Production and quality control for the CMS iRPC

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Abstract

During the upcoming High Luminosity phase of the Large Hadron Collider (HL-LHC), the integrated luminosity of the accelerator will increase to 3000 fb^{-1}. The anticipated experimental conditions during this period including higher background rates, event pileup, and the probable aging of current detectors pose significant challenges for all existing experiments at the LHC, including the Compact Muon Solenoid (CMS) experiment. To maintain the high performance of the CMS muon system, several upgrades are being implemented. For the Resistive Plate Chamber (RPC) system, an improved version of the existing RPCs (iRPC) will be installed in the forward region on the 3rd and 4th endcap disks of CMS, extending the RPC coverage in the high pseudorapidity region up to 2.4. The iRPCs have reached a mature stage in the production stream at CERN and Ghent. This poster presents the production facilities and the selection procedures for the certified RPC gaps and chambers.

Motivation

To address the high particle rate and significant pileup environment anticipated during the High Luminosity phase of the Large Hadron Collider (HL-LHC), the Compact Muon Solenoid (CMS) Collaboration has proposed installing new RPC chambers [1]. Improved Resistive Plate Chambers (iRPCs) will be added to the two outer stations of the CMS endcap region, RE3/1 and RE4/1, extending coverage to a pseudorapidity of up to 2.4, as illustrated in Figure 1. These advanced gaseous detectors in the forward regions will be capable of managing the high particle rates effectively.

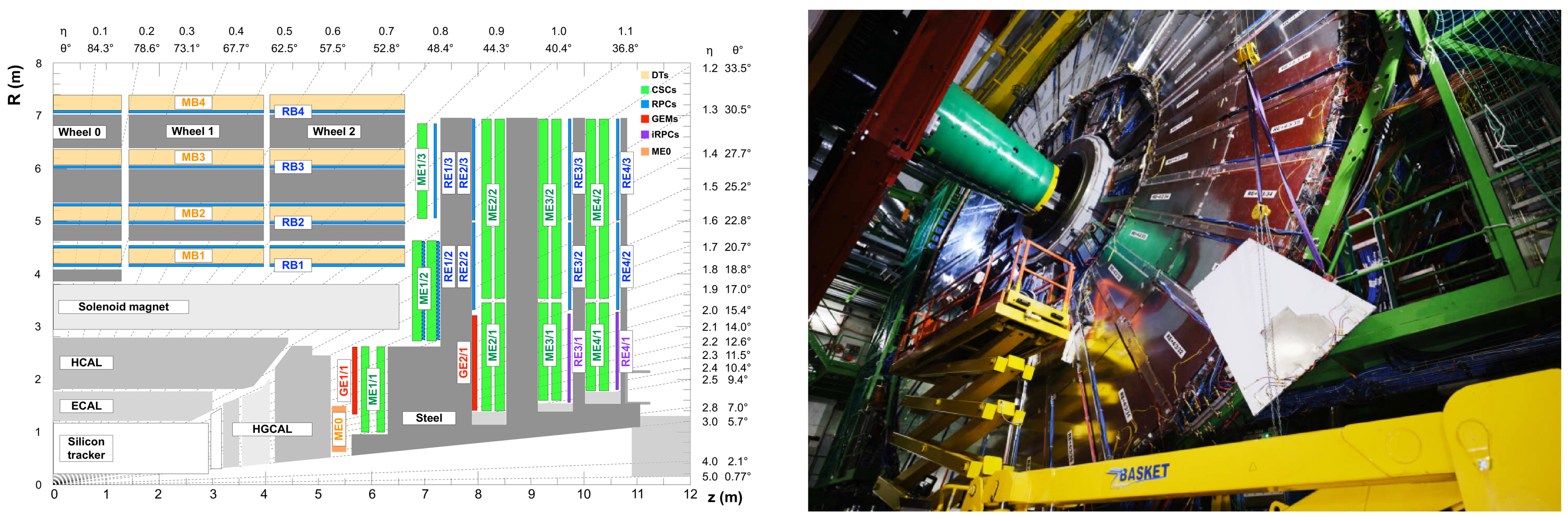

Figure 1: Left: A quadrant of the CMS experiment. In purple, the local of the two iRPC stations - RE3/1 and RE4/1. Right: Installation of one demonstration chamber.

