Characterization of irradiated SiPM for the TOP detector at the Belle II experiment

Padova meeting
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Content

Done:

- Fit gain as function of bias voltage and extract breakdown voltage for low irradiated modules
- Darkcount rates for low irradiated modules
- Time resolutions for low irradiated modules

To Do:

- Extract breakdown voltage for highly irradiated modules
- Check time resolution of highly irradiated modules

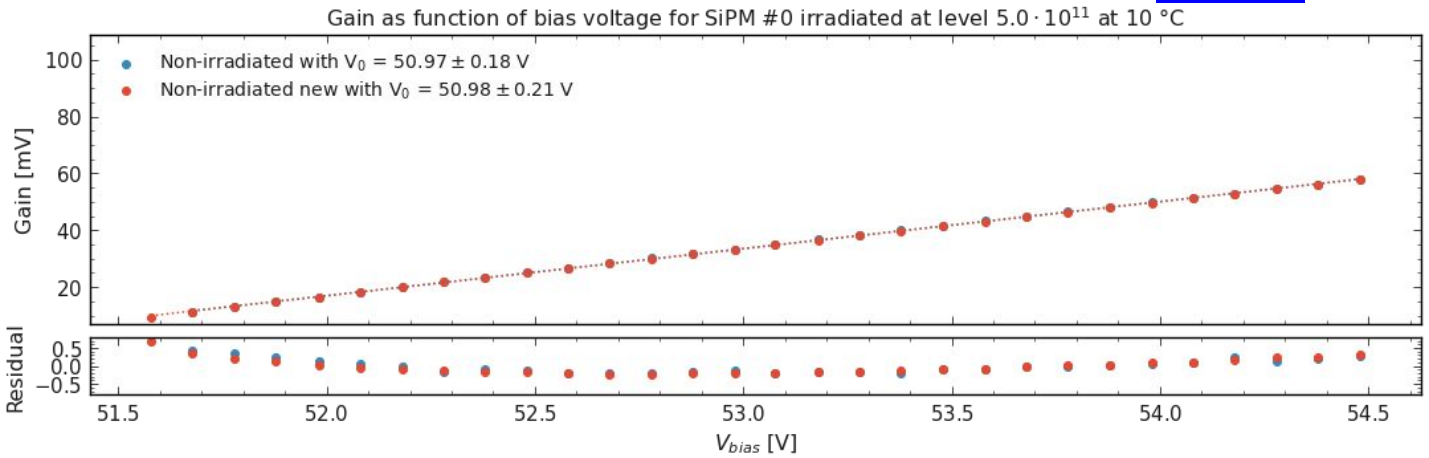
Tests with irradiated modules in Padova

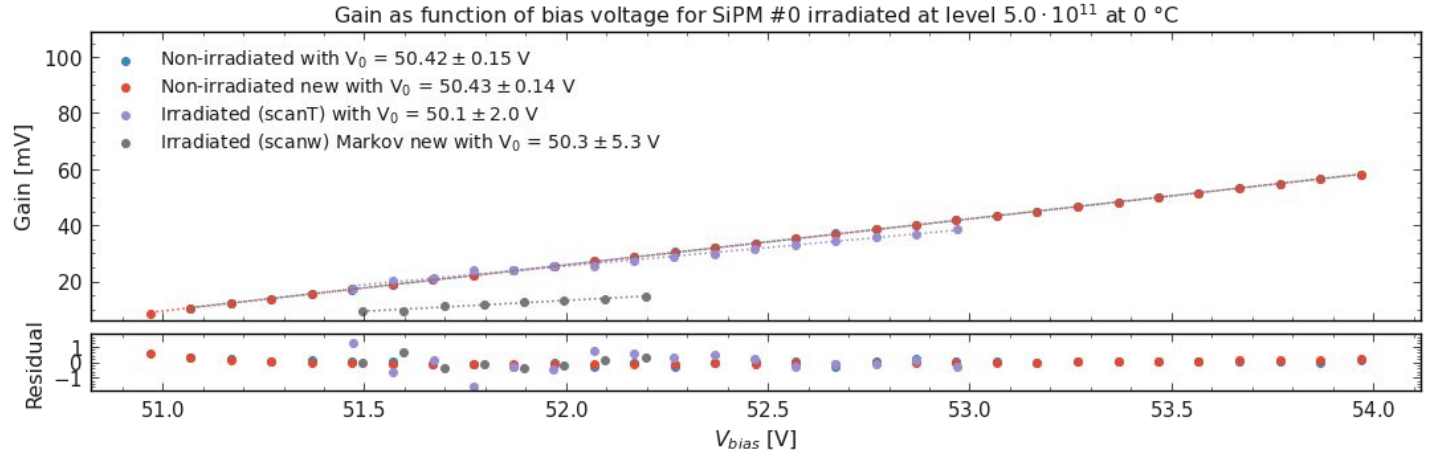
- In Belle II, MCP-PMTs with extended lifetime have been installed and they have limited lifetime depending on accumulated charge.
- We are trying to understand if they eventually can be replaced with SiPMs.
- We irradiated 24 SiPMs modules with different neutron fluxes and tested by laser.
- Sixteen of them are processed to study their response.
- Collected data are read from modules and analyzed.

Index	Producer	Dimension [mm×mm]	Pitch [μm]	Neutron 1 MeV eg/cm^2 fluence
0	Hamamatsu	1.3 × 1.3	50	$5.0{\cdot}10^{11}$
1	Hamamatsu	1.3 × 1.3	50	$2.0{\cdot}10^{11}$
2	Hamamatsu	1.3 × 1.3	50	$1.0{\cdot}10^{11}$
3	Hamamatsu	1.3 × 1.3	50	$5.0{\cdot}10^{10}$
4	Hamamatsu	1.3 × 1.3	50	$2.0{\cdot}10^{10}$
5	Hamamatsu	1.3 × 1.3	50	$1.0{\cdot}10^{10}$
6	Hamamatsu	1.3 × 1.3	50	$5.0{\cdot}10^{9}$
7	Hamamatsu	1.3 × 1.3	50	$1.0{\cdot}10^{9}$

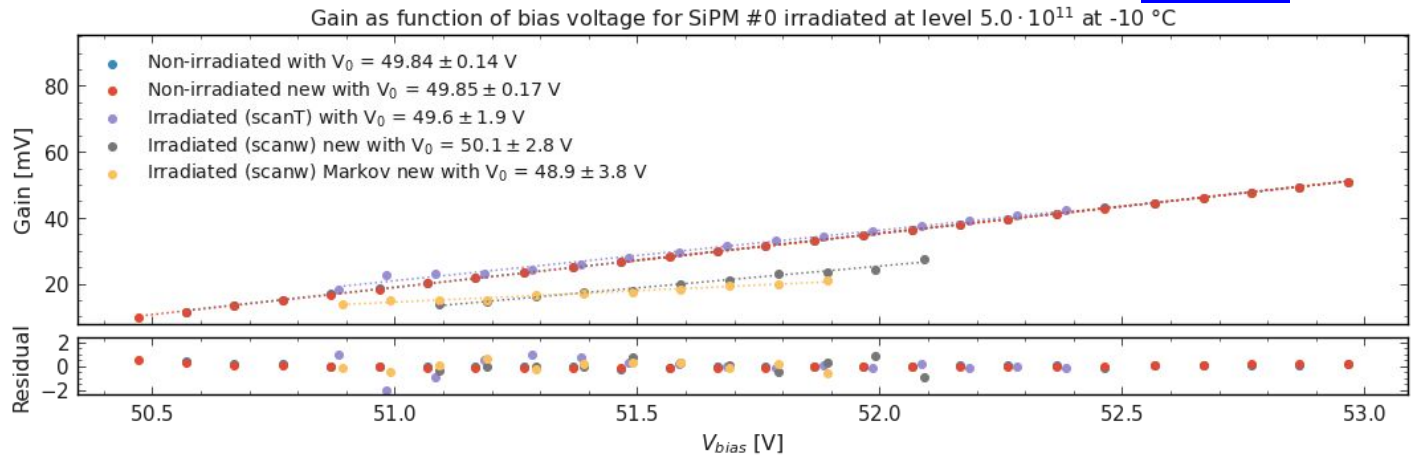
SiMP #0

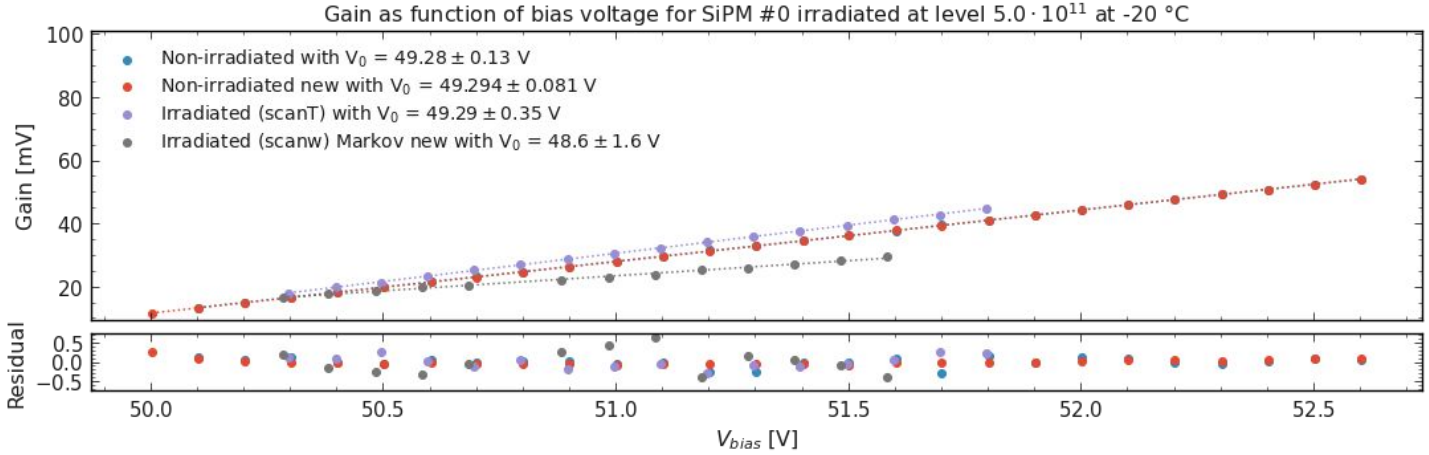
Gain as function of bias voltage



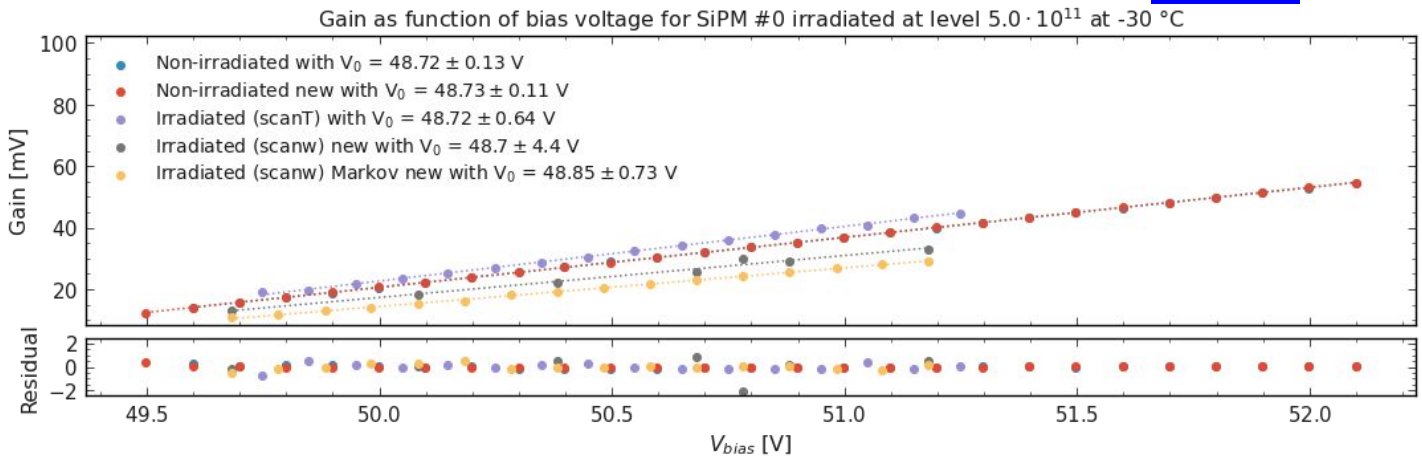


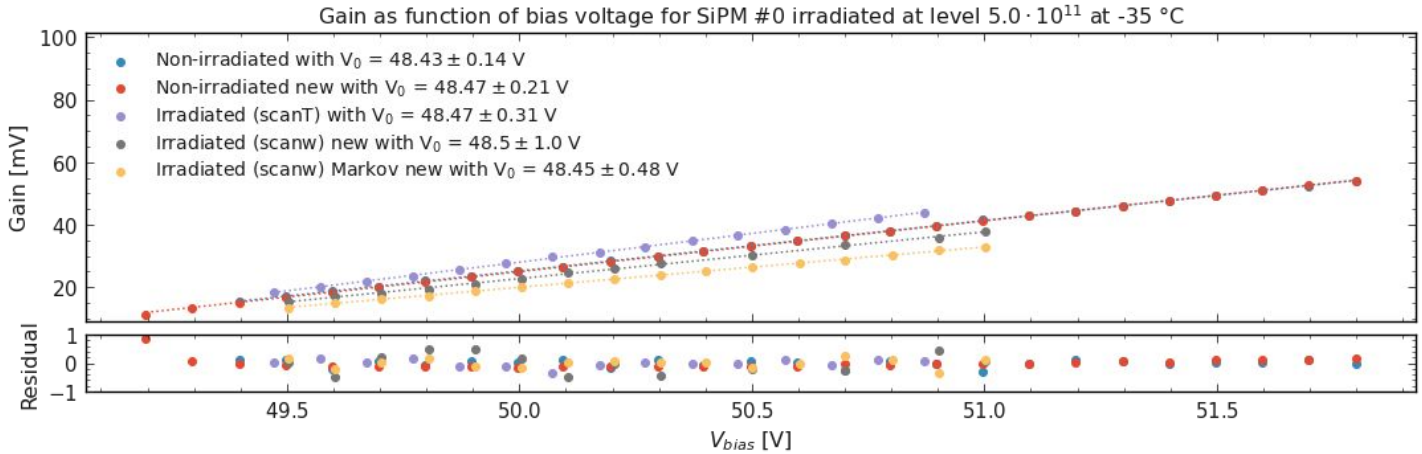
Gain as function of bias voltage



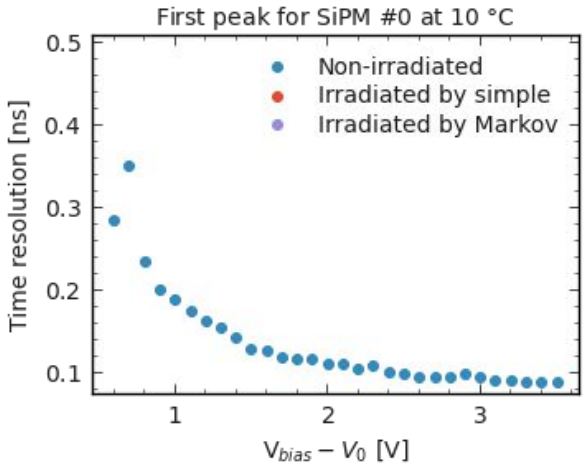


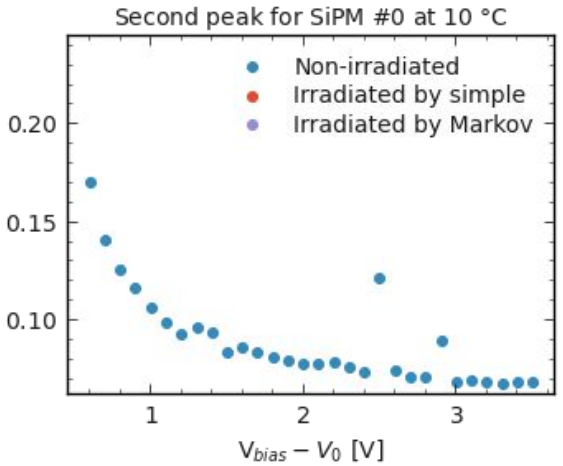
Gain as function of bias voltage

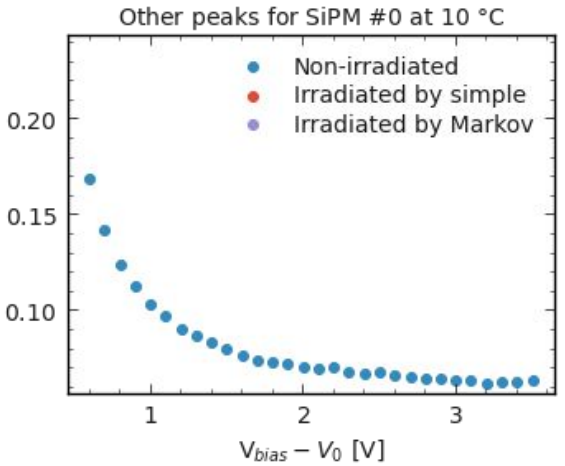


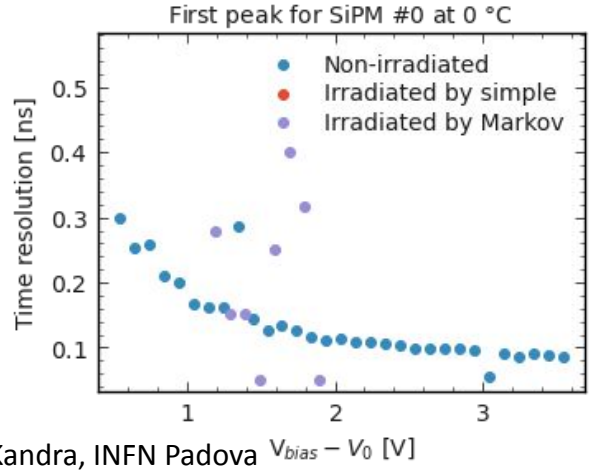


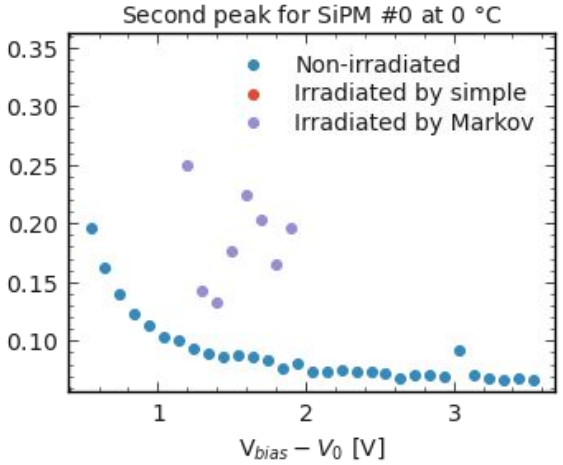
Time resolution

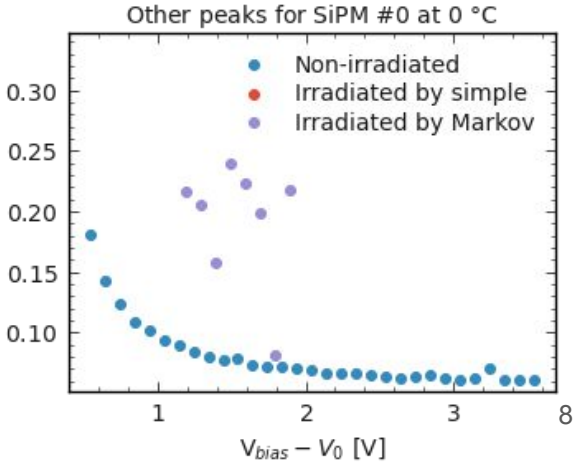




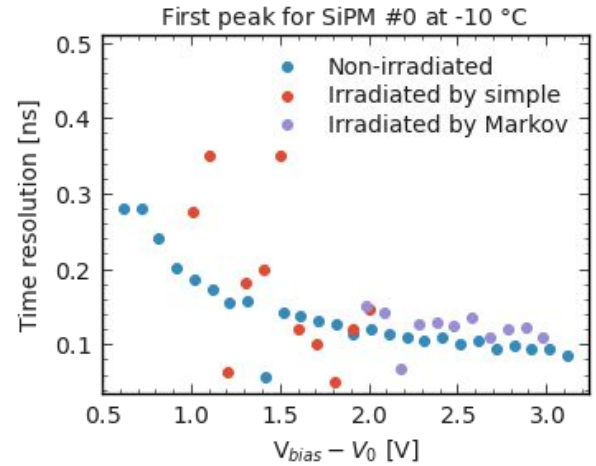


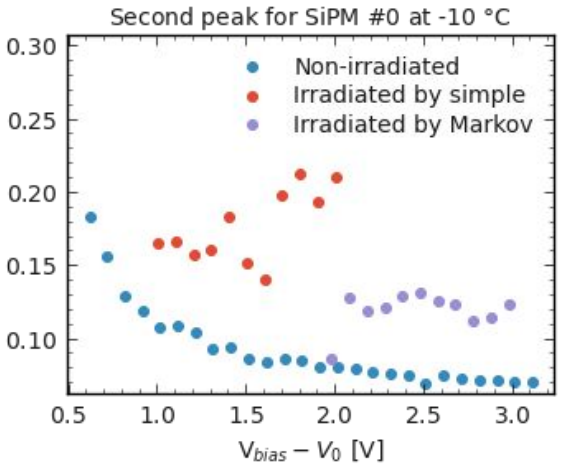


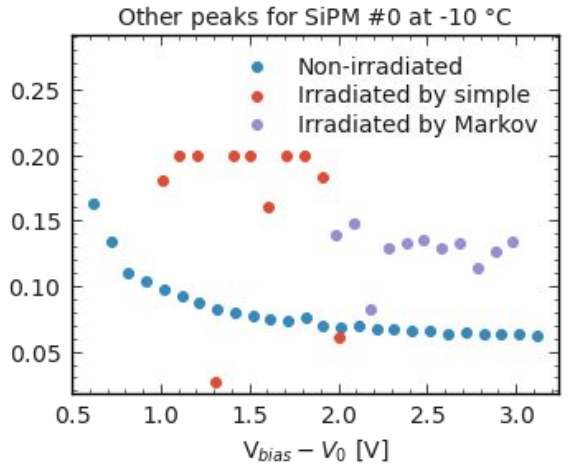


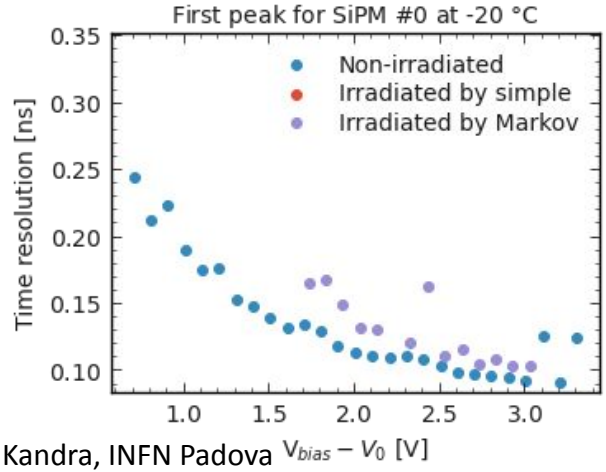


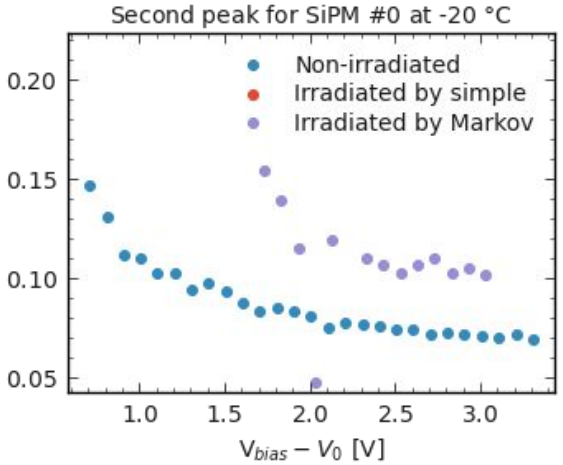
Time resolution

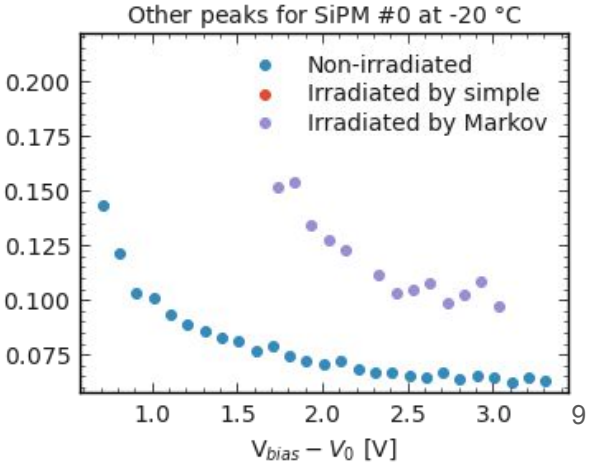




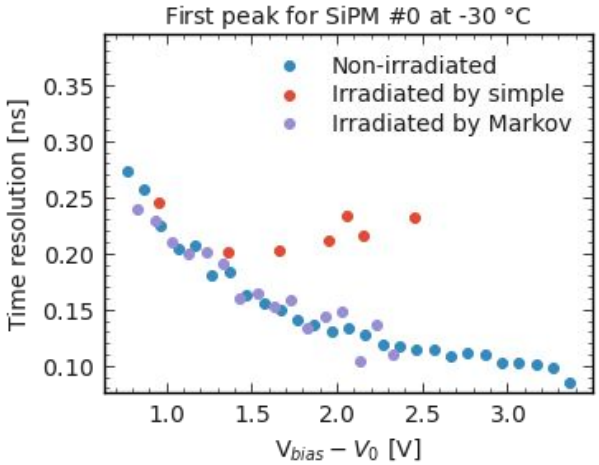


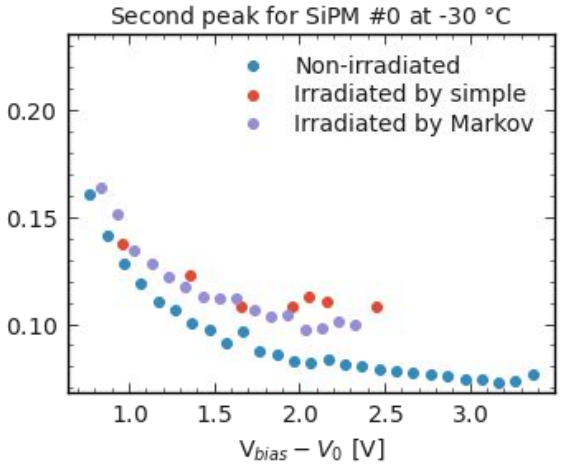


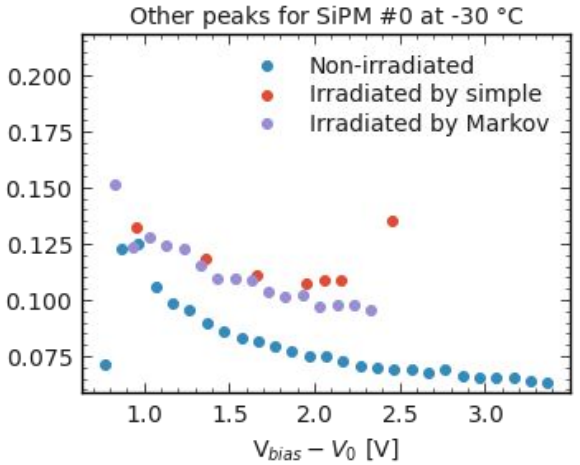


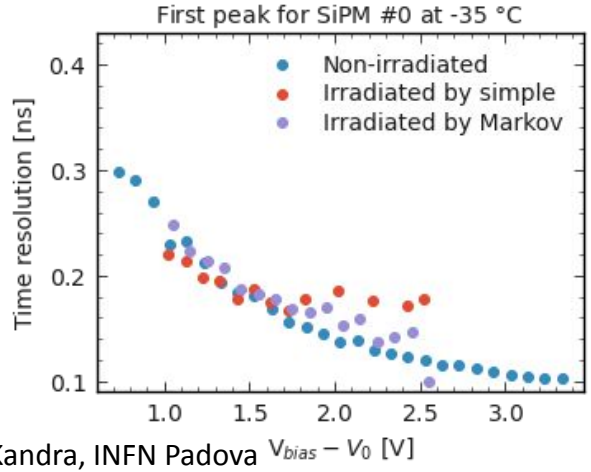


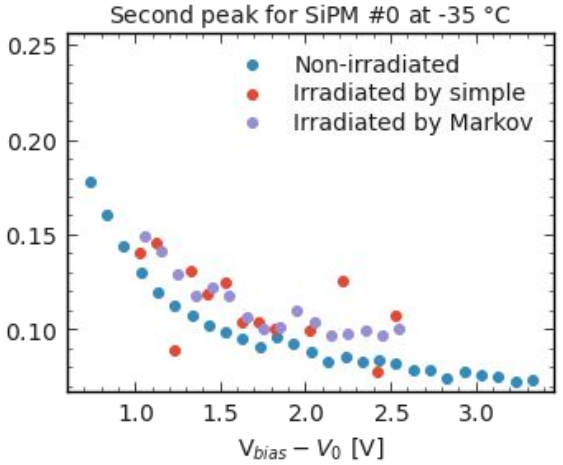
Time resolution

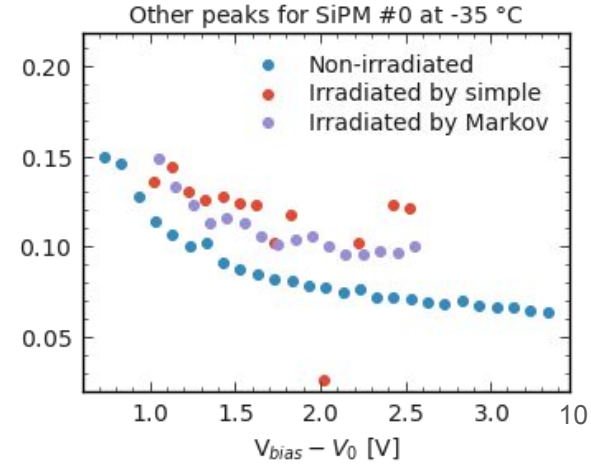




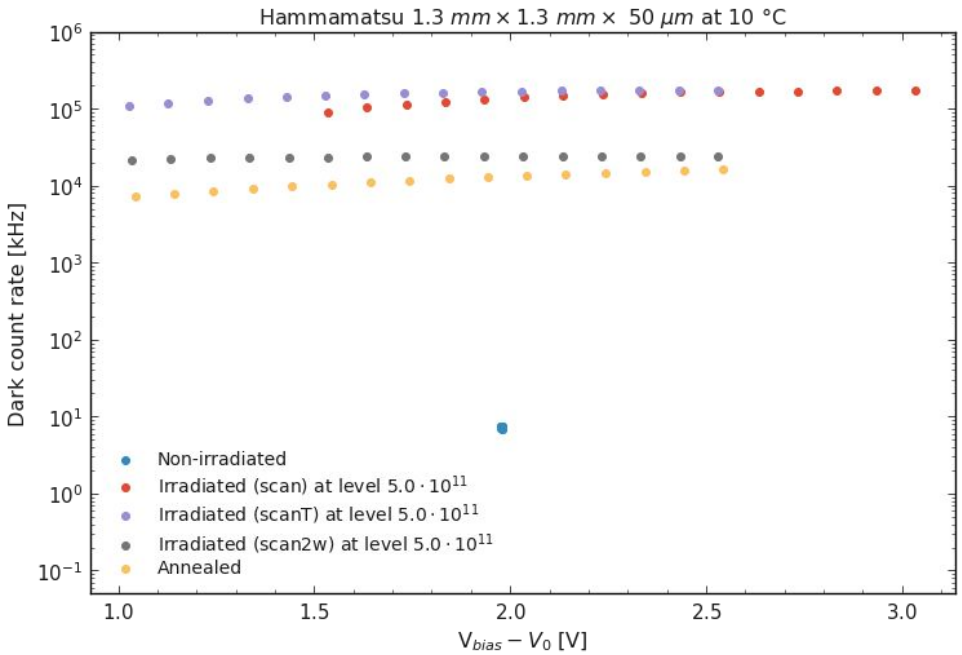


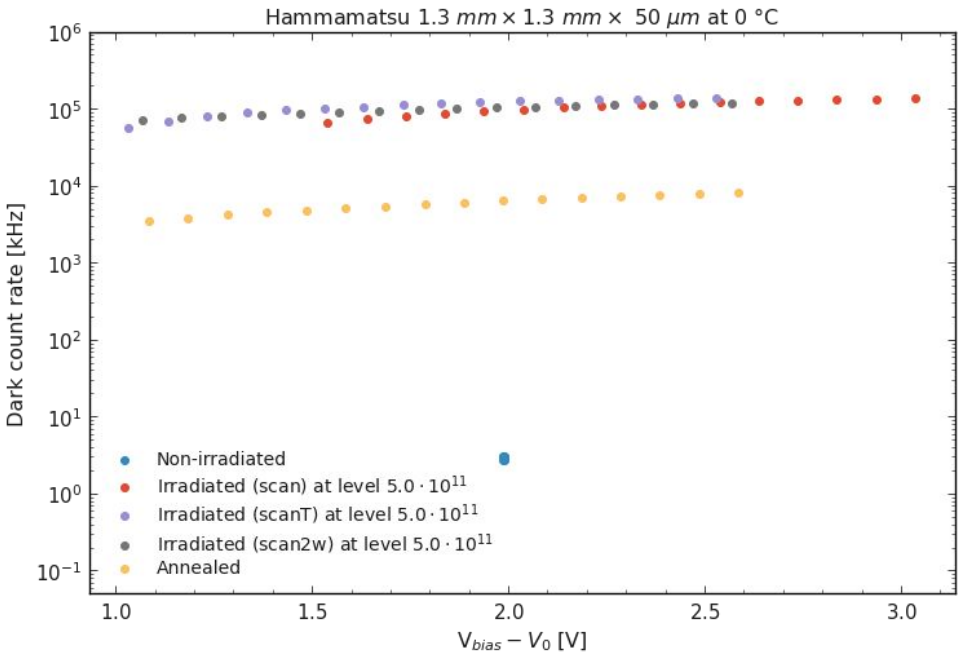






Dark count rate





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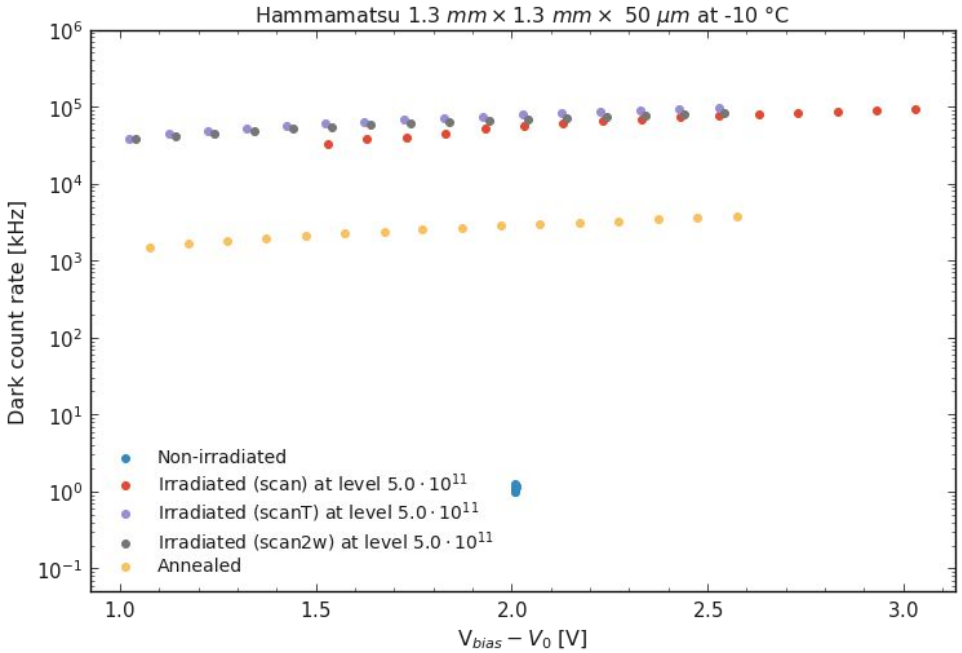

