Update on Investigator test-beam analysis

- Bias scan for mini-matrix with pitch of 28 µm -

CLICdp Tracker-Meeting

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Outline:

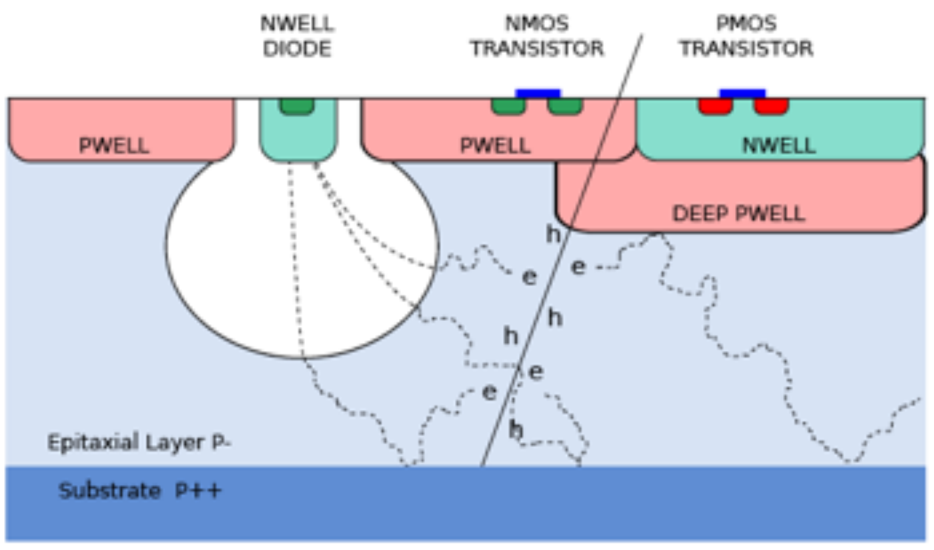
- Introduction
- Reconstruction
- Quality cuts in the analysis
- Results
- Summary & outlook

Introduction

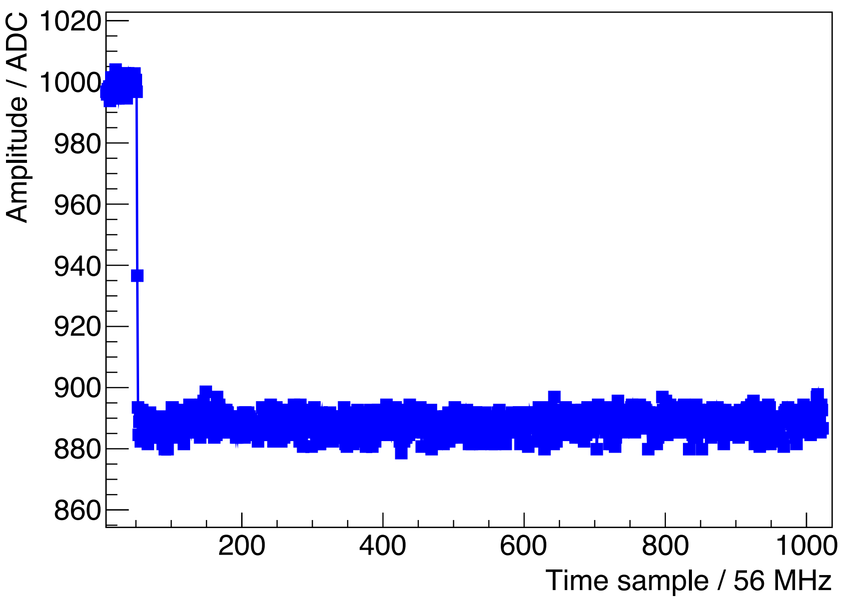
ALICE investigator chip

ALICE investigator chip, TowerJazz 180 nm CMOS imaging process:

TowerJazz technology:



Waveform:



- Contains two times 134 matrices with 8x8 pixels
- Different pitch from 20 μm to 50 μm, various implant width and spacing between collection diode and p-ring
- Selected mini-matrix connected to 64 ADCs on readout board, to record full waveform of all pixels with a 65 MHz sampling
- Data from test-beam in June: Investigator placed in centre of the Timepix3-telescope setup

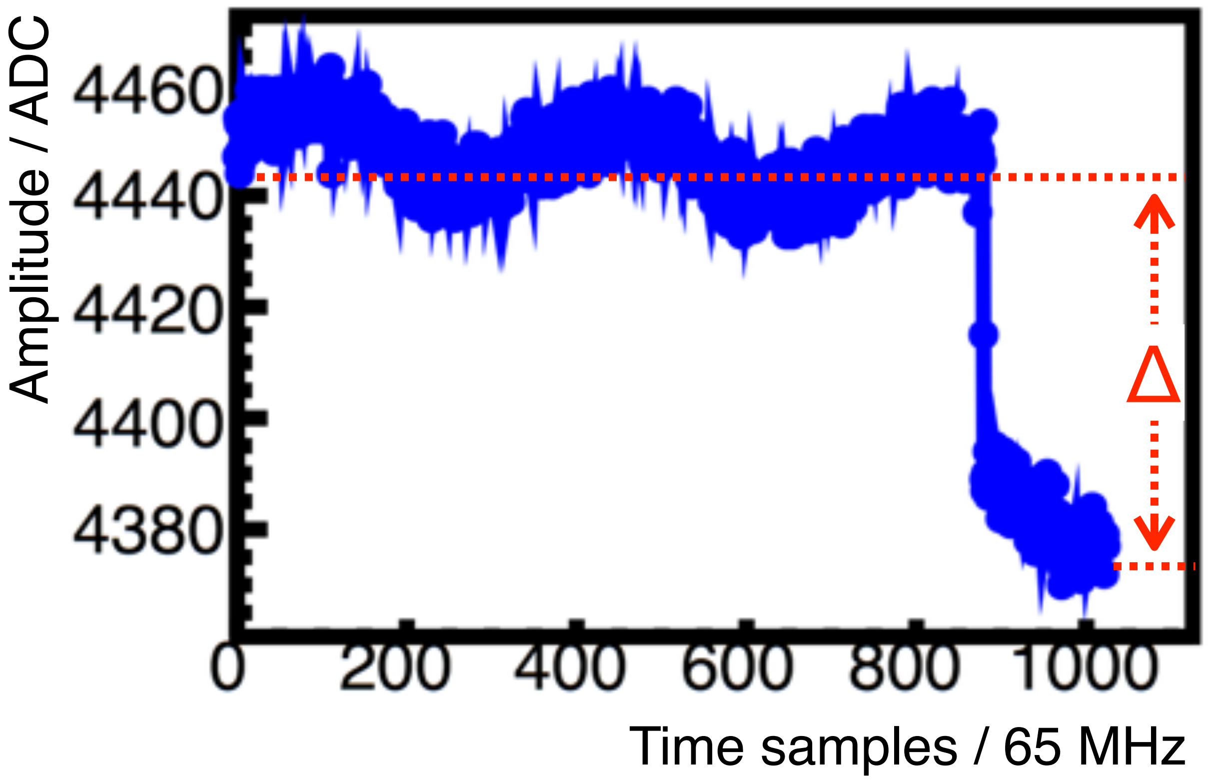
Reconstruction

- Hit definition and common mode filter
- Definition of signal and noise
- Definition of timing observables

Hit definition and common mode filter

Perform for each event:

1.) Select pixels with no hit:



- Calculate for each pixel:
  $\Delta = \text{Amplitude}(t_{first}) - \text{Amplitude}(t_{last})$
- If there exists a $\Delta > 10$:
  Pixel is hit candidate
- If there exists no $\Delta > 10$:
  Pixel is not a hit candidate

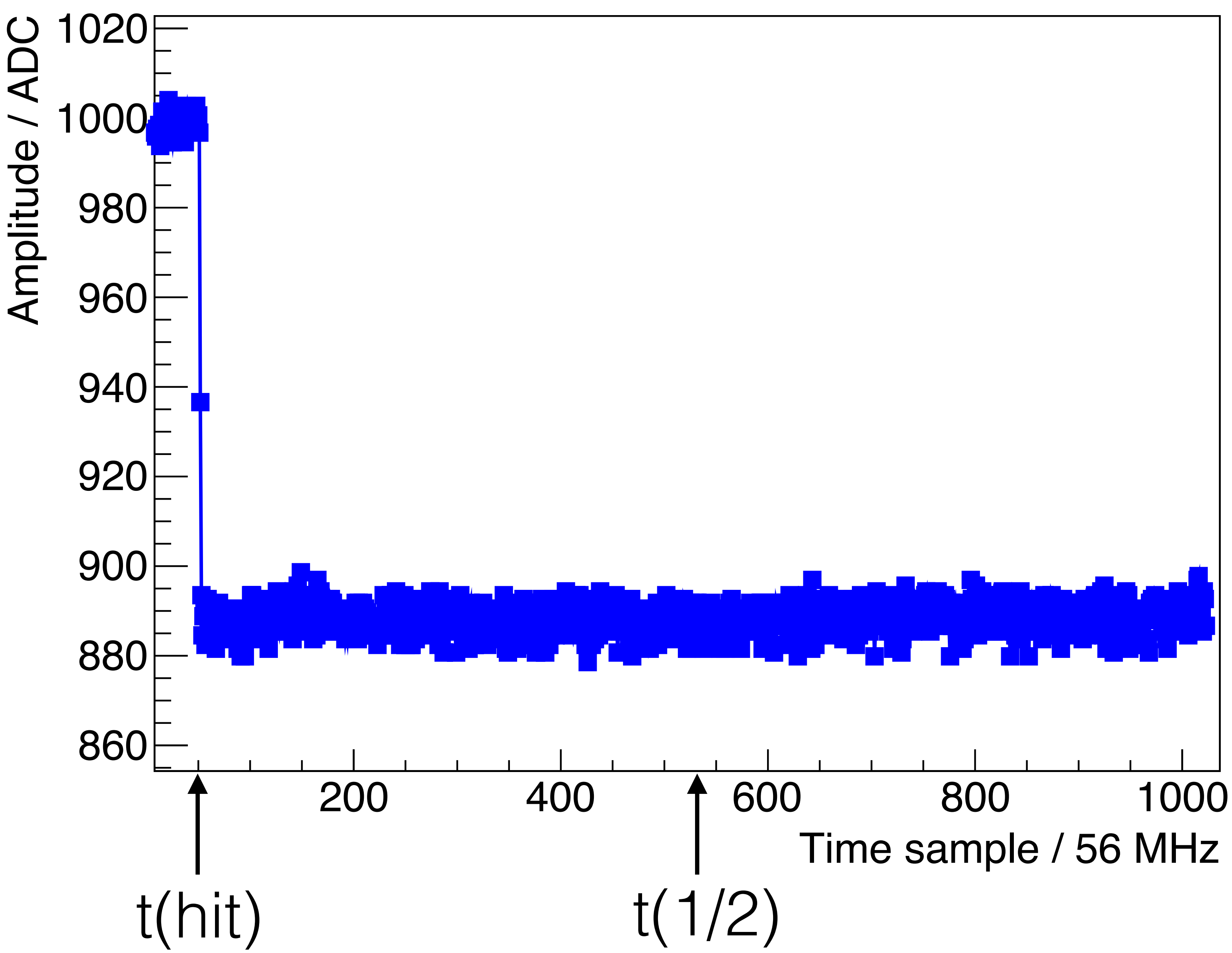
↳ Pixel is used for common mode calculation if it is not a hit candidate

