Ultimate
Low-Light
Level Sensor
Development

Studies of SiPM behaviour under continuous background light illumination

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2018/04/27

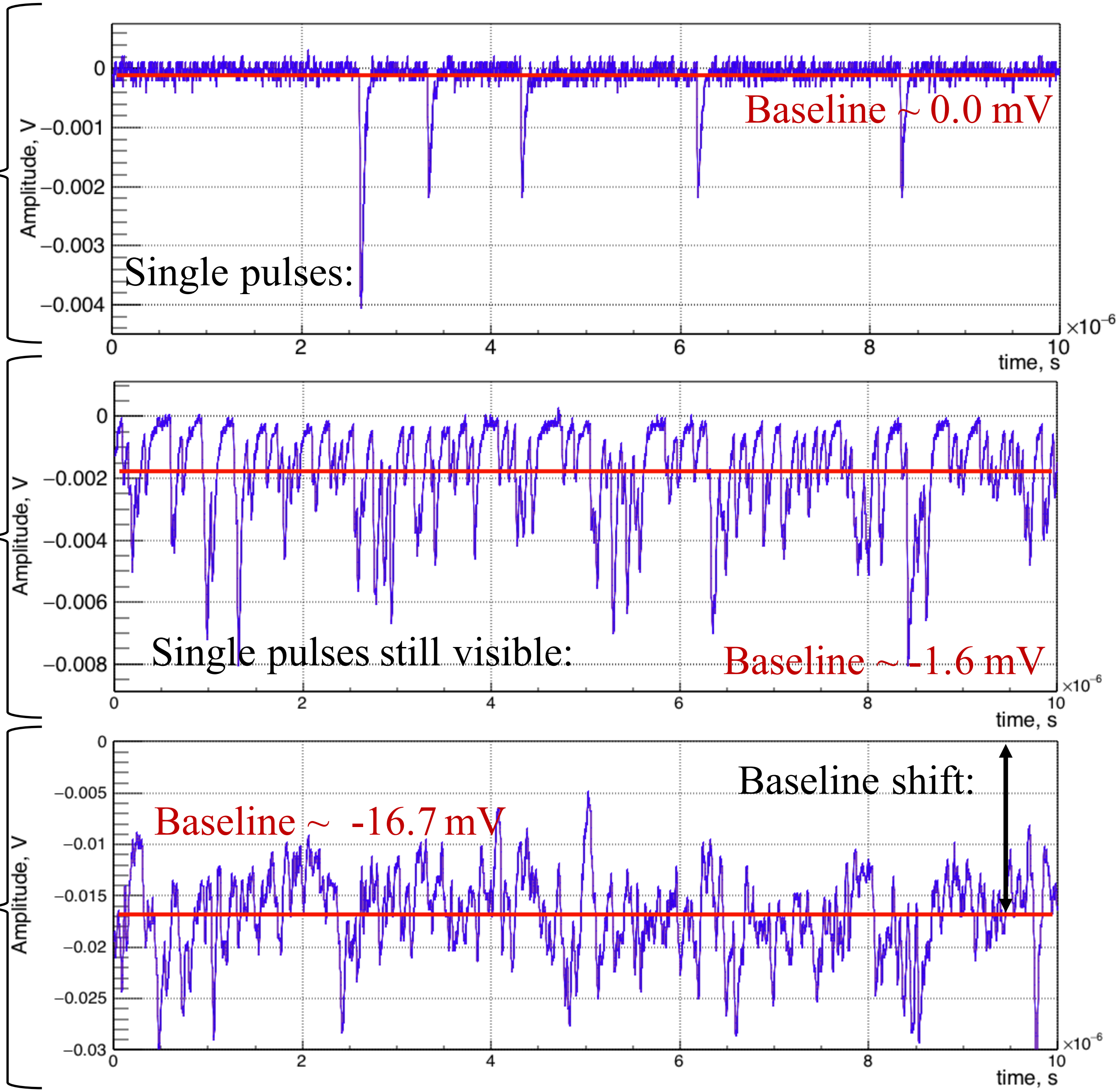
Continuous background light illumination:

Typical Waveform:

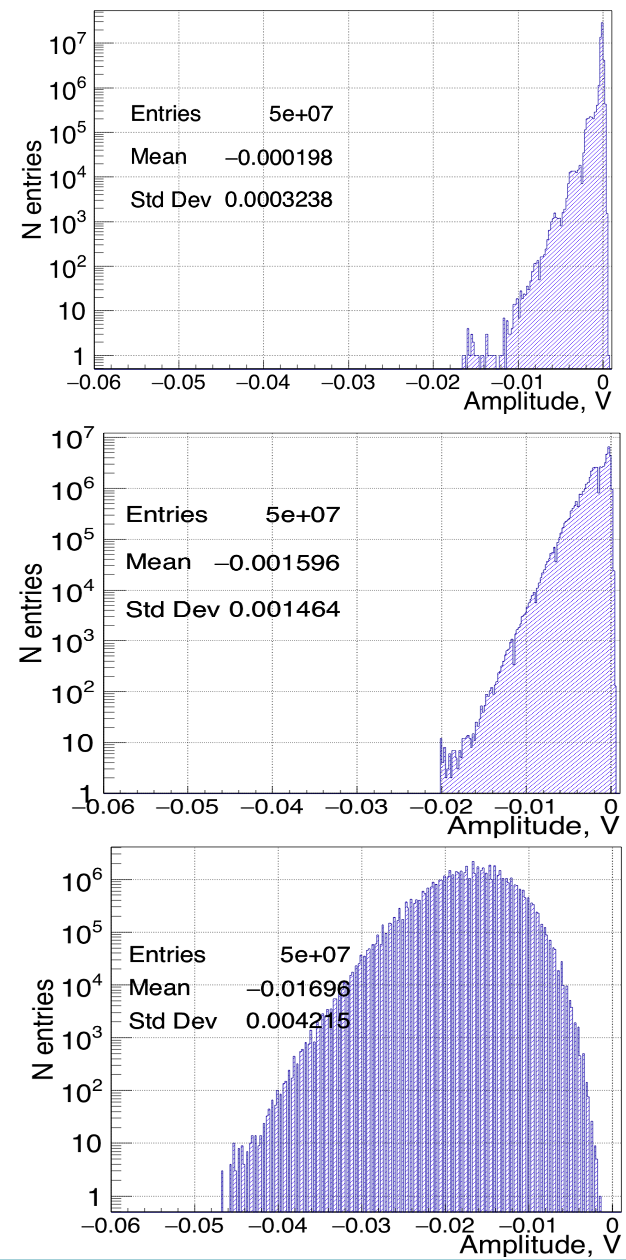
Dark:

40.9 MHz:

660 MHz:

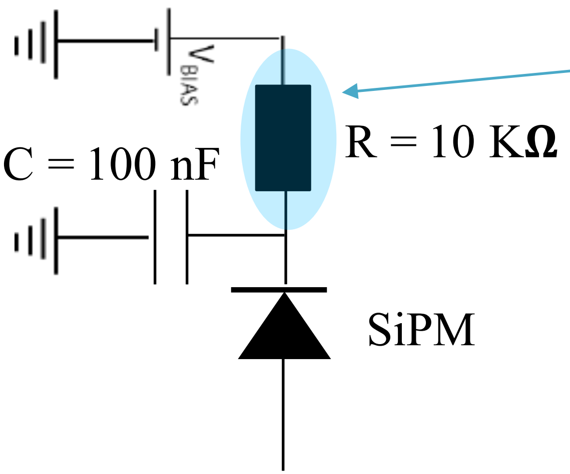


10k Waveforms:



Where is the problem?

Typical SiPM connection scheme:



R_{bias}

- ☺ Protection
- ☺ Noise filter
- ☹ Voltage drop: $V_{drop} = R_{bias} \times I_{SiPM}$

$I_{SiPM} = Gain \times N_{\gamma}$

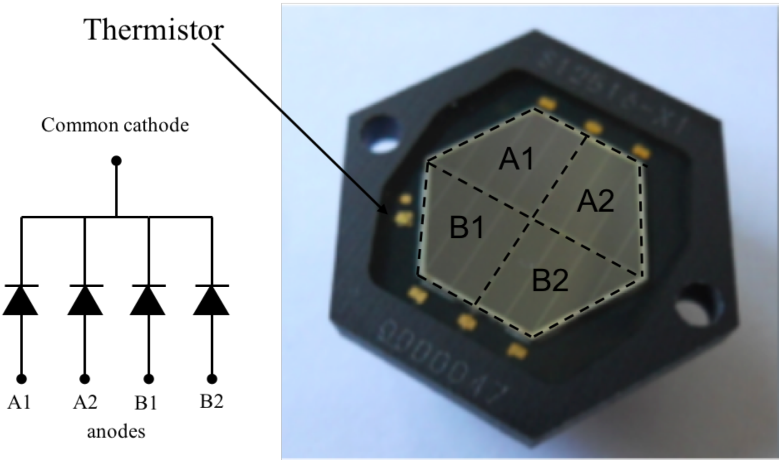
$$\Delta V = V_{bias} - V_{BD} - V_{drop}$$

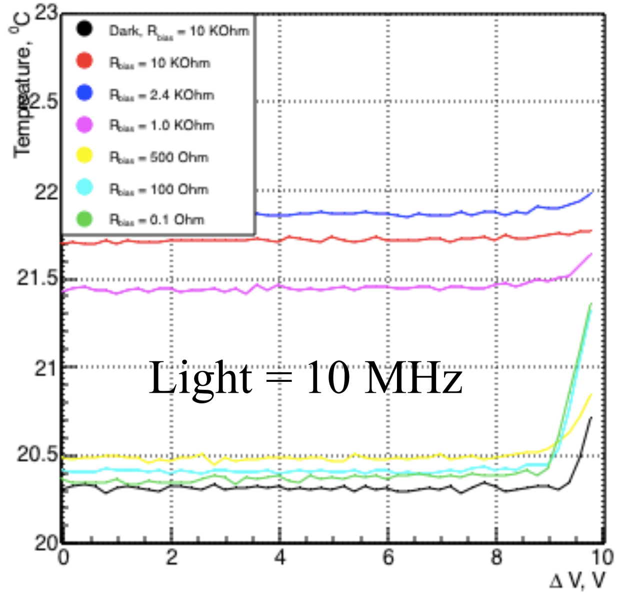
$$N_{\gamma}\nearrow \Rightarrow V_{drop}\nearrow \Rightarrow \Delta V\searrow$$

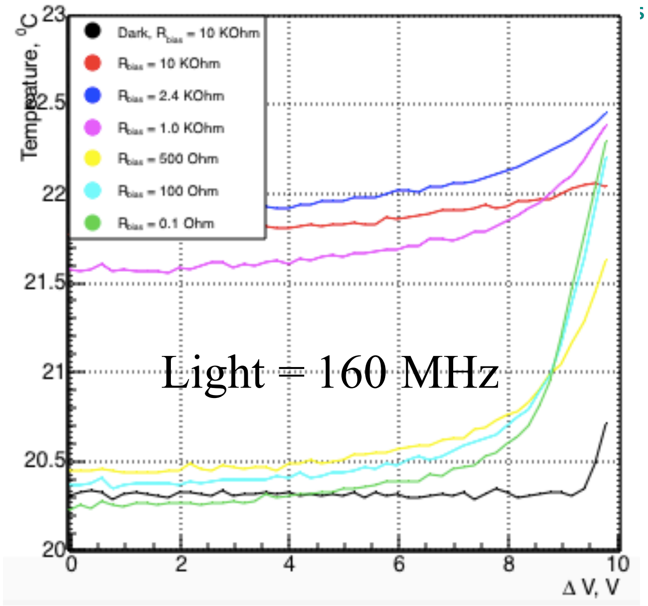
Voltage drop affects:

- Electrical parameters: Gain, Amplitude
- Optical parameters: PDE
- Noise parameters: DCR, P_{XT}, P_{AP}

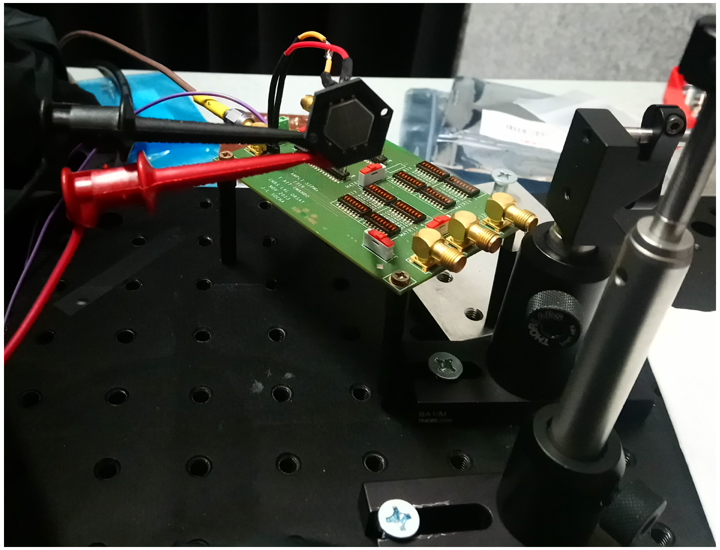
Do we need R_{bias}?

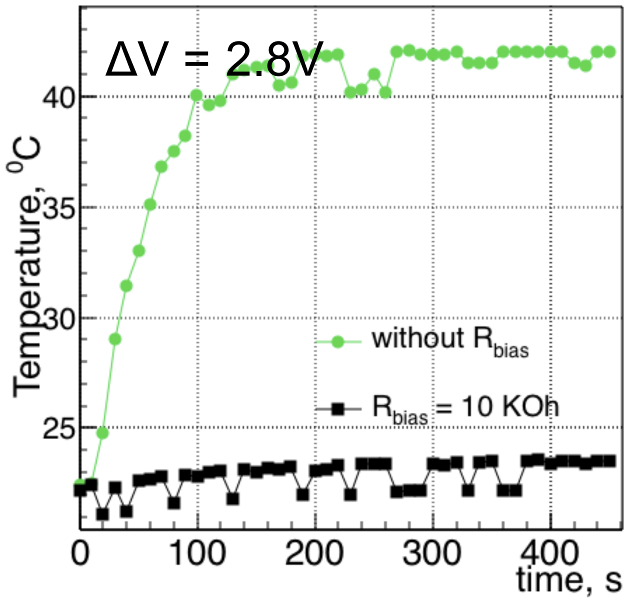






SiPM under indoor light:



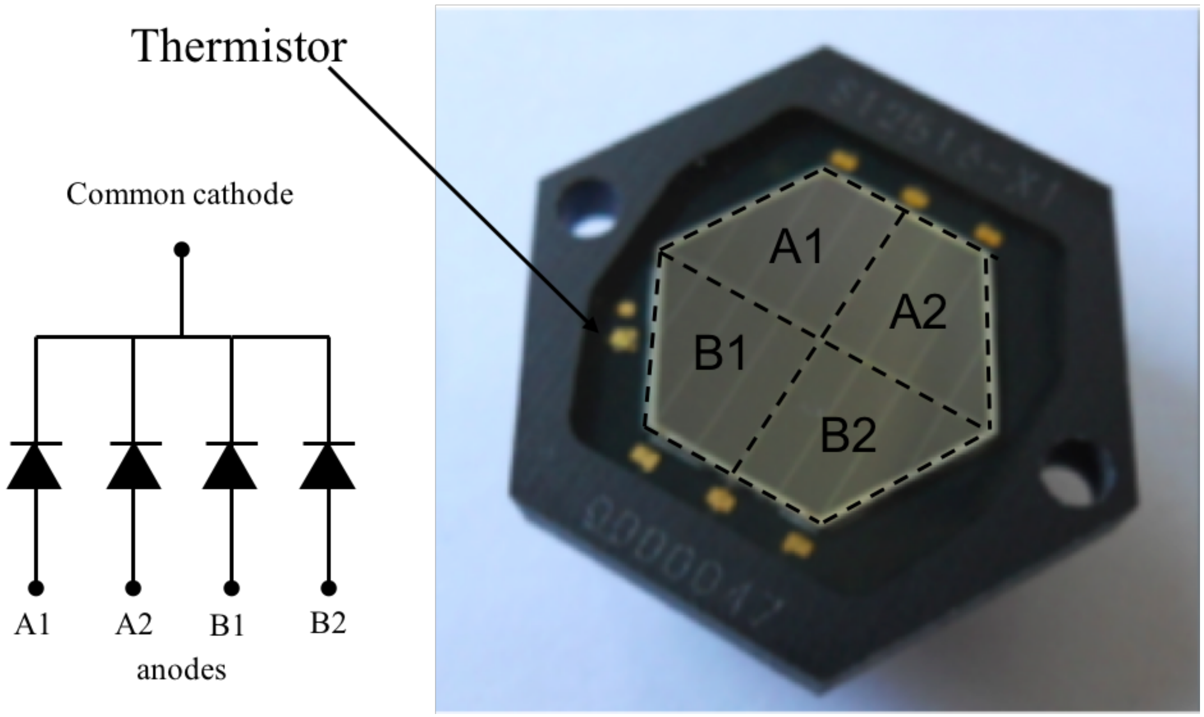


Without R_{bias} => self heating ⇒ T↗ => ΔV↘

Light flux and ΔV define R_{bias}

To study the V_{drop} the SiPM should be well characterized

Monolithic Hexagonal 6 mm side Hamamatsu S10943-2832(X):



We need to know:

- Gain;
- PDE;
- Amplitude;
- Signal shape;
- DCR;
- P_{XT};
- V_{BD};
- R_q;

Experimental set-up @ UNIGE/Ideasquare:

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continuous light

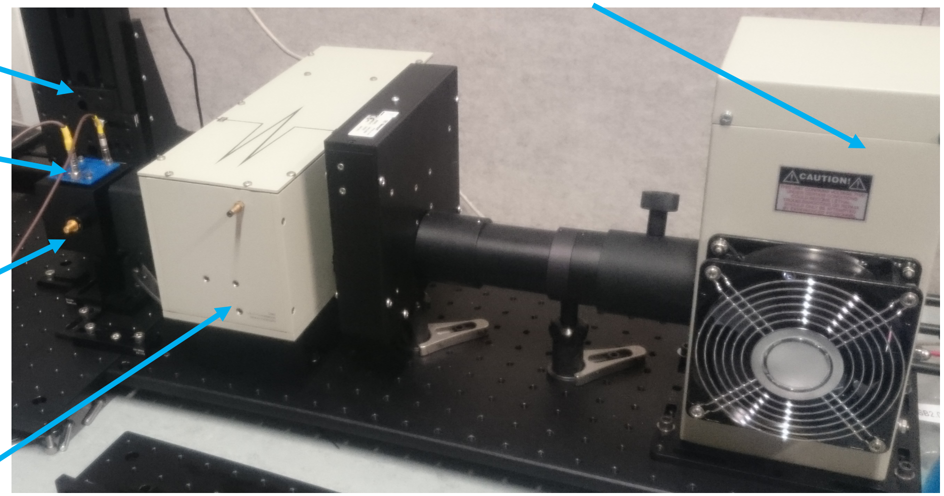
Translation stage

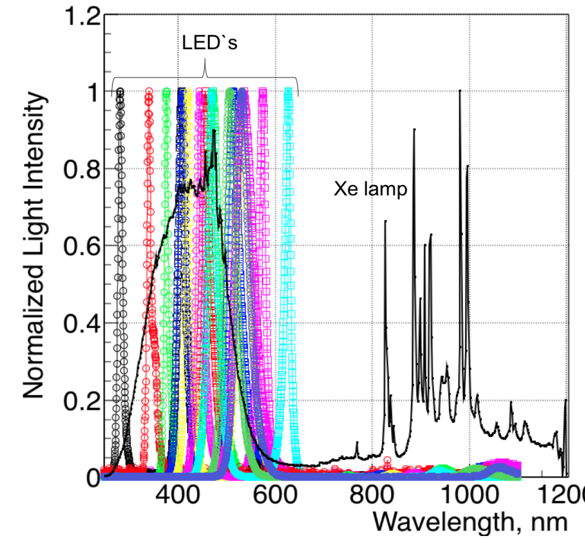
Photodiode (S1337-1010BQ)

Integration sphere

Monochromator

Xe 75 W lamp: 260 ÷ 1800 nm





pulsed light

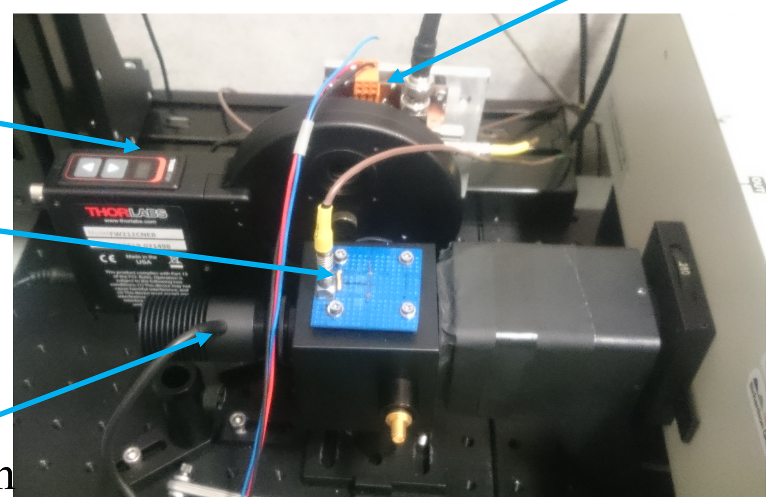
ND filters (81.3% ÷ 0.01%)

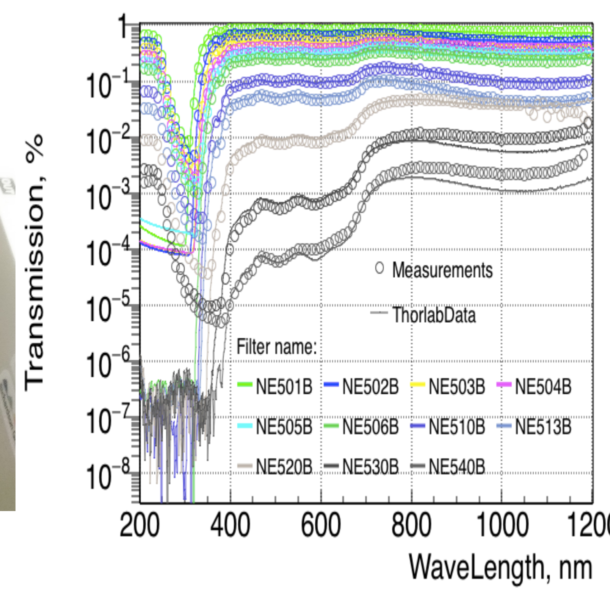
Photodiode 10x10 mm^2 (S1337-1010BQ)

