CMS RPC Upgrade Program

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Abstract

The LHC will be upgraded in several phases that will allow significant expansion of its physics program. The luminosity of the accelerator is expected to exceed $5 \times 10^{34}\ cm^{-2}s^{-1}$. In order to sustain the harsher conditions and to help maintaining good trigger efficiency and performance the Resistive Plate Chambers (RPC) system of the CMS experiment will be upgraded. The present RPC system would continue to operate, and it would be upgraded with new Link Boards system. In addition, the coverage of the RPC system would be increased up to pseudo rapidity of 2.4 by installing a new generation of improved RPCs (iRPCs). Their design and configuration are optimized to sustain higher rates and hence to survive the harsh background condition during HL-LHC operation. The iRPC are equipped with newly developed electronics designed to read out the detectors from both sides, allowing in this way a good spatial resolution along the strips O(cm). The status of the upgrade project is presented.

CMS RPC Upgrade

The CMS RPC upgrade for Phase-2 [1] compreehends **(1) the replacement of a the current Link System**, which connects the Front-End Boards (FEBs) to the trigger processors, by a new one, redesigned from scratch and **(2) the extension of the pseudorapidity coverage of the RPC system**, by adding new chamber from $|\eta| = 1.9$ up to 2.4, namely stations RE3/1 and RE4/1. Those new chamber will be assembled with a Improved Resistive Plate Chambers (iRPC) technology, with does the readout of signals, in both ends of the strip. The timing difference per hit and strip, is used by the iRPC Front-End to estimate the spatial position of the hit in the longitudinal direction. The current RPC chambers can only read the transverse hit position.

Both upgrades are important in order to cope with expected high rate of the HL-LHC scenario, in which a Inst. Luminosity of $5 \times 10^{34}\ cm^{-2}s^{-1}$ would provide a bckground ate of up to 700 Hz/cm^2 (already including a safety factor of 3). Also, the upgrades woiuld enhance the redundancy of the CMS Muon System, resolve ambiguities in the endcap triggering and allow improvements of the RPC system to Trigger and reconstruction. Figure 1 presents a quadrant of the CMS Muon system, showing Drift Tubes (DT) chambers in yellow, RPCs in light blue, and Cathode Strip Chambers (CSCs) in green. The locations of new forward muon detectors for the HL-LHC project are indicated in red for Gas Electron Multiplier (GEM) stations (ME0, GE1/1, and GE2/1) and violet for improved RPC stations (RE3/1 and RE4/1).

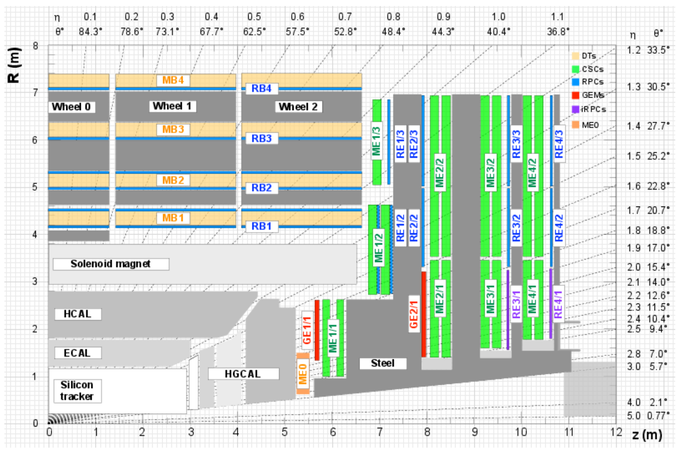


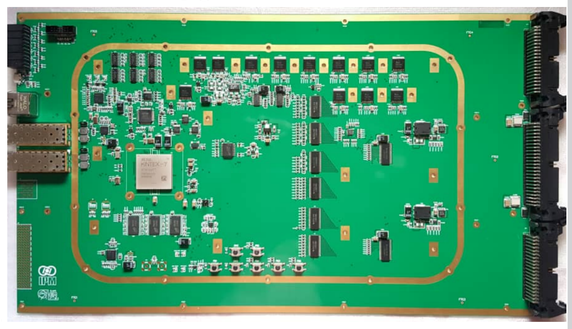
Figure 1: CMS Muon system for the Phase-2 Upgrade.

New Link System

In the CMS experiment, the RPC chambers are readout, controlled and monitored through the Link System, which consists of 1592 electronics boards, divided in two kinds, known as the Link boards (LBs) and Control Boards (CBs), LBs can work as Master LB of Slave LB.

The HL-LHC high rates will required an increase of the available TX bandwidth and time readout time resolution. The new link system is being developed around the use of modern components and FPGAs (Field Programmable Gate Array), following a radation hard design. **The data transmission rate between the new Link system and CMS back-end electronics increases to 10.24 Gbps and resolution of the Muon hit time improves to 1.5 ns**, close to the RPC chamber instrinsic resolution, which is achieved by implementeing a high resolution 96-channel Time-to-Digital Converter (TDC) in the link board FPGA. Each TDC channel comprised of 16 bins where each bin had a time scale of 25/16 ns. The experimental results showed that there existed a 1.56 ns resolution for the implemented TDC channels.

