The Compact Muon Solenoid Experiment

Conference Report

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ASSEMBLY and CHARACTERIZATION OF RESISTIVE PLATE CHAMBERS IN INDIA FOR THE CMS DETECTOR

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Abstract

The Compact Muon Solenoid (CMS) experiment is a general purpose detector being operated at Large Hadron Collider (LHC) facility at CERN. The RE4 upgrade project was envisaged to improve the Level-1 trigger efficiency in the forward region, when LHC would run at its full designed energy and luminosity after the first Long Shutdown (LS-1, 2013-2014). About 200 RPCs were built for the upgrade at three assembly sites in India, CERN and Ghent. India contributed to 50, RE4/2 RPCs along with 200 Cu-cooling units for the entire upgrade for which the assembly and characterization of RPCs was carried out jointly by Nuclear Physics Division-BARC and Panjab University-Chandigarh. The gas-gaps after their arrival from KODEL, South Korea, underwent mechanical tests for leak and popped spacers, followed by electrical tests for long term monitoring of leakage currents. After the assembly, each RPC was evaluated for its efficiency, cluster size, noise and strip profiles. The Cu-cooling units build at BARC were also tested according to the quality control protocols for any leakage. All the relevant data was uploaded onto the CMS-RPC data base prior to dispatch of RPCs to CERN. At CERN, the RE4/2 type and RE4/3 type RPCs were assembled to a Super Module (SM), which was further tested for the leaks in the Cu-cooling systems. The SMs were then transported to Point 5 and both the End Caps (RE4) were successfully installed and commissioned in the summer of 2014.

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Assembly & characterization of Resistive Plate Chambers in India for the CMS detector

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1 Introduction

The Technical Design Report (TDR) for the muon trigger for the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) facility envisages to have four layers of Resistive Plate Chambers (RPCs) in the forward region ($1.2 < \eta < 1.6$) [1]. During Run-I, CMS experiment had three layers of RPCs in the end-caps. The operation of the CMS RPC muon system during the first three years of LHC data taking was outstanding [2]. The present RPC trigger logic, from the end cap, requires hits in at least three layers, which causes the observed drop in efficiency for the end-caps with only three stations, being close to 80%. Adding the 4th layer in the end-caps, enabling a 3-out-of-4 trigger logic in those regions, will bring the RPC endcap performance to a similar level as in the barrel region, to 95%. After long shut-down, LHC is going to run at its full designed luminosity. In order to increase the Level-1 trigger efficiency, it was proposed to install the fourth end-cap layer during the long shut-down (2013-2014). The fourth layer consists of 2 rings denominated as RE4/2 and RE4/3, each having 36 chambers. Both end-caps will be instrumented with a total of 144 chambers with another 56 chambers as spares, adding to 200 chambers for the RPC upgrade project. The end-caps RPCs consist of three trapezoidal bakelite gas-gaps (top narrow, top wide and bottom gas-gaps) configured as a double gap RPC [3, 4, 5], with each RPC having a segmented readout strip along η , called as η partitions. The entire assembly with gas flow pipes, HV cables, Cu-read-out strips, Cu-Faraday-cage and mylar insulation is housed inside a Honey Comb Panel (HCP). The assembly and characterization of the RPCs in India is done at two dedicated and independent laboratories at Nuclear Physics Division, Bhabha Atomic Research Center, Mumbai and Panjab University, Chandigarh. Lab-

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oratory set-up at Department of Physics, Panjab University, Chandigarh is shown in Figure 1.

2 Characterization of gas-gaps

The trapezoidal gas-gaps, manufactured using bakelite sheets, have nozzles in the four corners for gas flow. The 2 mm gap uniformity is maintained using button spacers between the bakelite sheets. The gas-gaps after being fabricated at Korean DETector Lab. (KODEL), South Korea, are dispatched to the respective assembly sites in a phased manner. The gas-gaps undergo mechanical tests in terms of leak and spacer tests followed by electrical tests for leakage current at each assembly site.

Fig. 1 Experimental laboratory set-up at Department of Physics, Panjab University, Chandigarh for assembly and characterization of RPCs.

