Readout Electronics ASIC Characterization

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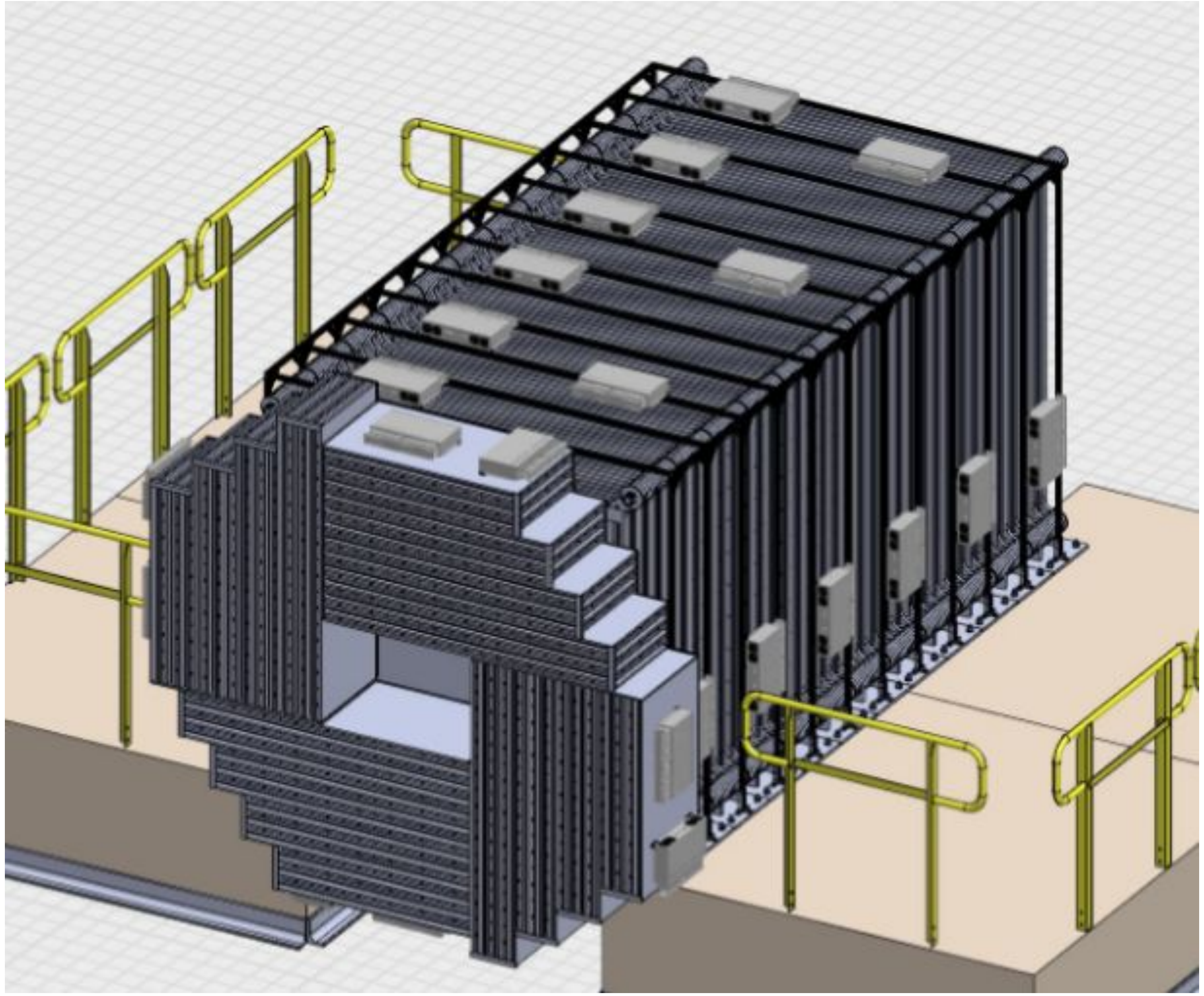
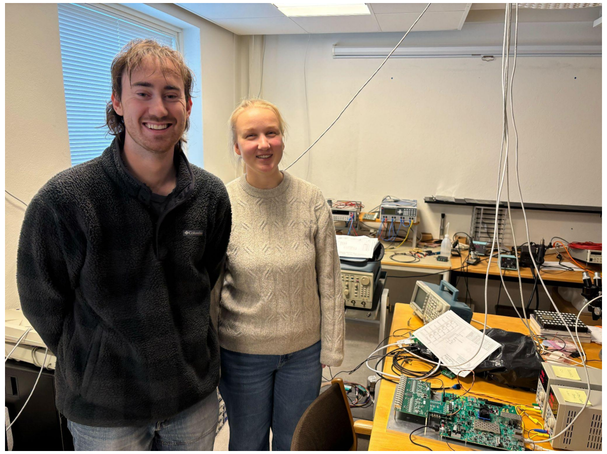
Under supervision of Hannah Herde and Erik Wallin

LDMX's Hadronic Calorimeter



T. Akesson et al. (the LDMX Collaboration). *LDMX – The Light Dark Matter eXperiment*. arXiv:2508.11833, August 2025.

- Scintillator bars with SiPMs at the ends.
- Uses the High Granularity Calorimeter ReadOut Chip (HGCROC).
- In Lund we work on characterizing the HGCROC:



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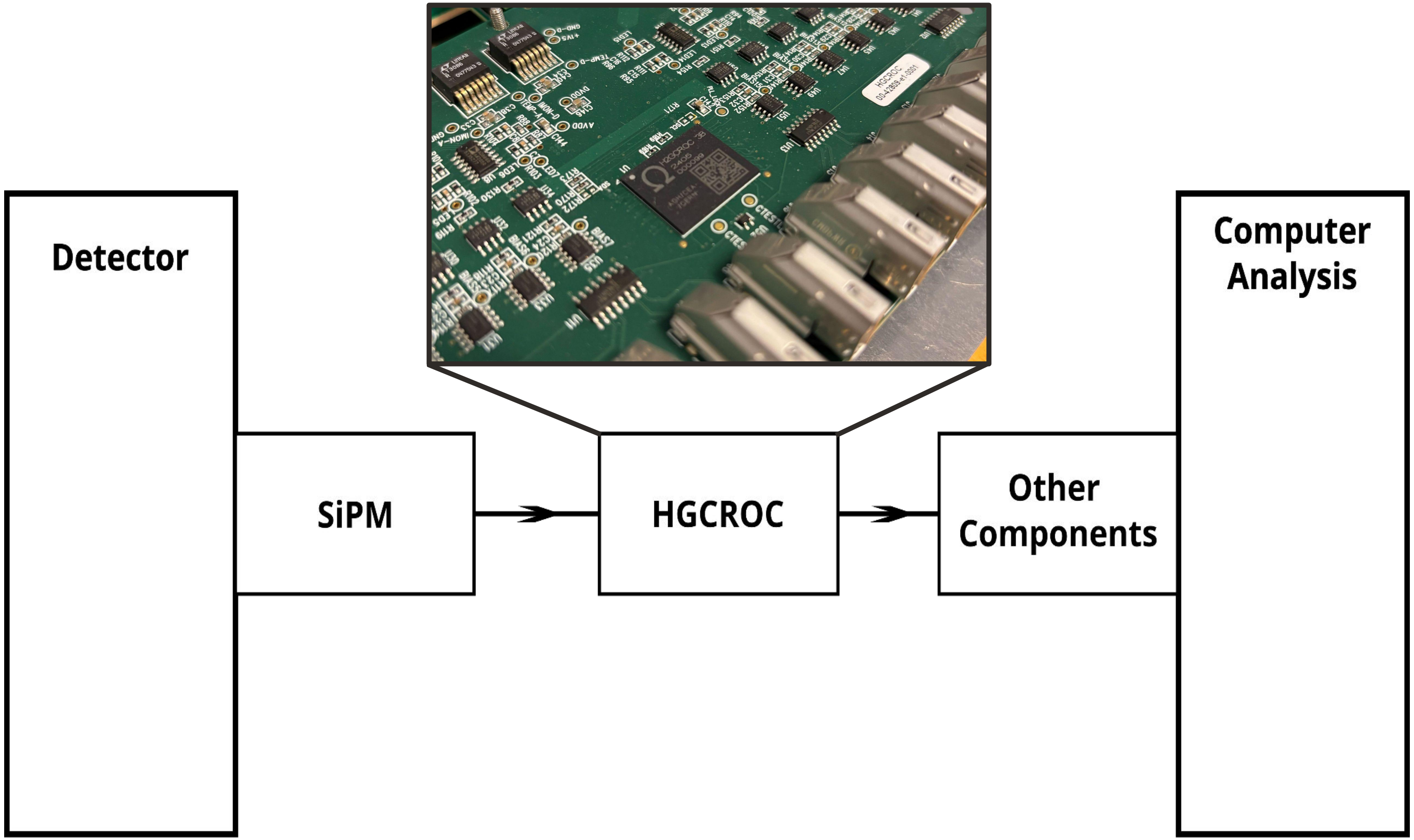
Readout path



General HGCROC facts:

- 72 channels.
- Includes an ADC and two TDCs.
- Transmits output data at 1.28 GHz

