Status of CMS Commissioning

DISCRETE ´08 Valencia, Spain

- ❑ Introduction: CMS design and engineering solutions
- ❑ Detector completion
- ❑ Detector commissioning, operation experience and performance
  - First beams
  - Cosmic runs
- ❑ Summary

Design Criteria for Physics

- **Robust and redundant Muon detector for triggering, identification and momentum measurement**
  - High efficiency & low contamination
  - Hermetic detector coverage
  - di-muon mass resolution < 1% at 100GeV/c.
  - charge determination for muons with momentum ~ 1 TeV/c
  - $\Delta p_T/p_T \sim 5\%$

- **Central tracking system**
  - high resolution
  - good reconstruction of secondary vertices

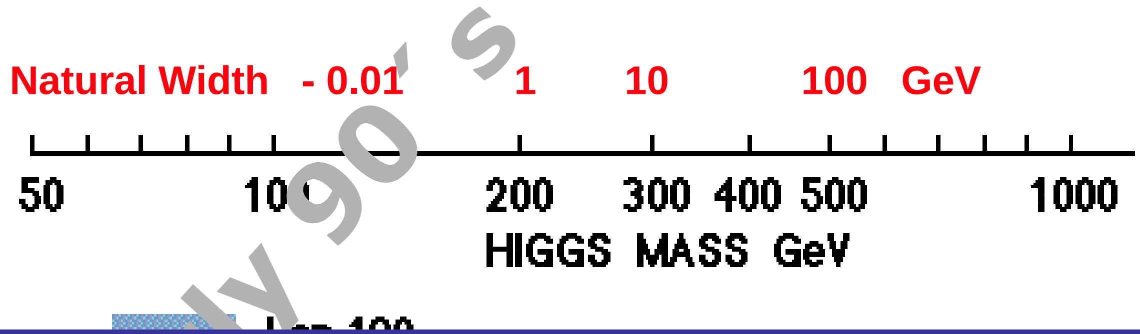
- **Electromagnetic calorimetry**
  - Hermetic and highly granular
  - di-photon mass resolution < 1% at 100 GeV/c2.
  - High energy resolution, ~ 0.5% @ E_T ~ 50 GeV

- **Hermetic calorimetry system**
  - good resolution for detecting and measuring “missing” E_T
  - reconstructing the mass of jet-pairs.

From the early 90´s

Benchmark Reaction: SM Higgs

At the LHC the SM Higgs provides a good benchmark to test the performance of a detector



LHC environment

High Interaction Rate

pp interaction rate **1 billion interactions/s**

Data can be recorded for only ~10^2 out of 40 million crossings/sec

Large Particle Multiplicity

~ <20> superposed events in each crossing

~ 1000 tracks stream into the detector every 25 ns

High Radiation Levels

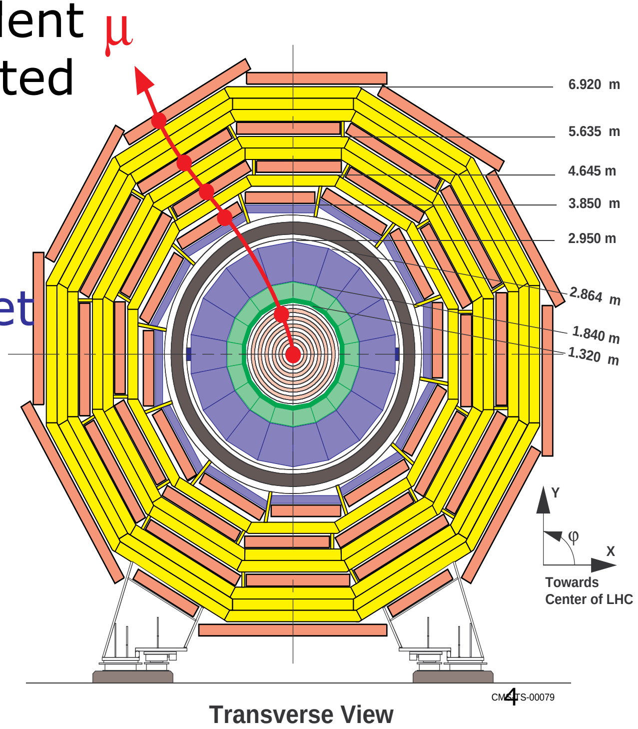
Key Technological features

- **Muons**

  Redundant precision measurements inside an instrumented iron yoke

  4 Stations of 32 r-φ measurements - Barrel Drift Tubes (DT)
  24 r-z measurements – Endcap Cathode Strip Chambers (CSC
  Interleaved RPC trigger layers (6 in the barrel, 3 in the endcaps)
  Precision alignment system to link barrel and endcap

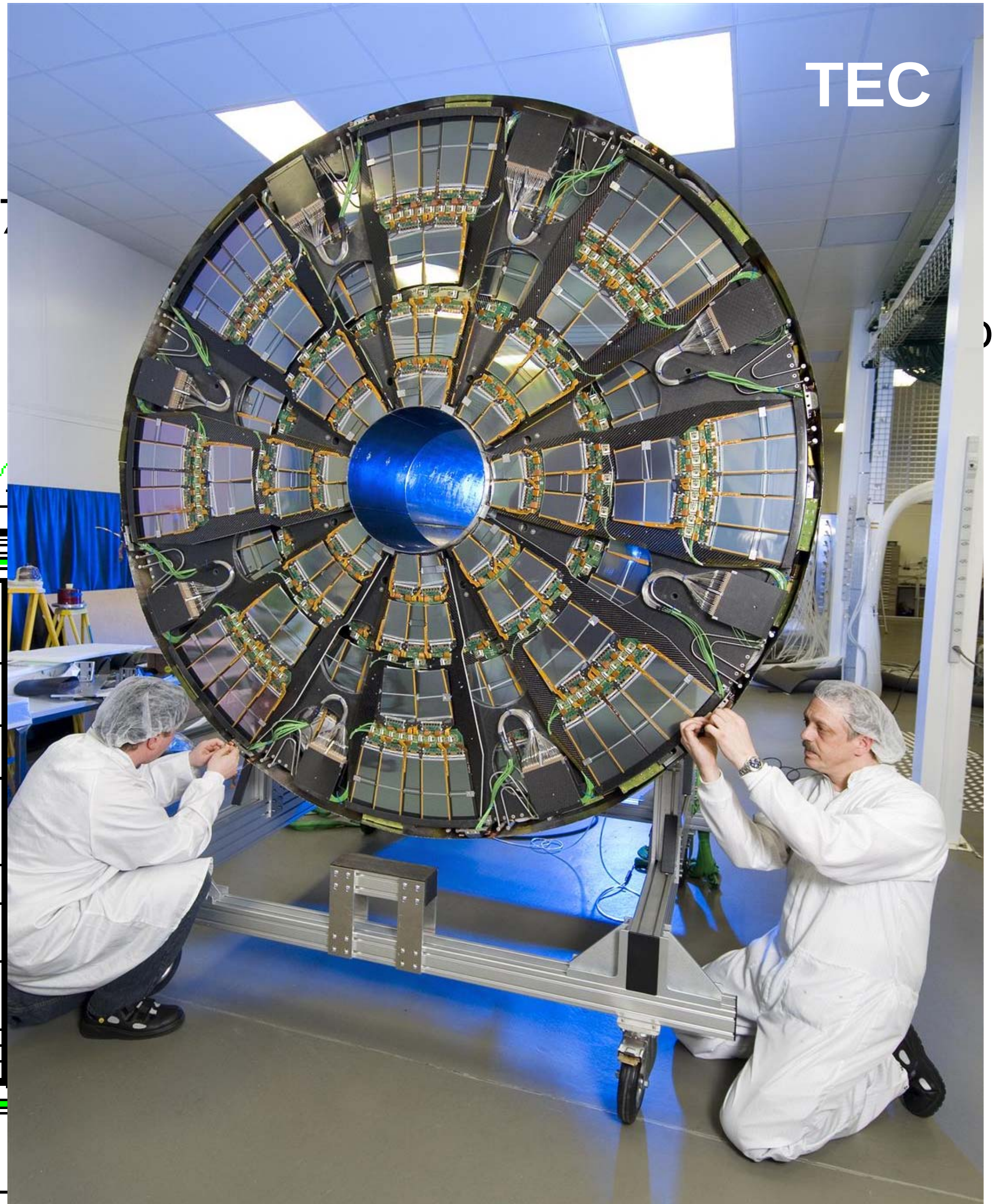
  → Very Compact Muon System with independent momentum measurement if iron is saturated



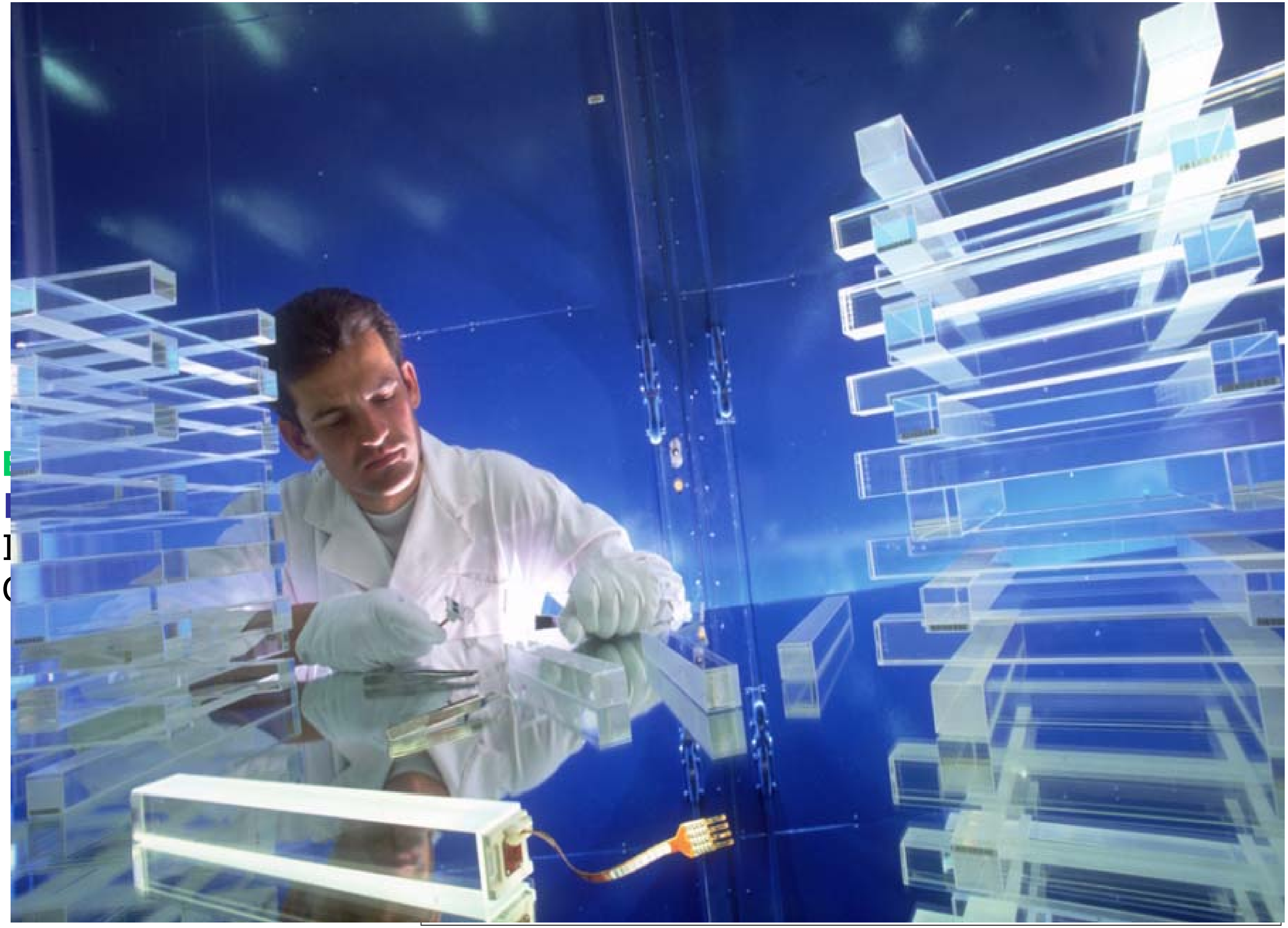
- **Super Conducting Solenoid**

  Enormous dimensions 13m long, 6m diameter
  Central tracking and calorimetry inside the magnet
  Strong field (4T) with very large BL^2
  Stored energy at full field 1.6 GJ

