

MuPix 8 Results

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for the Mu3e Collaboration

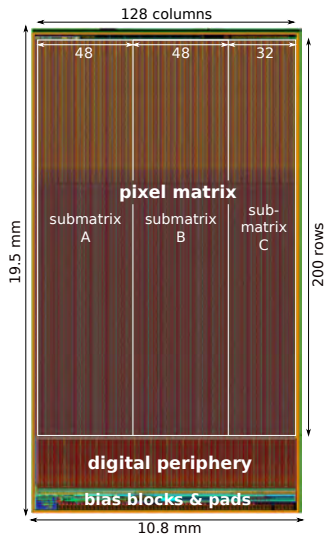
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DPG Frühjahrstagung Würzburg



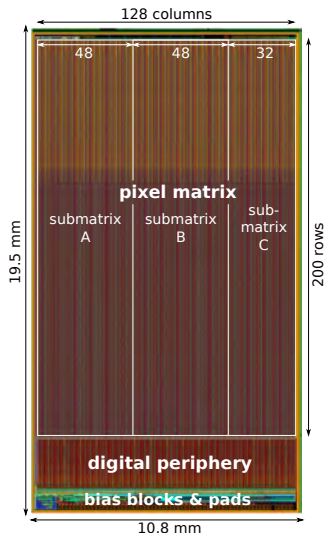
MuPix8

- First large HV-MAPS prototype for Mu3e
- $19.5 \times 10.8 \text{ mm}^2$
- $80 \times 81 \mu\text{m}^2$ pixel with 1 diode each
- 200×128 pixel



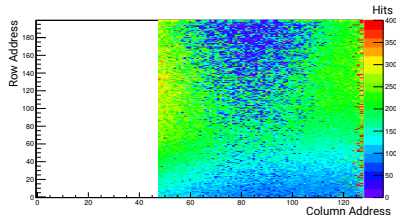
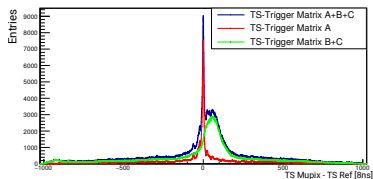
MuPix8

- 3 submatrices with different line drivers
 - A with Source Follower
 - B+C with Current Driver
- 4 LVDS links with 1.25 Gbit/s (A,B,C and copy or Mux)
- Only small sample size so far due to production issues



Submatrices

- Source Follower (A) like previous MuPix prototypes
 - Current Driver (B+C) new
 - A worked out of the box, B+C did not as good
 - Worse timing and no good default working point
- Focus on A, B+C postponed



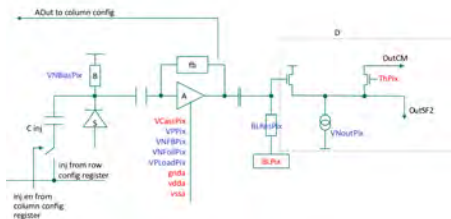
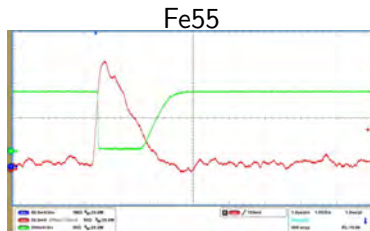
Setup

- Sources: Fe55, Sr90, Injection (1 or more Pixel)
- Most measurements done with an oscilloscope
- Biased by scope trigger and measurement setup
- Amplifier output of 1 pixel in col 0 studied
- Hitbus (OR of comparator outputs in one col) for ToT



Amplifier Output

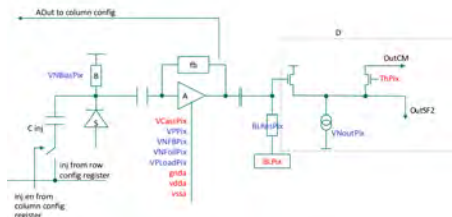
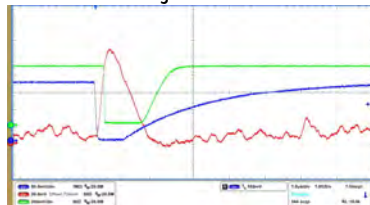
- Nice triangle pulses
 - Fe55 (1600 e⁻) ≈ 100mV
- $C_{fb} \approx 2.5\text{fF}$



