

Characterizations after γ irradiation at GIF++

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Recap

In our study, we characterized five SiPM boards before and after being irradiated with γ rays, emitted by a ^{137}Cs source (primarily with an energy of 662 keV). Each board was irradiated with a different dose, as shown in the following table

Board #	Rads	Distance	Side
5	10	1,94 m	Right
6	100	0,45 m	Right
8	100	0,45 m	Right
9	100	0,45 m	Right
10	1000	0,45 m	Left

Recap

Throughout this whole work, we will refer to the sensors calling them “**New**”, “**Pre Gamma Irradiation**”, and “**Post Gamma Irradiation**”.

This nomenclature was issued to represent the different stage in the life of our boards, in which the measure was taken (each of them at -20° C).

To be clear:

- Our boards were characterized right after we received them, brand new, and so the set of measures is marked as “**New**”
- Then, the boards underwent a proton irradiation at the TIFPA facility in Trento (each board took a different dose as stated in the next table), and followed a cycle of annealing, thus the measure are marked as “**Pre G.I.**”
- Lastly, our boards were irradiated by a γ -ray beam at the GIF++ facility, and then annealed again, so this set of measures is called “**Post G.I.**”

Recap

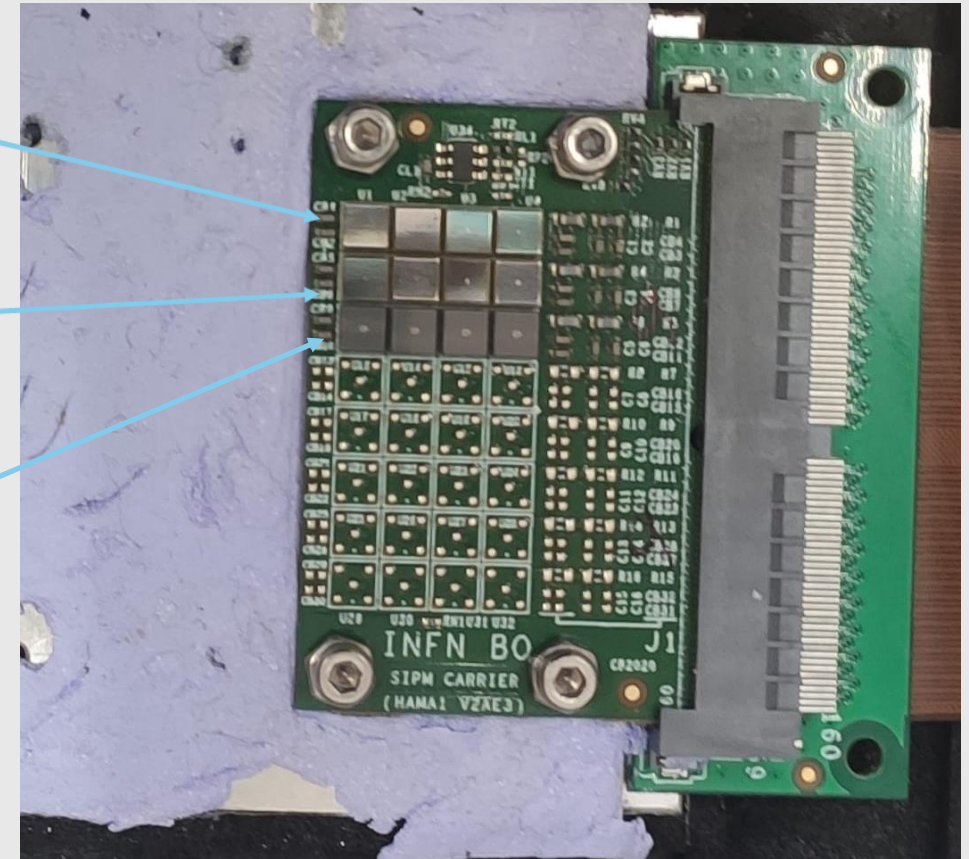
Proton energy used at the TIFPA facility for the proton irradiation and respective K factor

Board #	Proton energy	K factor
5	145 MeV	1.11
6	75 MeV	1.5
8	45 MeV	2.0
9	25 MeV	2.5
10	18 MeV	3.0

Recap

The analyzed boards contained 3 rows of SiPMs, each one composed of 4 sensors of the same kind:

- **Type A:** Hamamatsu S13360-3050
 - Pixel pitch: 50 μm
 - Photosensitive area: 3 mm x 3 mm
 - Fill factor: 74%
- **Type B:** Hamamatsu S13360-3075
 - Pixel pitch: 75 μm
 - Photosensitive area: 3 mm x 3 mm
 - Fill factor: 82%
- **Type C:** Hamamatsu S14160-3050
 - Pixel pitch: 50 μm
 - Photosensitive area: 3 mm x 3 mm
 - Fill factor: 74%

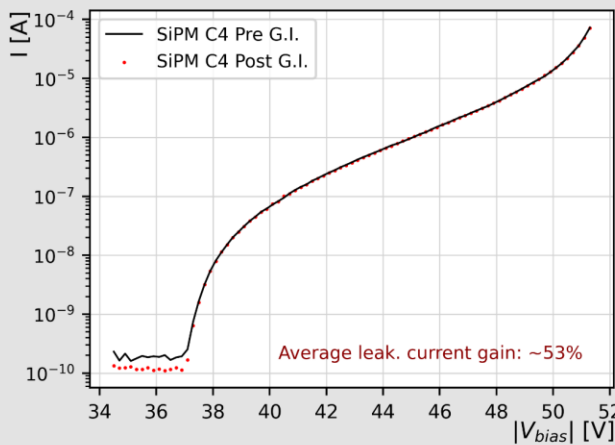
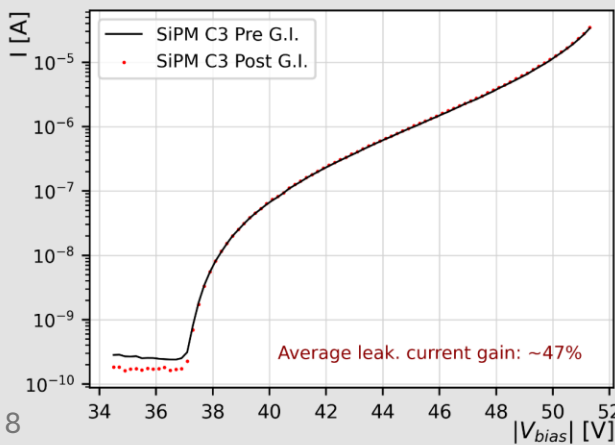
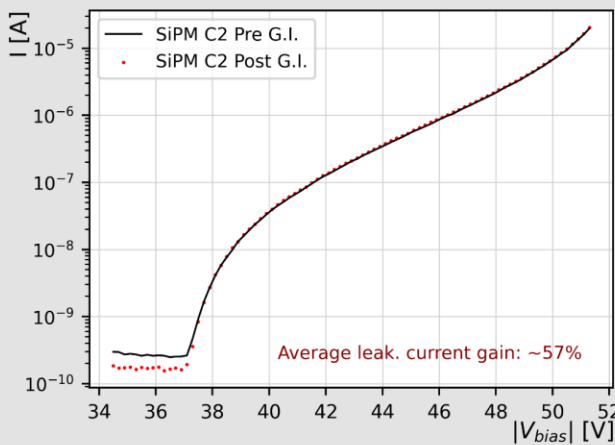
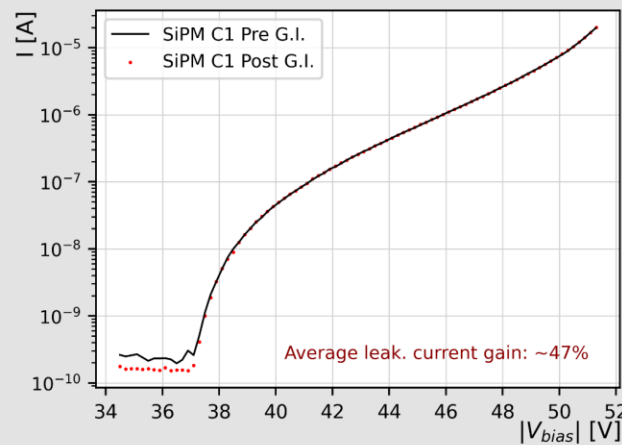
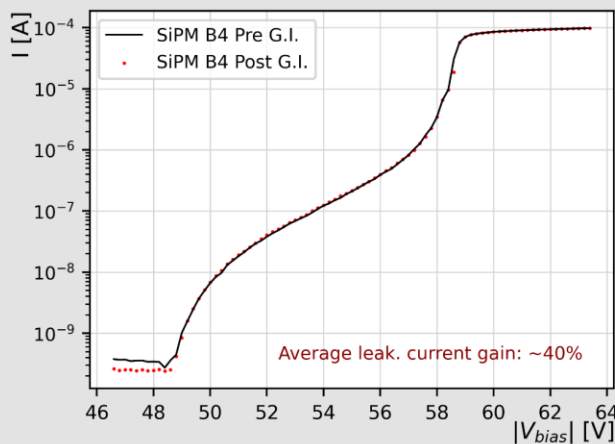
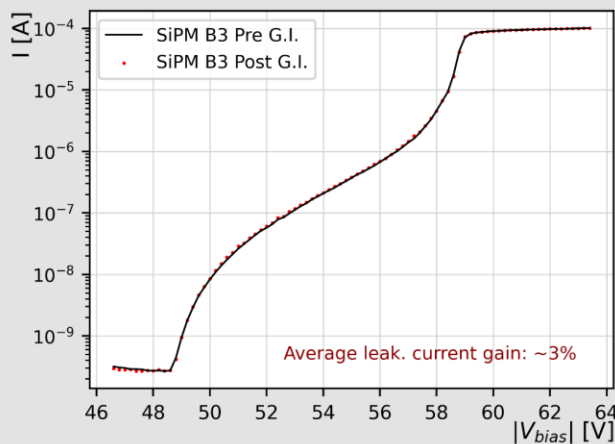
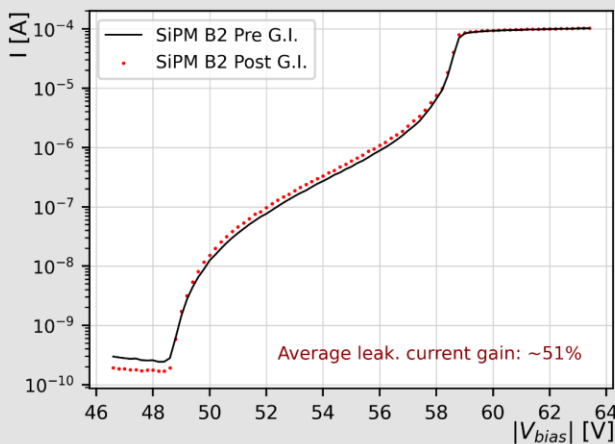
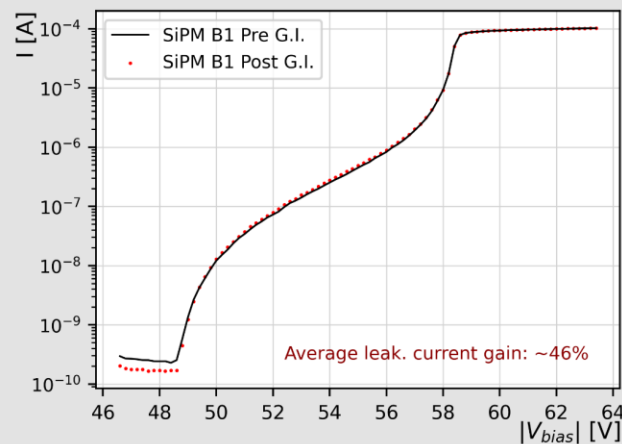
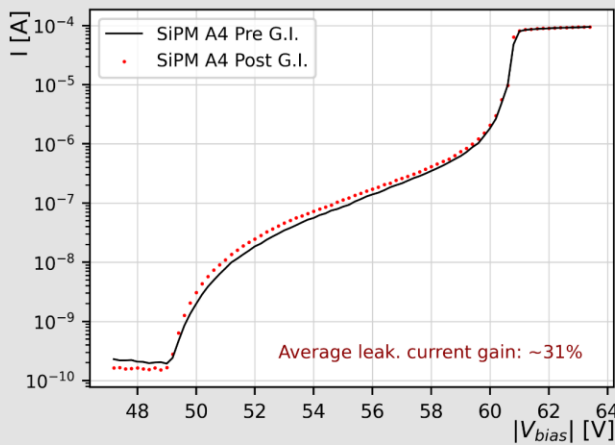
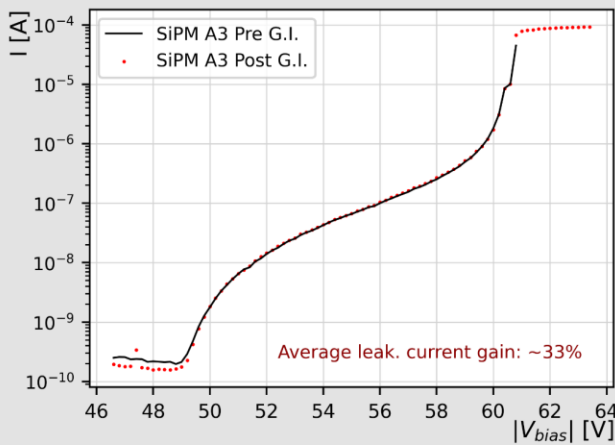
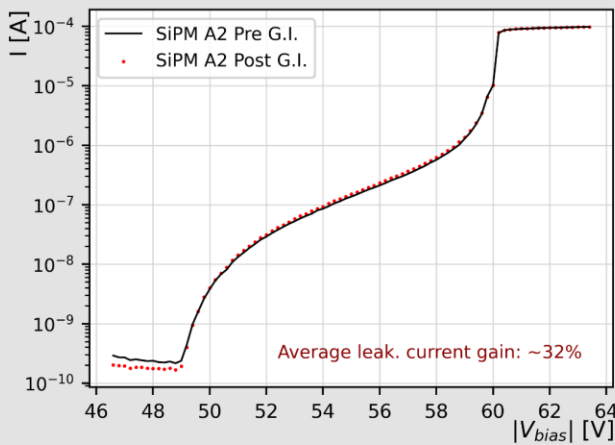
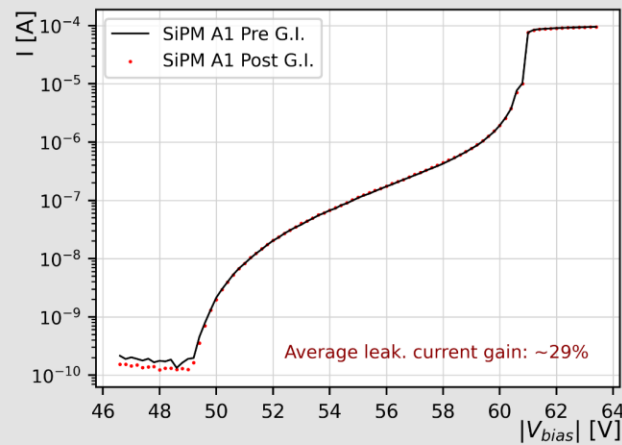


