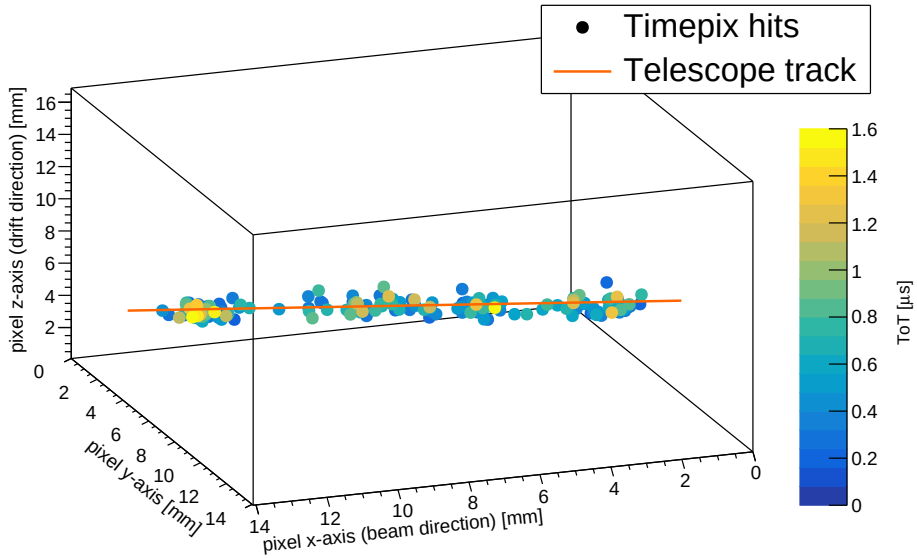


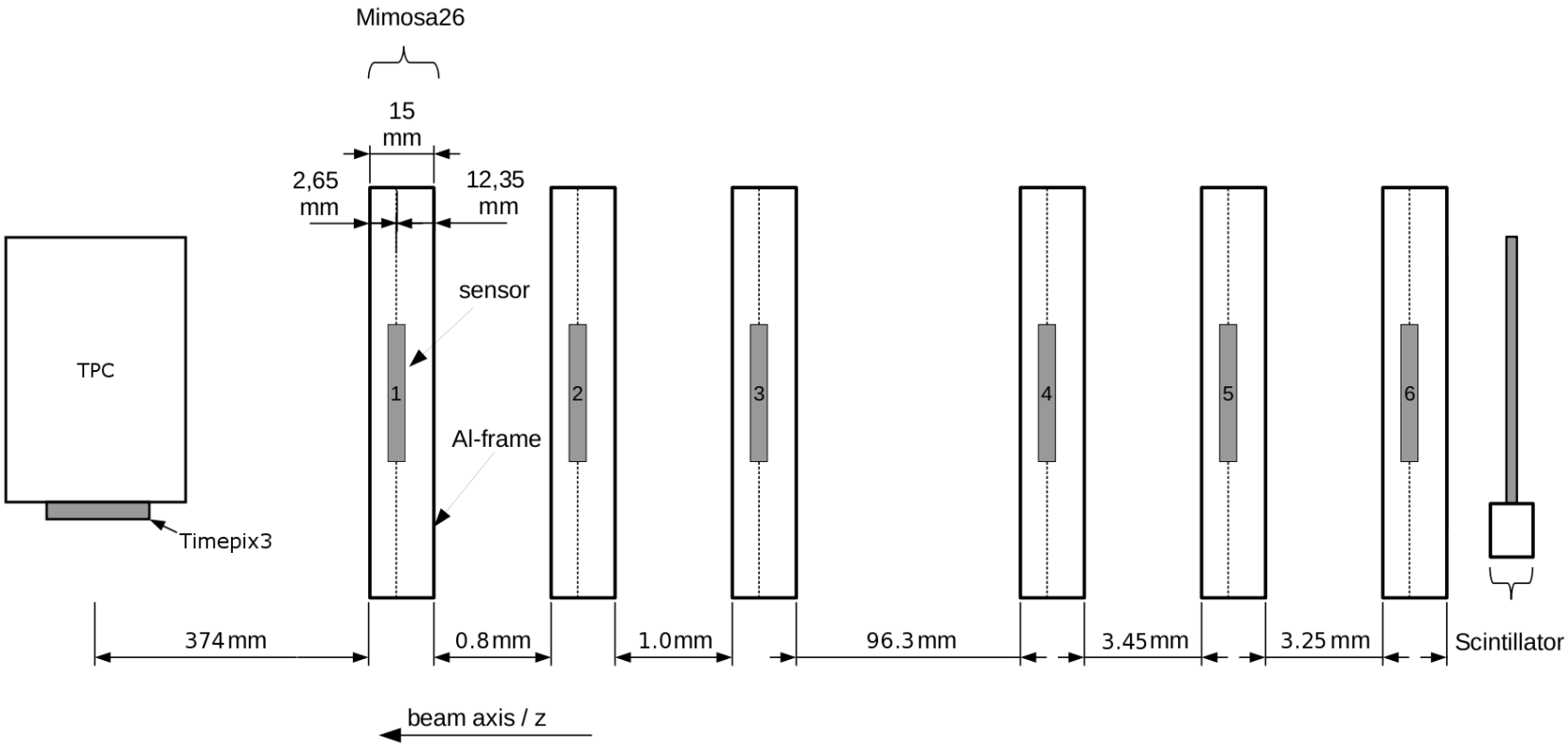
Testbeam analysis of a single chip timepix3 ingrid

