ÖAW AUSTRIAN ACADEMY OF SCIENCES

SMI – STEFAN MEYER INSTITUTE FOR SUBATOMIC PHYSICS

pLGAD: A Novel Detector Concept for Low Energy Particles

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Vienna Conference on Instrumentation (VIC), 2022
February, 2022

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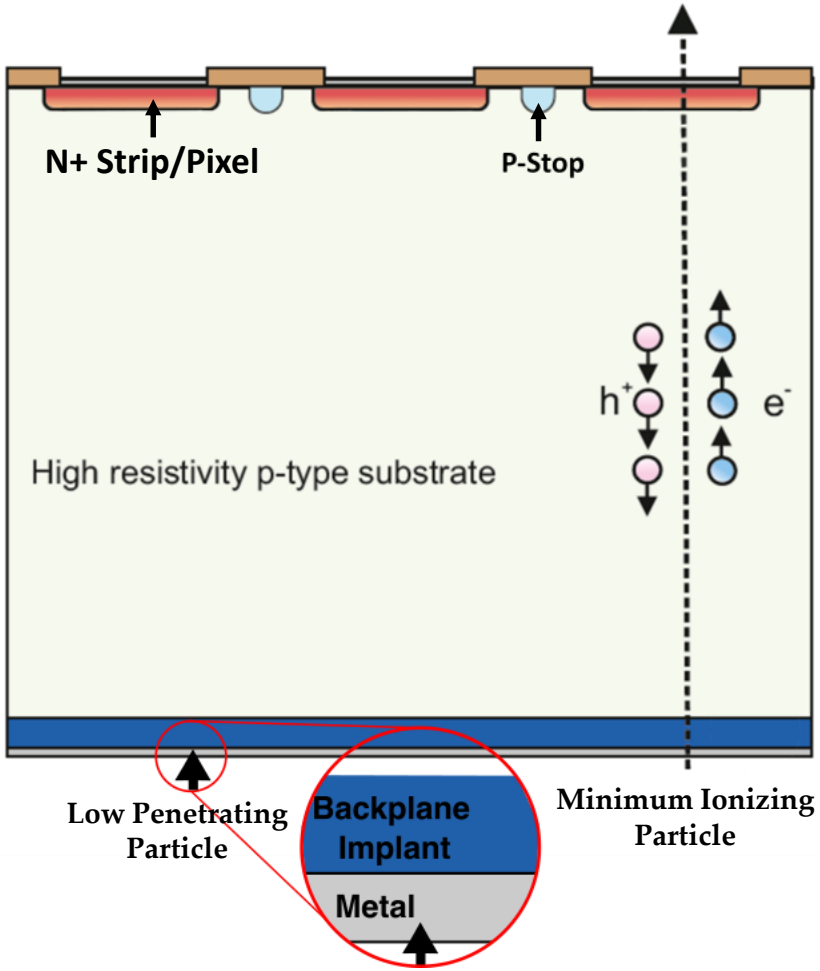
Motivation & Challenges

