CMS: Muon Hardware System & MTCC Experience

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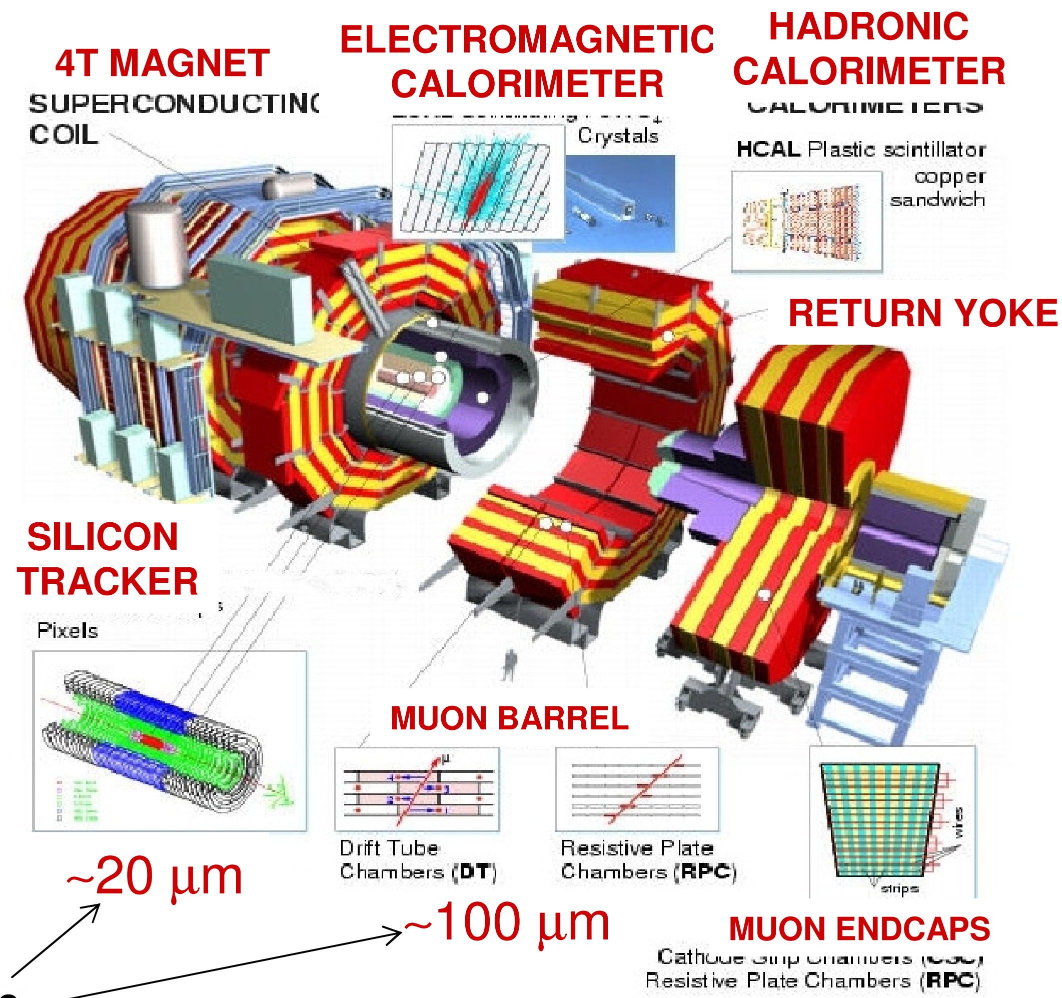
Outline

- The CMS Muon Spectrometer
  - Features
  - Need for alignment
- The hardware alignment system
- Magnet Test & Cosmic Challenge experience
  - Hardware alignment (Setup and Results)
    - Barrel system
    - Endcap system
    - Link system
  - Validation and offline alignment

The CMS Muon Spectrometer

Weight:	12.500 t
Diameter:	15.0 m
Length:	21.6 m
B Field:	4 T

- **Design Criteria**
- **Very good lepton ID (e and mu)**
- **And tracking system (B=4T) to measure the particle p**
- **Detectors capable to operate with high radiation levels (up to 1MGy in 10 years)**
- **Fast response technologies (beam crossing time 25 ns)**
- **Good detector hermeticity**



~20 μm

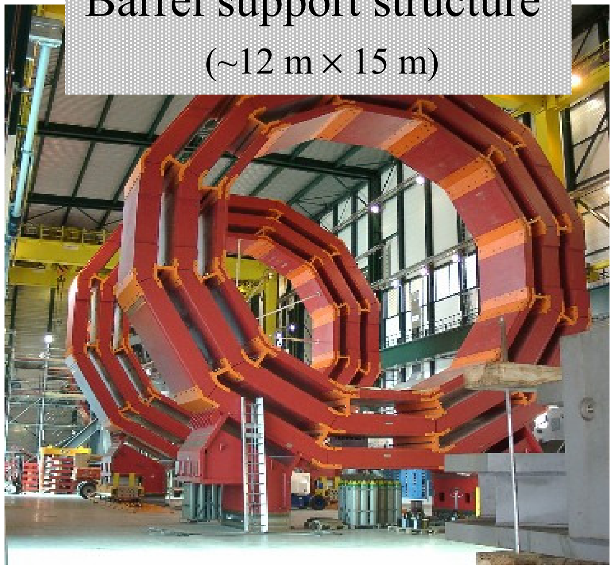
~100 μm

~75-100 μm

Spatial precision

The CMS Muon Spectrometer

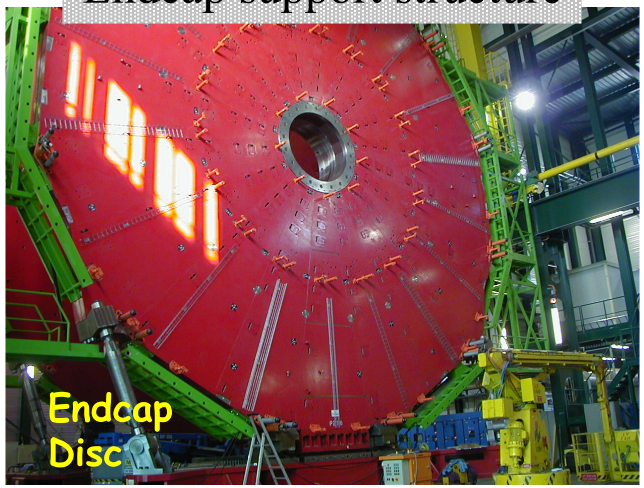
Barrel support structure
(~12 m × 15 m)



- **<u>Mechanical structures are large and not rigid</u>. Significant motions and deformations expected (and being confirmed by survey and MTCC results)**
  - **~1-3 cm B on/of**
  - **5-15 mm gravitational effect**
  - **< 500 μm operation (Temp. And humidity)**

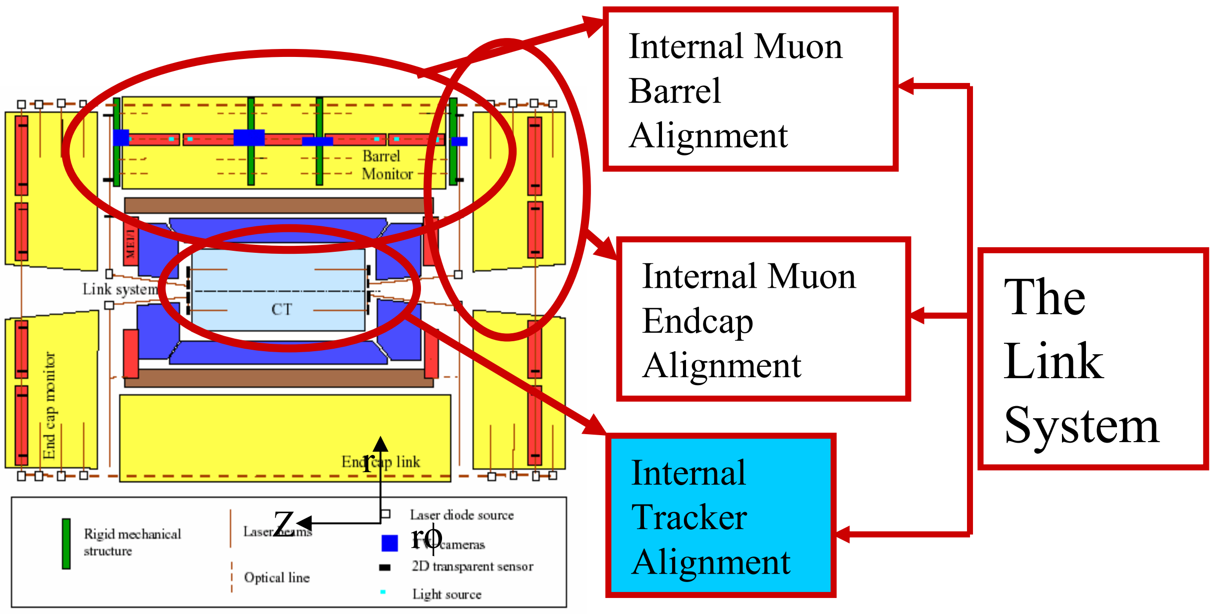
- **Maximum allowed misalignment (not to degrade momentum measurement)**
  - **σRΦ 200 μm**
  - **At level of mm in Z**

Endcap support structure



Hardware alignment system

Aim: Tracker internal alignment and monitoring the muon chambers relative positions (barrel and endcap) and with respect to the tracker.

