

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

Hamamatsu modules

Padova meeting 23/09/2024

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Tests with irradiated modules in Padova

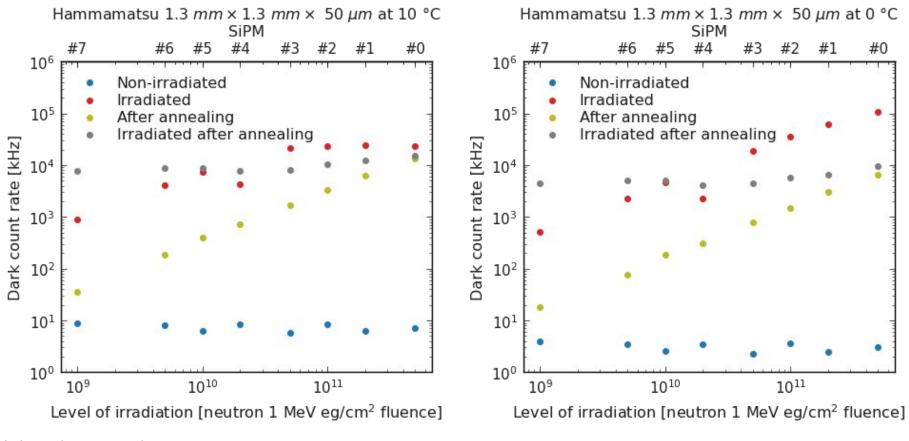


- In Belle II, MCP-PMTs with extended lifetime have been installed and they have limited lifetime depending on accumulated charge.
- We are trying to understand if they eventually can be replaced with SiPMs.
- We irradiated 24 SiPMs modules with different neutron fluxes and tested by laser.
- Sixteen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

Index	Producer	Dimension	Pitch	Neutron 1 MeV
		$[mm \times mm]$	$[\mu \mathrm{m}]$	$\rm eg/cm^2$ 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	$1.0 \cdot 10^{9}$
dava				

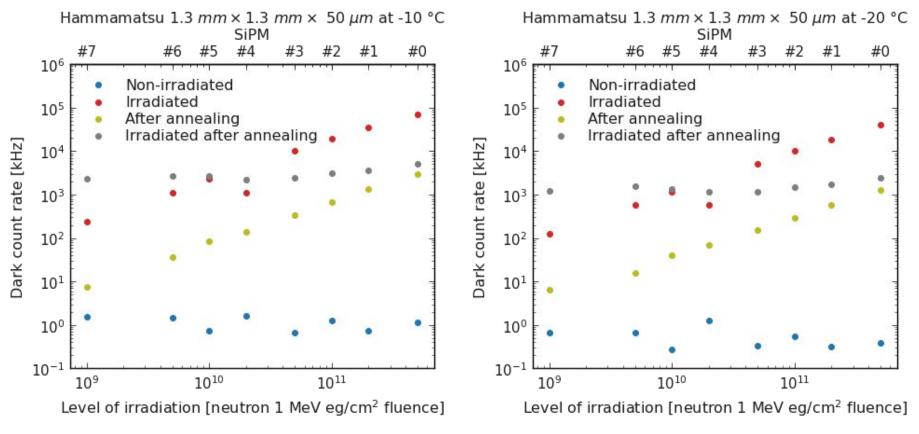
Dark count rate as function of level of irradiation





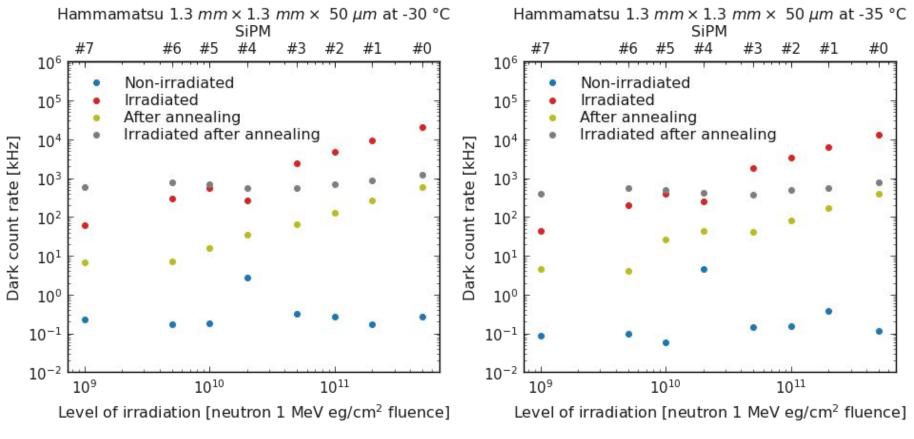
Dark count rate as function of level of irradiation





Dark count rate as function of level of irradiation





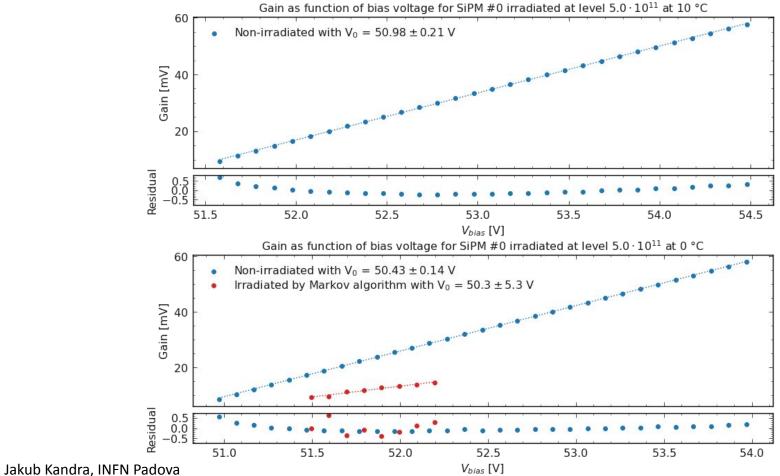


SiMP #0

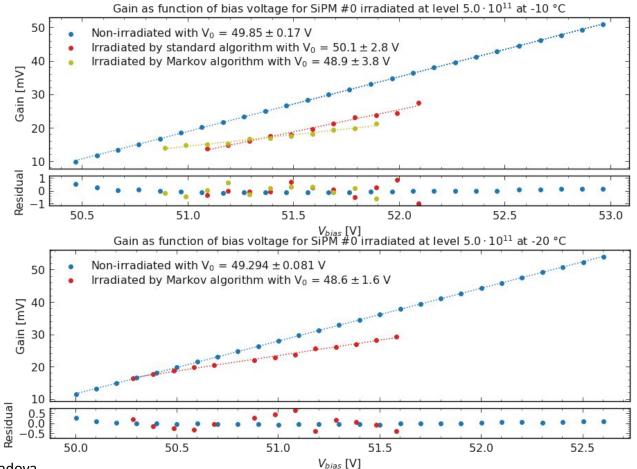


Gain as function of bias voltage for SiPM #0

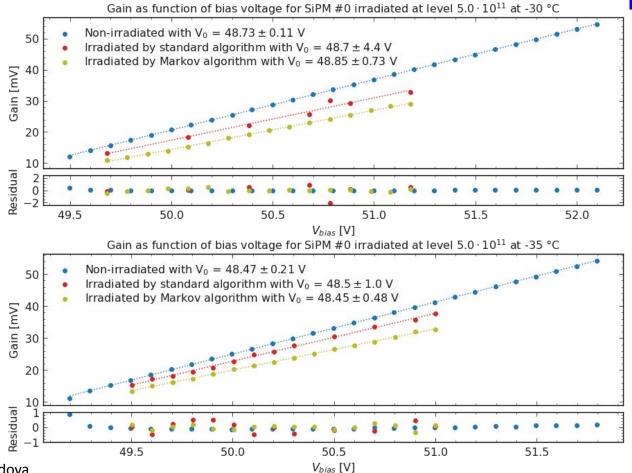








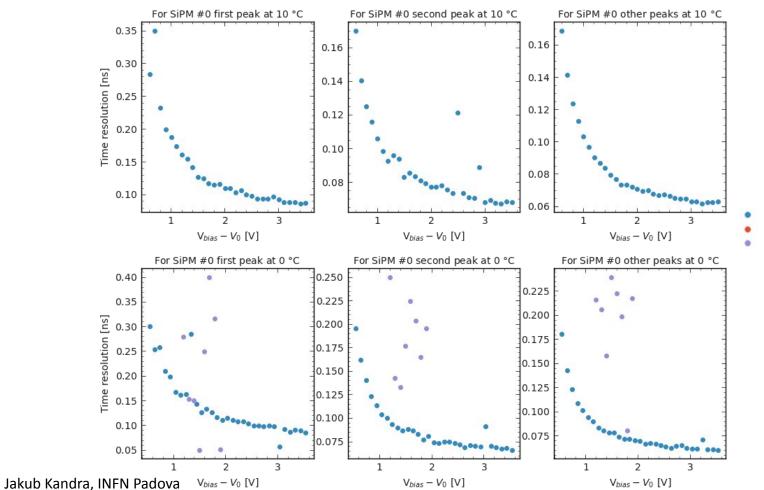




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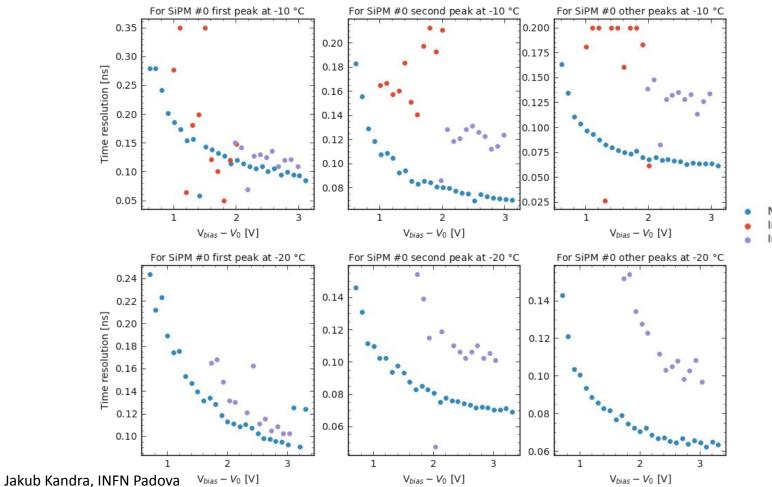
Time resolution for first, second and other photon peaks for SiPM #0





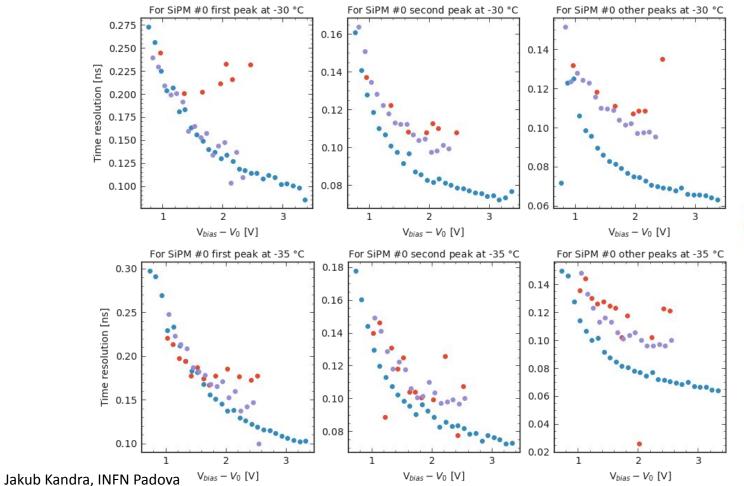
Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm









