APTS OpAmp Update

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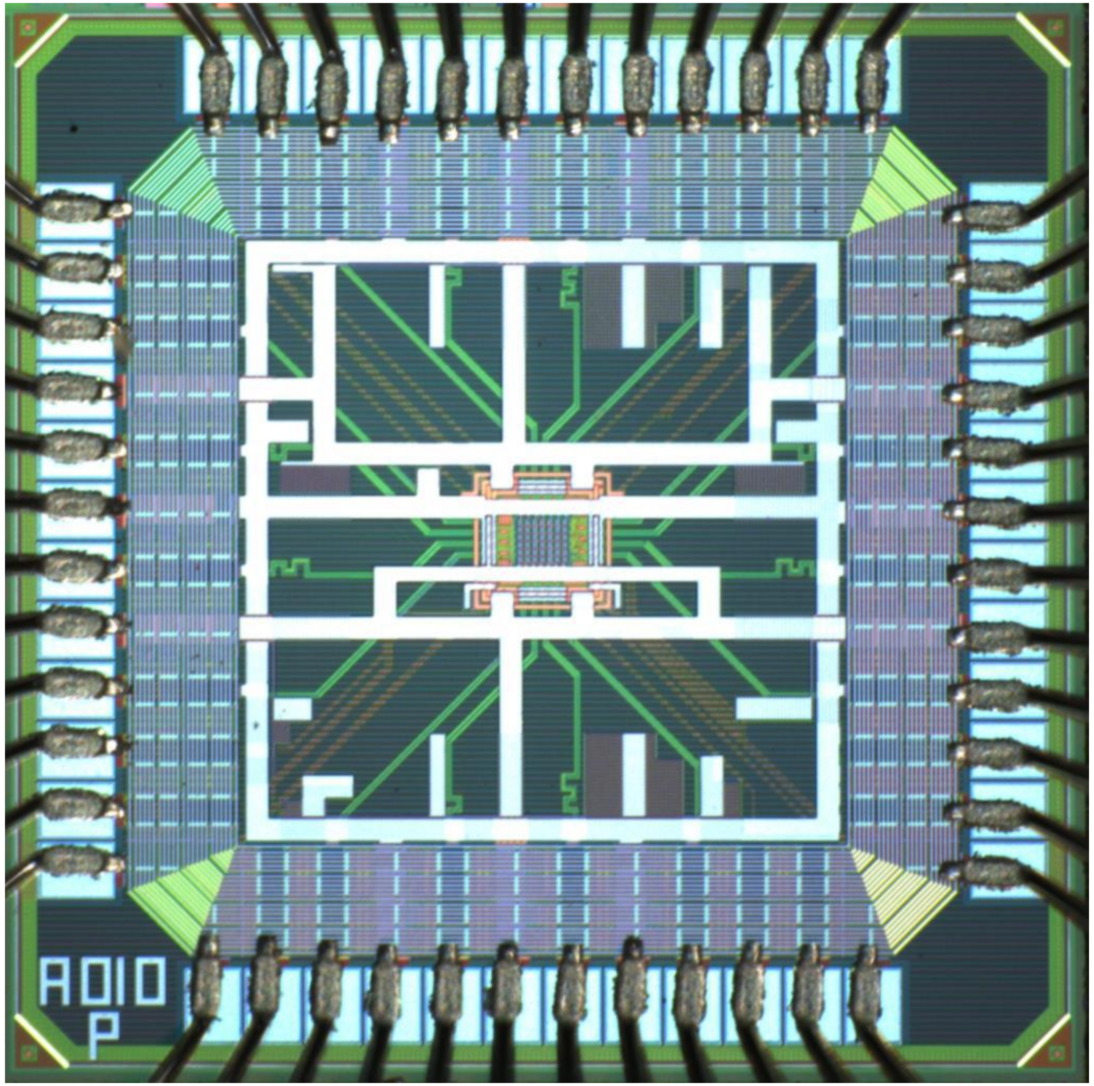
APTS OpAmp

- APTS (Analogue Pixel Test Structure) is one of test structures of the first chip submission (MLR1) in TPSCo65 nm CMOS imaging process
- Detailed characterization of the smaller feature size (ALPIDE is 180 nm CMOS process sensor)
- 2 variants of the APTS chip:
    - APTS Source Follower (SF):
        - Frontend based on source follower structure
        - Robust readout but slow
    - APTS Operational Amplifier (OA):
        - High speed OPAMP buffers out frontend output
        - Study charge collection properties and timing features of the sensor
        - 50 Ω terminating resistance on board
        - Identical frontend as APTS SF

Pixel matrix implementation

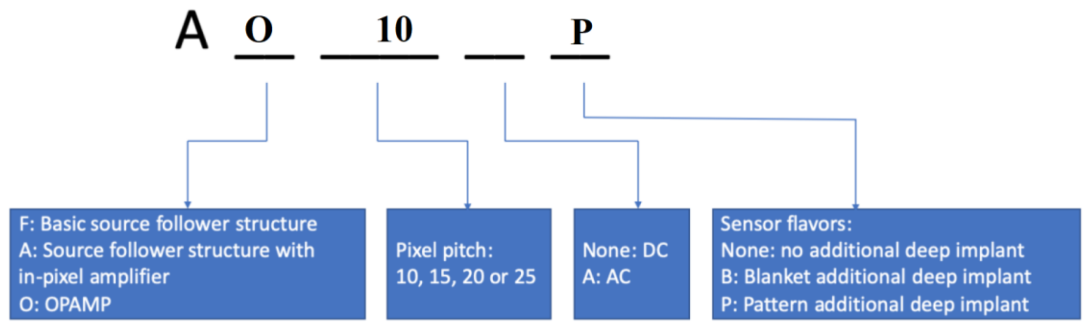
- **Matrix sizes**: 6×6 pixels matrix
- **Readout**: only central 4x4 pixels are analogue read out
- **Pixel pitch**: square pixels of **10**, 15, 20, 25 µm
- Innermost 2 ×2 pixels are connected to SMA outputs to be read via oscilloscope
- External 12 pixels are read via (slow) ADCs

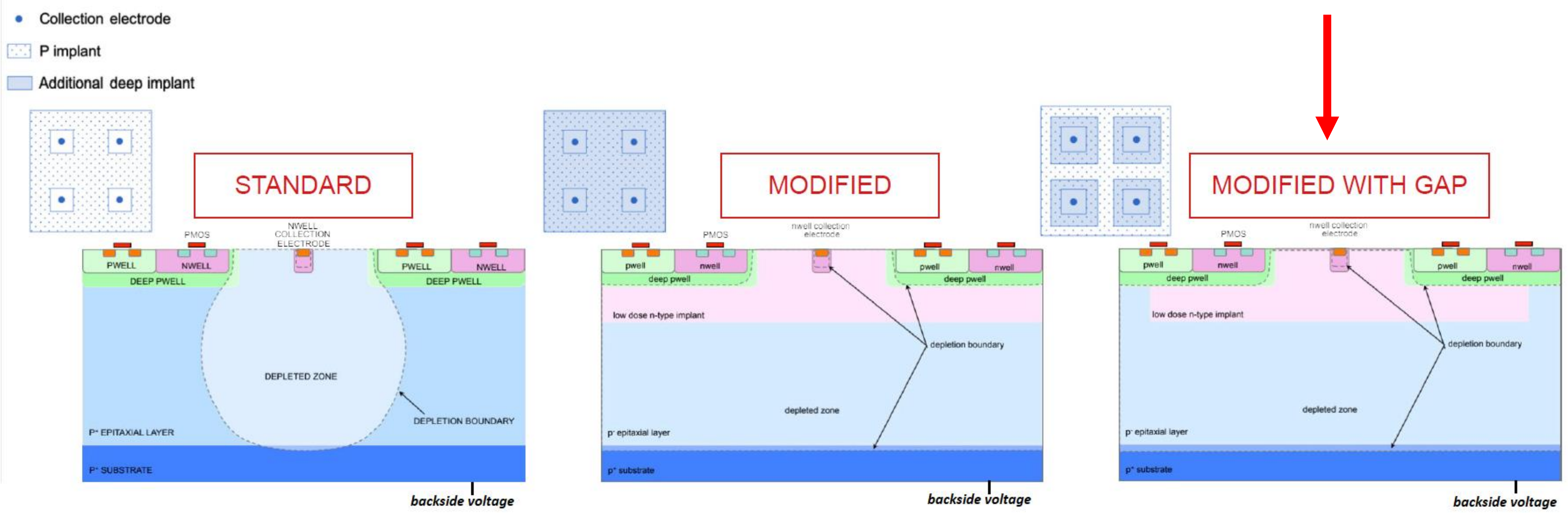


Sensor features

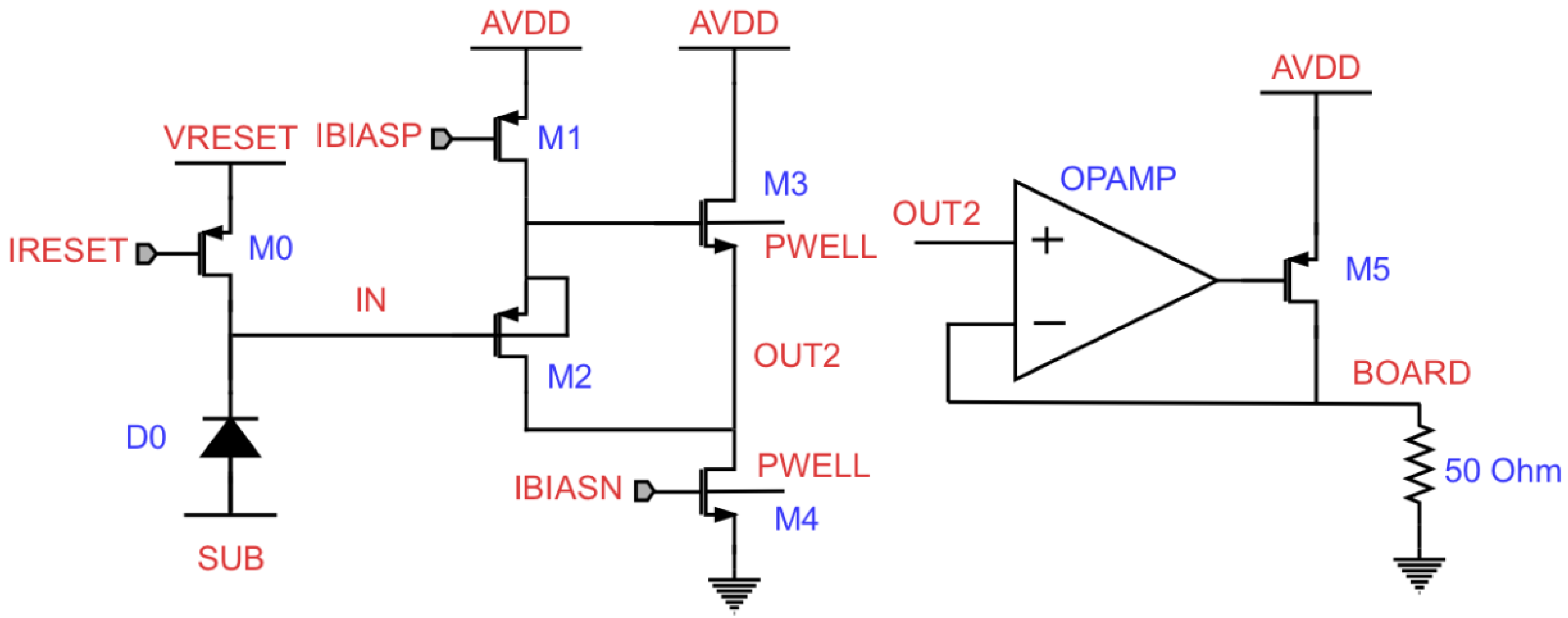
- Sensor based on 65nm TPSCo CMOS imaging process
- 3 different pixel flavours:
  - Standard process
  - Modified process
  - Modified with gap

- Sensor under test in Bari





Pixel fronted APTS OpAmp schematic version



- All operation parameters are fixed except V_{reset} which can be optimized at varying $V_{substrate}$
- $V_{substrate} = V_{p-well}$
- Charge injection system to calibrate chip
  - V_h voltage generated by DAC + injection capacitance C_{inj}

Current Studies

- Calibration:
  - Gain calibration
  - Pulsing calibration
  - V_h scan calibration

- ^{55}Fe spectrum measurements

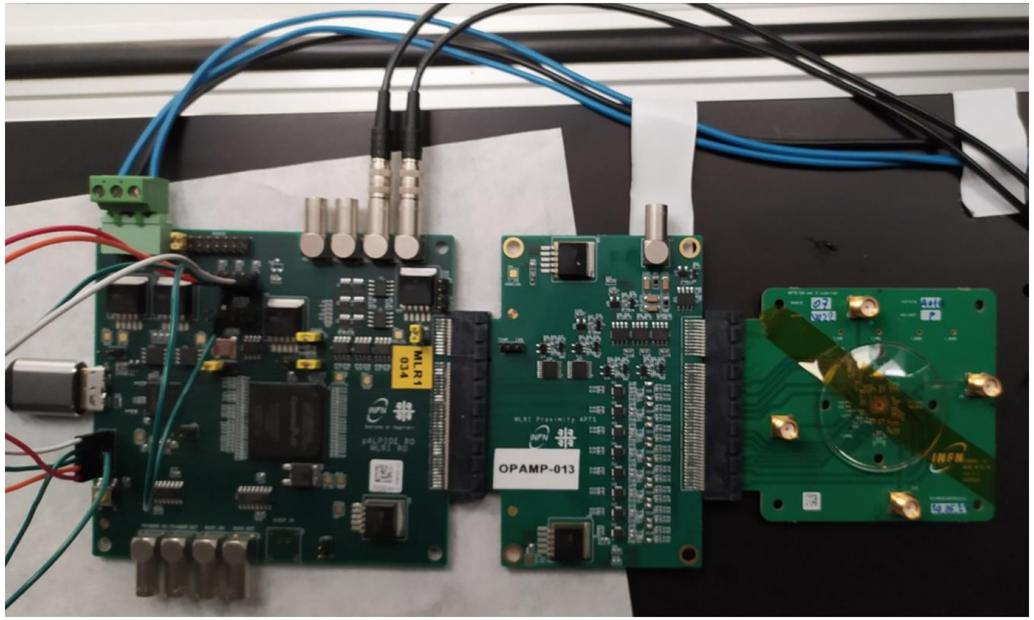
Experimental Setup

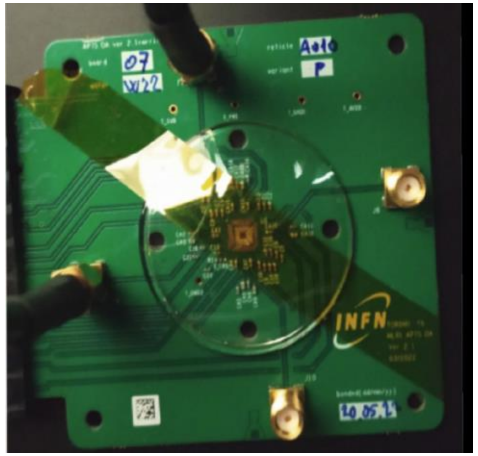
- MLR1 DAQ board connected via USB to DAQ machine
- Oscilloscope connected via TCP port to DAQ machine
- Power supply connected via USB to DAQ machine

