

Test-beam analysis for CLICTD December 2019 data

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17.01.2020



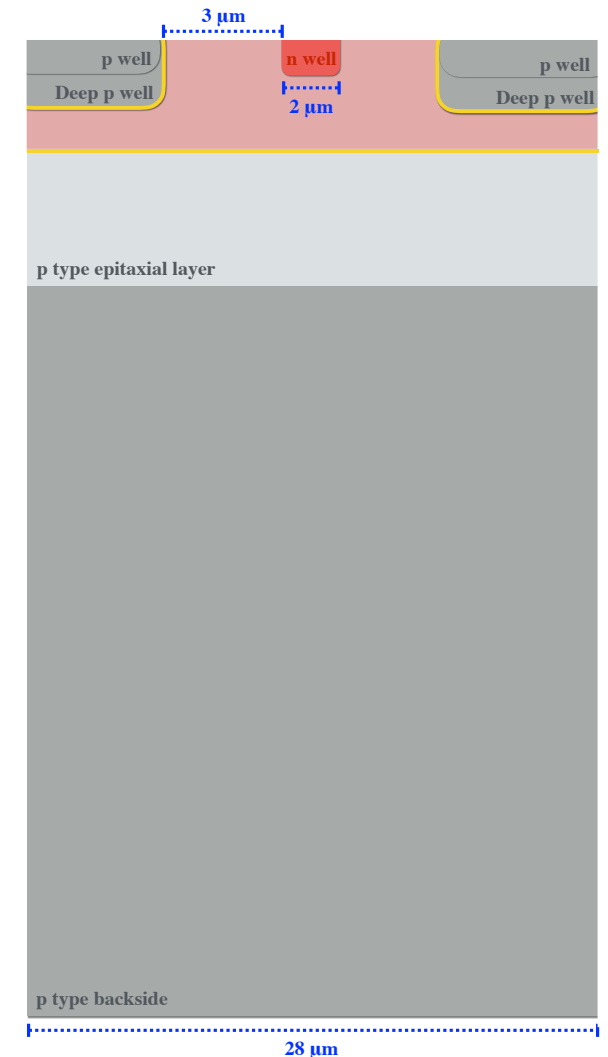
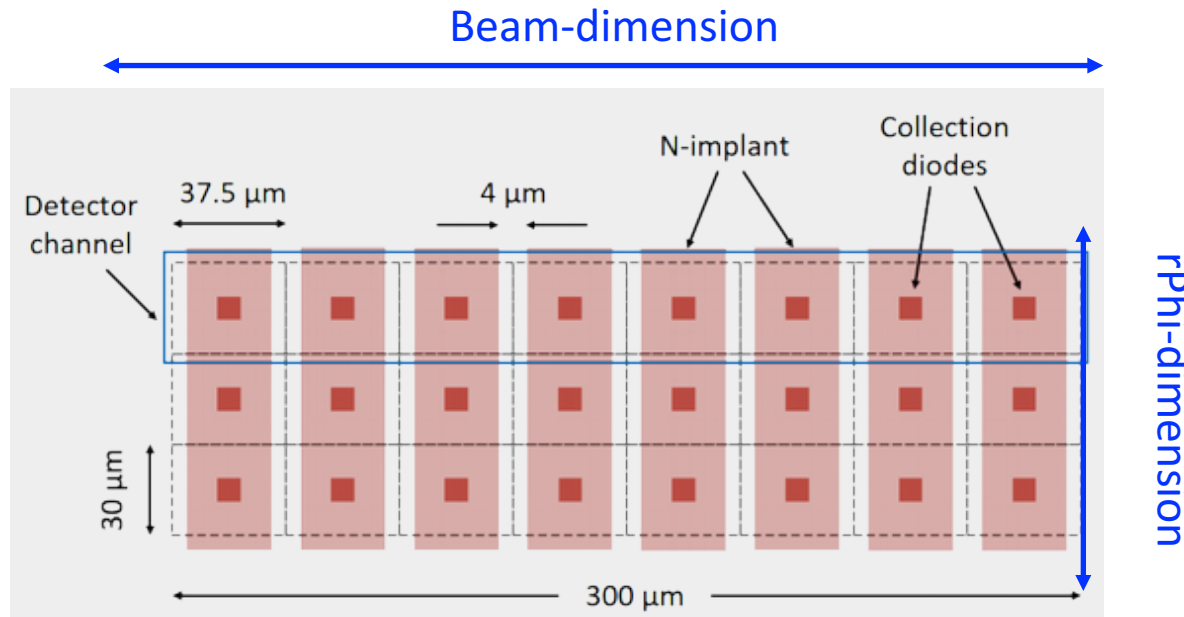
Analysed data

CLICTD - a fully integrated small collection electrode CMOS chip for the CLIC tracker:

- 180nm modified CMOS imaging process
- 30 μm x 37.5 μm pixel size, implemented on epitaxial layer of 30 μm
- 8 pixels combined in common digital channel:

Analysed data -6V/-6V bias p-well/substrate:

- Sample A1 with no gap in n-layer along rPhi-dimension
- Sample B1 with gap in n-layer along rPhi-dimension
- Gap in n-layer to speed up charge collection and reduce charge sharing



Data analysis in Corryvreckan

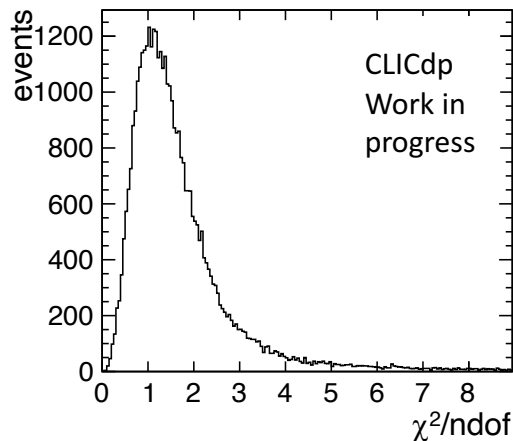
Masking:

- Masking of matrix edges + individual masking for each threshold, voltage, process

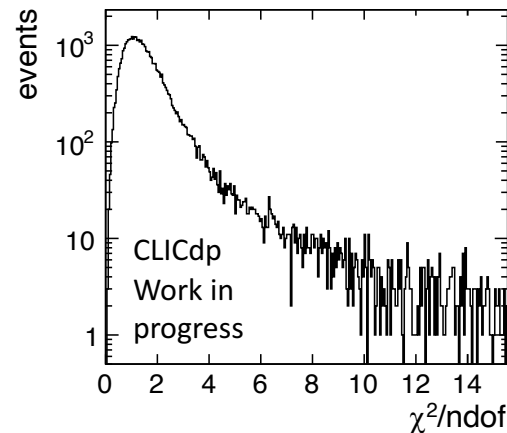
Track reconstruction:

- Use Timepix3 for track reconstruction → track timestamp from Timepix3
- GBL with requirement of hit on each plane (all 6 MIMOSAS + Timepix3) → see Lennart's talk

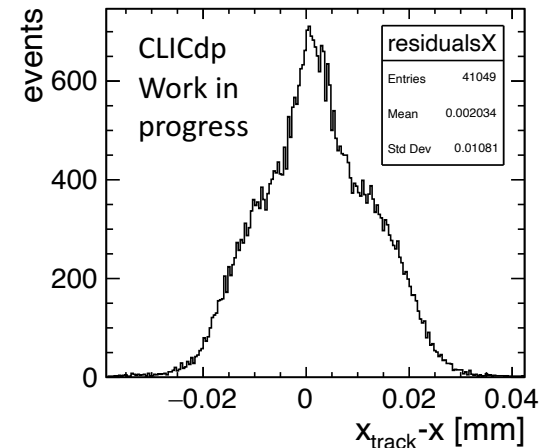
χ^2/ndof – linear y-scale:



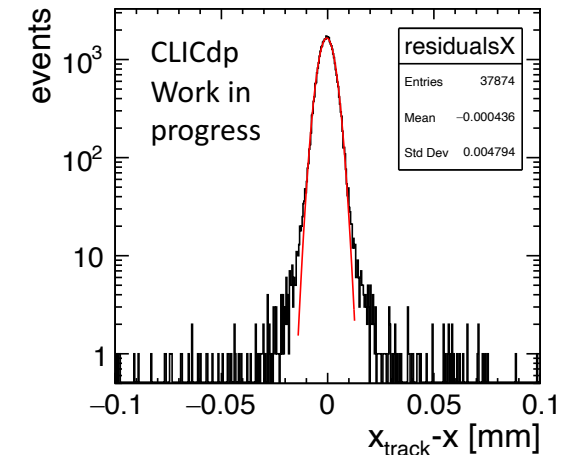
χ^2/ndof – log y-scale:



X-residual on TPX3:



X-residual on first MIMOSA downstream plane:



CLICTD Analysis:

- Time-walk correction for each cluster size (see previous talk: <https://indico.cern.ch/event/856474/contributions/3655841/>)
- No correction for non-linear charge sharing at the moment (work in progress)

Comparison of both process variants at **nominal threshold & -6V**

No gap in n-layer: nominal threshold of 250 DAC, baseline during test-beam of 231 DAC

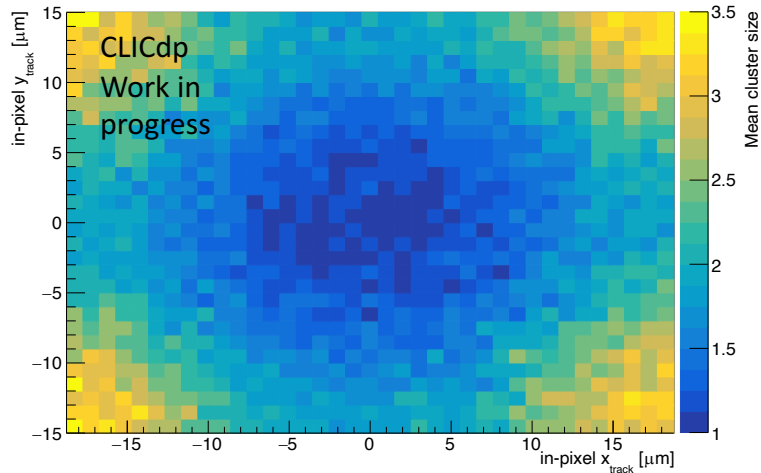
Gap in n-layer: nominal threshold of 266 DAC, baseline during test-beam of 245 DAC

Total cluster size - comparison of process variants

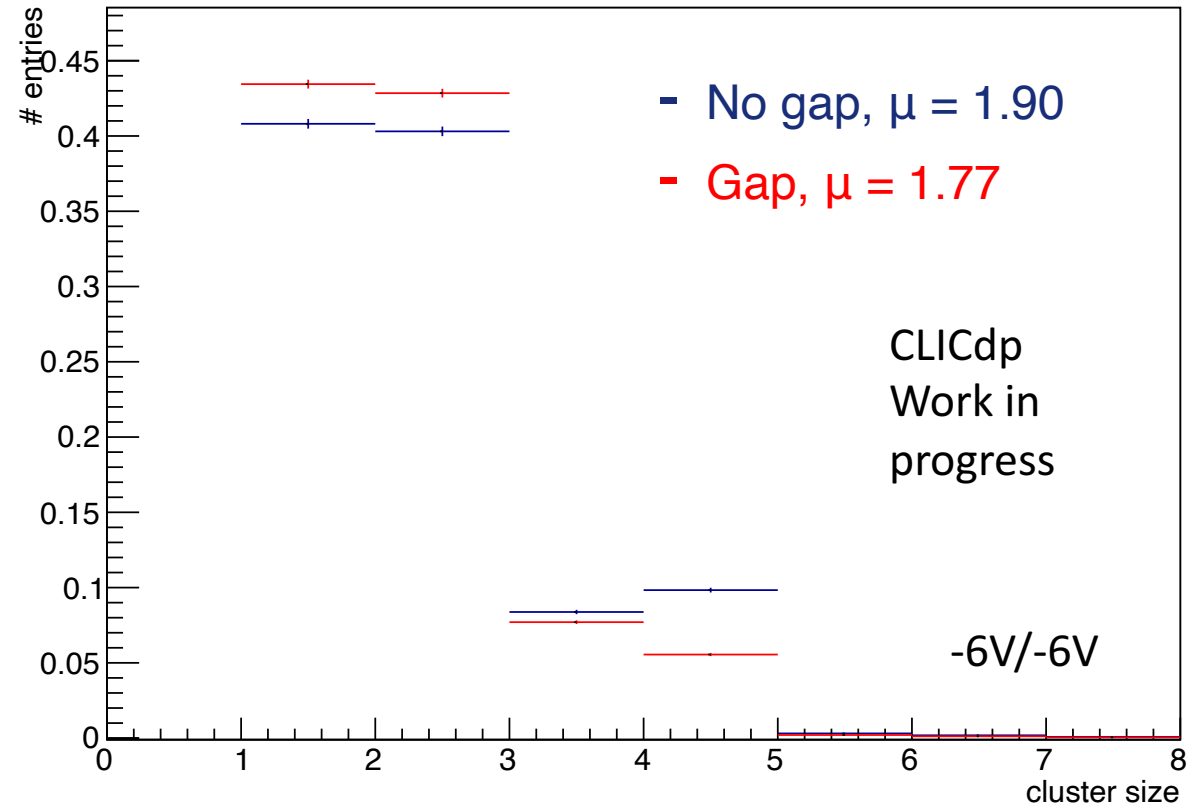
No gap in n-layer: nominal threshold of 250 DAC, baseline during test-beam of 231 DAC

Gap in n-layer: nominal threshold of 266 DAC, baseline during test-beam of 245 DAC

In-pixel cluster size - no gap:

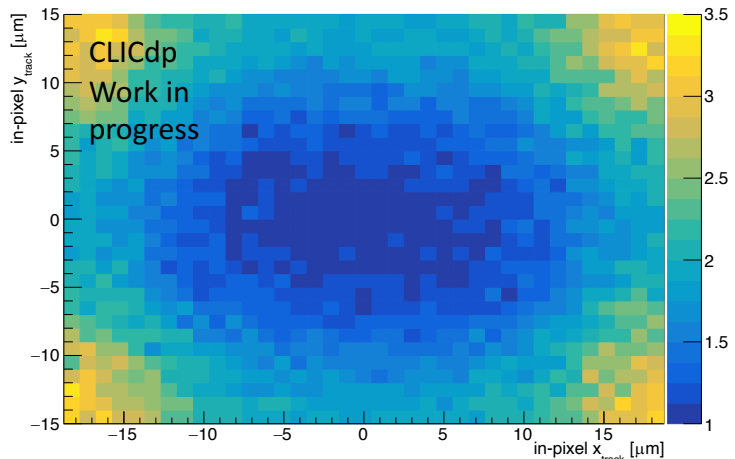


Cluster size distributions for both process variants:



→ Smaller cluster size for process variant with gap in n-layer at nominal operation threshold

In-pixel cluster size - gap:

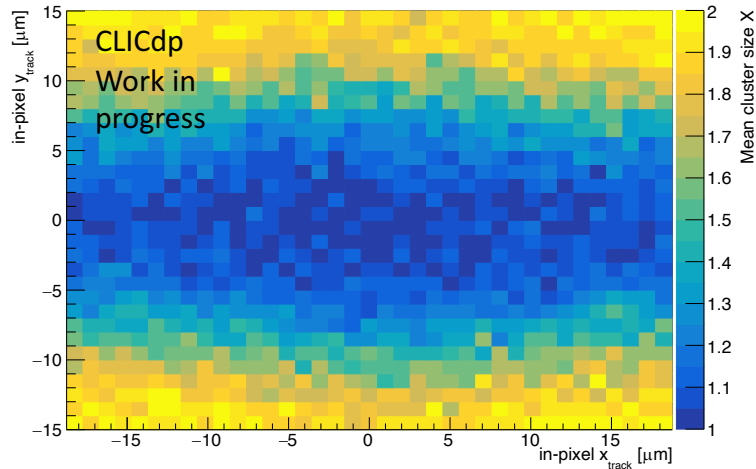


Row cluster size – comparison of process variants

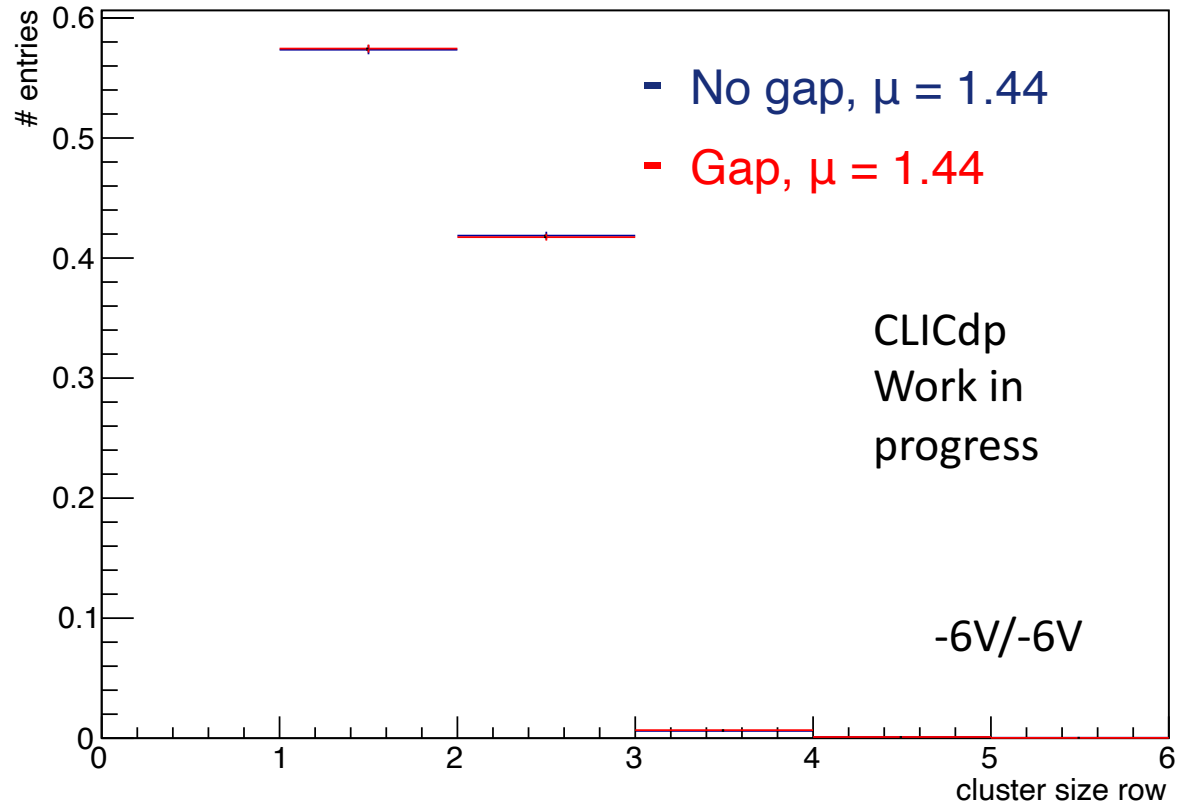
No gap in n-layer: nominal threshold of 250 DAC, baseline during test-beam of 231 DAC

Gap in n-layer: nominal threshold of 266 DAC, baseline during test-beam of 245 DAC

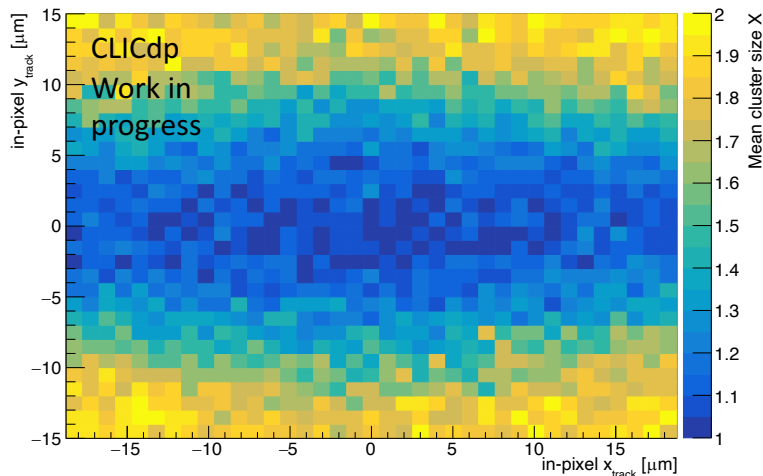
In-pixel row cluster size - **no gap**:



Cluster size row, distributions for both process variants:



In-pixel row cluster size - **gap**:



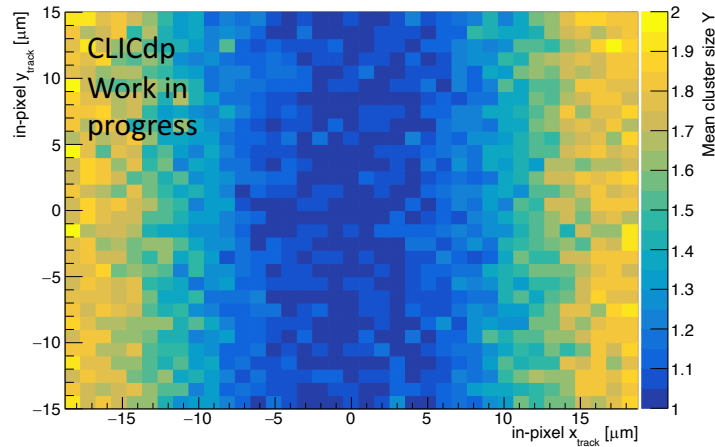
→ Very similar row cluster size indicates that we are at very comparable thresholds for both process variants (t.b.c)

Column cluster size – comparison of process variants

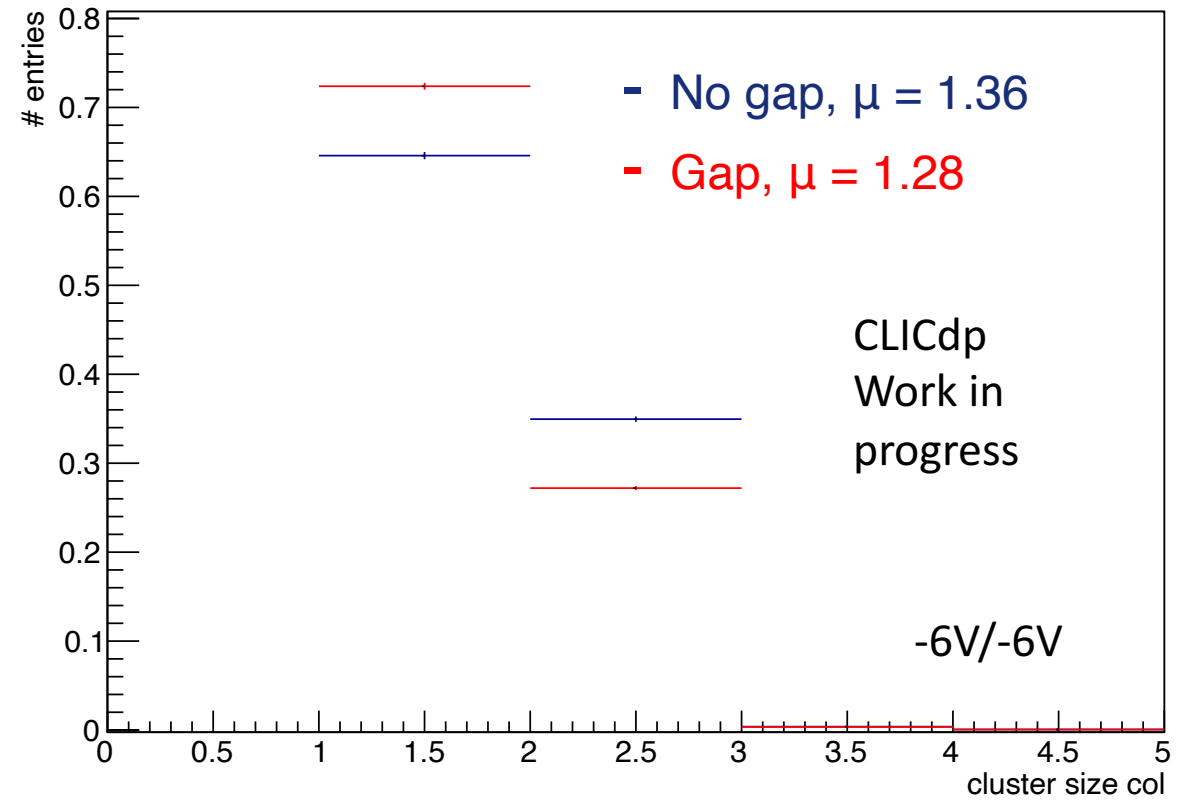
No gap in n-layer: nominal threshold of 250 DAC, baseline during test-beam of 231 DAC

Gap in n-layer: nominal threshold of 266 DAC, baseline during test-beam of 245 DAC

