Commissioning of the Muon Barrel chambers of the CMS experiment

- SIF 2006 -

Torino, 22/09/2006

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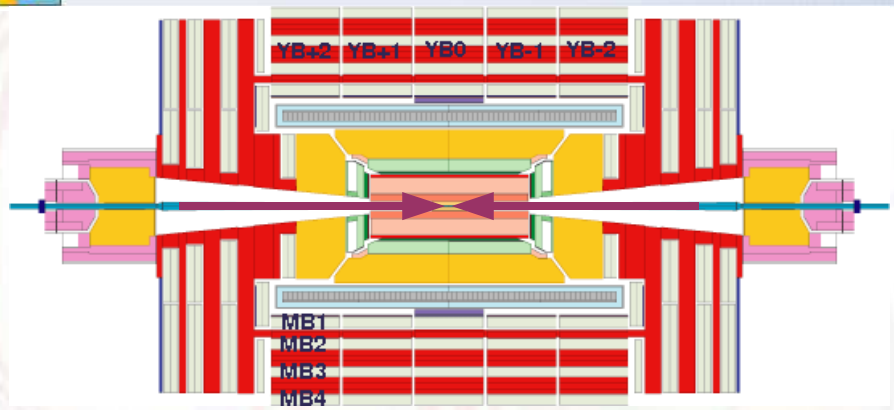
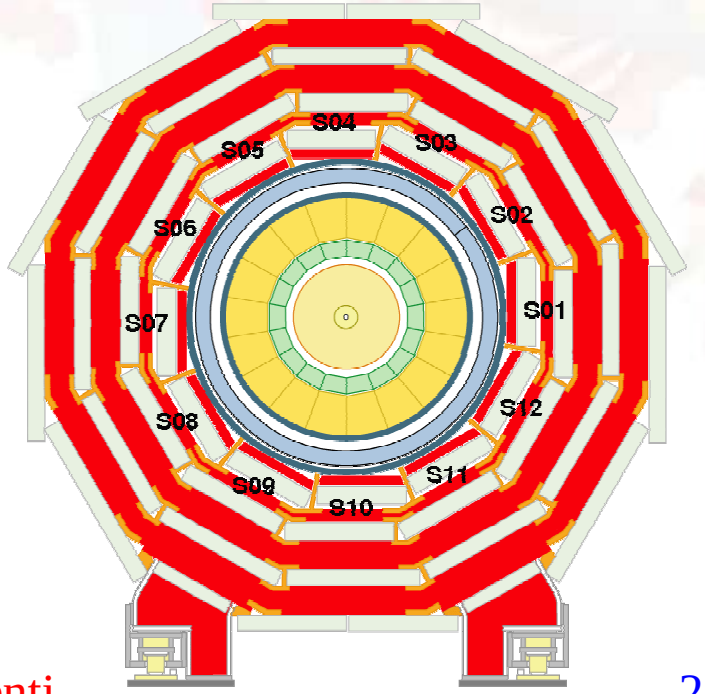
System Overview



Longitudinal view

Cross sectional view



- **CMS barrel muon detection consists of wire chambers (and RPCs)**
- **Each chamber (DT) equipped with local electronic (Minicrate)**
- **DTs are organised in:**
  - 5 wheels (YB-2 - YB+2)
  - 4 stations (MB1-MB4)
  - 12 sectors (S01-S12)
- **Total: 250 DTs**

Chamber Installation

- **146/250 chambers installed:**
  - 42/50 chambers in Wheel +2
  - 42/50 chambers in Wheel +1
  - 40/50 chambers in Wheel 0
  - 13/50 chambers in Wheel -1
  - 9/50 chambers in Wheel -2

- **Installation stopped for Magnet Test / Cosmic Challenge (MTCC), will be resumed in November.**
- **The chambers in vertical sectors (S01-S07) will be installed underground.**

Chamber commissioning

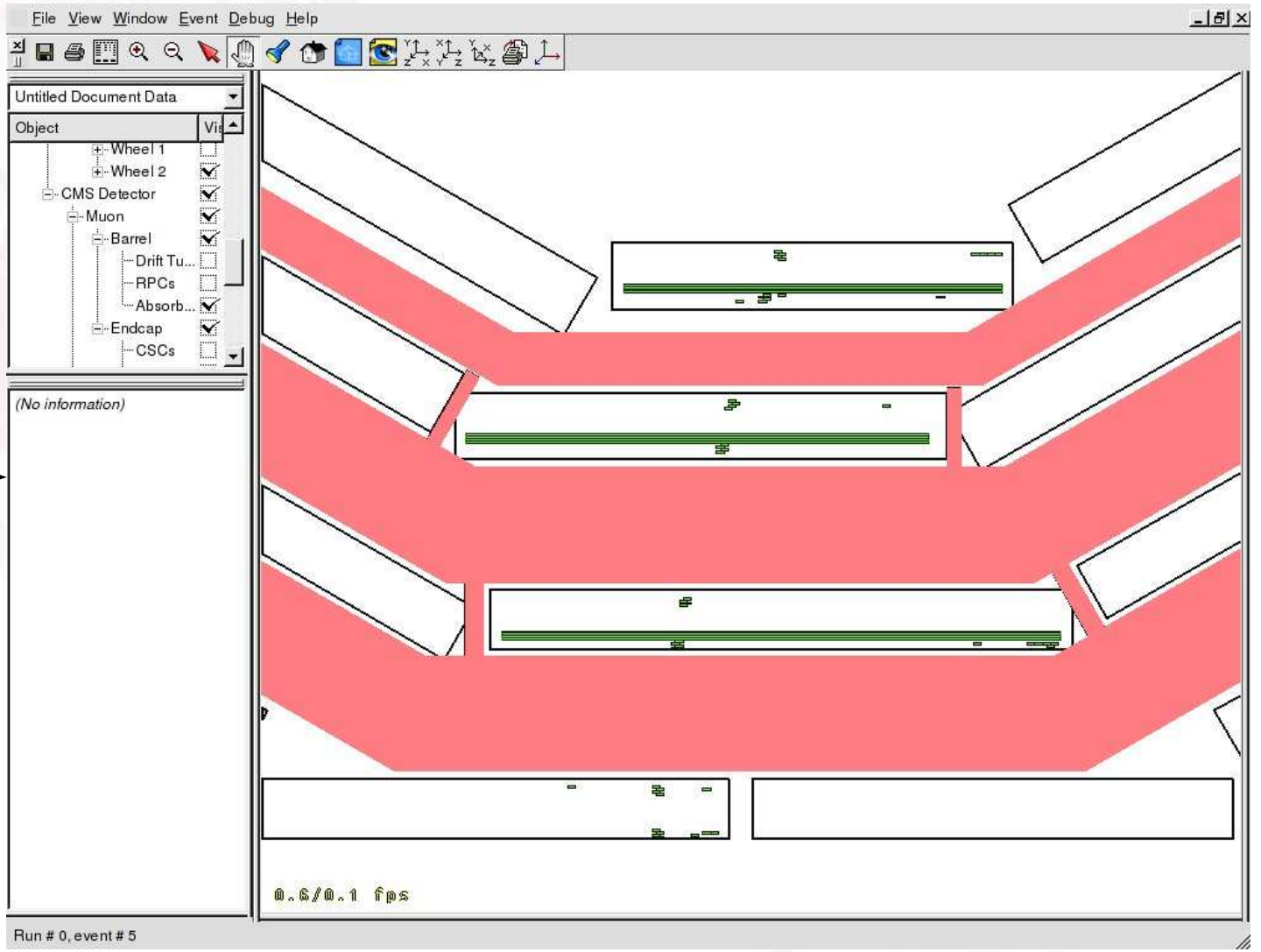
- **Commissioning team: ~20 persons from Aachen RWTH, Bologna Univ & INFN, Madrid CIEMAT, Padova Univ & INFN, Torino Univ & INFN.**
- **Commissioning status: 124/250 chambers done.**
  - 42/50 in Wheel+2
  - 42/50 in Wheel+1
  - 31/50 in Wheel 0
  - 9/50 in Wheel-1
  - 0/50 in Wheel-2
- **Chamber commissioning stopped in June due to Magnet Test / Cosmic Challenge.**

Magnet Test / Cosmic Challenge

- **The MTCC consists in:**
  - Commissioning of the Magnet and related systems,
  - Mapping of the magnetic field,
  - Data acquisition with a sector of CMS:
    - Muon system (DT, RPC, CSC),
    - Calorimeter (ECAL, HCAL),
    - Tracker.
- **Started in June, will last until end October.**
- **DAQ and trigger integration successful**
- **Data taking satisfactory (see cosmic muons →)**

