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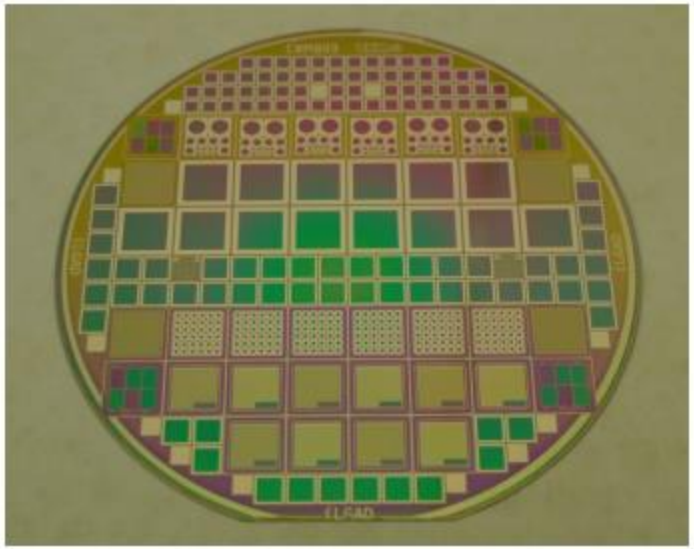
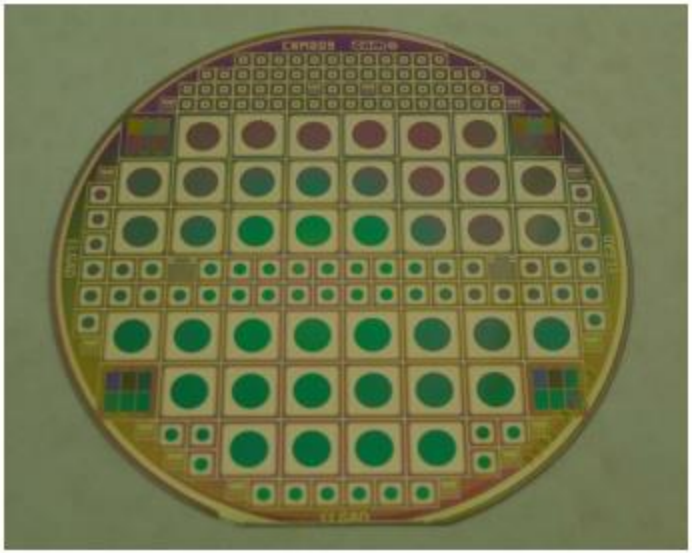
Developed inside the RD50 collaboration & AIDA -2020 WP7 on Advanced Hybrid Detectors.

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

In-depth study of Inverse-Low Gain Avalanche Detectors





Tredi 2017, Trento, Feb 2016

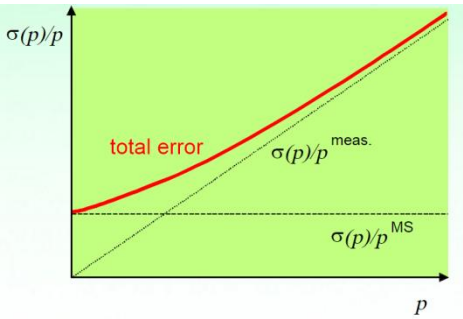
Iván Vila
Instituto de Física de Cantabria (CSIC-UC)

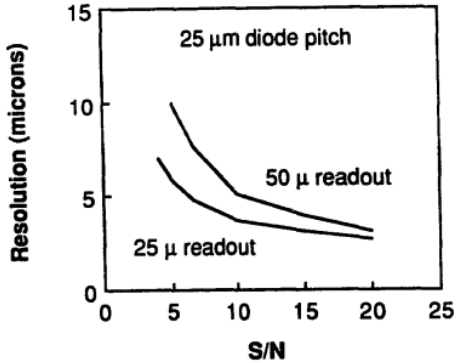
Outline

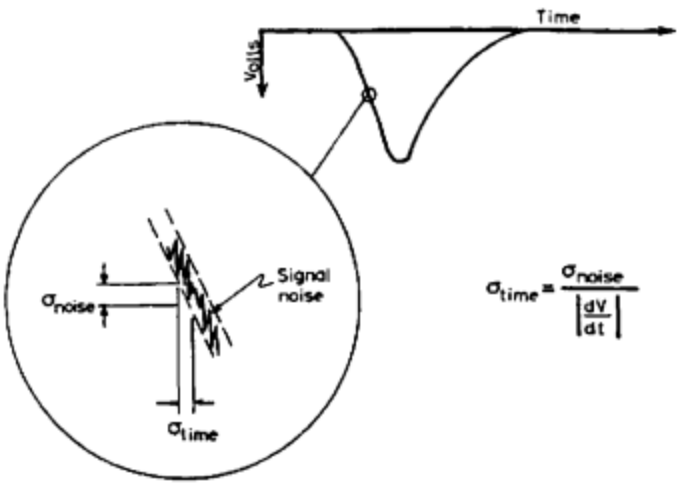
- Introduction to the Inverse-LGAD Concept
- Electrical characterization.
- Laser characterization:
  - TCT (Red & IR transient currents)
  - CSA (Beetle ROC).
- MIP characterization (test beam at SPS).
- Summary and outlook.

Motivation:

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



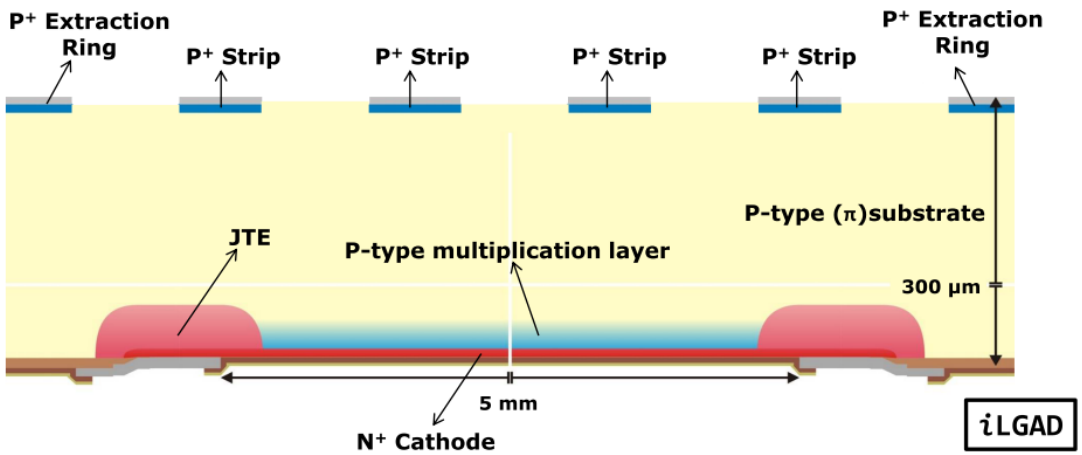




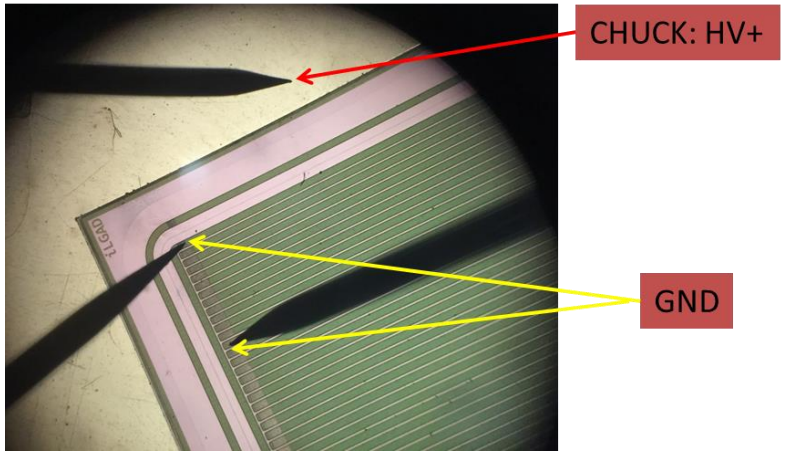
Prototype description (CNM run #8533)

