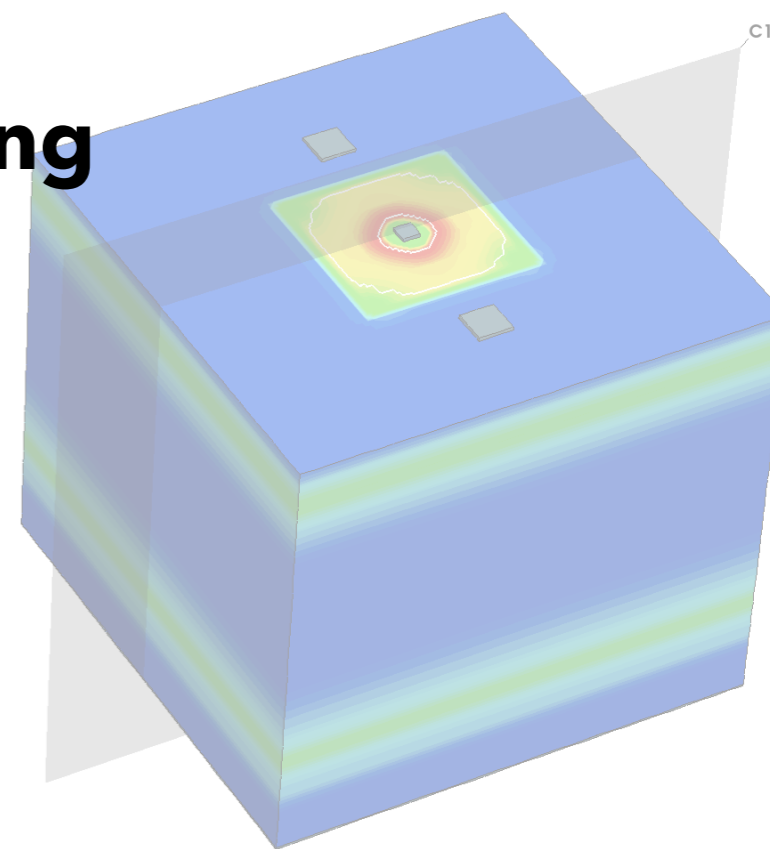


FIRST LOOK INTO ALLPIX- SQUARED + TCAD SIMULATIONS FOR CLICTD

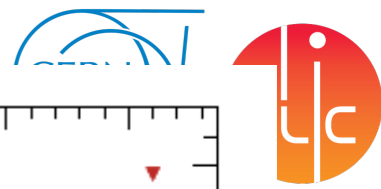
Katharina Dort

Vertex & Tracker Meeting

27/03/2020



ALLPIX SQUARED + TCAD SIMULATIONS

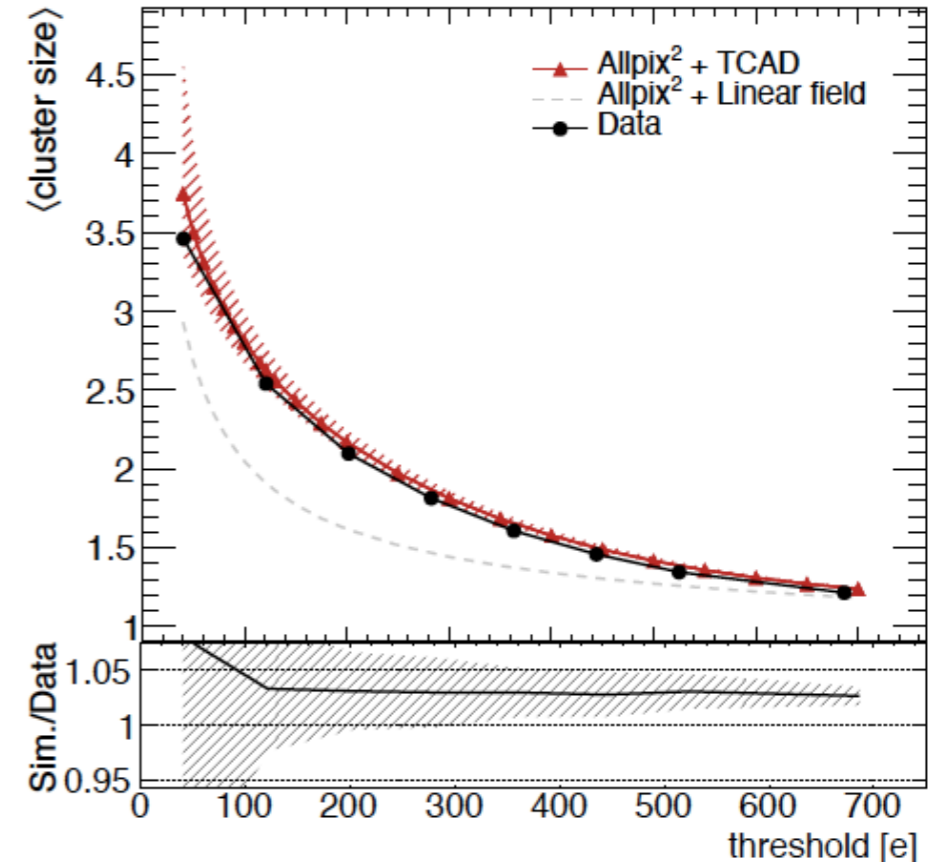
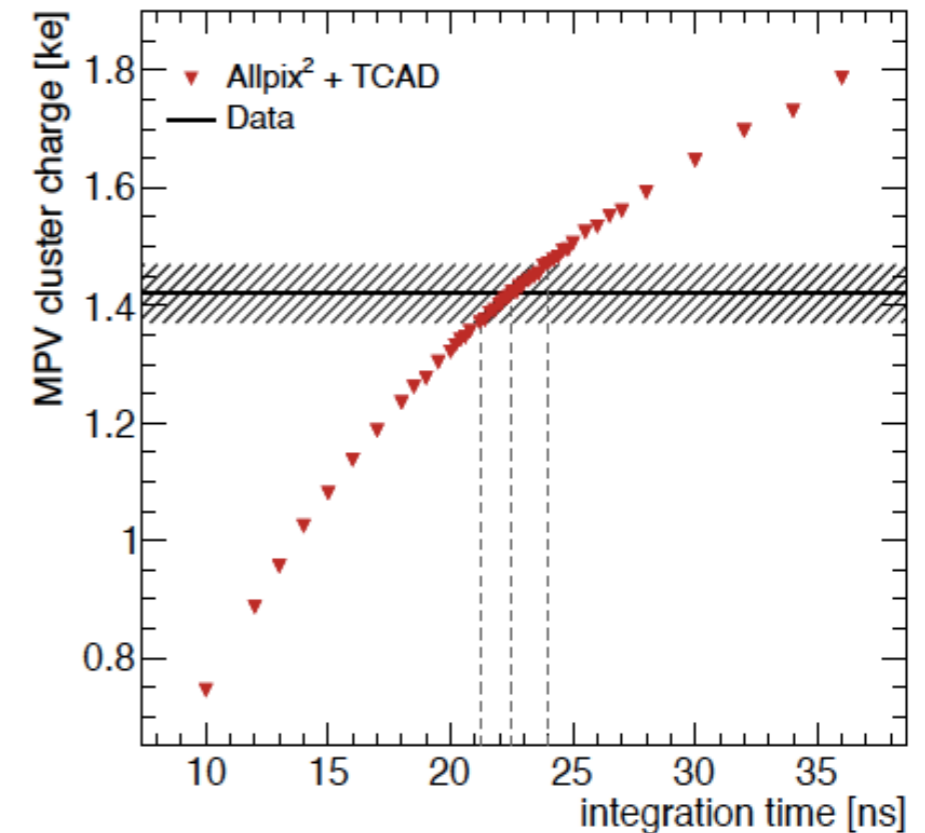


Simulation of full detector response

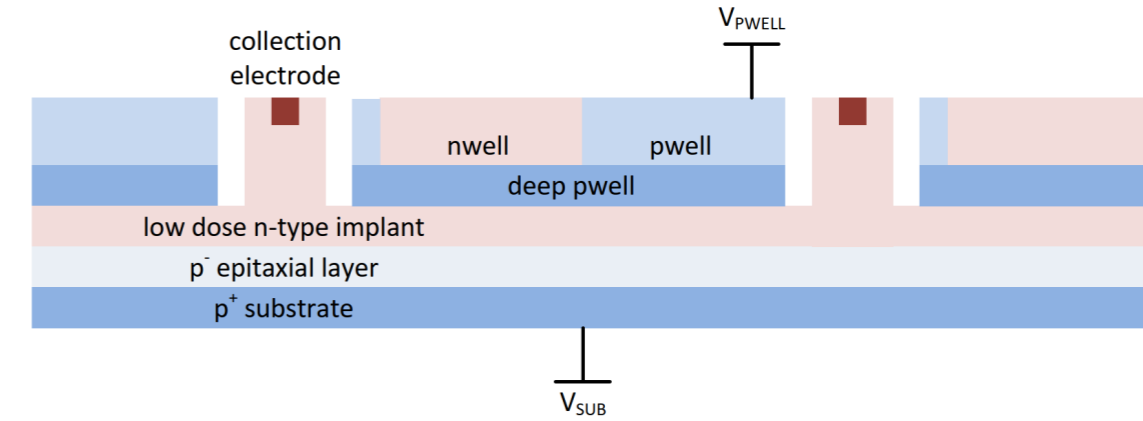
- Allpix Squared (AP2) is a Monte Carlo simulation framework for silicon vertex and tracker detectors
NIM A 901 (2018) 164-172
- 3D TCAD simulations are needed to model electric field which is imported into Allpix Squared simulations
- ➔ High statistics and accurate field modeling
- Validation of simulation with Investigator test-chip (developed within ALICE ITS upgrade)

