CMS Muon System Alignment

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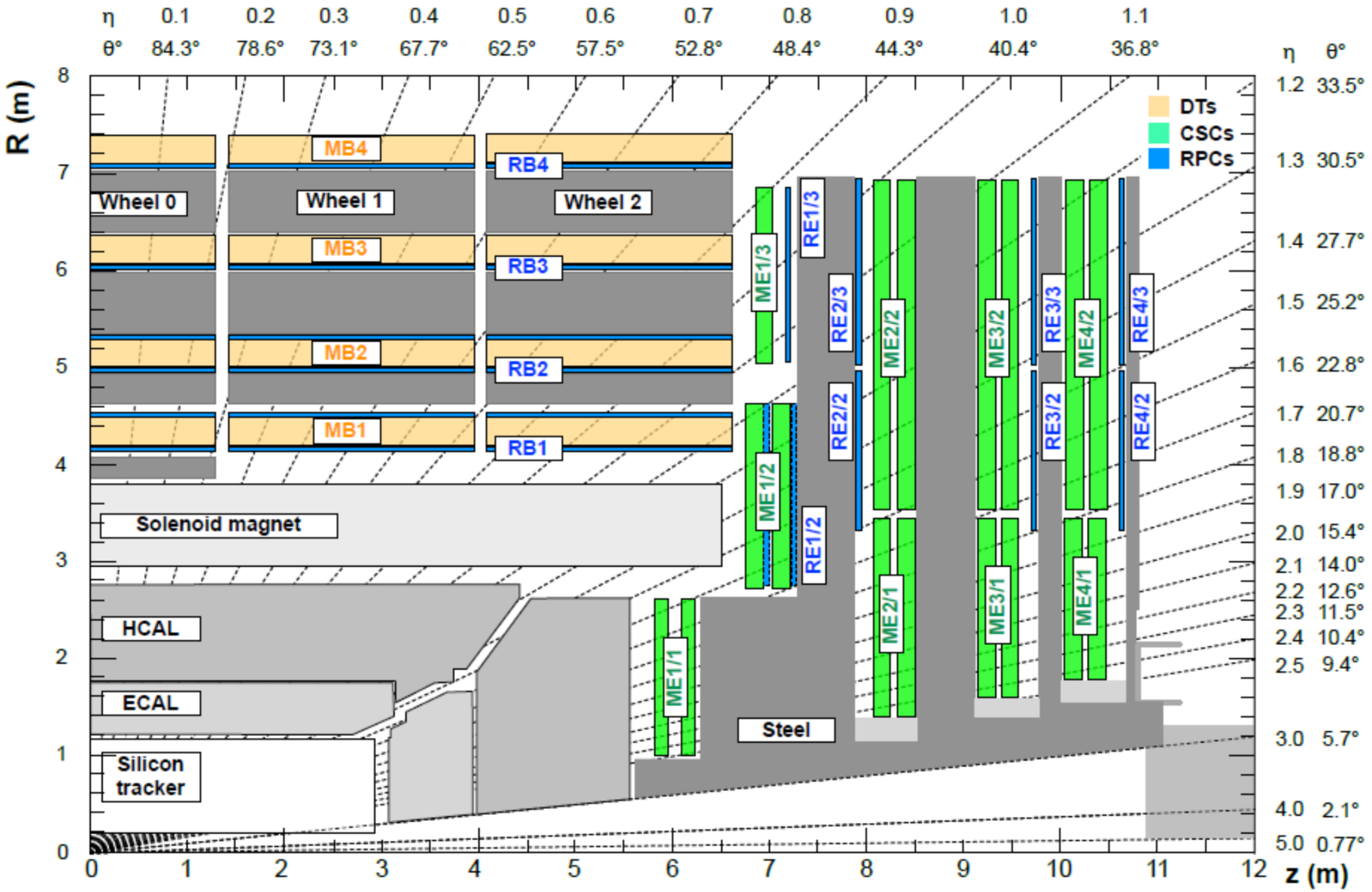