In-pixel column cluster size - no gap:

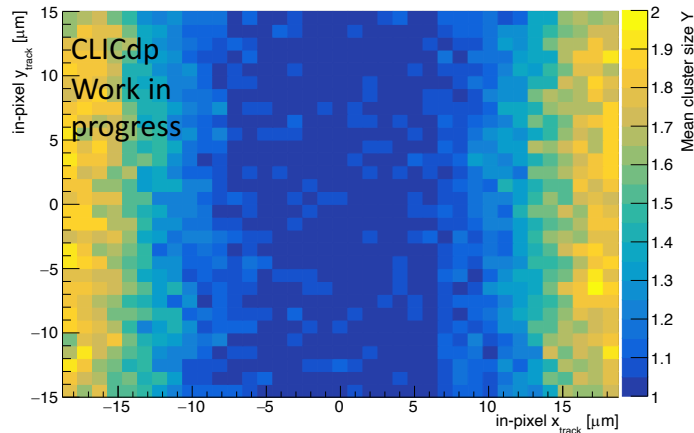


Cluster size column, distributions for both process variants:



→ Reduction of cluster size due to gap in n-layer

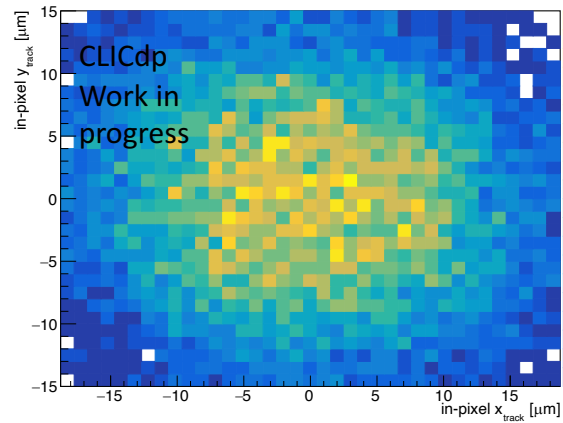
In-pixel column cluster size - gap:



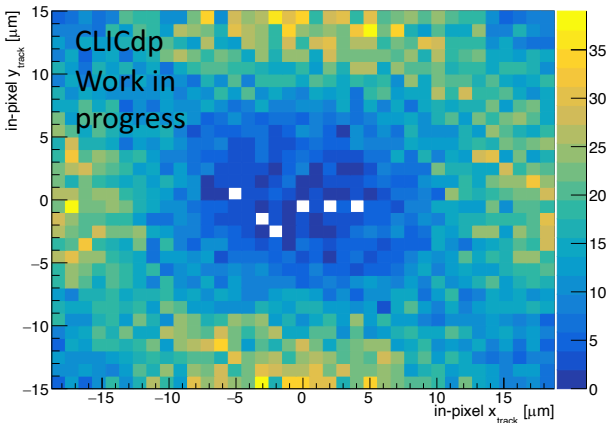
In-pixel hit map for different cluster sizes – different process variants

No gap:

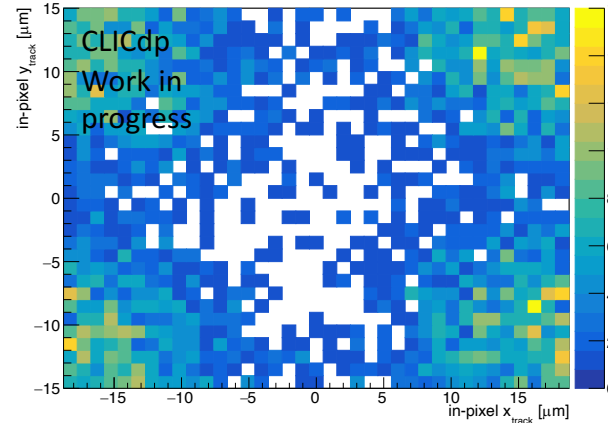
DUT 1-pixel cluster map



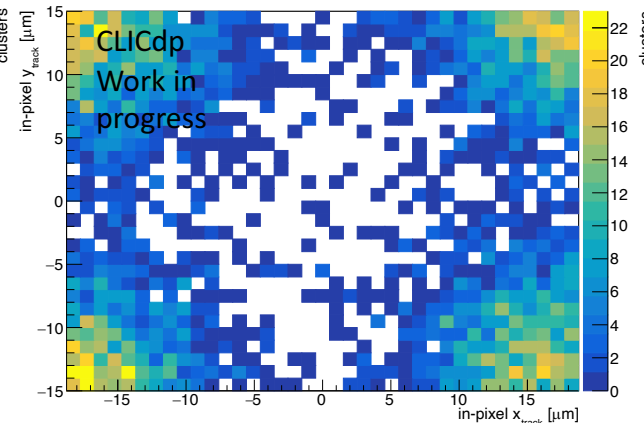
DUT 2-pixel cluster map



DUT 3-pixel cluster map

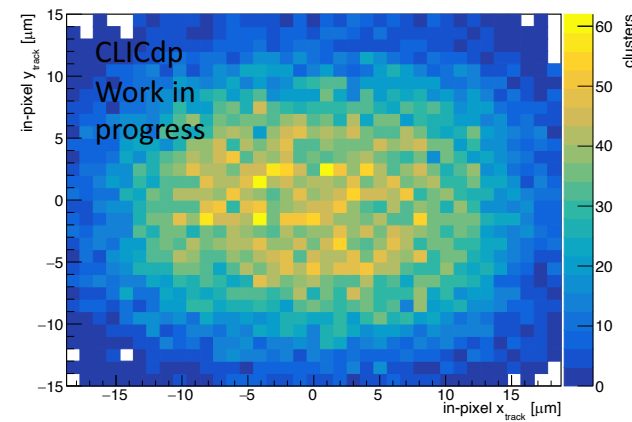


DUT 4-pixel cluster map

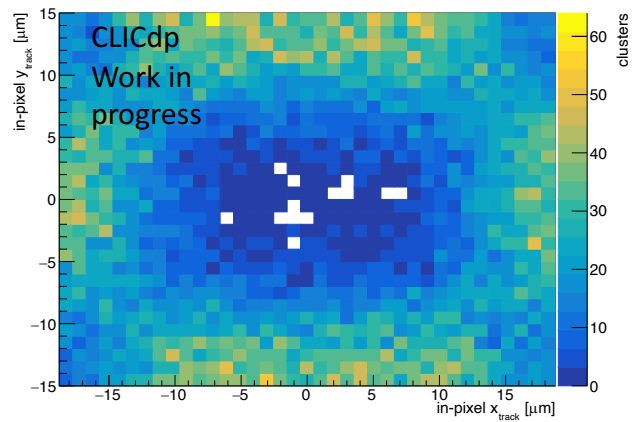


Gap:

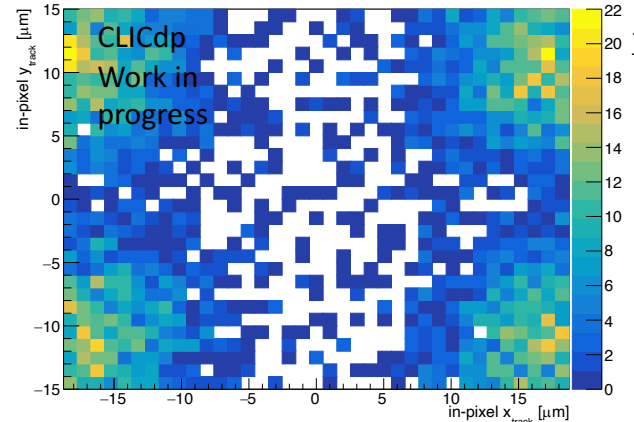
DUT 1-pixel cluster map



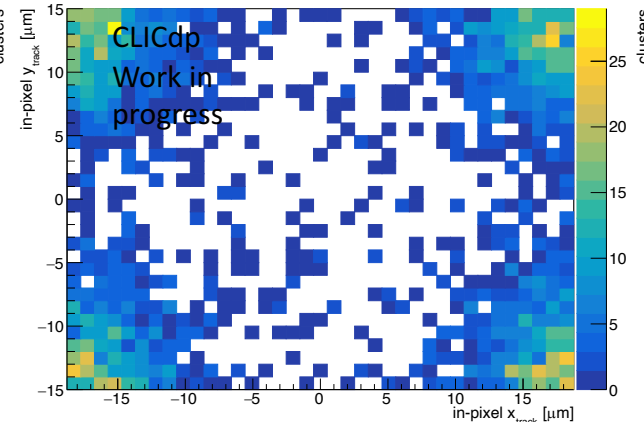
DUT 2-pixel cluster map



DUT 3-pixel cluster map

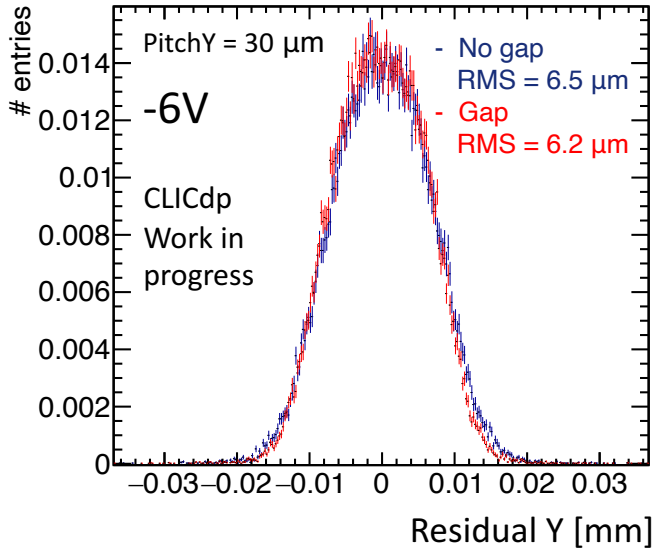


DUT 4-pixel cluster map

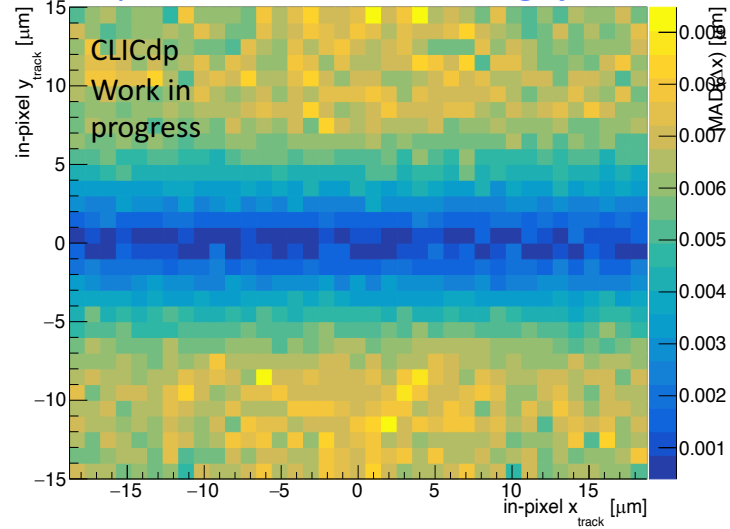


Spatial resolution – different process variants

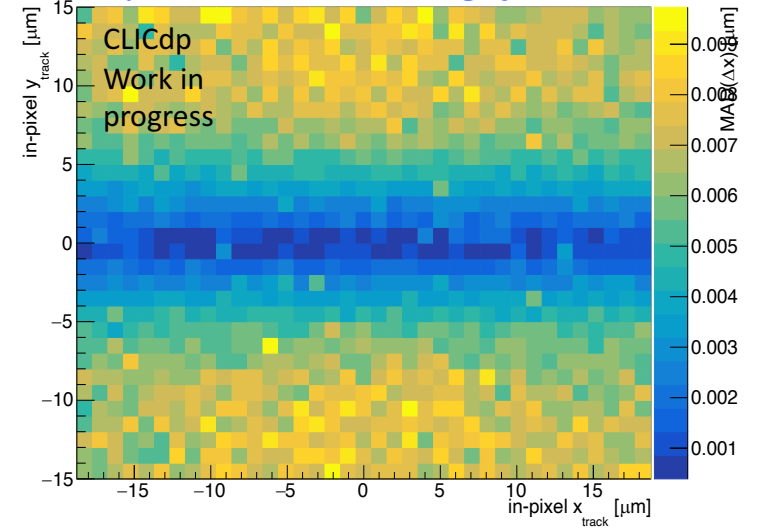
Row residual distribution:



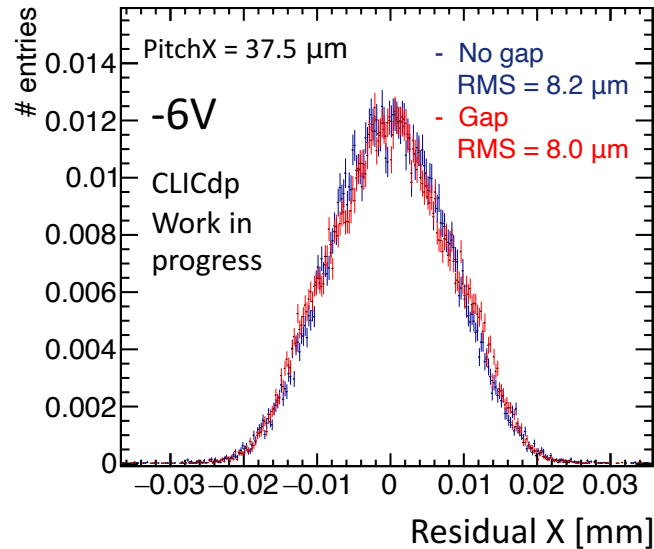
In pixel row residual – no gap:



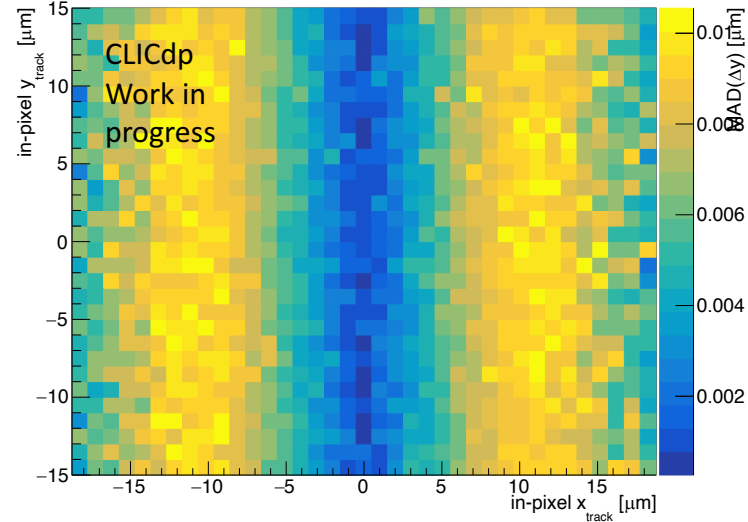
In pixel row residual –gap:



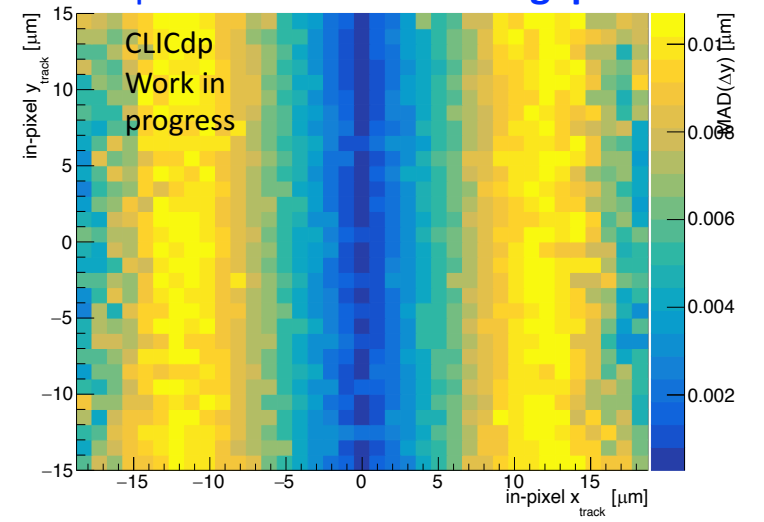
Column residual distribution:



In pixel column residual – no gap:



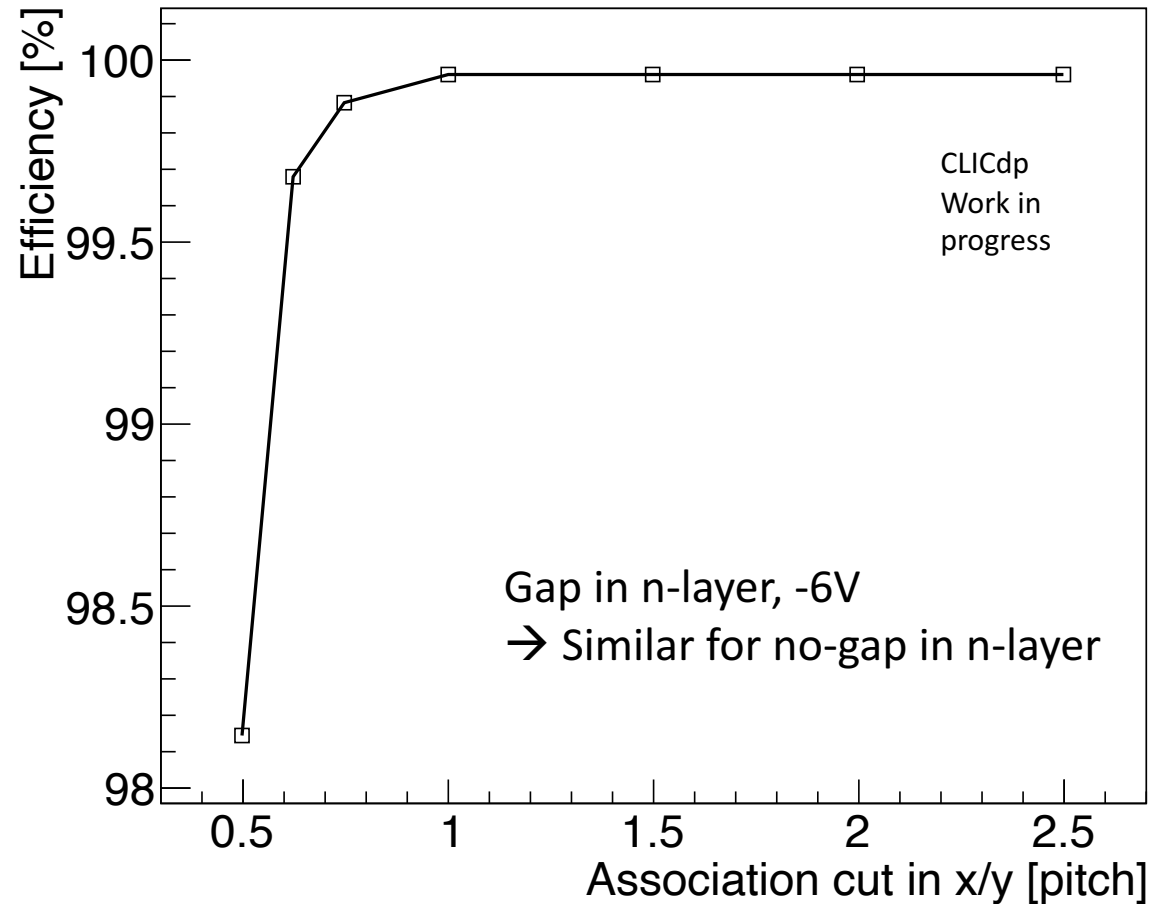
In pixel column residual –gap:



→ Already without correction for non-linear charge sharing and without unfolding track resolution on DUT < 7 μm

Efficiency – different process variants

Efficiency vs. track matching spatial cut:



Efficiency values for association cut of 2xpitch:

No gap in n-layer: $99.9883 + 0.0016 - 0.0019$

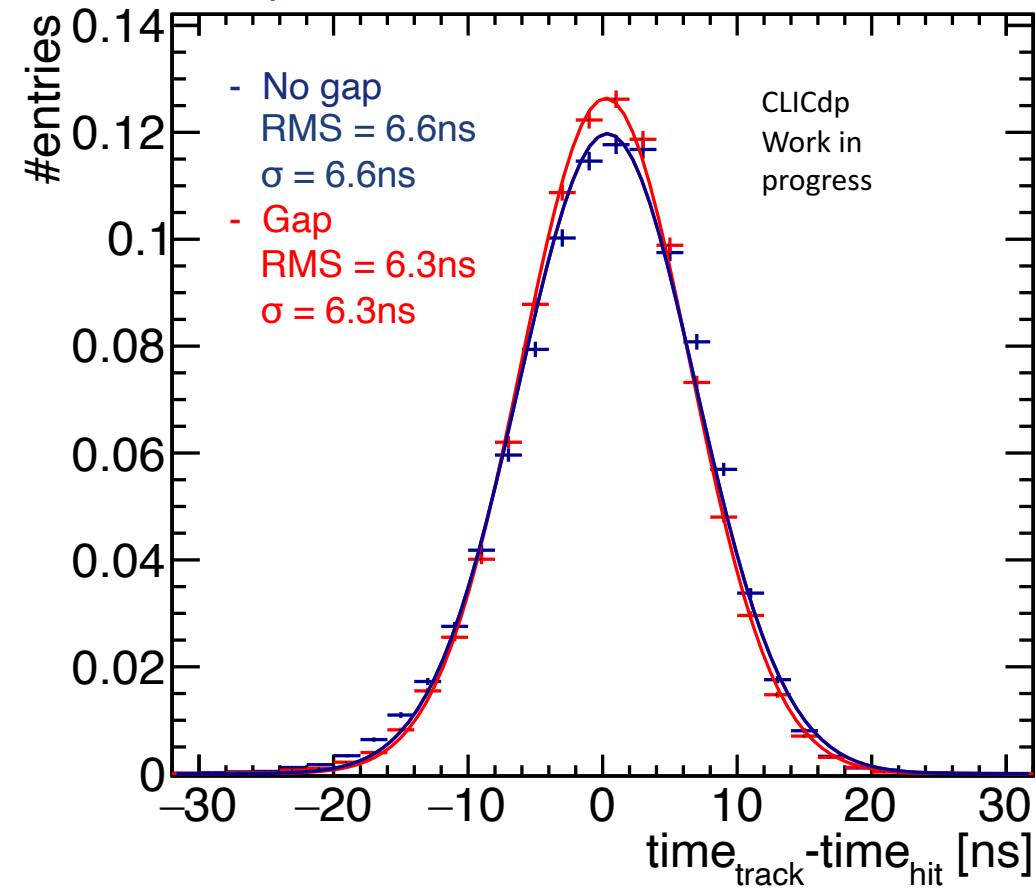
Gap in n-layer: $99.9618 + 0.0013 - 0.0015$

→ Efficiency > 99.9% for both process variants.

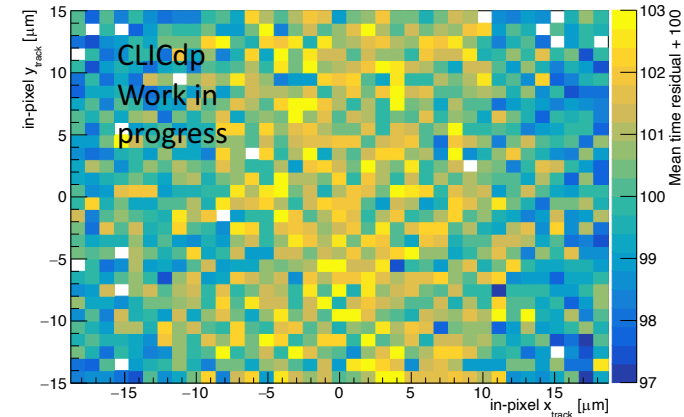
→ Note: no eta correction applied.

