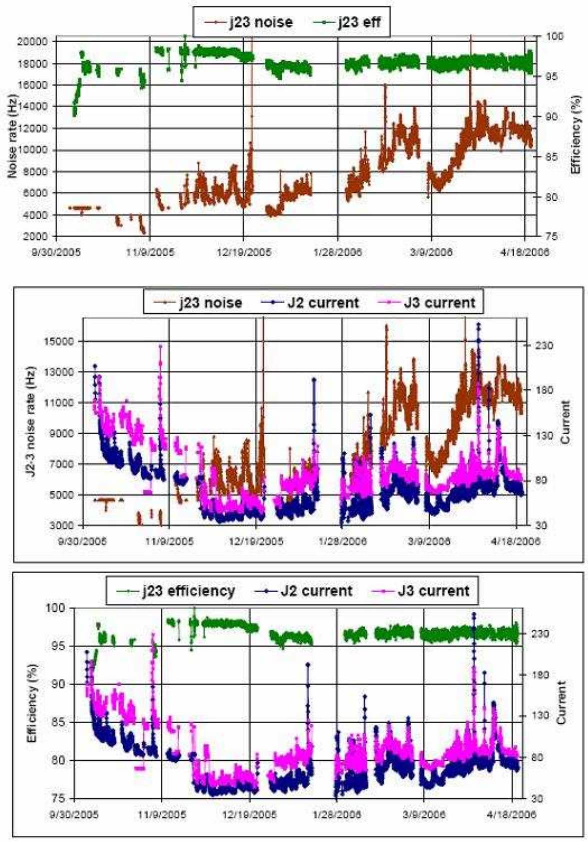


Figure 2. Long term stability monitoring plots of J2 and J3 RPCs.

glass procured from Japan. The same procedure for fabrication and testing as in the case of earlier RPCs was followed for these new chambers. Two of these new chambers (called J2 and J3) are currently being operated in the avalanche mode, in which a gas mixture of freon (R134a) and isobutane in the proportion 95.5 : 4.5 by volume is used. The chambers are operated at a high voltage of 9.3 kV. Since the pickup signals in the avalanche mode are in the range of few millivolts, external amplification has been provided by preamplifiers of gain 10. The rest of the electronics and data acquisition chain is the same as that used earlier [6].

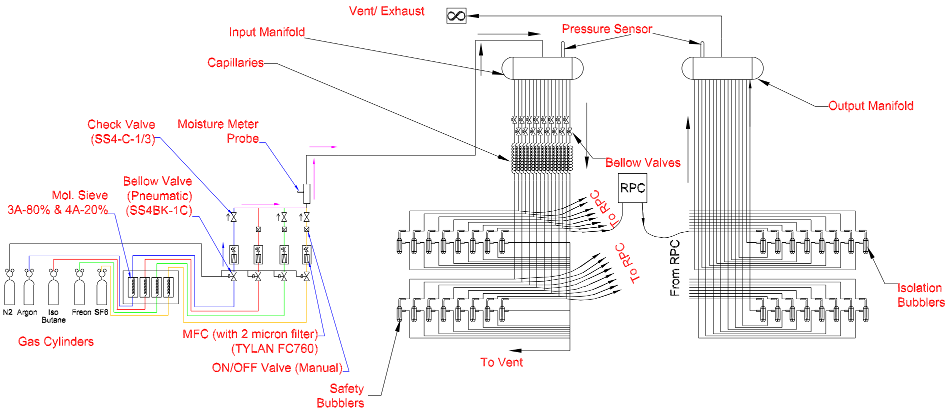
A comprehensive monitoring system for the periodic recording of the detector currents of these two RPCs (J2 and J3) together with the ambient parameters such as temperature, pressure and relative humidity both inside and outside the laboratory has been designed and implemented. Using this data several correlations between the ambient parameters and the RPC operating characteristics could be established. The long term stability tests were started on these two chambers from September 2005. As can be seen from the plots in figure 2, the performance of these chambers, characterised by their efficiency, leakage currents and noise rates, have not changed over the last seven months. These tests indicate that the aging problem associated with the previous RPCs is related to the quality of glass plates used to fabricate those RPCs. While continuing with this long term stability test, we are also in the process of fabricating large-sized chambers using glass obtained from the same Japanese source.