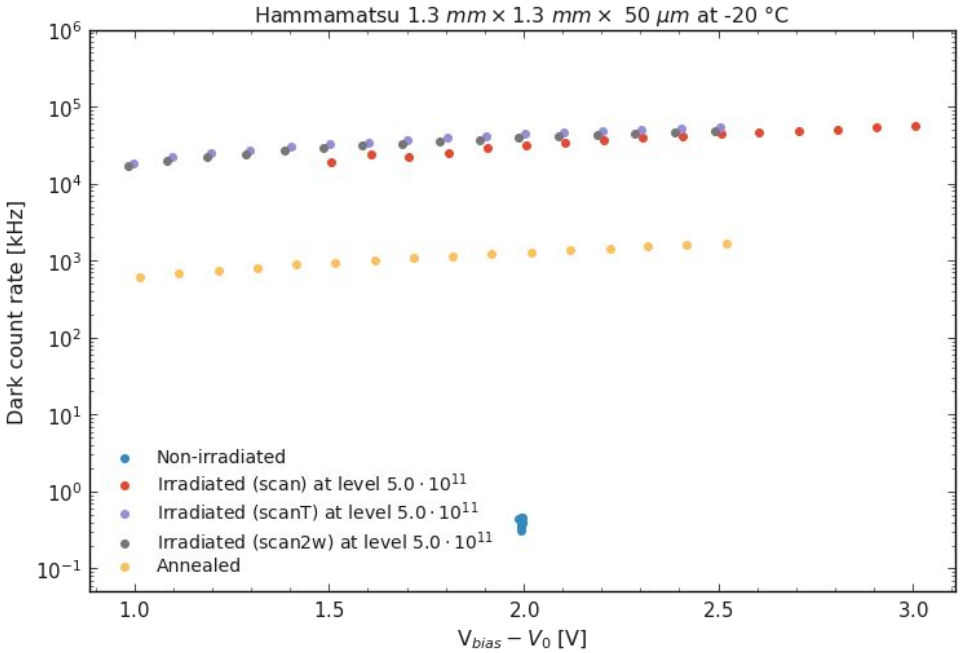

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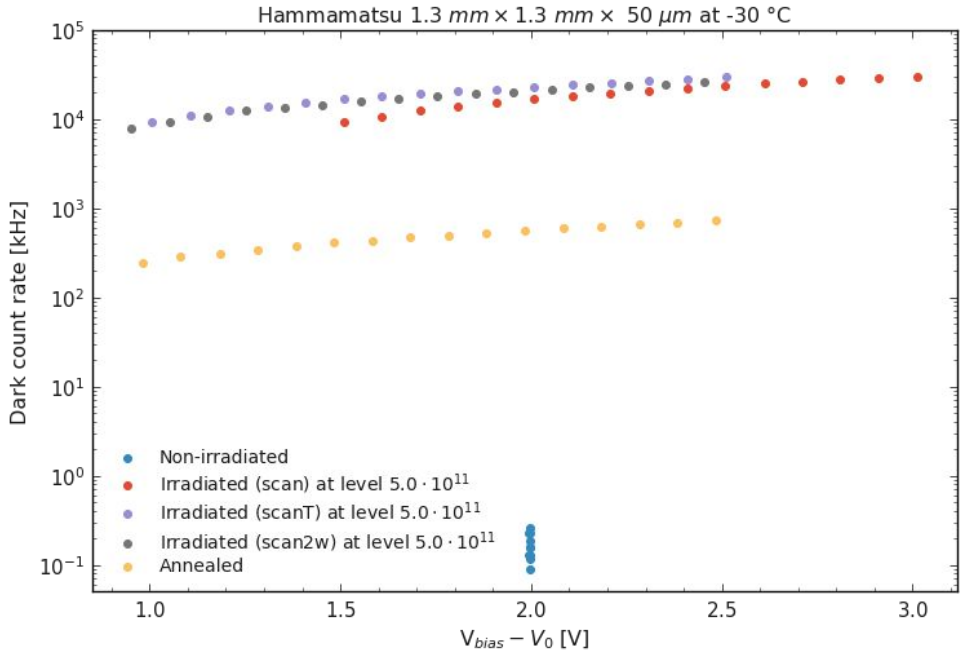
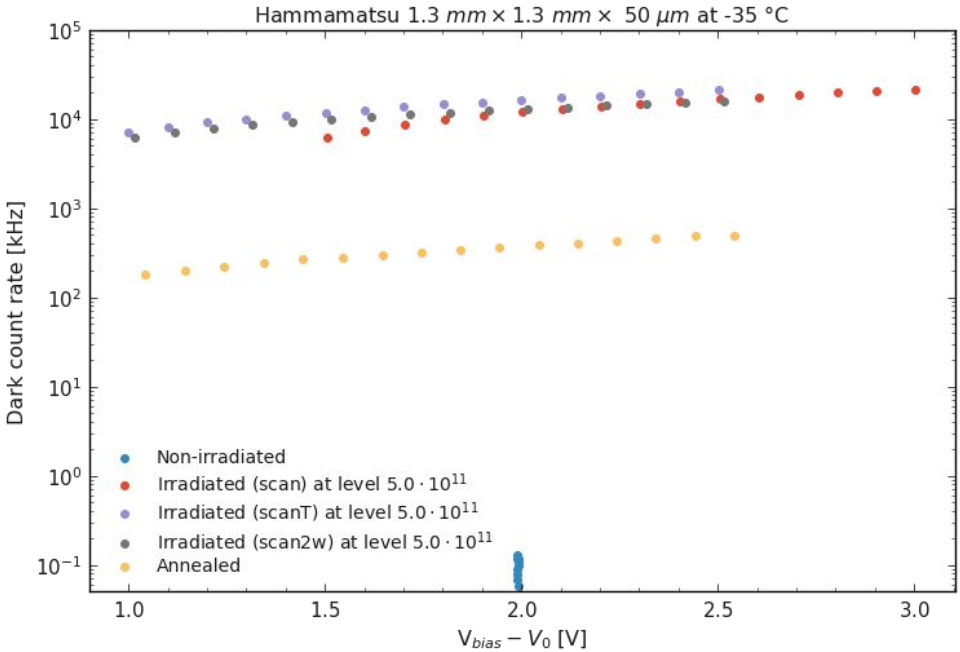
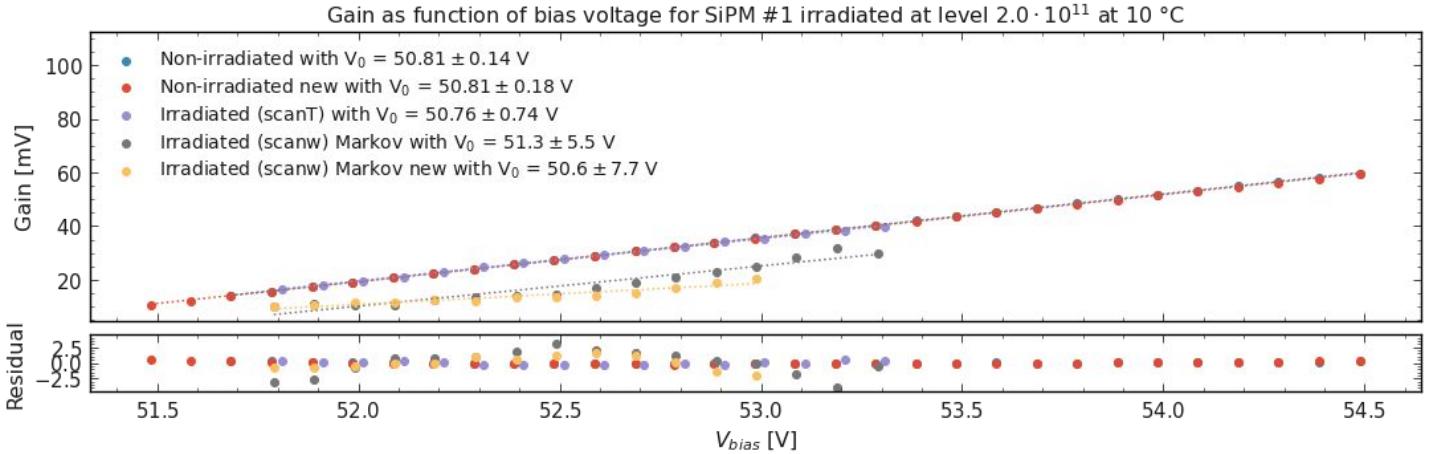
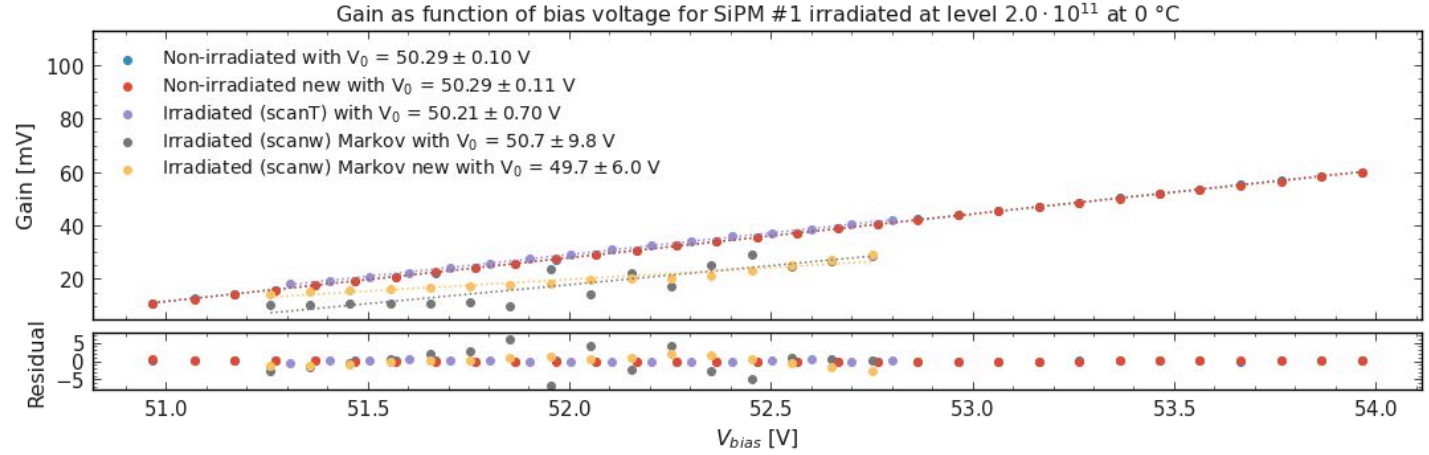




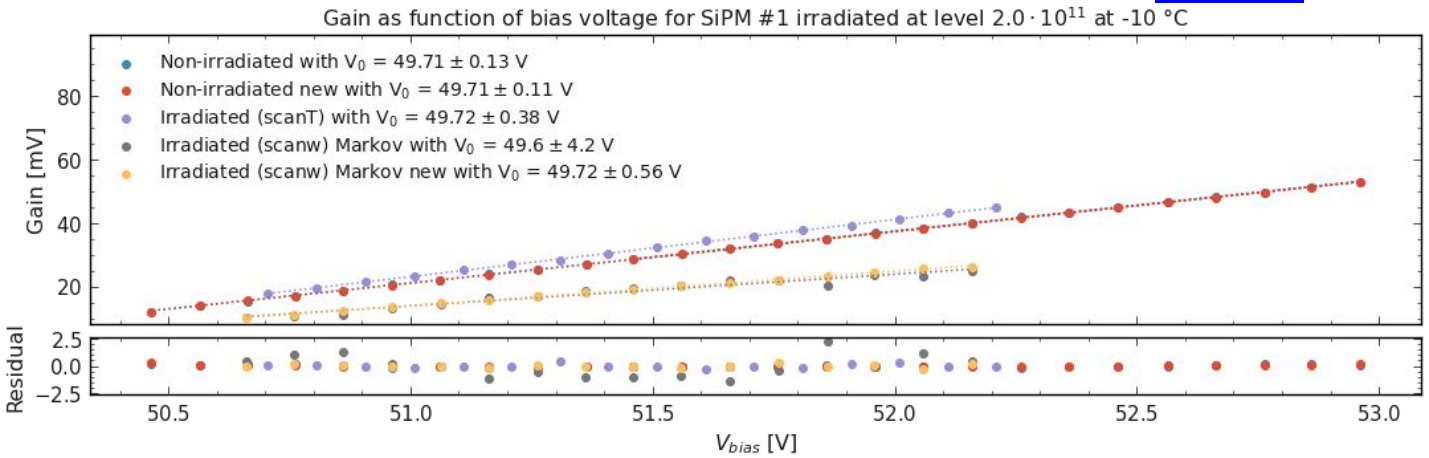
SiMP #1

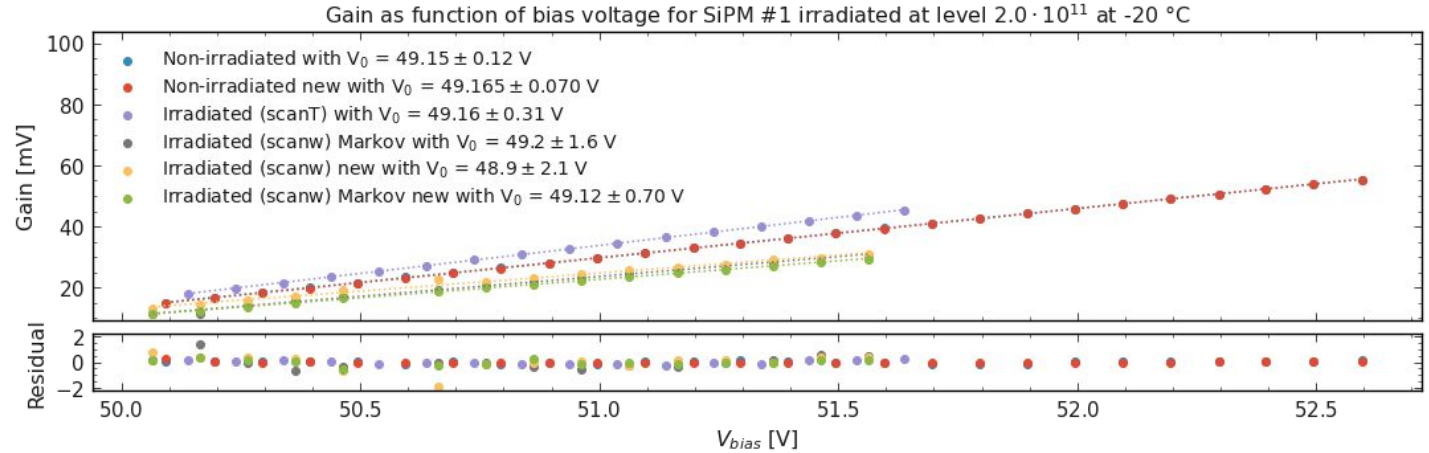
Gain as function of bias voltage



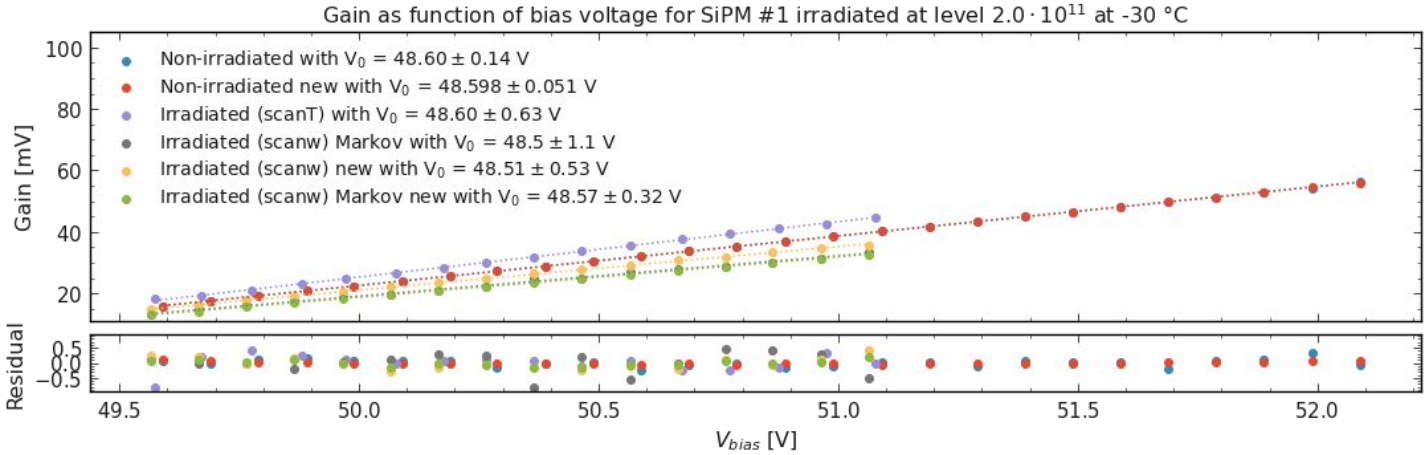


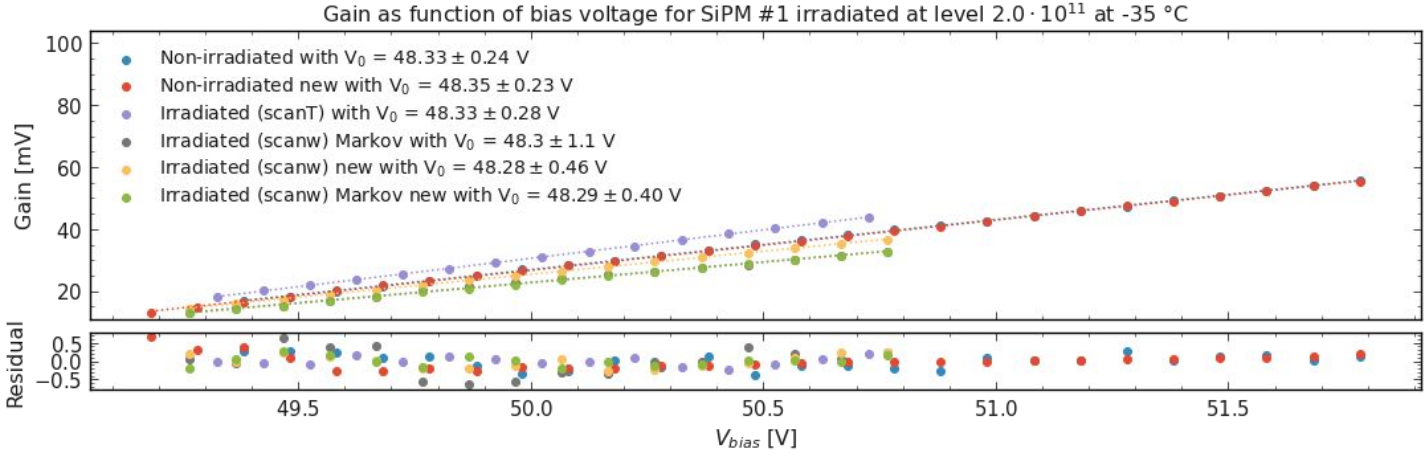
Gain as function of bias voltage



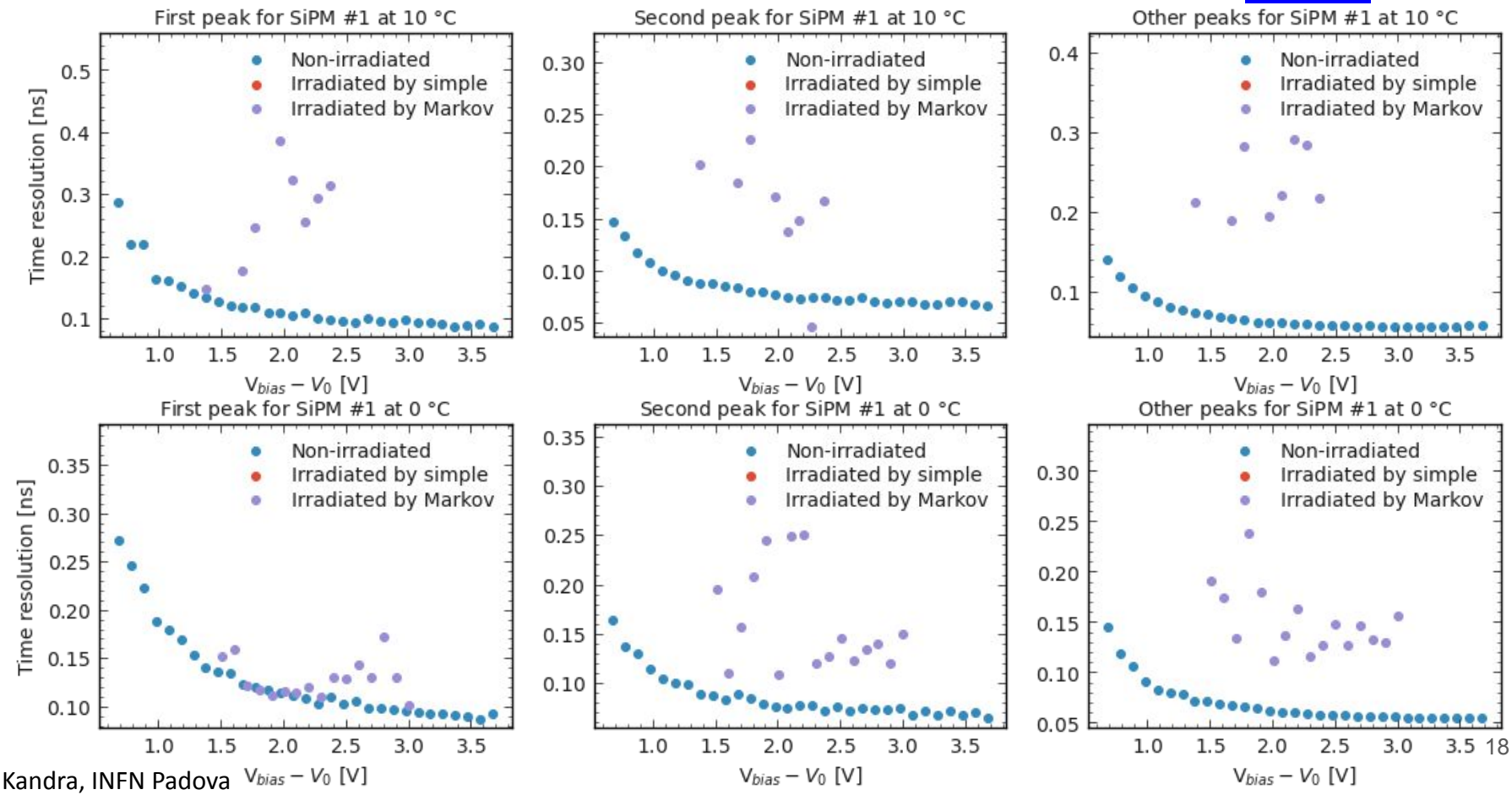


Gain as function of bias voltage





Time resolution



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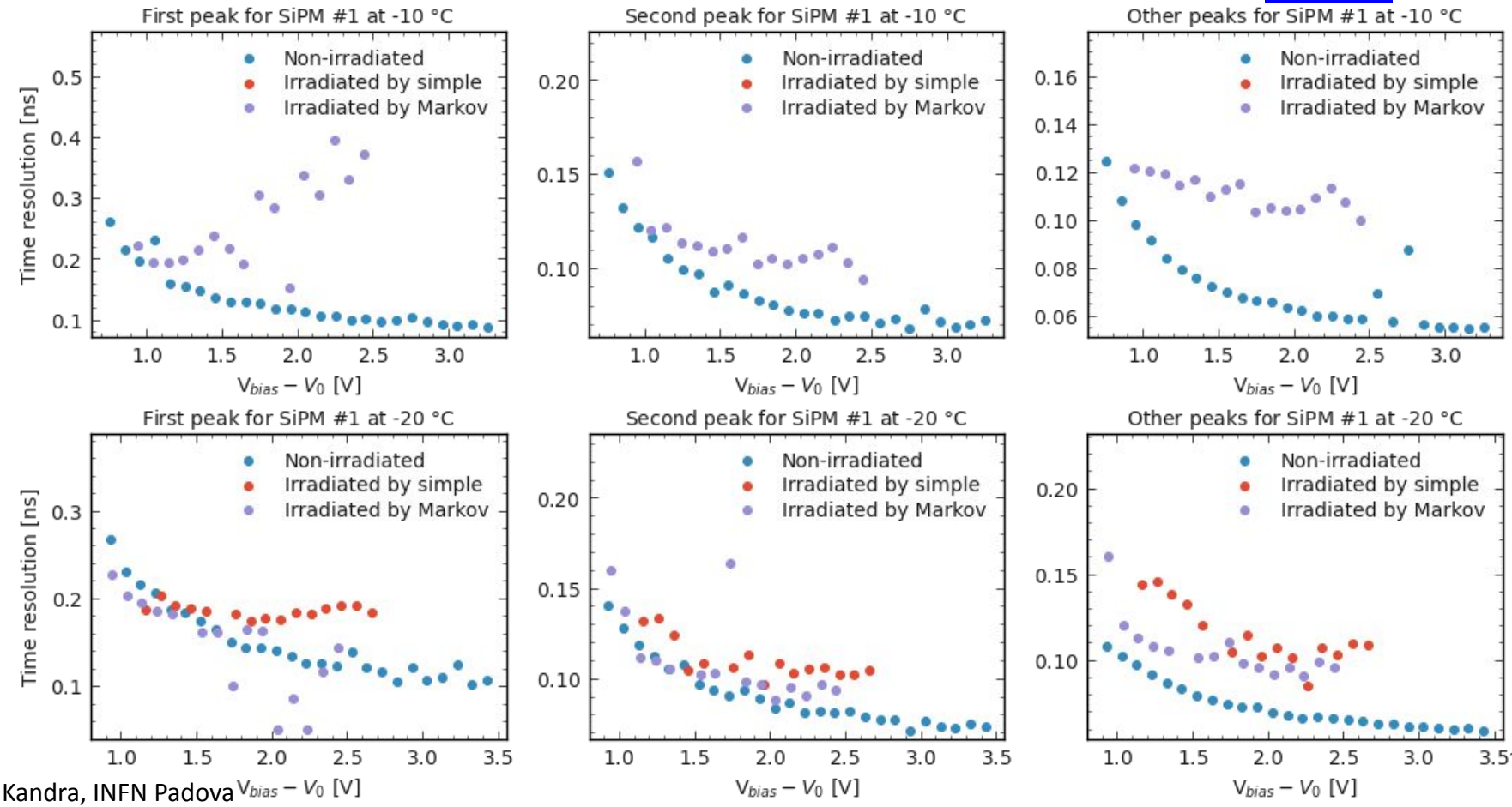
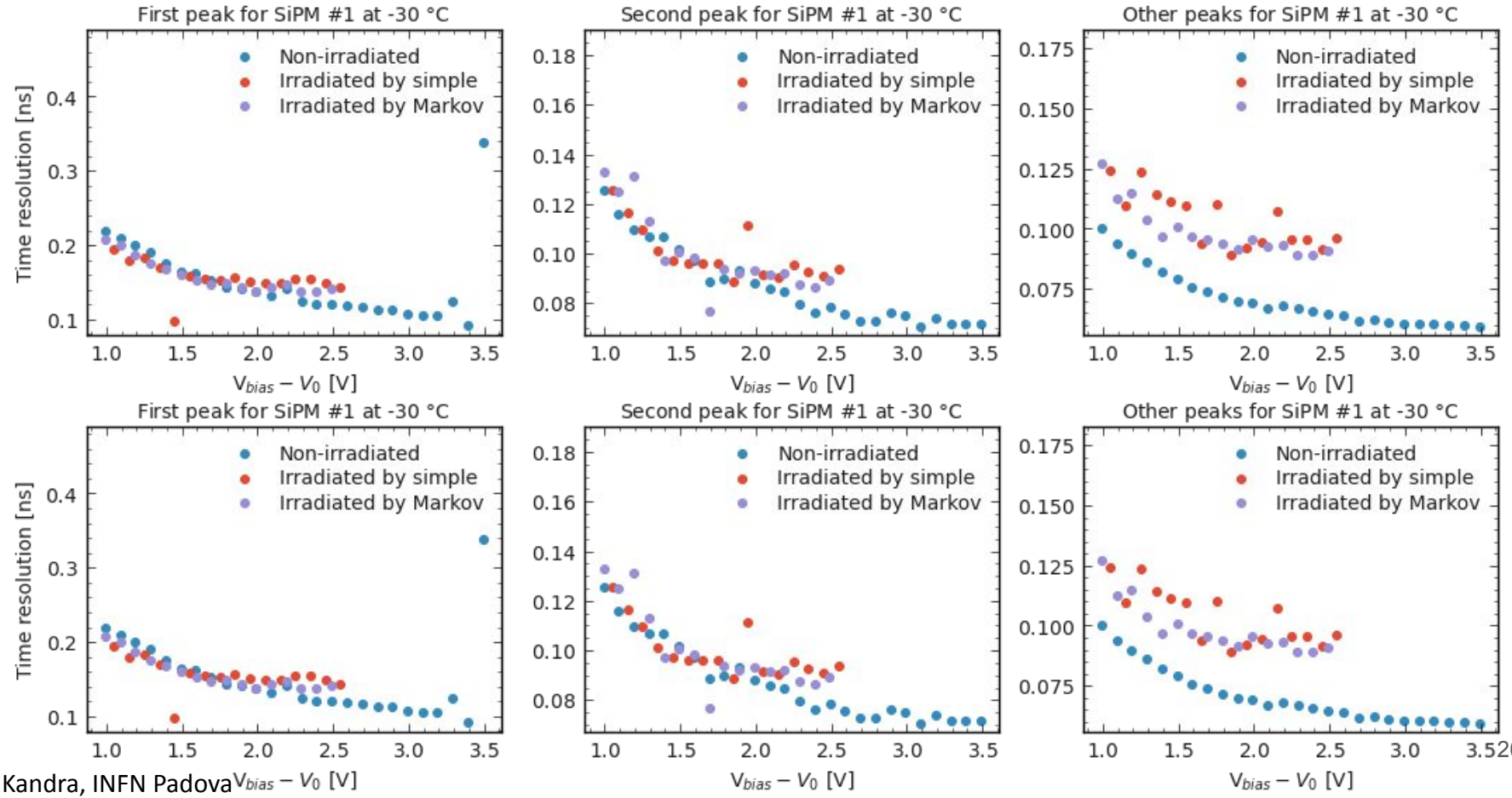
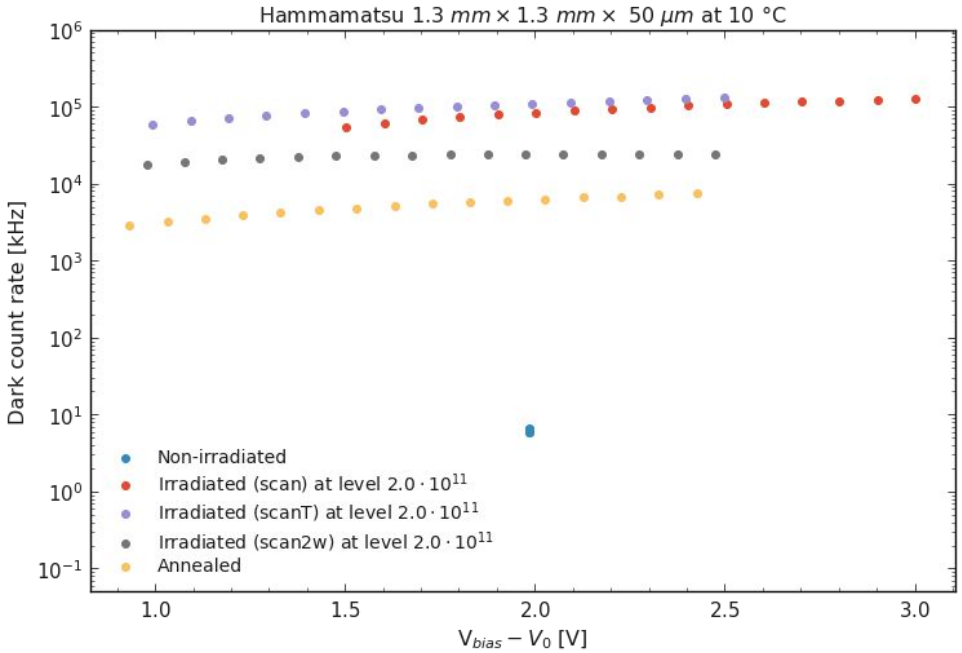
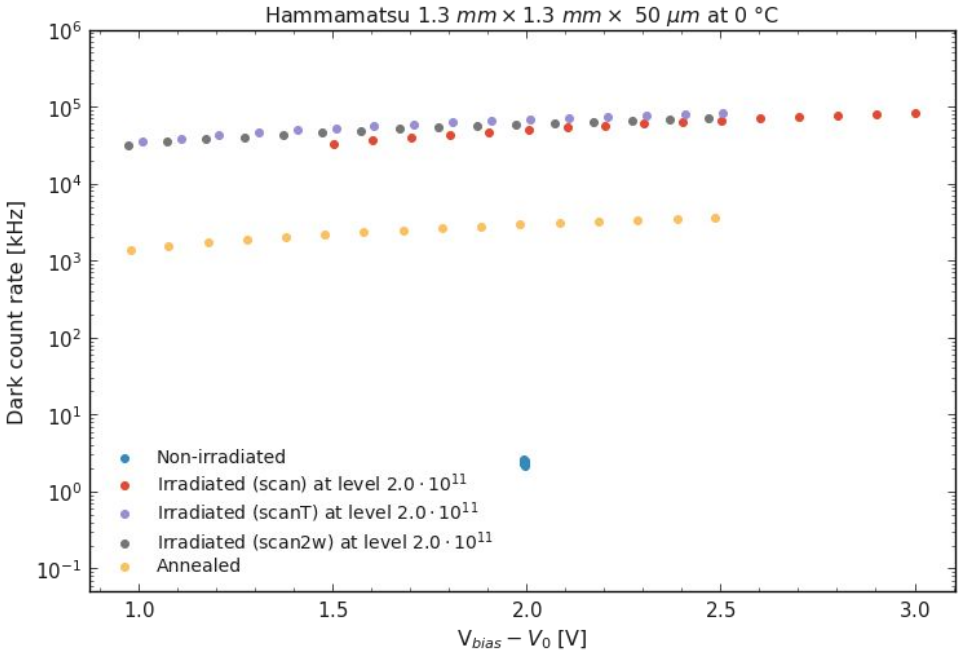


Time resolution



Dark count rate





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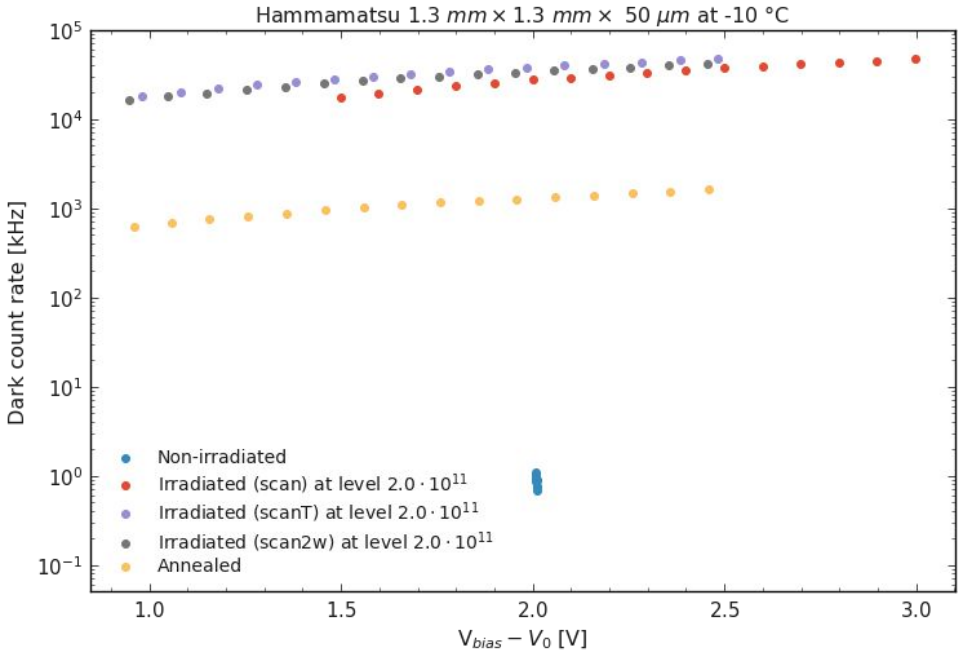
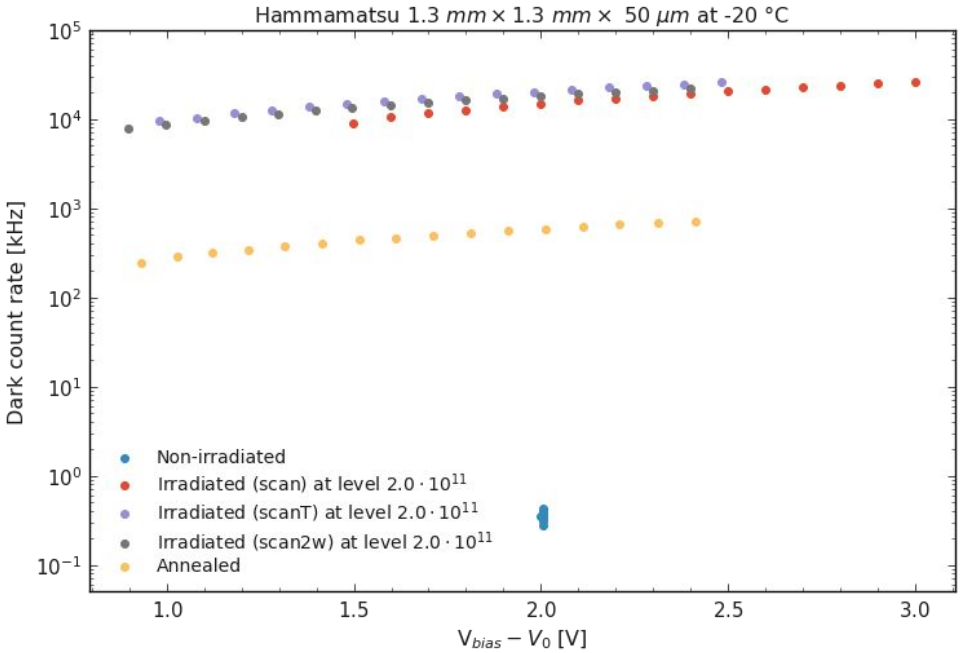
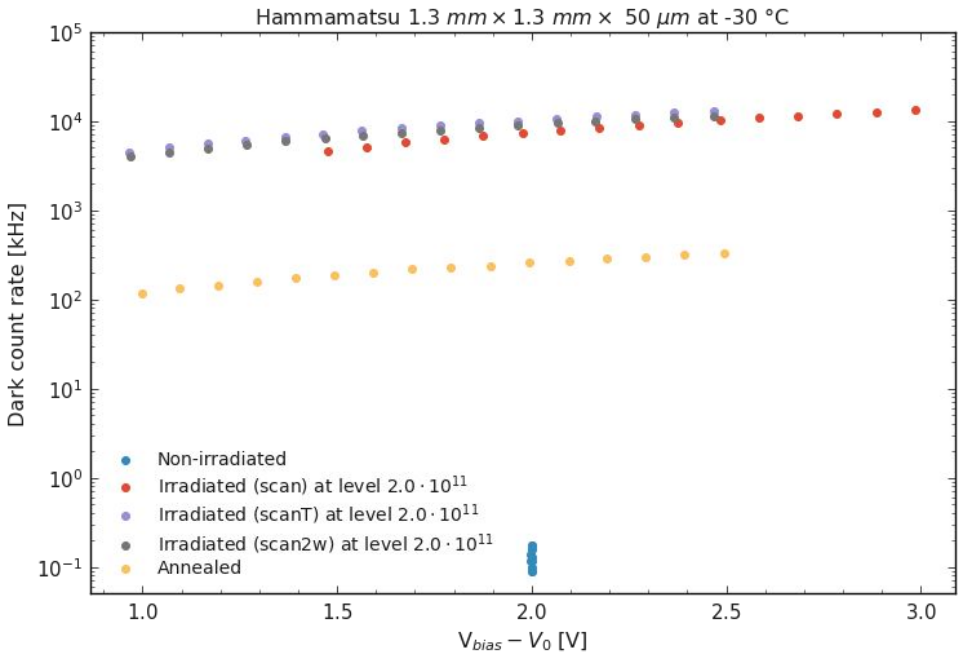
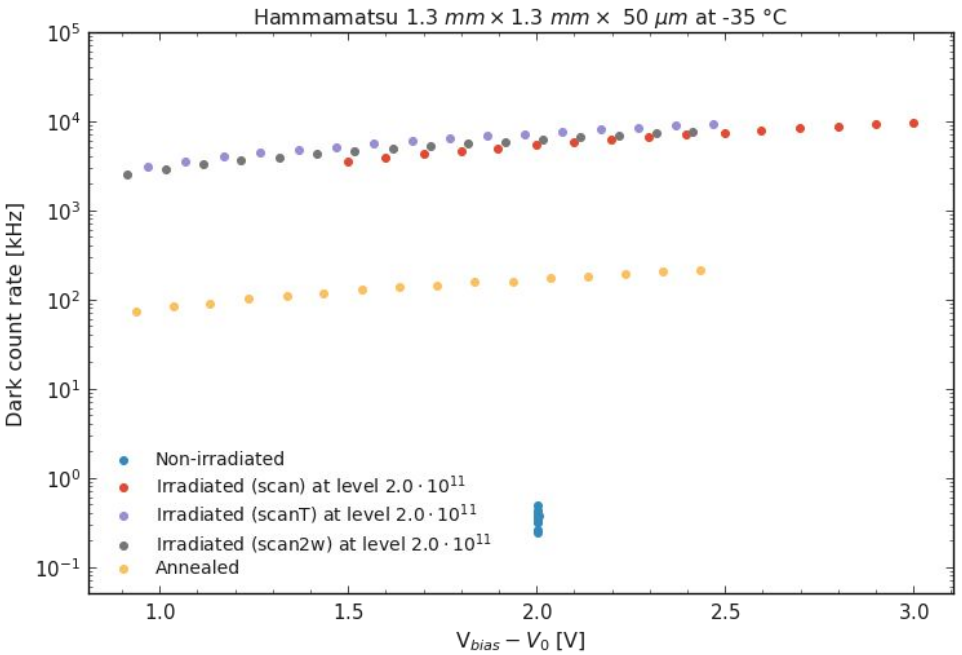