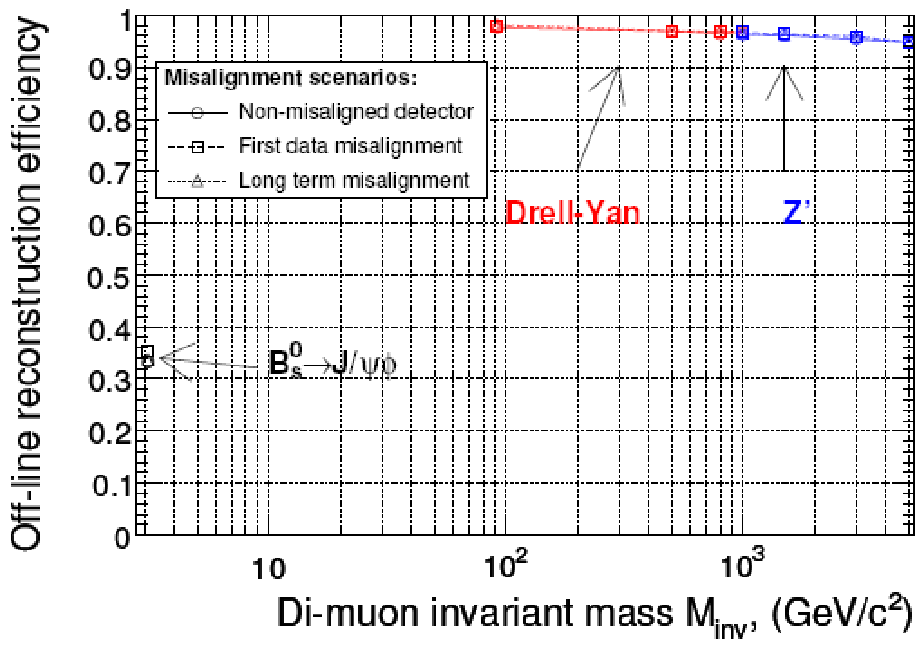
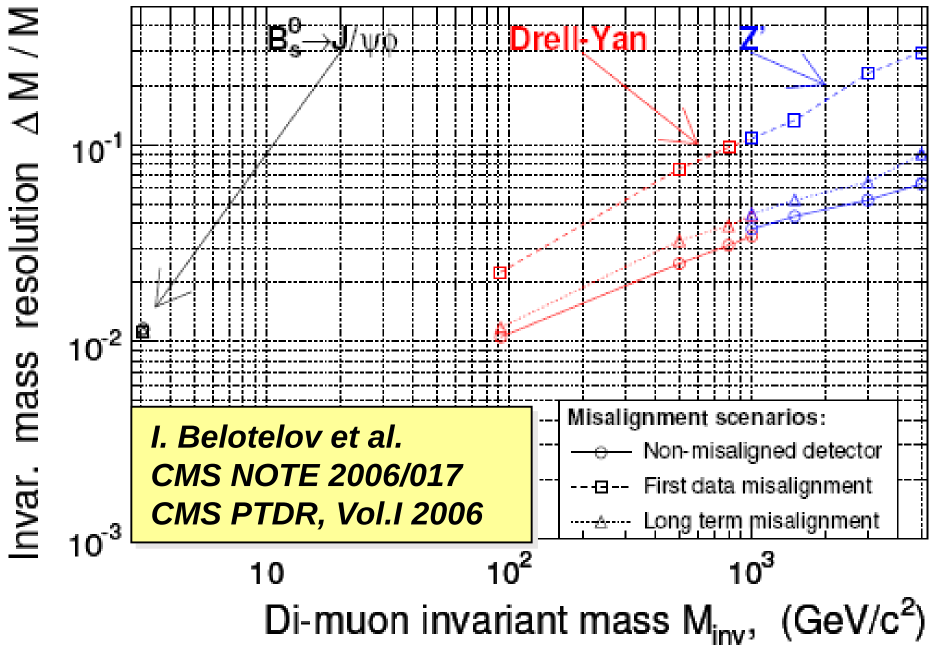
CMS Layout



