Gain measurements of the latest IMB-CNM fabricated nLGAD detectors

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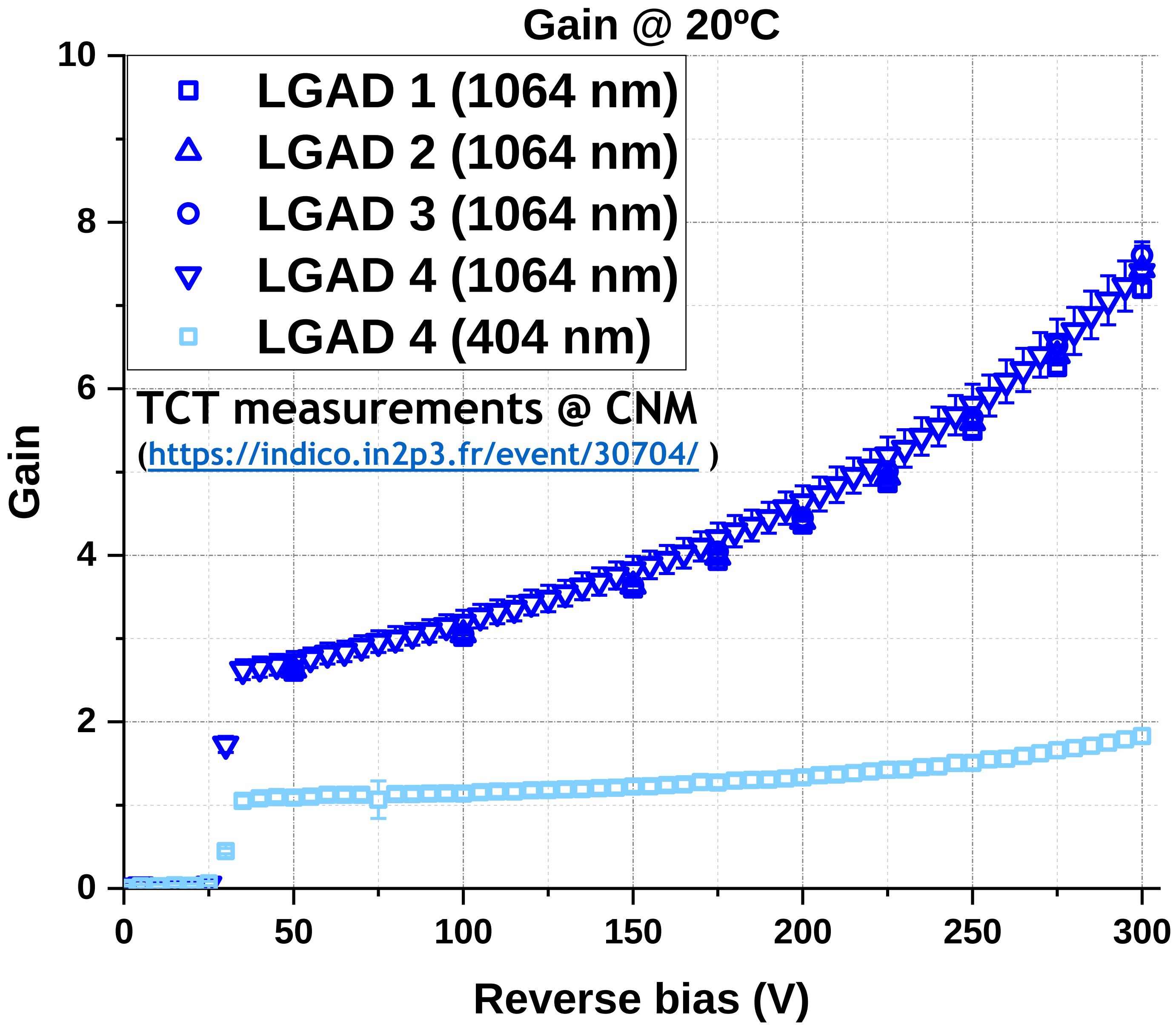
Outline

- Motivation
  - ➢ LGAD gain response to high and low-penetrating particles
  - ➢ nLGAD concept
- First CNM nLGAD engineering run : CNM-nLG1-v1
- Second CNM nLGAD engineering run : CNM-nLG1-v2
  - ➢ TCT Gain response to UV, visible and IR light
  - ➢ Road ahead

Motivation : LGAD Gain for low penetrating particles



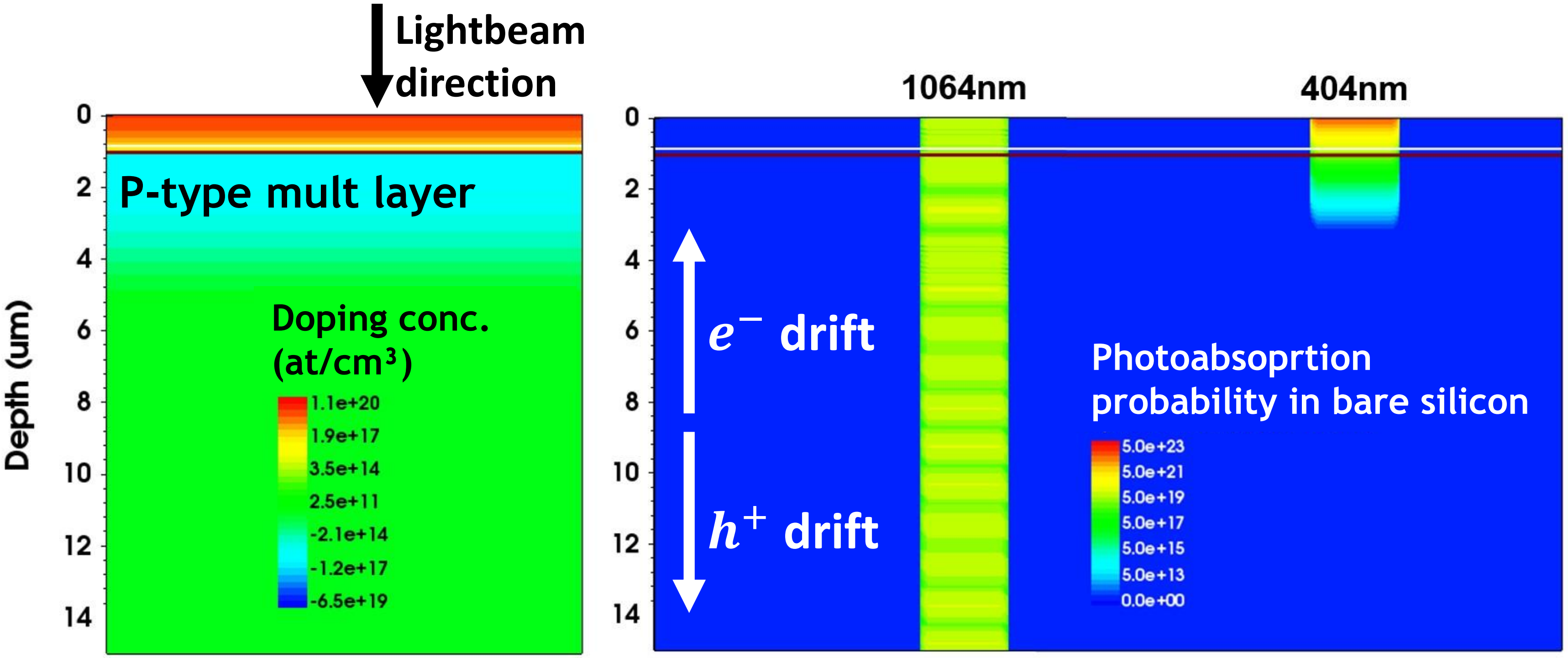
- For low penetrating particles, an LGAD (**thickness = 50 µm**) gain response is reduced if compared to a high penetrating particle.

- Penetration depth (inverse of attenuation coefficient) in silicon:
  - **404 nm (blue) → $\approx 0.1\ \mu m < 50\ \mu m$**
  - **1064 nm (IR) → $\approx 1000\ \mu m > 50\ \mu m$**

- Can we build up an **LGAD more sensitive to low penetrating particles**, such as soft X-rays and low energy protons?

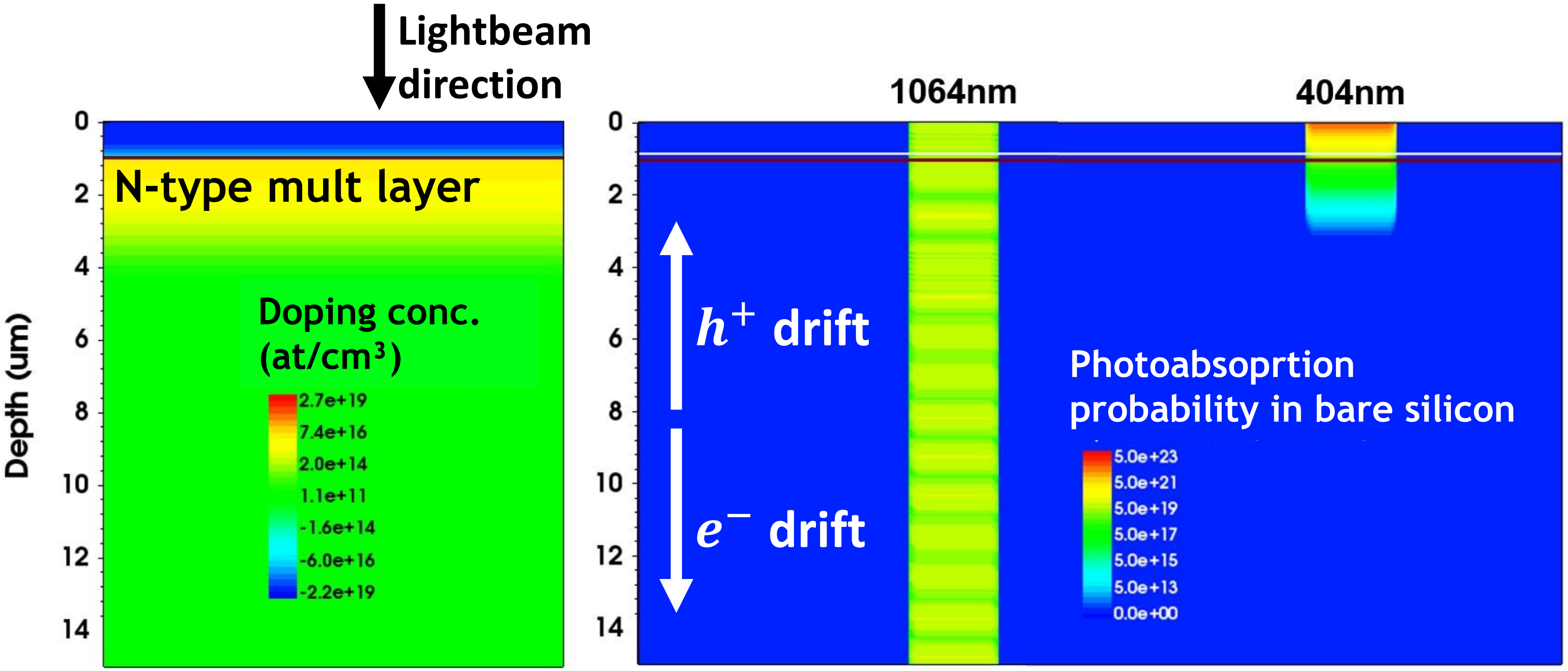
Motivation : Avalanche mechanism for electrons and holes

