Si-microstrip LGAD detectors for cosmic-ray space-borne instruments

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2) INFN – Sezione di Perugia
3) INFN – Sezione di Bologna
4) INFN – Sezione di Tor Vergata
5) Università degli Studi di Perugia

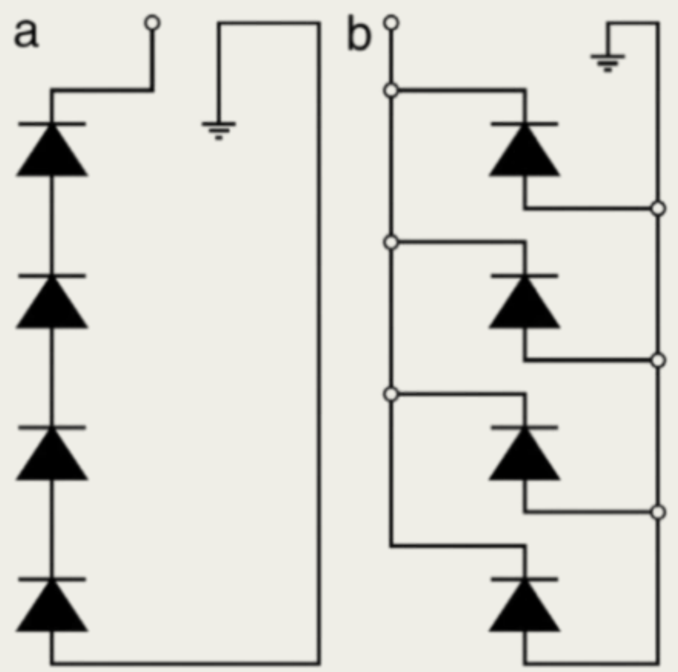
+ many thanks to L. Pacini (INFN - Sezione di Firenze)

PRIN: Pentadimensional Tracking Space Detector

Collaboration:
- Italian Space Agency
- INFN

Goal:
Adapt the LGAD to the spatial environment by means of special geometries to keep under control the electrical capacity while maintaining unchanged the temporal performance.

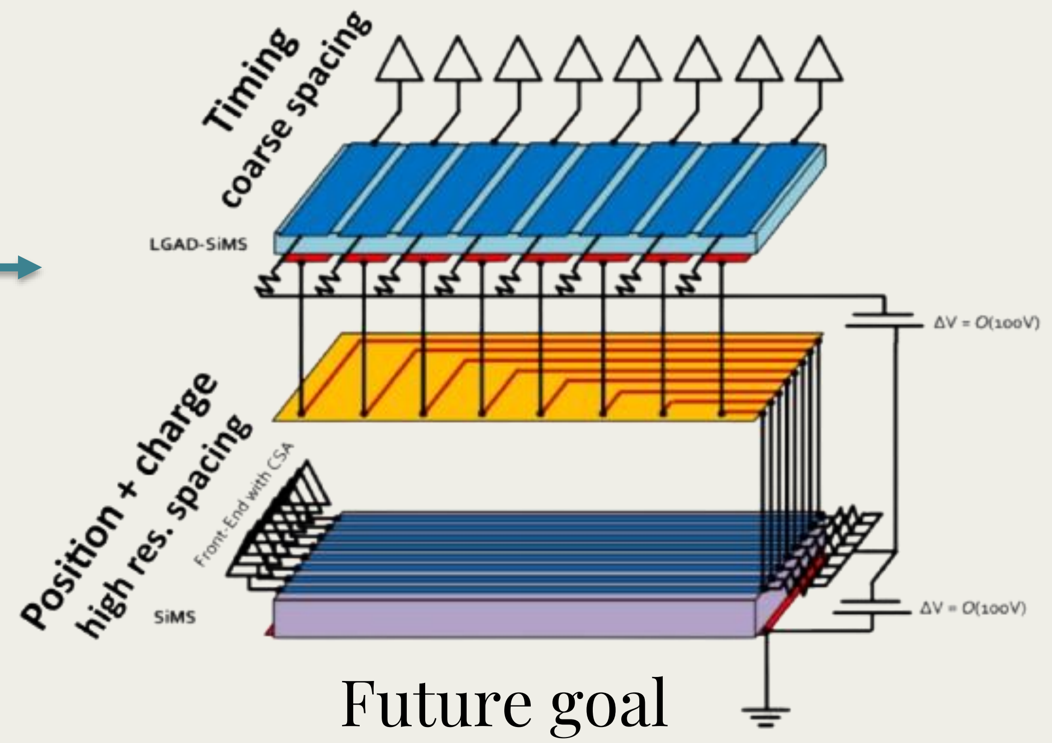
For SiPMs:
- a) «serial» readout:
  - ✗ bias voltage doesn't scale with the number of sensors
  - ✓ total capacity decreases with increasing number of sensors
- b) Traditional «parallel» readout:
  - ✓ bias voltage independent on number of sensors
  - ✗ total capacitance increase with the increasing number of sensors



Can we do the same for LGADs? →

$$ENC_{preamp} \propto C_{tot}$$

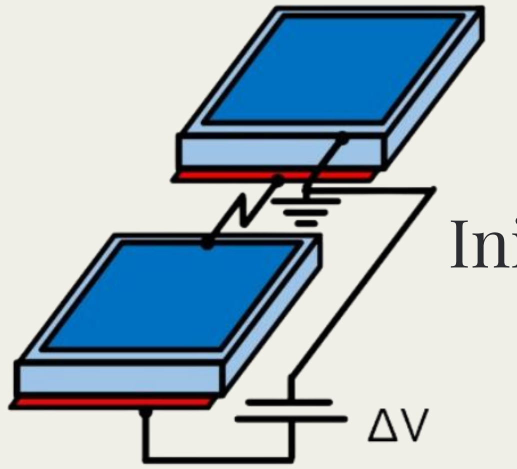
$$C_{tot} = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)^{-1}$$



Future goal

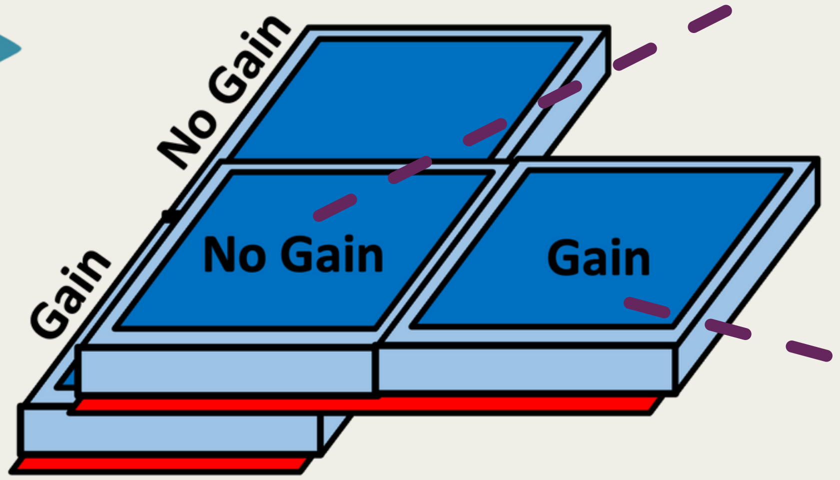
LAB TEST

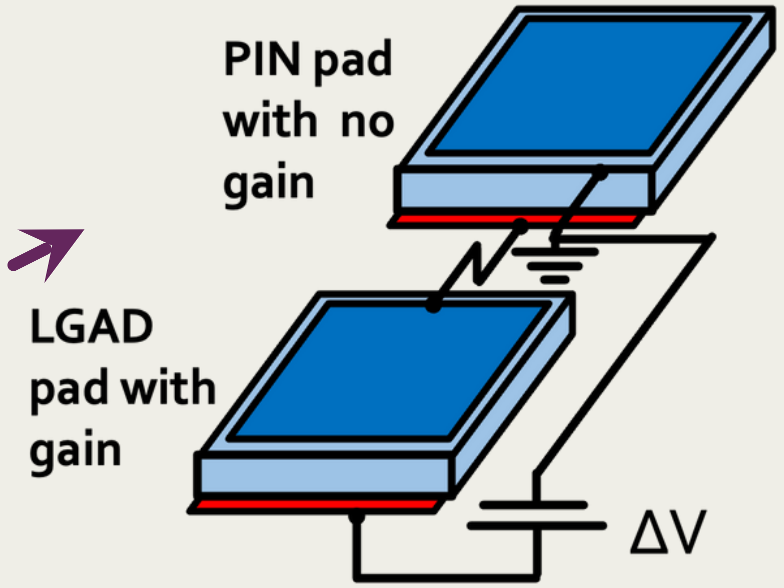
We started with the characterization (Thanks to F.Moscatelli) of 7 pairs of PIN-LGAD test structures (FBK from the MoveIT project)

