Quality Certification 4 (QC4) for RE4 in the Upgrade in CMS

2015 J. Phys.: Conf. Ser. 651 012005

(http://iopscience.iop.org/1742-6596/651/1/012005)

Quality Certification 4 (QC4) for RE4 in the Upgrade in CMS

S. Carpinteyro Bernardino on behalf of CMS colaboration.
Facultad de Ciencias Física Matemáticas, Benemérita Universidad Autónoma de Puebla.
E-mail: `bernardinocarpinteyro@cern.ch`

Abstract. The CMS muon system consist of Drif Tubes (DTs) in barrel region, Cathode Strip Chambers (CSCs) in the end-cap region and Resistive Plate Chambers (RPCs) in both regions. The RPCs with their excellent time resolution were chosen as dedicated muon trigger detector for the CMS experiment. After the Long Shutdown 1 (LS1) the LHC luminosity should reach $10^{34}cm^{-2}s^{-1}$ thus it is necessary to improve the level 1 trigger efficiency of the CMS detector for this high luminosity, to achieve that a 4th RPCs layer (RE4) in both end-caps of the CMS detector and all the components must be installed and completely validated. Based on the valuable experience (Barrel & Endcap) are defined several steps of Quality Certification (QC): QC1 (Components), QC2 (Gaps), QC3 (Chambers), QC4 (chambers & Super Modules), QC5 (Commissioning at P5). In this work is presented some results of QC4.

1. Introduction
After the Long Shutdown 1 (LSD1) the LHC luminosity should reach $10^{34}cm^{-2}s^{-1}$ [1]. Therefore during the LSD1 the Compact Muon Solenoid (CMS) collaboration is upgrading several subsystems in the detector. In the end-caps, CMS is using Cathode Strip Chambers (CSCs) as muon tracking and trigger detectors, while Resistive Plate Chambers (RPCs) serve as dedicated trigger detectors, and improve the muon reconstruction [2]. In particular, the instrumentation of the muon system, will be extendeded in both end-caps to ensure efficient muon triggering and reconstruction in that region at high luminosities. The RPCs are widely employed for the muon trigger systems thanks to their fast time resolution (∼1ns), suitable space resolution (∼1cm) besides its low production cost. The RPC developed by R. Santonico in the early 80s, are parallel plate gas detectors, made of highly resistive plates such as glass or bakelite coated with graphite to provide the anode and cathode and are operated either in avalanche or streamer mode with a typical combination of gas mixture [3, 4]. They are designed to create an avalanche and then also configured to arrest the avalanche from spreading out. The fourth end-cap layer is being installed during the long shutdown (2013-2014), then LHC will operate with its full designed luminosity. A common Quality Control (QC) protocol for the chamber and Super Modules (SM) production has been carefully prepared for each level of the construction [5]. Some results of individual components need to satisfy detailed specifications are presented in this work.

2. Region End-cap 4 (RE4) Upgrade
As the instantaneous luminosity of the LHC continues to increase over time during Phase 1, the CMS experiment has to ensure that the detector can operate in a stable and efficient manner for

the increasingly high particle rates. In particular, the muon system should be able to keep its trigger rate and efficiency under control. CMS will among other things extend its RPC system with a fourth layer in both endcaps [1, 2]. The RPC upgrade is essentially driven by the impact of the instantaneous peak luminosity on the trigger system [3] with the RPC trigger requiring hits in at least three stations, the endcap systems with only three stations does not have the necessary redundancy to control the trigger rate at the increased luminosity which causes the observed drop in efficiency for the endcaps with only three stations, while preserving high trigger efficiency. Adding the fourth layers in the endcaps, enabling a 3-out-of-4 trigger logic in those regions, will bring the RPC end-cap performance to a similar level as in the barrel region. In figure 1 the RPC Level-1 Trigger Efficiencies performance is simulated for the present system with three stations and the four station after the upgrade.

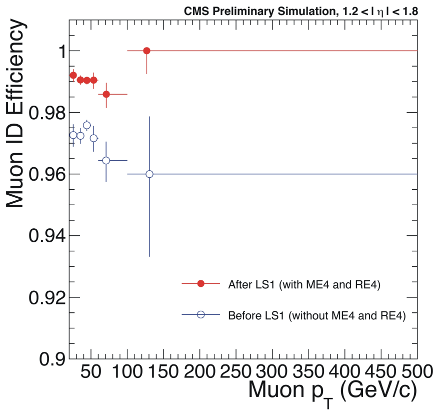

Figure 1. Simulated efficiencies with and without RE4 and ME4.

