

# nLGAD detector gain performance in the deep and near-ultraviolet (UV) spectral range

26<sup>th</sup> International Workshop on Radiation Imaging Detectors (IWORID2025)

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## Outline

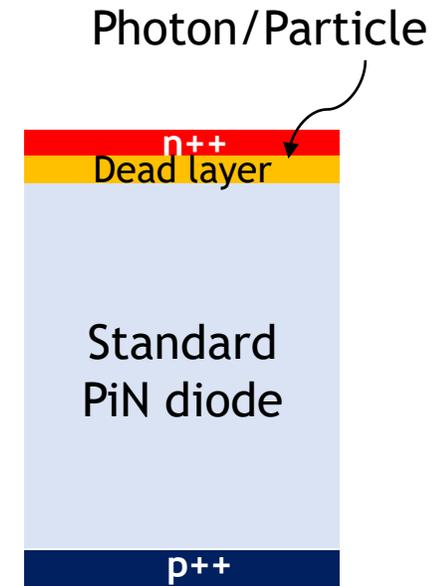
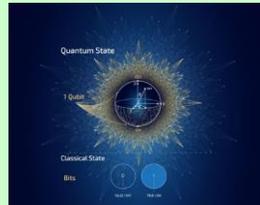
- Motivation
  - Why study low-penetration radiation?
- Introduction to Low Gain Avalanche Diodes (LGAD)
  - What are LGADs and the novel nLGAD “flavour”?
- Measurement setup
  - Transient Current Technique (TCT)
- Spectral Gain Response
  - Measurements under deep-UV and near-UV radiation
- Conclusions & Future

# Why study low-penetration radiation?

# Why study low-penetration radiation?

- Near-surface phenomena are challenging for traditional Si detectors due to recombination effects, which reduce quantum efficiency (depth around 1  $\mu\text{m}$ )
- Even more challenging is single-photon detection, which is crucial in many fields such as:

- quantum information
- fluorescence microscopy
- biomedical imaging
- soft X-ray astronomy (< 1 keV)
- deep-UV in fusion experiments etc.

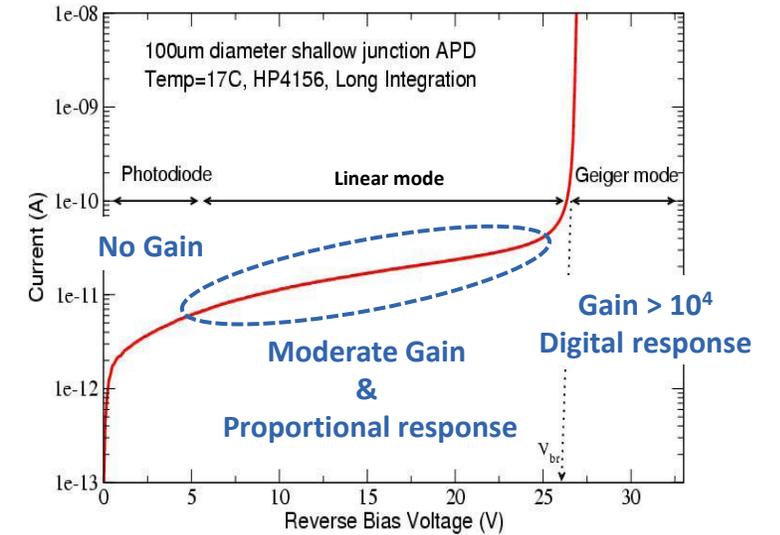


Low surface e-field & Recombination of e-h pairs

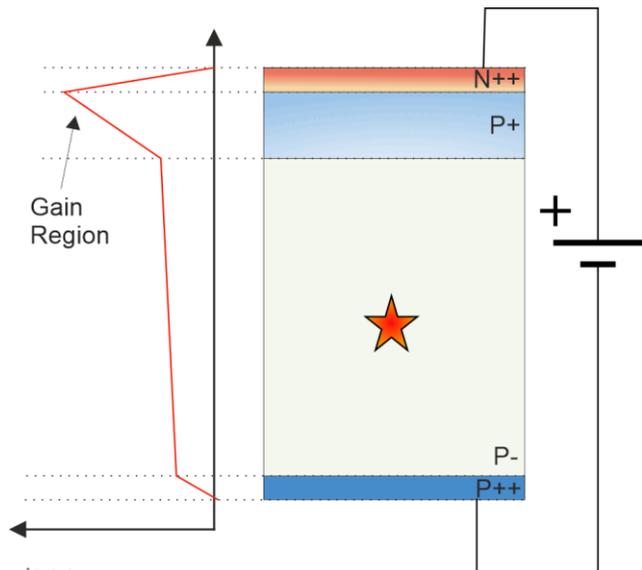
# Low Gain Avalanche Diodes (LGAD)