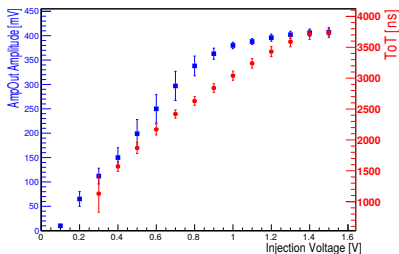
Amplifier Output

- Nice triangle pulses
- Fe55 (1600 e^-) \approx 100mV
- $C_{fb} \approx 2.5\text{fF}$
- Fe55 equivalent injection voltage \approx 250mV
- $C_{inj} \approx 1\text{fF}$
- Peak to Peak noise \approx 20mV
- SNR \approx 17 (assuming uniform noise)

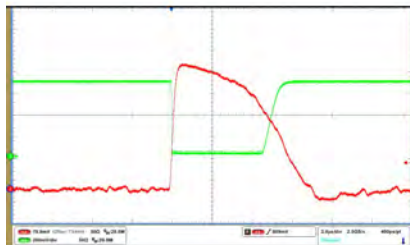
Injection



AmpOut Saturation



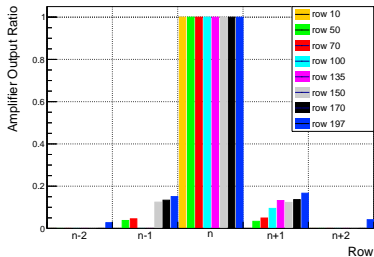
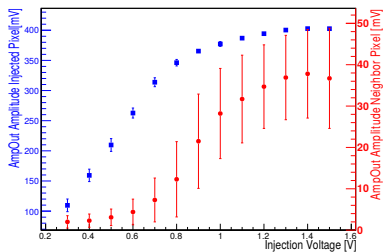
Sr90 @ -2V HV



- Error bars = standard deviation
- AmpOut saturates, no longer triangular
- ToT less affected

Line Crosstalk

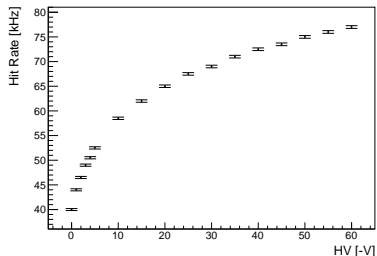
Row 100 \rightarrow Row 101



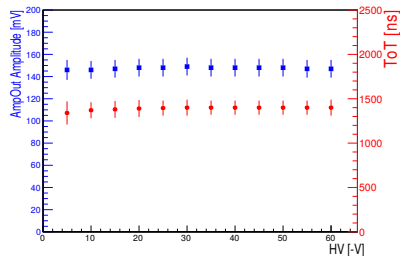
- Crosstalk small compared to signal (Fe55 5.9keV \approx 100mV)
- Should be small for low momentum electrons (\approx 8 – 12keV for 20 – 30 μ m depletion)

HV Dependence

Fe55

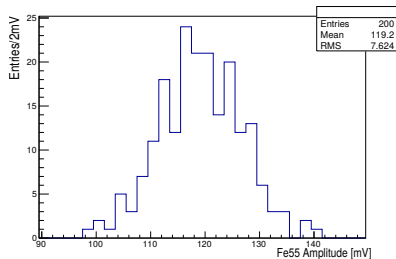
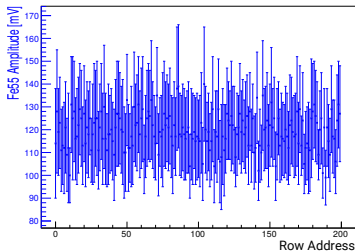


Injection



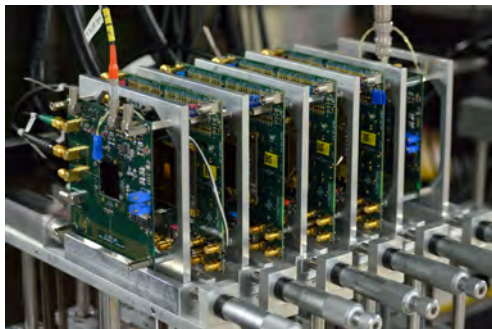
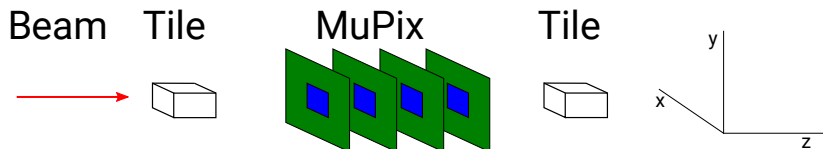
- Depletion volume and pixel capacity depend on bias HV
- Signal shows only little dependence on HV/pixel capacity

