Report on RPC Performance Studies
(Summer Student Project 2022)

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Abstract

Performance studies related to the RPC detector at the CMS experiment have been done. The cluster size distribution of clusters sent to L1 Trigger before and after cleaning the noisy hits has been studied. The angular distributions of the offline DT and CSC segments, extrapolated to the RPC detector planes have been studied exploring different data streams.

Contents

1 Introduction

The main purpose of the CMS detector [1] design is to build a detector of moderate size that measure the particles born in collisions, optimised for measuring muons. To measure the particles momenta, CMS uses a solenoidal magnetic field of 3.8 T. The inner tracker and calorimetry systems are installed inside the coil, while the muon system is outside it. During Run 2 of LHC data taking, the CMS muon system was composed by four gaseous detector technologies – Drift Tube chambers (DT), Cathode Strip Chambers (CSC) and Resistive Plate Chambers (RPC) . A trajectory of a muon passing through CMS is shown in Figure 1.

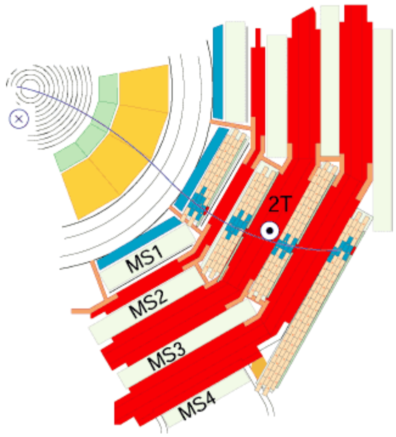

Figure 1: A muon trajectory in the transversal CMS plane (perpendicular to the LHC beams).

Resistive Plate Chambers (RPCs) [2] are fast gaseous detectors that provide a muon trigger system parallel to those of the DTs and CSCs. RPC has been chosen in both the barrel and endcap as dedicated trigger detectors. Because they have a fast response and good time resolution ($\sigma < 1.5ns$), they guarantee a precise bunch crossing assignment of the muon tracks. RPCs consist of two parallel plates, both made of a very high resistivity plastic material and separated by a thin gas volume as shown in Figure 2.

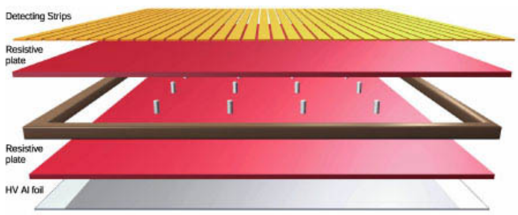

Figure 2: A schematic view of a resistive plate chamber

The CMS L1 trigger (Level 1 trigger) explores three different track finding algorithms to trigger muons. The track finders act in different pseudorapidity regions [3]. These track finders are: the Barrel Muon Track Finder (BMTF), Overlap Muon Track Finder (OMTF), and Endcap Muon Track Finder (EMTF). These track finders use Trigger Primitives (TP) from all muon detectors and try to identify patterns compatible with muon tracks and assign a transverse momentum to these candidates. This information is further processed on later stages to decide whether the event is kept or not. The RPC TPs are clusters of fired strips as a response to a single hit. RPC system participates in all the track finders since it covers both the barrel and the endcap as shown in Figure 3 (right) and sends hits to the corresponding firmware – TwinMux (in the barrel), CPPF (in the endcao), and OMTF (in the overlaped region) as shown in Figure 3 (left).

