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The Compact Muon Solenoid Experiment

Conference Report

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First results of CMS RPC performance at 13 TeV

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Abstract

In May 2015, the Large Hadron Collider (LHC) at CERN, collided, for the first time, protons at the record-breaking center-of-mass energy of 13TeV. The LHC restarted after a two-year technical stop, know as Long Shutdown 1 (LS1), needed for servicing and consolidating the CERN accelerator complex. The Compact Muon Solenoid detector, a general-purpose detector at LHC, benefited from LS1 by performing crucial tasks necessary to operate the detector at higher energies. In particular, the Resistive Plate Chamber (RPC) system, one of the three muon detector technologies in CMS, was serviced, re-commissioned, and upgraded with 144 new chambers to enhance muon trigger efficiency. The CMS RPC collaborations has exploited early data samples at 13TeV for detector performance studies. These data allowed for a first characterization of the newly installed chambers. The results obtained are presented here.

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First results of CMS RPC performance at 13 TeV

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Abstract: The muon spectrometer of the CMS (Compact Muon Solenoid) experiment at the Large Hadron Collider (LHC) is equipped with a redundant system made of Resistive Plate Chambers (RPCs) and Drift Tube (DT) chambers in the barrel, RPC and Cathode Strip Chambers (CSCs) in the endcap region. In this paper, the first results of the performance of the RPC system during 2015 with the LHC running at 13 TeV is presented. The stability of the RPC performance, in terms of efficiency, cluster size and noise, is reported.

Keywords: Resistive-plate chambers; Trigger detectors

Contents

1 Introduction

Muons provide a clean signal to detect interesting events over complicated backgrounds at the LHC [1]. The muon system in the Compact Muon Solenoid (CMS) experiment [2] has the following primary functions: muon triggering, transverse momentum measurement, muon identification and charge determination. The muon system allows to identify the muons produced in many Standard Model processes, like top quark, W and Z decay, and they well-known Higgs Boson on top of them [3]. Hence a robust and redundant muon spectrometer is needed to provide

The muon system, described in detail in [4], uses three different technologies; drift tubes (DT) in the barrel region, cathode strip chambers (CSC) in the endcap region, and resistive plate chambers (RPC) in both the barrel and endcap, and it covers a pseudorapidity region $|\eta| < 2.4$. The DTs and RPCs in the barrel cover the eta region $|\eta| < 1.2$, while the CSCs and the RPCs in the end-caps cover the eta region $0.9 < |\eta| < 2.4$. The barrel region is divided into 5 separate wheels (named ±2, ±1 and 0) while the endcaps in 4 disks both in the forward and backward directions (named ±4, ±3, ±2, ±1). The 4th disk of the RPCs has been installed during the LHC long shutdown in 2013−2014 (LS1). Each wheel is divided into 12 sectors while every disk into 36 sectors. In total there are 1056 RPC chambers, covering an area of about 3950 m^2, equipped with about 137,000 readout strips. The CMS RPCs are double-gap chambers with 2 mm gas width each and copper readout in between. The bakelite bulk resistivity is in the range of $2 - 5\ 10^{10} \Omega cm$. They operate in avalanche mode with a gas mixture of 95.2% $C_2H_2F_4$, 4.5% iC_4H_{10} and 0.3% SF_6.

2 RPC working point calibration

During the data taking in Run I and Run II, HV calibrations were carried out on collision data to optimize the Working Point (WP) for each chamber and monitor the performance as a function of the time. The WP has been defined as the HV corresponding to the 95% of the maximum efficiency plus 100 V for the barrel and 150 V for the endcap. In order to take into account atmospheric pressure variations, the applied HV was corrected for pressure variations defining the effective HV

(HVeff), by the formula $HV_{app} = HV_{eff}\frac{P}{P_0}$.The temperature of the cavern is overall constant on time, thus no temperature correction has been applied. Figure 1 shows no significative variations on the working point. The high voltage shift between barrel and endcap chambers depends on few differences in the assembly parameters and different definition of the working point.