MLR1 DAQ board
Serial DAQ- 00090101054B2109

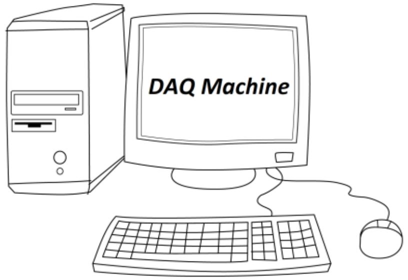
Proximity board
OPAMP-013

Carrier Card
Chip: AO10 P W22 (in Bari, 21 September 2022)





Power supply
Rohde&Schwarz HAMEG HMP4040

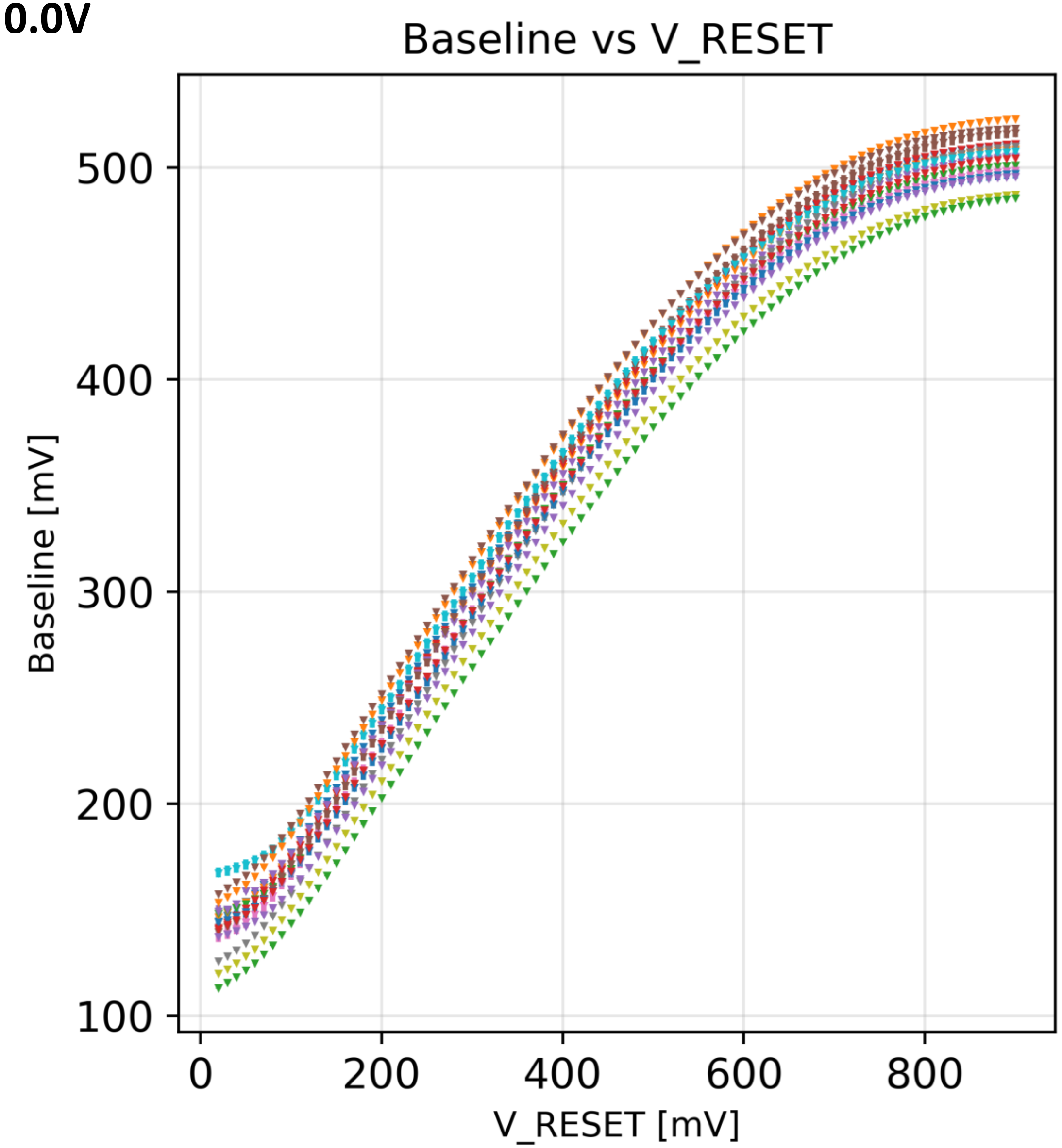


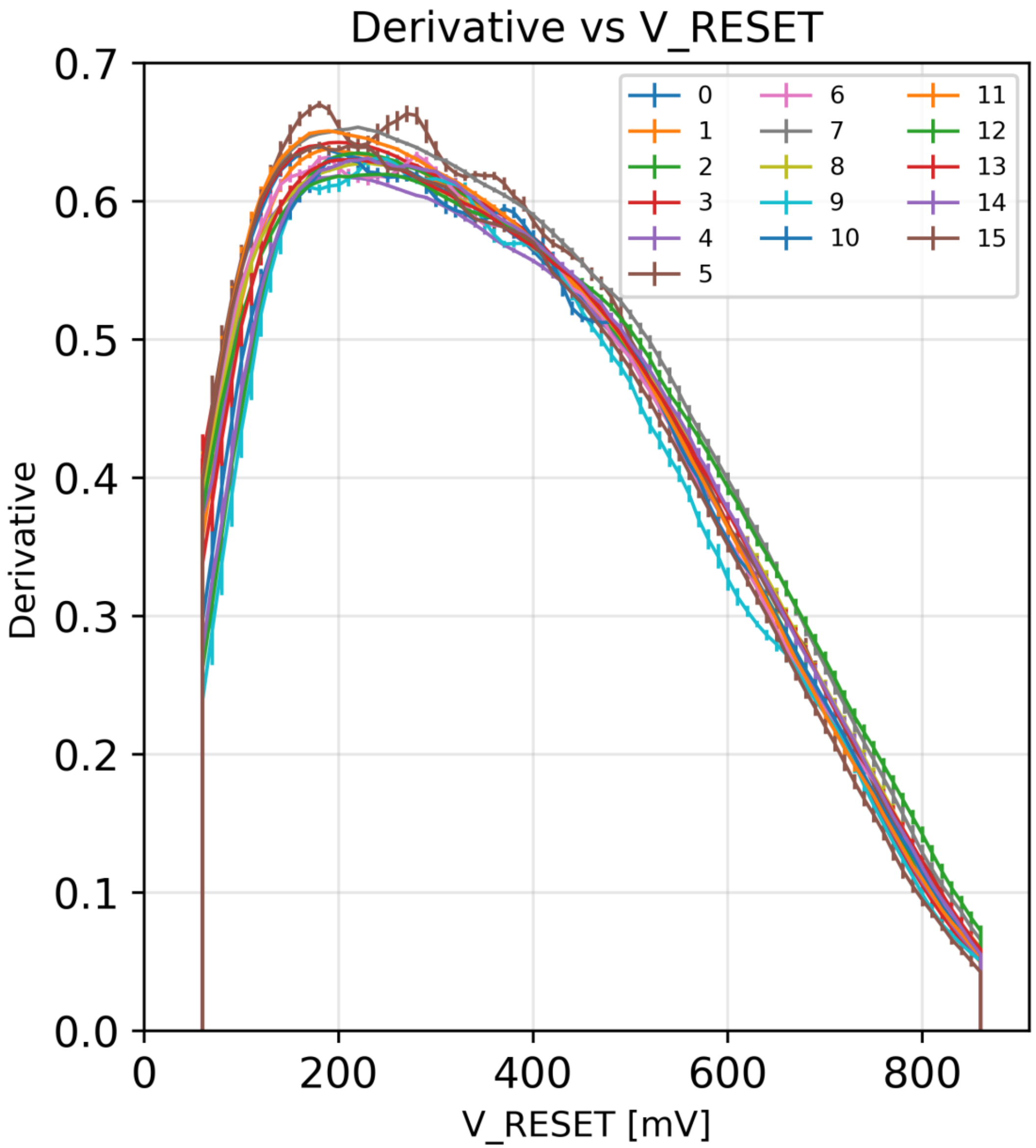
Oscilloscope
Rohde&SchwarzRTO1044 (4 Ghz BW - 20 Gsa/s)

Gain calibration

- Measure the baseline of the 16 pixels at varying V_{reset} (20 mV to 900 mV interval)
- Data processing and analysis produce mean and rms of *Baseline* and $dBaseline/dV_{reset}$

V_{bb} = 0.0V

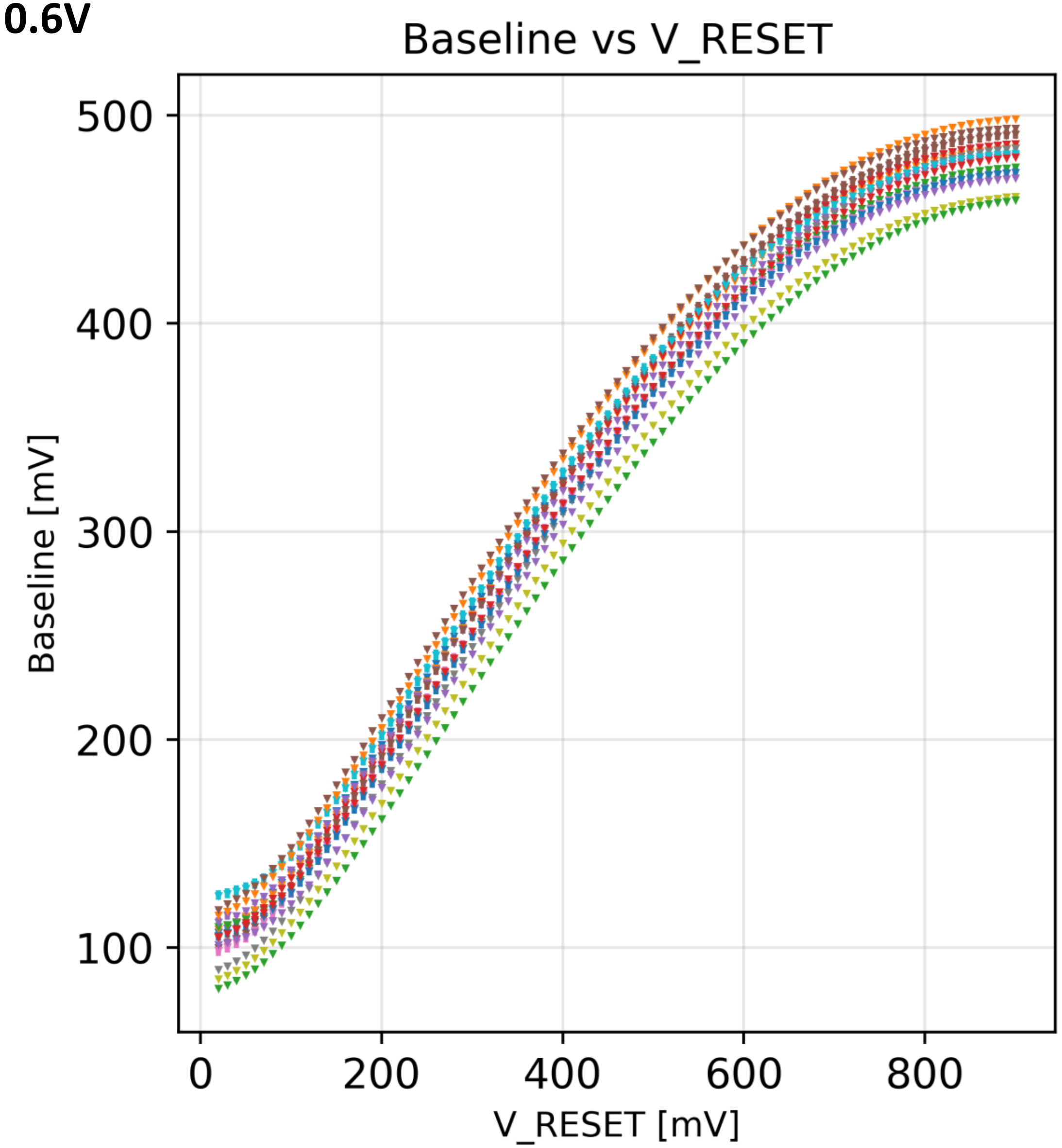


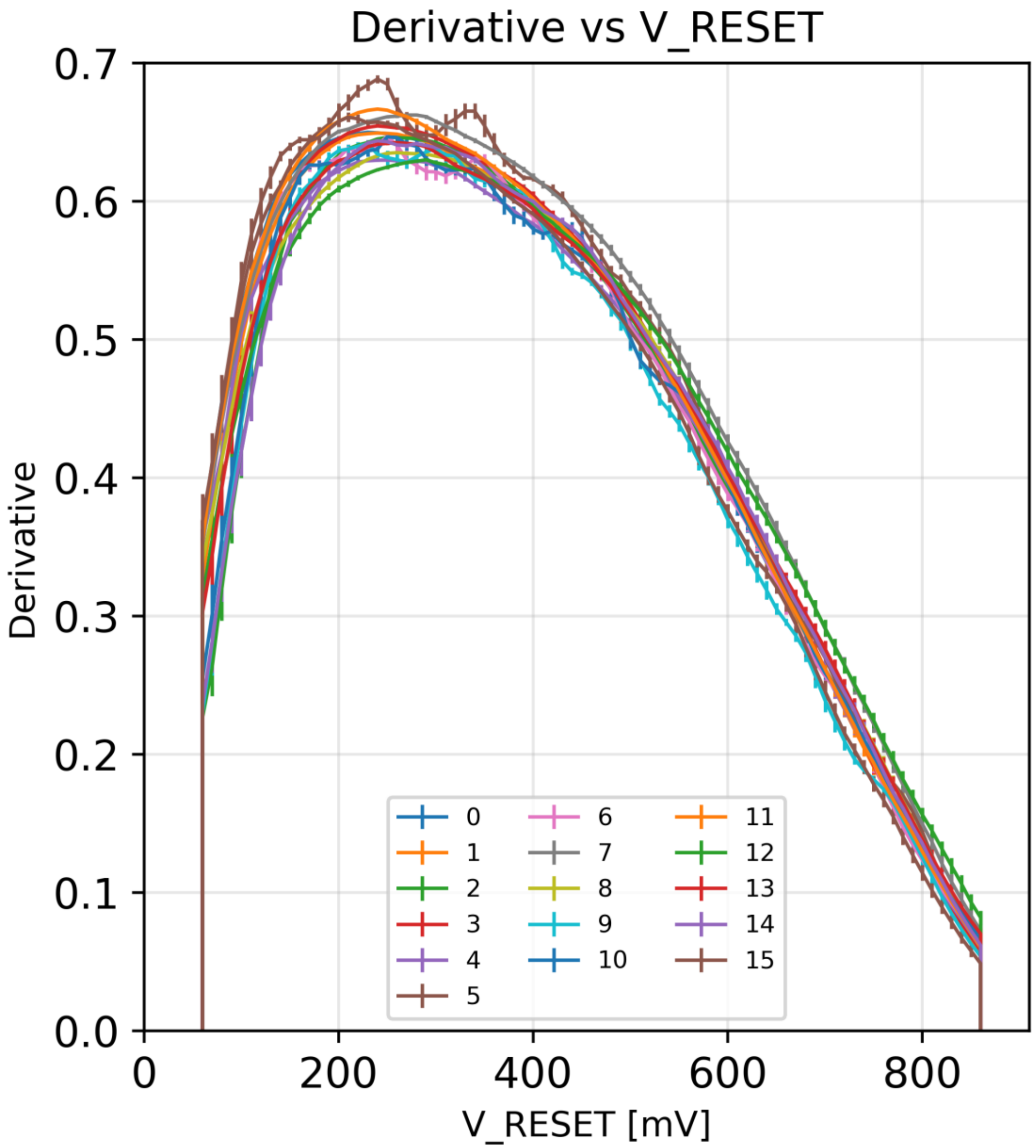


Gain calibration

- Measure the baseline of the 16 pixels at varying V_{reset} (20 mV to 900 mV interval)
- Data processing and analysis produce mean and rms of *Baseline* and $dBaseline/dV_{reset}$

