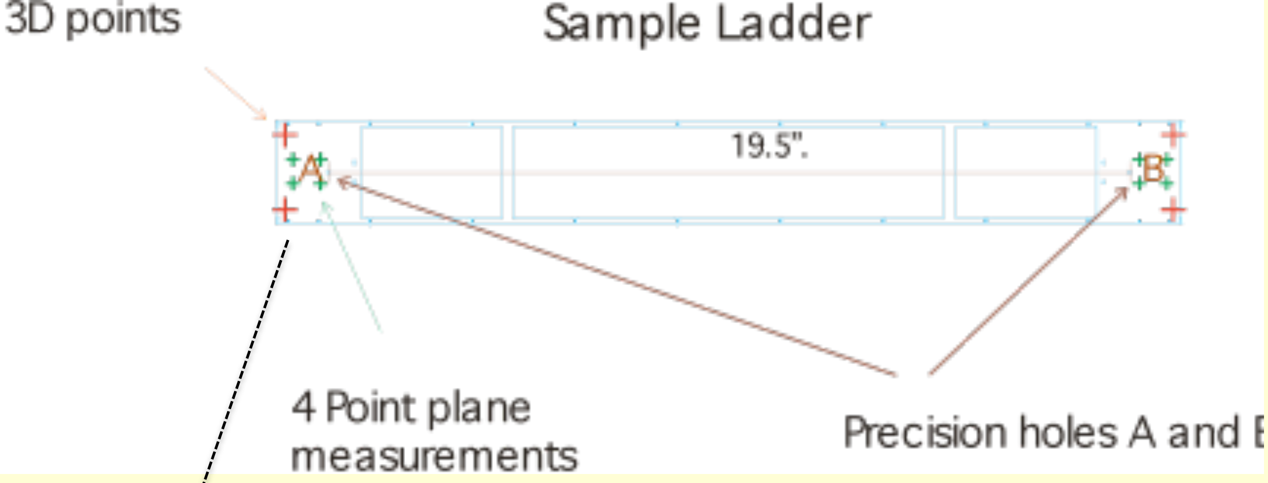
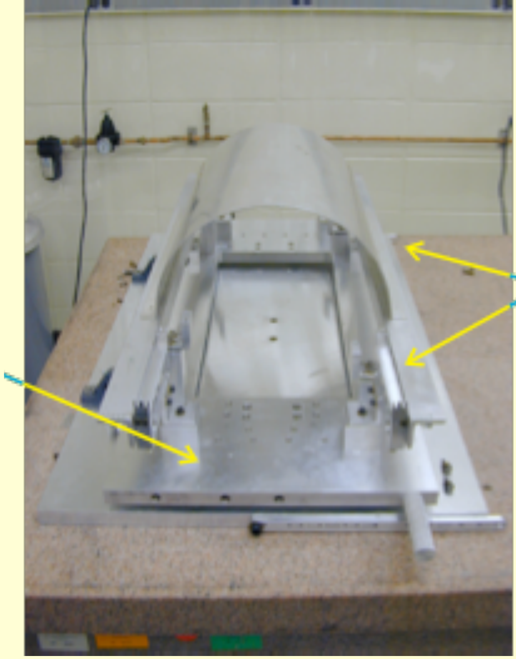
Survey notes