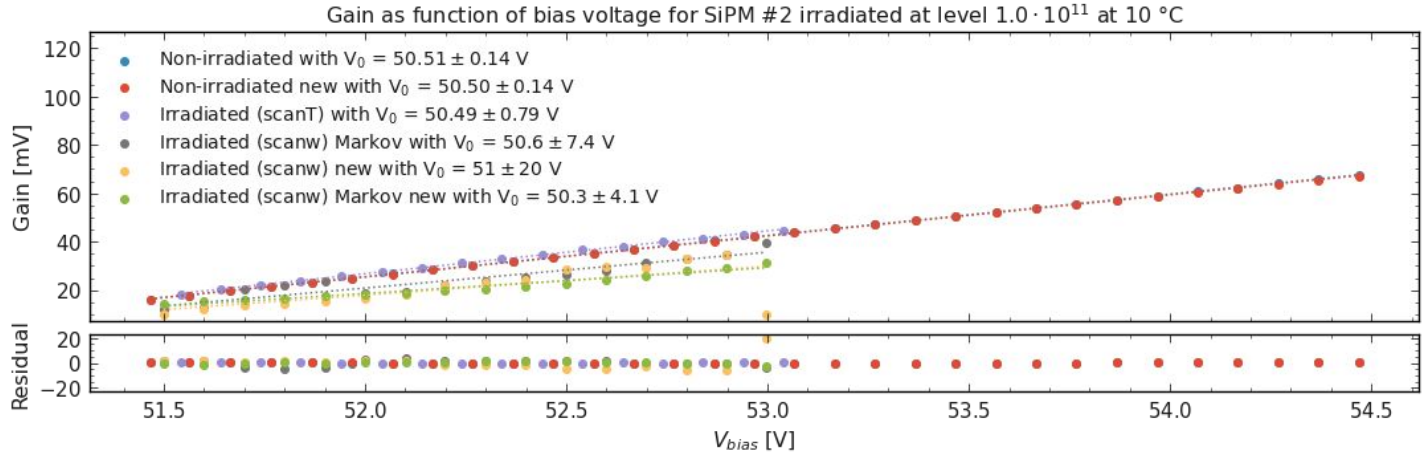
Dark count rate

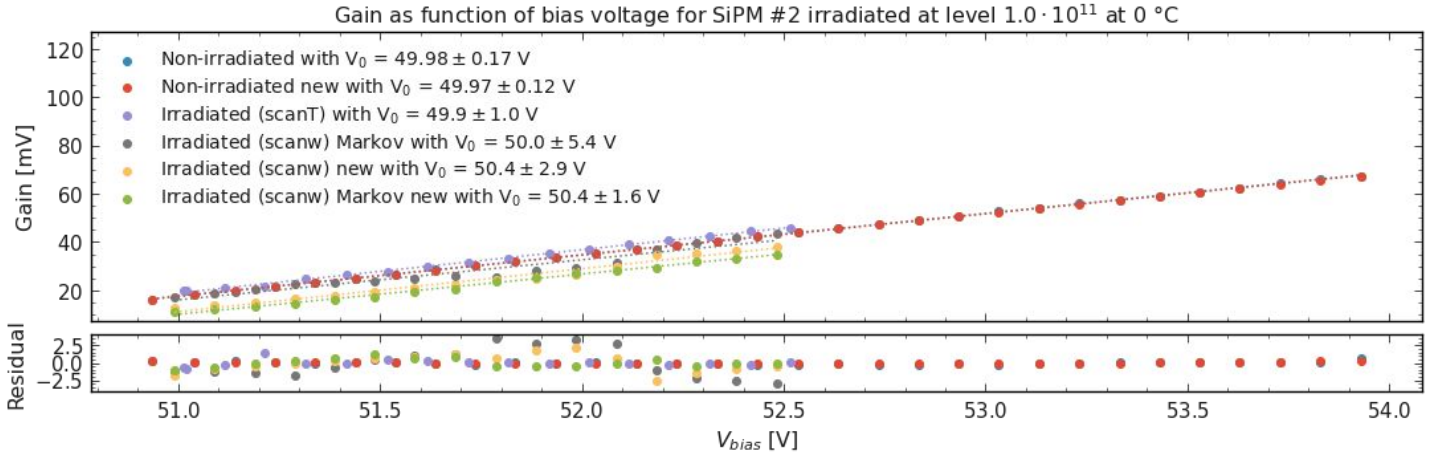




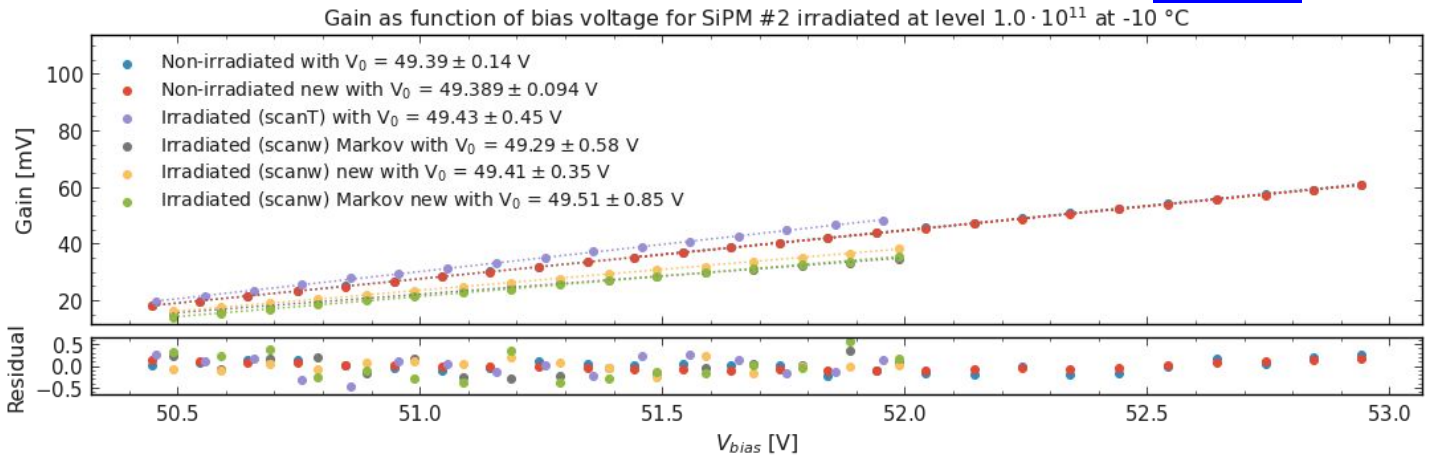
SiMP #2

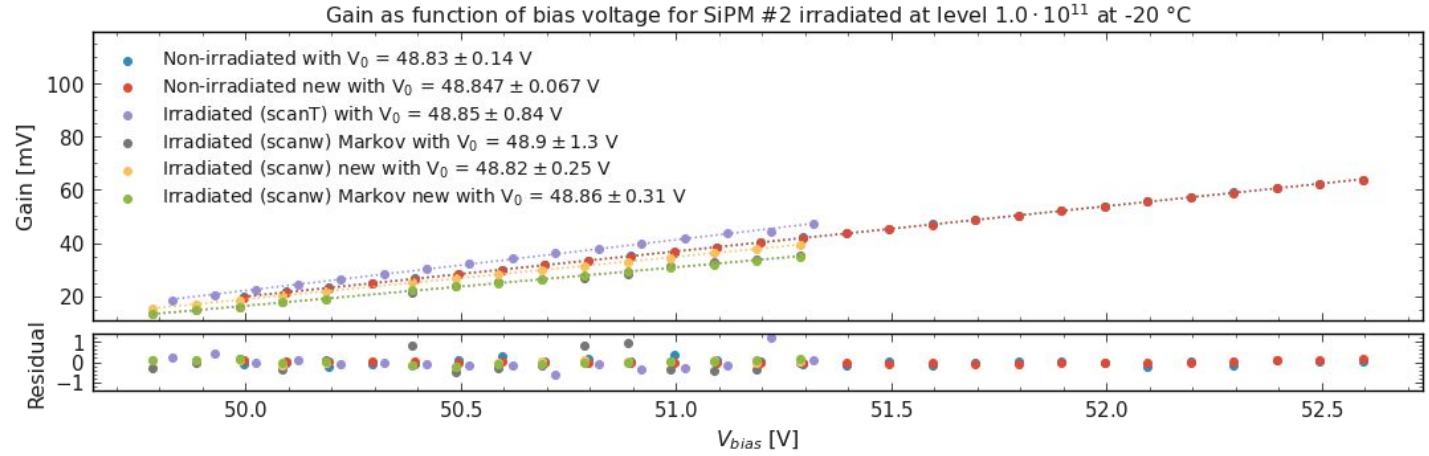
Gain as function of bias voltage





Gain as function of bias voltage





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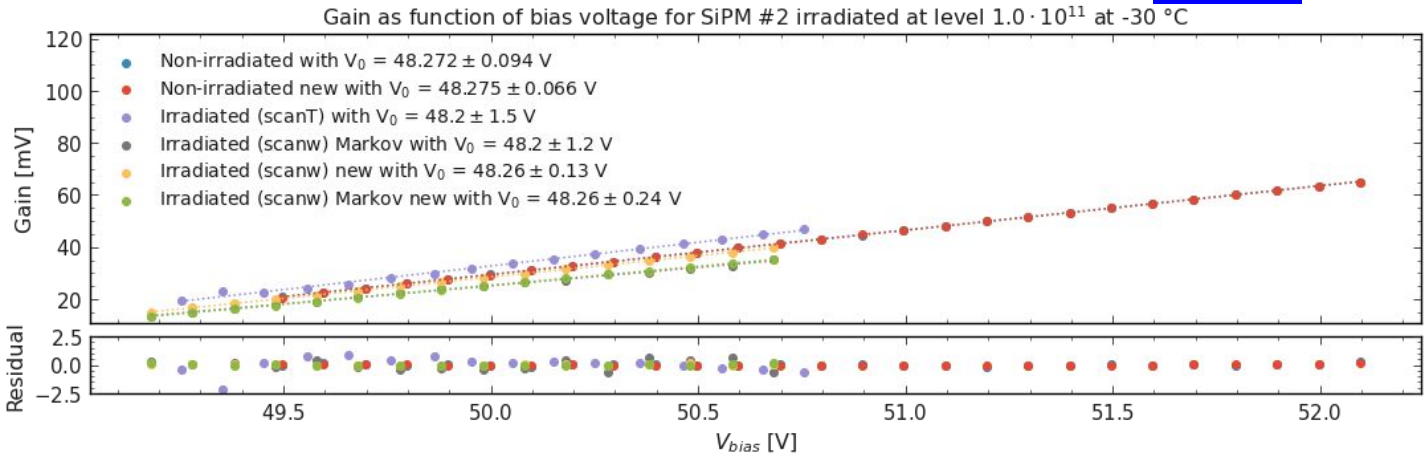
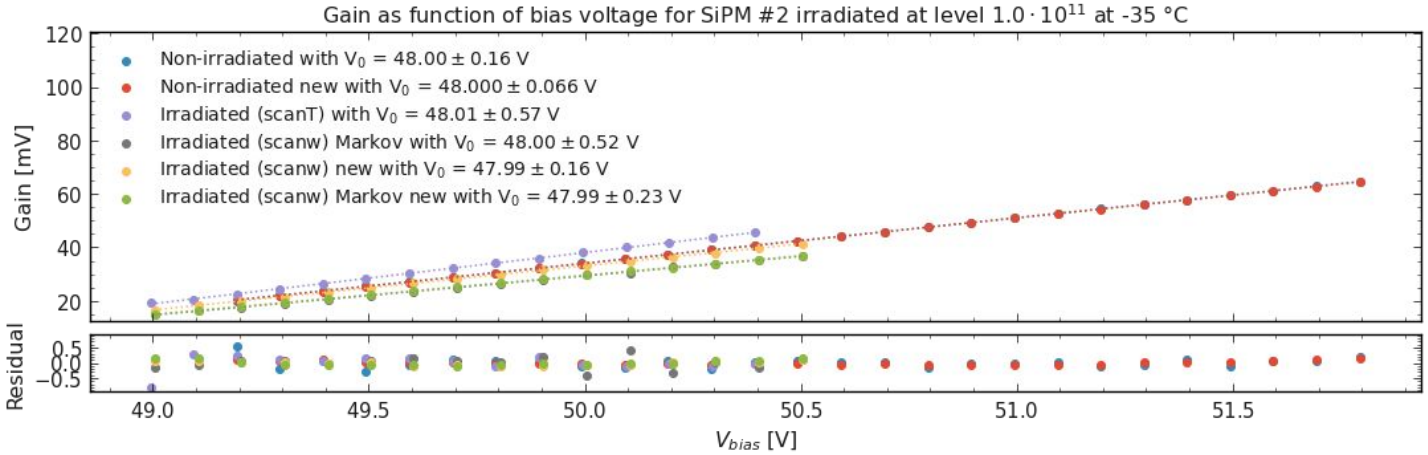
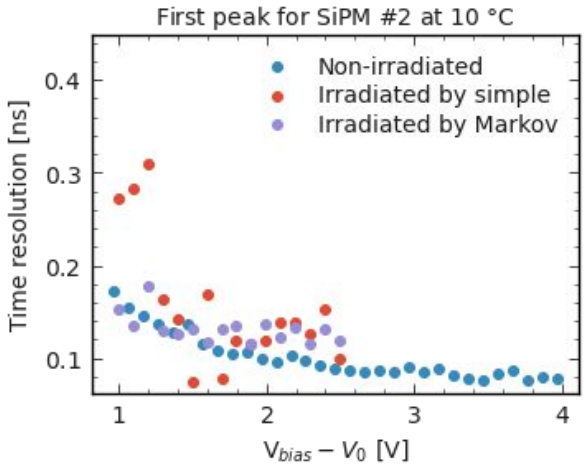
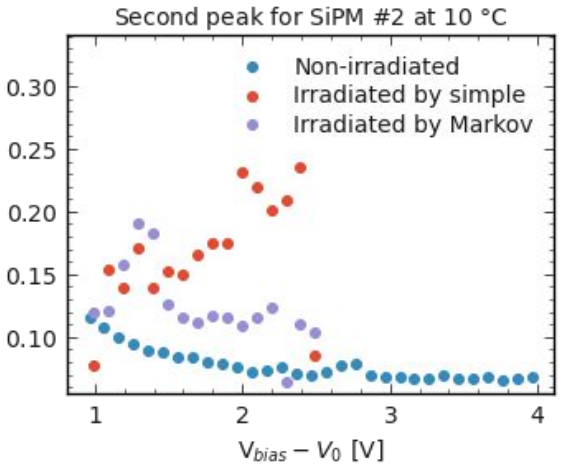
Gain as function of bias voltage

