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The Compact Muon Solenoid Experiment

Conference Report

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CMS Drift Tubes performance

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Abstract

The CMS muon barrel system includes 250 Drift Tubes (DT) stations that require 172,000 readout channels for triggering and measurement of the muon transverse momentum. After the first Long Shutdown (LS1) of CMS, the fraction of active channels remains higher than 99%. The spatial resolution ranges between 200 and 250 μm in the phi direction, and the intrinsic time resolution is about 2ns. In addition the DT system showed excellent performance during Run 1, with very low associated down time and only a small fraction of data not qualified by the data certification procedure. However, the conditions anticipated for the High Lumi (HL)-LHC will require an upgrade of the on-board electronics to deal with the higher radiation environment and the higher trigger rate. Replacement of the so-called mini-crates installed alongside the chambers is scheduled for LS3.

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1 Introduction

The CMS detector [1] has a large coverage for muon detection, combining endcap and barrel chambers, and also redundancy using different technologies. Standard Model physics as well as new phenomena searches, as supersymmetry or exotica searches, are relying on the ability of the detector to trigger and measure the muon momentum up to the TeV scale.

2 CMS Drift Tubes chambers

The CMS muon barrel Drift Tubes (DT) system [2] consists of 250 DT chambers organized in five wheels. From the interacting point, a central muon crosses four chambers Fig.1. Each chamber MB1, MB2 and MB3 is made of three superlayers (2-ϕ and 1-θ) except the MB4 made of two ϕ superlayers. Each superlayer contains four single layers. For a central muon, there is a maximum of 32 ϕ hits and 12 θ hits. Finally the DT system covers the region up to η = 1.2

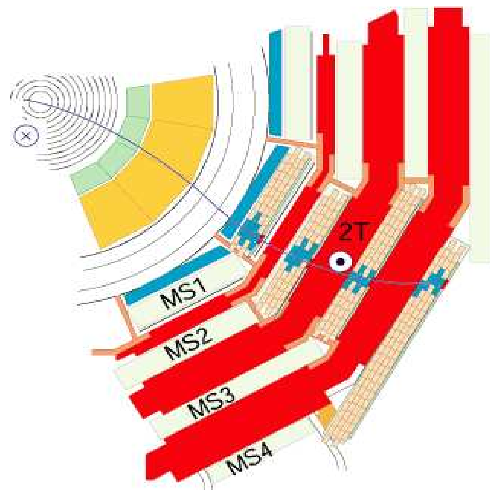


Figure 1: Overview of the CMS DT muon barrel system.

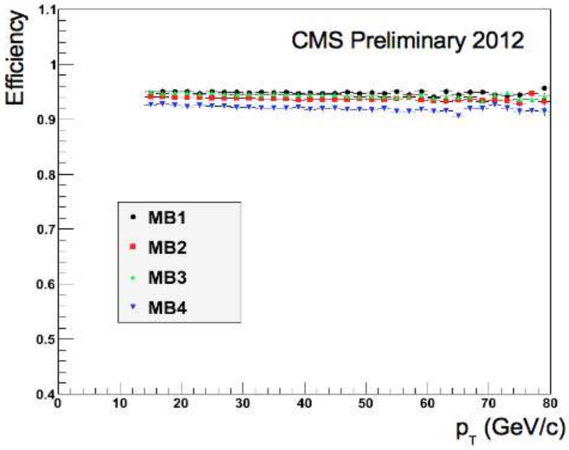
The individual cell has a section of $42 \cdot 13$ mm and is equipped with anode wire, strip and cathode. There is a total of 172,000 such tubes in the muon barrel system. The gas mixture is made of Ar/CO2 with relative fractions 85/15.

3 DT performance

DT chambers showed an excellent performance in overall during run 1, causing very small down time for CMS as well as very tiny amount of data not qualified ”good” for physics. The different performances [3] are described below. First of all, the DT local trigger efficiency is very high independently of the muon transverse momentum (p_T) Fig.2. This efficiency is computed assuming a reconstructed track passing through the chamber and thus considering the relative ratio of detected hits in the same chamber. All four types of chambers are reaching the same level of efficiency as shown on Fig.2.

