Overview

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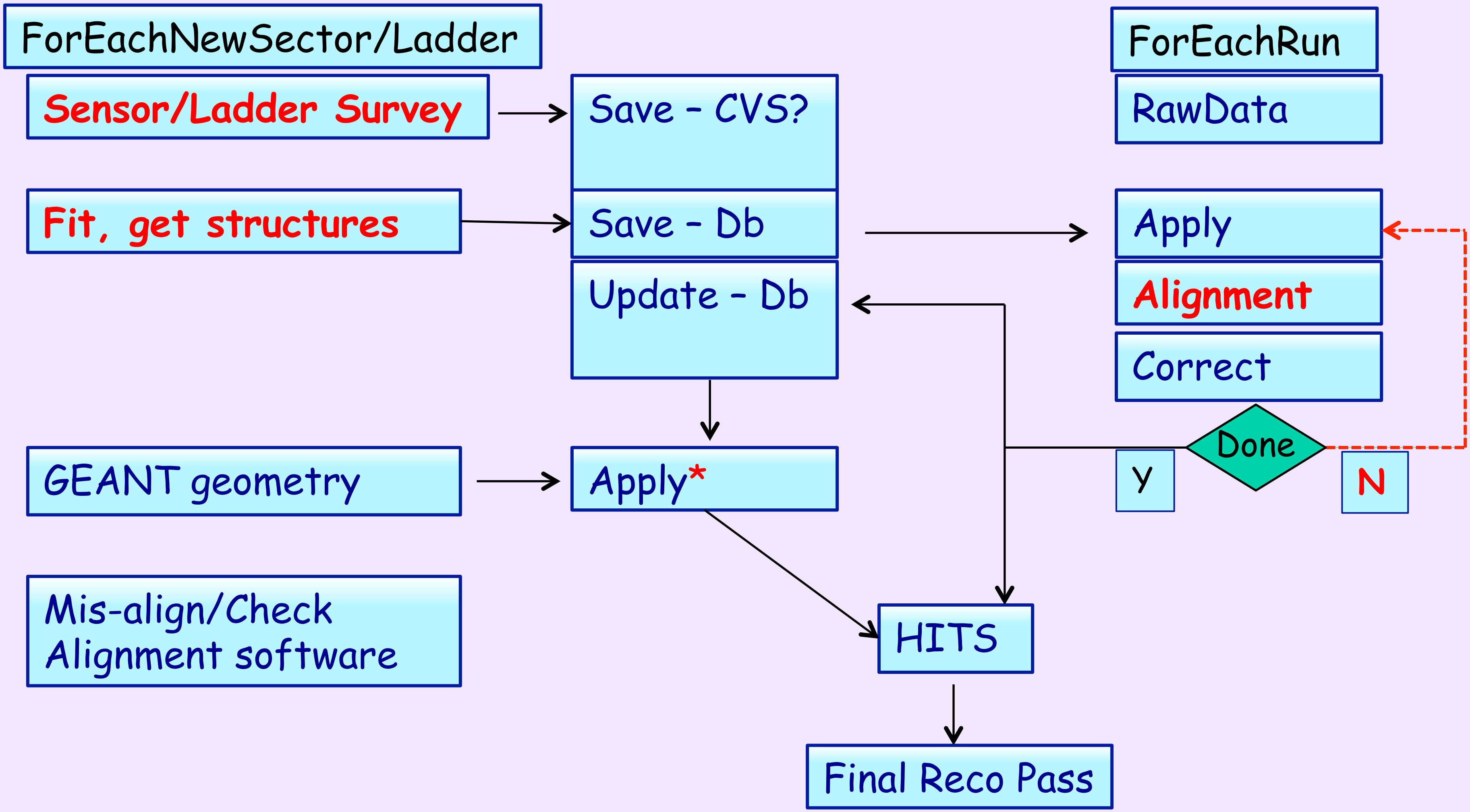
Outline

- Task(s) overview
- Hierarchy of Coordinate systems
  - Required precisions in Survey
- Survey structures needs/usage
  - see also other talks
- Alignment methods and needs
- Schedule, Manpower
- Open issues