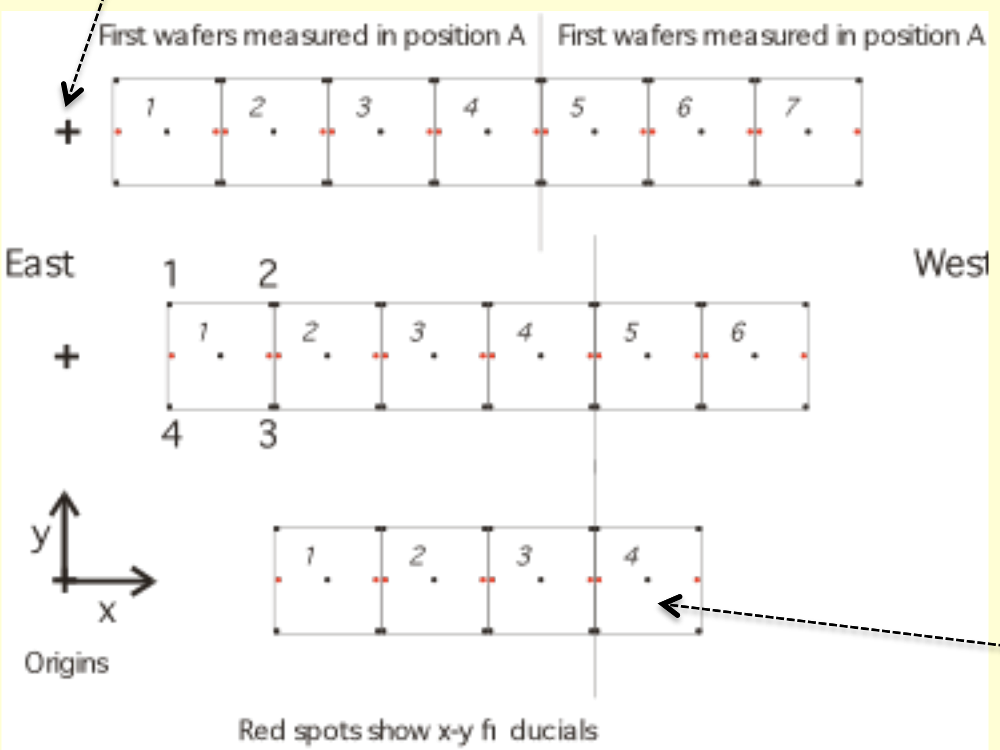
Spiros Margetis

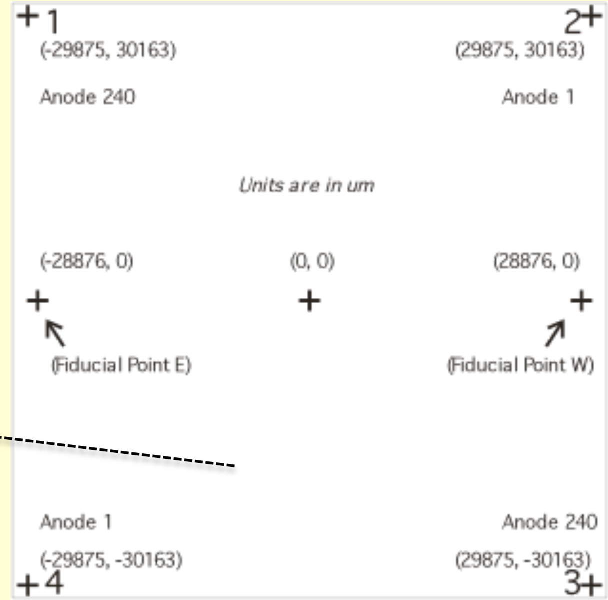
Definitions

- There are 'Global' and 'Self' Alignment methods
- We lack a hardware monitoring system. Once installed we rely on specs and software
  - Software can be checked with simulations (->need geometry)
- In SSD/SVT we used the:
  - STAR (Global) coordinate system (for Clamshell/Sector) placement
  - Local (Wafer/Ladder) system for Ladder placement
- Systems and Math not intuitive. Watch your step