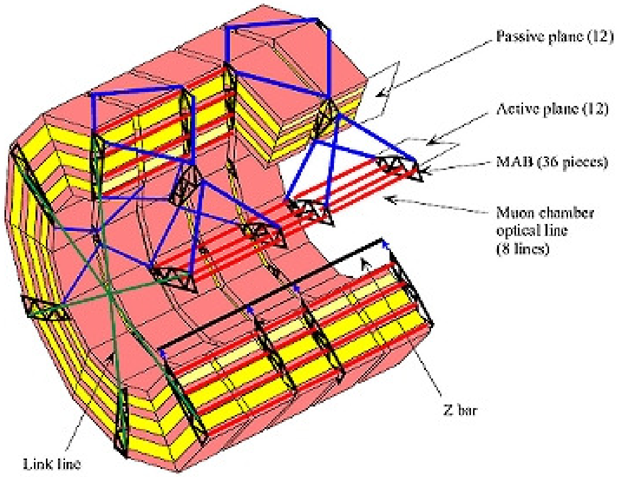


Design Constraints

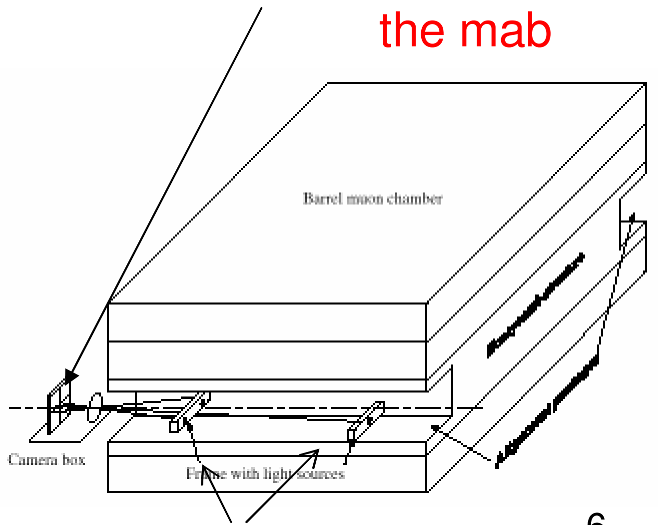
- **Hermeticity (the system must adapt to the detector geometry and the lack of space)**
- **Dynamic range (several cm)**
- **Radiation resistant**
- **B y ΔB components immunity**

Barrel hardware alignment

- **Provide information of the relative positions and orientations of barrel chambers**
  - **Cameras placed at external rigid structures (MABs) attached to the wheels observe reference points at the chambers**
  - **The relative position of chambers is calculated with triangularizations.**



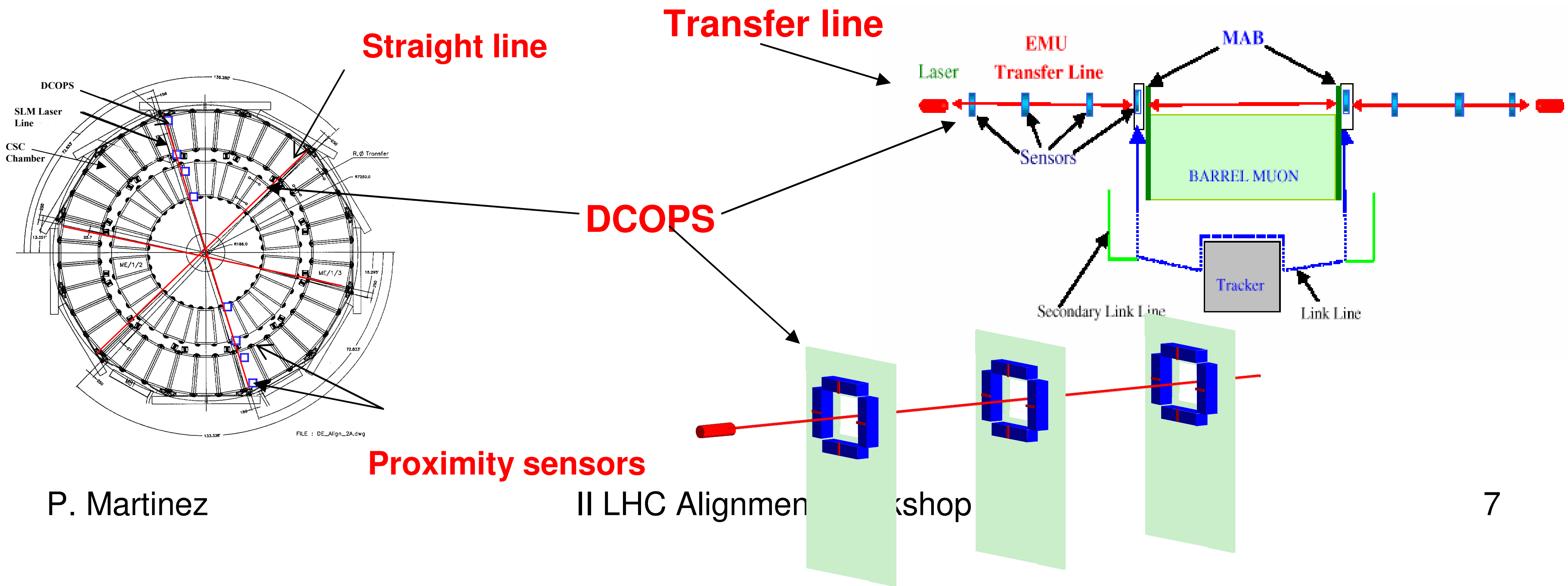
Camera placed in the mab



Leds at reference points

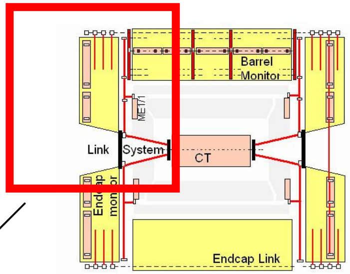
Endcap hardware alignment

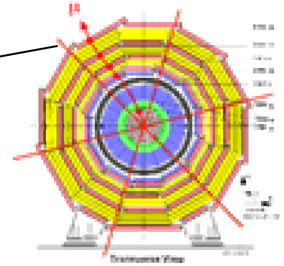
- **Relative positions and orientations of endcap chambers and alignment of each endcap with respect each other.**
  - **Laser lines intercepting CCD cameras called DCOPS**
    - **Six axial transfer lines measures relative position between stations and the two endcaps**
    - **Three straight lines to align internally chambers inside a single station.**
  - **Proximity sensors used to complement laser measurements**
    - **Radial distances between inner rings and outer rings and between outer rings and transfer lines.**
    - **Also to measure azimuthal distances in the first station**

