Development and characterisation of large area glass Resistive Plate Chambers for the ICAL detector at INO

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Introduction

The India-based Neutrino Observatory (INO) collaboration is proposing a 50 kton magnetized iron tracking calorimeter (ICAL) to make measurements on atmospheric neutrinos [1]. ICAL will have dimensions of $16\times48\times12$ m^3 and a modular structure consisting of a stack of 140 layers of 6 cm thick iron plates interleaved with 2.5 cm gaps to house Resistive Plate Chamber (RPC) gas detectors. About 27000 RPCs of dimension 2×2 m^2 will be needed for this experiment. A dedicated R&D effort is currently underway to develop and characterise RPCs which are needed for this experiment.

Earlier work

Our earlier work on small (30×30 cm^2) and medium sized (90×120 cm^2) RPCs has been reported in Ref. 2. The noise rate, efficiency, time and charge distributions compare favourably with those reported worldwide for both the *avalanche* and *streamer* modes of operation. However when the RPCs were operated in the streamer mode they had much shorter lifetimes ranging between a week and a month [3].

A second RPC test station equipped with a sophisticated 16-port gas mixing, telescope and data acquisition systems allowed measurements with a stack of 10 RPCs of size 30×30 cm^2. These RPCs were again operated in the *streamer* mode and were used to track cosmic ray muons and record their timing [3]. However these RPCs, made using glass procured from local companies and from Japan, also showed 'aging'. After operating normally for several months, their efficiencies dropped over a period of days with a simultaneous increase in the noise rate and leakage currents [4]. Several possible causes for the RPC 'aging' were looked into such as possible impurities in the gases used, differences in glass composition and surface quality, visible light transmission and reflectance. No definite conclusion could be drawn from these studies [5].

On the other hand, two RPCs constructed using glass procured from Japan and operated in the low gas gain avalanche mode (using a gas mixture of Freon (R134a) and Isobutane in the proportion 95.5:4.5 by volume) has been running at efficiencies >90% for the last 2 years since September 2005. These tests indicate that the mode of operation of the RPC is at least one of the factors deciding its lifetime [6].

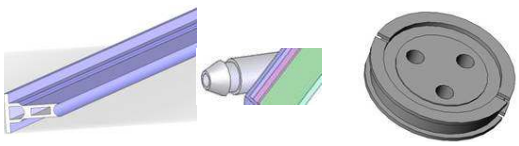

Fig. 1 Spacers (left), gas nozzles (middle) and buttons (right) developed using polycarbonate material

Developments for 1m × 1m RPCs

RPC fabrication involves deploying a large number of materials as well as many assembly procedures. Local vendors were developed for each of the materials required in the RPC. These are: (1) 2/3 mm thick float glass sheets (2) MFC based gas mixing unit (3) various gases (R134a, isobutene, argon and SF_6) (3) polycarbonate spacers, gas nozzles and buttons (4) conducting paint with the appropriate surface resistance for the electrodes (5) epoxy glue for joining together different parts in the RPC (6) copper or aluminium coated foam or G10 sheets for the RPC signal pickup panels (7) polyester films for insulating the pickup panels from the high voltage applied to the resistive anode and cathode and (8) aluminium honeycomb panels for the RPC housing. Each of these materials went through several iterations of testing and improvement and optimization.

The construction of 1 m^2 RPCs required the development of assembly and quality control procedures including the fabrication of a number of useful jigs such as the one ensuring uniform pressing during the gluing of the glass electrodes to the polycarbonate spacers by creating a small pressure difference in a plastic bag surrounding the RPC and the ambient atmosphere, that are extremely useful in production of good quality detectors. Coating of semi-resistivity paint on the electrodes, assembling and gluing of chambers, leak testing of the finished chambers are some of the important assembly procedures. The coating of conductive paint, design, fabrication and operation of the gas mixing system was done in collaboration with local vendors/manufacturers.

Characterisation of 1m × 1m RPCs

Fig. 2 A stack of large area RPCs under study (left) and the data acquisition system (right)

Several 1m×1m RPCs, using glass electrodes of thicknesses 2 and 3 mm procured from Japanese, Italian and Indian suppliers, were built following the developments mentioned earlier. Cosmic muons were used to test these RPCs placed in a stand fabricated in house. Fig.2 shows this stack along with the electronics and DAQ systems used for this detector arrangement.

The cosmic ray muon trigger for the RPC detector stack was generated using a scintillator paddle based telescope. The RPC signal profiles, charge and time resolutions, RPC efficiency as a function of high voltage (Fig.3), effect of different gas mixtures on above characteristics were studied. and the validation of The various front-end electronics designs were also validated using this setup.

In conclusion we are ready to make the RPCs required for the prototype ICAL detector being installed at VECC, Kolkata. Further work is required for making still larger area (4 m^2) RPCs which part of the design goal of the 50 kton ICAL neutrino detector.

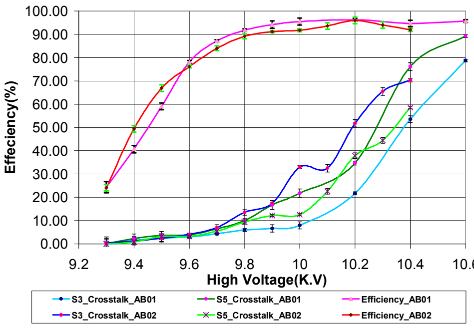

Fig. 4 Efficiency, timing resolution and cross-talk plateau characteristics of a couple of large area RPCs under study

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References

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