RPC Clustering Algorithm and Hit Reconstruction

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One of the upgrades of CMS RPC system is the installation of new chambers - the improved RPC - with a new readout technology, achieving a space resolution along the strip of about ~2cm, enabling the inclusion of the RPC hit in the CMS muon reconstruction. The main characteristic of the iRPC is the two side strip readout which makes a new clusterization algorithm necessary. The algorithm was developed during the test beams at GIF++ and its implementation at CMS Software is under development. In this poster we present the main idea of the algorithm, the final hit reconstruction in the chamber, and the results obtained in the test beams.

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.

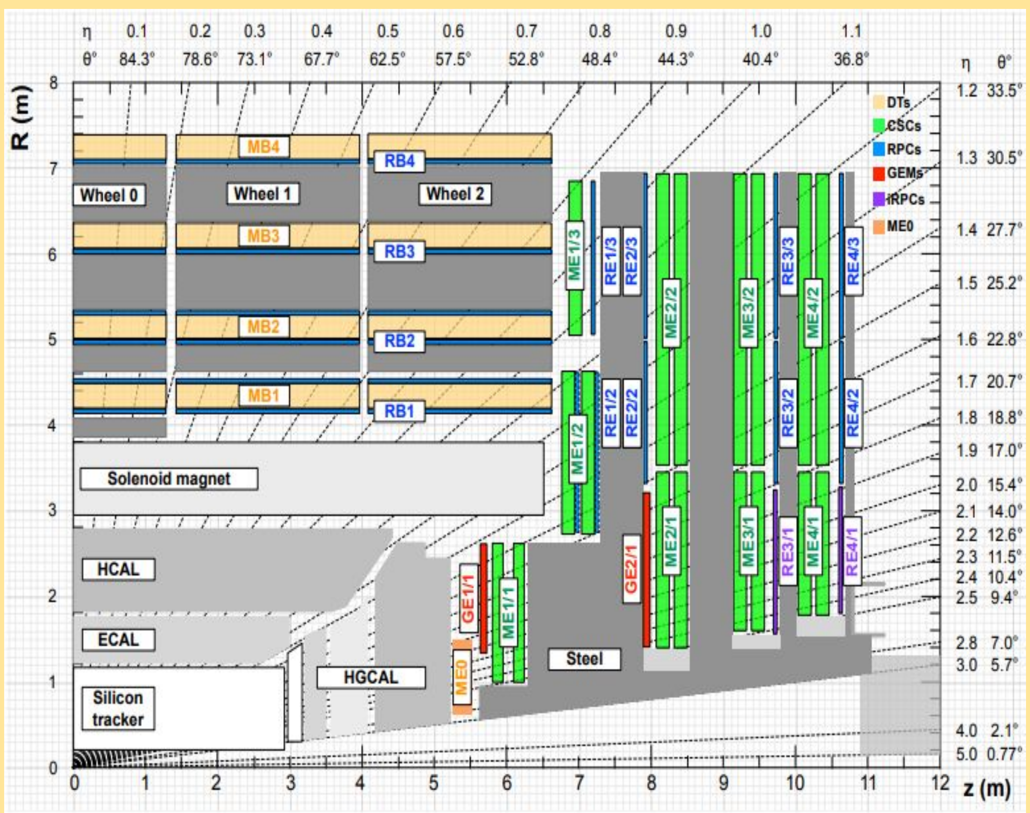

Figure 1: A quadrant of the CMS Experiment. The Muon System is indicated.