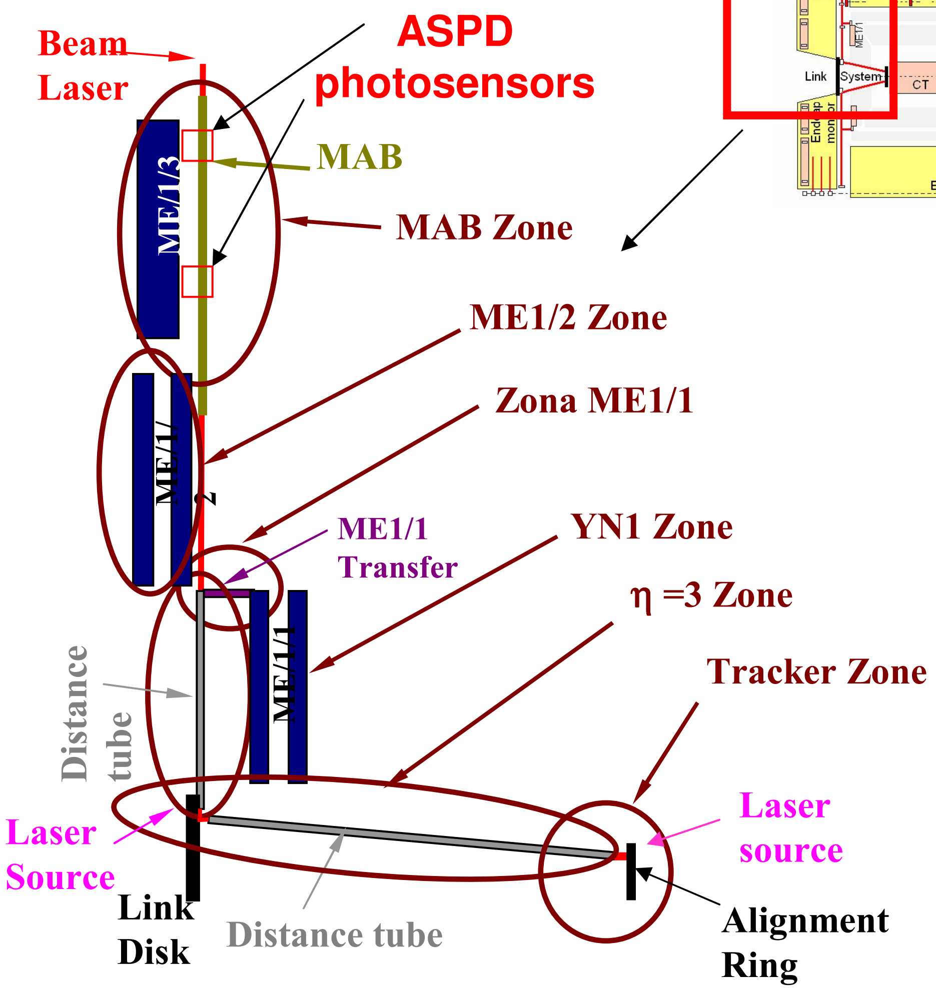


Link hardware alignment

- **Align barrel, endcap and tracker subsystems with respect to each other. Alignment of ME1 chambers**



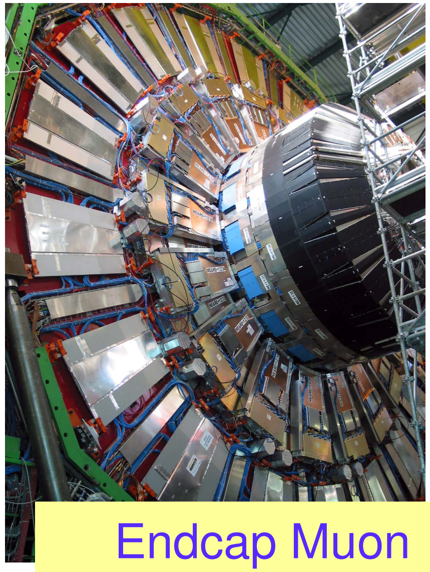




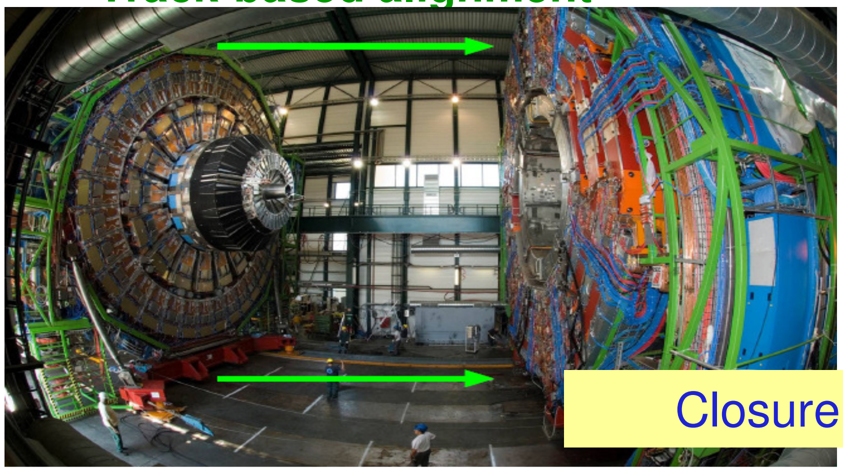
- **Laser lines:**
  - **Laser lines intercept transparent photosensors (ASPD)**
  - **Rigid structures: Alignment ring & link disk are used as reference**
  - **From Alignment Ring (tracker) to Link Disk (YE+1): Connection Tracker + Endcap**
  - **From Link Disk to MABs (radial lines): Connection Endcap+Barrel**
  - **From Transfer plates to ME1 chambers: Connection Endcap+ ME1 Chambers**
- **Proximity sensors and clinometers:**
  - **To complement and obtain redundancy.**

MTCC: overview

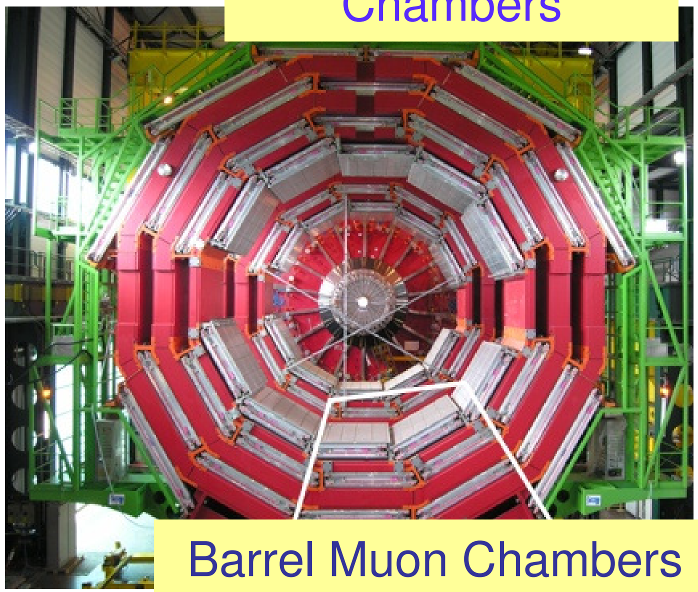
- **During Summer (phase I) and Autumn (phase II) 2006**
- **Magnet Test goals**
  - Commission the magnet for the first time at 4T and field mapping.
  - Check closure tolerances
  - **Validate the muon alignment system**
- **Cosmic Challenge goals**
  - Operate for the first time the whole sub-detector chain in a 20^{o} slice.
  - Check sub-detectors performance under the effect of B field and synchronization between them
  - **Track-based alignment**