LED`s :

280, 340, 375, 405,
420, 455, 470, 505,
525, 530, 565 & 572 nm

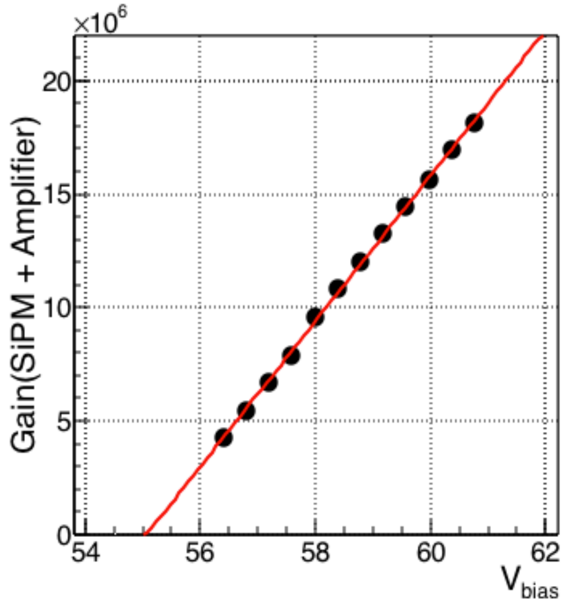
SiPM

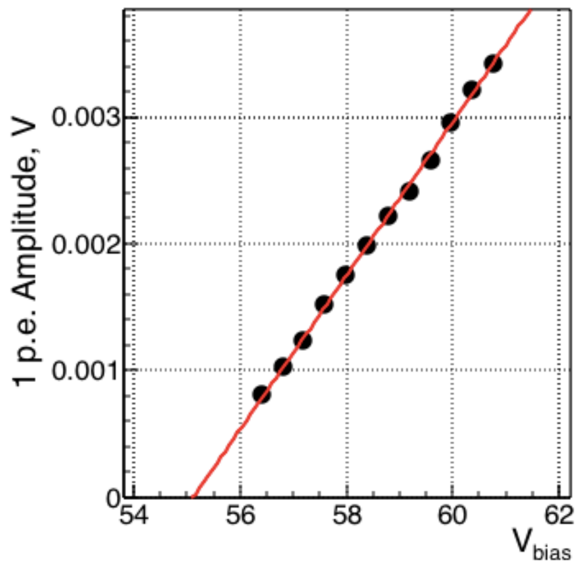


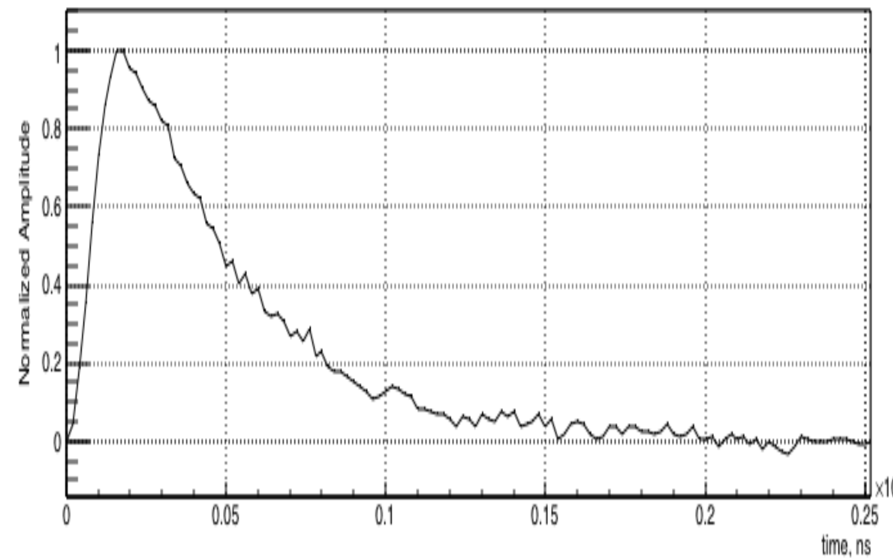


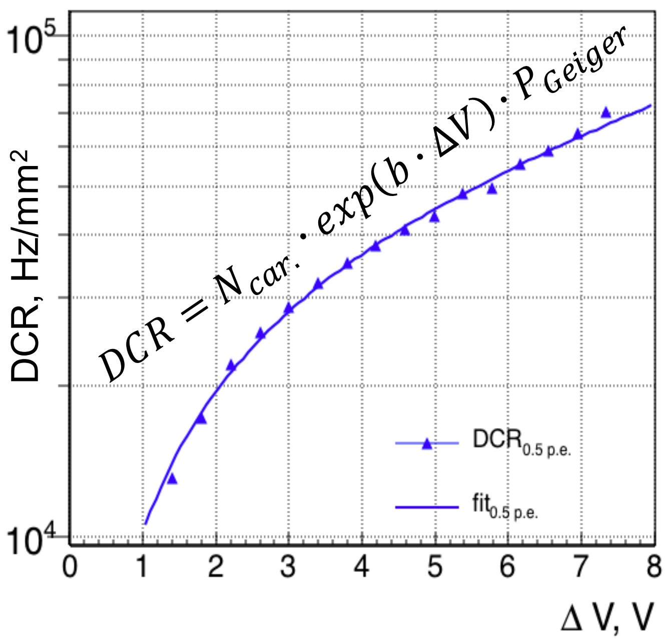
Can be used for: PDE, DCR, P_{XT}, P_{AP} measurements

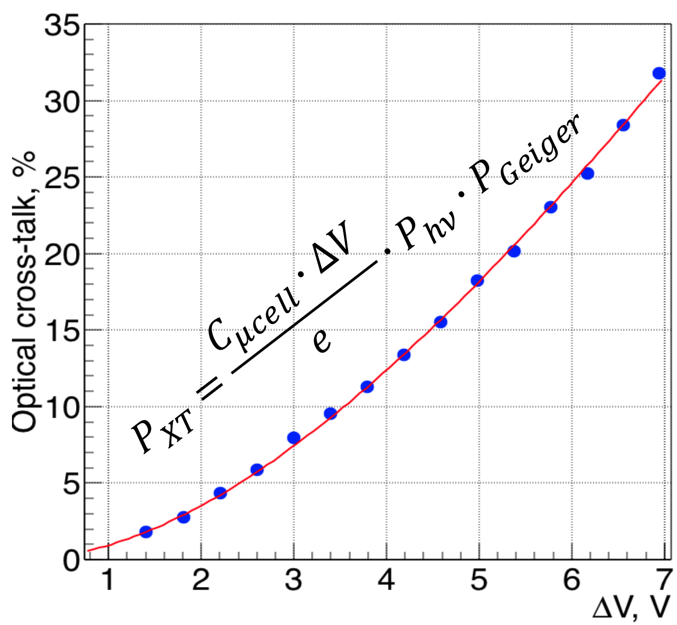
SiPM parameters: Gain, Amplitude, DCR, P_{XT}…











Electrical parameters:

- V_{BD}
- $C_{\mu cell}$

SiPM parameters: PDE

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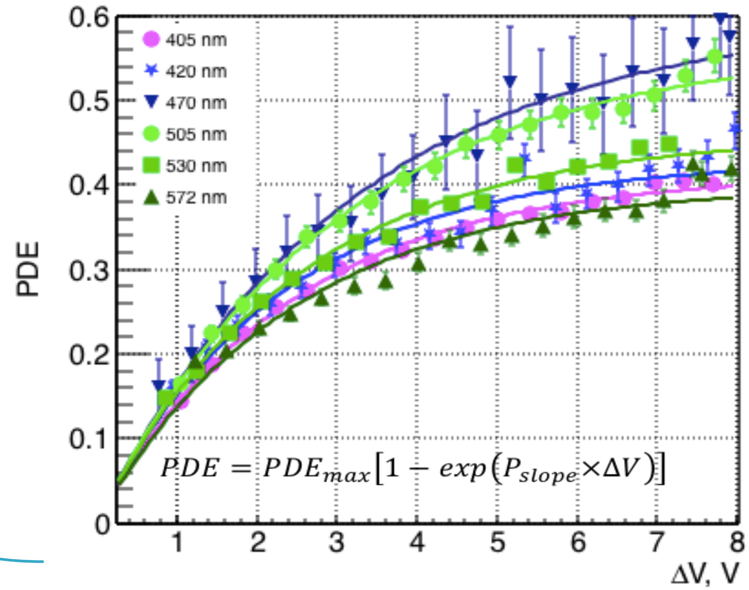
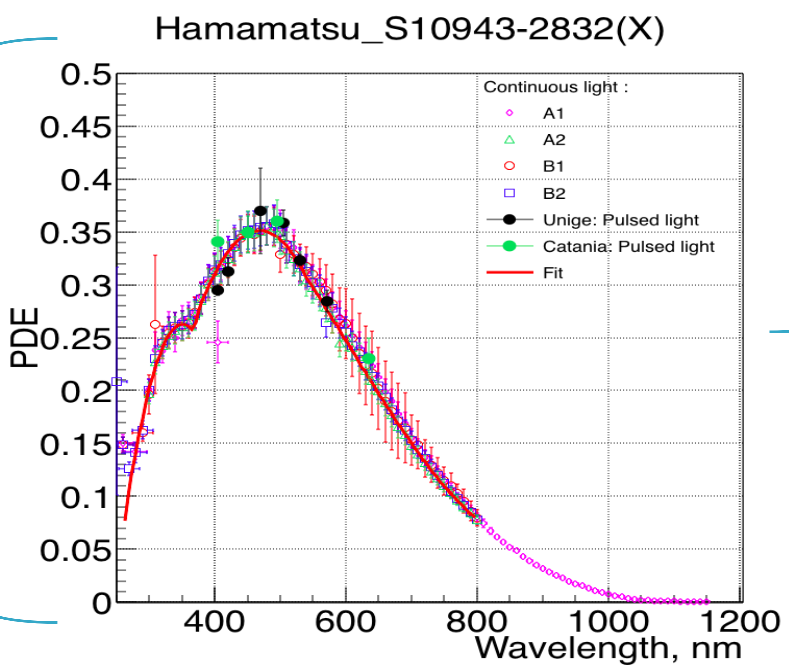
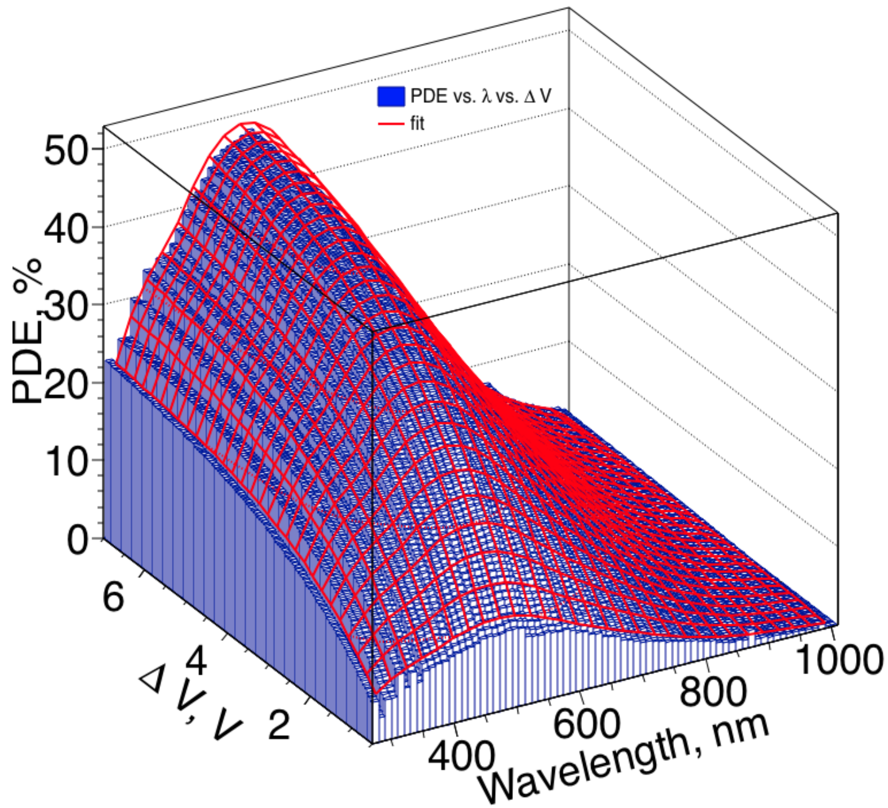
pulsed light
(absolute PDE)



continuous light
(relative PDE)





