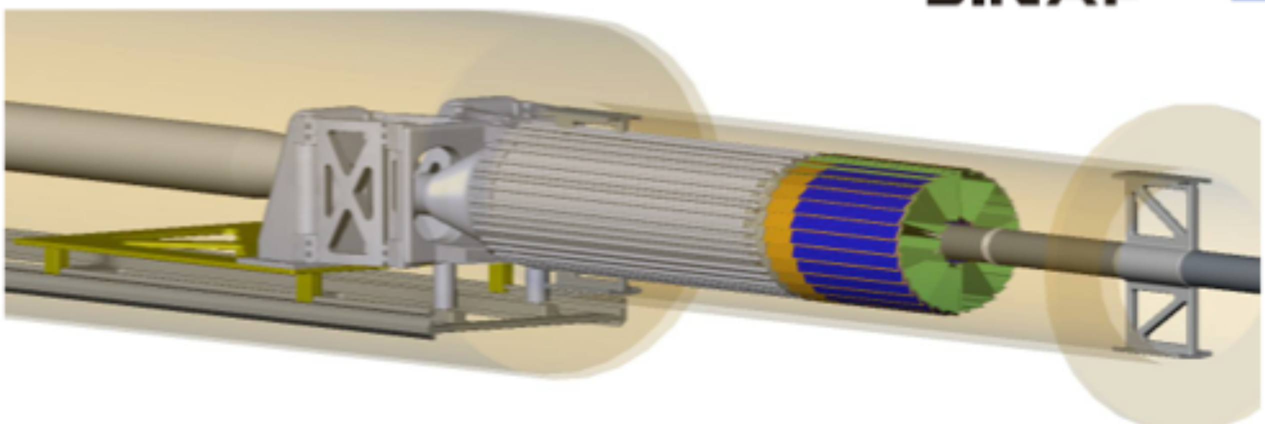

Survey/Alignment Calibration of STAR HFT Pixel Detector

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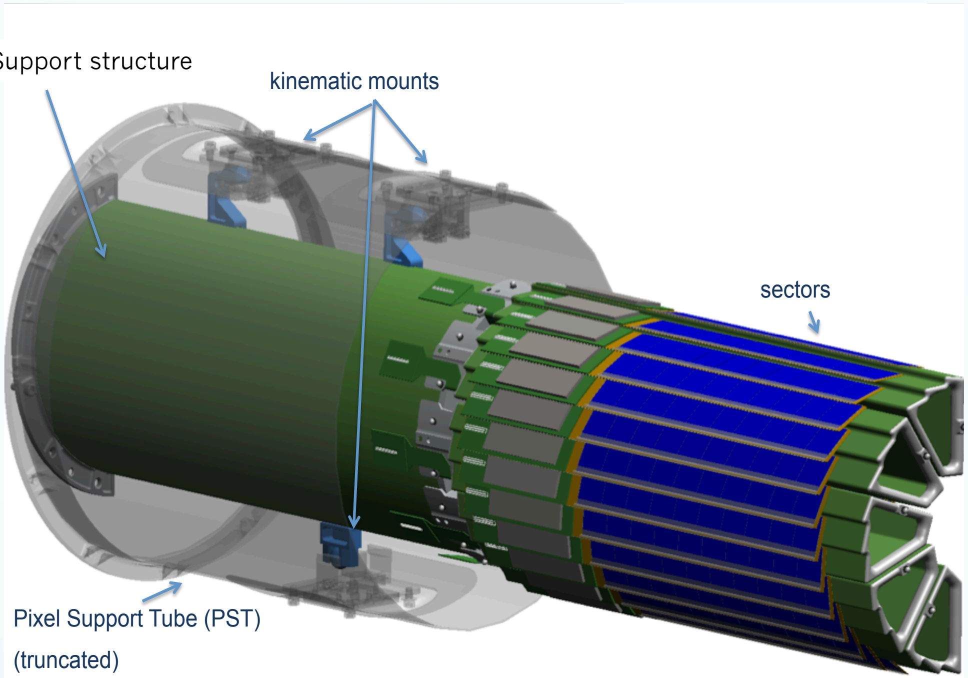
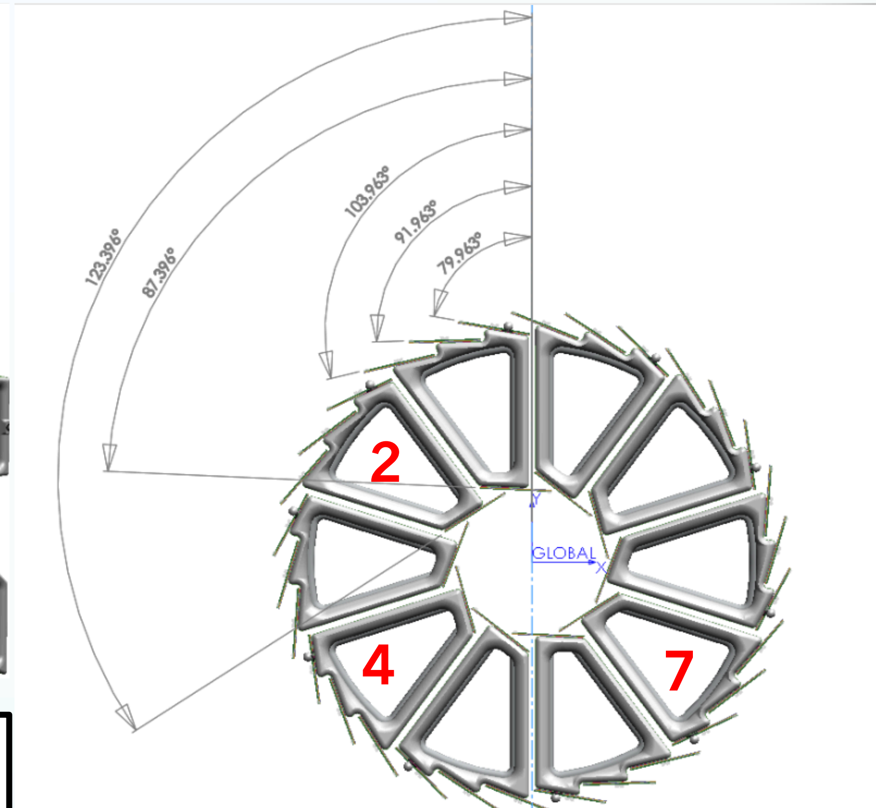
DNP 2013 Fall Meeting ,Newport News,VA

