UNIVERSITÄT BONN

Influence of DCD parameters on pedestal noise

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SI LAB
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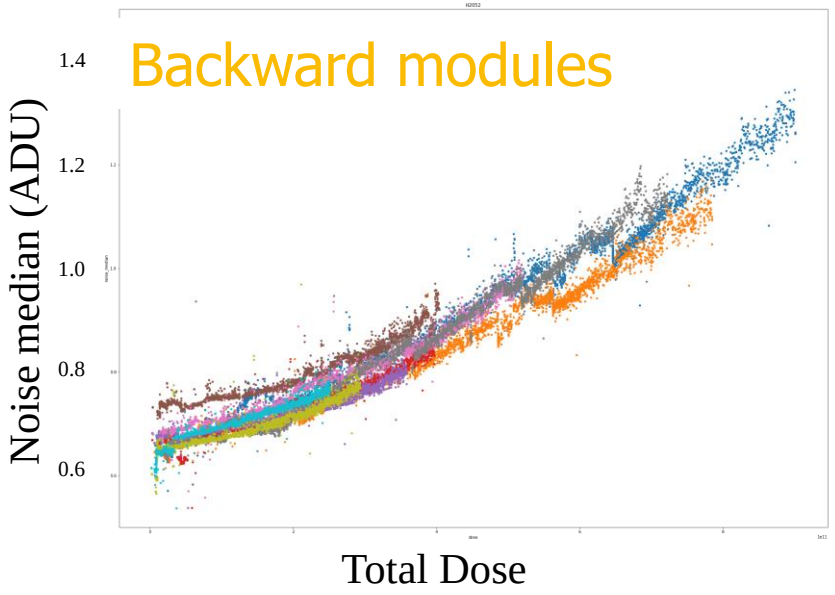
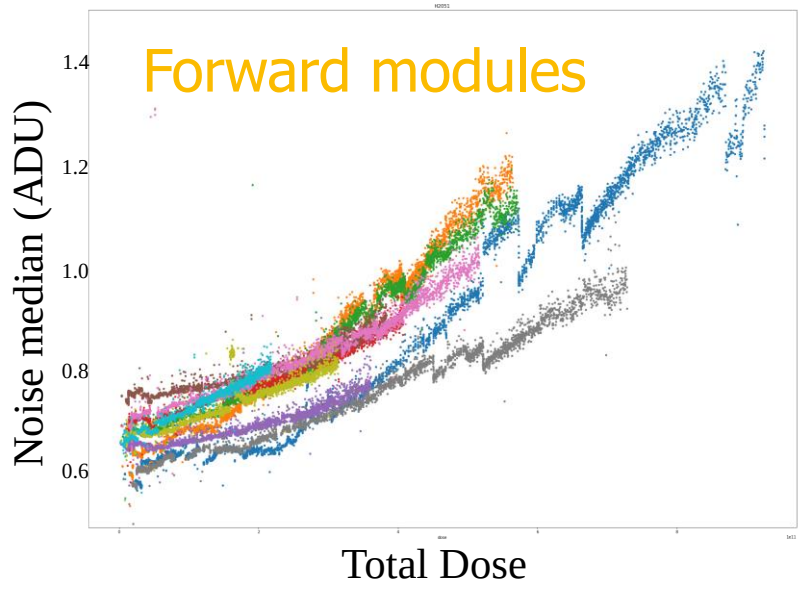
Belle II

Increase of pedestal noise at PXD1

- Pedestal noise = standard deviation of mean drain current in DEPFET pixel
- Noise median went from 0.5 to 0.7 ADU up to 0.9 to 1.4 ADU during operation time as the sensors face radiation
- Unclear cause of the increased pedestal noise

→ Investigate effects of digitization of DEPFET currents





https://pxd.belle2.org/USER/Bjoern/pedestalnoise/
Björn Spruck

PXD modules

- Thickness of active area: 75 µm
- Row-wise rolling shutter readout
- Drain current read with ~20 µs integration time

6 Switchers

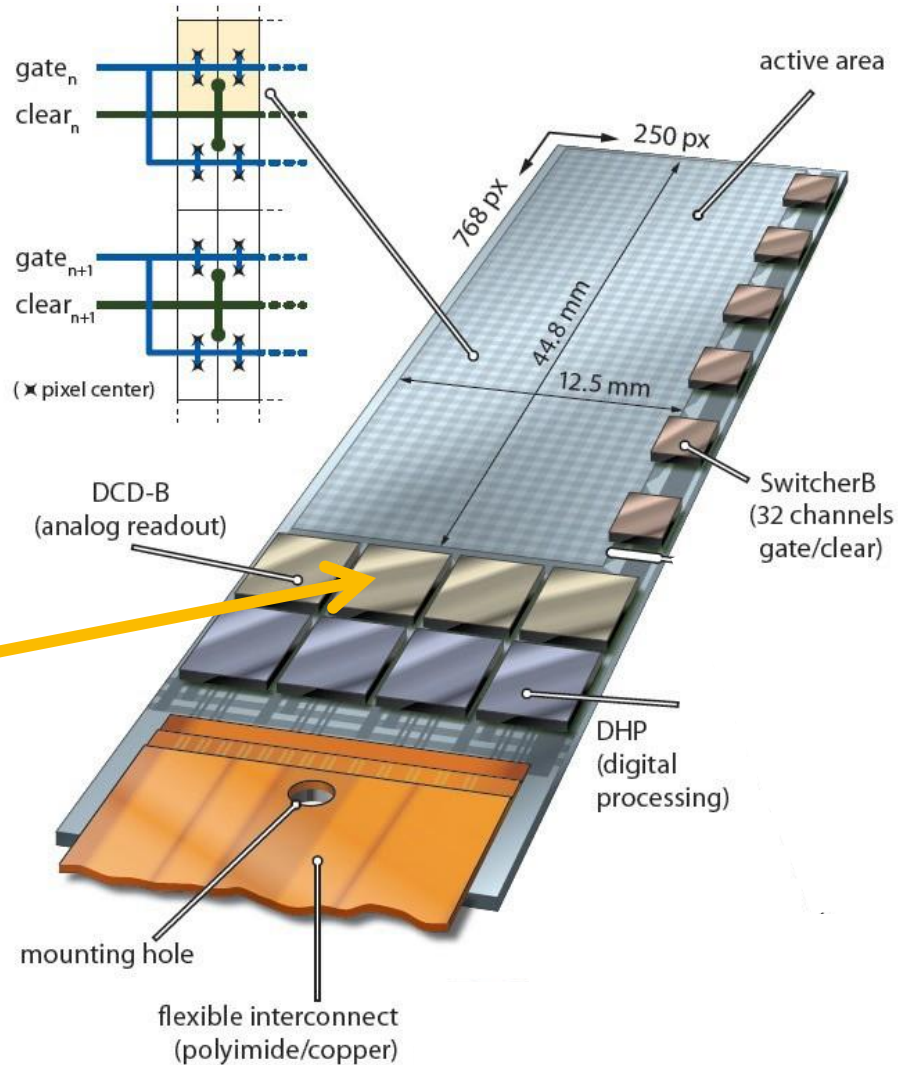
- Control gate and clear lines

4 Drain Current Digitizers (DCD)

- Amplify and digitize drain current
- 256 Analog to Digital Converters (ADCs)