Tuning of simulation to data

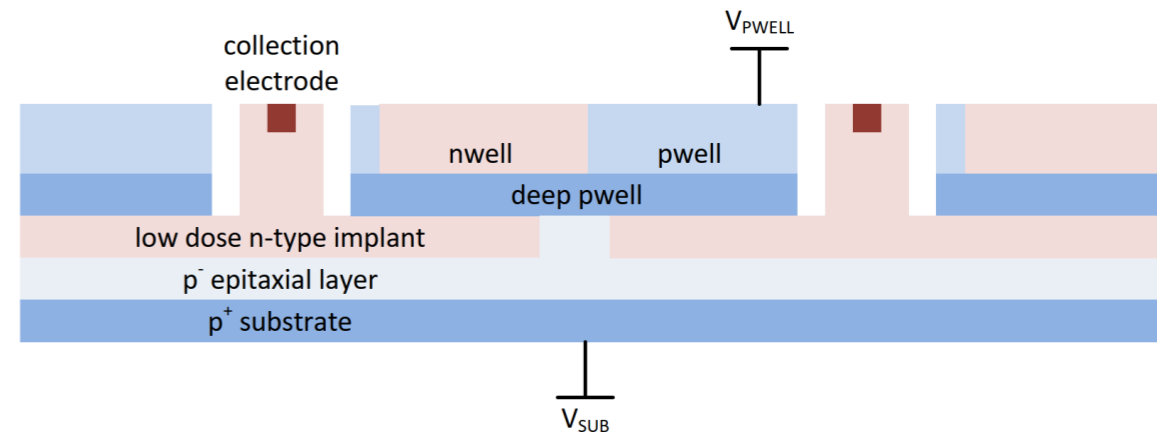
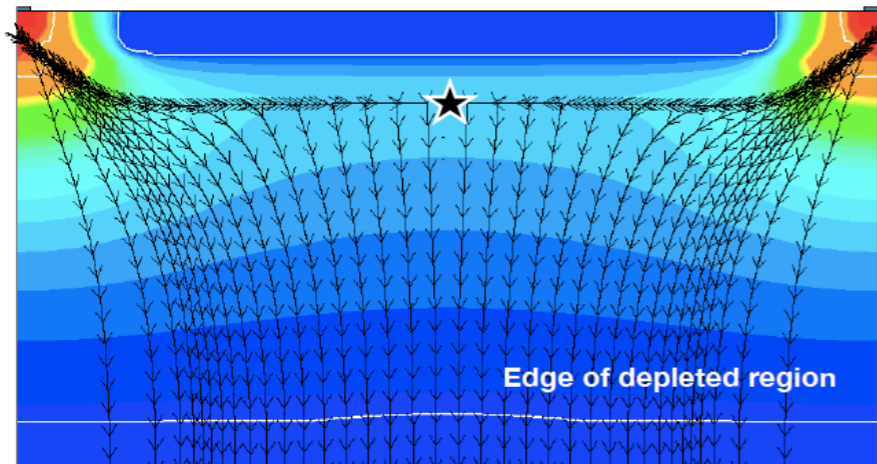
- Simplified model for signal formation: final state of charge carriers collected at electrode equivalent to integrated induced current
- Charge collection is halted after fixed integration time -> only charges in volume around collection electrode contribute to signal
- Tuning of simulation by comparing most probable value of cluster charge between data and simulation



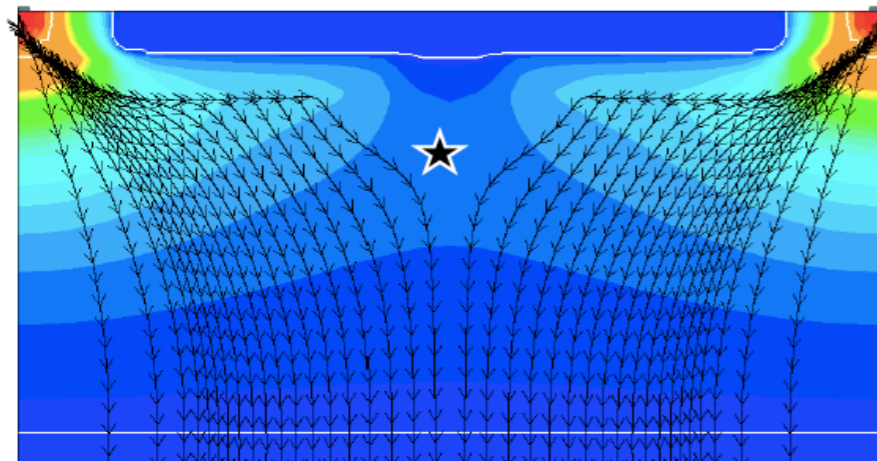
- CLICTD chip designed in monolithic 180 nm CMOS imaging process targets CLIC tracker requirements
- Complex electric field in sensor as can be seen from Magdalena's TCAD simulations



Continuous N-type implant

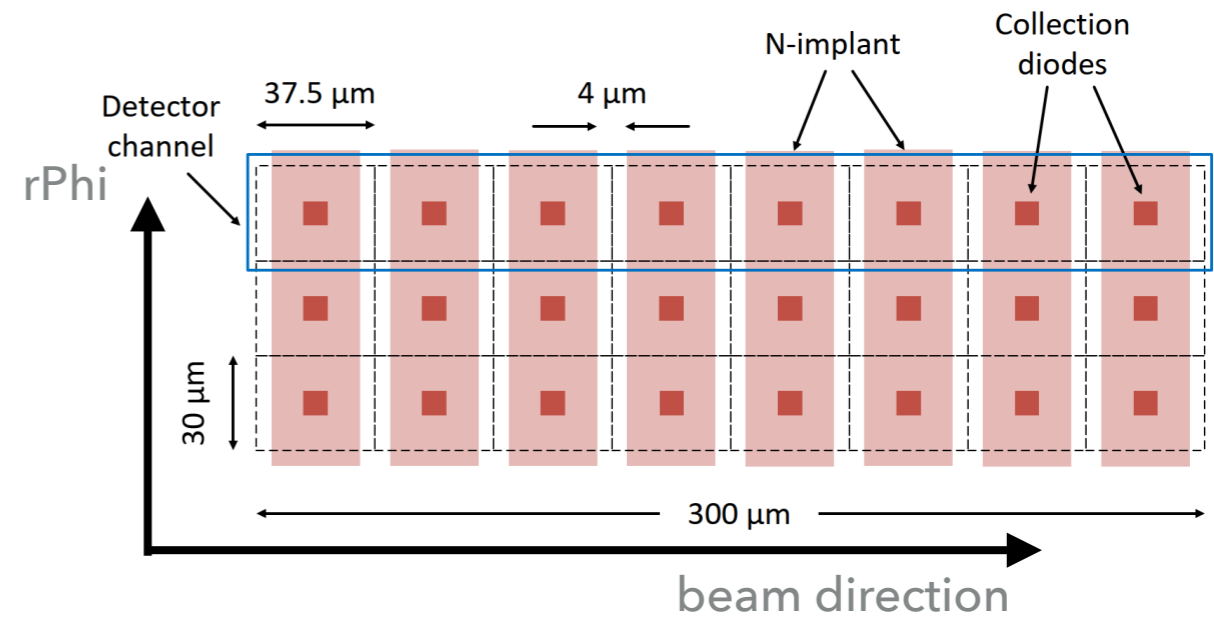
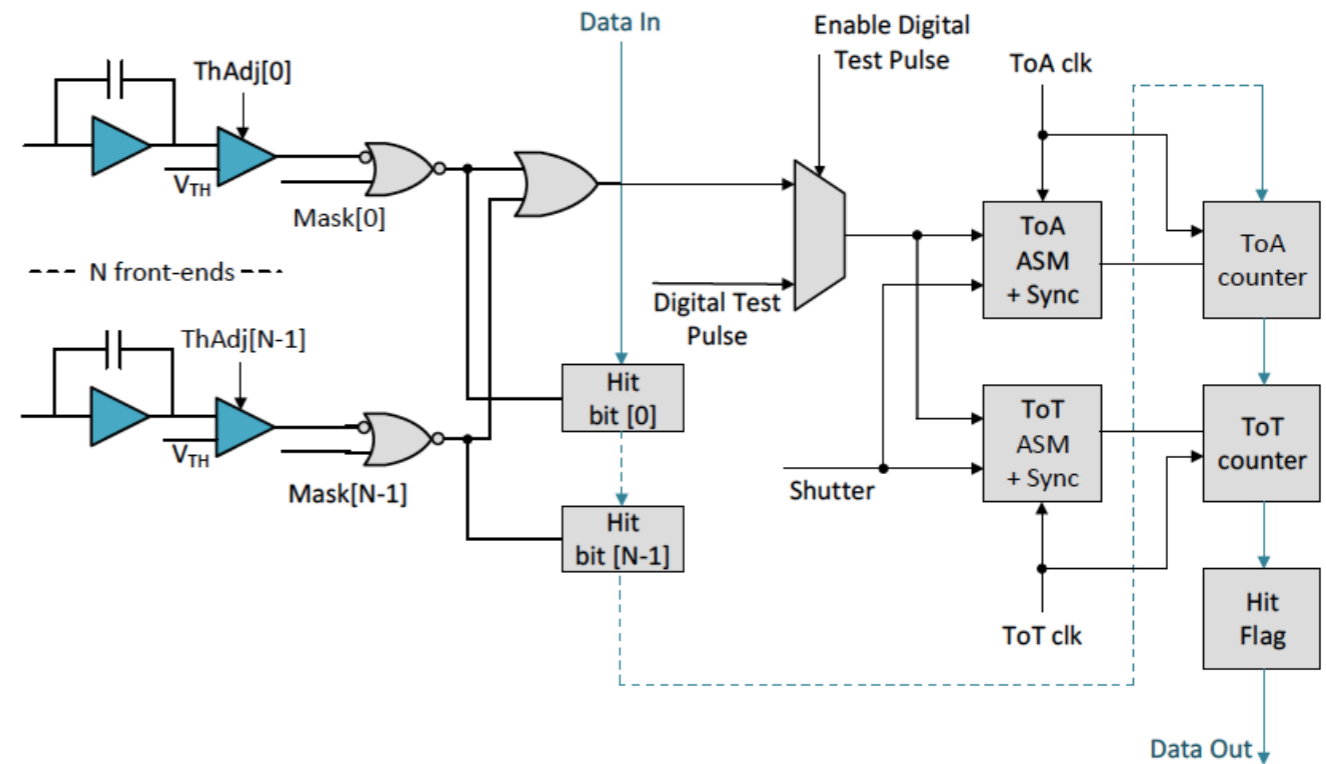