# Low Gain Avalanche Detector

- Proposed by IMB-CNM in 2014
- Proportional response (linear mode operation)
- Better sensitivity (Gain)
  - S/N ratio increased
  - Excellent timing resolution (~ 30 ps)
  - MIP detection for HEP
- Thin detector integration with the same signal and higher collection efficiency



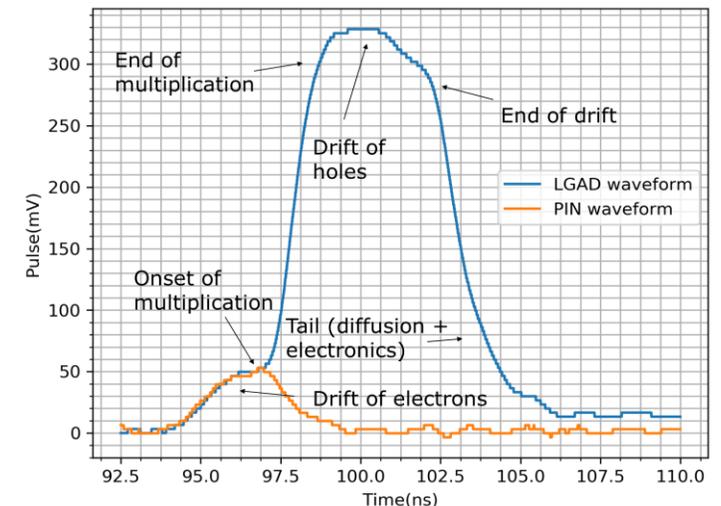
[1] A.G. Stewart et al. in Proc. of SPIE, Vol. 6119, 2006



## Original paper

G. Pellegrini, et al., *Technology developments and first measurements of Low Gain Avalanche Detectors (LGAD) for high energy physics applications*, Nucl. Instrum. Methods A 765 (2014) 12.

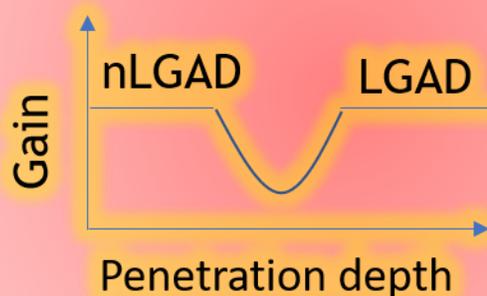
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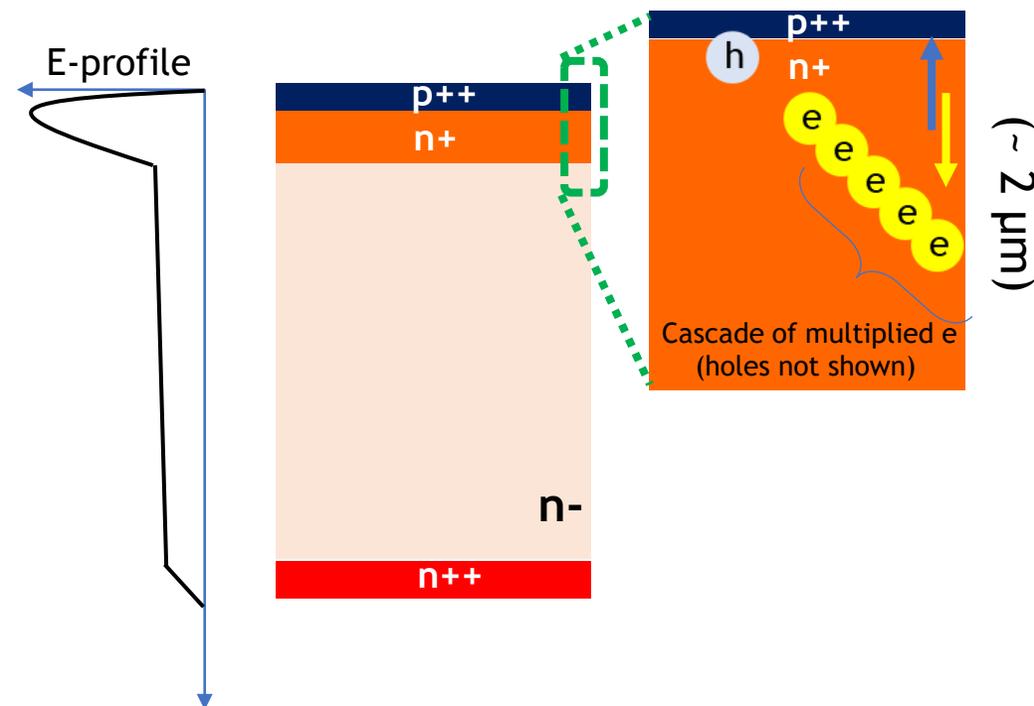
# nLGAD Technology

