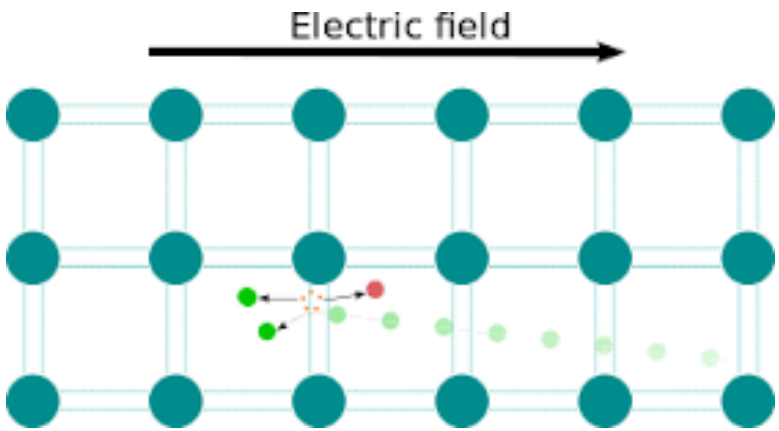
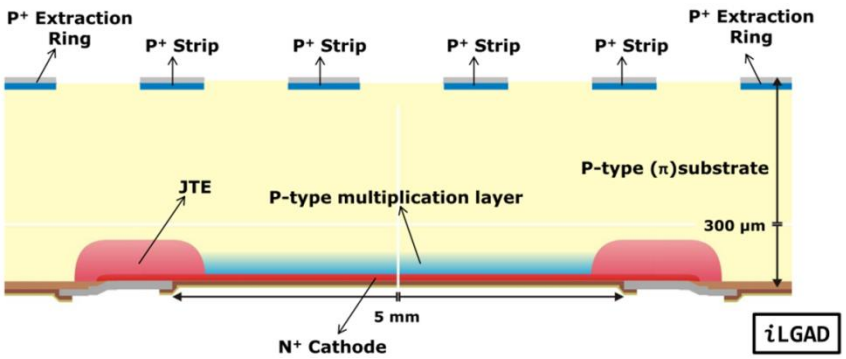
Update on the I-LGAD characterization





RD50 Workshop, CERN November 22th, 2016

Iván Vila
Instituto de Física de Cantabria (CSIC-UC)

The Team

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CERN

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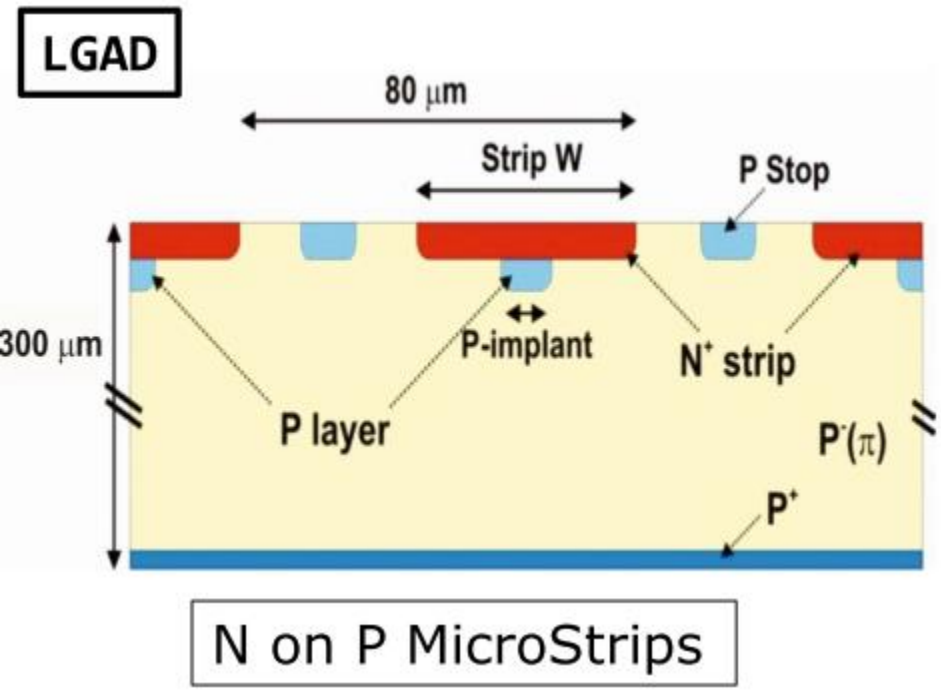
IMB-CNM (CSIC)

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

Outline

- Strip LGAD (n-in-p) & Inverse LGAD (p-in-p)
- I-LGAD Electrical characterization.
- I-LGAD Transient Current Characterization.
- I-LGAD Test beam characterization: initial results.
- Summary and outlook.

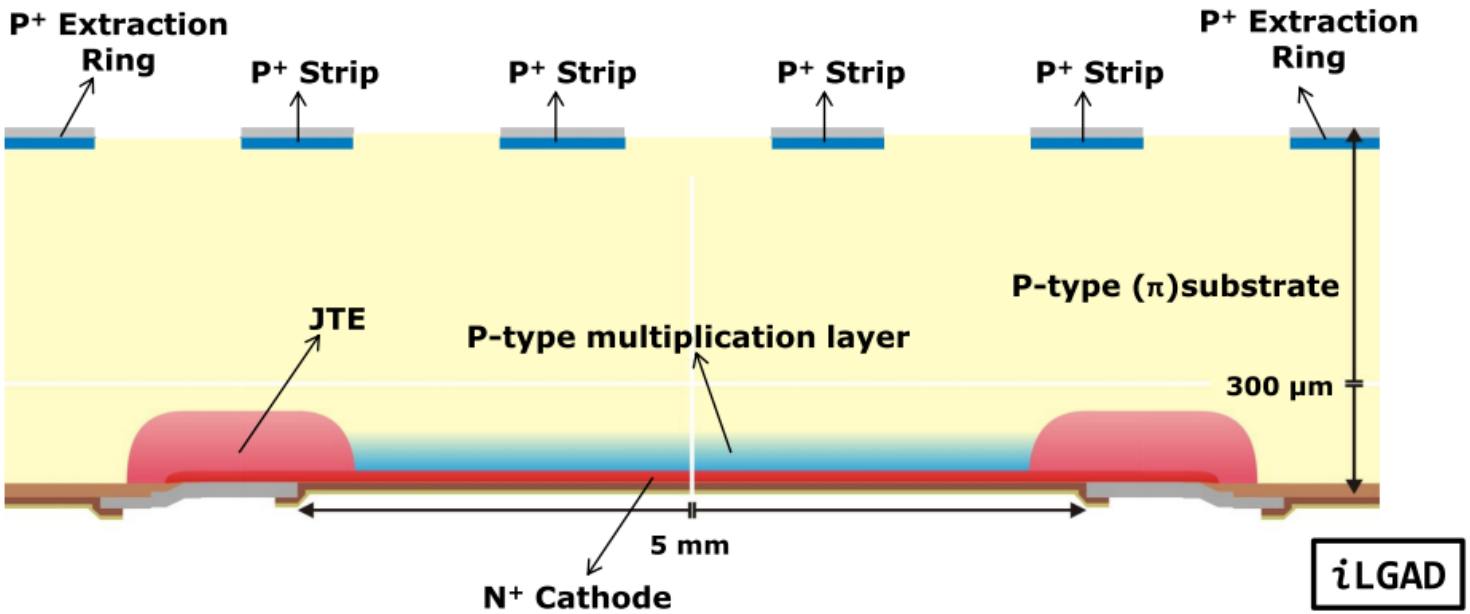
Strip LGAD (CNM run #7859)



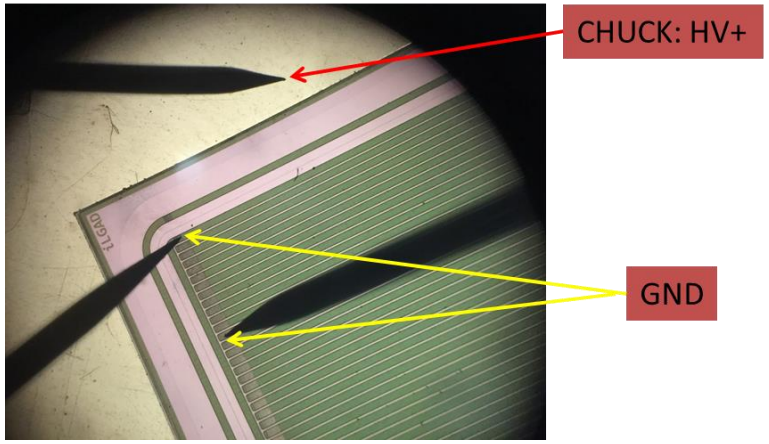
Full TCT characterization including detailed gain spatial mapping (presented at Trento Workshop 2016 & Torino RD50 Workshop)