Gap in N-type implant



- Bias voltage applied to substrate and p-wells
- Best sensor performance expected at -6V / -6V
- Simulation shown here were only made at this bias voltage and for a continuous n-type implant

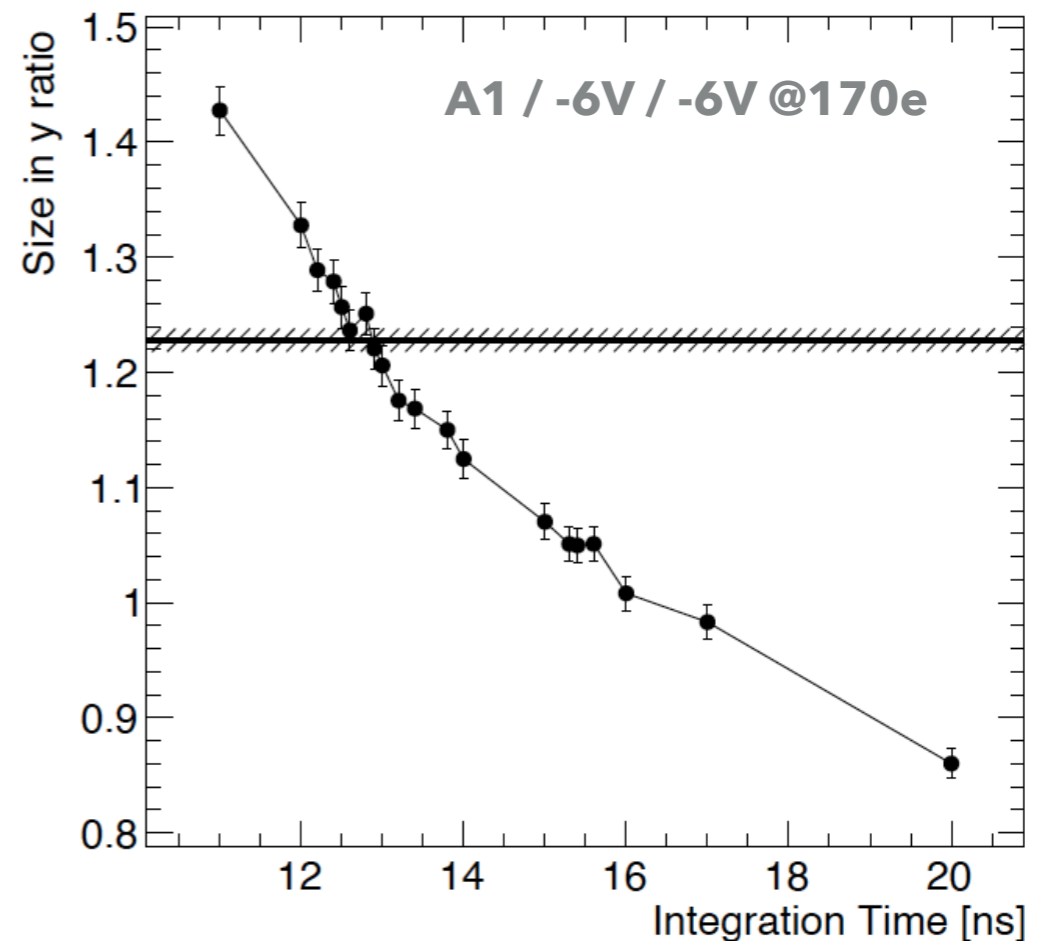
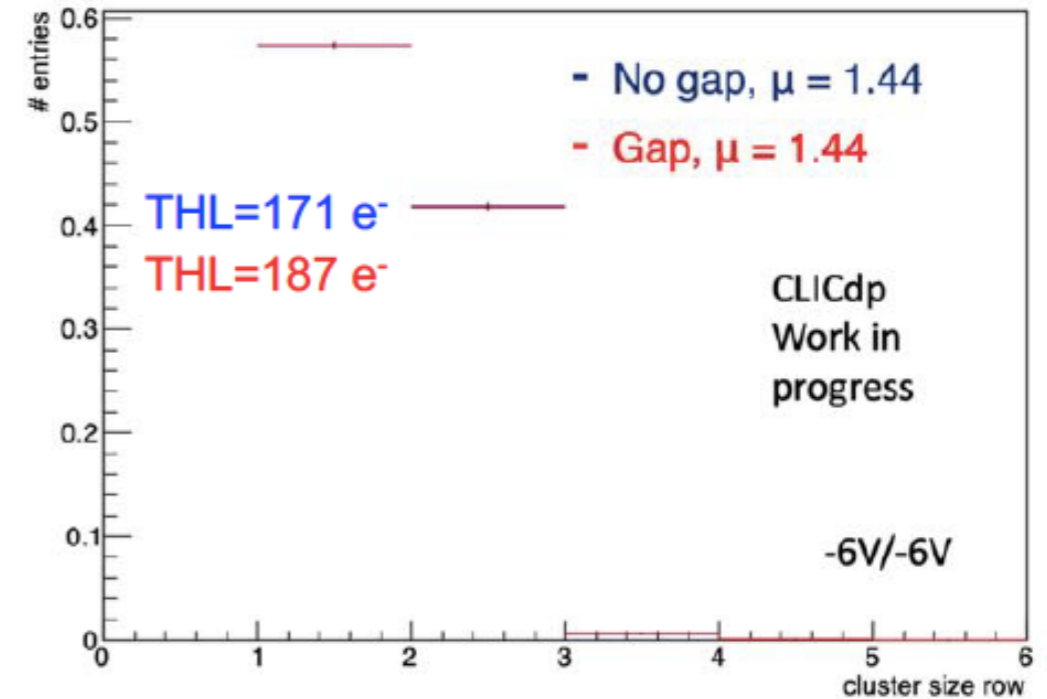
- Matrix size: 3.84 mm x 4.8 mm divided into 128 rows and 16 columns
- Detector channel: 300 μm x 30 μm with each channel segmented into 8 pixels
 - ➔ Save space for digital circuitry while maintaining charge collection speed and low capacitance
 - ➔ Pixel information combined with OR-gate
 - ➔ Binary hit information for sub-pixels available



