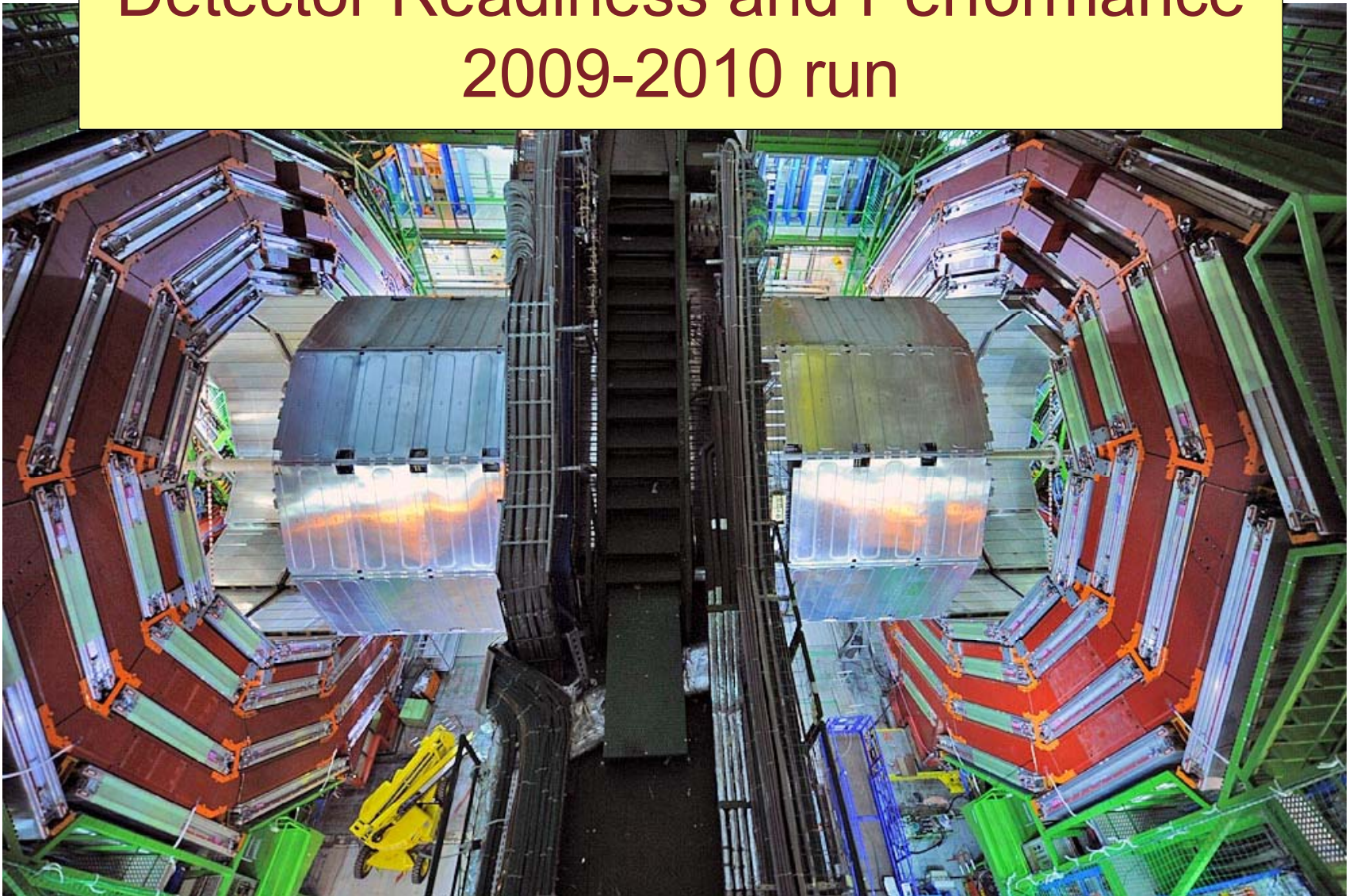




CMS

Detector Readiness and Performance 2009-2010 run



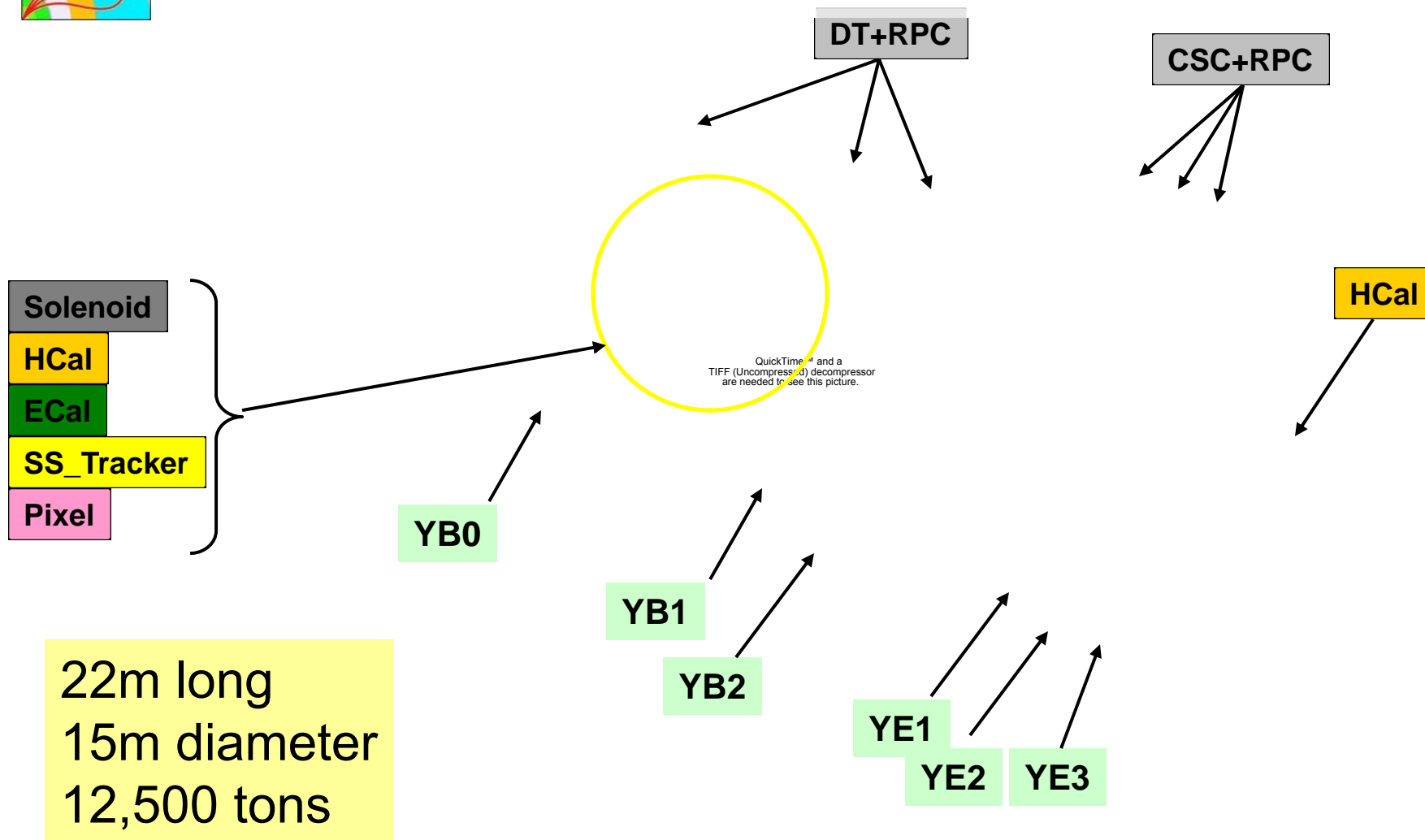
Berkeley - May 6, 2009

Nicola Bacchetta



The CMS Detector

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.