## Drawbacks of standard LGAD

- In “*low energy physics*” - range i.e. penetration depth of the radiation decreases, so the gain starts to diminish



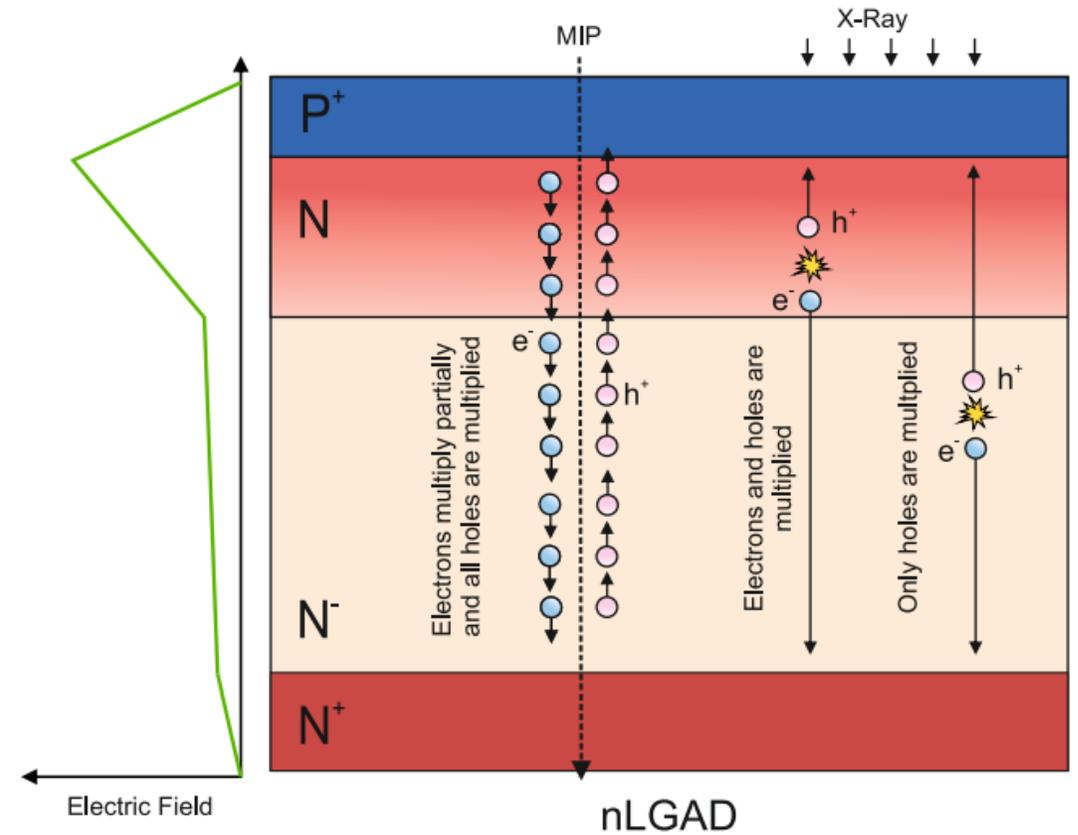
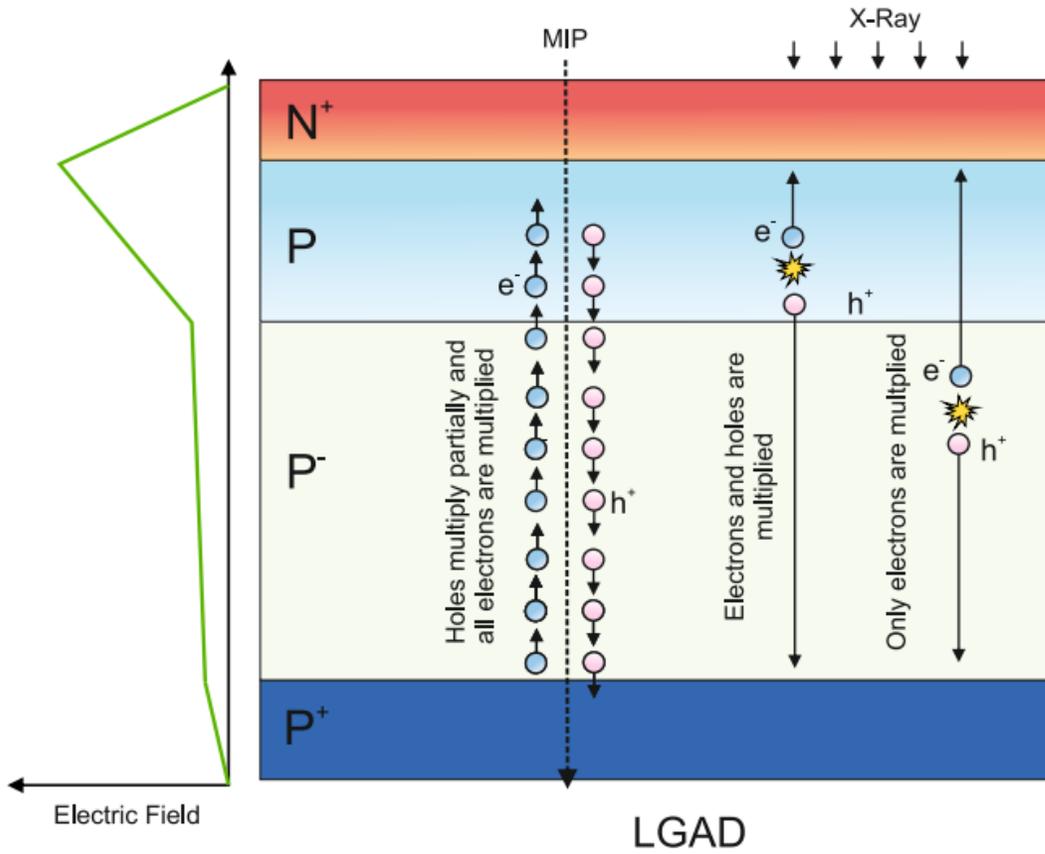
- To mitigate this effect
  - nLGAD technology



