RDG Radiation Detectors Group

Gain measurements and spectral response of the latest IMB-CNM fabricated nLGAD

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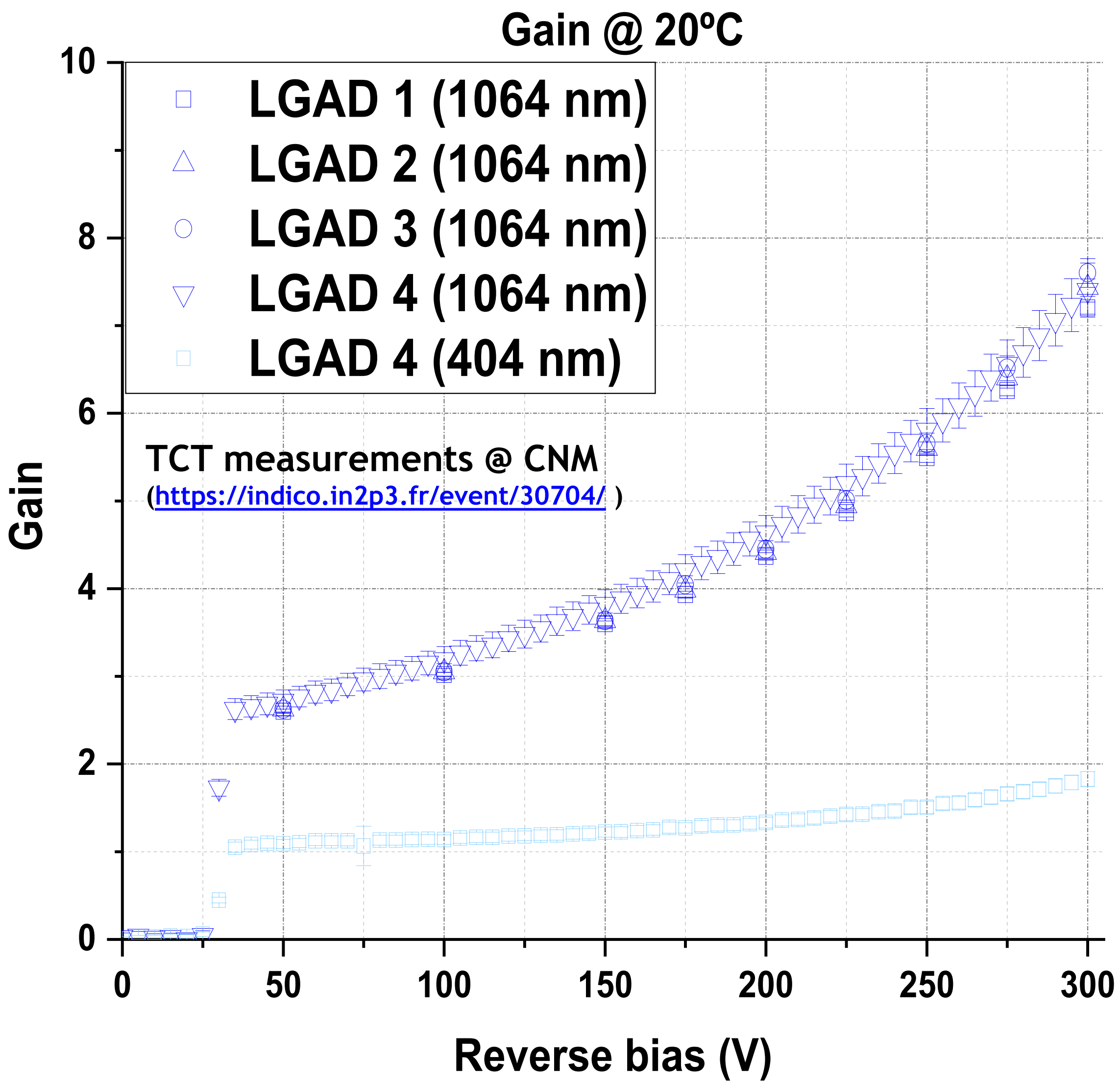
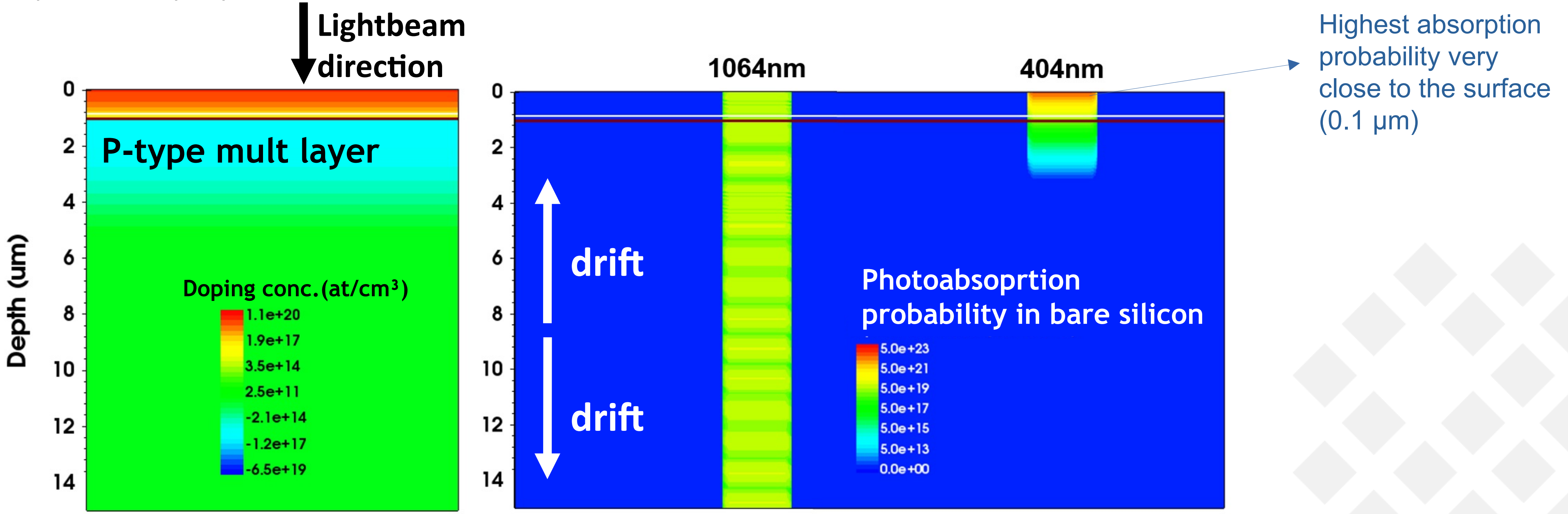
Motivation



- Typical LGADs (thickness = 50 μ) have a **lower gain response for low-penetrating** (LP) particles than for high-penetrating (HP) ones
- Although the charge generation mechanism differs, the effect is equally expected for photons and charged particles
- Photon detection: penetration depth (goes inversely with attenuation) in silicon:
  - 404 nm (blue) → ≈ 0.1 μm < 50 μm
  - 1064 nm (IR) → ≈ 1000 μm > 50 μm
- Can we build up an **LGAD more sensitive to low penetrating particles**, such as soft-X rays or low energy protons?