The CMS Detector

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

- Key design features:

- Compact !
- Strong Solenoidal Magnet @ 4T
- Full coverage on muons up to high pseudorapidities
- Redundant muon trigger
- Inside solenoid calorimetry and tracking

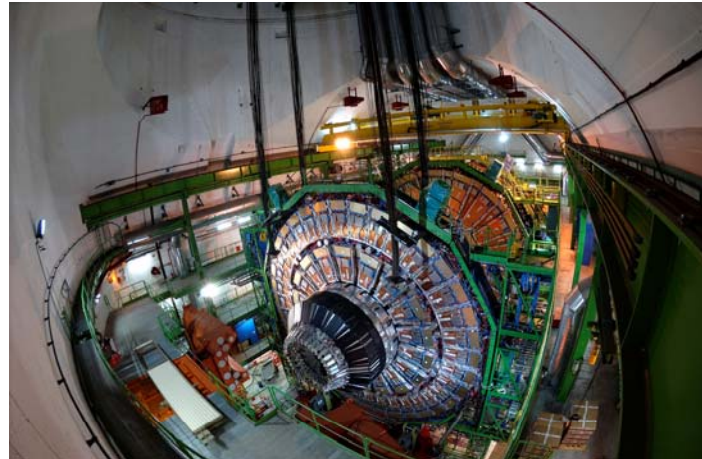
- Good **muon** ID and P resolution over a wide range of momenta ($|\Delta\eta| < 2.5$), good dimuon mass resolution ($\Delta < 1\%$ at 100 GeV/c²), and the ability to determine unambiguously the charge of muons with $p < 1$ TeV/c.
- Good charged particle momentum resolution and reconstruction efficiency in the inner **tracker**. Efficient triggering and offline tagging of $\Delta\tau$'s and b-jets, requiring **pixel** detectors close to the interaction region.
- Good **electromagnetic** energy resolution, good diphoton and dielectron mass resolution ($\Delta < 1\%$ at 100 GeV/c²), wide geometric coverage ($|\Delta\eta| < 2.5$), measurement of the direction of photons and/or correct localization of the primary interaction vertex, $\Delta\pi^0$ rejection and efficient photon and lepton isolation at high luminosities.
- Good missing E_T and dijet mass resolution, requiring **hadron calorimeters** with a large hermetic geometric coverage ($|\Delta\eta| < 5$) and with fine lateral segmentation ($\Delta\eta\Delta\phi < 0.1 \times 0.1$).



The CMS Detector

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Piece	Lowered Date
YE+3	30-Nov-06
YE+2	20-Dec-06
YE+1	9-Jan-07
YB+2	19-Jan-07
YB+1	1-Feb-07
HB+	13-Feb-07
YB0	28-Feb-07
HB-	14-Mar-07
YB-1	11-Oct-07
YB-2	17-Oct-07
YE-3	10-Dec-07
Tracker	14-Dec-07
YE-2	11-Jan-08
YE-1	22-Jan-08



- Built on surface and lowered in the collision hall piece by piece



The CMS Detector

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

CMS ready for beam 3-9-2008



The CMS Magnet

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

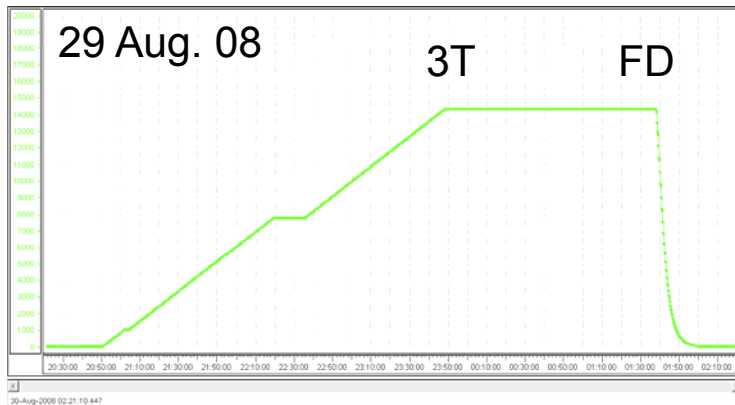
- A solenoid has been opted for because, for a similar bending power, the overall size of a solenoidal system is smaller than for a toroid
- nominal magnetic field of 4 T in a 5.9 m diameter and 12.5 m long warm bore, leading to a stored energy of 2.7 GJ.
- These characteristics make this superconducting solenoid the largest and most powerful one ever built.



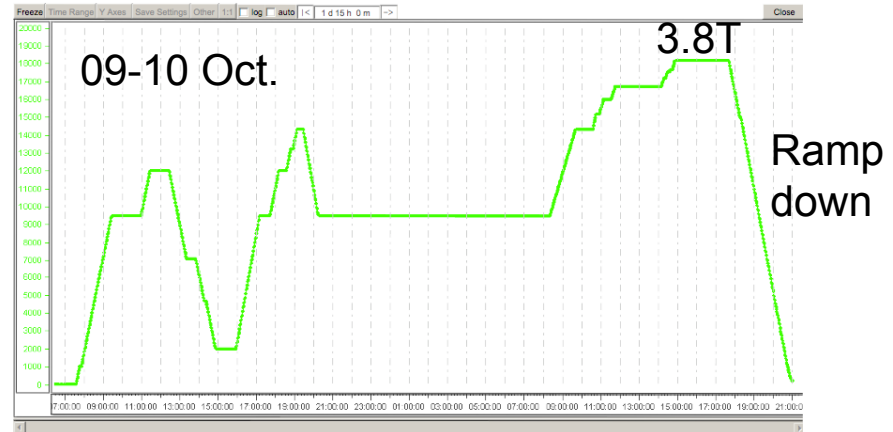
The CMS Magnet

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

- Commissioned and operated:
 - on surface during the 2006 MTCC data taking period.
 - In the collision hall prior to LHC start on 10-9-08, and CRAFT 10/11 2008.



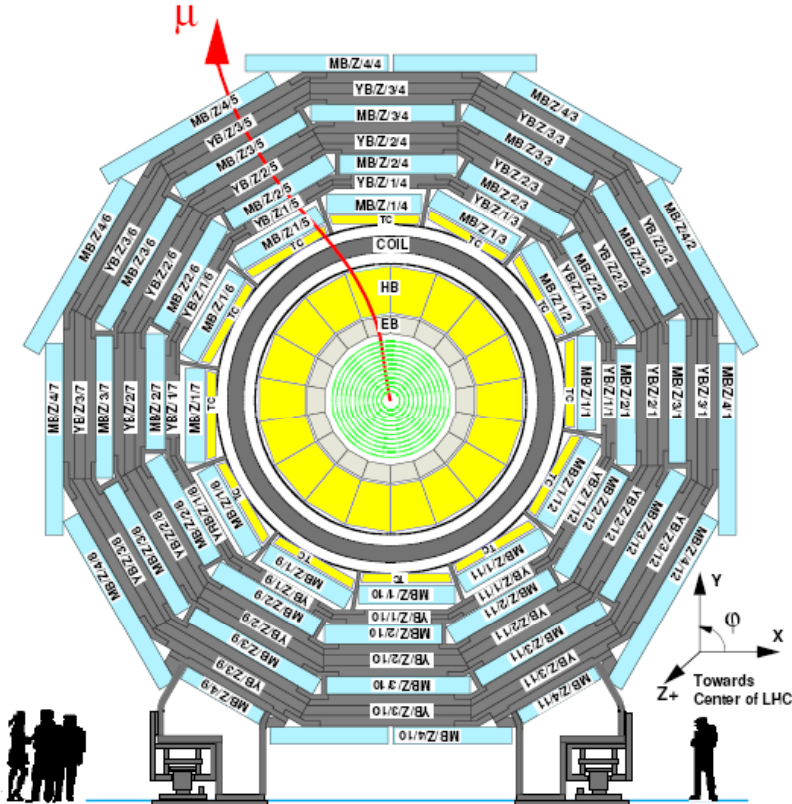
Successful magnet tests up to 3T with FD and cryo recovery



