

UPDATED CALIBRATION FOR CLICPIX2+PLANAR ASSEMBLIES

Vertex and tracking meeting

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29/5/2020

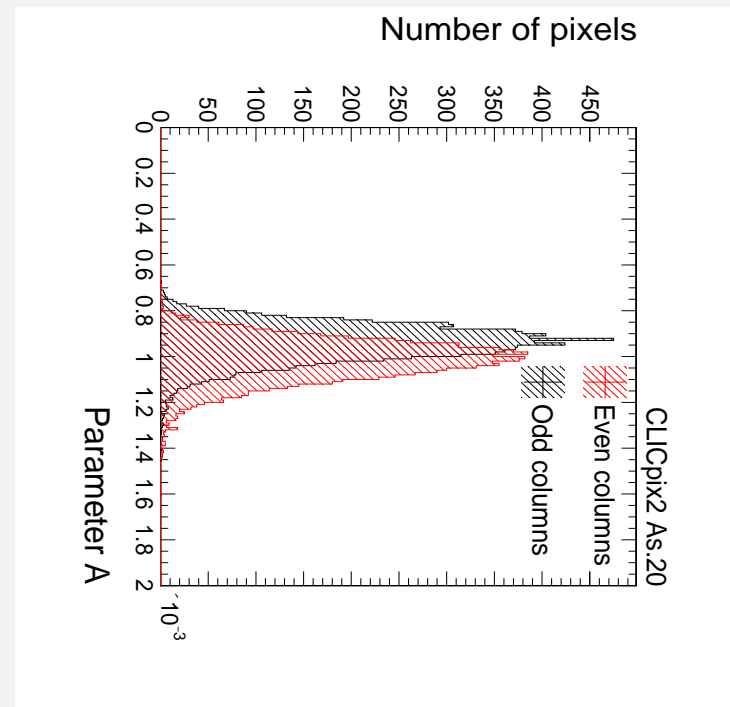
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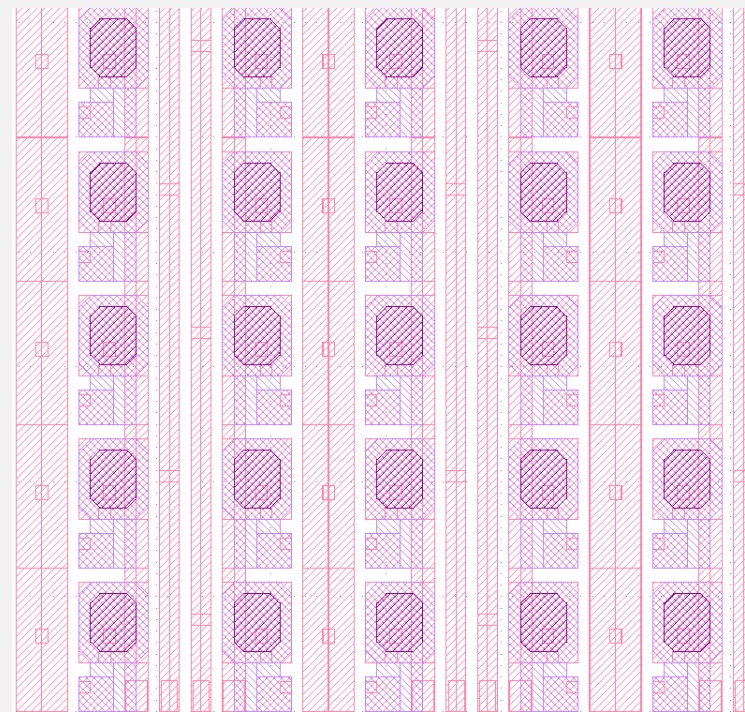
INTRODUCTION

- Discussed last meeting (5/5/2020) the differences in capacitance seen between odd and even columns of CLICpix2+planar assemblies during calibration.
- Surrogate function parameters of the ToT calibration curves had a clear systematic differences.



INTRODUCTION

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- Surrogate function parameters of the ToT calibration curves had a clear systematic differences.
- Difference due to the mirrored column design of the ASIC.
- Suggestion: try pixel-by-pixel threshold calibration



Top metal layer of CLICpix2 ASIC

I) THRESHOLD CALIBRATION FOR ODD AND EVEN COLUMNS

Aim to convert threshold units from THL DAC to electrons.

Original threshold calibration procedure:

- X-ray fluorescence measurements using copper and iron targets are used
- threshold scan can locate the threshold that corresponds to the energy of the fluorescence peak
- graph of energy vs. threshold provides the e/THL DAC calibration constant for the assembly

Updates to this procedure:

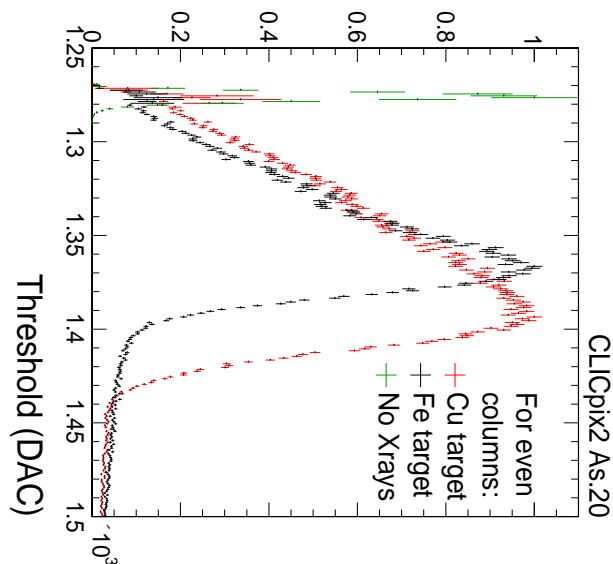
- Initial idea was pixel-by-pixel determination of the fluorescence peak position of each target
 - unfortunately not enough statistics in the data set
- Good compromise is to determine the threshold of the fluorescence peaks separately for odd and even columns

Top row: histogram of counts vs. threshold for copper and iron target.

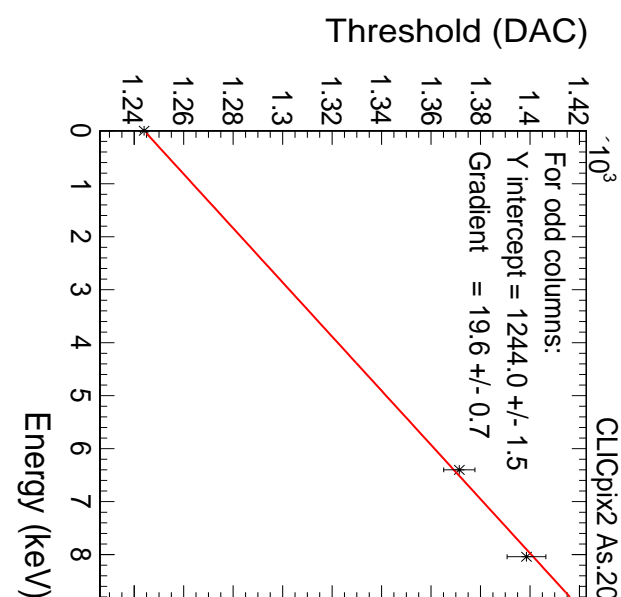
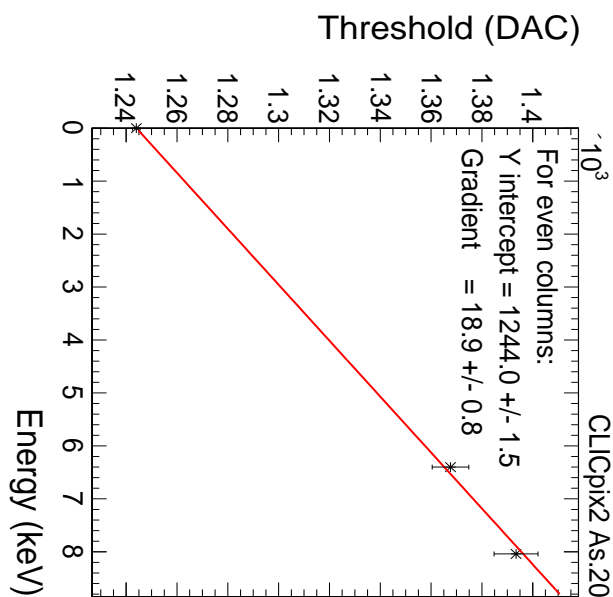
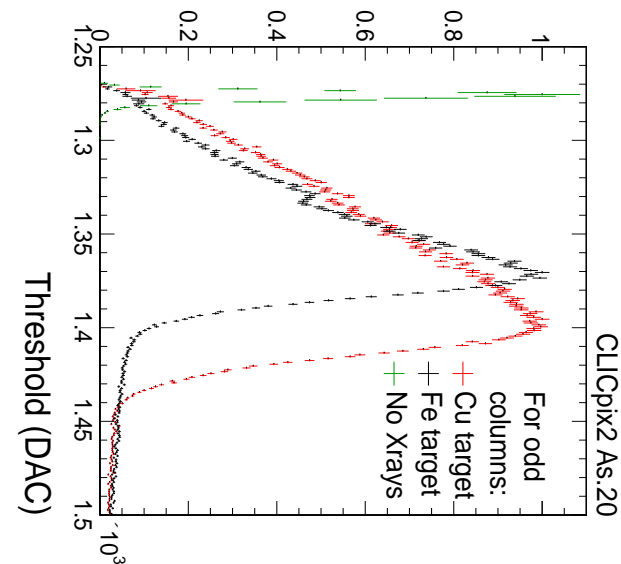
Note that only single pixel clusters are taken into account in this analysis.

Gaussian fit to high-threshold range of peak used to find the corresponding threshold.

Normalised counts of single pixels



Normalised counts of single pixels

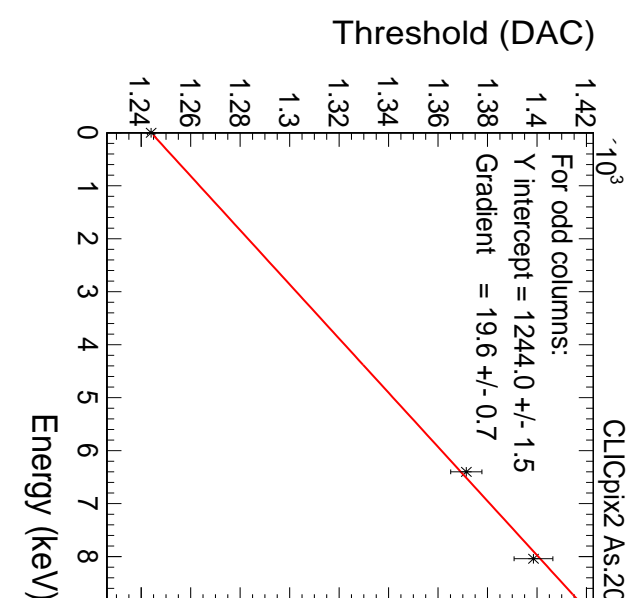
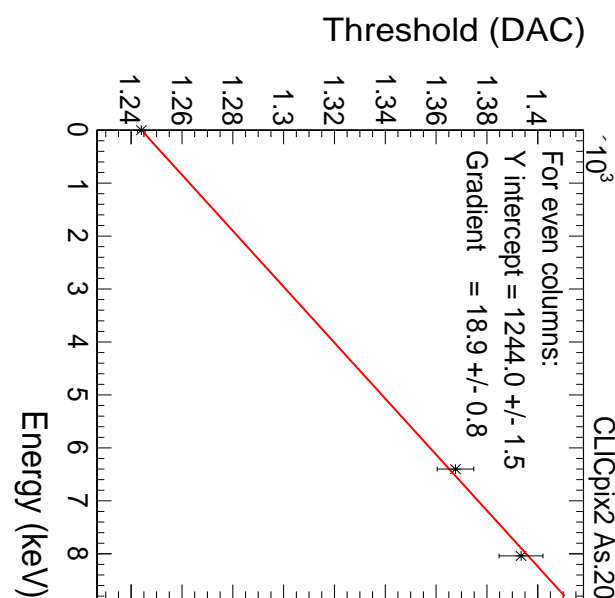
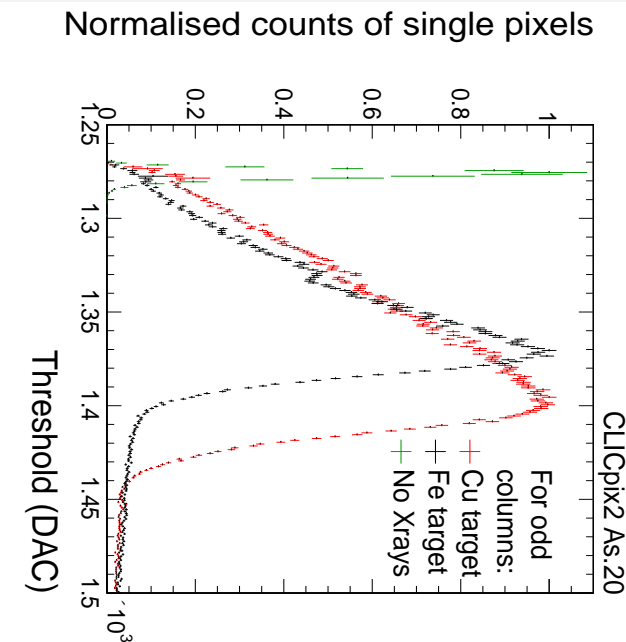
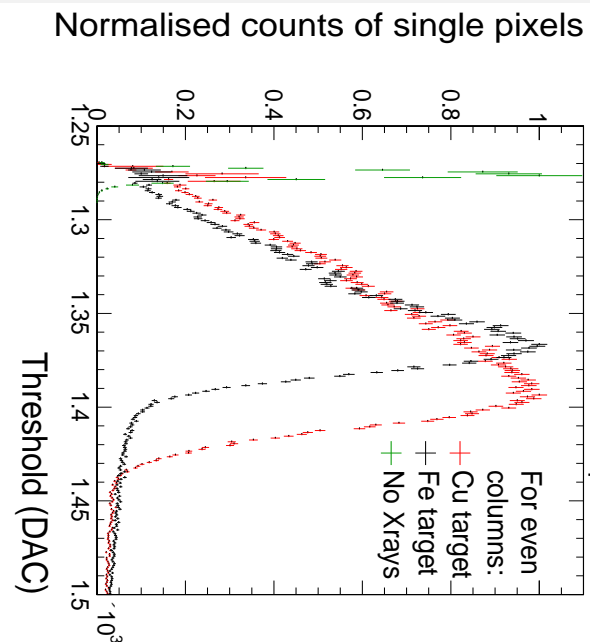


