Feasibility of RPC operation in low charge production mode for its use in high rate environment

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Introduction

The widely used gaseous detector in high energy physics experiments, Resistive Plate Chamber (RPC) [1] suffers from the disadvantage of low rate handling capability ($\sim$ 100 Hz/cm^2). This limitation has been overcome to an extent by using electrodes of lower bulk resistivity and operating the detector in avalanche mode which has made it possible to handle rates upto a few kHz/cm^2 with more than 90% efficiency [2, 3]. RPCs with rate handling capabilities of 15 kHz/cm^2 or more are needed for future accelerator-based high energy physics experiments, like CBM, ATLAS (HL-LHC) etc. Some ways to increase the rate capability, like, reduction of electrode resistivity, its thickness have the adverse effect of increase in leakage current and counting rate which in turn accelerates the ageing of the detector. Another way to increase the rate capability is by operating the detector in low charge production mode. The present work describes the simulation of the processes leading to signal generation in a typical RPC due to passage of muons and explores the conditions to operate it in low charge production mode. The effect of operating conditions on the produced charge has been presented. The efficiency of the detector at this condition for different electronic thresholds has been calculated and an optimum condition to operate the detector has been reached.

Simulation scheme

The passage of a high energy particle or radiation through the RPC gas chamber creates primary ionizations along its track. Due to the presence of electric field, the electrons and ions from each ionization point start moving towards the anode and the cathode respectively. During their travel they may undergo further ionizations with the gas molecules depending on the energy of the moving particles. The movement of all those charges induces a current on the conductive readout coupled to the gas chamber. We have used Garfield++ [4] to simulate the dynamics of signal generation due to passage of 1000 muons, each of energy 2 GeV passing through the detector with randomly varying zenith angle between 5° - 25° and azimuthal angle between 0° - 360°. The electric field within the detector has been supplied manually whereas the primary ionization and the transport properties of the electrons have been calculated using the C++ versions of HEED [5] and Magboltz [6], respectively.

Induced charge

The current signal induced on the RPC read-out strip has been calculated for the passage of muons. Each signal shape has been integrated within 40 ns window to find the induced charge. The calculations have been

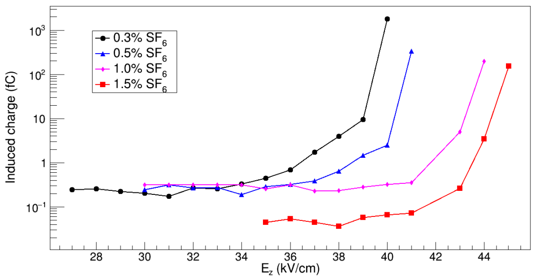

FIG. 1: Variation of induced charge with the applied field for gas mixtures containing different amounts of SF_6 with $C_2H_2F_4$ and 4.5% i-C_4H_{10}.

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repeated for different applied field across the RPC gas chamber and for different gas mixtures. Figure 1 shows the variation of induced charge with the applied field for the gas mixtures containing different amounts of SF_6 with $C_2H_2F_4$ and 4.5% i-C_4H_{10}. It can be seen that higher value of applied field increases the charge production as it helps the produced charges to gain higher kinetic energy and in turn create more ionizations. SF_6 is a highly electro-negetive gas and reduces charge production by attaching the electrons. This effect is also evident from figure 1.

Detection efficiency

The important factor in operating the detector in high rate environment is to restrict its charge production within a small value (50 fC in present case). To select the proper conditions to meet this criteria, the fraction of contained events which produces a charge less than 50 fC has been found out at different conditions. The method to calculate the fraction of contained events at any given condition is depicted in figure 2, and is defined as the fraction of events producing charge less than 50 fC. The general method of selecting valid

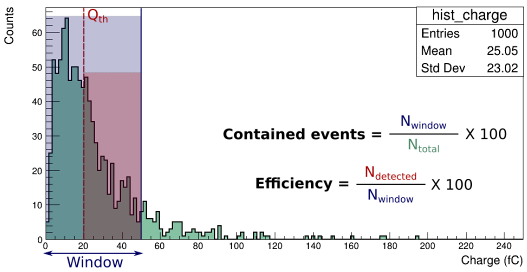

FIG. 2: Selection of contained events within 50 fC window and scheme of calculation of detection efficiency in crossing Q_{th} = 20 fC charge.

events and not the inherent detector noise is to pick only those events which can produce a charge greater than a judicially chosen set threshold. The detection efficiency of the RPC is affected by the chosen threshold. The efficiency of muon detection has been calculated as the fraction of events that can produce a charge greater than a specific threshold, Q_{th} compared to the total number of events producing a charge contained within a fixed window. Figure 2 depicts the scheme of calculating the detection efficiency in crossing Q_{th} = 20 fC threshold for the events contained within 50 fC window. The variation of detection ef-

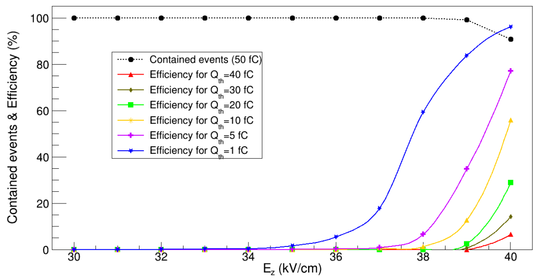

FIG. 3: Variation of RPC efficiency with the applied field for different charge thresholds, when operated with $C_2H_2F_4$ + i-C_4H_{10} (4.5%) + SF_6 (0.5%). Fraction of events producing induced charge $\leq$ 50 fC is shown in black dashed line.

ficiency for different set thresholds with the applied field has been shown in figure 3 where the RPC is operated with $C_2H_2F_4$, 4.5% i-C_4H_{10} and 0.5% SF_6. The fraction of contained events within 50 fC window is shown in the same figure by a black dashed line.

Conclusion

It is possible to produce a charge as low as 50 fC by operating the detector in low field region and using a high amount of SF_6 in the gas mixture. Choosing a lower threshold helps to obtain higher efficiency.

References

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