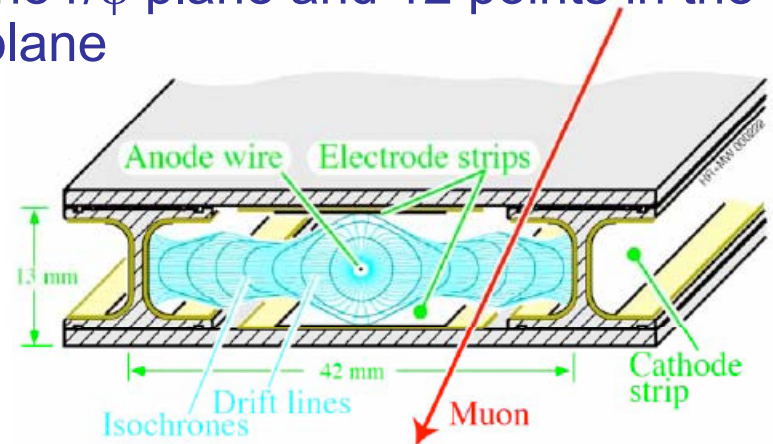
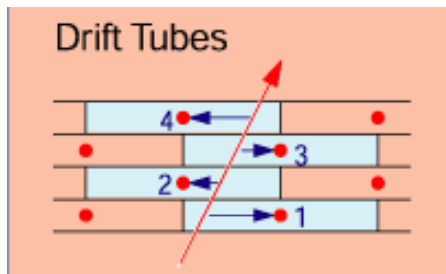
Successful ramp up to 3.8T after solving forward region mechanical issues.

- Although ramped up to 4T, 3.8T chosen as the CMS operation point (18,000 amps)
- Stably operated at 3.8T from October 16th until November 8th

The Muon System: DT



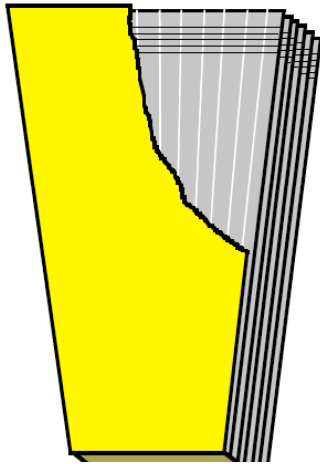
- 250 Drift Tubes chambers cover the barrel region ($|\eta| = 1.2$)
- Organized into 4 stations (MB1-MB4) coupled with RPC chambers
- Each station has 3 superlayers (2 r/ϕ and 1 r/θ). MB4 has only 2 r/ϕ superlayers.
- Each superlayer has 4 layers of staggered drift tubes \uparrow a central muon may have up to 32 points in the r/ϕ plane and 12 points in the r/θ plane



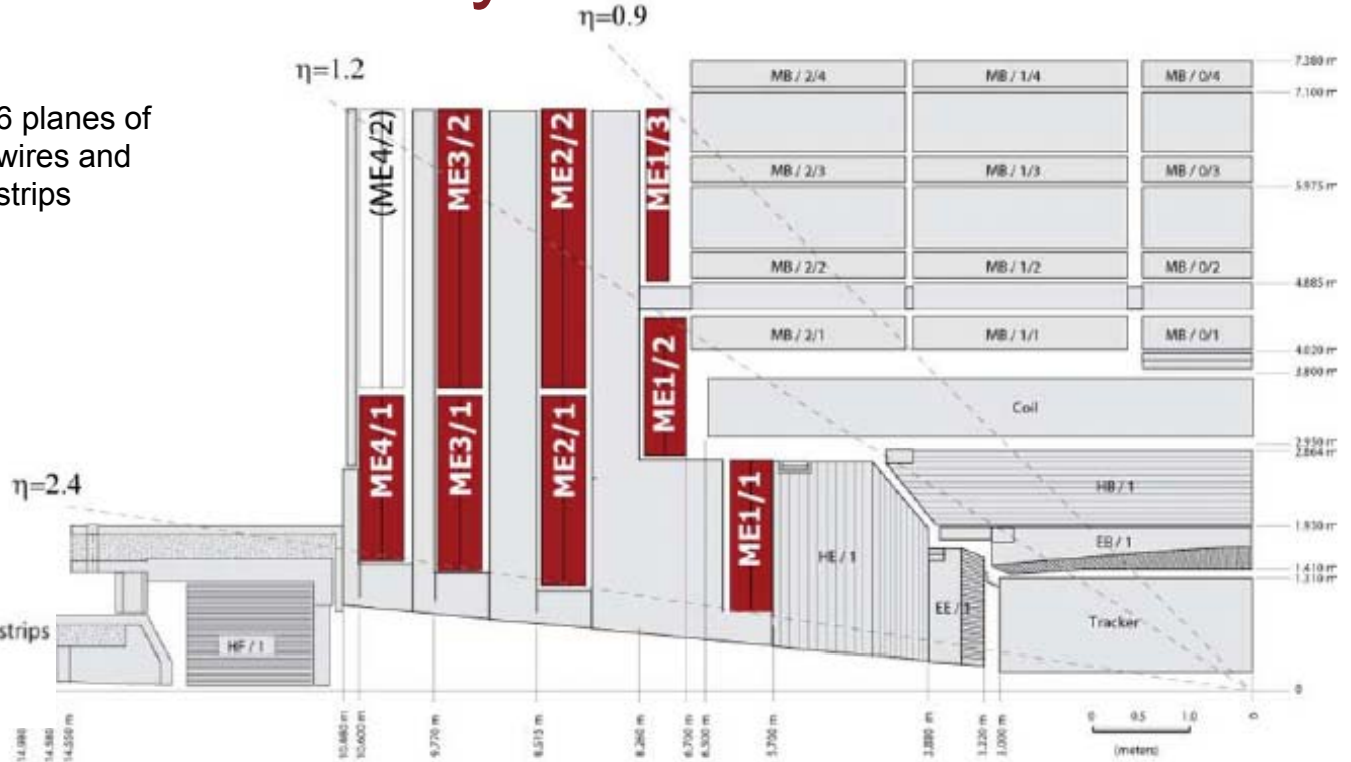
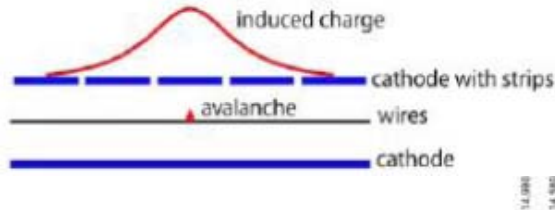