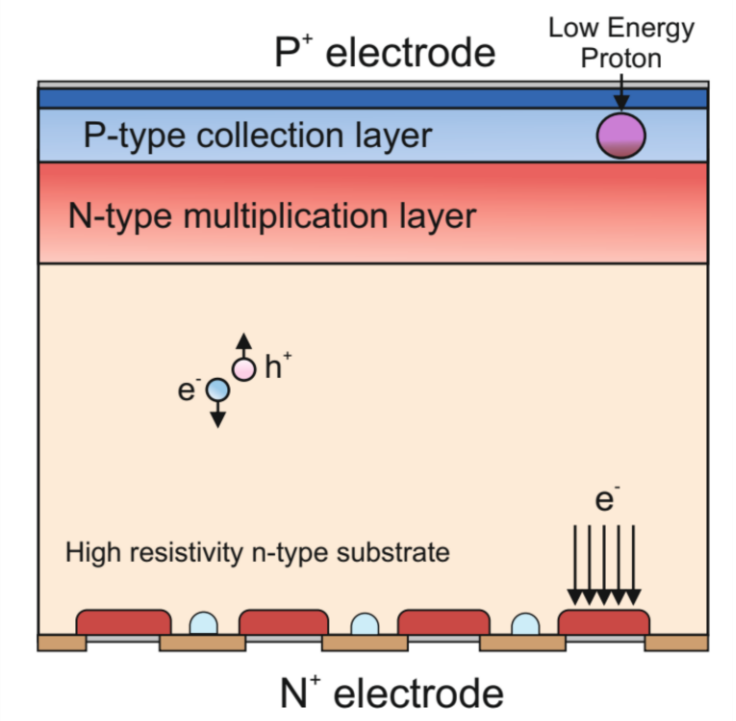
- Detection of low penetrating particles i.e. particles with range of hundreds of nanometers in silicon
- Challenges using HEP Detectors for such particles
  - Thick Entrance windows
    - Thick passivation layers (dead layer)
    - Thick backplanes (fieldstop)
  - Low Signal to Noise Ratio
  - Consequently: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



Need for New Detector

Challenges	→	Our Solution
	Conventionally Available	Custom Development
Entrance Window	Thick (High recombination rate near surface → CCE < 1)	Unstructured, Thin (Low penetrating particles can penetrate deeper in the active sensor area)
SNR	Low (e.g. Signal of approx. 3100 e^-/h^+ pairs for 15 keV protons)	High (Uniform Internal Gain)
Detection Efficiency	Low	High

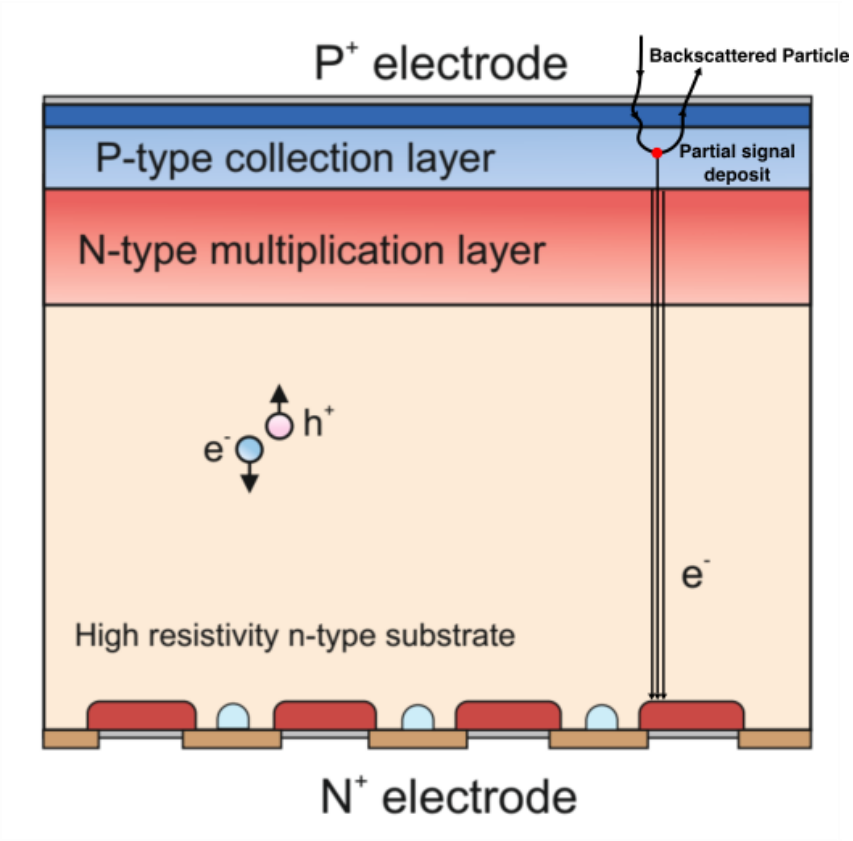
Proton Low Gain Avalanche Detector (pLGAD) Structural Concept