3. Resistive Plate Chambers (RPC)

Resistive Plate Chambers are widely employed for the muon trigger systems at the Large Hadron Collider (LHC) thanks to their fast time resolution, suitable space resolution and low cost. The basic design of a RPC consist of two parallel resistive plates such as glass or Bakelite (phenol-formaldehyde polymers) about 3 mm thick, separated by a gas gap whose width is maintained by spacers [3, 4]. The gas is kept at atmospheric pressure and DC voltage is applied to the plates via a layer of graphite paint on their external surface. The graphite electrodes are covered with an isolating layer that is etched with a thin copper layer that works as a pickup pad to detect any movement of charge within the chamber.

As the voltage on the anode is increased from zero, various modes of operation of chambers are encountered; Recombination mode where the field is not enough for the primary electrons to drift to the anode and they are lost by recombination to the positive ions. The second region is ionization mode where the field is enough for the electrons to reach the anode, but still not enough to multiply, nevertheless all of them are collected. The next region is called the proportional mode region; here above the critical or threshold voltage multiplication starts and the detector signal is proportional to the original ionization, thus the chamber can be used for energy measurement.

Increasing the voltage further one encounters the region of limited proportionality where multiplication reaches saturation. Thus gain no longer increases whith the voltage but avalanche transits into Streamer. In this region of operation there is a strong probability of photoemission from avalanches where secondary avalanches merge with original avalanche creating a streamer. This mode of operation has advantage of very large gains, hence simpler electronics is needed. Nevertheless, the gas mixture requires a strong quencher as one of its components. Increasing voltage further still more one reaches the Geiger or discharge mode which is dominated by tremendous amount of photoemission where the full length of anode is arrested by avalanche. To operate in this mode the HV needs to be pulsed and very strong quenchers are needed.

4. Quality Control (QC)

A full central control on the production at the level of components & chambers [5]. Based on the valuable experience (Barrel & Endcap) has defined several steps for the QC:

- QC1: Components, RPC-Technical Coordination.
- QC2: Gaps, Kodel+Assembly sites.
- QC3: Chambers, Assembly sites: CERN, Mumbai, Ghent.
- QC4: Chambers & Super Modules, 904 CERN.
- QC5: Commissioning at P5, 904 CERN & P5.

For each step; Quality Protocols to assure manufacture process reliability are established. QC protocols to select the good objects which are inside the technical specifications ranges are applied. Documentation protocols: RPC construction Data Base (DB) are used [6, 7].

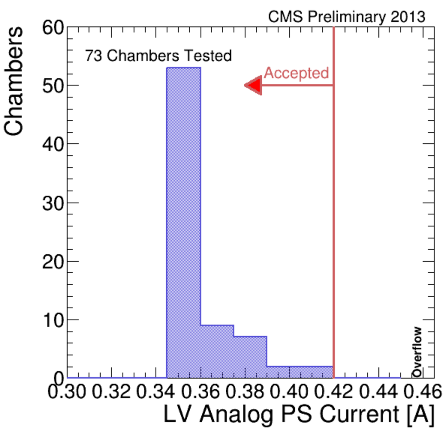

Figure 2. Signal current for analogic signal sent to Front-End Board (FEBs).

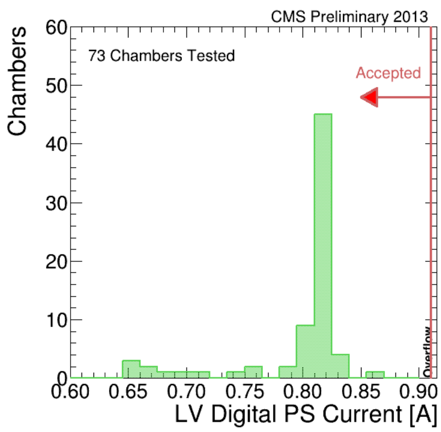

Figure 3. Signal current for digital signal sent to Front-End Boart (FEBs).

