

Sensor: 104857, Date: 15/07/2023  
IV-Characterisation: 104857\_HPK

## LCD-HGCAL Sensor Testing

October 24, 2023

- Measurement: 104857\_HPK
- **Date: 15/07/2023**
- **Test station: HPK**
- Chuck temperature: 25.0 degrees Celsius
- **Sensor: 104857**
- Size: 8 inches
- $N_{\text{cells}}$ : 199
- Doping: p-type, p-stop: comm.
- active thickness: 300  $\mu\text{m}$
- Irradiation: 0 neq/cm<sup>2</sup>

## Location of intermediate files

- (raw) measurement file:

/ eos/ user/ h/ hgsensor/ HGCAL\_test\_results/ Results/ Hamamatsu/ HPK\_Upload/ Full/ S15591-01/ 2309/ OBA49339/ IV/ 8-198-300F-L6-P5295-01-104857-0-IV.txt

- formatted file:

/ home/ data/ hgsensor\_iv/ Hamamatsu\_Preproduction\_OBA49339/ formatted/ 104857\_HPK.txt

- voltage-corrected file:

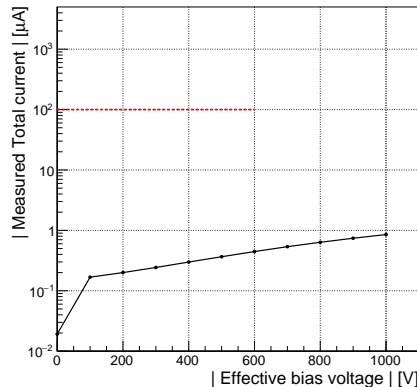
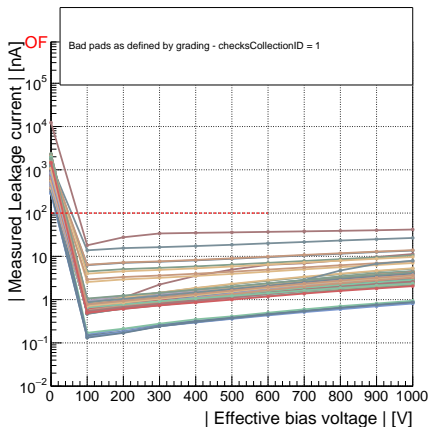
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- temperature-scaled file:

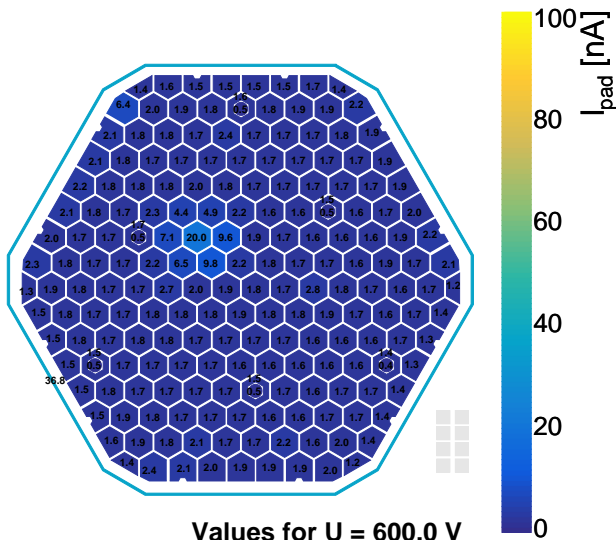
/ home/ data/ hgsensor\_iv/ Hamamatsu\_Preproduction\_OBA49339/ temperature\_scaled/ 104857\_HPK.txt

# All-cells IV

- Left: IV curves for all channels. Shown in the legend are only the curves for pads defined as bad by the grading performed with the indicated checksCollectionID.
- Right: Total current measured as the mean of the last 50 channels (if available - otherwise all). Absolute values are used both for voltages and currents.



# Hexplots, interpolated bias voltage of 600 V



# IV Grading of the sensor

## Info:

- Last measured voltage point: 1000.0 V;
- Expected depletion voltage for sensors of thickness 300  $\mu\text{m}$ : 250 V;  $250 \times 1.5 = 375.0$  V.
- IV scan performed well above 1.5 times the expected depletion voltage.

## Grading:

- Sensor has been graded with checksCollectionID 1.
- Global characteristics:
  - Current at 600V I600 (normalised to 20 deg Celsius):  $\leq 100$   $\mu\text{A}$  integrated over the sensor and guard rings: **Passed**
  - $I800 < 2.5 \times I600$ : **Passed**
  - Number of bad pads  $0 \leq 8$  for full-sized sensors: **Passed**
  - Allowed number of adjacent bad pads  $\leq 2$ : **Passed**
- Per-pad characteristics used to define bad pads if any of the following are met:
  - Current at 600V I600 (normalised to 20 deg Celsius)  $> 100$  nA/pad: **0** pads, namely []
  - $I600 > 10$  nA and  $I800 > 2.5 \times I600$ : **0** pads, namely []
  - $I600 \leq 10$  nA and  $I800 > 25$  nA: **0** pads, namely []

Sensor has **PASSED** the requirements.