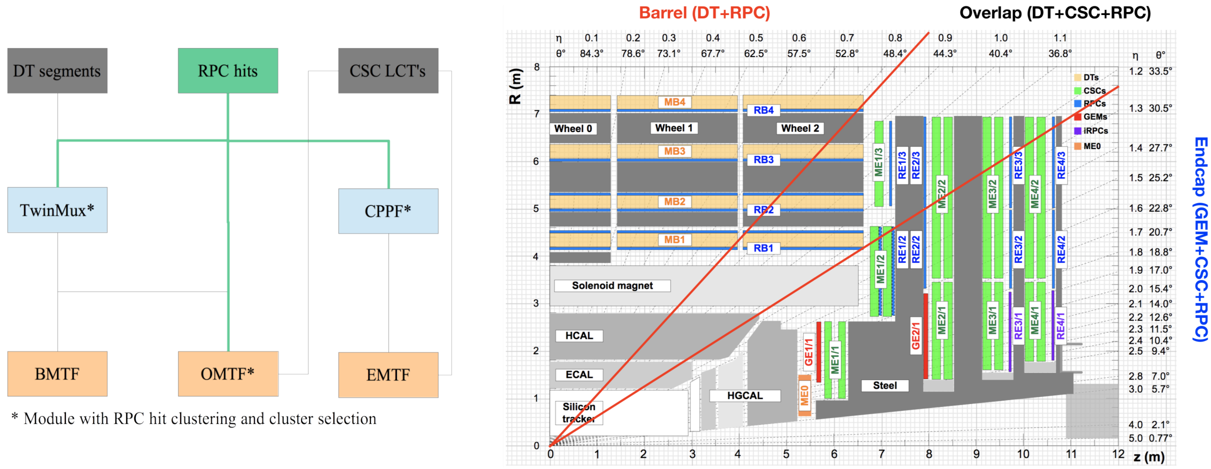

Figure 3: Left: Block diagram of the CMS Level-1 Muon Trigger architecture. Right: One quadrant of the CMS detector, with the Muon detectors in color.

2 Performance studies

2.1 RPC timing studies

The first part of my task was to study the algorithm that build common RPC + DT trigger primitives and in particular the part that cleans the RPC hits caused by eventual spurious electronics noise or hits caused by the background radiation. Any background source could affect the muon trigger performance and pattern recognition of muon tracks. In particular, spurious hits due to noise or to radiation background could promote low transverse-momentum muons to higher momentum. For this study we explored a dedicated algorithm, so called **RPCHitCleaner**. The algorithm builds RPC clusters and cleans the ones that have larger cluster size – more than 4 fired strips.

In Figure 4, we compared the clusters before and after cleaning. In the histogram We excluded noisy events, with cluster size > 10 and representing a percentage of 1.79% of the total number of events, because they refer to the rare very noisy events which are cleaned on the trigger level. The BX window and cluster size for each of the clusters before and after cleaning is shown in Figure 5.

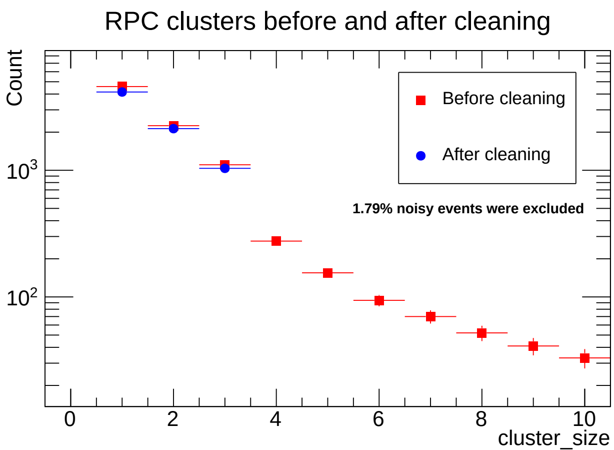

Figure 4: Comparison between RPC clusters before and after cleaning using the RPCHitCleaner algorithm.