The Muon System: CSC

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



6 planes of wires and strips

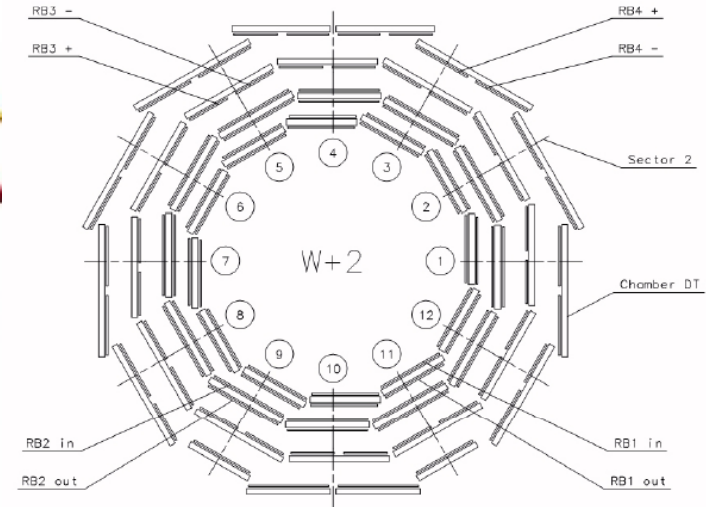
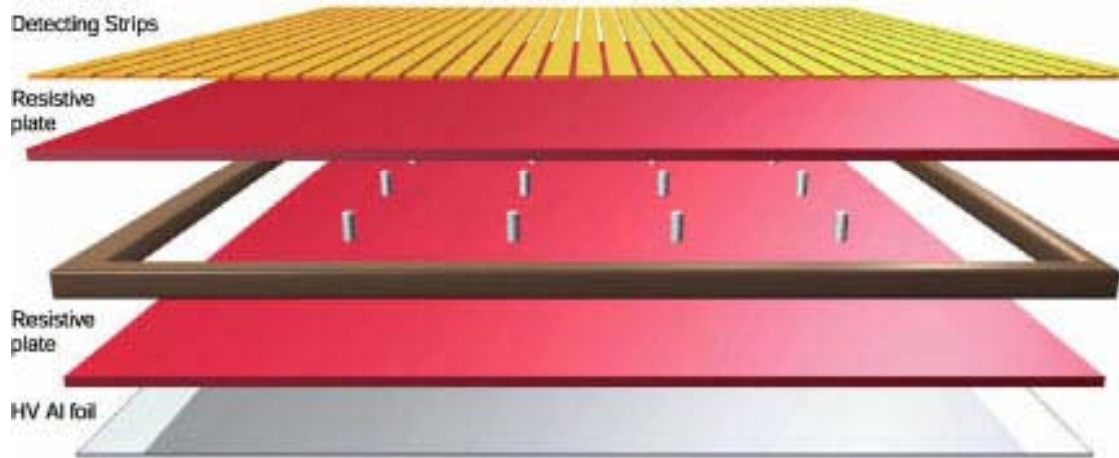


- 468 Cathode Strip Chambers covers the $|\eta|$ region 0.9-2.4
- Operate in a large inhomogeneous field based on MWPC concept with also cathode strip readout
- 6 planes per chamber
 - Phi measured by centroid fit on strips
 - R and Bx-id from wires
 - Resolution of $\sim 100 \mu\text{m}$

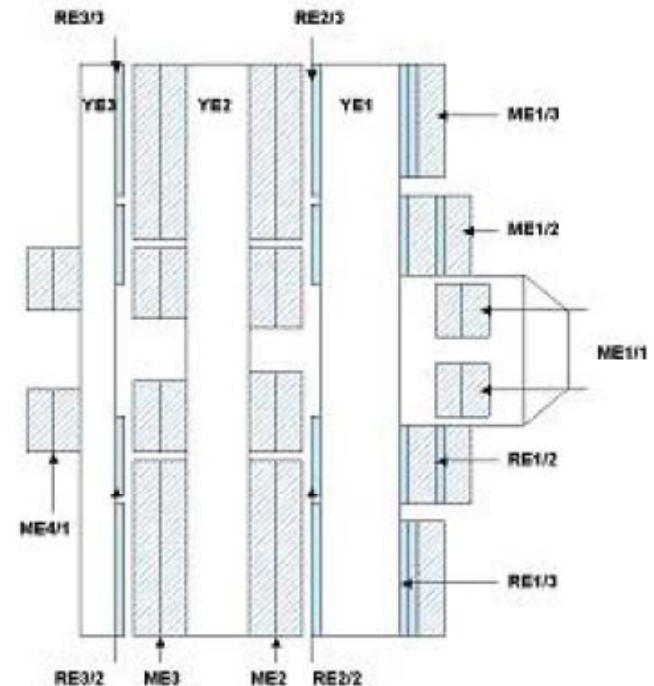


The Muon System: RPC

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



- Double gap chambers
- Operate in avalanche mode (lower gain, higher amplification) to cope with hit rates up to $\sim 1\text{KHz}/\text{cm}^2$
- Fast response and very good timing resolution ($\sim 3\text{ns}$) for unambiguous Bx id.
- 6 stations on the barrel wheels and 4 on the forward disks.





Calorimetry: HCAL

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

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TIFF (Uncompressed) decompressor
are needed to see this picture.

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TIFF (Uncompressed) decompressor
are needed to see this picture.

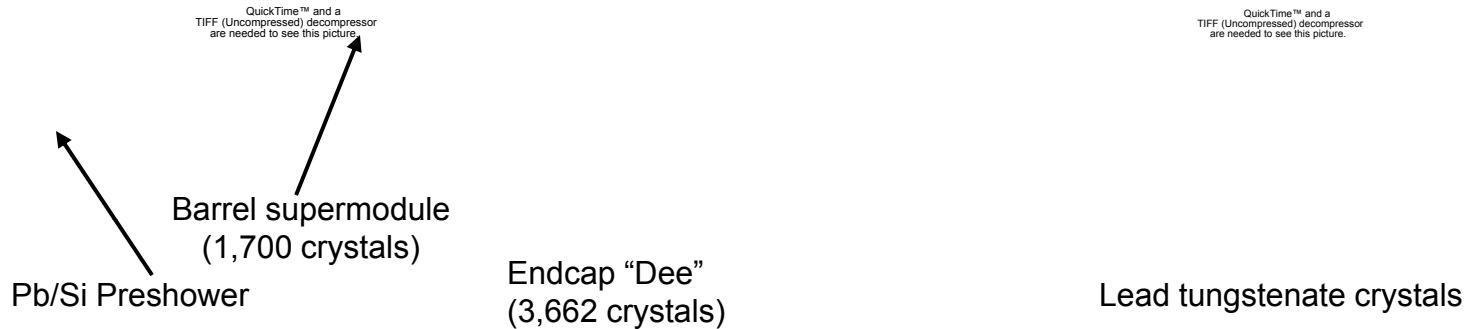
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

- Organized into a barrel (HB)+tail catcher outside the solenoid (HO), endcap (HE) and forward (HF).
- Brass/Scintillator calorimeter (HB $|\eta| < 1.5$) organized in wedges ($\Delta\phi\Delta\eta = 0.087 \times 0.087$) with 17 sampling layers on a single WLS fiber. Total of $\sim 11\lambda$ with HO. Similarly HE covers the region $1.3 < |\eta| < 3$ and HF $3 < |\eta| < 5$.
- Optical signal readout via HPD (HB,HO,HE) and conventional PMT for HF
- HF functions also as luminosity monitor for CMS (Zero counting)

