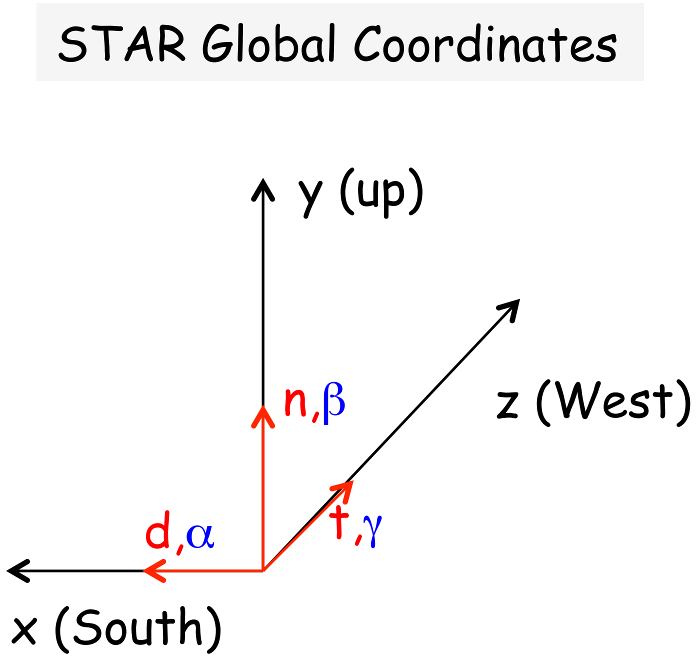
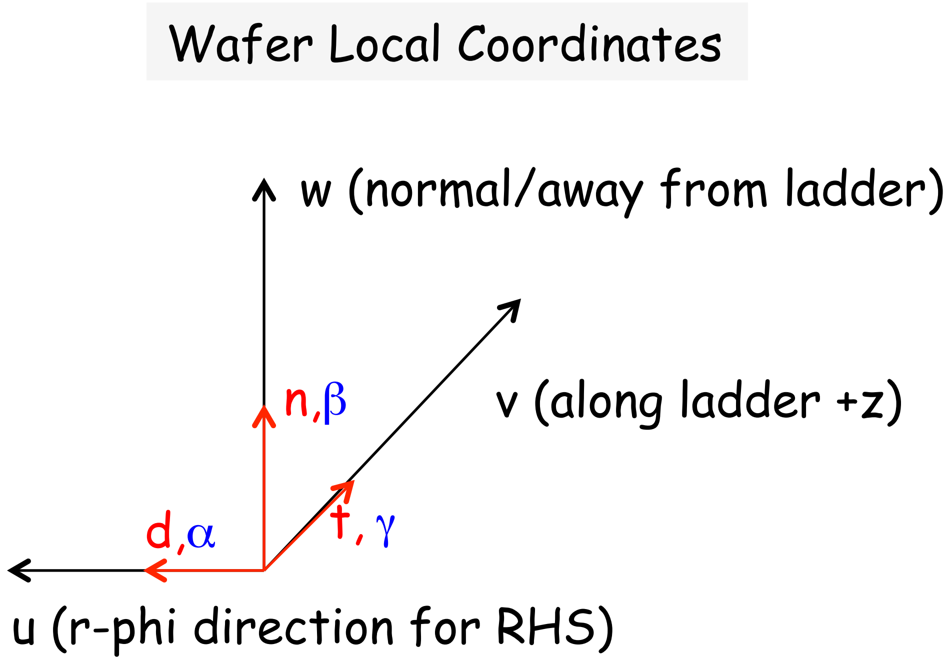
Alignment Details

S. Margetis, KSU

Definitions

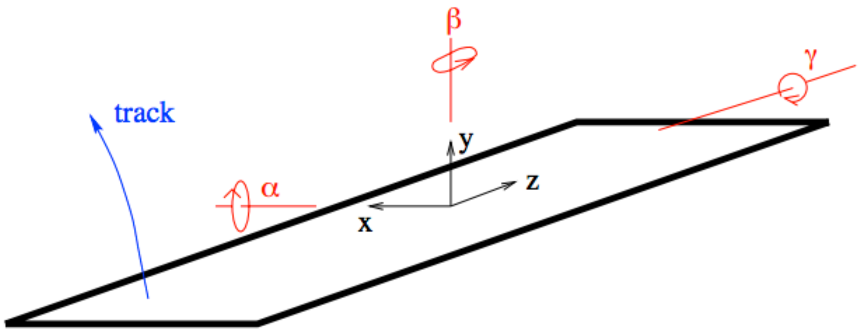




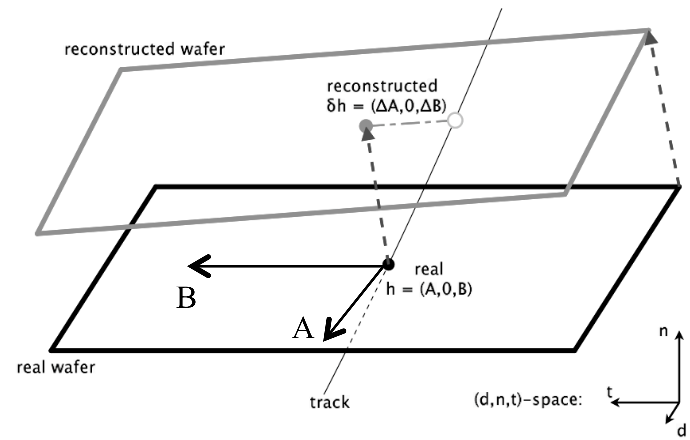
- Local v (along ladder) is fixed and along global +z
- Local w (normal to u-v [wafer] plane). Points away from exposed surface
- Local u (r-phi on wafer plane) varies so it forms a RHS with v-w (u,w,v)

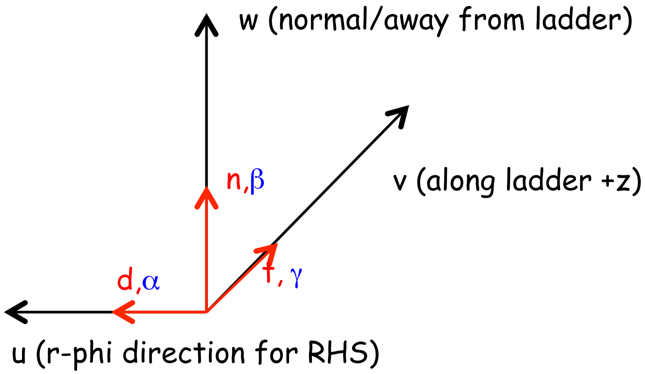
Wafer Local Coordinates Details

D. Chakraborty, J. D. Hobbs



Gene Van Buren et al.

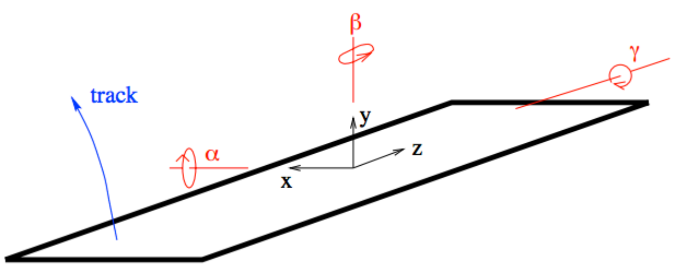




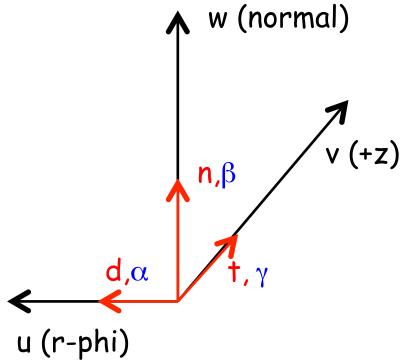
- We use the above RHS notation (u,w,v)
- Karimaki et al (CMS) use the (u,v,w) notation. In that system v=- (our v) otherwise system is left-handed
- So the documentation is confusing…needs some straightening up….

Wafer Local Coordinates Details

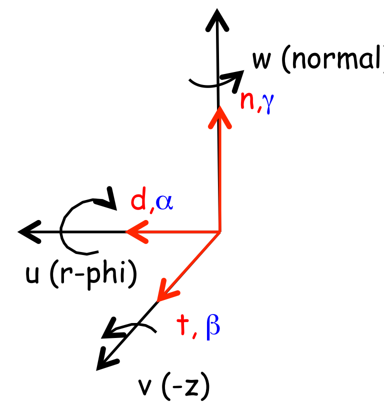
D. Chakraborty, J. D. Hobbs



Gene Van Buren et al.



