# Characterizing and Optimizing DAMIC Skipper CCD Parameters

EMILEE WURTZ
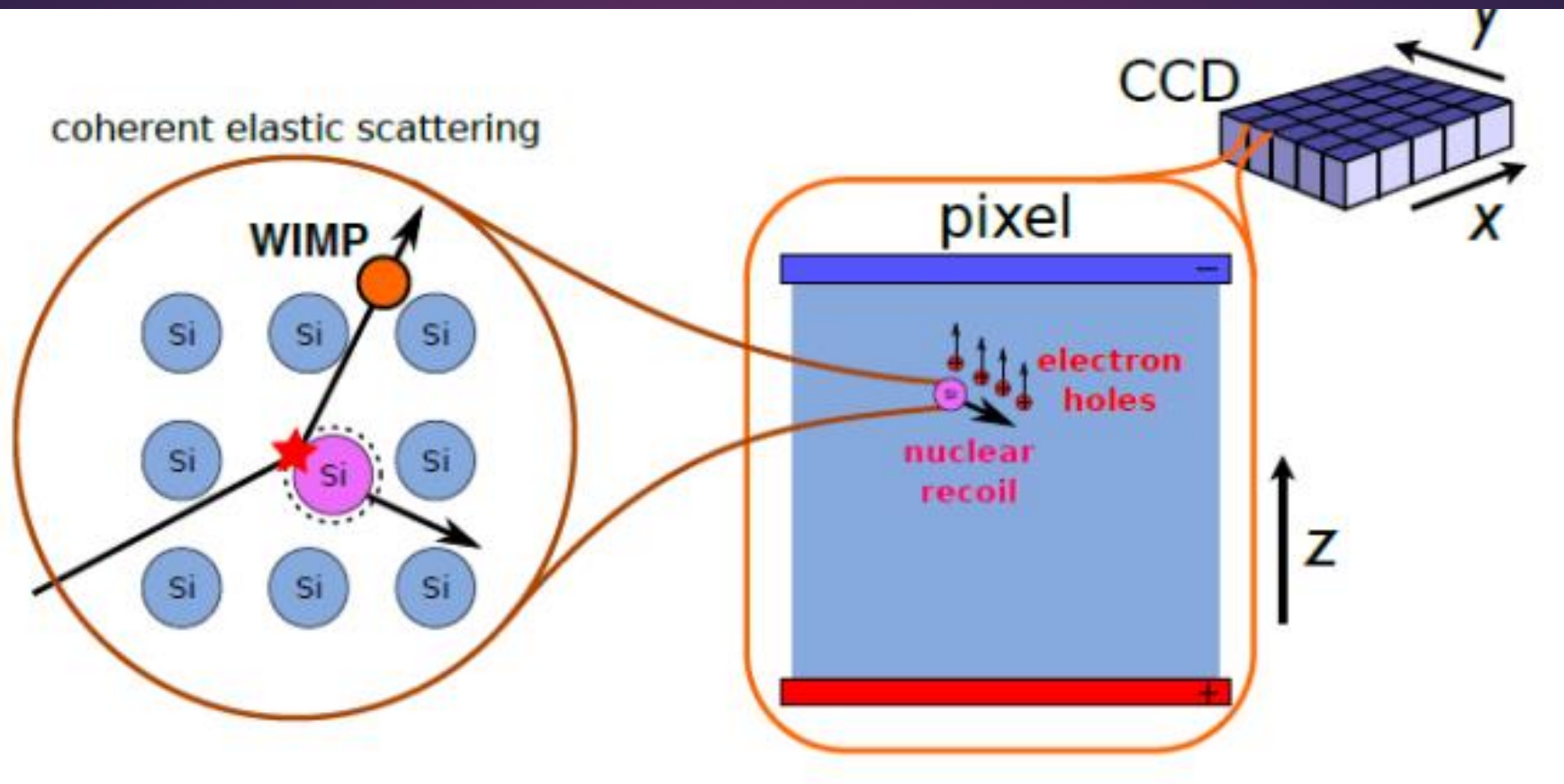
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2019 UNIVERSITY OF WASHINGTON INT REU
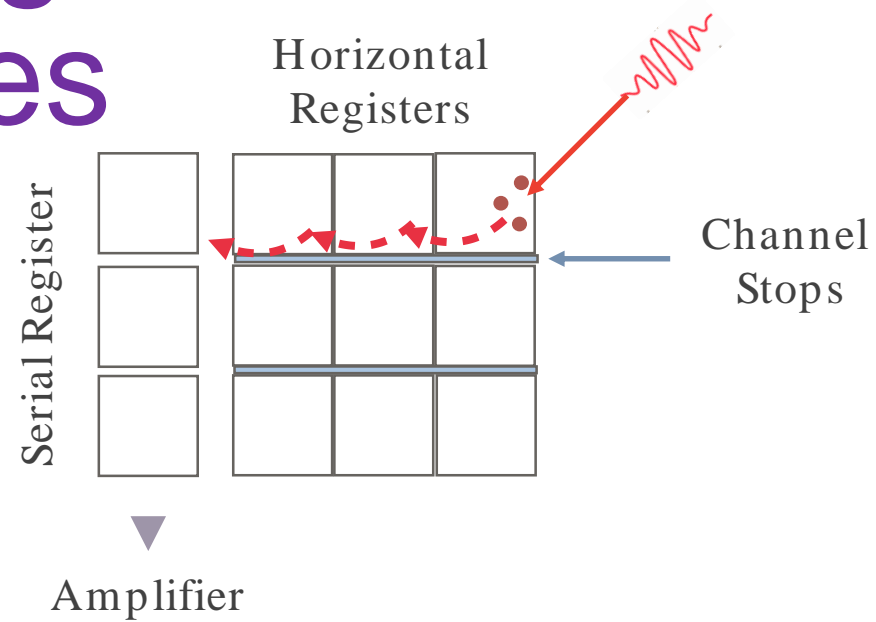
# CCDs in the Search for Dark Matter

▶ **CCDs** (Charge-Coupled Devices) are imaging devices that generate electron hole pairs from interaction with photons

▶ **Damic-M** aims to use CCDs to search for dark matter particles, in particular the WIMP

