Gas gain properties of the CMS iRPC chamber

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On behalf of CMS Muon Group

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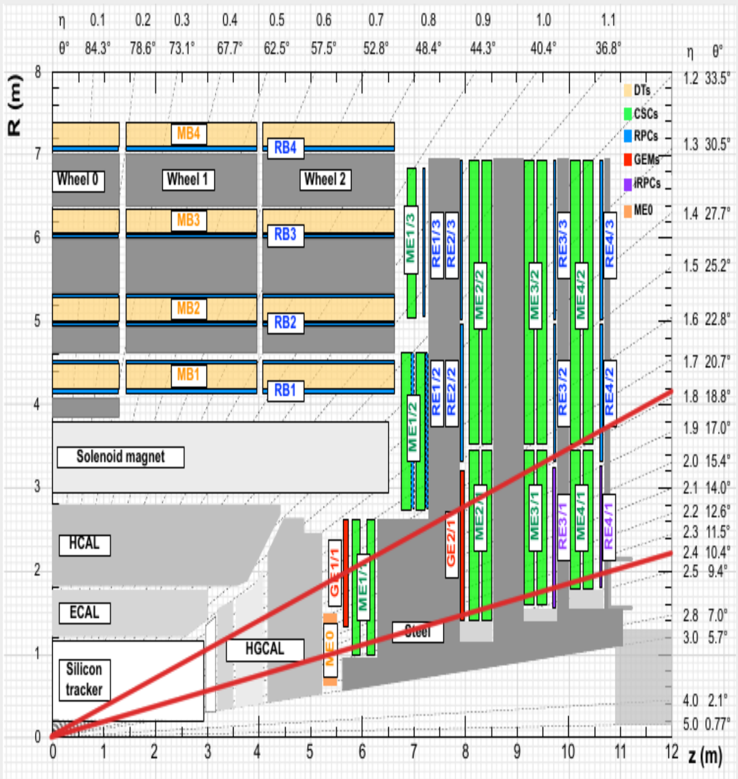
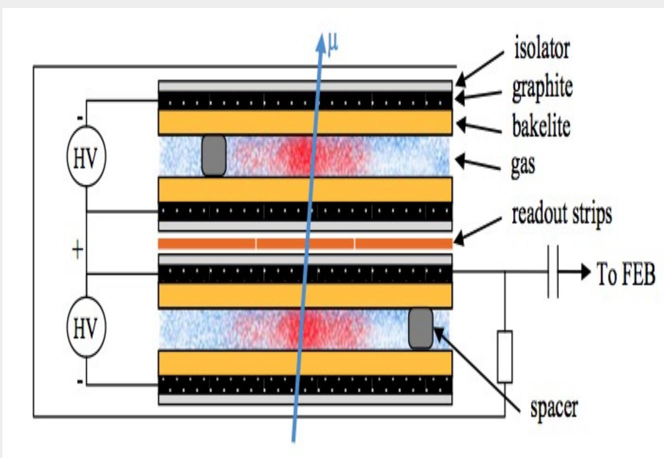
Abstract: The improved Resistive Plate Chamber (iRPC) chambers are designed using thin low resistivity High-Pressure Laminate gaps. They are proposed to equip the very forward region of the Compact Muon Solenoid (CMS) detector, as they can stand rates above 2 kHz/cm². To withstand 3 times higher rates than the actual CMS RPC chambers, the HPL thickness was reduced from 2 mm to 1.4 mm. The behavior of the gas gain of the chamber corresponding to the total charge production for minimum ionizing particles have been parameterized as a function of the atmospheric pressure. The resulting behavior was found compatible with the one already measured for RPC chambers.

Introduction



During the High Luminosity LHC phase (HL_LHC), the instantaneous luminosity in the CMS experiment is expected to increase up to a maximum of 5 − 7 × 10^{34} cm^{-2} s^{-1} which is 5 times higher than LHC nominal luminosity. To deal with the expected high particle rate in the very forward region of CMS experiment, the new improved Resistive Plate Chamber (iRPC) will be installed in RE3 / 1 and RE4 / 1 regions [1].

The iRPC at the CMS experiment is consisting of double-gap RPCs sandwiching with a pick-up strip plane in the middle. Each gap is made of two 1.4 mm High Pressure Laminate (HPL) electrodes with resistivity in the range of 1 to 3 × 10^{10} Ω.cm, which is lower than the resistivity used in the CMS RPC, separated by a gas gap of the same thickness and containing a gas mixture of $C_2H_2F_4(95.2\%)$, $iC_4H_{10}(4.5\%)$ and $SF_6(0.3\%)$.



