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Data-driven performance evaluation method for CMS RPC trigger system using 2011 data at LHC

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Abstract. The compact muon solenoid (CMS) is one of the four experiments which is getting and analysing the results of the collision of protons at LHC. The CMS trigger system is divided into two stages, the level-1 trigger and high-level triggers, to handle the large stream of data produced in collision. The information transmitted from the three muon subsystems (DT, CSC and RPC) are collected by the Global Muon Trigger (GMT) Board and merged. A method for evaluating the RPC system trigger efficiency with data from *pp* collision was developed using the features of GMT. The results of the study with the real data of 2011 are shown and discussed here along with the comparison of Monte Carlo results.

Keywords. LHC; CMS; level-1 trigger; muons; resistive plate chambers.

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1. Introduction

The LHC [1] provides *pp* and heavy-ion collisions at high interaction rates. The incoming rate of 10^9 interactions per second should be reduced by a factor of at least 10^7, since it is impossible to store and process the large amount of data associated with the resulting high number of events, and a drastic rate reduction has to be achieved to preserve the events of physical interests. This task is performed by the trigger system of CMS [2] in two steps called level-1 (L1) Trigger [3] and high-level trigger (HLT) respectively. The muon trigger, a part of L1 trigger, is further subdivided into three independent subsystems: cathode strip chambers (CSC) in the forward region, drift tube (DT) chambers in barrel and resistive plate chambers (RPCs) in both barrel and end-cap regions. The information provided by the three subdetectors is processed by the global muon trigger (GMT), a hardware-implemented algorithm, which performs the task of combining and merging information from muon subdetectors and finally forwarding it, per event, to the L1 trigger logic (Global Trigger, GT) up to four muon candidates.

2. A data-driven method for muon trigger performance evaluation

The task of the GMT algorithm is to collect the regional trigger information (DT/CSC, RPC). The features of GMT algorithm can be exploited for evaluating, in a data-driven fashion, the trigger performance of each muon subsystem by using its complementary one as reference. For example, to evaluate the RPC trigger system efficiency in the barrel, we select the events in which the GMT candidates have been supplied by the DTs and amongst these, the number of events in which the same candidates contain the information from the RPCs as well (i.e. the matched candidates) are counted up. The efficiency values drawn in such a way are then compared with MC-truth efficiency, evaluated as a ratio of all the GMT candidates (matched or not) arising from RPC regional candidates to the total number of generated events. Tracks reconstructed in the muon system during the software-based trigger stage (HLT) are used to deal with those one-muon events which contain more than one GMT candidates. Such tracks called L2 tracks are reconstructed through the muon system layers starting from a seed which represents a vector and the seed contains the information about the L1 accepted GMT candidate associated with it. Thus the information about the GMT candidate is extracted from the L2 track seeds. The goal of the study is to obtain the best possible agreement between data-driven and MC-truth efficiencies for method validation. The other point is to make the method useful for further physics analysis and least possible dependence on the transverse momentum.

3. Results, discussion and conclusions

Figure 1 shows the comparison of efficiencies obtained with the two methods containing muons coming from W decay without any geometrical cuts and with η along with the comparison for 2011 real data samples. The comparison of the same efficiencies for earlier Monte Carlo samples can be found in [4]. It is clear from the efficiency plots that the geometrical discontinuities present in the muon system in pseudorapidity η and azimuthal angle ϕ heavily affect the efficiency behaviour over the transverse momentum range. As stated above, the geometrical design of muon system is such that subsystem triggers cannot have high efficiencies in correspondence with geometrical cracks: the GMT algorithm is designed in such a way as to increase the efficiencies in such regions for the L1 muon trigger as a whole, while for a single subsystem this point is not circumventable. Hence optimal geometrical cuts in (η, ϕ) space have been introduced in order to rule out the