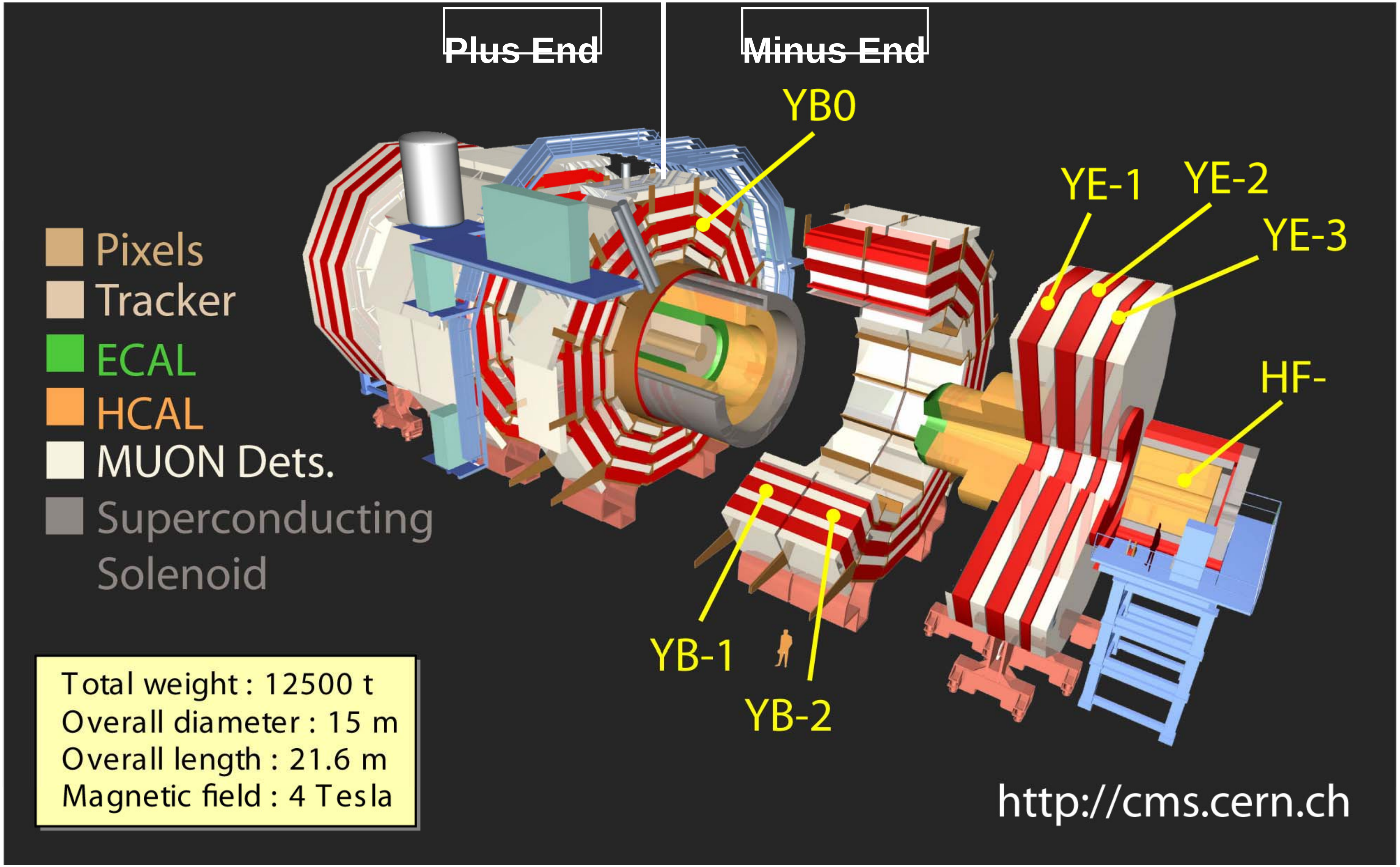
Key Technological features



Key Technological features



The CMS Detector

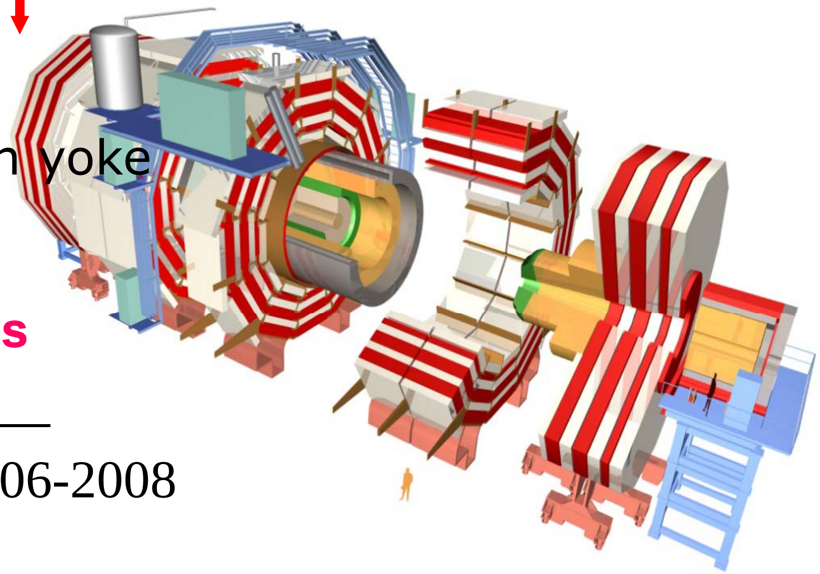


Assembly Sequence

SURFACE : *independent of underground Civil Engineering*

2000-2007

* construct magnet barrel yoke & pre-cable
* prepare solenoid vac tanks
* construct endcap yoke & pre-cable
* assemble hadron calorimeters
* install muon chambers (barrel+endcap) in yoke
* assemble coil & insert in vac tank
* insert HCAL inside coil
• **Test magnet + parts of all subsystems**
*separate elements and lower sequentially



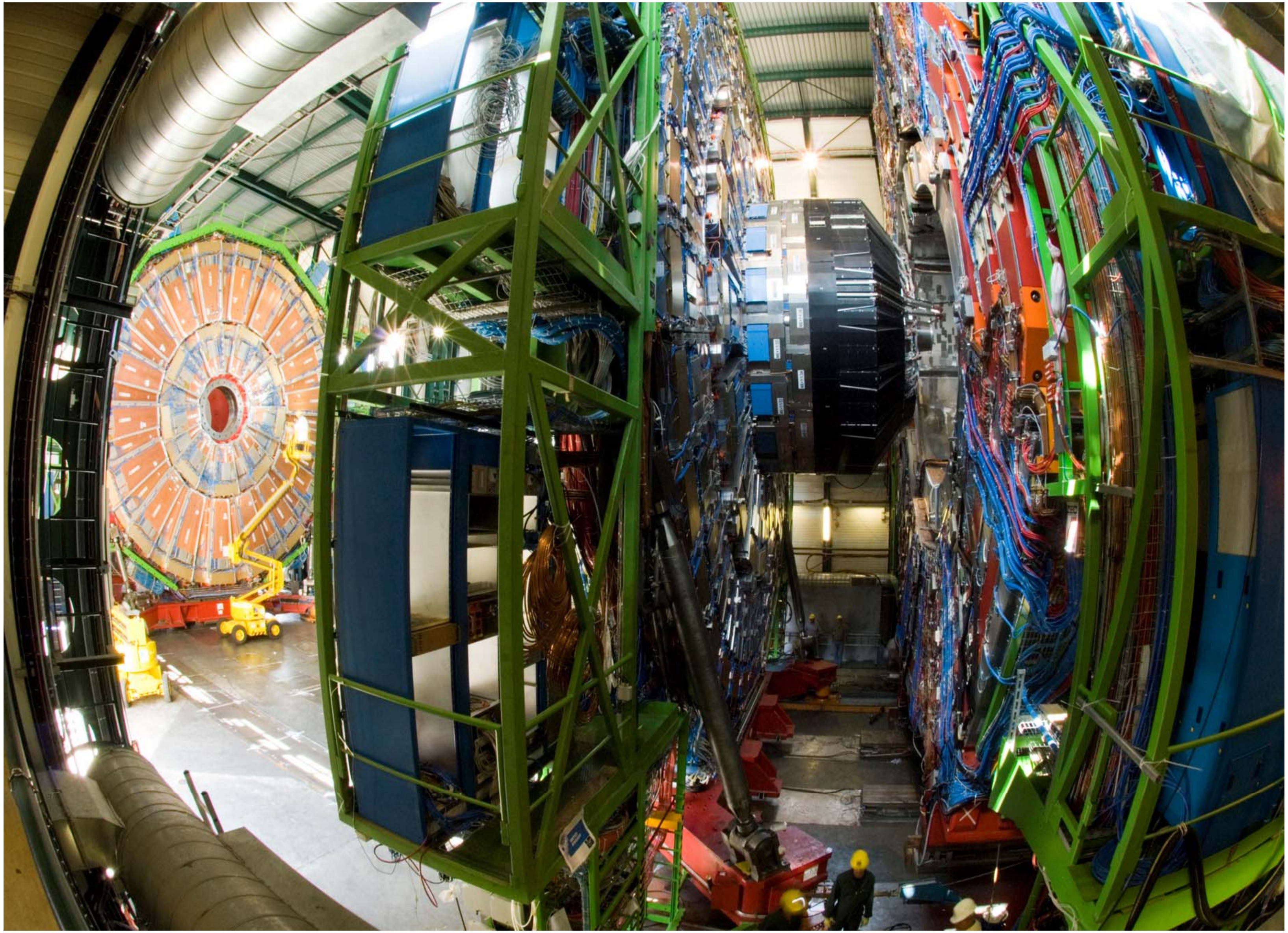
UNDERGROUND :

2006-2008

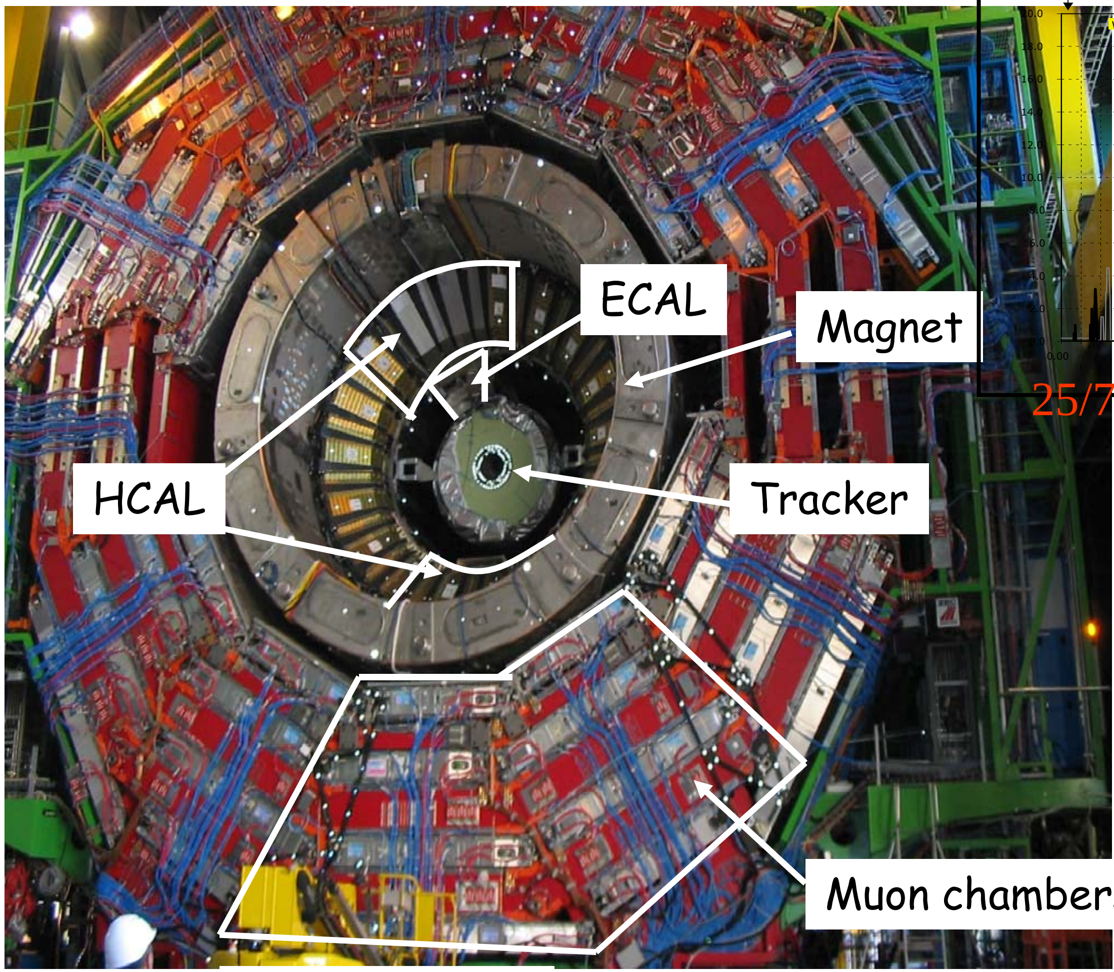
* re-install HCAL
* install ECAL barrel & cable central wheel
* install Tracker & cable
* install beampipe & bake-out
* install ECAL endcaps
* close & finish commissioning

15 heavy lowerings of objects of 380 tons -1920 tons

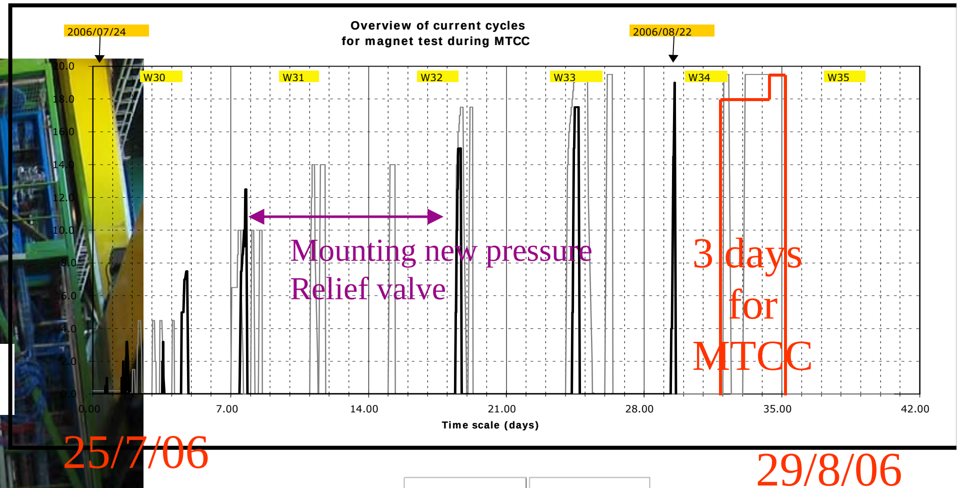
First Closure of CMS (summer 2006)

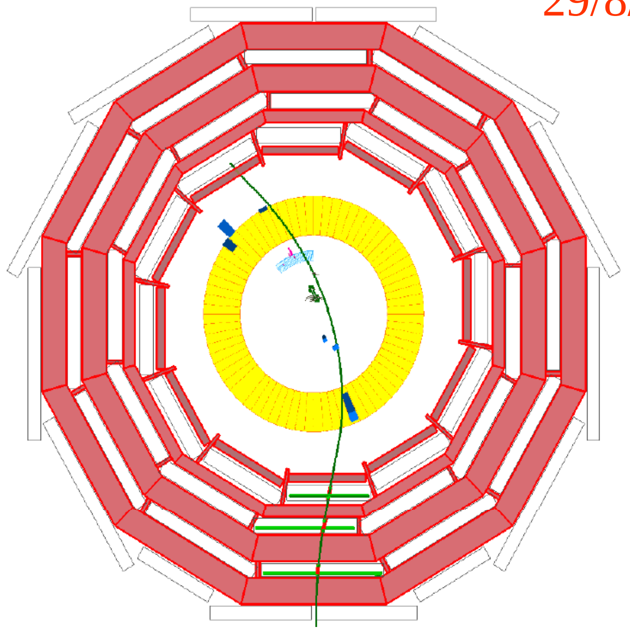


Magnet Test & Cosmic Challenge (MTCC)



