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Commissioning, Operation and Performance of the CMS Drift Tube Chambers

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Abstract

The CMS muon spectrometer, designed to trigger, identify, reconstruct and measure muons with high efficiency and accuracy, is equipped with Drift Tube chambers (DT) in the barrel region. The DT system has been fully commissioned using cosmic muons with and without magnetic field, and during months of cosmic data taking has provided millions of triggers to the rest of the CMS detector. This contribution will describe the challenges in the operation of the DT system, including calibration procedures, monitoring and reconstruction performance, and the result of the analysis of the collected cosmic data.

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Commissioning, Operation and Performance of the CMS Drift Tube Chambers.

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Abstract

The CMS muon spectrometer, designed to trigger, identify, reconstruct and measure muons with high efficiency and accuracy, is equipped with Drift Tube chambers (DT) in the barrel region. The DT system has been fully commissioned using cosmic muons with and without magnetic field, and during months of cosmic data taking has provided millions of triggers to the rest of the CMS detector. This contribution describes the challenges in the operation of the DT system, including reconstruction performance, and the result of the analysis of the collected cosmic data.

Key words: LHC, CMS, Muon Spectrometer, Drift Tube, DT, Commissioning

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1. Design of the CMS Drift Tube System.

The CMS detector is described in [1]. Its design is based on a large super-conducting solenoid providing an intense (3.8 T) magnetic field which allows independent muon tracking inside and outside the coil. The inner tracking system is based on a silicon tracker while the muon spectrometer is hosted in the iron return yoke of the solenoid.

High p_T muons will provide a clear signature for many interesting signals at the LHC. The muon spectrometer is therefore required to provide a robust and reliable trigger and an accurate momentum measurement event without the contribution of the central tracker.

To cope with these requirements the muon spectrometer [2] is composed of three different subsystems, all of them used both for tracking and for triggering. In the barrel ($|\eta| < 1.2$) where the track occupancy and the residual magnetic field are low, drift tube detectors (DT) are installed. In the endcaps cathode strip chambers (CSC) are employed covering the region up to $|\eta| < 2.4$. Both in the barrel and in the endcaps ($|\eta| < 2.1$) a third system, composed by resistive plate chambers (RPC), is present.

The drift tube system is composed by four stations of chambers at different radii, named MB1, MB2, MB3 and MB4, with a segmentation which follows that of the iron yoke, consisting of five wheels along the z axis, each divided into 12 azimuthal sectors.

Each chamber (Fig. 1) is composed by 3 *superlayers*: 2 of them measuring the bending coordinate (r-ϕ) and one measuring the angle of the track with respect to the beam line (r-z). Each superlayer is composed of 4 staggered layers of parallel drift cells.

The cell has a size of 42×13 mm^2 with a 50 μm diameter stainless steel anode wire at the centre. The distance of the track from the wire is given by the drift time of electrons produced in the ionization; to improve the distance-time linearity, additional field shaping is obtained with two insulated strips kept at a positive voltage, glued on the the planes in correspondence of the wire. Typical operational voltages are +3600 V, +1800 V and -1200 V for the wires, the strips and the cathodes, respectively. The gas is a 85%/15% mixture of Ar/CO$_2$, which provides good quenching properties and a saturated drift velocity of about 5.4 cm/μs.

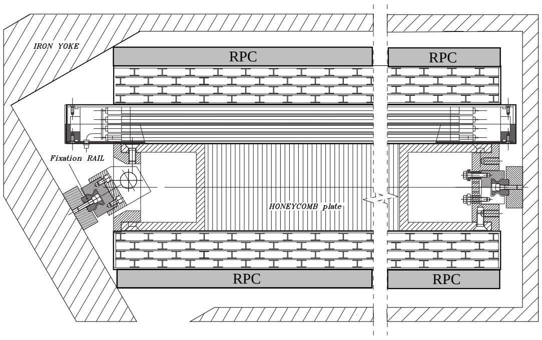

Figure 1: Schematic view of a DT chamber of the type used in the first and second measurement stations. The two resistive plate chambers of the muon station are also shown.

The multilayer structure of the DT chambers allows to:

- reconstruct track segments in each chamber improving the resolution w.r.t. single cell;
- minimize the effect of soft δ-rays and neutron background;
- self-trigger in the chamber exploiting a generalization of the mean-timer technique.

2. Commissioning of the System.

The commissioning activity started in 2005, in parallel with the installation of the detector, and mainly consisted in the ac-

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quisition of cosmic ray data. The first phase was dedicated to the test of the standalone components of the DT system while, starting with the Magnet Test & Cosmic Challenge in 2006 various integration tests with the other CMS subsystems have been carried out.