- **Impact ionization rate is higher for electrons than for holes** (https://doi.org/10.1016/0038-1101(70)90139-5)
- In a traditional LGAD, a high-penetrating particle (e.g. 1064 nm light) has a higher gain response than a low-penetrating particle (e.g. 404 nm light) due to the **direction of the carriers drift** : e^- are the major contributor to trigger the avalanche mechanism for 1064 nm IR light, while h^+ are for 404 nm light, so **Gain (1064 nm) > Gain (404 nm)**

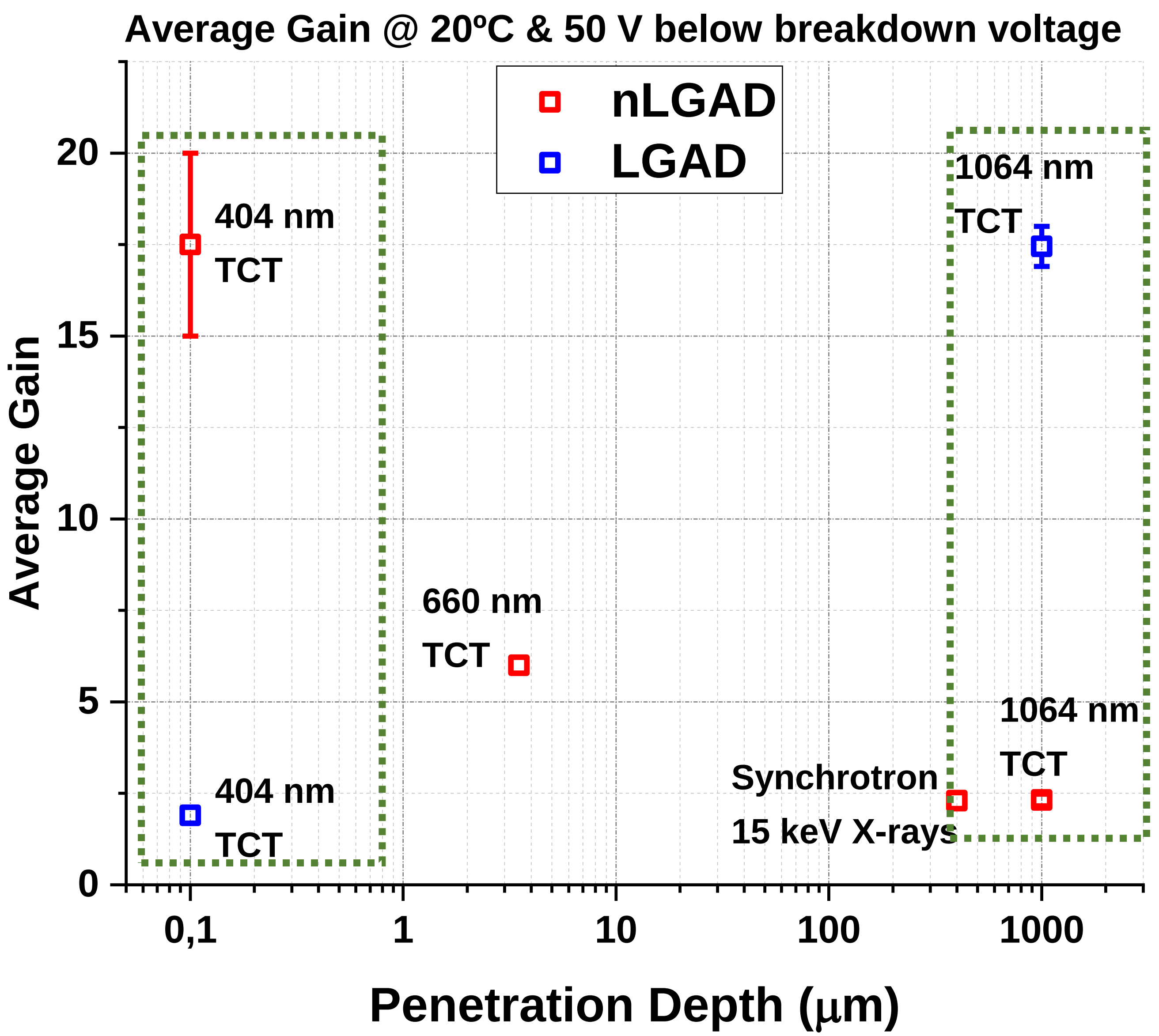


Motivation : Avalanche mechanism for electrons and holes

- **Impact ionization rate is higher for electrons than for holes**
- By **exchanging the conductivity type** of all layers in an LGAD (electrodes, mult layer and bulk), we obtain an **nLGAD** and the situation is reversed : h^+ are the major contributor to trigger the avalanche mechanism for 1064 nm IR light, while e^- are for 404 nm light, so **Gain (1064 nm) < Gain (404 nm)**



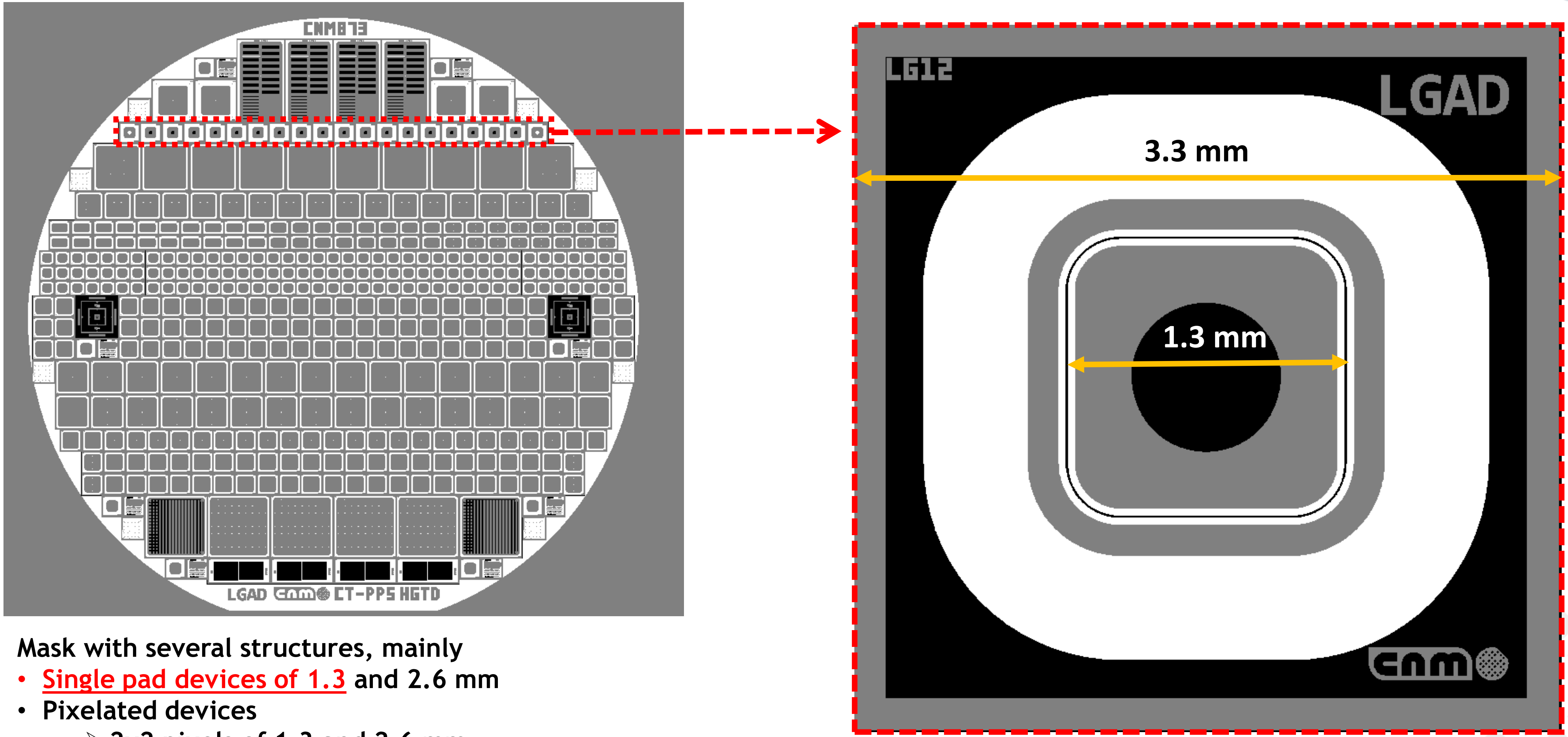
First nLGAD engineering run at CNM : CNM-nLG1-v1



- Mask containing only single-pad diodes of 275 μm thickness
- **Gain measurements of the first prototypes showed the potential of nLGADs** for low penetrating particle detection (soft x-rays, low energy protons, etc)

- **Plot results and analysis were reported in https://doi.org/10.1016/j.nima.2023.168377**
- **Penetration depth data :**
  - https://www.nist.gov/pml/x-ray-mass-attenuation-coefficients (NIST)
  - https://doi.org/10.1002/pip.4670030303