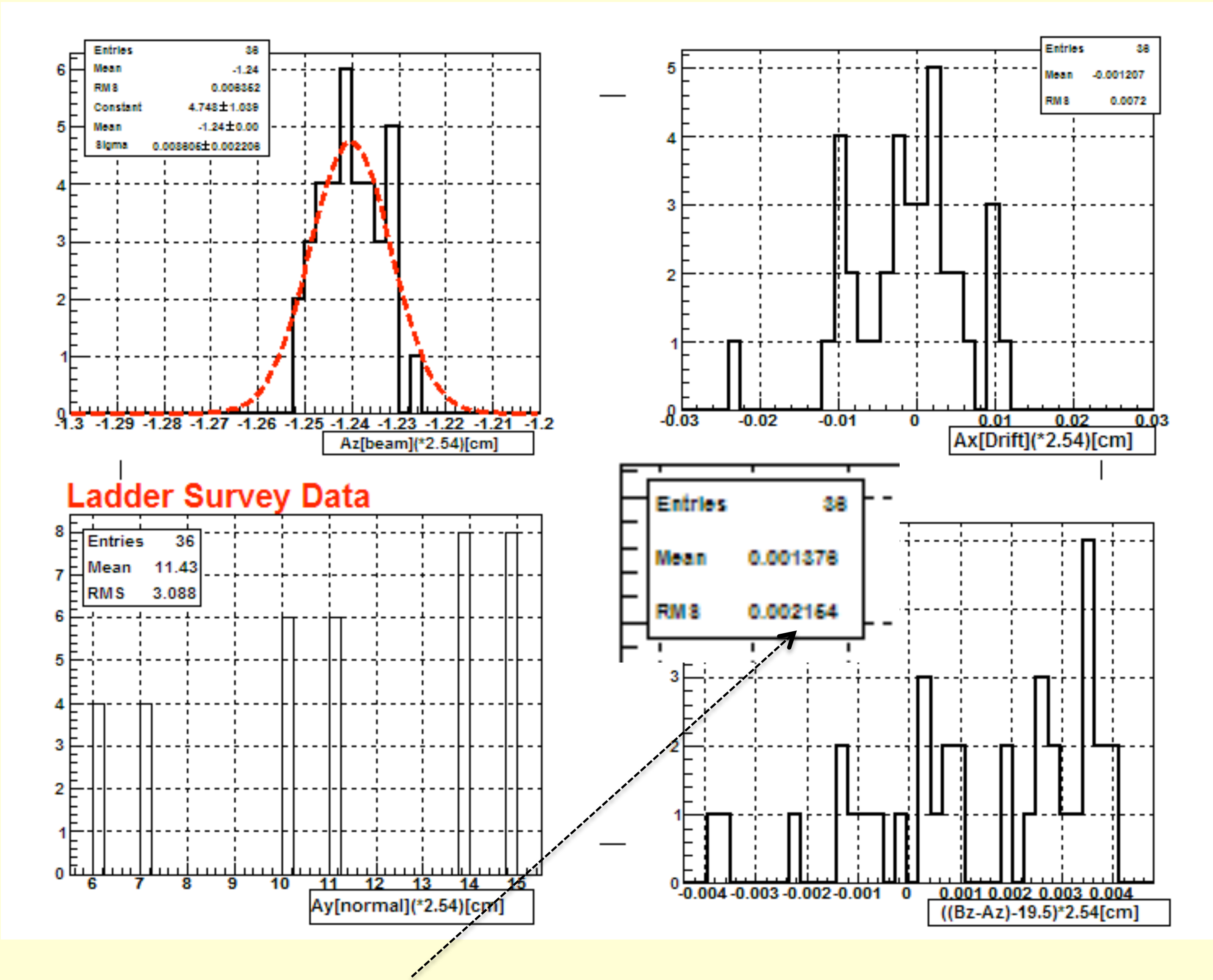






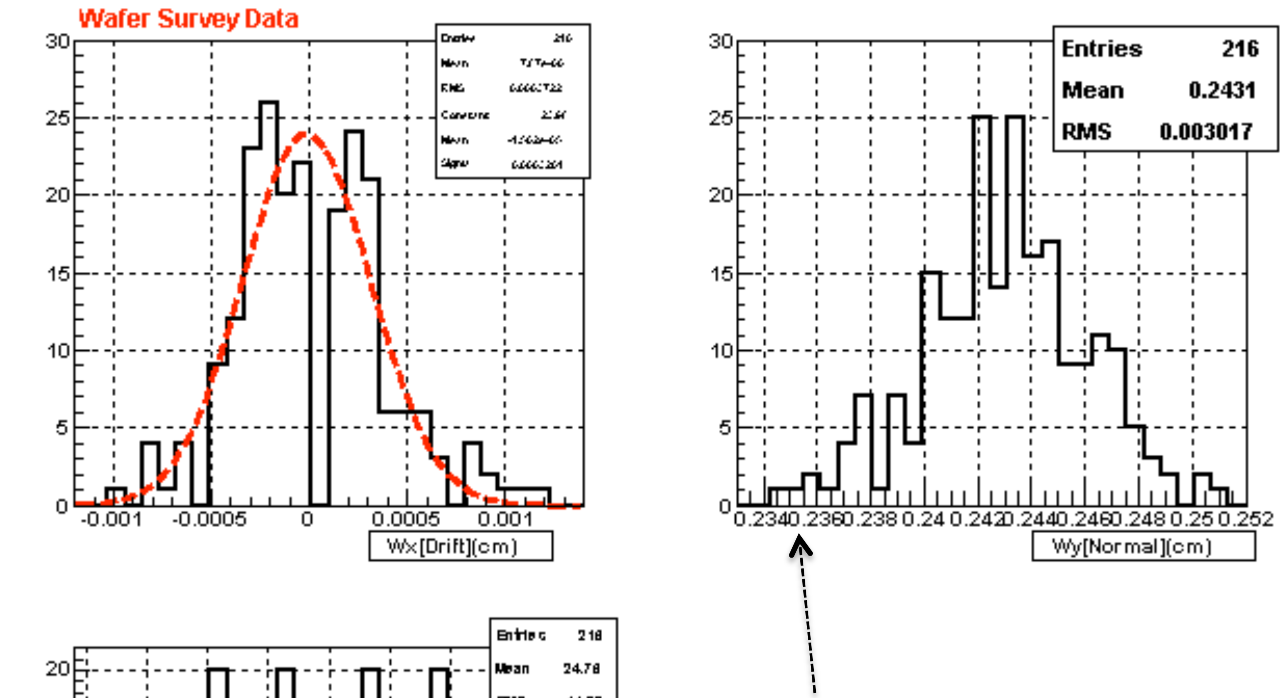
Survey systems/methods not much different

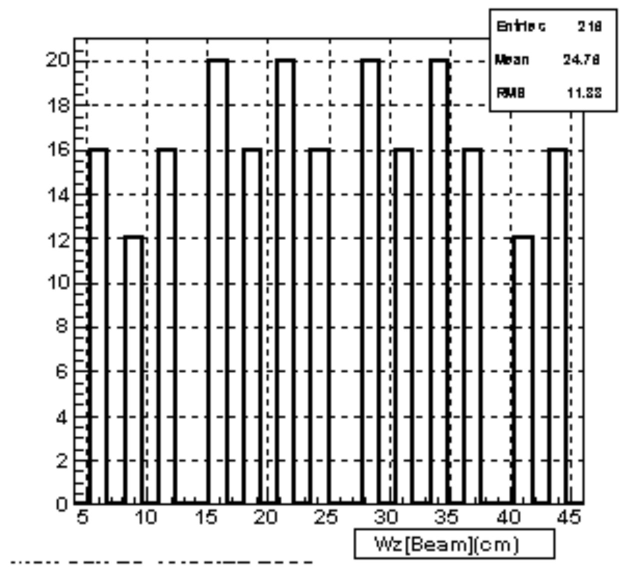
SURVEY OF LADDERS ON SHELLS (example)



Error of about 25 microns

SURVEY OF WAFERS ON LADDERS (example)





Nominal position 0.235
(.2500-0.0150)
Glue 80 micron thicker !!!