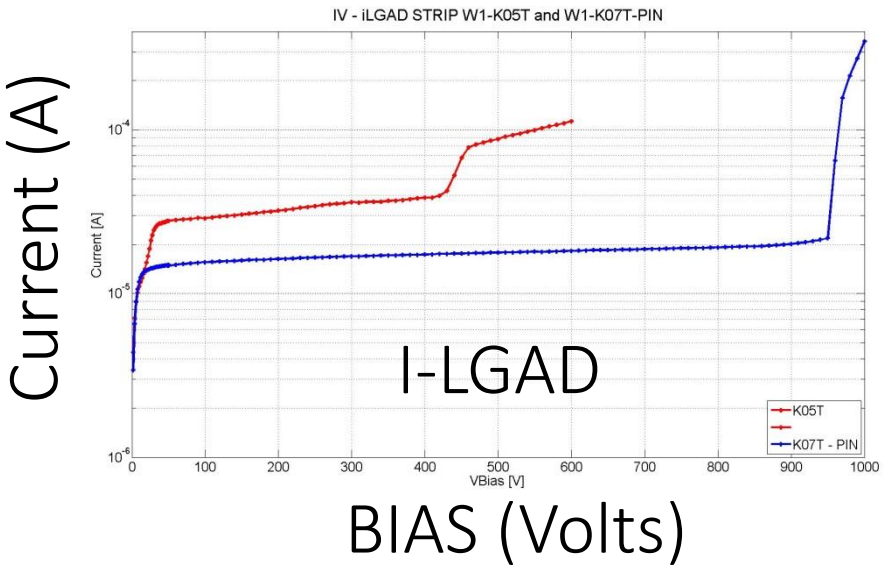
- P-in-P LGAD with segmented cathode (ohmic contact, “readout of holes”)
- DC strips, 160um pitch, 1.8E13/cm^2 imp. dose

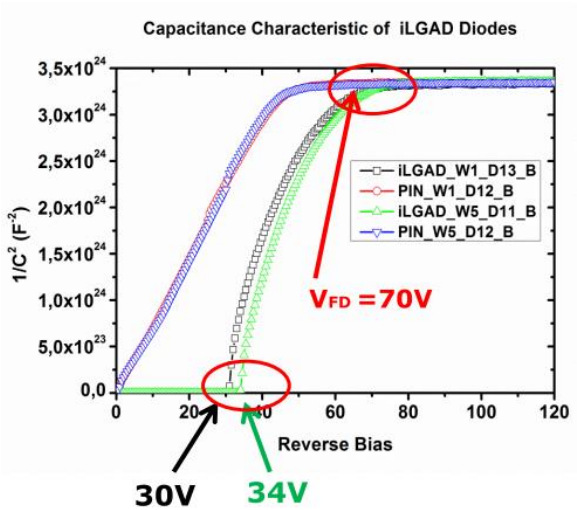
(W1-K05 & W1-K03 STR.45.160.8000.06.12)

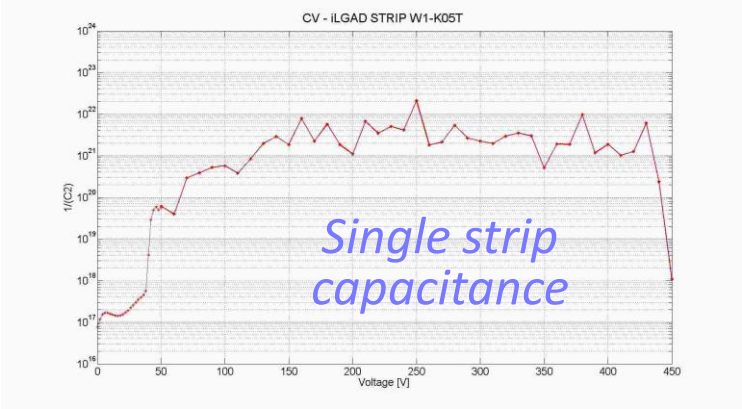


Electrical Characterization



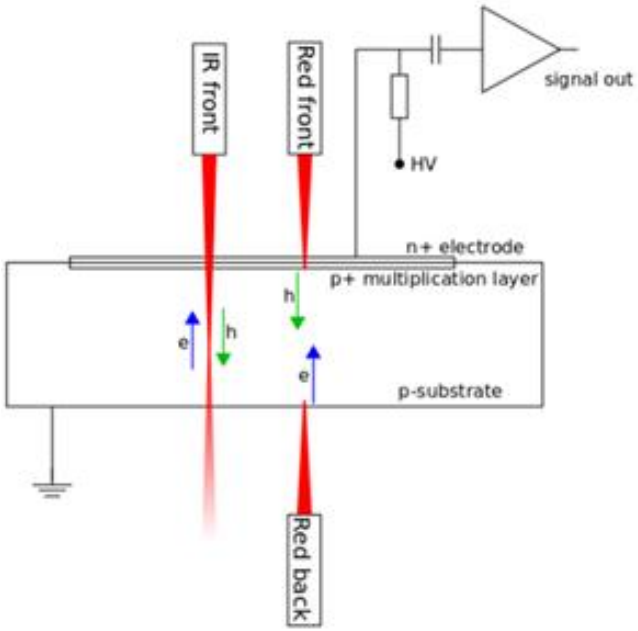


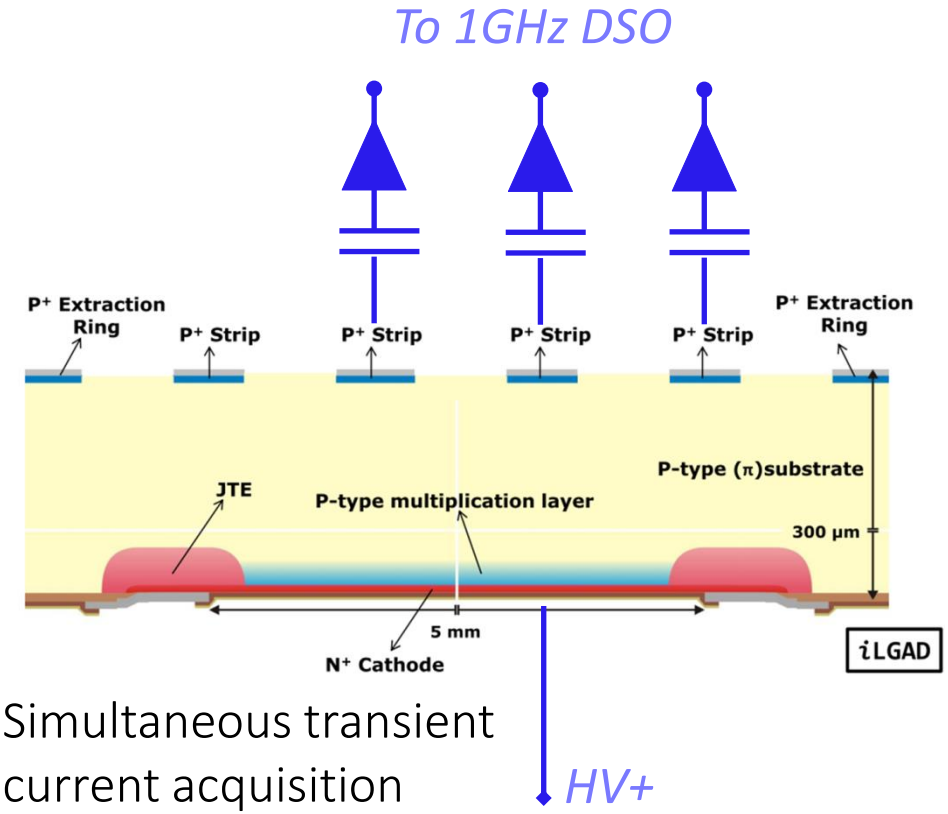




Laser Characterization: TCT

- Transient Current Distinct signature of signal amplification.
- Comparison of measured transient vs. TCAD simulations.