4 Data Handling Processor (DHP)

- Store data for further processing

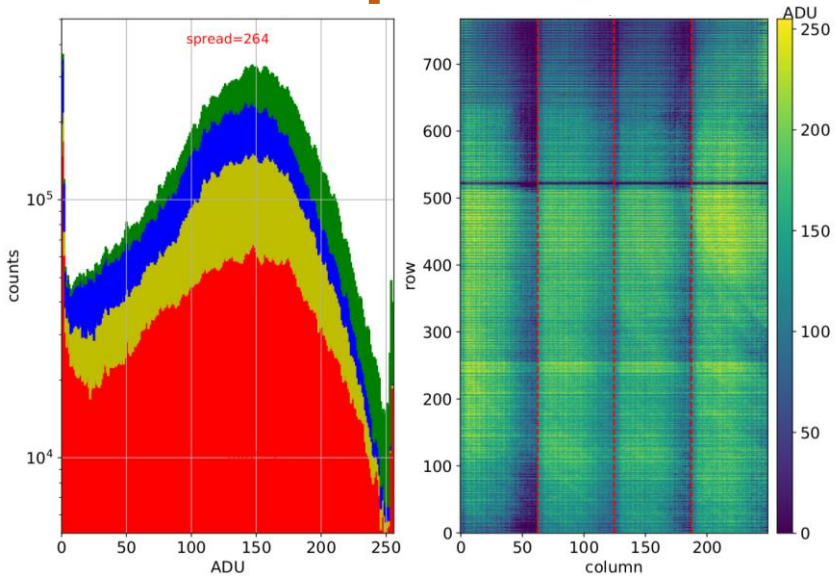


Pedestals

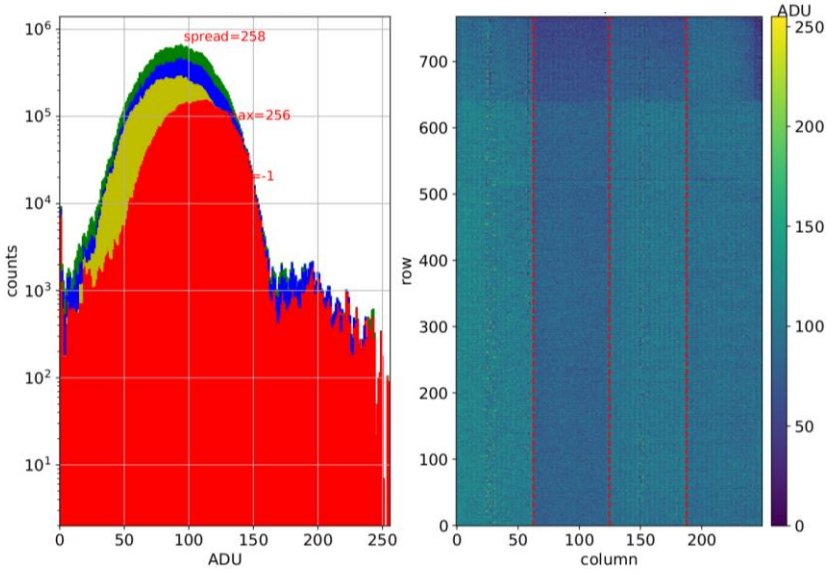
W55_IF @ SiLab

- Aim for narrow pedestals in dynamic range which have low noise
- Homogenous pedestal distribution throughout the matrix
- Corrections to pedestals can be applies such as Analogue Common Mode Correction (ACMC) and offsets

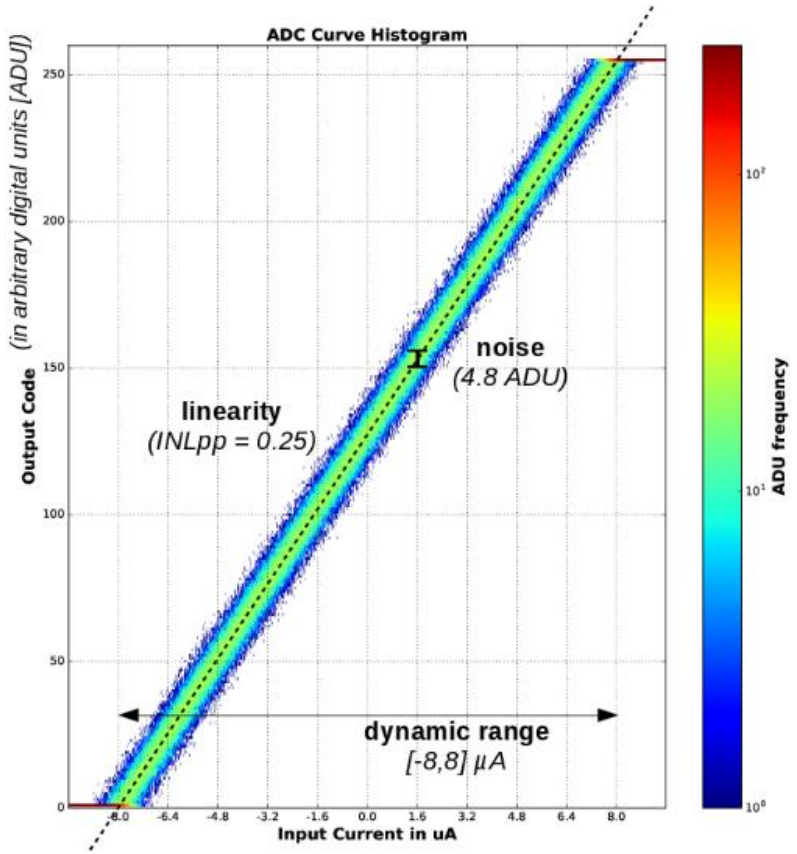
Raw pedestals



ACMC & OFFSET ON



Characteristics of the DCD



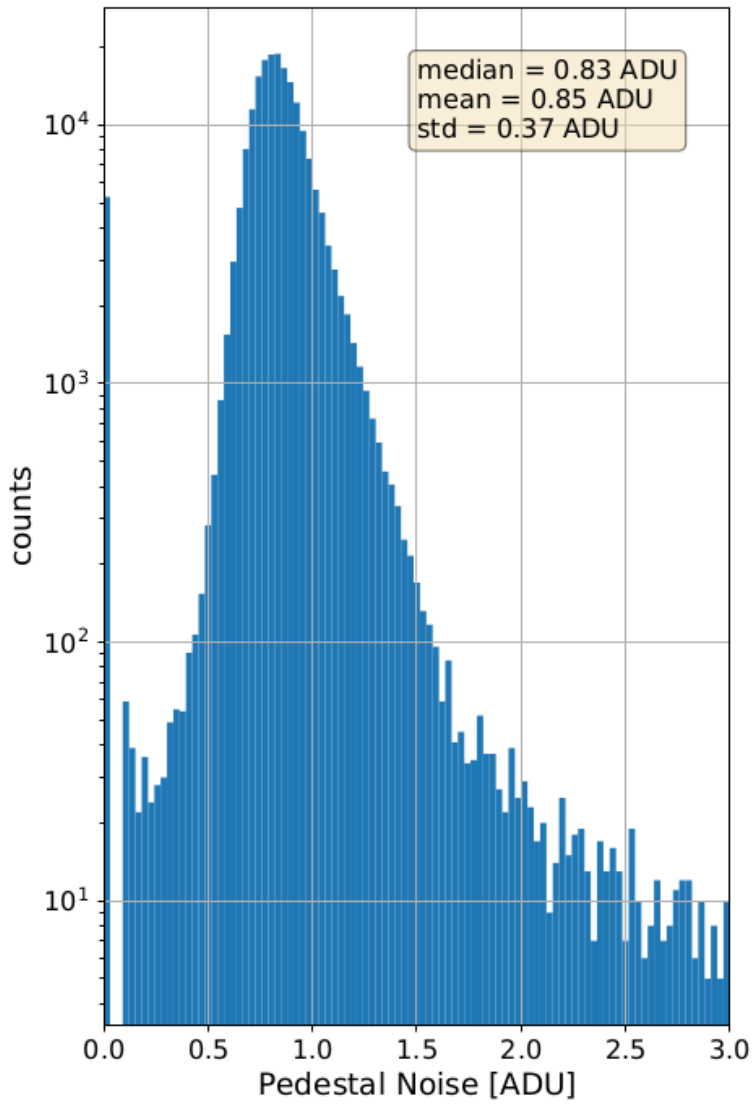
[ADC scan](#) at PXD WebHome Confluence

- DCD Parameters are optimized during module characterization
- Determine good channels based on criteria of linearity, range, gain, missing codes and noise
- Four parameters of the DAC and two reference voltages influence the operation of ADCs

