Andrea Parenti
INFN and Università di Padova
(*on behalf of the CMS Muon Collaboration*)

The CMS Muon System and its Performance in the Cosmic Challenge

RT2007 conference, Batavia IL, USA

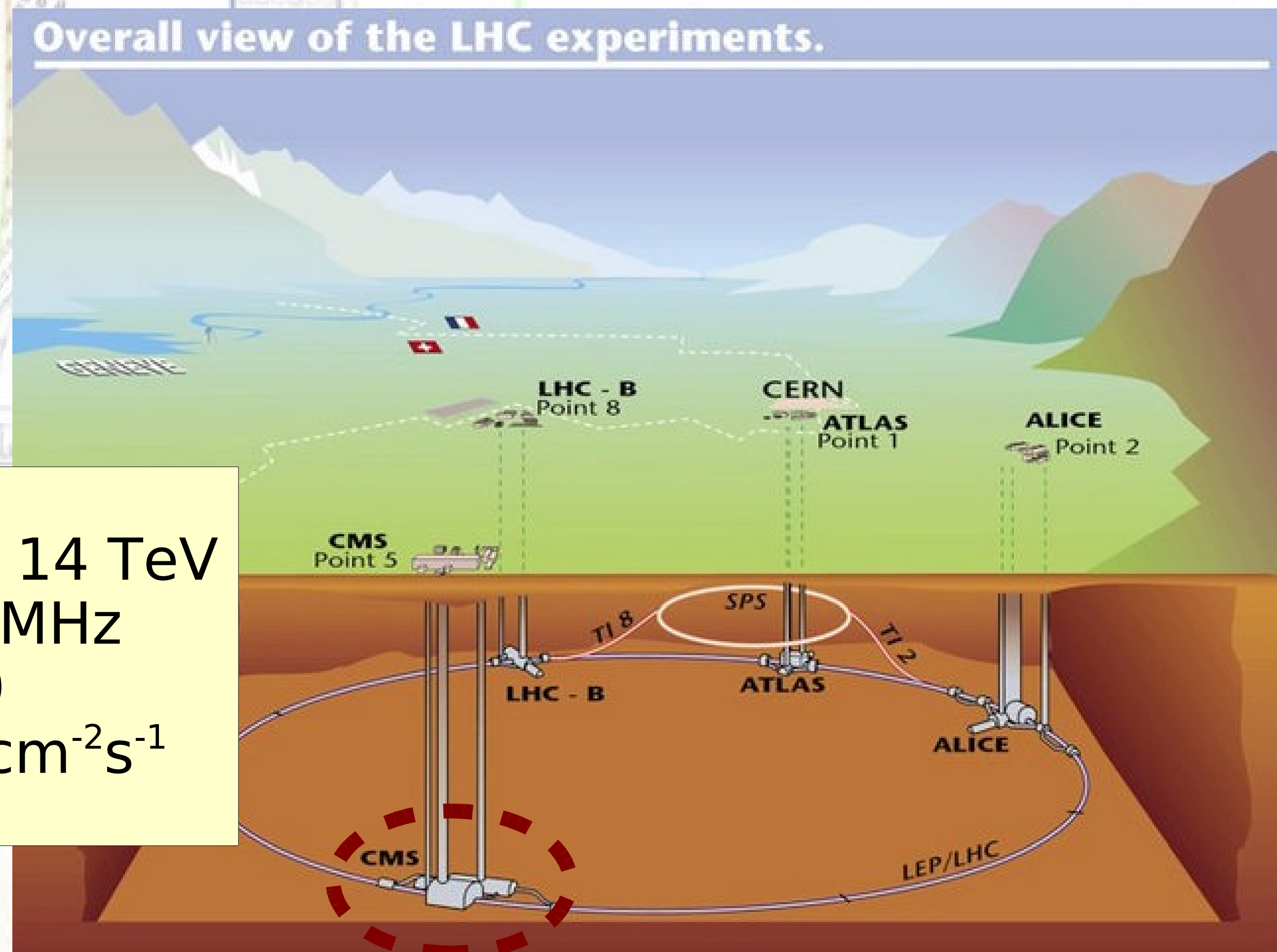
May 03, 2007

Outline

- **Description of the Compact Muon Solenoid (CMS) detector at Large Hadron Collider (LHC), Geneva**
- **Goals of the Magnet Test / Cosmic Challenge (MTCC) – (summer/fall 2006)**
- **Results of the MTCC**
- **Conclusion**

The LHC

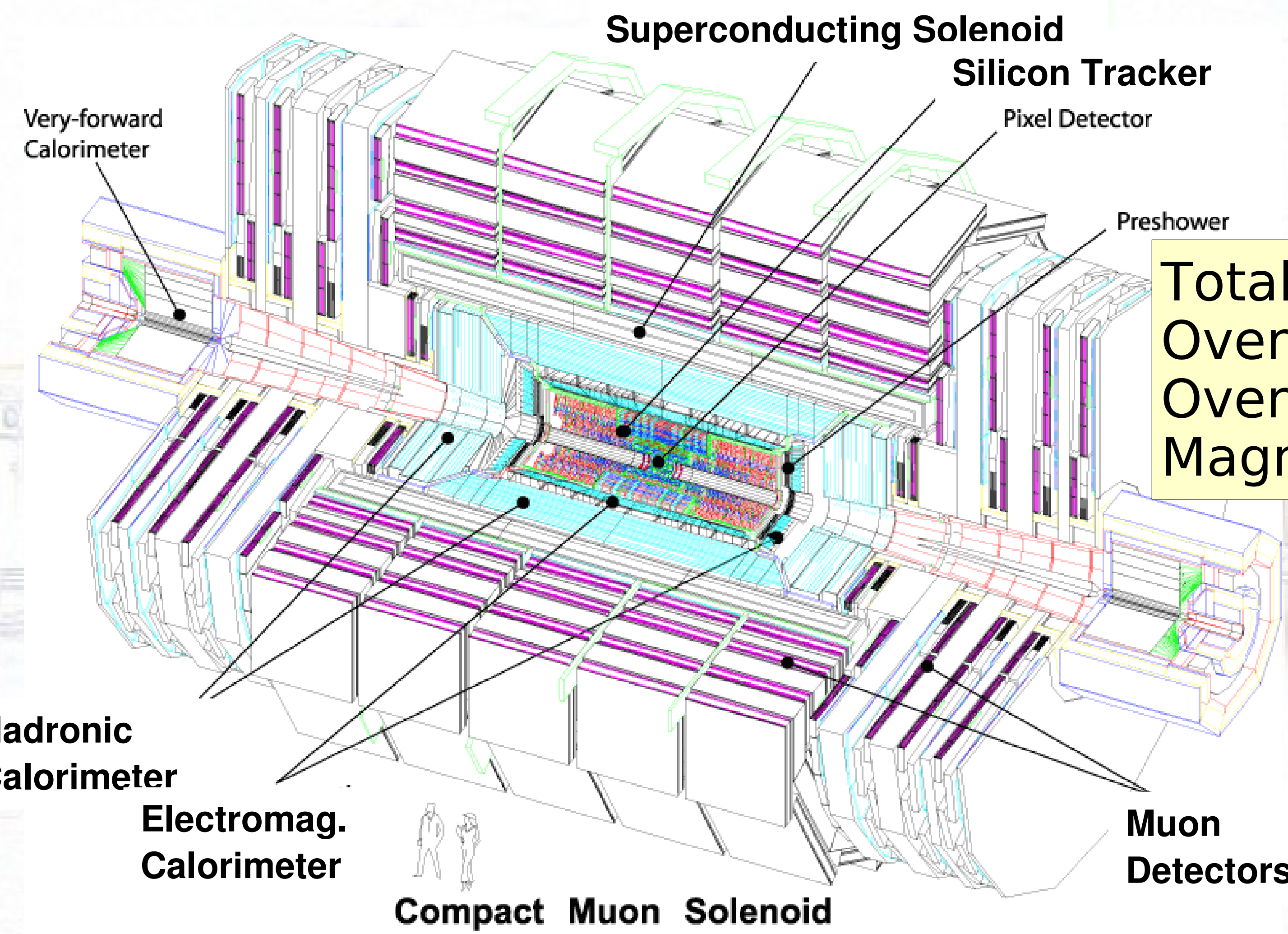
- **LHC is a pp collider near Geneva, Switzerland.**
- **Main aim: search of Higgs (expected rate ~10^{-2} Hz)**
- **An artistic view of LHC and its experiments:**



Center-of-mass-energy: 14 TeV
Bunch crossing rate: 40MHz
pp Interactions/BX: ~20
Design luminosity: 10^{34}cm^{-2}s^{-1}

The CMS detector

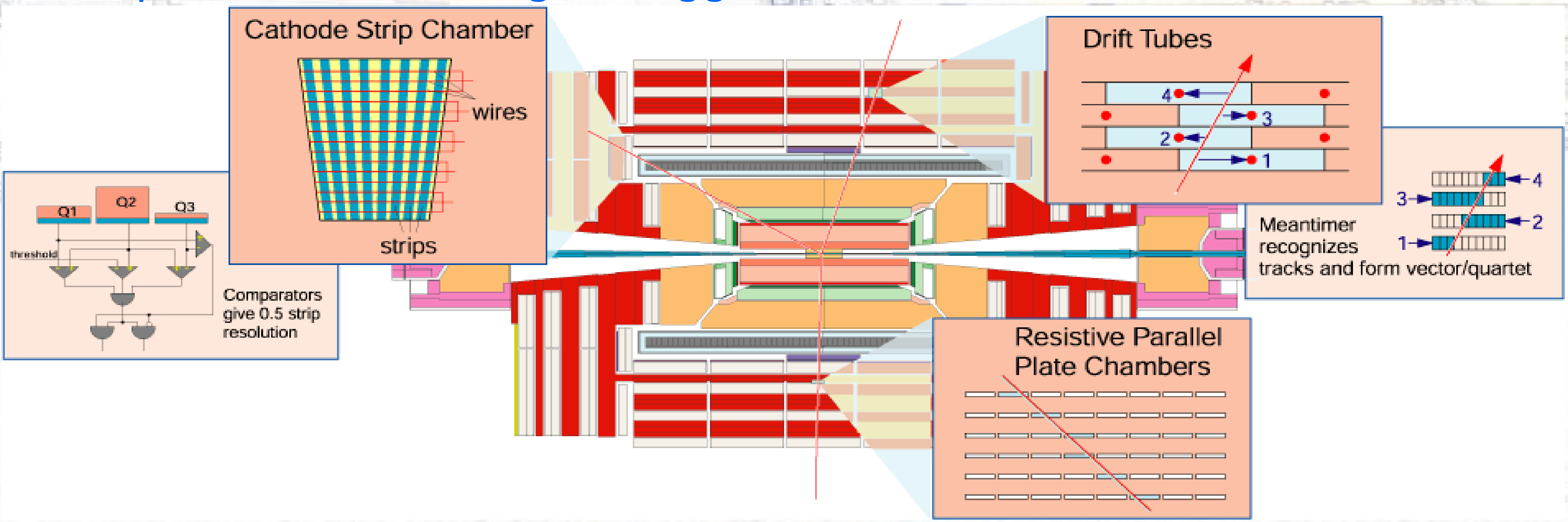
- **CMS is a multipurpose detector for pp collisions at LHC**
- **Center-of-mass energy is $\sqrt{s}$=14 TeV**



Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

CMS muon detectors

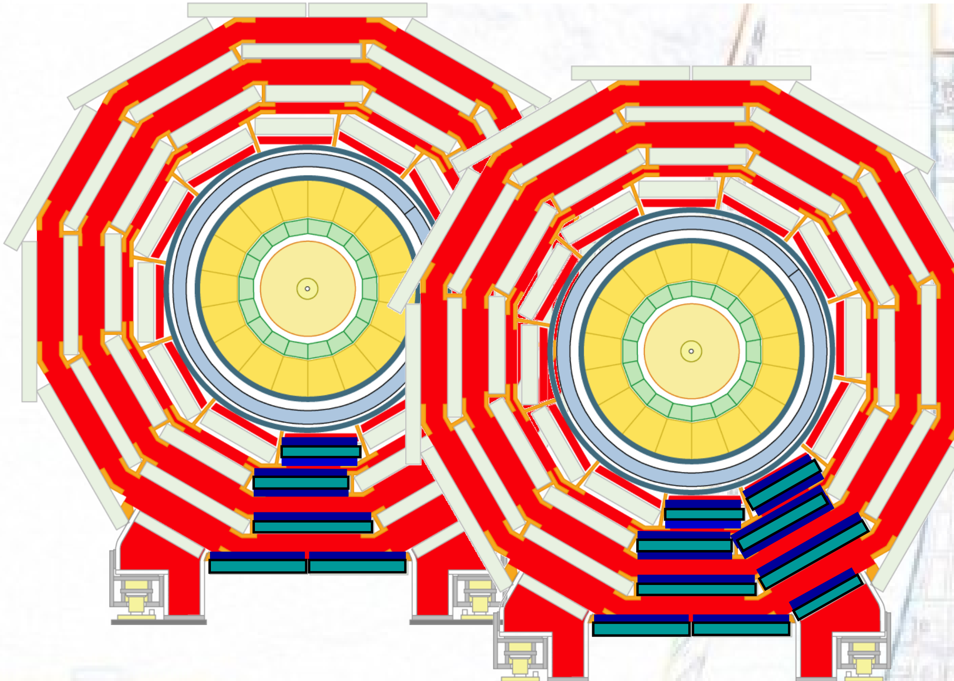
- **Barrel region**
  - Resistive Plate Chambers (RPC) provides a fast and precise response for trigger
  - Drift Tube Chambers (DT) for a precise measurement of the position (and also give trigger)
- **Endcap regions**
  - Again RPCs
  - Cathode Strip Chambers (CSC) for a precise measurement of the position (and also give trigger)

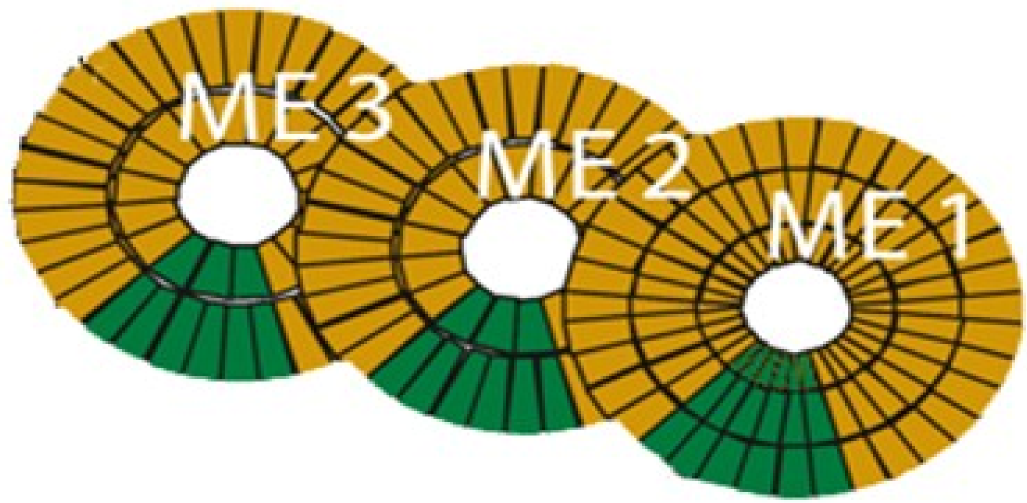


MTCC goals

- **Goals of the Magnet Test:**
  - Test magnet functionality (up to B=4T), including cooling, power supply and control systems
  - Mapping of the magnetic field
  - Check closing tolerance
- **Goals of the Cosmic Challenge:**
  - Operate a detector slice of 20^{o} (~5% of CMS): Muon system (DT, RPC, CSC), HCAL, ECAL, tracker.
    - Test trigger/DAQ chains, DQM, DCS, reconstruction
  - Checks efficiency and syncronization of different trigger generators on the same cosmic muon track
  - Perform detector specific studies (eg effect of B-field)

Muon set-up for the MTCC

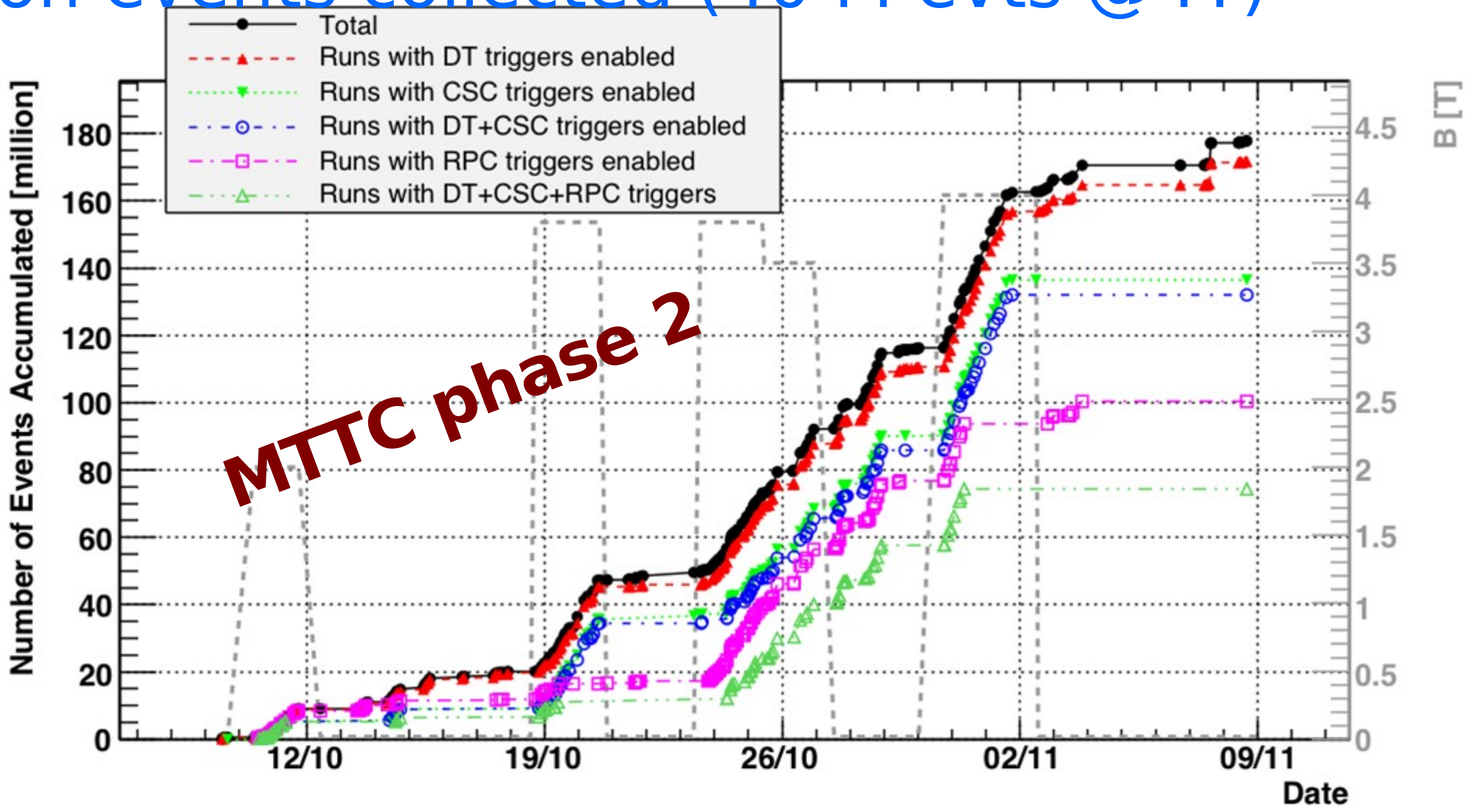




- **Barrel part:**
  - 3 sectors in 2 wheels
    - 20 Drift Tube (DT) chambers
    - 9 barrel Resistive Plate Chambers (RPC)
- **Endcap:**
  - 3 sectors in 3 rings
    - 36 Cathode Strip Chambers (CSC)
    - 9 endcap RPC

