CMS RPC activities during LS2 and Commissioning

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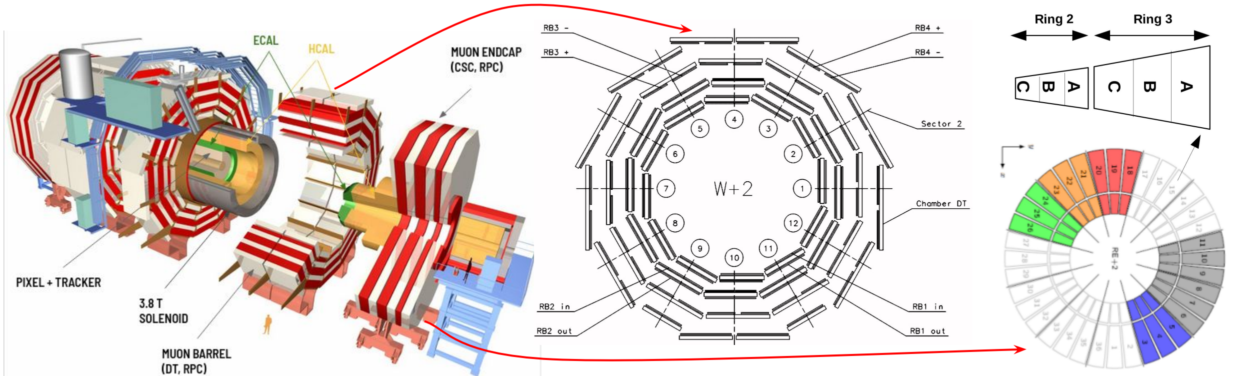
ABSTRACT: The second LHC long shutdown period (LS2) was a crucial opportunity for the CMS Resistive Plate Chambers (RPC) to complete their consolidation and upgrade projects. The consolidation includes detector maintenance for gas tightness, HV (high voltage), LV (low voltage) and slow control operation. Dedicated studies were performed to understand the behaviour of RPC currents with comparison to RUN 2. This paper summarises the activities performed and commissioning of CMS RPC on the surface (For RE4) and for full detector in CMS cavern in different operating conditions.

