Overview of the CMS RPC upgrade program

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The Resistive Plate Chambers (RPC) system will be upgraded to sustain the harsher HL-LHC conditions and to help maintain good trigger efficiency and performance of the CMS experiment. The present RPC chambers would continue to operate and a new link system will be installed improving the timing resolutions of the RPC system up to 1.5 ns to cope with the expected higher background. The communication rate with the readout electronics will be increased to 10.24 Gbps. Readout and control electronics will also be upgraded. Boards with customized FPGA will be installed to process data from the experimental cavern and distribute it to the CMS trigger and DAQ systems. Coverage of the RPC system will be increased to a pseudorapidity of 2.4 by installing a new generation of improved RPC chambers (iRPCs), which are equipped with new electronics designed for 2-dimensional readout. The status of the RPC upgrade project will be presented.

The CMS RPC Upgrade Program

To operate on HL-LHC conditions and to help maintain good trigger efficiency and performance of the CMS experiment, the RPC team has been working on two major upgrades: the replacement of the current Link System and the extension of the RPC coverage from |η|=1.9 up to 2.4.

To extend the RPC coverage an improved version of the RPCs (iRPCs: RE3/1 and 4/1) will be installed in the forward region of the 3rd and 4th endcap disk as can be seen in Figure 1.

The readout and control system will be also redesigned to deal with CMS Level-1 Trigger Phase-2 design.

The upgrade [1] will allow improvements of the RPC system to trigger and reconstruction, as well as an improvement of the RPC time resolution, which is essential in the HL-LHC phase.

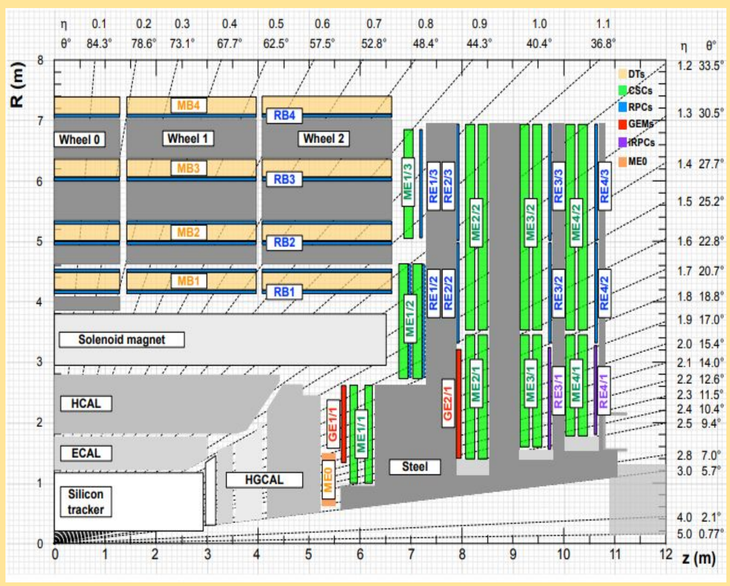

Figure 1: A quadrant of the CMS Experiment. The Muon System is indicated.

Link System Upgrade

The data from the RPC front-end boards are sent to trigger and readout via a Link System, which consists of 1592 electronics boards, divided into the Link boards(LBs) and Control Boards (CBs).

The new link system is being developed around the use of modern components and Field Programmable Gate Array (FPGA), following a radiation hard design. The new FPGAs can process several signals from many RPC detectors in parallel and the data transmission rate between the new Link system and RPC back-end electronics will increase to 10.24 Gbps while the resolution of the Muon hit time improves to 1.5 ns.

These improvements will provide several advantages:

- background hits arriving out of time can be identified and removed,
- triggering on slow heavy stable charged particles becomes possible, and
- the synchronization of the RPC system is facilitated.

This is achieved by (1) using GTX transceivers of the FPGA, plus preprocessing of data, and (2) implementing a high resolution 96-channel Time-to-Digital Converter (TDC) in the link board FPGA.

