

pLGAD: A Novel Detector Concept for Low Energy Particles

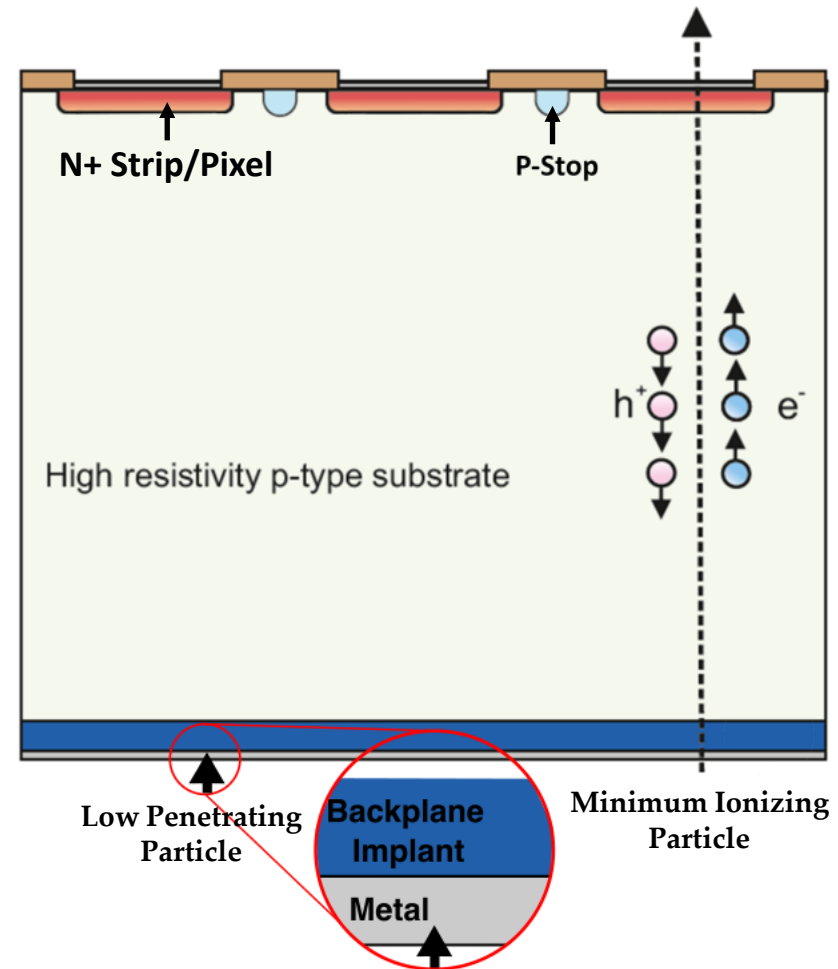
Waleed Khalid for the NoMoS & IMB-CNM Collaboration
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Motivation & Challenges

- Detection of low penetrating particles i.e. particles with range of hundreds of nanometers in silicon
- Challenges using HEP Detectors for such particles
 - Thick Entrance windows
 - Thick passivation layers (dead layer)
 - Thick backplanes (fieldstop)
 - Low Signal to Noise Ratio
 - Consequently: Low detection efficiency



Need for New Detector

Challenges



Conventionally Available

Entrance Window

Thick

(High recombination rate near surface → CCE < 1)

SNR

Low

(e.g. Signal of approx. 3100 e⁻/h⁺ pairs for 15 keV protons)

