Glass RPC detector R&D for a mega neutrino detector

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***Abstract*–India-based Neutrino Observatory (INO) collaboration has proposed a 50 kTons magnetised iron calorimeter (ICAL), whose primary goals are to precisely determine oscillation parameters of the atmospheric neutrinos, to study matter effects on the oscillations and finally to use it as a long baseline detector for the neutrino beams. Good tracking and energy resolutions, good directionality (translating to a time resolution of better than a ns) and charge identification of the detecting particles are the essential requirements of ICAL detector. The ICAL detector will cover an area of about 100,000 m^2 and will use about 30,000 glass Resistive Plate Chambers (RPCs) of about 2 m × 2 m in area as active detector elements.**

An aggressive R&D program to develop and characterise RPCs operating in the avalanche mode was undertaken. We will describe our R&D efforts towards developing these devices and will present the results of their characterisation studies.

I. Introduction

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].

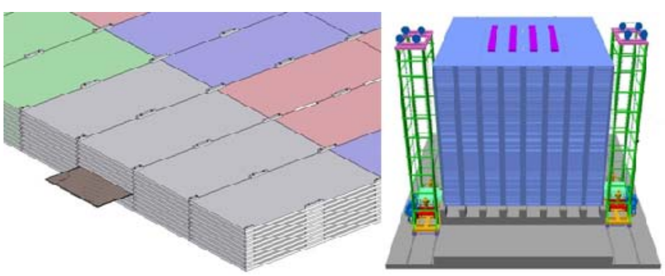

Fig. 1. Conceptual design schematic of INO ICAL detector

Shown in Fig. 1 (left) is the construction sequence of ICAL detector. ICAL is built layer by layer using 4000 mm × 2000 mm × 56 mm (thick) low carbon steel plates, locked in position using spacers [2], [3]. A gap of 40 mm 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 1.3 Tesla, which helps charge identification of the detecting particles. One of the three modules of ICAL is shown Fig. 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 Table I.

Table I. Salient features of ICAL detector and RPCs

Element	Value
No. of modules	3
Module dimensions	16 m ×16 m ×14.5 m
Detector dimensions	48.4 m ×16 m ×14.5 m
No. of layers	150
Iron plate thickness	56 mm
Gap for RPC trays	40 mm
Magnetic field	1.3 Tesla
RPC dimensions	1.84 m× 1.84 m
Readout strip pitch	30 mm
No. of RPCs/Road/layer	8
No. of Roads/Layer/Module	8
No. of RPC units/Layer	192
No. of RPC units	28,800
No. of readout strips	3,686,400

II. Detector R&D

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.

Fig. 2. A prototype RPC unit shown along with its front-end preamplifiers

To begin with, a large number of single gap glass RPCs of area 30 cm × 30 cm as well as a few of area 120 cm × 90 cm 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

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died of sudden aging when operated continuously [6]. We have subsequently fabricated a large number of RPCs of area 100 cm × 100 cm (Fig. 2) and operated them in the avalanche mode (using a gas mixture of R134a:Isobutane: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 1 ns.

Fig. 3. An RPC stack tracking cosmic ray muons

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 0.3 mm 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].

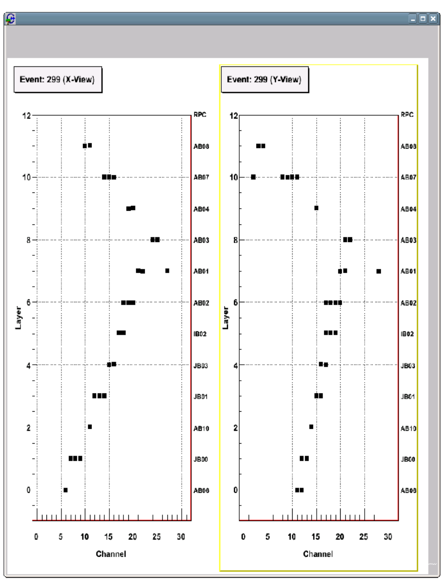

Fig. 4. An interesting cosmic ray muon event tracked by the stack

III. Results

Fig. 3 is a picture of the stack of 12 RPCs of 1 m × 1 m in area, along with the front-end electronics mounted in the racks installed on either side of the stack [10]. The stack is in uninterrupted 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.

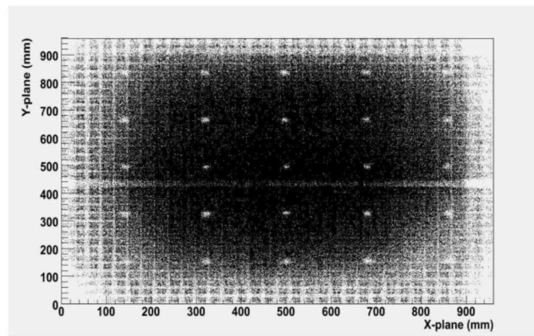

Fig. 5. Tomography of an RPC detector cosmic ray muons

Shown in Fig. 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 (Fig. 5). Pitch (30 mm) of the pickup strips used for the RPC readout as well as dead space due to the button-shaped spacers (11 mm in diameter) are clearly visible.

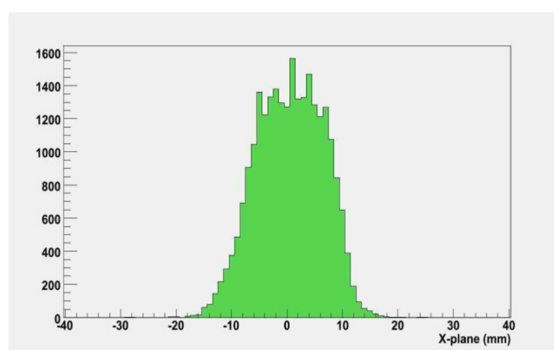

Fig. 6. Distribution of residuals between the track and strip coordinates

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

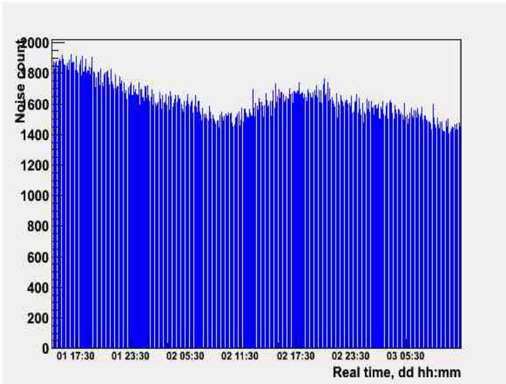

Fig. 7. RPC strip noise rate time profile

The individual strip counting rate (or noise rate) provides an excellent measure for monitoring the long term stability of the RPC detectors. Shown in Fig. 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.

IV. FUTURE WORK

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 1.84 m $\times$ 1.84 m, is in progress.

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