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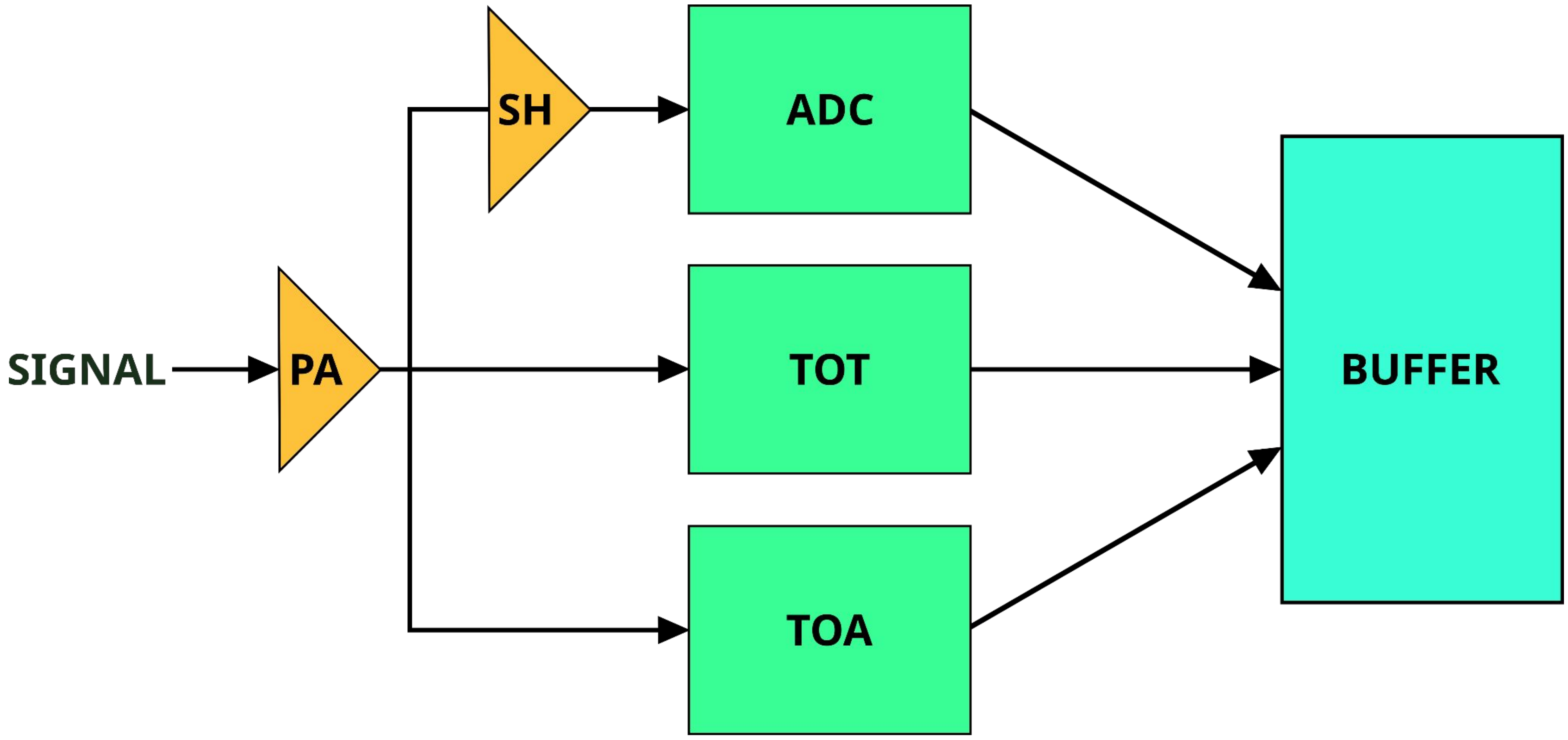
Readout path



Calibration with charge injections

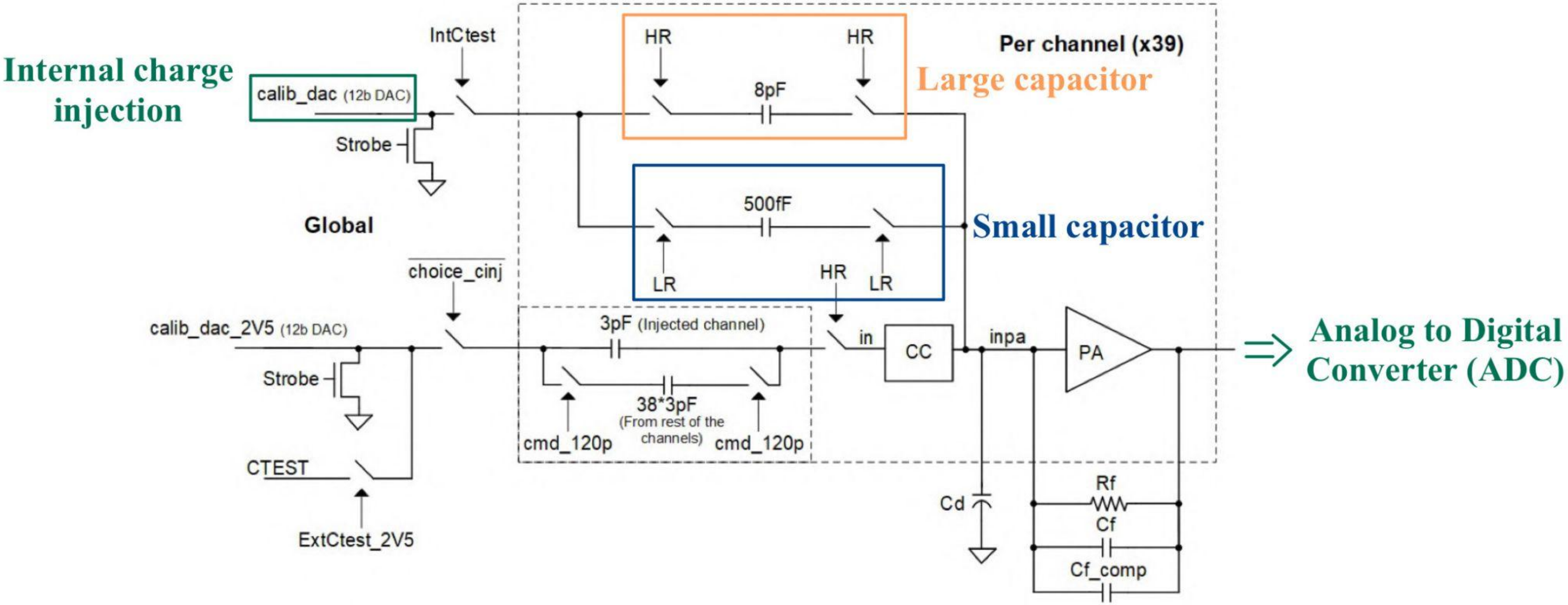


FIGURE 4.43 – *Internal and External injection schematic.*

Adapted from José González Martínez. Design and characterization of readout ASICs for SiPM detectors in pico-second timing measurements for the CMS HGCAL experiment. Micro and nanotechnologies/Microelectronics. Institut Polytechnique de Paris, 2024. English.

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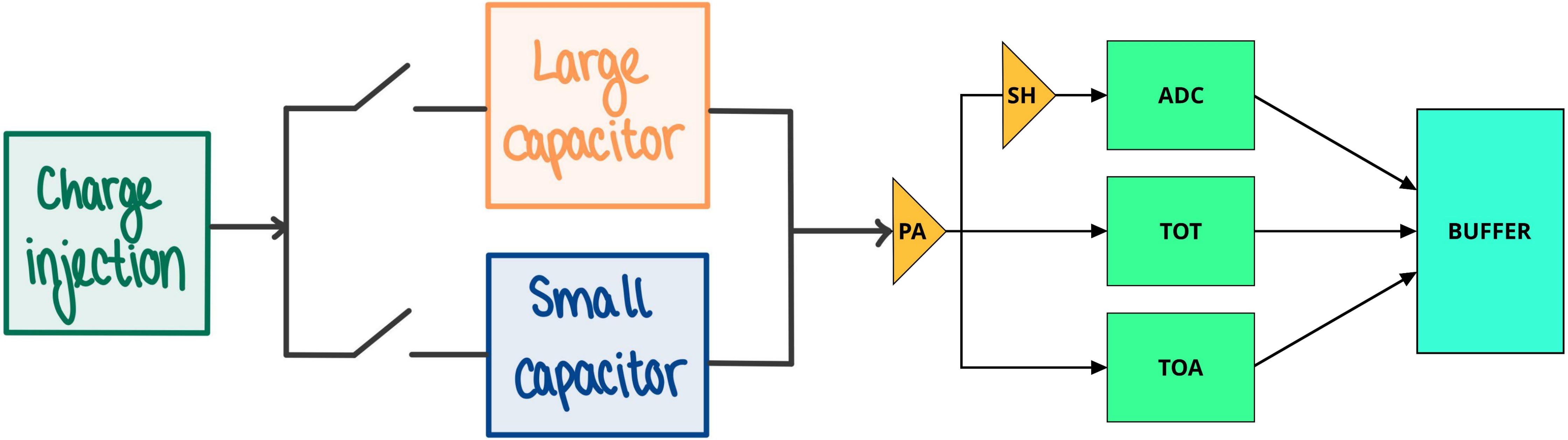
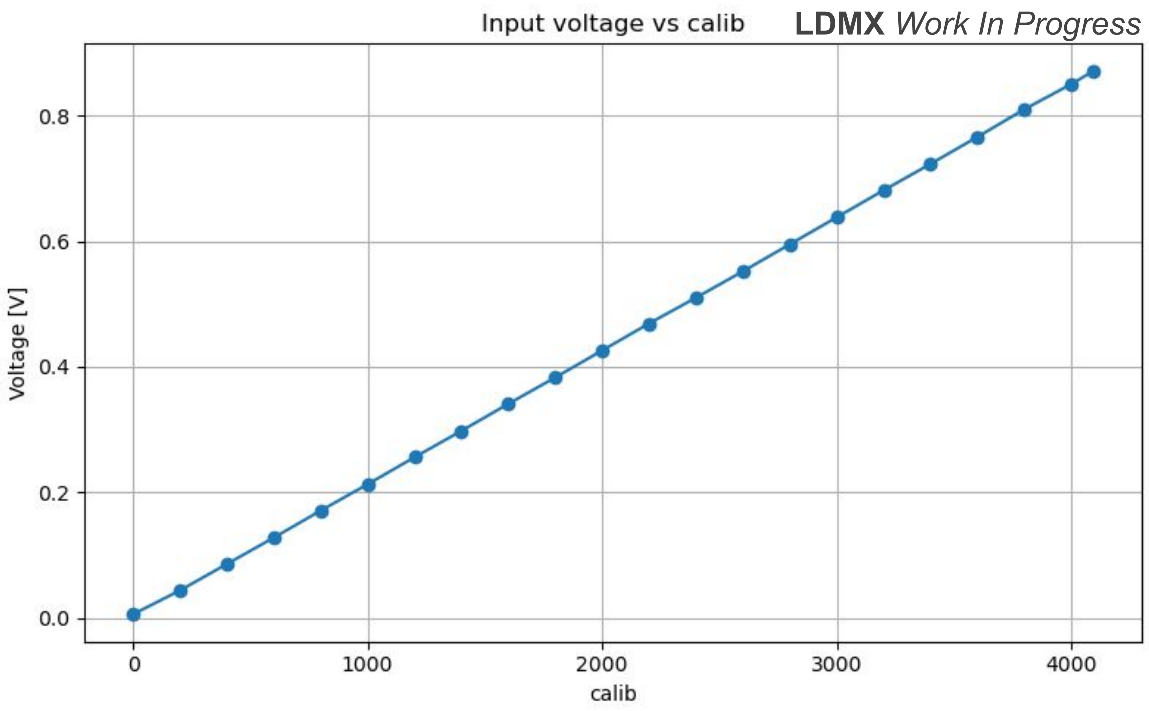
Charge injection



