CMS RPC Activities During LHC LS-2

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Abstract

The second LHC long shutdown period (LS2) is an important opportunity for CMS Resistive Plate Chambers (RPC) to realize their consolidation and upgrade projects. The consolidation includes detector maintenance in terms of gas tightness, HV, LV and slow control operation. All services for the RPC Phase-II upgrade, namely RE3/1 and RE4/1, were anticipated for installation to LS2. The upgrade of the gas system comprises big pipework from the service through the experimental cavern and up to the CMS detector as well as significant modification of some of the existing gas racks. The cooling system for the RE4/1 detector is branched off from the existing YE3 mini manifolds while the RE3/1 chambers will be connected in series with the existing RE3 cooling loops. Thousands of kilometers of HV, LV cables and optical fibers are to be installed for servicing the new detectors and reading their signals. For optical fibers it is foreseen to carry out quality control tests before and after installation (in situ) using an optical time-domain reflectometer (ODTR). The hardware including racks, crates, power distribution boxes, service and communication lines for the upgrade power system should be prepared during LS2. HV and LV power board upgrade is planned for LS2 in view of replacing already obsolete or to-become-obsolete components and be ready for a post-LS2 production.

1. RPC Performance during RUN-2

Fraction of inactive channels during 2018 was 3.5% due to:

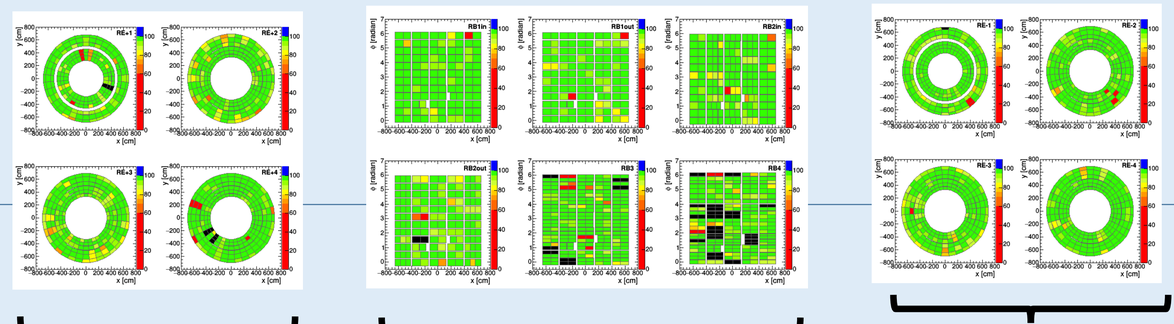
- 26 leaky (barrel) chambers, disconnected from the gas in order to reduce the leak rate + 6 OFF for LV/HV issues.

Chambers with lower efficiency:

- 50 RPC are working in single gap mode (HV connector problem)
- 22 RPC with no properly threshold setting due to the failure of the LV distribution board

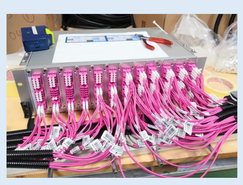
CMS is undergoing an intensive upgrade and maintenance program during the current two-year break ("Long Shutdown 2" or LS2) in order to ensure an excellent performance of the detector in the subsequent physics program. RPC group is profiting this shutdown to perform every possible maintenance for the problems explained above.

Figures represents efficiency map of entire RPC system (1056 chambers) as measured with 2018 data (60fb^{-1}). Full performance results can be found in [1].