Second CNM nLGAD Fabrication Run : CNM-nLG1-v2

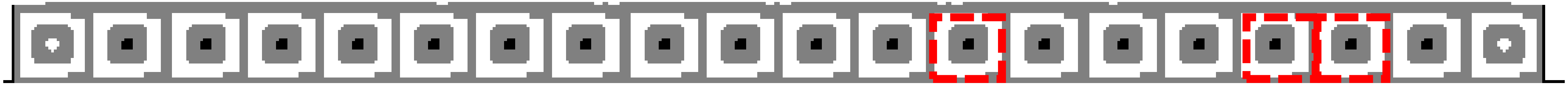


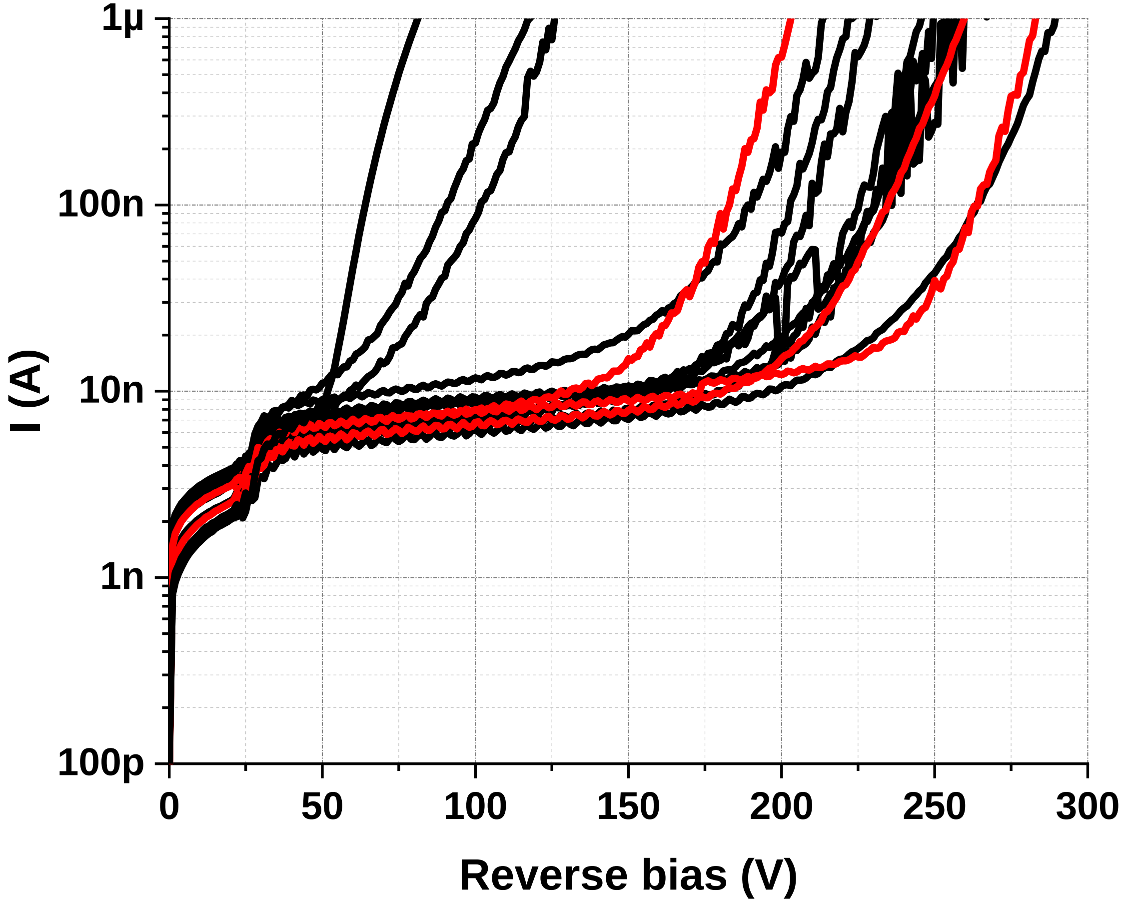
Mask with several structures, mainly
- Single pad devices of 1.3 and 2.6 mm
- Pixelated devices
  - 2x2 pixels of 1.3 and 2.6 mm
  - 1x2 pixels of 1.3 mm
  - 8x8 pixels of 1.3 mm

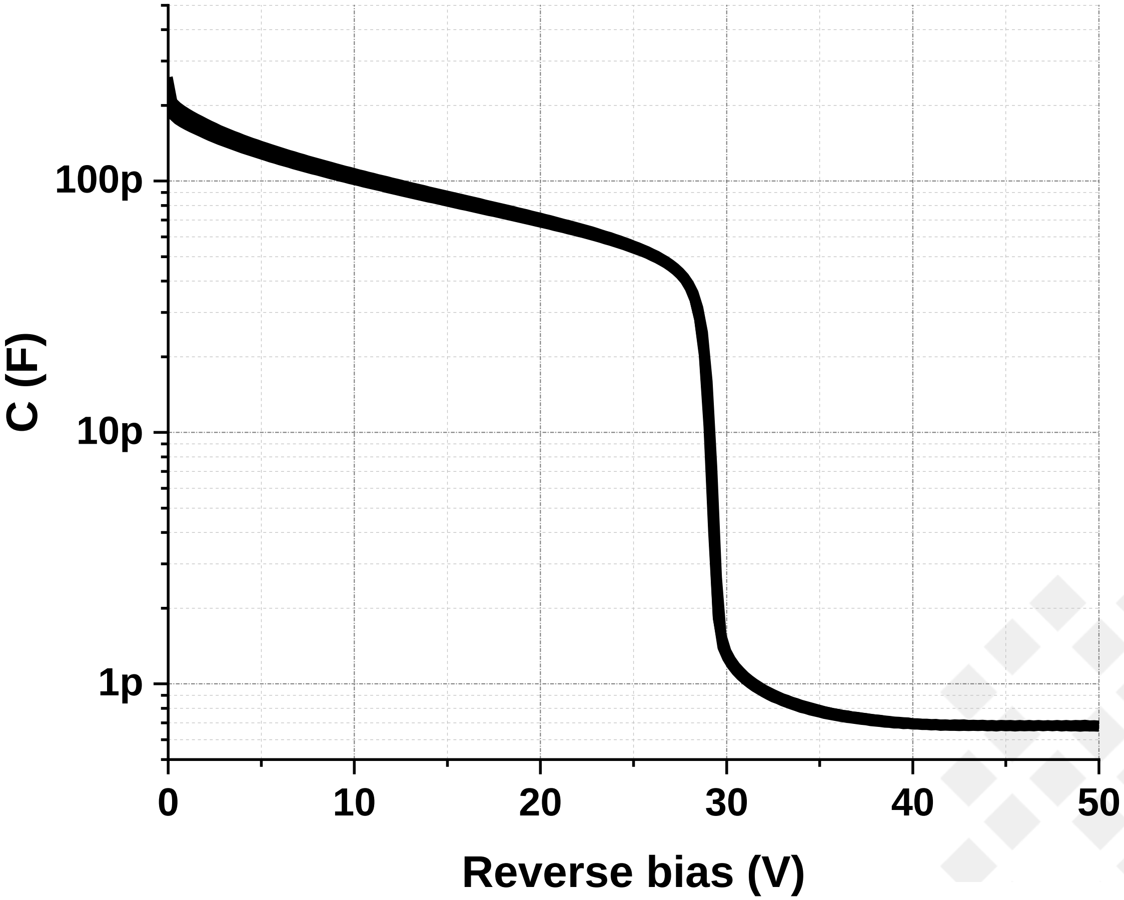
275 µm thickness

CNM nLGAD Run nLG1-v2 : IV & CV of single-pad diodes of 1.3 mm

Single-pad diodes are being tested via TCT with UV light (369 nm), visible light (404 nm) and IR light (1064 nm)



