Crash Course: LArPix Front-End Response and Calibration

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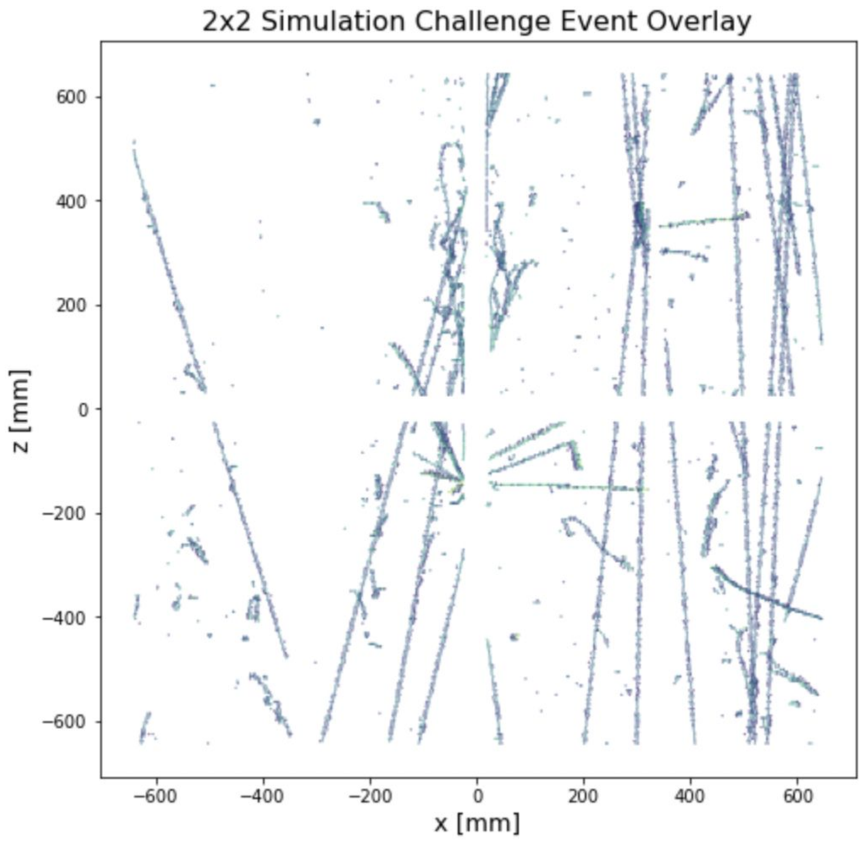
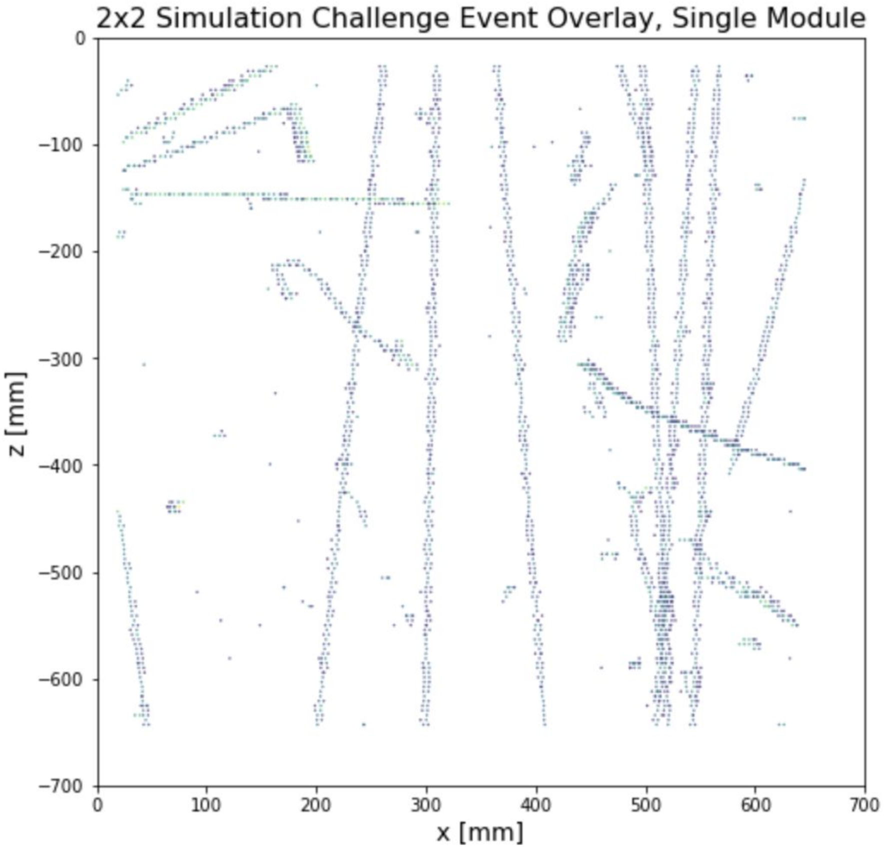
2x2 Analysis Workshop, January 21, 2022