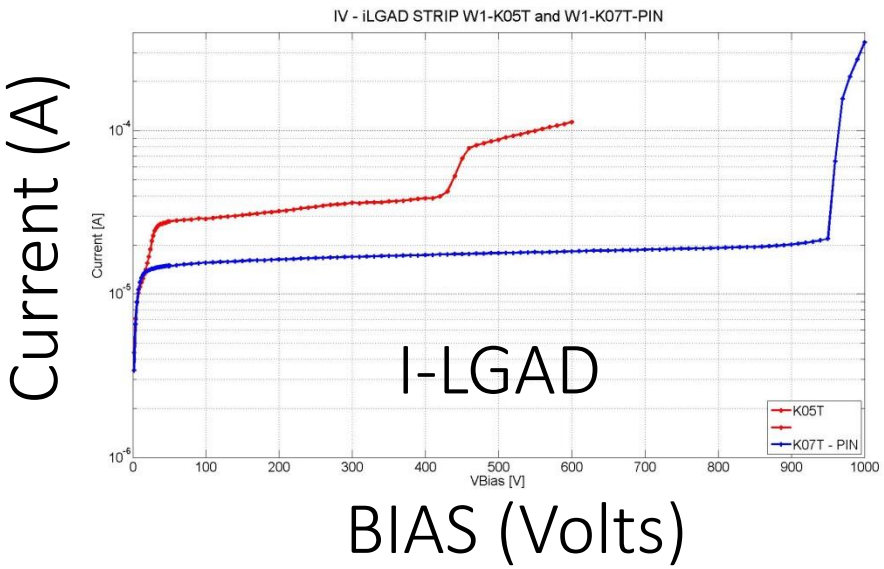
Inverse- LGAD (CNM run #8533)

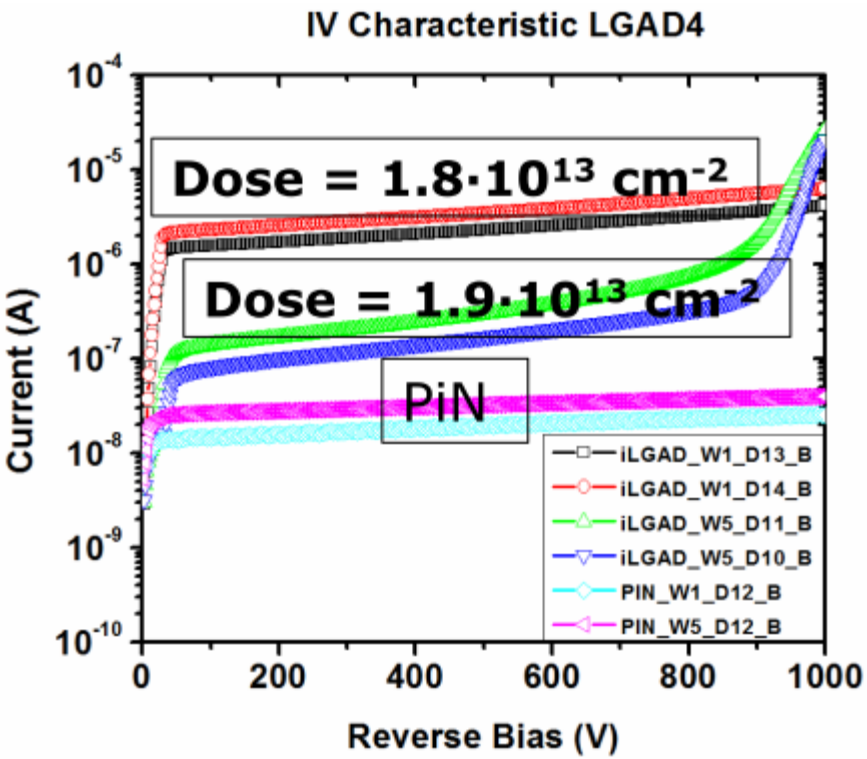
- P-in-P LGAD with hole readout (ohmic contact segmented)
- W1-K037 STR.45.160.8000.06.12



I-LGAD: Electrical Characterization



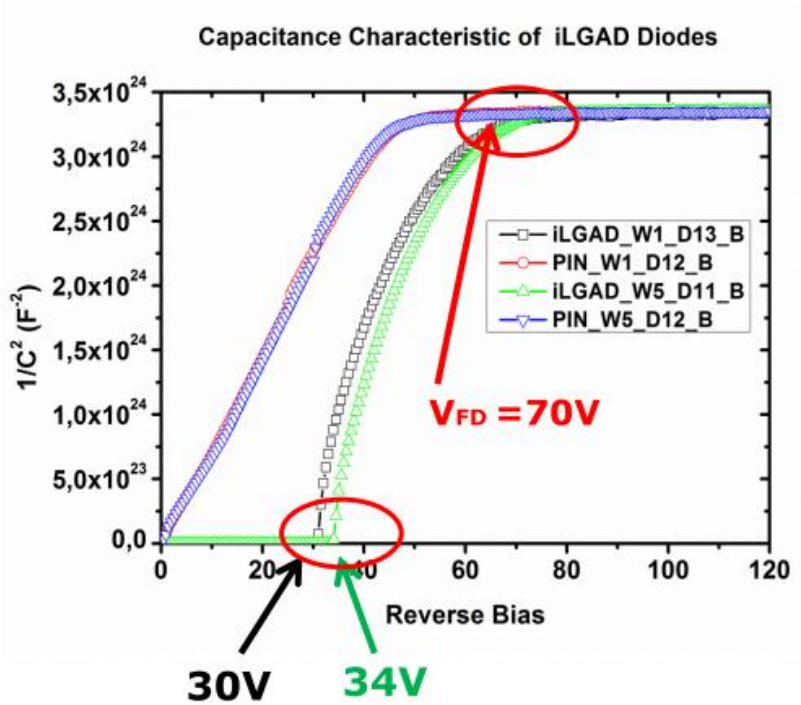


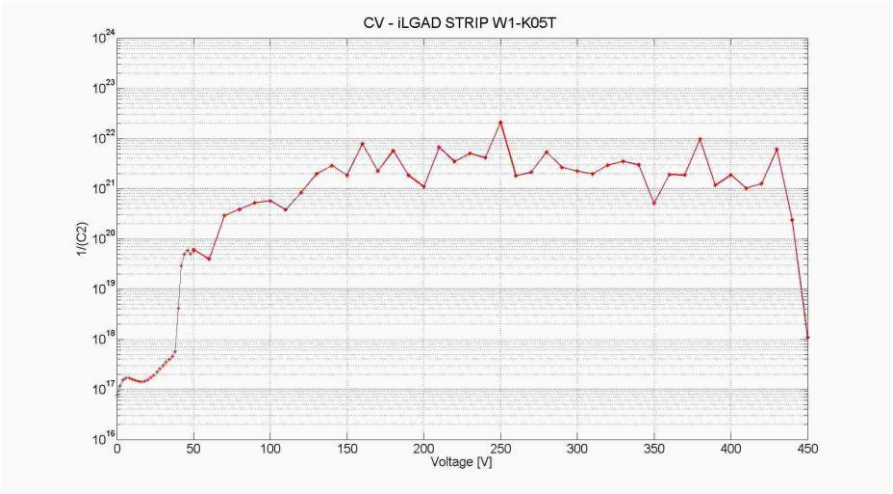


PAD DIODE

Inverse-LGAD: CV

– PADs vs I-LGAD depletion

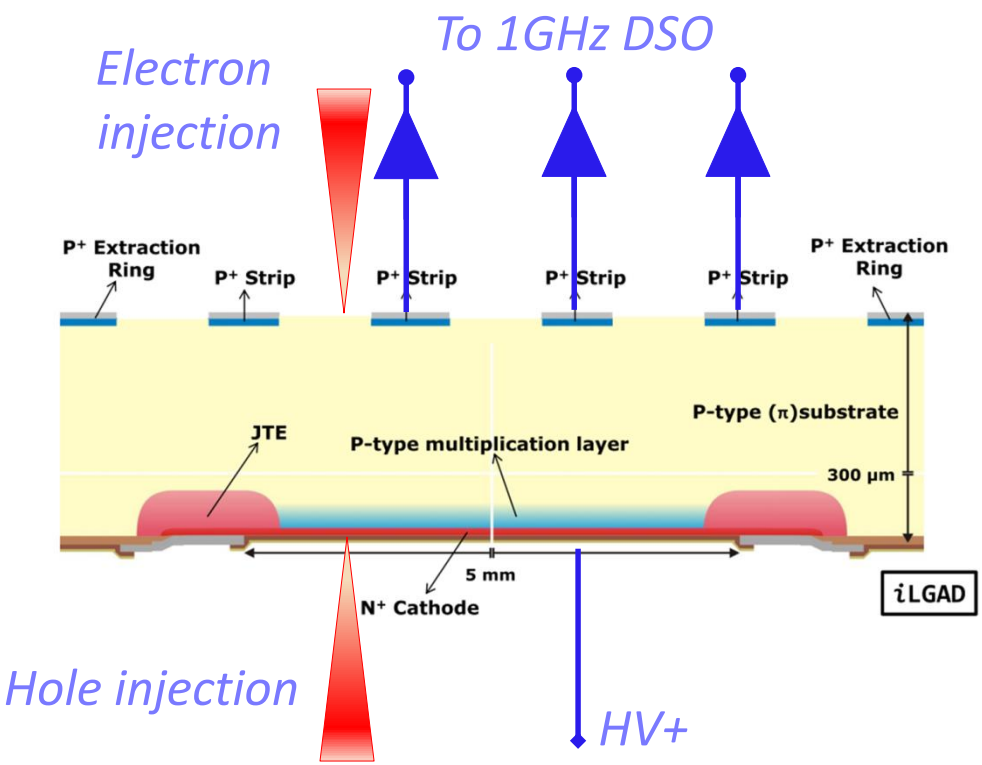




TCT Electron injection

Multi-channel TCT on DC strips.