2.) Calculate & apply common mode filter:

- Average waveform of pixels which are no hit candidates = common mode
- Subtract common mode from each pixel

Definition of signal & noise

Calculate signal & noise for hit candidates:



Signal:

Mean amplitude after t(hit)
—
Mean amplitude before t(hit)

Noise:

If t(hit) > t(1/2):

Noise
=
Fluctuation before t(hit)

If t(hit) ≤ t(1/2):

Noise
=
Fluctuation before t(hit)

(cut out a few time samples close to t(hit))

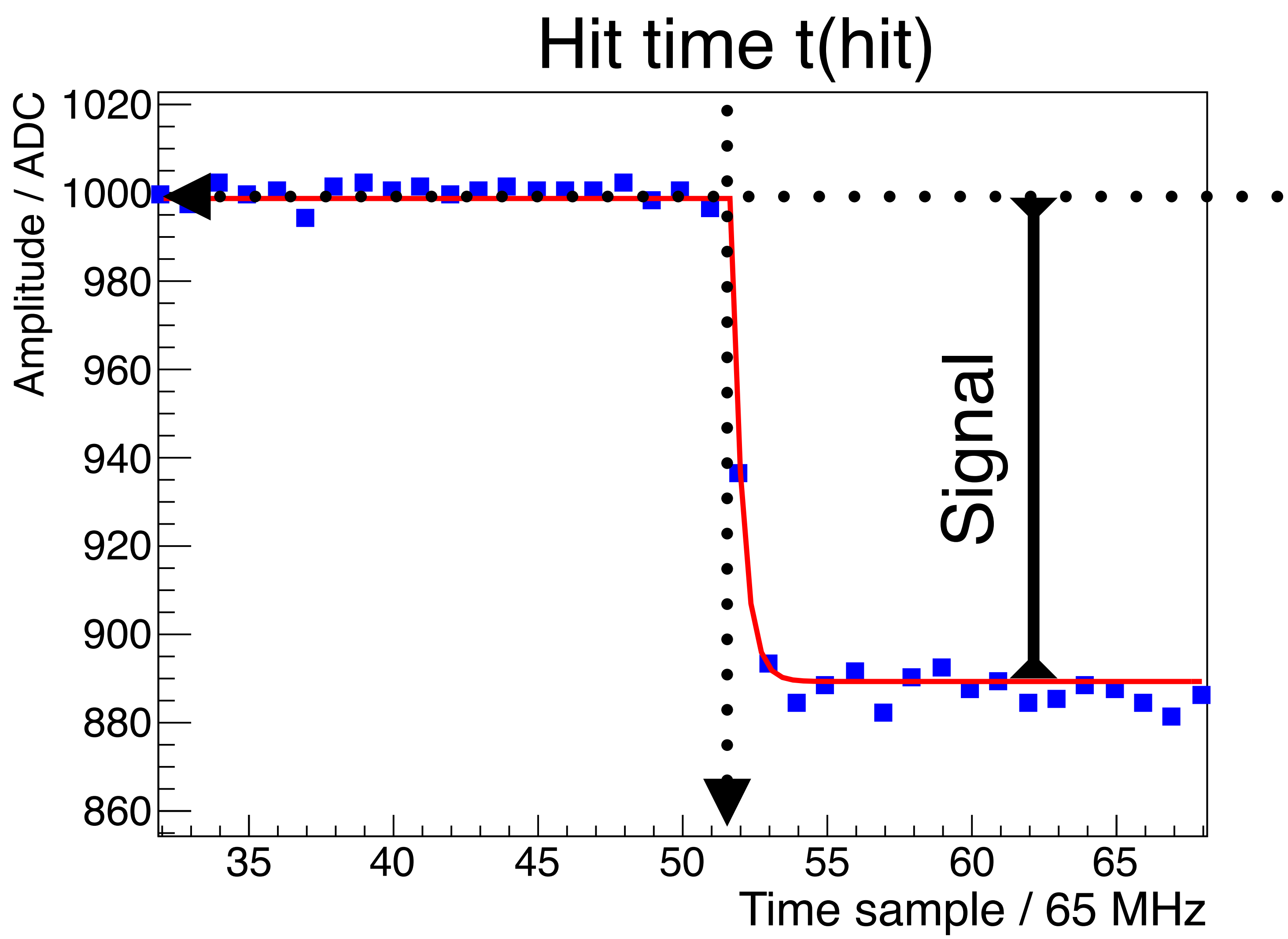
↳ A hit candidate is only taken into account as a hit if Signal/Noise > 10

Definition of timing observables

- Fit Function to Waveform of pixels with hit (t = time sample):

$$\text{Function}(t) = \begin{cases} \text{Pedestal} & t \leq t(\text{hit}) \\ \text{Pedestal} + \text{Signal} * (e^{[t-t(\text{hit})]\,/\,t(\text{rise})} - 1) & t > t(\text{hit}) \end{cases}$$

- Example of Function fitted to Waveform of pixels with hit:



The rise time t(rise) defines the slope of the function.

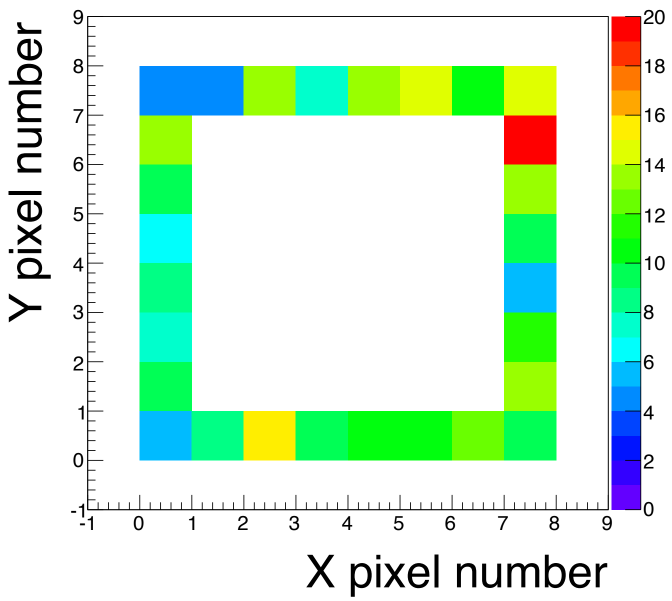
Quality cuts in the analysis

Quality cuts in the analysis

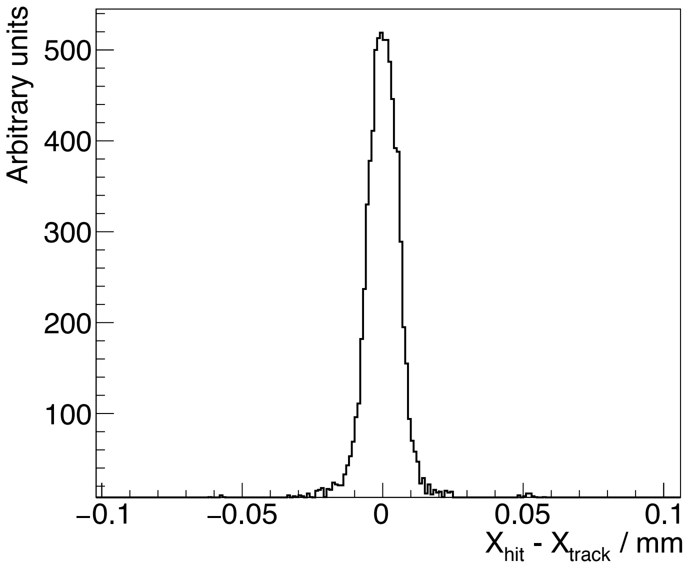
Cuts on all observables:

- Masking of edge pixels
- Cut on track-cluster matching: Δ(hit,track position) < 100 μm

Example of mask of edge pixels:



Example of residual distribution:

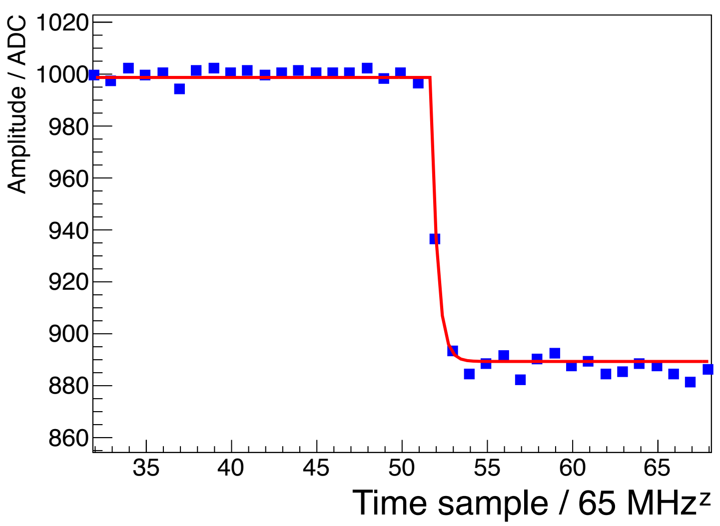


Cut only on timing observables:

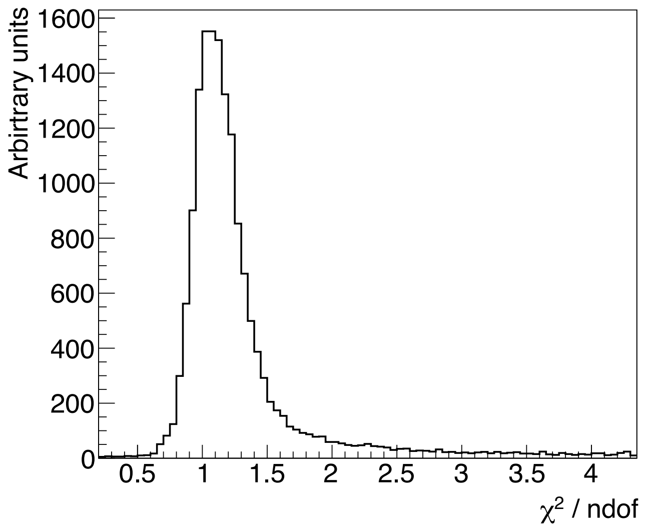
- Cut on χ^2/ndof of waveform fit: $0.8 < \chi^2/\text{ndof} < 1.2$

↳ Different values to be investigated (ongoing)

Example of fit to waveform:



Example of χ^2/ndof distribution:



Results for different bias voltages

- Mini-matrix with a pitch of 28 μm -

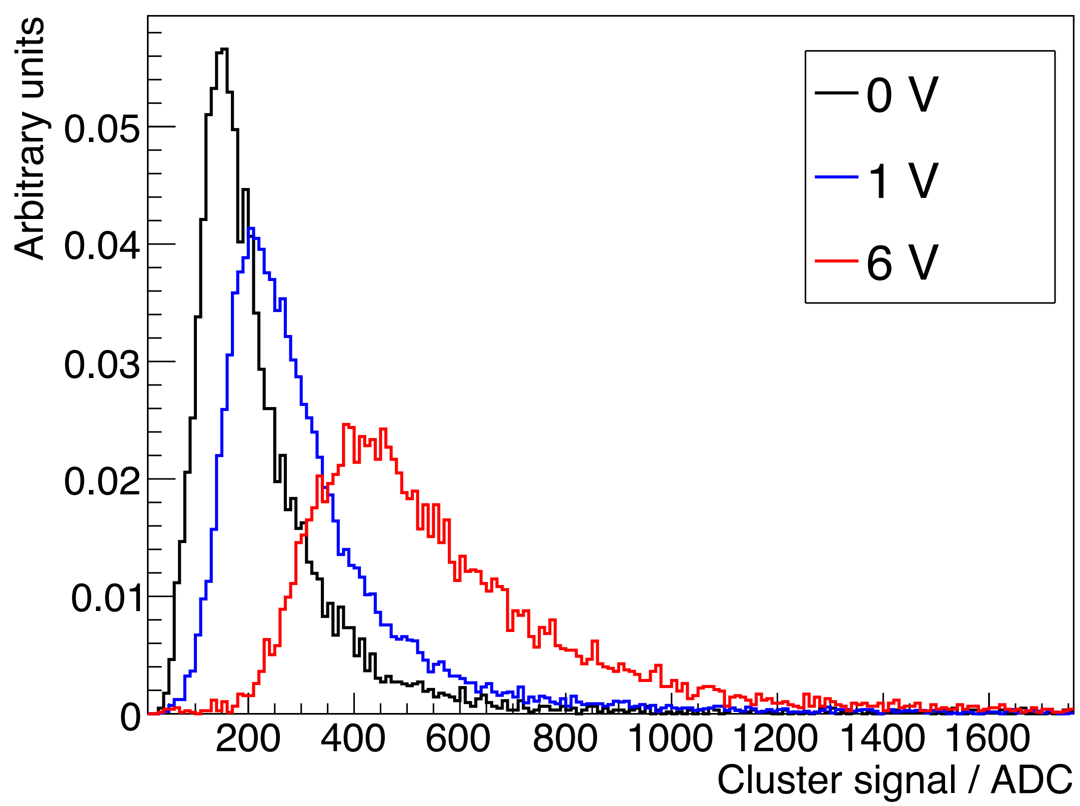
- Cluster signal
- Cluster size & resolution
- Timing
- In-pixel studies

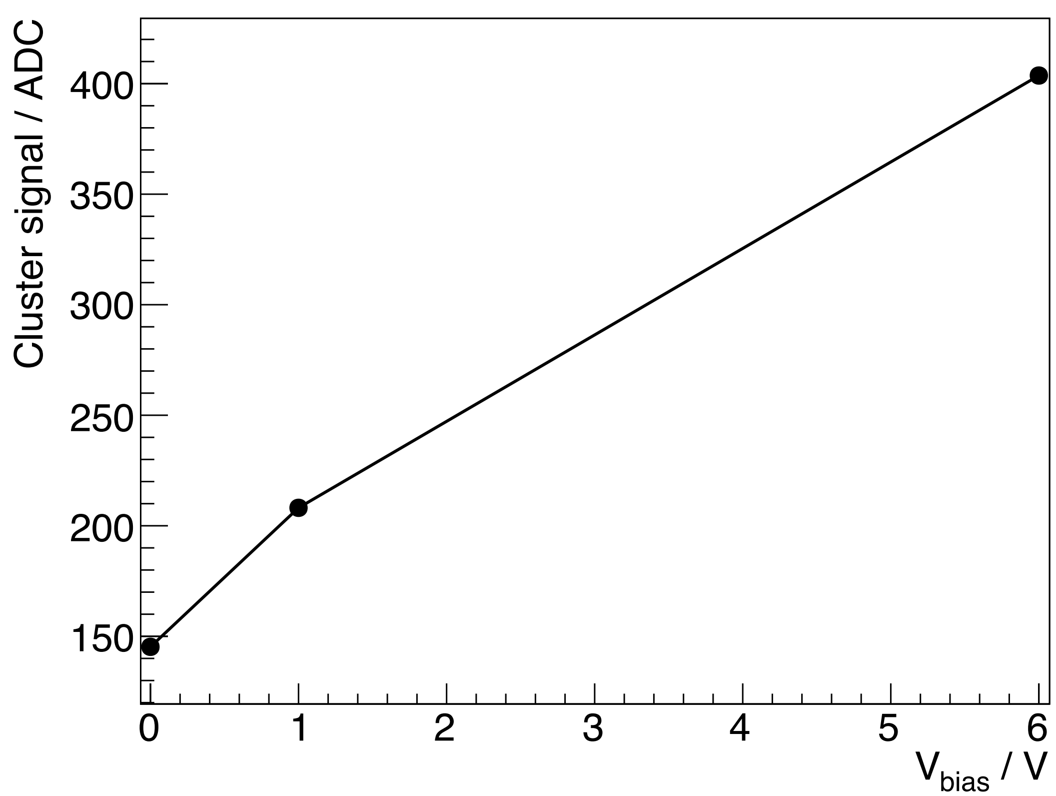
Cluster signal

Motivation:

- Prove expected behaviour:
  - Smaller depletion region
  - More recombination in non-depleted region
  - Smaller cluster signal for lower bias voltages

Results:





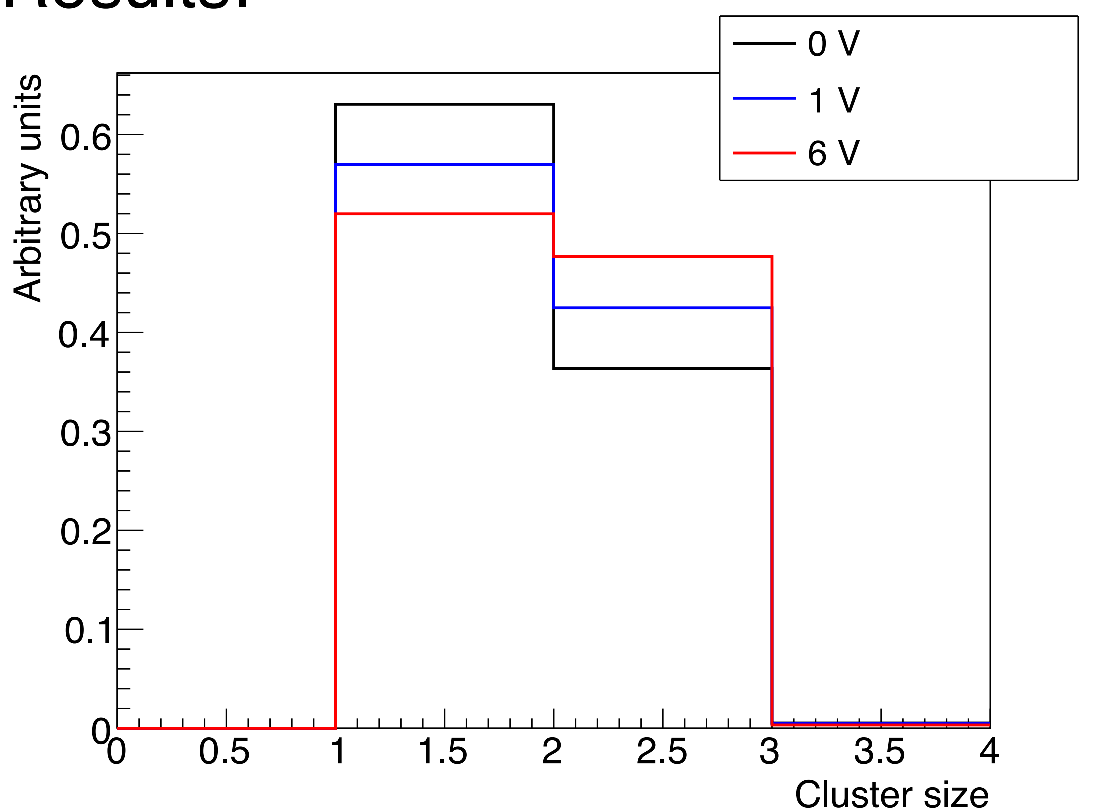
↳ Cluster signal shows behaviour expected from recombination