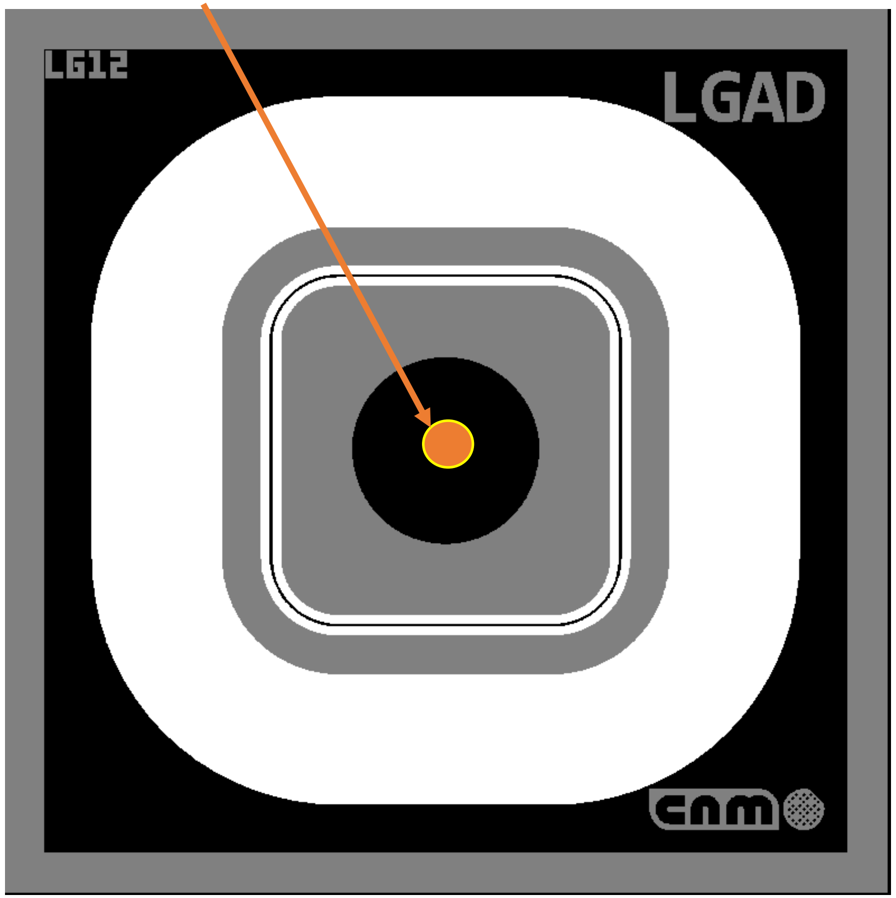




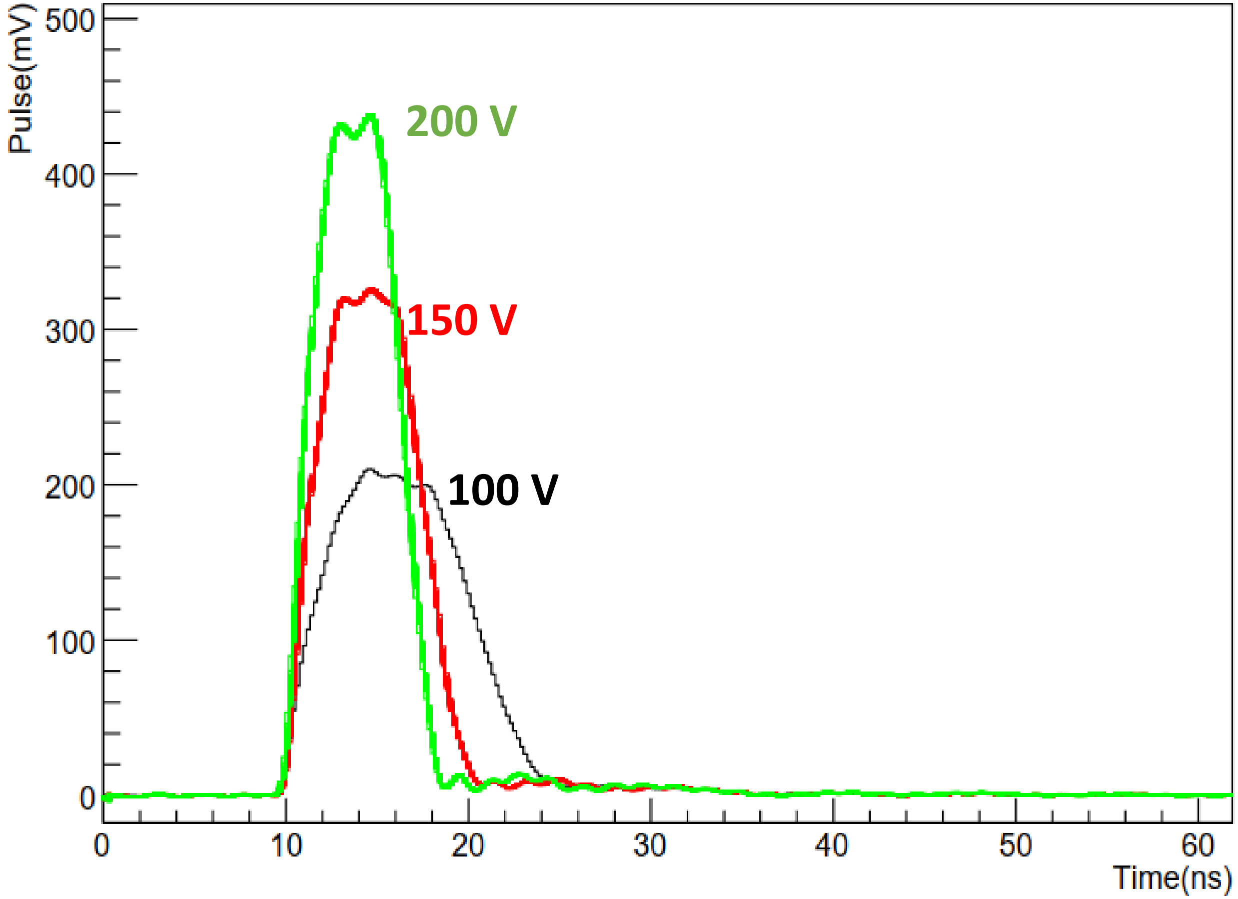
CNM nLGAD Run nLG1-v2 : Method to extract the gain

TCT 404 nm light, Max intensity, 1kHz, 20ºC → Voltage Scans in the center @ 20ºC

Projection of beam on entrance window :
$\approx 60\ x\ 60\ \mu m^2 < 700\ \mu m^2$ (window size)



10000 averaged waveforms per voltage point



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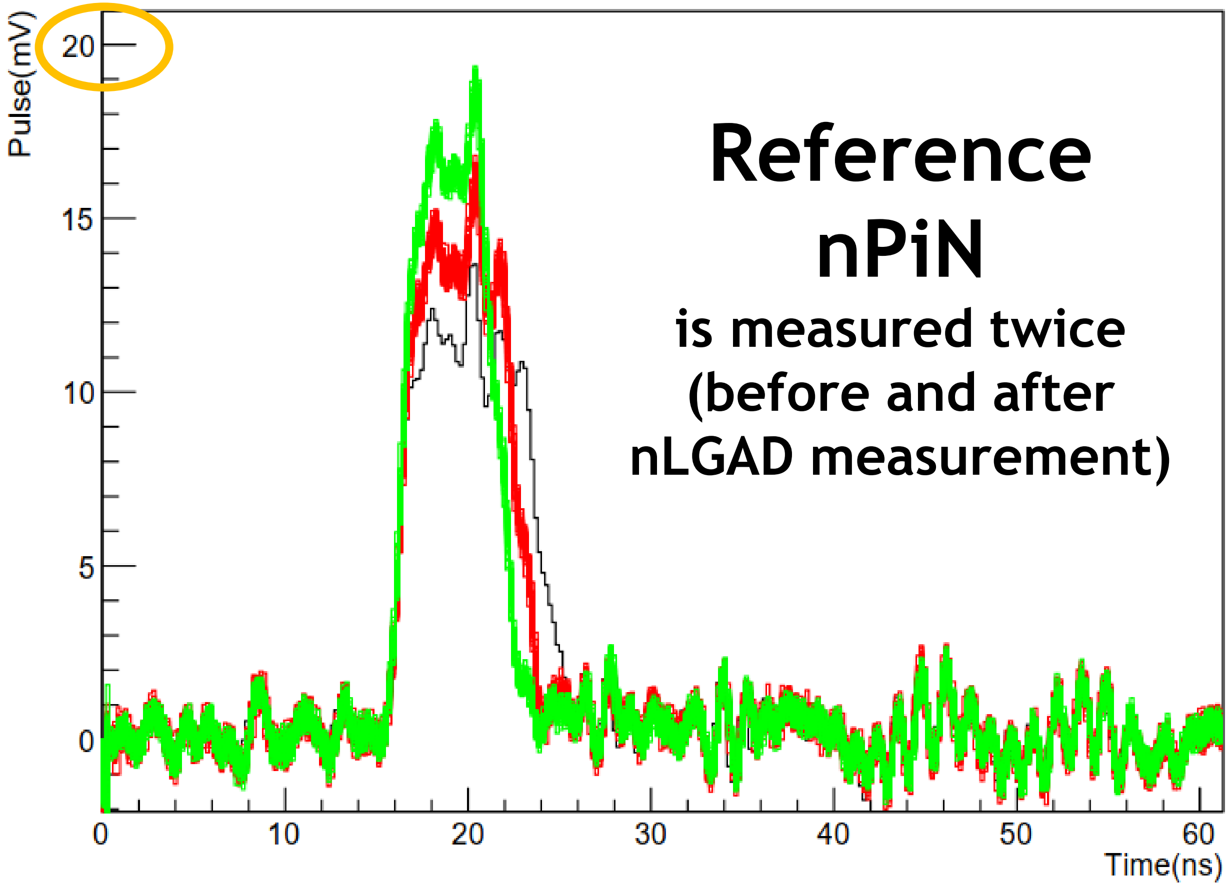