The observed level of background is shown to be linear with the increase of the instantaneous luminosity during run 1 (Fig.3). There is a dependency as a function of the wheel, from central to external wheels. As this background in the DT system is mainly induced by the neutron gas filling the experimental cavern, the most affected parts are the outermost chambers (MB4) in the top sectors.

Two key parameters are the spatial and time resolution of the DT system. Figure 4 shows the ϕ and θ view resolutions. In the ϕ view the typical resolution ranges between 200 $\mu\mathrm{m}$ and 250 $\mu\mathrm{m}$. The observed ”hat” shape is explained for both ϕ and θ views by some geometrical differences: a longer path in the external wheels in the ϕ direction leads to a better resolution and the contrary in the θ view. An additional slight geometrical effect is giving a hierarchy from the MB1 to the MB3 in the θ view. Finally the worse resolution, in the MB4, is due to the absence of the θ superlayer.



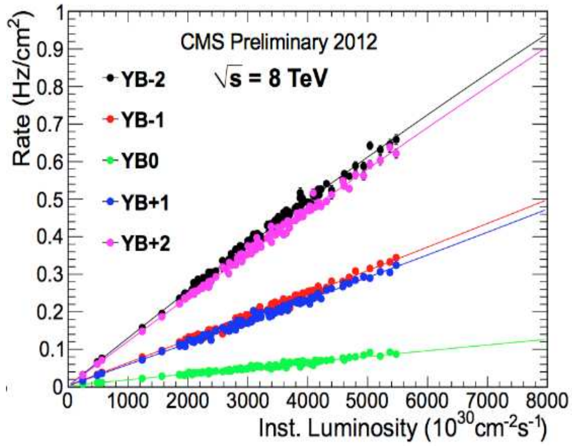
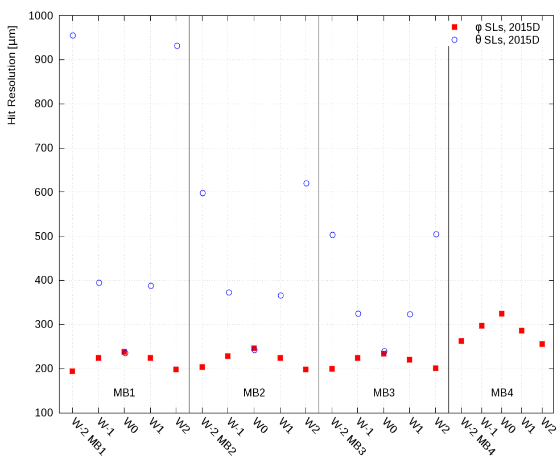


Figure 2: The DT local trigger efficiency is presented as a function of the muon η value.

Figure 3: The background in the DT system is measured for all luminosities during run 1.

Figure 5 shows the time resolution obtained compiling run 1 data. Considering the in-time tracks and fitting the central peak, the DT time resolution is assumed to be about 2ns.



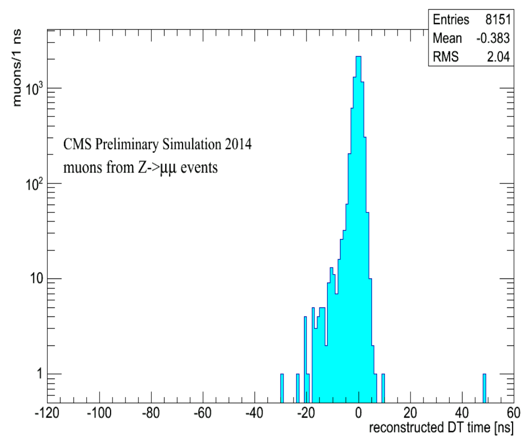


Figure 4: The hit resolution is presented for both ϕ and θ directions, per wheel and per chamber.

Figure 5: The time resolution is computed from the fit to the central peak.

4 Long Shutdown 1 work

During the Long Shutdown 1 (LS1), a lot of repairs and maintenance work was performed for two years in the DT system [4]. The fraction of active channels was again higher than 99% at the beginning of run 2. In addition some new hardware was installed during LS1 in order to get a more robust system: the Trigger Sector Collectors (TSC) and the Read Out Servers (ROS) were extracted from the experimental cavern to be placed in the service cavern (Fig.6). The main advantage is the accessibility of those critical components. Some copper to optical fiber (CuOF) signal converters were deployed as well as well the optical fibers going up to some OFCu located in service cavern (Fig.7). The commissioning tests performed during LS1 showed the comparable performance of the new electronics by comparison with previous electronics chain.