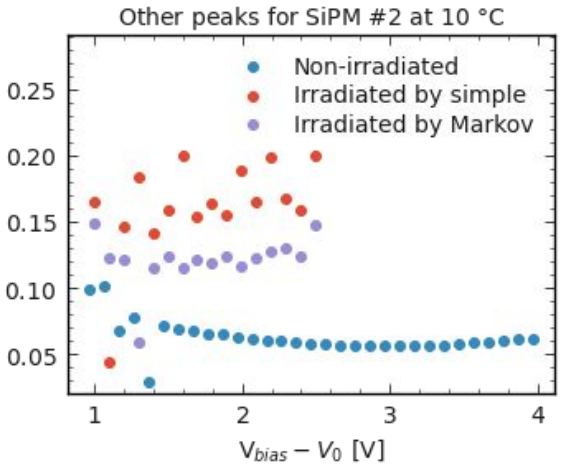


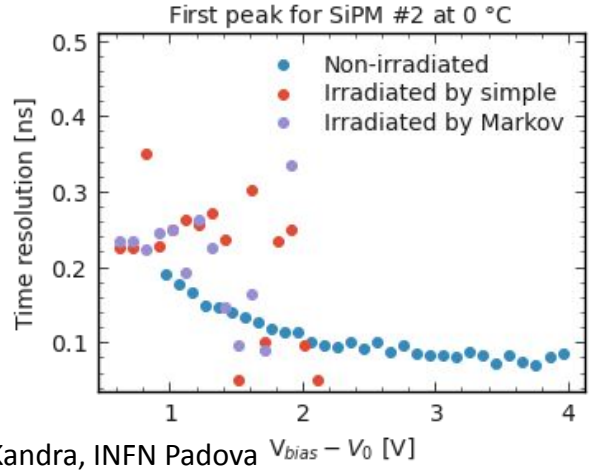


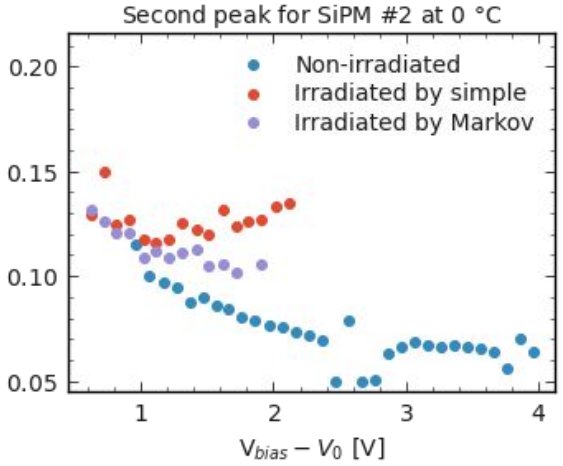
Time resolution

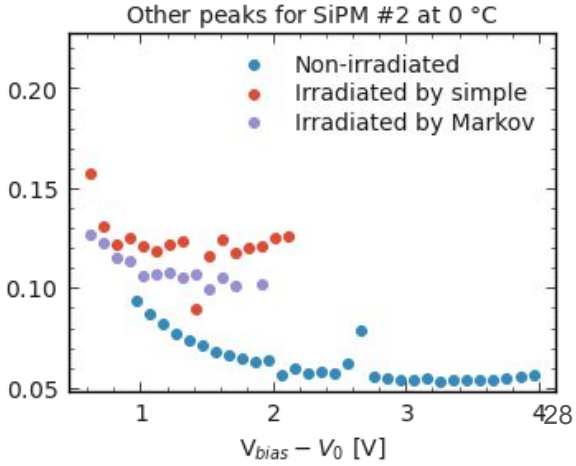




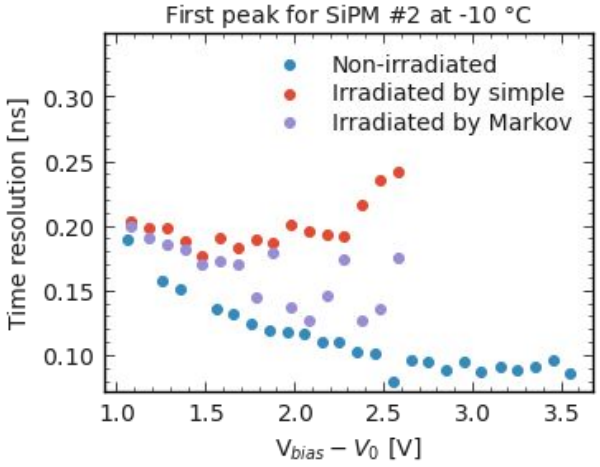


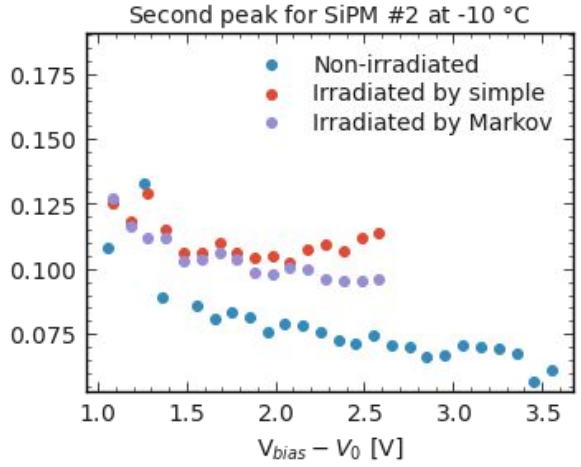


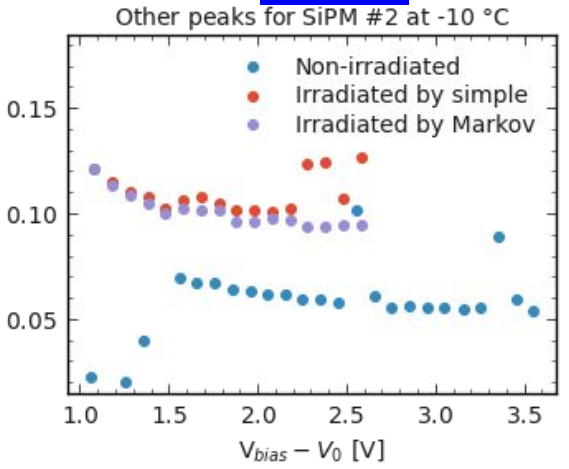


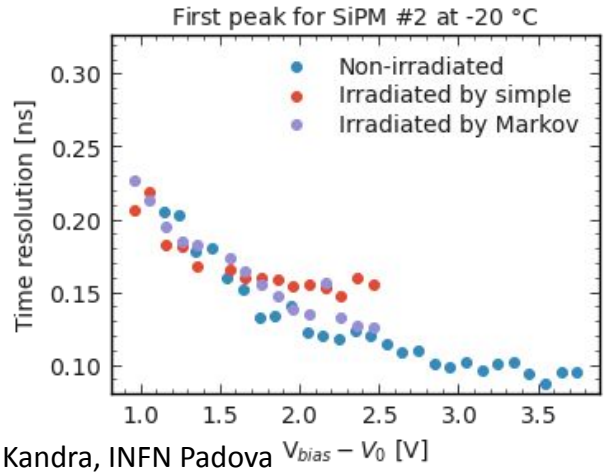


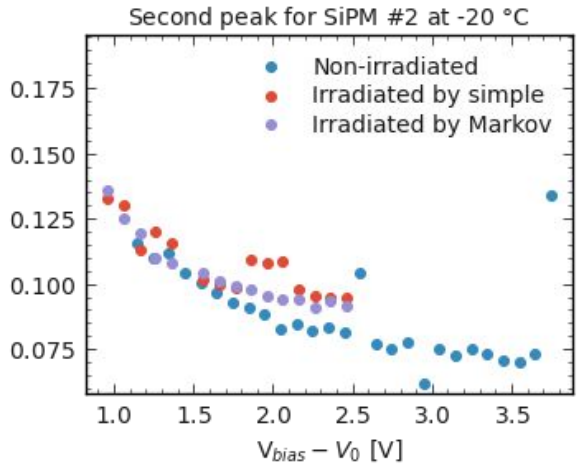
Time resolution

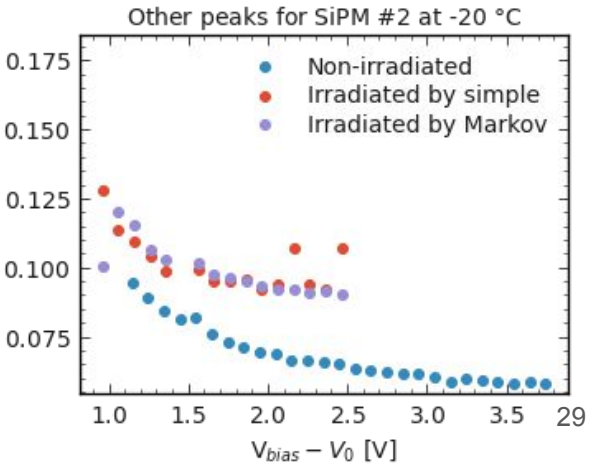




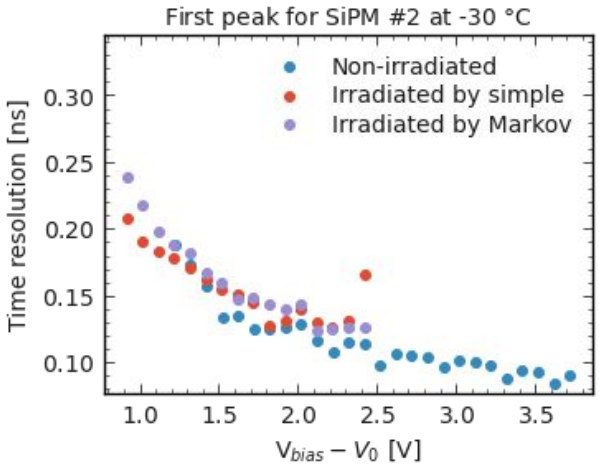


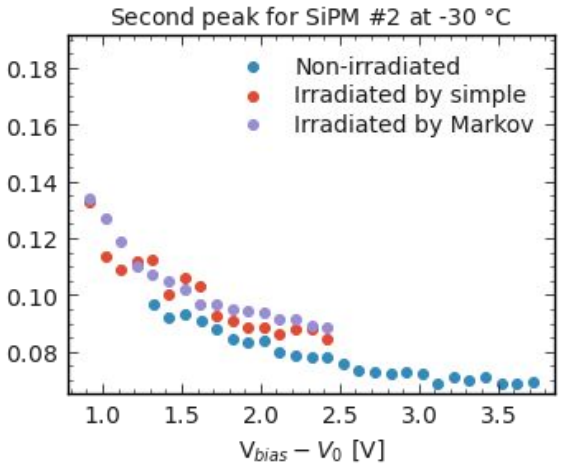


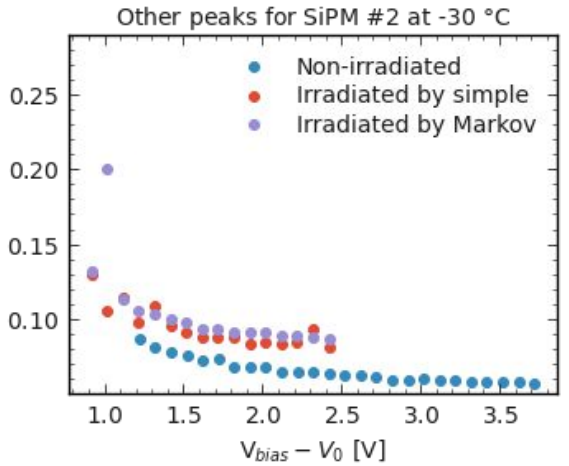


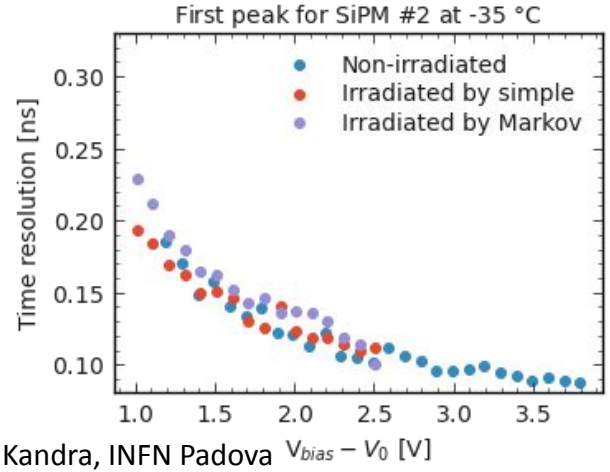


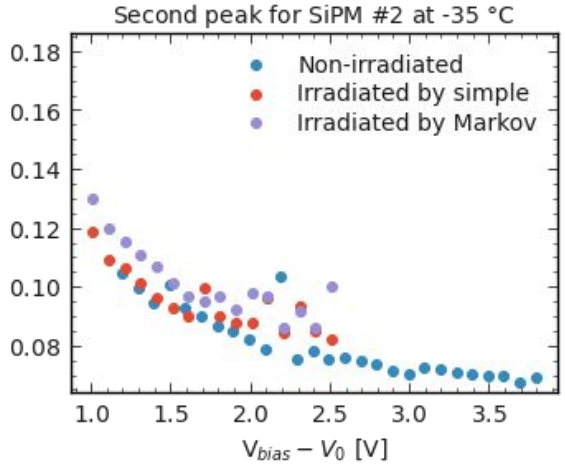
Time resolution

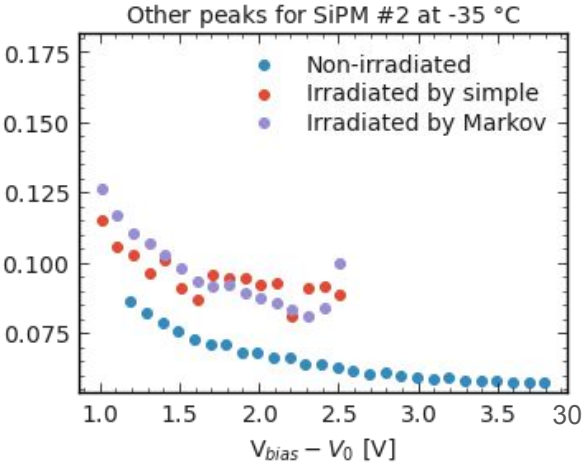




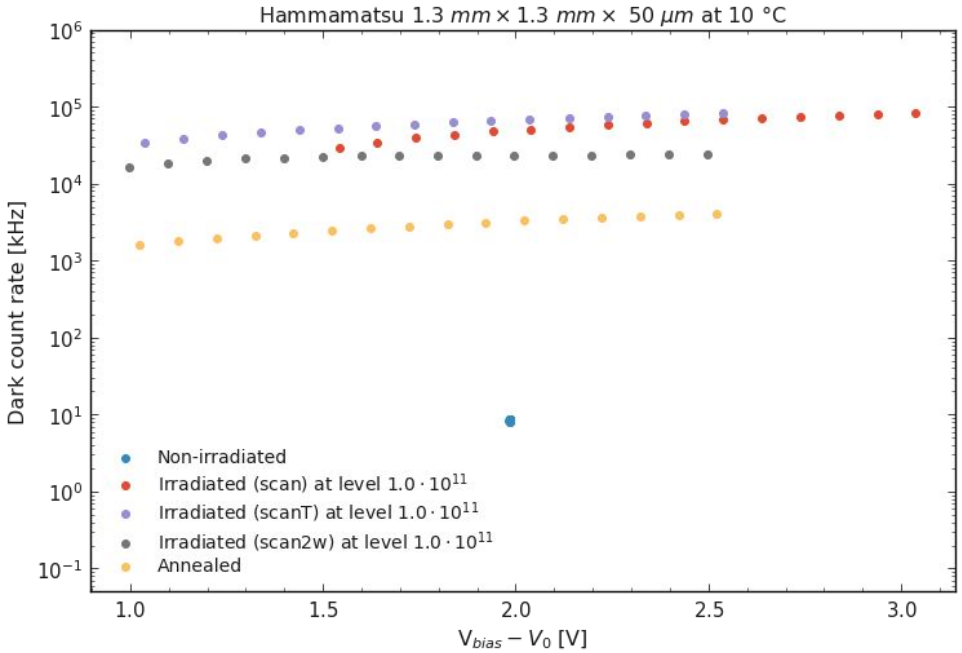


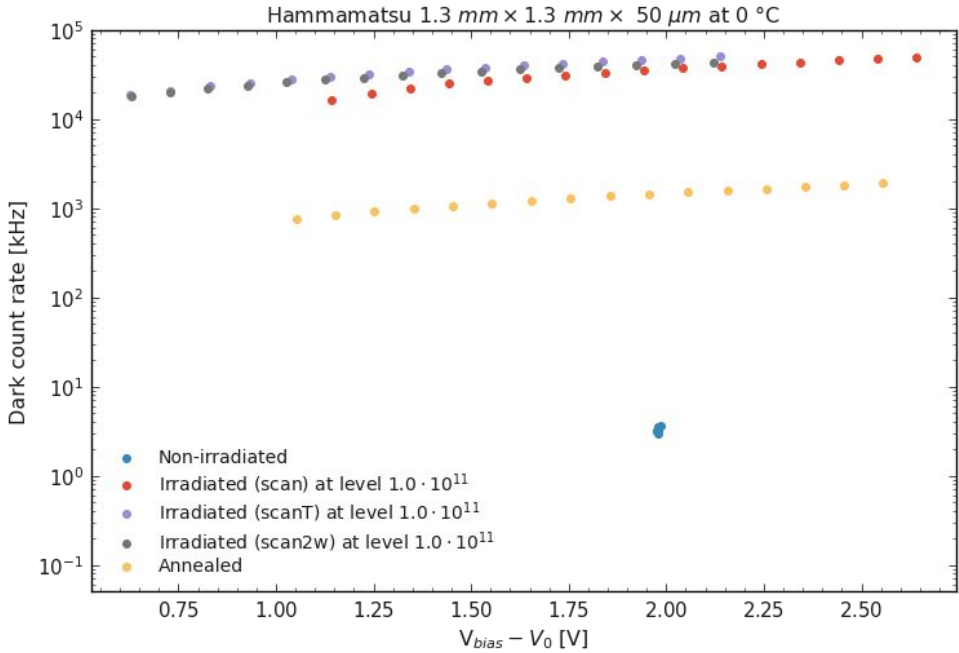




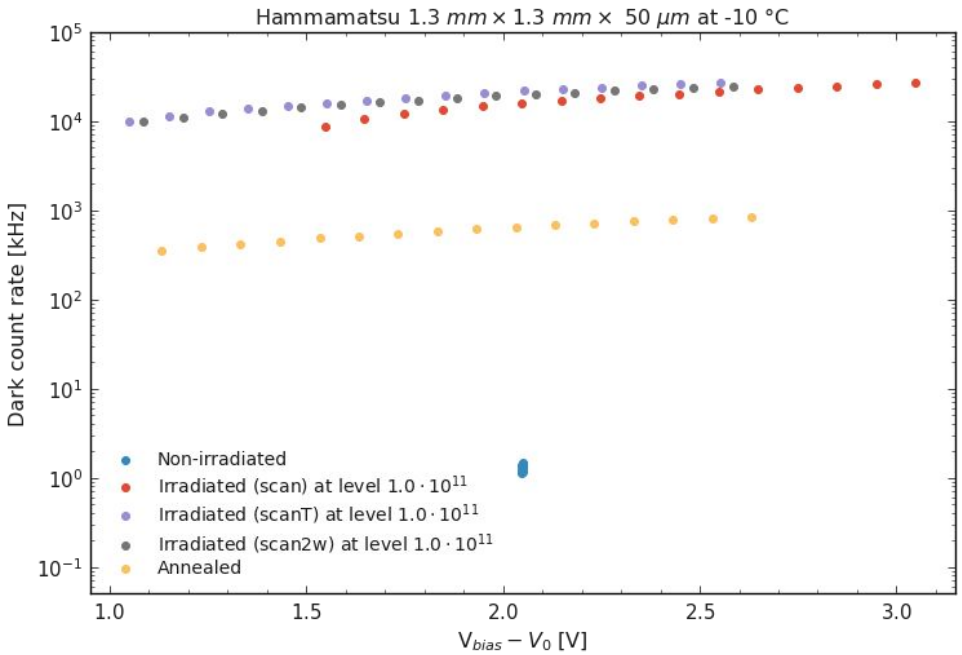


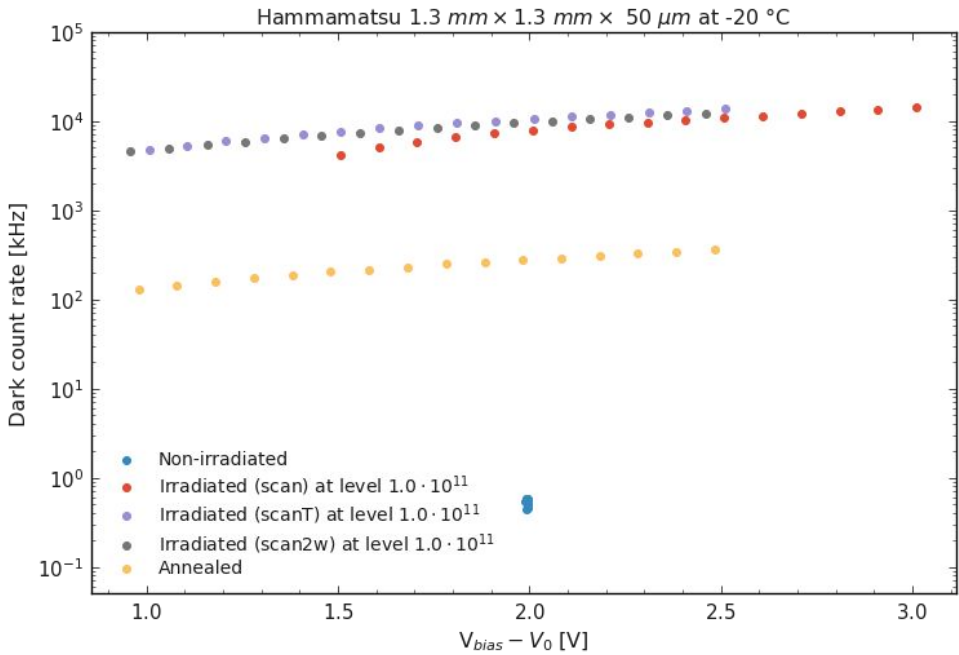
Dark count rate



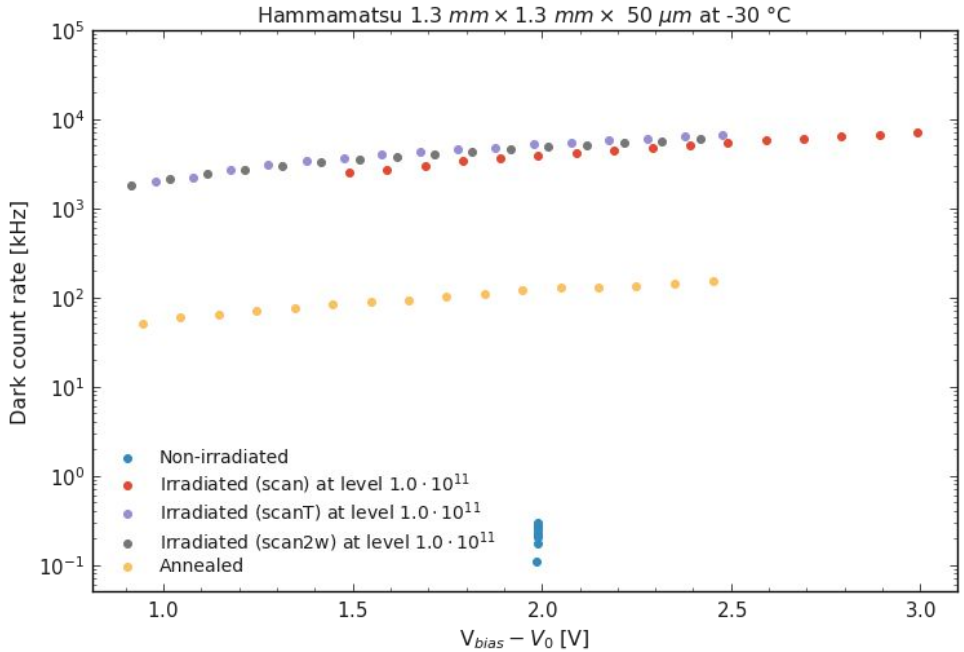


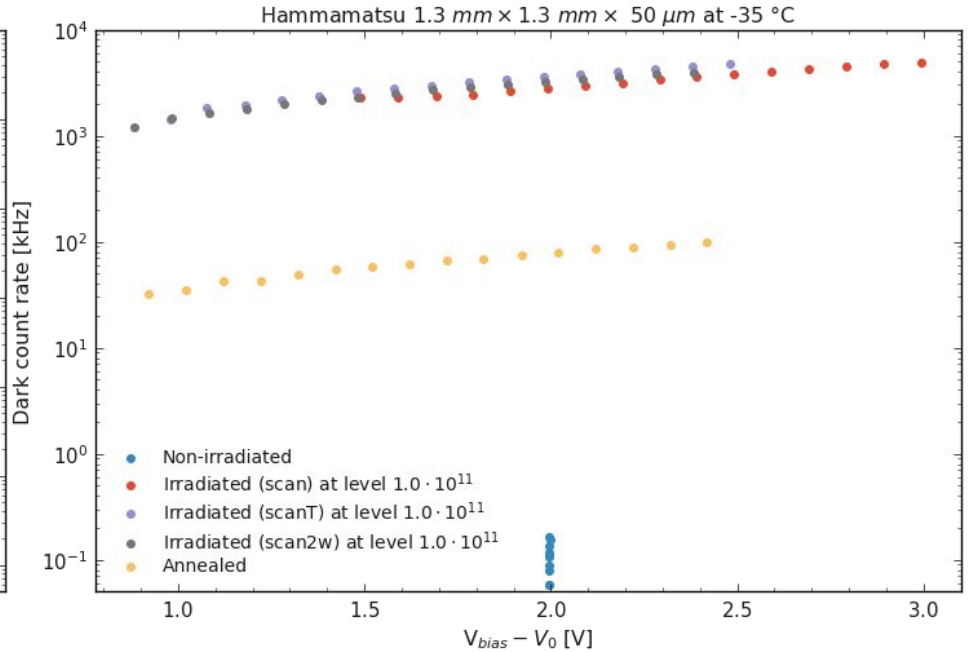
Dark count rate





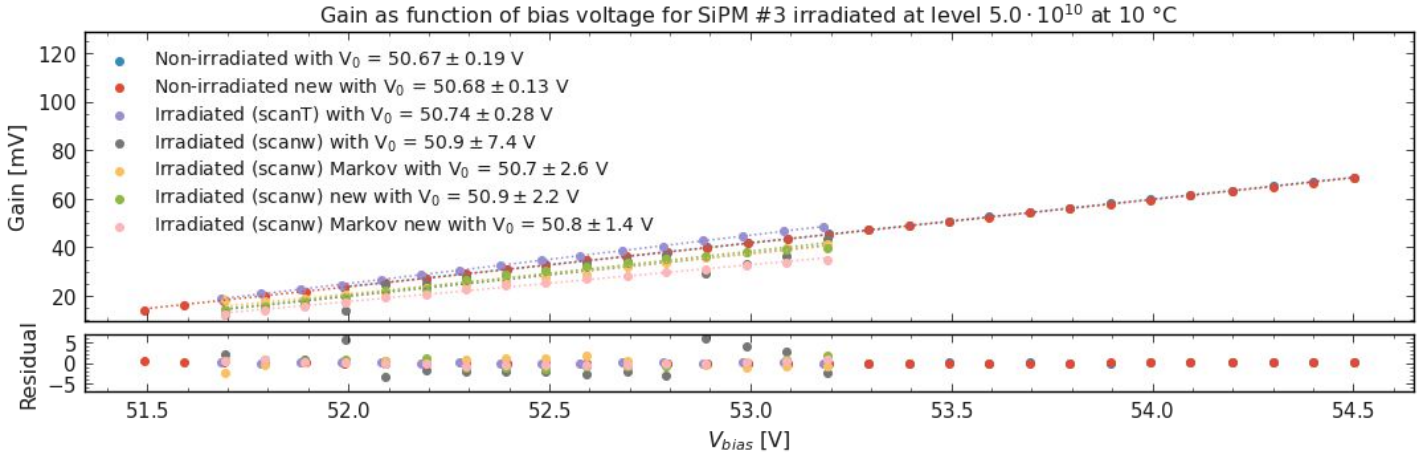
Dark count rate

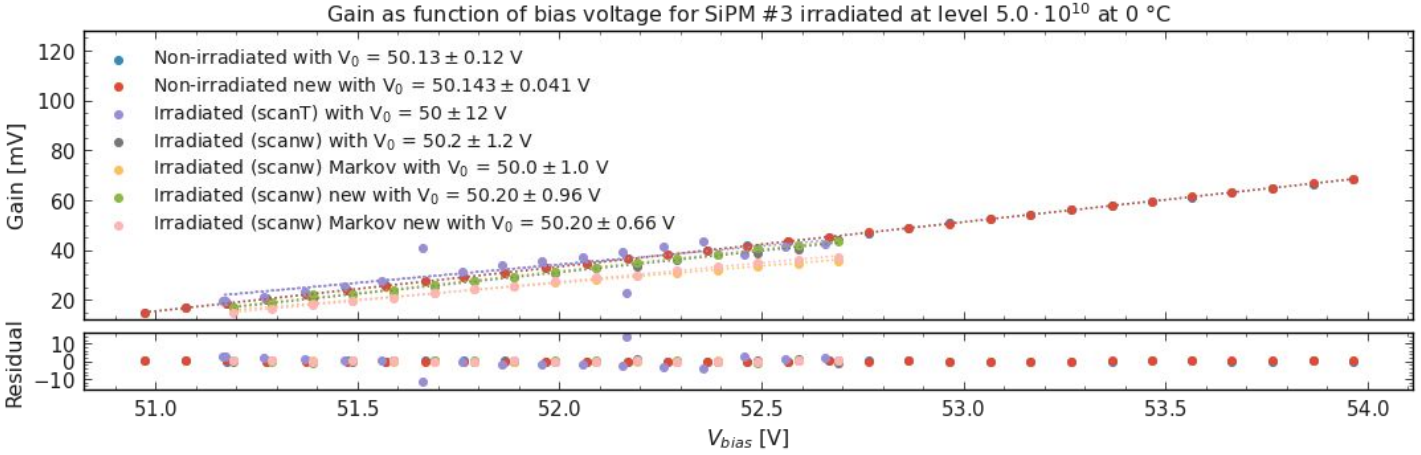




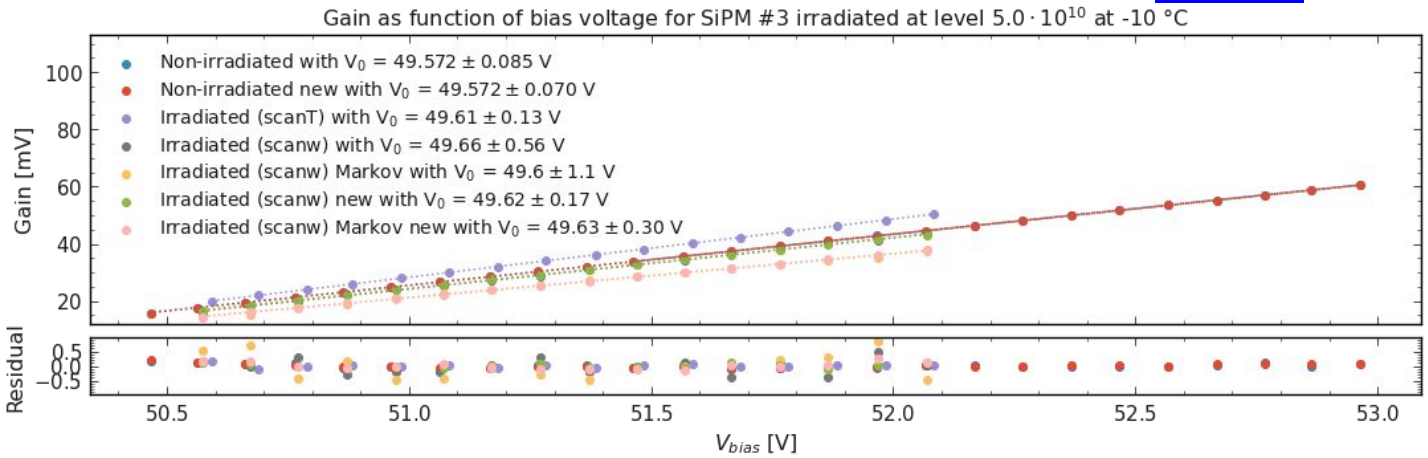
SiMP #3

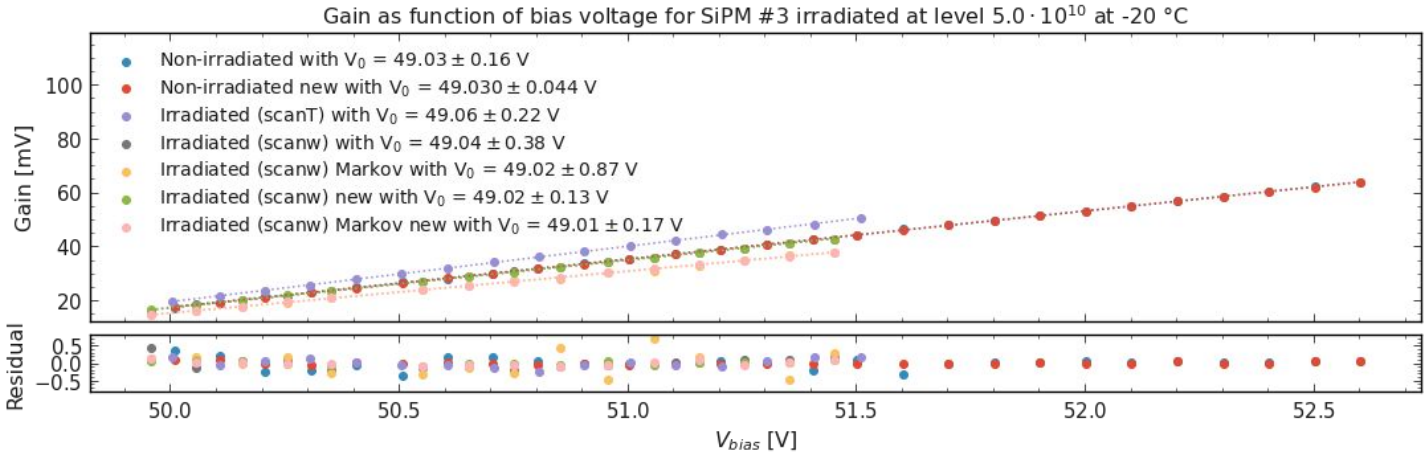
Gain as function of bias voltage



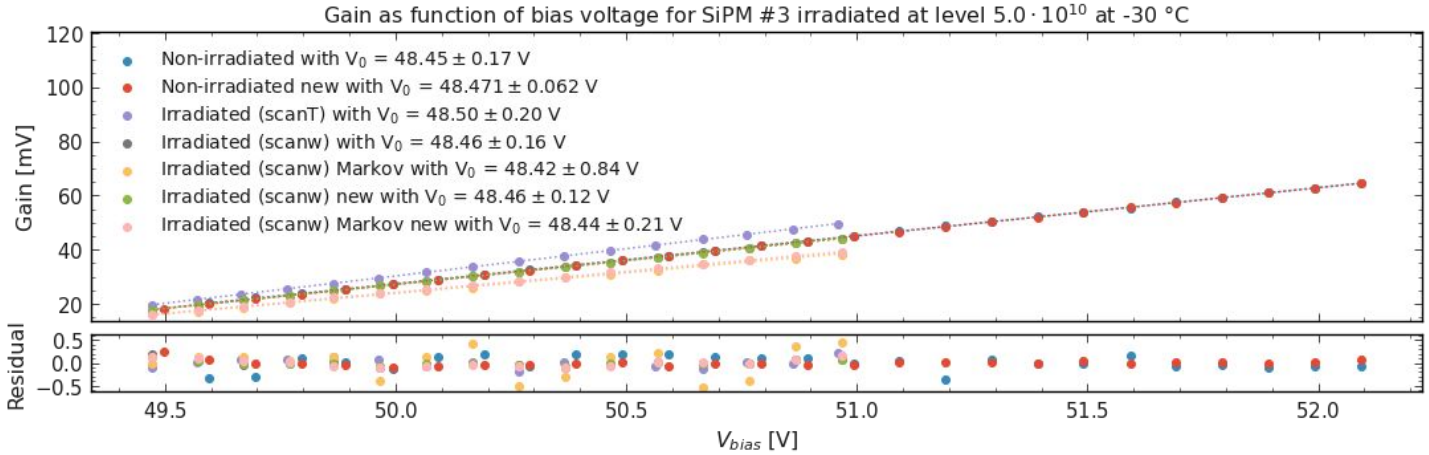


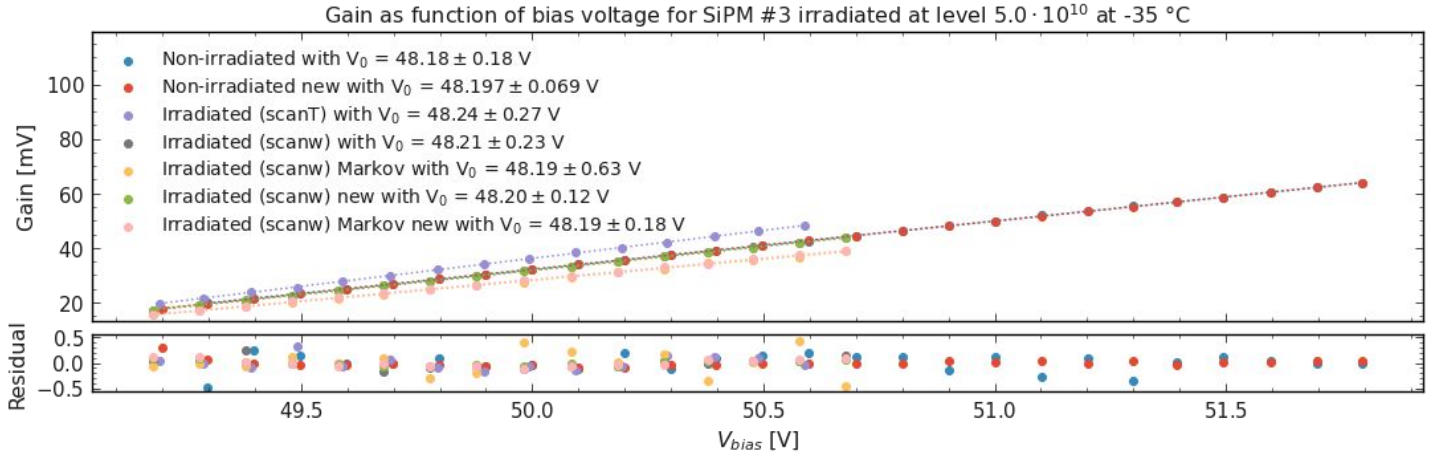
Gain as function of bias voltage



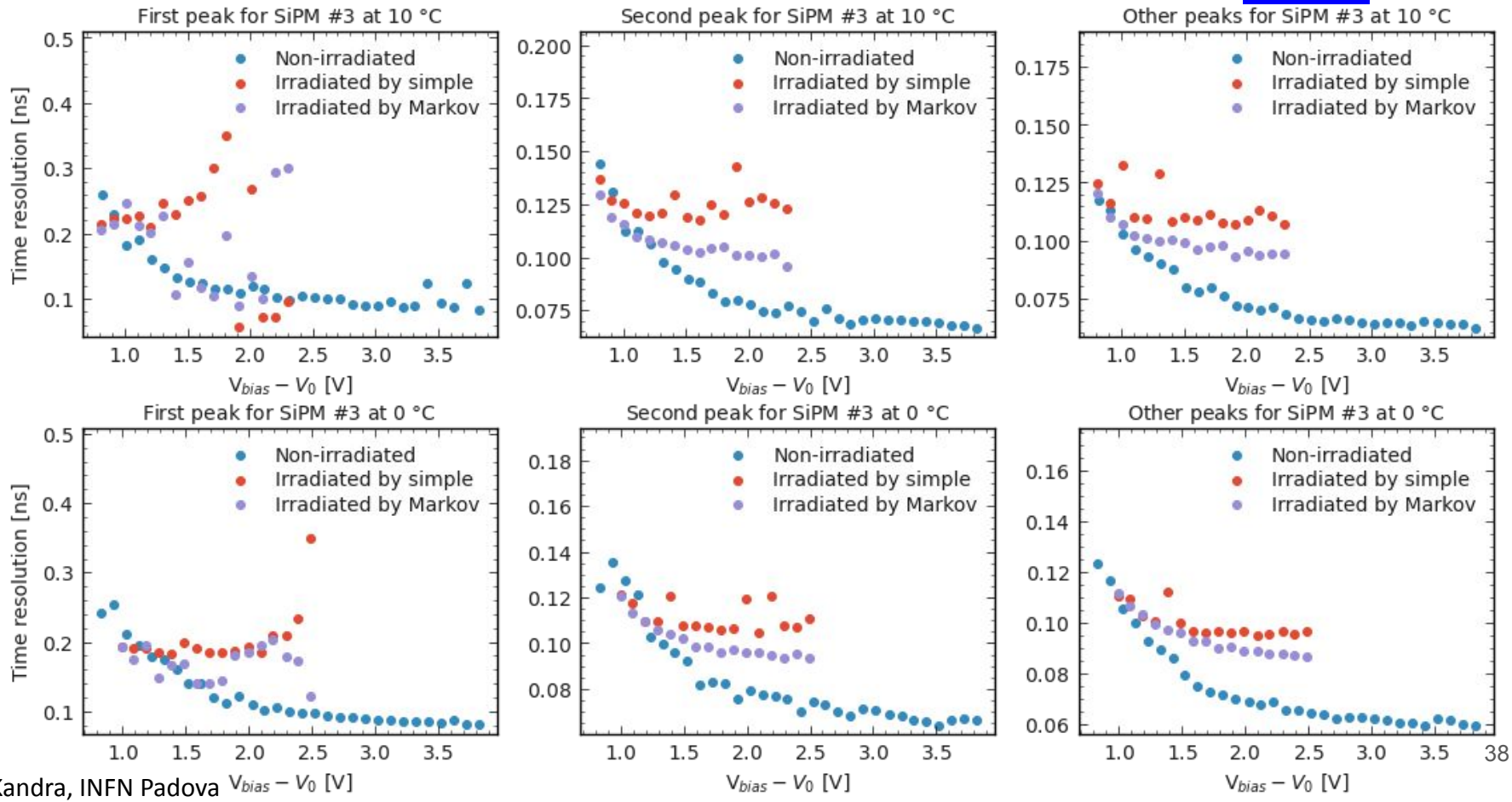


Gain as function of bias voltage

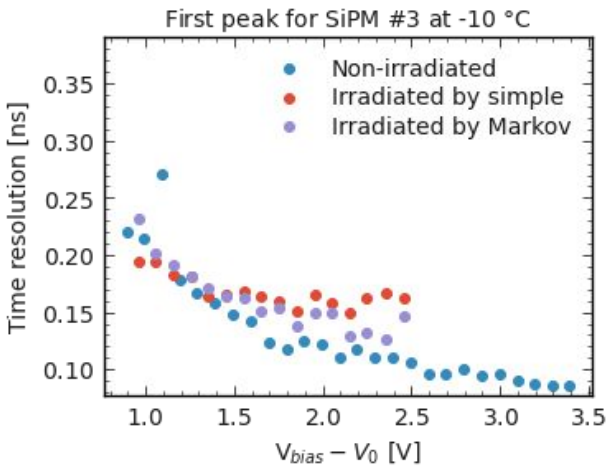


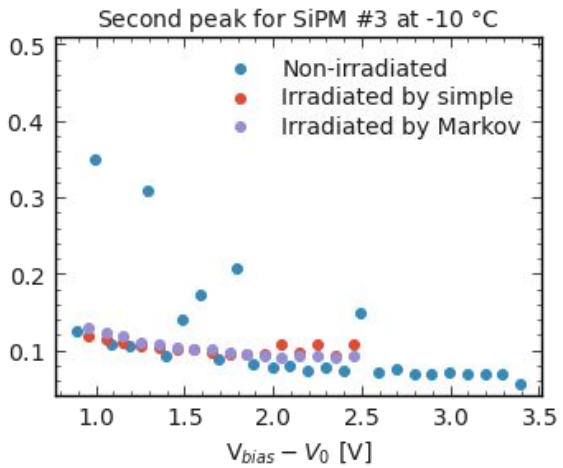


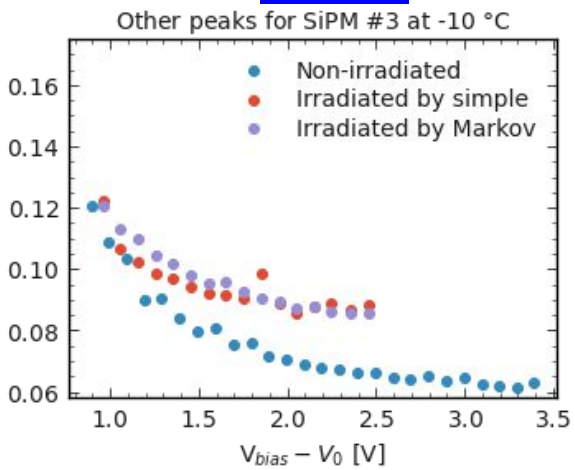
Time resolution

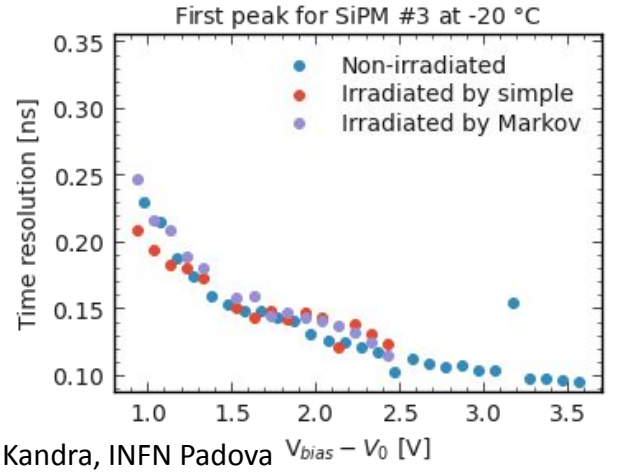


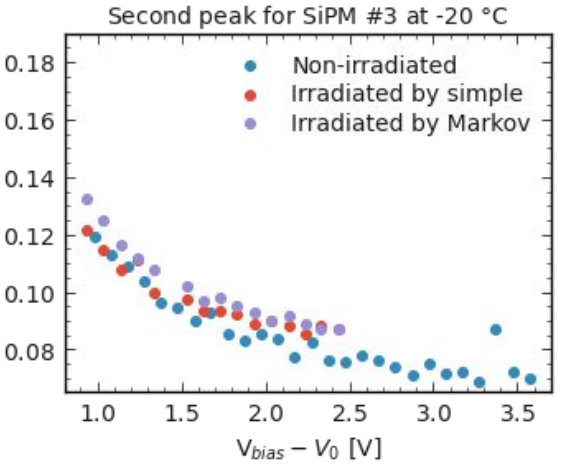
Time resolution

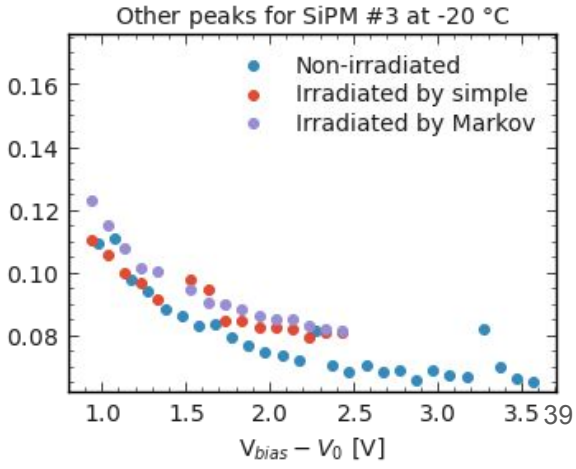




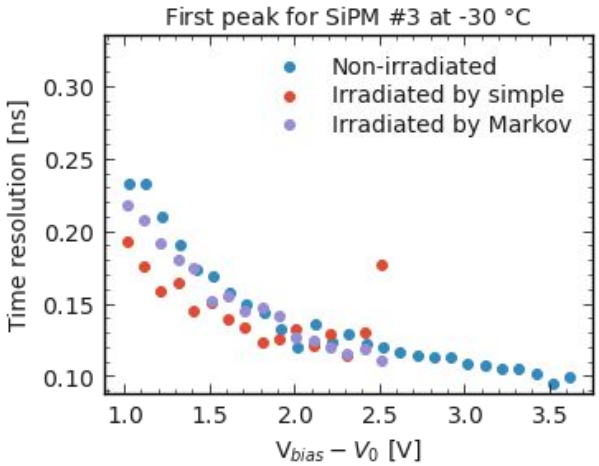


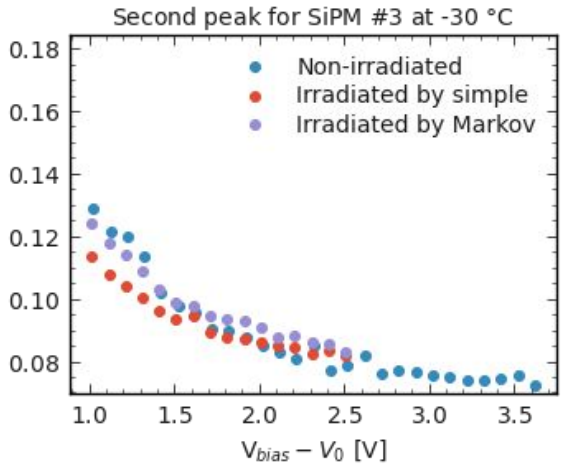