- 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

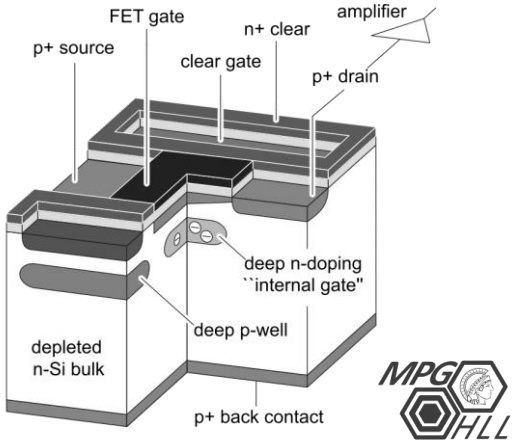
Detection of Backscattered Particles

- 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)



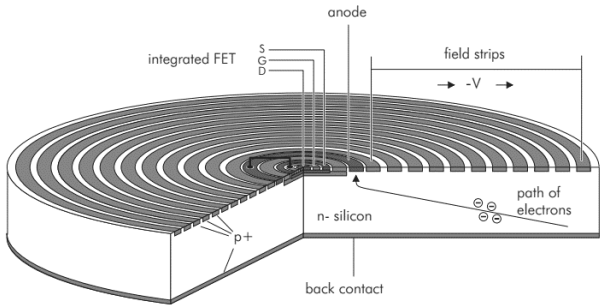
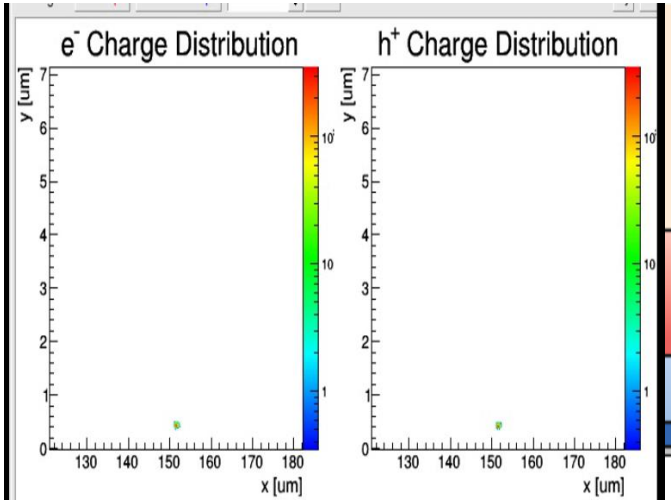
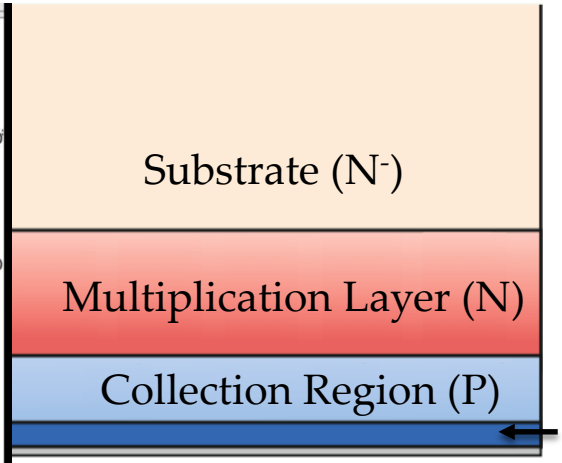
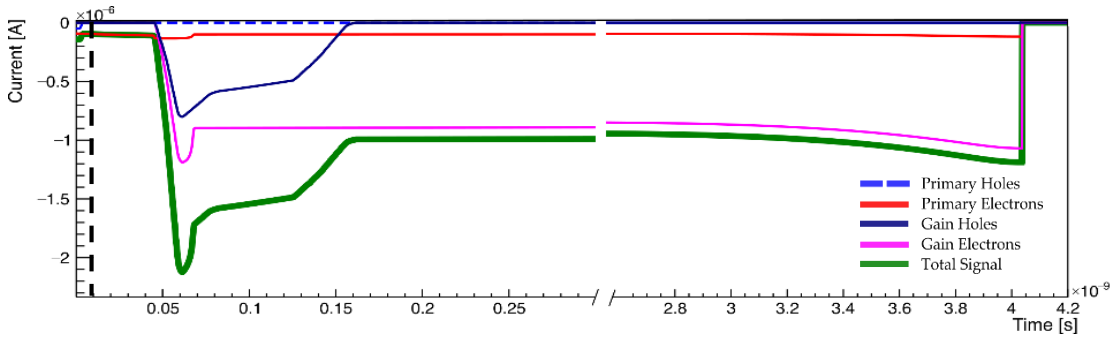


