JUNO ITALIA MEETING

ROMA, 28/03/2023

JUNO-TAO Front-End Boards & SiPM tiles characterization

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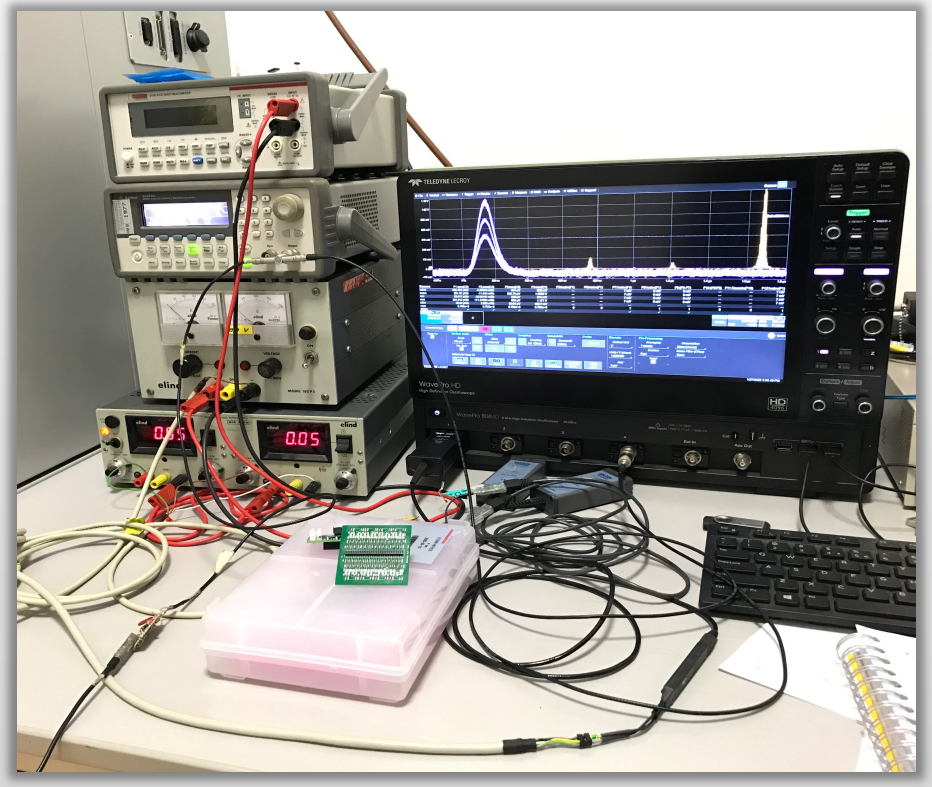
Outline

- Experimental setup & instruments
- FEBs connection & supply
- Figures of merit
- Tiles characterization
- Conclusions

Experimental setup

Tile characterization performed @ -50°C (less DCR)

CLIMATE CHAMBER

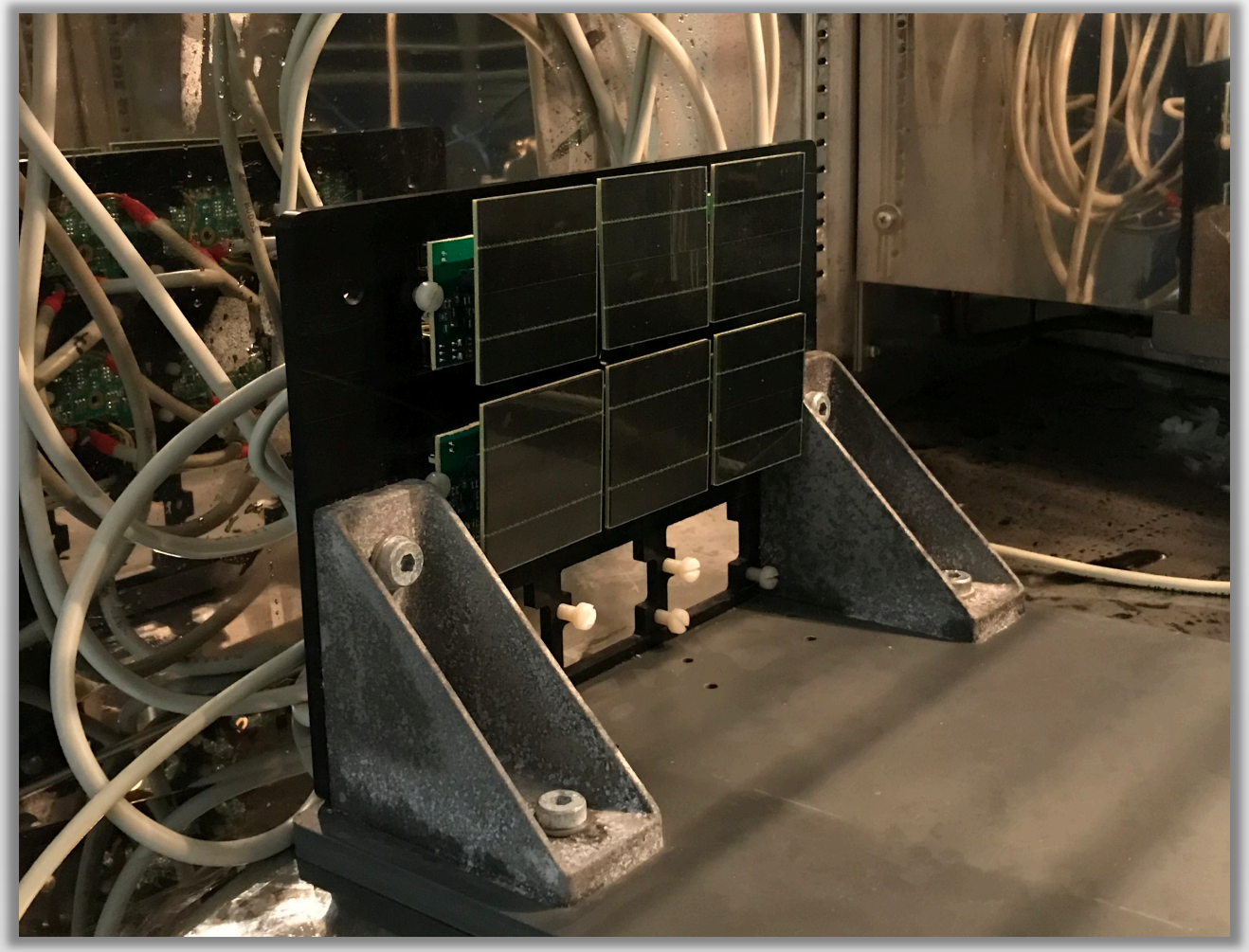


SUPPLY & READOUT

- Low-Voltage power supply
- High-Voltage power supply
- 407nm-80ps LASER source
- LeCroy WavePro Oscilloscope