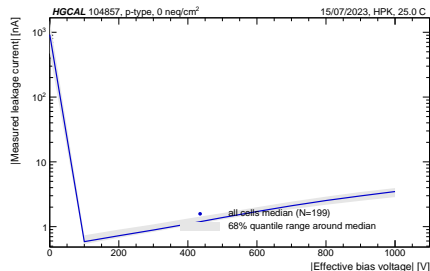
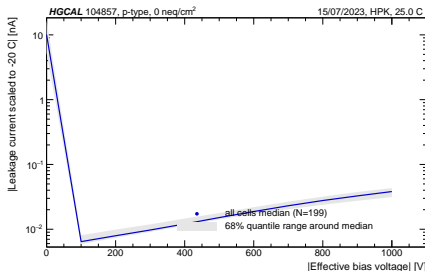
**WARNING:** The following pads were masked at least once before or at 600V: [].

# Median IV vs. Voltage

- All cells, independent of cell geometry, enter the median and inter-quantile range computation.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^{\circ}\text{C}$ , as stated in Equation 1.

$$I_{-20} = I_T \cdot \left( \frac{T_{-20}}{T} \right)^2 \cdot \exp \left( \frac{E_g}{2 \cdot k_b} \cdot \left( \frac{1}{T} - \frac{1}{T_{-20}} \right) \right) \quad (1)$$

- Right: Cell leakage current at  $25.0^{\circ}$  as measured, i.e. without temperature scaling.

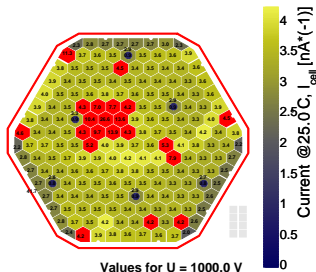
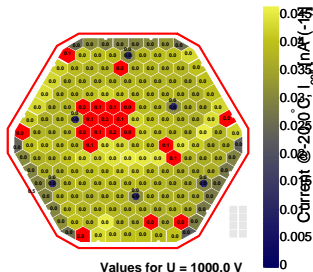
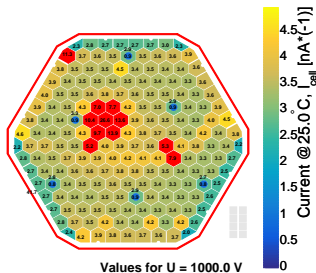
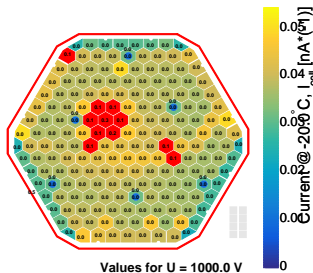


# Leakage current Hexplots

## Description of the following figures:

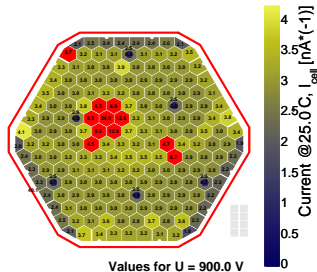
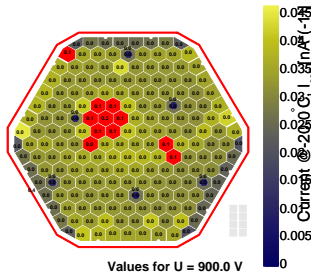
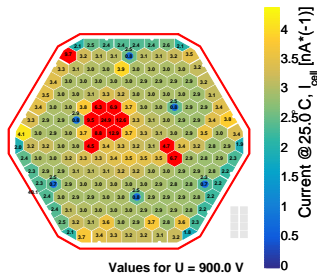
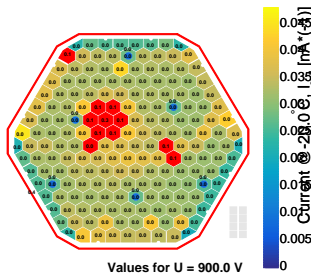
- The maximum of the color scale is defined to be the median of all cells connected to the sensor plus  $1.5 \times$  the 50-84% inter-quantile range.
- Top-left: Currents are normalised to a reference temperature  $T_{-20} = -20^{\circ} \text{C}$ , as stated in Equation 1.
- Top-right: Cell leakage current at  $25.0^{\circ}$  as measured, i.e. without temperature scaling.
- Bottom-left: Currents are normalised to a reference temperature  $T_{-20} = -20^{\circ} \text{C}$ , as stated in Equation 1 with colour scale according to the highest bias voltage (absolute value).
- Bottom-right: Cell leakage current at  $25.0^{\circ}$  as measured, i.e. without temperature scaling with colour scale according to the highest bias voltage (absolute value).