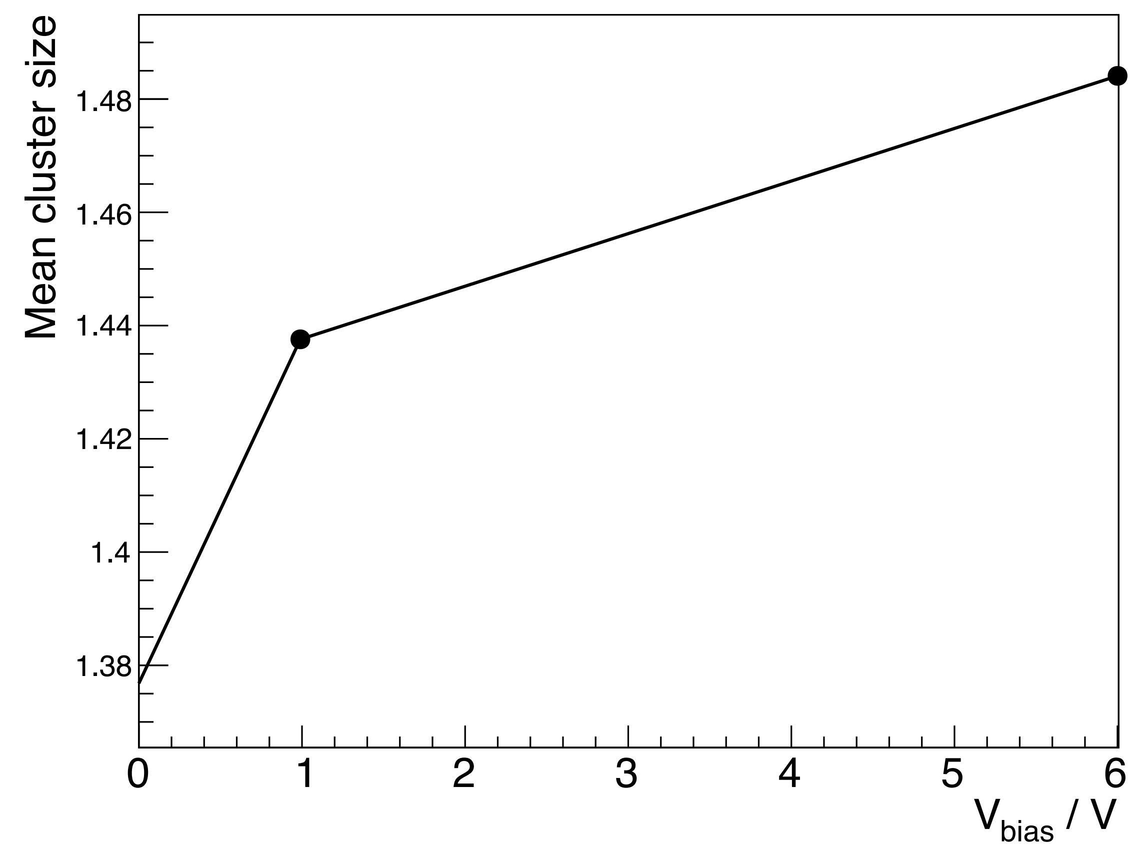
Cluster size

Motivation:

- Expect correlation with signal created in sensor
  - Higher signal created in sensor
  - Larger cluster size

Results:





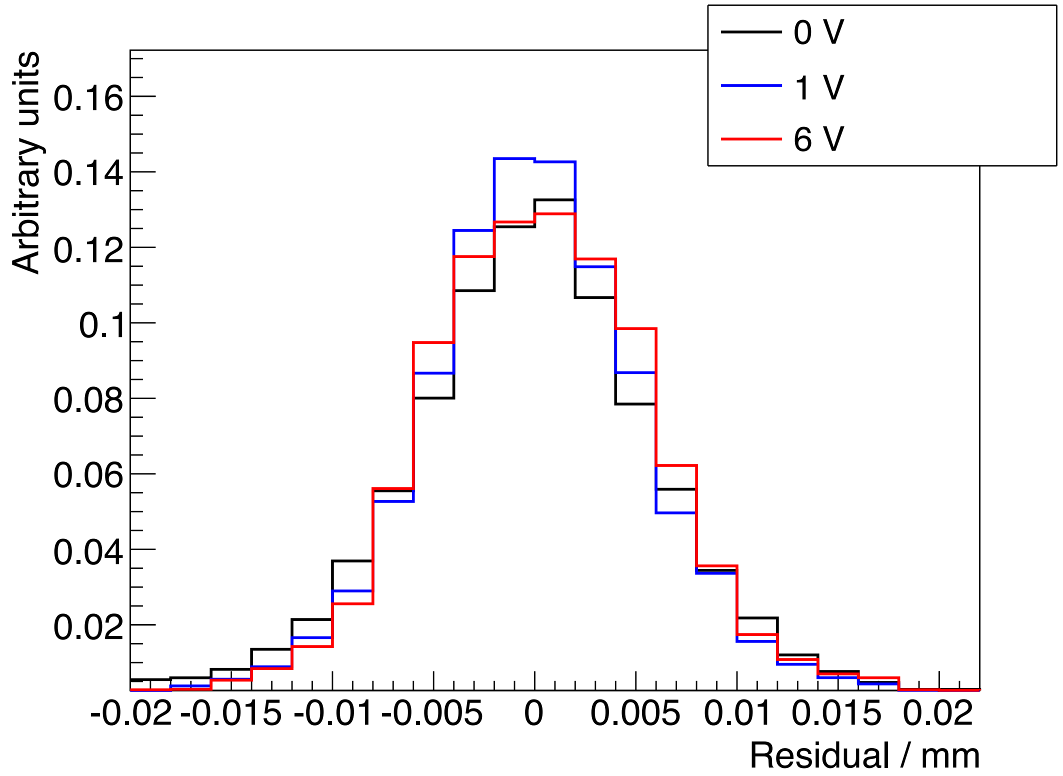
↳ Effect maybe not strong because S/N-cut and / or DAQ is not optimal (to be investigated)?

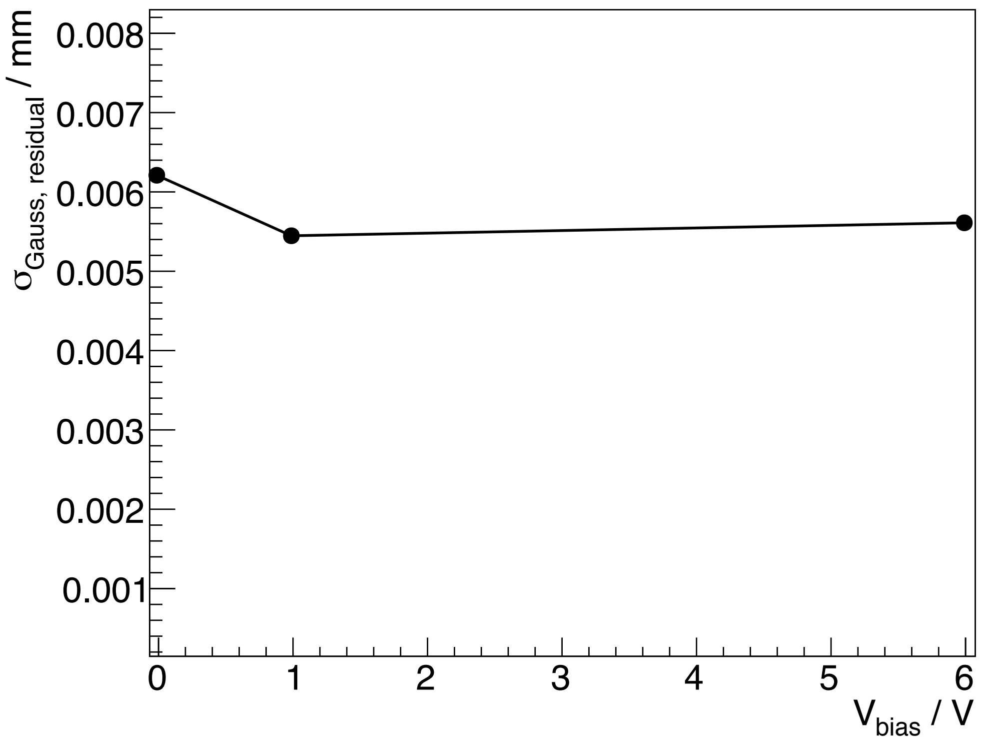
Resolution

Motivation:

- Expect correlation with cluster size dependancy on the bias voltage:
  - Higher signal created in sensor
  - Larger cluster size
  - Better resolution

Results:





↳ Not much better than expected binary resolution of ~ 0.008 mm

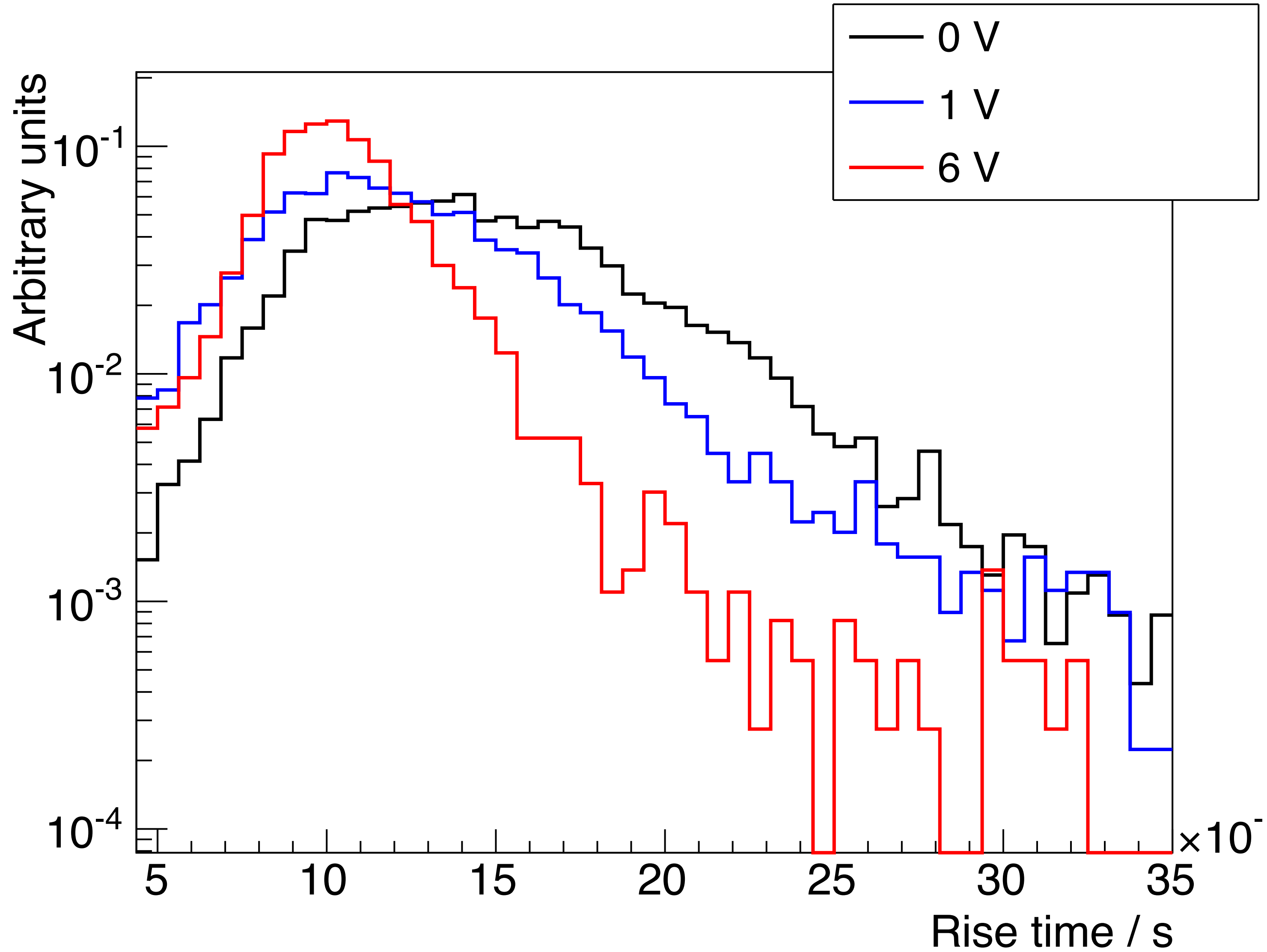
↳ η-correction performed on too less statistics (ongoing)?

Rise time

Motivation:

- Lower field through lower voltage
- Diffusion in larger un-depleted regions for lower bias voltage
- Expect "slower" signals with larger rise time for lower voltage

Results:



↳ Agreement with expectation

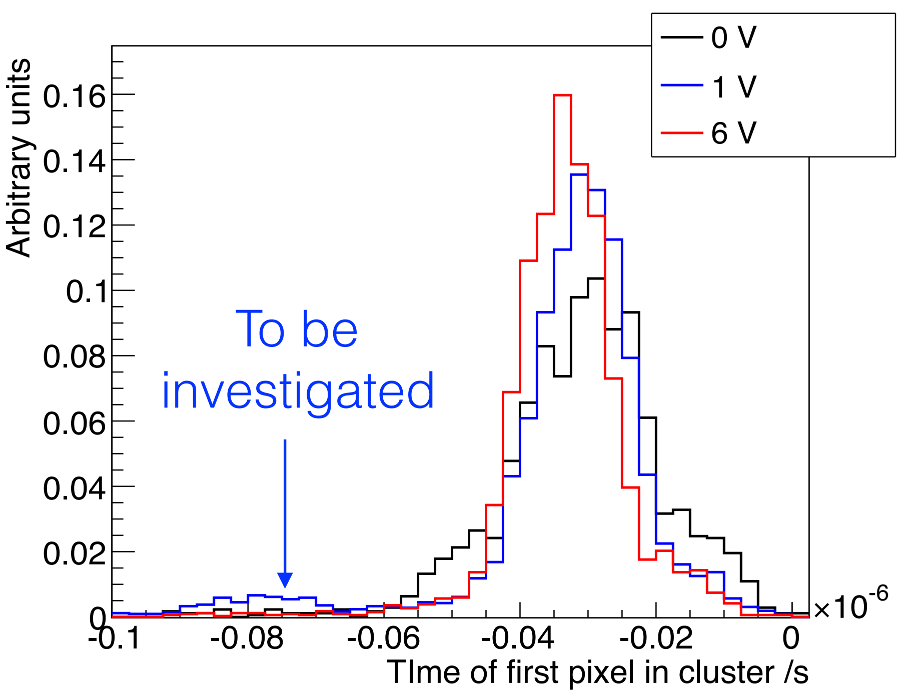
Hit time

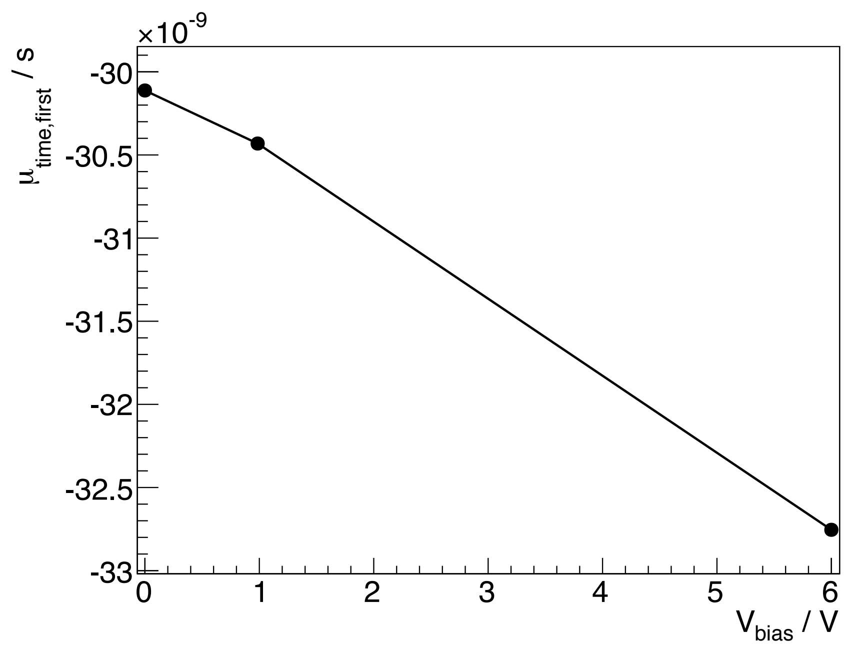
Motivation:

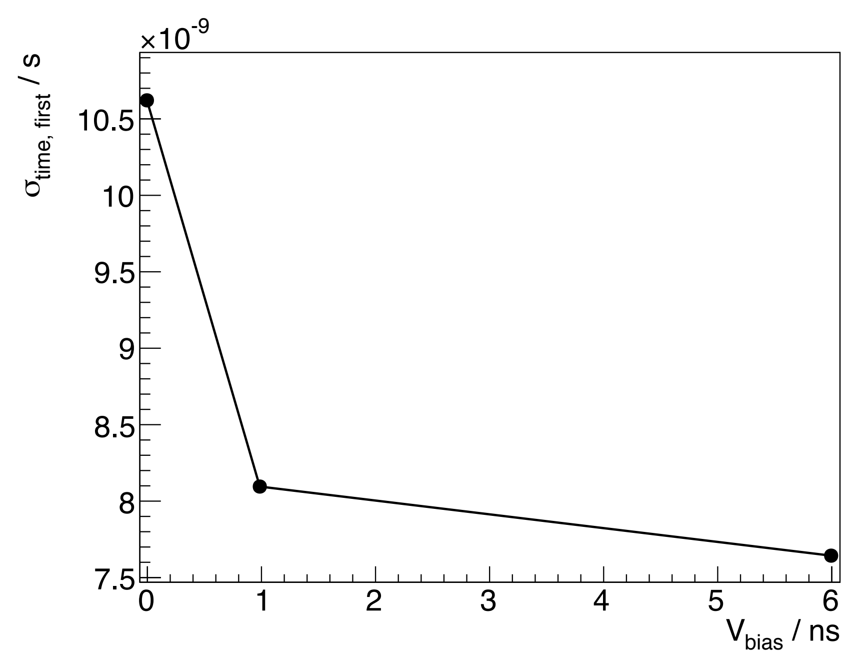
- Lower field through lower voltage
- Diffusion in larger un-depleted regions for lower bias voltage
- How does this effect the hit time of the first pixel in the cluster?