CMS quadrant.
Muon system parts are painted in color.

Detector misalignment effects





Сильное влияние на разрешение и незначительное на оффлайн эффективность

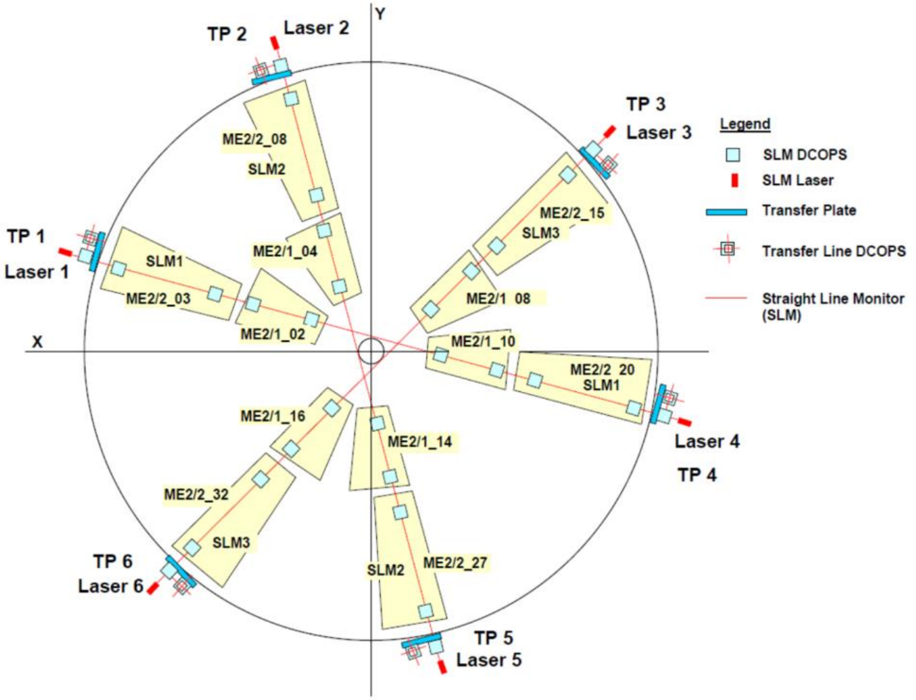
Alignment system description

The CMS alignment system consists of four independent parts. Three of these parts deal with the internal alignment of the tracker, DT, and CSC systems. A fourth part, called the Link system, locks all four parts together in a common reference frame, allows simultaneous monitoring of the barrel and endcaps, and monitors the displacements of heavy structures during the critical closing phase and during normal operation. The muon alignment system is designed to provide continuous monitoring of the muon chamber positions in the entire magnetic field range between 0T and 4T, and to meet the challenging constraints of large radiation and magnetic field tolerance, wide dynamic range, high precision, and tight spatial confinement. The system is based on a number of precise rigid structures independently supported by the tracker and by each yoke element. These structures contain optical sensors that look at the relative positions of chambers within the same yoke element. The connection among the structures located on the various yoke elements is possible only when CMS is closed, and is obtained through a network of laser beams, local distance sensors, and digital cameras.

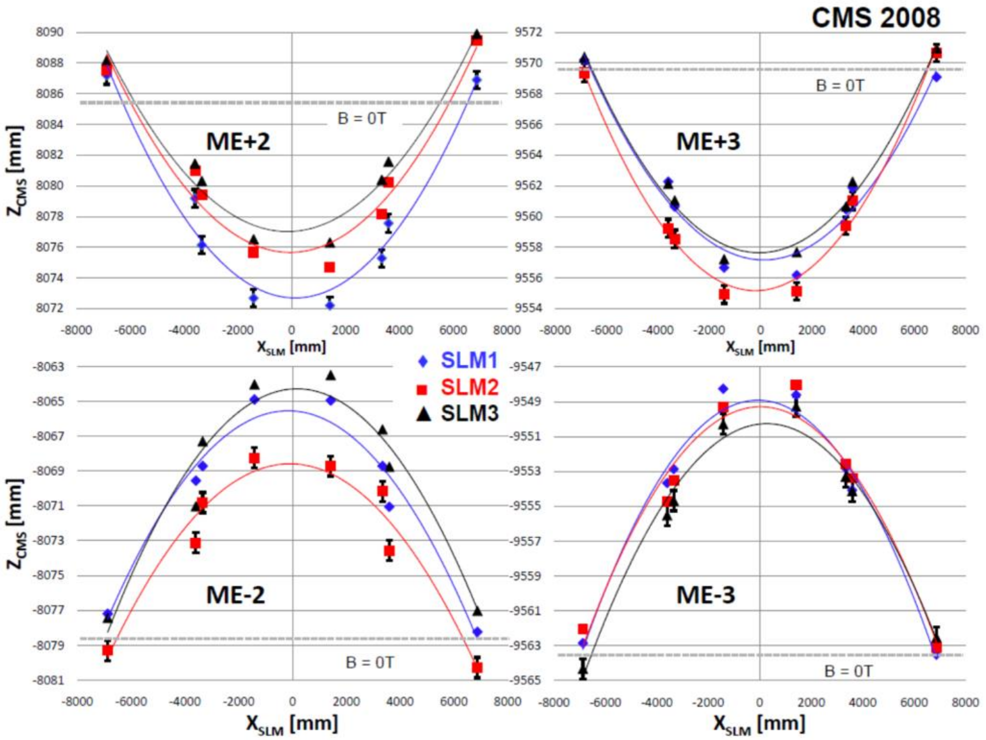
The aim of the muon alignment system is to provide position information of the detector elements with a precision comparable to the intrinsic chamber resolution.

(from CMS PAPER CFT-09-017)

Hardware alignment of endcap muon stations



Schematic *rφ* view of Straight-Line Monitors in the ME2 station. Locations of axial transfer lines running perpendicular to the plane and across endcaps are indicated. Optical sensors and other alignment components are also shown.



Yoke disk deformations at B = 3.8 T in ME2 and ME3 stations measured with straight-line monitors. Points shown correspond to positions of CSC alignment pins and are fitted with second order polynomials.

Results from 2010 JINST 5 T03019

Alignment of endcap muon stations with tracks

The reference-target algorithm:
The “reference-target” algorithm divides the tracking volume into two regions: a “reference” (the tracker), in which normal track-fitting is performed, and a “target” (the muon chambers), in which unbiased residuals are computed from the propagated tracks.