I – V analysis

Pre vs Post γ -irradiated sensor graphs

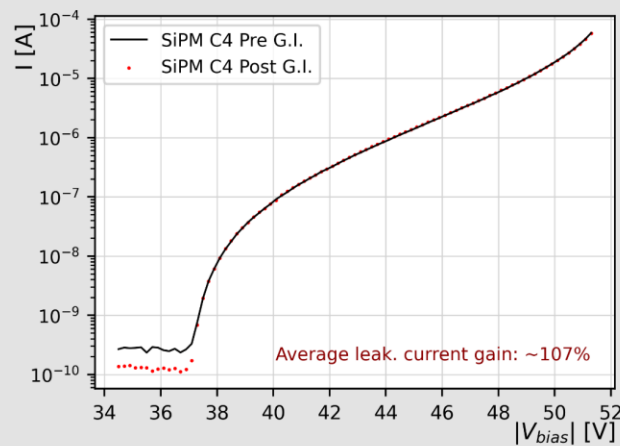
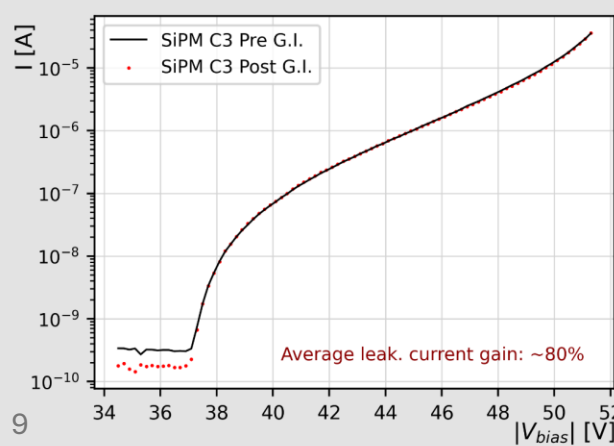
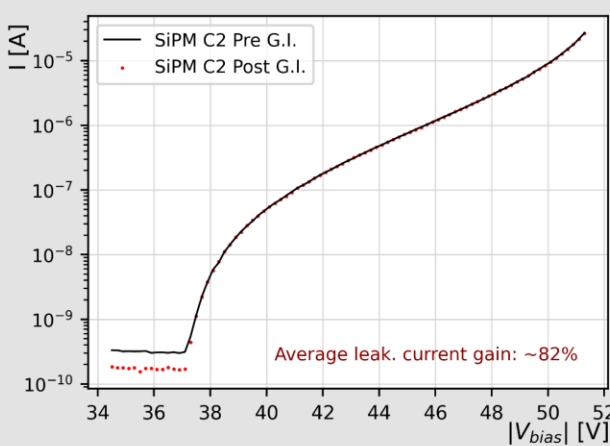
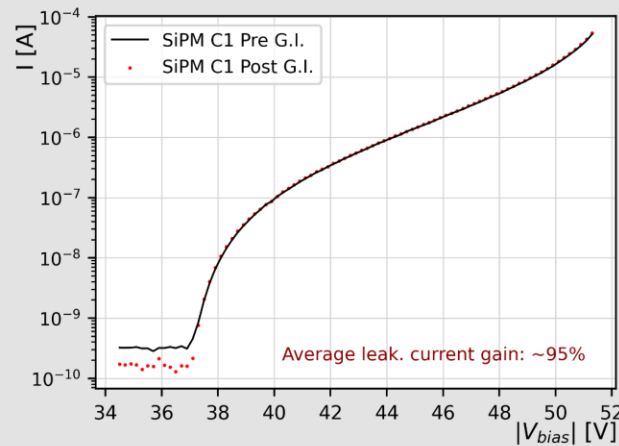
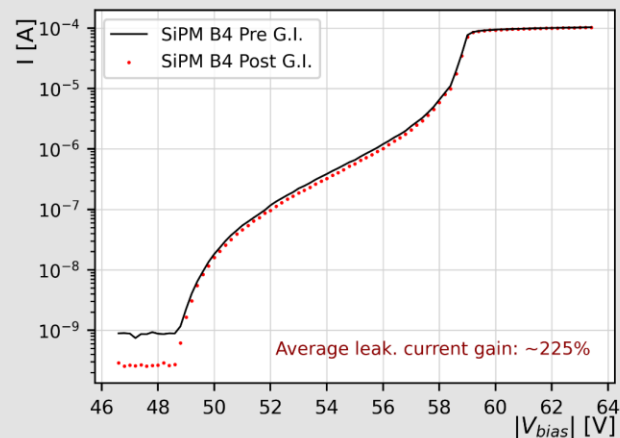
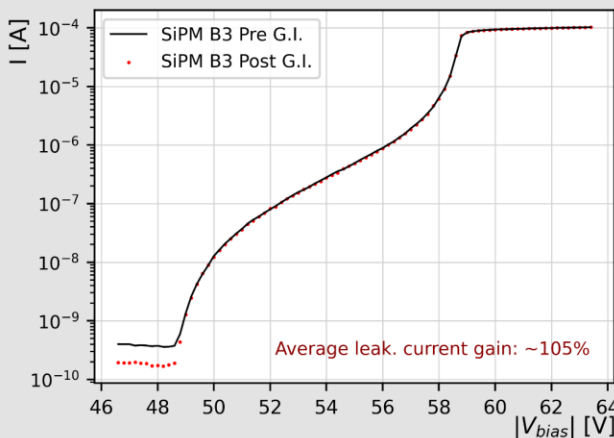
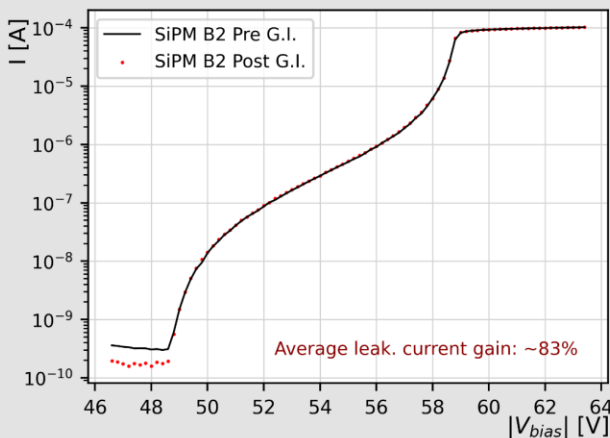
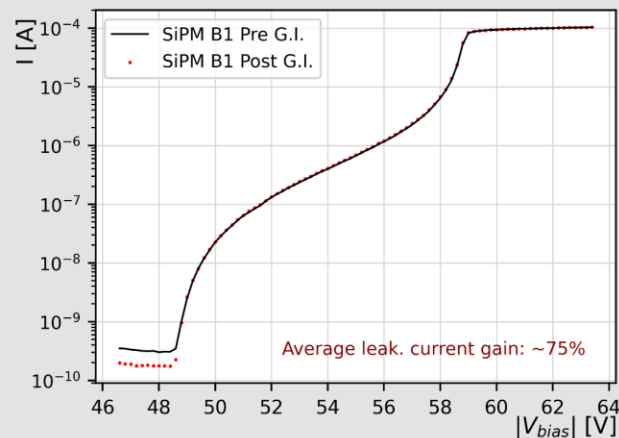
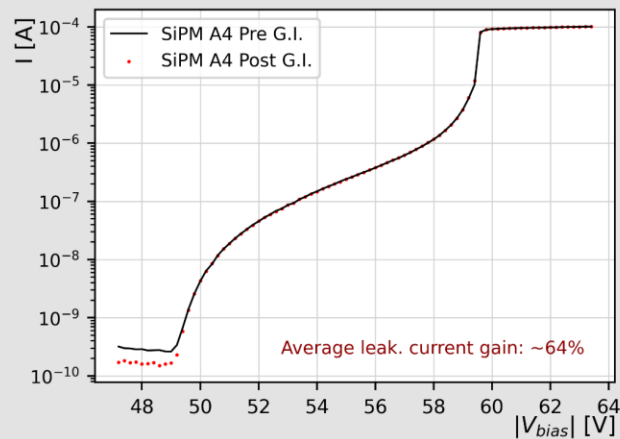
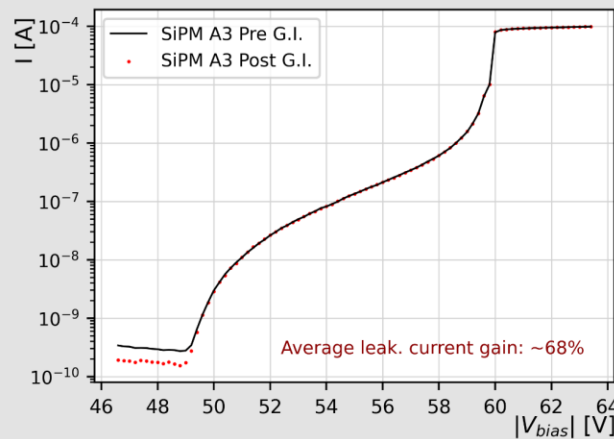
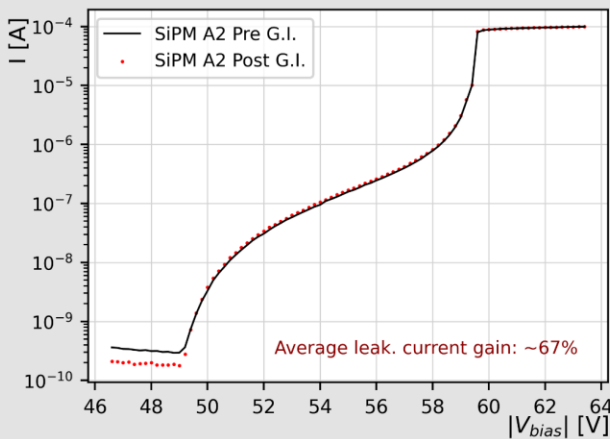
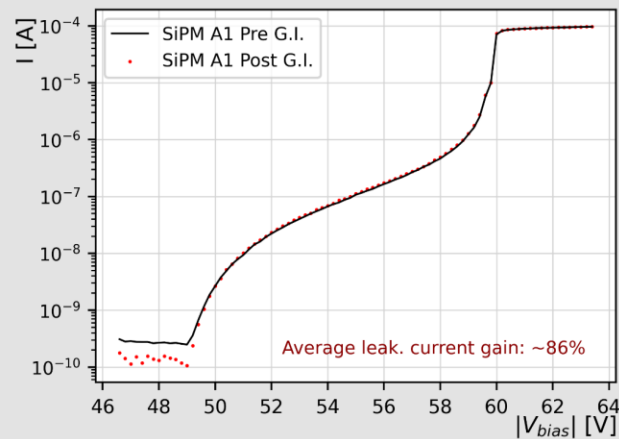
Board #5

Cosenza's Group



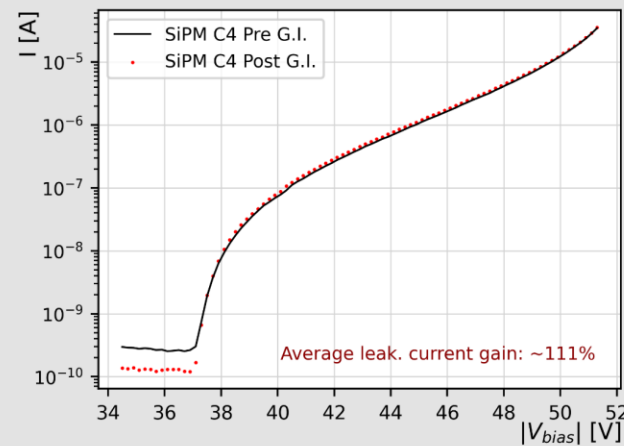
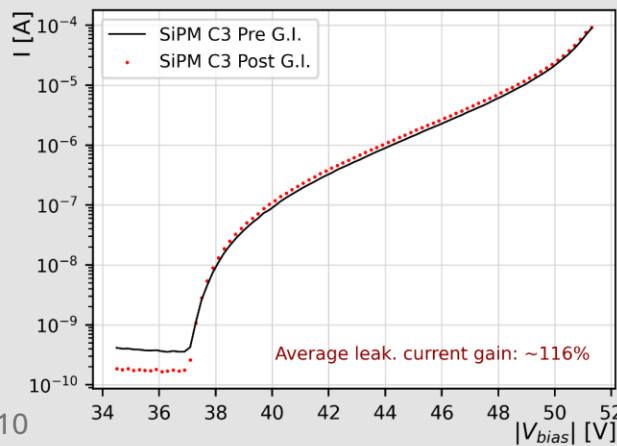
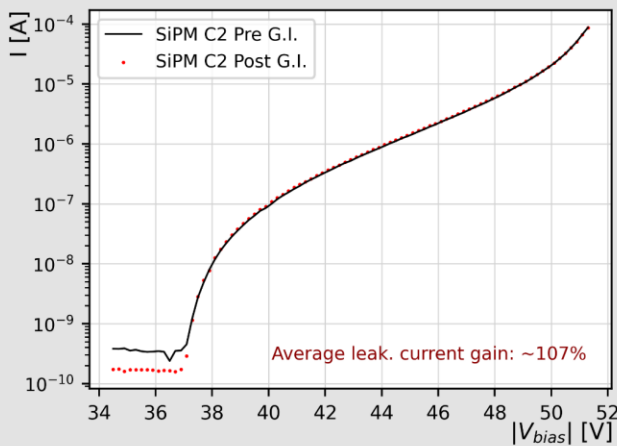
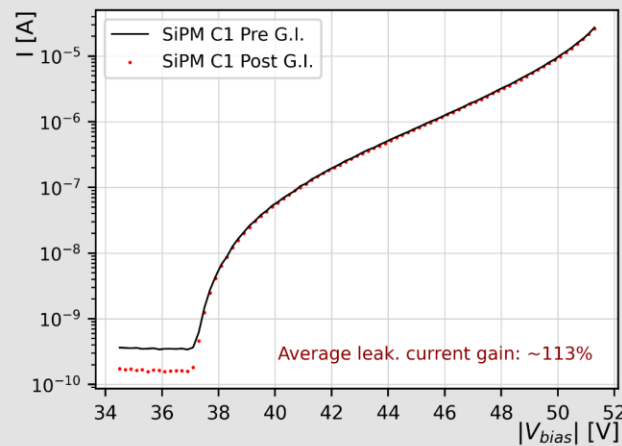
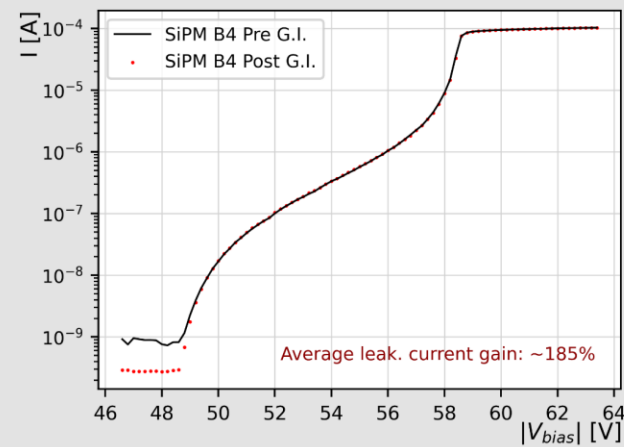
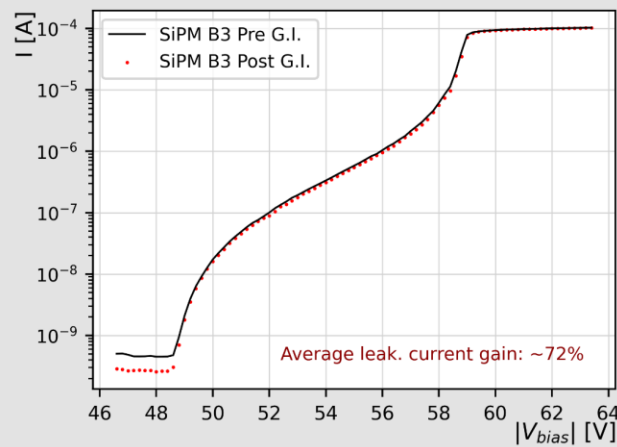
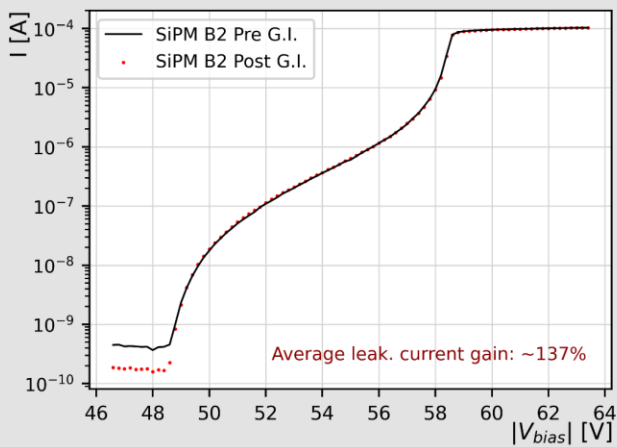
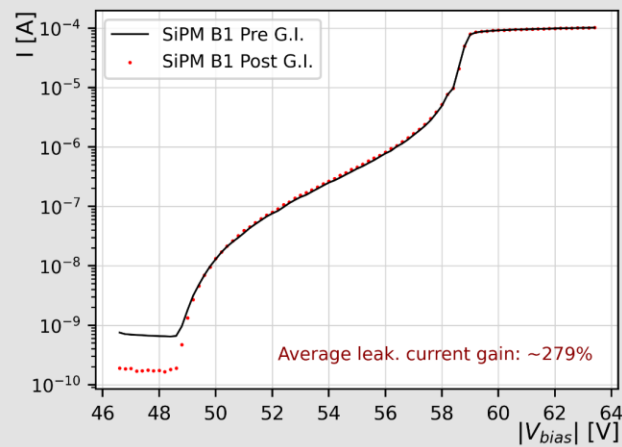
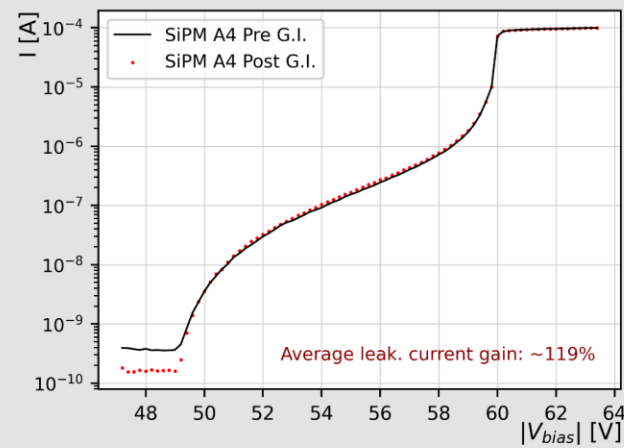
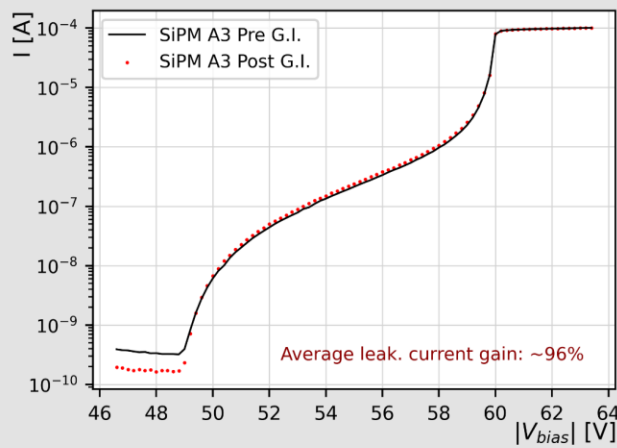
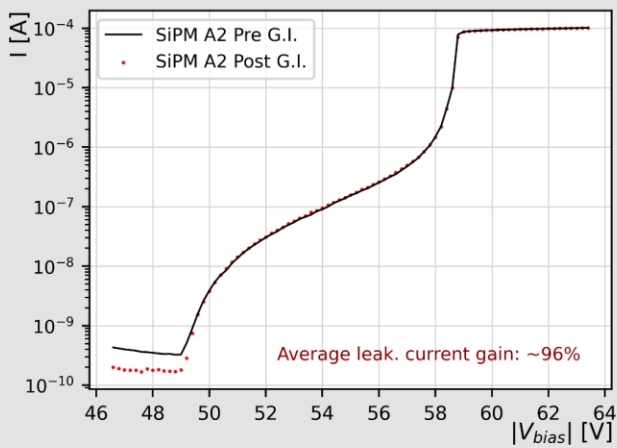
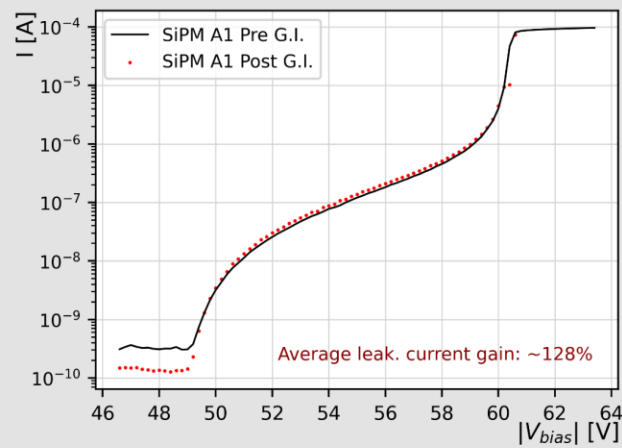
Board #6