Outline

- *Introduction to STAR HFT pixel detector*
- *Survey and Track Based Sector Alignment*
- *Summary on Alignment Status*

The Pixel Prototype





Pixel detector

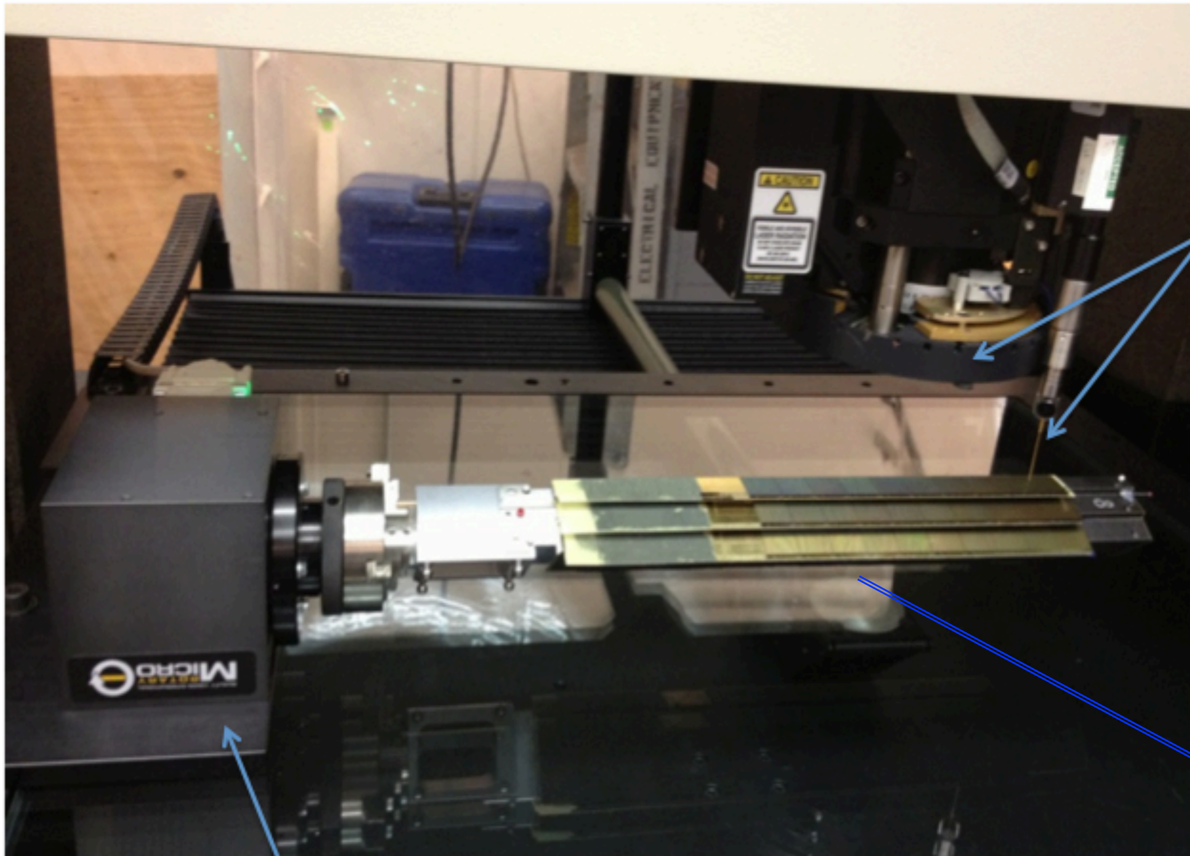
- ✓The innermost sub-detector of HFT
- ✓10 sectors
- ✓3 ladders at outer layer and 1 ladder at inner layer for each sector
- ✓~356M 20.7×20.7μm pixels
- ✓Resolution ~ 10 μm

In Run-13, three sectors (sector 2,4,7) together with full supporting set have been successfully put into STAR detectors as pixel detector prototype

Pixel Sector Survey Work

- The goal of the survey is measuring within the hit error any deviation for each component from their designed position
- Survey work has been done deep into the sensor level
- Survey information was written to pixel geometry database

Pixel Detector Sector Survey



vision and stylus probes, both with μm level precision

A Coordinate Measuring Machine is specifically used for the sector survey.