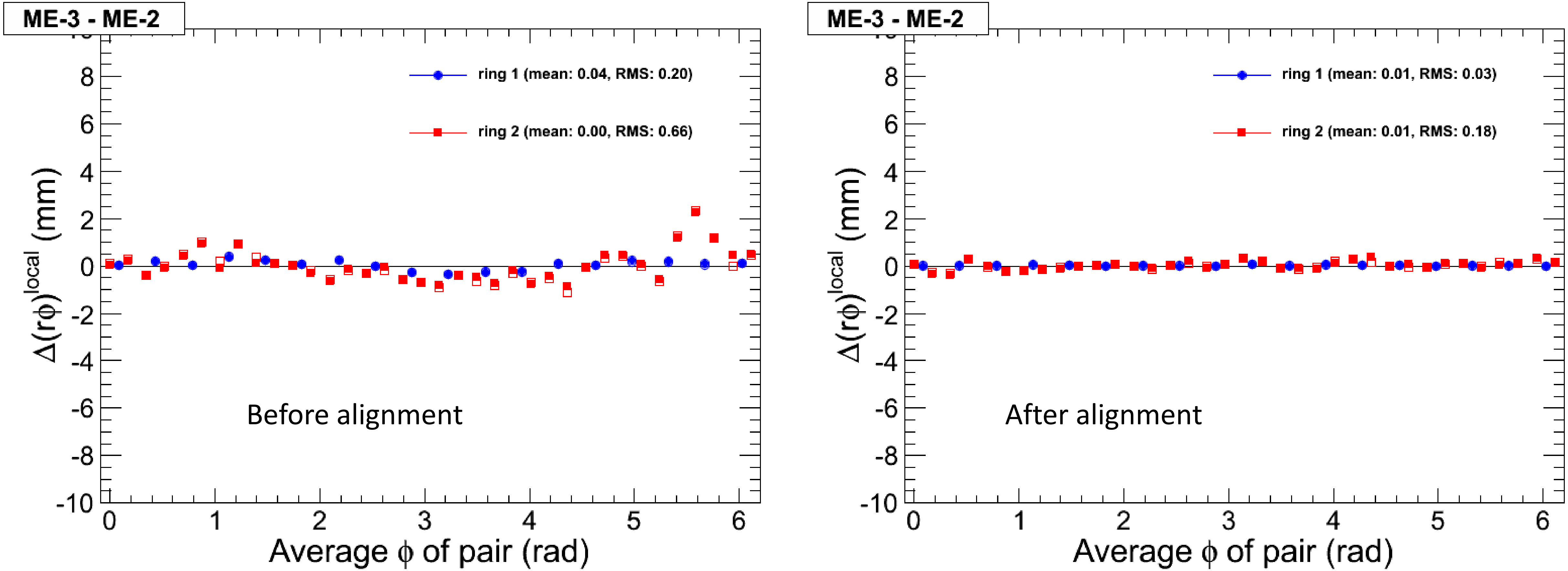
1.Select only “good” tracks to use for alignment

- transverse momentum: 30 GeV<$p_{\mathrm{T}}\ GLB$<200 GeV
- impact parameter w.r.t. beam spot position: Dxy<0.2
- number of hits in Tracker segment: $nhits\ in\ TK$>15
- normalized $\chi 2$ for Tracker segment: $\chi 2 n.d.f.$ <10

2.Propagate selected tracks to Muon system

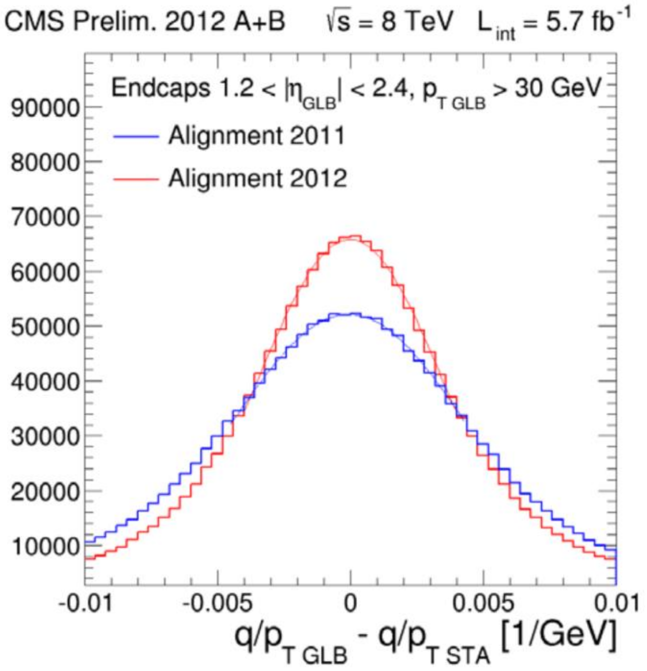
- number of CSCs with hits per track: ≥2
- number of hits per aligned chamber:
  - in CSC: $\boldsymbol{nhits\ CSC} \geq \mathbf{5}$