Improved RPC

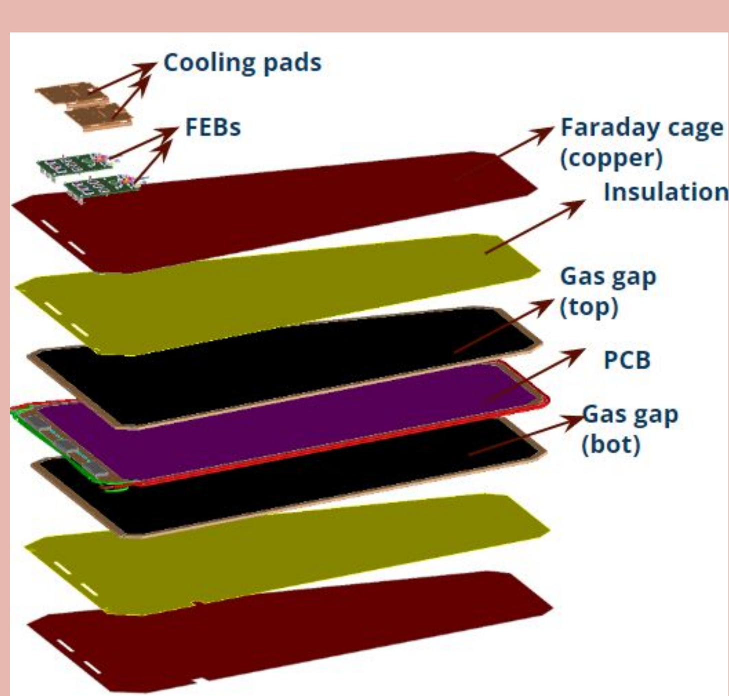

Figure 2: Exploded view of the iRPC

The iRPCs [2] are wedge-shaped double gas gap chambers, similar to the existing CMS-RPCs, with radially oriented readout strips positioned between the gas gaps. These gaps consist of two High Pressure Laminate (HPL) electrodes coated with a thin resistive layer of graphite, on Fig. 2 there is a exploded view of the iRPC. The thickness of both the electrodes and the gas gaps has been reduced from 2 mm to 1.4 mm.

Readout Principle

- iRPCs are equipped with 2 readout panels (PCBs): 0.6 mm thin, embedded with 48 strips, and equipped with a FEB [3].
- Three ERNI connectors of each FEB reads 96 channels. Each of the two ends of a strip is connected to a different PETIROC.
- If amplitude of the signal > channel threshold -> PETIROC sends an output signal to the associated TDC channel.
- The 2D position information is obtained by reading out the strips from both ends (Low Radius (LR) and High Radius (HR)) and then measuring ΔT.
- A detailed overview of the iRPC readout system can be seen on Fig. 3

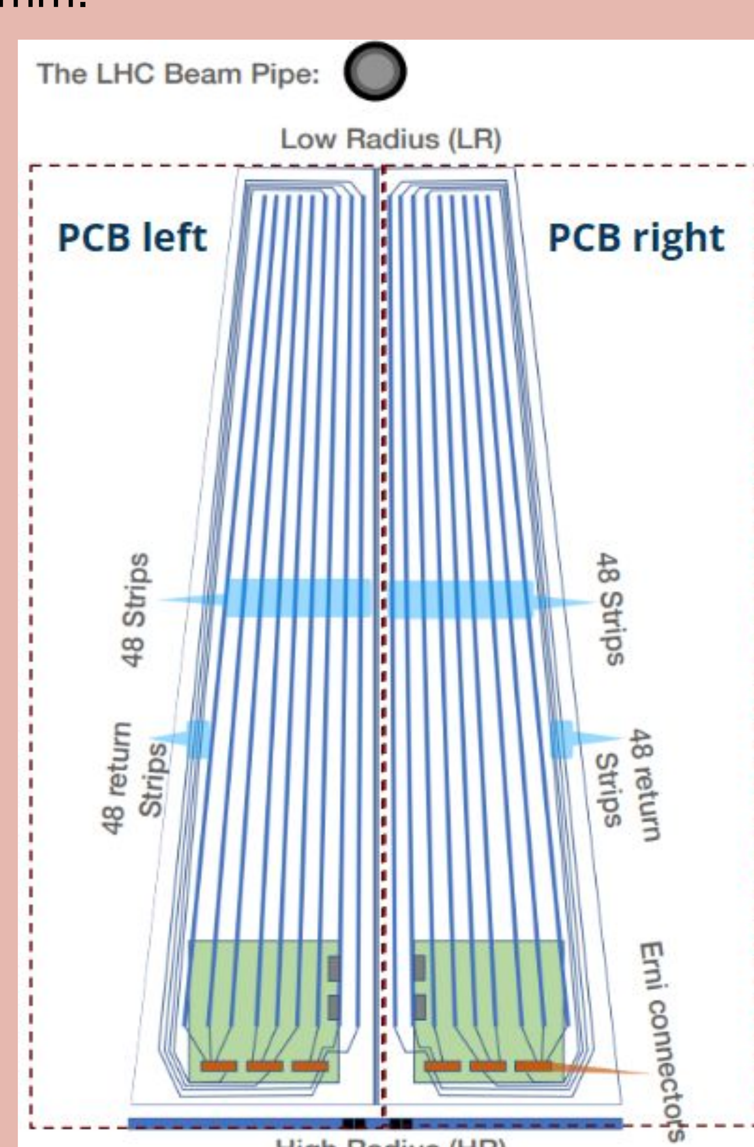

Figure 3: iRPC readout system overview.