5 Detectors integration



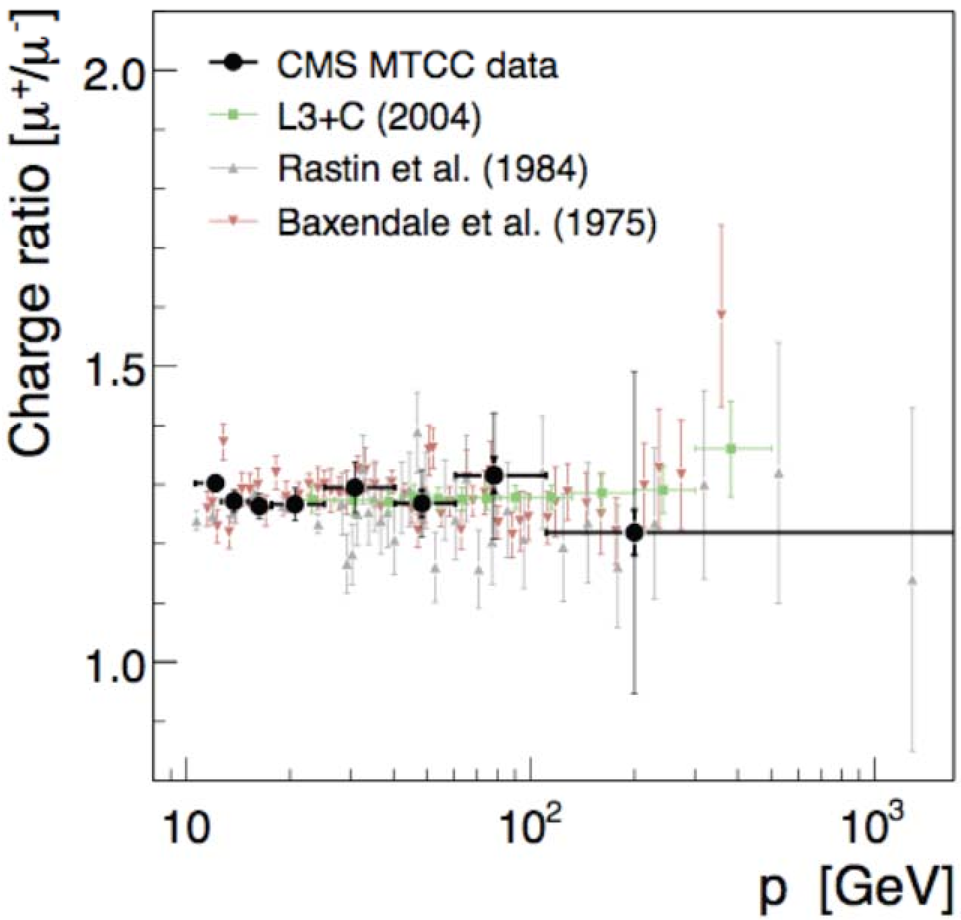


Run 2605 / Event 3981/ B 3.8 T/27.08.06

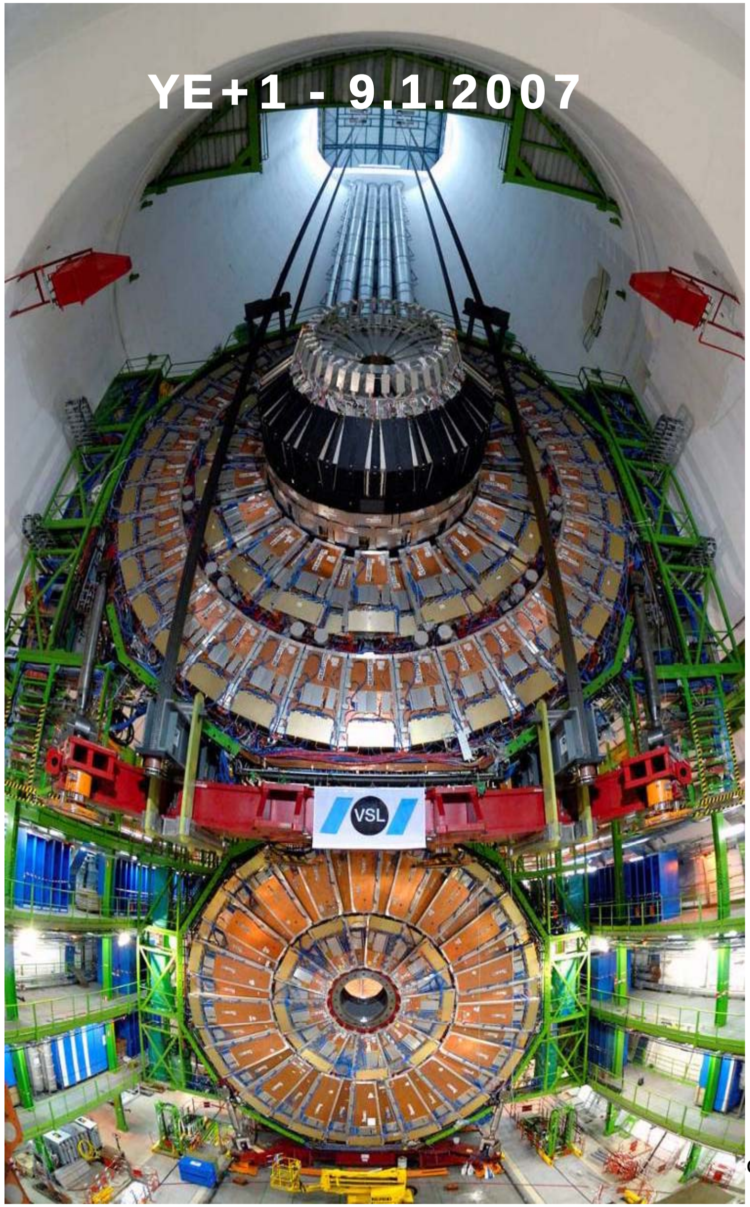
"First" CMS (Cosmics) Physics Result

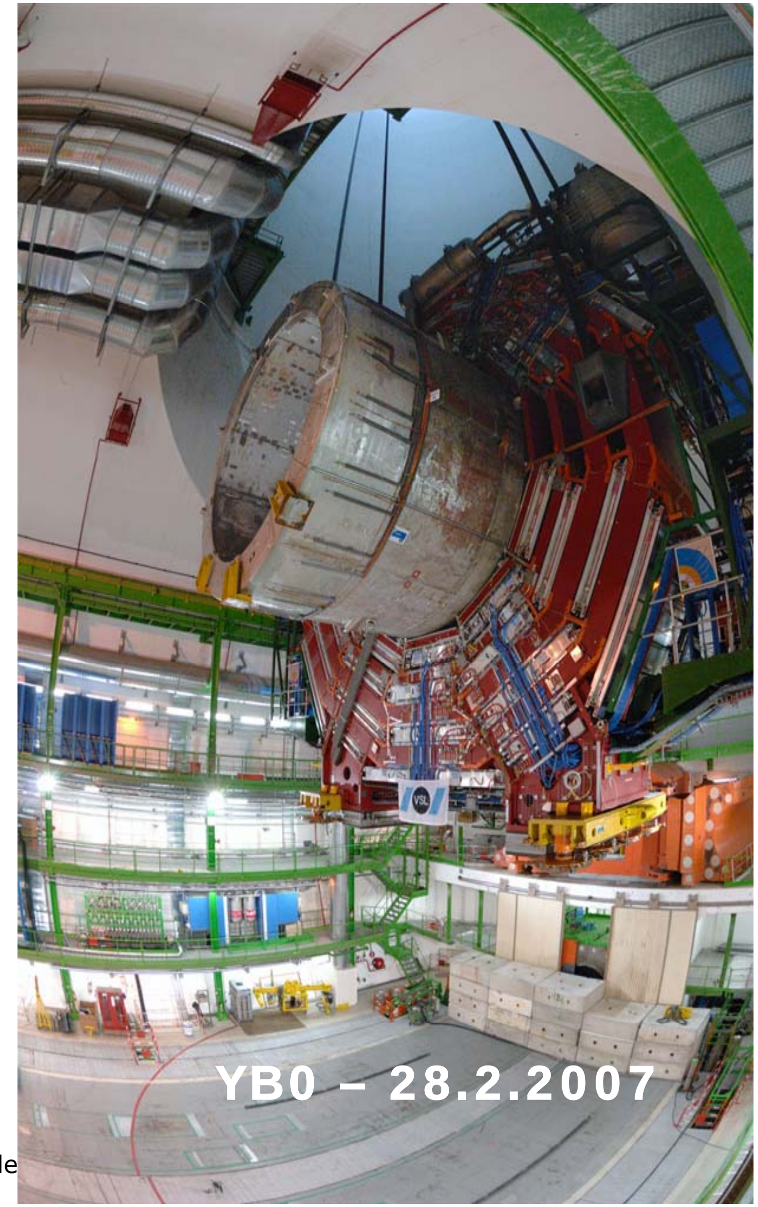
15 M of cosmic muons, with stable 3,8T field and ~ 5% of the Muon detector

CMS Note 2008/016
M. Aldaya, P.Garcia-Abia (CIEMAT)