General Flowchart of Survey/Alignment Tasks



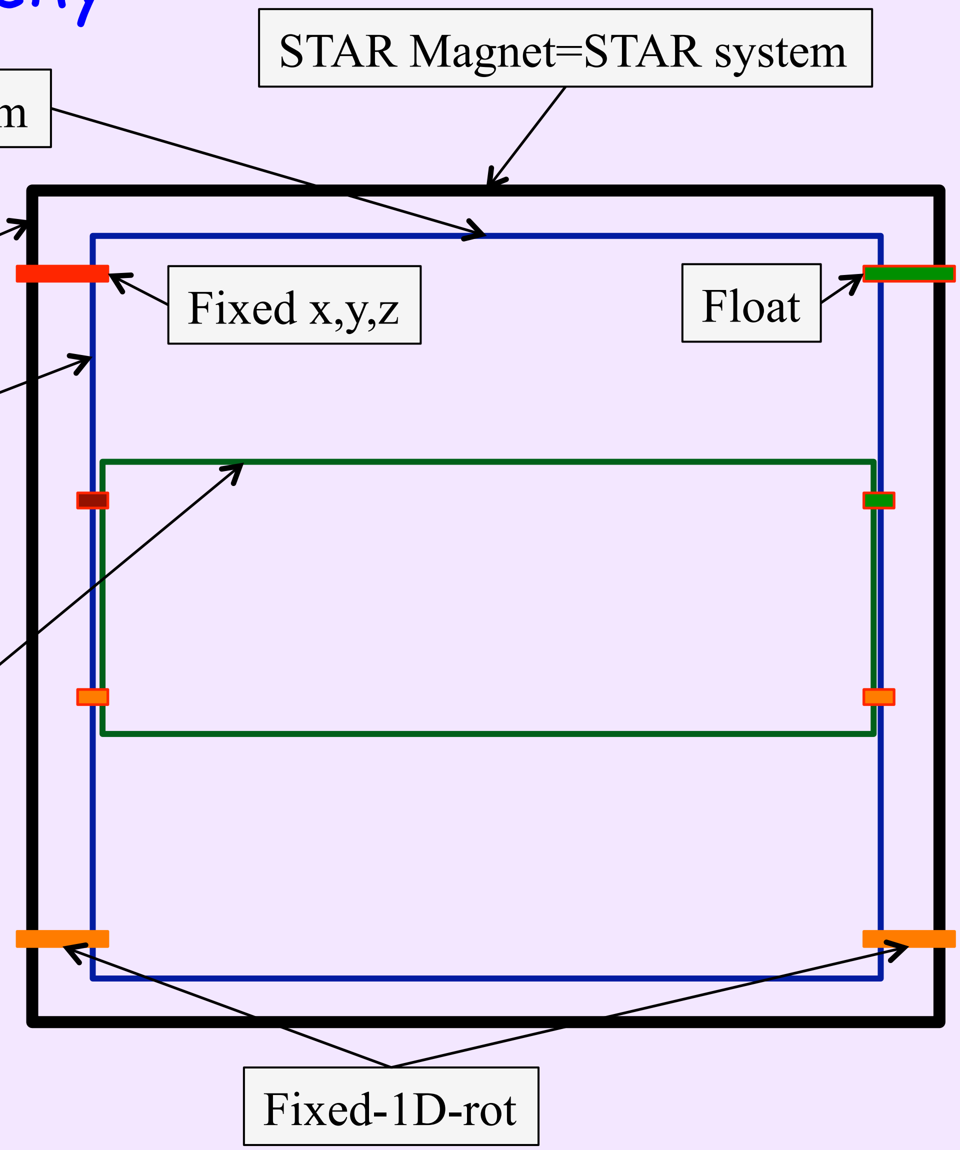
* VMC, STV ready

Task features

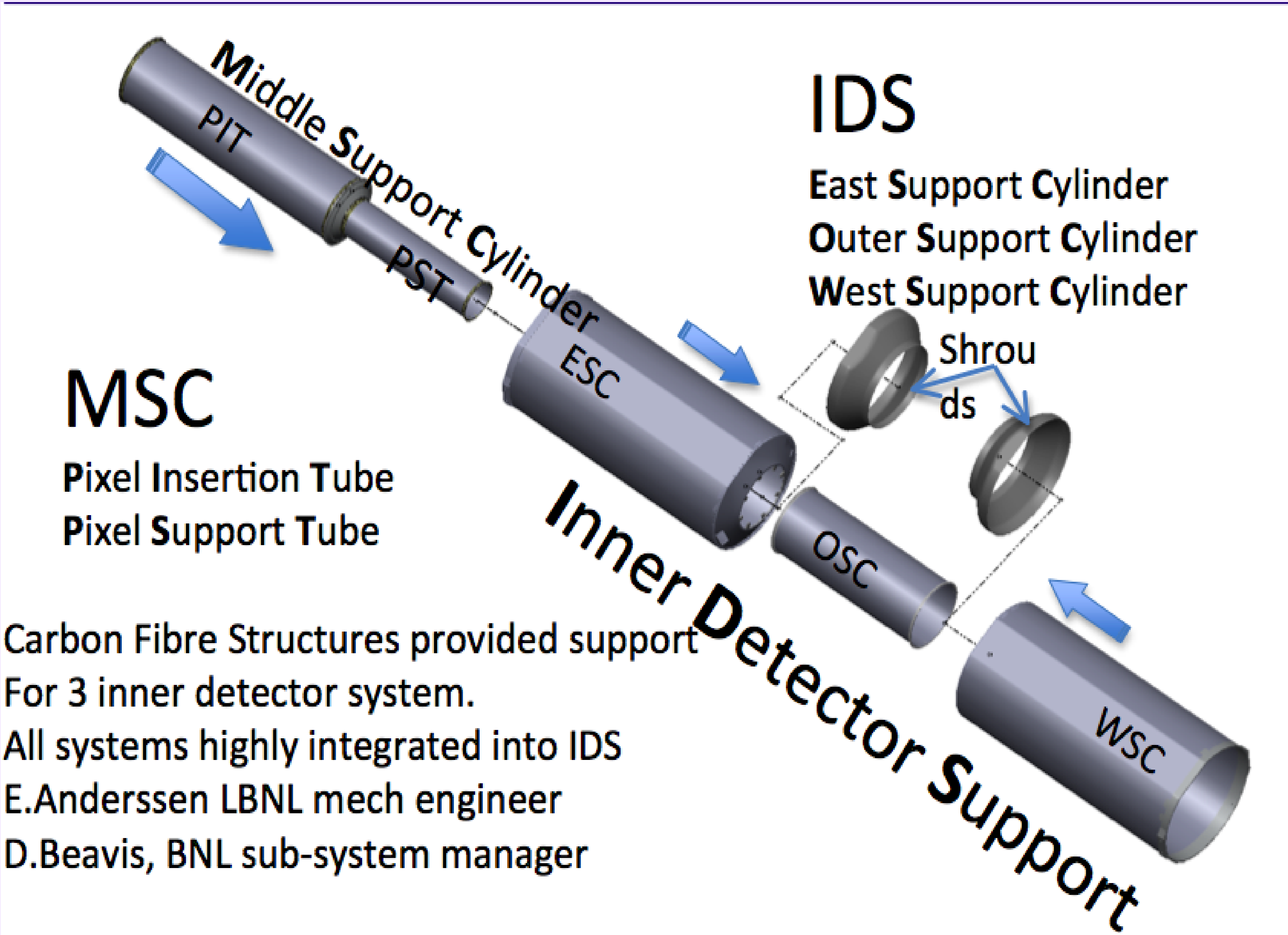
- Anything we build or touch needs Survey
  - e.g. versioning of same physical PXL sector after repairs
- Survey will freeze position of sensors on ladders and ladders on sector (PXL). Help also with sector on hemisphere (PXL). For SSD/ IST will freeze position of sensors on ladder
  - Alignment can check for gross mistakes but never move sensors on ladder or PXL ladder on sector. Note: this has been our way, not a universal truth
- Survey raw measurements can be saved externally (CVS). Geometry and fitted parameters reside in the Db with a timestamp
- For each yearly Run the in-situ position of major detector elements needs to be rechecked