	Even	Odd
Copper	1393	1399
	± 17 THL DAC	± 16 THL DAC
Iron	1368	1371
	± 14 THL DAC	± 13 THL DAC

Gaussian fit to high-threshold range of peak used to find the corresponding threshold.

Bottom row: linear fit to the points corresponding to the target materials and the baseline.

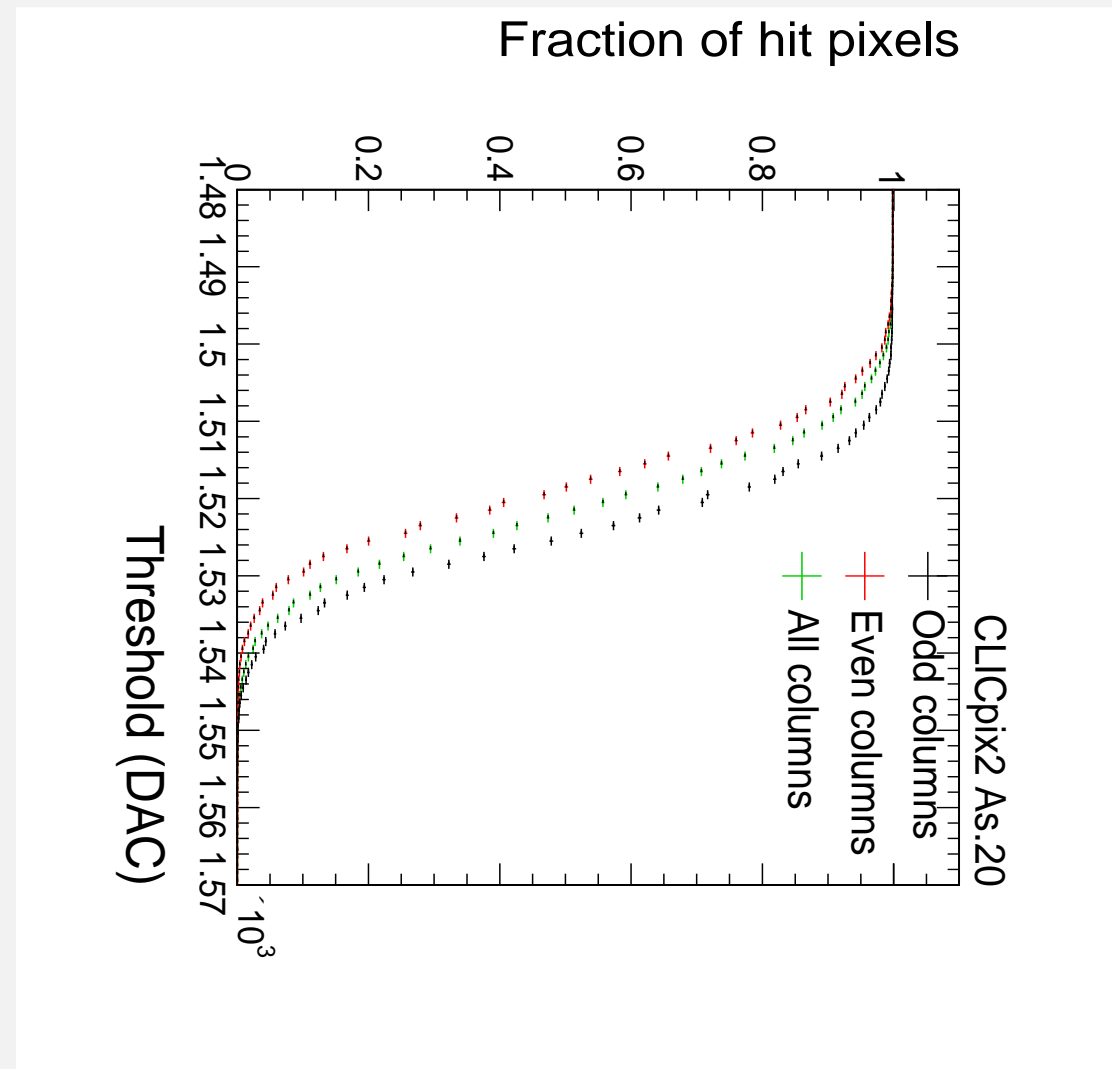
Gradient = e/THL DAC calibration factor.



	Even	Odd
Copper	1393	1399
	± 17 THL DAC	± 16 THL DAC
Iron	1368	1371
	± 14 THL DAC	± 13 THL DAC
Gradient	18.9	19.6
	± 0.8 e/THL DAC	± 0.7 e/THL DAC

2) TOT CALIBRATION: E/VM AND CAPACITANCE

- For CLICpix2 ToT calibration, utilise results of the threshold calibration, therefore this also needs to be updated.
- Threshold calibration used to calculate the capacitance of the test pulse capacitor and an electrons per millivolt conversion factor.
- Procedure:
 - for fixed test-pulse height, perform a threshold scan
 - plot fraction of hit pixels vs. threshold
 - fit Gauss error function to this s-curve
 - mean of the fit provides the threshold δ corresponding to the test-pulse height used

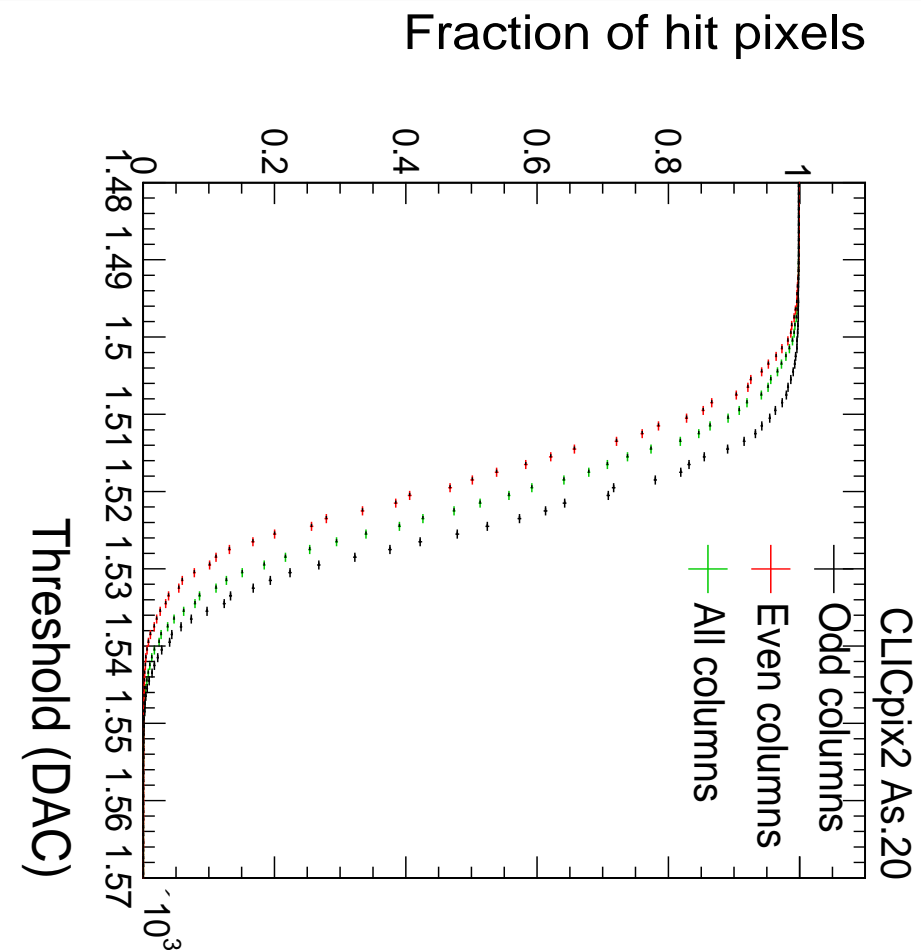


2) TOT CALIBRATION: E/VM AND CAPACITANCE

- Update: use separate curves for odd and even columns and appropriate e/THL DAC factor in calculations

$$\begin{aligned} \text{Conversion factor } \left(\frac{e}{mV}\right) &= \frac{n_e * 10^{-3}}{V_{TP}} \\ &= (THL_{mean} - THL_{baseline}) * factor_{e \text{ per } THL} * \frac{10^{-3}}{V_{TP}} \end{aligned}$$

$$\text{Capacitance} = \frac{n_e * Q_e}{V_{TP}}$$

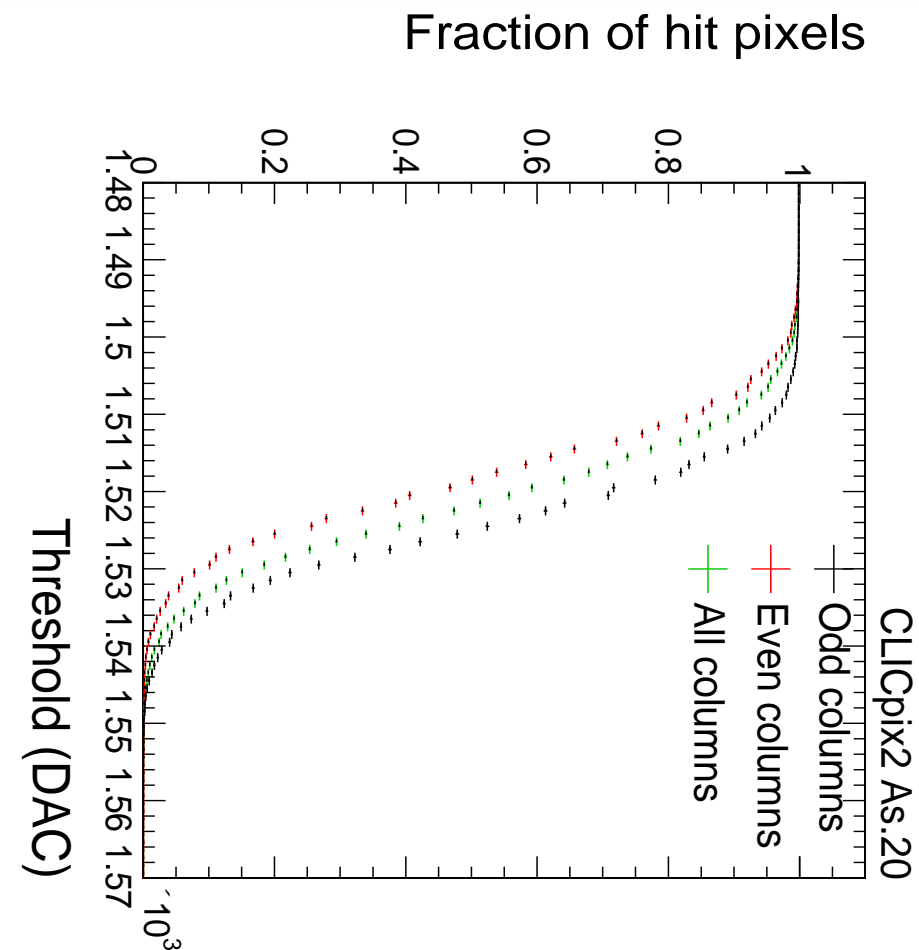


2) TOT CALIBRATION: E/VM AND CAPACITANCE

$$\begin{aligned} \text{Conversion factor } \left(\frac{e}{\text{mV}}\right) &= \frac{n_e * 10^{-3}}{V_{TP}} \\ &= (THL_{\text{mean}} - THL_{\text{baseline}}) * \text{factor}_{e \text{ per THL}} * \frac{10^{-3}}{V_{TP}} \end{aligned}$$

$$\text{Capacitance} = \frac{n_e * Q_e}{V_{TP}}$$

	Even	Odd
S-curve mean	1518	1525
	± 0.078 THL DAC	± 0.086 THL DAC
e/mV factor	64.17	68.24
	± 2.31 e/mV	± 2.87 e/mV
Capacitance	10.28	10.93
	± 0.37 fF	± 0.46 fF