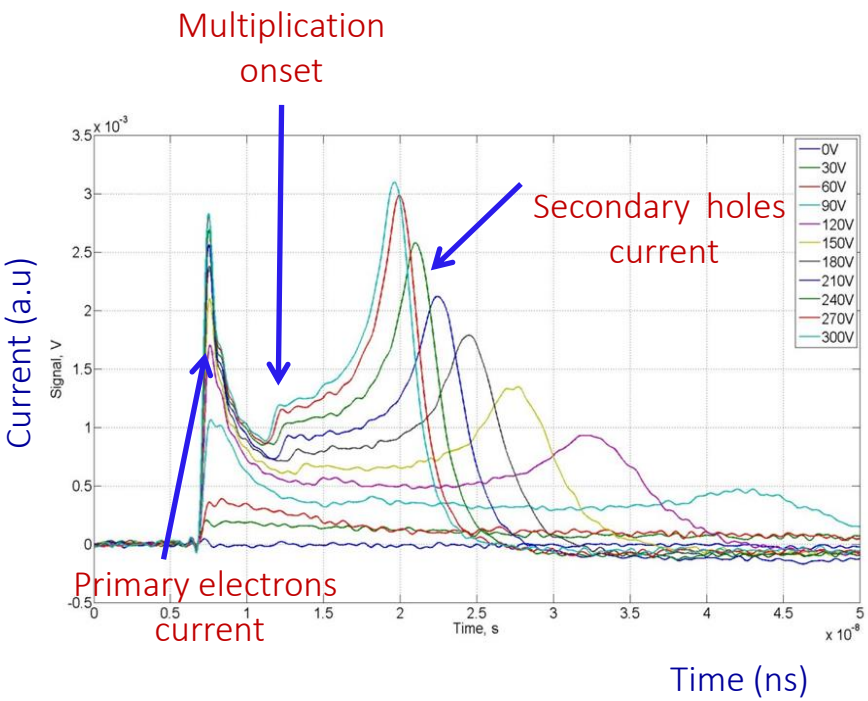


Simultaneous transient current acquisition

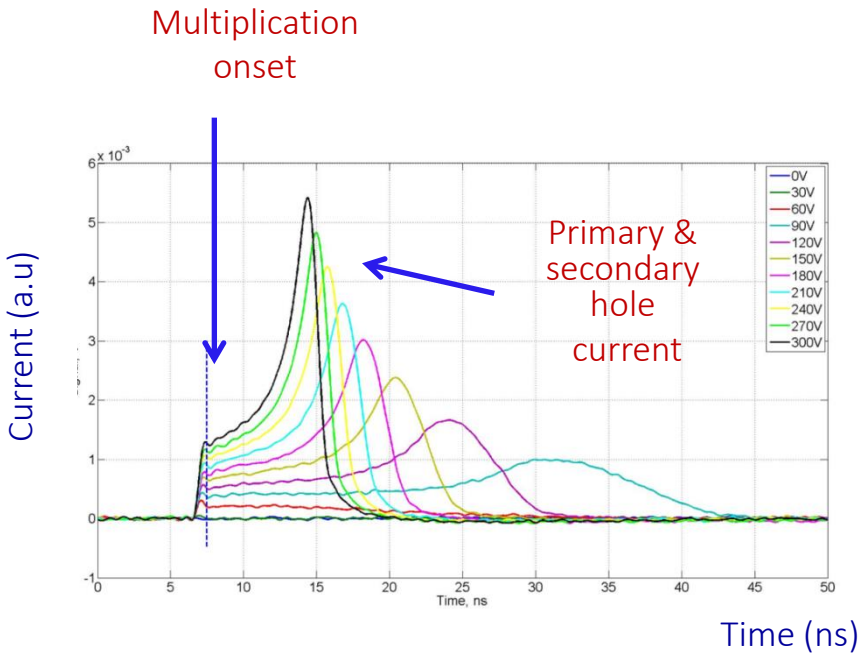
(up to three strips)

Transient Current: Red laser TCT.

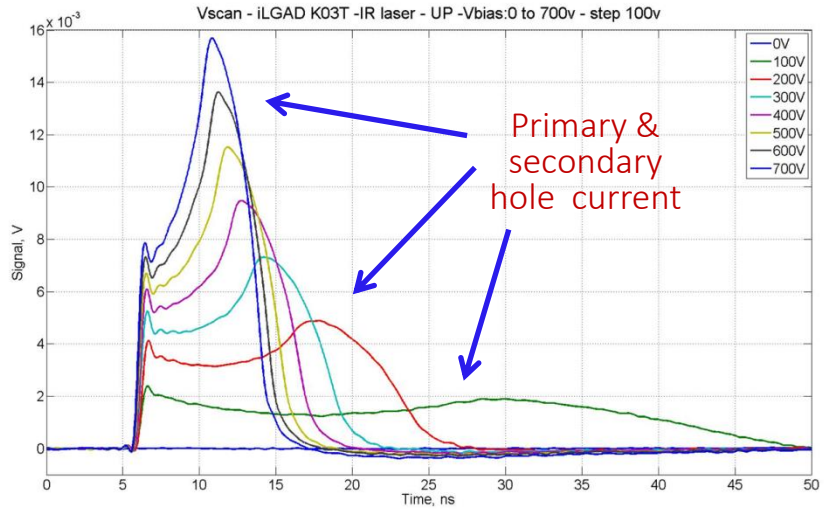
Electron Injection



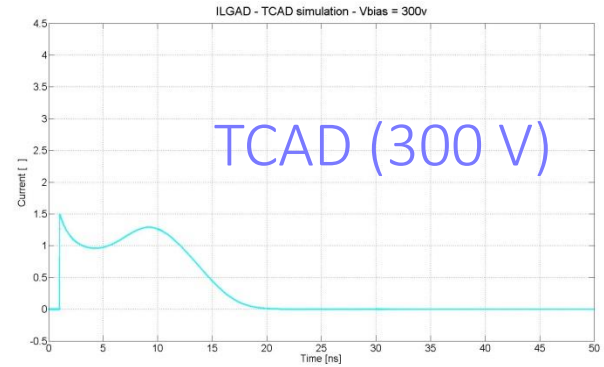
Hole injection

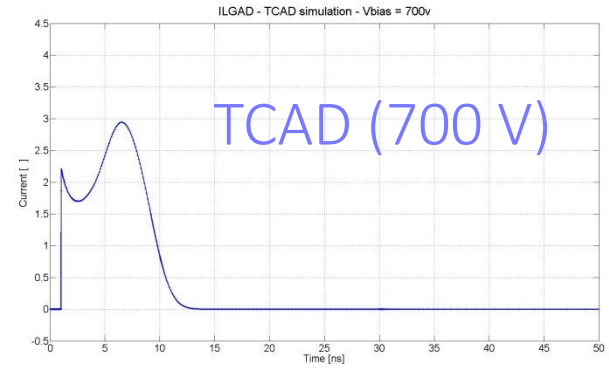


MIP Response Emulation: Infrared laser vs TCAD Simulation



Infrared laser Transient Current (MIP emulation)