Fig. 2 Variation in over-pressure with time used to calculate leak rate for a gas-gap (left) and variation in over-pressure use to perform spacer test (right). The number of spikes corresponds to number of spacers in the gas-gap.

2.1 Mechanical tests of the gas-gaps

Since the gas-gaps are transported through a large distance to the respective assembly sites, their mechanical properties are evaluated through leak and spacer tests before they are assembled. The gas-gaps are visually inspected to check for any type of bulges on the gap surface, improper graphite/pet coating, broken nozzles or excess glue, etc. The qualified gas-gaps then undergo nozzle test to ensure the proper flow of gas through all the four nozzles of each gas-gap. Leak test of the gas-gaps is performed once at an over-pressure of 5 mbar and then at 20 mbar. The decrease in over-pressure with time (dP/dt) is measured and gas-gap is rejected if fails to pass the quality control (QC) criteria as shown in table 1.

The spacers, used to maintain uniform gap between bakelite sheets, may get popped up because of insufficient bonding of the glue at the fabrication site, though sufficient care is taken to keep the spacers pressed. The spacers may also get popped up because of mishandling of the gas-gap and a gas-gap, even with a single popped spacer cannot be used for assembly and has to be rejected. For spacer test, a template with known spacer position is placed over the gap and each spacer position is pressed to record the fluctuations in the pressure. For intact spacers, the fluctuations in the pressure are in the range of ± 0.5 mbar, whereas for the same pressure applied in the non-spacer region, resembling a popped up spacer, corresponds to large fluctuations (± 1 mbar and beyond). Figure 2 shows the variation in over-pressure during leak test (left) and spacer test (right) for one of the gas-gap.

Table 1 Quality control criteria for RE4/2 gas gaps [6]

Gas-gap (RE4/2)	Top Narrow	Top Wide	Bottom
dP/dt [10^{-7} mbar/ms]	5.00	5.00	6.66
Leak Current (I_{max}) [μA]	2.0	2.0	3.5

2.2 Electrical tests of the gas-gaps

Each gas-gap is purged with RPC gas mixture (R134a : Iso-butane : SF6 :: 95.2 : 4.5 : 0.3) with 40% Relative Humidity (RH) in the gas mixture at a flow rate of 5 litres per hour for 48 hours, before undergoing the dark current tests, which include high voltage scan (voltage is ramped upto 10 kV) and stability test (voltage is kept constant at 9.7 kV for 72 hours). The acceptance criteria for the gas-gaps is that, during the stability tests the increase in dark current should be less than 50% and $I < I_{max}$, as mentioned in table 1. The gaps, with low and stable leakage currents, passing the acceptance criteria are selected for the assembly of RPCs.

After passing the acceptance criteria, the gas-gaps are integrated into an RPC along with Cu read-out plane, front end electronics and Cu cooling system. After the full assembly of an RPC, it is subjected to its performance evaluation in terms of efficiency, cluster size, noise and strip profile in the cosmic hodoscope (figure 3) prior to their dispatch to CERN. Standard RPC gas mixture with 40% humidity in the gases is used for the efficiency scan. Figure 4 shows the results from efficiency measurements as a function of high voltage for one of the chamber assembled at Panjab University.

Timing diagram for the 3F trigger logic. The diagram shows three input signals: Scintillator detector-1, RPC, and Scintillator detector-2. The Scintillator detector-1 and RPC signals are ANDed to produce a 2F signal. This 2F signal is then ANDed with the Scintillator detector-2 signal to produce the final 3F trigger signal. A box indicates the efficiency formula: $\eta = \frac{2F \text{ events}}{3F \text{ events}}$.

4 Summary

India contributed to 50, RE4/2 type RPCs along with 200, Cu cooling sets for the entire upgrade for which the assembly and characterization of RPCs was carried out jointly by Nuclear Physics Division-BARC and Panjab University-Chandigarh. The performance of the RPCs assembled in India was found to be quite satisfactory. At CERN, the RE4/2 type and RE4/3 type RPCs were mated to form a Super Module (SM). The SMs were then transported to Point 5 and both the End Caps ($\pm$ RE4) were successfully installed and commissioned in the summer of 2014 (figure 5).

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Fig. 5 Photograph of one of the RE4 endcap after installation of RPC detectors with highlighted Indian contribution.