# CMS muon detector and trigger performances

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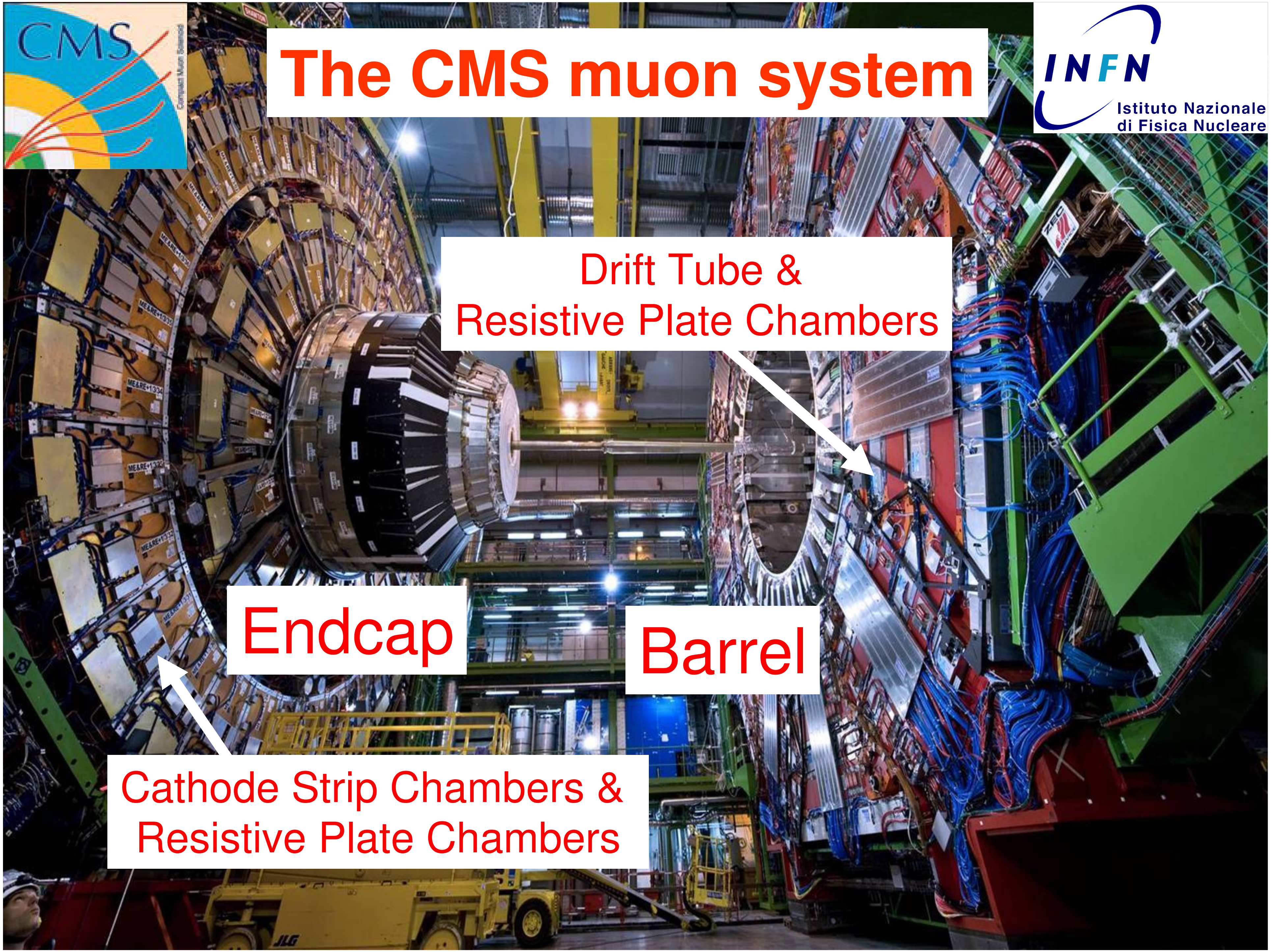
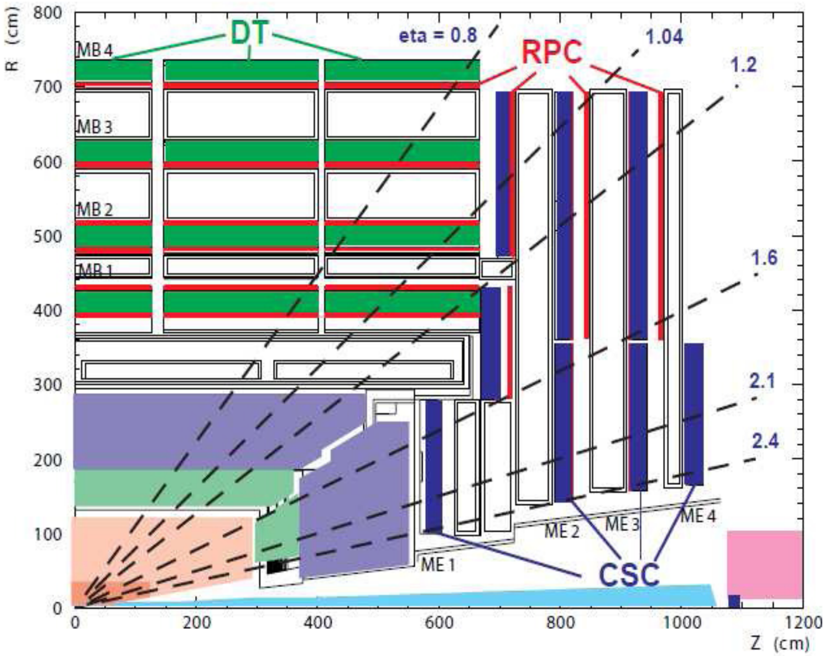
On behalf of the CMS Collaboration

12th Vienna Conference on Instrumentation – VCI2010

# The CMS muon system



# The CMS muon system



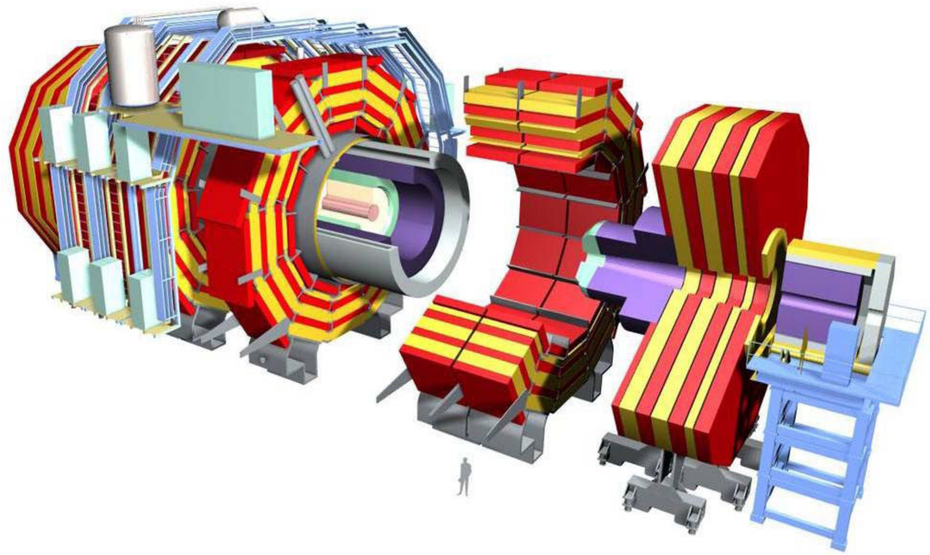

3 different technologies of gaseous detectors

Drift Tube (DT) in the barrel ($|\eta|<1.2$)
Cathode Strip Chambers (CSC) in the endcaps ($0.9 < |\eta| < 2.4$)
Resistive Plate Chambers (RPC) both in barrel and endcaps (up to $|\eta|=1.6$)

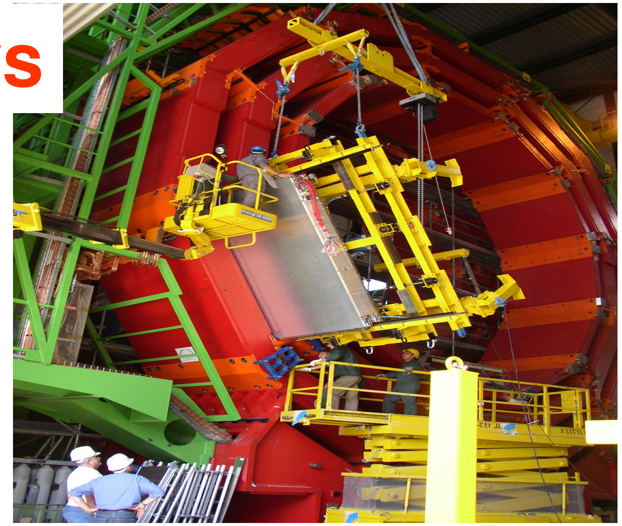
All detectors used both in triggering and reconstruction

Barrel: 5 Wheels
Endcap: 4 Disks per side

Total Weight: 14,500 tons
Overall diameter: 14.60 m
Overall length: 21.60 m
Magnetic Field: 3.8 T



# Commissioning with Cosmic Rays



- Until 2006 independent commissioning and assembling of detectors

- August 2006: Magnet Test/Commissioning Challenge
  - Test & mapping of magnet at 4T on surface, global data taking with a fraction of each CMS sub-detector