Measuring the input voltage

- Charge injections follow
$$Q = V \cdot C$$
- To vary Q we vary the voltage via the parameter `CALIB`, corresponding to a 12-bit DAC
- Thus `CALIB` ranges from 0 to 4095
- Measured corresponding input voltage to each `CALIB` value
- Linear, with maximum at 0.871 V



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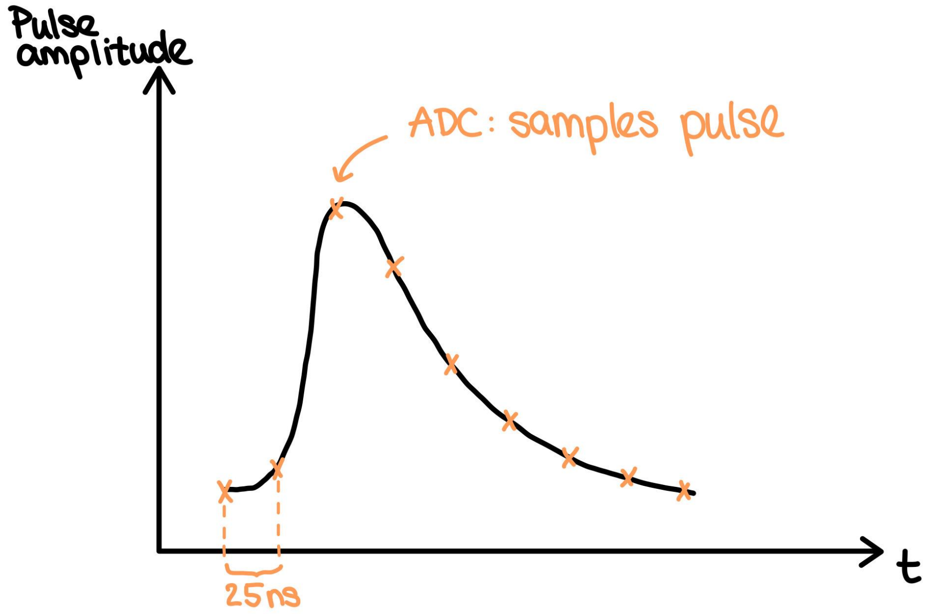
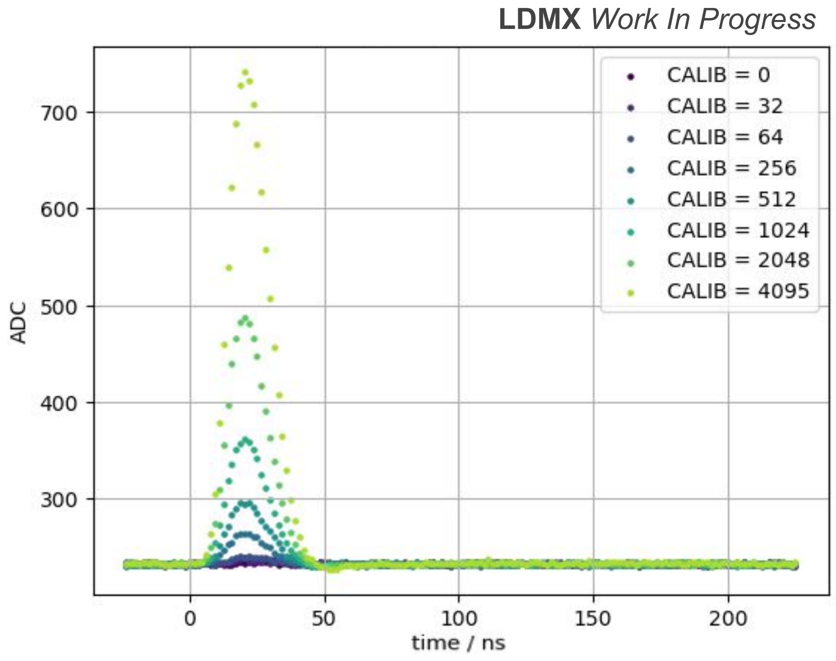
Analog to Digital Converter (ADC)

- ADC samples pulse with a certain time interval
- Converts analog signal into digital signal
- 10-bit ADC, so ADC ranges from 0 to 1023

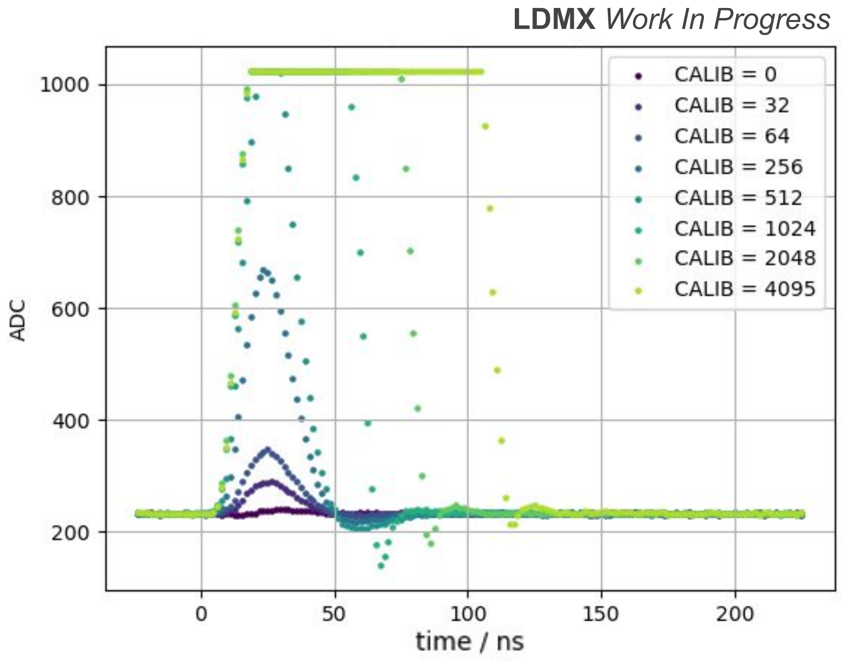


Charge injections: ADC against time

- Plot ADC samples over time
- Did scans on randomly chosen channel for both small and large capacitor
- Saturation only with large capacitor



Small capacitor: 500fF



Large capacitor: 8pF

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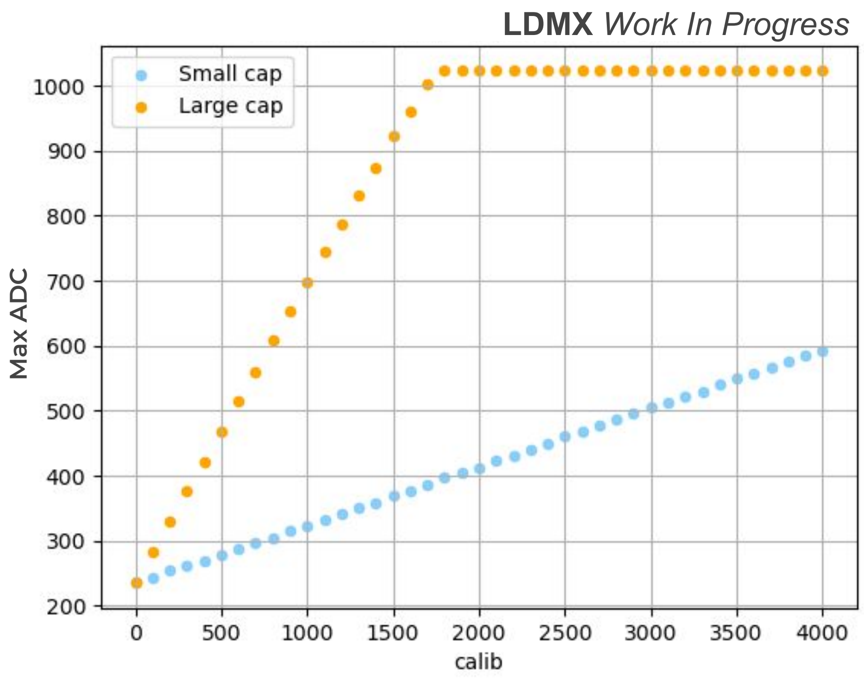
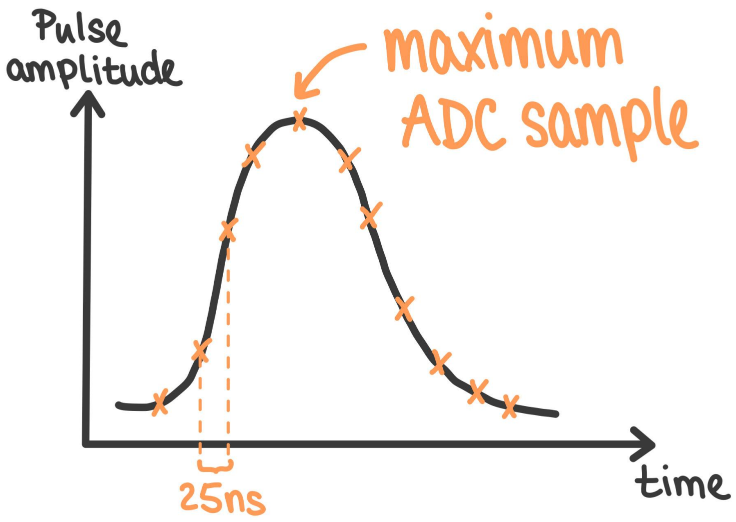
ADC linearity