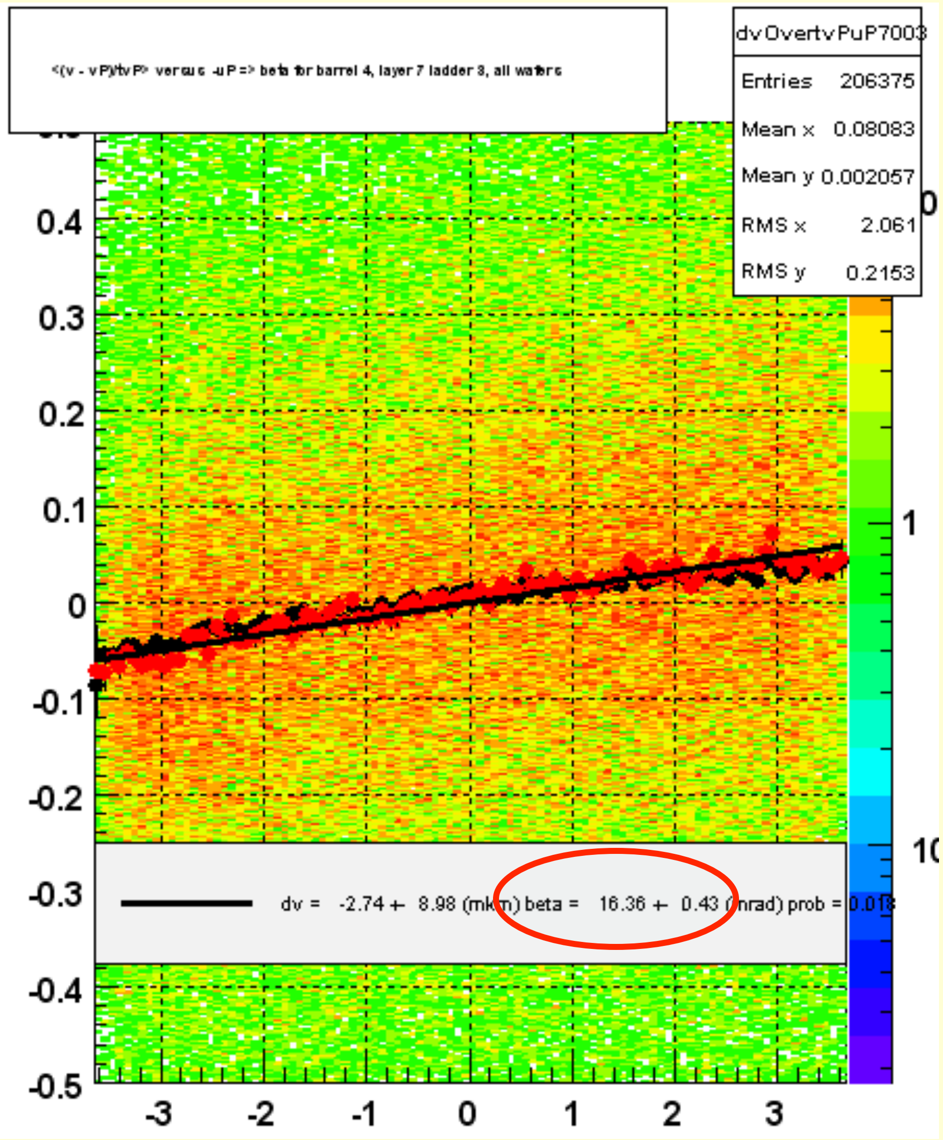
Error of a few microns (taken into account)