V_{bb} = 0.6V

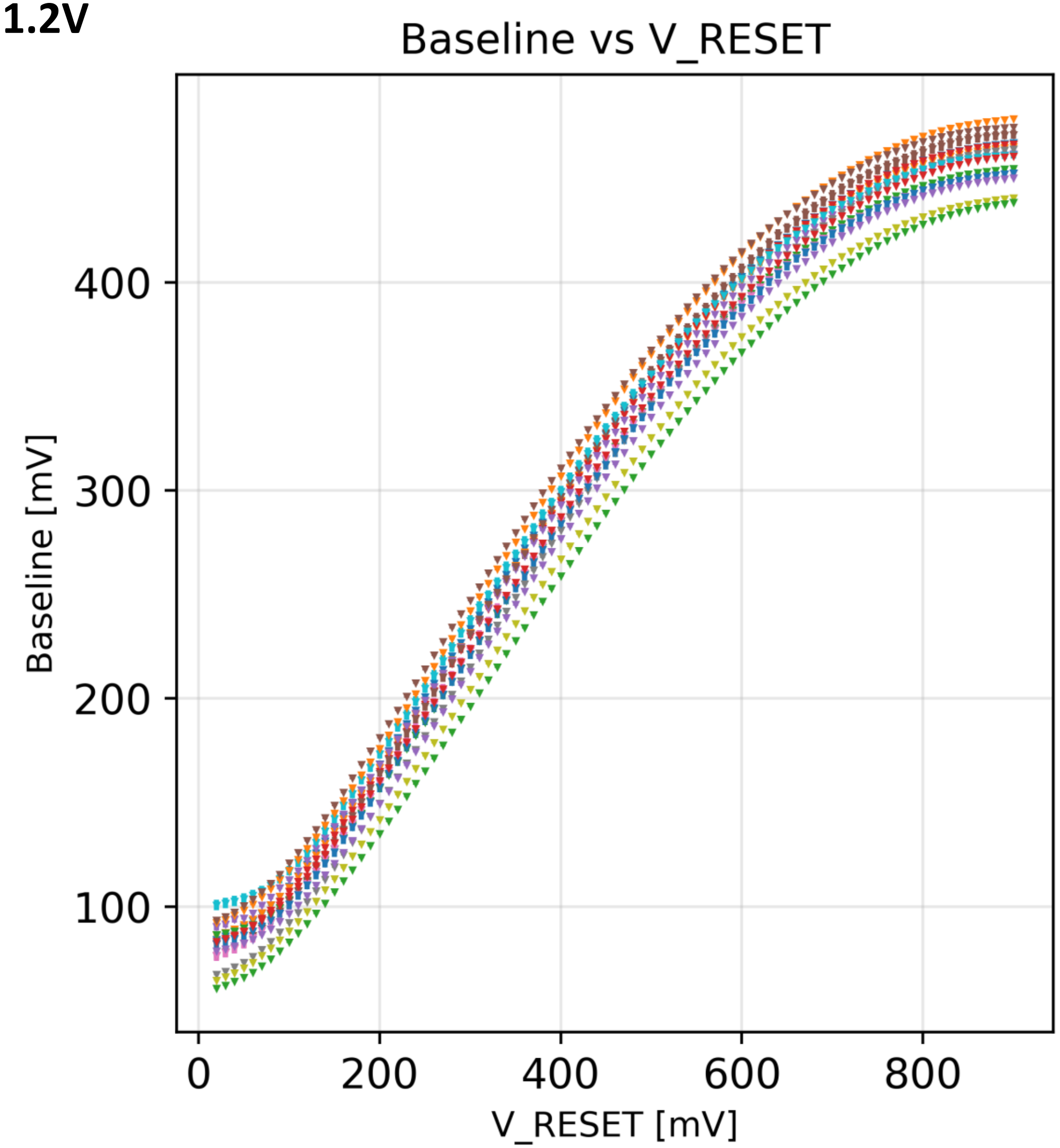


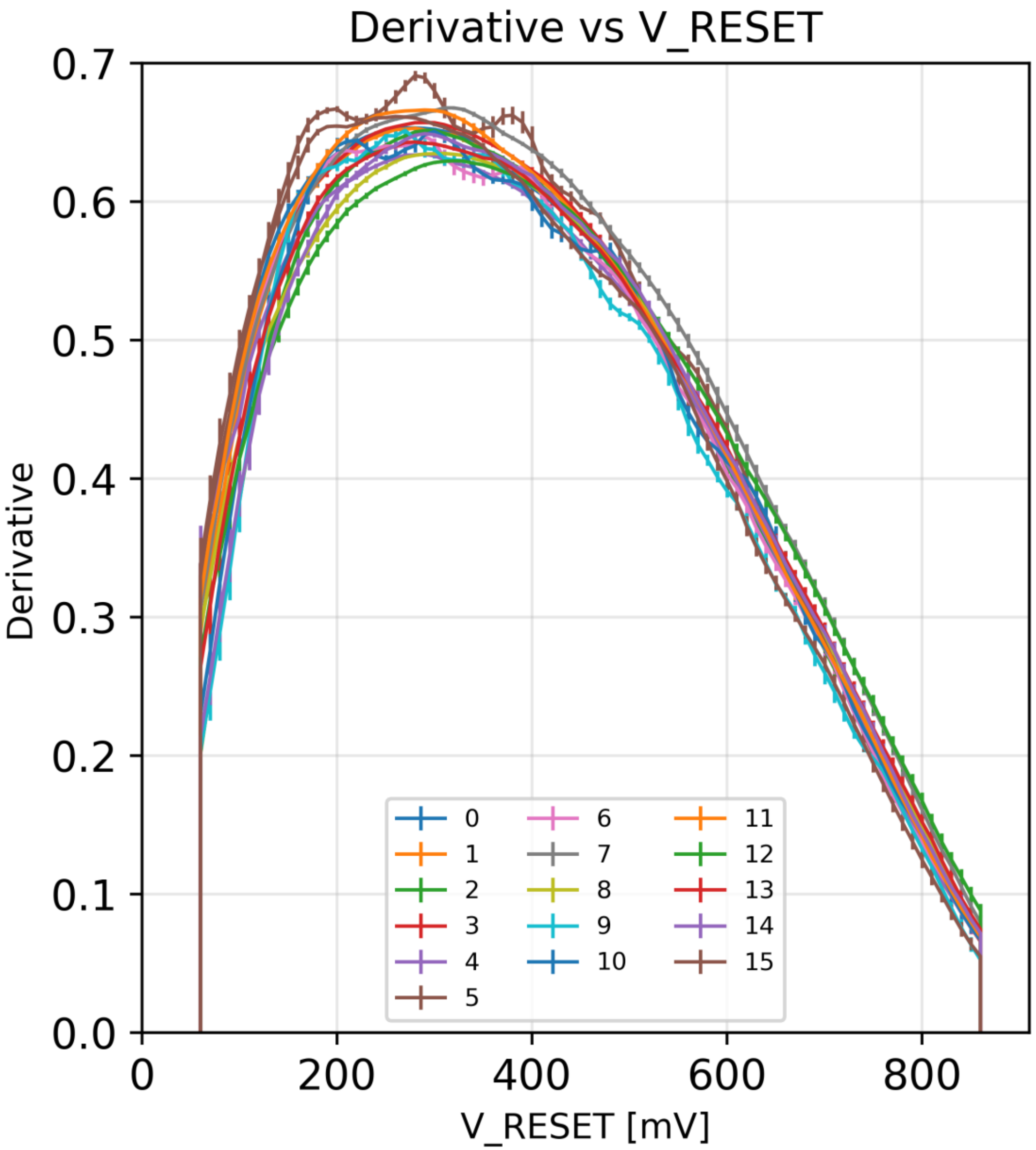


Gain calibration

- Measure the baseline of the 16 pixels at varying V_{reset} (20 mV to 900 mV interval)
- Data processing and analysis produce mean and rms of *Baseline* and $dBaseline/dV_{reset}$