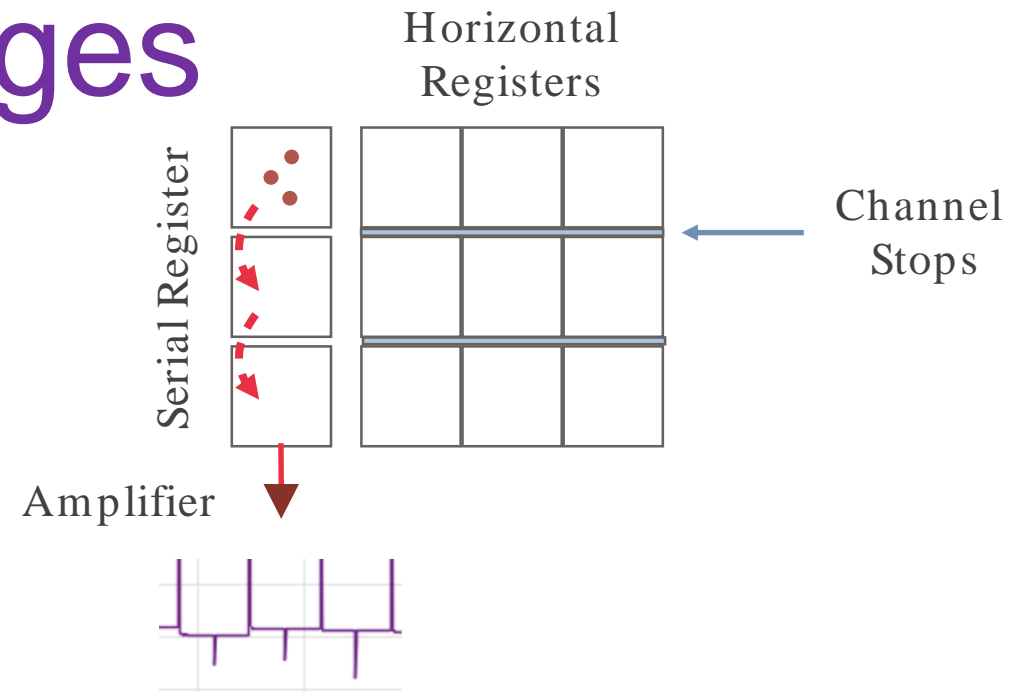▶ **Skipper CCDs** achieve high levels of sensitivity by measuring charge several times
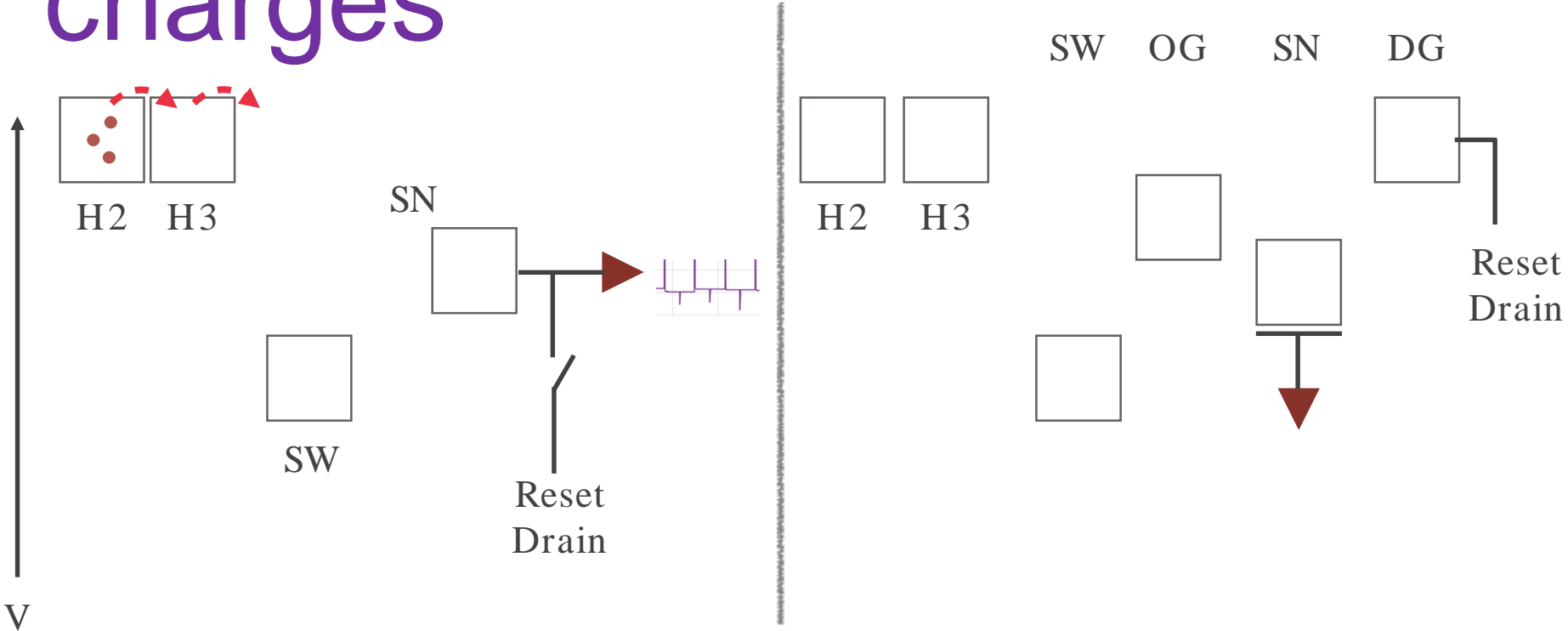
# WIMP Scattering Interaction
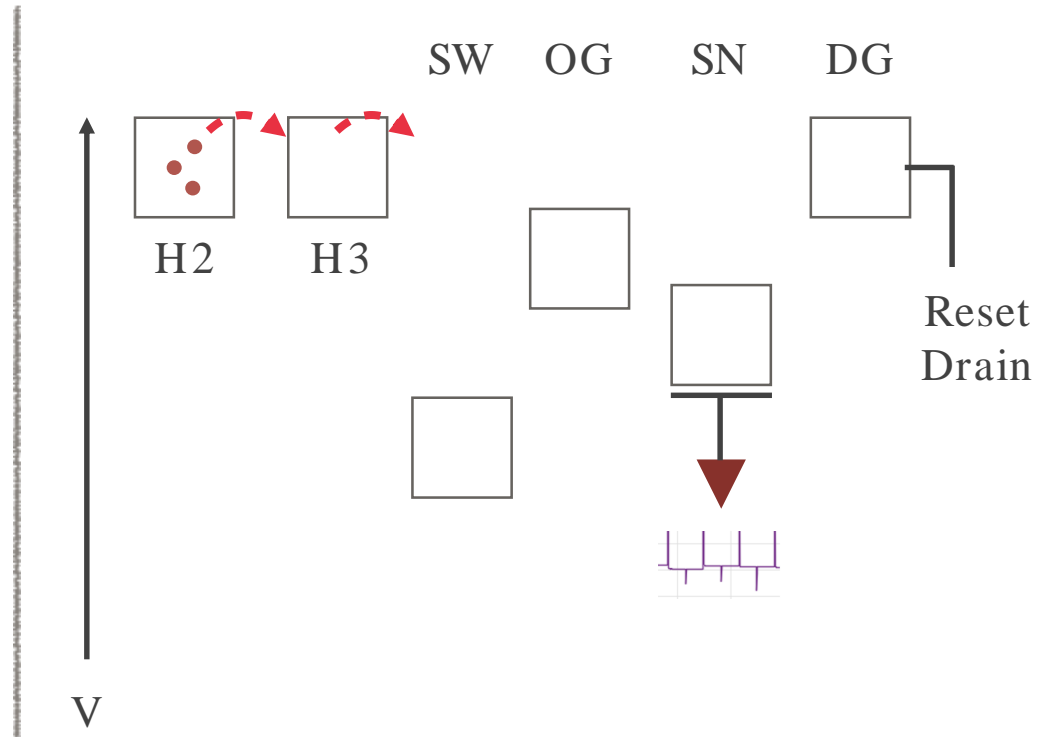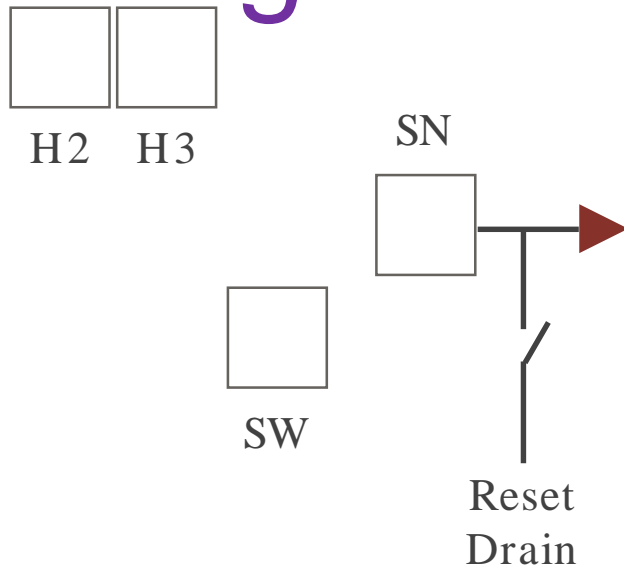
# CCD: Moving charges