Karimaki -CMS



$$x = x_d = u \quad \Rightarrow \quad \delta x = \delta x_d = \delta_u$$

$$y = x_n = w \quad \Rightarrow \quad \delta y = \delta x_n = \delta_w$$

$$z = x_t = -v \quad \Rightarrow \quad \delta z = \delta x_t = \delta_v$$

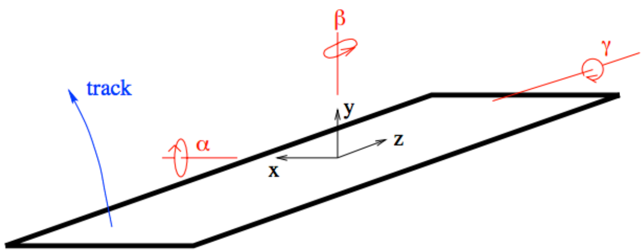
$$a = \phi_d = a \quad \Rightarrow \quad \sin a = \delta\phi_d = \delta_a$$

$$\beta = \phi_n = \gamma \quad \Rightarrow \quad \sin\beta = \delta\phi_n = \delta_\gamma$$

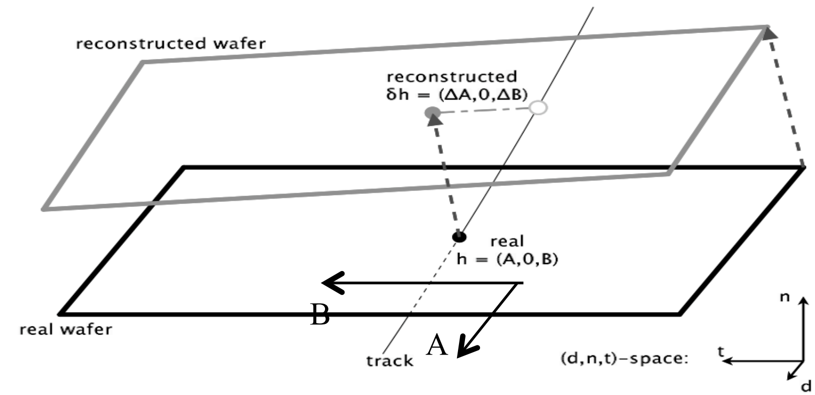
$$\gamma = \phi_t = -\beta \quad \Rightarrow \quad \sin\gamma = \delta\phi_t = -\delta_\beta$$

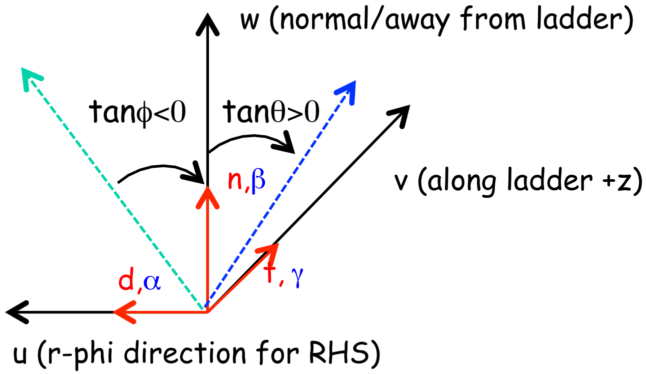
Wafer Local Coordinates Details

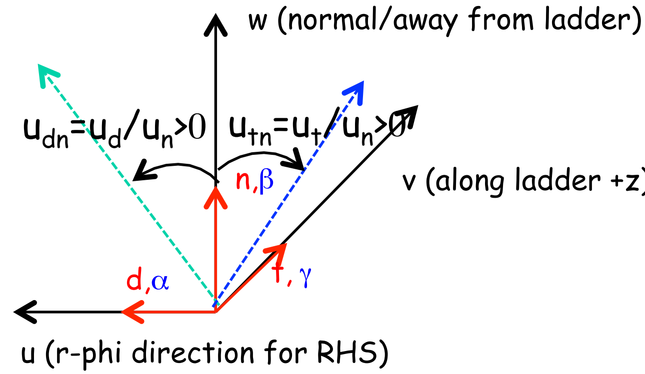
D. Chakraborty, J. D. Hobbs



Gene Van Buren et al.







- Uses correct correction = du = $v_{prediction} - v_{hit}$
- track-plane angles use α,β,γ convention for sign
- $u_{dn} = -\tan\phi$
- $u_{tn} = \tan\theta$

- Uses $v_{hit} - v_{prediction}$ so it needs a (-) sign
- track-plane angles sign comes from component
- $u_{dn} = -\tan\phi$
- $u_{tn} = \tan\theta$

See next page for more details

The hit-track residual Δx in the direction perpendicular to the axial strips is given by

$$\Delta x \equiv x_{track} - x_{hit} = \delta x + z \sin\beta + \tan\phi(\delta y + z \sin\alpha + x \sin\gamma) - f(\vec{B}, \phi) \qquad (1)$$

$$\Delta A = -B\delta\phi_n - \delta x_d + v_{dn}[A\delta\phi_t - B\delta\phi_d + \delta x_n]$$

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

...which after the convention corrections reach agreement with the exception of Chakraborty that has a sign problem [must be a typo]

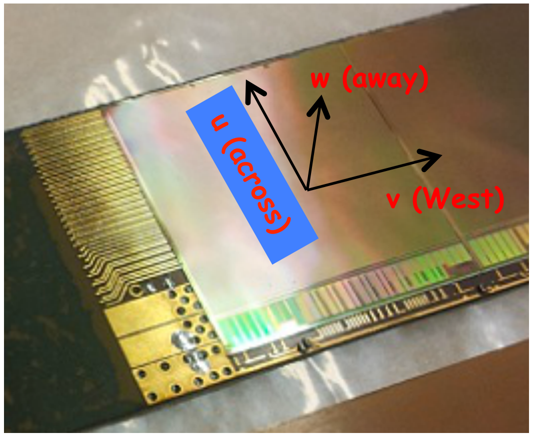
$$\Delta x = -\Delta A = \delta x_d + B \sin\beta + \tan\phi(\delta x_n - B\delta\phi_d + A\delta\phi_t)$$

$$\Delta x \equiv x_{track} - x_{hit} = \delta x + z \sin\beta + \tan\phi(\delta y + z \sin\alpha + x \sin\gamma) - f(\vec{B}, \phi)$$

Need to reconcile this sign – most likely a typo
My Math shows others to be right

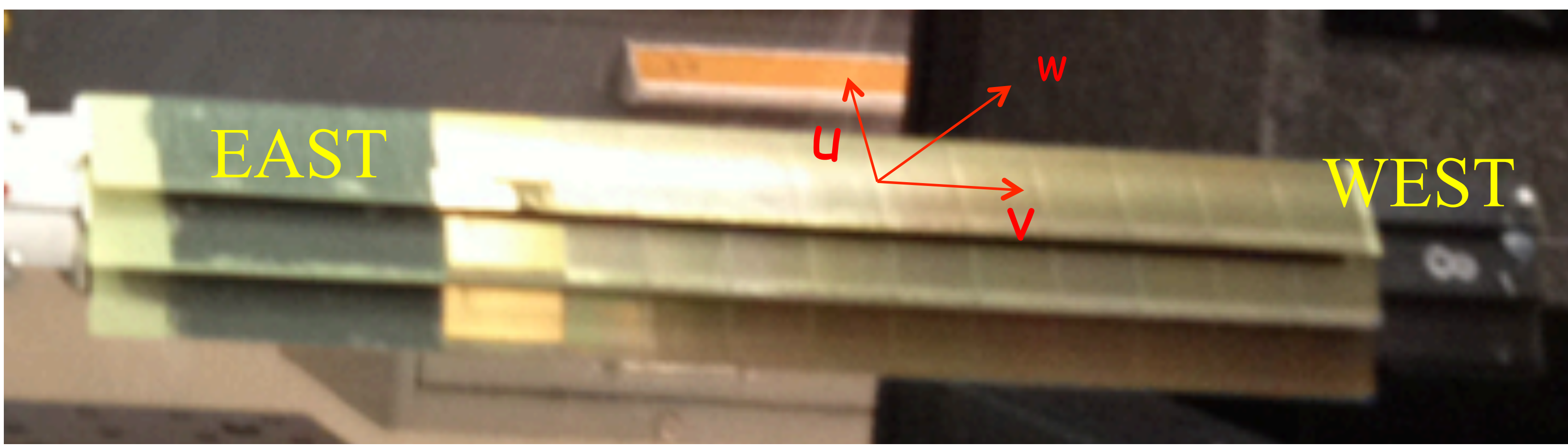
Local PXL system definitions (offline)