## n-type LGAD (nLGAD)

- n-substrate
- Inverted implantation polarity
  - Electron driven multiplication when charge is generated prior to reaching the gain layer

# LGAD vs nLGAD



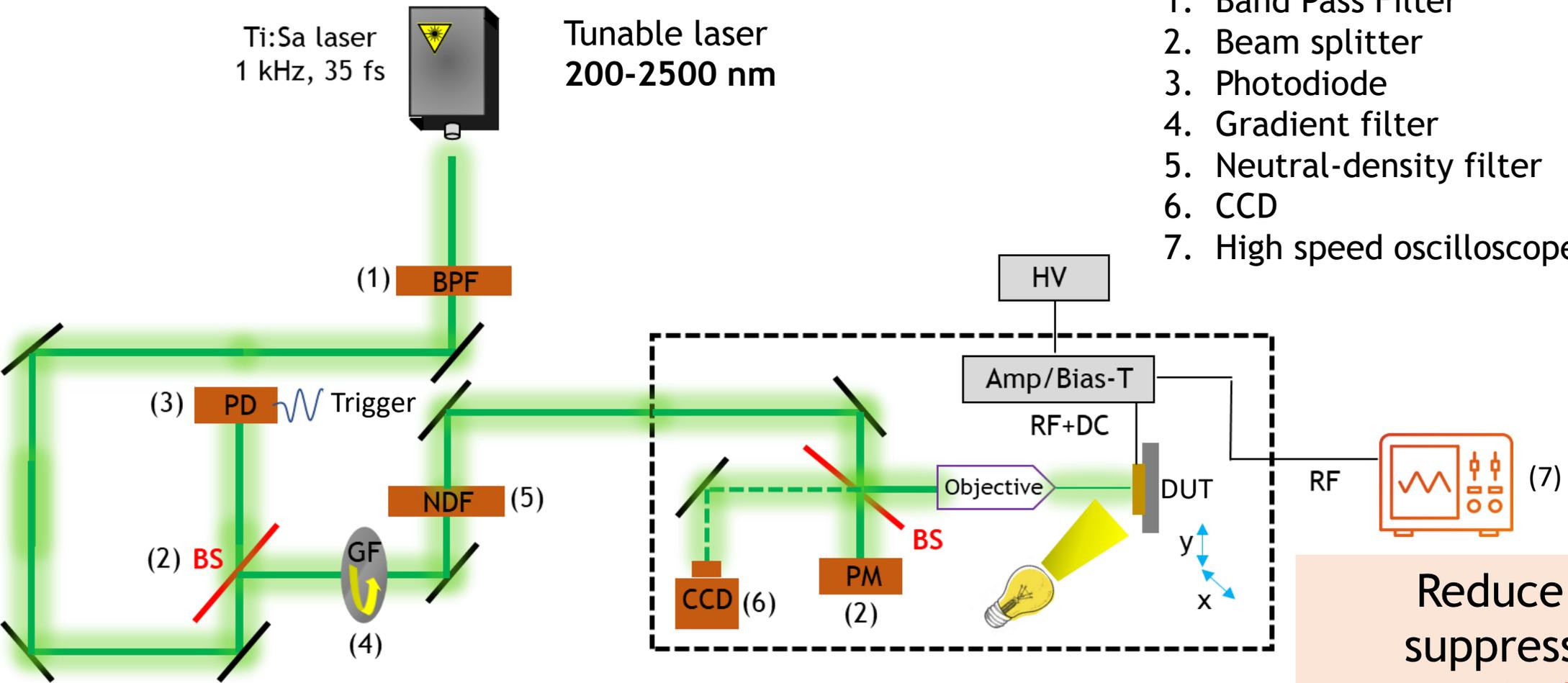
# Results & Measurements

# Transient Current Technique (TCT)

Ti:Sa laser  