V_{bb} **= 1.2V**

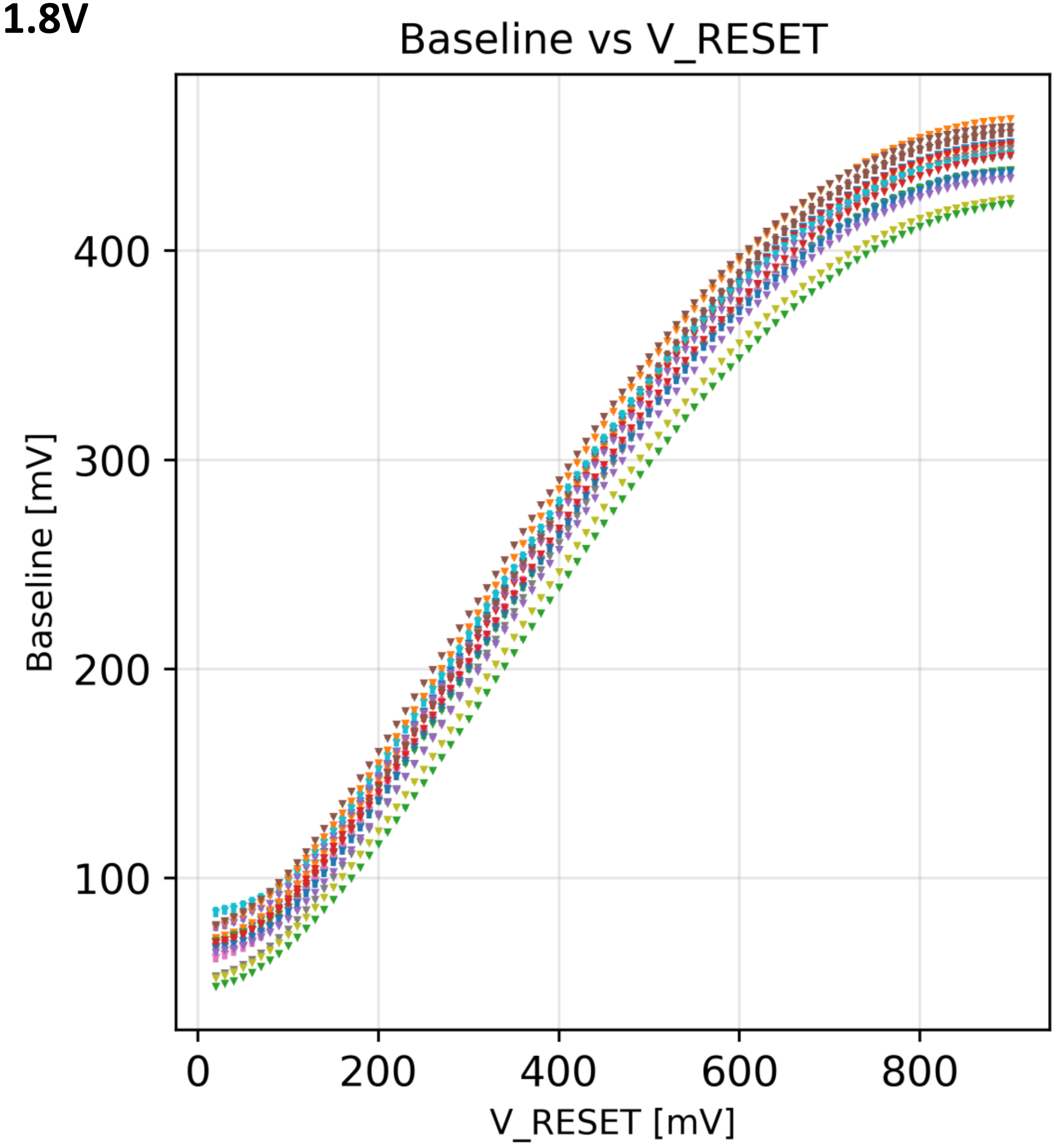


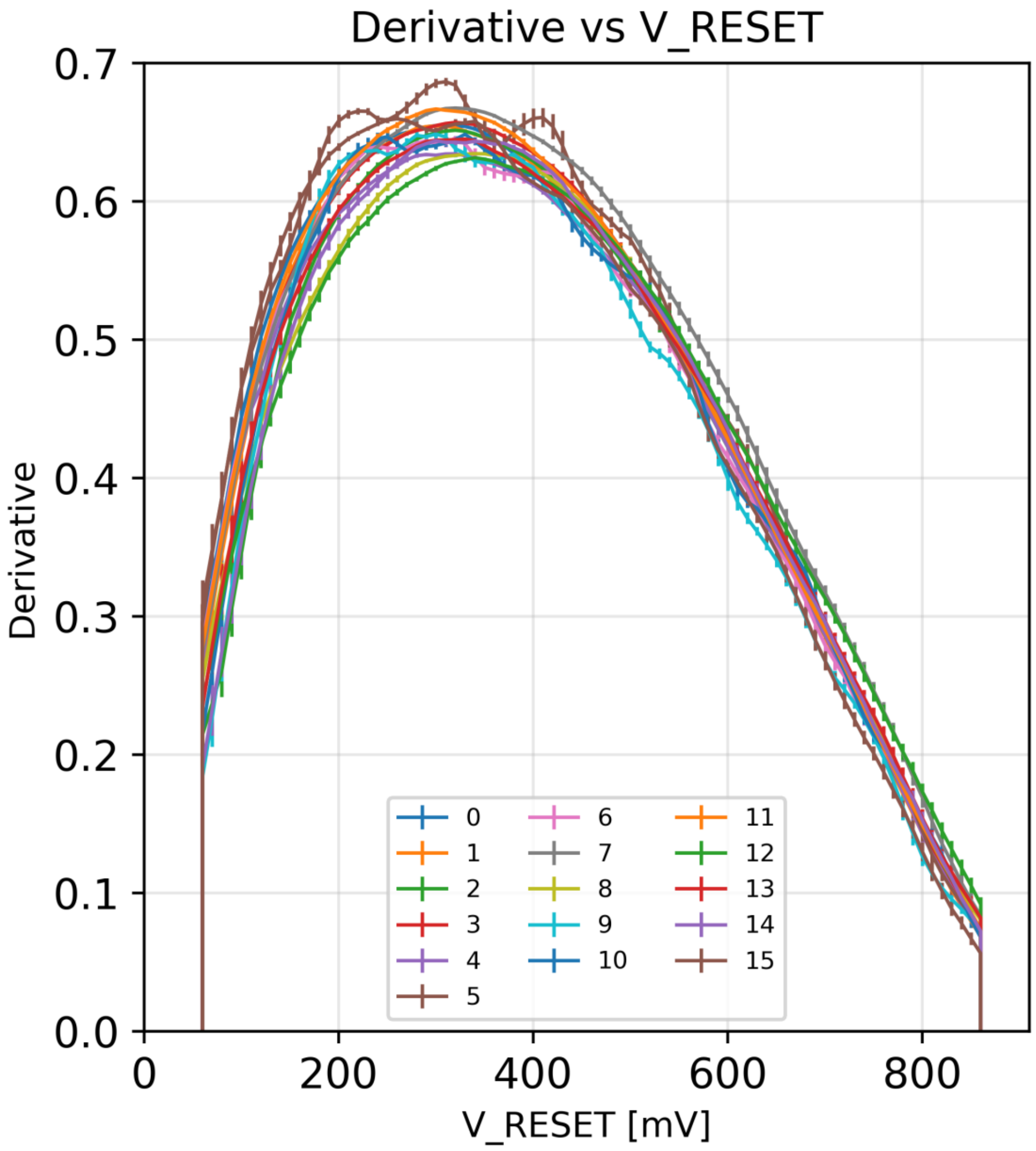


Gain calibration

- Measure the baseline of the 16 pixels at varying V_{reset} (20 mV to 900 mV interval)
- Data processing and analysis produce mean and rms of *Baseline* and $dBaseline/dV_{reset}$

V_{bb} = 1.8V

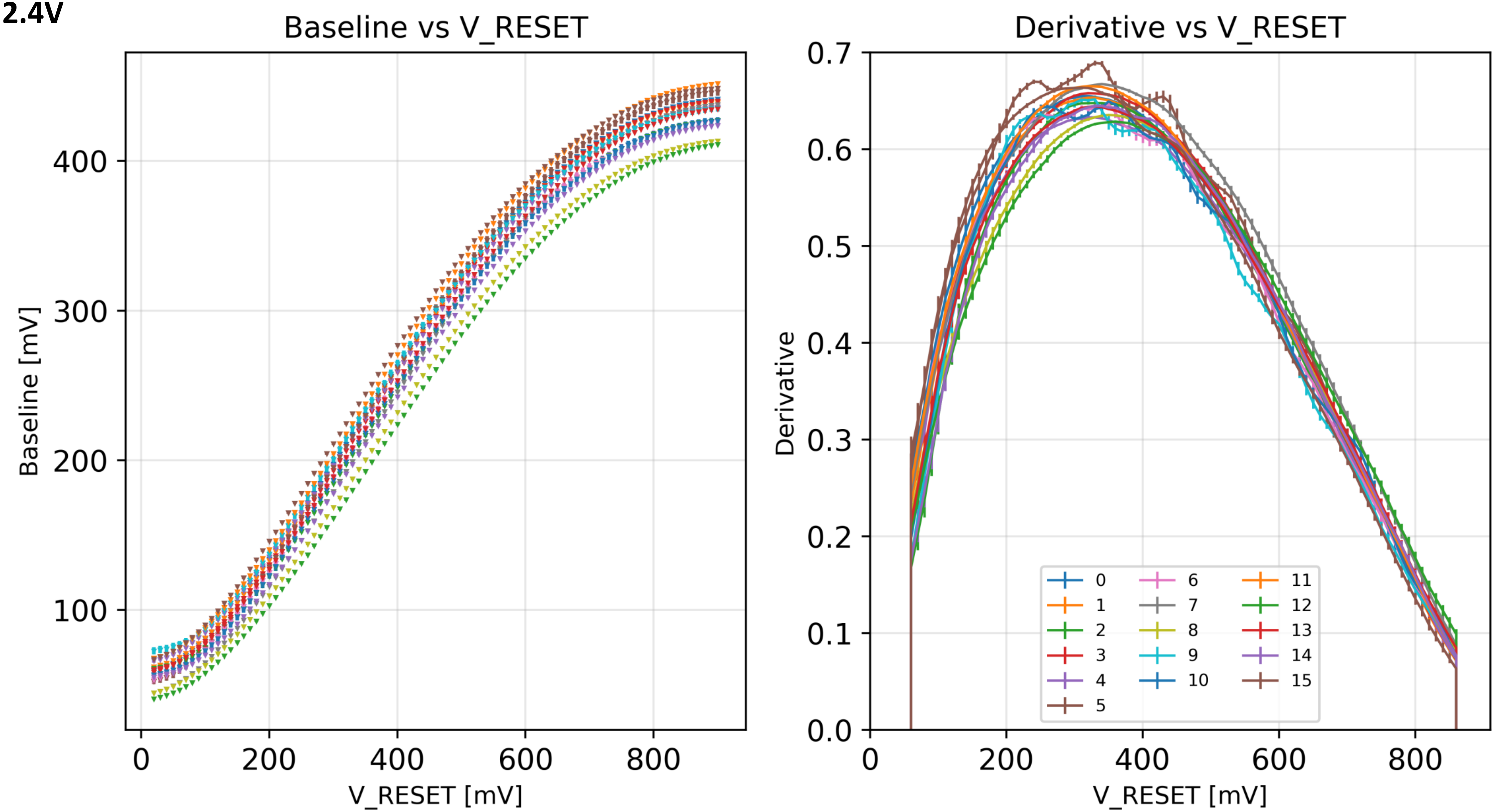




Gain calibration

- Measure the baseline of the 16 pixels at varying V_{reset} (20 mV to 900 mV interval)
- Data processing and analysis produce mean and rms of *Baseline* and $dBaseline/dV_{reset}$

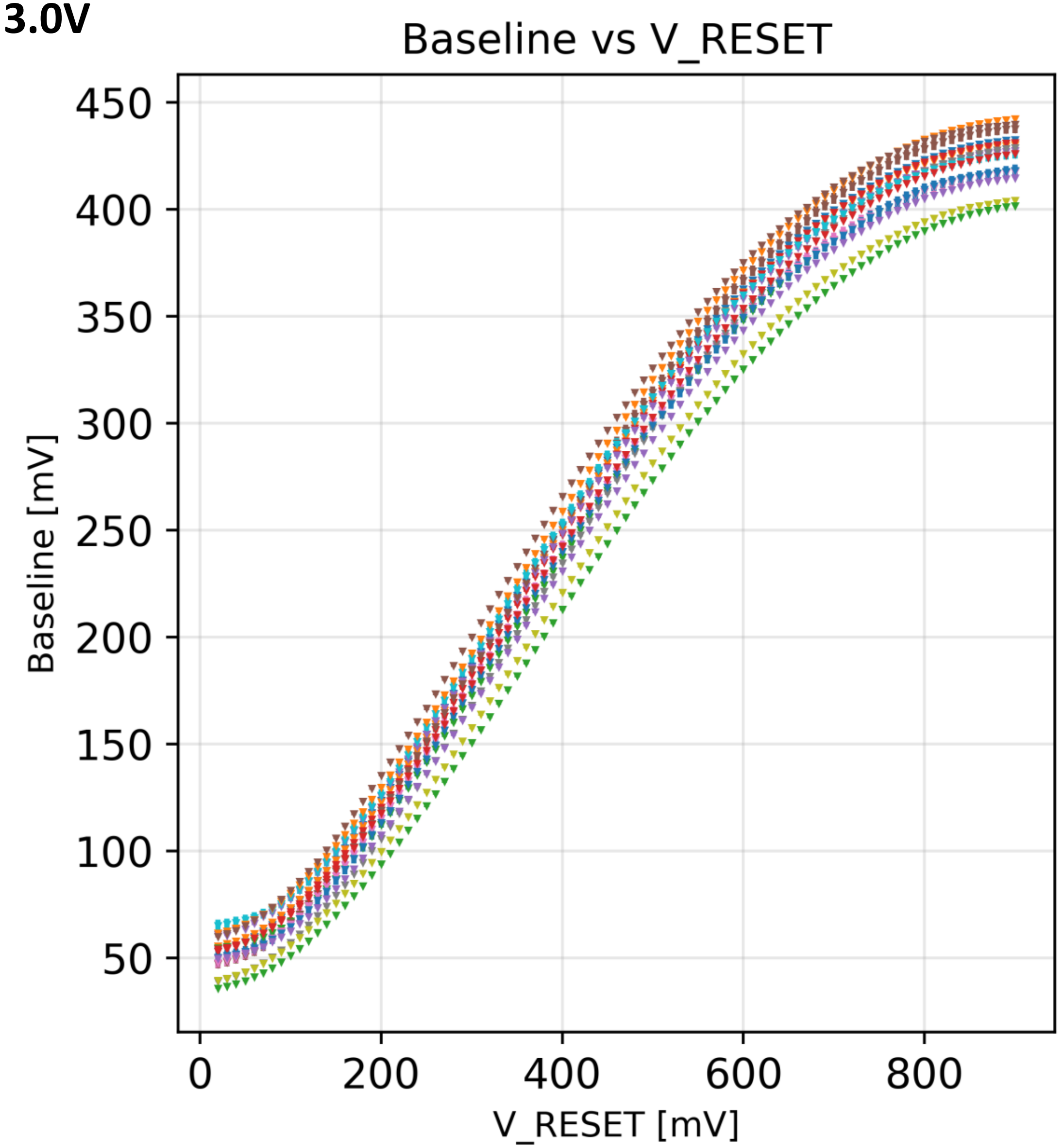
V_{bb} = 2.4V

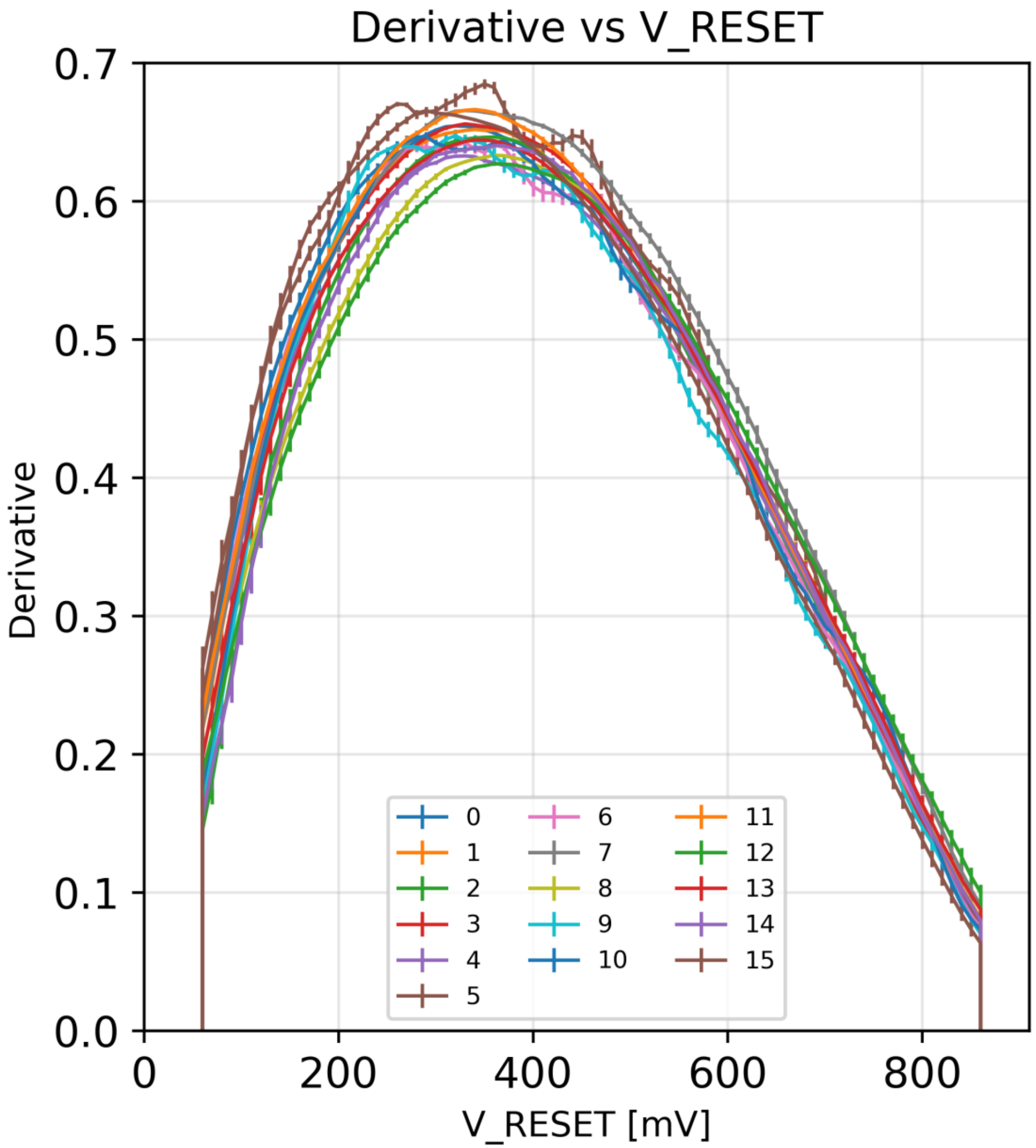


Gain calibration

- Measure the baseline of the 16 pixels at varying V_{reset} (20 mV to 900 mV interval)
- Data processing and analysis produce mean and rms of *Baseline* and $dBaseline/dV_{reset}$