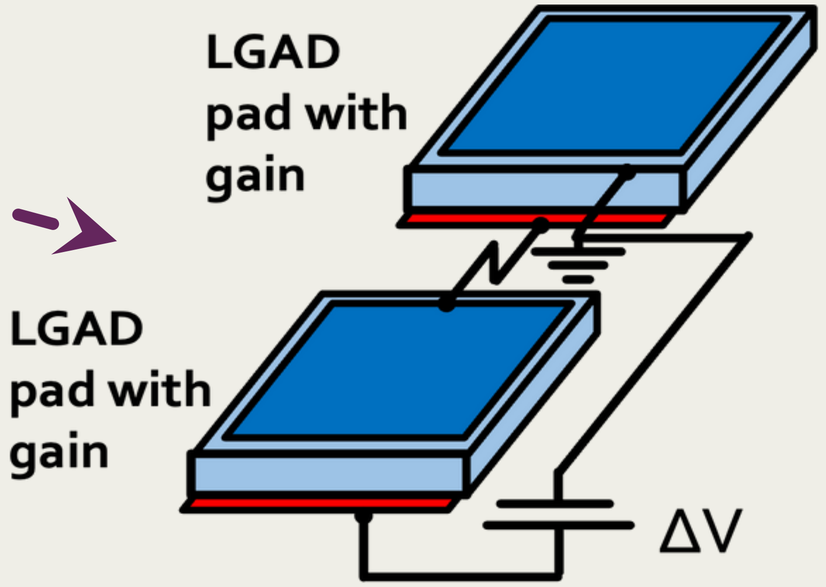


Initial prototype

Then two devices have been glued together with two little drops of connective glue

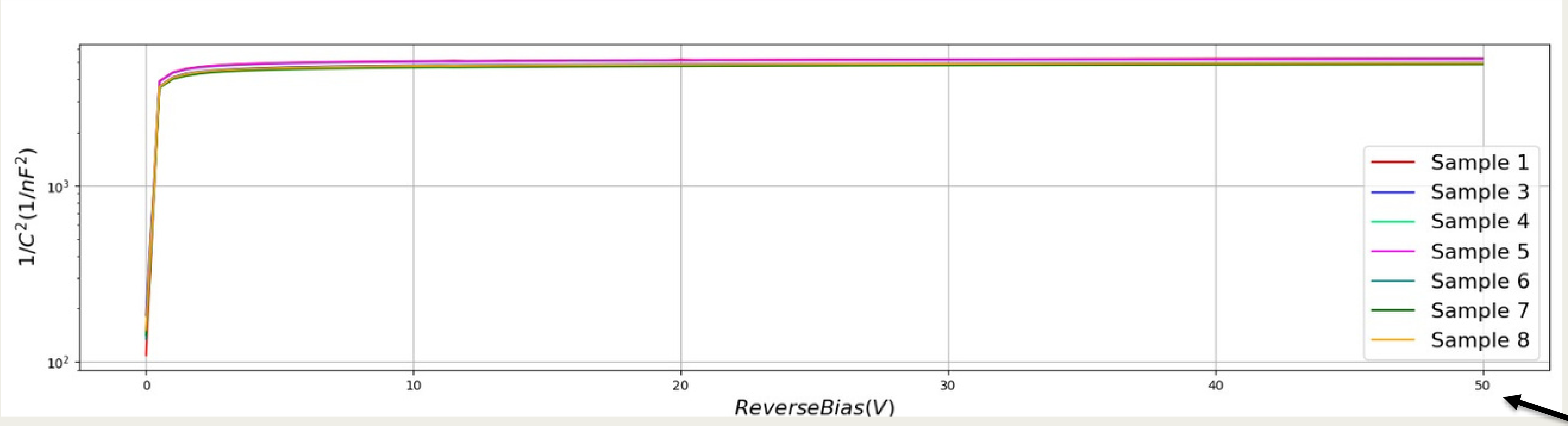




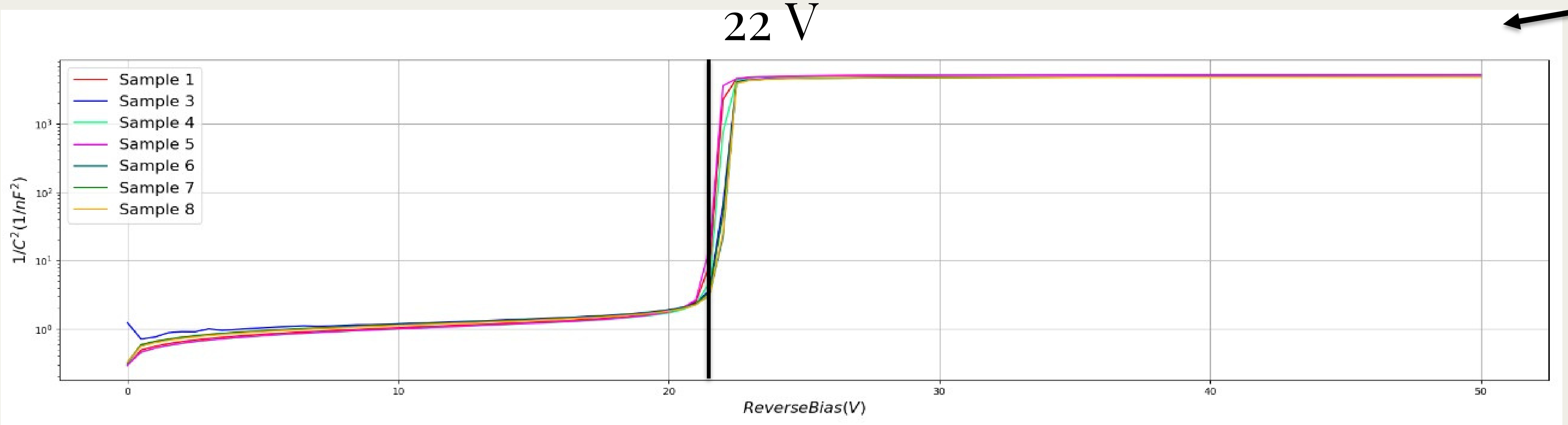


LAB TEST

$$\frac{1}{d} \propto C \propto \frac{1}{\sqrt{V}}$$



22 V



-CV:

PIN ~ 13.9 -14.7 ± 0.2 pF

LGAD ~ 13.9 -14.7 ± 0.2 pF

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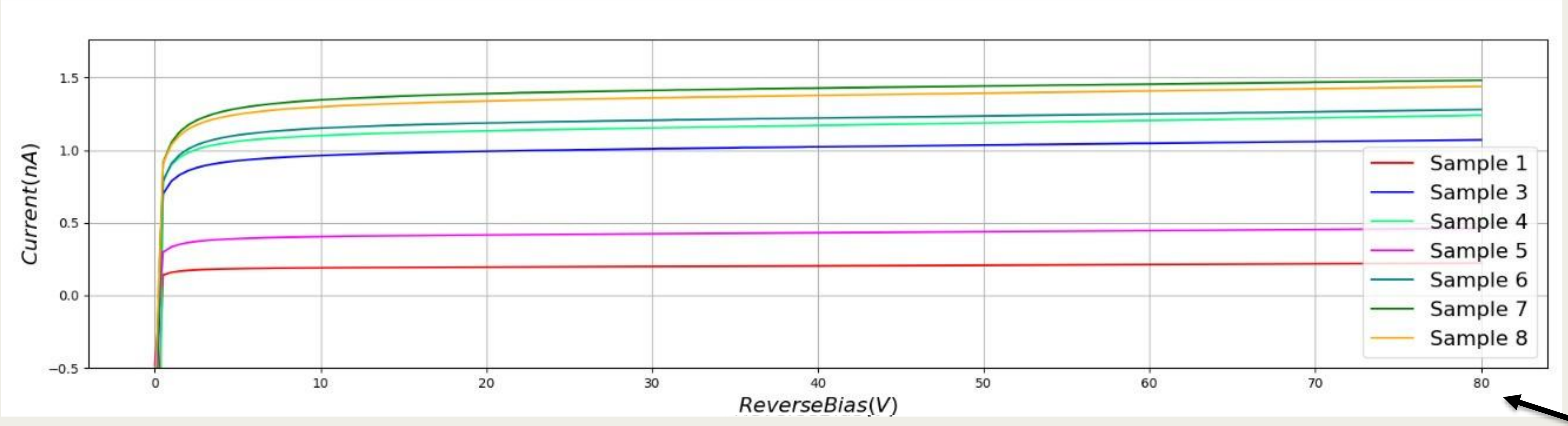
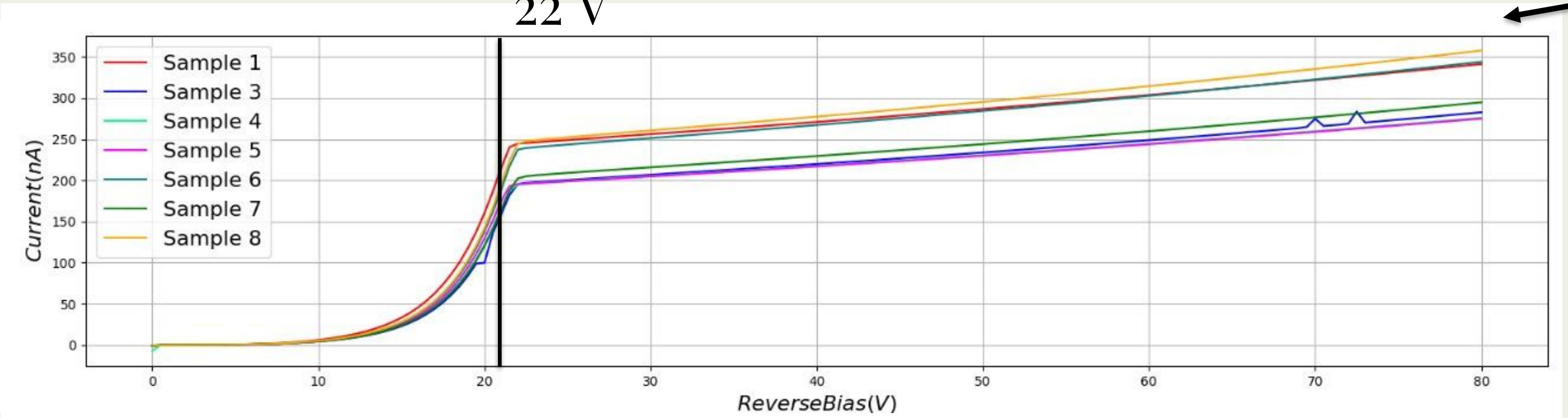
LAB TEST

$$i_m = -qvE_w$$



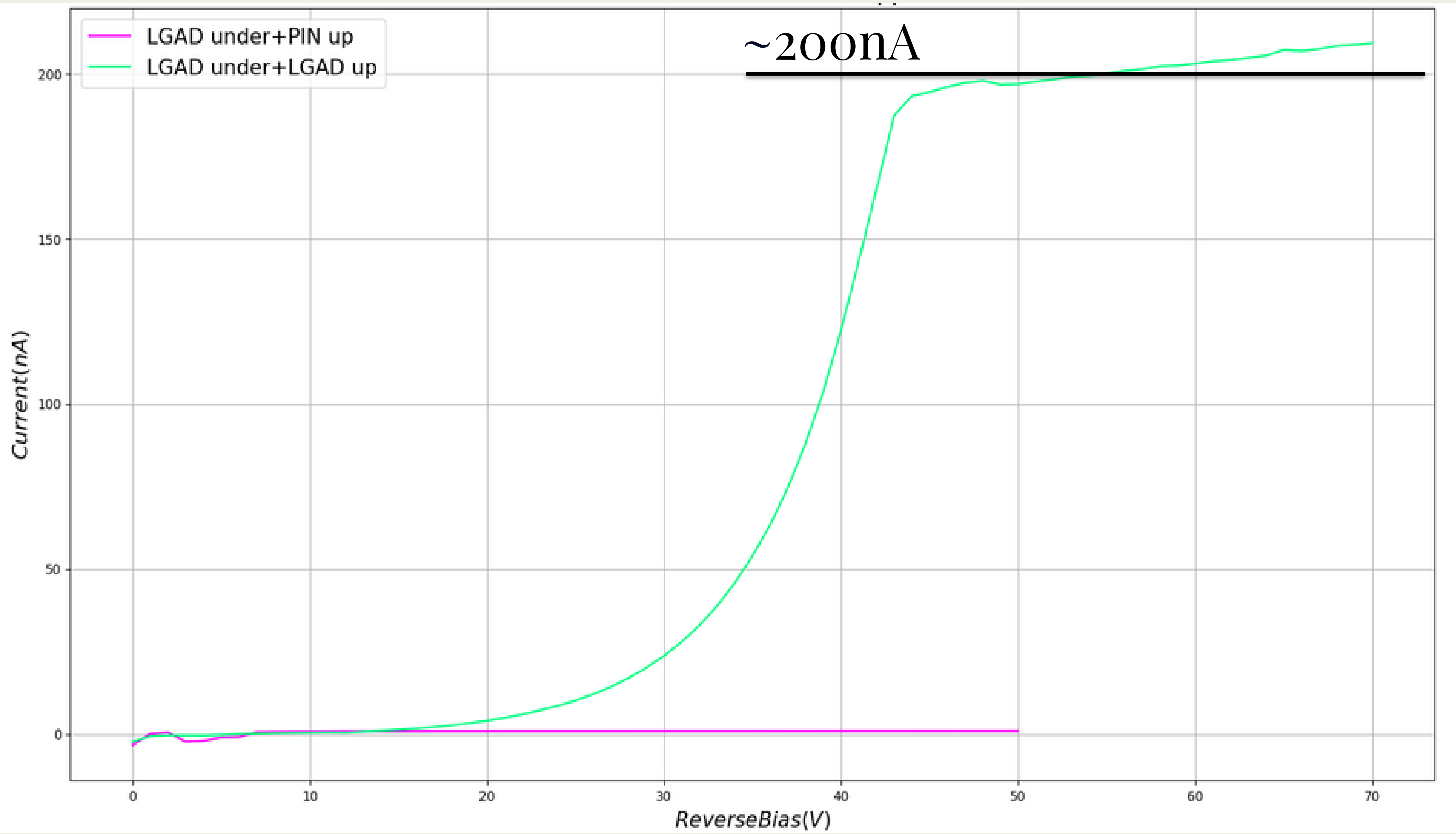


-IV:

PIN 0.5-1.5 nA

LGAD ~ 250-350 nA

MEASUREMENTS MADE ON THE FINAL DEVICE:



I-V:

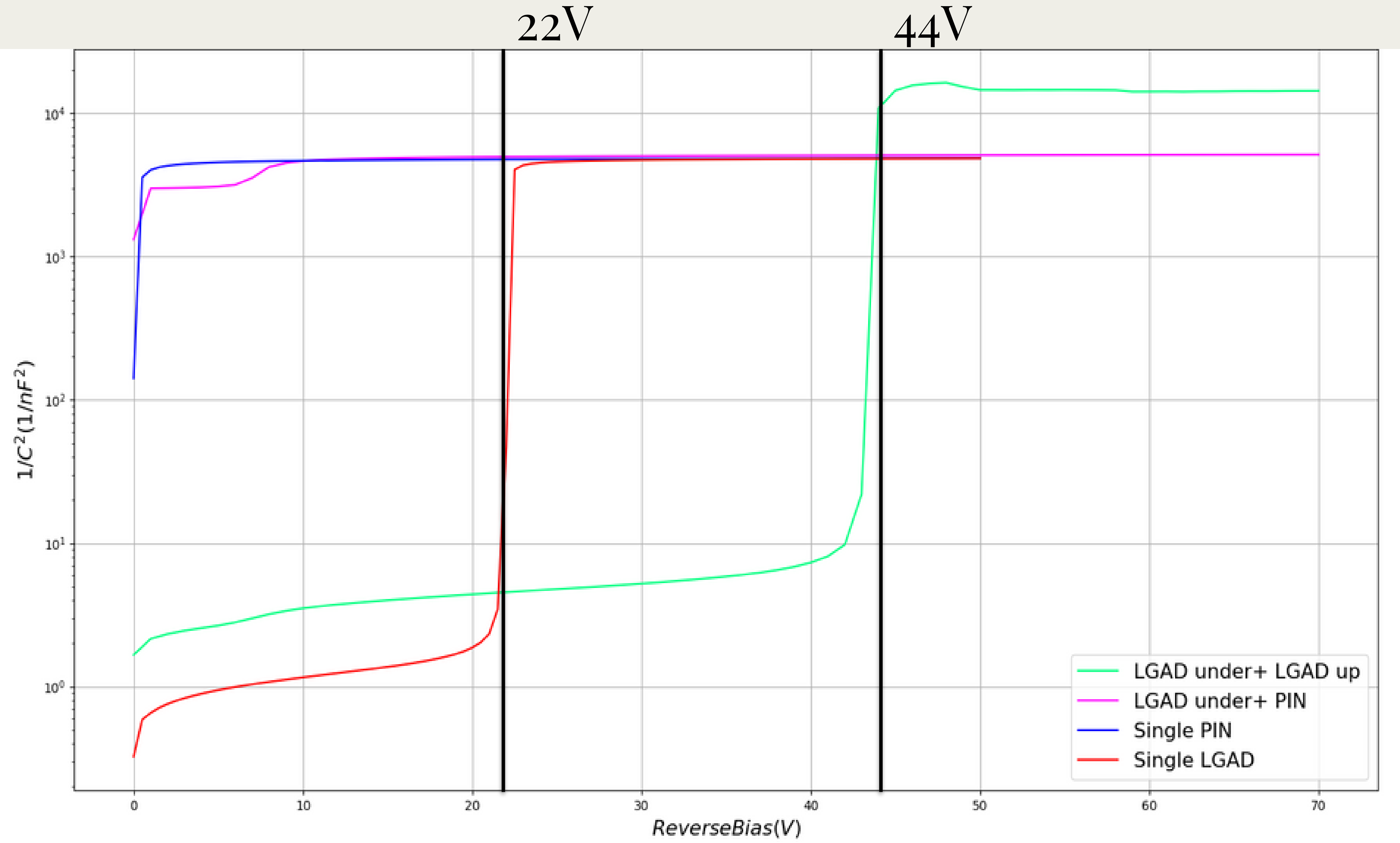
LGAD-LGAD ~ 200nA,

PIN-LGAD ~ 1nA

Both work!

Since the current flowing through the devices must be the same, the total leakage current is determined by the device with the lowest current. In the LGAD-LGAD case, it is even lower than expected.

MEASUREMENTS MADE ON THE FINAL DEVICE:



C-V:

LGAD ~ 13.9 -14.7 ± 0.2 pF

PIN ~ 13.9 -14.7 ± 0.2 pF

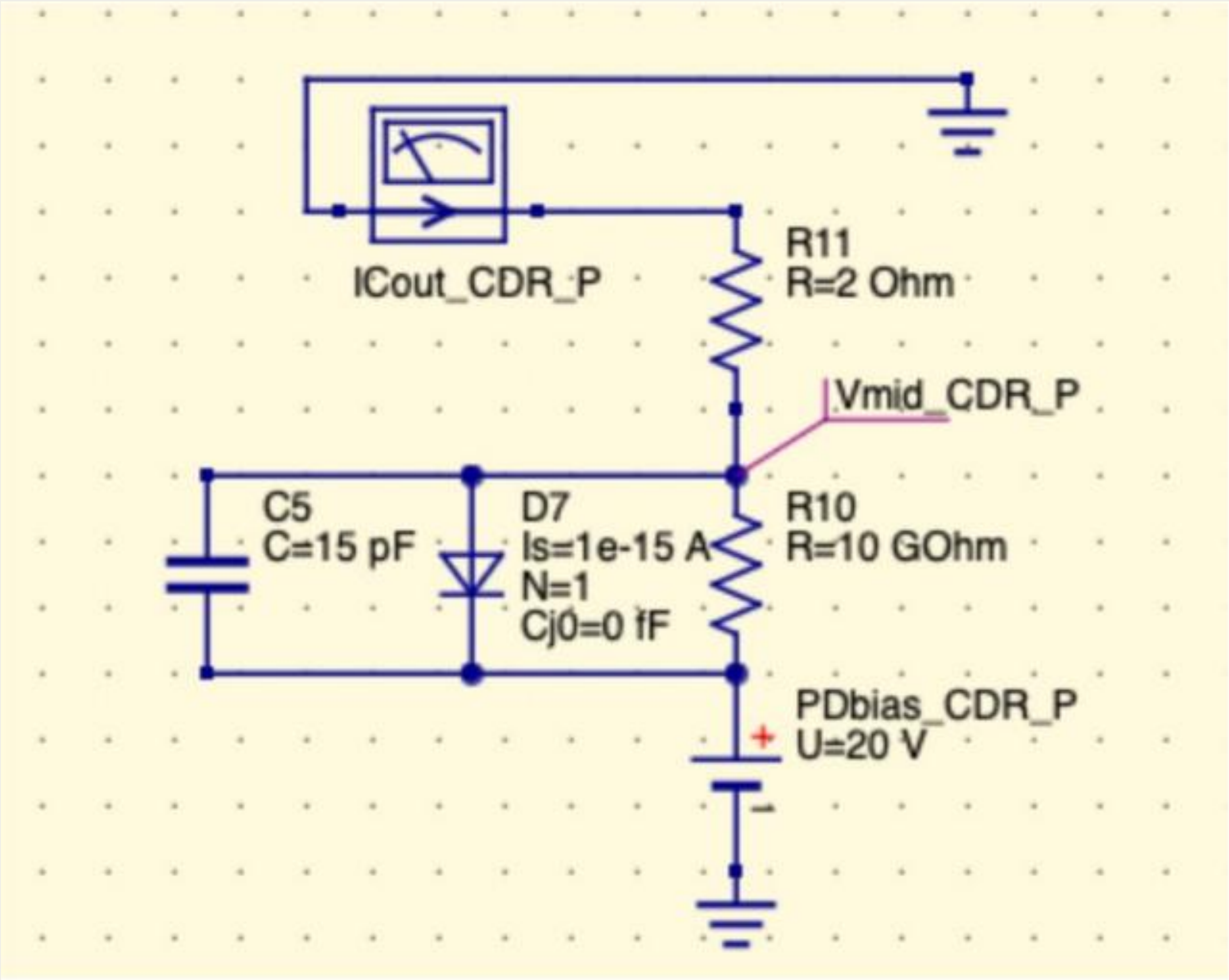
LGAD-LGAD ~ 8.3 ± 0.2 pF

PIN-LGAD ~ 13.9 -14.7 ± 0.2 pF

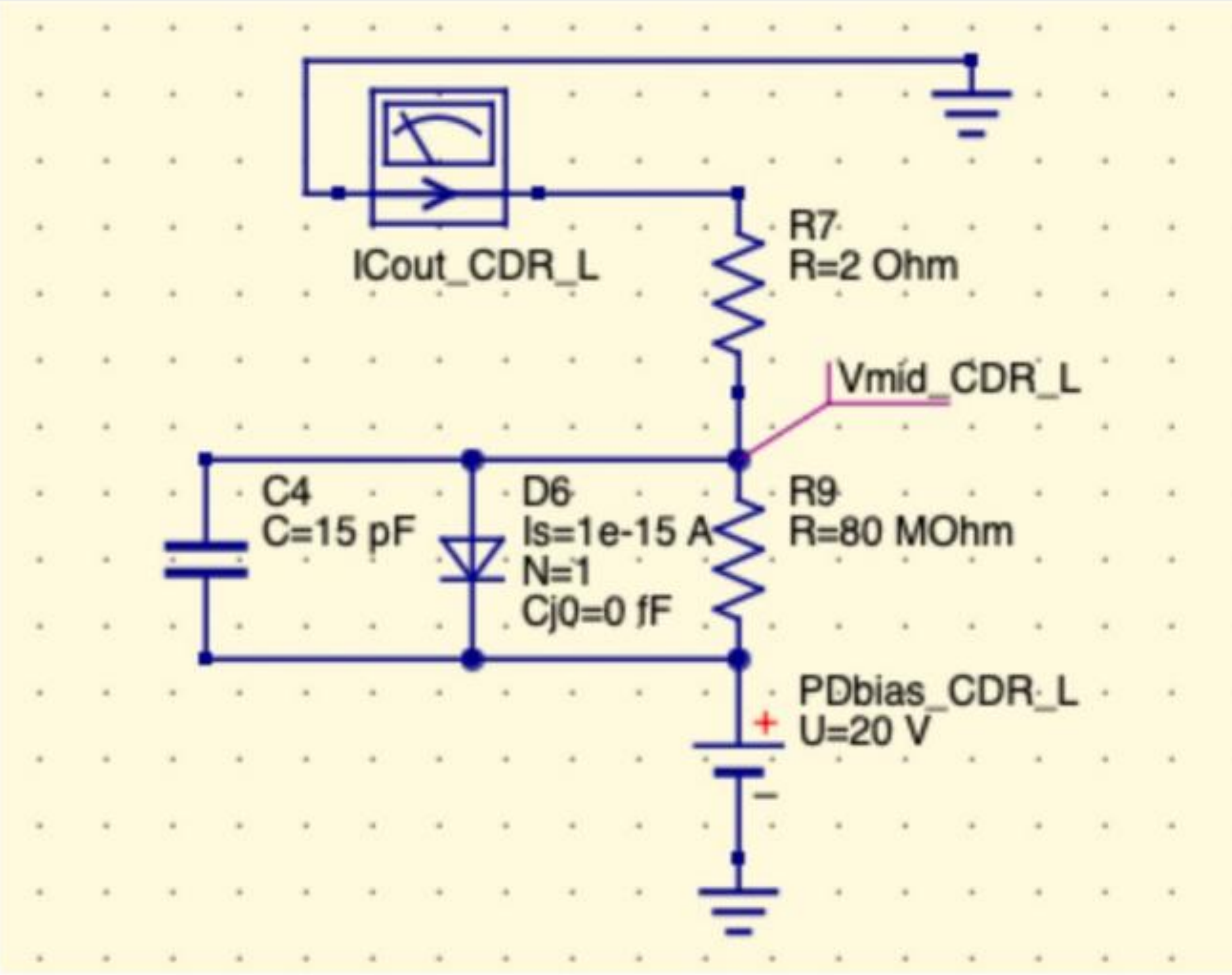
For the LGAD-LGAD case everything seems to work, even though we were expecting to measure 7pF and we measured 8pF. To be understood.
For the PIN-LGAD case we hadn't thought but the result is obvious

Thanks for the attention!