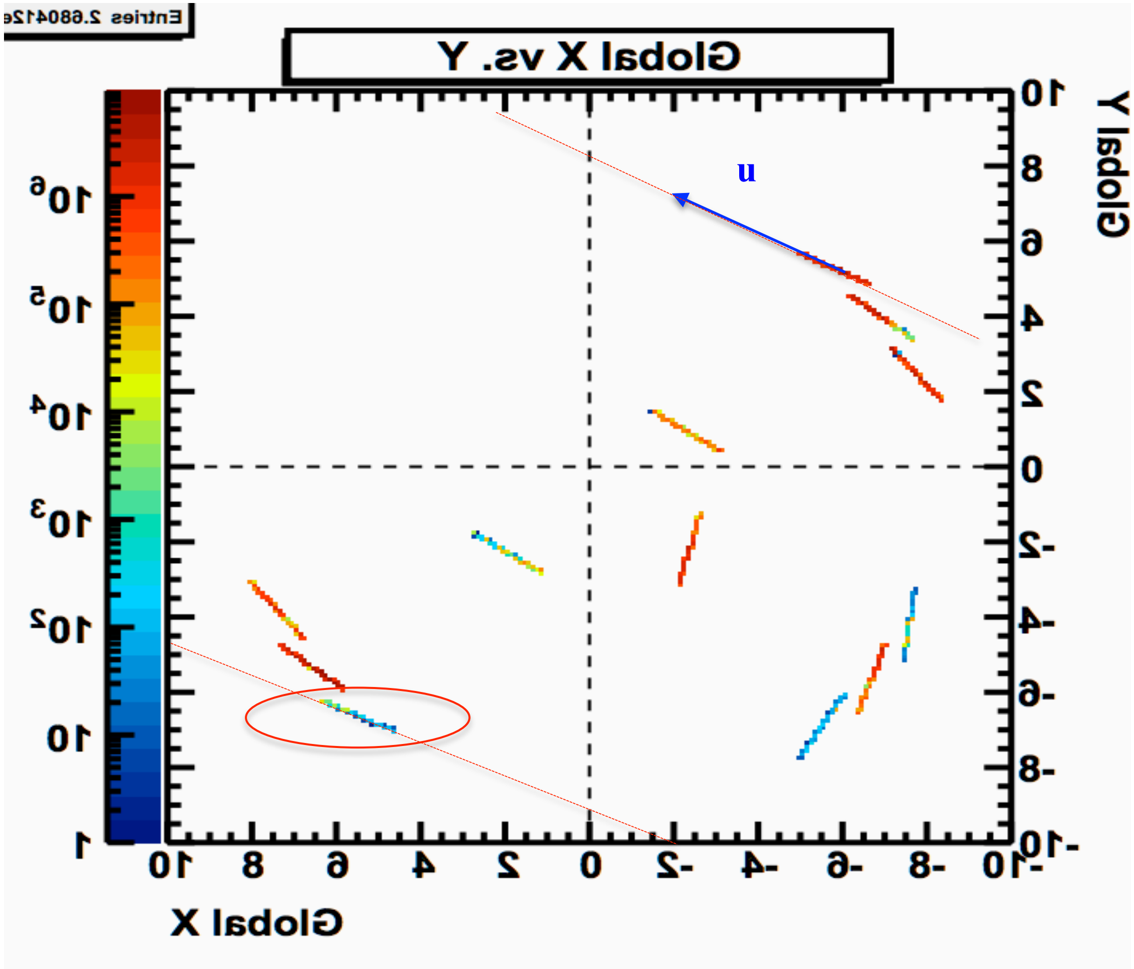
sensor

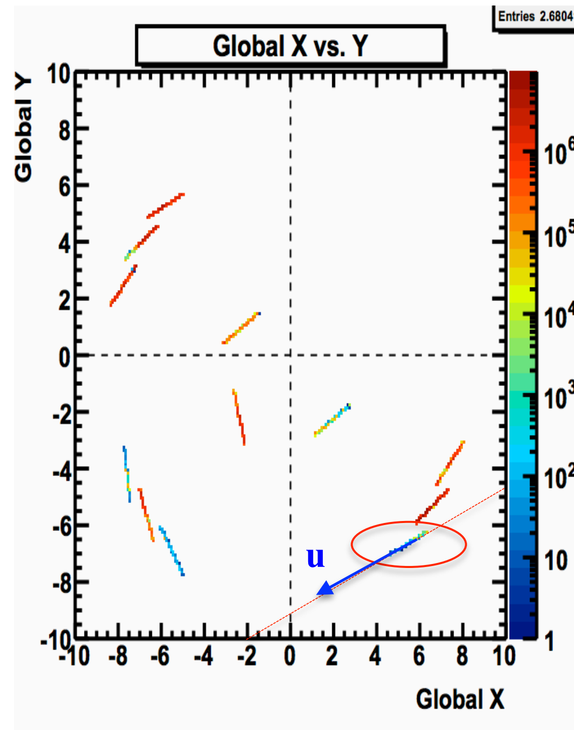


- PXL Sector origin is the same as STAR global
  - use same convention as in SSD/IST (as a whole) and IDS to simplify software

ladder




Entries 2.680412e
Global X vs. Y
u
Global X
Global Y


Entries 2.680412e
Global X vs. Y
u
Global X
Global Y

Offline use of Geometry Info

- Local-to-Global transforms are done in terms of **TGeoHMatrix**
- This can be e.g. the center of a sensor or a pixel.
- d,n,t are unit vectors and α, β,γ the corresponding rotation angles in x,y,z [u,w,v] directions [RHS] . d_x is the unit vector d projection on the x-axis etc

TGeoHMatrix definition

$$\begin{pmatrix} x_G \\ y_G \\ z_G \\ 1 \end{pmatrix} = \begin{bmatrix} \hat{d}_x & \hat{n}_x & \hat{t}_x & d_x \\ \hat{d}_y & \hat{n}_y & \hat{t}_y & d_y \\ \hat{d}_z & \hat{n}_z & \hat{t}_z & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x_L \\ y_L \\ z_L \\ 1 \end{pmatrix}$$

Local to Global transformation - definition

$$x_G^i = R \cdot x_L^i + T^i$$

$$x_G = \left(\hat{d}_x \cdot x_L + \hat{n}_x \cdot y_L + \hat{t}_x \cdot z_L \right) + d_x$$

For small rotations [8]

$$\begin{pmatrix} x_G \\ y_G \\ z_G \\ 1 \end{pmatrix} = \begin{bmatrix} \hat{d}_x & \hat{n}_x & \hat{t}_x & d_x \\ \hat{d}_y & \hat{n}_y & \hat{t}_y & d_y \\ \hat{d}_z & \hat{n}_z & \hat{t}_z & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x_L \\ y_L \\ z_L \\ 1 \end{pmatrix} \rightarrow \begin{pmatrix} x_G \\ y_G \\ z_G \\ 1 \end{pmatrix} = \begin{bmatrix} 1 & -\gamma & \beta & d_x \\ \gamma & 1 & -\alpha & d_y \\ -\beta & \alpha & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x_L \\ y_L \\ z_L \\ 1 \end{pmatrix}$$

Successive small rotations are additive, group Abelian(!) [$\alpha^2=\beta^2=\gamma^2=\alpha\beta=\ldots=0$]

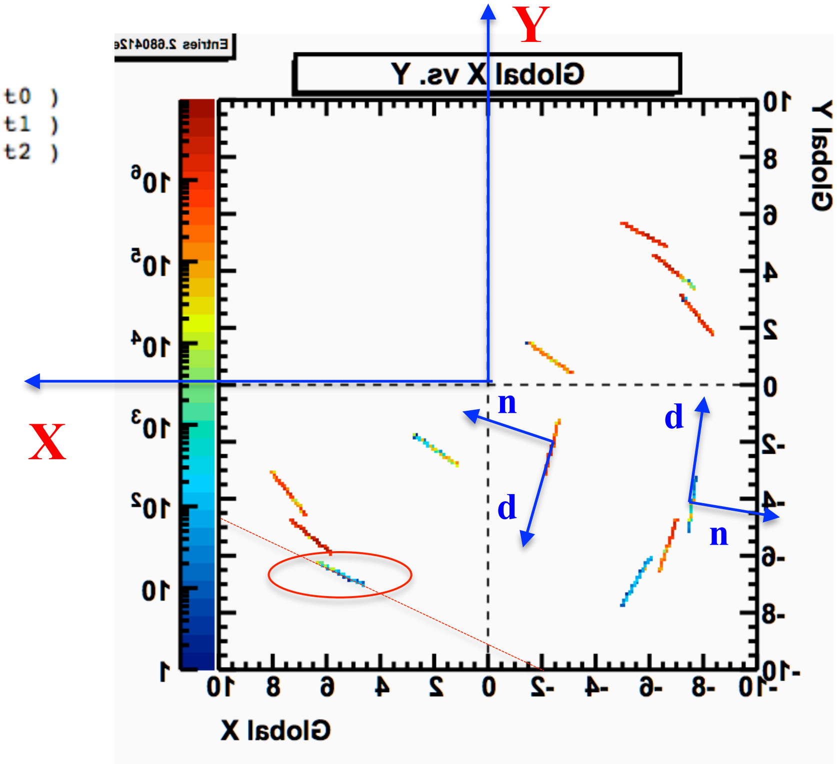
$$R = R_1 \otimes R_2 = \begin{bmatrix} 1 & -\gamma_1 & \beta_1 \\ \gamma_1 & 1 & -\alpha_1 \\ -\beta_1 & \alpha_1 & 1 \end{bmatrix} \bullet \begin{bmatrix} 1 & -\gamma_2 & \beta_2 \\ \gamma_2 & 1 & -\alpha_2 \\ -\beta_2 & \alpha_2 & 1 \end{bmatrix} = \begin{bmatrix} 1 & -(\gamma_1+\gamma_2) & (\beta_1+\beta_2) \\ (\gamma_1+\gamma_2) & 1 & -(\alpha_1+\alpha_2) \\ -(\beta_1+\beta_2) & (\alpha_1+\alpha_2) & 1 \end{bmatrix}$$

That is why we use multiplications to move from one system to another

PG = Tpc2Global *GL * PI *DP * SD * WLL;

PXLInGlobal=Tpc2Magnet*IDS2Tpc*PXL2IDS*DShell2PXL*Sector2DShell*(Pxl-Sector)

```
//:Pointer to data:  Survey.time.C:
//   Translation from local to Master
//   m = R*l + t
//           ( r00 r01 r02 ) (xl)   ( t0 )    ( r00 r02 r01 ) (xl)   ( t0 )
//       R = ( r10 r11 r12 ) (yl) + ( t1 ) =  ( r10 r12 r11 ) (zl) + ( t1 )
//           ( r20 r21 r22 ) (zl)   ( t2 )    ( r20 r22 r21 ) (yl)   ( t2 )
// SVT
// Id = 0                                  for SvtOnGlobal
// Id = [0, 1]                             for ShellOnGlobal,
// 0 is the x (South) Shell, 1 is the -x (North) Shell"
// Id = 1000*barrel + ladder               for LadderOnSurvey
// Id = 1000*barrel + ladder               for LadderOnShell
// Id = 1000*barrel + 100*wafer + ladder  for WaferOnLadder
//
// SSD
// Id = 0                                  for SsdOnGlobal
// Id = sector [1-4]                       SsdSectorsOnGlobal
// Id = 100*sector + ladder                SsdLaddersOnSectors
// Id = 7000 + 100*wafer + ladder          SsdWafersOnLadders
struct Survey {
  long    Id;
  double r00, r01, r02, r10, r11, r12, r20, r21, r22;
  double t0, t1, t2;
  double sigmaRotX, sigmaRotY, sigmaRotZ;
  double sigmaTrX, sigmaTrY, sigmaTrZ;
  char    comment[32];
};
```



$$\begin{pmatrix} x_G \\ y_G \\ z_G \\ 1 \end{pmatrix} = \begin{bmatrix} \hat{d}_x & \hat{n}_x & \hat{t}_x & d_x \\ \hat{d}_y & \hat{n}_y & \hat{t}_y & d_y \\ \hat{d}_z & \hat{n}_z & \hat{t}_z & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x_L \\ y_L \\ z_L \\ 1 \end{pmatrix}$$

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

Example: PXL Sector-4 Ladder-1 and 2

```
   {  120, 0.2654888, 0.9641139, 0.0000000,-0.9641139, 0.2654888, 0.0000000, 0.0000000,-0.0000000, 1.0000000, -2.19933,
-1.51911,    0.00000,    0.001,    0.001,    0.001,    0.001,    0.001,    0.001}// PXMO_1/PXLA_4/LADR_1/PXSI_1/PLAC_1
   {  130,-0.1385336,-0.9903577, 0.0000000, 0.9903577,-0.1385336, 0.0000000, 0.0000000, 0.0000000, 1.0000000, -7.40004,
-3.53066,    0.00000,    0.001,    0.001,    0.001,    0.001,    0.001,    0.001}// PXMO_1/PXLA_4/LADR_2/PXSI_1/PLAC_1
```

