CMS Muon Drift Tubes HL-LHC Slice Test

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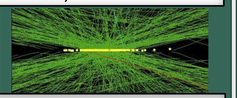
The Compact Muon Solenoid experiment aims to upgrade its electronics and detector performance to improve the data taking and a precise reconstruction of all the particles in high pile-up conditions of the High Luminosity LHC

Overview

The Compact Muon Solenoid (**CMS**) **Drift Tube** (**DT**) muon detector, built for standing the Large Hadron Collider (**LHC**) expected integrated and instantaneous luminosities, will be used also in the High Luminosity (**HL-LHC**) at a **5x larger instantaneous luminosity** and, consequently, much **higher levels of radiation**, reaching **~10x** the LHC integrated luminosity.

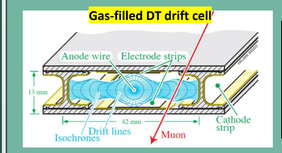


To tolerate the **HL-LHC** data taking conditions, the detector electronics of the CMS Drift Tubes chambers need to be replaced during Long Shutdown 3. The first prototype of the HL-LHC electronics for the **On detector Board for the DT** chambers (OBDT) has been installed in CMS connected to the DT chambers of one out of sixty sectors and integrated in the central data acquisition and trigger system.

CMS Drift Tube System

The CMS detector is placed at Point 5 (P5) of the LHC

The DT chambers are one of the important parts of the CMS muon system responsible for identifying, measuring and triggering on muons by the precise measurement of their position.

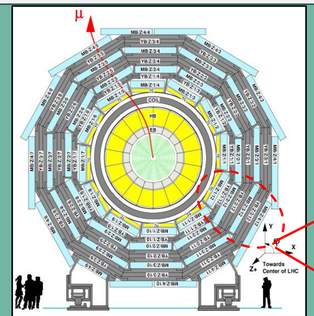


DT drift cell: rectangular cell, 4.2 x 1.3 mm, gas mixture: 85% (Ar)15% (CO_2), almost constant drift velocity: ~54 μm/ns

Approximately 172000 DT cells in total

DT chamber: parallel layers (L) of cells grouped in 4 Ls form a super-layer (SL), 2 SLs in r-φ and 1 SL r-z (for 3 innermost stations)

DT chamber frontend pulses carrying the time information of the chamber **hits** reach both the legacy on-detector electronics, so called minicrate, and the **OBDTs** through specifically designed splitter boards that take consideration to the signal integrity. *Thirteen OBDTs* distributed in five mechanical frames which also take care of the thermal interface to the water-cooling loop are installed in this sector.

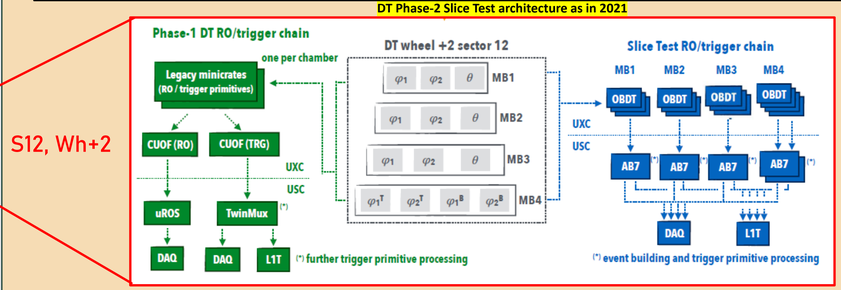


250 DT chambers in total
4 concentric rings of stations (MB1 to 4)
12 sector slices (S1 to12) 5 wheels in the CMS muon barrel (YB -2 to +2)

Slice Test

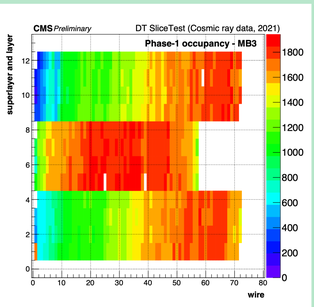
The OBDT board is focused on a Polarfire FPGA, it digitizes the pluses that come from the Front-End Boards inside the chambers. FPGA sends digitalized and formatted data to 5 AB7 boards through its 5 optical links. A new trigger system based on high performing FPGAs is being designed and will be capable of providing precise muon reconstruction and bunch crossing identification.

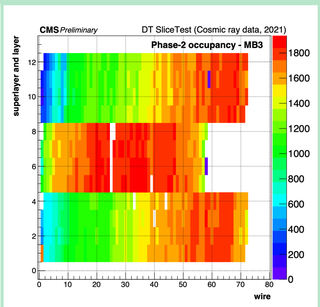
DT Phase-2 Slice Test architecture as in 2021

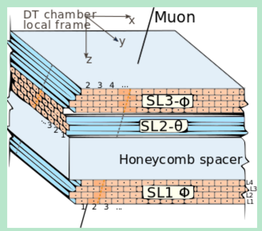


Results

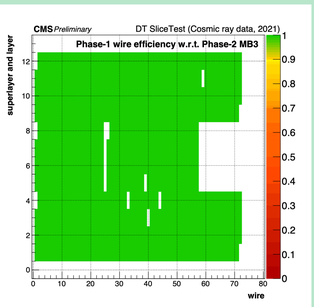
The results presented are obtaining during the Slice Test 2021 data taking campaign of cosmic rays, currently on-going. The signals from the chambers are split and reach both the **legacy (Phase-1)** and **Phase-2** demonstrator chains, which will allow them to operate in parallel during LHC collisions.