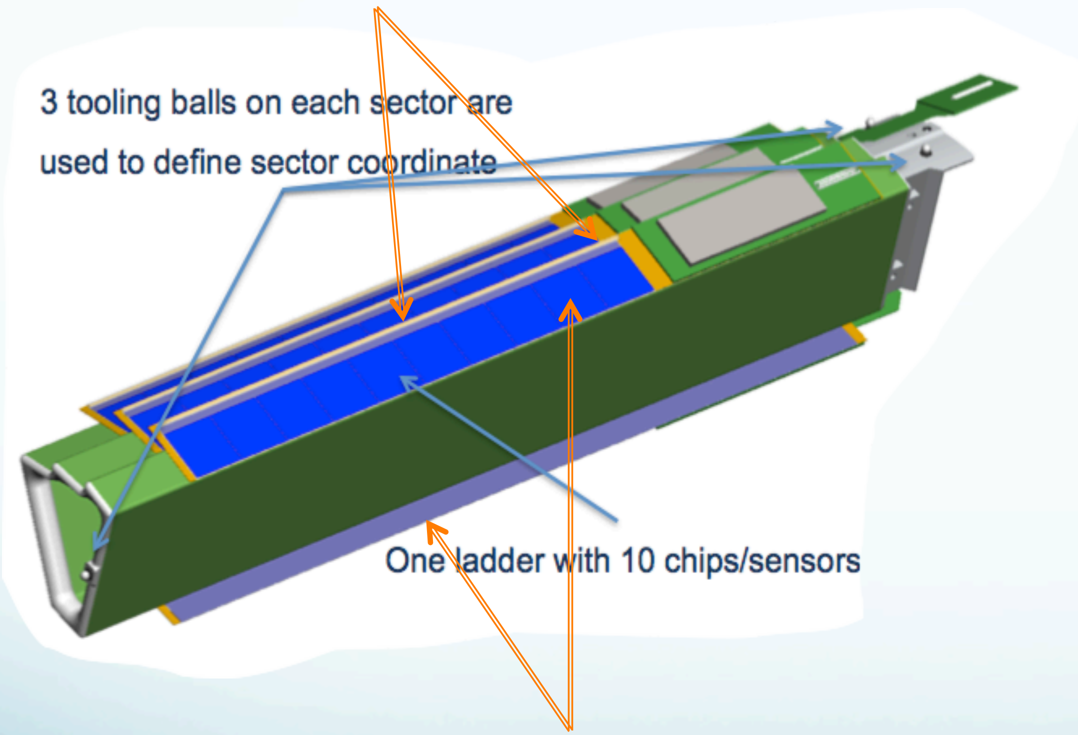
Pixel Sector

In order to probe different ladder surfaces, the rotary head rotates the sector to different angles

Sensor Level Measurement Precision ～10 micron

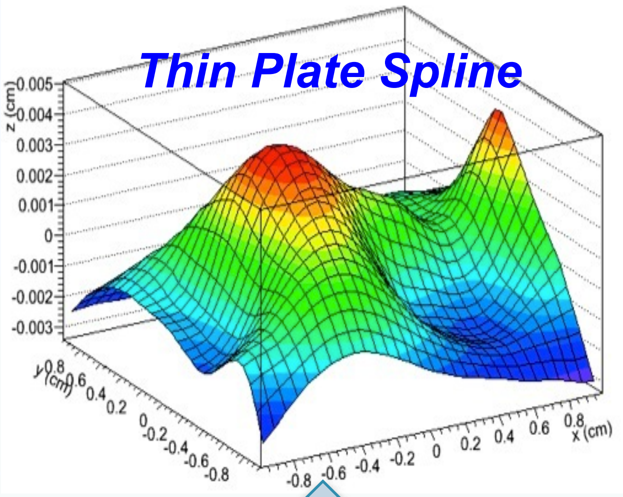
Sector Survey of Pixel Detector

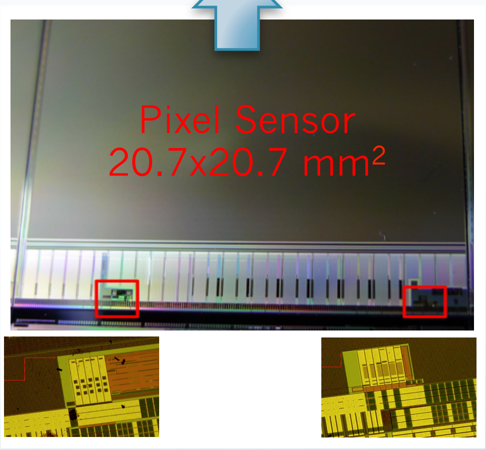
Sensor to Ladder alignment → By survey



Ladder alignment in sector→ By survey

Please refer to F.Videbaek and J.Bouchet's talks



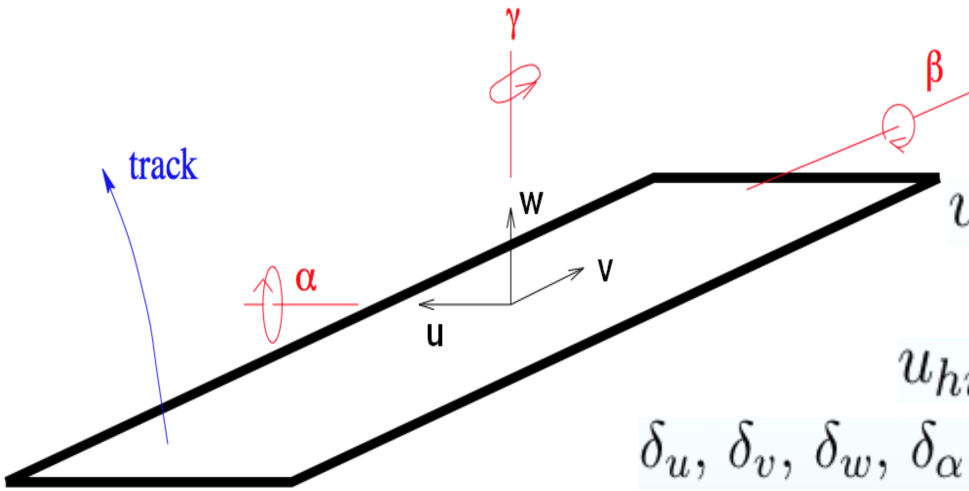


Sensor surface → By survey

(Survey Repeatability < 10 μ m)

Track Based Alignment Procedure

The sector alignment is based on minimization of the residuals between the track projection and the hit positions of all detectors starting from initial sector internal survey information.