Kees Ligtenberg

Nikhef

November 20, 2017

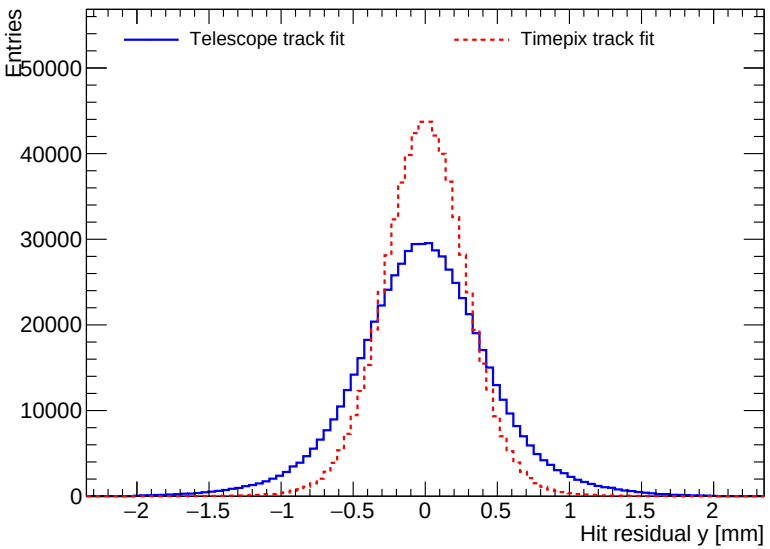
Detector setup

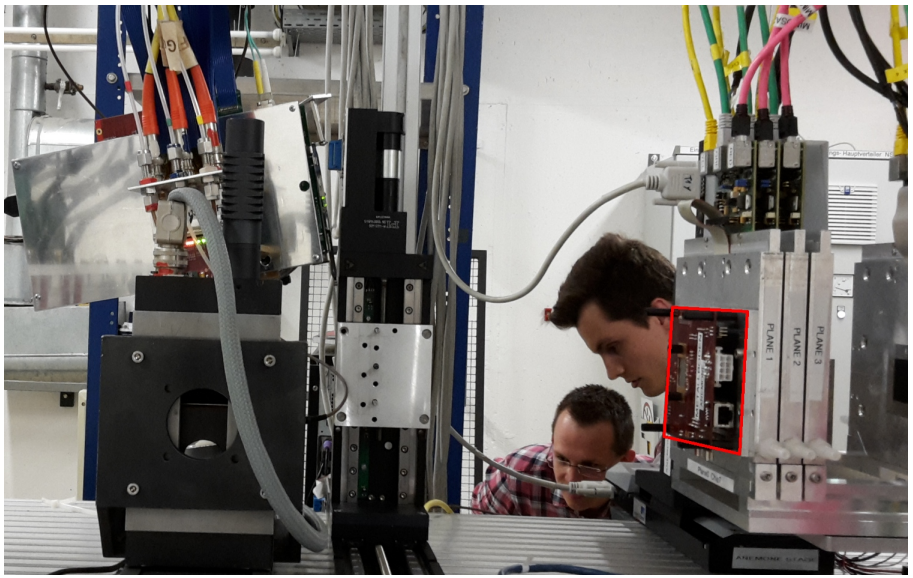


Adapted from Thesis Pascal Wolf Bonn, 2016

Triggered by a scintillating plane
6 mimosa planes and timepix TPC

FEI4 between telescope and TPC





- Fit from telescope does not match the timepix3 hits
- Possibly caused by the FEI4-chip being attached to the telescope (for timing in some setups)
- FEI4 is used for ATLAS IBL that has a radiation length of 1.5%. (And each mimosa plane has 0.1%)
- Could have caused a scatter of about $\sim$0.7 mRad

Matching and selection

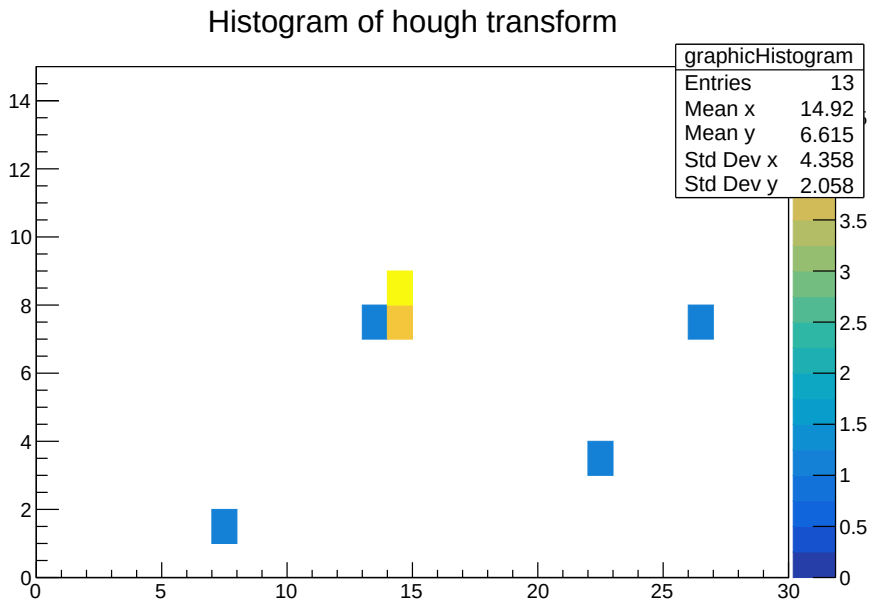
- Each telescope frame (115.2 µs) can have a range of triggers
- Try to decode trigger number in timepix using rising edge only
- Save timepix tracks within 400 ns of a trigger

For each frame, attempt to match all events of the timepix with triggers in the range

Cluster finding

Find clusters from hits binned by position

- Fill 30×15 (12×12) bins for telescope (TPC)
- If more than 3 (6) hits in one bin, try to merge up to 8 neighbours
- If cluster has more than 10 (5) hits



Fit procedure

- Independently align telescope
- Rotate and shift Timepix3 to match telescope frame (beam is parallel to z-axis)
- Do ToT and time walk corrections
- Do a double simple linear regression fit in the telescope frame
  - Errors in directions perpendicular to z-axis
  - In telescope frame the tracks direction is almost parallel to z-axis, therefore z-errors were neglected
- Match Timepix3 and telescope clusters
- Add final plane crossing of telescope as a point with 10 μm errors to Timepix3 fit

Hit errors

Assign errors to hit:

- $\sigma_y^2 = \frac{0.055^2}{12} + D_T^2(z - z_0)$
- $\sigma_x^2 = \frac{1.56ns * v_{\text{drift}}}{12} + D_L^2(z - z_0)$

