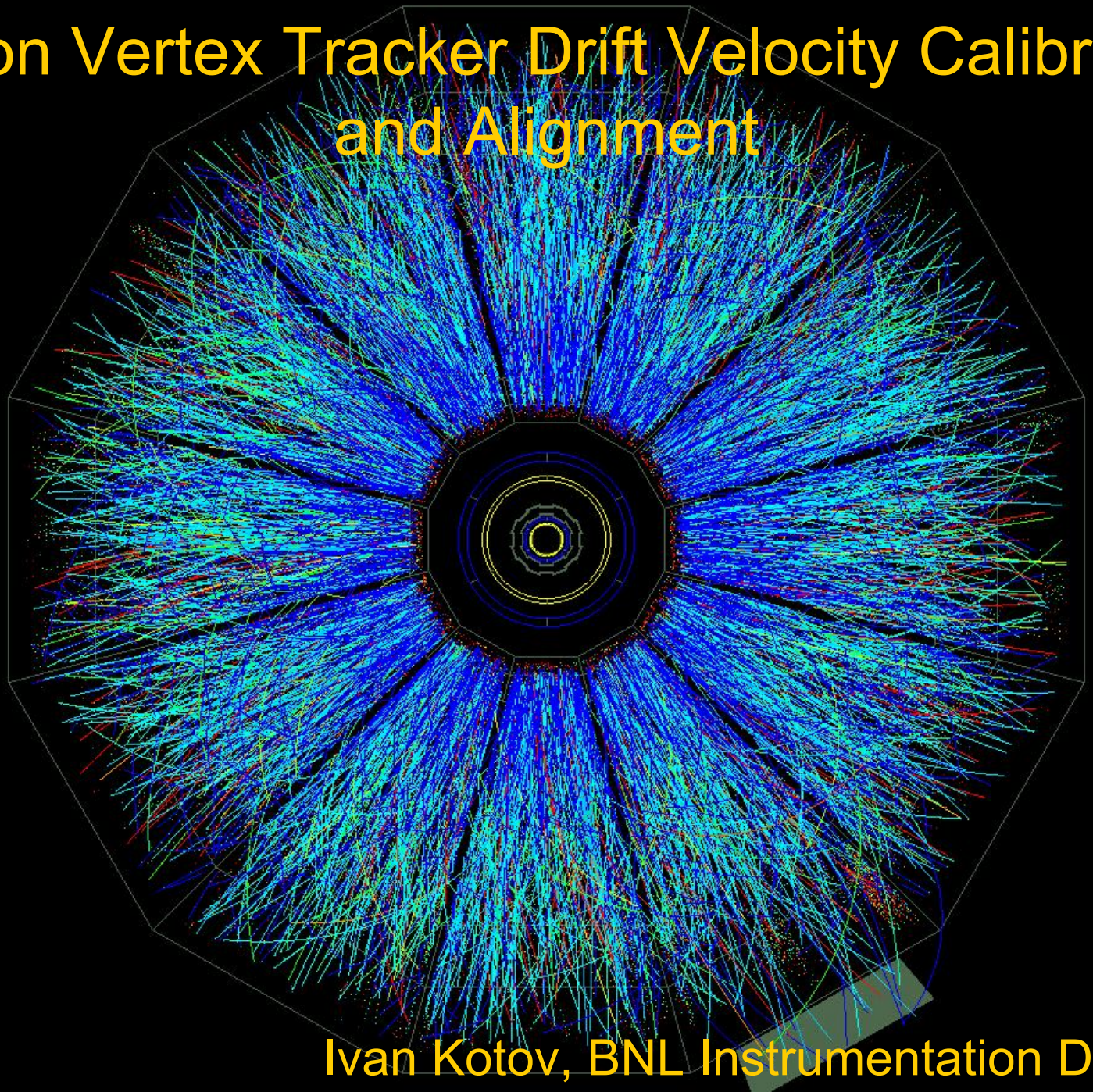
Silicon Vertex Tracker Drift Velocity Calibration and Alignment



Ivan Kotov, BNL Instrumentation Division

Outline:

- Introduction
  - STAR experiment
  - STAR tracking environment
- Tracking Detectors Details
- Calibration procedures
- Alignment
- Results

Collaborators:

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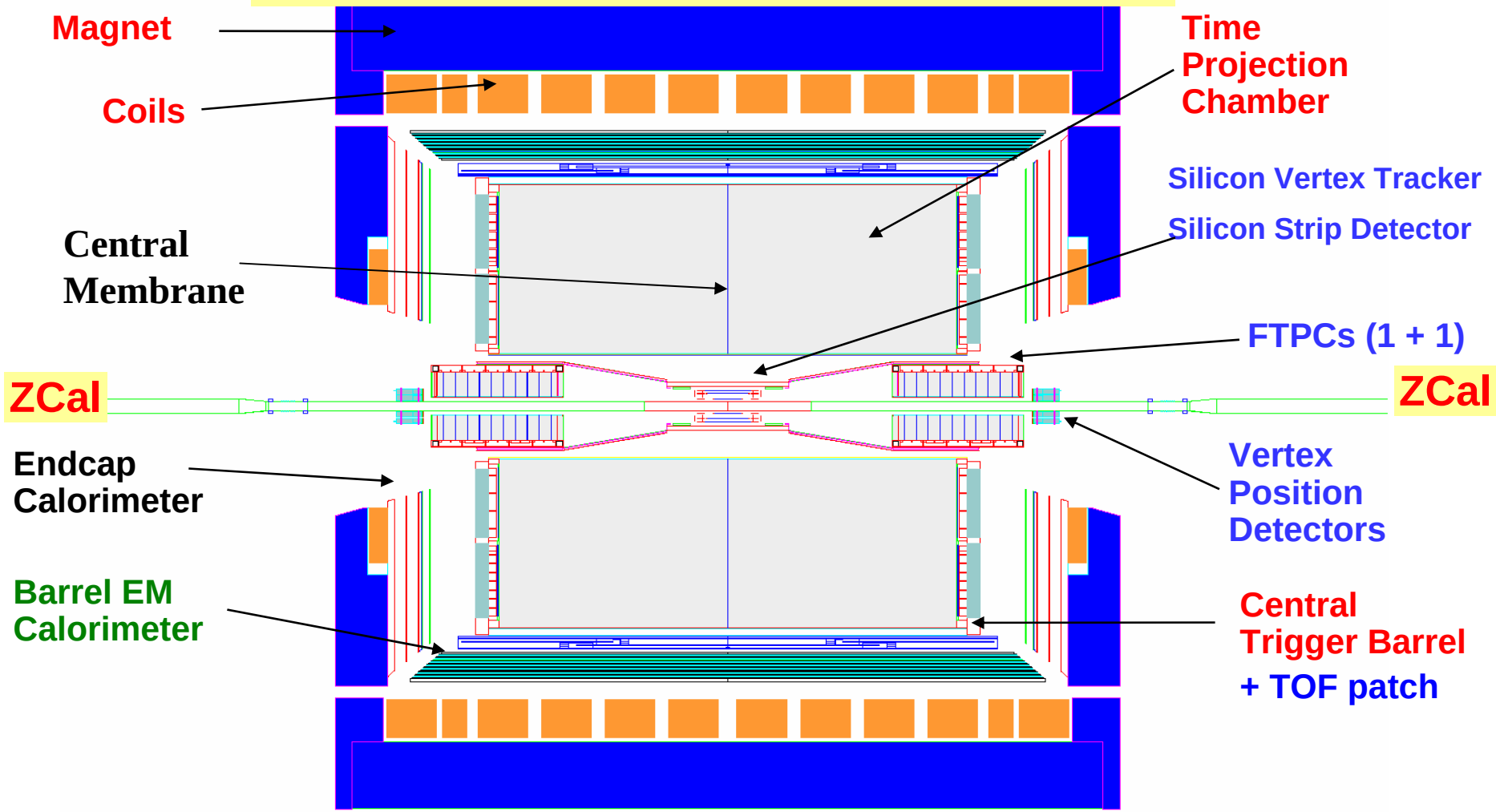
The STAR Detector

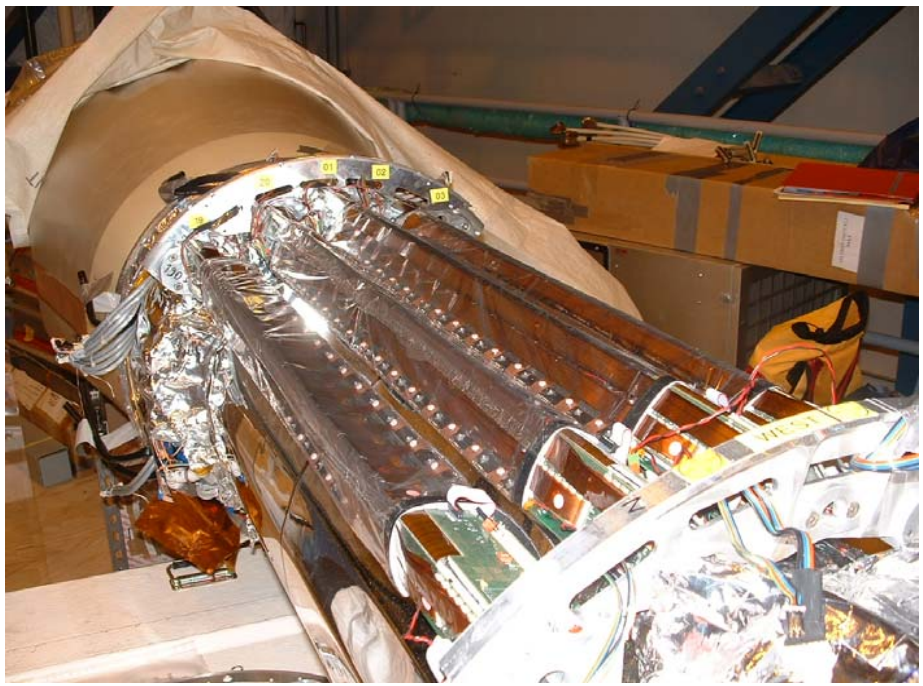


Time Projection Chamber

- TPC radial coverage 60 -190 cm
- spatial resolutions:
  - $\sigma_{r\phi} \approx$ **600** μm and $\sigma_z \approx$ **1200**μm for Inner Sectors
  - $\sigma_{r\phi} \approx$**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 ~2×10^{-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