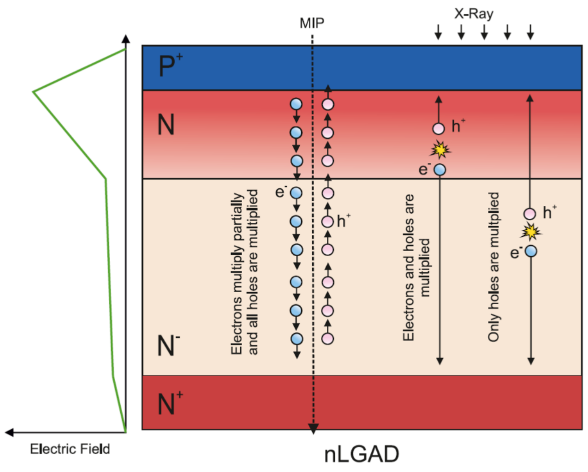
Motivation

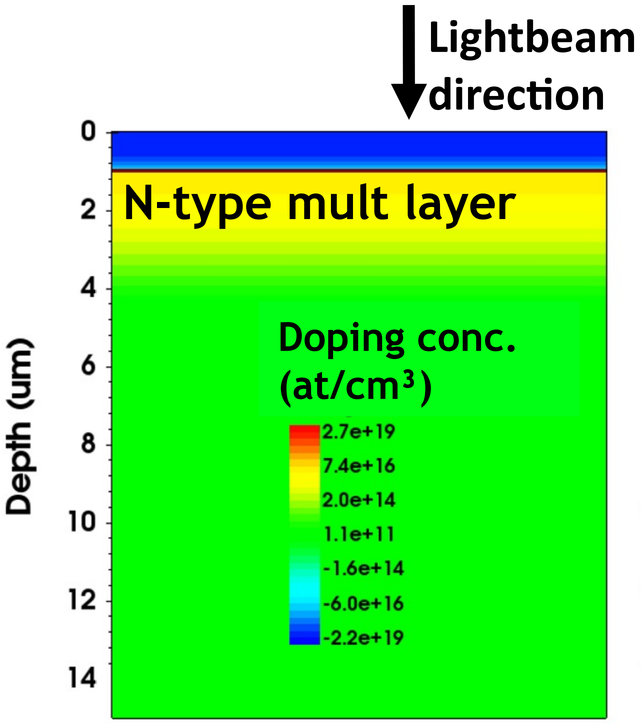
- Tradicional LGADs: different gain response for HP (e.g. 1064 nm photons) and LP (e.g. 404 nm photons) species: Who triggers the avalanche?
  - HP particles: **Avalanche mainly triggered by e^-** crossing the multiplication layer on their drift way.
  - LP particles: e-h pairs almost exclusively generated within the n-side of the junction. **Avalanche mainly triggered by h^+**
- Impact ionization rate is higher for electrons than for holes [https://doi.org/10.1016/0038-1101(70)90139-5]. Therefore: Gain (HP) > Gain (LP)

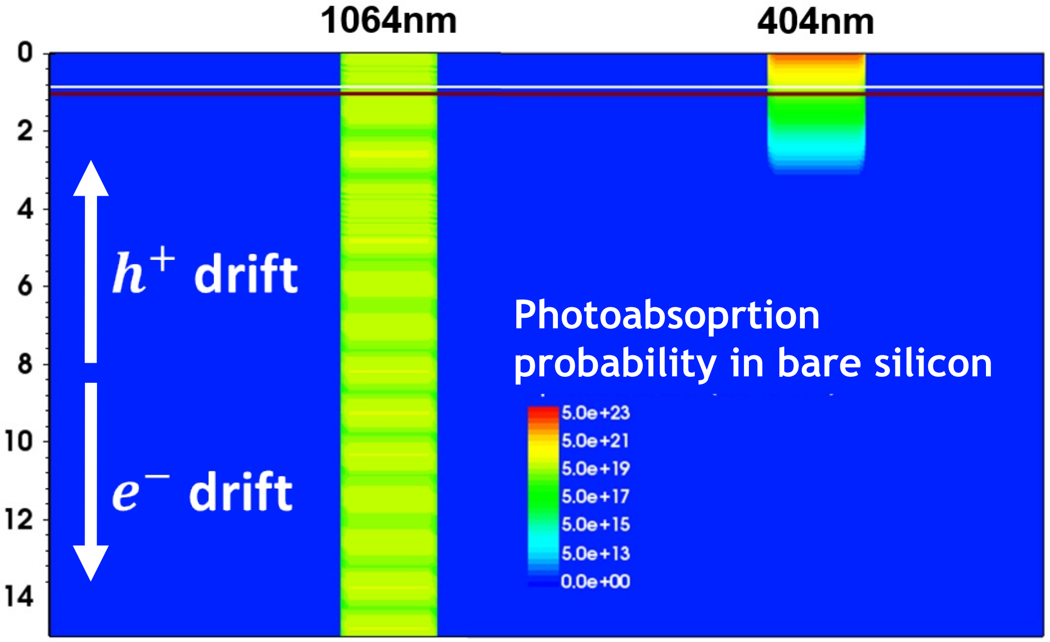


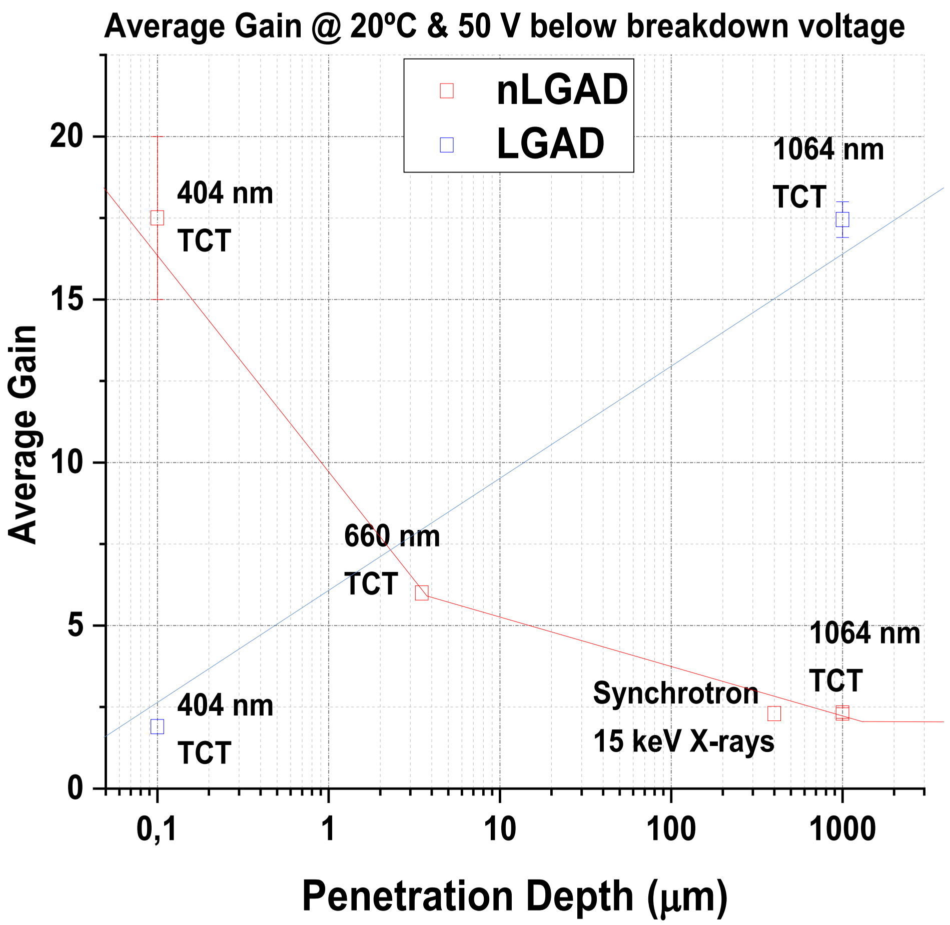
Motivation: nLGAD concept

- **nLGAD concept**: Inverting implantation polarity of all the layers, we get an electron-driven avalanche for LP species:
  - Gain LP > Gain HP