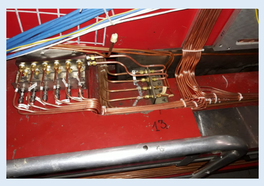


2. Upgrade Services

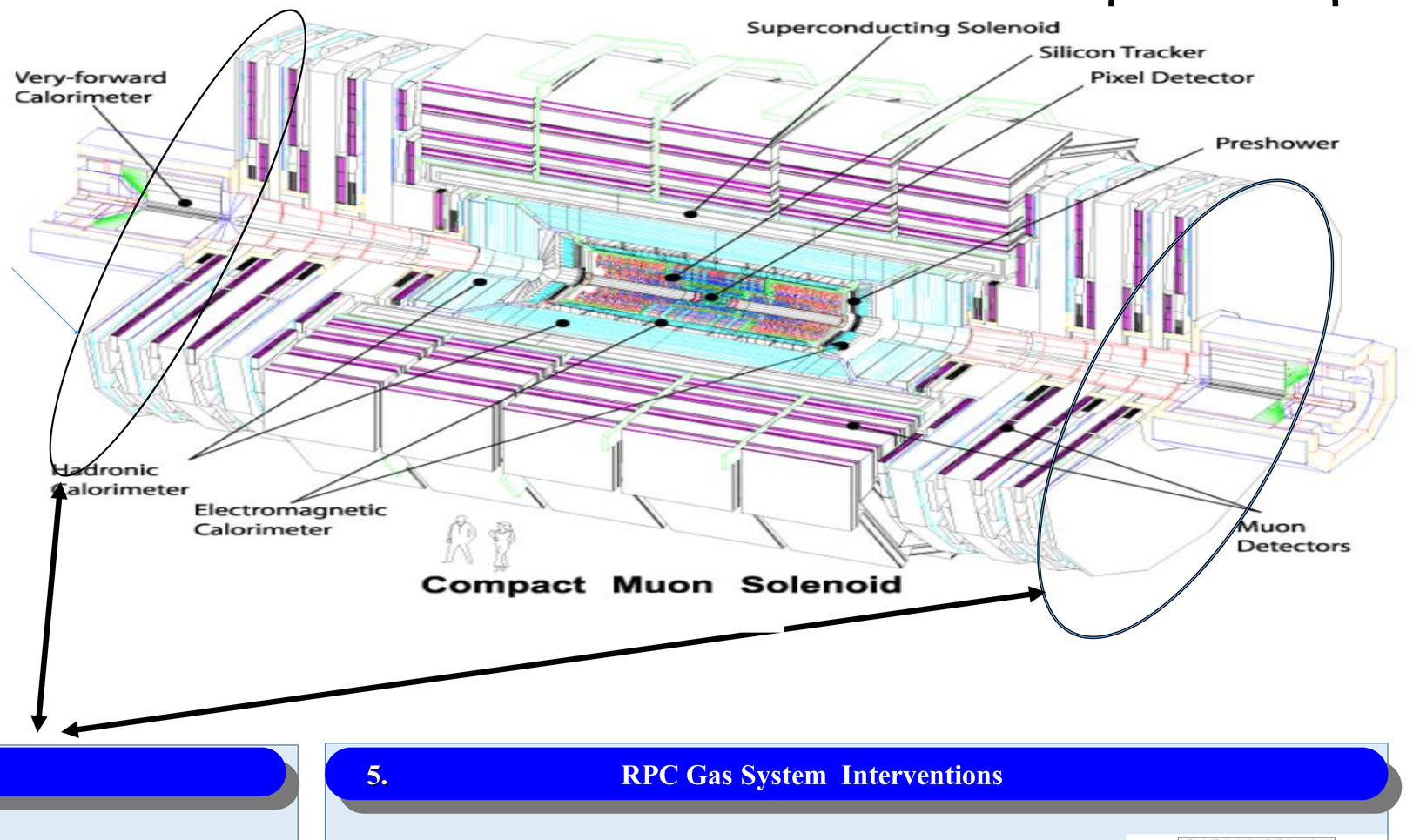
One of the ongoing activities during LS2 is to install thousands of kilometers of HV, LV cables, support equipment, gas pipes from gas distributor racks to the chambers and optical fibers for servicing and reading the signals of new detectors (iRPC) which are to be installed in the inner most ring of endcap stations 3 and 4. For optical fibers it is foreseen to carry out quality control tests before and after installation (in situ) using an optical time-domain reflectometer (ODTR). Installation of services of RE-3/1 and RE+4/1 is already completed.



Fiber Optics for upgrade



Gas services for RPC upgrade

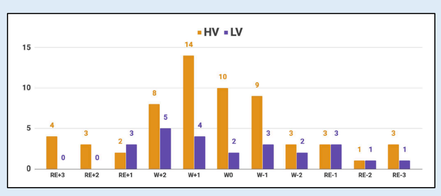


3. HV/LV Maintenance

A key factor of and RPC performance is the applied high voltage (HV). The CMS RPC achieve their optimal performance with, around, 9.5 kV applied in each gap. The goal for the HV maintenance is to identify which part of the HV supply system is causing the current leak and fix it the best possible way.

The low voltage (LV) and control maintenance aim is to make sure that the Front-End Boards (FEBs) are powered and configurable, which means the LV power system is working from supply board to the cable, signal cables are in good state and properly connected to the chambers and link boards, and on-detector electronics including FEBs and Distribution Boards (DBs) are working fine.

Around 50% of HV and LV problems have been recovered.



HV/LV Problems distribution

4. RE4 Interventions

One of the key interventions during LS2 is to dismount 72 super modules(SM) from two RE4 stations (in the external disks of CMS or "endcaps") for maintenance and to create the space for partner muon detectors (CSC) extraction for their electronics upgrade. The first intervention on this campaign was done from the 12th to 22nd of March 2019 by extracting 36 SM from RE+4 station [2]. The extraction of RE4 super modules of about 4 meters long and weight of 230 kg each was challenging. This was the very first extraction of this type of modules as the 4th Endcap station was installed during LS1 and none of the SM has ever been extracted.

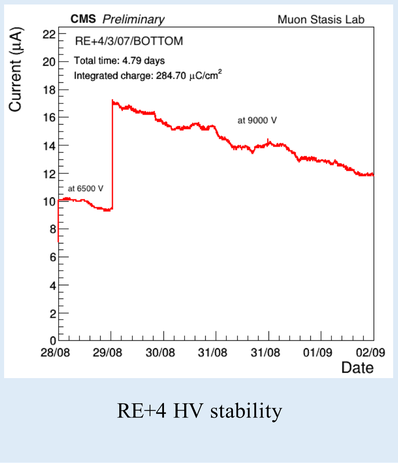
A new lab with a controlled environmental conditions was built on CMS LHC P5 surface to house extracted RE4 stations . A new gas mixture was prepared by CERN Gas Group to flux RE4 chambers. All of this parameters are monitored in the newly developed WebDCS RE4 interface system.