SIMULATION



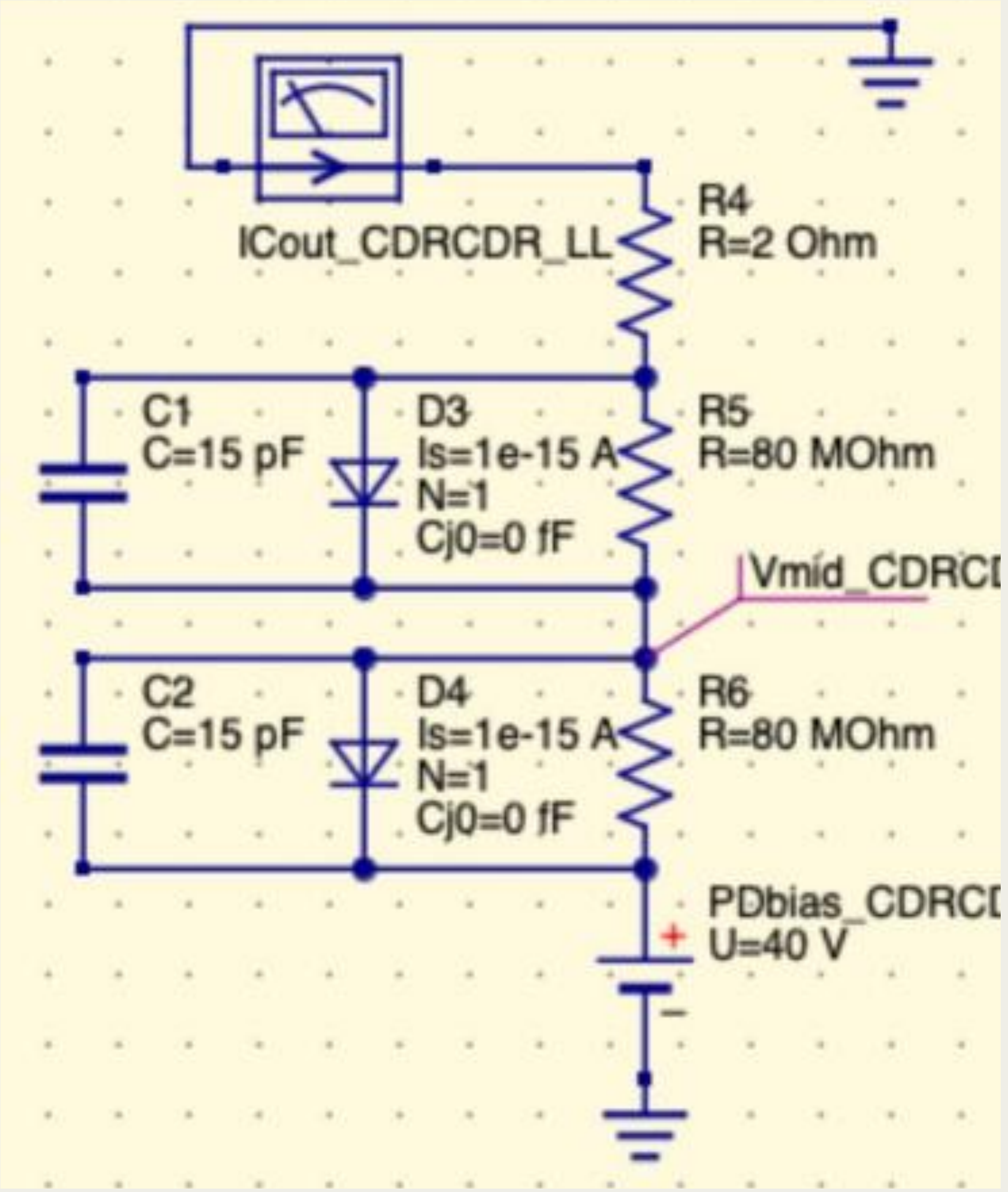
Circuit diagram of a PIN

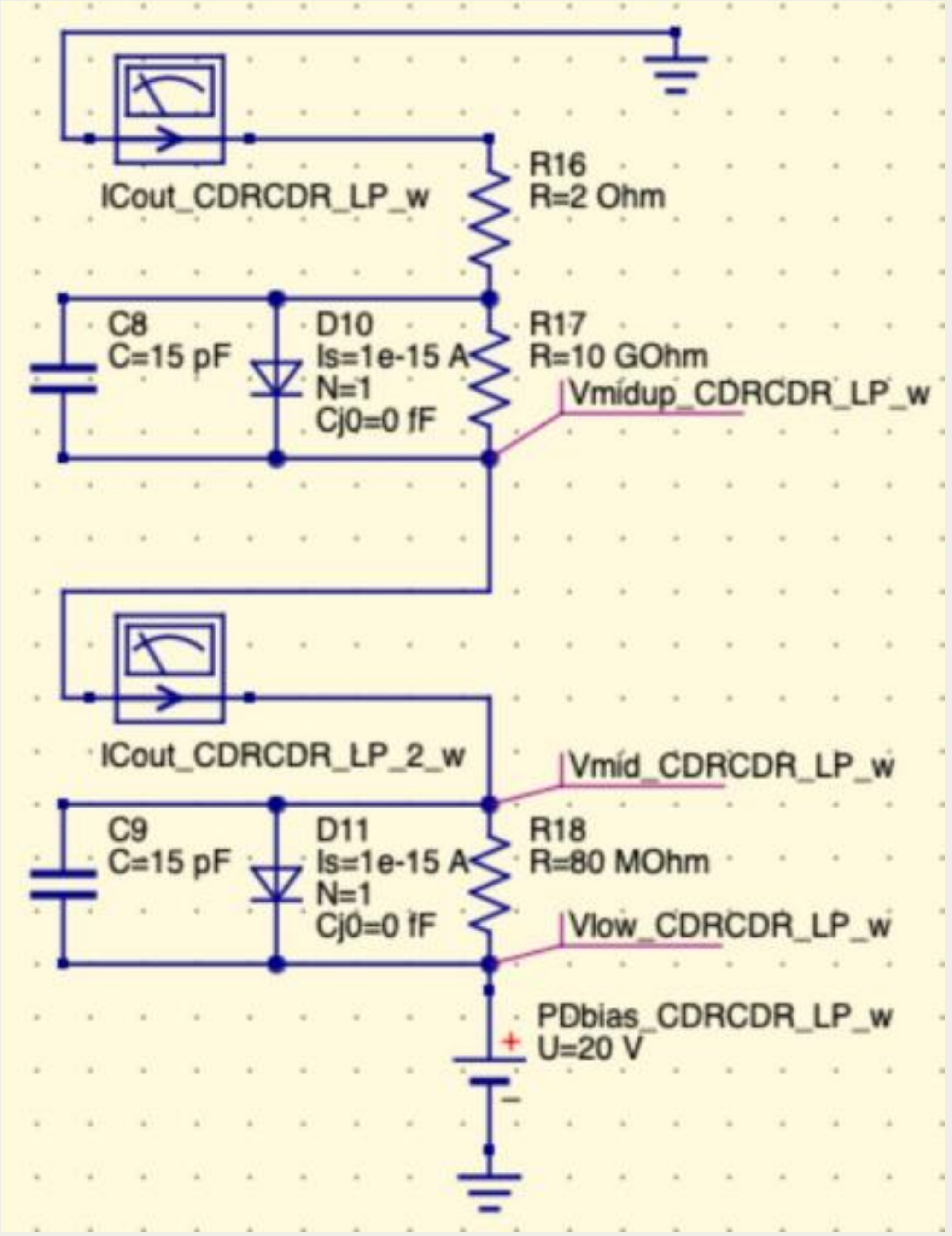


Circuit diagram of an LGAD

SIMULATION

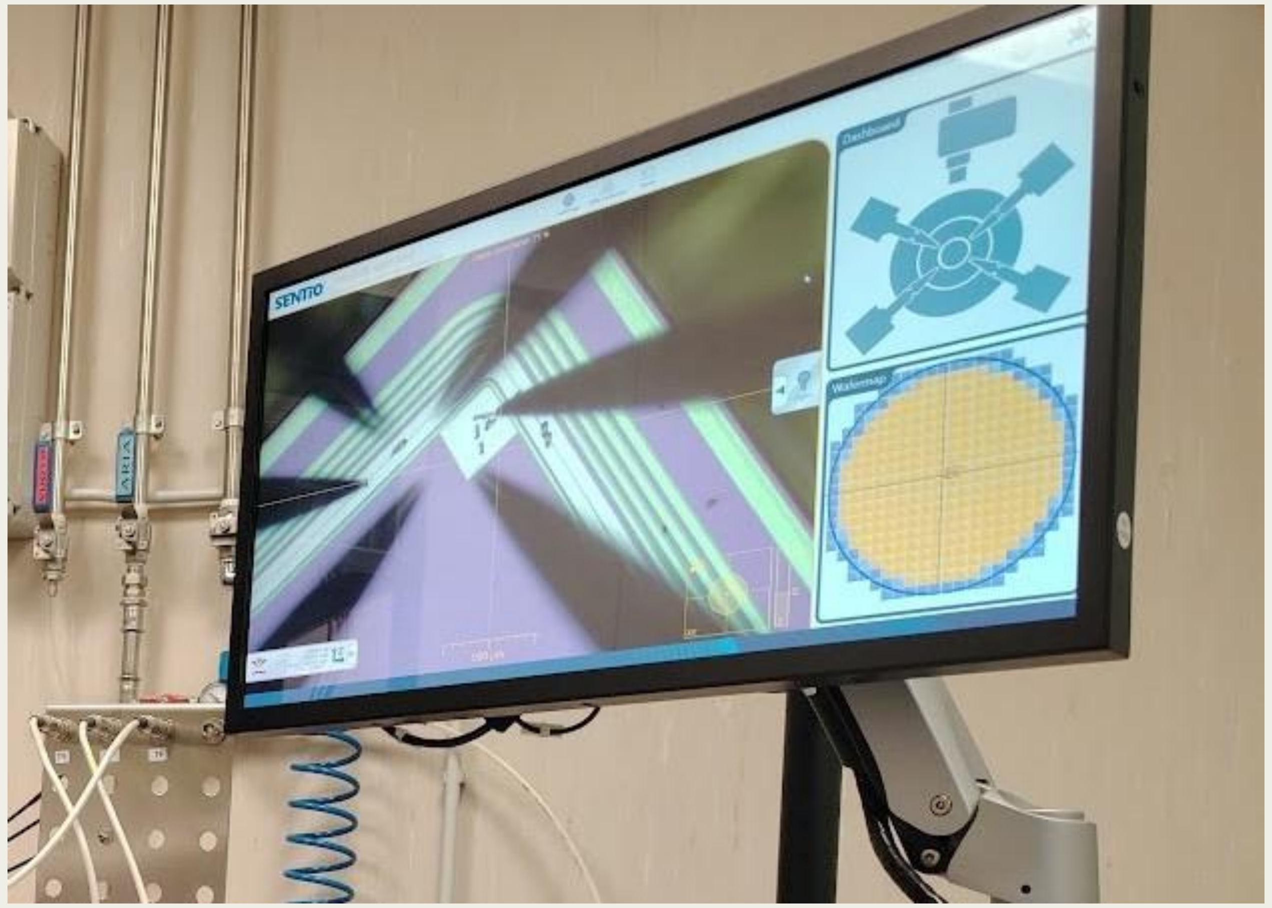
Circuit diagram of the LGAD-LGAD couple





Circuit diagram of the LGAD-PIN couple

PROBE STATION



Probe station used in the Perugia's Clean Room

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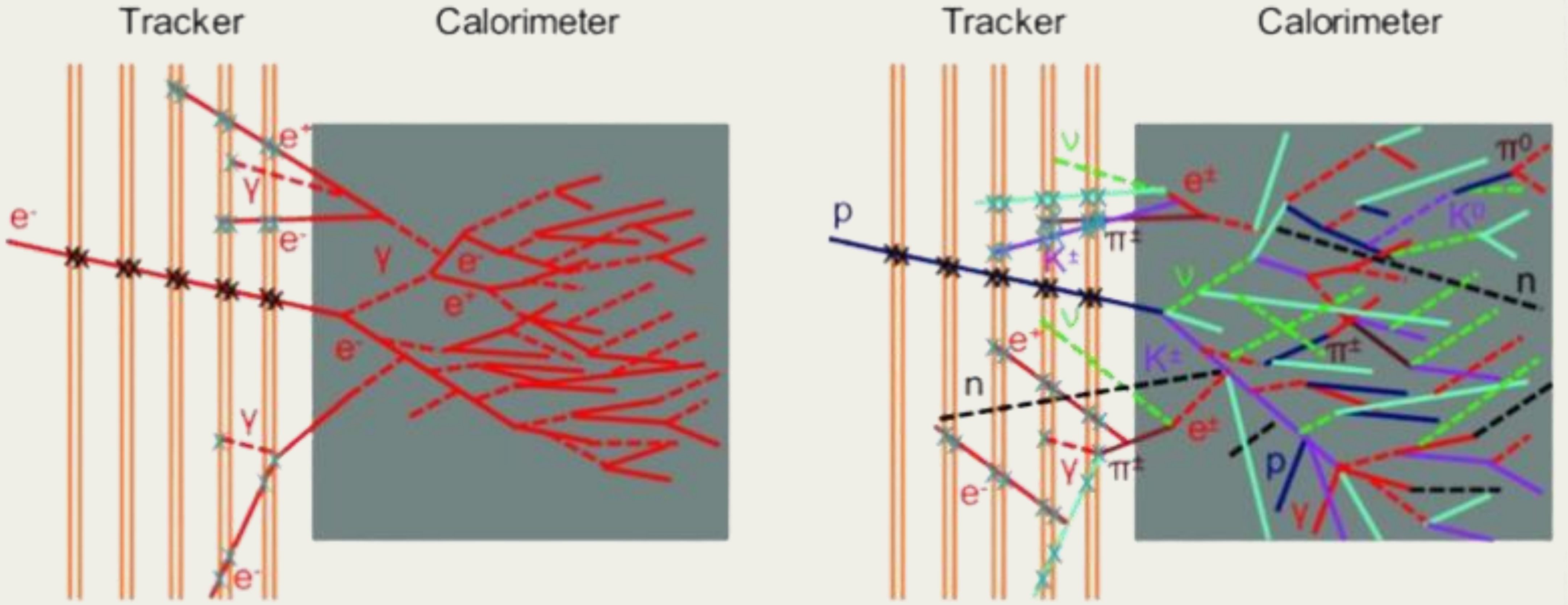
IMPROVEMENTS ENABLED BY TEMPORAL MEASUREMENTS



Improvements that temporal measurements can implement:

- They can be complementary to those performed by ToF (on the order of picoseconds).
- They improve the identification of particle trajectories in environments with a high interaction rate.
- They help remove ghost hits by better separating the signals received by the strips.