Endcap Muon Chambers

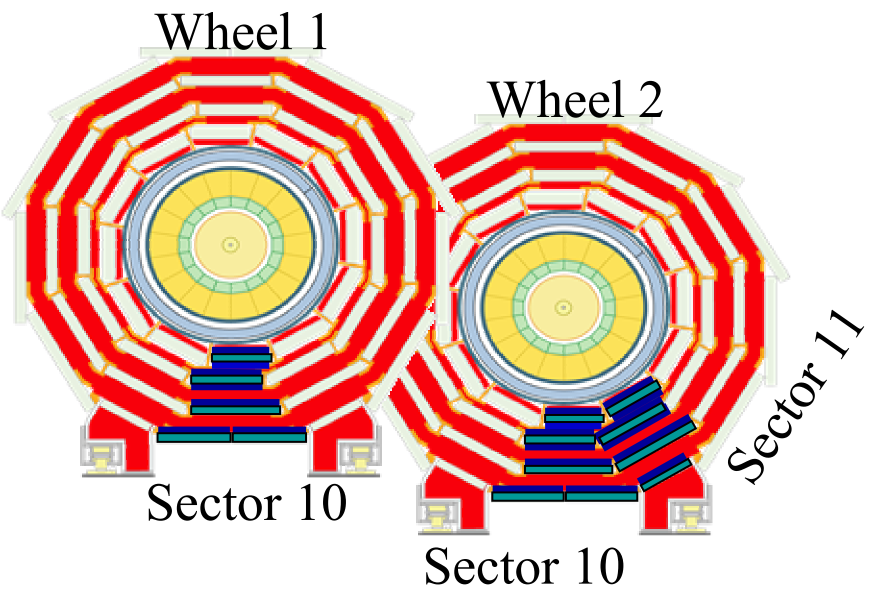


Closure of CMS

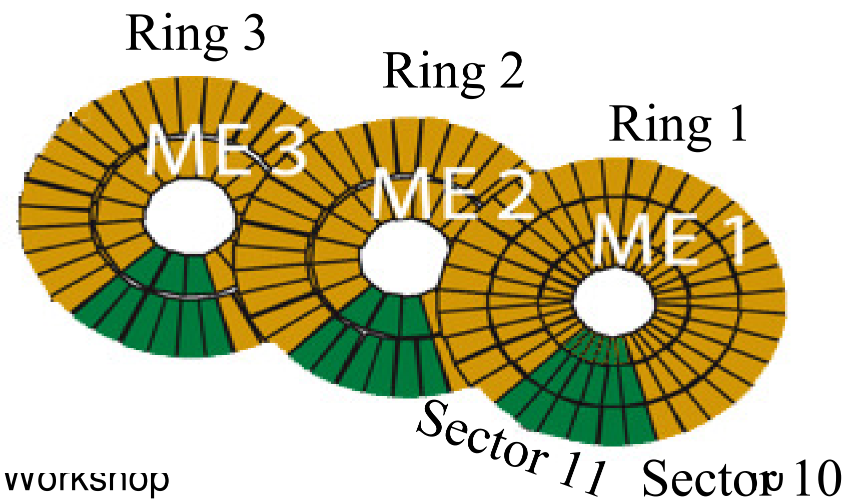


Barrel Muon Chambers

MTCC Setup: muon system



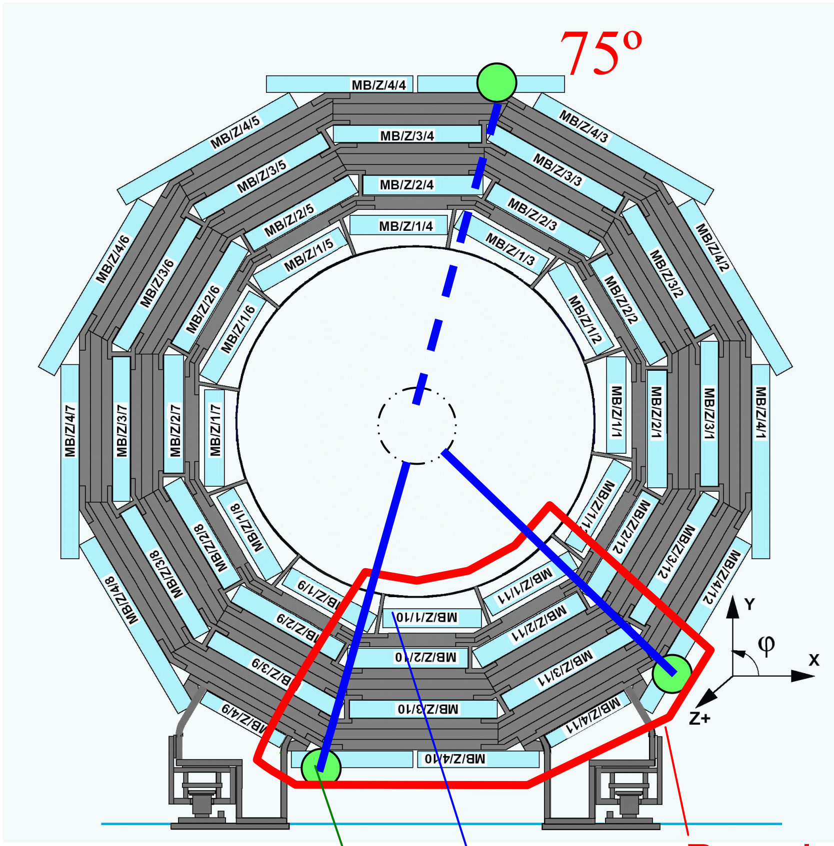
- 14 barrel Drift Tubes (DT)
  - 4 stations per sector
  - 2 sectors in wheel 2
  - 1 sector in wheel 1
- 21 barrel Resistive Plate Chambers (RPC)
  - Same sectors as for DT
- 36 end cap Cathode Strip Chambers (CSC)
  - 3 stations with 60 trigger sector
  - ~ 36000 channels
- 9 end cap Resistive Plate Chambers
  - 9 Chambers on ring 2 and 3 of disk 2



MTCC Alignment Setup

1/3 of muon alignment system

- Barrel alignment system was implemented for sectors 10 and 11 in all the wheels
- Positive endcap alignment system was basically fully implemented.
- The link system was instrumented for three laser lines

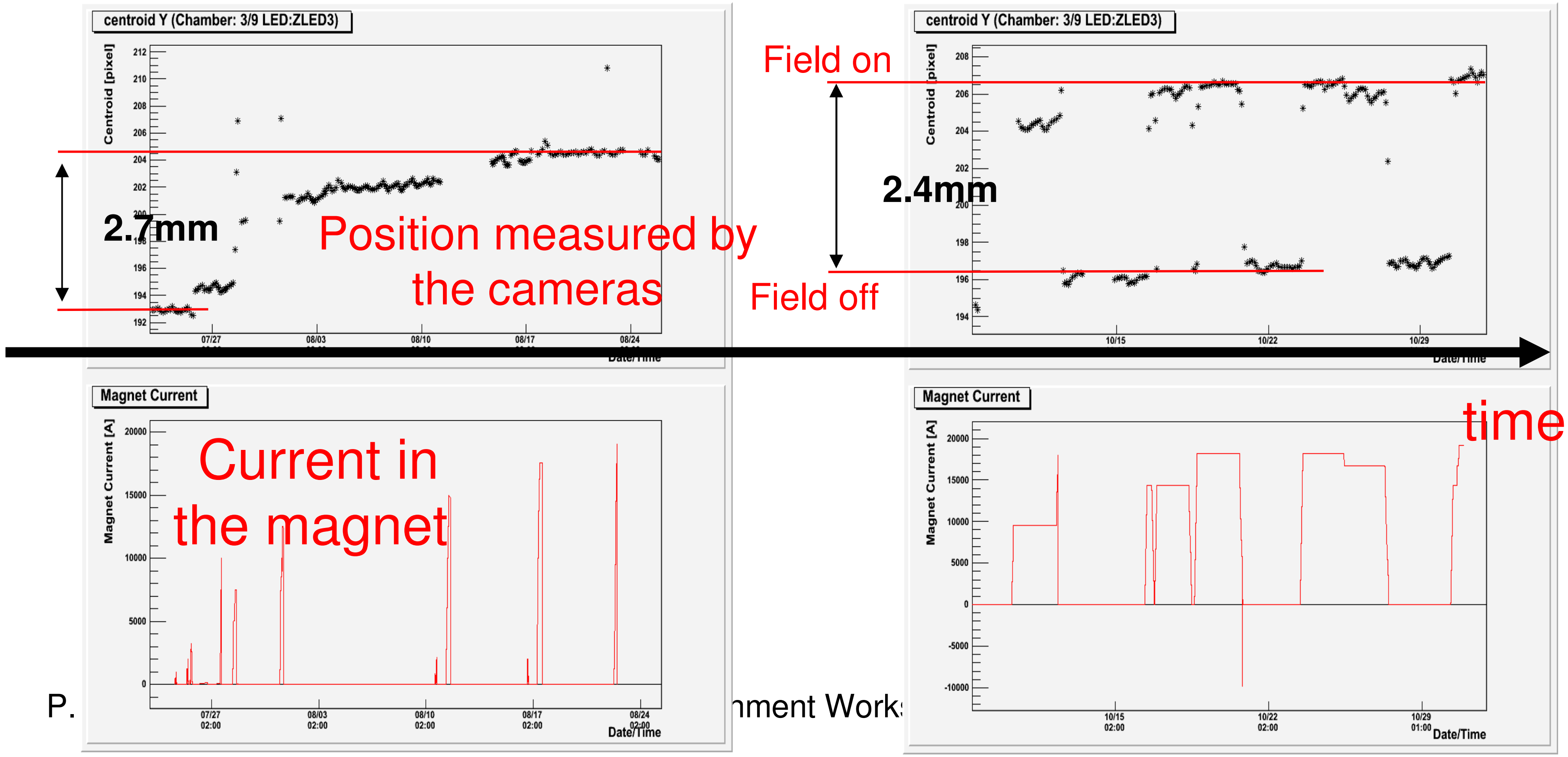


Barrel Hardware Alignment Results

- Compression of barrel chambers along Z axis towards IP is detected

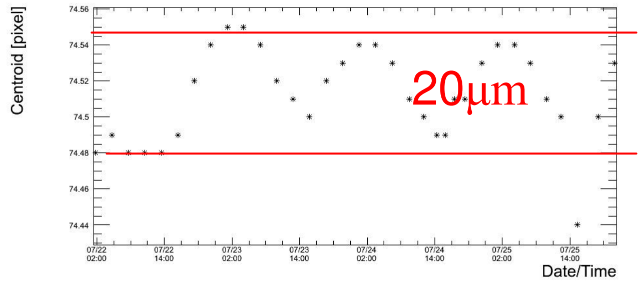
Permanent: not recovery when the magnet is off