where D the diffusion coefficient

Selection cuts

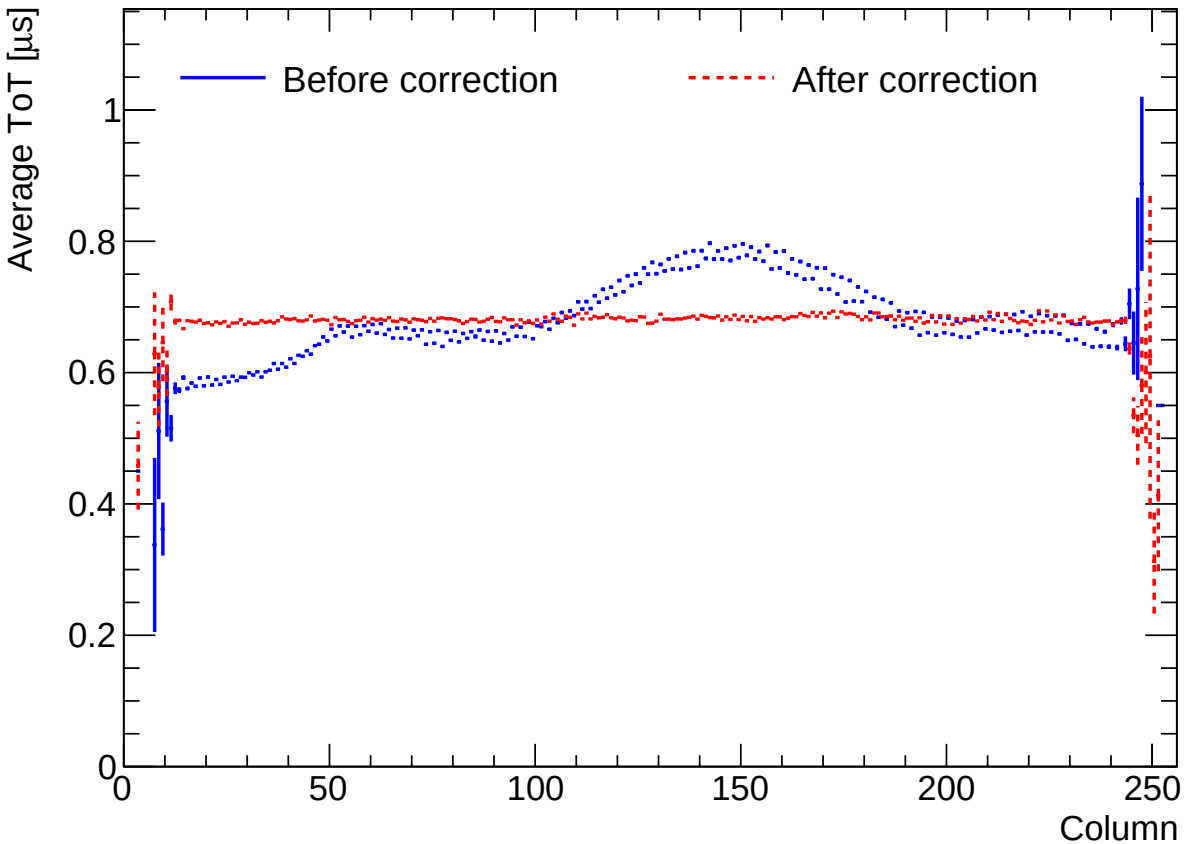
Telescope
At least 4 planes hit
Fit and reject extreme outliers ($> 700\ \mu m$)
Telescope fit goes through tpc
Timepix3
Hit ToT $> 0.15\ \mu s$
At least 20 hits
Exactly one cluster
Cut hit outliers ($> 3\sigma_{drift}$, $> 2\sigma_{plane}$)
Fit goes through front and back (pixel row)
Matching
Fits closer than 1 mm in both x and y at center of tpc
A unique match
Histograms
At least 30 TPC hits in fit
At least 75% of total number of tpc hits in fit

Tests from run 347

Run 347	
length	60m
triggers	4 733 381
V grid	350 V
E drift	280 V/cm
rotation	17 degree
	0 degree
threshold	800e

- Used first 1 000 000 telescope frames:
  - 461 426 triggers of which 330 925 with matching tracks
- A drift speed of 75 μm/ns was *assumed*