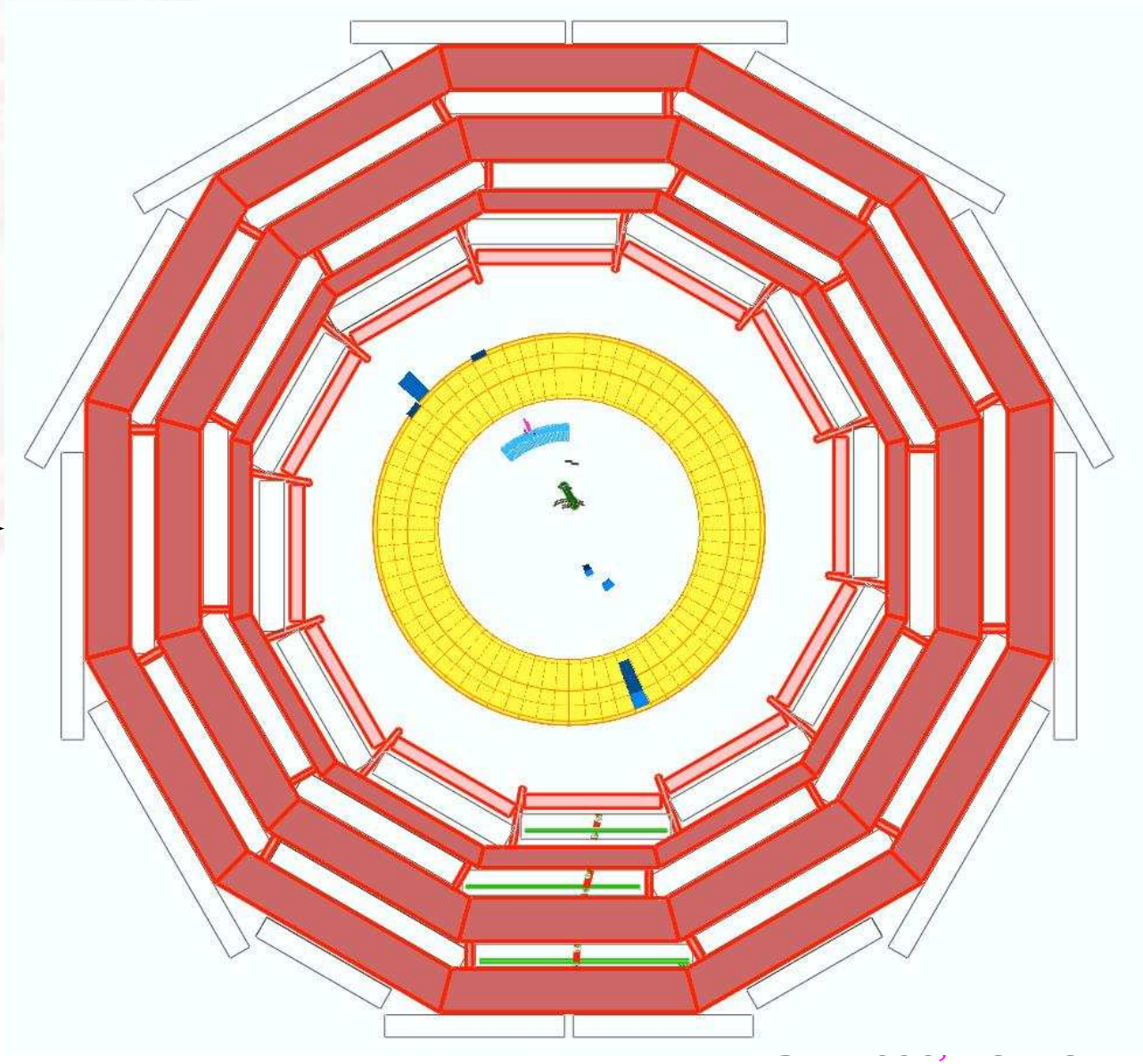
A cosmic muon from MTCC

28.07.2006:
A cosmic muon detected by DTs at B=1T



Another cosmic muon

27.08.2006:
A cosmic muon detected by tracker, ECAL, HCAL, DTs at B=3.8T



Commissioning procedure

- **Cabling of the chamber** **connecting LV, RO, TRG, clock, DCS. Hand-made connections!**
- **Test on-chamber readout and trigger electronics with dedicated procedures**
  - Several ROB and TRB testing procedures
  - If errors are found commissioners try to fix it (success depends on experience with electronics).
  - No fix → leave chamber to the expert and/or move to next one
- **Take testpulses** **TP fed directly to FEB, no wire test**
- **Cosmics data taking** **test performance of all cells + readout**
  - 3 (MB1,2,3) and 2 (MB4) configurations, respectively
  - Depending on chamber orientation, data taking rates ~80 - 500 Hz
- **Data analysis and diagnostics**
  - Calibration (t0 and tTrig)
  - Analysis and diagnostic with Hanytheta run
- **Required time and manpower: a team of 2 people is needed, manage 1-2 chambers per day** **(depends on cabling time, chamber performance, data taking time)**
- **In the last weeks of commissioning we operated 2 set-up's in parallel with 3 people on shift; a third set-up is foreseen.**

Interventions on chambers

124 chambers (= 50% of the total) commissioned so far.

- **Interventions due to chamber problems:**
  - 1 chamber (YB+2 MB3 S09) uninstalled to fix a HV problem (wire discharge, HVB replaced)
  - 1 chamber (YB0 MB3 S06) uninstalled to fix a LV short in theta-SL FE-cover
  - 2 chambers failed pre-installation tests (YB+1 MB4/10, MB4). One was due to a broken ground fork that was fixed with installed chamber in place. The other chamber failed HV pre-install test and went back to ISR for repair.
  - 1 chamber (YB+2 MB1 S04) with many noisy channels, fixed by disconnecting the slow ctrl cable shield from splitter board ground
  - Summary:

Intervention	Number of chambers	Fraction of all 124 chambers
Chambers to be un-installed for repair	2	2%
Chambers failing SX5 pre-installation test	2	2%
Minor interventions (noise, FEB)	1	1%

- **No HV problems after long time operation observed! Commissioning is mainly a test of the on-chamber electronics.**

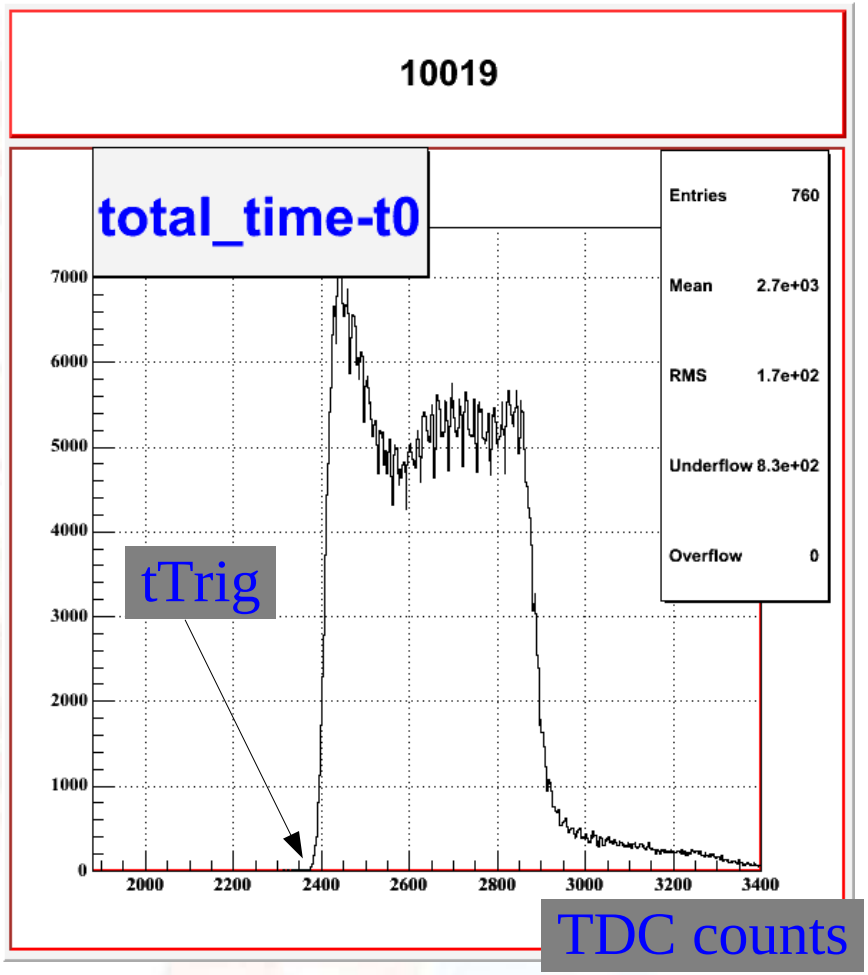
Interventions on minicrates

- **Replaced components during Chamber Commissioning and Cabling:**

Intervention type	No. of this component	YB+2		YB+1		YB0	
	YB+2, +1, 0 124 chambers	Chamber + Cabling	Percentage of total no.	Chamber + Cabling	Percentage of total no.	Chamber	Percentage of total no.
TRB replaced + fixes	252	6	2.3%	8	3.2%	1	0.4%
Cabling errors and minor fixes	124	4	3.2%	6	4.8%	2	1.6%
Link board replaced	124	2	1.6%	1	0.8%	-	-
ROB replaced	252	-	-	1	0.4%	-	-
FEB replaced	~2020	2	0.1%	1	0.05%	-	-
ROS link board replaced	124	1	0.8%	-	-	-	-
Noise	124	2	1.6%	1	0.8%	-	-