Goal of this talk: understanding ‘fuzziness’

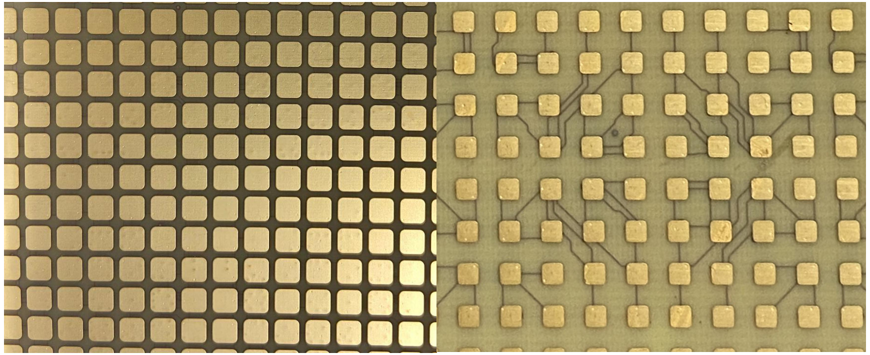


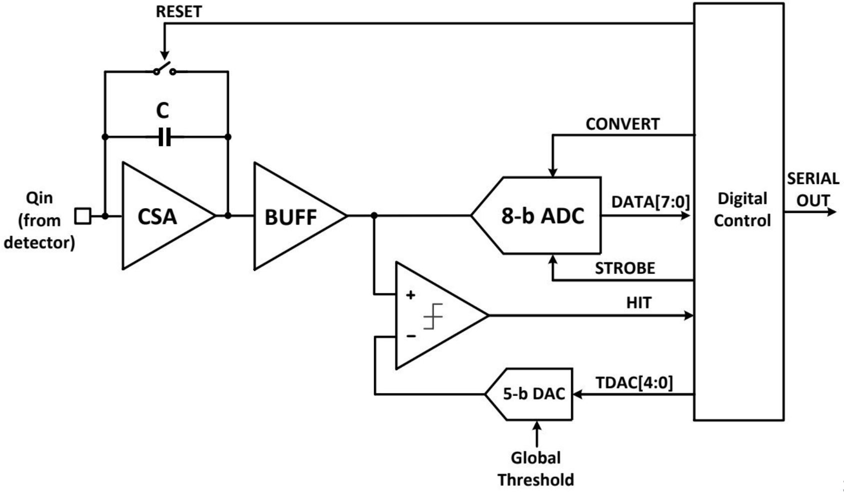


LArPix Readout

- Pixel readout board consists of PCB with embedded electrodes (pixels)
  – Geometry varies in Module 2 with smaller pitch and fill factor
  – Pixels routed to LArPix ASIC Qin
- Charge integrates on CSA until global threshold is exceeded
  – CSA continues to integrate 16 clock cycles (1.6 us, configurable)
  – CSA voltage digitized
  – CSA reset with 1 clock cycle of dead time

