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Resistive Plate Chambers for 2013-2014 upgrade of CMS

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Abstract

The Compact Muon Solenoid (CMS) detector operates at the Large Hadron Collider (LHC) at CERN. It was proposed to install the fourth endcap (+,- RE4) consisting of Resistive Plate Chambers (RPCs) for the CMS muon Endcap system, in order to improve its Level-1 trigger efficiency and thereby completing the full implementation of the TDR, after which LHC will run with its full designed luminosity. This station is currently being installed in the first Long Shutdown (LS-1) of LHC during 2013-2014. In this presentation, we will discuss about the entire procedure of standardization of leak and spacer tests for the gas-gaps, the new design for the Cu cooling system, assembly, testing and characterization of RPCs which is being executed in a synchronized way at the three assembly sites at CERN, BARC-Mumbai and University of Ghent, Belgium. In this talk the RPC chamber production and commissioning will be described in detail. Few preliminary results will be shown.

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Resistive Plate Chambers for 2013-2014 muon upgrade in CMS at LHC

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ABSTRACT: During 2013 and 2014 (Long Shutdown LS1) the CMS experiment is upgrading the forward region installing a fourth layer of RPC detectors in order to complete and improve the muon system performances in the view of the foreseen high luminosity run of LHC. The new two endcap disks (+,- RE4) consists of 144 double-gap RPC chambers assembled at three different production sites: CERN, Ghent (Belgium) and BARC (India). The chamber components as well as the final detectors are subjected to full series of tests established in parallel at all the production sites. All assembly and test operations have been engineered in order to standardize and improve detector production. In this work the complete chamber construction, quality control procedures and preliminary results will be detailed.

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Contents

1. Introduction

During the LHC (Large Hadron Collider) Long Shutdown (LS1), the Compact Muon Solenoid[1] (CMS) experiment is undergoing a series of upgrades in order to cope with future increased beam luminosity. In particular the muon system is being upgraded with installing a new layer of Resistive Plate Chambers[2] (RPC) detectors in the endcap regions. Before this upgrade only three RPC layers were installed. The presence of a forth RPC detector station, called RE4, is going to increase the overall robustness of the CMS muon spectrometer while improving the trigger efficiency adopting a three-out-of-four stations majority trigger logic.

The RE4 project is carried out by several institutions and countries. The RPC gas gaps are produced in Korea while Pakistan, Italy and Finland are working on the front-end electronics, DAQ and power system. India is producing and testing 200 cooling sets. Bulgaria, Georgia Mexico and Pakistan are responsible for detector assembly and testing. India, Italy and Pakistan are building the chamber services (gas, cooling and cabling). China provides the readout strips and mechanical frame boxes, and participates in the chamber construction and testing at CERN.

The RE4 project consists of 72 super-modules, each of which is made by two RPCs, for a total of 144 double-gap RPCs. The RE4 detectors are going to instrument two disks, called RE+ and RE-, located at detector extremities, each disks is made of two rings: the inner ring is called RE4/2 while the outer ring is called RE4/3. In each of the two rings there are 36 trapezoidal shaped detectors, as shown in Fig. 1, built in three different assembly sites: India (BARC), Belgium (Ghent University) and Switzerland (CERN). BARC and Ghent are in charge of 25% of the production respectively RE4/2 and RE4/3 while the remaining 50% of the production is carried by CERN who work on both chamber types RE4/2 and RE4/3.