Detection Efficiency

Low

Our Solution

Custom Development

Unstructured, Thin

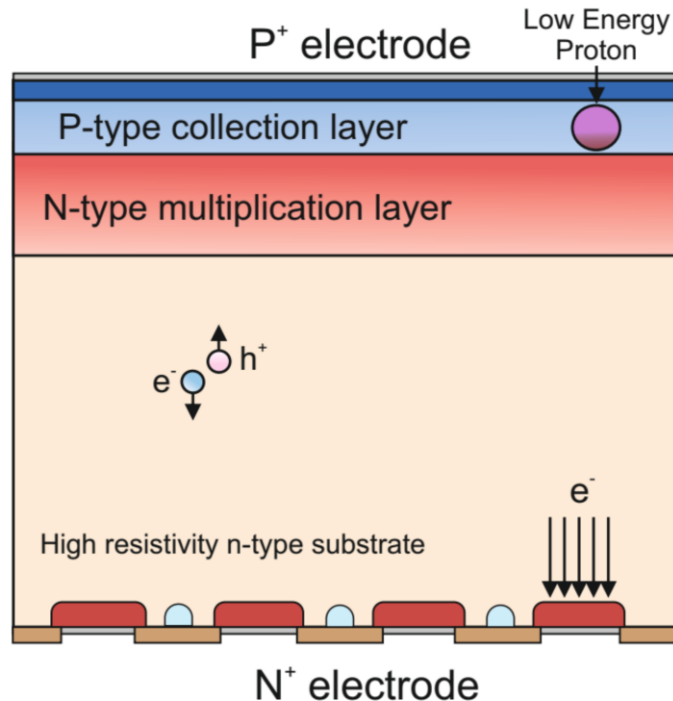
(Low penetrating particles can penetrate deeper in the active sensor area)

High

(Uniform Internal Gain)

High

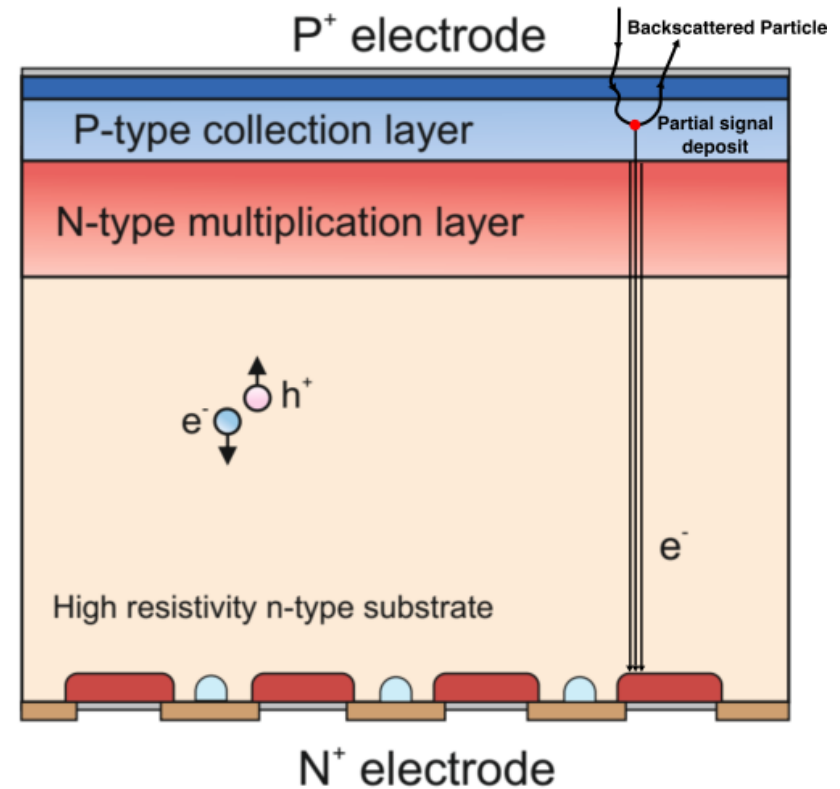
Proton Low Gain Avalanche Detector (pLGAD) Structural Concept



- Polarity is chosen so electrons drift to the readout side after crossing the multiplication layer
- No amplification of leakage current as holes have smaller saturation velocity