Reference system hierarchy

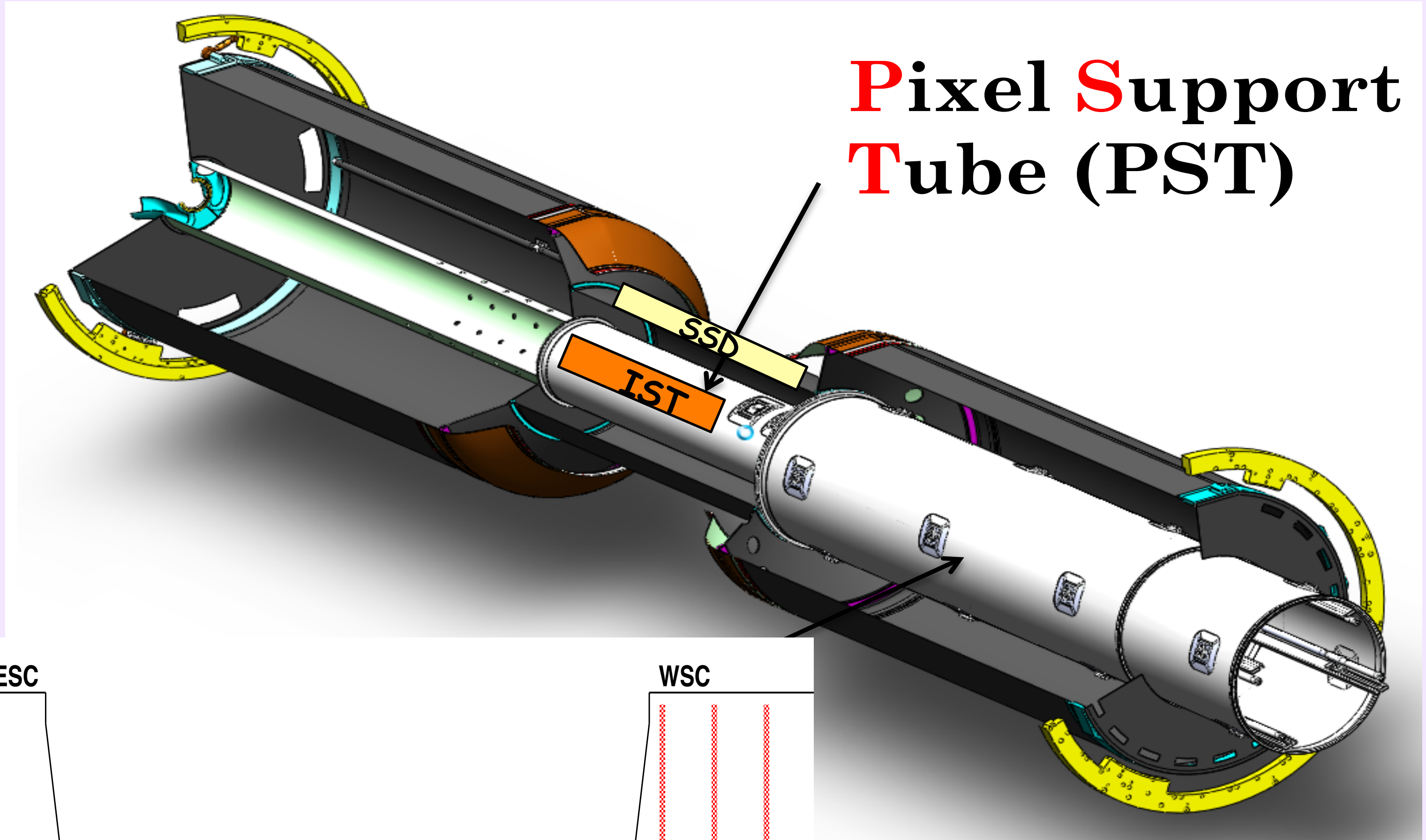
- Star Magnet defines overall system (Field map)
- TPC is the first important system for HFT (relative positioning), attached to Magnet
- **ESC/WSC** attached to TPC wheel. It defines the HFT system's relation (as a whole) to TPC system
- See next slides for systems inside the HFT complex
- Beam line constraint (new) is not a factor (?)