Silicon Strip Detector

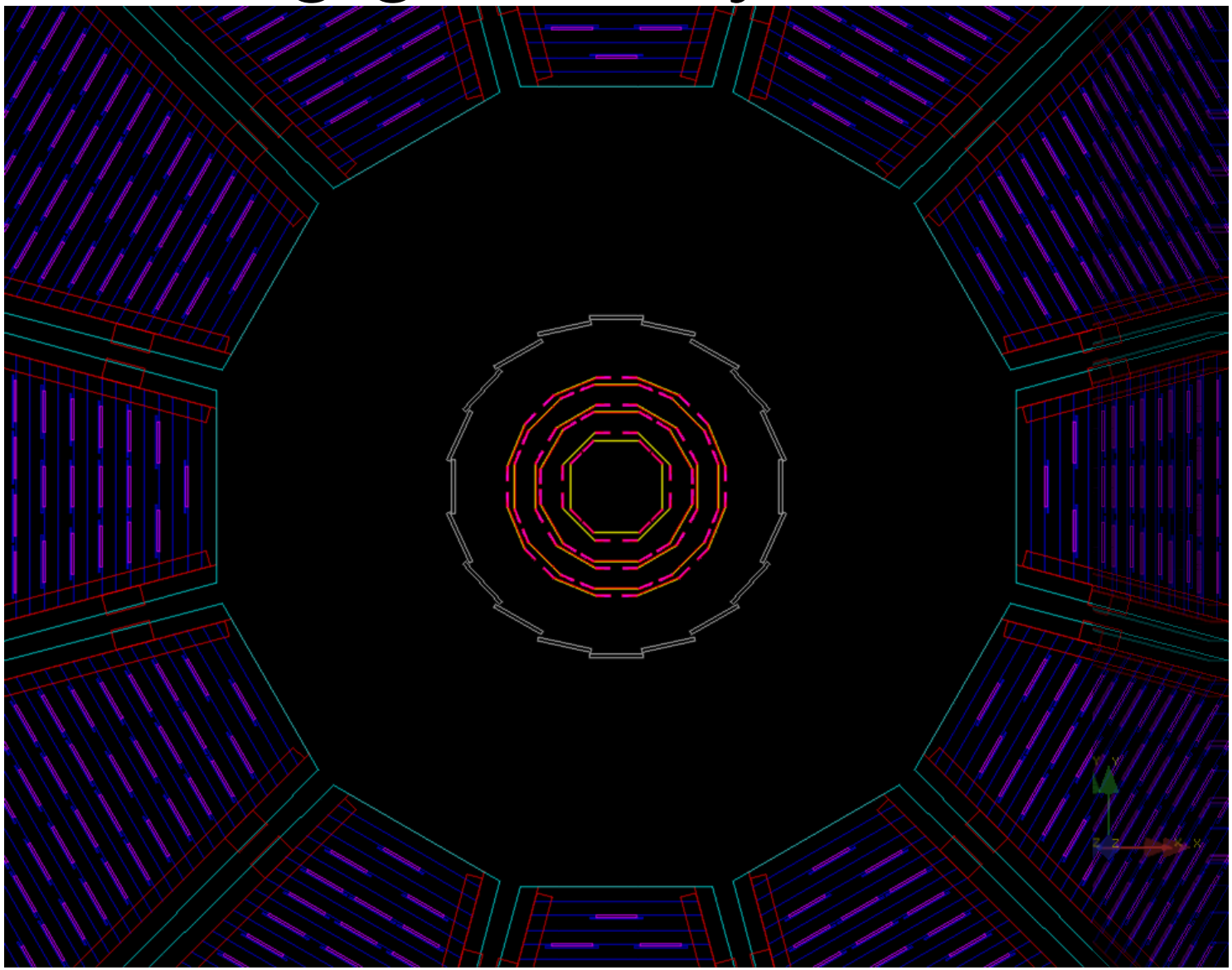
- double sided technology with 35 mrad stereo angle
- 20 ladders with 16 wafers each, at R~23 cm, on 4 rigid sectors
- strip pitch: 95 μm; strip length: 4 cm
- intrinsic resolution ~ 30 μm ($\rho\phi$) $\times$ 860 μm(Z).
- provides an intermediate point for track matching between the TPC and SVT



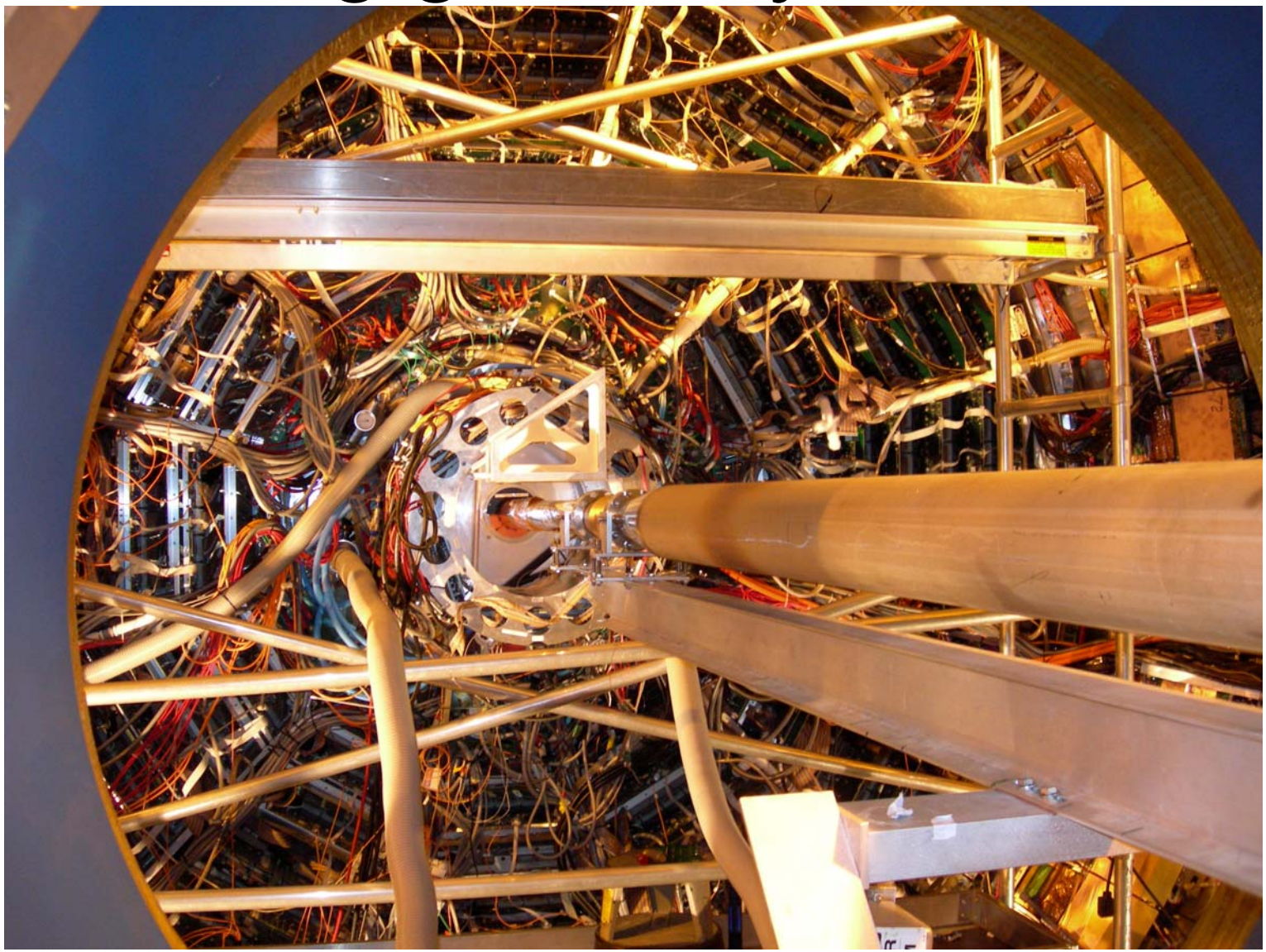
SVT - Silicon Drift Detector

- electrons drift in $\rho\phi$ direction (perpendicular to TPC drift direction)
  - maximum drift length 3 cm
  - maximum drift time 4.5 microsec
  - number of time bins 128 → "time bin" ~ 250 microns
- anode pitch is 250 microns
- "pixel" $\rho\phi \times z$ = 250 μm (time bin) $\times$ 250 μm (anode pitch)
- spatial resolution expectation ~ 80μm $\times$ 80 μm
- drift time → coordinate conversion requires **calibration**

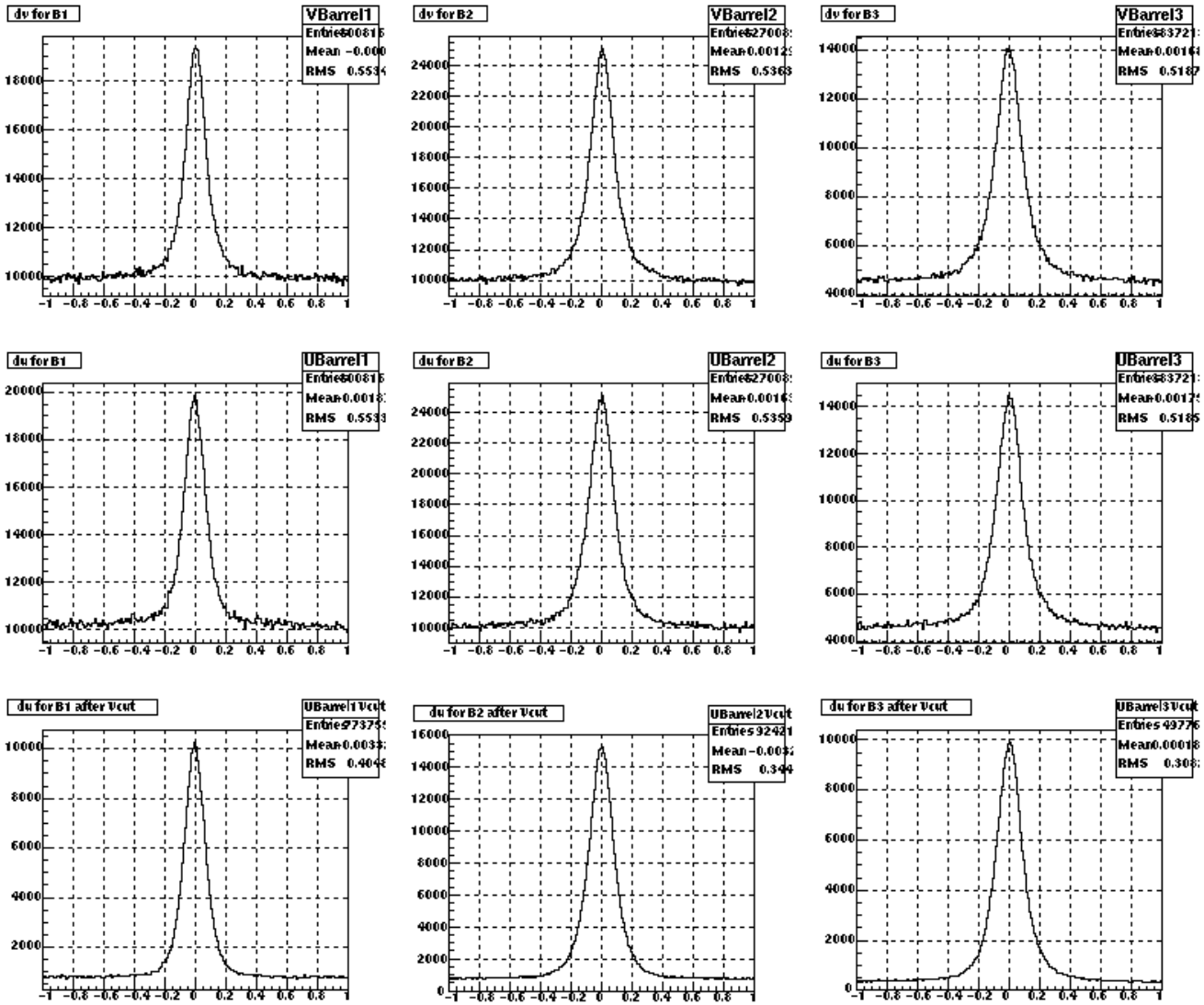
STAR tracking geometry



STAR tracking geometry 2007



TPC track ←→ SVT hit matching



Calibration & Alignment Strategy

- TPC calibrations & corrections
- SSD alignment relative to TPC (using tracks reconstructed in TPC only)
- SVT initial drift calibration
- SVT alignment relative to TPC+SSD
- SVT drift correction

Calibration & Alignment: What to keep an eye on?