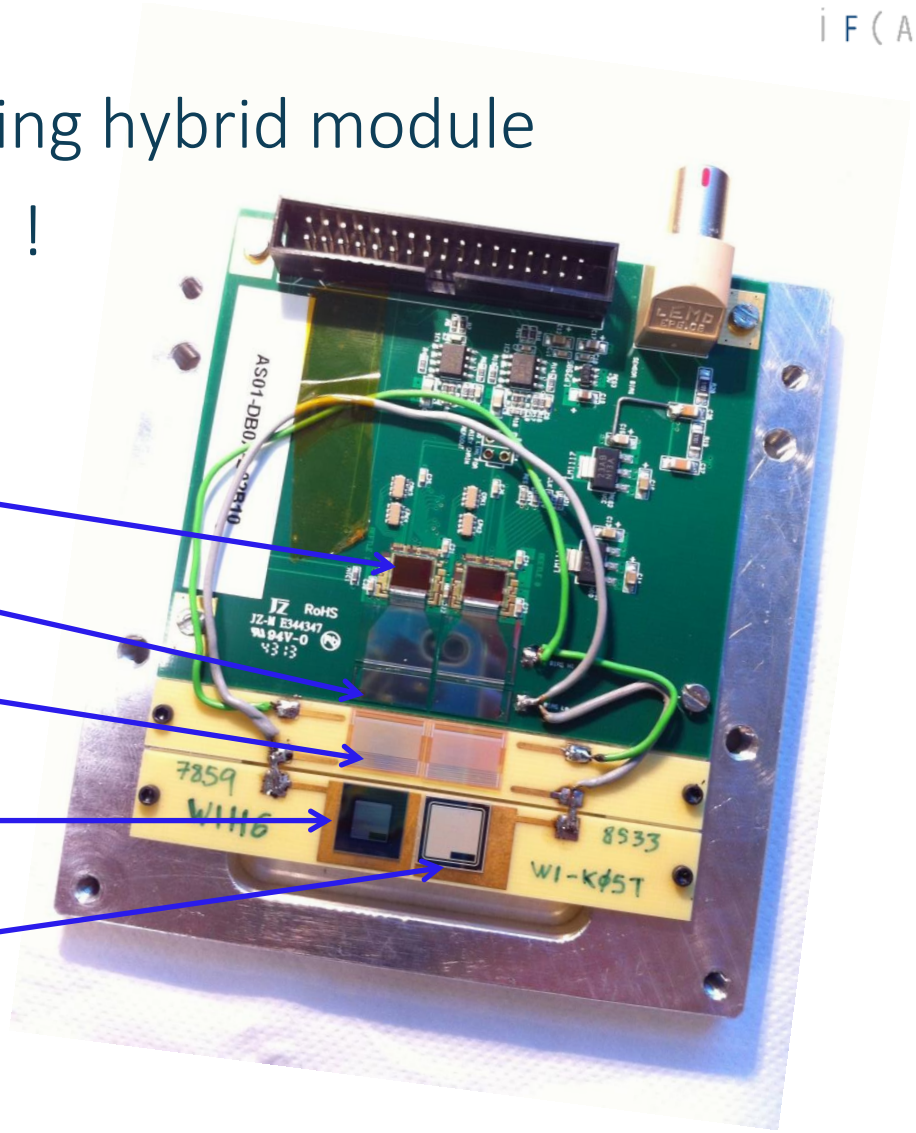




MIP Response: Test Beam testing.

First ever multi-channel tracking hybrid module

Based on I-LGAD & Strip LGAD !