Survey geometry + Calibrations: Based on day 155 from Long, got it 7/5
FIRST PASS ESTIMATED Corrections

SECTOR 2

dX mkm	dY mkm	dZ mkm	alpha mrad	beta mrad	gamma mrad	Comment
-250	-200	0	5	-5	0	PXL sector 2 Ladder 1
-500	-250	-380	5	-5	0	PXL sector 2 Ladder 2
-200	-200	0	5	-5	0	PXL sector 2 Ladder 3
-170	-200	-500	5	-5	0	PXL sector2 Ladder 4

SECTOR 4

80	-300	-300	1	1	0	PXL sector 4 Ladder 1
-30	150	-300	1	1	0	Ladder 2
-80	220	-420	1	1	0	Ladder 3
-200	300	-400	1	1	0	Ladder 4

Survey geometry + Calibrations: Based on day 155 from Long, got it 7/5
FIRST PASS ESTIMATED Corrections

SECTOR 7

-430	-280	50	-10	10	10	PXL sector 7 Ladder 1
-800	-350	350	-10	10	10	Ladder 2
-450	-350	200	-10	10	10	Ladder 3
-200	-250	50	-10.	10	10	Ladder 4

Local to Global

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

$$x_G^i = R \cdot x_L^i + T^i$$

Global to Local

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

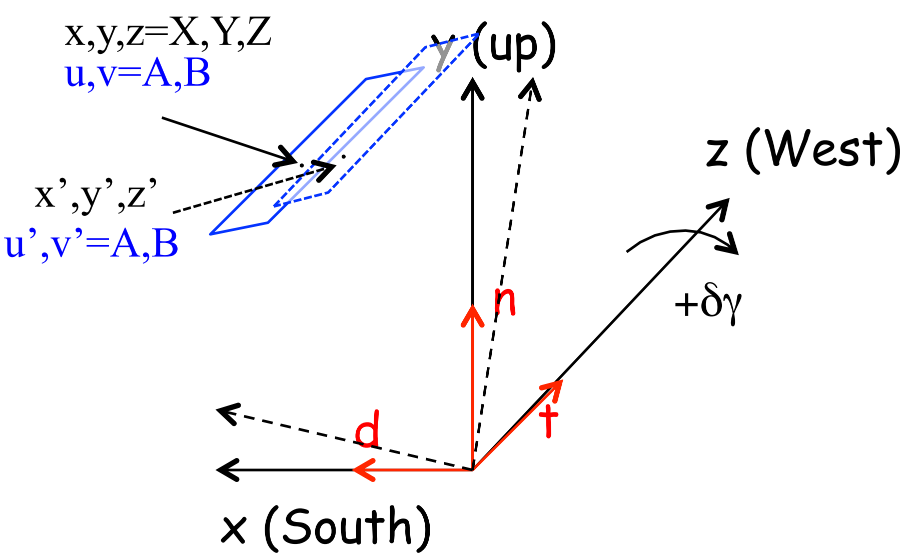
$$x_L^i = R^T \cdot (x_G^i - T^i)$$

Inverse turns out to be just the transpose of the original matrix

$$1 = R \otimes R^{-1} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \Rightarrow R^{-1} = \begin{bmatrix} 1 & \gamma & -\beta \\ -\gamma & 1 & \alpha \\ \beta & -\alpha & 1 \end{bmatrix} = R^T$$

Example: small rotation only in **Global system** around z-axis, $\delta\gamma$ ($\delta\alpha=\delta\beta=0$)

NOTE: All transformations are Local-to-Master type: $x_G^i = R \cdot x_L^i + T^i$



Global system

$$\begin{pmatrix} x' \\ y' \\ z' \\ 1 \end{pmatrix} = \begin{bmatrix} 1 & -\delta\gamma & 0 & 0 \\ \delta\gamma & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x = X \\ y = Y \\ z = Z \\ 1 \end{pmatrix}$$

$$x' = x + (-\delta\gamma)\cdot y = X - \delta\gamma \cdot Y$$

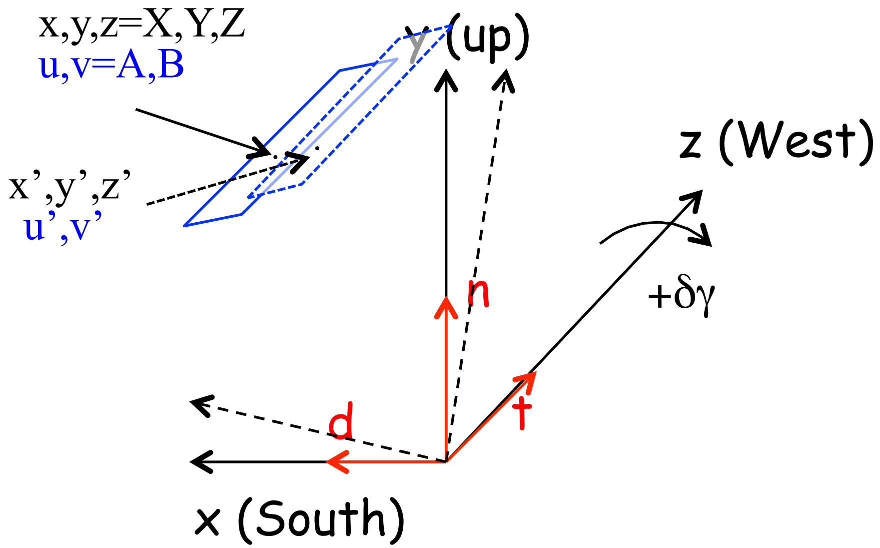
$$y' = \delta\gamma \cdot x + y = X \cdot \delta\gamma + Y$$

$$z' = z = Z$$

Backup -1

Example: small rotation only in **Global system** around z-axis, $\delta\gamma$ ($\delta\alpha=\delta\beta=0$)

NOTE: All transformations are Local-to-Master type: $x_G^i = R \cdot x_L^i + T^i$



Global system

$$\begin{pmatrix} x' \\ y' \\ z' \\ 1 \end{pmatrix} = \begin{bmatrix} 1 & -\delta\gamma & 0 & 0 \\ \delta\gamma & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x = X \\ y = Y \\ z = Z \\ 1 \end{pmatrix}$$

$$x' = x + (-\delta\gamma) \cdot y = X - \delta\gamma \cdot Y$$
$$y' = \delta\gamma \cdot x + y = X \cdot \delta\gamma + Y$$
$$z' = z = Z$$

In **Local system** the same appears as rotation by $\delta\gamma$ **plus** a translation by **Δr**=(r'-r)

$$\begin{pmatrix} u' \\ w' \\ v' \\ 1 \end{pmatrix} = \begin{bmatrix} 1 & -\delta\gamma & 0 & -\delta\gamma \cdot Y \\ \delta\gamma & 1 & 0 & \delta\gamma \cdot X \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} u = A \\ w = 0 \\ v = B \\ 1 \end{pmatrix}$$

$$u' = u + (-\delta\gamma) \cdot Y = A - \delta\gamma \cdot Y$$
$$w' = A \cdot \delta\gamma + X \cdot \delta\gamma = (A + X) \cdot \delta\gamma$$
$$v' = v = B$$

Offline Structures

Fixed for all HFT detectors

Fixed by PXL SURVEY

HFT PXL

PG = Tpc2Global *GL * PI *DP * SD * WLL;

PXLInGlobal=Tpc2Magnet*IDS2Tpc*PXL2IDS*DShell2PXL*Sector2DShell*(Pxl-Sector)

Fixed for PXL by Offline

Offline Structures

HFT PXL

PG = Tpc2Global *GL * PI *DP * SD * WLL;

PXLInGlobal=Tpc2Magnet*IDS2Tpc*PXL2IDS*DShell2PXL*Sector2DShell*(Pxl-Sector)

Survey Structures

HFT PXL

WLL = LS * SL * PS (TPS fn);