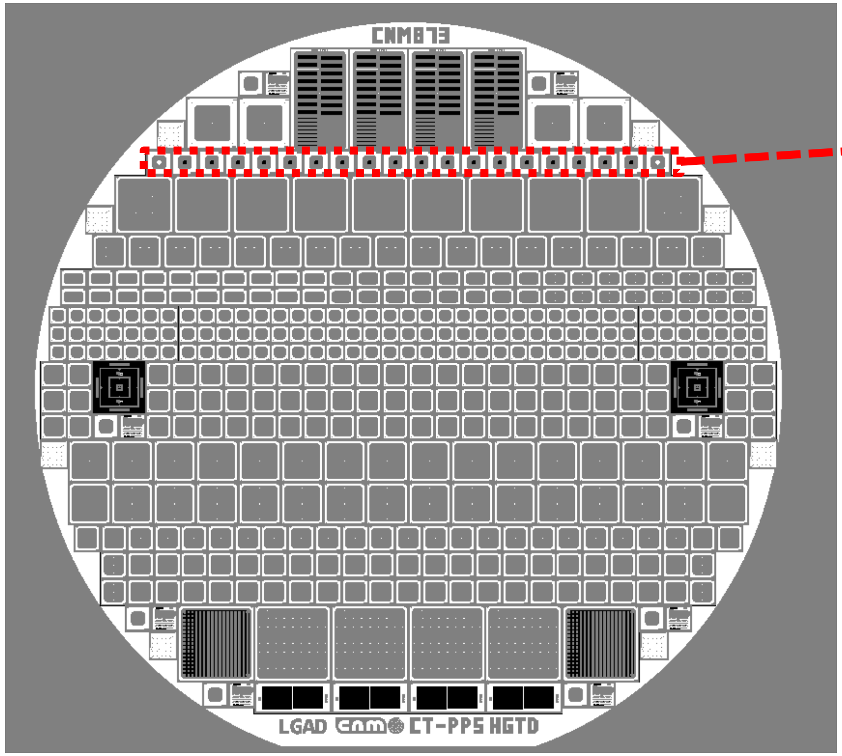


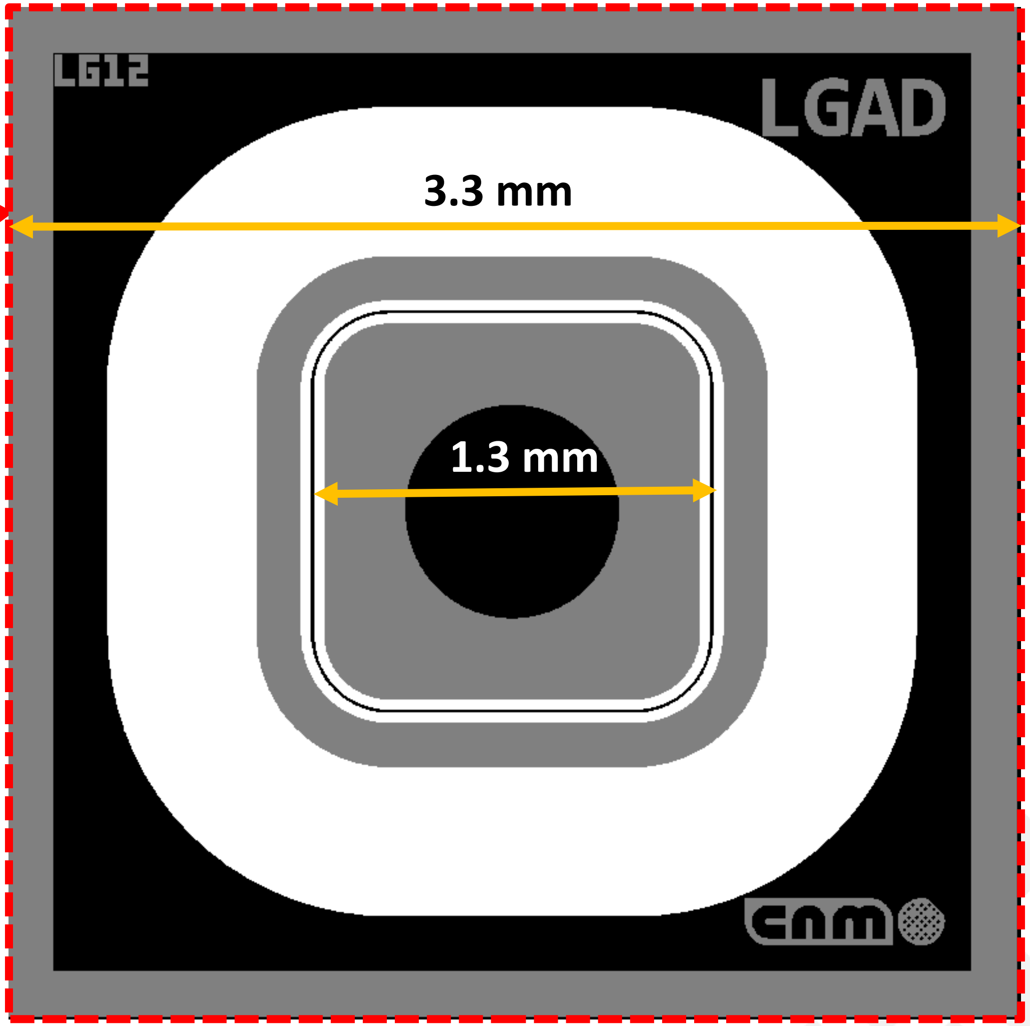
CNM-nLG1-v1

- Mask containing only single-pad diodes. 275 µm thick devices
- Gain measurements of the first prototypes showed the potential of nLGADs for LP particles detection
  - Plot and analysis 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

2nd Run: CNM-nLG1-v2

CNM-nLG1-v2





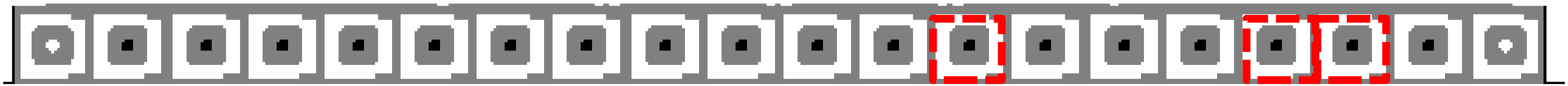
Adapted mask set with several structures, mainly:

- Single pad devices of 1.3 and 2.6 mm
- Pixelated devices (design issue)