Scan over four parameter spaces:

- DCD RefIn vs AmpLow
- IPSource-Middle
- IFBPBias
- IPSource vs IPSource2

Pedestal noise

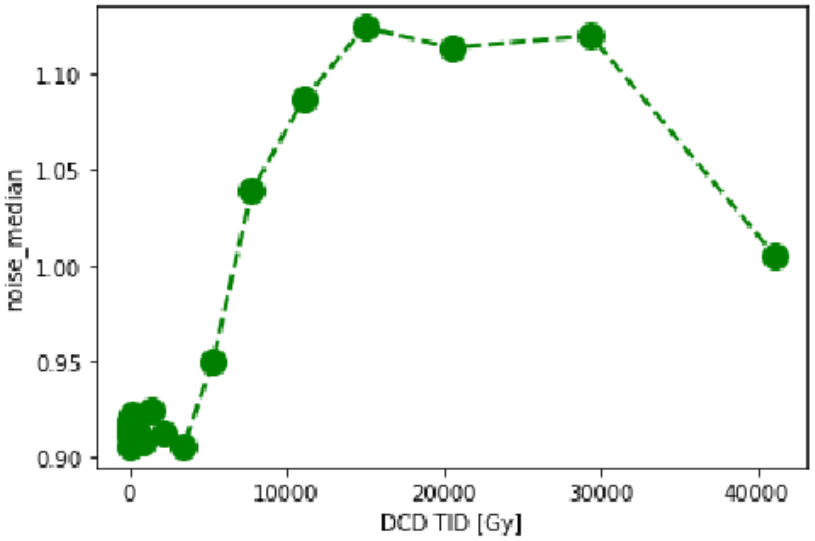


- Record drain currents over 100 frames
- Pedestals: Mean drain current I_D in each pixel
- Pedestal Noise: Standard deviation of I_D in each pixel

→ Use median of the pedestal noise distribution as estimator for the whole module

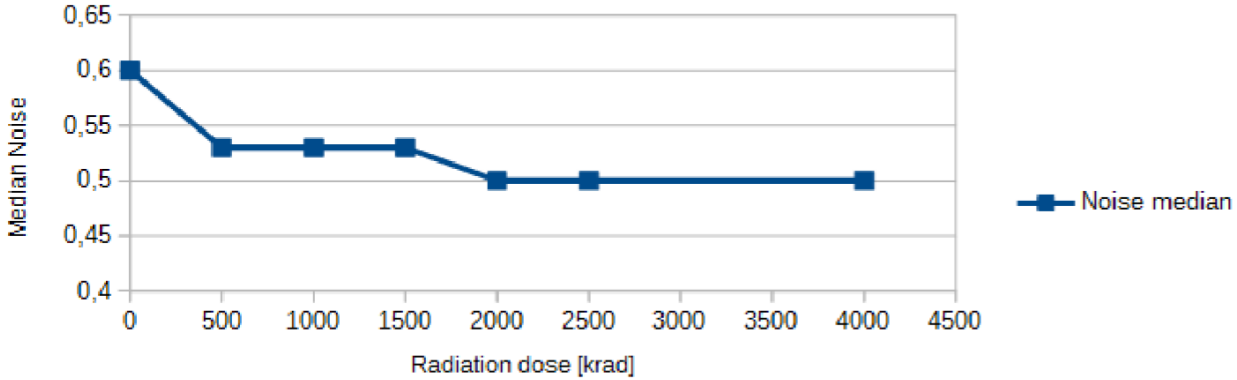
Past studies of DCD influence on noise

- X-Ray Irradiation of whole modules in 2021
- Increase of pedestal noise at approx. 4000 Gy (= 400 krad) of 0.2 ADU



Results of 2020/2021 X-Ray irradiation, indico

- Irradiation of only DCD in 2016
- No influence of irradiation on the pedestal noise until 4000 krad



DCDB4.x performance, Talk at B2GM, October 2016

→ Comparability of results?

DCD Pedestal Noise Analysis

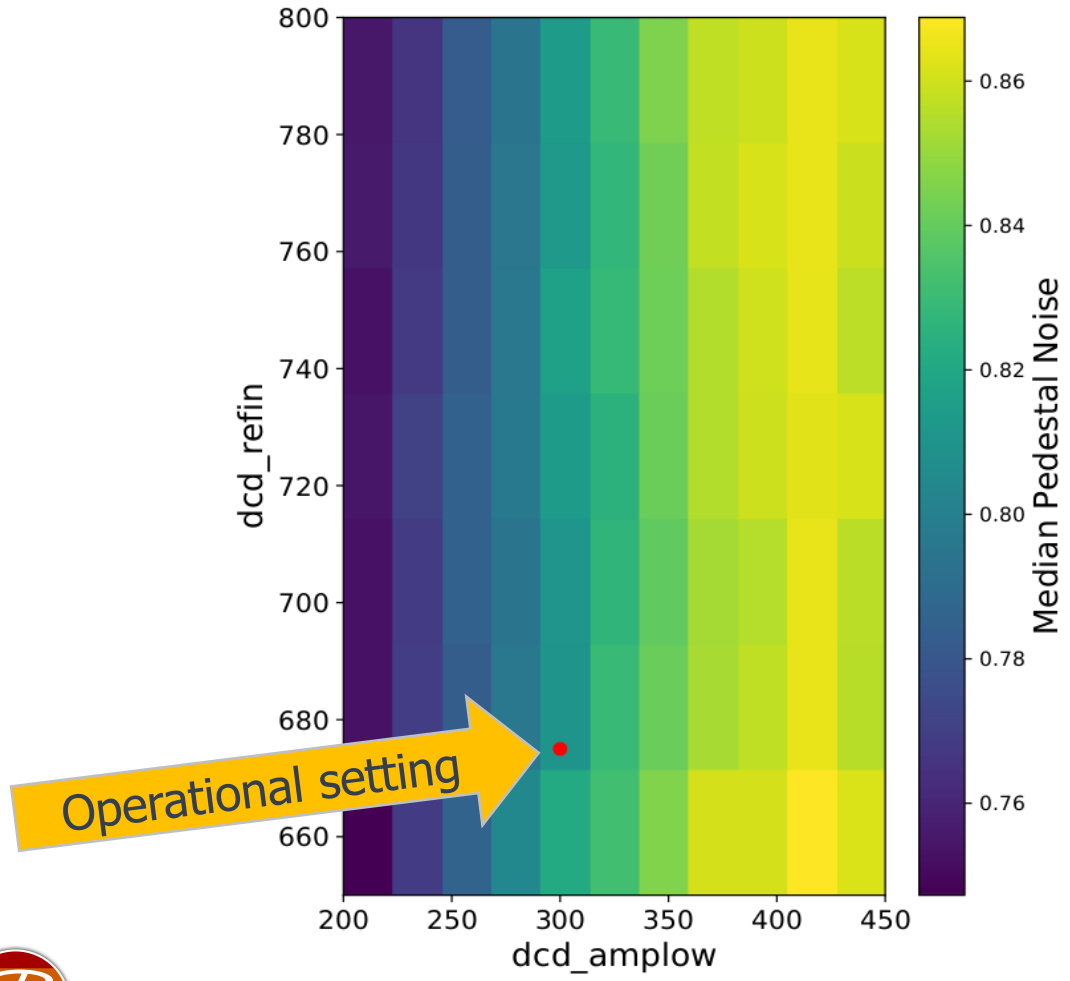
Which influence does the change of DCD parameters have on pedestal noise?

