Readout electronics for LGAD sensors

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Silicon Detectors with Internal Gain and Proportional Response

The aim of LGAD sensor is to improve the performance and stability against radiation of PiN diode detectors for tracking applications.

- Proportional Response (linear mode operation)
- Good efficiency and spectral range
- Better Sensibility
- Thin detector integration with the same signal and higher collection efficiency
- Better signal/noise ratio

After Irradiation

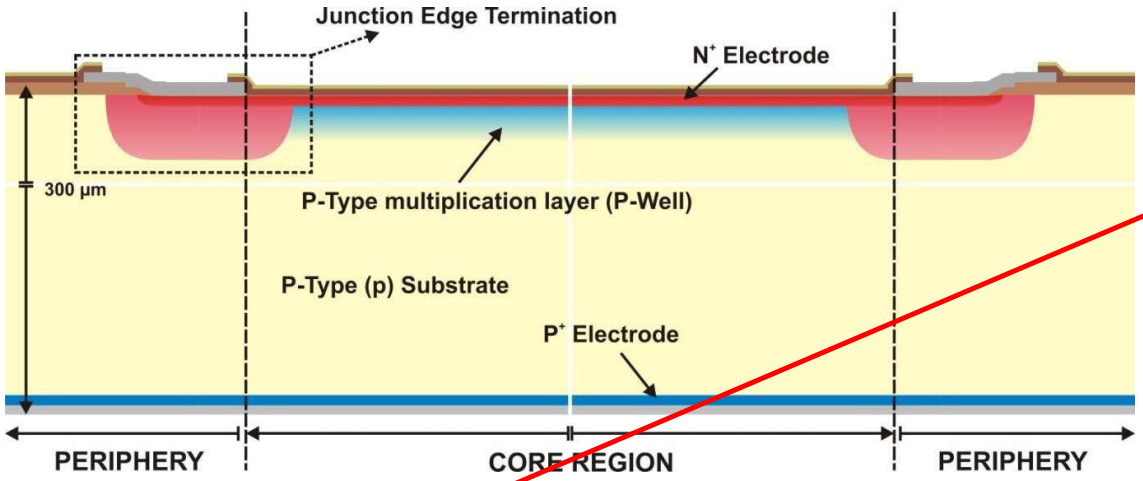
- Similar pre & post irradiation signal (higher quality signal + lower noise increment)
- Lower increment of the power consumption

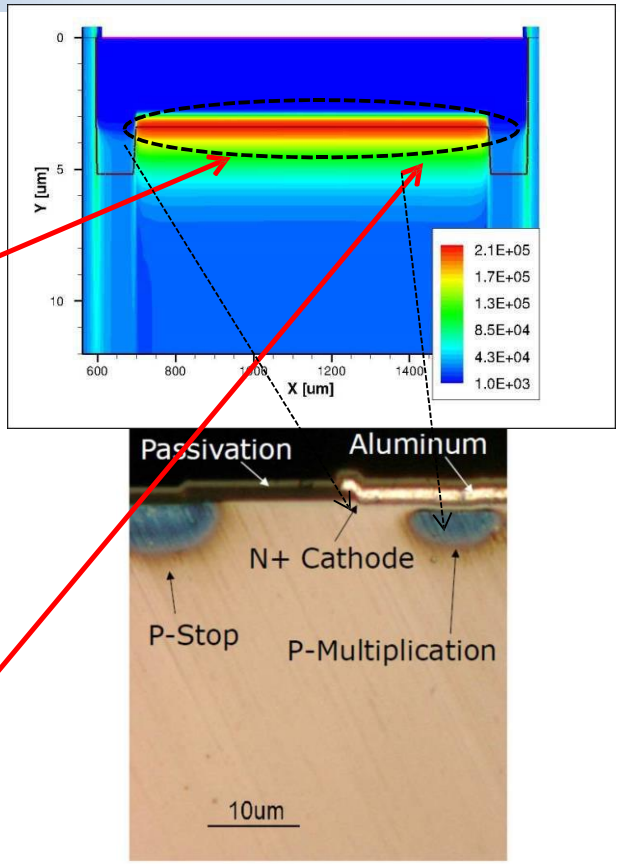
Why Low Gain?

- **High Gain implies higher levels of multiplication noise (inherent to the stochastic process of multiplication), spoiling the improvement of the Signal to Noise ratio.**
- **Collection times are increased with gain (more charge to be collected), increasing the trapping efficiency and avoiding the off-setting of the charge loss.**
- **Avoid cross-talk among adjacent pixels/strips.**

