Glass RPC detector R&D for a mega neutrino detector

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The India-based Neutrino Observatory (INO) collaboration is planning to build a massive 50kton magnetised Iron Calorimeter (ICAL) detector, to study atmospheric neutrinos and to make precision measurements of the parameters related to neutrino oscillations. Good tracking, energy and time resolutions as well as charge identification of the detecting particles are the essential capabilities of this detector[1].

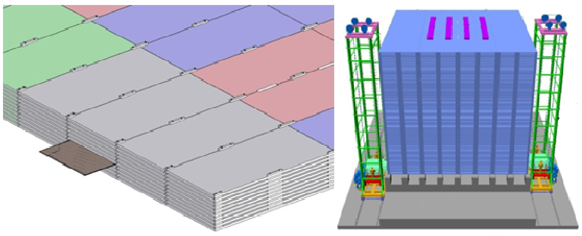

Figure 1: Conceptual design schematic of INO ICAL detector

Shown in Figure 1(left) is the construction sequence of ICAL detector. ICAL is built layer by layer using 4000mm × 2000mm × 56mm (thick) low carbon steel plates, locked in position using spacers[2][3]. A gap of 40mm space is provided between layers to insert active detector elements – Resistive Plate Chambers (RPCs). RPCs are fast, planar and gaseous detectors. The detector is magnetised to a field of about 1.3Tesla, which helps charge identification of the detecting particles. One of the three modules of ICAL is shown Figure 1(right). The trolleys shown on either side of the detector are used to install and service RPCs and front-end electronics. Top view of the magnetic coils, which are used to generate the magnetic field are also shown.

Salient features of the ICAL detector and some of the important RPC related parameters are shown in the following table.

No. of modules	3
Module dimensions	16m × 16m × 14.5m
Detector dimensions	48.4m × 16m × 14.5m
No. of layers	150
Iron plate thickness	56mm
Gap for RPC trays	40mm
Magnetic field	1.3Tesla
RPC dimensions	1,840mm × 1,840mm × 24mm
Readout strip pitch	30mm
No. of RPCs/Road/Layer	8
No. of Roads/Layer/Module	8
No. of RPC units/Layer	192
No. of RPC units	28,800 (97,505m²)
No. of readout strips	3,686,400

Table 1: Salient features of ICAL detector and RPCs

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A dedicated effort for design and development of large area glass RPC detectors, leading to their large scale low cost industrial production is in progress. To begin with, a large number of single gap glass RPCs of area 30 × 30 cm^2 as well as a few of area 120 × 90 cm^2 were developed, using glass procured from local market and operated in the streamer mode[4][5]. While the results obtained from the characterization studies of these chambers were consistent with those reported in the literature, we had a serious problem with the stability of their operation – they had died of sudden aging when operated continuously[6]. We have subsequently fabricated a large number of RPCs of area 100 × 100 cm^2 (Figure 2) and operated them in the avalanche mode (using a gas mixture of R134a:Isobute:SF_6 in the ratio 95.15:4.51:0.34), without facing any aging problems. The chambers show typical efficiencies over 98% and timing resolutions of about 1nS.

Figure 2: A prototype RPC unit shown along with its front-end preamplifiers

A sophisticated gas mixing and distribution system, which works on four different input gases has been designed and fabricated as part of this R&D work[7]. It features Mass Flow Controllers to precisely mix the gases to required proportion and 0.3mm diameter stainless steel capillaries to control the mixed gas into 16 pneumatically controlled output channels. An open loop gas recovery system using fractional condensation is also being developed for the ICAL detector[8]. Another success story is development of a suitable paint and an automated painting plant for glass electrode coating[9].

Figure 3: An RPC stack tracking cosmic ray muons

Figure 3 is a picture of the stack of 12 RPCs of 1m × 1m in area, along with the front-end electronics mounted in the racks installed on either side of the stack[10]. The stack is in un-interrupted operation now for about a couple of years. Some of the parameters that are tracked on day to day basis are the RPC efficiencies for cosmic ray muons, absolute and relative timing resolutions as well as the stability of RPCs based on the monitoring data of the individual strip rates. Apart from studying various characteristics and long term stability of the RPCs under test, the stack is also being used to study and optimise a number of parameters concerning the RPC gap, chamber design, gas mixture, readout electronics etc.

