# A TIMEPIX3 FRONT-END SIMULATOR PLUGIN FOR ALLPIX2

4TH ALLPIX SQUARED WORKSHOP

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# OUTLINE

- Introduction – Aim of research

- Implementation of new features:

  - ❖ New preamplifier model for improved low signal modeling,

  - ❖ System noise

- Results of clustering analysis

- Conclusions

# MOTIVATION



- Study the limits of Timepix3 in spectroscopic X-ray imaging with data driven architecture.

- Study of spatial resolution and spectral performance.

- Simulation has to match the actual detector response as close as possible.
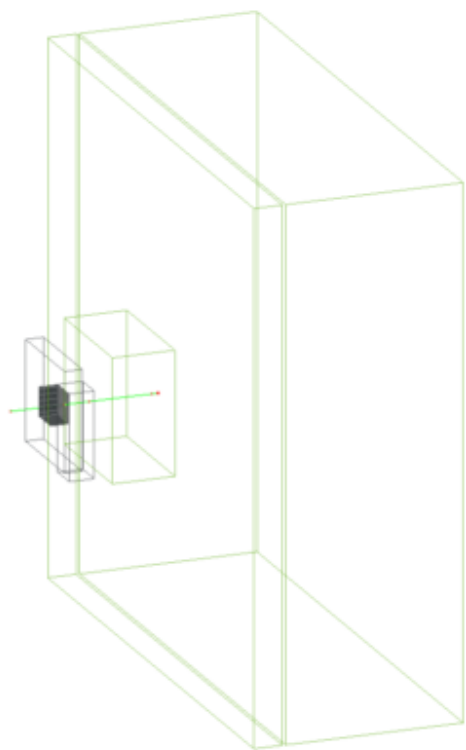
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pixel_size = 55um 55um

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sensor_excess = 1mm

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bump_cylinder_radius = 17.0um
bump_height = 20.0um

chip_thickness = 700um
chip_excess_top = 0um
chip_excess_bottom = 1610um
chip_excess_right = 10um
chip_excess_left = 10um

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thickness = 1.76mm
size = 3.5mm 3.5mm
location = "absolute"
offset = 0 0 1.85mm
material = "g10"

[support]
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size = 15mm 15mm
material = "copper"
location = "absolute"
offset = 0 0 3.13mm

[support]
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material = "aluminum"
location = "absolute"
offset = 0 0 6.125mm
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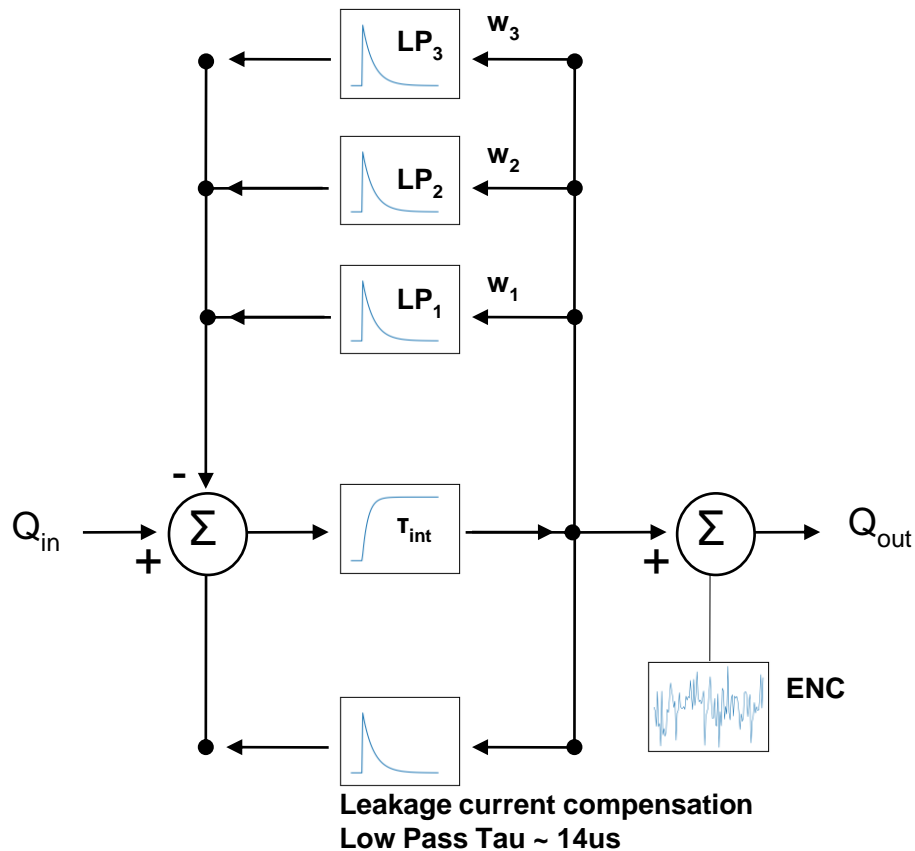
# NEW PIXEL PRE-AMPLIFIER MODEL