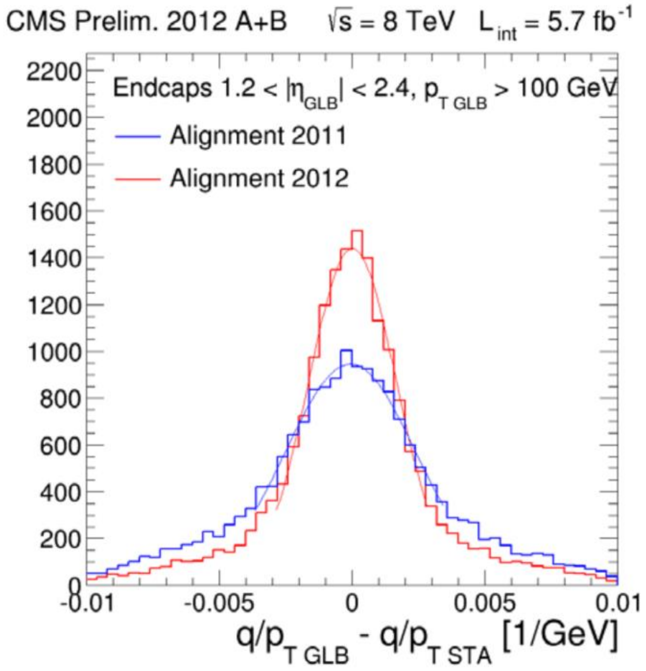
Compare segment positions in chambers in two neighboring disks



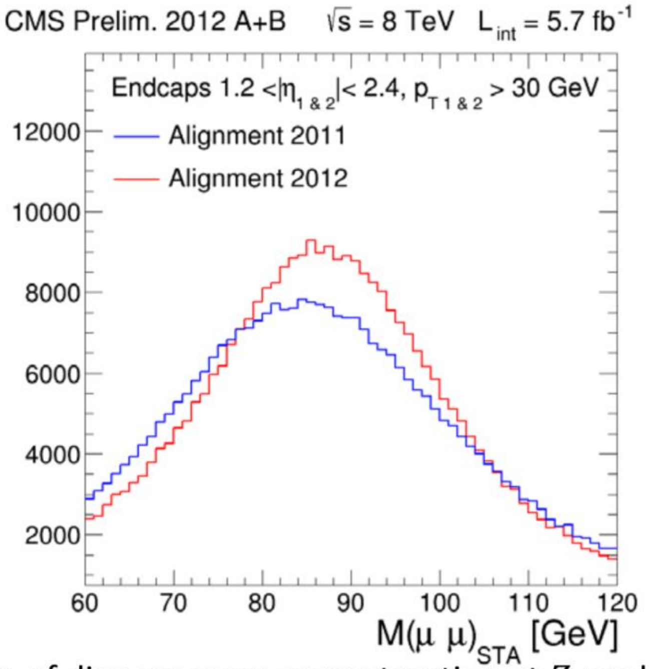
Distance between track segments in two stations of endcap. Plots are from report of Yuriy Pakhotin at CSC weekly meeting, 20 February 2013.

Improvement of alignment of endcap muon stations





pT Resolution in Endcaps $(1.2<\eta<2.4)$



Resolution of dimuon mass reconstruction at Z-peak
(Use **STA+STA** pair of muons with pT>30 GeV)

Improvement of alignment in 2012. Plots are from report of Yuriy Pakhotin at CSC weekly meeting, 20 February 2013.

Alignment of layers within CSC

$$\Phi = \sum_{i=1}^{N}\sum_{j=0}^{5}\left(\frac{(X_{ij}^{t} - X_{ij}\cos(\alpha_j) + Y_{ij}\sin(\alpha_j) - \Delta x_j)^2}{\sigma_{xj}^2} + \frac{(Y_{ij}^{t} - Y_{ij}\cos(\alpha_j) - X_{ij}\sin(\alpha_j) - \Delta y_j)^2}{\sigma_{yj}^2}\right)$$

$$X_{ij}^{t} = a_i z_j + b_i$$

$$Y_{ij}^{t} = c_i z_j + d_i$$

$$\begin{cases} \Phi'_{\Delta x_j} = 0 \\ \Phi'_{\Delta y_j} = 0 \\ \Phi'_{\alpha_j} = 0 \end{cases}$$

From first two equations we derive Δx и Δy and substitute them into third one.

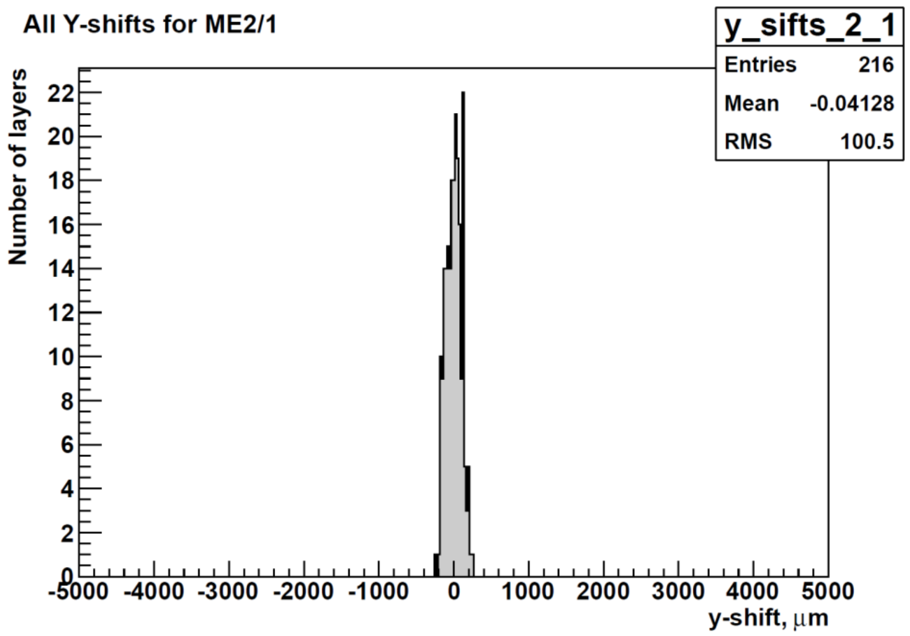
For each 6-hit segment we find parameters of track projection for both X and Y coordinates.