Results:

- Use hit time of first pixel in cluster to be independent from charge sharing







early hit ⟷ late hit

↳ Later hits for lower bias voltage

↳ Wider distribution of hit time for lower bias voltage

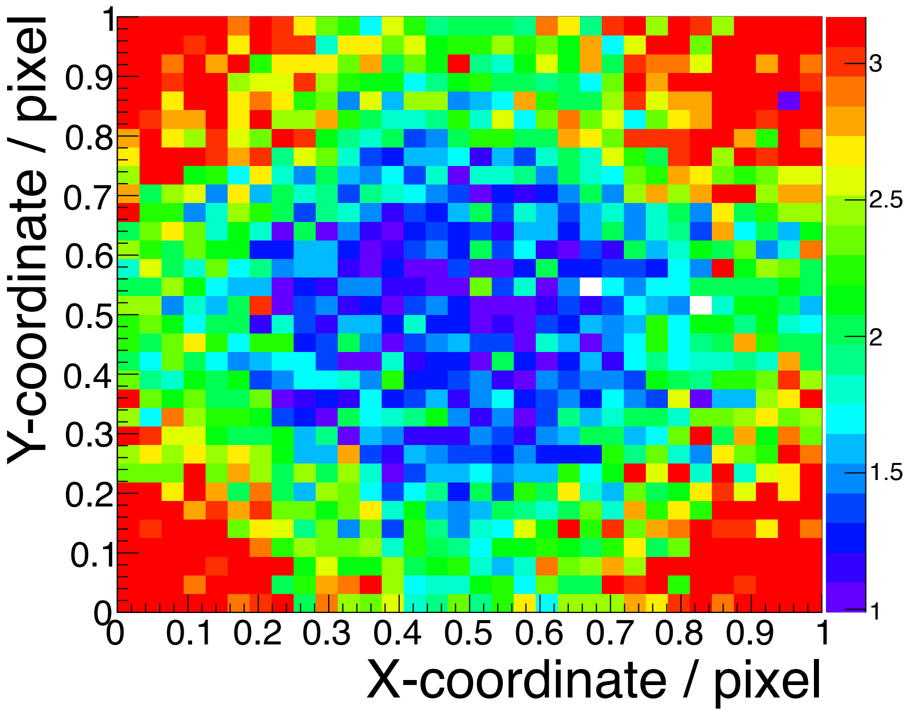
In-pixel cluster size

Motivation:

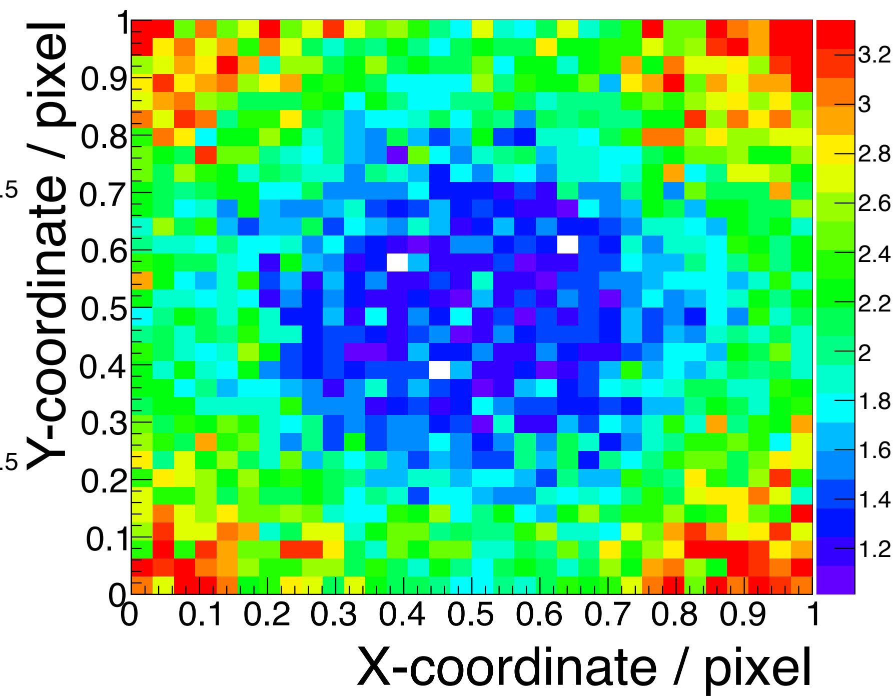
- Validate reconstruction on sub-pixel level
- Study behaviour of charge sharing within single pixel cell in dependance of the bias voltage

Results for different bias voltages:

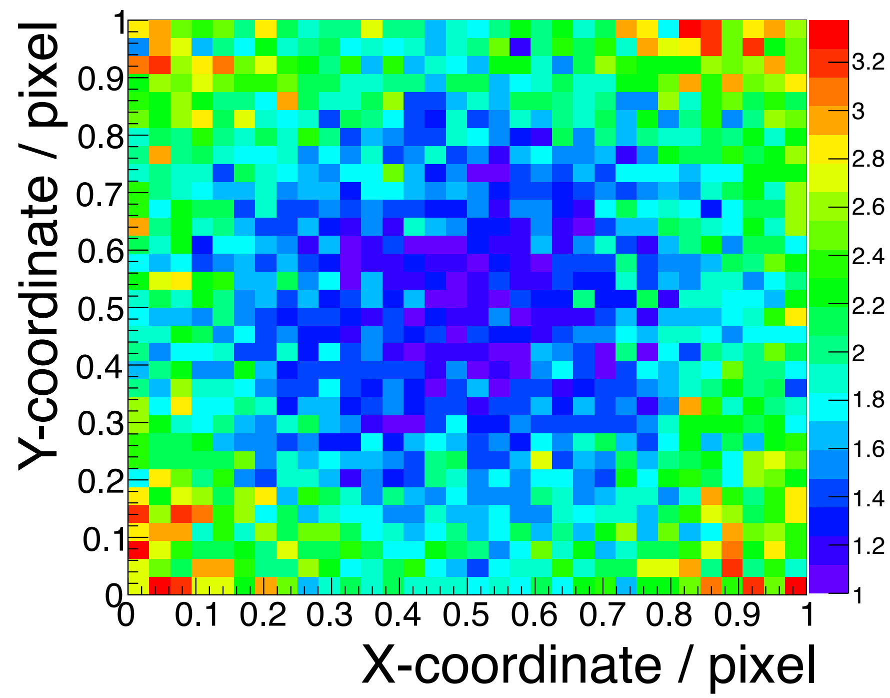
V_{bias} = 6 V:



V_{bias} = 1 V:



V_{bias} = 0 V:



↪ In pixel structure of cluster size clearly visible and according to expectations

↪ Less charge sharing at the pixel edges and corners for lower bias voltage

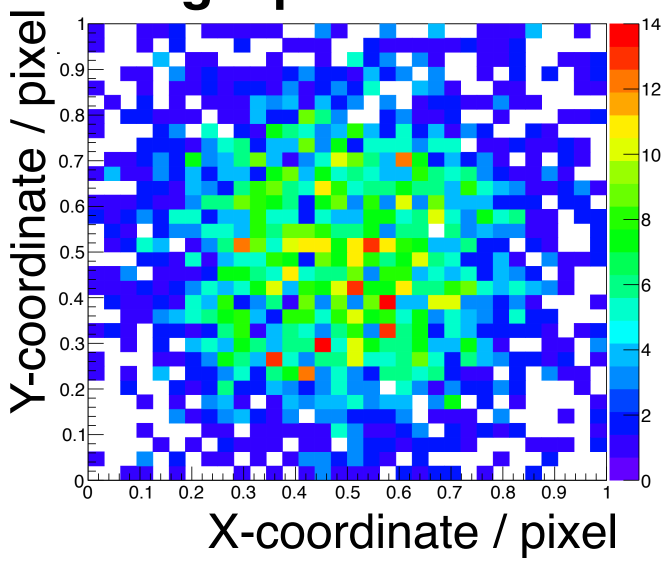
In-pixel hit map for different cluster sizes

Motivation:

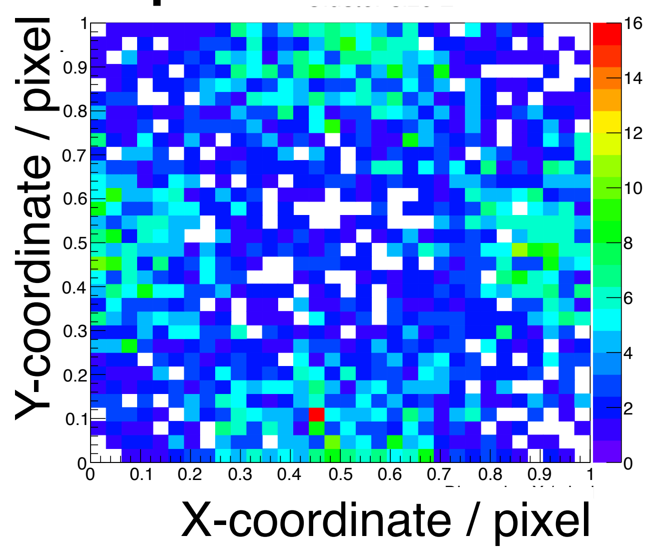
- More detailed understanding of charge sharing on sub-pixel level

Results V_{bias} = 6 V:

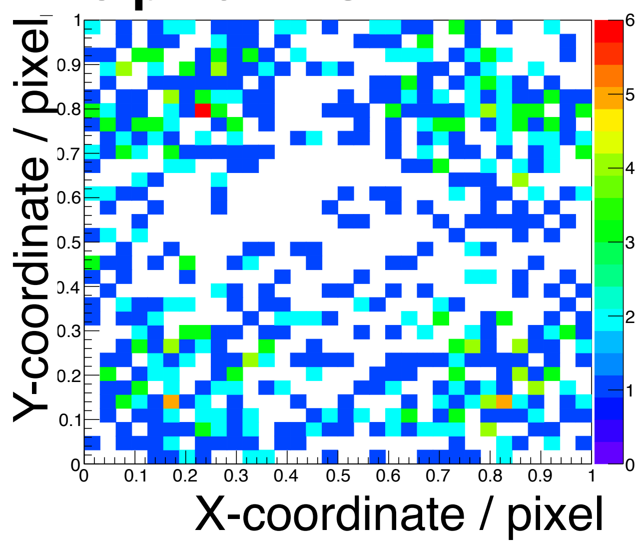
Single pixel hits:



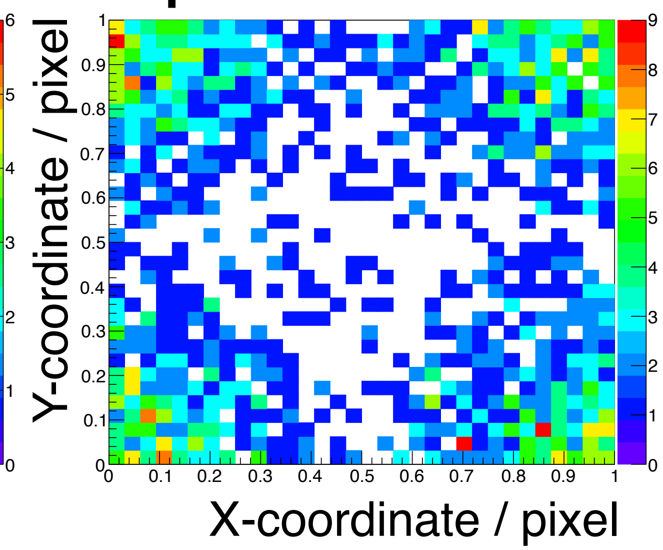
2 pixel hits:



3 pixel hits:

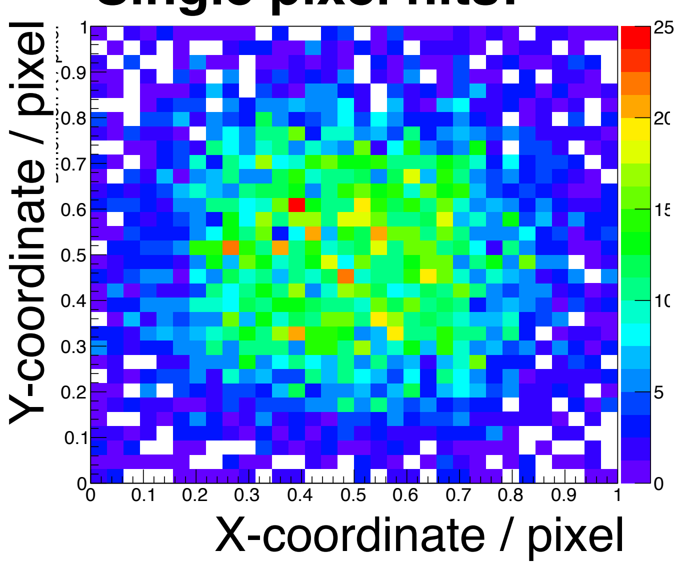


4 pixel hits:

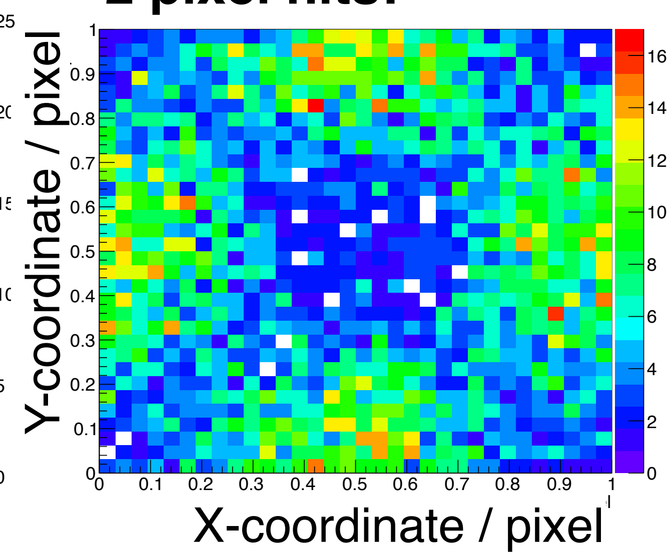


Results V_{bias} = 1 V:

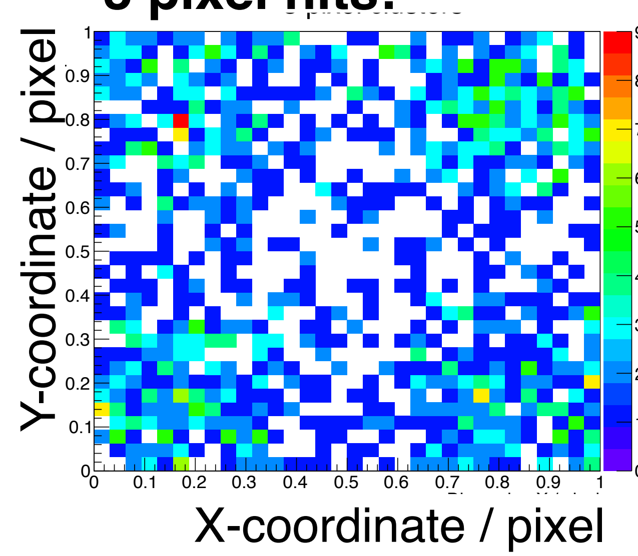
Single pixel hits:



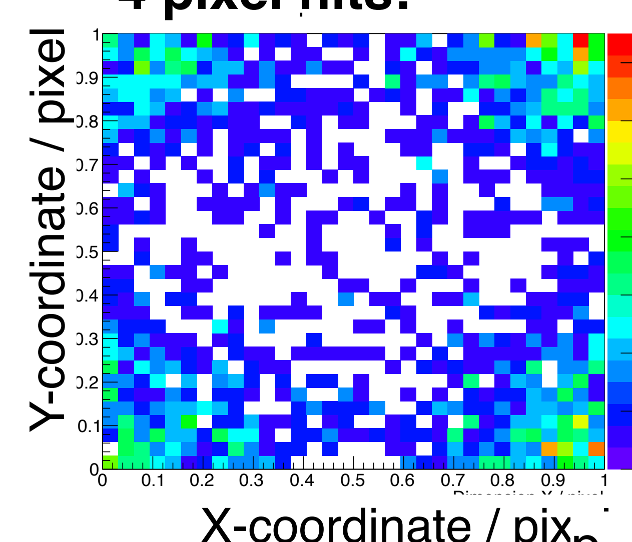
2 pixel hits:



3 pixel hits:



4 pixel hits:



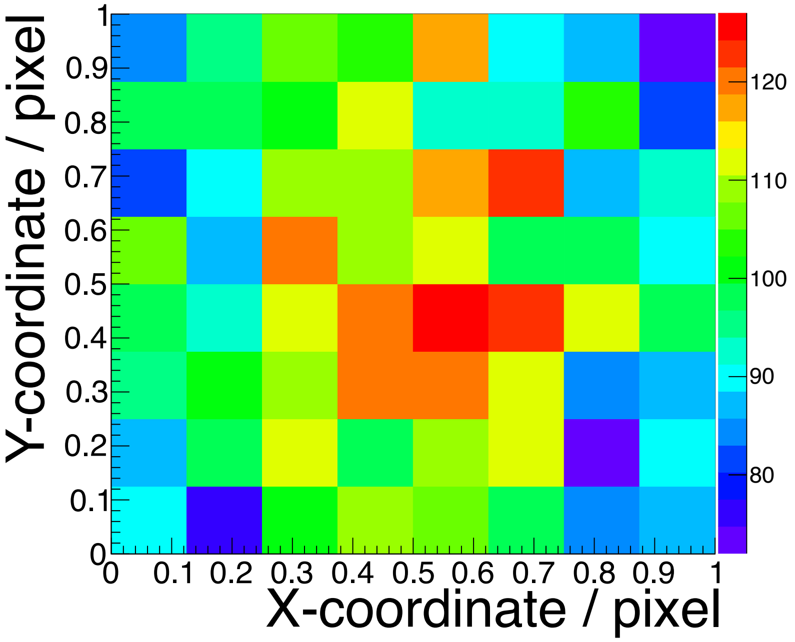
In-pixel hit map

Motivation:

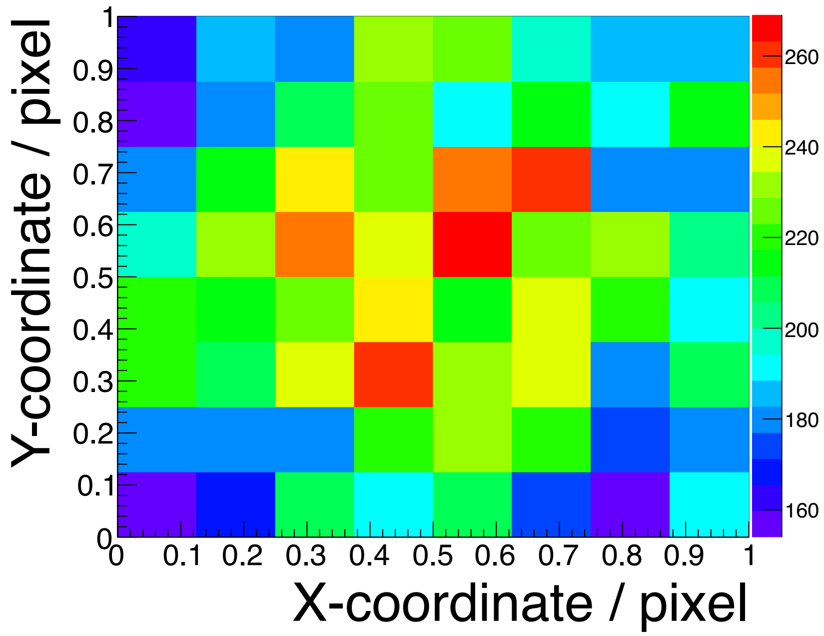
- Obtain measure of relative efficiency within the pixel in dependance of bias voltage