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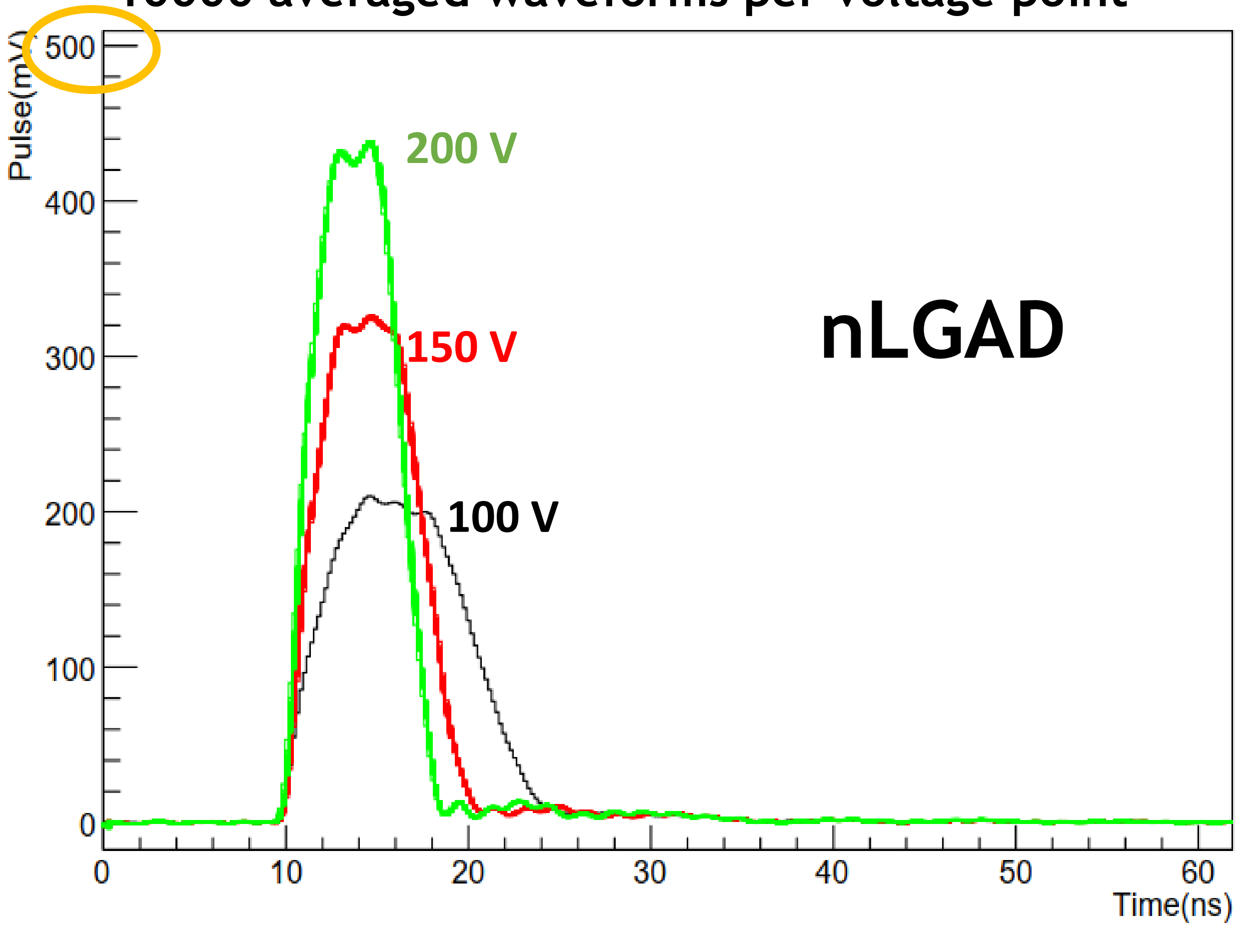
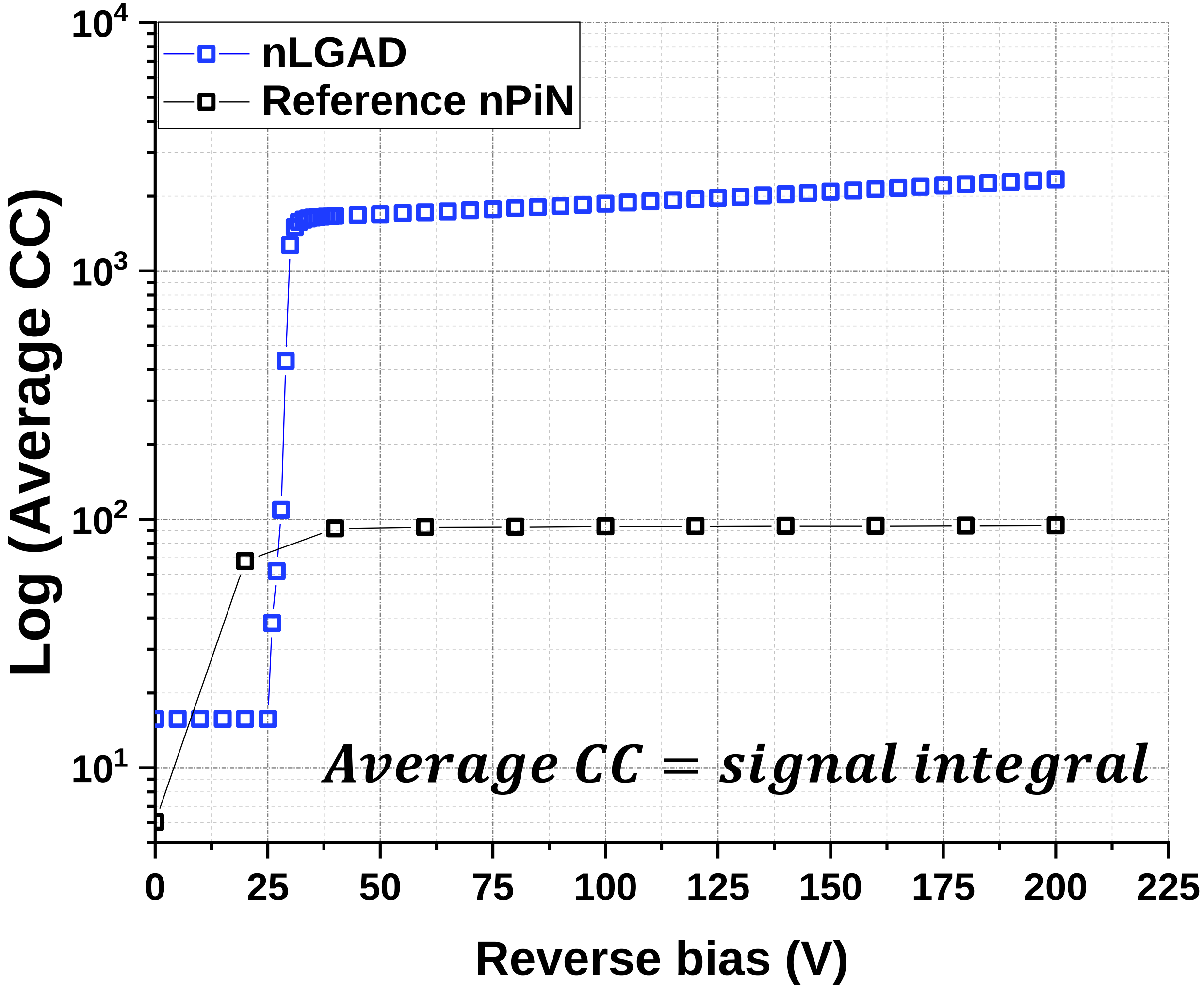
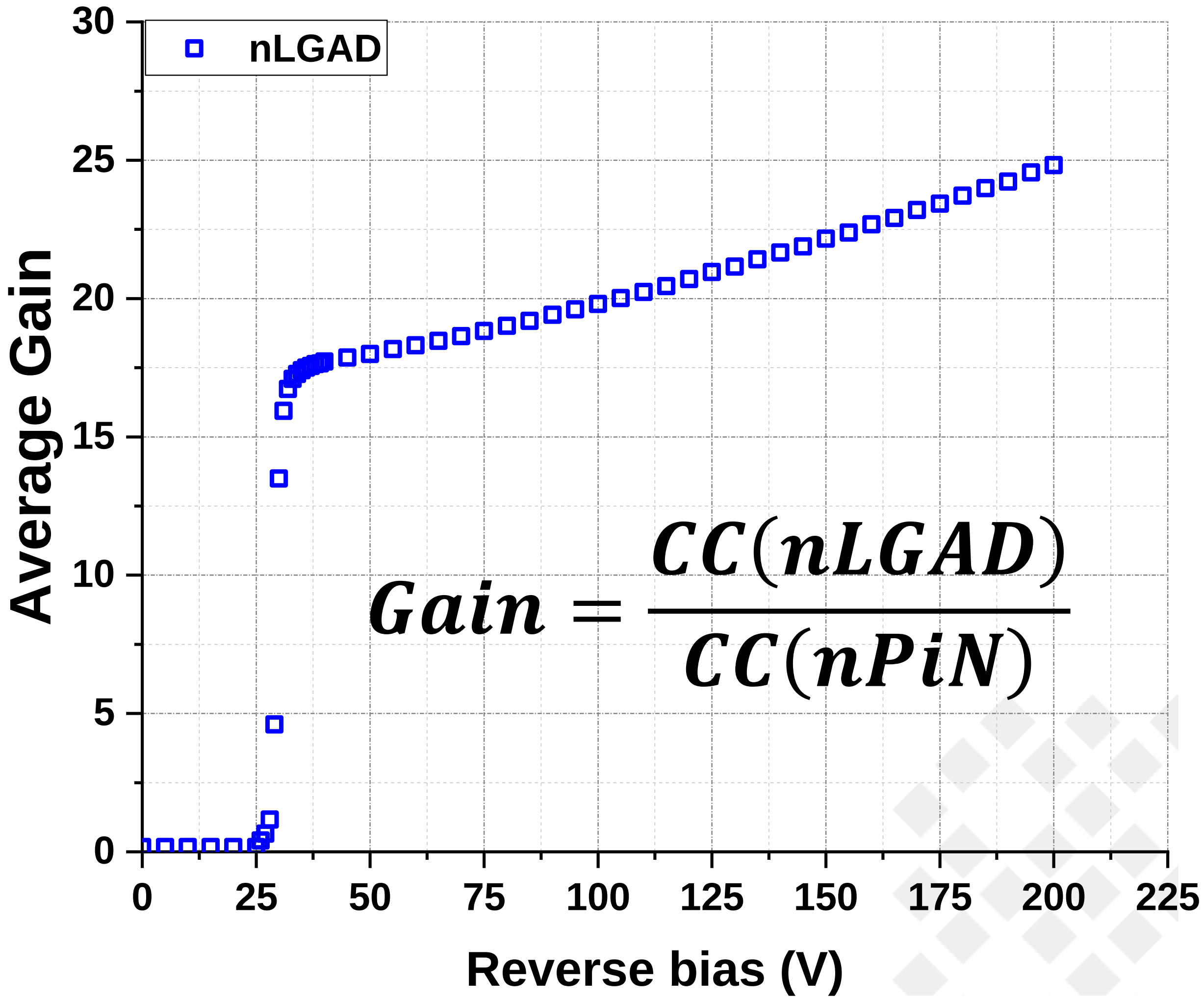