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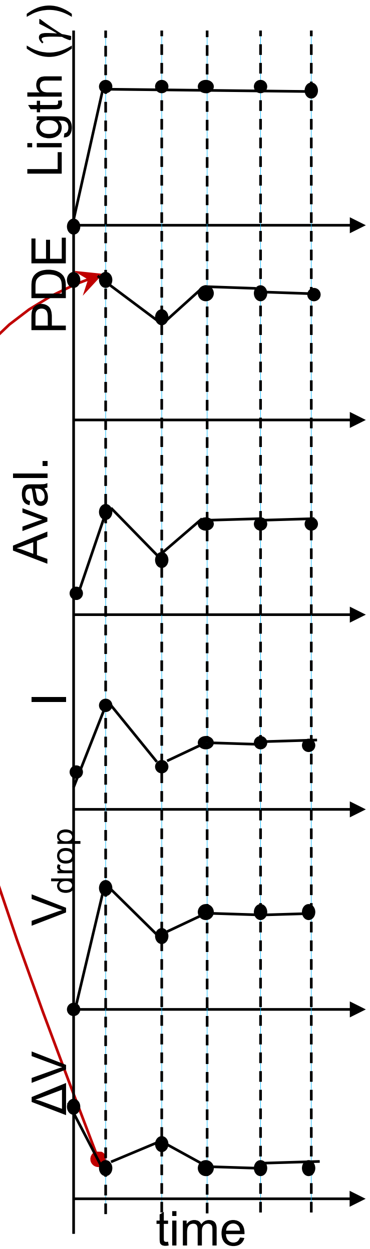
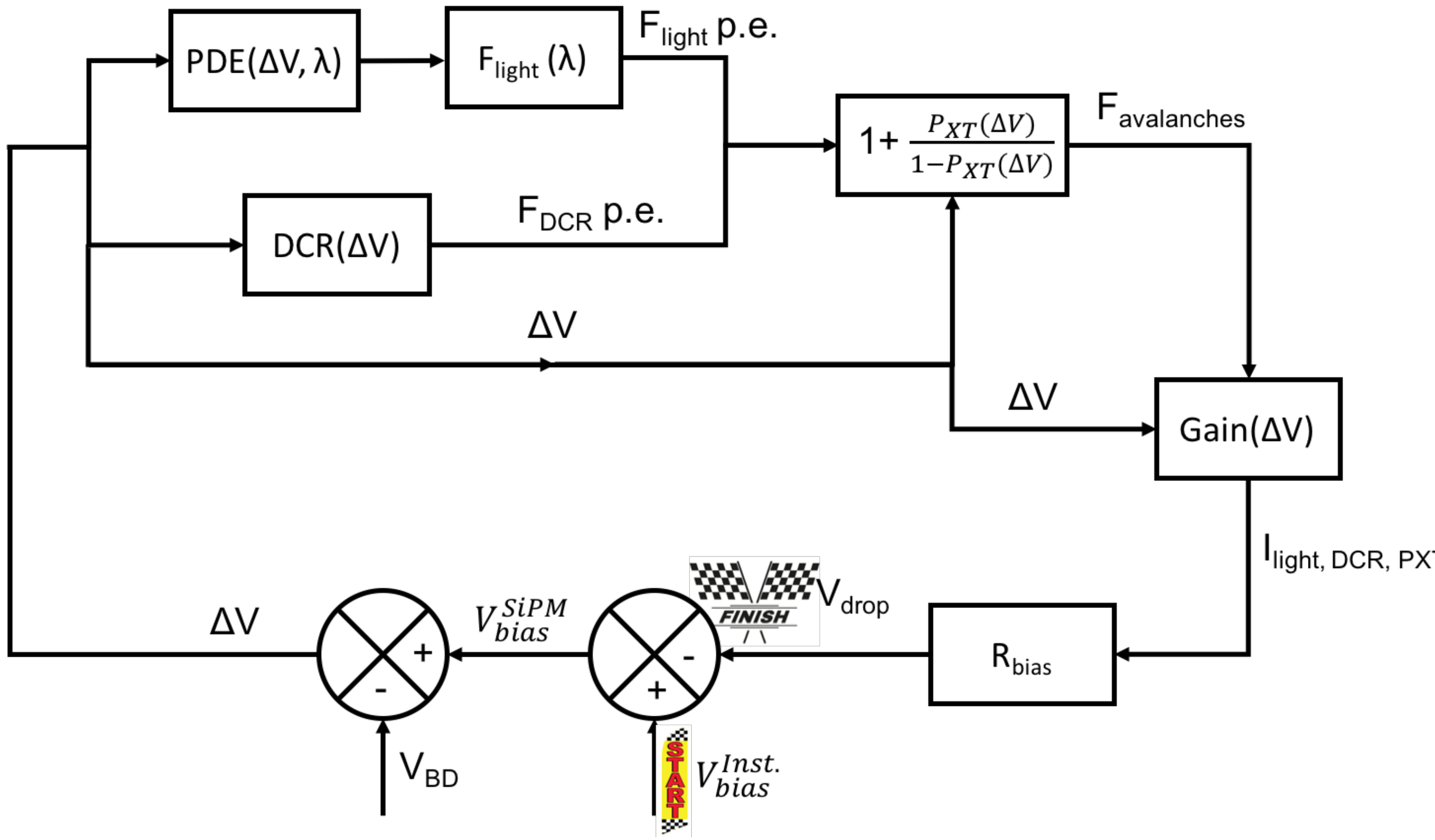
Simulation idea:





Input parameters: V_{BD}, $C_{\mu cell}$, R_{bias}, DCR(ΔV), PDE(ΔV, λ), P_{XT}(ΔV)

Inputs to simulation:

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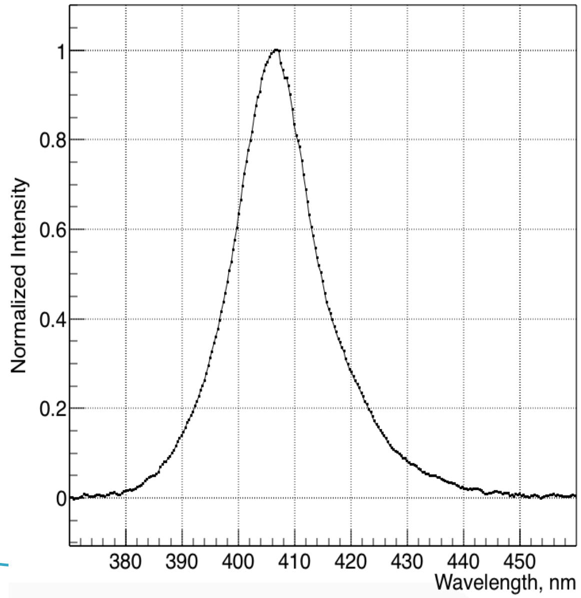
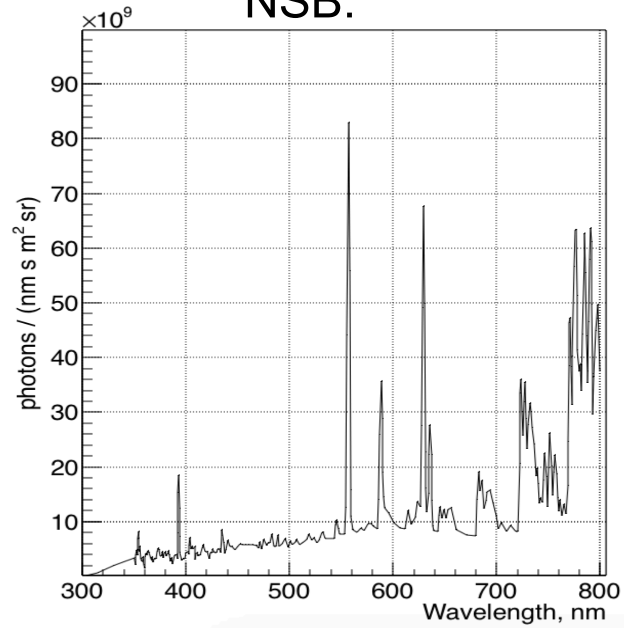
Light sources

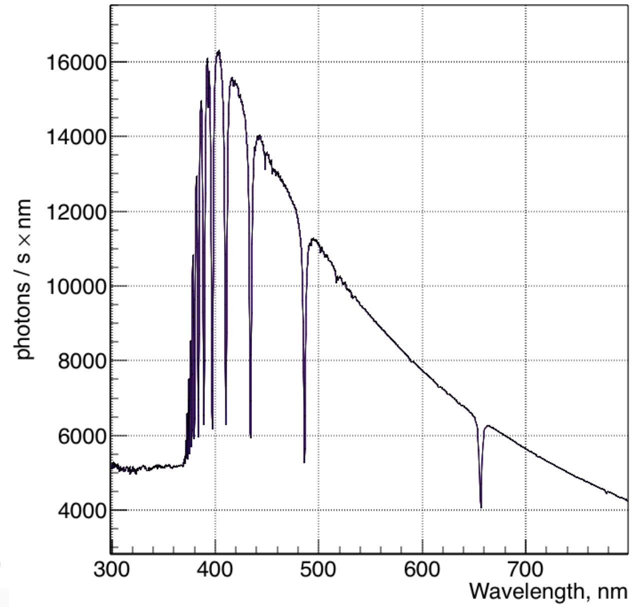
LED:



NSB:

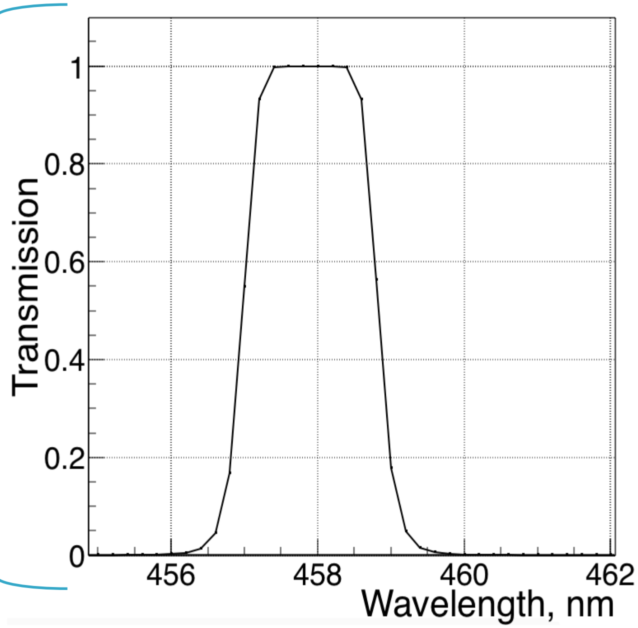


Star:

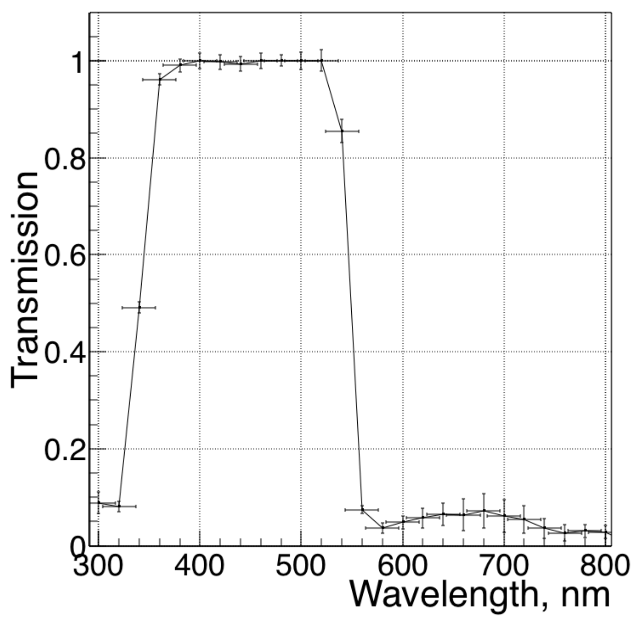


Optics

Filter:



Window:



Various combination of light sources and optics can be used

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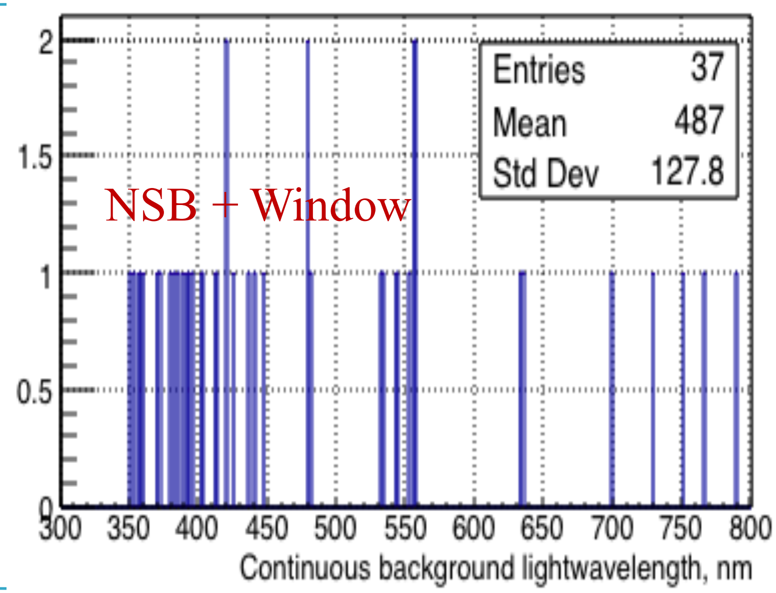
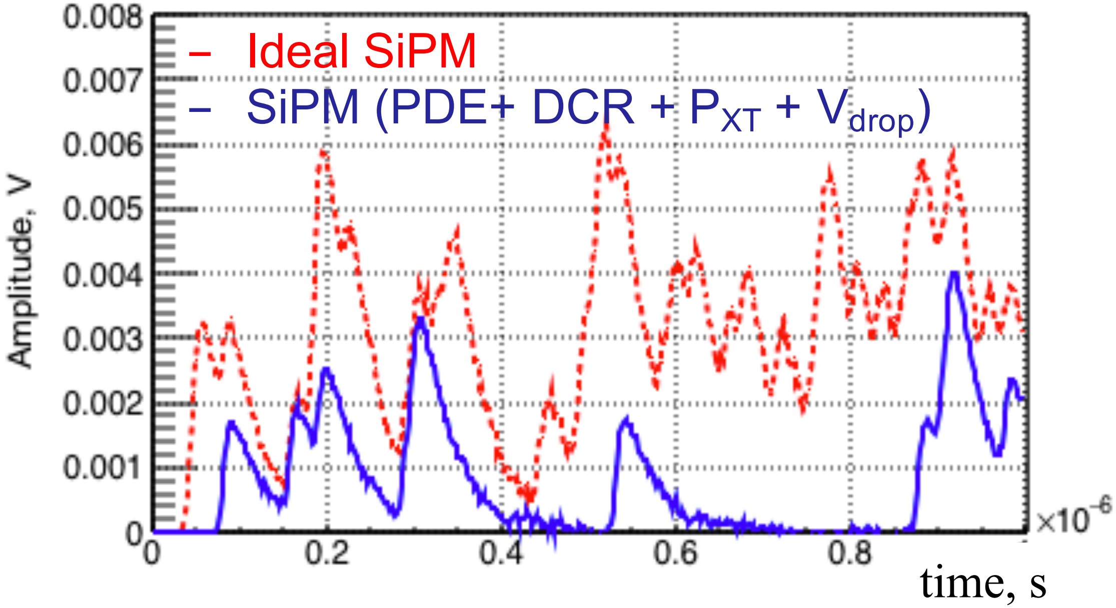
Typical Simulation Results: Single waveform sim.

Light spectrum:

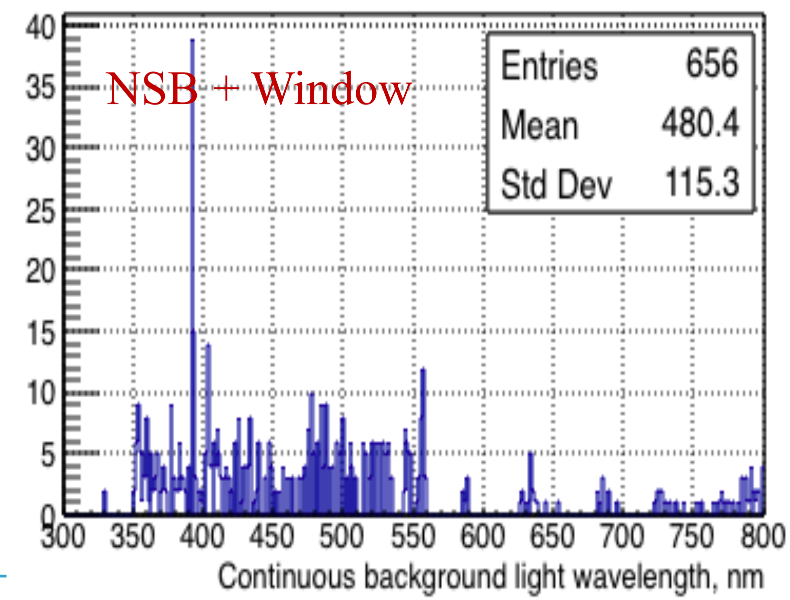
Typical Waveform:

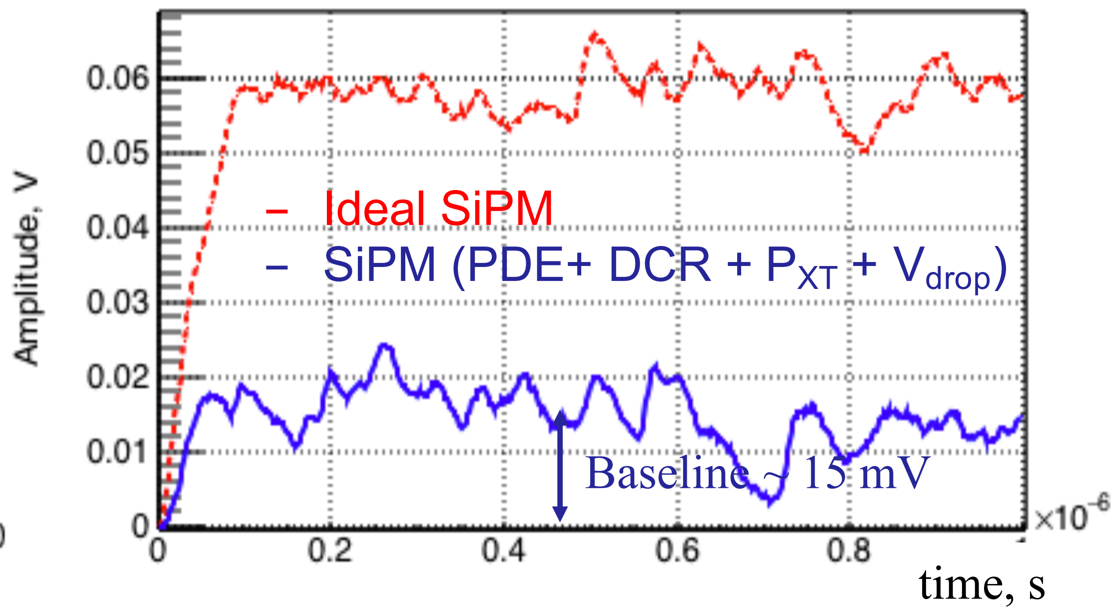
40.9 MHz





660 MHz





Typical Simulation Results: Average waveform sim. (1)

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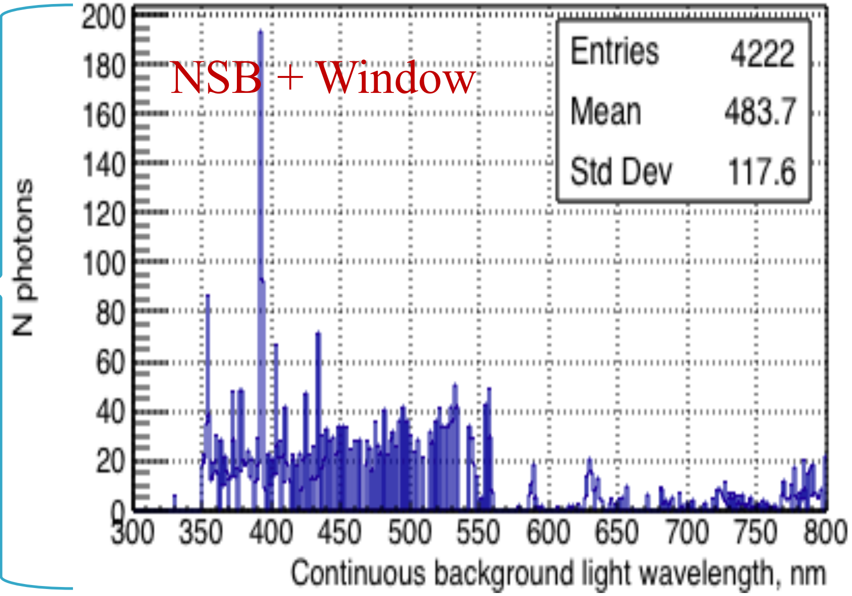
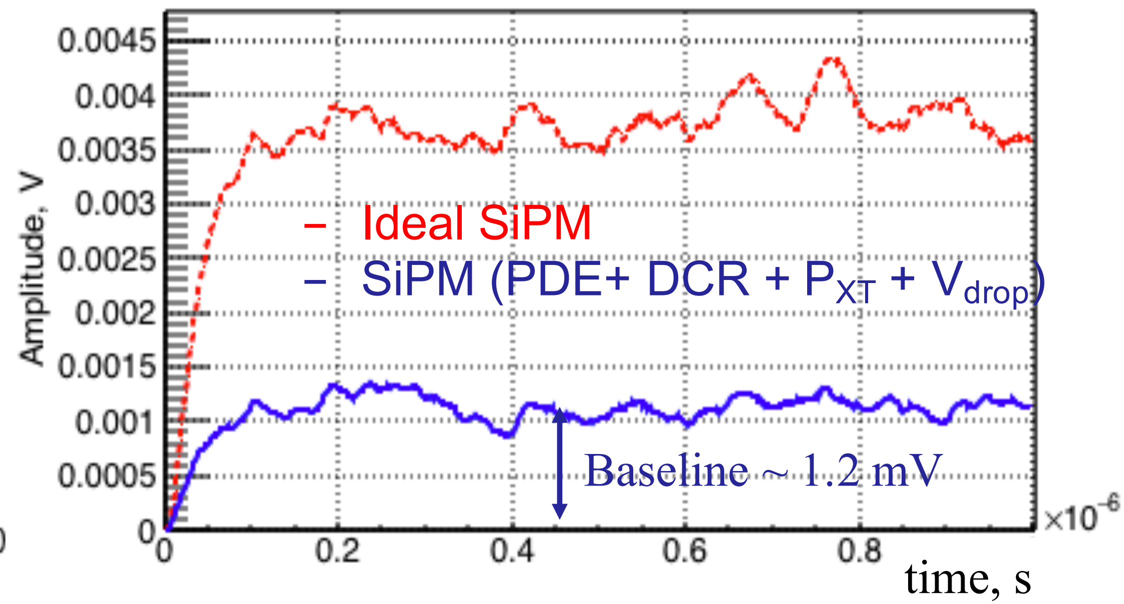
Light spectrum:

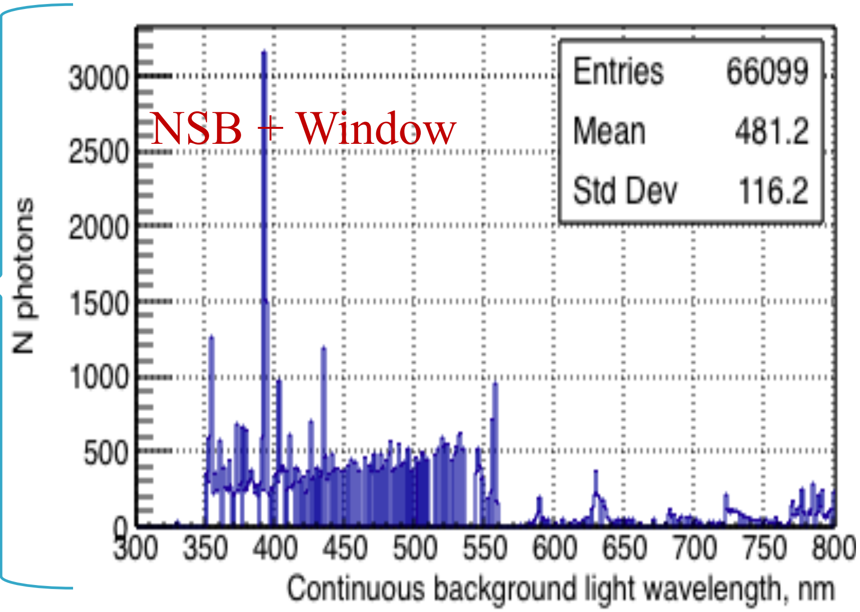
Typical average Waveform:

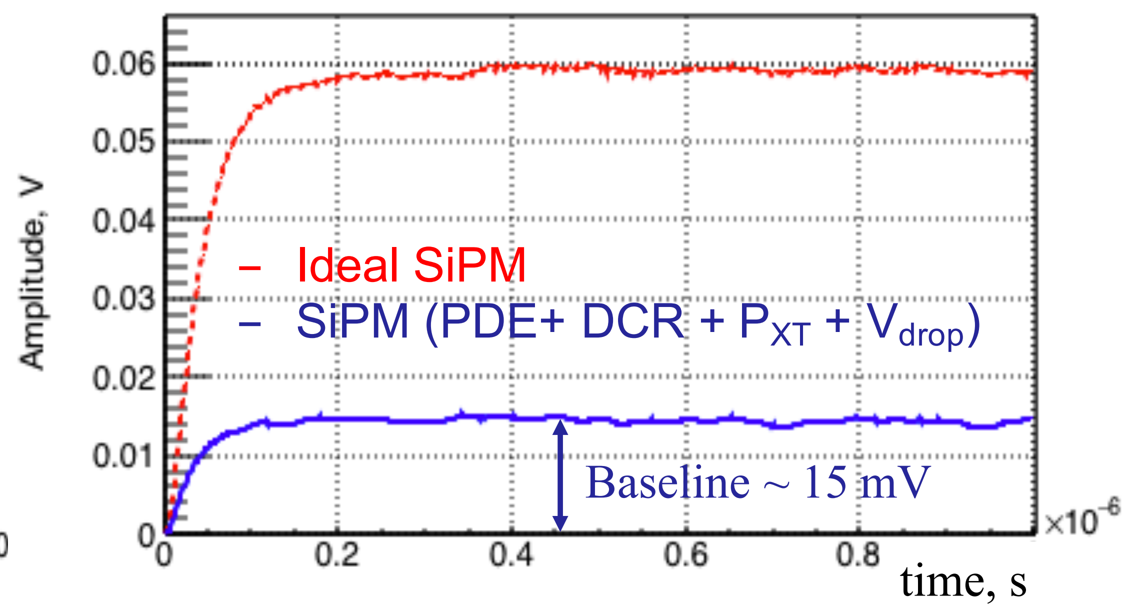
40.9 MHz





660 MHz





Typical Simulation Results: Average waveform sim. (2)

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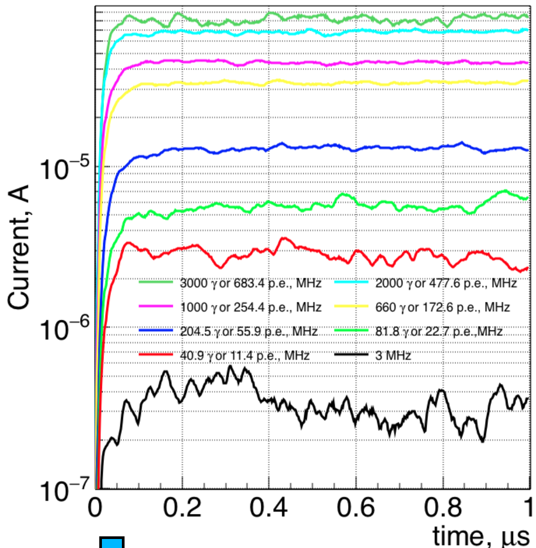
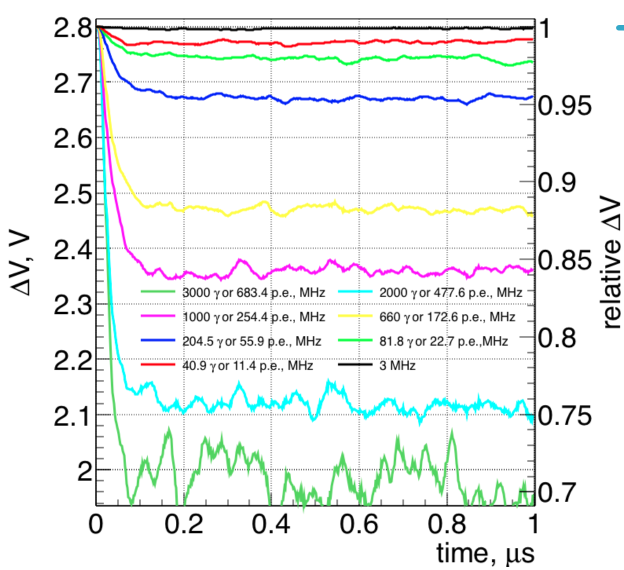
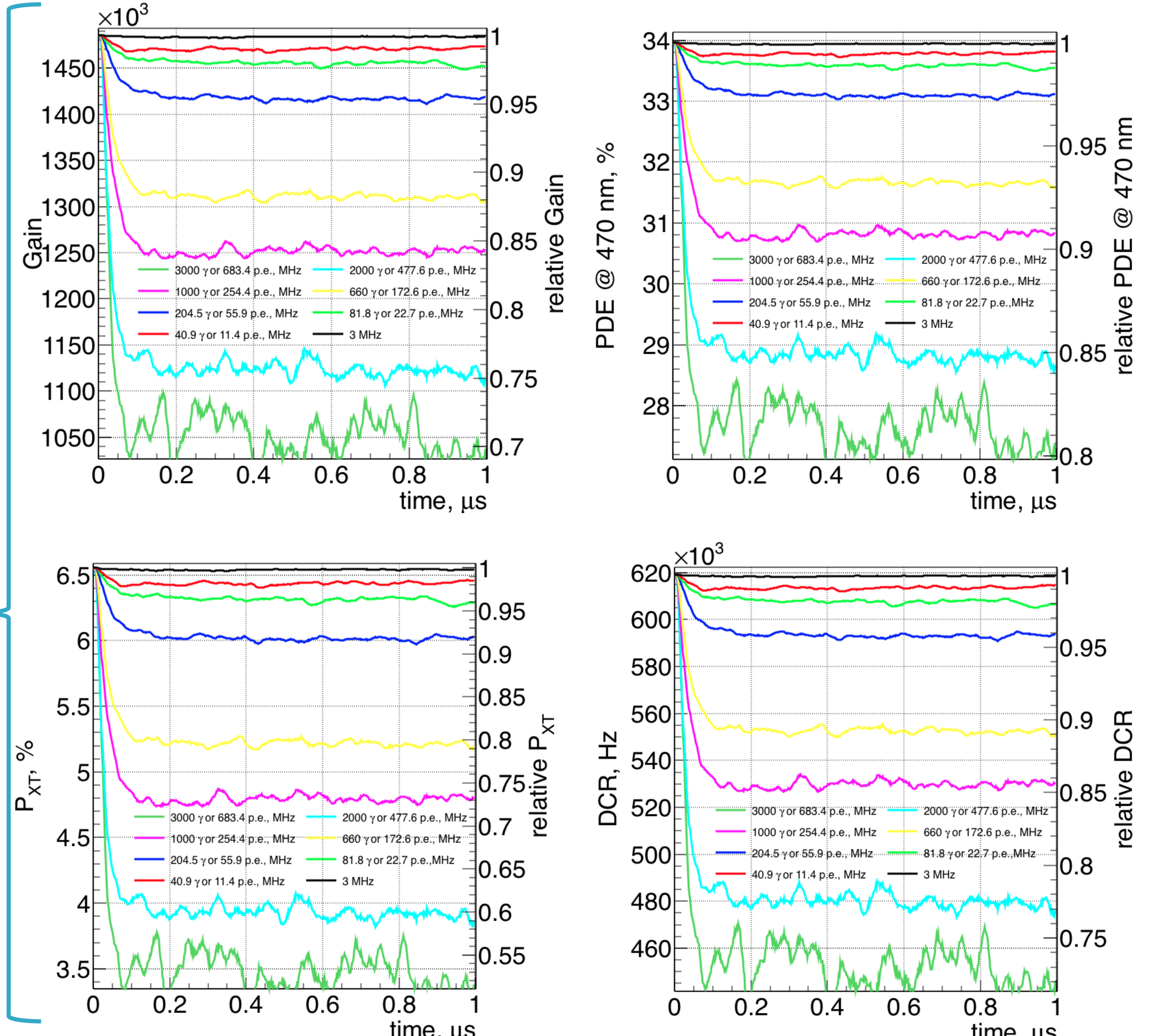