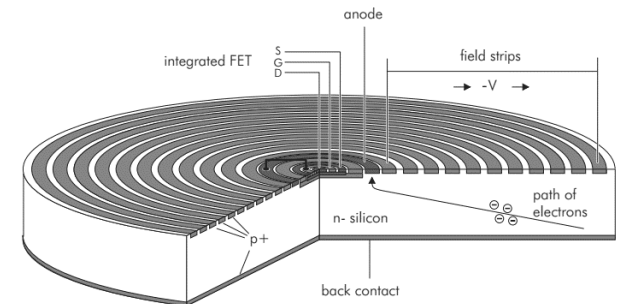
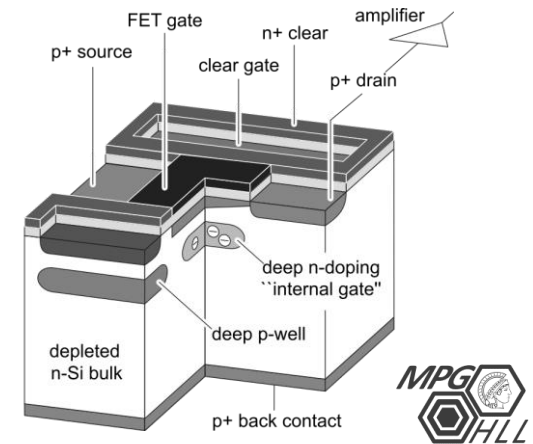
Detection of Backscattered Particles

- Due to introduction of collection layer, the detector is more sensitive to smaller signals
- Sensitivity can be **useful to study backscattered particles** for correction of data



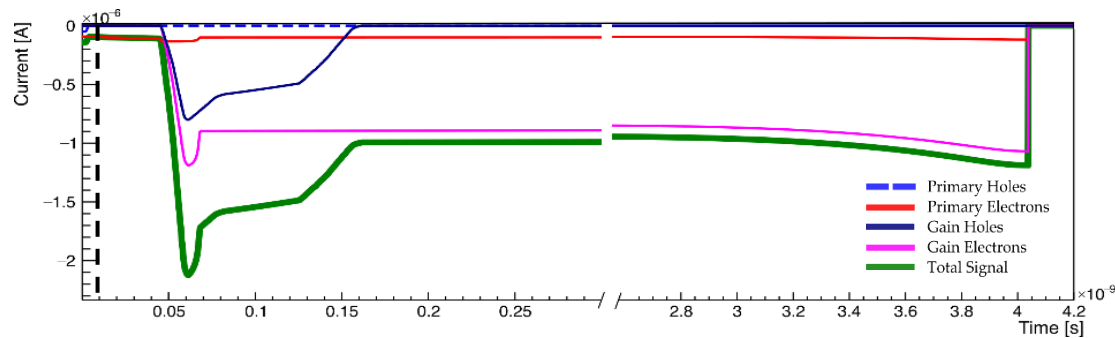
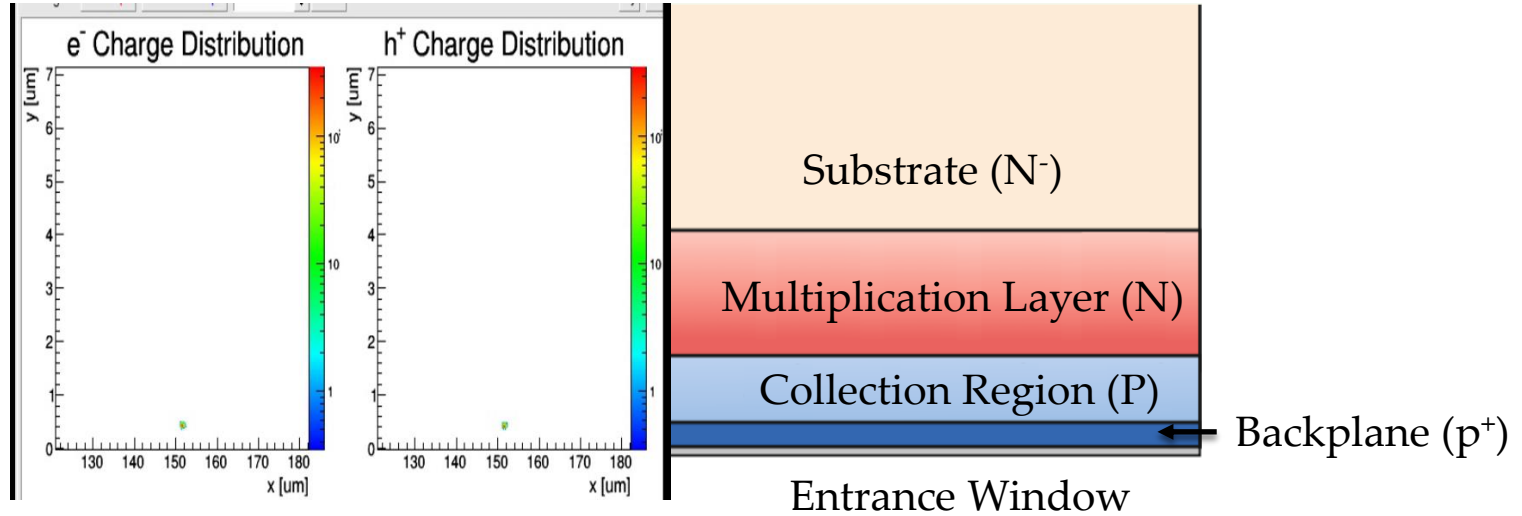
Add. comparison to DEPFETs and SDDs