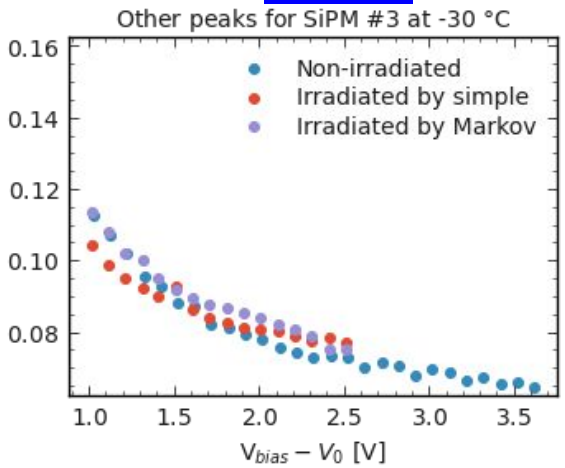


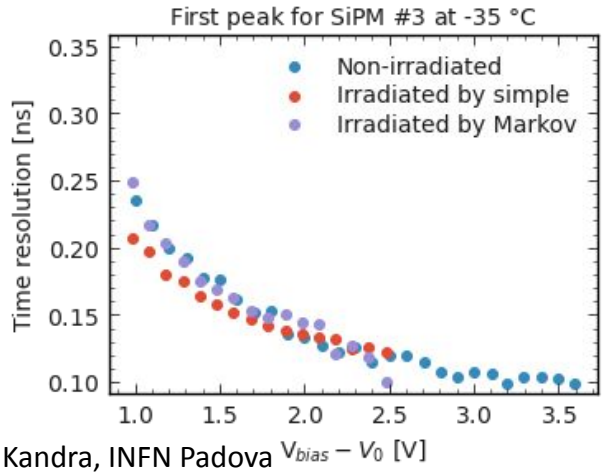


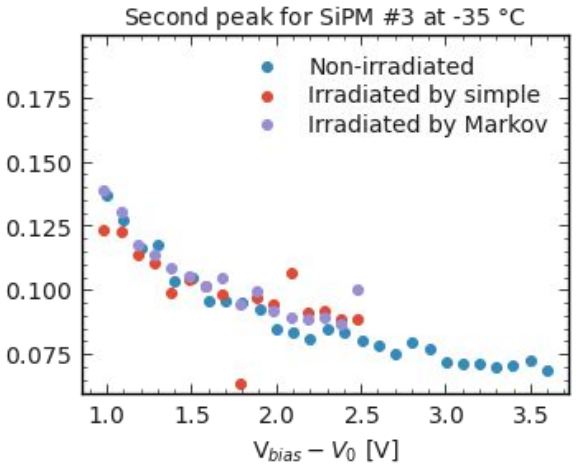
Time resolution

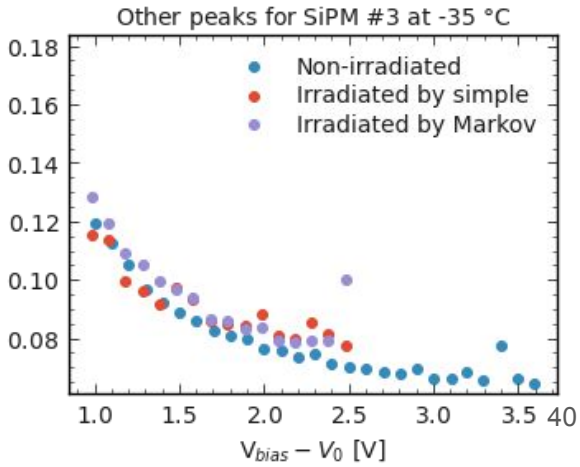




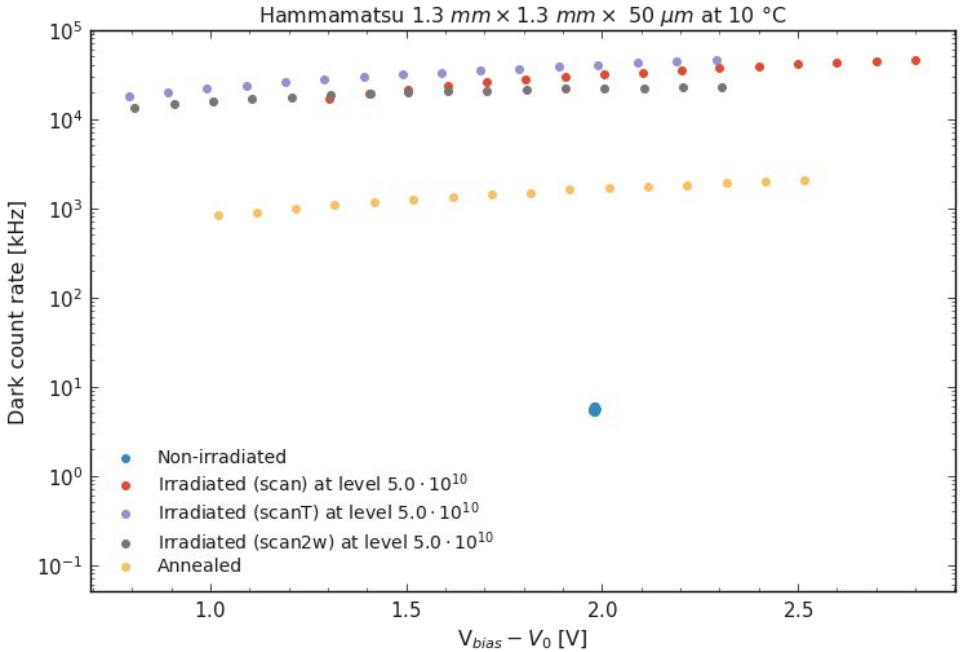


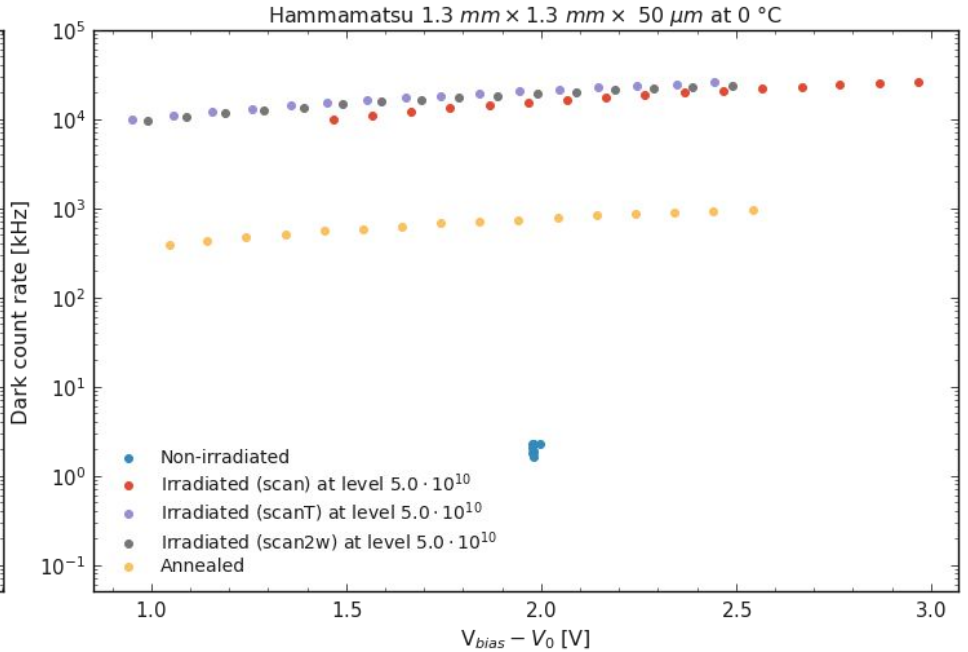




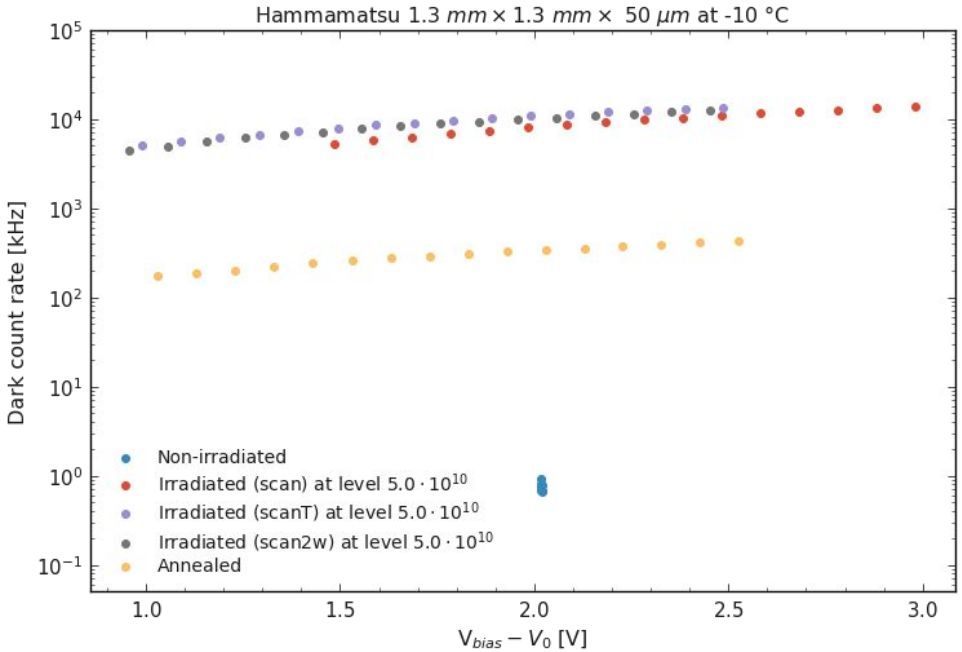


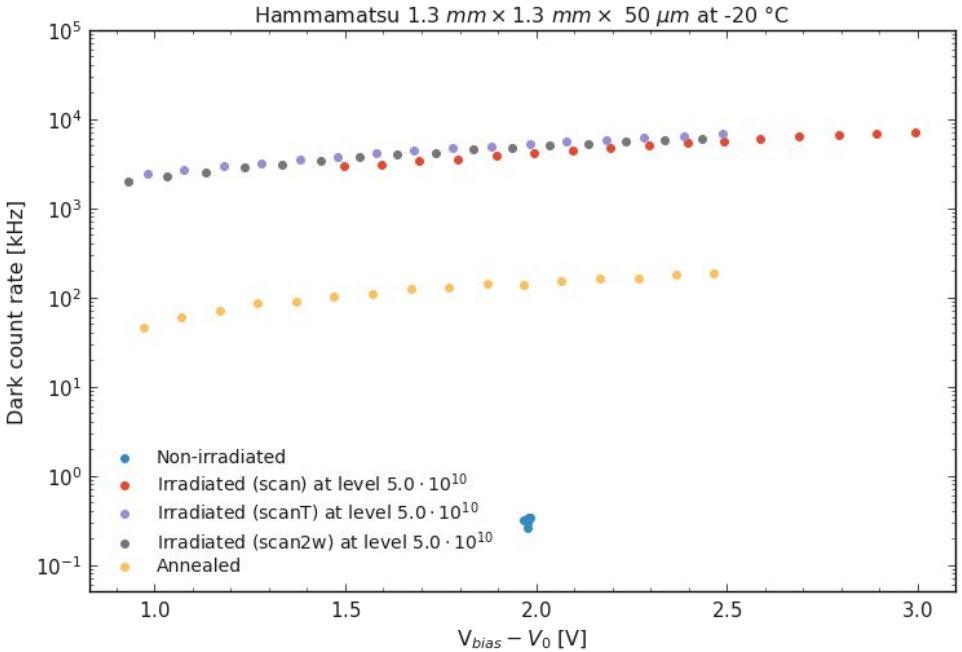
Dark count rate



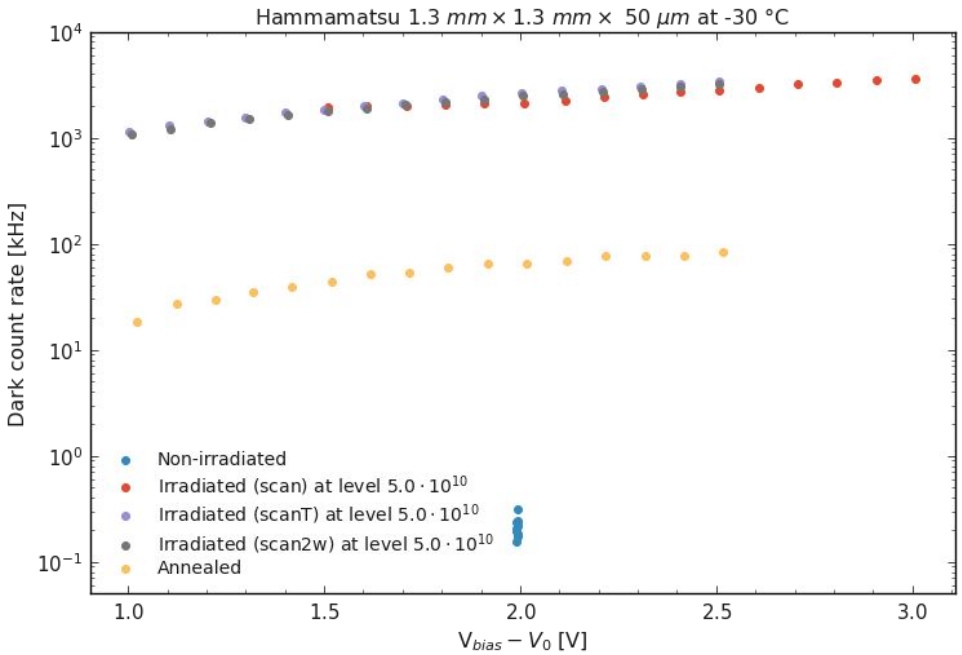


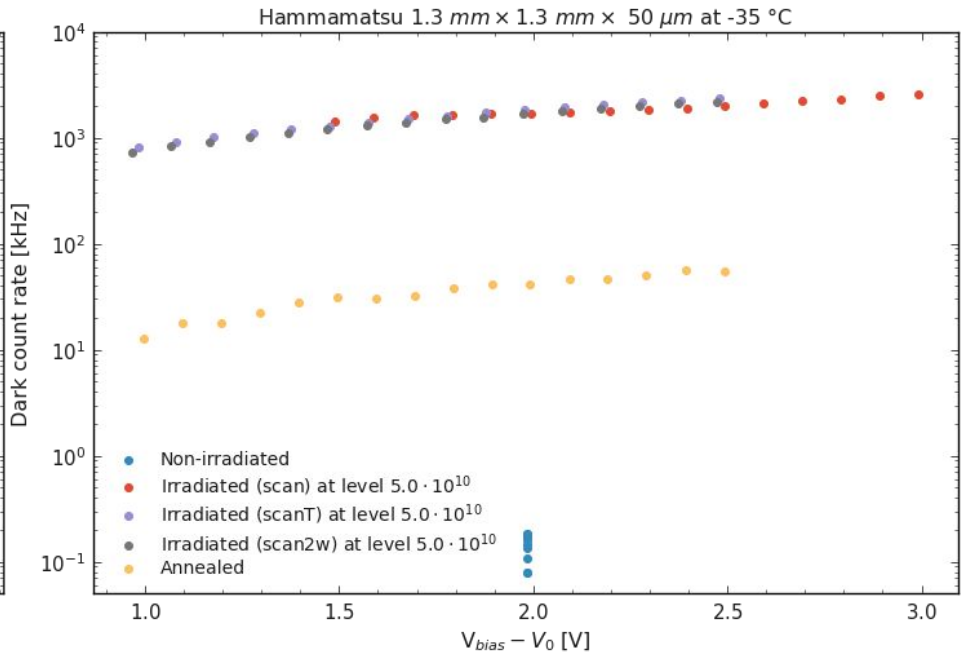
Dark count rate





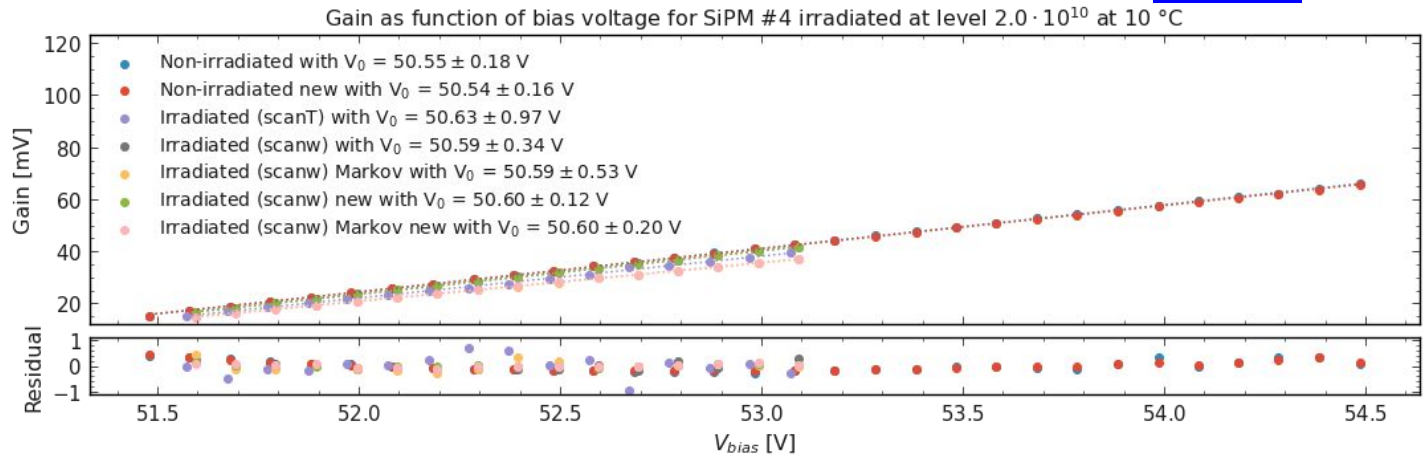
Dark count rate

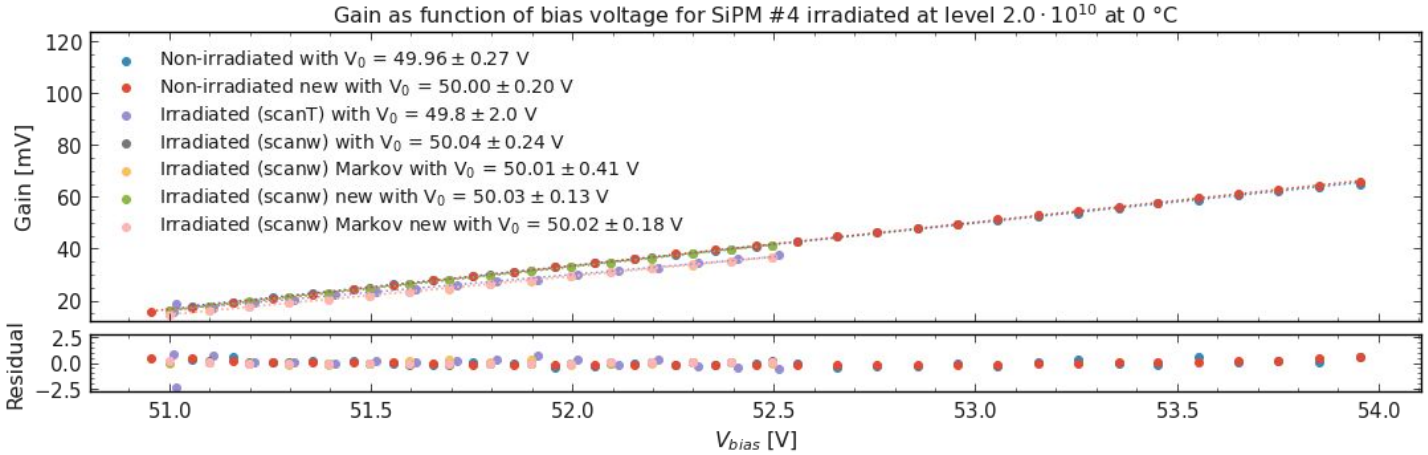




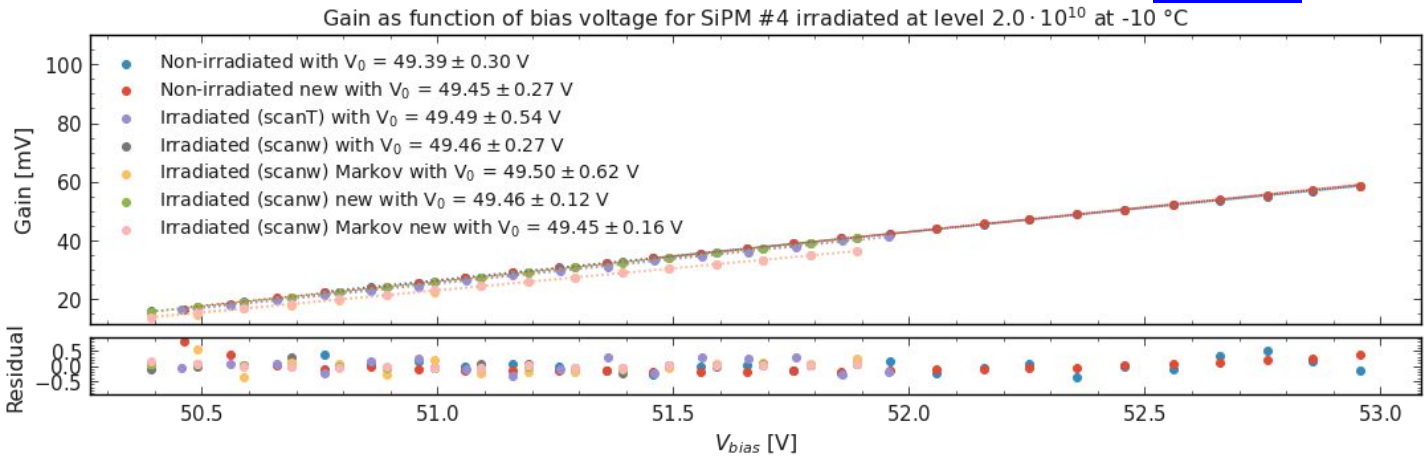
SiMP #4

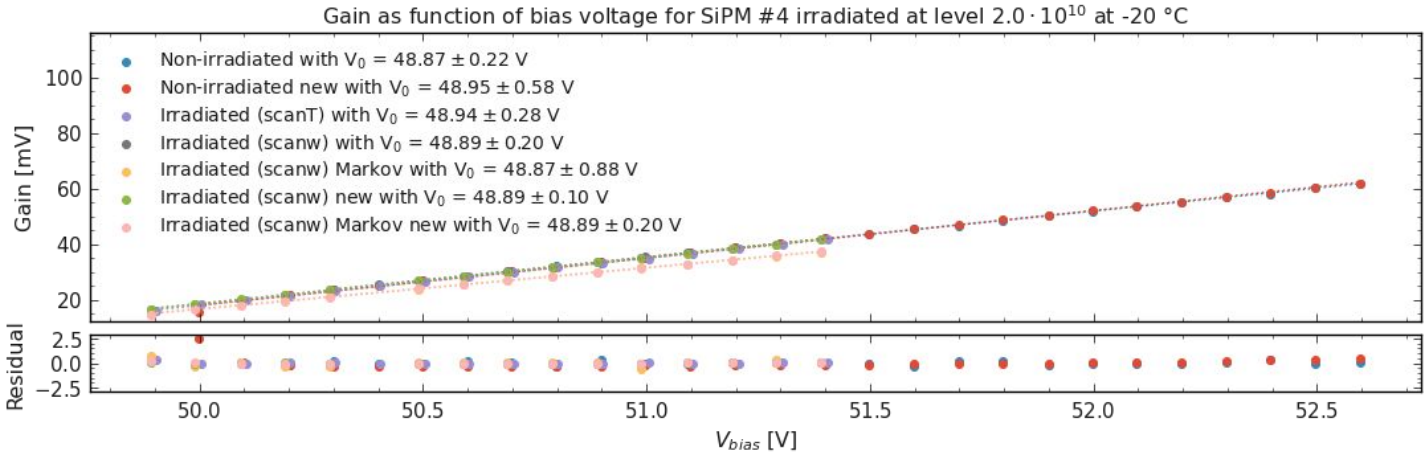
Gain as function of bias voltage



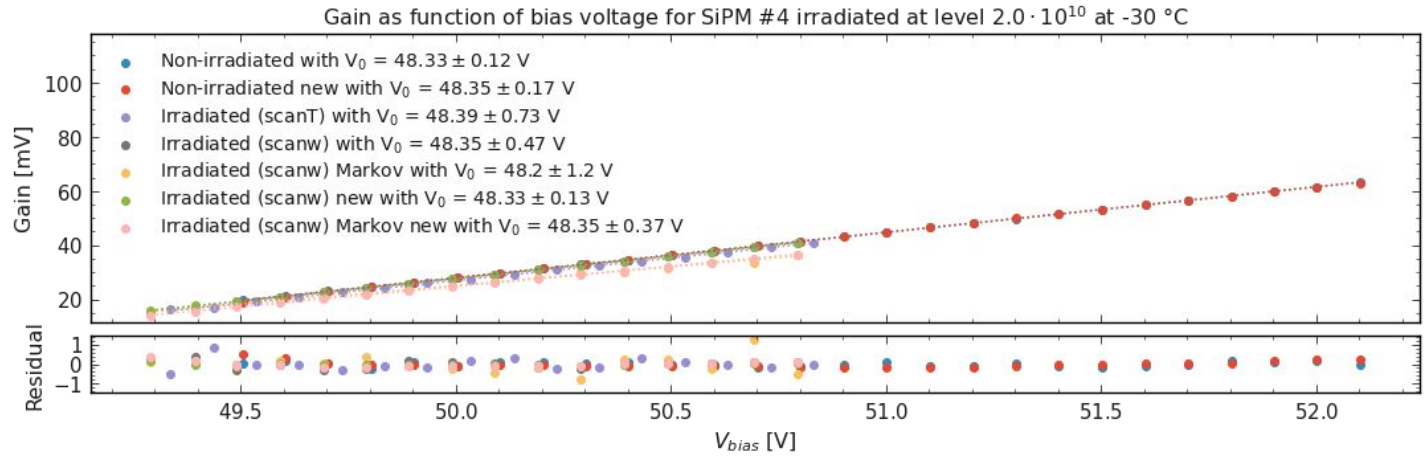


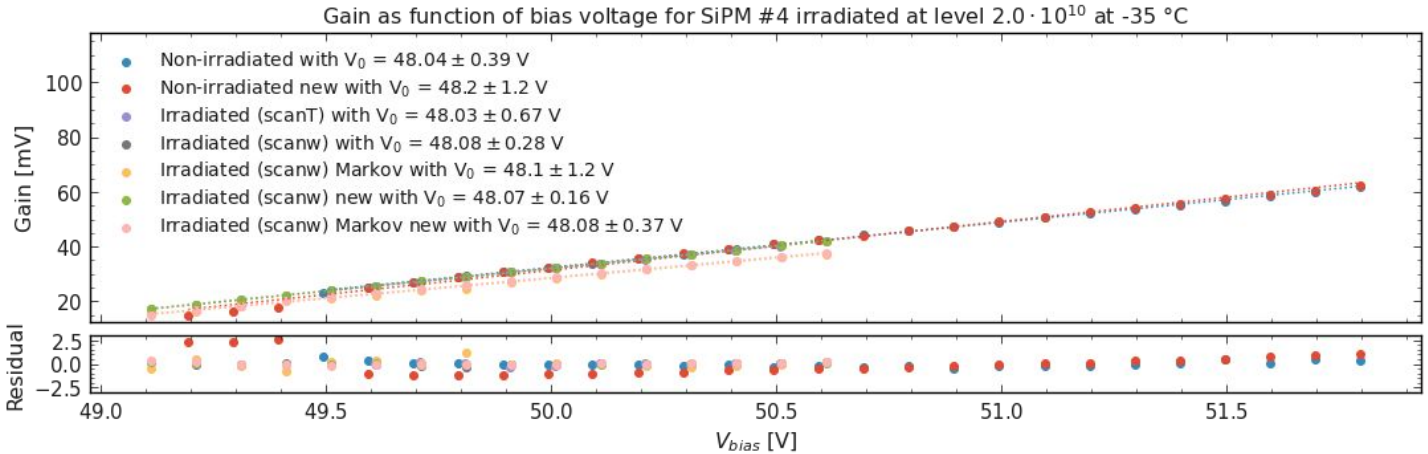
Gain as function of bias voltage



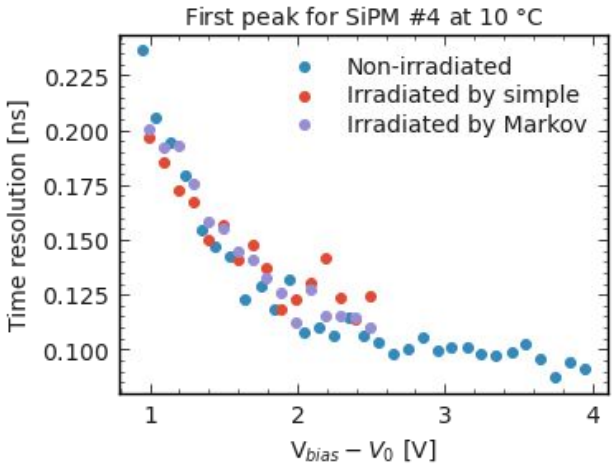


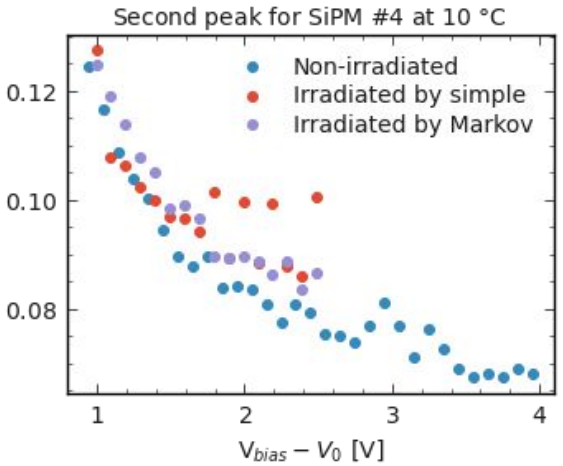
Gain as function of bias voltage

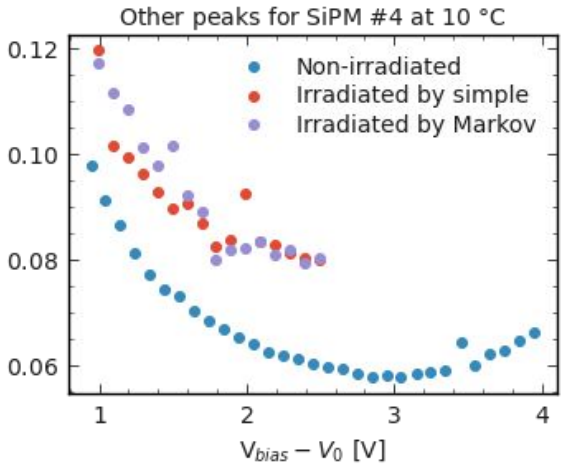


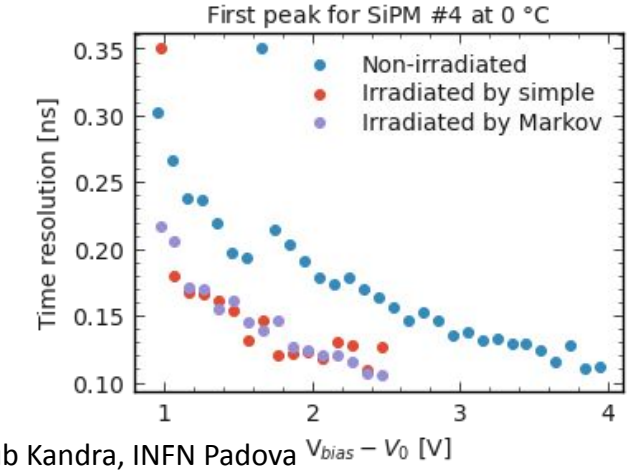


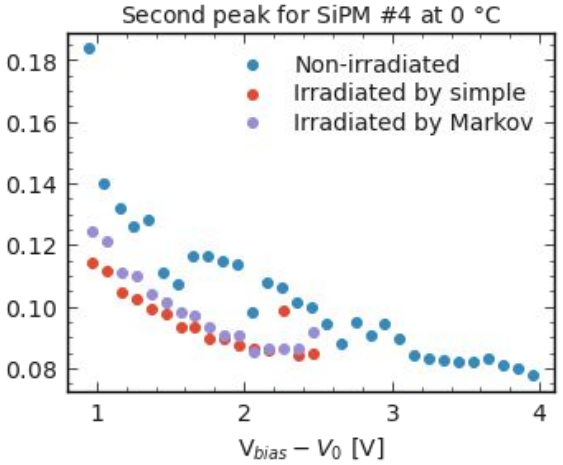
Time resolution

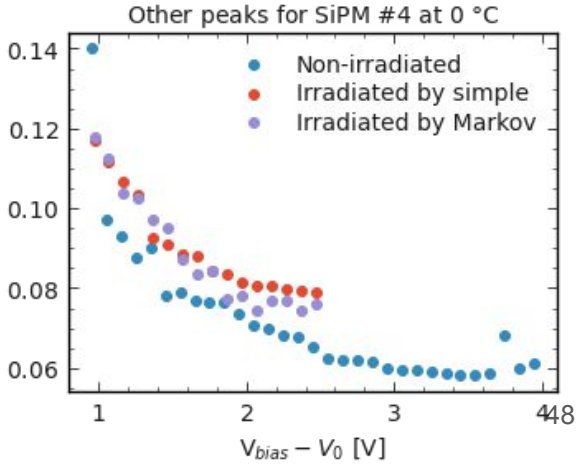




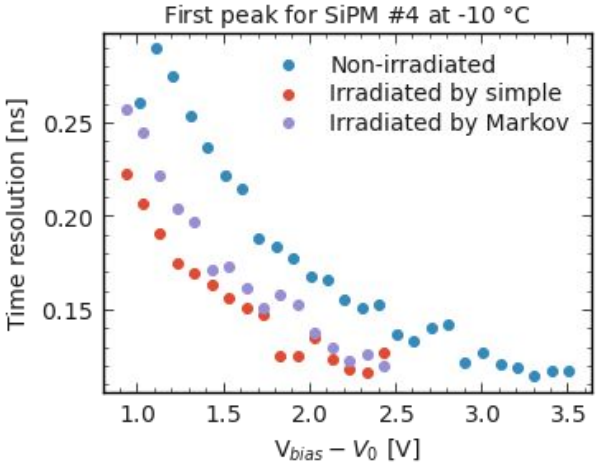


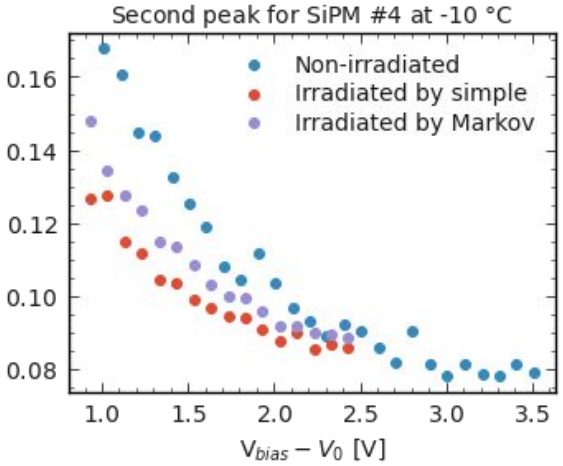


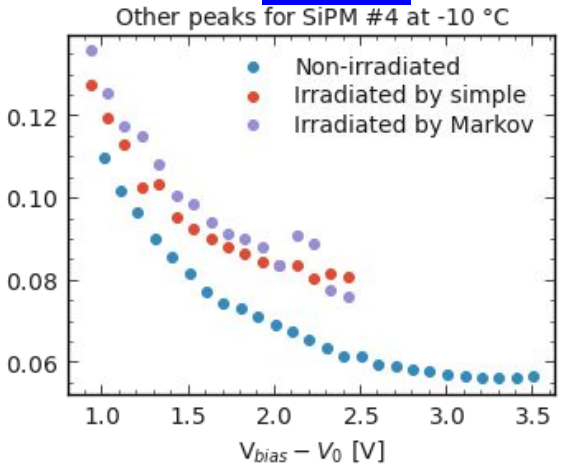


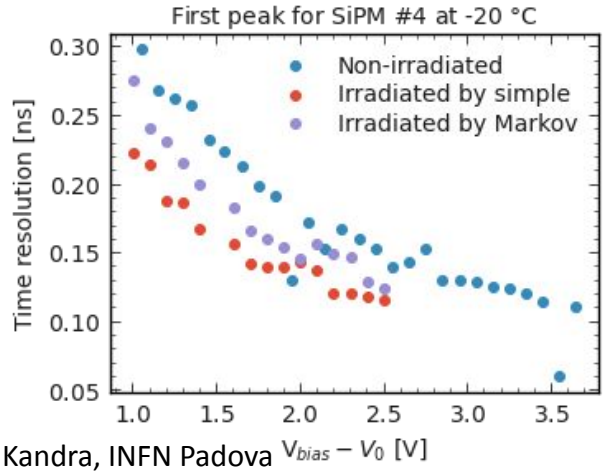


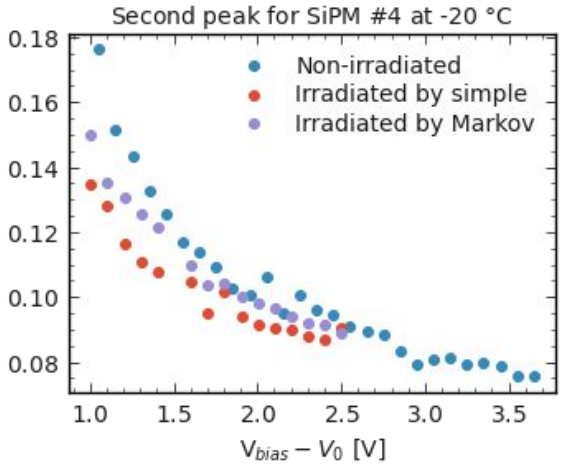
Time resolution

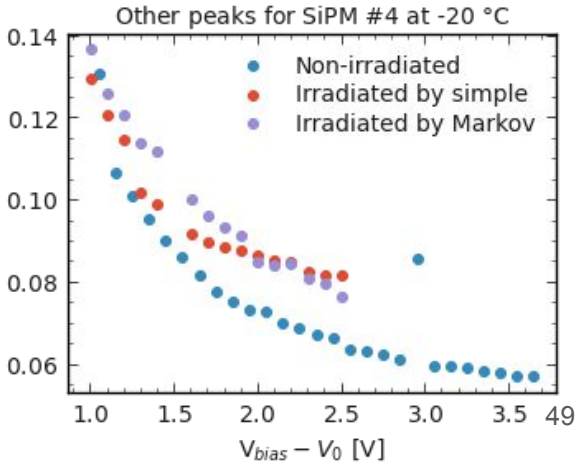




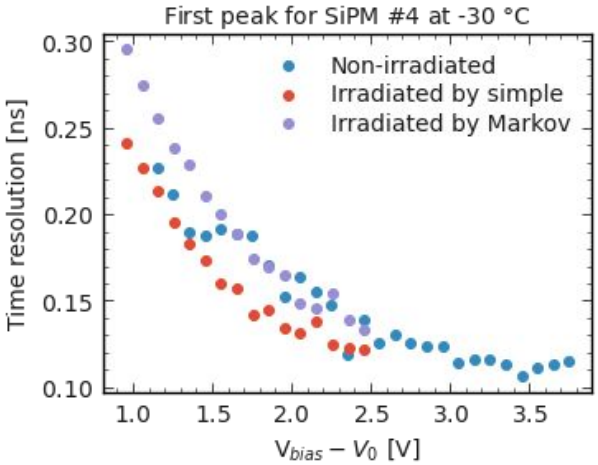


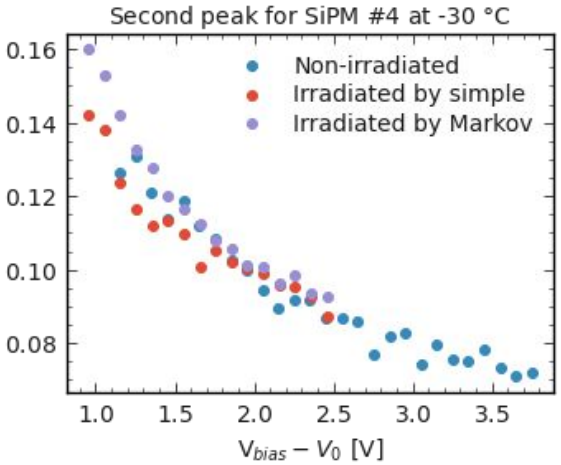


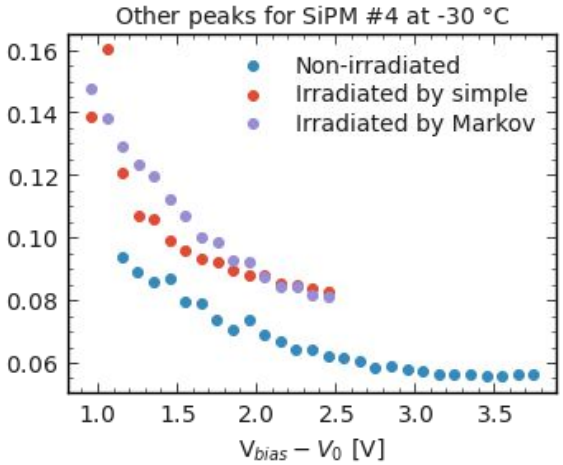


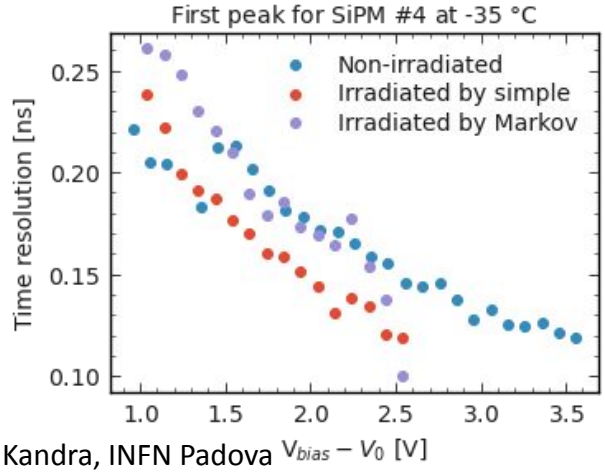


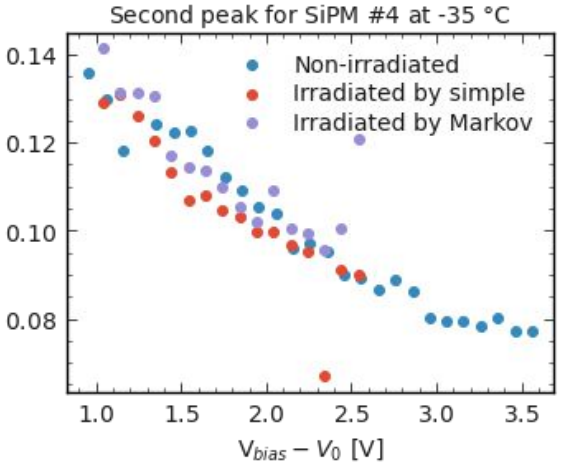
Time resolution

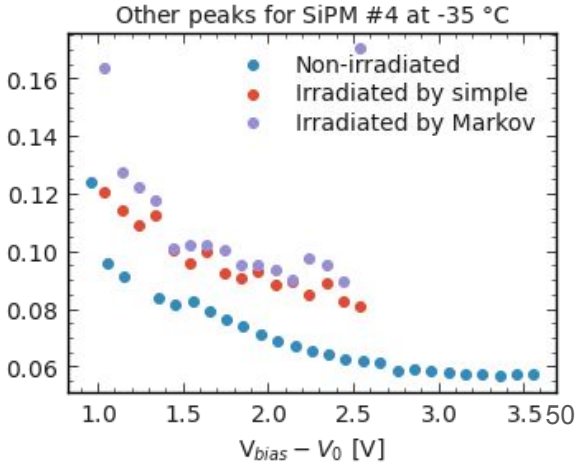




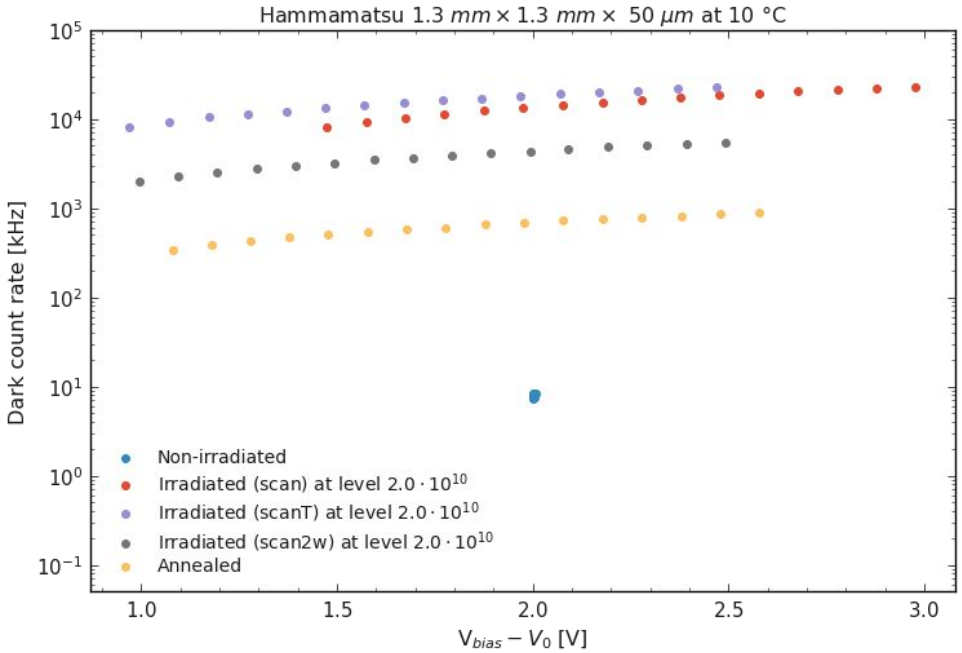


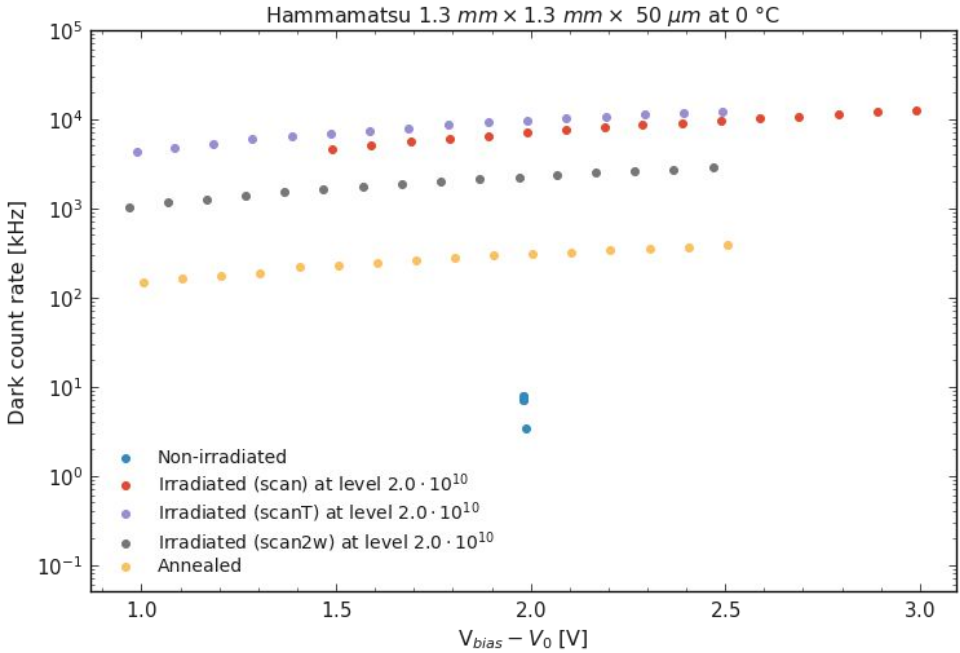