# Hexplots, nominal bias voltage of 1000.0 V

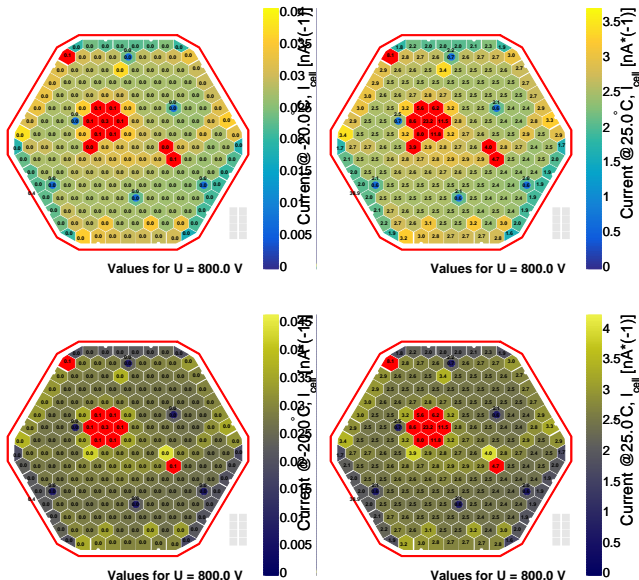




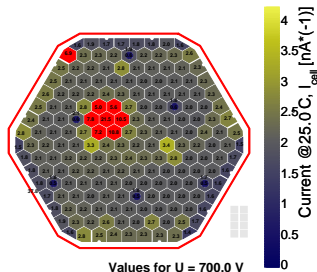
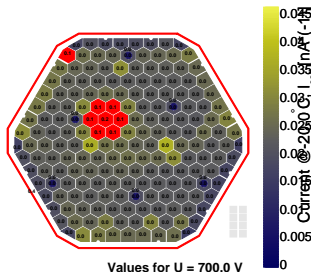
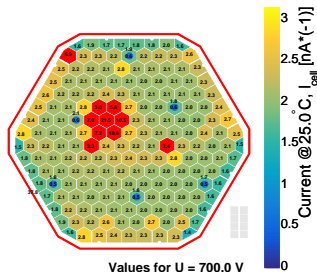
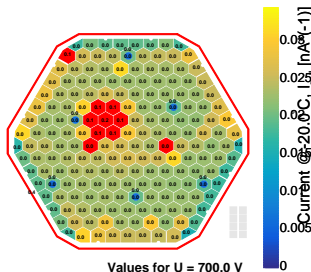
# Hexplots, nominal bias voltage of 900.0 V



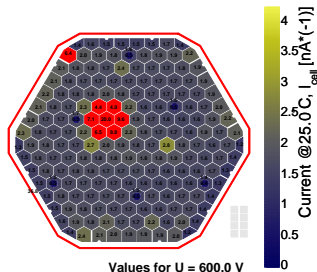
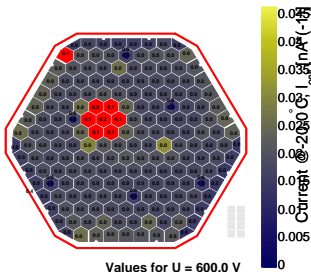
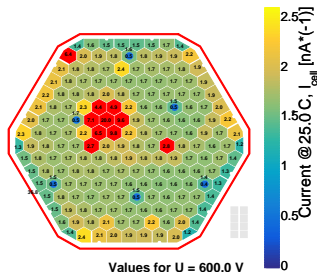
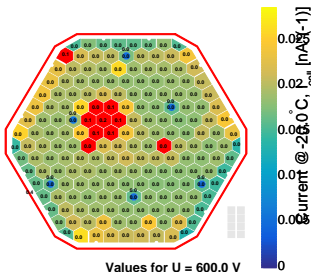
# Hexplots, nominal bias voltage of 800.0 V



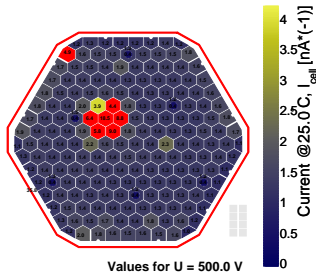
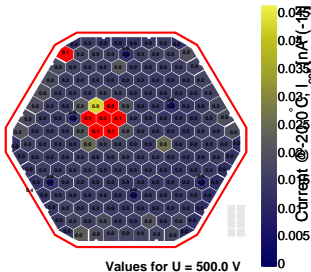
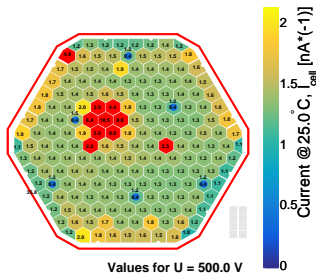
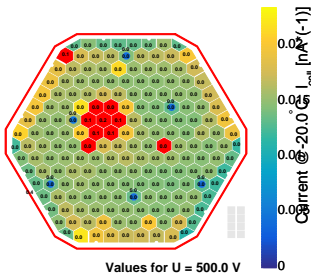
# Hexplots, nominal bias voltage of 700.0 V