I. Tapan,etal.,NuclearInstrumentsandMethodsinPhysicsResearchA388 (1997)79.

LGAD Basics. Low Gain Detector

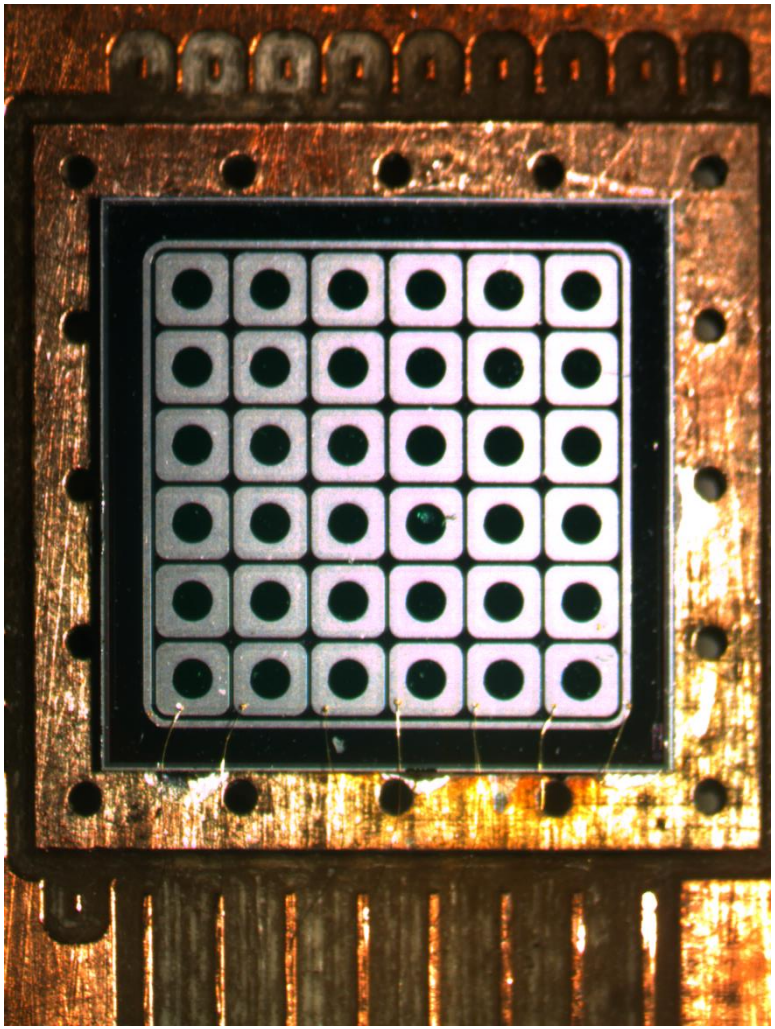




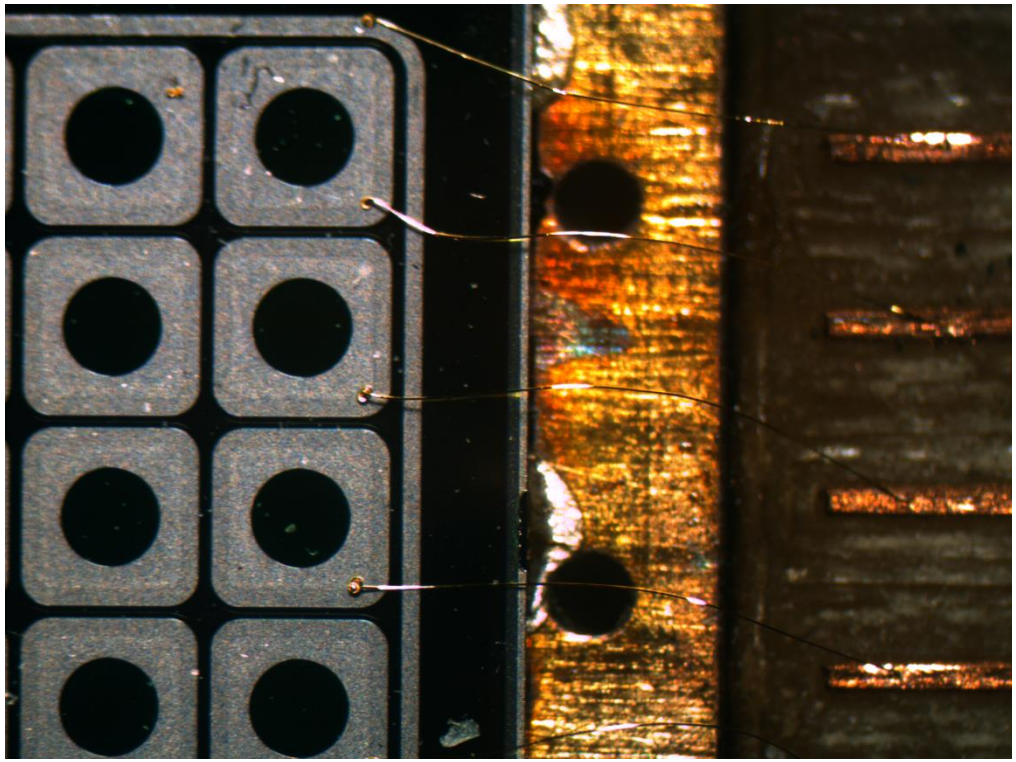
- **Core Region**
  Uniform electric field, high enough to activate mechanism of **impact ionization** (multiplication)
- **Termination**
  High electric field confined in the **core region**
- **Periphery**
  Dead region. **Charges** should not be collected. **Reduction** of the surface **leakage currents**