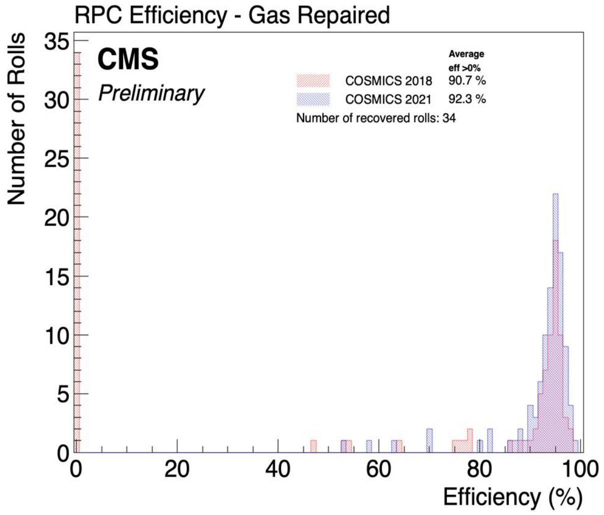
Introduction

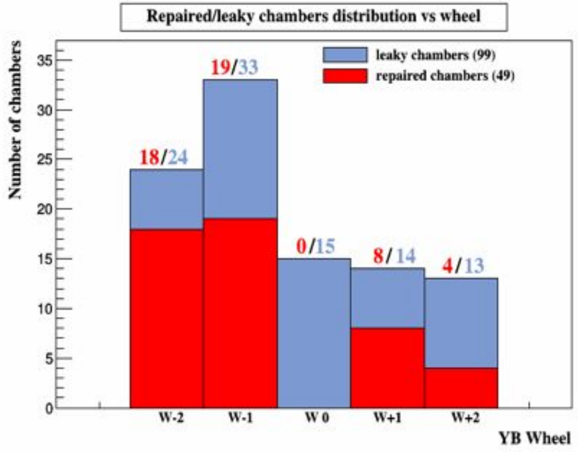
The CMS [1] muon system uses three different types of detectors technologies [2]: cathode strip chambers (CSC) in the endcap region, drift tubes (DT) in the barrel region and resistive plate chambers (RPC) in both regions. The CSCs and the RPCs covers the region $0.9 < |\eta| < 2.4$, while the DTs and RPCs in the barrel covers the region $|\eta| < 1.2$. The RPC system contributes not only for muon identification and reconstruction, but for the trigger system. The CMS geometry is divided into two regions, barrel and endcap. The barrel region is divided into 5 wheels, called W±2, W1±, W0, while the endcap region is divided into 8 regions, called RE±4, RE±3, RE±2, RE±1. A wheel consists of 4 muon stations (RB1, RB2, RB3, RB4) at increasing radius and is divided in 12 sectors in ϕ, while the endcap is divided in 36 sectors. There are 1056 RPC chambers in total, covering an area of more than 3000 m². They work in double-gap mode, where each gap is 2 mm width and each copper strip readout is a plane located between the gas gaps. The gas mixture used is composed of 95.2 % $C_2H_2F_4$, 4.5 % iC_4H_{10} and 0.3 % SF_6 with a relative humidity of 40-50 % [3]. The second LHC Long Shutdown period (LS2) has been a great opportunity for the CMS RPC complete their consolidation and upgrade projects. The consolidation project includes the detector maintenance for gas tightness, High voltage (HV), Low voltage (LV) and slow control operation. Also, dedicated studies were performed to understand the behaviour of RPC currents with comparison to RUN 2.



RPC gas system repairs

One of the main activities during the LS2 was gas repairs: 49 out of 99 gas leaky RPC were repaired. All problems were located in the barrel, out of which 17 chambers were off in Run 2. To realize these interventions a method to extract the chambers was developed, in which dedicated tools for partial chamber extraction were built in order to allow the reparation of broken gas components upon identification of their exact location by using a endoscope. In the end, the leaks were identified due to cracks and/or broken pipes. The activities still ongoing but improvements can be already seen. The left plot below shows that the efficiency increased after the repair campaign. Some leaky chambers were presenting high currents they were put in single gap mode operation. After successful repair, they were put back to double gap, explaining the gain in 1.4 % on the average efficiency. The right plot shows the comparison of leaky and repaired chambers in the barrel wheels.





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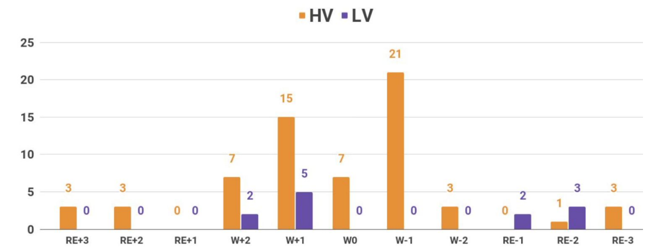
HV/LV Maintenance

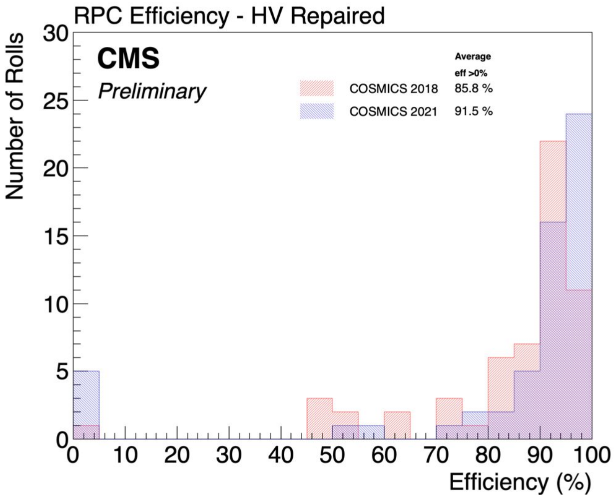
The applied high voltage (HV) is one of the main parameters to monitor in order to study the RPC performance. Is important to keep the RPCs in the working point (WP) to achieve good performance. In general, the CMS RPC WP are between [9, 9.8] kV with an average of 9.5 kV. The HV problems could be at any part of the HV system: broken connectors, either in chamber or in cable, problematic gaps, channels in HV boards, etc. The goal of the HV maintenance is then to identify which part of the system is showing problems and fix it with the best possible solution.