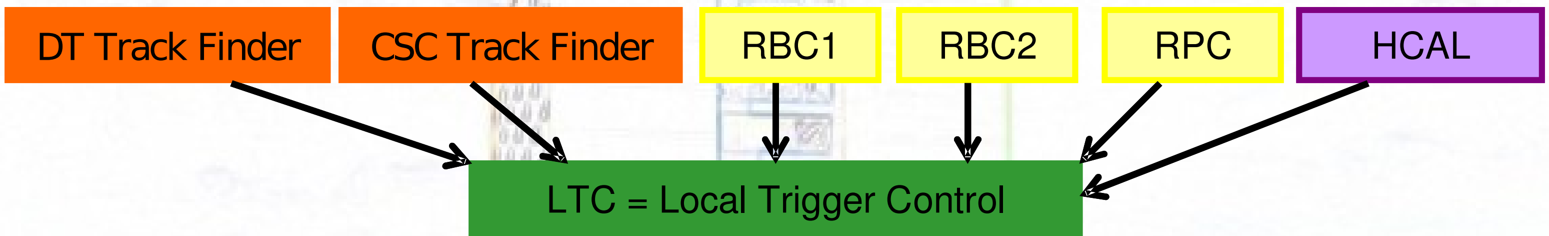
MTCC – collected events

- **MTCC phase 1 (Aug 2006)**
  - Muon detectors, HCAL, ECAL, tracker
  - 50 million events collected (1M evts @3.8T)
- **MTCC phase 2 (Oct-Nov 2006)**
  - Muon detectors, HCAL, field mapper
  - 180 million events collected (40 M evts @4T)

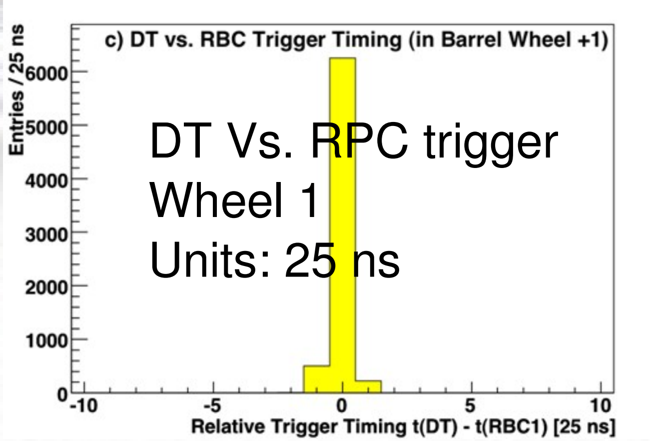


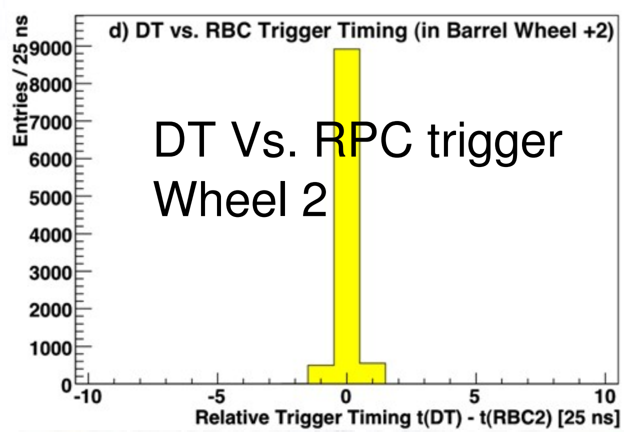
A. Parenti

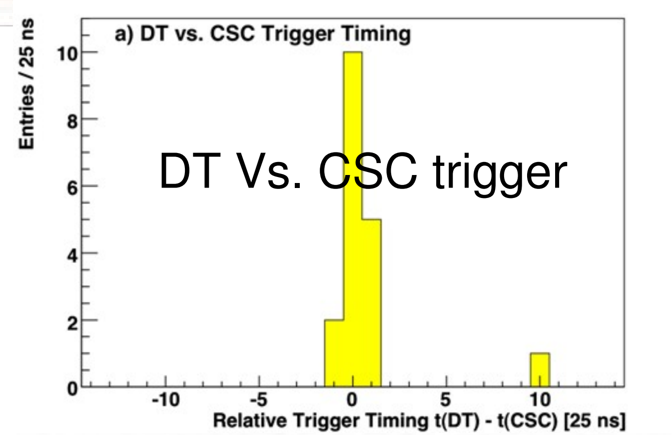
Synchronization of subdetectors



- **Random arrival of cosmics makes synchronization more difficult than at LHC; cosmics arriving on the edge of the 25 ns clock cannot be unambiguously assigned to the "bunch crossing"**
- **Anyway, very good synchronization obtained.**

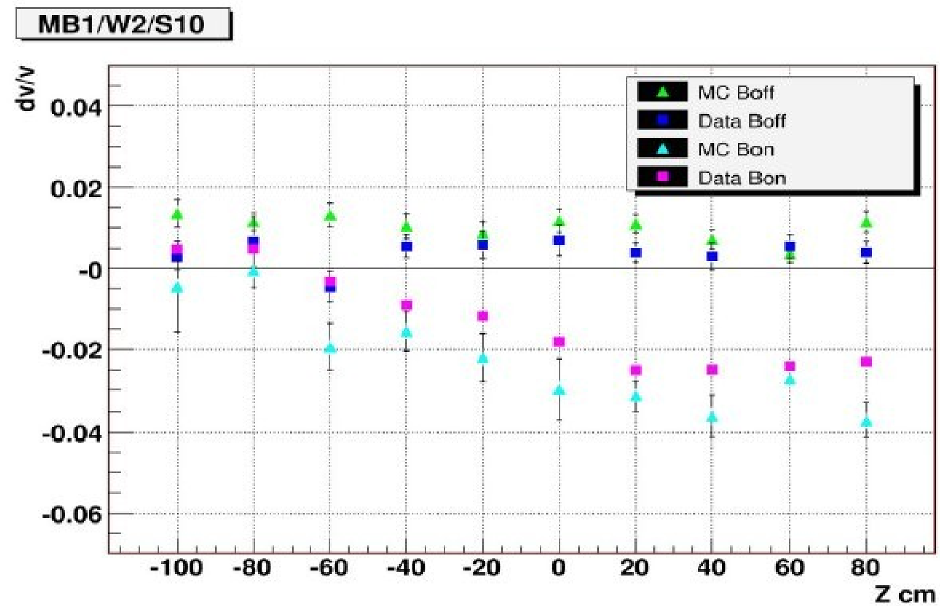




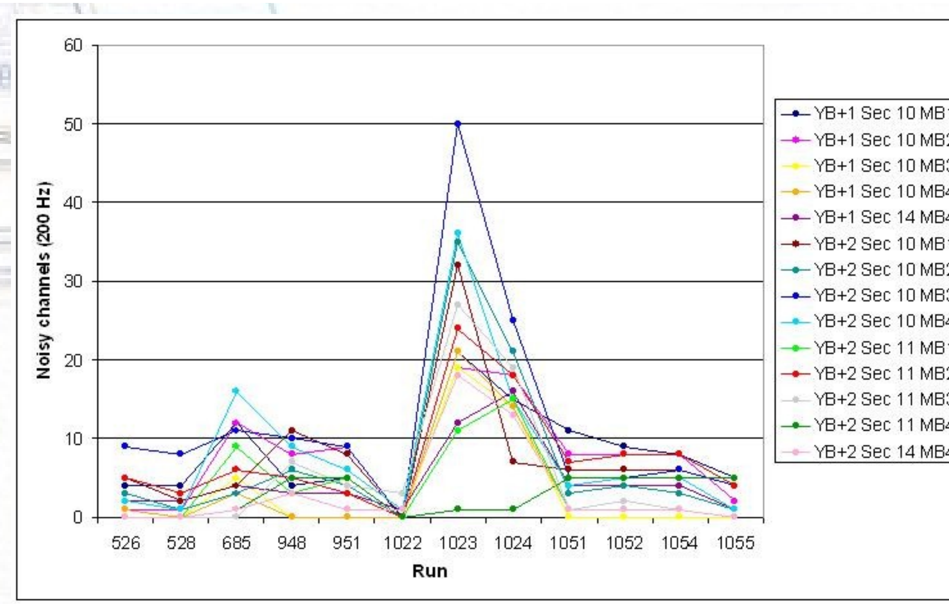


Analyses of DT data

- **Drift velocity varies up to 3.5% in B-field in MB1 (closest chamber to magnet)**
  - the effect is expected from simulations
  -



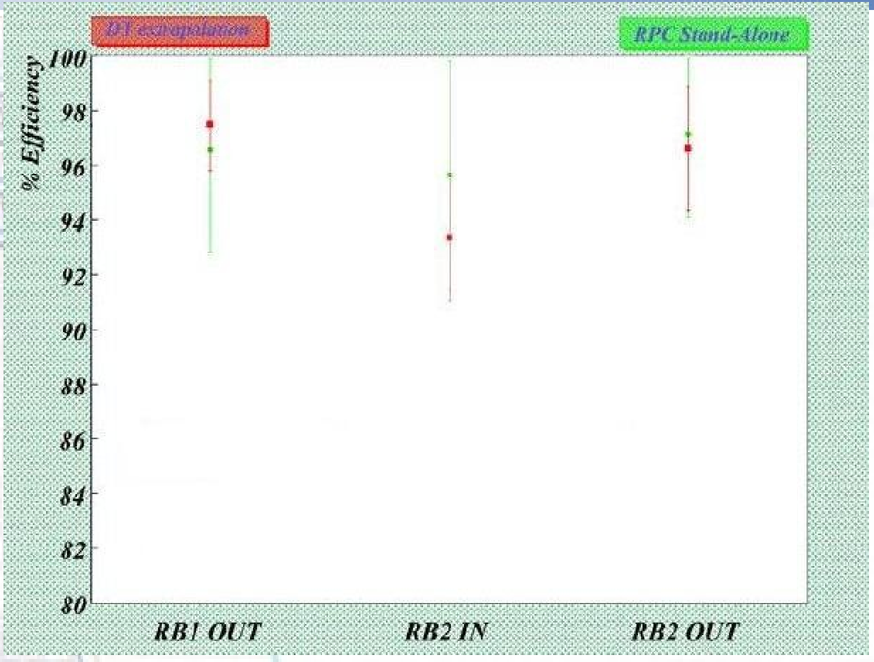
- **Noisy channels (ie having rate > 200 Hz): less than 1%**
  - they are more in two runs (but low statistics)