PXLInSector=Ladder2Sector*Sensor2Ladder*Pxl2Sensor

Assumptions

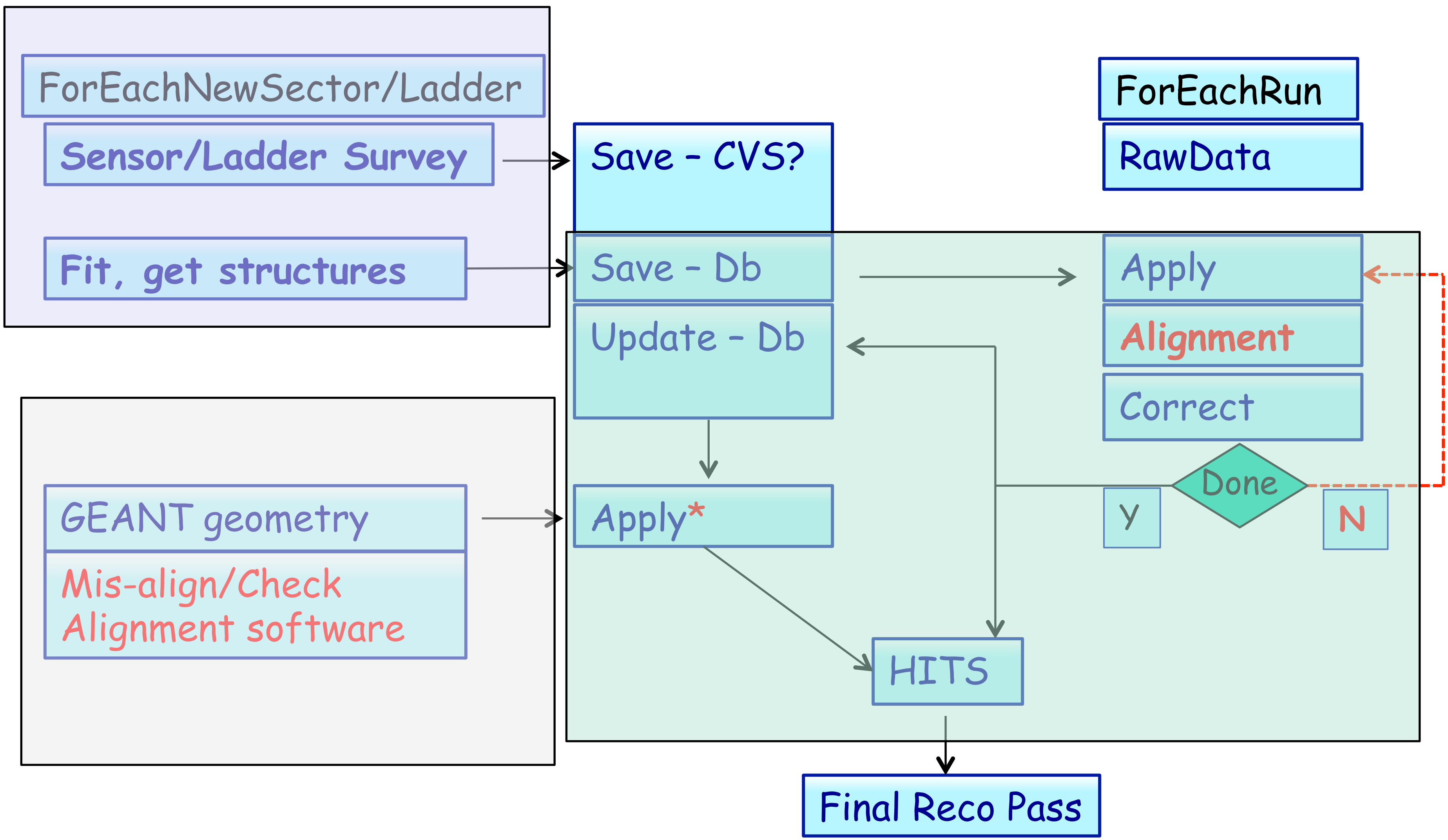
- Survey and Offline systems will differ. Data formats will differ too. Transform from one system to other possible.
- Origin of coordinate systems should be as close as possible to geometrical center of the module -> minimize effects
  - easy to work also with GEANT volume-placing matrices
  - unless there is a clear reason for not doing this
- Sensor center is center of active area
- Ladder center in-between sensors 5-6 (geometrical center)
- Sector center (proposed) to be the innermost (ladder #4) center due to the importance of first layer, rotated 180 by necessity (see next slide)
- TPS fits are assumed to be done on single sensor basis
  - pixel functions/parameters will be tagged with sensor ID

HFT Alignment Procedures

S. Margetis, KSU

- Introduction
- HFT Configuration – System hierarchy
- (thoughts on) Proposed procedures
- Tools/Implementation (Jonathan)
- Plans, Timeline and Issues
- Summary

Flowchart of Geometry/Survey/Alignment



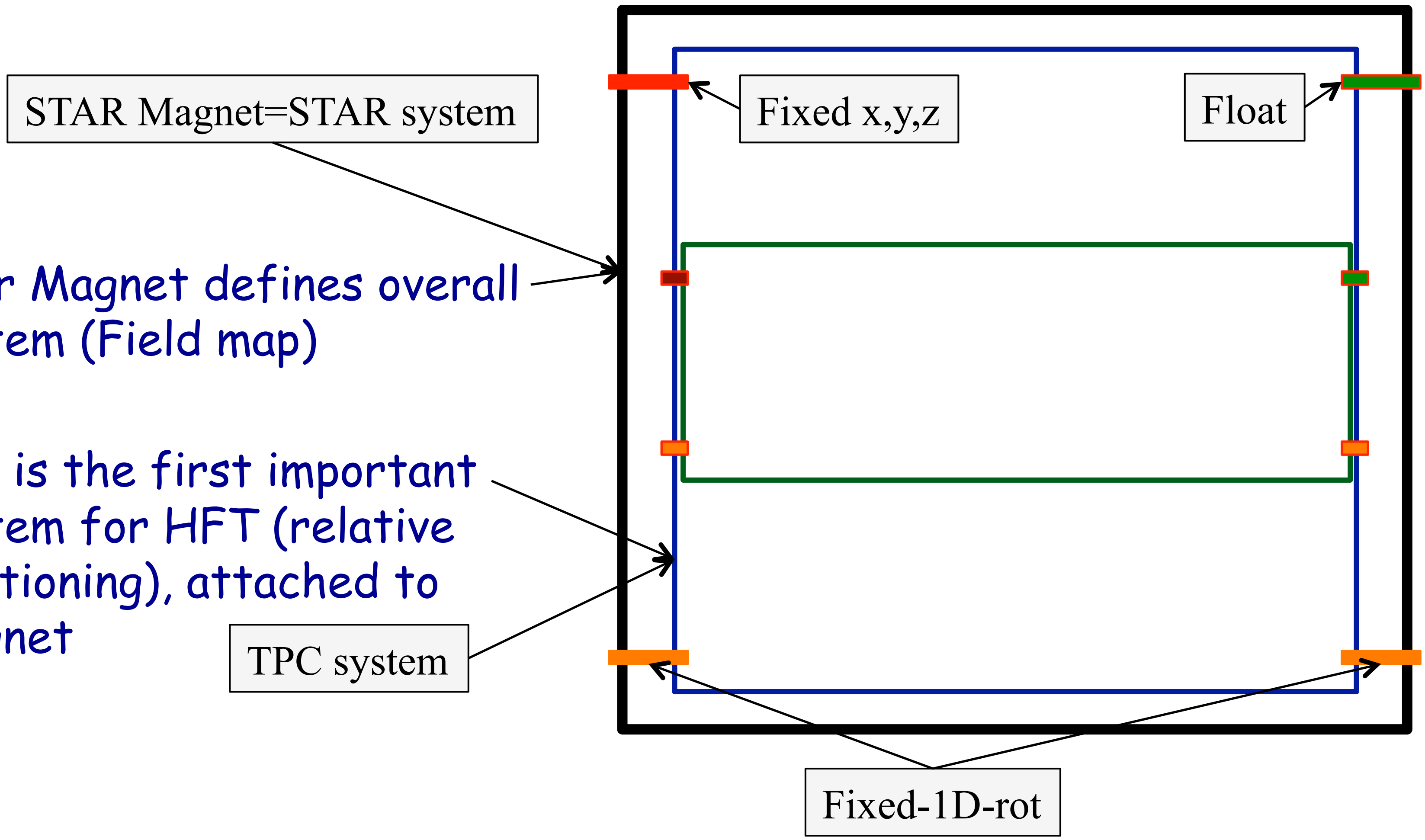
* VMC, STV ready

Introduction

- Anything we build or touch or use needs Modeling, Survey and in-situ Alignment
  - i.e. versioning
- Survey will freeze position of sensors on sectors (PXL). Help also with sector on hemisphere (PXL?). For SSD/IST will freeze position of sensors on ladder and ladder shape
- For each yearly Run the in-situ position of major detector elements needs to be rechecked