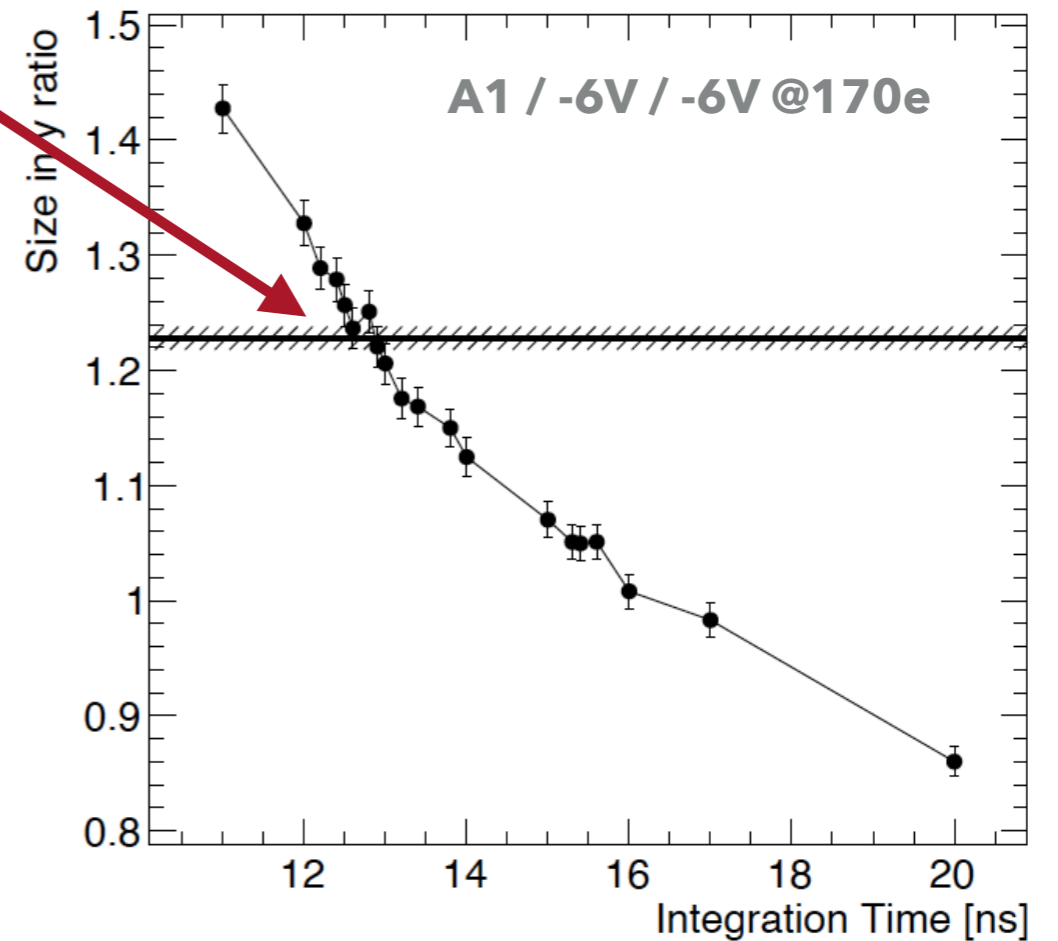
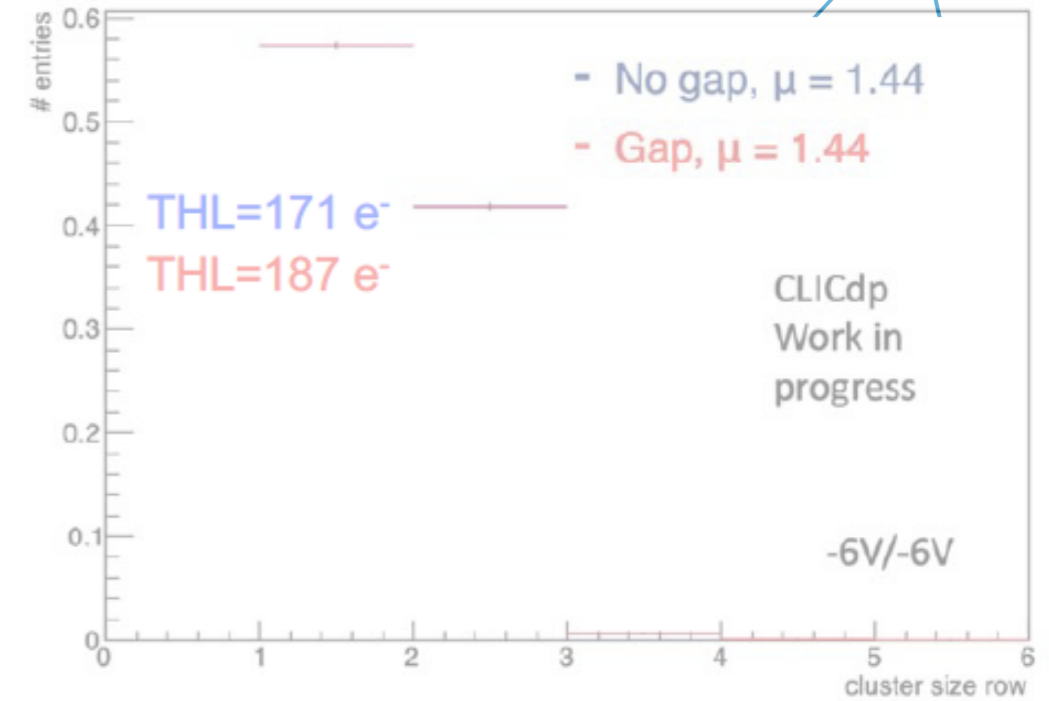
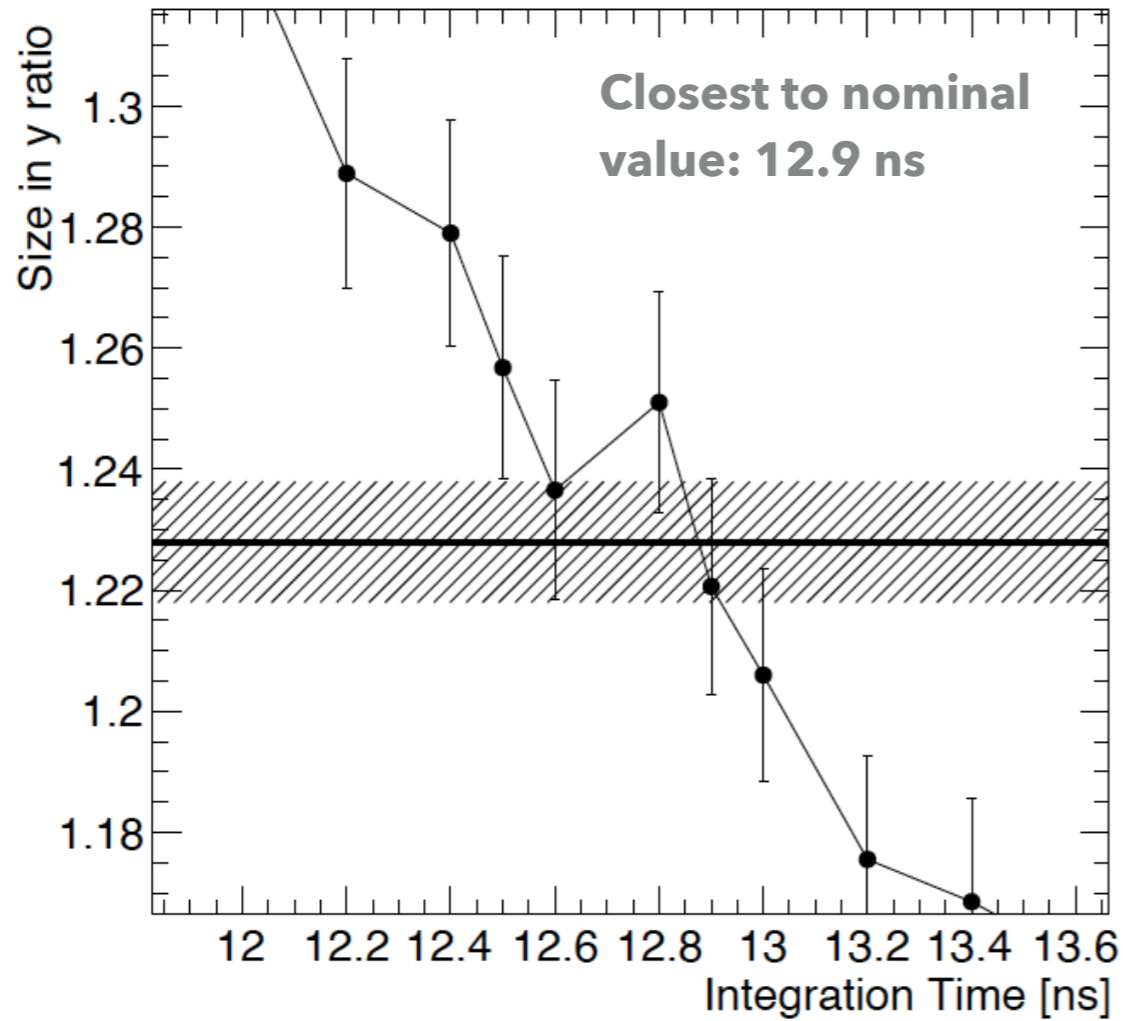
- Tuning of CLICTD simulation to MPV of cluster signal problematic due to
 - ToT not calibrated (yet)
 - Coarse ToT binning
 - Tuning only against a single value
- Inspired by talk from Jan Hasenbichler (ALICE collaboration) : tuning against a variable which is sensitive to the amount of charge sharing in a pixel

<https://indico.cern.ch/event/813597/contributions/3727778/>

- For now: ratio between clusters with size 1 and size > 1 in y (pitch: 30 μm) for a fixed threshold
- Possible improvement:
 - Using cluster size in y ratio from multiple thresholds