*Image Courtesy of M. Simpson

Signal Shape (Weightfield2 Simulation Video)





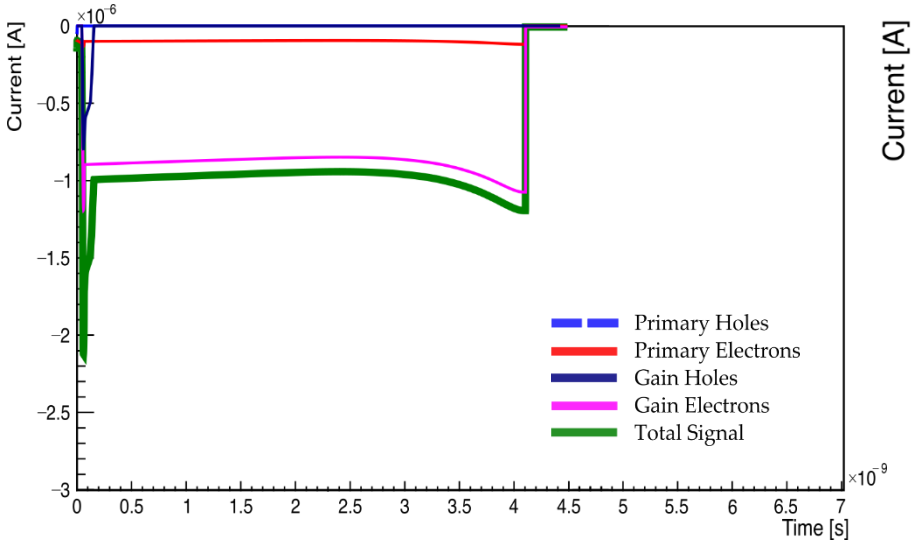


*Watch in slide show mode for proper animations