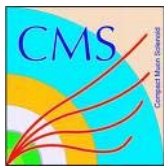


Calorimetry: ECAL

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

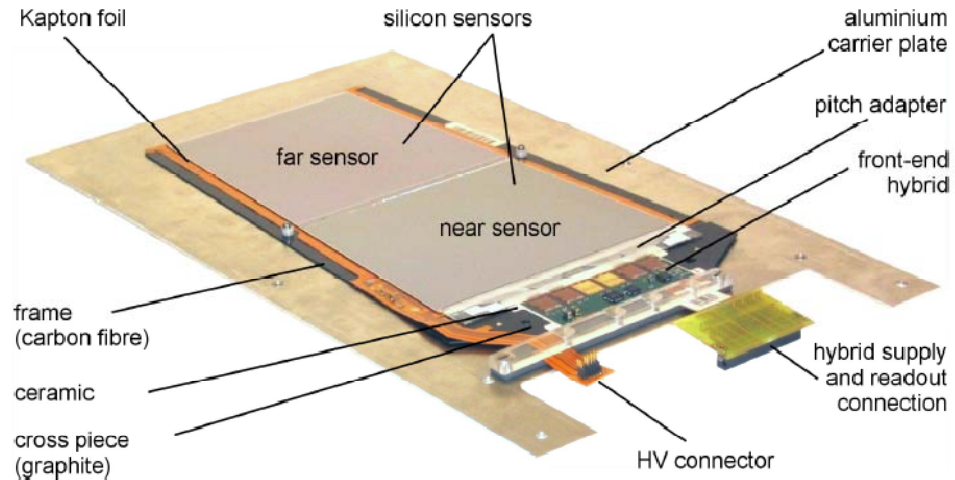
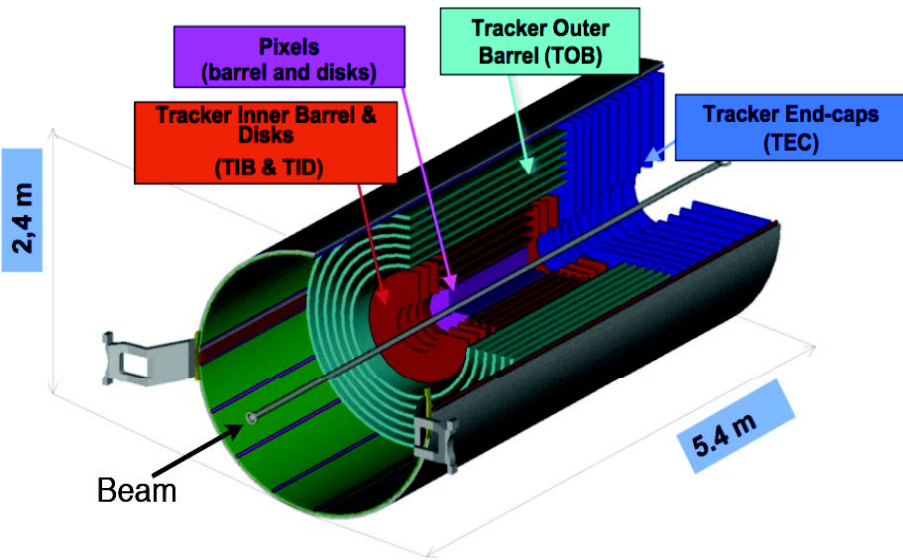


- Homogeneous crystal calorimeter ($\sim 10\text{m}^3$ of PbWO_4 , 90 tons)
- Energy resolution of 0.5% at high E
- 36 barrel supermodules ($|\eta| < 1.5$) and 4 *Dees* ($1.5 < |\eta| < 3$)
- Light signal from the crystal is readout via APDs(Barrel) and VPTs(Endcaps)
- $\sim 80\%$ of light emitted in 25ns.
- $\sim 25 X_0$



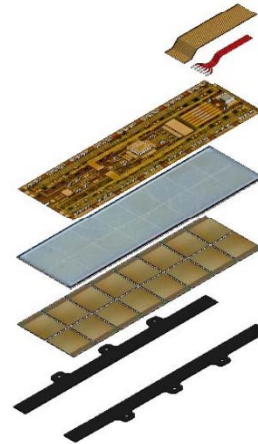
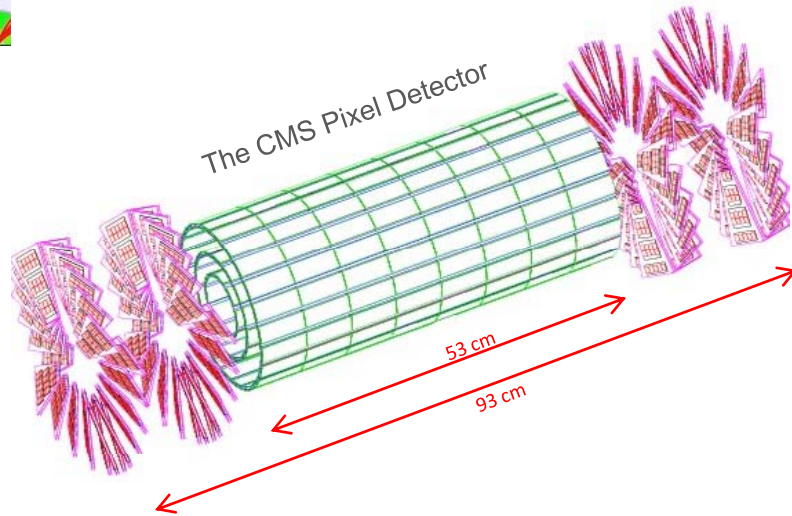
Tracker: Silicon Strip

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

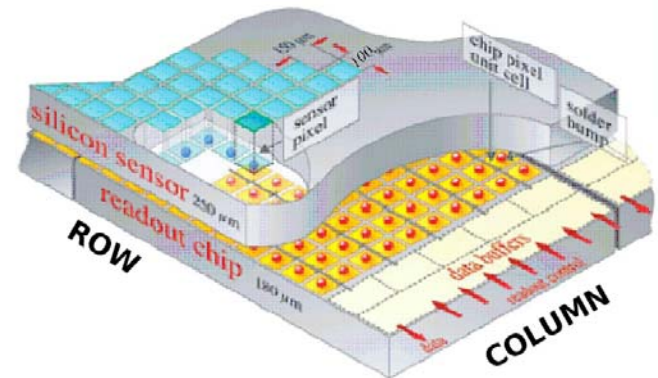


- Inner barrel and disks (TIB/TID), Outer barrel (TOB) and endcaps (TEC)
- 9.3M channels, 200m² total silicon
- 10 layers (4 double sided stereo)
- Covers the region from 20cm to 120cm and up to $|\eta| < 2.5$ (barrel $|\eta| < 1.2$)
- Strips are readout out via APV25 (analog output, 0.25um technology)

Tracker: Pixel



Modules of the Barrel Pixel Detector

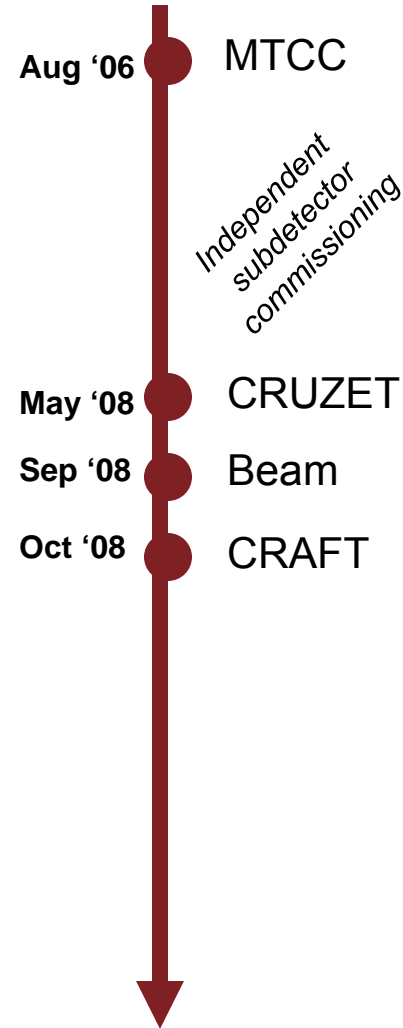


- Forward Pixel Detector (**FPix**) has two disks on each side at 34.5 cm and 46.5 cm with 672 modules
- Barrel Pixel Detector (**BPix**) has 3 layers of radii 4.3 cm, 7.2 cm and 11.0 cm with 768 modules
- ReadOut Chip (ROC) bump bonded sensor pixels with $52 \times 80 = 4160$ pixels per ROC
- Total 15,840 ROCs for 66 million pixels
- Automatic zero-suppression
- Each pixel has a programmable threshold (adjusting this is called trimming)