CNM nLGAD Run nLG1-v2 : Method to extract the gain

TCT 404 nm light, Max intensity, 1kHz, 20ºC → Voltage Scans in the center @ 20ºC



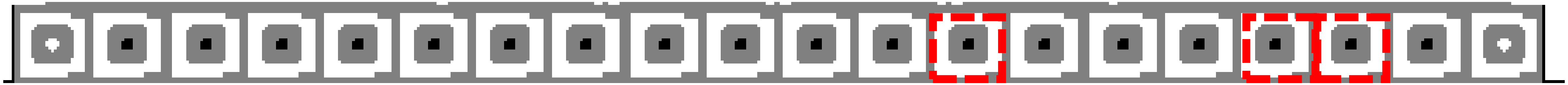
$$Average\ CC = signal\ integral$$

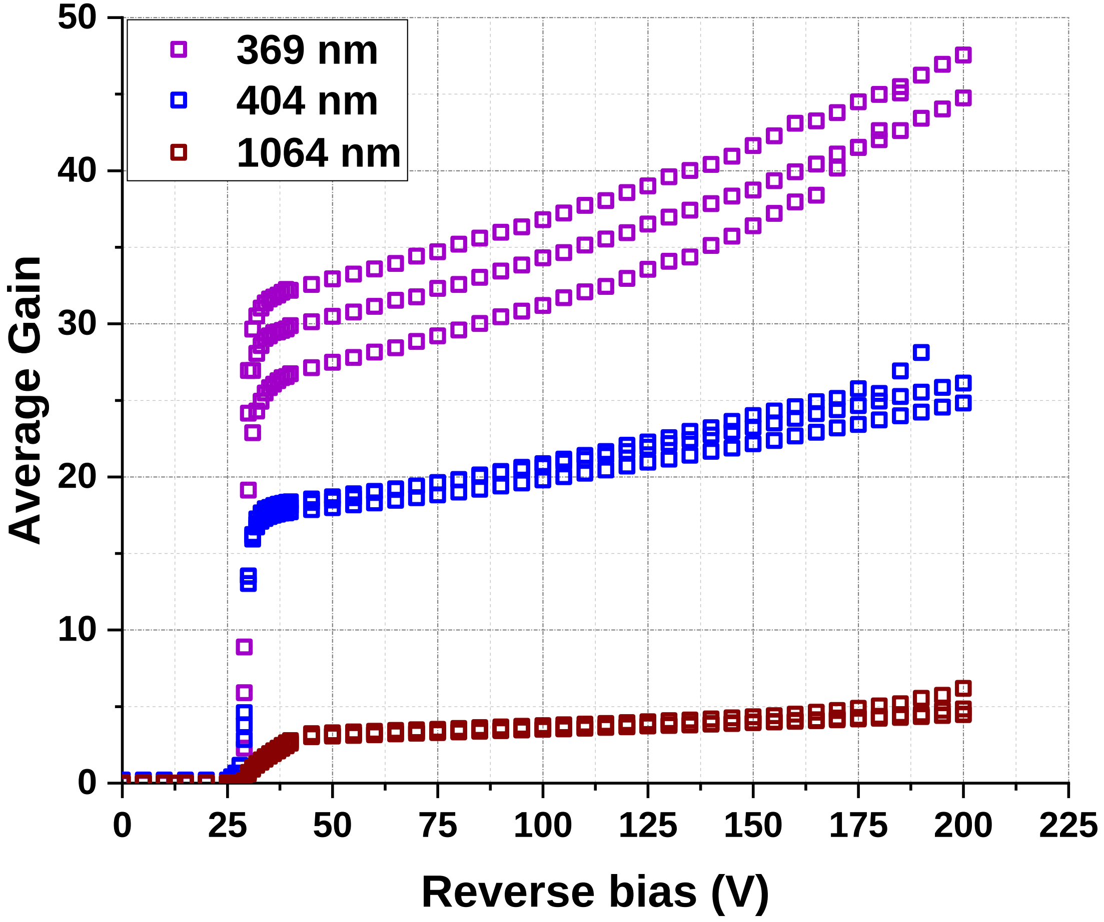


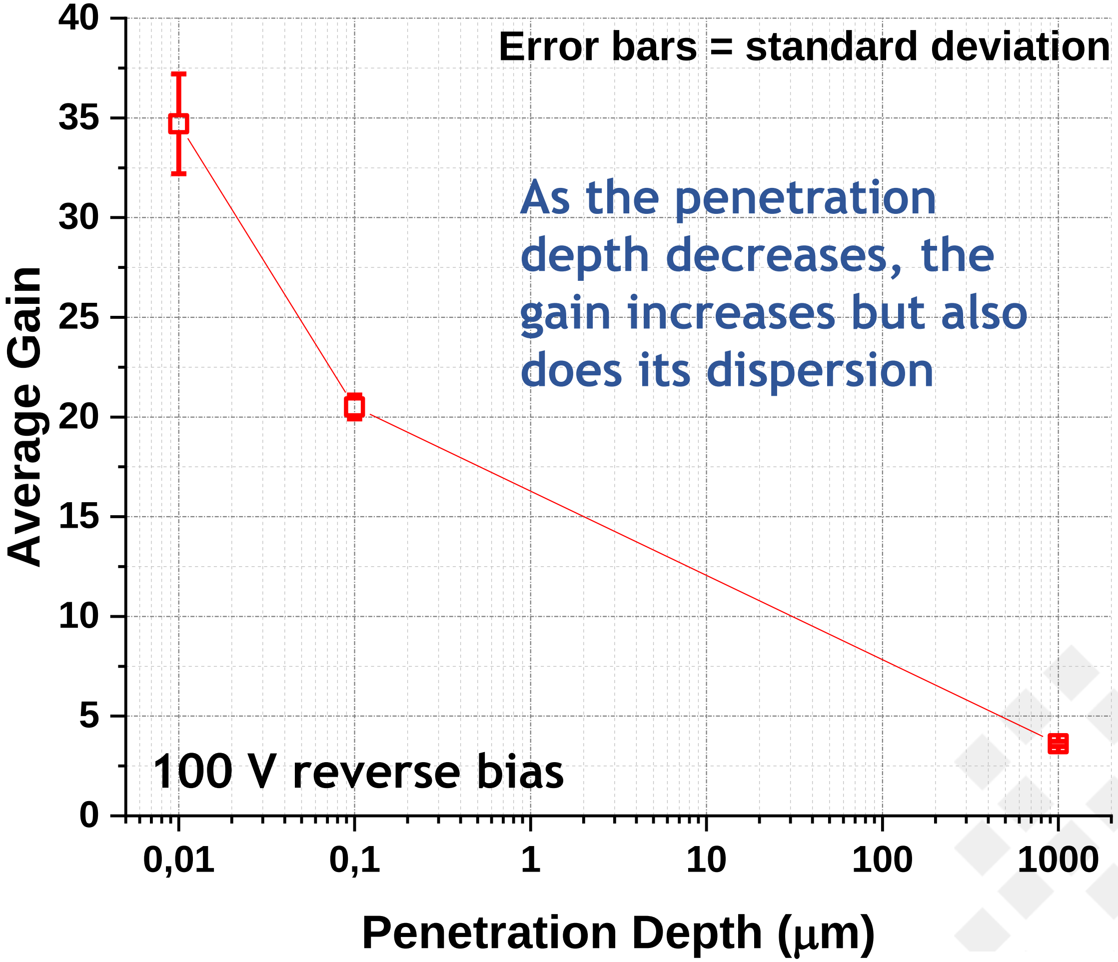
$$Gain = \frac{CC(nLGAD)}{CC(nPiN)}$$

CNM nLGAD Run nLG1-v2 : Method to extract the gain

TCT measurements with UV light (369 nm), visible light (404 nm) and IR light (1064 nm), Max intensity, 1kHz & 20ºC

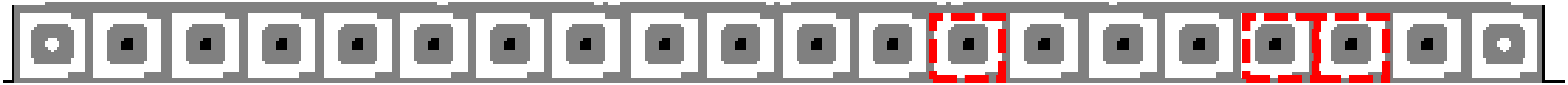


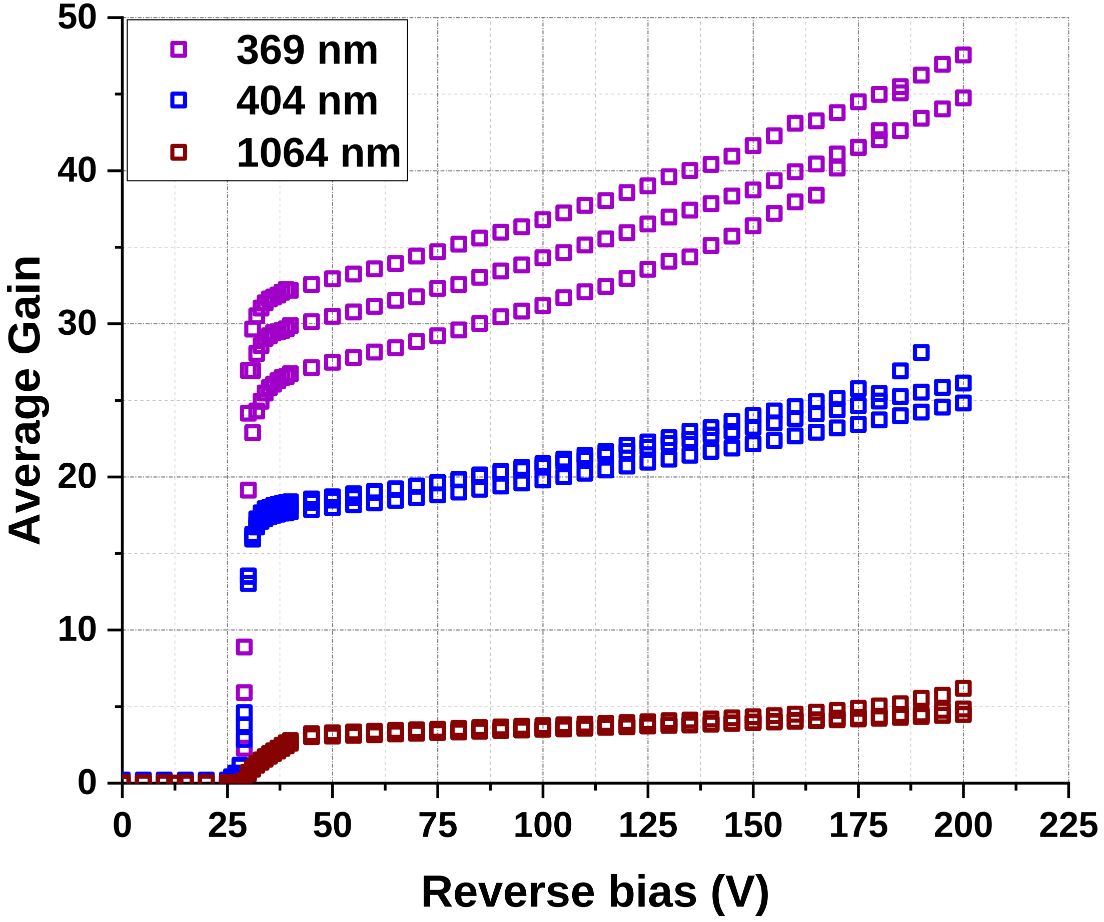




Road ahead

TCT measurements with UV light (369 nm), visible light (404 nm) and IR light (1064 nm), Max intensity, 1kHz & 20ºC





- Test all single-pad devices with an opening window (study of gain uniformity)
- TCT measurements sweeping intensity
- TPA measurements ongoing at CERN
- TCT measurements with other wavelengths (red of 660 nm)
- Gain measurements with X-ray photons or low-energy proton ions

Acknowledgments

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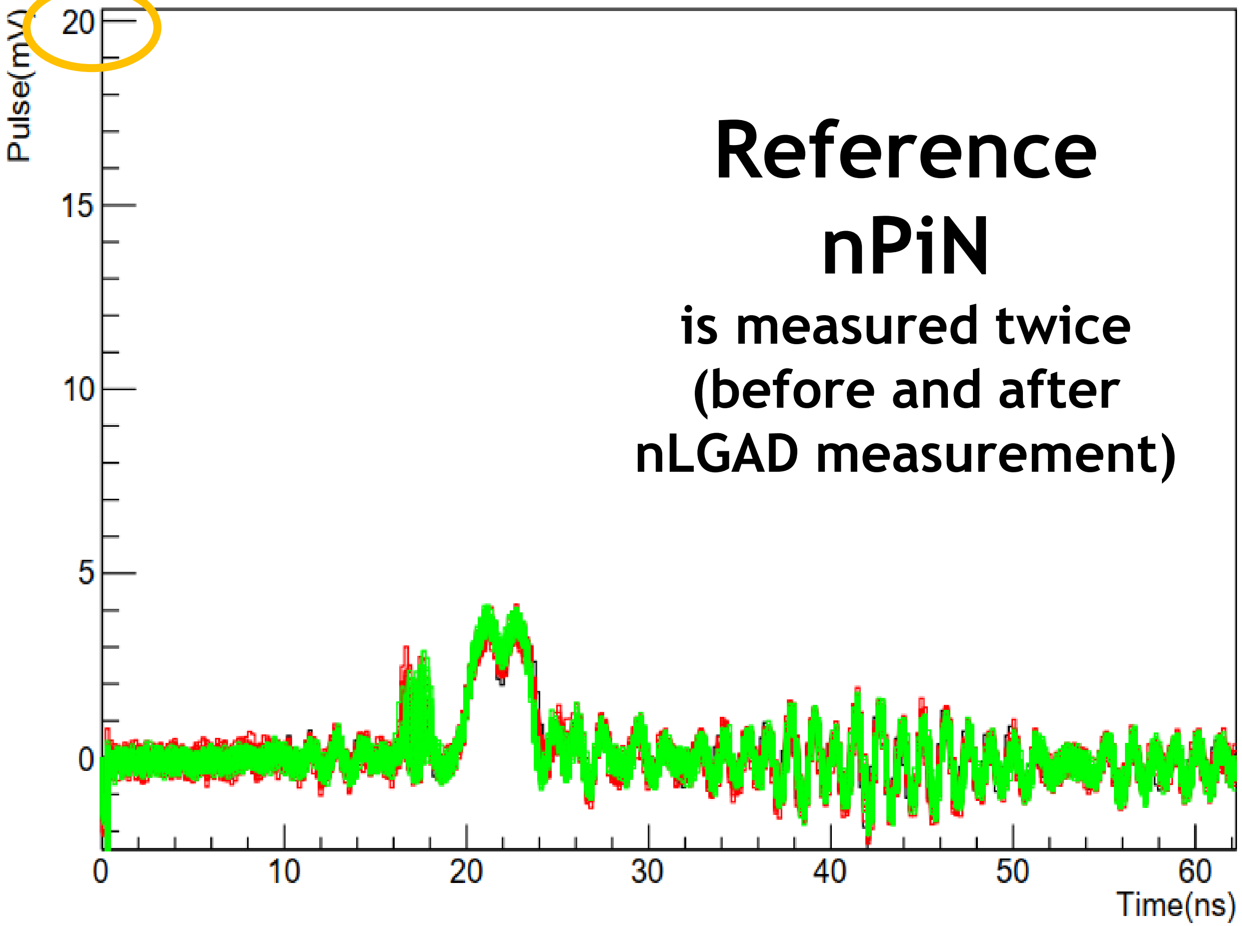
Thanks for your attention!