Horizontal Registers

Serial Register

Channel Stops

Amplifier

# CCD: Moving charges

Horizontal Registers

Serial Register

Channel Stops

Amplifier

# CCD: Measuring charges

H2    H3

SW

SN

Reset
Drain

SW    OG    SN    DG

H2    H3

Reset
Drain

V

# Skipper CCD: Measuring charges

H2    H3

SN

SW

Reset
Drain

SW    OG    SN    DG

H2        H3

Reset
Drain

V

# Skipper CCD: Measuring charges

H2   H3

SN

SW

Reset
Drain

SW   OG   SN   DG

H2   H3

Reset
Drain

V
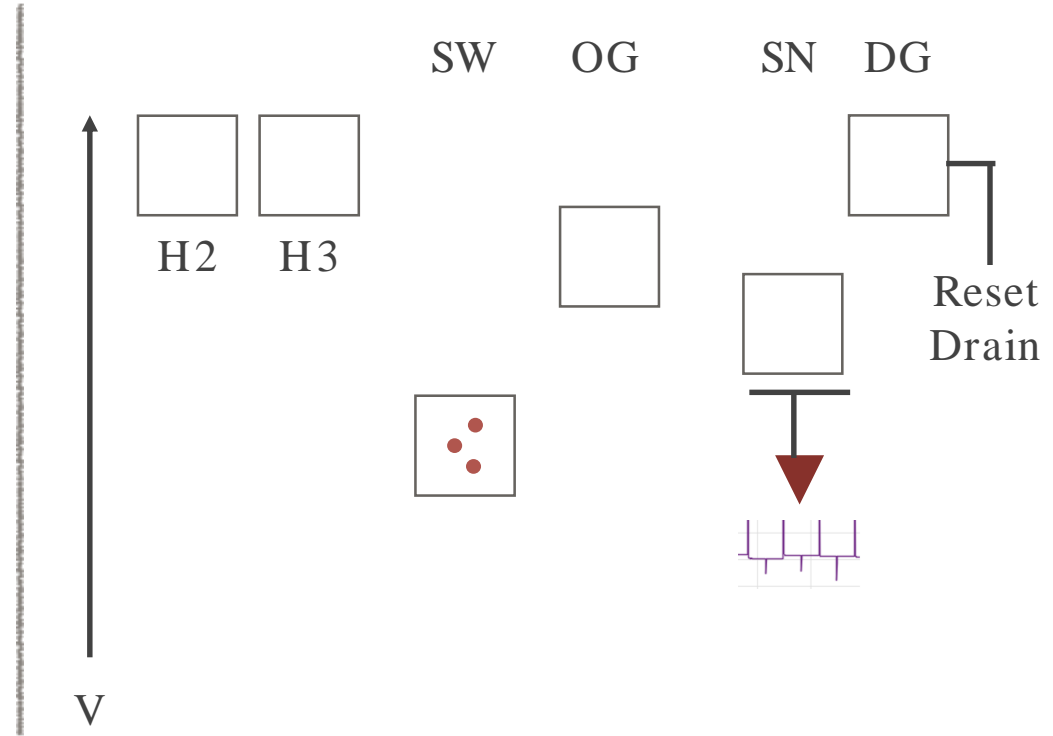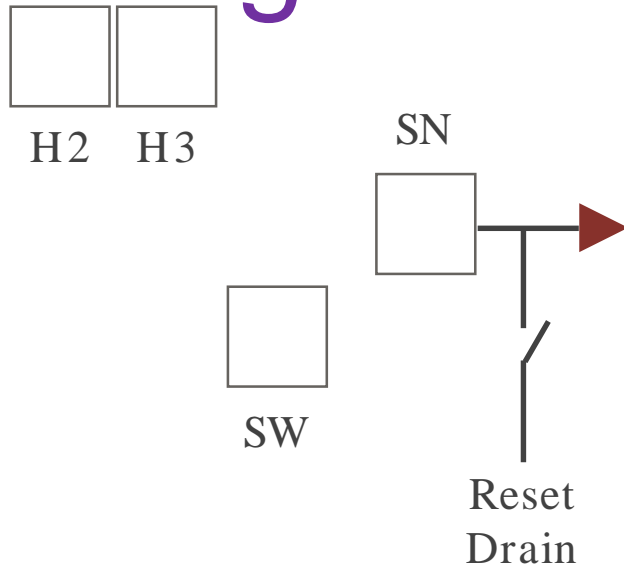
# Findings