1 kHz, 35 fs

Tunable laser  
200-2500 nm

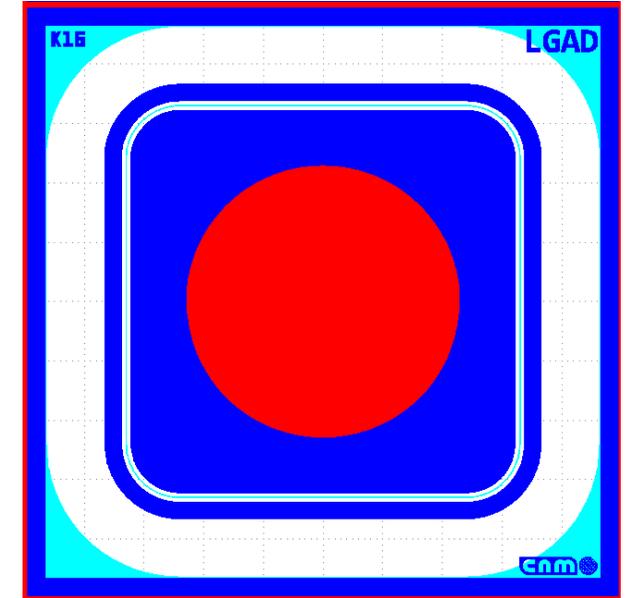
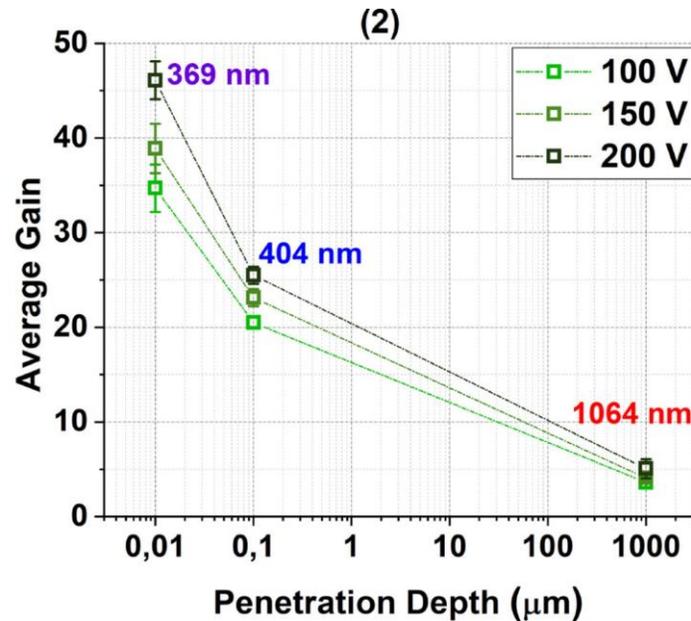
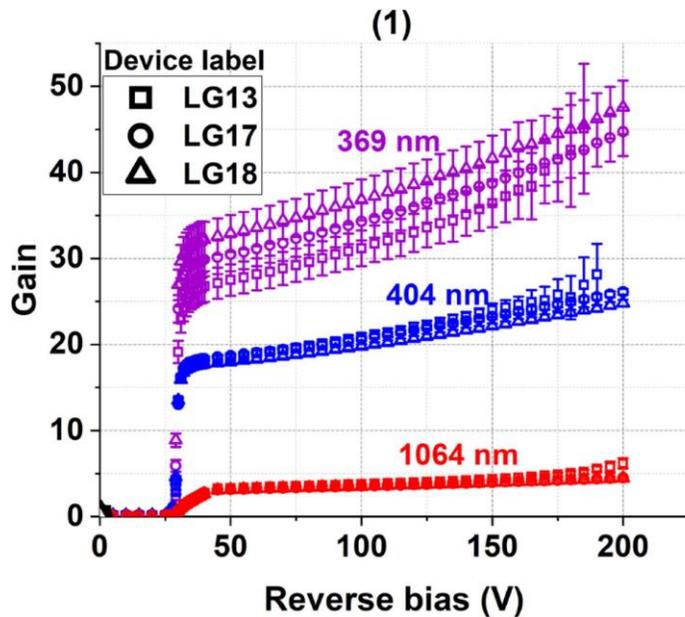
1. Band Pass Filter
2. Beam splitter
3. Photodiode
4. Gradient filter
5. Neutral-density filter
6. CCD
7. High speed oscilloscope