Cosenza's Group



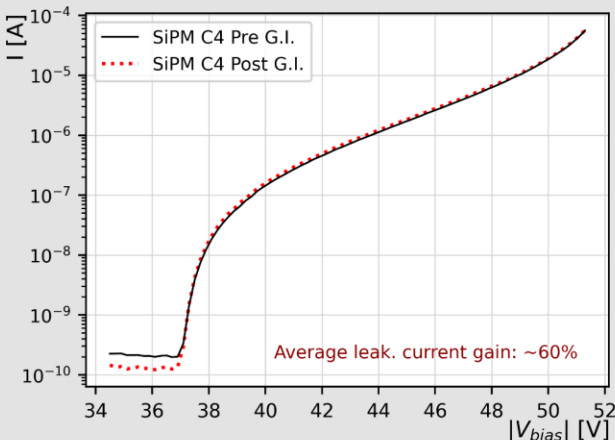
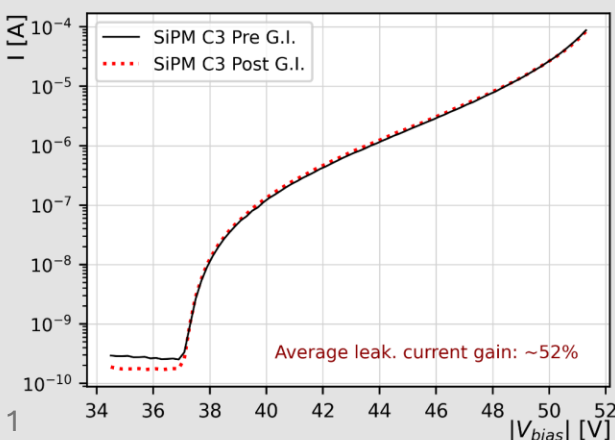
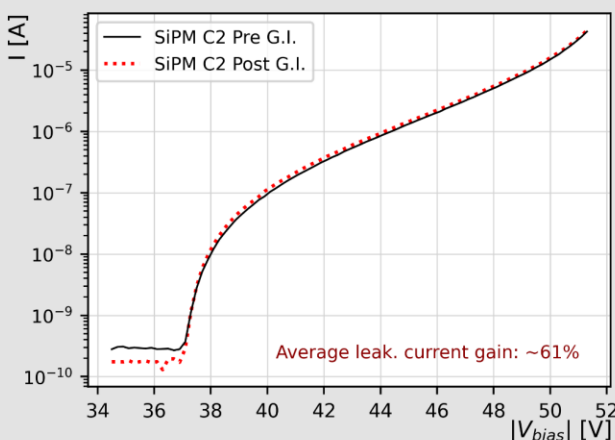
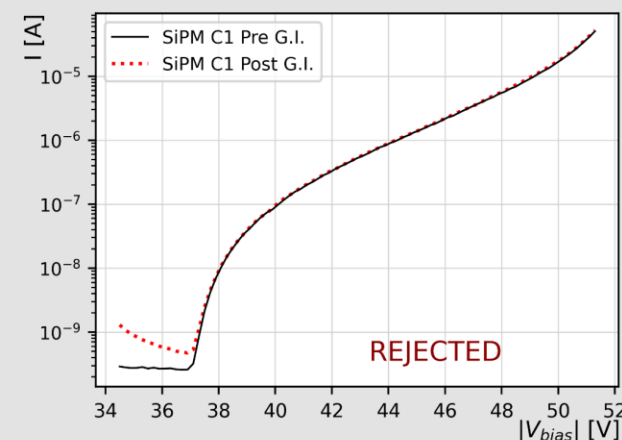
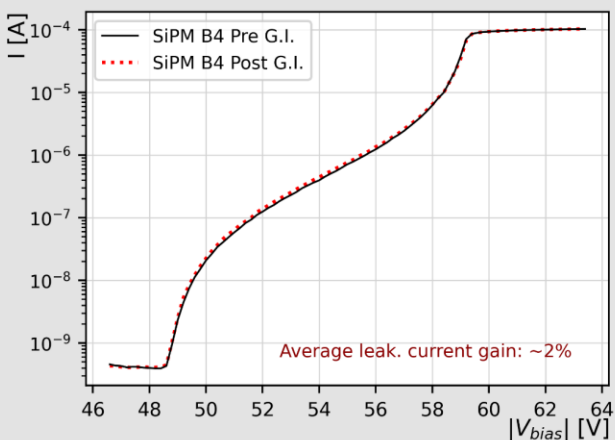
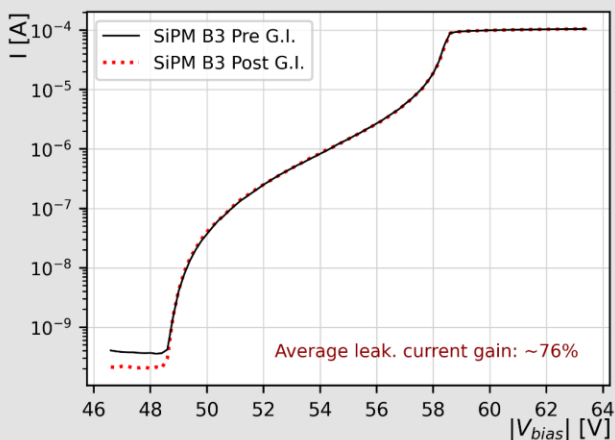
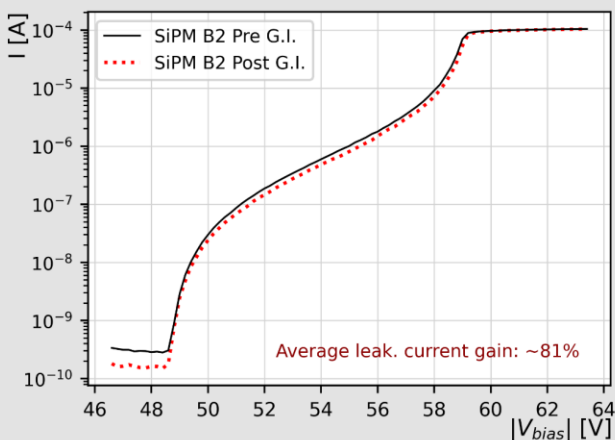
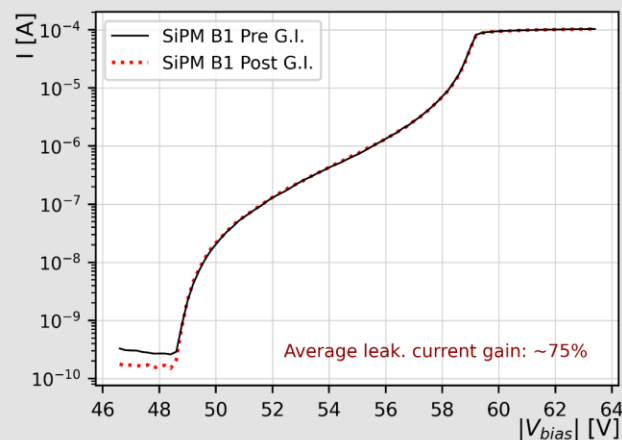
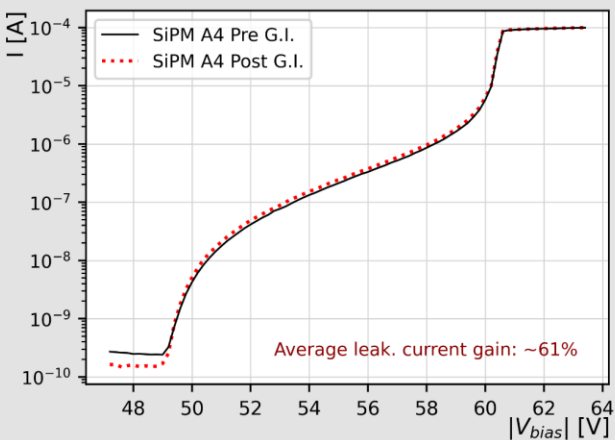
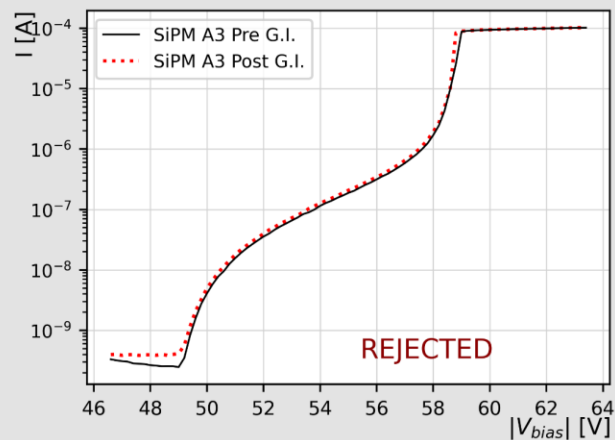
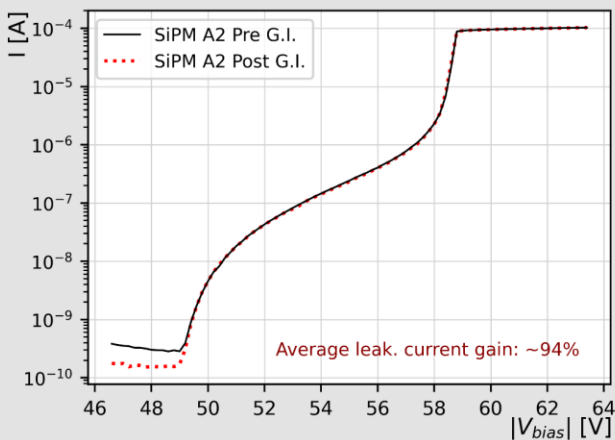
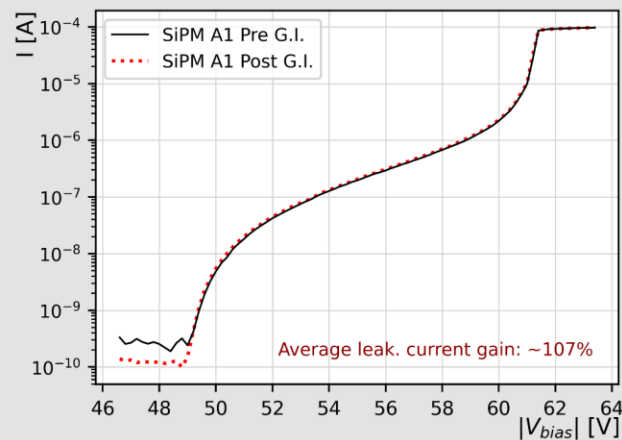
Board #8

Cosenza's Group



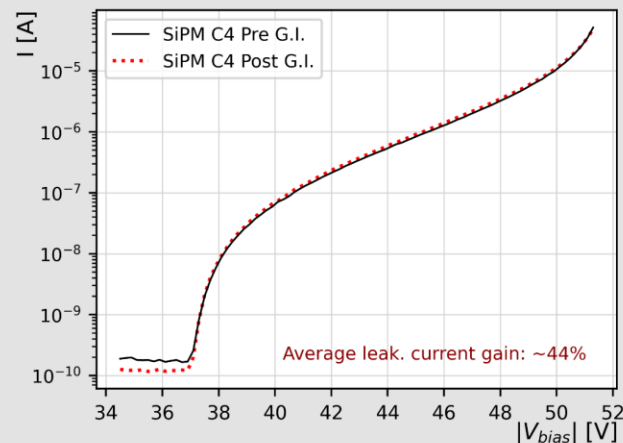
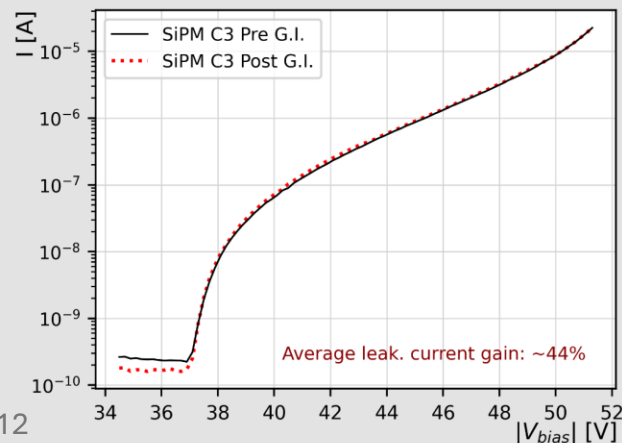
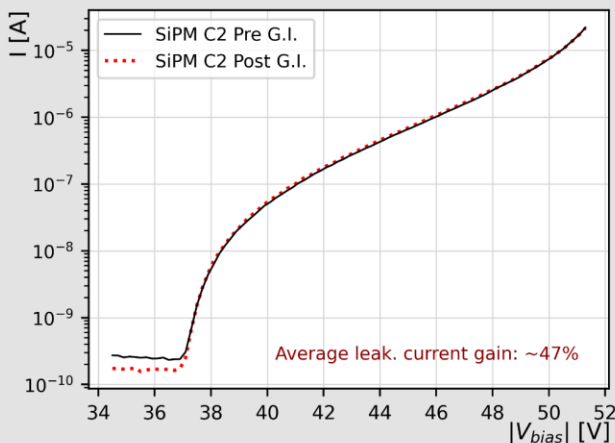
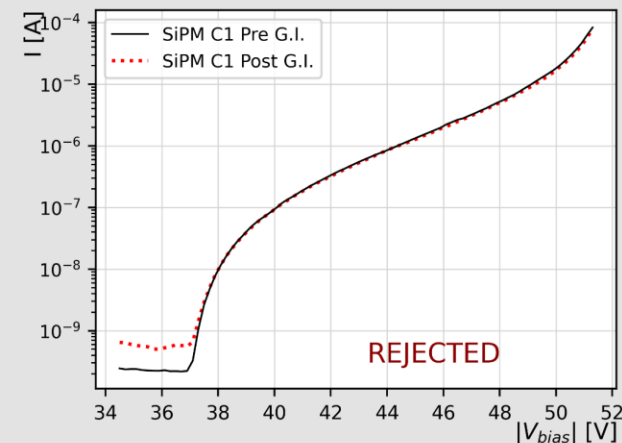
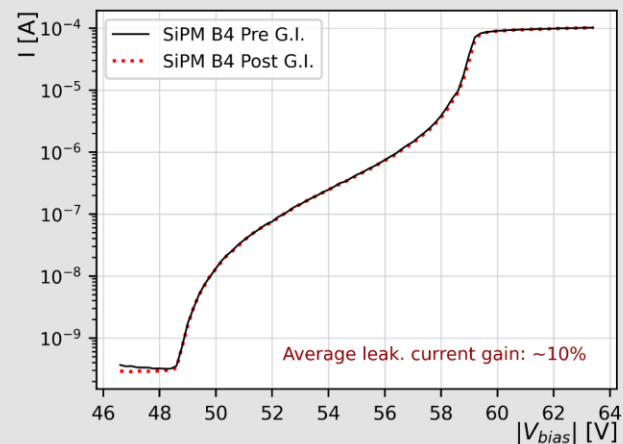
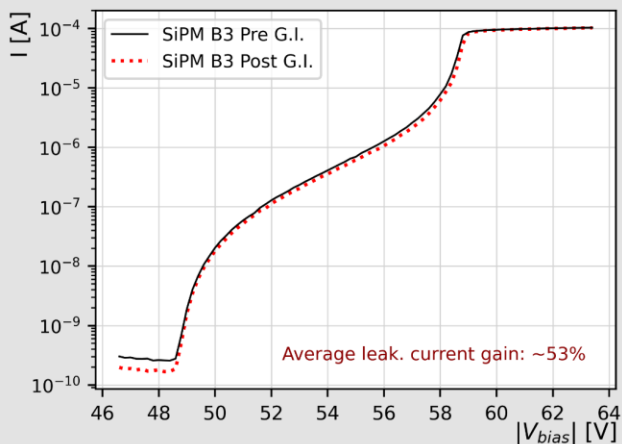
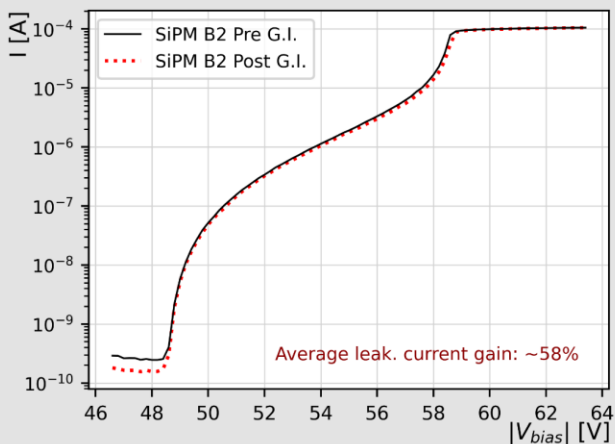
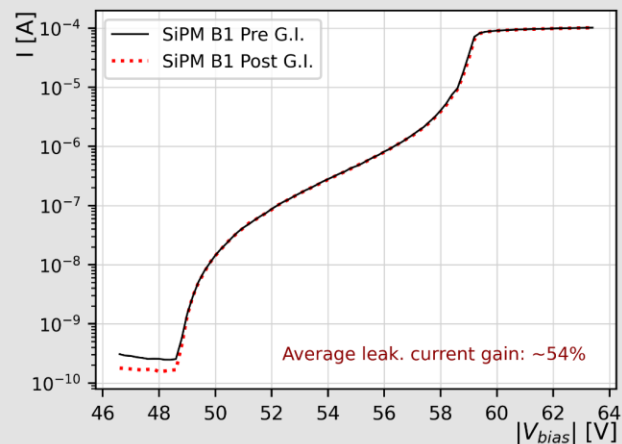
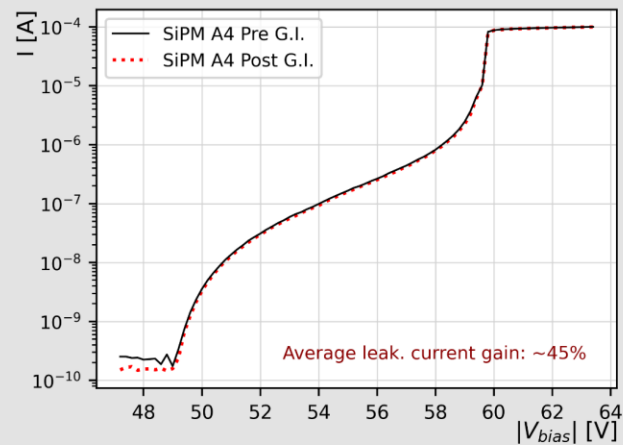
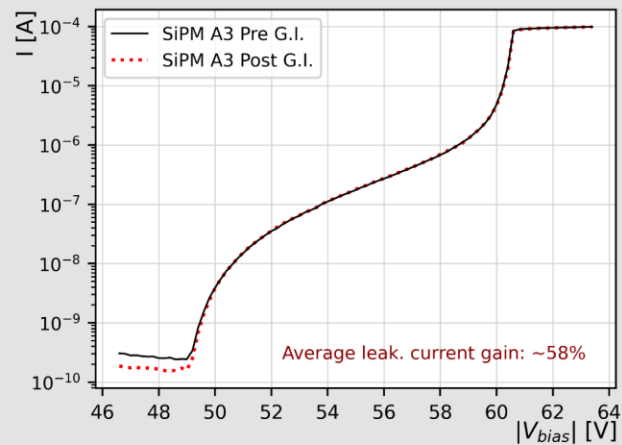
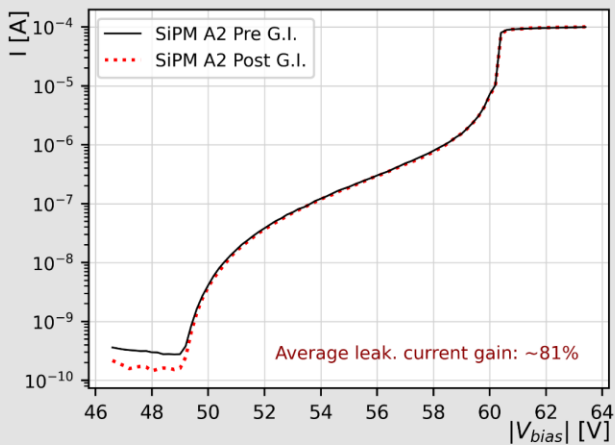
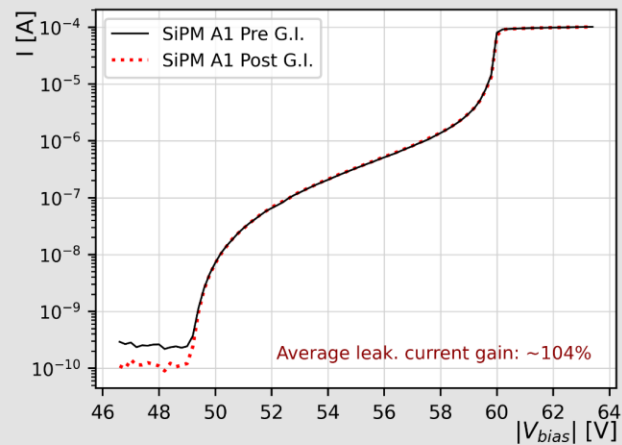
Board #9