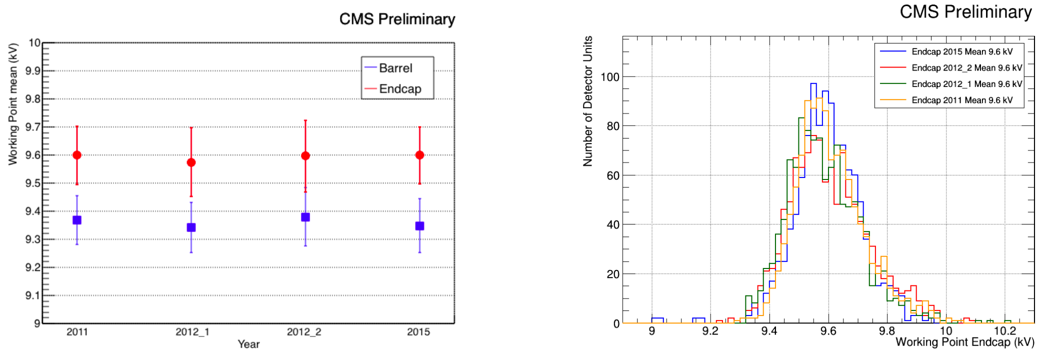

Figure 1. Left: Barrel and endcap mean working point trough the LHC working years. The error bars represent the obtained standard deviations. Right: the HVeff distributions for the Encap as measured at the 95% of the efficiency for the same runs as for the working point.

3 RPC performance stability

During RUN2, the chamber performance was monitored run-by-run to guarantie the stability of the system.

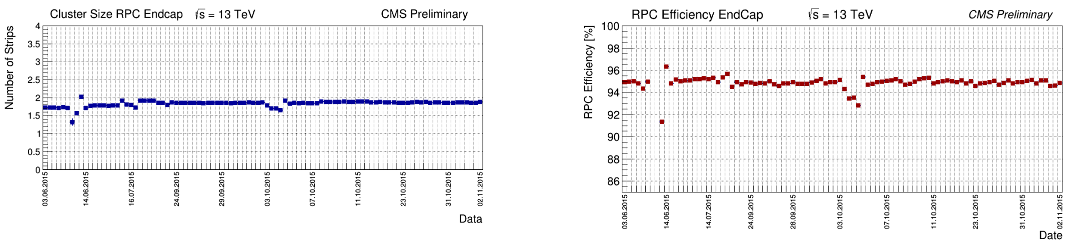

Figure 2. Left: end-cap average cluster size vs. time. Right: end-cap average efficiency vs. time.

Since November 2012, the applied HV is corrected as follows : $HV = HV_{eff}(1 - \alpha + \alpha p/p_0)$ [8], for pressure. Reducing α from 1 to 0.8 (where p_0 = 965 mbar) to balance the over-correction of the formula.

Keeping the cluster size stable over the time was one of the greatest successes achieved at the end of Run I. Figure 2 shows the efficiency and the cluster size for the end-cap measured during 2015. The fluctuation in Figure 2 in the middle of June are due to the performed HV scan, and the fluctuations in the beginning of October are due to the performed threshold scans. The scans for HV and threshold are done during dedicated calibration runs.

Figure 3 shows the chambers efficiency map as measured in 2015 for one wheel and for one disk. Most of the chambers have an efficiency of more than 94%, except for few cases, whose lower efficiency is due to known hardware problems.

