Update on Investigator test-beam analysis

CLICdp Tracker-Meeting

20.06.2016

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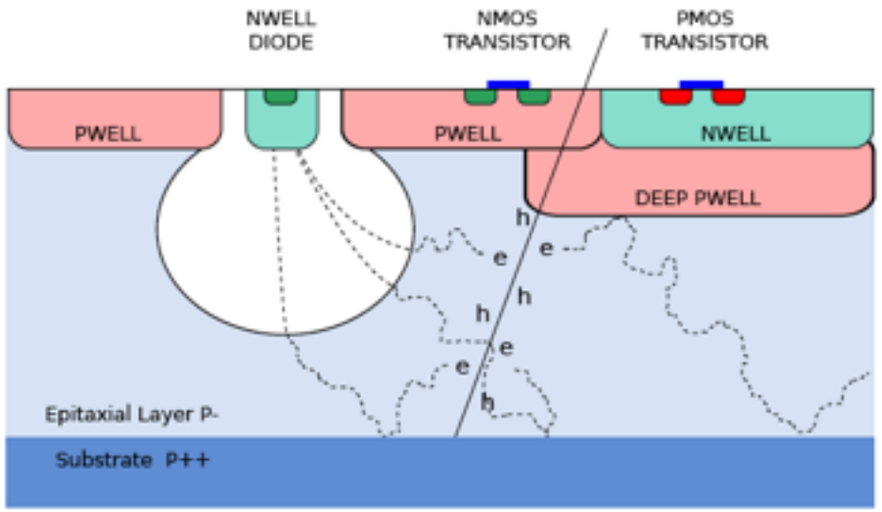
Introduction

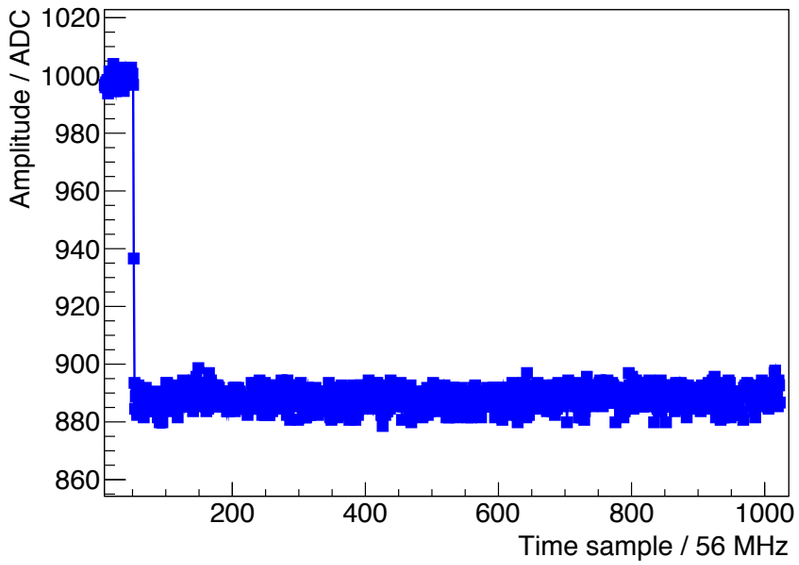
ALICE investigator chip

ALICE investigator chip, TowerJazz 180 nm CMOS imaging process:

TowerJazz technology:



Waveform:



Integration in Timepix3-telescope:

- 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**
- Investigator placed down-stream in the Timepix3-telescope setup
- Successful **integration and synchronisation of investigator readout system in the Timepix3-telescope data taking**

Event selection

Summary of event selection

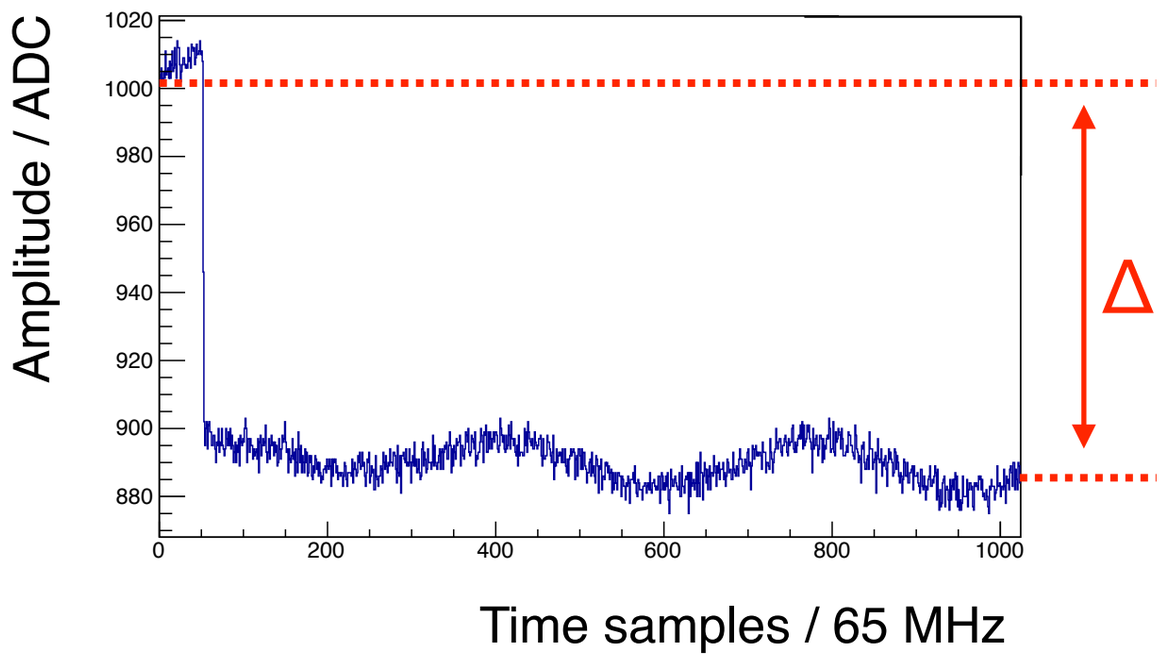
Select NO hit-candidates

- Pixel with $\Delta \leq 10$
- Used to calculate common-mode

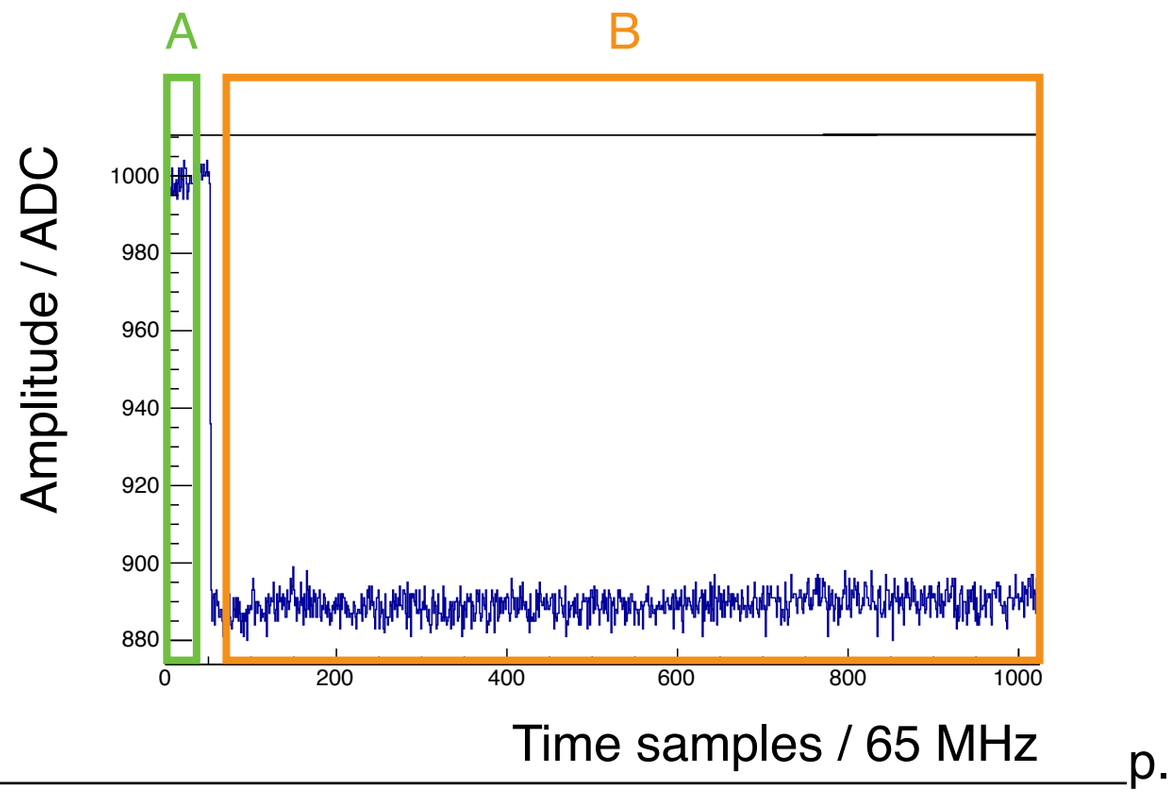
Select hit-candidates:

- Pixel with $\Delta > 10$
- Apply common-mode correction
- Calculate signal (S) as
  mean amplitude in B
  minus mean amplitude in A
- Calculate noise (N) as
  RMS of amplitude values in B
- Cut on S/N > 5
- Fit e-function to waveform to extract the timing (backup slide)