Row Dependence Signal

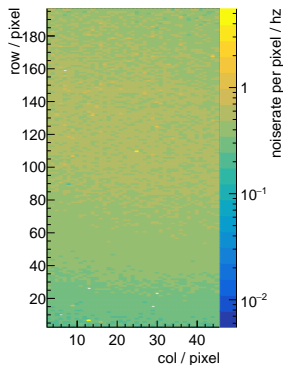
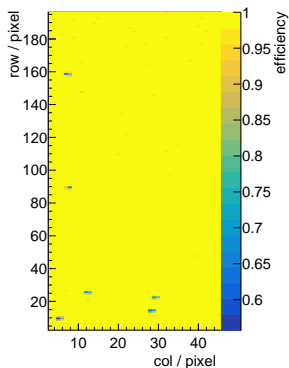


- No dependence on row for signals

MuPix Telescope with 4GeV Positrons @DESY



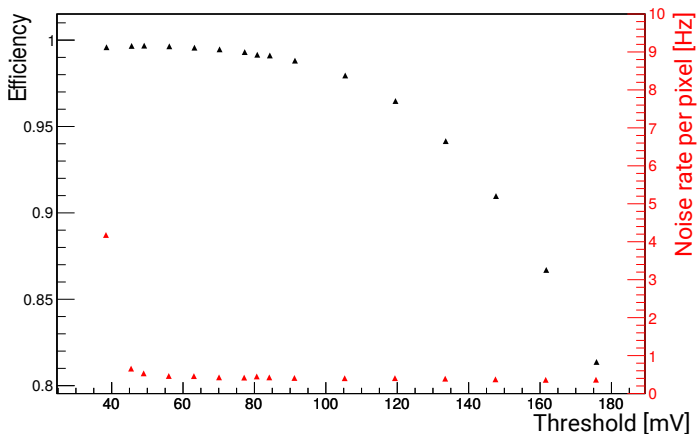
Efficiency and Noise



- Overall efficiency: 99.7%
- Chip untuned
- Noise rate ≈ 0.5 Hz per pixel

- Noisy pixels ignored
- HV = - 60 V
- Low threshold (45 mV)

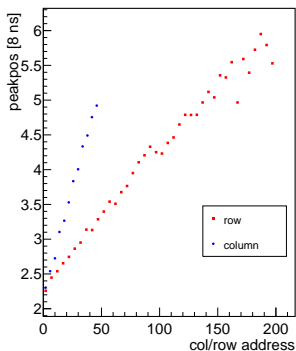
Thresholdscan at -60V



- Up to 25 noisy pixels ignored in analysis
- Broad operation region of over 40 mV

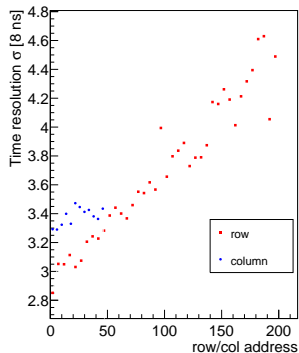
Timing Dependence

Delay



Likely related to
Clock Distribution

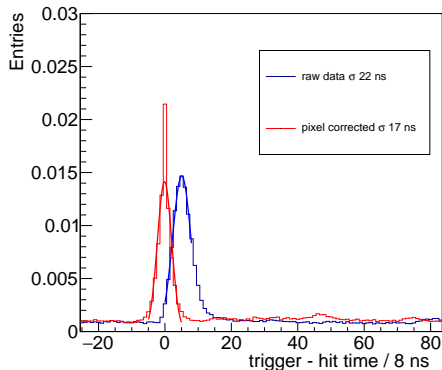
Resolution



Variation probably
due to line capacities

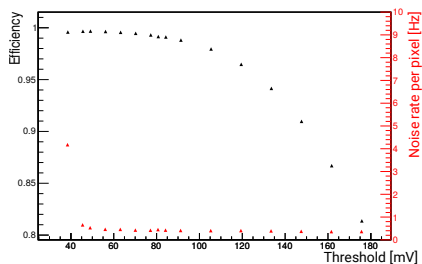
Corrected Time Resolution

- Correction for delay gives significant improvement
- Analysis limited by sample size
- Possible improvement by tuning