G. Pellegrini et. al., NIM A Volume 765, 21 November 2014, Pages 12–16

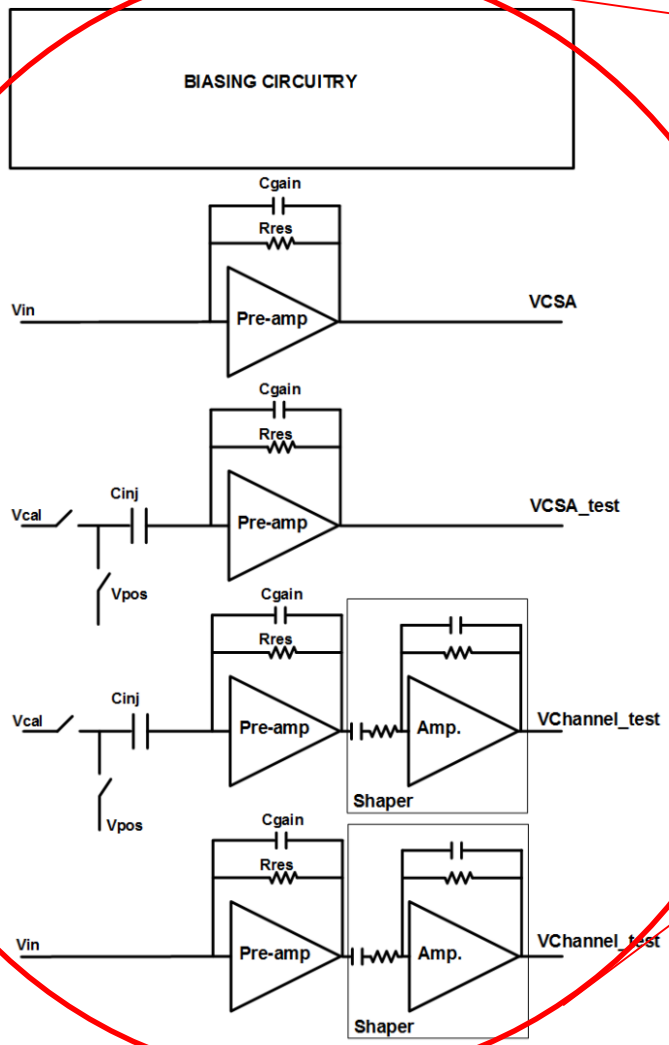
Pixelated LGAD

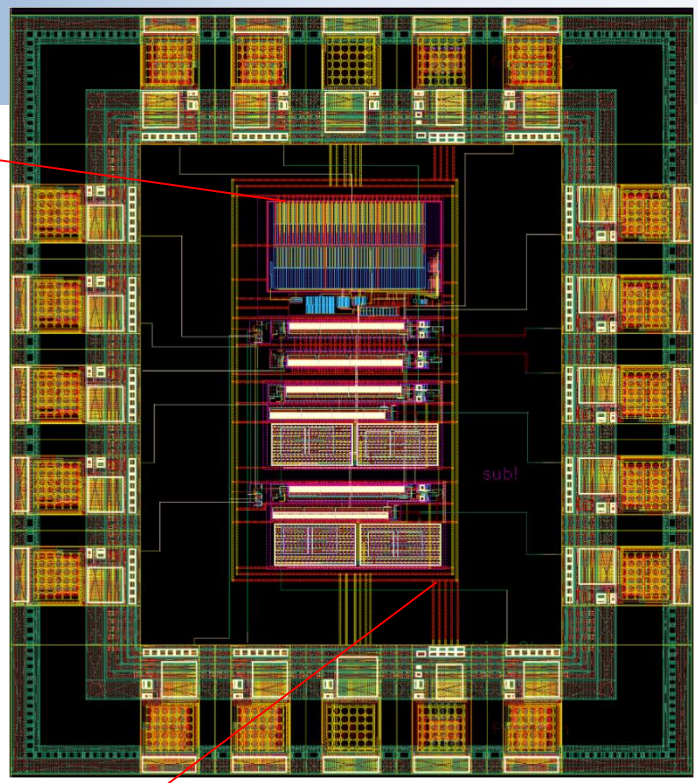


- 6x6 LGAD Matrix
- Surrounded by ring (must be biased)
- We use a dedicated front-end to characterize it



Front-end ASIC



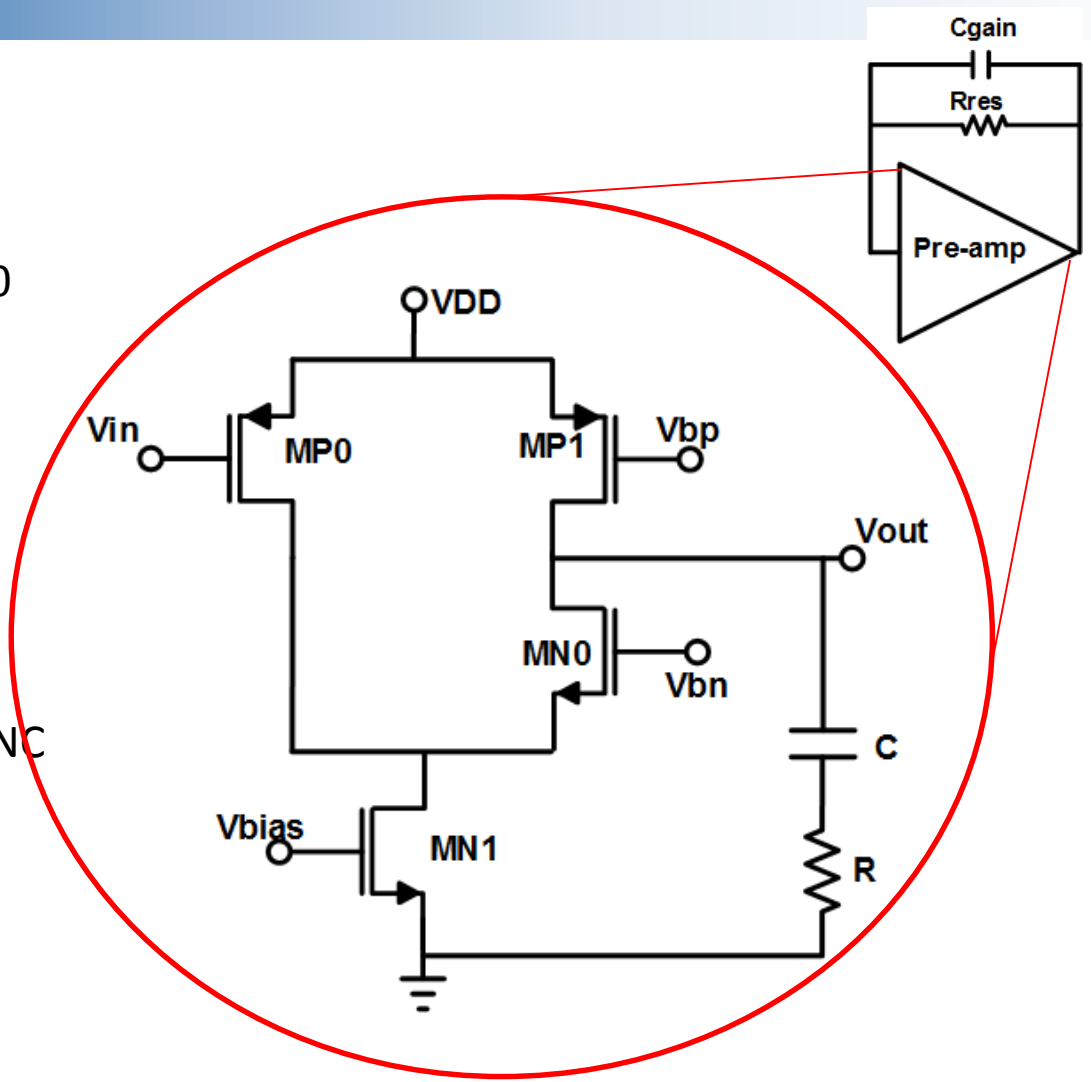


- 180 nm Technology from AMS
  - Cost
  - Good noise performance
- The fabricated prototype is 0.865 mm x 0.965 mm