Experimental setup

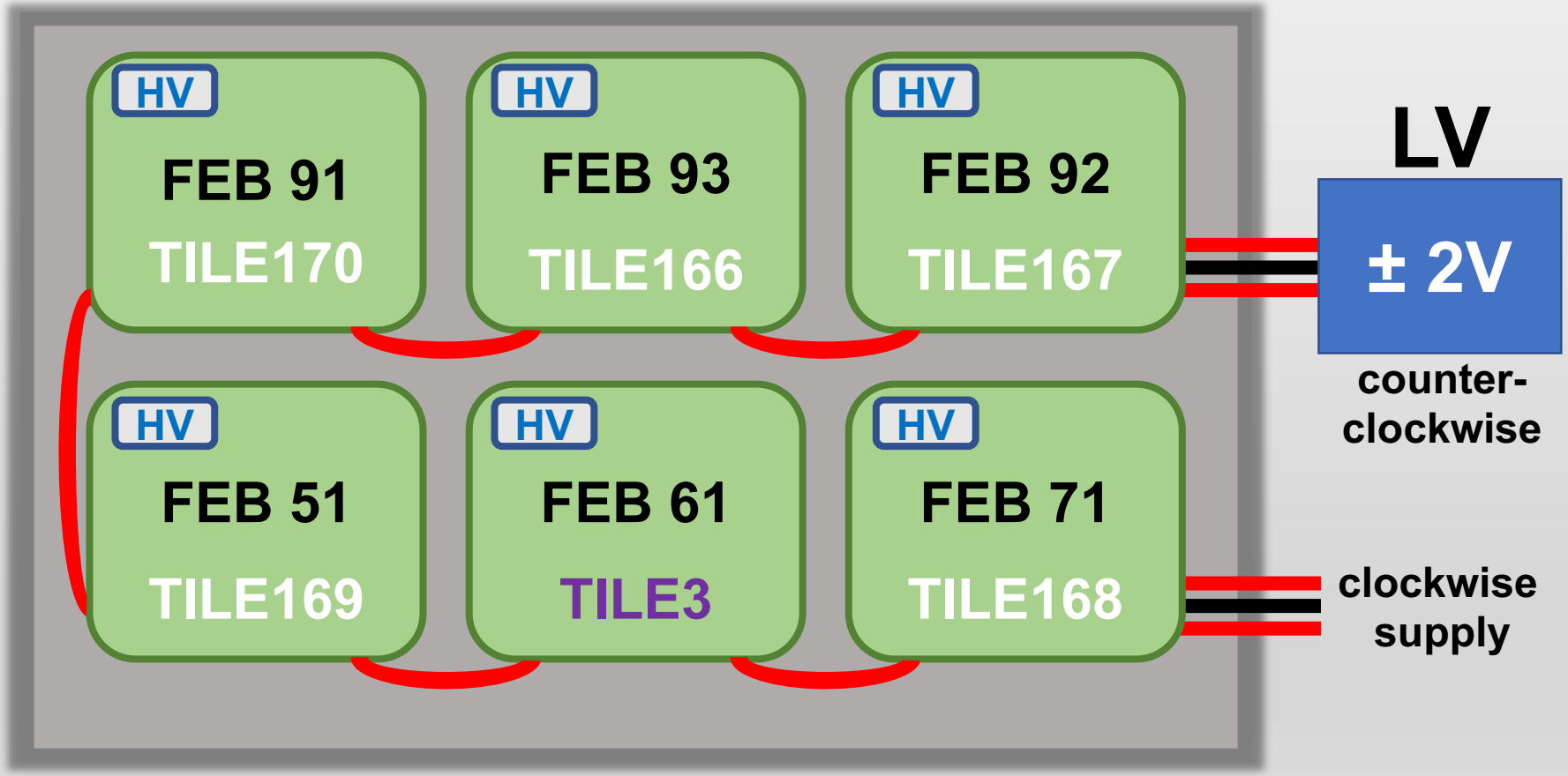
6 FEB+TILE tested at one time – 12 channels



- Each FEB needs 80 mA at +2V and 80 mA at -2V @ -50°C
- Shorter cables can be used to bring supply to the other FEBs on the row

FEBs supply & connection

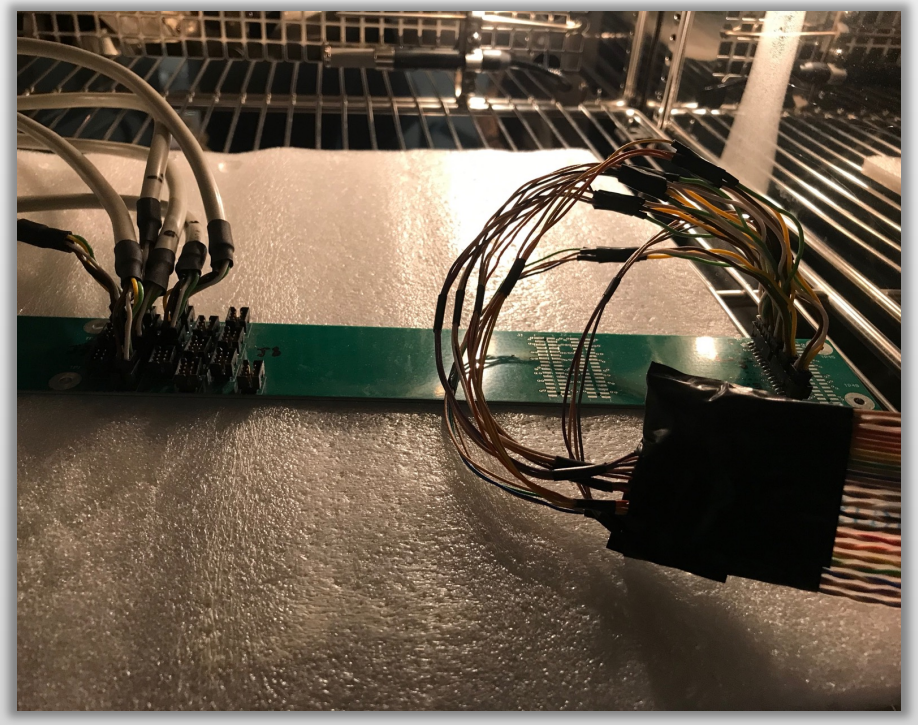
FEBs Low-Voltage supply in chain
High-Voltage power supply splitted for all 6 tiles