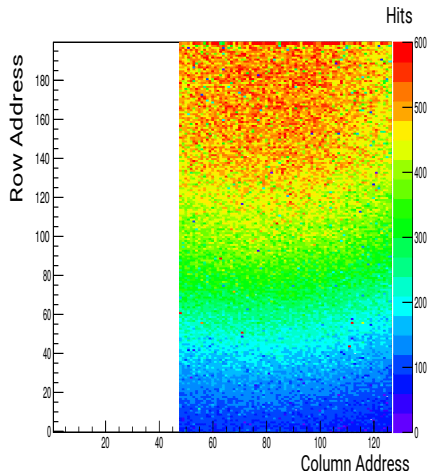
Summary

- MuPix8 as first large scale prototype in operation
- High efficiency and wide range without much optimization
- Time resolution ok but can be improved
- Lots of testbeam data left to analyze



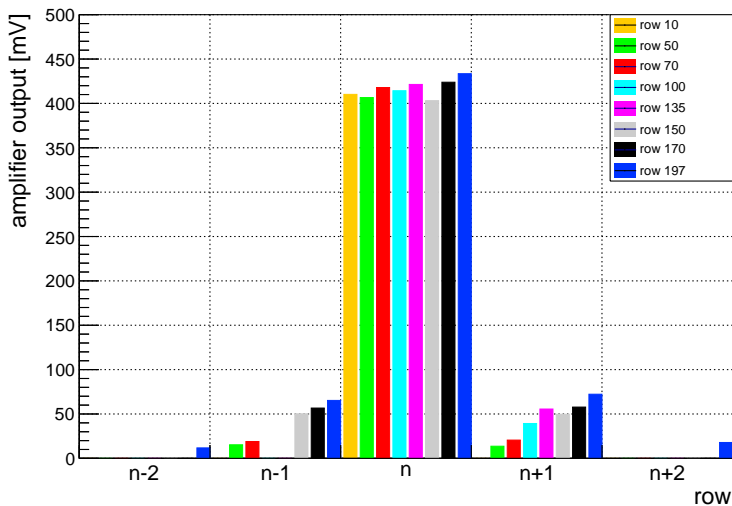
Outlook

- Improvements by Tuning
- More measurements in the lab
- Lots of new features in the MuPix8 barely explored
- Measurements with B+C