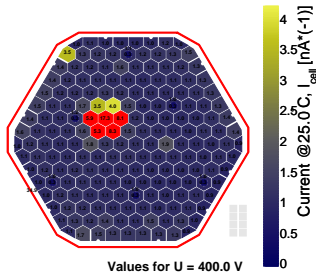
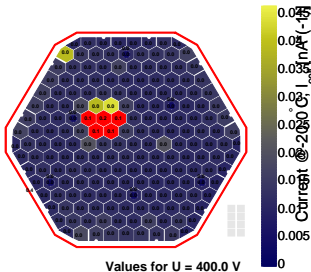
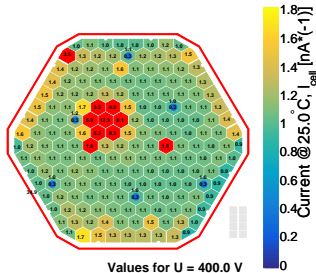
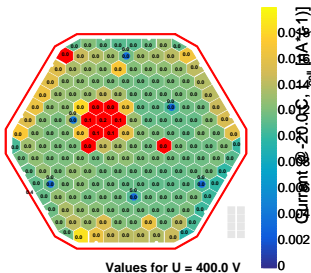
# Hexplots, nominal bias voltage of 600.0 V



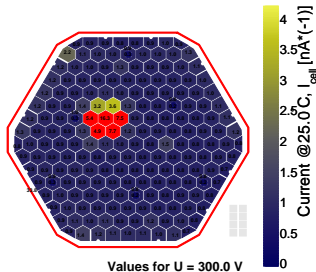
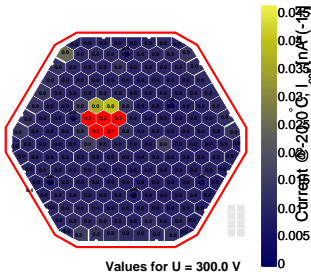
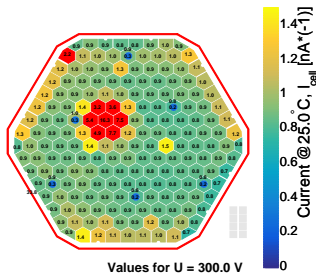
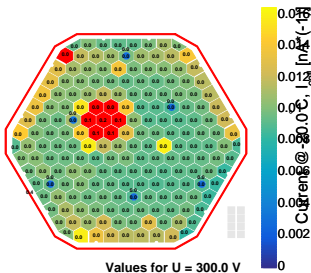
# Hexplots, nominal bias voltage of 500.0 V



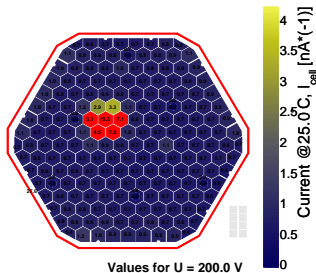
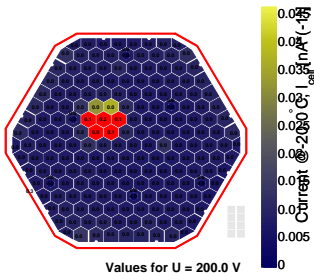
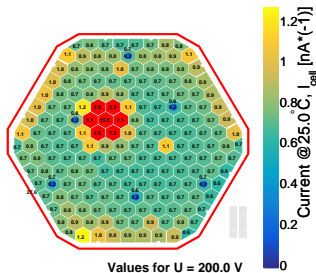
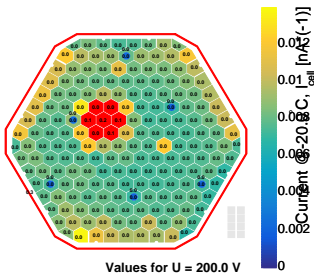
# Hexplots, nominal bias voltage of 400.0 V



# Hexplots, nominal bias voltage of 300.0 V

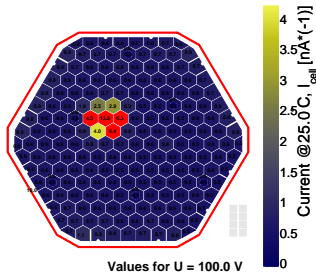
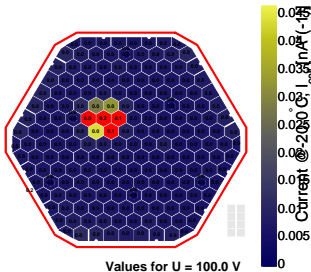
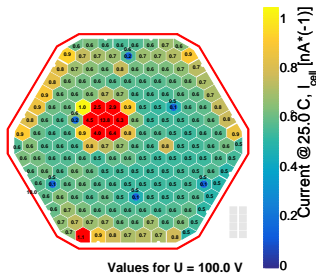
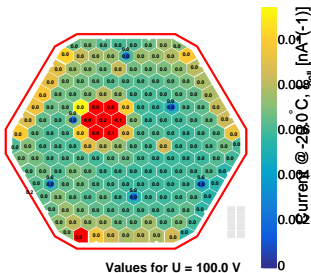