$$V_{drop} = R_{bias} \times I_{SiPM}$$

$$\Delta V = V_{bias} - V_{BD} - V_{drop}$$





Results: V_{drop}

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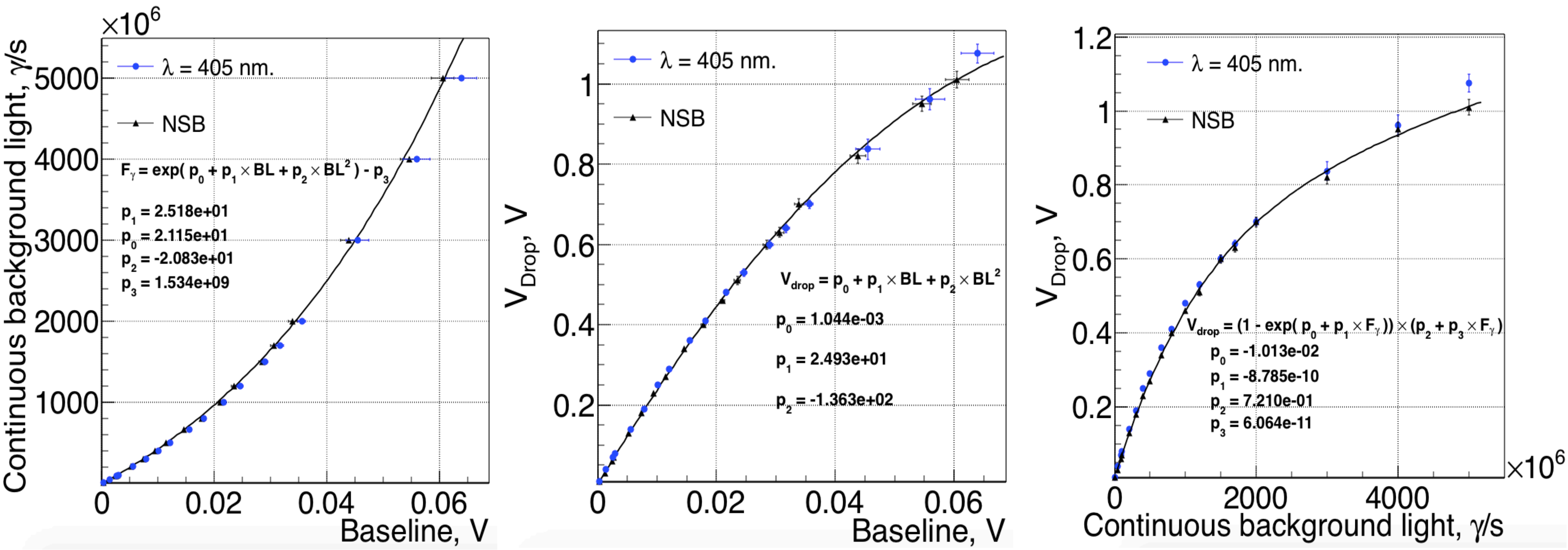
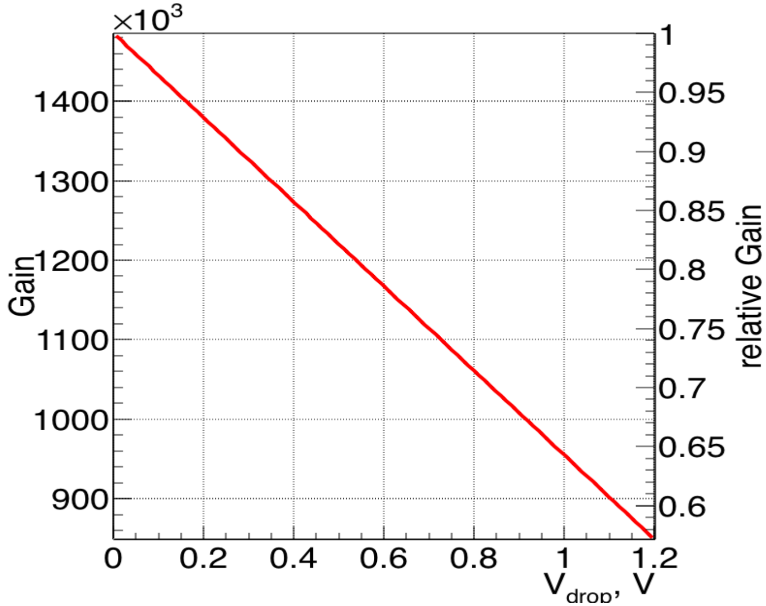
from real data baseline can be calculated:

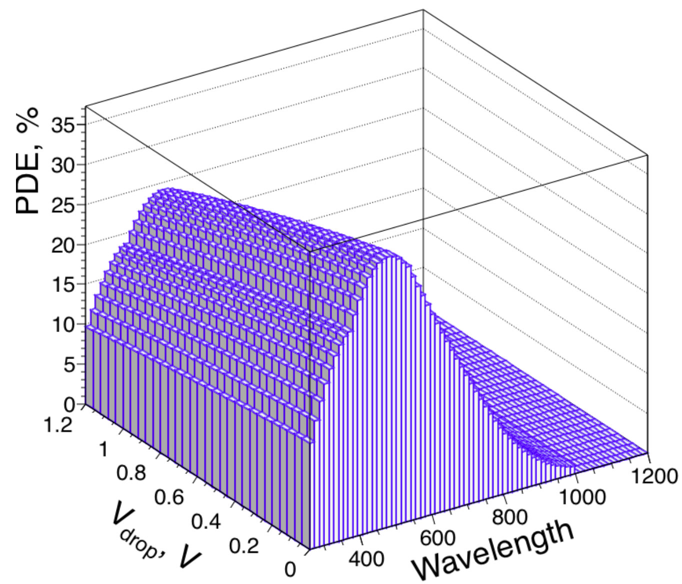


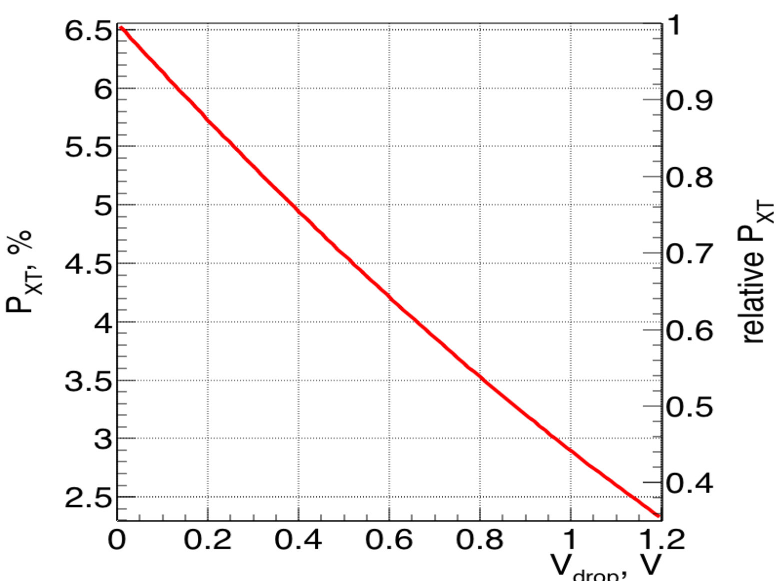
From simulation: $V_{drop} = F(Baseline)$ → Gain, PDE, Amplitude, P_{XT}, DCR

