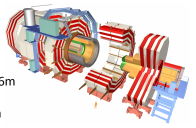
# Calibration of the Barrel Muon Drift Tubes of CMS

Giorgia Mila, University & INFN of Turin on behalf of The CMS Collaboration

## Introduction (CMS & DT system)

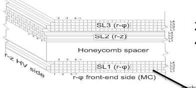
The **C**ompact **M**uon **S**olenoid is a general purpose detector designed to run at the **L**arge **H**adron (p-p) **C**ollider



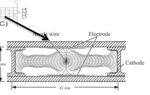
total weight: 12500T
overall diameter: 14.6m
overall length: 21.6m
magnetic field: 4tesla

From inner detectors to outside:
- tracking system
- electron + hadron calorimeters
- superconducting magnet
- return yoke iron + muon spectrometer (CSC + RPC + DT)

The CMS Drift Tube are used as tracking detectors in the barrel muon spectrometer



2φ SLs + 1 θ SL
4 layers for each SL



anode: +3.6KV
cathode:-1.2KV
strips: +1.8KV

The precision of the muon position measurements strongly depends on the knowledge of the Drift Time & Drift Velocity of the ionization products.

→ The main DT calibration goal consists in computing:
- Time Pedestal from TDC measurement (Drift Time)
- Drift Velocity geometrical dependence

## Drift Tube Calibration

### Time Synchronization

The TDC measurement contains the Drift Time + other contributions

$$t_{TDC} = t_0^{pulses} + \underline{t_{tof} + t_{prop} + t_{offset}} + t_{drift}$$

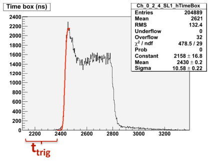
inter-channel synchronization

$t_{tof}$ : time from IP to the cell
$t_{prop}$ : anode propagation time
$t_{offset}$ : trigger latency

$$\boxed{t_{trig} = t_{mean} - k\sigma(t_{mean})}$$

$t_{trig}$ : time pedestal
$t_{mean}$ : rising edge inflection point
$\sigma(t_{mean})$ : width of the rising edge fit

TDC Time Distribution



Algorithms
- the $t_{mean}$ is computed fitting the rising edge of the TDC time distribution with the integral of a Gaussian
- the k factor is tuned by requiring the minimization of residuals on the reconstructed hit position

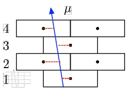
### Drift Velocity Calibration

Drift Velocity depends on:
- gas purity, temperature, pressure, electrostatic configuration within cell configuration

→ hardware monitoring
- muon impact angle, magnetic field

→ calibration with linear velocity choosing a proper granularity within detector

Algorithm:
Mean Time technique to compute the Maximum Drift Time



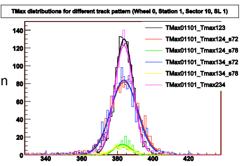
$$T_{max2}^{123} = \frac{t_1 + t_3}{2} + t_2$$

$$T_{max3}^{234} = \frac{t_2 + t_4}{2} + t_3$$

different formula for different pattern
$<T_{max}>$,$<\sigma_{Tmax}>$ : weighted mean

$$v_{drift} = L/2 \cdot 1/ < T_{\max} >$$

$$\mathrm{Res} = \sqrt{2/3}\, v_{drift} \cdot < \sigma_{T\max} >$$

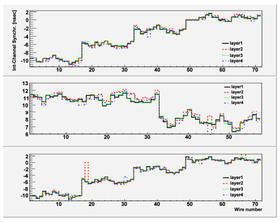


## Results from Cosmic Run at 4 Tesla

### Interchannel Synchronization

Due to the signal path length to the read-out electronics

Calibration performed using dedicated runs:
- test pulses injected to the FE electronics
- acquisition during Abort Gap (≈1MB/sec)



inter-ch synch for MB3, granularity per wire

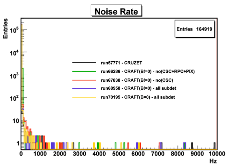
The trend of the graphs (by "steps") reproduce the distance of the FE boards in a single chamber from its centre
Max inter-channel synch correction : ≈10ns

### Noise Calibration

Main role: "clean" the Time Box distribution before fitting the rising edge to find the Time Pedestals

Definitions
- "noise hit" : hit registered before the rising edge of the TDC Time Distribution
- "noisy cell" : cell with a rate of noisy hits > 500Hz

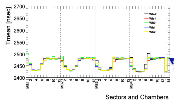
Results
- very low number of noisy cells : ≈ 20 in the whole DT system
- noise stable for all the data taking period
- no influence by B field or other subdetectors
- geometrical distribution – higher concentration in :
  - more internal chambers (MB1)
  - extremity of the cell layers



### Time Pedestal Calibration

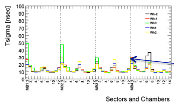
Performed using a factor k=-0.7 obtained minimizing the reconstruction residuals [ $t_{trig}=t_{mean}\times\sigma(t_{mean})$ ]

Results



Distribution of the mean of the inflection point of the fit to the rising edge of the Time Boxes

The difference of values between above/below sectors explained by the Time Of Flight of Cosmics



Distribution of the slope of the rising edge of the Time Box

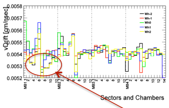
The contribution of the slope is ≈10ns which originates from the distribution of the arrival time of the Cosmics.

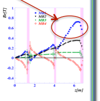
The vertical sectors:
- do not participate to the trigger
- have more inclined and worse defined tracks
- have lower statistics

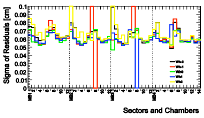
### Drift Velocity Calibration

The Drift Tube velocity has an approximate constant value of 54.3 μm/ns

Fluctuation are originating from cell non-linearity due to:
- Angle of tracks [ higher in sectors with chambers in vertical plane ]
- Magnetic field [ higher in more internal chambers for the outer wheels ]





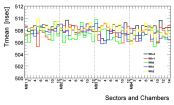


The validation of the Calibration procedure is performed computing the residuals of the reconstructed distances from the wire.

The distribution of the σ of the residuals for the triggering sectors is an indication of the Drift Tube resolution ≈ 500μm if random arrival time of Cosmics is left uncorrected. [CMS trigger designed for bunched muons (40Mz) with fixed t.o.f.→ additional smearing of (25/√12)ns ≈ 400μm due to Cosmics random arrivals] A straight line fit leaving as additional free parameters the drift velocity and the time of passage of the muon provides the expected chamber resolution of 200μm

## Results from LHC startup Monte Carlo simulated events

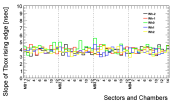
### Time Pedestal Calibration



Mean value of the fit to the Time Box rising edge:
- Time of Flight from the interaction point is already subtracted
- An average value ≈ 507ns is shown
- Fluctuation due to time of propagation of the signal along the wire (≈2ns)

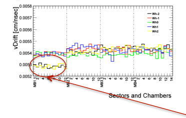
  [ absorbed in Cosmics data by other higher experimental fluctuations ]

σ of the fit to the Time Box rising edge:
- constant on the average value of ≈ 3ns

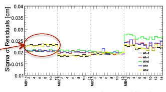


### Drift Velocity Calibration

Drift Velocity computed with the Mean Time technique



Distribution of the standard deviation of the residuals directly proportional to the hit resolution



The path length increases due to the effect of B perpendicular to the wire on the Drift path
→ Drift velocity "apparently" decreases and the resolution becomes worse