- All the parameters are closely coupled; change in one will affect many others

- Summing Well Hi and Lo being far apart provided best results

- OG is incredibly sensitive and serves as the integral change to all other parameters

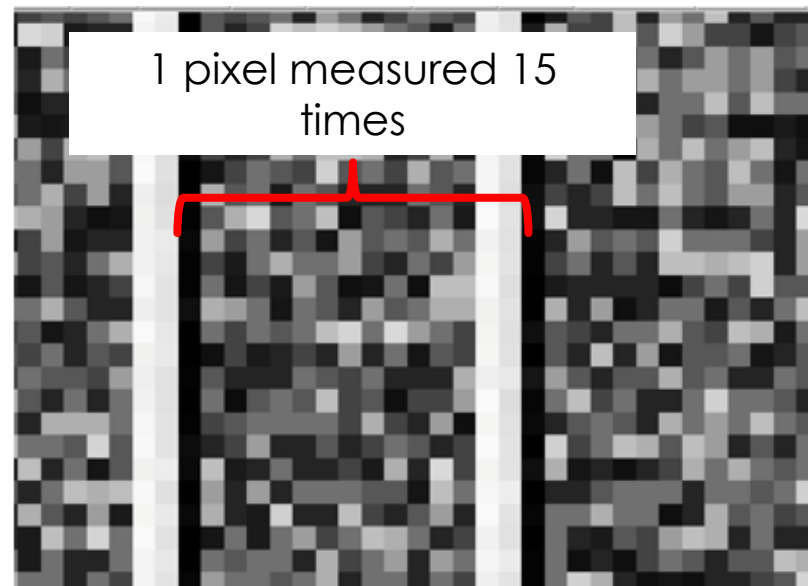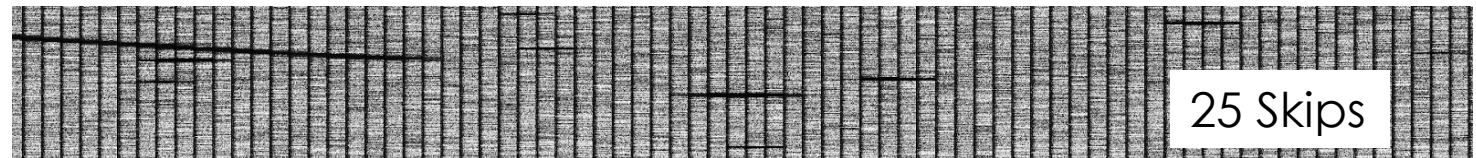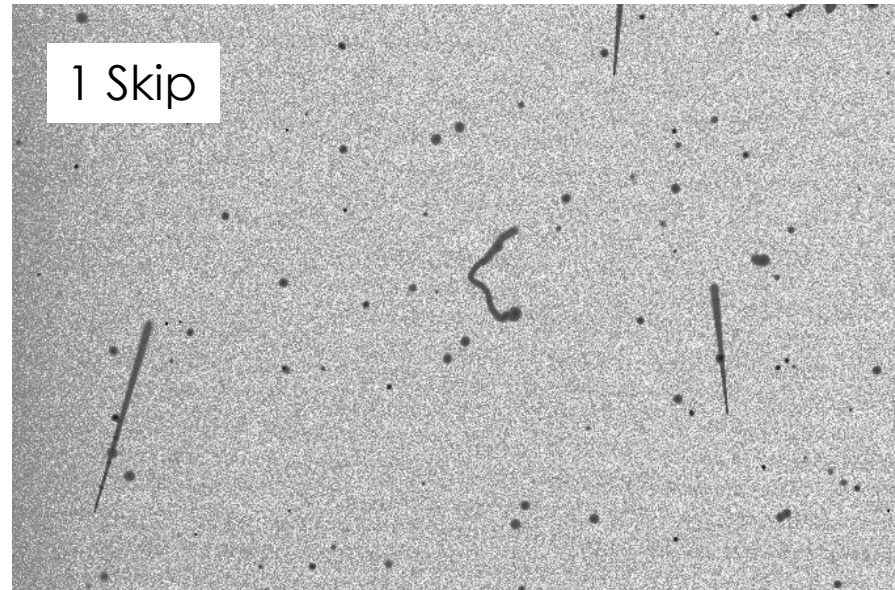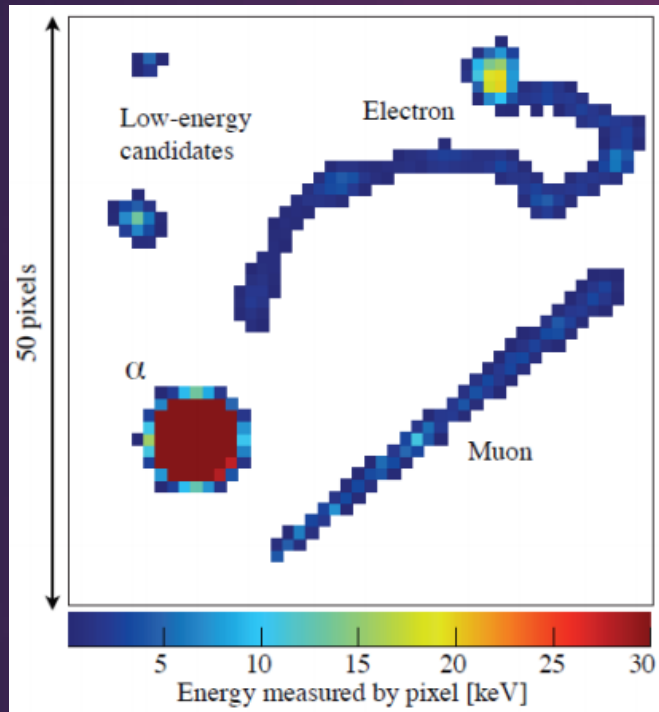- Drain and Reference Voltage have to change per amplifier and CCD