- Plot the maximum ADC value of each pulse against the injected charge
- Expectation: linear behaviour
- Indeed, both capacitors show linear behaviour for all channels
- Large capacitor saturates the ADC



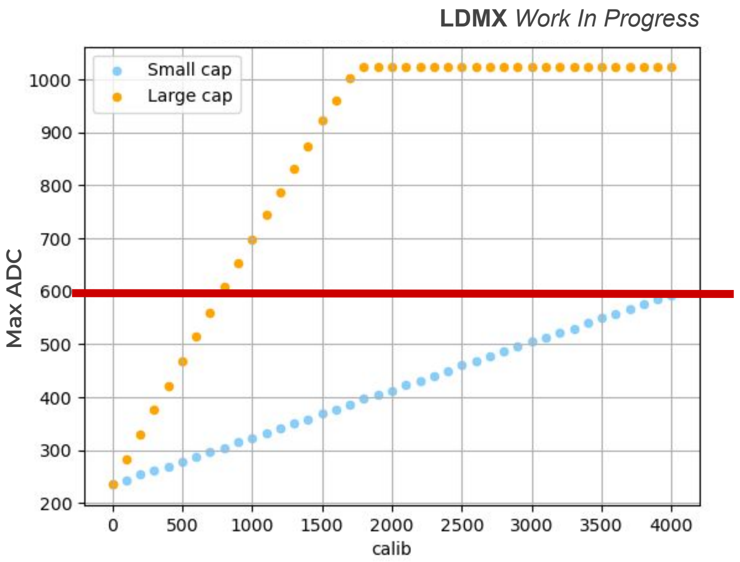
(only every 5th measurement plotted for clarity)

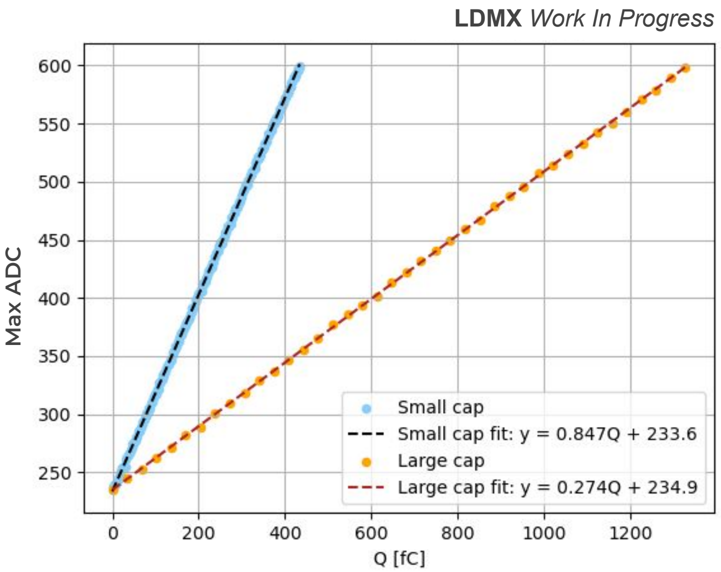


ADC linearity: Convert CALIB to charge

- Use that $V_{max} = 0.871\text{V}$ (measured) and $\texttt{CALIB}_{max} = 4095$
- Exclude values with ADC > 600
- Conversion will be:

$$Q[\text{fC}] = \frac{\texttt{CALIB}}{\texttt{CALIB}_{max}} \cdot C[\text{F}] \cdot V_{max}[\text{V}] \cdot 10^{15}$$





(only every 5th measurement plotted for clarity)

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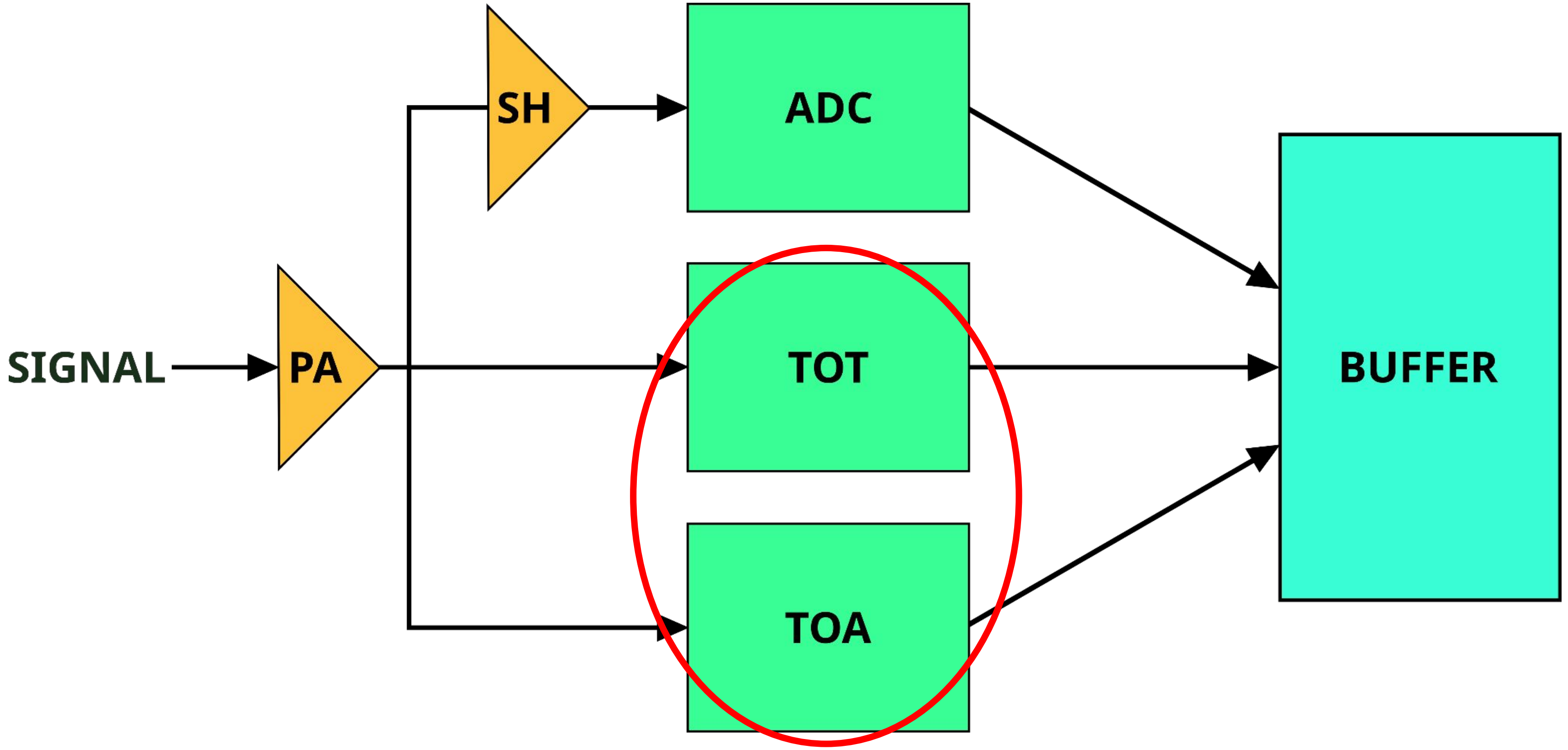
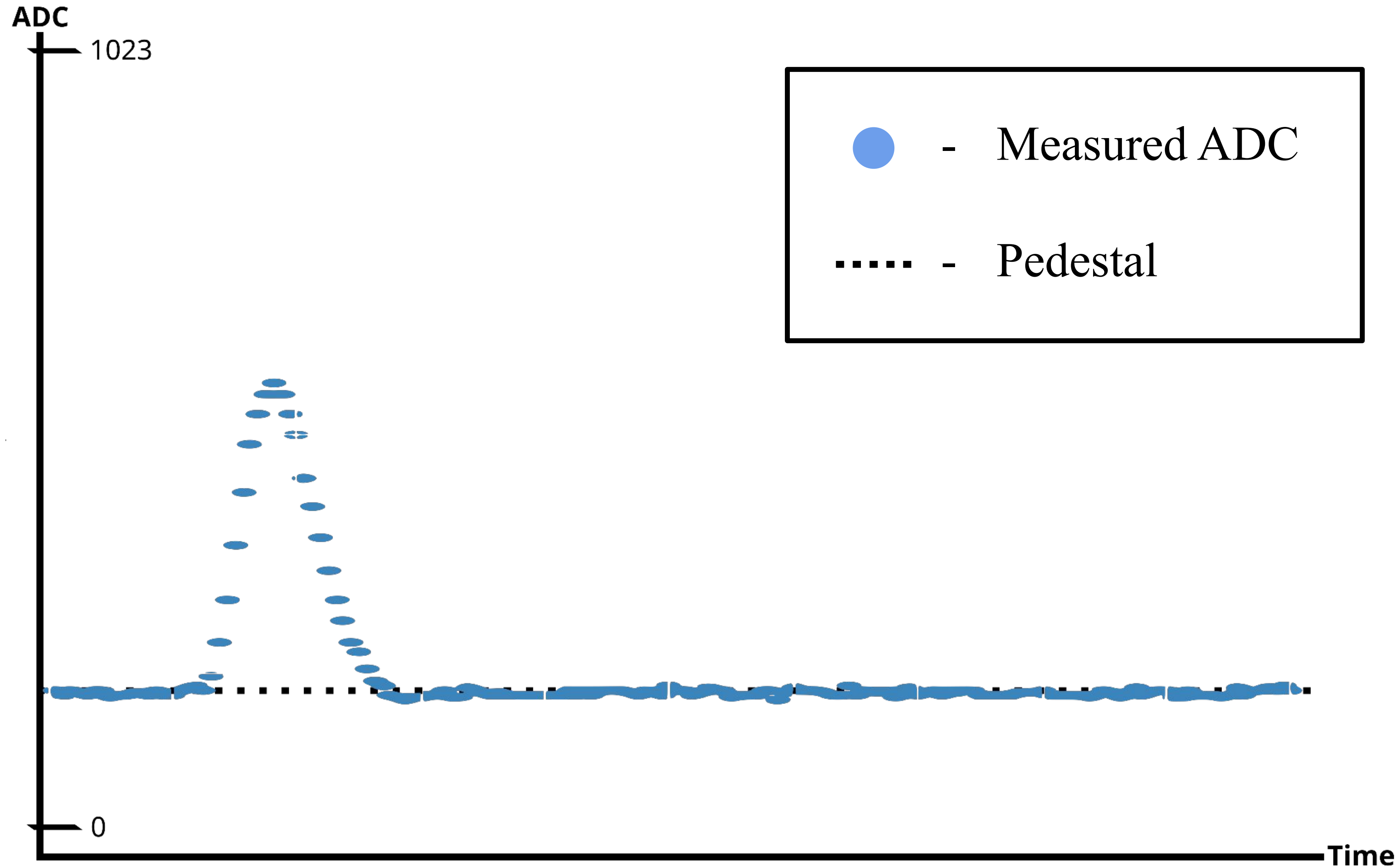
Time Over Threshold