Sensor Local Coordinate System

- $u,\ v,\ w$ - Track prediction in local system
- $t_u,\ t_v$ - Track direction tangents
- $u_{hit},\ v_{hit}$ - Hit position on measurement plane
- $\delta_u,\ \delta_v,\ \delta_w,\ \delta_\alpha,\ \delta_\beta,\ \delta_\gamma$ - Misalignment parameters

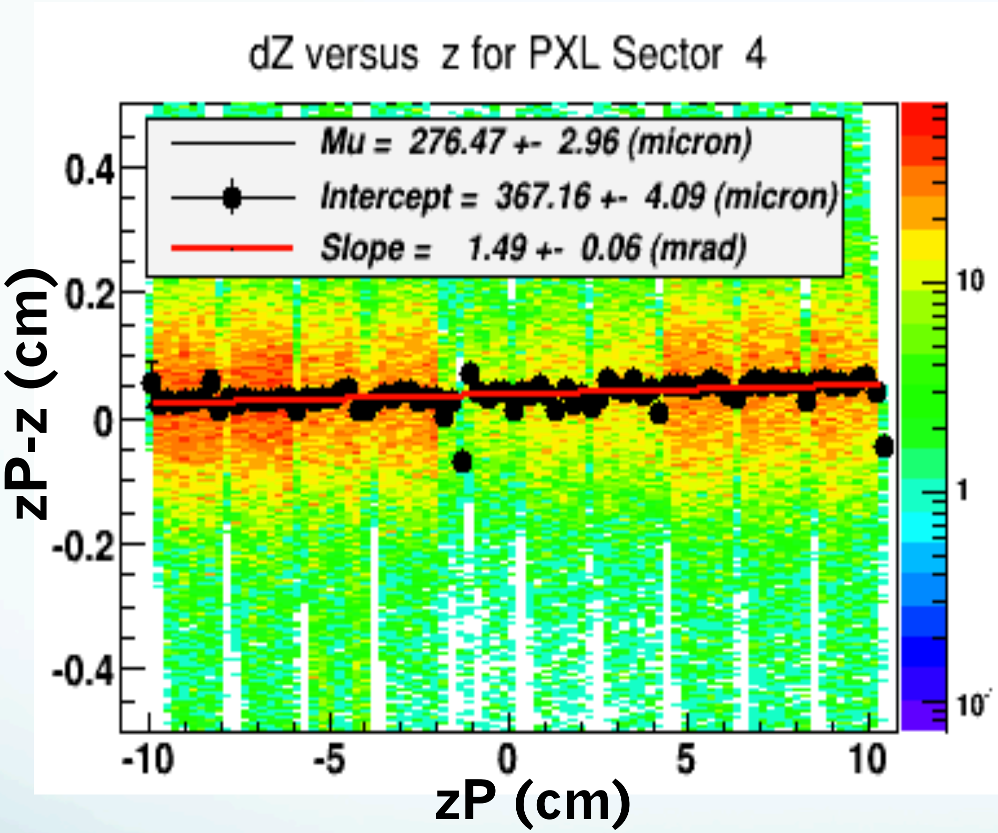
Residual

$$u - u_{hit} = \delta_u + t_u(\delta_w + v\delta_\alpha + u\delta_\beta) + v\delta_\gamma$$

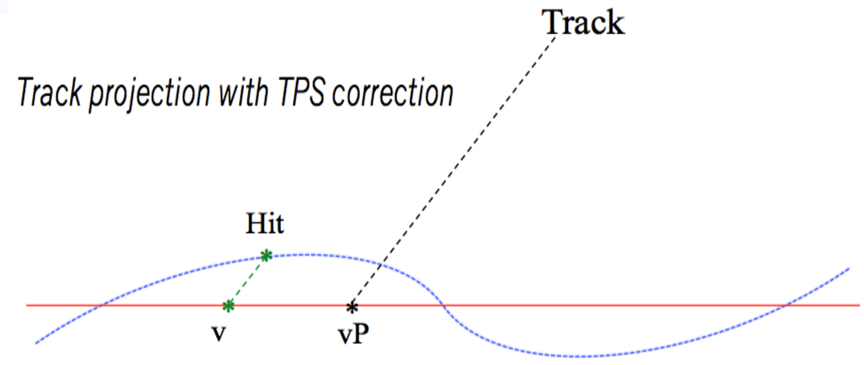
$$v - v_{hit} = \delta_v + t_v(\delta_w + v\delta_\alpha + u\delta_\beta) + u\delta_\gamma$$

Similar algorithm in global coordinate system

Shift Alignment



Global Residual along Z : dZ = zP-z



- **Hit global coordinates : x, y, z**
- **Hit local coordinates : u,w,v**
- **Track projection position after TPS correction:**