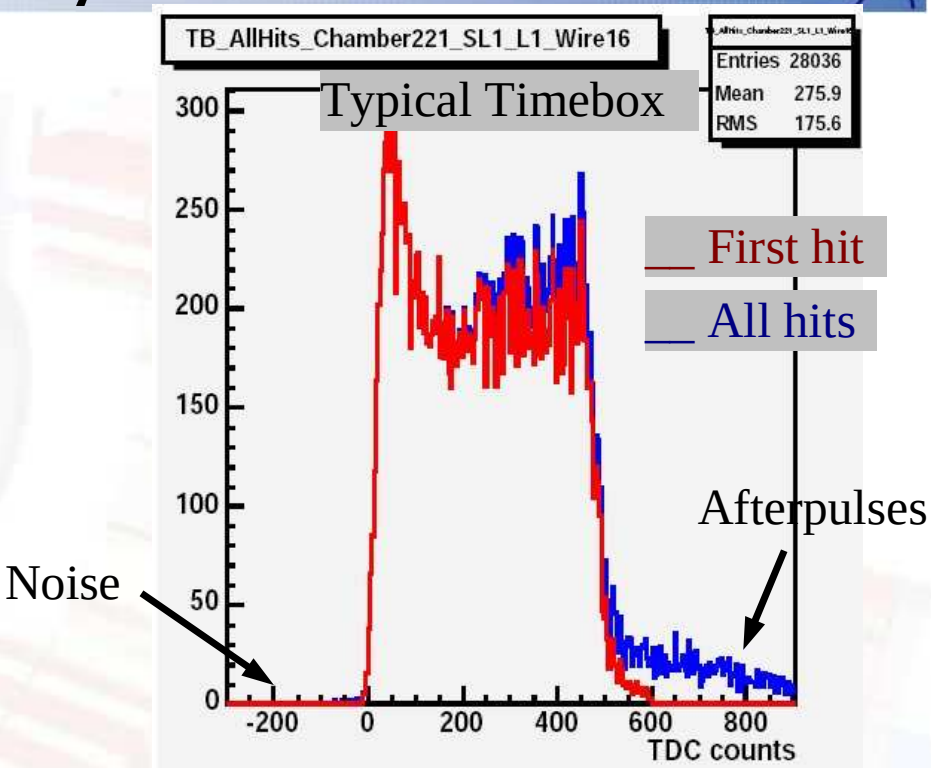
Data Analysis: t0 and tTrig

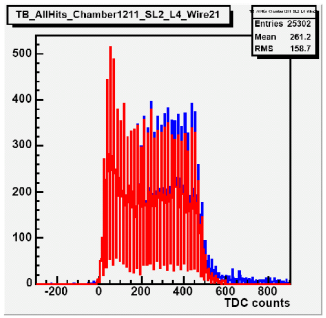
- **t0 is the arrival time of the Test Pulse signal, and varies channel by channel depending on cable lengths, clock line lengths, ...**
  - $t0_i$ evaluated for each channel wrt average t0, and subtracted in order to synchronise channels.
- **tTrig is the value you have to subtract to all times (once corrected for the t0) in order that the time box starts from 0. It is a unique value. We calculate 3 tTrig, one for each SL, but they must coincide within the errors.**



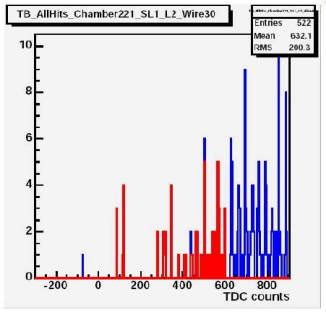
Cosmic data analysis: Timebox

- **From the study of Timebox we identify:**
  - Noise (hits with tDrift<0)
  - Dead channels (few entries)
  - Disconnected channels (0 entries)
  - Missing cathode voltage
  - Bad gas mixture
  - ....

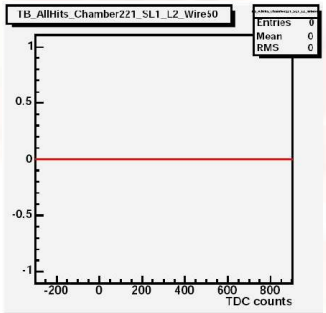




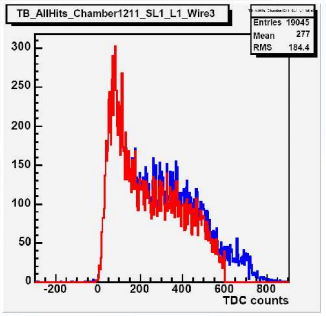
Noisy channel



Dead channel



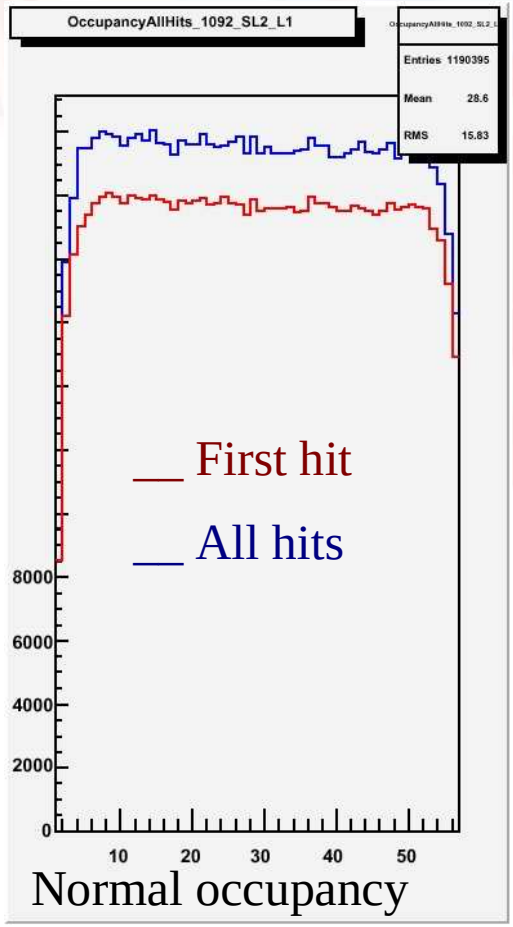
Disc. channel



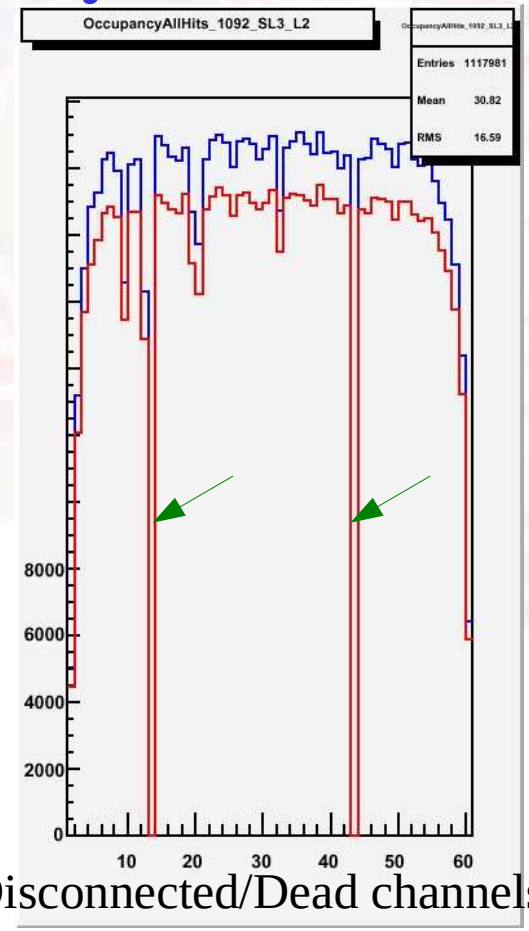
Missing cathode

Cosmic data analysis: occupancy

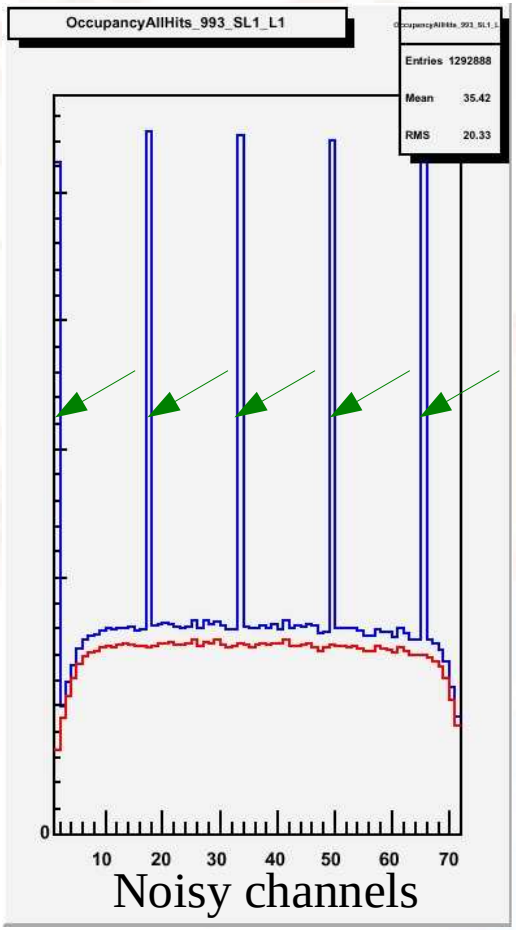
- **In the occupancy plots we see disconnected/dead channels and noisy channels:**