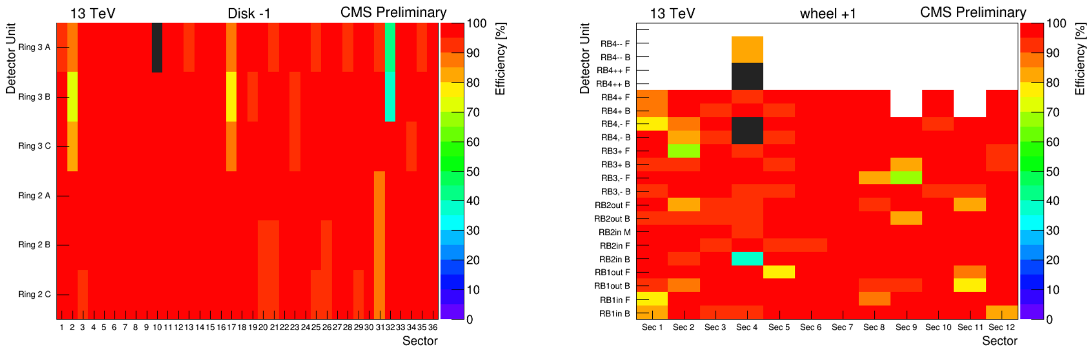

Figure 3. Left: chambers efficiency map for the disk +1. The 36 sectors are shown on x axis and the 6 η partitions on y axis. Right: chambers efficiency map in wheel +1. The plot shows the 12 sectors on x axis and the 6 RPC layers on y axis (RB1in, RB1out, RB2in, RB2out, RB3, RB4).

4 Noise and Background rates

The intrinsic chambers noise and background radiation levels could have an impact on the performance of the system: high rates can affect the trigger performance and the reconstruction of the muon tracks. Before every proton beam fill, the intrinsic noise rate is measured in order to mask noisy strips where needed. In 2015 the percentage of inactive channels was stable between 2 and 2.5%.

The RPC rate is measured also during the cosmics data taking in between the collisions runs. Figure 4 represents the rate level in barrel, endcap and system average from 2011 to 2015. Fluctuations in the rate are mainly due to post−collisions radiation, threshold value optimization vs efficiency and operating channels number change. Though the blue and the green curves show similar drift behavior, no significant spike correlations are observed . The overall trend show minor increase in the system rate with time, which is well below the official CMS requirement of rate < 5 Hz/cm^2. The end points of the barrel and endcap curves (2015 data taking) get close together since we have lower noise in the RE4 (around 0.05) which lowers the average of the measured endcap rate.

5 Conclusion

CMS RPC system operated well during RUN2 (2015) delivering good triggers and data for physics: At the end of RUN2, the fraction of active channels was about 98.6%. Most of inactive channels have been already recovered during LS1. After the LS1 running with increasing instantaneous luminosity and 13 years after the first RPCs have been assembled, the detector performance is within CMS specifications and stable with no degradation observed: average efficiency was found to be about 94%, average cluster size was ~ 1.87 strips, and the intrinsic noise was ~ 0.13 Hz/cm^2.

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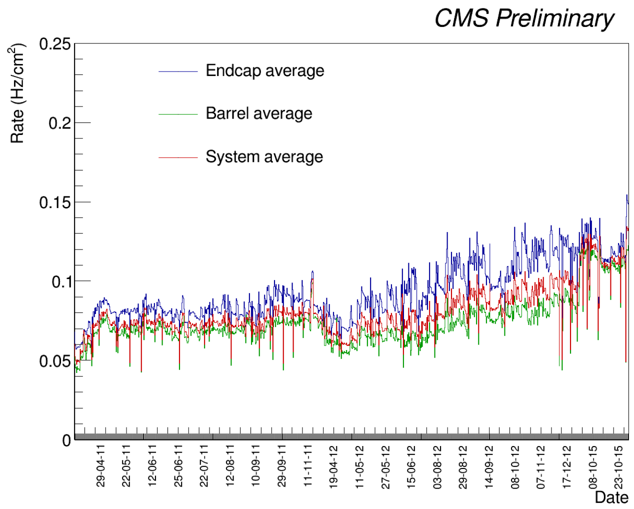

Figure 4. RPC cosmic rate distribution.

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