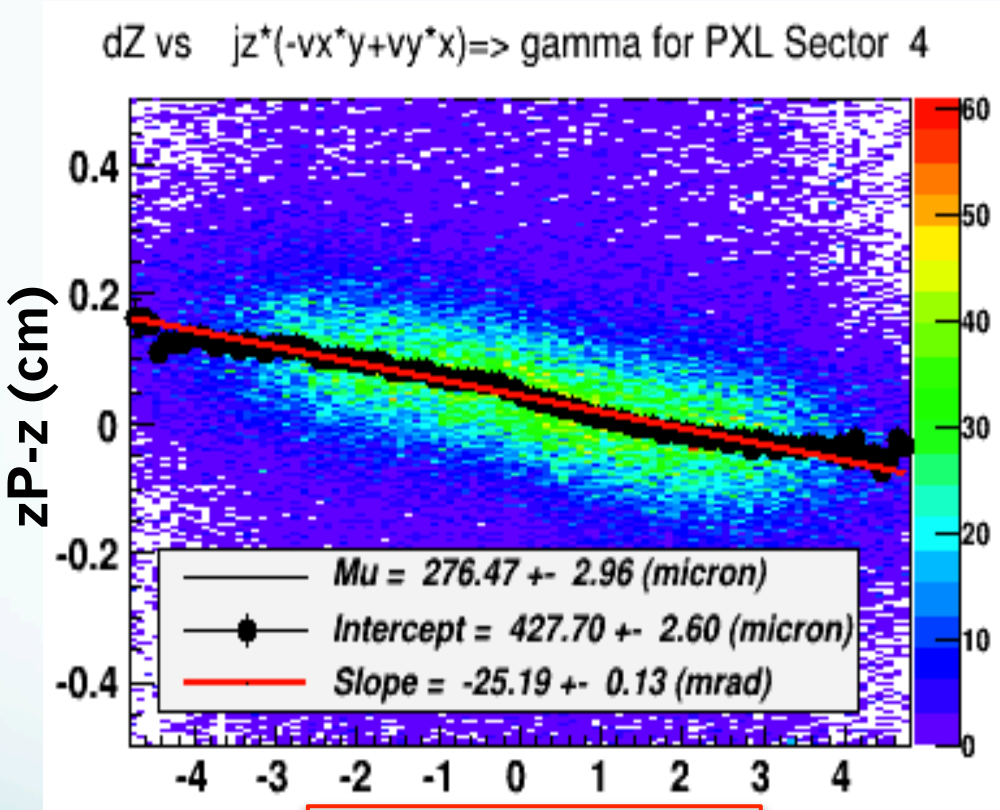
  Global Coordinate: xP, yP, zP

  Local Coordinate: uP, wP, vP

Example - Pixel Sector 4
Shift alignment Parameters

dX (micron)	dY (micron)	dZ (micron)
−815.5+-4.5	−1730.0+-9.0	367.2+-4.1

Rotation Alignment



jz*(-vx*y+vy*x) (cm)

Matrix Element in Global Alignment Algorithm

Track – Pixel Hit Based Alignment Algorithm

Global Coordinate System

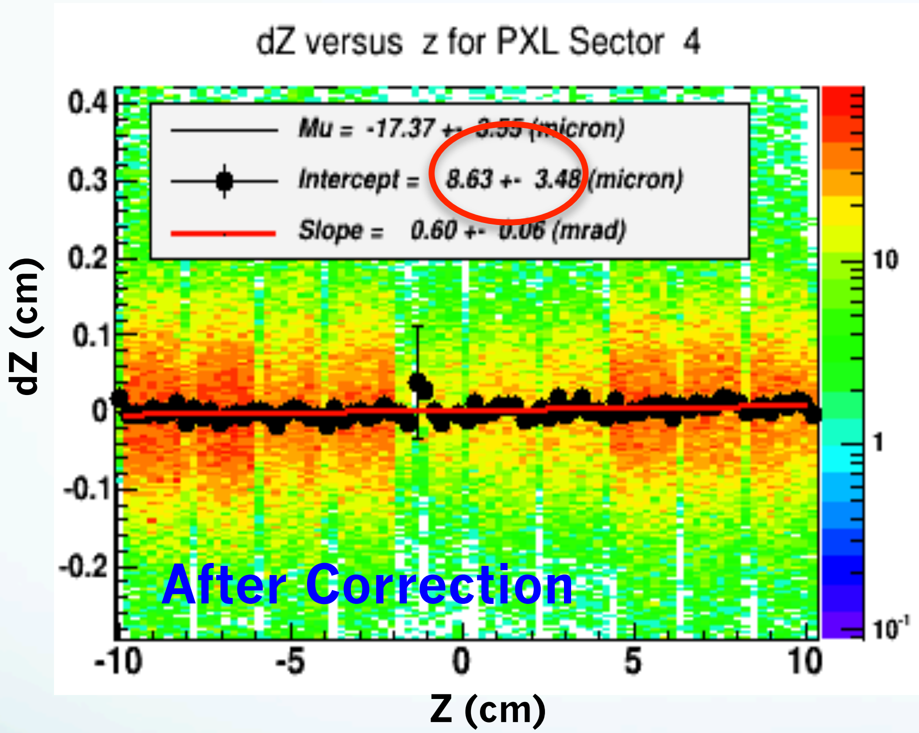
$$\vec{X}_{hit} - \vec{X} = \partial\vec{X}/\partial\vec{\Delta} \times \vec{\Delta} \equiv \mathbf{G} \times \vec{\Delta}$$