Figure 2: A RPC Link Board prototype for Phase-2 Upgrade.



Conclusion

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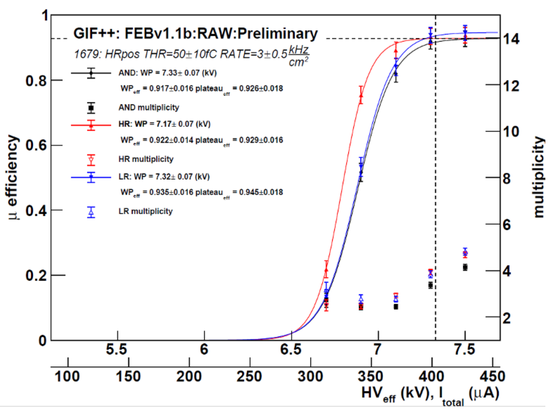
iRPC FEB

Bla bla bla ...

Figure 3: A capition for iRPC FEB.



This plot shows s-curves with dependencies of Muon Efficiency versus High Voltage Effective (HVeff) for the second version of FEB with PETIROC2B (FEBv1b). Also, this slide showing the mean value of multiplicity for each side. AND efficiency showing without crosstalk impact. Data was taking during GIF++ (ATT=3.3) cosmic tests (September-November 2019). Scintillators placed in the HR of the chamber and covered about 20cm. This setup includes three protected with leads scintillators inside GIF++ (without outside scintillators) HR: 500-480=20DACu. (50±10fC)

LR: 500-480=20DACu (50±10fC)

HIGH VOLTAGE EFFECTIVE (X-axis)

Effective HV takes into account the change in pressure and temperature with respect to an HV reference value V0 at given pressure P0 and temperature T0.

Bla bla bla ...

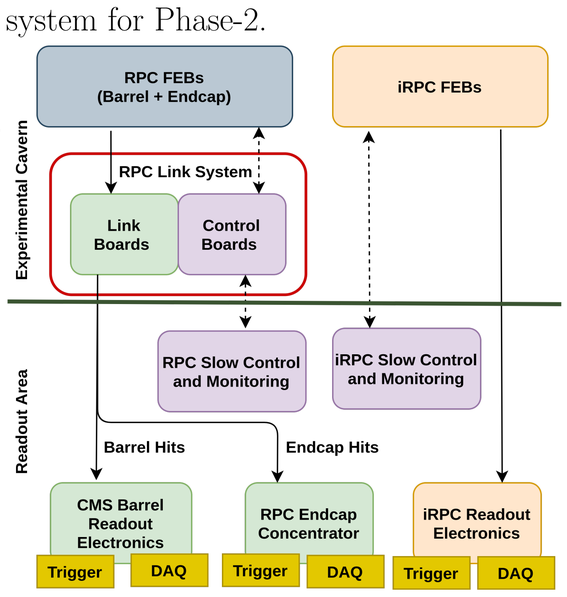
Readout and Control Electronics

An extensive Phase-2 upgrade program is also scheduled for CMS Level-1 Trigger [2]. Since RPC is the only Muon detector present in both CMS Barrel and Endcap region, its contribution to CMS Level-1 Trigger upgrade program is relevant.

The readout and control system (also called back-end) of the RPC (Figure 4) system will be redesigned in order to **(1) include readout and control of new hardware; (2) cope with the requirements of the Level-1 Trigger Phase-2 design; (3) sustain maintenability of the system by replacing obsolete hardware.**

The new readout, control and monitoring hardware will be installed in the CMS Services Area, away from CMS radiation, and will follow the CMS specfication of common hardware plataforms for Phase-2, specifically, Serenity boards [3], with ATCA form factor. Its links will be composed by Slow Control/Monitoring channels (dashed lines) and readout channels (solid lines). Barrel RPC hits are expected to be distributed to a common CMS Barrel (RPC + DT) hardware, while endcap and iRPC hits will go to dedicated RPC boards. Those hits will later be distributed to CMS Muon Track Finders and DAQ.

Figure 4: RPC readout and control system for Phase-2.



Demonstrator

Bla bla bla...

References

[1] Thomas Hebbeker and Andrey Korytov. "The Phase-2 Upgrade of the CMS Muon Detectors". In: (Sept. 2017).

[2] Alexandre Zabi et al. "The Phase-2 Upgrade of the CMS Level-1 Trigger". In: (2020).

[3] Andrew Rose et al. "Serenity: An ATCA prototyping platform for CMS Phase-2". In: *PoS* TWEPP2018 (2019), p. 115.