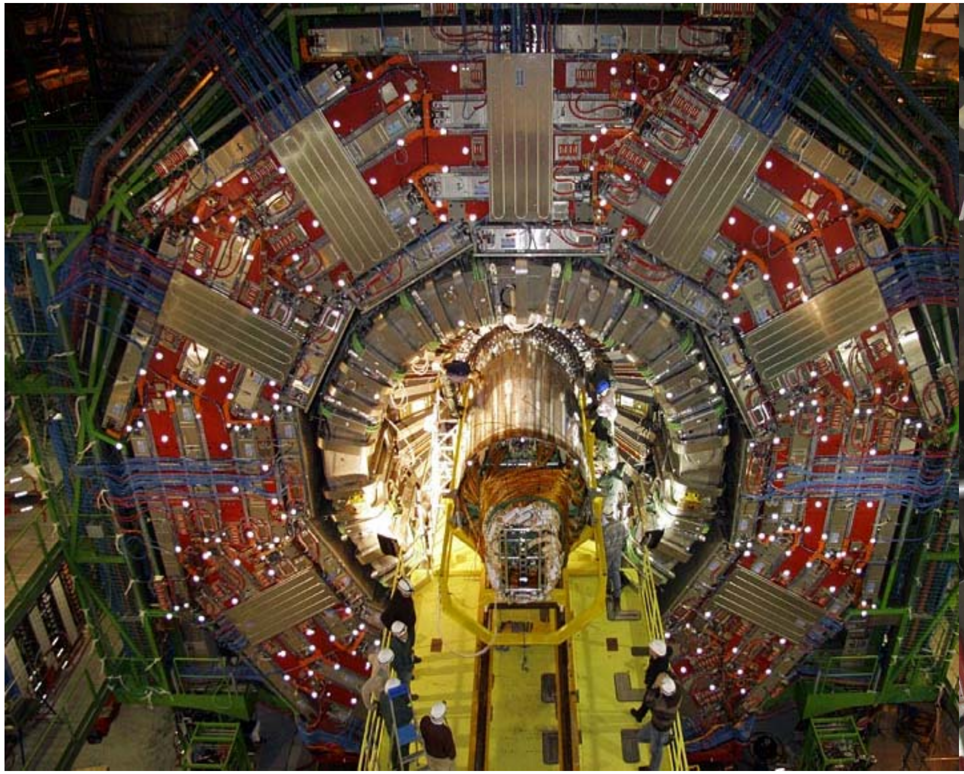


Assembly from Surface to Underground
Endcap Disks – Barrel Wheels

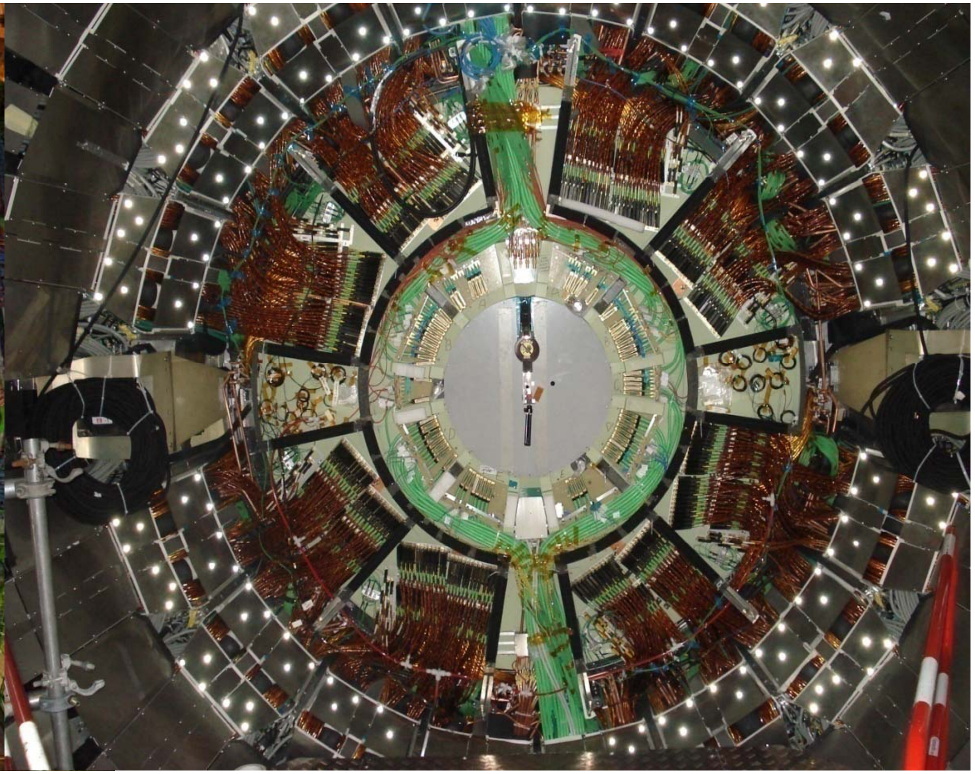




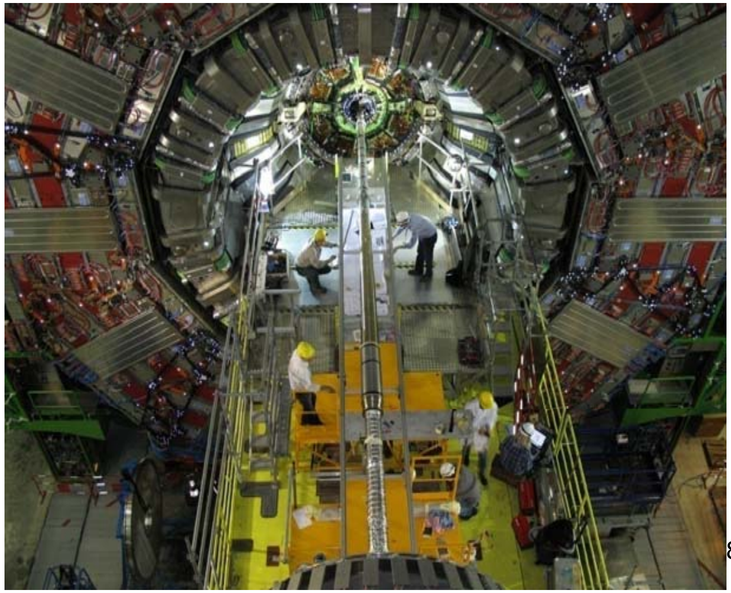
50000 hours of work in 8 months



Dec. 2007 – Tracker installed



Apr. 2008 Connection completed

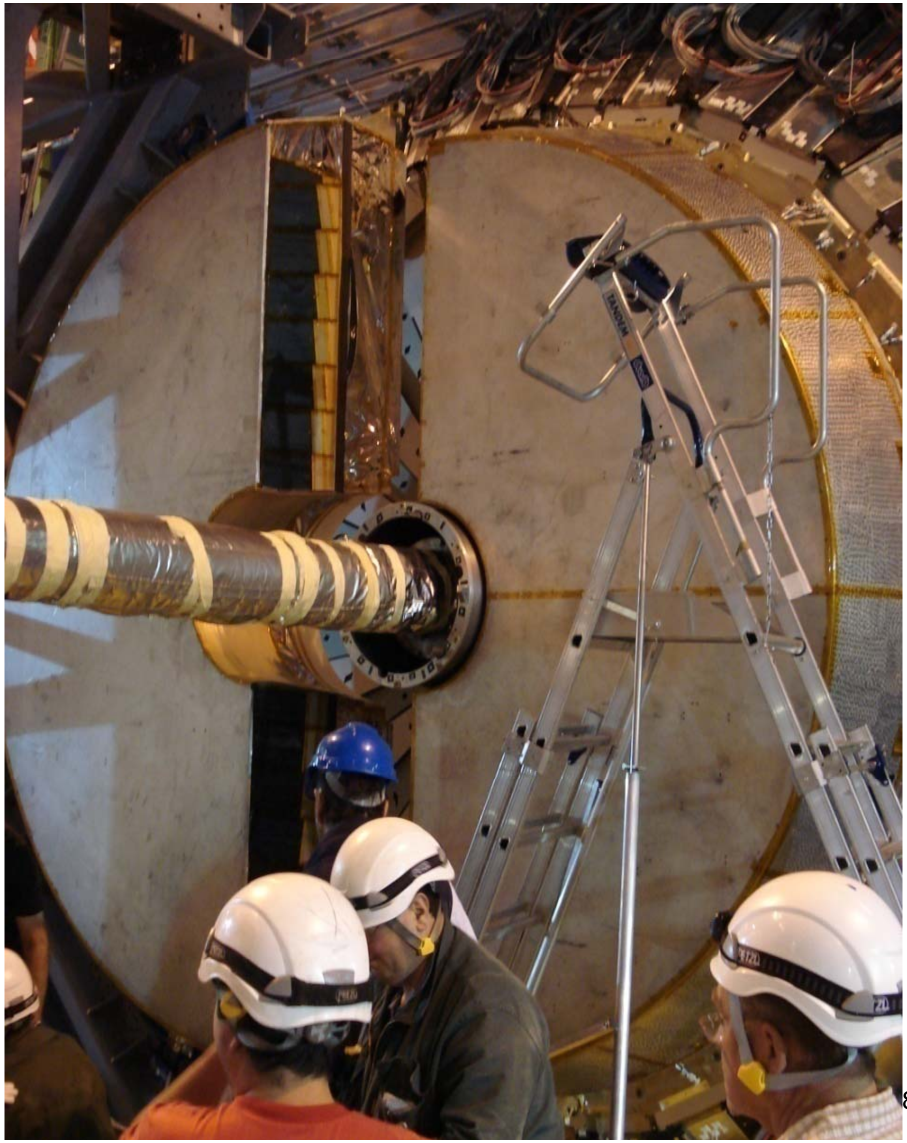


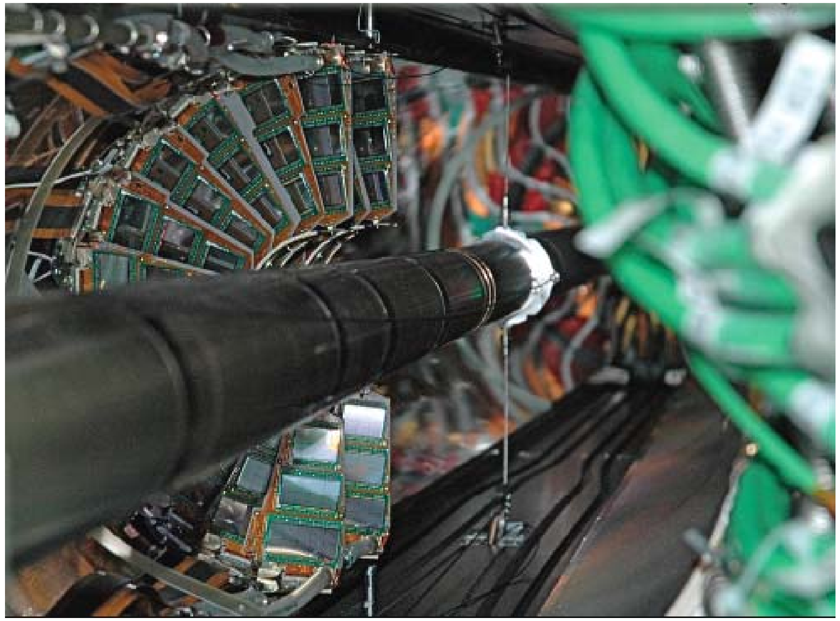
Beam Pipe Installation 18.4. – 10.6.

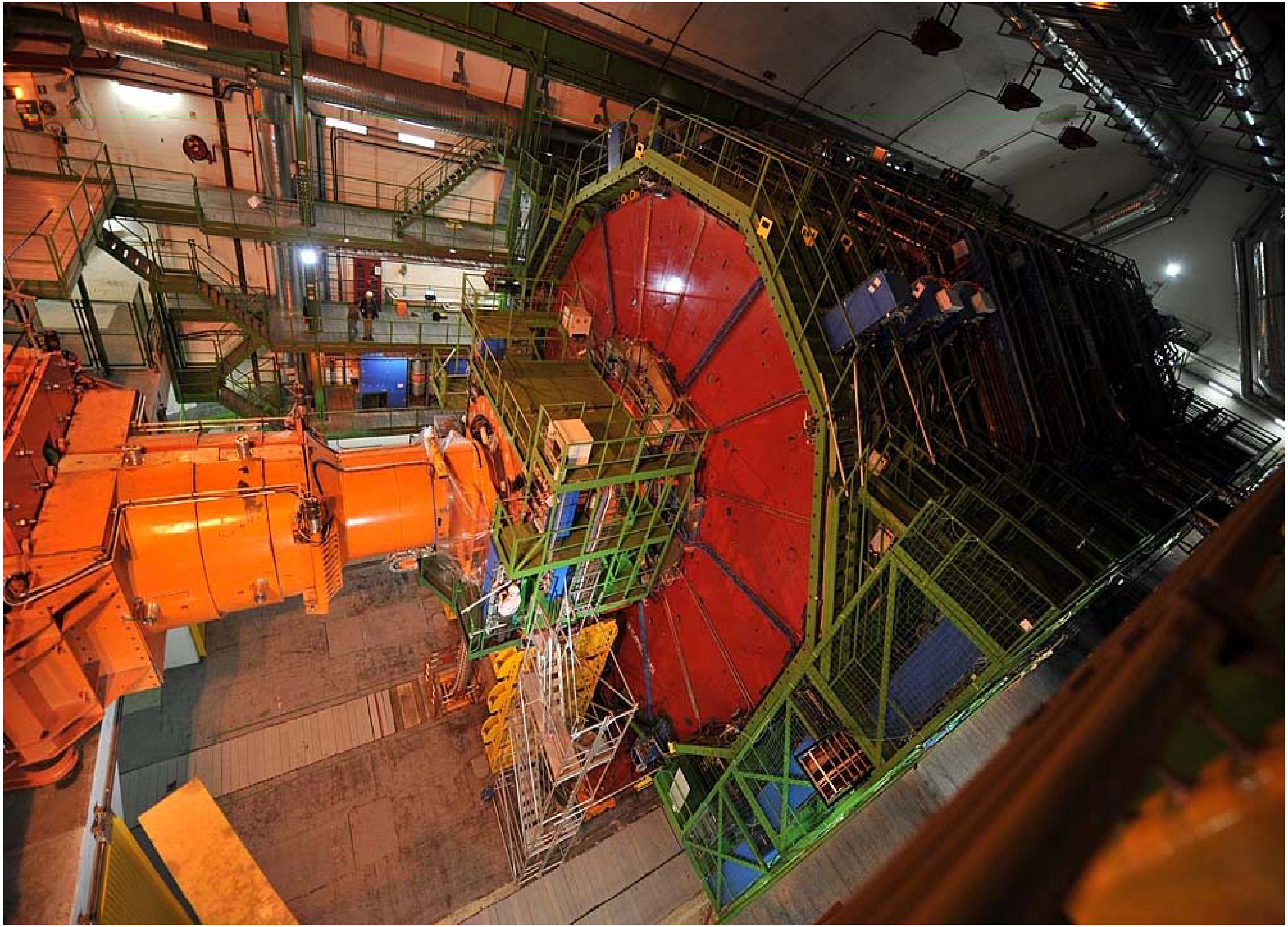
Overall 44m in 9 pieces

4m long Be central section braised to conical stainless steel cones connecting to endcap cones

