Performance of the improved RPC demonstrators for the CMS Phase II upgrade

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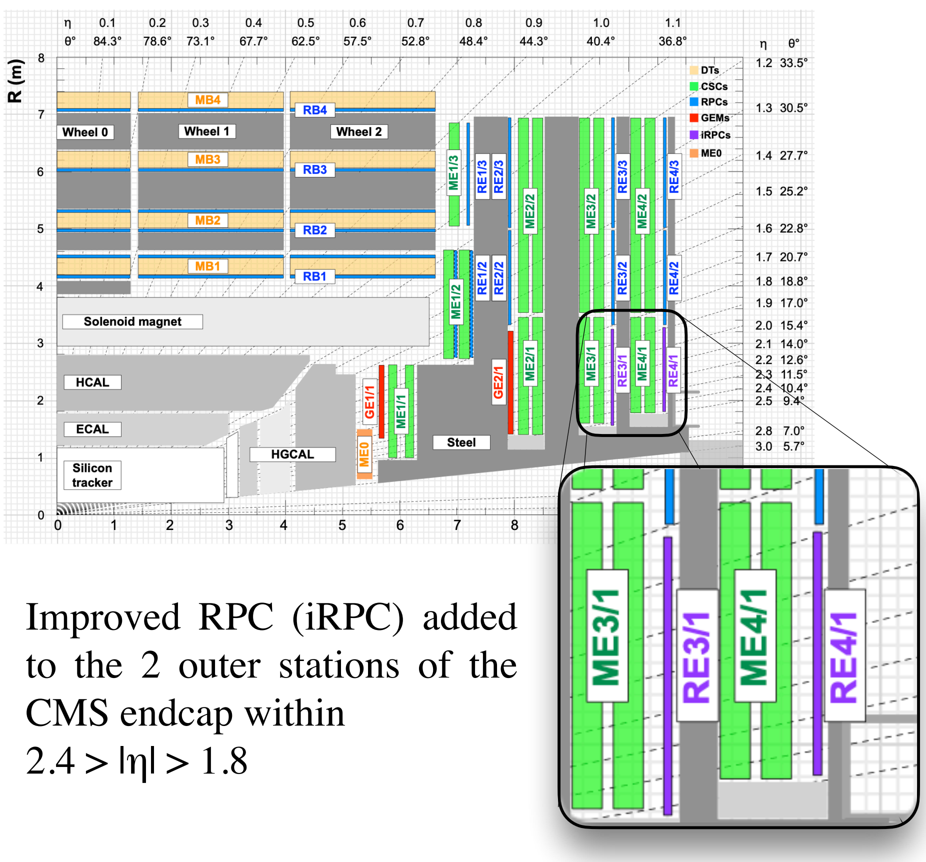
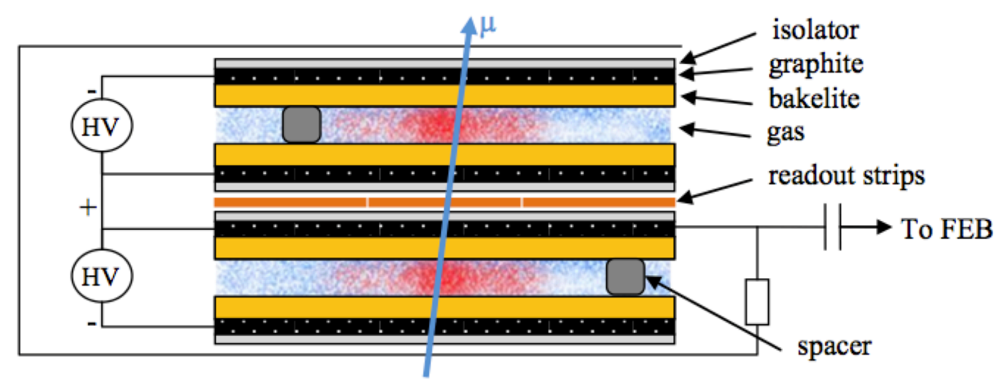
1.Motivation

In order to cope with the high particle rate and high pileup environment of the HL-LHC, the CMS collaboration proposed[1] installation of new RPCs.