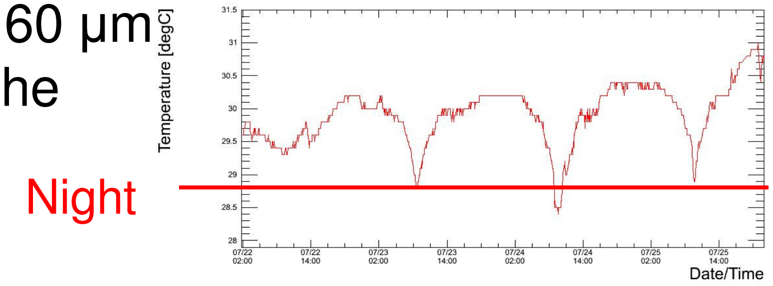
Elastic deformation: following the field

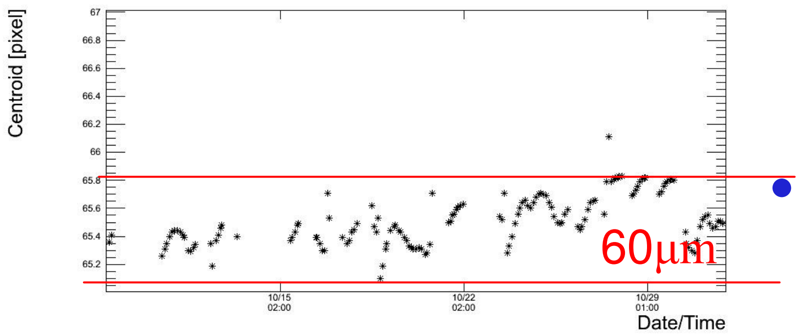


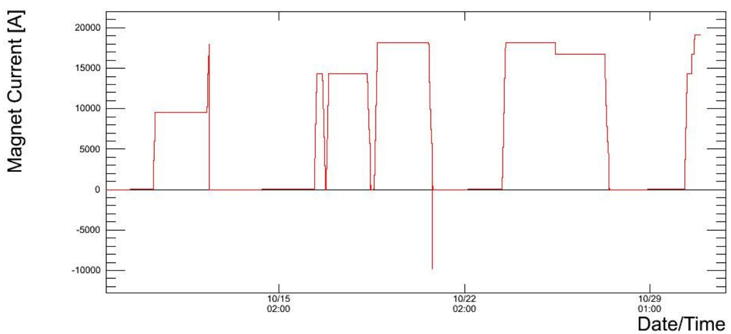
Barrel Hardware Alignment Results

- Measurement of thermal effects
  - The measurement of the cameras correlates with temperature (day-night differences)
  - The system is monitoring 20 μm and 60 μm (see below) movements, well below the requirements for physics





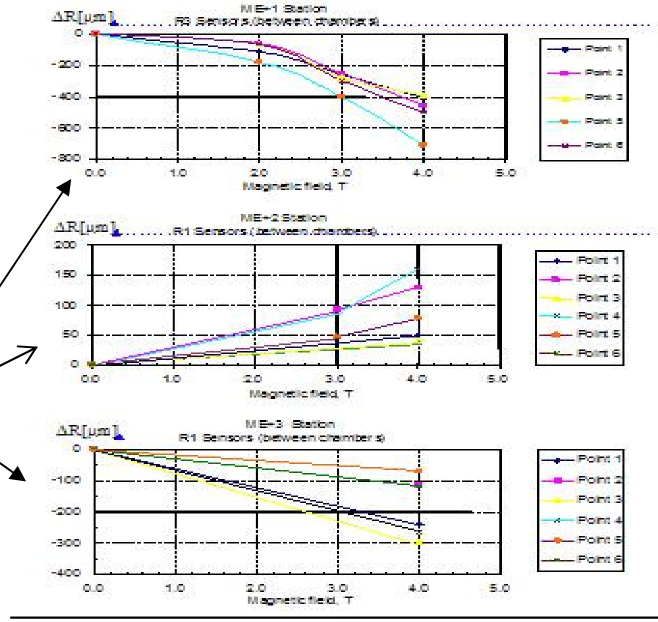




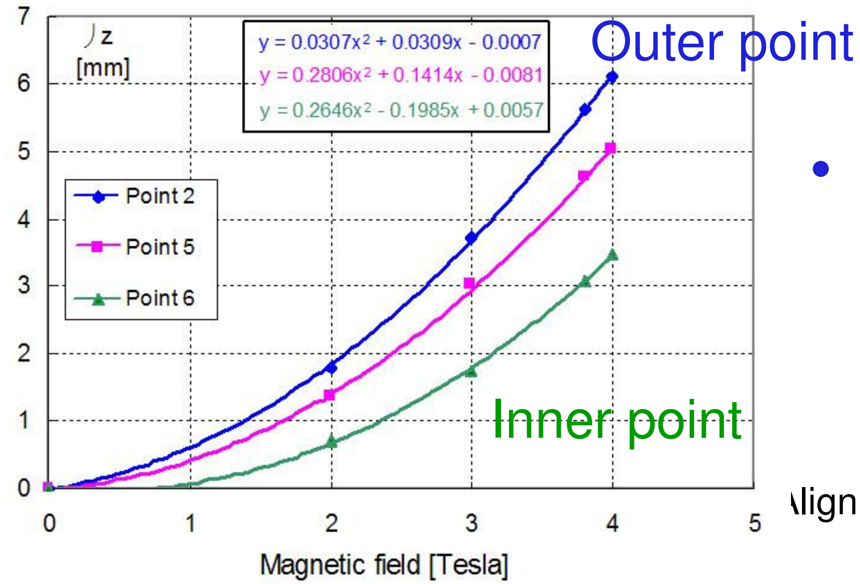
- Stability of Chamber in Phi
  - Small motions below 60 microns: not affecting Physics
  - Fine structure correlated with the magnetic field

Endcap Hardware Alignment Results

- Radial distance between inner chambers and outer chambers:
  - Significant displacement of inner chambers (500 μm for the first disk and 100-200 μm for the others)
  - Different signs of motion (see next slide)



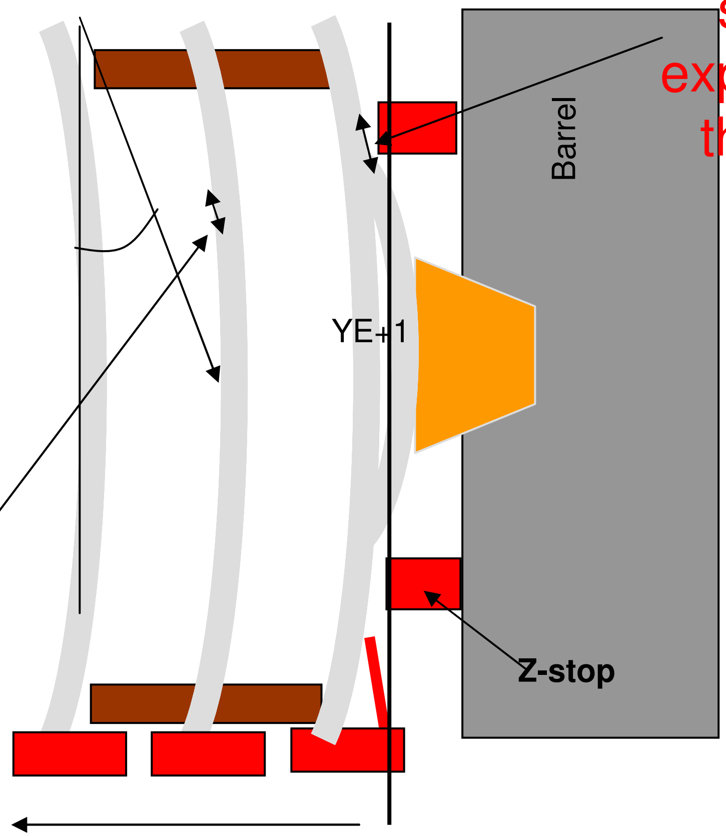
Magnetic field (Tesla)



- Bending of the disk away from the barrel in the Z direction.
  - Larger in the outer part of the disk