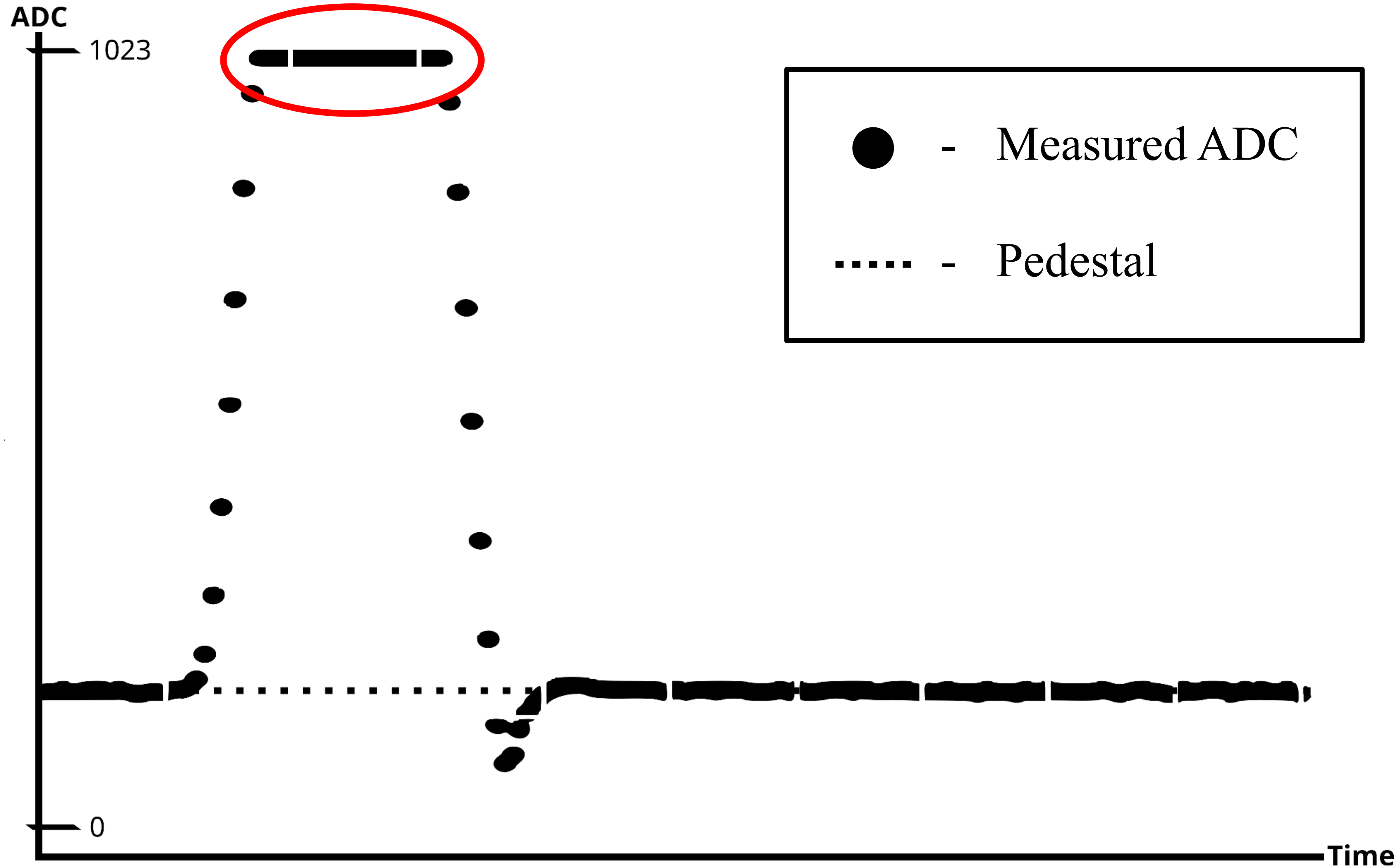
- Time Over Threshold (TOT)
- Time Of Arrival (TOA)

A small pulse



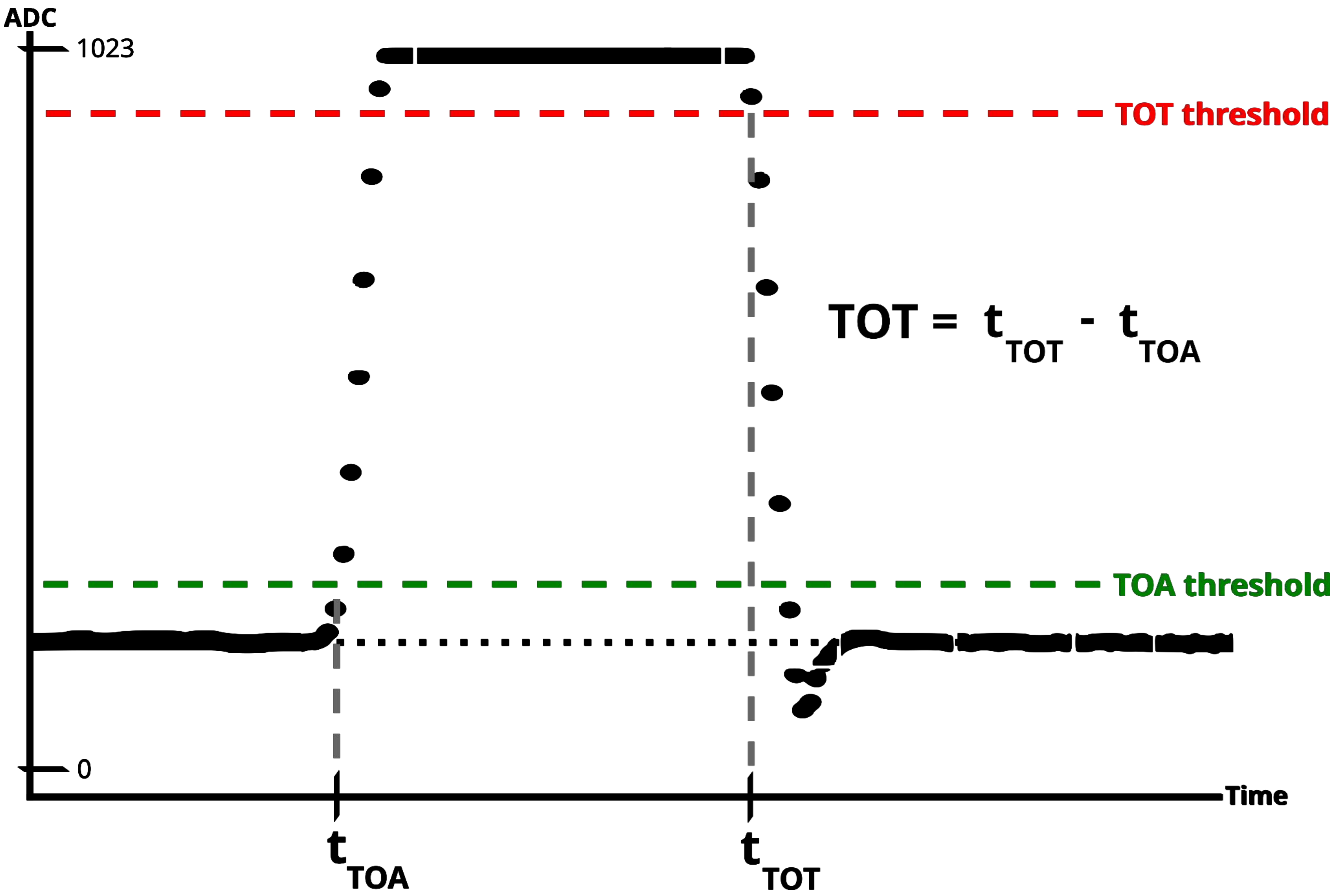
- We have the full information of the pulse shape ✓