Improved RPC (iRPC) added to the 2 outer stations of the CMS endcap within 2.4 > |η| > 1.8

2.The iRPC Chamber



Double-gap iRPC detectors with each gap made of two 1.4 mm low-resistivity High Pressure Laminate electrodes are separated by a gas gap of the same thickness.

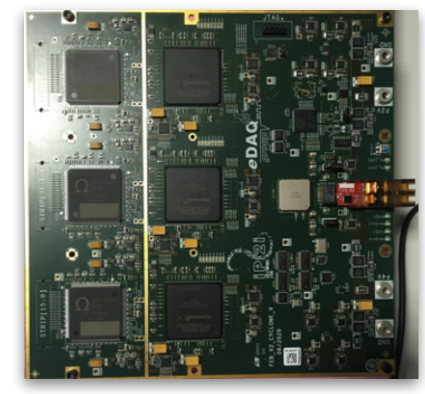
The new layout reduces the amount of the avalanche charge produced by the passage of a charged particle through the detector. This improves the RPC rate capability by reducing the needed time to collect this charge.

3.The Front End Board

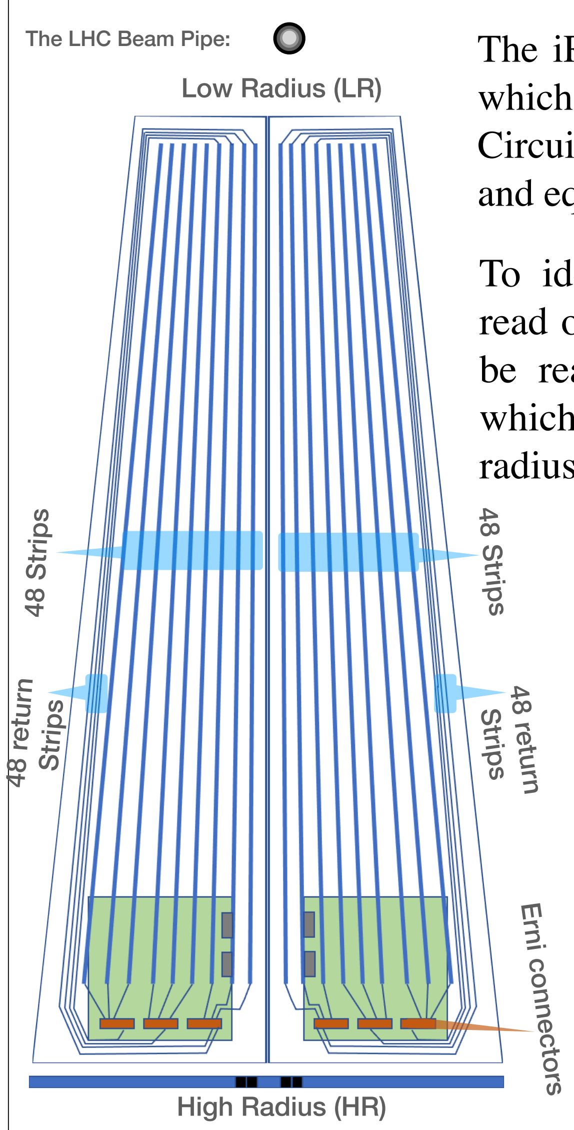
To cope with the lower charge signal of the iRPC at the same time to keep the iRPC efficiency high, the new front-end electronics (FEB v2.2) are designed. The new FEB is sensitive, has low-noise and high time resolution.

The FEB v2.2 composed of :

- 3 Erni connectors with 32 channels each
- 6 ASICs PETIROC[2] 2C (top & bottom)
- 3 FPGAs Cyclone V (non rad-hard)
- GBTx/ GBT-SCA/VTRx



4.The iRPC readout principles



The iRPC is equipped with two readout panels which are made of a thin (0.6 mm) Printed Circuit Board (PCB). Each PCB has 48 strips and equipped with a FEB.