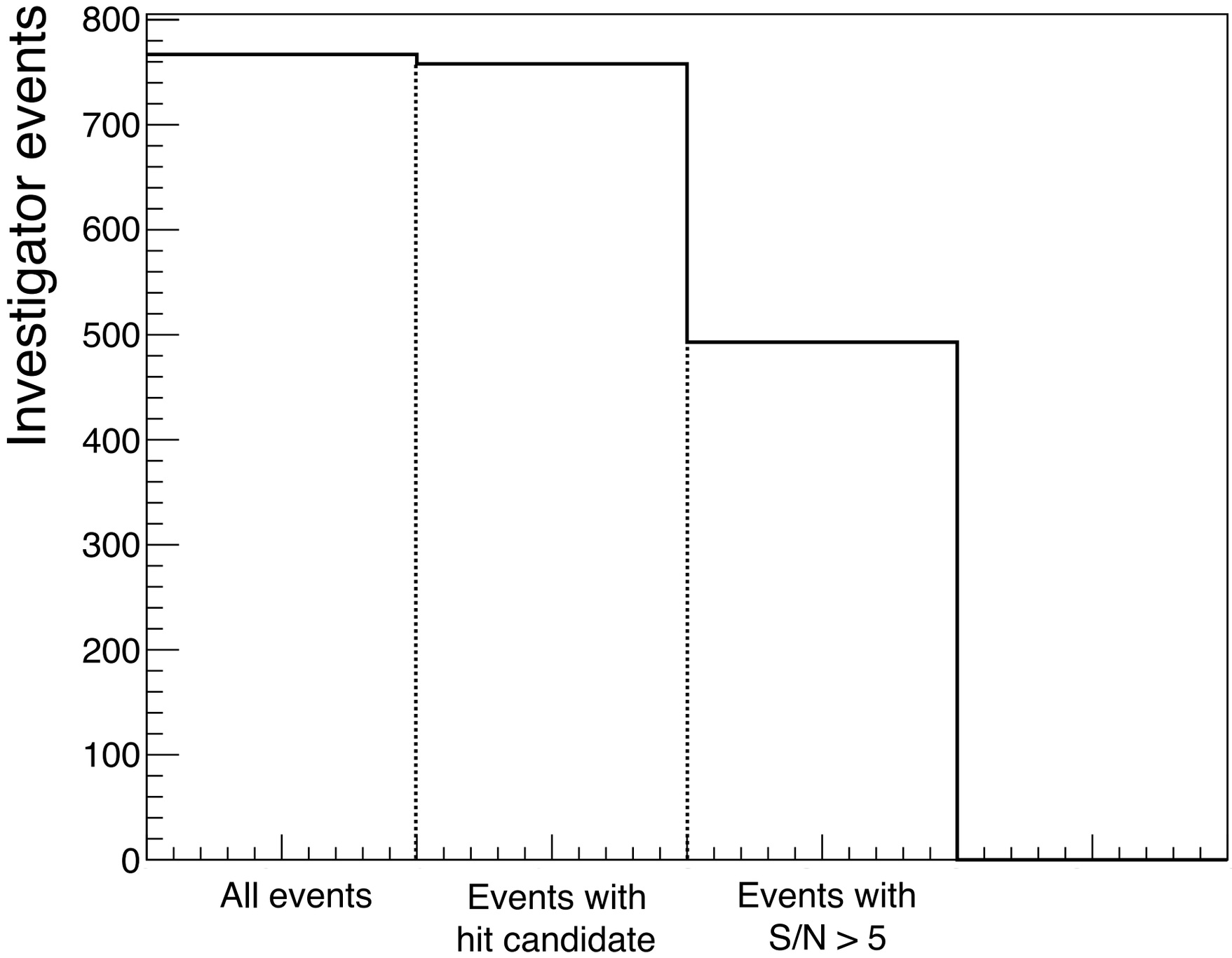
Before common-mode correction:



After common-mode correction:



Event yield for different cuts in event selection

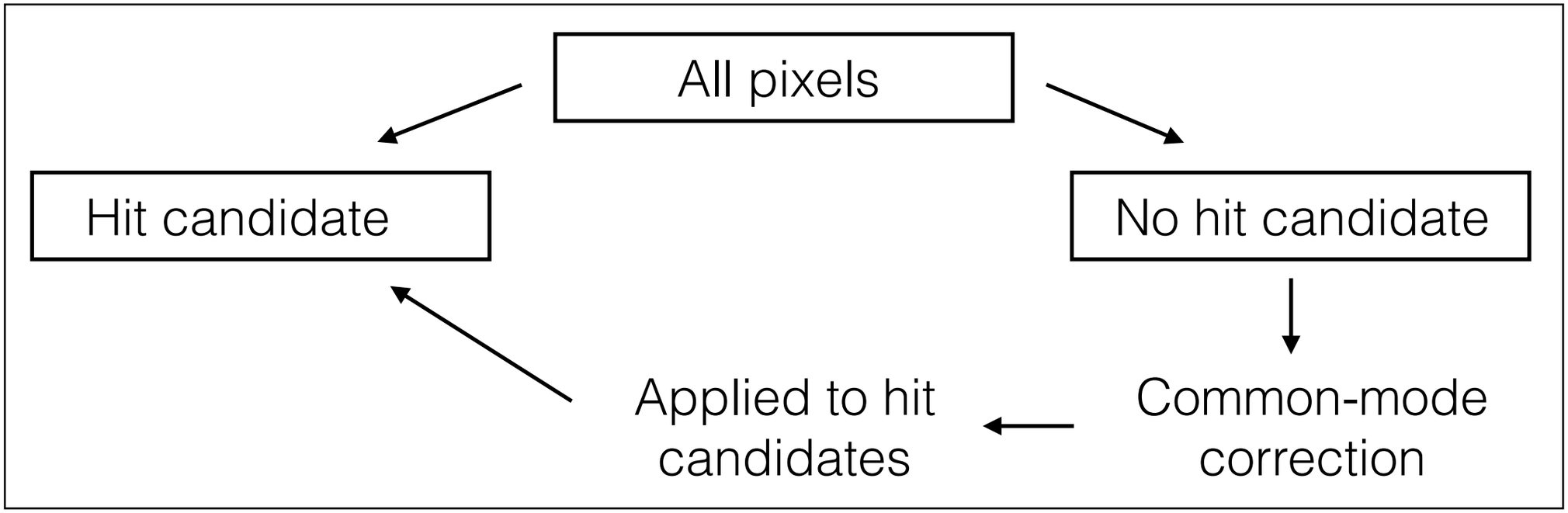


1. No event loss due to cut on hit-candidate (next slides)
2. Event loss of ~1/3 due to cut on S/N

Event yield for different cuts in event selection

1. No event loss due to cut on hit-candidate:

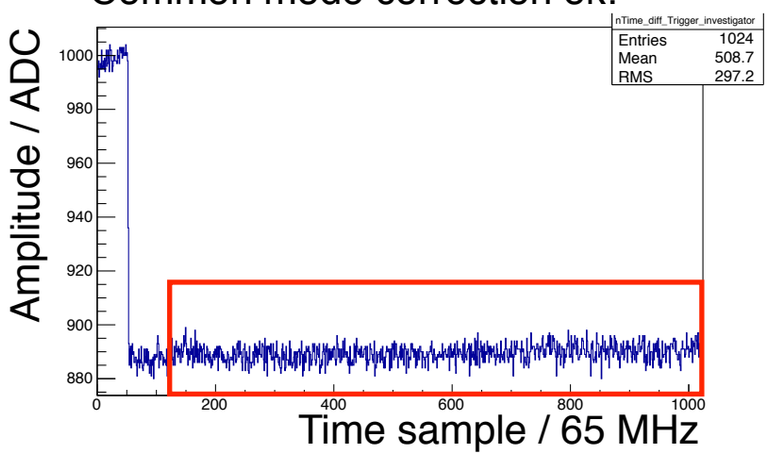
   Good for signal efficiency, but:



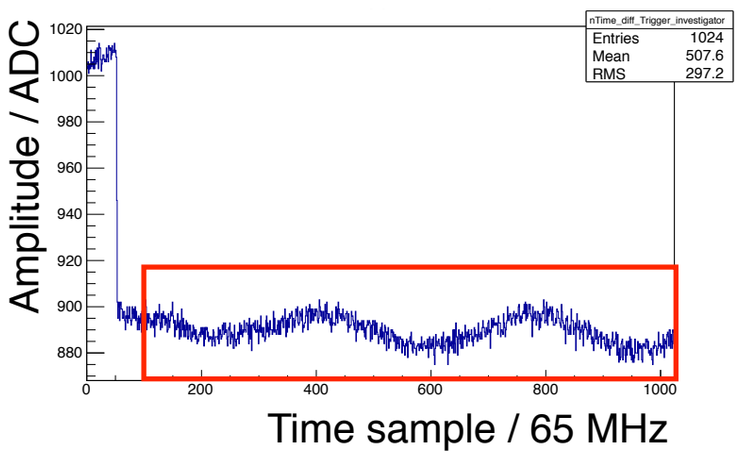
→ If cut on hit-candidate too loose, not enough pixels for common-mode calculation

→ Can be quantitatively checked by histograms of noise:

Common mode correction ok:



Common mode correction not ok:

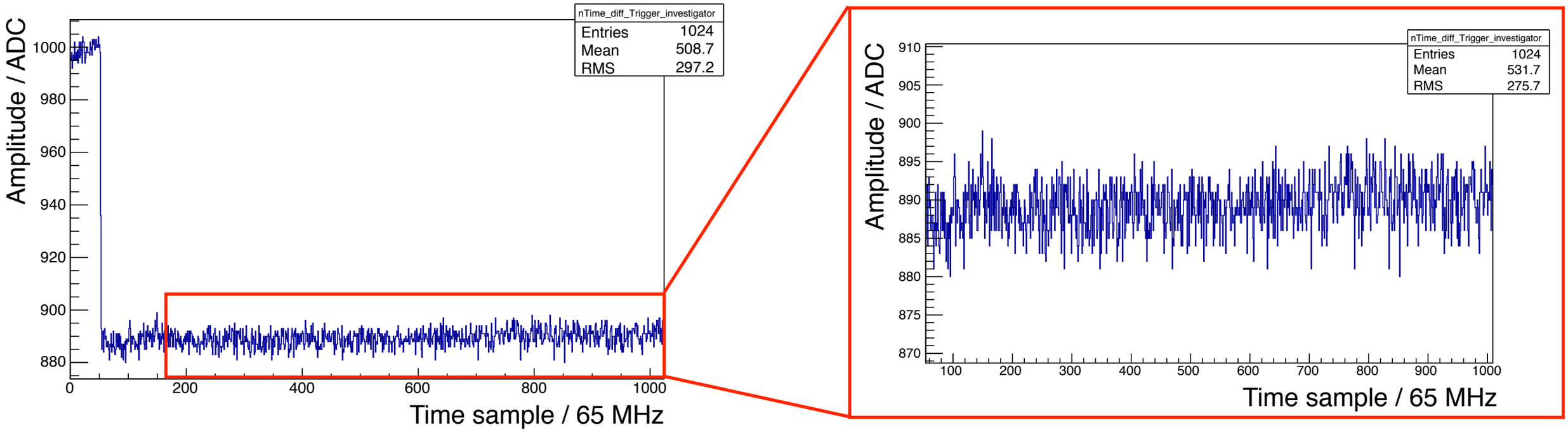


→ Noise defined as RMS of Amplitude values in red box

→ Noise gets much larger if common-mode correction is not ok.