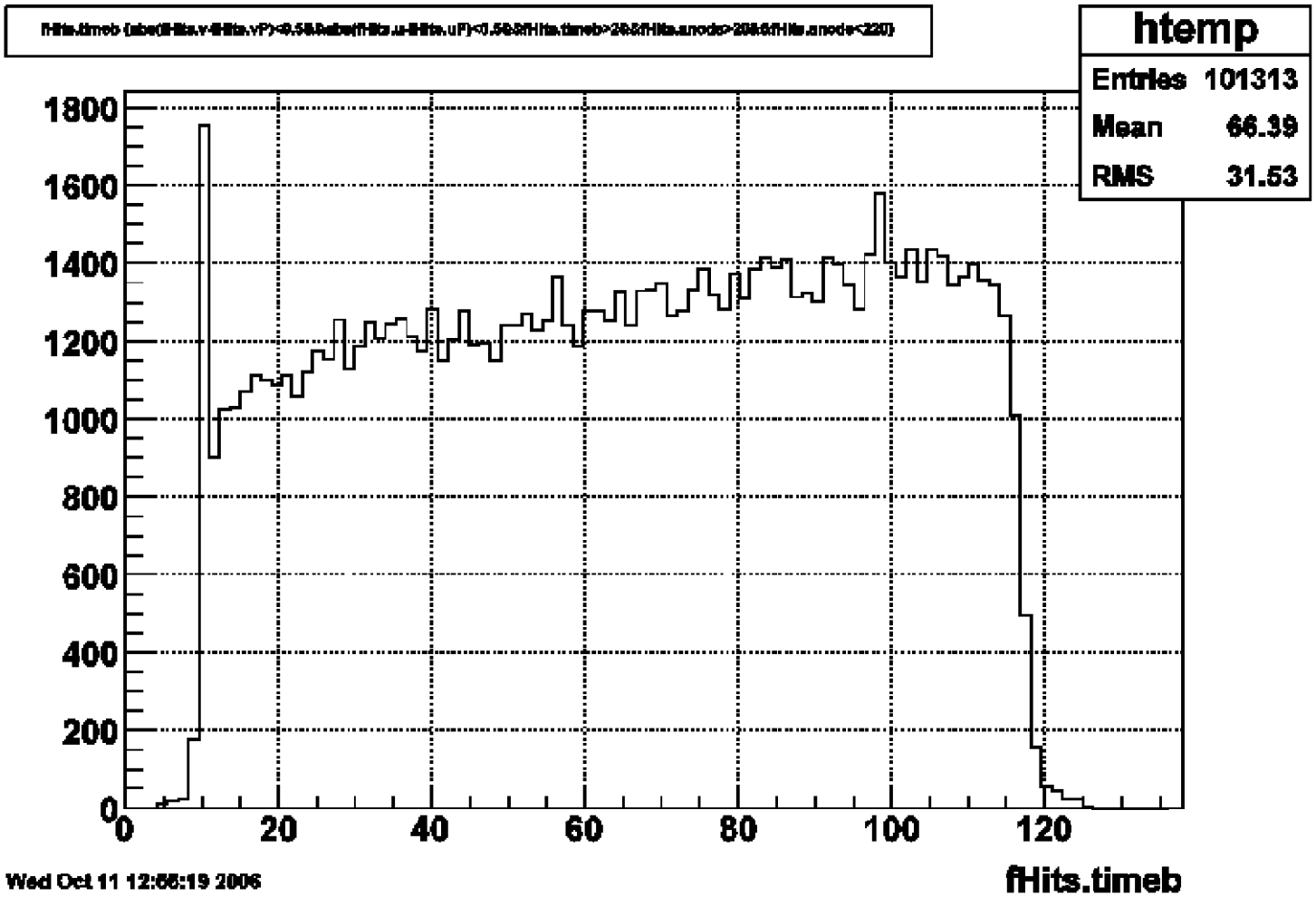
- TPC distortions
  - clean data: low luminosity & low background
  - TPC gas, pressure, lasers are stable → drift velocity calibration is at its best
- Statistic needed:

  1 mm → ~20 micron: reduction factor 50

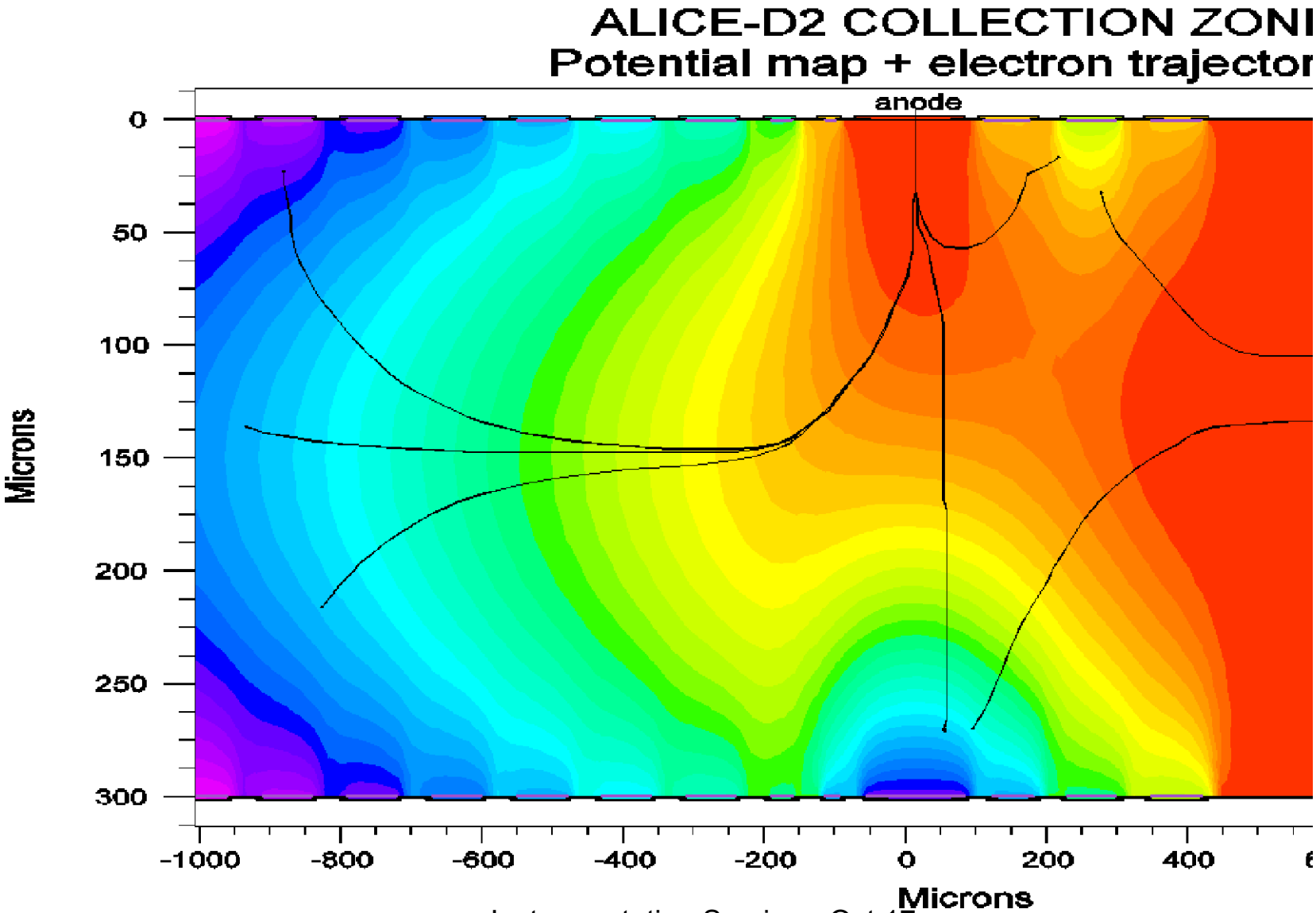
  → ~2,500 tracks per SVT sensor

  → data sample with ~250,000 tracks

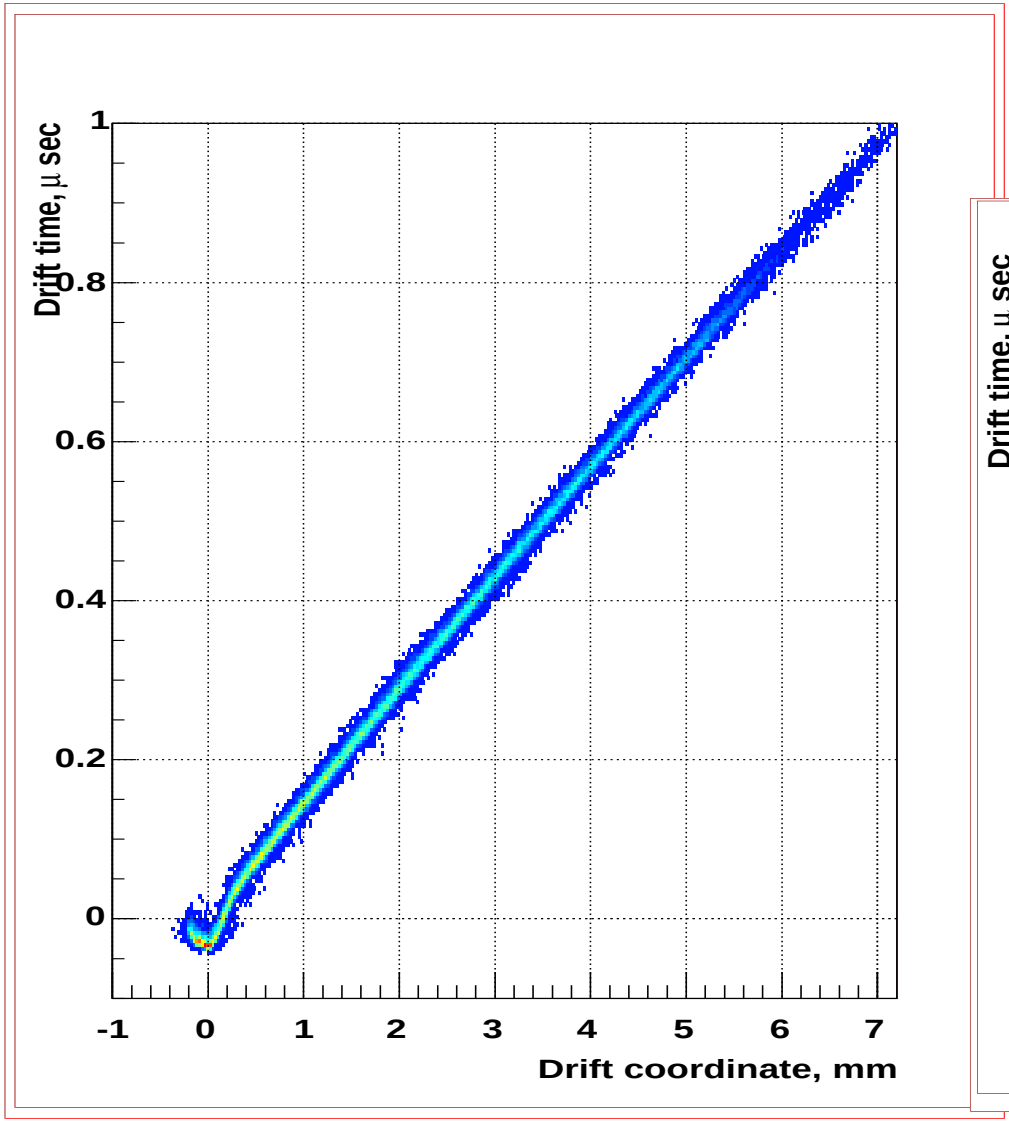
Drift time distribution

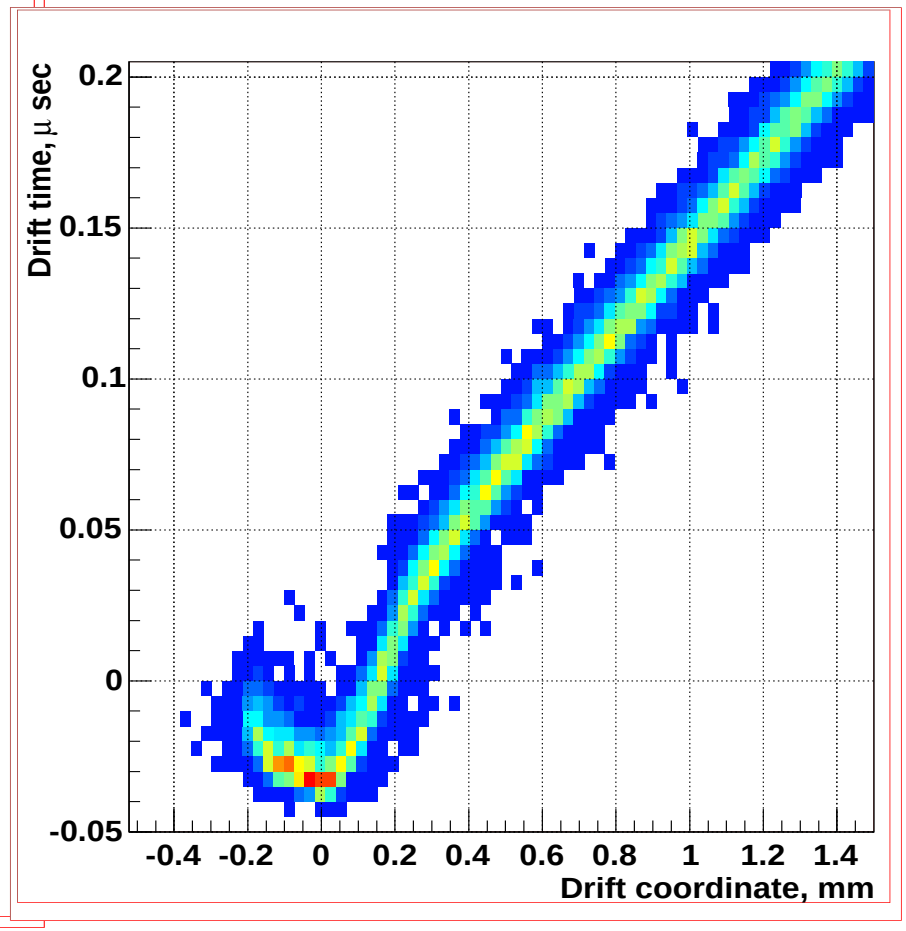


Drift time distribution: leading edge (1)