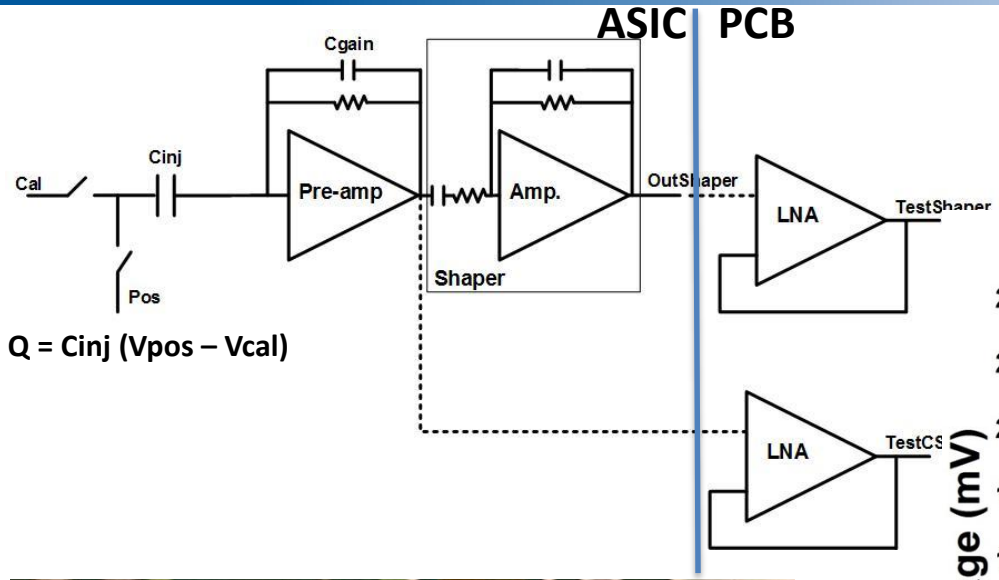
Front-end ASIC

Design in AMS 180 nm

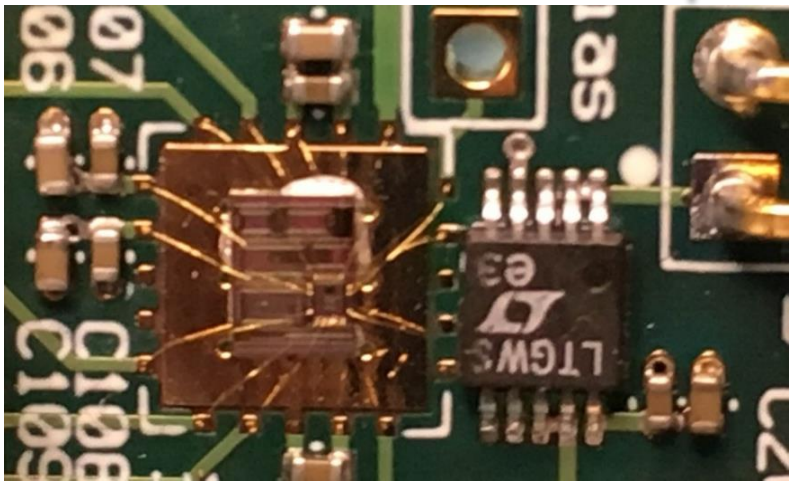
- Power supply: 1.8 V
- Power consumption x channel < 160 uW
- Pre-amp is the main noise contribution of the circuit.
- Pre-Amplifier:
  - Gain ~ 67,5 dB
  - GBW ~ 19,5 MHz
  - PM ~ 63º
- Optimum L and Ibias to maintain ENC below 700 e- with a C_d of 20 pF
- CSA with two gains (100fC, 500fC)
- CR-RC shaper with a folded cascade structure. C's and R's are passive.