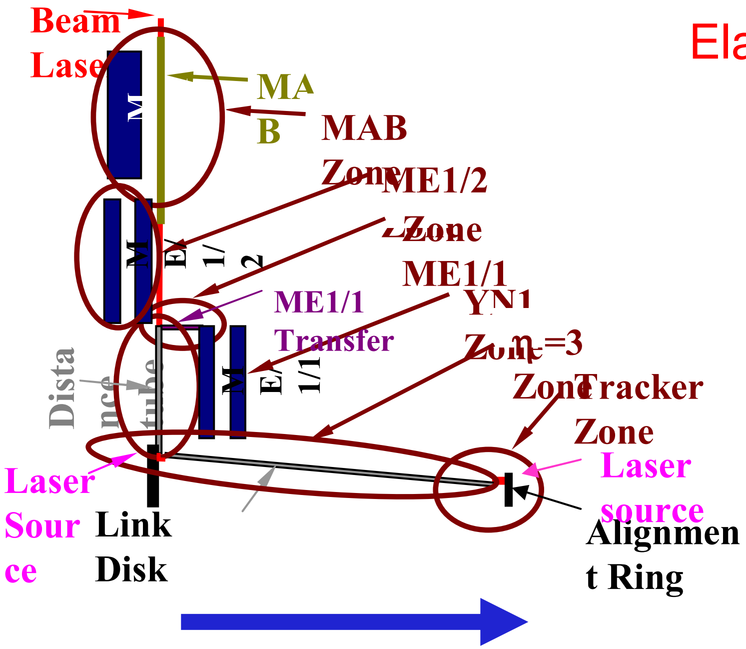
Endcap Hardware Alignment Results

- Complete analysis indicates a deformation and displacement of the endcap disks
- Effect is larger in the first one
- This is compatible with finite element calculations for the magnetic force



Link Hardware Alignment Results

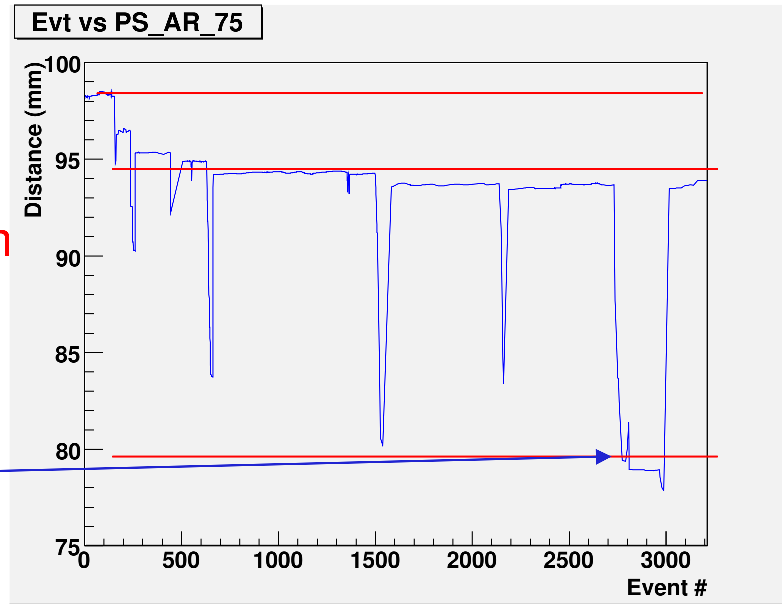
- Distance measurement shows a displacement of the first endcap disk towards the interaction point
- Coherent with barrel measurements



Permanent 6mm

Elastic ~ 15mm maximum

B field on

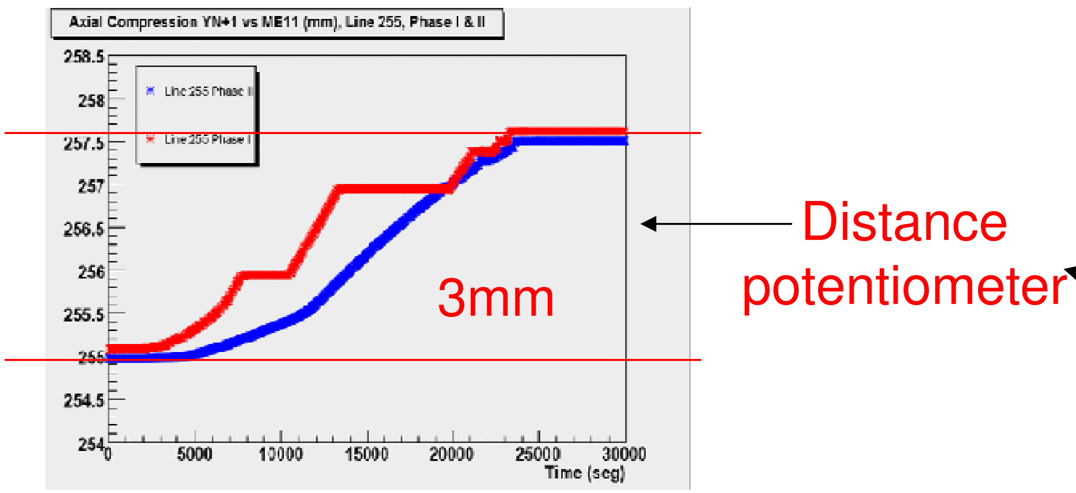


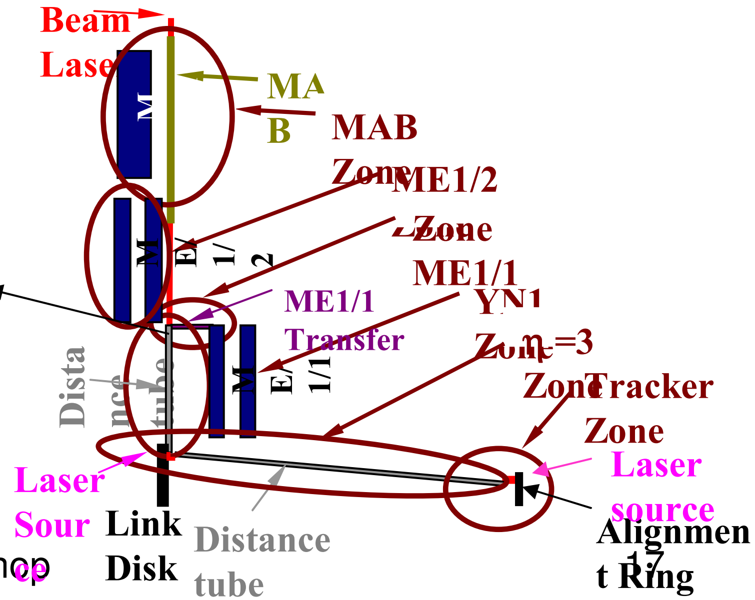
time

Link Hardware Alignment Results

- ME1/1 suffers and independent Z displacement from the endcap of 3 mm towards the IP
- Same behaviour observed in both phases of Magnet Test
- Comparison of global results in good agreement with photogrametry performed over the alignment systems.

Phase I **Phase II**





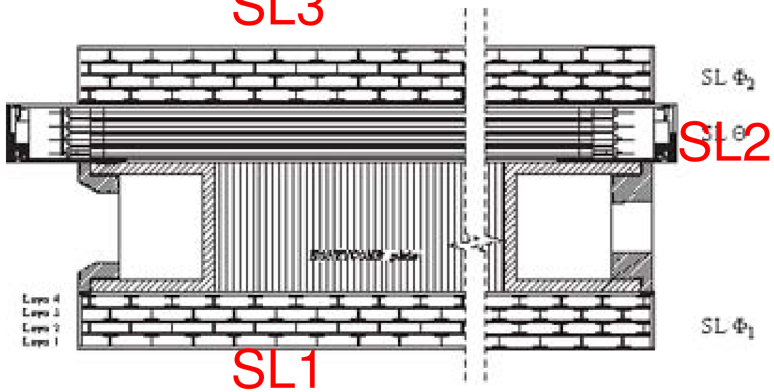
Survey & Offline alignment

- Complementary approaches to alignment were performed during the magnet test
  - Test alignment tools and software
  - Test alignment with tracks algorithms
  - Crosscheck results with hardware alignment systems
    - Still in a very preliminary stage in some cases
- Available information
  - Survey measurements
    - Internal geometry of chambers
    - Position of chambers in wheels
    - Alignment system components
  - Quality control measurements
    - Internal geometry of chambers
  - Tracks

Internal alignment of chambers

- **DT Chambers: Alignment of internal layers**
  - **Aim: to provide the internal geometry of DT chambers**
  - **Each chamber has three Superlayers (two for phi measurement and one for theta)**
    - **Each superlayer contains four layers**
  - **There are different sources of information**
    - **<u>Survey</u>: Provide information about the relative position and orientation of superlayer 2 and 3 with respect to superlayer 1**
    - **<u>Quality control measurements</u>: Provide information about the displacement in the Phi direction of the layers inside a Superlayer**
    - **<u>Tracks</u>**
  - **The three sets of information are crosschecked in order to see if they are compatible.**
    - **Excelent agreement!**