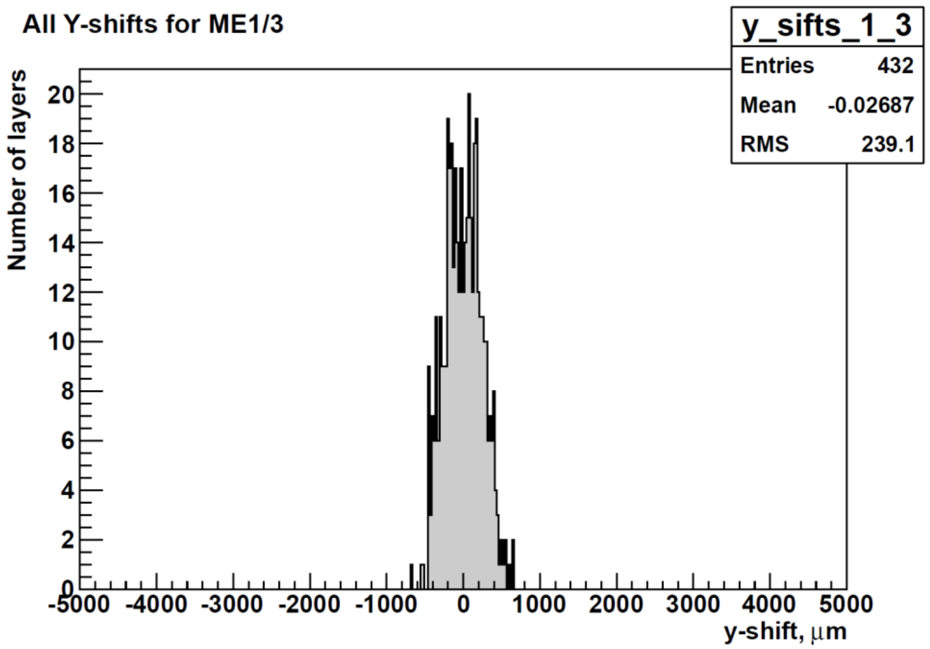
As a result, for each layer we obtain trigonometric equation of following kind:

$$A[\cos^2(\alpha_j) - \sin^2(\alpha_j)] + B\cos(\alpha_j)\sin(\alpha_j) + C\cos(\alpha_j) + D\sin(\alpha_j) = 0$$

Here equation coefficients are some sums of raw measurements.