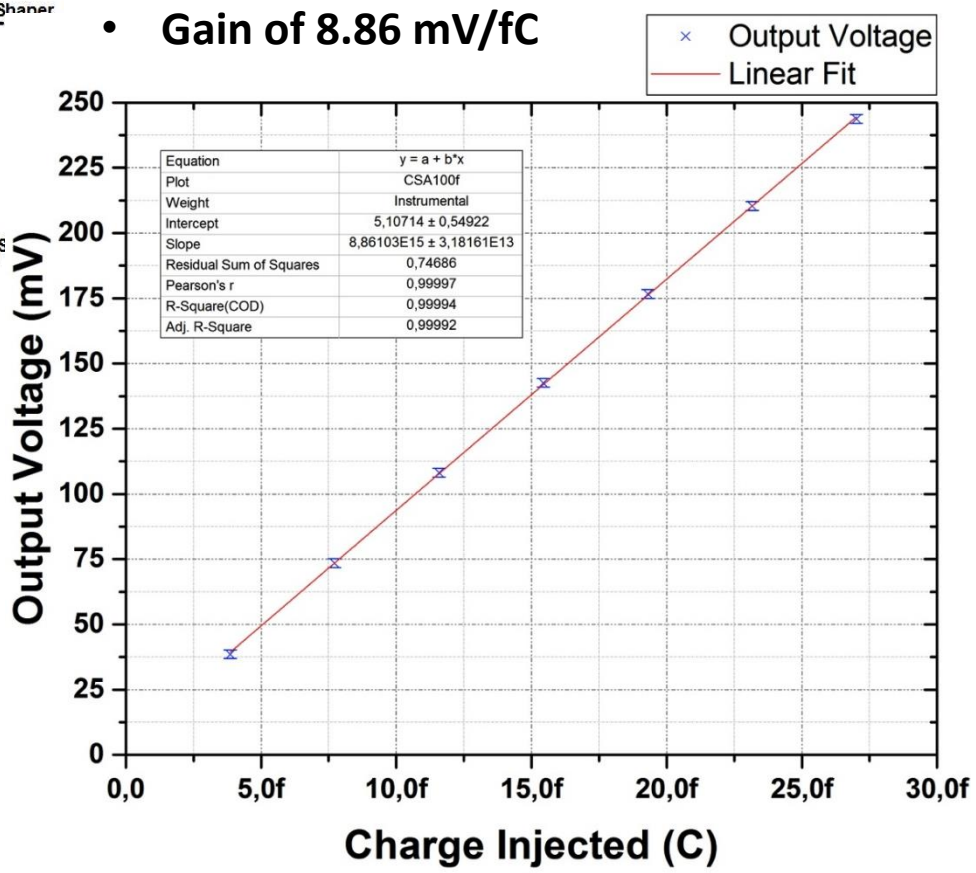
Front-end : Characterization



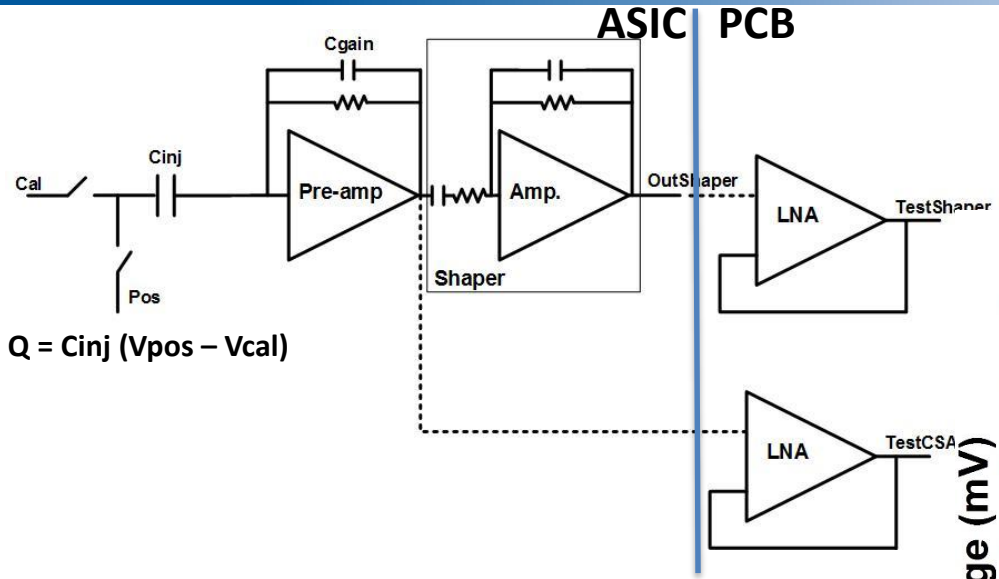
Q = Cinj (Vpos – Vcal)



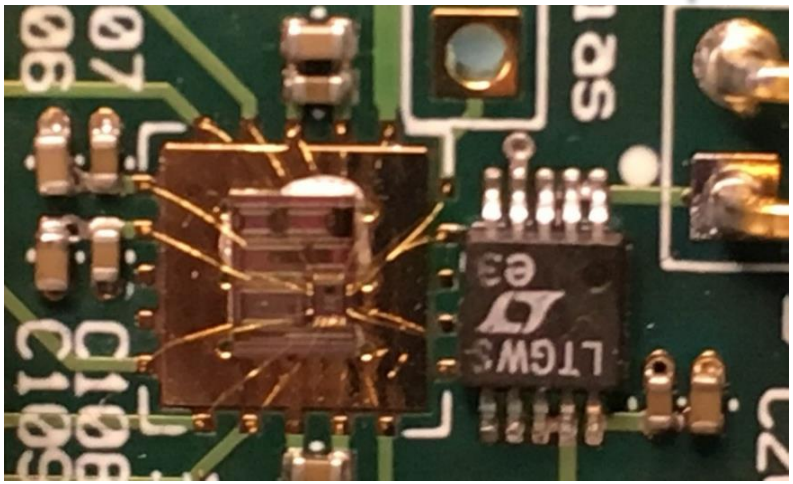
- Amplitude of the output pulse for the CSA when the injected charge is below 30 fC
- Gain of 8.86 mV/fC