# Hexplots, nominal bias voltage of 200.0 V

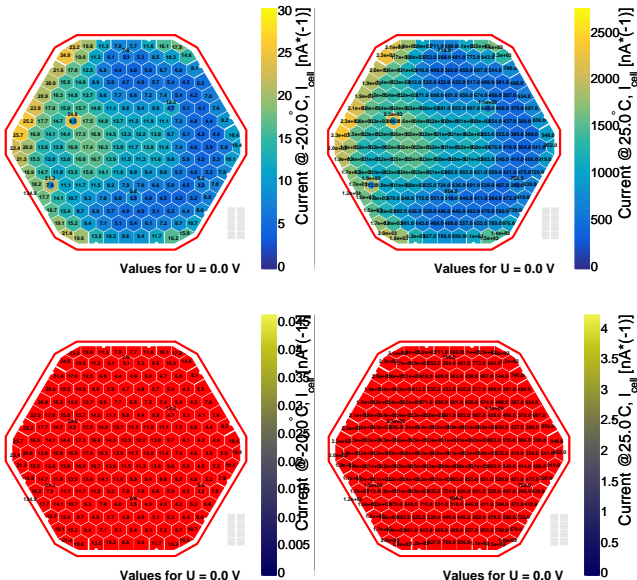




# Hexplots, nominal bias voltage of 100.0 V

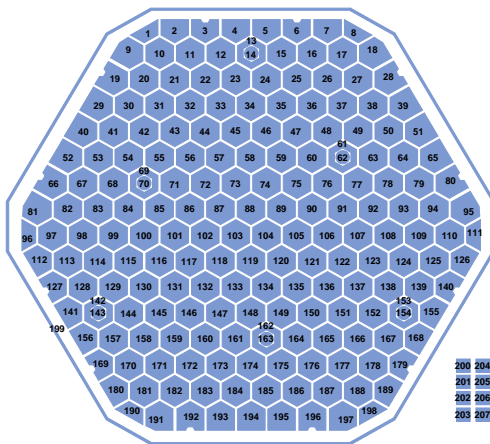


# Hexplots, nominal bias voltage of 0.0 V



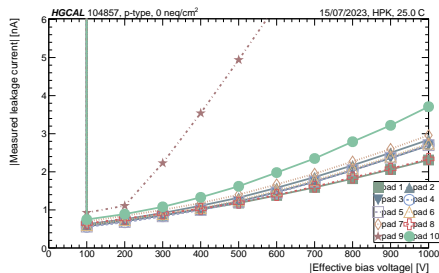
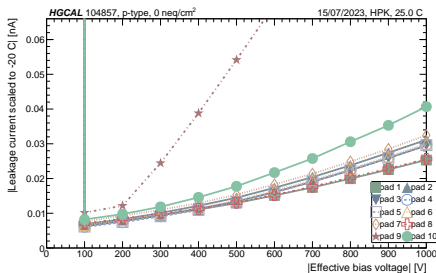
# Channel mapping

- Illustration of the channel pad numbers for the subsequent figures.



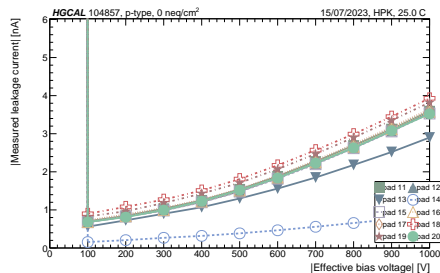
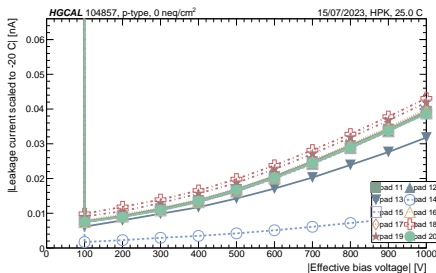
# Per-cell IV curves, pads 1-10

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



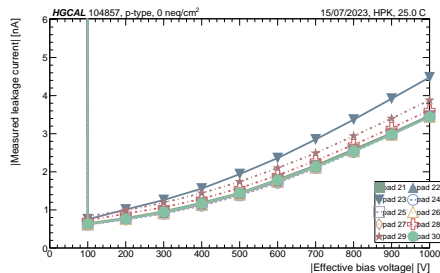
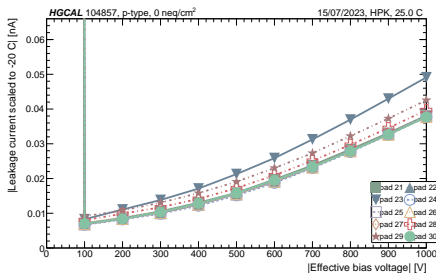
# Per-cell IV curves, pads 11-20