**Leakage current compensation**
**Low Pass Tau ~ 14us**

- Added additional pole to the transfer function

- 3 parallel 1st order Butterworth low-pass filtered feedback loops

- Tanh feedback tapering

- Separate leakage current compensation with a long time constant
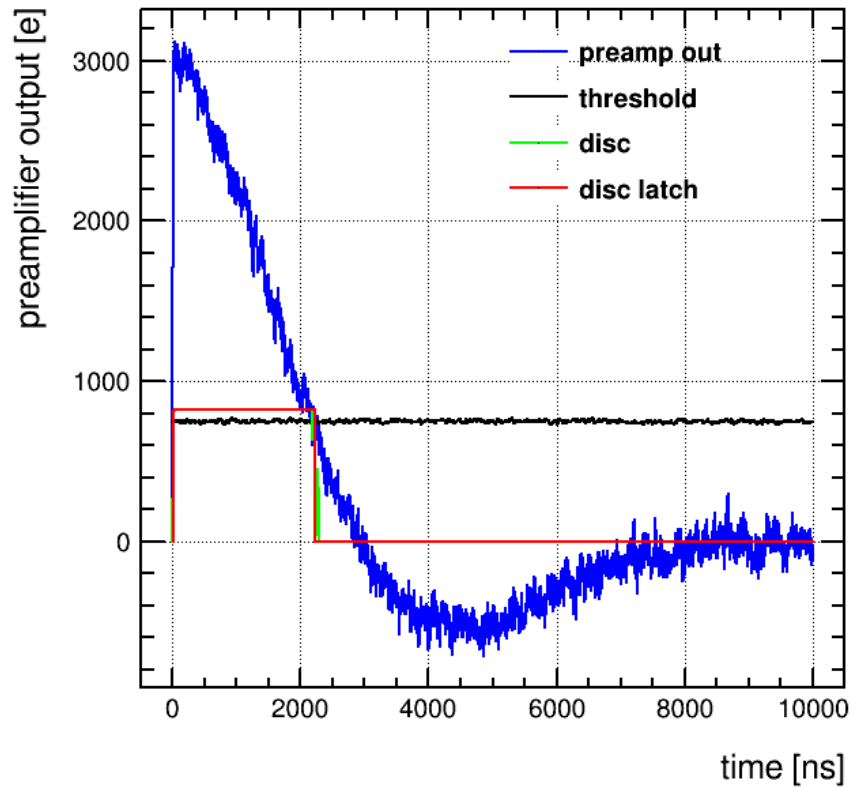
- Improved modelling of low input response and pre-amplifier undershoot