Beetle ROC

Fan in DC

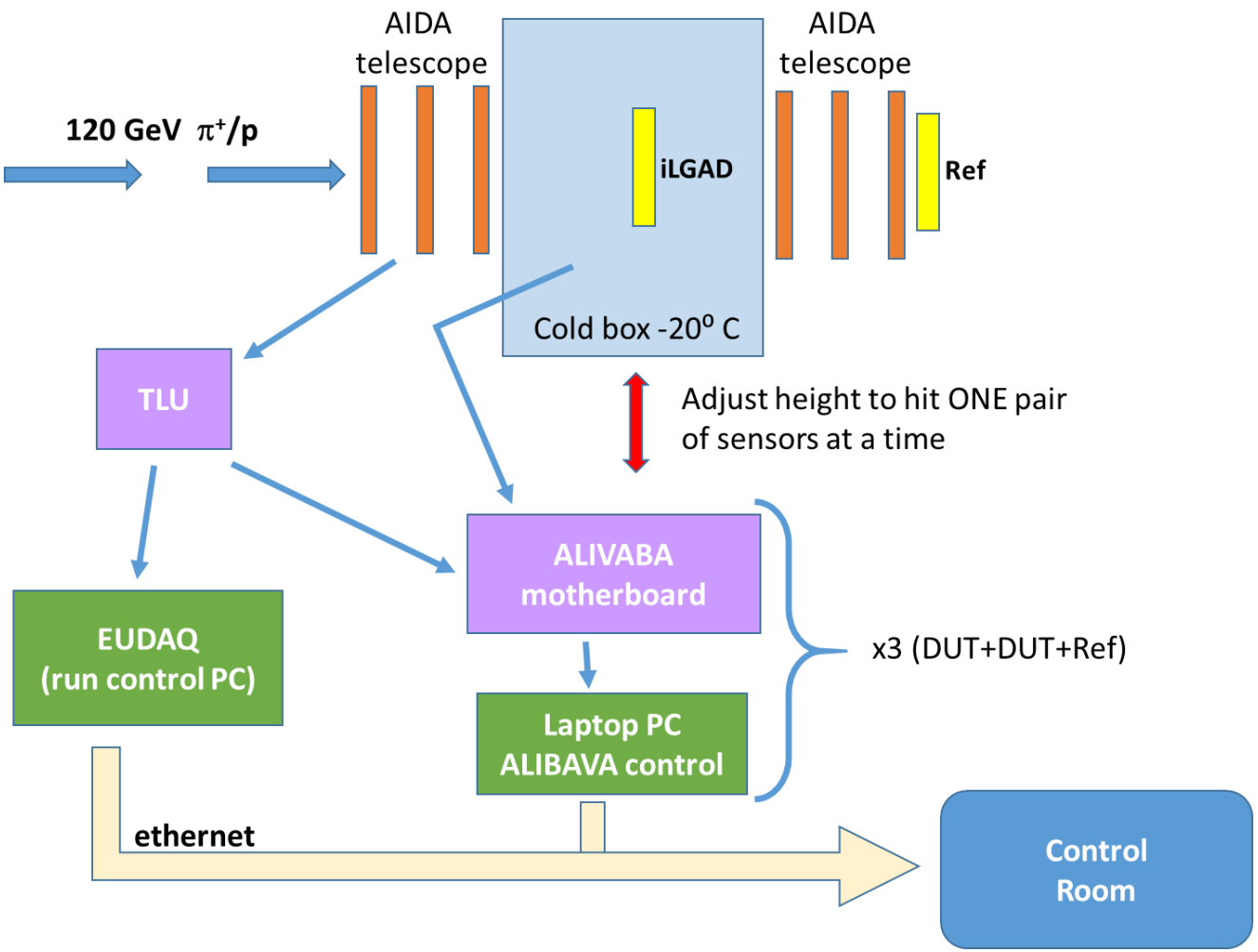
Fan in AC

Strip LGAD

I-LGAD

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

Test beam: AIDA-2020 WP7 Setup AKA as Atlas ITK setup ☺



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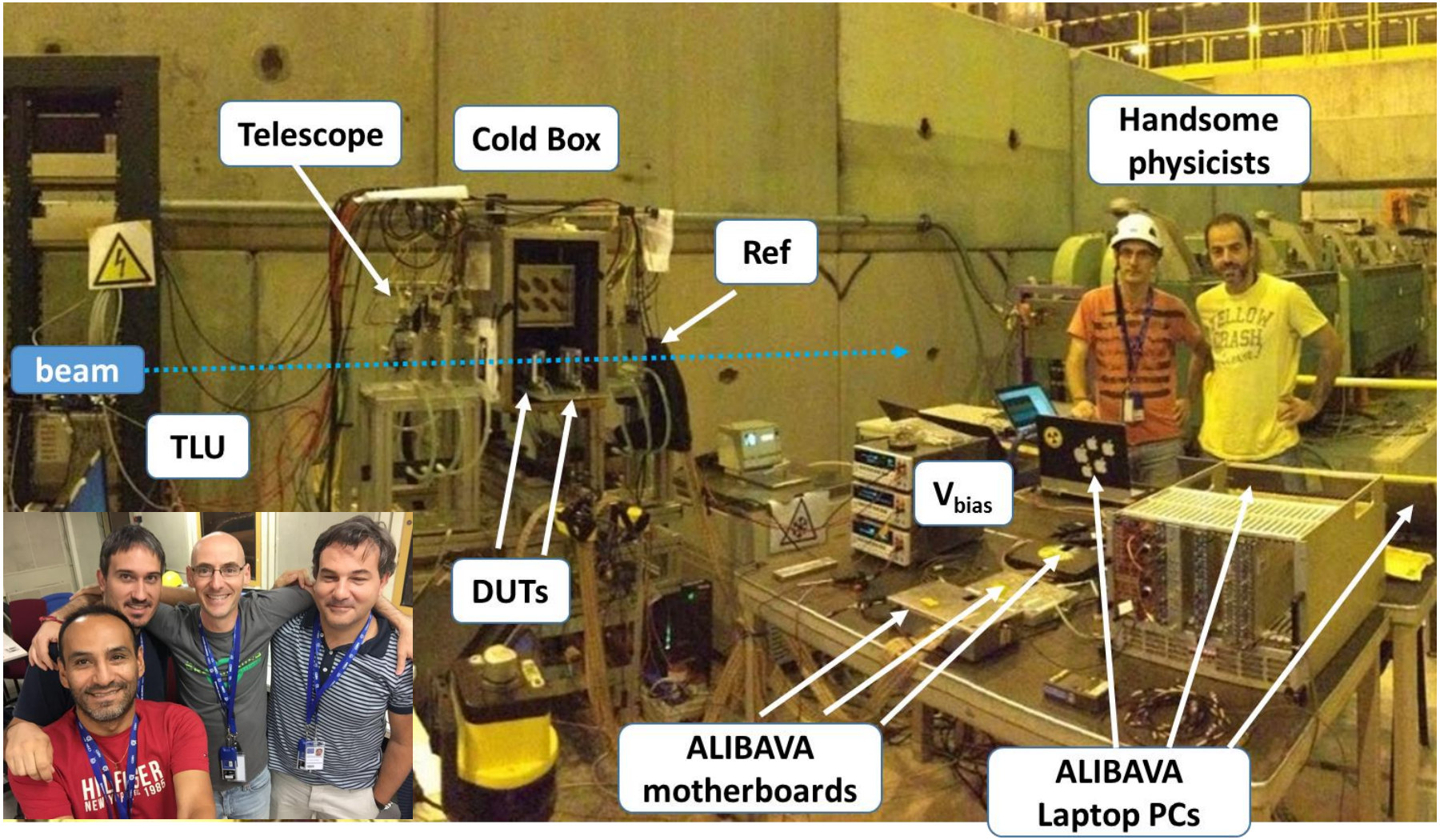
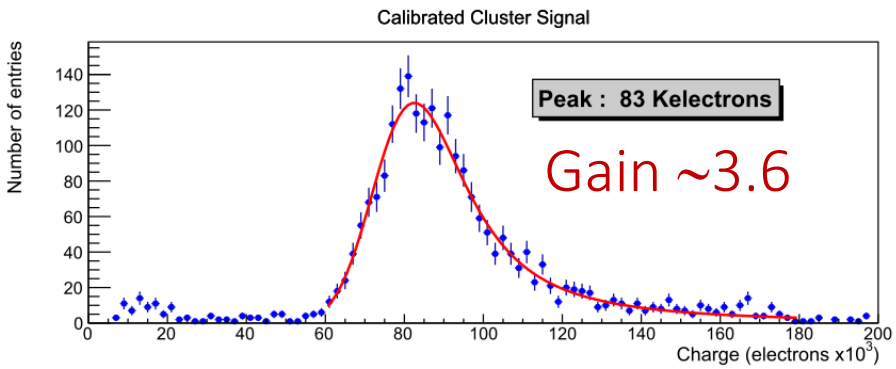
Test beam: Set-up



Test beam: Gain determination

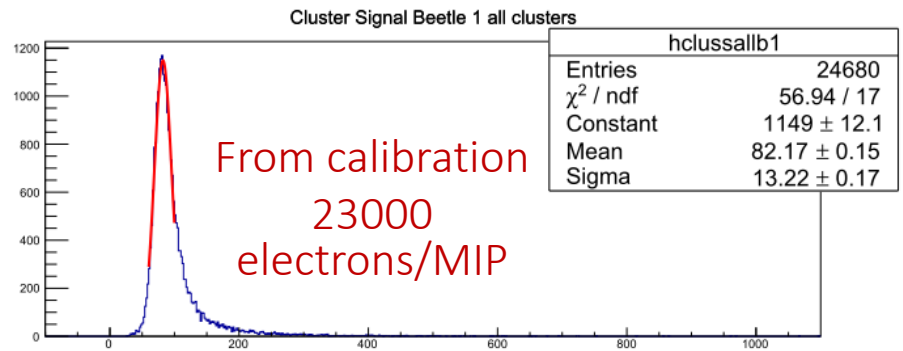
- Gain ≡ Charge Most Probable Value I-LGAD/ MPV Reference PIN
- Reference sensor and I-LGAD same thickness
- Dependence of the beetle gain (electrons/ADU) corrected (see **G. Gomez** talk on 3D sensors)

I-LGAD
(Room temp. 400 Volts)