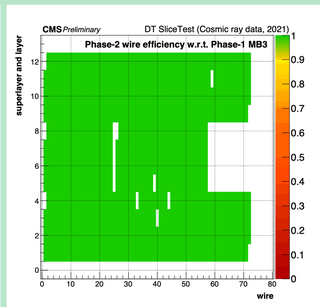




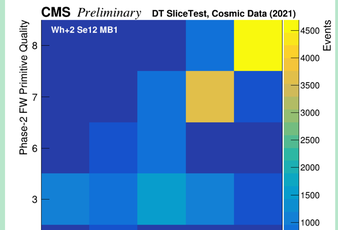


Hit occupancy for the different DT cells of the Slice Test MB3 station as measured by the Phase-1 (left) and Phase-2 (right) readout electronics



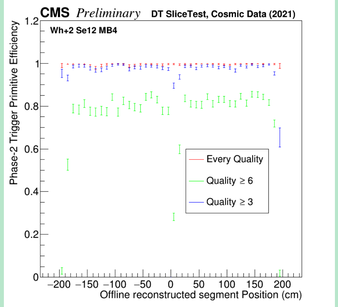


Relative **efficiency** to detect a hit with the **Phase-1** readout, when a hit is recorded by the **Phase-2** readout (left) and vice versa (right). When a hit is detected by one of the two readout systems, it is detected also by the other one



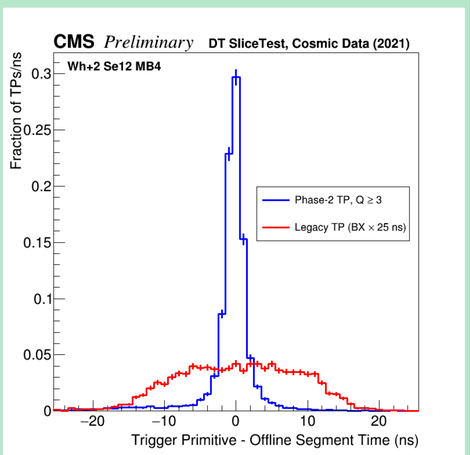
2D distribution of the **Phase-2** Trigger Primitive (**TP**) Quality obtained by the AB7 board vs the number of **hits associated** to the offline reconstructed segment (phi view).

Quality	Description
1	3 hit track
3	4 hit track
6	3+3 hit track
7	4+3 hit track
8	4+4 hit track



Efficiency of finding a **Phase-2** TP in any BX with respect to the local position of the **offline segment reconstructed** out of hits detected by the Phase-1 system considering every primitive (**red**), primitives built with more than 4 hits (**blue**) and primitives with more than 6 hits, i. e. 3 or more hits per Superlayer (**green**) for the DT Slice Test data in 2021 in MB4 Sector 12 Wh+2. Selected segments are built with more than 4 hits and have an inclination in the radial coordinate smaller than 30° with respect to the direction perpendicular to the chamber. No geometrical matching between the offline segment and the TP is required.

Difference between trigger primitive's time and the offline reconstructed segment time in a cosmic sample collected in. For **Phase-2** only primitives fitting at least 4-hits are in order to be compared with the **legacy** system. The improved online time resolution in **Phase-2** reflects in this particular sample (unbunched cosmic muons) as a lower fraction of triggers at a wrong bx, i.e. 12.5 ns away from the time the muon crossed the chamber.



Conclusions

- For HL-LHC **DT electronics** will be **fully replaced** while keeping the existing chambers
- **Prototypes** of the **Phase-2 On-Board DT electronics** are **integrated** on-site in CMS
- The full **Slice Test** data taking chain has been operated very satisfactorily, showing the optimal efficiency of the designed Phase-2 electronics and good **performance is** obtained
- The performance of hit detection and offline reconstruction is in line with the one of the Phase-1 system (already exploiting the ultimate DT cell resolution)
- Significant **improvement** in the **Phase-2** Level-1 DT local trigger resolution
- Plan to run this Phase-2 parallel system in collisions during **Run 3**, which will allow us to test final pre-production prototypes under realistic conditions (radiation, magnetic field) and further refine trigger algorithms

References

[1] CMS Collaboration, The Phase-2 Upgrade of the CMS Muon Detectors, CERN-LHCC-2017-012, **CMS-TDR-016,2017**

[2] Andrea Triossi et al, Electronics Developments for Phase-2 Upgrade of CMS Drift Tubes https://pos.sissa.it/343/035/pdf

[3] Andrea Triossi, A New Data Concentrator for the CMS Muon Barrel Track Finder, http://cds.cern.ch/record/1712905

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