– I-LGAD (r#8533) manufactured as DC mini sensors

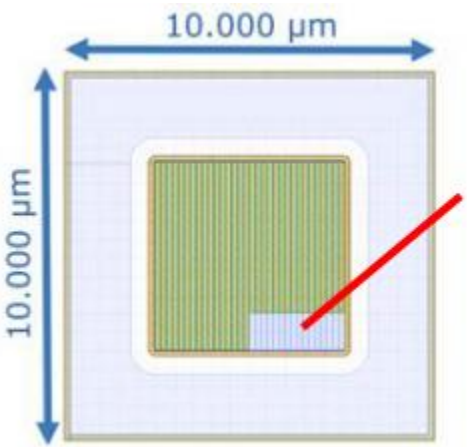


Simultaneous transient current acquisition (up to three strips)

Electron/hole injection (670nm red laser back-side illumination)

Inverse-LGAD TCT: Electron injection

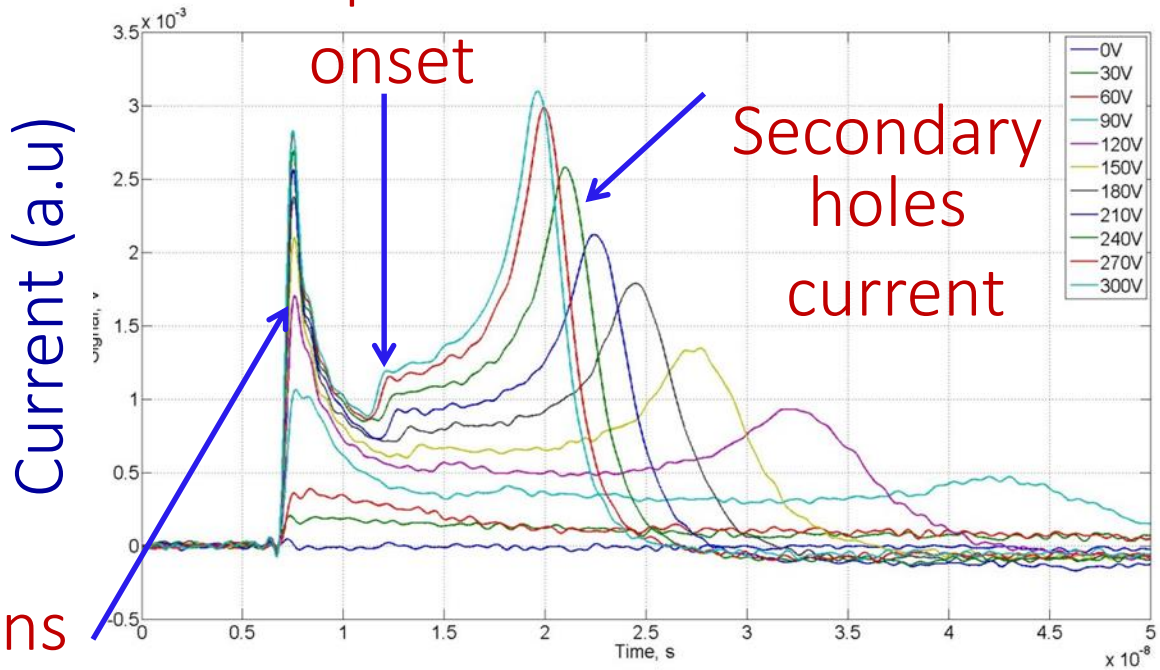
first observation of signal amplification (presented at Torino RD50)



Primary electrons current

Multiplication onset

Secondary holes current

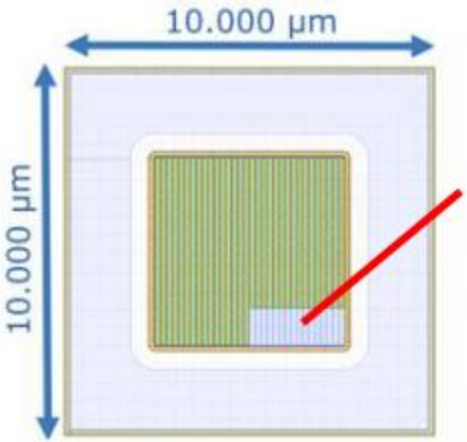


Current (a.u)

Time (ns)

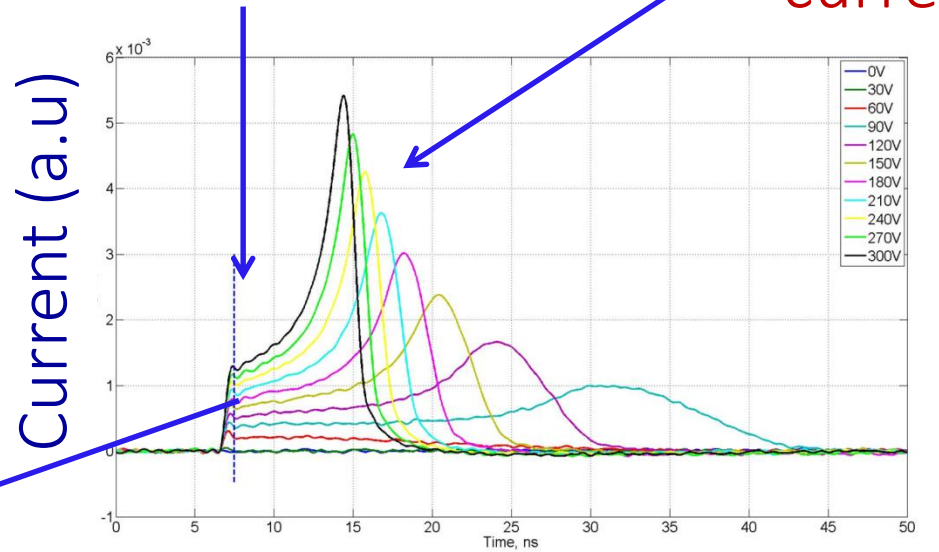
– Electron injection (FRONT SIDE !)

Inverse-LGAD TCT: Hole injection
first observation of signal amplification

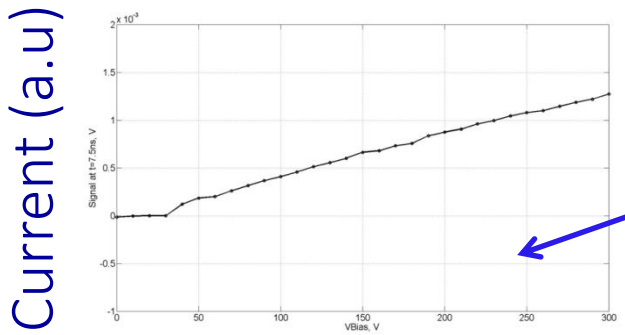


Multiplication onset

Primary & secondary hole current



Time (ns)



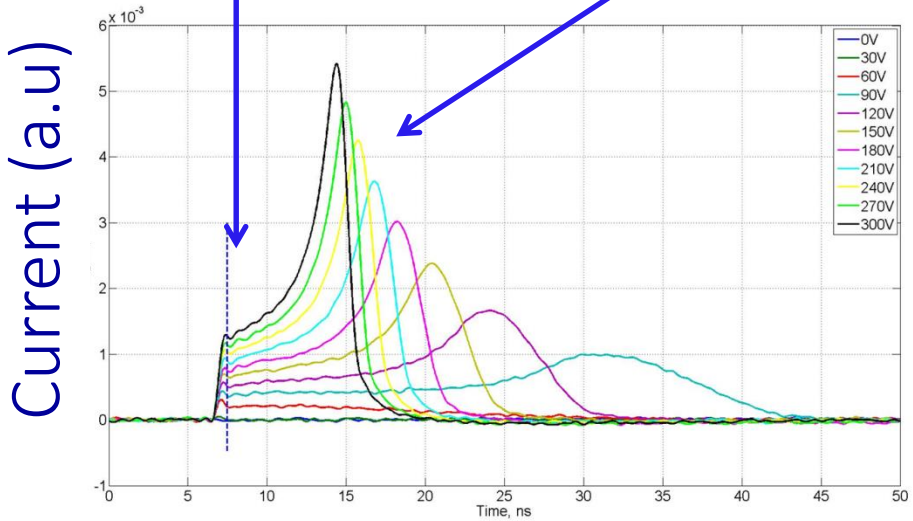
Vbias (ns)

– Hole injection (BACK SIDE !)