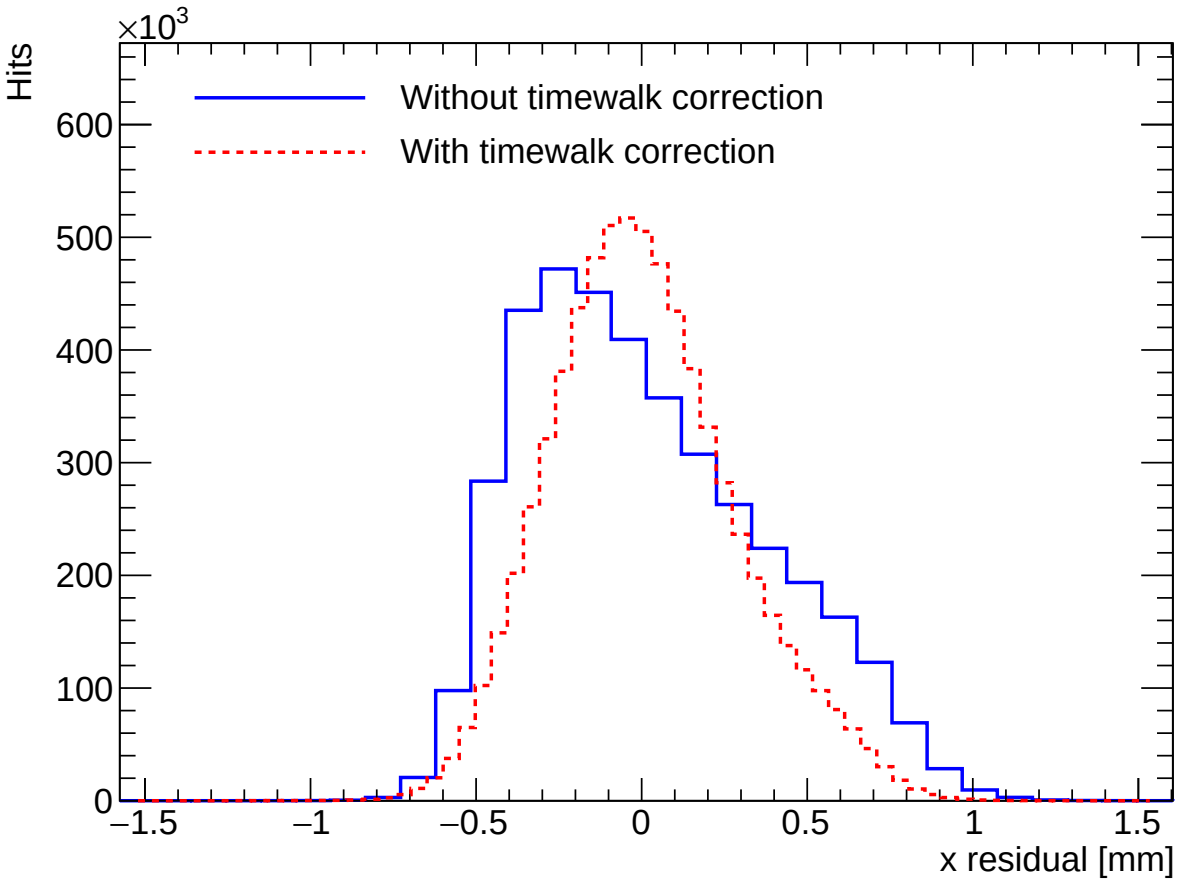
ToT-correction



Differences in odd and even column numbers in ToT

Corrected by introducing a factor for each column

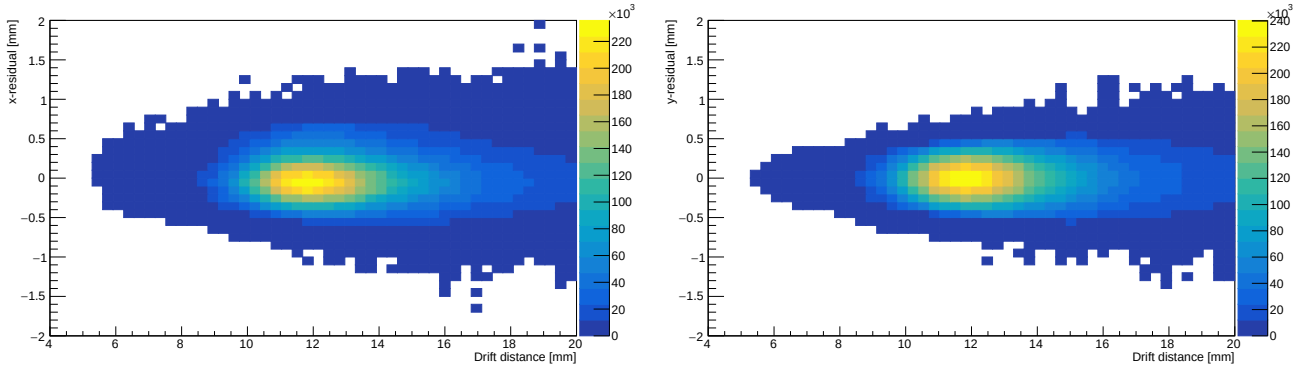
Time walk correction



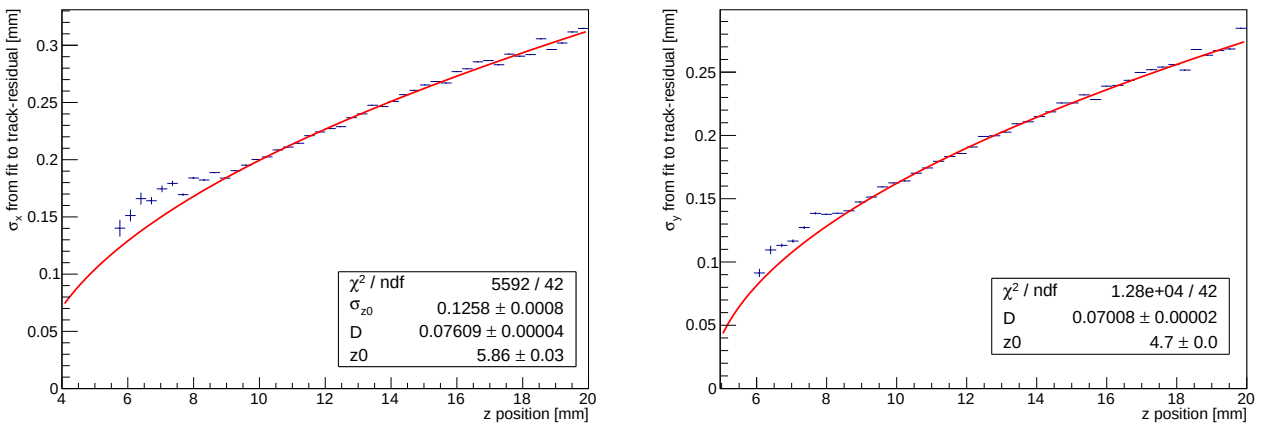
Timewalk corrected by fitting $\delta x_{\text{timewalk}} = \frac{c_1}{t_{\text{ToT}} + t_0} + x_0$

Find diffusion from residuals

Plot residuals in 2-dimensional histogram

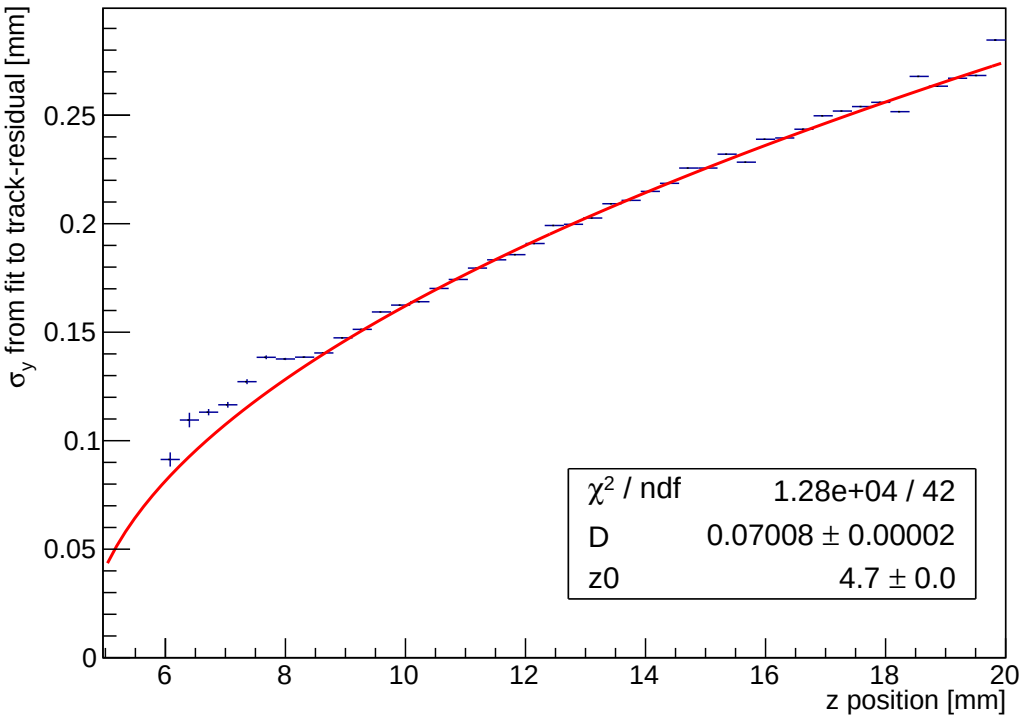


Fit gauss to y-slices and put σ in graph



Fit $\sqrt{\sigma_{z0}^2 + D^2(z - z_0)}$ to graph, and get results $\rightarrow$