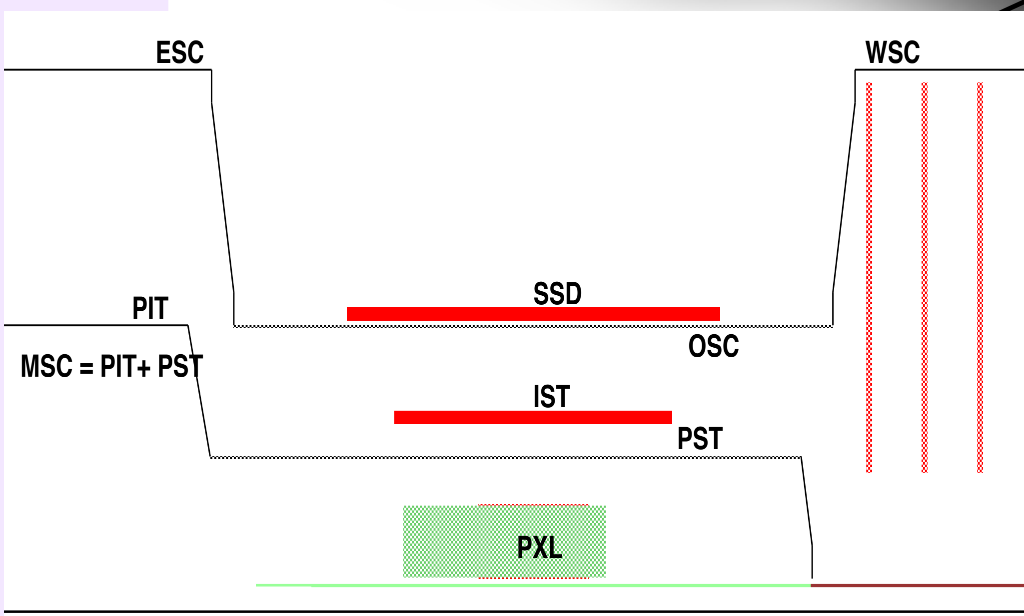


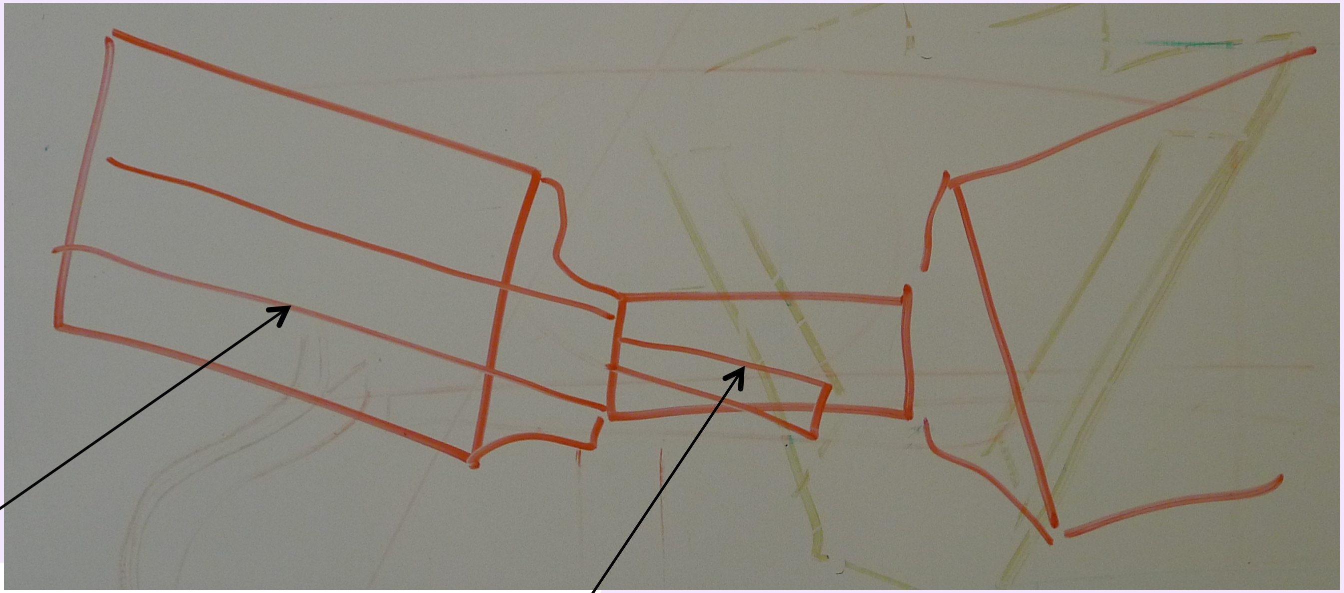
Experts please watch following slides – I need your input/comments