SL3

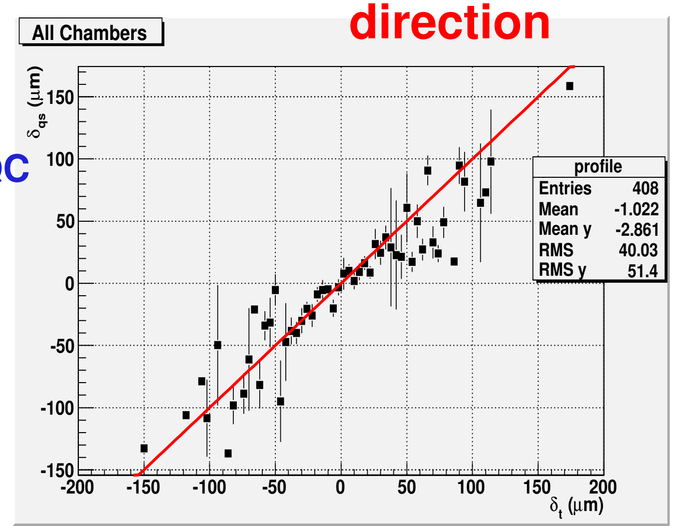


SL2

SL1

displacement in x direction

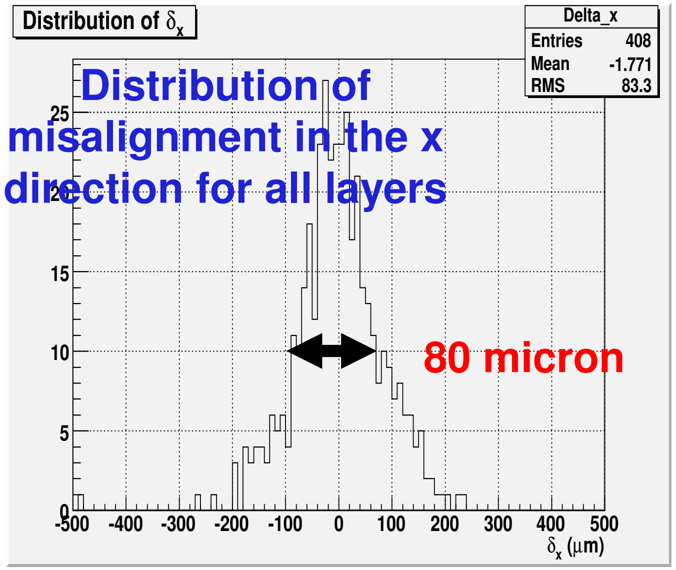
Survey+QC

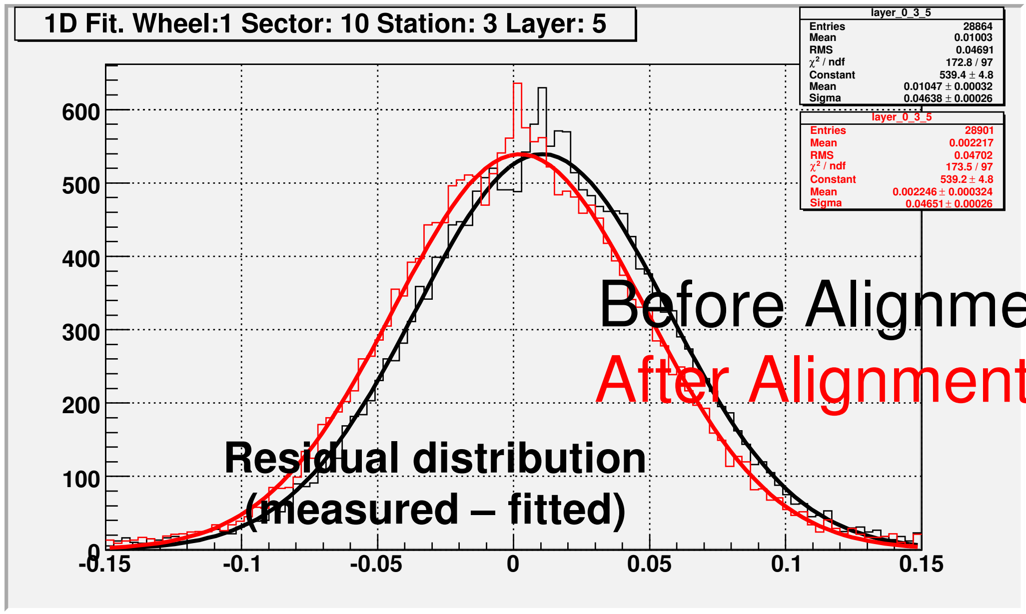


tracks

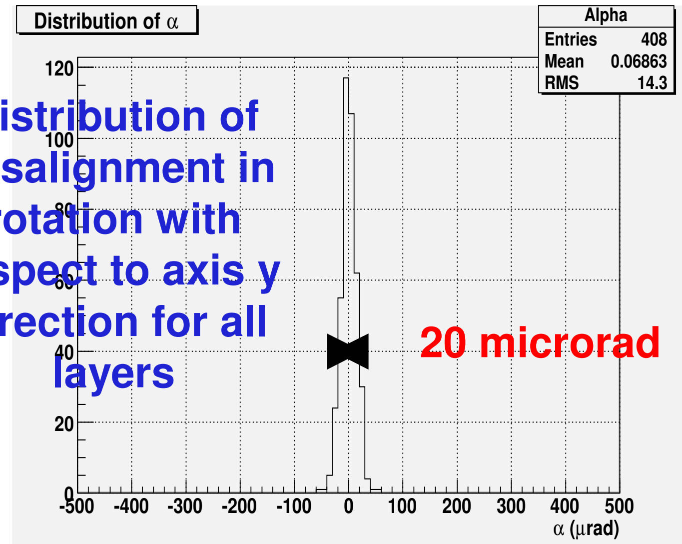
Internal alignment of chambers

- **A Blobel-like alignment with tracks is applied using survey and Quality Control measurements as additional information**
  - **Focus on the alignment of the 8 phi layers**
  - **Deviations of about 80 microns are found for displacement and of the order of 20 microrad for angles**
- Corrections are injected into CMS software, and residual distributions of MTCC runs are improved