Diffusion in pixel plane perpendicular to track

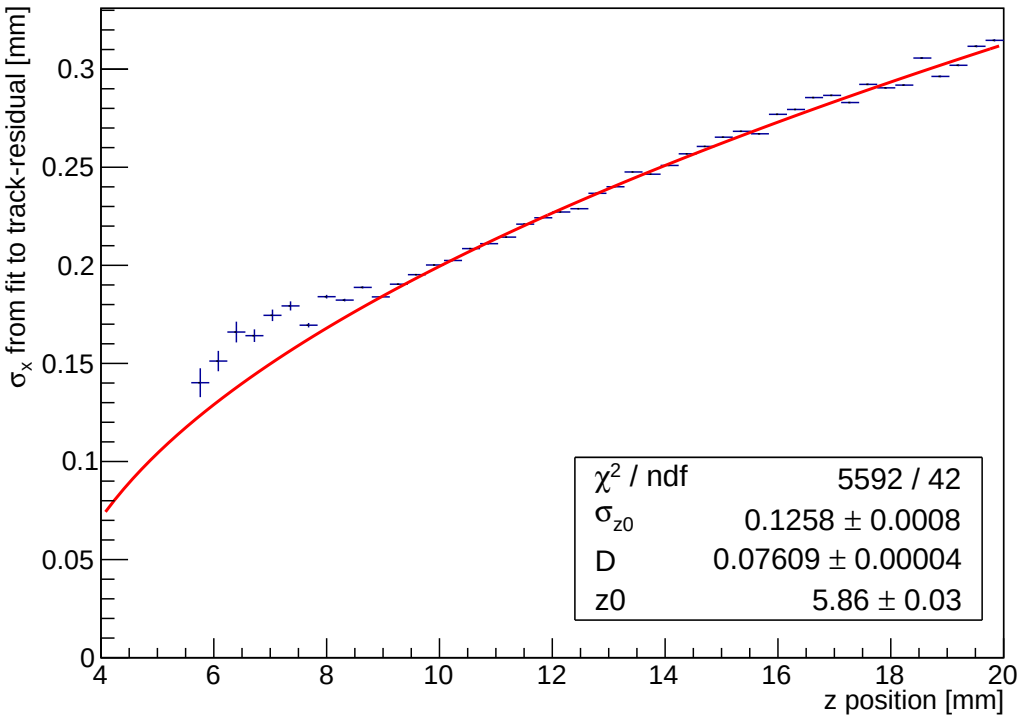


Fix $\sigma_{z0} = 0.055/\sqrt{12} = 0.0159mm$

$D_T = 70\,\mu m/\sqrt{mm}$

From laser test $D_T = 98\,\mu m/\sqrt{mm}$ at $330V$ and $v_{drift} = 66.4\mu m/ns$