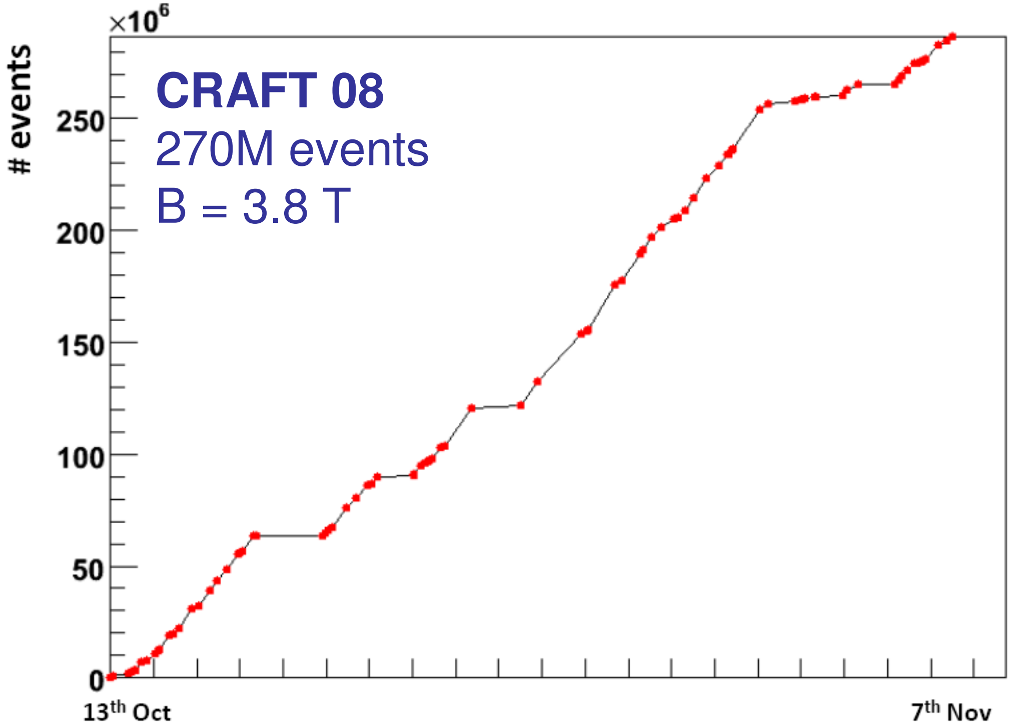
- May-August 2008: Weekly "global runs" + Cosmic Runs At Zero Tesla (**CRUZET**)
  - Entire CMS integrated; 300 M events, B off

- Sep 2008: First beams
  - Beam splash events; beam halo

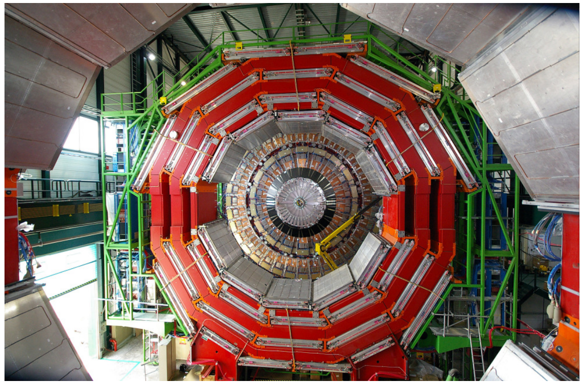
- Oct 2008: Cosmic Run at Four Tesla (**CRAFT 08**)
  - 270M events, full detector, nominal B field

- Aug 09: **CRAFT 09**
  - 300M events

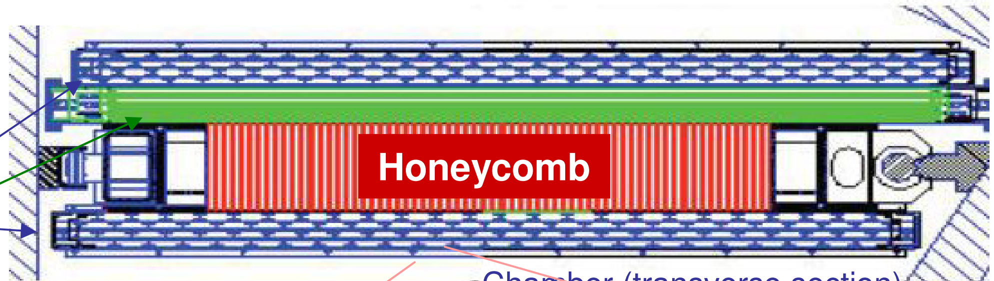
- December 2009: **LHC collisions**
  - first muons from LHC collisions



# Barrel: Drift Tubes (DT)

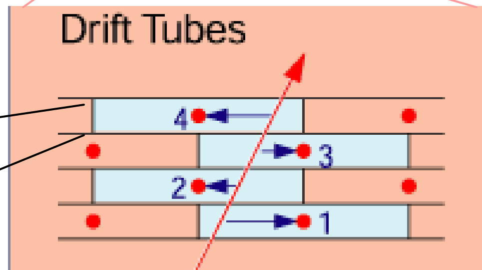


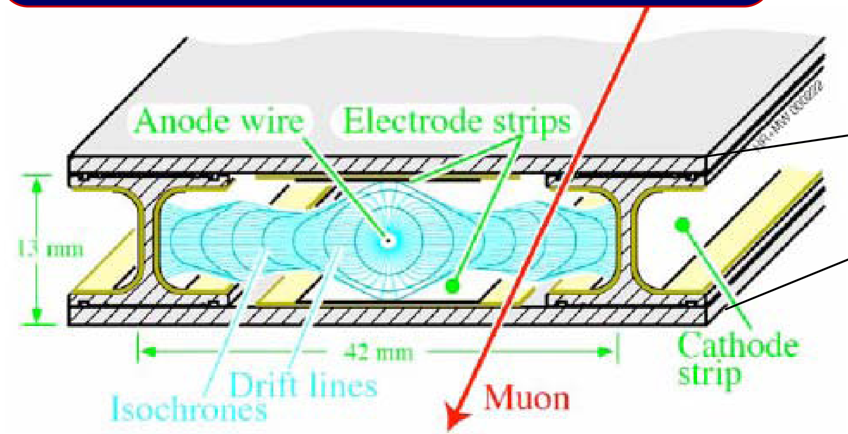
250 chambers (50 per wheel)
5 wheels / 12 sectors / 4 stations
Readout channels>170k




Chamber (transverse section)

- (4+4) layers in the bending coordinate (Φ)
- 4 layers measuring *z* (Θ) (except in outermost station)



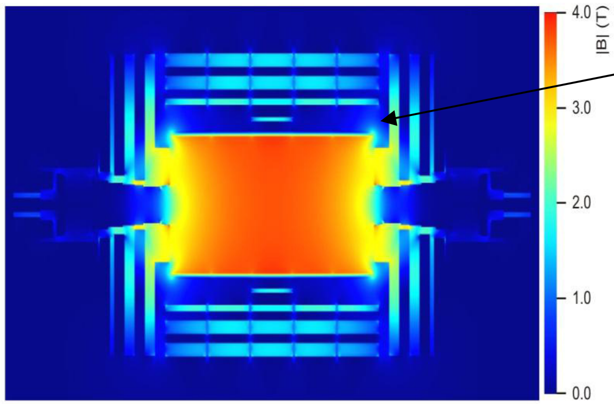



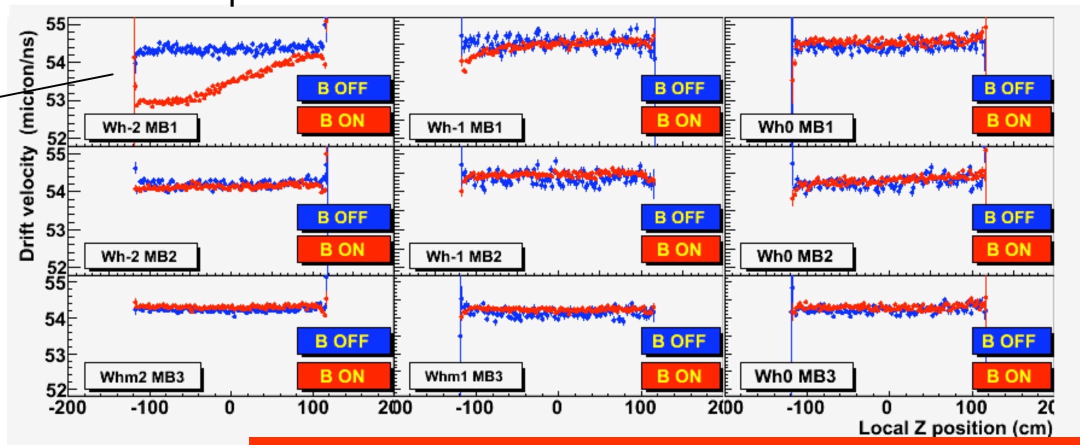

Gas mixture: Ar/$CO_2$ (85/15) %
Anode wire: 3.6 kV
Electrode strips: 1.8 kV
Cathode: -1.2 kV
Vdrift ~ 55 μm/ns → Max drift time ~380 ns
Single wire resolution ~ 200 μm
Local reconstruction (r-Φ) ~ 100 μm

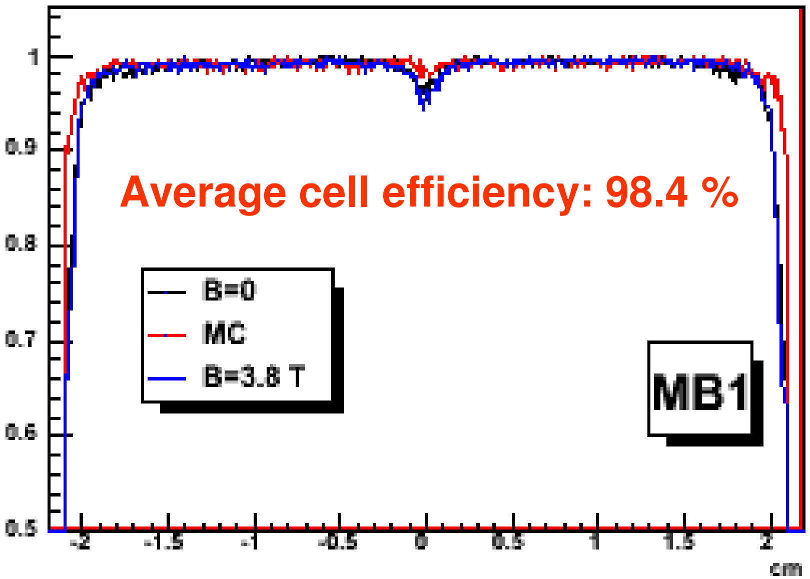
# DT performance with Cosmic rays

**More details in C. Battilana Poster**

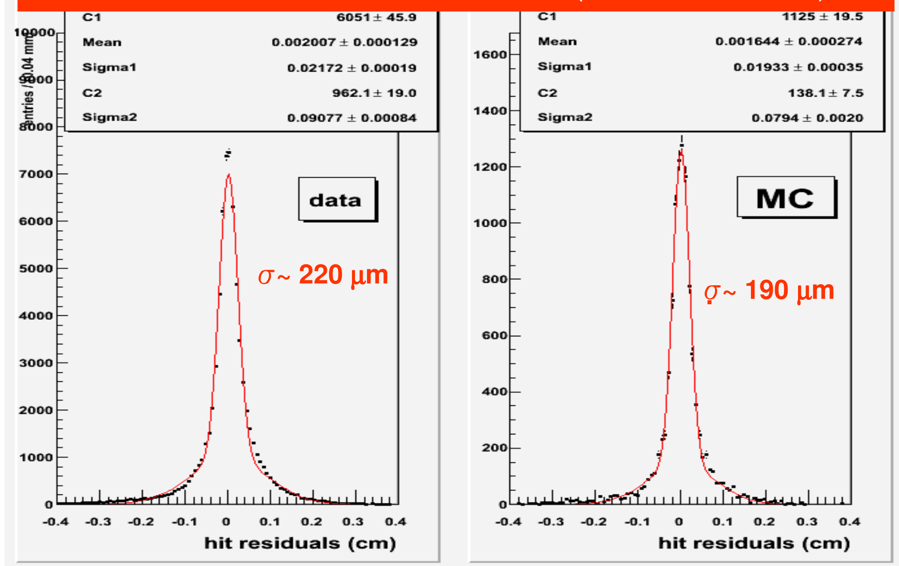
**Drift velocity in the Drift Tubes:** Innermost chambers in outermost wheels affected by B-field with a deviation up to 3%