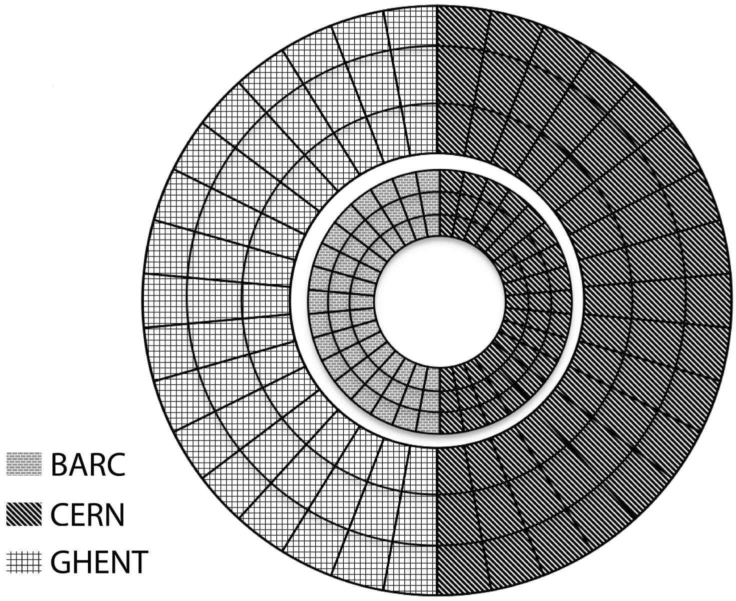

Figure 1. Schematic layout of one of the two new endcap disks.

2. Chamber design, production and quality controls

The RE4 project is inheriting the chamber design from the already existing RPC Endcap chambers. The detector configuration relies on 2 mm double-gap RPC built using the HPL with resistivity of the order of 10^{10} Ωcm. The top layer of the double gap is segmented in two parts while the bottom layer is only one, so a chamber is made of three kind of different gap geometries. The readout strips are mono-dimensional and segmented in three η segments with increasing strip pitch from 1.5 cm to 4 cm.

The HPL panels (≈3500 m^2) were produced in Italy by Puricelli firm (Milan) and preliminary validated by INFN (Pavia) before the panels were cut by RIVA firm (Milan). The HPL surface cleaning took place at General-Tecnica (Frosinone) before the final shipment to Korea where the HPL panels are assembled to form RPC gaps. The Korean gap manufacturing site is performing several measurement on the HPL panels to ensure the correct resistivity, thickness, color and roughness. Moreover, once RPC gaps are fabricated, the gap manufacturing site performs a gas leak and spacer test to ensure the quality during gap construction. Gaps are also subjected to an high voltage (HV) scan to measure the dark current and to a current monitoring at the expected operating voltage (9.7 kV) over one week. After this first validation, called Quality Control 1 (QC1), a box containing a number of gaps between 30 and 40 is dispatched from Korea to chamber assembly sites.

The second quality control (QC2) pursues the objective of validating the RPC gaps performance repeating some of the test performed in Korea.

In this second phase, the three assembly sites perform gap visual inspection, gas tightness, spacer test, and electrical dark current measurement. During the visual inspection each gap is characterized with a detailed checklist which ensures that no any visible damage is present and gap is eligible to be used. The gas gap spacer and leak tests check that no any gap spacer is detached and leak is within specification (0.4 mbar/10minutes). The last test of QC2 concerns the high voltage scan that aims at measuring the dark current and its stability over a period of 3 days. At QC2 an overall rejection factor of $\sim$10% has been found.

After a set of three gaps is fully validated by assembly sites, the chamber construction and commissioning shall begin. The quality control at the level of the chambers (QC3) foresees: chamber visual inspection, gas tightness, electrical and dark current measurement, cosmic muon commissioning by means of a dedicated cosmic ray telescope. During the visual inspection each chamber undergoes a detailed checklist to validate the manufacturing process of the chamber. Then the leak test measures the chamber gas leak in order to check whether, during chamber manufacturing, the gap gas inlet are correctly connected to chamber service panel. In the electric test the front-end boards are powered and checked while the gaps are subjected to an high voltage scan to ensure that the RPC gaps operate without problems. Finally the core of the QC3 protocol is the chamber by chamber performed high voltage scan that aims at characterizing detector response while measuring main detector performance parameters such as efficiency, cluster size and noise. Since the RE4 chambers are based on double-gap RPCs, each detector is subjected to three independent efficiency scans using three different configuration: double-gap, top single-gap, bottom single-gap. During one efficiency scan, 7 runs at different effective HV are taken, from 8.5 to 10 kV; in each run, 10k events are collected in approximately 2 hours. The scan is performed using the effective high voltage to corrects the applied voltage on each RPC chamber maintaining its gain constant against environmental changes. The applied HV is corrected according to the environmental pressure according to Eq.(2.1) [3]:

$$HV_{eff} = HV \cdot \frac{p_0}{p} \tag{2.1}$$

where p_0 = 990 mbar.