Endcap ECAL & Barrel-Forward Pixels

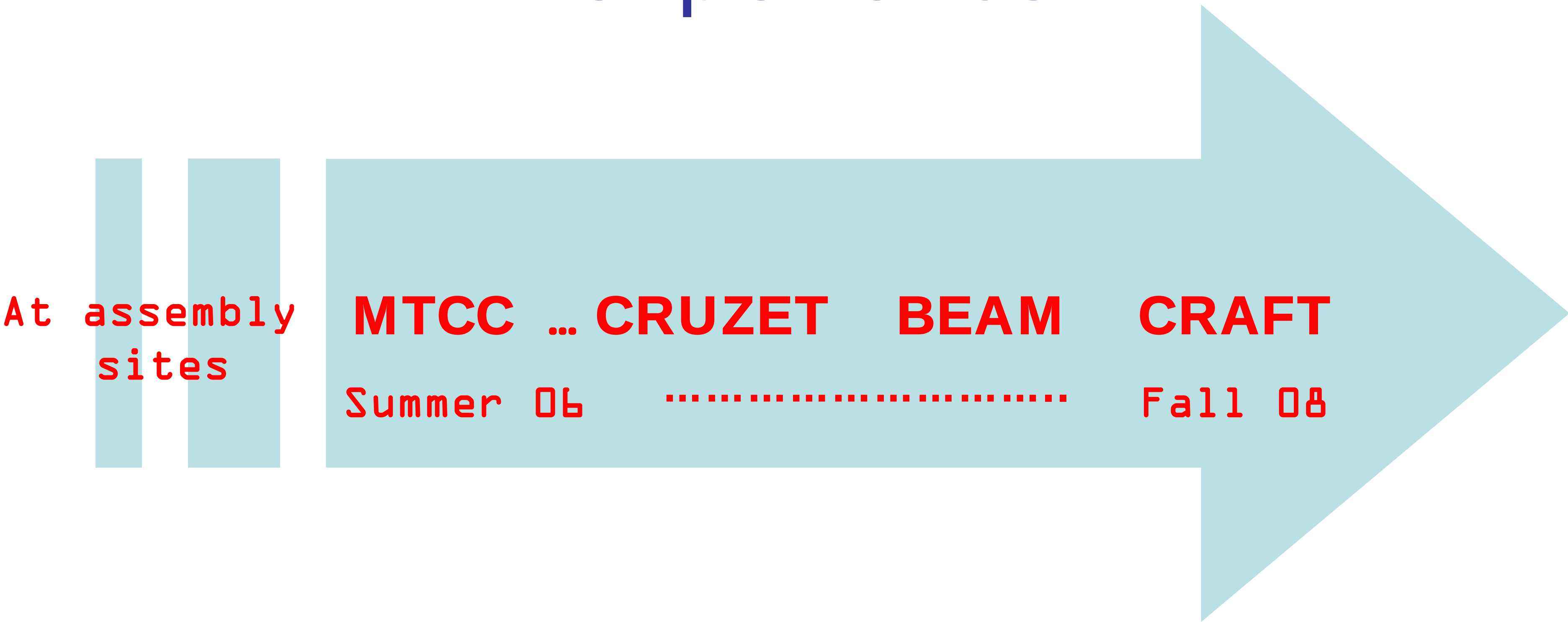






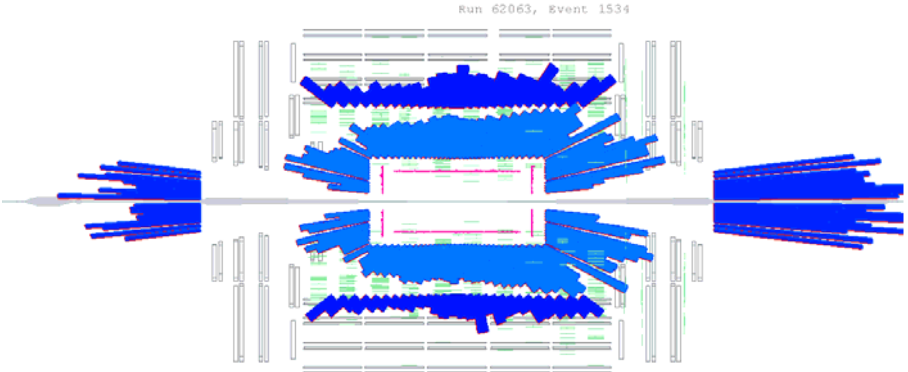
Sept 3, 2008 20:30 CMS was closed

Commissioning, detector performance and operation experience



First LHC Events at CMS: Collimators Closed

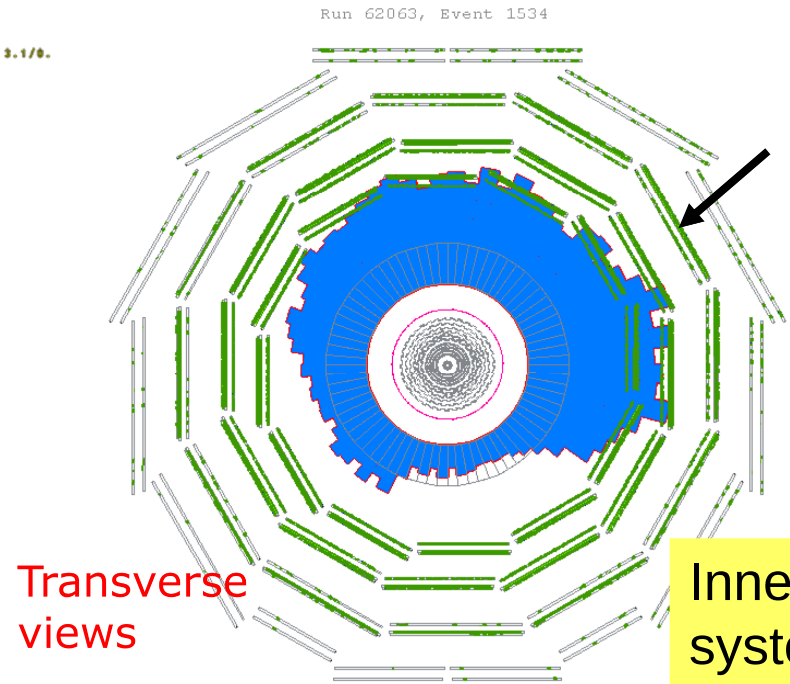
HCAL energy



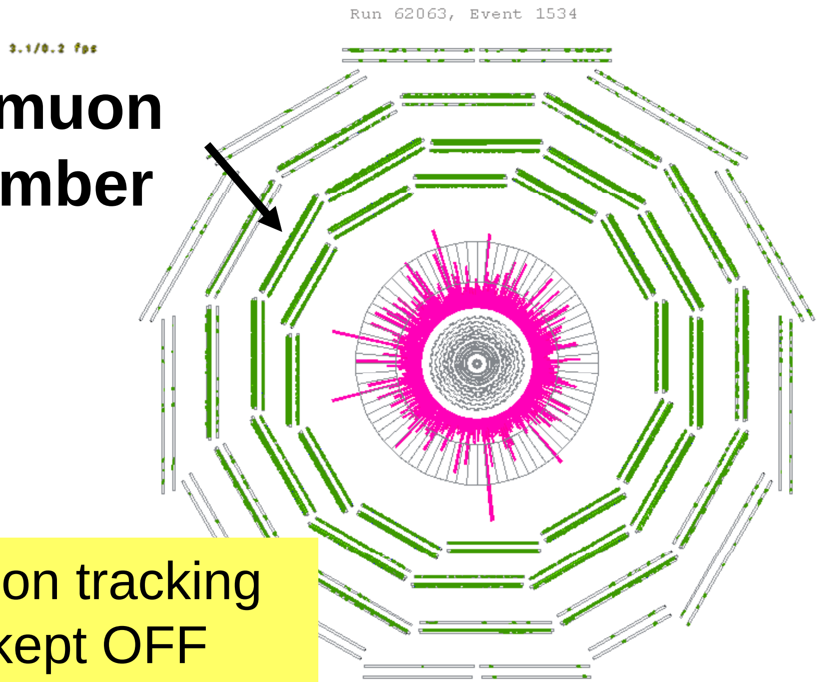
ECAL energy

particle debris

Longitudinal views



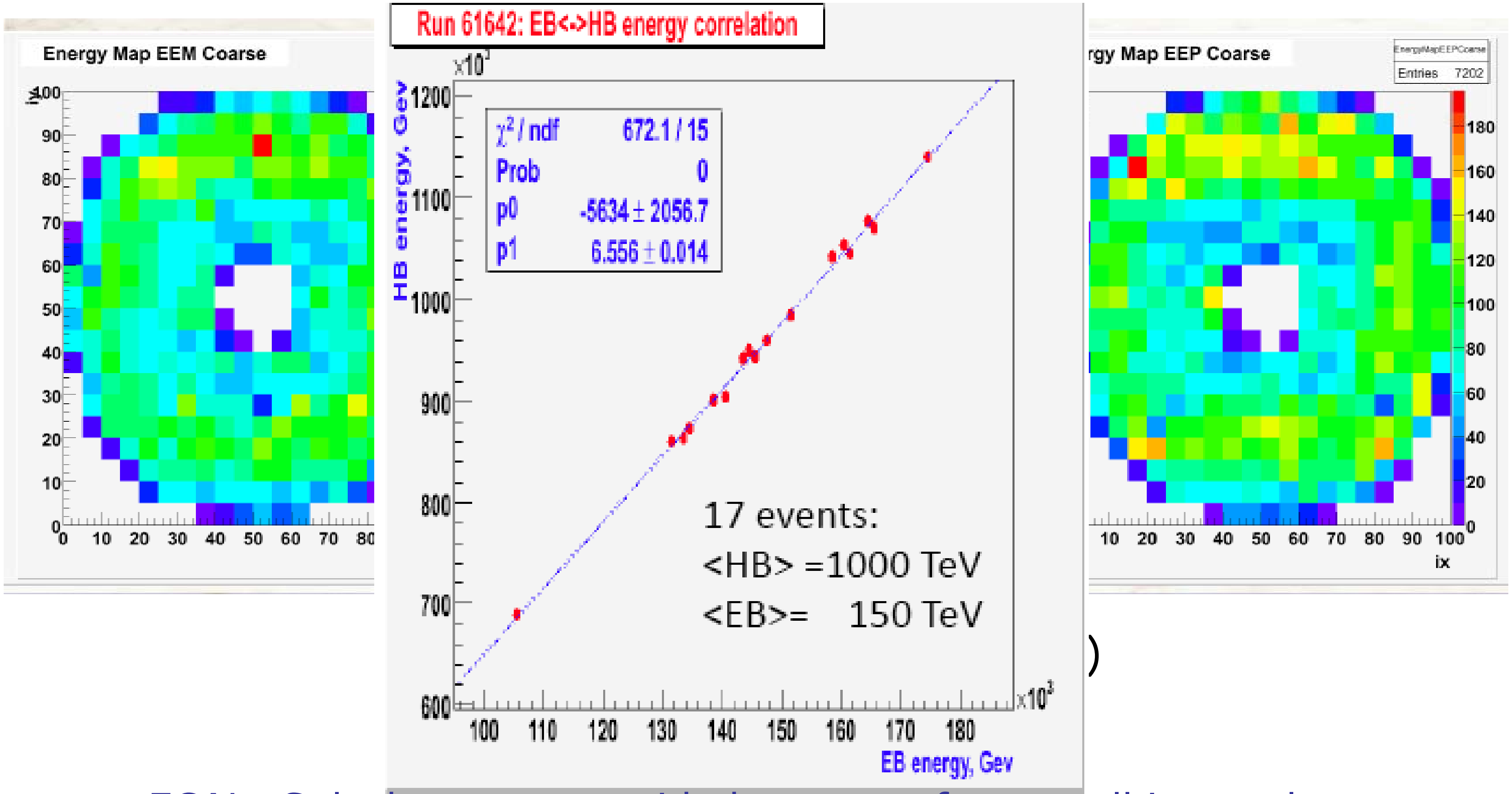
DT muon chamber hits



Transverse views

Inner silicon tracking systems kept OFF

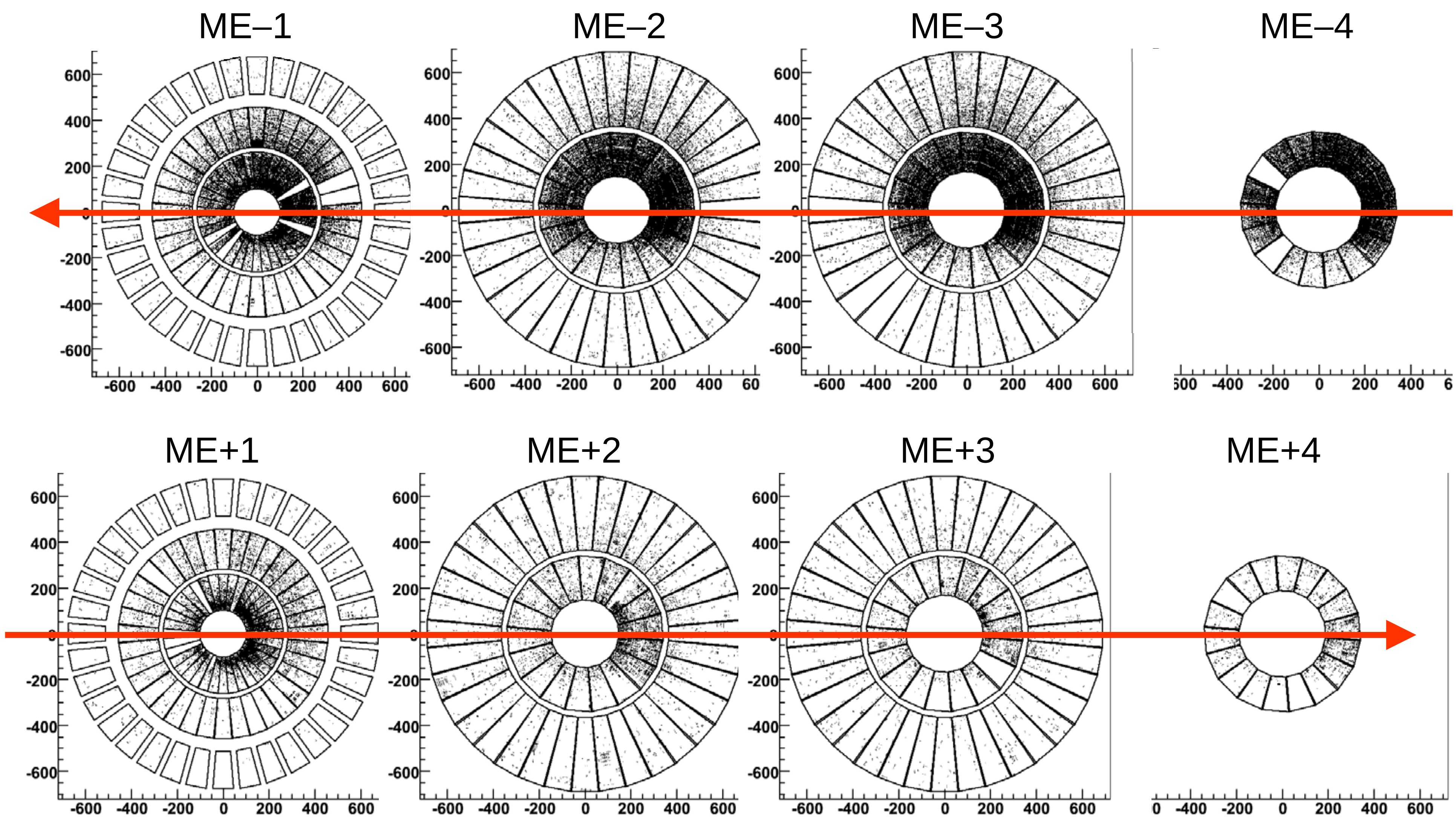
Calorimeter Timing from beam splash events



ECAL: Splash events provided a source for overall internal synchronization.

Crystals were time aligned to within 1ns

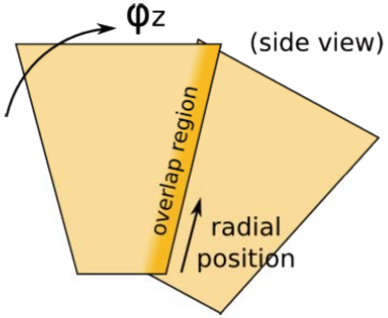
CSC Chamber Alignment - Beam Halo



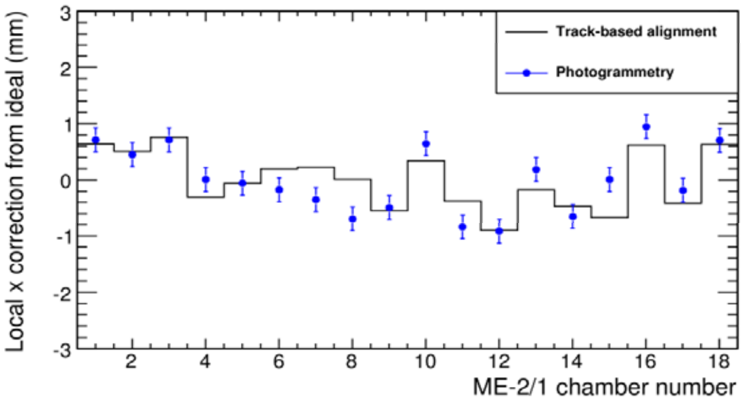
CSC Chamber Alignment: Beam Halo

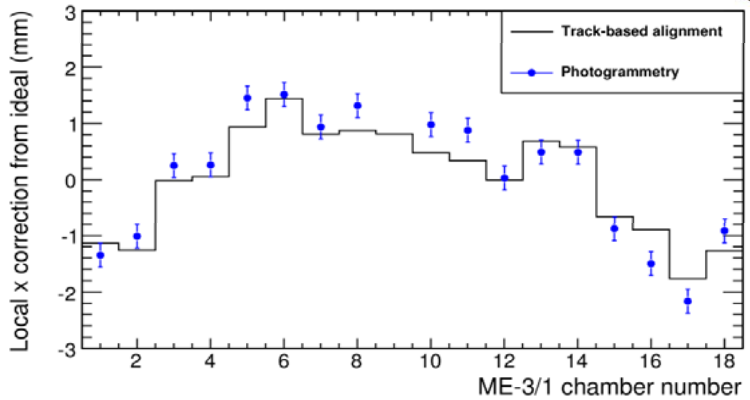
- Used halo muons from 9min of captured LHC beam for endcap muon alignment (CSC)