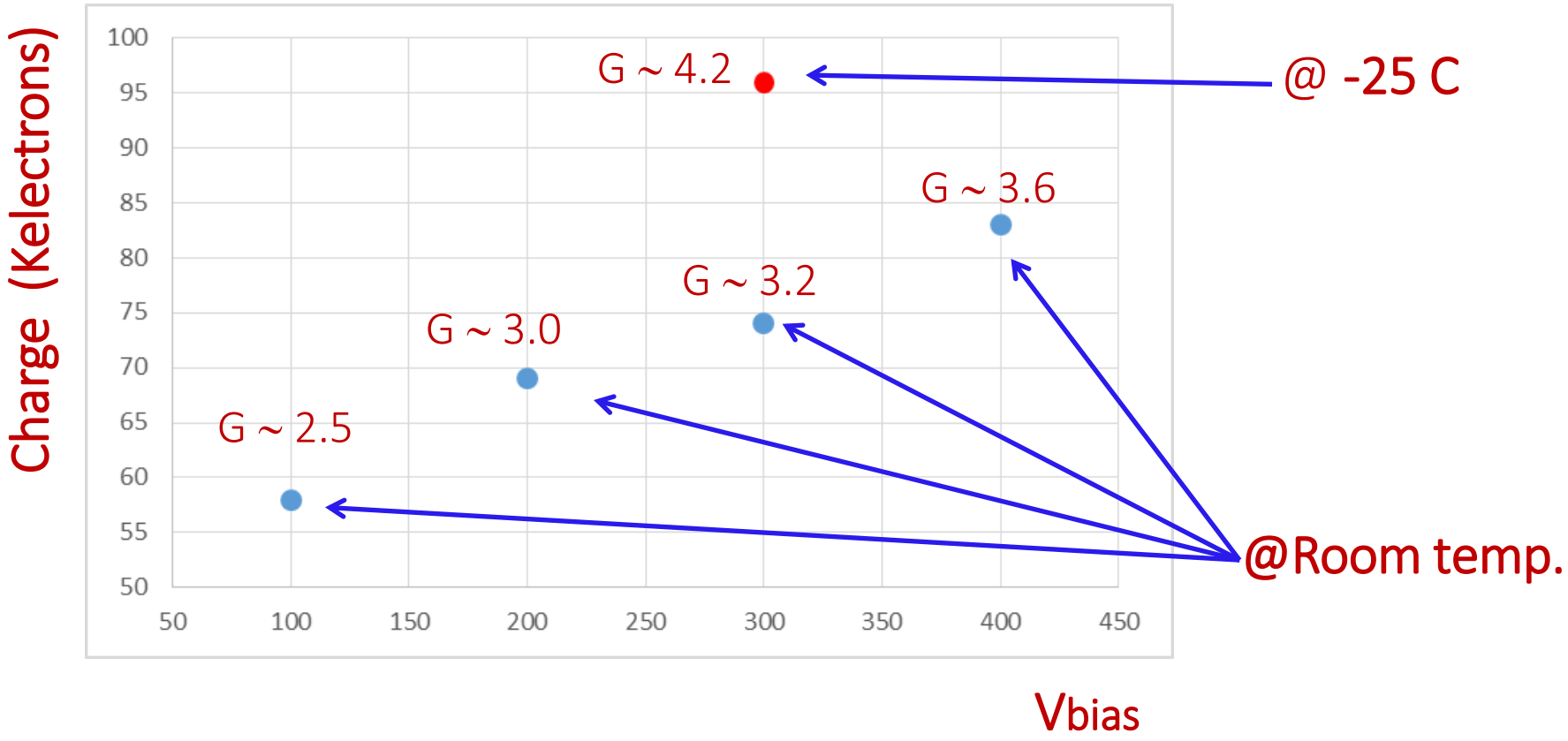
Cluster Charge

Standard Strip
(Room temp. 200 Volts)

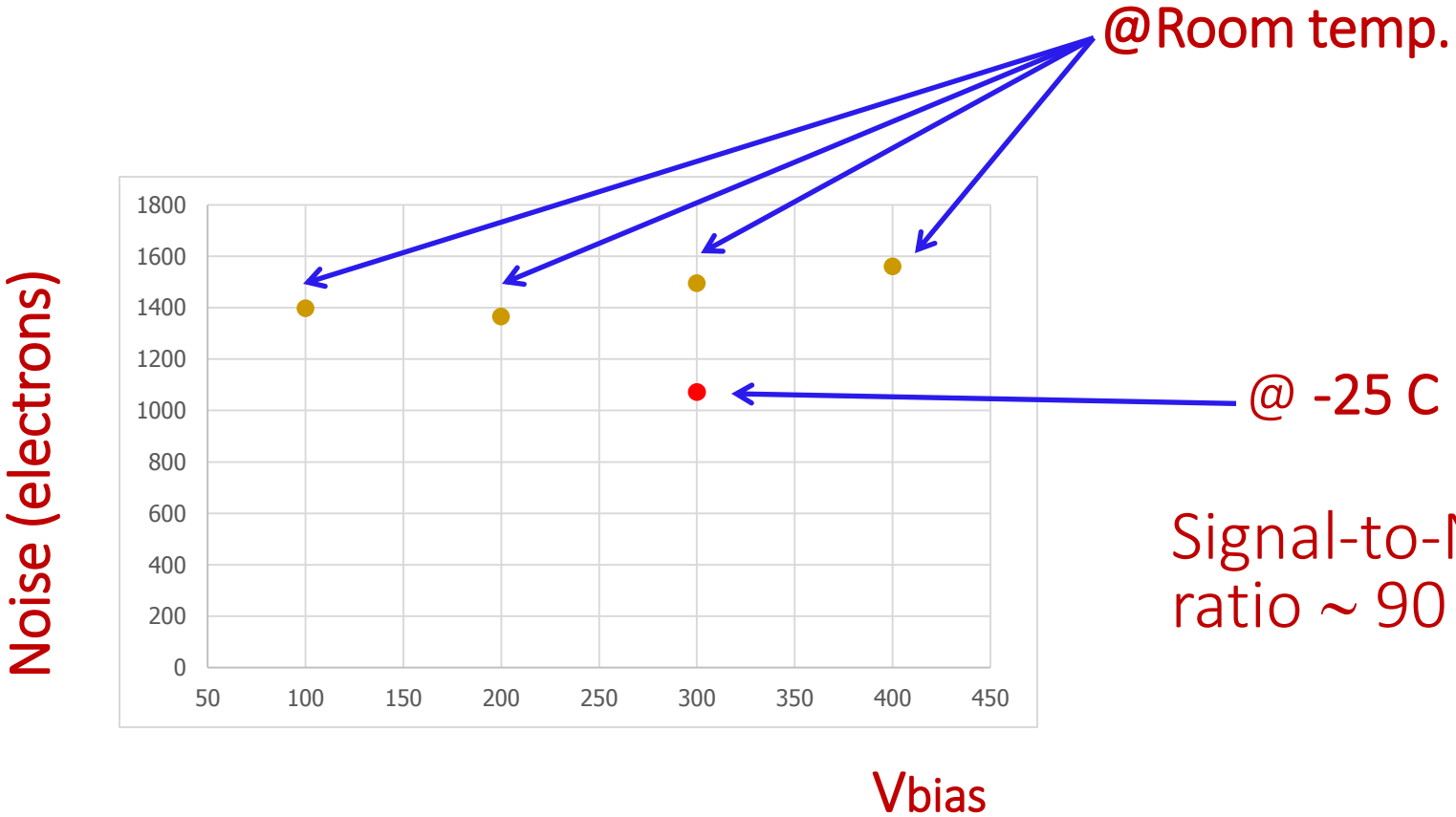


Cluster Charge (ADU)

Test beam: Charge vs V_{bias}

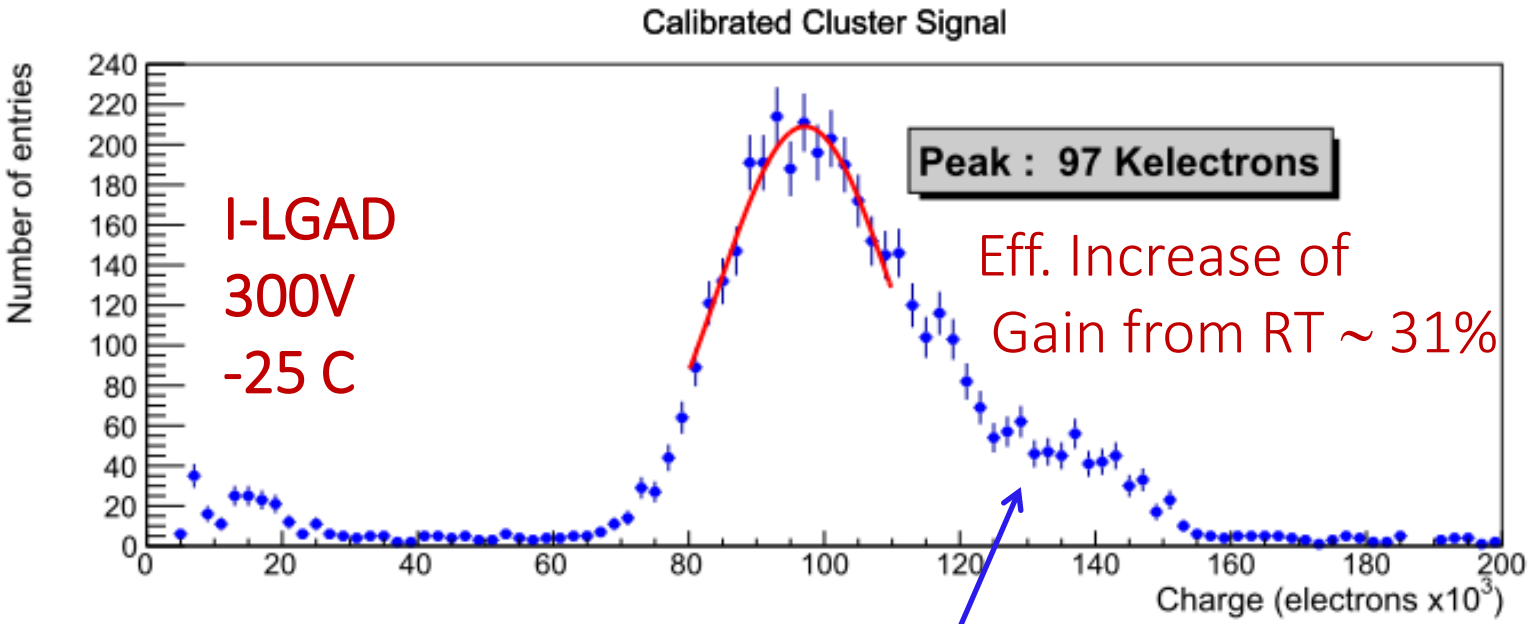


Test beam: Noise vs. V_{bias}



Signal-to-Noise ratio ~ 90 !!!