Reduce the suppression:  
Z scan is done so that laser is defocused

# 1<sup>st</sup> nLGAD run results

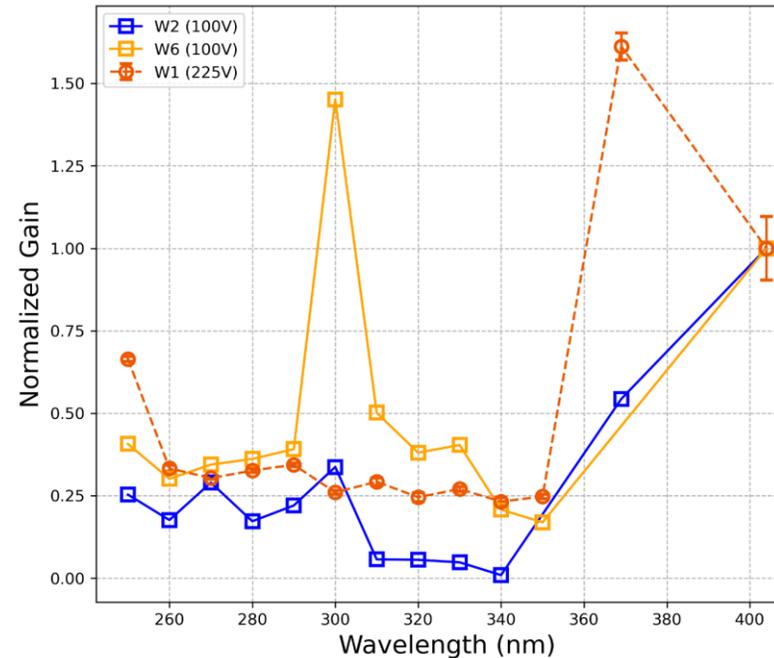
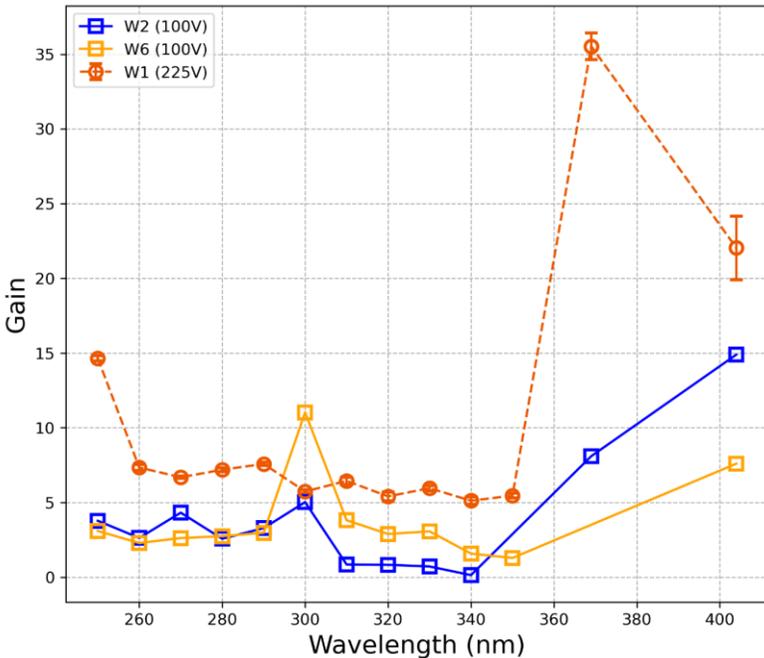
- Concept confirmed
  - lower penetration depth translates to higher gain
- Single pad detectors for now



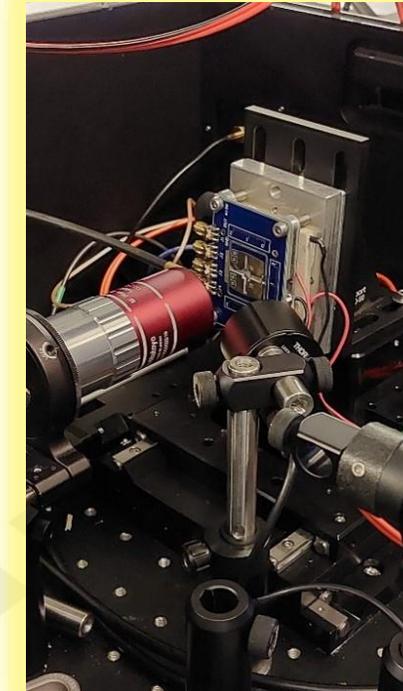
[1] Villegas, J., Torres, C., Manojlovic, M., Jimenez-Ramos, M. C., Moffat, N., Lopez, J. G., & Hidalgo, S. (2025). *nLGAD gain response to low-penetrating particles*. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 1072, 170208. <https://doi.org/10.1016/j.nima.2025.170208>