Measurements:

- Unirradiated W55_IF module at laboratory
  ACMC & Offsets ON VS ACMC & Offsets OFF
- Irradiated PXD1 modules at KEK
  Operational temperature VS Zero degrees

DCD Voltages AmpLow vs RefIn

W55_IF @ SiLab



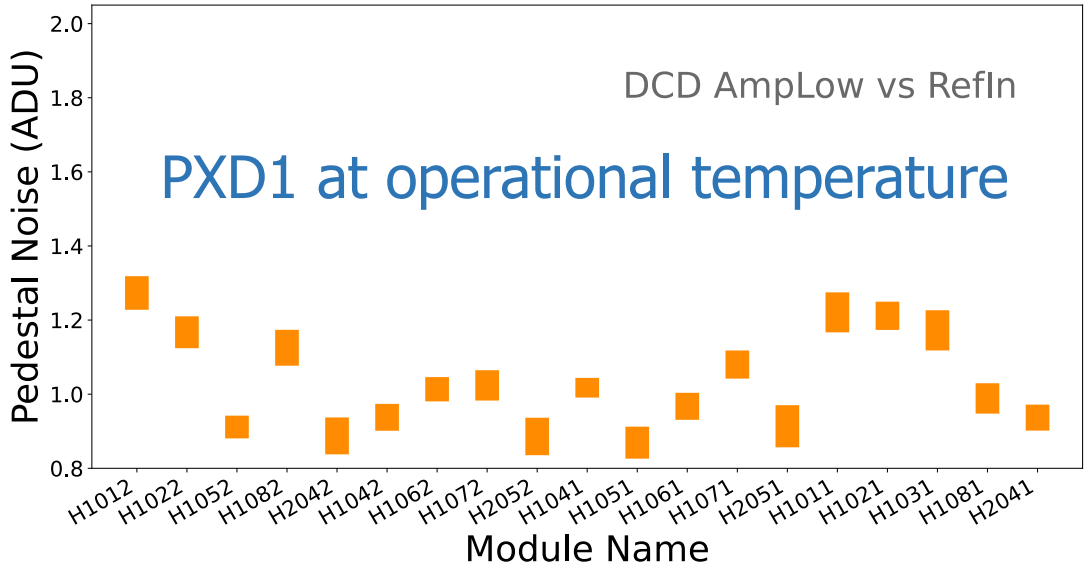
ACMC & OFFSET ON

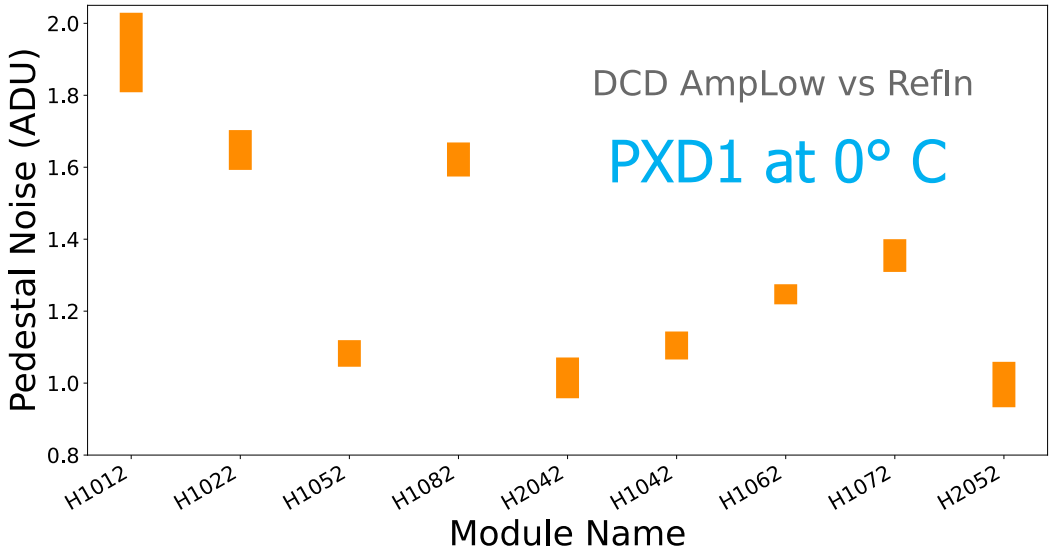
- Two-dimensional parameter scan over DCD AmpLow and RefIn
- Quantify noise for the whole module through median value at each scan point
- Median noise through the scan ranges within 0.75 to 0.87 ADU

→ Change of 0.12 ADU

Temperature dependence of noise spread
DCD AmpLow vs RefIn

- Scan of the irradiated PXD1 modules at KEK
- Noise ranges in order of 0.1 ADU during scan at operational temperature
- Higher temperature leads to increase in noise





