On aging problem of glass Resistive Plate Chambers

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Introduction

India-based Neutrino Observatory (INO) collaboration is proposing a large magnetized iron tracking calorimeter of total weight 50 kton using atmospheric neutrinos as source[1]. The proposed detector will have a modular structure of lateral size 48 m X 16 m and will consist of a stack of 140 layers of 6cm thick iron plates interleaved with 2.5 cm gaps to house RPC detector layers. A total of 27000 RPCs of dimension 2m X 2m will be needed for his experiment. Shown in Fig. 1 is the INO detector concept.

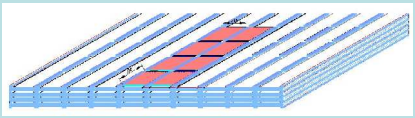

Fig. 1 INO detector concept

RPC R&D effort

Several single gap (2 mm) glass RPCs of area 30 cm X 30 cm as well as a few of larger size 120 cm X 90 cm were built and tested. The V-I characteristics of these detectors were studied. The noise rate was found to be a reliable way of monitoring the stability of the RPC. Streamer plateau efficiencies of over 90% for various gas mixtures have been obtained for minimum ionizing particles as seen from Fig. 2. For all these studies, while Argon fraction in the gas mixture was kept at 30%, R134a and Iso-butane were added to the rest of 70%.

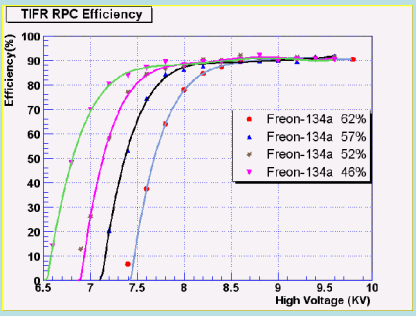

Fig. 2 Plateau characteristics for different gas mixtures

Measurements of the charge linearity and time response of the RPC as a function of applied HV have been made. The typical time resolution, σ, of the RPC when operated in the HV plateau is about 1.2 nsec(Fig 3). The cross talk between the adjacent pickup strips is found to be less than 6%.

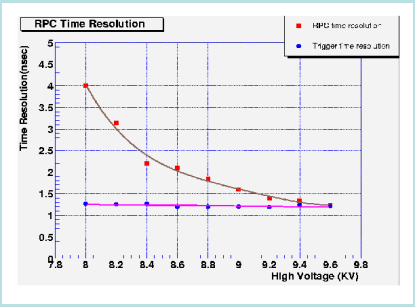

Fig. 3 Time resolution in streamer mode

Aging problem

The first encounter we had with the aging problem was when we operated the RPC, results of which are shown in Figs 2 and 3, continuously for a few months. We had noticed that its efficiency dropped suddenly, while the noise rate and chamber current have shot up. The chamber couldn't be revived. The problem was identical to that reported in the literature[2,3]. The chamber was broke open and the inner surfaces of the electrodes were scanned under Atomic Force Microscope (AFM) [4] and Scanning Electron Microscope (SEM). Shown in Fig. 7 are pictures of two (anode and cathode) damaged electrode and raw glass surfaces.

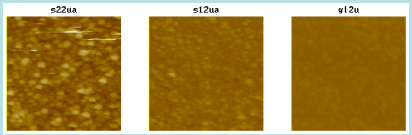

Fig. 7 AFM scans of damaged electrodes and raw glass

The SEM images of the same damaged electrode and a raw glass are shown in Fig 8.

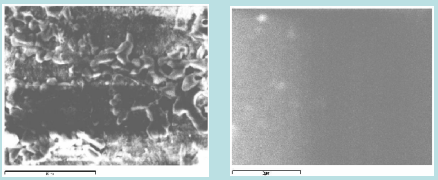

Fig. 8 SEM scans of damaged electrode and raw glass

Element analysis was also performed again both on damaged electrode and raw glass sample, results of which are shown in Fig 9 and the inset tables. The structures shown in the AFM and SEM scans were found to be rich in Fluorine confirming the reasoning that Freon (R134a) gas contaminated with moister forms Hydro Fluoride (HF), which actually damages the RPC.

Element	Atomic%
Oxygen	28.45
Fluorine	40.31
Sodium	11.82
Magnesium	2.00
Silicon	17.41

Element	Atomic%
Oxygen	64.19
Fluorine	4.17
Sodium	6.29
Magnesium	2.11
Silicon	23.25

Fig. 9 Element analysis results of damaged electrode and raw glass

The structures on the damaged electrodes were found to loose deposits on the electrodes rather than permanent damaged regions on the glass. This was demonstrated by the AFM images shown in Fig. 10. On the left plate, we have shown the damaged surface, while on the right, we show the same sample which was wiped clean by a dry rough tissue paper.