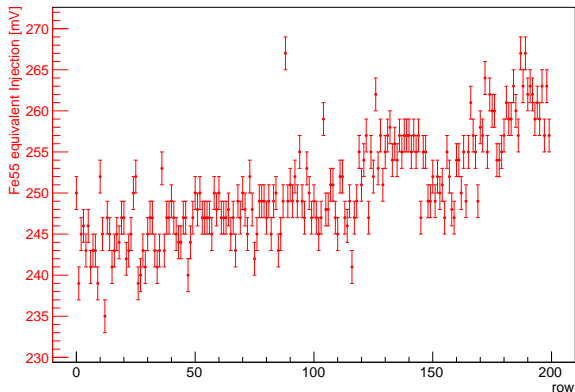


BACKUP

Crosstalk Absolute

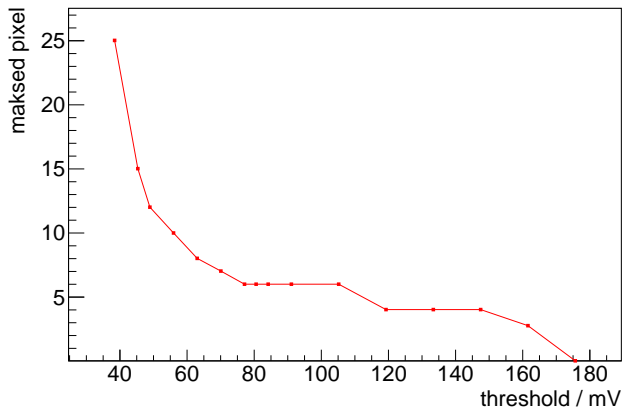


Row Dependence Injection



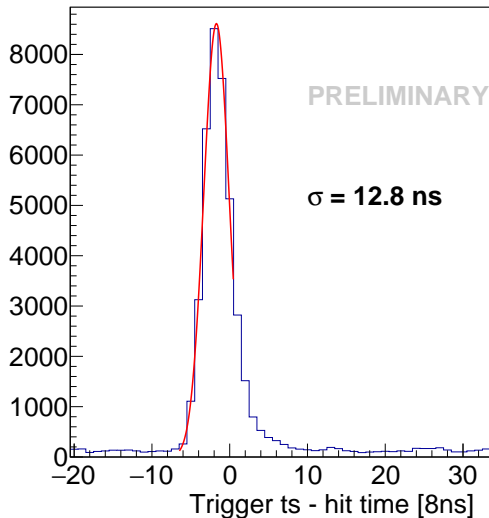
- Injection shows a row dependence
- Likely due to line capacity

Masked pixels

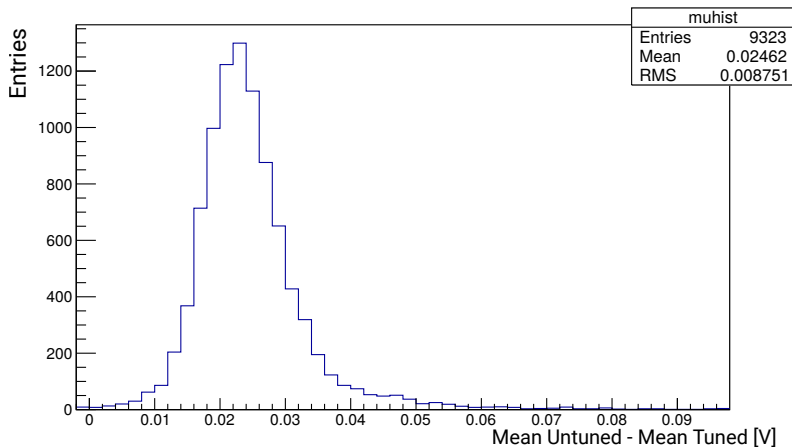


Pixels with a factor 10 more rate
as the average and at least 2 Hz rate are masked

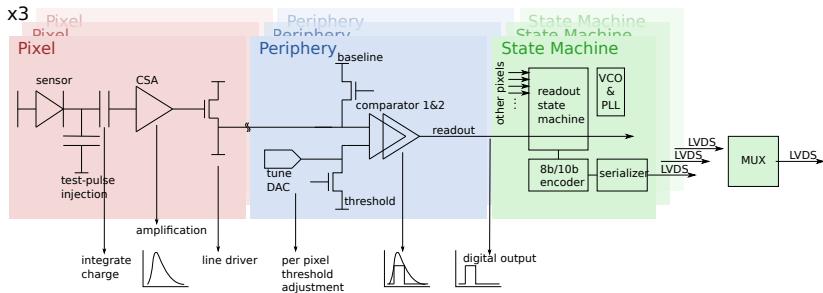
Timing with higher Current



Tuning

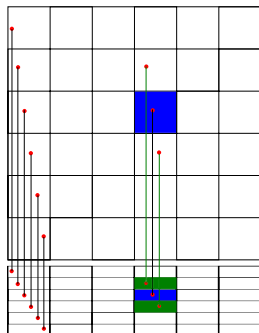


MuPix8 readout



Crosstalk and clustering

- Particle induced clusters fire up to 2x2 pixels
- Analog lines between active pixel and digital periphery are crosstalk affected \rightarrow row dependence
- Only track assigned clusters ≤ 3 considered in crosstalk analysis
- Difference between horizontal and vertical cluster sizes correspond to crosstalk



