“CMS Drift Tubes System during LHC 2010 Operation”

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1. Introduction

A key point of CMS (Compact Muon Solenoid) [1] is its ability to trigger on and reconstruct muon tracks at high luminosities. This task is performed by various CMS subdetectors, among them, the DT (Drift Tube) chambers.
The 250 DT chambers are hosted in the five wheels of the CMS barrel, with a total of 172,200 drift cells. Each wheel is divided in 12 sectors each covering ~30º around the interaction point and each sector is organized in four stations of DT chambers named MB1, MB2, MB3 and MB4 going from inside to outside. A DT chamber is made of three (or two in the outer layer) Superlayers, each consisting of four layers of rectangular drift cells staggered by half a cell, which provide track measurement in the magnetic bending plane (r, Φ) and in the Z position along the beam line.
DT read-out electronics is designed to perform time digitization of the signals generated by charged particle tracks and further data merging to achieve a read-out of the full detector at a Level-1 trigger rate of 100 kHz.
The purpose of the DT trigger system is to provide muon identification and precise momentum measurement, as well as bunch crossing identification. It provides an independent Level-1 muon trigger to the experiment, selecting the four best muon candidates on each event.

2. DT System Operation at LHC 2010

On March 30, 2010 LHC started operations at 7 TeV center-of-mass energy. Commissioning of the machine through all the year allowed achieving a maximum instantaneous luminosity of 2 10^{32} cm^{-2} s^{-1}. Out of the 47.03 pb^{-1} delivered by LHC, CMS has recorded 43.17 pb^{-1}. Operation of the DT system during this period has been outstanding. The DT contribution to the total CMS downtime during data taking was negligible. Major fraction of the DT downtime was due to the manual resynchronization command that allowed recovering blocked channels in event of sporadic bursts of noise that fill up the read-out buffers or unlock the channels. Though the rate of these very noisy events is low, in the order of a few per week, an automatic resynchronization procedure was setup in August 2010 to speed up the recovery to few microseconds and since then, the downtime has been negligible.
Only one run (1 hour 30 minutes long) has been certified as bad during all the year due to an incident with a temperature sensor that triggered a false alarm and powered off one wheel.
Out of the 172,200 channels of the DT detector, more than 99.6% have been operating properly through the entire data taking. Disconnected high voltage channels remain at the level of 0.1%, and the loss in detector acceptance because of failures in the read-out and trigger electronics is about 0.4%.
In summary, stability and reliability of the DT detector has been very satisfactory and the failure rate of the electronics modules has been low and within our expectations. The main point of concern at present is due to the overheating of some low voltage connectors for which several actions are under study. In addition, background rates versus luminosity during 2010 running have been studied and extrapolations to higher luminosity are consistent with expectations except for the MB4 chambers where it seems they could be slightly higher than expected.

3. DT Detector Performance

Final trigger and reconstruction performance of the detector depends on a careful tuning of all of its components. In particular, for DTs, trigger synchronization, time pedestal and drift velocity computation are key parameters to insure optimal performance.
Trigger synchronization must be achieved at three levels: intrachamber

synchronization, chamber-to-chamber relative synchronization and subsystem-to-subsystem synchronization. The last two items depend on a coarse synchronization (in multiples of bunch crossings (BX) period, 25 ns) that was already achieved during cosmic rays data taking campaigns. However, a fine synchronization (with a precision of a few nanoseconds) with the LHC machine clock that depends mainly on the muon time of flight from the interaction point to the chamber was only possible after some months of data taking. Up to four iterations have taken place based on the available statistics. Results obtained show that the BX identification probability is in good agreement with the design parameters [2].

The DT local trigger (DTLT) efficiency in a station was evaluated using minimum-bias events and decays from W and Z bosons, and was found to be in agreement with TDR [2] expectations.

The main goal of the DT calibration is the determination of the relationship between the arrival time of the ionization signal and its spatial position. This includes the computation of the time pedestal to be subtracted to each cell drift time and the measurement of the drift velocity inside the chambers. This time pedestal takes into account contributions due to the interchannel time difference due to the electronics inside the chamber, the Level 1 trigger latency, the time of flight of the muon and corrections due to the propagation time of the signal along the anode wire. Proper corrections have been performed to take into account the changes in the trigger timing configuration. The drift velocity obtained is around 55.5 μm/ns for all the r- Φ Superlayers except for the MB1s of the external wheels where a lower value is observed because of the Lorentz angle induced by the stronger magnetic field.

The local hit reconstruction in the DT system is directly dependent on the variations in the time pedestal, as well as the drift velocity calibration. The spatial hit resolution is determined from the distribution of hit residuals with respect to the reconstructed segments of the muon trajectory, obtaining resolutions within 300 μm for r-Φ Superlayers and slightly worse at outermost station (MB4), being larger for r-Z Superlayers when moving towards the external wheels. In addition, measurements of the local segment reconstruction efficiency (track reconstruction within a chamber) are typically of ~90% or higher.

Radiation background in the detector as a function of the luminosity has also been studied. The number of noisy cells (>500 Hz) in the DT chambers due to intrinsic or electrical noise is usually very low (~20) and pretty stable. A non-track background sample by requiring only 1-2 hits within a Superlayer was studied. Integrating over the full 1.25 μs read-out window, the DT measured the rates of out-of-time backgrounds originated mainly from slow neutrons and punch-through activation as well as contamination from hits originated at other bunch crossings (pile up). The results show a clear trend as the luminosity increased, with higher backgrounds as a function of Z, because of the shielding provided by the iron yoke inside the barrel. Higher rates are observed in the MB1s and MB4s, the first ones due to the punch-through of the particles from the hadron calorimeter, while the second ones are the mostly expose to the slow neutron gas permeating the cavern. A Φ asymmetry is seen in the MB4s due to the cavern geometry and the steel supports.

In summary, the performance of the DT system during LHC 2010 data taking has been outstanding, providing very valuable data for the physics analysis.

4. References

[1] CMS Collaboration, The CMS experiment at the CERN LHC. JINST 3 S08004. 2008.

[2] Trigger and Data Acquisition project, Volume I The Level-1 Trigger Technical Design Report CERN/LHCC 2000-38 (15 December 2000).