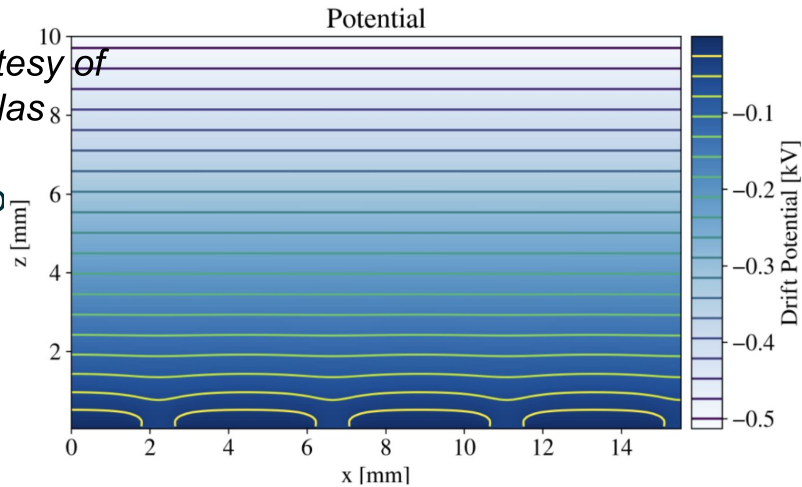
Modules 0, 1, 3 Module 2





Pixel Response Modeling

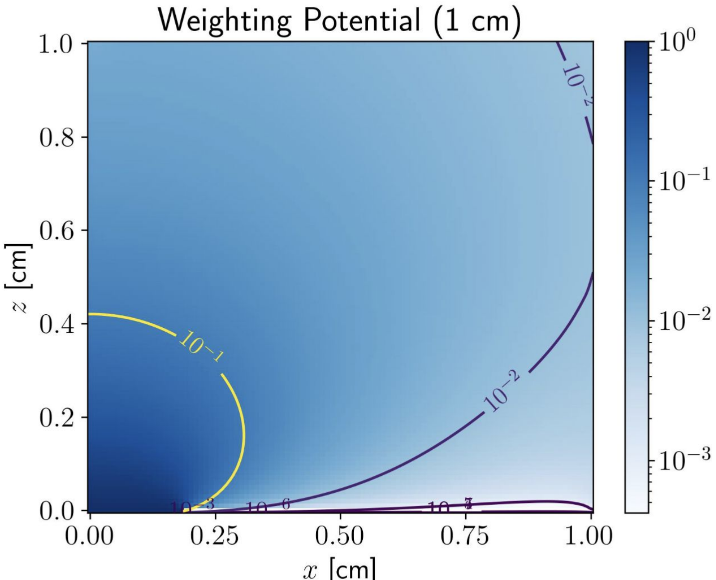
Plots courtesy of Dan Douglas

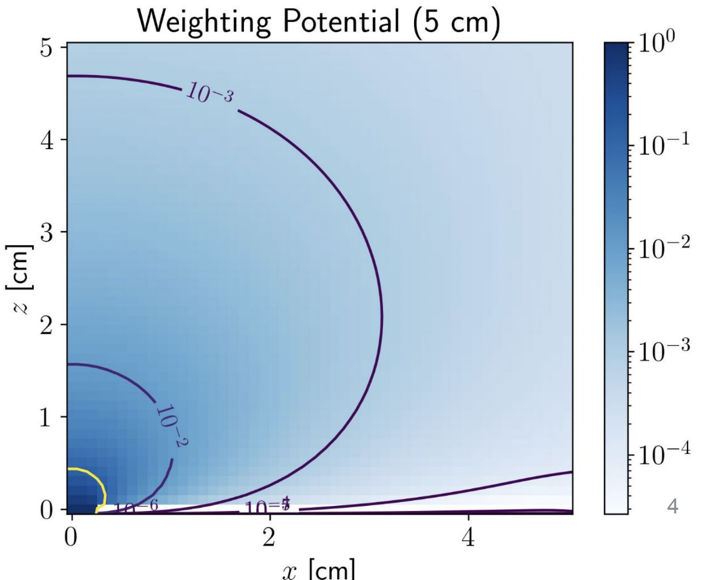


- Requires model of drift field, electrode (pixel) response to moving charge, LArPix front-end impulse response
  - Drift field determined with numerical solution to Poisson equation
  - Pixel electrode response to drifting charge given by electrodynamics, Shockley-Ramo theorem