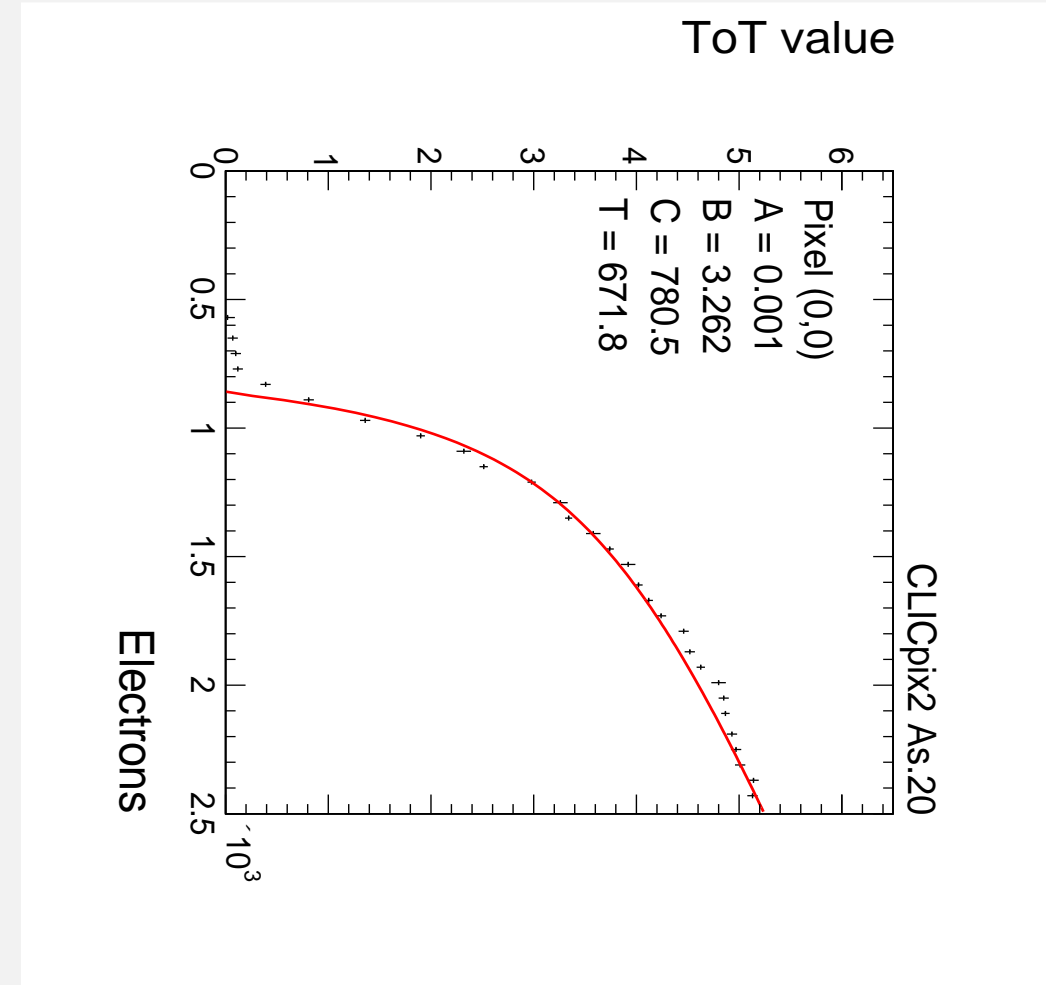
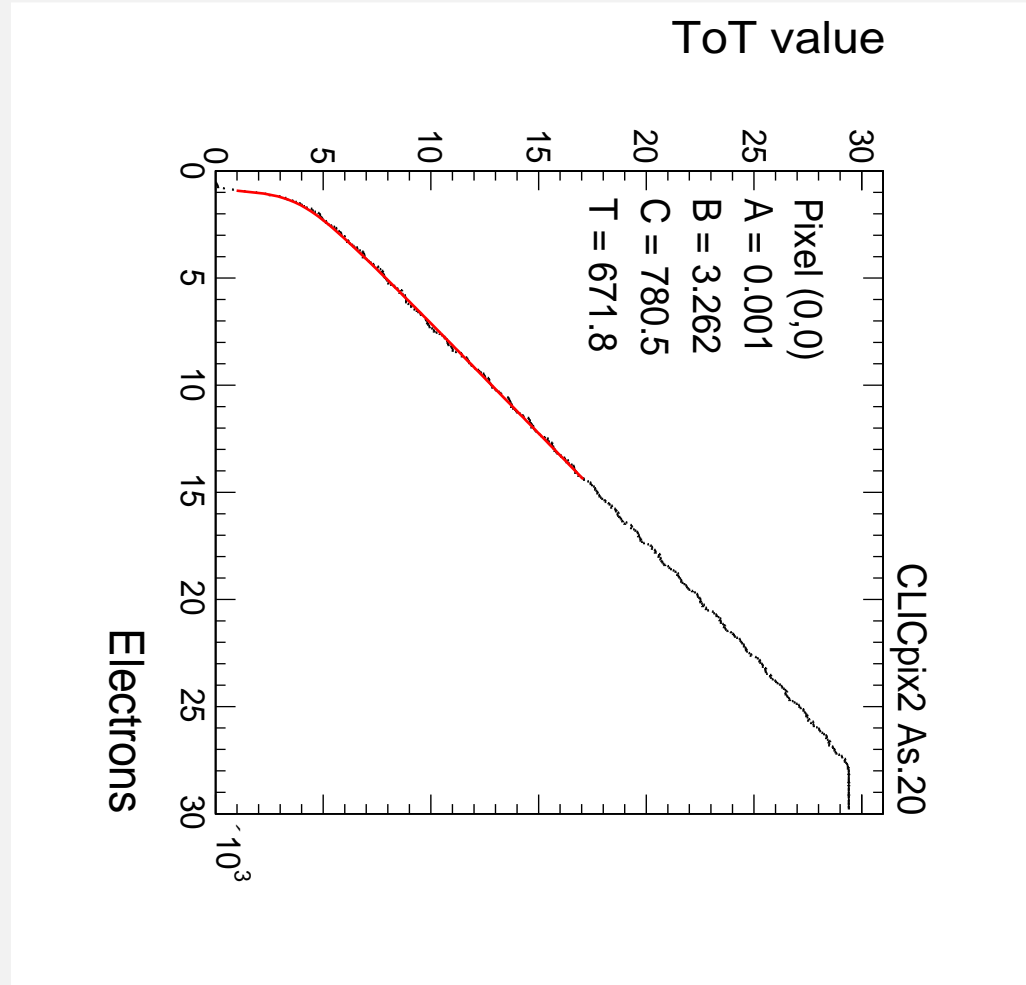


3) TOT CALIBRATION: CALIBRATION CURVES

- For the calibration curves of ToT vs. electrons, use the same procedure as before:
 - for fixed threshold, perform a scan of test-pulse height
 - convert test-pulse height in mV to electrons using conversion factor
 - plot ToT vs. electrons
 - fit surrogate function to parameterise curve
- Update: now use appropriate e/mV conversion factor for odd and even columns.

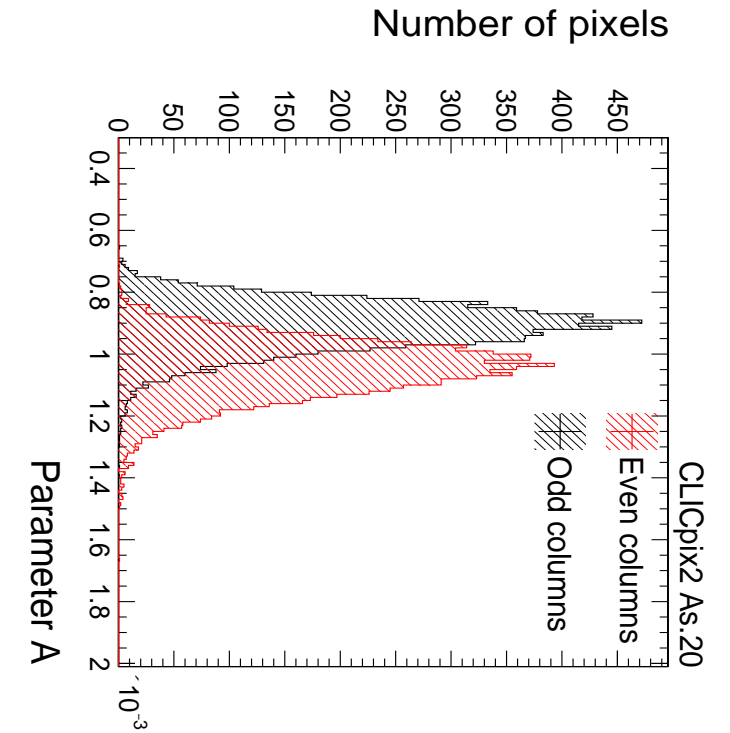
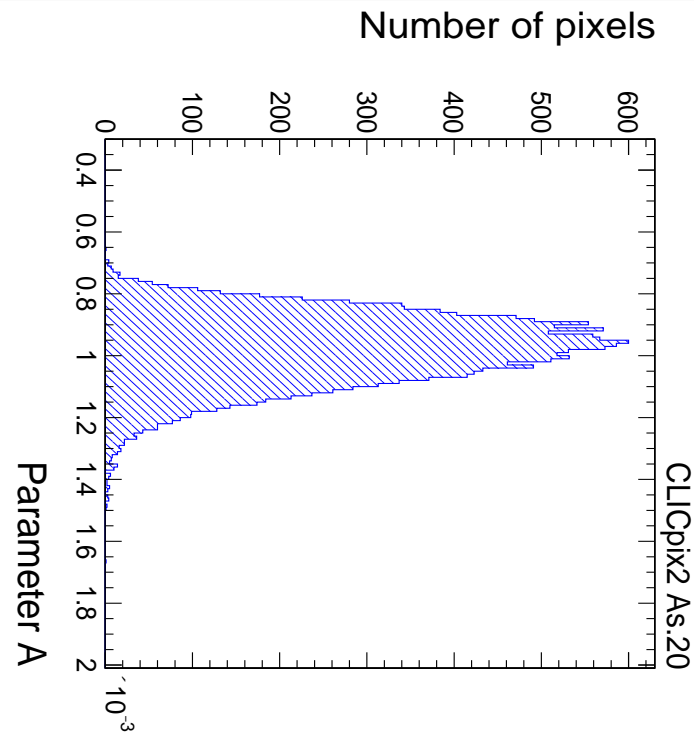
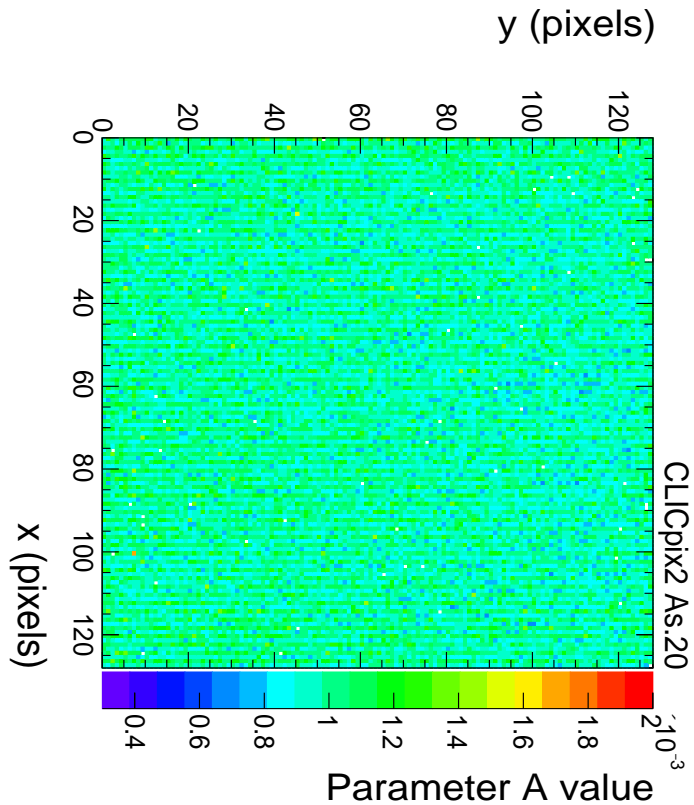
$$\text{surrogate function} = Ax + B - \frac{C}{x - T}$$