V_{bb} = 3.0V

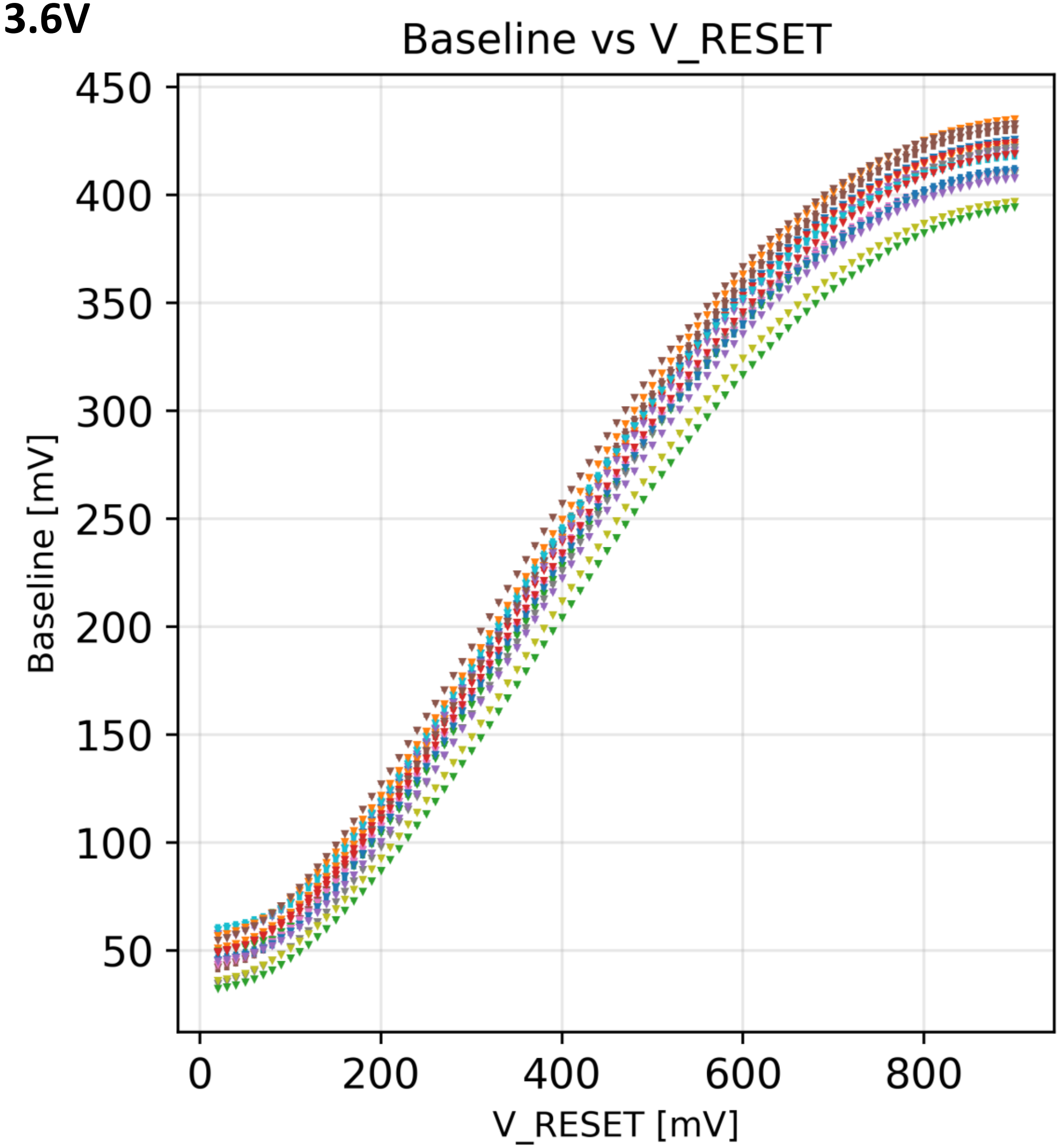


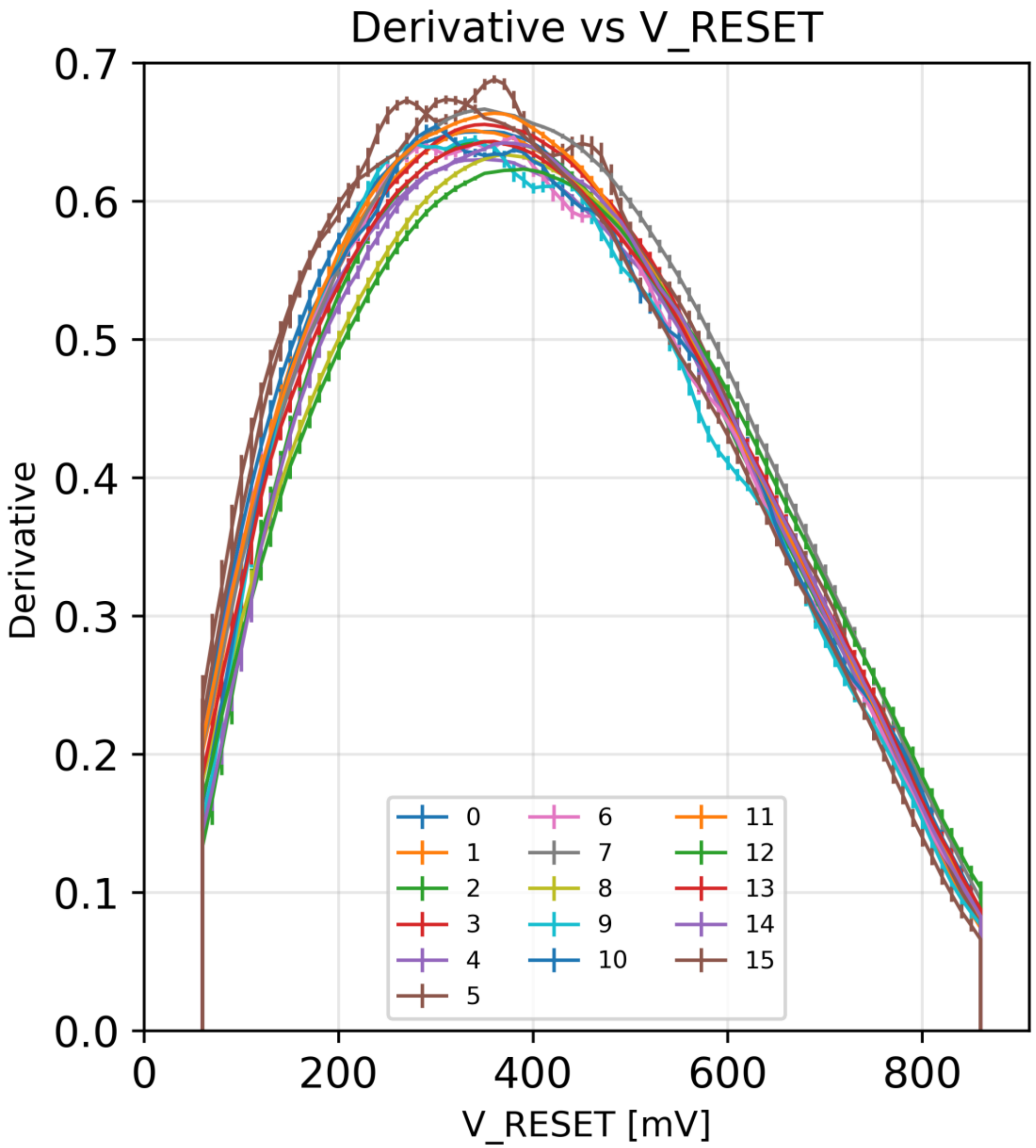


Gain calibration

- Measure the baseline of the 16 pixels at varying V_{reset} (20 mV to 900 mV interval)
- Data processing and analysis produce mean and rms of *Baseline* and $dBaseline/dV_{reset}$

V_{bb} = 3.6V

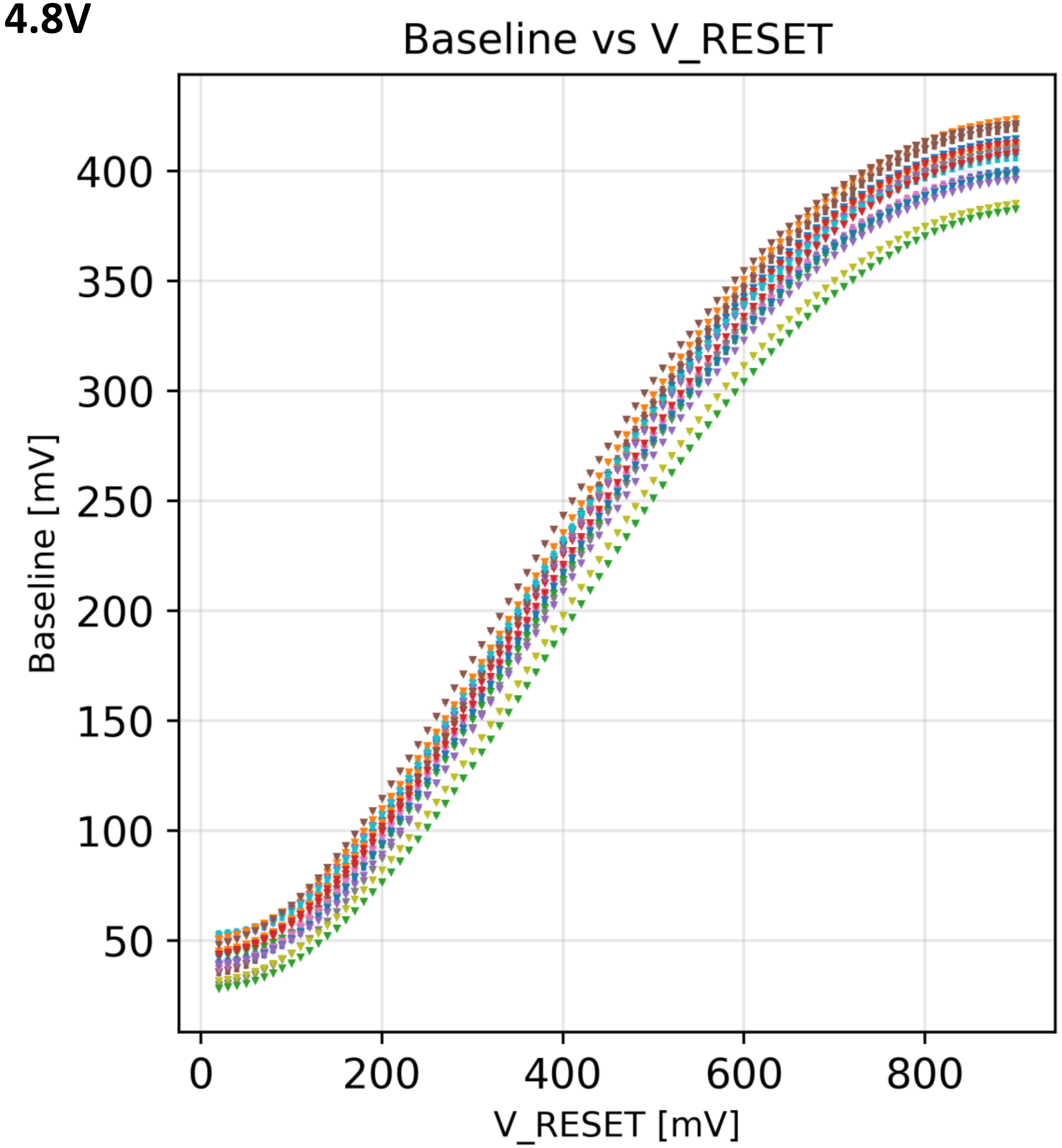


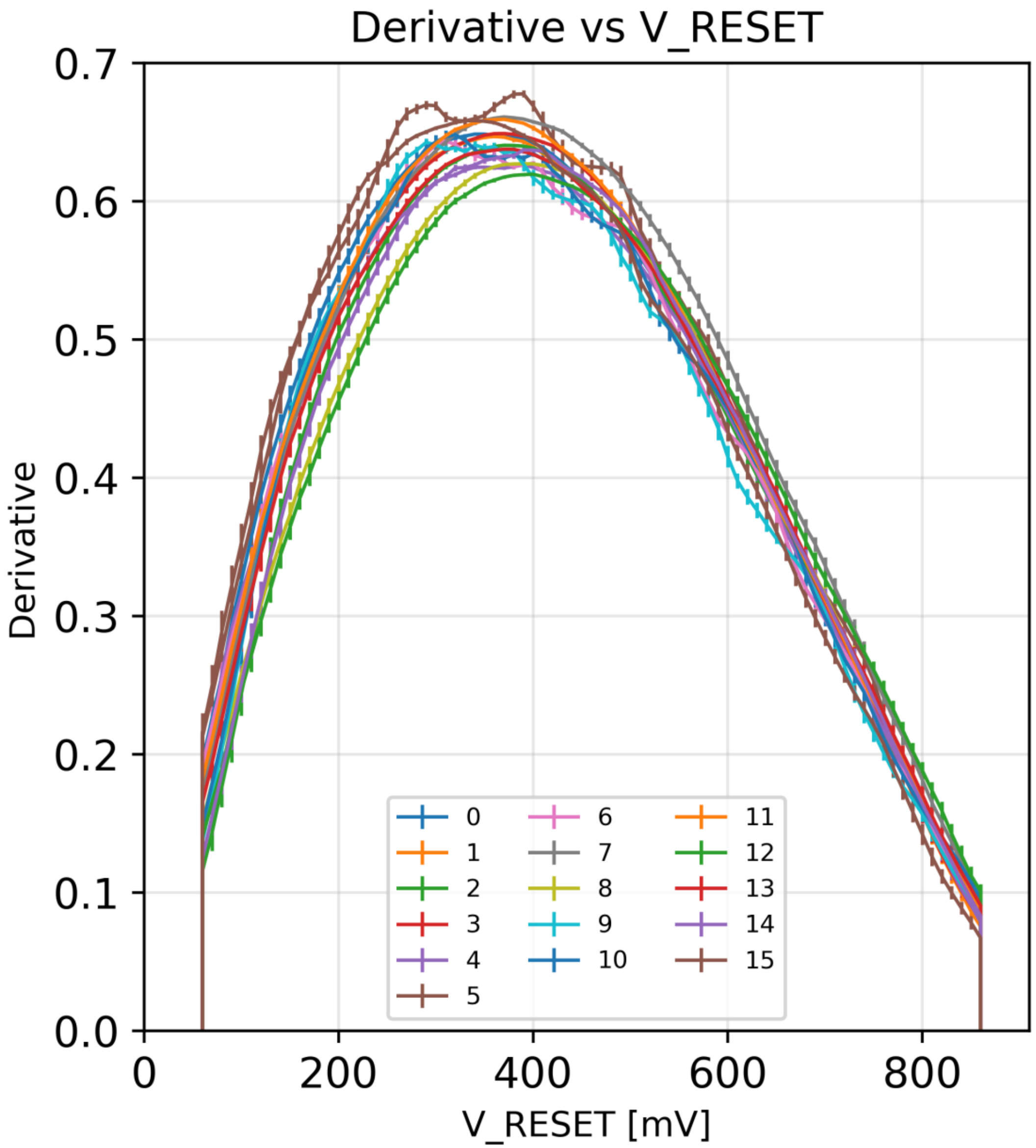


Gain calibration

- Measure the baseline of the 16 pixels at varying V_{reset} (20 mV to 900 mV interval)
- Data processing and analysis produce mean and rms of *Baseline* and $dBaseline/dV_{reset}$