Timing residuals - after time-walk correction for different cluster sizes

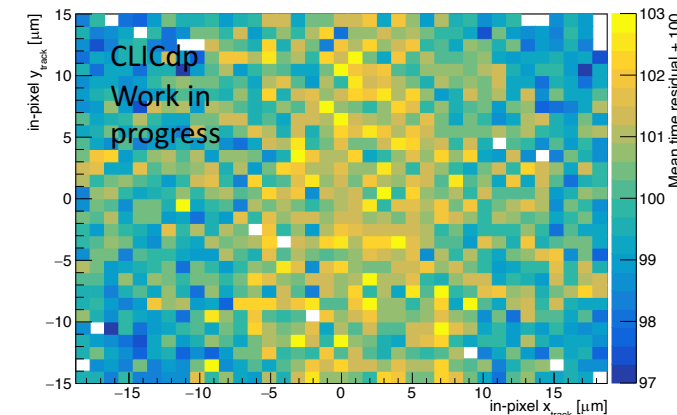
Temporal residual distribution:



In-pixel time residual - no gap:



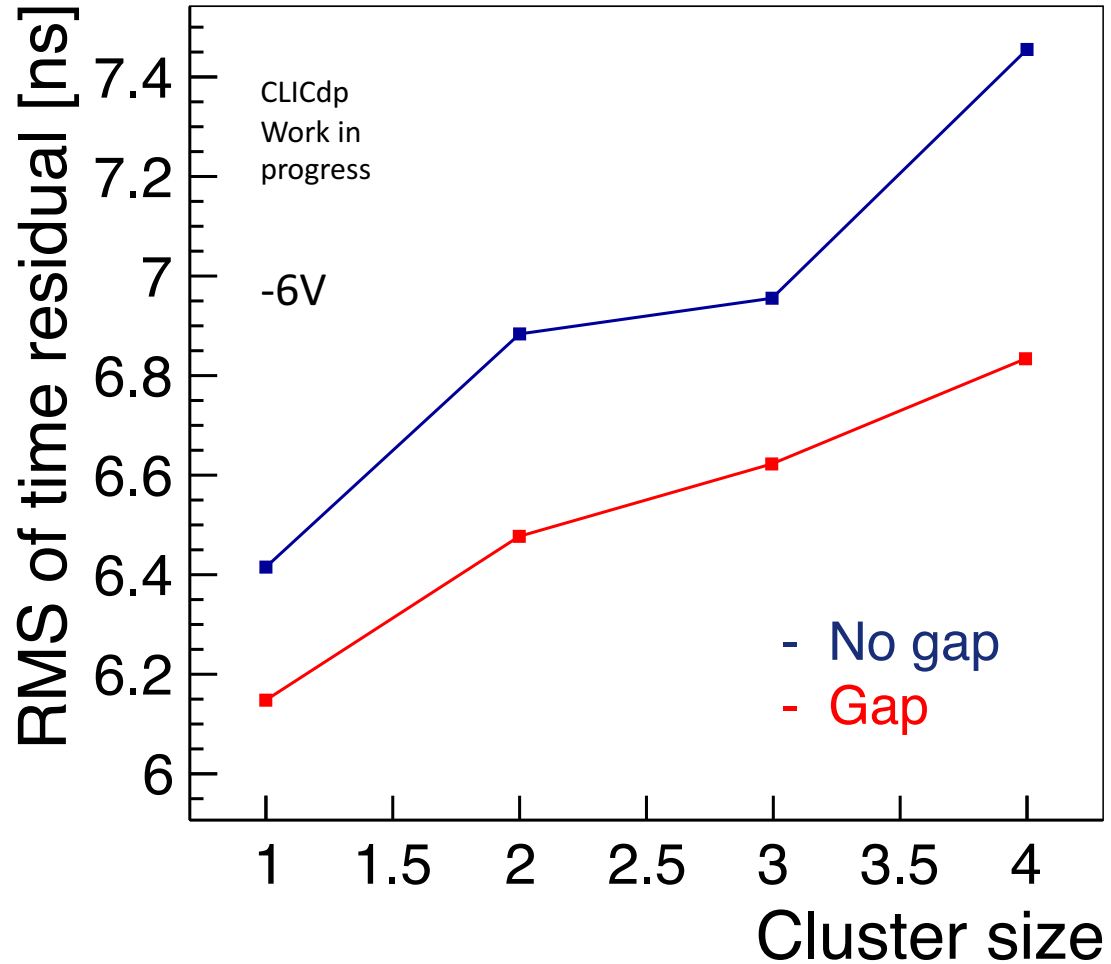
In-pixel time residual - gap:



- Temporal residual distribution close to Gaussian after time-walk correction for different cluster sizes
- Slight deviation from Gaussian still observable for process variant with no gap in n-layer (to be investigated)
- Ongoing work, Jens: characterisation/improvement of reference time-stamp from TPX3
- In-pixel time residuals suggest further room for improvement of CLICTD time-stamp
- Overall: close to 5ns required for CLIC tracker, slightly more precise process variant with gap in n-layer

RMS of temporal residual vs. cluster size

RMS of temporal residual distribution as a function of cluster size:



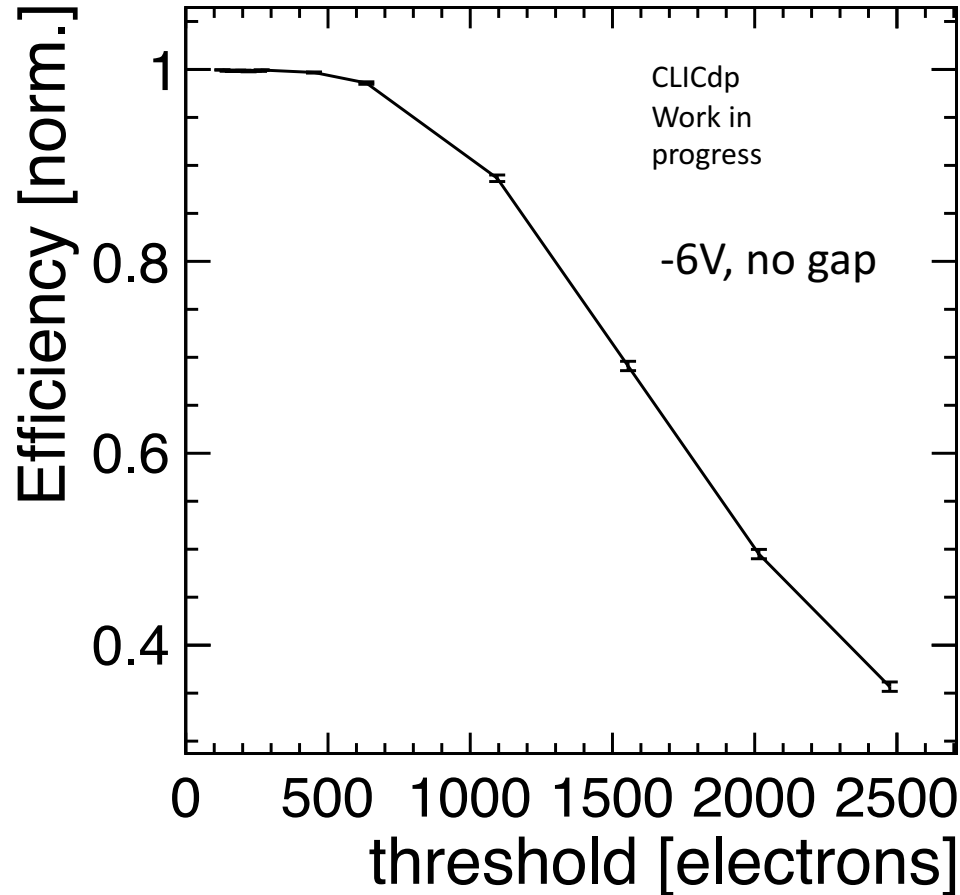
→ Offset in RMS of time residual between gap and no gap in n-layer not dependent on cluster size