charge sharing

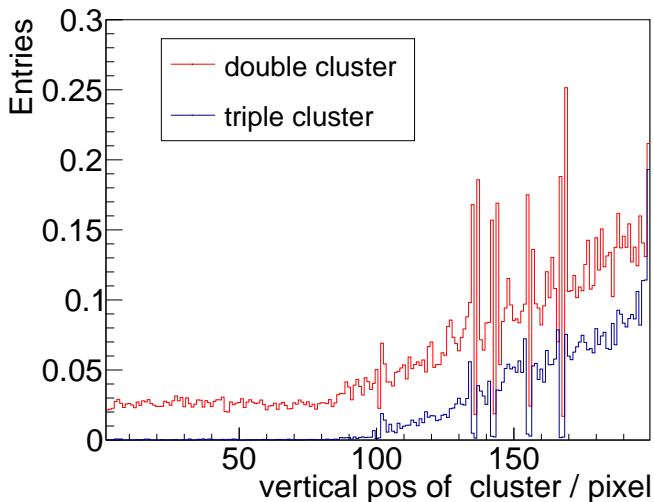


charge sharing / crosstalk



crosstalk

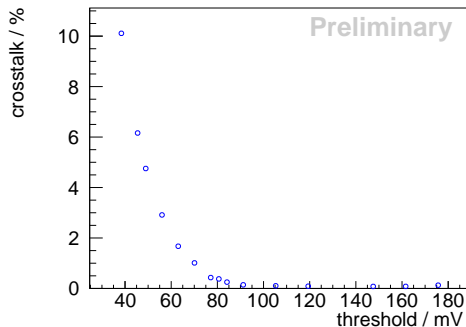
Crosstalk Row Dependence



Crosstalk Thresholdscan

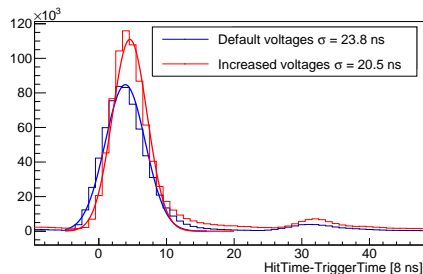
- Average crosstalk over sensor
- Ignores row dependence
- Heavily dependent on threshold

- $$\frac{N_{cluster,vertical} - N_{cluster,horizontal}}{N_{cluster}}$$



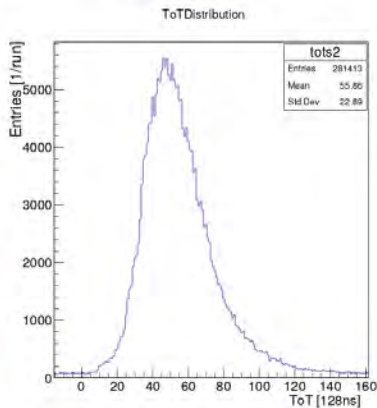
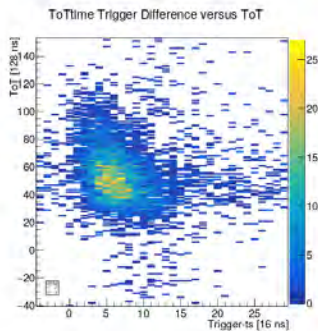
Increasing Supply Voltages

- $VDD/VDDA = 1.9\text{ V}$
- $VSSA = 1.1\text{ V}$
- Time resolution improves by 15%



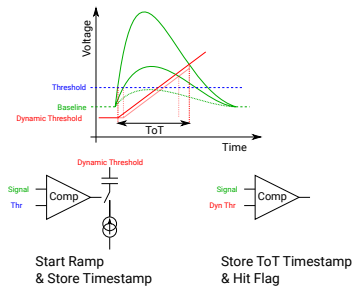
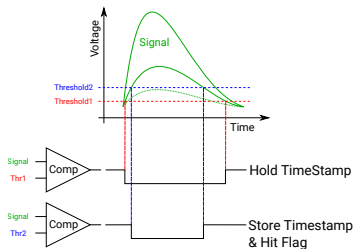
ToT and timewalk measurements

ckdivend1=0x1, ckdivend2=0xf

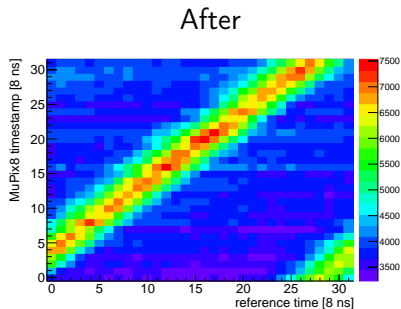
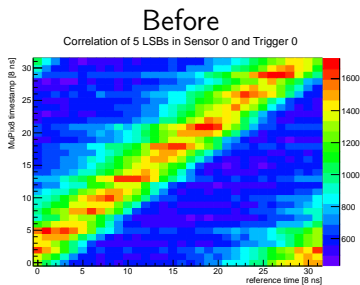


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Timewalk Correction



Timing with higher supply Voltages



Timing with higher supply Voltages