Drift time distribution: leading edge (2)





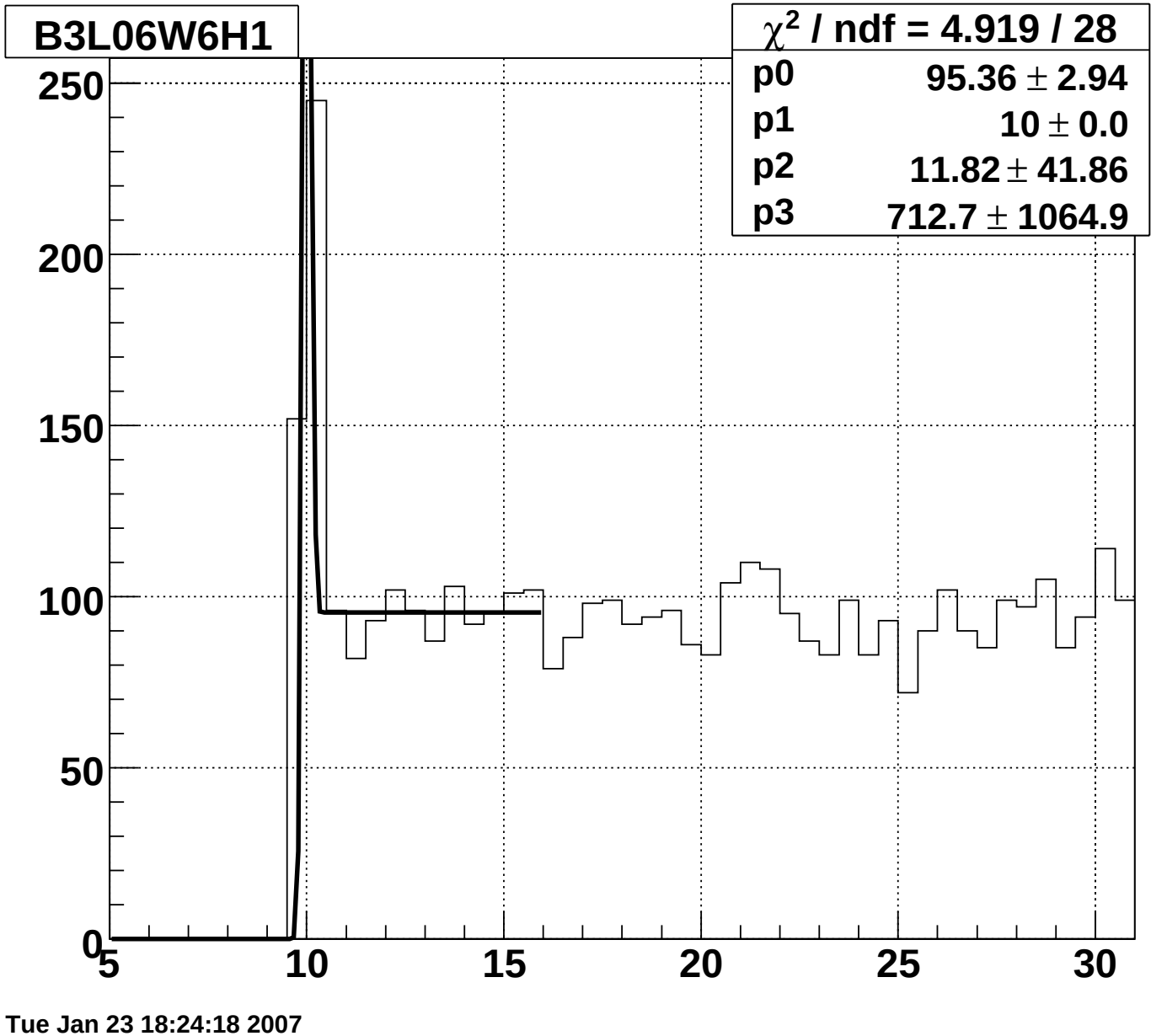
Drift time distribution: t_min fit

- t_min:

step function

+ gaussian

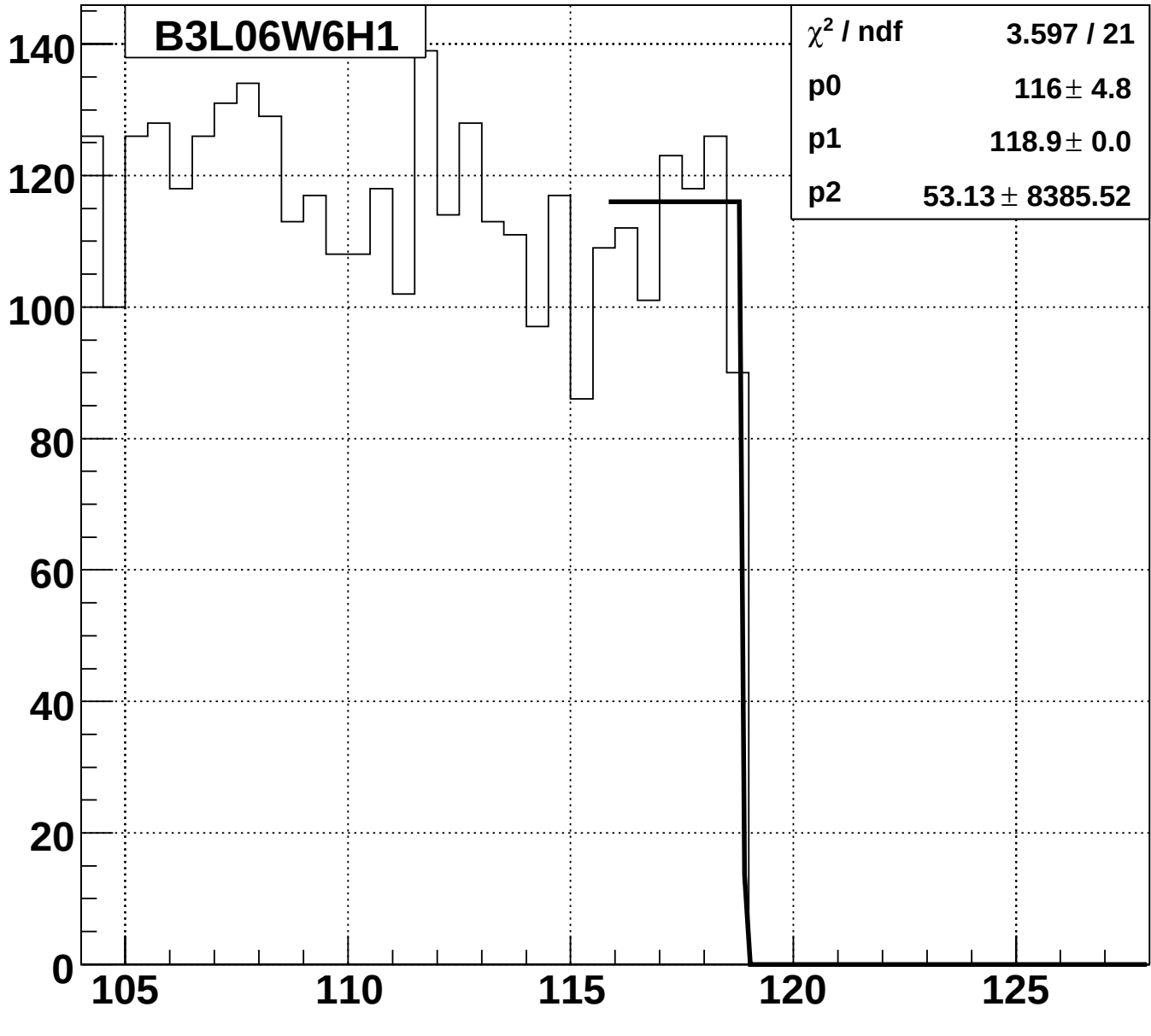
fit example



Drift time distribution: t_max fit

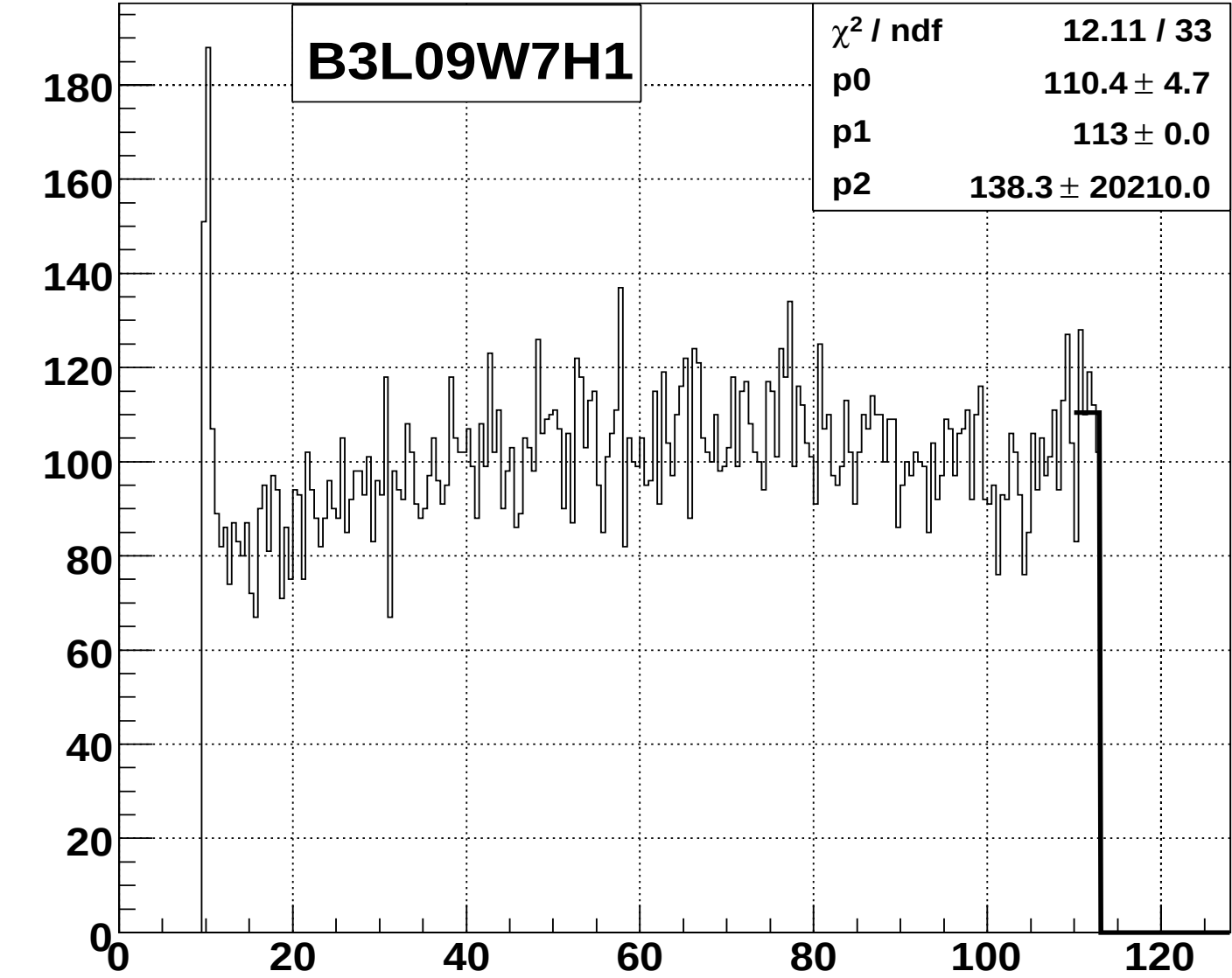
- t_max:
  step function

  fit example



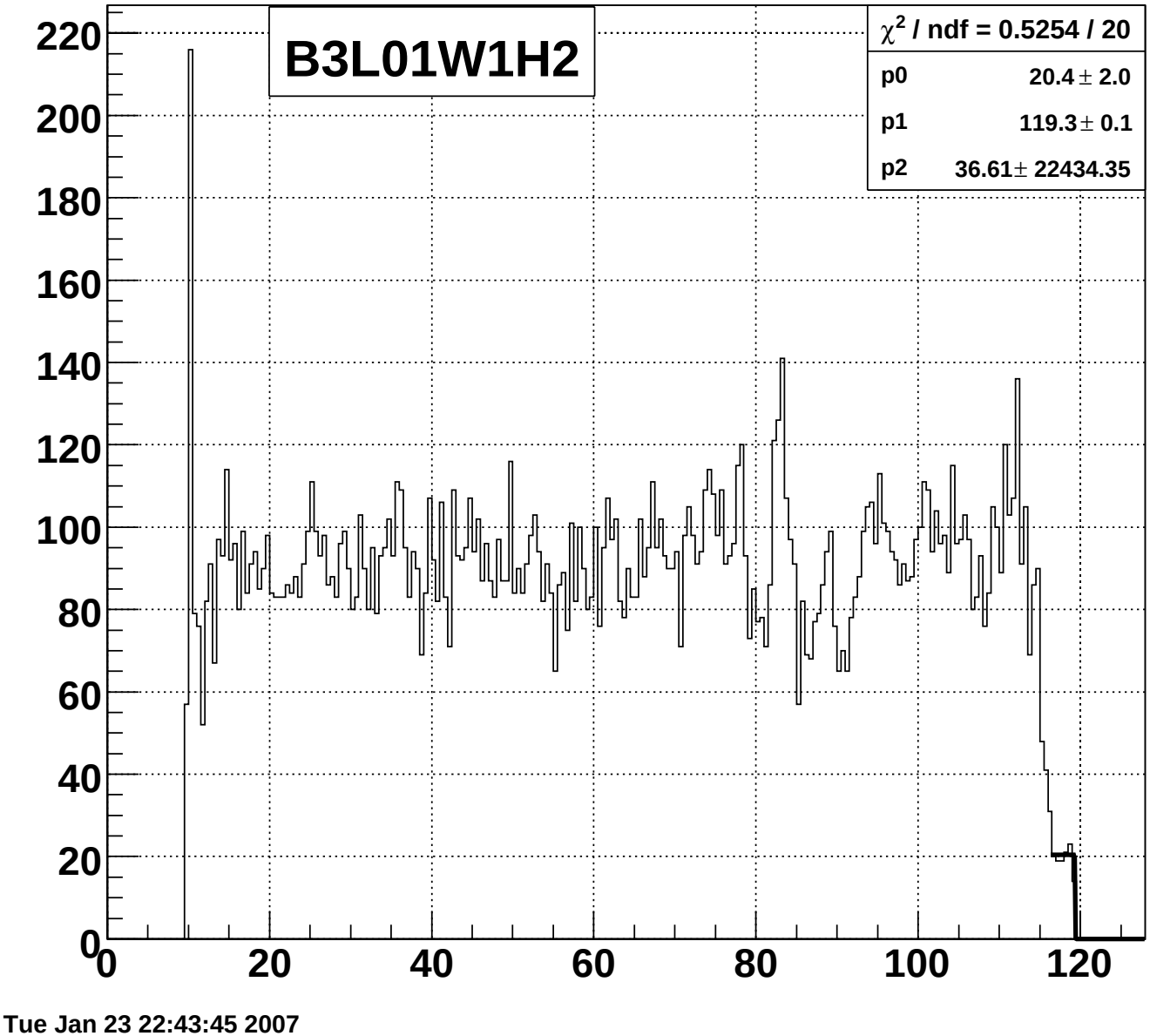
Drift time distribution: t_max special cases