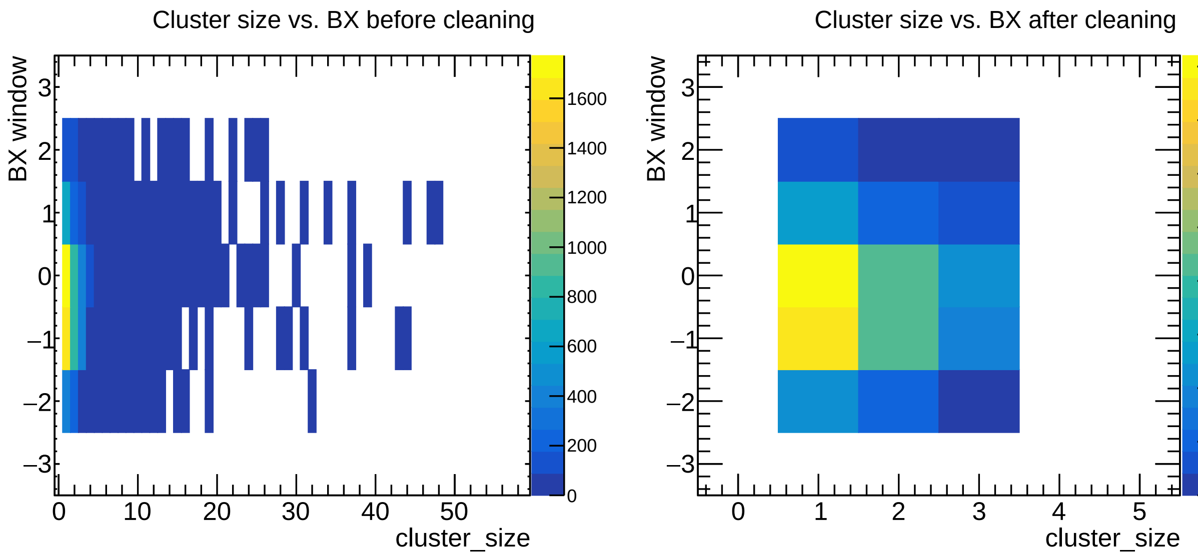

Figure 5: The BX window and cluster size for RPC clusters before and after cleaning.

2.2 Segment extrapolation studies

For the RPC detector performance studies, a particular problem with the offline analysis code for the efficiency measurements was encountered for the endcap station 4. In order to spot the problem, different directions of investigations have been taken into account. In particular, the impact angles of the extrapolated segments carry very important information whether the segments are really associated to the prompt particles coming from the interaction point or not. That's why such investigation has been done and here we present the results. The distribution of the impact angles of the extrapolated segments is shown in Figures 6 and 7 for the monitoring and express streams respectively.

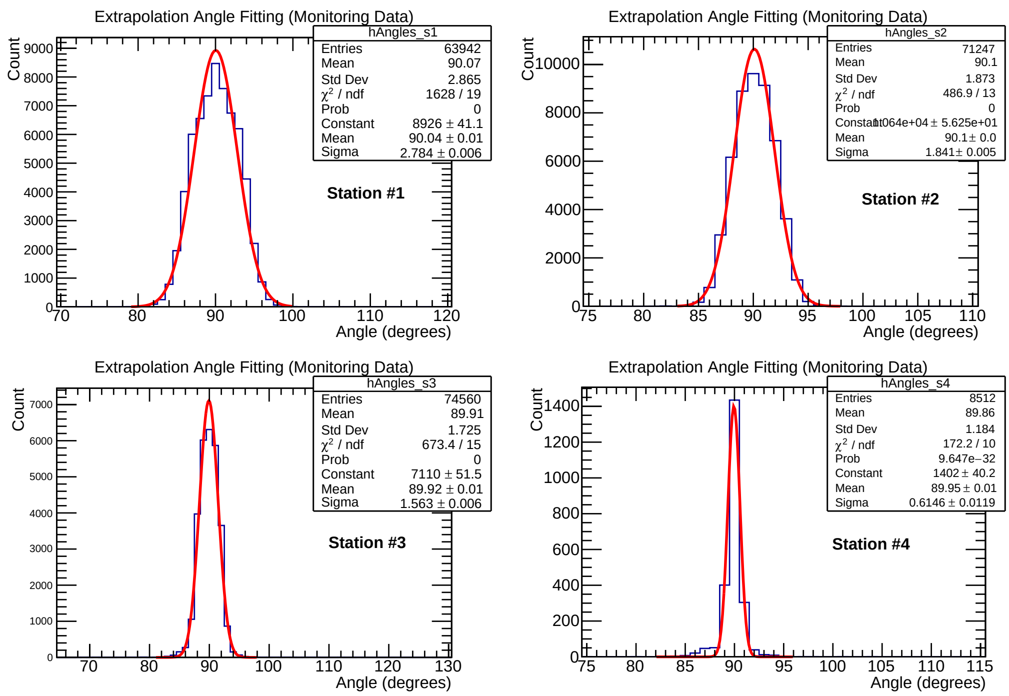

Figure 6: Impact angles of the extrapolated CSC segments to the RPC plains for all the endcap stations using the monitoring stream fitted to a Gaussian.