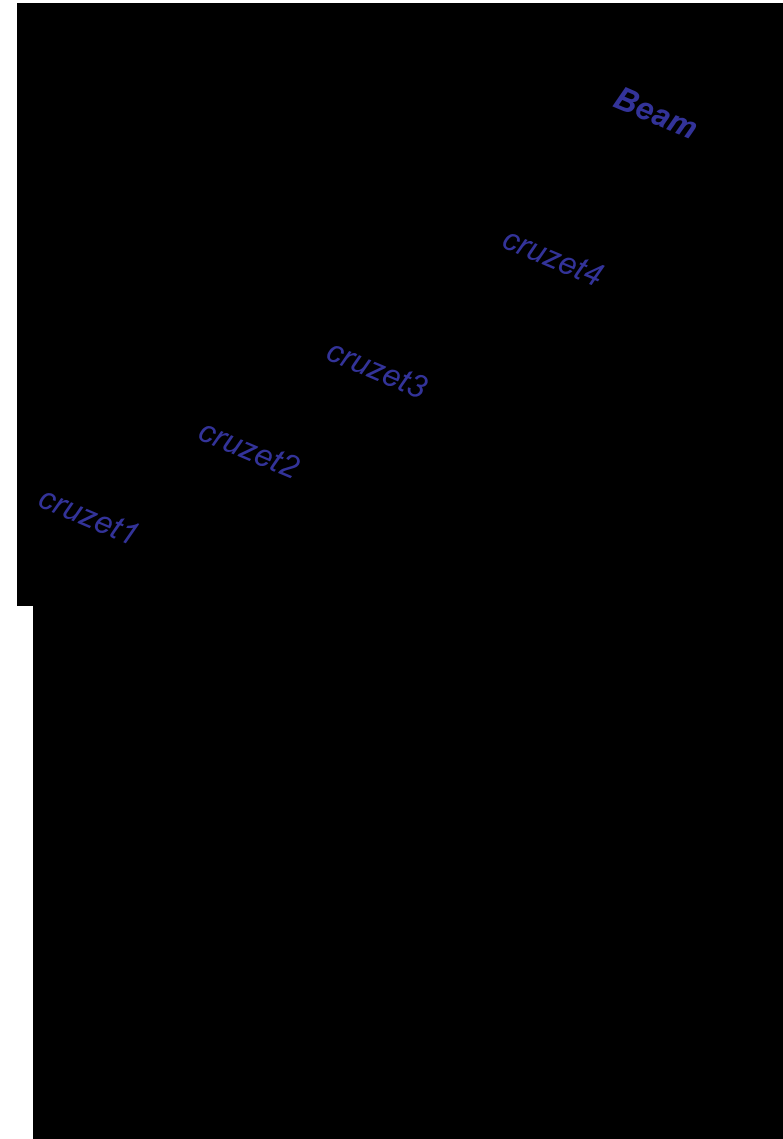


Performance

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



- Once lowered, CMS as a whole took data for the first time in May '08 during a series of data taking periods (magnet OFF) culminated with first beam on Sep 10th
- Beam was recorded with CMS magnet OFF
- After Sep 19th much work went into being able to operate safely with Magnet ON and data taking (CRAFT) resumed using cosmics.
- CRAFT was a test also to operate the detector continuously and check for data taking efficiency.





Beam Splash Events

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Beam 1 ($\sim 2 \times 10^9$ protons) stopped at upstream collimators.
Big splash of particles passing through CMS

- Good tool to study trigger synchronization, internal subdetector timing, correlate energy deposited in calorimeters.
- Everybody likes it except Tracker (both SS and Pixel OFF)



Beam Splash Events

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

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QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Collimators closed



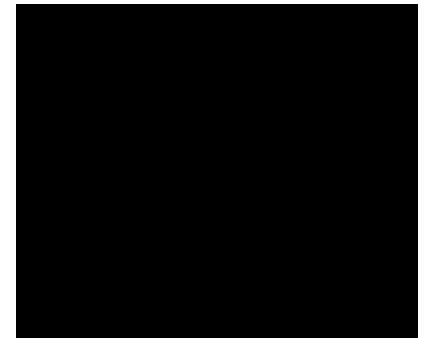
Beam 1 (2×10^9 protons)



Hcal (Blue)
ECAL (cyan)
DT (green)

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



LHC tunnel profile visible



Beam Splash Events

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

- Time difference between predicted pulse arrival time and mean pulse arrival time, before and after using delays tuned from beam splash events.
 - Note that HCAL Barrel region was already tuned with prior data.
 - HCAL now timed in at nanosecond scale



Beam Splash Events

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

- Correlation between the ECAL barrel energy deposited and various beam loss monitors devices along the beam (left).
- Correlation between ECAL and HCAL energy deposited (right).



Beam Halo events

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

LHC Tunnel profile

- Used to align the CSC detectors using beam-halo tracks passing through the overlapping region of chambers.
- Accuracy achieved $270 \mu\text{m}$ in $r\phi$ and 0.35 mrad in ϕ_z using 9,000 useful muons collected in 9 min of LHC beam.

- HE peak energy location and amplitude before and after beam RF capture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.



Performance: Cosmic Data taking (CRAFT, Oct/Nov 08)

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

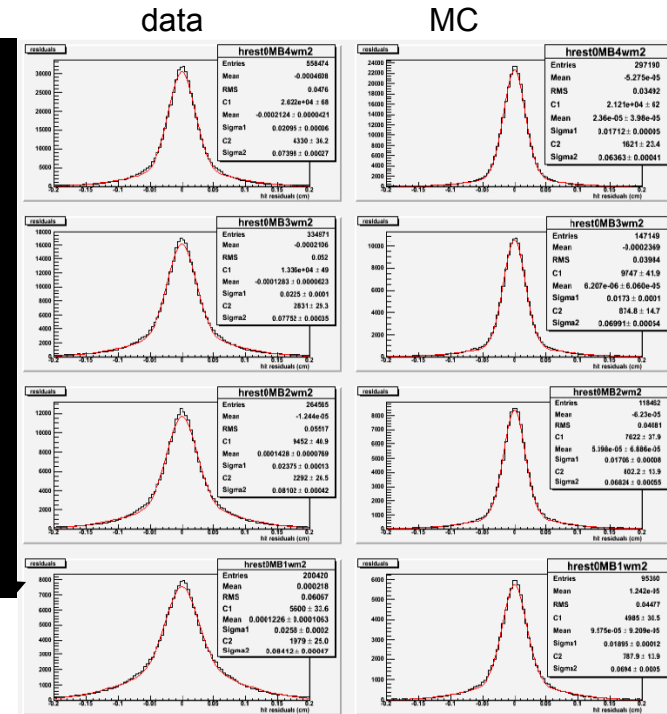


- A cosmic event recorded by CMS



CRAFT: DT

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



- DT efficiency very good
- Residuals between 200-260 μm in reasonable agreement with MC
- Drift velocity:
 - Up to 3% discrepancy in some location due to not so good description of local B-field
 - New B-field calculation are now in much better agreement.



CRAFT: HB

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Test Beam 2006

$P_\mu = 150 \text{ GeV}/c$

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

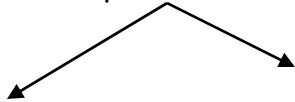
- Look at the energy deposited in HCAL as a function of the muon momentum:
 - Typically 2~3 GeV in HCAL.
- Good agreement with
 - MC simulation
 - Test beam data from 2006.