The aim of the low voltage repairs (LV) is to guarantee the powering and required configuration of the front-end board (FEBs). Which means that all stages of the system to be checked: FEBs chips, thresholds values, signal cables in good state, signal cables well connected to the chambers and to the link boards and the distribution boxes (DBs).

During the LS2 an extensive repair campaign is being performed. In total 65 HV repairs were done out of those 45 HV new trips developed in LS2 as the system was subjected to multiple power cycles, due to COVID issues. Besides that, 12 LV (Thresholds) repairs were successfully performed.

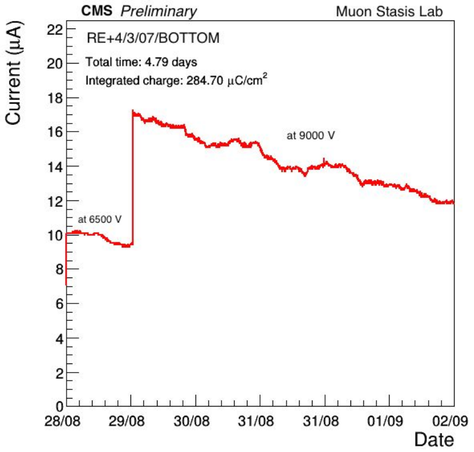
The right plot below shows that with the HV maintenance the average efficiency has increased ~6 % by recovering the chambers from single gap to double gap operation mode.

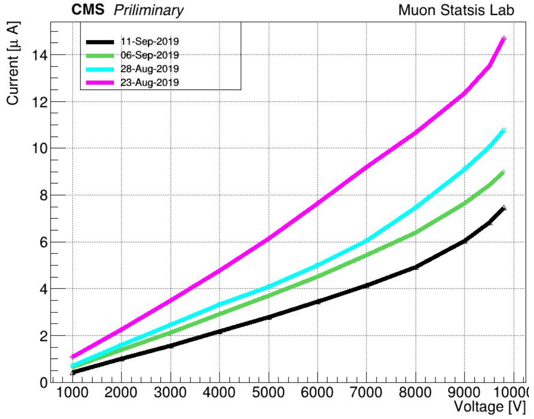




RE4 activities

The fourth endcap muon stations RE+4 and RE-4 were extracted during LS2 to allow the CSC ME4/1 extraction to replace the electronics. A new laboratory with controlled environmental conditions (temperature and relative humidity) was built in a building at Point 5 to house these supermodules. All scans and monitoring were possible thanks to a new webDCD RE4 software. However, when powered on the surface the currents were found higher than their last values at the end of RUN 2. A known source of increase of the current is the F^- production, in which the higher the concentration of this ion in the the gas greater the current. As the chambers were in open air for months this effect can be discarded, as this effect takes place in the presence of high backgrounds, which is not the case. So far, there is no explanation to this effect, it could be due to different environmental condition. Nonetheless, when chambers are under stable HV for long periods, the currents decreases to values comparable to the ones at the end of RUN 2, as the left plot shows. In turn, the right plot shows four HV scans, in which is easy to see the fast decrease of the currents in four weeks. Also, the exponential decay behavior of the currents was observed, in which the average recovery time was found to be around 15 days. Studies are ongoing to understand the reason of increase.