SSD

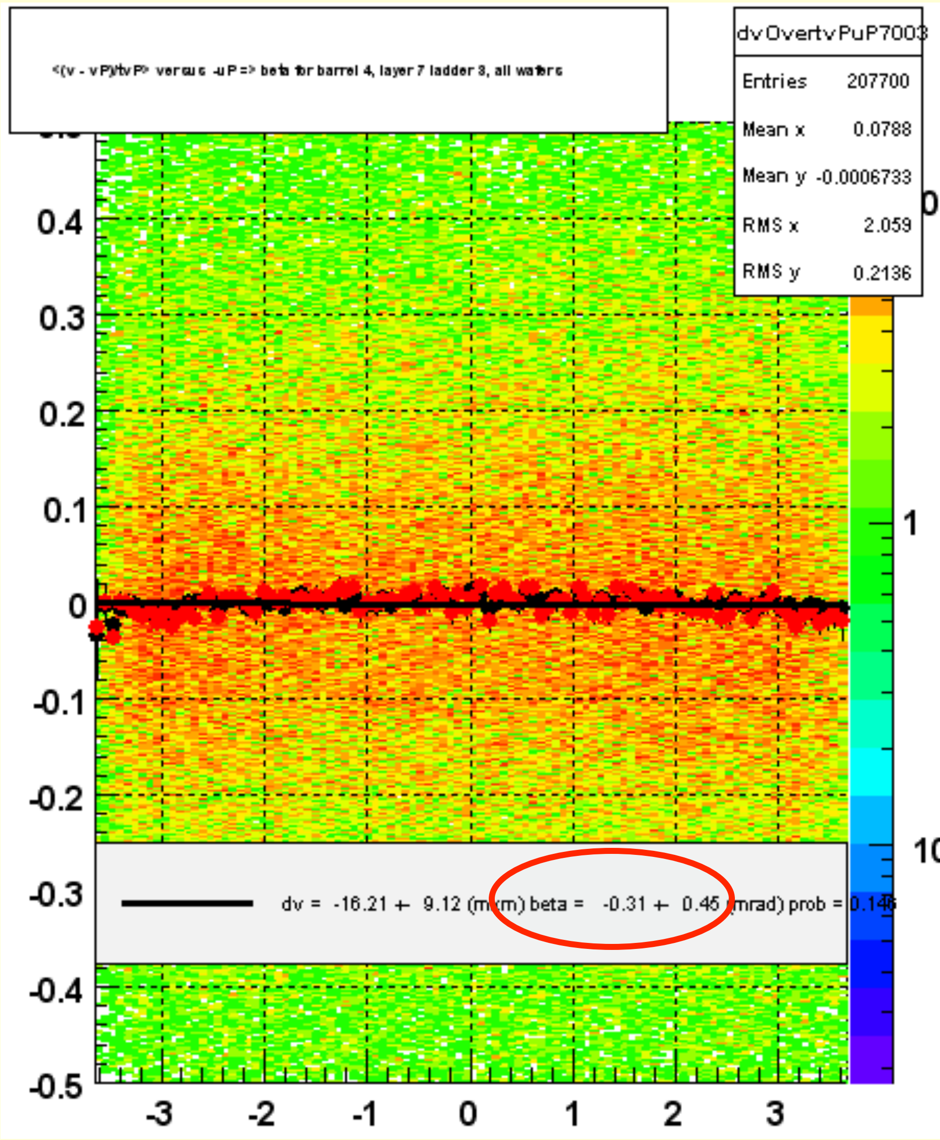
- First non-drifting detector after TPC
  - Important to have good survey info
- Survey info had poor CMM depth resolution
  - Lilian Martin put it in STAR-Db
  - Wafers looked fine on ladders but ladders showed significant rotation and translation shifts in situ (see next picture)
    - Unexpected
- We need to re-survey the ladders, redefine fiducial marks on ladders and support (Eric) and find a way to relate them
  - Ladder orientation(s) -> to check gravitational sagging

We discovered by ‘accident’ the Lorentz angle effect

BEFORE



AFTER



Example of correcting a SSD individual ladder rotation around the z-axis

IST

- In principal very similar to SSD but…
  - 1D really
  - No previous experience
  - Different mounting
- Need prototype and tests

PIXEL

- It is engineered to need minimum Soft-alignment work
  - We rely heavily on survey
- We need to decide on ladder representation
  - Need measurements and analysis to do this
- We need survey of all critical structures
  - See slides from Howard Wieman