$$i = q\boldsymbol{v} \cdot \boldsymbol{E}_0(\boldsymbol{x})$$

***i* - current on electrode**
***v* - charge velocity**
***E_0* - weighting field**

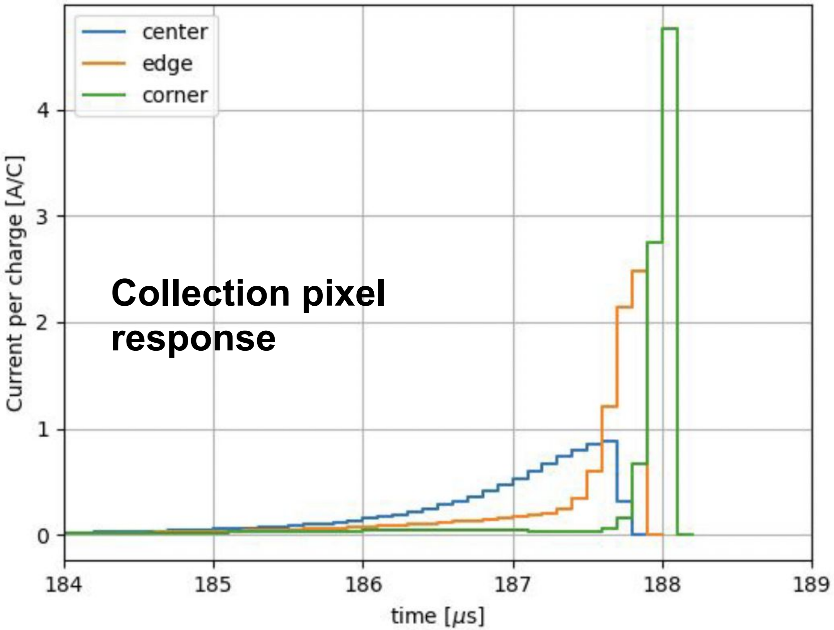


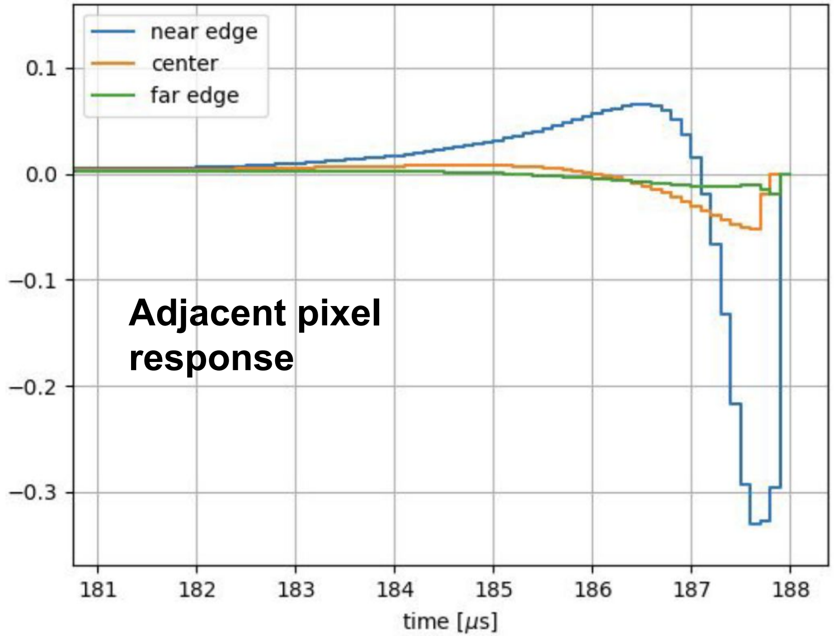


Modeled Current Response

Plots courtesy of Dan Douglas

- Current response highly dependent on charge position relative pixel center
- Bipolar response on adjacent pixels