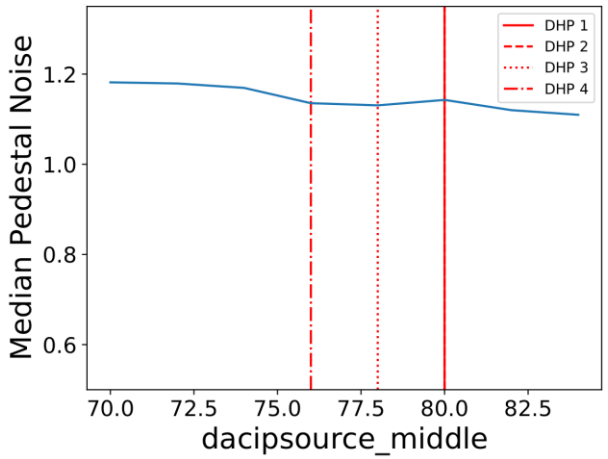
DAC IPSource Middle

W55_IF @ SiLab

- Noise changes of ~0.07 ADU in unirradiated and irradiated modules

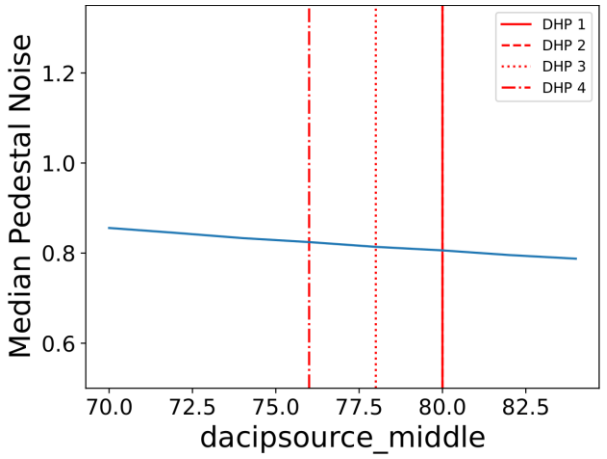
ACMC & OFFSET OFF

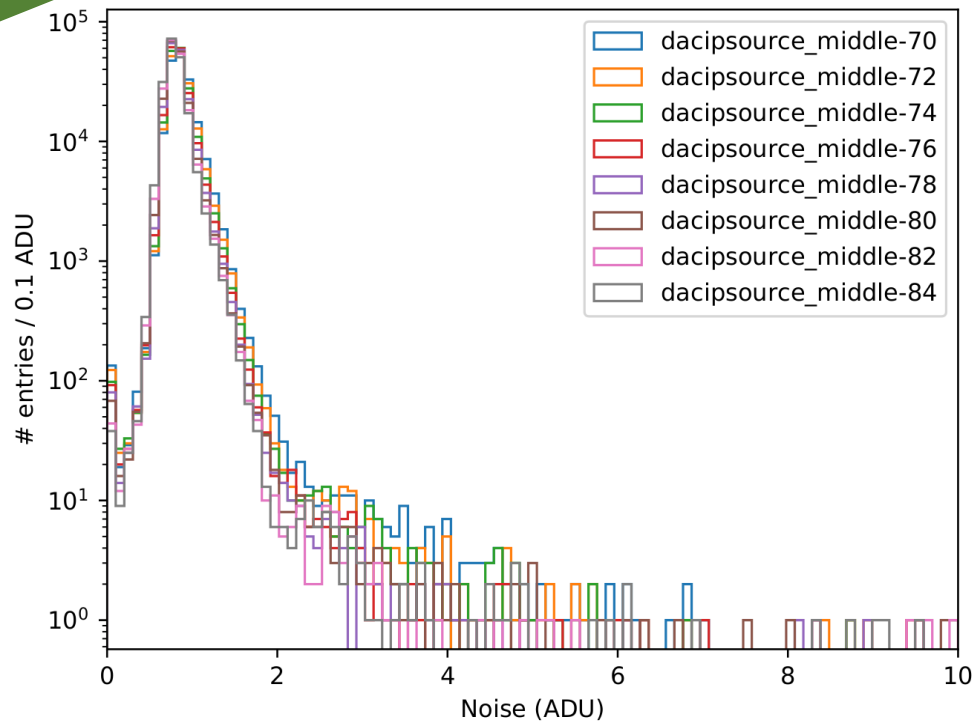
1.110 – 1.182 ADU



ACMC & OFFSET ON

0.788 – 0.856 ADU

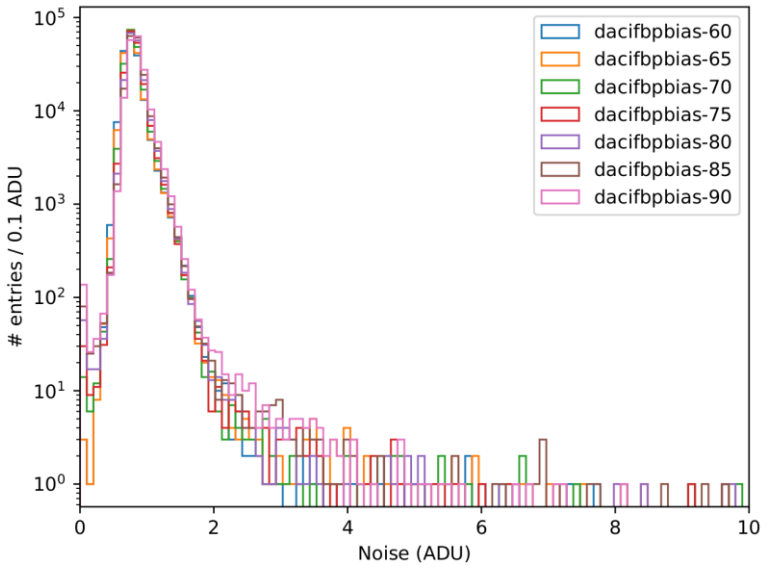




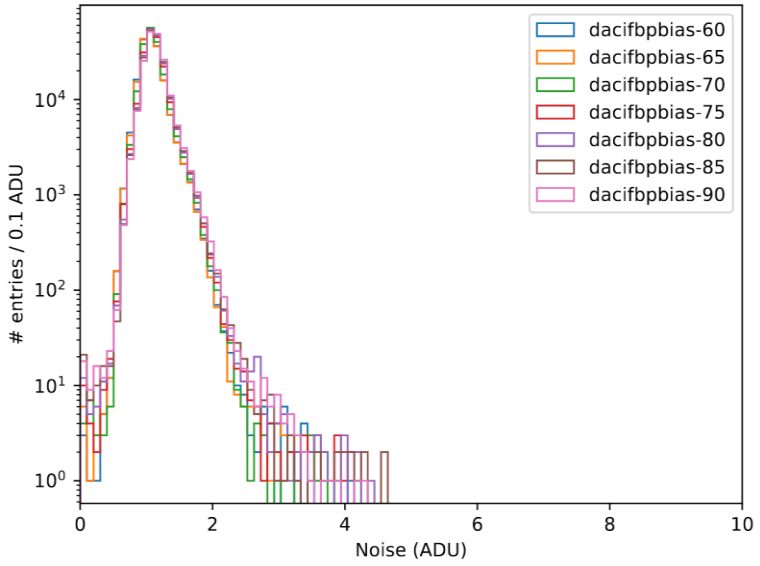
Noise spectra of DAC IFBPBias scan

- Overall similar noise spectrum throughout the scan
- Irradiated modules show higher pedestal noise

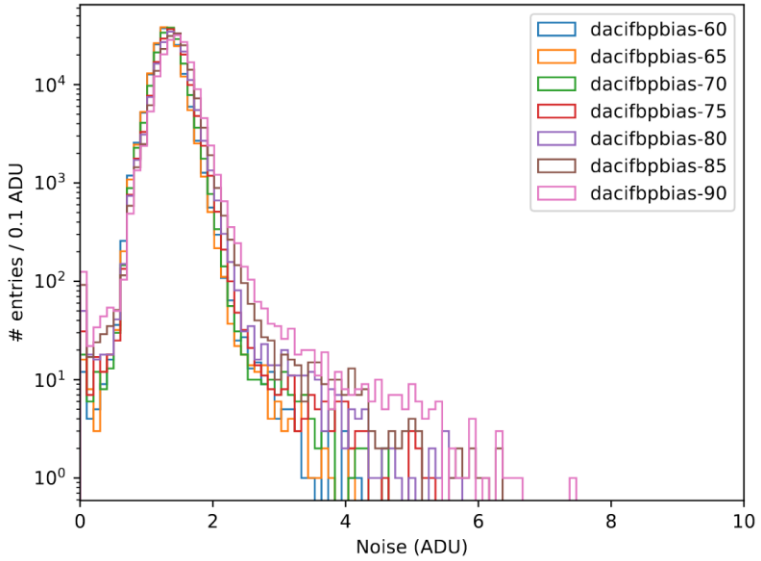
W55_IF @ SiLab
Unirradiated
Median noise: 0.762 – 0. 833 ADU