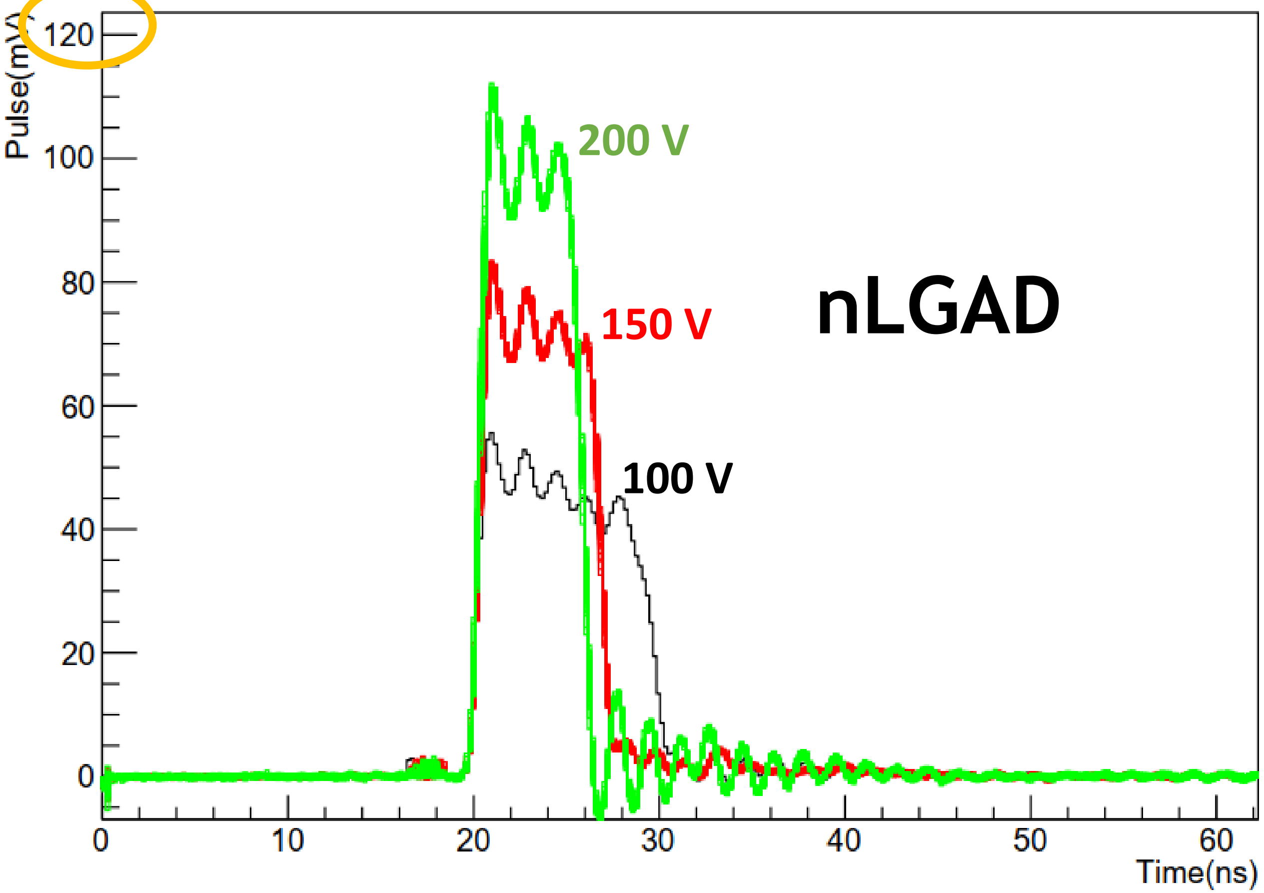
Back-up slides

TCT 369 nm light, Max intensity, 1kHz, 20°C → Voltage Scans in the center @ 20°C

20000 averaged waveforms per voltage point

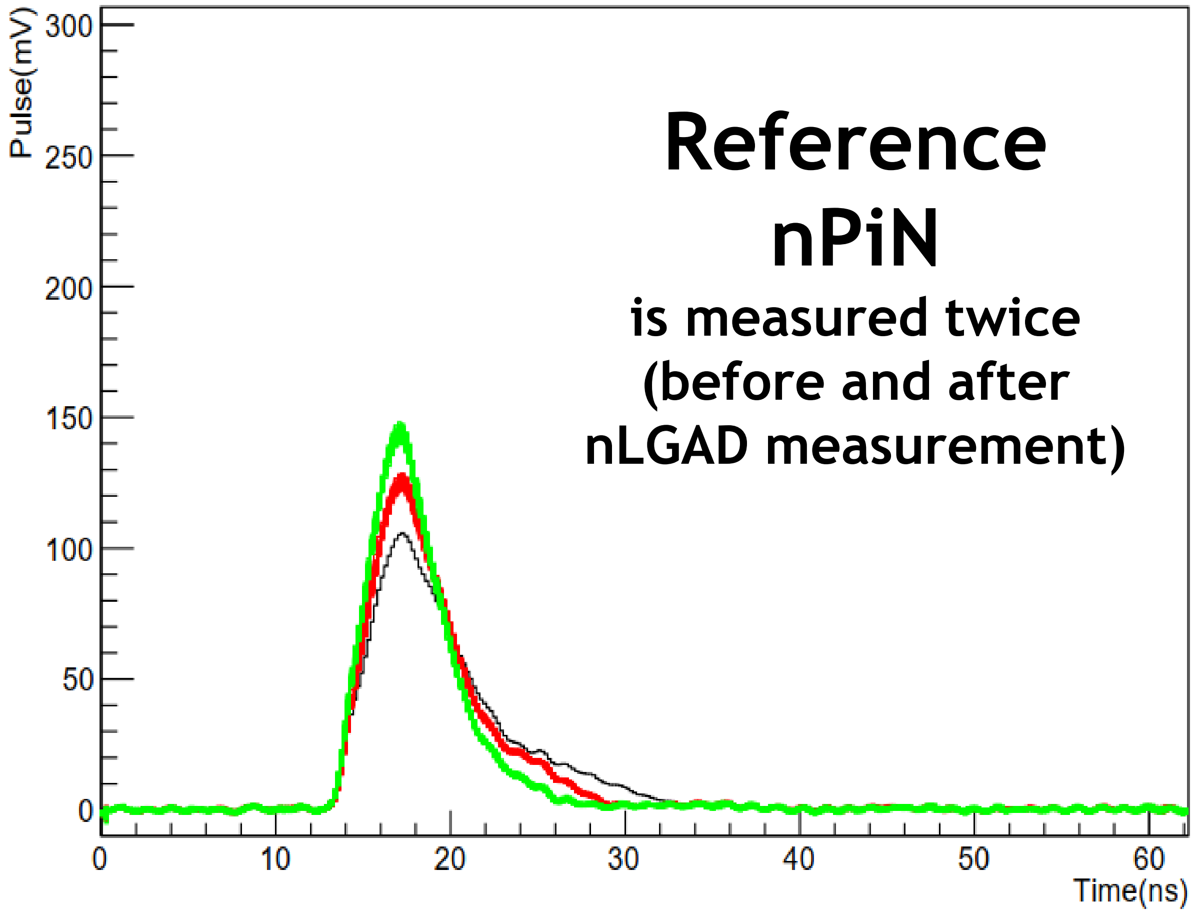


10000 averaged waveforms per voltage point

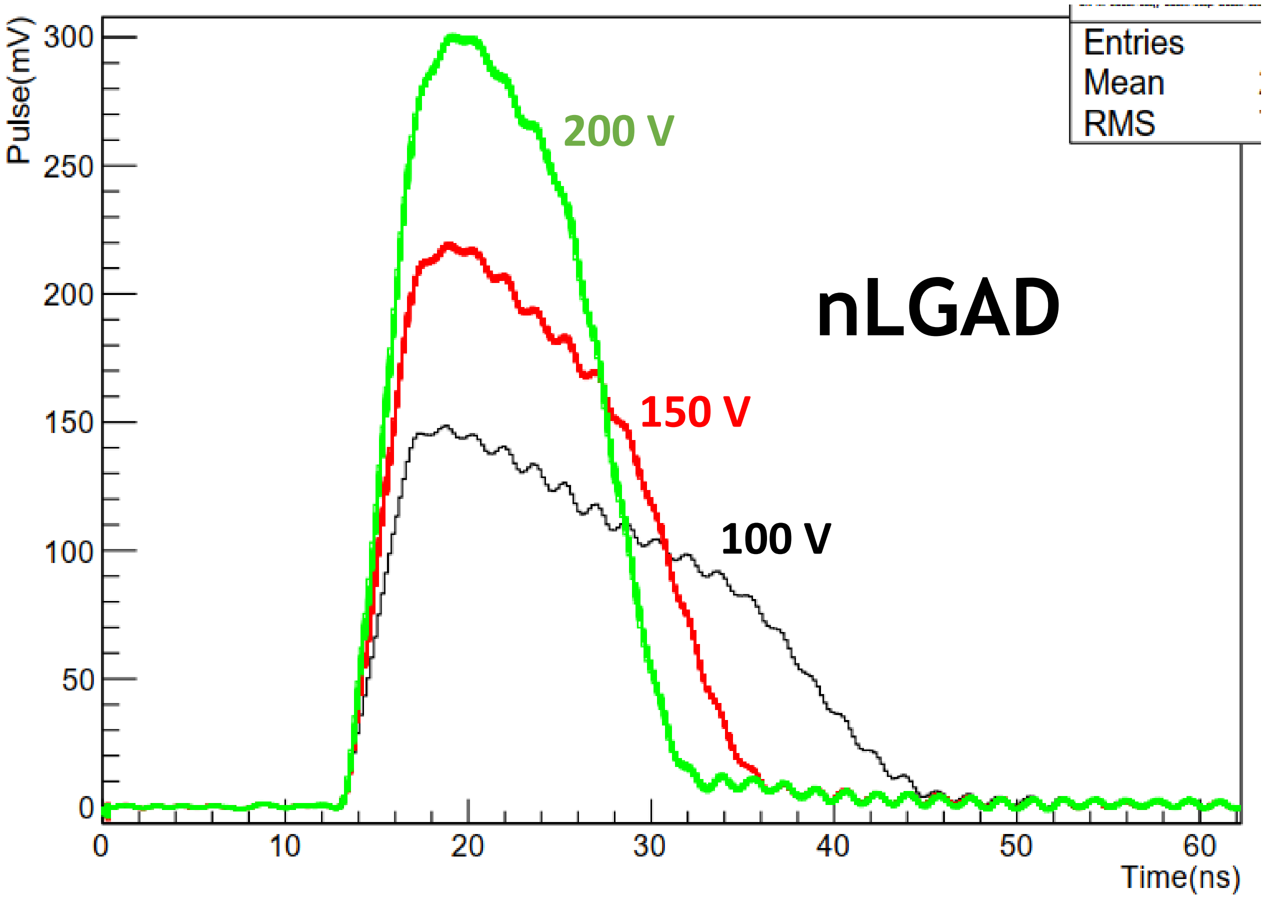


TCT 1064 nm light, Max intensity, 1kHz, 20°C → Voltage Scans in the center @ 20°C