- Results: ToT calibration curves still fit the data set well in the linear and low-ToT regions



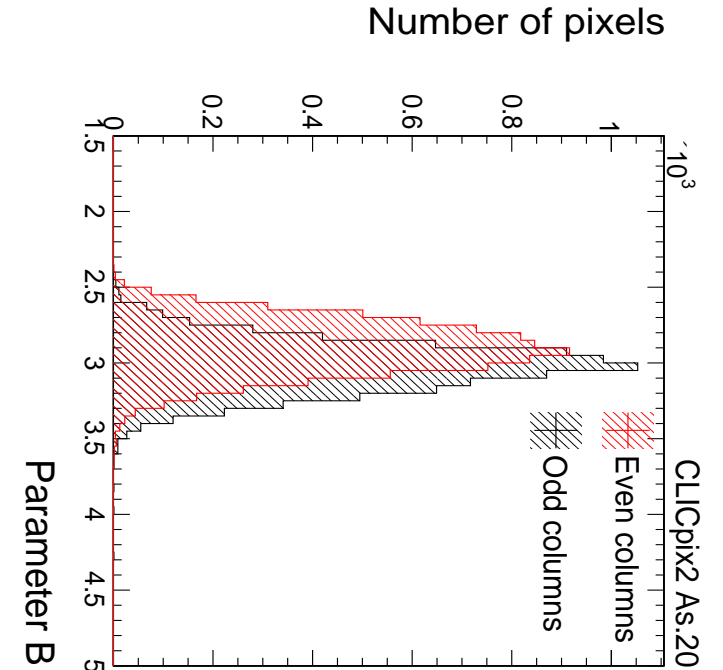
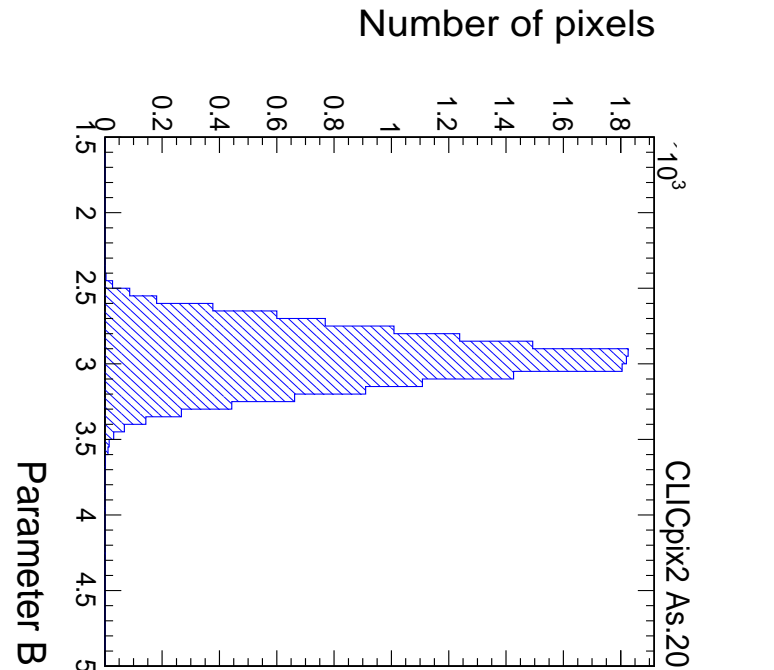
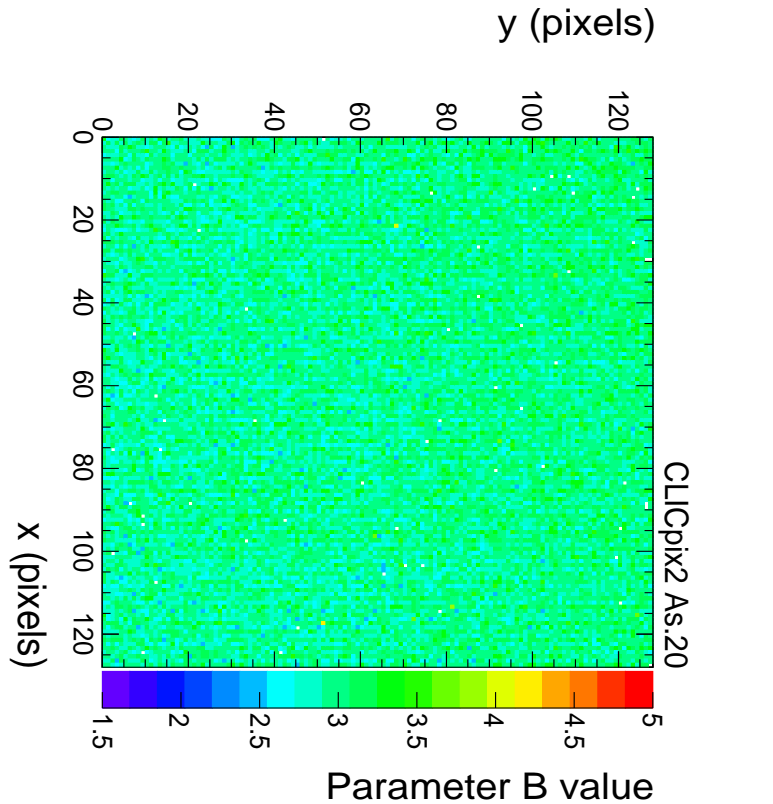
$$\text{surrogate function} \\ = Ax + B - \frac{C}{x - T}$$

- In surrogate function, A parameter describes gradient of the linear region
- See significant difference in this parameter between odd and even columns
- To be expected, since use a different e/mV factor for odd and even columns, increasing the difference in the gradient



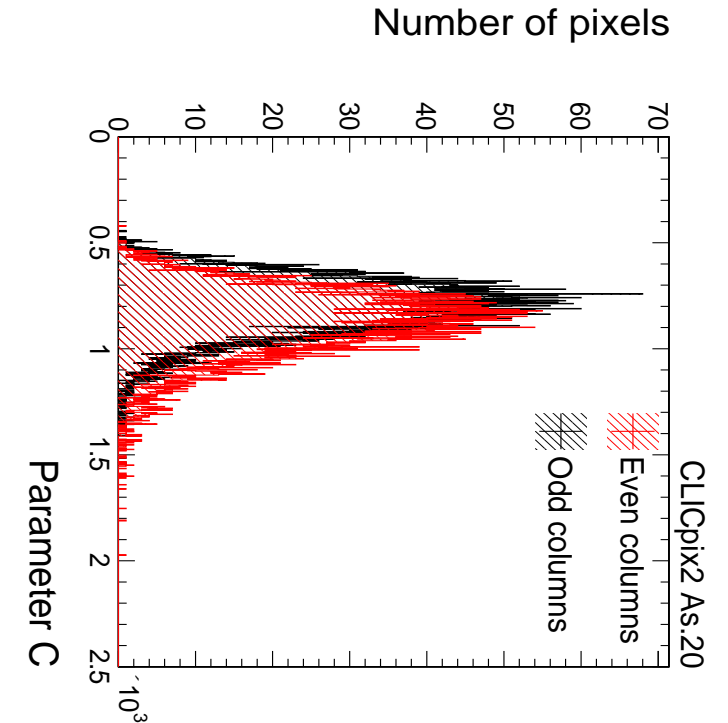
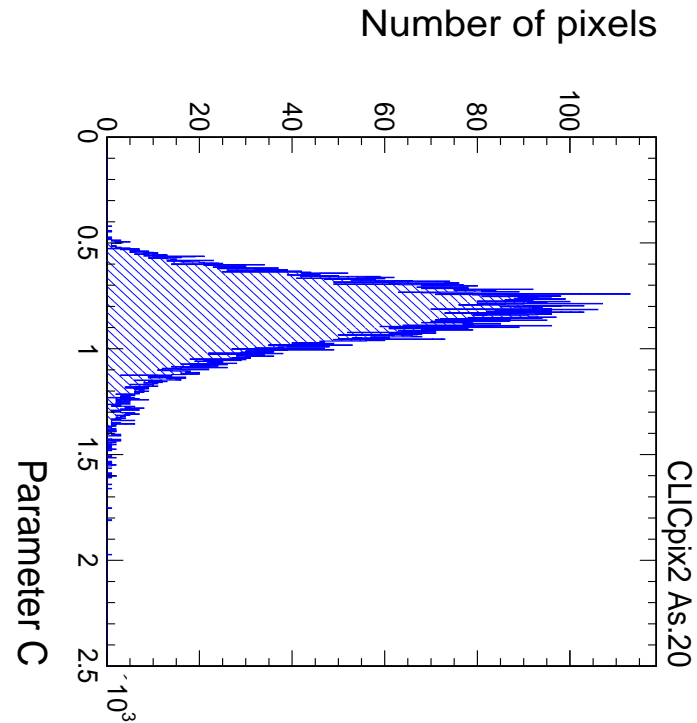
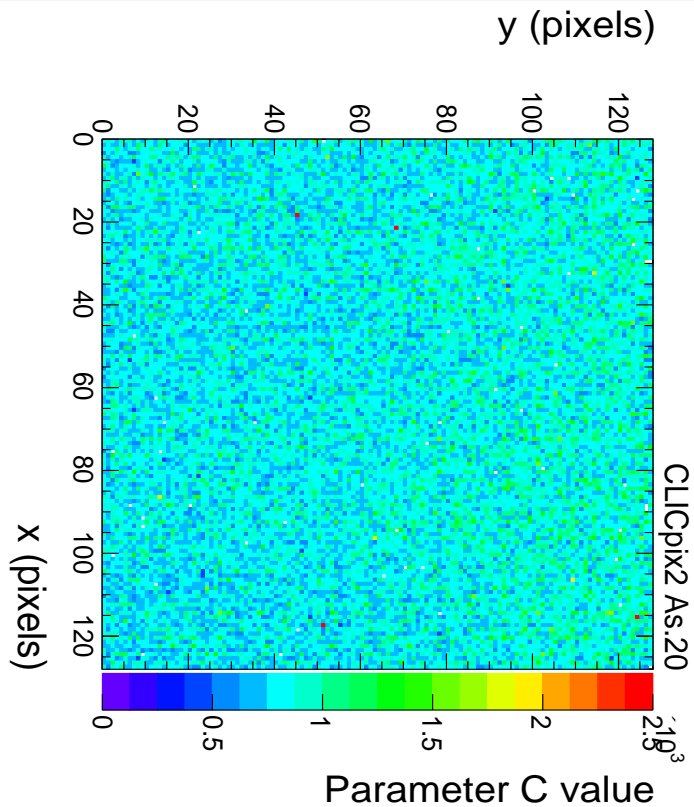
$$\text{surrogate function} \\ = Ax + B - \frac{C}{x - T}$$

- In surrogate function, B parameter describes y intercept of the linear region
- Very similar distributions for odd and even columns