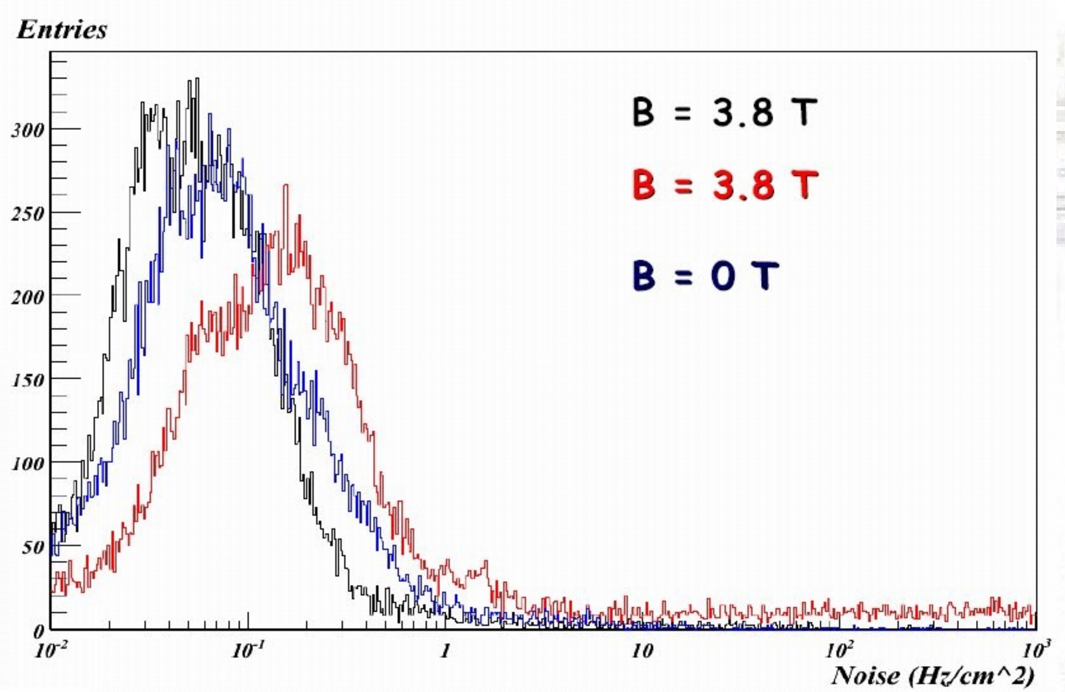
- **… and much more (trigger efficiency, single cell eff…)**

RPC data analyses

- **RPC local efficiency**
  - evaluated with DT) extrapolated tracks, or RPC standalone tracks
  - high efficiency (independent on method

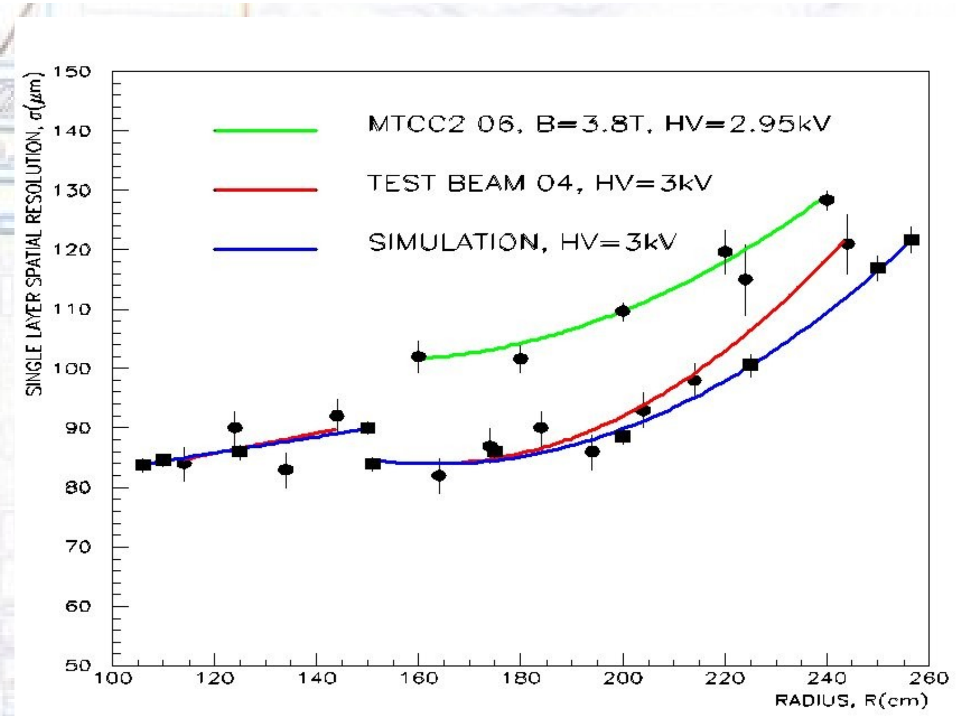


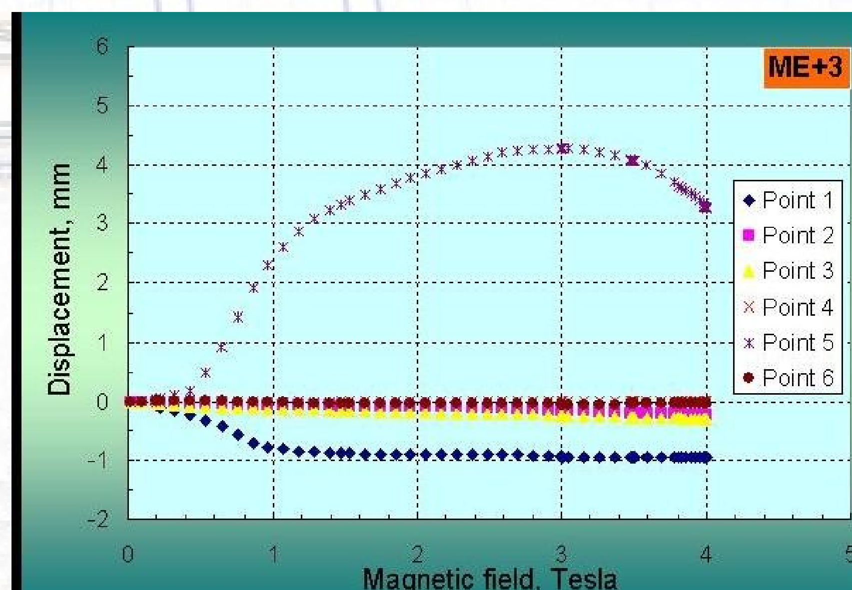
- **Noise distribution for RPC strips. Threshold is**
  - 220 mV (black histo)
  - 205 mV (blue and red)
- **… and much more (cluster size, alignment, crosstalk…)**



CSC data analyses

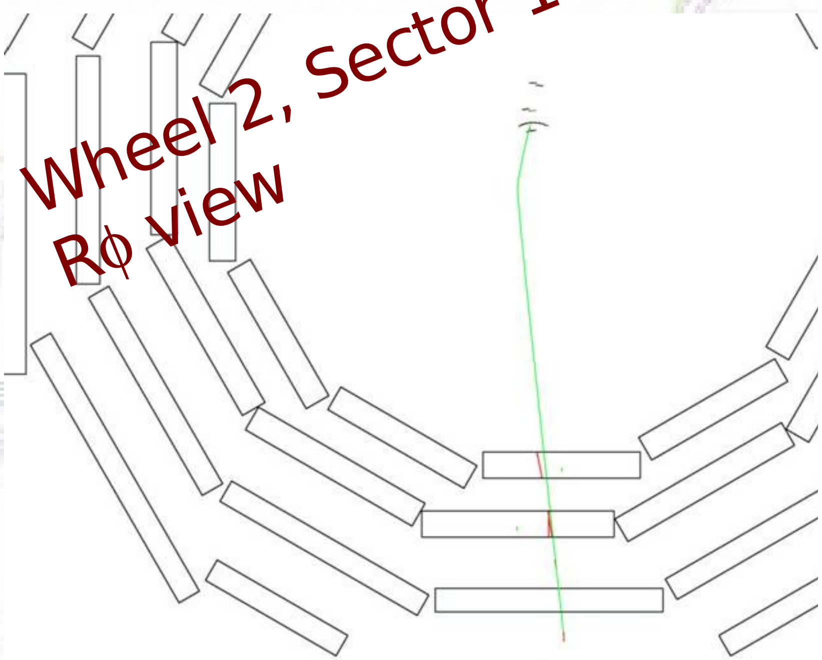
- **Single layer resolution**
  - 150 μm required by CMS
  - 120 μm attained in beam test (worse in MTCC due lower HV)
- **B-field causes deformation of detector**
  - maximum displacement ~5mm at 4T
  - maximum tilt 3-4 mrad
- **... and much more ...**