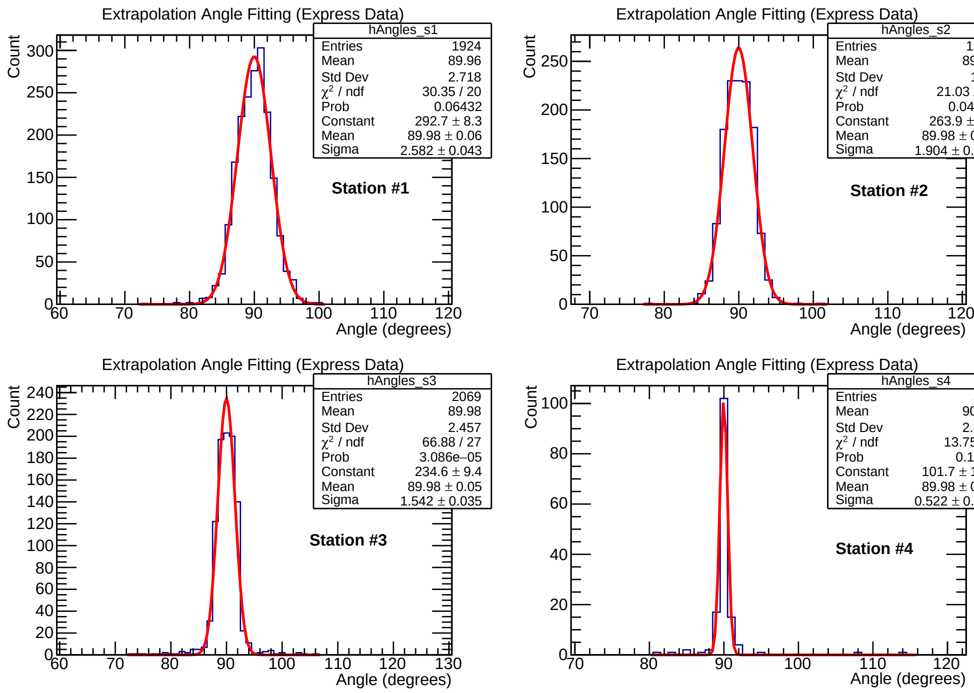

Figure 7: Impact angles of the extrapolated CSC segments to the RPC plains for all the endcap stations using the express stream fitted to a Gaussian.

As shown in Figures 6 and 7, all the impact angles of the extrapolated segments are pointing to the 90° angle which shows that here are prompt particles and because of this, obviously it means that extrapolation works good.

In the end, we found that the problem is caused by a particular missing record in the geometry data base and it is not caused by wrong extrapolations. After the relevant fix the correct efficiency measurements have been restored. Figure 8 shows the efficiency measurement of the endcap station 4 before and after solving the problem.

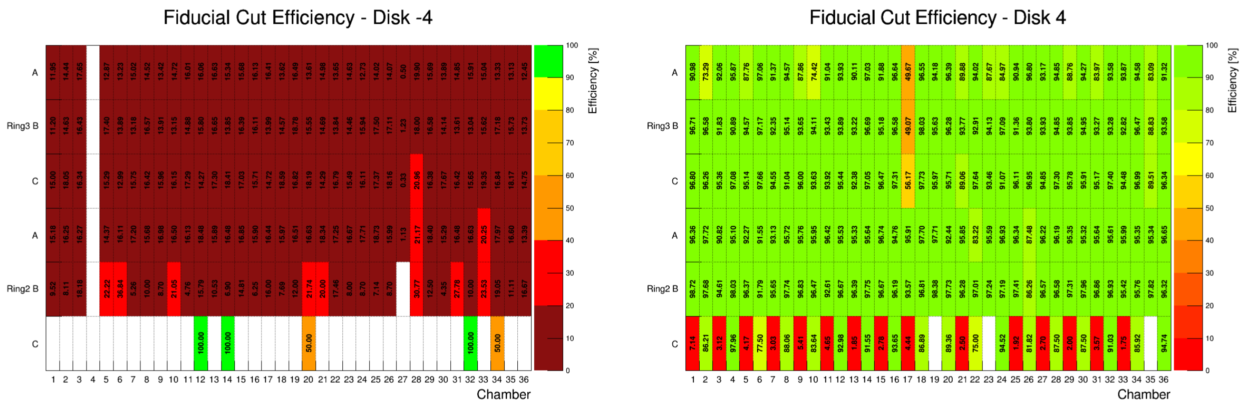

Figure 8: Efficiency plot of the endcap station 4 before(left) and after(right) solving the problem.

List of Figures

References

[1] CMS, the Compact Muon Solenoid: Technical proposal. 12 1994.

[2] M. Abbrescia et al. The RPC system for the CMS experiment at the LHC. *Nucl. Instrum. Meth. A*, 508:137–141, 2003. doi: 10.1016/S0168-9002(03)01336-6.

[3] A. Samalan et al. RPC system in the CMS Level-1 Muon Trigger. *JINST*, 15(10):C10007, 2020. doi: 10.1088/1748-0221/15/10/C10007.