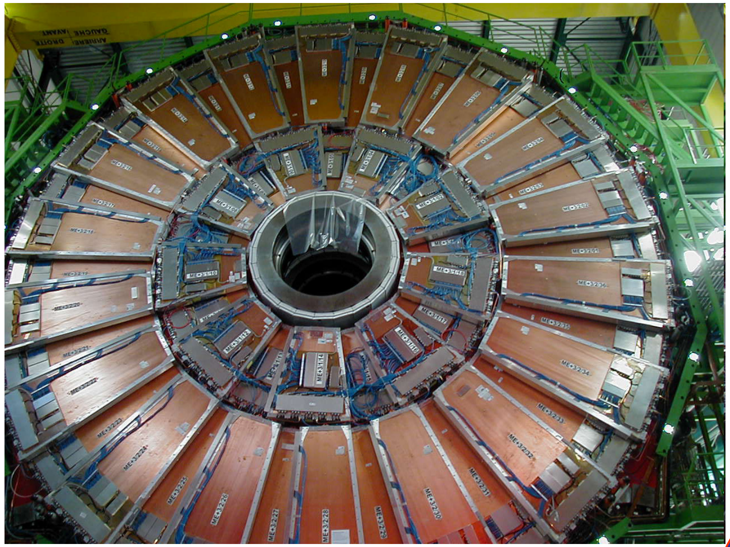




Hit Residuals - Wheel -2, station 1 (horizontal sector)



# Endcap : Cathode Strip Chambers (CSC)

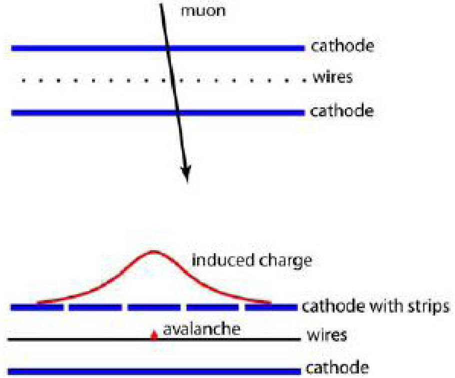


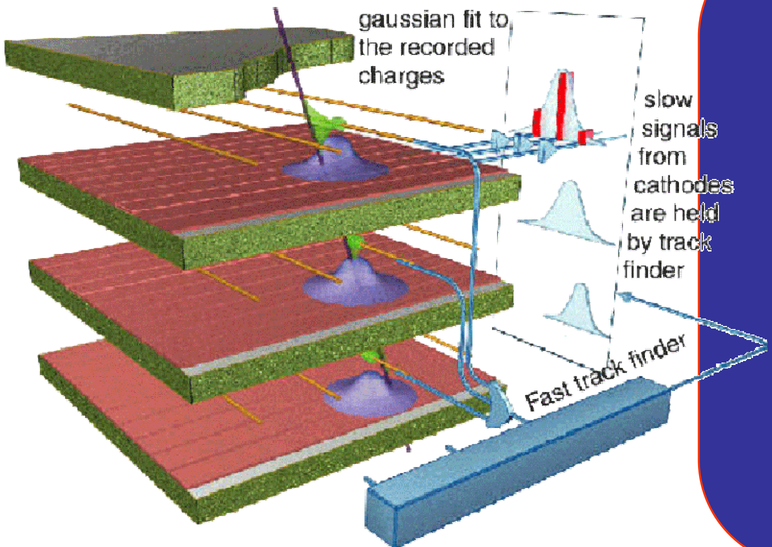
Tracking and triggering in the endcaps.
CSCs used due to higher B field and rate

468 chambers, >400k channels.

- 4 disks/endcap,
- 1, 2 or 3 rings/disk
- 18 or 36 chambers/ring

2 million cathode strip chamber wires.



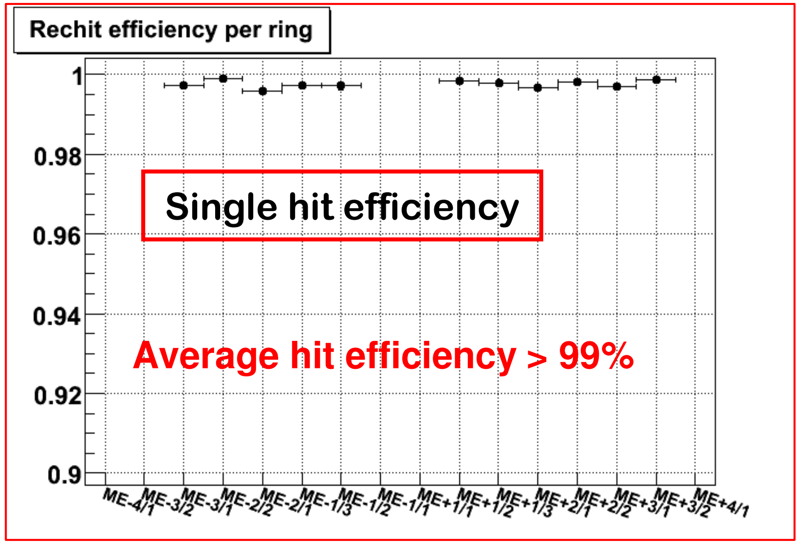



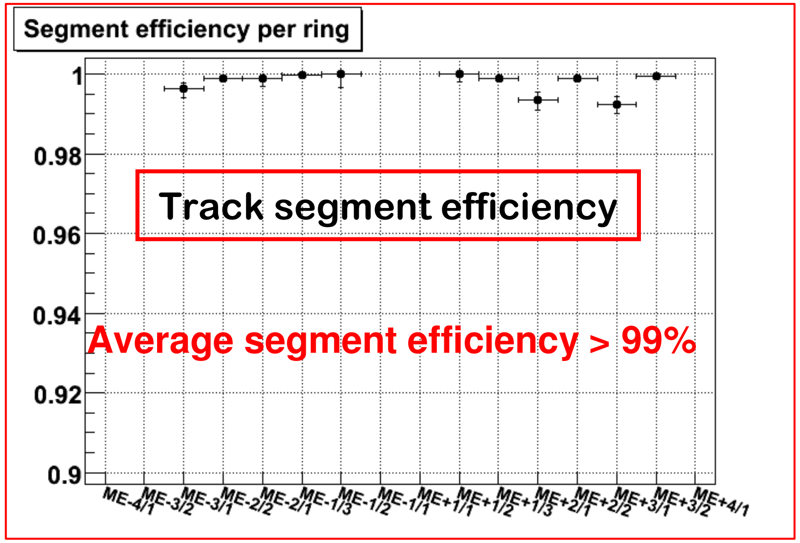

## MWPC chambers with cathode strip readout

- 6 layers per chamber
  - 9.5 mm gap, $Ar/CO_2/CF_4$ (40/50/10)%
- Bending coordinate ($\Phi$) measured by centroid on strips
  - Strip pitch 8.4-16 mm
- Fast response from wire group (r coordinate) for BX identification

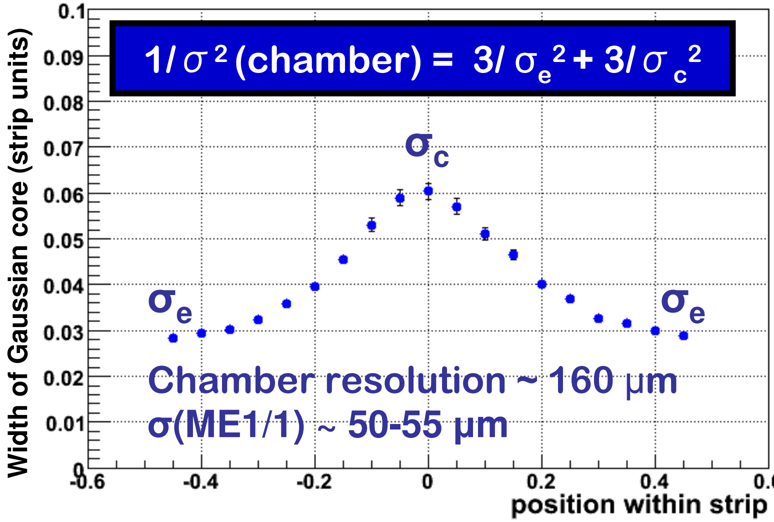
- Design resolution
  - ~150 $\mu$m/chamber
  - 75 $\mu$m for the innermost chamber that operate in a critical region (less spaced, tilted wires; smaller strips; smaller gap)

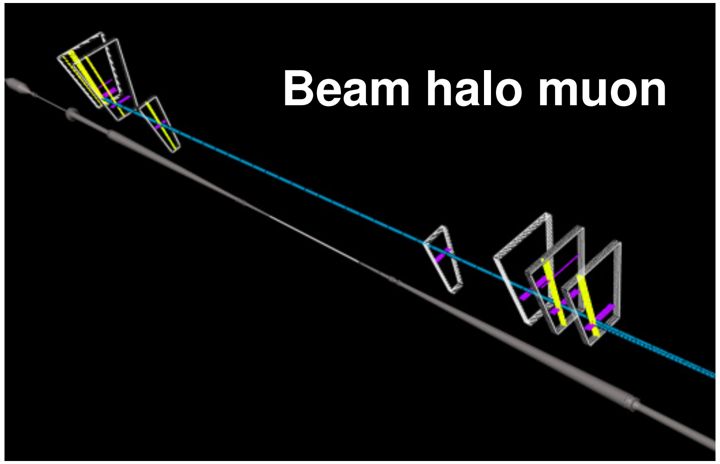
# CSC performance with Cosmic rays




Gaussian fits to residuals distributions (ME2/2). Variation with track position within the strip