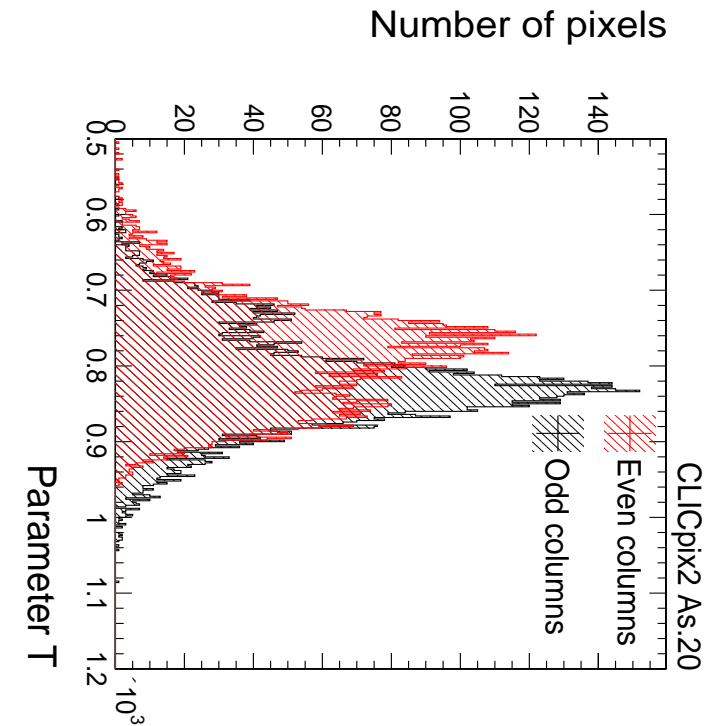
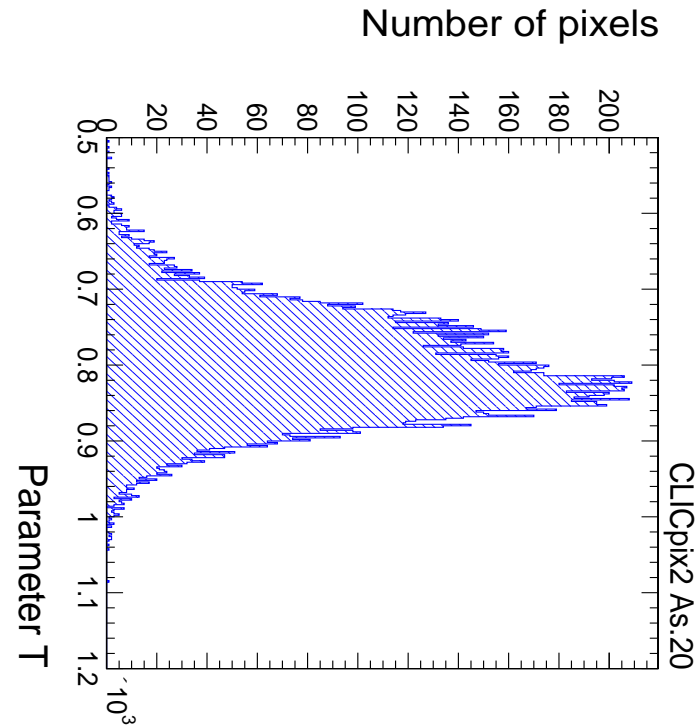
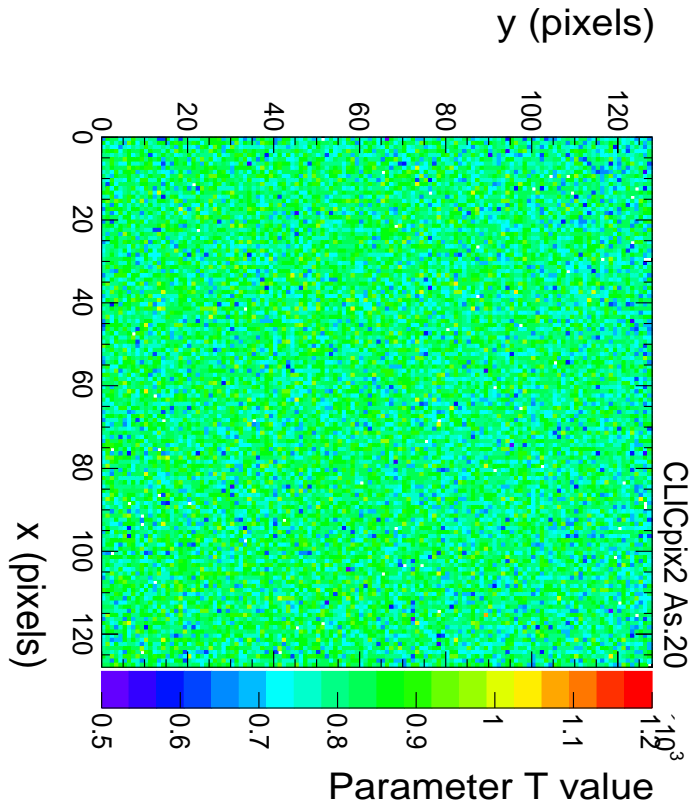
$$\text{surrogate function} \\ = Ax + B - \frac{C}{x - T}$$

- In surrogate function, C parameter describes curvature of the function at low ToT. Hard parameter to constrain, due to low statistics in this range.
- In 2D, see difference in parameter between top and bottom rows of the matrix.
- Still see large spread of values in 1D, with a tail to higher C values.

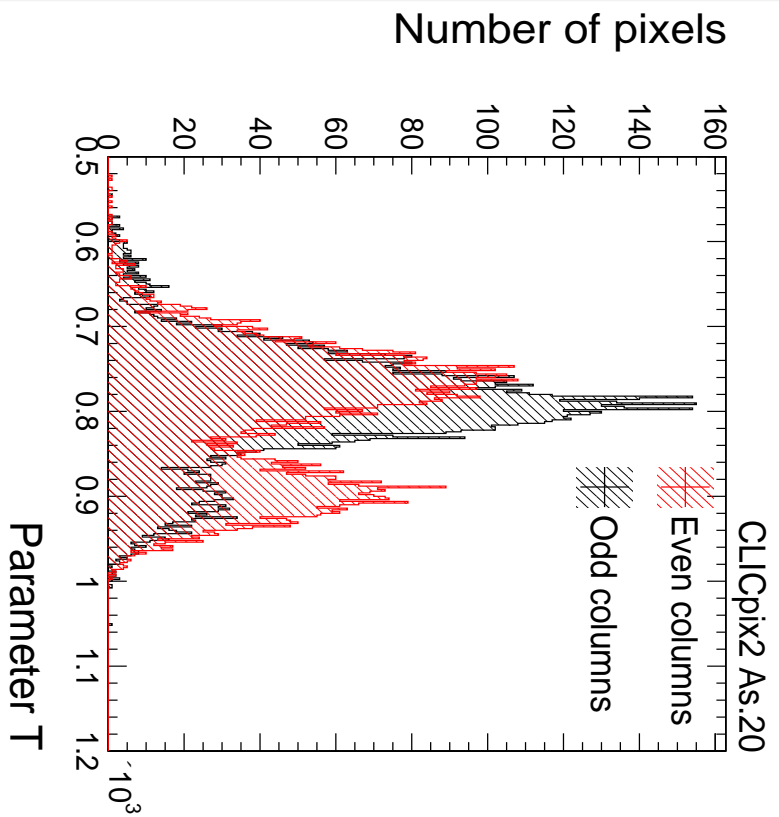


$$\text{surrogate function} \\ = Ax + B - \frac{C}{x - T}$$

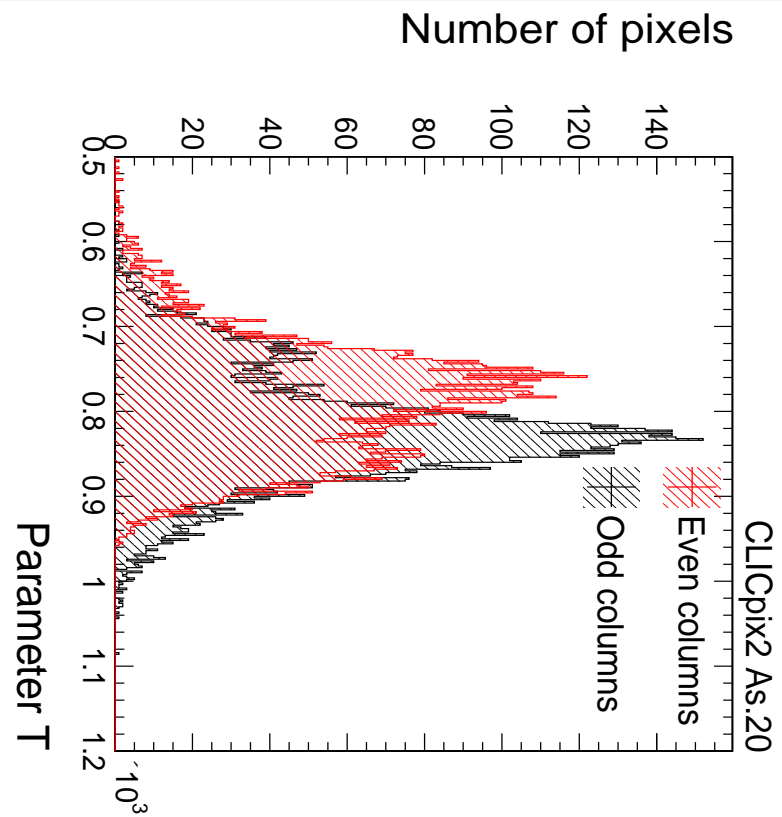
- In surrogate function, T parameter describes x intercept. This is an interesting parameter to constrain as this is the threshold level in electrons.
- See double peaked structure for both odd and even columns



Using 'old' calibration method

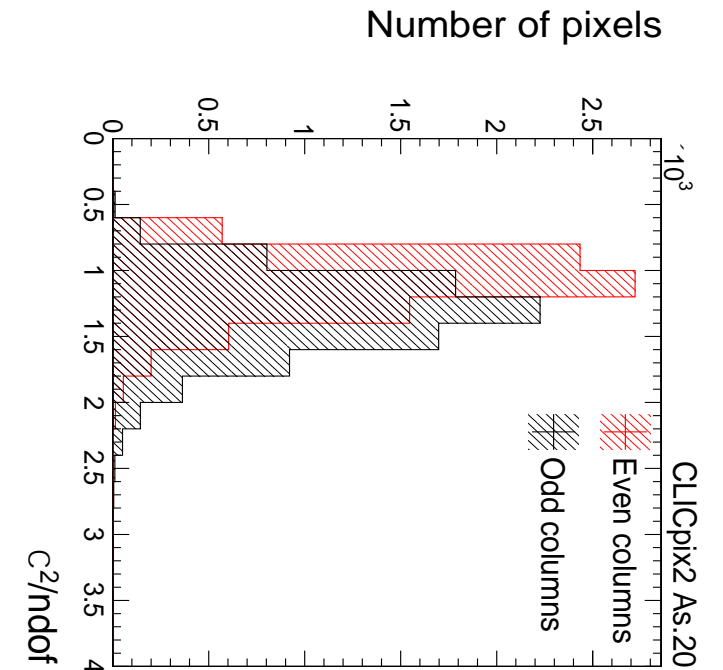
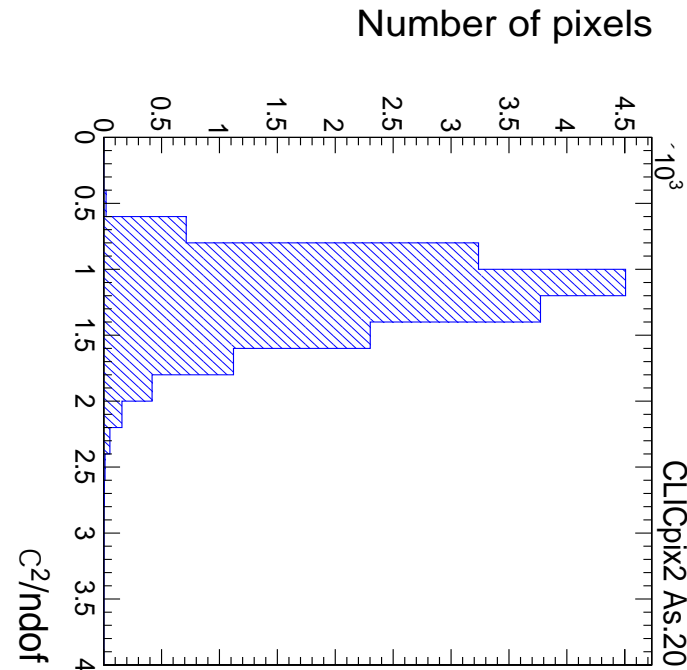
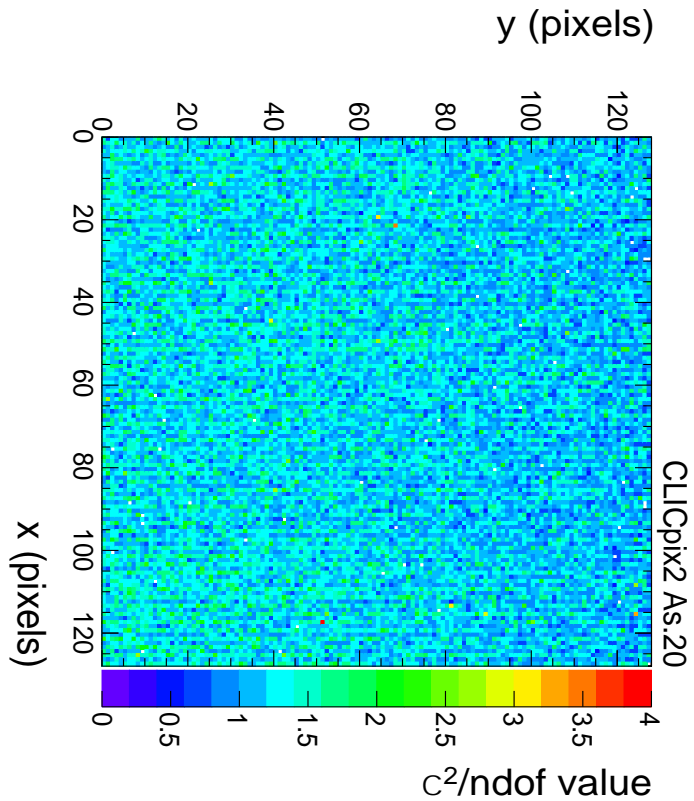