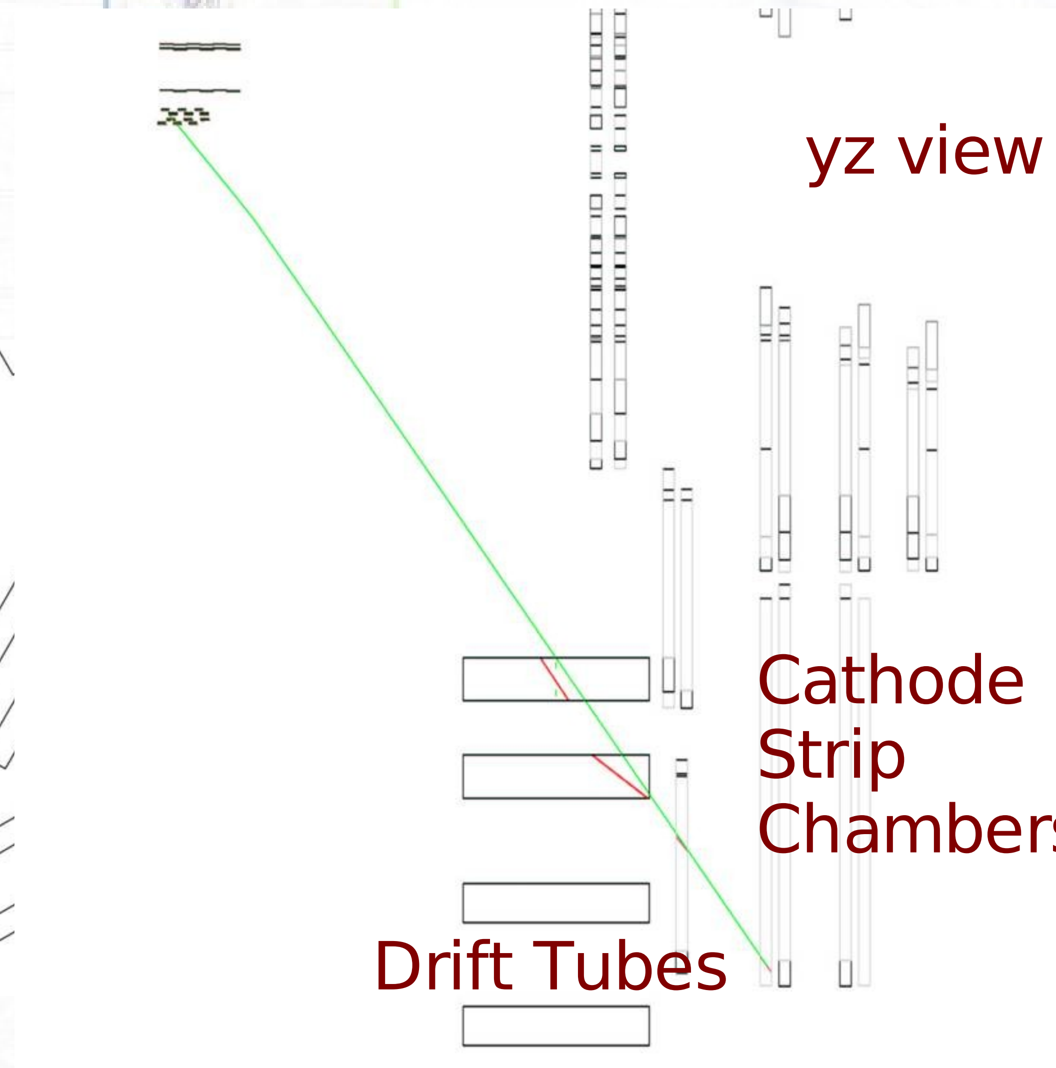




Global reconstruction

- **Global track reconstructed using CSC, DT and tracker**
  - 8 CSC hits
  - 15 DT hits
  - 6 tracker hits





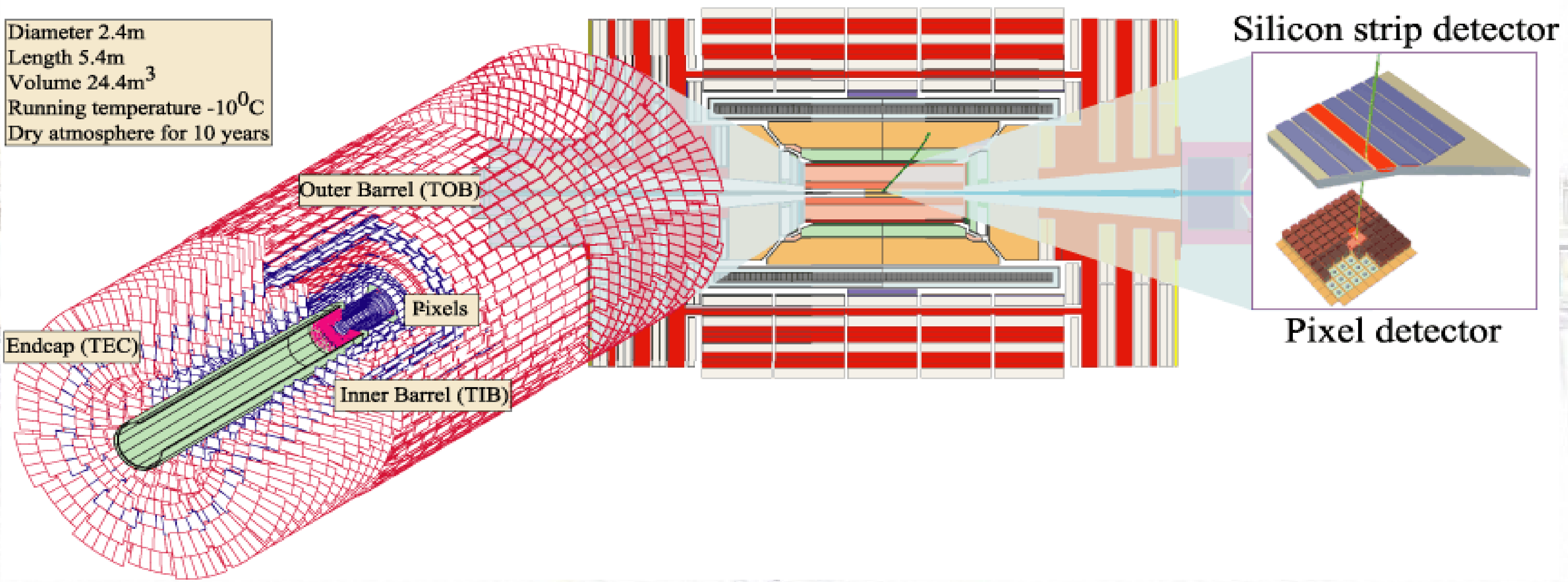
Conclusion

- **In summer/fall 2006 a slice (5%) of full CMS detector has been operated continuously**
  - No sign of performance deterioration was seen
- **DAQ and trigger were succesfully integrated and operated**
- **Collected data were analyzed in order to evaluate detector performance and test reconstruction algorithms**

Additional Slides

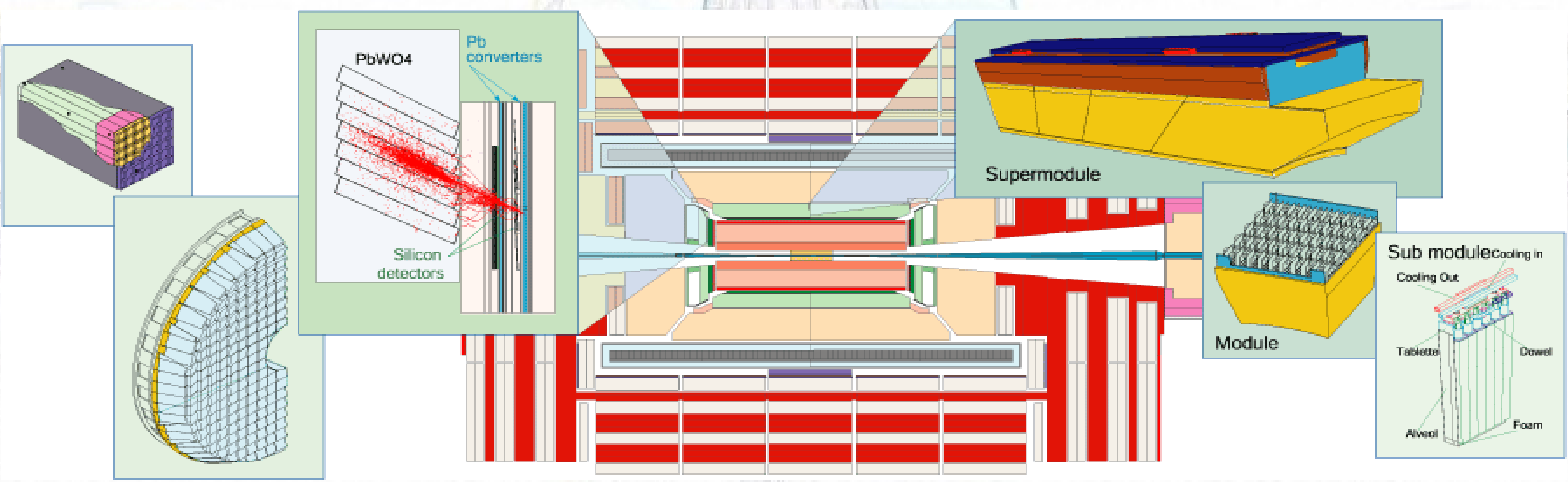
CMS tracker

- **The CMS collaboration decided to use an all-silicon solution for the tracker. In total the CMS tracker implements 25,000 silicon strip sensors covering an area of 210 m². Connected to 75,000 APV chips, one has to control 9,600,000 electronic readout channels, needing about 26 million microbonds.**