# LOW SIGNAL MODELING

Feedback saturation, linear ToT increase
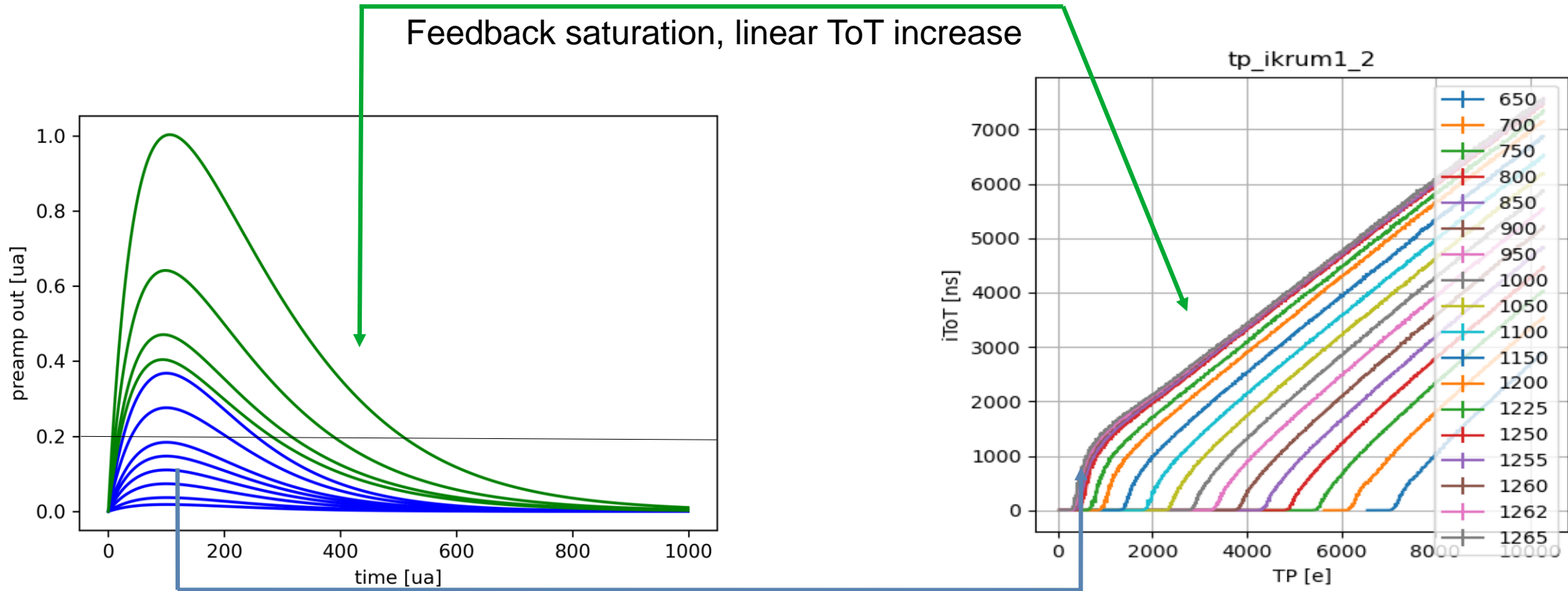


Small signal, constant return to zero

# SYSTEM NOISE



Independent bandwidth filtered noise channels for
1. pre-amplifier,
2. feedback and
3. threshold noise