# Changes Tested

- Different Sequencers with various parameters firing at different times

  - Result: OG firing with RG being most promising

- Changing the rise/fall time of the different gates

  - Result: Little to no difference

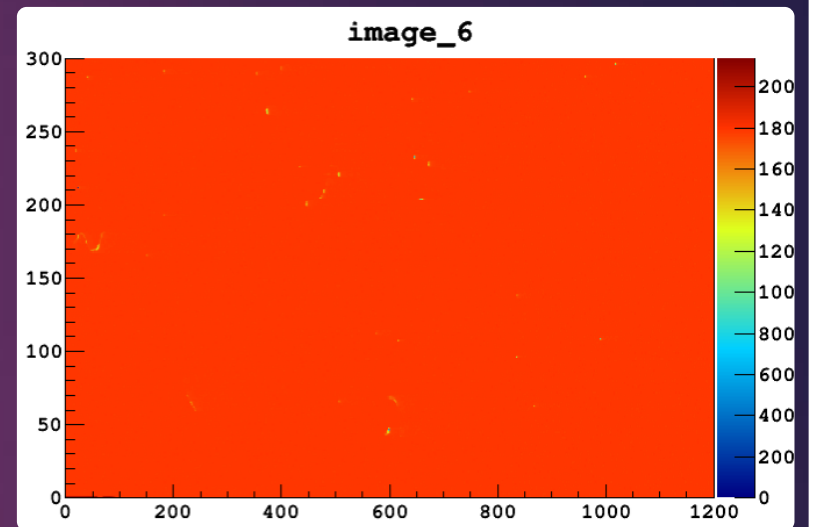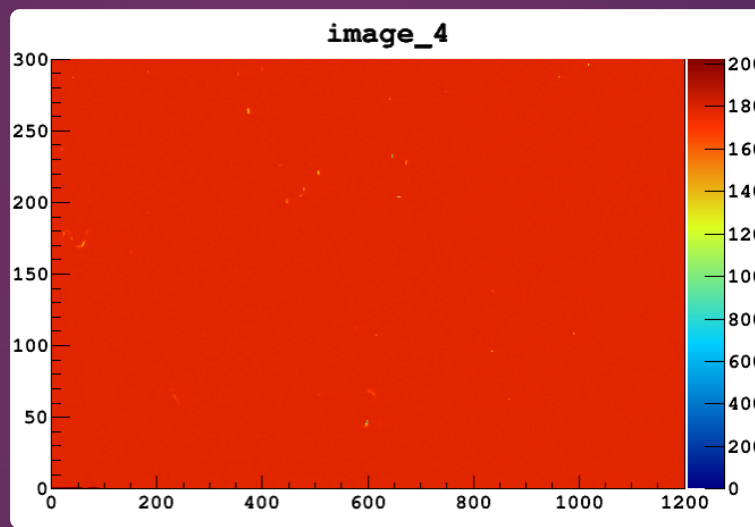- Keeping charge in different gates for various lengths of time
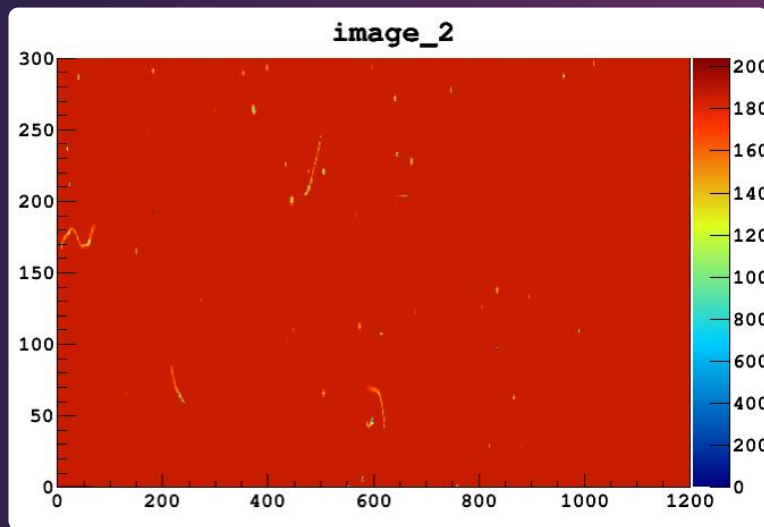
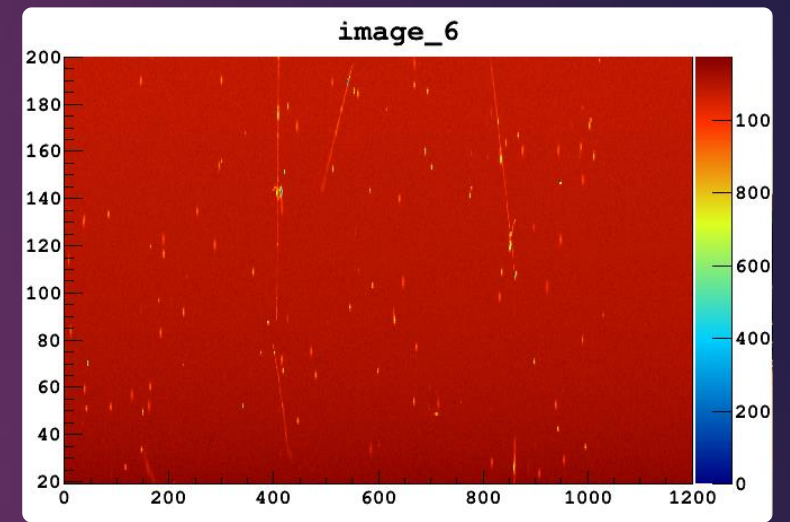  - Result: Little to no difference
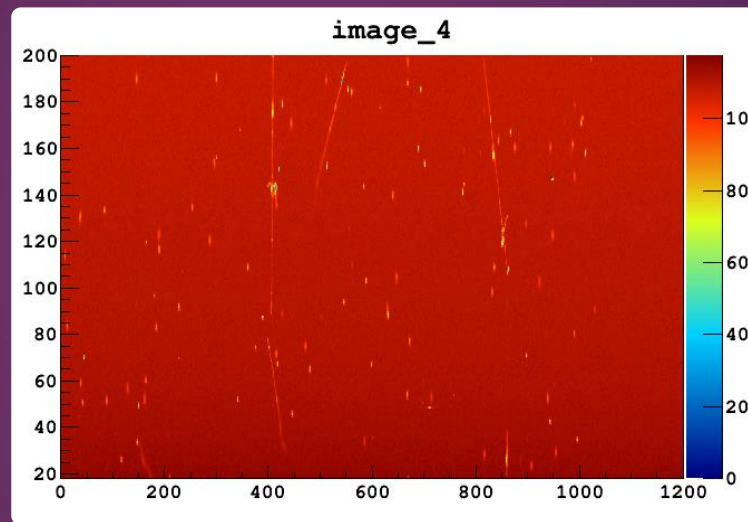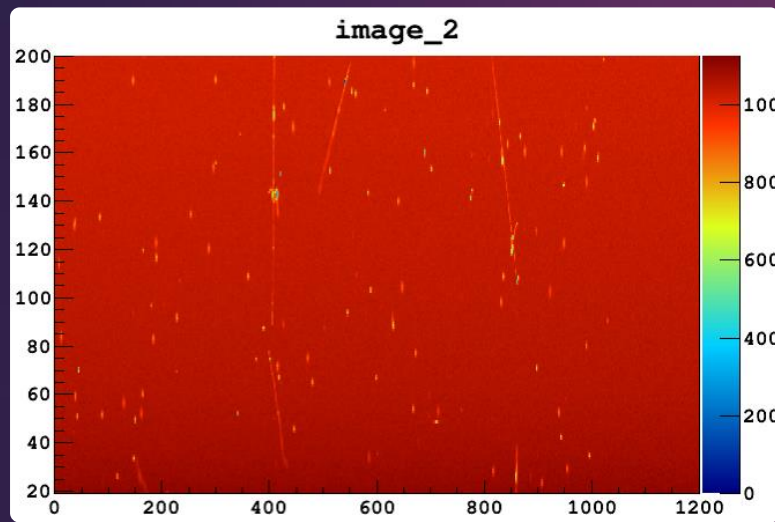
# Optimizing Images

What we look for?