  Good agreement with photogrammetry

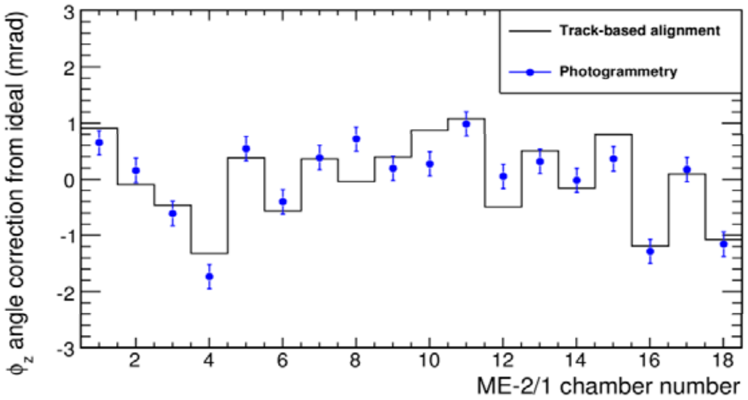


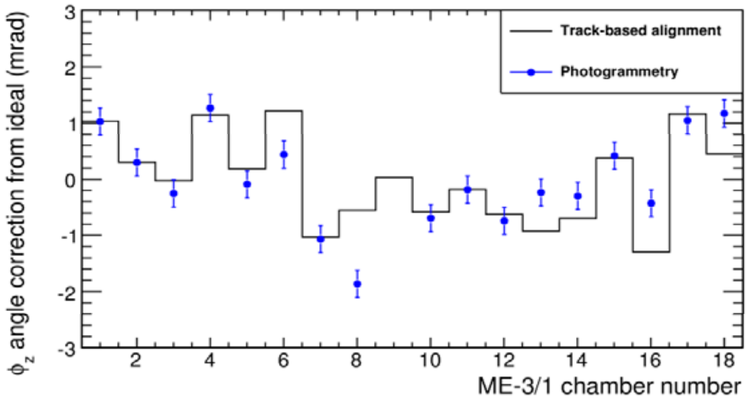
~phi displacement





phi rotation





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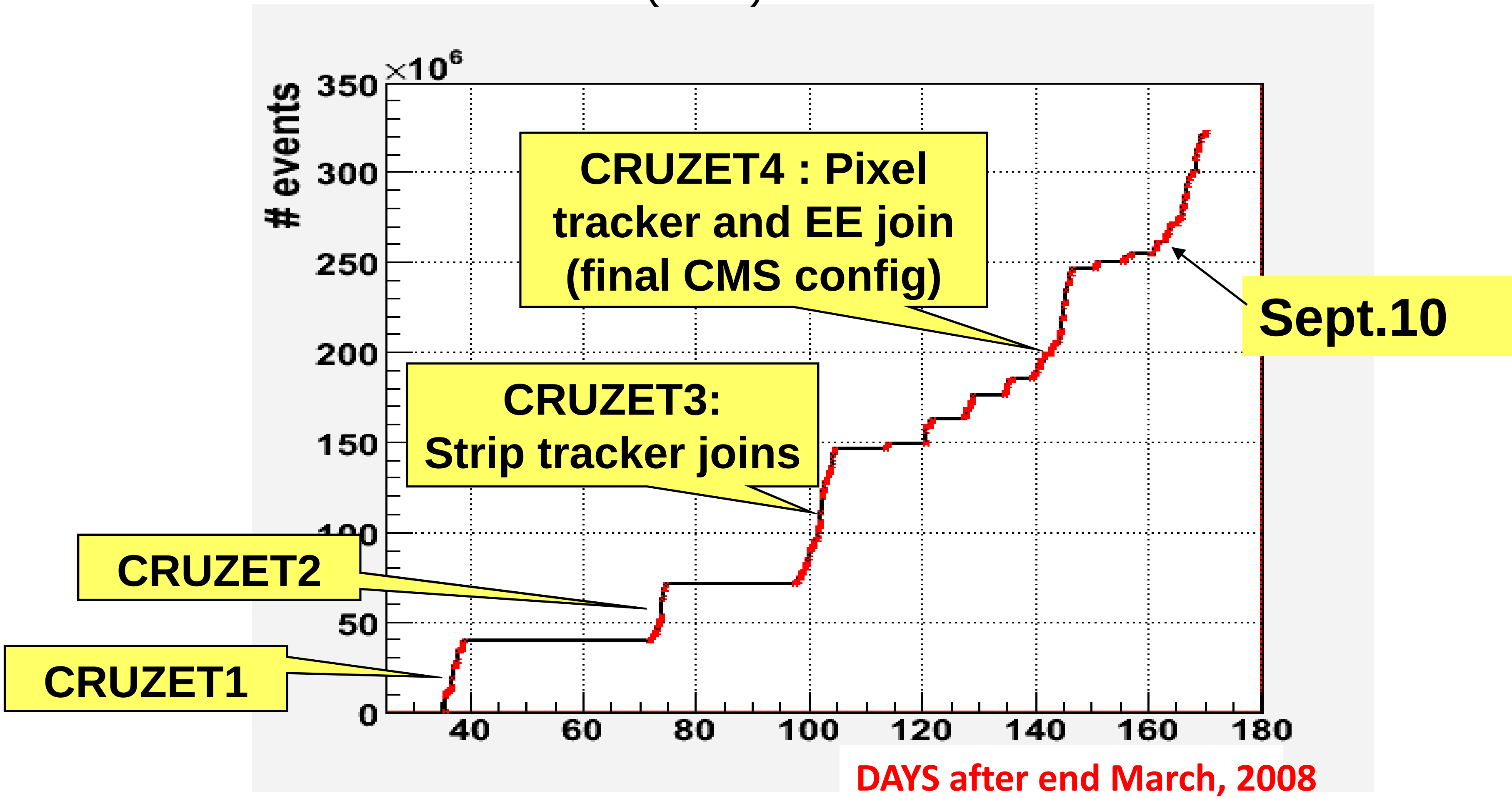
2008 **C**osmic **Ru**ns at **Ze**ro **T**esla (CRUZET)

Events collected by CMS in global runs during 2008 prior to and a little after first LHC beams (B=0)

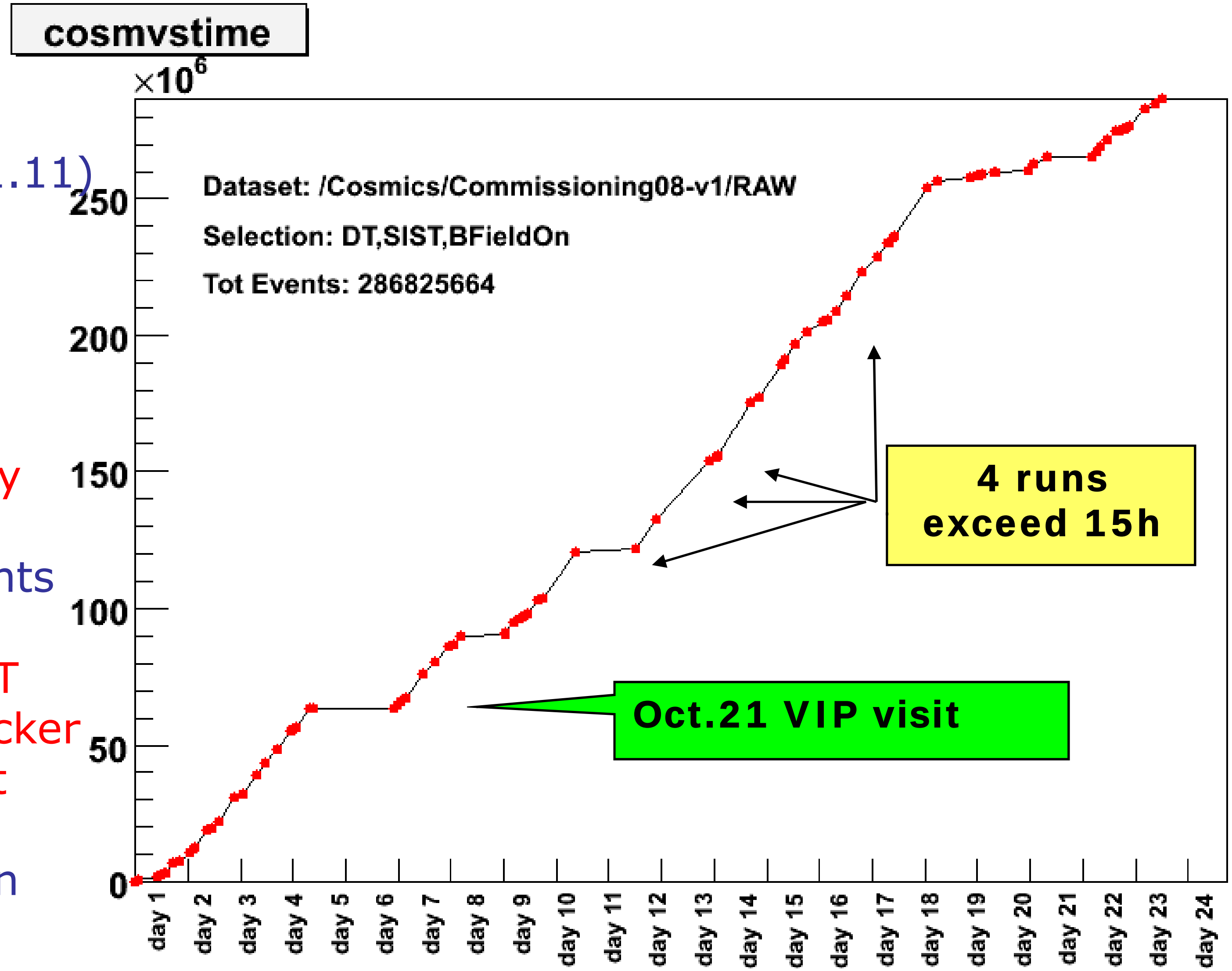


Cosmic Run at Four Tesla (CRAFT)

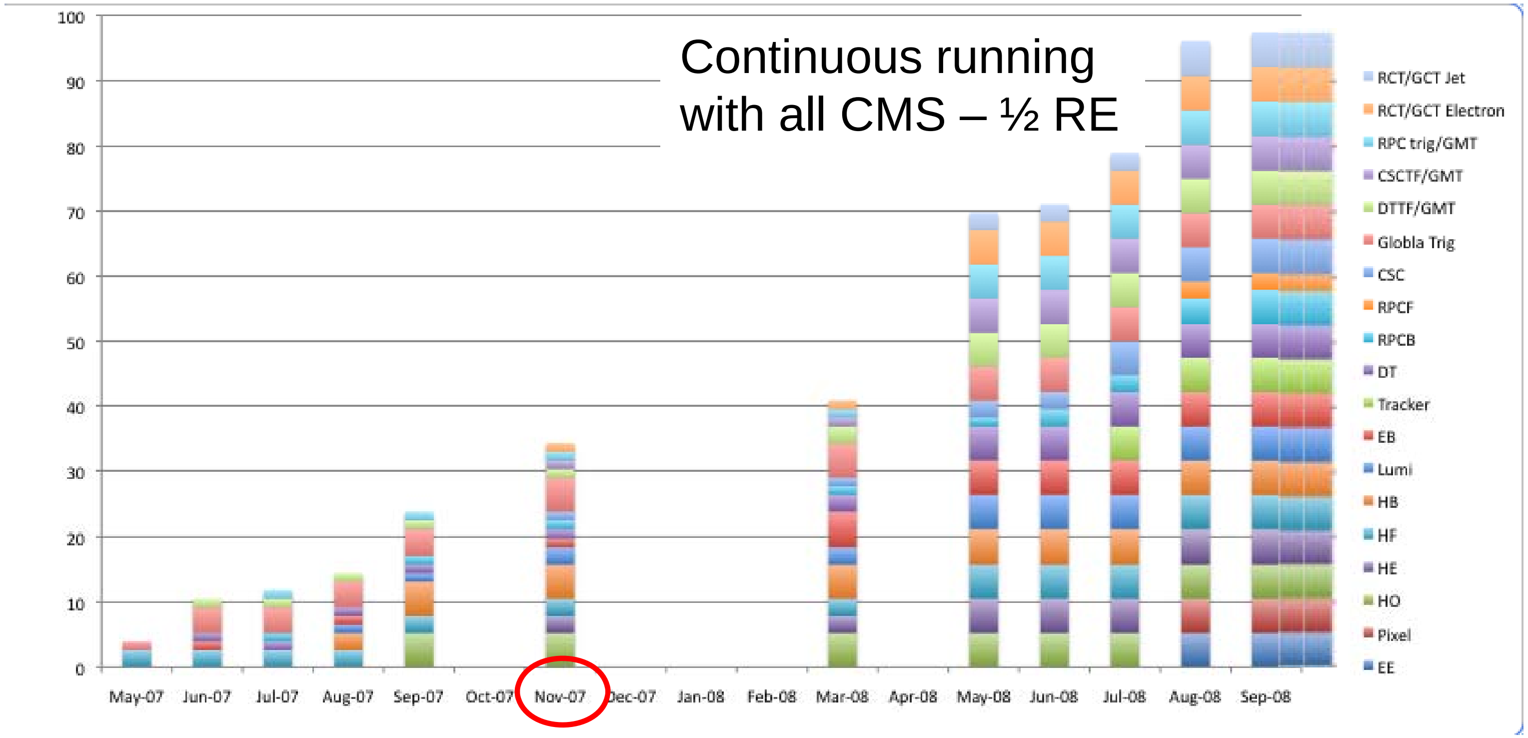
Ran 4 weeks continuously (from 13.10 to 11.11)
- 19 days with B=3.8T

Operational experience
- 60% efficiency

370M cosmic events collected in total
290M with B=3.8T and with strip tracker and DT in readout
- 194M with all components in



CMS Global Runs in 2007/8 Before LHC



- Global Run Nov-Dec 2007:
  - 10M events in 8 days
  - 3 TB data volume (raw, reco)
- CRAFT Oct-Nov 2008:
  - 10M events in 10 hours, 2TB/hour
  - 380 TB data volume (raw, reco, debug) and growing with datasets

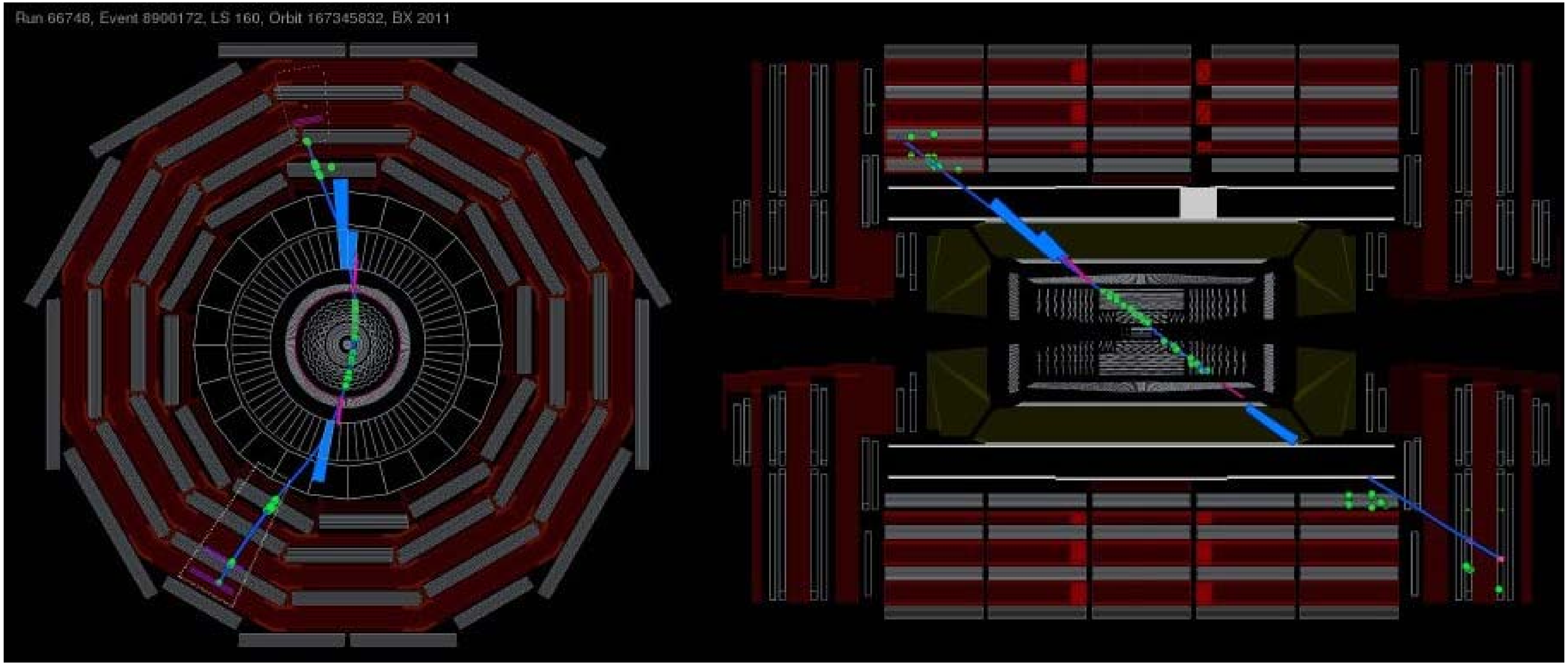
CRAFT Data Handling

- Repacking (production of RAW) → ***Latency: few minutes***
- Reconstruction (production of RECO)
- Harvesting (production of DQM root files)
- Alignment and Calibration
- Skimming (at T1s)

(Reconstruction, Harvesting, Alignment and Calibration) → ***Latency: few hours***