Each cosmic telescope is equipped with two scintillator layers (top and bottom) that form the trigger. The chamber front-end boards are connected via flat cables to TDCs to tag and record all hits. The analysis routine performs a tracking algorithm to reconstruct cosmic muon tracks using three reference chambers installed in the telescope.

After a successful cosmic test, every chamber is powered on and monitored for about three weeks in order to check its stability over time (QC4). If dark current is found to be stable, a pair of chambers, one RE4/2 and one RE4/3 type, is assembled into a super-module (fig. 2. This assembly task reduces the amount of time needed to install all RE4 detectors at CMS. Since the RE4/2 and RE4/3 chambers share the same cooling circuit and gas pipes, and are mechanically attached to the same structure, several commissioning protocols are performed before the real detector installation at CMS (Fig. 2).

3. Detector performance

The RPC gap performance is evaluated during QC2 at assembly sites. The leak rate test, shown in Fig. 3, is performed measuring the pressure drop in time of each gap initially pressurized to 20 mbar over ambient pressure. At the end of this test also all gap spacers are checked in order to

Figure 2. One of the two CMS endcap disks fully instrumented with RPC detectors.

spot any detached one. Once the leak and spacer test successfully ended, the gaps are subjected to an high voltage scan to measure the dark current response. During this test the high voltage is ramped from 1 kV to 10 kV with steps of 1 kV up to 8 kV and step of 100 V between 8 kV and 10 kV. Fig. 3b shows the dark current distribution at the 10 kV. Moreover after the high voltage scan all gaps are kept at 9.7 kV for 3 days for monitoring possible dark current drift correcting with pressure and temperature.

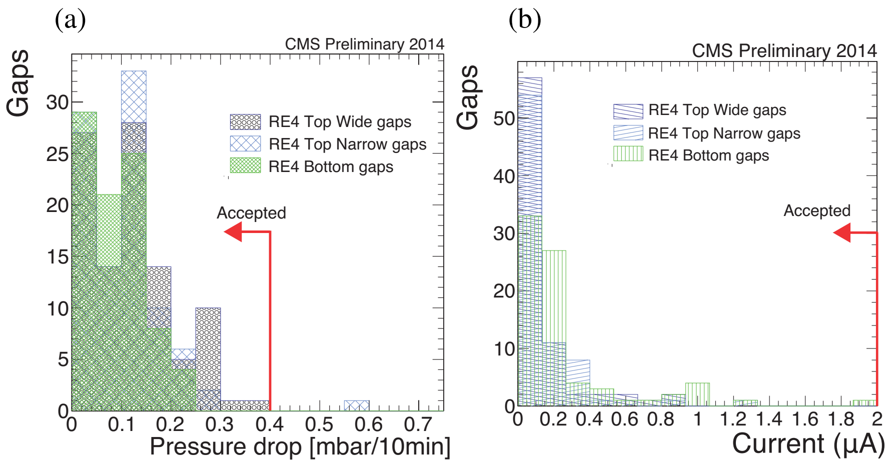

Figure 3. Dark current and leak rate distributions of gaps adopeted for the RE4 detector construction.

During QC3, assembly sites have the mandate to fully commission each detector. Using the tracking telescope, the performance of RPC detectors under test is evaluated and each chamber fully characterized. Fig. 3a shows the average cluster size distribution evaluated in the three different η segments at the expected working point with the distribution shown in Fig. 3b.

The expected working point is defined adding 150 V to the efficiency at 95%. The Eq.(3.1)[4]