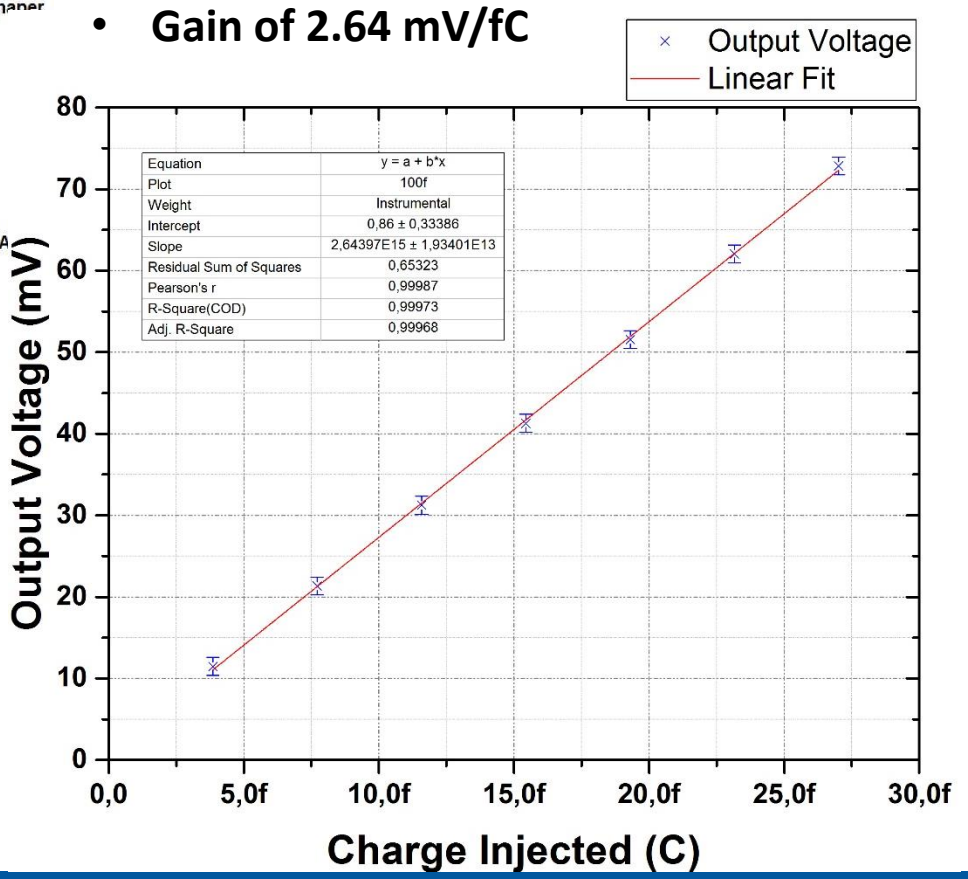
Front-end : Characterization



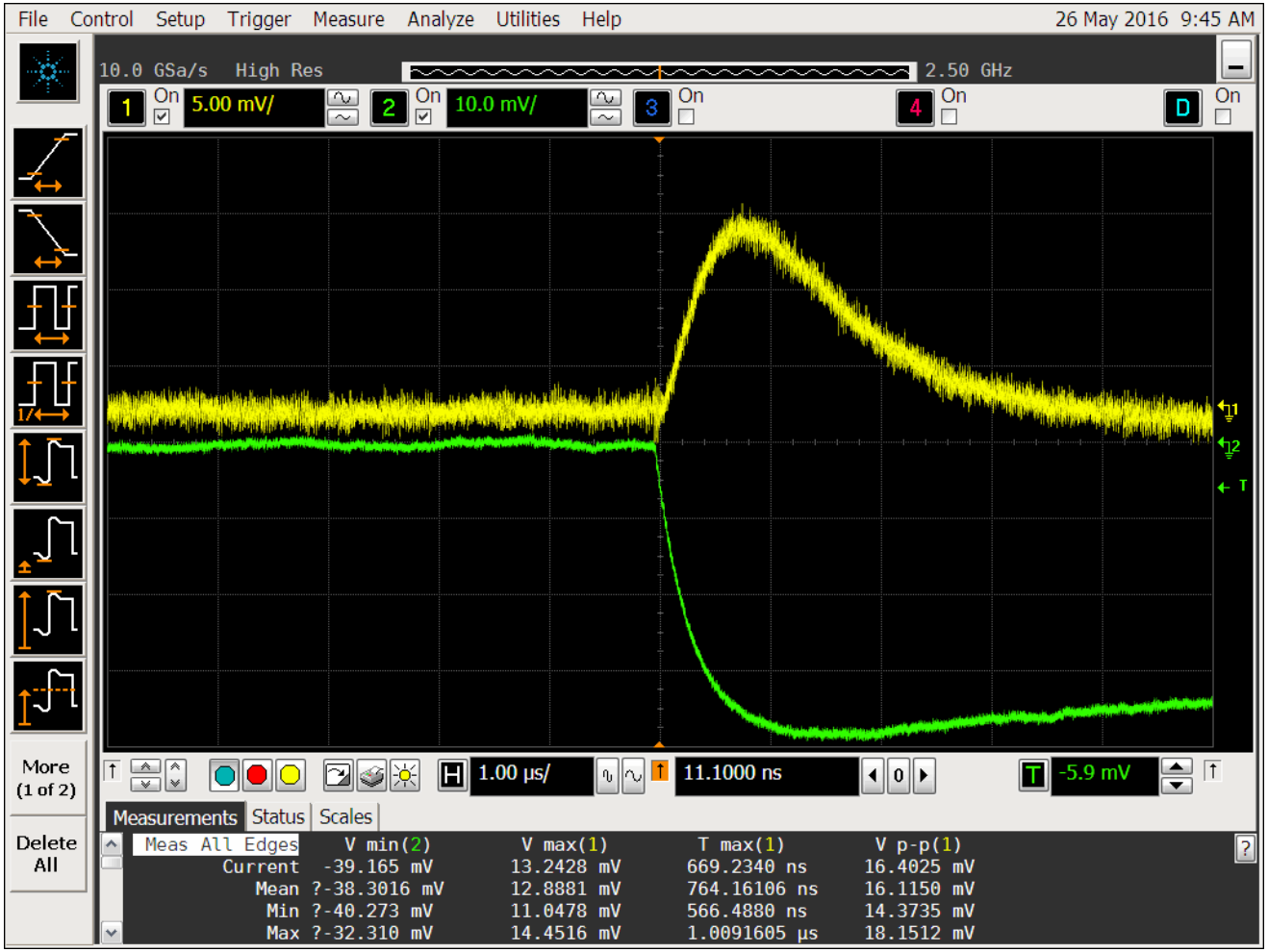
Q = Cinj (Vpos – Vcal)



- **Amplitude of the output pulse for the Shaper when the injected charge is below 30 fC**
- **Gain of 2.64 mV/fC**