The iRPC chamber

An iRPC chamber consists of a double-gap detector, Figure 2, each made of two 1.4 mm High Pressure Laminate electrodes coated with a thin graphite resistive layer separated by a gas gap of the same thickness, Figure 3. The strips are integrated in a large trapezoidal printed circuit board(PCB) made of two parts. Each PCB comprises 96 readout strips in total.

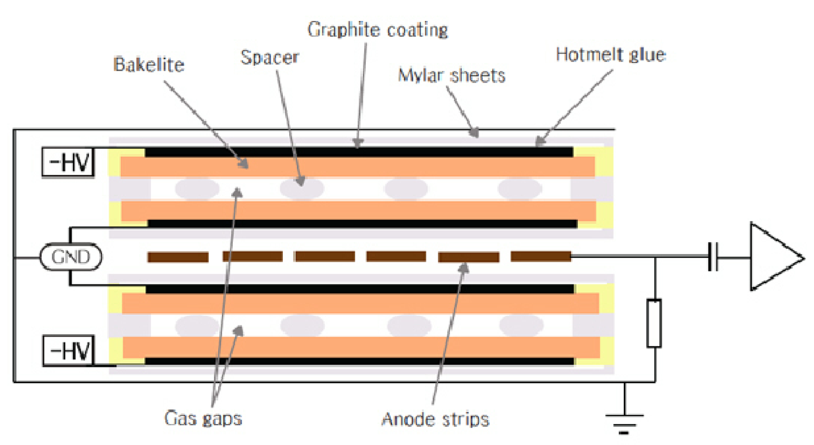

Figure 2: Double-gap RPC schema

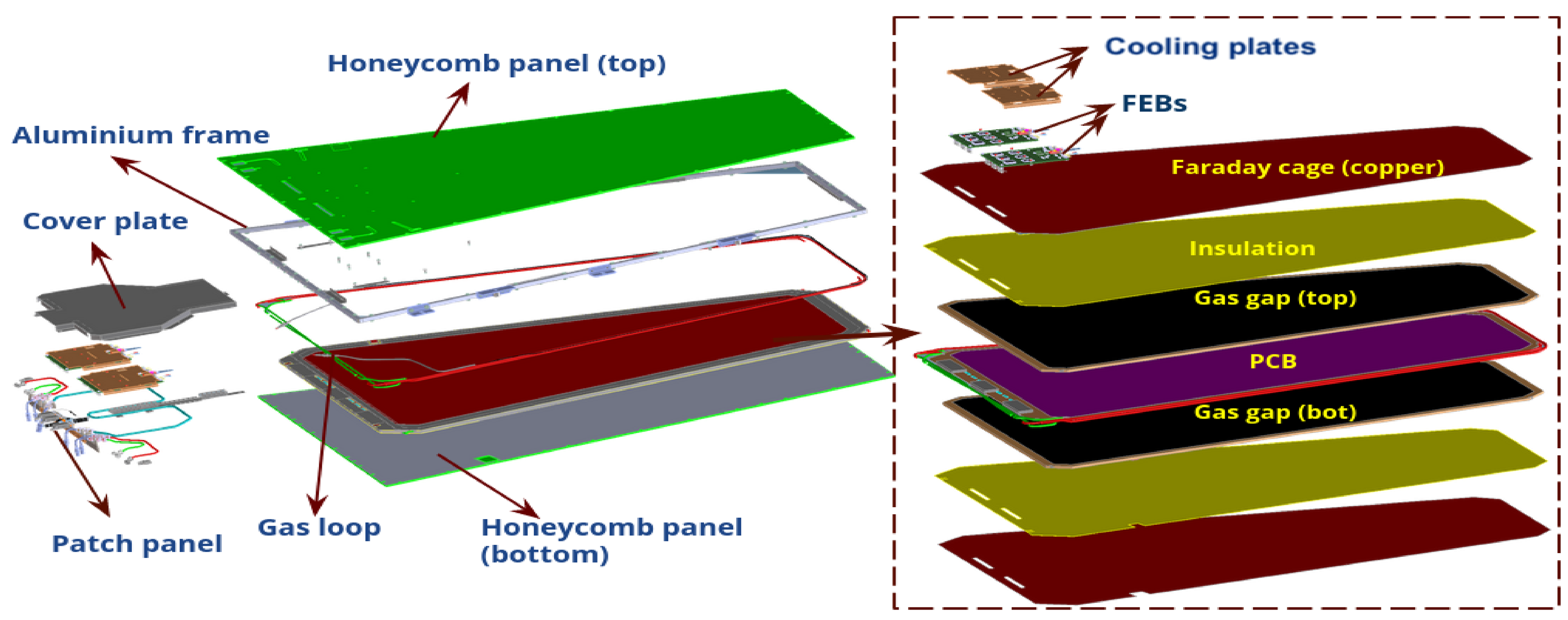

Figure 3: iRPC layers exploded view

iRPC production

To study the detector behaviour under real LHC conditions such as high background rate, noise, magnetic field, etc., and to integrate the new RPC stations into the CMS detector control software and data acquisition system, a number of iRPC demonstrator chambers were assembled and installed in CMS during the second LHC Long Shutdown period. Two iRPCs were installed in 2022 in CMS. Gap-level as well as chamber-level Quality Control tests were performed on the site following standardized protocols.

Quality Control tests (QC)

The gap-level quality control (QC) includes visual inspection of the gaps, verification of the spacer conditions, gas tightness tests, and dark current measurements. The gas tightness and spacer tests for iRPCs are conducted at an overpressure of 15 hPa above atmospheric pressure. During the high voltage (HV) test, the dark current is monitored at 16 HV points, and its variation aligns with the expected trend. Figure 5 shows the results of the gap-level QC tests performed on one gap. At the chamber level, QC is performed using a cosmic test setup, which assesses spatial resolution, noise rate, detector efficiency, and muon cluster size, as depicted in Figure 6. The final step is the long-term stability test, shown in Figure 7.

Figure 4: Cosmic test stand for gaps validation

Production steps

Procure and test components ⇒ send components to assembly sites ⇒ Assemble chambers (CERN and Ghent) ⇒ Final QC at CERN

QC1 - Chamber Components
HPL (INFN), Strip PCB (Lyon), FEB (Leon) Cooling System (Georgia)

QC2 - Gaps
Gap in KODEL (gas leak, spacer bonding, dark current scan)

QC3 - Chambers @assembly sites
- Leak and dark current
- Cosmic tests (noise, efficiency, cluster size and HV)

QC4 - Chambers @CERN
- Cooling, Gas leaking, Dark Current Scan
- Long term HV stability
- Cosmic with final FEBs