# 1<sup>st</sup> and 2<sup>nd</sup> nLGAD run results

- The detectors are sensitivity to deep and near-ultraviolet light (UV)
  - Penetration depth  $\lesssim 10$  nm
- Single pad detectors for now



nLGAD detector gain performance in the deep and near-ultraviolet (UV) spectral range



We acknowledge ELI Beamlines  
(Czech Republic)  
Femtosecond optics

- First nLGAD productions at IMB-CNM showed **good performance** for low penetrating radiation, with optimal response (**linear gain over 20-40**) in the **blue** and **near UV** range
- **Medium UV region** (down to 250 nm) explored: signals with gain observed. However, **gain seems to be significantly lower than for the near UV range.**
- New designs explored and new run being fabricated to improve response in DUV range.
- ELI TCT facility remarkable and helping us to develop DUV sensors for the future

# Application: SoftPix project

# SoftPix project

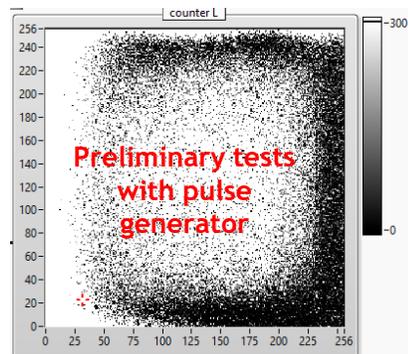
## What was the goal?

- Production of photon counting pixelated detector with high spatial resolution (55 μm pitch)

## How?

- Bump-bond the USJ-nLGAD and AC-LGAD with Timepix4 and Medipix3 ASIIC

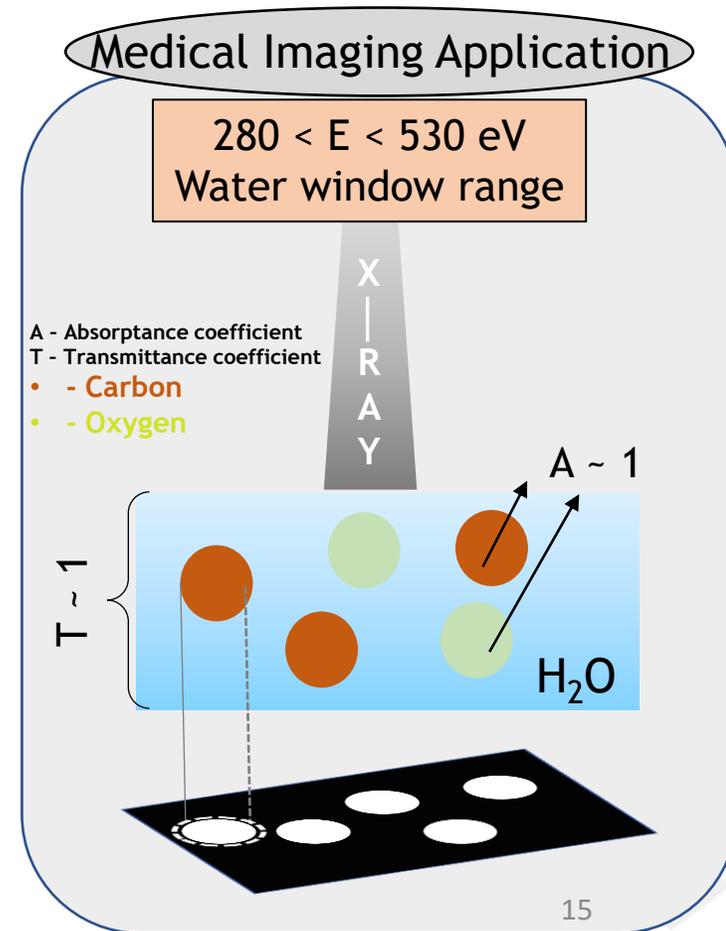
## Graphene



- For biopsy (for example after a mammography)
- images *on the spot*
  - soft X-rays detected by a Timepix-LGAD device would give better contrast than hard X-rays
  - adequate resolution