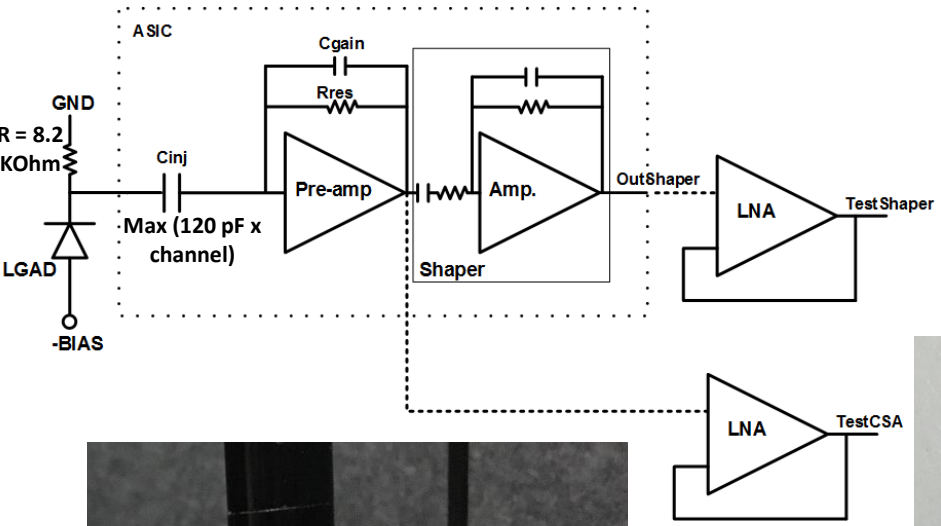


Front-end : Noise

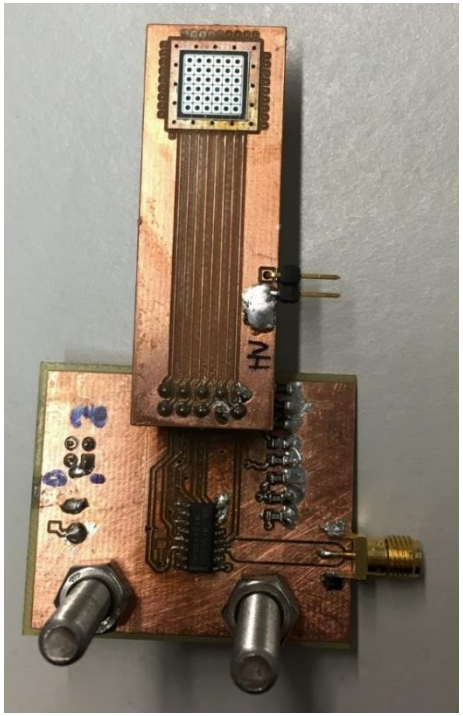


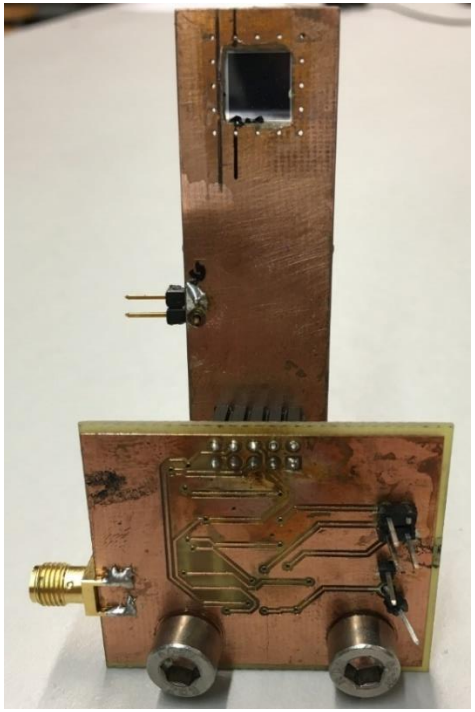
- **Charge injected equivalent to 24000 e-**
- **Vrms noise at lab: 0,73 mV**
- **Shaper output (yellow)**
- **CSA output (green)**

LGAD Test



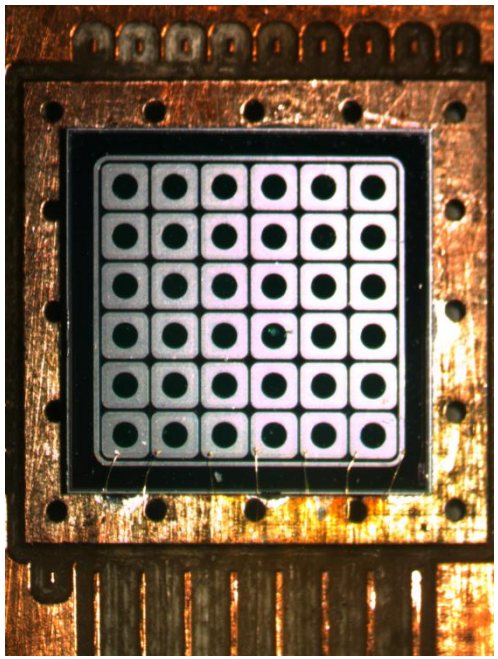
- LGAD back illuminated
- uPositioners and Motors used to move the board with steps of 100 um
- Red laser pulsed at 1’5k Hz
- LGAD biased @ 420V
- 100 um pinhole