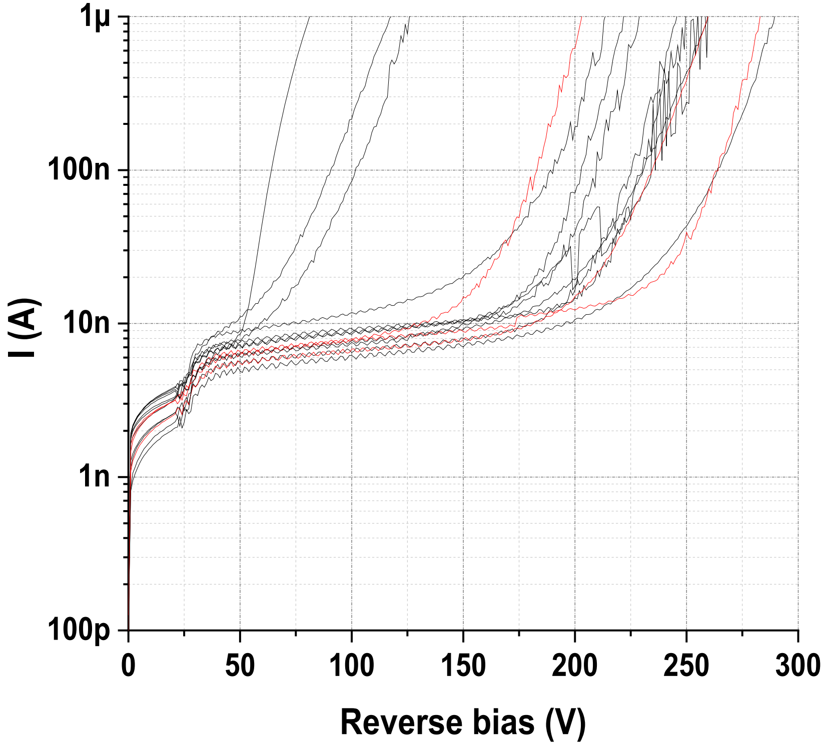
275 µm thick

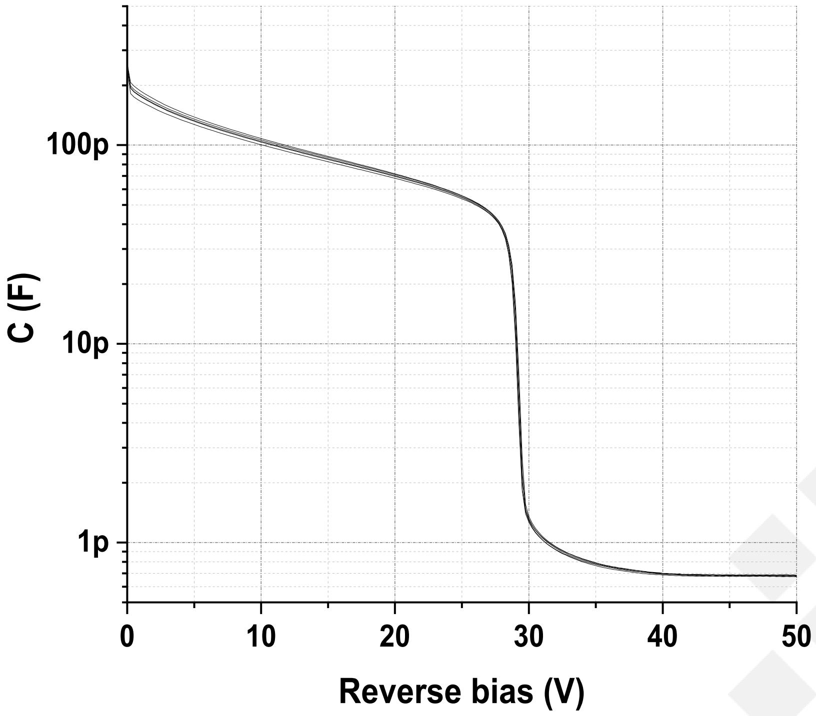
CNM-nLG1-v2: Tests

Selected samples (single-pad diodes) TCT-tested: UV light (369 nm), visible light (404 nm) and IR light (1064 nm)



[J. Villegas - TREDI2024]