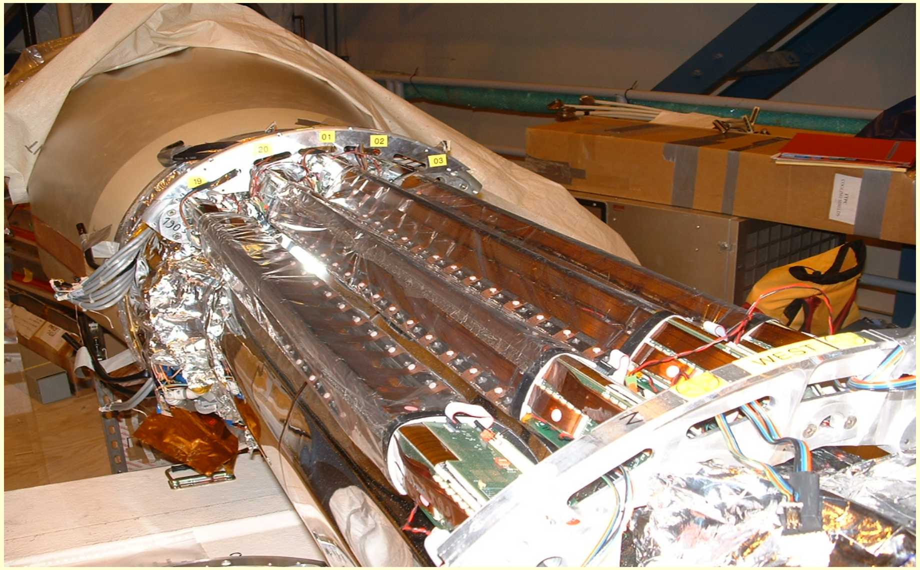
Spares

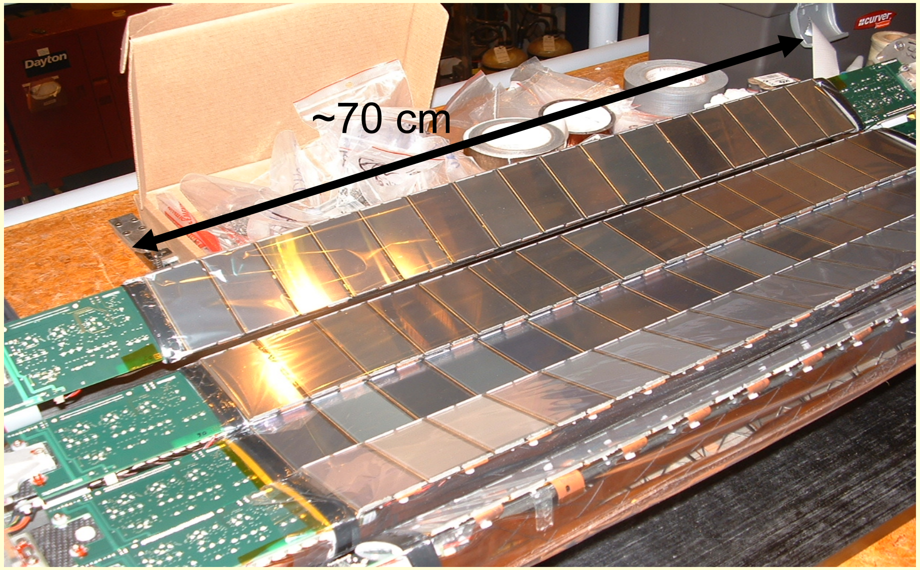
TPC

- TPC radial coverage 60 -190 cm
- spatial resolutions:
  - $\sigma_{\rho\phi} \approx$ **600** μm and $\sigma_z \approx$ **1200**μm for Inner Sectors
  - $\sigma_{\rho\phi} \approx$**1200** μm and $\sigma_z \approx$ **1600**μm for Outer Sectors
- electrons drift in **E** || **B** field (z direction)
  - maximum drift length ~ 2m
  - lateral diffusion is reduced
- drift velocity is monitored by laser system: precision ~2 $\times 10^{-4}$ → systematic error in z direction less than 40 μm
- distortions due to **E** X **B** effects: space charge, E field distortions
  - are monitored by DCA (distance of closest approach) of the track at the primary vertex and kept on the level better than ~100μm
- GMT and Inner Silicon Dets will help calibration/ monitoring

SSD - A single layer of 2-side Silicon Strip Detector

- It wraps around the SVT as a fourth layer.
- Its primary **purpose** is to provide an **intermediate (non-drifting) point** for track matching **between TPC and SVT** (or whatever comes next) .
- 20 ladders with 16 wafers each mounted on 4 rigid Sectors at ~23 cm from the beam.
- Installed in STAR for Run IV, became **fully functional in Run V**.
- Strip pitch: 95 μm. Strip length: 4 cm. Stereo angle between p- and n-strips is 35 mrad.
- Intrinsic **resolution** should be better than **~30 μm** ($\rho\phi$) × 860 μm (Z).
- **Big Advantage: Non-drifting** technology.
  - Of course there is a Lorentz shift of holes and electrons in $\rho\phi$ direction due to our 5 kG magnetic field (with Lorentz $\theta_{holes} = 4.4° \rightarrow 4.4\mu m$ and $\theta_{electrons} = 1.6° \rightarrow 1.6\ \mu m$) which produces a sizable effect in Z direction (~ 200μm) due to the stereo angle. But it is clear how to account for this effect.





Figures of merit for SVT/SSD precision.

- **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** for charm decay ($c\tau \sim 100\mu m$) registration with a vertex detector:
  - $\sigma^2_{DCA} = \sigma^2_{vertex} + \sigma^2_{track} + \sigma^2_{MCS}$ (the same for non-bending plane),
  - **primary vertex resolution**: $\sigma_{vertex} \sim 600\ \mu m / \sqrt{N_{good\ tracks}}$, for central Au+Au collisions turns out to be **better than 20 μm** (for minimum biased events ~100 μm), (all 3 terms improve with HFT)
  - **track pointing resolution**: $\sigma_{track} \sim 2\ \sigma_{XY}$ in our case, where σ_{XY} is intrinsic detector precision $\oplus$ alignment errors,
  - **Multiple Coulomb Scattering** (MCS): $\sigma_{MCS} \sim 170\mu m / p(GeV/c)$ (from simple analytic estimations)
  - from **requirement** that the **track pointing resolution** should be **comparable with MCS @ 1 GeV/c** then **detector resolution** (including alignment) should be **$\sigma_{XY} < 80\ \mu m$** and **$\sigma_z < 80\ \mu m$** for both bending and non-bending planes.