Event yield for different cuts in event selection

Expected single pixel noise for working common mode correction:

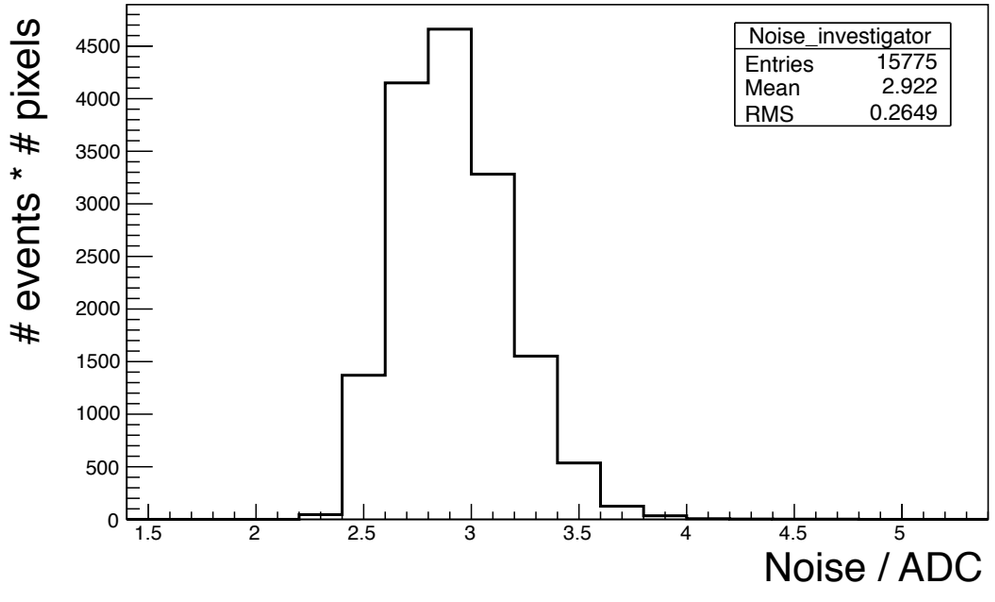


→ Expect single pixel noise of a few ADC if common-mode correction works

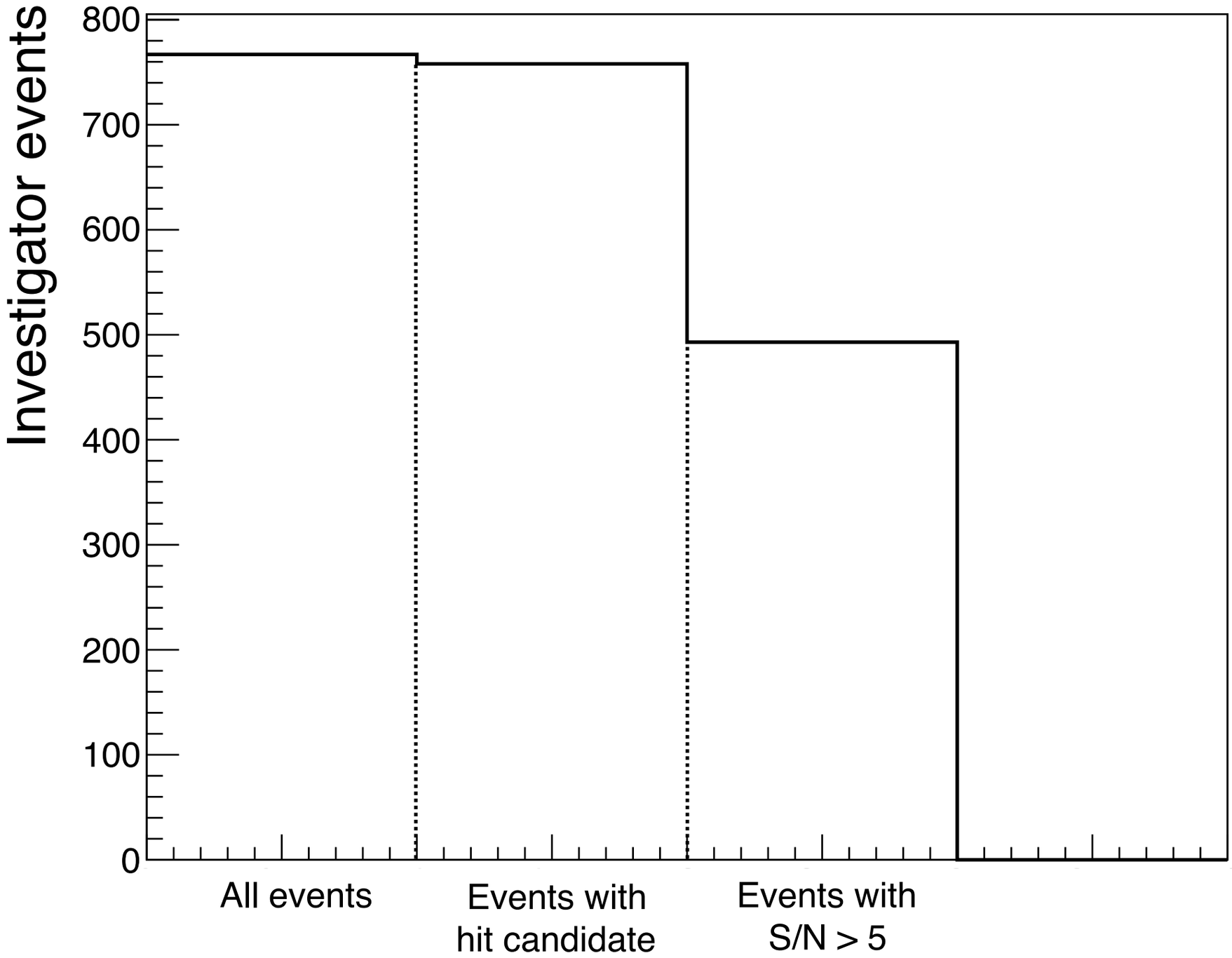
Single pixel noise after common-mode correction:

- Well matching expectation for working common-mode correction

→ **Well defined cut on hit-candidate.**



Event yield for different cuts in event selection



1. No event loss due to cut on hit-candidate → ok (see previous slides)
2. Event loss of ~1/3 due to cut on S/N (next slides)

Event yield for different cuts in event selection

2. Event loss of ~1/3 due to cut on S/N:

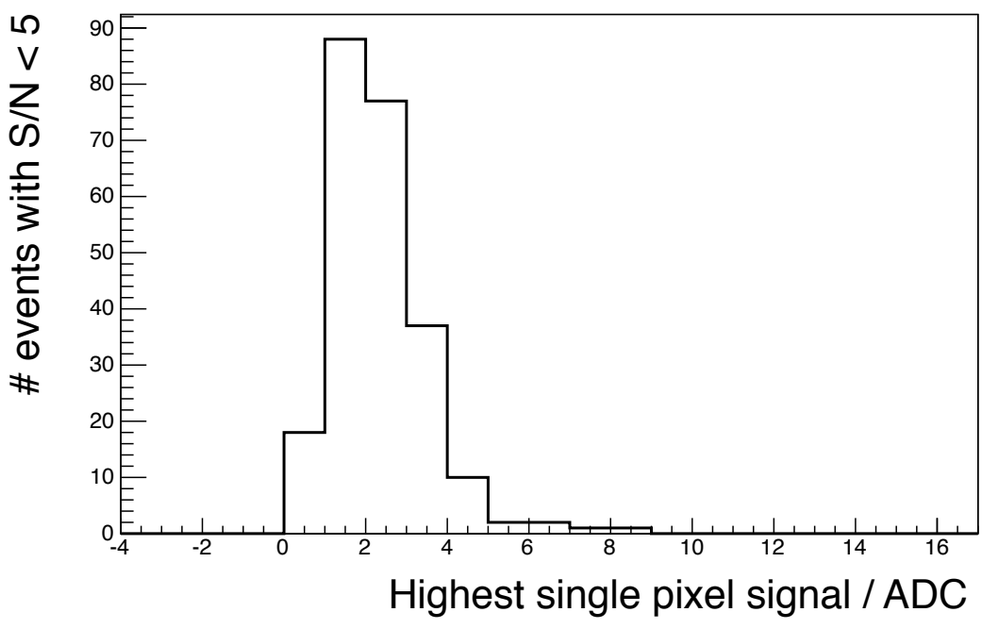
Explanation / hypothesis:

- Record of pedestal run before run with beam
- Analysis of noise from pedestal run
- DAQ in data taking with beam gets triggered if a amplitude crosses amplitude/noise>10