3. Development of 16-channel gas mixing system

A new 16-channel gas mixing and distribution system using mass flow controllers (MFC) was designed and developed recently to be used for flowing gas to the proposed prototype detector with 12 RPCs. It mixes four input gases viz. argon, freon (134A), isobutane and SF_6 using the volumetric method. The mixed gas can be supplied simultaneously into 16 individually controlled output channels. The gas flow rate in each of the output channels is kept the same using flow resistors. The return gas from the connected chambers is collected in a common manifold before it is finally vented out into the atmosphere. Gas flow at every stage of the system is achieved through the use of electrically or pneumatically operated switches or valves. The system is equipped with a host of sensors and monitoring devices and appropriate displays of various crucial operating and quality control parameters.

The main components and salient features of the system are:

1. *Input gas purifier columns*: Four (one for each input gas) *in-situ* rechargeable molecular sieve-based columns, mounted on the input gas lines in order to absorb moisture, oil traces and other contaminants from the input gases.
2. *Gas mixing section*: This crucial section is based on Tylan-made FC-760 model mass flow controllers (MFCs). The input section of these filters have 2 μm dust filters. Flow rates of individual gases, calibrated in standard cubic centimetre per minute (SCCM), are settable from, and displayed on, the front-panel. Small amounts of water vapour are added in the gas mixtures used for bakelite RPCs. A provision has been made in this section for the same.
3. *Moisture meter*: A microprocessor-based commercial (SHAW make) capacitive type sensor with a suitable display, in PPM as well as the dew point, is mounted on the mixed gas line to monitor the moisture content in the mixed gas.
4. *Distribution unit*: The mixed gas is distributed into 16 individually controlled gas outlets in parallel. This is achieved by using SS capillaries, 2 m long and 200 μm diameter, as flow resistors. A pressure sensor is mounted on this line to indicate the inside pressure of the system. A Parker-made fine particle filter is mounted on this unit in order to purify the mixed gas further, before it enters the chambers.
5. *Safety bubblers*: These bubblers are mounted on individual output lines in order to take care of the back pressure exerted from, and to protect the RPCs from damage due to, over pressurising.
6. *Isolation bubblers*: These bubblers serve the dual purpose of preventing back diffusion of air into the RPCs as well as indicating the flow of gas through



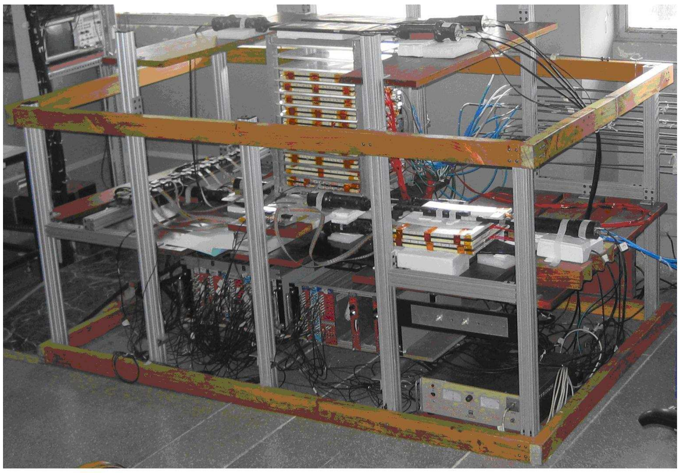
(a) Schematic of the system

(b) Front view of the system

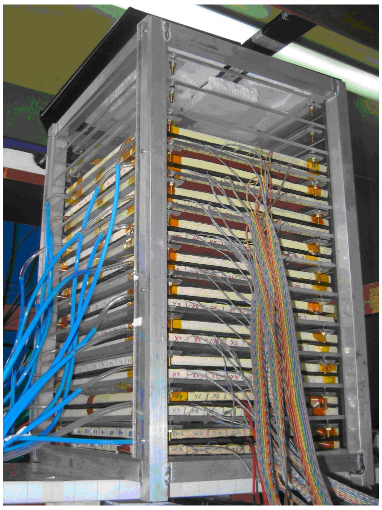
Figure 3. New gas mixing and distribution system.

the chambers. The silicon oil levels in the safety and isolation bubblers are chosen taking into account the pressure gradient in the gas system.