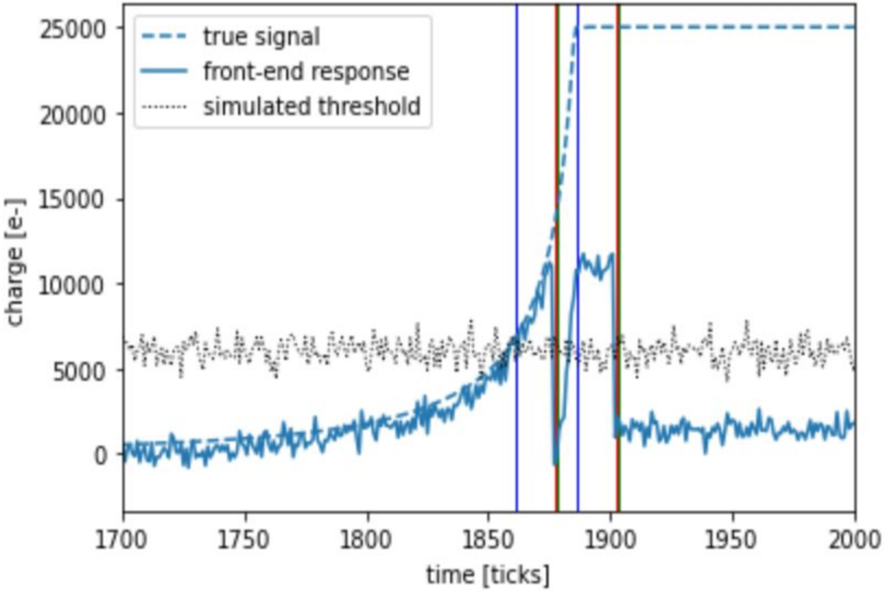




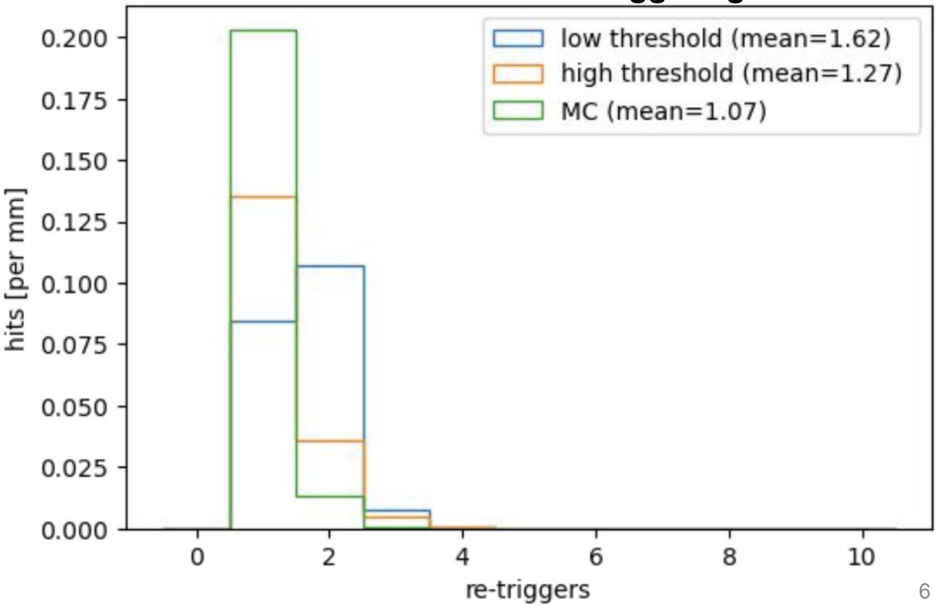
Plots courtesy of
Peter Madigan

Far Field Induced Hits

- For large charge distributions (relative to channel thresholds) triggering can occur on far-field induced charge
- Time between hits related to shape of current response (derivative of CSA voltage) and channel threshold