1. Tracks!

2. Little to no loss of charge between skips

3. Pixel distribution follows Gaussian curve

4. Noise reduces by a factor of $1/\sqrt{N}$, where N is number of skips

# Tracks and Skips
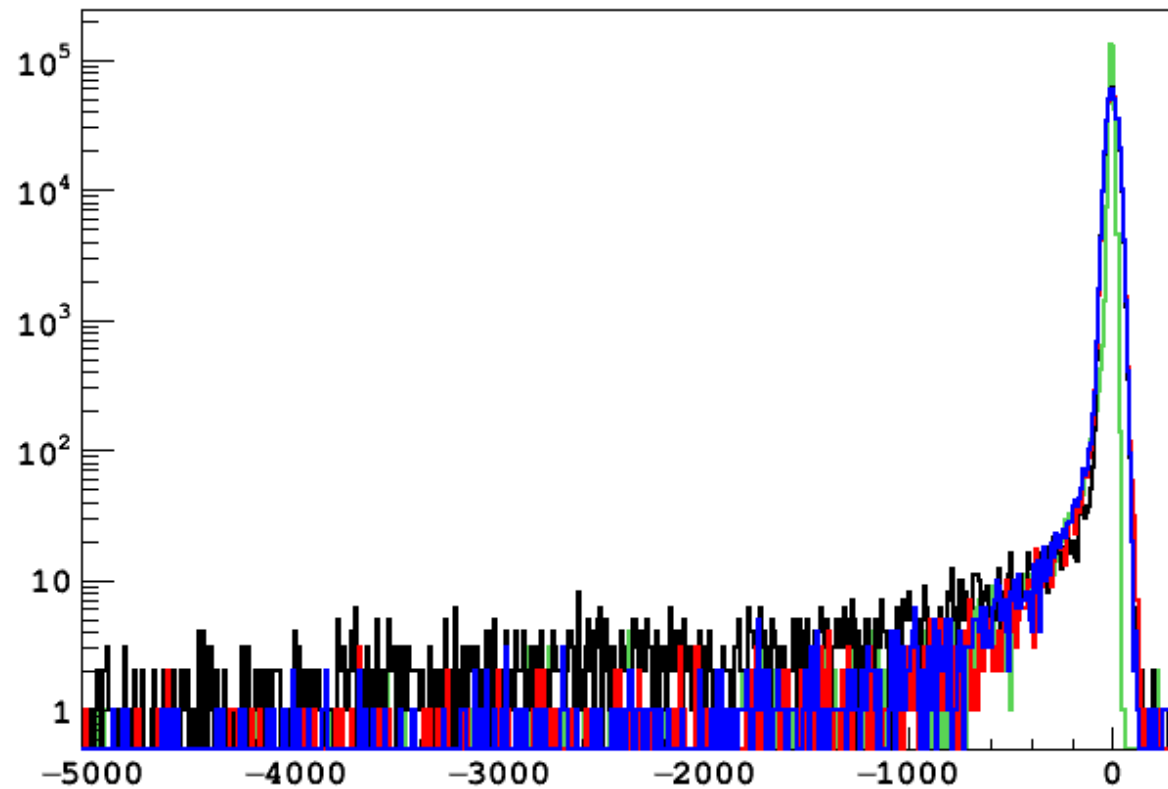


Low-energy candidates

Electron

50 pixels

α

Muon

Energy measured by pixel [keV]