Using separated even-odd column calibration



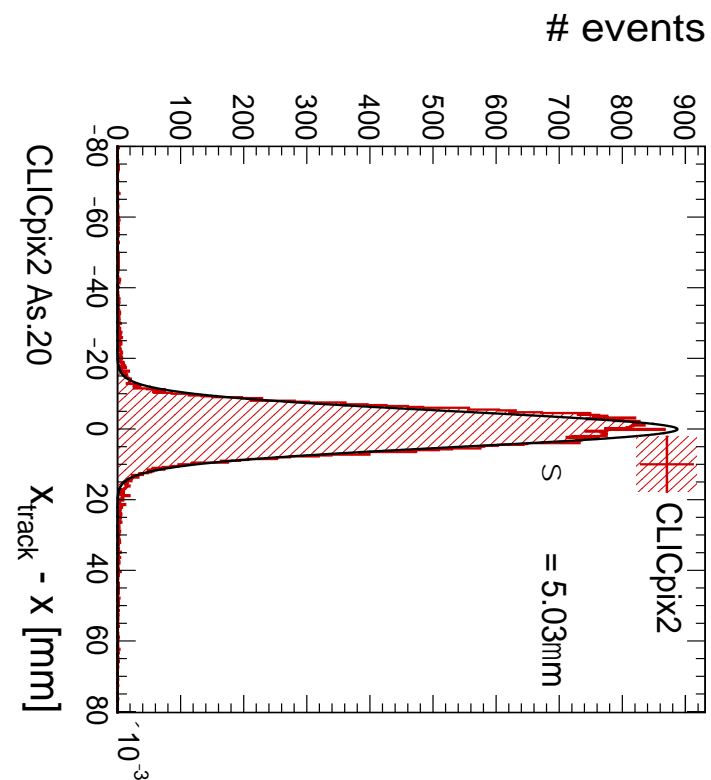
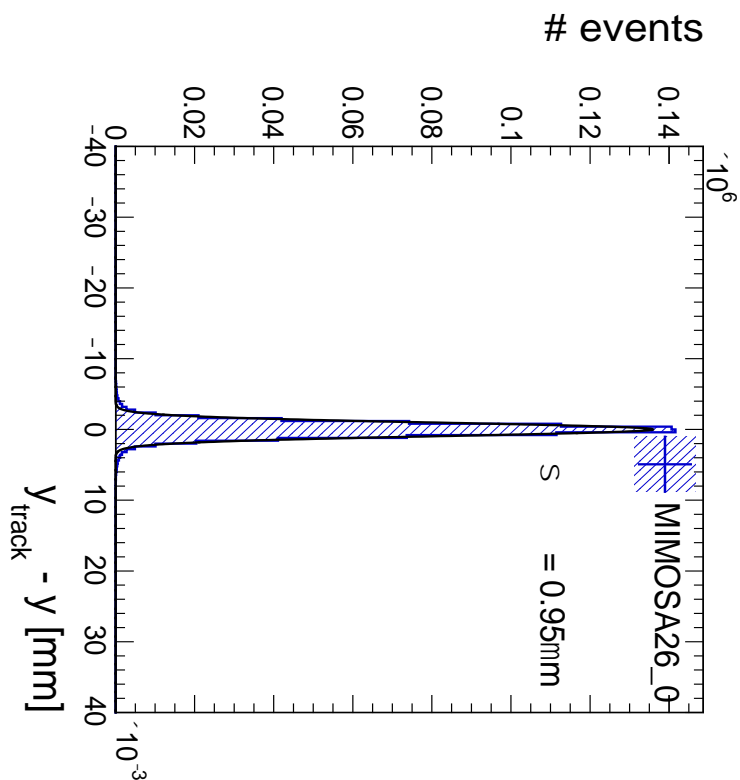
$$\text{surrogate function} \\ = Ax + B - \frac{C}{x - T}$$

- In surrogate function, **B** parameter describes y intercept of the linear region
- In 2D, see more apparent row difference, comparing top and bottom halves of the matrix.
- For both odd and even columns, obtain a χ^2/ndof close to ~ 1



4) TEST-BEAM RESULTS

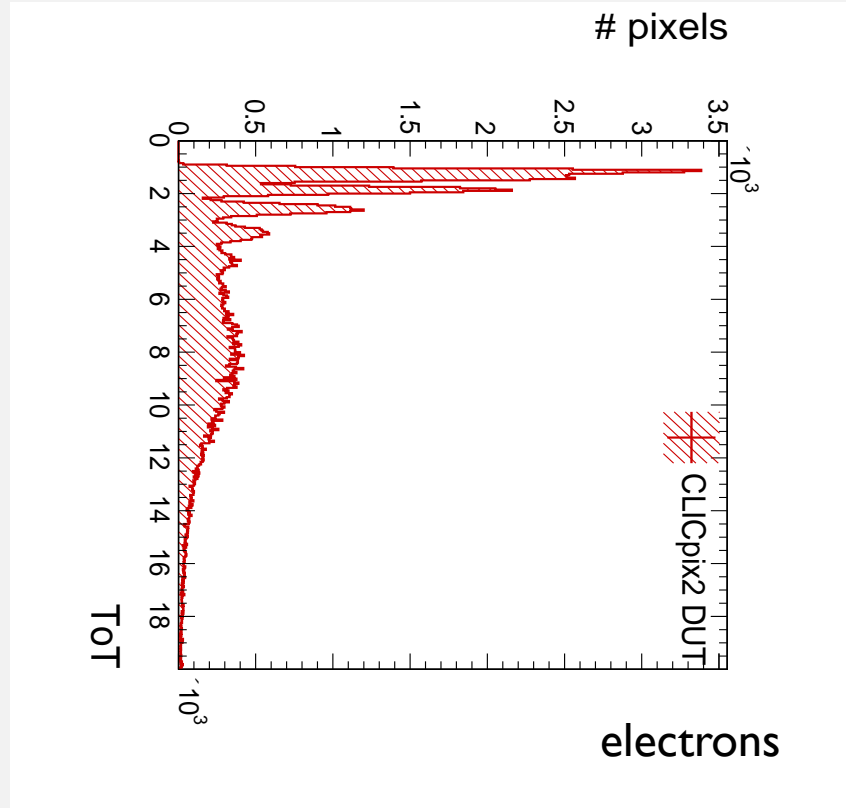
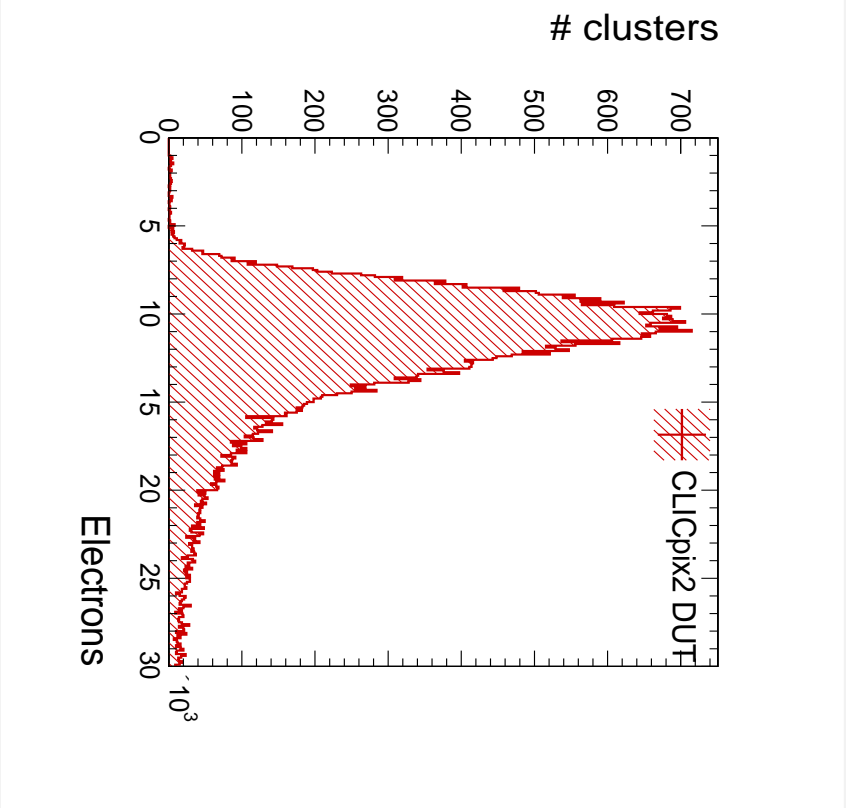
- Re-ran test-beam analysis of DESY data using the new ToT calibration.
- Data from July 2019 test-beam at DESY using assembly 20 (130um sensor) at a bias voltage of -25V and a threshold of ~ 885 electrons.



ASSOCIATED CLUSTER AND PIXEL CHARGE

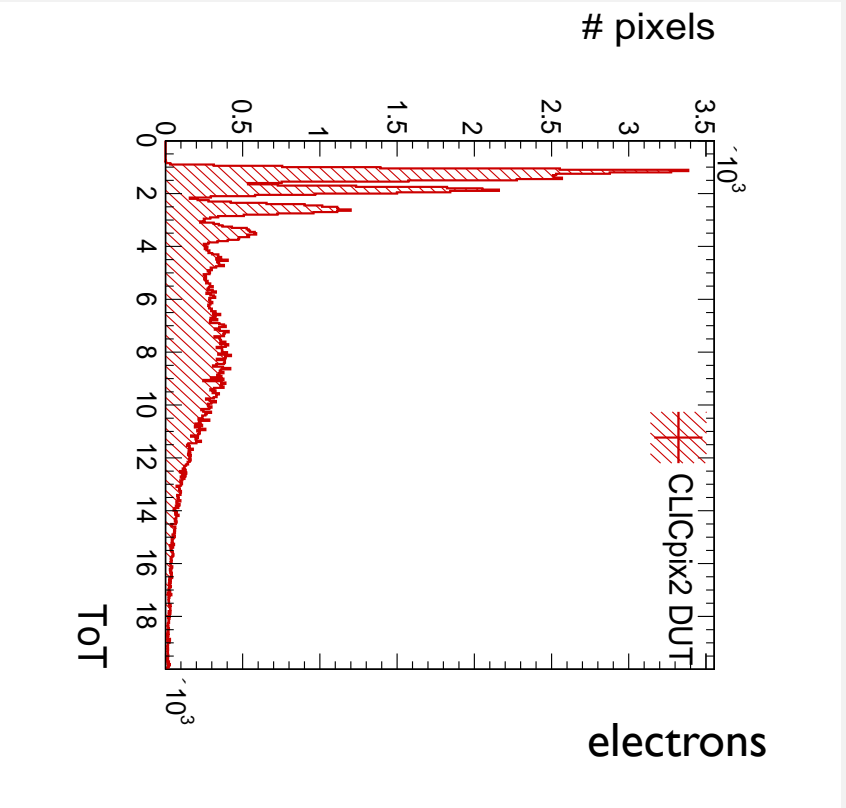
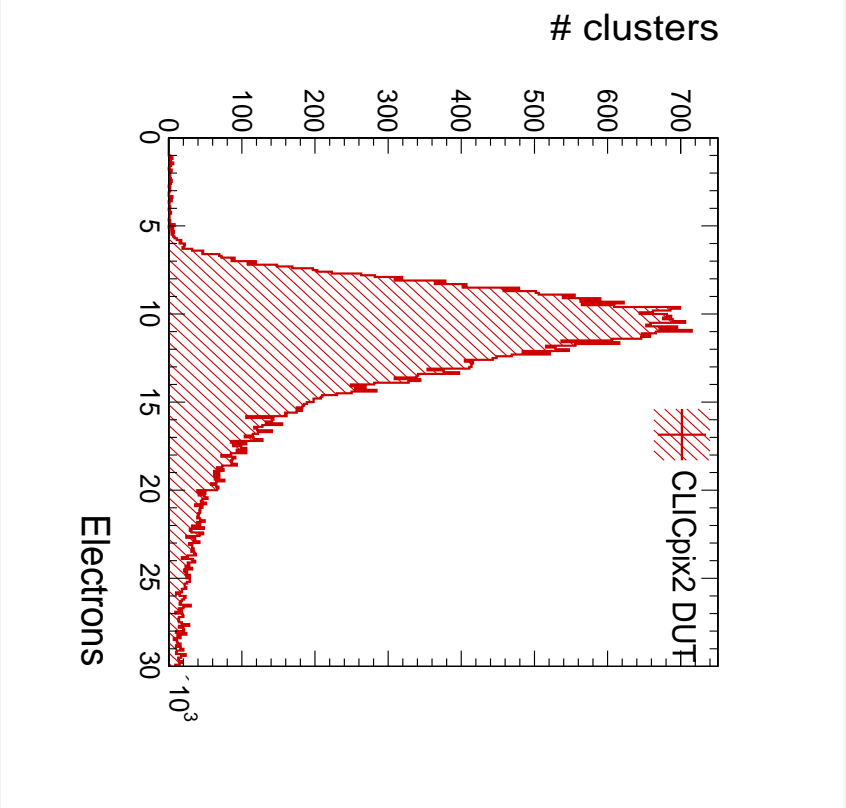
- Associated cluster charge has landau-gauss shape that is expected, peaking around ~10,200 electrons.
- Is this what we expect?