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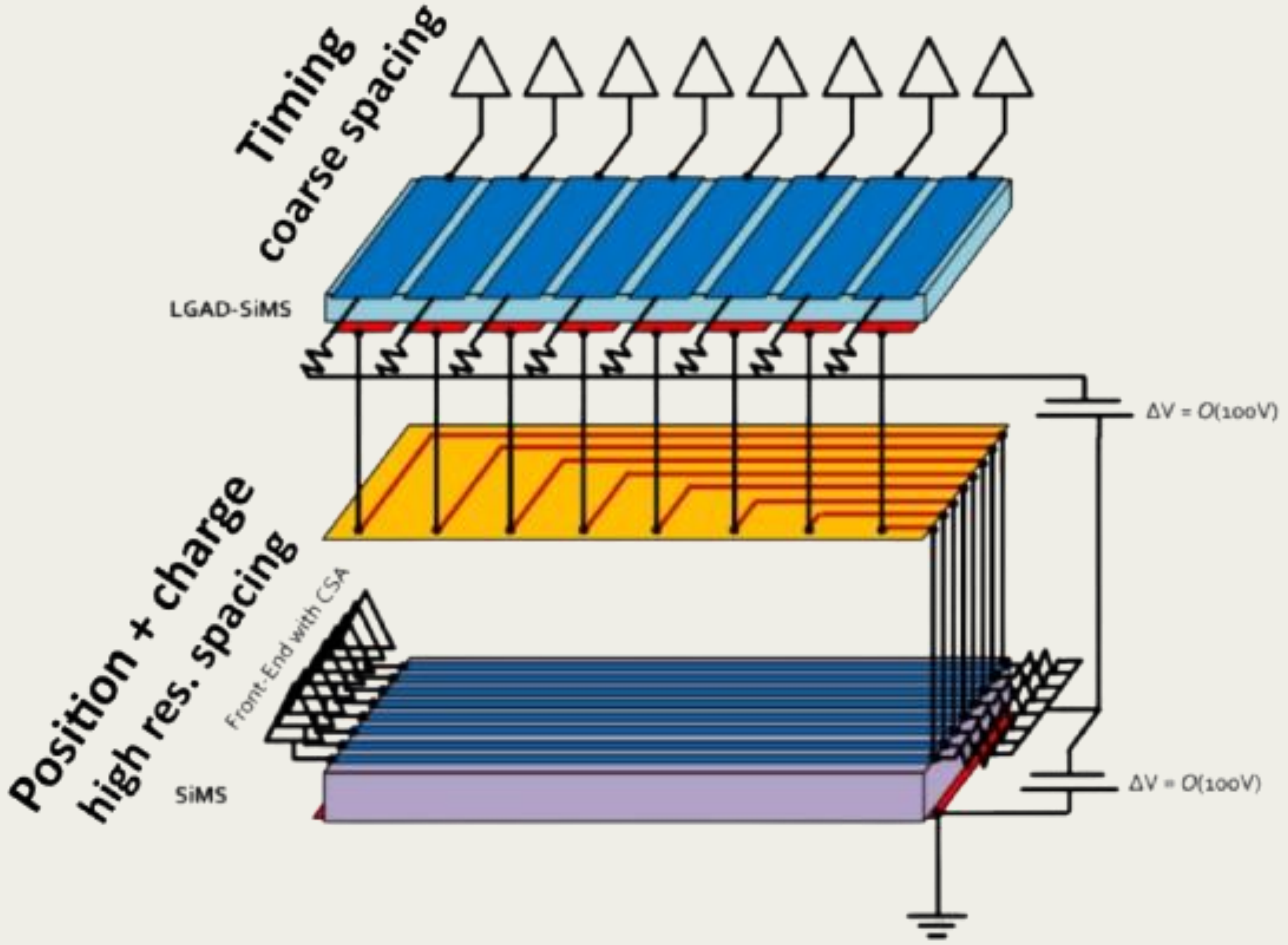
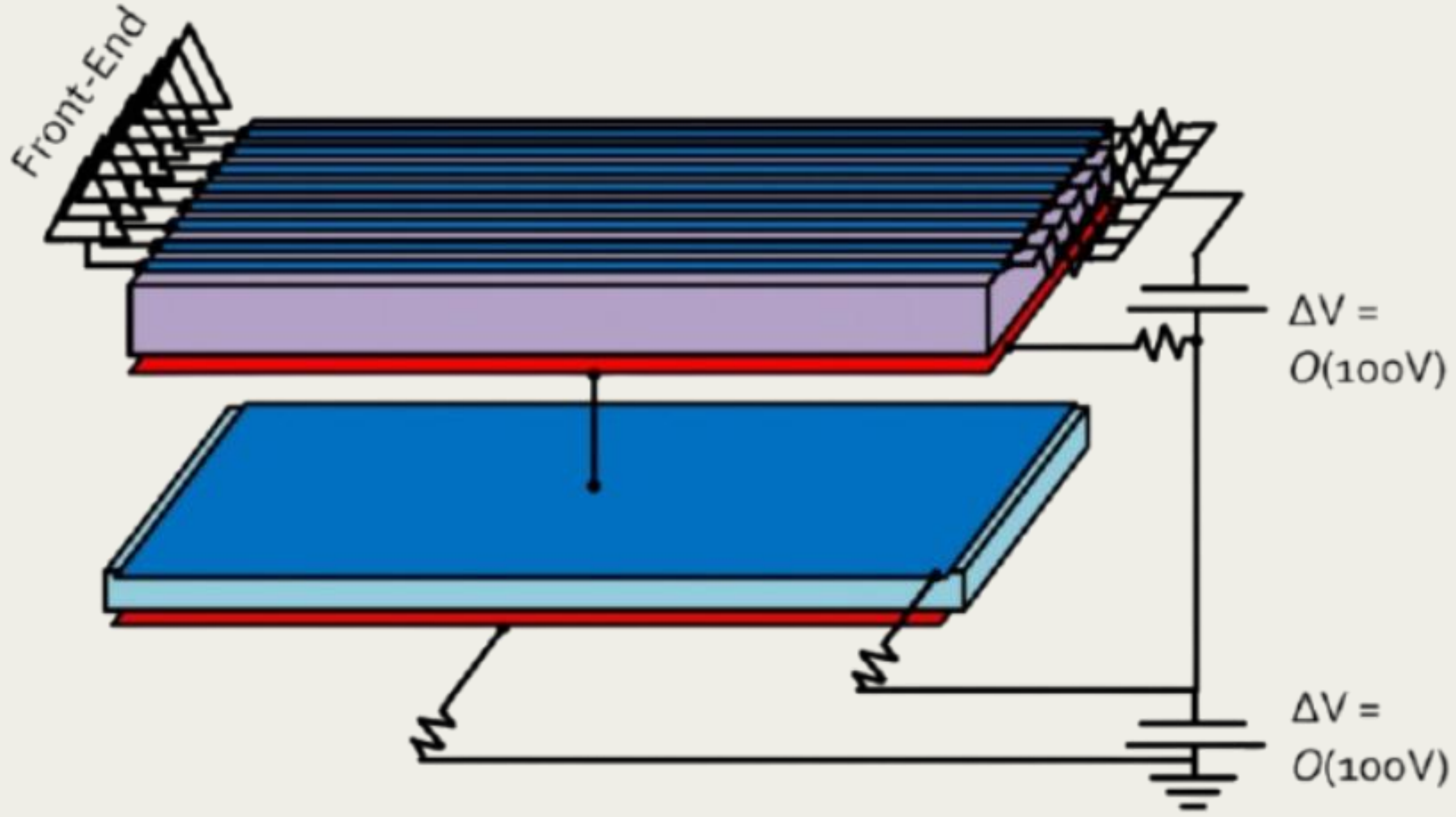
NOISE SOURCES

Other noise sources include:

- **Jitter:** fluctuations in time measurement due to electronic noise.
- **Ionization:** statistical variations in the primary charge generation process.
- **Signal distortion:** alterations of the signal during transport and readout.
- **TDC:** uncertainty arising from the fact that the TDC, having a finite number of bins, discretizes the signal.