1 Skip

25 Skips
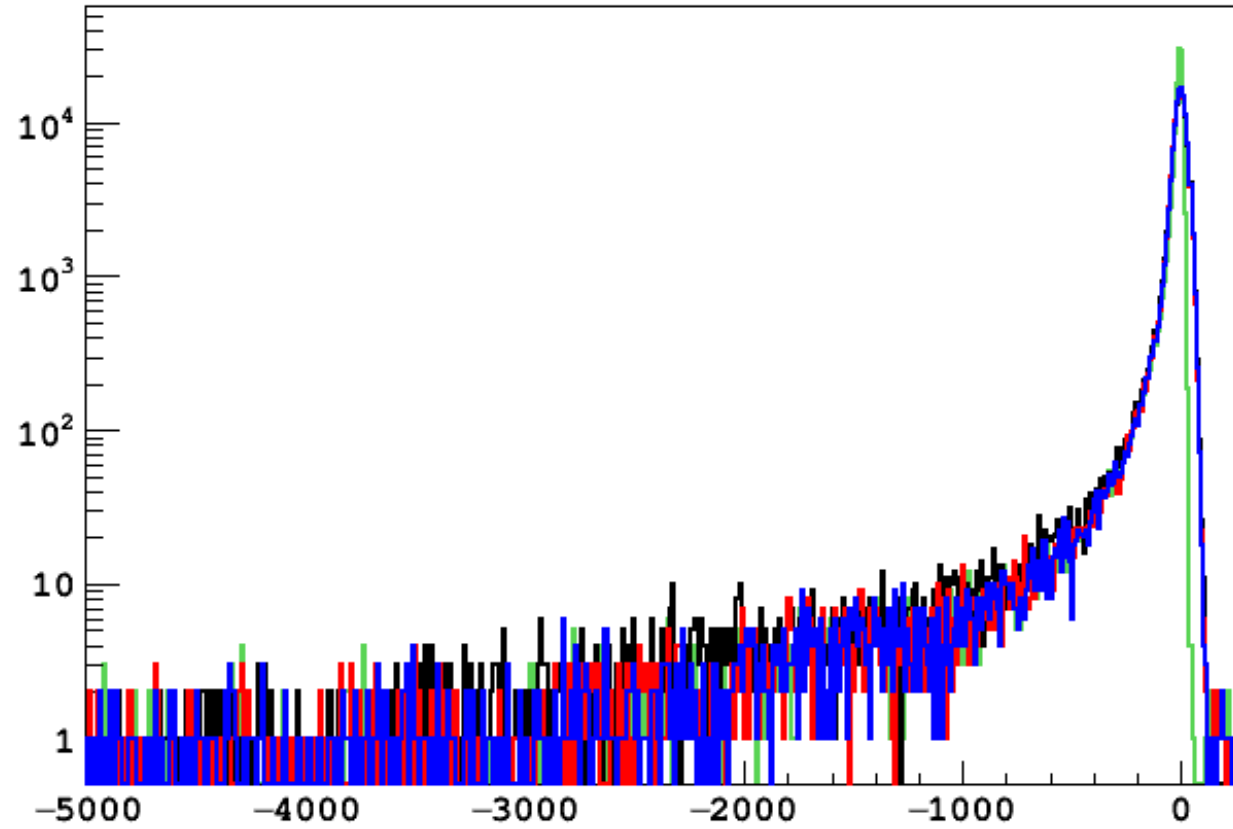
1 pixel measured 15 times

# Charge Loss between Skips
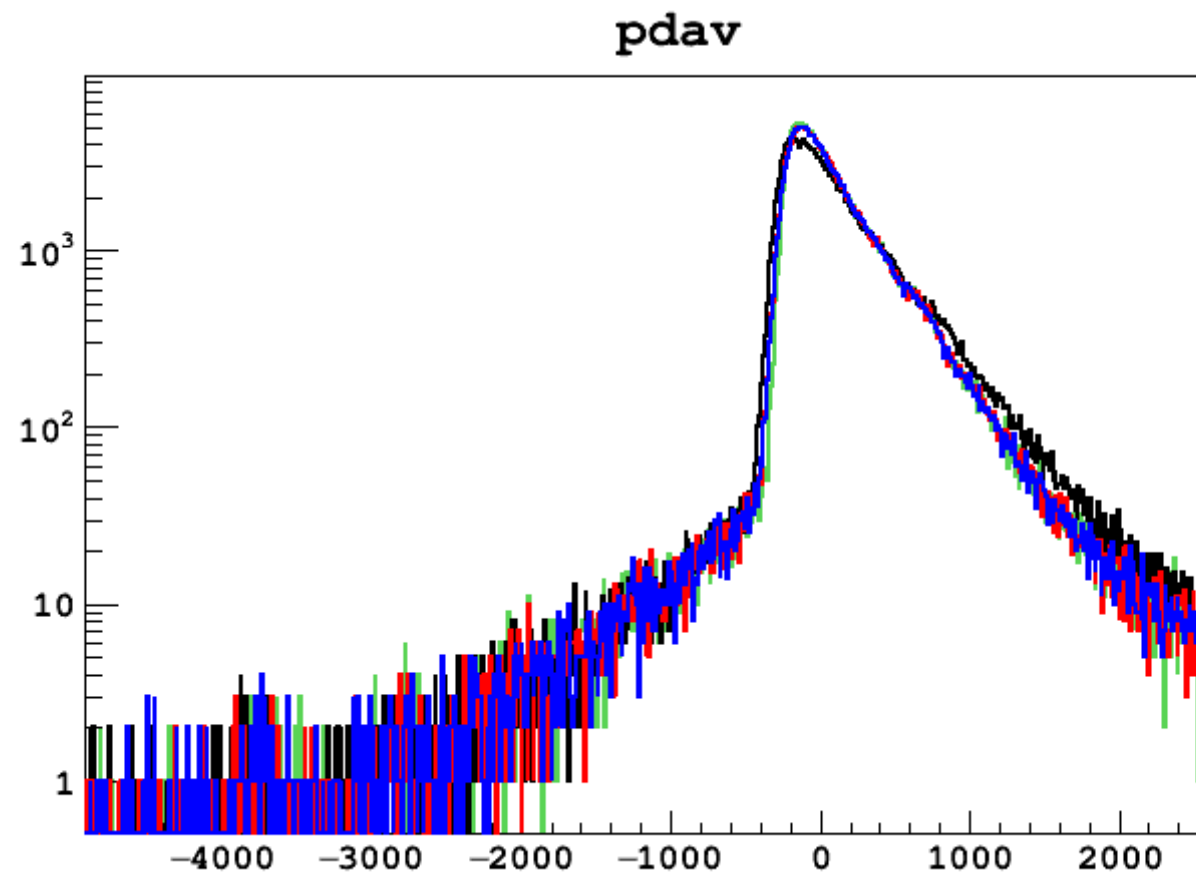
# Minimal Charge Loss
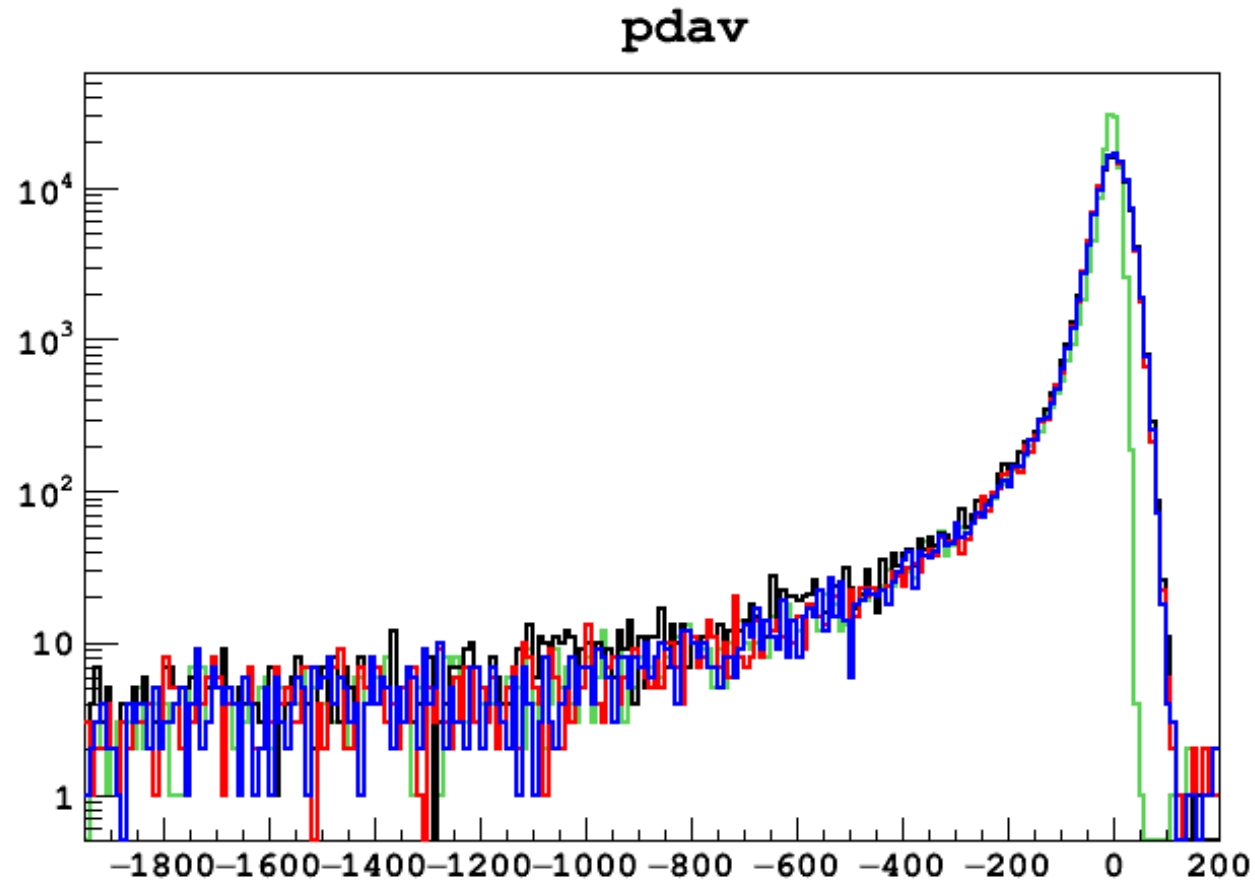
Average Image
Image 2
Image 4
Image 6