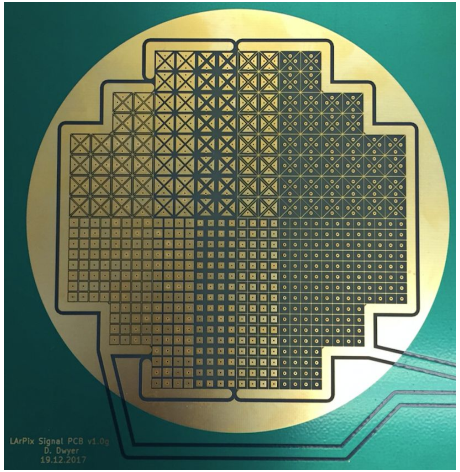


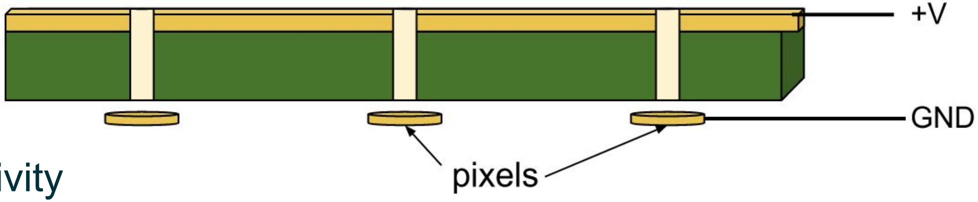
Module 0 Far-Field Triggering

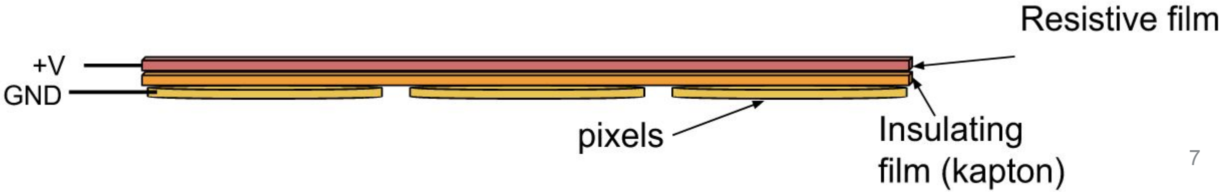


Pixel R&D

- Far field induction is product of PCB, not ASIC
  - Relatively faster, cheaper R&D cycles possible
- Active R&D on mitigation strategies for different contributions
  - Weighting field modification
    - Pixel fill factor reduction
    - Charge focussing grid
  - Near-pixel drift field
    - Pixel geometry optimization
  - Others
    - Changes to pixel surface conductivity with resistive film (effective high-pass filter)