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



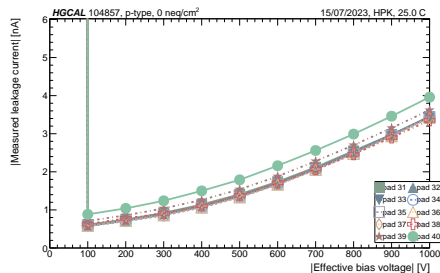
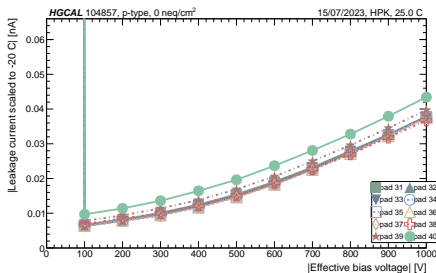
# Per-cell IV curves, pads 21-30

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



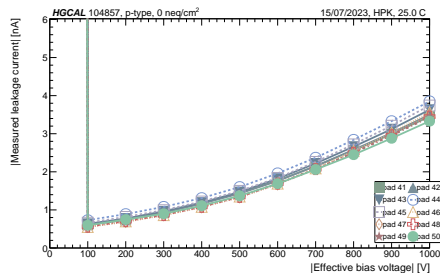
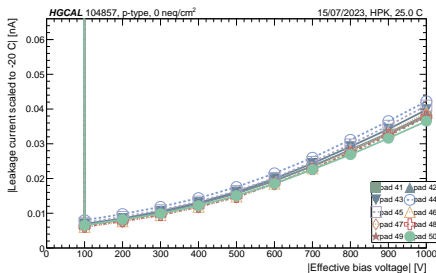
# Per-cell IV curves, pads 31-40

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



# Per-cell IV curves, pads 41-50

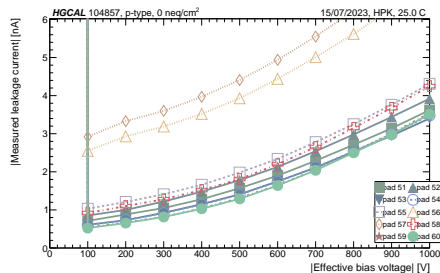
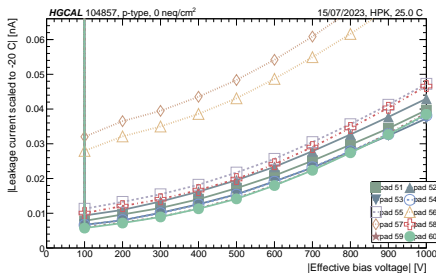
- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.





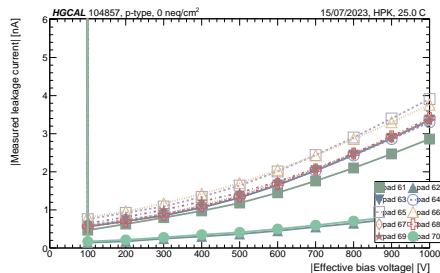
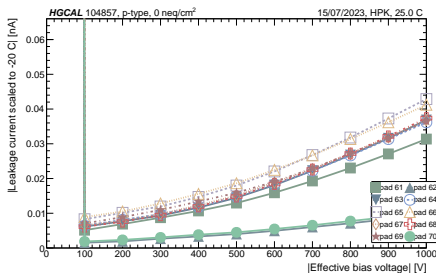
# Per-cell IV curves, pads 51-60

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



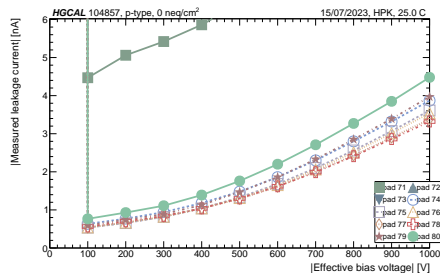
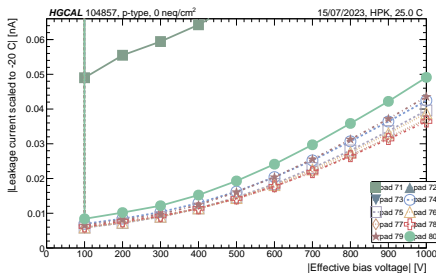
# Per-cell IV curves, pads 61-70