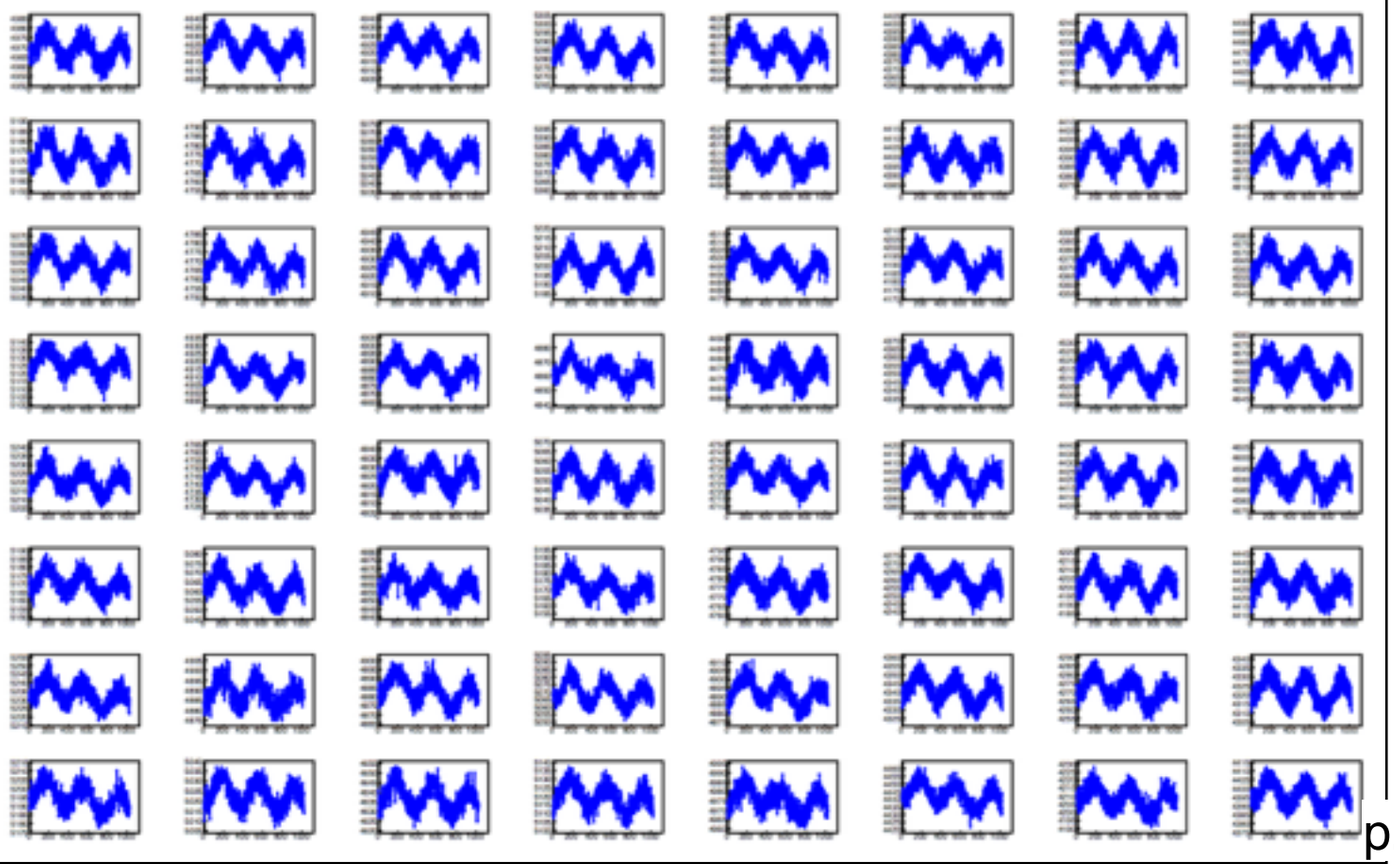
→ Common-mode can trigger DAQ

→ These events contain no signal and are cut out by analysis

Explanation / validation:



→ Well defined cut on S/N

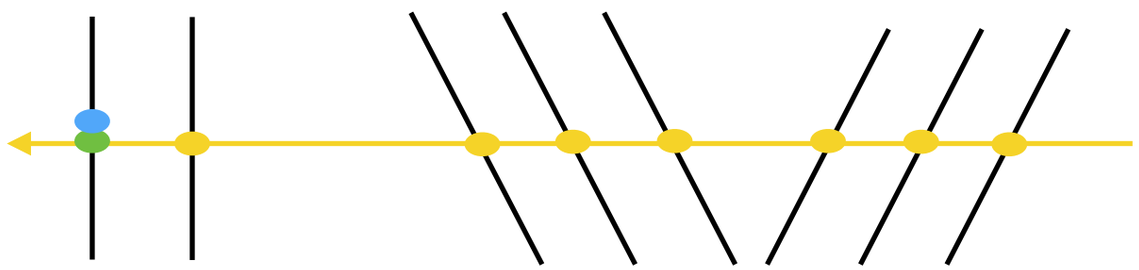


Analysis of selected events

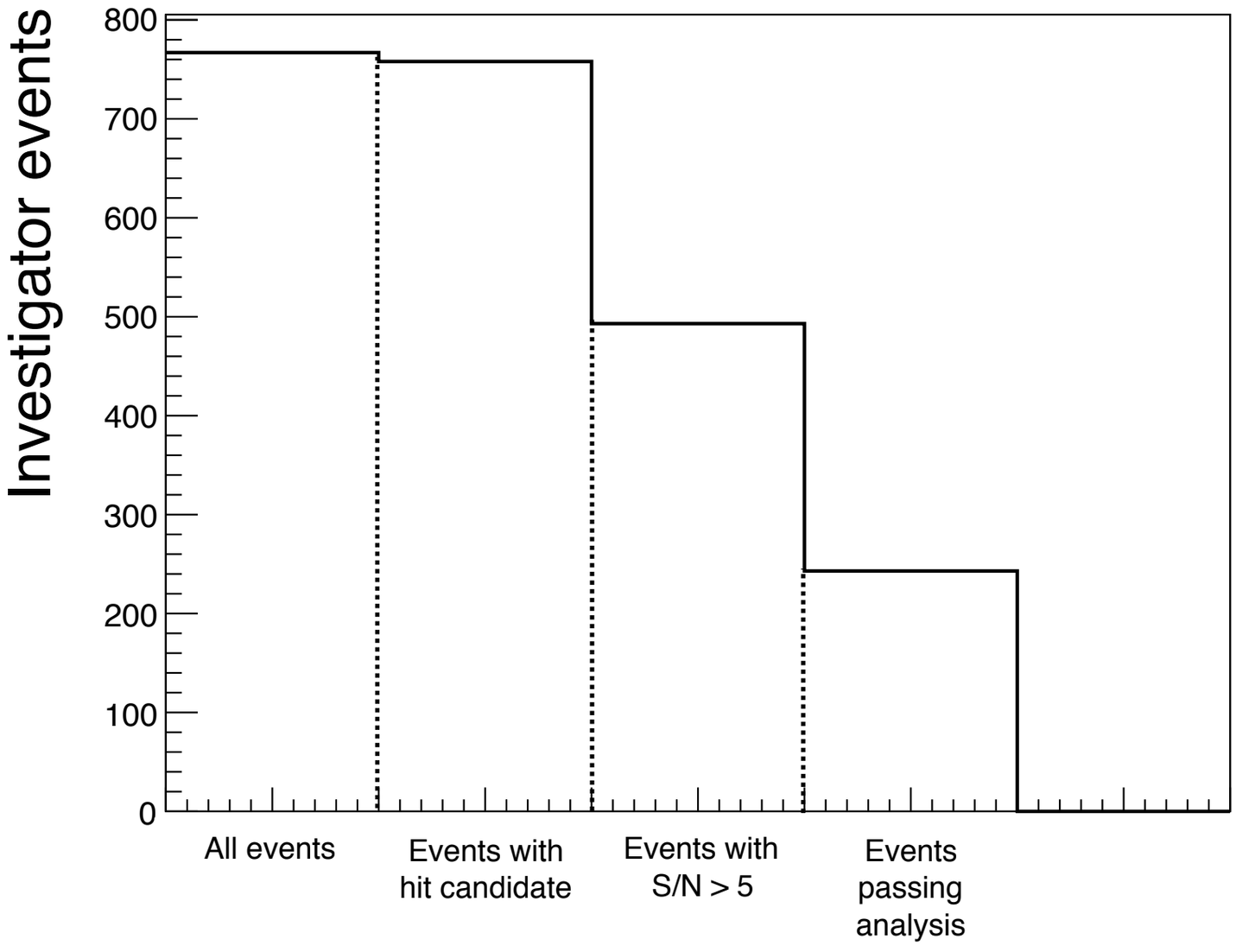
Analysis of selected events

Usual work-flow implemented in EUTelescope-framework:

1. Data-converter (stores events which are selected as described before)
2. Clustering
3. Hit-calculation
4. Alignment of telescope
5. Telescope track-fitter
6. Interpolation of telescope track on investigator
7. Matching of interpolated telescope tracks with hits on investigator



Event yield in analysis of selected events



Potential event loss because of:

1. Masking of clusters at the edge (next slide)
2. Missing planes because of issue in data taking
3. Event length
4. Telescope track not well reconstructed because of other issues

Event loss due to masking of clusters at the edge

Main reason of event loss because:

- Mainly single-pixel clusters
- Loss of 28 of 64 pixels by masking the edges
- Loss of ~44% of statistics

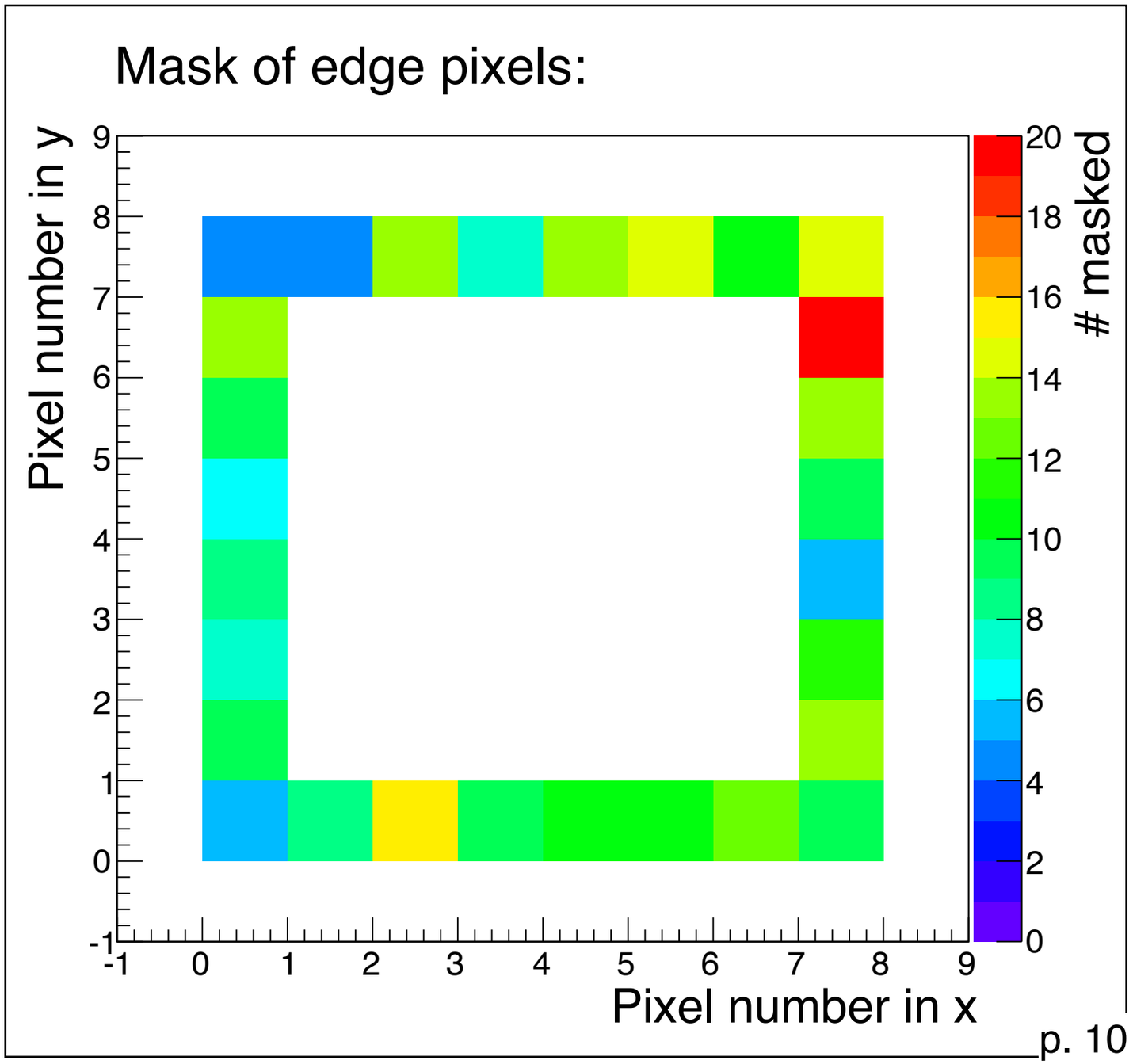
→ Switch off the edge-mask

→ Still loss of ~15% of events

→ Check other possible reasons:

Potential event loss because of:

1. Masking of clusters at the edge
   → ok (see this slides)
2. Missing planes because of issue in data taking (next slide)
3. Event length
4. Telescope track not well reconstructed because of other issues



Event loss due to missing planes

Reason:

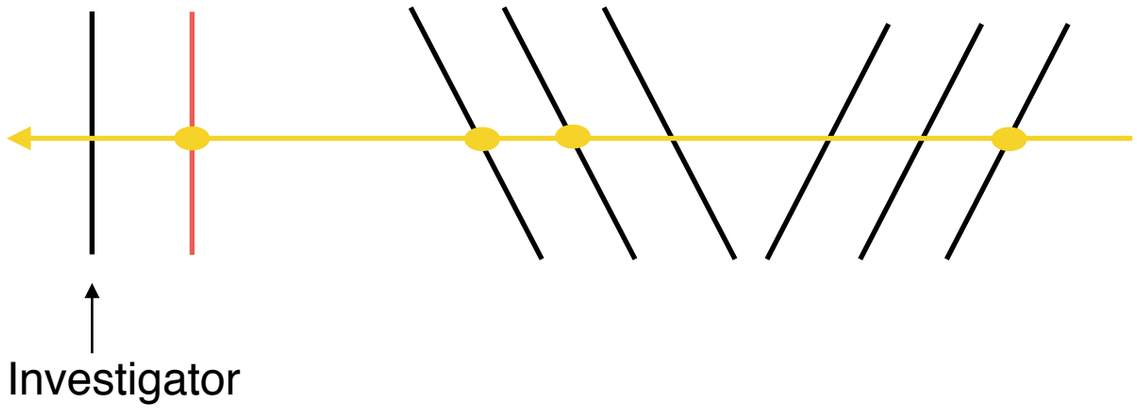
- Issues during test-beam with telescope-planes stopped sending data
- Track required to have a hit on all 7 planes

→ Tracks can be lost because of this issue

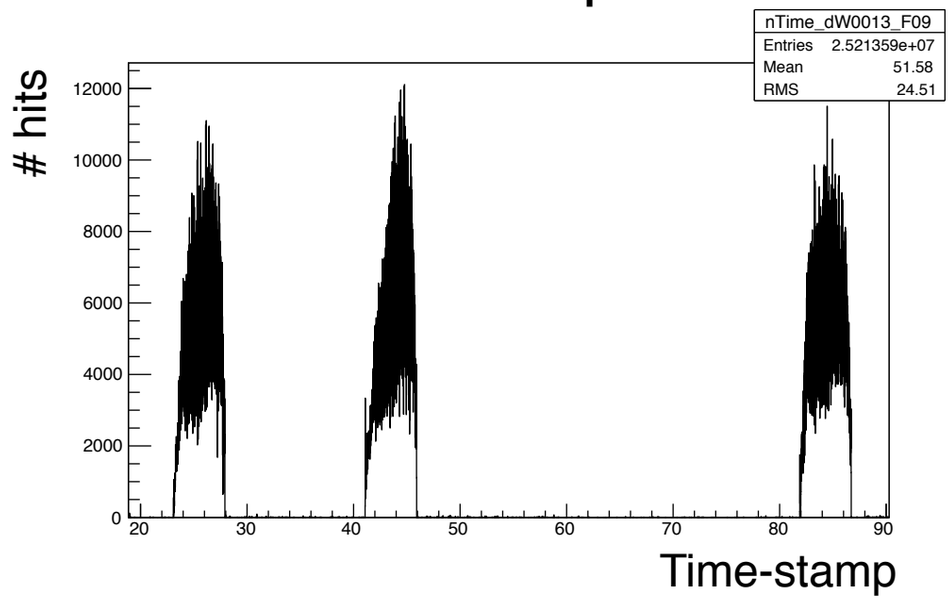
Can be excluded because requirement in track finding has been adjusted:

- Modified such that a track is required to have a hit on at least 4 planes with a hit, including a hit on the plane before the investigator:

Sketch of track finding requirement



Time of hits on last plane:



- Time of hits on last plane presented for same run that event yield on previous slide
- Modified requirement in track finding already used for event yield on previous slide

→ **Event loss NOT due to issue of telescope planes stopped sending data**

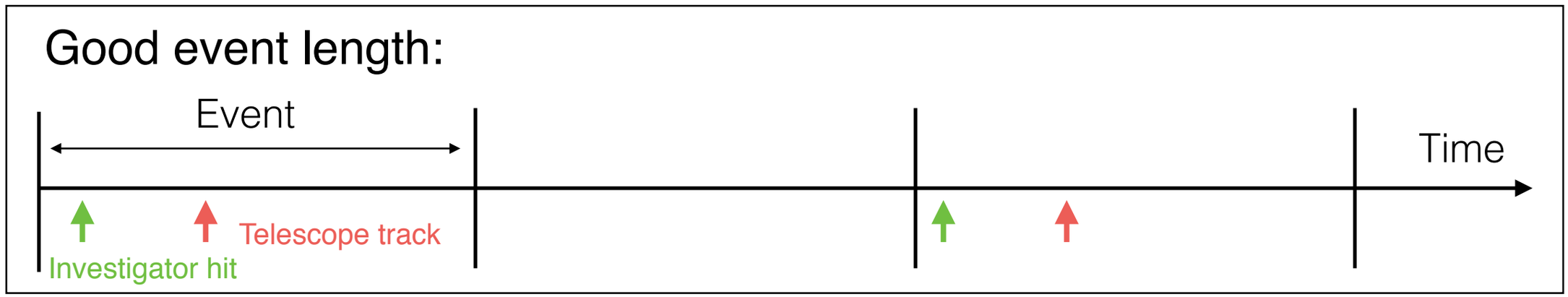
Event loss due to event length

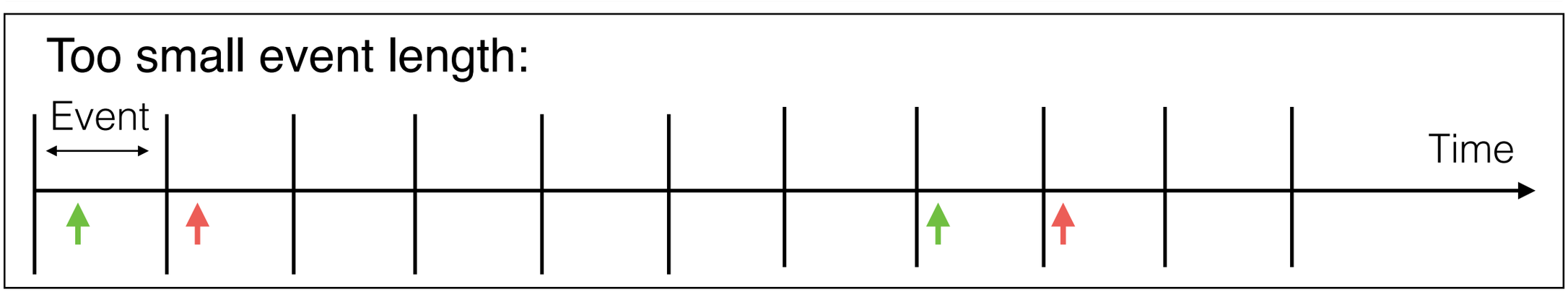
Reason:

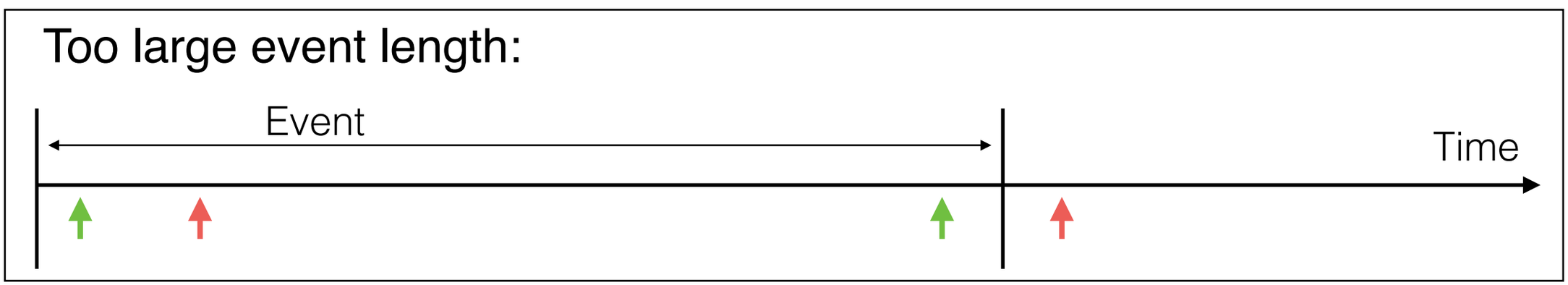
- Apply cut on residual

→ Cut out of investigator hits which can not be matched to a telescope track

→ Event length can influence matching efficiency:





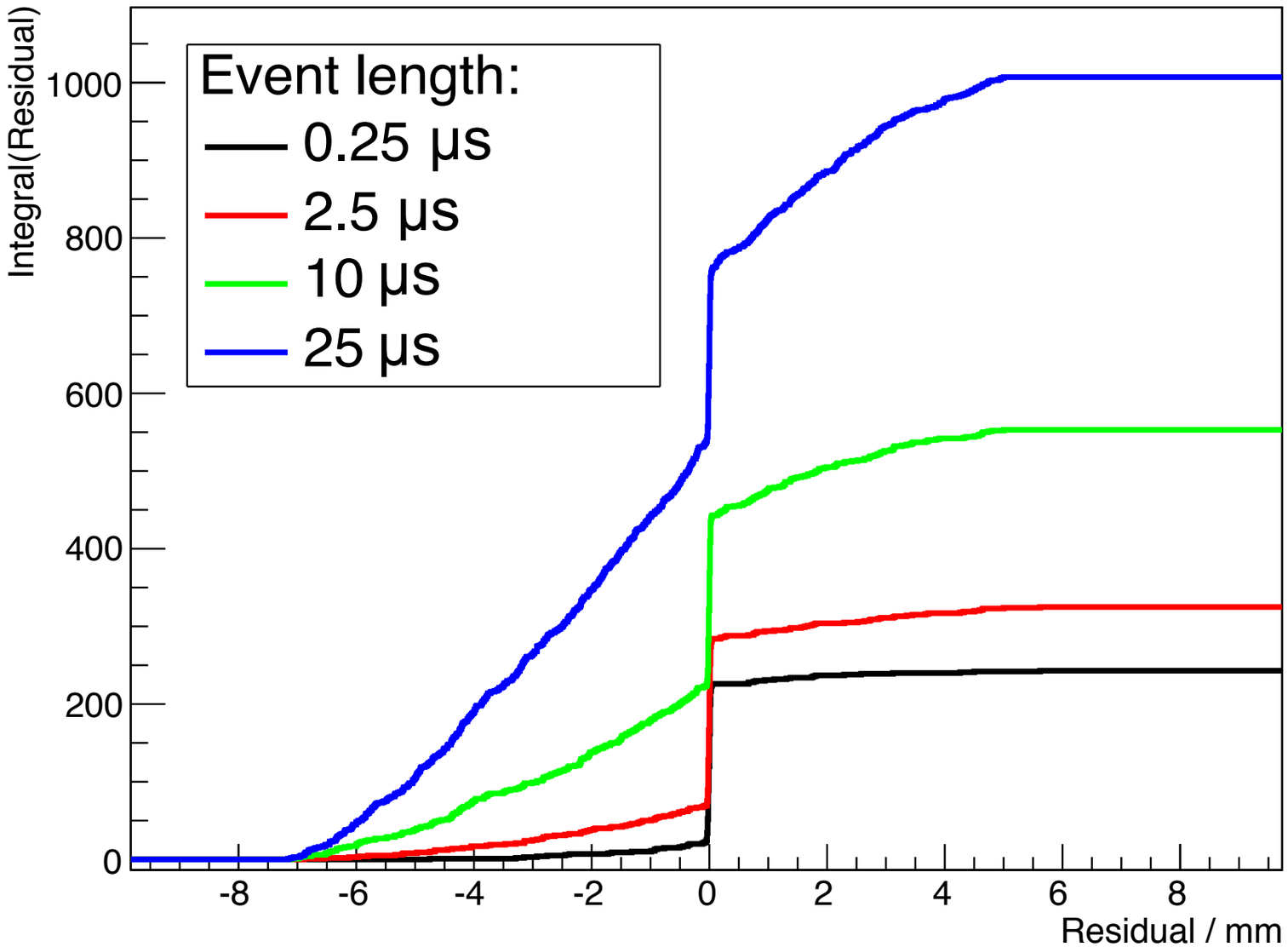


→ If we select a too small or large event length, we can bias the timing results!

Event loss due to event length

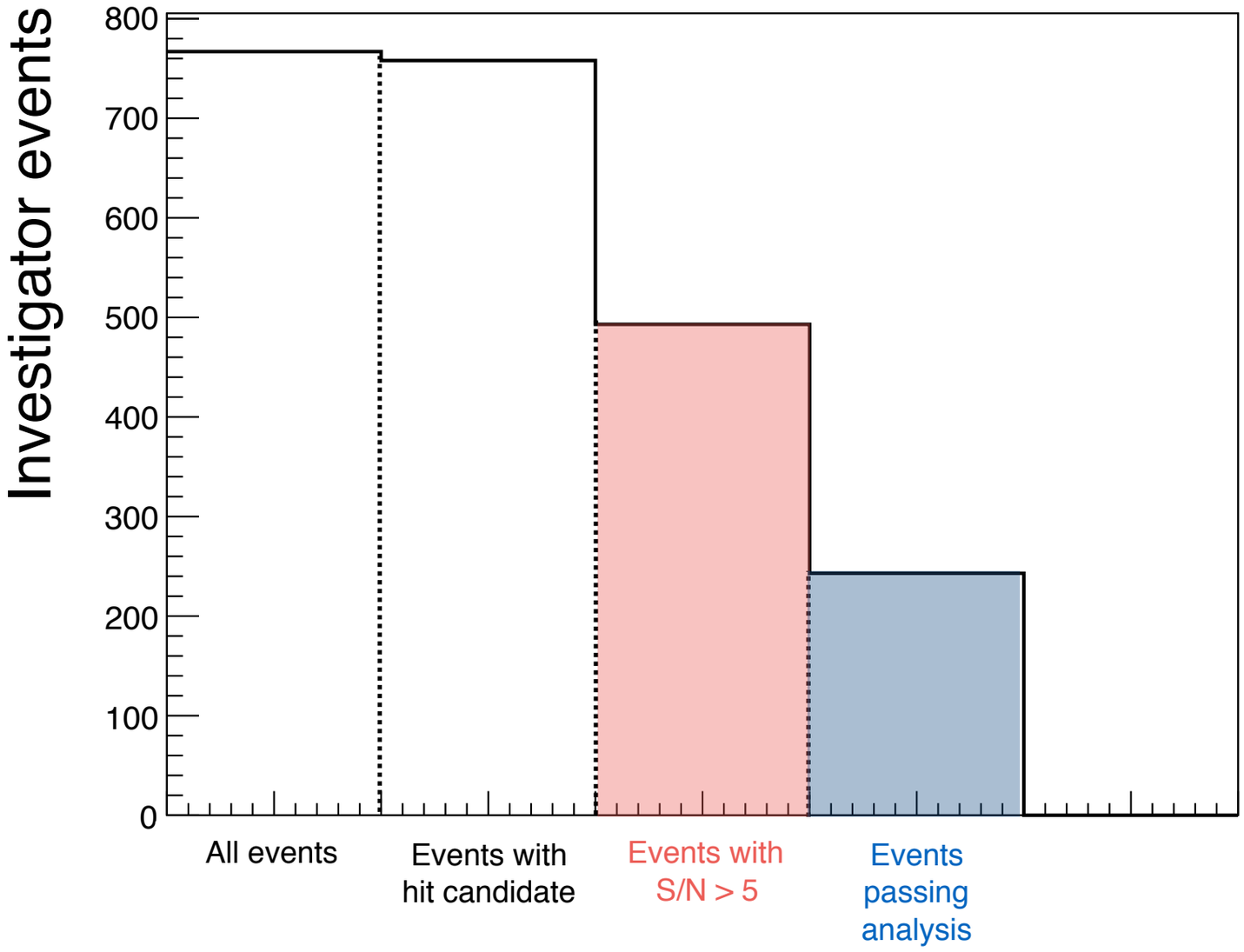
Lower cut on residual and check how residual distribution changes for different event length:

- Look at integral of residual distribution
- Information at which residual value entries are added for different event length



→ Event loss NOT due to event length

Summary / event yield in analysis of selected events



- Loss of events triggered by the common mode ✓
- Loss of events mainly because of edge pixel masking ✓ (needs further investigation)

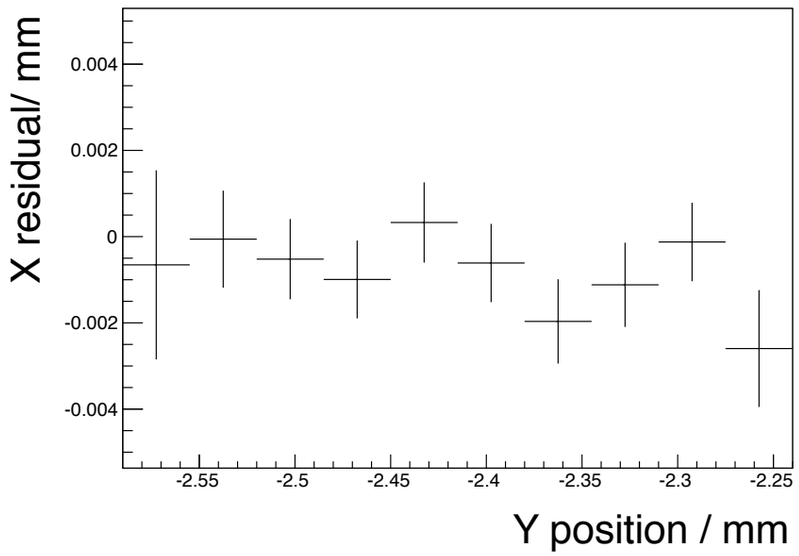
→ Selected events most likely not biased

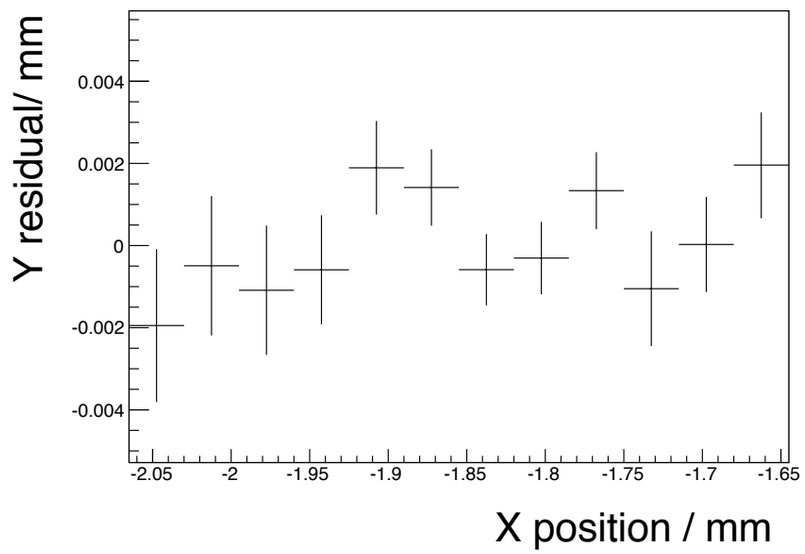
→ Can look at results (next slides)

Some results

Pitch of 55 µm / V_{bias} of 6V

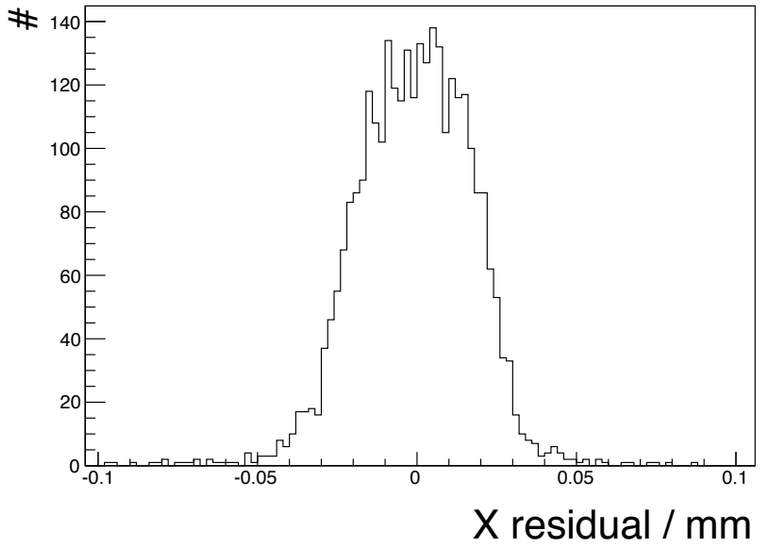
Examples of alignment plots:

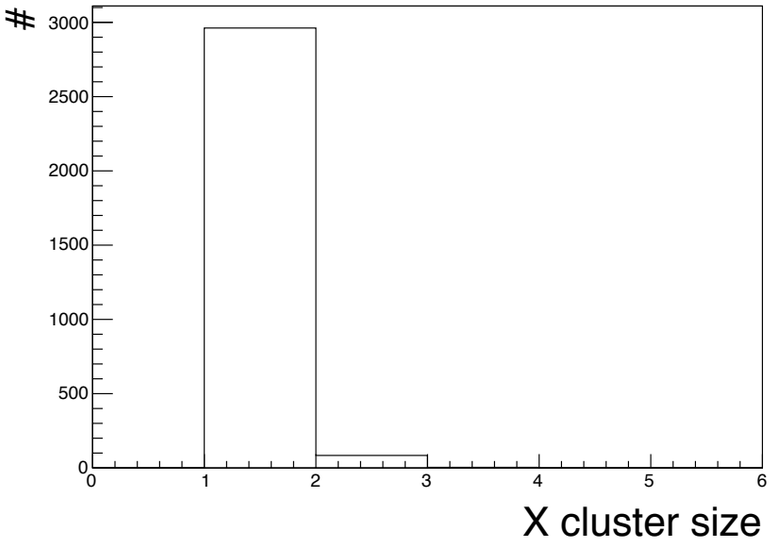


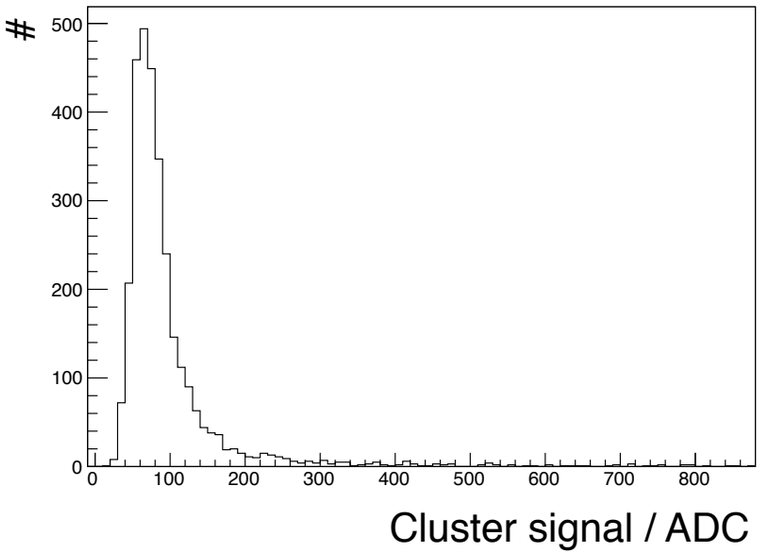


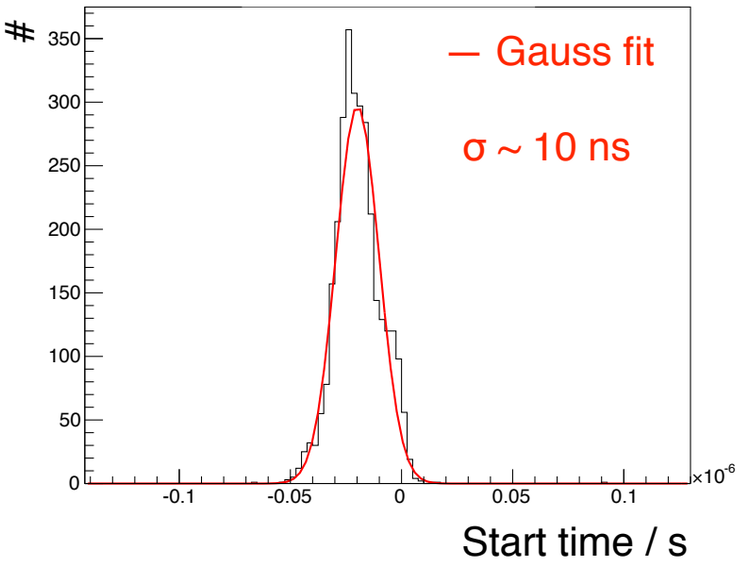
→ Alignment ok

Results:



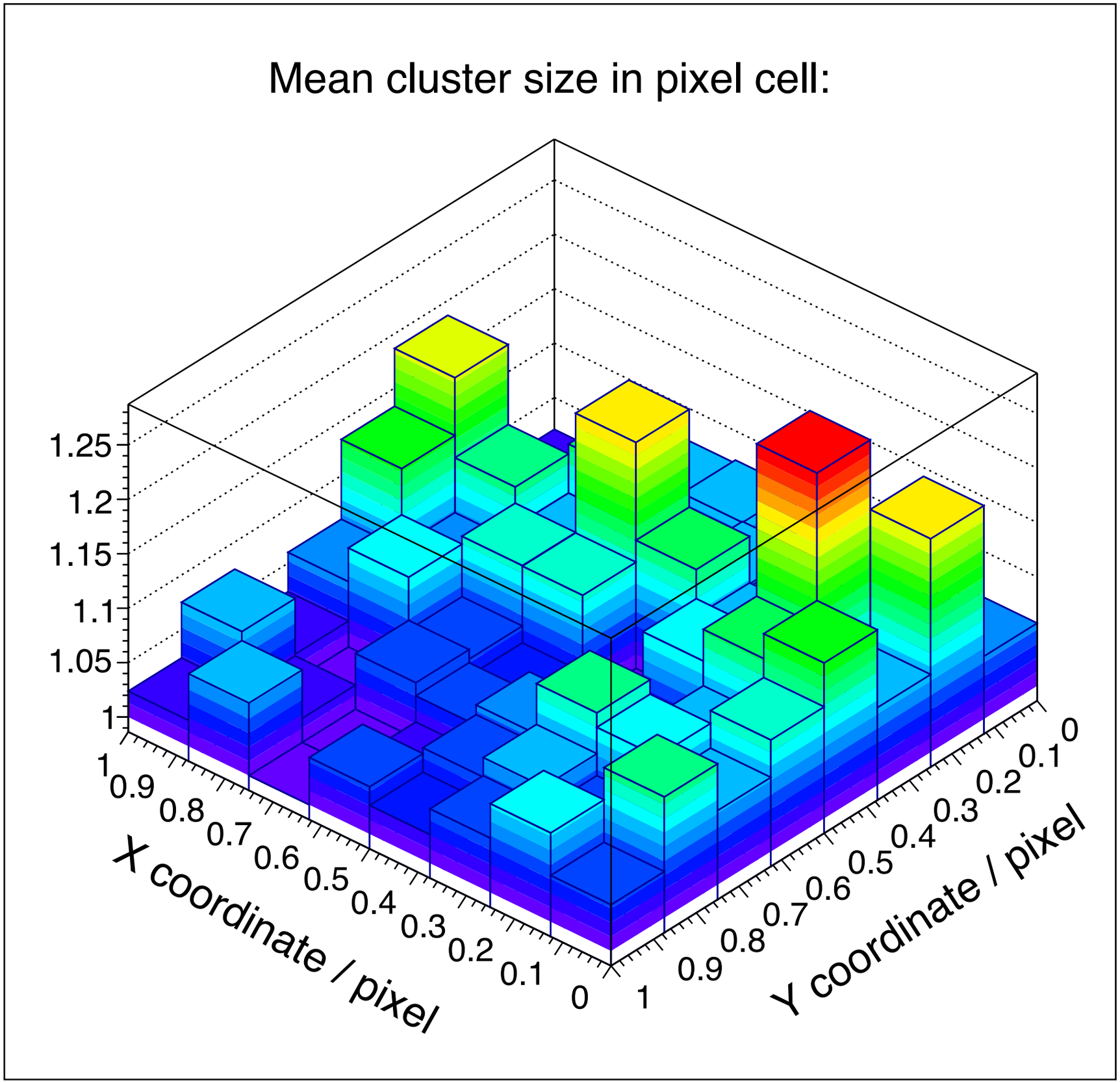






→ Double structure in start time needs further investigation

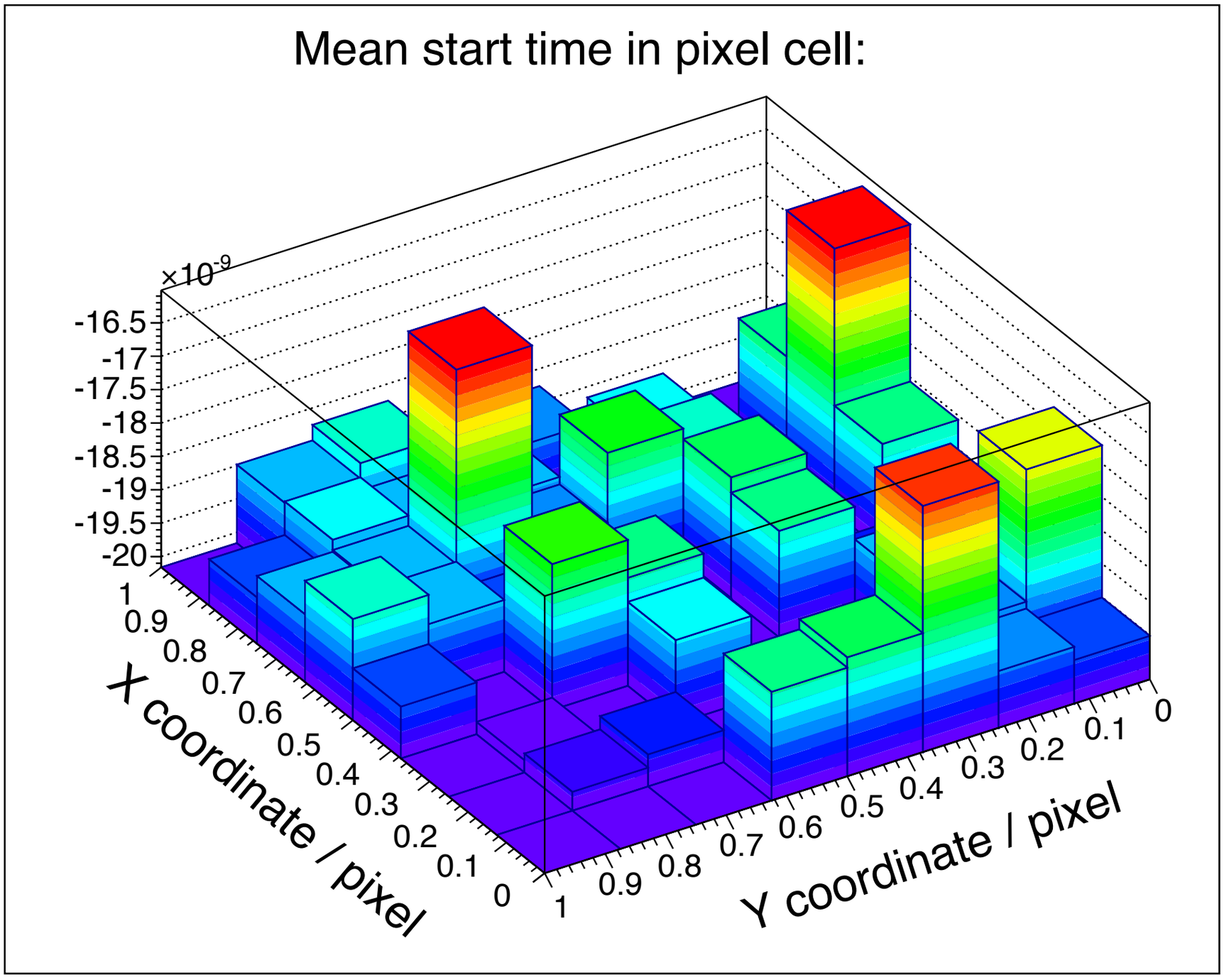
Pitch of 55 µm / V_{bias} of 6V



- Pixel structure clearly visible
- Some misalignment left?
- Need more informations about pixel layout
- Need more statistics

→ **Next test-beam soon!**

Pitch of 55 µm / V_{bias} of 6V



- Same structure visible than for cluster size
- Seems like one faste timing is correlated with lower cluster size

→ To be confirmed in next test beam

→ Conclusion for next test-beam:

- Collect large statistics for mini-matrix with smaller pitch
- Larger variation of in-pixel cluster size due to more charge sharing at pixel edges
- Try to determine correlation with in-pixel timing

Summary & outlook

Summary & outlook

Investigator analysis has been setup:

- Integrated in EUTelescope framework
- Extraction of observables from full analog waveform

Study of event yields for different analysis steps:

- Gained understanding and confidence in analysis

Results:

- In-pixel results seem to be very promising
- Need more statistics and better pointing resolution

Suggestions for next test-beam (starts this Wednesday 22.06.2016):

- Large statistic runs, especially for mini-matrices with smaller pitch
- In general, focus on large statistics for a few matrices than to scan all matrices with lower statistics

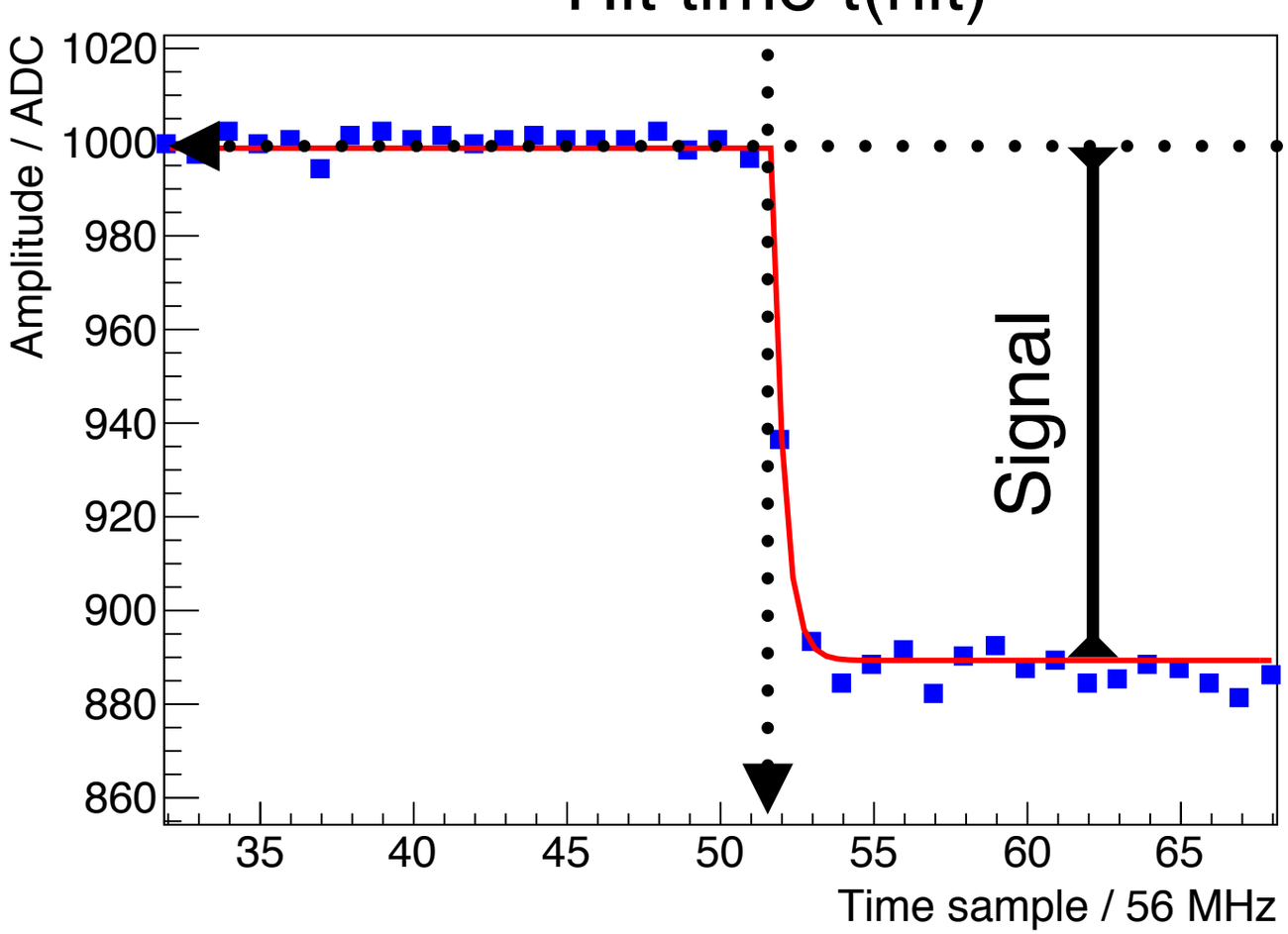
Backup

Definition of timing observables

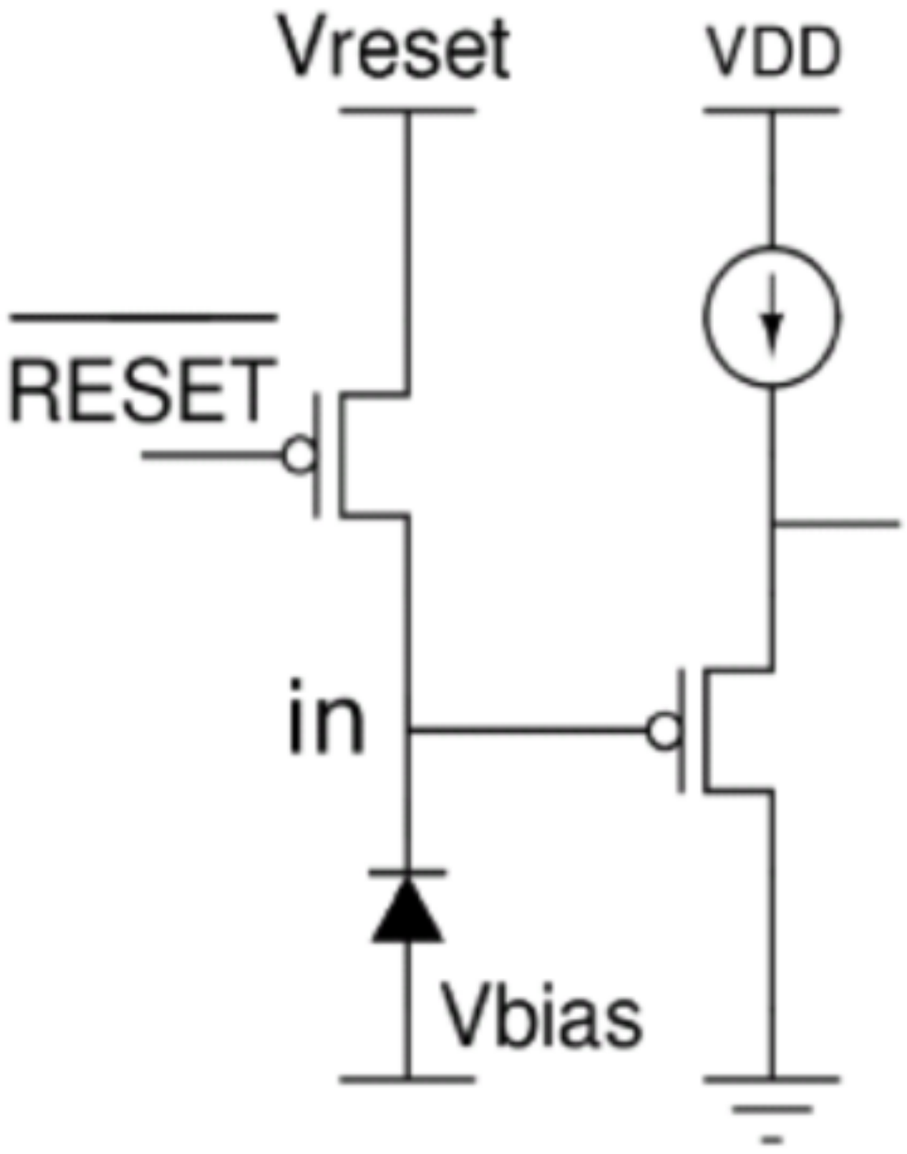
- Fit Function to Waveform of pixels with hit (t = time sample):

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

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



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


Vreset
VDD
RESET
in
Vbias