tmax : short drift

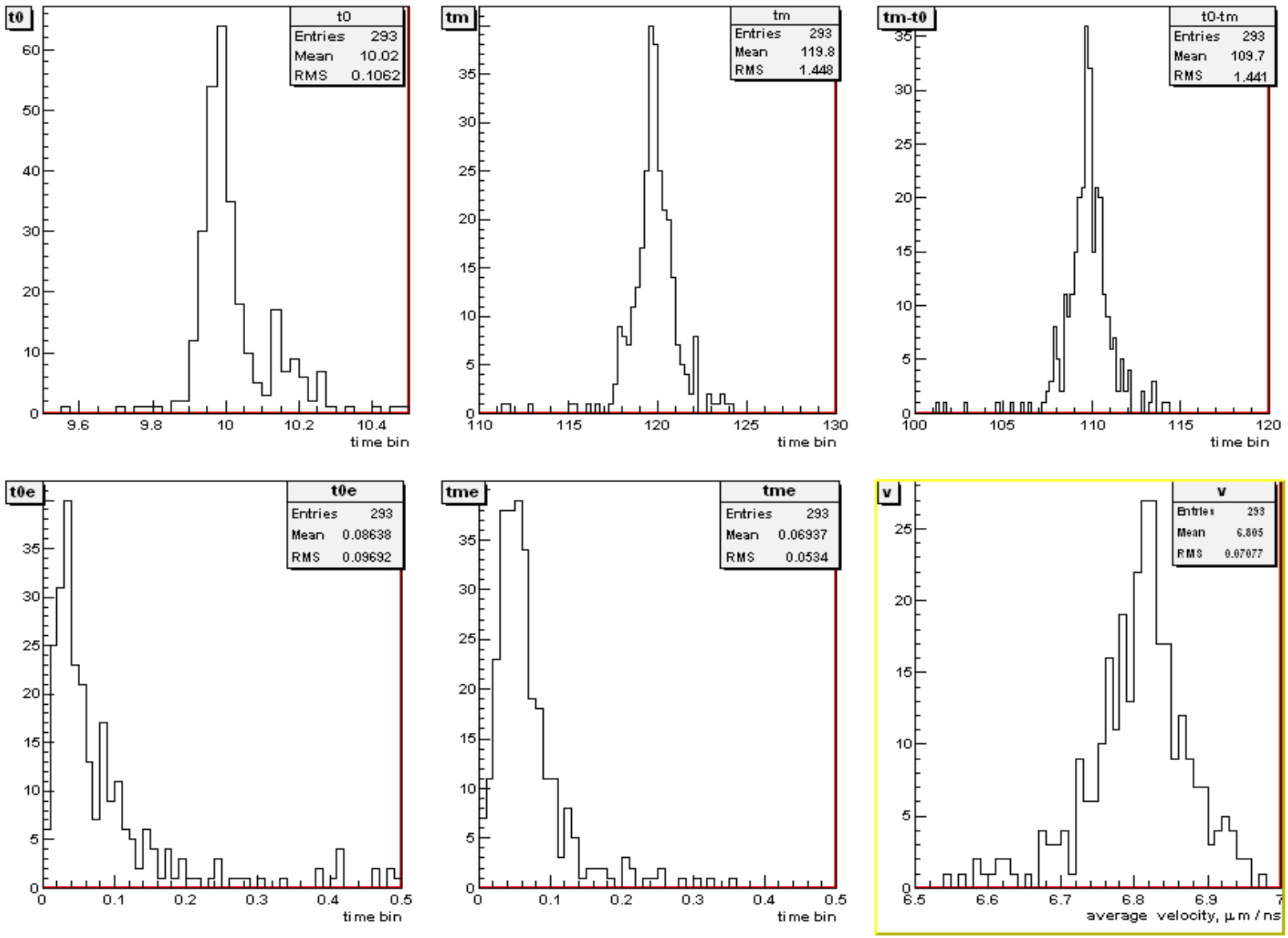


Drift time distribution: t_max special cases

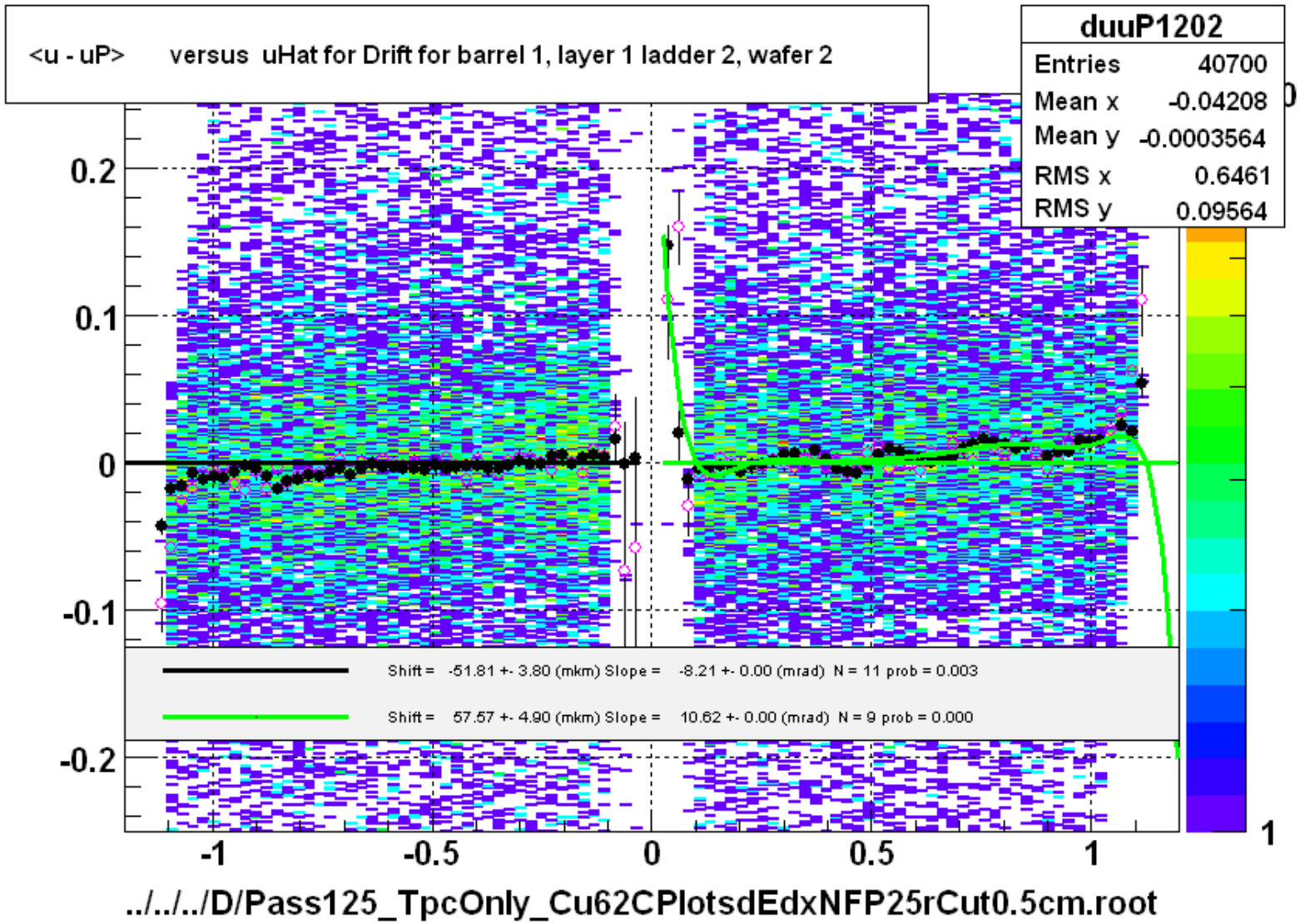
HV zone problem



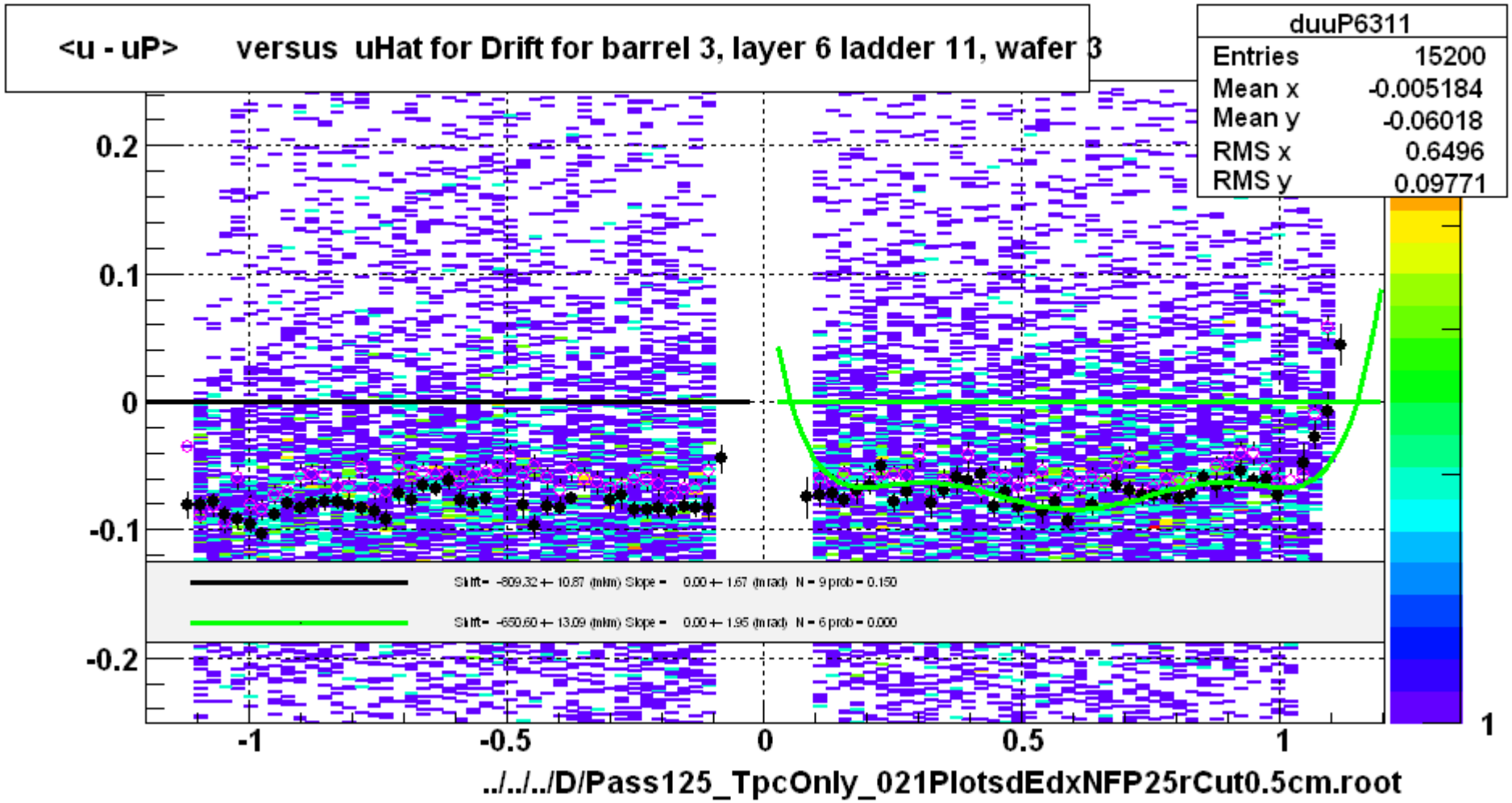
fit results CuCu62:



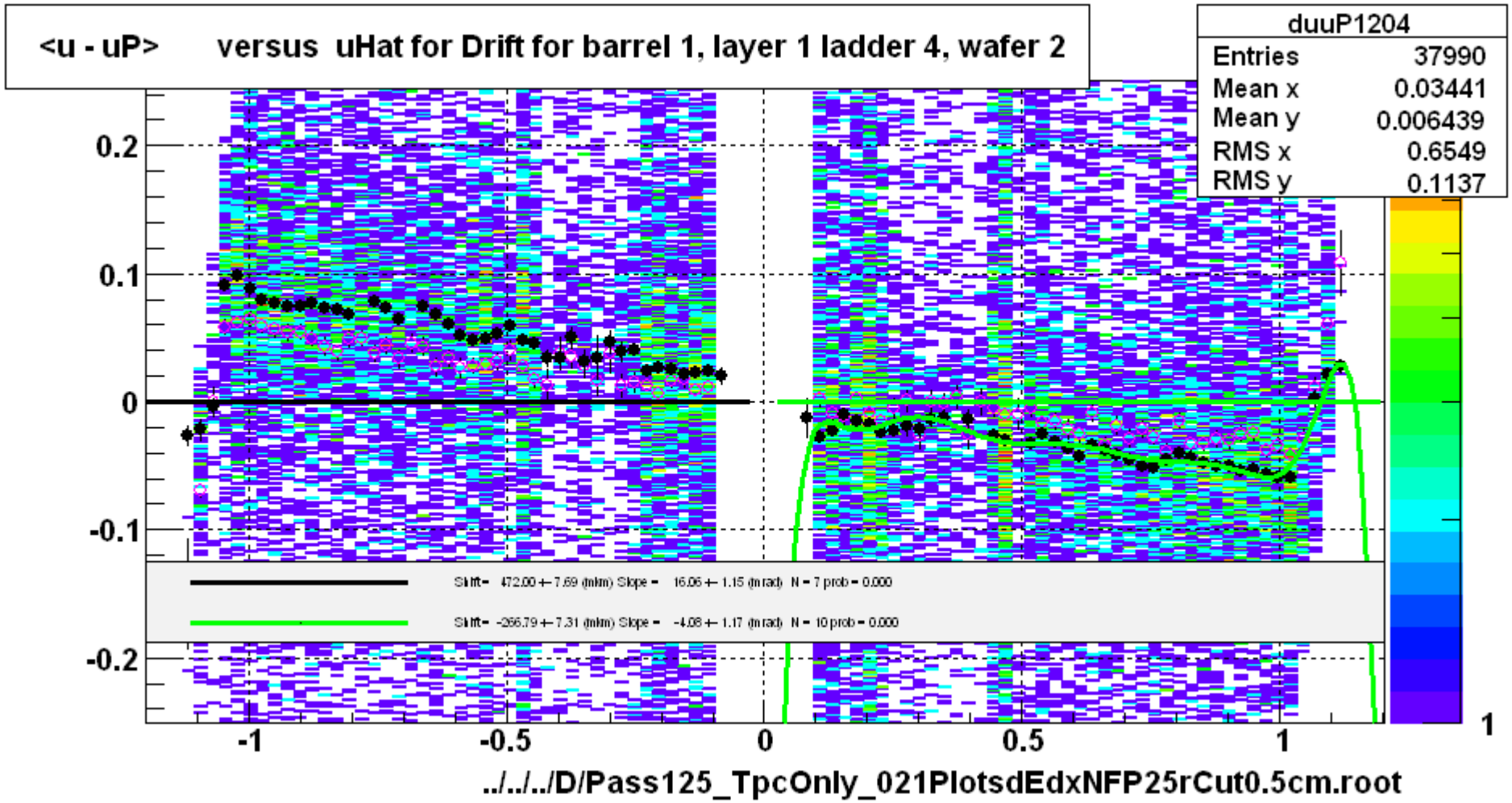
Drift: hit – track, example



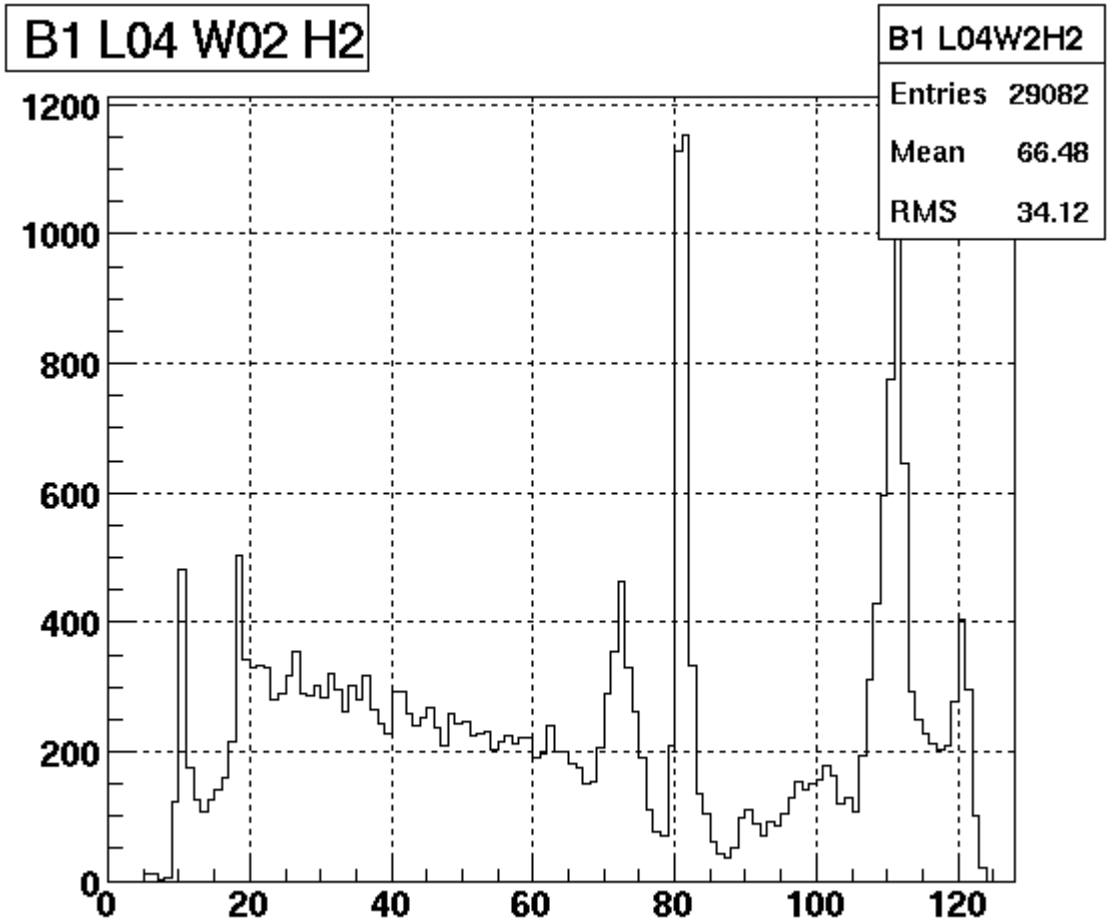
Drift: hit – track, overall shift



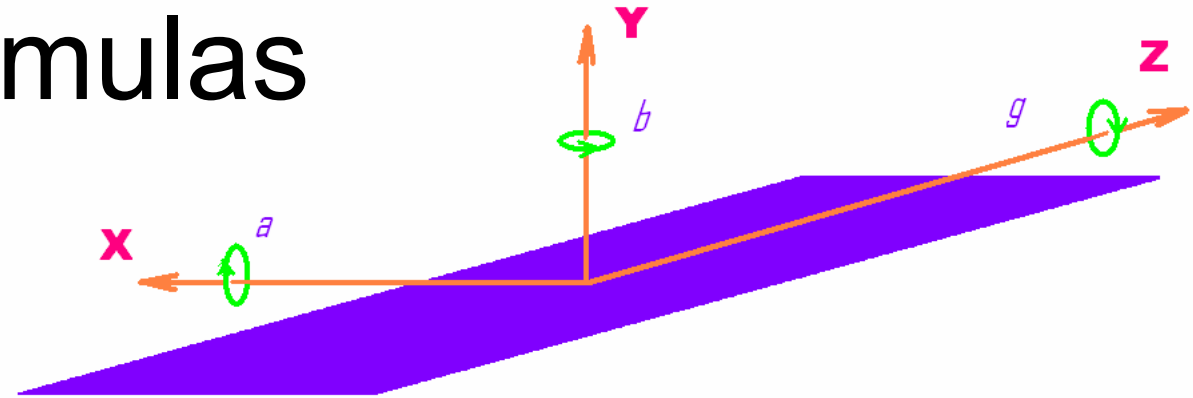
Drift: hit – track, non-linear sensor



Drift: TimeBin distribution, non-linear sensor



Alignment formulas



$$\Delta x = x_{track} - x_{hit} = \delta x + z \cdot \sin\beta + \tan\phi \cdot (\delta y + z \cdot \sin\alpha + x \cdot \sin\gamma)$$

$$\Delta z = z_{track} - z_{hit} = \delta z + x \cdot \sin\beta + \tan\vartheta \cdot (\delta y + z \cdot \sin\alpha + x \cdot \sin\gamma)$$