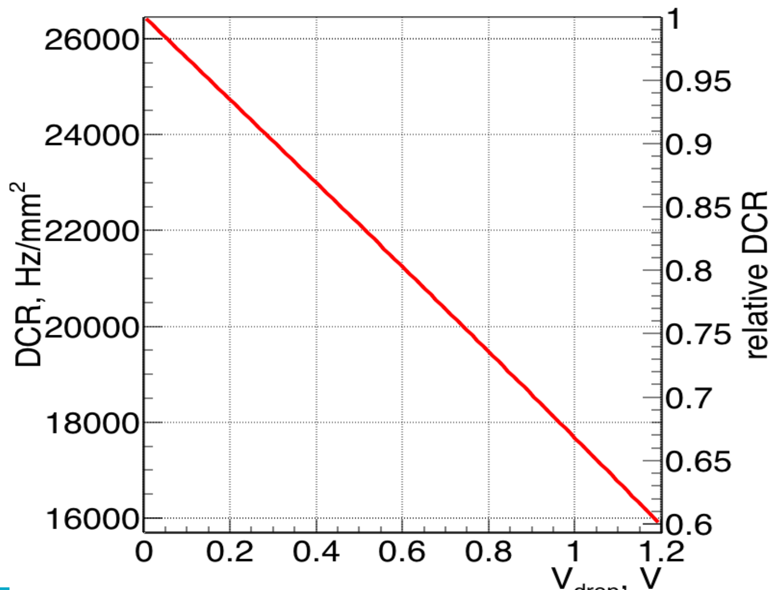
Results: V_{drop}

From simulation: $V_{drop} = F(Baseline)$ → Gain, PDE, Amplitude, P_{XT}, DCR



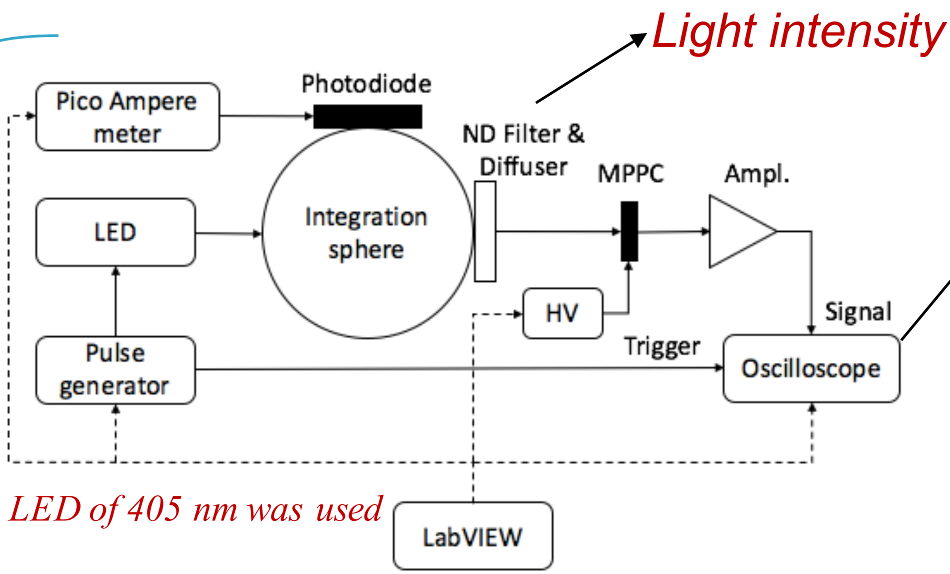


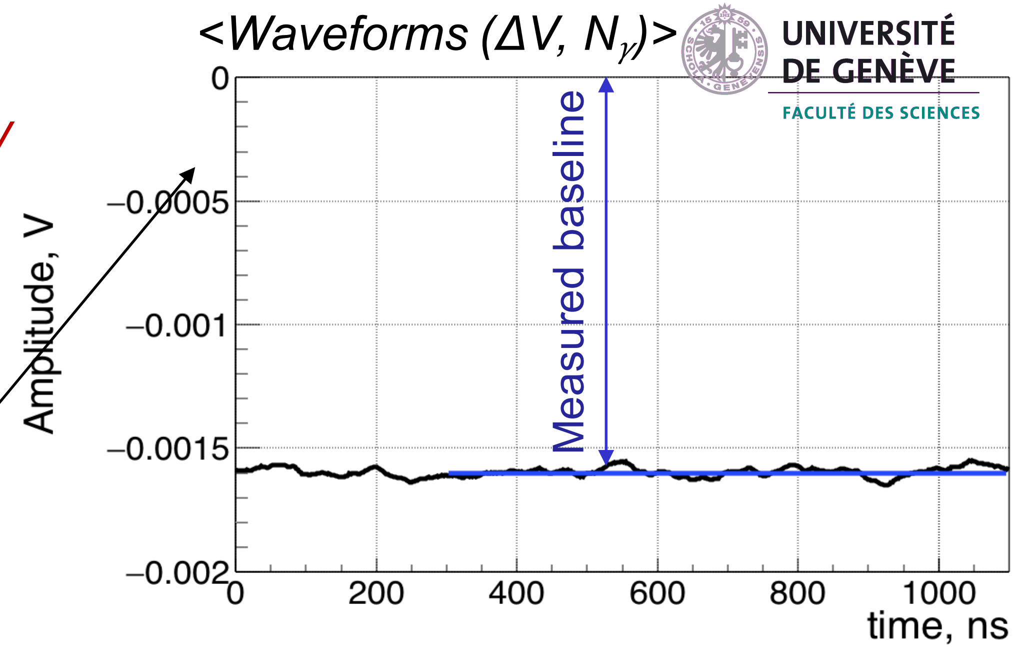




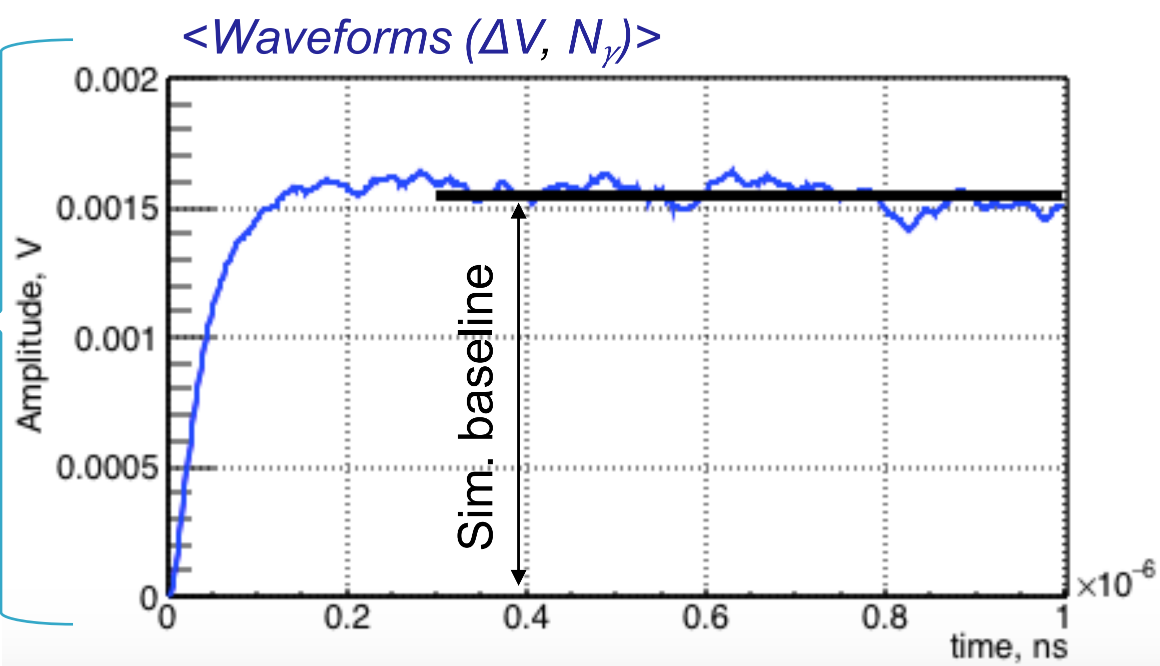
Simulation vs. Measurements :

Measurements





Simulation



Simulation vs. Measurements :

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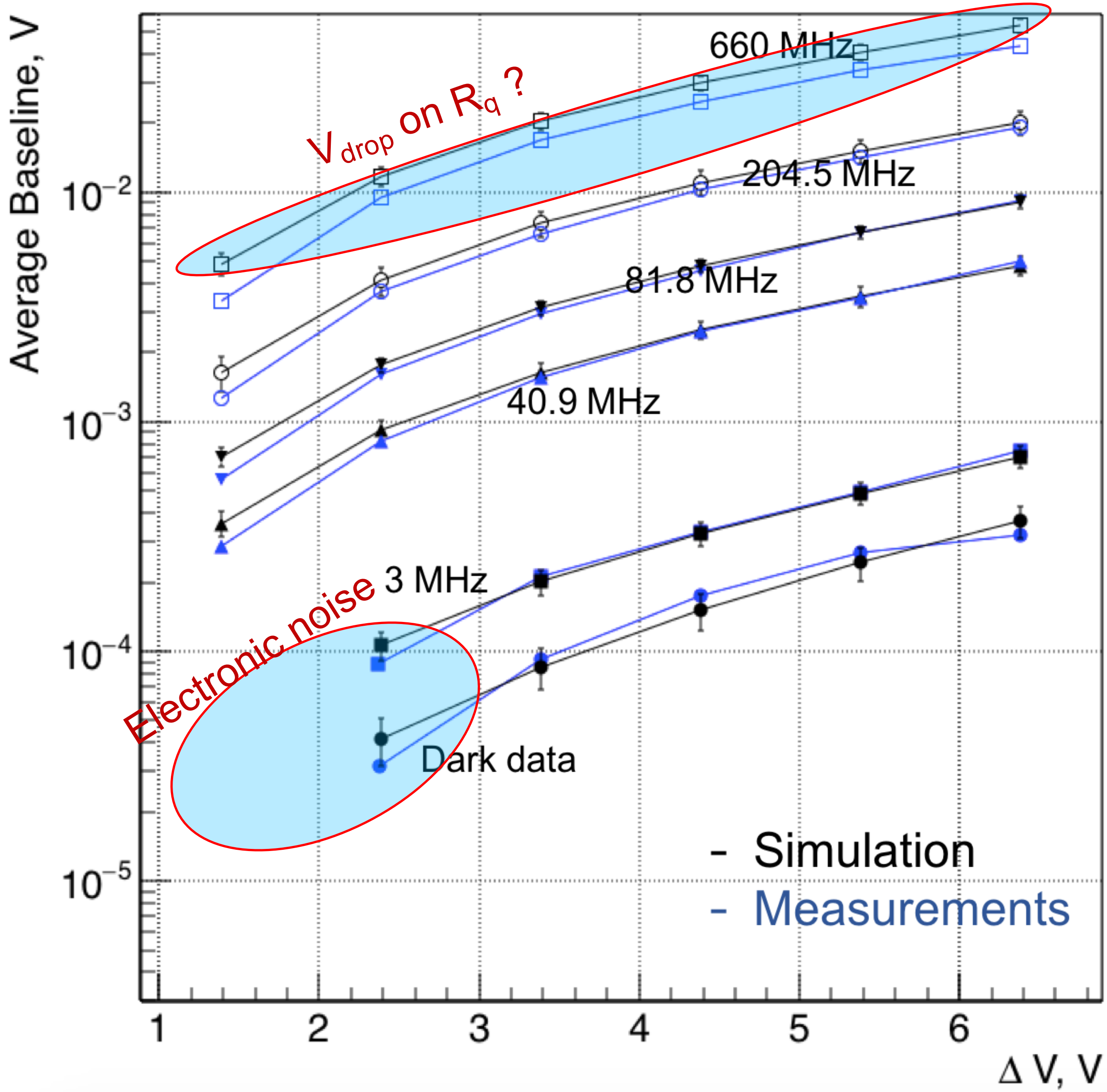

Conclusions & Outlook:

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Hex. Hamamatsu S10943-2832(X) was characterized:

- Gain, Amplitude, PDE, DCR, PXT;

Toy Monte Carlo was developed:

- Waveforms (baseline) vs. Continuous light illumination;
- SiPM parameters vs. Continuous light illumination:
  - Current, Gain, Amplitude, PDE, DCR, P_{XT}

Validation of Toy Monte Carlo:

- Done for Hex. Hamamatsu S10943-2832(X)

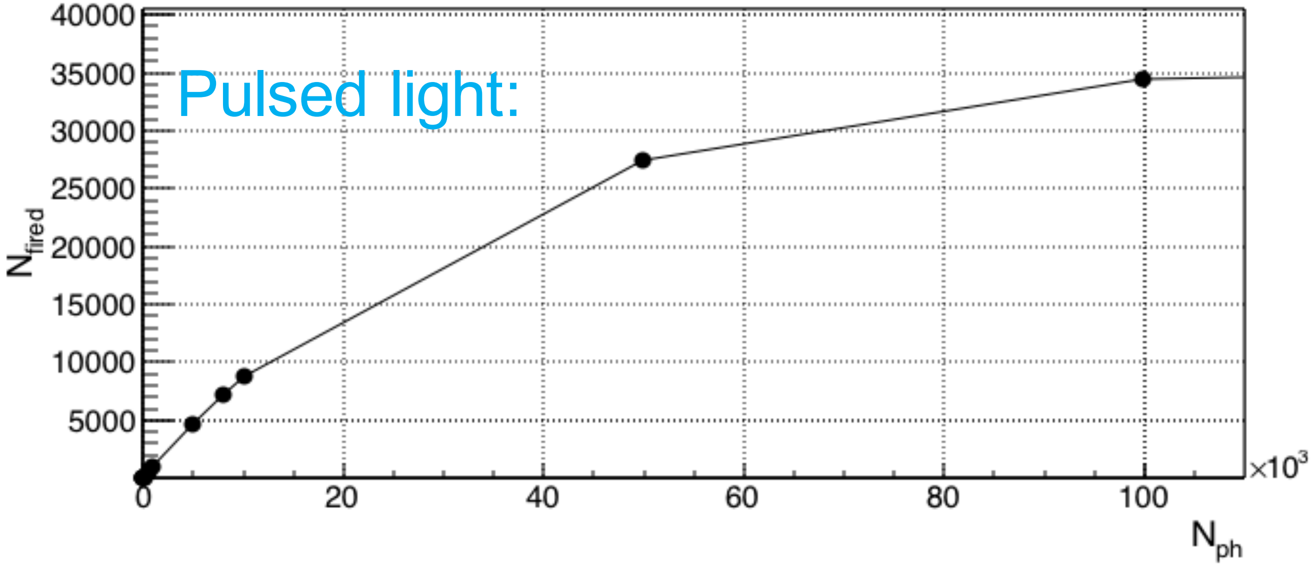
Next Steps:

- Develop and test compensation loop for V_{drop}
- Test simulation of another small SiPM

SENSE

Additional slides

SiPM saturation: Calculation



$$N_{fired} = N_{cell}(1 - e^{-\varepsilon N_{ph}/N_{cell}}) = N_{cell}(1 - e^{-N_{pe}/N_{cell}})$$