Due to the thin thickness of the gas gap, the number of charges generated by the passage of charged particles in the gap will be reduced and absorbed faster in the thinner electrodes which increases the sensitivity and rate capability of the detector.

A sensitive, low-noise, high-time resolution Front-End Electronics Board (FEB v2.2) [2] is used to handle low charge signal with a threshold below 50 fC and keep the iRPC efficiency as high as in the usual RPC [3].

Motivation

The applied high voltage (HV_{app}) of the RPC chamber is corrected to keep its gain constant against the environmental changes that can affect the chamber's working point. It is corrected according to the environmental pressure and temperature using the following equation (1) [4,5].

$$HV_{app} = HV_{eff}\left[(1-\alpha) + \alpha \frac{P}{P_0}\frac{T_0}{T}\right] \qquad (1)$$

where: HV_{eff} is the effective high voltage, P is the environmental pressure, P_0 is the reference pressure equal to 990 mbar, T is the environmental temperature, T_0 is the reference temperature equal to 293.15 K and α is the correction coefficient which is used to determine the gas gain inside the RPC gas gap. It is measured for 2mm gap RPC and found to be equal to 0.8 [6]. The target was to find α value for 1.4 mm gap iRPC as a function of the atmospheric pressure.

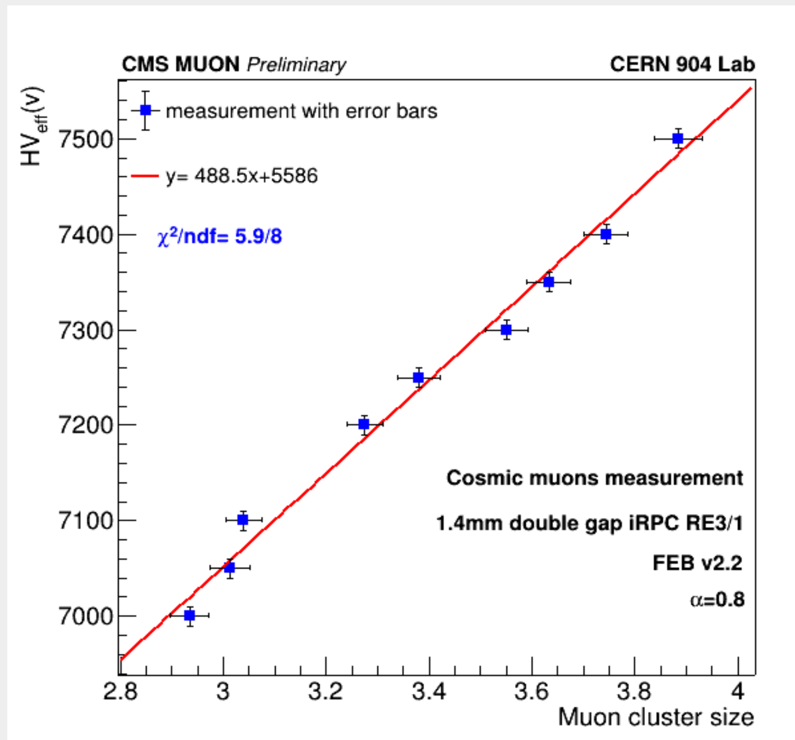
Method

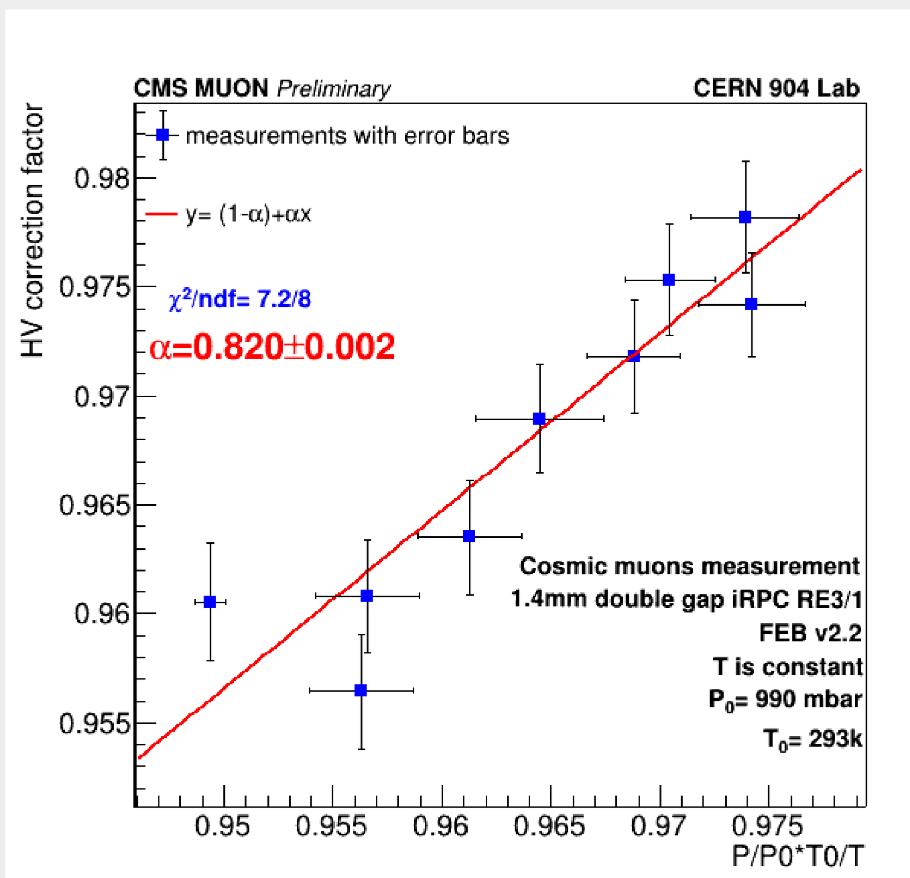
The idea was to collect data to calculate α value. The data was collected in 904 laboratory at CERN, where the temperature was controlled by an air conditioning system at $293.5 \pm 0.5\,K$. The experiment started a day with particularly bad cyclonic conditions. Pressure as low as 943 mbar was observed. During the next days while the situation was progressively improving we performed regular scans up to P = 966 mbar.

1. We performed a HV scan measuring the efficiency and cluster size with P-T correction. With the efficiency curve, we estimated the HV working point corresponding to the efficiency plateau. The cluster size measurement was used to obtains $HV_{eff}^{0.8} = f(cs)^{0.8}$. We verified that during the period of the scan the weather conditions were stable.