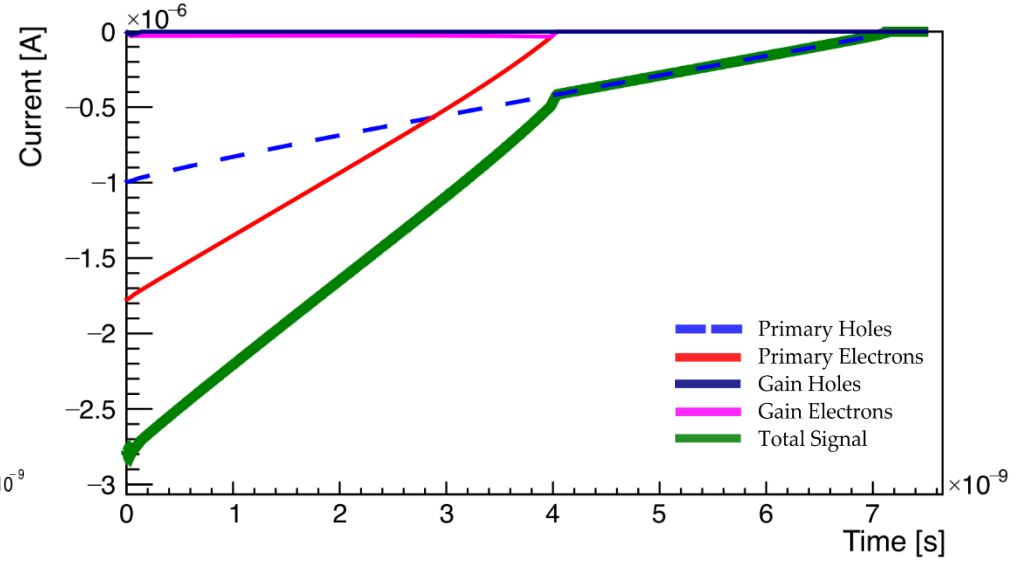
Assuming a gain of 10

Signal Comparison (Weightfield2 Simulation)

15 keV Proton



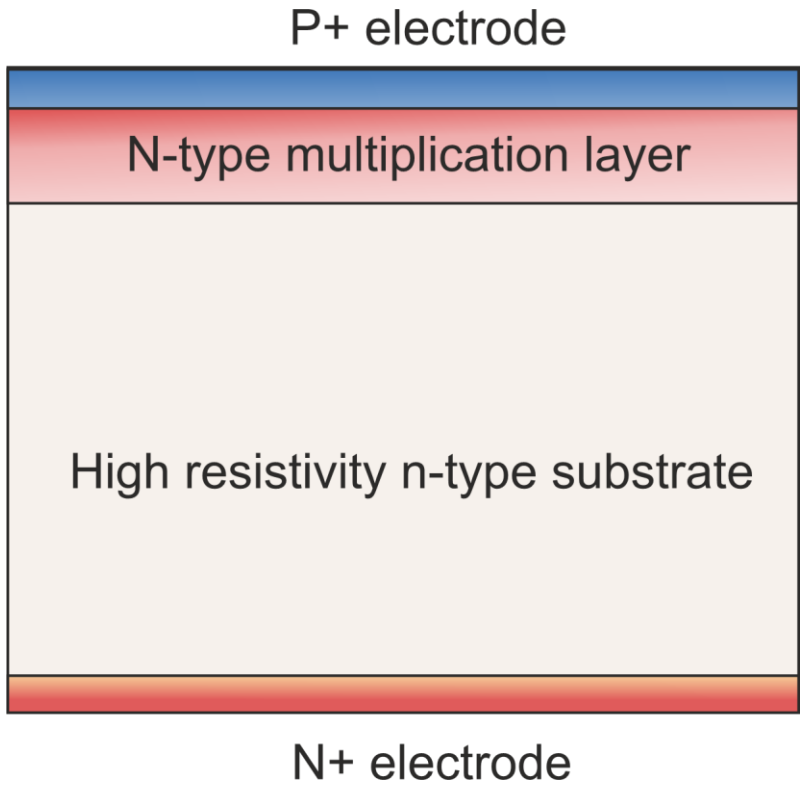
Minimum Ionizing Particle (MIP)