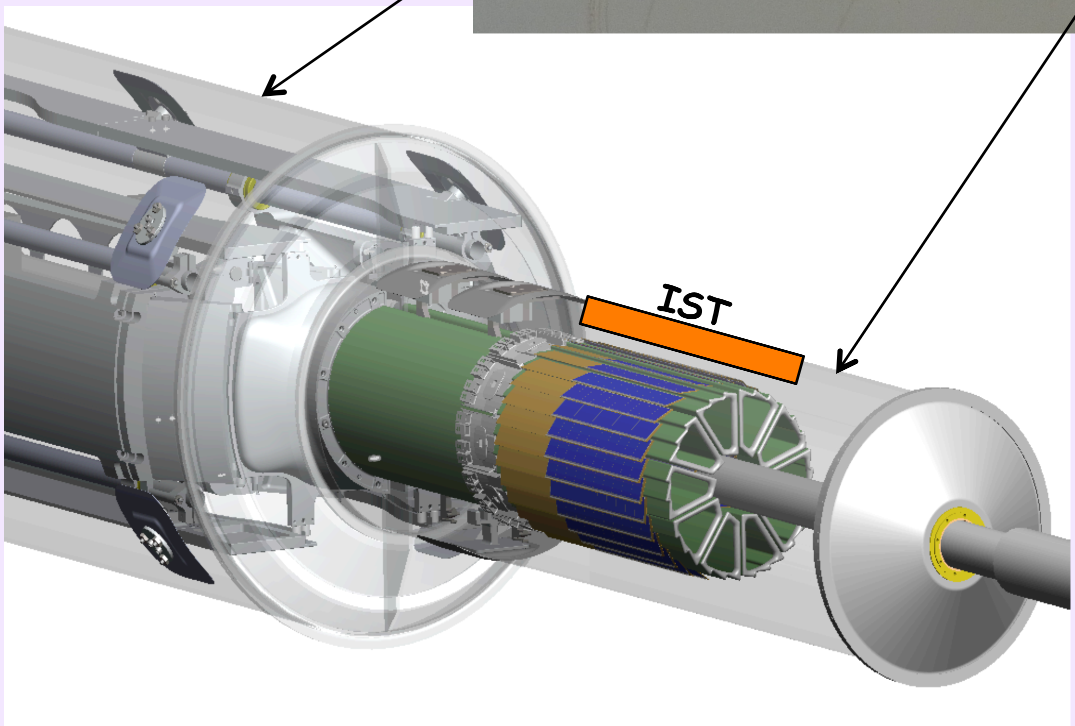

IDS
East Support Cylinder
Outer Support Cylinder
West Support Cylinder
MSC
Pixel Insertion Tube
Pixel Support Tube
Middle Support Cylinder
PIT
PST
ESC
OSC
WSC
Shrou
ds
Inner Detector Support
Carbon Fibre Structures provided support
For 3 inner detector system.
All systems highly integrated into IDS
E.Anderssen LBNL mech engineer
D.Beavis, BNL sub-system manager