- In contrast to DEPFETs & SDDs, a pLGAD sensor
 - is a lot **cheaper**.
 - can be operated **w/o cooling**,
 - requires **only one operation voltage**,
 - is compatible with off-the-shelf DAQ systems,
 - has a **higher timing resolution**,
 - can be combined with other readout structures, as long as electrons are being collected (n-in-n)



*Image Courtesy of M. Simpson

Signal Shape (Weightfield2 Simulation Video)

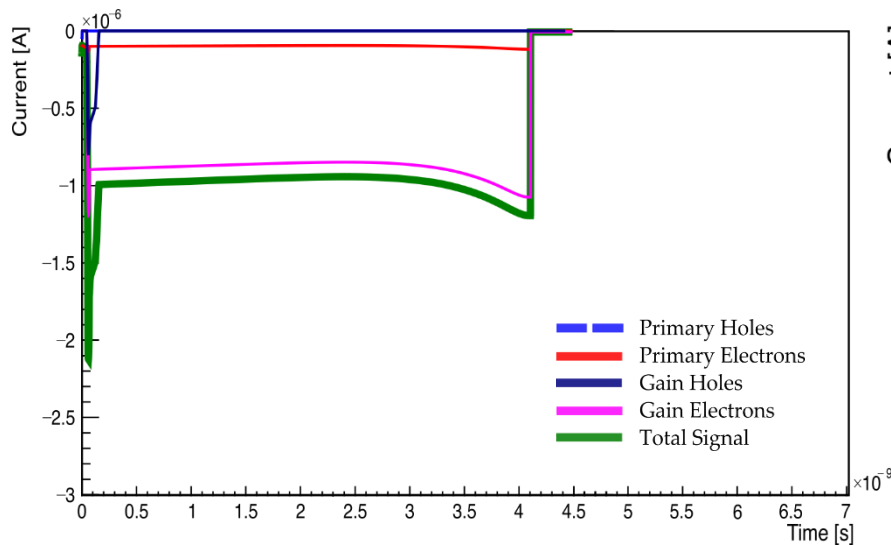


*Watch in slide show mode for proper animations

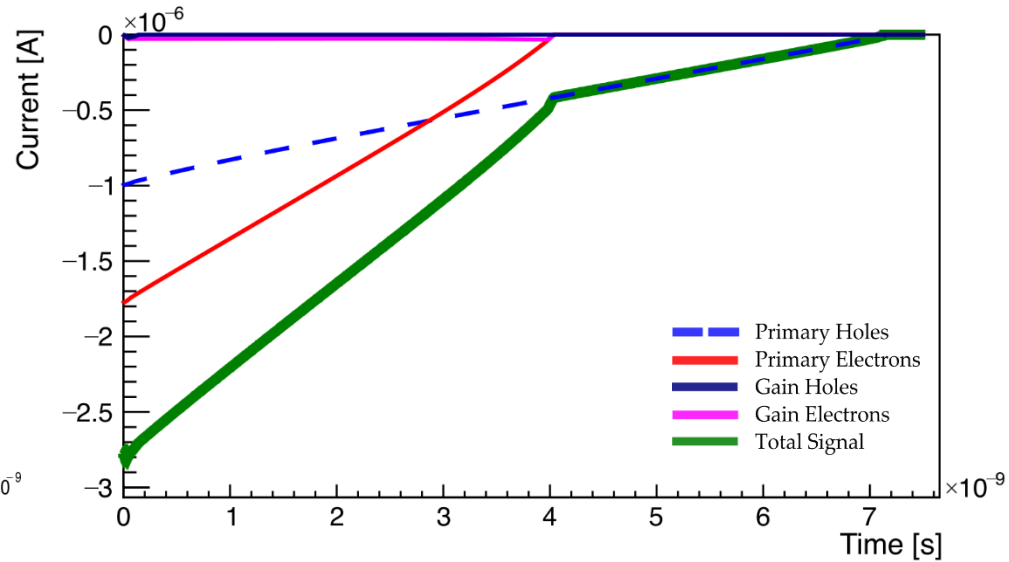
Assuming a gain of 10

Signal Comparison (Weightfield2 Simulation)

15 keV Proton



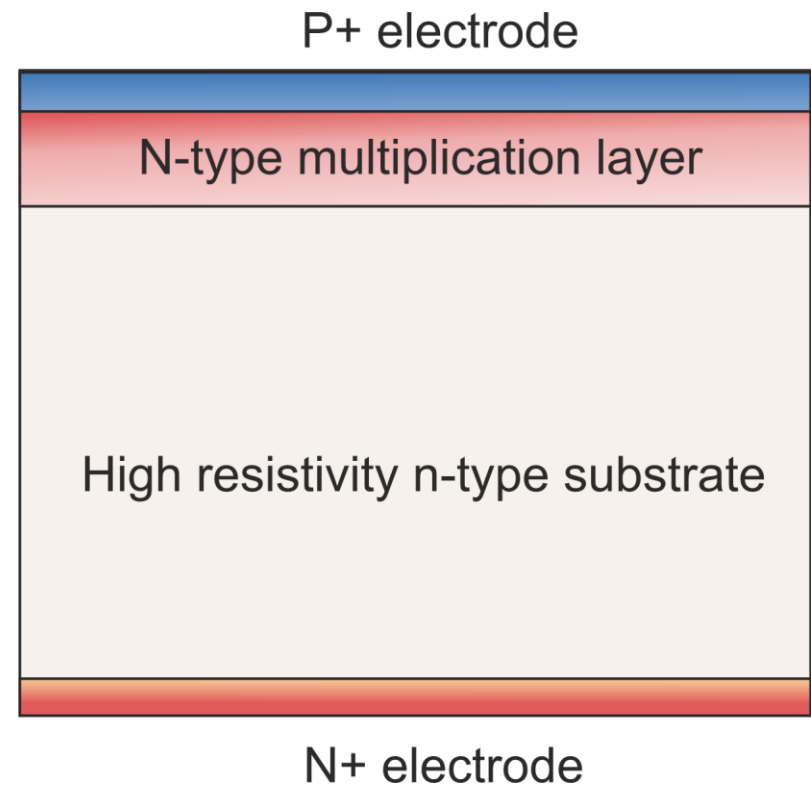
Minimum Ionizing Particle (MIP)