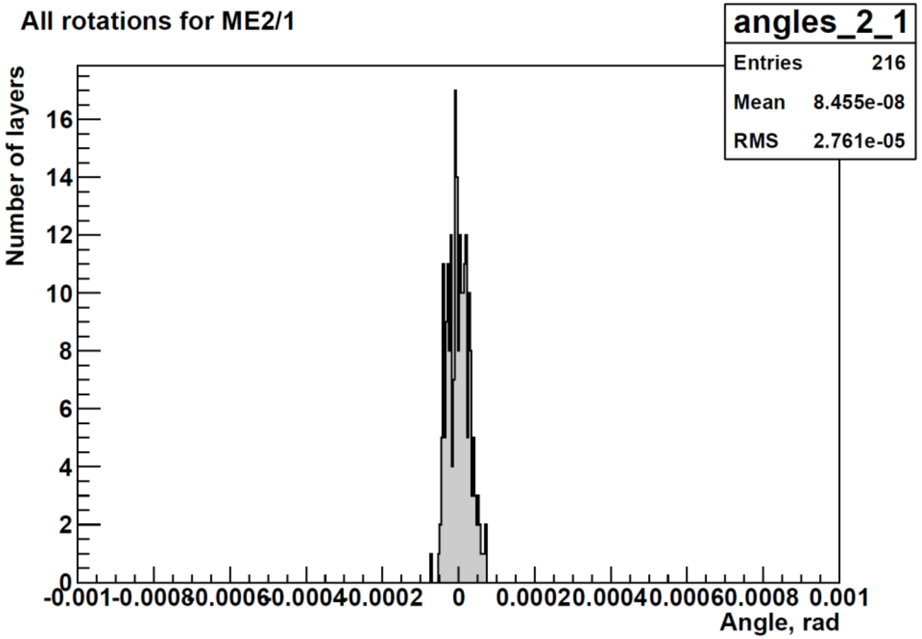
Y-shifts result

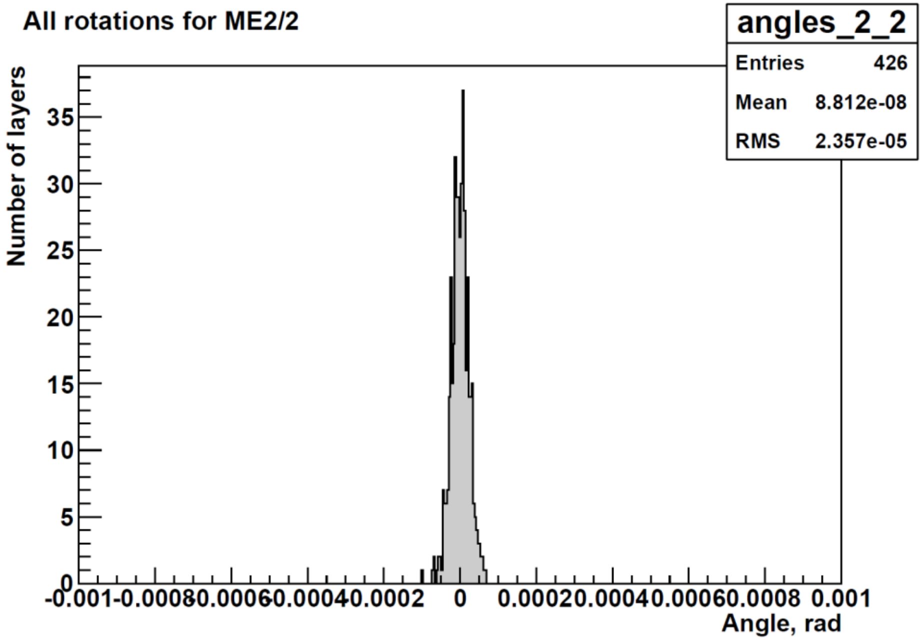




Local Y-shifts for ME2/1 and ME1/3 stations for 2010AB data.
Y-shifts are negligible comparing to wiregroup width (few cm). All other stations have similar pictures.

