

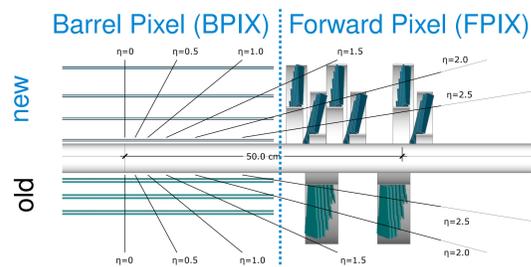
Alignment of the Upgraded CMS Pixel Detector

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Matthias Schröder for the CMS Collaboration

CMS Pixel-Detector Upgrade in 2017

- Goal: maintaining and improving tracking performance at higher luminosities

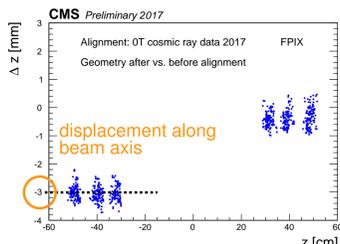


- One more barrel layer, one more forward disk
- Inner layer closer to interaction point: better impact parameter resolution
- Lower material budget
- Detector and service in same mechanical envelope

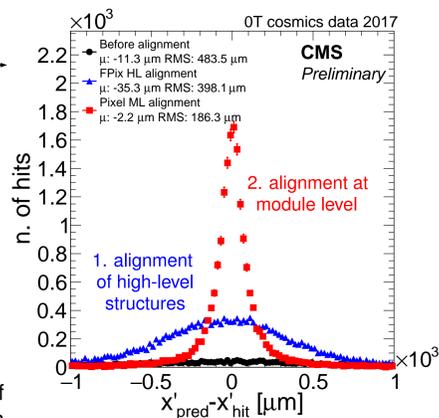
- Position resolution $\sigma_{\text{pos}} = \underbrace{\sigma_{\text{intrinsic}}}_{\mathcal{O}(10)\mu\text{m}} \oplus \sigma_{\text{alignment}} \rightarrow$ **need $\sigma_{\text{alignment}} \lesssim \mathcal{O}(10)\mu\text{m}$**

1. FPIX-Alignment with Cosmic-Ray Data

- Mis-alignment of 3 mm along beam axis w.r.t. initial geometry corrected

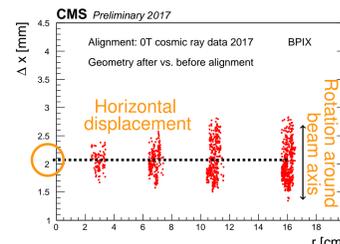


- Greatly improved local precision (width of track-hit residual distribution) after each iteration

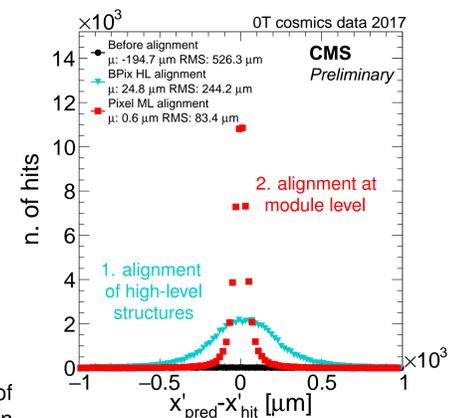


2. BPIX-Alignment with Cosmic-Ray Data

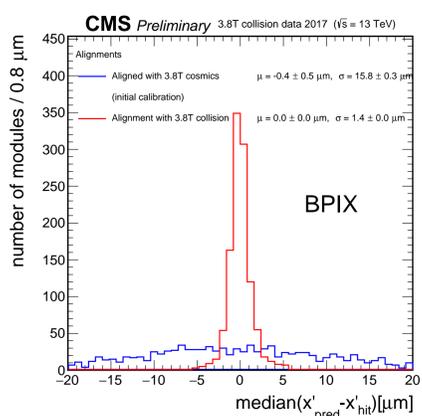
- Mis-alignment of 2 mm in horizontal plane w.r.t. initial geometry corrected



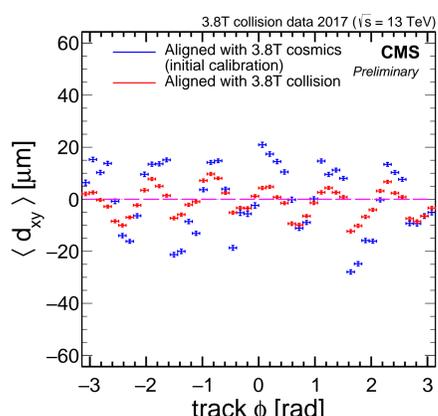
- Greatly improved local precision (width of track-hit residual distribution) after each iteration



3. Pixel-Alignment with Cosmic-Ray + Collision Data

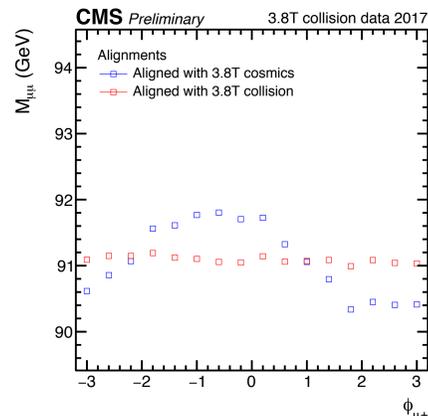


- Distribution of median track-hit residuals in each module
 - Mean at 0 for ideal alignment
 - Width quantifies alignment precision (includes statistical component)
- Great improvement after alignment with collision data

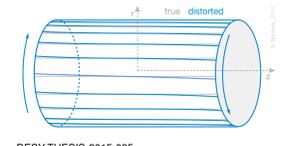


- Average impact parameter $\langle d_{xy} \rangle$ relative to primary vertex
 - Expect $\langle d_{xy} \rangle = 0$ for ideal alignment
- 6-fold structure in transverse plane
 - Imprint of inner-layer structure
 - Bias at level of intrinsic hit-resolution

4. Full-Tracker Alignment with Cosmic-Ray + Collision Data



- "Weak modes" in alignment: coherent mis-alignments that leave χ^2 invariant



- Can lead to systematic error in track-momentum measurement
- Controlled e.g. with adding mass constraint in $Z \rightarrow \mu\mu$ events
- Alignment eliminates ϕ dependence of reconstructed Z-boson mass

Summary

- Pixel-detector alignment at $\lesssim \mathcal{O}(10)\mu\text{m}$ level required to meet physics goals
- Precision achieved with track-based alignment procedure using cosmic-ray and collision data

[1] CMS Collaboration "Alignment of the CMS silicon tracker during commissioning with cosmic rays" JINST 5 T03009 (2010)
[2] CMS Collaboration "Alignment of the CMS tracker with LHC and cosmic ray data", JINST 9 P06009 (2014)
[3] <https://twiki.cern.ch/twiki/bin/view/CMSPublic/TkAlignmentPerformancePhaseIStartUp17> (2017)
[4] <https://twiki.cern.ch/twiki/bin/view/CMSPublic/TkAlignmentPerformanceVertex2017> (2017)