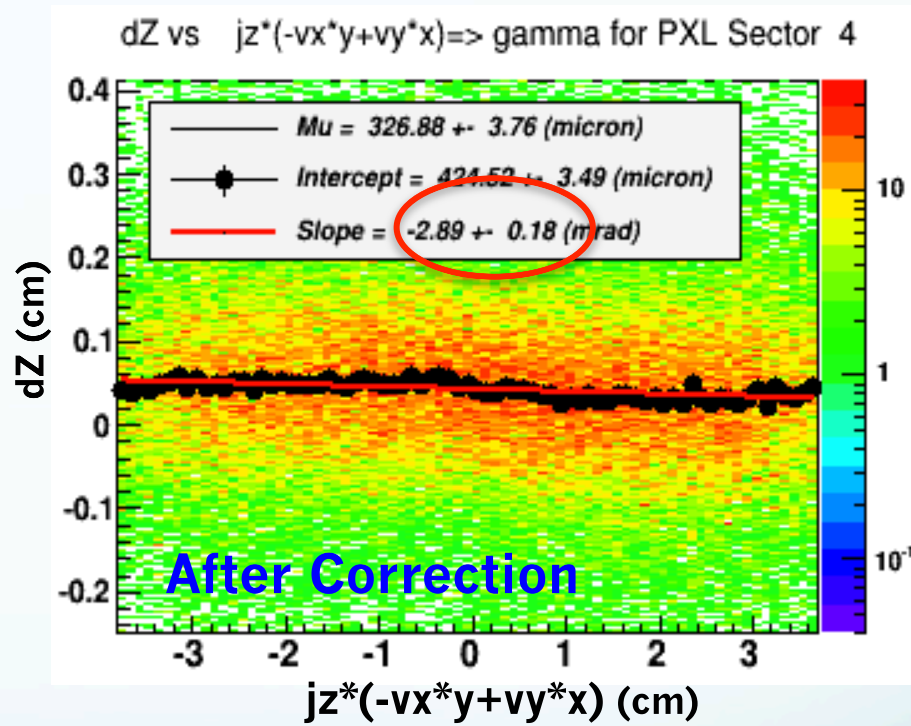
(See Backup for Detail)

Example - Pixel Sector 4 Rotation alignment Parameters

alpha mrad	beta mrad	gamma mrad
1.20+-0.02	2.20+-0.02	-25.19+-0.13

After Correction – Pixel Sector



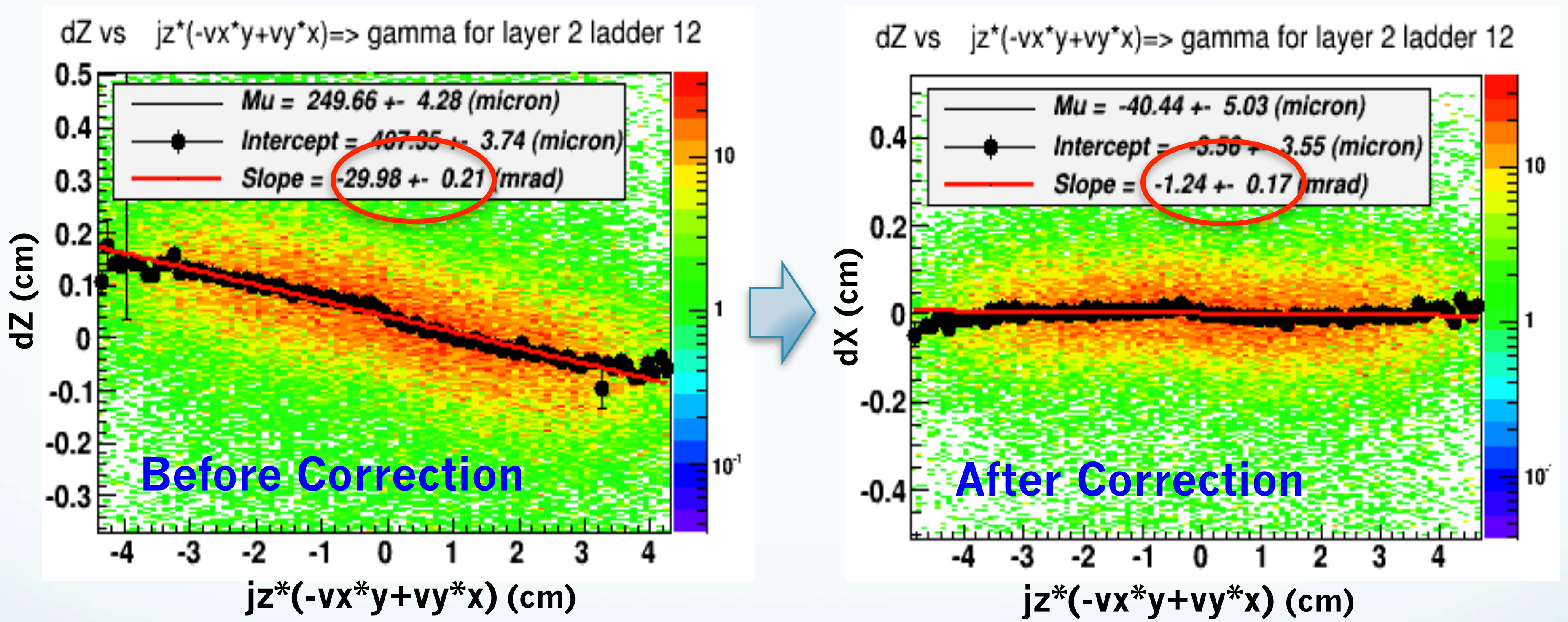


After correction, significant reduction of misalignment can be seen

Shift along global Z (Left) and Gamma rotation (Right)

Figures are shown for Sector 4 after correction

After Correction – Component Ladder



After correction, significant rotation correction can be seen in the component ladder (layer2-ladder12) of the sector 4

Summary- Pixel Alignment Status

I. Survey work of under sector levels has been well finished. For the upcoming run14, pixel survey will be done up to the half pixel level. PXL alignment will basically rely on the survey measurement.