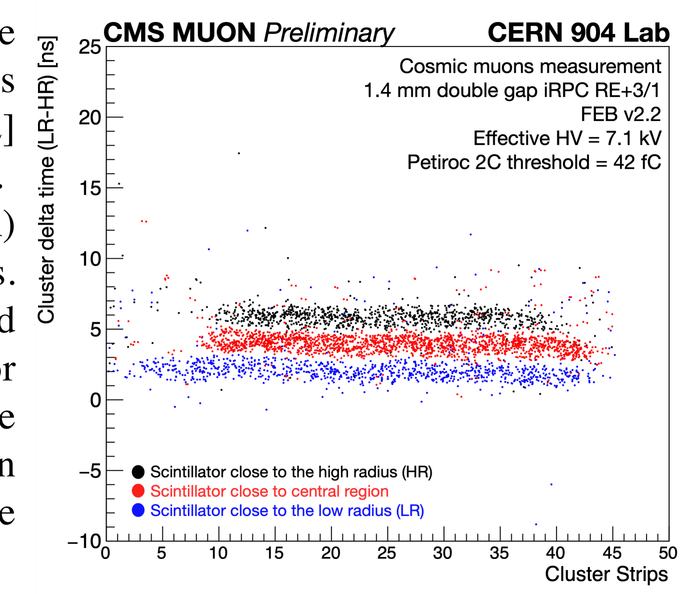
To identify the position along the strip, the read out of the iRPC detectors are designed to be read out from both sides of a strip end which are called low radius (LR) and high radius (HR), using timing information.

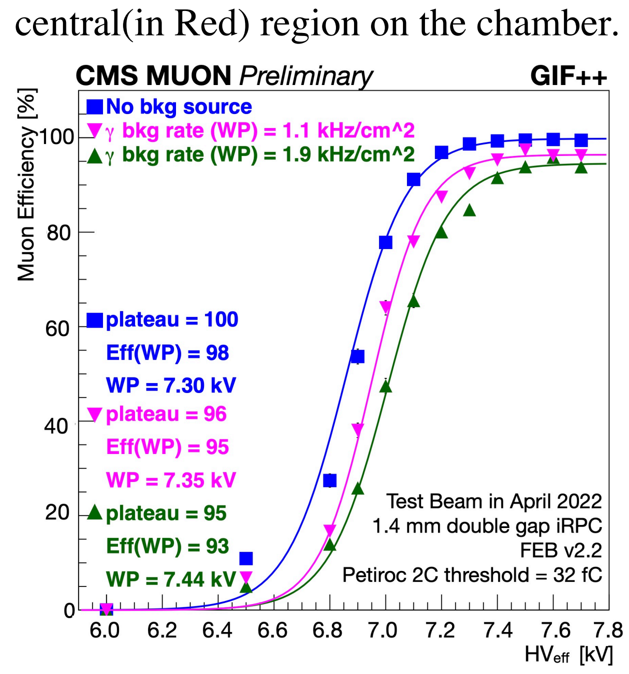
3 Erny connectors for each of the FEB reads in total 96 channels. In FEB v2.2 each of the 2 ends of a strip is connected to a different PETIROC.

When the amplitude of the signal generated by a particle crossing the detector is higher than the threshold of the channel, the PETIROC sends an output signal to the associated TDC channel. The position of the particle hit along the strip is obtained by measuring the difference between the two signal arrival times (ΔT)[4].