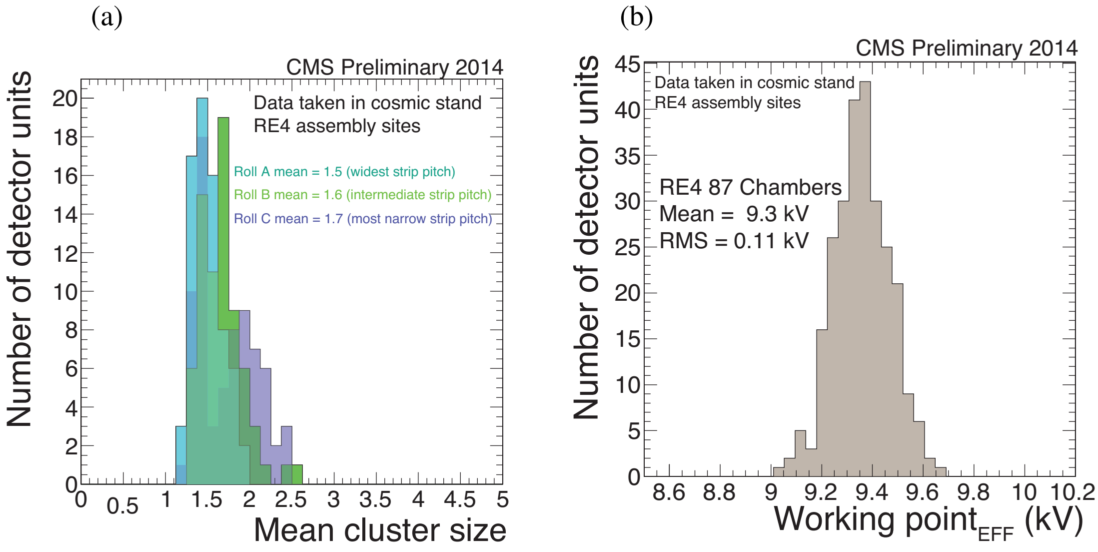

Figure 4. Mean cluster size at the expected nominal HV working point of commissioned RE4 detectors.

107 describes the efficiency along the high voltage scan and it is used to fit the data-points.

$$\eta = \frac{\varepsilon_{max}}{1 + e^{-\lambda(HV_{eff} - HV_{50\%})}} \tag{3.1}$$

108 The overall average maximum efficiency in double gap mode (ε_{max}) is shown in Fig. 5a while
109 the high voltage at 50% efficiency ($HV_{50\%}$) is depicted in Fig. 5b.

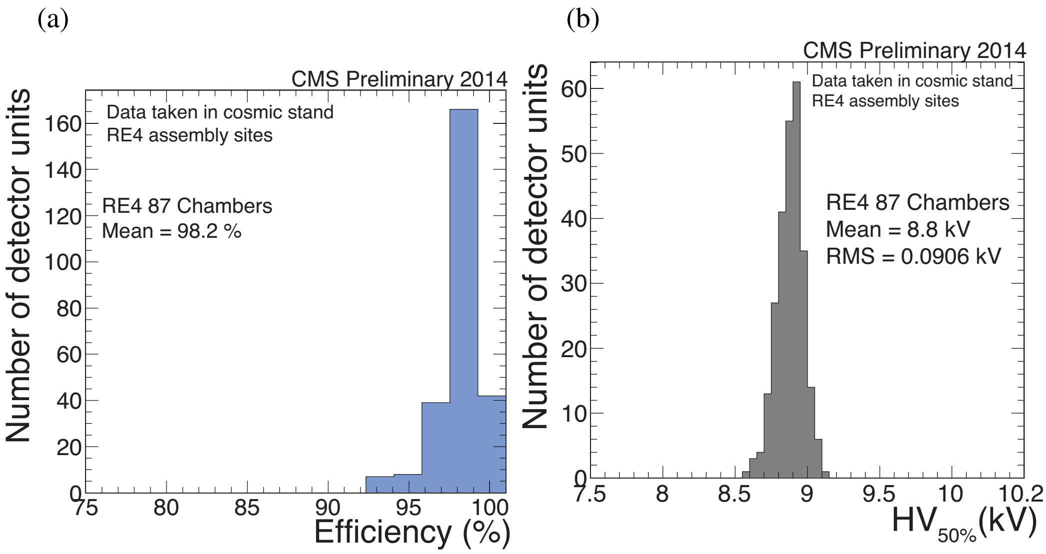

Figure 5. a) Average maximum chamber efficiency (extrapolated from the plateaux curve, see Eq.(3.1). b) High voltage distribution at 50% efficiency (as defined in Eq.(3.1).

4. Conclusions

RPC collaboration built and commissioned more than 144 RPC chambers, including spares, in about two years. The full operation was done on schedule and in the budget thanks to the very good organization and the professional job done by every Institution. Today both disks have been instrumented and the commissioning is going on in order to be ready for summer 2014.

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