δx – sensor displacement in X

ϕ – angle between track and sensor in rϕ plane

ϑ - angle between track and sensor in rz plane

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

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

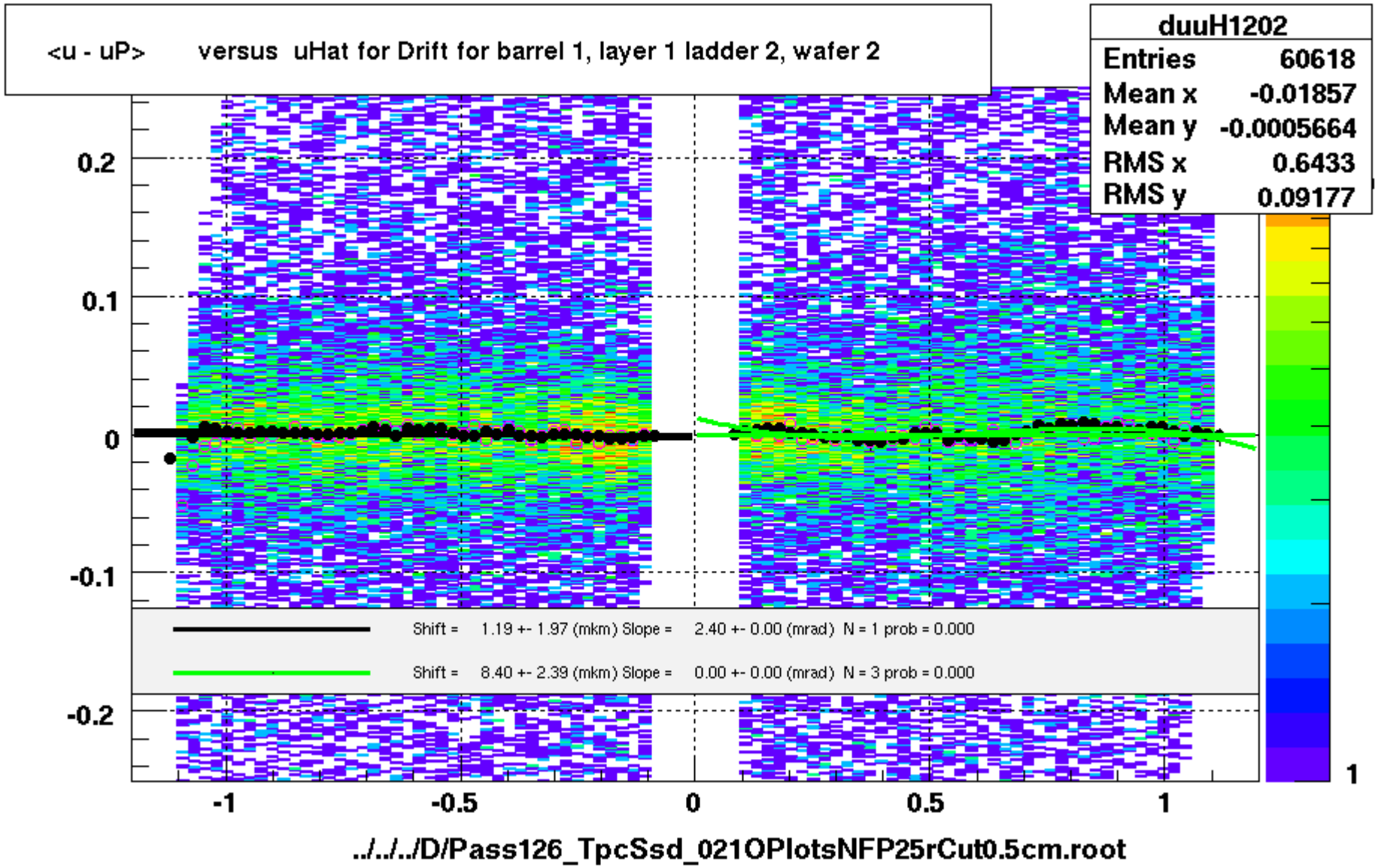
- Check consistency and
- re-evaluate SVT & SSD hit errors

Assumed:

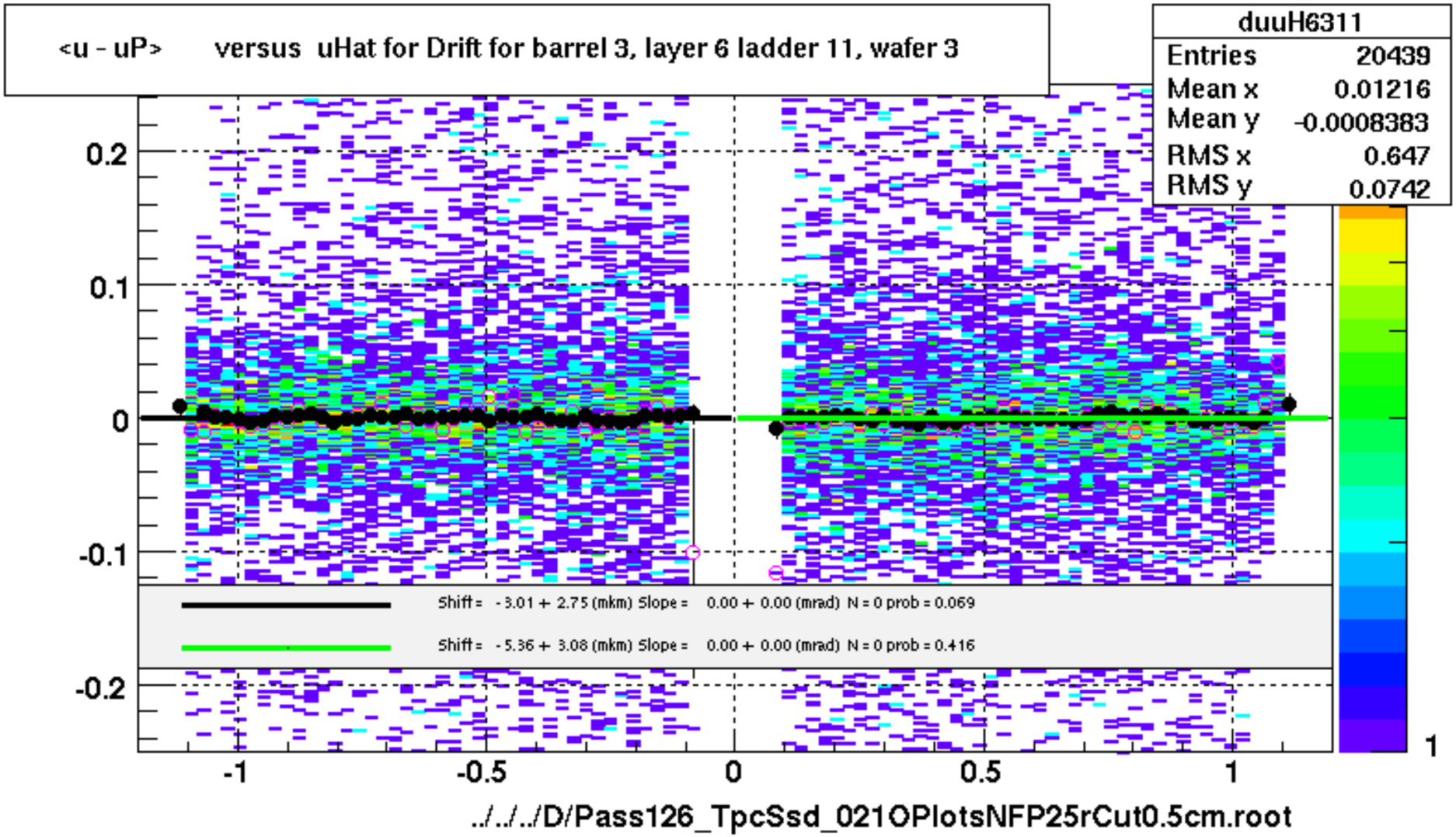
– Rigid body model: ignore possible twists effects, gravitational/stress sagging etc.

– Frozen wafer position on ladder from survey data, i.e. ladder is the lowest level degree of freedom for alignment.

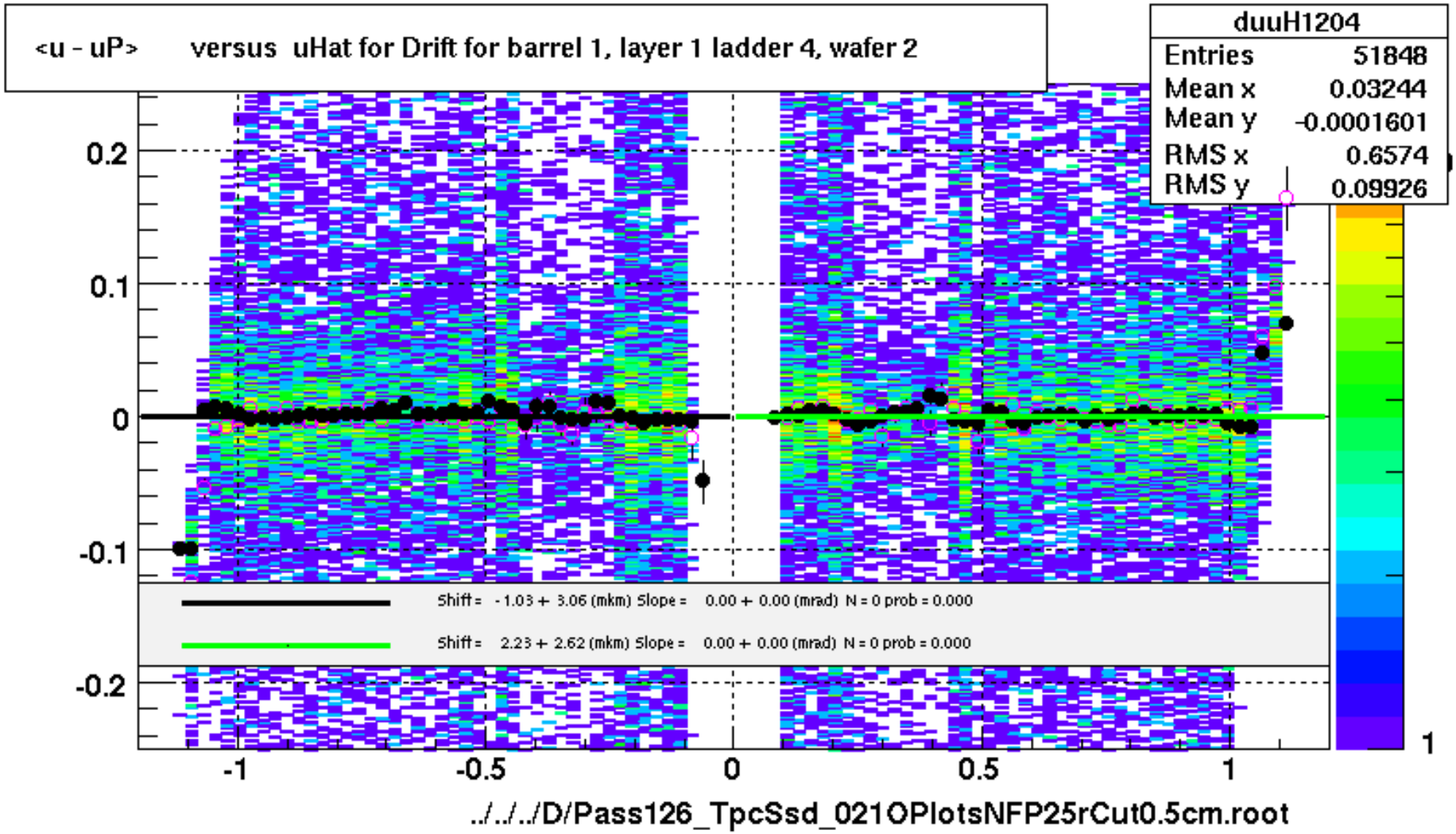
Drift: hit – track, example after corrections



Drift: hit – track, overall shift, after corrections



Drift: hit – track, non-linear sensor, after corrections



SVT and SSD resolutions after Calibration&Alignment

Calibration&Alignment procedure for Run V has been done for 3 data samples : 62 GeV FF, 200 GeV RF and FF

Resolution has been estimated from hit pull analysis.