CRAFT: ECAL

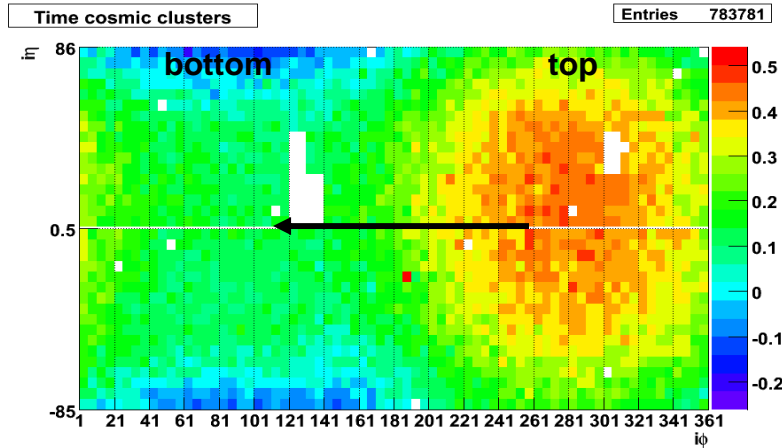
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

LV problems solved



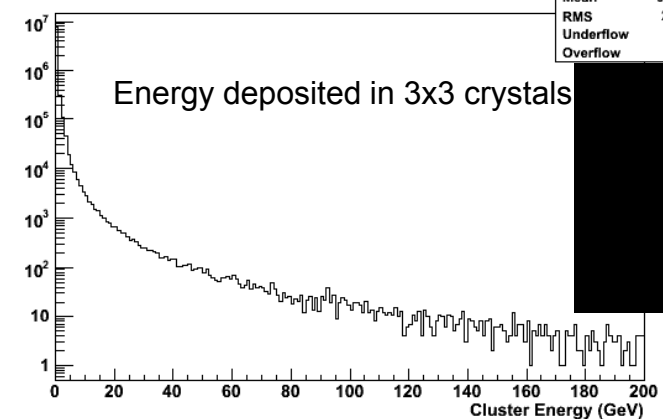
Shaft asymmetry

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



- EB occupancy map of clusters (APD gain = 200, 4 times nominal). Cluster seeded from single crystal >130MeV or two adjacent crystals >2X43 MeV (left)
- Average cluster timing. Noticeable the time of flight of cosmic ray muons from top to bottom of EB.

energyHigh_AllClusters, run 200



Stopping power in PbWO4



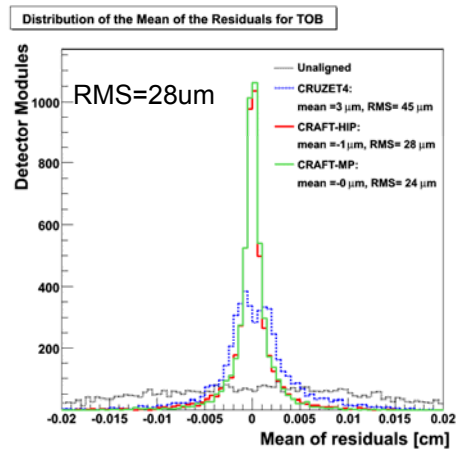
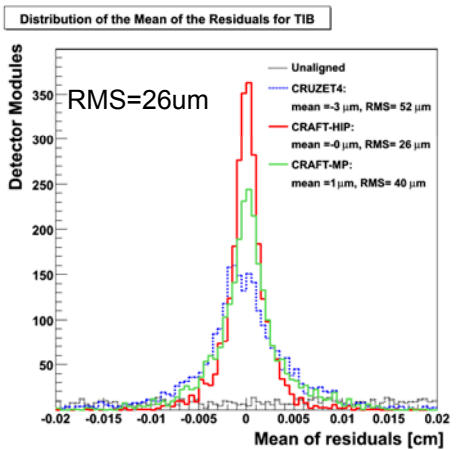
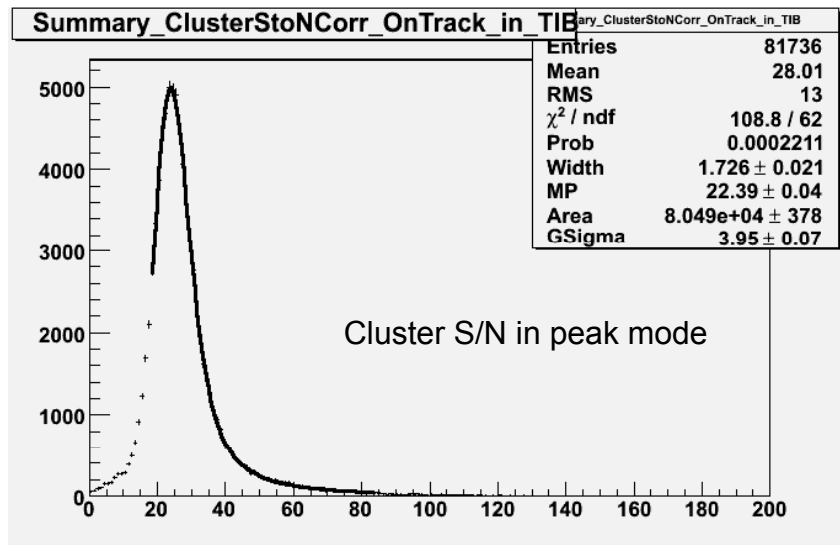
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



CRAFT: Silicon Strips Tracker

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

- Strip Tracker
 - TOB: 98.2% (0.6% recoverable)
 - TIB/TID: 96.9 % (1% recoverable)
 - TEC+: 99.2%
 - TEC-: 97.8 % (1.7% recoverable)
- Aligned to 25-30um using cosmic data !





Performance: Cosmic Data taking (CRAFT, Oct/Nov 08)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

- Pixels

- Barrel pixels: 99.1%

- Forward pixels: 94.0% (addressed during this shutdown)

- Enough data in the barrel to align to 50um

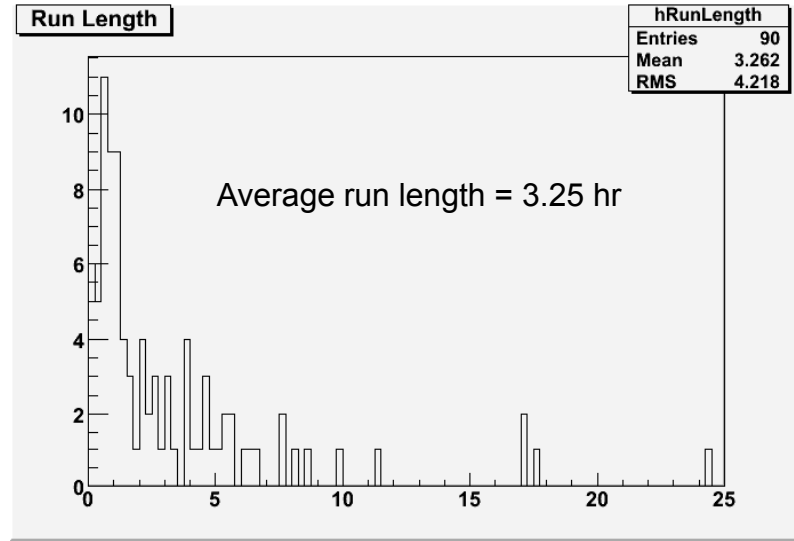
- Cluster charge distribution understood for both barrel and forward



Performance: Cosmic Data taking (CRAFT, Oct/Nov 08)

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

- Ran 4 weeks continuously from 13-Oct to 11-Nov
 - 19 days with B=3.8T
- 370M cosmic events collected in total
- 290M with B=3.8T and with strip tracker and DT in readout
 - 194M with all components in
- Average data-taking efficiency was 60%, with periods of up to 24h at 100% efficiency
 - Earlier CRUZET efficiency was about 50%
 - 10% inefficiency due to magnet cooling incidents (leading to Magnet ramp down)
 - 30% inefficiency for problems encountered between runs



Infrastructure Downtime(16-10/14-11)