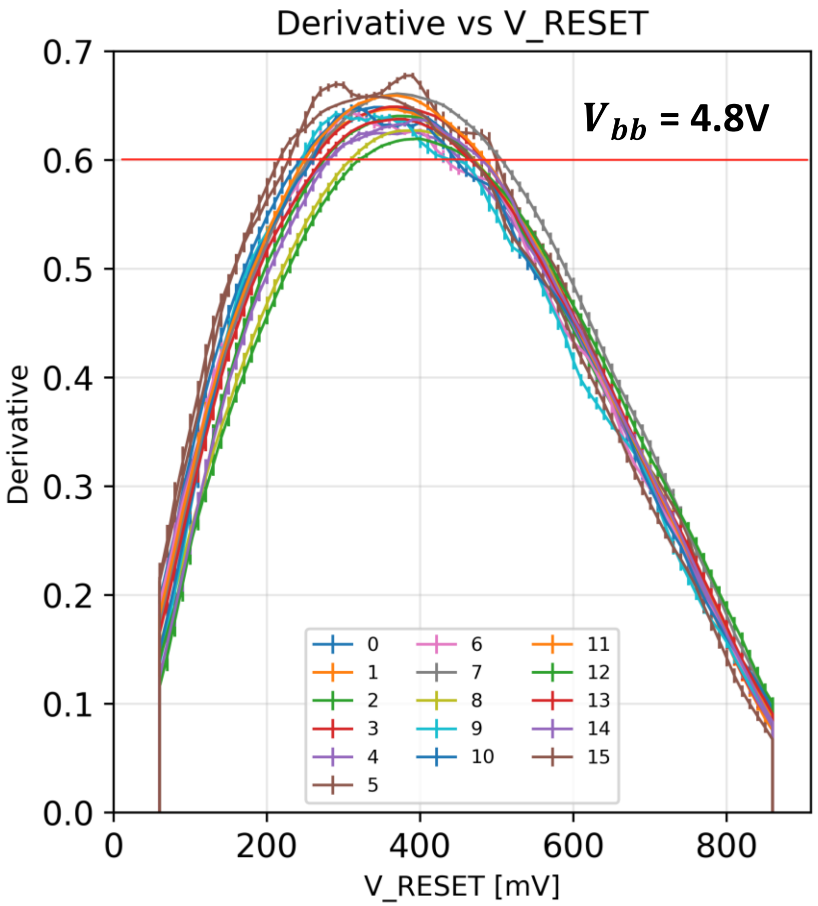
V_{bb} = 4.8V





Pulsing calibration

- The current analysis processes only the internal pixels
- Acquire test pulses produced by the proxy board (V_h DAC) and injected via injection capacitance in the pixels frontend
- V_{reset} is measured where $\frac{dBaseline}{dV_{reset}} > 0{,}6$ for the injected charge corresponding at **fixed** $V_h = 1200mV$



- Analysis produces the optimal V_{reset} for each V_{bb} applied (**working point**)

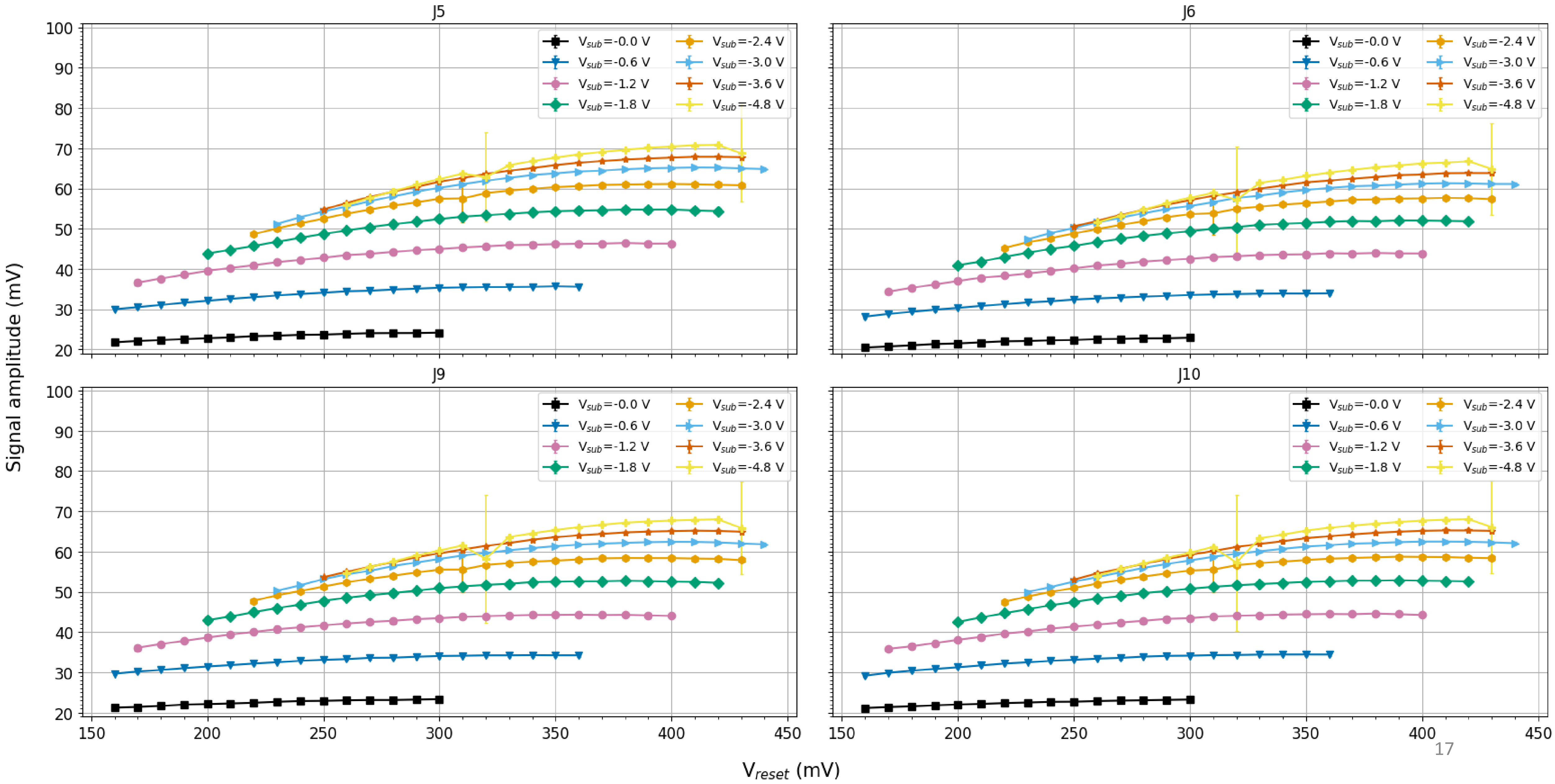
Operation Point W22AO10Pb18

$V_{bb}\ (V)$	$V_{reset}\ (mV)$
0.0	260
-0.6	310
-1.2	350
-1.8	370
-2.4	390
-3.0	390
-3.6	400
-4.8	400

Working point configuration: maximum signal amplitude, maximum gain, minimum signal falltime

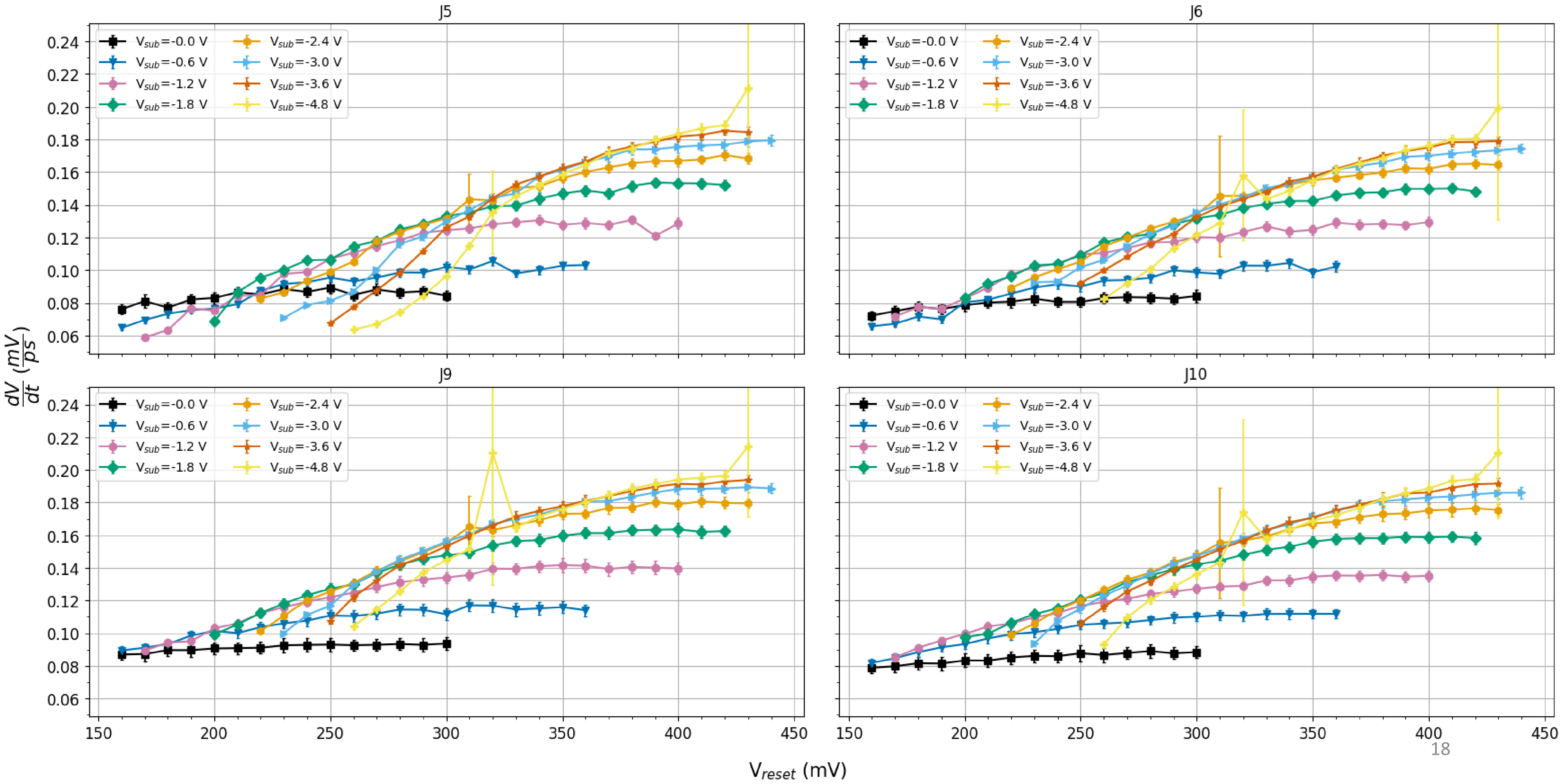
Pulsing calibration output: Signal Amplitude

working point configuration: maximum signal amplitude, maximum gain, minimum signal falltime



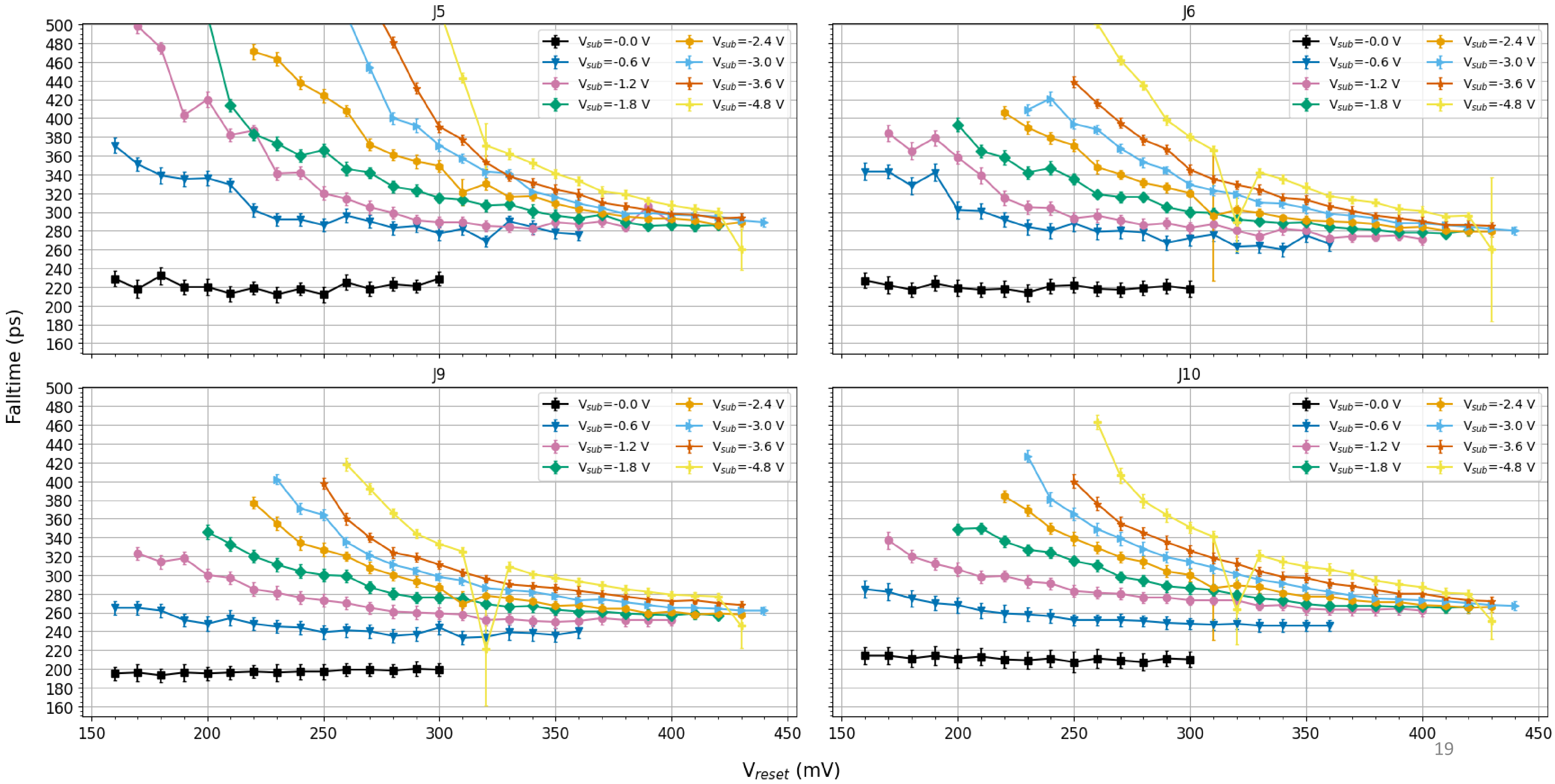
Pulsing calibration output: dV/dt 10%-90%

working point configuration: maximum signal amplitude, maximum gain, minimum signal falltime