Inverse-LGAD TCT: Hole injection
Collectec charge vs. Vbias

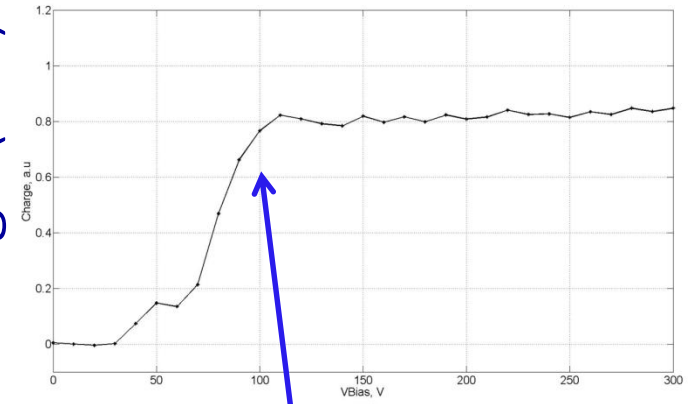
Multiplication onset

Primary & secondary hole current



Current (a.u)

Time (ns)



Charge (a.u)

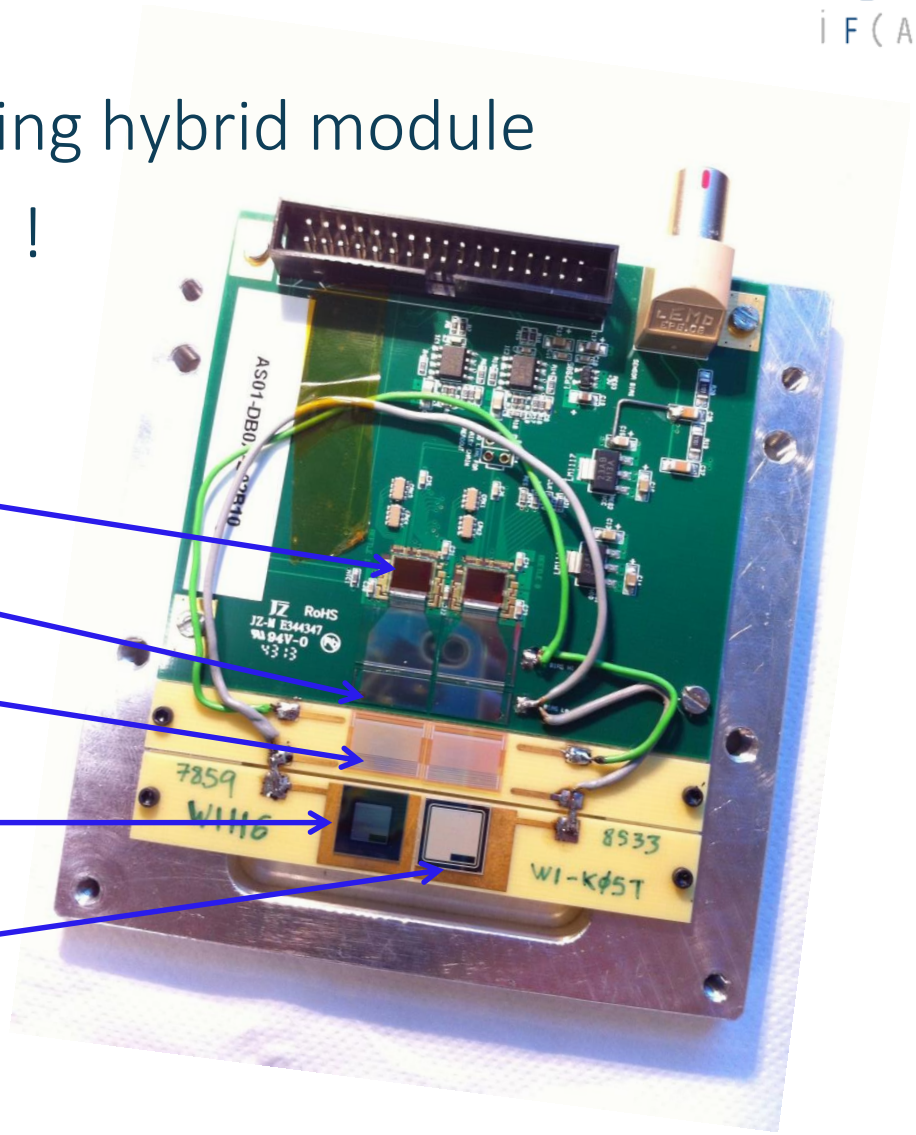
Vbias (ns)

Coherent with CV characterization

Inverse-LGAD Test Beam testing.

First ever multi-channel tracking hybrid module

Based on I-LGAD & Strip LGAD !