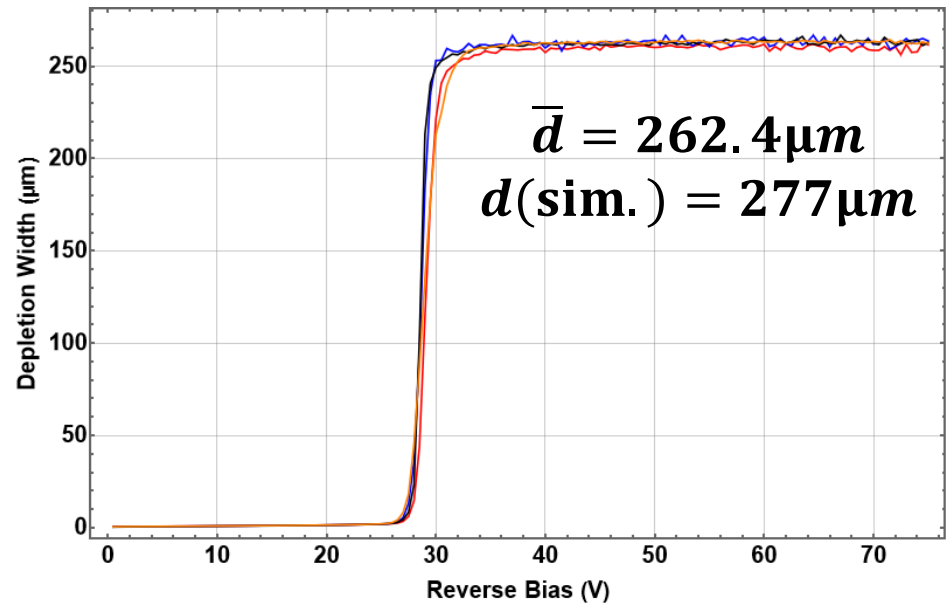
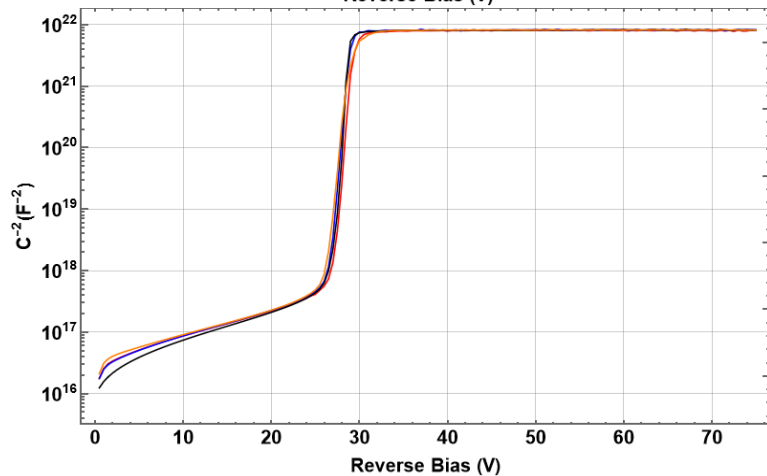
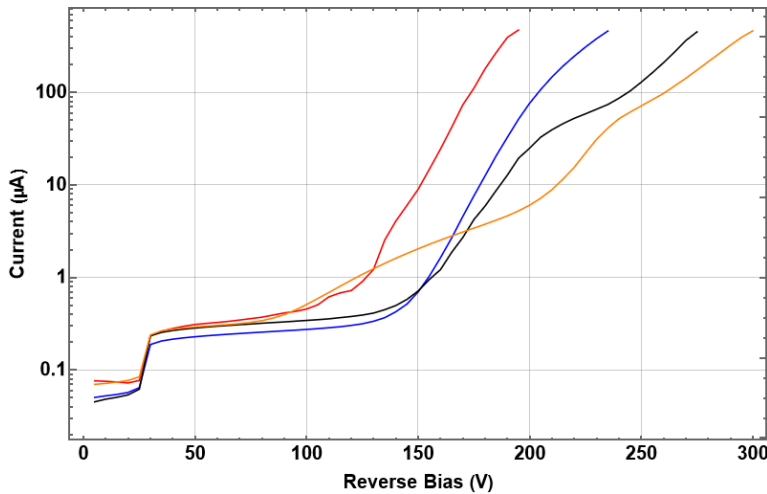
Behaves like a planar sensor for MIPs

First Production Run for Proof of Principle

- 4 diodes (5.3x5.3 mm², single channel) from 1st Production run chosen
 - No collection region in the first run
 - A reverse polarity iLGAD with thin backplane, unstructured entrance window, and shallow multiplication implant
- IV and CV measurements conducted
- TCT measurements to follow
- Will provide proof of principle
 - Collection region will be introduced in the next production run