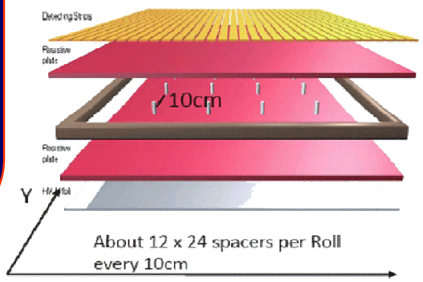


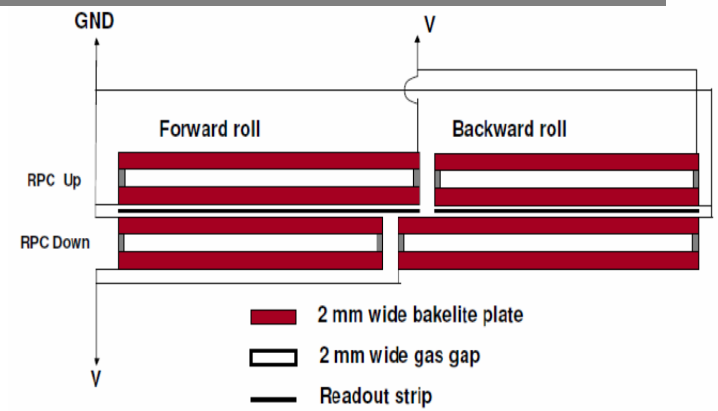



# RPC: Resistive Plate Chambers

- Double-gap in avalanche mode to cope with hit rates up to ~1KHz/cm$^2$
- $C_2H_2F_4$/iso-$C_4H_{10}$/$SF_6$ (96.2/3.5/0.3)%; closed loop
- Strips measure bending coordinate ($\Phi$~1 cm resolution)
- Fast response; very good timing resolution (~2ns)

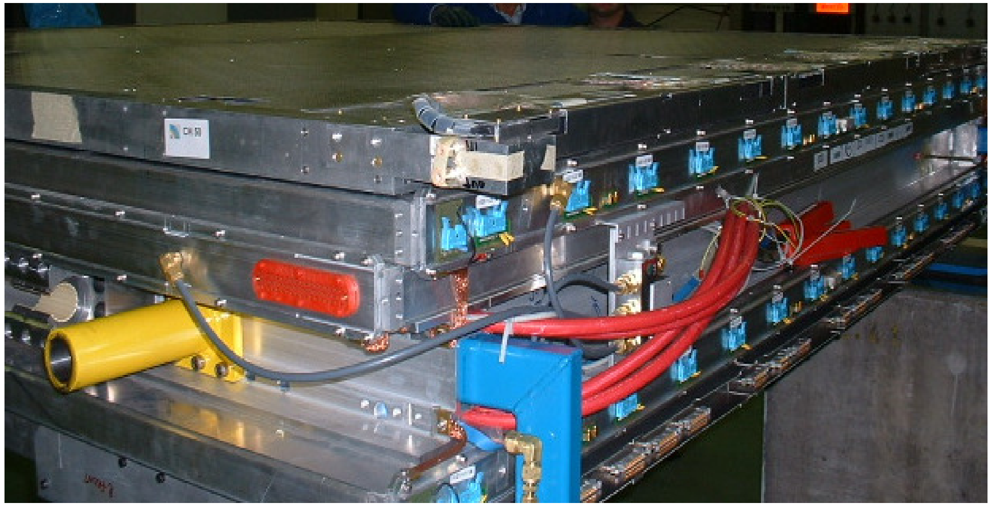
RPC used both in reconstruction and triggering in barrel and endcaps




BARREL
480 chambers (72 per wheel)
5 wheels / 12 sectors / 6 stations
Readout channels > 50k

ENDCAPS
432 chambers (72 per Disk)
6 Disks / 2 rings / 36 stations
Readout channels > 40k

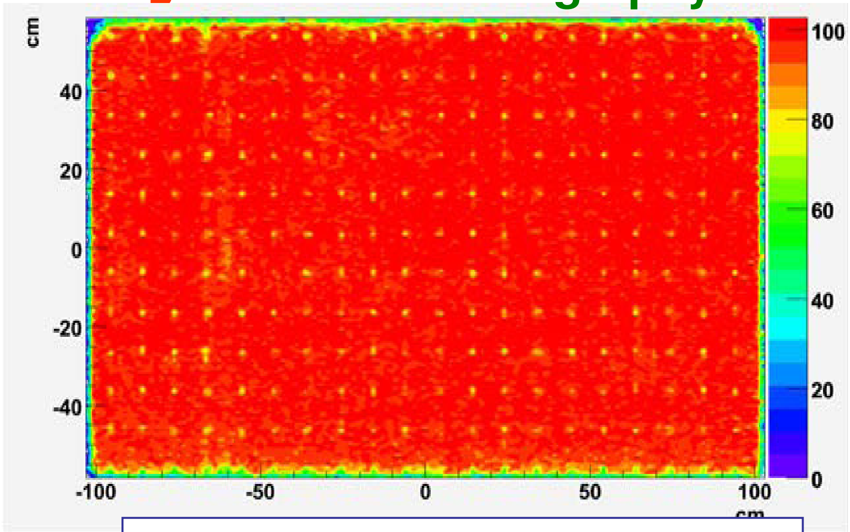


# RPC performance with Cosmic rays

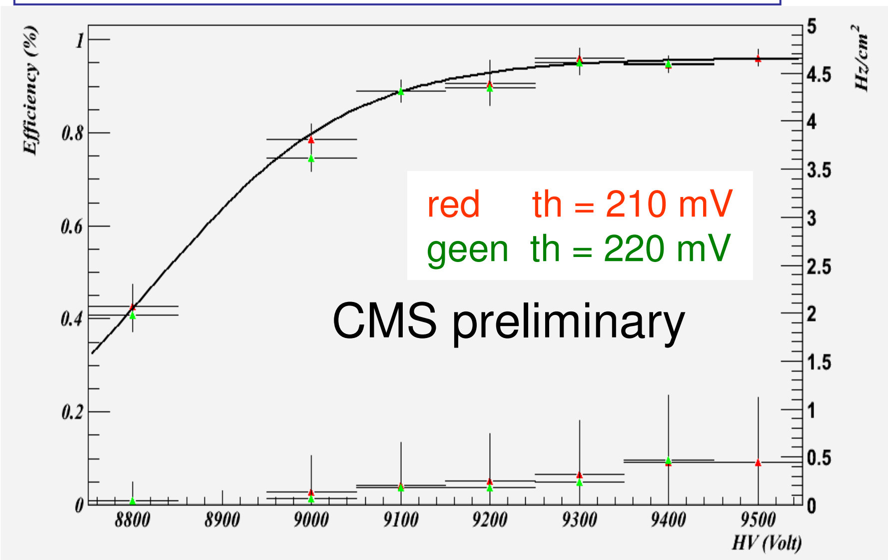
Efficiency above 90% estimated from extrapolation of DT/CSC segments