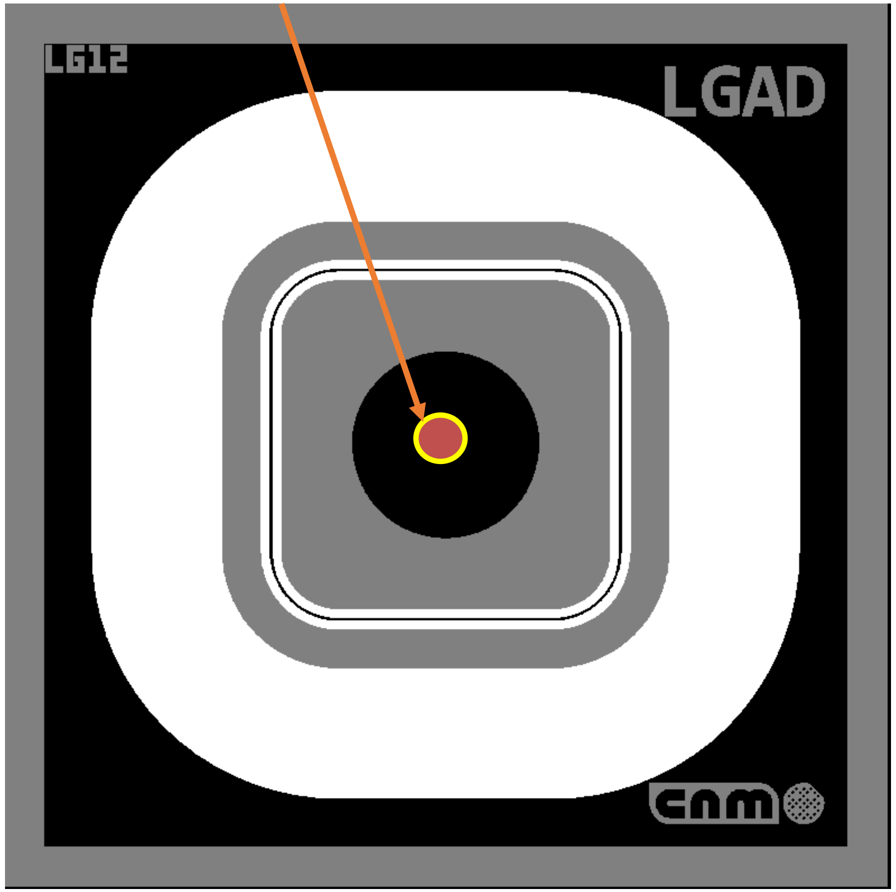


CNM-nLG1-v2: Tests

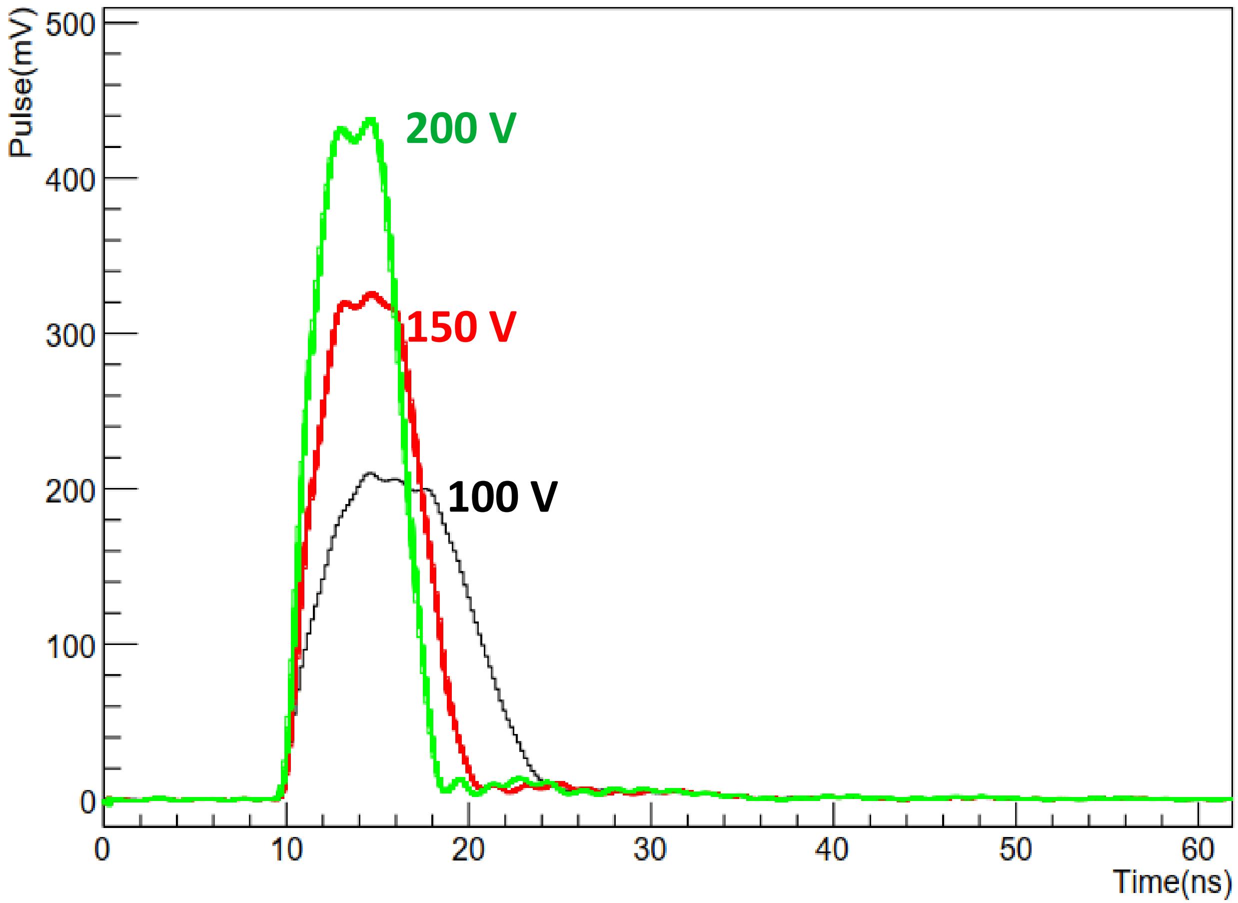
TCT 404 nm light, Max intensity, 1kHz, 20ºC → Voltage Scans in the center @ 20ºC

[J. Villegas - TREDI2024]

Projection of beam on entrance window :
d ≈ 60 μm (spot) < d = 700 μm (window)



10000 averaged waveforms per voltage point



CNM-nLG1-v2: Tests

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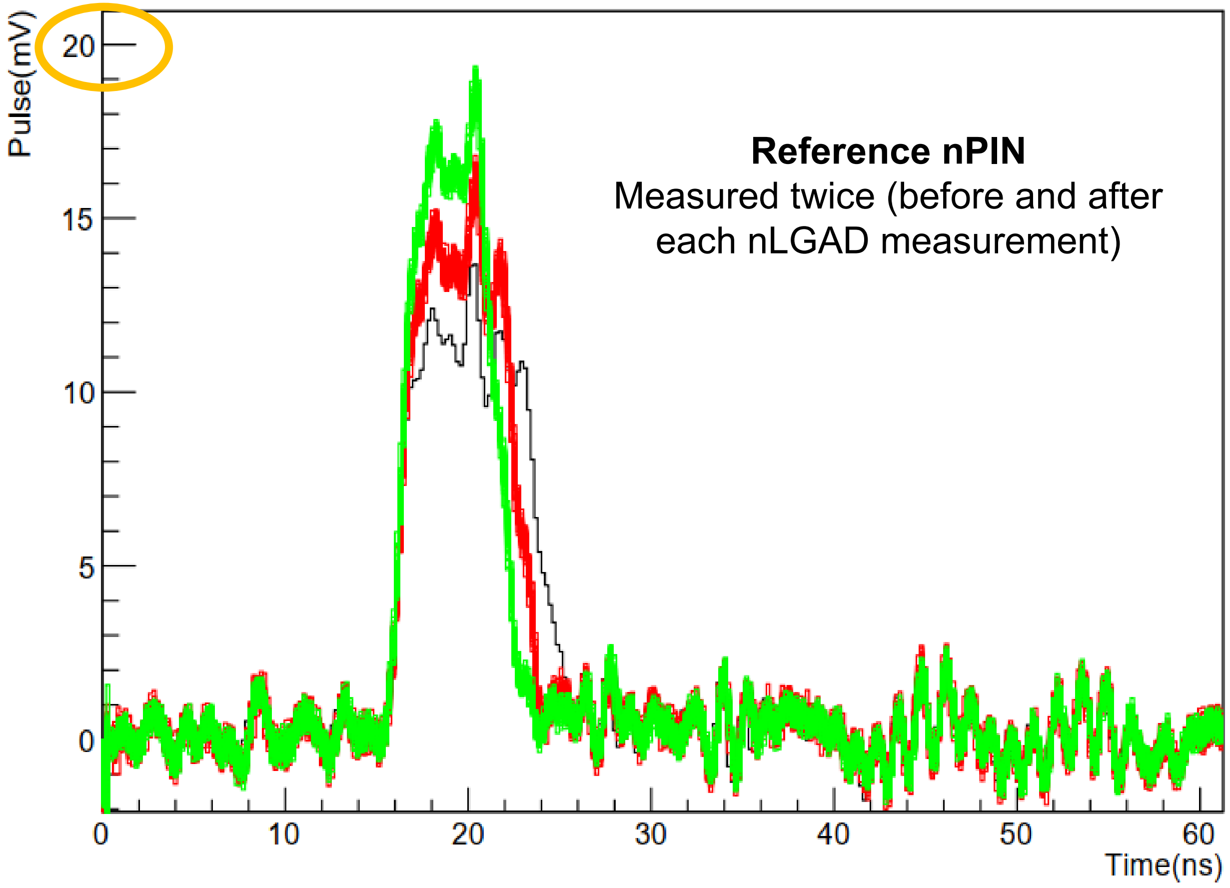

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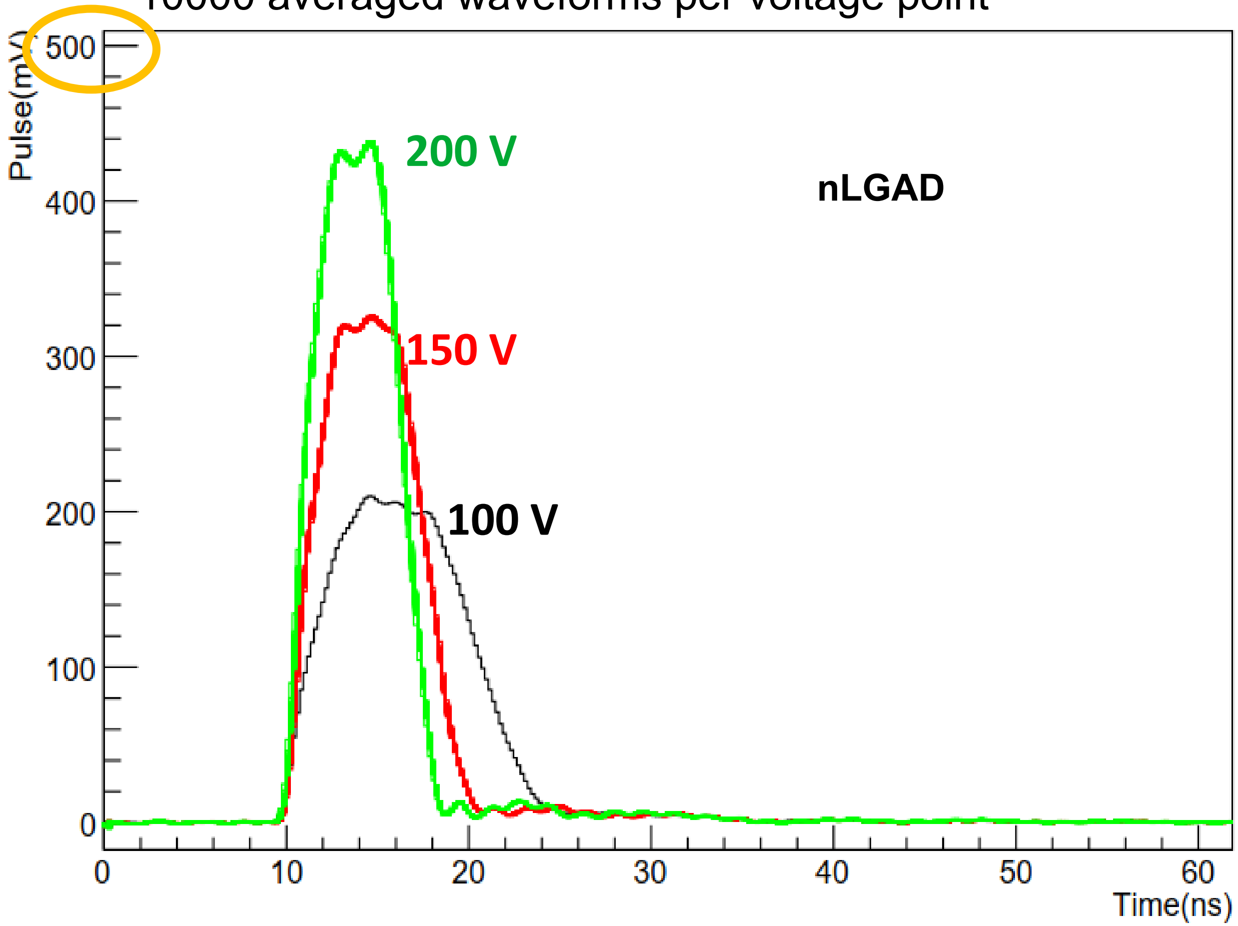