- Glitch filtered discriminator for ToA/ToT registration

# TOT CALIBRATION
# TEST-PULSE VS SIMULATION
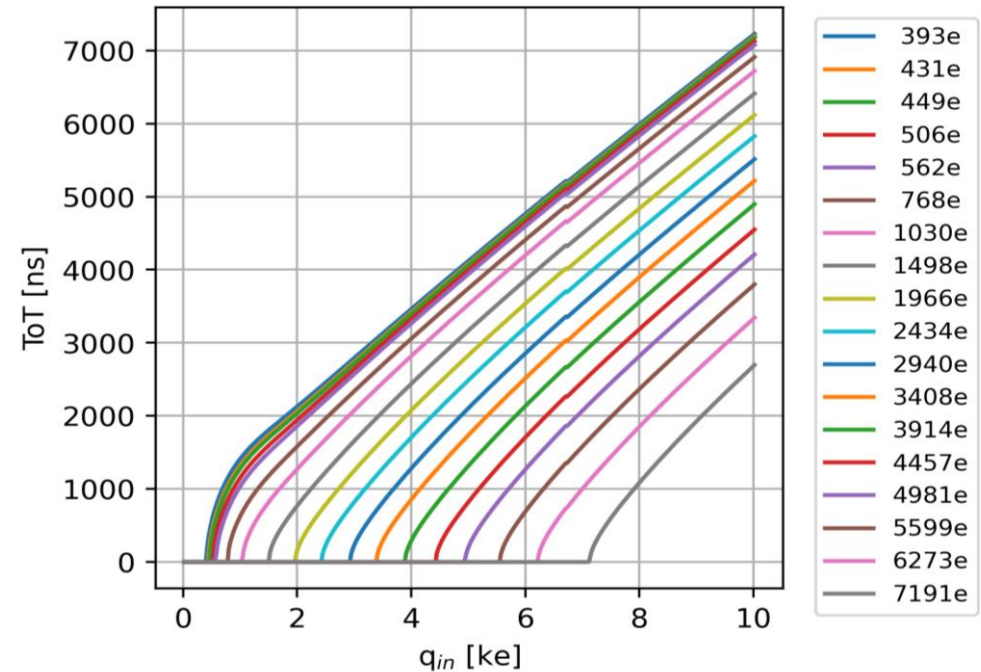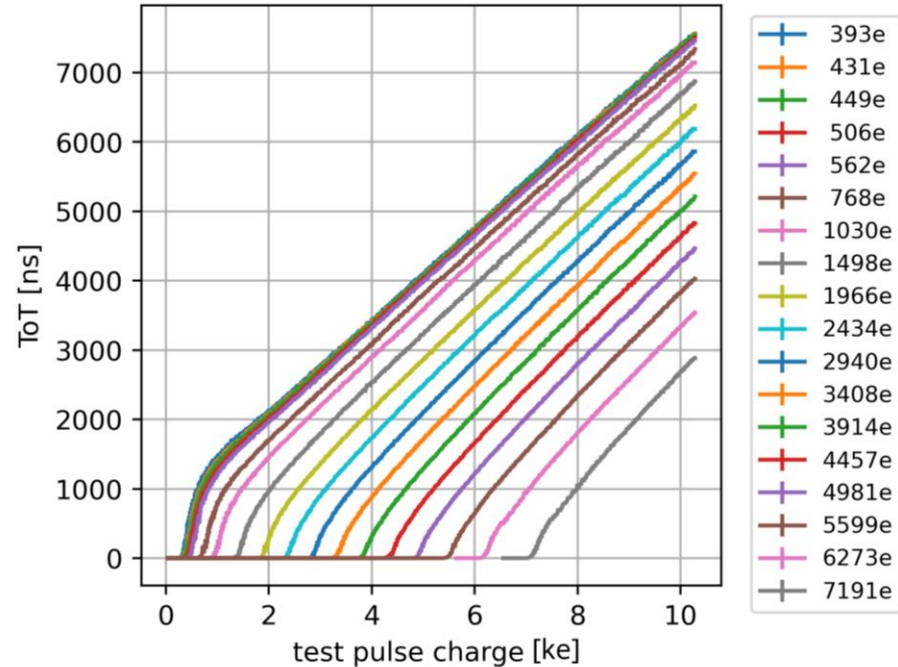


**Single pixel test-pulse, all other pixels disabled**
Measurement for thresholds below 750e include noise hits, ToT
response curve shape still preserved

**Corresponding test pulse simulation**
Feedback current values do not exactly match
Shape and evolution of ToT response very well reproduced
over a large range of threshold values

# AIM

**GOAL**: Sub-pixel resolution for spectral X-ray imaging with Timepix3

Problem: Sub threshold losses due to charge sharing.

Solution:  Probability maps for initial position and energy for a given cluster

$\downarrow$

- Realistic simulation of the front-end response with Allpix squared  ✓

- Signal distribution maps of deposited charge

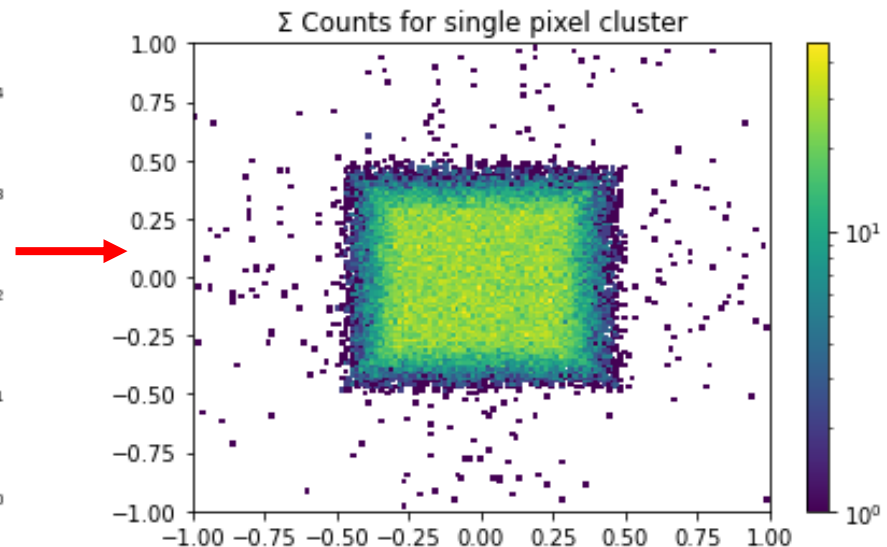# CLUSTERING ANALYSIS
# SINGLE PIXEL "CLUSTER"