W13_IB @ PXD1
Irradiated, lowest dose
Median noise: 0.921 – 0.964 ADU



W02_IB @ PXD1
Irradiated, highest dose
Median noise: 1.021 – 1.094 ADU

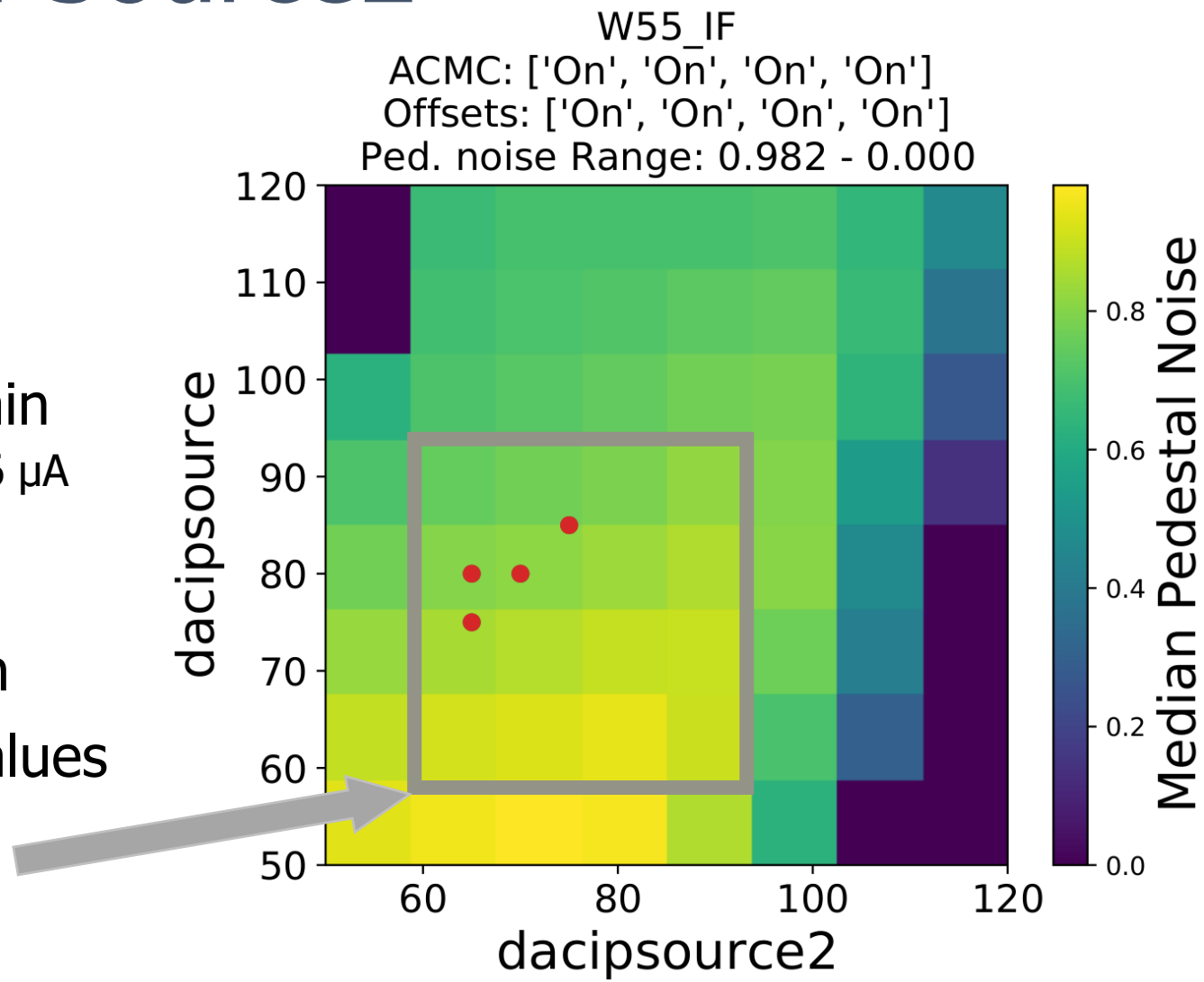


DAC IPSource vs IPSource2

W55_IF @ SiLab

ACMC & OFFSET ON

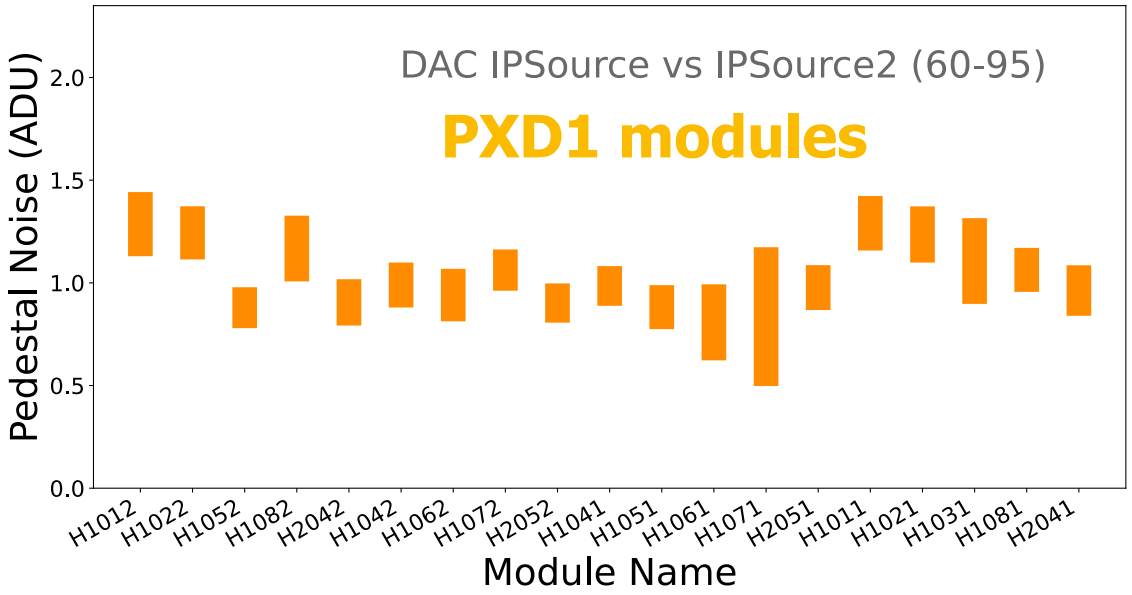
- DAC parameters influence ADC gain
  - IPSource 64 = total dynamic range of 16 µA
  - IPSource 120 = 32 µA range
- Same value of IPSource and IPSource2 are preferred by design
- ADC scan only entails IPSource values from 60 to 95