Beetle ROC

Fan in DC

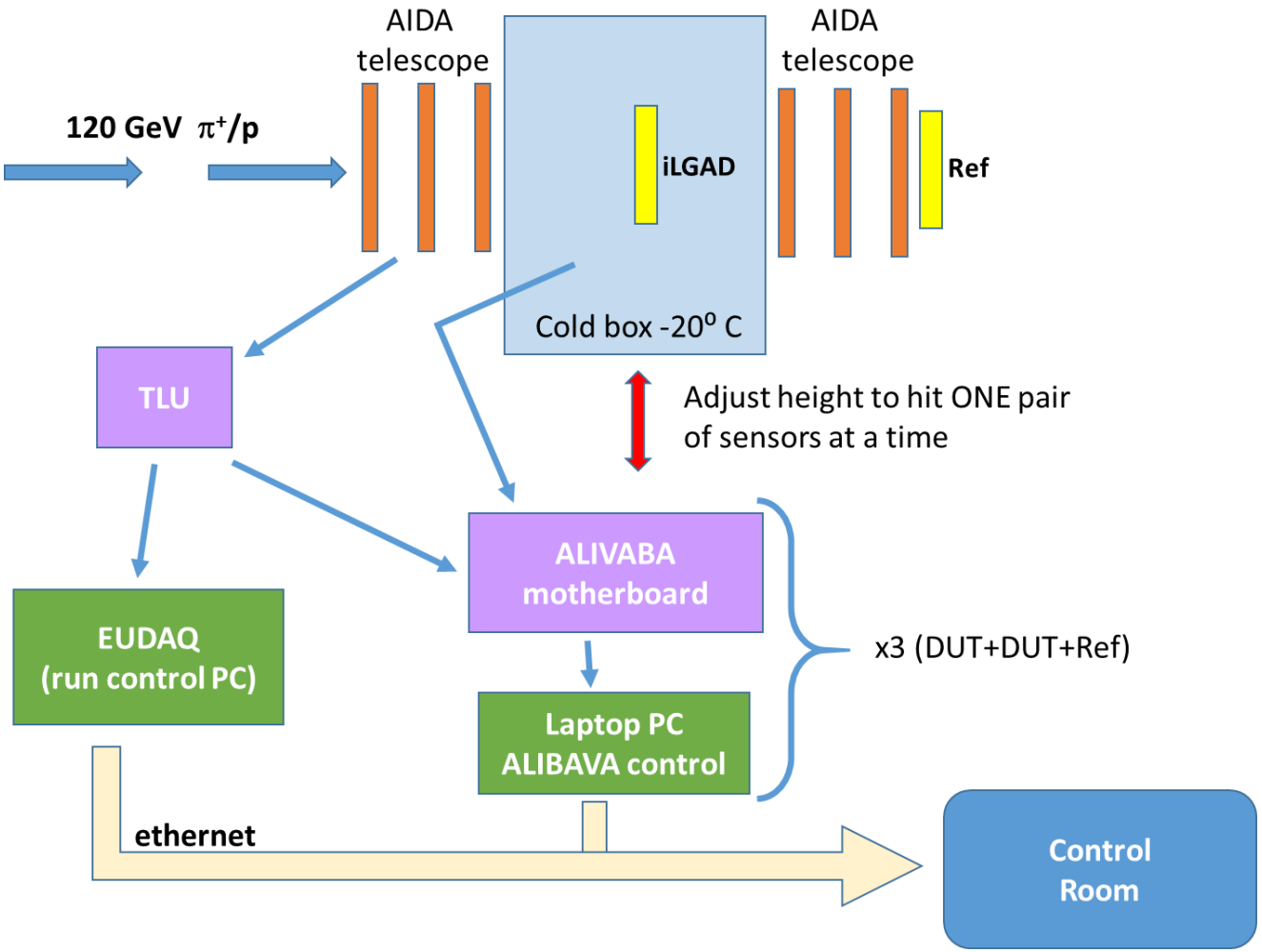
Fan in AC

Strip LGAD

I-LGAD

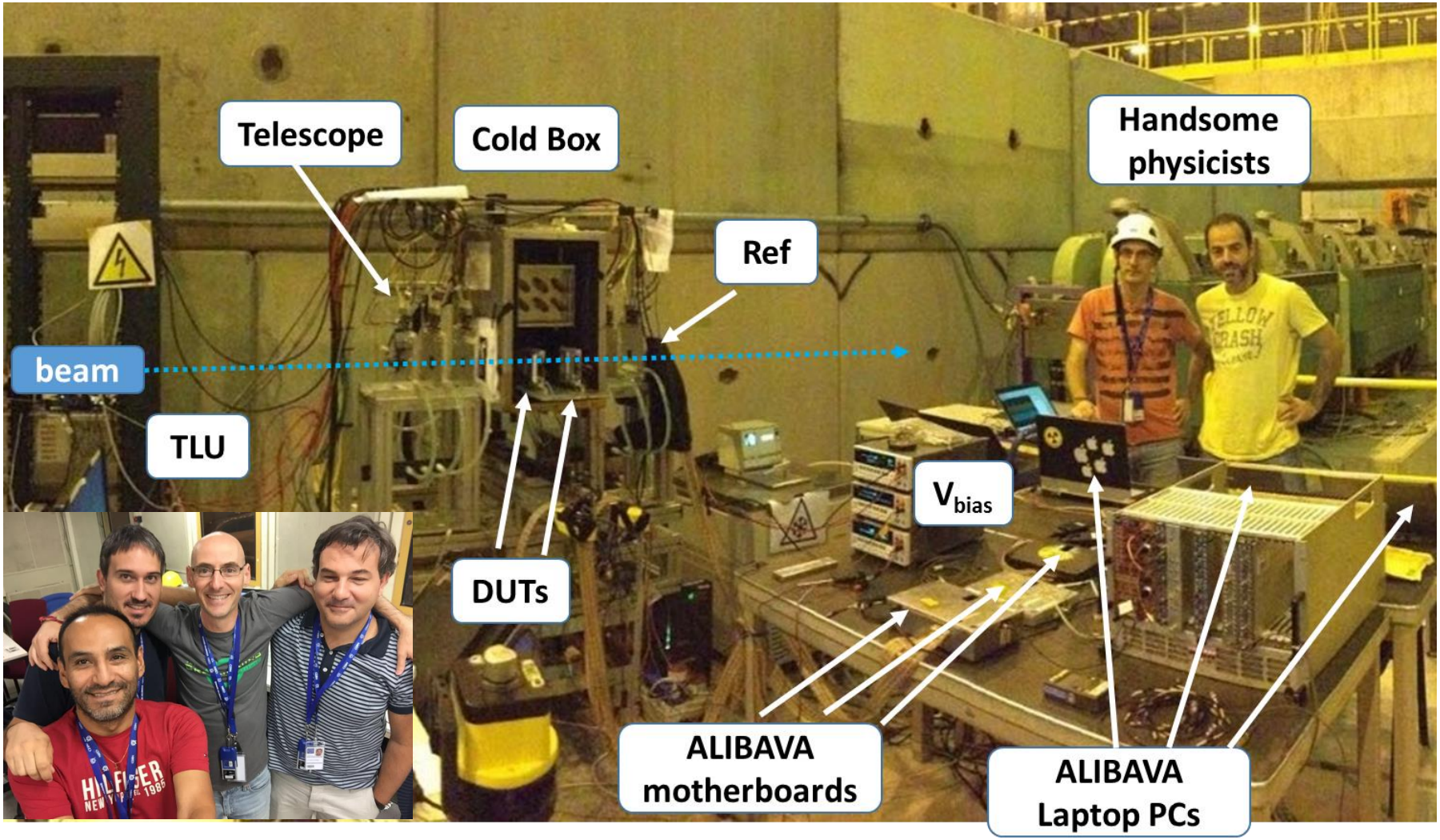
(8533W1K05T, 45 strips
160 mm, non-irradiated)

Inverse-LGAD TB: AIDA-2020 WP7 Setup AKA as Atlas ITK setup ☺



This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

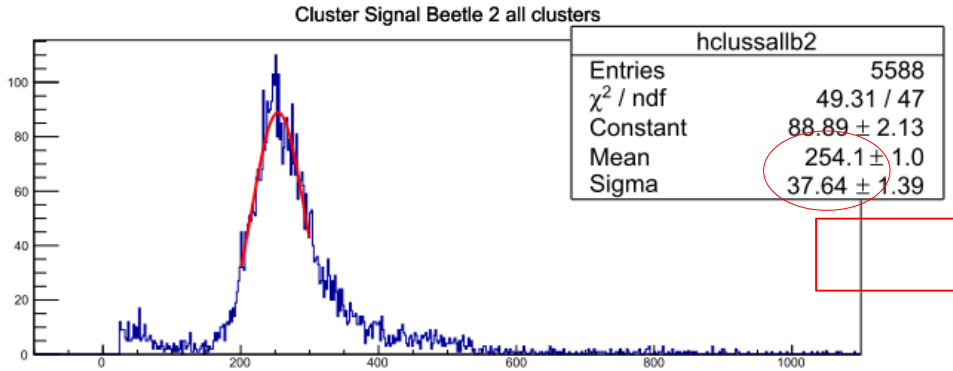
Inverse-LGAD TB: Set-upo



Inverse-LGAD TB: Gain determination

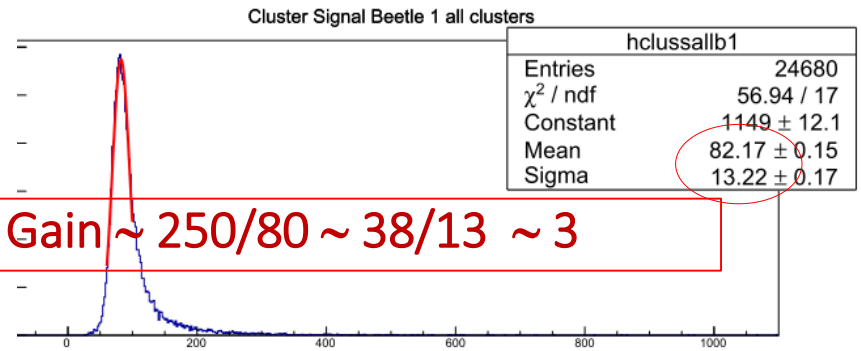
- Gain ≡ Charge Most Probable Value I-LGAD/ MPV Reference PIN
- Reference sensor and I-LGAD same thickness

I-LGAD
(Room temp. 400 Volts)



Cluster Charge (arb. Units)

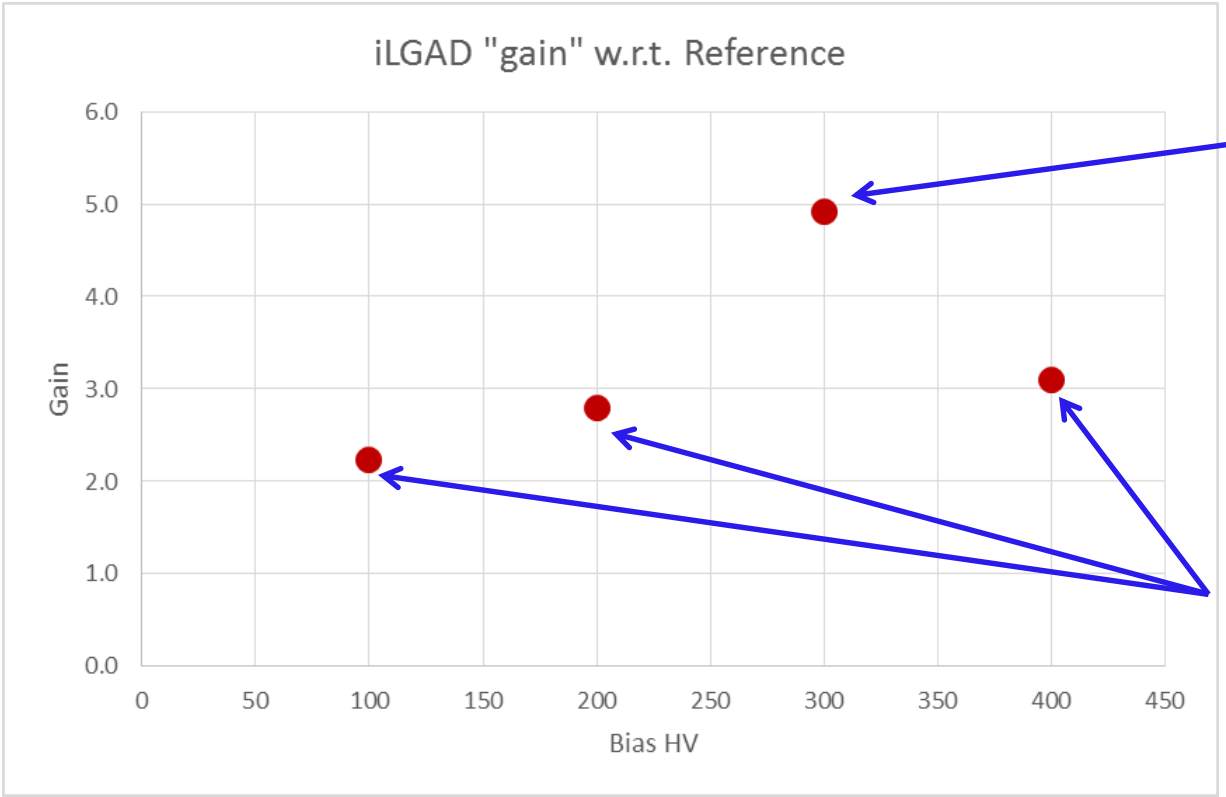
Standard Strip
(Room temp. 200 Volts)



Gain ~ 250/80 ~ 38/13 ~ 3

Cluster Charge (arb. Units)