Cosenza's Group

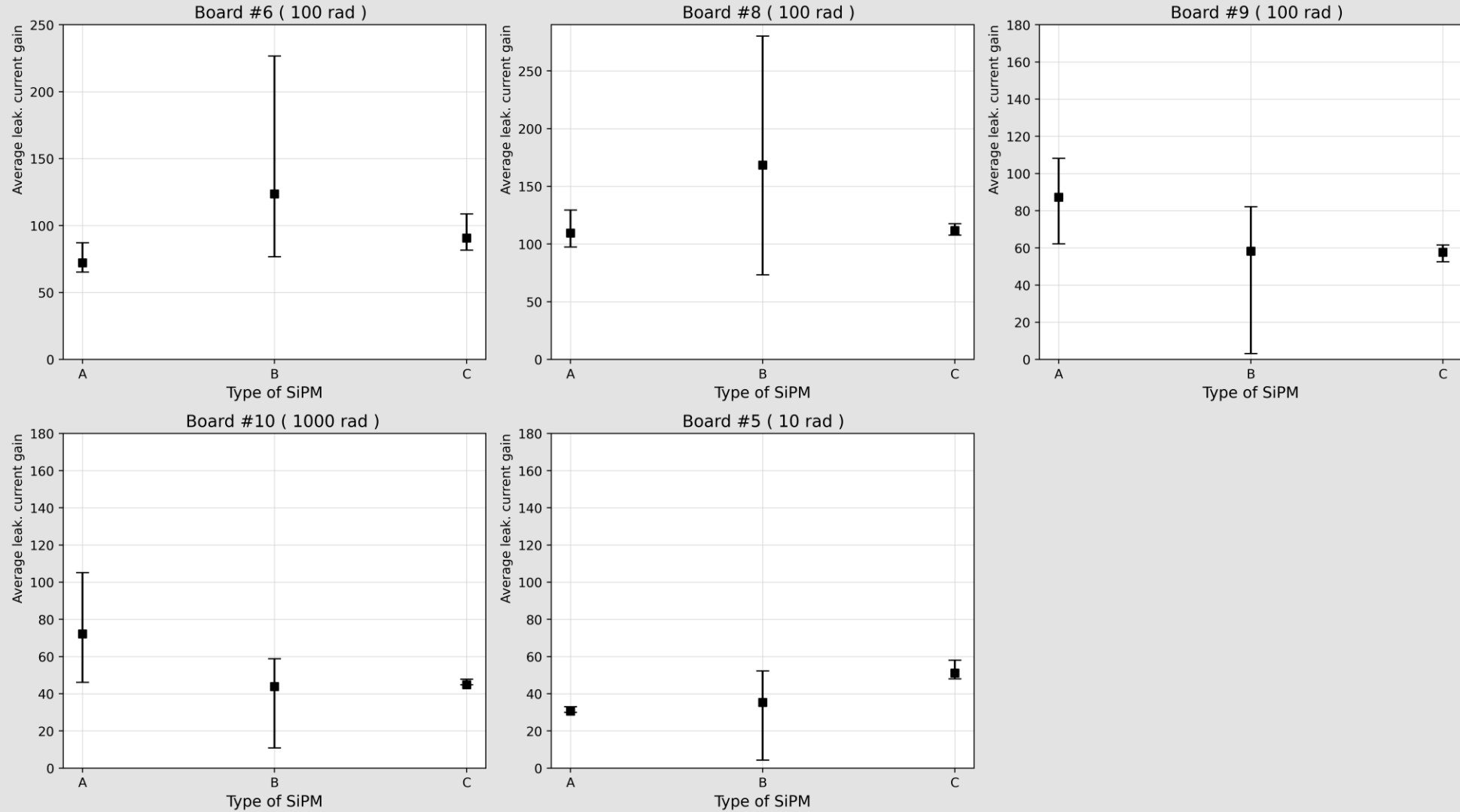


Board #10

Cosenza's Group



Graphs of the average current gain displayed by type of sensor



* The value on the y depicts the % gain referred to the irradiated case.

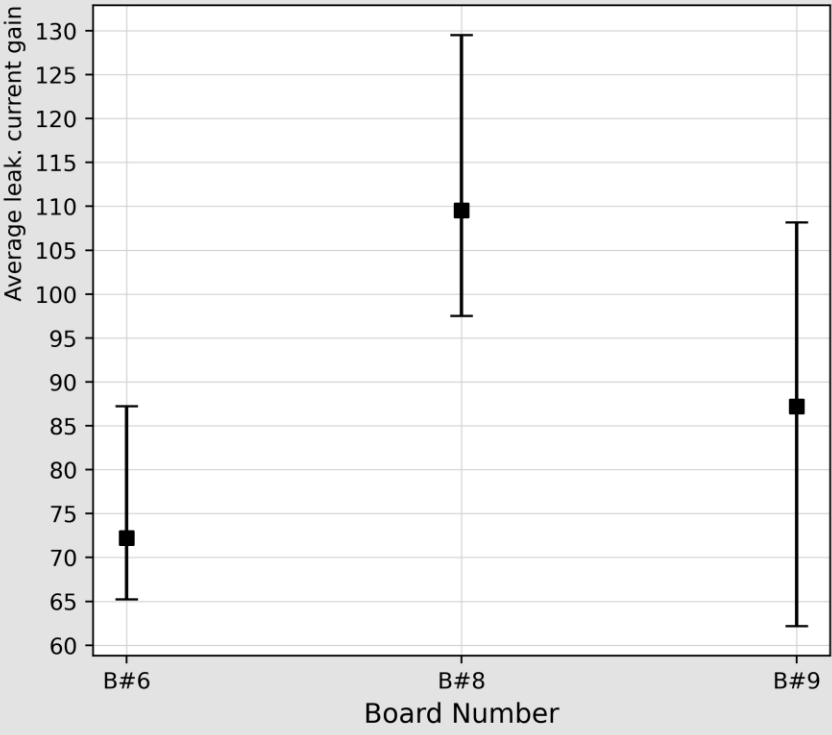
Average current gain displayed by type of sensor

Speaking of numbers, we reported the ΔI between irradiated and not irradiated case in pA , for a better understanding of the percentuals:

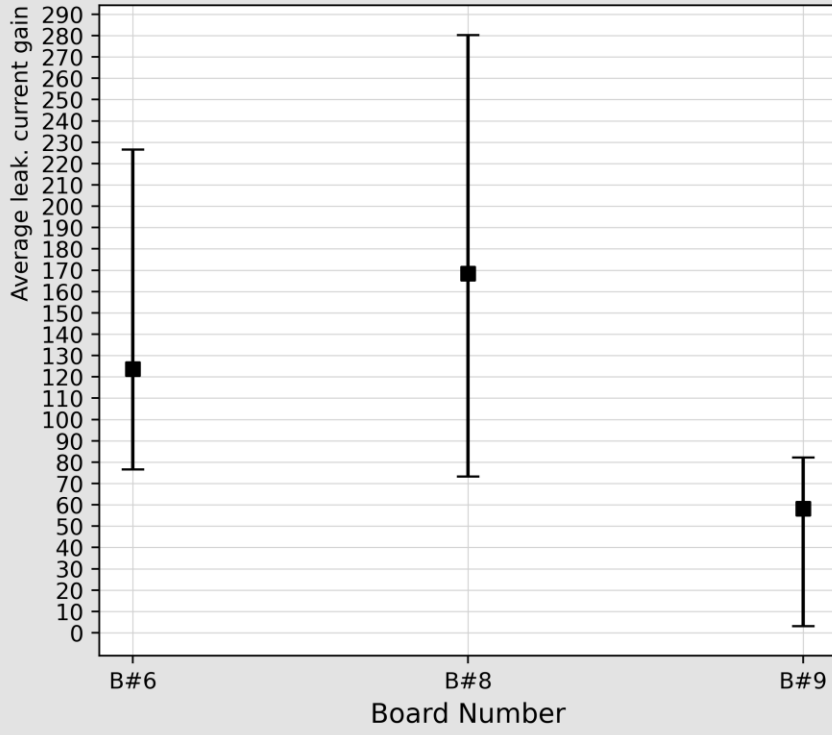
	Board #5			Board #6			Board #8			Board #9			Board #10		
Sensor Type	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ΔI (pA)	51 ± 8	70 ± 13	86 ± 14	122 ± 11	273 ± 31	146 ± 16	188 ± 14	378 ± 44	178 ± 44	136 ± 17	105 ± 14	97 ± 9	92 ± 13	42 ± 8	49 ± 6

Comparison between 100 rad boards

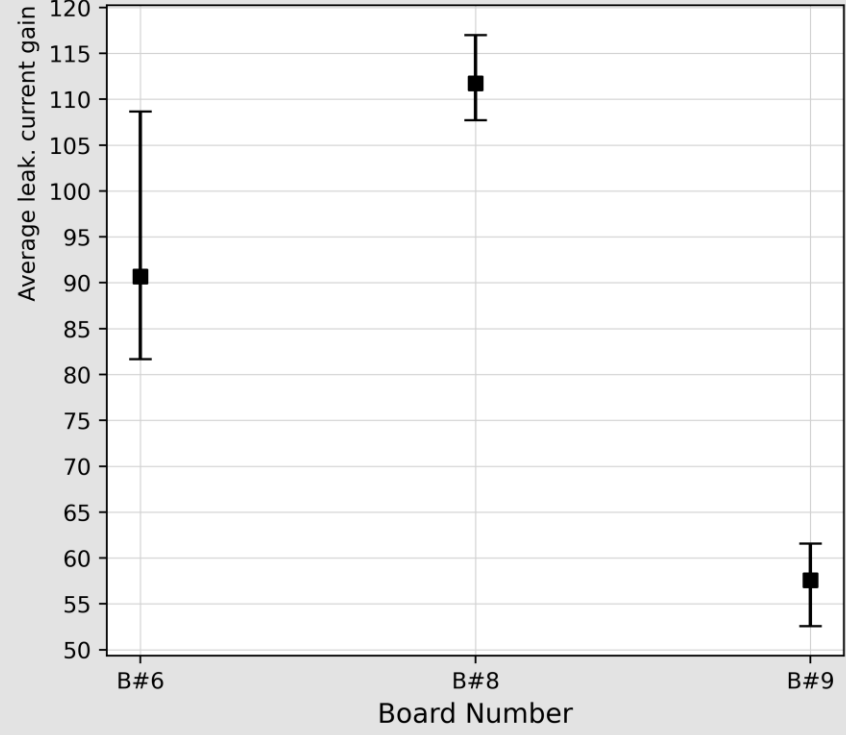
A Sensor



B Sensor



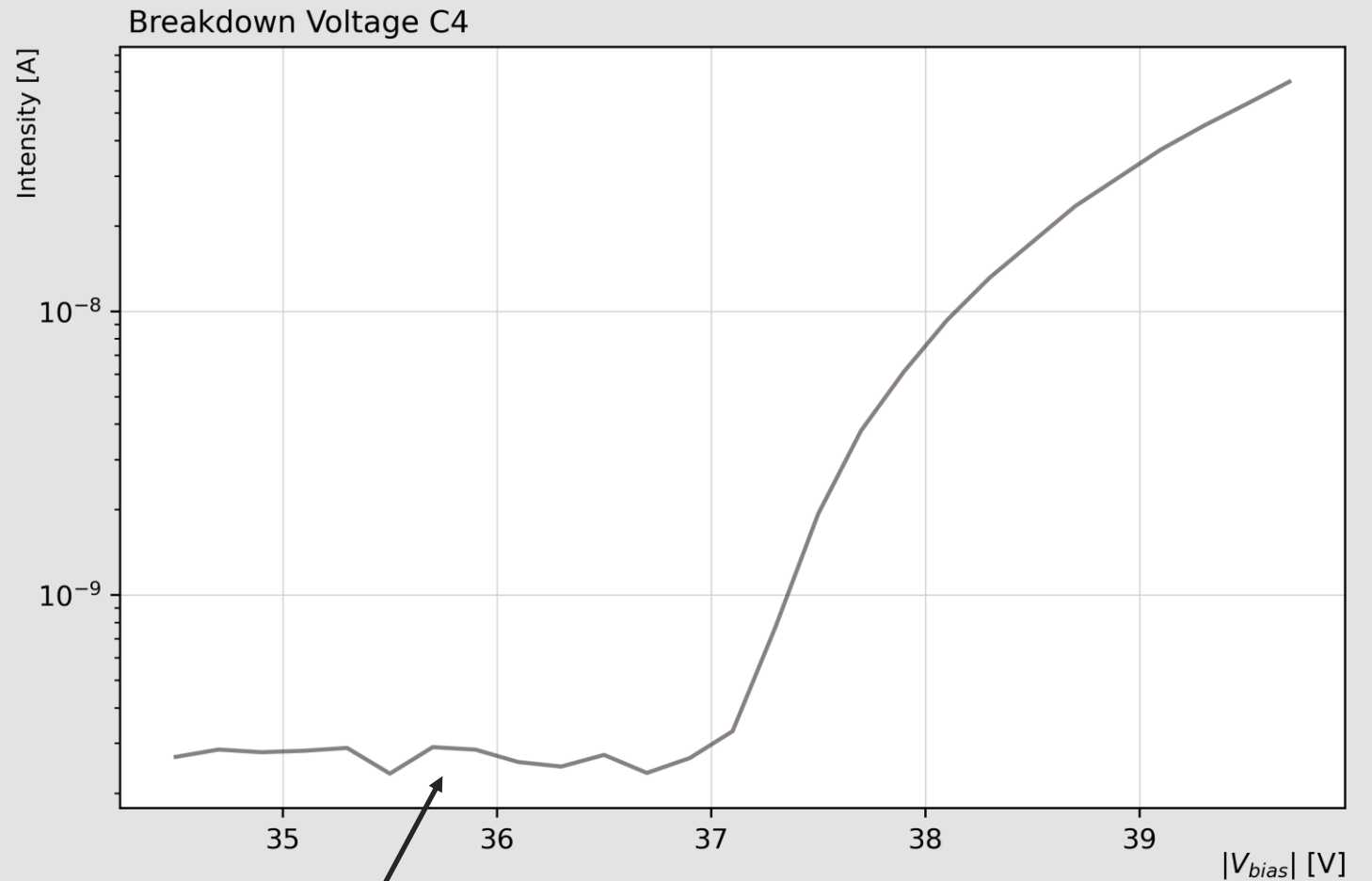
C Sensor



With this analysis we can say that the gain is surely between 61-128% for the A type sensor, between 2-279% for the B type sensor and between 52-116% for the C type sensor for boards irradiated with 100 rads.