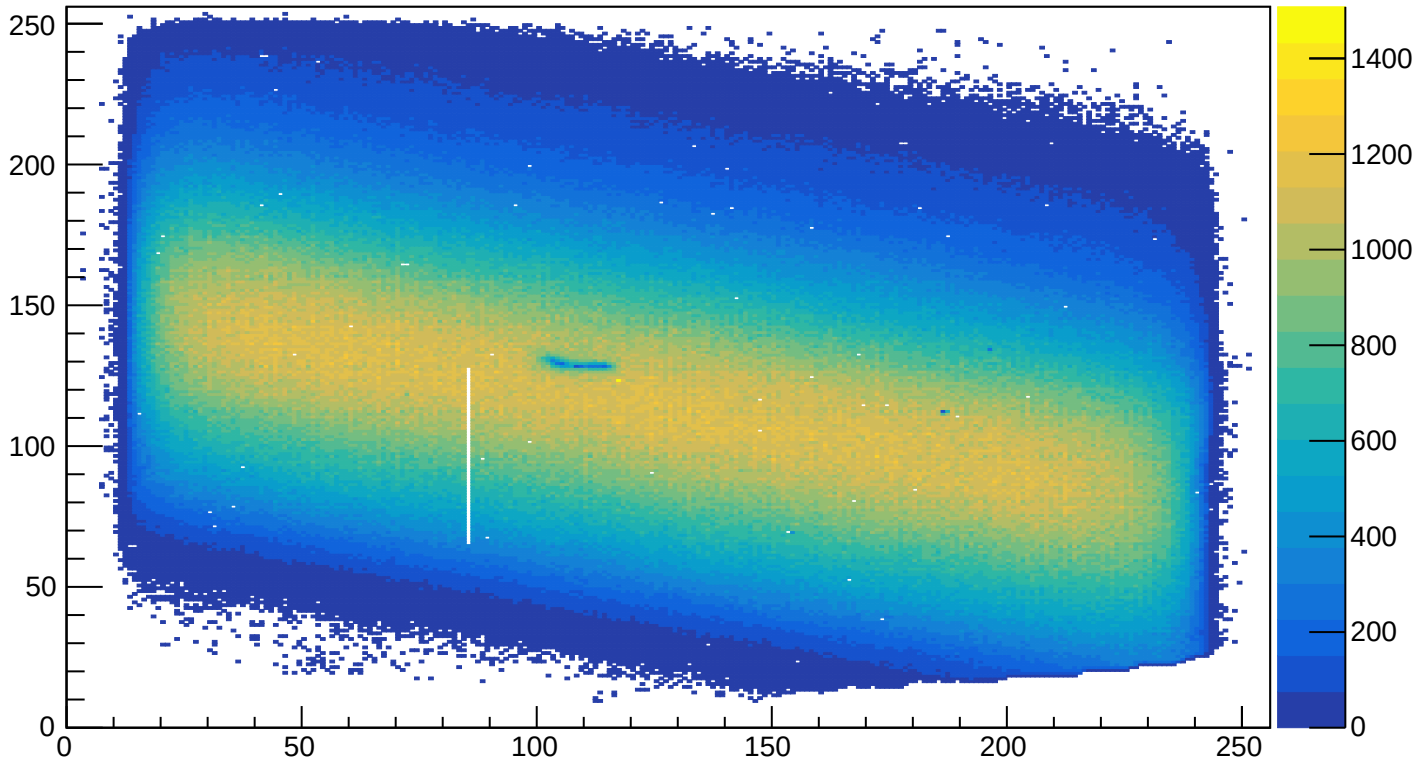
Diffusion in drift direction



$D_L = 76\,\mu m/\sqrt{mm}$

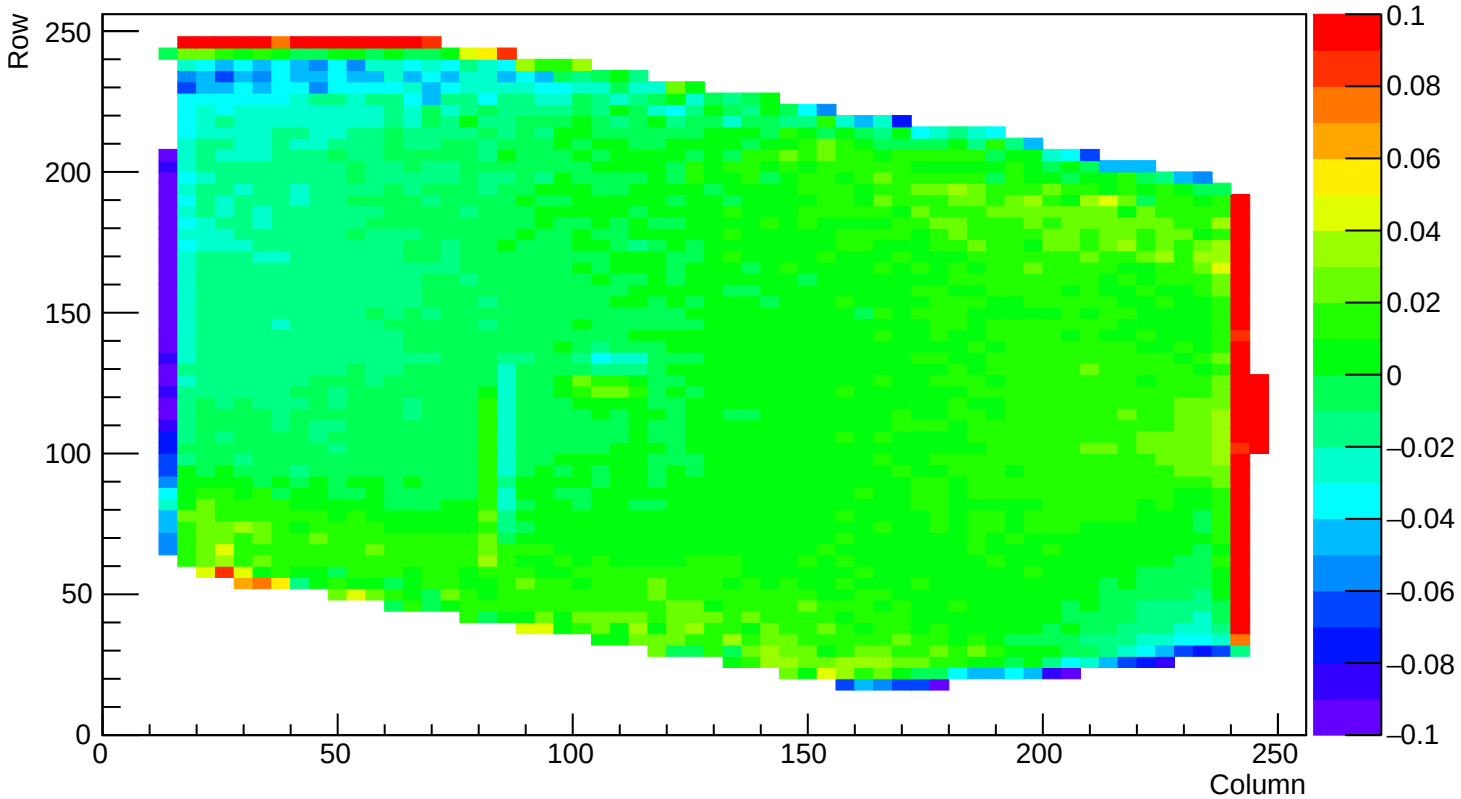
From laser test without time walk correction $D_L = 80\,\mu m/\sqrt{mm}$ at $330\,V$ and $v_{drift} = 66.4 \mu m/ns$

Hitmap



Note some defects

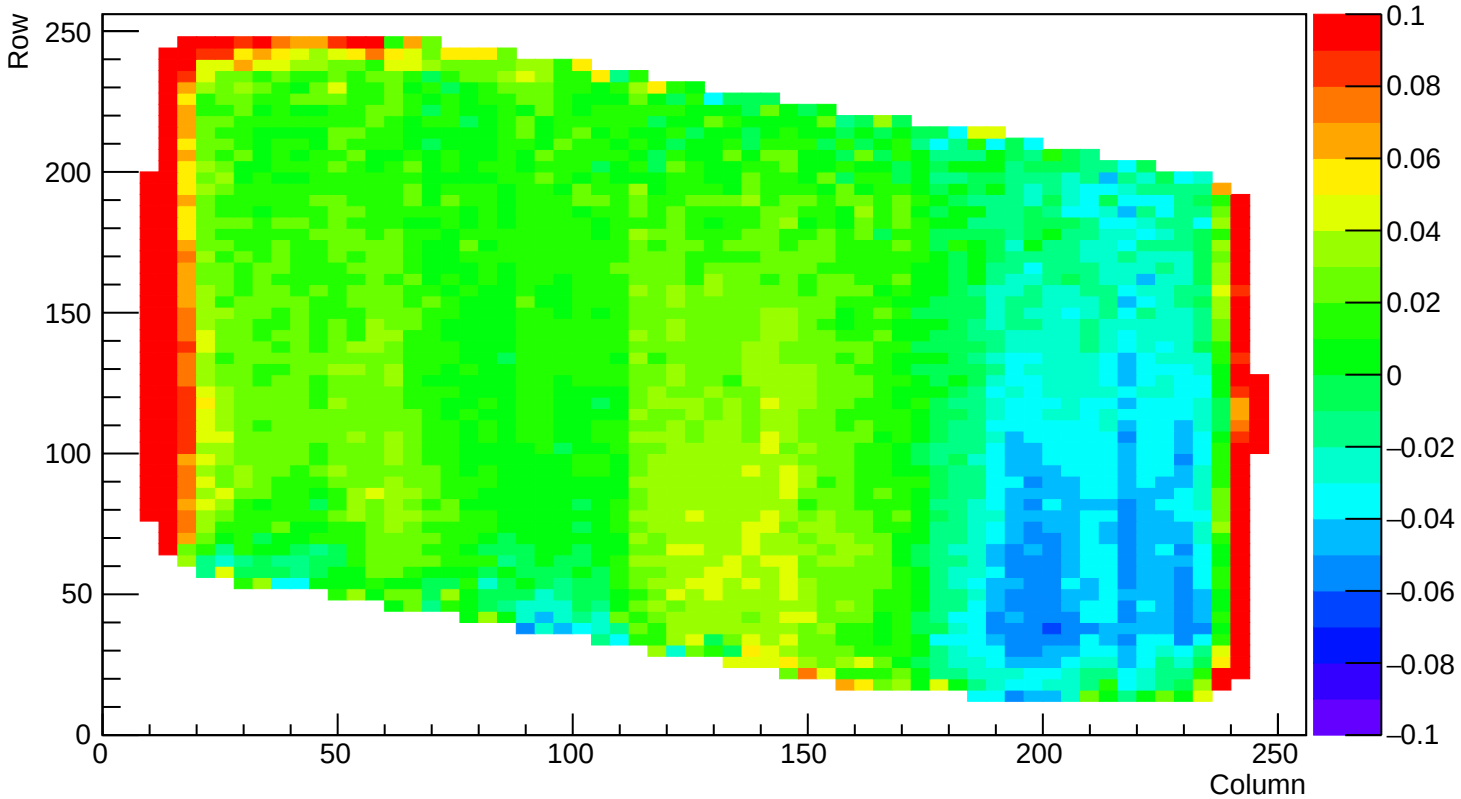
Deformations in pixel plane perpendicular to track