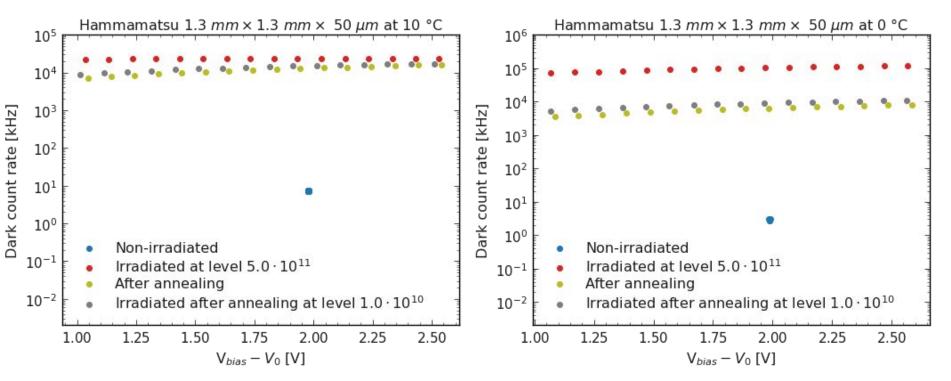


Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm

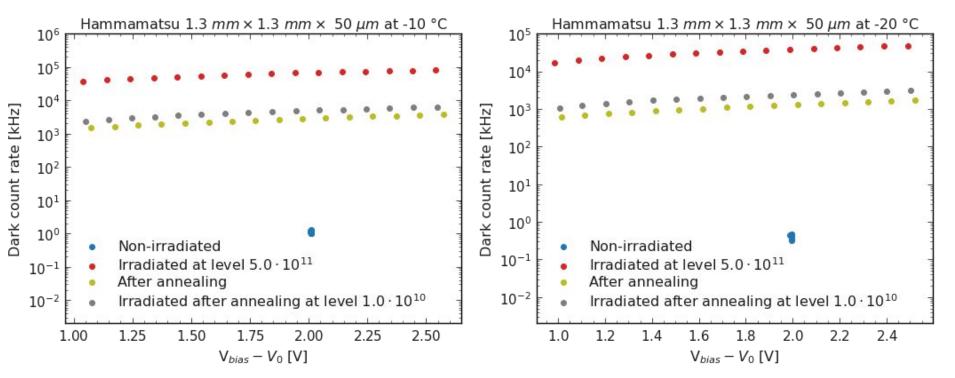


Dark count rate for SiPM #0

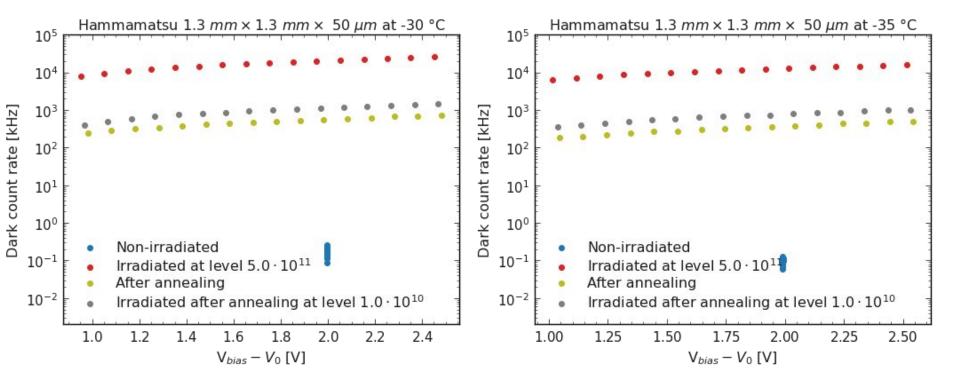












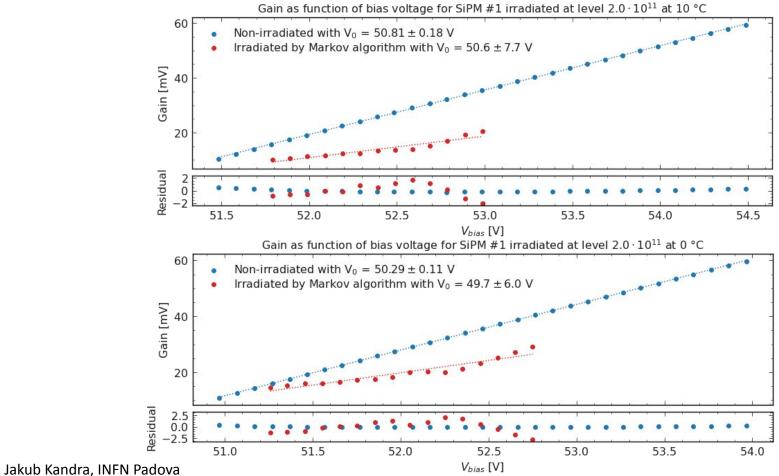


SiMP #1

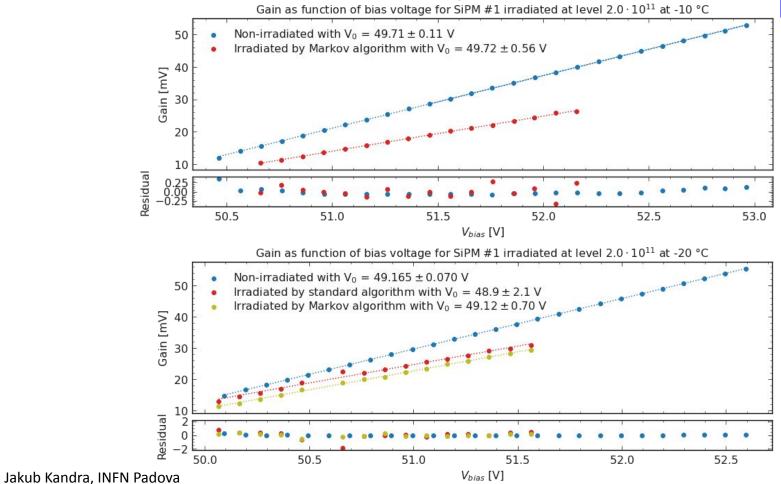


Gain as function of bias voltage for SiPM #1

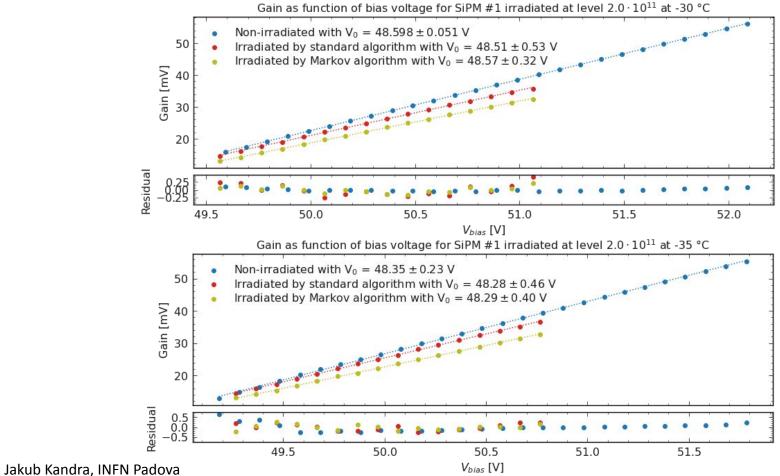








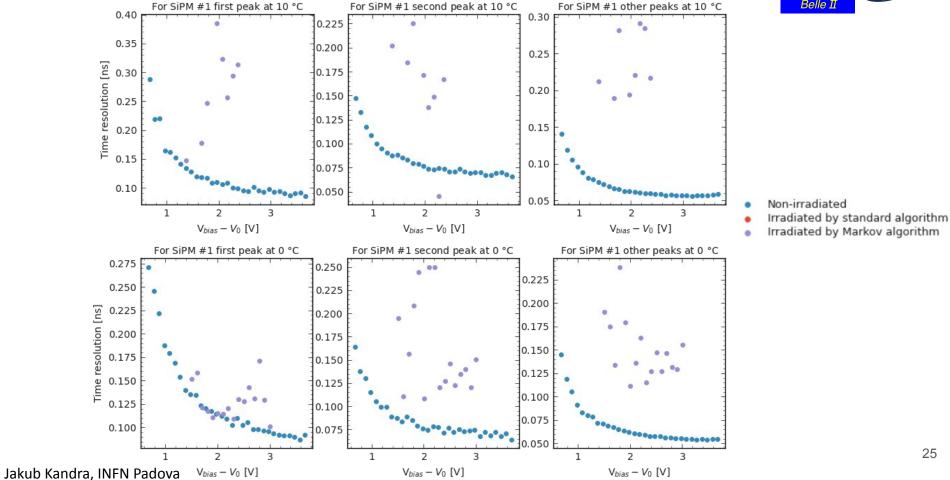




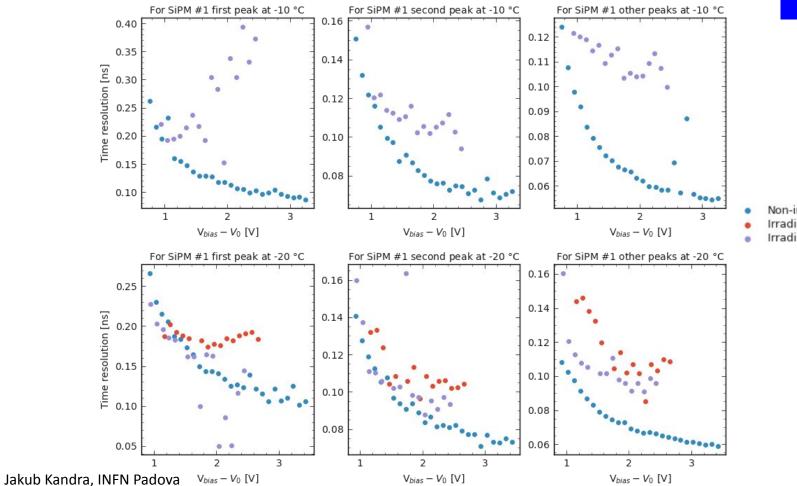


Time resolution for first, second and other photon peaks for SiPM #1



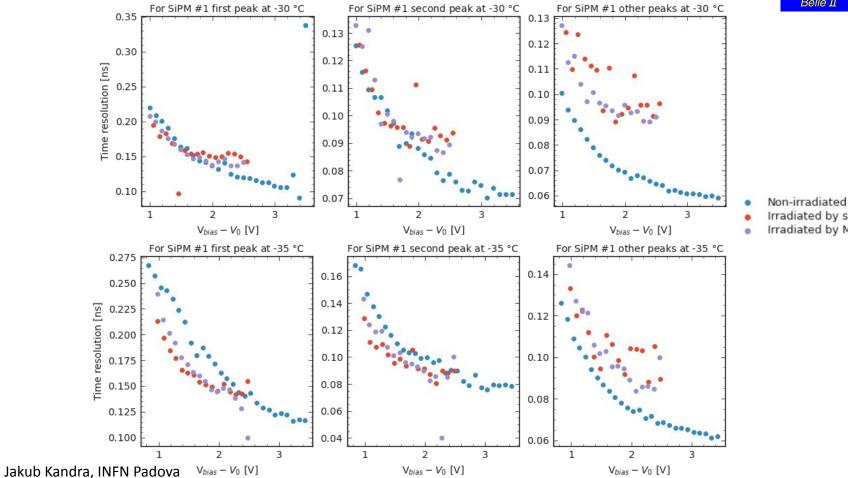






Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm



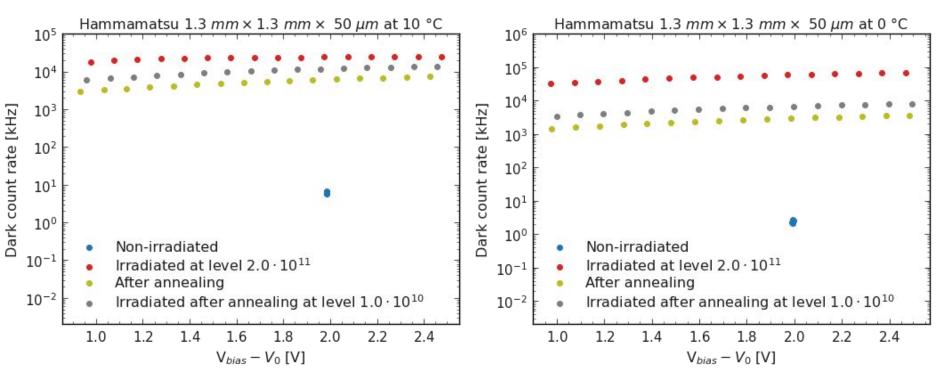


Irradiated by standard algorithm Irradiated by Markov algorithm

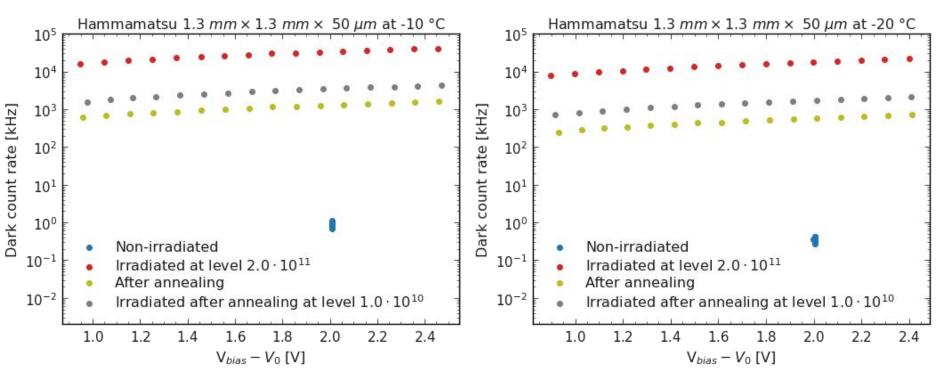


Dark count rate for SiPM #1

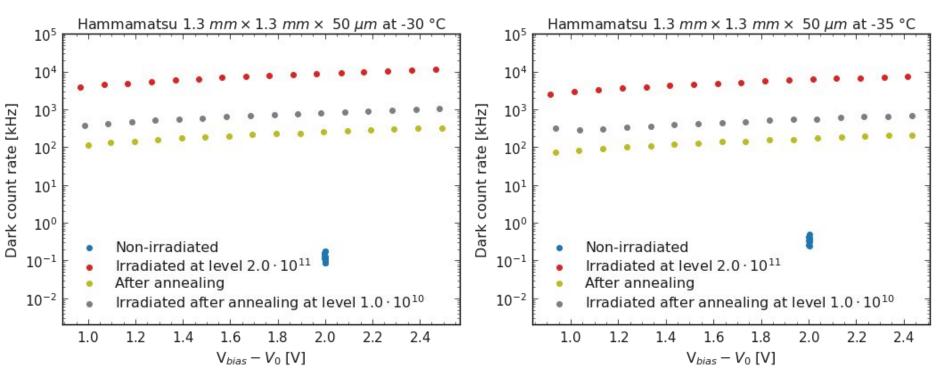