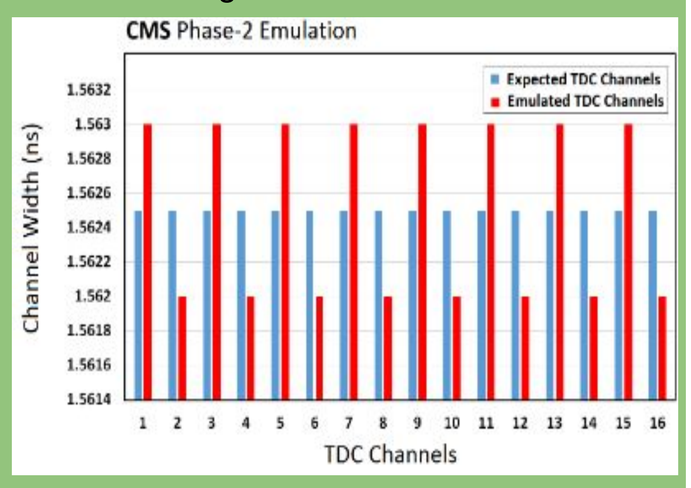

Figure 2: The performance of implemented TDC.

Each TDC channel consists of 16 bins with a time scale of 25/16 ns. Figure 2, shows the emulated channel width, in agreement with the expected 1.56 ns [2].

Readout and Control System Upgrade

In order to be in agreement with the CMS Level-1 Trigger [3], the readout and control system of the RPC system will be redesigned to: (1) include readout and control of new hardware; (2) cope with the requirements of the CMS Level-1 Trigger Phase-2 design; (3) sustain maintainability of the system by replacing obsolete hardware.

The new readout, control, and monitoring hardware will be installed in the CMS Services Area and will follow the CMS specification of common hardware platforms for Phase-2, specifically, Serenity boards [4].

The Barrel RPC hits are expected to be distributed to a common CMS Barrel (RPC + DT) hardware, while the Endcap and iRPC hits will be directed to dedicated RPC boards. Those hits will later be distributed to CMS Muon Track Finders and DAQ.

Improved RPC

The iRPC chambers will be installed in stations 3 and 4, complementing the already existing Cathode Strip Chambers (CSC). This detector upgrade is driven by the necessity to increase the number of hits per muon track up to |η| = 2.4. By reading out signals from both ends of the RPC strips, an excellent time resolution of ~1.5 ns, and much improved hit localization in the radial direction (~2 cm) can be achieved [1].

The CSC system can identify and trigger muons in the endcap region with high efficiency, but there are “dips” of reduced trigger efficiency at some values of |η|, due to the presence of high-voltage spacers inside the CSC chambers. Including RPC hits into the trigger primitive stub finding algorithm helps to eliminate these dips. Figure 3 shows the efficiency of finding trigger primitive stubs at the level of station 3 and station 4, with and without the addition of the current RPC and new iRPC information.

