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A feedback algorithm for the Gas Gain Monitoring system of the CMS RPC Muon Detector

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The Gas Gain Monitoring system of the Resistive Plate Chamber muon detector, in the Compact Muon Solenoid experiment, provides fast and accurate determination of the variation in the working point conditions due to gas mixture changes in the closed loop recirculation system. Performance and developments on the algorithms used are presented. Preliminary results on an HV feedback algorithm are reported.

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1. Introduction

The muon system of the Compact Muon Solenoid[1] (CMS) experiment, at the LHC pp collider of CERN, Geneva (Switzerland), uses three different detector technologies: Drift Tube Chambers (DT), Cathode Strip Chambers (CSC) and Resistive Plate Chambers[2] (RPC). The RPCs are responsible for muon trigger along with CSC and DT, bunch crossing identification and fast muon transverse momentum measurement.

The operation of the CMS RPC system is strictly correlated to environmental variables, to the ratio of the gas components, and to the presence of pollutants that can be produced inside the gaps during discharges. The CMS RPCs are bakelite-based double-gap RPCs operated with a 95.2% $C_2H_2F_4$ - 4.5% Iso-C_4H_{10} - 0.3% SF_6 gas mixture with an around 40% relative water vapour content. By design, the RPC gas system runs in closed loop[3], with a fresh injected amount of gas limited to only 10%, so the collection of contaminants could be a serious problem that must be monitored. The Gas Gain Monitoring system (GGM)[4],[5] aims to verify the gas quality[6],[7],[8]. While GGM design parameters and construction have been presented previously[9],[10], in this paper the status and collected results during 2011 data-taking are presented and discussed along with preliminary results on a temperature, T, and pressure, p, feedback algorithm.

2. The Gas Gain Monitoring System setup

The GGM (Fig. 1) is based on single-gap bakelite RPC detectors 2 mm-thick gaps of 50×50 cm^2 area. The setup is installed, on surface, in the CMS SGX5 building, close to CMS assembly hall, to profit from maximum cosmic muon rates necessary to provide a fast response.

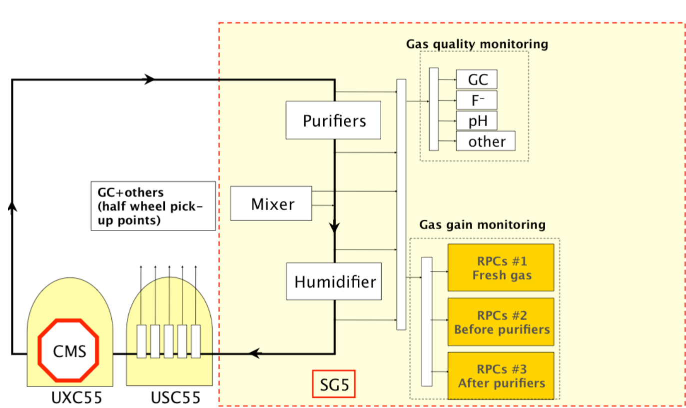

Figure 1: The GGM system integrated into CMS closed loop gas system.

The GGM consists of a cosmic-ray telescope of twelve RPC single gaps arranged in three sub-system: "Fresh Gas", "Before purifiers" , "After purifiers". The first sub-system (two gaps) is operated with the fresh CMS RPC gas mixture and is used as reference. The second sub-system (three gaps) is operated with gas coming from the CMS RPC closed-loop gas system and extracted before the gas purifiers, while the third sub-system (three gaps) is operated with gas extracted after the gas purifiers. The purpose of GGM is to monitor any deviation of the working point of the CMS RPC detector. This is accomplished comparing the signal of cosmic muons in gaps flushed with different gas origin. The GGM system runs continuously in a fully automatic way, each data sample consists in 10^4 events that are collected every 30 minutes and the analysis is completed online providing to RPC operation a prompt working point measurement.

Each chamber of the GGM has a double side copper pad read-out, the signal is read-out by a transformer based circuit that allows to algebraically subtract the two signals, which have opposite polarities, and to obtain an output signal with subtraction of the coherent noise and with an improvement by about a factor 4 of the signal to noise ratio.

The GGM RPC read-out pads are connected to a VME (VERSABUS Module Eurocard) ADC (Analog to Digital Converter) that is controlled by a semi-automatic DAQ system.

All environmental parameters are continuously monitored: temperature, pressure and relative humidity sensors are installed in the gas line before and after each chamber also atmospheric variables are recorded. The accuracy of the temperature sensor is $\pm 1^\circ$C in the range 0–40°C and the resolution is 0.1°C. The relative humidity sensor has an operating range from 2% to 98% with a 0.1% resolution, ± 1% absolute accuracy. The barometer operational range is between 700 mbar 1050 mbar with a 0.1 mbar resolution and a ± 1 mbar accuracy.

