Low-gain operation of low resitivity glass Resistive Plate Chamber (RPC)

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Introduction

Future collider experiments such as Compact Muon Solenoid (CMS) and A Toroidal LHC Apparatus (ATLAS) at the High Luminosity Large Hadron Collider (HL-LHC) [1, 2], Compressed Baryonic Matter (CBM) at Facility for Antiproton and Ion Research (FAIR) [3] will have to deal with unprecendented level of particle fluxes arising from high luminosity proton/heavy ion collisions. This demands the need for high count rate capable detectors to ensure maximal collection of data.

RPCs [4] are versatile detectors used in many particle and astroparticle physics experiments mainly for the detection of particles such as muons. RPCs with bulk resistivity $\rho \sim 10^{10}\ \Omega\,\mathrm{cm}$, are currently operating at rates of $\sim 1\ \mathrm{kHz\,cm^{-2}}$ in experiments like the CMS [5]. Experiments such as the CBM in the 3$^{\mathrm{rd}}$ and 4$^{\mathrm{th}}$ stations of its Muon Chamber (MuCh) subsystem would require ~ 10 $\mathrm{kHz\,cm^{-2}}$ rate capabilty. The rate capability R_C of an RPC is given by

$$R_C = \frac{V}{\rho t \langle Q \rangle}, \qquad (1)$$

where V is the voltage drop across the electrodes, t is the electrode thickmess and $\langle Q \rangle$ is the average/mean charge produced per event. To increase the rate capability an RPC should have lower bulk resistivity, and lower mean charge production (low gain). However, they cannot be reduced to arbitrarily low values as they will lead to adverse effects such as ageing, reduced mechanical stability and reduced position resolution.

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We are trying to improve the rate capability of RPCs by operating them at a lower gain using low resistivity electrodes. We present results from a low resistive glass RPC with $\rho \sim 10^{10}\ \Omega\,\mathrm{cm}$ bulk resistivity. The glass has been developed by Tsinghua University, Beijing and manufactured by Bjoptics, China.

Experimental setup

The setup consists of a 32 cm × 30 cm glass RPC made of low resistivity electrodes of 2 mm thickness in coincidence with a scintillator telescope. The RPC gas gap is 2 mm thick and conductive graphite coating is applied on the electrodes with a surface resistivity of $\sim 1\ \mathrm{M\Omega/\square}$. Gas mixture containing r134a, *i*-butane and SF_6 is flown through the RPC with different concentrations with the help of a gas mixing system. A schematic of the setup is shown in figure 1. RPC

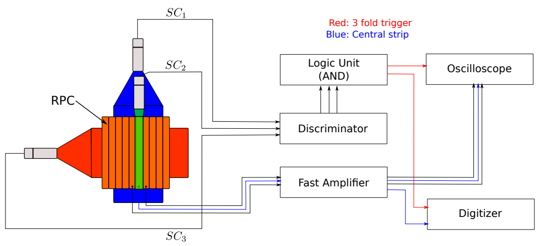
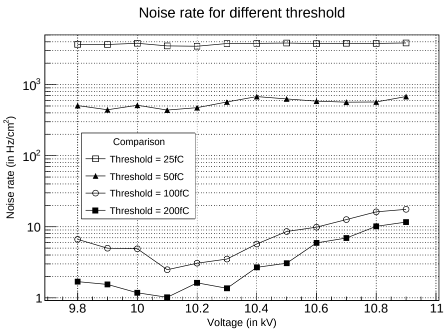
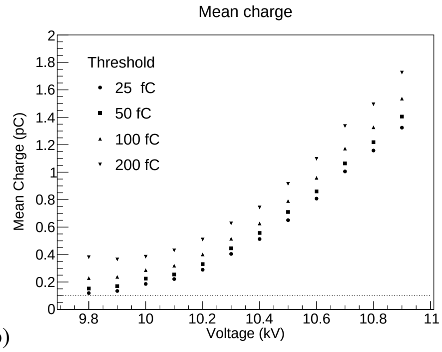


FIG. 1: Schematic of the RPC experimental setup.

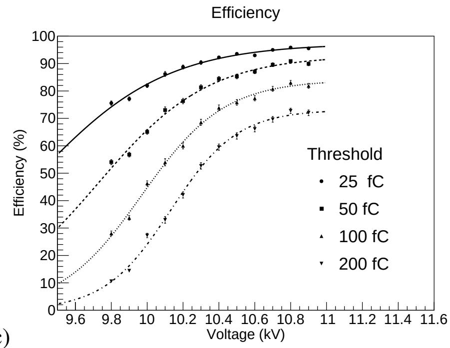
readout is made of a foam filled polycarbonate honeycomb having copper strips of 2.8 cm width and 30 cm length on one side and aluminium sheet on the other (ground). The scintillator telescope consists of plastic scintillators SC_1, SC_2 and SC_3 arranged as shown in figure 1. SC_2 has a width of 4 cm and is used to select particular strips. Signals of all the detectors are processed using NIM electronics (for generating trigger, applying HV bias



(a)



(b)



(c)

FIG. 2: (a) Singles noise rate at various thresholds. (b) Mean charge at various thresholds. (c) Efficiency at various thresholds. Gas composition: r134a : *i*-butane : SF_6 :: 95.2 : 4.5 : 0.3.

and amplifying RPC signals) and VME Digtizer and Digital Storage Oscilloscope (for analyzing RPC signals). Data acquisition in the oscilloscope and digitizer are triggered by a 3-fold trigger generated by the telescopic coincidence of Scintillator paddles. RPC signals are integrated within a window of 50 ns.

Results and conclusion

Various parameters of the RPC such as noise rate, mean charge and efficiency are shown in figures 2(a), 2(b) and 2(c) respectively. It can be seen from figure 2(a) that the pulses below a threshold of 100 fC are noise with very little variation as a function of voltage. With the current electronics its difficult to reduce the electronic noise levels. However, from (1) and looking at figures 2(b) and 2(c), considering $\rho = 3 \times 10^{10}\ \Omega$cm one can see that it is possible to achieve a rate capability of ~ 4 kHz cm^{-2} ($\langle Q \rangle \sim 400$ fC) with an efficiency of 55-60% and a rate capability of ~ 10 kHz cm^{-2} ($\langle Q \rangle \sim 150$ fC required) is not achievable with a 2 mm electrode currently. But an efficiency of $\sim$ 40-50% may be achievable with an electrode of $\sim$ 1 mm thickness as it relaxes the mean charge requirement $\langle Q \rangle \sim 300$ fC. The efficiency could be improved by using a double/multigap geometry ($\sim$ 10% $\uparrow$), reducing the electrode thickness (relaxes the mean charge requirement, $\sim$ 5% $\uparrow$) and better frontend electronics ($\sim 5-10\%$ $\uparrow$). We are doing further studies in these directions.

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References

[1] Lagarde, F. et al, arXiv:1807.05680, 2018
[2] Schmidt, B., J. Phys.: Conf. Ser.706, 2016, 022002
[3] Chattopadhyay, S et al, TDR, GSI-2015-02580, 190 S, 2015
[4] Santonico, R. and Cardarelli, R., Nucl. Inst. Meth. A 187 (1981) 377.
[5] The CMS collaboration, TDR, CERN-LHCC-97-032.