RE4 dismounting

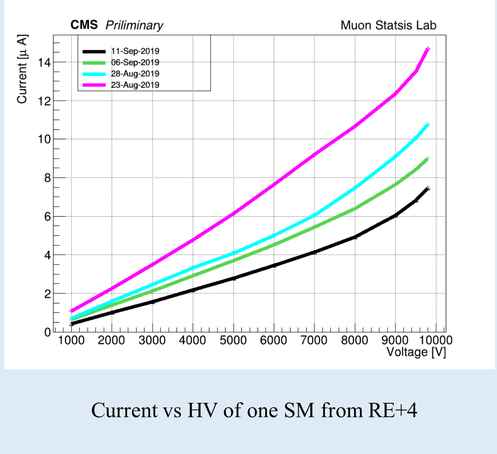
Muon Stasis Lab

When powered at the surafce, currents were found higher. Possible reason could be the different environmental conditions. Also these chambers were in open air for several months. With keeping the chambers under HV stability currents found decreasing to the nominal values as shown in plots below. A procedure was developed and all chambers went through this recovery conditioning for 4 weeks. Only one chamber disqualified due to high currents which is replaced with a spare one.

Dedicated noise scans were also performed to spot any dead or noise strips and functionality of front boards (FEBs). All FEBs which found faulty were replaced with spare ones.



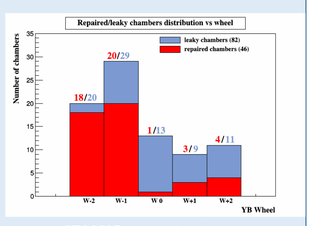
RE+4 HV stability



Current vs HV of one SM from RE+4

5. RPC Gas System Interventions

Gas leak was identified in 82 barrel RPC chambers due to cracked or broken pipes. The RPC leak repair campaign has given the highest priority during LS2. Dedicated tools have been built for this purpose for partial extraction and cutting the covers after identifying the exact location of leak using an endoscope. Activity is ongoing and plot below represents the current status of repair in 5 barrel wheels.



HV/LV Problems distribution

5.1 RPC Gas system consolidation

In order to minimizing pressure variations in the chambers, possible source of new leaks, two modifications on the gas system are ongoing:

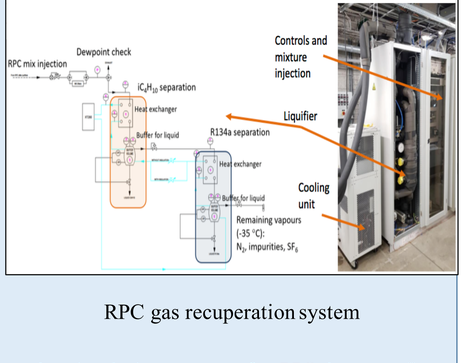
1. Pressure regulation valves
   - Automatic valves will be added to the manual return-manifold-rack-pressure-regulation valves in order to reduce chamber pressure variations and equalize pressure between different zone of detector (crucial in particular during gas refill procedure after YETS or LS)
   - 3 type of prototypes installed and tested in November 2019 (ASCO, GULES and Burkerd)
2. Dummy chambers
   - The pressure used to control the new automatic valves will be measured by using dummy chambers instead of, as it is now, real chambers (regulation not possible in presence of leak in chamber).

5.2 $C_2H_2F_4$ recuperation system

CERN EP-DT Gas team is currently carrying out an R&D to develop the first $C_2H_2F_4$ recuperation system:

- ✔ Prototype0 installed in CMS in December 2019 and connected to RPC exhaust.
- ✔ The system is running since J anuary 2020. Preliminary results:
  - started flowing ~ 300 l/h
  - recuperation efficiency about 100%
  - recuperated $C_2H_2F_4$ contains some impurities of iC_4H_{10} or SF_6 (under study)

Increase of total gas mixture flow up to ~ 1000 l/h and understand source of the and re-use of recuperated $C_2H_2F_4$.



RPC gas recuperation system

Full details can be found in Roberto's talk "Development of new gas recuperation and recirculation systems for RPC detectors"

References

[1] M. A. Shah et al., " The CMS RPC detector performance and stability during LHC RUN-2 ", Journal of Instrumentation, Volume 14, November 2019
[2] https://cms.cern/news/resistive-plate-chambers-are-getting-dolled?fbclid=IwAR1qk01xa_htuvxrvFrWcTZ-9YeXoPJkH9GCsi2GDECPy7ziPS8C29mfZWk

Conclusion

In the coming months, detector experts will work hard to consolidate the RPC detector and gas system for future operations. All the repaired components will be installed, commissioned and tested in order to prepare the detector for excellent data delivery once the LHC resumes operation in 2021.