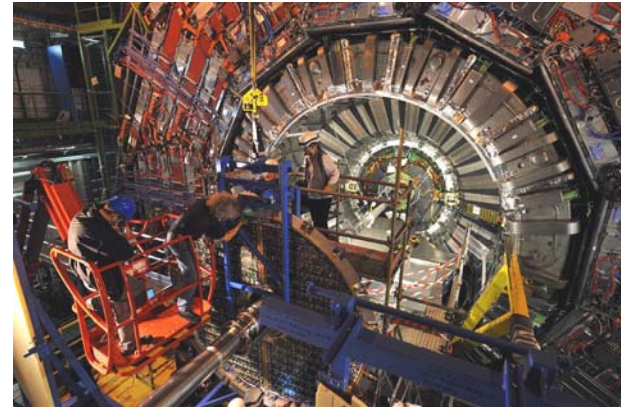
Date	hour	duration (hours)	Reason	SYSTEMS					
				Magnet	Cooling	Gas	Network	Inertion	Electrical
20-10	23:00	38	LHC inauguration day	slow dump					
24-10	8:00	10	no cooling to power converter due to leak detection system above limit (<-11/hr)	slow dump	Copper circuit stopped				
26-10	13:30	25	no cooling to power converter due to leak detection system above limit (>-11/hr). Now 2l/hr	slow dump	Copper circuit stopped				
3-11?	?	1	Magnet lost communication to equipment in USC55.				LHC Technical Network down		
5-11	13:00	22	problem with the cold box restarted but with problems helium transfers did not work properly.	current lowered to match helium on IC					
6-11	3:00		broken circulation pump. Bypassed.	slow dump	Copper circuit stopped				
7-11	12:00	4	water leak detected on the yoke circuit (ring -1,-2)		Endcap and Yoke circuits stopped				
11-11	8:00		?		rack circuit				
13-11	10:00	1	?		Endcap rack				



Main activities during the shut-down

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

- Installation of Preshower (ES) detector (1)
- Extraction, repair and re-insertion of the forward pixel detector (2)
- Refurbishment of the tracker cooling plants (3)
- Miscellanea intervention on muon chambers (DT, CSC and RPC) (4)
- Final commissioning of the endcap RPC (neg. side).
- Main infrastructure (power, cooling, network, etc.) maintenance



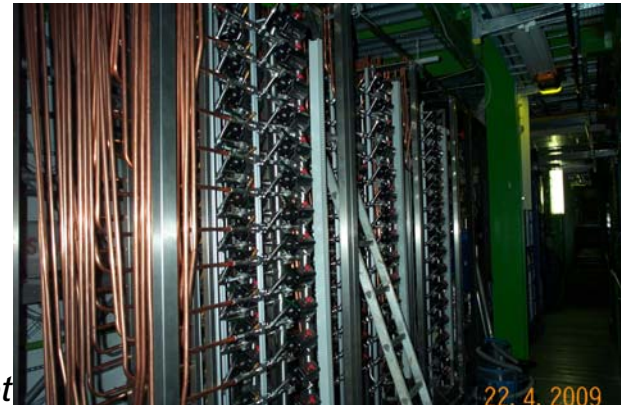
(1)



(2)



(4)



(3)

1) Maintenance & Operation

2) Software, Computing & Physics Analysis

Jan

Feb

Mar

Apr

May

Jun

Jul

Aug

Sep

Oct

Install ES1
Install ES2

Tracker Cooling Plant Revised

Close CMS
Magnet Tests

CRAFT

CRAFT Contingency &
pre-beam maintenance

CMS READY for Beam

Release CMSSW3_0
(limited validation, step towards 3_1)

Full validation of 3_1 (incl.
production and physics)

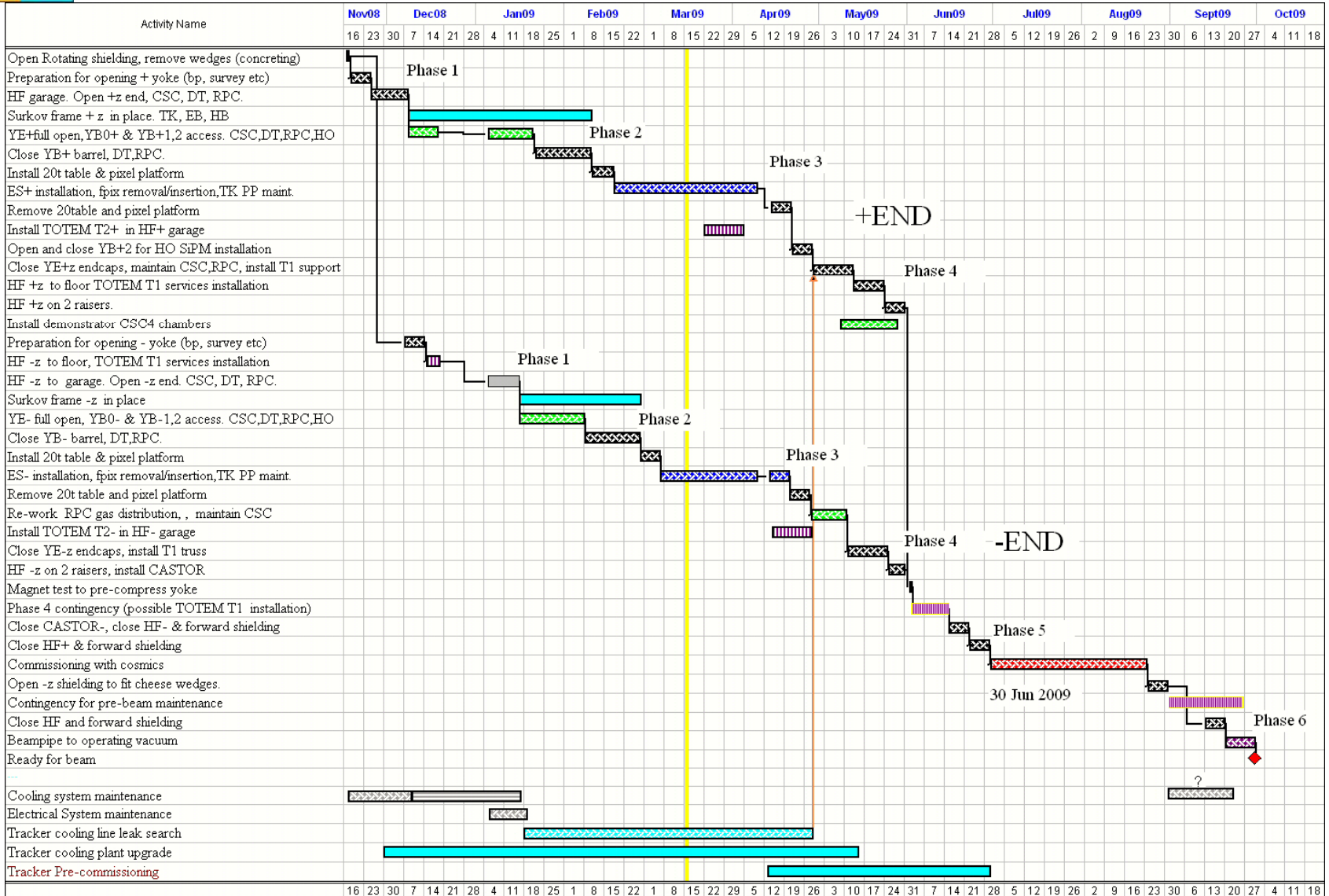
Use 3_1 widely
CMS gets familiar with 3_1

CMS READY for Beam



Schedule: details

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.





Conclusions

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

- All major components integrated, well functioning and commissioned
- Excellent performance of all subdetectors
- Timing of the experiment already at a very good level (\sim ns)
- DAQ and trigger stable
- More data (cosmic) to come before beam we'll give us the opportunity to tune the detector even better.
- Continuous running such a complex detector with high data taking quality and efficiency will be the next challenge