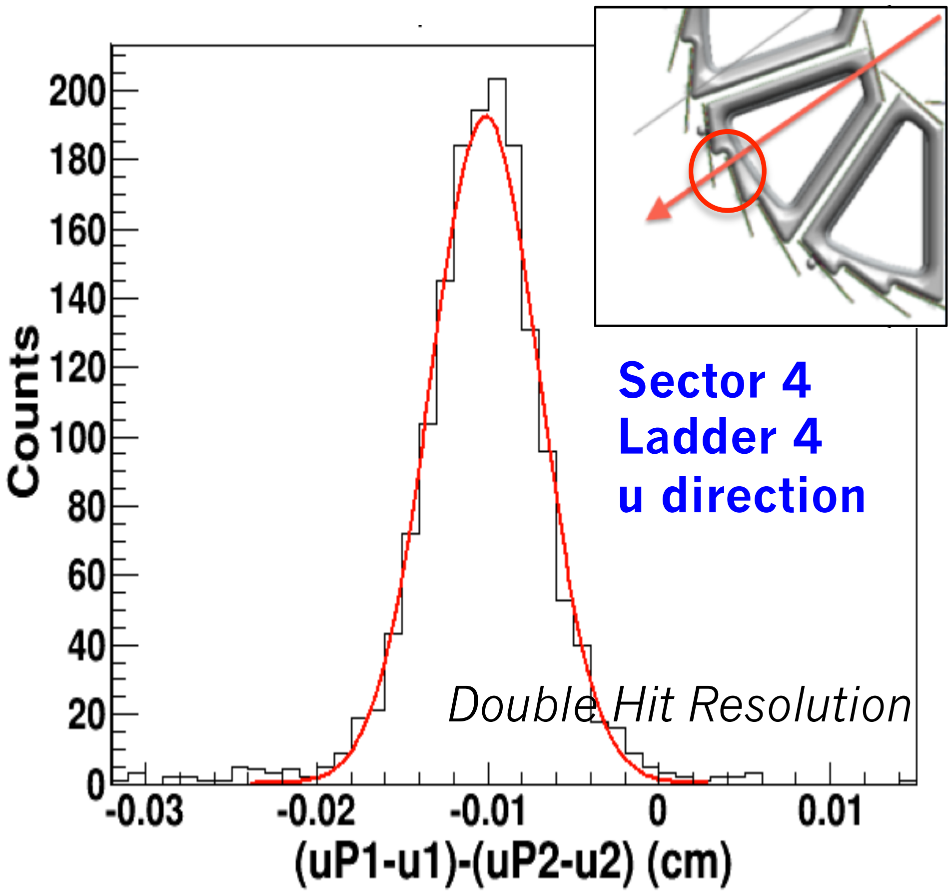
II. Alignment software for above sensor levels has been set up and macros to generate the geometry tables and overwrite these geometry are ready.

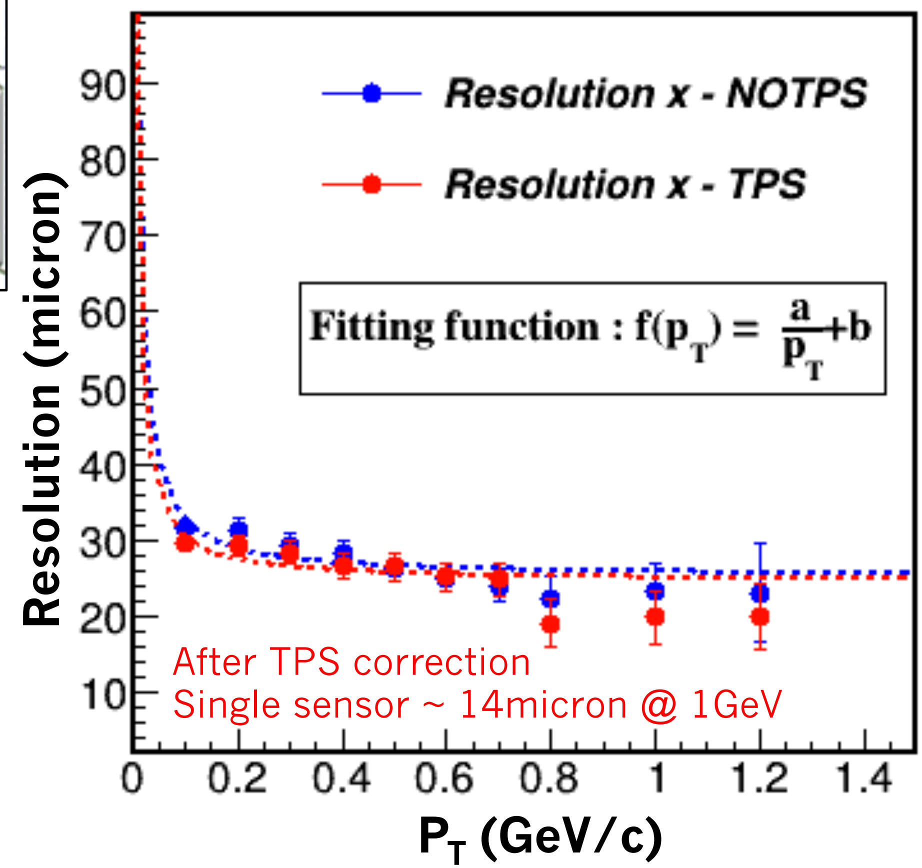
III. The effectiveness of small angle approximation in current alignment algorithm in dealing with cross-talk between rotations and shifts are under investigation by way of realistic simulation.

IV. Pixel sector alignment and alignment performance check with pixel hit in tracking are on-going

Thanks！

Backup - Pixel Hit resolution





With TPS correction, a few microns' improvement of the pixel hit resolution can be seen especially in the relative high pt region

Backup -Track based Alignment Algorithm

Misalignment of the detector in Global Coordinate System (GCS)