A large pulse



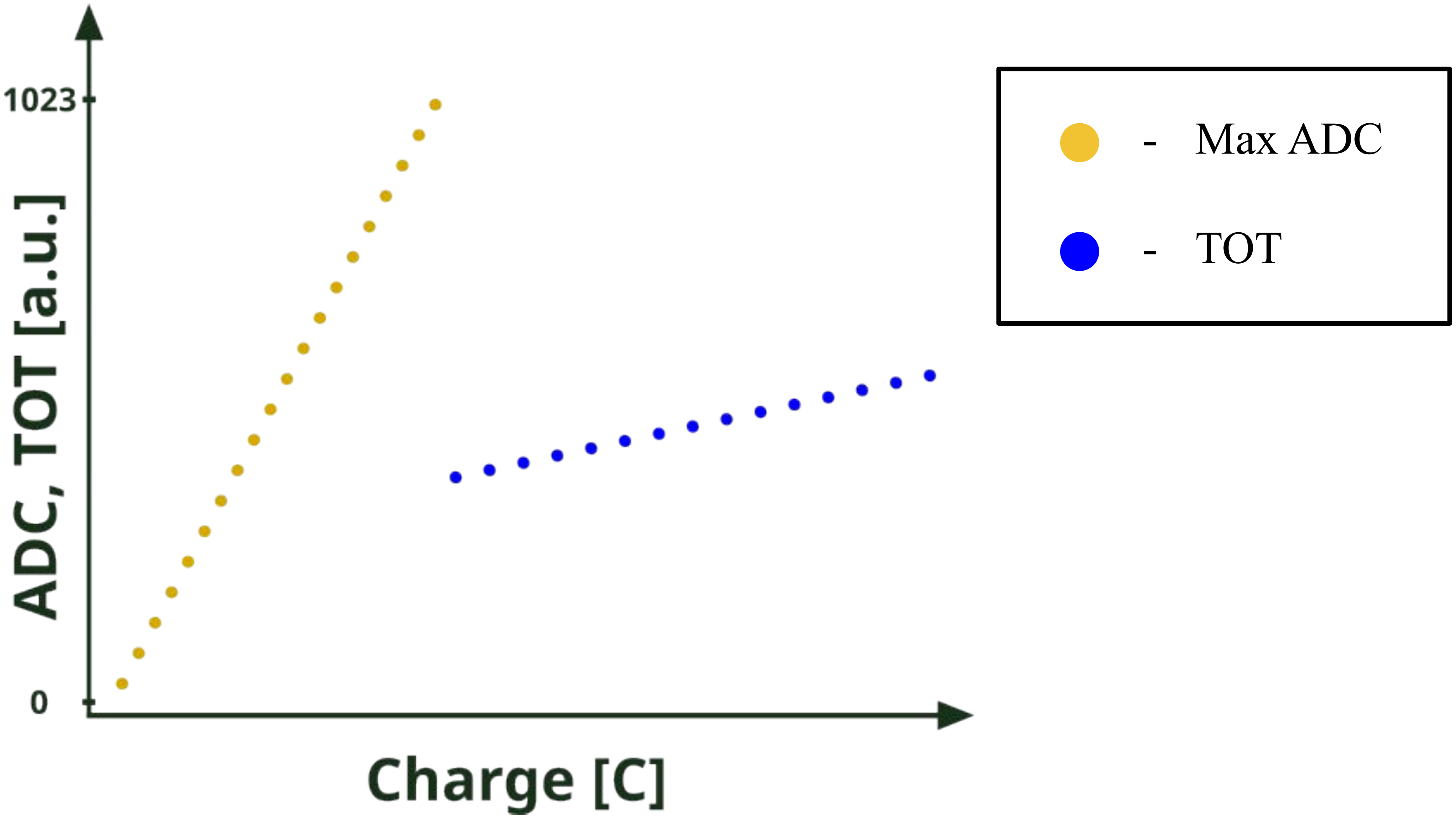
- We're missing information about the pulse shape in the "saturated regime"
- To account for the loss of information, we turn to measurements in time

Time Over Threshold

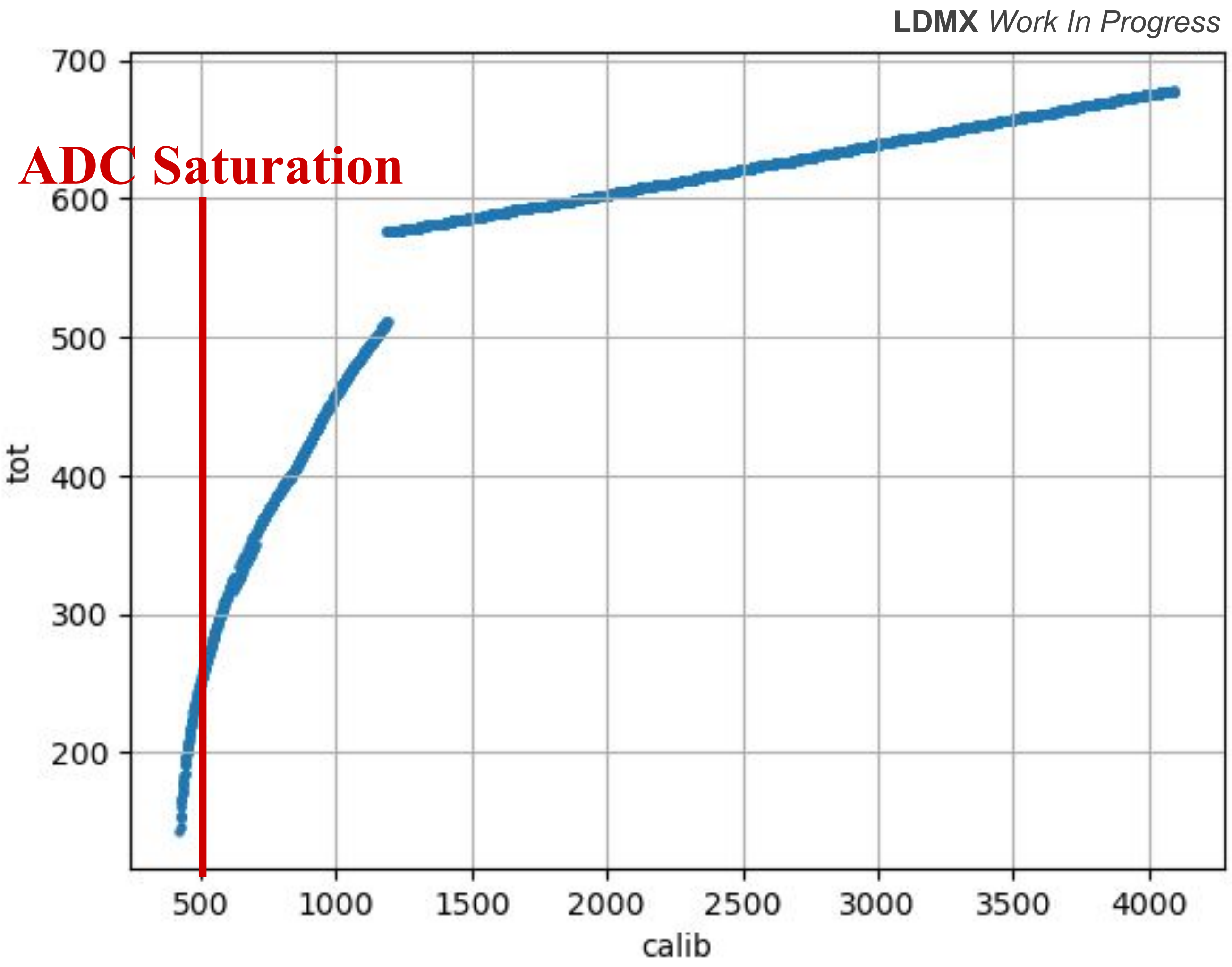


- TOT is calculated as the **time** between the triggers of the TOT threshold and the TOA threshold

TOT expectation



TOT measurements



Two regimes:

1. `CALIB` < 1190:
   Semi-linear regime.

2. `CALIB` >= 1190:
   Linear regime.