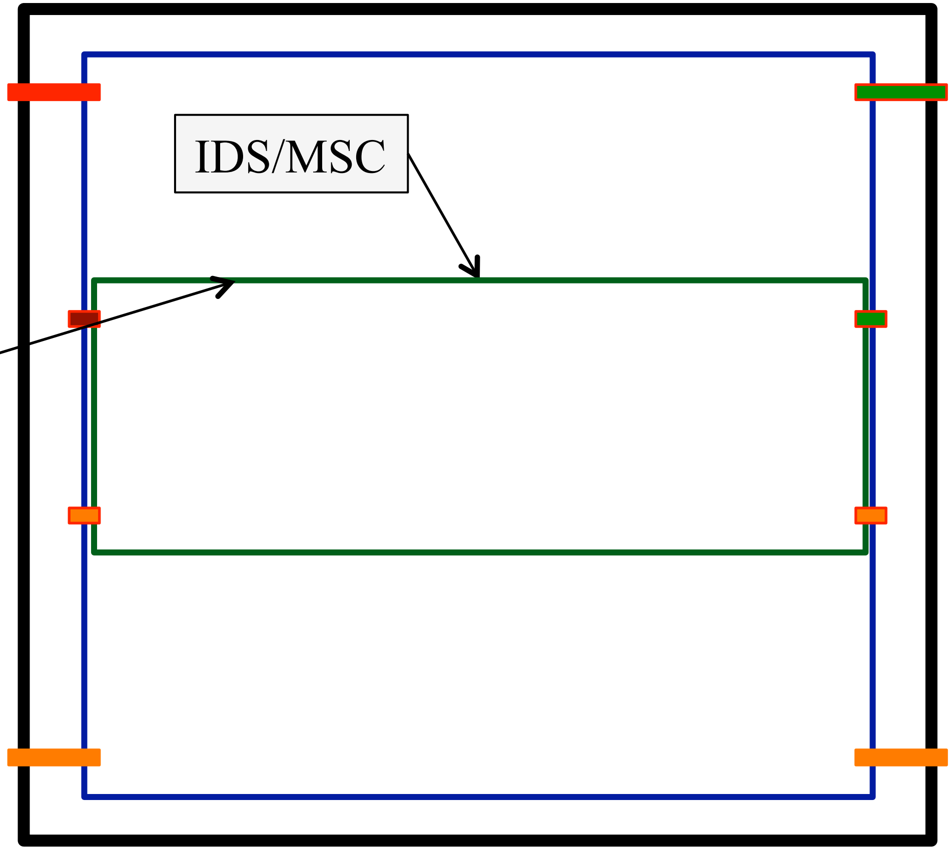
Reference System Hierarchy

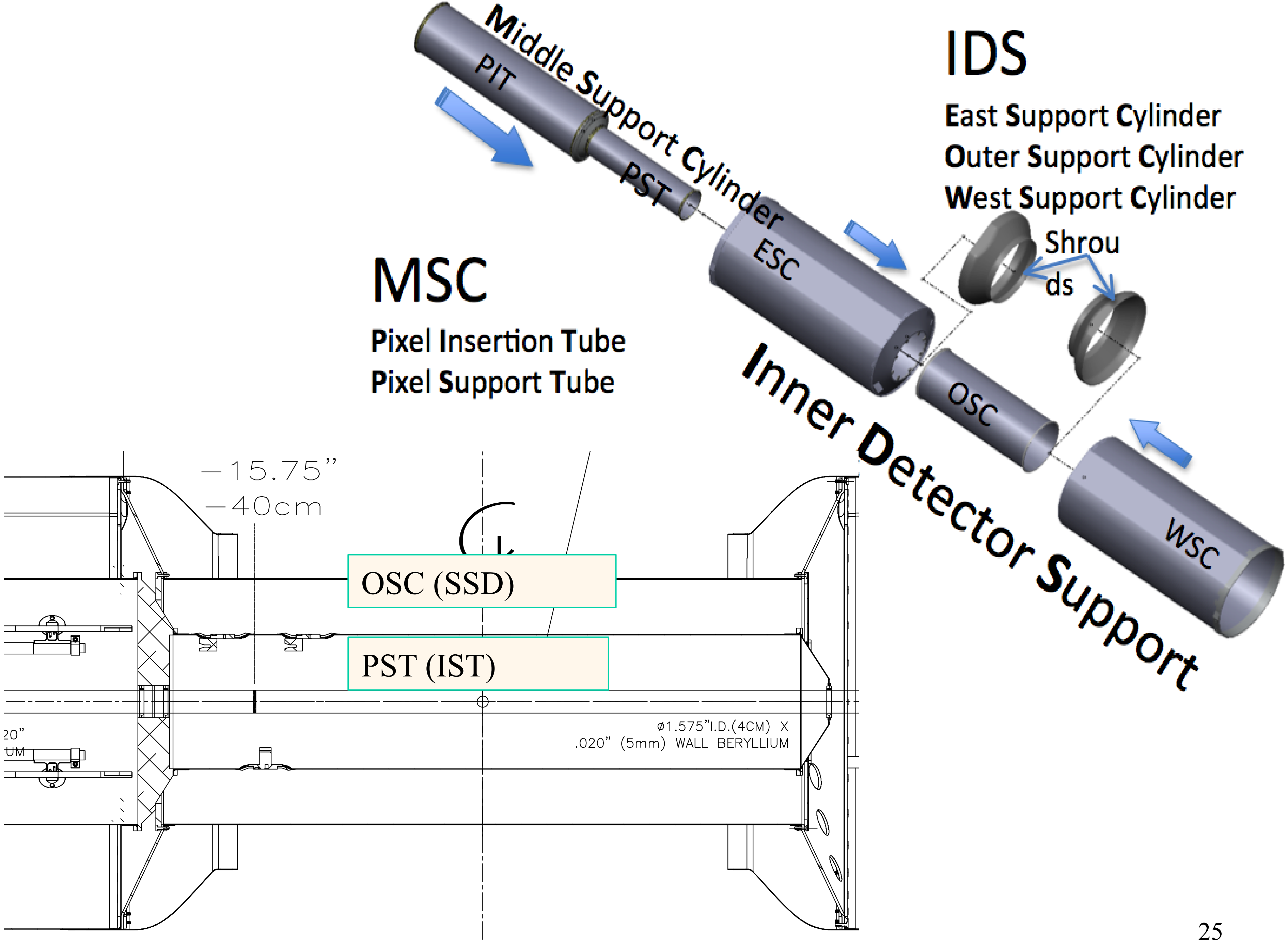
- Star Magnet defines overall system (Field map)
- TPC is the first important system for HFT (relative positioning), attached to Magnet



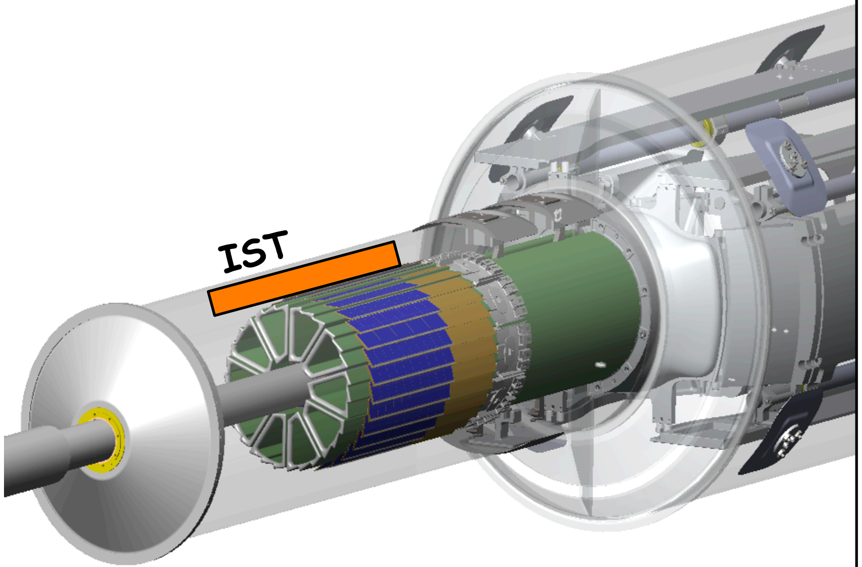
- **ESC/WSC** attached to TPC wheel. It defines the HFT system's relation (as a whole) to TPC system

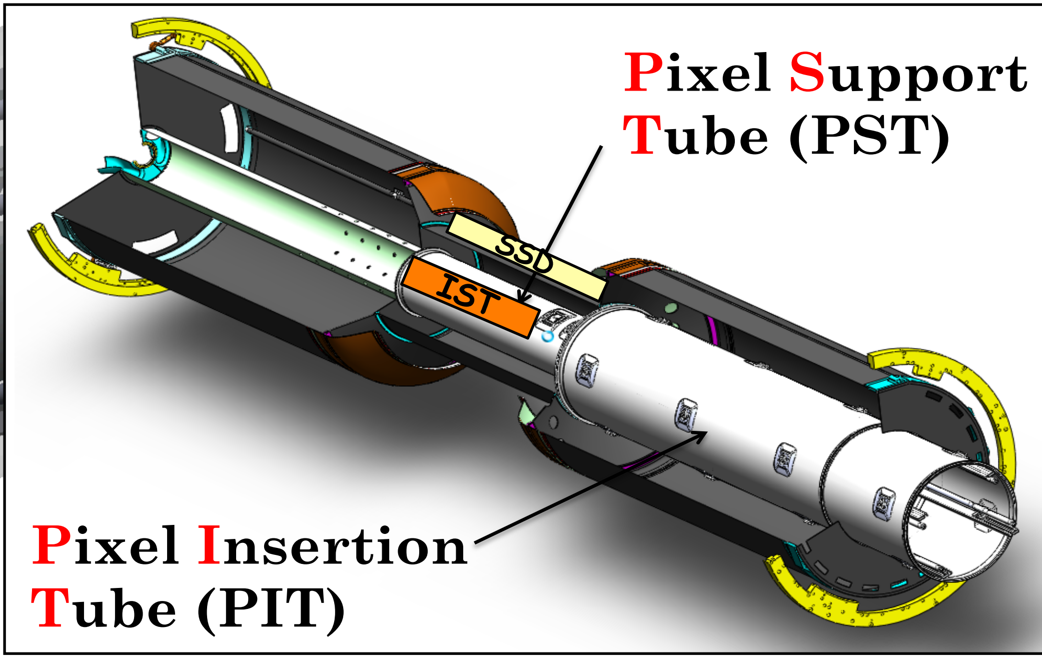
- See next slides for systems inside the HFT complex

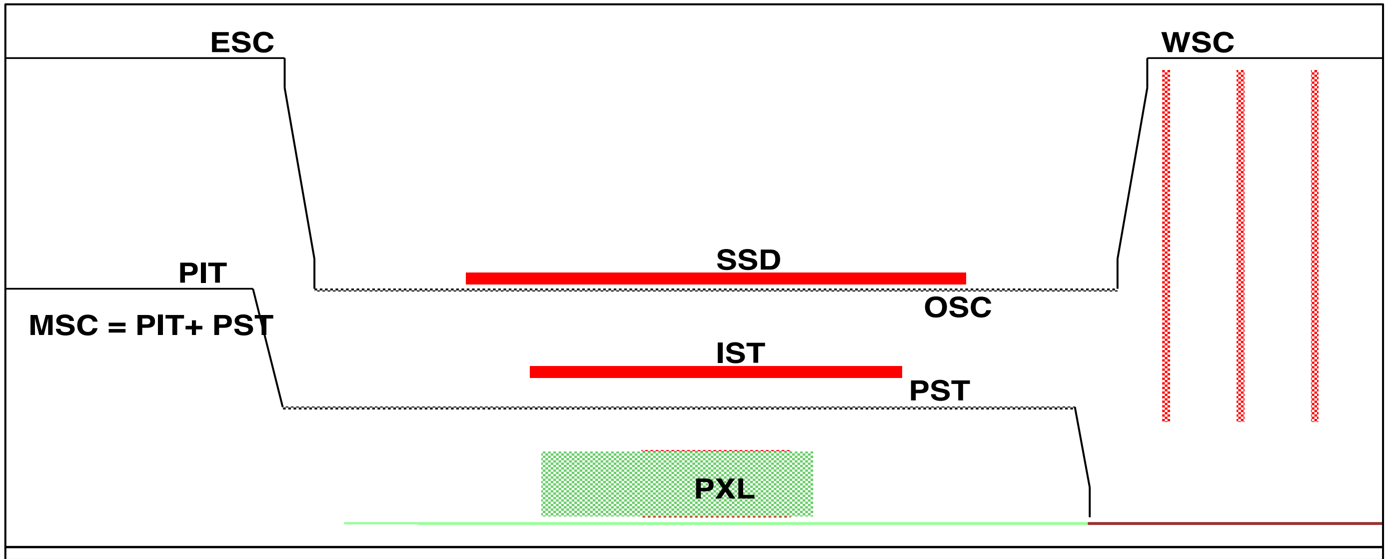



IDS
East Support Cylinder
Outer Support Cylinder
West Support Cylinder
MSC
Pixel Insertion Tube
Pixel Support Tube
Middle Support Cylinder
PIT
PST
ESC
Shrou
ds
OSC
WSC
Inner Detector Support
−15.75”
−40cm
OSC (SSD)
PST (IST)
ø1.575”I.D.(4CM) X
.020” (5mm) WALL BERYLLIUM