3. Feedback algorithm

An HV (High Voltage) feedback function was added in 2011 to compensate for environmental conditions that affect the GGM chambers response. Such an algorithm has constituted a test ground for application of an HV feedback to the full CMS RPC system. This solution aims to corrects the applied voltage on each RPC chamber maintaining its gain constant against environmental changes that would modify the working point of the chamber. The applied HV is corrected according to the environmental pressure and temperature. The algorithm keeps stable the effective HV as in the Eq. 3.1 [11]:

$$HV_{eff} = HV \cdot \frac{p_0 \cdot T}{p \cdot T_0} \tag{3.1}$$

where p_0=965 mbar and T_0=293 K.
Figure 2(a) shows correlation plots between the anodic charge of one chamber against environmental pressure while Fig. 2(b) against temperature demonstrating that the chamber is working at almost fixed gain independently of environmental variables. The correlation plot in Fig. 2(b) shows a residual dependance of anodic charge on temperature which is being studied in order to apply correction factors to Eq. 3.1. Figure 2(c) shows the charge distribution of a GGM chamber that exhibits a working point stability of σ = 0.07 pC during about one month thanks to the HV feedback corrections.

In March 2011 a problem occurred to the CMS RPC gas Mass Flow Controller (MFC) leading to a wrong mixture injected into the closed loop. It was concluded that the faulty MFC was delivering about 34% more SF_6 than designed. The content of SF_6 increased from 0.3% to 0.34% affecting the RPC working point. The gain variation was shown by means of a series of HV scans which spot the faulty MFC (Fig. 3(a) as example) and confirmed the presence of a wrong gas mixture. The function η adopted to perform the HV efficiency scan fit is described by the Eq. 3.2 [12]:

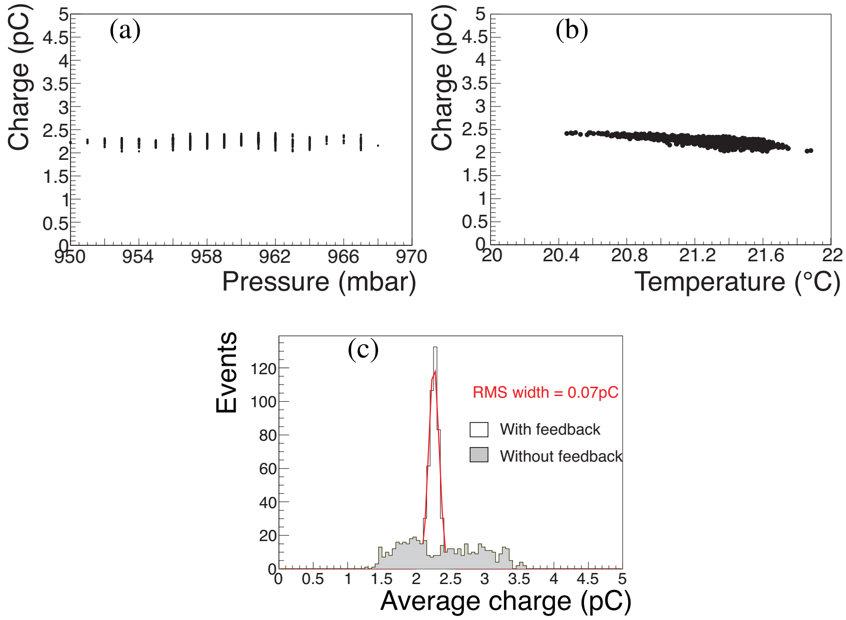

Figure 2: (a) Correlation plot between GGM RPC anodic charge against environmental pressure with the pressure and temperature feedback. (b) Correlation plot between GGM RPC anodic charge against environmental temperature with the pressure and temperature feedback. (c) Stability comparison between average charge (black histogram) and average charge using the HV feedback (empty histogram).

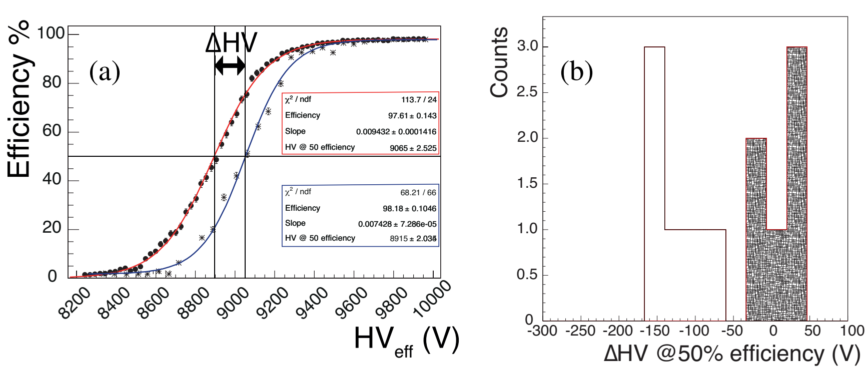

Figure 3: (a) Typical GGM high voltage scan performed during January 2010 (star) and April 2011 (full circle). (b) Difference in voltage between the HV scans performed in April 29th 2011 (correct gas mixture) with respect to and March 3th 2011 (empty histogram - wrong gas mixture) and January 10th 2010 (hatched histogram - correct gas mixture).

$$\eta = \frac{\varepsilon_{max}}{1 + e^{-\lambda(HV_{eff} - HV_{50\%})}} \tag{3.2}$$

Fig. 3(b) shows the difference (in voltage) at the 50% efficiency between HV scans performed with good and wrong gas mixture. The difference between April (good mixture) - March (wrong mixture) shows about 100 V difference at 50% efficiency.

4. Conclusions

Results from the GGM System for the CMS RPC Detector have been reported on. GGM is performing up to specifications, moreover a feedback algorithm was tested and provides good stability. Further studies are ongoing to improve anodic charge stability against temperature variations.

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