- Noise below 1 Hz/cm2
- spacial resolution 1.1 cm

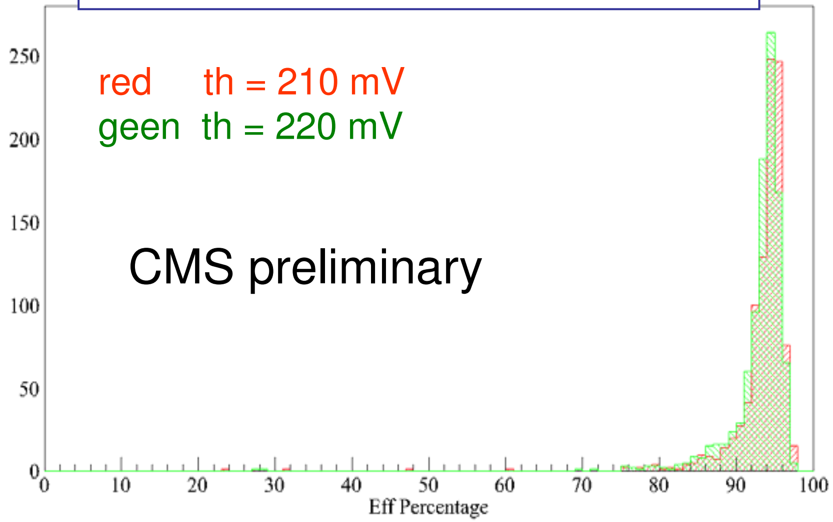
**RPC muongraphy**




**Efficiency and noise vs HV for two different electronic thresholds**



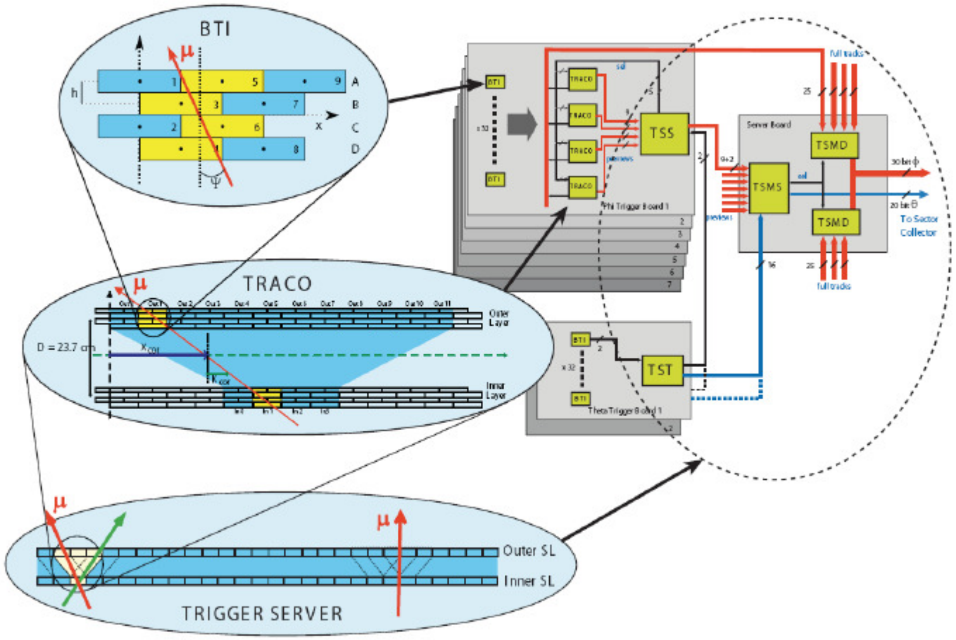

**Efficiency at 9.3 kV for two different electronic thresholds**

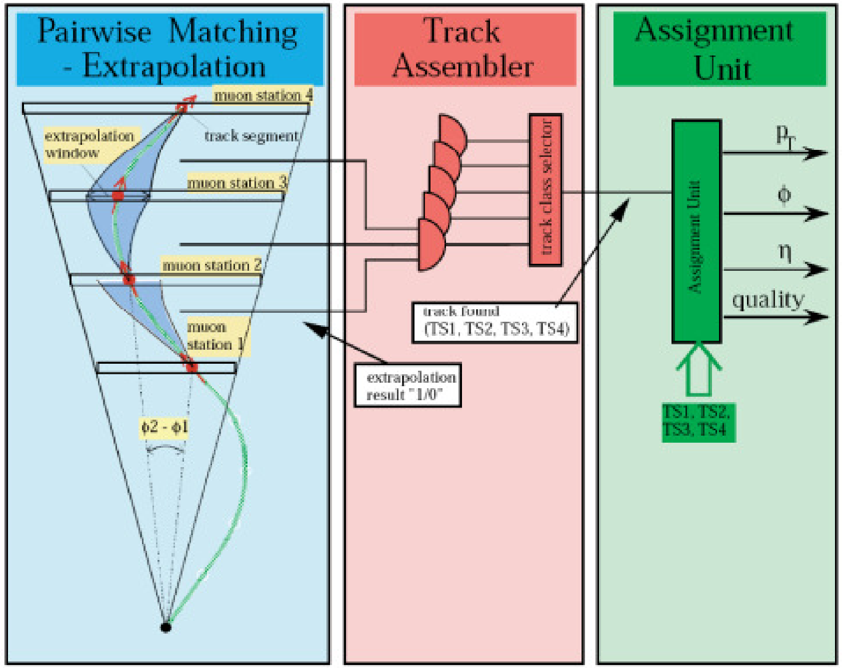


# DT trigger

- Search for hits aligned in each muon station.
- Up to 2 muon segments per station for each BX
- A ghost suppression mechanism to remove fake or wrong candidates

Trigger electronics at chamber level




- Trigger segments from each station are matched together according to predefined Look-up-Tables
- pt, position, charge and quality are assigned

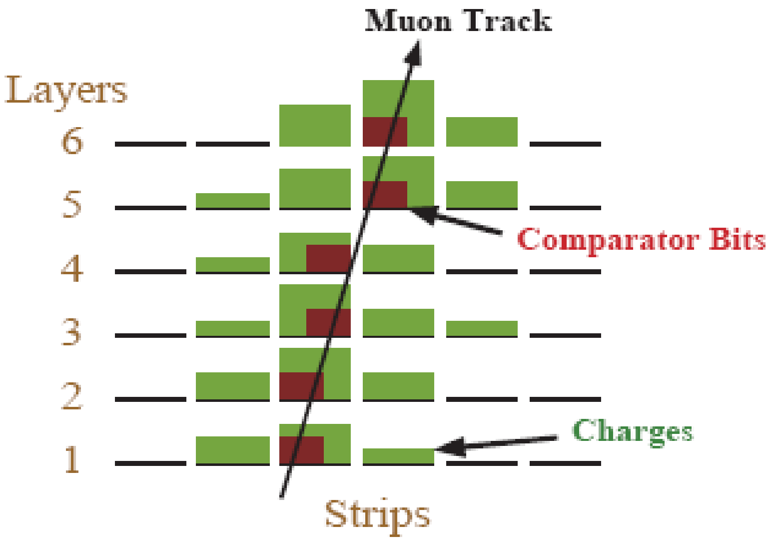
# CSC trigger

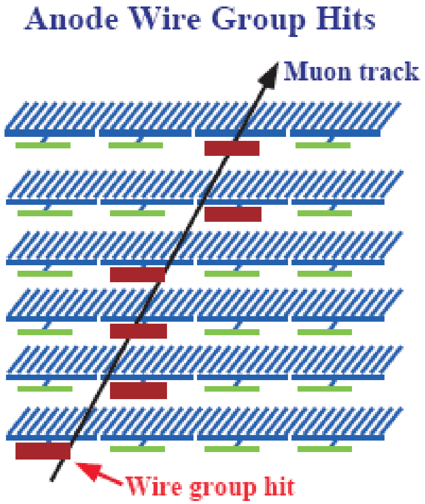
**Cathode view**

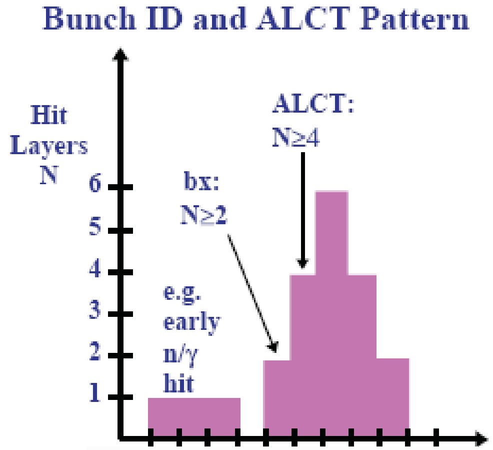
**CathodeLocalChargedTrack (CLCT) :**
6 layers provide a (~ 1 mm) measurement of position in r-$\Phi$

**Anode view**

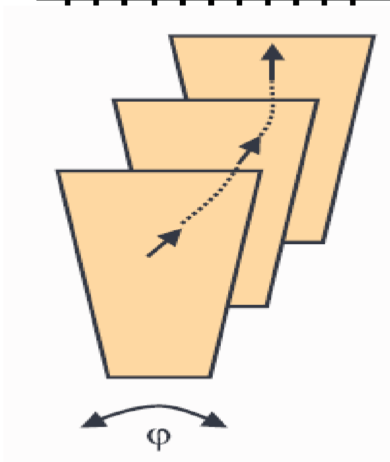
**AnodeLocalChargedTrack (ALCT):**
BX identification (~ 4.5 ns precision)
the coincidence of ≥ 4 layers define a muon segment



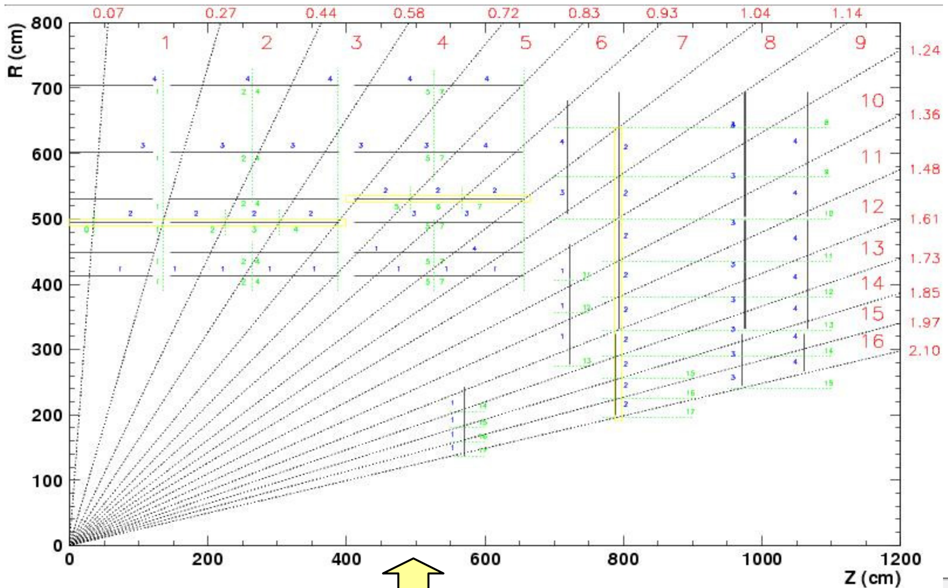




**Track Finder:** reconstruct tracks and assign pt, $\Phi$ ,η and quality
select 4 highest quality candidates to send to the Global Muon Trigger



# RPC trigger

More details in A. Osorio Poster

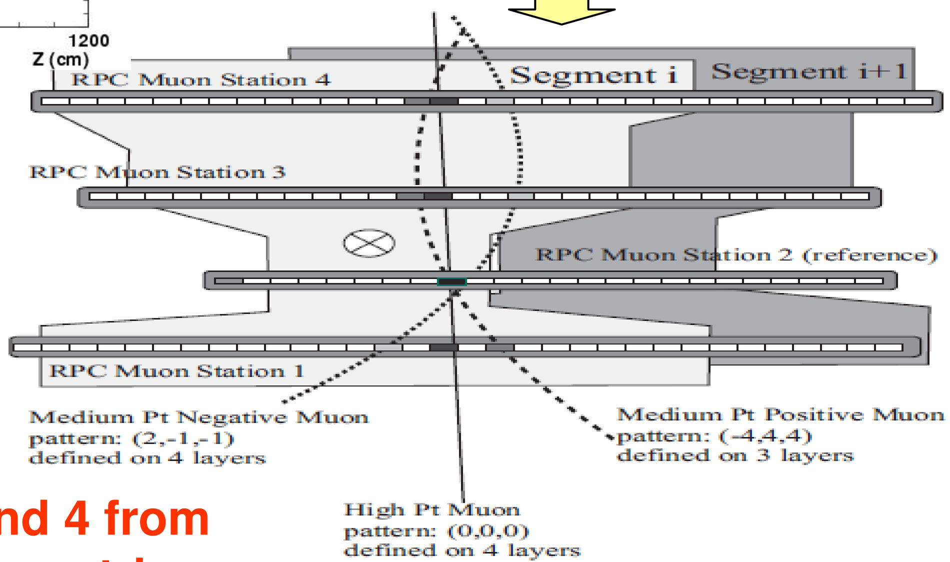



The detector is divided in 33 geometrical regions (towers) along the η coordinate according to the position on a reference layer