General Layout







Reference systems - comments

- In general survey accuracy of critical components (relative pixel and/or sensor positions) expected to be better than acceptable values

- Will soon need surveyed positions of IDS targets
  - to build 'ideal' position Db
  - Sub-millimeter accuracies acceptable -> Tracks will fix them

- All this information is represented as matrices (position/orientation) of their center-of-gravity. These matrices are used to define Local to Global transforms

GEANT geometry can/should be synchronized with Realistic Volume hierarchy instead of the current 'patch-the-hit' scheme

- VMC environment will facilitate this

Local <-> Global transforms

OLD SSD

WG = Tpc2Global * GL * SG * LS * WLL;
WaferInGlobal=Tpc2Magnet *SsdinTpc*SectorInSSD*LadderInSector*WaferInLadder

HFT SSD

WG = Tpc2Global * GL * LO * WLL;
WaferInGlobal=Tpc2Magnet *IDS2Tpc*Ladder2IDS*WaferInLadder

HFT IST

WG = Tpc2Global * GL * PI *LO * WLL;
WaferInGlobal=Tpc2Magnet *IDS2Tpc*PST2IDS*Ladder2PST*WaferInLadder

HFT PXL

PG = Tpc2Global *GL * PI *DP * SD * WLL;
PXLInGlobal=Tpc2Magnet*IDS2Tpc*PXL2IDS*DShell2PXL*Sector2DShell*(Pxl-Sector)

Alignment methods (outline only)

- There are 'Global' and 'Self' Alignment methods
  - Global uses mostly 'external' track information
  - Self uses mostly 'internal' track information
  - For HFT we propose a mix (more Self !)
- We have successful 'Global' methods already in place (SVT/SSD)
  - TPC distortions, t0, 'track tof' etc is a problem
- In HFT system we have significant sensor overlap to make use of 'Self' alignment methods. We also have high precision PXL info with excellent sector rigidity, survey info, placement.
- We need to use this advantage

We lack a hardware monitoring system. Once detectors are installed we rely on survey and alignment software

The hit-track residual Δx in the direction perpendicular to the axial strips is given by

$$\Delta x \equiv x_{track} - x_{hit} = \delta x + z \sin\beta + \tan\phi(\delta y + z \sin\alpha + x \sin\gamma) - f(\vec{B}, \phi) \quad (1)$$

and for the direction parallel to the axial strips (in double sided ladders)

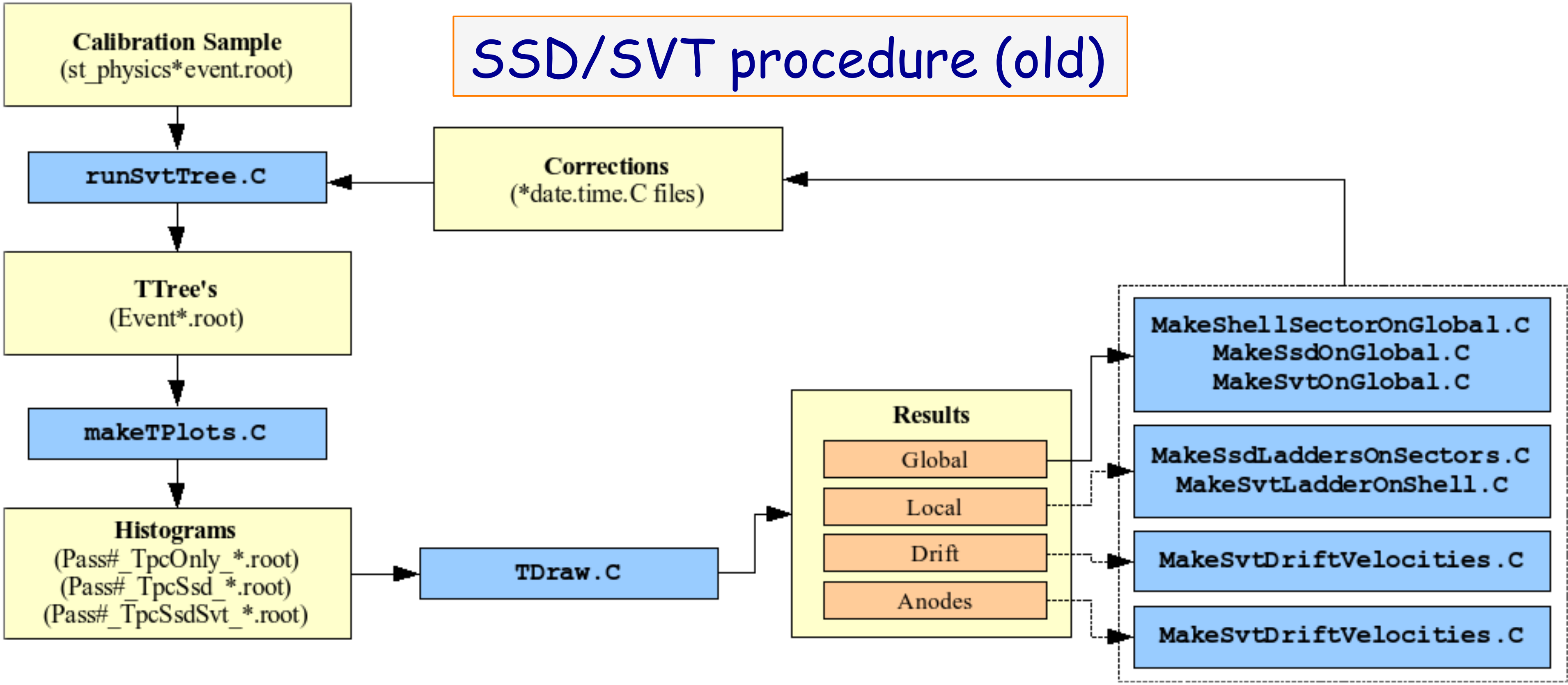
$$\Delta z \equiv z_{track} - z_{hit} = \delta z + x \sin\beta + \tan\theta(\delta y + z \sin\alpha + x \sin\gamma) \quad (2)$$

The simplest approach to determining the alignment parameters is to use the means of the following histograms(for the Δx case):

1. the distribution of residuals integrated over y, z, and ϕ, which gives δx directly,
2. the residual vs. z which gives $\sin\beta$,
3. the residual vs. $\tan\phi$ which gives δy,
4. the residual/$\tan\phi$ vs. x which gives $\sin\gamma$,
5. and the residual/$\tan\phi$ vs. z which gives $\sin\alpha$.

D.Chakraborty, J.D.Hobbs, D0 note Oct.13, 1999

SSD/SVT procedure (old)



The sequence to be followed for each detector is:

1) **SSD Alignment**: (TPC tracks Only)

   Global - SSD on Global and Sectors on Global;

   Local - SSD Ladders on Sectors;

2) **SVT Alignment**: (TPC+SSD hits on tracks)

   Global - SVT on Global and Shells on Global;

   Local - SVT Ladders on Shells; (Drift Velocities);

3) **Consistency Check**: (TPC+SSD+SVT hits on tracks)

   Global;Local (ladders);Drift Velocities;

- For alignment we use “good” (well defined) tracks fitted with the primary vertex. (e.g. NFP, pt cuts)
  - Use of primary tracks significantly improves precision of track predictions in HFT and reduces influence of systematics.
  - Good statistics is a must (up to a point)(see example in Jonathan’s talk)(50-100K hits per wafer/sensor)

- In order to minimize TPC space-charge distortions, tracking errors (mismatches) and PXL pileup we will need to use low luminosity and low-medium multiplicity data as the alignment sample

- Method is iterative since it is precise for small deviations

HFT Proposed Procedure:

Remember: PXL detector is a big asset (c.f. TPC)

1. Global Alignment of PXL
   - Relative alignment of PXL sectors and halves using overlap region AND halves using Event vertex found by each half
   - Relative alignment of PXL and TPC [TPC primary tracks]
     - Iterative->(PXL, PXL half, sector)
   - Exact sequence/interplay needs to be determined
2. Primary tracks with TPC+PXL hits
   - Alignment of IST ladders with respect to PXL
3. Primary tracks with (All – SSD) hits
   - Alignment of SSD ladders
4. Check

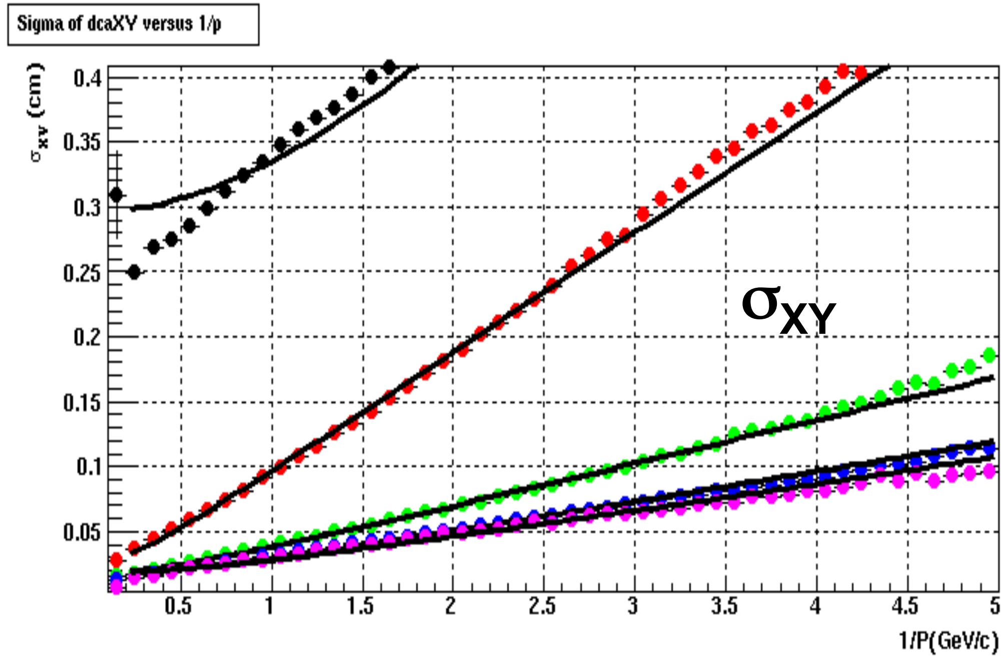
- We assume that sensors on ladder and ladders on sectors are pre-surveyed to specs

