The CMS Tracker Alignment in p-p Collisions

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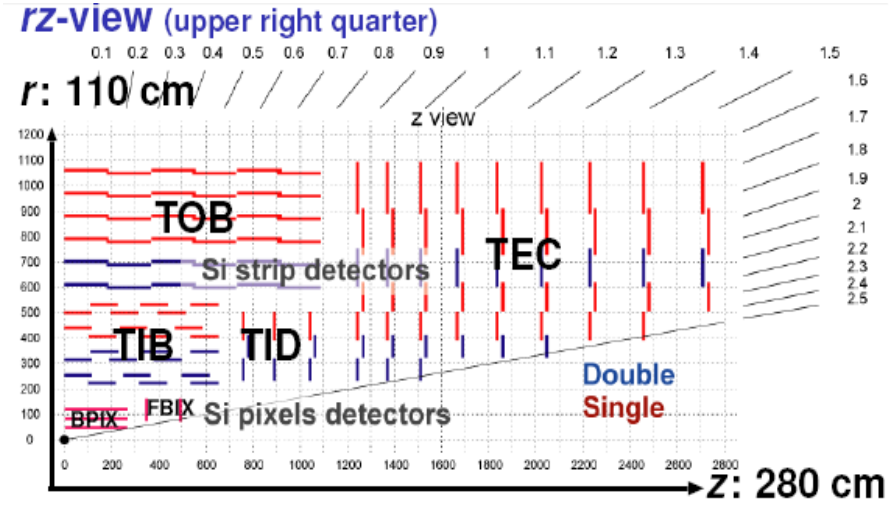
The CMS Tracker



All Silicon

- 1440 Si pixel modules
- 15148 Si strip modules
  - 24244 strip sensors in total
  - Strips generally measure *r*-φ direction

Alignment Challenge: 200k parameters (taking into account that sensors are not flat)

The Track Based Alignment Using Millipede II Algorithm

Global Fit Approach

- Simultaneous fit of all parameters: shifts, track parameters etc.
- Minimise Sum of Squares of Residuals:

$$\chi^2(p,q) = \sum_{j}^{tracks} \sum_{i}^{measurements} \left(\frac{m_{ij} - f_{ij}(p,q_j)}{\sigma_{ij}} \right)^2$$

- Provides alignment solution in one step: All correlations from tracks are taken into account

Features: Computing Aspects

- Optimized for speed
  - Iterative MINRES, CPU intense parts parallelized using OpenMP
- Stand alone Fortran program, Reading binary input
- Optimized for memory space

Alignment Strategy & Results During 2011 pp Collision ($1fb^{-1}$)

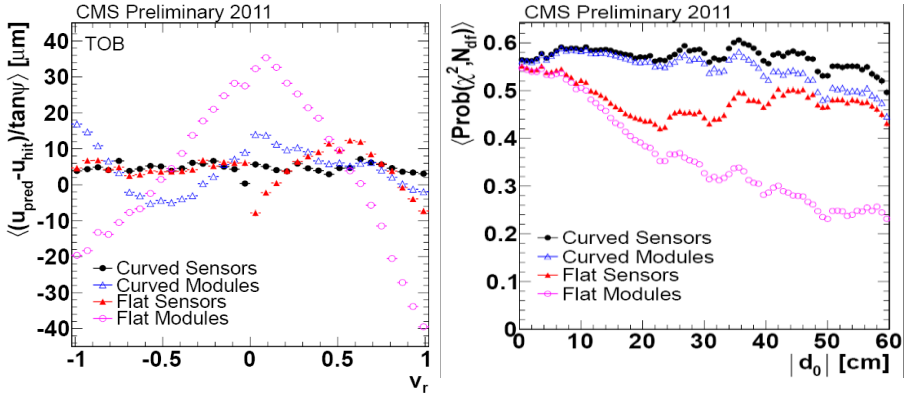
Determination of Module Surface Deformation

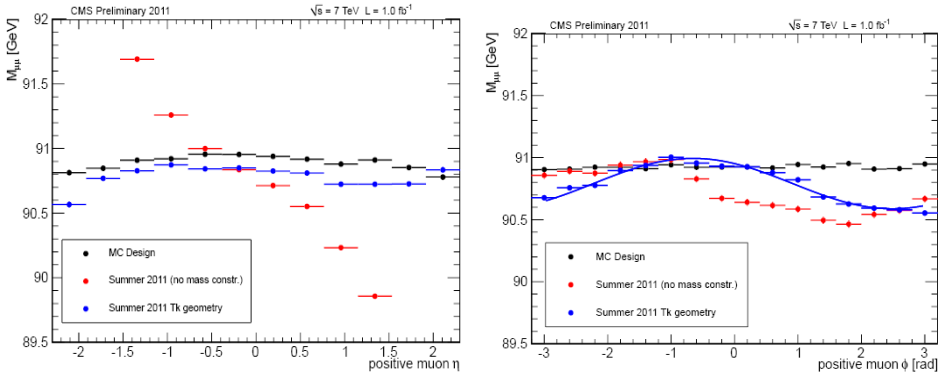
- Sensor surfaces can be bowed
- Kink within two daisy chained sensors
  - Typical kink is 2 α^{δ} = 1.6 mrad
  - Larger effect than sensor bow
- Alignment: Determination of "bows" & "kinks"
- Residual *du,* track slope *tan ψ* :
  - map residual perpendicular to sensor, validated by *dw = du/ tan ψ*

Comparison of alignments with different module shape parameterizations

The Weak Mode Issue

- Minimising residuals can be insensitive to certain global distortions
- These weak modes might affect track parameters significantly
- Twist cured adding external information from Z → mummu decay
- Re-parametrise muon tracks by common fit object: 9 instead of 2x5 parameters
- Add Z mass as virtual measurement in alignment contributes in removing the twist dependence





2011 CMS Tracker Alignment has provided desired precision for physics analysis discoveries