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Estimation of the Level-1 Trigger efficiency of the RPC detectors of the CMS experiment using cosmic muon data

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Abstract

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Estimation of the Level-1 Trigger efficiency of the RPC detectors of the CMS experiment using cosmic muon data

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Abstract

For the estimation of the Level-1 trigger efficiency of the RPC detectors of the muon system of the CMS experiment at the LHC, two data driven methods, Tag&Probe and DTvsRPC, have been studied using cosmic muons. The results presented are based on the data collected by the CMS detector during 2008. These two methods are found to provide good estimates of the RPC trigger efficiency, and they are also in good agreement with each other within the geometrical acceptance.

Key words:

RPC, CMS, Level-1 Trigger

1. Introduction

The Level-1 (L1) trigger of the Compact Muon Solenoid (CMS) experiment is designed to identify physics objects like electrons, muons, photons, jets and missing (transverse) energy which come from the hard proton-proton collisions at the LHC. A detailed description of CMS can be found in ref. [1]. The central feature of the CMS apparatus is a superconducting solenoid, 12.5 m in length and 6 m internal diameter. Within the field volume are the silicon pixel and strip trackers, the crystal electromagnetic calorimeter and the brass-scintillator hadron calorimeter. The outermost sub-system of the CMS detector are the muon chambers. The muons are measured in the pseudorapidity window of $|\eta| < 2.4$, with detection planes made up of drift tube chambers (DT), cathode strip chambers (CSC) and resistive plate chambers (RPC) embedded in the steel return yoke. Matching the muons measured in the muon chambers to the tracks measured in the silicon tracker of the CMS detector results in a transverse momentum resolution between 1 to 5%, for trans-

verse momentum values upto 1 TeV/c, ref. [2]. Beyond the magnet yoke endcaps are iron quartz forward hadron calorimeters (HF). The Level-1 trigger is the starting step of physics event selection, and a decision is required for each bunch crossing, *i.e.* 25 ns. The L1 trigger involves the calorimetry and muon systems as well as some correlation of information from these systems. The muon trigger information is obtained from RPC, CSC and DT chambers. The excellent spatial precision of DT and CSC ensures sharp momentum thresholds and their multi-layer structures help in reducing background. RPCs are dedicated trigger detectors and have excellent time resolution, which is needed for the identification of the bunch crossings. Complementary features of DT, CSC and RPC detectors allow to build two trigger systems which deliver independent information about a track. Another important advantage of the two systems is the possibility for cross-checks and cross-calibrations. A detailed description of the performance of CMS Level-1 trigger using cosmic muons can be found in ref. [3].

In this paper, Section 2 describes the CMS muon

chambers, the data sample used for this study and the event selection criteria. In Section 3, the methodology of the data driven methods used for the estimation of the RPC efficiency is described. Section 4 explains the results of RPC trigger efficiency. The conclusions are drawn in Section 5.

2. CMS Muon Chamber and Data Sample

The barrel region of muon chambers in the CMS detector extends upto ($|\eta| < 1.2$) and consists of 4 concentric stations of 250 DT/RPC chambers. It is divided into 5 wheels along the Z direction, which in turn, have 12 sectors in the transverse plane, each covering an azimuthal angle (Φ) of 30° . Wheels are labelled consecutively from YB-2 for the furthest wheel in -Z direction to YB+2 for the furthest wheel in +Z direction, while sectors are labelled in the order of increasing Φ beginning with the sector centered at $\Phi = 0$. Sectors 3 and 4 in wheels YB-1 and YB+1, respectively, host the chimneys for the magnet cryogenic lines. There is a gap of 20 cm between wheels 0 and 1 and gap of 12 cm between wheels 1 and 2. The two innermost stations have a sandwiched layer of RPC chambers in between DT chambers, whereas the two outermost stations each consist of DT chambers coupled with 1, 2, or 4 RPC chambers depending on the sector and the station.

Since cosmic muons are a constant source of particles penetrating the detector placed in a cavern more than 100 m under ground, they are ideal for detector commissioning which includes calibration, alignment, understanding of reconstruction algorithms and monitoring of the many sub-systems of the detector. In this analysis, cosmic muon data collected during the running period of CMS detector in 2008, acronymed as CRAFT08, have been used. A detailed description of the reconstruction of the cosmic muons can be found in ref. [4]. The CMS detector was operated at the full magnetic field $B = 3.8$ Tesla. The RPC high voltage during the CRAFT08 run was 9.2 kV.

Muon tracks have been selected in an event based on the following selection criteria.

- Though, in principle, the cosmic muons can traverse the detector from any direction, only those tracks have been selected which pass from top to bottom. With CMS convention of coordinates, the Y-axis is the vertical pointing upwards, so the

tracks going from top to bottom should have a negative y-component of the momentum.

- Tracks with momenta greater than 5 GeV/c must have a sufficient number of hits both in the DT and RPC chambers. The minimum required number is 20.