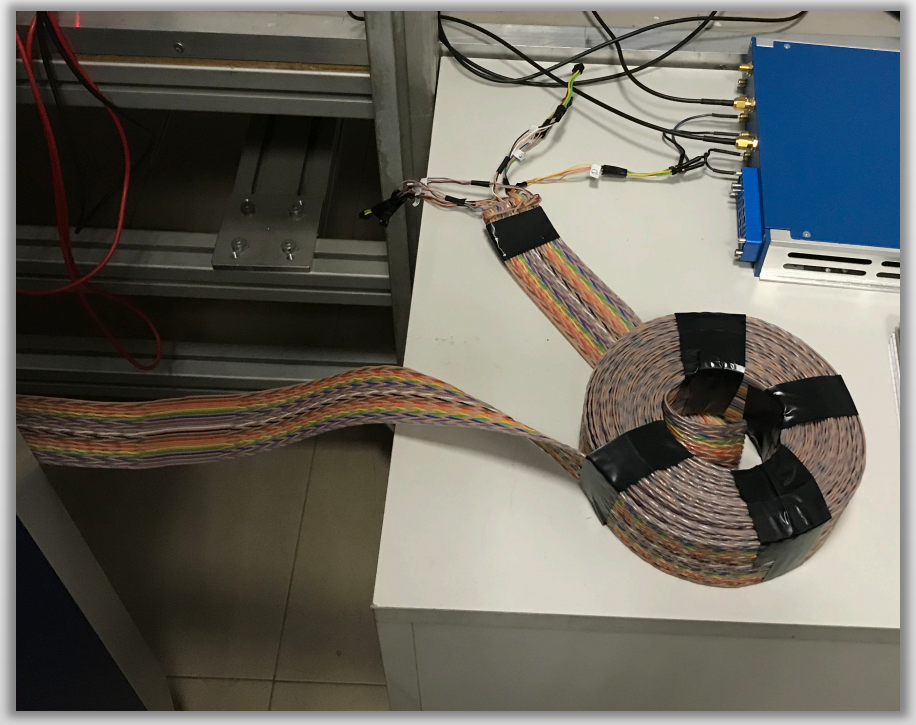
$I_{LV\text{-}BIAS}$ ~ 80mA x $\#_{FEB}$ @ -50°C

FEBs supply & connection

6x 3m output connectors with flange and 12-meter twisted differential pair cable



Inside climate chamber



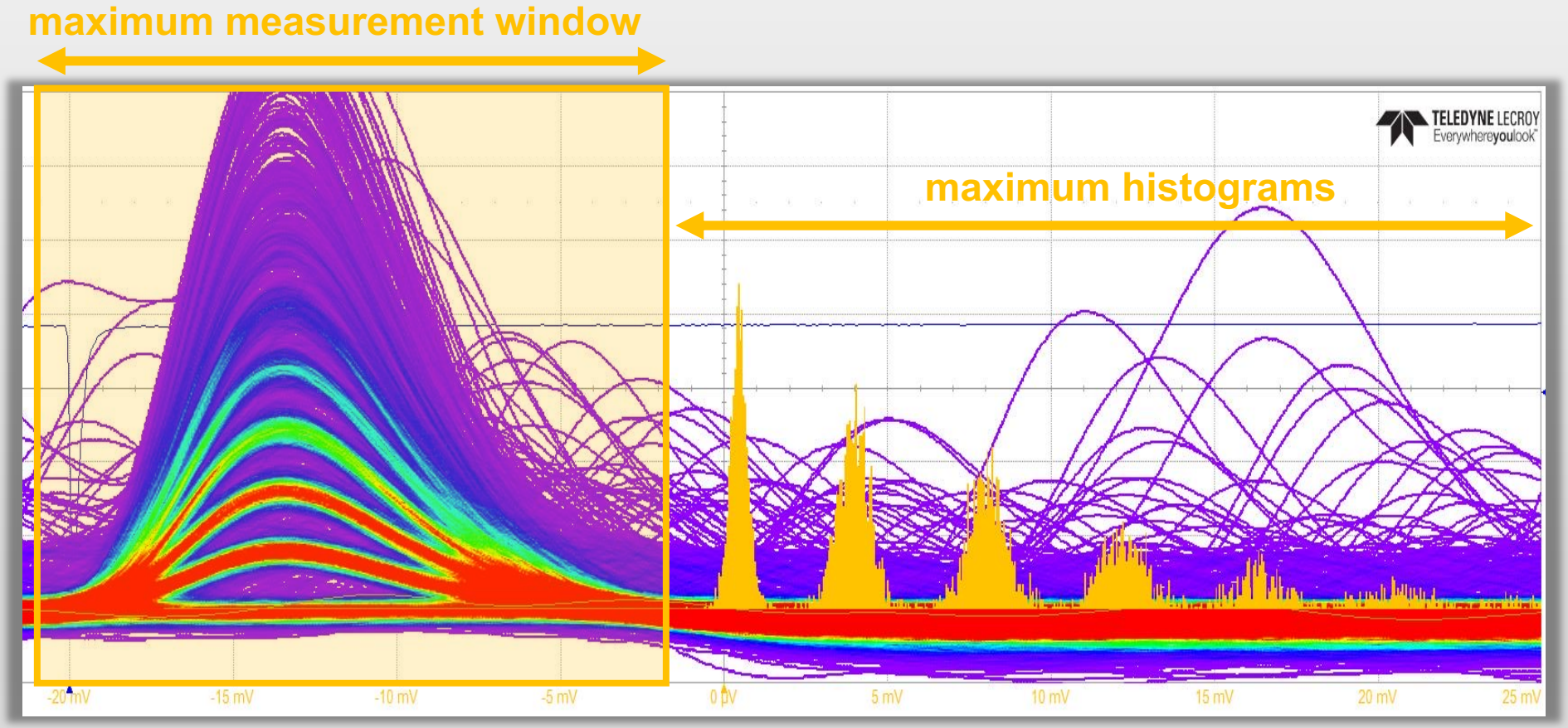
Outside climate chamber

Differential signals recombined by means of a transformer

(mismatched impedance: $50\Omega_{OUT}$ // $50\Omega_{IN}$ Oscilloscope DC-coupling)