Pulsing calibration output: Fall-Time 10%-90%

working point configuration: maximum gain, maximum signal amplitude, minimum signal falltime



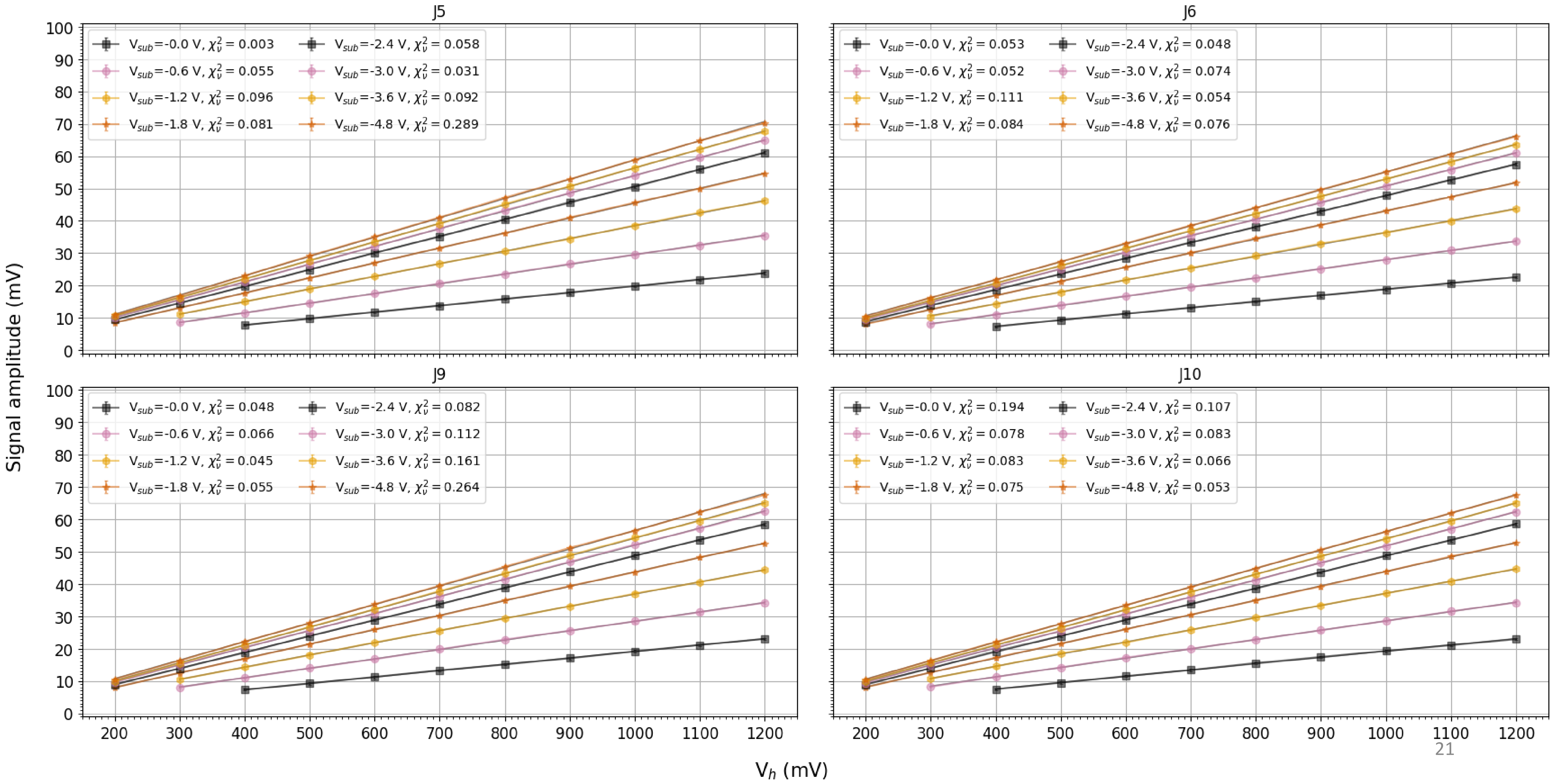
V_h scan calibration

- The current analysis processes only the internal pixels
- For the working points defined in the pulsing calibration, acquire test pulses produced by the proxy board (V_h DAC) at varying injected charge (V_h scan default range: $200\ mV$ to $1200 mV$ in steps of $100 mV$)

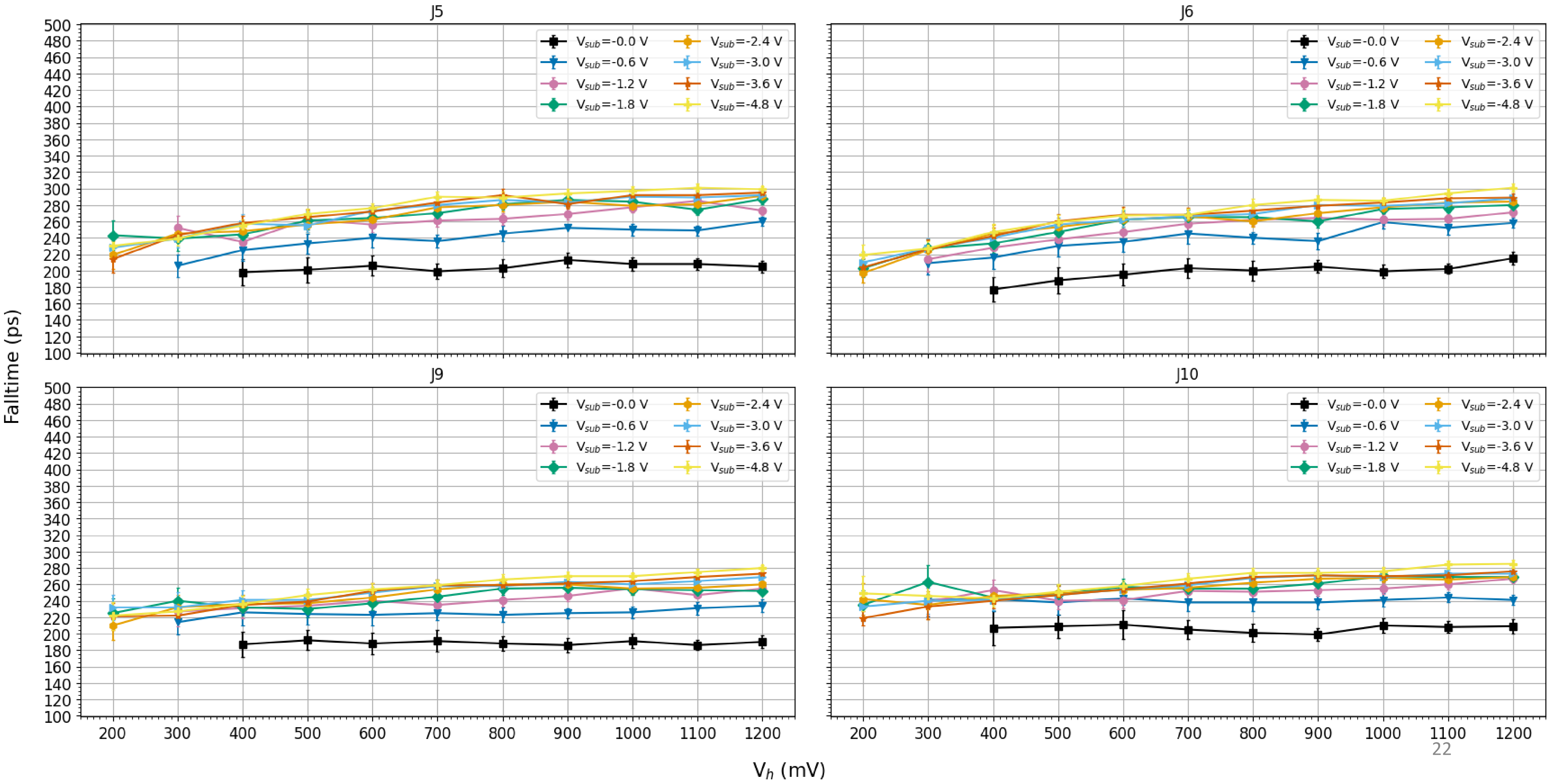
Operation Point W22AO10Pb18

$V_{bb}\ (V)$	$V_{reset}\ (mV)$
0.0	260
-0.6	310
-1.2	350
-1.8	370
-2.4	390
-3.0	390
-3.6	400
-4.8	400

V_h scan calibration output: Signal Amplitude



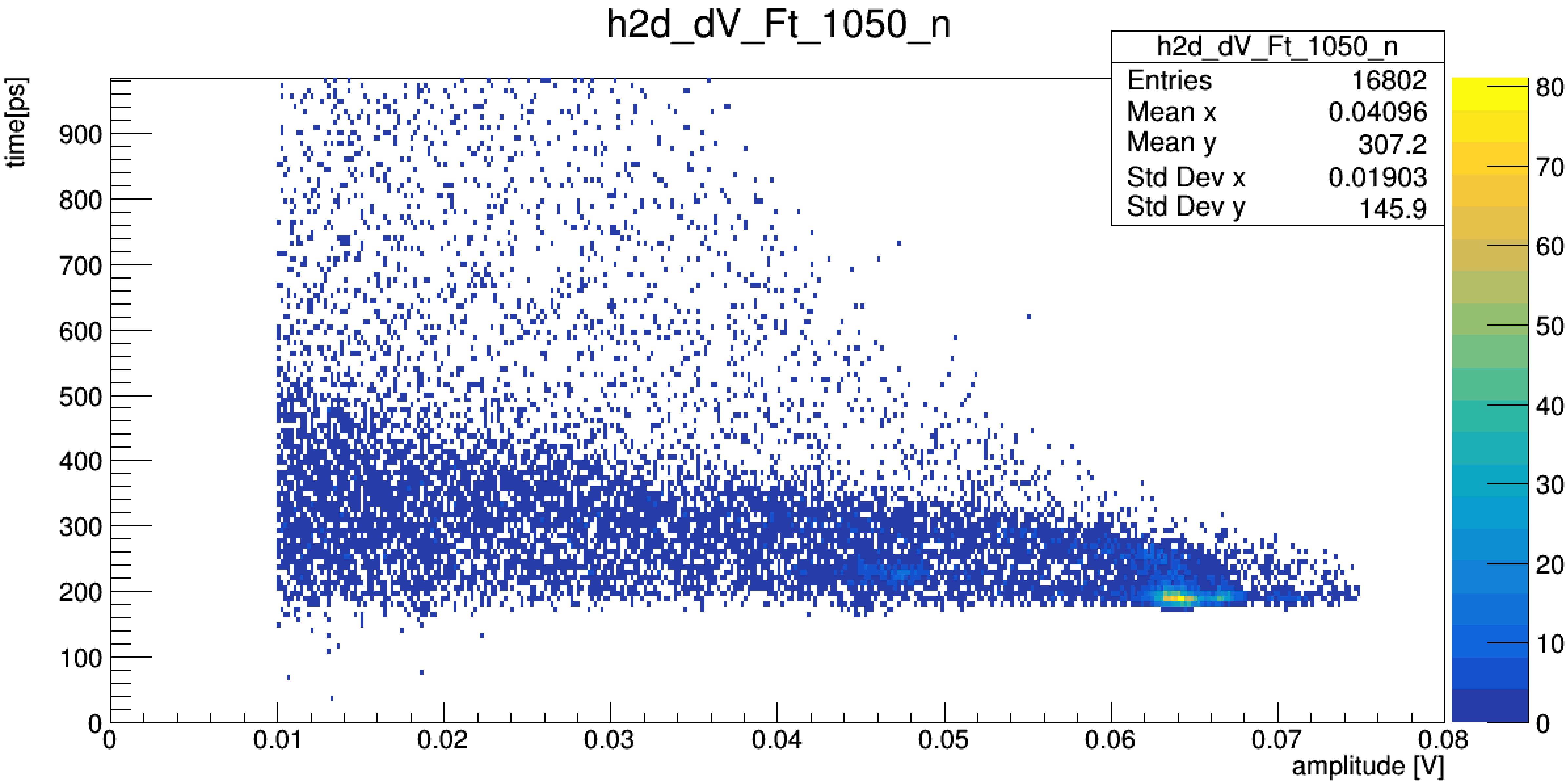
V_h scan calibration output: Fall-Time 10%-90%



