On aging problem of glass Resistive Plate Chambers

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Resistive Plate Chambers (RPCs or chambers) were chosen to be the active elements for a 50 KTon neutrino detector, which is proposed to be built by the India-based Neutrino Observatory (INO) collaboration. The detector will use about 27,000 RPCs each of 2×2 m^2 in area. As part of the feasibility study for construction of this massive detector, a dedicated R&D programme is currently underway to develop and prototype RPCs as well as to study their characteristics, ultimately leading to their large scale production required for building the detector.

We have developed a large number of single gap glass RPCs of area 30×30 cm^2 as well as a few of larger size 120×90 cm^2 and operated them in the streamer mode using gas mixture, consisting of Freon134a/Ar/iso-C_4H_{10} in the proportion 62/30/8. We have studied their Voltage versus Current, charge linearity and noise rate characteristics, cross talk between the adjacent pickup strips etc. We have obtained plateau efficiencies of over 90% for minimum ionizing particles using various gas mixtures and measured typical time resolution to be about 1.2 nsec, when the RPCs were operated in their HV plateaus. These results are being presented in another contribution to this workshop. While the results mentioned above are consistent with those reported in the literature, the RPCs were observed to suffer severe damage when operated continuously for a few months.

We have noticed that the glass RPCs after continuous operation, loose their efficiencies quickly while the chamber current and noise rates shoot up. Average size of the streamer is also observed to grow larger continuously till the chamber is damaged. Increasing the high voltage doesn't help in improving the performance. Going by similar experiences reported by other researchers, we have suspected possible contamination of gas mixture with high levels of moisture as the main reason for this problem. At this stage, we have taken corrective steps in terms of switching over to better quality of gases, installing moisture filters in the gas line, replacing the gas lines by metal or better quality tubing. We have also studied the inner surfaces of the damaged glass electrodes under Atomic Force Microscope (AFM) as well as Scanning Electron Microscope (SEM). While the AFM images have shown structures and their dimensions similar to those reported by the Belle experiment group, the SEM has indicated excess concentrations of Fluorine and Sodium and depleted concentration of Oxygen in the damaged electrodes. We have also observed that the deposits on the electrodes are flaky in texture and could be scrubbed off easily. However, the measurements we have performed on the input gas lines didn't show excessively large levels of moisture in the gas, which was reported to be main reason for formation of these deposits.

One of the most prominent feature of this damage is that, before the noise rate starts shooting up, there seem to be a few bursts of discharges taking place in the chamber. These breakdowns are randomly distributed over the glass electrodes and there was no particular spot noticed with continuous discharge. The observations seem to suggest that these discharges start from spots on the glass corroded by the Hydro Fluoride (HF), formed due to moisture in the gas mixture containing Freon.

We have studied for comparison, using the same test setup, single gap bakelite RPCs of CMS design along with a small and large area INO RPC in the avalanche mode. While the INO RPCs failed after a couple of months of continuous operation, the CMS RPC did not show any sign of aging or damage. This study has largely ruled out explanation based on the ionic model of the glass electrodes as a cause for the damage of the chamber. Charge exchange mechanism must work well in order to prevent the charging of electrodes. Any charge buildup on the electrodes may lead to local sparking. Persistent breakdowns will damage the surface and will cause a corona. We expect the charge buildup in the avalanche mode of operation to be much less compared to that in the streamer mode. But, the above study seems to indicate that charge buildup may not be the reason for the damage of the chambers in our case.

The hypothesis that seem to be most plausible in our case is the local sparking caused by glass surface defects, surface cleanliness, whiskers or even the Malter effect. The surface defects help accumulating more moisture on the glass surfaces and accelerate formation of HF. This explains why the damage starts only after the RPC was operated for some time and also for the prior bursts in the noise rates before leading to run a way condition. The presentation will discuss these mechanisms responsible for the damage of RPCs, our studies and measurements and a possible solution to this serious problem.