References

[1] CMS Collaboration, The Phase-2 Upgrade of the CMS Muon Detectors, CERN-LHCC-2017-012 (2017).
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[3] CMS Collaboration, Front-end electronics for CMS iRPC detectors, JINST 16 (2021) C05002.
[4] R. Guida, GIF++: The new CERN Irradiation Facility to test large-area detectors for HL-LHC, IEEE Nuclear Science Symposium and Medical Imaging Conference (2015) 1–4.
[5] A. Samalan, M. Thiel, et al., Improved resistive plate chambers for HL-LHC upgrade of CMS, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 1060 (2024).

Clustering algorithm

The clustering process consists of three steps:

- **Step 1**: The signals are filtered to retain only paired signals, where each HR signal must have a corresponding LR signal in the same strip.
- **Step 2**: Signals from each readout side (HR and LR) are clustered separately, forming "one-side clusters."
  - The algorithm starts the HR(LR) cluster from the earliest HR(LR) signal.
  - Neighboring strips are added to the cluster if they meet the condition |ΔT(reference strip, neighboring strip)| < 3ns.
  - The process is repeated for the edge strips.
  - The position and time of the one-side cluster are defined as the average of the signals within the cluster.
- **Step 3**: HR and LR one-side clusters that match in strip number position with |ΔStrip(HR, LR)| < 1 are combined to form the final cluster.
  - The final cluster's strip number position is the average of the HR and LR one-side clusters.
  - The final cluster's ΔT is the difference in time between the LR and HR one-side clusters.
  - The cluster size is determined by the number of strips used in the clustering.
  - The final x-y cluster hit position will be evaluated with ΔT and strip number

Results

The algorithm was designed and validated during test beams conducted at the Gamma Irradiation Facility (GIF++) at CERN [4], utilizing the 150 GeV muon beam from the Super Proton Synchrotron (SPS) beam lines. Additionally, the facility features a 13 TBq 137Cs gamma source, which is employed to simulate various levels of gamma background.

Figure 4 shows the cluster size for the collected events that are outside muon window (mostly gammas) and inside muon window (mostly muons) at working point as a function of gamma background rates. The statistical uncertainty is present for the cluster size. The new front-end electronics (FEB v2.2) with Petiroc 2C ASIC was used. The detailed and extensive results of the iRPC test beams can be found in reference [5].