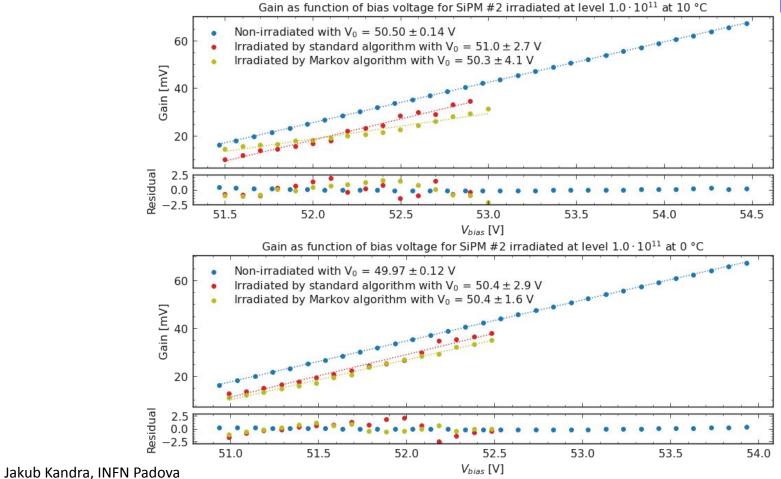


SiMP #2



Gain as function of bias voltage for SiPM #2



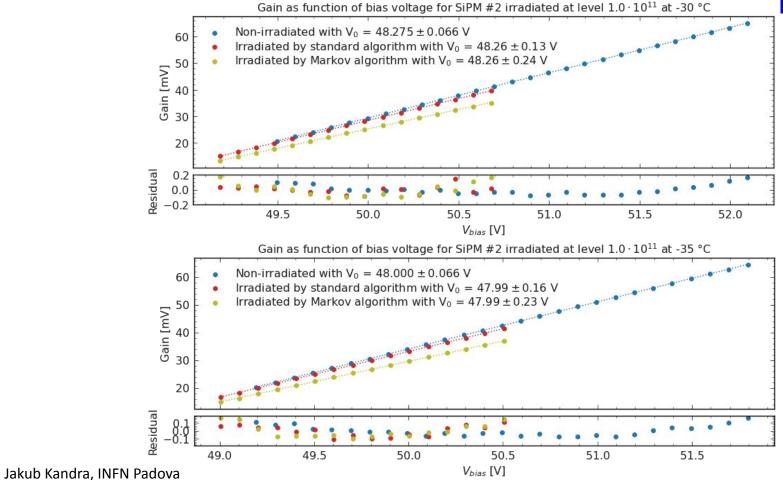




Gain as function of bias voltage for SiPM #2 irradiated at level 1.0 · 10¹¹ at -10 °C 60 Non-irradiated with $V_0 = 49.389 \pm 0.094 V$ Irradiated by standard algorithm with $V_0 = 49.41 \pm 0.35$ V 50 Irradiated by Markov algorithm with $V_0 = 49.51 \pm 0.85$ V Gain [mV] 40 30 20 Residual 0.5 0.0 -0.550.5 51.0 51.5 52.0 52.5 53.0 V_{bias} [V] Gain as function of bias voltage for SiPM #2 irradiated at level 1.0 · 10¹¹ at -20 °C Non-irradiated with $V_0 = 48.847 \pm 0.067 V$ 60 Irradiated by standard algorithm with $V_0 = 48.82 \pm 0.25$ V Irradiated by Markov algorithm with $V_0 = 48.86 \pm 0.31$ V 50 Gain [mV] 40 30 20 Residual 0.25 0.00 -0.25 50.0 50.5 51.0 51.5 52.0 52.5 V_{bias} [V]

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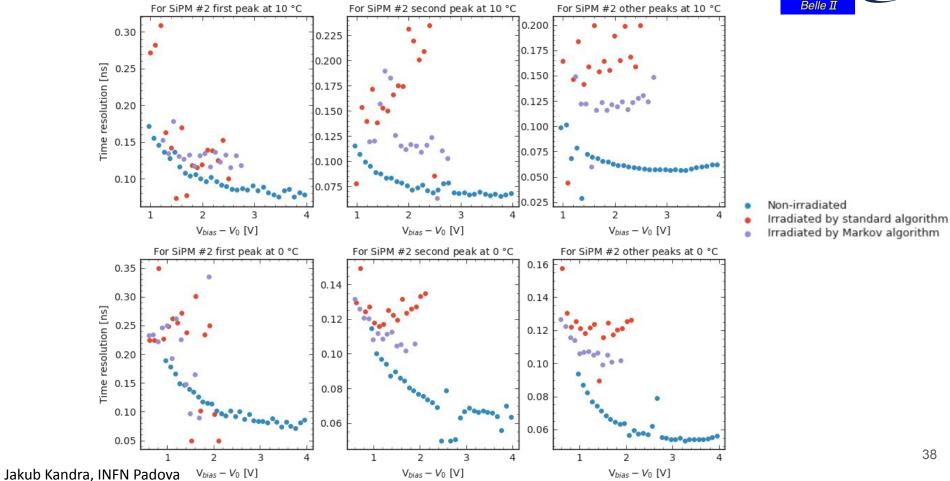