Precision requirements for HFT alignment

- Pointing accuracy is ultimate figure of merit: DCA resolution (in bending XY $\equiv r\phi$ plane: σ_{DCA}), and resolution in non-bending plane: σ_z
  - $\sigma^2_{DCA} = \sigma^2_{vertex} + \sigma^2_{track} + \sigma^2_{MCS}$ (the same for non-bending plane)
  - primary vertex resolution: $\sigma_{vertex} \sim 3\mu m + (120\ \mu m / \sqrt{N_{ch}})$; for central Au+Au collisions turns out to be ~5 μm
  - track pointing resolution: $\sigma_{track} \sim 1.5\ \sigma_{XY}$ [in our case, where σ_{XY} is intrinsic detector precision (~10μm)] $\oplus$ alignment errors
  - multiple scattering (MCS): $\sigma_{MCS} \sim 20\mu m / \beta p$ (GeV/c) (for thin PXL)

Overall mis-alignments of < 10 μm or <MCS are acceptable

DCA resolution



- SVT/SSD example

Number of Silicon Points fitted to track	σ_{XY} @1GeV/c (μm)
0 - ● TPC only	3350
1 - ● TPC+SSD	967
2 - ● TPC+SSD+SVT	383
3 - ● TPC+SSD +SVT	296
4 - ● TPC+SSD +SVT	281

- With increasing no. of fitted Si points it is improved by ~ order of magnitude.
- Contribution from tracking (constant term) is comparable with MCS @ 1 GeV/c

Tasks

- Need to finalize the PXL sensor representation in Db (prototype sector)
- Need to setup Data formats, code to deliver matrices etc
- Need to know/map the (realistic) error of every survey step
- Need to start simulations to determine alignment software performance
- Need to rework GEANT geometry synchronization (STV, VMC)
- Need to finalize SSD procedures and initialize/define IST ones
- Need to include gravitational sagging in SSD and IST (?) model
- Need to keep/use expertise around

Plans/Timeline

Some of these efforts need to go in parallel

- It will take about a month or two to setup the chain and clean up the code for all HFT subsystems (current environment)
  - Includes software, Db structures, Hit, conventions
- We can do (some) tests in current environment or begin porting to VMC (with help)
- By the end of the year we would need to have defined and have established working interfaces to Survey for PXL
- Full chain ready to work with cosmics/data when available

Only then, when done, we can start looking at other packages

Summary

- The building up of a working chain is coming along
- All 3 needed efforts are moving along (Geo, Sur, Al)
- Benefited enormously from previous experience as we hope to benefit from current experience
- A lot still needs to be done
- Target to have a working chain for data beginning of the year is not unrealistic

Backup-2

References

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3. “Correcting for distortions due to ionization in the STAR TPC”, G. Van Buren et al.,NIM A566:22-25,2006.
4. “The STAR Silicon Vertex Tracker” A large area Silicon Drift Detector”, R.Bellwied et Al., NIM A499: 640, 2003.
5. “The STAR silicon strip-detector (SSD)”, L.Arnold et al., NIM 2003 A499: 652, 2003.
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7. “Sensor Alignment by Tracks”, V.Karimaki et al.,CMS CR-2004/009 (presented at CHEP 2003)
8. http://phys.kent.edu/~margetis/STAR/HFT/Survey/SVTSmallScaleSelfAlignment.pdf
9. http://phys.kent.edu/~margetis/STAR/HFT/Survey/SVT_Alignment_JPCSL.pdf

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and for the direction parallel to the axial strips (in double sided ladders)

$$\Delta z \equiv z_{track} - z_{hit} = \delta z + x \sin\beta + \tan\theta(\delta y + z\sin\alpha + x\sin\gamma) \quad (2)$$

$$\begin{aligned} \Delta A &= -B\delta\phi_n - \delta x_d + v_{dn}[A\delta\phi_t - B\delta\phi_d + \delta x_n] \\ \Delta B &= A\delta\phi_n - \delta x_t + v_{tn}[A\delta\phi_t - B\delta\phi_d + \delta x_n] \end{aligned}$$

The simplest approach to determining the alignment parameters is to use the means of the following histograms(for the Δx case):

1. the distribution of residuals integrated over y, z, and ϕ, which gives δx directly,
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D.Chakraborty, J.D.Hobbs, D0 note Oct.13, 1999

Small Scale Self-Alignment with the SVT

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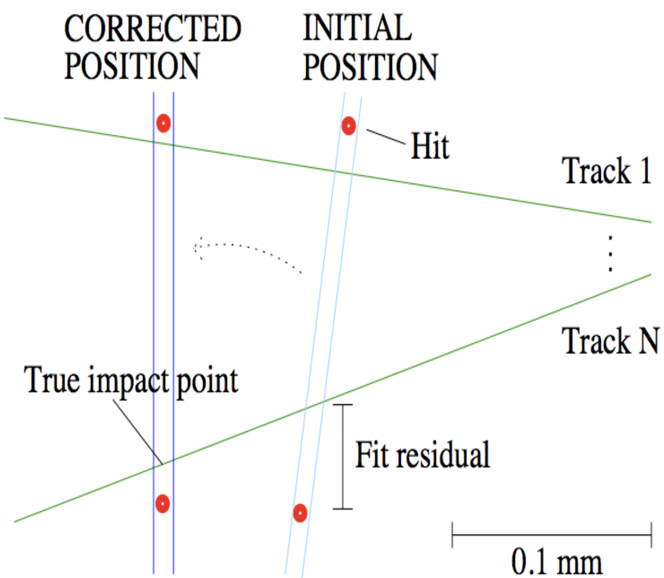

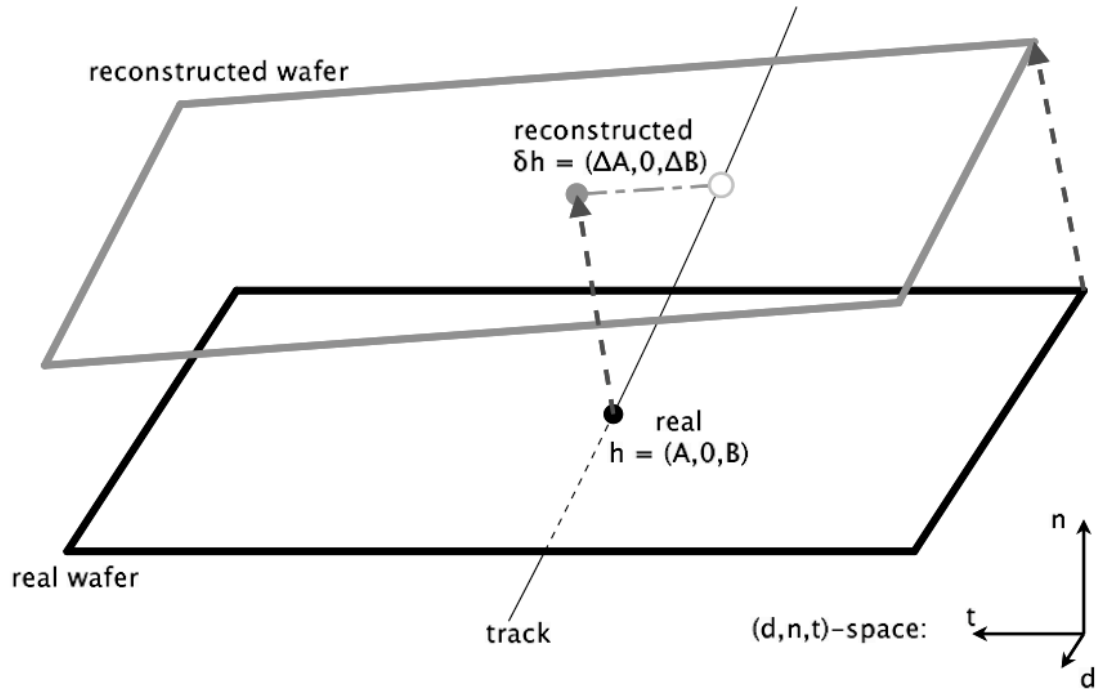

$$\Delta A = -B\delta\phi_n - \delta x_d + v_{dn}[A\delta\phi_t - B\delta\phi_d + \delta x_n]$$
$$\Delta B = A\delta\phi_n - \delta x_t + v_{tn}[A\delta\phi_t - B\delta\phi_d + \delta x_n]$$

http://drupal.star.bnl.gov/STAR/comp/calib/svt/selfalign

A. Appendix. Jacobian of measured hit position deviation from predicted track ones with respect to misalignment parameters.

1. *Misalignment of the detector in Global Coordinate System (GCS)*

- $\vec{j} = (j_x,\, j_y,\, j_z)$ - track direction cosinuses 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 perpendicular to measurement plane in GCS,
- $\vec{\Delta} = (\Delta_x,\, \Delta_y,\, \Delta_z,\, \Delta_\alpha,\, \Delta_\beta,\, \Delta_\gamma)$ - misalignment parameters: shift and rotation with respect to X,Y,Z axises, respectively.
- $\vec{x}_{hit} - \vec{x} = \mathbf{G} \cdot \vec{\Delta} =$

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

2. *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 tangenses 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.
- $$\vec{u}_{hit} - \vec{u} = \mathbf{L} \cdot \vec{\delta} = \begin{pmatrix} -1 & 0 & t_u & t_u v & -t_u u & v \\ 0 & -1 & t_v & t_v v & -t_v u & -u \end{pmatrix} \vec{\delta}$$
- $(u_{hit} - u) = -\delta_u + t_u(\delta_w + v\delta_\alpha - u\delta_\beta) + v\delta_\gamma;$
  $(v_{hit} - v) = -\delta_v + t_v(\delta_w + v\delta_\alpha - u\delta_\beta) - u\delta_\gamma;$