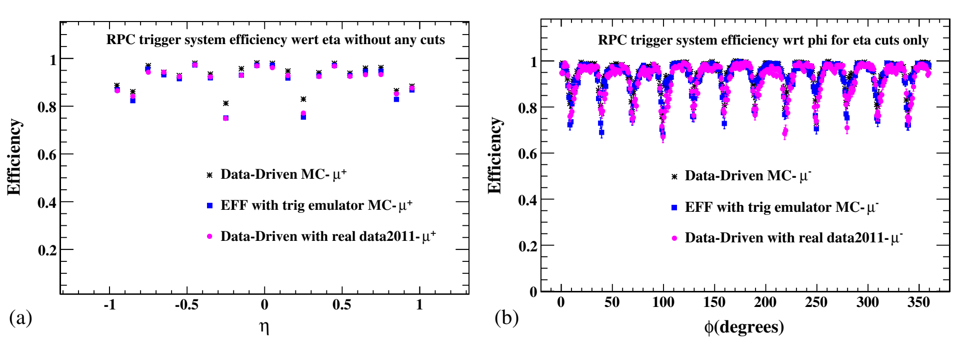

Figure 1. Comparison of efficiencies for muons coming from W deay. (**a**) shows efficiencies along η without any geometrical cuts. After removing the effects of cracks along η, (**b**) shows the efficiencies along ϕ.

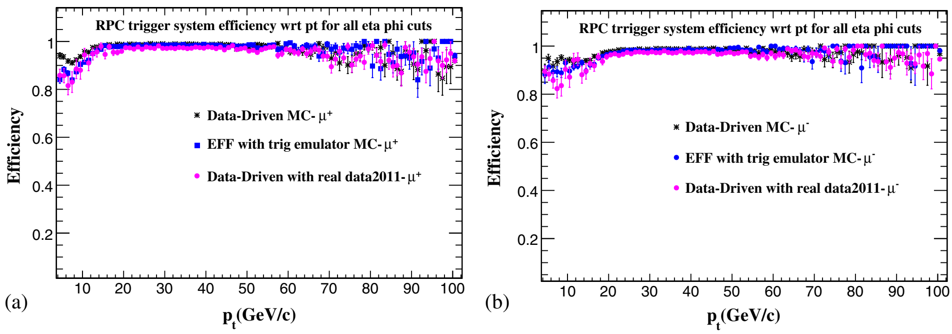

Figure 2. RPC trigger efficiencies with respect to the transverse momentum. The comparison after all the geometrical cuts for (**a**) positive muons and (**b**) negative muons are also shown.

regions where the RPC trigger system is not fully efficient. The different sets of ϕ cuts for positive and negative muons are applied due to their opposite bending in magnetic field depending upon their charge. After applying all the cuts, efficiencies approach 97% and transverse momentum curve shows flat distribution as shown in figure 2. The difference in efficiency between two methods for low p_{t} muons arise from the bias introduced by the GMT algorithm for low-momentum muons. Indeed, muons with very low momenta (up to $\sim$5 GeV/c) in general hit a lower number of layers thus producing low-quality regional trigger candidates. Therefore, such candidates are accepted by the GMT algorithm, only if they are matched by the complementary subdetector and this overestimates the efficiency for very low momenta with respect to the efficiency with trigger emulator. As the momentum increases, the efficiency decreases because the muons go through intersector cracks without enough bending to leave further hits in other sectors. When the momenta are higher, the efficiency values also will be higher because of the higher probability of most of the muons with so high a momentum to succeed in creating high-quality DT and RPC regional and hence the GMT candidates.

Thus, by ruling out the geometrical regions of CMS muon system in (η, ϕ) space which are intrinsically inefficient, the muon trigger efficiencies drawn with the data-driven method and the MC-truth method show a good agreement and a step-wise trend with respect to transverse momentum for both the Monte Carlo and real data samples, except for the low-p_{t} region. The results shown here are obtained with muons of wide p_{t} spectra, leading to the conclusion that the method does not depend on any particular physical process and thus is relevant as a complementary approach to the 'tag and probe' method which, however, needs a careful procedure of background rejection to avoid biases.

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