Methods

- Methods can naturally be split into two parts:
  - Calibration of SVT Drift velocities on hybrid level, and
  - Alignment of detectors:
    - **Assumed (after checking with survey data):**
      - Frozen **wafer position** on ladder from **survey data**, i.e. **ladder** is the **lowest level** degree of freedom.
      - **Rigid body** model: ignore possible twist effects, gravitational/stress sagging etc.

- The methods are **interconnected** and this supposes **iterative** procedure i.e.
  - using average drift velocities to do alignment and
  - after the alignment, check and correct drift velocities
  - …and iterate

SURVEY

- Survey was performed for both SSD and SVT
- For the SVT we got information about:
  - Wafers on Ladder (High precision [<1micron] Nikon camera)
  - Ladders on Clamshells (~25 micron accuracy)
- No survey info for relative Clamshell placement
- No survey in situ
- No re-survey after water leakage or ladder replacement
- No hardware position monitoring in situ
- No cosmics or Z0
- **Only wafer position on ladder used. The rest just as a starting point for software**

Procedure (further details)

SVT drift velocity: the first approximation of SVT drift velocity is obtained from t_min, t_max fits for each hybrid.

TPC only tracks

- Global alignment of SSD (+SVT) with respect to TPC
- (Local) Alignment of SSD ladders: ladders translations up to ~200 μm and rotations (especially around y-axis) of up to ~20mrad. After fine tuning the majority had translations of < 20 μm and rotations <0.5mrad, all within errors.

TPC + SSD tracks

- (Global) Alignment of SVT Clam Shells
- (Local) Alignment of SVT ladders
- Correction to SVT drift velocities. SVT drift velocities have been refitted including extra dependence on drift distance and anode (up to 3rd degree Tchebyshev). This fit reduced hit residuals from ~100 μm to ~10 μm.

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

Methods (alignment) II

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

- **Precision of the method is checked with simulation (blind)**

  - Accuracy ~10 μm in detector position and ~0.1 mrad in its rotation.
- There is a **problem** when we start **far from minimum** because there are significant **correlations** among alignment parameters.
- To solve this problem as a starting point we use **Least-Squares Fit** with above derivatives to get first approximation for the parameters.
  - The precision of this method is less than slopes method but it does provide a reasonable approximation to use slopes.

Step 3) SVT Ladder Z-tuning using TPC+SSD info

- Although SVT Shells, as a whole, were good on the average, individual Ladders showed Z-translations up to ~400mkms (but the bulk around 100mkms). We believe that this discrepancy between survey and in-situ positions is due to work done on Shells after the survey was completed (water pipe leakage). Also 2 Ladders were replaced and serviced.

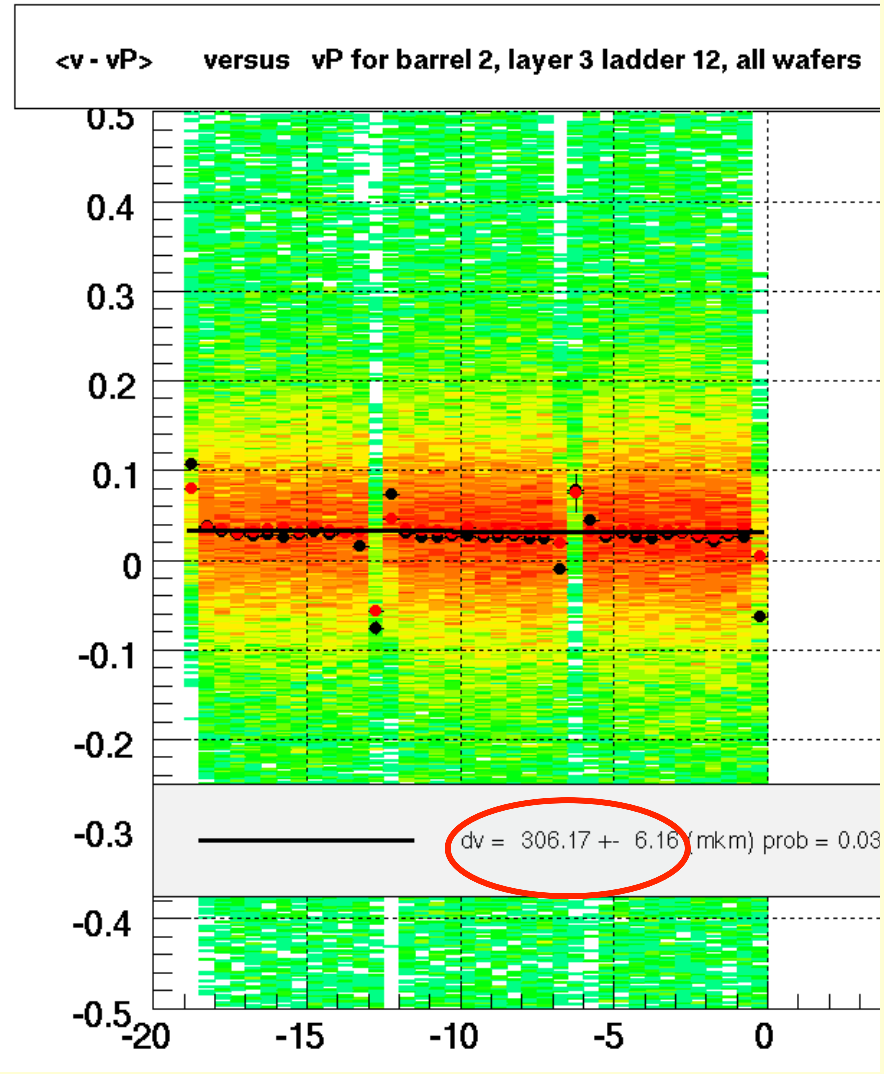
- *Touching the detector after the survey is done should be avoided*