- Tuning of CLICTD simulation to MPV of cluster size distribution



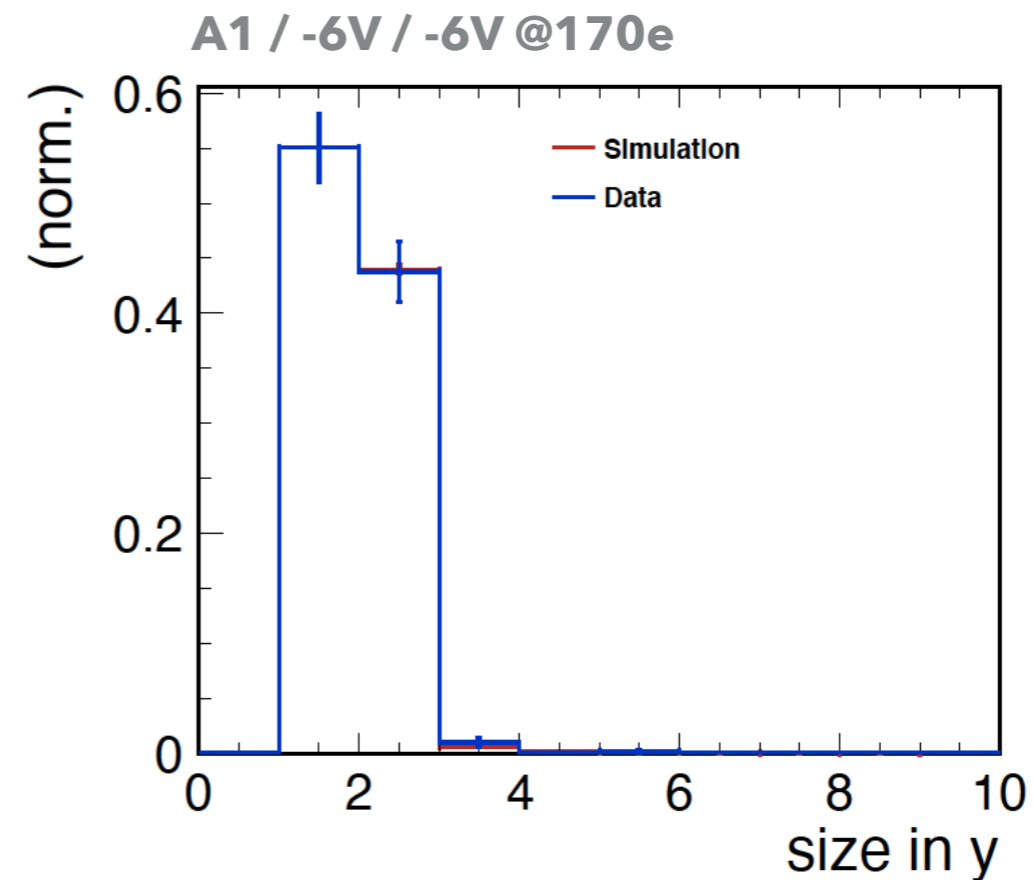
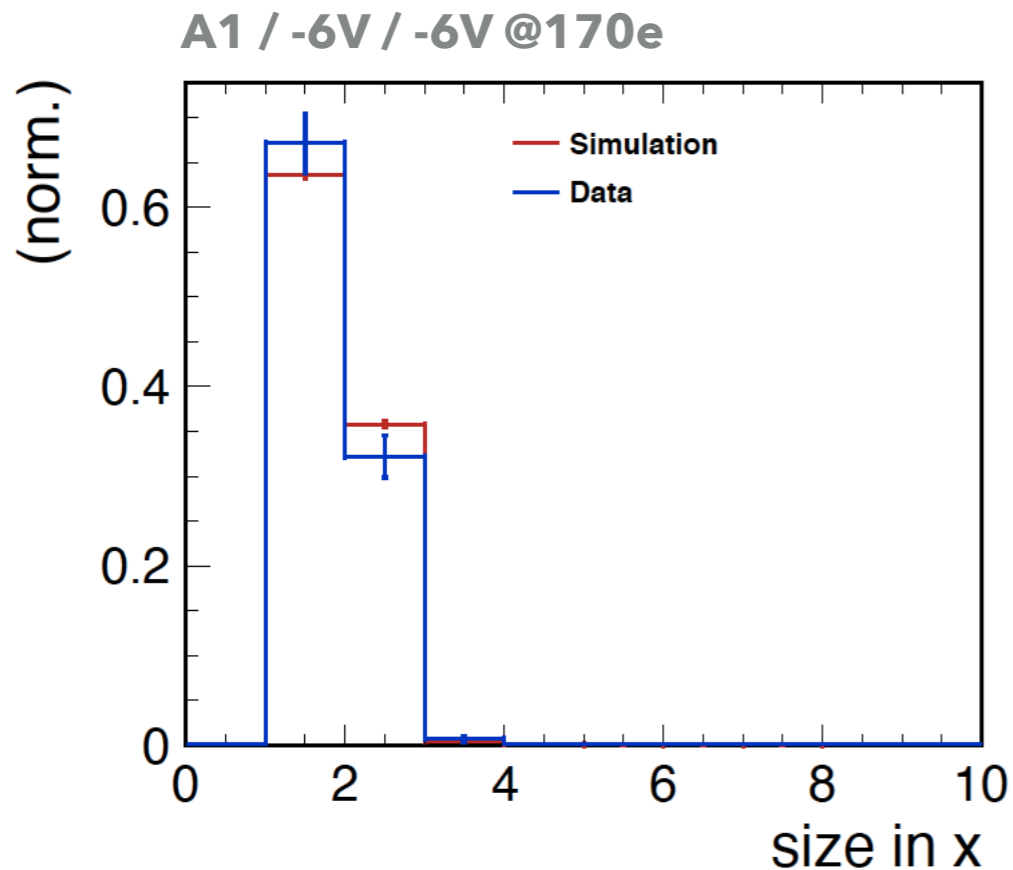
- Insufficient cluster size selection
- For a fixed threshold in y (pitch: 50 μm) for a fixed threshold

- Possible improvement:
 - Using cluster size in y ratio from multiple thresholds

COMPARISON TO TEST-BEAM DATA: CLUSTER SIZE



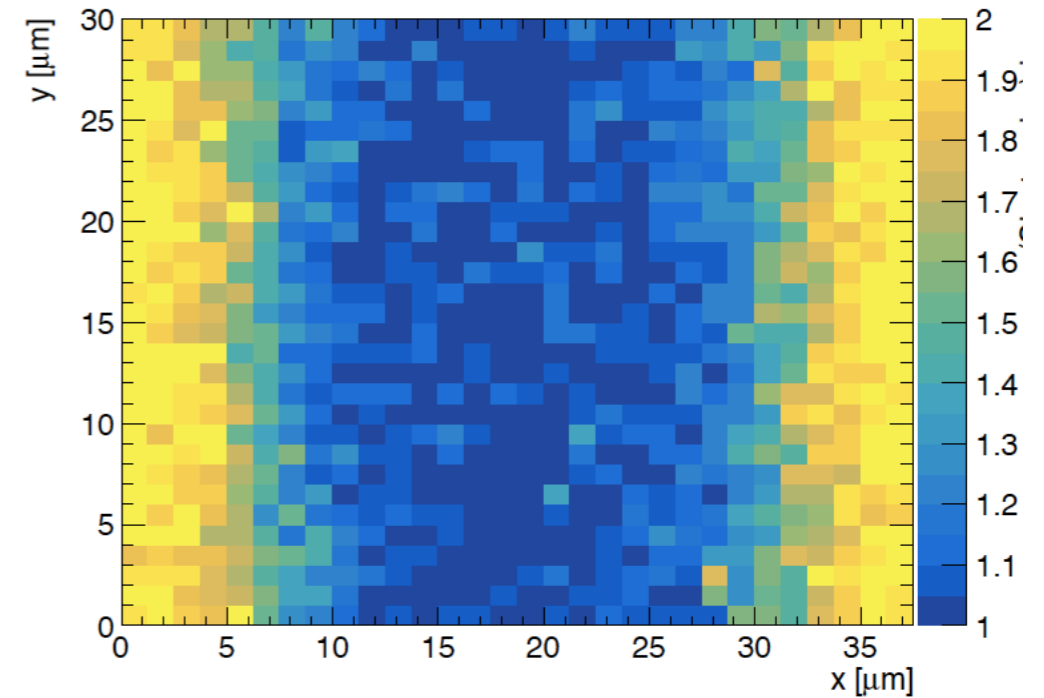
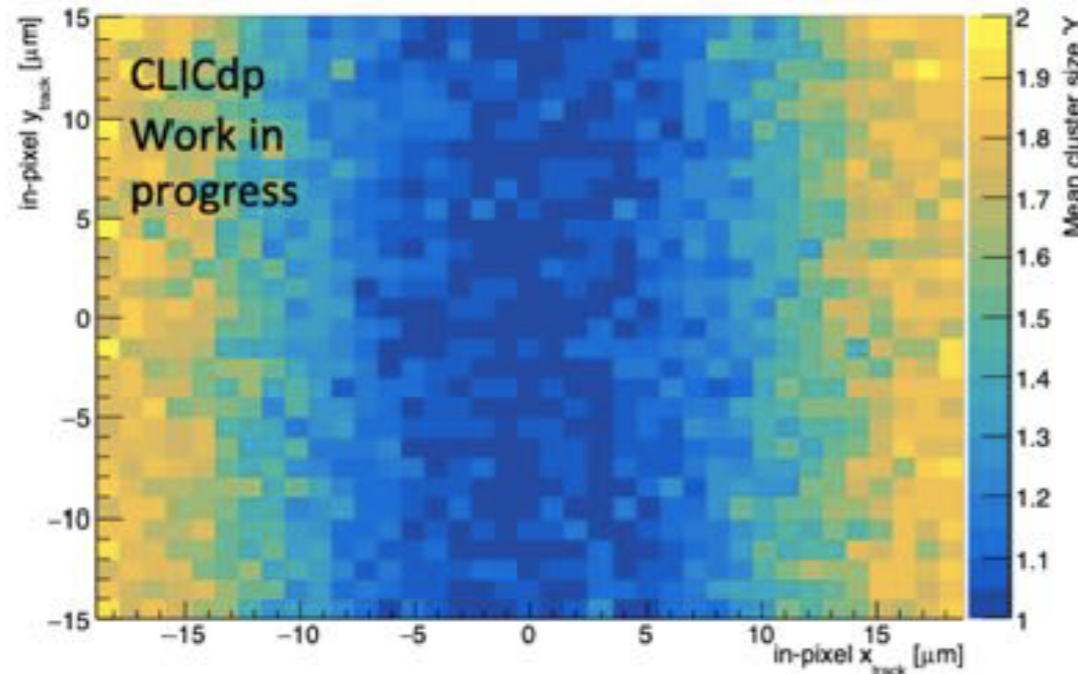
- **Disclaimer:** error bars shown in simulation and data **do not** include uncertainty on threshold and on the cluster size ratio in y
- Deviation between data and simulation within the (statistical) errors
- Cluster size in y matches very well since cluster size ratio in y was used for tuning
- Not yet understood why only one spatial dimension matches very well while the other is off (but may not be significant taking the errors into account)