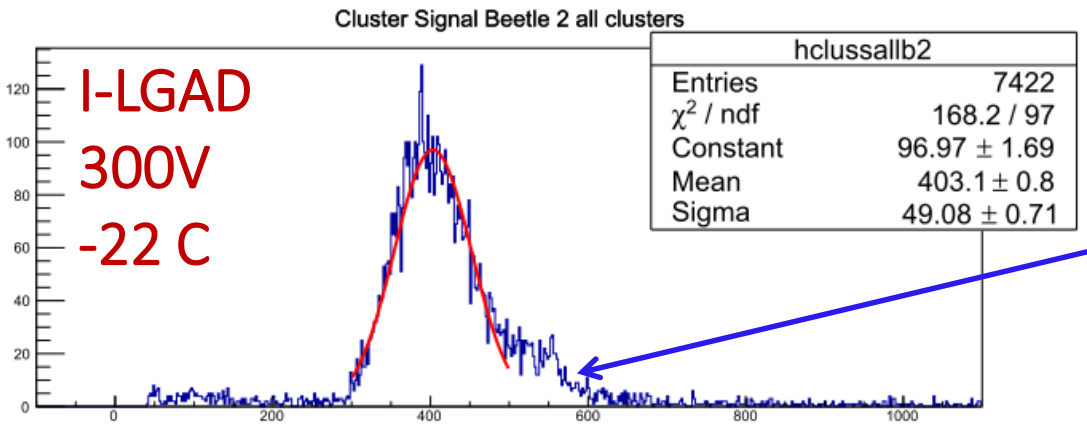
Inverse-LGAD TB: Gain vs V_{bias}



@ -22 C

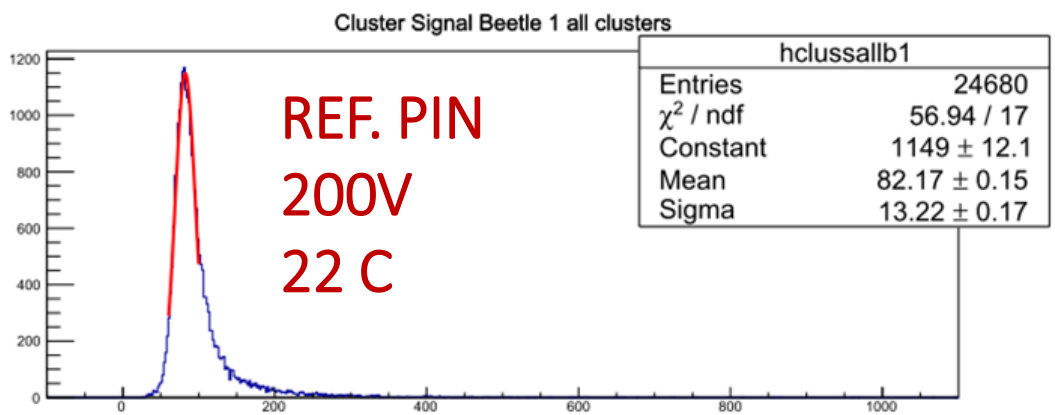
@Room temp.

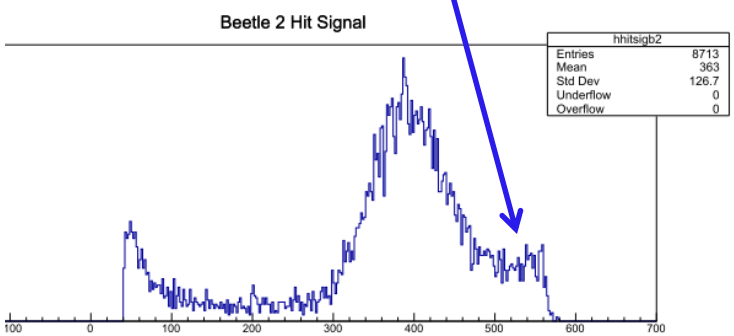
Inverse-LGAD TB: Charge spectrum shape @ -22 C



Spectrum shape modified by sub-optimal front-end

Sharp drop in charge spectrum originated by ADC saturation





Summary

- First I-LGAD based hybrid module for tracking.
- Test beam at SPS (AIDA-2020) with Alibava readout (non-optimal for relatively large gain regimes).
- Very preliminary results confirm typical LGAD characteristics: signal amplification, gain vs Vbias dependence, etc.
- A very large increase of the gain ~ 66% observed in the gain at expected detector cooling temperatures (around 20 degrees).
- Tracking and proper treatment of noise in progress

Outlook (borrowed from Salva)

– First promising steps towards a very high-precision tracking detector with built-in timing but still… a road full of bumps ahead, that is, plenty of fun.

- **Double Side** Technological Process
- Using **4 inch** Wafers

- **Higher** Active Area. **6 inch** Wafers

- **Lower** Pitch Size. 50 µm
- **Thin** Devices (< 200 µm)
  - ✓ **SOI, SOS** Wafers
  - ✓ **Timing** Applications
- **Radiation Hardness**
  - ✓ **Gallium** Implantation
  - ✓ **Carbon** Doping

- **AC** Design
  - ✓ **Polysilicon** Layer
  - ✓ **1-2 Additional Mask** Levels

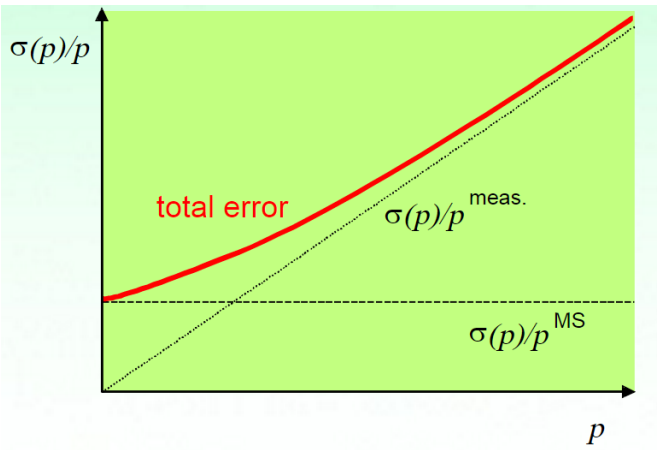
- **More Complex** than **3D** Fabrication Process

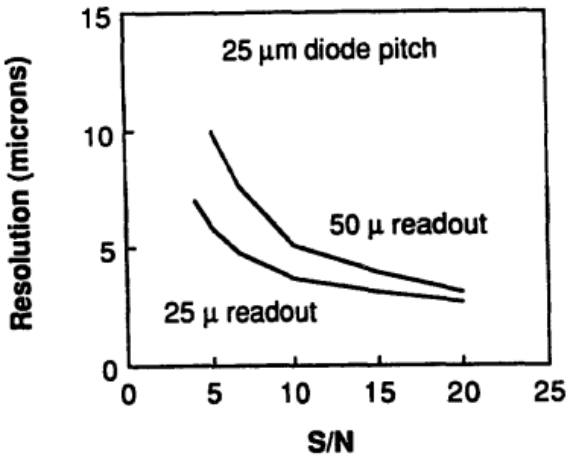
THANK YOU!

Special thanks to Florentina Manolescu (bonding lab), Federico Ravotti (irrad facility), Esteban Currás and Sofia Otero (SSD)

Motivation for a strip detector with integrated signal gain

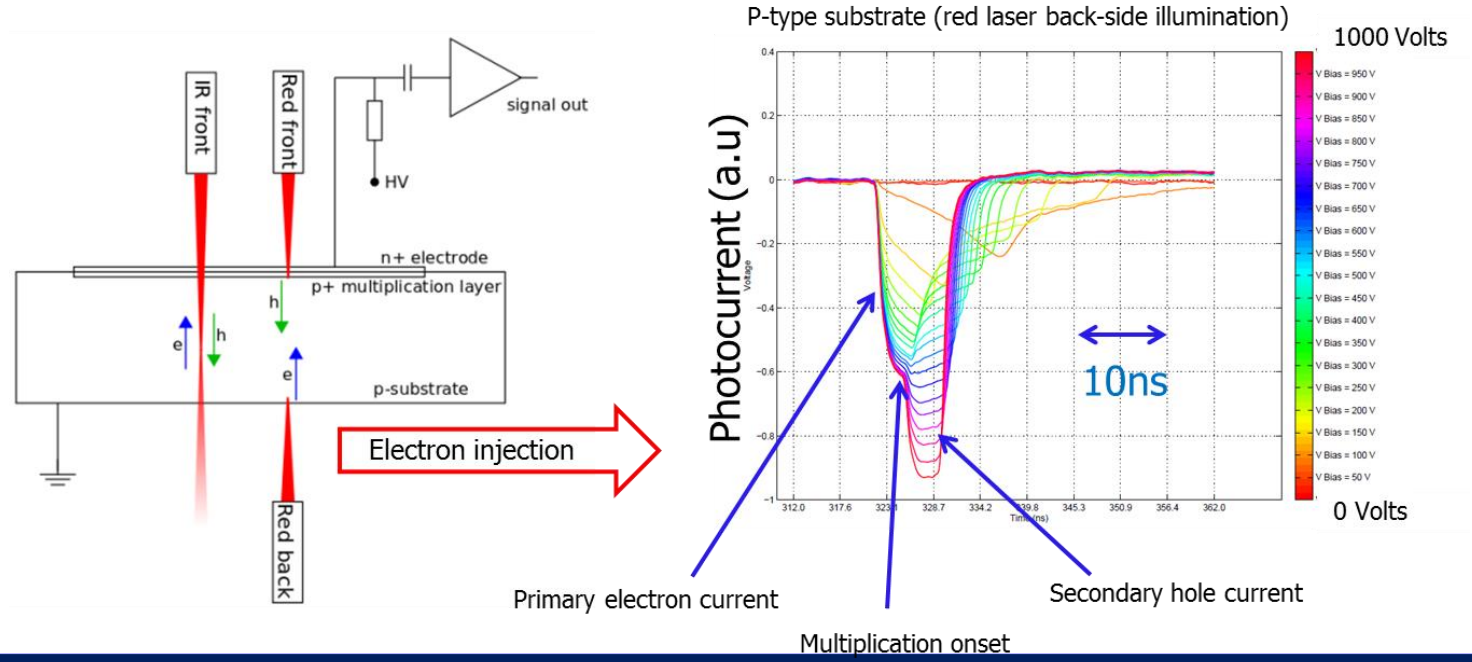
- Integrated signal amplification increases the Signal-to-Noise ratio increasing the tracking resolution:
  - Thinner detectors (reduction of the **multiple scattering**)
  - Improved **intrinsic hit resolution**.