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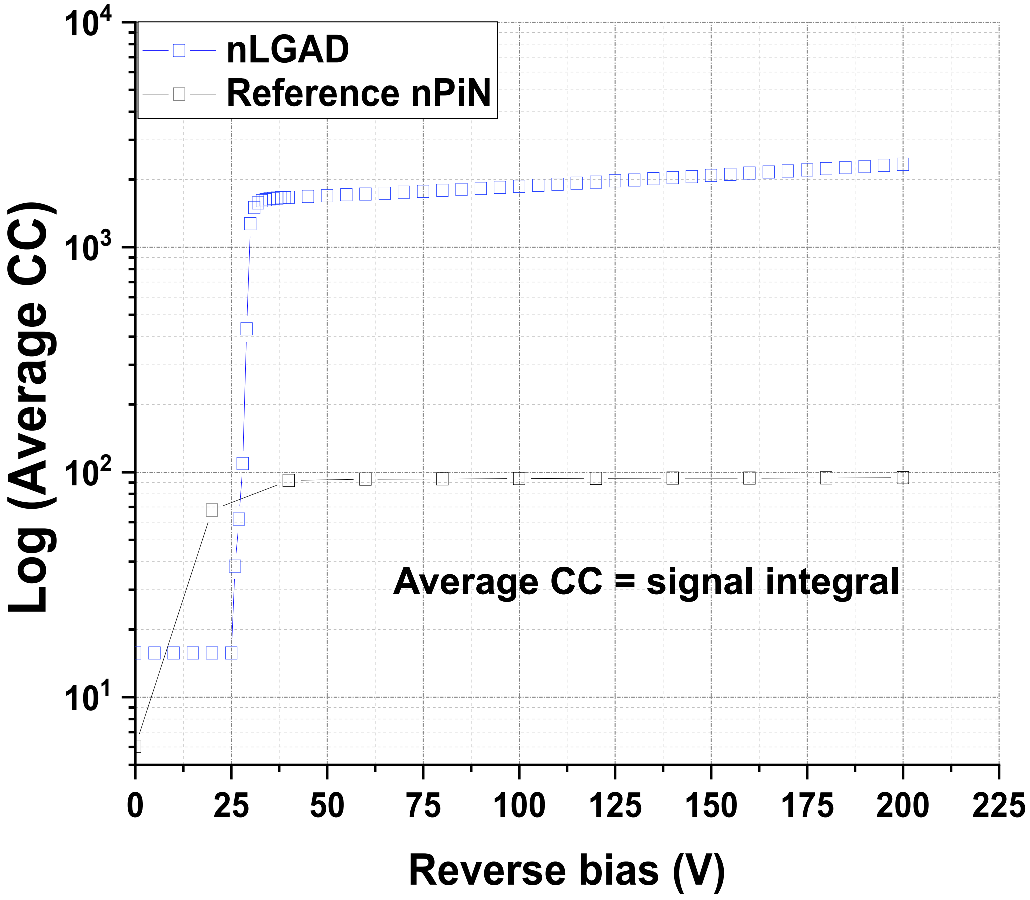