General Layout





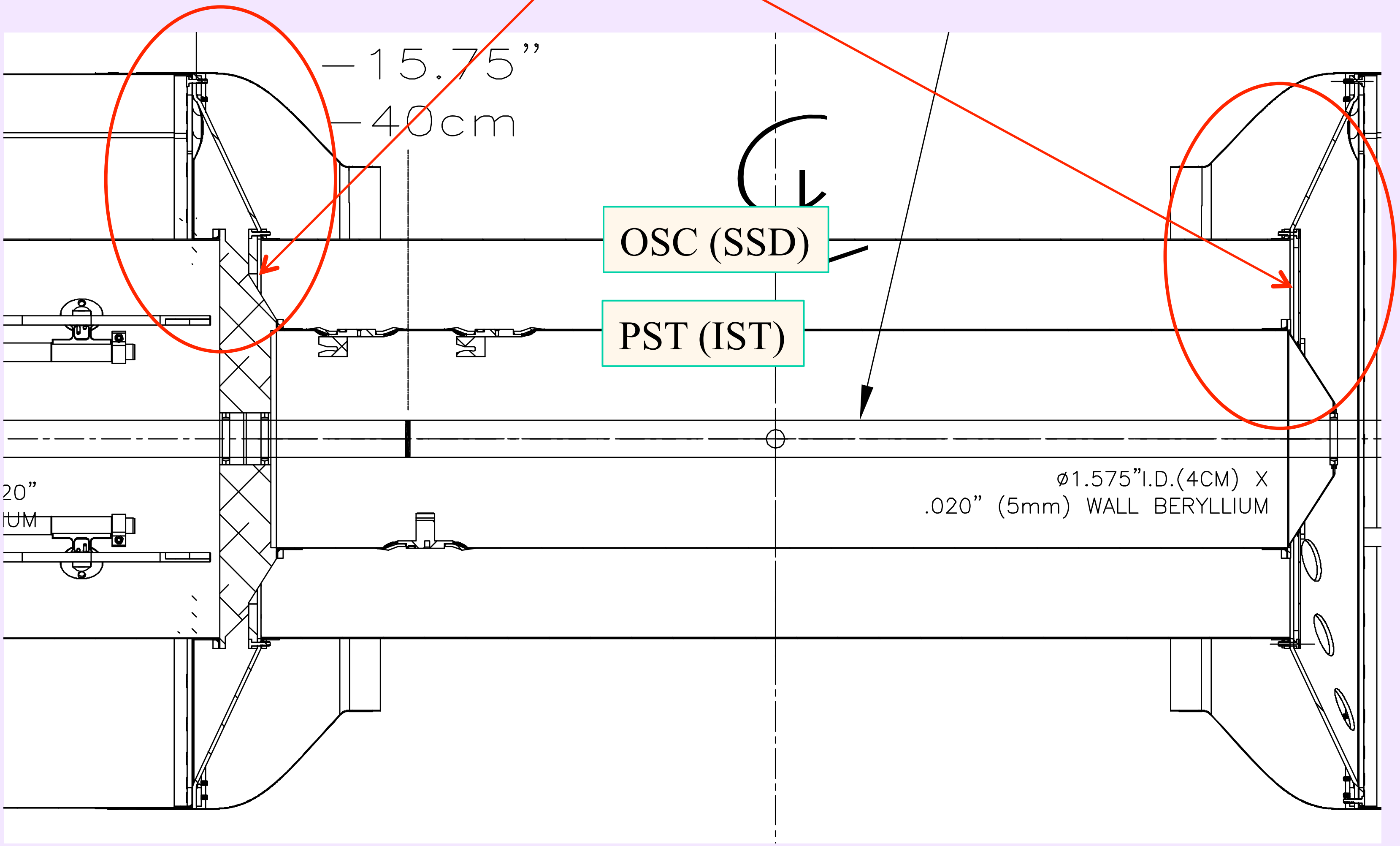




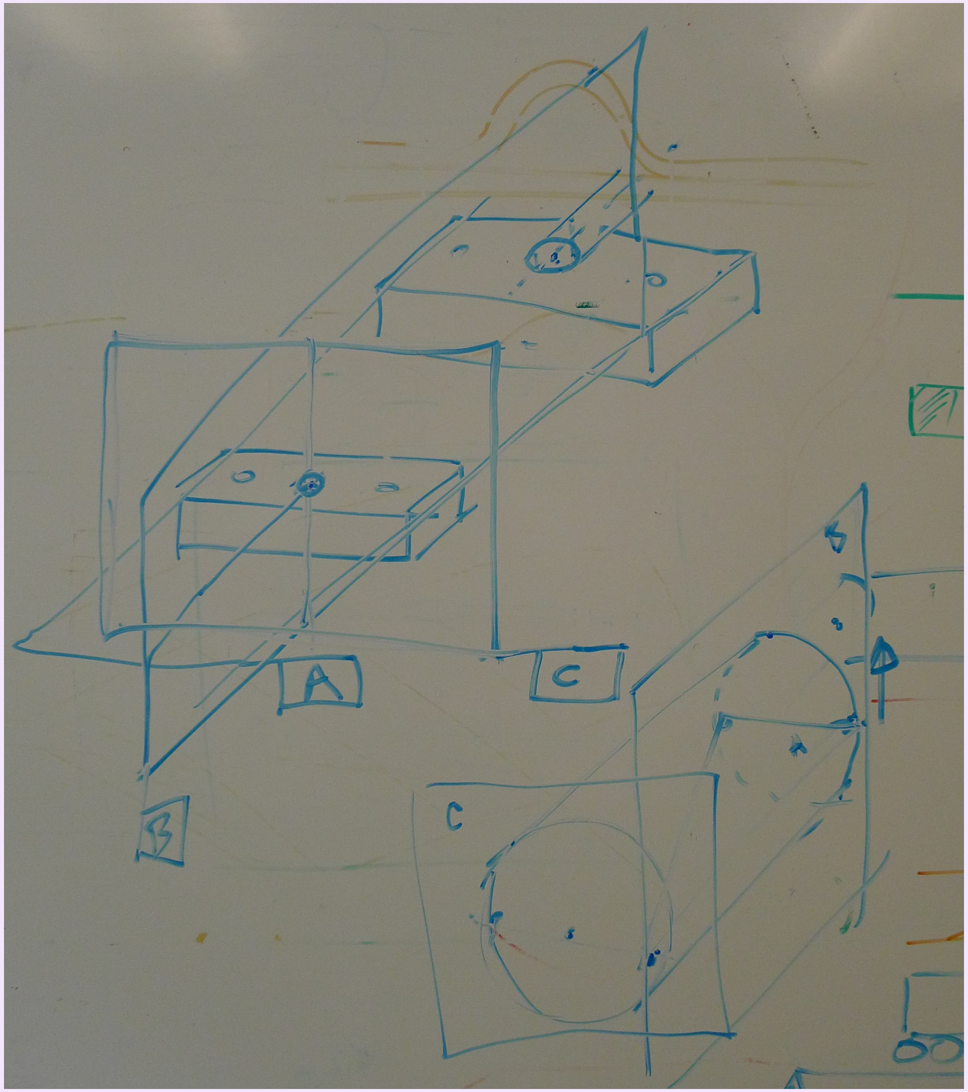
- The IST and PXL is a common/co-moving system

- The SSD is independent

But…OSC and PST are connected(?)



Eric's system definitions



- Three targets define the basic plane A
- The other two B,C are defined as:
  - B is normal to A
  - C is normal to A.and.B
- Targets are surveyed with hundreds of microns accuracy
- General rule: Definition of reference center (0,0,0) should be at the center of gravity of active elements

Reference system(s) issues

- In general (see next talks) survey accuracy of critical components (relative pixel and sensor positions) expected to be better than minimum acceptable values
- Need expected/surveyed positions of targets
  - to build 'ideal' position Db
  - Sub-millimeter accuracies acceptable -> Tracks will fix them
  - Need input on anticipated (design) in-situ position errors and estimated repeatability margins. ***Example***:

Precision requirement:

- Pixel relative to Pixel location: 20µm (RMS over entire PXL?)

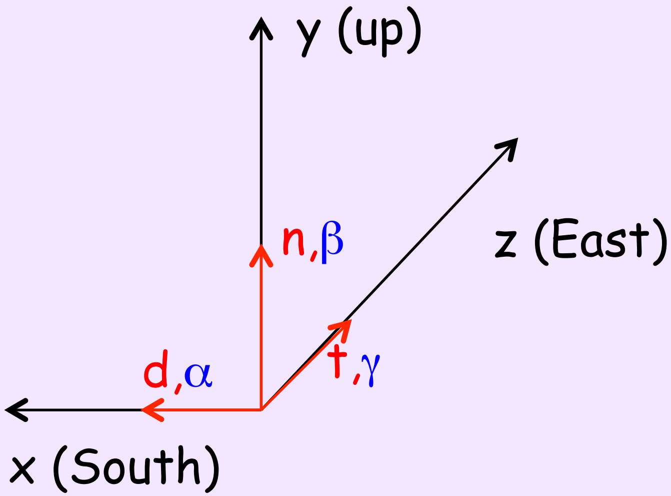
- PXL detector relative to STAR coordinate system: within 200 µm (?)