2. We took scans at different P with HV_{app}= 7 kV, which is close to the working point then we measured the cluster size.
3. We fit α_0 from equation (1) using $7\,kV / f(cs)^{\alpha=0.8} = (1-\alpha_0) + \alpha_0 P/P_0 T_0/T$
4. With the obtained α_0, we calculated α analytically.
5. We recalculated step 1 with α.
6. We check the self-consistent result using $7\,kV / f(cs)^{\alpha} = (1-\alpha) + \alpha P/P_0 T_0/T$

Results

The relation between the effective high voltage and muon cluster size as a result of performing a HV scan with P-T correction to measure the relation between $HV_{eff}^{0.8} = f(cs)^{0.8}$ obtained in step (1) described above. It is well described by a linear regression as shown. The measurements are done at CERN 904 lab on RE3/1 chamber with the FEB v2.2.





The figure shows the Self-consistent extraction of the α parameter from the cluster size measurement at different P values as described in step (6). We found that its value very close to the one of 2mm gap RPC chambers where the difference was 0.02 which gives a correction of 10 V for the effective WP of iRPC chamber.

$$\alpha(1.4\,mm) = 0.820 \pm 0.002\,(stat \oplus syst) + 0.067\,(meth).$$

Each HV point was collected in 40 minutes to stay with stable pressure condition. The limited size of the sample (1000 cosmic events) was reflected in the $(stat)$ uncertainties. They were squared summed with systematic uncertainties corresponding to the fluctuations of the pressure and temperature during the test. We also observed that constraining the constant part of the correction factor to $(1-\alpha)$ or leaving it free in the fit gives slightly different results. We included it into methodology uncertainties.

Conclusion

The value of the α parameter is well estimated for 1.4 mm gap iRPCs and it is found that it increases by around 0.02 compared to α used in the 2 mm gap RPCs, we get to the conclusion that α can be kept at 0.8 while accounting for the uncertainty of 10 V on the working point of the iRPC.

References

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