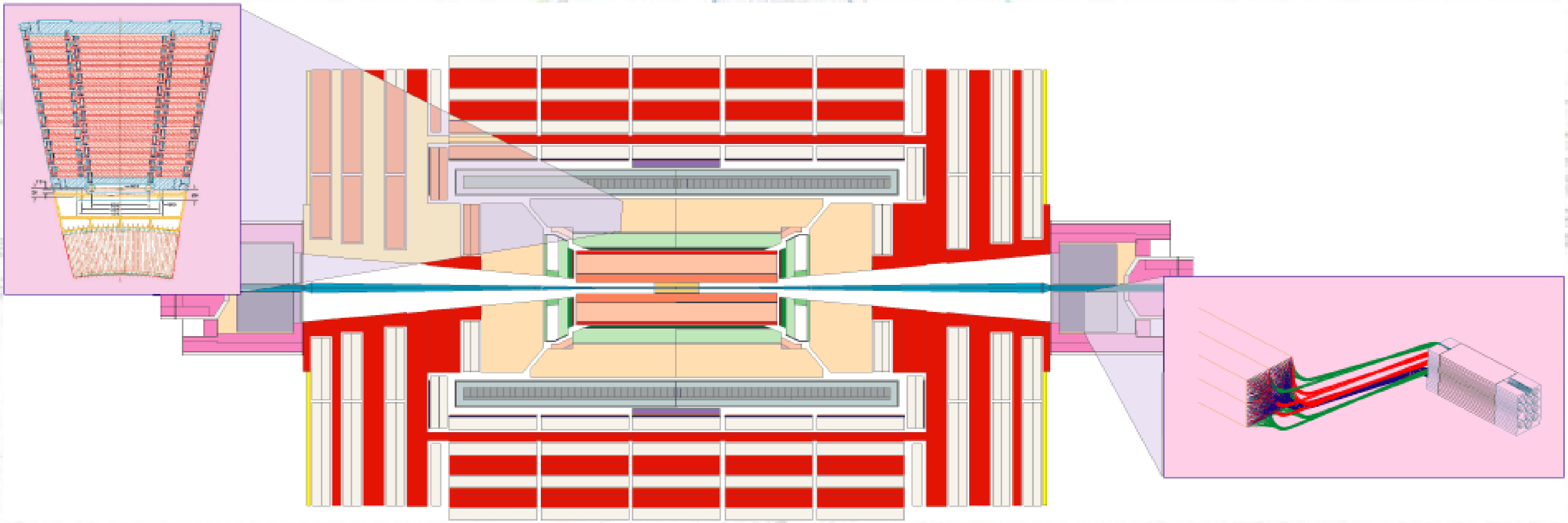
CMS ECAL

- **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).**



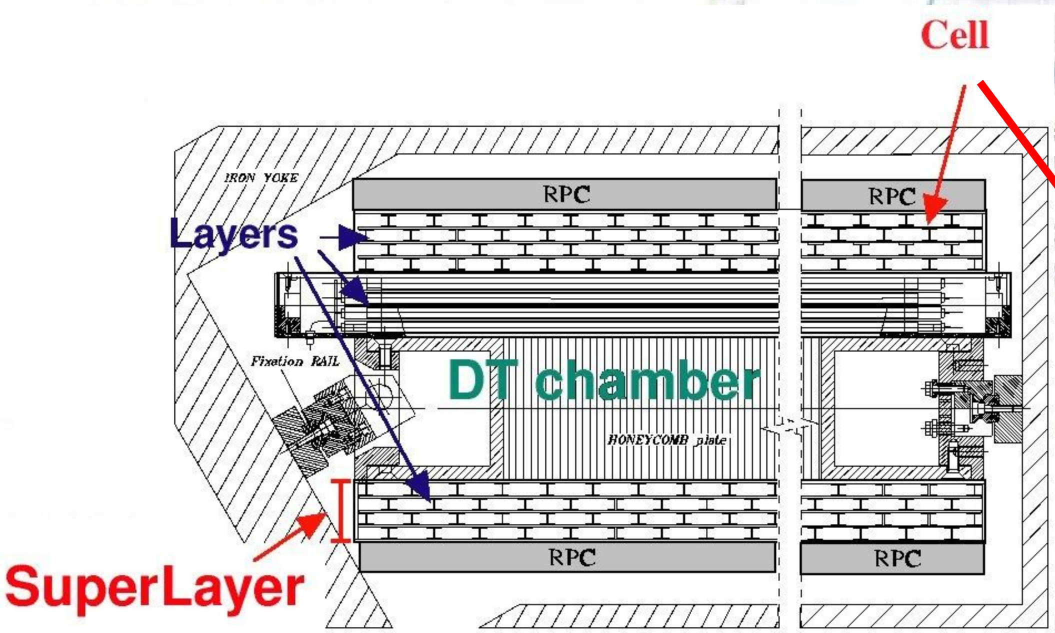
CMS HCAL

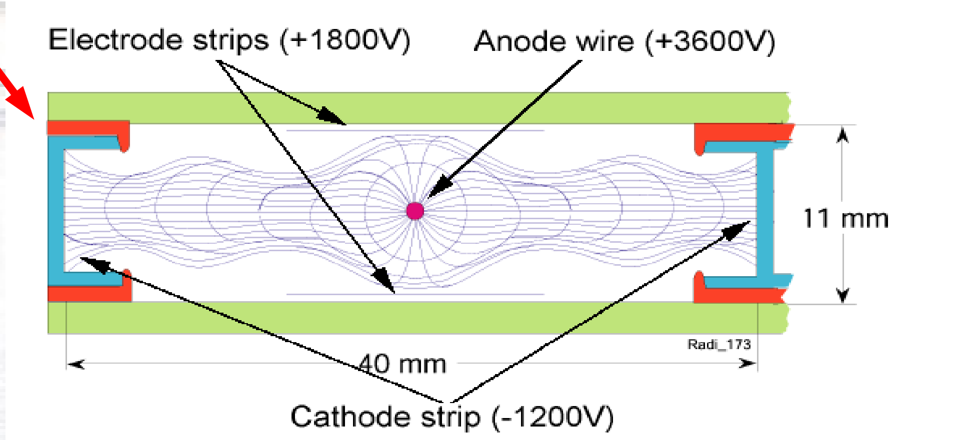
- **The hadron barrel (HB) and hadron endcap (HE) calorimeters are sampling calorimeters with 50 mm thick copper absorber plates interleaved with 4 mm thick scintillator sheets.**
- **Because the barrel HCAL inside the coil is not sufficiently thick to contain all the energy of high energy showers, additional 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.**



Drift Tube Chambers

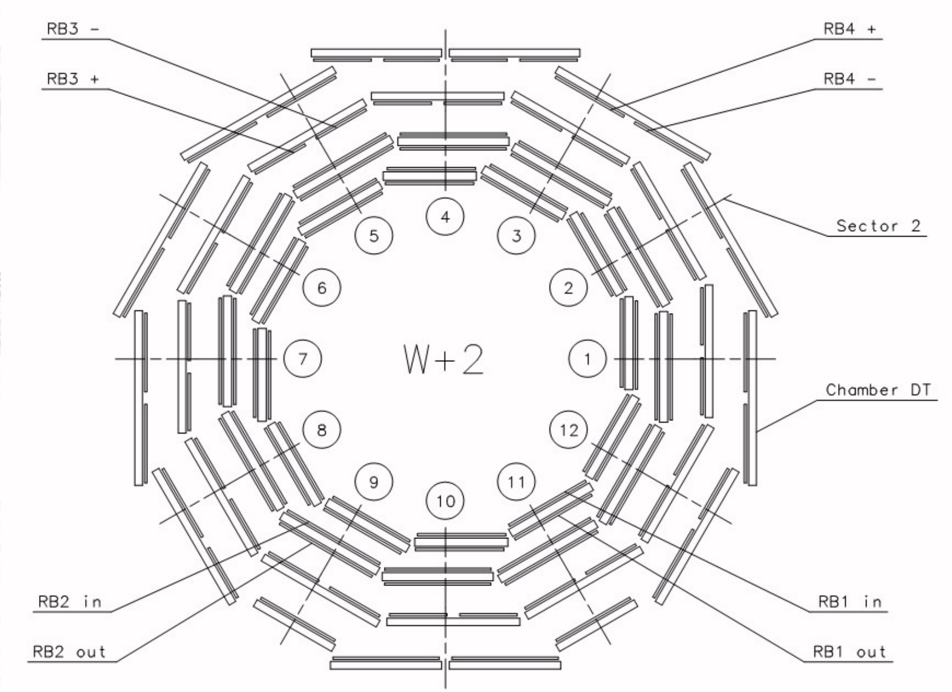
- **Drift Tubes (DTs) are wire chambers. Only anode is read.**
- **Nominal voltages: +3600V (anode), +1800V (electrode), -1200V (cathode).**
- **Gas Mixture: Ar (85%) + CO_2 (15%).**
- **Single cell resolution: 200 μm.**

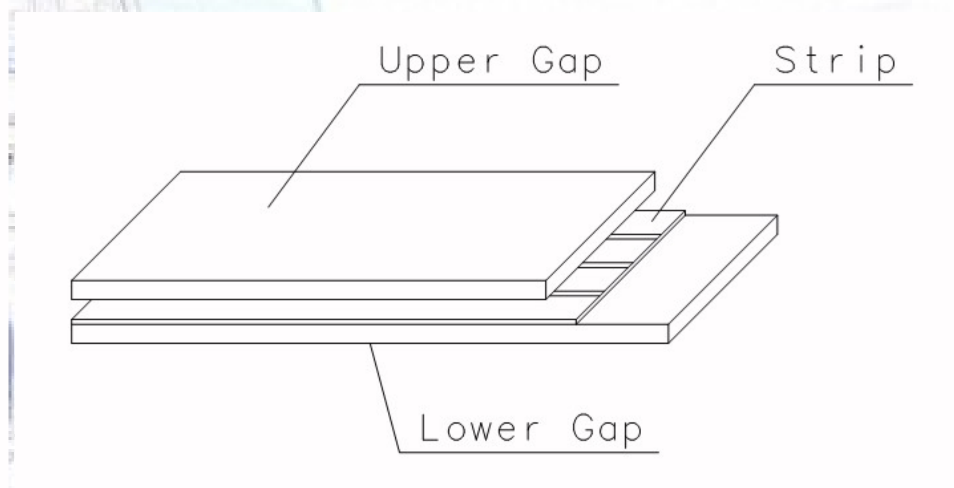




Resistive Plate Chambers

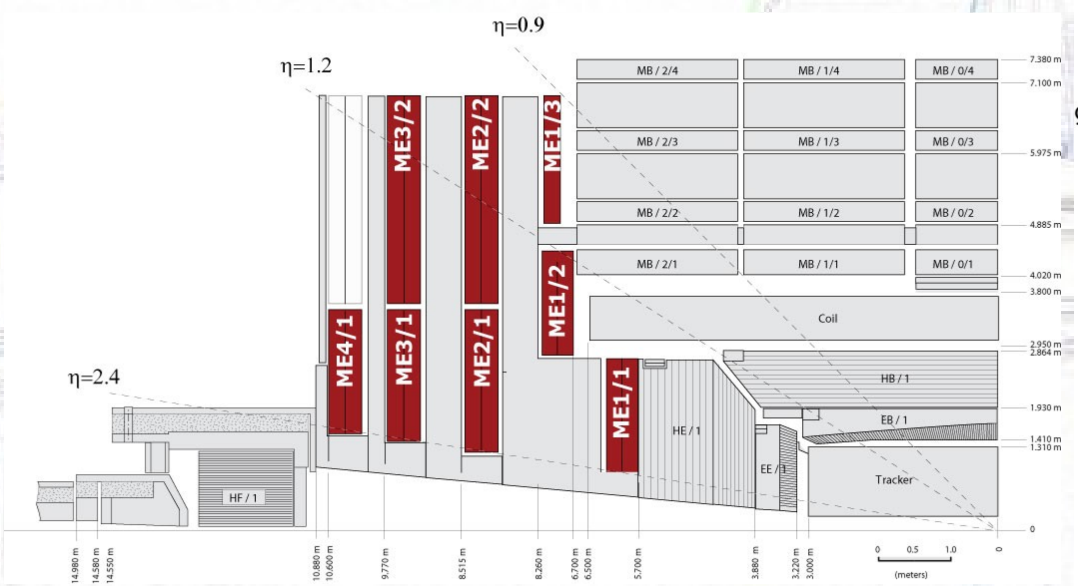
- **Resistive Plate Chambers (RPCs) are fast gaseous detectors.**
- **Gas mixture: $C_2H_2F_4$ (96.2%)+*iso*C_4H_{10} (3.5%)+SF_6 (0.3%).**
- **Good spatial resolution (1.2 cm).**
- **Very high time resolution (1ns).**