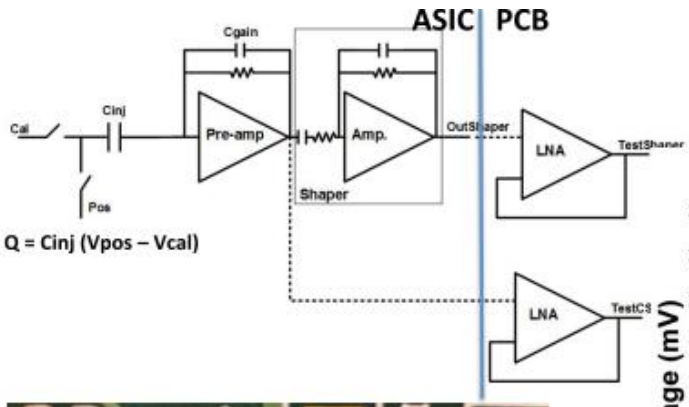
Test beam: readout front-end saturation.

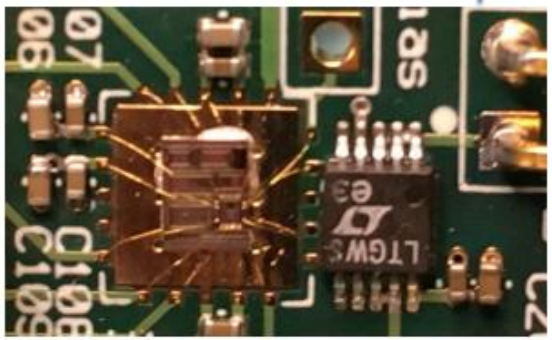


Spectrum shape modified by sub-optimal front-end

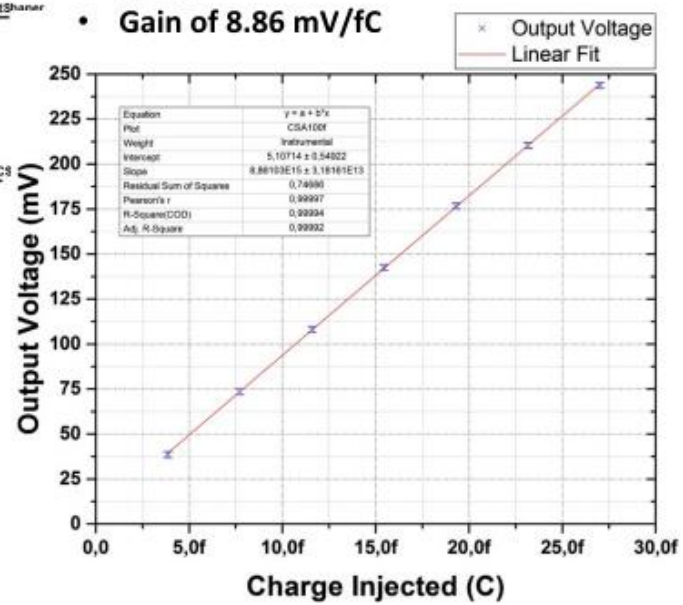
Sharp drop in charge spectrum originated by ADC saturation

Dedicated front-end electronics: preamp+shaper





- Amplitude of the output pulse for the CSA when the injected charge is below 30 fC
- Gain of 8.86 mV/fC



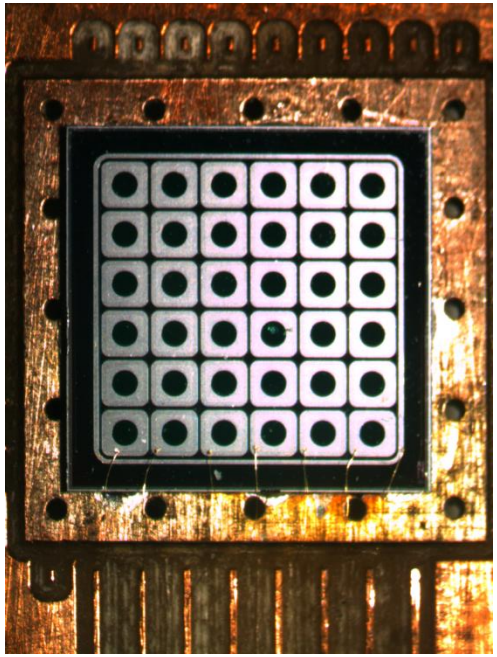
Optimized to maintain ENC below 700 e- with a C_d of 20 pF

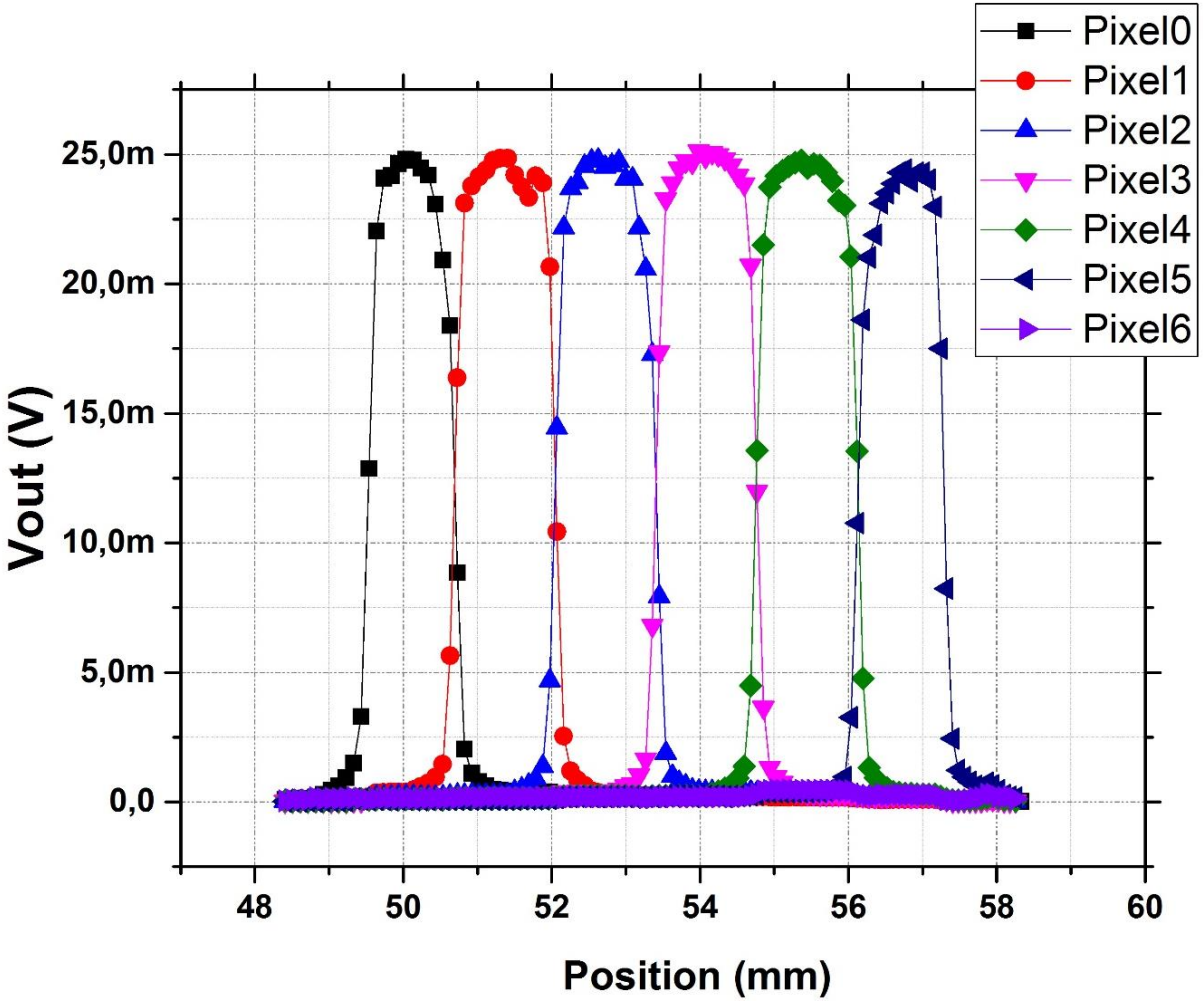
CSA with two gains (100fC, 500fC)