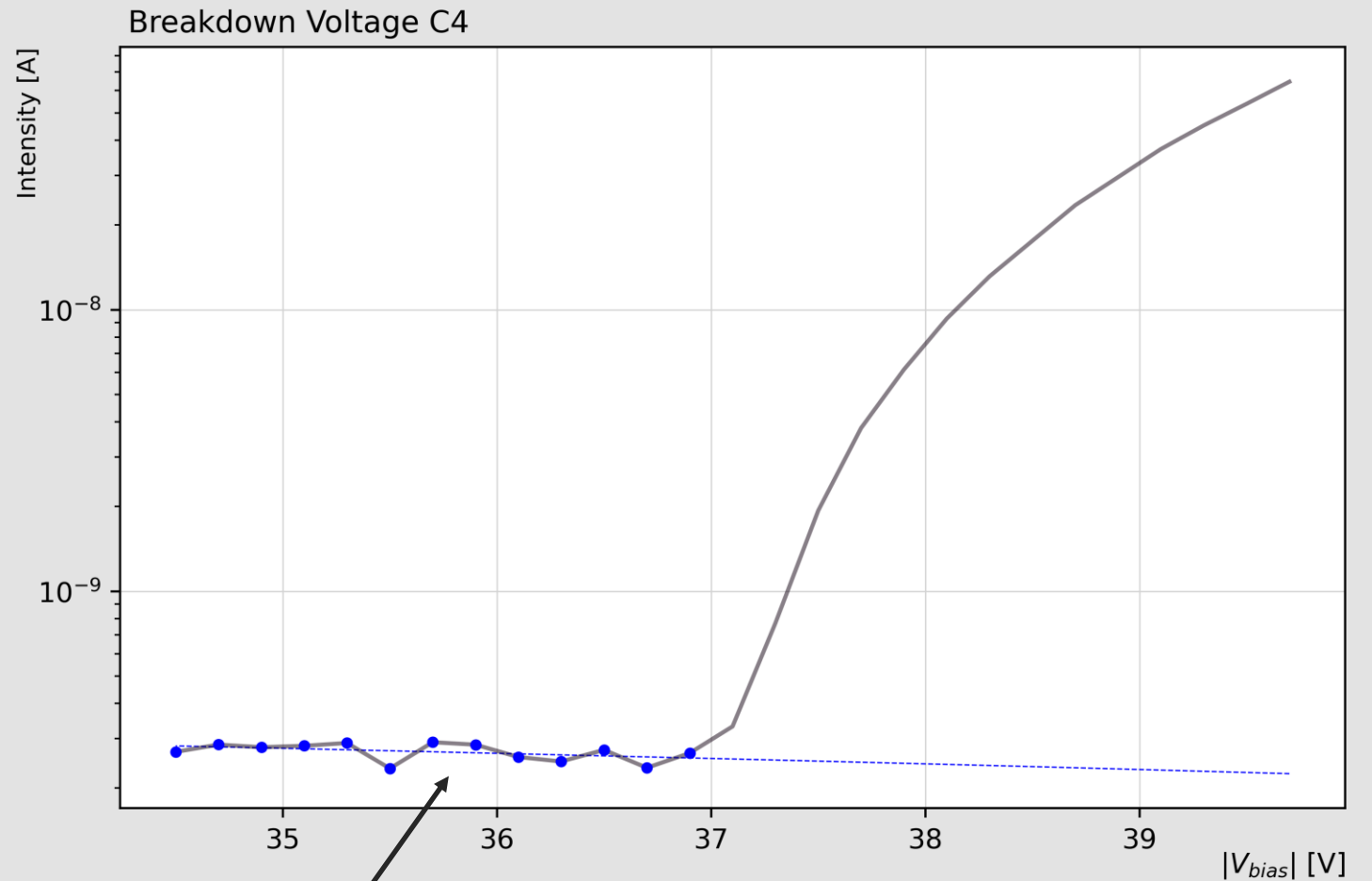
A brief analysis on breakdown voltages

How we
processed
them



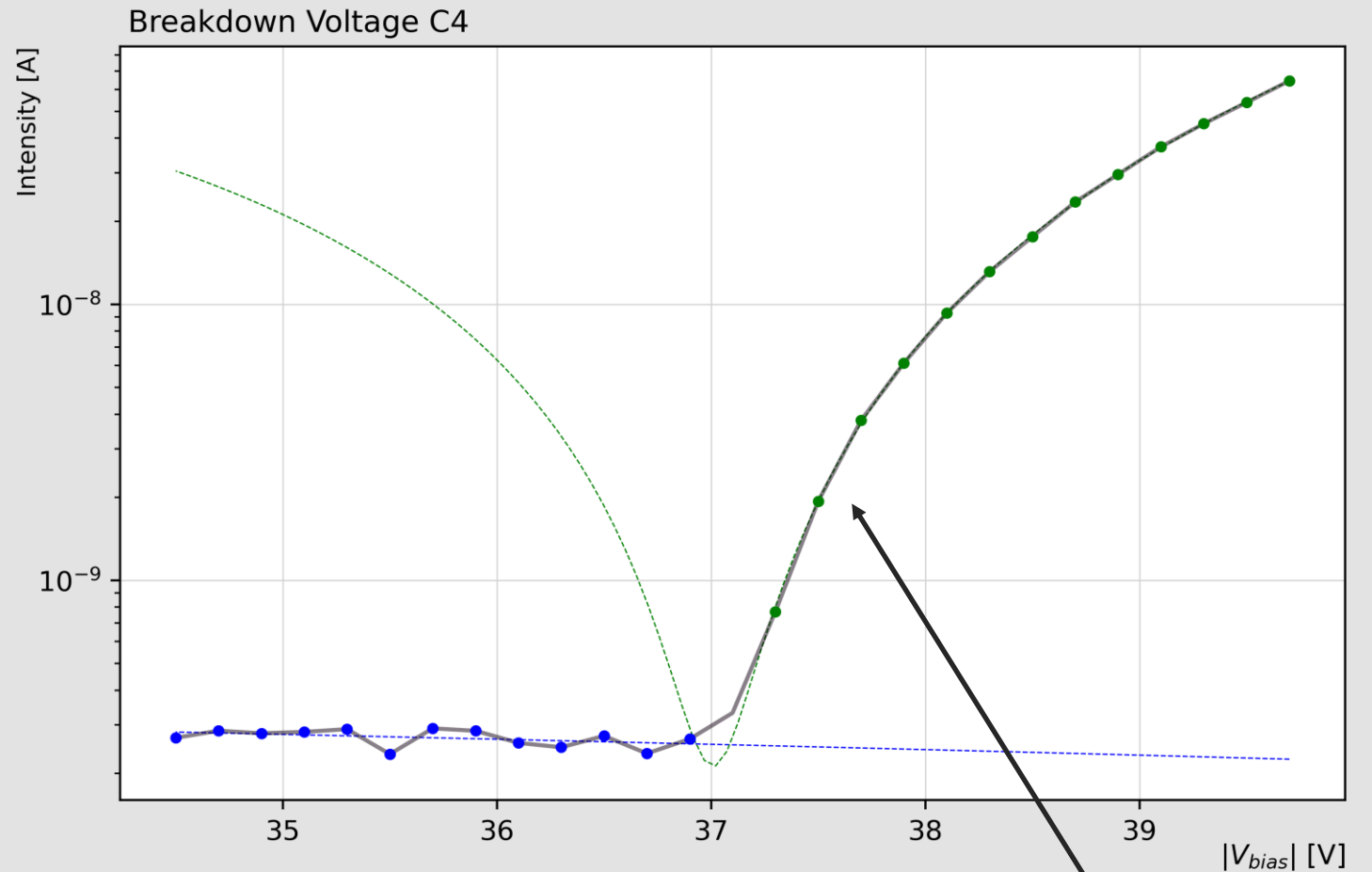
First things first, we plotted the crop of our attentioned area, in which we expect to find the breakdown voltage.

How we
processed
them



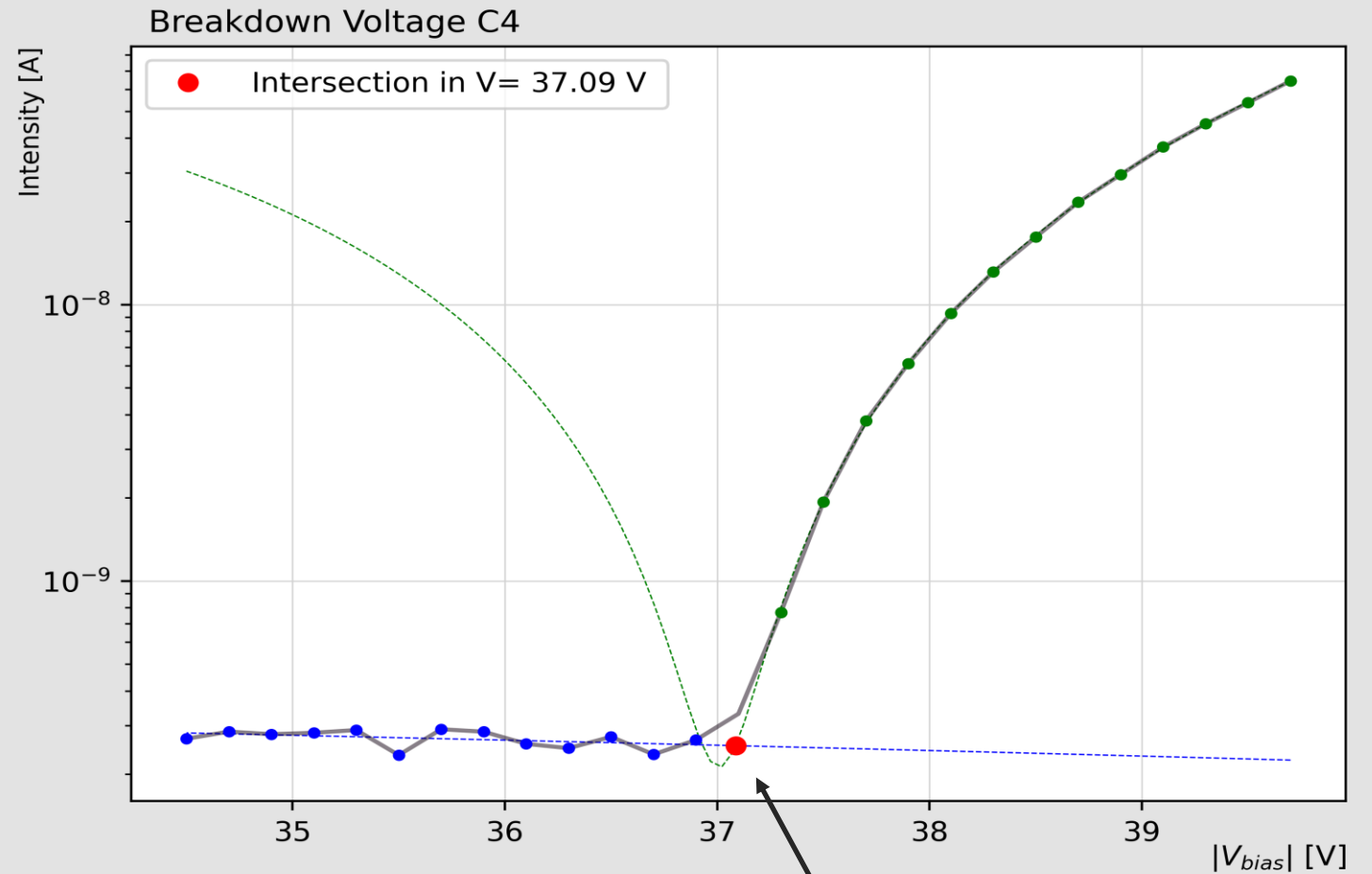
Then, we fitted the points representing the baseline of our I – V curve (the linear part before the breakdown) with a first order function and graphed the resulting line in blue.

How we
processed
them



The third step is to fit the post-breakdown zone with a third order function (a cubic), with every parameter weighted by the contribute of the I-V curve real points (in green)

How we
processed
them



The last thing to do is to calculate mathematically the intersection between the two curves and plot it, inserting the corresponding value in a little legend over the graph.

Breakdown voltage difference between normal and irradiated sensors.

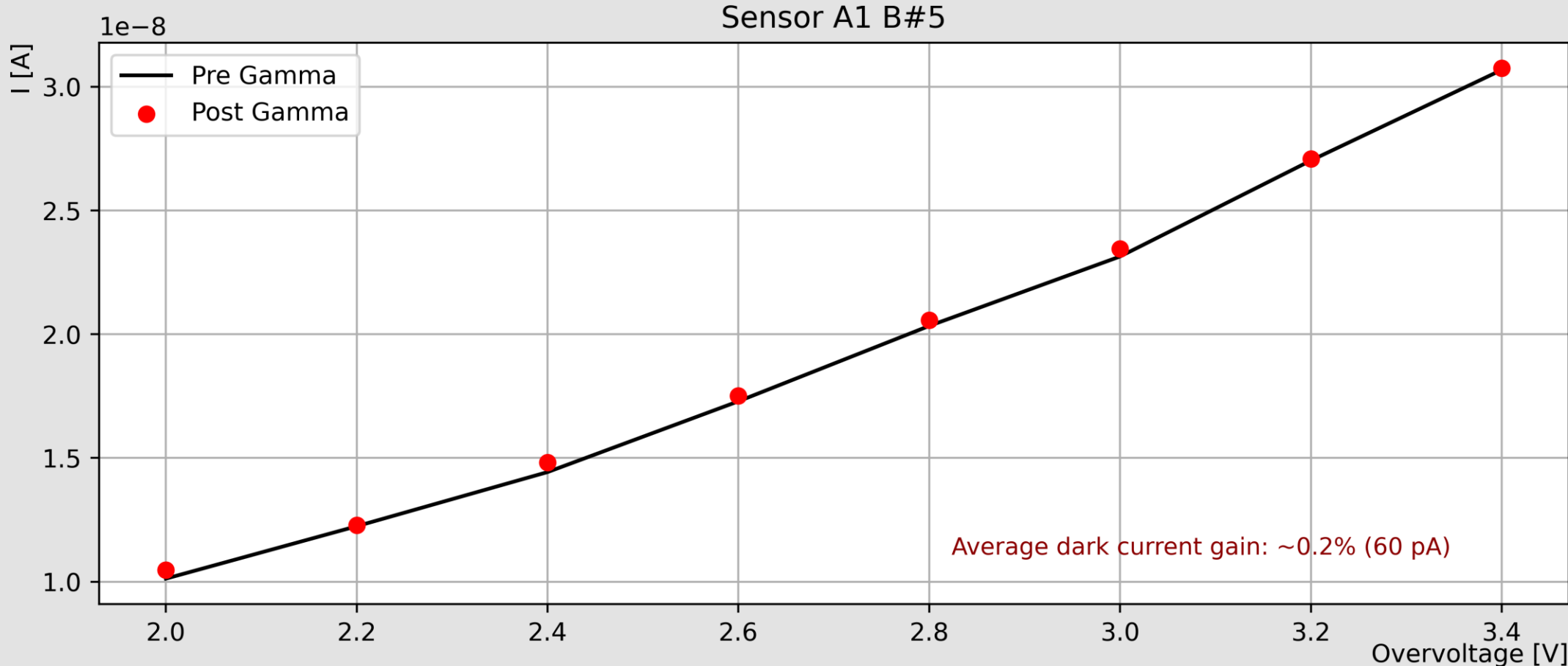
	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
B#5	0.02 V	0.02 V	0.03 V	0.02 V	0.02 V	0.02 V	0.0 V	0.05 V	0.02 V	0.04 V	0.06 V	0.06 V
B#6	0.02 V	0.05 V	0.02 V	0.04 V	0.03 V	0.03 V	0.04 V	0.01 V	0.01 V	0.01 V	0.02 V	0.03 V
B#8	0.03 V	0.02 V	0.06 V	0.04 V	0.04 V	0.02 V	0.01 V	0.04 V	0.02 V	0.02 V	0.02 V	0.02 V

As expected, we don't see a big change in breakdown voltages for expositions at such low photon fluence.

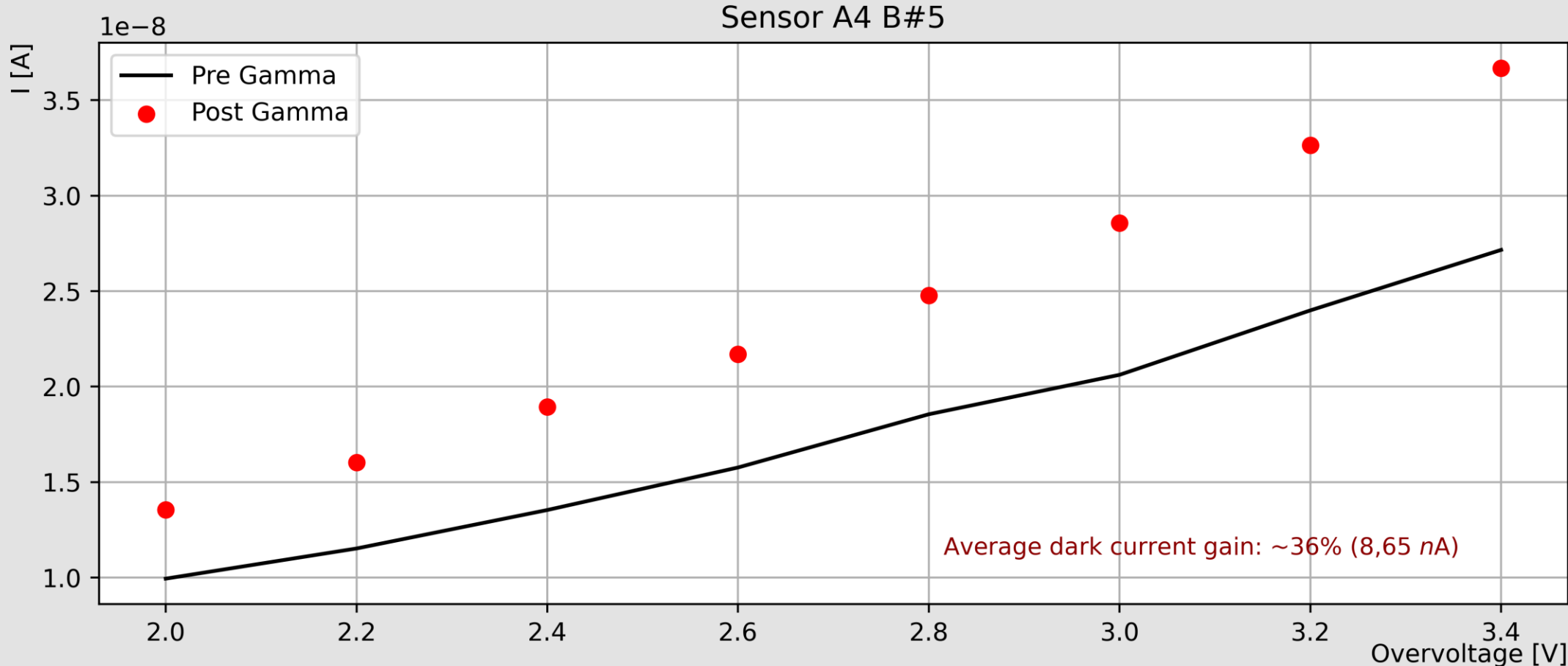
3V overvoltage analysis

Best, worst and average cases

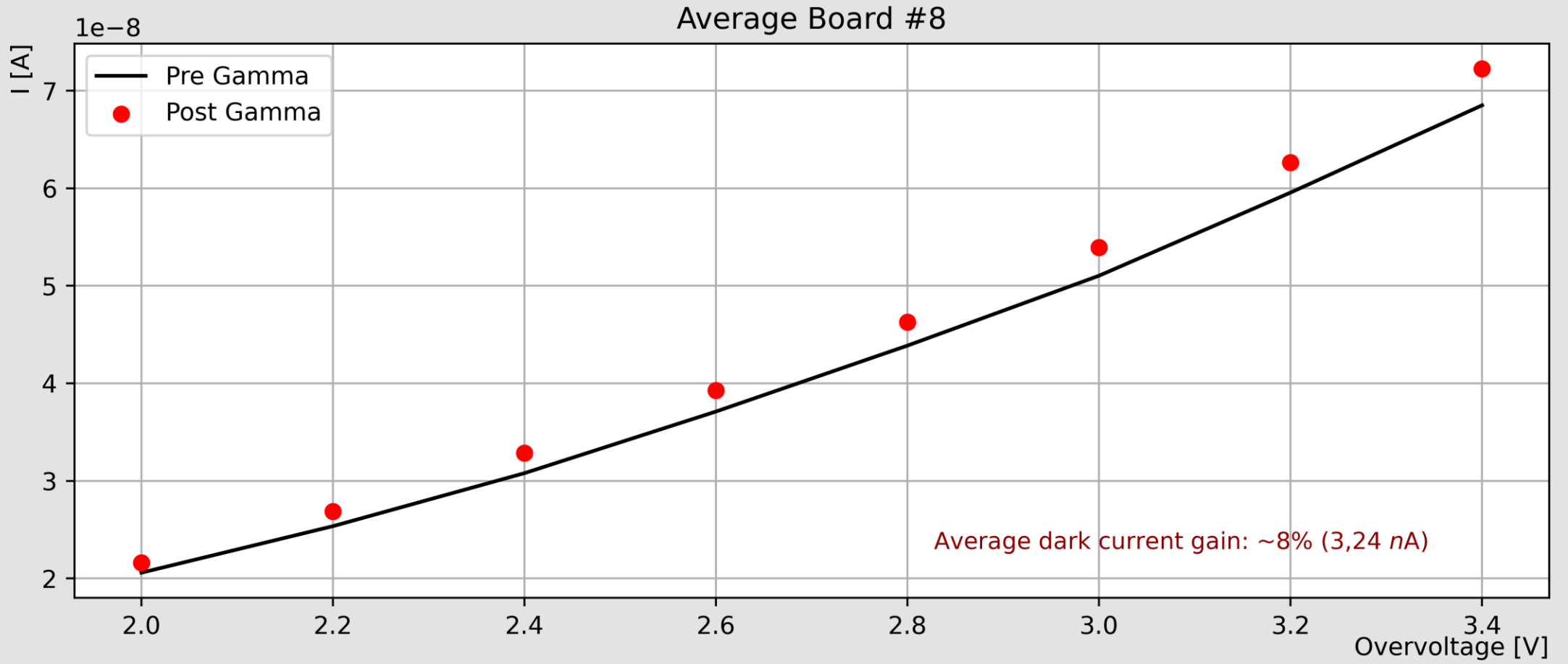
Best case at 3V overvoltage zoom



Worst case at 3V overvoltage zoom



Average case at 3V overvoltage zoom



In conclusion

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To summarize the results of this study, we focused on three main areas of interest:

- **Pre-breakdown region**

- In this part of our analysis, we expected to observe changes in the reverse leakage current of our SiPMs. In particular, we expected an increase in intensity considering the irradiated case, but strangely we observe the opposite. Moreover, we cannot identify a clear pattern in the behaviour of our sensors with respect to the absorbed dose.