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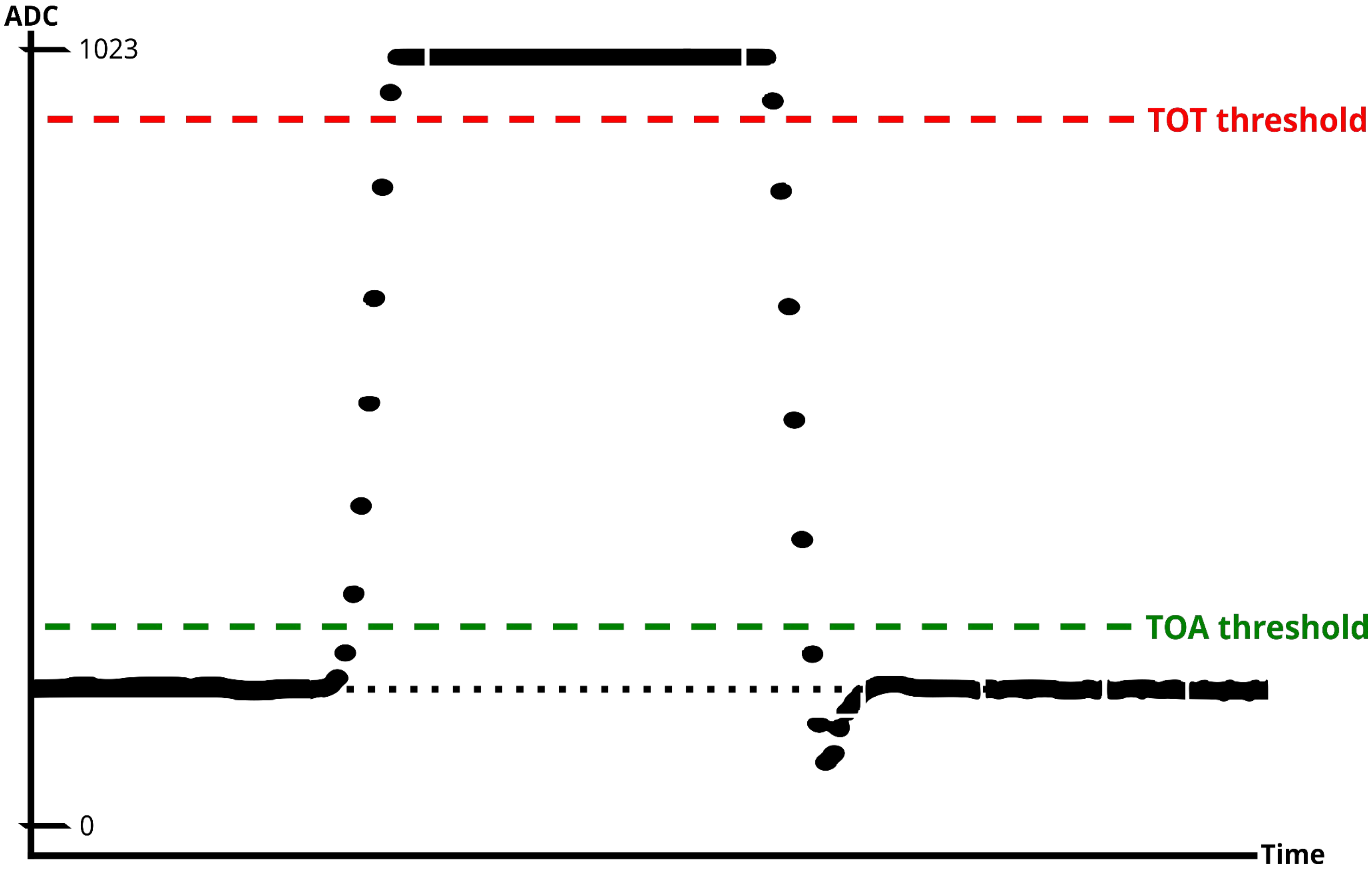
How to set the TOT threshold



- We want a healthy overlap between the ADC and TOT, so we set the TOT threshold slightly below ADC saturation.

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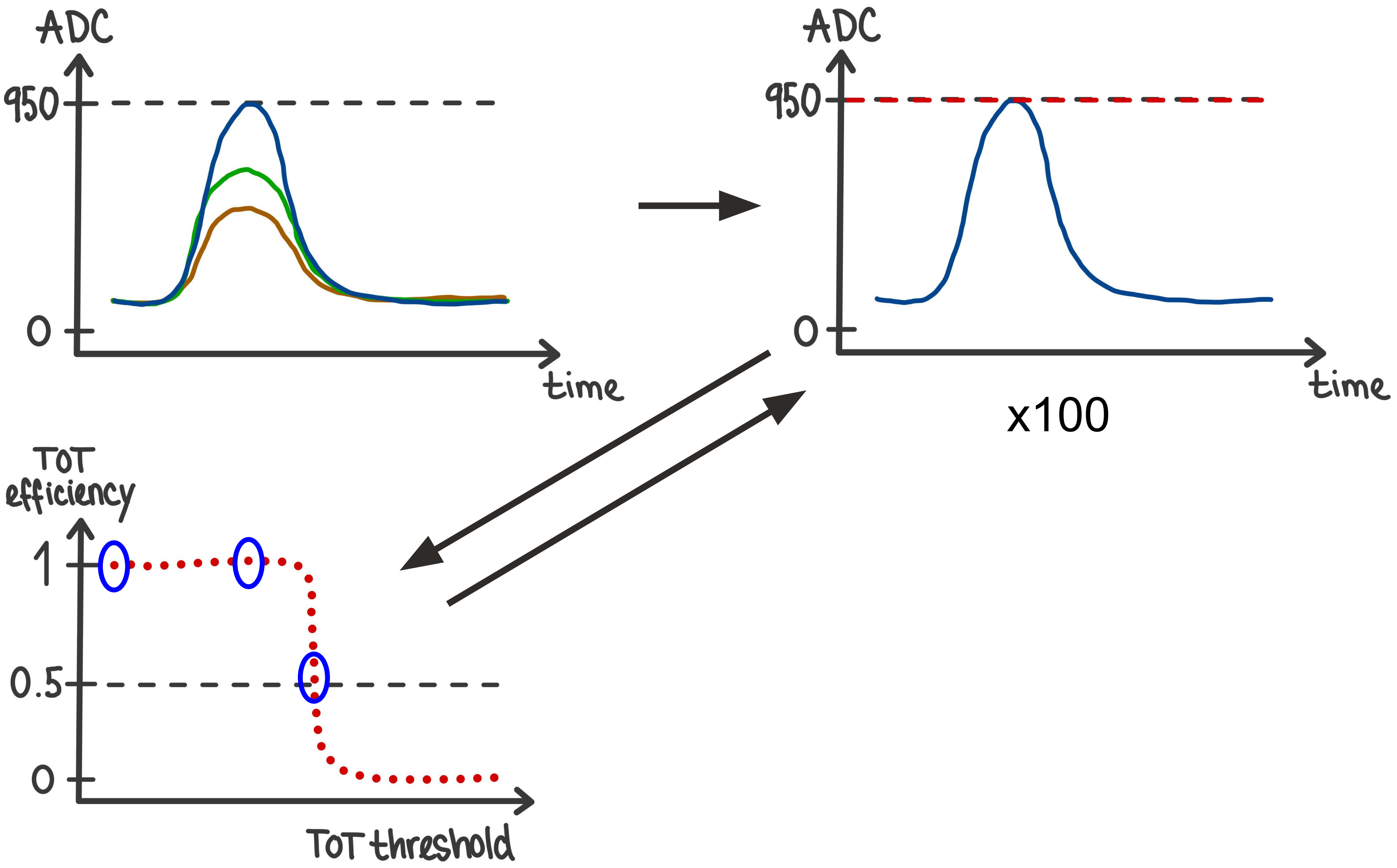
How to set the TOT threshold



1. Find the correct `CALIB`

2. Scan TOT threshold parameter.

3. Calculate the TOT efficiency.

4. Iterate steps 2 & 3 until a TOT threshold with 50% efficiency is found.

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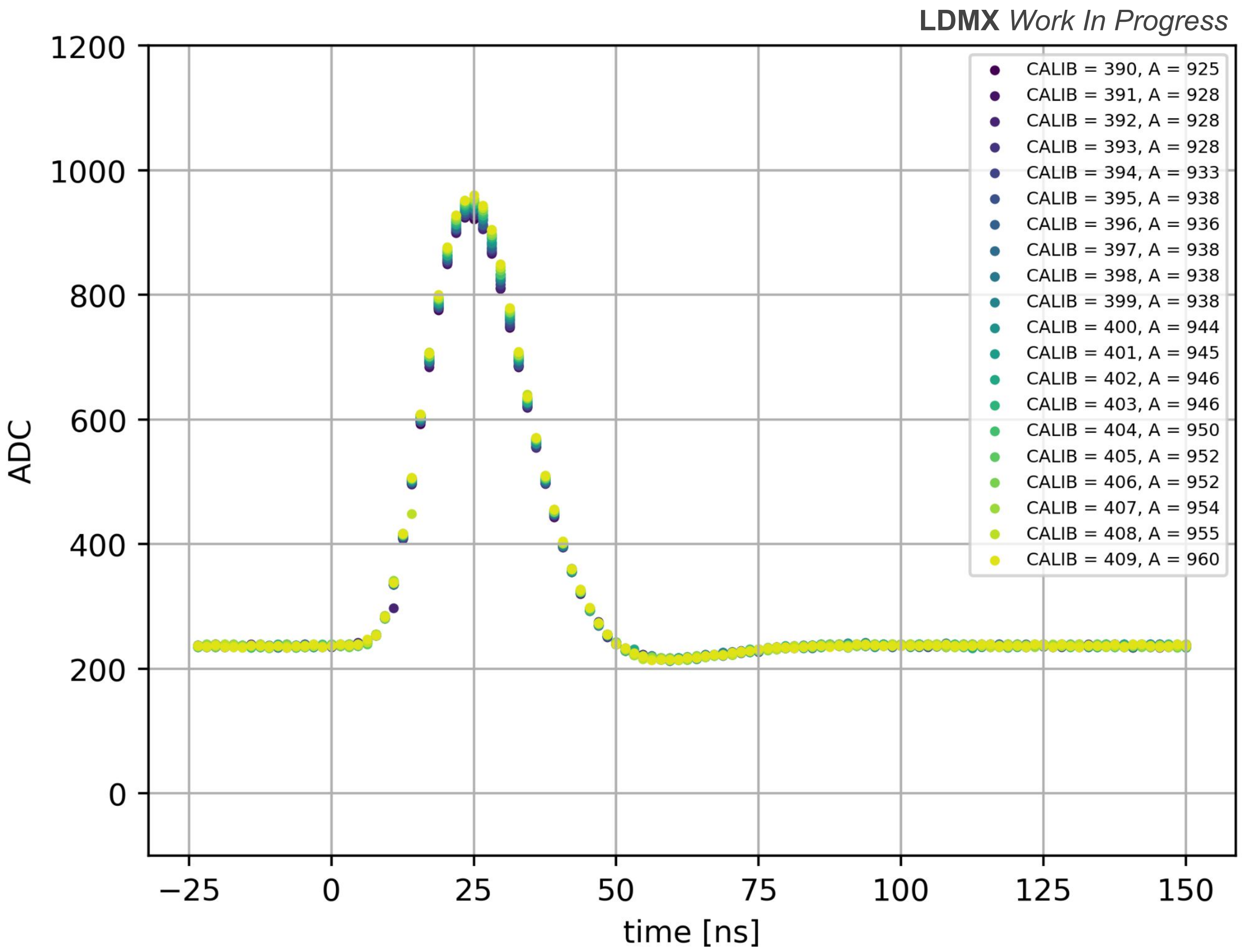
How to set the TOT threshold: Example



- `CALIB` was found to be 404.
- The TOT threshold parameter was found to be 383.