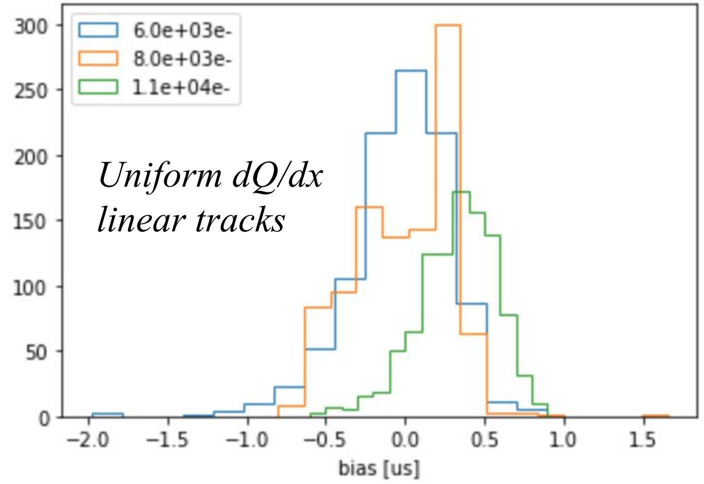


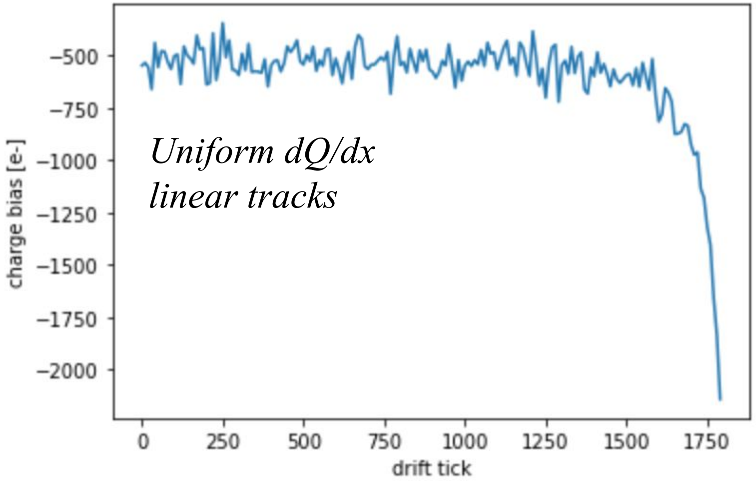


Calibration (and difficulties)

- Direct response model calibration is implausible
- Low level hit merging is possible
  - For track like deposits, far field hits are relatively simple to tag
  - Toy MC study→minimal charge/timing bias for uniform, linear tracks
  - More study needed for shower-like
- *Care needs to be taken not to disturb shower reconstruction*
- Feature is present in MC→high level validation of calibration studies are possible
  - Great care, improvements needed for MC (next slide)
- Any calibration should be studied in parallel with 'raw' hits