5. Quality Certification level 4 (QC4)

Quality Certification level 4 is divided in 3 parts; QC4-1, QC4-2 and QC4-3. The goal of the first part of the certification QC4-1 is to validate that RPC parameters are still in range. QC4-1 have the stages: Connectivity test, Electrical test, Leak test and HV Long Stability test is the only test which is carried out in the QC4-2 phase. If all the QC4-1 & QC4-2 test are successful the chambers can be used for the assembly of super modules in QC4-3.

Connectivity test starts with a visual inspection, then the connectivity with the use of a frequency meter check for bad or disconnected strips and for no dead or too noise chambers. The frequency meter send a signal directly to strips and then is returned to check that they are working well.

In Electrical test an analogical signal and digital signal are sent to Front-End Board (FEBs). For analogic signal the current must be less than 0.42mA and for digital signal the current must be less than 0.91mA. The plot in figure 2 summarize the value for analogic current response of chambers are acepted if i-analog <0.422mA. For this test all the chambers are in range. The

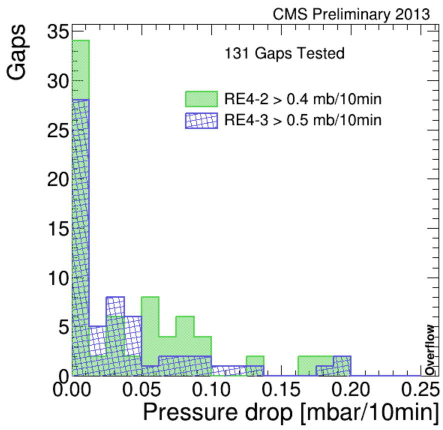

Figure 4. Pressure drop for RE4-2 chambers and RE4-3 chambers.

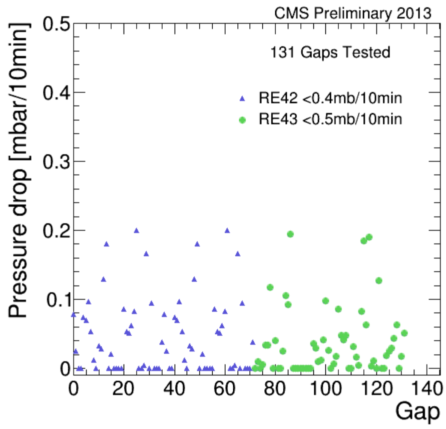

Figure 5. Distribution of pressure drop for chambers.

plot in figure 3 summarize the value for i-digital current response of chambers are acepted if i-digi <0.422mA. For this test all the chambers are in range. for the analog low voltage (LV) power supply (PS) and around 0.25A for the digital PS. Adding the Distribution Board, every chamber should draw about 0.36A from the analog PS and 0.75A from the digital PS plus 50-100 mA for the distribution board. In the second step in the Electrical Test the threshold in the FEBs is checked that the value is 215mV, in case the threshold is adjusted.

In Gas Leak there are four kind of RPC gas leaks and they are classified in; Large gas leak, normal gas Leak, Acceptable gas leak, and no gas leak.

The pressure drops is measured for each chamber in a time interval of 10 minutes in stable conditions. These measurements were taken with a tool provided by CERN gas group called Gas Leak Box. For all the chambers the gas leak are in range therefore all them are accepted for this test, the results are showed in figures 4 and 5.

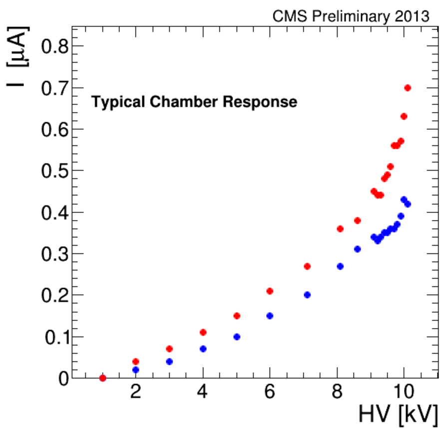

Figure 6. Typical chamber response in HV Scan test.

The three HV jupiter connectors are changed by a tripolar connector, therefore all RPC chambers need to undergo HV Scan test. The test is started by applying 1kV to each gap to detect broken connections and electrical short circuits. Then the high voltage is raised by 1kV every 10 minutes up to 8kV. Then to 9kV by 0.5kV, at this voltage gas avalanches begin to develop. Finally the high voltage is raised to 10kV in steps of 0.1kV. In figure 7 is showed an example of how an operational chamber should responds to the HV Scan test.