Cones cover 2.5 ° in ϕ (8 strips) on the reference layer

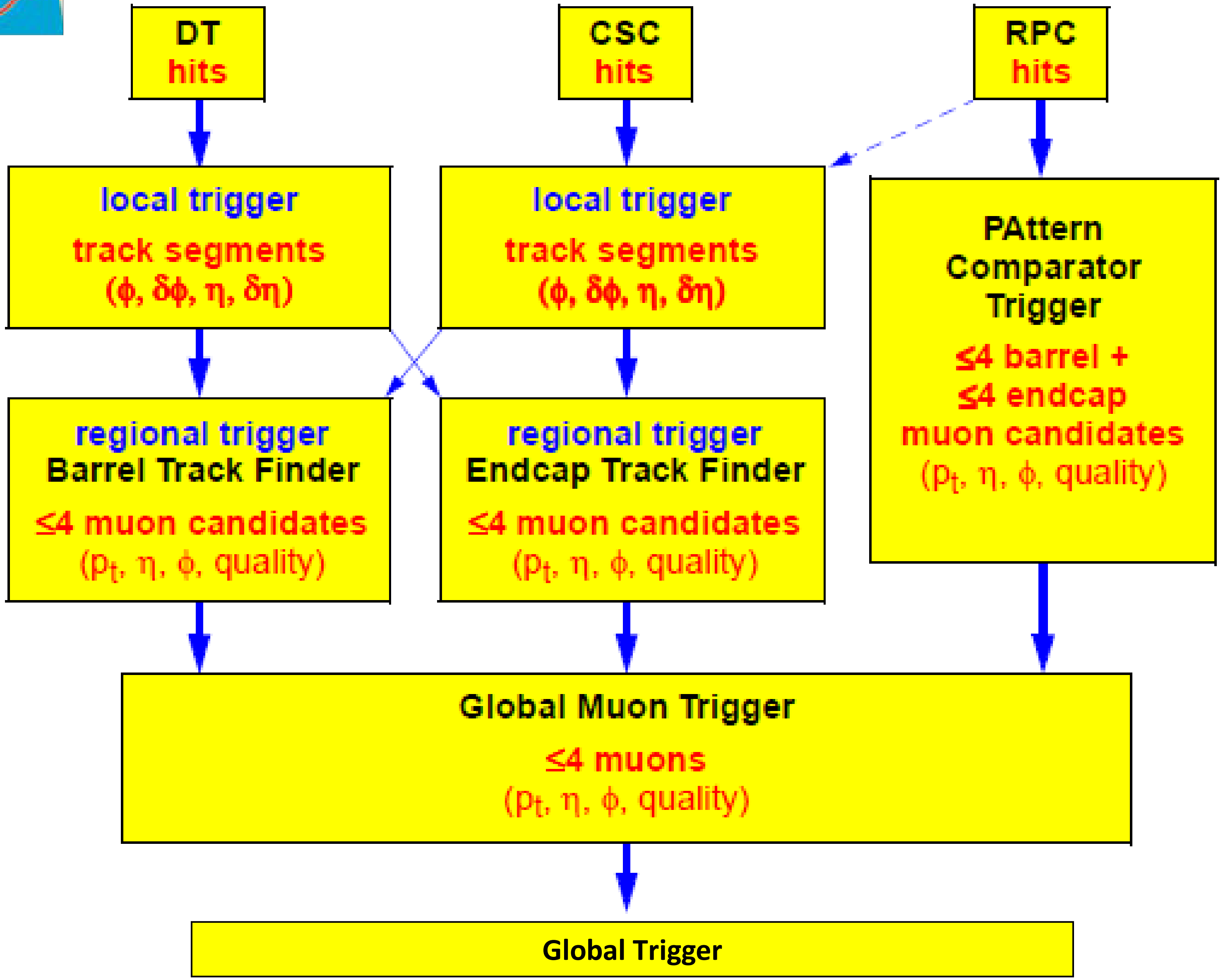
3-6 layers per cone depending on the tower.

PAC algorithm: strips in the cone matched to a set of pre-determined patterns.




**Select 4 higher pt muons from barrel and 4 from end-caps and deliver them to Global muon trigger**

# Muon Global trigger

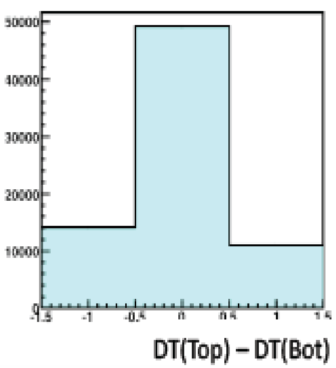


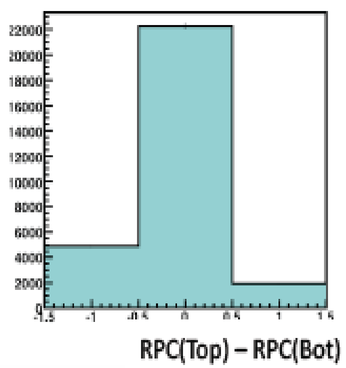
# Muon trigger performace with Cosmic Rays

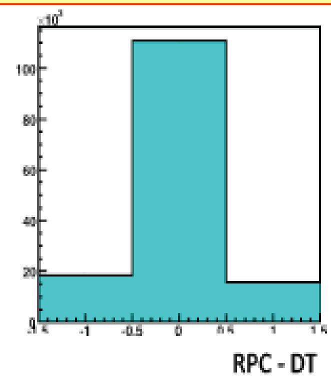
Istituto Nazionale di Fisica Nucleare

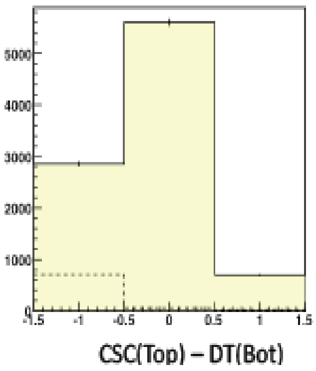
**Relative synchronization:** most of events in same BX, CSC synchronization improved during CRAFT exercise