Hit Merging Biases

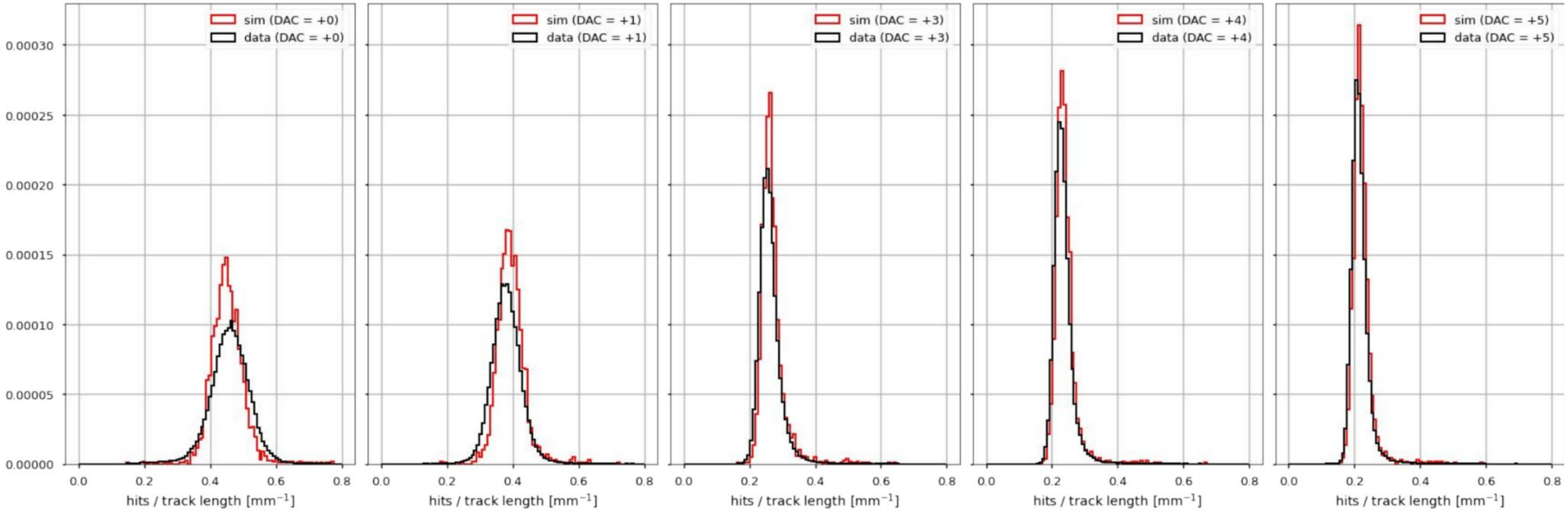




Data/Sim Comparison

Plots courtesy of Peter Madigan

- Response model is very good–but not perfect
  - Evident mismatch observed on short integration time scales
    - Electrostatic model near pixels, front-end impulse, charge outside radius?
  - Limited by range of integration times on ASIC (3-16 clock cycles)
- **Module 3 action item:** variable larpix clock→very high integration time studies



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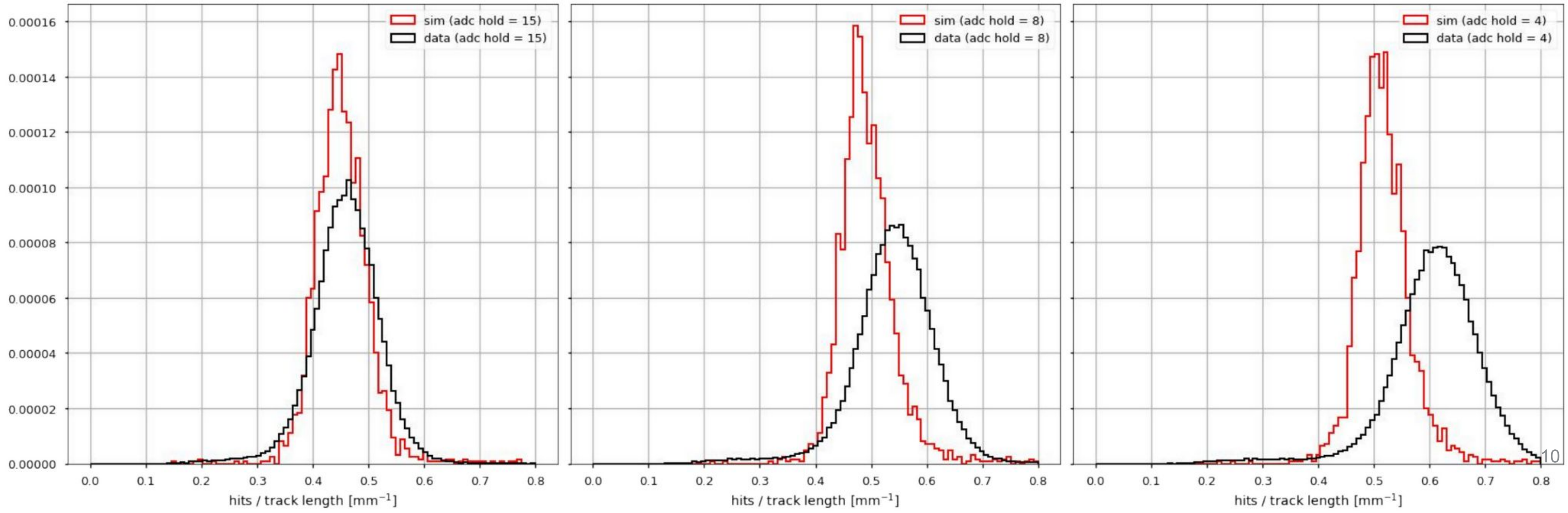

Summary

- Far-field induced hits are well understood physically, but very difficult to model
  - Feature is present in simulation, but front-end response models need careful study
- Direct response model calibration not plausible for arbitrary charge distribution
  - Hit merging can be simple
  - Care needs to be taken in MC studies for validation
- Active Pixel R&D adjacent to ASIC design
- Action items for Module 3 run→special runs for data/MC comparison