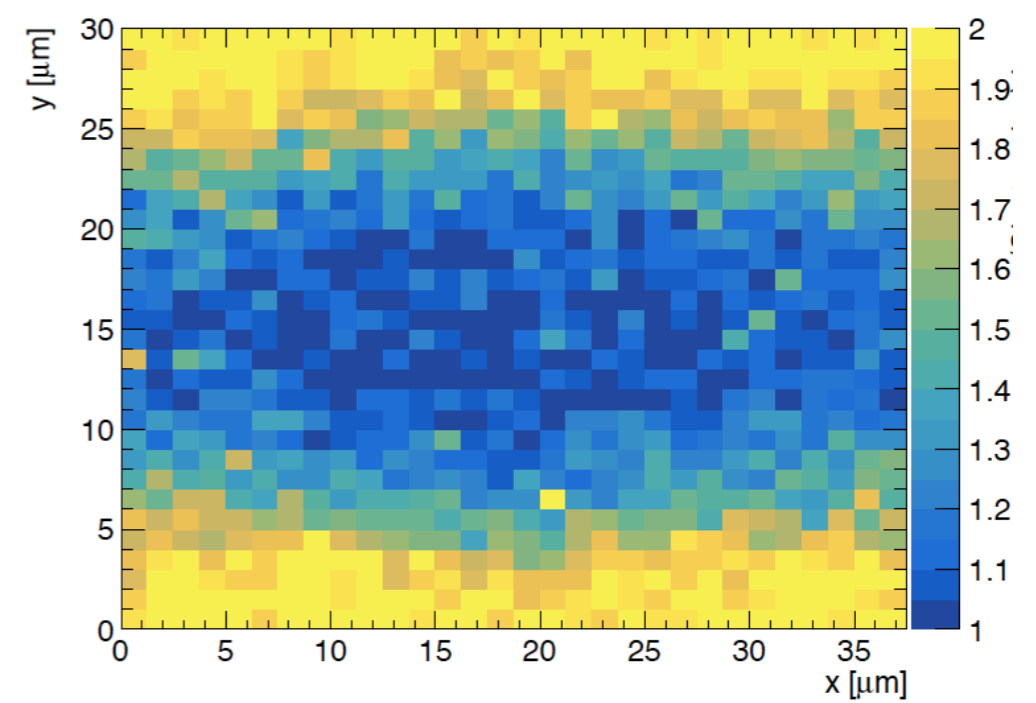
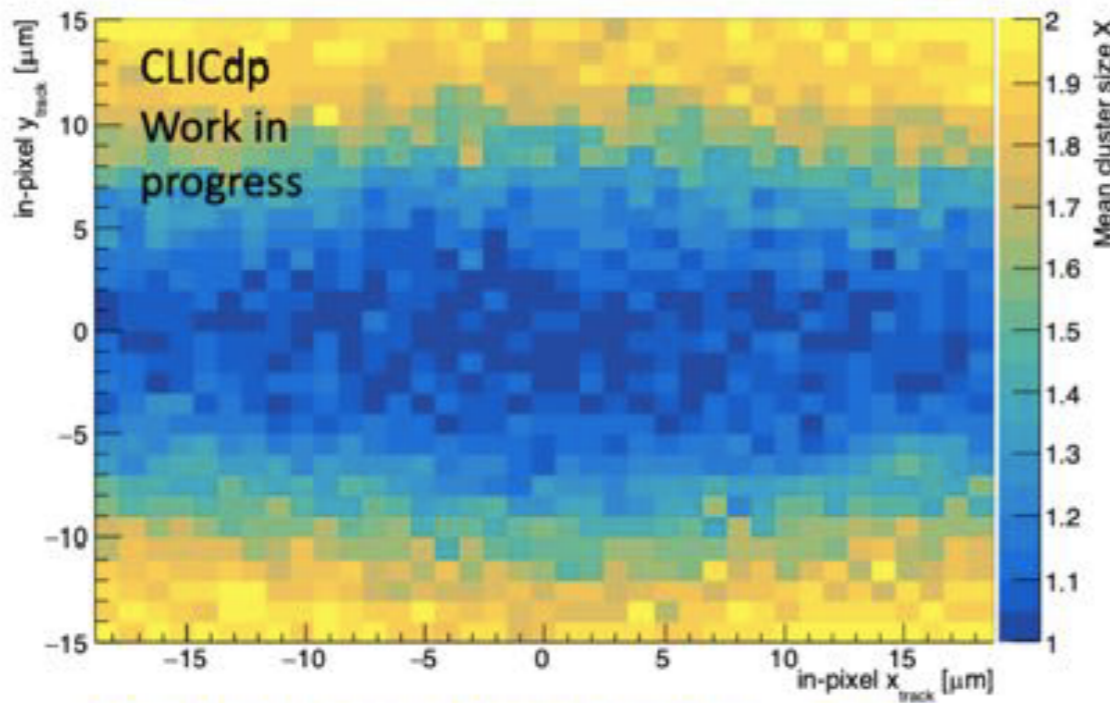
COMPARISON TO TEST-BEAM DATA: CLUSTER SIZE



Cluster size in x



Cluster size in y

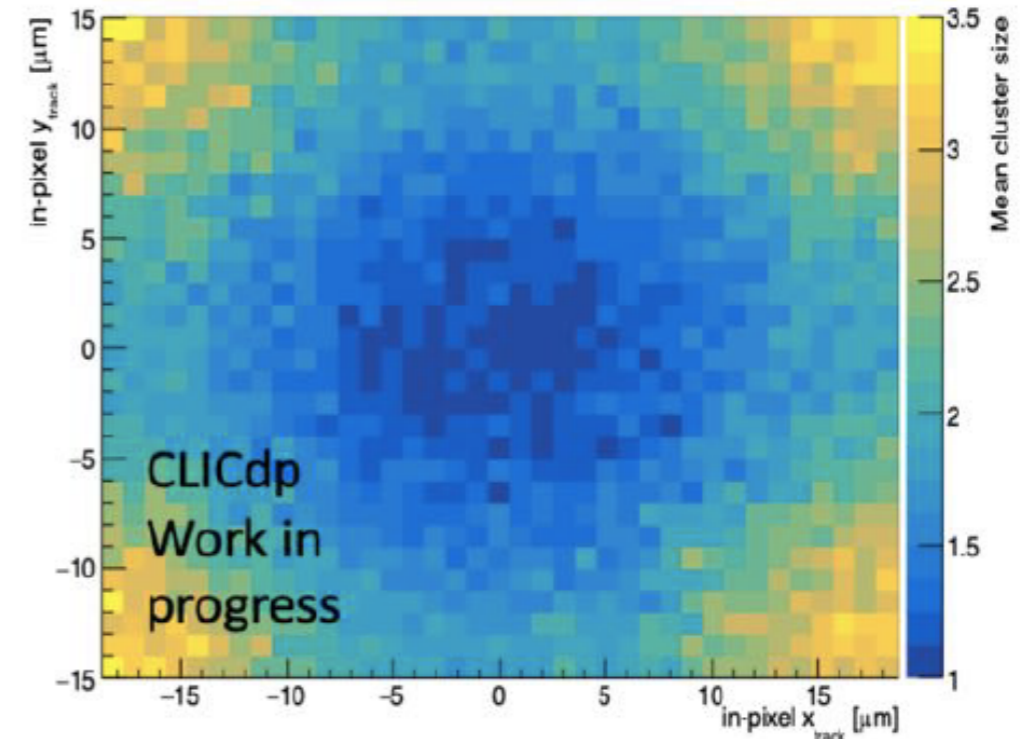


- For in-pixel plots: track resolution was modeled by a Gaussian with a sigma of 2.2 μm

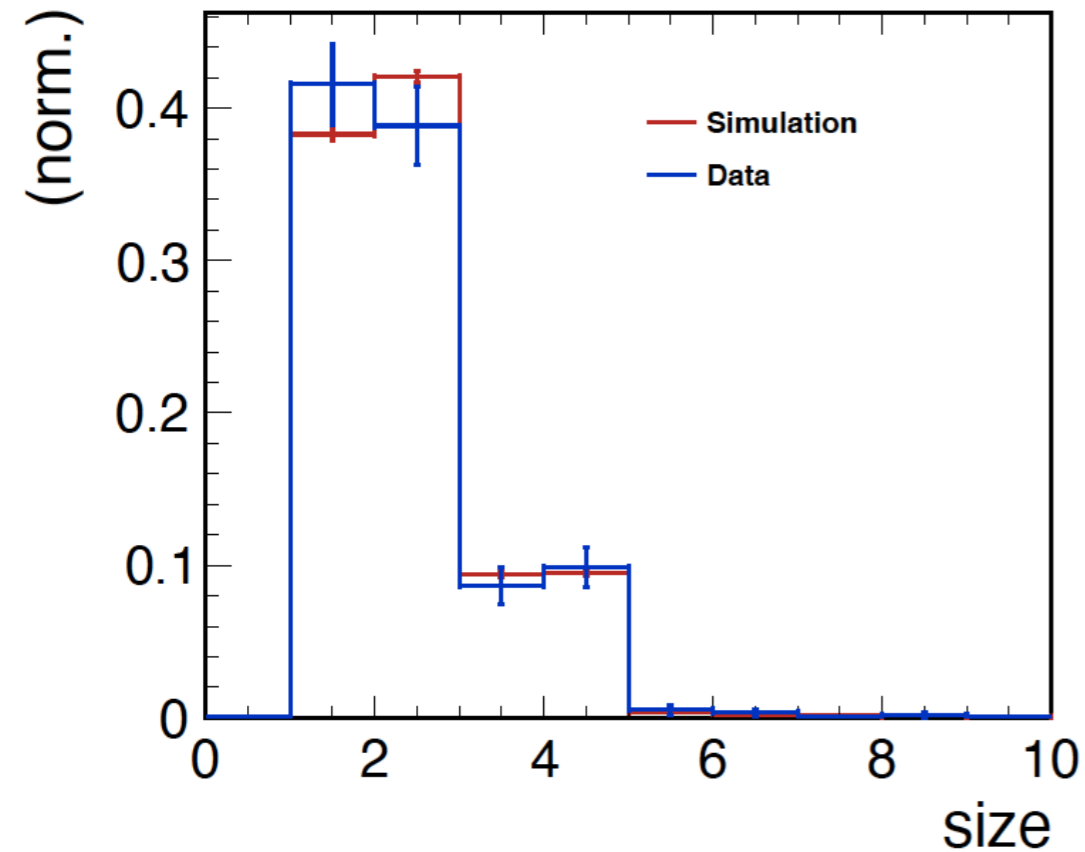
COMPARISON TO TEST-BEAM DATA: CLUSTER SIZE