pdav

Average Image
Image 2
Image 4
Image 6

pdav
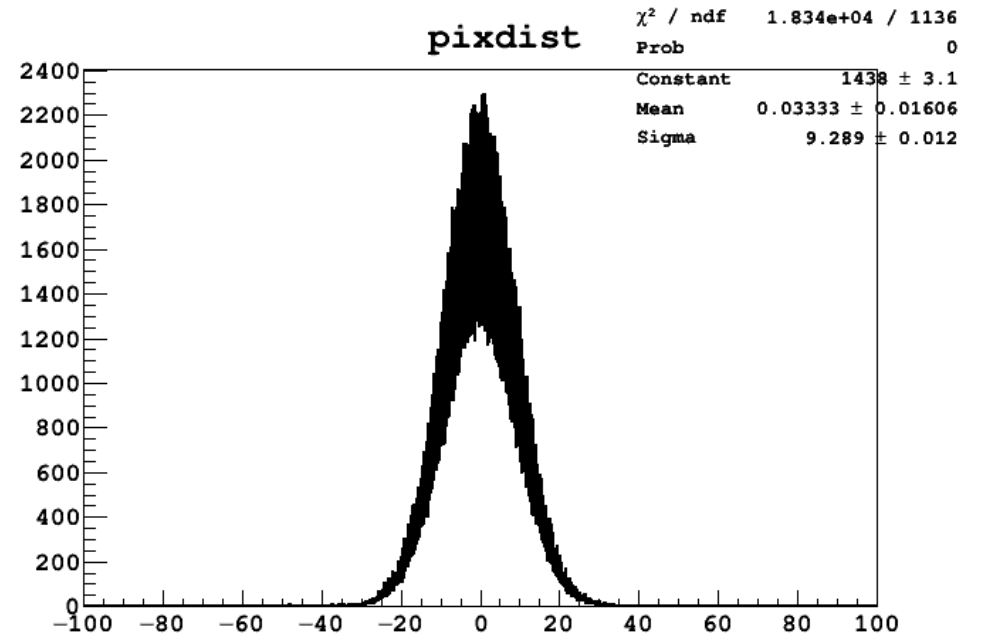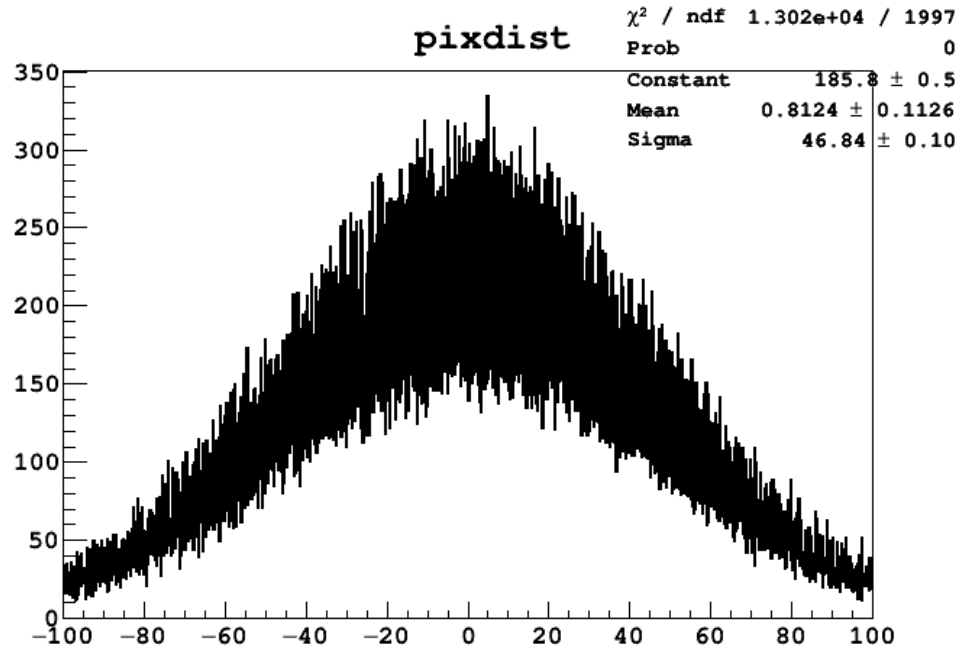
Charge Not Following Gaussian

pdav

Charge Following Gaussian

# Noise Reduction



| RMS - raw | RMS - runav | Reduction Factor | Expected |
|---|---|---|---|
| 79.17 adu | 46.84 adu | 2.85 | 5 |

| RMS - raw | RMS - runav | Reduction Factor | Expected |
|---|---|---|---|
| 22.40 adu | 9.289 adu | 5.81 | 5 |

# Conclusions and Future Steps

▶ We have a better understanding of the different parameters, but they still surprise us!

▶ Not all CCDs or their amplifiers function the same

▶ Unable to see good charge transfer and the proper $\frac{1}{\sqrt{N}}$ noise reduction simultaneously

▶ Continue to try and find the balance between these two factors

▶ Decrease sources of noise

▶ Get single-electron response!

# Thank You

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