5.Performance of iRPC with/out background radiation

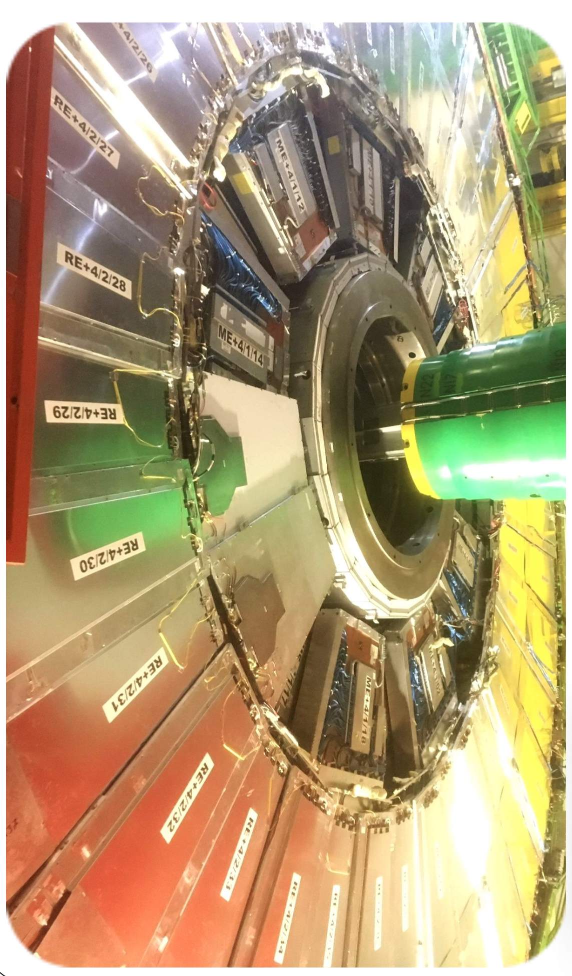
The iRPC detector's performance studies have been carried out in the CERN 904 Laboratories and Gamma Irradiation Facility (GIF++) [2] located on one of the SPS beam lines of CERN. The Figure on the right shows the ΔT(LR-HR) after clustering as a function of cluster strips. Three different colours represent the triggered hits after clustering where the scintillator coincidence adjusted to be located three different positions that are close to LR(in Black), close to HR(in Blue) and at the central(in Red) region on the chamber.





The Figure on the left shows efficiency as a function of effective high voltage (HV_{eff}) with(pink and green) and without(dark blue) background. At 1.1 kHz/cm² which is above the expected background rate of Phase II (~700 Hz/cm²), the efficiency at working point (WP) is measured as 95%. At the 3 times safe factor of back ground radiation (~2 kHz/cm²), the efficiency at WP is measured as 93%. The data is collected at the GIF++ during the April 2022 test beams. The 13 Tbq Cs^{137} is used as gamma source.