Timepix3 Readout
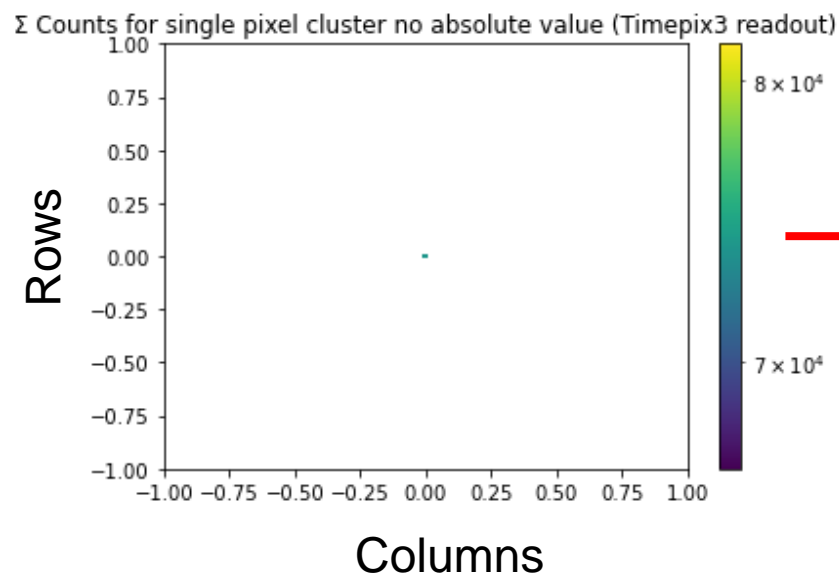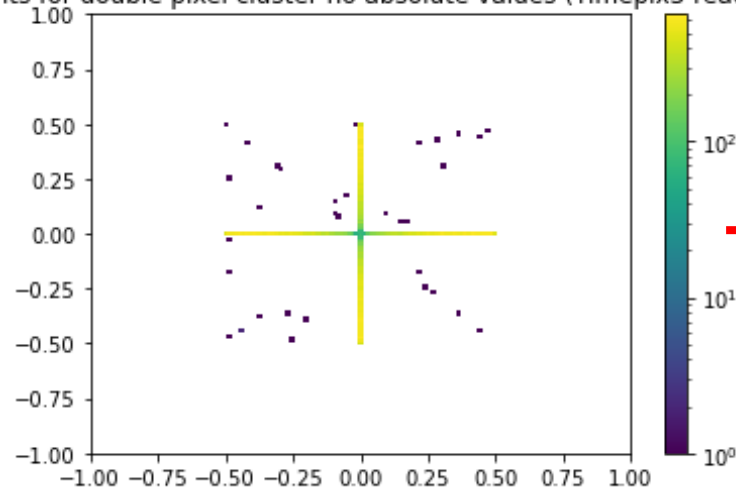
Charge collected in Pixels
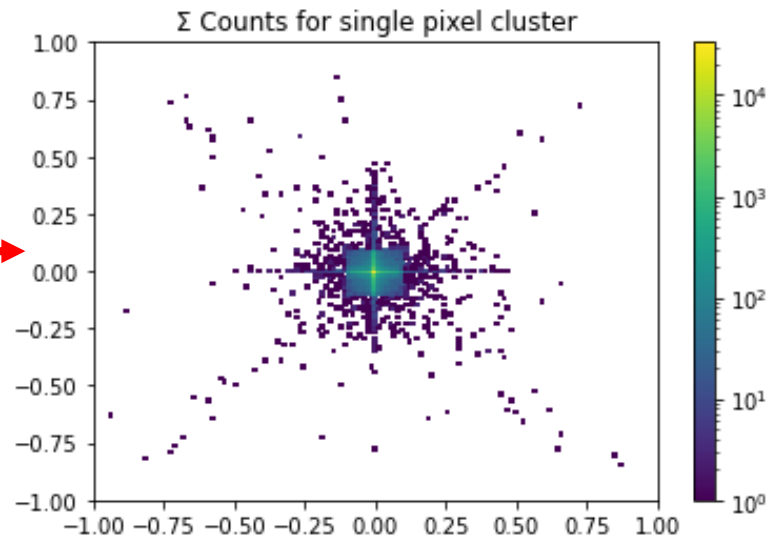
Charge deposited in the Sensor