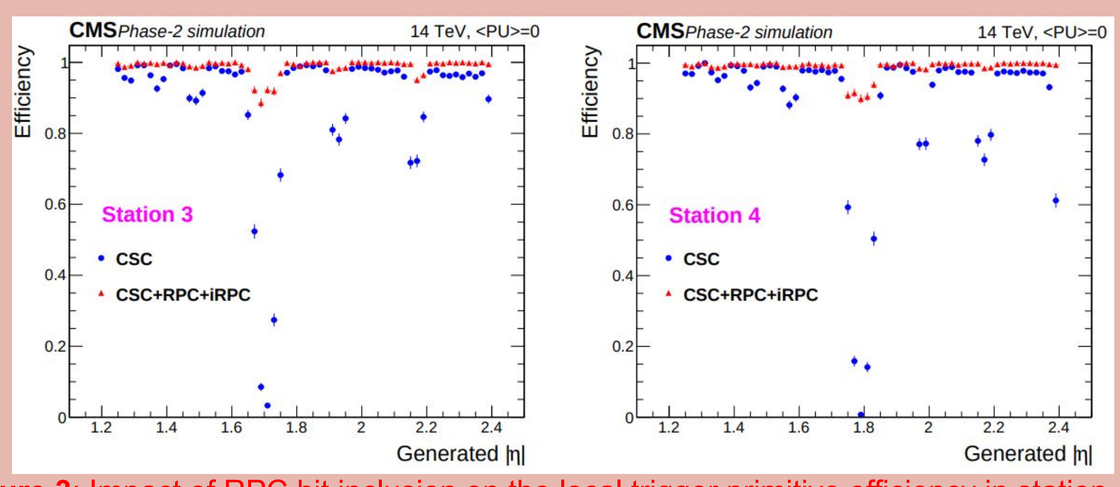

Figure 3: Impact of RPC hit inclusion on the local trigger primitive efficiency in station 3 (left) and station 4 (right). The contribution of iRPC begins above |η|=1.8.

Technical specification of iRPCs

The higher rate capability with respect to the current RPC detectors will be achieved by:

- shortening the recovery time of the electrodes
- reducing the total charge produced in a discharge

Specifications and details:

- thinner electrodes and a narrower gas gap (1.4 mm)
- double gap design
- reduced working point from 9.5 kV to 7.1 kV
- baseline choice of material: High Pressure Laminate (HPL), also called Bakelite
- electrode resistivity: 0.9 to 3.0×10^{10} Ω cm

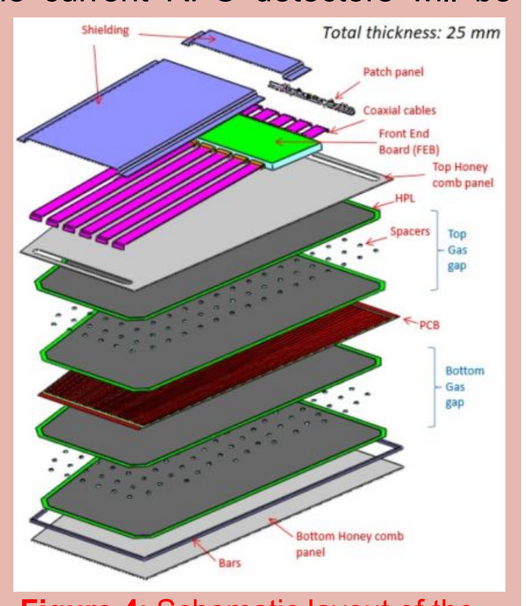

Figure 4: Schematic layout of the iRPC chamber.

For iRPCs, any possible aging effect will decrease due to the reduction of the integrated deposited charge. The new improved front-end electronics will offer higher signal amplification. Figure 4 shows the schematic layout of the iRPC chamber.

Conclusion

The prototypes of the upgrade activities described in this poster are expected to be installed in CMS for the Run3 data-taking, starting in 2022, for validation propose. The commissioning of prototypes is expected for the next year and irradiation tests are also planned.

References

[1] Thomas Hebbeker and Andrey Korytov. “The Phase-2 Upgrade of the CMS Muon Detectors”. In: (Sept. 2017).
[2] B Boghrati, V Amoozegar, M Ebrahimi, R Ghasemi, M Mohammadi Najafabadi, E Zareian, A Samalan, M Tytgat, N Zaganidis, GA Alves, et al. "CMS Phase-2 Upgrade of the RPC Link System". Journal of Instrumentation, 16(05):C05003, 2021
[3] Alexandre Zabi et al. “The Phase-2 Upgrade of the CMS Level-1 Trigger”. In: (2020).
[4] Andrew Rose et al. “Serenity: An ATCA prototyping platform for CMS Phase-2”. In:PoSTWEPP2018 (2019), p. 115.