- Data are being analyzed at the CERN CAF and at Tier-2 centers

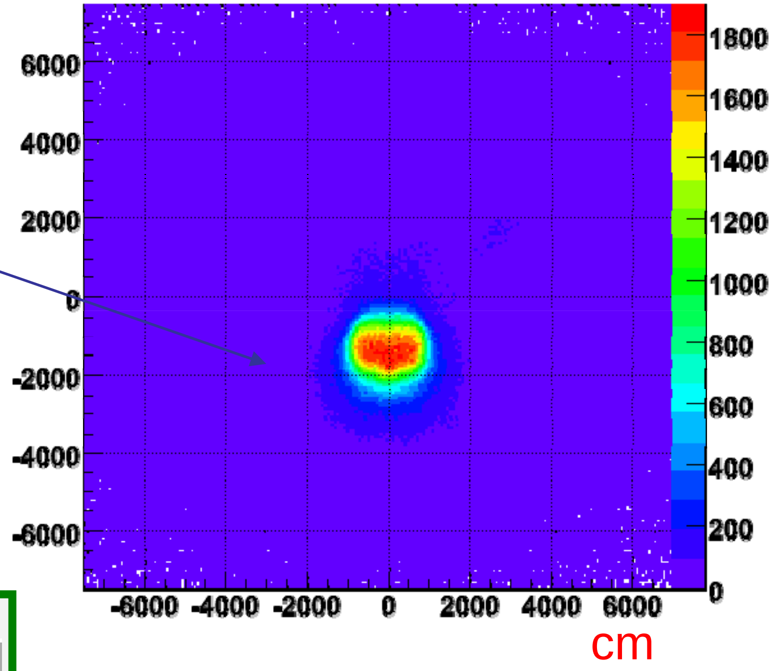
Cosmic muon going through barrel and both endcaps



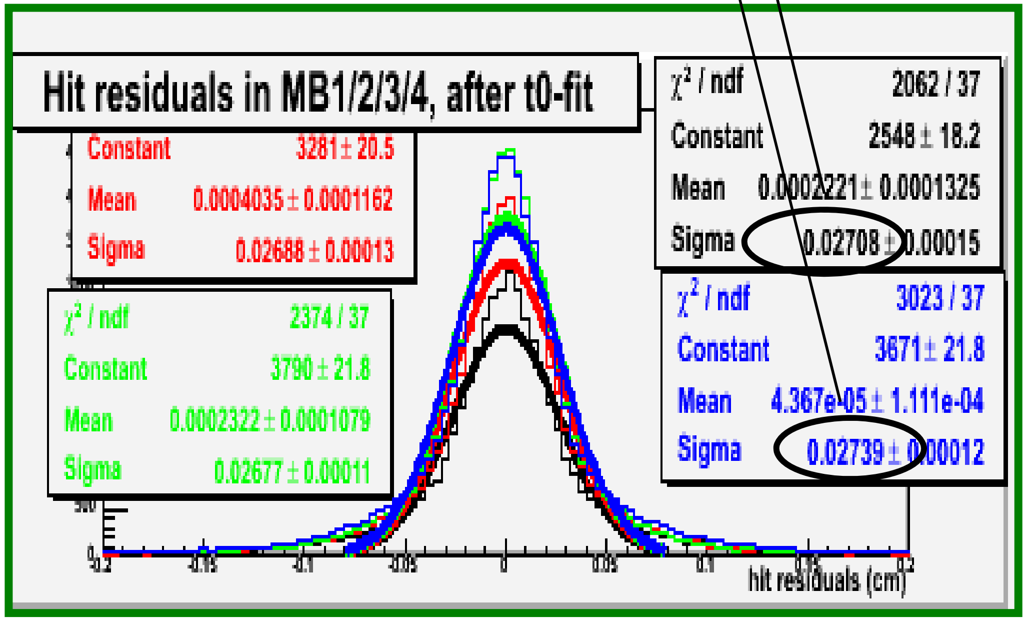
Muon DTs – CRUZET data

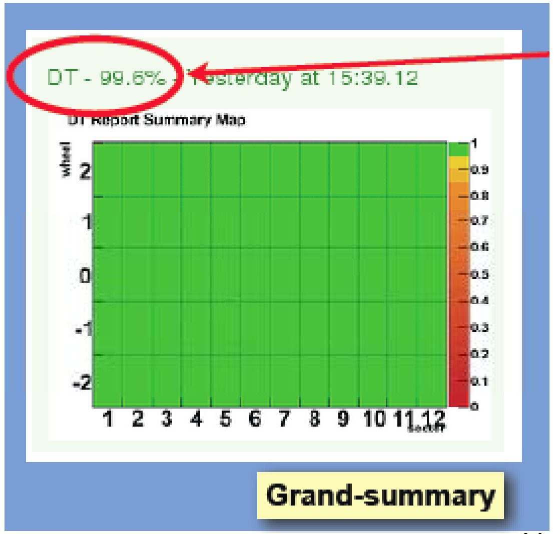
Cosmics tracks extrapolated to the surface (CMS coords)

Can clearly see the shaft

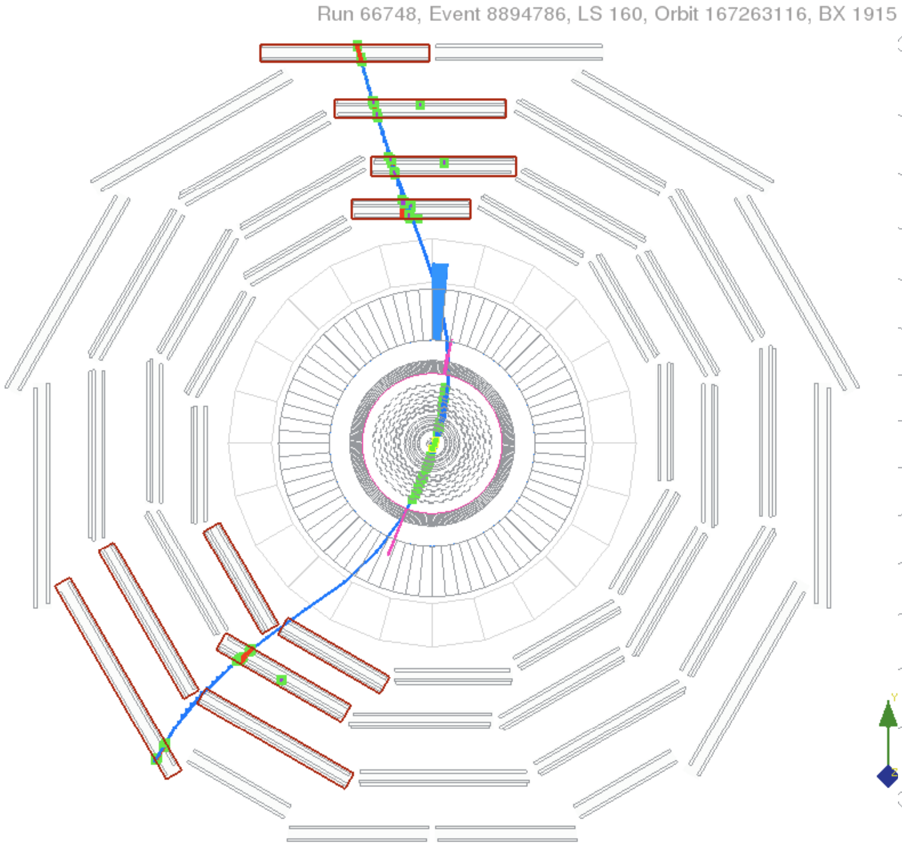


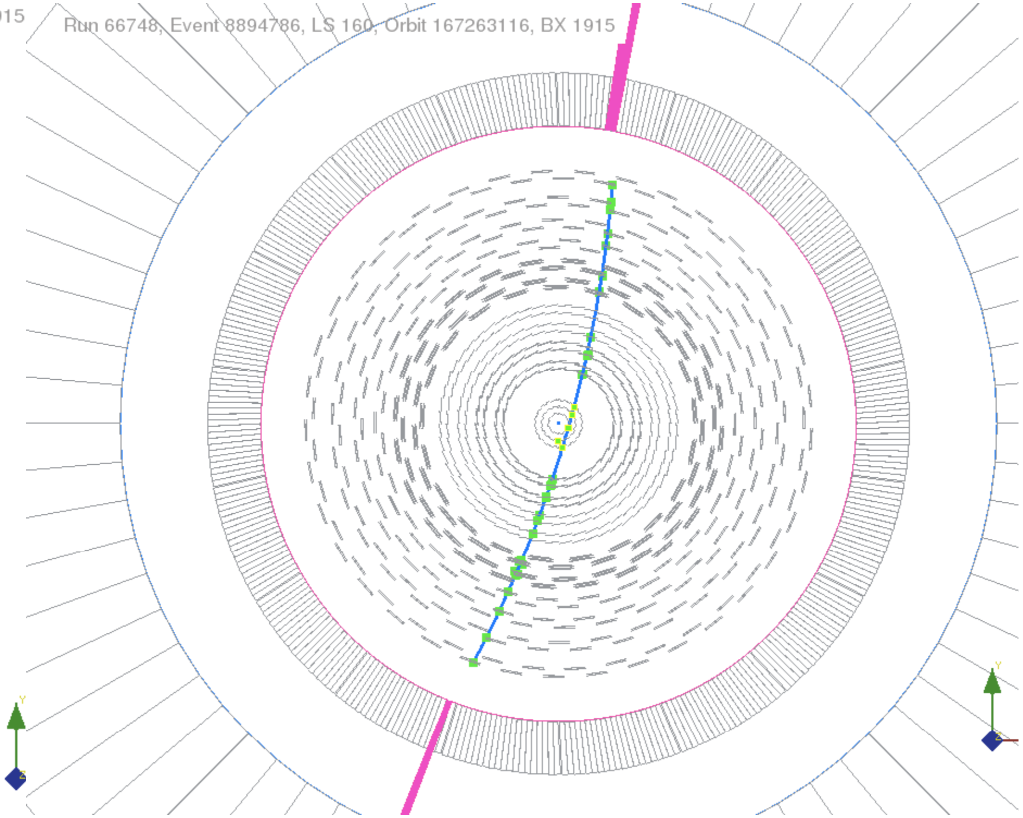
MB1: 271 µm
MB2: 269 µm
MB3: 268 µm
MB4: 274 µm



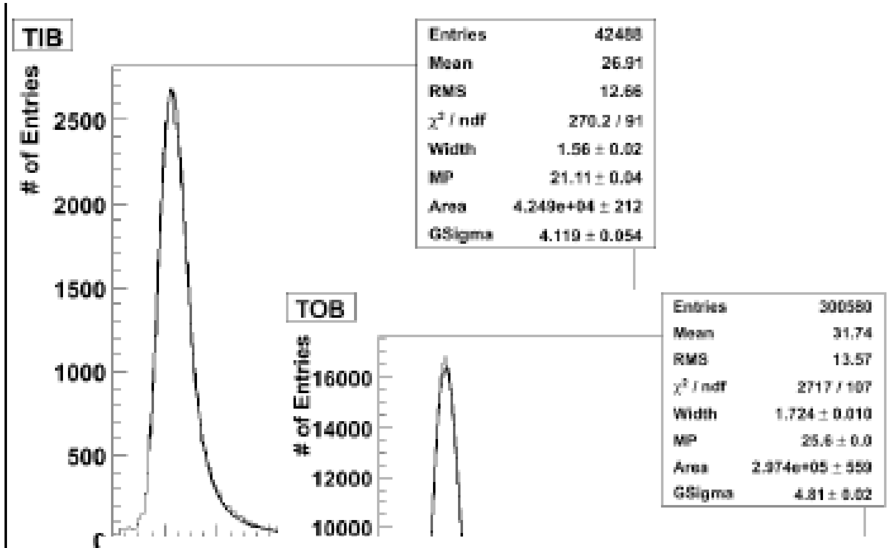


Cosmic muon going through pixels



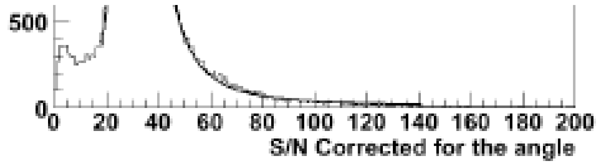


Tracker Commissioning

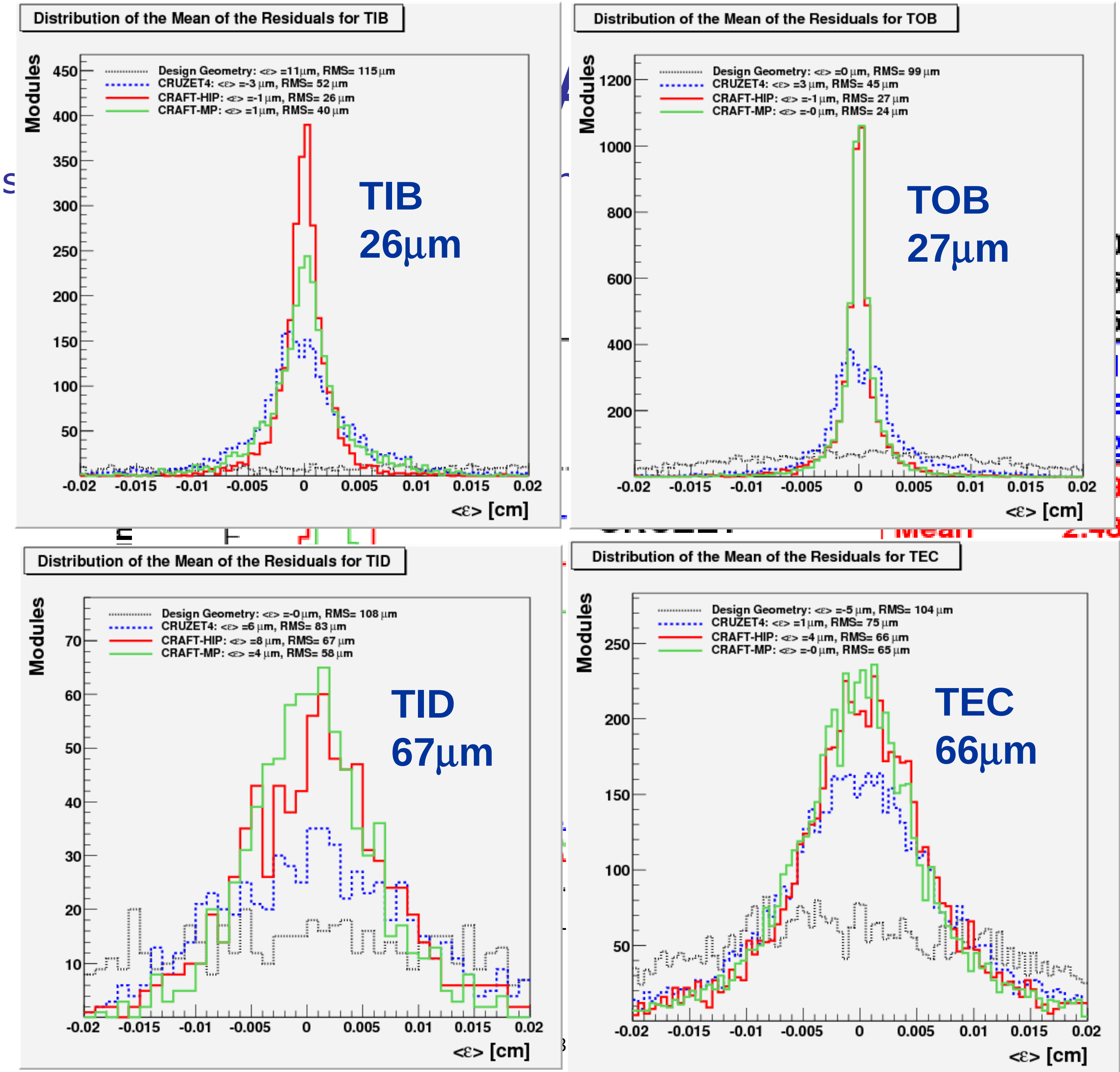


- Nice Landau shape obtained in all subdetectors.
- S/N measured:
  - ❑ 21.1 in TIB
  - ❑ 25.6 in TOB
  - ❑ 28.3 in TEC
    (mean over all geometries)