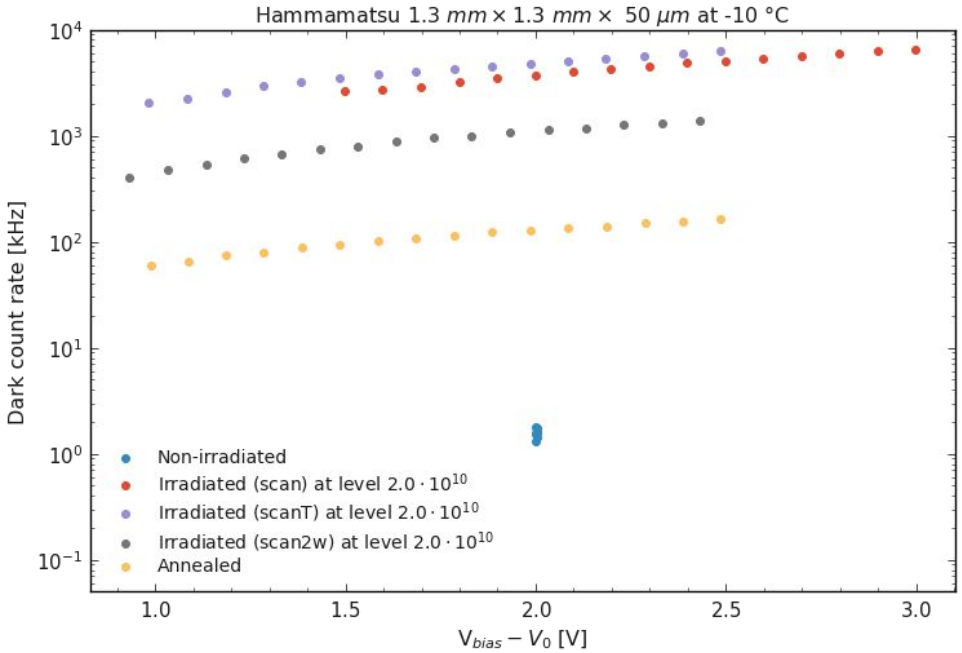


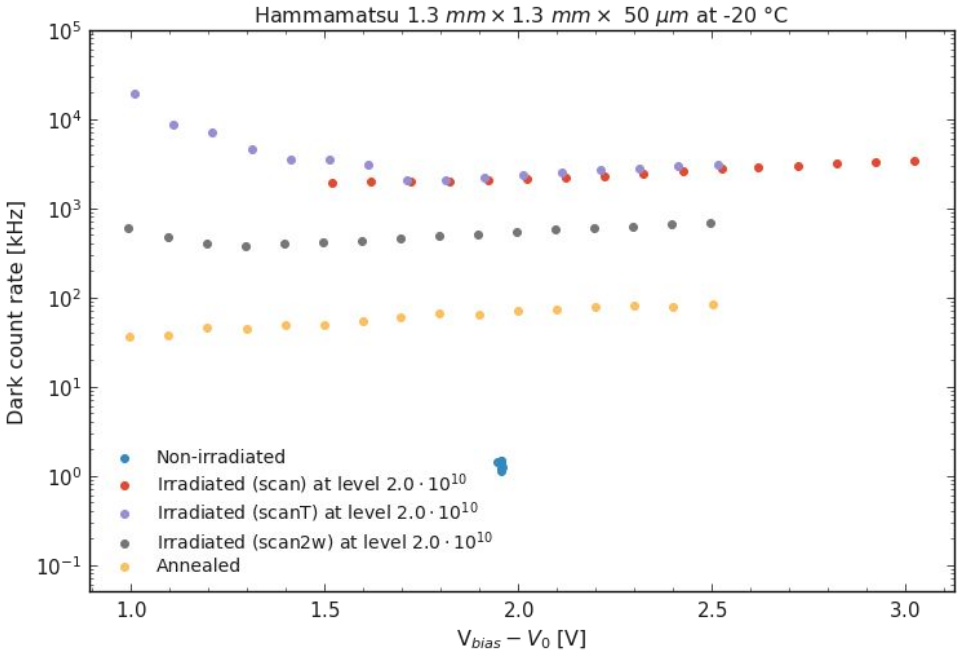
Dark count rate



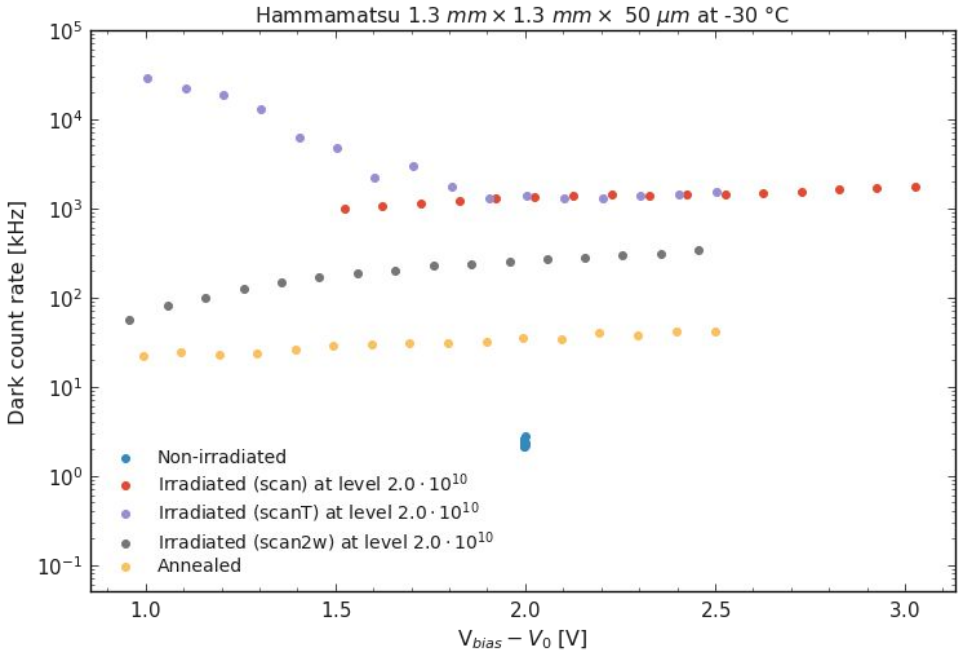


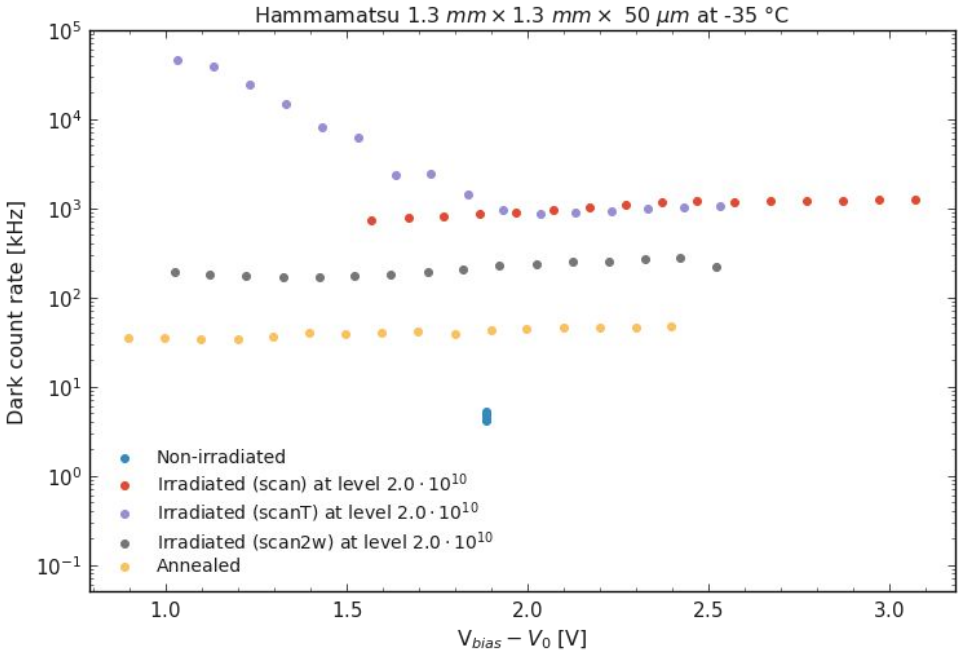
Dark count rate





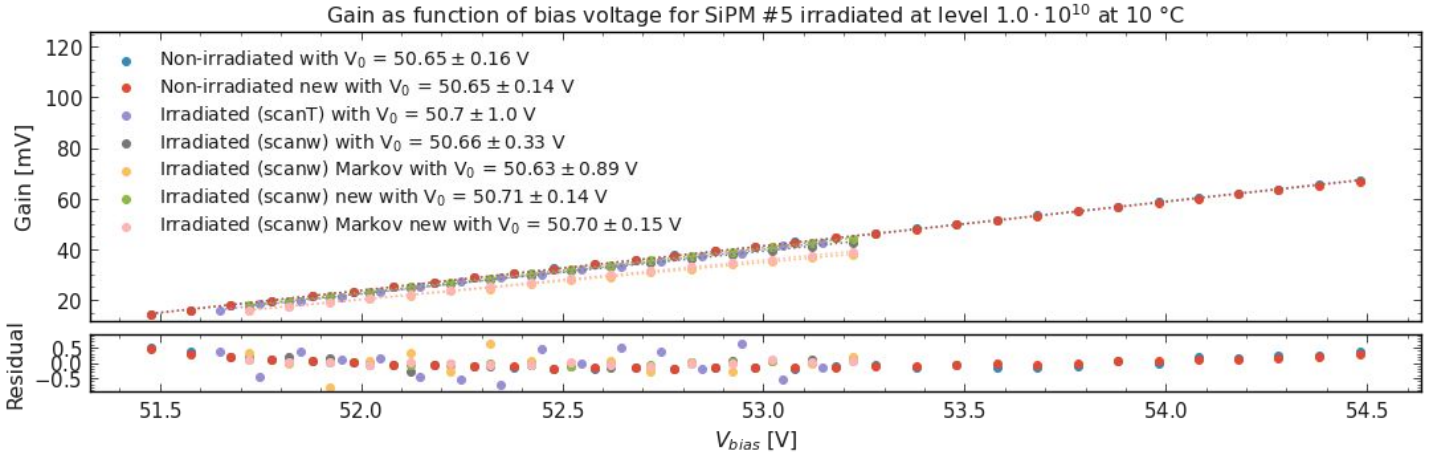
Dark count rate

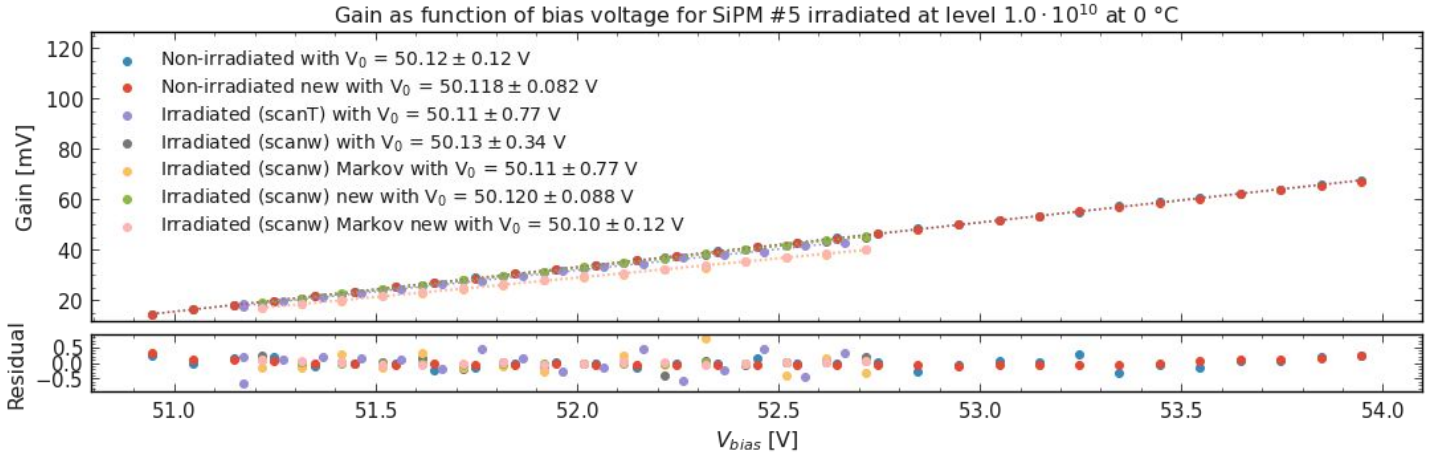




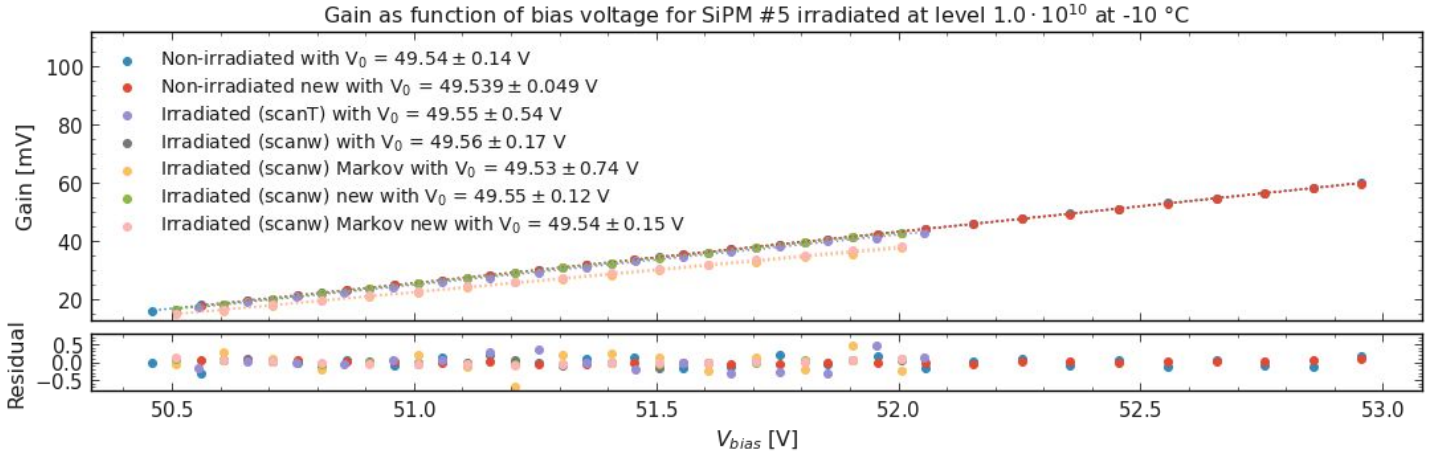
SiMP #5

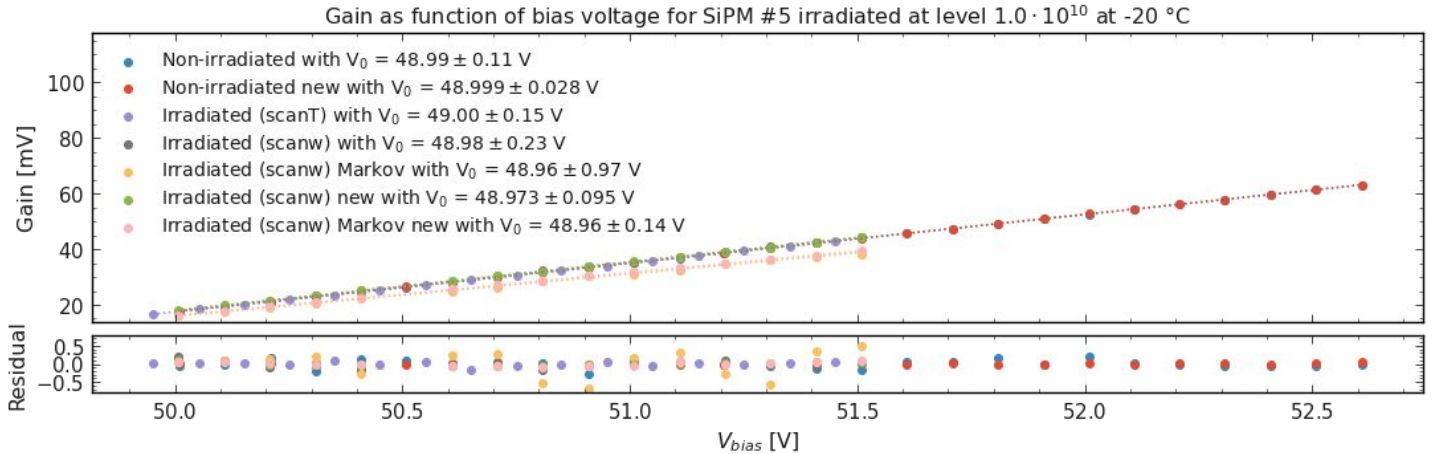
Gain as function of bias voltage



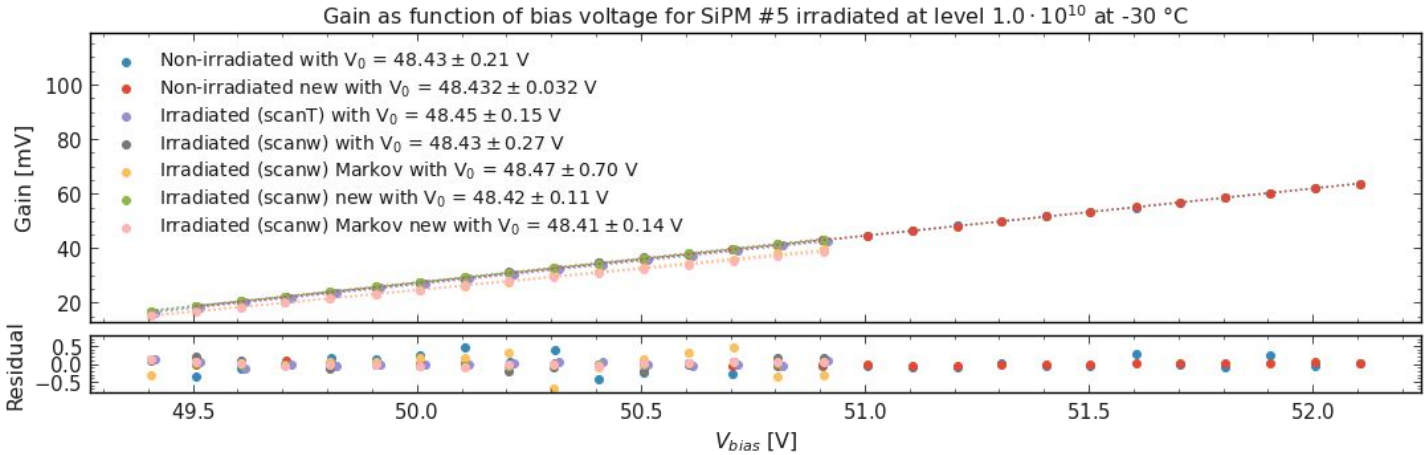


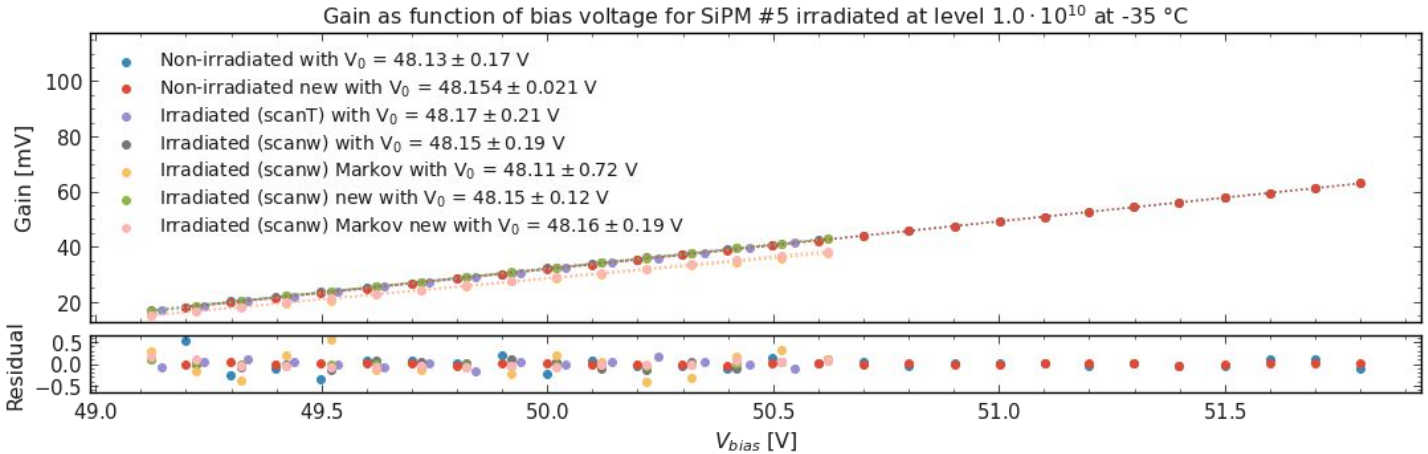
Gain as function of bias voltage



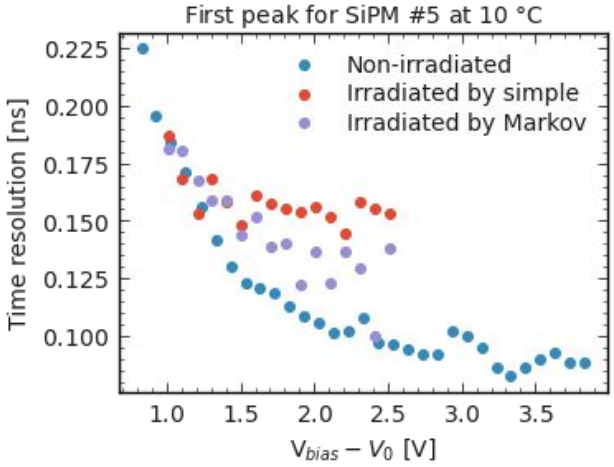


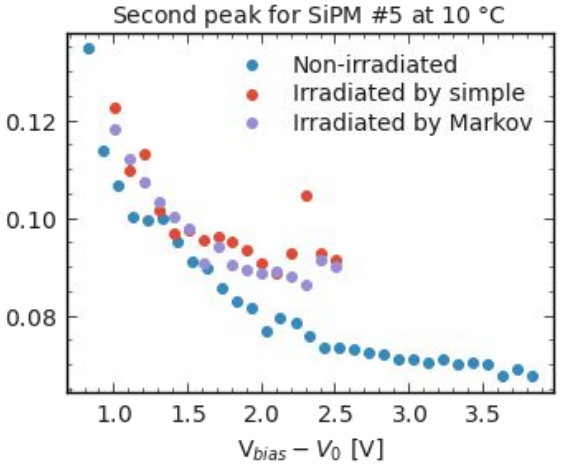
Gain as function of bias voltage

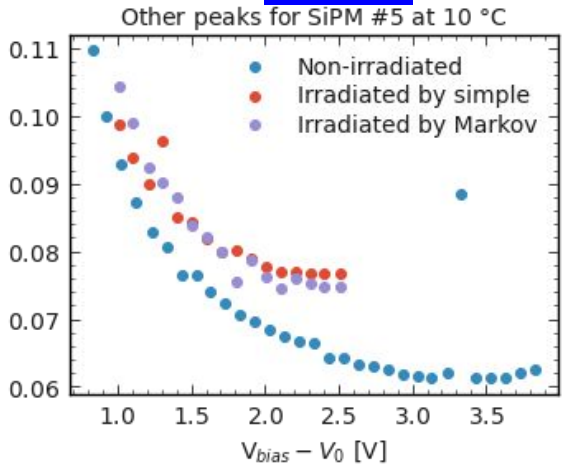


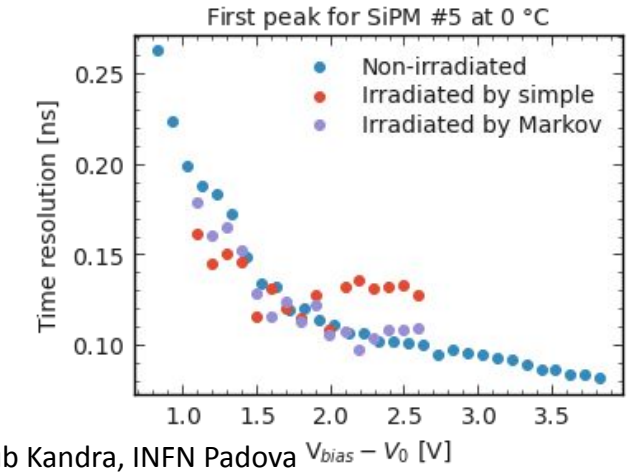


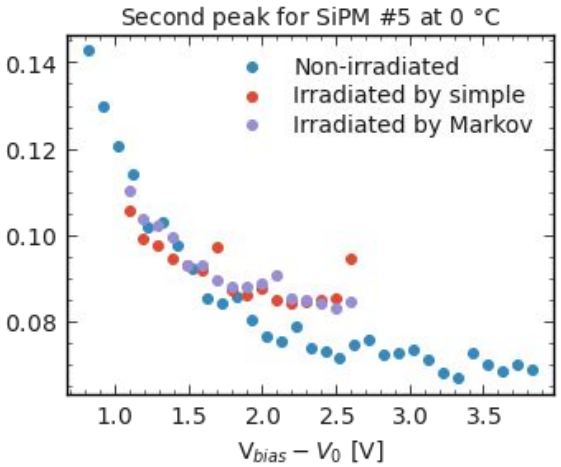
Time resolution

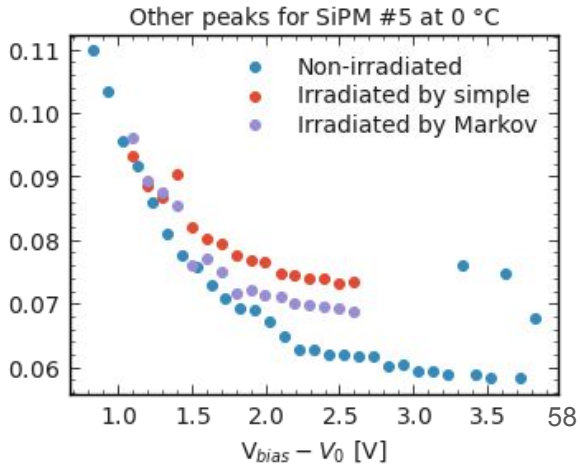




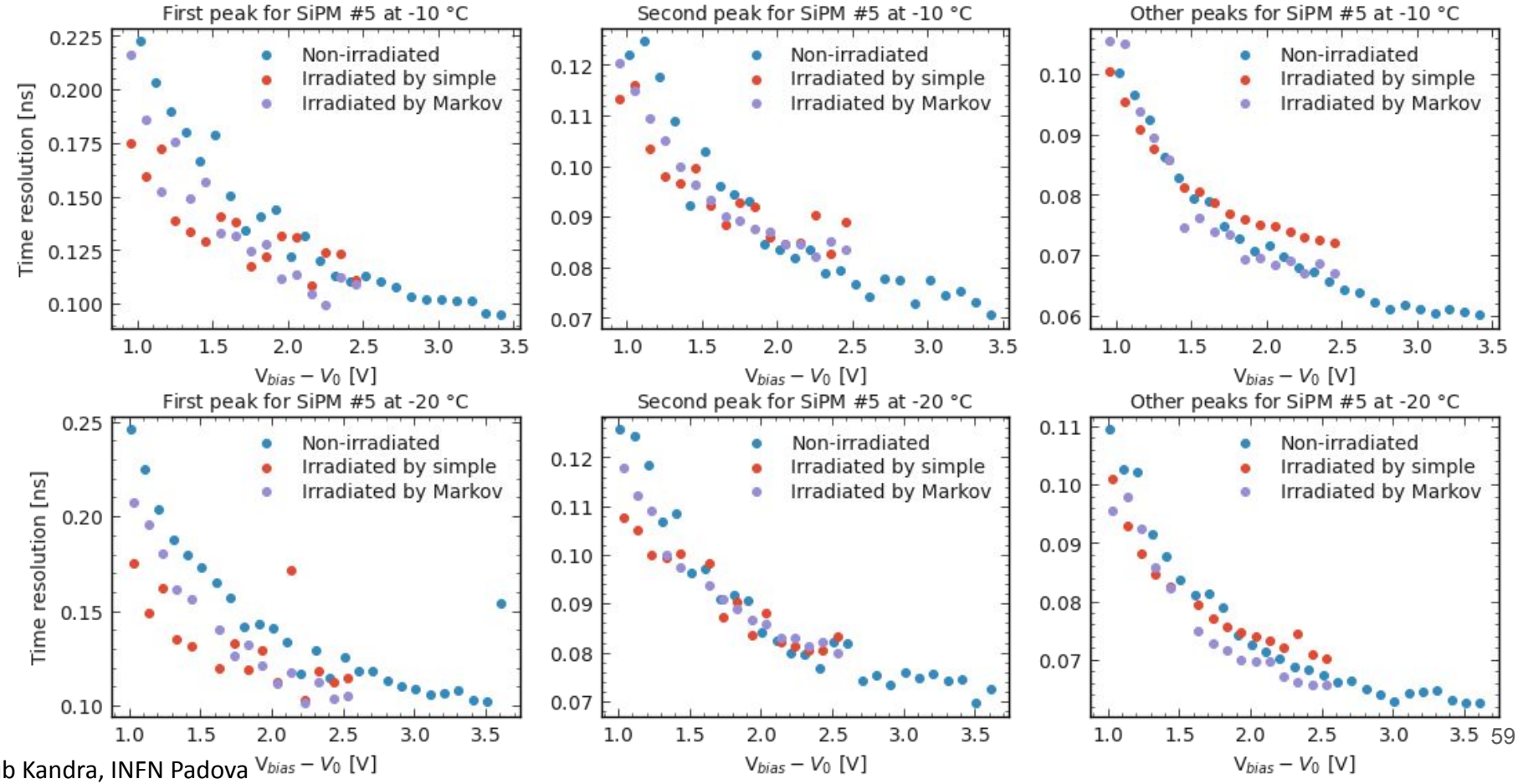




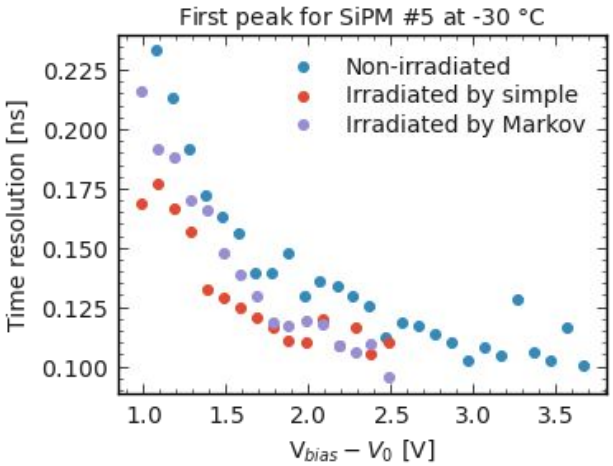


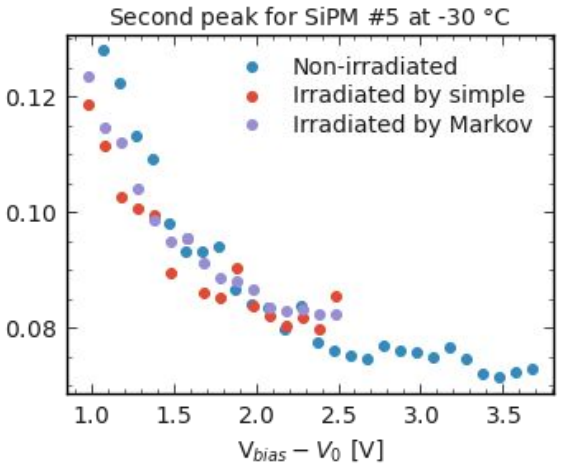


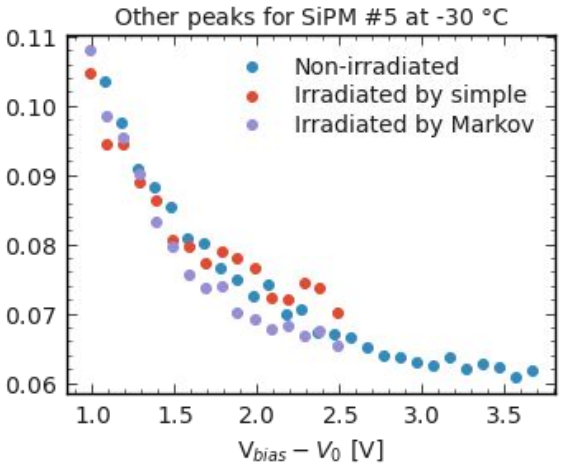
Time resolution

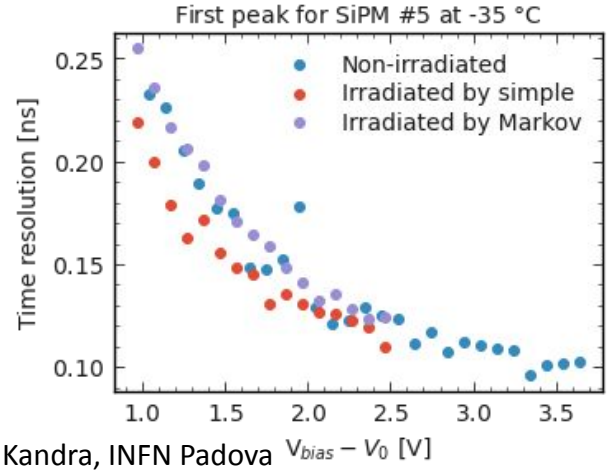


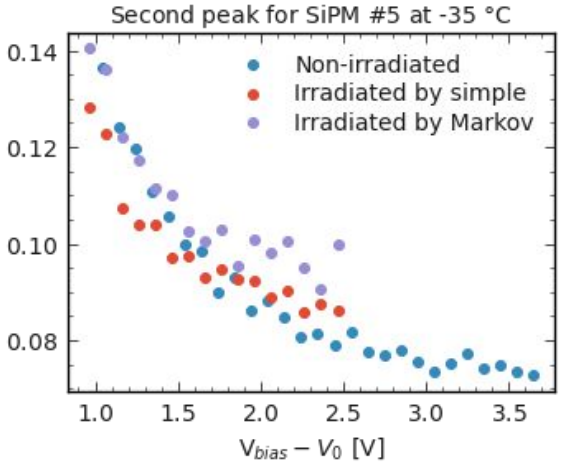
Time resolution

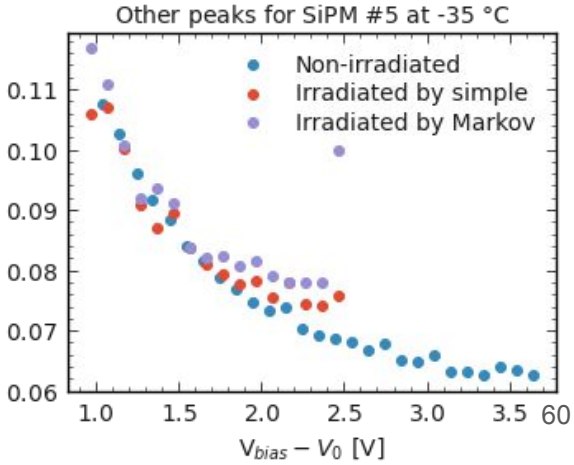




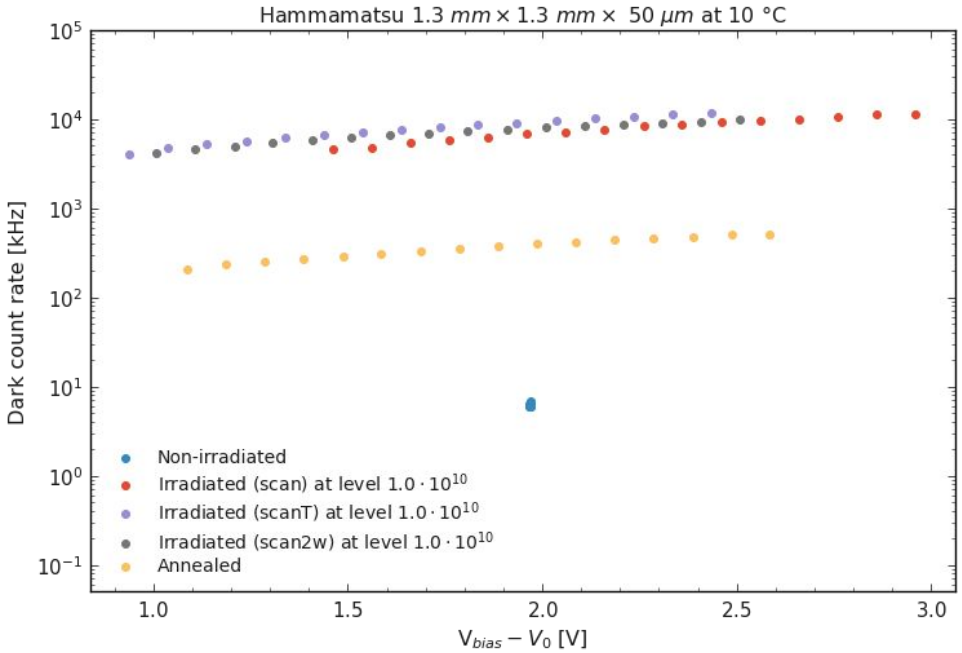


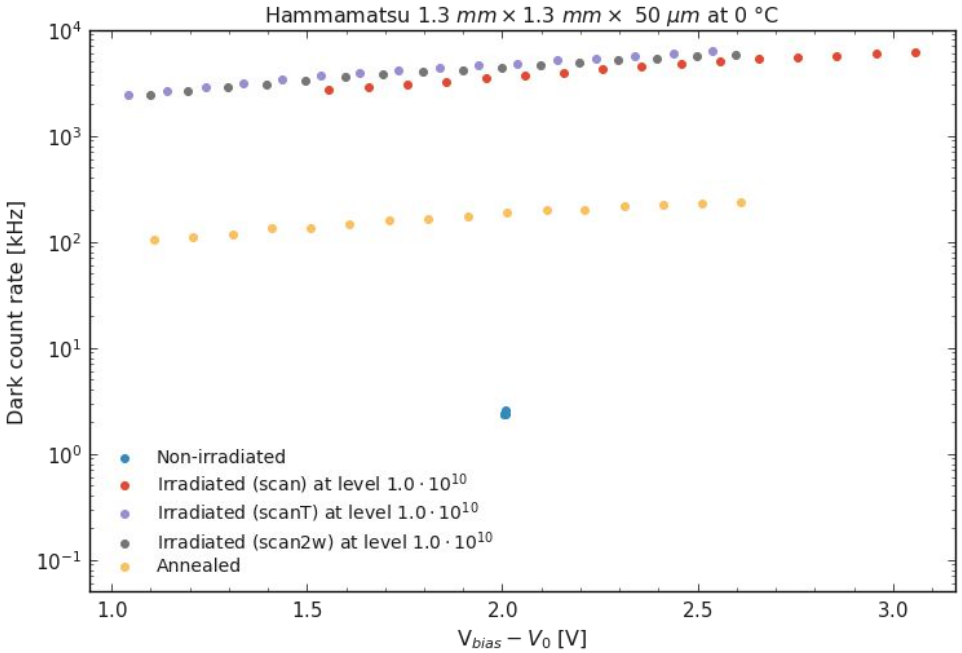




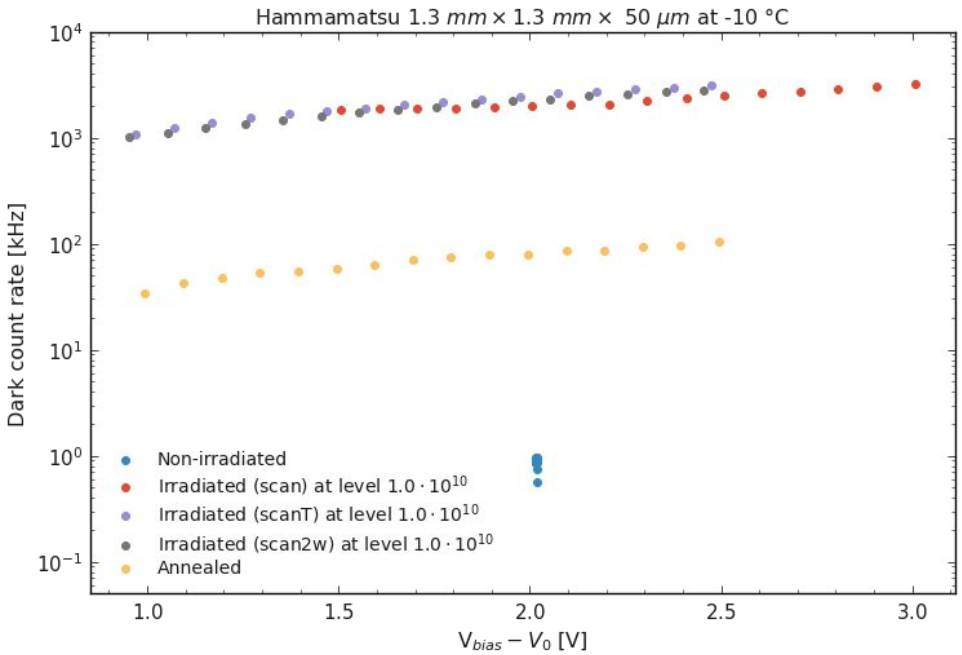


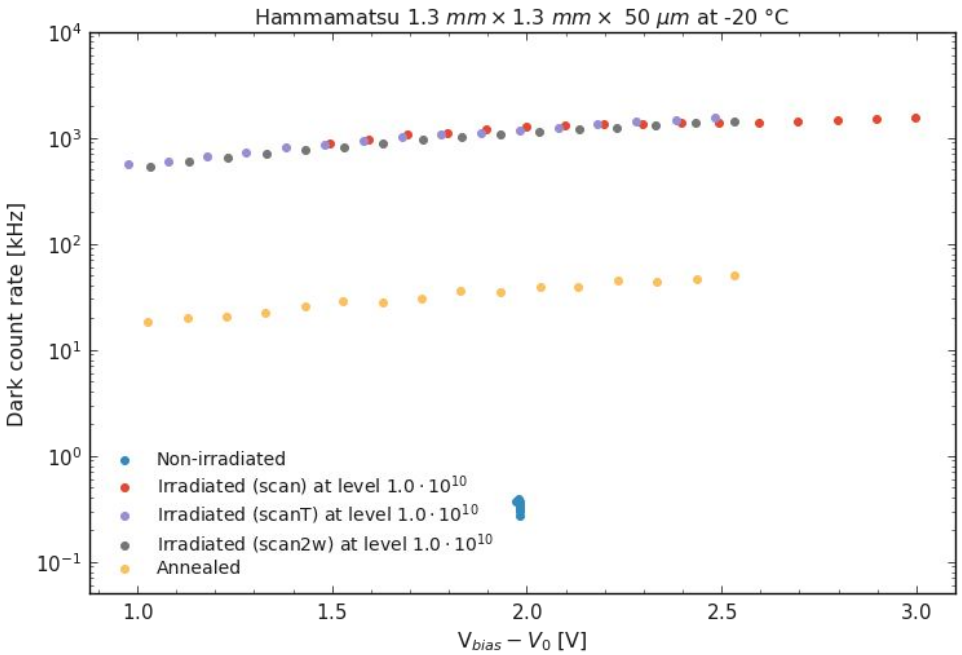
Dark count rate



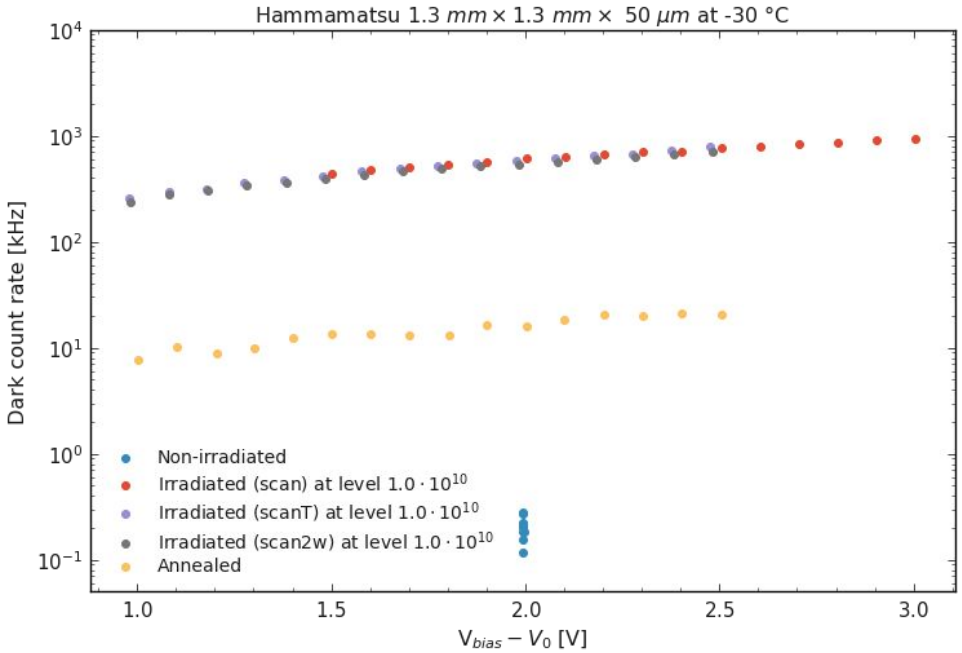


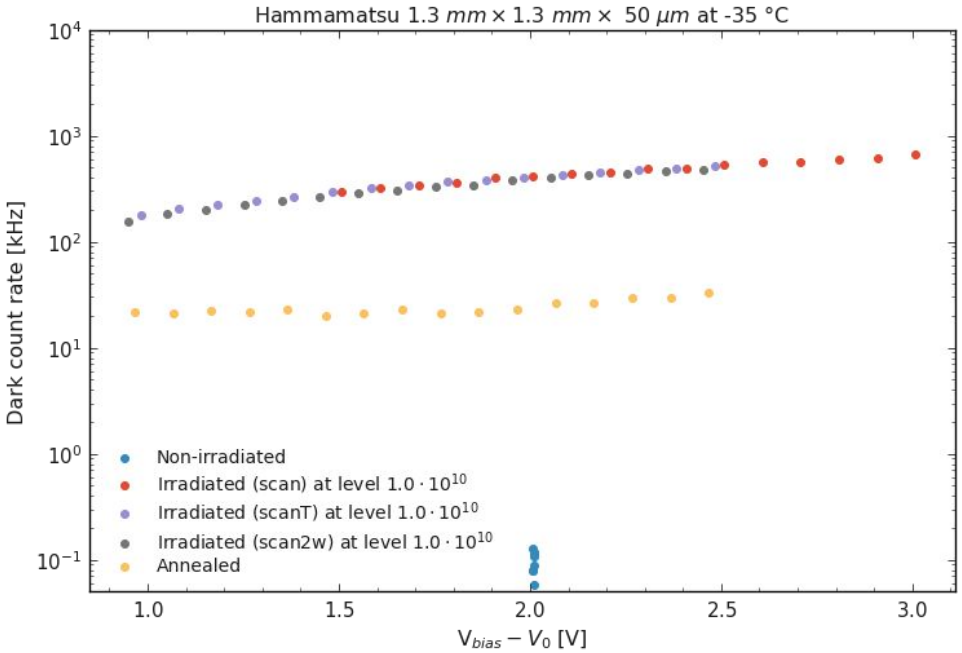
Dark count rate





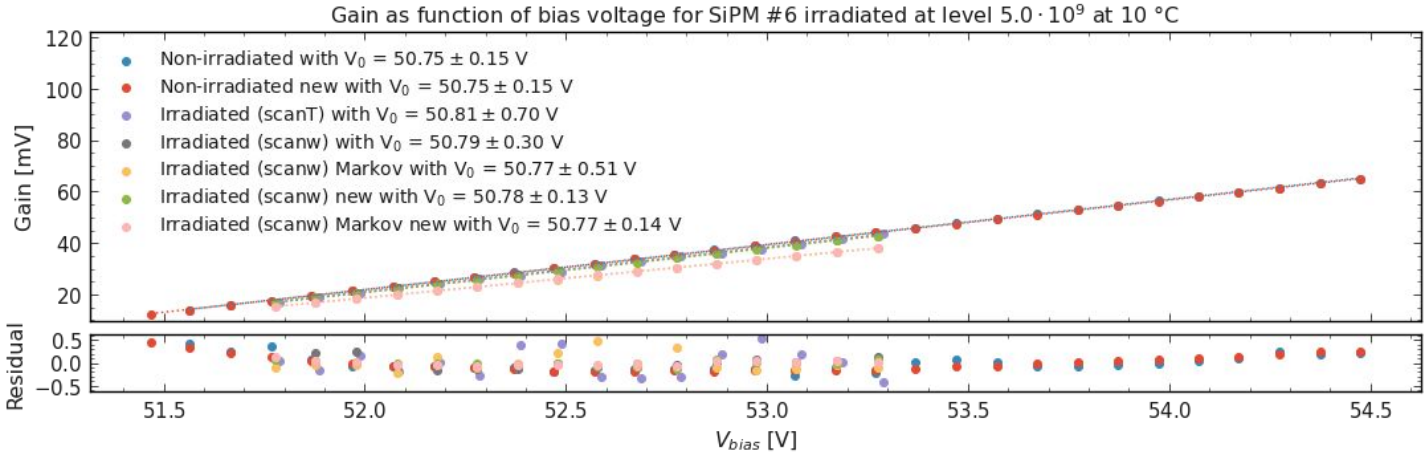
Dark count rate

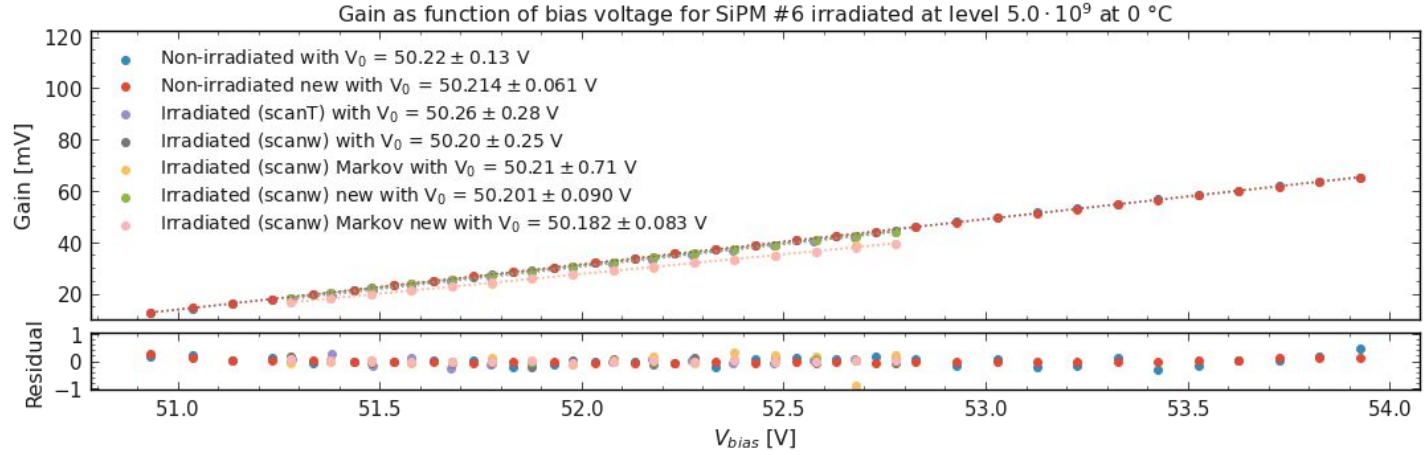




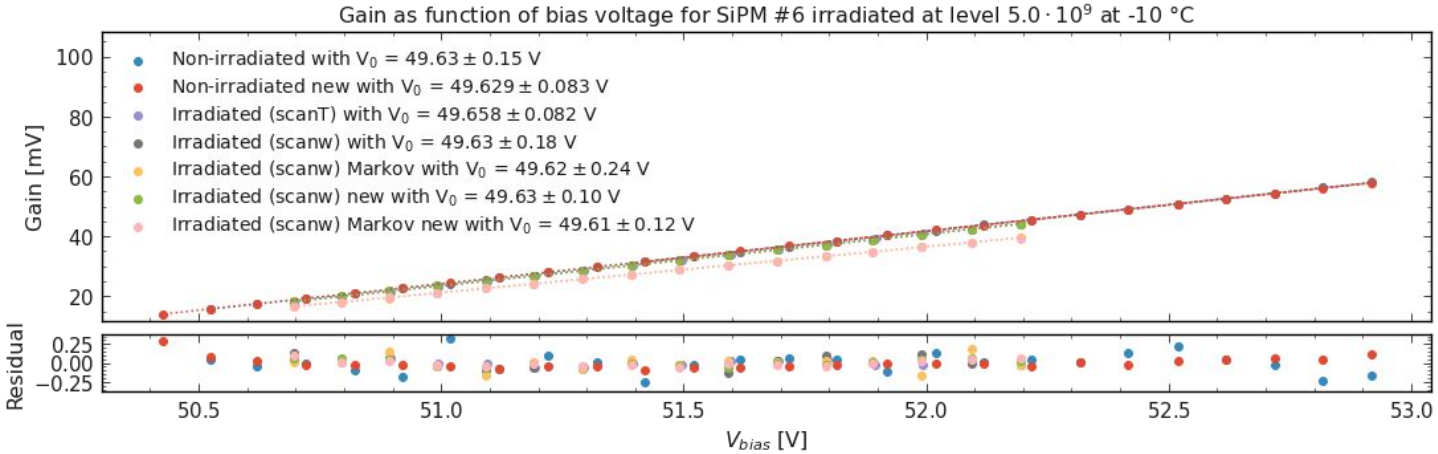
SiMP #6

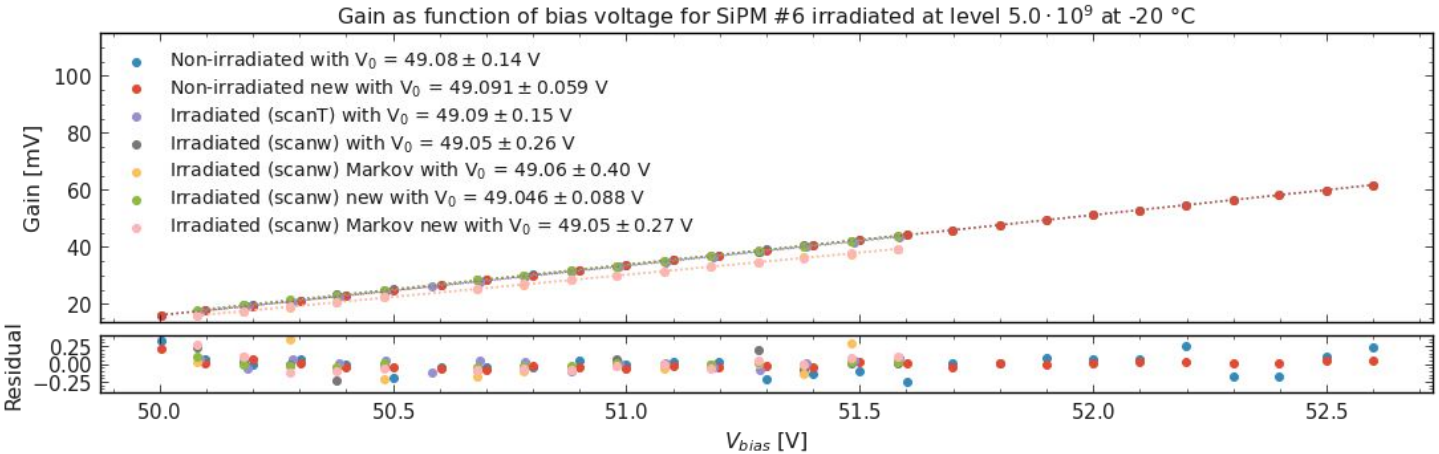
Gain as function of bias voltage for



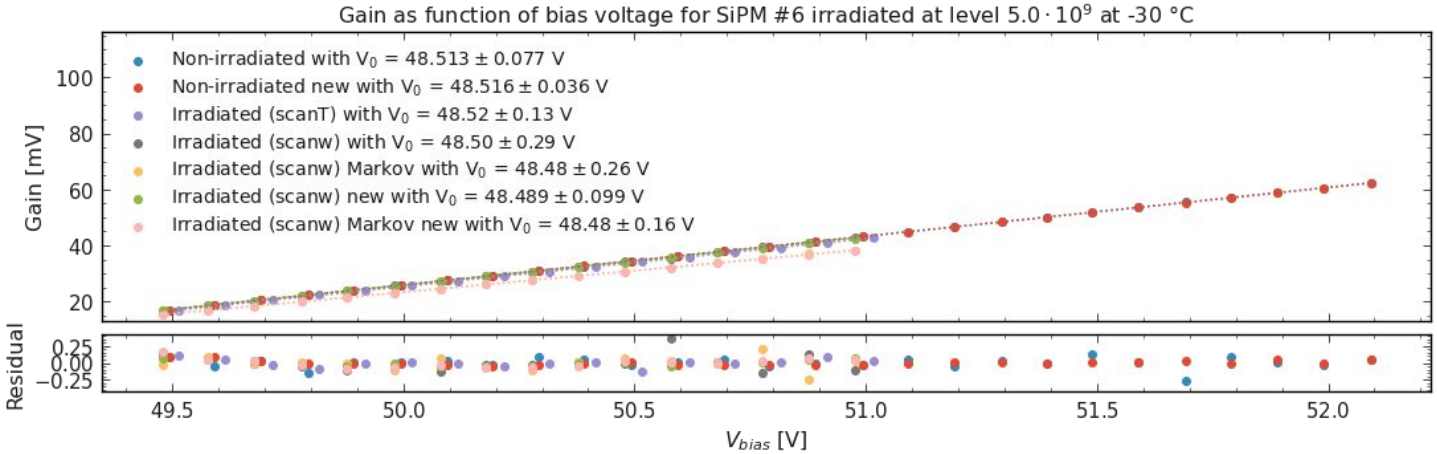


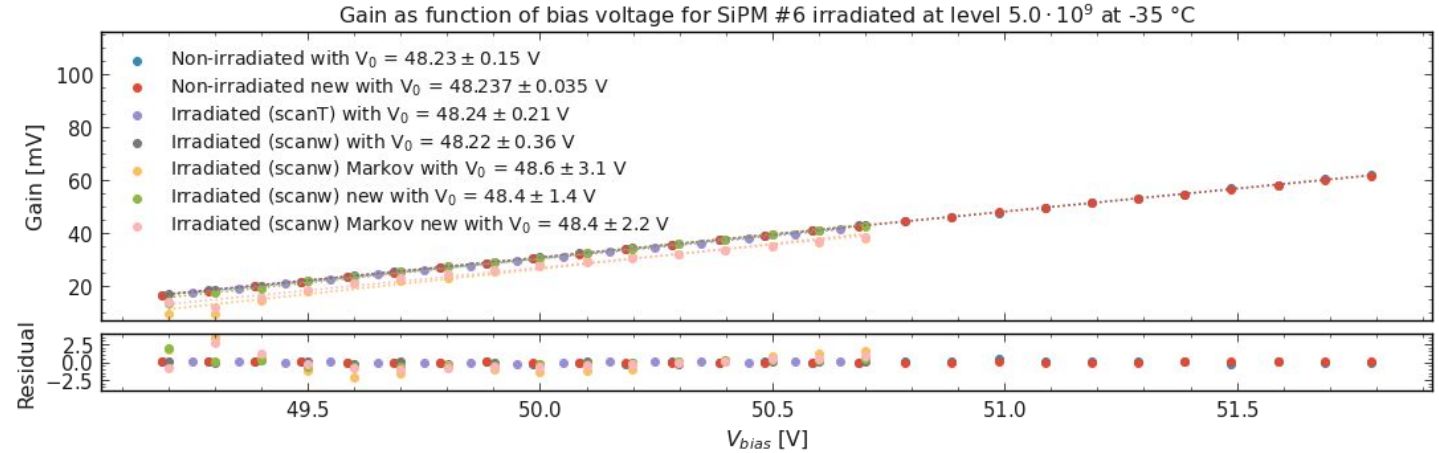
Gain as function of bias voltage for