7. *Exhaust manifold*: The return gas from all connected chambers is collected into this manifold, and a single output is provided to vent the used gas into the



(a) Cosmic ray muon telescope

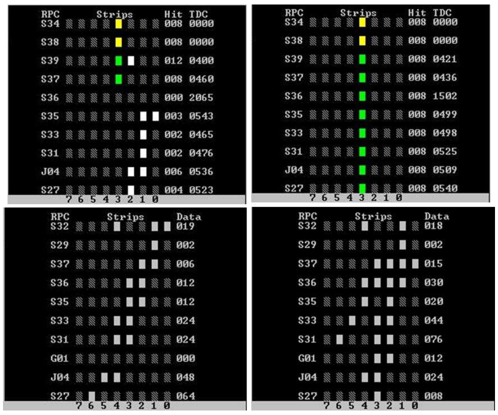


(b) Stack of tracking RPCs

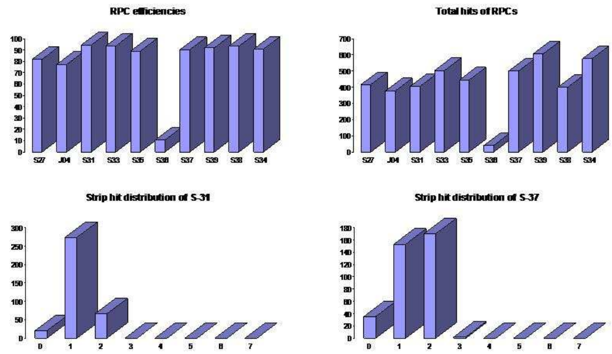
Figure 4. Muon tracking setup using RPC stack.

atmosphere. This manifold too has a pressure sensor to indicate the system pressure with reference to the ambient room pressure.

8. *Remote control and monitoring*: The required flow rates of individual gases in the system can be set and monitored through a PC interface. Other important system parameters such as pressures at various stages of the unit can also be monitored using this interface. While a schematic of the gas mixing and distribution system is shown in figure 3a, figure 3b is a photograph showing the front view of this system.



(a) Tracked events



(b) Extracted parameters

Figure 5. A few results from muon tracking stack.

4. Tracking of cosmic ray muons using small size RPCs

A separate laboratory has been setup for this test, in which the newly developed 16 channel gas mixing unit described above was installed. The RPCs for this setup were fabricated using the same materials and fabrication procedures and parameters as those described earlier. Float glass of thickness 2 mm and size 30 × 30 cm was used. A suitable rack to house 12 RPCs of the above size was fabricated. The rack allows easy access to any individual chamber in the stack. It also integrates a spring loaded mechanism to keep the signal pickup panels pressed uniformly against the chambers.

The cosmic ray muon telescope seen in figure 4a was set up using seven scintillator paddles. These include one narrow paddle of 2 cm width to define the telescope window such that it centres on an individual signal pickup strip as well as two more to veto muons which are passing outside the strip of interest. This allowed a measurement of the cross talk between adjacent strips.

A stack of 10 RPCs, as seen in figure 4b was mounted in the above-mentioned rack such that the signal pickup strips of all the chambers were well aligned geometrically.

The chambers were operated in the streamer mode, using a mixture of argon, isobutane and freon (30:8:62 by volume) from the new gas system described above. The operating high voltage for the tests was kept at 8.6 kV. The high voltage supply current was monitored online to diagnose any possible instability in the RPC operation.

The signals from the pickup strips were transmitted through twisted pair cables onto patch panels, where the line impedances are transformed in order to match those of the NIM electronics. The RPC strip analog signals are fed to discriminator and latch modules. The cosmic ray telescope trigger signal is used as the strobe signal for the latch modules, which record binary information in the presence or absence of a signal on the RPC strip of interest for every trigger. The counting rates of the RPC strips of interest are measured with scalars using the corresponding logic signal. The logic signals from the strips are also used to record the timing information from the RPC, with respect to the cosmic muon trigger, using TDC modules. The strips of only one pickup panel are read out.

Figure 5a shows some interesting cosmic ray muon induced tracks recorded using the above setup. Muons arriving at different angles could be captured simply by relocating the telescope window. This has demonstrated that indeed these prototype chambers are capable of effectively tracking cosmic ray muons. The information recorded in these tests could also be used to extract other parameters of interest, such as efficiency, noise rate and timing of individual RPCs and their long term stability. Shown in figure 5b are individual RPC efficiencies with reference to cosmic ray tracks, their total hit distributions and strip hit multiplicity distribution patterns of a couple of RPCs. Parameters such as temperature, barometric pressure and relative humidity are also being monitored on-line in order to collate and correlate the dependence of chamber performance on these ambient parameters.

5. Conclusions and future plans

We have successfully built and characterised many small and large area RPC prototypes. The test results obtained were on the expected lines. We have also demonstrated tracking of cosmic ray muons using a stack of RPCs. Our current understanding is that the aging problem associated with the previous RPCs is related to the quality of glass plates used to fabricate those RPCs. We have therefore initiated comparitive studies on samples of glass from local market versus the glass imported from Japan [7]. Studies done so far on the surface quality, element analysis and transmittance of the samples have however not yielded any conclusive results.

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