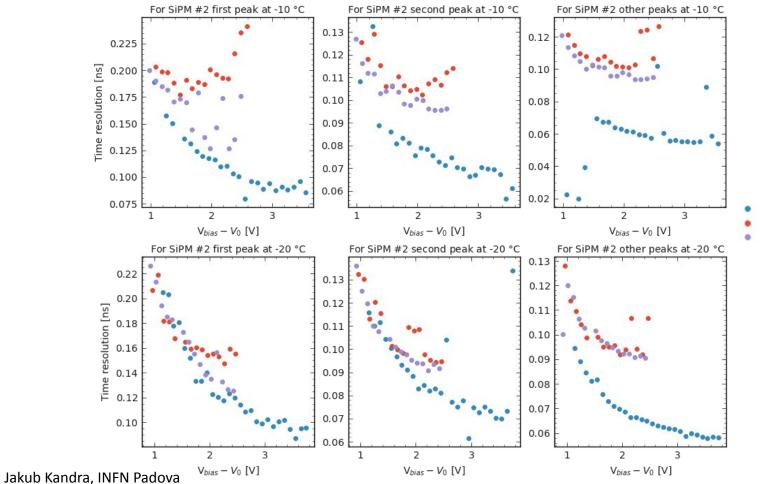


Time resolution for first, second and other photon peaks for SiPM #2



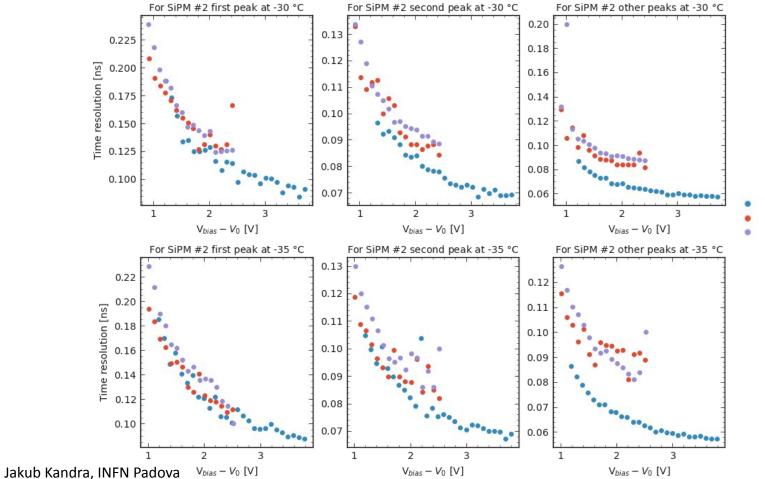






Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm



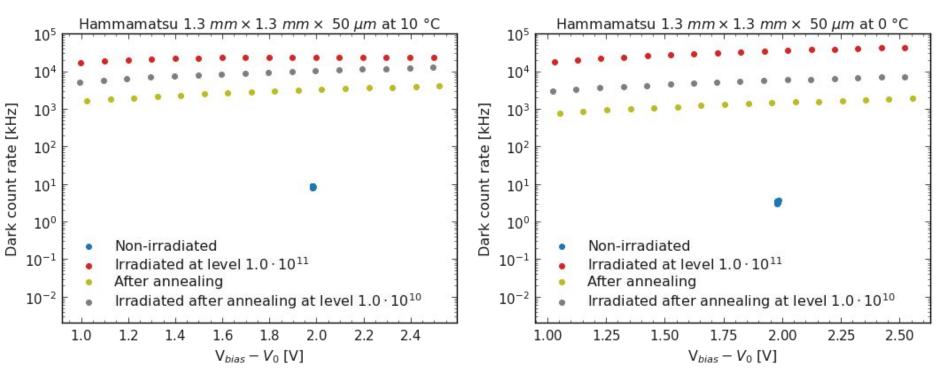


Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm

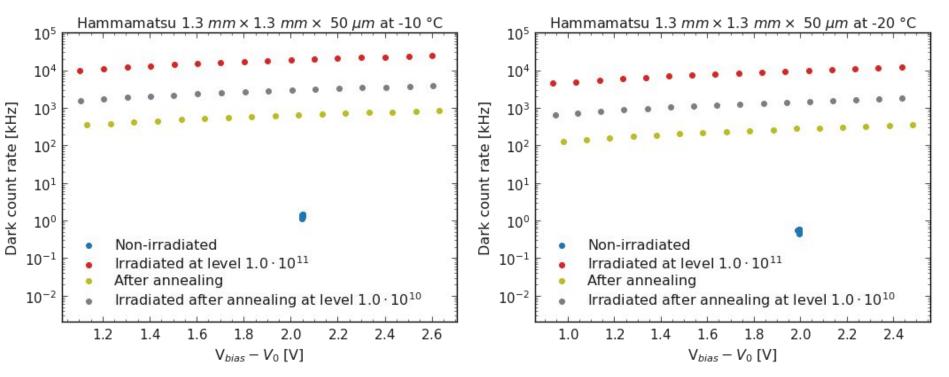


Dark count rate for SiPM #2

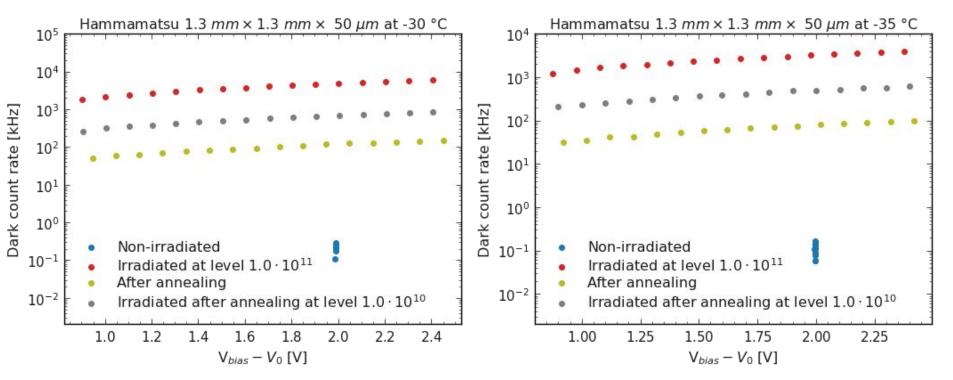












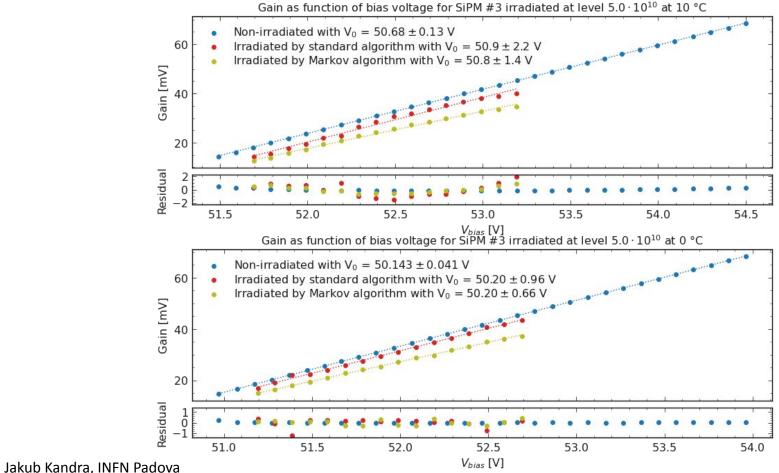


SiMP #3

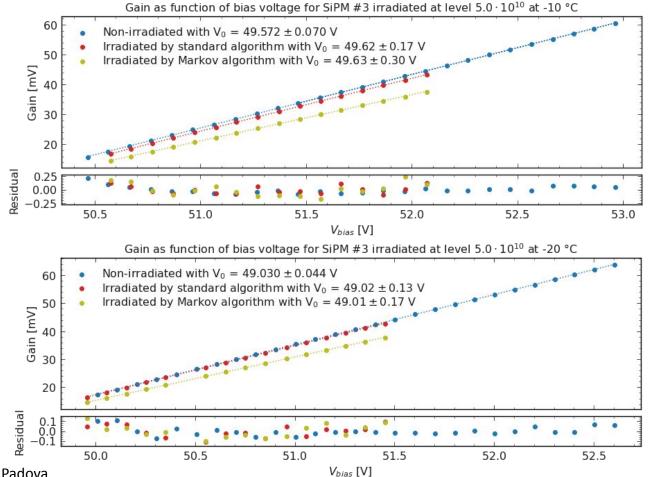


Gain as function of bias voltage for SiPM #3





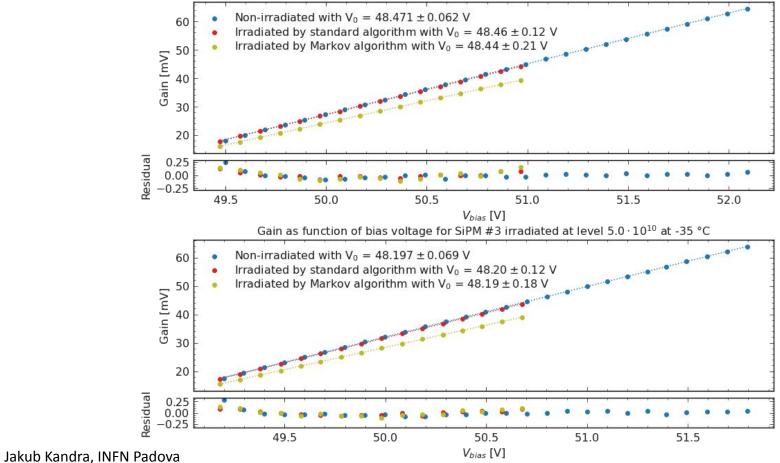




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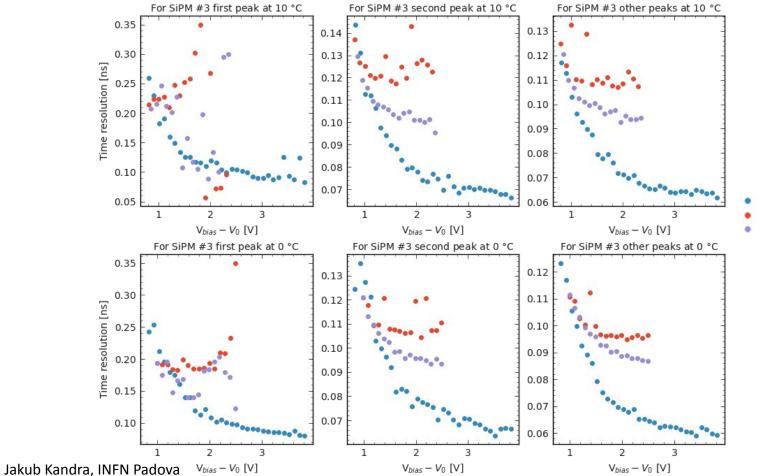
Gain as function of bias voltage for SiPM #3 irradiated at level $5.0\cdot10^{10}$ at -30 °C





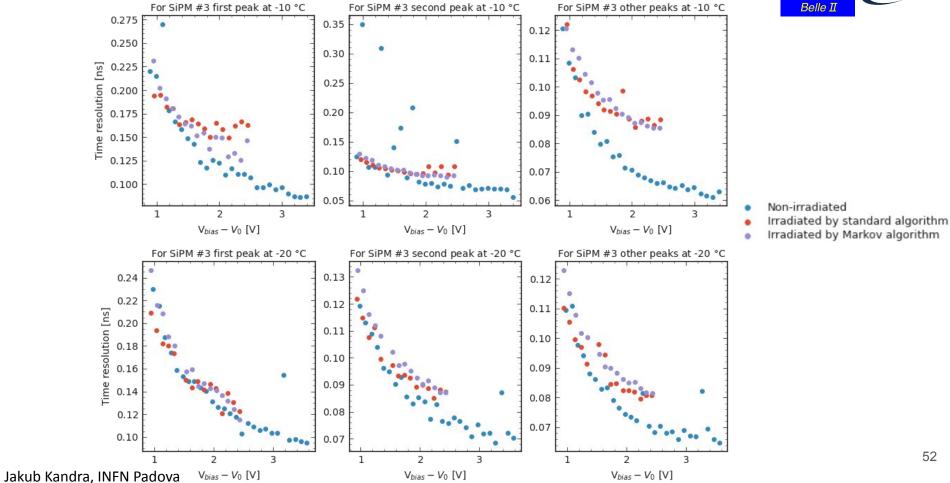
Time resolution for first, second and other photon peaks for SiPM #3