# CLUSTERING ANALYSIS
# DOUBLE PIXEL CLUSTERS

Timepix3 Readout
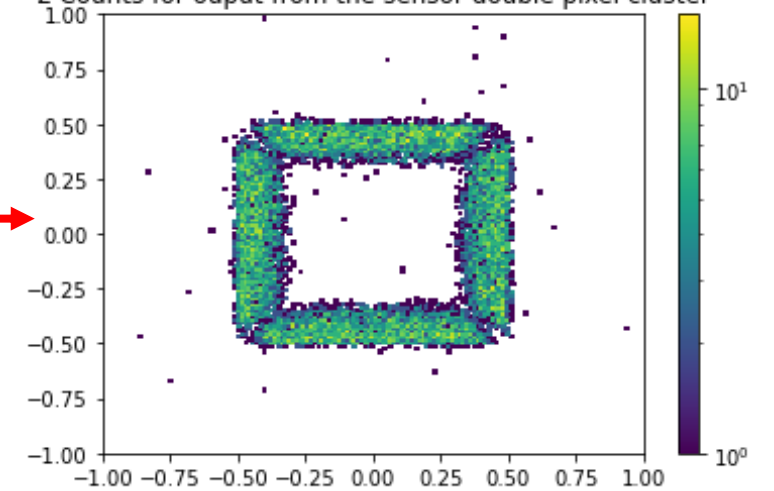
Charge deposited in Pixels
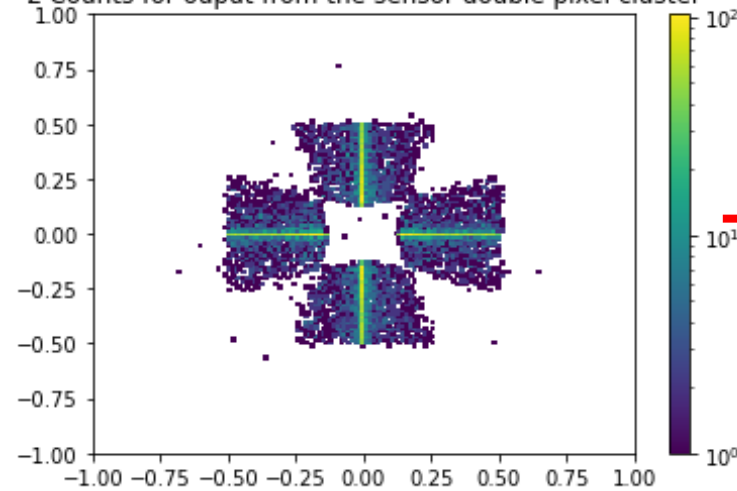
Charge deposited in the Sensor
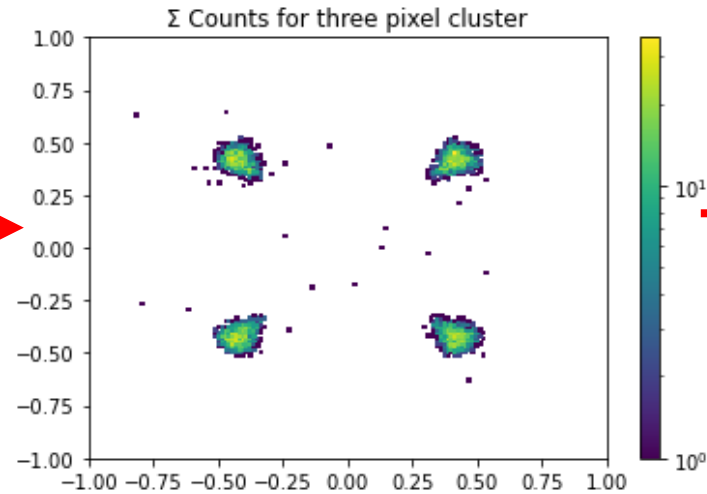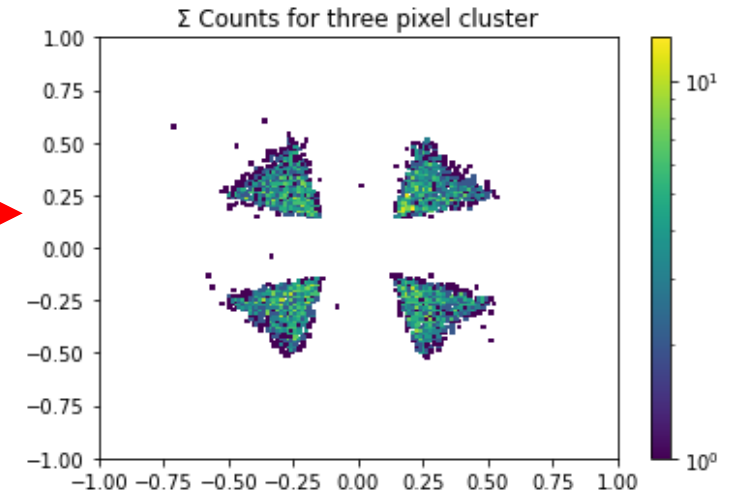
# THREE PIXEL CLUSTERS