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



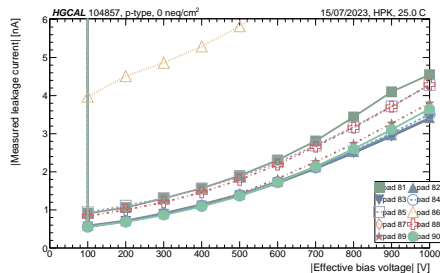
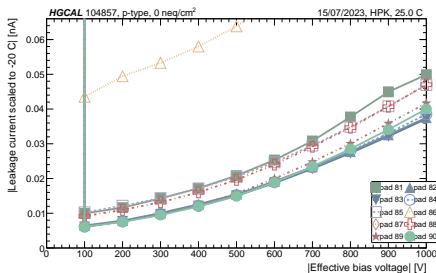
# Per-cell IV curves, pads 71-80

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



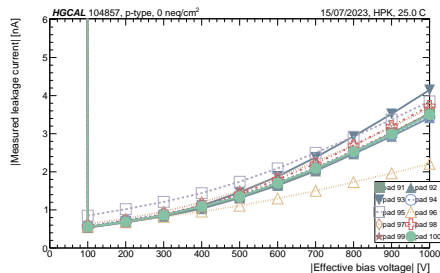
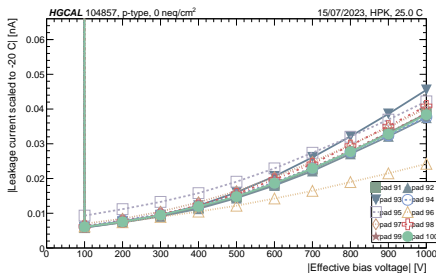
# Per-cell IV curves, pads 81-90

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



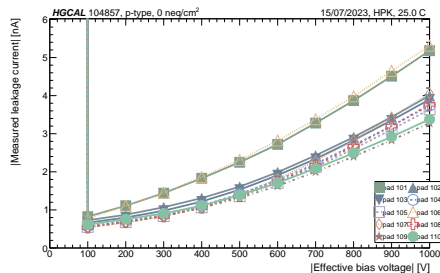
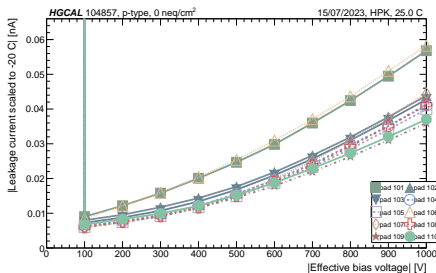
# Per-cell IV curves, pads 91-100

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5\times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^{\circ}\text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^{\circ}$  as measured, i.e. without temperature scaling.



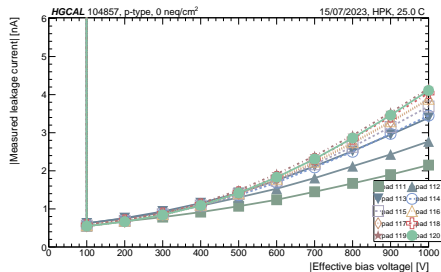
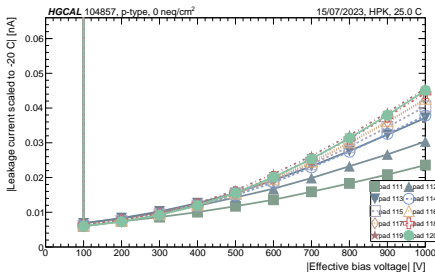
# Per-cell IV curves, pads 101-110

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5\times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ\text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



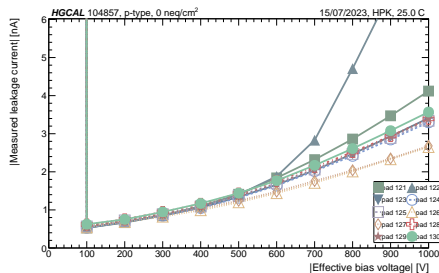
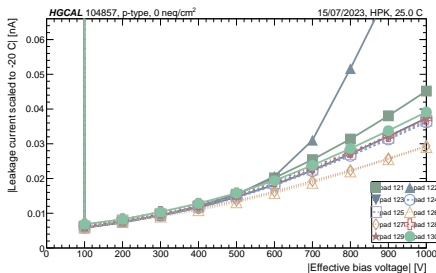
# Per-cell IV curves, pads 111-120

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



# Per-cell IV curves, pads 121-130

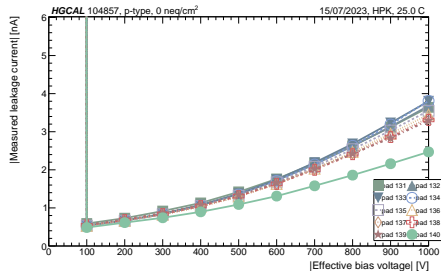
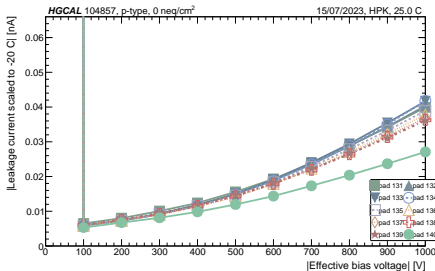
- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.