Partition	Modules by design	Modules disabled	Modules in DAQ	Number of connections	Missing connections	% active
TOB	5208	4	5196	12043	19	99.5 %
TIB/TID	3540	0	3481	9012	14	98.2 %
TEC +	3200	6	3183	7506	4	99.4 %
TEC -	3200	2	3192	7535	9	99.6 %

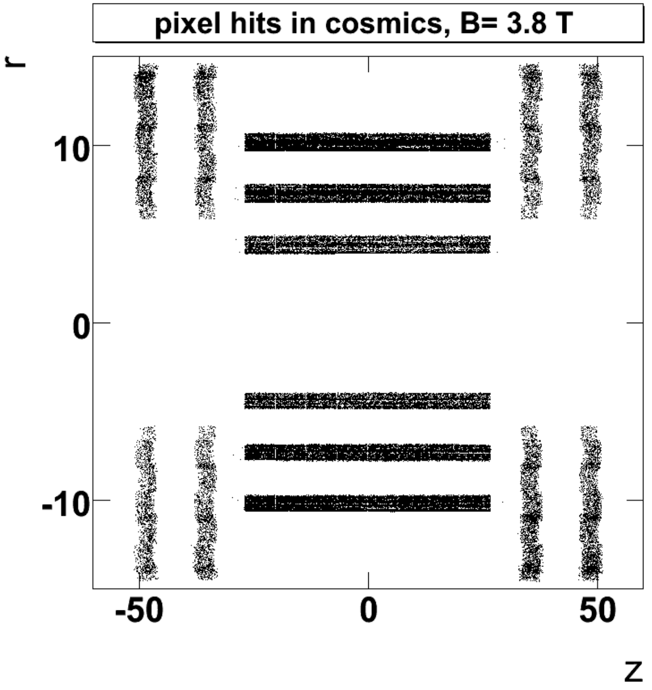


- Us



Distribution of the Mean of the Residuals for TIB
Design Geometry: <ε> =11μm, RMS= 115μm
CRUZET4: <ε> =-3 μm, RMS= 52 μm
CRAFT-HIP: <ε> =-1 μm, RMS= 26 μm
CRAFT-MP: <ε> =1μm, RMS= 40 μm
TIB
26μm
Modules
<ε> [cm]
Distribution of the Mean of the Residuals for TOB
Design Geometry: <ε> =0 μm, RMS= 99 μm
CRUZET4: <ε> =3 μm, RMS= 45 μm
CRAFT-HIP: <ε> =-1 μm, RMS= 27 μm
CRAFT-MP: <ε> =-0 μm, RMS= 24 μm
TOB
27μm
Modules
<ε> [cm]
Distribution of the Mean of the Residuals for TID
Design Geometry: <ε> =-0μm, RMS= 108 μm
CRUZET4: <ε> =6 μm, RMS= 83 μm
CRAFT-HIP: <ε> =8 μm, RMS= 67 μm
CRAFT-MP: <ε> =4 μm, RMS= 58 μm
TID
67μm
Modules
<ε> [cm]
Distribution of the Mean of the Residuals for TEC
Design Geometry: <ε> =-5 μm, RMS= 104 μm
CRUZET4: <ε> =1 μm, RMS= 75 μm
CRAFT-HIP: <ε> =4 μm, RMS= 66 μm
CRAFT-MP: <ε> =-0 μm, RMS= 65 μm
TEC
66μm
Modules
<ε> [cm]

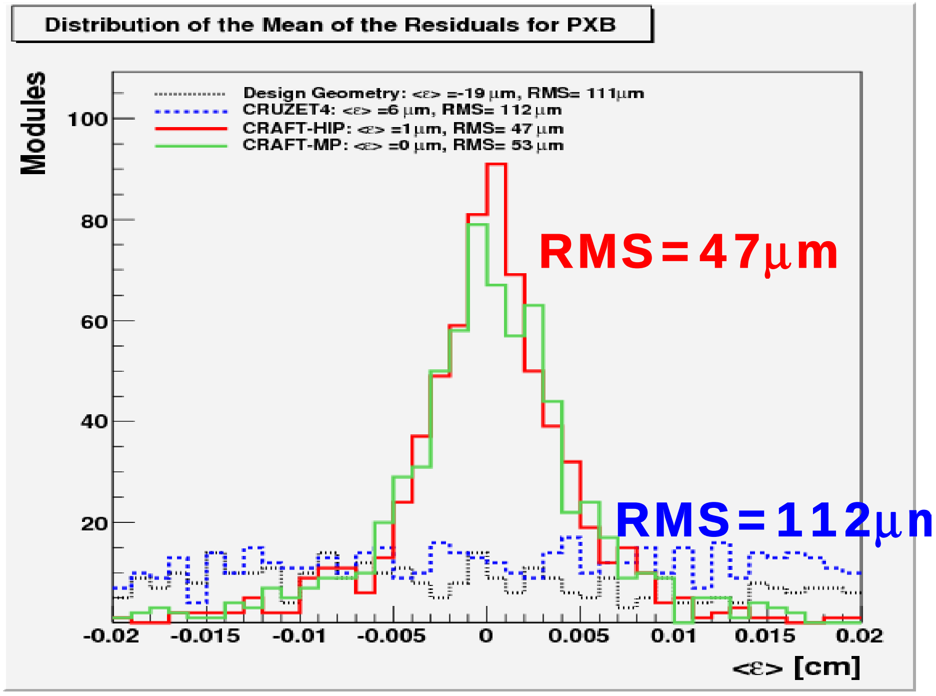
Pixels Commissioning



Barrel Pixel: *99.13%* of the detector operational

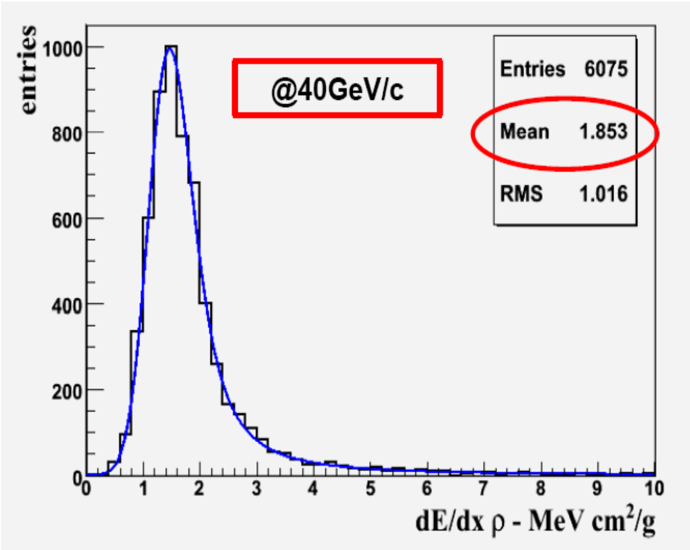
Forward Pixel: *93.98%* of the detector operational

(6.02% LV connection lost after installation)



- Mean of the residuals for the transverse coordinate from two methods (all modules)
- 55K tracks yielding 200-350 hits per module

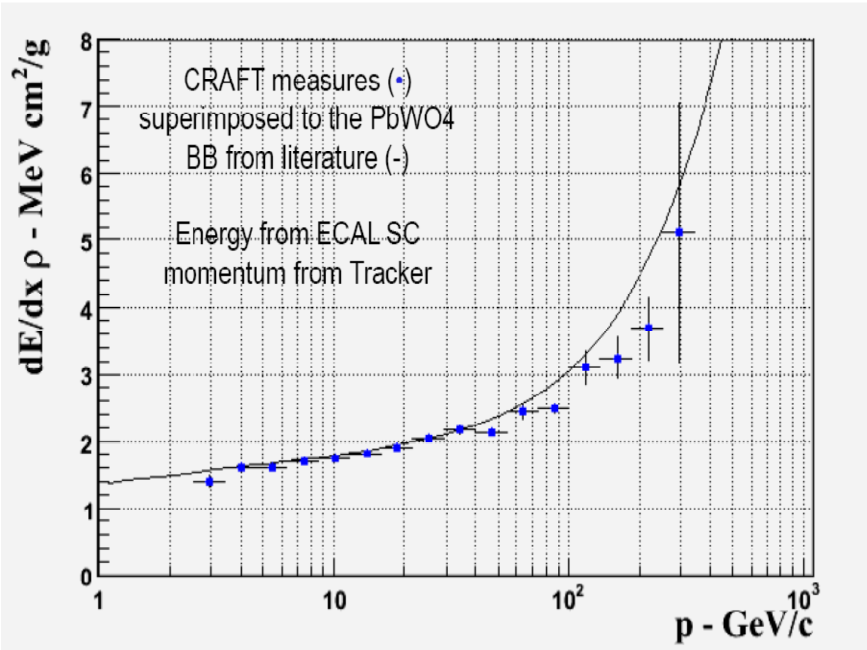
Muon signal in ECAL

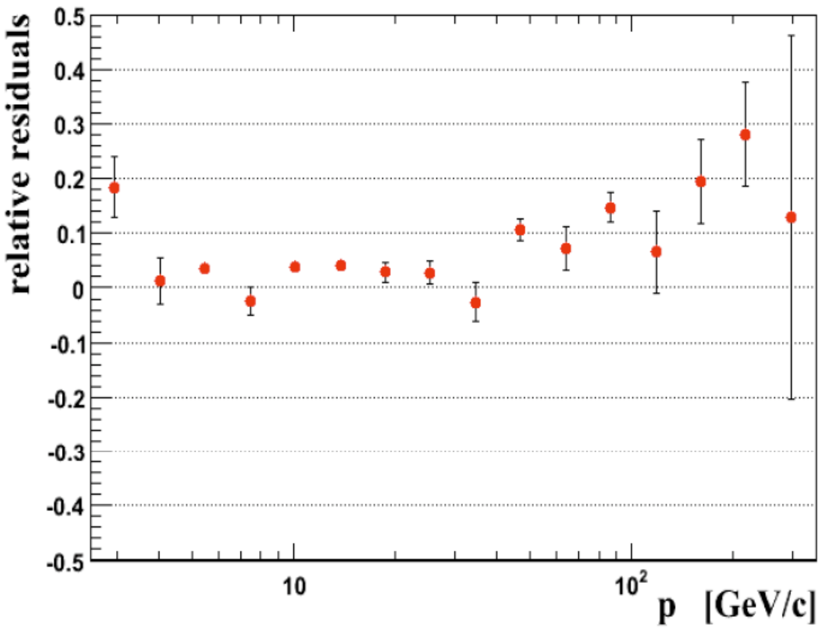


Measured dE/dX in barrel with pointing muons as a function of muon momentum (measured from tracker tracks)

Good agreement with $PbWO_4$ expected stopping power

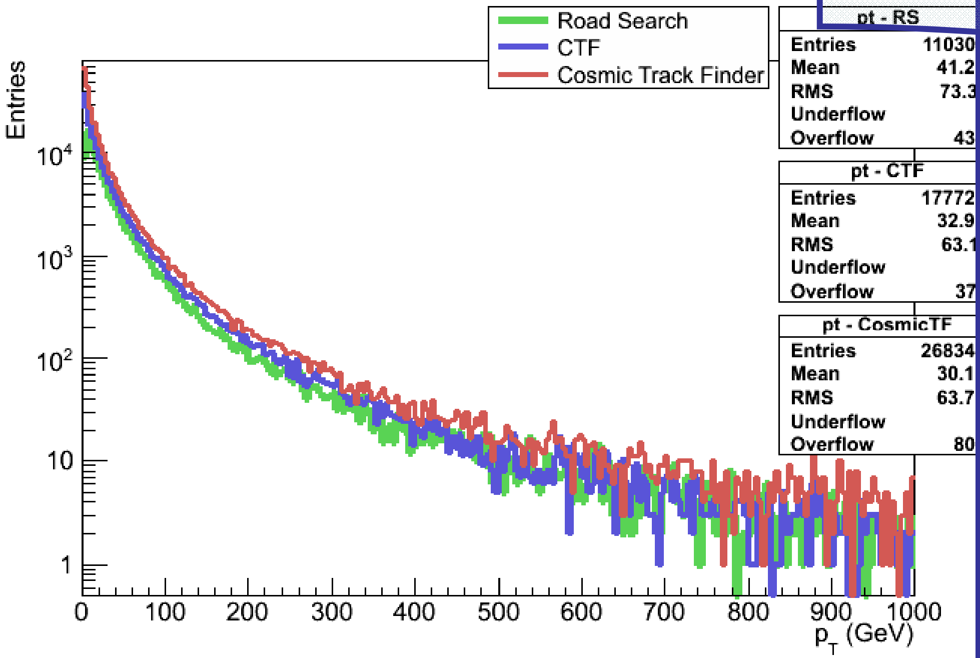
Ongoing studies to understand region below 3 and above 100 GeV/c





Cosmic Data Analysis

Nearly 7M tracks in 280M events with Tracker information
- 500K with p_T>100 GeV/c



Charge asymmetry

Angular distribution:
Radiography of P5, sky map

Muon timing measurements:
CMS as TOF → Search HSCP

Astrophysics studies:
point sources, moon shadow

Cosmic TeV muons

Multi-muon events

Absolute muon flux

...

Detector commissioning
&
Training on data analysis

Summary

- **CMS became a running experiment !**
- **The experiment operated well over the past months with the solenoid working at the operating field.**
- **All indications from first beams and Cosmic Runs are that sub-detectors, DAQ, Trigger, offline, computing and analysis systems are performing well.**
- **However, there are still issues to be solved or improved**
  - **Understanding of the fringe field mainly in the forward region**
  - **Finalization and installation of the *Pre-shower detector***
  - **Some left out repairs and cut edges due to the rush of the assembly in past summer (services and cooling repairs)**
- **In spring/summer 2009, we will restart with a complete and even better CMS detector expecting exciting LHC physics.**