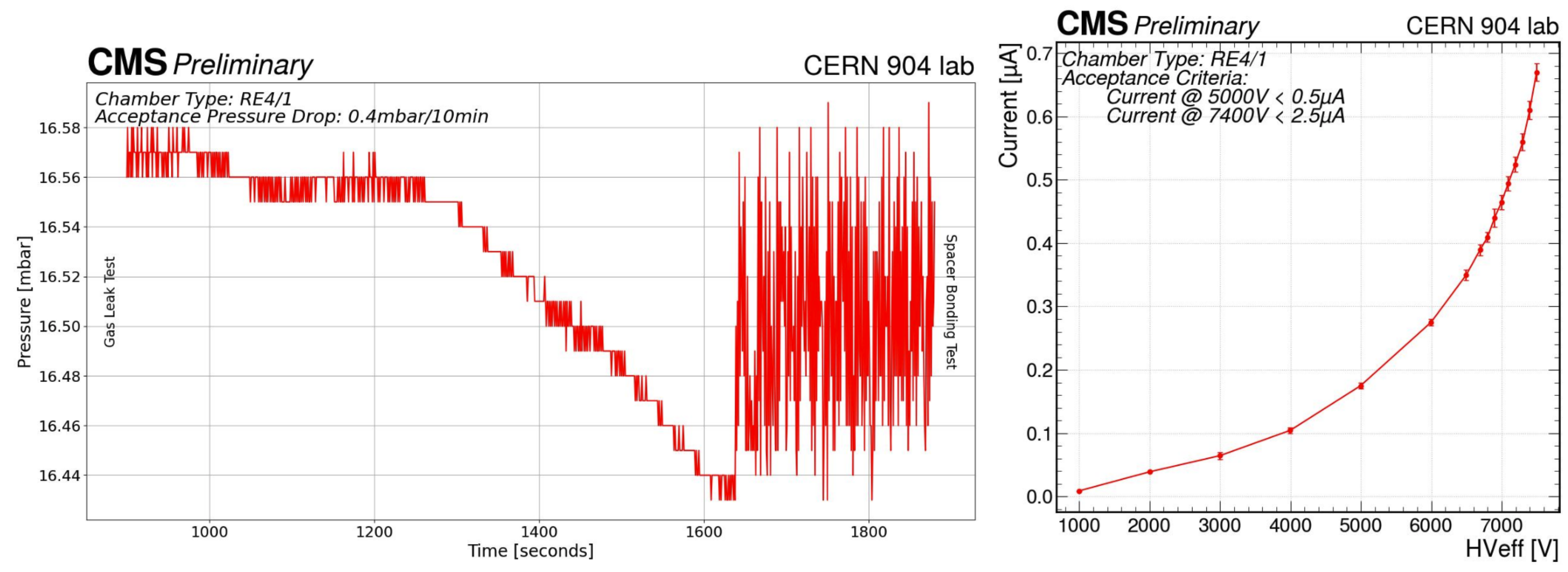

Figure 5: QC2 for iRPC gaps - Left: this plot shows the gas leak tightness and spacer bonding test for an iRPC gap at CERN 904 iRPC assembly site. The gas leak test showing just a 0.13 mbar/10 min pressure drop, well below the accepted limit of 0.4 mbar/10 min. The spacer bonding test shown indicated smooth transitions between spacer components, ensuring good bonding quality. Right: this plot shows the dark current dependence on the effective high voltage for an iRPC gap. The linear ohmic region corresponds to where the current is linearly proportional to the voltage. In this region, the electric field across the gap is not high enough to initiate a significant electron avalanche. After that, in the exponential region, the electric field is strong enough to initiate electron avalanches, where each electron that is freed by ionization can cause additional ionization events exponentially.