3. Methodology of Data Driven Methods Studied for the Efficiency Measurement

Two data driven methods, Tag&Probe and DTvsRPC, have been studied for the estimation of the Level-1 trigger efficiency of the RPC detector in CMS. A detailed description of the study of the RPC detector can be found in ref. [5]. The basic principle of both methods is to look for an independent trigger which enforces the trigger under study to get fired in an ideal case. In case of the Tag&Probe method, an independent trigger is checked in the bottom half of the detector. If a trigger is found in the bottom half, i.e., lower part of the detector, that implies that the muon coming from the top direction has indeed traversed the detector and must have passed the trigger detectors (DT and RPC) on the top. The DTvsRPC method makes use of the redundancy of the CMS muon system. Based on this fact, if a hit is found in one sub-detector, there must be a hit in the other sub-detector which is under study. For estimating the RPC efficiency by this method, the DT trigger hit is checked in any part of the detector, which in turn requires that the RPC trigger has to be fired in its vicinity.

3.1. Tag&Probe Method

In this analysis, a track is propagated up to the second muon station ($R = 500$ cm, average radius of the second muon station) using a stepping helix propagator. The direction of propagation of the track in the bottom and top halves is determined using the outermost (first hit point) and the innermost position (last hit point) of the track at the second muon station respectively. First the track is propagated in the bottom half and if the 2D distance ($r = \sqrt{x^2 + y^2}$) of the outermost position from the interaction point at the second station is greater than 500 cm, it is propagated in the direction opposite to the momentum of the track. Otherwise, if r is less than 500 cm, the propagation proceeds along the momentum direction. The low momentum tracks which curls back to upper half are rejected by requiring the

transverse angle Φ of the propagated position to be negative. If a DT trigger candidate is found within the angular cone of 50° or a RPC trigger candidate is found within the angular cone of 30° of the propagated position of track, that track is identified as the **tag**. The tagged track is then propagated upto the second muon station taking the innermost position of the track in the top half. If the 2D distance of the innermost position is greater than 500 cm, it is propagated along the momentum of track, otherwise opposite to the momentum. The propagated position of track at the second muon station in the top half is matched with the RPC trigger candidates. If a RPC trigger candidate is found within the angular separation of 50° in the vicinity of the propagated track position, that track is identified as the **probe**.

3.2. DTvsRPC Method

The RPC trigger efficiency can be estimated in any direction of the detector using this method, but in the present analysis only top half of the muon detectors is estimated. The track is propagated upto the second muon station in top half using the stepping helix propagator. The propagation direction is decided using the innermost position of the track at the second station same as described in the Tag&Probe method. For the estimation of the RPC efficiency, first DT trigger candidates are looked in the vicinity of the propagated position of the track and if a matched DT trigger candidate is found, then the RPC trigger candidates are checked whether they are matching with track or not. This method has the limitation that it does not give reliable estimation of the trigger efficiencies in the regions where DT and RPC triggers have correlated inefficiencies, like gaps between sectors, wheels and chimneys etc.

4. RPC Trigger Efficiency

Figure 1 shows the z-Phi map of the RPC trigger efficiency estimated by using the Tag&Probe method. The drop in efficiency in some of the z-Phi regions is because of the gaps between adjacent wheels and cracks between adjacent sectors. Since only the tracker-pointing tracks have been considered, the effect of gaps between wheels YB $\pm$ 1 and YB $\pm$ 2 is not so visible. Figure 2 shows the z-Phi map of the ratio of the RPC efficiency estimated with the two methods. It is clear that they are in good

Fig. 1. z-Phi map of RPC trigger efficiency using the Tag&Probe method.

Fig. 2. z-Phi map of ratio of RPC trigger efficiencies estimated by using the Tag&Probe and DTvsRPC methods.

agreement over most of the z-Phi regions except for the gaps between wheels and sectors. DT and RPC triggers have correlated inefficiencies in these gap regions, so the efficiency estimated using the DTvsRPC method is over-estimated in these regions. To see the performance in the absence of these geometrical regions, some selection cuts have been applied to select the central region of RPC chambers in the top 3 sectors, which are described as follows:

- ($|z| < 100$ cm)
OR ($|z| < 300$ cm and $|z| > 200$ cm)
OR ($|z| 550$ cm and $|z| > 450$ cm).
- ($\Phi > 0.96$ rad and $\Phi < 1.13$ rad)
OR ($\Phi > 1.48$ rad and $\Phi < 1.66$ rad)

Fig. 3. Effect of the geometrical acceptance on the RPC trigger efficiency estimated by using the Tag&Probe.

Fig. 4. Comparison of the RPC trigger efficiencies estimated by using the two methods after acceptance cuts.

OR ($\Phi > 2.01$ rad and $\Phi < 2.18$ rad).

Figure 3 shows the RPC trigger efficiency as a function of the muon transverse momenta estimated by using the Tag&Probe method with and without the acceptance cuts. Figure 4 shows the comparison of the RPC trigger efficiencies estimated by using the two methods after applying the acceptance cuts. So the Tag&Probe and DTvsRPC methods both provide a good estimation of the RPC trigger efficiencies, which are also consistent with each other over most of the momentum ranges except at very low momentum values.

5. Conclusions

The two independent data driven methods for the estimation of the Level-1 trigger efficiency of the RPC chambers of the CMS detector have been discussed based on the cosmic muon data collected during 2008. The estimates of the trigger efficiencies using the Tag&Probe and DTvsRPC methods are in good agreement at the central region of the RPC chambers. Hence either of these two methods can be used to estimate the Level-1 trigger efficiency of the RPC chambers, and results from both methods can be combined to reduce systematic bias in the estimation.

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