→ Larger RMS for larger cluster sizes could indicate room for improvement

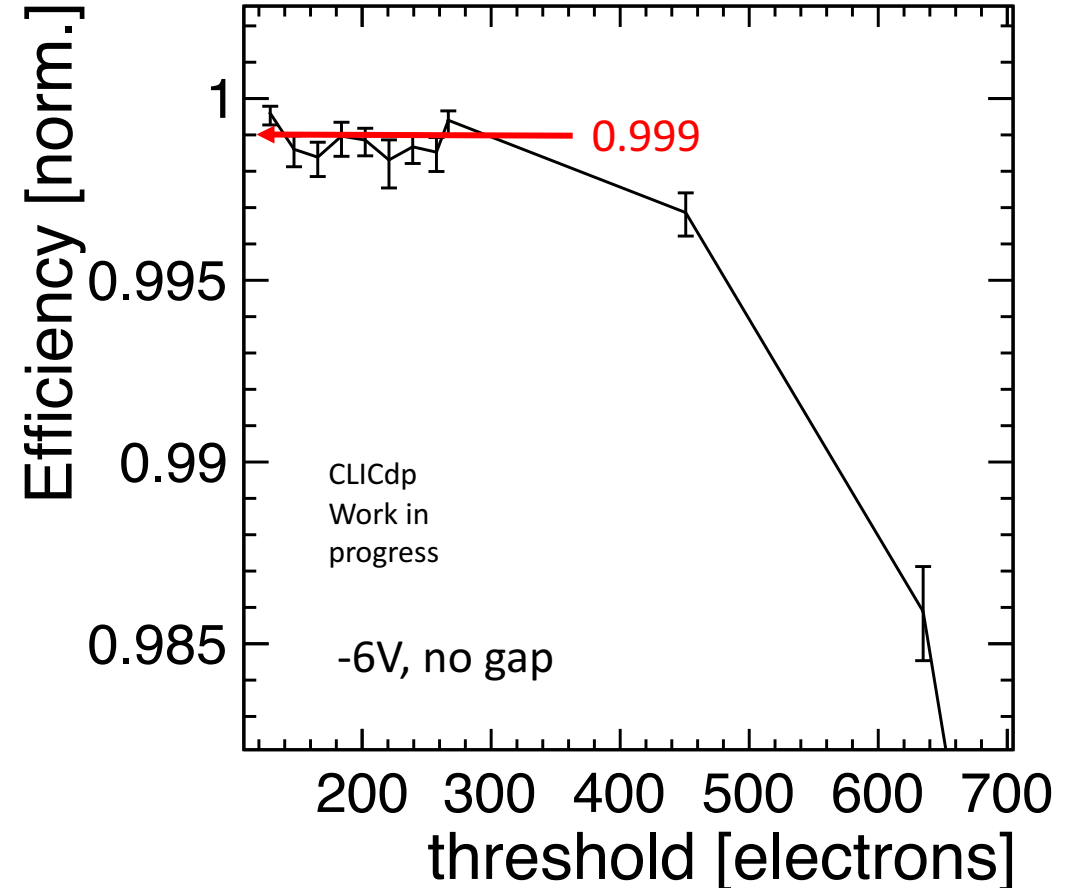
Threshold scan for
process with no gap in n-layer at -6V

Efficiency vs. threshold – process with no gap in n-layer

Efficiency vs. threshold – full range:



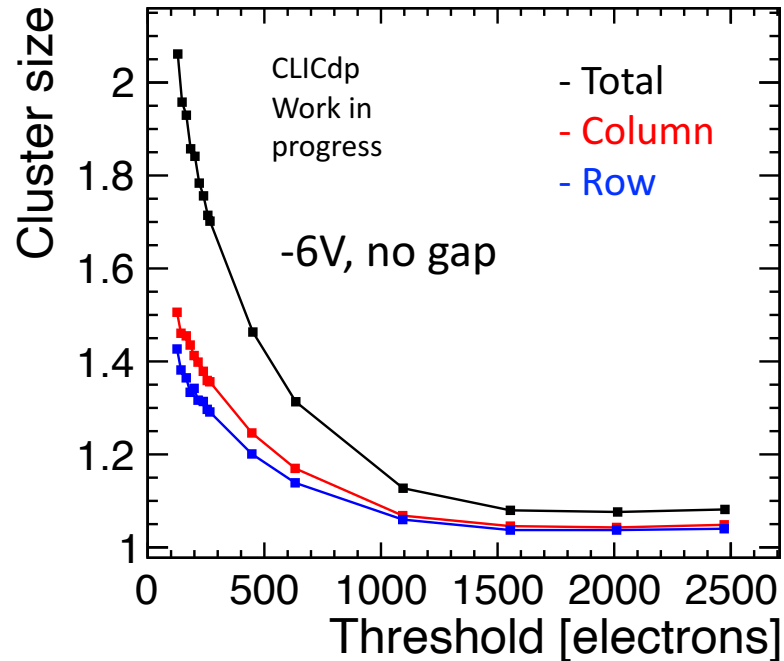
Efficiency vs. threshold – zoom:



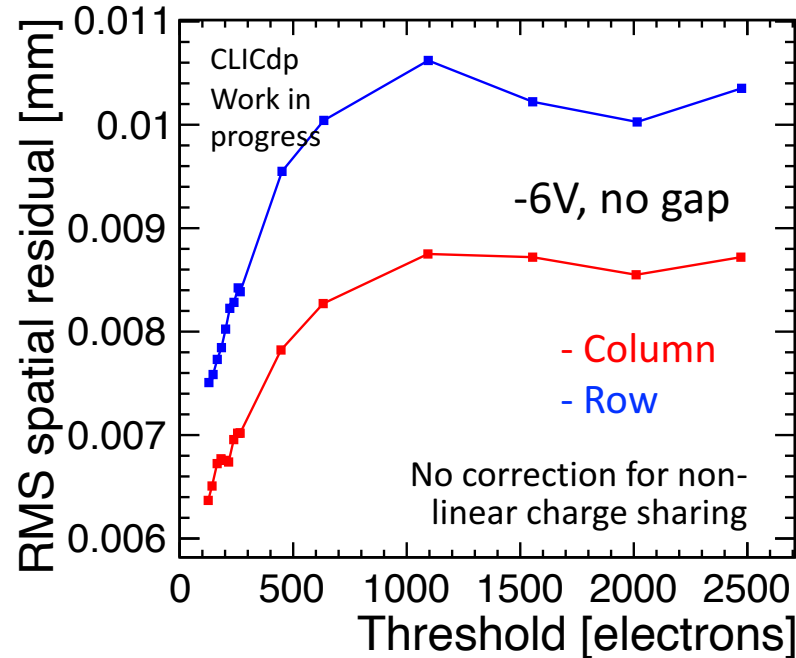
- Note: using first estimate of calibration factor showed in Katharina's previous talk
- Threshold scan at p-well voltage of -3V showed immediate drop of efficiency
- Larger efficient operation window due to lower bias on p-wells (lower threshold, less charge sharing → t.b.c)
- More data points in efficiency roll-off planned for next test-beam (end of February)

Cluster size & resolution vs. threshold – process with no gap in n-layer

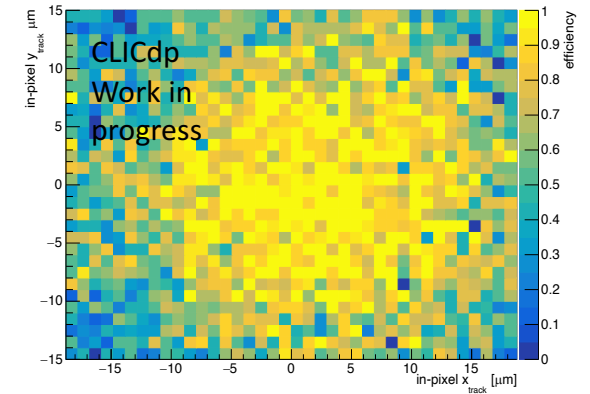
Cluster size vs. threshold:



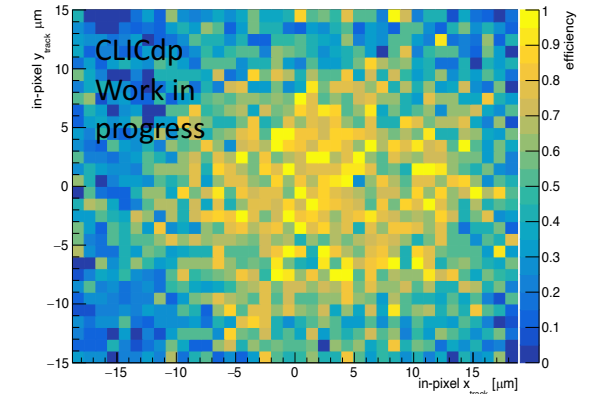
RMS of spatial residual vs. threshold:



In-pixel efficiency 1500 electron threshold:



In-pixel efficiency 2000 electron threshold:



- Significantly reduced charge sharing at higher threshold reflected in degraded spatial residual
- Cut into efficiency at pixel corners reflected in improved resolution at very high threshold
- Residual of last threshold point under investigation

Summary:

- GBL track reconstruction gives access to detailed in-pixel resolved studies → thanks to Lennart & Simon!
- Observed expected differences for process variants
- Both process variants close to requirements for CLIC tracker

Outlook:

- Analysis of further data:
 - Comparison of threshold scan for different processes using threshold calibration
 - Comparison of different voltages using threshold calibrations
- Improvement of reco:
 - Correction for non-linear charge sharing
 - Improvement of hit time correction

Technical notes

- Masking of matrix edges + individual masking for each threshold, voltage, process
- Time-walk correction for each cluster size
- GBL with requirement of hit on each plane
- 2nd t₀:
 - Only 1 out of ~ 80 analysed runs with second t₀
 - Runs efficiency not OK: 3068 → 2nd T₀
- Other issues:
 - Time jump run 3033
 - Run not on eos but in good run list: 3073