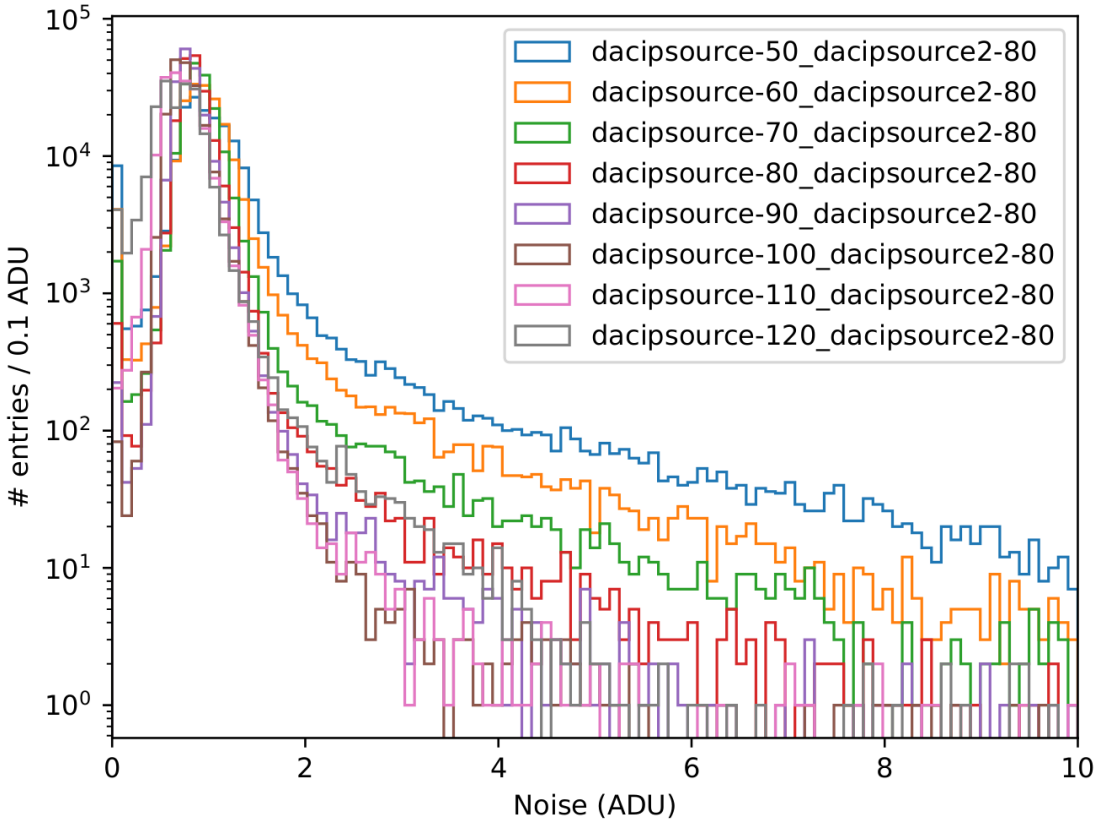
Pedestal noise spectrum

IPSource vs IPSource2

- IPSource influences gain of DCD
- Extended scan range brings module out of operatable state→ noise = 0
- Noise change in order of 0.2 ADU



W55_IF @ SiLab
Unirradiated

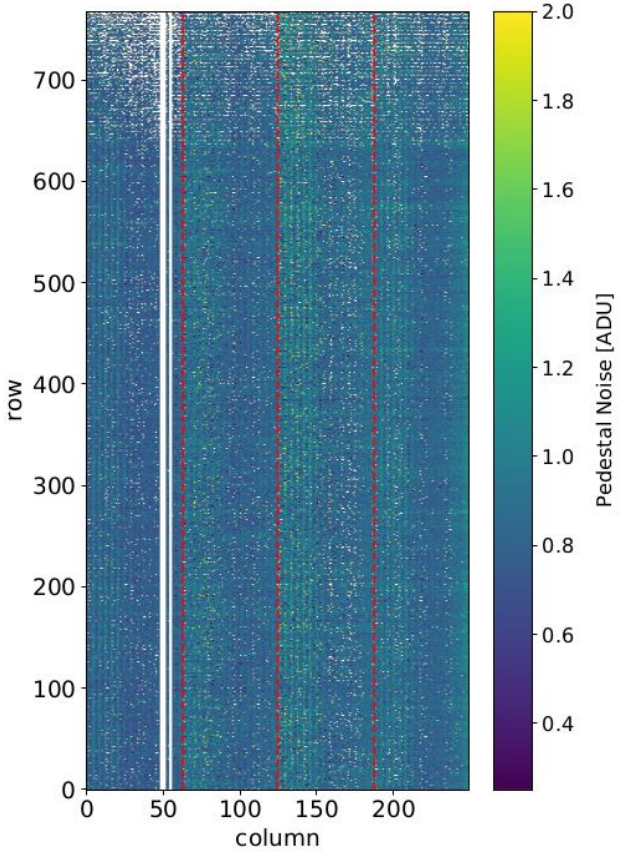


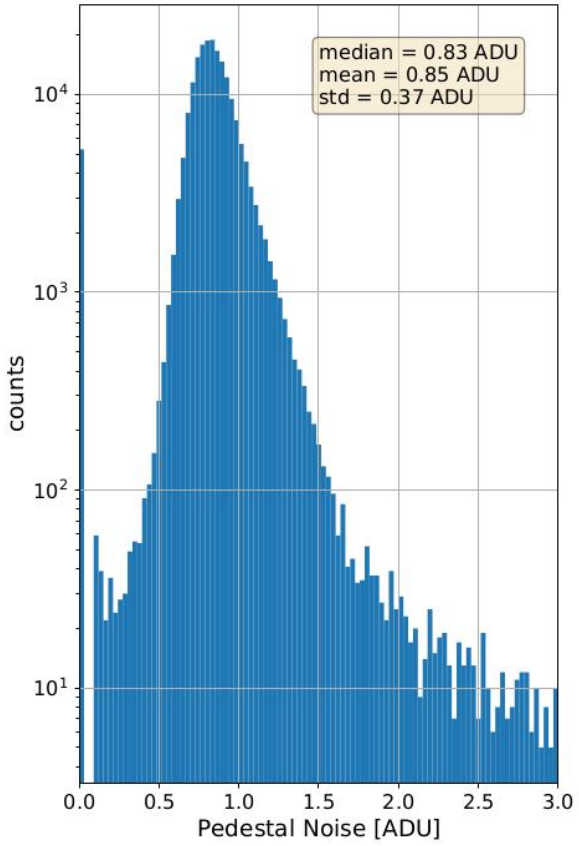
Pixel-wise pedestal noise

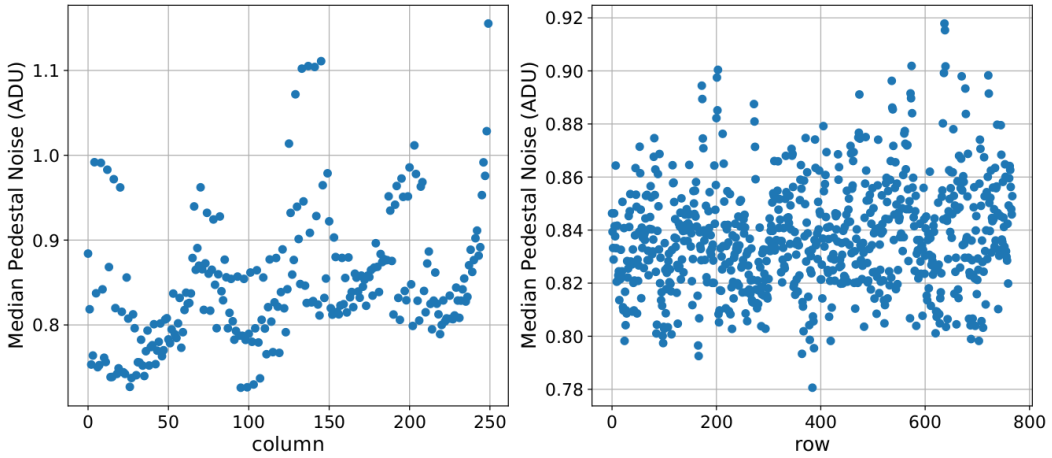
W55_IF @ SiLab

IPSource = IPSource2 = 80

ACMC & OFFSET ON







- Corresponds to operational setting
- Higher noise at one side of the DCD

Conclusion and outlook

W55_IF @ SiLab
Unirradiated
ACMC & OFFSET ON

DCD RefIn vs AmpLow: 0.12 ADU
IPSource-Middle : 0.07 ADU
IFBPBias : 0.08 ADU
IPSource vs IPSource2: ~ 0.2 ADU

- Observed higher noise for:
  - ACMC and offsets turned off
  - Irradiated modules
  - Higher temperatures
- Similar behaviour of unirradiated and irradiated modules throughout the DCD parameter scans