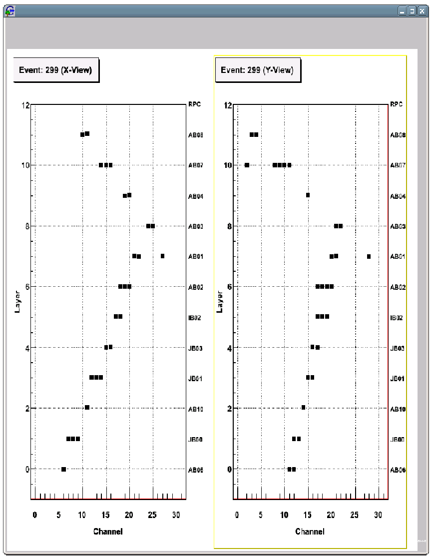

Figure 4: An interesting cosmic ray muon event tracked by the stack

Shown in Figure 4 are two views of a pair of cosmic ray muons tracked by the stack. More than 150,000 such events are recorded per day. These tracks are used to build a tomography of the RPC (Figure 5). Pitch (30mm) of the pickup strips used for the RPC readout as well as the dead space due to the button-shaped spacers (11mm in diameter) are clearly visible.

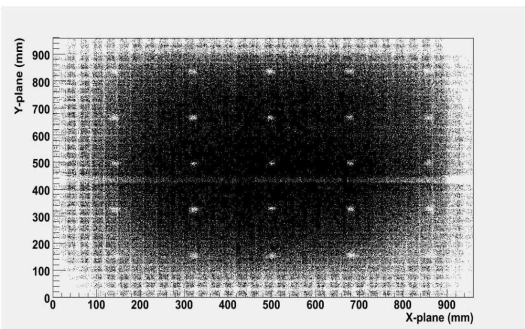

Figure 5: Tomography of an RPC detector using cosmic ray muons

We have also studied the distribution of the residuals between the track and hit pickup strip coordinates (Figure 6). The width of the distribution is as expected for pickup strip widths of 28mm. The average strip multiplicity for the cosmic ray muon data is also found to be a little over 1.

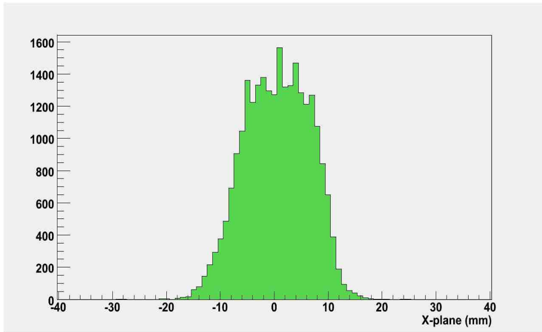

Figure 6: Distribution of residuals between the track and strip coordinates

The individual strip counting rate (or noise rate) provides an excellent measure for monitoring the long term stability of the RPC detectors. Shown in Figure 7 is the noise rate time profile of an RPC pickup strip. As can be seen, the noise rate reflects effect of 24-hour day-night variations in the ambient conditions.

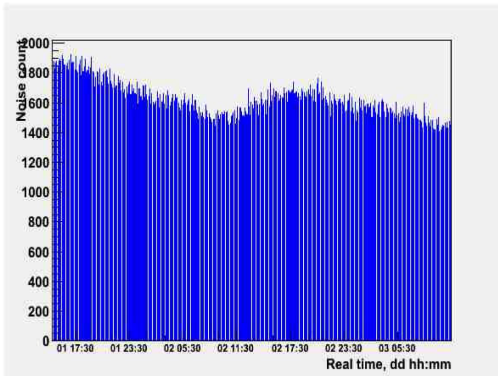

Figure 7: RPC strip noise rate time profile

While the RPC stack is collecting wealth of data and the ICAL prototype detector is being commissioned, work on development and characterisation of ICAL baseline RPCs of dimensions 1.84m × 1.84m, is in progress.

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