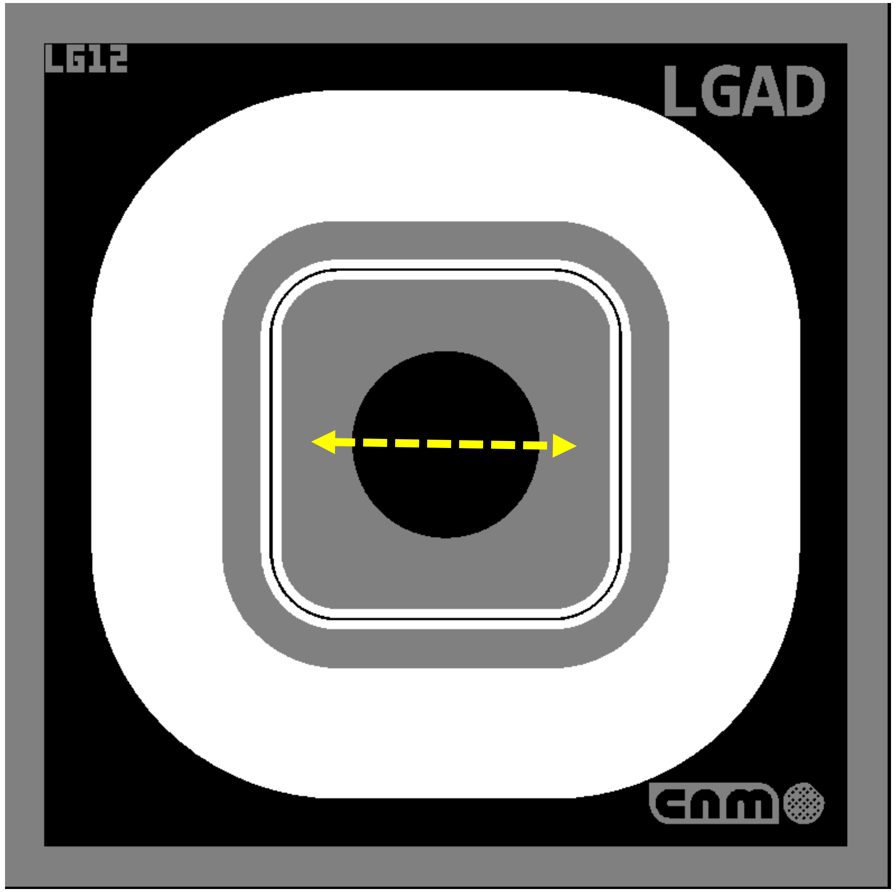
10000 averaged waveforms per voltage point



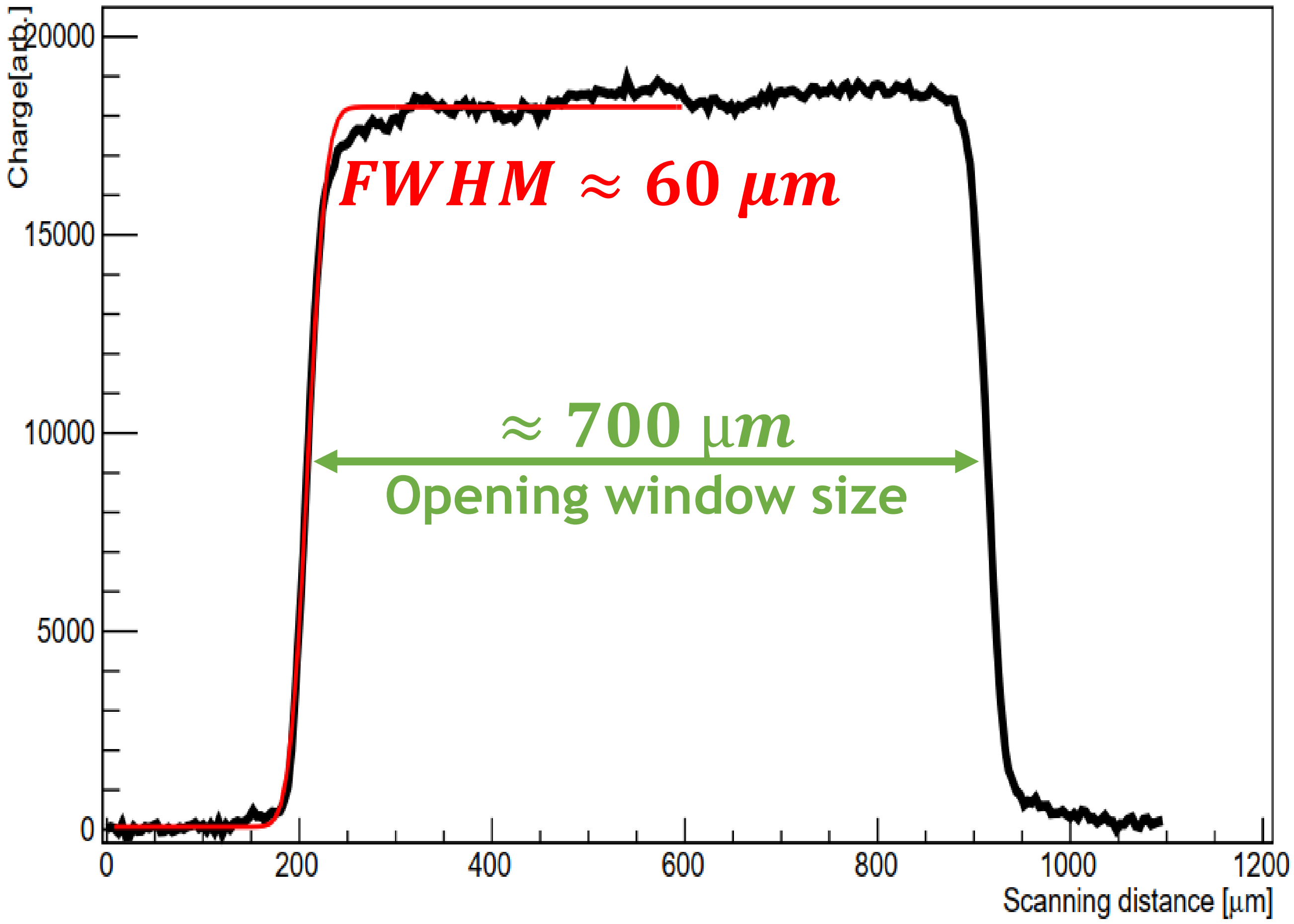
10000 averaged waveforms per voltage point



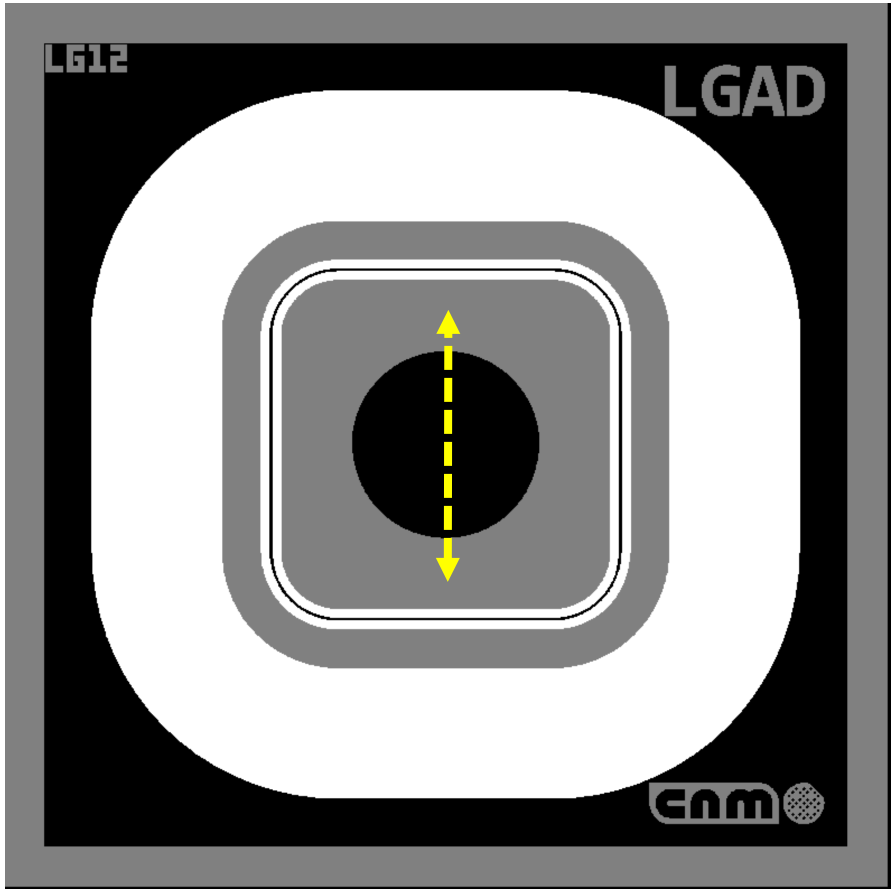
TCT 404 nm light, Max intensity, 1kHz, 20°C → Line Scans @ 100 V @ 20°C



CC (Integrated signal) vs position



TCT 404 nm light, Max intensity, 1kHz, 20°C → Line Scans @ 100 V @ 20°C



CC (Integrated signal) vs position