- Deviation for small cluster sizes (however still in error bars!)
- Most likely, deviations in total size can be traced back to the slight mismatch in cluster size in x

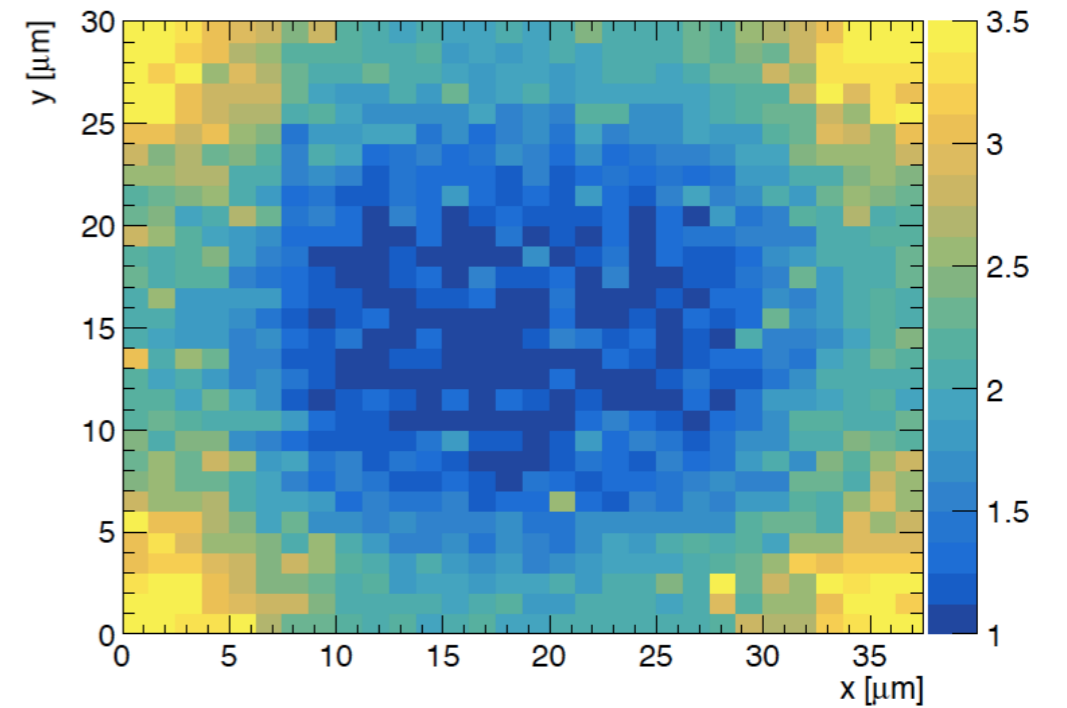
Data



A1 / -6V / -6V @170e

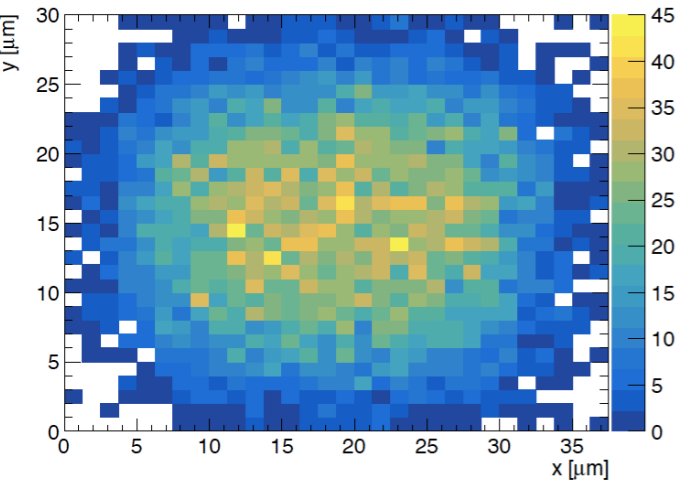


Simulation

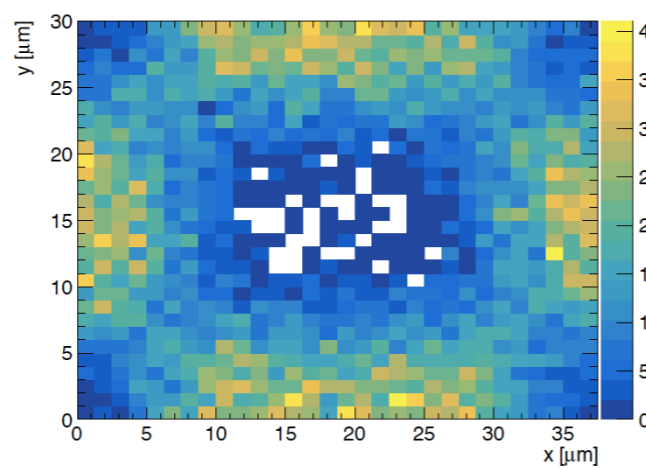


Simulation

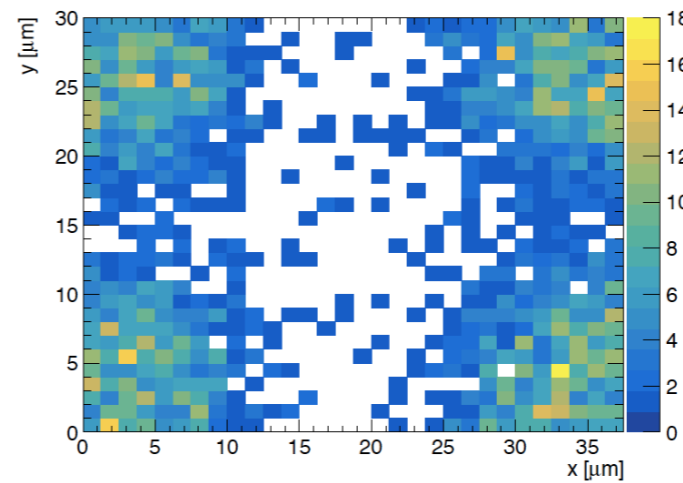
1-pixel cluster



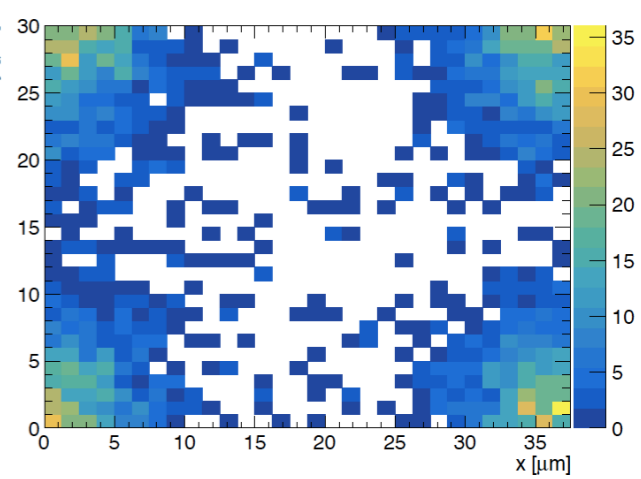
2-pixel cluster



3-pixel cluster

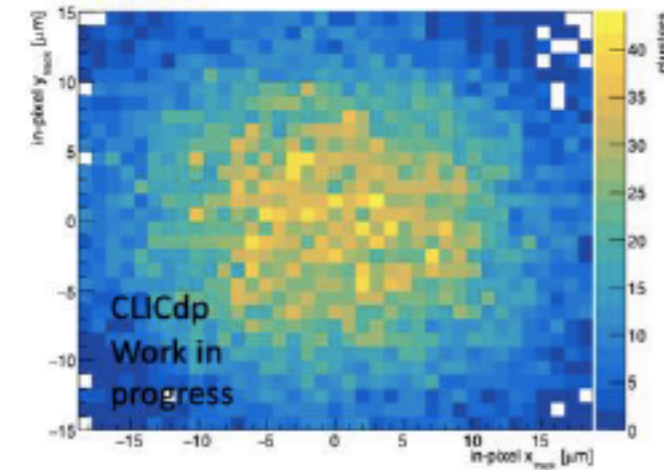


4-pixel cluster

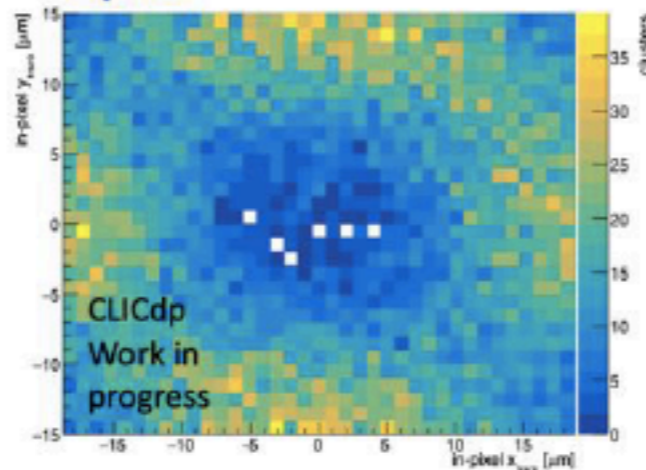


Data

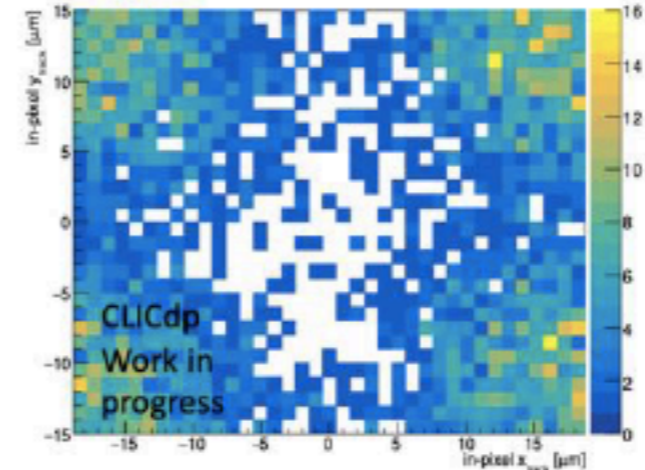
1-pixel clusters:



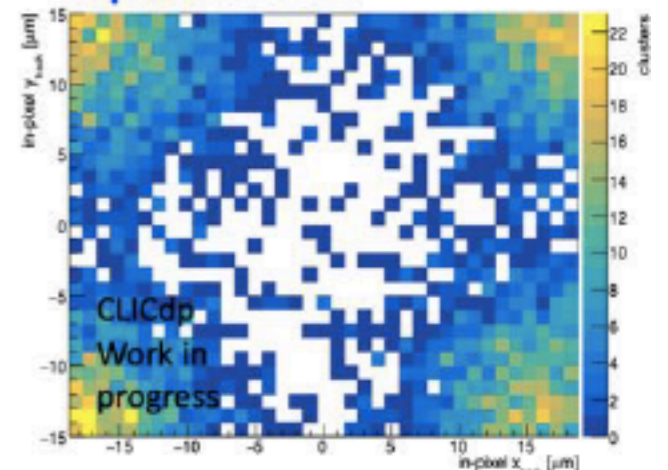
2-pixel clusters:



3-pixel clusters:



4-pixel clusters:

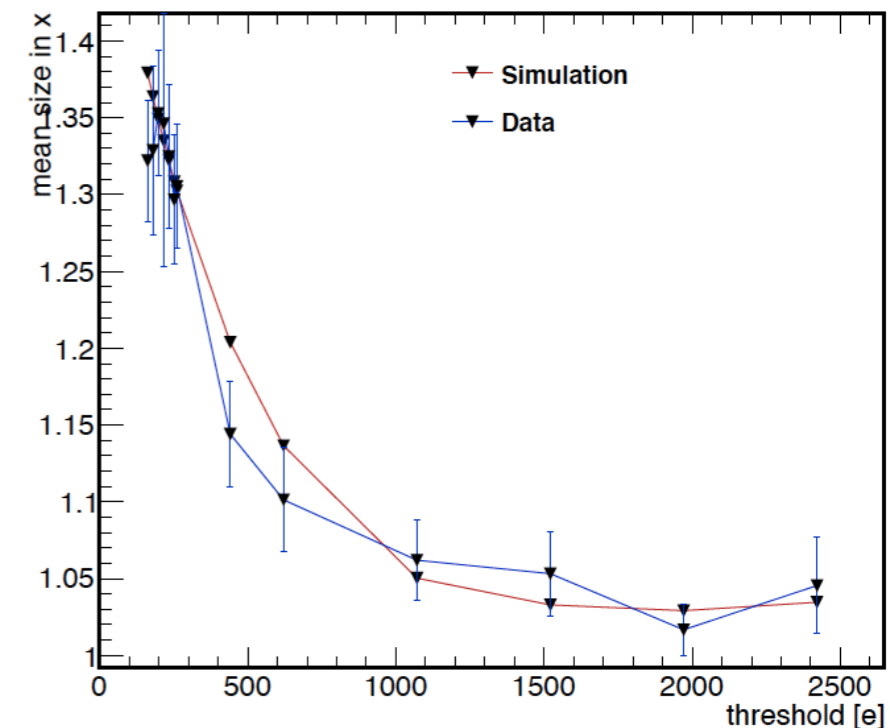
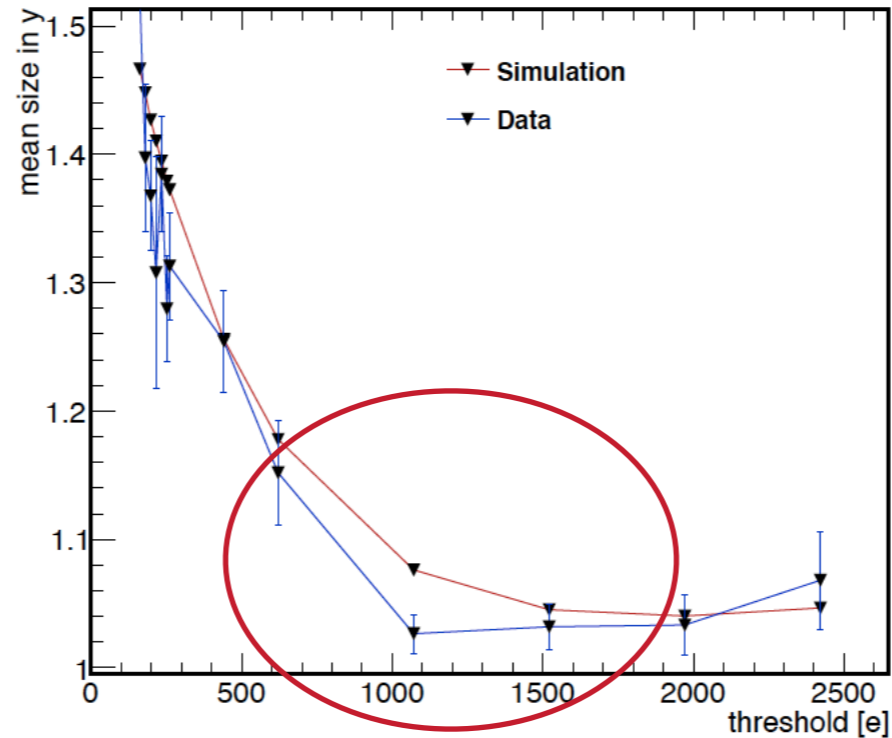
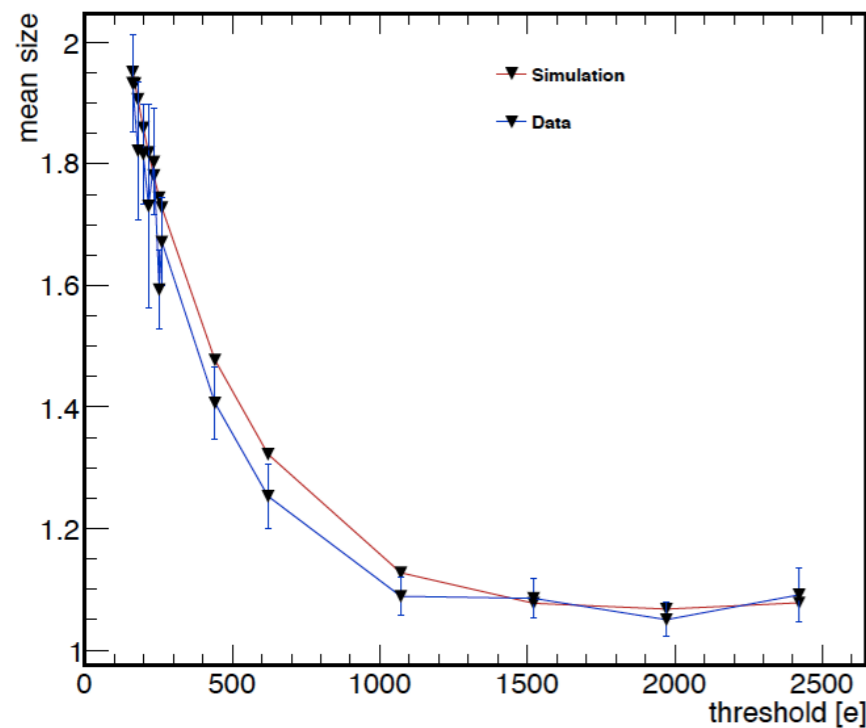


- Deviation from cluster size 1 in the pixel edges

COMPARISON TO TEST-BEAM DATA: THRESHOLD SCANS



- For data: large error bars but **more statistics are available** (work in progress)
- **Deviations** at threshold values $\sim 500e - 1500e$ have to be understood
- Tuning could be modified such that the ratio for **more than one threshold** is taken into account





Summary

- APSQ+TCAD simulations are used to characterize CLICTD
- Modified tuning scheme necessary as **tuning against cluster signal not ideal** for CLICTD
 - For now: **tuning against cluster size ratio in y** as indicator for amount of charge sharing

Short-term Outlook

- Include **uncertainty on threshold calibration**
- Using more test-beam data to reduce statistical error
- Check impact of parameters used for **simulation of digitization step** (e.g. threshold dispersion, noise etc.)
- Tuning against **cluster size ratio for more than one threshold**
- Studying at **other process variant + lower bias voltages**

Thank you!