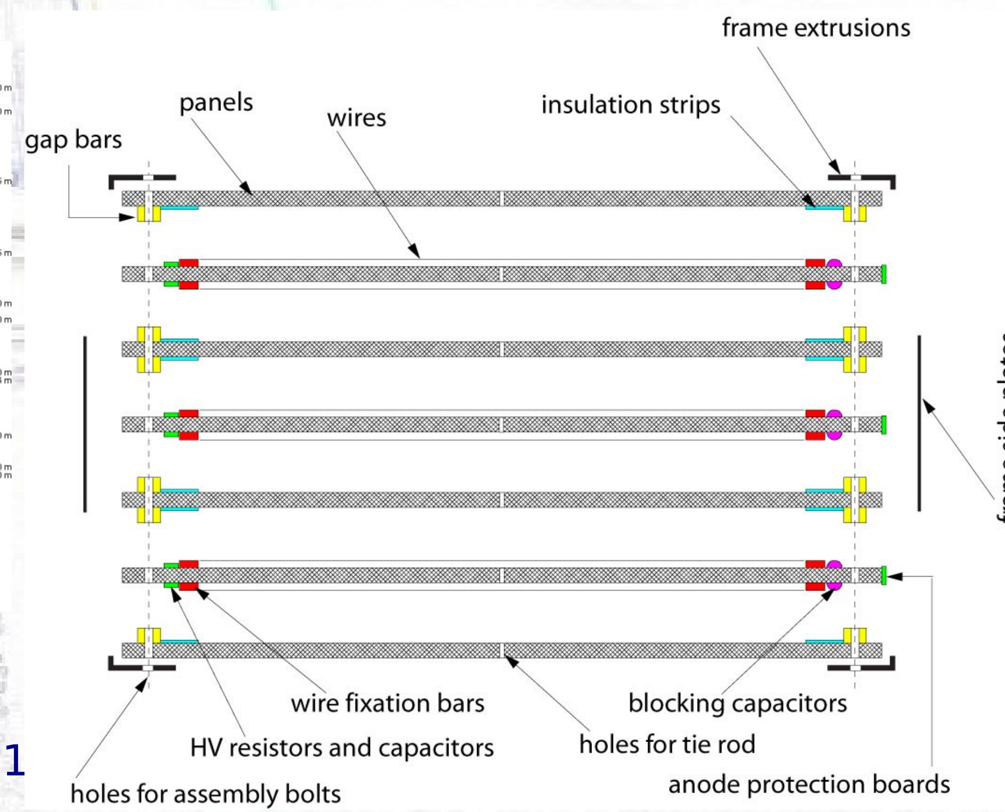




Cathode Strip Chambers

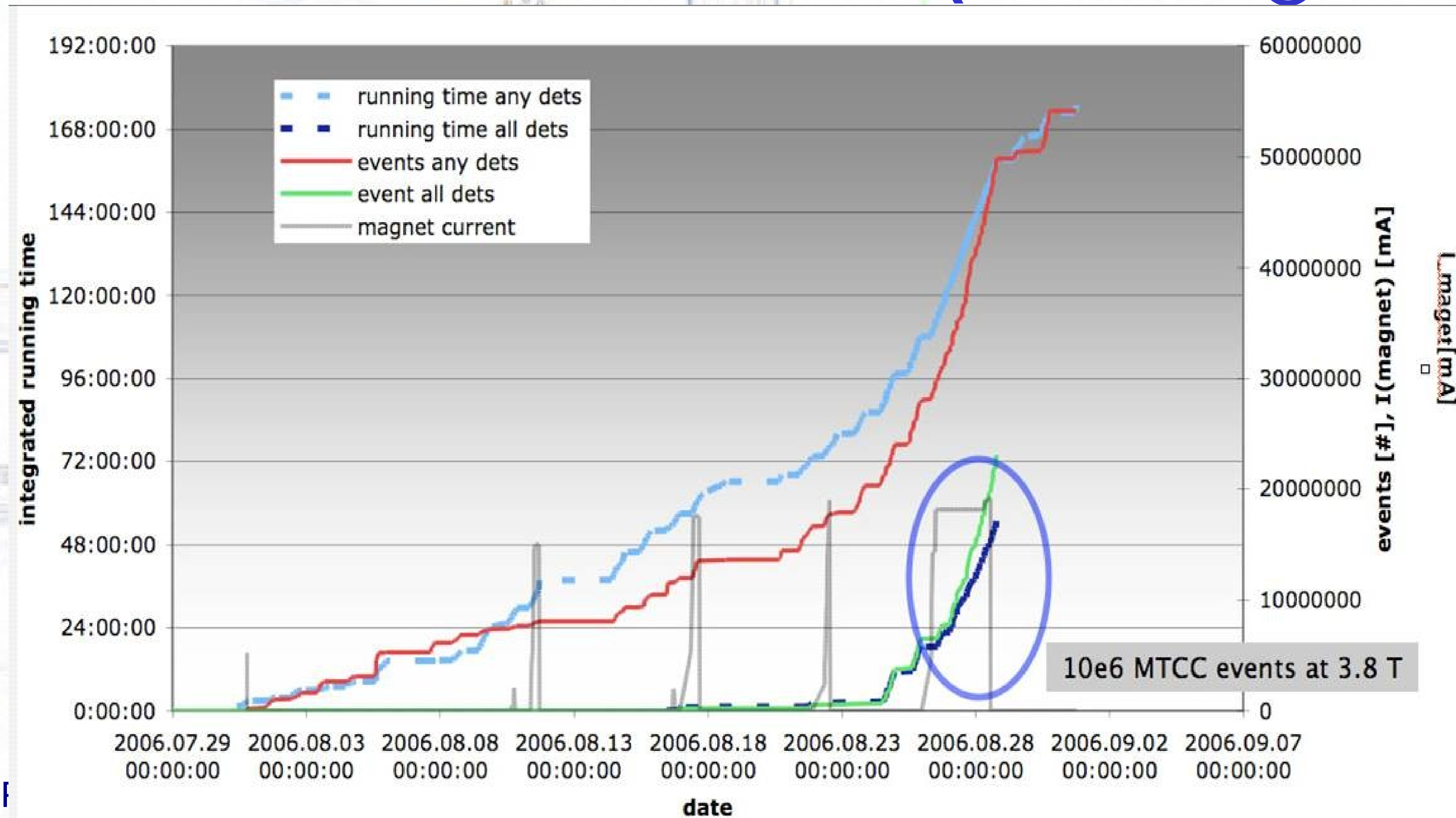
- **Cathode Strip Chambers (CSCs) are multiwire proprtional chambers. Wires and strips are read.**
- **Gas mixture: Ar (40%)+CO_2 (50%)+CF_4 (10%).**
- **75-150 μm resolution in rϕ depending on chamber.**
- **Fast response (30±3 ns) make them suitable for trigger.**



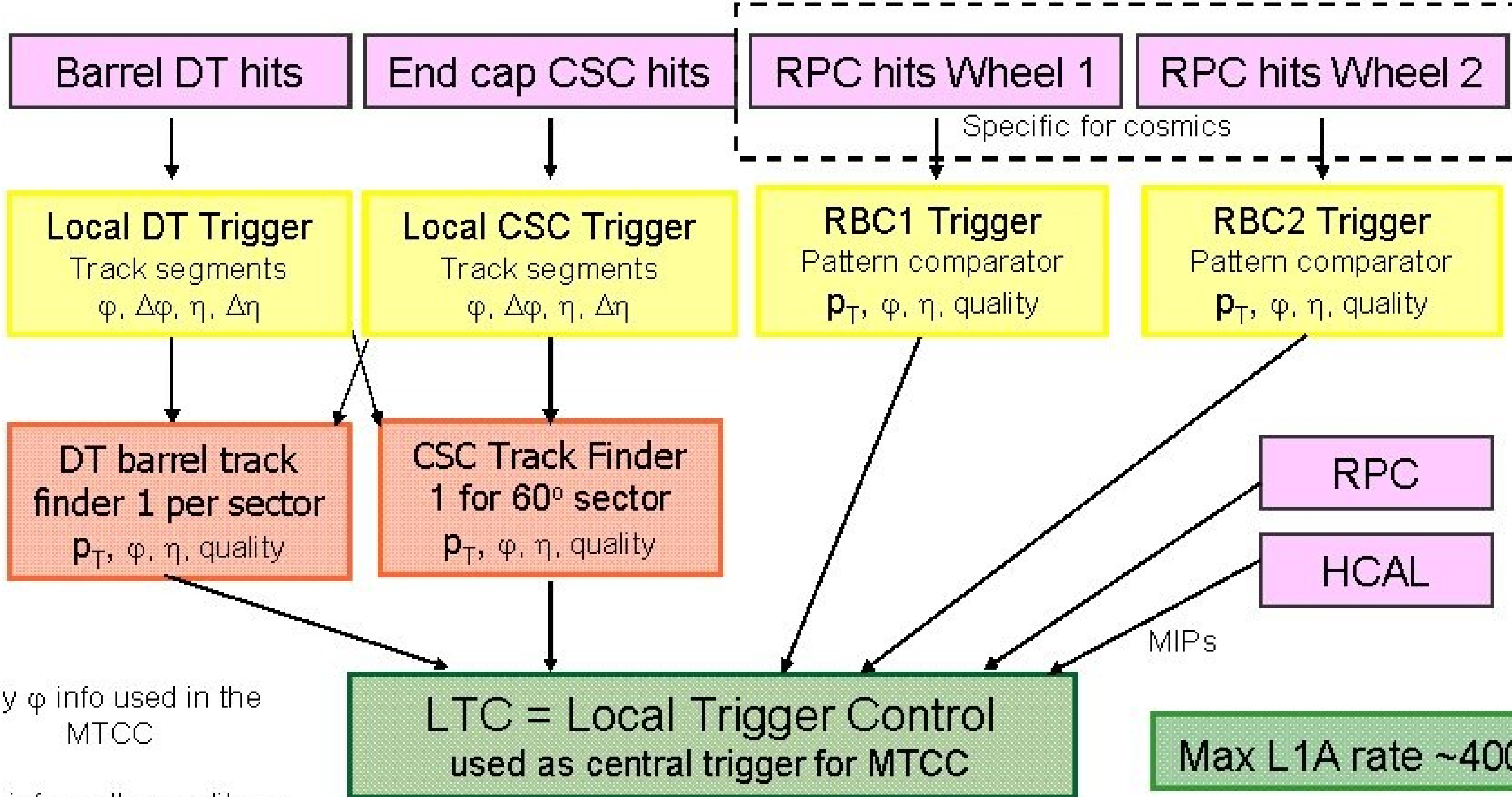


MTCC phase 1

- **170 hours data taking in Aug 2006**
- **Muon detectors, HCAL, ECAL, tracker**
- **50 million events recorded (1M evts @ 3.8T)**