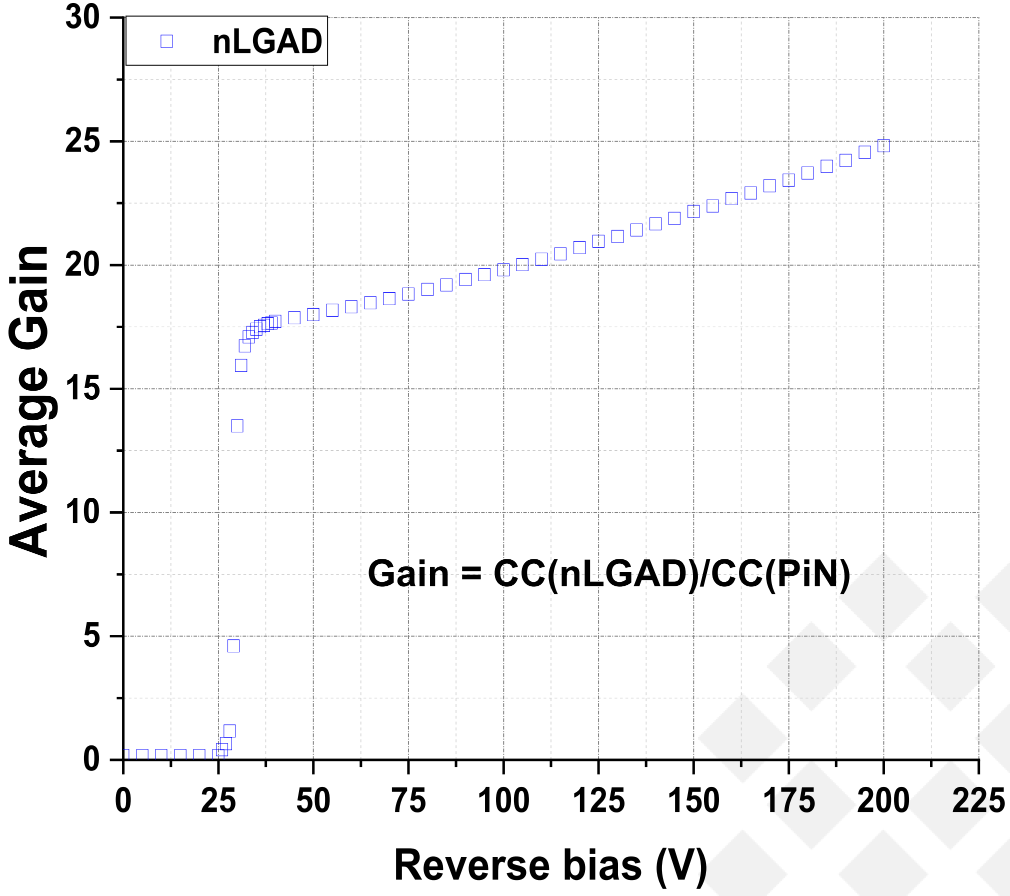

CNM-nLG1-v2: Tests

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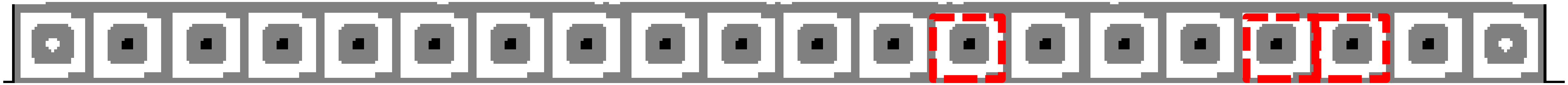
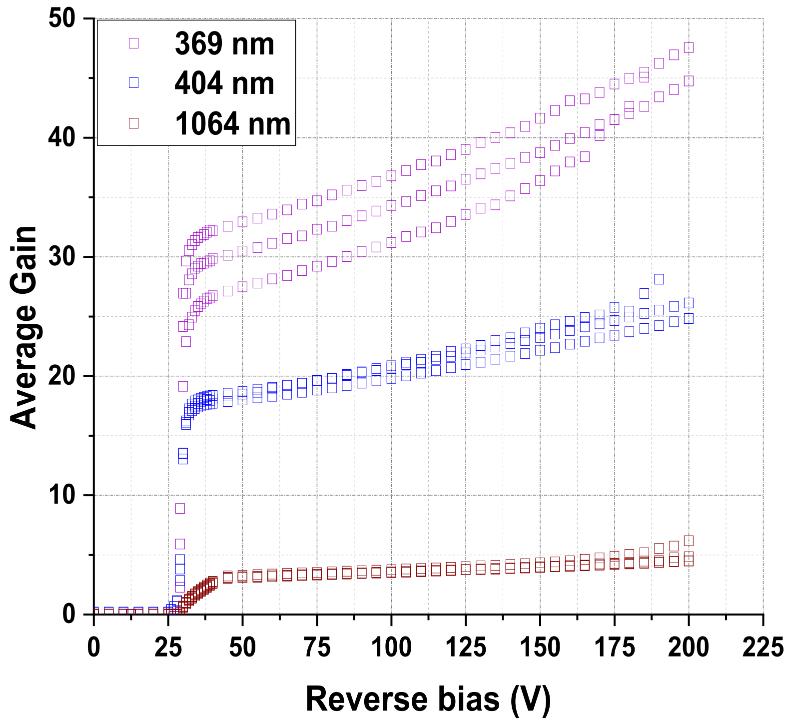
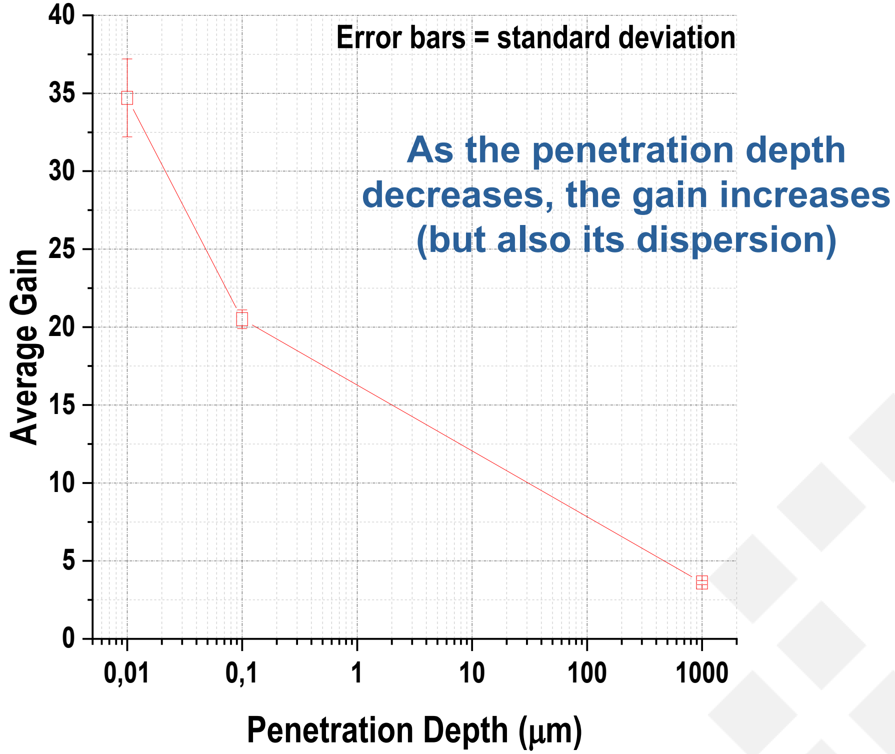


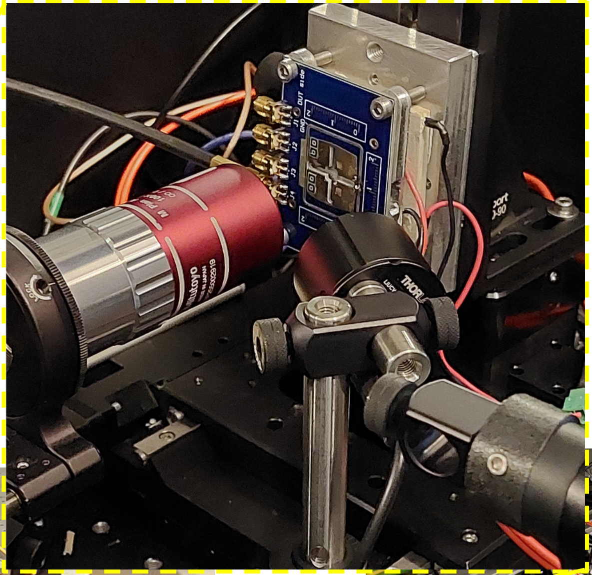
[J. Villegas - TREDI2024]