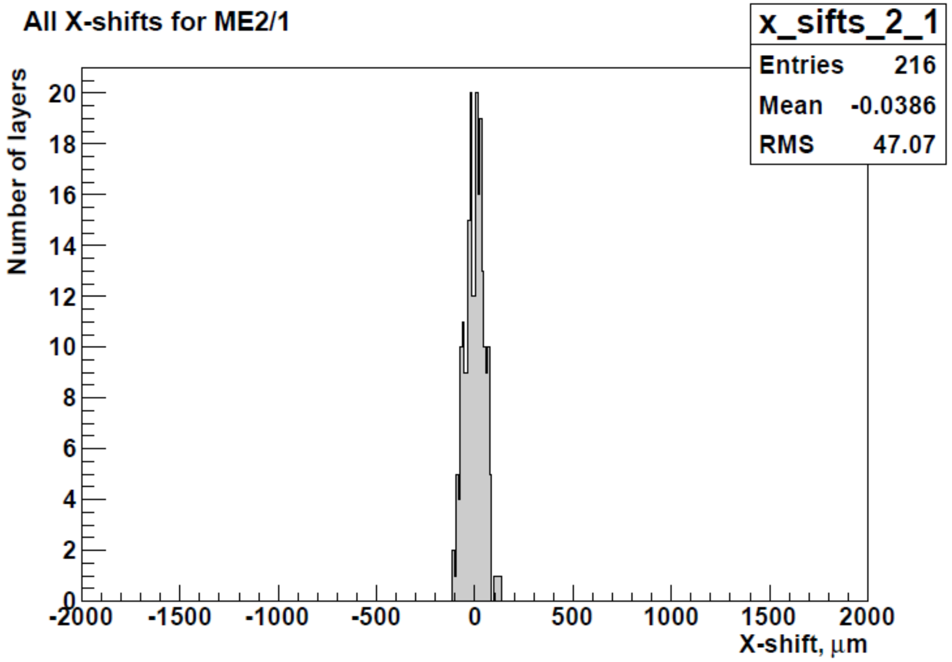
Plane rotations



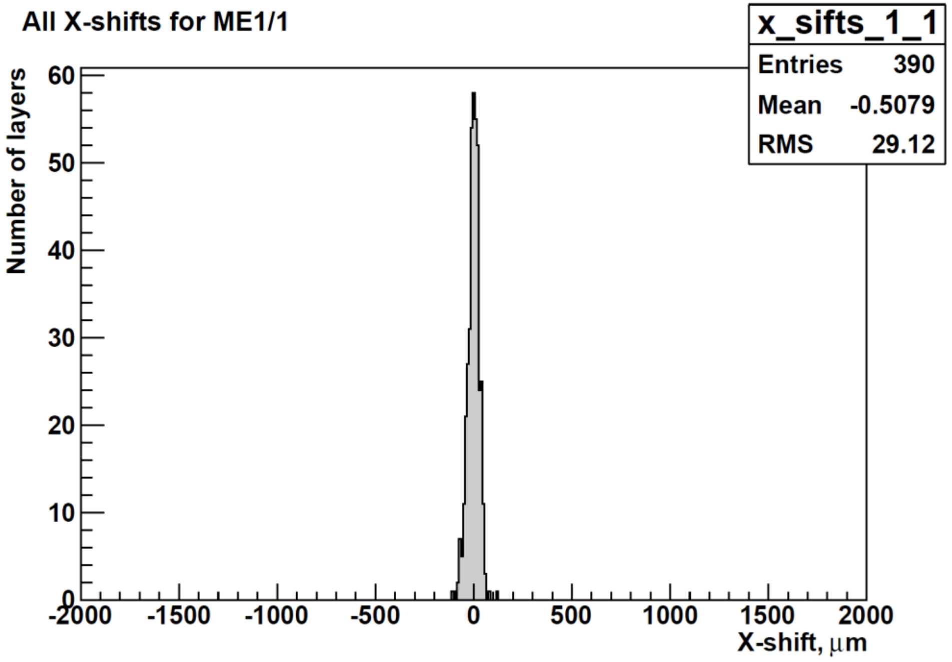


Rotations of CSC planes for ME2/1 and ME2/2 stations. All other stations have similar pictures. Angles of rotations are rather small. 0.0001rad*1000mm=0.1mm

X-shifts



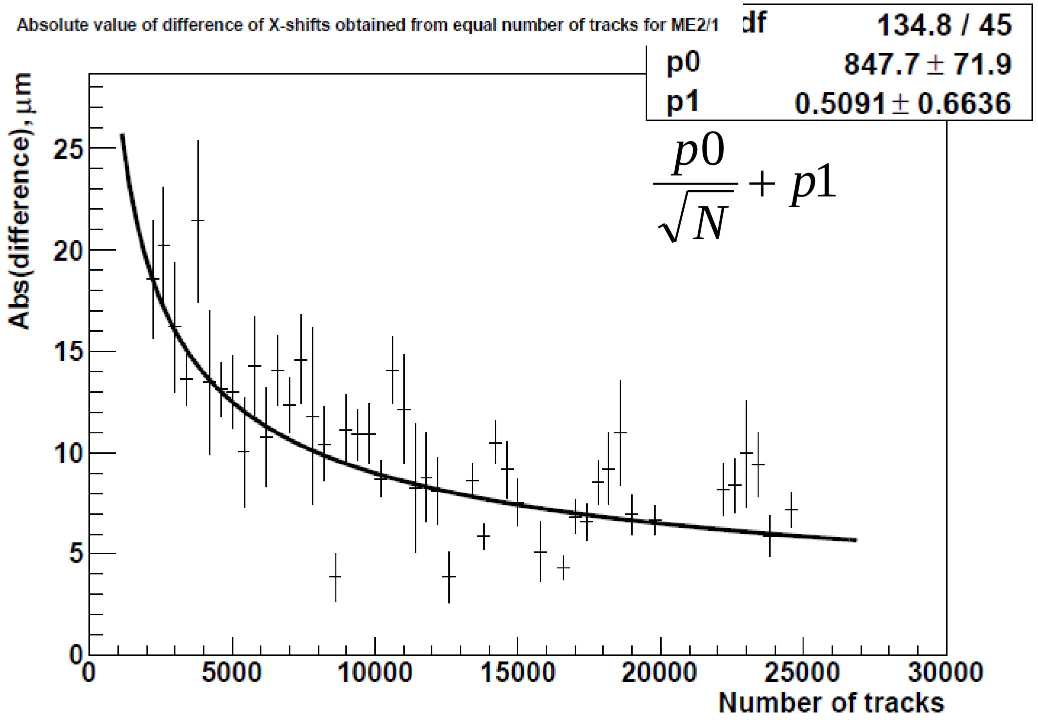
ME2/1



ME1/1

RMS of plane displacement along precise coordinate is less than 50μm. Other stations have similar results.

Influence of statistics on precision



Influence of the statistics on precision of X-shift estimation for ME2/1. Other stations have similar pictures.

Two equal size sets of tracks were taken. The absolute value of the difference between two obtained X-shifts is histogrammed (TProfile).
Each point is the average absolute value of the difference between two results at the corresponding number of tracks in a set.
The precision of result increases as inverse square root of number of tracks.
Note, that for 5000 tracks we have about 12μm error (up to 20μm for other stations).

Conclusion

- CSC position in global reference frame is defined with hardware alignment and then further refined with track-based alignment algorithm
- CMS cathode strip chambers alignment have significant influence on muon momentum resolution
- Layers within CSCs are well aligned (chamber manufacturing quality is good)