L1 trigger generation at MTCC



Only φ info used in the MTCC

No info on the quality or p_T of the track processed by the LTC

'LHC-like' clock generated every 25ns

Max L1A rate ~400 Hz

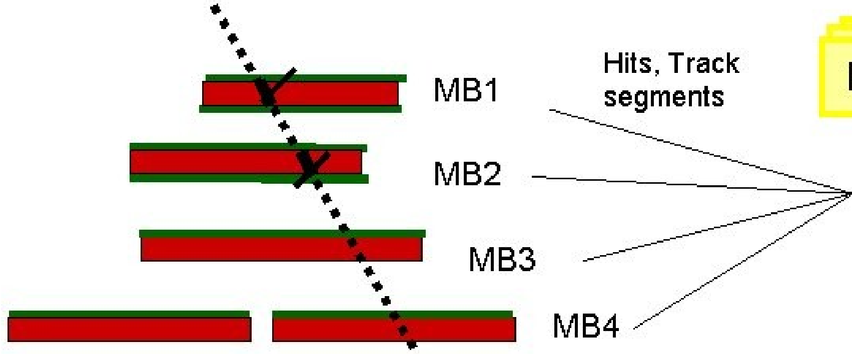
At LHC ~ 100kHz

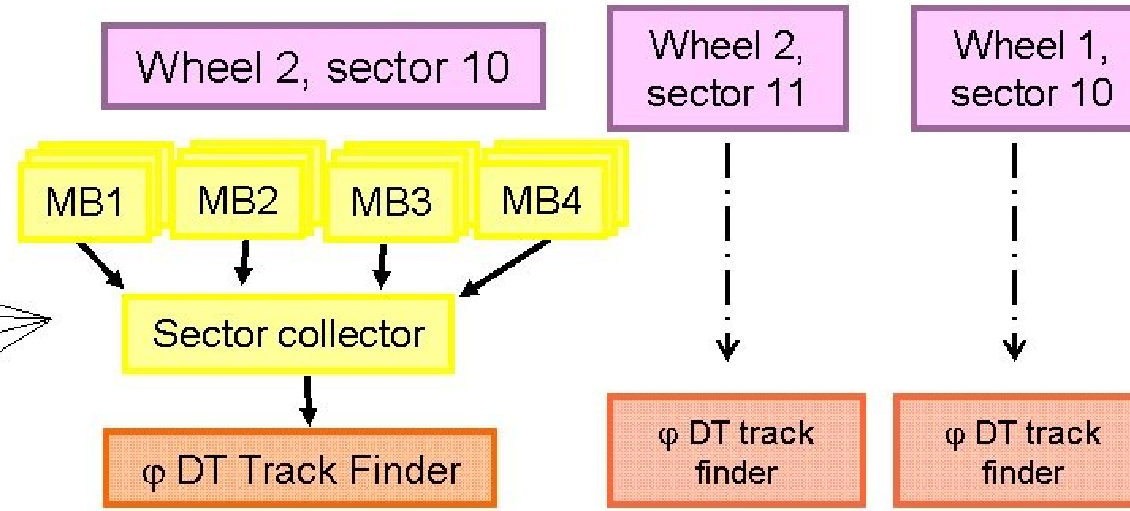
Synchronization of subdetectors

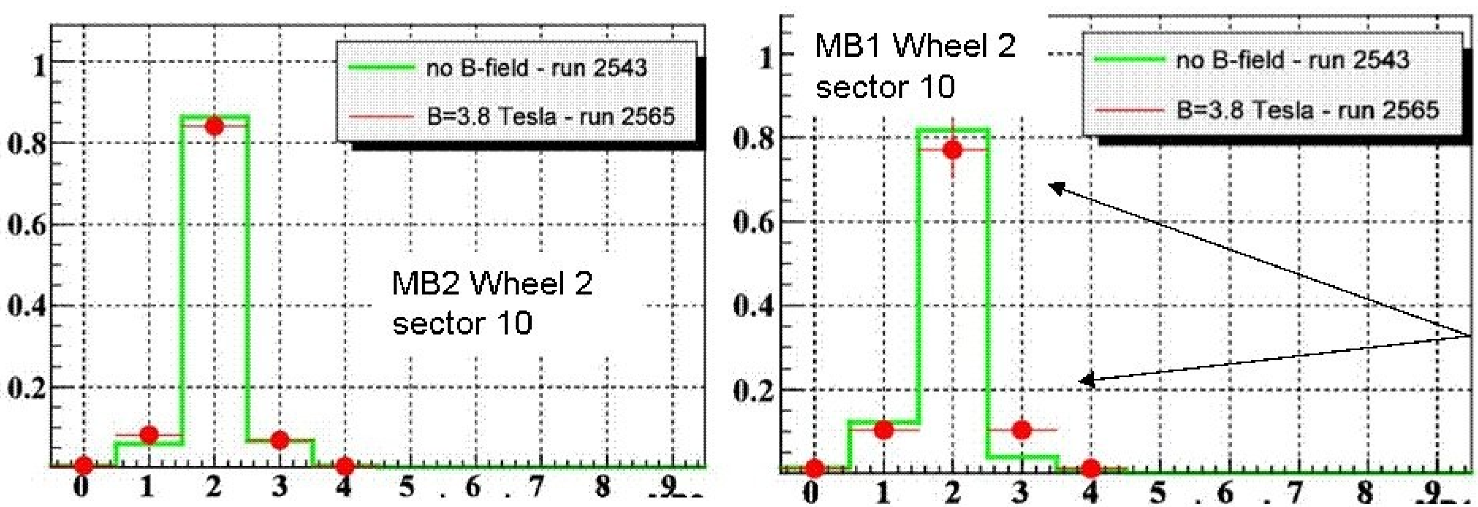
- **Random arrival of cosmics makes synchro more difficult than at LHC.**
- **Each sub-system did a local synchronization, then they were timed in:**
  - in MTCC, DT and RPCs had same BX in 90% of cases
  - in LHC we expect this - from simulations - to become 99%

Local DT trigger synchronization

- Coincidence of two chambers in one sector: rate ~ 200 Hz







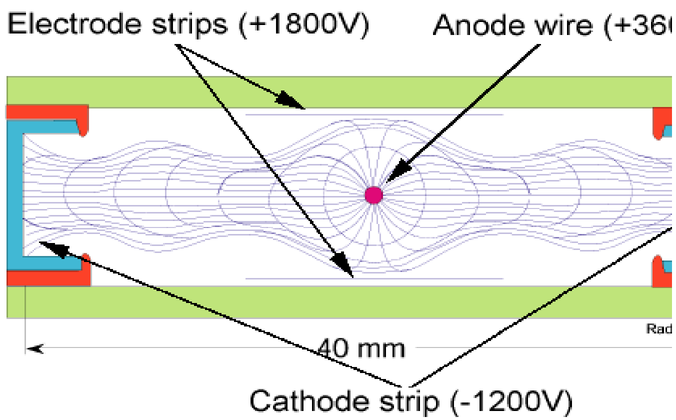
Bunch crossing at the input of the φ DT track finder

B off: Good synchronization

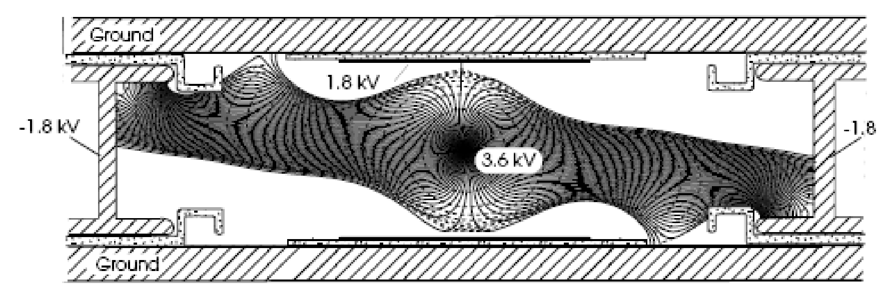
B on: 6% triggers move to a different bunch crossing in MB1 (due to changes in the drift velocity)

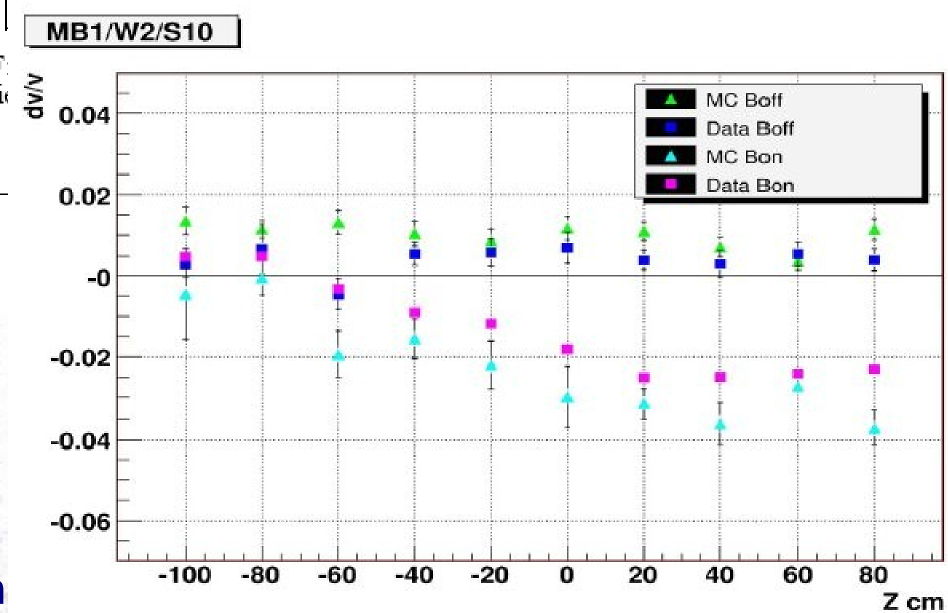
DT drift time

No magnetic field:
drift time is proportional to position



In magnetic field:
drift trajectories are distorted





Drift velocity varies up to 3.5%
in MB1, the chamber closest to the magnet:

Global reconstruction

- **Event by event correlation of ϕ angle measured by tracker and drift tubes:**