- After the SVT Ladder fine Z-tuning the majority has translations of <20mkm

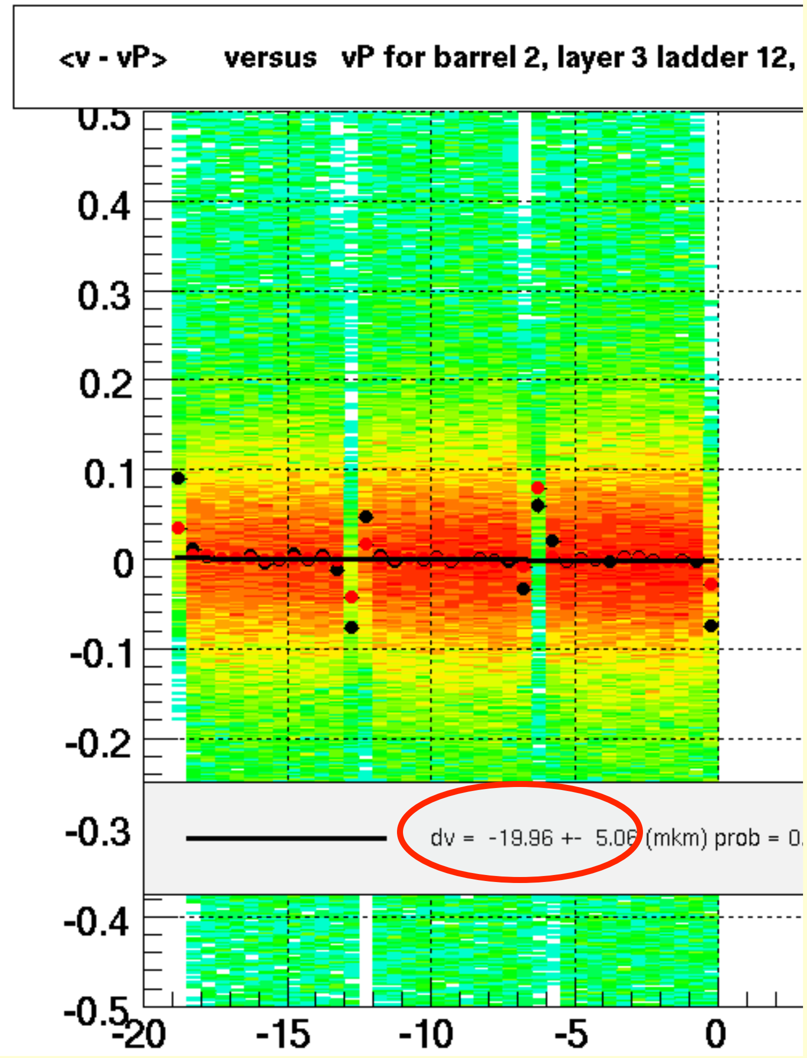
http://www.star.bnl.gov/STAR/comp/reco/SVT/Alignment/Pass49_Q/Ladders

- See next slide for example

BEFORE



AFTER



Example of fine tuning the z position of an SVT ladder using TPC+SSD info

SVT Internal (Self) Alignment Effort

- Though not a 'must have' we would like to have this done for consistency checks
- This is an ongoing effort since currently we do not have a successful method
- We have worked so far on several approaches:
  - An iterative method on track/vertex fitting
    - The SVT/SSD hits are associated with tracks using the TPC tracks and then fitted.
    - The event vertex is determined, the tracks refitted with the vertex and the hit residuals determined
    - A correction is determined and the process starts again with the new hit positions
    - **Initial results encouraging**
  - The Millipede code was also tried as is
    - Problem of strong correlation of parameters is still not resolved
    - A modified version of this approach is currently under investigation

Summary

• Recent interest in charm physics re-focused STAR’s interest in its vertex detectors

• The presence of drift silicon technology (like in ALICE) complicates the task of Alignment

  • but also presence of non-drifting detectors (strips or pixels) will prove invaluable

• Our Global Alignment approach and techniques were successful to overall shifts better than 20 mkm

  • which for this device is sufficient

• The Self-Alignment methods are still under development.

• STAR has an funded R&D active pixel effort for an ultra thin device @ 2cm from the vertex