Timepix3 Readout
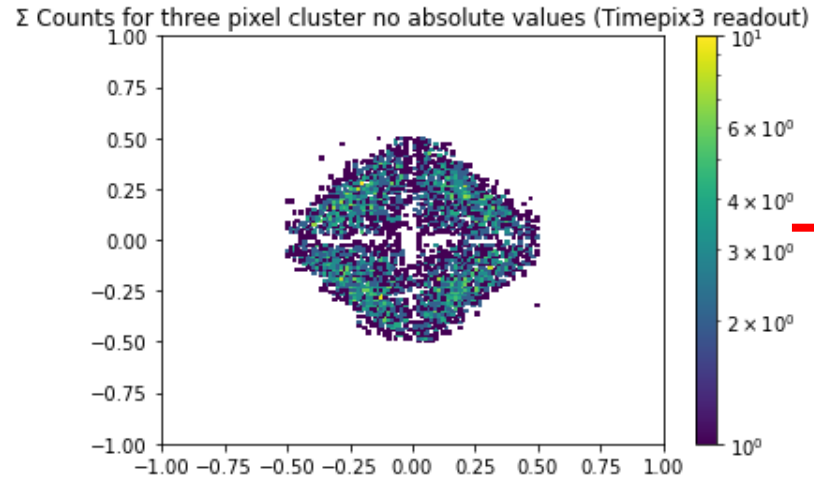
Charge collected in Pixels