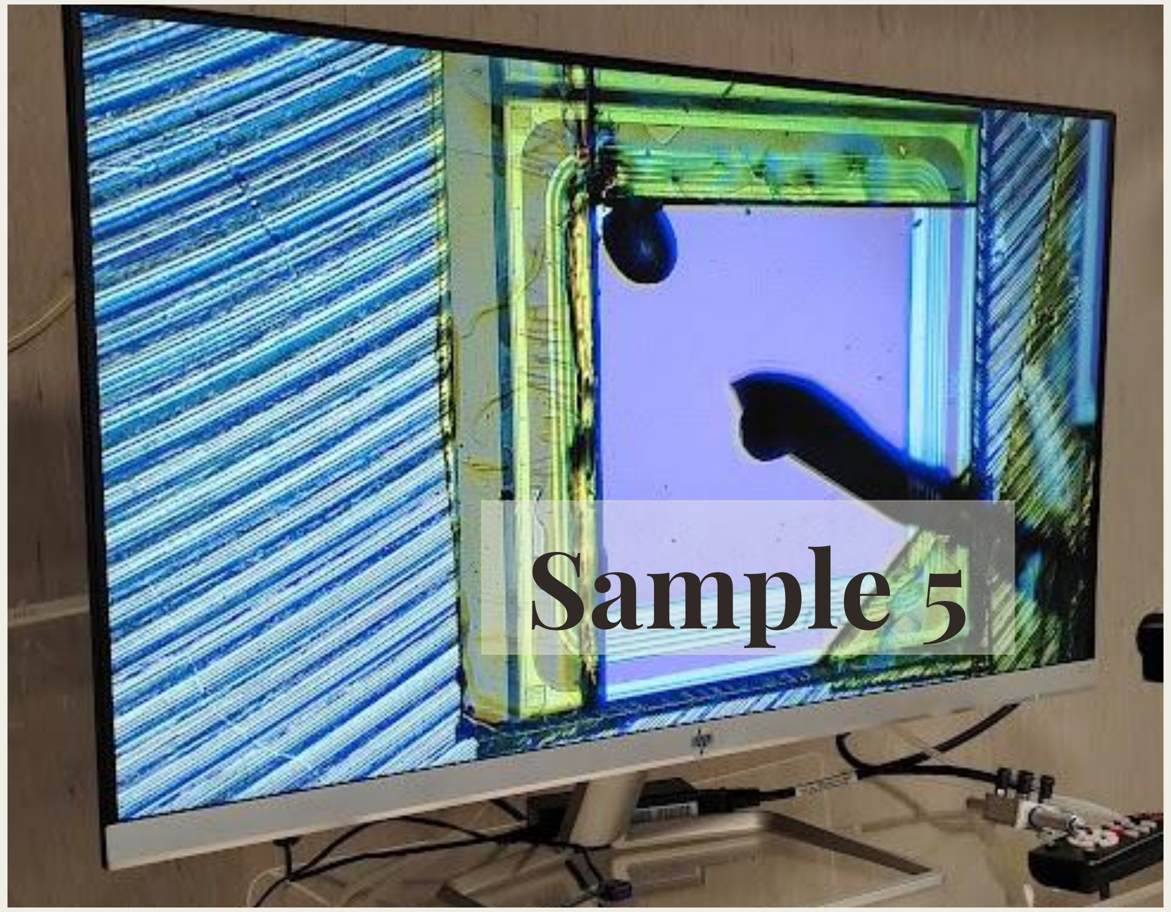
FUTURE POSSIBILITY



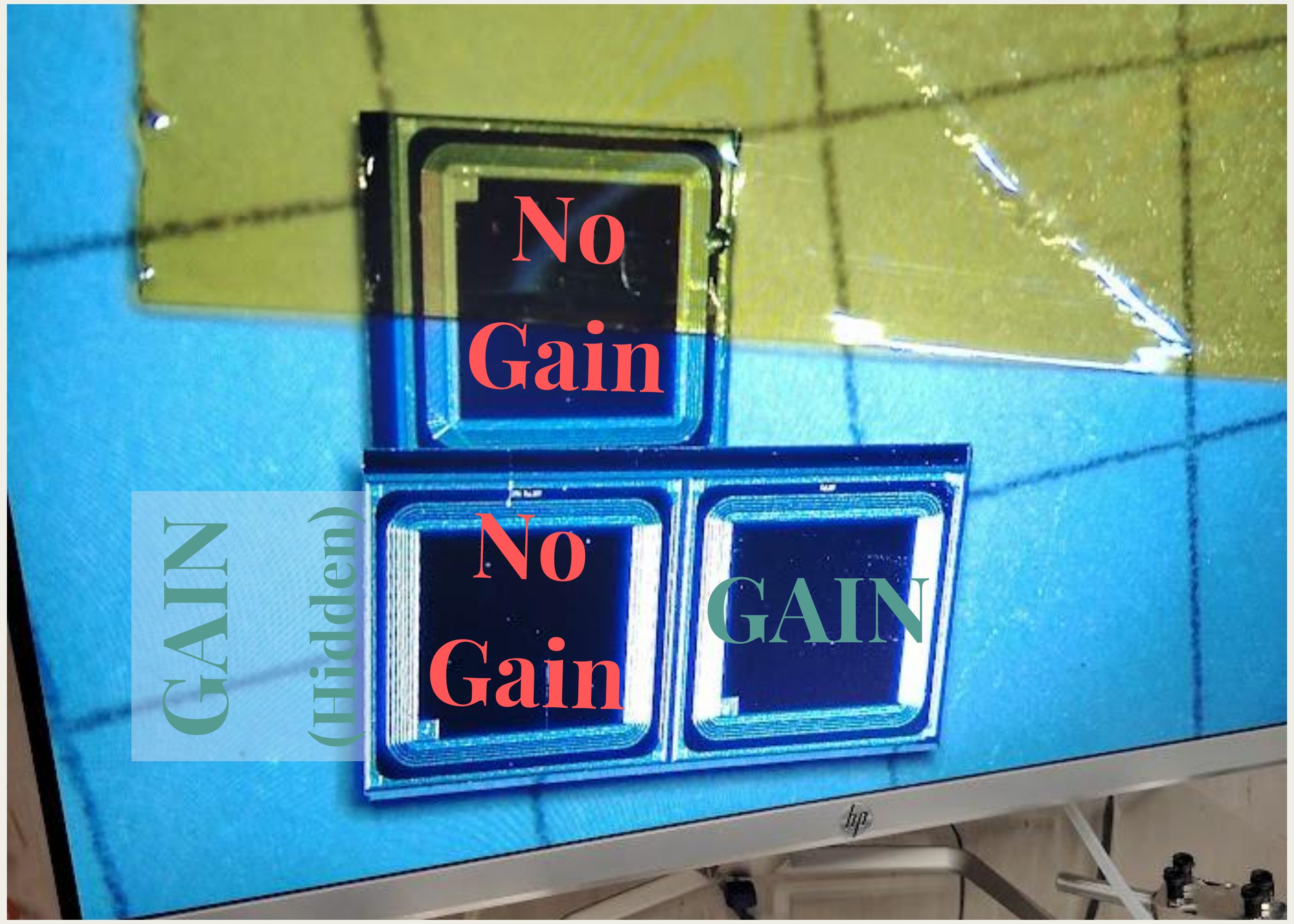


Possibility for future devices

EXPERIMENTAL SETUP



Two devices (sample 3 and sample 5) had been glued together with two little drops of connective glue



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