Normal occupancy



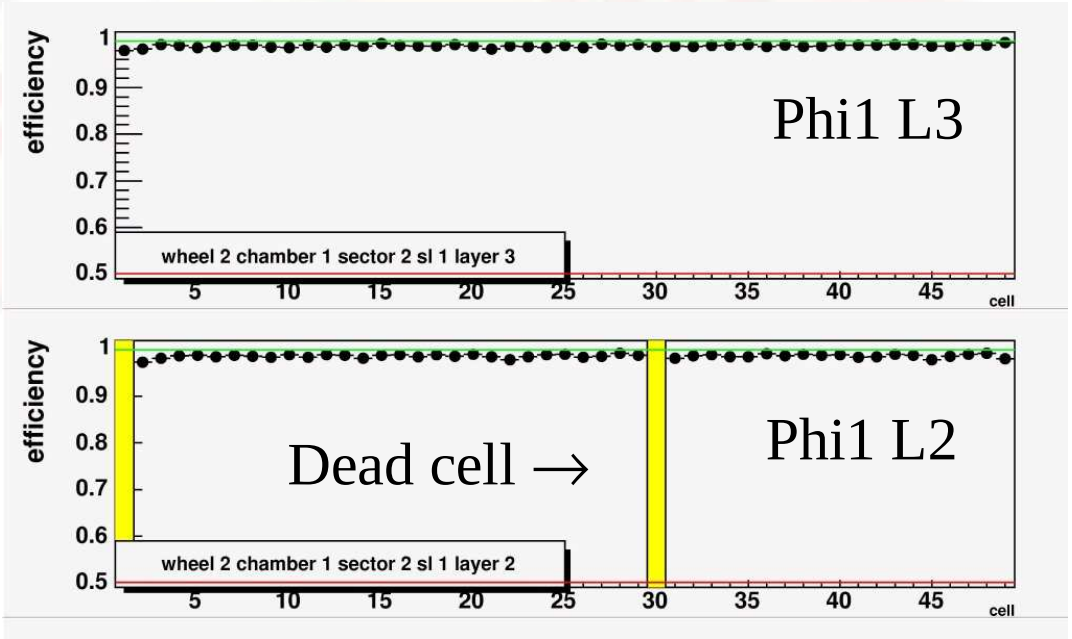
Disconnected/Dead channels



Noisy channels

Local cell efficiency

- **Local cell efficiency = Nh/Ntrack**
  - Nh = subset of Ntrack where hits are found within the considered cell or its 2 neighbours.
  - Ntrack = number of tracks reconstructed in both Φ superlayers, with at least 5 points (for Φ cells), or in Θ superlayer, with at least 3 points (for Θ cells), and traversing the considered cell.
- **Efficiency of good cells is usually better than ~99%**



Summary

- **146/250 DT installed, 124/250 commissioned:**
  - Only 4 major interventions on chambers
  - Major interventions on some % of minicrates
- **Installation/Commissioning stopped due to MTCC, will be resumed in November.**
- **Chambers are working well in MTCC → see cosmic muon pictures**


Additional Slides

Trigger Rates

- **Trigger rates depend on configuration and sector. Actually these are DAQ rates**

Sector	HHandHL [Hz]			Hanytheta [Hz]			Default [Hz]		
	MB1	MB2	MB3	MB1	MB2	MB3	MB1	MB2	MB3
S02	100	110	180	130	160	240	155	200	250
S03	160	210	-	225	280	420	260	340	480
S06	85	130	170	120	170	230	170	220	260
S08	85	95	100	120	140	150	145	160	175
S09	160	165	195	240	250	260	290	305	310
S10	100	180	190	140	230	260	170	-	300
S11	80	120	135	120	150	120	140	185	250
S12	80	100	100	125	140	150	165	160	170

- **Trigger configurations:**
  - HHandHL: High-High (4-4 hits) or High-Low (4-3 hits) correlated in both phi SLs
  - Hanytheta: HH + HL + H_uncorrelated if confirmed by theta SL (not for MB4)
  - Default: HH + HL + H_uncorrelated

Trigger Configurations

1) default = default config.

Trigger = HH + HL + H_uncorrelated

2) H_anytheta = uncorrelated H must be confirmed by the Theta SL (either H or L).

Trigger: HH + HL + H_uncorrelateds(if Theta).

3) Phi1_only = as H_anytheta but BTI of SL Phi2 are masked, so ONLY PHI1 triggers.

Trigger: H_inner(if Theta)

4) Phi2_only = as H_anytheta but BTI of SL Phi1 are masked, so ONLY PHI2 triggers.

Trigger: H_outer(if Theta)

5) Theta_only = ONLY H triggers from SL Theta.

Trigger: H from Theta

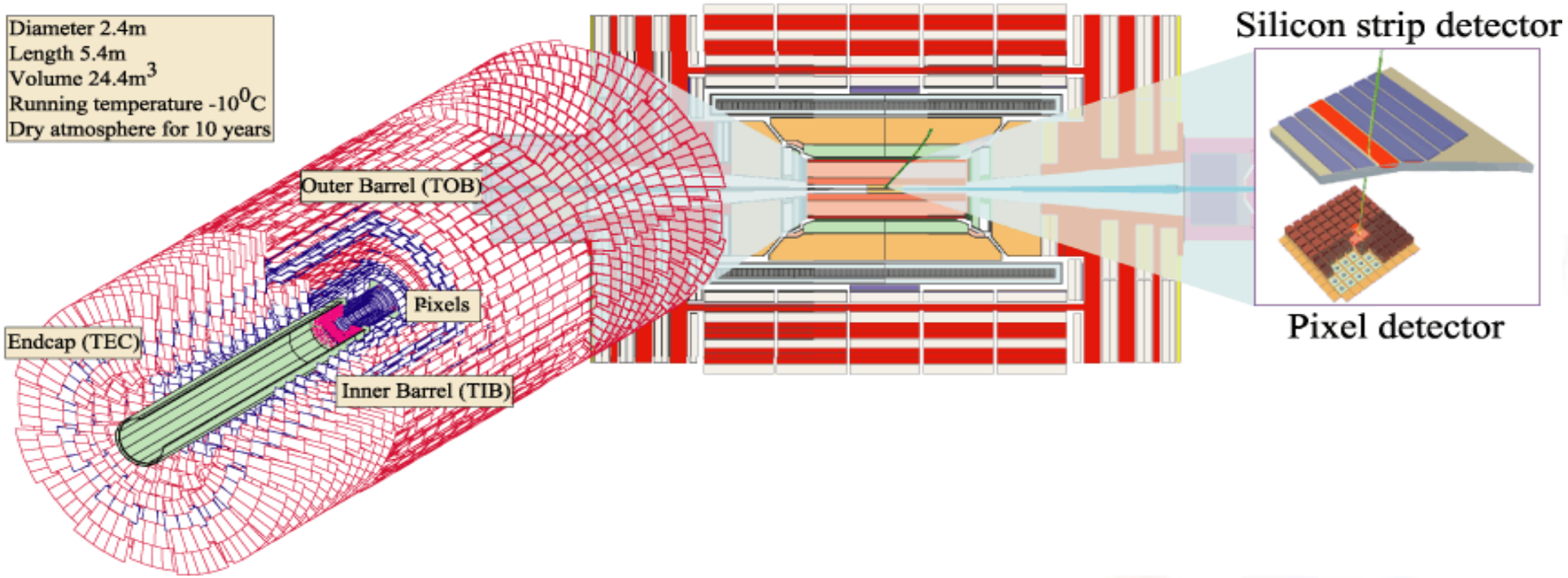
6) HH+HL = is the H_anytheta config. but the Theta BTI are masked, so

Trigger: HH + HL

7) verticalonly = is default configuration but with the minimal angular acceptance - practically only vertical tracks -.