- $\vec{j} = (j_x,\, j_y,\, j_z)$ - track direction cosines in GCS on measurement plane
- $\vec{X} = (x,\, y,\, z)$ - track prediction in GCS on measurement plane
- $\vec{X}_{hit} = (x_{hit},\, y_{hit},\, z_{hit})$ - hit position in GCS on measurement plane
- $\vec{v} = (v_x,\, v_y,\, v_z)$ - direction of normal to measurement plane in GCS
- $\vec{\Delta} = (\Delta_x,\, \Delta_y,\, \Delta_z,\, \Delta_\alpha,\, \Delta_\beta,\, \Delta_\gamma)$ - misalignment parameters: shift and rotation

$$\vec{X}_{hit} - \vec{X} = \partial\vec{X}/\partial\vec{\Delta} \equiv \mathbf{G} \times \vec{\Delta}\mathbf{G} =$$

$$\begin{pmatrix} -1 + j_x v_x & j_x v_y & j_x v_z & j_x(-v_y z + v_z y) & -z + j_x(v_x z - v_z x) & y + j_x(-v_x y + v_y x) \\ j_y v_x & -1 + j_y v_y & j_y v_z & z + j_y(-v_y z + v_z y) & j_y(v_x z - v_z x) & -x + j_y(-v_x y + v_y x) \\ j_z v_x & j_z v_y & -1 + j_z v_z & -y + j_z(-v_y z + v_z y) & x + j_z(v_x z - v_y x) & j_z(-v_x y + v_y x) \end{pmatrix} \vec{\Delta}$$

Misalignment of the detector in Local Coordinate System (LCS)

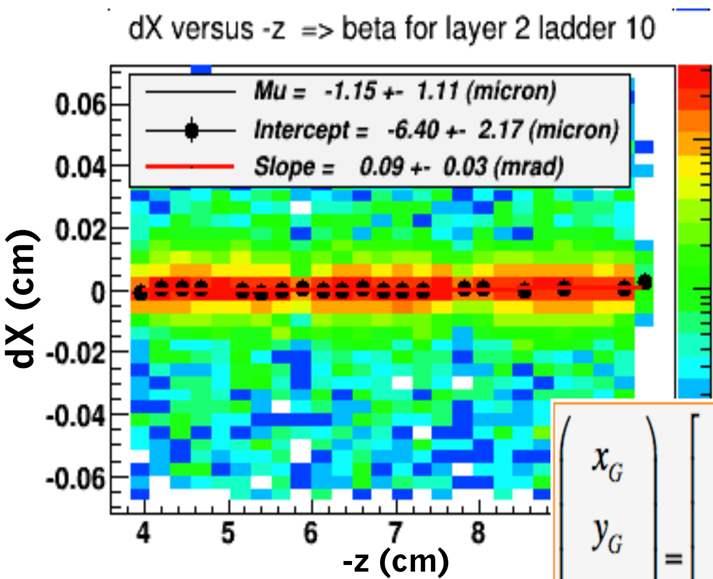
- $\vec{u} = (u,\, v,\, w \equiv 0)$ - track prediction in LCS on measurement plane
- $(t_u,\, t_v)$ - track direction tangents in Local Coordinate system (LCS) on measurement plane
- $\vec{u}_{hit} = (u_{hit},\, v_{hit})$ - hit position in LCS on measurement plane
- $\vec{\delta} = (\delta_u,\, \delta_v,\, \delta_w,\, \delta_\alpha,\, \delta_\beta,\, \delta_\gamma)$ - misalignment parameters shift and rotation with respect to local u,v,w axises, respectively

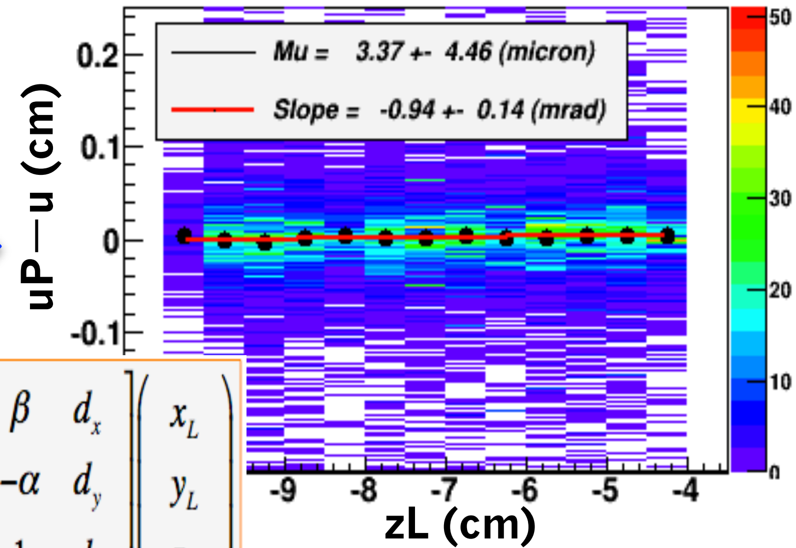
$$\vec{u}_{hit} - \vec{u} = \partial\vec{u}/\partial\vec{\delta} \equiv \mathbf{L} \cdot \vec{\delta} = \begin{pmatrix} -1 & 0 & t_u & t_u v & -t_u u & v \\ 0 & -1 & t_v & t_v v & -t_v u & -u \end{pmatrix} \vec{\delta} =$$

$$\begin{pmatrix} u_{hit} - u \\ v_{hit} - v \end{pmatrix} = \begin{pmatrix} -\delta_u + t_u(\delta_w + v\delta_\alpha - u\delta_\beta) + v\delta_\gamma \\ -\delta_v + t_v(\delta_w + v\delta_\alpha - u\delta_\beta) - u\delta_\gamma \end{pmatrix}$$

Fisyak, Yuri V. et al.
J.Phys.Conf.Ser. 119 (2008) 032017

Backup-Local residual distribution (check)





$$\begin{pmatrix} x_G \\ y_G \\ z_G \\ 1 \end{pmatrix} = \begin{bmatrix} 1 & -\gamma & \beta & d_x \\ \gamma & 1 & -\alpha & d_y \\ -\beta & \alpha & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x_L \\ y_L \\ z_L \\ 1 \end{pmatrix}$$