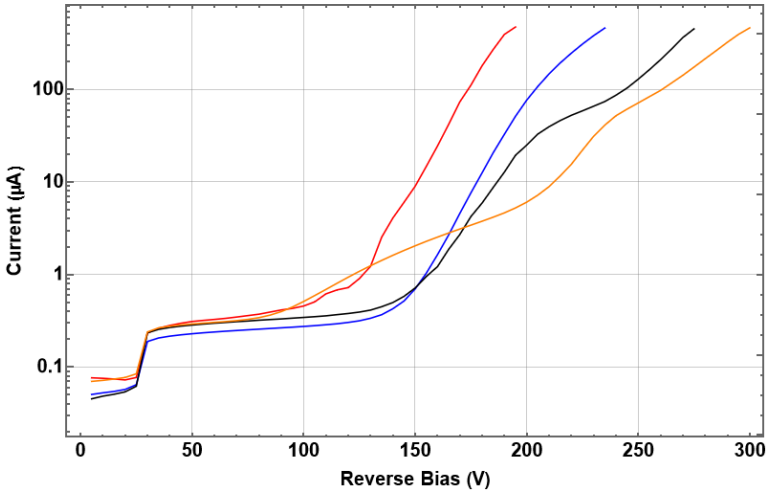
Behaves like a planar sensor for MIPs

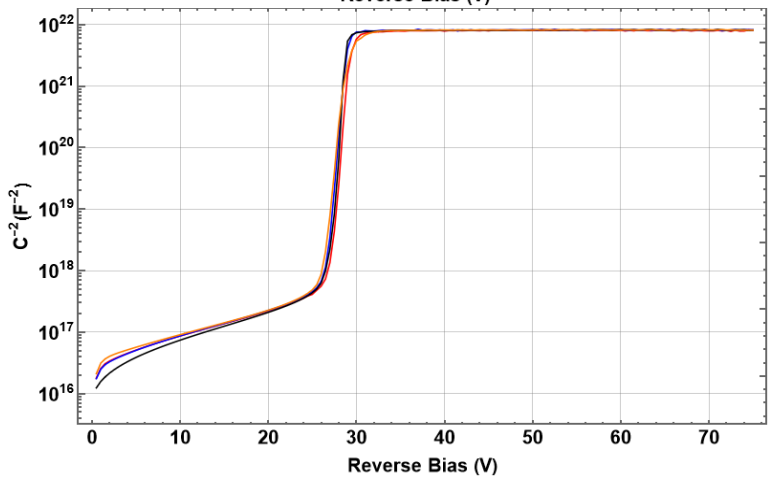
First Production Run for Proof of Principle

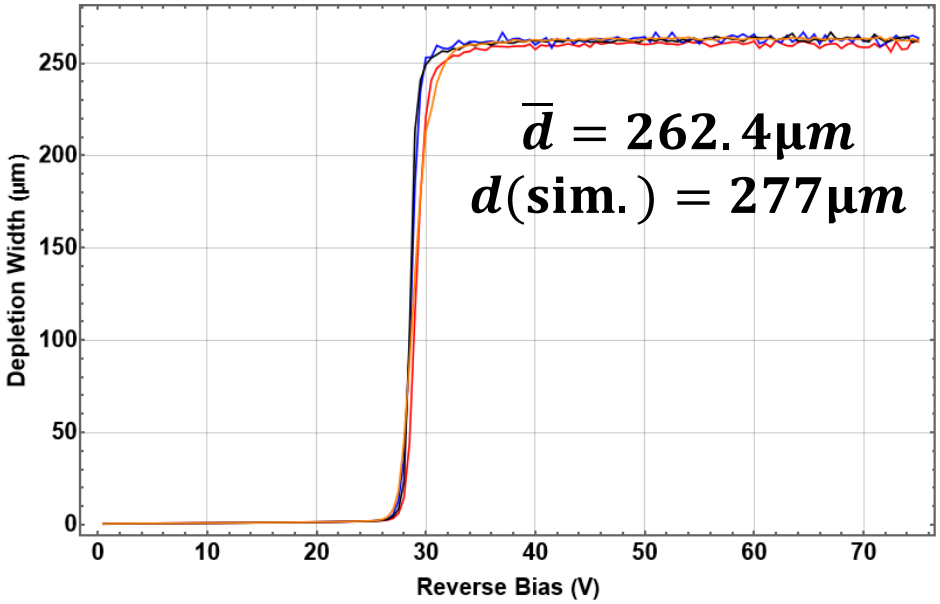
- 4 diodes (5.3x5.3 mm^2, single channel) from 1st Production run chosen
  - No collection region in the first run
  - A reverse polarity iLGAD with thin backplane, unstructured entrance window, and shallow multiplication implant
- IV and CV measurements conducted
- TCT measurements to follow
- Will provide proof of principle
  - Collection region will be introduced in the next production run