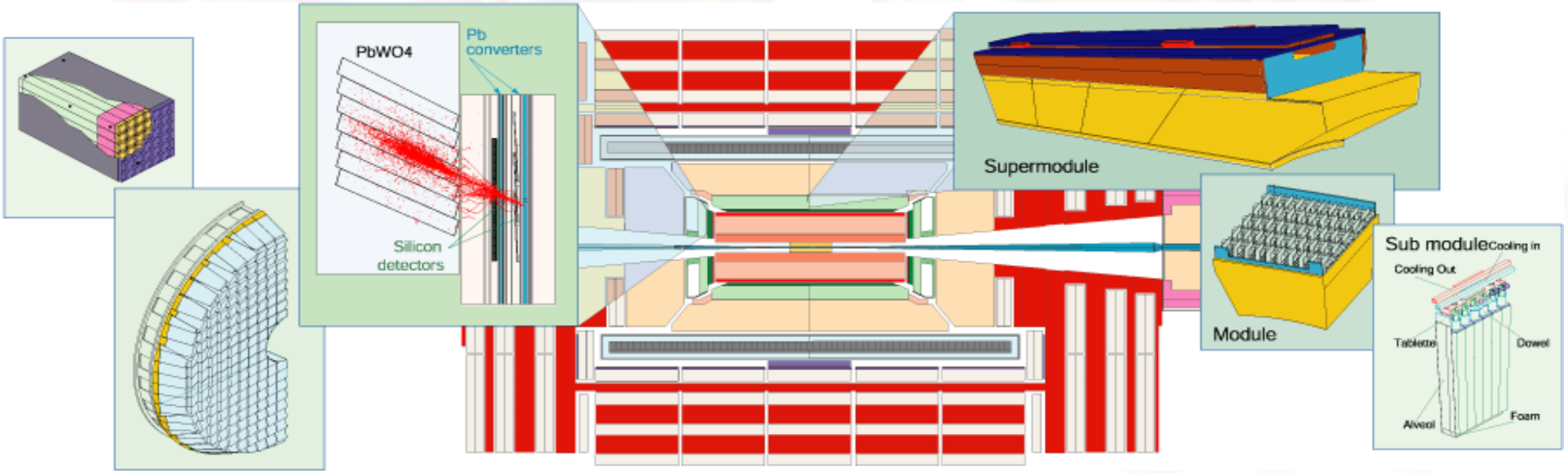
Tracker

- **The CMS collaboration decided to use an all-silicon solution for the tracker. In total the CMS tracker implements 25000 silicon strip sensors covering an area of 210m^2. Connected to 75000 APV chips, one has to control 9600000 electronic readout channels, needing about 26 million microbonds.**



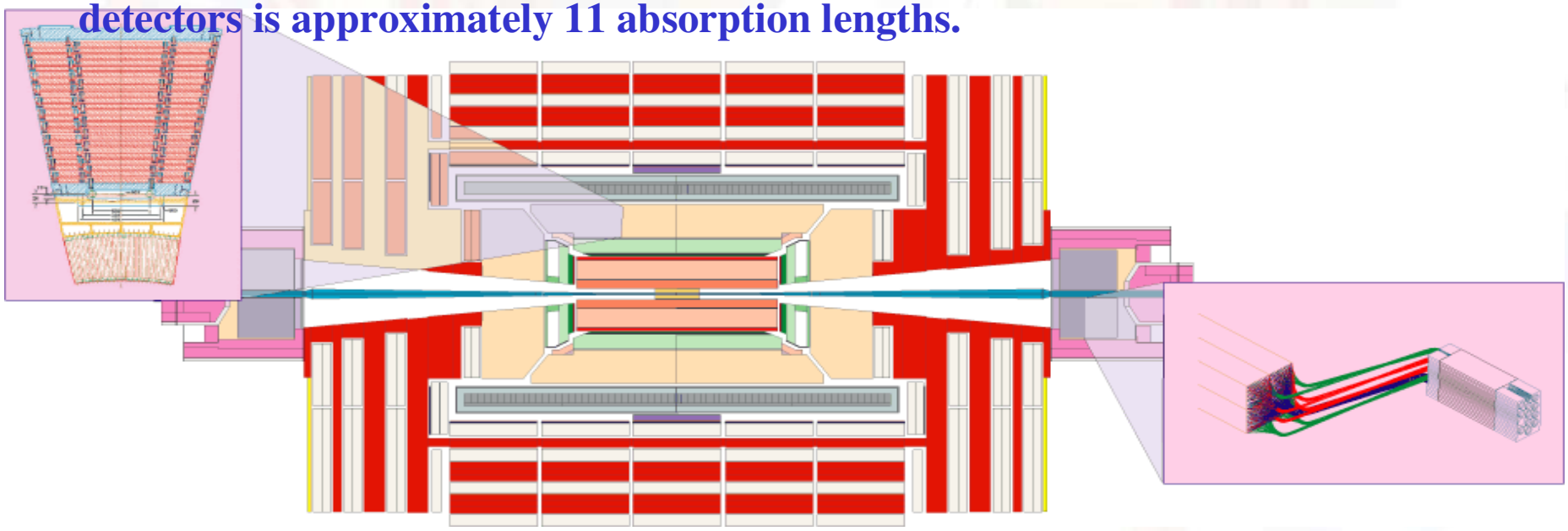
ECAL

- The CMS electromagnetic calorimeter will consist of over 80,000 lead-tungstate ($PbWO_4$) crystals equipped with photodiodes.
- $PbWO_4$ has a short radiation length and a small Moliere radius and is a fast scintillator.
- The crystals have a total thickness of 26 radiation lengths (23 cm).



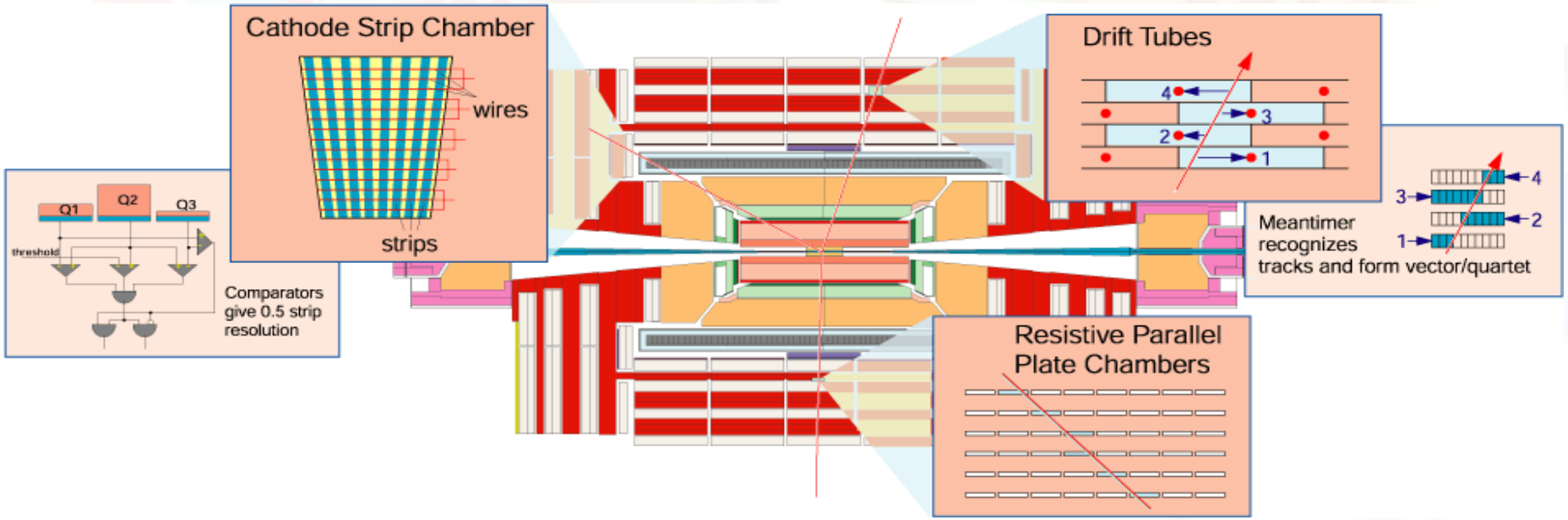
HCAL

- **The hadron barrel (HB) and hadron endcap (HE) calorimeters are sampling calorimeters with 50 mm thick copper absorber plates interleaved with 4 mm thick scintillator sheets.**
- **Because the barrel HCAL inside the coil is not sufficiently thick to contain all the energy of high energy showers, additional scintillation layers (HOB) are placed just outside the magnet coil. The full depth of the combined HB and HOB detectors is approximately 11 absorption lengths.**



