Performance of the CMS Muon System in LHC Run-2

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Abstract

The CMS muon system has played a key role for many physics results obtained from the LHC Run-1 and Run-2 data. It presently consists of three detector technologies equipping different regions of the spectrometer. Drift Tube chambers (DT) are installed in the CMS muon system barrel, while Cathode Strip Chambers (CSC) cover the CMS end-caps; both serve as tracking and triggering detectors. Moreover, Resistive Plate Chambers (RPC) complement DT and CSC in barrel and end-caps respectively and are mostly used in the trigger. Finally, Gas Electron Multiplier (GEM) chambers are going to be installed in the muon spectrometer endcaps at different stages of the CMS upgrade programme. A slice test consisting of 10 GEM chambers is being presently operated in parallel to the rest of the muon spectrometer. The performance of the different muon detectors and the muon trigger, evaluated using data collected at 13 TeV centre-of-mass energy during the LHC Run2, will be presented in this report in all of its aspects.

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Abstract

The CMS muon system has played a key role for many physics results obtained from the LHC Run-1 and Run-2 data. It presently consists of three detector technologies equipping different regions of the spectrometer. Drift Tube chambers (DT) are installed in the CMS muon system barrel, while Cathode Strip Chambers (CSC) cover the CMS end-caps; both serve as tracking and triggering detectors. Moreover, Resistive Plate Chambers (RPC) complement DT and CSC in barrel and end-caps respectively and are mostly used in the trigger. Finally, Gas Electron Multiplier (GEM) chambers are going to be installed in the muon spectrometer endcaps at different stages of the CMS upgrade programme. A slice test consisting of 10 GEM chambers is being presently operated in parallel to the rest of the muon spectrometer. The performance of the different muon detectors and the muon trigger, evaluated using data collected at 13 TeV centre-of-mass energy during the LHC Run2, will be presented in this report in all of its aspects.

Keywords: Gaseous detectors, Muon spectrometers, Performance of High Energy Physics Detectors, CMS

1. The CMS Muon System

The Compact Muon Solenoid (CMS) is a general purpose detector operating at the CERN LHC collider. Muons are part of the signatures of many analyses performed within the CMS physics programme. For this reason, CMS is equipped with a robust and redundant muon system that performs efficient muon identification, improves the measurement of the transverse momentum ($p_T$) for muons with energies in the regime of $O(100)$ GeV/c and provides standalone trigger capabilities.

During the LHC Run-2, muons are triggered and reconstructed in CMS using three different types of gaseous detectors, positioned within the steel flux-return yoke of the magnet solenoid. Four stations of Drift Tubes (DT) chambers equip the barrel of the muon system, covering a pseudorapidity region up to $|\eta| < 1.2$. Similarly, the muon spectrometer’s end-caps are equipped with four stations of Cathode Strip Chambers (CSC) which cover the $0.9 < |\eta| < 2.4$ range. Each DT (CSC) chamber is built of 8 (6) detector layers measuring the muon trajectory in the transverse plane. Both DT and CSC are used as tracking detectors and participate in the trigger. Additionally, 6 (4) layers of Resistive Plate Chambers (RPC) equip the muon system barrel (end-caps) covering up to $|\eta| < 1.8$ and are mostly used to improve the trigger robustness. Overall, the CMS muon spectrometer consists of 250 DT chambers, 540 CSC chambers and 1056 RPC chambers.

A slice test consisting of 10 chambers of Gas Electron Multiplier (GEM) detectors equips a fraction of the negative CMS end-cap. It is presently being operated to acquire installation and commissioning expertise in view of future upgrades.

2. The CMS Muon Detectors Performance

From the hits reconstructed within a single DT or CSC chamber, segments are built out of straight-line track fits. Moreover, hits from adjacent RPC strips are combined into clusters. The efficiency to reconstruct DT and CSC segments or RPC clusters is measured with a Tag-and-probe method. Opposite-sign dimuon pairs, coming from the same interaction vertex, are selected out of a sample of events collected with a single-muon trigger. Tags are defined as reconstructed muons satisfying tight selection criteria that are geometrically matched with the trigger. Probes muons are selected using looser selection criteria, tuned case by case to avoid biases in the measurement. Track trajectories from probes are propagated to the muon stations. A chamber is considered efficient if a reconstructed segment (cluster) is found within a given geometrical window around the propagated probe track. A chamber-by-chamber map of the CSC segment reconstruction efficiency is presented in Fig. 1. In general, efficiency is above 95%, with few exceptions typically due to chambers affected by known hardware problems, either sporadic, or that need intervention to be repaired. Similar conclusions, documented respectively in [3] and [4], hold for DT and RPC.

The CMS muon reconstruction starts from single detector elements (i.e. inner tracker or RPC clusters and DT/CSC segments) and builds tracks in parallel in the inner tracker and in the muon spectrometer. Tracks built out of the two detector systems are then combined and refitted using algorithms that improve the measurement of the $p_T$ of muons with energies of the order of a few hundreds GeV/c, with respect to the tracker-only fit. Figure 2 compares, for tracker-only and combined muon tracks, the RMS of relative $q/pt$ residuals, computed as the relative difference between the momentum measured from the upper and lower leg of cosmic ray muons crossing CMS. Only muons traversing the CMS pixel detector are used for this study, to mimic muon topologies from collisions. More details about
Figure 1: Efficiency (in percent) of each CSC chamber to provide a locally reconstructed track segment as measured with Tag-and-probe using 2017 data.

Figure 2: The RMS of the relative $q/p_T$ residual as function of muon $p_T$ for muons from cosmic rays. Results from the inner tracker measurement (red) are compared with the ones of combined muon system + inner tracker fits (black).

Figure 3: A comparison showing the BX assignment distribution of local trigger primitives in the muon barrel for DT-only (red) or combined DT+RPC (black) trigger segments.

Results for local reconstruction efficiency are presented, the impact of the muon chambers on the measurement of the $p_T$ of high energy muons is discussed and the use of muon detector information within the L1T is highlighted. Overall, the CMS muon system performs remarkably, and plays a crucial role in fulfilling the experiment physics programme.

References

[1] CMS collaboration : Performance of the CMS muon detector and muon reconstruction with proton-proton collisions at $\sqrt{s} = 13$ TeV, JINST, DOI: 10.1088/1748-0221/13/06/P06015

3. Conclusion

This document briefly summarises the performance of the CMS muon system with data collected during the LHC Run-2.