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Summary and outlook

- ADC is linear!
- We are investigating the jump in TOT.
- We have stable methods for running tests on multiple HGCROC boards. Andreas tested and sent boards for the slice test that showed same electronic performances.
- Andreas is currently working on a method to calibrate the TOT threshold for all channels.

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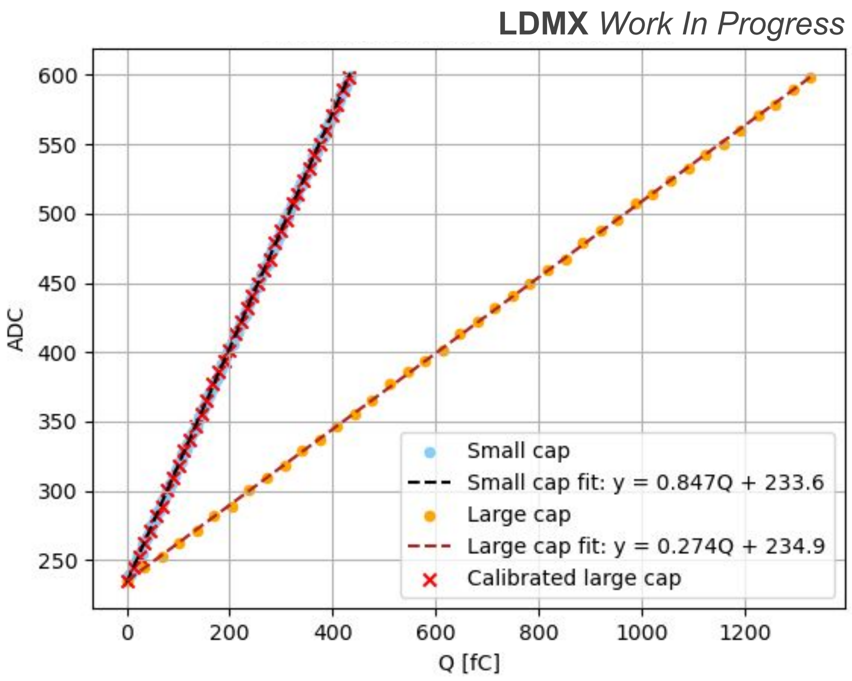
Backup slides

Large capacitor calibration

- Linear fit of both small and large capacitor data
- Require corrected ADC values to be the same as from small capacitor
- Calibrated charge will be:

$$q' = \frac{m_h \cdot q_h + b_h - b_l}{m_l}$$

- Purpose: enables comparison between small and large capacitor



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Large capacitor calibration: Derivation

- Assume small capacitor has correct capacitance
- Use that to calibrate the large capacitor
- Define linear fits:
  - large capacitor: $y_h = m_h \cdot q_h + b_h$ (small cap analogously)
- Corrected values have same slope and intercept as small cap:

$$y' = m_l \cdot q' + b_l$$

- Take ADC value from large cap, thus $y' = y_h$
- Solving for q':

$$q' = \frac{m_h \cdot q_h + b_h - b_l}{m_l}$$

- Plot corrected charge values q' with y_h

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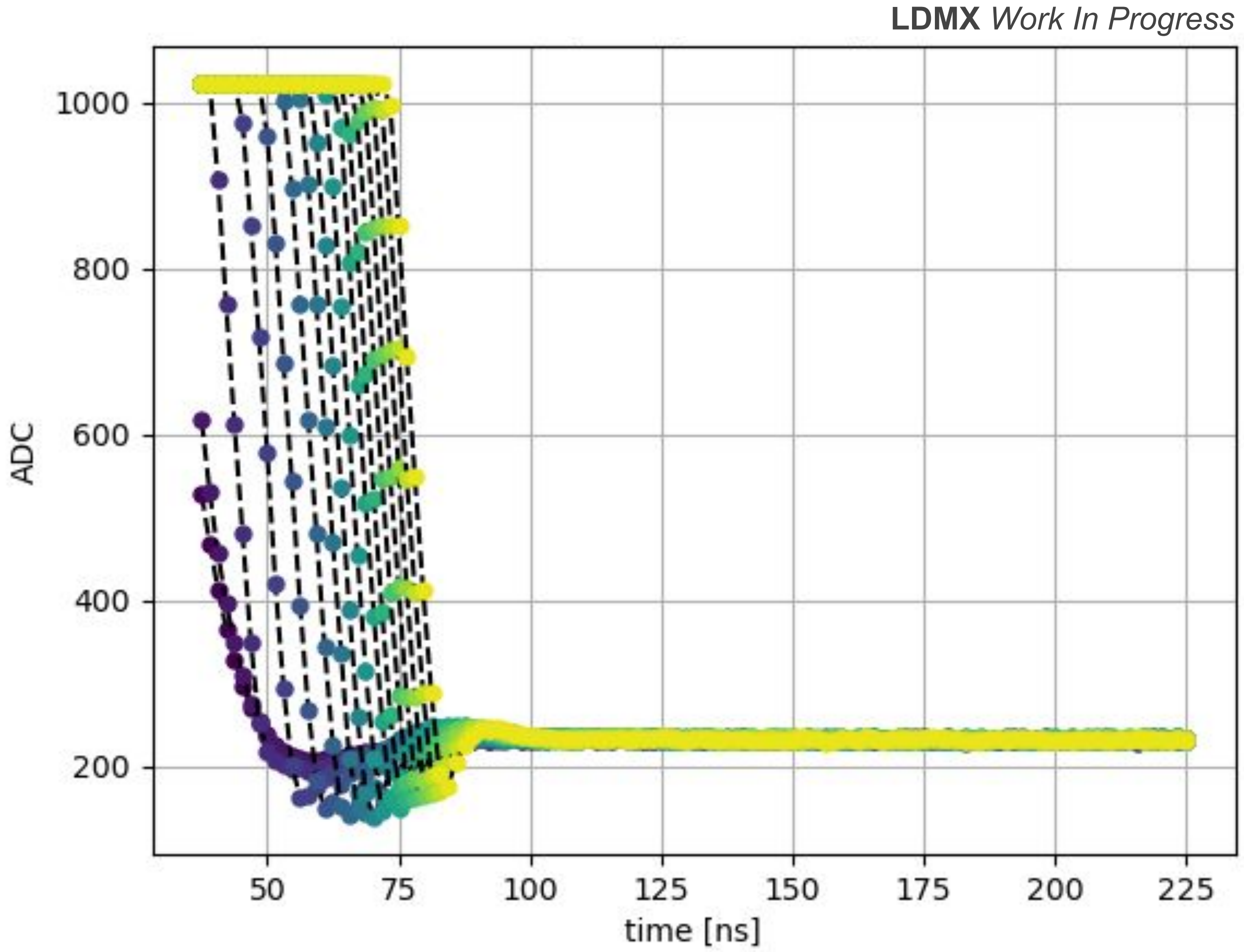
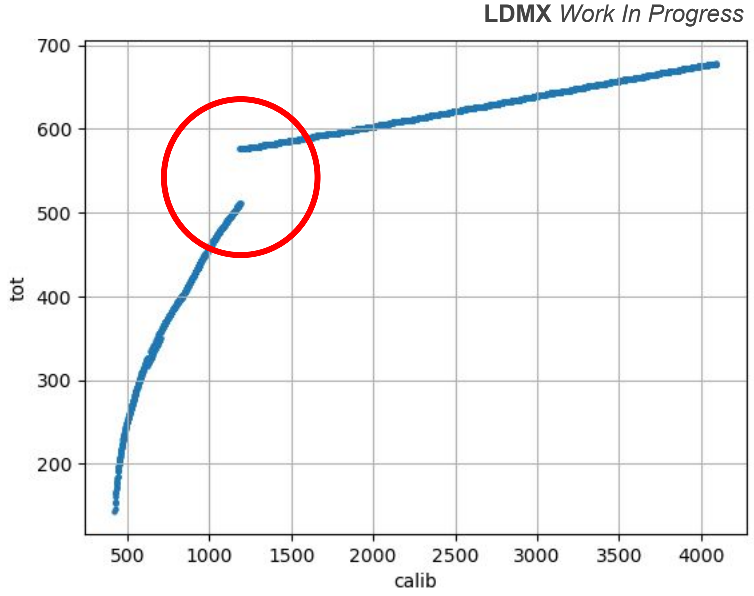
The pulse at the “jump”





- There is no observable gap in the region where the TOT jumps.