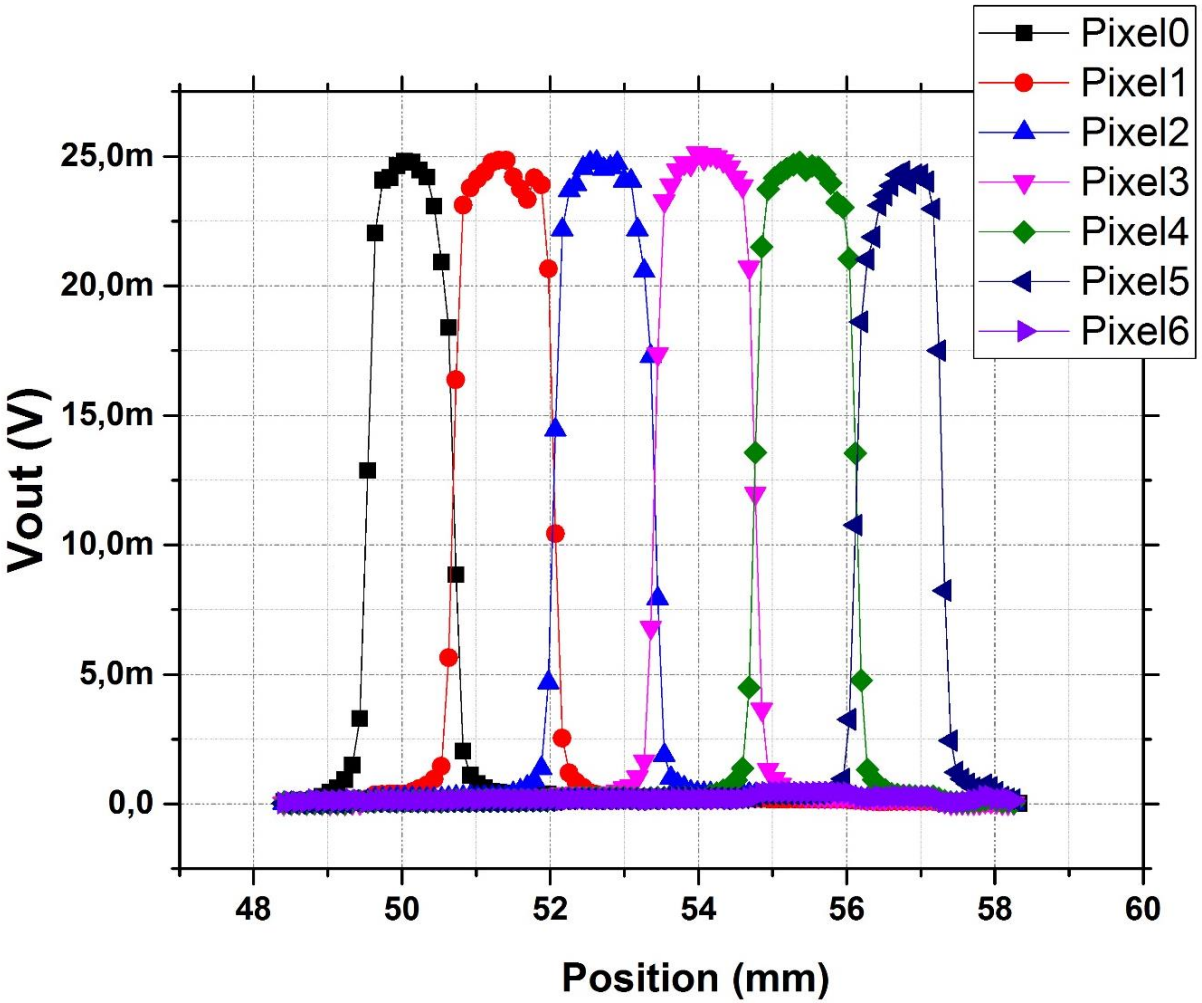




LGAD Test: CSA + Shaper

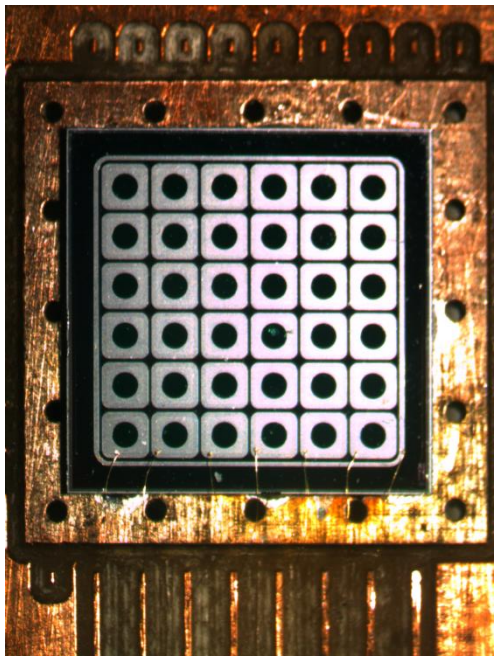
- LGAD back illuminated
- Ring included (Pixel6)
- Pulsed laser
- LGAD biased @ 420V
- 100 um pinhole
- Vrms noise 0.73 mV

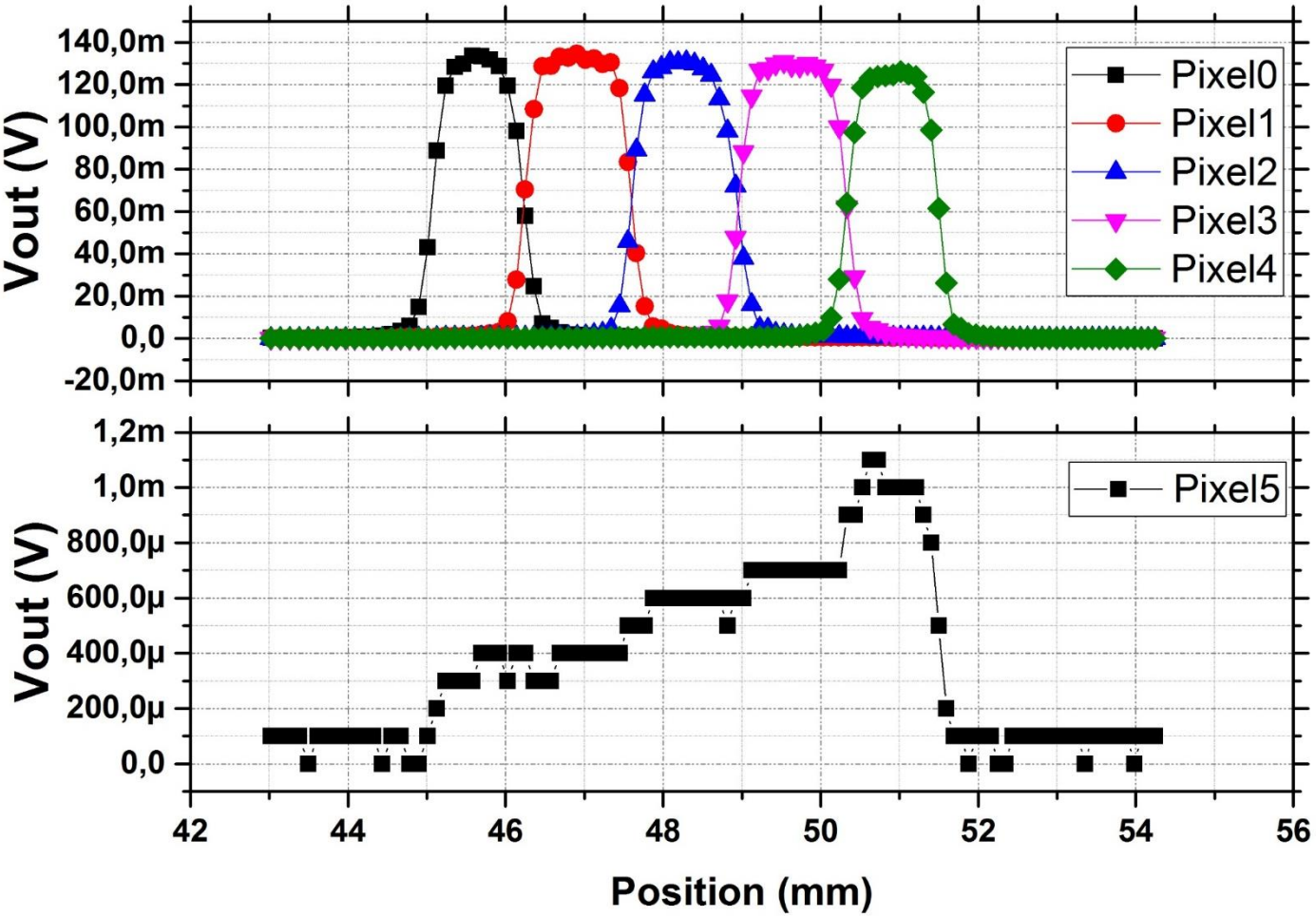




LGAD Test: Crosstalk

- LGAD back illuminated
- Ring not included
- Pulsed laser
- LGAD biased @ 420V
- 100 um pinhole
- Vrms noise 0.73 mV





Conclusions and future plans

- **Pixelated LGAD matrix measured for first time with a proprietary ASIC**
- **We have designed a very front-end with a simulated ENC below 1000 e- with a C_d of 20 pF.**
- **Power consumption per channel is 157 uW. Power off capabilities are implemented.**
- **Design the whole channel**
- **We are open for collaborations, just contact us ☺ :**
  - **oalonso@el.ub.edu (ASIC and Test part)**
  - **salvador.hidalgo@csic.es (LGAD and sensors part)**