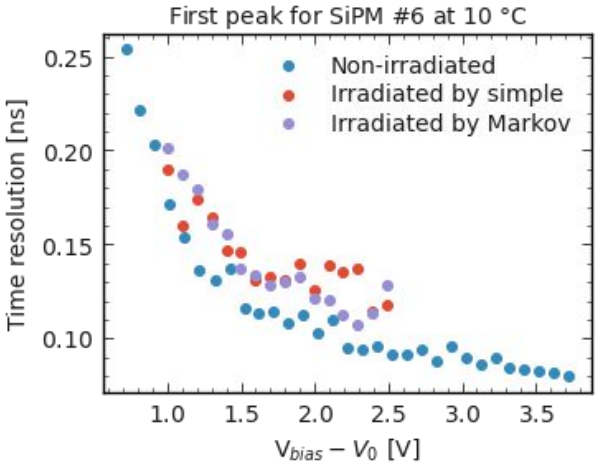


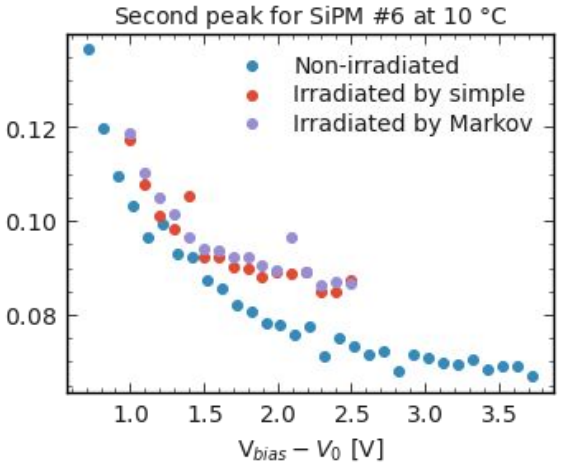
Gain as function of bias voltage for

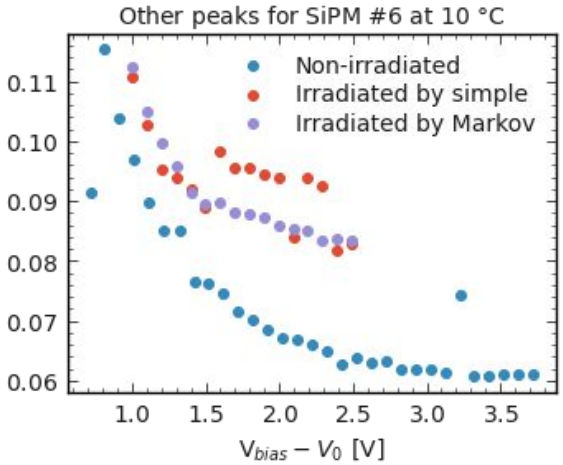


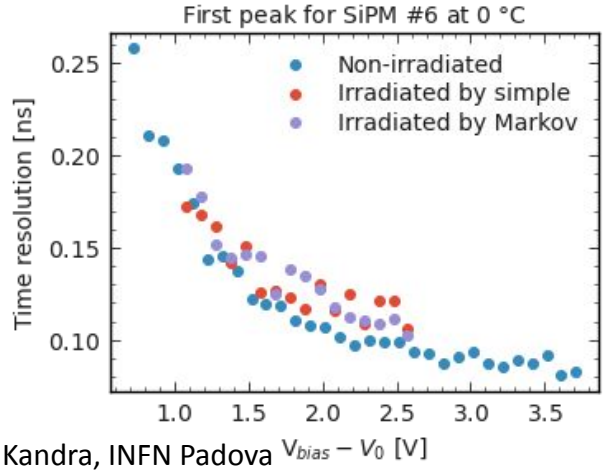


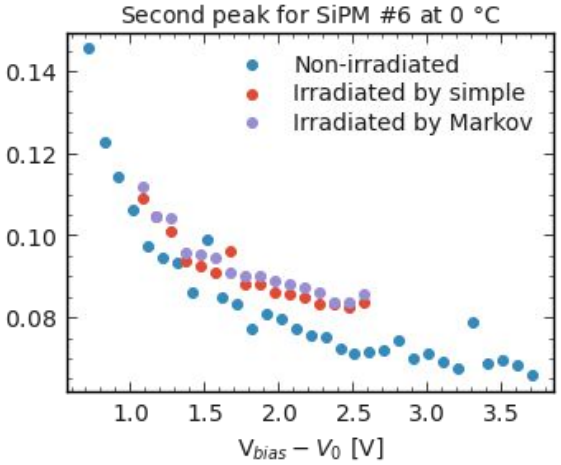
Time resolution

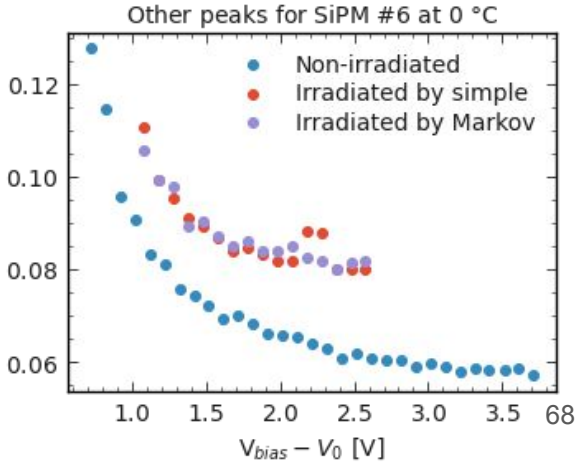




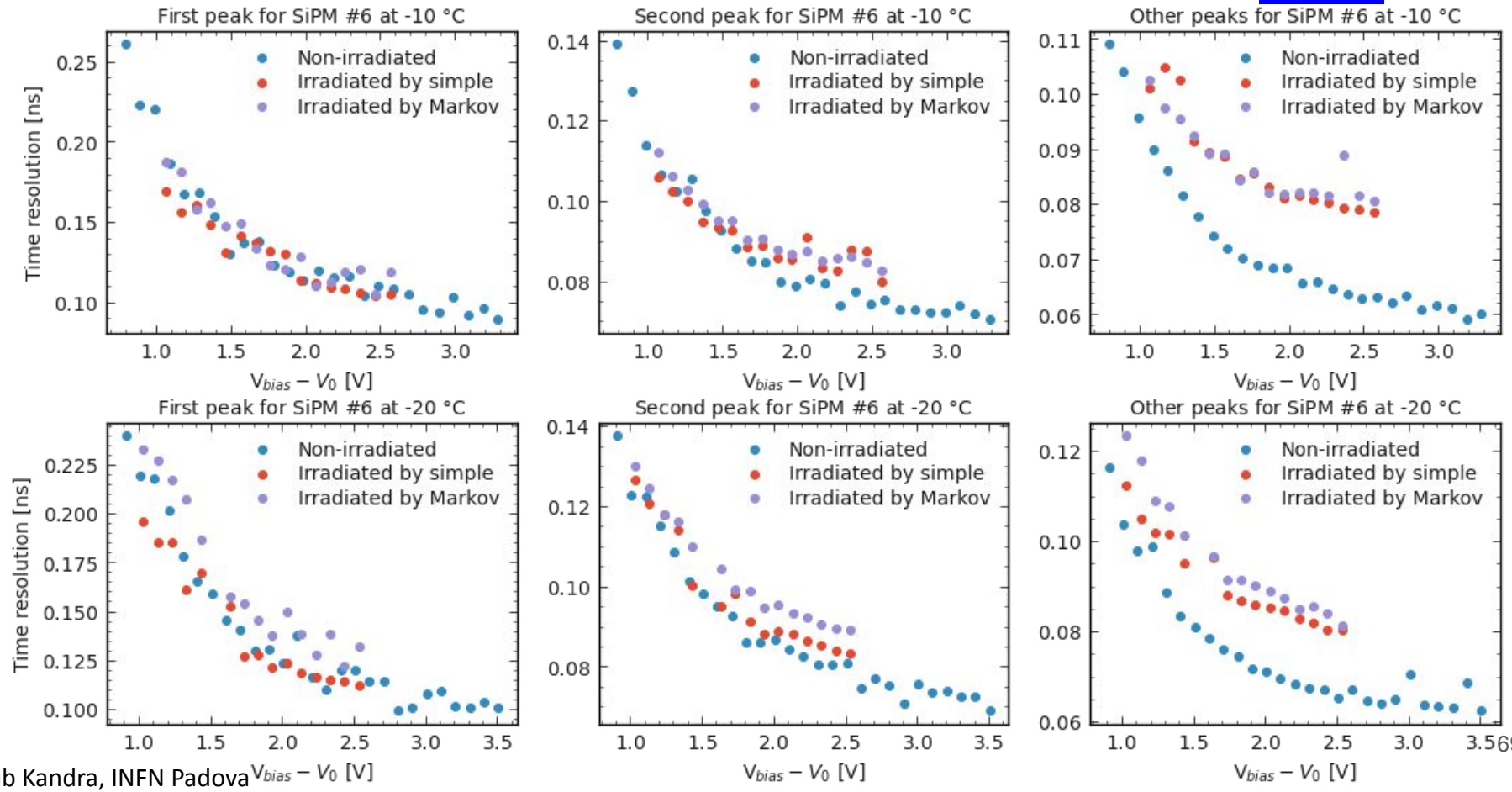




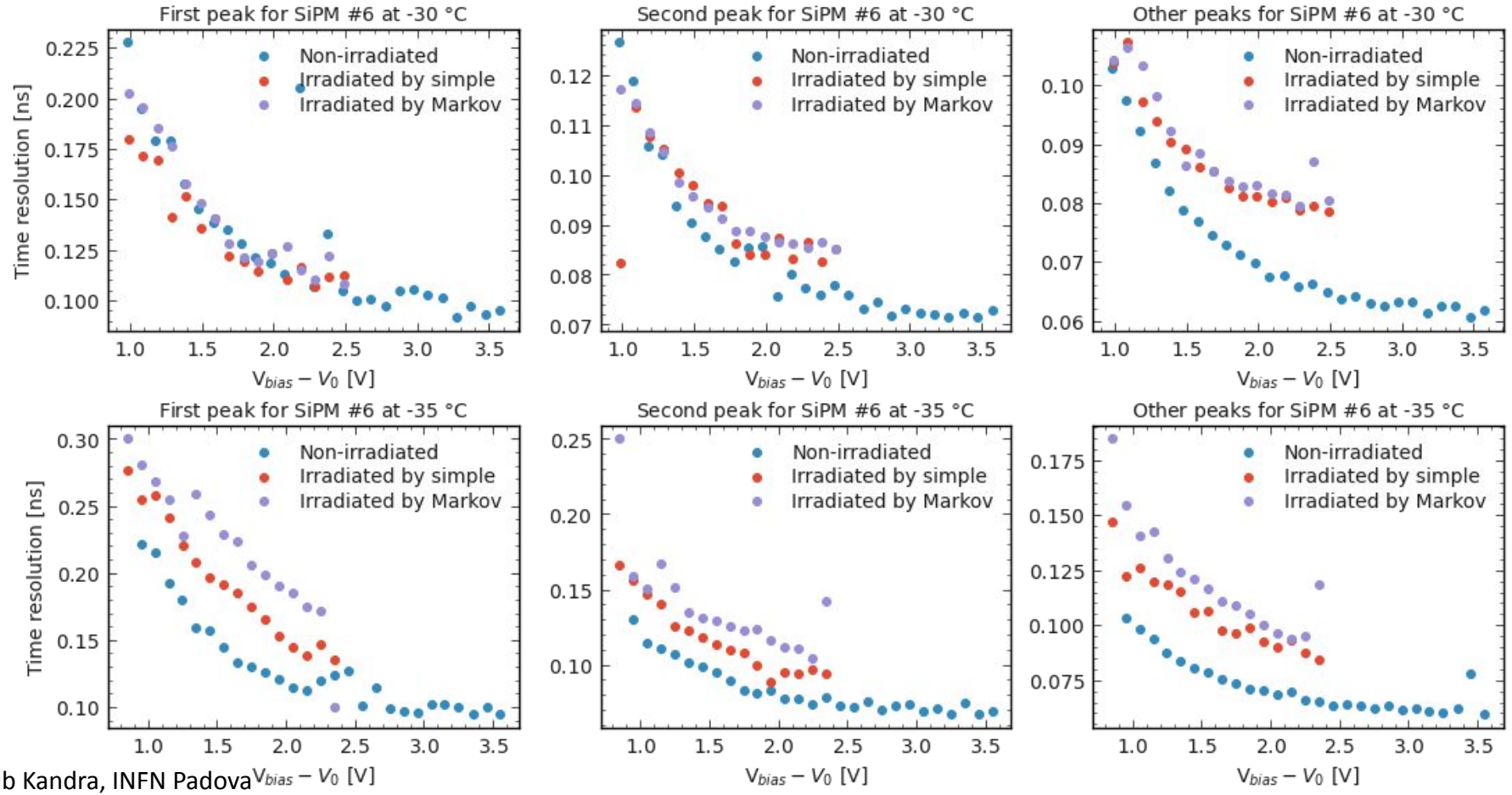




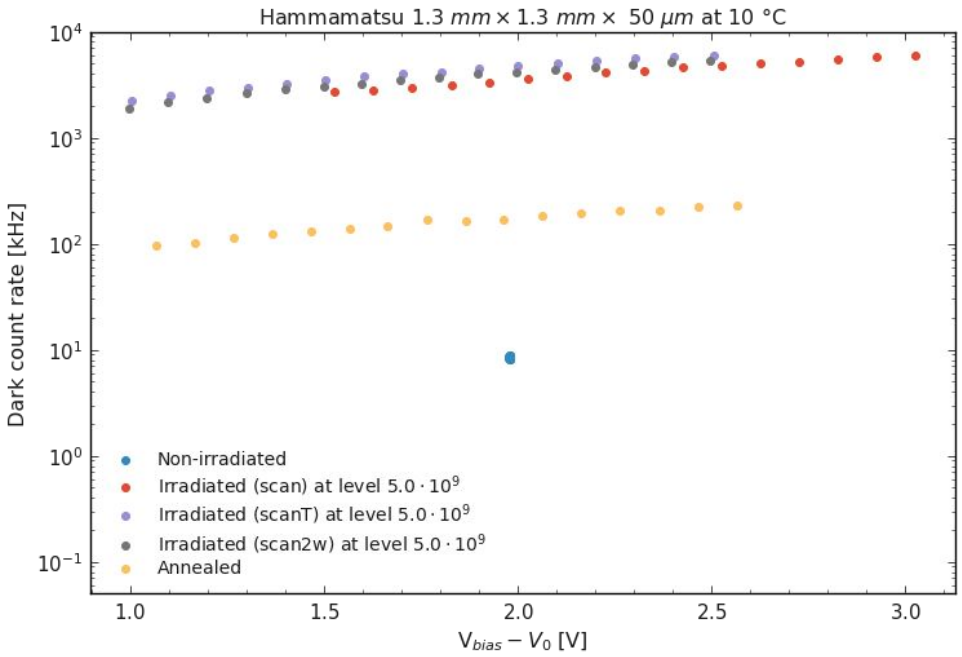
Time resolution

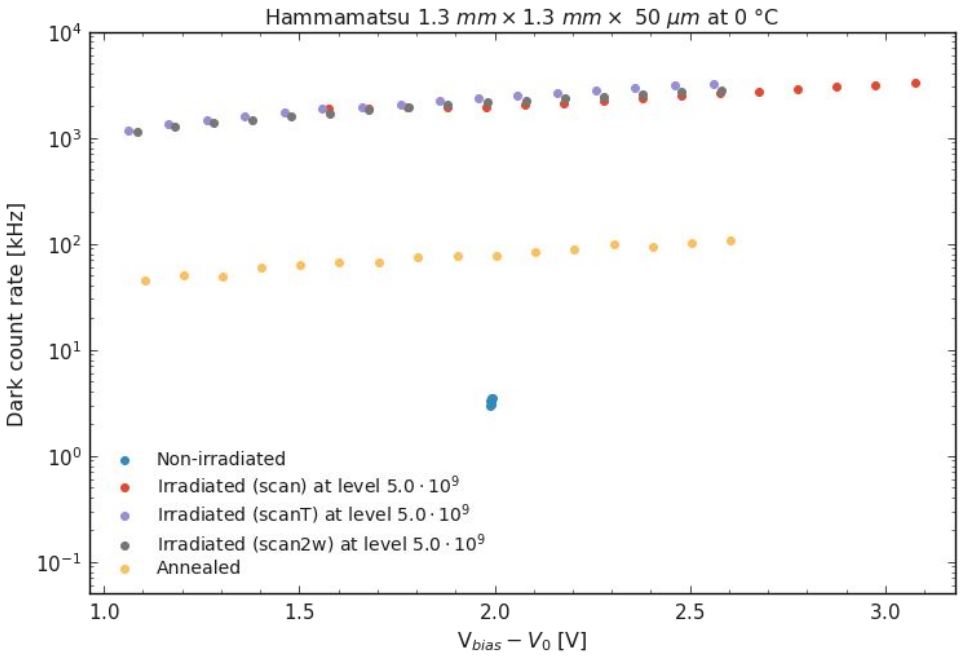


Time resolution

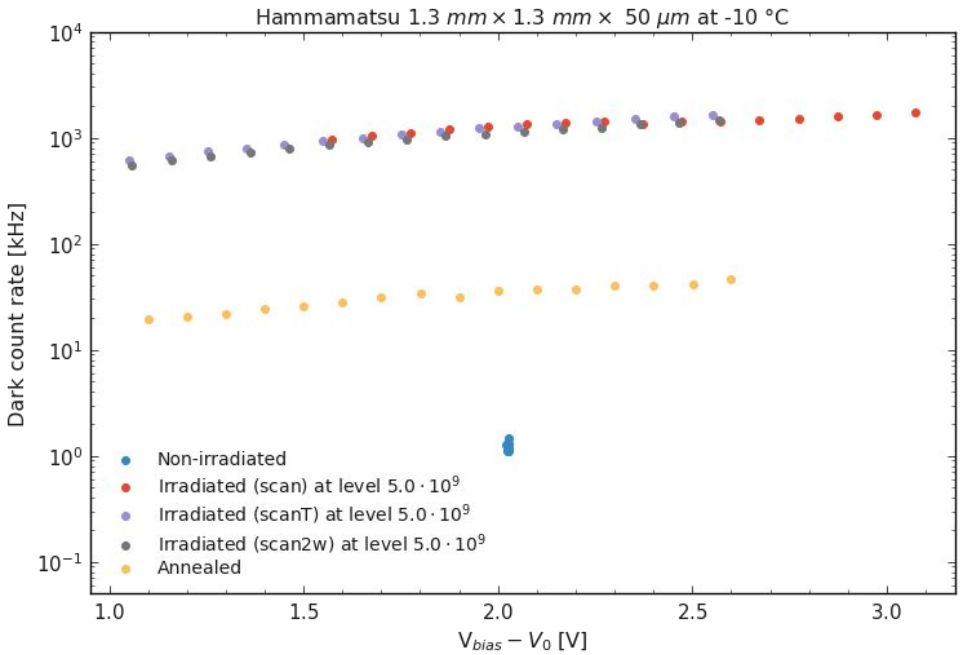


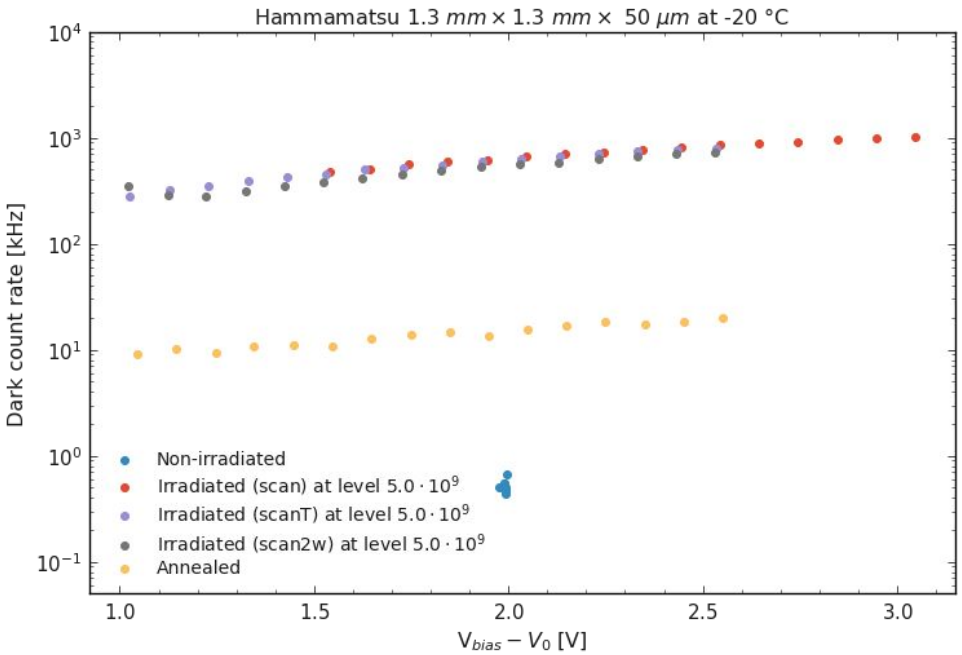
Dark count rate



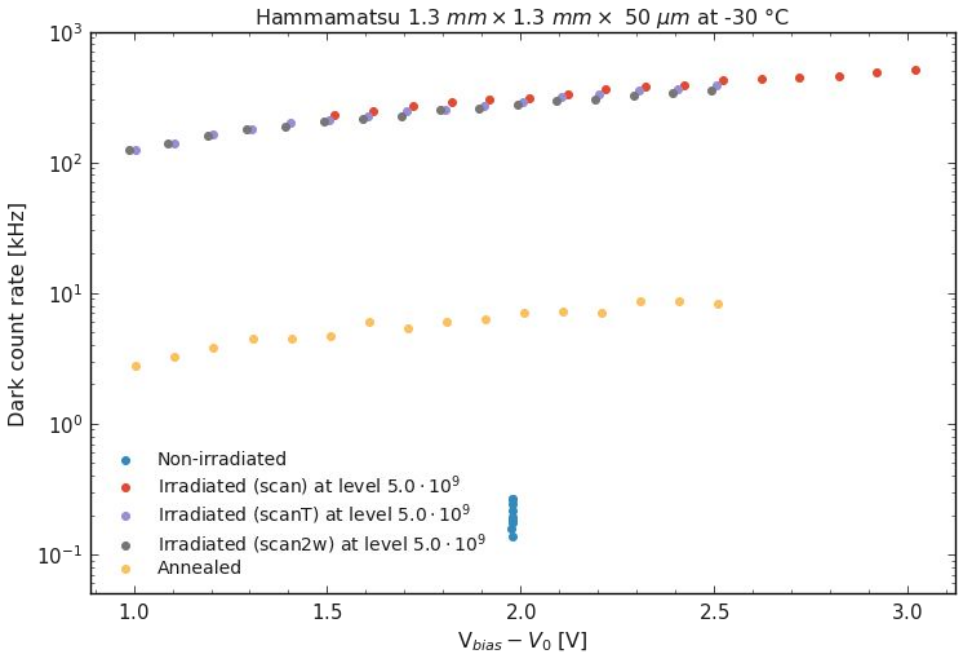


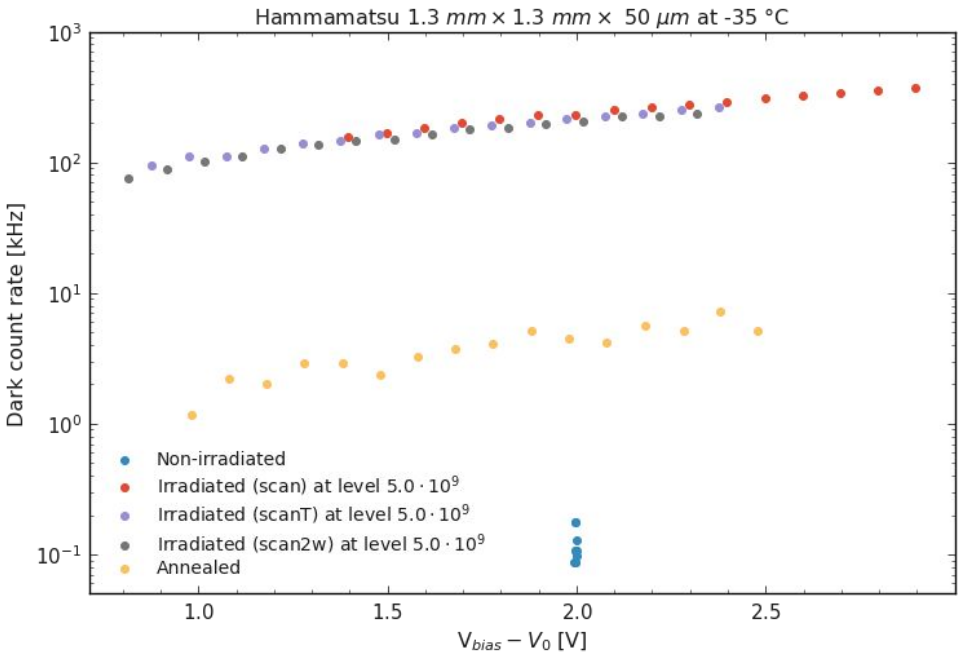
Dark count rate





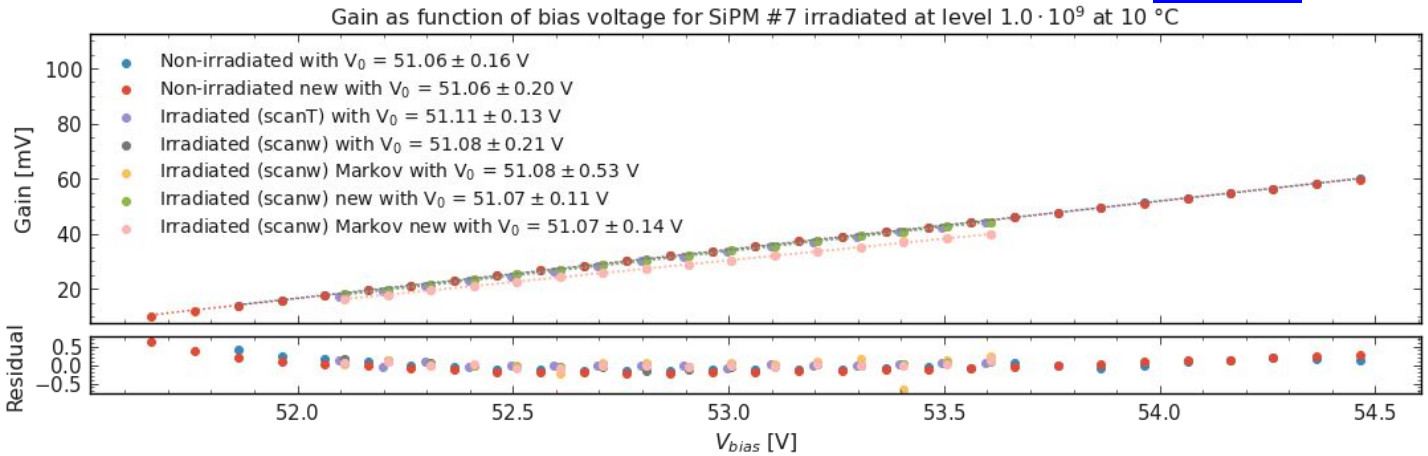
Dark count rate

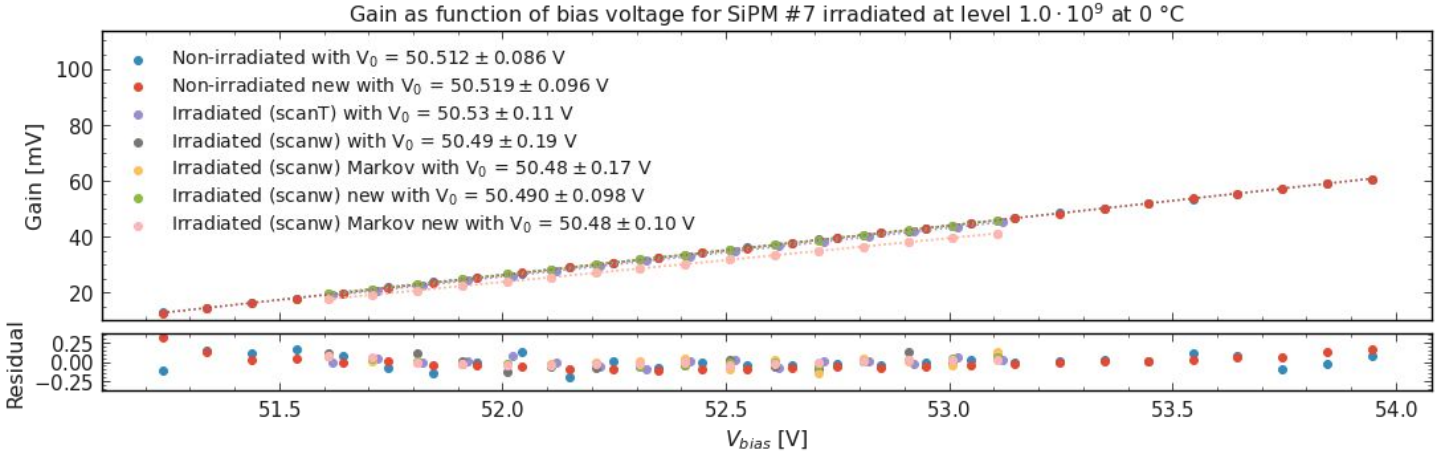




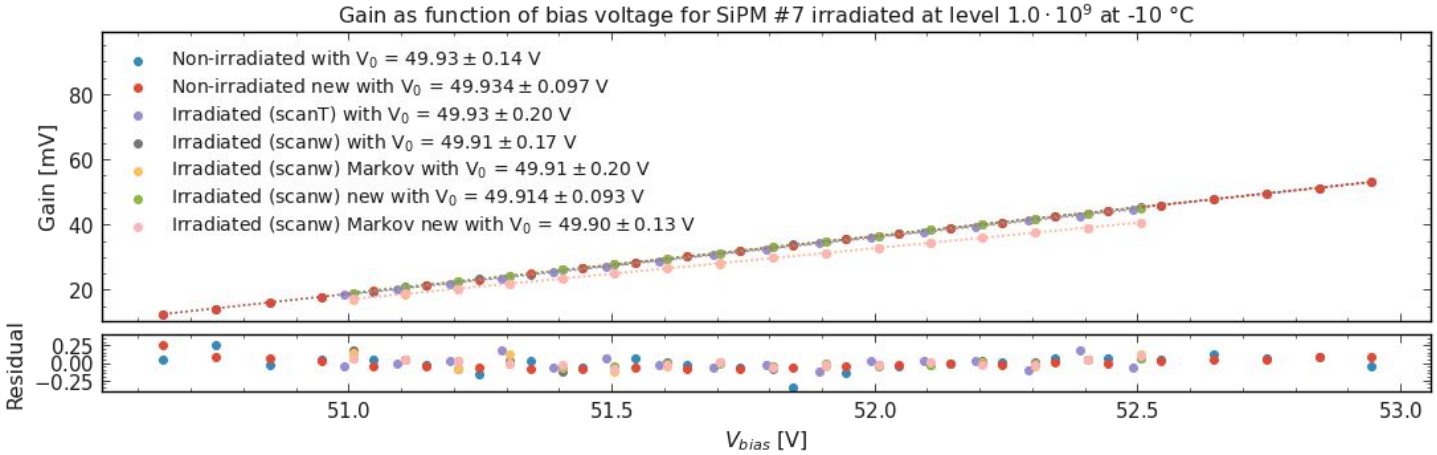
SiMP #7

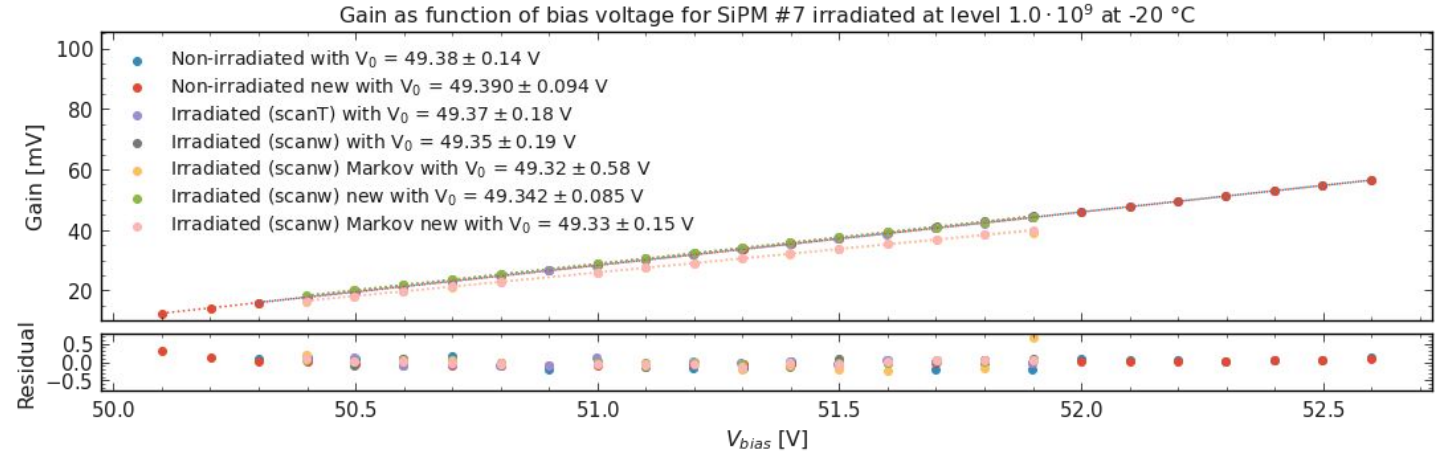
Gain as function of bias voltage for



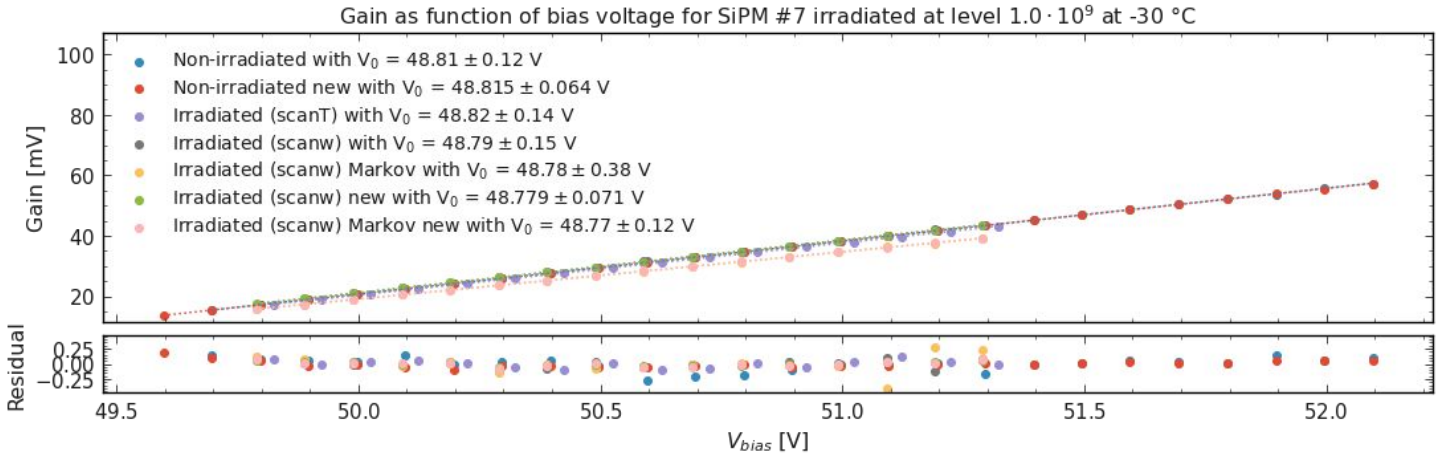


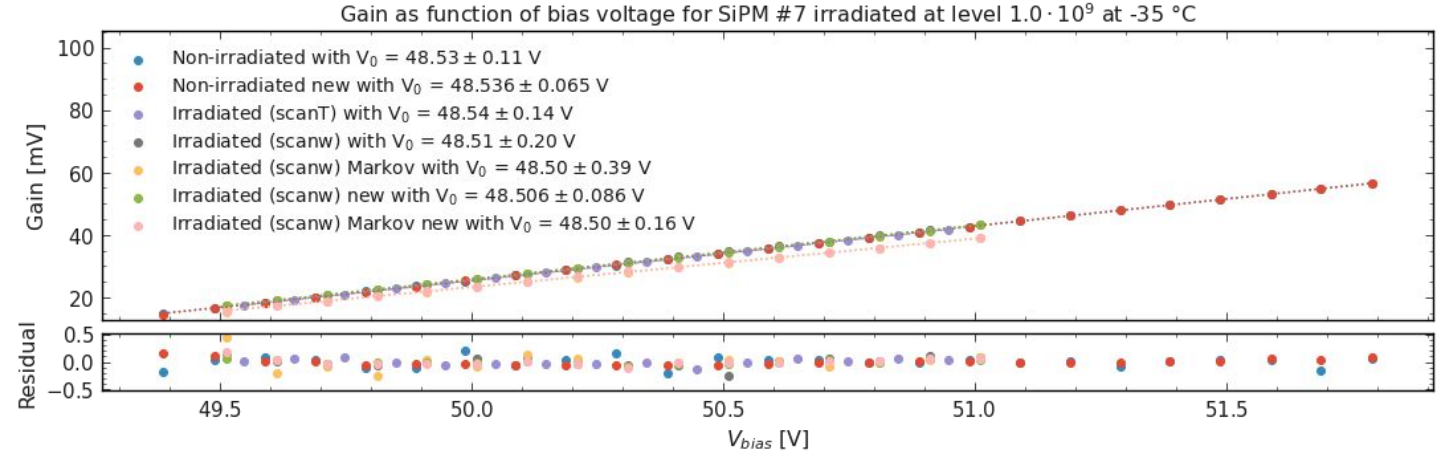
Gain as function of bias voltage for



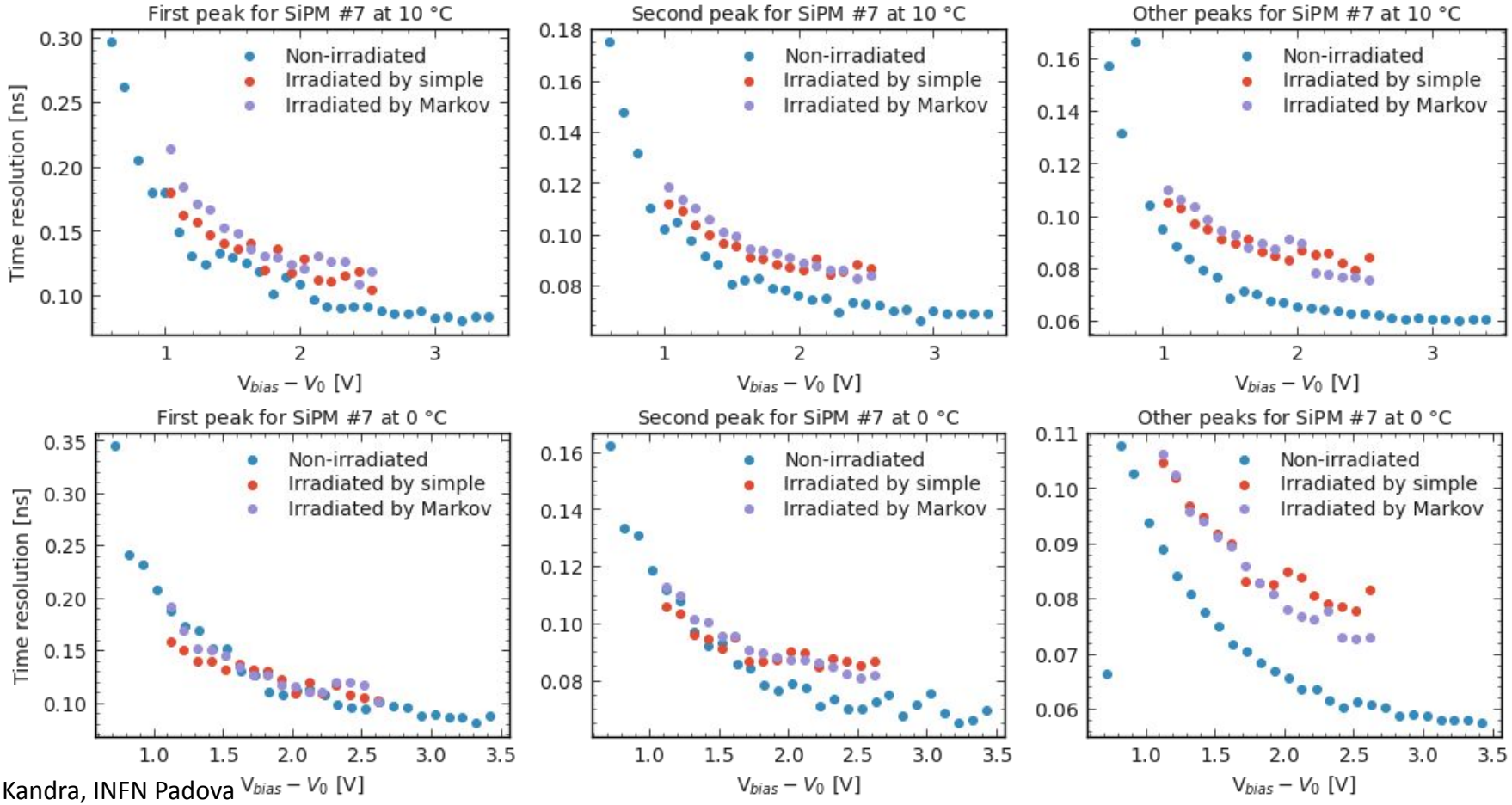


Gain as function of bias voltage for

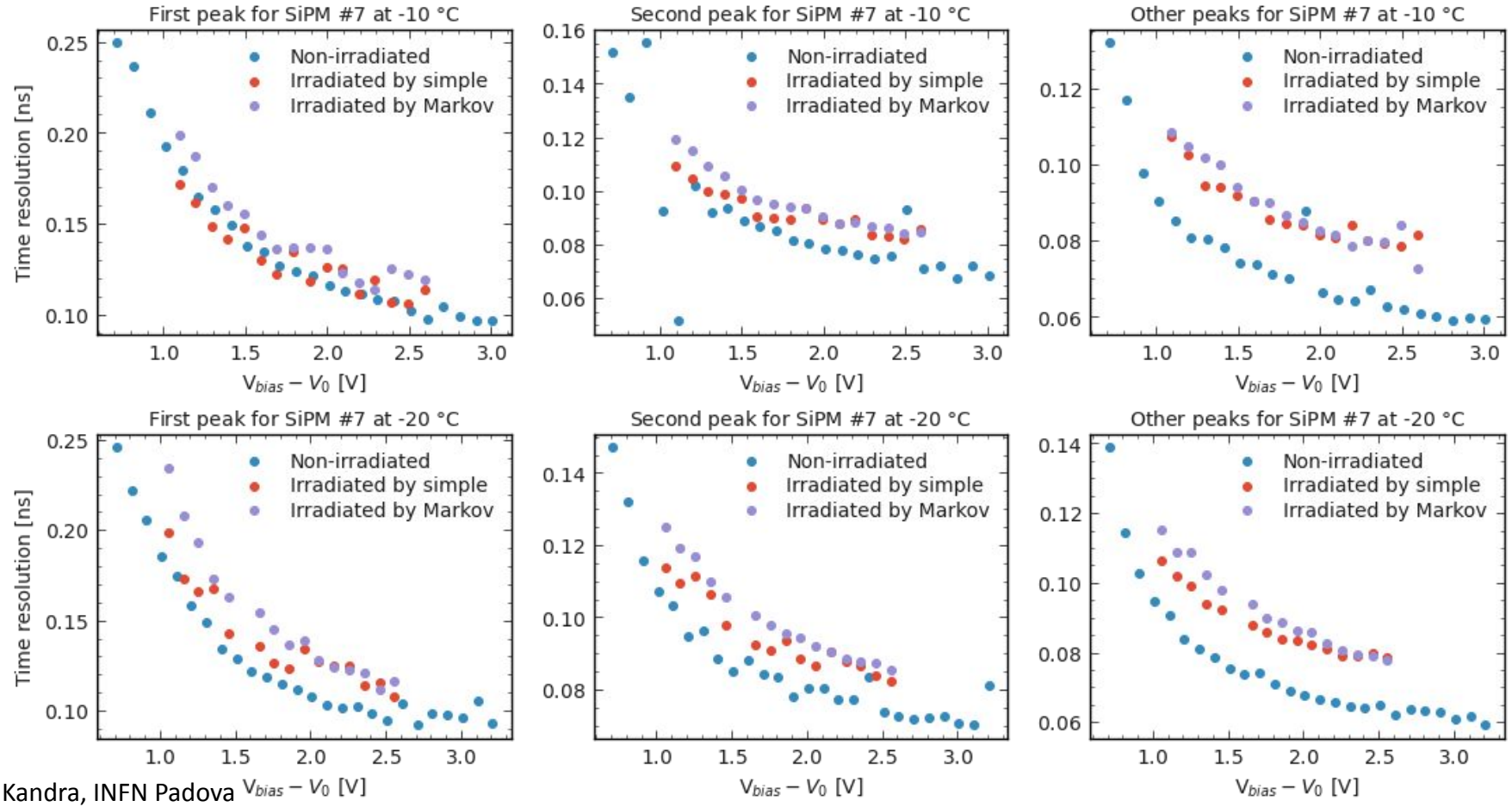




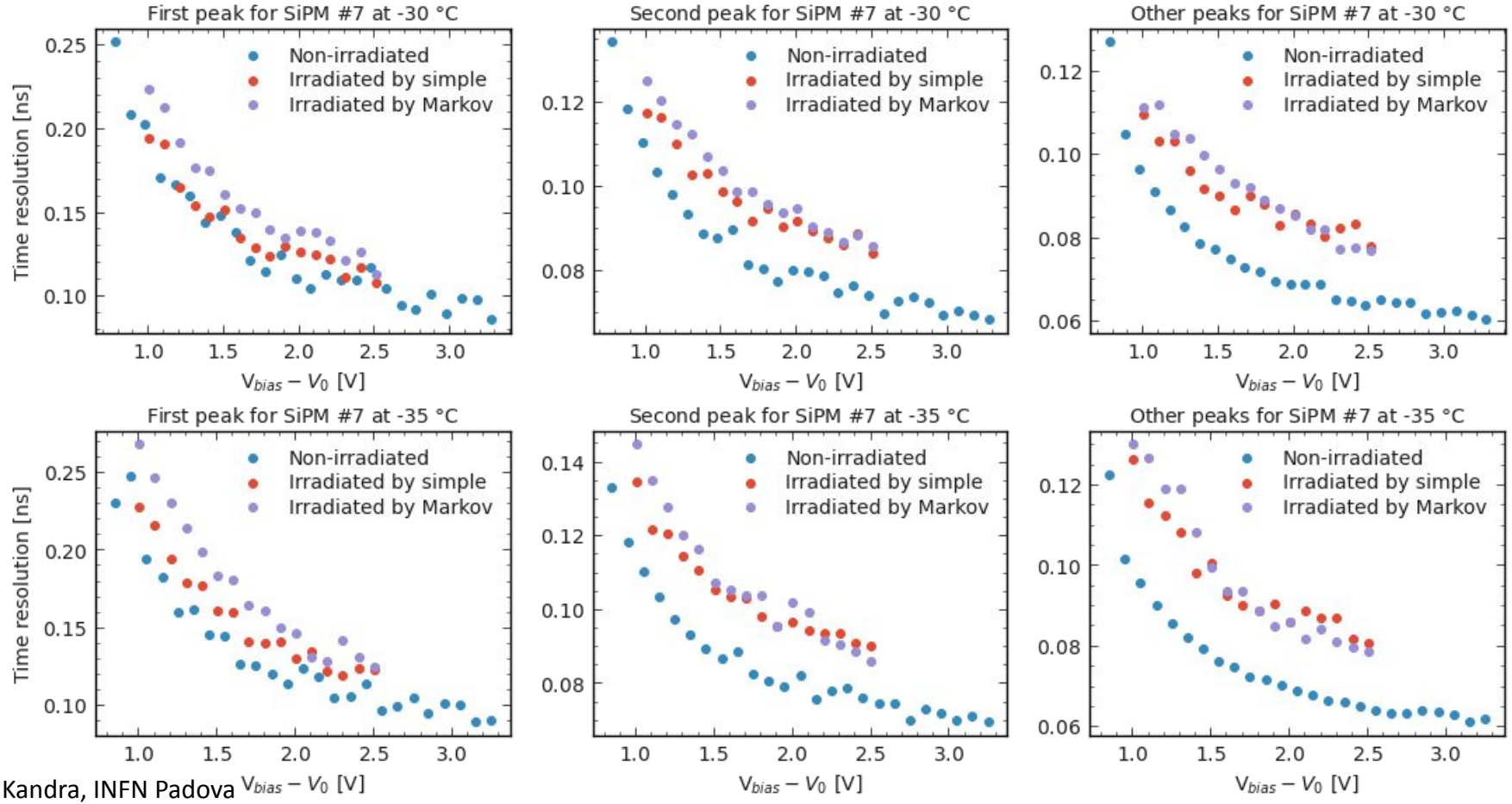
Time resolution



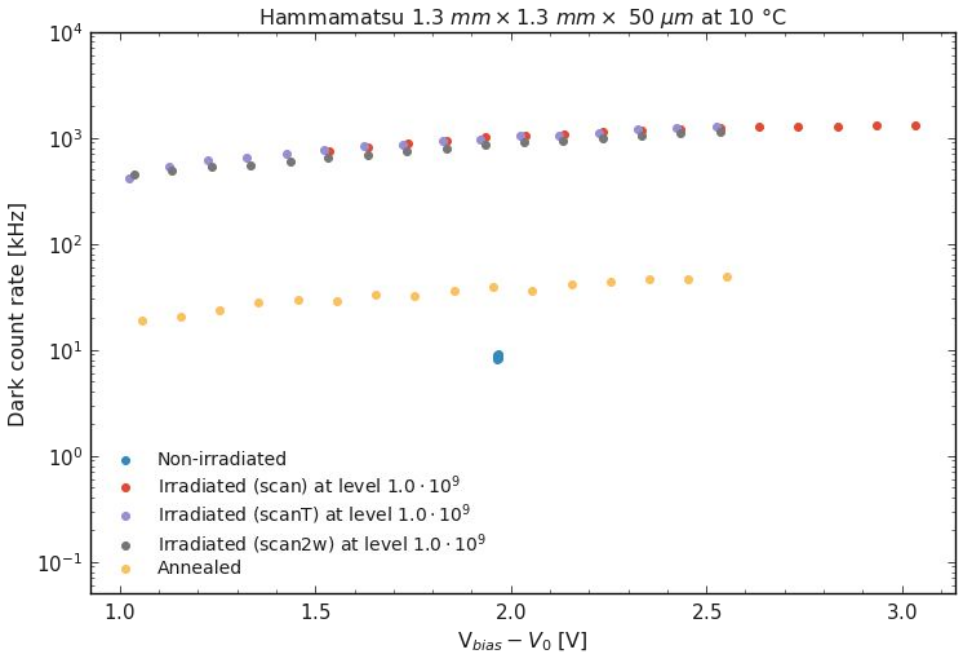
Time resolution

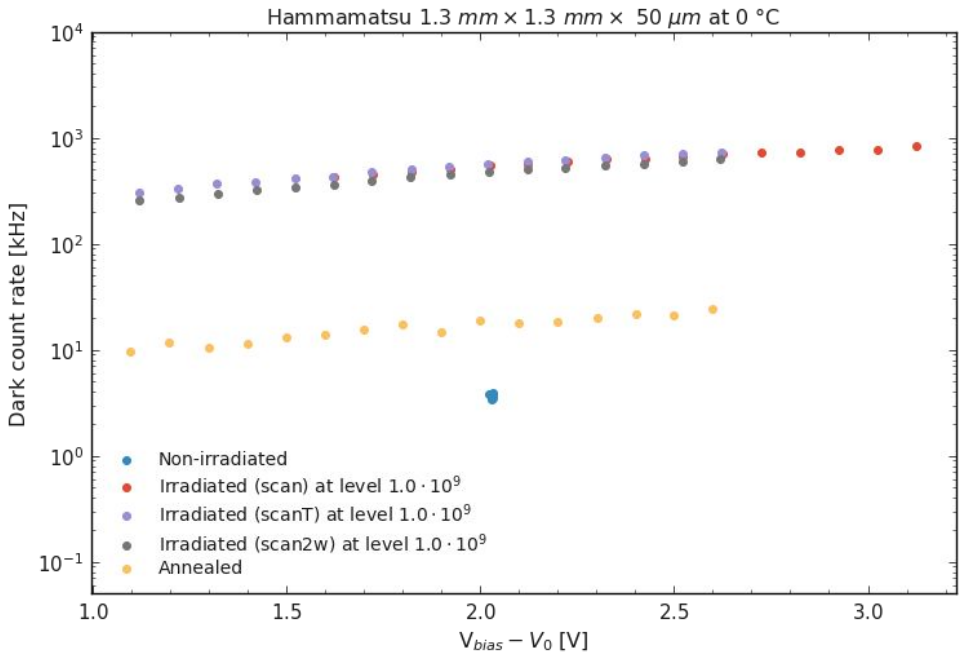


Time resolution

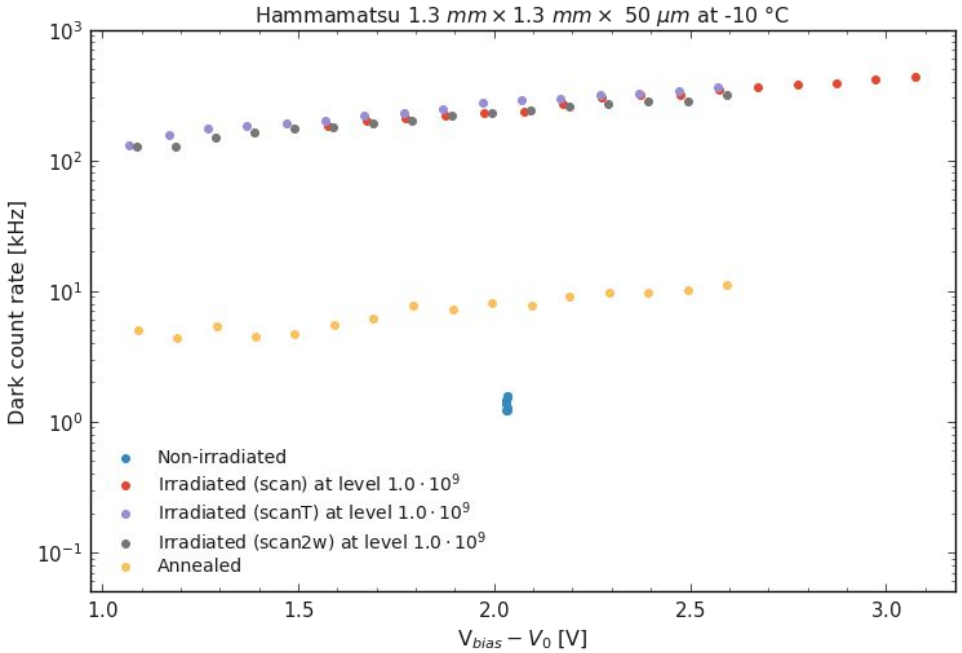


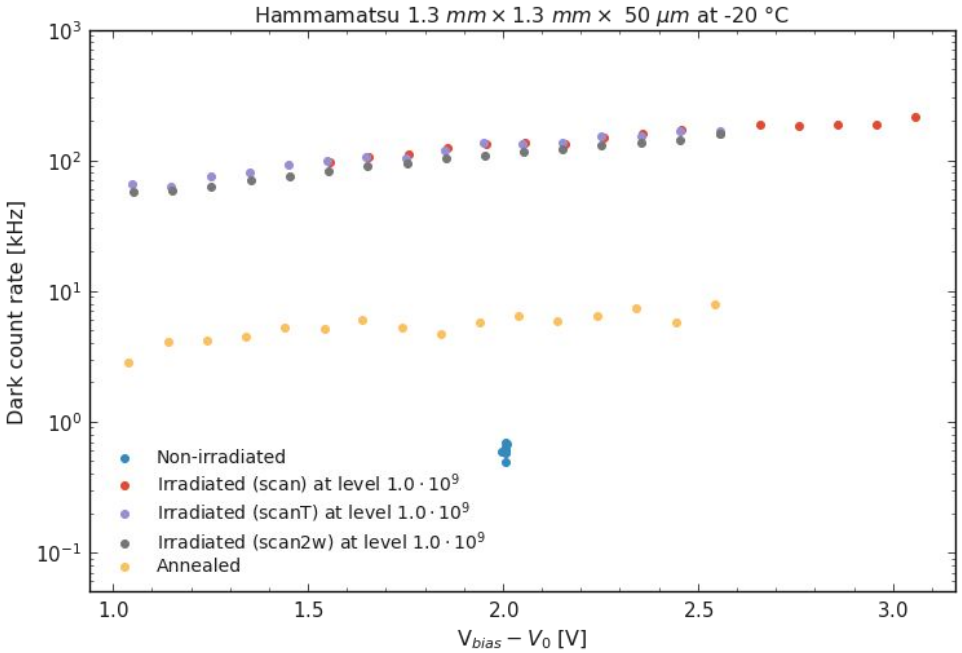
Dark count rate



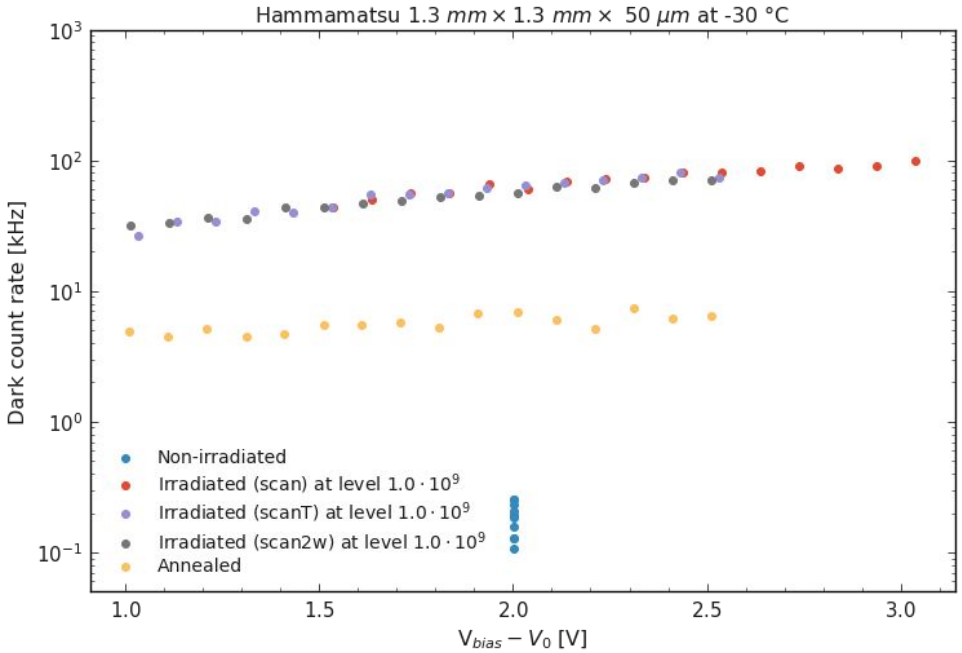


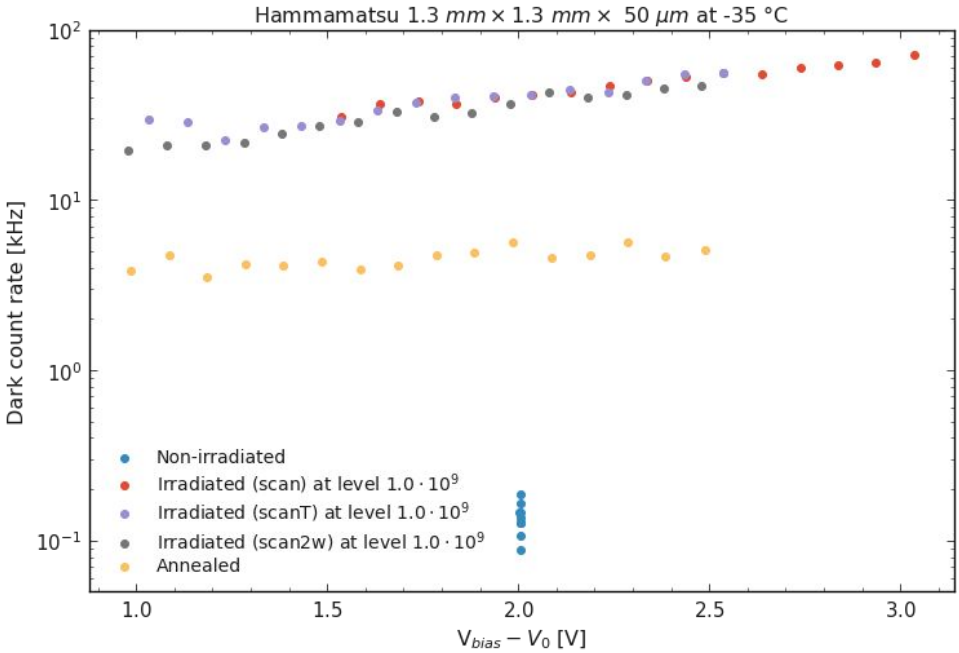
Dark count rate





Dark count rate





Backup

Breakdown voltages at temperatures for SiPMs

Index of SiPM		0	1	2	3	4	5	6	7
Producer		Hamamatsu	Hamamatsu	Hamamatsu	Hamamatsu	Hamamatsu	Hamamatsu	Hamamatsu	Hamamatsu