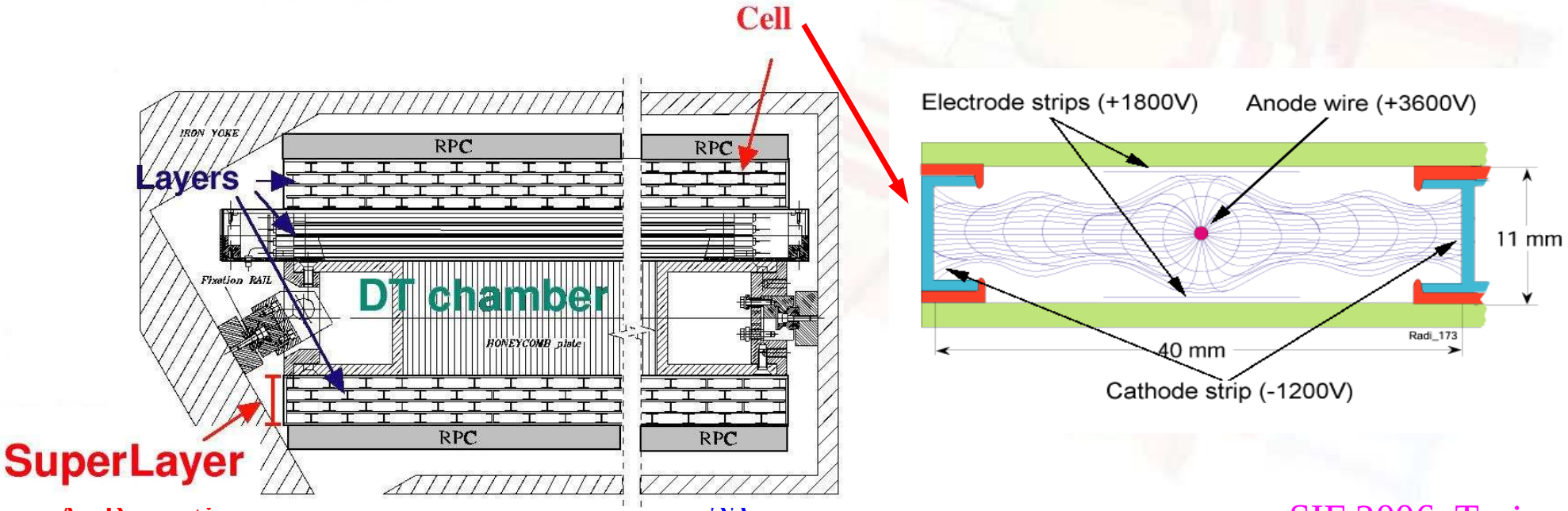
Muon Detector

- **CMS will use three types of gaseous particle detectors for muon identifica-tion: Drift Tubes (DT) in the central barrel region, Cathode Strip Chambers (CSC) in the endcap region and Resistive Parallel Plate Chambers (RPC) in both the barrel and endcaps. The DT and CSC detectors are used to obtain a precise measurement of the position and thus the momentum of the muons, whereas the RPC chambers are dedicated to providing fast information for the Level-1 trigger.**



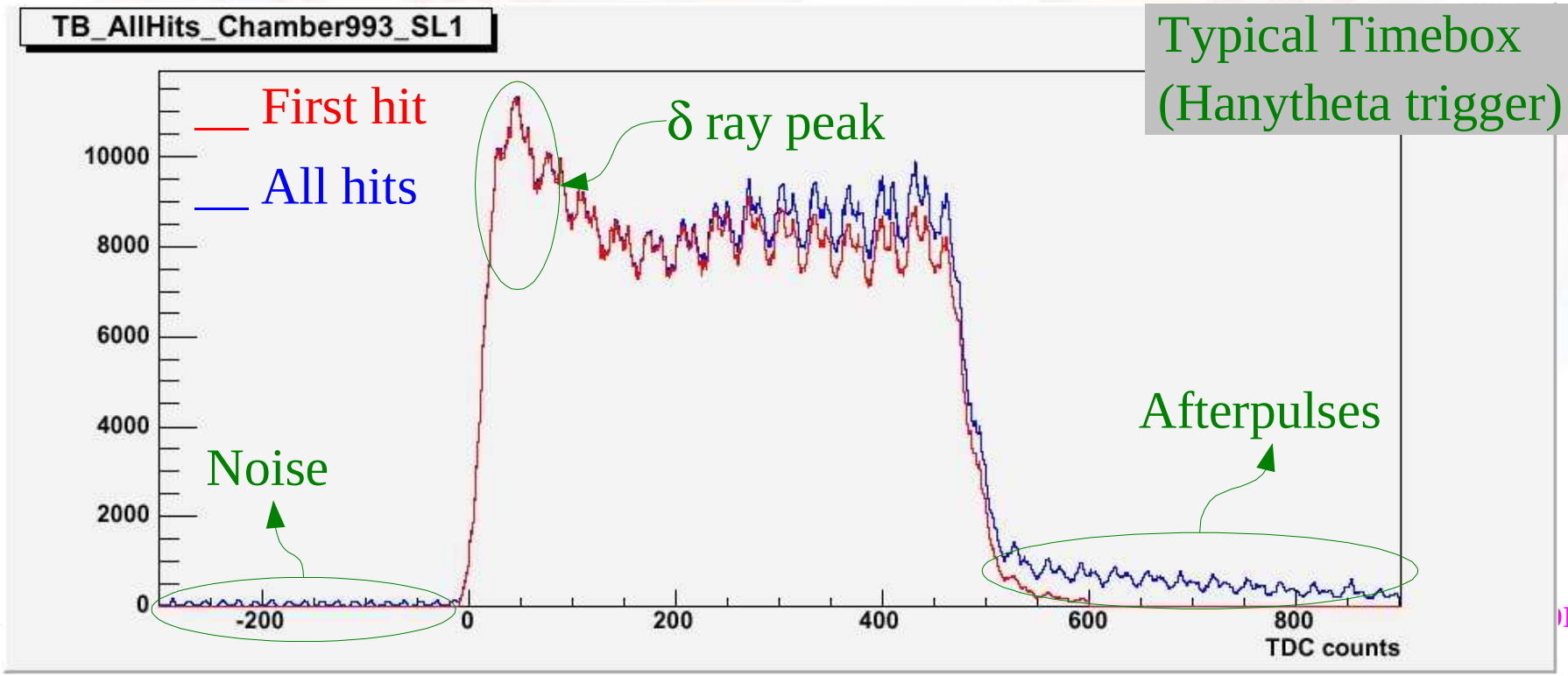
DT chambers

- **Nominal voltages: +3600V (anode), +1800V (electrode), -1200V (cathode).**
- **Gas Mixture: Ar (85%), CO_2 (15%).**
- **Single cell resolution: 200 μm.**
- **Max drift time: 380 ns.**