H.Wieman:14 Nov 2011

- GEANT geometry can/should be also synchronized with Reality instead of the current 'patch-the-hit' scheme
  - STV, VMC environment different from current Geant3

Offline use of Survey Info

Definitions



- Survey info is used in initial Local-to-Global transforms and inverse
- Done in terms of **TGeoHMatrix**
- General form is: $x_G^i = R \cdot x_L^i + T^i$
- This can be e.g. the center of a sensor or a hit. For PXL sensors a distortion function (TPS output) will take care of individual pixels in a wafer.
- n,d,t are unit vectors and β,α,γ the corresponding rotation angles, RHS

TGeoHMatrix definition

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

Transform example

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

Local <-> Global transforms

A series of matrix multiplications

Example: $STAR/StarDb/Geometry/ssd/SsdOnGlobal.upgr01.C

```
WG            = Tpc2Global * GL       * SG           * LS            * WLL;

WaferInGlobal= Tpc2Global *SsdinTpc*SectorInSSD*LadderInSector*WaferInLadder
```

```
// SSD and SVT as whole
St_Survey *SsdOnGlobal = (St_Survey *) GetDataBase("Geometry/ssd/SsdOnGlobal");
Survey_st *OnGlobal       = SsdOnGlobal->GetTable();
  GL.SetRotation(&OnGlobal->r00);
  GL.SetTranslation(&OnGlobal->t0);
// SSD sectors in SSD/SVT system
St_Survey *SsdSectorsOnGlobal = (St_Survey *) GetDataBase("Geometry/ssd/SsdSectorsOnGlobal");
// ladders in the SSD sector coordinate systems
St_Survey *SsdLaddersOnSectors = (St_Survey *) GetDataBase("Geometry/ssd/SsdLaddersOnSectors");
// wafers in the SSD ladder coordinate systems
St_Survey *SsdWafersOnLadders = (St_Survey *) GetDataBase("Geometry/ssd/SsdWafersOnLadders");
```

Alignment methods (outline only)

- There are 'Global' and 'Self' Alignment methods
  - use 'external' track info or 'internal'

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

- We have successful 'Global' methods already in place
  - Software can be re-checked with simulations [->need (now have) geometry]. In SVT era precision was 10 microns and 0.1mrad
  - In PXL era should practically vanish
  - Specific alignment procedures might be different (next slide)

- We now have significant sensor overlap to make use of 'Self' alignment methods. Industry standard is '*Millepede*' code which was successfully used in Alice and elsewhere

Procedure

OLD ->

TPC only tracks

- **Global alignment of SSD (+SVT) with respect to TPC**
- **(Local) Alignment of SSD ladders:**

TPC + SSD tracks

- **(Global) Alignment of SVT Clam Shells**
- **(Local) Alignment of SVT ladders**

TPC + SSD + SVT tracks

- **Check consistency and**
- **re-evaluate SVT & SSD hit errors**

Statistics needed:
1 mm → ~20 micron: reduction factor 50
→ ~2,500 tracks per SVT sensor
→ data sample with ~250,000 tracks -> 250K CuCu events

NEW ->

PXL detector is a big asset (avoid TPC distortions):

Primary tracks with TPC+PXL hits

- **Relative alignment of PXL halves (check survey)**
- **Alignment of IST ladders with respect to PXL**

Primary tracks with (All – SSD) hits

- **Alignment of SSD ladders**

- For alignment we use "good" (well defined) tracks fitted with the primary vertex.
  - Use of primary tracks significantly improves precision of track predictions in Silicon detectors and reduces influence of systematics.

- In order to minimize TPC space-charge distortions (and PXL pileup) we will need to use low luminosity data

Figure of merit for HFT alignment.

- Pointing accuracy, aka Impact parameter resolution:
  - DCA resolution (in bending XY $\equiv\rho\phi$ plane: σ_{DCA}), and resolution in non-bending plane: σ_z, is figure of merit
  - $\sigma^2_{DCA} = \sigma^2_{vertex} + \sigma^2_{track} + \sigma^2_{MCS}$ (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 Coulomb Scattering (MCS): $\sigma_{MCS} \sim 20\mu m / \beta p$ (GeV/c) (for thin PXL)
  - Overall mis-alignments of < 10 μm are acceptable (no big impact)