CDR Figures of Merit

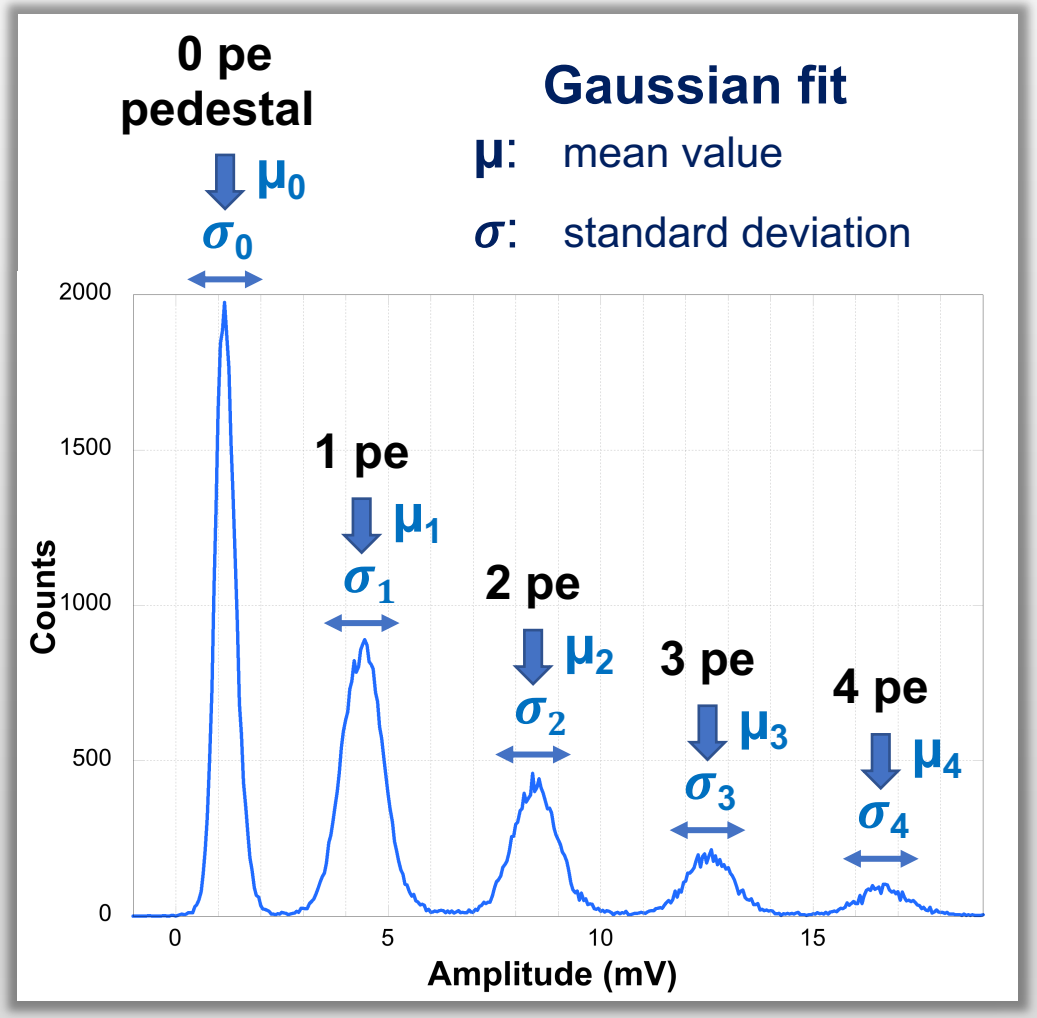
4 figures of merit with specific requirements, defined in the TAO CDR (May 17, 2020)



Typical acquired waveforms from the tile @ -50°C

Histogram related to the maximum of each acquisition in a defined time window

CDR Figures of Merit



Maximum Histogram

4 photoelectrons + pedestal (zero)

LASER / DARK

- **Signal-to-Noise Ratio**

$$SNR = \frac{\mu_1 - \mu_0}{\sigma_0} \geq 10$$

- **Single PhotoElectron Resolution**

$$\text{RES} = \frac{\sigma_1}{\mu_1} \times 100 \leq 15\%$$

DARK

- **Crosstalk**

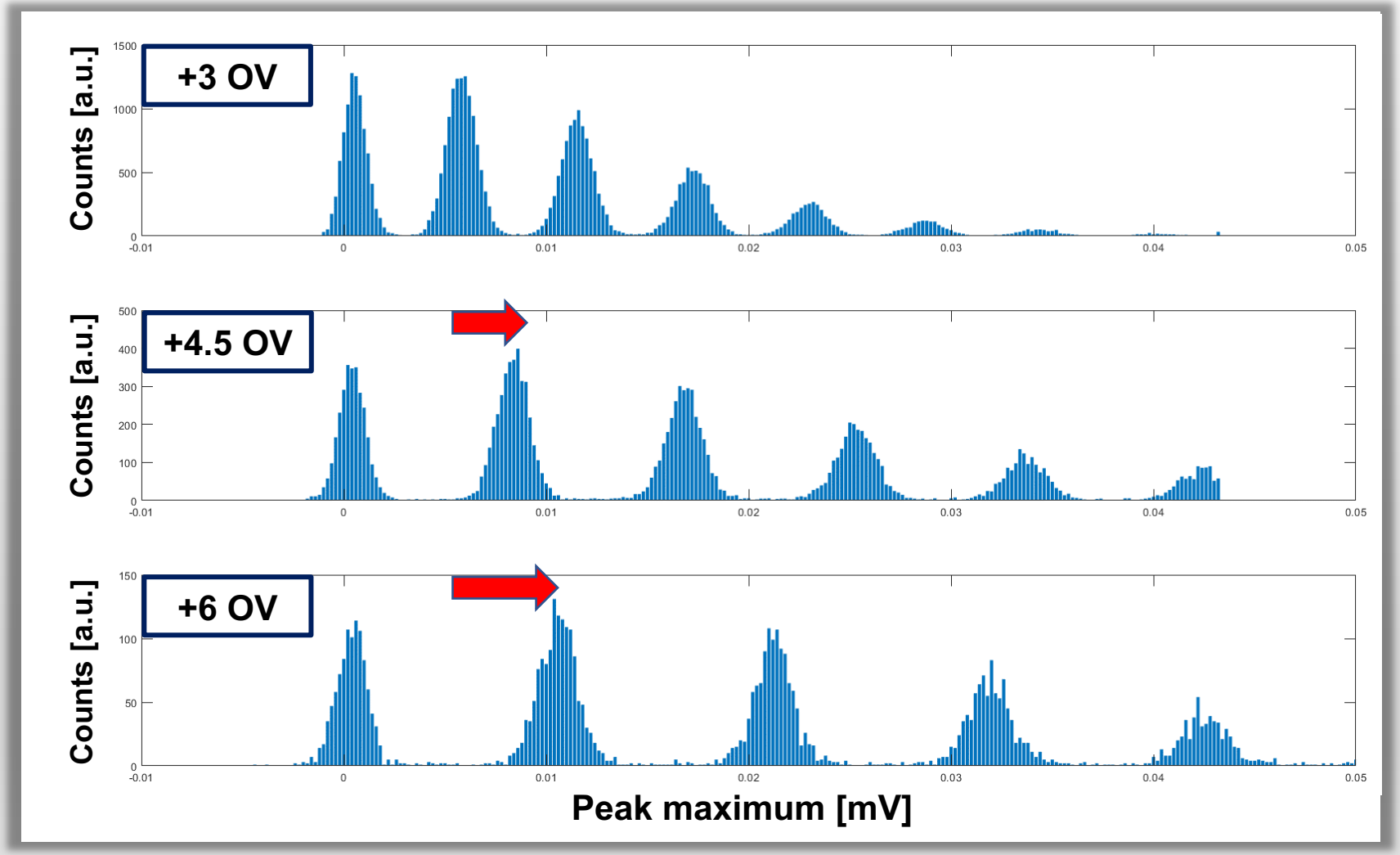
$$\text{XTLK} = \frac{N_{2+}}{N_1} \times 100 \leq 20\%$$

- **Dark Count Rate**

$$\text{DCR} = N_{1+} \leq 100 \quad [\text{Hz/mm}^2]$$

Tiles Characterization

Test result with different Over Voltages (V_{OP} = +3 OV)



