Development of glass multigap RPC for PET Imaging

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Introduction

One of the few stringent requirements to be satisfied by the detectors for TOF-PET (time of flight-positron emission tomography) imaging is extremely good time resolution, as we need to detect two photons produced by positron annihilation simultaneously. All over the world, mainly scintillator-based detectors are being used for PET Imaging. Due to the high cost of the existing systems, extensive R&D is being performed to find an alternative detector. Multi-gap Resistive Plate Chamber (MRPC) with time resolution $\sim$ 100 ps or less is considered to be a good alternative [1, 2].

MRPC is a gas filled detector made with highly resistive (bulk resistivity $\sim 10^{11}$-10^{12} Ω cm; *e.g.* bakelite, glass) electrodes consisting of several small gas gaps (0.2 mm to 1 mm) and operates at atmospheric pressure [3]. Small gap improves the time resolution. A number of small gas gaps with equal width are made by inserting intermediate resistive plates between the two outermost resistive plates. The high voltages (HV) are applied only to the external surfaces of each stack of plates and the intermediate plates are electrically floating, thus one can build the detector by stacking plates separated by suitable spacers. Pickup strips are located outside the stack and insulated from the high voltage electrodes. A passing charged particle creates an avalanche in the gas. Signals on the pickup electrodes are induced by the movement of charge in the gas; in case of the MRPC the fast signal is generated by the fast movement of electrons towards the anode. Since the resistive plates act as dielectrics, the induced signals can be caused by the movement of charge in any of the gas gaps between the anode and the cathode pickup strips. In this way the observed induced signal on the pickup strip becomes the sum of the individual avalanche signals in any of the gaps of the MRPC, but the time jitter is expected to be reduced due to the smaller subgap of the MRPC [4].

Bakelite-based double gap and four gap MRPCs have been fabricated and tested in streamer mode with a gas mixture of argon, iso-butane and tetrafluroethane (R-134a) in 55/7.5/37.5 volume mixing ratio [5]. In both the cases the efficiency plateau above 95% has been obtained. The time resolution for the double gap module was poorer ($\sim$ 2 ns σ) since in that case the total gas gap is 4 mm (2mm $\times$ 2) producing a larger time fluctuation in the arrival time while in case of four gap module total gas gap is 2.4 mm (0.6 mm $\times$ 4) with small subgaps reducing the time jitter in the signal arrival time giving a better time resolution ($\sim$ 850 ps σ) as reported earlier [5].

Two glass MRPCs, one with 2 gaps and the other with 6 gaps with 200 μm gas gap have been fabricated and tested in avalanche mode with R-134a, iso-butane and SF_6 in 95/4.5/0.5 volume mixing ratio. In this study the efficiency, counting rate, leakage current and time resolution of the module have been measured. Method of fabrication and preliminary test results of the glass-based MRPCs will be presented.

Fabrication of glass MRPC

One double-gap and one six-gap module of dimension 20 cm $\times$ 14 cm with 200 μm gas gap each have been fabricated. Both the modules have been made with 600 μm thick float glass obtained from GSI, Germany. One polycarbonate frame with two diagonal grooves for metallic gas nozzles, has been built for each detector. Uniform separation between the plates have been maintained by

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using four 200 μm thick G-10 edge spacers and two button spacers. Graphite layers are painted on the outer surfaces of two outermost glass plates. HV leads are connected on the graphite layer by two small 20 μm thick copper tape. The active area (glass area) of each detector was 16 cm $\times$ 9.5 cm. The picture of the double-gap MRPC before graphite coating is shown in FIG. 1.

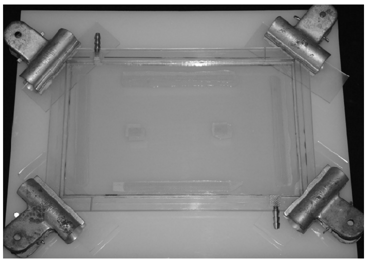

FIG. 1: Double-gap glass MRPC.

Results

In this study the efficiency, counting rate, leakage current and time resolution of both the double-gap and six-gap modules has been measured in avalanche mode in the same cosmic ray test bench mentioned in Ref.[6]. The trigger is made by the coincidence signal from three scintillators (Sc I, Sc II and Sc III). The signal from the pick up strip after amplification is taken in coincidence with the trigger.

In both the RPCs the maximum leakage current has been found to be less than 200 nA (at 6.5 kV for double-gap and at 10.5 kV for the six-gap module). The efficiency increases with the increase of the applied voltage and saturates at $\sim$ 40% for both the modules. One of the reasons behind this small value of efficiency is the small value of total gas gap (2×200 μm for the double-gap and 6×200 μm for the six-gap module). The time resolution of both the MRPCs has been measured in the same process as described in the Ref.[7]. FIG. 2 shows the spectrum of the time difference between the START signal (trigger) and the STOP signal (from MRPC) for the six-gap MRPC at an applied HV of 9.5 kV. From this spectrum the intrinsic time resolution of the MRPC is calculated. The intrinsic time resolution of the six-gap module is found to be $\sim$ 440 ps σ whereas that of the double gap module was $\sim$ 510 ps σ assuming that the start detector has the same time resolution as the MRPC.

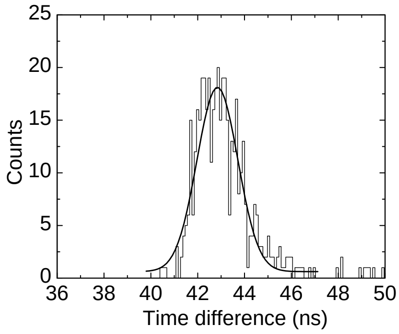

FIG. 2: The distribution of the time difference between the MRPC and the master trigger.

Conclusions and outlook

In conclusion, double-gap and six-gap glass MRPCs have been fabricated and tested in avalanche mode. In both the cases the efficiency plateau at $\sim$ 40% has been obtained. The time resolution was found to be much better than the bakelite MRPC operated in the streamer mode.

Acknowledgement

I would like to thank Prof. Satyajit Saha and Prof. Sudeb Bhattacharya of SINP for their valuable suggestions in course of this work.

References

[1] A. Blanco, et al., Nucl. Instr. and Meth. A 508 (2003) 88.

[2] C. Lippmann, et al., Nucl. Instr. and Meth. A 602 (2009) 735.

[3] E. Cerron Zeballos, et al., Nucl. Instr. and Meth. A 374 (1996) 132.

[4] S. Narita, et al., Nucl. Instr. and Meth. A 602 (2009) 814.

[5] A. Banerjee, et al., Proceedings of the International Symposium on Nuclear Physics, Volume 54, (2009), 662.

[6] S. Biswas, et al., Nucl. Instr. and Meth. A 602 (2009) 749.

[7] S. Biswas, et al., Nucl. Instr. and Meth. A 617 (2010) 138.