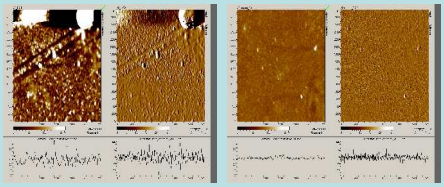

Fig. 10 AFM scans of damaged electrode and after wiping it clean

Further studies on aging

We have tried operating the RPCs in lower gain avalanche mode by the changing the gas to two-component mixture of Freon (R134a) and Iso-butane in the ratio of 95.5:4.5. This didn't result in drastic improvement with regard to the aging of the chamber. Shown in Fig. 11 is a efficiency monitor for about last 10 days of a RPC before getting damaged.

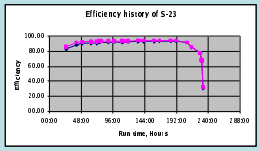

Fig. 11 Efficiency history of a RPC getting damaged

A parameter called streamer size has been devised and was monitored during long term tests of the RPC. The streamer size indicates the fraction of single strip hits for a cosmic ray muon trigger to its sum with the adjacent strips. We find that the streamer size parameter increases monotonically with time, indicating that the size of region which is getting damaged is also increasing. This is ultimately leading to a run a way condition.

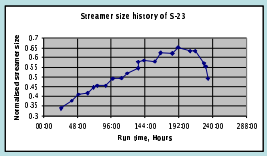

Fig. 12 Streamer size history of the RPC

Shown in Fig. 12 are the noise rate history of the RPC and its individual strip rates. We see from the plot on the right, that the increase in the noise rate is not a local phenomenon.

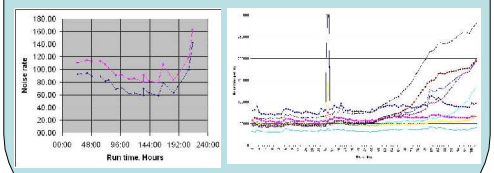

Fig. 13 Noise rate and individual strip rate history

Recovery of a damaged RPC

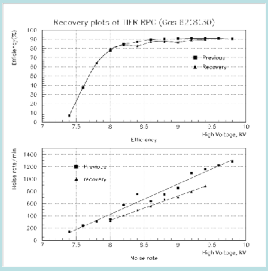

Fig. 14 Recovery characteristics of a damaged RPC

Following the recipe suggested by H.Sakai *et al* [2], i.e purging the damaged chamber by pure Argon bubbled through 25% Ammonia solution for 24 hours without electric field, we could recover the efficiency and brought down noise rate. In Fig. 10, we show the recovery characteristics of this chamber. However, the chamber didn't sustain the recovery for long time later.

Conclusions

We have successfully developed and built many small and large area glass RPC prototypes. We have obtained results which are consistent with those reported in the literature. We are however, currently facing a serious problem with regard to their sudden aging after continuous operation. The problem was observed both with the streamer and avalanche mode of operation. We have made some preliminary measurements for the moister levels in the gas mixture that we use and found that the moister levels weren't high. We have also installed moister filters on the gas lines, but found that that it didn't solve the problem. We are currently working on better monitoring of moister levels using in-situ sensors, monitoring of various ambient parameters such as temperature, relative humidity and barometric pressure as well as trying with different glasses for electrodes etc.

Infrastructure development

A gas system capable of mixing and distributing four gases was developed (Figs. 4 and 5). The gas is usually mixed in a buffer cylinder and flown from there into the RPC under test. Alumina based moister filter and dust filters are mounted on the gas system's output line. RPC test system consisting of a scintillator paddle based Cosmic ray telescope as well as a NIM/CAMAC based DAQ system was also developed(Fig. 6). Various RPC assembly and QC jigs were also developed.

Fig. 4 4-component gas mixing system

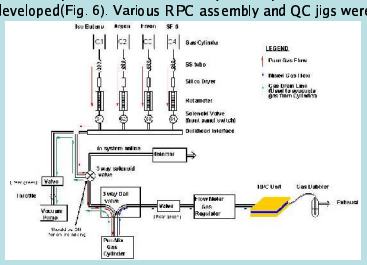

Fig. 5 Schematic of gas mixing system

Fig. 6 Cosmic ray telescope and DAQ system

References

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