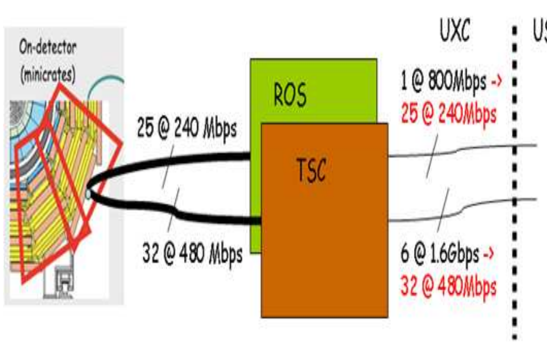


Figure 6: Schematic view of the DT electronics before LS1.

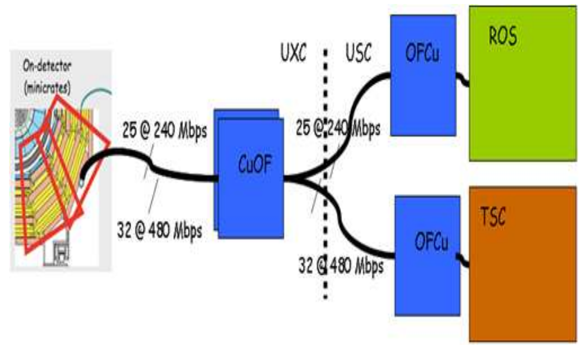


Figure 7: The DT electronics was already improved during LS1, putting TSC and ROS in the service cavern.

5 Electronics upgrade

Some longevity tests and several failure rate estimations showed that there is no need to upgrade the detector itself in the gas volume. On the contrary, several arguments came in favour to upgrade the electronics for phase 2 High Luminosity (HL) program: the radiation issues due to the increased luminosity, the intrinsic Level 1 trigger limitations in the current electronics called MiniCrate (MC), and also the need to get a more robust system by transferring some functionalities in the service cavern.

The first step of the trigger chain upgrade will be performed during phase 1 (run 2): a TwinMux system will be completed, allowing to combine the informations of the DT chambers and two others sub-systems, Resistive Plate Chambers (RPC) and Hadron Outer (HO), to get the trigger primitives. The redundancy will improve the resolution for instance in the gaps between the wheels and should avoid the repetition by the trigger processors. The TwinMux system is expected to be completed in 2016.

The second step of the electronics upgrade for phase 2 [5] will consist in replacing all the readout and trigger boards currently in the MC. The new board, called On Board Electronics for DT (OBEDT), will contain the digitization of the signals as well as the slow control Fig.8. The trigger primitive functionality will be transferred outside the experimental cavern. The design of the new boards is still on-going and the replacement should occur during LS3, that should begin possibly after 2023.

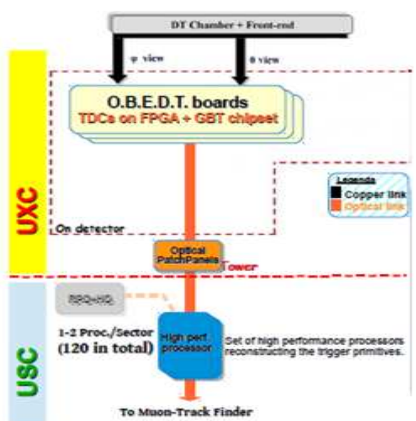


Figure 8: The upgraded electronics will consist of new mini-crates and the transfer of the Level 1 functionality to the service cavern. It will be replaced during LS3.

6 Conclusion

The DT system showed an excellent stability and performance during run 1 as well as the beginning of run 2. The data quality reached indeed the maximum possible level and the DT chambers delivered a very high trigger efficiency. The detector benefited from the improvements performed during LS1 and restarted in run 2 with a renewed and better efficiency. Finally, the long-term upgrade phase 2 program will be dedicated to the electronics replacement, to deal with HL-LHC environment and higher trigger rate.

Acknowledgments

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References

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