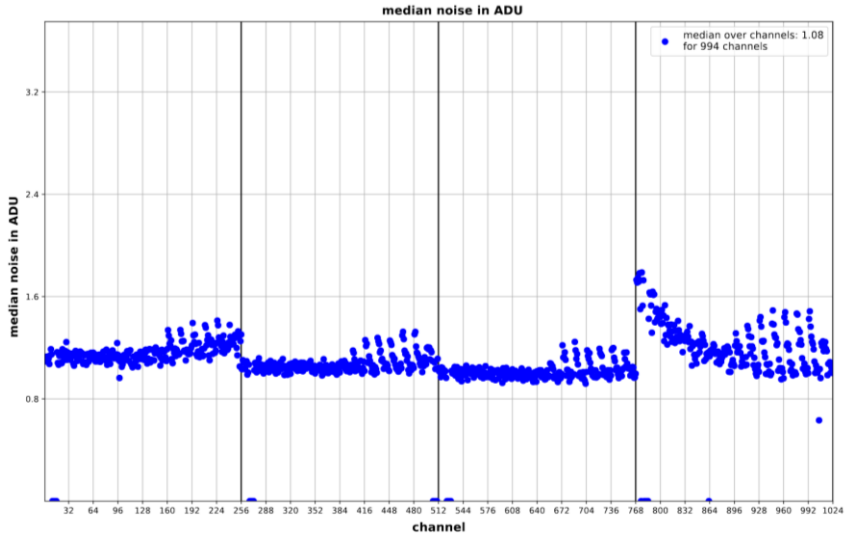
→ Disentangle radiation effects through study of modules with irradiated DEPFETs and unirradiated DCDs

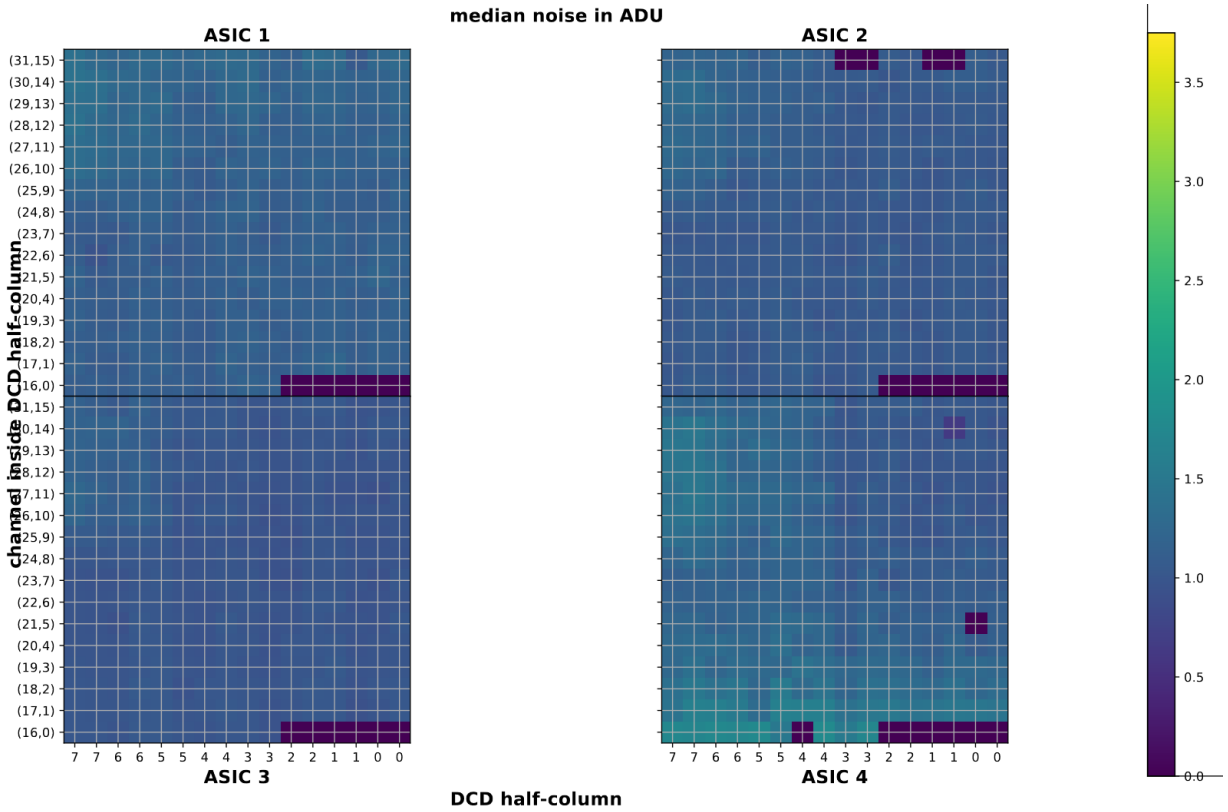
Backup

Pedestal noise on DCD

W55_IF @ SiLab

- From ADC scan during module characterization
- One side of DCD shows increased median noise





https://elog.belle2.org/elog/PXD-Mass-Testing/23094

Tuning parameters of DCD performance

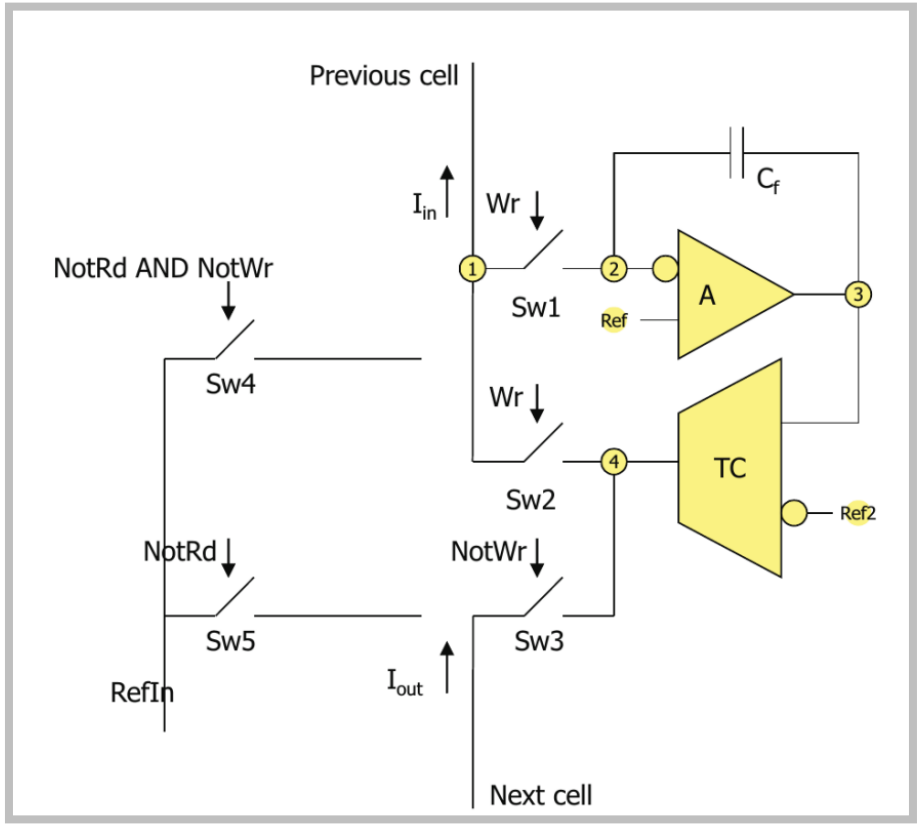
- Entails current memory cells and comparators
- Capacity C_f acts as the memory element, the amplifier A and transconductance T

DAC parameters

- IPSource adds and reduces currents at node 4
- T has adjustable current sources for sourcing (FBPBias) and sinking (PSource2)

DCD Voltages

- AmpLow is ground potential at A
- RefIn is a fixed potential reference at several nodes



Simplified layout of single CMC