6.Performance of iRPC at the CMS



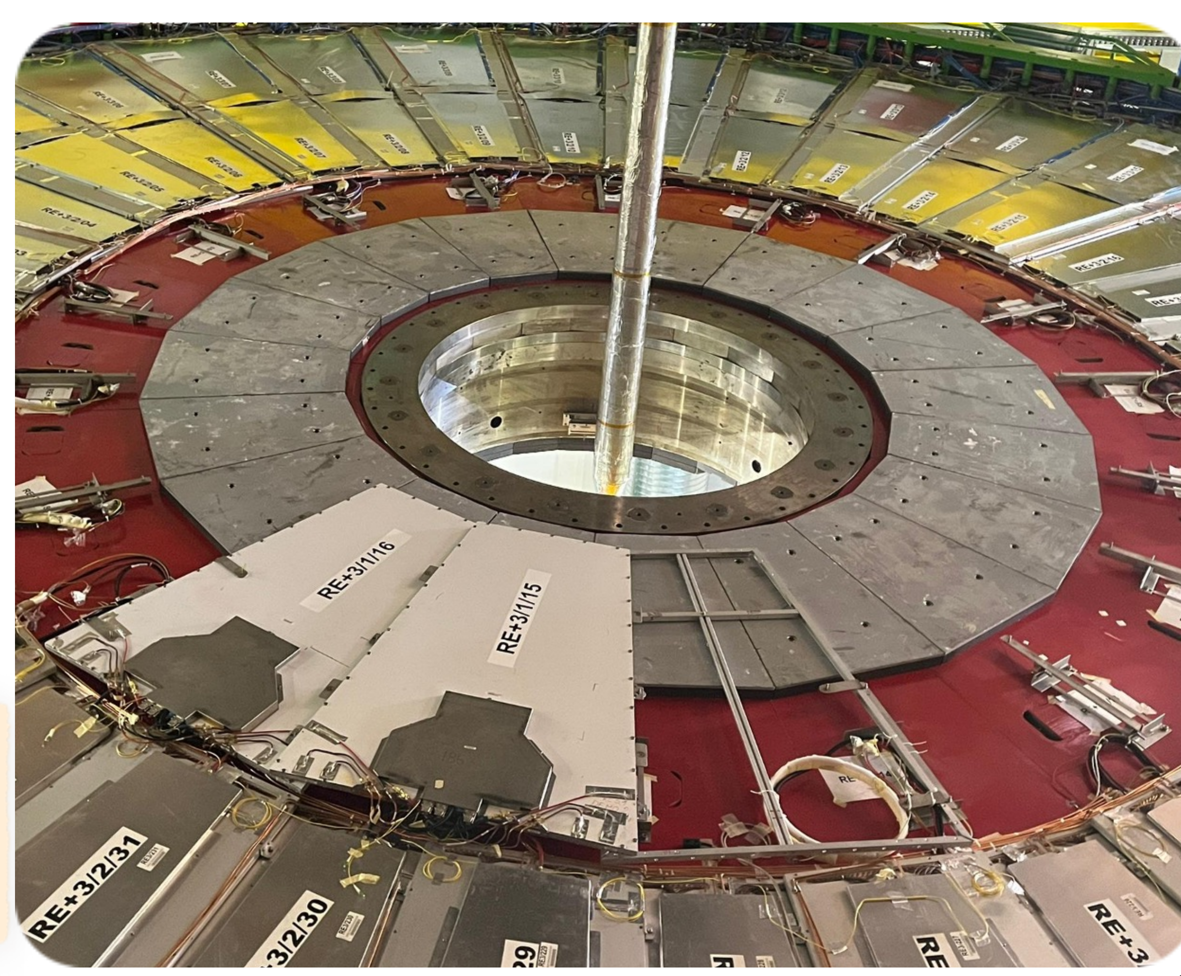
Four demonstrator chambers have just been installed in CMS cavern at the end of LS2. The picture on the left and right exhibit the final position of the demonstration chambers RE+4/1/15,16 and RE+3/1/15,16 respectively.

Recent commissioning of demonstrator chambers at CMS Cavern showed/confirmed:

- low noise (~1 Hz/cm²) with final CMS endcap disk grounding,
- normal/stable operation temperature in CMS endcap closed mode and CMS endcap water cooling,
- normal operation in 3.8T magnetic field

Conclusion

As a result of successful performance at CERN 904 Lab, GIF++ and at the CMS cavern, currently, demonstrator iRPCs are getting ready for taking data during Run3 to further validate the performance for Phase II operations.



References

[1] CMS Collaboration, "The Phase-2 Upgrade of the CMS Muon Detectors," *CERN-LHCC-2017-012*, No. CERN-LHCC-2017-012. CMS-TDR-016,(Sep 2017).

[2] R. Guida,"GIF++: The new CERN Irradiation Facility to test large-area detectors for HL-LHC," *2015 IEEE Nuclear Science Symposium and Medical Imaging Conference*, Vol. , No. , 1-4,(2015).

[3] Petiroc, a new front-end ASIC for time of flight application,"2013 IEEE Nuclear Science Symposium and Medical Imaging Conference," , Vol. , No. 1-5, 2013

[4] K. Shchablo, I. Laktineh, M. Gouzevitch, C. Combaret, and L. Mirabito. Performance of the cms rpc upgrade using 2d fast timing readout system. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 958:162139, 2020. Proceedings of the Vienna Conference on Instrumentation 2019.