Results:

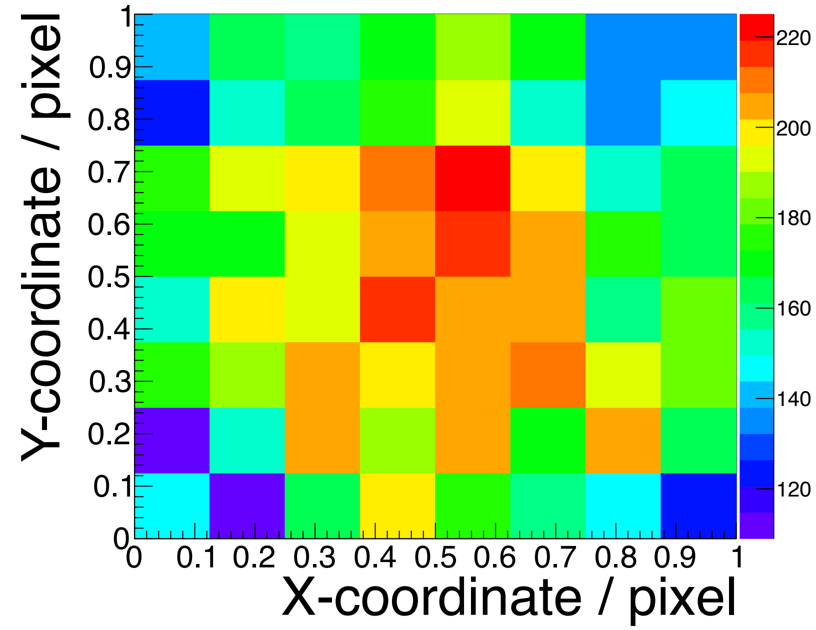
V_{bias} = 6 V:



V_{bias} = 1 V:



V_{bias} = 0 V:



↪ Already at 6 V the count rate drops to the pixel edge

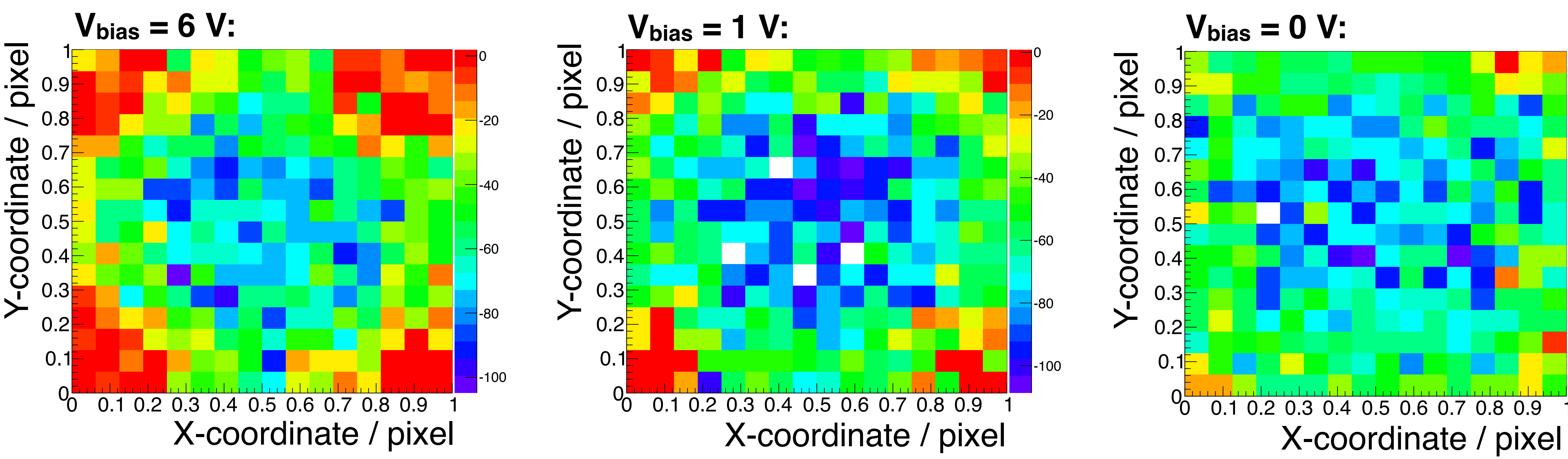
↪ Drop of count rate to the pixel edge larger for lower bias voltages

In-pixel timing

Motivation:

- Validate timing on sub-pixel level
- Study behaviour of timing within single pixel cell in dependance of bias voltage

Results of **mean hit time of all pixels in cluster** for different bias voltages:



Red = late hit ⟷ blue = early hit

↳ In pixel structure of timing clearly visible

↳ To compare different bias voltages timing on single pixel level is needed to disentangle effect of cluster size (ongoing work)

Summary & outlook

Summary & outlook

Dependancy of signal, cluster size and resolution on bias voltage:

- Results agree with expectations, slower timing & lower signal for lower voltages

In-pixel studies:

- Analysis performing on a great level of detail
- Relative hit map across pixel structure shows drop at pixel edges and corners already at 6 V → inefficiencies already at 6 V

Missing bits / necessary next steps:

- In-pixel timing on single pixel level still missing
- Different S/N-cuts need to be investigated
- Different χ^2/ndof-cuts need to be investigated

} Wish-list on the analysis side

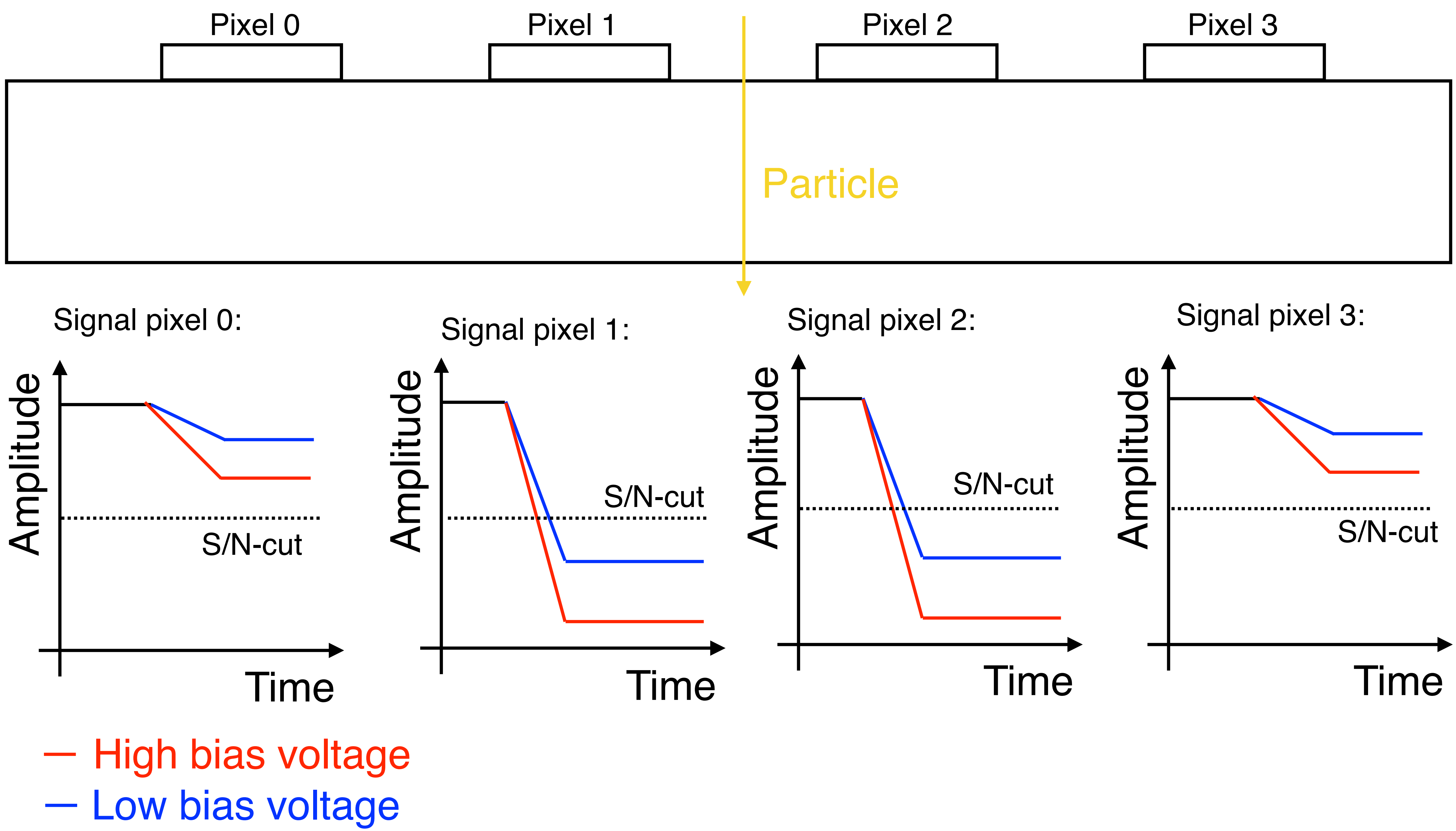
- Different DAQ-cuts need to be investigated
- More bias points (especially between 0 and 1 V) missing
- Need efficiency measurement in next test-beam

} Wish-list for the next test-beam

Backup

Cluster size

Less dependancy of cluster size on bias voltage because of too high S/N-cut?



↳ To be confirmed / studied