- **Breakdown voltage**

- Regarding the breakdown voltage, the difference between annealed and irradiated cases is four orders of magnitude smaller than our data (on the scale of hundredths of volts), thus, we can say that the variation on breakdown points is negligible for such low intensity of absorbed radiation.

- **Post-breakdown region**

- By analyzing this part of the measurements, we can observe that the curves essentially overlap. This lack of macroscopic changes between the annealed and irradiated sensors (circa 7-12% if we take a 3V overvoltage measure) represents an important result for us, because we can see that the operating regimes in which our diode is going to work are not affected by this type of radiation.

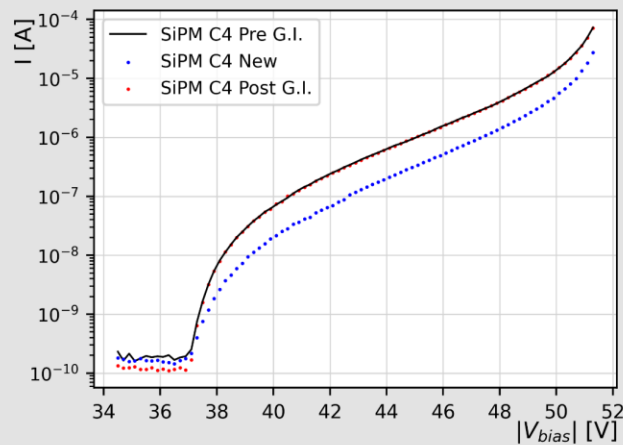
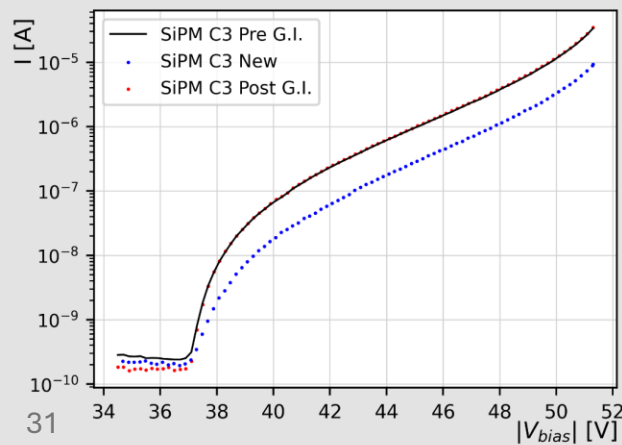
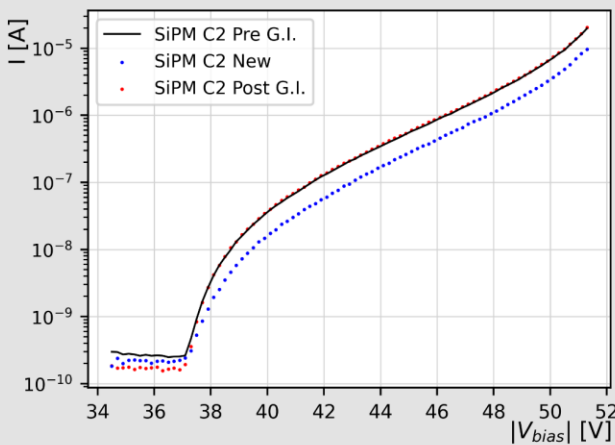
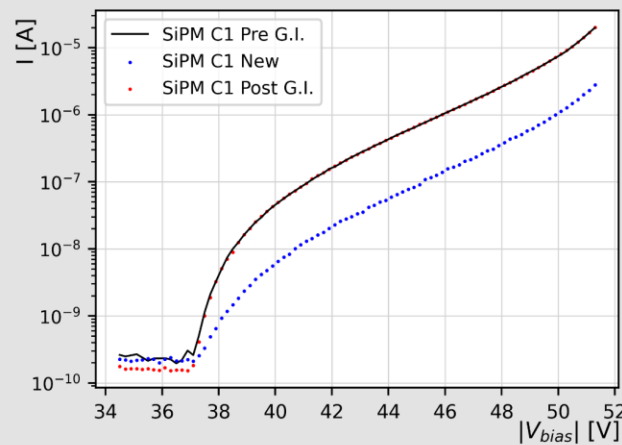
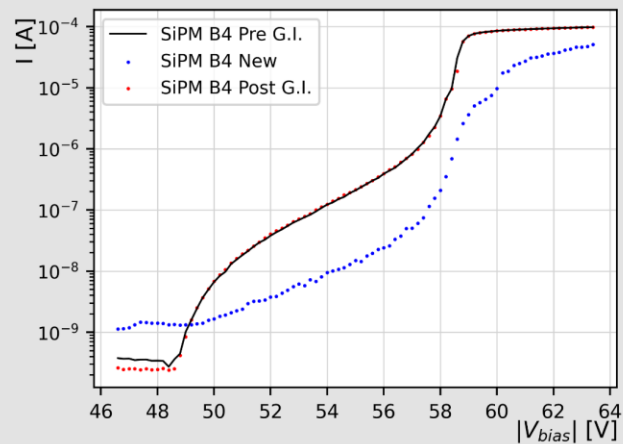
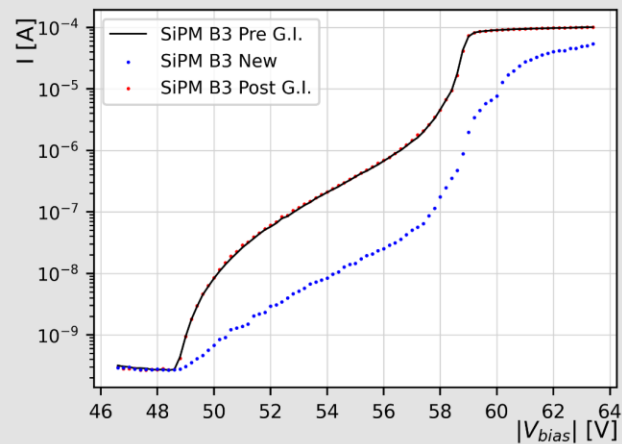
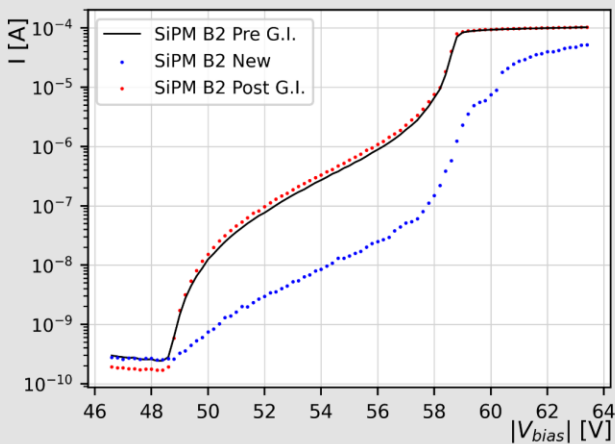
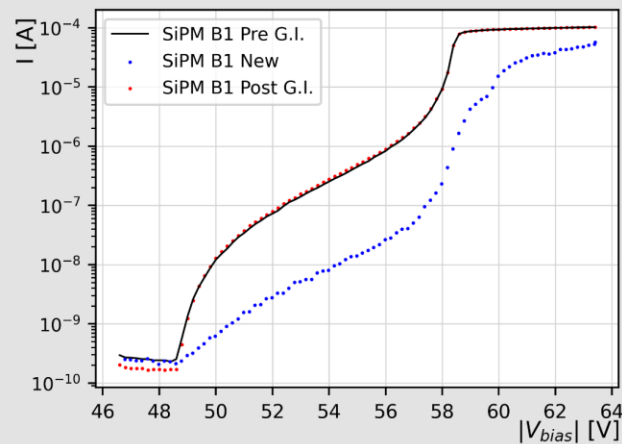
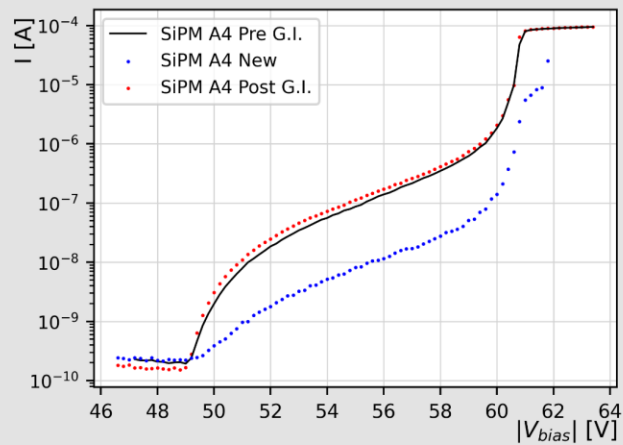
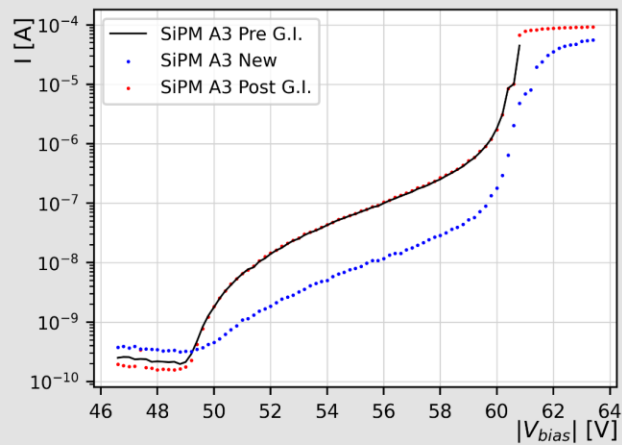
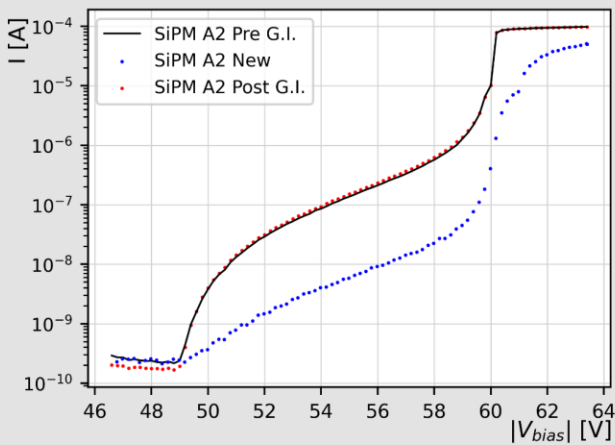
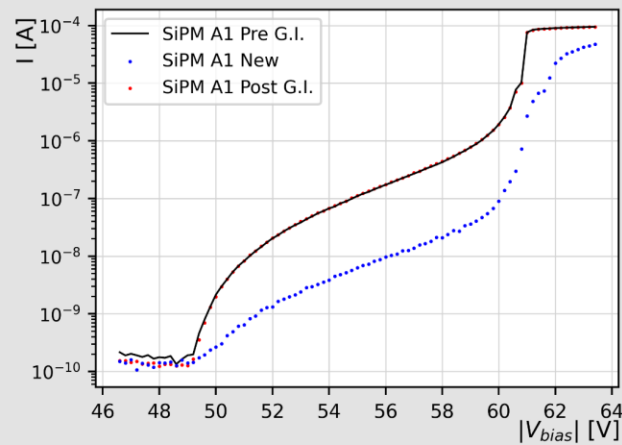
Thanks for the attention!

Backup slides

All N-Pre-Post graphs

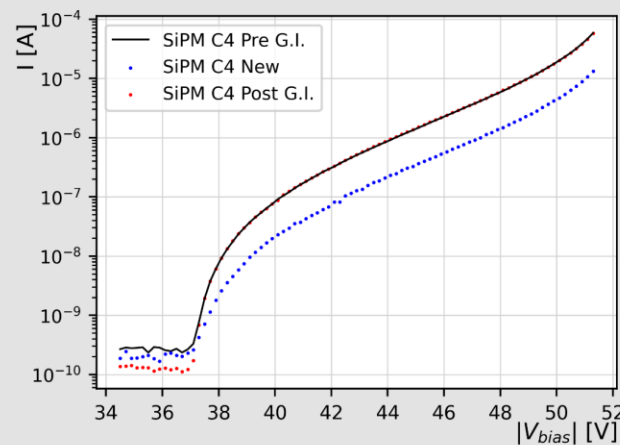
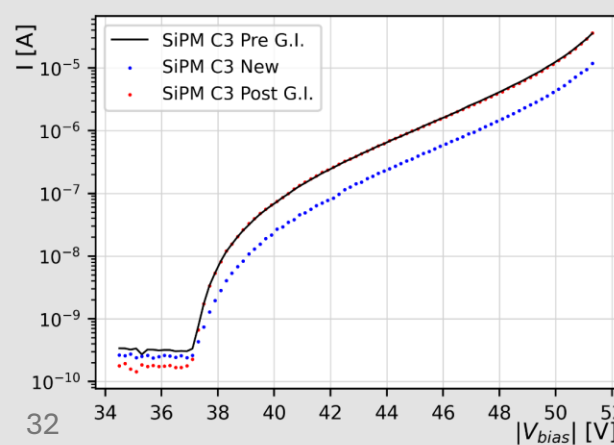
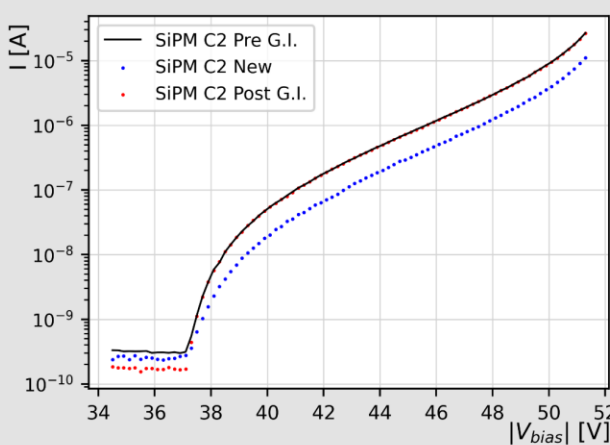
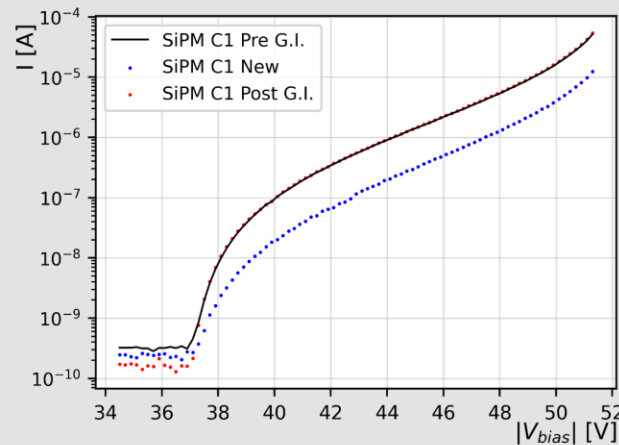
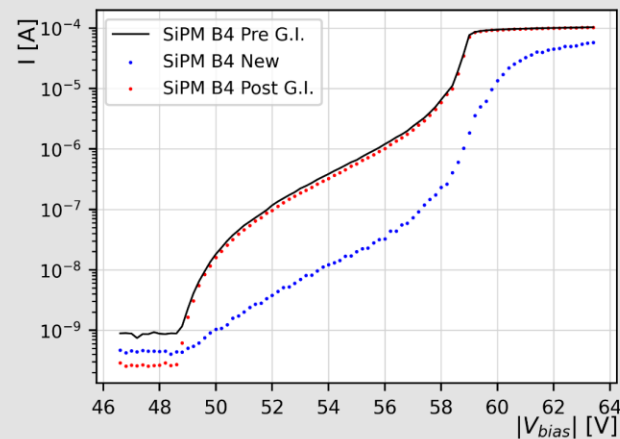
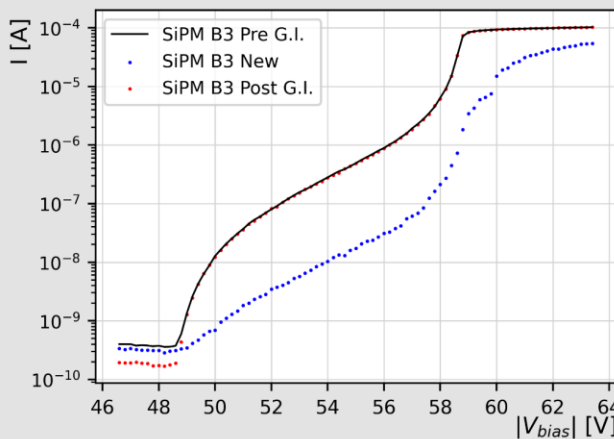
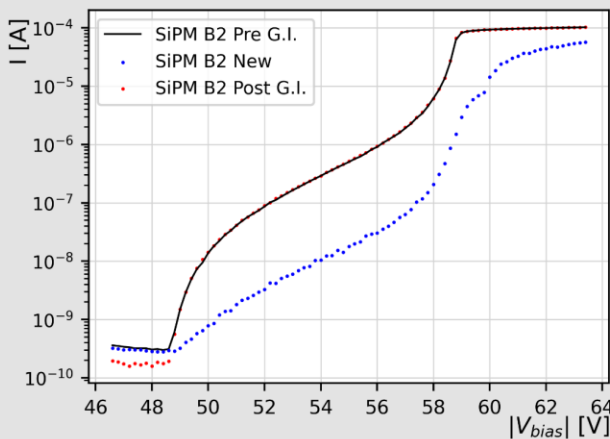
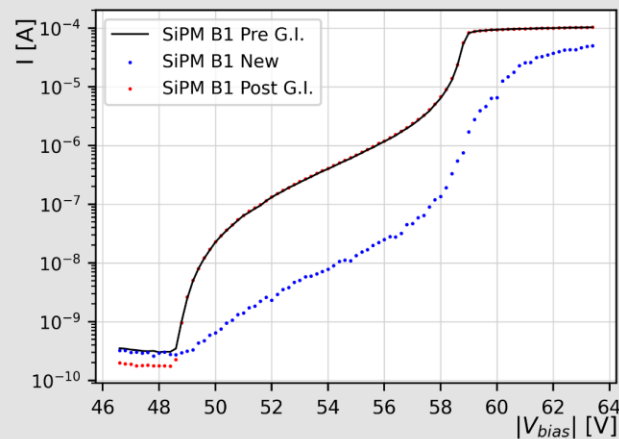
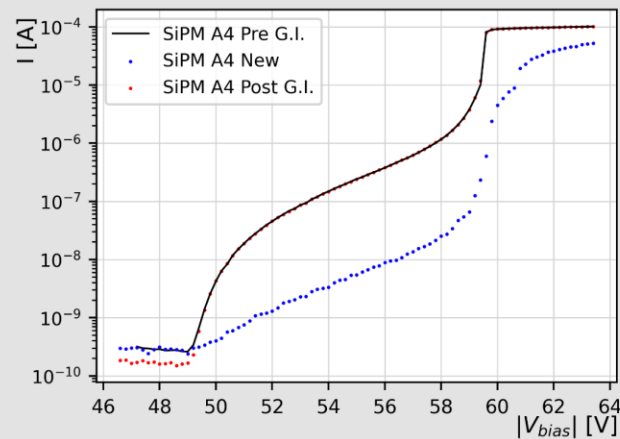
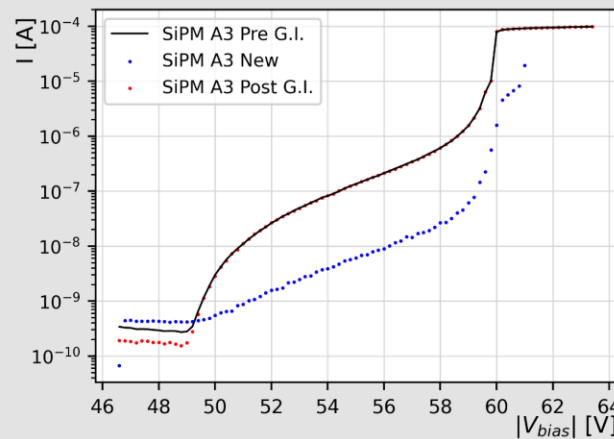
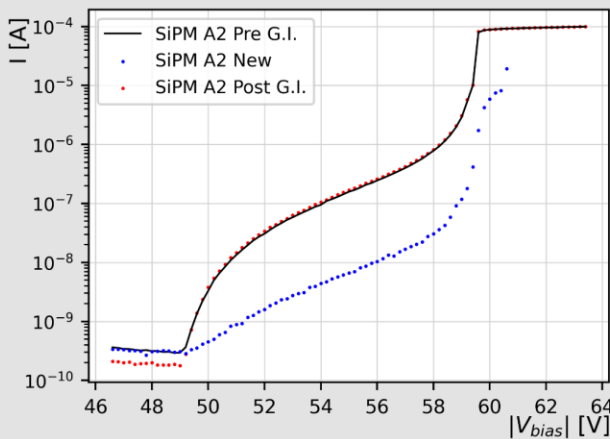
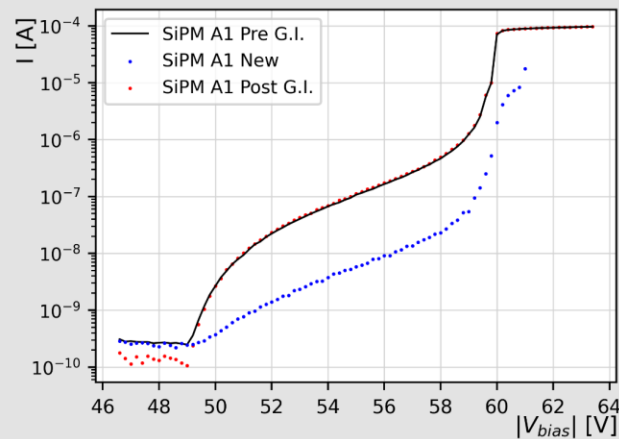
Board #5