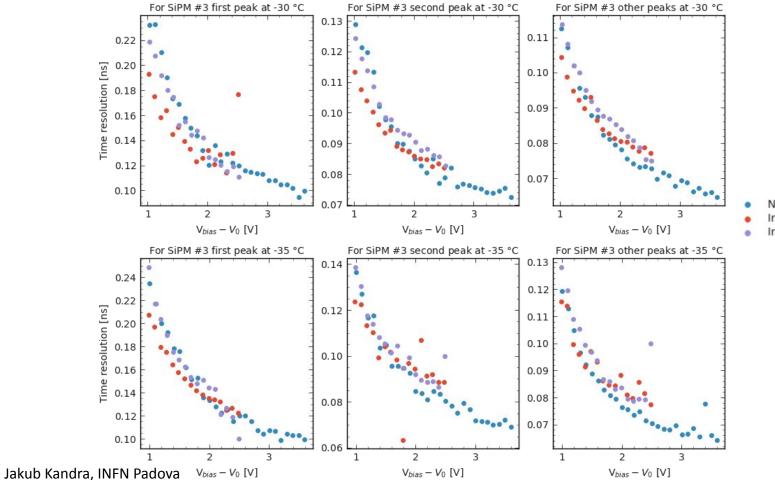


Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm







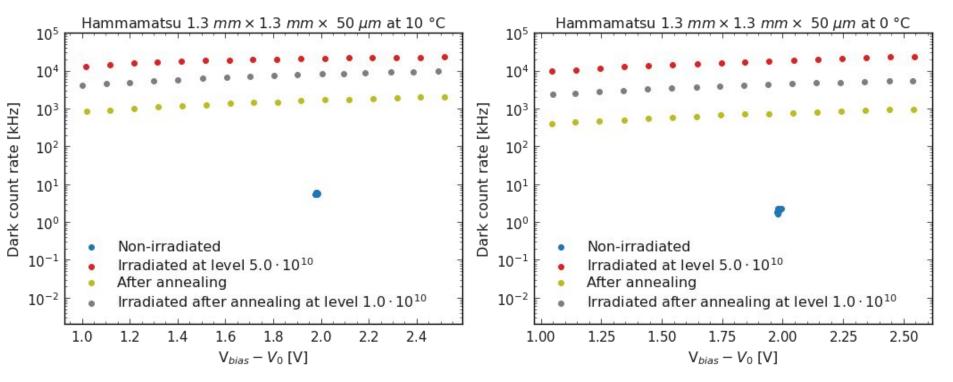


Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm

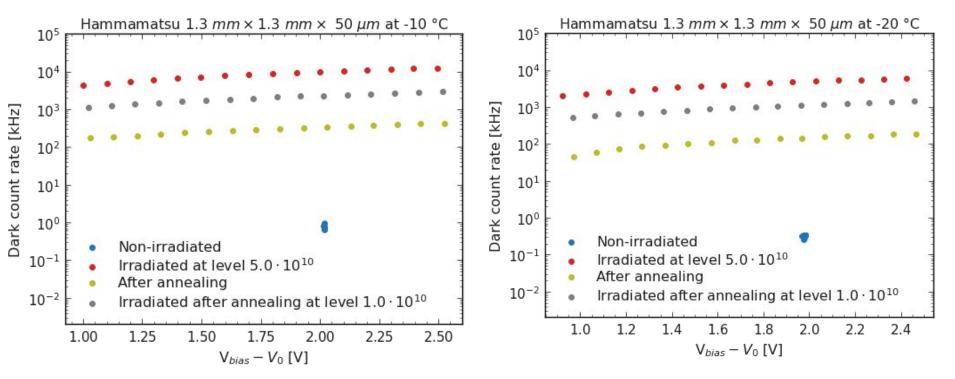


Dark count rate for SiPM #3

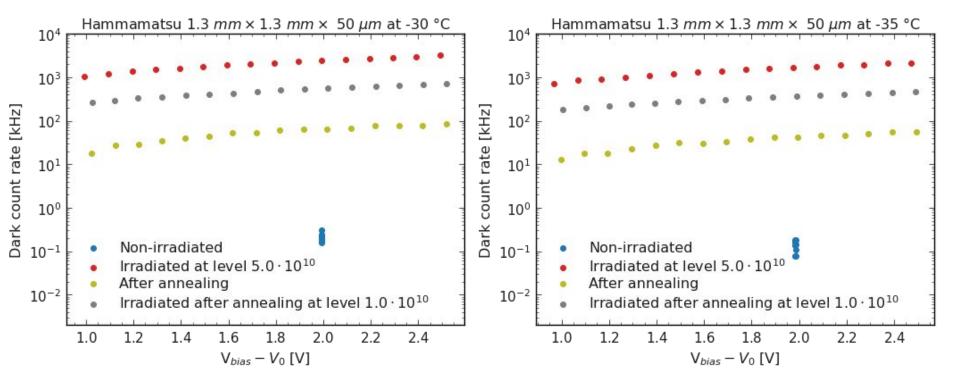












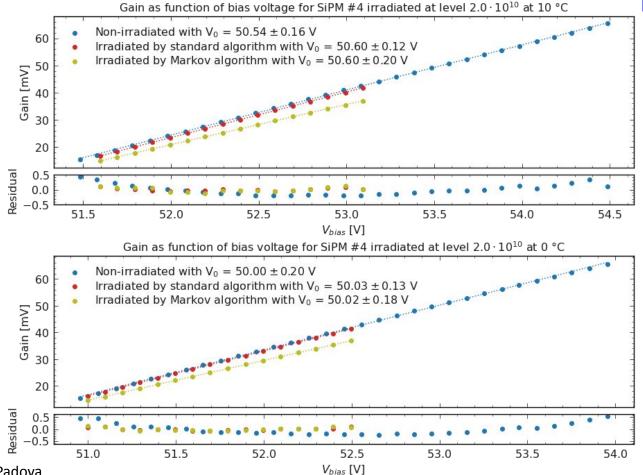


SiMP #4



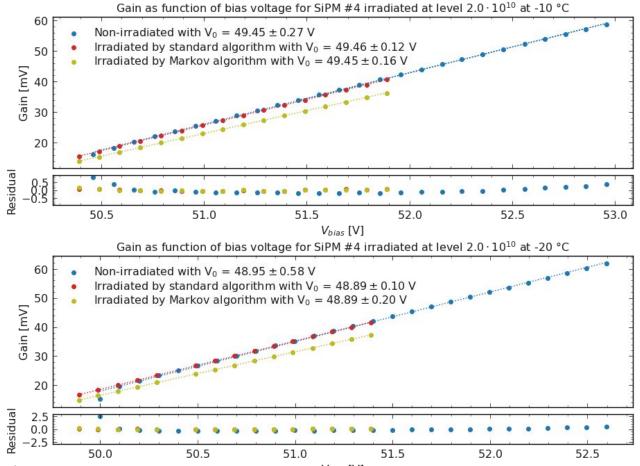
Gain as function of bias voltage for SiPM #4





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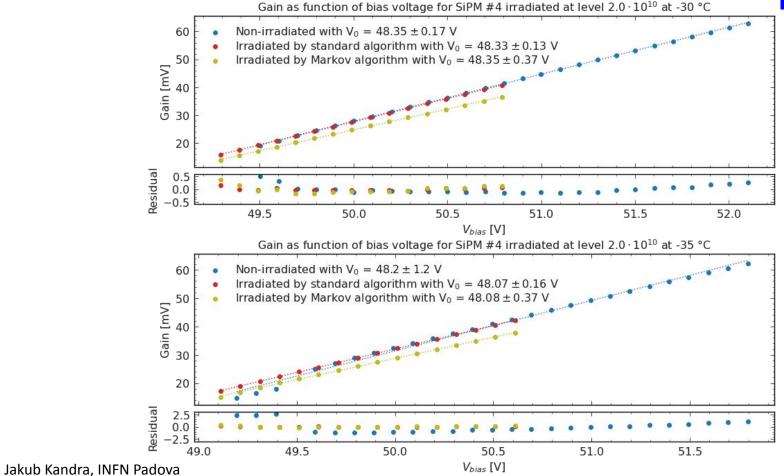




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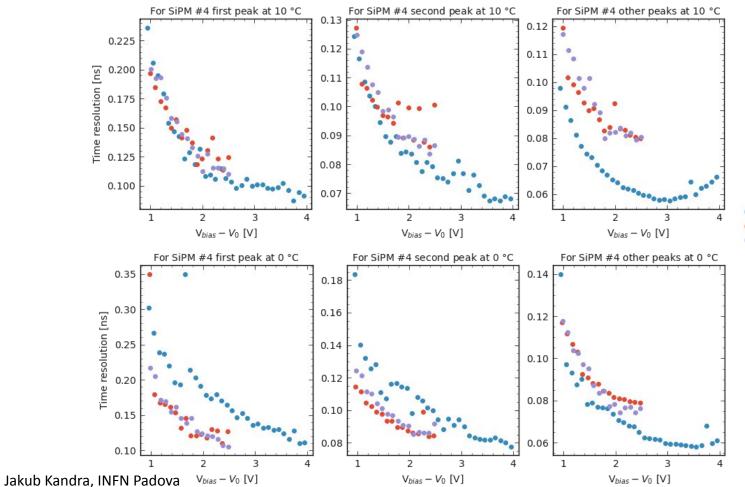








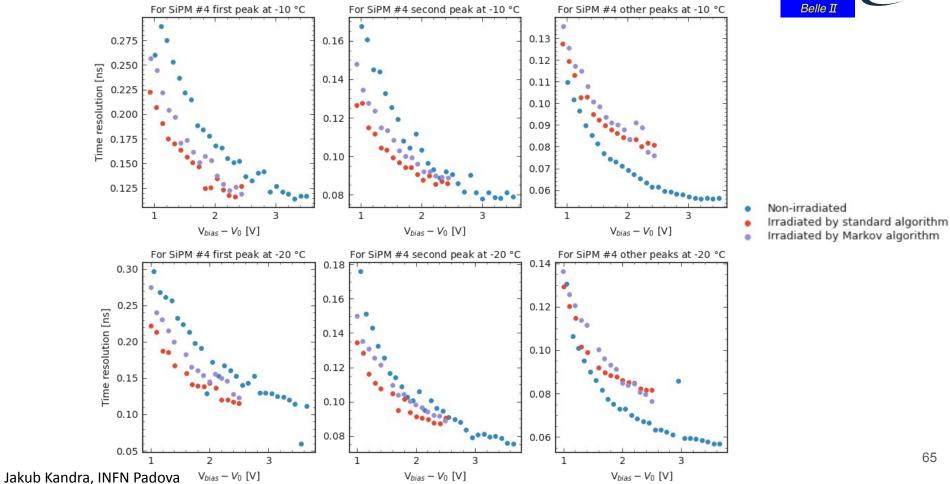
Time resolution for first, second and other photon peaks for SiPM #4