Two gain ranges: 100fC and 500fC

LGAD matrix characterization

- **LGAD back illuminated**
- **Ring included (Pixel6)**
- **Pulsed laser**
- **LGAD biased @ 420V**
- **100 um pinhole**
- **Vrms noise 0.73 mV**

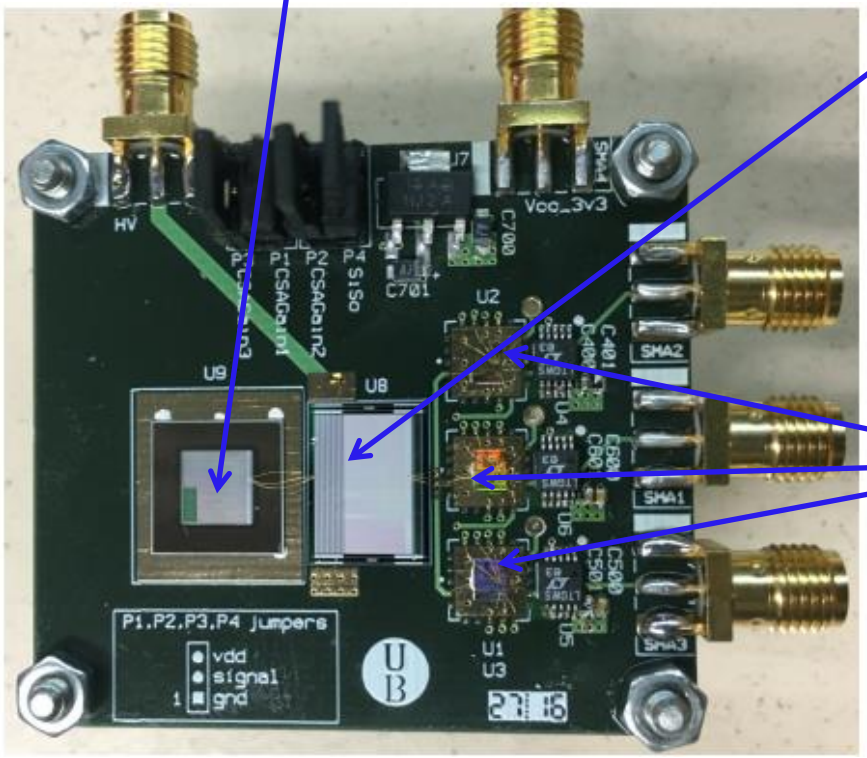




Fron-end electronics: s-LGAD integration

Strip LGAD (three strips bonded)

Fan-in with integrated coupling capacitors



Single channel preamp+shaper

Summary

- First characterization of a module with at SPS (AIDA-2020) with Alibava readout (non-optimal for relatively large gain regimes).
- Overall performance matches TCAD simulations and performance expectation.
- **Promising technology for achieving an ultra-low material budget tracking + built-in timing.**
- Analysis and measurements to be completed (May test beam at SPS.
- Dedicated readout front-end becoming a must.

Outlook

– I-LGAD prototypes (very limited sample tested) performing as designed.

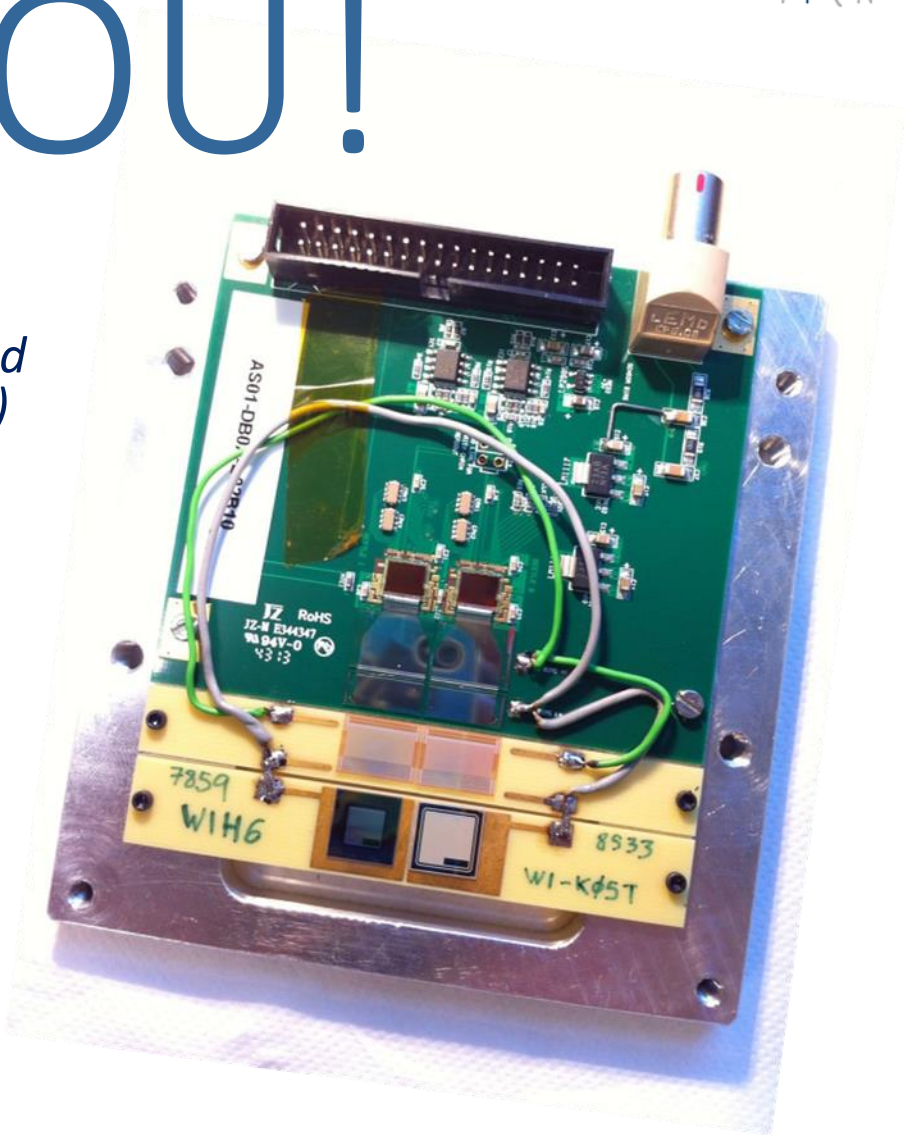
- **Double Side** Technological Process
- Using **4 inch** Wafers
- **Higher** Active Area. **6 inch** Wafers

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

(See Talk from Mar Carulla)

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

(from Salvador Hidalgo)

THANK YOU!

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