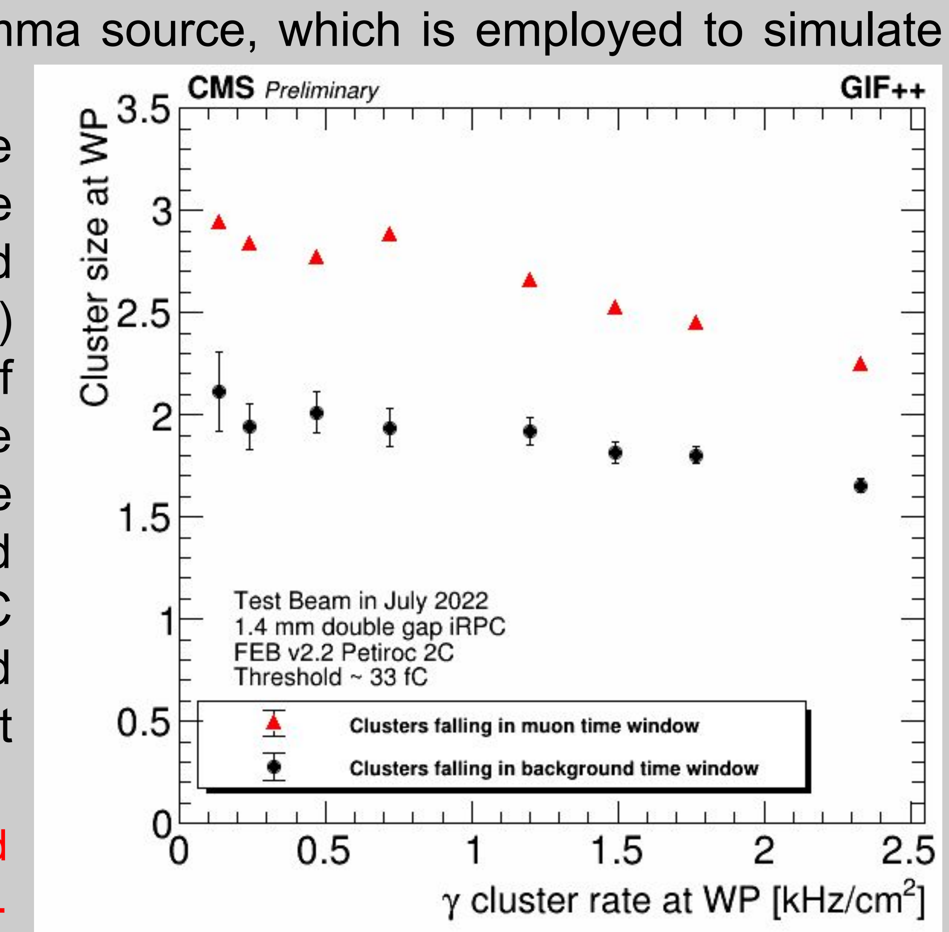

Figure 4: cluster size for the collected events during test beam at GIF++.

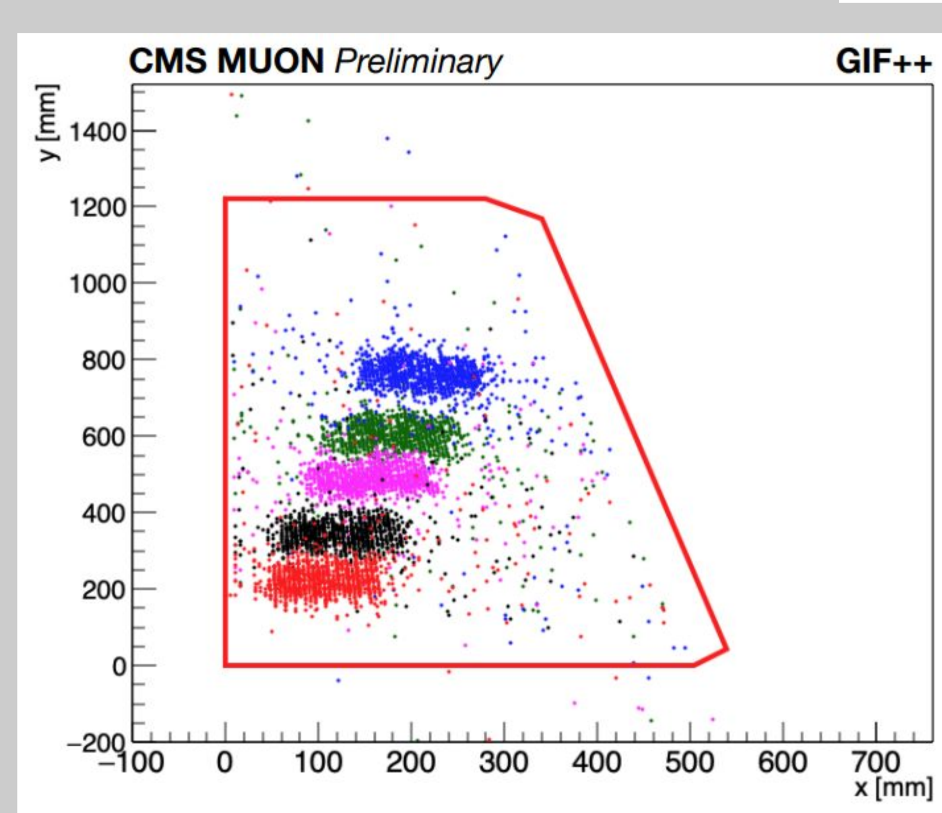

Figure 5 shows cluster hits on the chamber. To examine the chamber in different regions, the chamber was moved in respect to the scintillator used for triggering.

Figure 5: Cluster hits on the chamber, different colours represent data collected from different regions of the chamber.

Conclusion and Perspectives

Over the past years, the clustering algorithm has been developed and successfully validated using data from the GIF++ test beams. The cluster sizes match the expected results for both muons and gammas, and the shapes of the cluster hits correspond well with the format and size of the scintillator used for triggering.

This algorithm is now being implemented in the CMS Software (CMSSW) to handle RecHit reconstruction, aiming to be part of the final CMS-RPC hit reconstruction for the LHC Phase 2 period.

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