The main accent of QC4 fall down on the Long Stability test. During a long period the chamber current will be constantly monitored at 2 HV values. One cycle of 12 hours monitoring should consist of 10 hours of current monitoring. The chambers are alternately kept at 9.7kV for 10 hours, and at 6kV for 2 hours to observe the behaviour of the ohmic dark currents of the gas gaps, and this for a period of 4 weeks. If the dark current has a rising trend or is too high, the chamber is rejected and not used for further assembly. This cycle should be repeated more than 5 times for the 4 weeks. In this stage the chambers are cooling with CMS mix gas at 1atm pressure.

The value of the HV is corrected according to the pressure of the CMS mix gas; when the pressure of the gas increase then the HV is increased, when the pressure of the gas decrease then the HV is decreased.

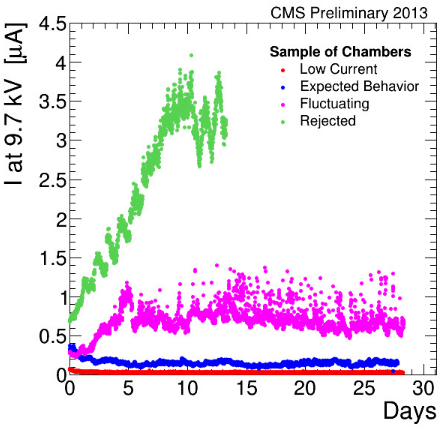

Figure 7. Diferent typical behavior for chambers under Long Stability test.

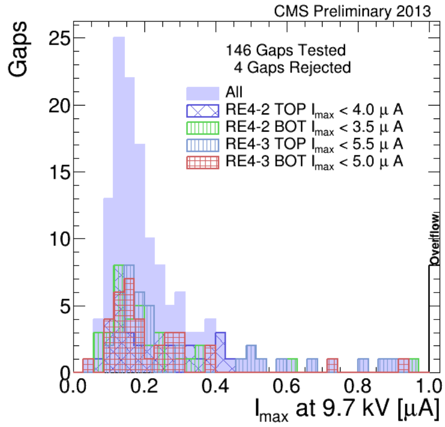

Figure 8. Distribution of number of gaps for current increment.

Is defined four main behaviour of the chambers under Long Stability test, see figure 7 where high resistivity is showed in reed for this case the current in the chambers is very small but different of zero. The expected behaviour in blue when the current in the chambers is into a well defined interval. The called Nervous behavior is showed in purple for this the current in the chambers is dispersed in a wide interval. For last we have the behavior for a reject chamber in green, in this case the current is always increasing indicating that something is wrong in the chamber.

In the plot in figure 8 the curren increment in the gaps when they are under Long Stability test at 9.7kV is showed and all them are in range.

6. General Chamber and Super Module Status

When all the QC4-1 & QC4-2 tests are successful for the chambers, this can be used for the assembly of Super Modules, where one chamber type 2 is coupled to a one chamber type 3 to form a Super Module assembly. Currently the 36 SM needed for the positive side of end-cap system have been delivered and the firts end-cap upgrade has been installed successfully. The production for the SM for the negative end-cap is ongoing and therefore the QC4 test is carry on for that chambers.

Acknowledgments

Acknowledgments I would like to thank the Eplanet program for the partial support gotten during my stay at CERN.

References

[1] CMS collaboration, The upgrade of the CMS RPC system during the first LHC long shutdown, 2012 JINST 8 T02002.
[2] CMS Collaboration, The CMS experiment at the CERN LHC, JINST 3 (2008) S08004.doi:10.1088/1748-0221/3/08/S08004.
[3] L.M. Pant, Resistive Plate Chambers for the RE4 upgrade of the CMS endcap system, 2012 JINST 7 P10025.
[4] V. K. Bhandari, Production of resistive plate chambers for CMS Experiment. EHEP Group, Departament of Physics, Panjav University Chandigarh, April, 2012
[5] https://apex.cern.ch/pls/htmldbc_msr/f?p=106.
[6] https://twiki.cern.ch/twiki/bin/view/Main/QC4Software.
[7] https://twiki.cern.ch/twiki/bin/viewauth/CMS/RPCOffLineAnalysis.