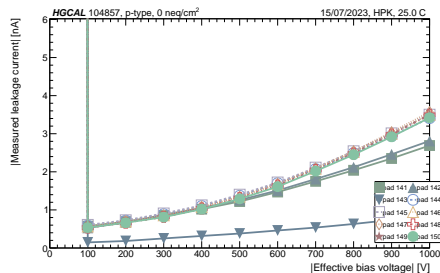
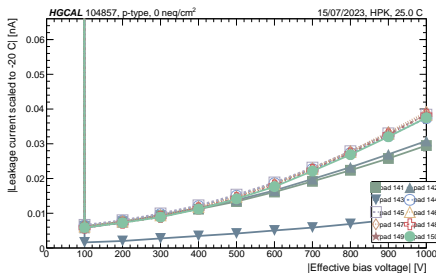
# Per-cell IV curves, pads 131-140

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



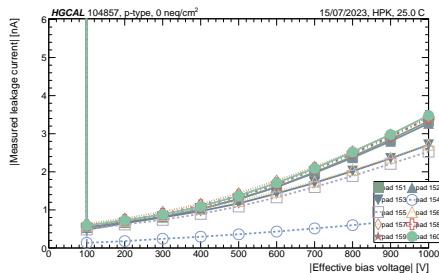
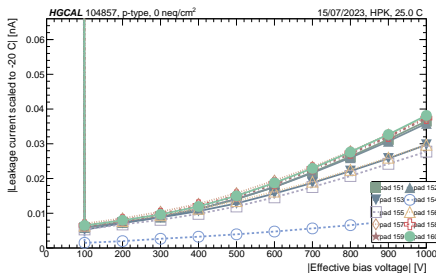
# Per-cell IV curves, pads 141-150

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



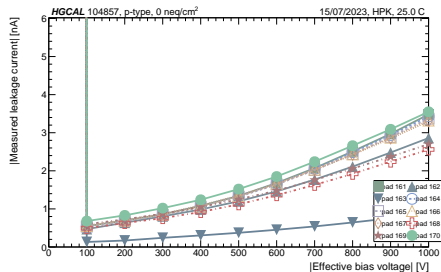
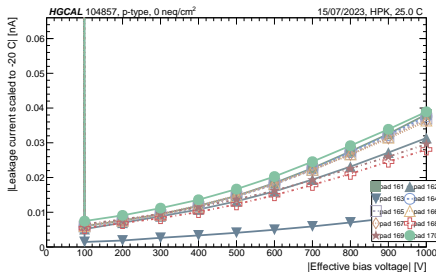
# Per-cell IV curves, pads 151-160

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



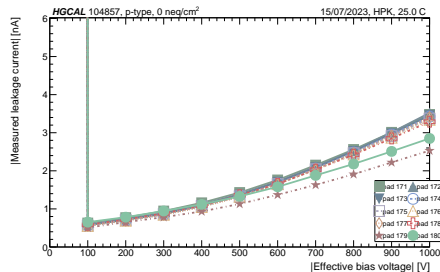
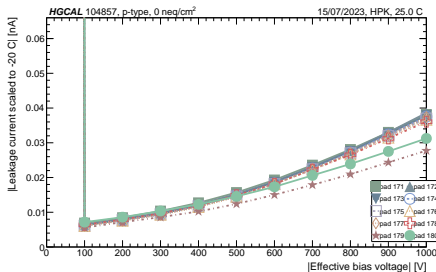
# Per-cell IV curves, pads 161-170

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



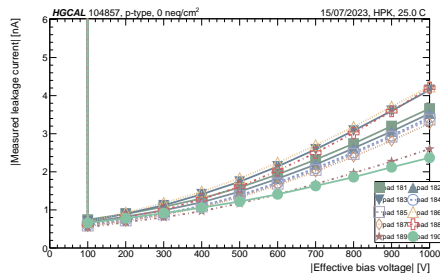
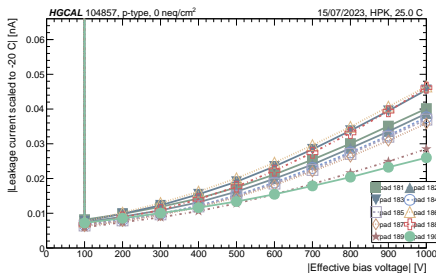
# Per-cell IV curves, pads 171-180

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



# Per-cell IV curves, pads 181-190

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.



# Per-cell IV curves, pads 191-199

- The maximum of the y-scale is defined to be the median of all cells plus  $1.5 \times$  the 68% central inter-quantile range.
- Left: Currents are normalised to a reference temperature  $T_{-20} = -20^\circ \text{C}$ , as stated in Equation 1.
- Right: Cell leakage current at  $25.0^\circ$  as measured, i.e. without temperature scaling.