✓ SNR, RES increasing

× XTLK, DCR increasing

Tiles Characterization

SiPM Hamamatsu Tile batch: S16088

HAMAMATSU

■ Structure

Parameters	Value	Unit
Number of channels	16 (4 × 4)	-
Effective photosensitive area	12.0(X) × 12.0(Y) (Connected 2 chips in parallel)	mm^2 /ch.
Coverage of photosensitive area	89.6	%
Pixel pitch	75	μm
Number of pixels / channel	25,564 (12,782 × 2 chips)	-
Window	Epoxy resin	-
Window refractive index	1.54	-
Package	Connector output (ERM8-020-09.0-S-DV-K-TR, SAMTEC)	-

Each tile delivered with its own calibration file, where V_{OP} of 16 SiPM are reported @ +25°C

SN.	Vop Variation[V]	Vop Average[V]
166	0.09	55.06
167	0.07	55.06
168	0.12	55.05
169	0.17	55.05
170	0.14	55.06
3	0.14	54.35

Temperature coefficient: +54 mV/°C

HV @ -50°C

V_{OP} – (0.054*75)

HV must be doubled, due to the series connection carried out by the FEB

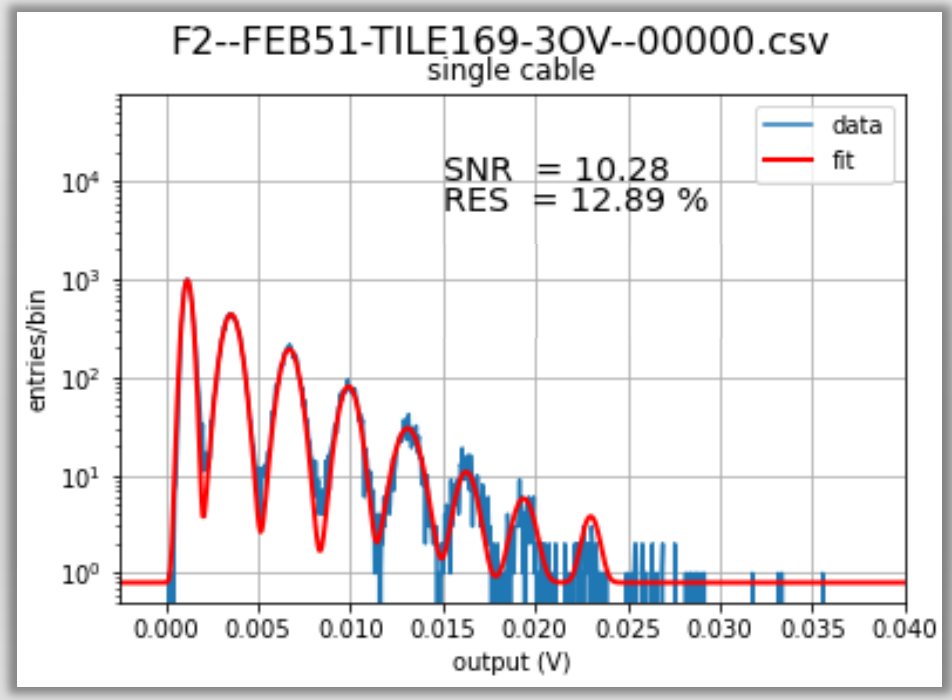
Tiles Characterization

Pre-production FEB (100 board) - LASER

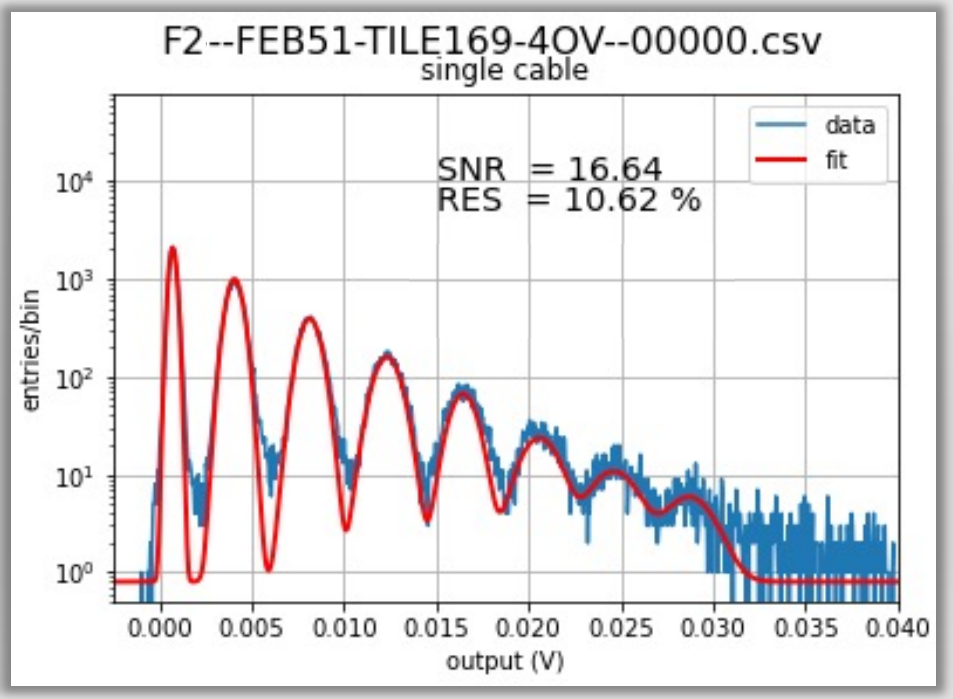
GAIN = 8.2k [V/A] * 1.95 [V/V] $R_{IN\ [TIA\text{-}OPAMP]}$ = 24.3 Ω