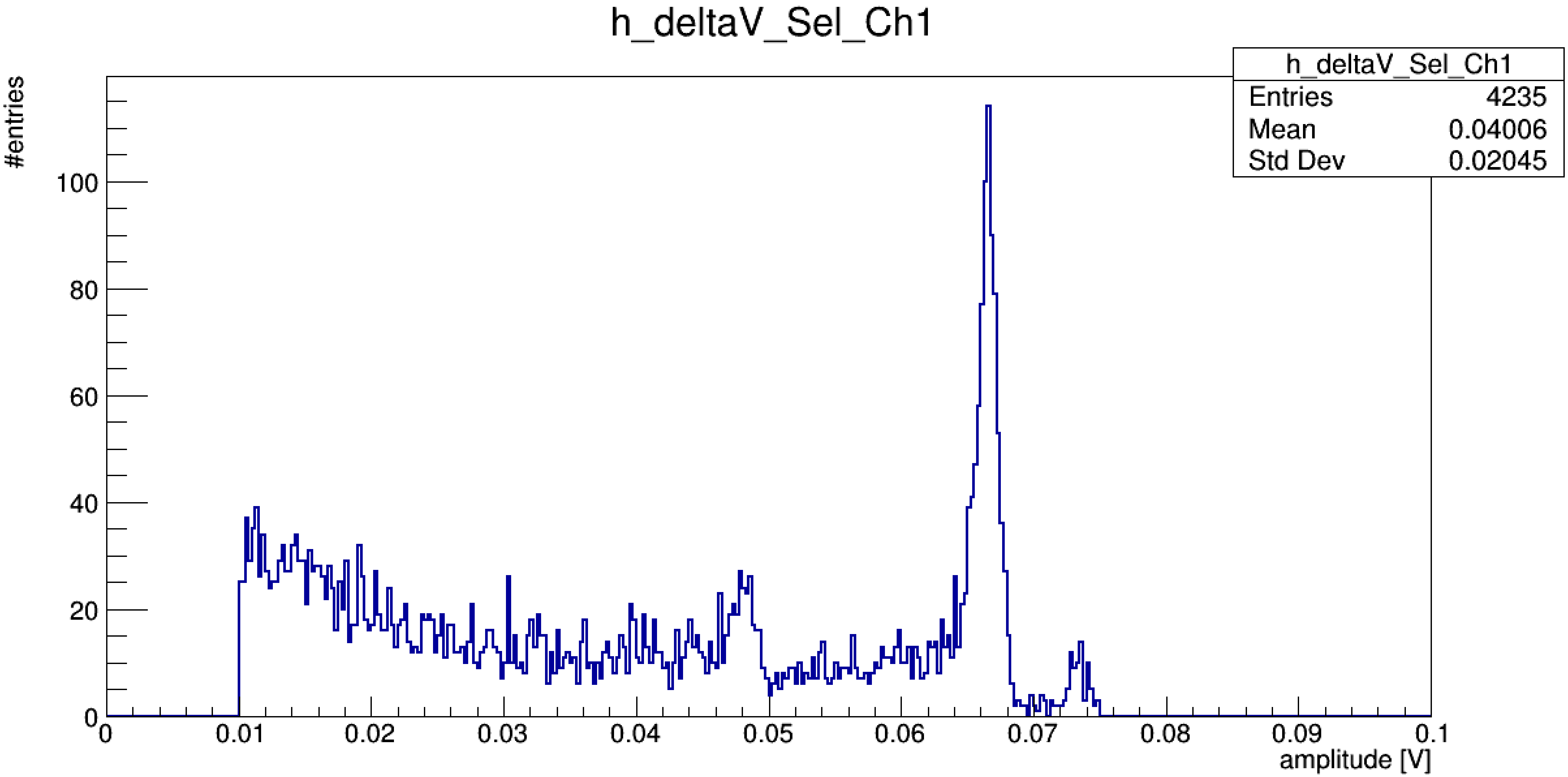
^{55}Fe spectrum measurements

Energy (keV)	Intensity (%)	Type
5.89875	16.57	$X_{K\alpha1}$
5.88765	8.45	$X_{K\alpha2}$
6.5128	3.40	$X_{K'\beta1}$
0.6385	0.524	X_L
125.949	0.00000013	γ

^{55}Fe Fall-Time 10%-50%



^{55}Fe spectrum measurements



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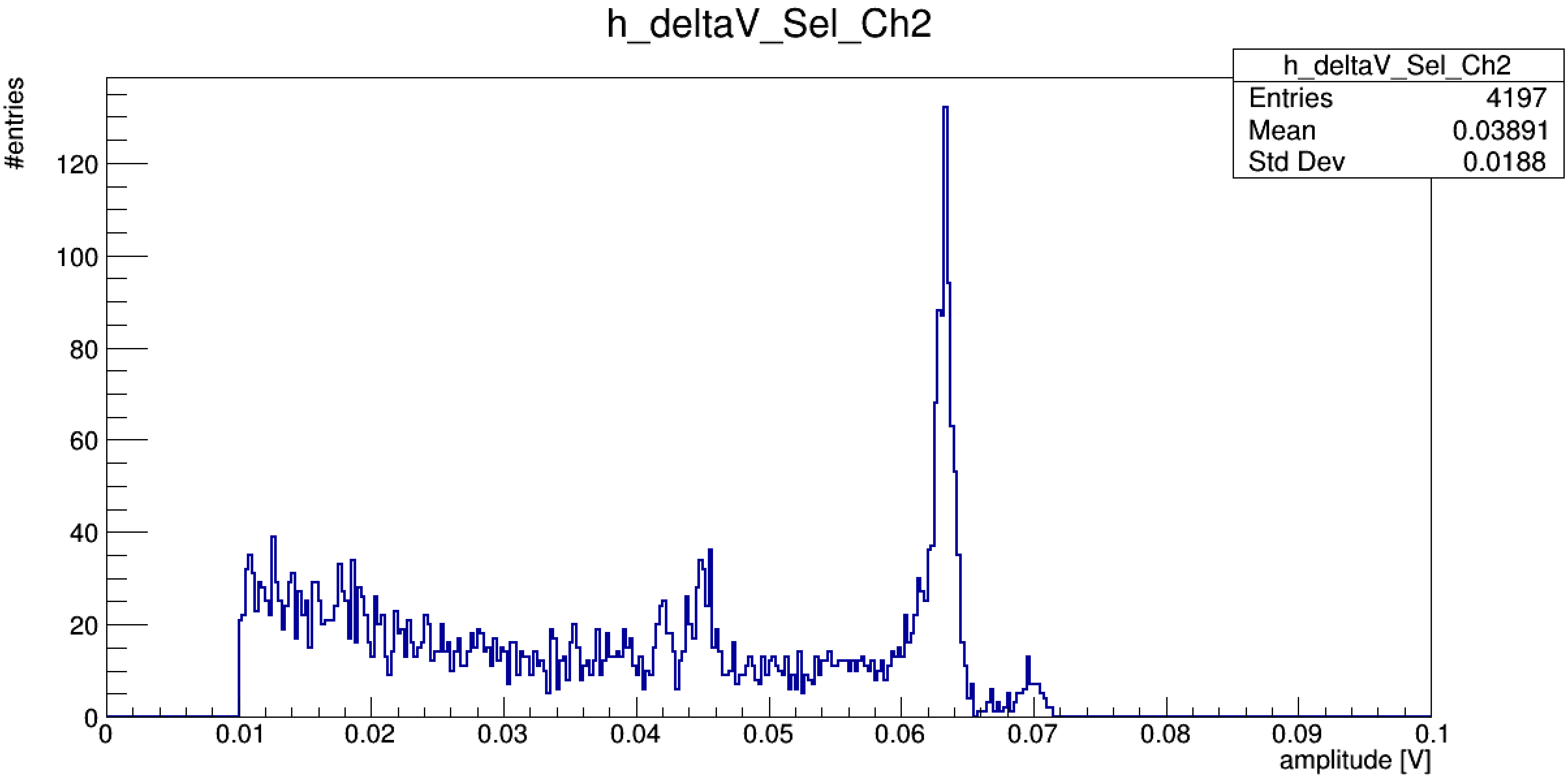

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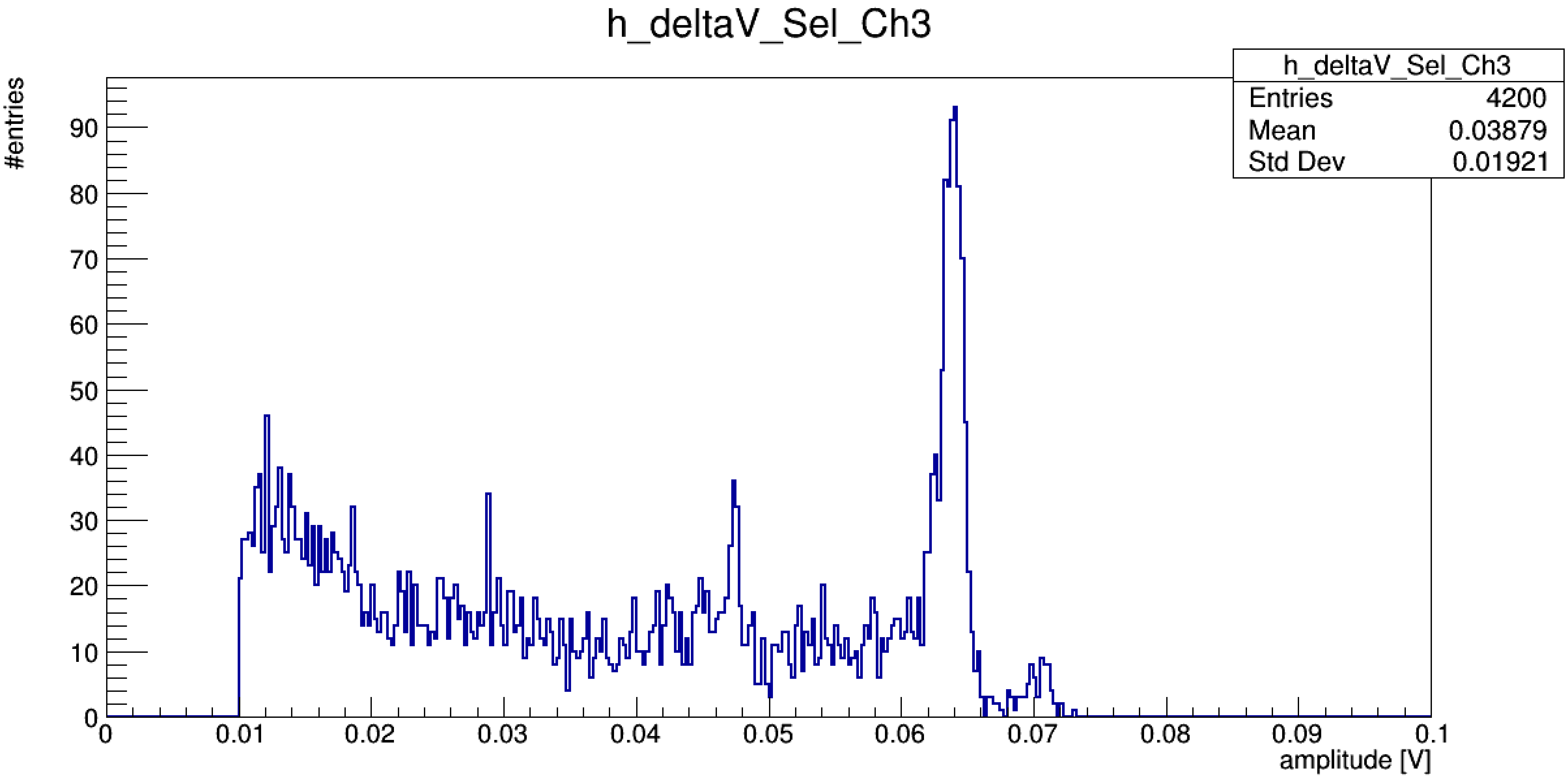

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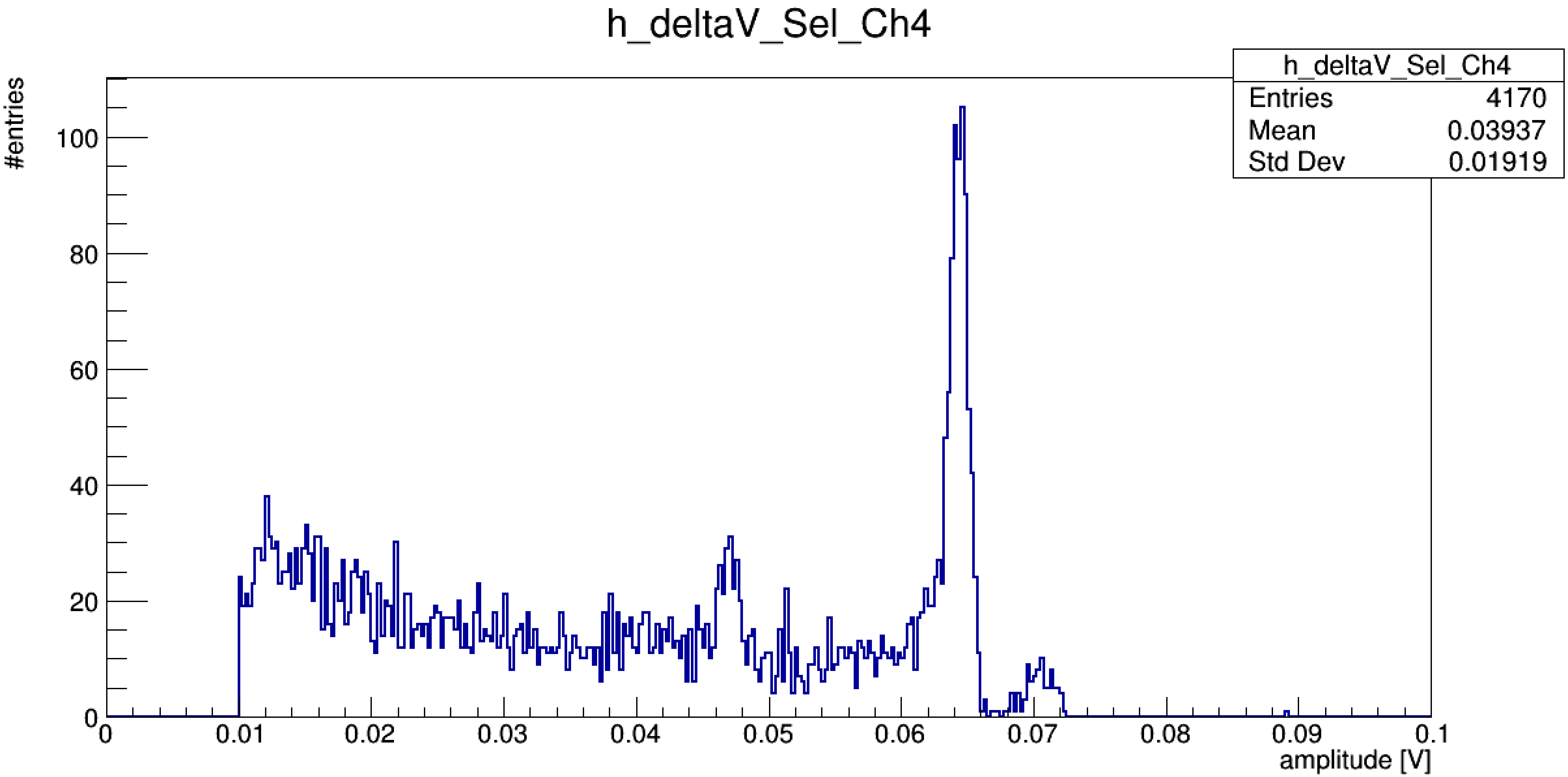

^{55}Fe spectrum measurements