for MIPs, expect ~80 electrons per um of silicon: $80 \times 130\mu\text{m} = 10,400$ electrons



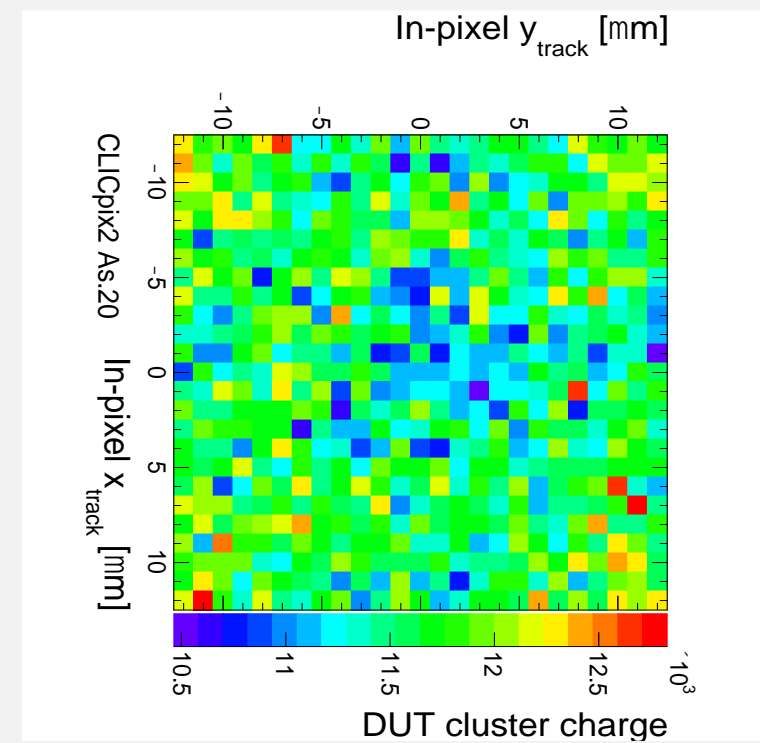
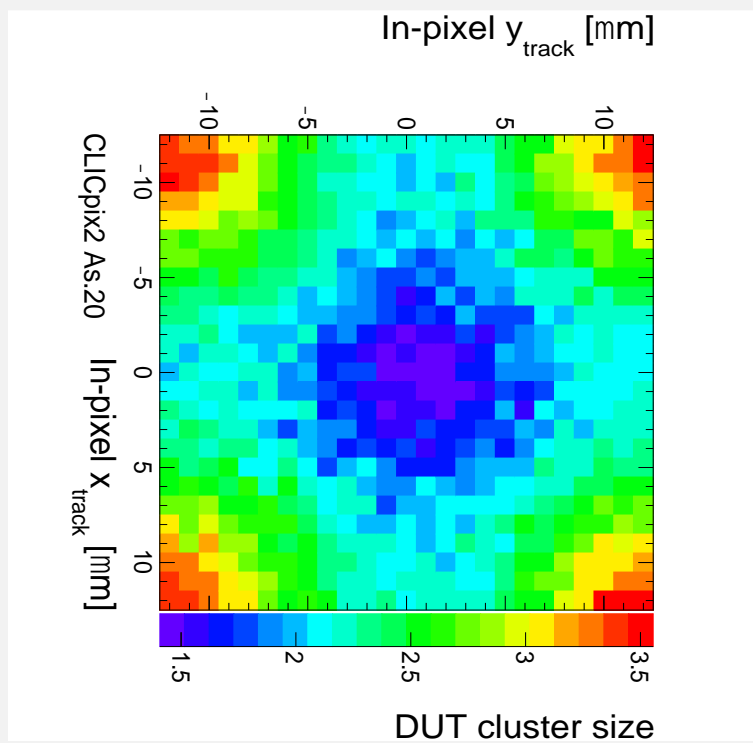
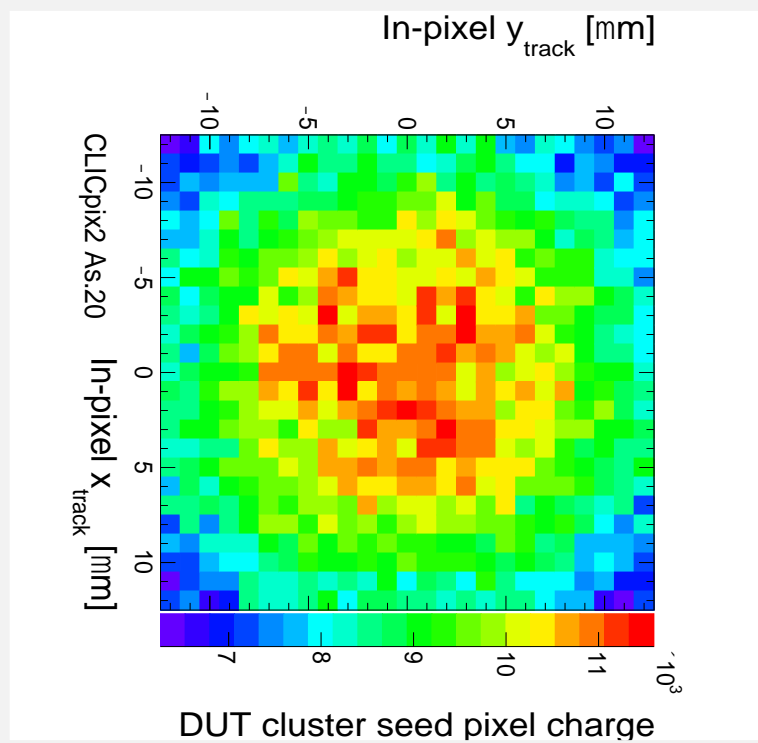
ASSOCIATED CLUSTER AND PIXEL CHARGE

- Associated pixel charge has peaked structure, occurs due to the integer nature of ToT measurements. (see backup slides for more detail).



IN-PIXEL CHARGE PLOTS

- In-pixel plot showing charge of the seed pixel of each cluster, where seed pixel has the highest charge in the cluster, follows the same pattern as the in-pixel cluster size, as expected.
- In-pixel plot of cluster charge is \sim uniform, this is expected as the charge of a particle should not depend on the position it hits within a pixel.

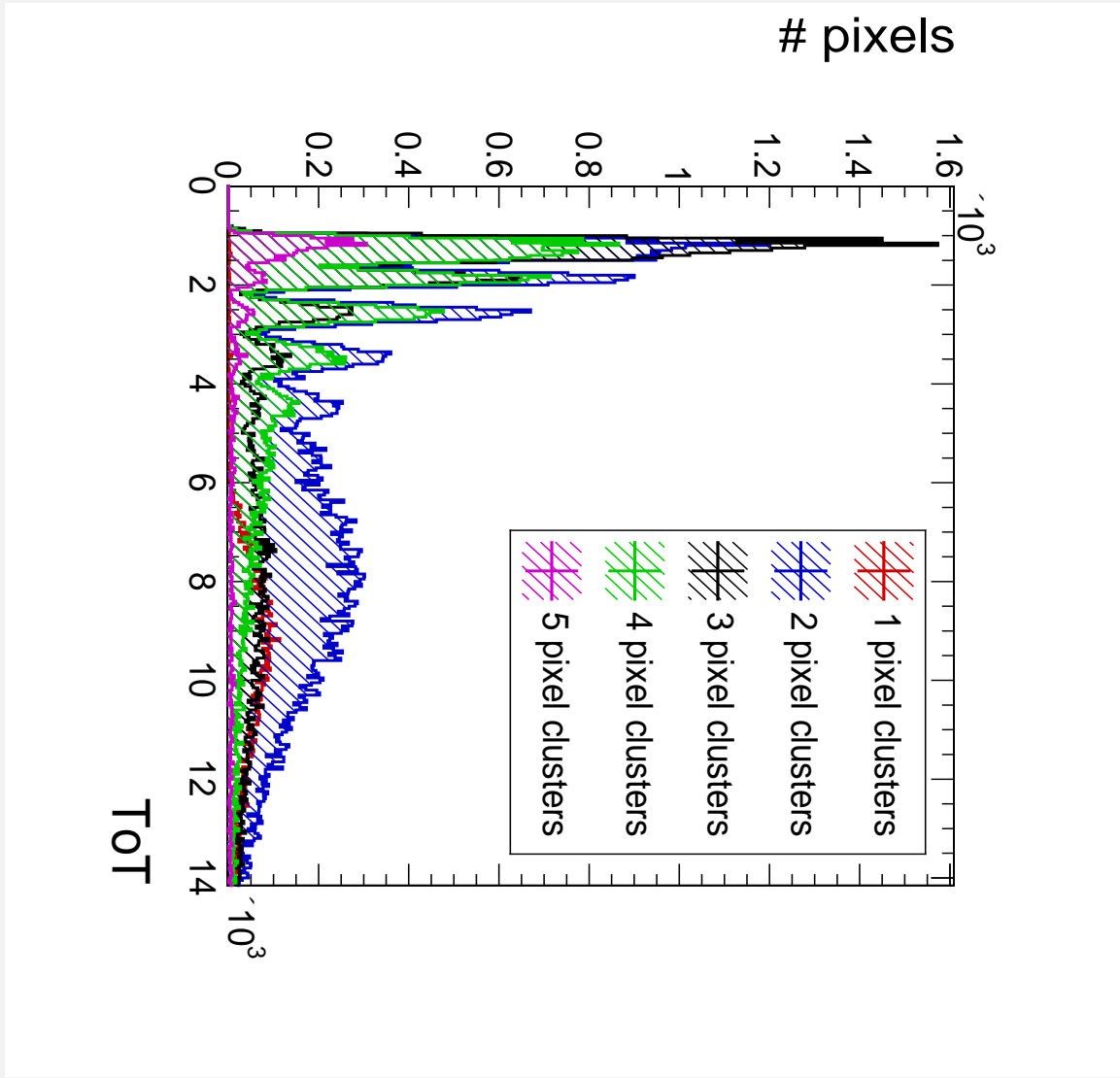
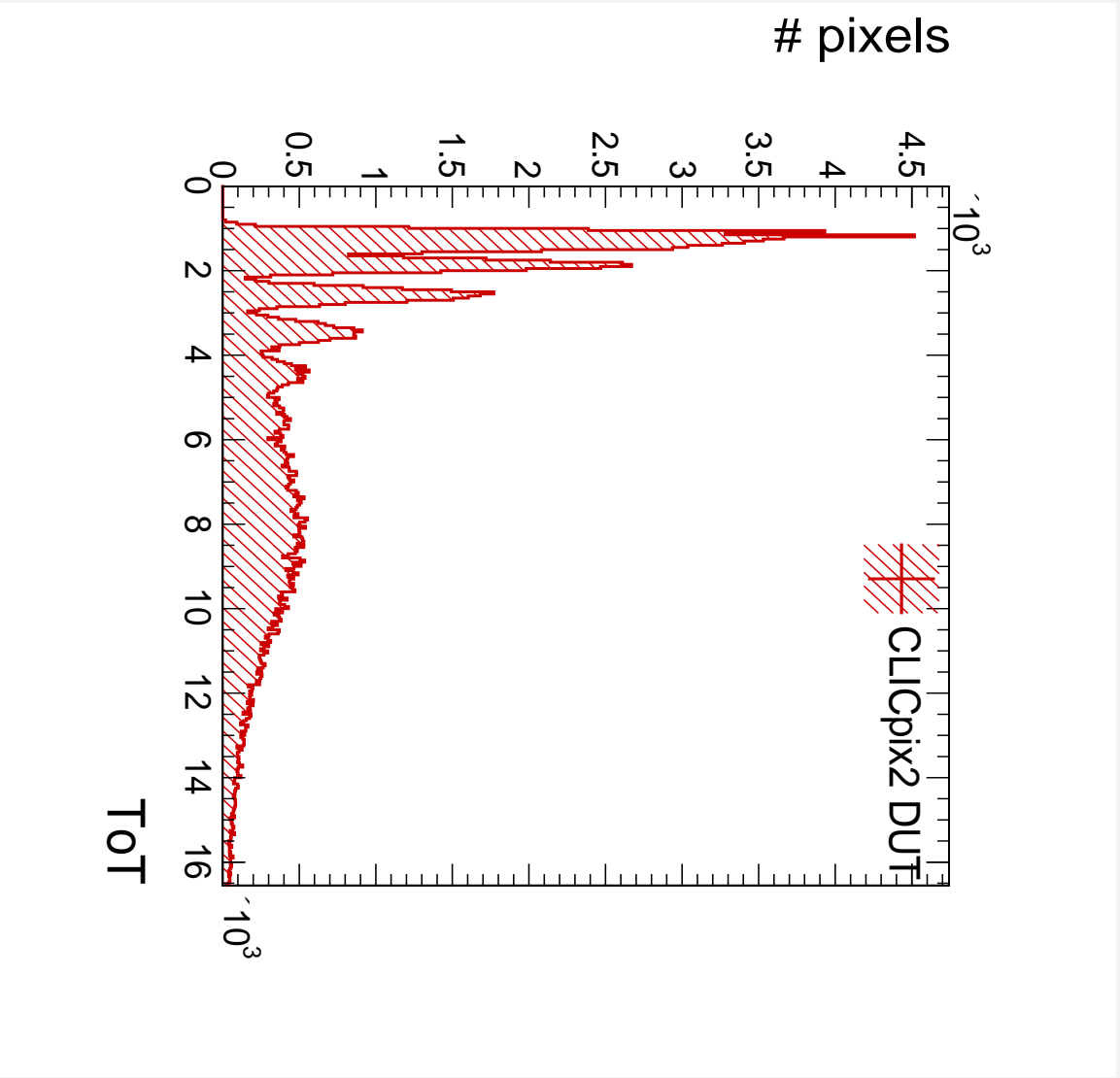