Gaussian fit over maximum histograms - LASER

+ 3V OV



+ 4V OV



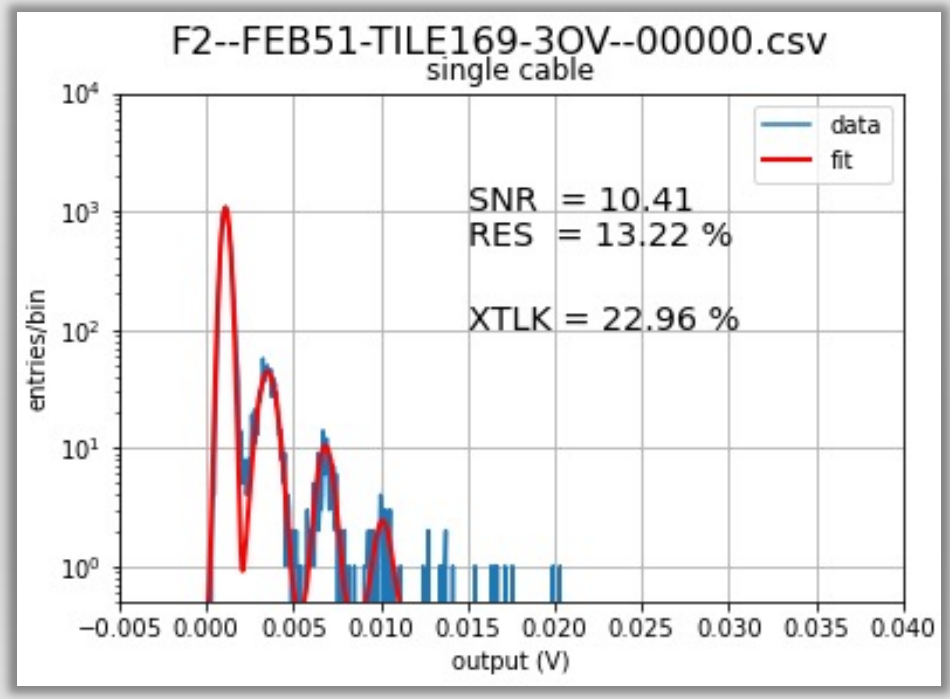
Tiles Characterization

Pre-production FEB (100 board) - DARK

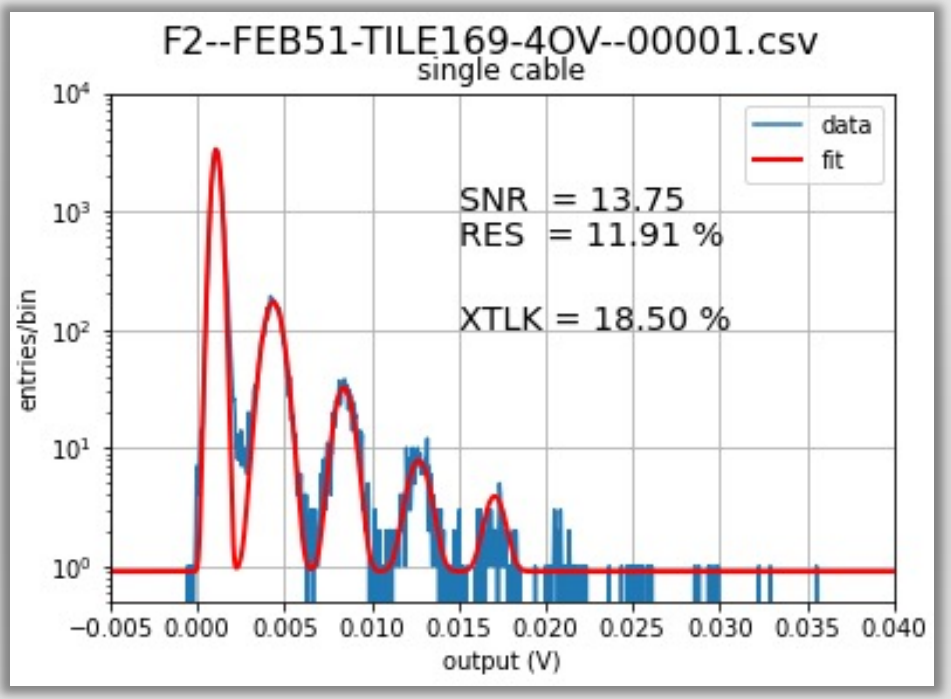
GAIN = 8.2k [V/A] * 1.95 [V/V] $R_{IN\ [TIA\text{-}OPAMP]}$ = 24.3 Ω

Gaussian fit over maximum histograms - Dark

+ 3V OV



+ 4V OV



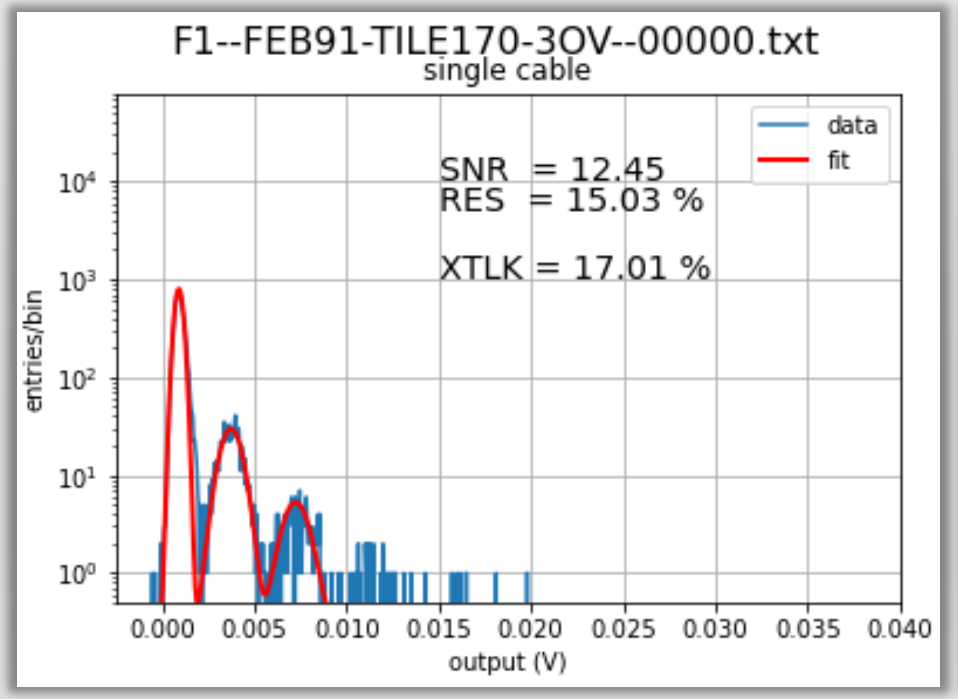
Tiles Characterization

1° modified FEB - DARK

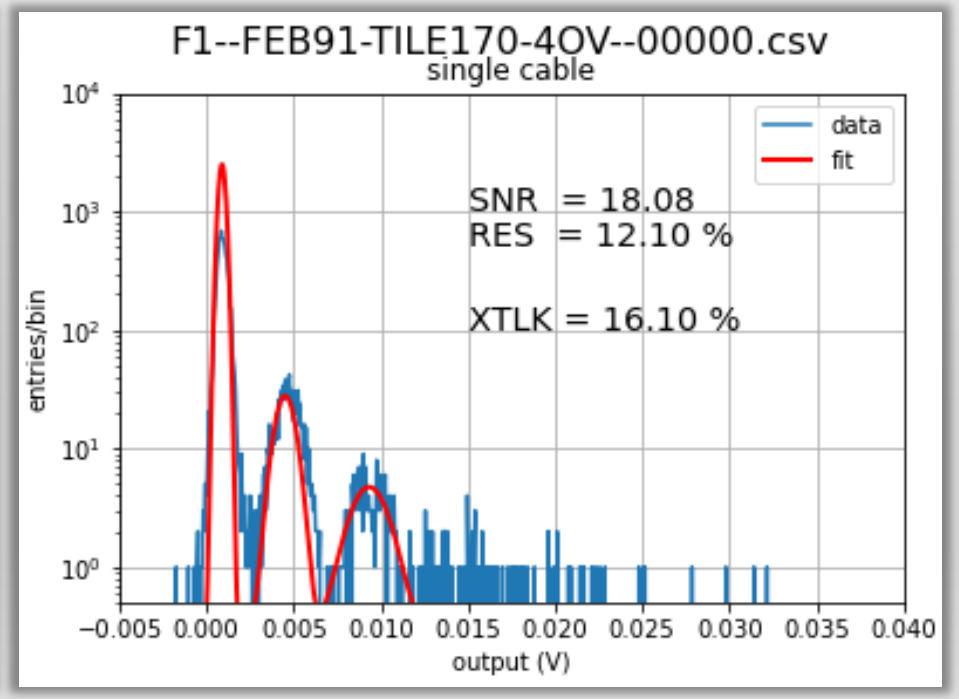
GAIN = 10k [V/A] * 1.95 [V/V] $R_{IN\ [TIA\text{-}OPAMP]}$ = 24.3 Ω