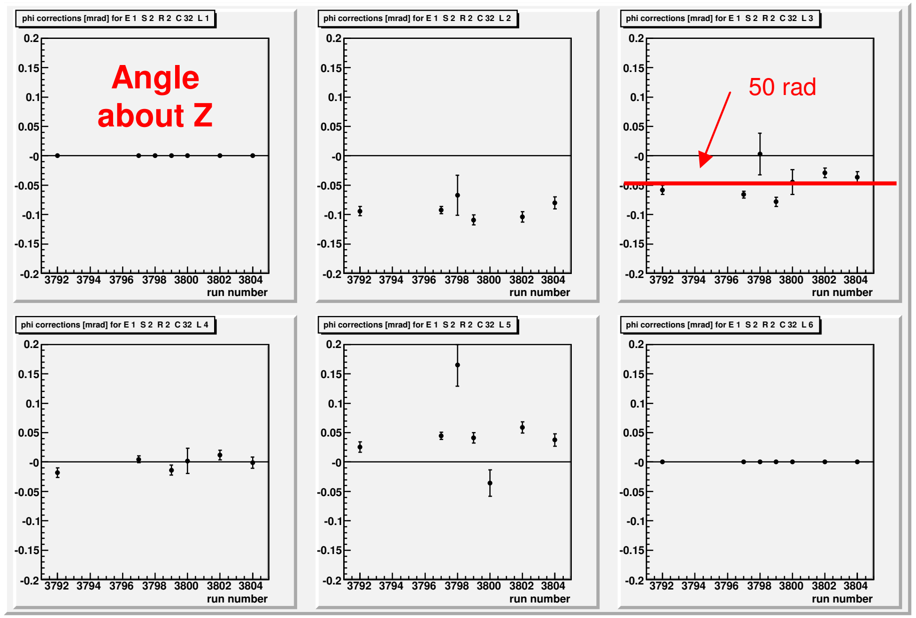


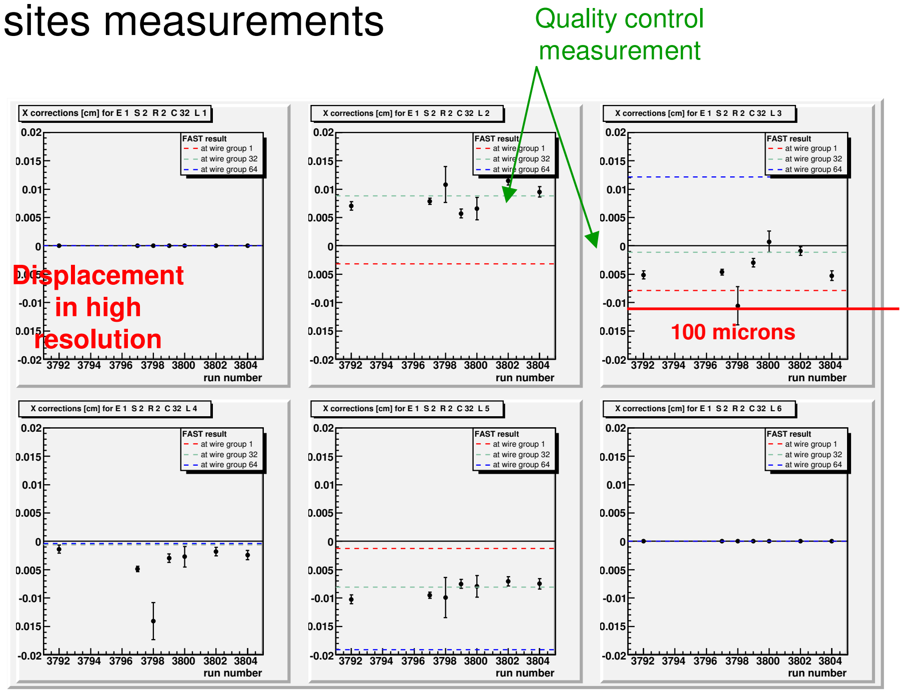
Workshop



Internal alignment of chambers

- CSC Chambers
  - Alignment with tracks is also performed over internal layers
  - Displacements of ~100 microns in the direction of high resolution and rotations of ~50 microrad about the Z axis are found (typically)
  - In good agreement with Quality control sites measurements

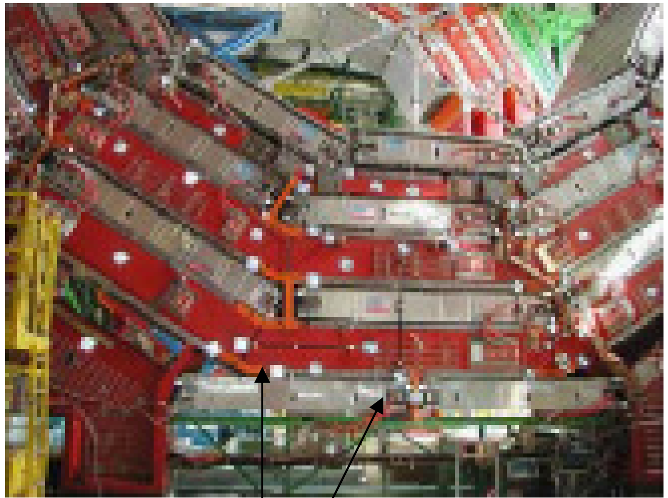




Six layers per chamber **Six layers per chamber**

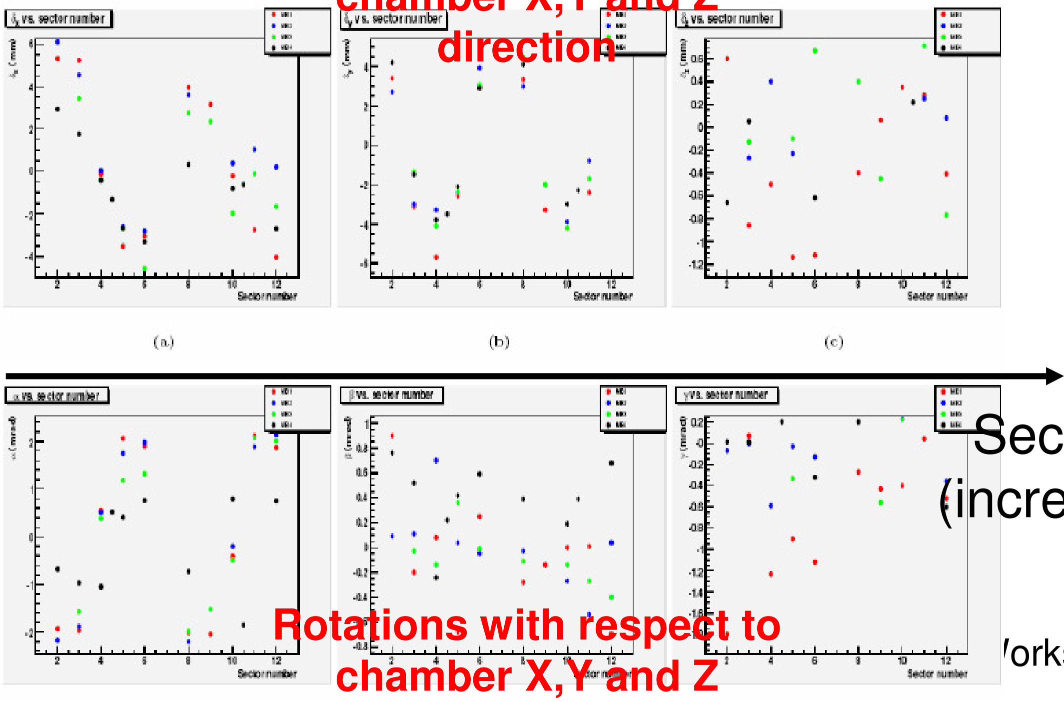
Survey of chambers & first geometry

- Photogrammetry of DT chambers was performed and processed to give a first MTCC aligned geometry
  - **Gravitational effect in wheels was detected (6 mm)**



Photogrammetry targets at muon chambers

Displacements in chamber X,Y and Z direction



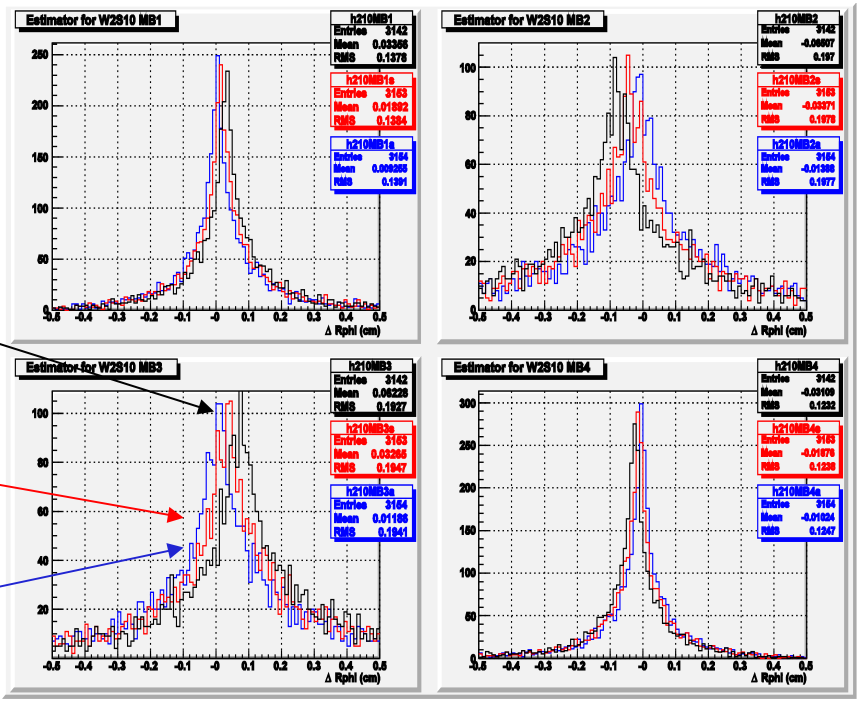
Sector number (increasing in phi)

Rotations with respect to chamber X,Y and Z direction

Survey of chambers & first geometry

- **MTCC runs were reconstructed using this geometry**
  - **A geometry database was created using software tools and with results provided by survey**
- Alignment with tracks algorithm was also applied
  - **Blobel-like approach for the phi coordinate**
  - **MTCC geometry showed displacements to the 1 mm level**
  - **After survey corrections displacements were corrected to the 250 microns level**
  - **Finally alignment with tracks reduced them to the 100 microns level**

The full software chain was tested with real data for the first time



Alignment estimator

Conclusions

- A hardware alignment system has been developed inside CMS in order to monitor the motions of tracking devices in a continuous way
- A fraction of the system was successfully instrumented and tested during the Magnet Test and Cosmic Challenge (2006)
  - The system performance was fine
  - Results actually reveal a bending and compression towards the interaction point (which was expected by finite element calculations on the magnetic force)
- Complementary survey and alignment with tracks are being performed and also tested at the MTCC
  - Applied for internal and external alignment of chambers
  - A first MTCC geometry provided
  - The full software chain was completed and tested successfully using real data.