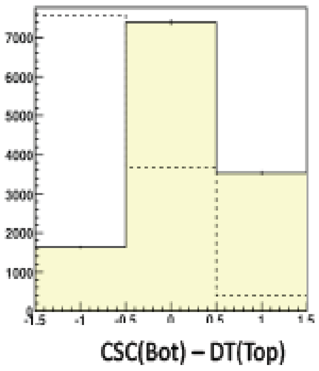
**CMS preliminary**



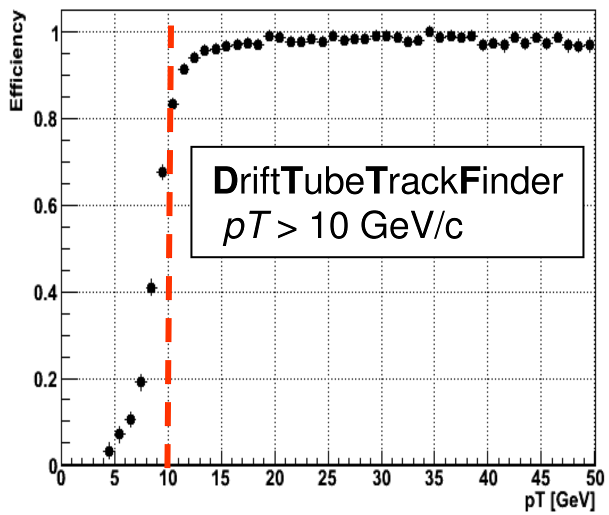



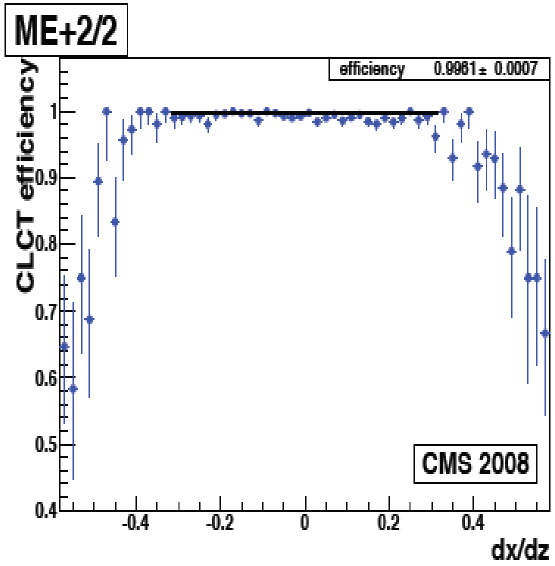



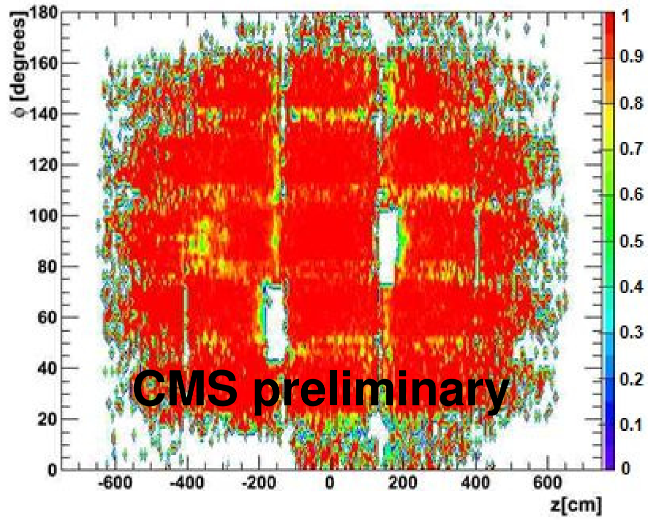

**DT track finder turn-on curves**
**Collision-like cosmics, bottom sectors**



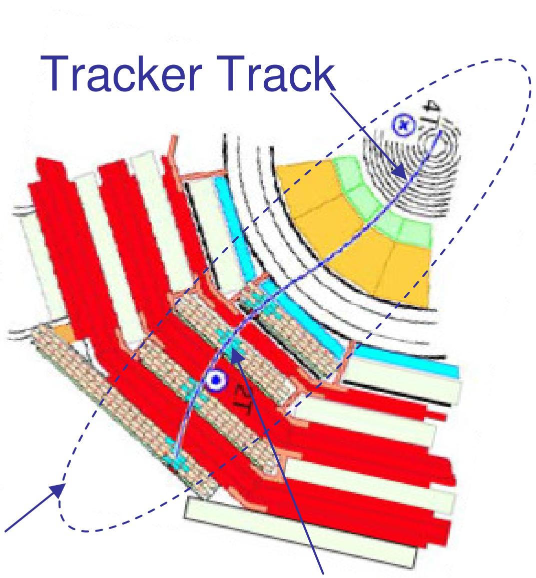

**CLCT efficiency vs dx/dz**




**RPC trigger efficiency vs DT trigger**



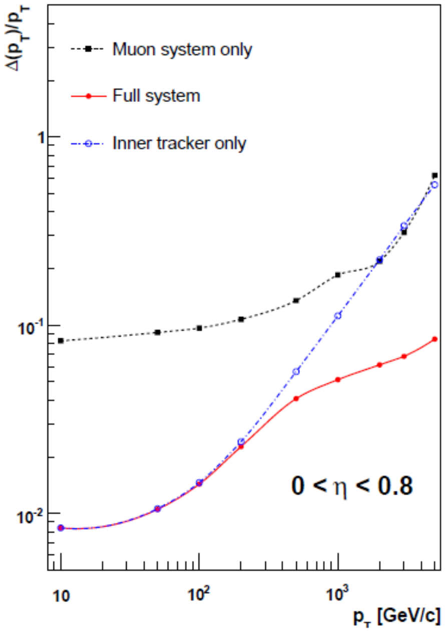
# Muon Reconstruction

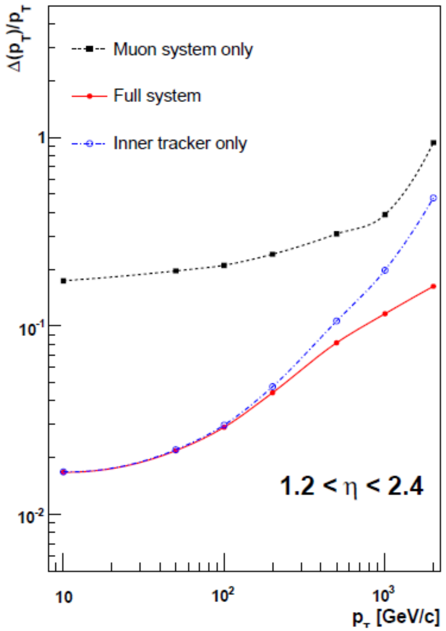


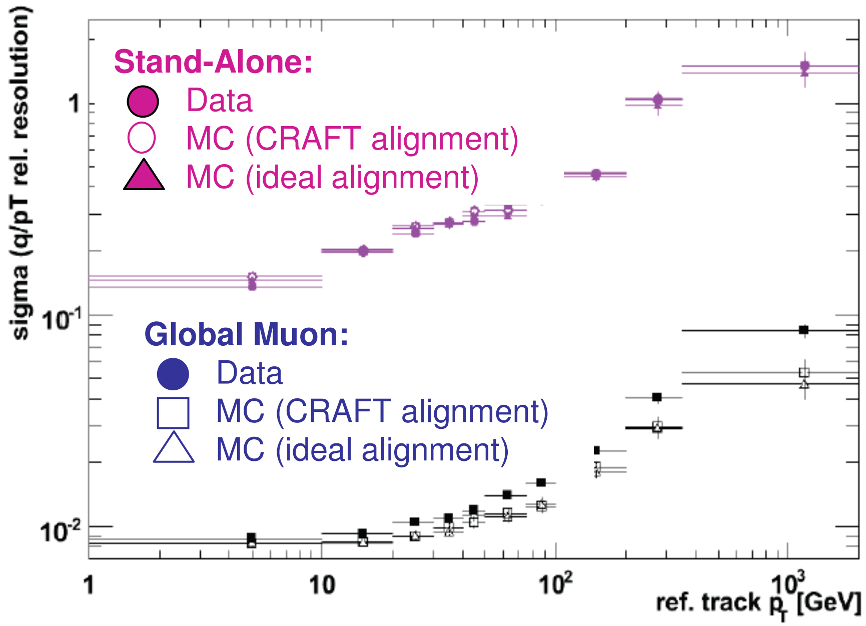

**Muon reconstructed independently both in Tracker and in muon system**

- Inner tracker dominates resolution up to 200 GeV/c due to multiple scattering in the iron
- Above 200 GeV/c, improvement from combined muon-tracker fit

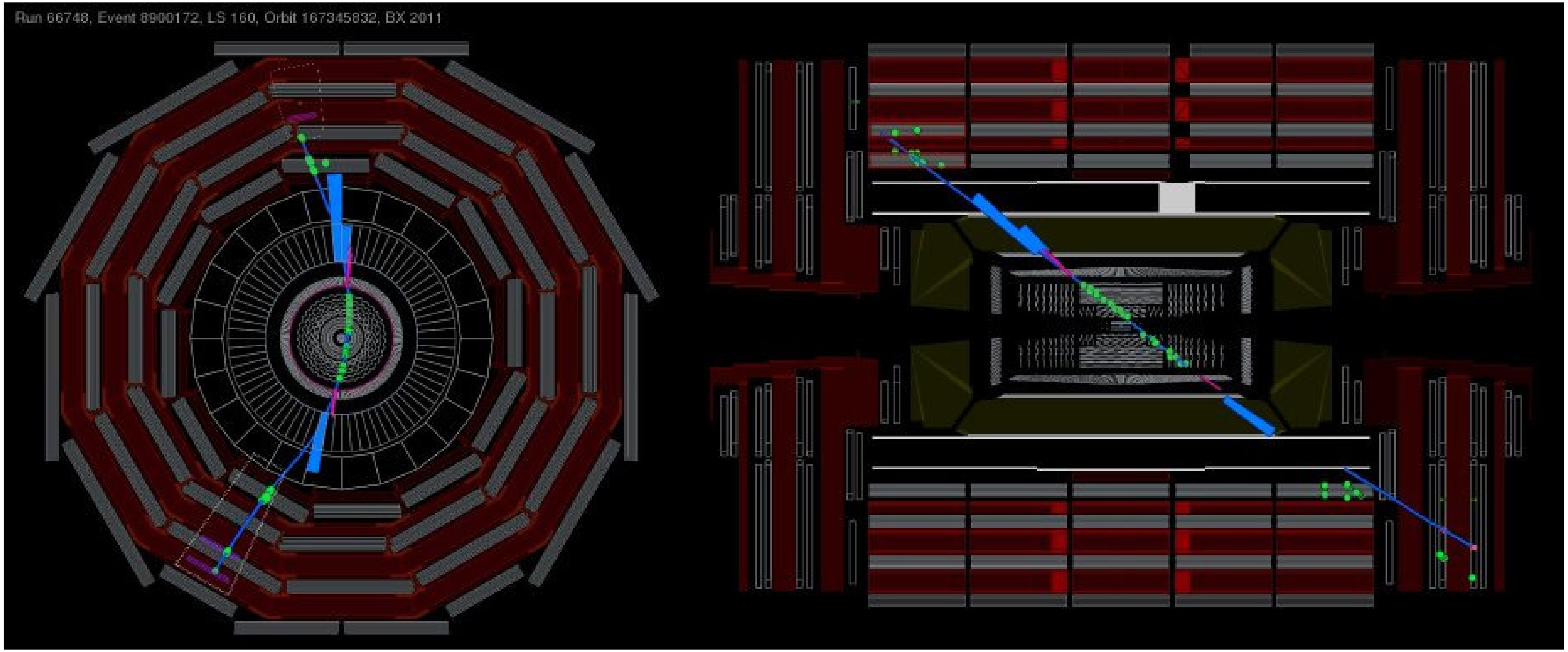
**Resolution measured by comparing bottom and top leg of the cosmic track**