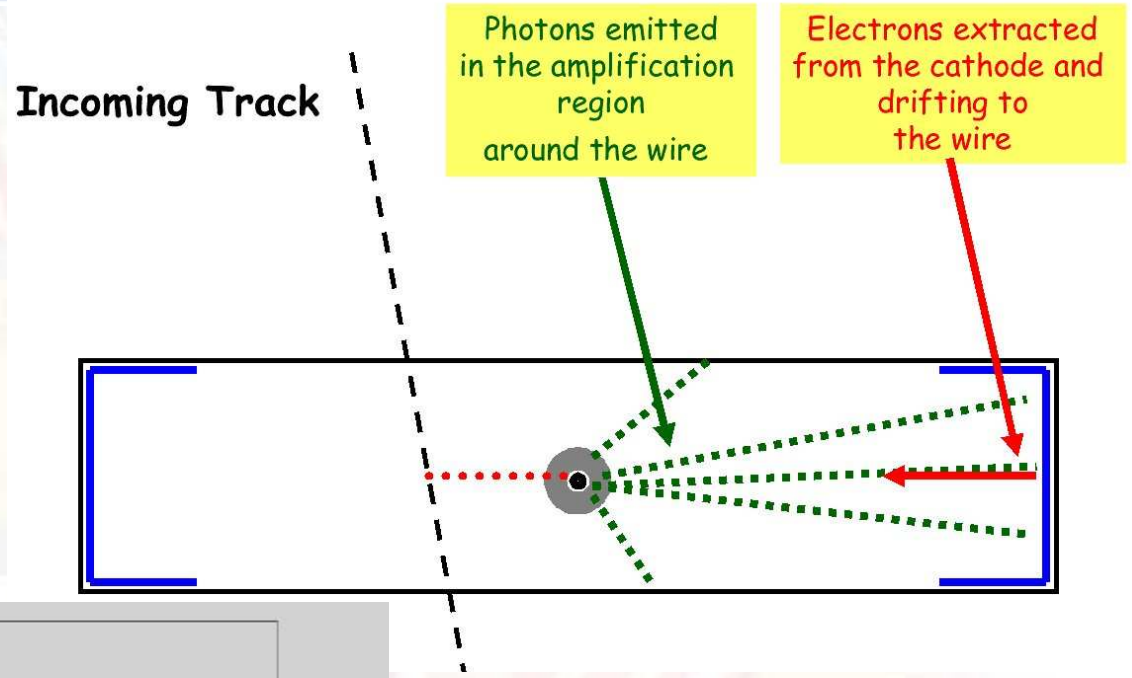
Timebox analysis

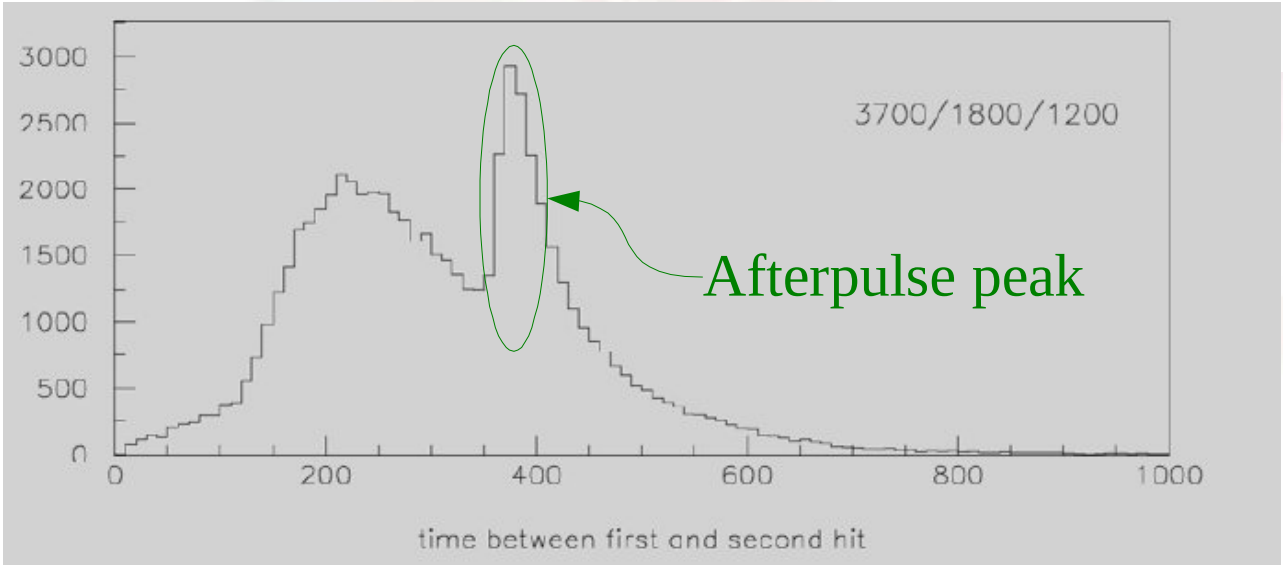
- **Maximum drift time: tMax = 490 TDC counts = 380 ns**
- **Noise (constant on all interval)**
- **Afterpulses: 2nd hits in tMax < tDrift < 2tMax**
- **40 MHz noise → due to electronics, does not affect time resolution**
- **Rise time: intrinsic cell resolution (~3ns) ⊕ random phase between cosmic muon and clock (~10ns)**
- **Peak at TDCcount=0: due to δ rays and consequent TDC deadtime (~100ns)**



Afterpulses

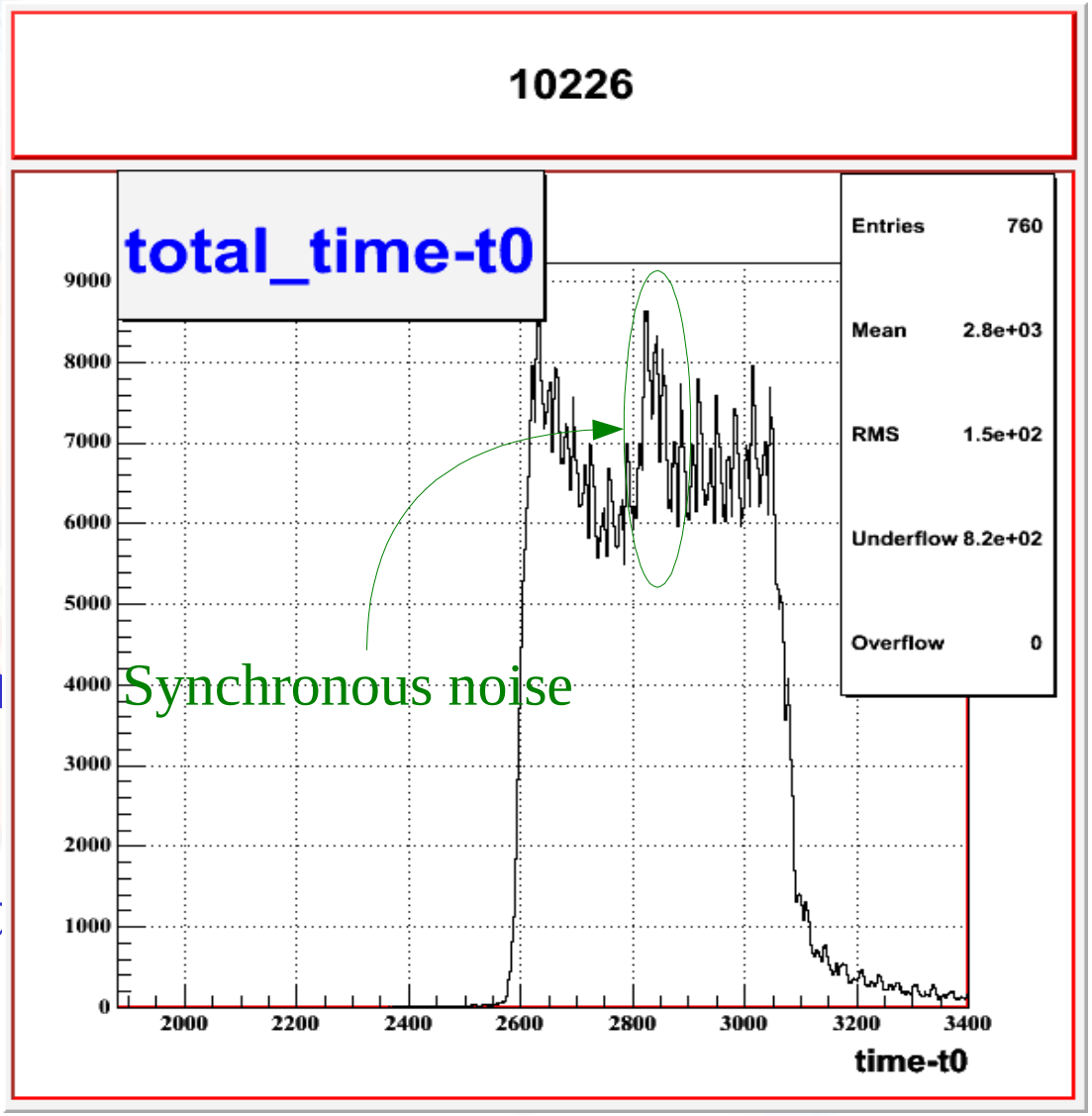
- **Afterpulse peak height and position depends on:**
  - HV
  - gas composition





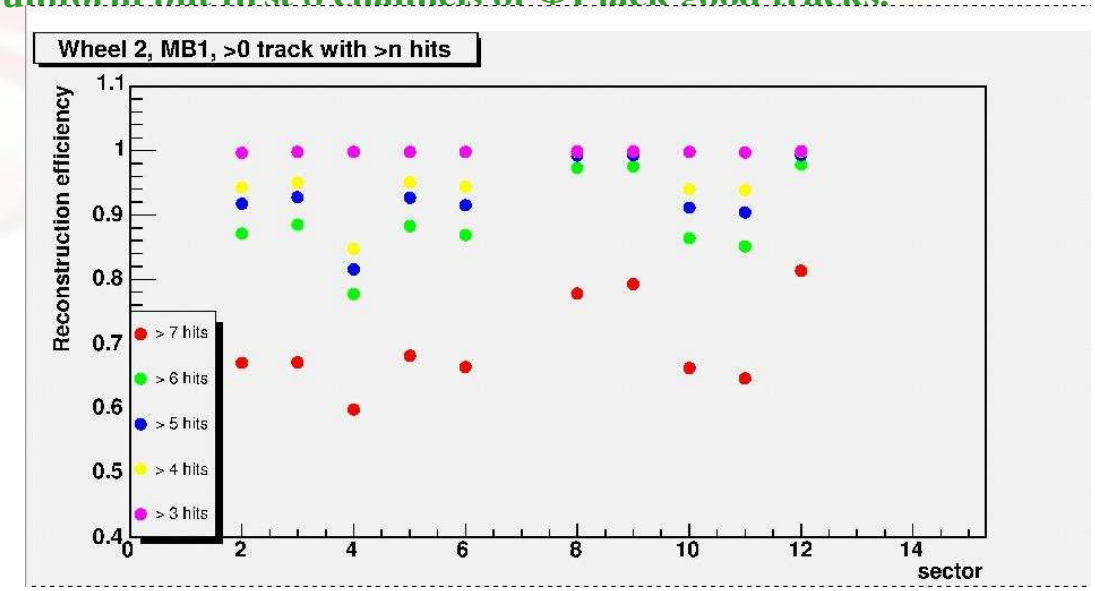
Timebox: Syncronous Trigger Noise

- **A peak appears with default trigger config**
- **Why?**
  - Noise in a cell induces signal in nearby cells, mimicking H_uncorrelated trigger
- **Solution: use of Hanytheta or HHandHL trigger**
- **Anyway rate is ~Hz, won't be a problem with beam data**



Data analysis: reconstruction efficiency

- **Reconstruction efficiency = Nn/NEvent**
  - Nevent = number of triggered events
  - Nn = number of events with at least one track reconstructed in both Φ superlayers, with at least n points (n = 4,...,8)
- **Reconstruction efficiencies are typically ~90%, independent of the sector (respectively chamber inclination) and station number.**
- **"Local efficiency" and "reconstruction efficiency" give complementary information. For example (seen in YB+2 MB4/1) raw hit occupancy is uniform but first 8 channels of Φ1 lack good tracks.**