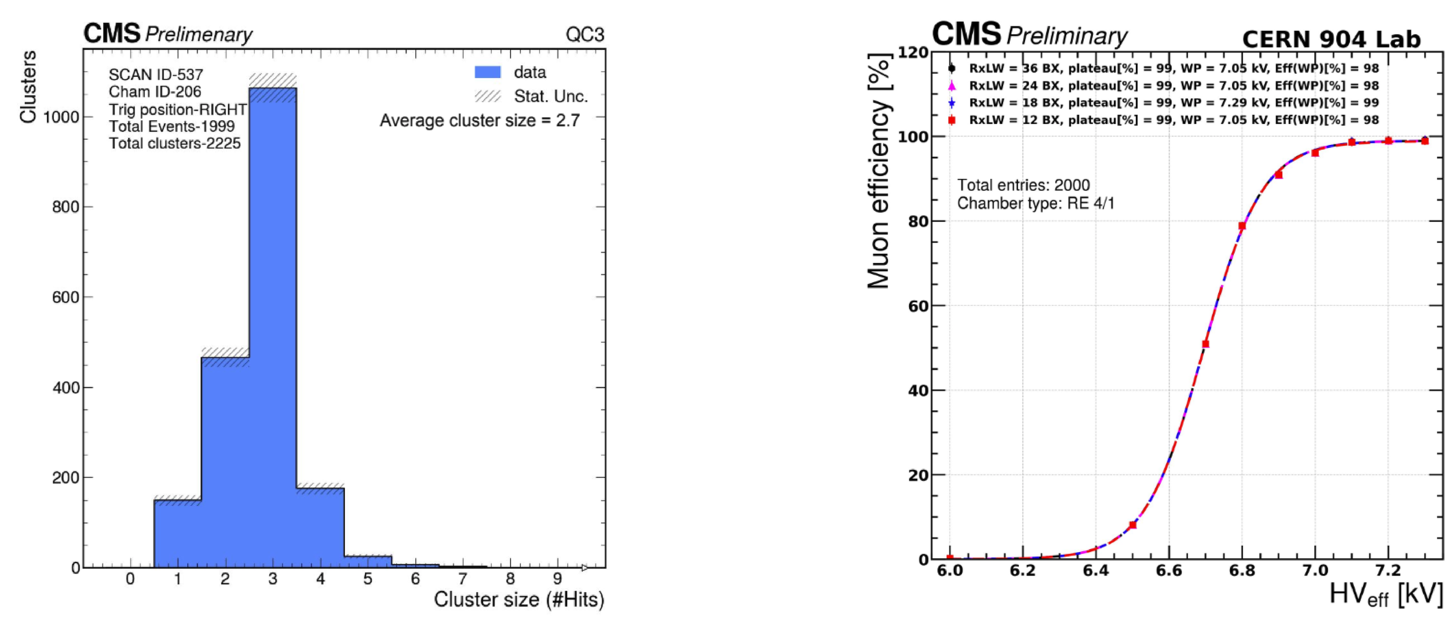

Figure 6: QC3 - Right: this plot shows the cluster size distribution at the working point, 7.05 kV. Cluster size is defined as the number of consecutive strips fired when a muon crosses a RPC detector. Strip widths of iRPC ranges from 0.6 cm to 1.23 cm. That is an important parameter that can affect spatial resolution and rate capability. Left: This plot shows cosmic muon detection efficiency versus effective high voltage. Efficiency at each high voltage is defined as the ratio of the number of detected muons to the total number of triggers. A detected muon is considered as at least one hit within the scintillator projected area. Maximal efficiency reaches 98% for all four different readout windows (RxLW). **Data collected with MicroTCA based backend and final version of the FEB.**

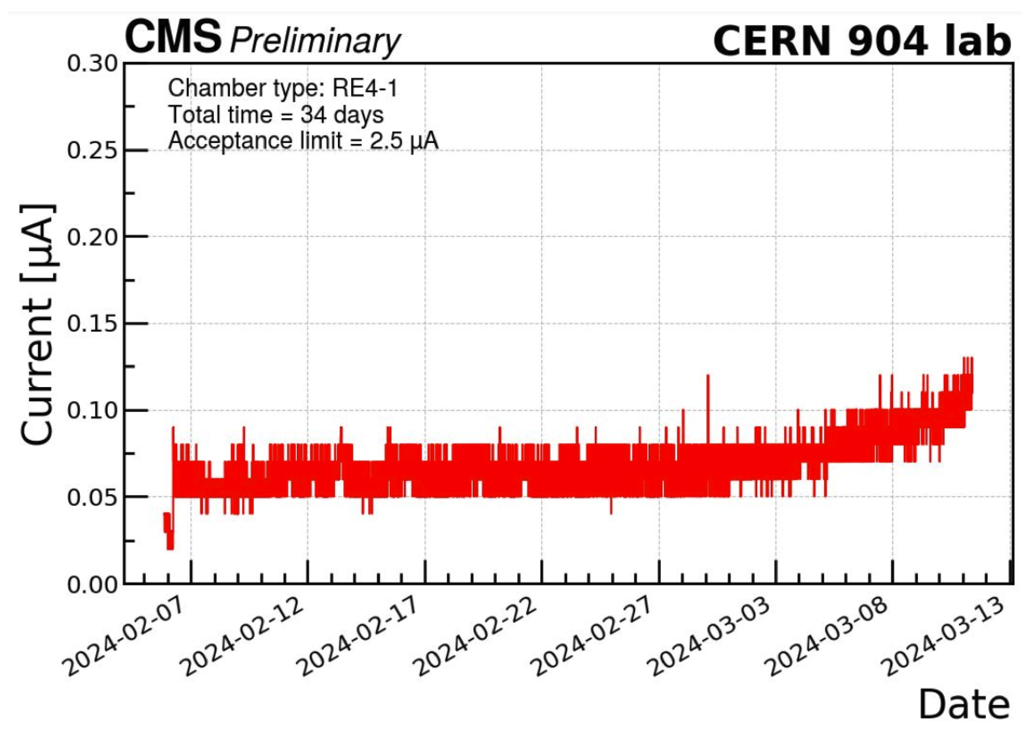

Figure 7: QC4 - Plot showing the long term stability chamber validation test. Showing the current of one of the two HV layers of an iRPC production chamber at 7 kV for a period of over a month. A chamber does not qualify in QC4 for installation in CMS if the current exceeds 2.5 μA.

Conclusions

The mass production and Quality Control of the improved Resistive Plate Chambers are going smoothly in both sites. A total of 57 chambers were assembled so far, 33 RE4/1 and 24 RE3/1. The first two mass production chambers were installed in the CMS detector and the last 70 chambers are scheduled for installation in the next winter break.

References

[1] CMS Collaboration, The phase-2 upgrade of the cms muon detectors, CERNLHCC-2017-012, CMS-TDR-016 (2017)
[2] S K Park et al. CMS endcap RPC gas gap production for upgrade, 2012 JINST 7 P11013
[3] A. Samalan et. al. Upgrade of the CMS Resistive Plate Chambers for the High Luminosity LHC, 2022 JINST 17 C01011

Thanks to the RPC group colleagues.