Deformatiosn in mm

Residuals are filled at expected row and column

Deformations in drift direction



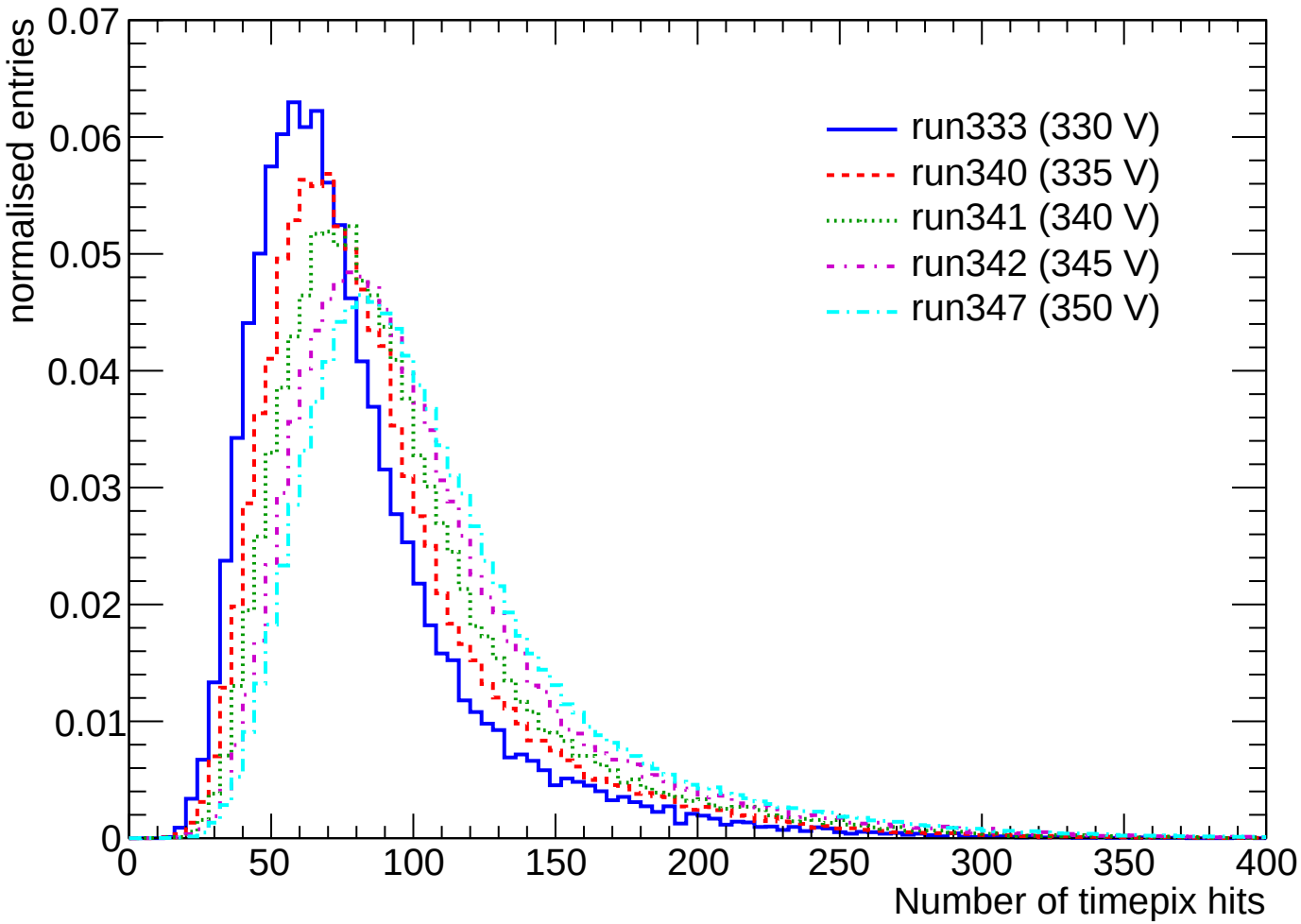
Deformations in mm

Residuals are filled at expected row and column

Conclusion

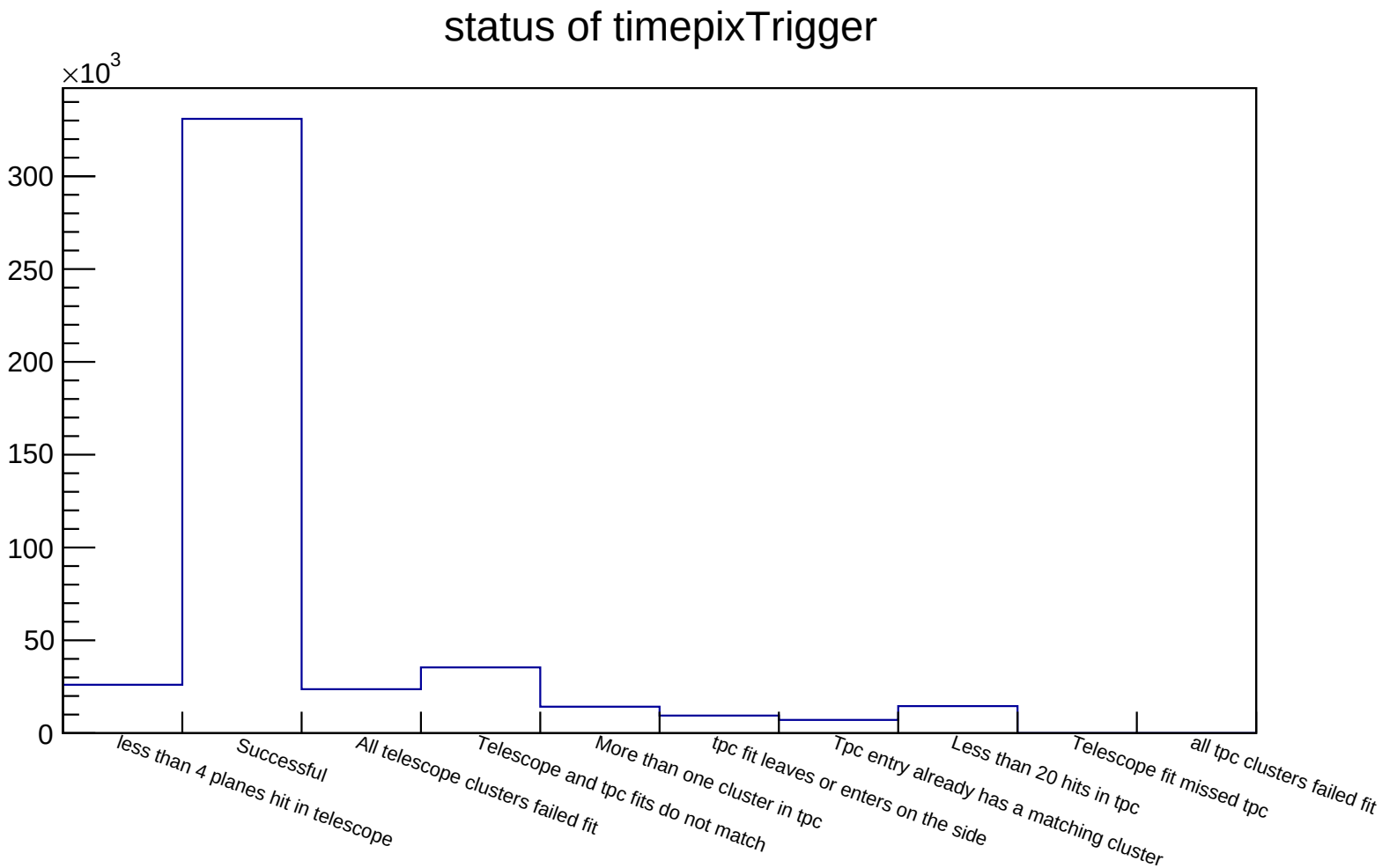
- Telescope track does not seem te be usable, possible due to material between telescope and Timepix3. A single point was used
- ToT was corrected and used for a time walk correction
- The diffusion coefficient fitted from data is $D_T = 70\,\mu m/\sqrt{mm}$ and $D_L = 76\,\mu m/\sqrt{mm}$
- Deformations in the pixel plane are found to be small ($< 20\,\mu m$)