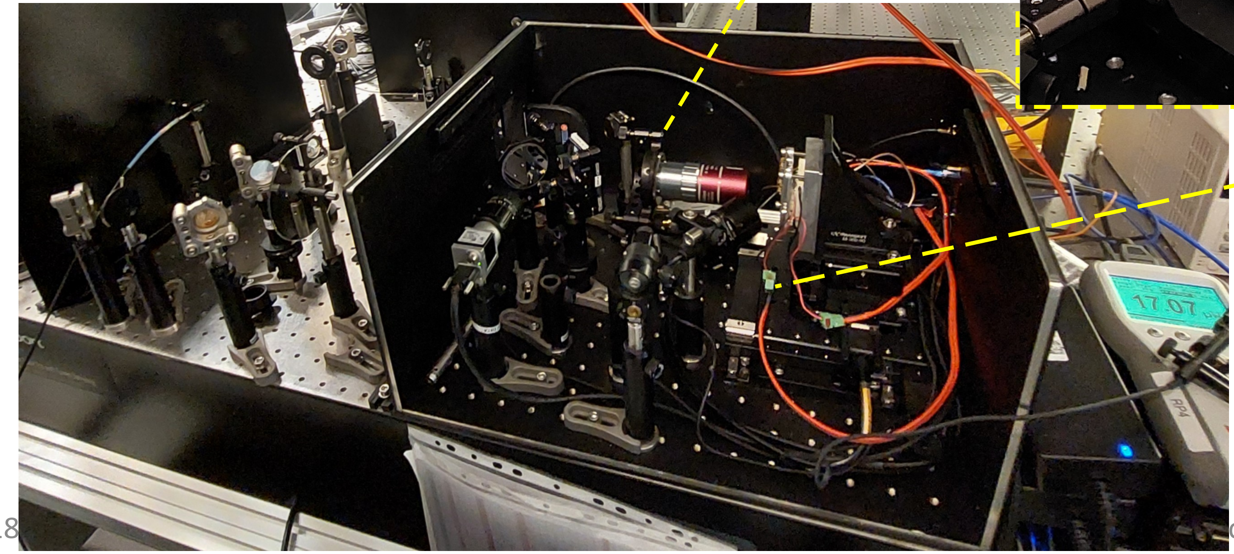


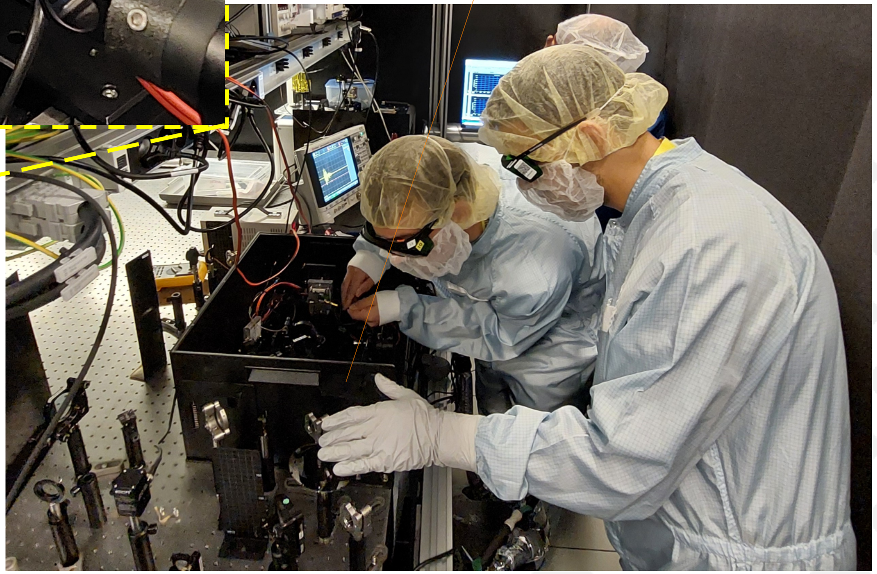
Laser beam time in ELI-ERIC (Czech Rep.): Early June 2024

- Same samples. UV-range explored more deeply (250 nm to 390 nm).



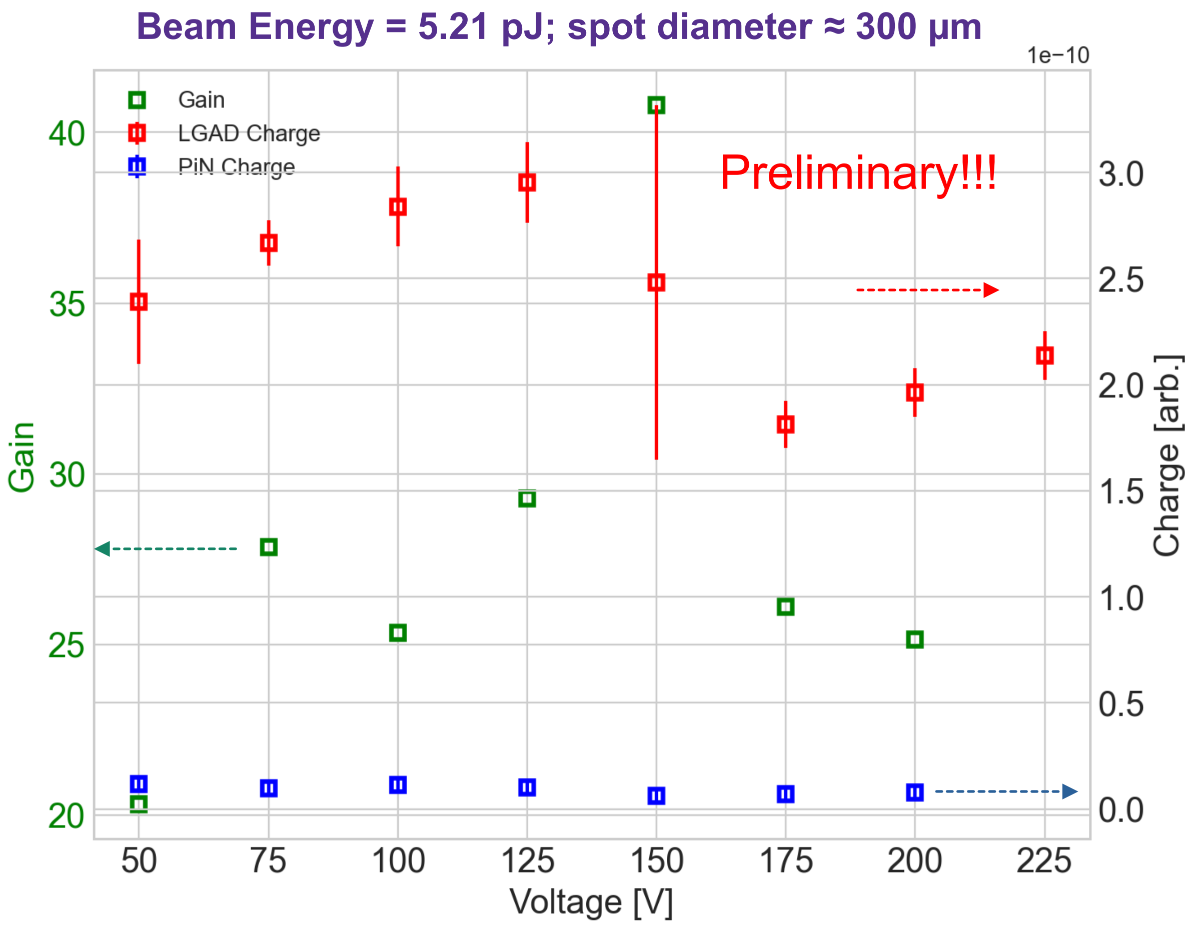
Control on the beam intensity





CNM-nLG1-v2: New Tests

Preliminary results with 250 nm



- Tested with different wavelenghts (250-390 nm)
- Wide range of intensities and voltage bias
- Very focusable laser (1µm spot by default)
- Results still under analysis

- Clear gain for LGADs even at 250 nm
- PiN data harder to analyse
- Seem to have gain suppression, in particular with higher intensities
  - Most of the data were taken with controlled defocus (to enlarge the spot)

- Second test campaign in Jul/Aug

Road ahead

- Further studies on **Run 2** (CNM-nLG1-v2):
  - Tests all single-pad devices (study of gain uniformity)
  - Second test campaign in ELI (end July 2024): systematic measurements at different WL and intensities
  - TPA measurements ongoing at CERN
  - Gain measurements with X-ray photons and low-energy protons (CNA-Sevilla)
- New **Run 3** (CNM-nLG2-v1) just finished:
  - Single pads only, mostly 3.3x3.3 mm^2. nLGAD and PiN
  - Passivation removed from the entrance window and low-energy implant for the ohmic contact
  - 150 mm wafers
- **Plans for the future**:
  - Promising scenario with soft X-ray applications which utilize water window (E ~ 500 eV)
  - We want to couple to Timepix3/Timepix4 ASICs and performe sub-threshold detection unsing the internal gain of the LGAD
  - Many potential applications on the UV range

Thanks for your attention

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Thanks for your attention!