Gaussian fit over maximum histograms - Dark

+ 3V OV



+ 4V OV



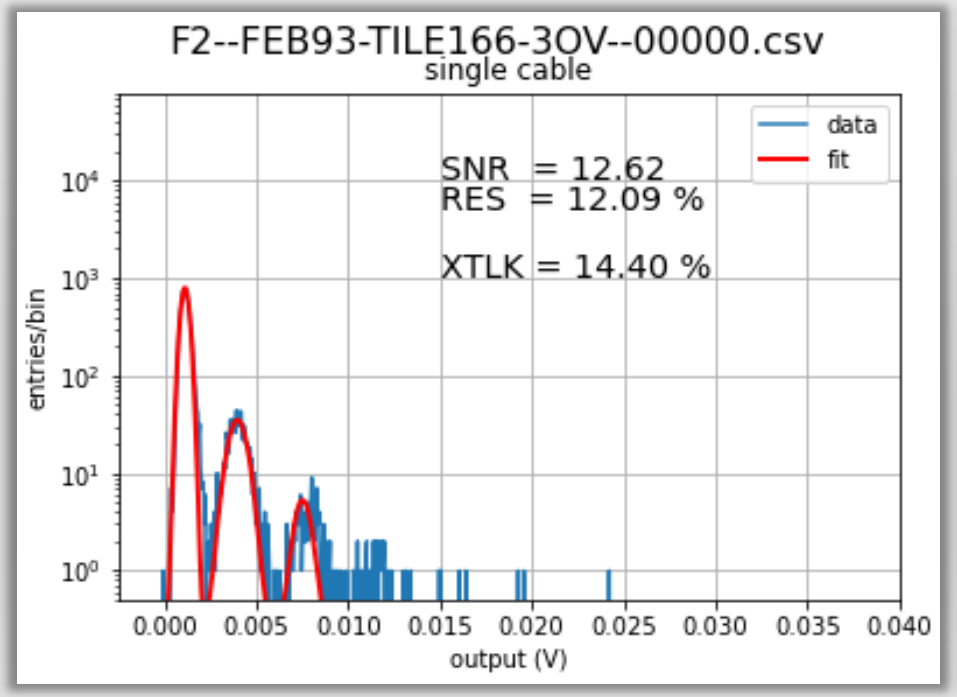
Tiles Characterization

2° modified FEB - DARK

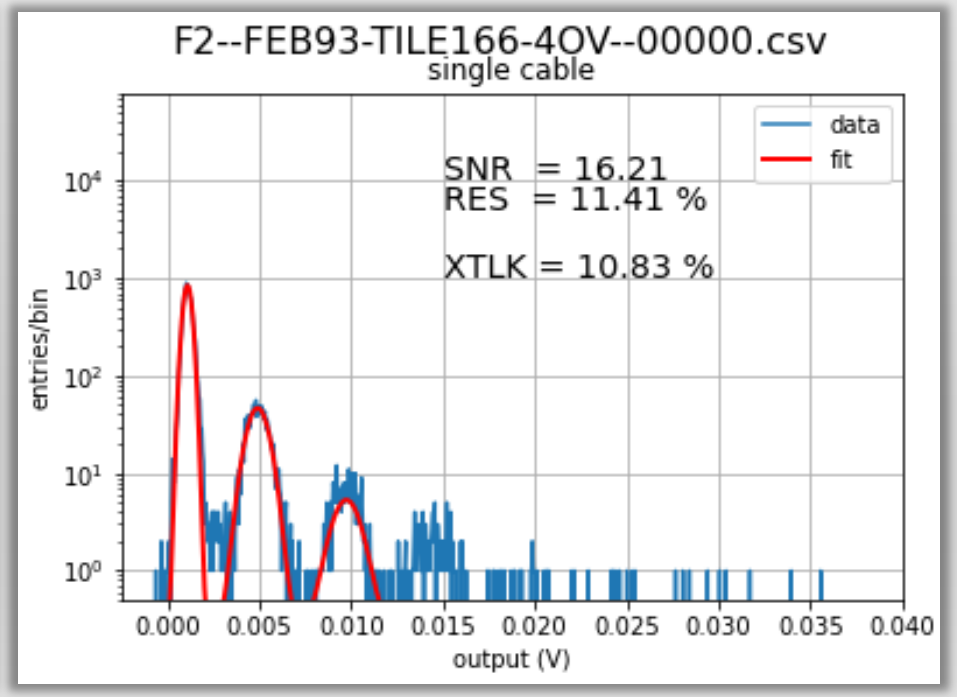
GAIN = 8.2k [V/A] * 1.95 [V/V] $R_{IN\ [TIA\text{-}OPAMP]}$ = 16 Ω

Gaussian fit over maximum histograms - Dark

+ 3V OV



+ 4V OV



Tiles Characterization

Dark Count Rate

Typ. 2000 / Max. 6000 (Typ. 13.9 / Max. 41.7)	cps/ch. (cps/mm²)