Results (average over 3 samples) are:

- SVT:
  - $\sigma_{\rho\phi}$ = 49±5 μm
  - σ_Z = 30±7 μm
- SSD resolution:
  - $\sigma_{\rho\phi}$ = 30 μm (set to design value since << MCS)
  - σ_Z = 742 ± 41 μm

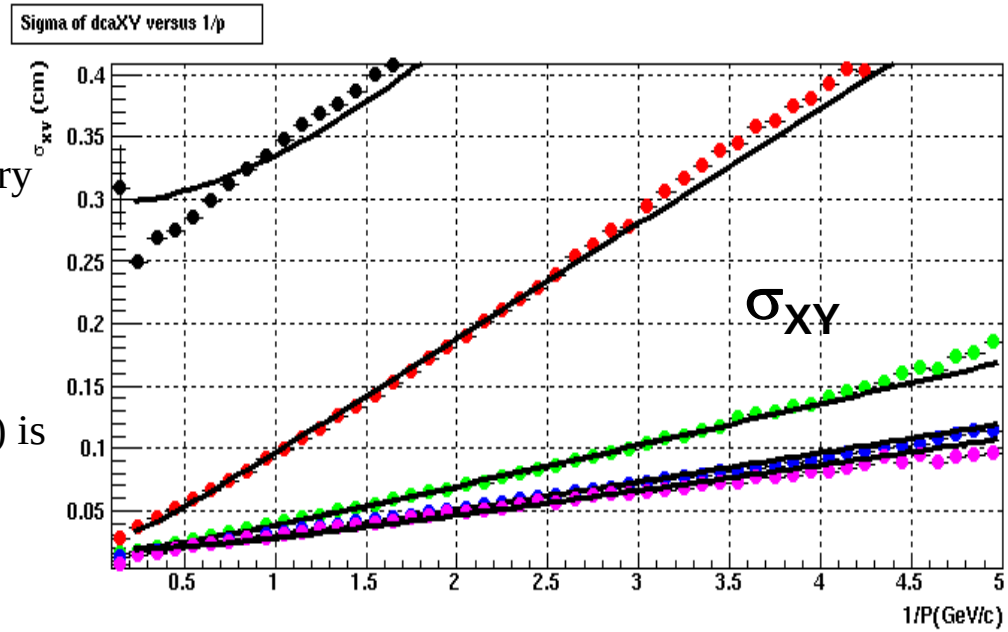
DCA resolution

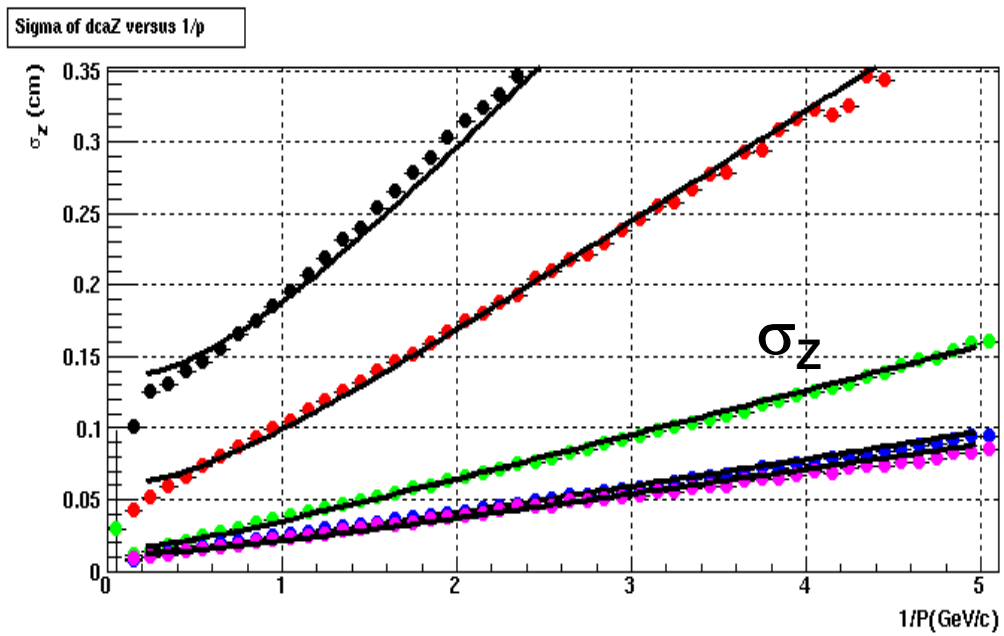
• DCA resolution = standard deviation of global track DCA with respect to the primary vertex.

•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 →

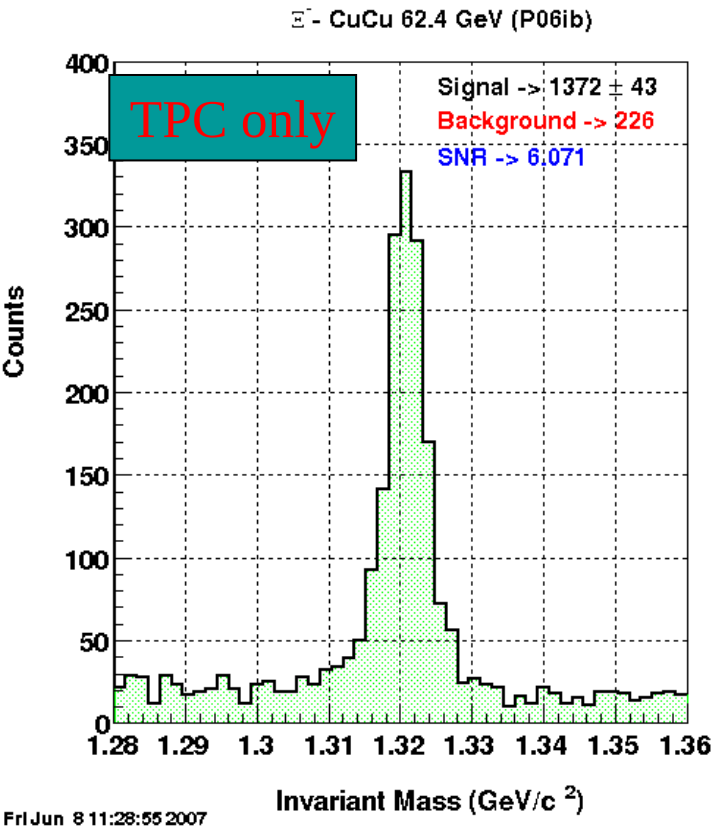
reached the goal !

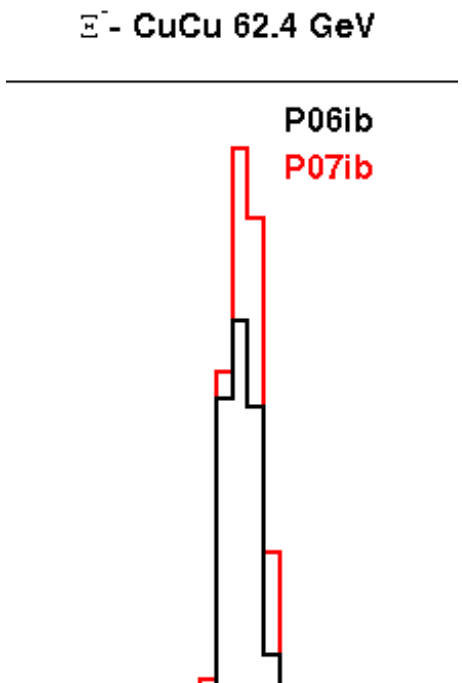


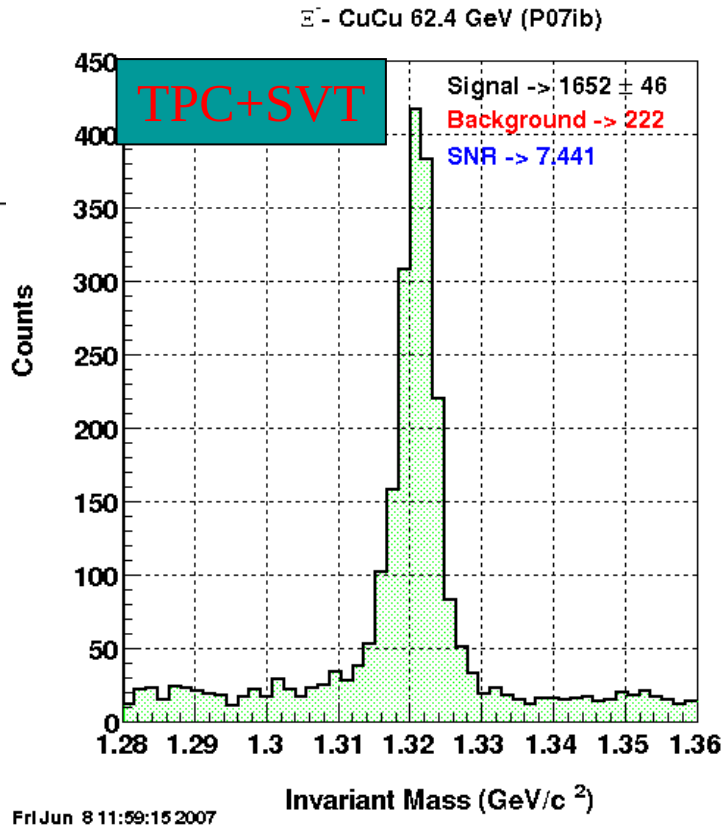


Number of Silicon Points fitted to track	σ_{XY} @1GeV/c (μm)	σ_Z @1GeV/c (μm)
0 - ● TPC only	3350	1840
1 - ● TPC+SSD	967	993
2 - ● TPC+SSD+SVT	383	351
3 - ● TPC+SSD+SVT	296	232
4 - ● TPC+SSD+SVT	281	212

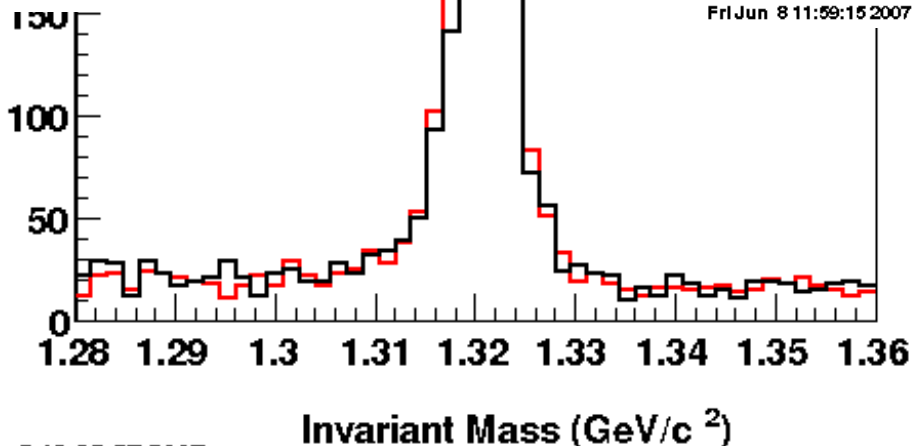
The SVT enhances physics signals







Zvert<30cm



Summary

- Recent interest in charm physics re-focused STAR's interest in its vertex detectors
- Our alignment approach and techniques were successful to better than 20 μm precision
- Calibration & Alignment work for Run V is completed and data re-processing is under way
- First physics checks look fine