Cosenza's Group



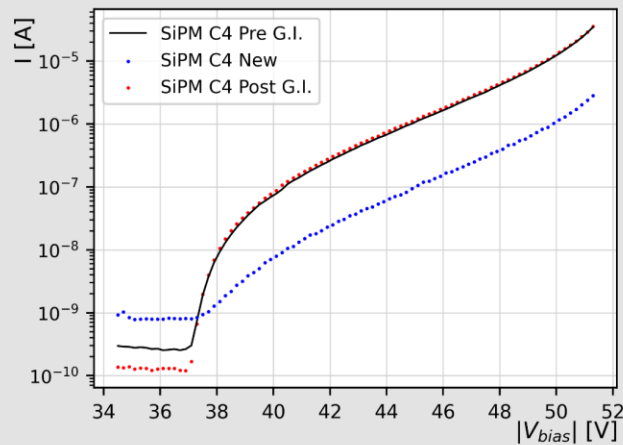
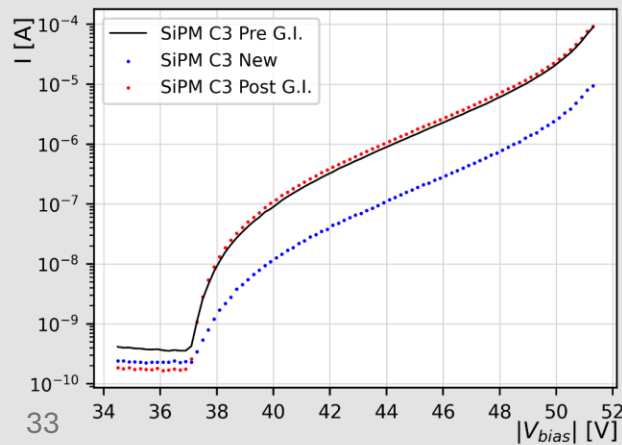
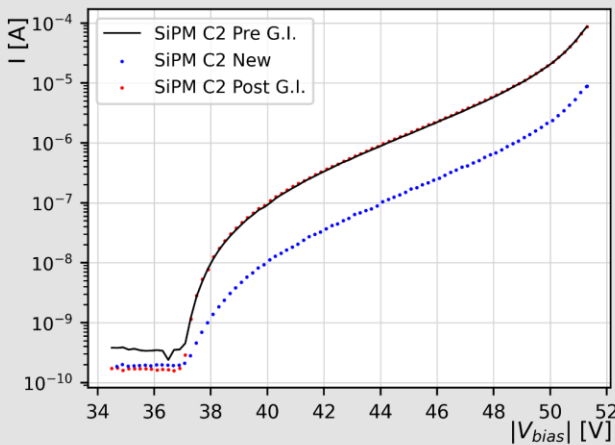
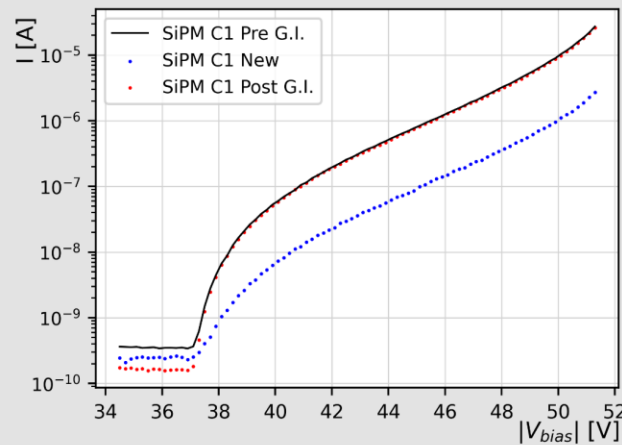
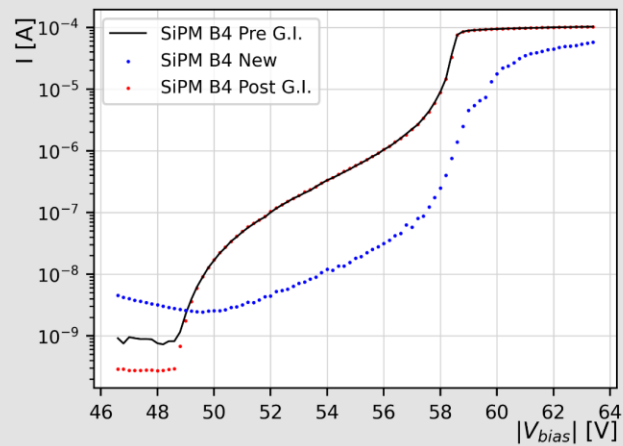
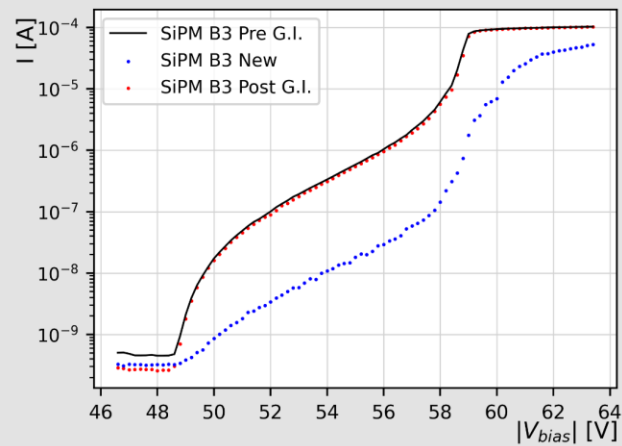
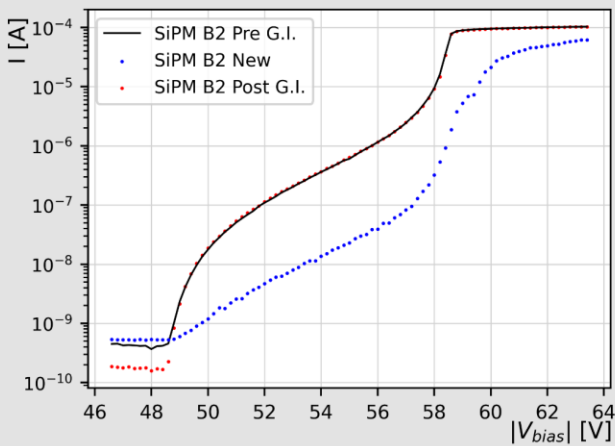
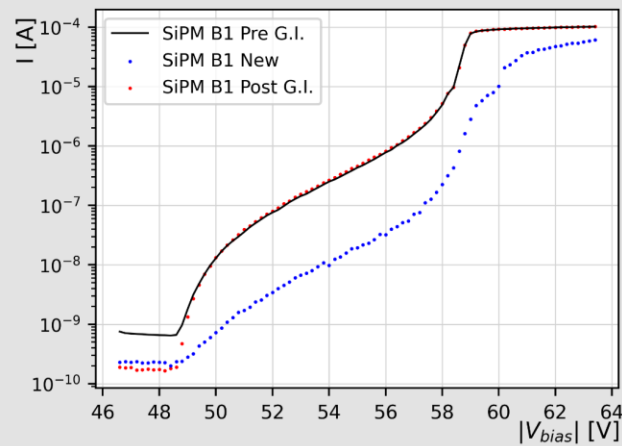
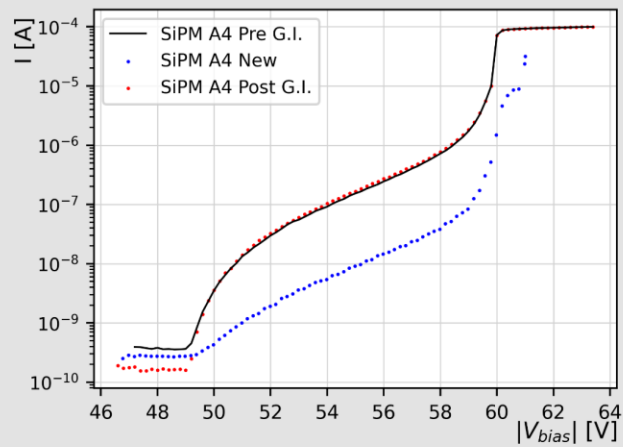
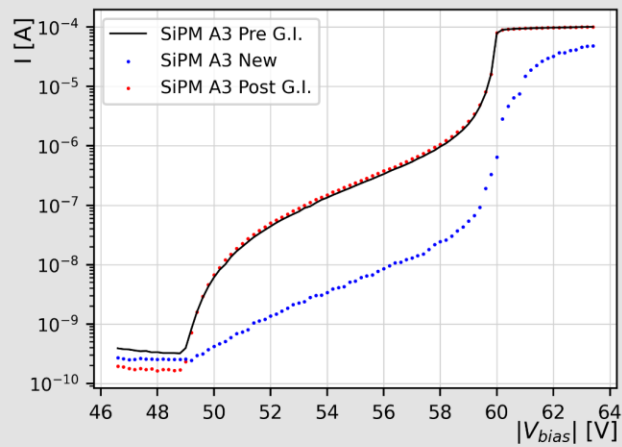
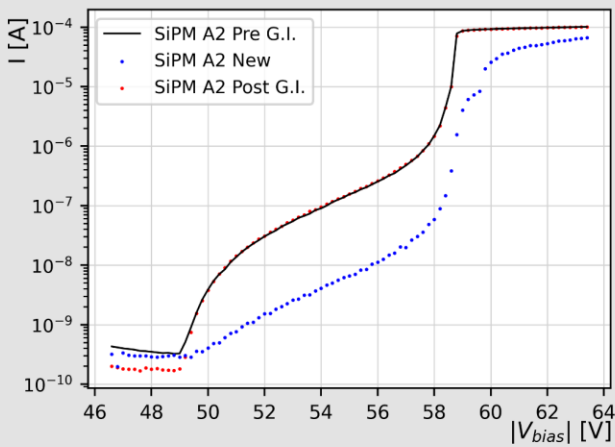
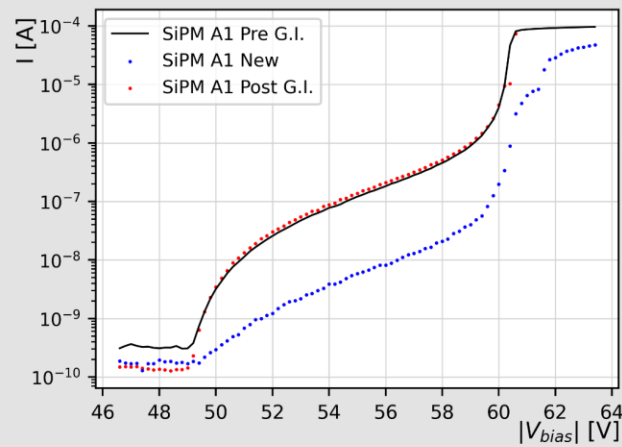
Board #6