CONCLUSION

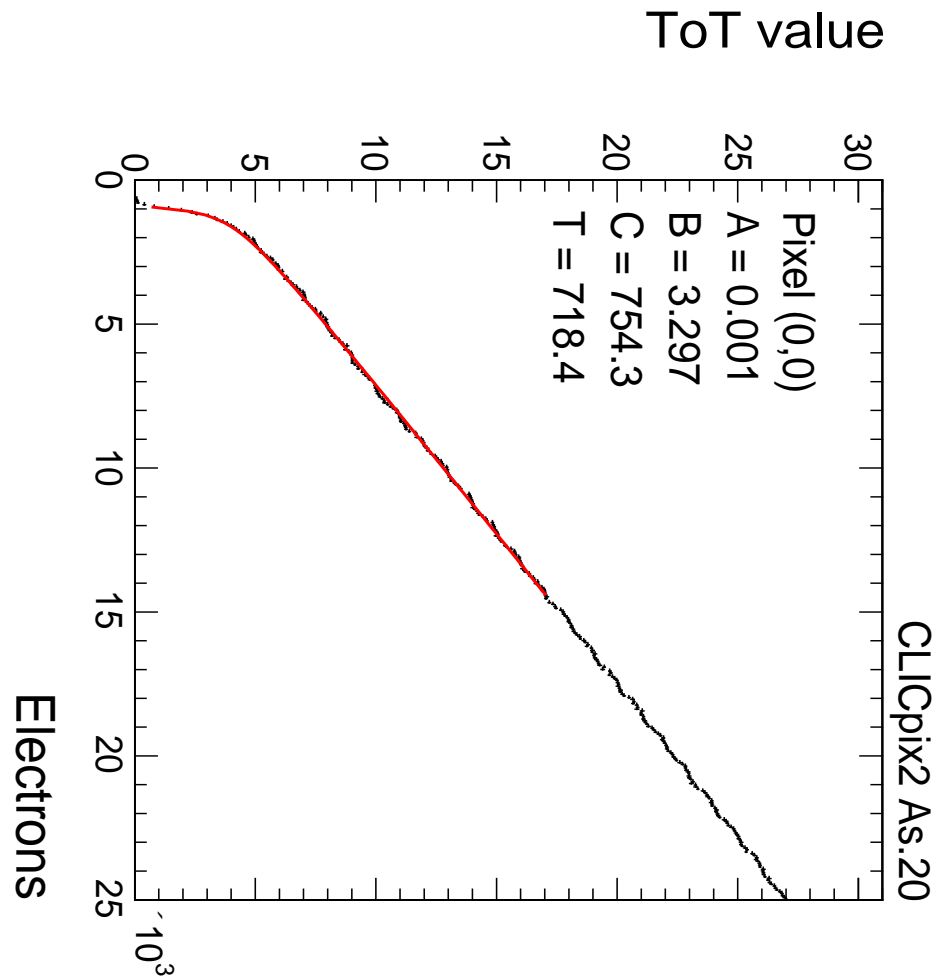
- Updated threshold and ToT calibration for CLICpix2 assemblies to be calculated separately for odd and even columns separately.
- Observe a $\sim 0.65\text{fF}$ difference in capacitance between odd and even columns using this method.
- Showed surrogate function parameters of ToT calibration curves for odd and even columns, where the T parameter has an interesting distribution.
- This calibration has been applied to test-beam data, the results of which agree very well with theoretical expectations.
- Next steps: apply an eta-correction to test-beam data, to correct for non-linear charge sharing between pixels.

BACKUP

ASSOCIATED PIXEL CHARGE DISTRIBUTION



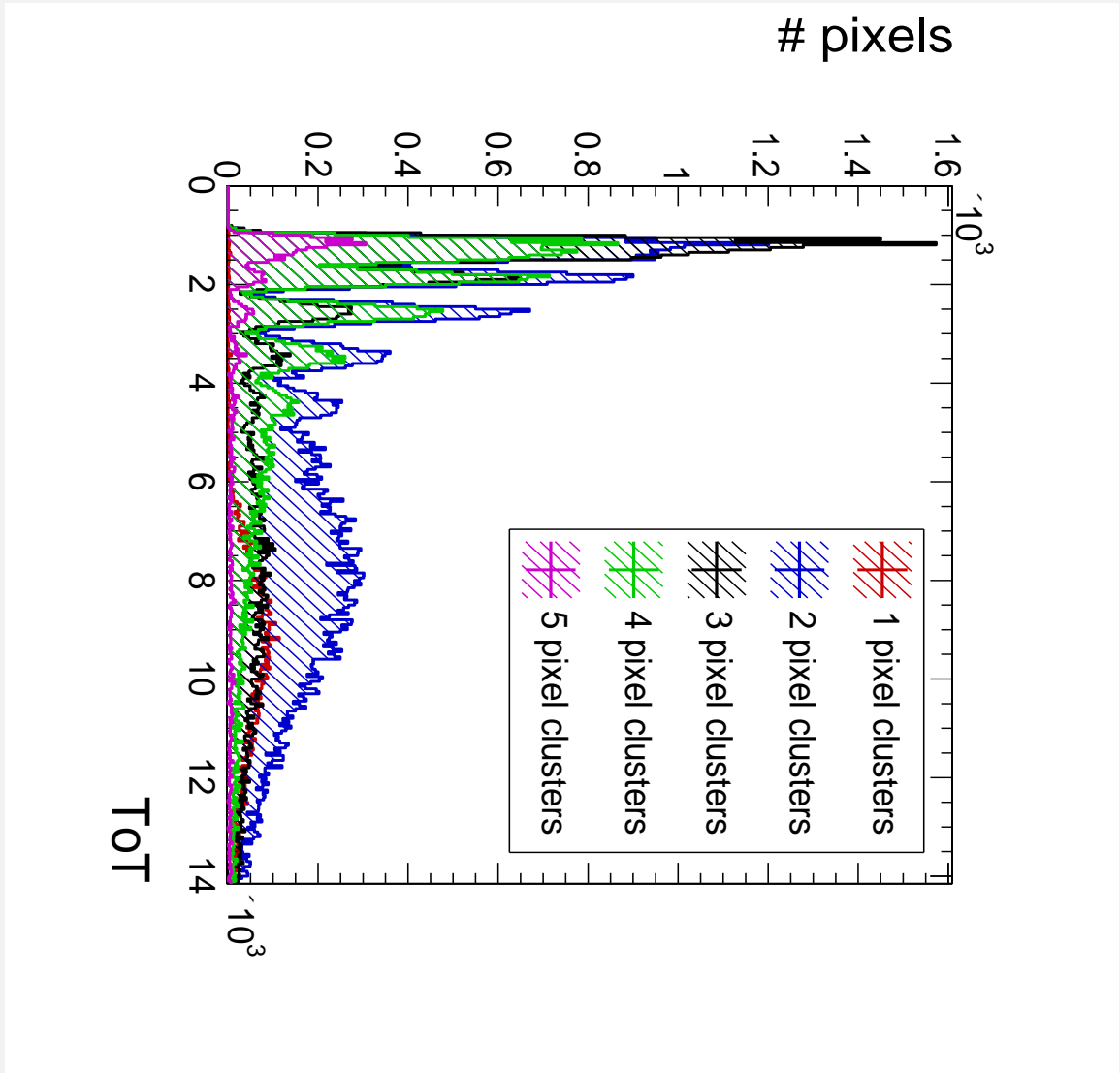
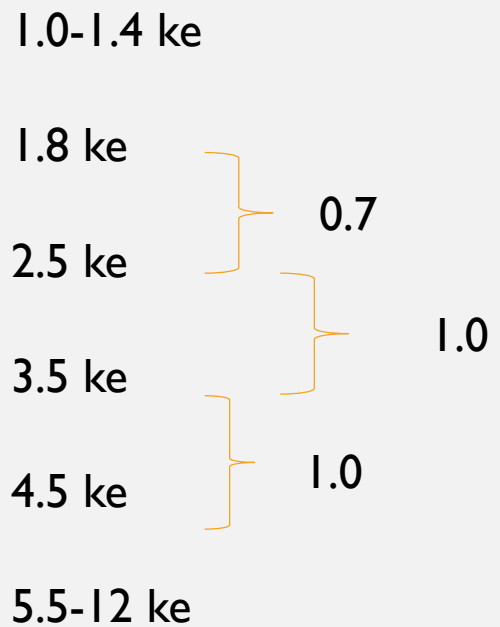
ASSOCIATED PIXEL CHARGE DISTRIBUTION (ROUGH CALCULATION)



- Steps of:
- ToT of 1 = ~1.0 ke } 0
 - ToT of 2 = ~1.0 ke } 0.2
 - ToT of 3 = ~1.2 ke } 0.4
 - ToT of 4 = ~1.6 ke } 0.6
 - ToT of 5 = ~2.2 ke } 0.8
 - ToT of 6 = ~3.0 ke } 0.9
 - ToT of 7 = ~3.9 ke } 0.9
 - ToT of 8 = ~4.8 ke }

ASSOCIATED PIXEL CHARGE DISTRIBUTION (ROUGH CALCULATION)

Peaks observed at:



ASSOCIATED PIXEL CHARGE DISTRIBUTION (ROUGH CALCULATION)

Steps of:

- 0
- 0.2
- 0.4
- 0.6
- 0.8**
- 0.9**
- 0.9**

Peaks observed at:

- 1.0-1.4 ke
 - 1.8 ke
 - 2.5 ke
 - 3.5 ke
 - 4.5 ke
 - 5.5-12 ke
- Annotations: 0.7 (bracketed between 1.8 ke and 2.5 ke), 1.0 (bracketed between 2.5 ke and 4.5 ke), 1.0 (next to 4.5 ke)