Next: looking at cross-talk at different voltages



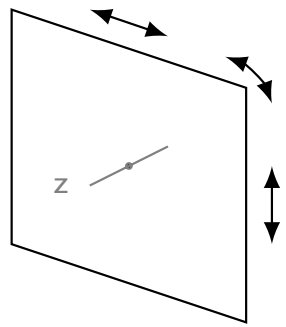
Number of hits at different grid-voltages

Indication of cut effects



Cuts are roughly in order presented before

Align telescope planes



Align with 3 degrees of freedom: x, y shifts and rotation around z
Fix z position and assume all detectors perpendicular to the z-axis

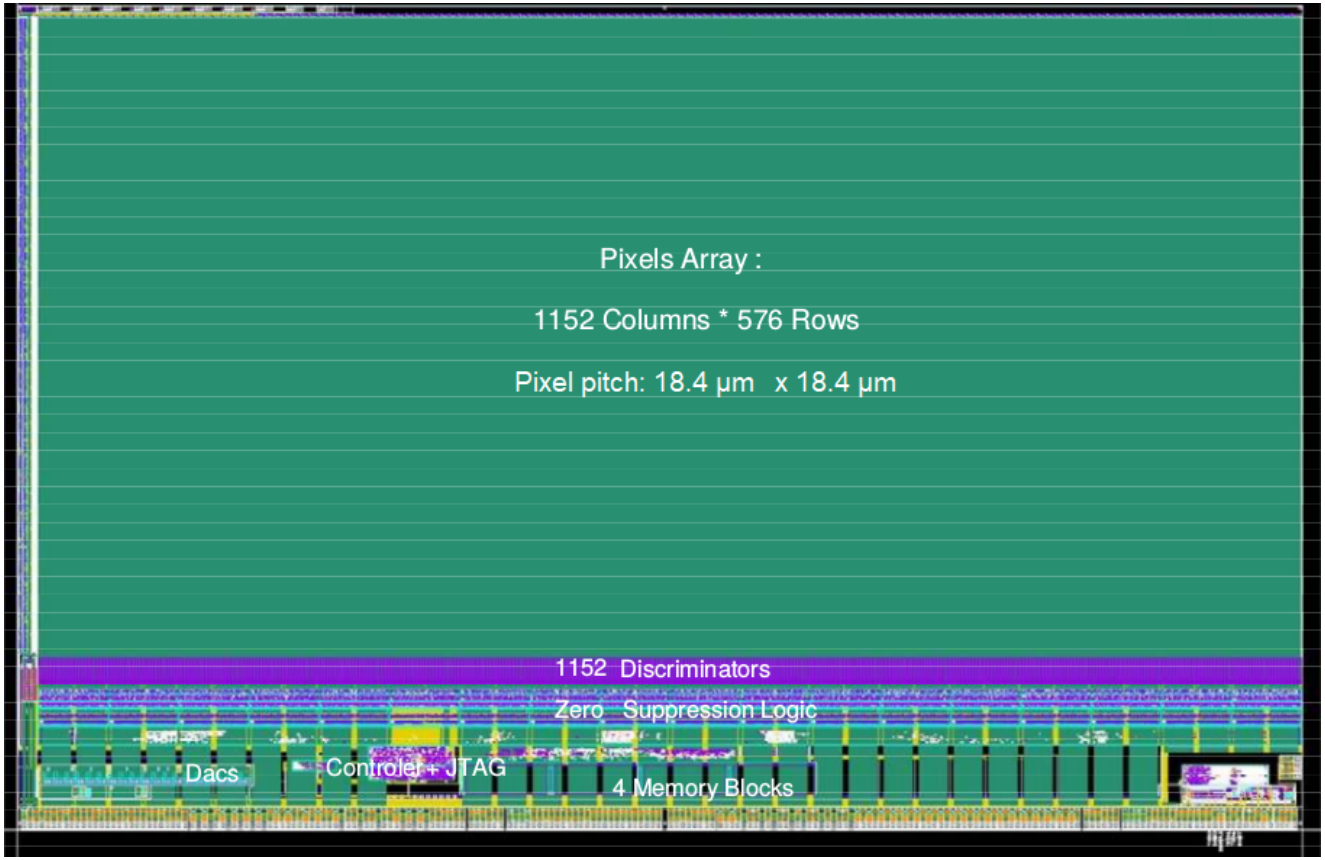
Find corrections from residuals

- Find mean of residuals using gaus fit
- Find rotation using histogram of $\Delta\phi = (yr_x - xr_y)/(x^2 + y^2)$, where x, y are the hit coordinates with respect to the average hit position and r is the residual, histogram is weighted by $\sqrt{x^2 + y^2}$

Telescope alignment procedure

1. Fit through points in plane 2 and 5
   shift planes 1,3,4,5,6 in x and y
2. Fit through points in plane 2 and 5
   rotate plane 5 around its average hit postition to match plane 2
3. Fit through points in plane 2 and 5
   rotate all planes around their average hit position
4. Fit through points in all planes
   check if converged.

Mimosa telescope



MIMOSA26 User Manual, 2011

Detector with digital silicon pixels

Rolling shutter readout with 115.2 µs per frame