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

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In-depth study of Inverse-Low Gain Avalanche Detectors

Tredi 2017, Trento, Feb 2016

Iván Vila
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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

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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)

To 1GHz DSO
Transient Current: Red laser TCT.

Electron Injection

- Primary electrons current
- Secondary holes current
- Multiplication onset

Hole injection

- Primary & secondary hole current
- Multiplication onset

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MIP Response Emulation: Infrared laser vs TCAD Simulation

Infrared laser Transient Current (MIP emulation)

TCAD (300 V)

TCAD (700 V)
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 😊

120 GeV $\pi^+/p$

Adjust height to hit ONE pair of sensors at a time

x3 (DUT+DUT+Ref)

TLU

EUDAQ (run control PC)

ALIVABA motherboard

Laptop PC ALIBAVA control

Control Room

Cold box -20° C

iLGAD

Ref
Test beam: Set-up

Telescope
Cold Box
Ref

beam

TLU

DUTs

ALIBAVA motherboards

ALIBAVA Laptop PCs

Handsome physicists

V_{bias}
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

Gain ~3.6

From calibration
23000 electrons/MIP

Standard Strip
(Room temp. 200 Volts)

Cluster Signal

Gain

Cluster Charge (ADU)

13
Test beam: Charge vs $V_{\text{bias}}$

Charge (Kelectrons) vs. $V_{\text{bias}}$

- @ Room temp.
- @ -25 C

$G \sim 4.2$
$G \sim 3.6$
$G \sim 3.2$
$G \sim 3.0$
$G \sim 2.5$
Test beam: Noise vs. $V_{\text{bias}}$

![Graph showing the relationship between Noise (electrons) and $V_{\text{bias}}$.](image)

- @Room temp.
- @ -25°C

**Signal-to-Noise ratio ~ 90 !!!**
Test beam: readout front-end saturation.

I-LGAD 300V -25 C

Spectrum shape modified by sub-optimal front-end
Sharp drop in charge spectrum originated by ADC saturation

Eff. Increase of Gain from RT ~ 31%
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

- **Lower** Pitch Size. 50 μm
- **Thin** Devices (< 200 μm)
  - SOI, SOS Wafers
  - Timing Applications

- **Radiation Hardness**
  - Gallium Implantation
  - Carbon Doping

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

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

(See Talk from Mar Carulla)

(from Salvador Hidalgo)
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