Characterization of First Production Run (without collection layer)



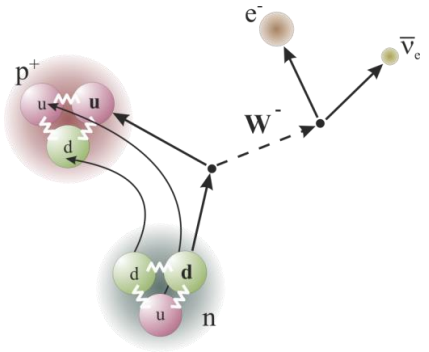




- **Stable performance** at low bias voltage
- **Full depletion** achieved at **~35V**
  - **Agreement** with **TCAD simulations**

Applications for Low Energy Physics

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



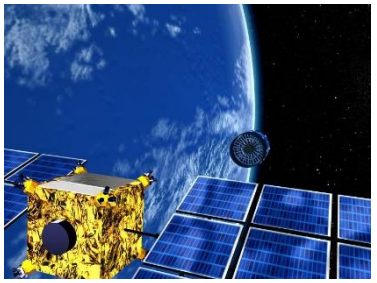


*Image Credit: ESS

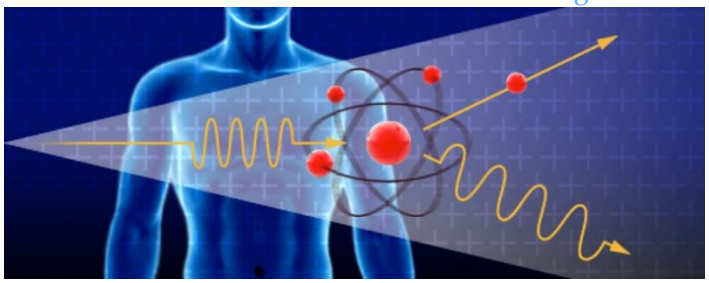
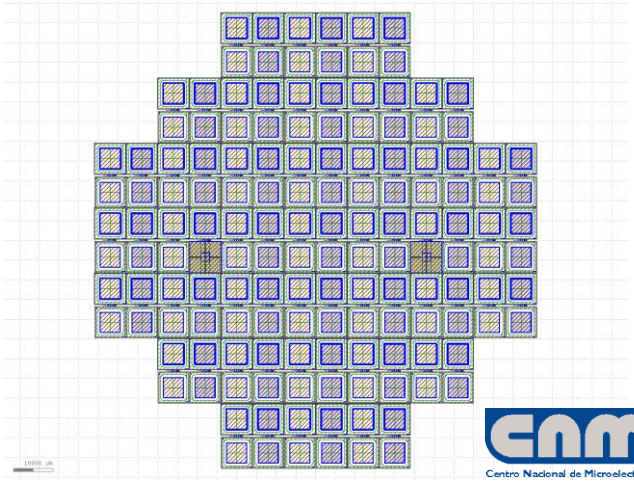
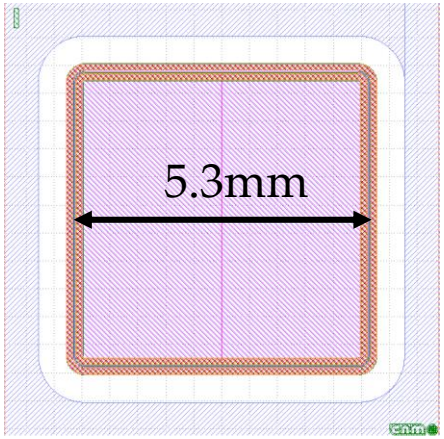


*Image Credit: McGill Medical Physics

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