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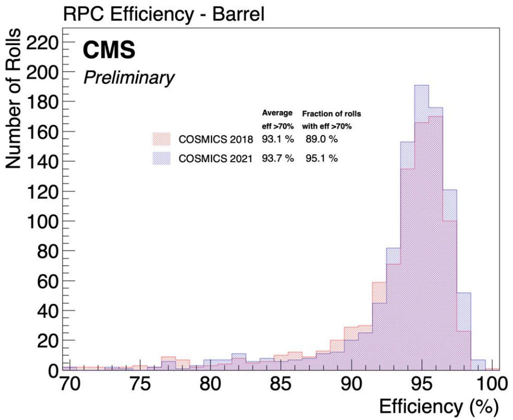
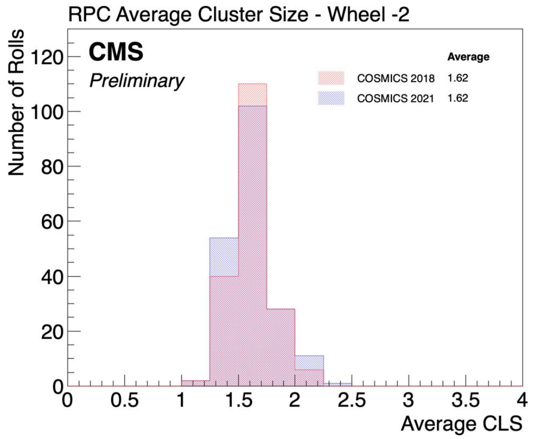
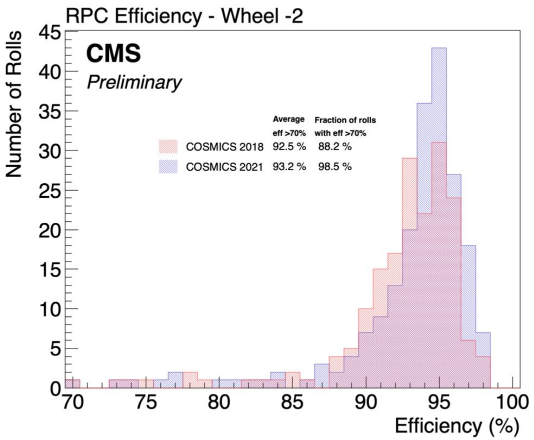
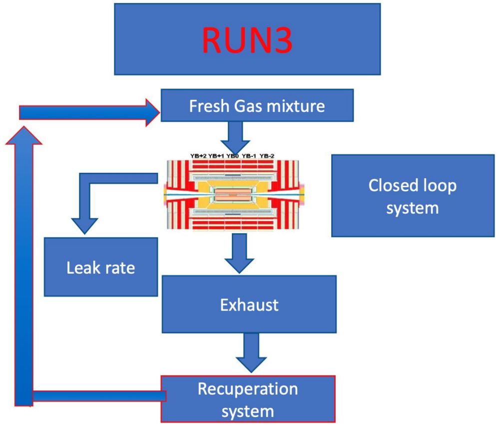
RPC Performance

After all interventions done in LS2, the performance of the detector now is improved w.r.t end of RUN 2. The left plot shows that the efficiency increased more than 6 % if we compare 2018 and 2021 for full barrel. Is worth to mention that these data were taken with cosmic runs. Also, the right plot shows that the cluster size is in accordance with the expected value. As already mentioned in the gas repair section, 49 out of 99 gas leaky RPCs were repaired. Besides that, aiming to minimize the environmental impact of the RPC gases, as $C_2H_2F_4$ and SF_6 have a very high global warm potential (GWP), the CERN EP-DT gas team have developed the first $C_2H_2F_4$ recuperation system with efficiency of 80 %. The schema can be seen on the right. In order to minimize the GWP for RUN 3, the RPC plan to turn off all the leaky chambers (3.5 % of total system), reducing the gas leaks from 900 to ~ 200 l/h. This will be done exactly as it is being shown in the same schema.









Conclusions

After operation in extreme conditions during RUN 1 and RUN 2, the RPCs shows a stable performance, with average efficiency around 95 % and average cluster size around 2 strips. The interventions done in LS2 were crucial to improve system's performance, as well as, to reduce the RPCs greenhouse gases (GHG) emission in the environment during RUN 3 data taking.

References

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[3] CMS collaboration, The Phase-2 Upgrade of the CMS Muon Detectors, Tech. Rep., CERN-LHCC-2017-012, CMS-TDR-016, CERN, Geneva (2017).