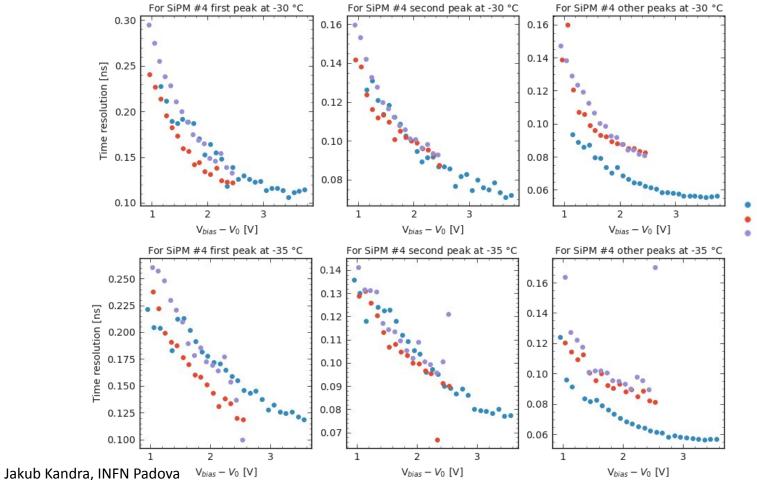


Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm







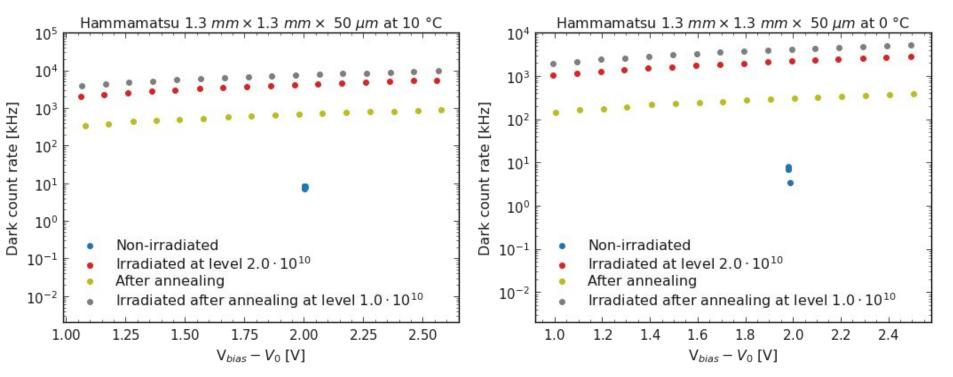


Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm

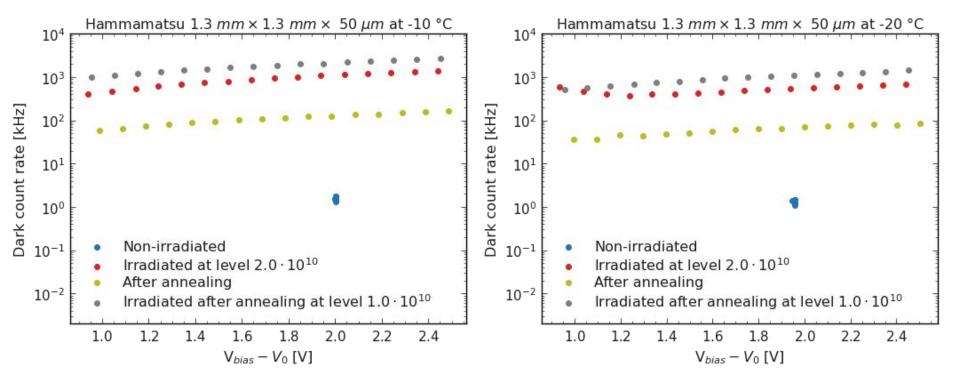


Dark count rate for SiPM #4

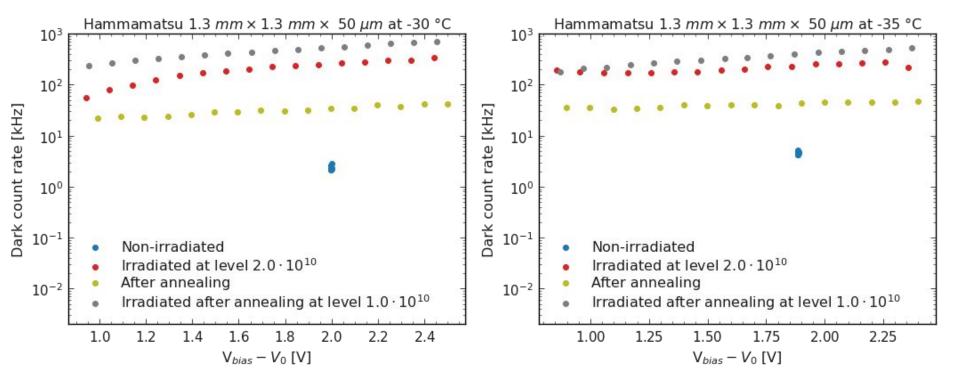












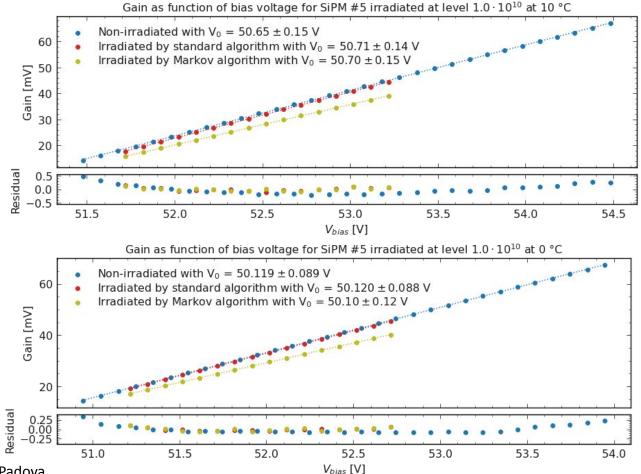


SiMP #5

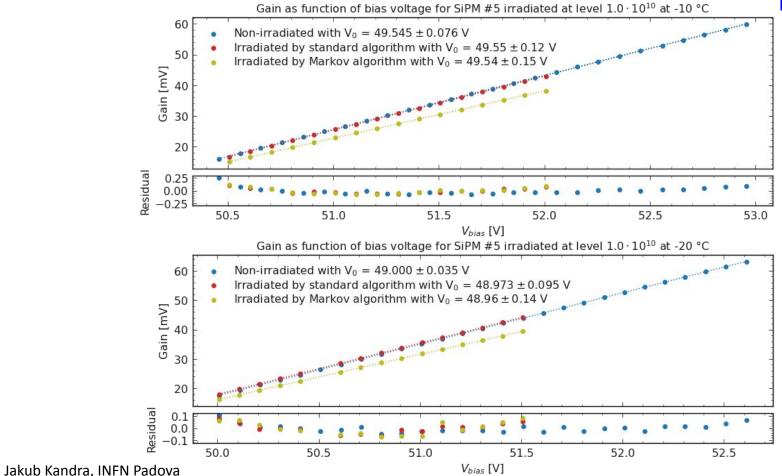


Gain as function of bias voltage for SiPM #5











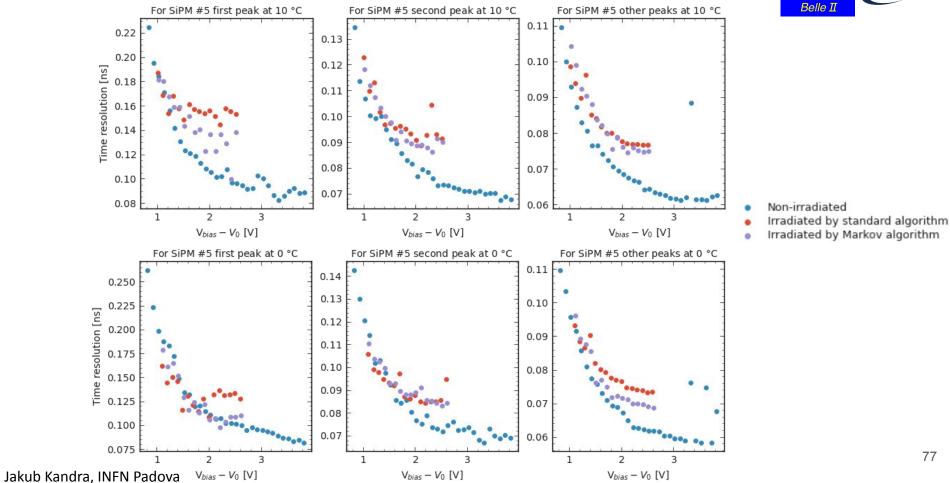
Gain as function of bias voltage for SiPM #5 irradiated at level 1.0 · 10¹⁰ at -30 °C Non-irradiated with $V_0 = 48.432 \pm 0.032 V$ 60 Irradiated by standard algorithm with $V_0 = 48.42 \pm 0.11 \text{ V}$ Irradiated by Markov algorithm with $V_0 = 48.41 \pm 0.14$ V 50 Gain [mV] 40 30 20 Residual 0.1 -0.149.5 51.0 50.0 50.5 51.5 52.0 V_{bias} [V] Gain as function of bias voltage for SiPM #5 irradiated at level 1.0 · 10¹⁰ at -35 °C 60 Non-irradiated with $V_0 = 48.154 \pm 0.021 V$ Irradiated by standard algorithm with $V_0 = 48.15 \pm 0.12$ V Irradiated by Markov algorithm with $V_0 = 48.16 \pm 0.19$ V 50 Gain [mV] 40 30 20 Residual 0.2 0.0 -0.2 -49.0 49.5 50.0 50.5 51.0 51.5 V_{bias} [V]

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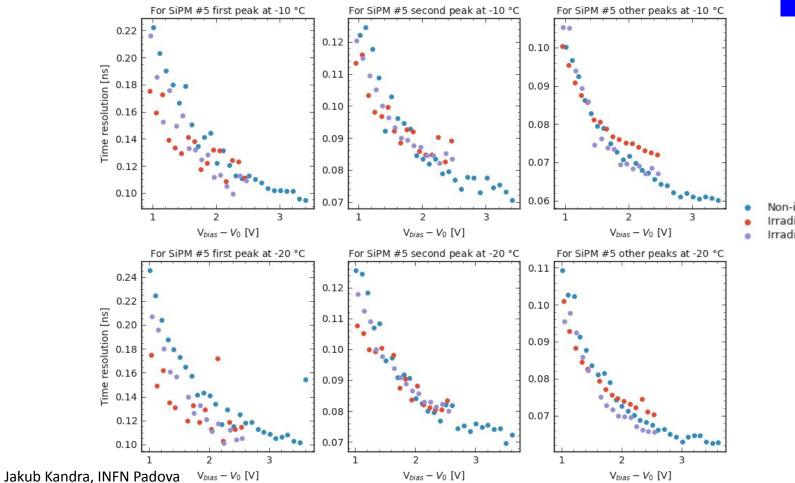