Cosenza's Group



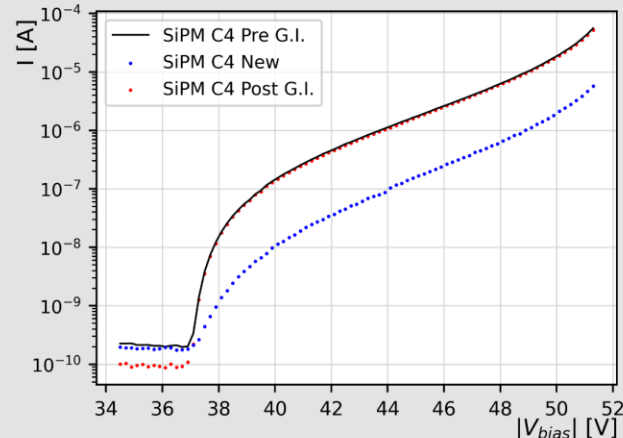
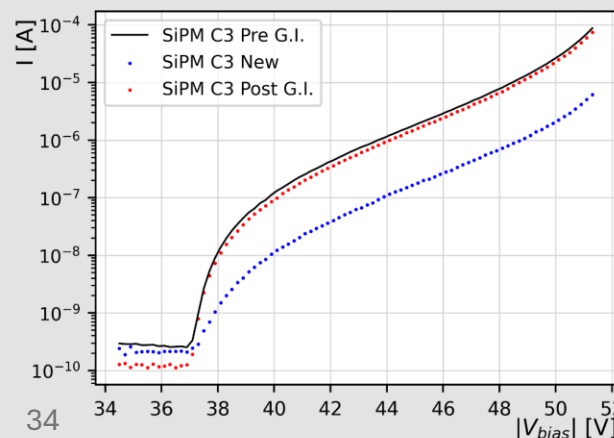
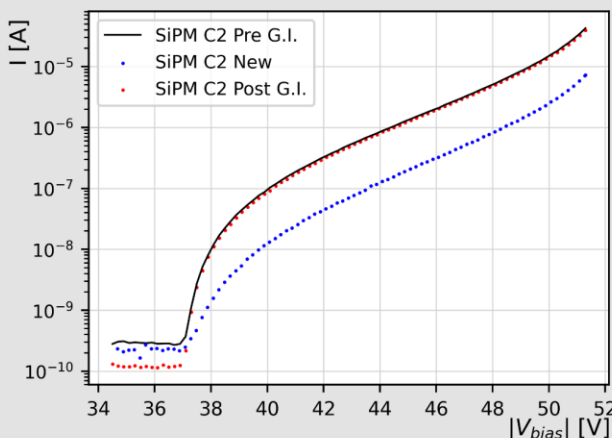
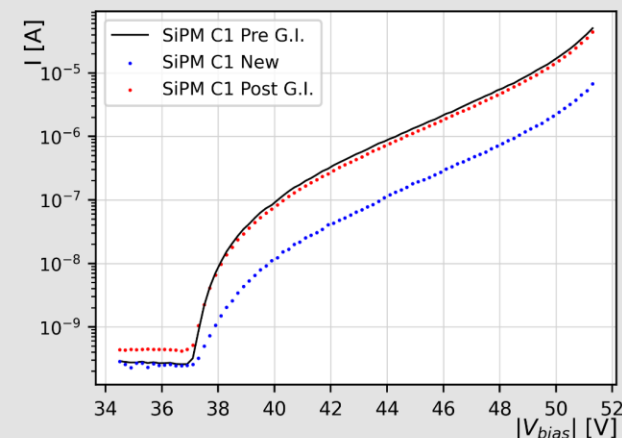
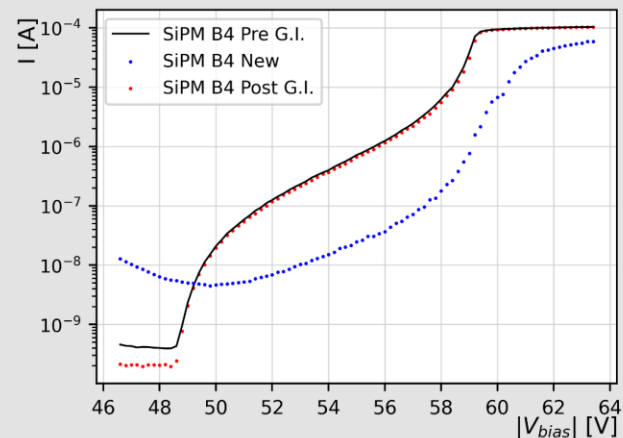
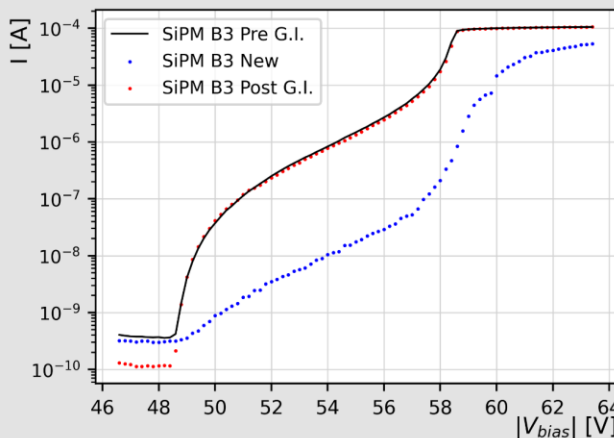
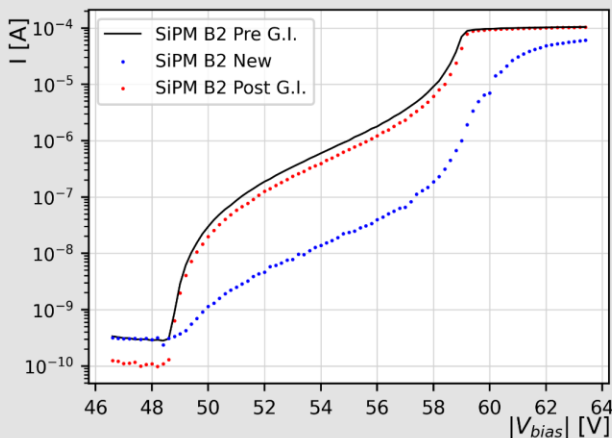
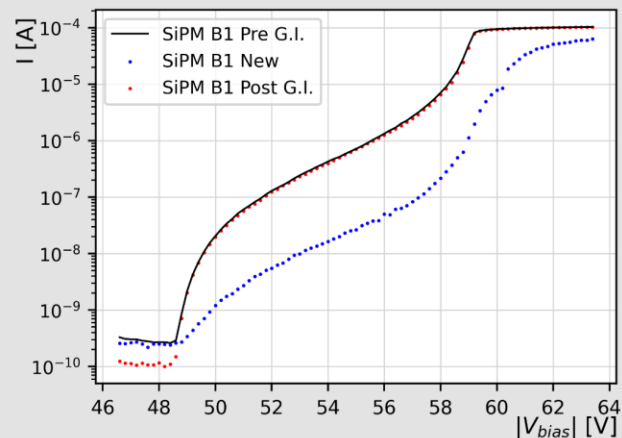
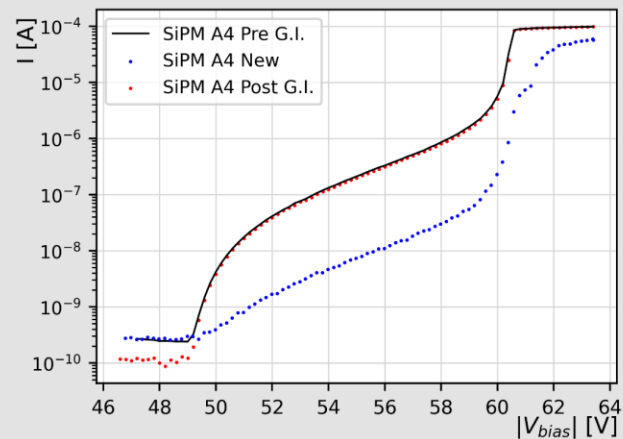
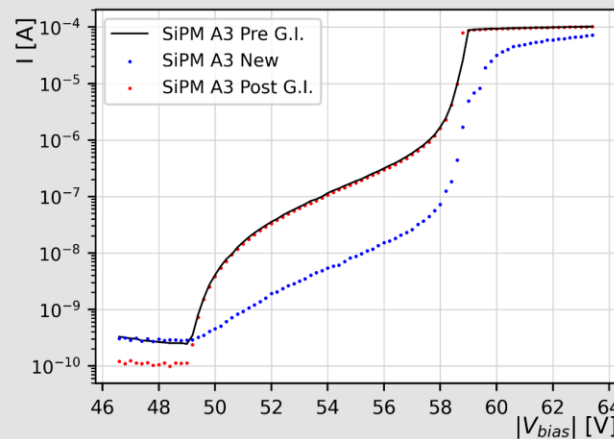
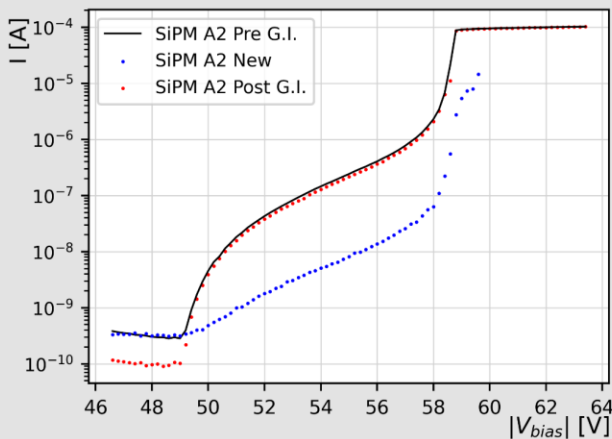
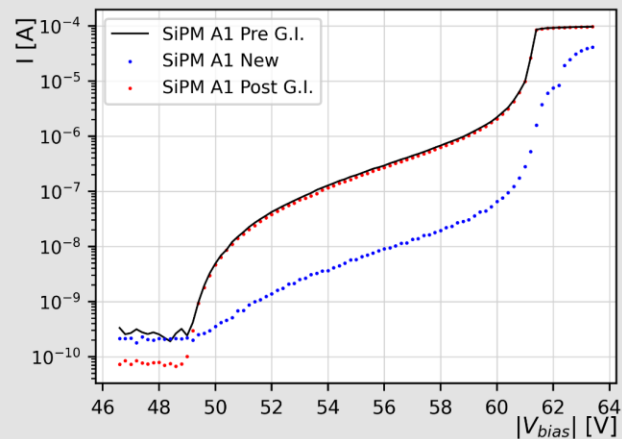
Board #8

Cosenza's Group



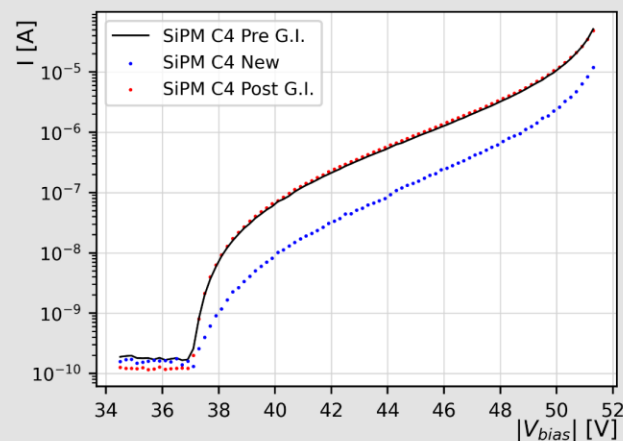
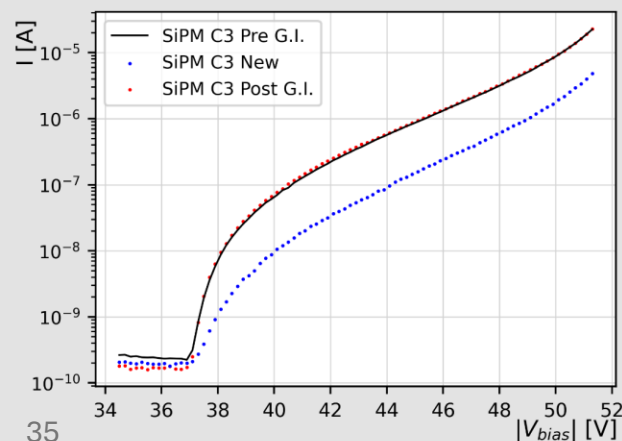
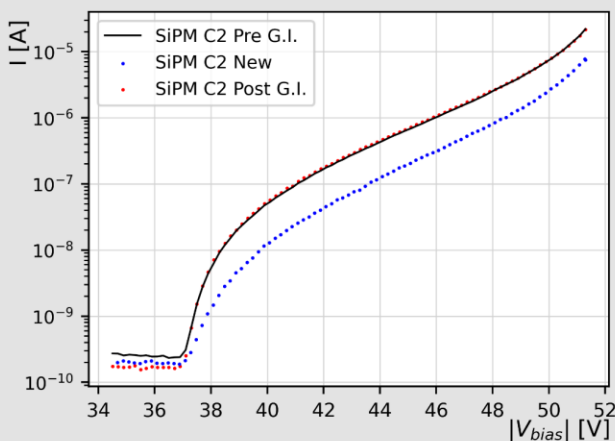
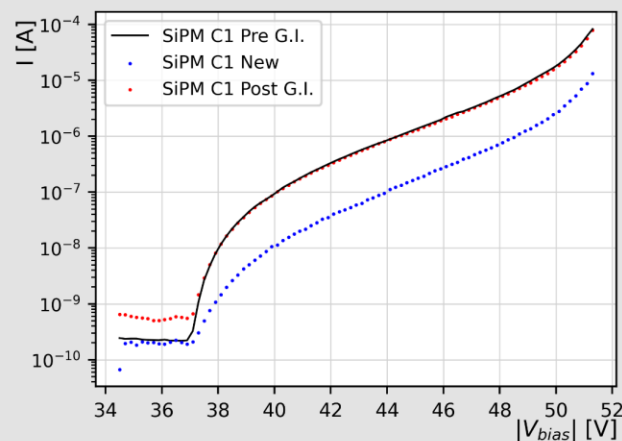
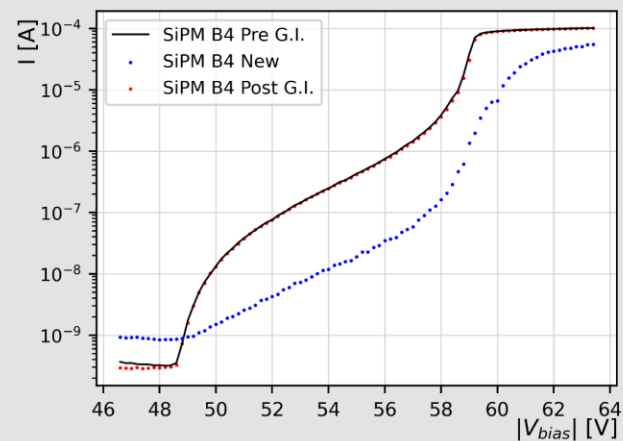
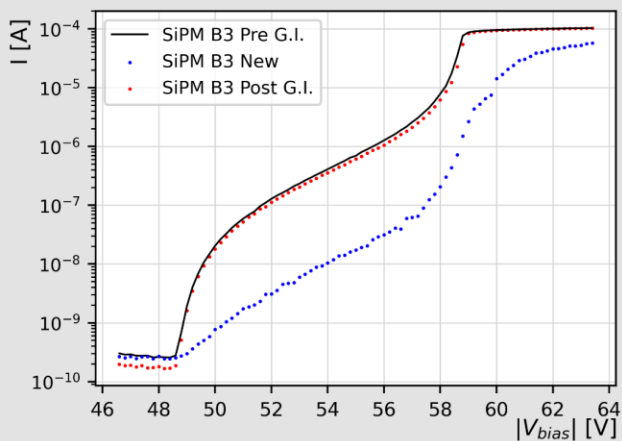
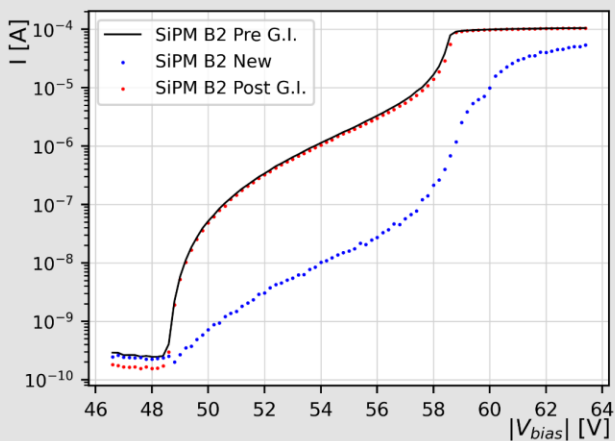
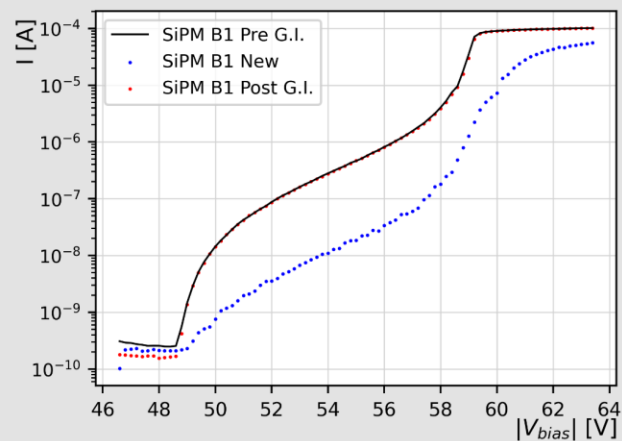
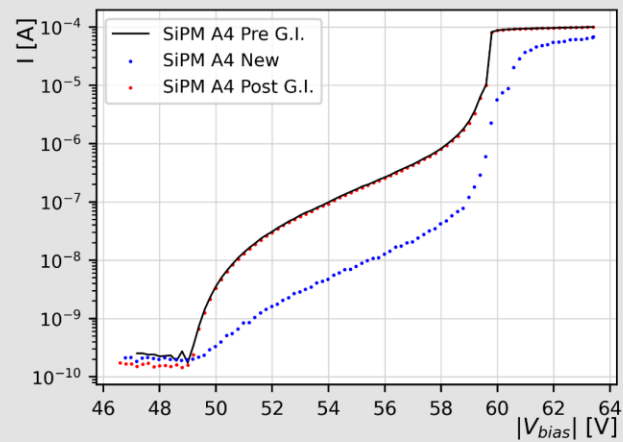
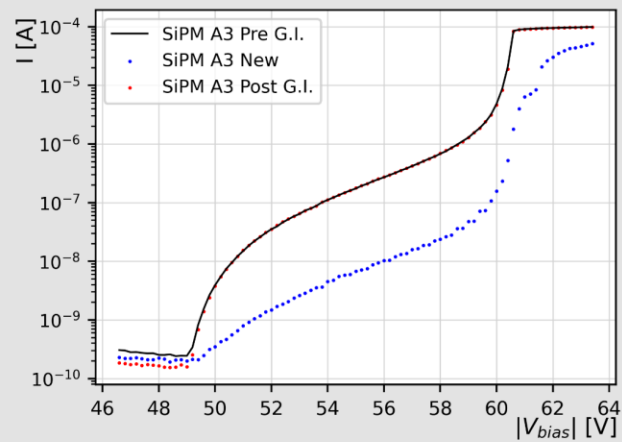
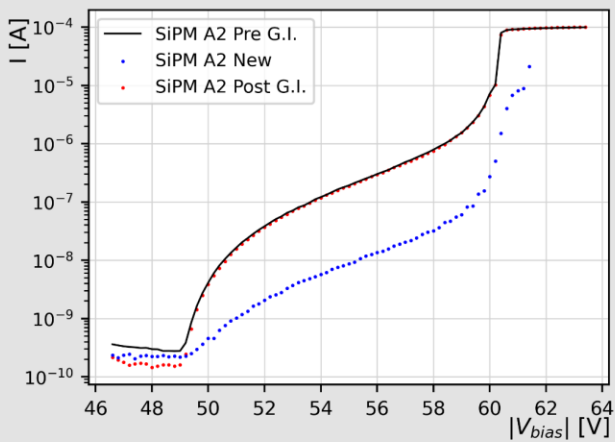
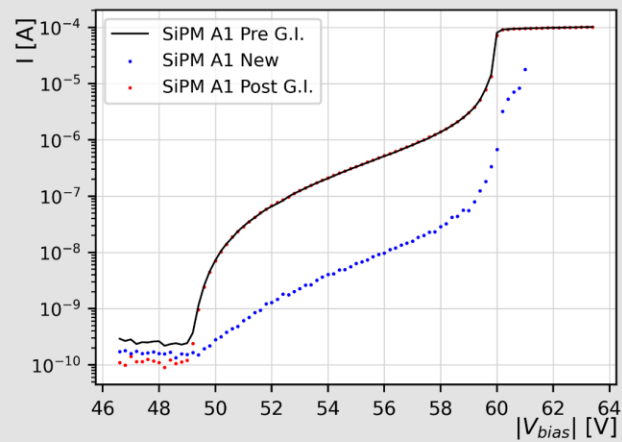
Board #9

Cosenza's Group



Board #10

Cosenza's Group



Comparative measures

Board #9 Box Comparison

Cosenza's Group