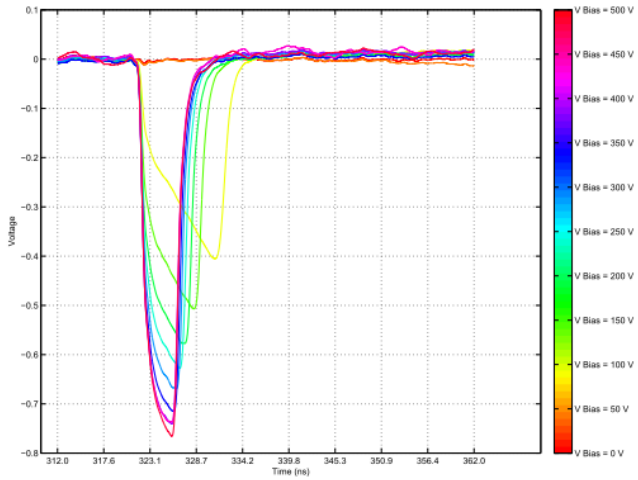
Methodology: Signal amplification footprint

- Distinct signature of signal amplification.
- Injections of electron into the anode: resulting transient current is a sequential contribution of primary electrons reaching the amplification layer and secondary holes drifting towards the anode.

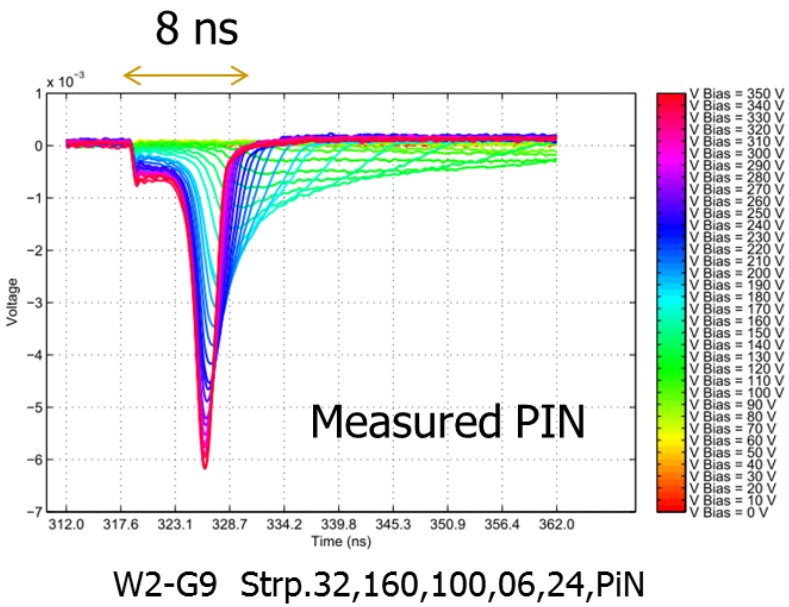


Transient currents: pad vs microstrips

– Transient current waveform shape dominated by weighting field (peaked at the collecting electrode):



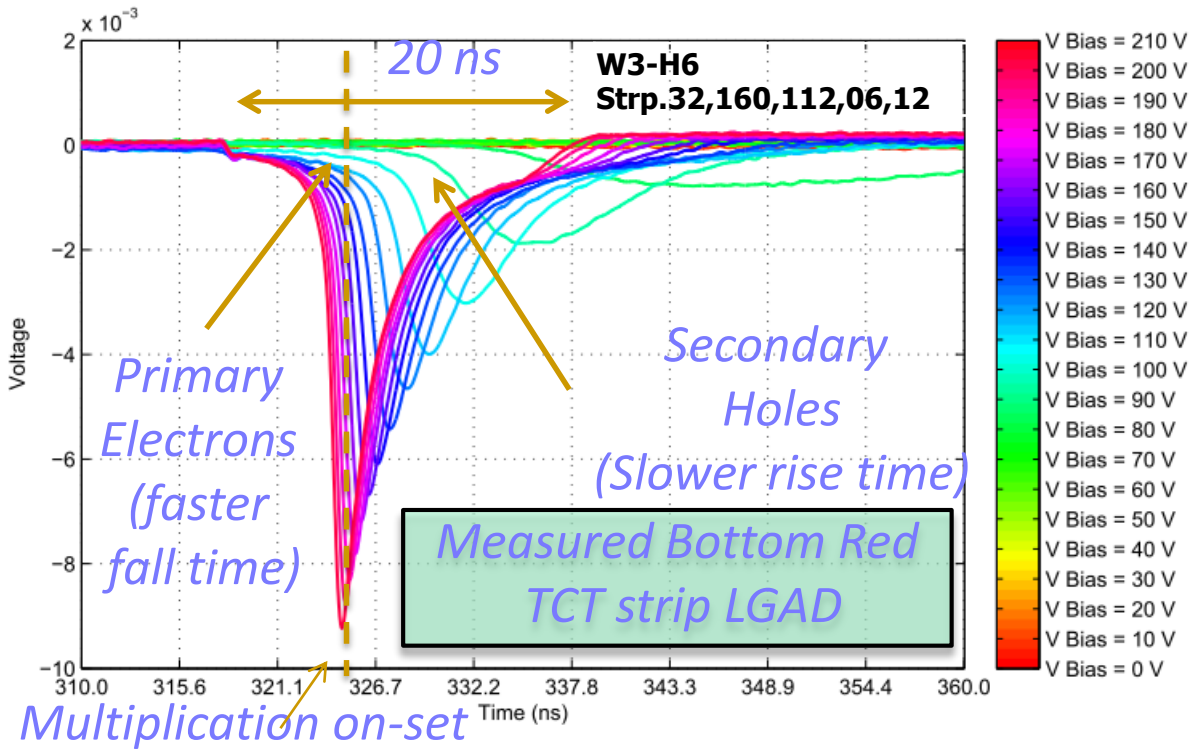
Pad like diode

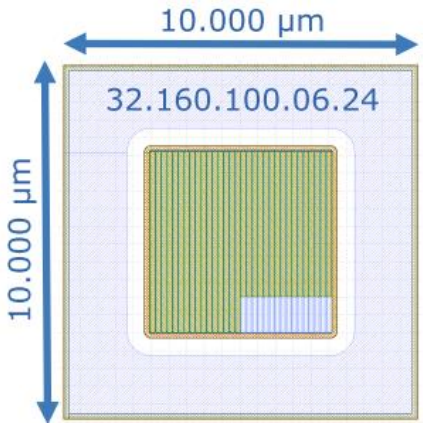


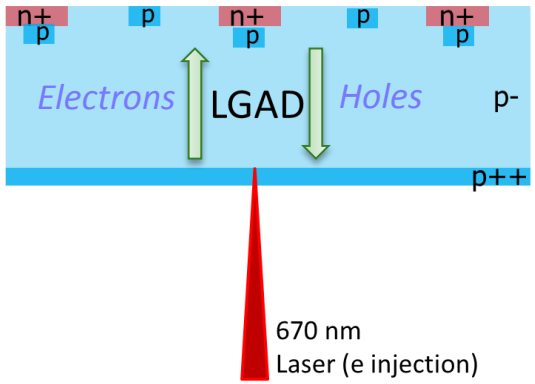
microstrip diode

LGAD strip: electron injection

- Signal gain observed:
  - Wider TCT pulses wrt to PIN
  - Charge increases vs HV
- Strip current waveform shows clear sequential electron and hole drift