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# Conclusions & Future

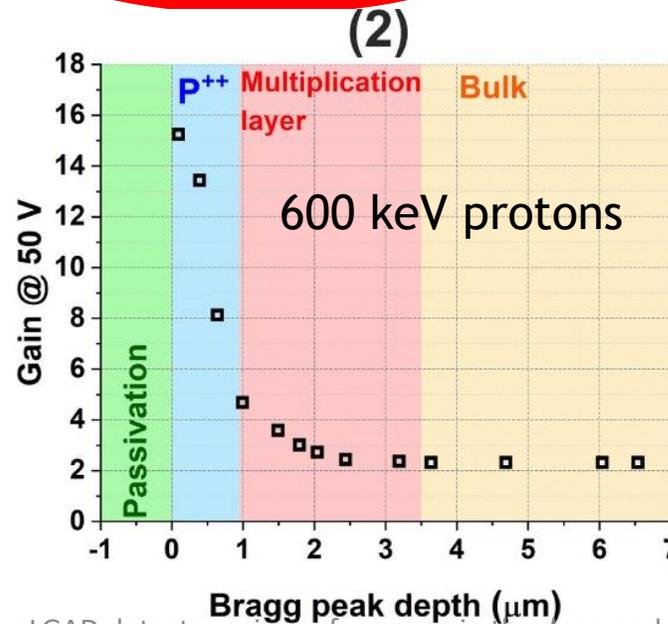
## Conclusions

- nLGAD seems like a promising technology for deep-UV, near-UV
- For Soft X-ray detection further adaptation is required
- High gain is preserved for low penetrating radiation
- Limited to low-energy physics

### Future

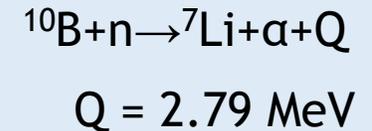
#### Low energy proton & ion detection

- Has repercussions in medical physics, particularly in ion cancer therapy using ions such as carbon
- In progress...

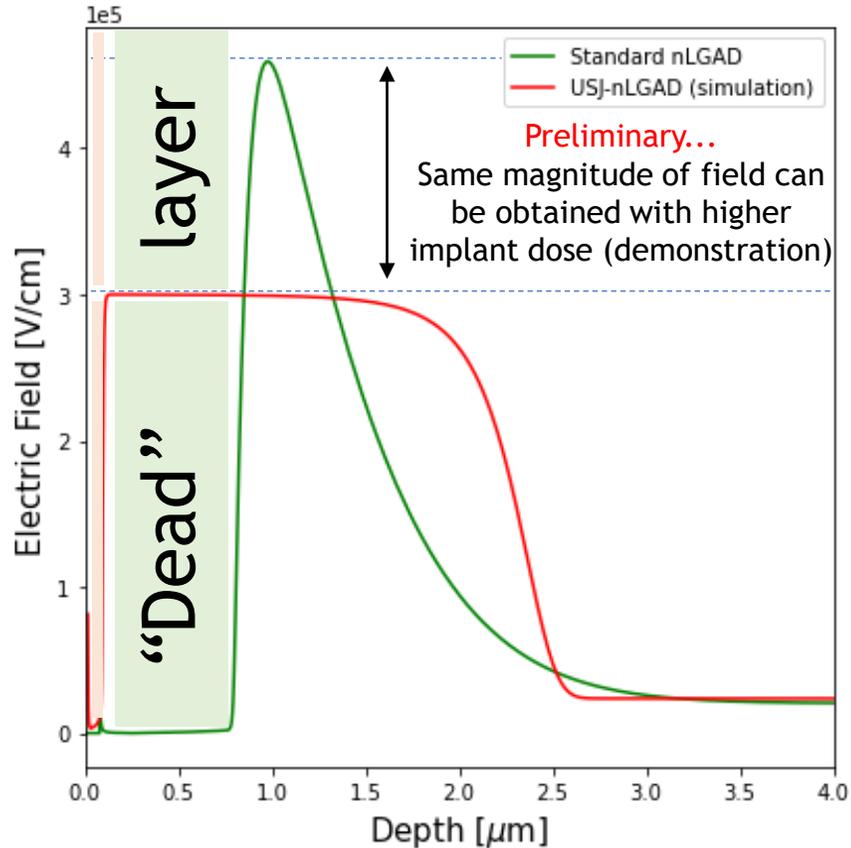


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#### α-particle in fusion experiments



# Ultra-shallow junction nLGAD (USJ-nLGAD): A New Benchmark in Low Penetration Radiation Detection Technology - work in progress...



## Key modifications

- Moving to low diffusivity p-type implant ( $\text{BF}_2$ )
- Moving to ultra low implantation energies
- Moving to laser annealing (minimum diffusion)
- Moving to deep multiplication implant for more uniform gain response
- Pixellated backside from 55  $\mu\text{m}$  to 220  $\mu\text{m}$  pitch
- Antireflective coatings ( $\text{MgF}_2$ )
- Dead layer (entrance window) minimized!
  - Quantum efficiency for Soft X-ray maximum

Ongoing...  
➤ October 2025

# Thank you!

## Acknowledgements



### Acknowledgements

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# Thanks for your attention

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