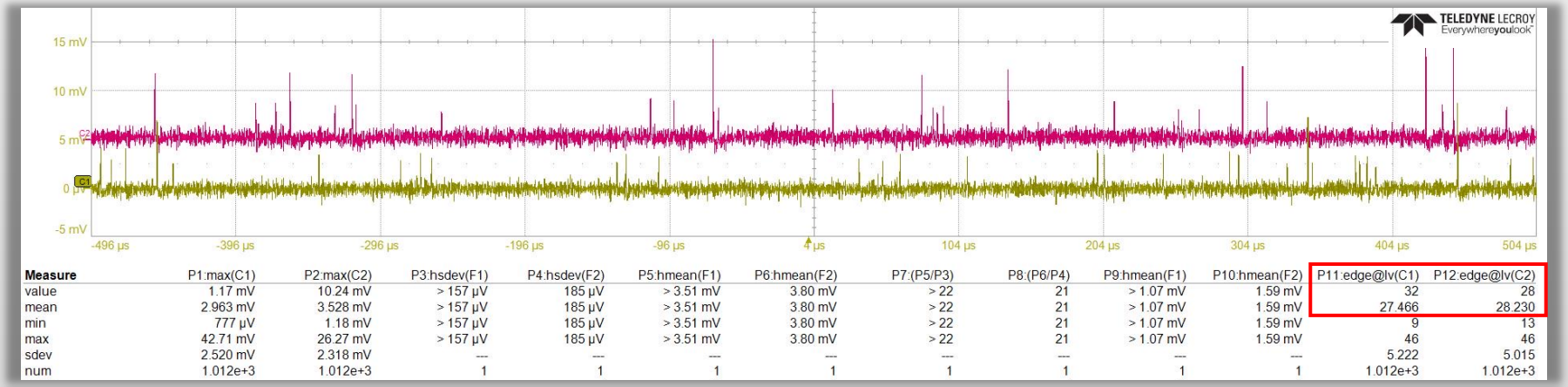
Count of events above a voltage threshold (halfway 0 and 1 pe) in 1 ms (averaged over 1k events, to simulate 1 second), normalized with overall area in a channel (12x12 mm² x8)

$$\mathbf{DCR} = (\overline{N_{1+}} * 1000)/1152 \quad [\text{Hz/mm}^2]$$

➡ ~25 [Hz/mm²] @ +3 OV

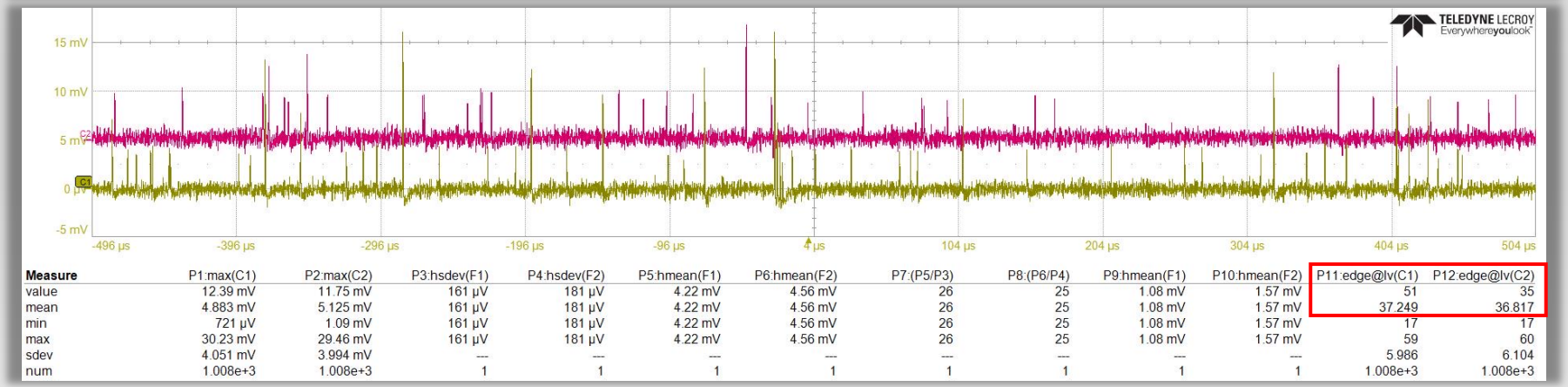
➡ ~32 [Hz/mm²] @ +4 OV

+ 3V OV



Measure	P1:max(C1)	P2:max(C2)	P3:hsdev(F1)	P4:hsdev(F2)	P5:hmean(F1)	P6:hmean(F2)	P7:(P5/P3)	P8:(P6/P4)	P9:hmean(F1)	P10:hmean(F2)	P11:edge@lv(C1)	P12:edge@lv(C2)
value	1.17 mV	10.24 mV	> 157 µV	185 µV	> 3.51 mV	3.80 mV	> 22	21	> 1.07 mV	1.59 mV	32	28
mean	2.963 mV	3.528 mV	> 157 µV	185 µV	> 3.51 mV	3.80 mV	> 22	21	> 1.07 mV	1.59 mV	27.466	28.230
min	777 µV	1.18 mV	> 157 µV	185 µV	> 3.51 mV	3.80 mV	> 22	21	> 1.07 mV	1.59 mV	9	13
max	42.71 mV	26.27 mV	> 157 µV	185 µV	> 3.51 mV	3.80 mV	> 22	21	> 1.07 mV	1.59 mV	46	46
sdev	2.520 mV	2.318 mV	---	---	---	---	---	---	---	---	5.222	5.015
num	1.012e+3	1.012e+3	1	1	1	1	1	1	1	1	1.012e+3	1.012e+3

+ 4V OV



Measure	P1:max(C1)	P2:max(C2)	P3:hsdev(F1)	P4:hsdev(F2)	P5:hmean(F1)	P6:hmean(F2)	P7:(P5/P3)	P8:(P6/P4)	P9:hmean(F1)	P10:hmean(F2)	P11:edge@lv(C1)	P12:edge@lv(C2)
value	12.39 mV	11.75 mV	161 µV	181 µV	4.22 mV	4.56 mV	26	25	1.08 mV	1.57 mV	51	35
mean	4.883 mV	5.125 mV	161 µV	181 µV	4.22 mV	4.56 mV	26	25	1.08 mV	1.57 mV	37.249	36.817
min	721 µV	1.09 mV	161 µV	181 µV	4.22 mV	4.56 mV	26	25	1.08 mV	1.57 mV	17	17
max	30.23 mV	29.46 mV	161 µV	181 µV	4.22 mV	4.56 mV	26	25	1.08 mV	1.57 mV	59	60
sdev	4.051 mV	3.994 mV	---	---	---	---	---	---	---	---	5.986	6.104
num	1.008e+3	1.008e+3	1	1	1	1	1	1	1	1	1.008e+3	1.008e+3

Conclusion

- **Characterization summary (DARK @ -50°C)**

FEB (OV)	SNR (>10)	RES (<15)	XTLK (<20)
8.2kTIA (+3 OV)	11.173 ± 0.66	15.053 ± 1.83	14.08 ± 7.69
8.2kTIA (+4 OV)	15.755 ± 1.21	12.978 ± 1.34	14.378 ± 3.28
10kTIA (+3 OV)	12.45	15.03	17.1
10kTIA (+4 OV)	18.08	12.1	16.1
16Ωin (+3 OV)	12.62	12.09	14.4
16Ωin (+4 OV)	16.21	11.41	10.83

DCR is about the same for all the FEBs and tiles, it changes with overvoltage:

~25 [Hz/mm^2] @ +3 OV ~32 [Hz/mm^2] @ +4 OV [<100]

- **Next steps:**
  - check results with other FEBs
  - check for the best configuration
  - 50 FEBs delivered to IHEP

Thank you for your attention