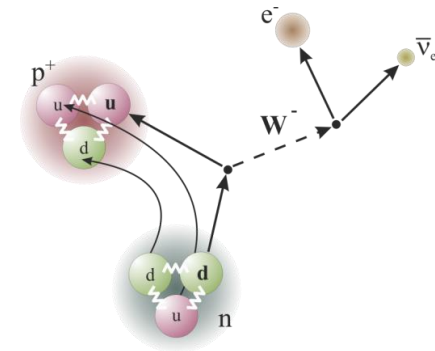
Characterization of First Production Run (without collection layer)



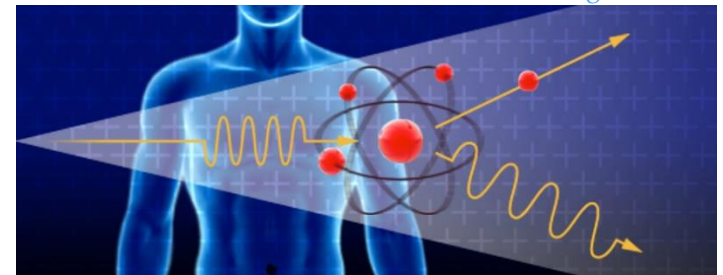
- **Stable performance** at low bias voltage
- **Full depletion** achieved at $\sim 35\text{V}$
 - **Agreement with TCAD simulations**

Applications for Low Energy Physics

- Neutron Physics
 - Proton detection from Neutron Beta Decay (e.g. NoMoS, Nab)
 - Neutron Detection
- Space Applications
- Medical Physics
- Ion physics
- Many more



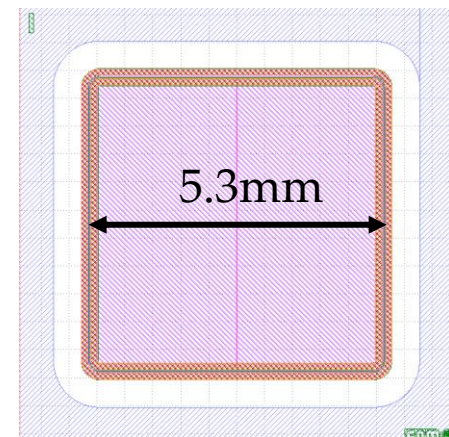
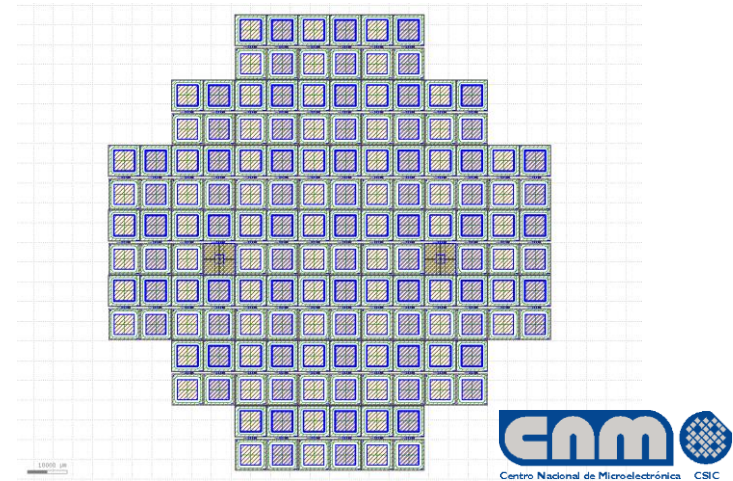
*Image Credit: ESS



*Image Credit: McGill Medical Physics

Outlook

- Characterization of first production run (reverse polarity iLGAD with deep implant) underway
- **TCT measurements** will soon be conducted
 - Will provide **proof of principle** before introduction of collection region
- **Beam line testing** at VERA (Vienna Environmental Research Accelerator) with low energy protons to be conducted later this year





Summary

- **pLGAD** – new detector concept to detect low penetrating particles
- Features of the detector include:
 - **Internal gain** with no Noise multiplication
 - **High timing** resolution
 - **Thin entrance window**
- **Cheaper** due to simple planar technology
- **Comparable** if not better than existing technology
- **Multiple applications** in low energy physics