Time resolution for first, second and other photon peaks for SiPM #5



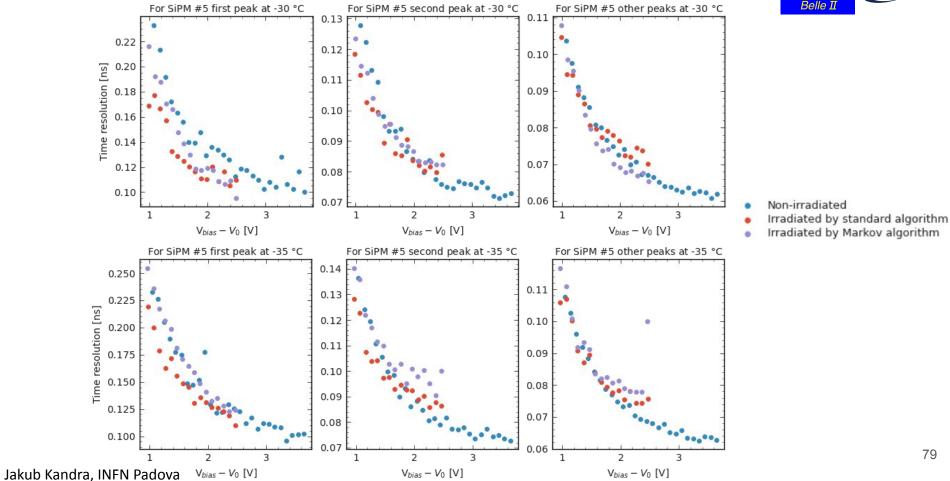






Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm

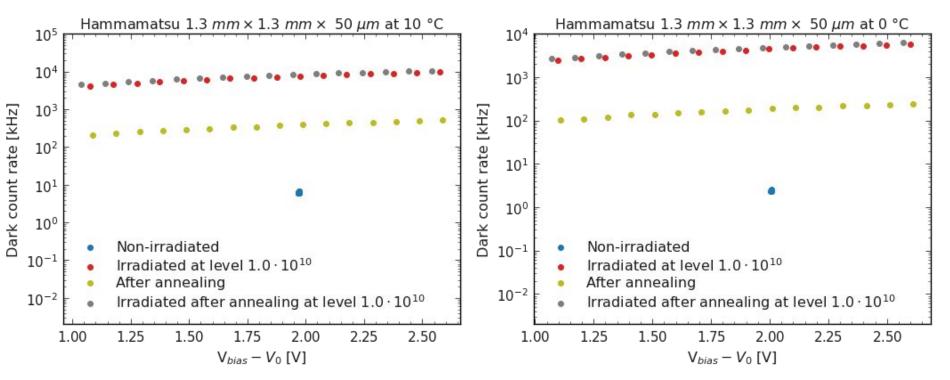




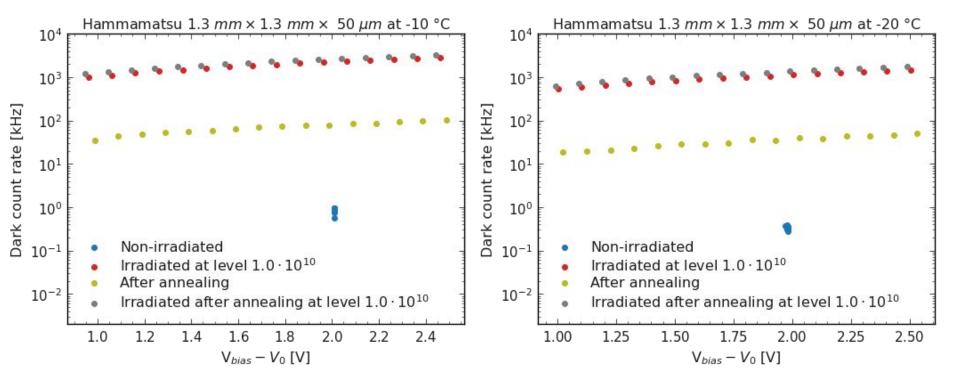


Dark count rate for SiPM #5

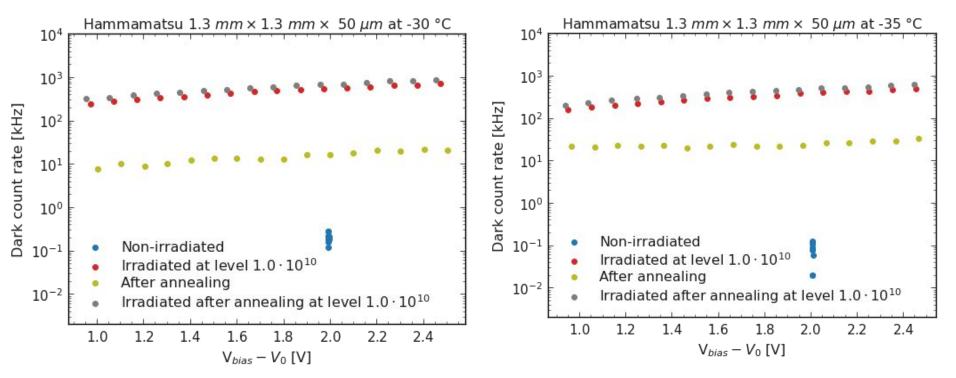












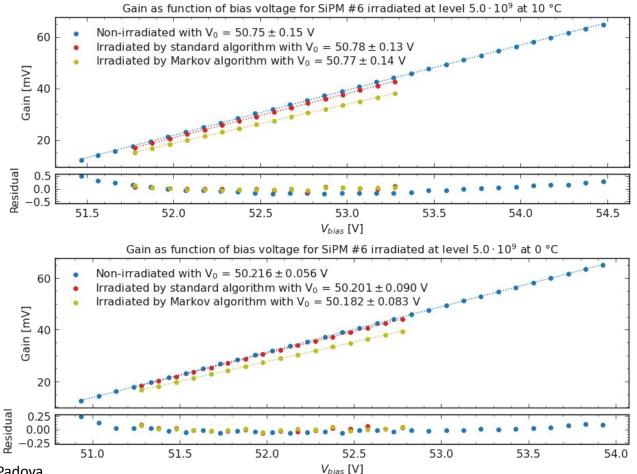


SiMP #6

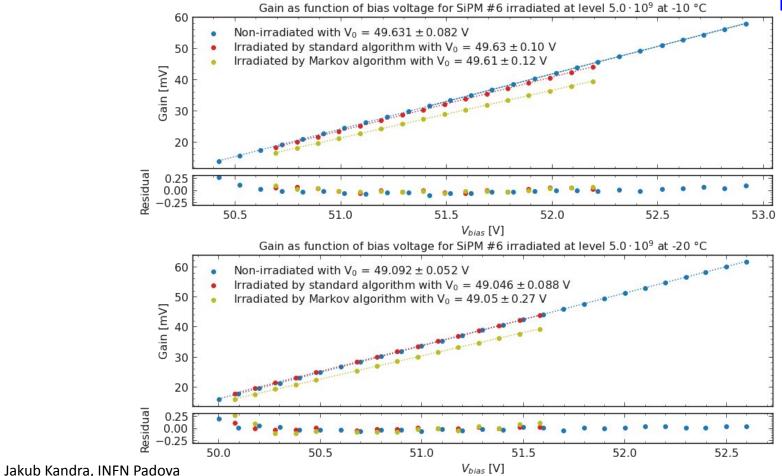


Gain as function of bias voltage for SiPM #6

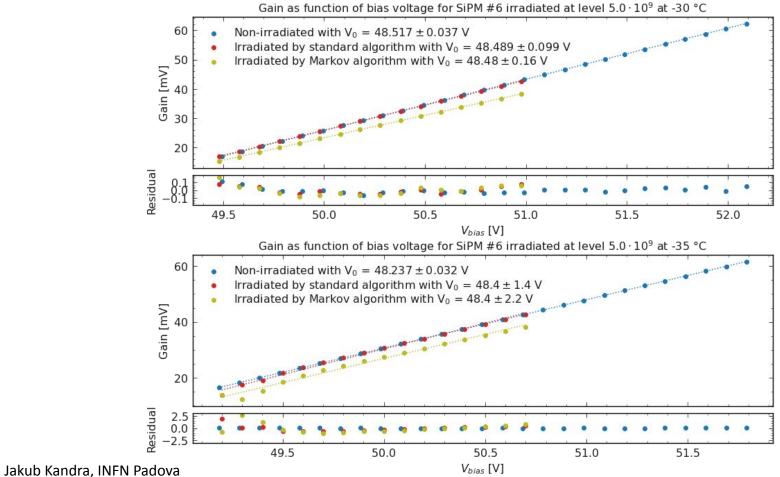








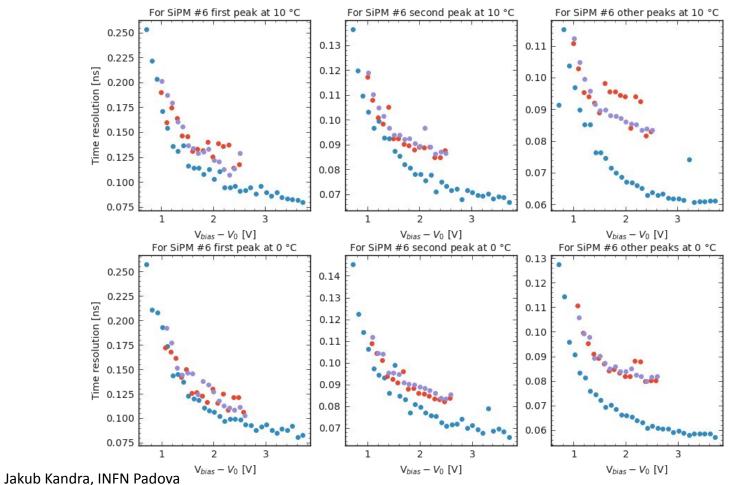






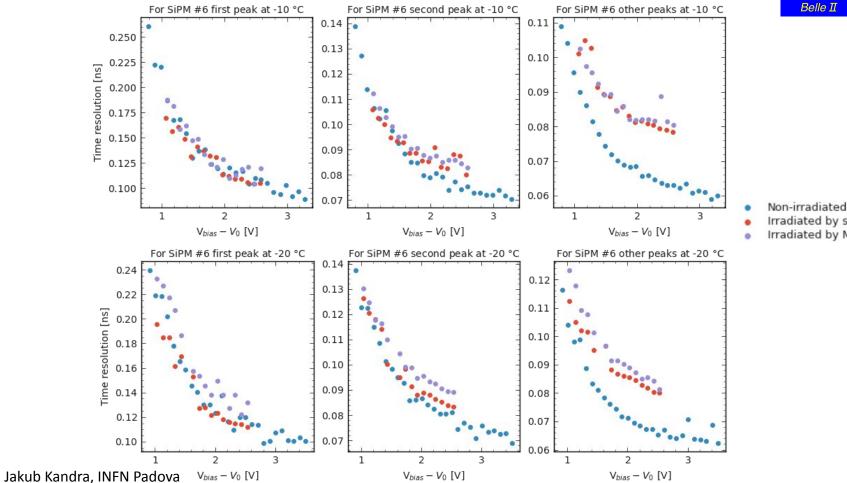
Time resolution for first, second and other photon peaks for SiPM #6





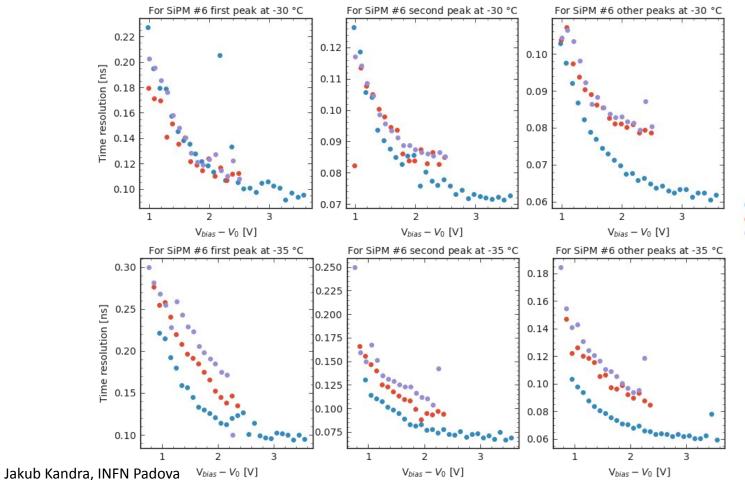
Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm





Non-Irradiated Irradiated by standard algorithm Irradiated by Markov algorithm



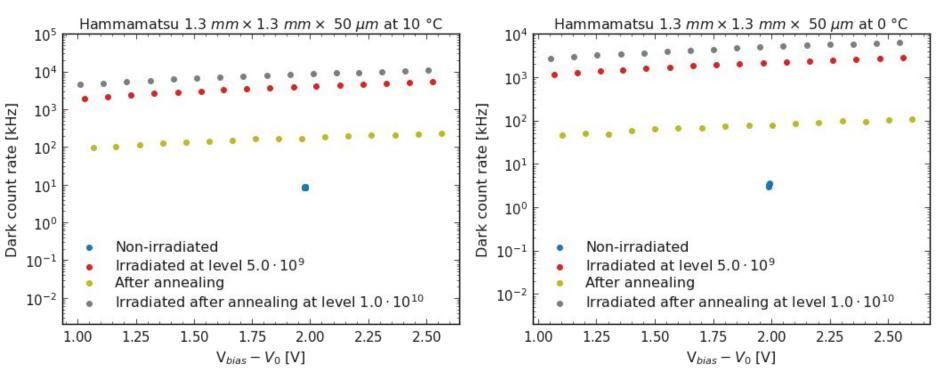


Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm

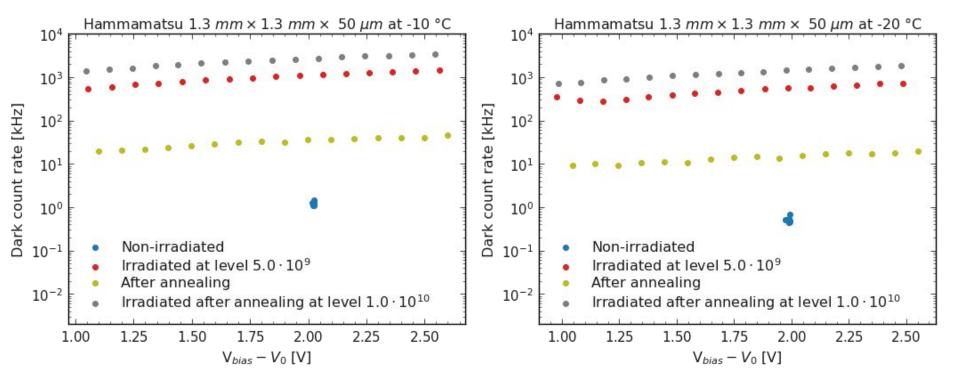


Dark count rate for SiPM #6

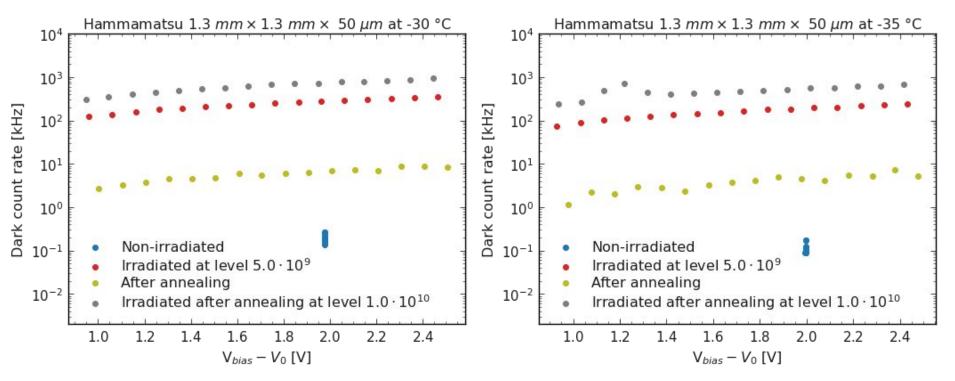












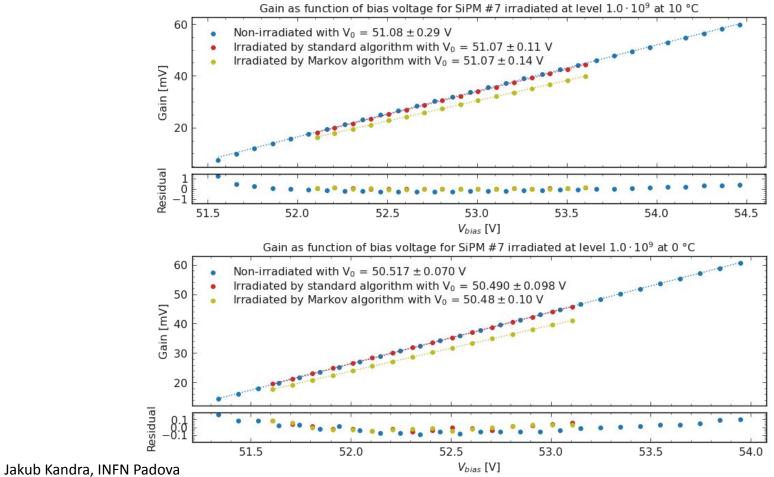


SiMP #7



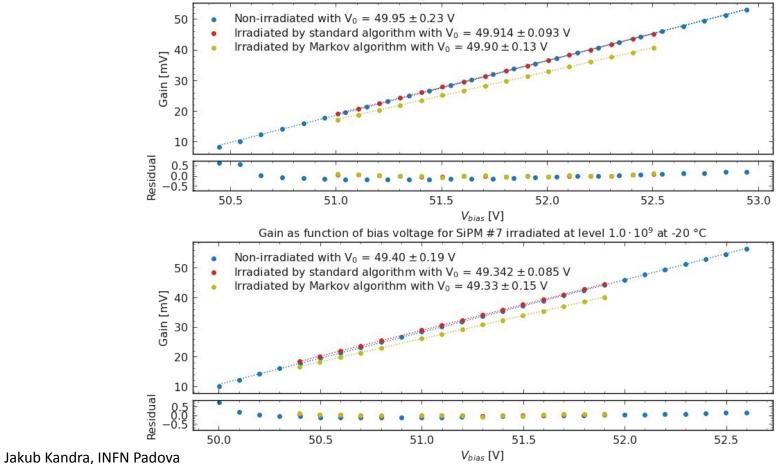
Gain as function of bias voltage for SiPM #7





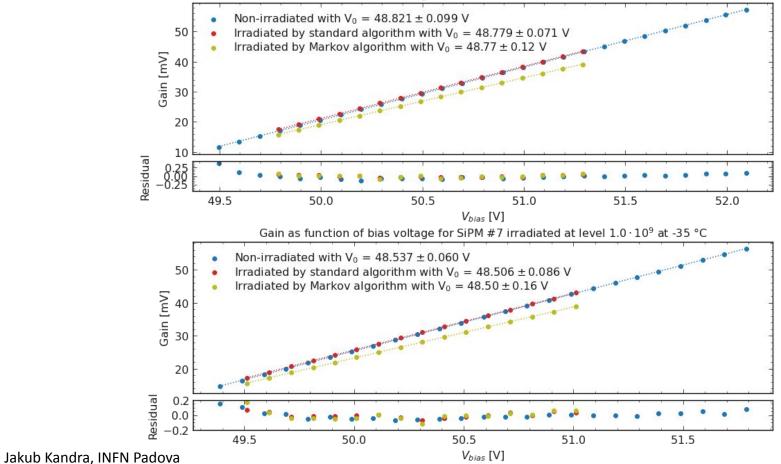


Gain as function of bias voltage for SiPM #7 irradiated at level 1.0 · 10⁹ at -10 °C



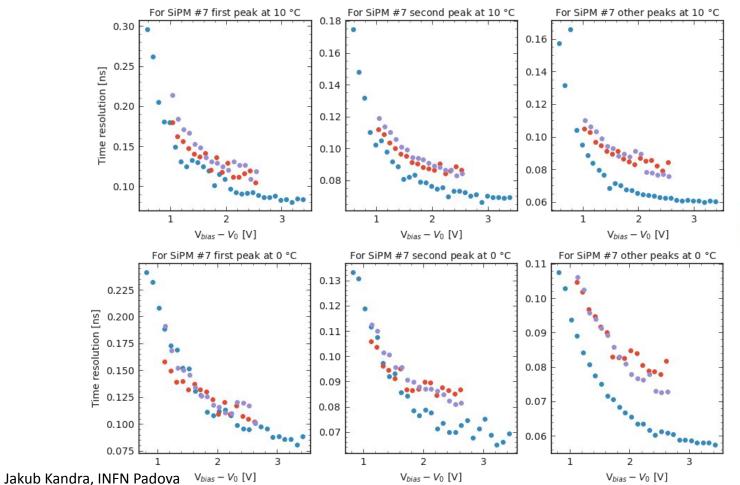


Gain as function of bias voltage for SiPM #7 irradiated at level $1.0 \cdot 10^9$ at -30 °C



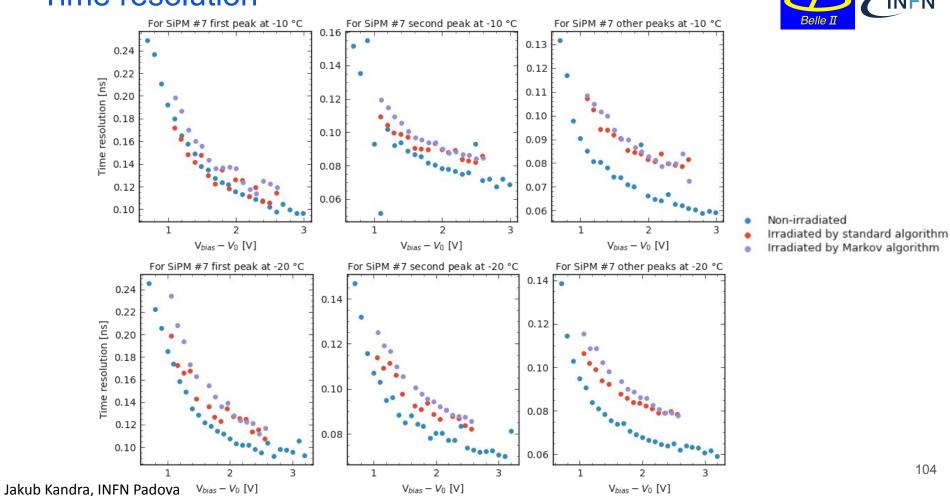


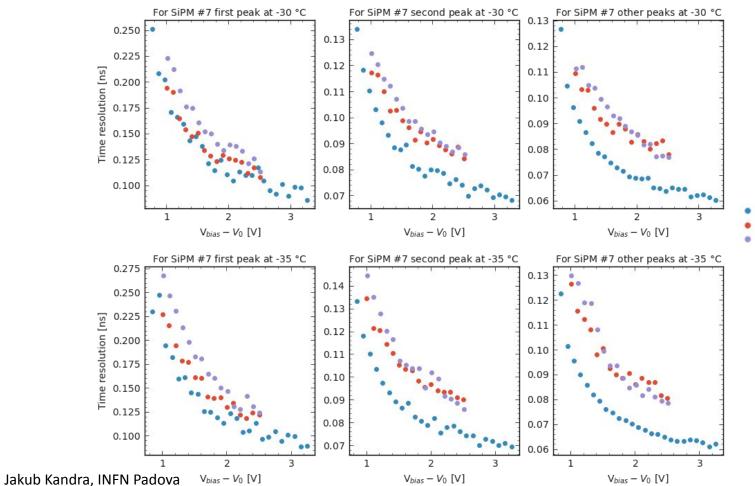
Time resolution for first, second and other photon peaks for SiPM #7





- Non-irradiated
 Irradiated by standard algorithm
- Irradiated by Markov algorithm





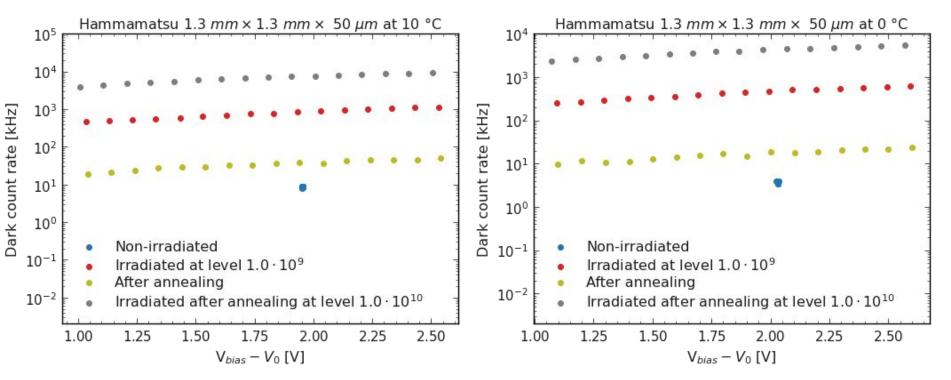


Non-irradiated
 Irradiated by standard algorithm
 Irradiated by Markov algorithm

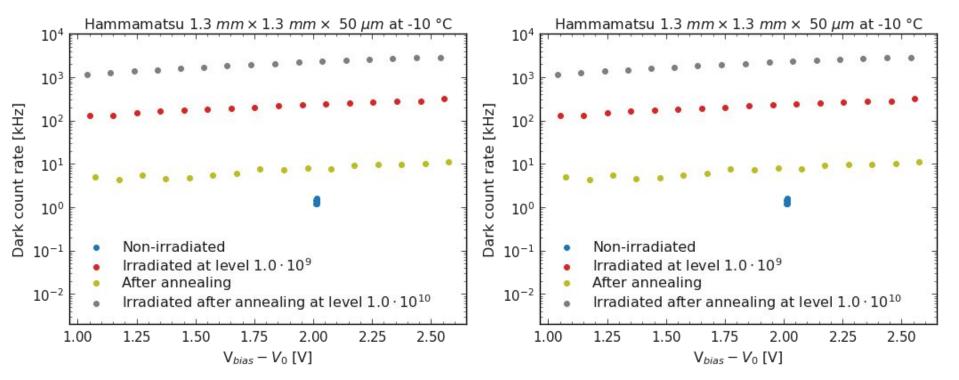


Dark count rate for SiPM #7

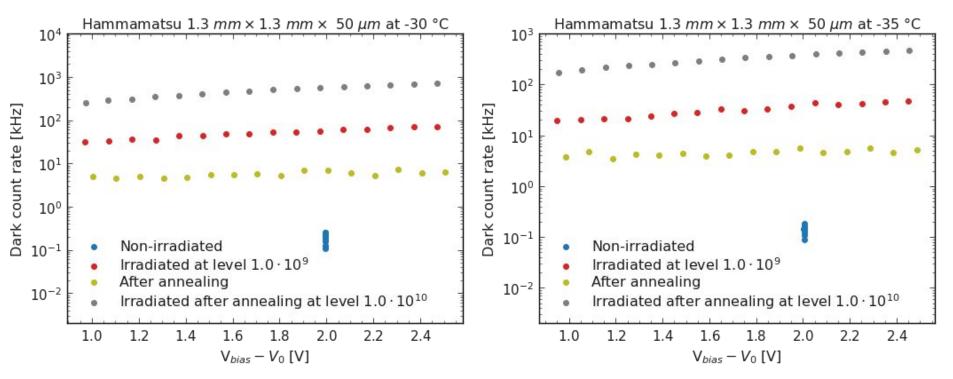














Backup