Schedule - Manpower

- Some sub-system estimates are in following talks

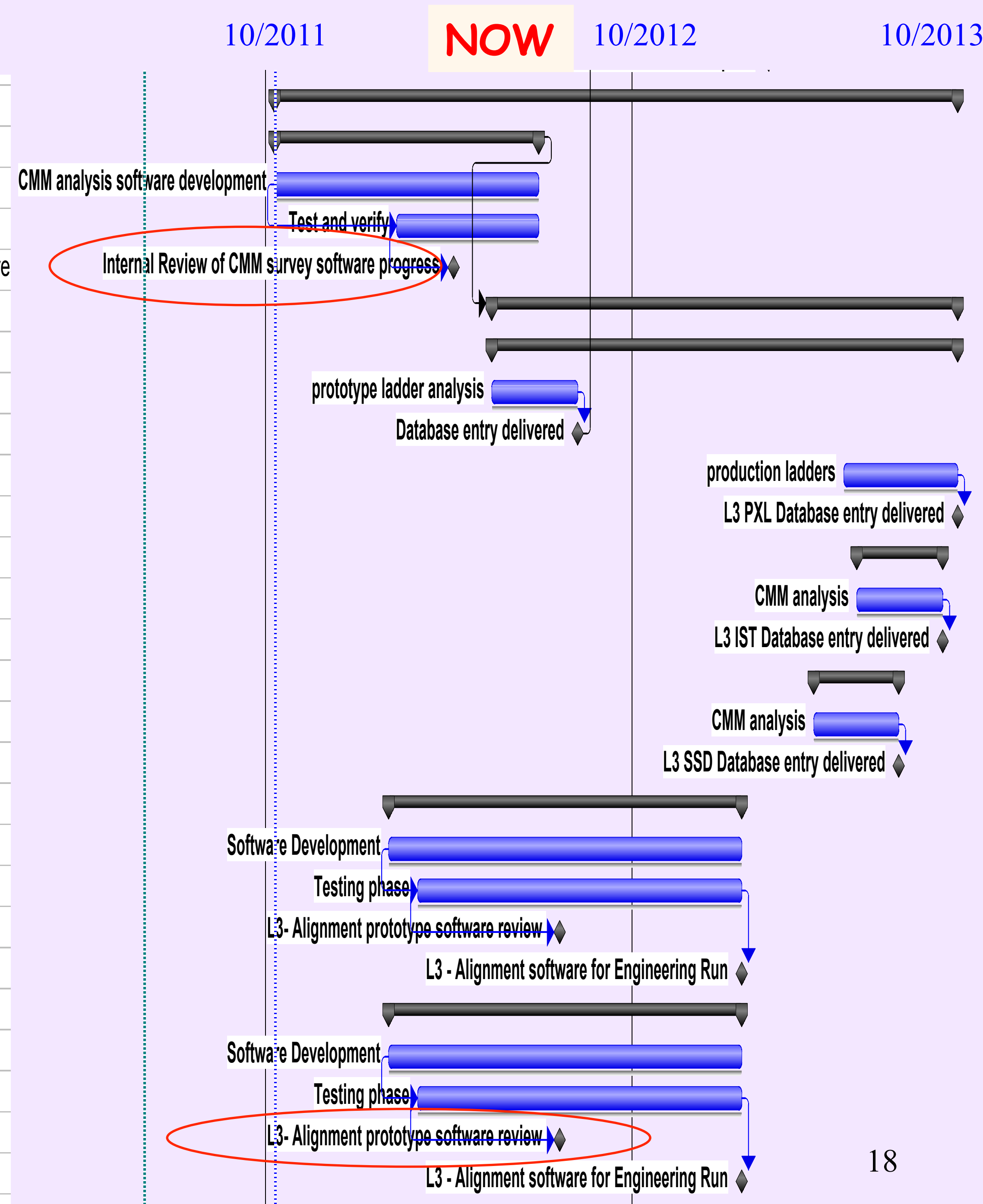
ID	Task-name	Duration	Begin-Date	Predecessors	Resources %-Person/FTE
1.6.5	**Calibration/Alignment**	**36 months**	**09/01/2010**		**500/4.7(2.0)**
1.6.5.1	SURVEY	15(7) months	09/01/2011		***190/2.3(1.1)***
1.6.5.1.1	PIXEL Survey	7(3) months	09/01/2011		190/1.1(0.5)
1.6.5.1.2	IST Survey	4(2) months	09/01/2011		190/0.6(0.3)
1.6.5.1.3	SSD Survey	4(2) months	09/01/2011		190/0.6(0.3)
1.6.5.2	GLOBAL Alignment	13(6) months	09/01/2011	1.6.2/1.6.3	***100/1.3(0.6)***
1.6.5.2.1	PIXEL Global Align.	7(4) months	09/01/2011		100/0.7(0.4)
1.6.5.2.2	IST Global Align.	3(1) months	09/01/2011		100/0.3(0.1)
1.6.5.2.3	SSD Global Align.	3(1) months	09/01/2011		100/0.3(0.1)
1.6.5.3	SELF Alignment	9(4) months	09/01/2011	1.6.2.1/1.6.2.2	***100/0.8(0.2)***
1.6.5.3	Test/Verify	3(2) months	09/01/2011	1.6.2.1/1.6.2.2	***100/0.3(0.1)***

ID	Task-name	Institutions	Name	% of time (max)	Years
1.6.5.1	SURVEY	LBNL, MIT, KSU, BNL	Postdoc+Stud.	2x30(40)	3
1.6.5.2	GLOBAL Alignment	LBNL, MIT, KSU, BNL	Postdoc+Stud.	2x20(30)	3
1.6.5.3	SELF Alignment	LBNL, MIT, Purdue, BNL	Postdoc/Stud.	50(60)	2

- We could use some more people here, especially a student ~50% at LBL
- SSD, IST situation less clear

Schedule

1.6.1.4	**Calibration and alignment**
1.6.1.4.1	**Survey Software**
1.6.1.4.1.2	CMM analysis software development
1.6.1.4.1.1	Test and verify
1.6.1.4.1.9	Internal Review of CMM survey software progre
1.6.1.4.5	**CMM analysis**
1.6.1.4.5.1	**Analysis of PXL**
1.6.1.4.5.1.10	prototype ladder analysis
1.6.1.4.5.1.11	Database entry delivered
1.6.1.4.5.1.12	production ladders
1.6.1.4.5.1.13	L3 PXL Database entry delivered
1.6.1.4.5.2	**Analysis of IST**
1.6.1.4.5.2.5	CMM analysis
1.6.1.4.5.2.6	L3 IST Database entry delivered
1.6.1.4.5.3	**Analysis of SSD**
1.6.1.4.5.3.1	CMM analysis
1.6.1.4.5.3.2	L3 SSD Database entry delivered
1.6.1.6	**Global Alignment**
1.6.1.6.1	Software Development
1.6.1.6.2	Testing phase
1.6.1.6.3	L3- Alignment prototype software review
1.6.1.6.4	L3 - Alignment software for Engineering Run
1.6.1.8	**Self Alignment**
1.6.1.8.9	Software Development
1.6.1.8.10	Testing phase
1.6.1.8.11	L3- Alignment prototype software review
1.6.1.8.12	L3 - Alignment software for Engineering Run



Open Items/Issues

- Need to finalize the PXL sensor representation in Db. This will be done with the survey of the prototype sector
- Need to setup Data formats, Db(s), code to deliver matrices
- Need to clarify/verify/define reference system (physical) dependencies and hierarchy
- 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 keep/use expertise around
- Need to rework/prioritize Software Summer activities

- See also sub-system specific issues

Summary

- Activity is picking up
- Critical mass/think-tank is building
- I do not see, or foresee, any show stoppers
- but…most of the work is still ahead of us