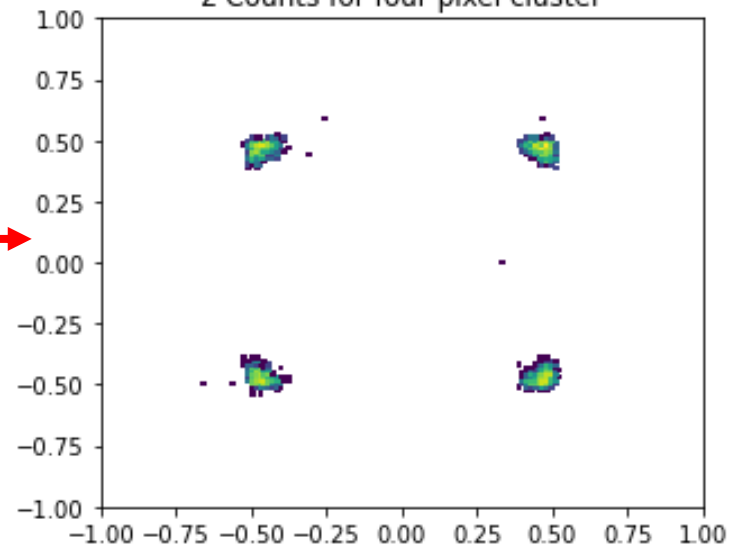Charge deposited in the Sensor

# FOUR PIXEL CLUSTERS

Timepix3 Readout

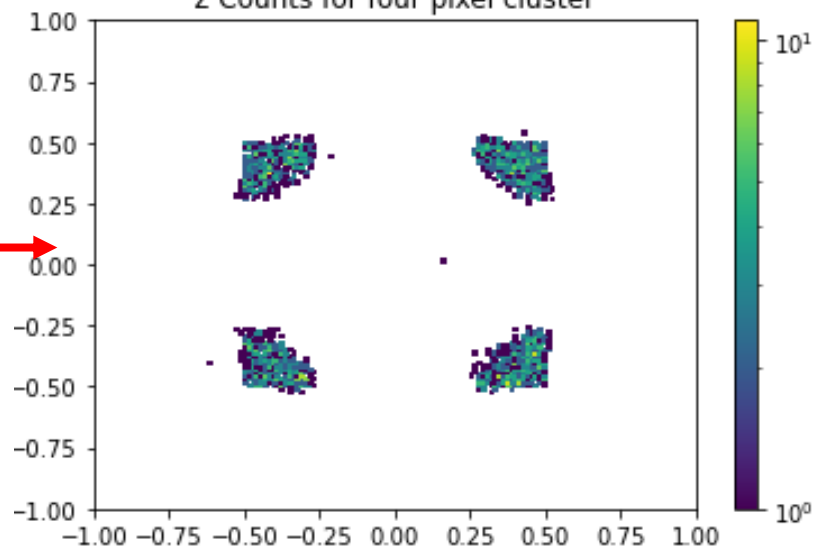Charge collected in Pixels
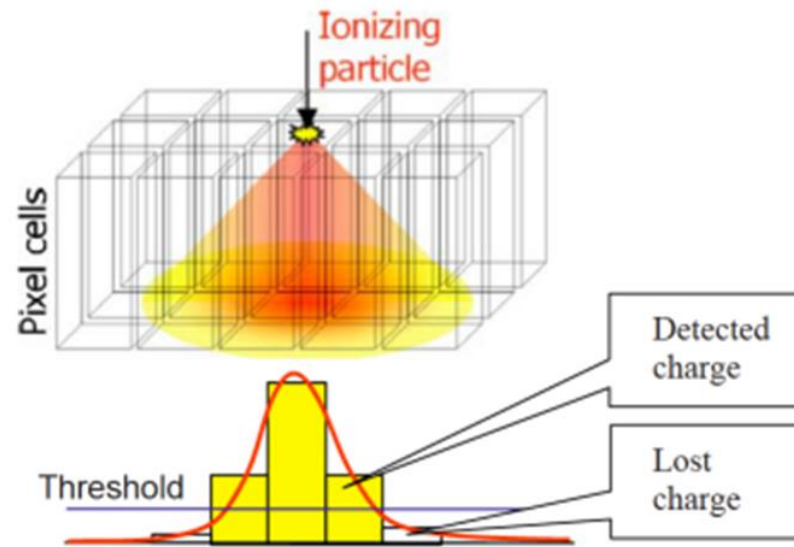
Charge deposited in the Sensor
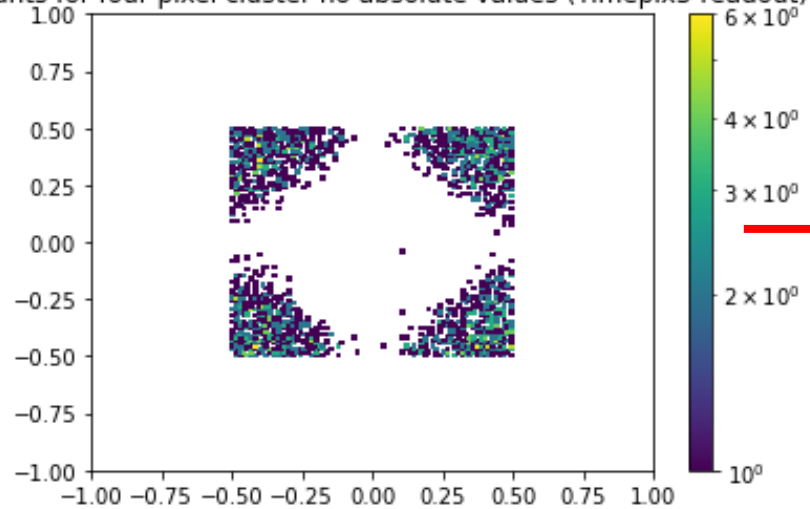
# CONCLUSIONS

- In reality the feedback and the time constant in the preamplifier are **not** fixed: they depend on the charge input.

- Limitations:

1. Effects with high input charges cannot be simulated properly (volcano effect)

2. Long simulation times due to long time constant for the leakage current compensation.

- The offset between the signal from the timepix3 readout for clusters of 1,2,3 pixels and the signal from the charge deposited in the sensor is significant.

**Next steps:**

- Inversion of maps to create probability maps for initial energy and initial interaction position
- Experimental verification of probability maps

# EXTRA SLIDES

# Charge sharing