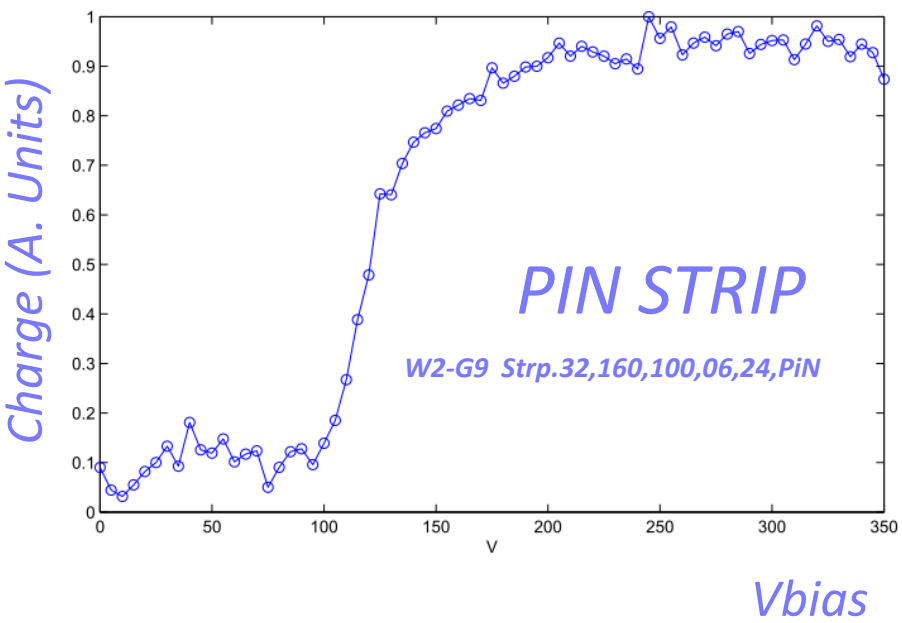


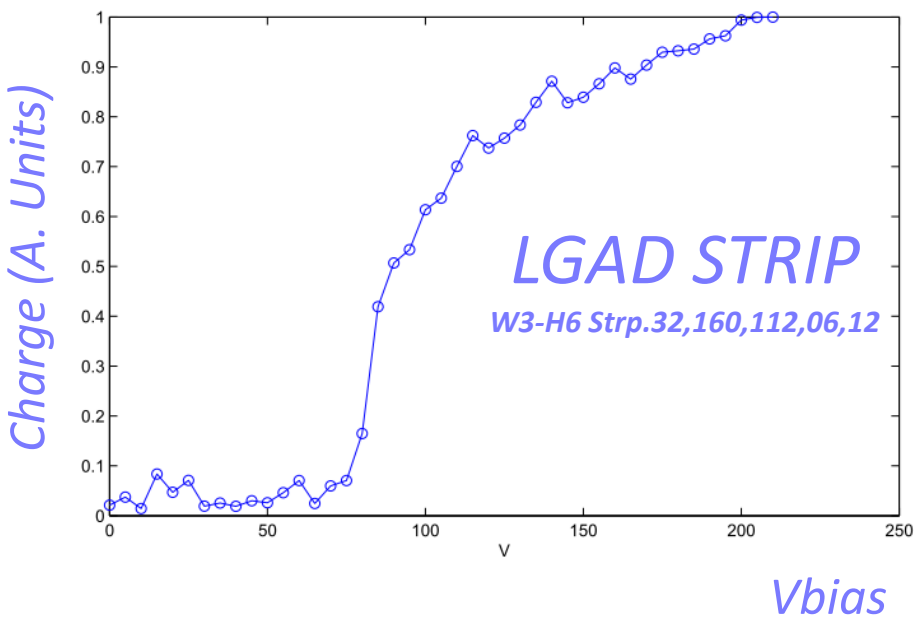




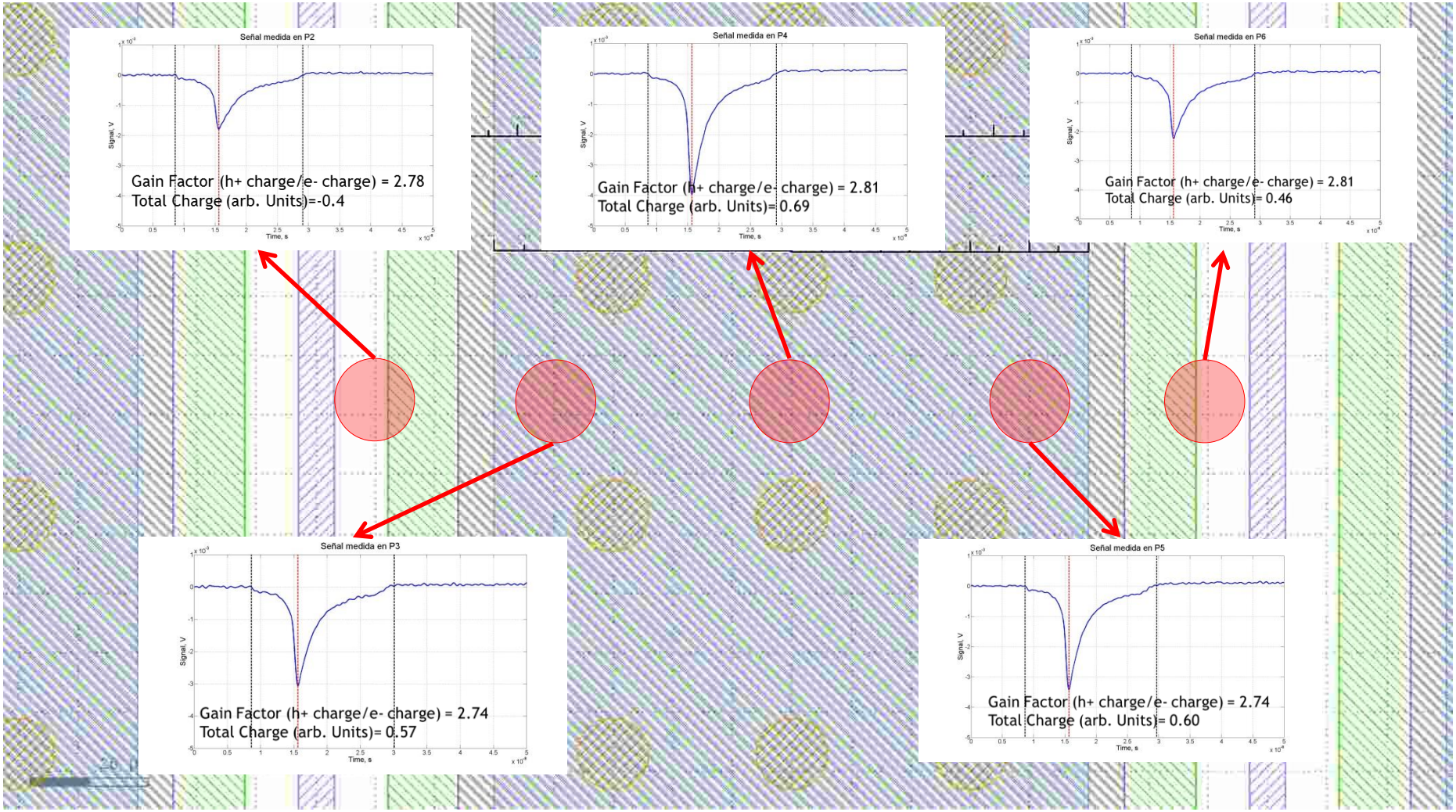
LGAD Strip: Signal vs V_{bias}

– Red laser, bottom TCT, electron injection (Integrated current transient curves)



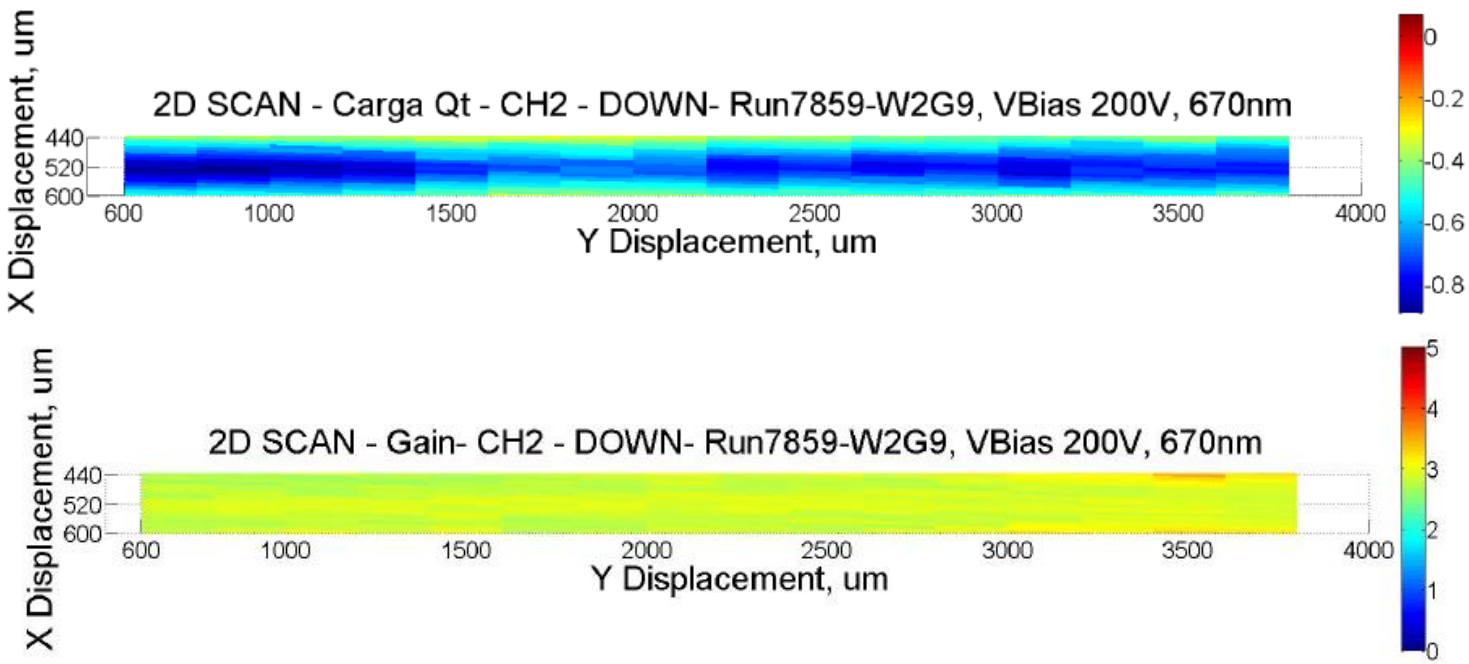


Strip LGAD: Gain Factor Uniformity:



Strip LGAD: Mapping the strip gain (1)

– Raster scan: electron injection into the anode at each point of the strip collecting charge back side area (+-80um around the strip center)



CHARGE MAP

GAIN MAP

Strip LGAD: Mapping the strip gain (2)