Interventions on Minicrates

Wheel	Total No. MC commissioned	Major interventions			Minor interventions		
		Chamber commiss.	Cabling	Percentage of both	Chamber commiss.	Cabling	Percentage of both
YB+2	42	2	3	12%	7	5	29%
YB+1	42	4	1	12%	10	3	31%
YB 0	31	1	To do	3%	2	To do	6%

Intervention type	YB+2		YB+1		YB0	
	Chamber commiss.	Cabling	Chamber commiss.	Cabling	Chamber commiss.	Cabling
TRB replaced + fixes	2	4	8	0	1	To be done
Cabling errors and minor fixes	2	2	3	3	2	
Link board replaced	2	-	-	1	-	
ROB replaced	-	-	1	-	-	
FEB replaced + fixes	-	2	1	-	-	
ROS link board replaced	1	-	-	-	-	
Noise	2	-	1	-	-	

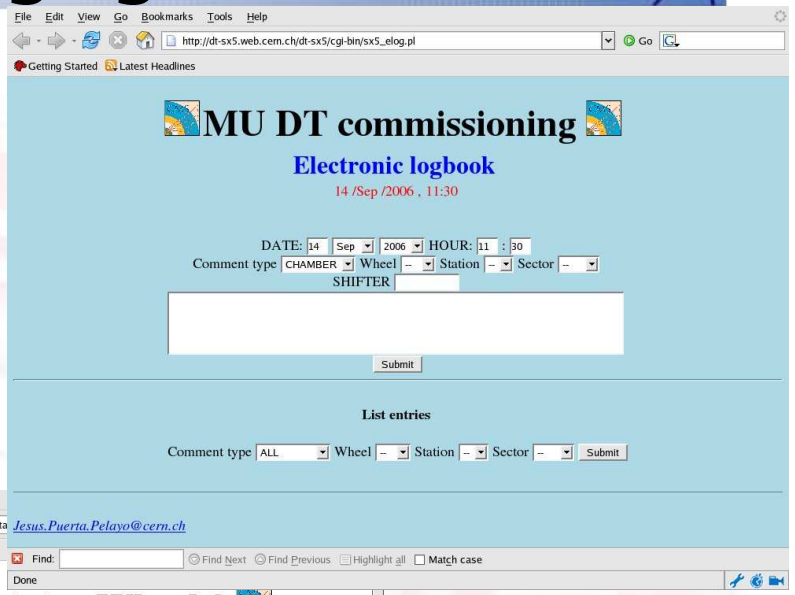
Torino

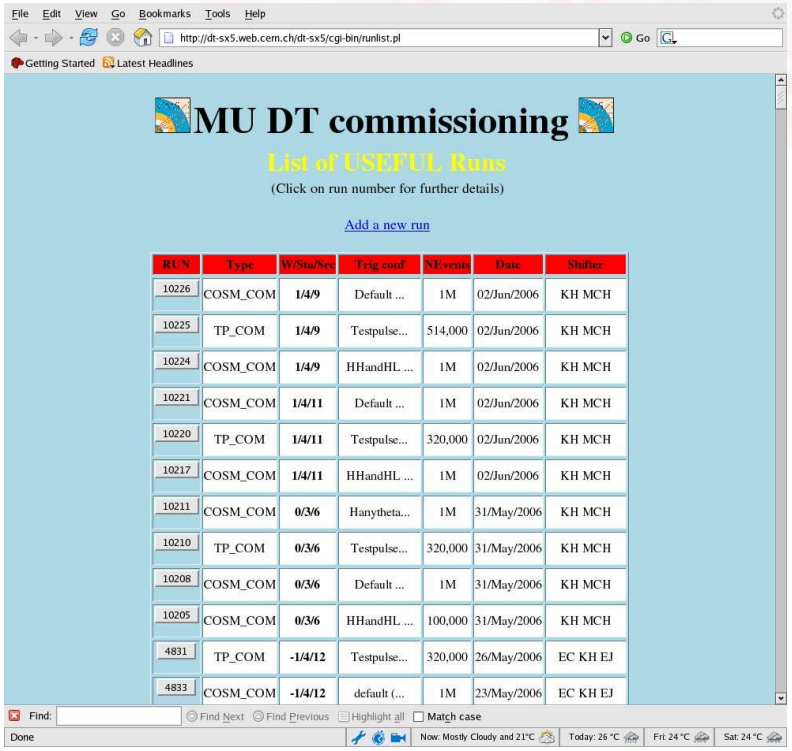
E-Tools for logging

E-Tools used since beginning of 2006 to store:

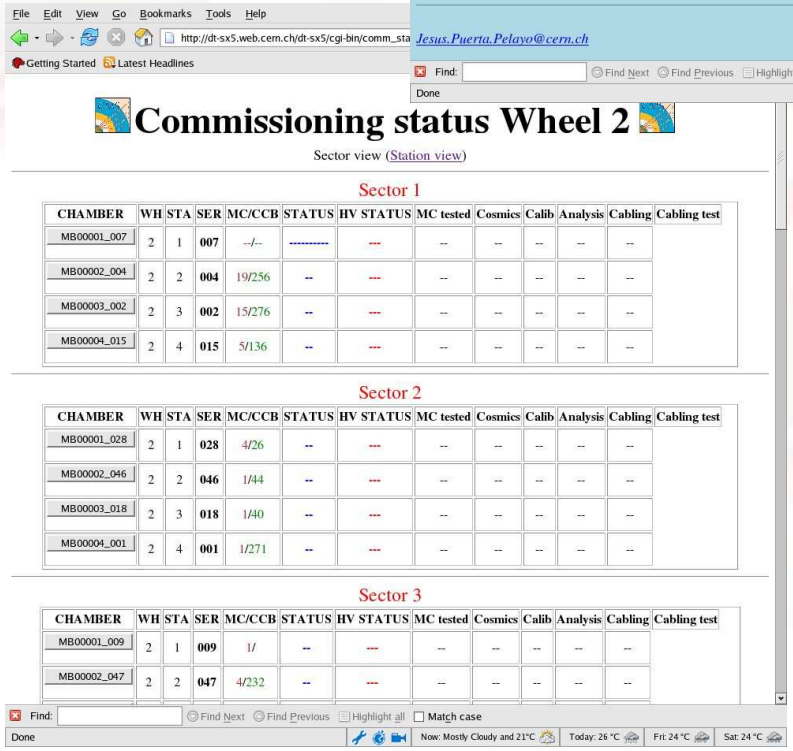
- Chamber status,
- Run list,
- Shift logbook,
- HV status.

They make easier the communicatin between shifters and off-line analysers.





RUN	Type	W/Sta/Sec	Trig conf	NEvents	Date	Shifter
10226	COSM_COM	1/4/9	Default ...	1M	02/Jun/2006	KH MCH
10225	TP_COM	1/4/9	Testpulse...	514,000	02/Jun/2006	KH MCH
10224	COSM_COM	1/4/9	HHandHL ...	1M	02/Jun/2006	KH MCH
10221	COSM_COM	1/4/11	Default ...	1M	02/Jun/2006	KH MCH
10220	TP_COM	1/4/11	Testpulse...	320,000	02/Jun/2006	KH MCH
10217	COSM_COM	1/4/11	HHandHL ...	1M	02/Jun/2006	KH MCH
10211	COSM_COM	0/3/6	Hanytheta...	1M	31/May/2006	KH MCH
10210	TP_COM	0/3/6	Testpulse...	320,000	31/May/2006	KH MCH
10208	COSM_COM	0/3/6	Default ...	1M	31/May/2006	KH MCH
10205	COSM_COM	0/3/6	HHandHL ...	100,000	31/May/2006	KH MCH
4831	TP_COM	-1/4/12	Testpulse...	320,000	26/May/2006	EC KH EJ
4833	COSM_COM	-1/4/12	default (...	1M	23/May/2006	EC KH EJ



Sector 1

CHAMBER	WH	STA	SER	MC/CCB	STATUS	HV STATUS	MC tested	Cosmics	Calib	Analysis	Cabling	Cabling test
MB00001_007	2	1	007	--/--	----------	---	--	--	--	--	--	
MB00002_004	2	2	004	19/256	--	---	--	--	--	--	--	
MB00003_002	2	3	002	15/276	--	---	--	--	--	--	--	
MB00004_015	2	4	015	5/136	--	---	--	--	--	--	--	

Sector 2

CHAMBER	WH	STA	SER	MC/CCB	STATUS	HV STATUS	MC tested	Cosmics	Calib	Analysis	Cabling	Cabling test
MB00001_028	2	1	028	4/26	--	---	--	--	--	--	--	
MB00002_046	2	2	046	1/44	--	---	--	--	--	--	--	
MB00003_018	2	3	018	1/40	--	---	--	--	--	--	--	
MB00004_001	2	4	001	1/271	--	---	--	--	--	--	--	

Sector 3

CHAMBER	WH	STA	SER	MC/CCB	STATUS	HV STATUS	MC tested	Cosmics	Calib	Analysis	Cabling	Cabling test
MB00001_009	2	1	009	1/	--	---	--	--	--	--	--	
MB00002_047	2	2	047	4/232	--	---	--	--	--	--	--	