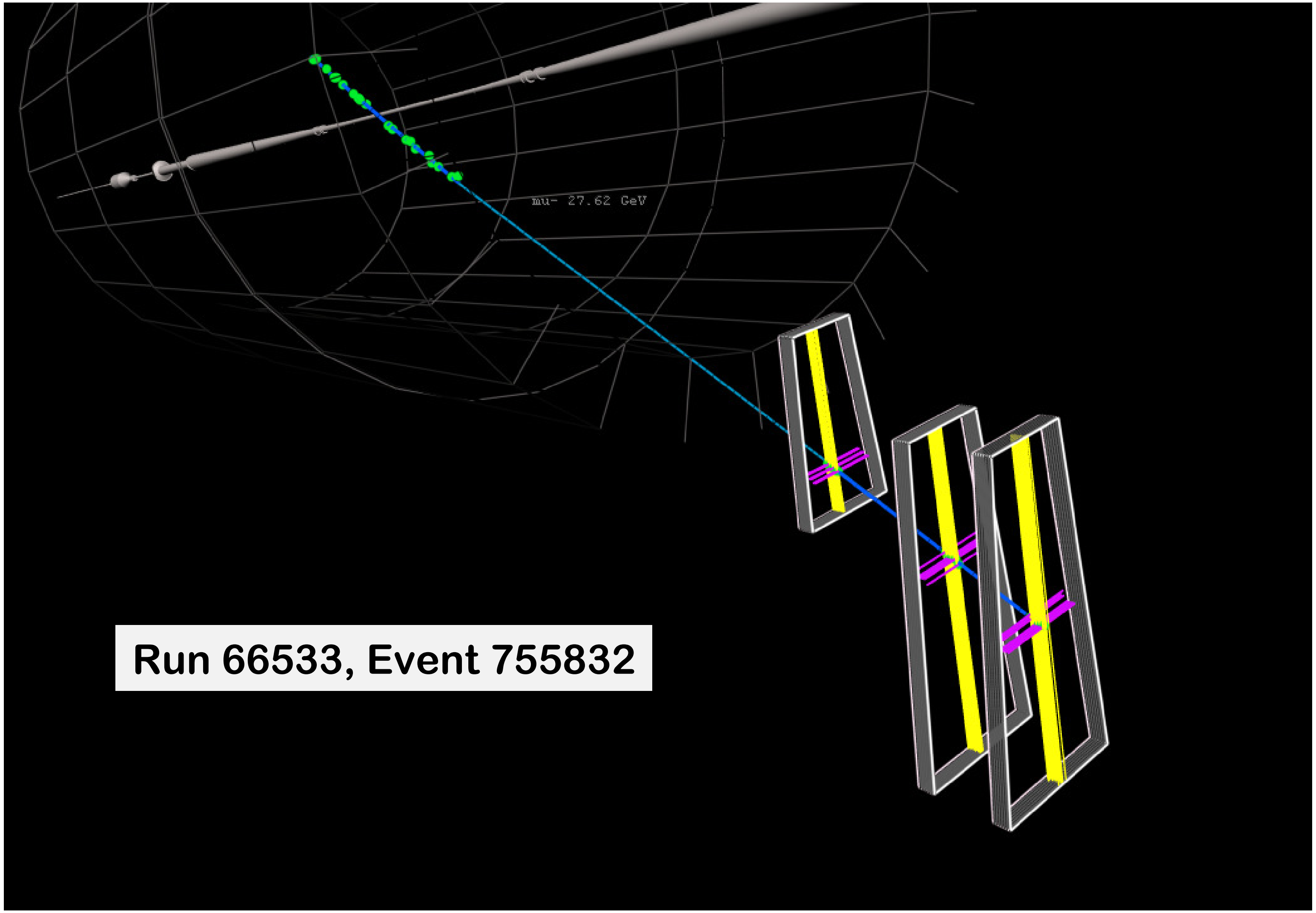



# Some nice Cosmic Muon

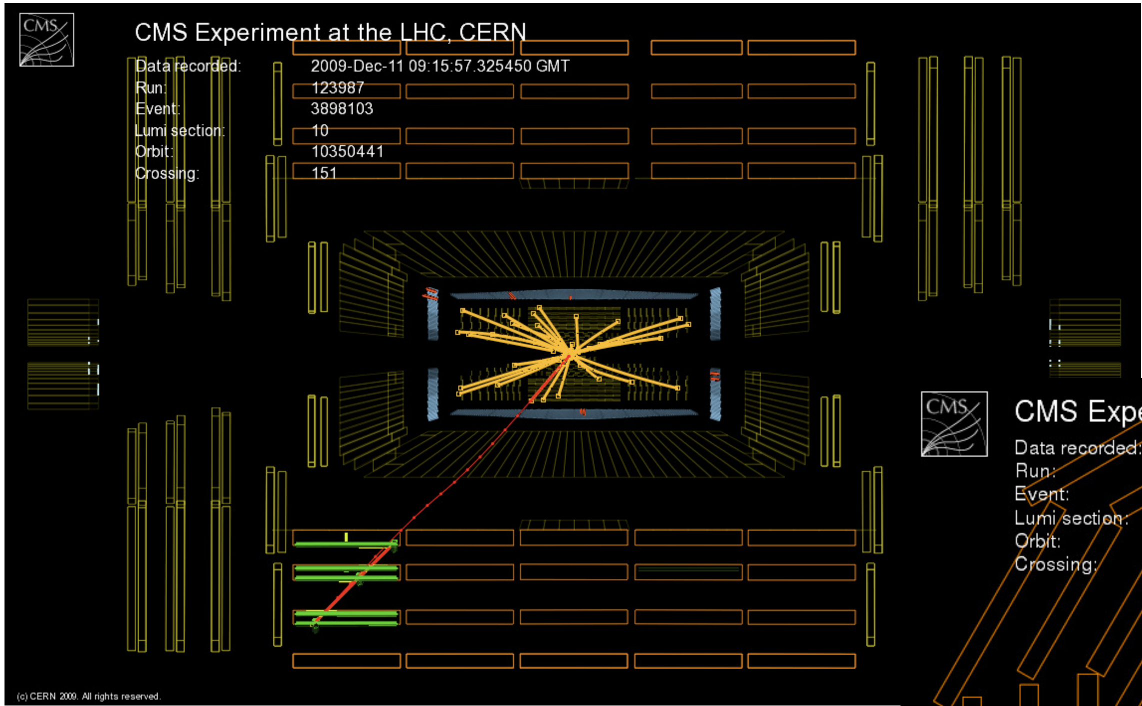


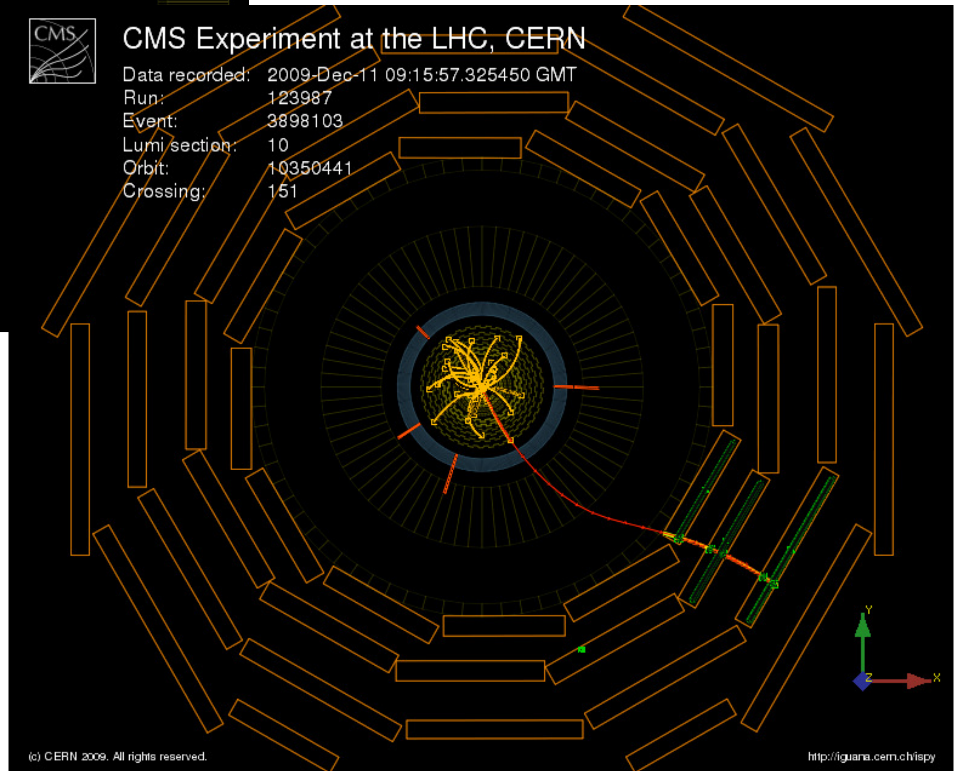
# Some nice Cosmic Muon



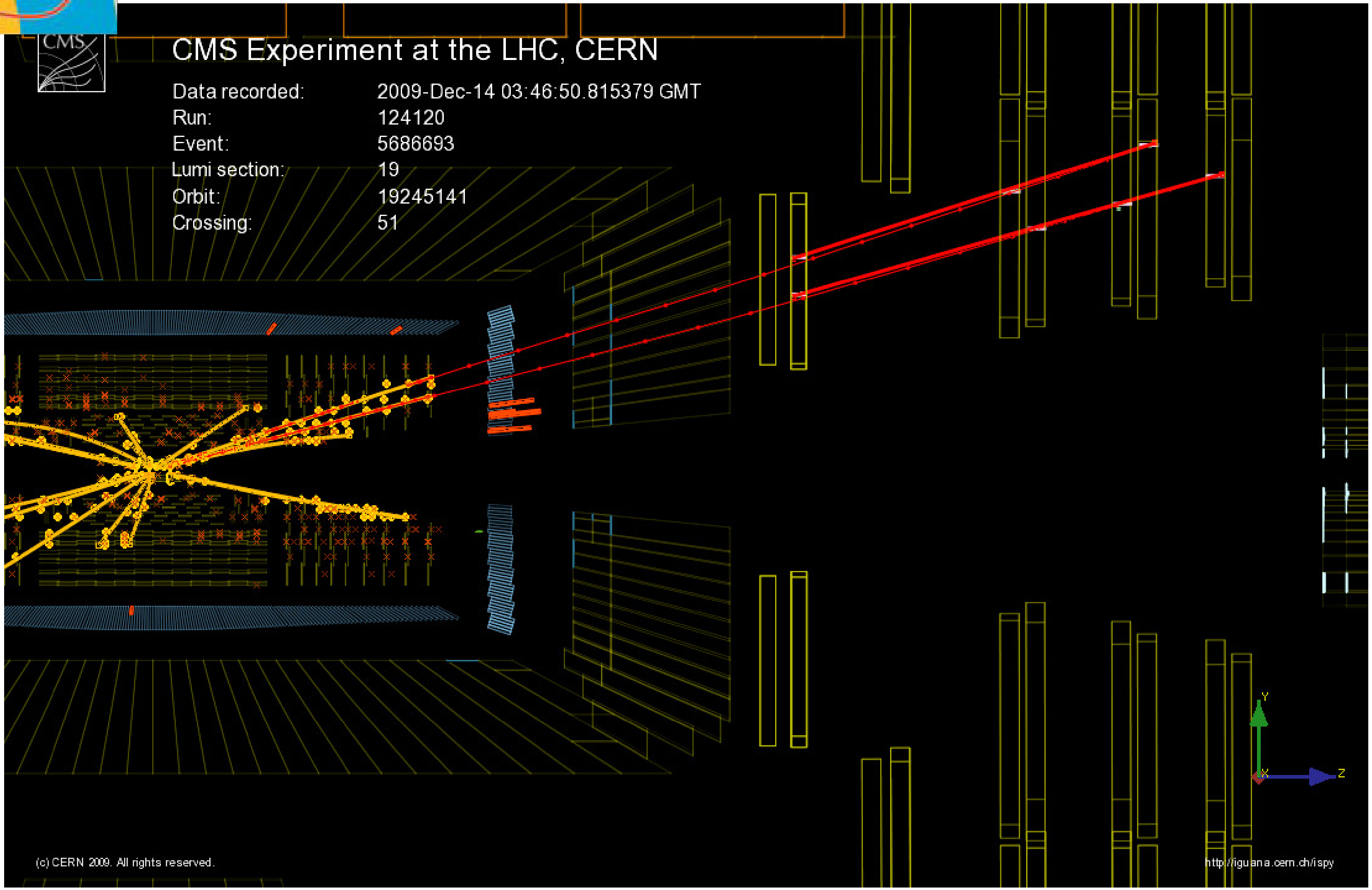
# LHC Collisions Data

# Barrel muon candidate



# Collisions at 2.36 TeV




$p_T(\mu_1) = 3.6$ GeV/c, $p_T(\mu_2) = 2.6$ GeV/c, $m(\mu\mu) = 3.04 \pm 0.04$ GeV/$c^2$

# Conclusions

## CMS made good use of the Cosmic Rays data

- More than 500 M events collected between 2008-09
- Sub-detector and trigger performance checked
- Mapping of magnetic field at level of 3 %
- Alignment precision comparable to 10 $pb^{-1}$ of LHC Data
- Reconstruction algorithm verified and tuned on real Data
- First muons from LHC collisions reconstructed

- **Ready for more muons from LHC collisions in few days**