Dimension [mm×mm]		1.3 × 1.3	1.3 × 1.3	1.3 × 1.3	1.3 × 1.3	1.3 × 1.3	1.3 × 1.3	1.3 × 1.3	1.3 × 1.3
Pitch [μm]		50	50	50	50	50	50	50	50
Temperature [°C]	Status	Breakdown voltage [V_0]	Breakdown voltage [V_0]	Breakdown voltage [V_0]	Breakdown voltage [V_0]	Breakdown voltage [V_0]	Breakdown voltage [V_0]	Breakdown voltage [V_0]	Breakdown voltage [V_0]
20	No-irradiated	51.6 ± 0.2	51.4 ± 0.2	51.1 ± 0.2	51.3 ± 0.2	51.1 ± 0.2	51.2 ± 0.2	51.3 ± 0.2	51.6 ± 0.2
15	No-irradiated	51.3 ± 0.2	51.1 ± 0.2	50.8 ± 0.1	51.0 ± 0.2	50.8 ± 0.2	50.9 ± 0.1	51.0 ± 0.1	51.3 ± 0.1
10	No-irradiated	51.0 ± 0.2	50.8 ± 0.1	50.5 ± 0.1	50.7 ± 0.2	50.5 ± 0.2	50.7 ± 0.2	50.8 ± 0.2	51.1 ± 0.2
0	No-irradiated	50.4 ± 0.1	50.3 ± 0.1	50.0 ± 0.2	50.1 ± 0.1	50.0 ± 0.3	50.1 ± 0.1	50.2 ± 0.1	50.5 ± 0.1
-10	No-irradiated	49.8 ± 0.1	49.7 ± 0.1	49.4 ± 0.1	49.6 ± 0.1	49.4 ± 0.3	49.5 ± 0.1	49.6 ± 0.2	49.9 ± 0.1
-20	No-irradiated	49.3 ± 0.1	49.2 ± 0.1	48.8 ± 0.1	49.0 ± 0.2	48.9 ± 0.2	49.0 ± 0.1	49.1 ± 0.1	49.4 ± 0.1
-30	No-irradiated	48.7 ± 0.1	48.6 ± 0.1	48.3 ± 0.1	48.4 ± 0.2	48.3 ± 0.1	48.4 ± 0.2	48.5 ± 0.1	48.8 ± 0.1
-35	No-irradiated	48.4 ± 0.1	48.3 ± 0.2	48.0 ± 0.2	48.2 ± 0.2	48.0 ± 0.4	48.1 ± 0.2	48.2 ± 0.2	48.5 ± 0.1
-40-A	No-irradiated	49.1 ± 6.9	49.0 ± 6.3	47.8 ± 0.3	49.2 ± 7.0	48.9 ± 5.7	49.1 ± 6.4	48.0 ± 0.1	48.2 ± 0.2
-40-B	No-irradiated	48.3 ± 4.4	48.0 ± 0.1	49.2 ± 2.7	47.9 ± 0.2	48.9 ± 3.6	49.3 ± 5.8	49.3 ± 5.5	49.2 ± 8.2
-40-C	No-irradiated	48.2 ± 0.1	49.1 ± 7.5	49.2 ± 2.8	49.2 ± 7.3	49.1 ± 2.7	48.3 ± 17.9	49.2 ± 6.8	49.2 ± 7.0
-40-D	No-irradiated	±	±	±	±	±	±	±	±

- Breakdown voltages for all modules at temperatures between 20 ˚C to -35 ˚C are fine.
- For all modules instead of #4 and #5, we are able to identify meaningful fit at -40 ˚C (green)
- For modules #4 and #5, it looks the data files -40-D is missing in database, right?