In particular, the understanding of the magnetic field is essential to fully exploit the tracking capabilities of the chambers. For this reason, in summer 2008, about three weeks of cosmic data-taking where devoted to a test of the whole CMS with the full magnetic field, collecting about 300 millions of events mostly triggered by the DT system. The high field is fundamental for the momentum resolution of the spectrometer but it also defines the environment in which the detector operates. In the barrel region most of the flux is contained within the iron plates of the yoke. The region where the DT chambers are placed should ideally be field-free. However, in the iron gaps and at the end of the coil the residual magnetic field is far from being negligible. There are spatially limited regions where the field in the radial direction can reach 0.8 T and is changing moving along the wires. The effect of this component on the drift-velocity was measured using cosmics and was observed to be of the order of 2% for tracks ortogonal to the cell plane, as shown in Fig. 2.

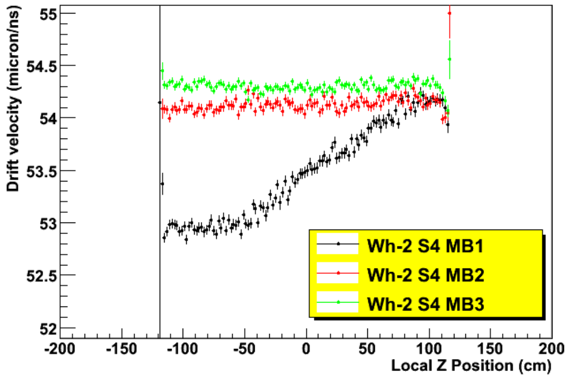

Figure 2: Measured drift velocity for vertical tracks as a function of the position along r-ϕ wires for the first 3 measurement stations of the the most external wheels. The effect of the residual B_r component of the magnectic field is visible in the first (most internal) station.

The commissioning has also been a test for the alignment procedures: cosmic muon tracks have been used to determine the internal alignment parameters of the chambers as well as their relative positions and their position with respect to the tracker.

3. Performance.

The overall performance of the DT system during the commissioning data-taking has been extremely satisfactory. The number of disconnected and dead channels was found to be below 0.1%, a value which fulfils the quality requirements. Also the number of noisy channels is well within the requirements: less than 30 cells out of almost 170000 show a random noise rate higher than 500 Hz with a discrimination threshold of 30 mV. The measured cell efficiency is on average higher than 98% for all the chambers.

The cosmic data have also been used to assess the performance of the muon reconstruction and identification algorithms, commissioning the whole software apparatus for online (High Level Trigger) and offline reconstruction. The first reconstruction step is the local reconstruction of track segments at the level of single chambers, starting from the one-dimensional hits in the cells, solving the left-right ambiguity of a single layer by means of pattern recognition. The resolution on the position of the single hit is about 200 μm while the resolution on the segment position and angle in the beding plane are $\sigma_x \sim 70\mu$m and $\sigma_\phi \sim 0.5$ mrad respectively. The cosmics data show already a satisfactory agreement between data and MC for the description of these resolutions.

The products of the local reconstruction are than used to perform the muon track fit in the spectrometer only (Standalone reconstruction) and using the tracker information (Global reconstruction). The contribution of the muon spectrometer to the Global momentum resolution becomes important above 200 GeV thanks to the larger lever arm with respect to the inner tracker; the design resolution for 1 TeV muons globally reconstructed is around 5%.

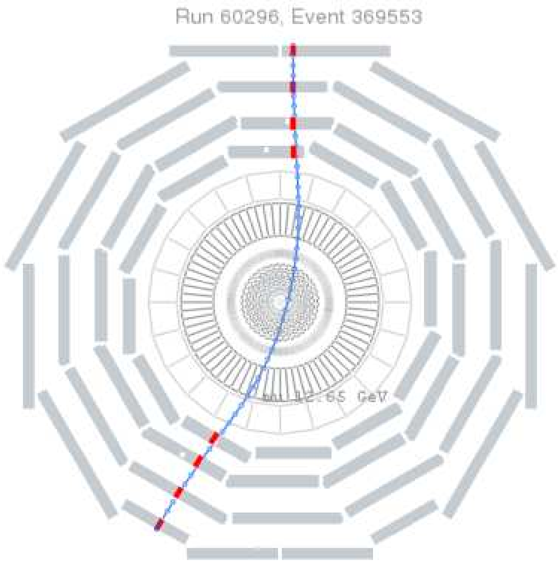

Figure 3: Event display of a cosmic muon bending in the CMS magnetic field (3.8 T). The DT segments are visible in red while the blue line corresponds to the reconstructed Global muon track with an estimated p_T of 12.6 GeV (Run 60296, event 369553).

References

[1] R. Adolphi *et al.* [CMS Collaboration], *The CMS experiment at the CERN LHC*, **JINST 3 (2008) S08004**.

[2] The CMS Collaboration, The Muon Project, Technical Design Report, CERN/LHCC 97-32, (1997).